Harold A. Wheeler's Legacy

Recollections of
Wheeler Laboratories

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Recollections of Wheeler Laboratories
During the Heyday of Radar

Edited by

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PREFACE

In the 50 years of Wheeler Laboratories' existence, first as an independent development laboratory and later through its association with the Hazeltine Corporation, the organization achieved a strong reputation among its peers, a reputation that surfaces even today. It was known not only for its creative and elegant designs of antennas, microwave assemblies, and other RF components, but also for the professionalism and cohesiveness of its staff; in short, for the excellence of the entire organization.

Those fortunate enough to launch their careers at Wheeler Labs, as it was usually called (sometimes abbreviated to WL) found it an exciting place to work and a training ground of the highest order. One example of this regard has been the occurrence of three reunions since the dissolution of the company, drawing former employees from all over the country. Another is the flow of correspondence among past employees not only in holiday greetings, but also in exchanges covering myriad topics.

It is hardly surprising that when in 1994 Dr. Wheeler suggested the preparation of an historical account and requested inputs from former staff members, there was an outpouring of interest and a flood of responses. Wheeler himself began organizing a book and drafting segments. So great was the volume that he determined to prepare not one book but two, the first covering his personal experiences during the period of the Labs and the second incorporating the submissions of others.

Unfortunately for all concerned, Dr. Wheeler died unexpectedly in the midst of preparing and organizing the material for publication, leaving folders full of incomplete papers. It fell to some of the "old timers" to pick up the task. A decision was made to focus on the second book, including within it a chapter covering Wheeler's central role. This volume embodies the result of that effort.

SECTION I

AN OVERVIEW OF WHEELER LABORATORIES

Wheeler Laboratories had its origins in the mind of Harold Wheeler soon after VJ Day in November 1945, when he decided that the time had come to leave long-time employment at Hazeltine Electronics Corporation in Little Neck, Long Island, and strike out on his own. He began by hanging his shingle in 1946 as “Harold A. Wheeler, Consulting Radio Physicist” at a vacated firehouse in Great Neck. Starting with only a secretary, he immediately began attracting clients, due to his awesome reputation as an inventor and developer of commercial radio equipment (pre-World War II) and military radio/radar gear during the war. Two engineers joined him later that year and Wheeler Laboratories was incorporated on January 2, 1947. (Using the notation promoted by Wheeler, this date would appear as 470102; this form will be used repeatedly in this volume.) Both men left later in the year for other career objectives, but their places were taken beginning in August and a rapid pattern of growth ensued.

Serving clients such as Bell Telephone Laboratories, Sperry, Raytheon, Westinghouse, and General Electric to mention only the largest, Wheeler Laboratories flowered as a source of design talent. The output included radar components, especially antennas and microwave “plumbing,” along with commercial communication antennas, and later optical devices.

The “old firehouse” location was superseded in 1949 by a modern building in Great Neck. In 1957 a specially designed building was opened at Smithtown, thirty miles to the east, to enable the design and measurements of antennas across an outdoor range. The engineering staff expanded continuously over the early years, reaching a peak of about 75 engineers in the 1960s.

In 1959 Wheeler Laboratories became a subsidiary of Hazeltine Corporation, but continued its subcontract work as before. Gradually its activities began to merge with those of the parent company as a result of two factors. One was Hazeltine’s desire to apply the Laboratory’s talents to its ongoing projects and marketing efforts. The second was the national recession which began about 1968 and which caused the military clients to retract their outside design support in favor of in-house resources. Finally, in 1970, Wheeler Laboratories was officially terminated and its remaining staff became regular employees of Hazeltine, though still carrying the name as an internal working group.

During these memorable years, Wheeler Laboratories gained a national reputation for its creative achievements in microwave and antenna design and development. Throughout their subsequent careers its engineers have carried with them a sense of pride in their accomplishments, and an enduring regard for the stimulating work environment created by Mr. Wheeler, with his invariable goal of excellence in all respects. This is the legacy of Harold A. Wheeler to the engineers of Wheeler Laboratories and of Hazeltine and, through them, to the engineering community at large.

SECTION II

HAROLD A. WHEELER, THE MAN WHO MADE IT HAPPEN

(Editor's Note: Harold Wheeler's sudden death on April 25, 1996 at the age of 92 was a sad occasion for his many friends and associates throughout the radio-electronics community worldwide, but especially for those who participated in the life of the Wheeler Laboratories. Dr. Wheeler's career, as a whole, has been described in various journals and magazines in connection with the many honors that have been bestowed on him.[1] Further information is incorporated in books written by Wheeler himself in connection with corporate activities, significant national programs and his own technical contributions.[2] For the present volume, Dr. Wheeler had made extensive notes in chronological format, but had drafted only a few segments before his death. Using these notes and other sources, Dave Dettinger has constructed the following abbreviated account.)

Harold Alden Wheeler had a lifelong fascination with radio waves. Born in 1903, he was one of a multitude of young men to embrace the emerging miracle of radio. Like others, he built his own sets and rigged his own antennas; unlike others, his was from the start a professional approach, not an amateur one. His brilliant mind, his compulsion for comprehensive understanding, and his instinctive creativity set him apart from all but a few of his contemporaries.

Wheeler's formidable reputation in the radio engineering community virtually guaranteed success for the consulting practice he opened in 1946 and the fledgling Wheeler Laboratories incorporated a year later. His strategic patents, his extraordinary problem-solving talents, and his frequent professional papers and lectures had won him the attention and respect of everyone he dealt with. A few highlights of his career are indicative.

As a boy, Harold was always to be found in his workroom at home experimenting with various scientific phenomena. During his high school years, his technical interest coalesced into a lively involvement with amateur radio; his call letters were 3QK. His spark transmitter and crystal receiver were assembled from components, many of them homemade. Having moved with his family from Mitchell, South Dakota to Washington, D.C. in 1916, he was able to listen to NAA, the Navy's nearby station and to follow its code transmissions (even during World War I, though it was officially prohibited to do so).

It was a direct result of this activity that his attention was drawn to the recurring problems of instability in the radio receivers of the day, where feedback in the tuned radio frequency (TRF) amplifiers would cause annoying squeals and howls. While an undergraduate at George Washington University, his experiments at home, coupled with summertime work at the National

Bureau of Standards, led him in 1922 to the independent invention of a neutralization scheme for broadcast reception. At this point, fate took a hand.

Harold's father, who had joined the U.S. Department of Agriculture, was sent in 1922 to attend the National Radio Conference. While there he made the casual acquaintance of Professor Alan Hazeltine of the Stevens Institute of Technology. A few months later, Harold and his father were eating at a restaurant in Hoboken when Hazeltine chanced to stop by and invited them both to visit at his office nearby. Harold soon took the opportunity to describe his neutralization technique. Hazeltine was astounded, announcing that he himself had a patent pending for the identical invention! As Wheeler put it, "Neither of us was ever the same again."

So impressed was Hazeltine with Harold's talents that he arranged an agreement to share royalties in exchange for any patent rights. In 1924, this agreement was formalized when the Hazeltine Corporation was organized as a public stock company to capitalize on the professor's patents; Harold became the company's first employee. Still an undergraduate, his energy was boundless. One investigation followed another, yet he was able to graduate at the head of his class, receiving the first award of the BS in Physics at George Washington University.

Professor Hazeltine also engaged Harold to work at his Hoboken laboratory during the summer of 1924 and of 1925, the year of his graduation. It was during this latter summer that Wheeler made what he called "the most important invention of my career, the Diode Automatic Volume Control (AVC) and Peak Detector." Now more commonly known as Automatic Gain Control (AGC), it has had a fundamental impact on the design of every radio receiver since that time. Its function is now so much taken for granted that it is hard to imagine the sensation it created at the time.

From George Washington it was on to graduate school at Johns Hopkins University, majoring in physics but with the clear objective of an engineering career. Here again, Harold was active in many areas. One important topic of study was wave filters, which became a specialty later on. His consulting work with Hazeltine never slackened. In 1926, he even found time for marriage to Ruth Gregory, and to start a family! Finally, in 1928, he elected to leave Johns Hopkins for full-time work with Hazeltine, thereby coming away without either the Masters or Doctors degrees. (The latter omission was corrected with honorary doctorates in 1972, 1978 and 1992.)

The years from 1928 until the start of World War II were happy and productive years for Wheeler at Hazeltine Corporation. The company itself prospered even through the Depression on the basis of a steady flow of patent royalties and the continuing demand for consulting services. The topics are too numerous to describe in any detail; it will suffice to mention a few, especially those in which Wheeler played a central role:

- The Neutrodyne receiver. Designed on paper by Professor Hazeltine, this product dominated the industry for several years, undergoing continual refinement by the Hazeltine engineers at the laboratory located in rented space on the Stevens campus in Hoboken.

- Uniform gain. Constancy of gain over the broadcast band is clearly a desirable feature in any radio receiver. Achieving it in the TRF receivers which preceded the superheterodyne (the patent for which was held by Armstrong and controlled by RCA to the exclusion of Hazeltine), was a particularly difficult requirement to meet.
- Improvements to the superheterodyne receiver. When finally in 1920 RCA released this technique by licensing it, Hazeltine became a source of information to its clients and developed various refinements.
- Television. Hazeltine's contributions included a camera tube, beam scanning for displays, the analysis of imaging, and wideband circuitry. Wheeler's historic paper on paired echoes was a by-product of this work.
- Test equipment and standardization. A component of special interest here is the "waveguide-beyond-cutoff" attenuator, dubbed by Wheeler the "piston attenuator."

It goes almost without saying that Wheeler played a significant role in all of these areas, generating more than 120 patents.

1940 brought abrupt change to the Hazeltine Corporation. World War II had begun in Europe, and American companies everywhere were asked to redirect their efforts toward the nation's defense. At once Hazeltine set about to identify opportunities matched to its recognized competence in radio technology.

The initial projects were small tasks in direction finders and other radio gear. One task in particular, the detector for anti-tank (metallic) land mines, is worth some attention for two reasons. First of all, it was an instant success; as the SCR-625 Mine Detector it was made in quantities of over 100,000 and used worldwide. The basic design is still in use today for civilian purposes as well as military. Secondly, its clever circuitry established Wheeler as an expert in the subject of mine detection and led directly to a contract with the Army ten years later at Wheeler Laboratories to study the detection of non-metallic mines.

The topic that dominated Hazeltine over the war years was Identification Friend-or-Foe (IFF). IFF originated in Great Britain as an adjunct to early warning radar and fire control radar; its function was to distinguish between friendly and hostile aircraft for interception purposes. Ultimately, every aircraft and ship of the allied forces was equipped with an IFF transponder, such that they could be interrogated from radar sites.

Hazeltine's strategic role in this endeavor was the direct result of an initiative by the president of Hazeltine, William A. MacDonald. Mac, as he was known, was himself an engineer whose career had begun after high school as a radio operator aboard ships, followed by a stint in the Signal Corps during World War I. In the Army, he was fortunate to be a member of a team headed by Major Edwin H. Armstrong, whom Wheeler regarded as a great inventor in the history of radio. Observing that there was a pressing need for the United States to bolster the efforts of the British in IFF as well as to supply American forces, Mac conceived of Hazeltine in the role of a central coordinator for the entire program, with large-scale production spread among radio companies for whom Hazeltine was already serving as a design and consulting resource. As a consequence, in 1941 the U.S. Army Signal Corps and the U.S. Navy selected Hazeltine for the redesign needed for manufacture in the United States, along with the responsibility for coordination of procurement.

Mac's plan had beneficial results for all the parties involved. The U.S. government was assured that some of the most experienced engineers in the country were at the helm of this critical wartime project. Hazeltine gained dramatic visibility in the military community as well as in industry. Hazeltine engineers were presented a glorious opportunity for creative design in a demanding but highly supportive environment. For Harold Wheeler, as Chief Consulting Engineer for the entire enterprise, the challenge was irresistible.

At this time, IFF was in its third stage of development, labeled Mark III. Mark I had been a blinking resonant reflector, responding to the radar's receiver on the radar's transmission frequency. Mark II was an improvement, intended to thwart enemy spoofing by responding on a separate frequency; this too was vulnerable. Mark III introduced an interrogator on a selectable frequency and a coded response on yet another frequency in the same band.

It is impossible here to do full justice to the scope of Wheeler's contributions to Hazeltine's war work. Instead, we shall focus on the particular aspects of his work which played an important role in post-war years at Wheeler Laboratories, even if it means passing over his influence in such critical areas as interrogator and transponder redesign, delay lines, landing beacons and test equipment.

The subject of antennas and RF circuitry claimed priority among Wheeler's activities. By this time, Hazeltine had long since left its quarters in Hoboken, moving first to New York City with a research laboratory in Bayside, Long Island, and finally consolidating its activities in a new engineering laboratory in the uplands of Little Neck, near Mac's home. As the war progressed, additional buildings were added; one of these was a small frame structure in the middle of a field behind the others, affectionately known as the antenna shack. Here some of Wheeler's best ideas bore fruit.

It might be well at the outset to describe an analytical tool that Wheeler was the first to apply, namely, the circle chart representing the polar plot of complex reflection coefficient. The chart was published in 1939 by Phil Smith of the Bell Telephone Laboratories (BTL). (Later on Phil became a client of Wheeler Labs for a Navy radar redesign task.) Phil presented the chart as a convenient graphical aid for converting reflection data—as obtained, for example, by measurements of standing waves using a slotted line—into values of resistance and reactance. He once told the writer that he never considered plotting data directly on the chart. Phil Carter of RCA published a similar chart the same year; Carter's chart converted to impedance magnitude and phase. Like Smith, it seems Carter did not suggest plotting data on the chart.

Wheeler's innovation was to recognize that the curves of measured impedance versus frequency that appeared when the data were plotted directly on the chart lent themselves to instant visual analysis. Having mastered the technique himself, he taught it to all of his engineers and to their clients as well. Nowadays, one can find such plots in any journal dealing with microwave components.

Nowhere was this technique to prove more powerful than in the design of Wheeler's Lifesaver Antenna. Intended for shipboard IFF, its outstanding performance and elegant design made it ubiquitous; it was manufactured by the thousands and used on all ships of the Allied nations. The objective of a close match to the transmission cable was met by adding a tiny resonant circuit within the insulator that supported the quarterwave radiator. This created a double-tuned impedance match that showed up on the chart as a small loop within a maximum standing wave ratio (SWR) of 1.1—a remarkable achievement for a frequency band of 17.5%. The writer, who was a member of Wheeler's group at the time, has never forgotten the exhilaration of the day when the loop first appeared on the chart.

A similar result was achieved in the design of a submarine antenna, in which the structural demands of the environment were turned to advantage by using double tuning to achieve a match of 1.5 SWR over the same band. As an additional feature, Wheeler was able to pinpoint the location of individual reflections in the transmission line by analysis of the impedance loci on the chart, a technique that became a universal tool of microwave engineers, especially at Wheeler Labs.

Achievements such as these antennas could not be publicized at the time because of security restrictions. Nonetheless, word spread through the defense community, and Wheeler's reputation spread with it, a significant factor in his later endeavors.

Midway through 1943, a successor program to Mark III was launched by a team of U.S. and U.K. engineers, based on concerns as to the vulnerability of Mark III. Designated Mark V, it was to operate in a frequency band around 1 GHz (Mark III operated below 200 MHz). This new, higher band, almost totally undeveloped at the time, brought with it new challenges in channel selection, pulse coding, smaller antennas, and new vacuum tubes capable of performing at the higher frequencies.

As before, Wheeler rose to the occasion, contributing in almost every aspect of the work. He proposed for the most common antenna a flat diamond shape as a vertical dipole; it was adopted and used for many years. He was a constant advisor in the design of lighthouse tube oscillators, frequency-selective tuners, and delay lines for the processing of coded pulses, as well as test equipment for all purposes. These were pressure-filled years for the entire Hazeltine staff and for the industrial engineers assigned to work with them. Though Mark V was not completed in time for use in World War II, the work formed the basis for the IFF in use today.

Let us return to Mark III IFF briefly to introduce the subject of Hazeltine's post-war posture. In 1942, the need was recognized for a rendezvous beacon to guide each company of paratroopers to its staging area during the invasion of Europe. A portable sample of a British unit known as Eureka was brought to the U.S. in March 1943 for production design and manufacture. Because of the extreme urgency, it was decided to carry out the entire task within Hazeltine; accordingly, a production line was set up at the Little Neck plant. The first unit came off the line in July 1943, and hundreds were delivered soon thereafter. Incidentally, the paratroop antenna was novel in many ways. Benefiting from Lifesaver experience, the performance was excellent, yet the entire antenna and its mounting could be folded into a package about 15 inches long and a few inches in diameter; the package was spring loaded, such that it sprang into full size when released (at some risk to the operator!)

Hazeltine's success with this manufacturing experience—previously Hazeltine had constructed only models—opened the eyes of management to the opportunities and rewards of production. Mac came to the conclusion that the company's best future lay in reorganizing for the manufacture of military equipment, placing only secondary importance on the continuation of patent licensing and engineering services (which included the development of television, soon to be in color). This prospect did not appeal to Wheeler, and in November 1945 he decided to leave Hazeltine after 21 years and to strike out on his own.

Accordingly, in February 1946 Wheeler left Hazeltine, taking with him only his secretary, Jean Leonhardt. He had no well-defined plan, and decided to open an office as a Consulting Radio Engineer, soon changed to Consulting Radio Physicist when his attorney advised him that the former title required a Professional Engineering license. He set up quarters on the second floor of the "old firehouse" on Northern Boulevard, Great Neck next door to the new firehouse, Manhasset-Lakeville Company Number 4.

Almost immediately clients appeared, typically seeking advice in areas where Wheeler's reputation was already established, such as small antennas and signal-limiting devices. The most important call, as it turned out, came from the Bell Telephone Laboratories (BTL) in Whippany, N.J.; BTL was headed by Robert Poole, whom Wheeler had met during summer work for Professor Hazeltine at Stevens. Hearing that Wheeler had left Hazeltine Corporation, he sought to enlist his help to relieve an overload of work at Whippany.

By this time, Wheeler had hired Bob Novick, a young Hazeltine engineer, to build a model of an inductance meter, a device originally conceived in 1936. Bob came in July 1946 with the expectation that he would leave the following year for graduate school and a teaching career. The model was built, but the market was not ready for it, and the project was later abandoned. Bob, however, went to work on some of the tasks identified by BTL.

With the encouragement of BTL, Wheeler decided it was time to incorporate, and on 470102 Wheeler Laboratories, Inc. came into being, with himself as President.

In anticipation of Bob Novick's departure, Mr. Wheeler (as he was always known at WL) contacted Dave Dettinger, who by this time had also left Hazeltine for a job in New York City. Dave had prospered there, but found nothing to match the stimulation and the training he had enjoyed under Mr. Wheeler's tutelage at Hazeltine. He was happy to join the fledgling enterprise and arrived for work in August. On his worktable, he found waiting for him a memorandum that is reproduced on the following pages in its entirety. Not only does it describe ongoing work at WL, but it epitomizes Mr. Wheeler's meticulous style.

Wheeler Laboratories, Inc.
259-09 Northern Boulevard
Great Neck, New York

Harold A. Wheeler
President

Telephone
Imperial 645

MEMORANDUM TO: D. DETTINGER

FROM: H. A. Wheeler 470814

SUBJECT: WORK PROGRAM

The following jobs will be your first assignments. Borrow from me the specifications for both jobs so you can copy in your notebook the information you will have to have for reference. Charge directly to these jobs numbers all work which contributes directly to the jobs, including the necessary specialized study and searching for technical information. Note that the jobs have a SECRET classification which applies mainly to the system and involves very little of the information we will be handling. Probably the exact frequency assignments comprise the only SECRET information that will appear in our work. Therefore use cryptic designations (A, B, C, D, etc.) on equipment, progress reports, correspondence etc. so that the actual frequencies will not appear anywhere outside of your laboratory notebooks.

Each Friday afternoon please prepare for me a weekly progress report under all of your active job numbers. Hand this memo and your time sheet to my secretary at the end of each week.

J-119 - X-Band Converter: This job has gone through the studying stage with my attention and some assistance from Novick. It was scheduled to be completed at the end of September with a grace period until the end of October for deliveries of models and reports. Some of this time was used up getting together special test equipment and making some policy decisions. I hope we can make the latter date or soon afterward. Possibly this means that we should try to complete preliminary experiments during September so that the construction of the final model can proceed during your absence early in October.

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J-120 - X-Band Hybrid Junction - , This work should proceed in parallel with J-119 but with second priority. This means it should occupy perhaps 1/3 of your time, including such time as you may be kept waiting for model work in J-119. J-120 has gone through a more intensive period of study and conference and is probably a much more difficult job because it involves an unusually high order of precision in the models. It is scheduled to be completed the end of November with a grace period until the end of December for delivery of final models and reports.

Both of the above jobs require substantially the same test equipment. The effort which has been devoted to assembling this test equipment has so far been charged to J-119. From now on we should charge J-120 with further work and materials devoted specifically to the test equipment. (The only exception would be gadgets which are useful only in J-119)

There will always be a few things you will wish to follow up which are definitely outside of the requirements of active job assignments. This includes some attention to current publications and also the prompt entry of ideas in your notebook. These ideas which are unrelated to the Bell Labs job numbers should be entered in a personal notebook which you will receive before long. This miscellaneous work during working hours should be entered as J-101 on your time record.

One of your principal problems will be the selection of one or two junior engineers of a caliber suitable to advance rapidly and assume positions of leadership in a couple of years. I have been looking for some months without any results but it is so important that we must continue to make an effort. The best junior engineers I have found available have been unemployed because they were foreign born and therefore cannot be granted interim clearance for work on Government projects. Final clearance requires such a long time that it would not help us. Only native Born U.S. citizens are granted immediate clearance on an interim basis. We have written to quite a number of applicants who have appeared in the IRE columns and we are now awaiting their replies. In the meantime please try to think of men within your acquaintance who might be interested, and also make an outline of a systematic plan for a continuing effort which may be necessary.

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The two tasks outlined in the memorandum signaled a significant shift from the technology so well understood at Hazeltine, as each presumed implementation in hollow waveguide. Without exception, all earlier components had been designed in frequency bands where wire elements or coaxial lines served for electromagnetic transmission. This was true, for example, for both Mark III and Mark V IFF, to say nothing of the radio designs that preceded them. The new work dealt with the microwave region, where rectangular waveguides were the norm and the simple TEM mode was replaced by higher-order modes of greater complexity. New skills needed to be mastered, new equipment was required, new problems and opportunities could be expected.

The staffing directed in the final paragraph of Mr. Wheeler's memo presented a daunting challenge for a young engineer with no prior experience in recruiting. However, what is most remarkable is that Mr. Wheeler could delegate such a critical function and be capable of standing aside as it was implemented. He never interfered with the process, but confined himself to offering occasional constructive suggestions and augmenting the hiring program when direct contact was in order. The first hires serve to illustrate this arrangement.

The first engineer hired, Jesse Karp, came to Dettinger's attention via a listing in a "jobs wanted" IRE advertisement. It happens that the listing was actually out of date, and Jess was already employed. Nonetheless, Jess responded and came to interview.

The second was a more unusual case in that the engineer was female, at a time when there were virtually no women employed in design roles in the entire industry. Patricia Loth was working at Hazeltine in the testing laboratory, but neither Mr. Wheeler nor Dettinger had any working contacts with her whatsoever. However, Dettinger had made her acquaintance in a recreational organization, where he was so impressed with her quick mind and instinctive creativity that he proposed her to Mr. Wheeler as a candidate. Mr. Wheeler was understandably apprehensive, but stuck to his commitment of non-interference. Her productivity was immediate, and soon Mr. Wheeler forthrightly proclaimed his conversion and fully accepted her as a member of his team. In addition to her technical accomplishments, Pat showed a faculty for training newcomers; ultimately she achieved a national reputation in her specialty.

The third hire responded to an ad placed in the IRE Proceedings. Ned Spencer, at work in Buffalo, N.Y., scouted Mr. Wheeler's publications, was impressed and made an appointment for an interview. Ned later became the manager of the antenna laboratory in Smithtown. Shortly afterwards, Peter Hannan came to Mr. Wheeler's attention through contacts at Stevens. He was hired for the summer of 1948 and returned the next year on a permanent basis; this pattern became common in subsequent years.

These engineers were soon augmented by three young engineers with experience at Hazeltine, where they were well known to both Mr. Wheeler and to Dave Dettinger—namely, Roderick Lowman, Henry Schweibert and Frank Williams. Soon after responding to a WL advertisement, Herbert Rickert was enlisted from the University of Illinois, where Mr. Wheeler arranged to have him interviewed by a distinguished colleague, A. L. Samuels.

It is tempting to extend this survey of early hires, but the focus of this chapter is Mr. Wheeler himself. What needs recounting is the burden of management he carried over and above his unceasing contribution of technical ideas and his personal consulting tasks. From the start he handled the legal and financial affairs of the company with only the assistance of one accountant, August Belfiore. He met repeatedly with current and prospective clients, negotiated contracts, and established working relationships. He planned for space and facilities, including machine shops and air conditioning. On the advice of Dave Dettinger, he hired an experienced machinist from Hazeltine, Al Paskevich, and then relied on Al's advice in hiring others. He hired secretaries and developed procedures for their work and for the production of engineering reports. He arranged for military security for the WL facilities (using ADT) and personnel clearances for staff members. He provided for maintenance and services. He instituted a retirement plan. Always concerned about the social life of the Labs, he arranged luncheons for special occasions such as birthdays, arranged picnics at Jones Beach, encouraged lunchtime sports, and hosted an annual dinner dance. The list goes on.

Mr. Wheeler had a knack for finding the right person for the job to be done. In his preliminary notes for this volume, he observes of his secretary, Jean Leonhardt, in an understatement, "She was a great help in the formative years." To this the writer would add that Jean was vivacious, knowledgeable, uniformly friendly and helpful. She later married one of the WL engineers, as did other secretaries.

Al Paskevich was not only a crackerjack machinist and demanding shop manager, a perfectionist at his trade; he was also a "key member of our staff" who managed in his quiet way to train a generation of engineers in the skills of mechanical drawing and construction.

For maintenance Mr. Wheeler selected a mail deliveryman, Charlie Wanskowski; there could not have been a happier choice. Charlie was utterly devoted and conscientious, always cheerful and willing. It is no exaggeration to say that he was loved by the entire staff.

In the case of Dave Dettinger, his initial WL engineer and later Chief Engineer, Mr. Wheeler wrote in his notes the following words, which are treasured by the writer: "In retrospect, it was Dave Dettinger, more than any other one person, who deserves credit for the development of Wheeler Laboratories up to an outstanding working organization. I take credit only for giving him and the other leaders a free rein, after soliciting and taking their advice, and providing company support."

Returning to the two tasks mentioned previously, they turned out to be the first small steps toward the technical specialty for which the Labs was best known, namely monopulse radar. First, though, a little background is in order.

In World War II, the need was recognized for tracking radar to provide all-weather automatic guidance for anti-aircraft batteries. Several types came into use before the war's end, notably the SCR-584 that saved the Anzio beachhead. Unfortunately, in the wartime rush, these units were designed individually, and their characteristics were poorly matched on the one hand to the search radars which identified their proper targets, and on the other hand to the gun controls themselves. Hence, it became a priority matter for the Army to repair this situation after the war was over.

The Army turned to BTL for a coordinated system, known as T-33; BTL in turn came to Wheeler Laboratories for some of the RF components of both the search and track radars, including the two mentioned in Mr. Wheeler's memo. In the midst of this work, a BTL engineer by the name of H. Trent Budenbom (always abbreviated to Bud) conceived a better way to perform the track function, and gave it the catchy name of monopulse (because in theory it was capable of determining target direction from a single radar pulse). He built a "lash-up" (his words) and demonstrated the potential of the concept. Next, he went to his management and proposed that his crude design be "Wheelerized."

Accordingly, the Labs work expanded rapidly, ultimately resulting in a neat package that met the objective and did so over the entire designated band of frequencies. New words entered the art: four-horn feed, monopulse comparator, channel phase equality.

Fortune smiled on the Labs in 1951, when the recruiting program that had been gradually developed yielded a bumper crop. Seven men joined WL: Henry Bachman, Bill Rohn and Eric Kraemer of PIB (better known as Brooklyn Poly; PIB continued to be WL's most prolific source of talent), Bob Wengenroth of RPI, Walter Kahn of Cooper Union, Herb Sawyer of MIT and Bruce Schwab of the University of Maine. These seven nearly doubled the engineering staff, but fortunately, the work expanded rapidly enough to absorb their efforts.

It happens that the monopulse initiative coincided with the Army's plan to bolster air defense by augmenting guns with anti-aircraft missiles. A program was hatched with the code name Nike; BTL was selected to lead it. The first phase was called Nike-Ajax, and to speed the task BTL employed, where possible, components of previous designs. This included the lens-type antenna of the T-33 tracking radar.

A lens was a sensible choice, in that it placed the bulky package of monopulse feed, comparator and connecting waveguides behind the aperture where it would not introduce reflections, as would have been the case with a front-fed reflector. The marriage of the various components was handled by BTL mechanical engineers (the standard arrangement BTL used with WL) and acceptable performance of the tracking radar was achieved in record time.

Almost immediately thereafter WL was asked to engage in critical tests of Nike-Ajax, with the objective of identifying potential improvements. The results indicated that the monopulse package was satisfactory, but that the lens antenna was deficient. Here came a dramatic breakthrough. Pete Hannan invented a totally new concept for the focusing element, namely, the twist-reflecting Cassegrain antenna.

Pete's concept was scrutinized by Mr. Wheeler and enthusiastically endorsed. When it was presented to the BTL project leader, Richard Hough (later to become President of ATT Long Lines), he authorized its development on first hearing. The design was a stunning success, and its application in the Nike-Hercules radar helped make that system a world favorite. Beginning with that example, Cassegrain antennas in one form or another have come to dominate satellite systems and many other applications as well.

The Nike work continued for twenty years, yielding powerful systems such as Nike-Zeus and ultimately Project Safeguard. These later systems introduced many features new to the antenna art, including multimode feeds, fences to overcome multipath, huge Luneberg lenses for tracking of multiple targets, waveguide simulation of mutual coupling among phased array elements, and others too numerous to describe. Mr. Wheeler played a central role in the later systems, supplying concepts for variable beamwidth and for artificial dielectric lenses suited to multibeam operation.

BTL delegated many other tasks to the Labs. To mention only a few they included: a Ku-band radar, a rapid-scan radar (APQ-49), guidance antennas for ballistic missiles such as Titan and Thor, and the naval radar antenna previously mentioned. All these benefited from Mr. Wheeler's advice and review.

Other major defense contractors came for assistance. Sperry, having heard of Hannan's Nike-Hercules antenna, came to inquire as to whether WL could design for them a special antenna capable of both tracking a target and supplying illumination for a homing missile. Dettinger, meeting with the Sperry project manager, suggested a variant of the twist-reflecting Cassegrain (actually an independent, on-the-spot reinvention of an idea Hannan had recorded earlier in a notebook) and made a quick estimate of cost. Lamb informally accepted both estimates at the same meeting, and subsequently confirmed by contract. Mr. Wheeler was delighted; this was WL's largest single project to that time, as measured in dollars committed. George Vaupel, who joined WL from Cooper Union in 1954, was appointed project leader and carried this major project through to a completely successful design product. As a critical element of the SPG-55A radar for Tartan missile guidance, it became an integral part of naval weaponry.

Sperry brought another task, a microwave filter assembly for use in an electronic warfare suite. Raytheon came for an improvement to the Hawk missile antenna. Sylvania came for design studies of a transportable antenna for ballistic missile detection. Westinghouse came for studies of a multibeam naval radar. General Electric came for consultation on a special monopulse radar.

Two commercial companies sought the help of Mr. Wheeler and his laboratory. One was Phelps Dodge Copper Products, who needed expert assistance in promoting Styroflex, a new type of coaxial cable. Communications Products, a small company in New Jersey that specialized in manufacturing communication antennas for base stations and related equipment, soon followed. Here came another breakthrough; Mr. Wheeler was able to devise for them a novel vertical array antenna (they called it the Stationmaster) which outperformed its competition at a fraction of the cost. The result—Stationmasters dot towers and mountaintops all over the world; about a half million were made. These antennas were most notable; other products included other antenna types, plus rigid coaxial lines and large waveguides, all refined by WL.

At this juncture, it is appropriate to note that all the work described above was performed on a time-and-material basis. WL established a standard hourly rate ($12 per hour for its engineers, $24 for Mr. Wheeler during most of its operating years) and an agreed overhead rate. The fact that commercial clients accepted this rate structure eased military acceptance of WL subcontracting arrangements. Exceptions to the time-and-materials approach were made only for direct military contracts, where cost-plus-fixed-fee was accepted instead. Several tasks fell into this category; these arose out of Mr. Wheeler's personal expertise.

One was a study of microwave breakdown initiated by the Navy's Bureau of Ships. The principal work was carried out by Bob Wengenroth and Dave Dettinger and yielded a tutorial report with recommended practices. The Navy was pleased and asked that WL set up for them of permanent test facility; this was declined as leading only to routine work.

A second was a study for the Army of possible techniques for detecting non-metallic mines. This request arose out of Mr. Wheeler's reputation as inventor of the SCR-625. Henry Schwiebert worked diligently with Mr. Wheeler, fabricating devices and testing them in a plot adjacent to the Great Neck building. It was to no avail; to everyone's disappointment the results were negative. No solution has yet been found.

A third was the development for the Signal Corps of a novel device pioneered at WL by Mr. Wheeler and Schwiebert, a set of fixed and rotary steptwists to permit angular alignment and/or rotation in rectangular waveguide. These beautiful products of the WL shop were universally admired.

The ever-increasing demand for the design of highly directive antennas pointed to the need for specialized testing capabilities. As early as 1953, Mr. Wheeler began a search for a suitable location on Long Island. He found one in Smithtown and in June of that year, persuaded the owner to sell a 12-acre strip of land that lay across a valley between two hills. At the near end could be placed a laboratory building with antenna mounts on its roof, and at the far end a source building, such that radiation patterns could be recorded with minimal interference from the ground between. Fred Van Davelaar, who joined WL in 1950 from Hofstra, designed the complete facility, including erection equipment to position antennas on the mounts, and operation began in 1957.

It should be borne in mind that during all these years, Mr. Wheeler was carrying what for an ordinary engineer would have been a full-time load of consulting work in addition to managing the Labs and guiding its technical work. Most of these tasks did not involve WL personnel. One that did is of special importance, dealing as it did with a vital Navy program to establish direct communications with submerged submarines by using very low frequency (VLF) radio waves. The frequencies employed were in the range of 15 to 30 kilocycles, just at the upper end of the voice spectrum. Even at these frequencies, a signal can penetrate only a few meters into the ocean; however, with sufficient transmitter power it can be received around the world.

Mr. Wheeler was asked by the prime contractor, DECO of Leesburg, Virginia to design a mammoth antenna capable of radiating the immense power required (1 megawatt continuously) with an efficiency of 50%. What was envisioned was essentially to convert a two-mile long peninsula at Cutler, Maine into the largest antenna ever built. This Mr. Wheeler accomplished with a grid of wires supported on 13 towers 1000 feet above the ground over a ground plane of wires extending into the ocean all around. The final assemblage is so mind-boggling that it has become a tourist attraction! At a certain point in the program, Mr. Wheeler arranged for a scale model of the antenna to be constructed in the basement of the Great Neck laboratory to permit some specialized measurements to be made. Aside from this, Mr. Wheeler required almost no WL assistance.

On top of these consulting jobs Mr. Wheeler was also asked to serve on two Department of Defense advisory committees. One of these (1950-1953) dealt with guided missiles; Mr. Wheeler chaired the Panel on Guidance and Control. The second (1962-1965) was the Defense Science Board; other members included Dr. Harold Brown, later Secretary of Defense, and Dr. Eugene Fubini, later assistant Secretary of Defense.

As if the above activities were not sufficient to occupy his time, Mr. Wheeler managed to develop and publish a total of 18 Monographs over this period, addressing a variety of subjects. He was continually active in professional affairs, helping to found the Long Island Chapter of the IRE (now merged into the IEEE), serving as its chairman, and also presenting frequent lectures. For the Labs, he not only presented timely lectures but also spearheaded WL participation in IRE convention exhibits, each of which had a novel tutorial flavor.

1959 was an important year for Wheeler Laboratories; it was the year in which Mr. Wheeler sold the Labs to the Hazeltine Corporation. For some time he had been concerned over the potential vulnerability of the relatively small, privately held corporation. He had explored various possibilities of union with some larger electronics company, and ultimately decided to join with the company he knew so well. According to Mr. Wheeler’s notes, “WL was acquired for a consideration of 10,000 shares of Hazeltine stock, having a market value of about $300,000... I was again appointed to the Board of Directors of Hazeltine Corporation with the title of Vice President.”

There was little or no immediate impact of the union on the work of the Labs. BTL continued to support work on the Nike program and other tasks, as did other clients. Differences in management practices were gradually resolved over the next decade. As a result, Hazeltine took the opportunity to involve WL engineers in their bidding for military procurement contracts and in support of research and development activities. One example was the need to overcome one of the technical limitations that prevented the use of IFF interrogators in high performance aircraft, thereby restricting such aircraft, for the purpose of identification, to the engagement of enemy aircraft only when within visible range.

The basic limitation for an airborne interrogator was that the IFF antenna would be too large for installation on the aircraft, and for integration with the airborne radar antenna. A major advance in the state of the art for IFF antenna design permitted WL engineers to overcome this limitation and to integrate a practical IFF interrogator antenna with the airborne radar for the F-4 aircraft. This resulted, beginning in 1966, in Hazeltine developing and manufacturing the very first airborne interrogator system, the AN/APX-76. The new antenna technology employed "invisible dipole" antenna elements mounted on the radar antenna so that the IFF antenna could be mechanically scanned with the radar antenna, achieve the required antenna pattern characteristics, and not interfere with (be invisible to) the performance of the radar. Since its introduction, the AN/APX-76 has become the most widely used airborne IFF interrogator.

Among the additional work for BTL was the design of two antennas for Telstar: one for the ground tracking radar, itself an adaptation of the Nike-Hercules, the other for the communication satellite itself.

With the advent of the laser in 1962, WL initiated an exploratory program, headed by Henry Redlien and Bob Kaplan. Redlien had previously made major contributions to the Nike program after joining the Labs in 1950 from Stevens; Kaplan had returned to WL after completing his doctorate at Cornell. The results were noteworthy, but after five years, it became apparent that WL was being outpaced by the explosive growth of the new technique at other organizations with greater resources, and the effort was terminated.

Mr. Wheeler's invaluable support to all of these ongoing tasks was abruptly preempted in 1965 by Hazeltine's litigation with Zenith Radio Corporation. The matter began with a patent infringement suit against Zenith, but escalated when Zenith countersued, claiming antitrust violations. The countersuit won in the original trial, with damages assessed at twice the book value of Hazeltine! The charge was basically invalid, and after protracted litigation a much-reduced penalty was assessed. (Even this was regarded as fraudulent by Mr. Wheeler, who viewed the entire process as an attack on the patent system.) Throughout this entire episode Mr. Wheeler's encyclopedic knowledge of the technology and history of the subject played a central role in Hazeltine's defense.

When the threat to Hazeltine's survival finally passed, major changes occurred in the company's top management. New directors were found to replace those who left during this difficult period. Hazeltine had a new president, and Mr. Wheeler was designated Chairman of the Board. In this role, he was able to institute two important reforms in the company, both long overdue: air-conditioning in all plants (handled by Fred Van Davelaar, who had rejoined Hazeltine), and an unconventional retirement plan (which anticipated the later requirements of ERISA.)

In 1968, at the age of 65, Mr. Wheeler "retired" from Hazeltine, but continued under contract as "Chief Consulting Engineer" until his "final" retirement in 1984. Even this was not final, in the sense that he continued under a retainer, writing books recording the history of the company at his new home in California until his death in 1996. He had outlived his wife Ruth and his son Alden, and was survived by his two daughters, Dorothy and Carolyn. At his funeral, Bachman was able to be present to offer a heartfelt tribute. Walter Kahn prepared and delivered a similar tribute at the subsequent IEEE AP-S International Symposium Award Banquet.

When Mr. Wheeler retired from the company management in 1968, Henry Bachman was made President of Wheeler Laboratories in his place. Henry had the misfortune to take the helm just as a national recession was about to shake the country, causing a severe downturn in the electronics industry. As might be expected, contractors such as BTL began to withdraw from subcontracts in order to preserve their own capabilities. The result was inevitable—layoffs at WL. Almost half of the WL engineers were terminated and began seeking employment elsewhere. The writer, who had left WL in 1961, remembers vividly receiving phone calls from former coworkers and attempting to provide suggestions. It was a painful period for everyone concerned.

Finally, in 1970 the remaining engineers were transferred to Hazeltine and integrated into a group designated Wheeler Laboratory; Bachman became a Vice President of Hazeltine. The Great Neck laboratory had been closed in 1969, but for some years Hazeltine continued to use the Smithtown antenna facility for testing antennas. Ultimately Smithtown was closed also, to be replaced at Greenlawn by a new state-of-the-art facility, including an indoor anechoic chamber designed by Bachman. It was dedicated in 1993 as the "Harold A. Wheeler Communication and Antenna Systems Laboratory (CASL)."

The CASL is truly a fitting tribute, a living memorial to a brilliant engineer with a lifelong love affair with radio waves, an indefatigable explorer of their characteristics and capabilities, and a creative genius in their application. Harold Wheeler unfailingly practiced the pursuit of technical excellence, and in so doing inspired all of his engineers to the same ideal.

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[1] 1. Frederik Nebeker, *Harold Alden Wheeler: A Lifetime of Applied Electronics* (Proceedings of the IEEE, August 1992), vol.80, no. 8

2. Frederik Nebeker, *Sparks of Genius: Portrait of Electrical Engineering Excellence (IEEE Press, 1994)*

[2] 1. Harold Alden Wheeler, *Hazeltine the Professor* (Hazeltine Corporation, 1978)

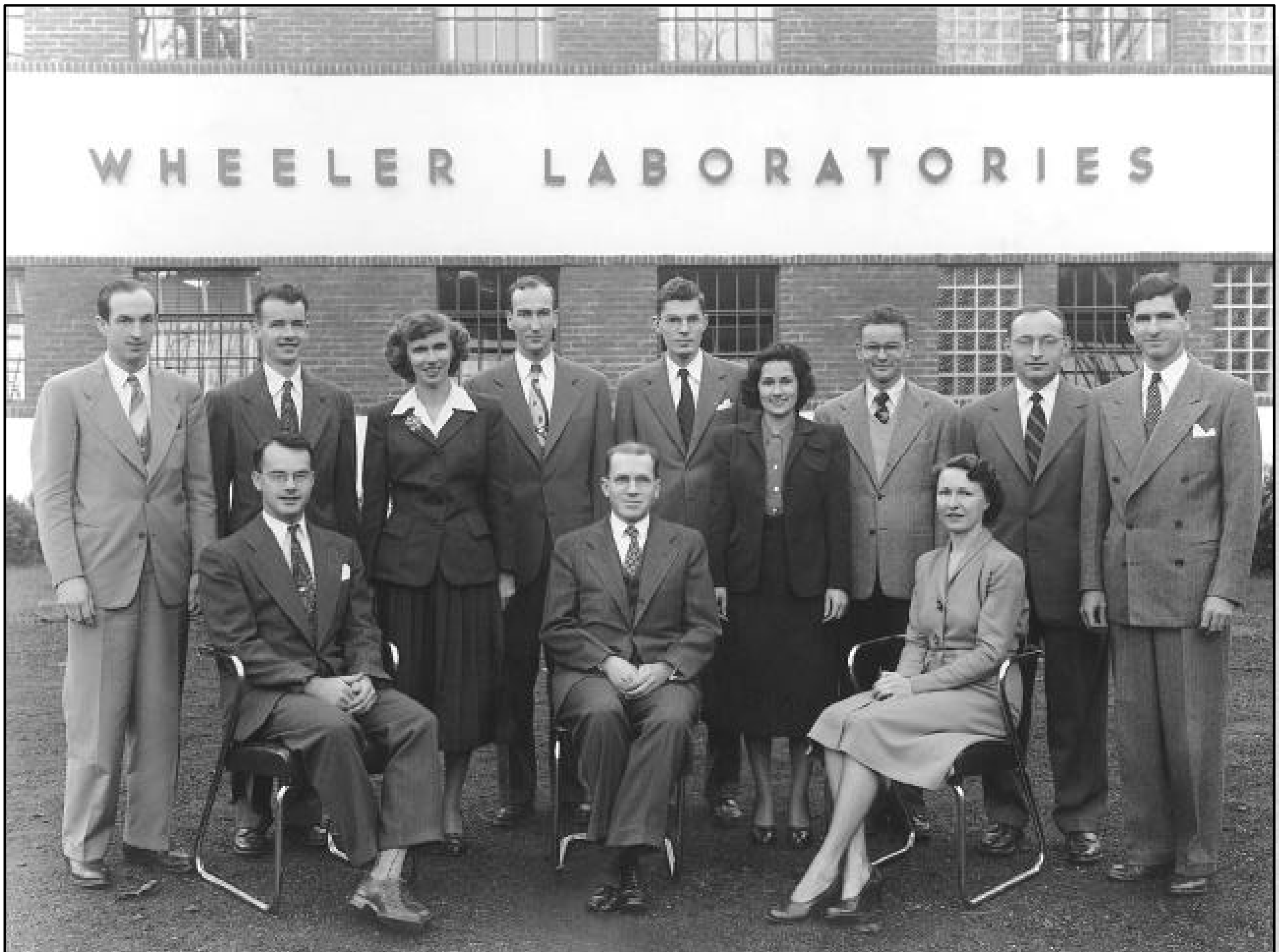
2. Harold Alden Wheeler, *The Early Days of Wheeler and Hazeltine Corporation - Profiles in Radio and Electronics* (Hazeltine Corporation, 1982)

3. Harold Alden Wheeler, *Hazeltine Corporation in World War II - IFF* (Pathfinder Publishing, 1993)

SECTION III

COLLECTED MEMORABILIA

(Editor's Note: Assembled within this section are various materials, including photos both from Mr. Wheeler's files and from other contributors, that reflect the people, places, and products of Wheeler Laboratories.)



Great Neck staff at new facility-1949

Seated *(left to right)* **Dave Dettinger, Harold Wheeler, Jean Sawyer**

Standing *(left to right)* **Rod Lowman, Henry Schwiebert, Pat Burgmyer (nee Loth), Herb Rickert, Bob Schott, Rose Rickert (nee Belfiore), Pete Hannon, Al Paskevich, Ned Spencer**

Wheeler Engineering Staff - 1958

First Row *(left to right)* **Harry Redlien, Herb Rickert, Ned Spencer, Dave Dettinger, Harold Wheeler, Frank Williams, Pete Hannon, Pat Burgmyer (nee Loth), Fred Van Davelaar**

Second Row *(left to right)* **Jerry Hanfling, Bob Hanratty, Dave Lerner, Bob Wengenroth, Henry Bachman, George Vaupel, Don Hastings, Joel Becker**

Third Row *(left to right)* **Lou Appleman, Al Lopez, Bob Kaplan, Ron Rudish, Pete Lubell, Bill Meserole, Irwin Koffman, Paul Meier**

Fourth Row *(left to right)* **Ray Tuminaro, Warren Elliot, Hal Guthart, Dick Peritz, Bob Puttre, Murray Novick, George Knittel, Roger Segall**

Wheeler Engineering Staff - 1966

First Row *(left to right)* **Dick Peritz, Irwin Koffman, Jerry Hanfling, Bob Hanratty, Pat Burgmyer, Pete Hannan, Ned Spencer, Harold Wheeler, Frank Williams, Henry Bachman, Harry Redlien, George Vaupel, Don Hastings, Joel Becker, Warren Elliot**

Second Row *(left to right)* **Sid Arnow, Bill Colosa, Paul Sroka, Marty Teichman, Greg Charlton, Ron Rudish, Sid David, Mike Lubelski, Vinny Mazolla, Al Lopez, Dick Frazita, Lou Botte, Gerry Dorman, Lawrence Papaleo**

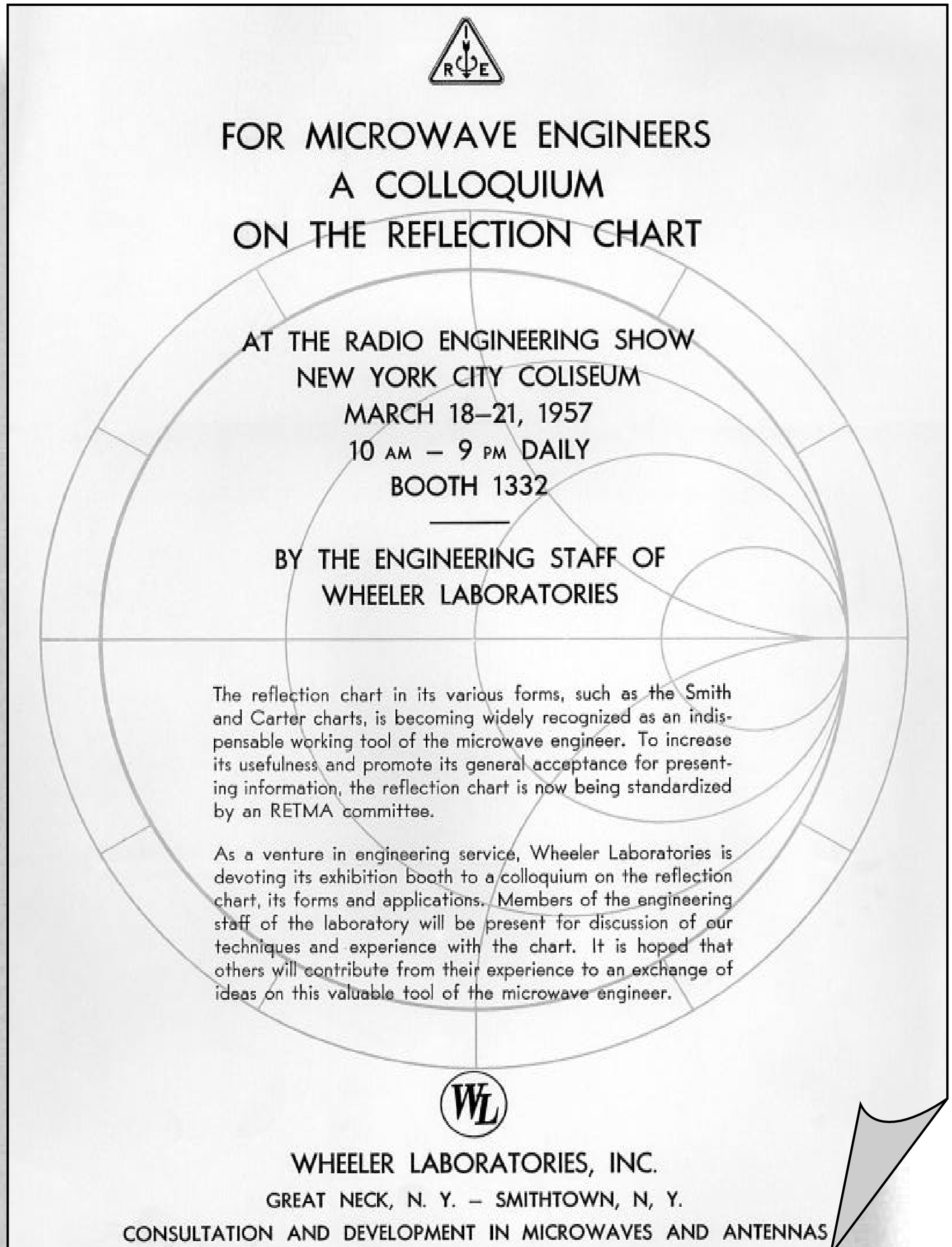
Third Row *(left to right)* **Joe Gaudio, Jim Papadopolous, Bob Millet, Rich Metrick, Brian Cullen, Jack Rosa, Dick Lodwig, Lou Walshak, Jim Maune, Rich Biondi, Joel Carpet, Manny Balfour, Walt Mohuchy**

Fourth Row *(left to right)* **George McGovern, Jeff Nemitt, Stu Litt, Herman Bilenko, George Scherer, Fred Engleking, Herman Heinemann, Ed Pinck, Howard Edelman, Chris Schlotterhausen, Len Steffek, Charlie Brozen**

Fifth Row *(left to right)* **Dick Giannini, Bob Puttre, Clive Knowles, Ron Schineller, Rich Kumpfbeck, Dick Flam, Mel Field**

Wheeler Laboratories Reunion - 1993

...on the occasion of Harold Wheeler's 90th birthday



FOR MICROWAVE ENGINEERS
A COLLOQUIUM
ON THE REFLECTION CHART

AT THE RADIO ENGINEERING SHOW
NEW YORK CITY COLISEUM
MARCH 18–21, 1957
10 AM – 9 PM DAILY
BOOTH 1332

BY THE ENGINEERING STAFF OF
WHEELER LABORATORIES

The reflection chart in its various forms, such as the Smith and Carter charts, is becoming widely recognized as an indispensable working tool of the microwave engineer. To increase its usefulness and promote its general acceptance for presenting information, the reflection chart is now being standardized by an RETMA committee.

As a venture in engineering service, Wheeler Laboratories is devoting its exhibition booth to a colloquium on the reflection chart, its forms and applications. Members of the engineering staff of the laboratory will be present for discussion of our techniques and experience with the chart. It is hoped that others will contribute from their experience to an exchange of ideas on this valuable tool of the microwave engineer.

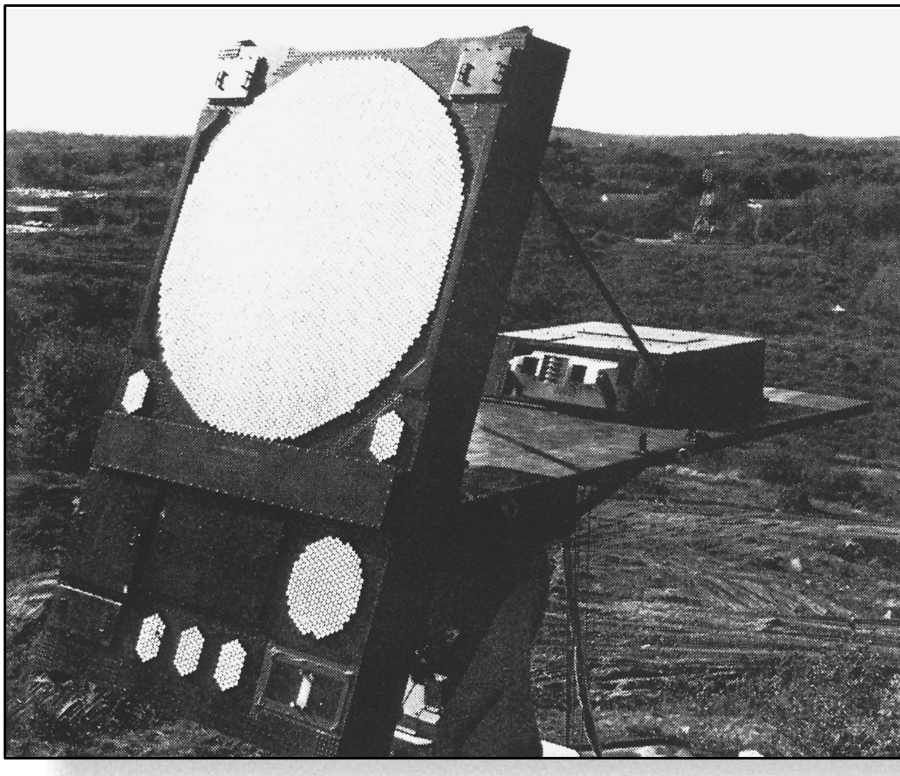
WL

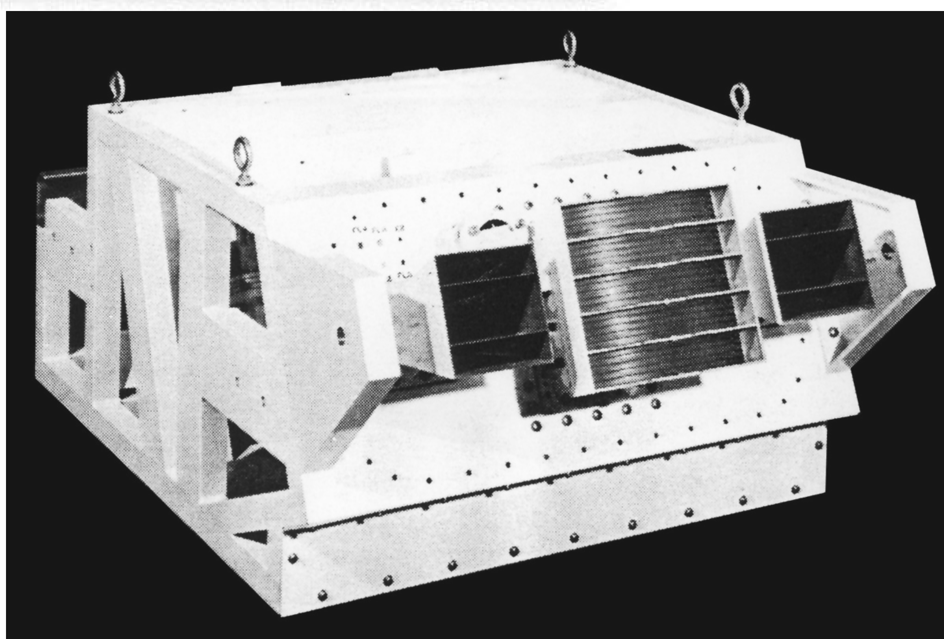
WHEELER LABORATORIES, INC.
GREAT NECK, N. Y. – SMITHTOWN, N, Y.
CONSULTATION AND DEVELOPMENT IN MICROWAVES AND ANTENNAS

WL Colloquium at IRE Show - 1957

WL Smithtown - 1957

Top **- Antennas under test**
Bottom, left **- Test-range source antennas**
Bottom, right **- Practical jokes**

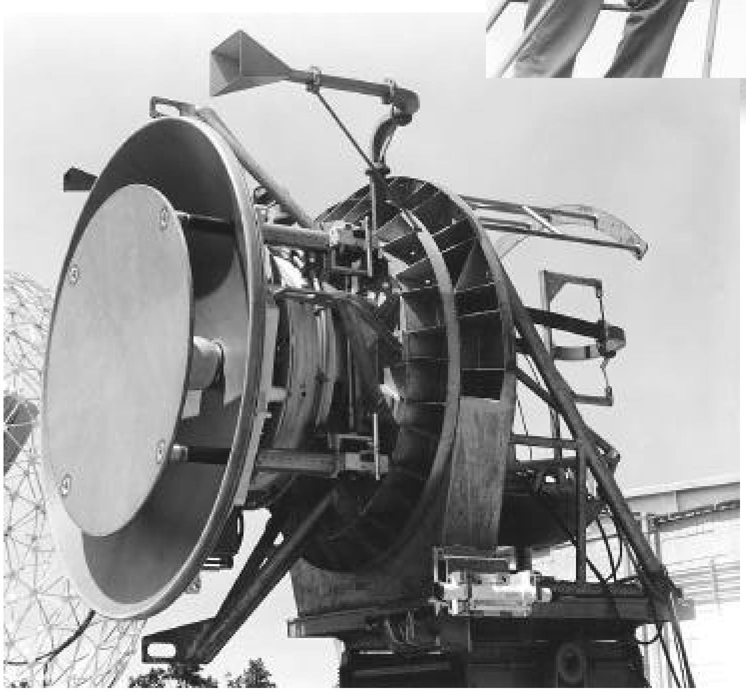




WL Contributions to Patriot - 1974

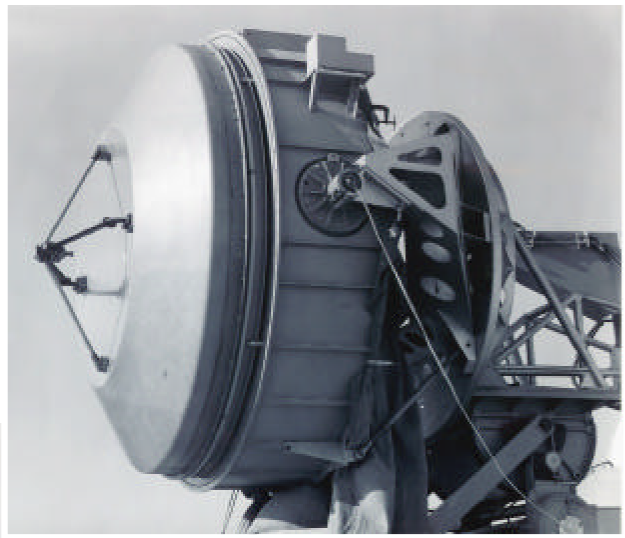
***Top* - Array lens developed at WL/ST (Courtesy of Raytheon Company)**

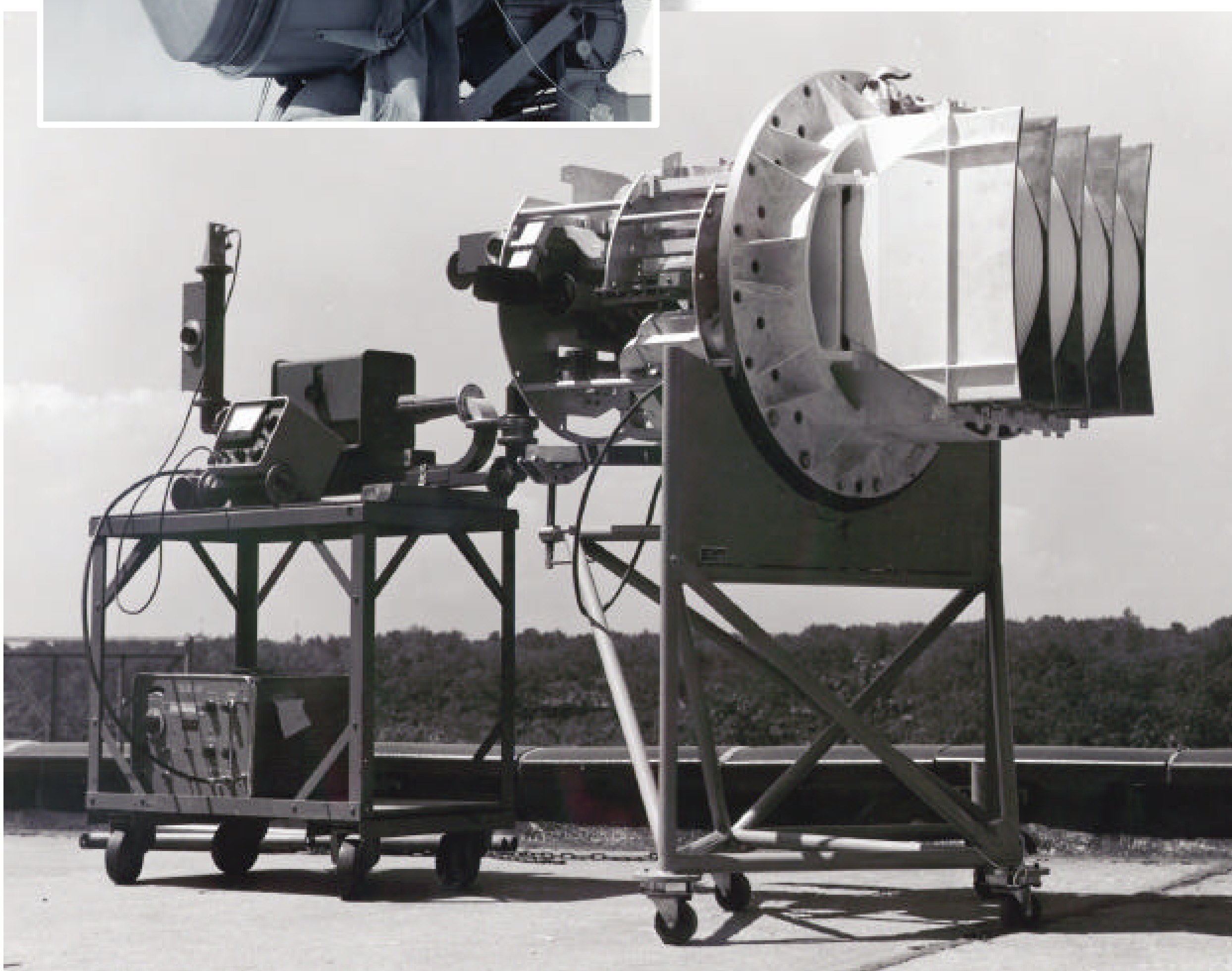
***Bottom* - Feed assembly developed at WL/GN (Courtesy of Raytheon Company)**



WL Antennas

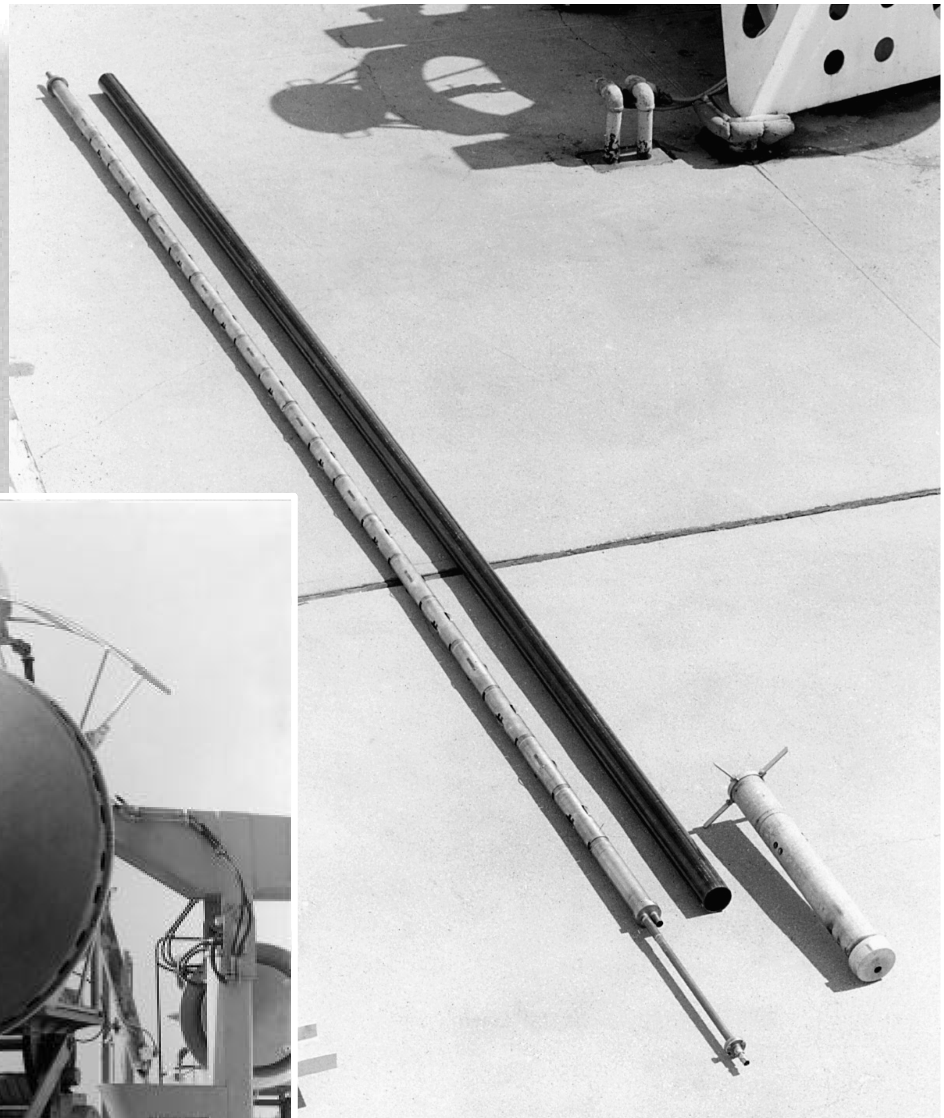
Top, left **- Cassegrain antenna for Nike-Hercules system**
Top, right **- Attaching sub-dish of a Cassegrain antenna**
Bottom **- Variable beamwidth Cassegrain antenna**





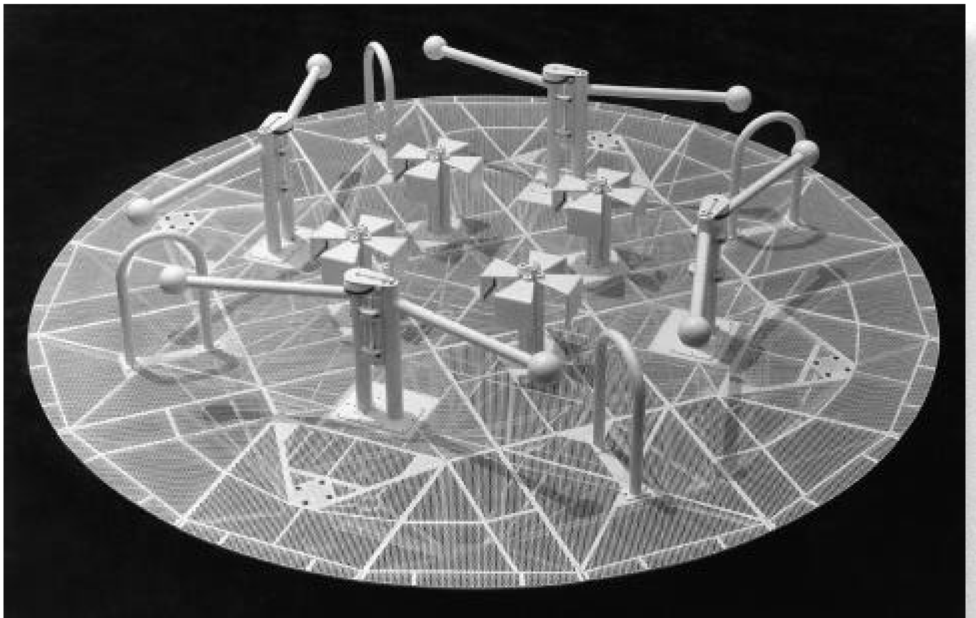
WL Antennas

Top, left **- Dual-feed Cassegrain antenna for SPG-55A system**
Bottom **- Independent control monopulse feed for large Cassegrain Nike-Zeus antenna**



WL Antennas

Right **- The Powermaster antenna**
Left **- Telstar communication satellite tracking antenna**



WL Antennas

Top **- Dazzle antenna feed**

Bottom **- Dazzle antenna**

WL Array Antennas

Top **- Cylindrical 40-foot diameter phased array**

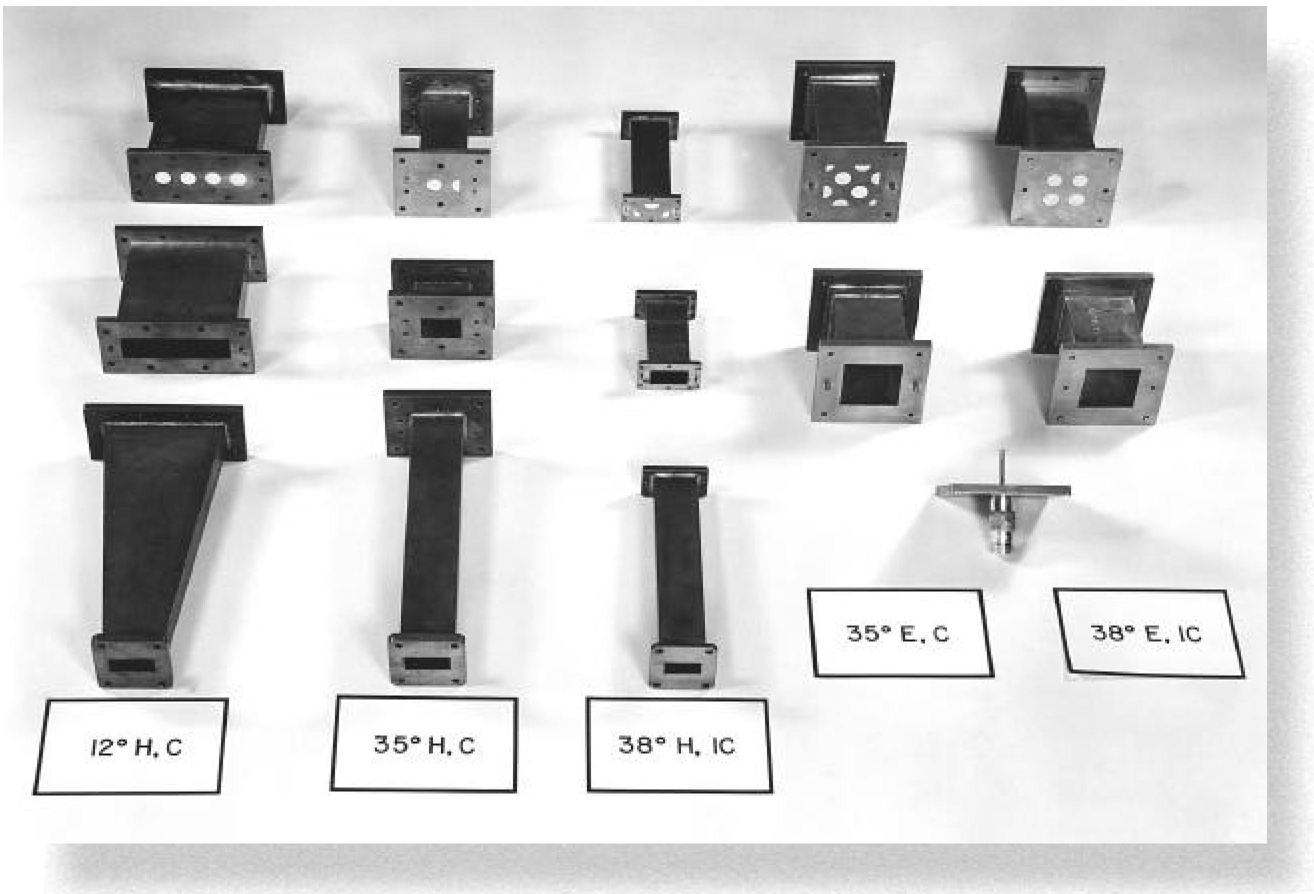
Bottom **- Planar 26-foot long open array for air traffic control**

Steptwists

Inset **- Rotary Steptwist for RG-96/U waveguide**
Bottom **- Fixed Steptwists**

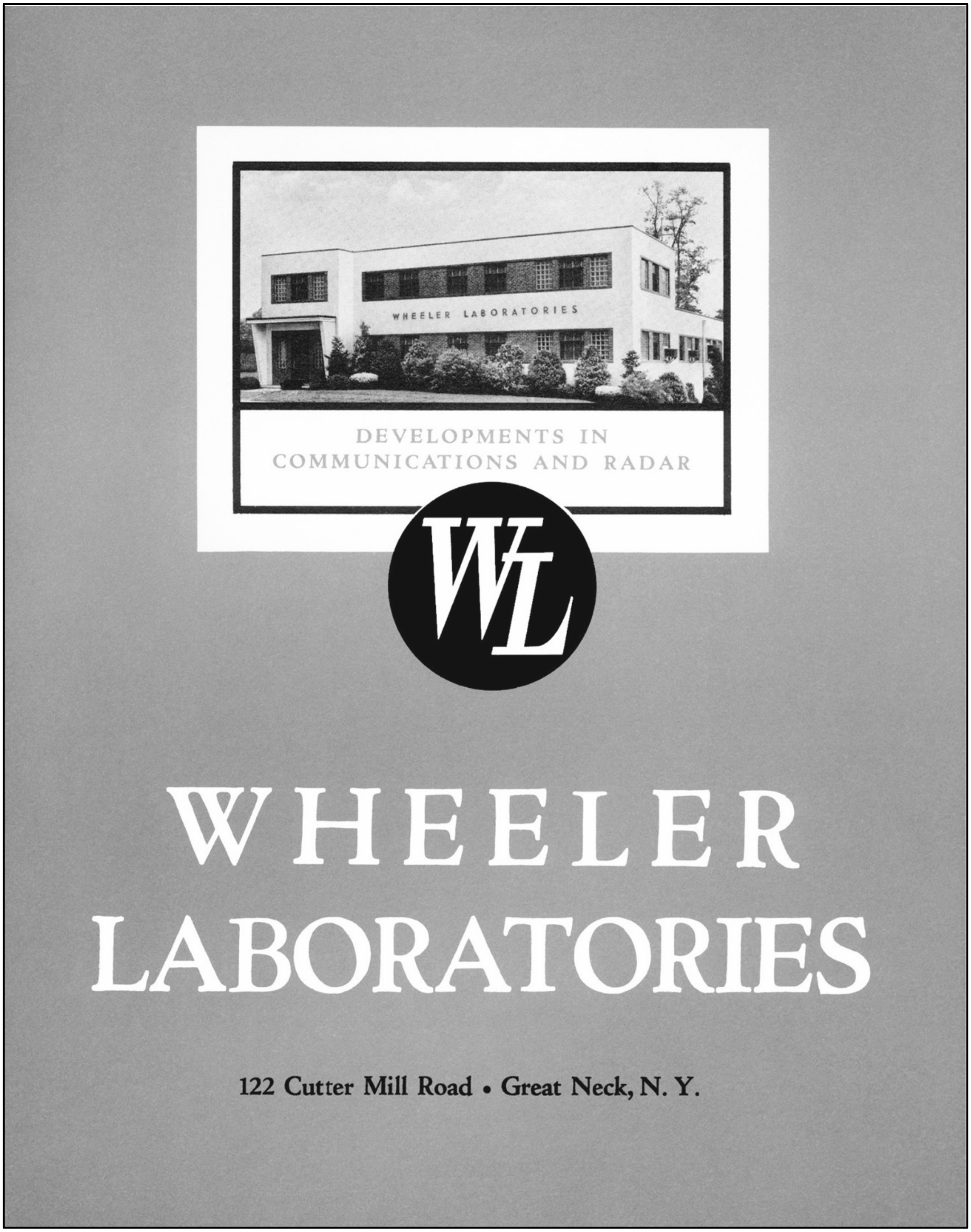
WL Simulators

- Parallel-plate simulator

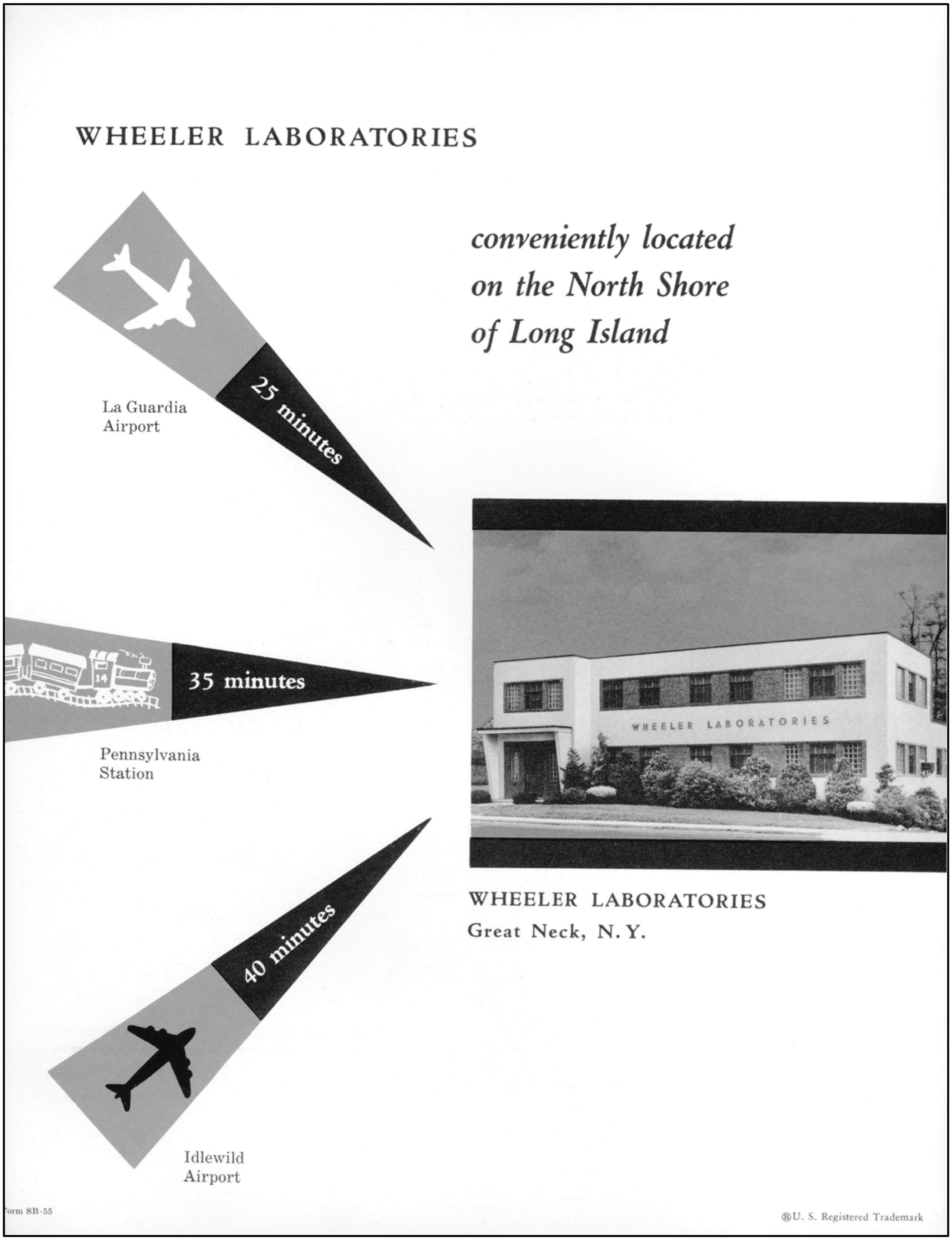


WL Simulators

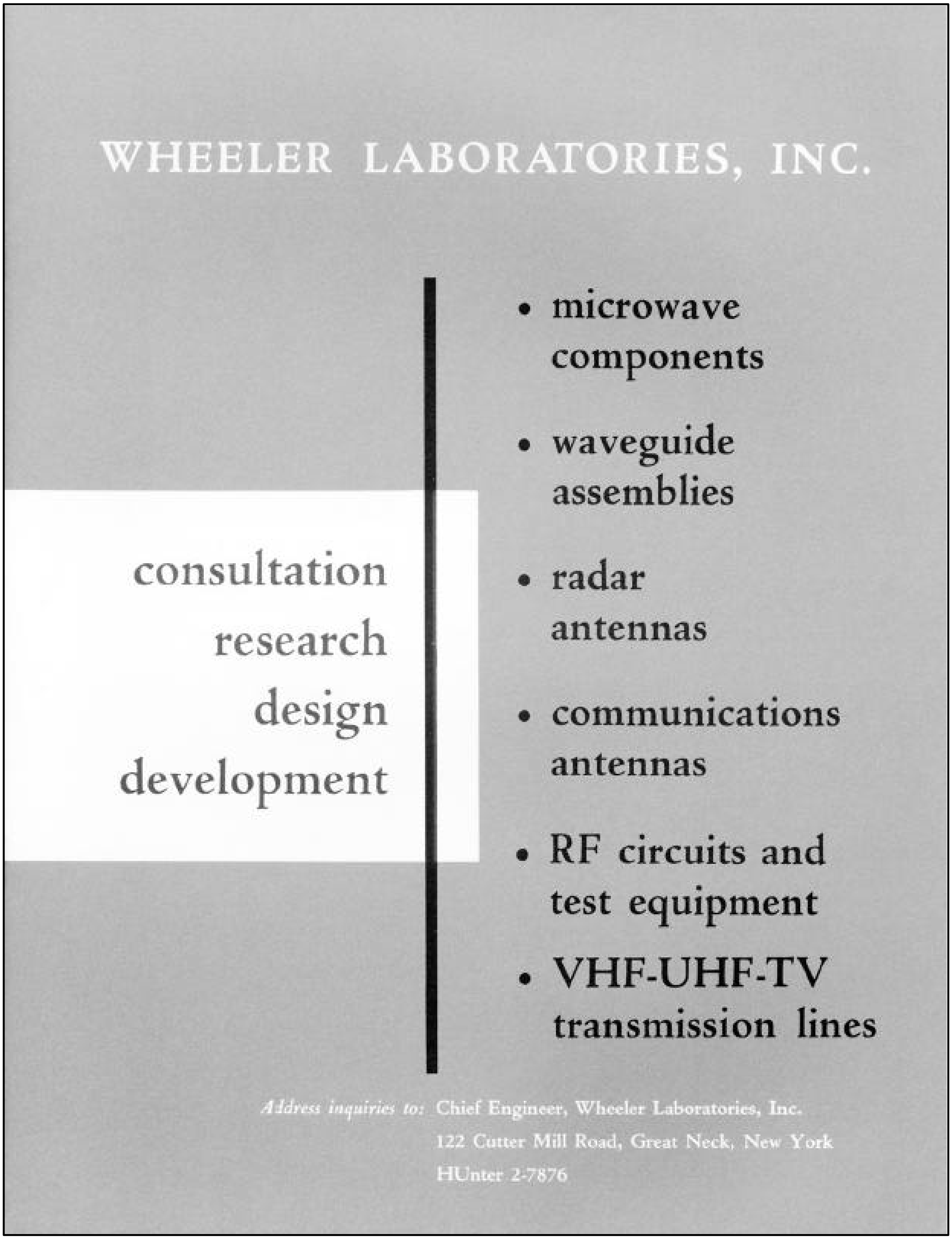
- For measuring active reflection of an infinite phased array



WL Brochure - 1955



WL Brochure - Cont



WL Brochure - Cont

In the field of microwave engineering, Wheeler Laboratories occupies a unique position as a laboratory devoted exclusively to consultation, design, and development. Working as an independent adjunct to some of the largest laboratories in the country, it has established a reputation for sound design and original invention. Its experience and ideas, supplemented by imaginative experimental techniques and powerful analytical methods, have contributed to major advances in the microwave industry.

Under the guidance of Harold A. Wheeler, its founder and president, the Wheeler Laboratories has shown continuous growth since its founding in 1947. The staff of engineers, starting with a small, selected group of experienced individuals, has been supplemented with carefully chosen recent graduates until now in 1955 it numbers about twenty engineers. Supporting facilities, including model shop, drafting, and secretarial personnel, have kept pace with the expanding program.

The present main building contains spacious laboratory rooms provided with the latest electronic test equipment, and a model shop utilizing modern precision machining facilities. In addition to the main building in Great Neck, a second building especially designed for antenna development and testing is planned for construction on a large plot of ground in Smithtown, Long Island.

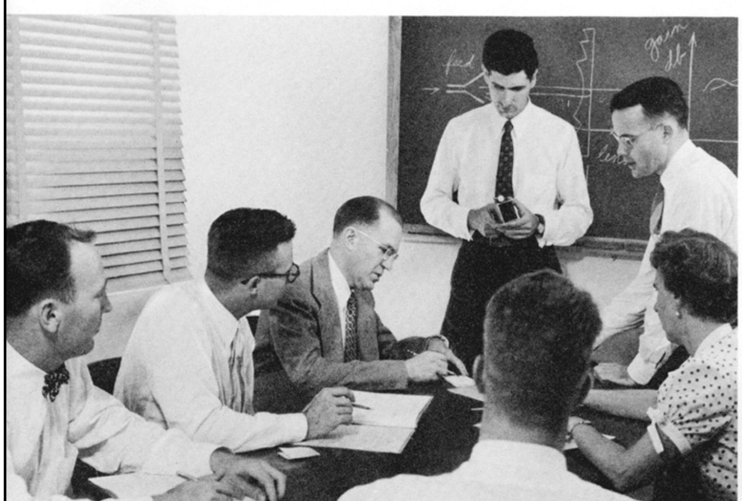
Wheeler Laboratories specializes in the development of custom-made assembly and component designs for its many industrial and military clients. Some indication of the diversity of the problems which have been successfully solved may be found in the variety of developments presented in this brochure. To those companies with unusual or difficult microwave problems, Wheeler Laboratories offers the expert services of its staff and supporting facilities for consultation, design and development.

2

WL Brochure - Cont

Harold A. Wheeler serves both as president of the Wheeler Laboratories and as director of the laboratory activities. Previously vice-president and chief consulting engineer of Hazeltine Electronics Corporation, he served 22 years with that company and its affiliates. He is the holder of over 150 U. S. patents and is a frequent contributor to the engineering journals. His chief interests and accomplishments have been in the fields of wave filters, antennas, electromagnetic field theory, wideband amplifiers, receiver design, communications and radar. Mr. Wheeler is a fellow of the I. R. E. and has long been a leader in its activities. Beginning in 1947 he has steadily built up the staff, resources and reputation of the Wheeler Laboratories.

HAROLD A. WHEELER and ENGINEERING STAFF

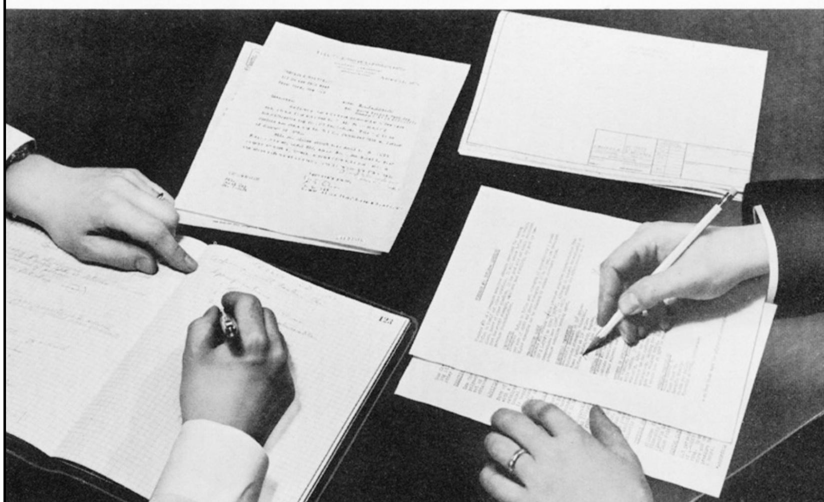


The essence of Wheeler Laboratories is the engineering staff. An integrated group of capable engineers selected from the leading colleges of the East, the staff individually and collectively are outstanding in their field. Each member, through a rigorous training in all aspects of practical engineering from basic measurement technique to advanced technical writing and administrative planning, becomes well qualified to assume responsibility, and each acquires an area of specialized knowledge in the microwave field. It is always possible, therefore, to pyramid the proper combination of leadership and coordination on as broad a base of abilities as any project requires. The collective experience and advice of Mr. Wheeler and the staff is always drawn upon, especially in the initial stages of a design project, and careful supervision is maintained throughout. The professional activity of the staff is evidenced by membership on the technical committees of the IRE and RETMA, and by numerous publications in engineering journals and technical magazines.

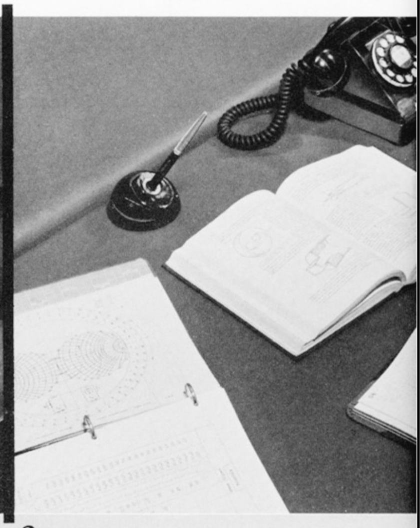
3

WL Brochure - Cont

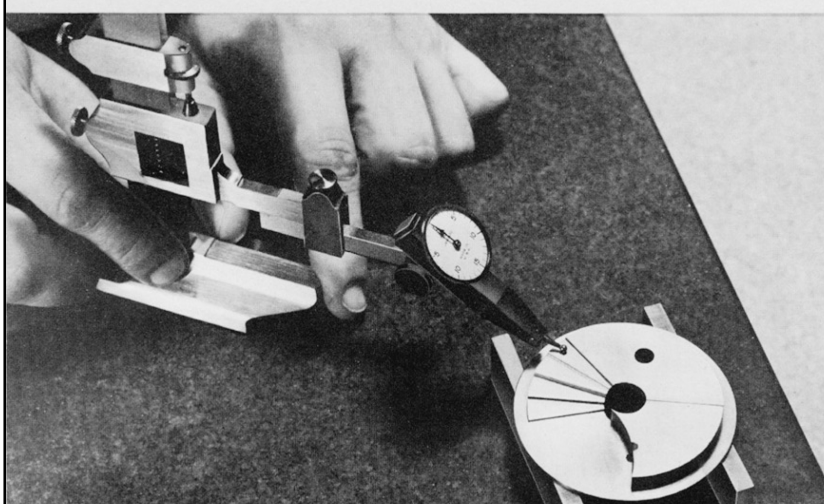
Let WHEELER LABORATORIES solve



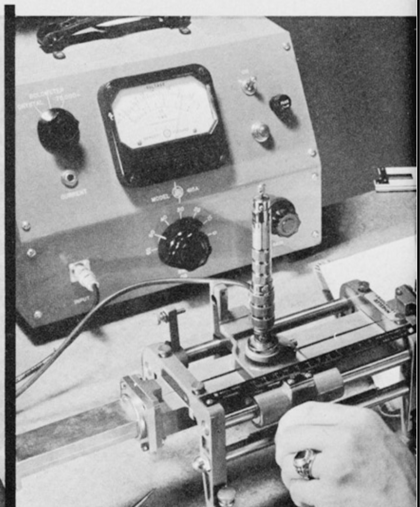
1. AN INITIAL CONFERENCE
with our engineers to outline your problem and discuss your requirements always yields ideas for practical, often novel, solutions.



2. THE DESIGN
is planned by capable engineers after reviewing our experience on similar problems, surveying the technical literature, and conferring with Mr. Wheeler and other staff members.



4. THE RESEARCH MODEL
is skillfully machined to close tolerances in the Wheeler Laboratories model shop, and carefully inspected.

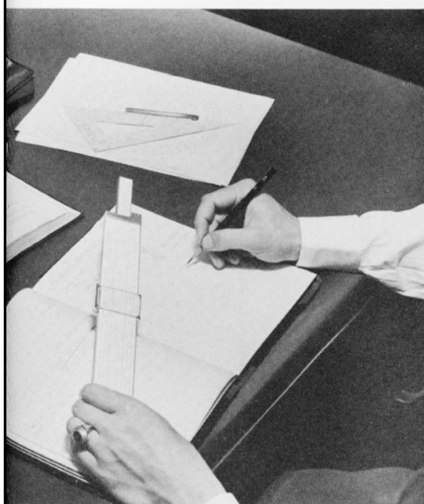


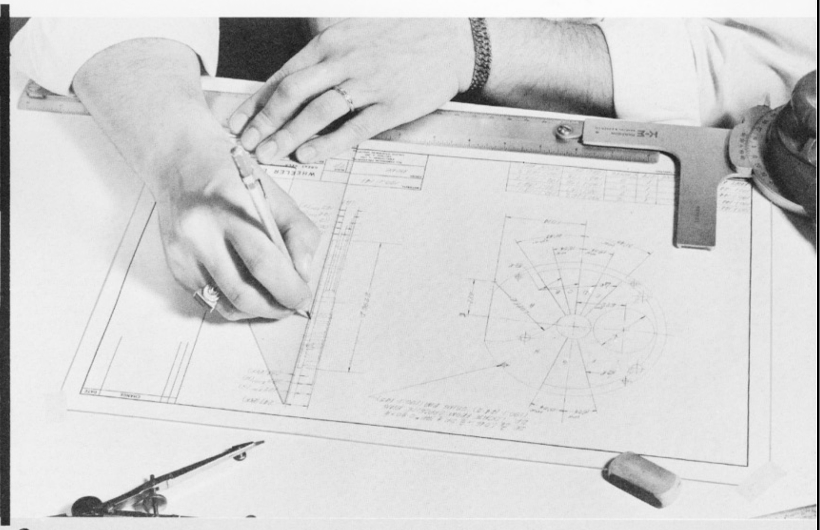
5. ELECTRICAL TESTS
of the research model determine the validity of the design and its suitability for your application. Modifications are made and tested until your objectives are attained.

4

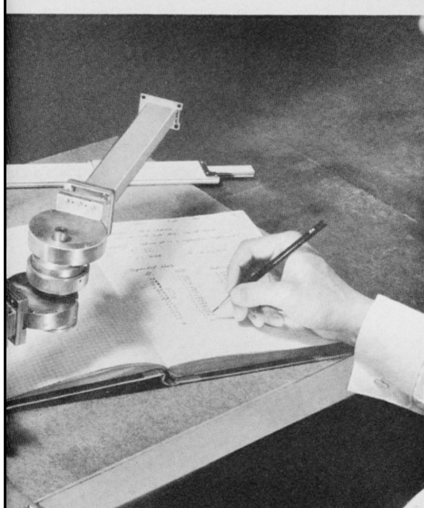
WL Brochure - Cont

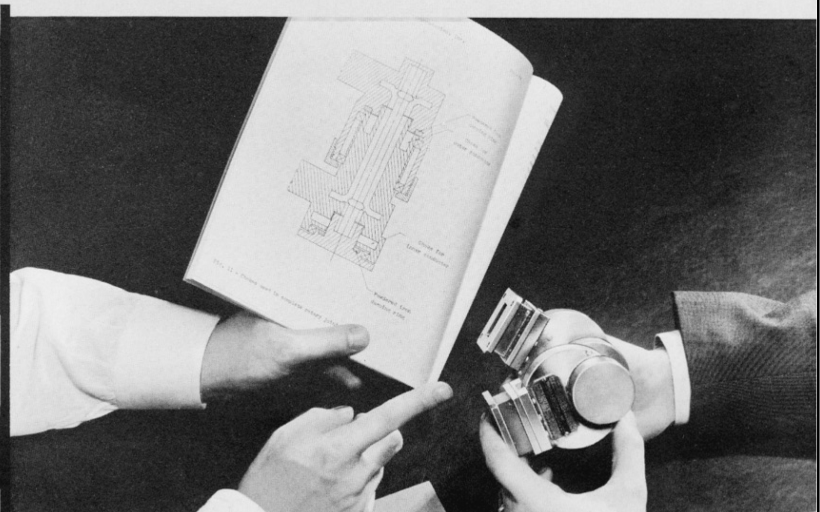
your microwave problems





3. DRAWINGS
of the research model embody our design and incorporate construction features which permit changes to be made economically as the design program progresses.





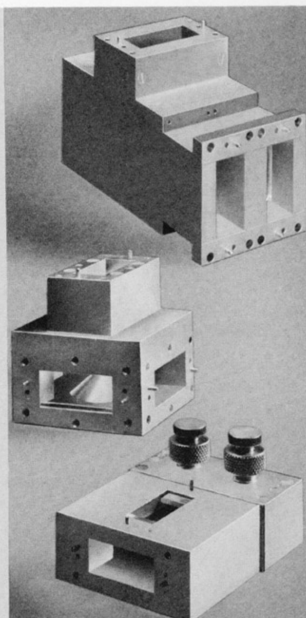
6. A COMPLETE REPORT
of the design theory, application, and performance is delivered to you at the completion of the work, together with the engineering model and drawings.

5

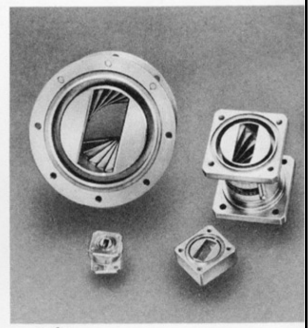
WL Brochure - Cont

Typical microwave problems solved

waveguide components

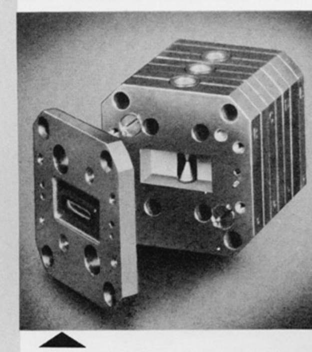


A specialty of the Wheeler Laboratories has been the adaptation of the simple Magic Tee waveguide hybrid junction to the solution of many complex design problems. It has been designed in many forms, each especially suited to the components with which it is associated in a particular application. For example, the hybrid-T form shown in the center is suitable for extended waveguide circuits, such as power-dividing networks or bridge circuits. When used as a balanced mixer, a compact form is achieved by bringing two of the arms out side-by-side instead of opposite, as shown at the bottom. Here the two mixer crystals are adjacent for easy connection to their common preamplifier. In another special application, paralleling of two arms in the other plane was desired, and achieved as shown at the top. All three junctions, although entirely different in outward form, represent the same electrical circuit and have been refined to the same high degree of performance.



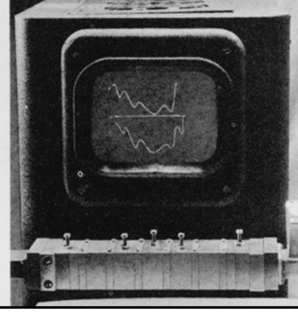
The step-twist is a unique Wheeler Laboratories development which provides a full 90° axial rotation of a waveguide in a minimum of length. Remarkably low reflection, high power capacity, and wide bandwidth have made this component useful in many complicated waveguide assemblies, and have resulted in its acceptance as a standardized universal waveguide part.

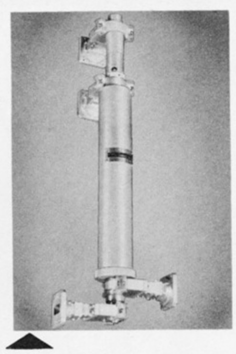
special developments



Several national suppliers of TR tubes have achieved unusual uniformity in commercially-produced wideband X-band TR tubes by tuning them against a comparison-standard dummy tube developed by the Wheeler Laboratories. The dummy is a rugged, demountable precision waveguide filter embodying the low-power design characteristics of the TR tube. The sections are individually tested and tuned to within .03% of nominal frequency, and assembled into a stable, permanent standard, closely approximating the ideal reflection and transmission properties of the TR tube.

The design and adjustment of microwave filters, normally an extremely tedious process, is greatly facilitated by automatic presentation of their reflection and transmission characteristics on an oscilloscope. At X-band, this type of display is made possible by the use of the Wheeler Laboratories Rapid-Sweep Oscillator in conjunction with suitable detection and display circuits. The rapid rate at which the oscillator sweeps through the entire frequency band permits instantaneous observation of the effects of adjustment on the reflection and transmission responses of the filter.





In some radar systems, as many as three antennas rotating on a single pedestal must be independently connected to the equipment below. The Wheeler Laboratories triple-channel rotary joint carries two high-power channels through rotatable waveguide-to-coaxial transitions, with provision for a third low-power channel, entirely in coaxial line, running through the center. The power capacity of the channels is limited only by the coaxial lines themselves, and the novel coaxial-to-waveguide transitions introduce extremely low reflection over a wide frequency range.

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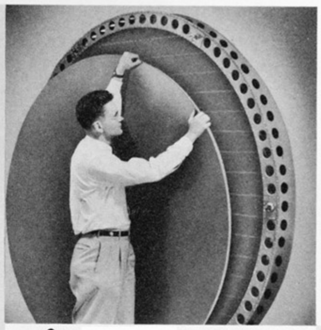
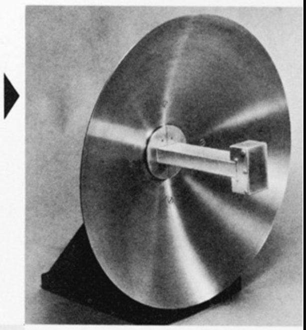
WL Brochure - Cont

by WHEELER LABORATORIES

antennas



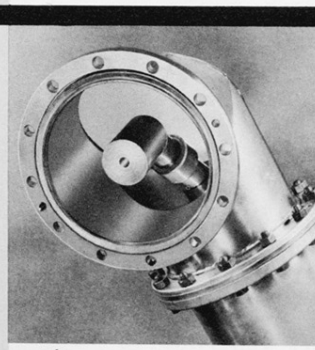
In designing a K-band antenna for a guided missile application, Wheeler Laboratories was able to take advantage of convenient and accurate X-band test equipment by working on the X-band scale model shown. This center-fed parabolic antenna features low side-lobes, low reflection, and high power capacity over its operating frequency band, combined with a simple, easily-fabricated configuration.



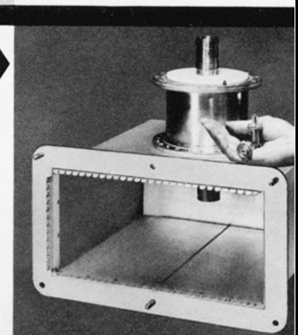
Some microwave antennas utilize a microwave lens to focus an incoming wave into the receiver. The performance of such a lens may be considerably improved by a process analogous to the coating of high-quality optical lens surfaces with a special film for removing reflections. For the Bell Telephone Laboratories, Wheeler Laboratories has designed such a coating for a microwave lens in the form of a plastic plate, made up of fiberglass skins separated by fiberglass honeycomb filler. The plate not only minimizes the surface reflections, but also protects the lens surface and acts as a wind cover.

The two antennas shown in the accompanying photograph have similar operating characteristics. Both provide omnidirectional coverage in horizontal plane, and vertical-pattern gain of about 6 db relative to a half-wave dipole. The antenna on the left represents the size of the best commercial type available when Wheeler Laboratories was asked by Communication Products, Co., to design a light-weight, low-cost, high-performance unit. The antenna on the right is the improved design, developed in a short time in close cooperation with the client.

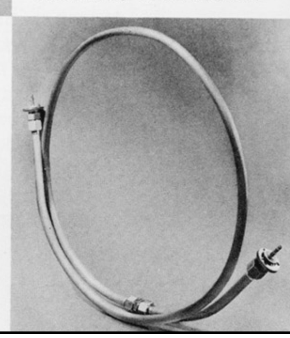
transmission lines



The two coax-to-waveguide transitions shown illustrate the wide range of application of Wheeler Laboratories waveguide techniques. The tiny unit is a typical design for military use in the region of 30,000 Mc. The large unit is a sheet-metal adaptation for commercial use in the UHF-TV band. By converting the coaxial output of a television transmitter to rectangular waveguide, it secures the advantages of lower attenuation, higher power-handling capacity, and reduced reflections in the long transmission line leading to the antenna.



The problem of designing an elbow bend for rigid coaxial line, matched over a two-to-one frequency band, was readily solved at Wheeler Laboratories by the application of powerful analytical methods. The 90-degree bend shown was developed for Communication Products, Co. All-metal in construction, with no unusual contours or tolerances, it has a VSWR within 1.02 over the entire UHF-TV band.



In the field of RF transmission lines, Wheeler Laboratories enjoys a unique position as consultant and designer. Shown above is a short section of Styroflex cable, manufactured by the Phelps Dodge Copper Products Corporation. During the early stages of its introduction in this country, Styroflex was extensively studied and tested by Wheeler Laboratories for conformance with the high standards set by the manufacturer. Later on, a complete set of connectors and adapters for Styroflex was developed, convenient to use and introducing negligible reflection.

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WL Brochure - Cont

WHEELER LABORATORIES

CUSTOM TEST EQUIPMENT

An important service of Wheeler Laboratories has been the development of custom-designed test equipment. Each piece has filled a client's particular need which could not be met by any other equipment available at the time. The few examples described below indicate the wide range of operation and application Wheeler Laboratories is prepared to cover in such designs.

RF INDUCTANCE METER

The Wheeler Laboratories Model 20 direct-reading inductance meter has been planned to fill the wide gap between the 1000-cycle bridge and the instruments for measuring inductance at the frequencies of normal radio operation.

It is designed for rapid and easy measurement of radio-frequency inductors at frequencies preselected for each range to minimize errors of measurement. In five decades, it covers continuously the ranges of 1 μh to 100 mh with an accuracy in the order of one percent. The values of inductance are read directly on the linear scale of a precision variable capacitor, with a propér decimal multiplier.

The instrument can also be used for precise direct measurement of small capacitance, and for indirect measurement of capacitors larger than 1000 μμf.

AUTOMATIC IMPEDANCE PLOTTER

Measurement of input impedance over the operating frequency band is indispensable for studying and adjusting microwave components, especially when the impedance locus is plotted on the polar plane of reflection coefficient.

The Wheeler Laboratories Automatic Impedance Plotter incorporates a novel waveguide circuit for the automatic measurement of input impedance, and suitable circuits to display it on a cathode-ray tube. The rapid-sweep oscillator enables the measurements to be made throughout the 8.5—9.6 KMc X-band, at a rate permitting a continuous visual presentation of the variations in impedance with frequency. This feature insures the observation of anomalies in the impedance locus caused by spurious resonances or similar effects, and also allows observation of the changes in the entire impedance locus as the component is adjusted.

Another useful feature of the device is the ability to select at will the reference terminal plane of the observed impedance, and to expand the scale of reflection coefficient magnitude. Permanent records of the impedance measurements are easily obtained by photographic methods.

X-BAND OSCILLATOR

Originally designed as a local oscillator in a tunable radar receiver, the Wheeler Laboratories Model 209 X-band Oscillator has found extensive use in our own laboratories and in numerous others as a convenient test-bench instrument.

The oscillator consists of a standard reflex-klystron tube, and an external wave guide cavity with non-contacting tuning plungers. The cavity setting and repeller voltage adjustment are ganged in a single calibrated control so that the oscillator can be tuned rapidly and continuously over the entire 8.5—9.6 KMc band with no more than ± 1 db change in output.

A mechanically-driven version of the Model 209 Oscillator, the Wheeler Laboratories Rapid-Sweep Oscillator, has been incorporated in a number of our specialized test equipments, and has recently been used as the basis of a commercial design manufactured by the Polarad Electronics Corp.

AMONG OUR INDUSTRIAL CLIENTS

AIRBORNE INSTRUMENTS LABORATORY
BELL TELEPHONE LABORATORIES
BENDIX AVIATION CORPORATION
BOONTON RADIO CORPORATION
COMMUNICATION PRODUCTS COMPANY
HENRY L. CROWLEY AND COMPANY
DELCO RADIO DIVISION, GENERAL MOTORS CORPORATION
GENERAL ELECTRIC COMPANY
MICROWAVE ASSOCIATES
PHELPS DODGE COPPER PRODUCTS CORPORATION
PICKARD AND BURNS
POLARAD ELECTRONICS CORPORATION
POLYTECHNIC RESEARCH AND DEVELOPMENT COMPANY
RAYTHEON MANUFACTURING COMPANY
SPERRY GYROSCOPE COMPANY
WESTERN ELECTRIC COMPANY

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WL Brochure - Cont

SUMMARY OF EXPERIENCE

MICROWAVE EQUIPMENT AND COMPONENTS

The Wheeler Laboratories developments listed below indicate the scope of our experience. The frequency code letters are the conventional band designations.

TYPE	DESCRIPTION	FREQUENCY BAND
Antenna	Communication types	VHF, UHF
Radar Antenna	Precision tracking types	X, K
Radar Plumbing	Complete waveguide assemblies	X, Ku
Radar Duplexer	Y-junction type; special wideband ATR assembly	X, Ku
Signal Generator	Packaged radar test equipment	Ku
Spectrum Analyzer	Packaged radar test equipment	Ku
Sweeping Oscillator	Reflex oscillator with mechanically driven external waveguide cavity	X
Wavemeter	Reaction type	Ku
Tunable Selector	Single-tuned and double-tuned; coaxial and waveguide	S, X
Oscillator	Externally tuned coaxial types and waveguide types, using reflex tubes	S, X
Crystal Mixer	Waveguide, hybrid-T, and coaxial types; single and balanced	S, X, Ku
Crystal Detector	Various fixed-tuned and tunable types for waveguide	X, Ku
Waveguide Tuner	Slide-screw and multiple-pin types	X, Ku
Power Divider	Adjustable directional coupler between waveguides	X
Phase Shifter	Waveguide trombone; dielectric vane in waveguide	X
Rotary Joint	Single, double, triple-coaxial types; circular-guide type; twist type	L, S, C, X, Ku
Step Twist	Fixed 90° units for full rated band width (40%) in 11 waveguide sizes; rotary units for same bandwidth	L, S, C, X, Ku, K, Ka
Waveguide Attenuator	Various fixed and adjustable types for low power	S, X, Ku
Directional Coupler	Various types, co-axial and waveguide	S, X, Ku
Hybrid Junction	Various contours in hybrid-T and forked types	X, Ku
Waveguide Bend	E and H plane, 90° mitered, wide band matched	UHF, X
Transition	Waveguide-to-coax, rectangular-to-circular waveguide	UHF, L, S, X, Ku
Matched Termination	Powdered-iron and carbon vane types for low power, waveguide and coaxial	VHF, UHF, L, S, X, Ku

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WL Brochure - Cont

SECTION IV

RECOLLECTIONS OF WHEELER LABORATORIES

(Editor's Note: In a letter dated 940301 and addressed to about 80 WL engineers, Mr. Wheeler introduced his "next project," namely, a book about Wheeler Laboratories. He planned to prepare an overall description and to include recollections written by staff members. He enclosed a "pattern" to assist them, but encouraged freedom of expression. His request drew 40 responses, one of which was volunteered by a secretary. In addition, he took it upon himself to provide biographies for four senior engineers who had died in the interim. These recollections are arranged in order of date of each staff member's arrival at WL.)

David Dettinger

My first glimpse of Wheeler Laboratories came on August 18, 1947 (470818), the day I reported for work. Arriving on the Long Island Railroad, I walked to Northern Boulevard as directed, found the new firehouse and turned in beside it past a plain wooden building that had housed the previous fire station. At the rear, I found a wooden stairway leading to the second floor, under a sign that read "Harold A. Wheeler, Consulting Radio Physicist."

I entered and found myself in a large open room equipped with several benches and desks. At the end toward the Boulevard were several offices, to the rear a small shop and utility rooms. Two men were at work: Bob Novick, whom I had known as a design engineer in a previous job, and Jack Irish, a mechanical engineer. Both of them (I had been told) were planning to leave the Laboratories soon for other careers. It was in fact this circumstance that was the immediate cause of my having been recruited. Mr. Wheeler emerged shortly from his office to greet me and to introduce his secretary, Jean Leonhardt. Very soon I was established at a table to begin background reading for the tasks ahead.

Mr. Wheeler was by this time a long-time acquaintance. It was he who hired me into the Hazeltine Electronics Corporation in 1942, having found my resume in a newsletter of Sigma Pi Sigma, the honorary college physics society, and invited me to Little Neck for an interview from my graduate studies at MIT. I was more than happy to accept his offer, for it had become clear that my degree program in theoretical physics was not matched to my talents or inclinations; I wanted a career in design engineering. Furthermore, World War II had begun, and I was driven to make a choice of wartime employment.

At MIT, I had already been made an offer of work in the Radiation Laboratory, but I had found the Institute a rather grim environment as compared with the friendly campus of my undergraduate university, St. Lawrence, located in upstate New York near the river of the same name. I had chosen St. Lawrence in part because of a family connection, and had been well satisfied with the physics and math courses, as well as the lively extracurricular activities that abounded. I particularly admired the heads of the physics and math departments, the latter a former instructor from MIT. My degree was a BS in Physics, granted in 1941; there arose various opportunities for postgraduate study. My enrollment at MIT was prompted by several factors, including its reputation and its generous scholarship assistance, which I had also enjoyed at St. Lawrence. However, when it came time for a job decision it was easy for me to choose Hazeltine over the Rad Lab, in large part because of the strong impression Mr. Wheeler made at my interview.

My work at Hazeltine was, in retrospect, perfectly matched to my natural instincts, involving as it did hands-on design of RF antennas and components for the IFF systems described in Wheeler's book, "Hazeltine Corporation in World War II - IFF." The need was urgent, the pace fast, and the results exciting. For the first two years, I worked directly under Mr. Wheeler, with the opportunity to absorb his ideas and his approach. One of the more important habits he taught me was to keep a detailed notebook record of my work.

The power of this latter practice came to play a significant role in my life when I was assigned to work on Mark V IFF (my previous work had related to Mark III). In 1944 Mr. Wheeler sent me for six weeks to the Combined Research Group (CRG), a multi-national team at the Naval Research Laboratory in Anacostia, MD, where study was beginning on RF components for the new frequency band, including the transmitter for the interrogator units. This subject was new to me; I looked for guidance to more experienced engineers. As was my habit, I took time to record each of our experiments in my notebook. Soon the others discovered that I had a full record, and began to turn to me for such information as test conditions and results. Gradually I found myself playing a more central role in the group's activities. By the time I returned to Hazeltine my self-confidence had grown to the point where I was ready for the team leader role which came my way because Hazeltine was the prime contractor for Mark V, and most of my co-workers were from subcontractors. Needless to say, this experience was invaluable.

At the close of the war, I left Hazeltine to take a position with the Teleregister Corporation on Chambers Street in New York City. Nominally I was their radio contact person in work they hoped to do for the CAA (now FAA), but in actuality I mostly contributed to their network for distributing stock market quotations. My office was on the 13th floor with a view of the Hudson River; the contrast with the Hazeltine laboratory was striking. What was missing was the clear opportunity for technical growth.

My new job at Wheeler Laboratories introduced me to a new technology, namely, waveguides and microwave devices, including large aperture antennas; my IFF experience had exposed me mostly to coaxial components and dipole-sized antennas. Quickly I located some texts and began to "bone up." In retrospect, this was very near the beginning of microwave technology; a seminal paper had appeared only four years earlier. What was available was principally material intended for the training of military technicians. The famous Radiation Laboratory Series (RLS) became available in 1948; my copy of Volume 9, Microwave Transmission Circuits, is grimy from use.

My first task was to design, under Mr. Wheeler's tutelage, a wideband X-band converter for use in the T-33 tracking radar for Bell Telephone Laboratories. (At that time "wideband" meant 12% for waveguide structures; early radars had been single frequency.) Our design was not only successful but pioneered a new technique for measuring conversion loss. I was delighted when Mr. Wheeler offered me the opportunity to present at the IRE Convention what was in fact totally his concept.

Our test equipment for this and other tasks was minimal, to say the least. For example, our signal generator was a field test set loaned to us by BTL; it embodied a 2K25 X-band klystron that had to be laboriously adjusted in setting a voltage for every measurement. Other parts that could not at that time be purchased were made up for us by Al Paskevich in his tiny shop.

From the start I was delegated by Mr. Wheeler to recruit young engineers for the growing workload that he was attracting. This I did with increasing success as my first clumsy attempts at searching and interviewing matured into a well-oiled and reliable team approach. An early success was my hiring of Patricia Loth, who had no direct training for our specialty but a phenomenal ability to absorb new concepts and a flair for design. I recall that she and I found ourselves saying one day, "It helps to think like a wave." Among the design efforts we shared was a restructuring of the Magic T described in the RLS which vastly increased its power capacity, thereby qualifying it as a central component of the monopulse assemblies Wheeler Laboratories was building for BTL.

At BTL there was an influential engineer by the name of H. Trent Budenbom, informally known as "Bud." Bud was a raconteur, owner of an imaginary parrot that spoke with the wisdom of Solomon. With keen insight he was championing the technique of monopulse simultaneous radar as a remedy for the vulnerability of conscan (sequential) tracking, and had himself built a crude microwave network to demonstrate its potential. However, his network had some inherent limitations that made it unsuitable for operation or manufacture, and he asked his management to support us in "Wheelerizing" the monopulse circuitry. The rest, as they say, is history. From this beginning ultimately flowed the Nike-Ajax and Nike-Hercules RF assemblies, as well as the more advanced derivatives for missile defense (all for BTL), plus many other variations for other clients such as Sperry, Sylvania, Raytheon, General Electric and Westinghouse.

Most visible in this monopulse development were the antenna reflectors and feeds and the hybrid networks that produced the needed sum and difference signals. Less visible but equally important to the success of these monopulse radars was the intensive effort applied to controlling the phase relation between the sum and different signals. This relation not only governed the sense determination of the derived error signals, but became a factor in the overall boresight accuracy of the radar by combining with other tolerances. The careful modeling of overall performance done by Harry Redlien revealed this latter effect, and others like it. I recall first recognizing the difficulty of maintaining this phase relation during a few days of study that I spent at Whippany in March 1950; I brought back a TR tube that seemed to introduce the greatest variations in the paths, being a highly resonant triple-tuned filter. Our study of this phenomenon led not only to a workable method for combating variations, but to new test concepts, such as a microwave bridge arrangement that not only permitted us to minimize the variations among TR tubes, but to actually increase the supplier's yield. Herb Rickert played a central role in this work.

Not all of our clients were military contractors. Phelps Dodge came for consultation on the characteristics of Styroflex Cable, for which they had purchased the rights from a German manufacturer; this expanded into an extended measurement program handled by Hank Bachman; it also led us to another client, Communication Products of Marlboro, New Jersey. This second relationship truly flowered. From a humble beginning of testing their commercial antenna offerings and supplying data for their catalogs, our work bore fruit in new designs, notably the "Stationmaster" antenna family, which "blew away" all competition. In addition to mobile and base station antennas we did creative work in transmission lines, both coaxial and waveguide. A minor contribution of my own in the latter area was discovering a rule for the optimum spacing for support beads in rigid coaxial line; I remember testing it with tiny metal balls strung along a length of waveguide.

This account of our work is only a sampling. I have emphasized projects in which I was directly involved and especially interested, along with those which came to receive significant attention. Unfortunately, much of our work was never adequately documented in the literature for reasons of military security or proprietary interest.

In 1949, came an announcement from Mr. Wheeler that excited us all—we were to have a permanent home! On October 4, the move took place into a brand new building on Cutter Mill Road, Great Neck. All of us were ready to leave the crowded old firehouse and the raucous fire whistle that blew next door every noontime. Everyone helped in lugging equipment, erecting benches, and reestablishing operations. The white front facade made an ideal location to blazon our name to passersby, and the open half of the second story provided at least a small area for outdoor antenna testing.

Throughout this period I had been living in rented rooms in Great Neck and finding most of my social life in Manhattan via the good old LIRR. Love bloomed in 1951 through a YMCA organization called Intercollegiate Alumni of New York, and in the next year I married Carolyn Poole, then employed as a reference librarian at Barnard College. We took an apartment at Great Neck Terrace where other Wheeler engineers had found space, and soon began raising a family; in a few years we bought a home in Port Washington and lived there very happily.

A second important move for the lab came about with the opening of the Smithtown Laboratory. As our antenna work expanded in Great Neck it became urgent that we provide an adequate test range of our own. As early as 1953, Mr. Wheeler, Hank Schwiebert and I had set off on exploring trips to examine potential sites further out on Long Island. On 530317, we walked up a dirt track on a farm hill to a crest where we could look across just such a valley. To my eternal amazement, the farmer agreed to sell us the strip we wanted right across the middle of his property! It took us several years of planning before we were able to occupy the carefully designed antenna building in 1957. Fred Van Davelaar did much of the planning, including the design of the hydraulic system to hoist antennas on and off the test mounts. The measuring apparatus itself was designed or chosen by Ned Spencer, who became the lab director when it opened for business.

My own perception of the Smithtown facility is somewhat idyllic. First of all, I did not have to relocate to a town fifty miles from New York City; neither did I need to commute daily, as did Ned. Secondly, my visits there at approximately monthly intervals gave me an impression like lapse-time photography, in which there always seemed to be something novel to observe. Third, everyone was uniformly hospitable, so that I always felt welcome; I can only hope that the Great Neck lab made the same impression. Fourth, the very activity of such a comparatively large test operation engendered a feeling of bustling progress; the results were generally exciting to review.

One lasting memory of Smithtown was generated on my final visit in 1961, just before I left Wheeler Laboratories for a new job in Massachusetts. At the time I was driving a tiny Fiat 600, and Ned carefully arranged that I should drive the two of us to work that day. The engineers had set up a farewell luncheon at a nearby restaurant. Midway through the meal I was handed a Polaroid print showing my Fiat atop one of the antenna mounts! Sure enough, when we returned from lunch there sat my little bugger, slowly rotating in the breeze.

This prank was one of a hundred that peppered (and salted) the years at the lab. From the “headlight” in the old lab to filling my bathtub with Jell-O, they reflected our high spirits and camaraderie. How can I ever forget the treasure hunt to locate my trumpet, or the 8-pound transformer in my hiking pack that I carried a couple of miles into the Adirondacks—and back! They also attested to the universal trust and corresponding irreverence of the team—witness the production of Wheeler Monograph #5A, “Generalized Transformer Concepts for A-P Supermarkets and General Feed Stores.”

Our clients always seemed startled by our low overhead and quick responses. In hindsight I too am surprised at the minimal administrative structure under which we operated. We had no technical writers, for example; every engineer was expected to generate his own reports, and a fair fraction of each supervisor’s time was devoted to teaching writing and editing. Fortunately for me, Mr. Wheeler handled most of the financial chores himself with the assistance of our accountant, Augie Belfiore. Of course, he also served as the spark plug in defining technical solutions and as the court of last resort when we hit dead ends. As Chief Engineer, my role was to launch new jobs, make personnel and space assignments, authorize equipment purchases, and review all our reports, among other duties. We needed no sales force; Mr. Wheeler was a magnet for new work, and others of us contributed in developing ideas and extending contacts with clients. We had such conscientious, hardworking machinists, secretaries and maintenance men that they did the work that might have required twice the number elsewhere.

Our problem-solving orientation and our pride in finding elegant solutions efficiently was perfectly matched to the time-and-materials formula under which we operated almost exclusively. Our clients found it both economical and flexible; it was accepted by military and commercial customers alike. It is doubtful whether this formula would be as readily acceptable today, despite its obvious advantages for new techniques and prototypes. In my later experience in the acquisition of military electronic systems I repeatedly observed cases in which first-time items could have been developed more economically and quickly with this formula than with fixed-price mechanisms; the essential ingredient, of course, is a relationship of trust, something that Wheeler Laboratories never lacked.

One exception to the time-and-materials formula that comes to mind was a small contract with the Navy's Bureau of Ships to study ways of making more reliable measurements of microwave breakdown. Here I worked with Bob Wengenroth to summarize what was known about the subject and to supplement this with tests at whatever high power facilities we could find, the objective being to define a standard approach for all to use. This took us to locations such as Raytheon in Waltham, Massachusetts, and General Electric in Syracuse, New York. It also involved us in the use of (and the protection from) radioactive cobalt. Our client, Ed Mroz, was so pleased with WL's results that he wanted to fund us in establishing a permanent test facility at WL, but we chose not to be tied down to an open-ended, routine assignment in favor of more exciting design opportunities.

When all is said and done, it remains the caliber of the engineering staff that set WL apart. I believe this was attributable to two factors: a streamlined recruiting and selection process, followed by an unsubtle training approach. One unusual feature of recruiting was the strong emphasis on hiring college juniors for summer jobs, and then making sure these jobs were rewarding. Only a fraction of these summer hires returned, since many went on to graduate school; however, the message they brought back to their schools was usually one of enthusiasm and recommendation. The interviewing process too was carefully designed; here a key feature was separating "selling" our openings from the technical assessment of the candidate. Training was immediate and continual, ranging from analyzing problems and designing experiments to verifying test procedures and documenting results, both in notebooks and in technical reports. Pat Loth was outstanding in this role.

Thirty-two years have passed since my departure from Wheeler Laboratories, yet the memories are fresh as ever. This is partly due to the pleasant associations that have continued in three reunions, in annual correspondence, and in frequent technical and/or social contacts. Even more so it is attributable to the direct relevance of the many skills and lessons learned over my fourteen years there, plus my earlier apprenticeship under Wheeler himself. The capability I developed in problem and tradeoff analysis and in technical writing has been invaluable, as have the management practices honed at a small company where cause and effect were almost instantly apparent.

My change of career into telecommunications systems engineering at The MITRE Corporation in Bedford, Massachusetts, meant that there would be few direct applications of the specialties I had known; this proved to be true. Occasionally there came opportunities to consult on microwave or antenna problems. One such case arose in connection with a troublesome rotary joint design. When pummeled by a MITRE engineer, the vendor responded, "Why don't you ask your own expert? Dave Dettinger designed one of the first multiple-channel joints." I was called in, and am proud to say that on the spot I was able to diagnose its anomalous behavior by calculating a spurious resonance, allowing me to recommend a fix. Other isolated cases involved AWACS antennas, tactical antennas, overmoded waveguide for the Cheyenne Mountain NORAD installation, and reviews of various microwave measurements, processes and results. A different opportunity to apply my early skills came about when in 1975 I gave up my telecommunications department to join the MITRE Institute, the company's education office, a position I still hold on a part time basis.

It is always rewarding to encounter the high esteem in which Wheeler Laboratories has come to be regarded. I confess to a sense of elation when a stranger chances to speak admiringly of our group. It must be evident by this time that I consider myself fortunate indeed to have launched my (several) careers in such a stimulating environment, where careful thinking was demanded and follow-through was the norm. It would be ideal if every young engineer could have such a head start. I owe a lifetime debt of gratitude to Mr. Wheeler and to my colleagues at the Wheeler Laboratories.

Jesse Karp

I am pleased to accept Mr. Wheeler's invitation to make this small contribution to his history of those illustrious years at WL. I joined the Laboratory in 1947. Out of City College in New York City with a degree in Physics and a few courses in Engineering, I was the first engineer on Dave Dettinger's staff. In a way, the chance to be interviewed was an accident, since it was based on a "jobs wanted" ad in the IEEE that was more than six months old. After I graduated college, I had been interviewed based on that ad and was working elsewhere for about six months when the Wheeler invitation came. As they explained after I was accepted, neither Harold nor Dave noticed the date on the IEEE or they would have assumed my ad to be out of date, and not sent the invitation to the interview. I quickly accepted that invitation and the resulting job offer. I recall being asked if I played chess, followed by other questions about the game. This unusual feature of the interview made as much of an impression as the promise of interesting work, and was probably responsible for my acceptance. I also welcomed an opportunity to transfer out of an unexciting firm whose future was limited, and which actually went out of business a year later.

I remained with WL until 1948, when I accepted a position with a larger engineering company. It wasn't until 1970 that I became reconnected with WL within Hazeltine Corporation, so my stay and contribution to those early years at the Laboratory were brief; I remember that time mainly for what WL did to mold my career. I should mention here that Pat Loth joined WL about two months after me, completing the staff at that time.

The most persistent impression made by that year at the Laboratory was the engineering discipline that Harold and Dave insisted upon. This discipline guided me throughout my career, and continues to serve me even now, when I am no longer actively employed. This discipline extended from the constant date format of "yymmdd"; to the notebook format which required right hand pages for designs, always signed and dated, and left hand pages for scribbles; to engineering discipline in general. I recall two copies of Smythe's book (was it "Electromagnetic Theory"?) so that one could see the front and back of a page at the same time.

I recall getting to work during a terrible 27-inch snowstorm in '47. WL was located then at Northern Boulevard (Route 25A), just inside New York City. There weren't any visible paths into the building, but it was occupied, so I trudged through the deep snow into the building. I found Mr. Wheeler and Mr. Dettinger down in the basement, sitting around a belly stove keeping warm. Both were dry. The reason for the "no paths" look outside was that earlier, Mr. Wheeler had gotten men from the Fire Department station right next door to dig such a clean path to the door with their plow that the path wasn't readily visible.

I once had an assignment to make some measurements at five frequencies on a piece that was being designed. The measurements were to take place on a Friday afternoon. Being in a hurry to catch an infrequent train on the Long Island Railroad which was the way I commuted to my apartment in Manhattan, I performed the measurements in a rush, causing me to duplicate one frequency and leave out another. That was not the only mistake I made before Dave installed a performance-related remunerative system that would be the envy of management in many of today's corporations.

As I stated previously, I had a degree in Physics that didn't require courses in engineering drawing, so I had no experience in that discipline. As a result, when I designed a slotted line probe, I handed the design over to the machinist as a combined assembly and detailed parts drawing, all in one; it was almost impossible to read. It took a lot of talent, but I recall that the machinist was very talented; the part was made, and it worked. Dave wasn't satisfied, however, and he persuaded me to study a book on engineering drawing that he recommended. At the same time, starting with a bonus for the week if there were no errors, I would be fined a small amount for each error I made in the future, either on the bench or in drafting. I learned quickly, because even small amounts were not insignificant in 1947.

Although there was a lot of hard work, and some lunchtime work-related problems such as figuring out how to solve a problem on a "slip stick" with only one push of the stick, there were satisfactions from the work, and pleasures from the personal associations. These included frequent practical jokes. I recall having the rollers stolen from my desk chair by Pat, who locked them up in a file cabinet, leaving me to guess where they had been hidden. There was also the time that pictures of men's ties taken from an ad in Esquire magazine were pasted all over the reflector of the Dazur lamp on my desk in reaction, I suppose, to the loud ties my wife used to buy me. I got even by hiding Pat's skis.

The impression that has remained with me ever since, though, was the discipline, which should be part of every engineer's training.

Patricia Loth Burgmyer

Let’s introduce me, first: I’m Patricia Loth Burgmyer, one of Mr. Wheeler’s earliest employees, now a retiree living in Florida with my husband Warren, six cats, and a computer. This chapter comprises a brief account of my background, including the story of working with BTL and growing with the Labs, a few unpublished stories behind growing with the Labs, some unpublished stories behind the story—memories of people and places—and a look back from 1994. No bibliography is included. (Does this sound like the way I taught so many of you to start a report?)

The Beginning

My first encounter with electronics was at the age of about four, when my father was building a radio set from the circuit diagram published in the Sunday paper and needed some extra hands to hold the spaghetti wire covering back from the joint he was soldering. The smell of rosin flux still takes me back to the scene of the green-wire coils and silver condensers, a wisp of smoke rising from the soldering iron. After my father’s death, we lived with my uncle, a doctor, who taught me to use a telegraph key and sounder, and to help him lube his Maxwell by reading the manual to find all the grease-cups. So of course, I always liked machines and knowing how they worked, and getting my hands dirty on them.

At school, most subjects were a pain until I hit Physics and Geometry—what fun! Through all-girls high school and college it was assumed that, like my mother and sister, I would become a teacher, probably of Mathematics. Nothing much else was available for a girl to make a living in those days, but as the next section reveals, I was rescued from this fate by an ad in the Times for math majors to be “ENGINEERS - FEMALE”!

After a year’s apprenticeship in the Physical and Electrical Standardization laboratory at Western Electric in Kearny, NJ, and several years in Hazeltine’s test lab in Little Neck, the big opportunity came. I had by this time become acquainted with a number of Hazeltine engineers through a social organization known as the Intercollegiate Alumni, which was sponsored by the YMCA for college graduates in New York City. This group of like-minded people from all over was unique in that it providing us during those war years with accessible meetings, trips, hikes, dances, and other social events. (No wonder that even today, over 40 years later, we still keep in touch through a newsletter!) Anyway, at Hazeltine, I had attended and really enjoyed a number of educational lectures by Mr. Wheeler, so when fellow IA’er Dave Dettinger called to offer me a position at Wheeler Laboratories, of course I accepted.

The Story

(Editor’s Note: The following profile by Dolores Matos was originally published in InPHAZe, the Hazeltine newsletter, March 1982)

When the war came along, employment felt the pinch. With the male population going into the armed services, women had job opportunities that were never opened to them before. Some of the electronics firms began recruiting female math majors. St. Joseph's College for Women in Brooklyn was one of the campuses visited by the Signal Corps in 1942. One of the students interviewed was Patricia Loth. On visiting their Red Bank plant, however, she couldn't operate a calculating machine—so she didn't get the job!

Shortly after graduation, Pat saw an ad by Western Electric in the New York Times for "ENGINEERS—FEMALE." After going through a battery of tests, she was hired for their Physical and Electrical Standards lab.

During the year Pat worked at Western Electric, she commuted from her home in Queens to the plant in Kearney, NJ, worked a 52-hour week, and took some electronics courses at Pratt Institute.

Looking for a job closer to home, Pat heard about Hazeltine in Little Neck, and sought an interview. The first question she was asked was "Can you type?" "I would have said no even if I could," Pat recalls. She was the first of a half dozen women hired in 1943 as junior production engineers to run type tests on IFF system components—transformers, capacitors, etc. "After the war the company began cutting back," states Pat. "I used to joke that we had a binary number of people, because every couple of months they cut our department back by one half. Eventually it got down to one person and myself, and then he left. I also became the chemist after that lab was disbanded completely."

A year earlier (1946), Harold Wheeler had left Hazeltine to open his own laboratory on Northern Boulevard. Pat sought greener pastures there. However, Mr. Wheeler wasn't sure she could do the work. "I had experience using Hazeltine slotted lines on some high frequency testing, a development Mr. Wheeler had supervised," Pat states, "and he was impressed that I had hands-on experience and could understand this type of work. He said he would try me."

The Wheeler staff soon consisted of about 12 engineers (Pat being the only woman). Microwaves were just beginning, and they had sub-contracts with Bell Labs. Increased work in military electronics for Bell encouraged Mr. Wheeler to expand to another building in Great Neck. It was here the first NIKE Missile system plumbing was developed. "Bell had their own people design the microwave components—the plumbing," Pat states, "and we rebuilt it in a way that made it producible. We worked with Western Electric on production. A lot of follow-on business resulted including plumbing and antenna designs for all the NIKE and Safeguard radars, and the guidance antennas for the first ICBMs." (This equipment is now used in launching all U.S. space vehicles.) "We also worked with Bell and Raytheon on the antennas for the ABM systems in North Dakota."

(It was during these years that Pat attended Polytechnic Institute in New York in the evening and earned the MS degree in Physics.)

While new work was also being developed in phased array radars, the NIKE contract with Bell was winding down. “We did not have a marketing department at Wheeler,” Pat states, “and while we did a lot of research and development, we did not know how to go out and get prime contracts. Hazeltine stepped in and took on Wheeler Laboratories as a subsidiary.”

Meanwhile, in 1957 Wheeler Labs had added a new building and antenna test range in Smithtown, housing about one half of the staff until about 1969, when the entire group was consolidated at Smithtown. Finally, Wheeler Laboratories became part of the Research Laboratories, Hazeltine Corporation, in 1971.

Pat, now a consulting engineer, had come full circle. During this same year (1971) she attended a Quarter Century Dinner and found herself at the same table with Warren Burgmyer. Pat and Warren discovered they had joined the company within 17 days of each other. They vaguely remembered running into each other during their Little Neck days. A friendship developed and they surprised their colleagues in February with the announcement of their engagement. Pat and Warren were married in May 1972.

Pat’s work in the Research Lab included such projects as the Sperry Mark 92 radar antenna design, and work on SEEK TALK and JTIDS. In June 1979 the Burgmyers retired to their home in Great Neck, where Pat is an independent consultant on microwaves and antennas.

Pat feels the opportunities for women in engineering should be the same as those for men: “Being a woman is insignificant to performing as an engineer, if you know what you are doing. Why make a difference?” She faults professional societies who form “women’s groups” within their matrix organization. “That is like setting up a society for people who are under 5’2” or have red hair” she states.

Pat is a senior member of IEEE, past chairman of IEEE Waveguide Standards Committee, and the recipient of the Charles J. Hirsch Award (1976), presented by the L.I. Section of IEEE.

Her favorite story is recalling an incident at a convention several years ago. “I was the only woman in attendance. As each speaker addressed the audience, they came up with such salutations as ‘lady—and gentlemen’ etc. When it came my turn to speak, I simply said ‘fellow engineers.’ They cheered.”

Why not?

<u>Stories Behind The Story</u>

Following are some memories of the people, places, and happenings that were my life and family for all those good years.

When I first began working at the “old” Lab over the firehouse in Great Neck, there were only a few of us: Mr. Wheeler and his secretary Jean Leonhardt; Mary Cozzie, a part-time secretary; Dave Dettinger and Jess Karp, the engineers; Al Paskevich, the machinist; and me, the new kid on the block. I'd had a crash course in practical joking at the old test lab at HC, and some of it carried over, in spite of Dave's valiant efforts to maintain a business-like atmosphere (and keep a straight face!).

For instance, the famous headlight, indicating occupancy of the unisex restroom, was once equipped with a microswitch at one of the workbenches so that whenever Jean or Mary peeked out of the office door before making a trek through the lab room, someone would switch on the "NO" signal, making the victim retreat. Finally, in desperation, one of them very discreetly asked that we check on the circuit—and of course, it then worked perfectly, to their great relief! Jesse was noted for his rather conspicuous neckties; one day he found all his desk, workbench, notebook, telephone, etc. covered with the small colored tie replicas from Haband—the product of months of saving by everyone. And Al? Well, he was absent a few days (big mistake) to have glaucoma surgery. We, of course, wishing to prevent further eyestrain, made paper-doll clothes and attached them firmly to all his calendar girls. After a few more engineers joined the gang, the Lunch Club emerged. A kitty was set up to buy bread, cold cuts, peanut butter, etc., to be set up on a small table in the lab. What a feeding frenzy... and what an opportunity! Polyfoam cut to resemble Wonder Bread, a tire tube cut like bologna, and a "peanut butter" container with pop-out snakes!

But seriously, folks, we learned a lot, and did a lot of really good work in those days, as evidenced by the increasing amount and complexity of the tasks given us by Bell Laboratories. And we had a lot of fun—picnics in the local park and at Jones Beach, and even in Mr. Wheeler's back yard! The big milestone was the move to the "new" Lab on Cutter Mill Road in Great Neck. Here we divided into groups for our increasing work assignments, and began having "supervisors" for the tasks and the lab rooms. I became housemother to several newcomers each year, and tried to carry on Mr. Wheeler's tradition of writing high-quality reports on high-quality work. This meant a lot of arm-twisting to get weekly progress reports (in English, not jargon) out of reluctant young tigers anxious to get on with their brilliant work instead of wasting time writing about it. But upon completing their first real technical report, in which they showed their understanding and achievement of an important advance, did they ever feel proud of themselves! Of course, Mr. Wheeler's review and always-helpful advice was a large factor in this accomplishment.

Our work with BTL on the original NIKE system antennas and plumbing developed into an extensive program of testing on the Whippany antenna range. Harry Redlien, Pete Hannan, Hank Bachman and I were the first contingent to take on part-time residence there to measure the precision tracking capability of the Cassegrain antenna Pete had developed and the high-power monopulse feed I had worked on. This was a "flat" range where the ground mirrored the distant source antenna to provide uniform illumination of the large antenna under test. (We found out the hard way that snowdrifts and tall weeds had to go!) The boresight-measuring device was a telescope attached to the antenna, looking at a checkerboard out at the source; the objective was for the electrical axis defined by the difference-pattern null to remain constant within a fractional angular milradian over the operating frequency band. Did it? Not at first, but after reams of carefully-collected data and much brain-straining analysis, the causes (multiple reflections) and cures were found and added to the design in the form of absorbers and serrations in strategic locations. As a result, the “double-dish” replaced “lens” antennas, and became the X-band workhorse still in use today for many civilian programs.

This early NIKE system worked so well the military gave Bell Labs the task of developing a number of much more sophisticated units for anti-missile defense (eventually called SAFEGUARD, and of course highly classified). The high-power, high-precision plumbing assemblies fell to the Great Neck part of Wheeler Labs, and the antennas—both Cassegrain and (shhh!) phased arrays were assigned to the new Smithtown laboratory and antenna range. The prototypes were designed mechanically by Bill Lightbowne and his wizards at BTL, and built by Charlie Passannante’s wonder-workers at FXR Machine Works. They were able to accomplish all the ultra-fine tolerances we asked of them to make these super components perform the way we knew they could. Later, the system construction was taken over by Raytheon at Bedford, and our association continued with them to help solve the problems of such a major undertaking. We collaborated on testing and redesign (when needed) of the array and reflector antennas, and the high-power plumbing of the antenna feeds. (A note from the present: I think our greatest contribution to Raytheon was Jerry Hanfling, one of “my” boys who eventually became Chief Engineer of the Patriot system—and you know how that performed in the Gulf War!)

Through all this, we all learned by experience (really the only way) to become engineers, draftsmen, machinists, programmers, technical writers par excellence, proposal writers, project managers, and in the words of a present-day series of ads, “all we could be.”

<u>A Few More Stories</u>

I can’t resist including a few more mostly non-technical stories and recollections from the olden days—please forgive any inaccuracies in an old lady’s memory!

In Great Neck, we occasionally had a collective luncheon at Lauraine Murphy’s restaurant, with of course a standard menu established by Mr. Wheeler as the most efficient way to use our time: a whiskey sour to start, followed by London broil with hot popovers, and ice cream puff with chocolate sauce for dessert. Delicious!

When I started in Great Neck, cars were in very short supply after the war. My first one was an ancient Ford coupe with a rumble seat and a stick shift; in this car Al Paskevich learned to drive, and it was in this car that we picked up Rod Lowman at the Union Turnpike stop of the IND subway. In the winter, we all squeezed inside and Rod lost the shine on his right shoe from the blast from the SouthWind gasoline-fired heater! Later, after I moved to Hicksville, our car pool comprised Harry Redlien’s jalopy with a manually-operated windshield wiper (you pulled a string from either side to make it travel), Frank Williams’ regal LaSalle, Bob McCullough’s V-12 Lincoln with its block-long hood, and my new(er) convertible. Days when I had the top down, the headgear was somewhat attention-getting as we traveled the parkway: Harry had a fishing cap with the longest bill I ever saw, Bob sported a beret with a huge pom-pom, I had a straw sombrero with multi-colored ball fringe, and Frank had a welding mask with a transparent front. Eventually we all acquired real cars, and the fun was gone.

The most enduring of the Great Neck tricks was the “sleeve block,” which became a rite of initiation for the newcomers. At the end of the day, they would find one jacket sleeve pulled through the other, with a large wood block captured in the pulled-through part; it was too large to pass through the cuffs above and below it. Some took it home that way; one actually cut the sleeve and lining; most finally wrestled it loose, and were rewarded by signing their name and date on the block for posterity and new victims.

My favorite hoax, however, was a double-gotcha we perpetrated on Frank Williams when he had become Chief Engineer. (Respect...what’s that?) Well, we kept telling Frank that he seemed to be putting on a little weight now that he was managing instead of working. So one day we sewed up a fairly obvious tuck down the length of his jacket in the back. He put on the jacket, and of course missed the buttonholes by several inches. Amid the jeering comments, he examined the jacket and triumphantly removed the stitches to show us he really wasn’t that fat. But we had also moved all the buttons over a few inches, and so...!

Returning again to the old Lab (where among other things, I learned from Dave Dettinger how to run a claustrophobic old X-band test set from BTL that had to be let out of its case every now and then) I worked on the design of a hybrid junction, a weird four-armed waveguide assembly. It had the “magic” property of taking waves entering any one port and sending them equally out two others, while nothing came out the fourth.

The mathematics of configuring the junction space were hopeless, so I used to resort to “wave psychology” to ease the waves happily around the corners in the right directions. I worked with Scotch tape and paper clips; Al Paskevich translated my drawings into beautiful museum-quality artifacts, and we wound up with a fine product. Since we had no photo lab in those days, I made a pen-and-ink cutaway sketch of the junction for the final report, and eventually did this for many of our subsequent reports. I also contributed to the figures and charts for Mr. Wheeler’s monographs, and had an intensive course in the importance of margins, the use of symbols, and standardizing graphics.

As the Lab grew, component design became more and more a team effort, and today I can’t point to any one design as mine—it was always “we” who did it. One area of specialization was “optimum” feeds for monopulse tracking antennas, custom designed for various uses, such as a variable-beamwidth Cassegrain. Pete Hannan had written and published the definitive paper on optimization, and my group applied his principles to make multimode, multi-layer (MMML) feeds for many bands. Strangely enough, us frailer members of the group such as Lennie Steffek, John Pedersen and myself always seemed to work on the sewer pipe-sized cast pieces for L-band feeds, while 6-foot-plus people like Frank Williams and Ron Schineller got the soda straw-sized miniature K-band and smaller projects.

I spent a lot of time on high-power testing of our designs at various facilities, and found it straight out of science fiction. My co-workers were Herman Heinemann, Lennie Steffek, Mario Napolitano, and Wheeler Laboratories’ Richie Kumpfbeck, as I remember. At first, Bell Labs had enough X-band power to zap our junctions and comparator assemblies so we could take them back to the Lab and worry over the burn marks until we understood what had happened, and how to fix it. Then we graduated to an L-band transmitter at Sperry (the "real thing" for the system) to feed our gigantic L-band comparator, which faced upward from the roof—we had to call LaGuardia airport for clearance to operate.

The entire setup was about three stories tall, all made up of catwalks and ladders leading up to where we worked. When an arc struck, it needed no special detectors; our ears rang from the sound. After many nights of working during the third shift (to avoid the union shop stewards) the problem was traced to a Sperry pressure window, and our assembly got a clean bill of health. When it finally went into the antenna, a new problem area appeared. We had told BTL many times that non-magnetic hardware was necessary everywhere, but it seemed that one or two ordinary bolts had been used in fastening the plastic pressure bubble over the feed. When the power was turned on, there was enough energy reflected back from the antenna subdish to heat the offending bolts red hot, and fry the flange of the bubble. After that, they believed us!

The last serious power problem we worked on was at Raytheon, where an S-band resonant ring pressurized with sulfur hexafluoride as a test setup seemed to have a "S-megawatt fuse" and broke down even when clean and empty. By using Mr. Wheeler's monograph on breakdown, we and the BTL engineer on the job determined that the system pulse length was supporting an arc hot enough to vaporize metal particles from the waveguide wall of a size to promote breakdown at the system frequency. The cure was a fast cutoff when an arc occurred; this not only fixed the problem, but earned the BTL engineer his Ph.D. and publication in the Bell System Technical Journal. All we got was a report classified SECRET and never seen again. This happened to much of our work, unfortunately. However, I heard from various sources that our TTR, DR, and similar antennas were in use from Ascension Island of the Atlantic Missile Range to Kwajalein and Meck Islands in the Pacific, as well as at the launch sites at Vandenberg AFB in California.

The multimode, multi-layer (MMML) feed proved so versatile and popular that it spread to many applications in many systems, and can be recognized as a WL trademark in tracking antennas. Its most serendipitous use came about when "optically-fed" array antennas appeared. Here the array face, open on both sides, was a honeycomb-like structure of "cartridges" containing computer-driven phase shifters for steering. The inner face was illuminated by an MMML feed, enclosed in an anechoic chamber supporting the array. What a neat idea! No moving parts, no lossy RF feed lines to the elements, super-fast steering over a large sector of space. And it used all the best of WL—array theory, array face design, radiators at each end of the cartridge, and of course MMML feed design! Raytheon built and tested a prototype in an "eyeball" mount and verified the antenna patterns for the benefit of skeptics unfamiliar with arrays. Again, high power problems occurred with the real thing—the reflection from the outer array face focused back into the chamber in a direction dependent on the steering, so the whole thing had to be lined with high-power absorber. I heard a story of a fire extinguisher on the wall having its plastic cone melted away during a test! This simple little antenna was originally designed for the lowly role of Missile Site Radar (MSR) among the big boys of PAR and MAR long-range detectors, but it performed so well in the field that it gradually took over many other system functions as well.

Raytheon developed another optically fed antenna, originally called SAM-D, for a mobile missile system. We designed the MMML feed assembly that sat in a little turret on a truck, and the WL array cartridges were made into a billboard-like structure that folded down over the truck for transport. And this became—Patriot!

A brief listing of the other projects I worked on at WL surprises me now with its variety: waveguide components in many bands, high-power antennas for the Delta and Titan vehicles, charts and analysis of response during flight trajectories, multi-layer radomes of various materials, aircraft antennas for adaptive systems, test programs of many kinds and of course, innumerable progress reports and technical reports to fill up the classified material files.

After retirement, I worked as a consultant for Hazeltine, Sperry, Lunn Industries (radome makers), and joined Paul Hammann's group of ex-BTL engineers to do studies for the Star Wars systems. It was interesting, but nothing like the old days. Time passes, and things change. To the best of my present knowledge, we have lost Bob Schott, Harry Redlien, Bob Wengenroth, Al Paskevich, Frank Williams and Charley Duke from Wheeler Labs, Bill Lightbowne and Paul Hammann, among others from BTL. They are all very much missed.

The End Is Not Yet

Our society today often sees women in the workplace as victims of discrimination, harassment, and a general deprivation of their "rights" and opportunities. Well, it was not so at all at Wheeler Labs. While at Hazeltine, the opportunities I had hoped for did not materialize, so I had promptly gone job-hunting, and most fortunately was found by WL. My starting salary was generous, and I always was more than satisfied with its progress over the years—how could it be so much fun to do this work and still get paid for it? My position also advanced in authority and prestige beyond my comprehension, since I always knew how much less technical and analytic ability I had compared to most of the others. I was just a quick study and a good technical writer who could take care of my people as I did the waves, keeping them happy and going in the right direction to do their very best work. Mr. Wheeler always treated me as he did all of us: with unfailing kindness, fairness, and respect. True, we had our differences of opinion, but they usually concerned weighty matters such as the use of the hyphen, or the relative merits of Carter vs. Smith Charts for impedance plots. (Two more people we have lost, and I knew them both.) Dave Dettinger was my mentor (although in those days the word wasn't used) and I owe him a tremendous debt for the way he made me develop the maturity and confidence to be an active part of the professional community for so many years. Truly, WL was the "kinder, gentler place" we all loved—and the end is not yet, as long as we can hold it in our memories and continue our "family reunions" as we have been able to do so far.

A View From The Past

On the following pages is a letter I wrote to Steve Ronzheimer, HC Chicago, in July 1985.

Dear Steve,

You had asked me for a description of the way Wheeler Labs trained new engineers and for suggestions of how these methods might be helpful to Hazeltine in getting and keeping its new employees. As I mentioned to you in our phone conversation, there are many differences between the two situations: the company itself, the type of work done, and the people concerned.

First of all, the company itself: Wheeler Laboratories (WL) existed as a small, independent engineering organization from about 1947 to 1971, part of that time as a subsidiary of Hazeltine Corporation (HC), but always as a self-recognized entity, with Mr. Wheeler at the head. The members still feel that they "belong"—the reunion held in 1983, long after the company had ceased to exist, drew remarkable attendance *(Editor's note: as did the 1993 reunion)*. Even when divided between the Great Neck and Smithtown locations, the general impression was always that all the staff knew each other, and that Mr. Wheeler knew each of us. HC, the much larger organization, with far more diversity in its operations, can only approach that "group" feeling in its smaller working units, although it does seem to have an excellent company loyalty, as shown by the ever-increasing number of over-25-year employees.

Next, the type of work: WL was more or less subsidized by the Bell Telephone Laboratories (BTL) as an extension of their engineering staff. Our efforts were closely monitored by BTL, and progressed in a mutually agreeable direction as the results became understood—we were usually developing equipment and techniques well beyond the state of the art. We were seldom required to submit or follow any detailed schedule of work, and the projects ran on for years. At HC, many projects are short-term, carefully planned price-competitive developments for various customers, and engineers will have multiple assignments. It is generally required that state-of-the-art components and techniques be used, and that problem solving be kept to a minimum. Even research projects tend to be limited in time and effort for exploring new developments.

The new engineers hired at WL, as at HC, were bachelor-degree graduates, some with undergraduate summer job experience. The educational background at that time, however, did not include much in the way of microwave theory, semiconductors, or computer experience, in contrast with the present. Recruiting at WL was carried out by some of the senior engineers, who visited the colleges and interviewed students recommended by professors of their acquaintance. Those who applied were evaluated for technical knowledge and the ability to apply it, and general attitude toward engineering. The number hired was small, to permit assimilation into the working groups at WL.

The organization at WL consisted of Mr. Wheeler, a Chief Engineer (Dave Dettinger was the first, and Henry Bachman was another), and a number of small groups of about two to six engineers assigned to various projects, each with a supervising senior engineer. Support included shop, drafting, technician, and secretarial staff. The principal product, according to our ads, was "Microwave Developments"; in my opinion, we also produced engineers! We delivered a few experimental models, detailed design information, and test results, and a considerable number of high-quality technical reports.

Unfortunately, most of the written work was classified information (some still remains so) and therefore very limited in circulation.

When a new engineer arrived to work at WL, his supervisor and work assignment had already been prepared by the Chief Engineer. After the usual paperwork, he would be given a notebook, a desk, and a working area in the same room. The supervisor would introduce him to the group, and briefly explain the group's task in general. At the new engineer's desk, the supervisor would then show him how to use the notebook, and write in it a "program" of his work for the next few days. The work would be discussed, equipment shown and explained, and the engineer told to bring his first results for review (usually by the end of the day). As time went on, reviews would be less frequent, usually at the end of each step in the assigned "program" of work.

Notebook entries would always be reviewed carefully for completeness and correctness. "Thinking on paper" in the notebook was encouraged, and the supervisor's comments and advice would be written in the book.

Periodically, the supervisor would hold group reviews of the project work to date, with discussion and explanations of results, outline of plans for the next period, and work assignments with priorities and schedules. This would then be presented to the Chief Engineer. If there were problems or significant progress, a conference would be held with Mr. Wheeler, and his view of the work would be recorded in the engineer's notebook.

A new engineer would be given writing assignments (in addition to the regular weekly progress reports by each person) as soon as practical, with instructions on the criticism and review procedure.

A feature at WL was the Report Checklist, a folder listing the steps to be followed (and initialed) in the preparation of a technical report. Three people were assigned: an author, a critic, and a reviewer. The reviewer, usually the Chief Engineer, saw the initial Brief Outline indicating the scope and content of the report, and read the final product as if seeing it for the first time. The critic, usually the engineer's supervisor, worked closely with the author through the detailed outline and draft stages, to the final master-typed stage. Before release of the report for delivery to the customer or for publication, Mr. Wheeler would also be asked to read it. The author could then be assured that his report was indeed a credit to himself and to WL.

In addition to developing writing skill, the new engineer was given opportunities to make oral presentations of his work—to his supervisor, to his group, to the Chief Engineer and/or Mr. Wheeler, and to the customer. WL had regular programs of two-hour "engineering seminars" for the staff, at which current work would be presented, and engineers were encouraged to present 20-minute technical papers at various IEEE symposia.

The new WL engineers were expected to do their own drafting and technician work when appropriate, so that they learned these procedures under supervision before they had to direct the support staff to perform them. The chief objective of training was the pursuit of understanding of the task, objectives, results, methods and procedures. The engineer's work was always directed and reviewed, to insure working at his best and most productive capability, and to share information and insights among the group and the staff. The supervisor's task was that of being always aware of what the members of the group were doing (and ought to be doing); he usually had no specific task of his own except for the administrative duties such as collecting time sheets etc., and of course the responsibility of planning and directing the group's efforts, under the supervision of the Chief Engineer.

I hope all of this is of help to you (and to HC).

Sincerely,
Patricia L. Burgmyer

Ned A. Spencer

I saw the WL ad in the Proceedings of the IRE (now the IEEE). A year out of MIT with a Bachelor's degree in Electrical Communication, this Florida boy had enough of the winters in Buffalo, New York at Bell Aircraft Corporation, though it was an interesting job on a radio/radar guided air-to-ground missile called Rascal. So, in 1948, I made an appointment to visit Wheeler Laboratories in Great Neck. I noted that in my copy of Terman's handbook, Mr. Wheeler had more references to his name than anyone else, except for G. H. Brown and Terman himself. I hoped that I would find a solid, professional organization—boy, did I hit it right!

When I reached my destination in Great Neck, however, I did have my doubts as I climbed the outside staircase to the second floor of the old fire station. The doubts all disappeared when the interview was over! Mr. Wheeler asked me a question about the sharpness of the cutoff of a low pass filter, such as would be used in a video amplifier. Somehow, I recognized that if it looked Gaussian, an input pulse would take on that same shape and not evidence the troublesome ringing that was so common in those days. What an introduction to the antenna patterns that I would be steeped in for the next two decades!

Reviewing my experience at "The Labs," there are two general areas that were memorable: new and improved skills, and technological developments. Actually, there were so many that it is hard to list but a few of the more notable ones.

<u>The Skills</u>

Shortly after I started at WL, I found that I was in the midst of a very experienced team of writers. Mr. Wheeler had written a host of technical papers and reports, Dave Dettinger, our Chief Engineer, was an eager and effective disciple, and engineering notebooks were our daily stock in trade. Nothing in school or in my previous employment had prepared me for this intensity of documentation. Writing reports was truly agony, as practically every paragraph had to be rewritten (because it just didn't say what was intended). Fortunately, Dave appreciated what we new people were going through, and set up both a system and a training program that brought us all into the process so that we could learn from each other. His report checklist formed the basis for a similar process that I helped establish at The MITRE Corporation, where I went after 22 years at WL/Hazeltine. Documentation remains one of the under-taught subjects in our engineering schools, and with the rise of software teams and concurrent engineering, it is needed more than ever.

It often seems that engineers tend to become introverted, preferring to work with "things" instead of with people. Our little group at WL, however, was people oriented—maybe to the extreme. Three examples come immediately to mind, and I have shared them with others often since I left WL, as illustrations of morale builders.

- When Rose Belfiore (now Rose Rickert) was the Lab secretary, she often took off her shoes to be comfortable at her desk. Somehow the shoes disappeared one day and she searched high and low for them. She finally found that the staff had obligingly filed them in a five-drawer cabinet under "S" for shoes.

- Individual responsibility was a valued characteristic at WL, and high on our list of priorities. I remember once being very pressed to do something (I don't remember exactly what it was, but Dave and Mr. Wheeler were waiting for me.) Just at that moment, Joel Becker came to me saying that he had finished his task and was all set for a new one. Unfortunately, I had no time to talk to him at that moment. When he insisted, "But what should I do?" I (foolishly) replied, "Use your ingenuity." When I returned from my meeting, I found that he had disassembled my swivel chair! Individual responsibility and ingenuity take many forms—I valued that experience and learned that staff is management's number one responsibility.

- Rare events do happen. When Dave and his bride, Carolyn, went on their honeymoon, the Lab just had to think of something to let them know of their endearment. We pooled all our keys and tried them at the nearby apartment that Dave had just fixed up. Wouldn't you just know, one key did fit—it was the key to Bob Wengenroth's parents' home in New Jersey! Once inside, we did some memorable things for the newlyweds to discover when they returned. The good-natured fun and real respect by "those Lab people" were more than matched by the equanimity and appreciation expressed by Dave and Carolyn. Childish? Perhaps, but it served, relatively harmlessly, to raise our consciousness out of the mechanics of our work to the real source of our strength—our people.

<u>The Technology</u>

By all reports, and by any measure, the team assembled at WL was outstanding in its accomplishments, both in quality and quantity. I will mention only three with which I was personally involved.

- We were trained, repeatedly and insistently, by Mr. Wheeler to be careful experimentalists and analysts. We once designed a multichannel rotary joint that applied a Wheeler concept for a waveguide-to-coaxial transition. This transition split the waveguide in half to form two paths, which were then joined back together in parallel at the coaxial line, thereby automatically achieving a 4:1 impedance advantage over all other types. It was then easy to obtain the remaining impedance reductions by gradual steps. The design was developed and implemented at WL, producing a very broadband transition. I wrote the report describing the rotary joint and included drawings giving the essential dimensions. When Bell Telephone Laboratories manufactured their first prototype of the rotary joint, they said it was horribly mismatched and all dimensions were as designed. I went to their facility at Whippany, New Jersey and sat down with their engineers, going over in detail their results. They were right—the rotary joint introduced substantial reflections—but what caused them? After checking all the dimensions that we could see, we went through the process of establishing short-circuit references across a band of frequencies and compared them to the amplitude and phase of the standing wave pattern of the complete rotary joint. (Interestingly, Bell, the inventors of the reflection chart, didn't use it themselves.) After a whole morning of such measurement and analysis, I said that all the evidence pointed to a dimensional error in the innermost part of the rotary joint at the waveguide-to-coax transitions. While this was greeted with much skepticism, they agreed to disassemble the entire unit and check those dimensions. By the end of the day, word came back that, indeed, the dimensions were in error! From that point on, everything was quickly resolved—and WL rose another notch in BTL's estimation.

- Displaying results in a meaningful manner was another of Mr. Wheeler's strengths. One of our tasks was to make a filter that separated a wide bandwidth of frequencies into hundreds of narrow-band channels. We planned to couple a cavity resonator to a waveguide feedline for each narrow-band channel, and then make a parallel chain of these resonators that would cover the entire bandwidth. Because the cavity-to-waveguide coupling would change with frequency, however, we would have to introduce additional loss into the cavities to ensure that the bandwidth of each channel would be similar. After starting into the process of developing a few of these narrow-band cavity resonators, it became apparent that we could balance off the natural variation that occurred in coupling with the natural variation of loss inherent in each cavity caused by skin-effect. The concept was exciting. If it worked, we would not have to introduce lossy material, make it adjustable, and risk its changing over time and temperature. But there were lots of factors that had to be managed concurrently to get this behavior, and that's where a nomograph integrating all the factors was introduced. The technique worked outstandingly. Today, a computer program would undoubtedly control an automated milling machine to do the whole job, but the visualization of the interaction and understanding of the relationships only come from such a graphic display. Later, when I was at the MITRE Corporation, I was able to apply a very similar nomographic technique to the problem of appropriately integrating receiver sensitivity, transmitted power, antenna gain, and antenna pattern characteristics to the problem of aircraft surveillance for the nation's air traffic control system.

- Finally, I must make note of how I came into contact with Mr. Wheeler's attention to detail. Probably the thing I can most brag about to my friends is our development of the Stationmaster antenna. This very unusual array of vertical elements produced a vertically polarized, omnidirectional pattern with gain (narrow vertical beam). The application is ubiquitous—fire stations, police stations, taxi bases, etc. Today, 40 years after its invention, it is as popular as ever. We developed it, patented it, and, working with Communication Products Inc., carried it through the trials of producing it. However, it was not until some time later that we really understood it! The occasion came about when Common Products Inc. agreed that we should make a super-duper Stationmaster—wideband, no preconceived constraints. So we made it out of copper and brass tubing instead of the dielectric-loaded cable that we had previously used. I had previously come up with a method for computing the gain (actually, the directivity) by first plotting the vertical pattern on special home-made graph paper, then using a planimeter to compute the area, which was the directivity. The process was reasonable, but required care in obtaining the pattern and in measuring its area. When we finished, our calculation was within 1/2 dB of the theoretical value—I was ready to celebrate. Mr. Wheeler, however, wanted to know what had happened to that 1/2 dB! Well, sure enough, we discovered that without the dielectric loading a "non-radiating" parasitic resonance was lurking there, causing the unexpected loss. Once we understood the effect, we handled it—differently for different antennas, but again I learned to watch out for those unexpected details. Interestingly, this phenomenon was used to demonstrate that a prior patent was not valid, and as a result, the Stationmaster patent withstood a challenge.

I am sure it is obvious that I, and all my colleagues at WL, have great respect, admiration, and friendship for Mr. Wheeler and for Dave. Our careers have been strongly influenced by them.

I'd like to conclude these reminiscences by acknowledging another member who also made a personal impact on me—our Chief Machinist, Al Paskevich. He always had time to teach a young engineer the concept behind tools, how to use them safely, how to solder and braze. Most of all, Al taught us respect—respect for our tools, our environment, and for our fellow man.

Peter W. Hannan

My association with Wheeler Laboratories began in 1948 with a summer job. I still remember being interviewed by Dave Dettinger, who asked me to describe something I had done that interested me. Fortunately, in my last year at Stevens Institute of Technology, a fellow student and I had built a Betatron, which accelerated electrons to relativistic velocities by means of a varying magnetic field. Somehow, I survived Dave's questions and got the job. Incidentally, I had chosen the Betatron project because it did not require an RF field to accelerate the electrons. What I did not know then was that the rest of my life would be involved with RF.

My task that summer was to design and measure an X-band (10 GHz) Cutler feed for a small reflector antenna. I constructed a wooden fixture to rotate a pickup horn around the transmitting feed to measure its radiation patterns, as shown in figure 4-1. Each point on the pattern was individually measured and plotted by hand on graph paper. A problem I had was that when the receiving horn came close to the feed waveguide, the signal strength readings became erratic. How could the peak gain and the half-power beamwidth be accurately determined when the peak of the radiation pattern could not be accurately measured?

Mr. Wheeler provided a solution to this problem in the form of graph paper with a square-law angle scale. Since the signal strength of the basic radiation pattern would be expected to vary with the square of the angle near the peak, plotting this part of the radiation pattern on the special graph would yield two straight lines, as shown in figure 4-2. The erratic values obtained near the feed waveguide were also plotted but were disregarded in drawing the straight lines. The peak signal level was considered to be at the intersection of the two straight lines.

Some time later, I used this approach to solve a different problem. In celestial navigation, a sextant is used to measure the angle from the horizon to the sun, moon, planet or star. Together with the time of observation, this angle yields one line of position on the earth. A second line of position crossing the first line is obtained by a second observation on another body, preferably located at a different azimuth to yield an accurate intersection of the two lines. The easiest body to use is the sun, and the easiest time to measure its elevation angle is at local apparent noon

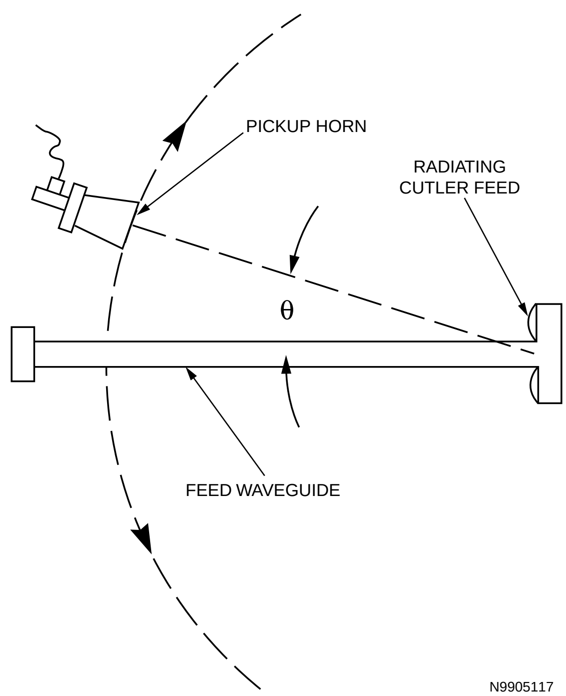

Figure 4-1. Measuring the Radiation Pattern of a Cutler Feed

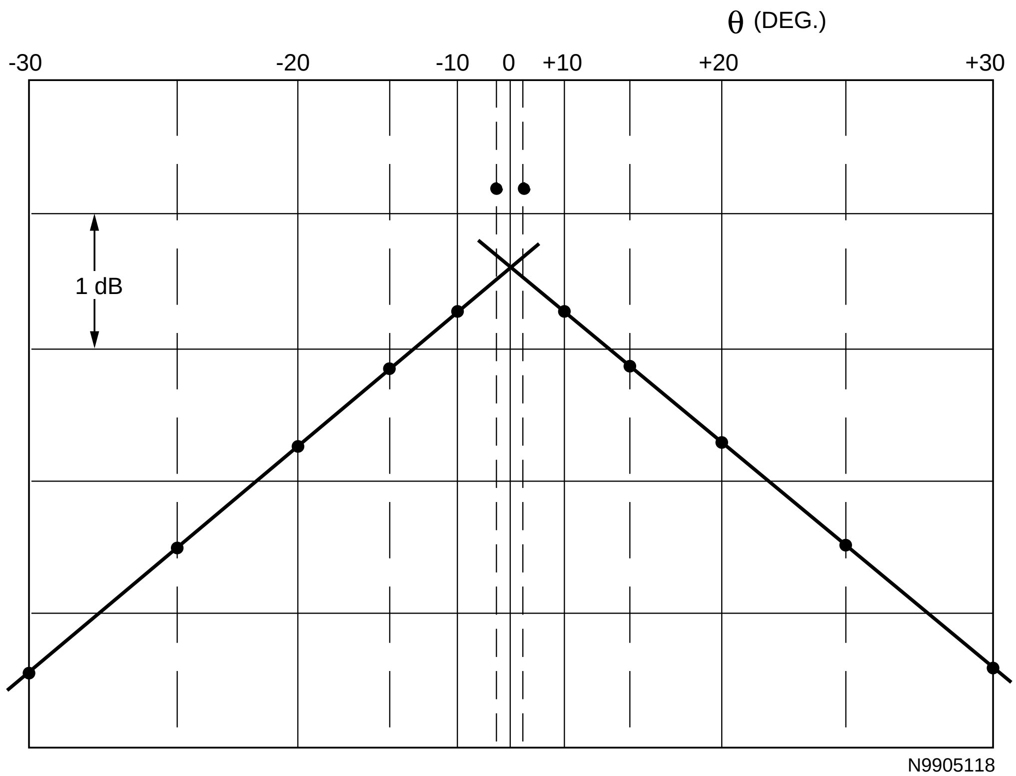

Figure 4-2. Special Graph Plots Pattern Peak Region as Two Straight Lines

when it is at maximum elevation; this observation yields one's latitude. Longitude could also be obtained if the time of maximum elevation could be determined but this is difficult to obtain accurately because the sun's elevation changes very slowly. However, with a modified form of Mr. Wheeler's square-law graph, I found that a series of elevation angle measurements versus time, when plotted on the special graph, would allow a single straight line to be drawn that yields the time of maximum elevation with surprising accuracy. I used this technique on some of my sailboat trips in the Bahama Islands.

Cassegrain Antennas

After working that first summer at Wheeler Laboratories in Little Neck next to the firehouse whistle, I spent a year at the University of Pennsylvania getting an MSEE degree. Then I returned to Wheeler Laboratories, where I worked on microwave waveguide component design. Dave Dettinger, Pat Loth, Herb Rickert, Ned Spencer and others in the new building in Great Neck developed an X-band monopulse comparator and waveguide assembly, and I was sent to Bell Telephone Laboratories at Whippany, New Jersey, to measure the performance of the complete Nike-Ajax radar tracking antenna that contained these components. It turned out that the antenna, which used a large metal-plate lens as its focusing element, gave performance that was not as good as desired.

A little while later, Bell Laboratories asked Wheeler Laboratories to design an improved tracking antenna for the Nike-Hercules system that would use our previously developed monopulse comparator. An ordinary reflector antenna was considered good, except that the comparator would have to be located out in front of the reflector, yielding a cumbersome antenna and pedestal structure. It occurred to me that a double-reflector antenna, based on the Cassegrain telescope principle, would be quite compact and would allow the comparator to be located behind the reflector, as desired. However, the secondary reflector, or sub-dish, would be so large as to create intolerable blocking of the antenna aperture. To solve this problem, I devised a polarization-twisting approach that made the sub-dish invisible to the vertically polarized wave radiated by the antenna. The technique involved closely spaced wires embedded in the fiberglass surfaces comprising both the main reflector and the sub-dish. Operation of this antenna is shown in figure 4-3.

The customer, Bell Laboratories, was enthusiastic about this approach and provided the mechanical engineering, fabrication oversight, and development funding needed to yield the antenna that was produced in quantity for the Nike-Hercules system. The eight-foot diameter antenna, seen on its pedestal in the upper left-hand photo on page 27, gave the hoped-for good performance.

In the years following, Wheeler Laboratories developed many more Cassegrain antennas for various different radar systems, testing each antenna at its new antenna test range at Smithtown. The upper right-hand photo on page 27 shows a four-foot monopulse Cassegrain being prepared for pattern measurement; the technician is attaching the sub-dish to the main reflector. The eight-foot SPG-55A Cassegrain antenna developed for Sperry and used in large quantities by the U. S. Navy is shown in the upper left-hand photo on page 28. This antenna had a different feed at each of the two focal points, as shown in figure 4-4. Another interesting Cassegrain monopulse antenna was developed with a moveable sub-dish that defocused the antenna to vary its beamwidth. A scale model of a much larger, high-power version of this antenna is shown under test in the lower photo on page 27.

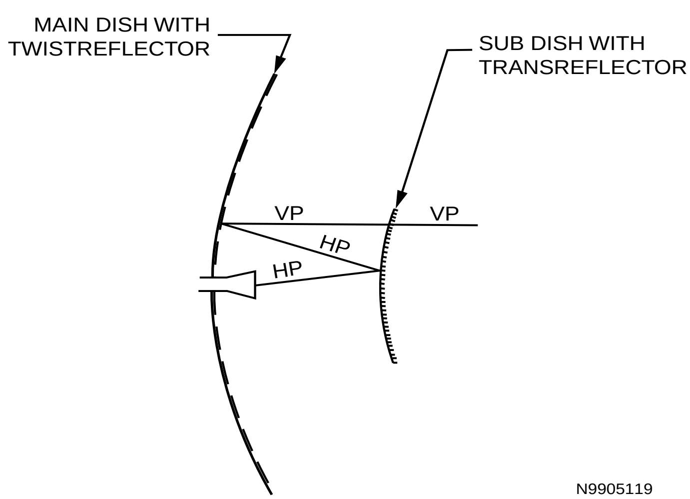

Figure 4-3. Polarization Twisting Cassegrain Antenna

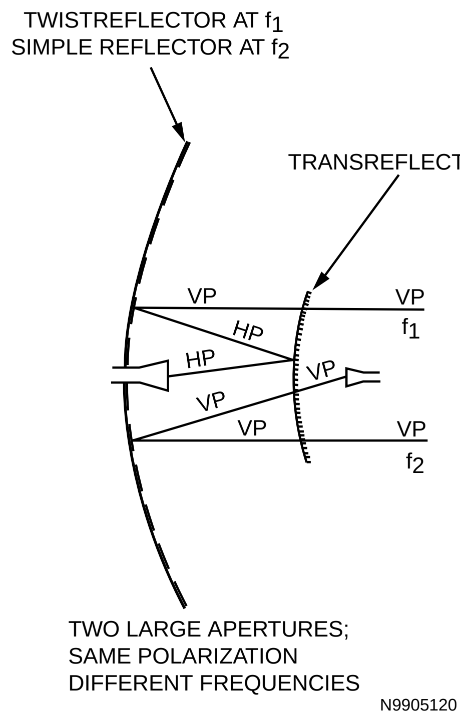

Figure 4-4. Dual Feed Cassegrain Antenna

Optimum Monopulse

The typical feed in the early monopulse antennas consisted of four square horns in a square cluster. In the sum mode, all horns operate together in phase to efficiently illuminate the antenna reflector. In the azimuth and elevation difference modes of the monopulse system, one pair of horns operates with a phase opposite to the other pair. This provides the two-lobed anti-symmetrical difference patterns used for target angle determination for the system. I came to realize, however, that the reflector illumination provided by the conventional feed in the difference modes was far too wide, causing high sidelobes and weak main lobes in the antenna difference patterns. The reason for this was that the feed size that gave good sum-mode performance was too small to give good difference-mode performance.

Once the problem was stated, the solution was apparent: design a feedhorn system in which the effective size of the feed aperture was independently controlled in the three modes of operation. I found a practical way to do this by using a combination of stacked horns and multiple waveguide modes, as shown in figure 4-5. A feed using this approach was developed at Wheeler Laboratories for the twenty-two foot diameter Cassegrain tracking antenna for the Nike-Zeus system, and it gave excellent performance. This feed is seen being tested at Smithtown in the lower photo on page 28. In later years, several similar feeds were developed at Wheeler Laboratories, including the feed for the Patriot system's tracking radar. This monopulse feed, seen between two transmit horn systems in the lower photo on page 26, used five stacked multimode horns.

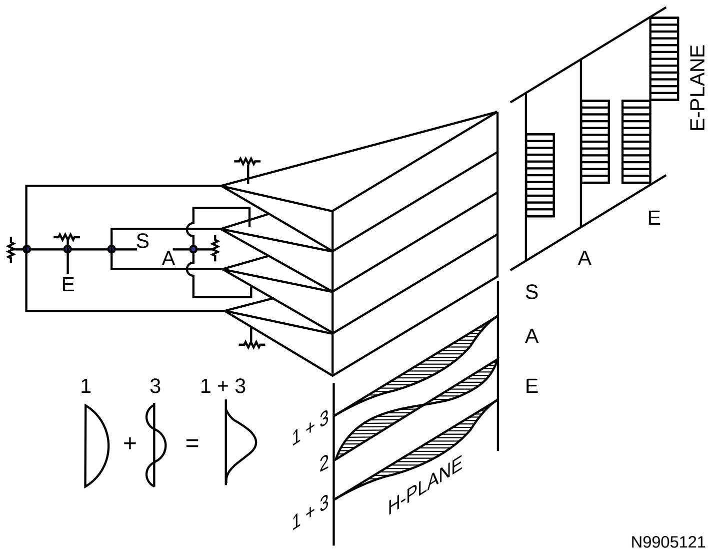

Figure 4-5. Independent Control Monopulse Feed

Phased Arrays

As RF components such as electronic switches and phase shifters became practical, another type of antenna became the subject of work at Wheeler Laboratories: the phased array. Although typically much more complex and expensive than a reflector antenna, they were also more versatile, permitting rapid electronic beam scanning, multiple simultaneous beams, and physical configurations that were able to conform to various shapes such as flat panels, circular cylinders, or streamlined aircraft fuselages. Along with Mr. Wheeler, Al Lopez, and others in Wheeler Laboratories, I contributed to this field at various times. One example is a general theory for uniform planar arrays with a large number of radiating elements in which the gain (g_r), realized by a typical radiating element, is given by:

$$\sum_{m=0}^{\max} \frac{g_r\,(\theta_m,\ \phi_m)}{\cos\ \theta_m} \;=\; \frac{4\pi A}{\lambda^2}\,(1-\left|R(\alpha,\beta)\right|^2)$$

where θ_m is the scan angle off broadside of lobe m, A is the area allotted to the element, and R is the active reflection coefficient of the phased array as a function of the interelement phasing α, β. The gain realized by the complete array at the peak of the lobe m is given by:

$$G_r\,(\theta_m,\,\phi_m) \;=\; n\ g_r\,(\theta_m,\phi_m)$$

where n is the (large) number of elements in the array. For a phased array with element spacing close enough to avoid grating lobes, the only value for m is zero, corresponding to the desired main lobe.

The active array reflection coefficient R varies with the interelement phasing that scans the beam, because of the mutual coupling between elements, as indicated in figure 4-6. This reflection-coefficient variation has been the subject of much investigation, including Mr. Wheeler's analysis called the grating-lobe series. The active array reflection coefficient can also be measured in simulators that we developed at Wheeler Laboratories. These simulators image an infinite planar array in the walls of a waveguide containing only a few elements. An example is shown in the photo on page 34; each of the five waveguides simulates a different scan angle or plane of scan.

One phased array developed by Wheeler Laboratories and Hazeltine as a team was a 40-foot diameter, 8-foot high cylindrical array for an air traffic control beacon system that communicated with aircraft transponders. It provided a vertical fan beam with a sharp-cutoff elevation pattern to discriminate against ground-reflected signals that otherwise could have interfered with air traffic control beacon system operation. The fan beam had two azimuth patterns: a sum and a difference pattern. This fan beam scanned electronically 360° in azimuth and a few degrees in elevation. The cylindrical array could be mounted around the tower supporting an existing rotating radar reflector antenna located at an airport, as seen in the upper photo on page 31. Each of the white columnar radomes seen in the figure enclosed four vertical linear arrays of 16 radiating elements each. There were a total of over 3500 radiating elements in this cylindrical array, which operated at L-band (1 GHz).

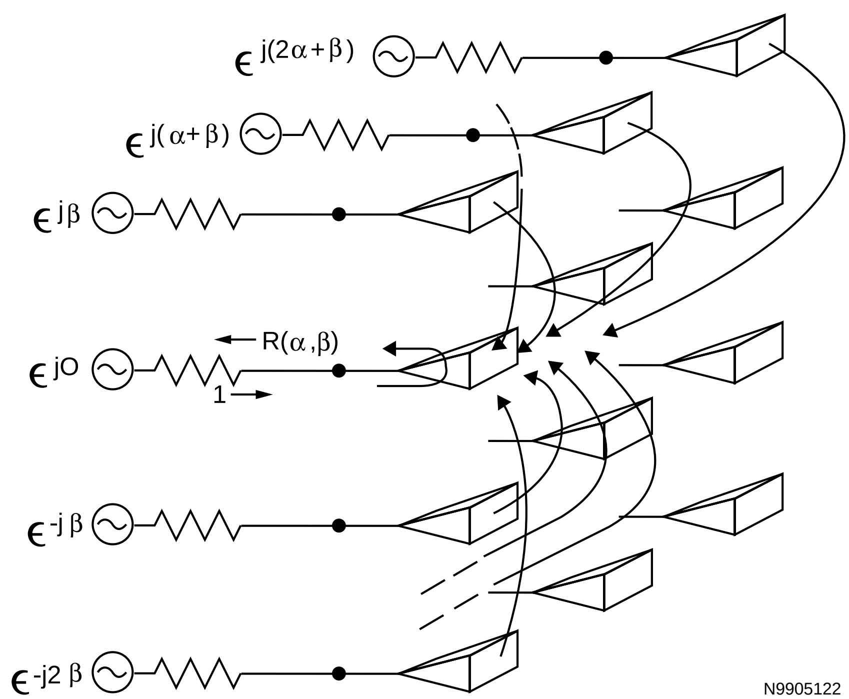

Figure 4-6. Mutual Coupling Causing Variation of Active Array Reflection Coefficient

An alternate approach for the same air traffic control application turned out to be less expensive, while still providing the essential features needed: a sharp cutoff elevation pattern and low-sidelobe sum and difference azimuth patterns. The Wheeler Laboratories/Hazeltine team developed a planar array that did not scan electronically, but rotated in azimuth with the radar antenna on which it was mounted. This planar array had a resonant reflecting plane that was open to the wind, but which prevented RF radiation to the rear, where no radiation was wanted. The array, seen at the top in the upper photo on page 31, is now in operation at hundreds of airports around the country. A closer view of this array under test at Smithtown is seen in the lower photo, also on page 31.

Development of the above two array antennas spanned the time when Wheeler Laboratories changed from a distinct subsidiary of Hazeltine to an engineering group in Hazeltine's Research Laboratory. This group of Wheeler Laboratories' engineers has continued to design interesting and innovative antennas right up to the time of this writing (1994). I have greatly enjoyed the many years spent at Wheeler Laboratories and Hazeltine, where I am currently still working full time in the antenna group.

Henry Schwiebert

(Editor's Note: Henry Schwiebert died in May 1993, just a week after Wheeler Laboratories held its third reunion. Dave Dettinger edited the following material, which was originally assembled by Mr. Wheeler for inclusion in this book. Henry's widow, Betty (Heathcote) currently resides in the town where Hank built their unique retirement "solar" house. Her address is 4718 Belvedere Dr., Post Office Box 1297, Julian, CA 92036.)

Henry (Hank) Schwiebert was born in the Bronx on April 8, 1921. He received his BSEE degree at the Polytechnic Institute of Brooklyn, and joined the war effort at Hazeltine in 1942.

He joined Wheeler Laboratories in 1948 and remained with the Labs for seven years, serving as an Assistant Chief Engineer under Dave Dettinger, and making major technical contributions in addition to his supervisory duties.

The first work for which he had primary responsibility (1948-1949) was the design of components for the Nike X-band radar for Bell Telephone Laboratories in Whippany. They included a feedhorn for the lens antenna and several waveguide components.

A major program which he conducted (1950-1954) was the development of the "steptwist" waveguide rotary joint. It started with a fixed-twist joint of several collinear sections at progressive angles of "twist." Then it developed into a rotary joint in which the successive sections were twisted at progressing angles. The mechanical simplicity and non-reflecting performance were outstanding. Mr. Wheeler worked closely with him on this project.

The Army Signal Corps had an ongoing problem of detecting non-metallic buried anti-tank mines. The problem had been the subject of various studies. Hank and Mr. Wheeler worked together on this project and submitted valuable findings on this challenging subject.

An absorbing hobby for Hank was building a 27-foot auxiliary schooner in his backyard. The launching of the elegant “Princess” (a name coined by his 6-year-old daughter Joan) was a neighborhood event. The family spent many vacations on their boat along the eastern seaboard.

After leaving WL in 1955, he worked until 1965 with Murray Crosby, a prominent engineer on Long Island; the company was Telectronics, later Crosby-Teletronics. Subsequently, he held a responsible position with Airborne Instruments Laboratory (AIL) on Long Island; AIL later became a division of Cutler-Hammer.

In 1975, the whole family moved to California, where Hank joined his brother-in-law, Thurston LeVay, (also an ex-Hazeltine engineer) in a private enterprise in the Los Angeles area.

Hank retired in 1986, and he and Betty settled in Julian, an old gold-mining town high in the Cleveland National Forest Mountain Range.

Roderic V. Lowman

I feel as though I have been associated with Harold Wheeler for my whole electrical engineering career; first at Hazeltine, then at Wheeler Laboratories, and finally, through the activities of the Institute of Electrical and Electronics Engineers (IEEE). It has been a remarkably rewarding association as I will explain later, but first let me give you a little background that led up to the fortunate coincidences of our converging career paths.

I was born on January 20, 1920 on a small farm just outside New Madison, Ohio. My parents were just recovering from moving my one-year-old brother and all their other worldly possessions by horse and wagon onto a farm they had bought at the height of the post-World War I real estate boom. It was a typical small farm of the time; we had no electricity or running water, no radio, the toilet was in the back yard and travel was by horse and buggy. When my younger brother arrived a year later, our very happy family was complete. My dad had studied to be a lawyer, but after practicing for one year he became disenchanted with the field and switched to farming, raising cows and operating the small dairy that supplied the milk to the town of New Madison (population 5003) for over a quarter of a century. Mother had been a Home Economics teacher, which prepared her well for her role as director of a WPA sewing project. That effort enabled us to prevent the bank from foreclosing the mortgage on the farm during the Depression.

I started my education as one of the two first-grade students in the local one-room school near the farm. After one year we moved into the newly completed New Madison school for the rest of my primary and secondary education. In junior high my brother and I decided to remedy our lack of radio by building crystal sets, giving us access to outside news and entertainment.

When I continued my education at Ohio State University, I became very concerned about the worsening world situation. It seemed to me that the major cause of conflict was the fear we have of those whom we do not know and do not understand. The best deterrent seemed to be better communications that would increase understanding. Being interested in engineering, the communications option of electrical engineering seemed an obvious choice.

Upon graduation in March of 1943, I was attracted to Hazeltine by a '42 classmate, Dave Bowman, and thus began a career-long association with Harold Wheeler. I started with his investigation of the use of the super-regenerative receiver in the transponder of IFF equipment that Hazeltine was building for the Navy.

After the war, I took a year off to complete my Master's degree at Columbia. By the time I graduated in l948, Harold had started Wheeler Laboratories and it was only natural that, given the opportunity, I should follow my mentor into a new challenge. It was during those glorious years between 1948 and 1951 that I had the closest association with Harold Wheeler and the other members of the Wheeler Laboratories staff.

Given the excellence usually associated with members of the Wheeler Laboratories staff, I was eagerly accepted in 1951 by AIL Systems for development of sophisticated reconnaissance and surveillance systems. For 33 years until I retired from AIL in 1985, I continued in the development of new techniques and systems for intercept, signal processing, direction finding, location, range finding, filtering and electronic countermeasures. Now, with my own consulting company, Techni-Quest, Inc., I have continued to be active in the electronics field.

At both Hazeltine and at Wheeler Laboratories, Harold Wheeler impressed upon me the value of working with professional organizations for the benefit of the profession and its members. In my many activities with the Long Island Section, the Region 1 committee and on national committees (including the 1983 delegation to China), I was in frequent contact with Harold and still relish this association.

Now back to those halcyon years at Wheeler Laboratories. A flood of memories well up from my subconscious at the mention of Wheeler Labs—some high-tech, some low-tech, some strictly frivolous.

Among the high-tech were the Wheeler Monographs, the regular technical sessions when staff members presented discussions of their work or other important areas they had studied, and the challenging contracts we had for the development of microwave devices for Bell Labs.

Among the low-tech memories were such mundane items as the "headlight" in the lab at the firehouse. When I started, the lab was on the second floor of the firehouse in Great Neck and consisted of a couple of offices, a lab area, a machine shop room and a single bathroom off a recessed hallway. Naturally, the bathroom was in use whenever you made an excursion in that direction. So we put a microswitch on the door to the bathroom and a "headlight" in the lab to minimize the number of unsuccessful trips. Then, there were the lunchtime discussions around the lab bench as we munched our bag lunches together.

I think you will better appreciate just how important the "strictly frivolous" was after I describe how very successful the lab was to the careers of the staff members, to our customers, and to the electronics industry on Long Island.

In the more than four decades since those Wheeler Labs days, I have often reflected on the number of important leaders of the electronics industry on Long Island that were former Wheeler Labs employees. In the IEEE, as Long Island Section chairman, historian and active for many years on the awards committee, I have often needed to search the records for those engineers with outstanding records of achievement. In doing so, I have observed that the electrical engineers employed by Wheeler Labs at any given time represented only a very small fraction of the total number of electrical engineers in Nassau and Suffolk counties. What is significant is that even so, a disproportionately large percentage of the engineers who were recognized for outstanding achievements, ingenuity, productivity or their willingness to give of their time for professional activities like the IEEE had been staff members at Wheeler Labs. A mighty impressive record and ample justification for characterizing Wheeler Labs as "A Training Ground for Excellence."

I have given a great deal of thought to why Wheeler Labs produced staff members with outstanding records of achievement. I attribute this remarkable success to the three E's: example, encouragement, and environment.

In the beginning there was no better example than Harold Wheeler. Soon, Wheeler-trained engineers provided multiple examples for new staff members.

Wheeler encouraged staff members to accept increasing responsibility. He encouraged them to learn to do everything, for in a small company there is less room for specialization and a great need for people who can pick up any part of the job.

But I believe that the most important contributor was the environment. I spoke earlier of some aspects of the environment, as I gave examples of the high-tech activities and the low-tech activities. Now I would like to return to the most distinctive, and I think the most important, part of the Wheeler Labs environment, the "strictly frivolous."

Last year The New York Times reported on studies that had been made of a number of companies. Those companies that produced the most inventive, most ingenious results were those which had an informal atmosphere and numerous harmless pranks among the staff members, both on and off the job. Though not in the study, there could be no better confirmation of their conclusions than Wheeler Labs. Because I think it was so important, I would like to conclude my chapter on the lighter side with several examples of the "strictly frivolous."

When our very excellent young machinist, Al Paskevich, got married, the whole staff turned out. It was a delightful, simple wedding ceremony enjoyed by all, and after the usual expression of best wishes to the bride and groom in the receiving line, Al and his bride climbed into Al's car. As we all waved them off to their honeymoon, Al raced the motor, let out the clutch, and went nowhere. Checking to be sure the car was in gear he tried again with similar results. After a suitable period of consternation Al got out to investigate and found that his co-workers had carefully lifted each of the rear wheels slightly off the ground with blocks under the axle so that the wheels were spinning uselessly in the air.

Dave Dettinger, an inveterate prankster himself, was a favorite target of the "strictly frivolous." When Dave and Carolyn were married, we bought a 16-inch war surplus plastic globe, secured a chain in the center, poured it full of 46 pounds of concrete, and painted it black. As Dave and Carolyn stood in the receiving line at the back of the church, we opened a door behind Dave, slid the chain around Dave's ankle and fastened it with a combination padlock recently retired from the security system. The wedding couple made a unique picture as Dave came out of the church with Carolyn on one arm, and carrying the ball and chain in the other. We pictured Dave, director of the lab and director of security, trying all the combinations he could recall in order to remove the chain. To our chagrin, the hasp of the lock was not the hardened steel we imagined and Dave's brother-in-law was able to cut it off with a hacksaw.

While Dave and Carolyn were on their honeymoon, his co-workers' fertile minds were not idle. Pooling all their keys they found one that opened Dave's apartment door. When the honeymooners returned they found that the furniture was pushed together in one corner of the room and covered with painter's drop cloths. Empty paint cans littered the floor. Determined to make short work of this mess, Dave dropped their bags and started to hang his coat in the closet, only to find it stuffed from top to bottom with wadded-up newspapers. A trip to the bathroom revealed that the bathtub was filled with gelatin.

After a suitable cleanup effort, Dave sought respite from all this with a cool drink from the refrigerator. As he opened the door, the doorbell rang; closing the refrigerator, he answered the door but found no one there. Returning to the refrigerator, the doorbell rang again. As you may have guessed, the doorbell had been connected to the light in the refrigerator. After restoring the apartment to a more livable condition the honeymooners collapsed into bed, turned out the light and found a pair of eyes leering at them from the ceiling. An artistic staff member had been busy with luminous paint!

Another year, after a vacation in Europe, Dave returned refreshed and eager to get back to work. Arriving at the lab a few minutes before 8 o'clock he found that the door was locked. Strange, Mr. Wheeler was always there early to open the lab. But he had his key, opened the door and found that the desktops were empty, the stools were all inverted on the lab benches and no one was around. Going to his office he found on his desk a note from the staff member left in charge explaining that while he was gone, Bell Labs had cancelled all their contracts and that they had to lay off the entire staff. Racing upstairs to Mr. Wheeler's office, he found Harold, enjoying the whole situation. Mr. Wheeler explained how the staff had asked to shift the workday a half-hour later just for the day to increase the reality of the hoax.

On another occasion, a staff member went out to lunch with a visitor and returned to find his compact automobile high in the air, rotating on the antenna turntable. On the middle of the roof was a bathroom plunger, simulating the test antenna as the little car continued its endless rotation. A view of this unique prank is shown in the lower right-hand photo on page 25.

These typical examples give you a flavor of life among the staff members of Wheeler Laboratories. Politically correct? Probably not, but who cares? These exploits generated a marvelous camaraderie and esprit de corps that sharpened the wits and developed the ingenuity that was continuously applied to the outstanding technical output of this premier development laboratory.

Rose A. Belfiore

When I, Rose Antoinette Belfiore, entered the world of engineering in June of 1944, I found a group of people that helped shape my future endeavors in the most marvelous ways. It seemed that there was a very special angel watching over me who sort of nudged me from one wonderful place of employment to another. My high school shorthand teacher assisted me in getting my first position at Hazeltine as a stenographer with a group of people who had various types of jobs. Soon, like a checker, I was moved to Department E-9 as secretary to the man in charge. It was here that my interaction with engineers really began. Most of my contacts were male engineers, with one exception; Patricia A. Loth was the only lady engineer amongst a large assortment of personnel employed at Hazeltine Electronics in Little Neck. These were still World War II years and the research and development was classified. I typed many bits of information that were foreign to me, so the secrets were safe.

I recall my nervousness when my boss, William Woodbury, would say, "I have some letters to dictate." Those were the days of Gregg shorthand, not word processors. And hearing words like superheterodyne, oscillation, microwaves, torque tests, etc., would cause my fingers to tremble as they made up symbols never taught in school. Fortunately, I had a fairly good memory and the letters or reports were typed and sent on their way. Although this was a serious and sad time in the life of our country, there was always time for lighthearted activities, thoughtfulness among the staff, and cheerful cooperation. Some of the people I met then still keep in touch.

After several years at Hazeltine, that angel again nudged. William Woodbury informed me that Daniel E. Harnett was forming a new company, Harnett Electric Co., and that it would be located in the town in which I resided. Was I interested in working for him, Thomas Boyne and John E. Gray? This was a challenge and it frightened me; however, if these men had faith in me, by golly, I would do it! The work was hard. I was the only secretary and Jane-of-all chores, handling the telephone calls, making payrolls, placing purchase orders, taking dictation from one of three men, bookkeeping and helping solve employee problems. It was not long before it was discovered that making balance sheets was not my forte and someone was hired to handle the books.

Just when I was getting pretty good at running the "front office" at Harnett Electric, that angel made an appearance once again. I was called into the office of the President who told me the company was going out of business. Harold A Wheeler had a company in Great Neck, NY and was in need of a secretary to work with his engineers. Was I interested? As I recall, there was no real "interview" with Mr. Wheeler. By the time I arrived in his office I had already been "transferred." Amazing how all three positions were Hazeltine-related.

My employment at Wheeler Labs began in September of 1948. It was a time of reunion for me as there were several Hazeltine engineers at work; one of these was Patricia A. Loth. Thus began one of the most rewarding times of my life. I loved working with these people. The initial impression I had of engineers was reinforced. Here I found intelligence, compassion, patience, and kindness. I can still see the engineers struggling with their most modern, manual calculator—the slide rule.

But, oh, the pranks! With all their serious research and design work the engineers still had time for levity and no one was exempt, with yours truly an easy target. There were times when it felt good to remove my shoes as I worked at my desk. One day my after my shoes disappeared, I located them in the small, one-room machine shop. Strewn from the doorway and partly across the room was a layer of metal shavings. Beyond the shavings sat my shoes. Another time, a lost lunch was located in the filing cabinet—under "L". It was I who left notes on engineers' desks stating "YNAH". This was to remind those whose hair had reached the tops of their shirt collars that they needed a haircut.

One particular engineer had his desk near mine; actually, we were back-to-back. But I can still see him with elbows on the desk, hands clasped to his head reading or writing. As I remember, he was very thin, tall, and quite good looking. He was hired in November of the same year I commenced at Wheeler Labs. I had typed correspondence regarding his employment and had already determined his marital status—single!

As Wheeler Labs was receiving more contracts and needed a larger staff, it was time to move to larger quarters. We moved to a brand new building on Cutter Mill Road in Great Neck, NY. Now we really became high-tech. Mr. Wheeler was always on the lookout for new and improved equipment. For the office, he had a modern switchboard installed. Also, the latest in duplicating was a Bruning machine which was huge and sat in a hallway. The old Royal manual typewriters were replaced by electric typewriters on which Mr. Wheeler had special Greek keys installed. This feature saved the time it took an engineer to pencil in the letters on reports. I was in the front office running the switchboard, greeting callers through a sliding window, typing reports, monographs and letters, and at times I became the "shipping department" as well. The switchboard provided a primary target for pranks. A favorite trick was for all the engineers to pick up their telephone receivers at once, causing all the lights on the switchboard to light up. Only the first time did I panic. As the engineering staff grew, so did our office staff.

I must mention here that Mr. Wheeler had one of the first health clubs for employees. It was called "the ping-pong room" and was the scene of many a tournament. This room was open to all employees during and after working hours.

One of the rules in the new facility was that all engineers had to keep their areas neat. So Fridays saw buckets of water and cloths and sleeves rolled up as the "shop" was given a cleaning. If this rule was ignored one might find a special Wheeler 3x5-inch note of admonition to the guilty engineer on Monday morning! Those 3x5-inch index cards were feared by us all. They were Mr. Wheeler's favorite way of communicating; sometimes the notes were scoldings and sometimes praises. One never knew!

The thin, good-looking engineer mentioned above, Herbert H. Rickert, hailed from the Midwest where life moved slowly and so did engineers. It took me three years to convince him he needed to settle down and put on some weight. We were married in July of 1951 and shortly after that, I resigned from Wheeler Labs. However, I was pleased to be invited back to assist when there was extra work to be done. After forty-two years of Italian-American cooking this ex-engineer is still putting on weight! I was not the only secretary who married a Wheeler engineer. Several girls who succeeded me found partners among the engineering staff.

It was not until 1967 that I began to feel the need for employment outside the home. After all four of our children were in school it was time to seek a job; however, circumstances dictated I be close to home. I chose to work part-time at the Princeton Theological Seminary. I worked as a secretary in several of the Seminary departments from Field Education to the Registrar's Office to the Speer Library. But the job I loved and held the longest was as Business Manager for "Theology Today," the Seminary quarterly publication.

Consistency, near-perfection, promptness and attention to good health were among Mr. Wheeler's beliefs. Because of my positive experience at Wheeler Labs so many years ago, I acquired skills and work habits that served me well so many years later.

Both my husband and I love to reminisce about our Wheeler days. Both agree we had excellent training in many areas and consider ourselves fortunate and blessed to have been able to work for such a remarkable man, Mr. Wheeler.

Herb H. Rickert

My friends call me Herb. For years, I signed letters and reports "Herbert H. Rickert" and between November 11, 1948 and April 10, 1959 I responded to numerous 3 x 5-inch index cards addressed to "HR". Those were the years that I worked at Wheeler Laboratories, first at 259-09 Northern Boulevard and then at 122 Cutter Mill Road in Great Neck, NY.

My path to Wheeler Labs was somewhat unusual. I think that I was probably the only Wheelerite ever to be hired by remote control, never having met any member of the staff until I showed up for work. I suspect that the powers that be later thought better of that employment scheme.

I was born and raised in the Midwest. I graduated from the University of Illinois in August of 1948, using the famous GI bill to pay most of my expenses, supplemented by construction jobs and by working as an electronics technician in the Physics Lab. I had gotten my basic electronics training in a 6-month wartime program called Engineering, Science, and Management War Training at the University of Kansas, followed by work as a technician at Wright Field. After an attempt to join the Merchant Marines, I was drafted into the Navy and ended up as an Electronics Technician 2/c. I spent the war going to service schools and then teaching basic electronics theory at a school at the Great Lakes Naval Training Center near Chicago, IL. It was a tough war.

When I graduated from U of I, jobs were not easy to find; a lot of ex-GIs were also out there looking. After a few interviews, I saw a classified advertisement in the Proceedings of the IRE for a job in Great Neck, NY, wherever that was. I answered the ad and a few days later I received a phone call from Harold A. Wheeler. He said they were interested and that he had arranged for me to be interviewed by Dr. A.L. Samuels, who was head of the Physics Department at U of I. Needless to say, I was impressed. For one thing, I knew a little about who Harold A. Wheeler was; I had prepared a paper on wideband amplifiers for a seminar during my senior year and one of my references was a paper that HAW had published in the IRE. The interview went smoothly. As I recall, Dr. Samuels did not ask any tough technical questions, but relied on input he had gotten from the two graduate students for whom I was working. Shortly after that I received a phone call, followed by a letter, offering me a job at $70 dollars a week, a princely sum for a guy who had been living on the GI bill.

Getting from Champaign, IL to Great Neck, NY was not the easiest thing to do for someone who couldn't afford a car. I packed all my worldly goods in a steamer trunk and sent it ahead by Railway Express. Then I caught a train to Indianapolis, changed to the NY Central to New York City, and finally, took the Long Island Railroad to Great Neck, arriving on a Saturday. I stayed at the Colony Hotel in Great Neck and walked over to the labs on Sunday, the day before I was due to report for work. I must say, I was not very impressed with the outside of the building and wondered what I had gotten into.

Monday morning, I walked to my new job and, arriving early, had to wait for someone to show up. As I recall, it was Mr. Wheeler in his Oldsmobile.

The laboratories were on the second floor of a small, box-like building. A real estate and insurance office was on the first floor. The WL entrance was accessible by way of a fire-escape-like staircase at the rear, along the side of the building. The door at the top of the stairs opened into the main room that, I judge, was about 30 feet square. This room contained several desks, storage cabinets, files and workbenches. To the right of the entrance was a door to the shop area, then another door leading to what now would be called a "unisex" facility and a small storage room. Mr. Wheeler's office was in the front of the building, through the main room. To the right of his office was a small room that contained the library.

The cast of characters when I joined WL comprised:

- Mr. Harold A Wheeler, an older man, always addressed as Mr.
- Dave Dettinger, Chief Engineer, always wore a bow tie
- Jean Leonhardt, secretary to Mr. Wheeler, very efficient
- Pat Loth, female engineer, leader in the practical joke area
- Ned Spencer, smiled a lot and went to Canada a lot (girlfriend)
- Rod Lowman, a willing participant in the practical jokes
- Hank Schwiebert, working to support his sailing hobby
- Rose Belfiore, a cute brunette secretary
- Al Paskevich, expert machinist

The main room was the work area for all of the above, except for Al, Mr. Wheeler and Jean. As a result the noise level, which at any time could include a typewriter clacking, a milling machine or lathe running next door, Dave cackling at one of his jokes, blowers running in test equipment, or ongoing phone conversations could be difficult at times, but particularly so at noontime, when the siren at the firehouse next door signaled 12 noon. I well remember sitting at my desk, trying to read a technical article, which I didn't understand, with my elbows on the desk and my hands over my ears.

When I joined WL, I had some RF experience, knew what a Smith Chart was, and could tell a 6-32 screw from 4-40 screw. Everything else was a learning experience.

Microwave design and test in those days was much different from the computerized operations of today; all our designs were empirical. We didn't have digital sweep generators, automatic network analyzers, desktop computers with Spice software or any of the other goodies that are used in this day and age. Making a Smith Chart plot was a laborious task that might take anywhere from an hour to the better part of a day. It involved tickling the adjustments on a klystron, a power supply, a wavemeter cavity, and the tuner on the basic measurement instrument, a slotted line. A series of measurements were made at each test frequency, using a short circuit in the test waveguide, followed by measurements of the device being measured, each measurement being duly noted in one's engineering notebook. Then followed the hard part, trying to figure out the relationship of the short circuit measurements with the device measurements.

My first experience at WL was at X-band (8.5 to 9.6 KMc, or GHz by today's standards). Later we moved up to Ku-band (15.8 to 16.2 GHz). Eventually, in later years, we were working at K-band (21 to 24GHz).

During the early years, we had to make much of our waveguide test equipment because it was not available commercially. This was particularly true at Ku-band. With help from the Rad Lab series, we designed devices such as attenuators, terminations, transitions and directional couplers. Then Al Paskevich turned them into hardware.

One Ku-band project I particularly remember involved a gold-plated balanced mixer assembly for BTL, Whippany, our best customer. This assembly was machined and assembled for WL at a little machine shop in Flushing, NY, run by a man named Goldsmith. I can still hear him say that the assembly was "100 percent perfect" in a slight German accent whenever we complained that there was a problem. After the assembly was finally completed, we shipped it to BTL, making the serious error of fastening it securely in a neat wooden box that we floated within a soft material inside a larger cardboard box. The shipment apparently had a tough time in transit; when it arrived at BTL, a goodly number of soft solder joints had broken. But one learns; after repair and an improved shipping container, the assembly made it safely to BTL. You have to understand that we didn't have a shipping department, or a purchasing department, or for that matter, a department of any kind; everyone in the organization had a hand in all of it.

During this period, we had a lunch club at noon. Someone would be designated as the buyer and visit the supermarket across the street to purchase the provisions. My problem with this arrangement occurred on the days that Dave was the buyer; he loved tongue and I hated it, but ate it anyway because he was my boss. Later, of course, things became more organized and the lunch club was no longer practical. The labs moved in the fall of 1949 to much larger facilities on Cutter Mill Road, and the group grew. Besides more engineers, we got a real phone system, more secretaries, more machinists, a janitor, a security system, and an accountant; we were going big-time. Mr. Wheeler and later, Dave had offices upstairs. There was a reception room and a receptionist/secretary (that cute brunette again). Al Paskevich set up shop downstairs. The engineers spread out to rooms on the main floor and, eventually, used space on the second floor and the basement. The antenna business expanded, resulting in the birth of the Smithtown facility, replacing the simple antenna facility in the basement.

During my employment at WL, a lot of interesting work was performed, but there was also a lot of horseplay. The stories abound: Dave returning from his honeymoon to a bathtub full of Jell-O and glowing stars on his bedroom ceiling; Frank Williams coming back from his honeymoon to find that the canned goods in his kitchen had lost all of their labels; Al Paskevich trying to drive away from the church after his wedding and finding that one back wheel had been lifted off the ground; and Frank, who was very careful with money, having to retrieve the free recording tape he had received at the labs in exchange for coupons after someone unrolled it and fed it through the windows, doors and hallways.

But the time came when I felt I had to move on. The work was interesting, the people were great, but I found that I was frustrated that I wasn't closer to the hardware that resulted from our work. We generated paper, test models, but no end product hardware. Another factor was my concern with the living conditions on Long Island, particularly the daily trip on the roads from my home in Westbury. I had the feeling that I was playing Russian roulette and that one day I was going to be a statistic: "Accident on LI Expressway Delays Traffic for Two Hours."

So, I took a job with General Precision in Pleasantville, NY. They designed and manufactured Doppler navigation equipment for aircraft. It was a good job with interesting work and an easy drive each day through the back lanes of Westchester County to the laboratories on a beautiful old estate. After about two years, and shortly after the cancellation of a major contract for equipment for the B-70, my manager talked me into leaving with him to form a microwave company, Douglas Research, a division of Douglas Microwave. That operation was doing reasonably well until my ex-manager, who was the salesman, had a heart attack; without a salesman out there bringing in new work, things slowed down. While I was on vacation in August of 1963, Douglas Microwave closed down Douglas Research and I was without a job.

After a short period on unemployment and a few job interviews, I convinced RCA ASTRO, near Princeton, NJ, that I was the man for them. Interestingly, that was the place that Dave Dettinger told me about during my unemployment, saying that it would be a good match for my interests. In November, 1963, I started a 22-1/2 year career with RCA, involving the design of circuits and antennas for frequencies from 130 MHz to 18 GHz. I retired on May 1, 1986 as Manager, Antenna Design and Test, making the decision to retire right after GE bought RCA; in retrospect, it was a wise decision. In 1992, Martin Marietta bought the division, resulting in another reorganization.

RCA ASTRO designed and built satellites: weather satellites, communication satellites, and scientific satellites. At last I was close to the end product, sometimes closer than I had ever imagined possible. Many times, before I became a manager, I was the test engineer for the flight device. Other times, I performed final tests on the complete satellite. For example, on one of the early communication satellites, SATCOM 1, I made the final range test of the antenna system before the satellite was shipped to Florida for launch. In fact, I cut myself slightly during those tests; a smear of my blood on the spacecraft escaped the notice of the Quality Assurance people and went into orbit with the spacecraft. That spacecraft operated successfully and is now out of service and in a parking orbit; someday, in the distant future, long after I have gone to the hereafter, it will crash back to earth, carrying a part of me with it.

My experience at WL shaped my life in many ways. I learned to design microwave equipment, starting with the requirements, searching the literature, sketching the test parts, making the required measurements, and recording the results in my engineering notebook. I recall one time when Dave caught me making tests on some device but not recording data in my notebook. He told me in no uncertain terms, “If it isn’t worth recording, it isn’t worth doing,” and I never forgot that. From then on, I recorded everything in my notebooks until later on, at RCA, I was chastised for “messing up the notebooks with useless stuff”; notebooks were “for inventions.”

I was influenced in many ways by my WL experience. My technical library contained many books given to me by Mr. Wheeler as Christmas presents. I found myself referring to notes and charts made during those years, and to Wheeler monographs. One time, at RCA, I was talking to a job-shop engineer and he pulled out a chart of drill sizes for tapping holes; it was a WL chart that I had made 15 years before.

Of course, the most lasting influence on my life is downstairs right now. On 510707, I married the cute brunette secretary. We had four children and now have five grandchildren, with another on the way.

Frank H. Williams

(Editorial Note by H. A. Wheeler: Unfortunately, Frank's sudden and unexpected death in 1994 did not allow him the time to write a personal chapter for this book, as he had intended. Therefore, I am composing this chapter with the intention of giving him proper credit for his major contributions at Wheeler Labs during the 18 years he spent with us. At the end appears Frank's obituary, published for his memorial service 940116. His wife of 44 years, Marilyn, resides in their longtime home at 161 Cabot Lane, Westbury, NY 11590.)

Frank first worked with me at Hazeltine during World War II, in the interval between 1942 and 1944. His time with me was interrupted during 1944 and 1945 by his service in the Navy as an instructor in ETM school at NRL. After the war he returned to Hazeltine as a development engineer. At WL, his management skills led to his appointment as Assistant Chief Engineer under Dave Dettinger, and when Dave left WL in 1961, Frank succeeded him as Chief Engineer. Frank was also Executive Vice President and a member of the Board of Directors. I have many personal recollections that stand out among his outstanding contributions at WL, for all of which I am grateful.

Frank first served as laboratory supervisor on several projects relating to radar and other microwave problems. He planned and conducted a valuable course in report writing for the entire engineering staff. In connection with our recruiting in various colleges, he presented talks on technical subjects, frequently with demonstrations. As Security Officer, he prepared company manuals on security procedures, and oversaw WL's compliance; as Treasurer, he was responsible for much of the management of the company.

Frank's most important individual contribution was taking charge of the largest project ever conducted in WL. On 511117, BTL in Whippany, NJ selected WL to design and deliver equipment for "Scan and Pulse Modification of Radar AN/APS-23 and Ground Position Indicator AN/APA-44" for the Army at Eglin Field. For this purpose, they reserved a third of our staff for a period that eventually became about three years. This equipment became the AN/APQ-49 (XA-1).

The "circuit" part of this equipment was contained in relay racks, and Frank directly organized and supervised its design and construction. Under his supervision, Ned Spencer was in charge of the "antenna" part, which comprised an X-band rotating scanning antenna and the associated microwave waveguide circuits ("plumbing"). An unusual feature of this design was the use of pressurized sulfur hexafluoride gas to prevent breakdown (sparking) by the high peak power in the X-band waveguides, including the junctions and rotary joint.

The equipment was delivered to Eglin Field in May 1954. Our engineers participated in the installation and testing. Its operation met all the requirements; the BTL engineers, among them Bill Tinus, Bill Higgins and Bill Lightbown, were extremely complimentary to WL on this accomplishment, with its economy of time and cost.

During his time at WL, Frank's leadership and many-faceted skills and abilities greatly contributed to the growth and success of WL, and we were very fortunate to have him with us.

FRANK H. WILLIAMS
March 10, 1921 - January 11, 1994

Frank H. Williams P. E. died suddenly on January 11, 1994, at the age of 72. Born March 10, 1921 in Pottstown, Pennsylvania to Edward Hale Williams and Margaret Greeley Ladd Williams, he was the fourth of five children. His father, a mechanical engineer, took the family with him when he traveled around the world setting up stove factories for General Electric, and Frank had especially fond memories of Rio de Janeiro, Brazil and high school in Shanghai, China.

His early interest and ability in mathematics and electronics led to his Electrical Engineering degree from Brooklyn Polytechnic Institute and his Professional Engineering license.

After a stint in the Navy where he taught engineering, he also was called to teach at Brooklyn Poly. Meanwhile, he started working at Hazeltine Corporation in Little Neck, New York, then moved from there to Wheeler Labs in Great Neck, New York, where he became Chief Engineer and Executive Vice President. Eighteen years at Servo Corp. in Hicksville, New York as Director of Advanced Technology rounded out his career.

During these years, Frank was very active in the Long Island Section of the IEEE (Institute of Electrical and Electronics Engineers, Inc.) and was elected its President in 1973. In 1984, he was awarded the 100th Anniversary Medal for service to that organization. As its representative on the Board of Directors of the East Coast electronics industry professional show known as ELECTRO, he became Show Director and then Chairman of the Board.

Henry W. Redlien

(Editor's Note: Henry Redlien's untimely death occurred in 1981, long before the initiation of this book. Mr. Wheeler therefore assembled the information herein for publication. It has been expanded and rearranged by Dave Dettinger.)

Henry W. Redlien, universally known as Harry, was Stevens Institute of Technology's second vital contribution to Wheeler Laboratories, following Peter Hannan. He joined the Labs in 1950, a year after receiving his BSEE degree; a year later he completed his MSEE degree there as well. Under the guidance of Pat (Loth) Burgmyer, Harry became an expert on the subject of monopulse radar, working for BTL on Army projects related to target tracking and missile guidance in the various Nike systems.

Over time, Harry became deeply involved in the development and measurement of various kinds of antennas for monopulse radar, including feed systems and reflector systems. His publications have become classic summaries of performance measures and general behavior of specialized antennas used in target tracking radars. With the trend toward phased-array antenna systems, Harry became an expert in this field as well.

During the period from 1962-66, the Labs engaged in research relating to the newly discovered subject of lasers. Harry became a key member of the research team, along with Bob Kaplan, Ron Schineller and Don Wilmotte.

About 1970, after the consolidation of the Labs with Hazeltine, a major effort was initiated to enter the competition for the future FAA Microwave Landing System (MLS). Harry became the technical leader of the endeavor with Dick Frazita and Mel Zelzer. The Hazeltine system was the clear winner in the technical competition; nevertheless, the FAA adopted the system demonstrated by Bendix. As a result, Harry was employed by Bendix, leaving Long Island for Towson, Maryland, where his widow Doris now resides at 534 Valley View Road.

Dr. Wheeler has said, “Harry was an inspired leader who handled difficult problems and contributed much to our work in his 25 years with our group. He was a good friend, and I enjoyed working with him.” Harry was a sportsman in every sense of the word, sailing on Long Island Sound and later on Chesapeake Bay, playing tennis and ping pong, hiking and swimming. “And,” Dave adds, “he was a great pal to ski with.”

Frederik S. Van Davelaar

“Whatever I have made of my life in the U.S. has been due to my wife Henny on the social/family front, and to my mentor Harold Wheeler on the professional and career side.”

I was born 210820 in Batavia, Dutch East Indies, of Dutch parents. As a career government official my father spent several tours of duty in the Overseas Territories, alternated with years back in the homeland, the Netherlands. As a result, I attended primary, secondary and higher education in both the Netherlands and the Dutch East Indies (now called Indonesia).

Because of the war threat in Europe, I began my higher education in Engineering Science at the Polytechnic Institute of Bandung. My studies were interrupted by the Japanese attack on Pearl Harbor, when the Dutch joined the U.S. and entered WWII. I joined the Army in January 1942 and was actively engaged in military action until May 1943 when I was captured by the Japanese and interned until VJ day in August of 1945. I returned to the Netherlands in January 1946 and continued my studies in the evening.

In May 1946 I joined the Physics Laboratory of the War Department as assistant to Professor J. L. Van Soest, and was employed until November 1948. My work offered a valuable introduction to the latest defense technology by staff members who had managed to escape the German onslaught in 1940 and who had gone to Cambridge and MIT to continue their research. During this time I also continued my evening studies.

In 1947 I married, and in November of 1948 emigrated to the U.S. I continued evening studies at Brooklyn Polytechnic Institute and Hofstra College, where I graduated cum laude with a BS degree.

In early 1950, I had the opportunity to be interviewed by Harold Wheeler and Dave Dettinger. In spite of a definite a language barrier that made an in-depth evaluation of my technical qualifications more difficult, the fact that I immediately interpreted correctly a twelve-digit number placed before me by HAW as “20 minutes and 36 seconds past 11 a.m. today” clinched my employment at Wheeler Laboratories. It took another eight months before my clearance came through and I could start work in Great Neck on 500918. That day was a most important turning point in my life, professionally, socially and economically. Harold Wheeler, his staff and his organization had a profound influence and effect on me in becoming an American and an engineer, to which I had always aspired.

As my first assignment I worked as part of Henry Schwiebert’s team on upgrading the APS-23 X-band bombing radar. Hank was an excellent teacher and I learned a lot from him. He was a calm, dedicated, innovative and practical engineer who never missed a minute in which he could be productive. Hank was the man who built a beautiful schooner from the ground up in his backyard! Our families became very close friends and to this day, we still are.

Family and social life were other aspects that were unique to Harold Wheeler and his organization. At the annual dinner dance, many lasting friendships were formed. Being a newcomer in the U.S., it was refreshing to see real democracy at work. And Mrs. Wheeler always made everyone feel as welcome a family member.

I continued working with Hank Schwiebert, developing a series of fixed and rotary steptwists that were to be used as standards. The work on rotary steptwists resulted in a challenge from Joe Besosa of the model shop, “If you can design a rotary steptwist for Ku-band so that it can be made, I can make it!” Joe and I worked on the project on weekends, and presented Harold Wheeler at the next dinner dance with a working and tested Ku-band rotary steptwist, smaller than a quarter in diameter, packaged in a jewelry box. This steptwist is shown in the upper photo on page 32; others are shown in the bottom photo on the same page.

Next I joined Ned Spencer’s team. With Frank Williams as project engineer, we worked on the X-band rapid-scan antenna for the APQ-49 bombing radar, which was evaluated at Eglin Field, Florida.

Frank had also organized the photography facilities, and he acted as the staff photographer. Pictures of new designs were an integral part of our reports to clients. With mostly classified work, in-house photography was a necessity. After a few years Frank trained me to take over this function, and later I trained Charles Wanczowski to succeed me, in turn. Charlie put us all to shame with the quality of his work!

At our regularly scheduled engineering meetings, members or the staff would take turns in presenting their assignment, and their solutions to problems stemming from the assignment. These meetings were very educational and functioned as an extension course in engineering, keeping us all up to date. Harold Wheeler would take his turn in presenting specific concepts, and I always marveled at his way of presenting complex problems in simple terms that would then lead to elegant solutions. I understand that it was this quality which made Harold Wheeler valuable to the administration during the war years.

With Harold's guidance through the years I developed my own pattern of thinking: keep it simple, practical, straightforward and honest, and the end product will be useful. This principle has served me well, even at highly diverse activities in later years.

The entire engineering staff became involved in the IRE (later IEEE), as one of the ways to keep up with technology. I became a member, later a senior member and eventually, a life member.

In the context of early valuable advice received, I might add Dave Dettinger's admonition as to how to obtain the best results and cooperation from others: "In America you should demand and expect perfection, but accept the best people can do, and compliment them on it." It turned out to be a very profitable formula to obtain the best effort and cooperation from people, worldwide.

My work developed more and more towards assisting the electrical engineering staff with the mechanical designs, and especially the producibility of their new electrical/microwave designs. I enjoyed both my involvement in a variety of projects and the extensive contact with clients, suppliers and contractors.

In 1955 I was entrusted with planning and supervising the construction of the antenna testing range in Smithtown. Included in this project were special features such as low-silhouette hydraulic cranes covering all roof antenna-mount placements, remote control source tower, hydraulic equipment elevator serving both roofs, and fully equipped windowed control rooms providing full vision of the equipment being tested on the roof. The Smithtown range was inaugurated in 1956. The heavy lifting equipment was tested again in 1961 when Dave Dettinger, returning from his farewell luncheon, found his car twirling around on a roof mount!

Ned Spencer became manager of the Smithtown range and I became his first assistant, responsible for handling operations as well as for supervision of both the mechanical design/drafting group and the model shop. Ned believed in delegating, yet was always available for advice when asked; it was a pleasure to work with him. The cooperation among all WL employees, suppliers and local officials was exceptional.

I had found my niche as an inter-discipline coordinator, project manager, and mechanical consultant. This kind of work set a pattern for the rest of my career, at WL/HC as well as elsewhere.

My last assignment at WL (1965-1966) involved the mechanical design, fabrication by the HC shop, and installation in Australia of a sub-dish for an eighty-foot dish tracking antenna located on the Woomera Missile Testing Range. The site of the antenna was in Mount Eba, at the rim of the Great Victoria Desert, partially down the range in the real outback. Henry Redlien and Don Hastings worked on the electrical design.

The fourteen-foot diameter sub-dish had to be constructed in segments or modules to fit in 4x4x4-foot crates for transport by Australian Airforce bush planes. Yet the assembly (shown from two angles in the photos on page 30) had to be rigid enough to withstand warping forces, and be suspended in such a manner as to maintain its focus despite uneven thermal, gravitational and dynamic stresses on the four support arms.

The project presented electrical, mechanical and logistical challenges that were all met. Harry, Don and I went to Australia in mid-1966 to supervise the installation and testing—a most interesting undertaking. With great forethought and unbeknownst to us, the crew in Smithtown had packed a stack of Playboy centerfolds in one of the crates. These turned out to be worth their weight in gold in getting any kind of cooperation from the Aussies in the lonely outback.
As soon as the mechanical installation was completed and before the electrical tests could begin, I was asked by Wheeler to return; Harry and Don stayed on to complete the testing. Harold Wheeler had assumed the position of CEO at HC during a difficult management transition period at HC. HAW asked me to transfer to HC and accept the task of modernizing and expanding the HC facilities.

I held the position of Department Head for Facilities and Services from August 1966 to June 1970. On Long Island, Hazeltine plants were modernized, consolidated, and new buildings were planned for land acquired in Greenlawn (now building 1). In Quincy, Massachusetts, we acquired land around a water-filled stone-quarry pit. An elaborate floating structure was built to test sonar devices in the quarry pit, and plans were drawn for a laboratory and further testing facilities adjacent to the quarry.

HAW retired in 1968 from his line duties and progress slowed down. By the time I left HC in June 1970, the new buildings had not been completed.

For the next fifteen years (1970-1985), I was employed as Director of Technical Operations of a new subsidiary of the Continental Grain Company, engaged in the building and subsequent operation of highly automated food-processing plants worldwide. I was approached for this position because of my work at WL/HC and my foreign background and education, which included several languages. My training at WL to use a basic, practical, yet uncompromising engineering approach paid off in many ways. A number of profitable industrial complexes were built with cooperation from, and appreciation by, both locals and government officials.

During my years at Continental I acquired my private pilot's license, and during my travels I often managed to spend time in the cockpits of foreign air carriers. All this made me keenly aware of navigational and airport approach and control problems, and interested in solutions to these problems. I was, therefore, very pleased to be able to re-join the ex-WL group at HC and to participate in the development of the microwave landing system (MLS) for the FAA. In January

1985 I joined the MLS group as a consulting engineer, reporting to Dick Frazita, the program's technical director.

It was very satisfying to return after fifteen years and find many members of the old WL group back in responsible positions. I see this as a direct result of Harold Wheeler's approach to "creating engineers." I considered it an honor to organize, with the help of many original Wheelerites, a reunion in June 1987 where some one hundred ex-Wheelerites, their wives and associates delivered a tribute to Harold Wheeler. The reunion said it all.

I retired in March 1988. I feel privileged to have been part of Wheeler Laboratories and to have had Harold Wheeler as my mentor.

Walter Kurt Kahn

I was born March 24th, 1929 in Mannheim, Germany. In the wake of the Nazi persecution of Jews in Germany, sometime during the summer of 1936 my family decided to emigrate. Two of my father's brothers had settled in Chicago around the turn of the century, and one of them provided the necessary affidavits, part of the lengthy process needed to secure our entry to the United States. We arrived in June of 1938. Consequently, I was educated in this country and became an engineer, and an academic, an unlikely career had I been raised in normal circumstances in Germany.

In 1947 I was graduated from Stuyvesant High School in New York. At that time it was my very good fortune to gain admission to the Engineering School of the Cooper Union for the Advancement of Science and Art. This was (and still is) an outstanding, very select school in lower New York City, endowed by Peter Cooper and his philanthropic union. Admission constituted the equivalent of a full-tuition scholarship. Some additional funds were provided by a New York State Regents scholarship. I was graduated 51DEE, Cooper slang for the class of 1951, day—as distinguished from part-time night—electrical engineering student.

Professor Jesse B. Sherman apparently recommended me to Wheeler Laboratories, and certainly highly recommended Wheeler Laboratories to me as a place where I might well begin work as an engineer in an excellent learning environment. I was invited for an interview at WL, and somehow I resolved to prepare for it. I vividly recall standing next to the tall white book shelves in the venerable library in the Cooper Union Foundation building looking up Wheeler, H. A. in the index of the heavy bound volumes of the *IRE Proceedings.* "The Interpretation of Amplitude and Phase Distortion in Terms of Paired Echoes," and "Formulas for the Skin Effect," were especially interesting and I spent some time reading them. I can not recall the exact date during the Christmas recess 1950-51 of my interview at WL, though I do recall meeting that day with Dave Dettinger and finally being ushered upstairs to meet with Mr. Wheeler. He struck me as a rather kind older gentleman (Wheeler was not yet 50). To get some feel for my understanding of electromagnetism, Mr. Wheeler asked me about—the skin effect.

On January 12th I received a letter from DD expressing an interest in my joining WL. Other good opportunities had presented themselves, and I did weigh them as well. However, after a further exchange of correspondence between DD and myself in which I made clear my interest in WL, I received a formal offer of employment dated April 21, 1951 followed by a letter dated April 27 confirming my employment at WL.

WL records furnished by DD indicate I reported for work 510611. I was assigned to work with a group working on what may have been WL's largest single job at the time, the RF circuitry for the NIKE monopulse tracking radar, a subcontract from Bell Telephone Labs. In retrospect I consider this fortunate in every way; the supervisor of the group was Pat Loth [Burgmyer], who had a gift for logical organization and always an attentive ear. I do not know if I ever told her of the shock that she delivered to her young charge with the casual remark that I had "an unusual and therefore valuable mode of thought." It had never occurred to me that I could be noticeably different in this respect.

With the singular exception of "Mr. Wheeler," relations among the entire staff were on a wonderfully informal first-name basis. A group, often including DD, POOH, PAL, HWR and HHR, made sandwiches and ate lunch together; I was invited to join in. This setting provided an opportunity for banter and practical jokes. I recall one time sliced Ivory Soap was substituted for American cheese.

On the other hand, when I met with the Chief Engineer to go over my work, he was unsparing in the exercise of his formidable critical faculties. Why did this page in my notebook not have the proper heading? Precisely which apparatus was used to make this measurement? Where had the frequency meter been inserted? Just where were the details of this calculation, and why weren't they done in the notebook? And so on, for a considerable period of discomfort.

During the following summer WL offered summer jobs to a number of undergraduates. One of these young fellows was assigned to make some slotted-line impedance measurements under my direction. At the time impedance measurements were tedious and time consuming; this time, however, I wasn't doing the measurements myself. So I laid out the work carefully, including (redundant) separate measurements of constituent parts to check against the results for the assembled component, and correction data for necessary coupling taper guides. When it was all done to my satisfaction, I proudly presented the information to Peter Hannan, a complete, systematically arranged sequence of data, hoping for a compliment on my capacities as a supervisor. After the usual interval of thoughtful silence, Pete came up with one. "Walter," he said, "this is the best data you've ever produced."

Harry Redlien (HWR) produced a beautiful series of reports on monopulse system operation to which I have often referred in the past, and still do from time to time. In the service he had been a meteorologist, so when rain or snow impended, we would turn to him for guidance. He would get up to look out the windows in several directions. He would characterize the cloud formation, estimate drift velocities, and launch into a general discussion of cloud formation with commentary on the potential of each type as a source of precipitation, though as we already knew from experience, he would never come around to a forecast.

One time, the monopulse group posed for a formal portrait in front of a blackboard upon which HWR had engraved a monopulse difference chart and significant equations from his report. This was an opportunity too good to miss. Jackets went off, ties were loosened, a bottle was featured prominently, cards were dealt, I put on “shades,” Pat sat on the edge of the table in the assumed pose of a gun moll. It made a great picture!

Mr. Wheeler gave careful thought to all important aspects of WL’s operation. Indeed, I am at a loss to cite an example of any aspect of WL operations that he did not deem important. Clearly one of the most important aspects, basic as it was to much of our design work, was the format for presentation of impedance data on the reflection coefficient plane. For this purpose, the laboratory used exclusively a series of “Hemisphere Charts” designed by Mr. Wheeler and copyrighted by WL. The logical superiority of these charts notwithstanding, the difference in coordinate conventions between these charts and the “Smith Chart” in general use was a frequent source of misinterpretation of WL data outside the laboratory.

Mr. Wheeler did not travel frequently; however, during one of these exceptional absences, his loyal staff gave some thought to the preparation of a suitable welcome home. (I must say, we always arranged some small welcome surprise to brighten the return of a staff member from his or her vacation. It had occurred to me that, if the polar plot of reflection coefficient were presented instead in the style commonly used for antenna patterns, that is, if the angular coordinate were plotted as abscissa and the magnitude plotted as ordinate, then the unit resistance and unit conductance circles of our Hemisphere Chart would plot as cosine arches—tracing out a large letter “W” across the chart. I prepared a large display example of such a chart and this was placed on an easel in Mr. Wheeler’s office together with an official-looking memorandum from the Chief Engineer. The memorandum called the attention of the staff to this new WL standard chart, adopted during his absence. I can only hope Mr. Wheeler ultimately appreciated the little in-joke into which we had lovingly put our best creative efforts. At the time (I was given to understand) he made no comment.

I was invited to periodic conferences with Mr. Wheeler to review progress on our job. There was no doubt at all that a conference with Mr. Wheeler was special, even though it was just at the end of an informal jaunt upstairs with a bunch of us who happened to be working together on the job. The conferences always started on time. Often another bunch, working on a different job, would just be taking their leave with a final comment. The WL notebook in which Mr. Wheeler invariably made whatever notes, sketches or calculations dealing with that other job might still be open on the table. As we took our seats, that notebook would be closed and another one, similar except for the identifying number of our job, would be opened in its stead. Wheeler’s attention would turn entirely to our job and its problems, and during the conference we would all become fully absorbed. Wheeler would always come up with some insight, some bon mot, or some rule that I would mentally squirrel away: “Broadband design means equally bad all across the band.” “Never make negative statements.” “Use three samples; two don’t confirm a trend, and four cost too much.” Perhaps we would have come upon some particularly interesting alternative just as our allotted time was up, or there might be a few additional words summarizing the consensus as to what should be done next. And that was it. Wheeler had the knack (discipline) to leave the limitlessly intriguing possibilities and, incredibly, give the next scheduled mundane matter the same full attention that our important job had just received. Much as I might aspire to manage my own time as efficiently, I would invariably fall far short.

Each year Mr. Wheeler would circulate a memorandum in which we were invited to list titles of two books we desired for our personal library. Christmas time, those two volumes would appear, personally inscribed. I continue to use these books frequently, and always reflect just a bit when I turn past Wheeler's signature. I reflect on the kindness, assistance and friendship of old(er) timers such as Ned Spencer, Herb Rickert and the vivacious Rose, as well; actually all of those who educated us.

Mr. Wheeler graciously supported our use of WL facilities for experimental work that we might present in fulfillment of requirements for a Master's thesis. Pat Loth had developed a variant of the conventional Hybrid-T (Magic-T) she called the H-plane Forked Hybrid-T, informally dubbed the "Pan-T." I had the idea to construct a complementary form, an E-plane Forked Hybrid-T, and proposed this as the topic of my Master's thesis at the Polytechnic Institute of Brooklyn (now Polytechnic University). Of course, I also needed to get Wheeler to approve the topic. He liked the idea, but was very pessimistic about the prospects of matching the T to obtain a practical level of performance. However, I was imbued with the foolhardy optimism of youth, and besides, I had an approach in mind. Wheeler gave his consent, and the approach, as described in a paper presented in Volume MTT-3, No. 6 of the IRE Transactions on Microwave Theory and Techniques, proved successful.

The experimental aspects of my Master's thesis apparently impressed my thesis advisor at the Polytechnic Institute, Dr. Leopold B. Felsen. He offered me a position as a research associate at the Microwave Research Institute (now the Weber Research Institute) in connection with which I would have ample opportunity to pursue a doctorate. I considered the offer carefully myself, and then sought Mr. Wheeler's advice. I am happy to say that this time he gave both his understanding and his encouragement. From Wheeler Laboratories, 540716, I was launched on my life's career as a Professor.

Robert D. Wengenroth

(Editor's Note: Mr. Wheeler initiated a chapter on Bob Wengenroth, who died long before this book was conceived. Dave Dettinger has added an introductory paragraph.)

Bob was a member of the illustrious group of young engineers who joined Wheeler Laboratories in 1951. Dave Dettinger recruited Bob at Rensselaer Polytechnic Institute, first meeting him there as he was returning for lunch at the student cafeteria after a night spent at the college radio station. Always a "ham," he had also spent two years as an Electronic Technician in the U.S. Navy before college.

Bob remained at the Labs for nine years, relocating in 1960 to Syracuse, NY where he was employed by General Electric Company. Unfortunately, Bob died at an early age in 1978, leaving his widow Elise (Lee), who currently resides at 19 Apricot Lane, Liverpool, NY 13090. Bob had been very active in the Power Squadron, the Onondaga Yacht Club, and the Coast Guard Auxiliary; Lee carries on in the Auxiliary working with prospective students for the Academy. Bob will always be remembered for his contagious enthusiasm and his jovial sense of humor, as well as for his outstanding talents as an engineer.

One of our projects required an accurate test of high-power pulse breakdown in a rectangular waveguide, and the measurement of the power level that would be handled before sparking. Bob became familiar with the current experience in several other laboratories, then standardized a “waveguide spark gap” made of hemispheric bumps on opposite faces of the waveguide. This was adopted as a standard in various other laboratories. In a joint paper with Dave Dettinger, the approach was published in the first issue of transactions of the newly organized Professional Group on Microwave Theory and Techniques (MTT).

Bob worked with Ned Spencer on the Model 209 X-band oscillator that was used in our X-band measurements for many years. In 1954, he developed several antennas for Communication Products Co. for use with base station transmitters. In 1956, he was in charge of the demanding design of an X-band multiplexer, to which he added a feature never previously identified. In these tasks, as in all others, his work was of the highest caliber.

Henry Bachman

My first contact with Wheeler Laboratories (WL) was with Frank Williams. We met in the halls of Brooklyn Poly, where he was recruiting new college graduates. As a result, I subsequently had the good fortune to join WL on 510618. I was one of a group of seven new graduates hired that summer. I am sure that we made an impact, if for no other reason than that the size of our group increased the engineering staff at the Cuttermill Road facility from eleven to eighteen. This was an early manifestation of what was to become an extraordinarily successful recruiting technique for new graduates.

Each year, following visits by many of us to various engineering schools to line up prospects, we would engage nearly the entire WL staff in recruiting these prospects during the Christmas college recess. The process generally involved two technical interviews, a tour, and a lunch, giving both of us, the interviewer and the recruit, an opportunity for a multifaceted look at each other. The success of our college recruiting activities was essential to the success of the laboratory, where it was necessary to rely on on-the-job training to develop the skills required in the then rapidly developing field of RF microwave and antenna development. Little, if any, of the theory or laboratory techniques required were taught in school, nor, for that matter, were they widely employed in industry at the time.

My own training started after just a few hours of procedural indoctrination on my very first day. My mentor was Pat (Loth) Burgmyer. She sat me down at a slotted line (the first one I had ever seen) and in a matter of hours, I was performing RF "impedance" measurements. Part of my tool kit was a "radius arm" calibrated in dBSWR that we used to plot our measurements on the Smith Chart of reflection coefficient. (I still have these in my desk drawer.) At WL, this technique was refined to the point where we did not bother to print the impedance coordinates on the chart, as we all learned to think in terms of reflection coefficient. This was the relevant parameter for the work we did.

I carried this refinement one step further, developing for my Master's thesis, in 1954, a waveguide circuit for the automatic swept-frequency measurement of reflection coefficient, which was plotted on a reflection-chart overlay on a cathode-ray-tube. This equipment was utilized at WL for many years before it was supplanted by subsequent techniques. Another development at WL was essential to the implementation of this automatic X-band impedance plotter. Until that development, measurements were made at discrete frequencies with a klystron signal generator that was painfully difficult to adjust for each measurement frequency. An optimum combination of a mechanical adjustment of an RF resonator and a voltage setting was necessary. Work at WL on monopulse radar waveguide networks required continuous frequency measurements to properly characterize these networks. For this, WL developed an automatic swept-frequency (12% bandwidth) X-band oscillator. This was the signal source that I employed for my automatic plotter. For a period, it was made commercially available by PRD (Polytechnic Research and Development Corp), until voltage-tuned TWT devices became available.

My first few weeks of work in Great Neck were in preparation for a field assignment at Bell Telephone Laboratories in Whippany, New Jersey. WL did not have an antenna test range at this time. We were to evaluate a lens-type antenna, then employed on the Nike Ajax air-defense tracking radar, for application to the to-be-developed Nike-Hercules wide-band monopulse radar. What was to have been an assignment of a few weeks away from home extended to many months in 1951, and again in 1952, as we demonstrated the inadequacies of the Nike-Ajax antenna for the monopulse application and developed the polarization-twisting Cassegrain antenna invented by Pete Hannan. Pete directed my work at Whippany that first year. I had the responsibility for the work at Whippany the following year, working with Matty Kabrisky, a classmate of mine who joined WL for the summer of 1952 while pursuing advanced degrees at Polytechnic. It was not unusual at WL to be given such a responsibility with only limited experience because of the careful attention paid to the preparation and development of the staff. Such attention was given to all facets of professional development. Supervisors, at every level, had the prime responsibility of sharpening the skills of those working for them. This included design and measurement techniques, technical writing skills, and supervisory training. Professional capabilities were augmented by assigned stand-up technical presentations to the staff (for the benefit of both the presenter and those in the audience), by encouragement and assistance in preparing technical papers for publication, and by active participation in IRE (later IEEE).

I remember Dave Dettinger encouraging me to work on the annual IRE Long Island Section Awards cocktail reception in the early 50s. This led to WL supporting my role as chairman of the AP and MTT Chapters, and then the Section, in the 60s. This encouragement and support of professional activities was an initiative that Wheeler had fostered at Hazeltine and continued there after WL was merged with Hazeltine in 1970. This made it possible for me to continue my IEEE activities, culminating in my term as president in 1987.

Notwithstanding the extensive involvement by WL in the Nike system development for BTL in the 50s, other clients sought us out as our reputation grew. As one consequence, I was fortunate to have a variety of assignments. One involved working with Phelps Dodge Corporation and later with Communications Products Corporation. After WWII, Phelps Dodge acquired technology from Germany to manufacture an essentially air-dielectric flexible coaxial cable, Styroflex. The soft aluminum outer conductor was supported by a helix made by winding a thin strip of dielectric, a few mils thick, around a copper tube, the inner conductor. Features of the cable were flexibility and long, continuous lengths with low dielectric loss and high velocity of propagation. Our job was to characterize the cable and verify the stability of the manufacturing process. This required the development of interface and coupling connectors and measurements of 1000-foot lengths of cable. I developed analytical methods to distinguish systematic errors from random ones.

Communications Products became a supplier of Styroflex cable for Phelps Dodge, the cable finding extensive use in the implementation of the TV broadcast infrastructure, which had explosive growth at the time. The laboratory's work for Communications Products involved developments for large (3-inch and 6-inch) diameter, rigid coaxial cable as well. These developments included the supporting dielectric "beads," which were "strung" periodically along the cable, and connectors required to assemble long runs from the 20 ft. lengths of this cable. While the long lengths of Styroflex cable could be measured on a large coil, the rigid cable had to be strung out along the ground for measurement purposes. This was done at the Communications Products facility on the New Jersey shore. I made very many trips on the Staten Island ferry from my home, which was still in Brooklyn at that time. A side benefit of this assignment was the memorable country lunches which Dave Dettinger and I had when we visited his family's farm, located near Communications Products, in Freehold, New Jersey.

Another of WL's projects also illustrates the overwhelming impact of television during the 50s. It was on New Year's Day in 1956 (?) that the first color TV transmission of a Rose Bowl game was beamed cross-country on the AT&T TD-2 microwave link. During this transmission, interference was observed which was ultimately found to have been caused by a Nike system high-power acquisition radar. Fortunately, at this time, both the microwave link and the radar development were the responsibility of AT&T. Bell Laboratories had developed the radar, and we were asked to help devise a solution to the interference problem. The problem was the radiation from the S-band (near 3 GHz) radar of spurious signals in the TD-2 system frequency band (near 4 GHz). The solution required that a very selective filter be inserted in the transmitter path of the radar, which operated at 1 MW peak power. The filter would have to reject the interfering signals without reflecting them back to the magnetron transmitter. Breakthrough developments by WL included an evacuated (vacuum) filter employed in a non-reflecting arrangement devised by Wheeler. Again, following the design work, I had the opportunity to perform unusual field measurements. To verify the performance of the filters, we located a TD-2 microwave transmission site in Berlin, Connecticut, which was nearby an interfering radar installation. Each evening after the eleven o'clock news, when the TV stations no longer transmitted programming, we would tear down and instrument the site. Interference measurements were made working through the night, until we put things back to normal again for the six o'clock morning news.

In 1961, when Dave Dettinger left WL for the MITRE Corp., Frank Williams assumed the role of chief engineer, and I succeeded Frank as assistant chief engineer in charge of the Microwave Development laboratory in Great Neck. This was a period of intense activity on antenna development for the Nike-Zeus anti-ballistic missile system. Much of this work was done in bench-type measurements in simulators at the Great Neck facility rather than at the Antenna Development Laboratory in Smithtown.

It was during this period that WL became more involved with the products of its parent, Hazeltine Corporation. Hazeltine acquired WL in 1959, but there was little collaborative work until the 60s when WL made a key invention, the "invisible" dipole. This invention made the airborne IFF interrogator feasible, and it became one of Hazeltine's most successful products.

Such contributions continue to this day. The WL group, now active within the Hazeltine Advance Technology Center under the leadership of Rich Kumpfbeck, was most recently responsible for antenna developments which have enabled Hazeltine to continue its leadership role in the latest generation of airborne IFF interrogator products. These continue as substantial contributors to Hazeltine's business.

When Wheeler became Chairman and CEO of Hazeltine in 1968, I assumed the leadership of WL. By that time, our work was closely tied to Hazeltine's R&D and new product development. During this period, with the conclusion of the war in Vietnam and diminishing defense budgets, defense industry companies faced very difficult times. In 1970, the situation was so serious that Hazeltine had to make substantial reductions in staff. The most difficult assignment of my entire career was working with Barney Loughlin, who was the leader of the Hazeltine Research Laboratory, to decide who was to stay and who had to go as we prepared to reduce the overall Hazeltine R&D staff to one-third. The day I had to face the staff with this announcement and the details was devastating.

Those who remained at WL were merged into the Hazeltine Research Laboratory where they continue today as the WL group, to which I have already alluded. Ed Newman, who at one time led the WL group, is now Vice President in charge of the entire research group at Hazeltine's Advanced Development Center. I myself became directly engaged in Hazeltine activities at the time of the merger. As one consequence of the technical and managerial skills learned at WL, I was able to accept increasing responsibilities at Hazeltine in almost every aspect of Hazeltine's activities. I served as Vice President of Quality, Manufacturing, and Engineering and led strategic planning activities. Most recently, I have been engaged in special projects for the Advanced Development Center. One is particularly relevant to the WL story.

In 1990, it was decided to give up the Smithtown antenna test facility after more than 30 years of support of the WL antenna development efforts. It was no longer a convenient location for the engineers who worked at the Greenlawn facility, nor was it equipped to support developments of low-observable antennas required by today's stealthy platforms. In addition, the property at Smithtown had become very valuable for other commercial purposes. I had the responsibility for the planning and implementation of a new $4M antenna test facility that was consolidated at Greenlawn. This included a new building addition with two 400-foot-long outdoor antenna ranges and a state-of-the-art, 30 ft. wide x 46 ft. long x 26 ft. high, compact-range anechoic chamber. On April 26, 1993, Hazeltine dedicated this Communication and Antenna Systems Laboratory to Harold A. Wheeler to recognize him as the founder of Wheeler Laboratories and as Hazeltine's first employee and former Chairman and CEO. It gave me the greatest pleasure on this occasion to have had the responsibility for the creation of this living memorial to someone to whom I owe over 40 years of career opportunity and enjoyment.

Herbert S. Sawyer

I was born on August 12, 1927, in Fort Fairfield, Maine, and attended primary and secondary schools in that town. In 1951 I graduated from Bowdoin College (Magna Cum Laude, Phi Beta Kappa) and MIT (Sigma Chi) under a combined program. My interest in electrical engineering was sparked by my hobby, amateur radio, which provided the only practical experience in electronics prior to entering the work force.

Dave Dettinger, to whom I had been recommended by Professor Guillemi, interviewed me in my dorm at MIT in the winter/spring of 1951. A subsequent trip to Wheeler Labs convinced me that it offered the opportunity I was seeking. The many cultural attractions of New York City also weighed in my decision. I had no other interviews.

Starting work at WL in June of 1951, my first major task was checking out a K-band magic tee under Herb Rickert's supervision. This activity introduced me to the practical applications of the Smith Chart, the mysteries of which I never fully mastered in spite of Herb's patient supervision.

For my second major task I joined a team under Frank Williams' supervision that was responsible for modifying an APS-23 airborne bomb/navigation radar to provide a rapid scan capability. Under Frank I developed a taste for systems development and testing. Particularly memorable was the way in which Frank taught me the methodical way to isolate and fix faults in a system. During this time I visited Bell Telephone Laboratories several times and observed the magnificent talent that was available in this institution. This work also afforded me the opportunity to visit Eglin Field in Florida when the system was shipped there for testing. These early experiences were enjoyable and gave me a good taste of what engineering was about. I left WL in 1954 when the APS-23 project was coming to a close.

In retrospect, I believe that the greatest benefit I received at WL came from the emphasis on engineering discipline that we all experienced there. The good habits that I learned during this time helped me for the rest of my career. We were required to keep detailed notebooks and write weekly progress reports—an activity that sometimes proved to be embarrassing upon realizing how little I had accomplished during the week. I learned then the importance of fully grasping the theory as well as the practice of engineering. In addition, emphasis was placed on expressing ideas logically and clearly; we even had a short course in writing clear reports.

There was also an emphasis on the professional aspects of engineering. We were encouraged to participate in the activities of the local engineering society (at that time called the Institute of Radio Engineers), and were required to give occasional presentations to our peers on our work. Harold Wheeler occasionally gave lectures on some of his major developments in the early days of radio and during World War II. I found these enjoyable not only for their historical and technical content, but also for their illustration of how outstanding engineering was accomplished.

While engineering discipline was the major focus of the work environment, there was also time for “play.” Several of the employees enjoyed practical joking and we frequently heard stories of jokes played on each other. Caught up in this atmosphere, Bill Rohn, Bruce Schwab and myself decided we would play a joke on Frank Williams. While he was absent we attached a variable gain device to his phone. I had the job of gradually adjusting the gain up and down during one of his conversations. I was amazed when he showed no reaction to the adjustments, but shocked when moments later he called the local phone company to complain about poor service, insisting that someone come out immediately to fix his phone. Under extreme stress (after all, wasn’t it a federal offense to tamper with the phone lines?) I confessed to Frank. He was very understanding, but said we’d have to call off the service man. I was instructed to call Mr. Zirnbach at the local office and tell him that the problem had been fixed. For 15 frantic minutes I tried to reach Mr. Zirnbach; the dummies at the phone office said there was no such individual. In the meantime Frank and a significant portion of the lab were at the switchboard enjoying every minute of it. I had failed to notice that Frank had depressed the phone switch when he made the service call. When I departed WL, some of my personal papers were stamped “H. Zirnbach.”

WL introduced me to my wife and lifelong companion, Jean Leonhardt.

After leaving WL I joined Airborne Instruments Laboratory where I became engaged in the design of electronic warfare systems. From there, the National Security Agency recruited me to assist our government in the practice of electronic warfare. Eventually I rose to Executive Level IV at that Agency.

I have always believed that those early years at WL were the best possible initiation into the engineering field. The disciplines I learned there I carried into other companies, larger than WL, which in my view were deficient in the attention they paid to the needs of young engineers.

George E. Vaupel

Remembering the WL portion of my engineering career is always a pleasurable experience. The technical work was innovative, interesting, and challenging and we all learned much from the key senior members of the staff who were hand-picked by Mr. Wheeler during WL's start-up period.

I will always remember and respect the key leaders, my peers and all of the employees with whom I worked after starting my employment with WL approximately 40 years ago during the summer of 1954. I look forward with pleasure to visiting with each WL person during our periodic reunions. Many of the staff members and I have maintained professional and social contacts during the ensuing years.

The friendly atmosphere at WL was always intellectually stimulating and sprinkled with good humor. The "staff talks" were always informative and many were inspirational; I can vividly remember some of those talks to this day. As a waveguide and antenna designer with no formal mechanical training when I joined WL, I really appreciated the Shop lectures by Al, Richard and other members of the Model Shop. The information and mechanical concepts that I learned from these lectures have had lifelong utility.

For most engineers, WL was their first professional employer, and who among us can not remember his or her first assignment at WL. As young engineers we learned to make bench-top measurements, engage in theoretical analysis (for which Mr. Wheeler always had a simple, elementary approach), supervise our colleagues, and make customer presentations. We learned skills that enhanced our professional careers.

My early assignments at WL included the design of a multiband filter and the design of a two-frequency antenna; both were for Sperry Gyroscope. Also included in my early experience were antenna tests at the Bell Labs antenna range in Whippany, NJ (before the Smithtown Lab was built) and the design of radiating elements for the Nike-X multifunction array.

In my opinion, the phenomenal success of the WL engineers as a group was the result of the institutionalizing of first, the WL interview process that resulted in an exceptional staff; and second, the training of the staff in problem-solving methodology, in the identification of the optimum solution to a problem, and in the development of interpersonal and presentation skills. As a representative of the engineering group I thank Mr. Wheeler, Dave, Pat, Ned, Al, Pete, Harry, and other key staff for their skill and patience in molding our young minds.

At WL we were all known by our initials, and most of these initials are forever engraved in my memory. Consequently, since most states utilize a three-character alpha code on their license plates, I am forever being reminded of WL friends when driving on the highway. How many faces can you associate with the names or initials found in this book?

Donald Franklin Hastings

I was born June 19, 1928 in Lindsay, California. At the age of two my parents moved to Missouri where I later attended and graduated from McHugh School, a typical rural one-room school with one teacher and 10 to 20 students in grades one through eight. Getting to and from school required a walk of one and a quarter miles. Water came from a hand pump outside; on cloudy days we used kerosene lamps for light, and on cold days a coal-burning potbellied stove kept us reasonably warm. I later received my high school diploma from Bronaugh High School. Following high school I enlisted in the Army Signal Corps and studied one year at the Signal Corps Radio and Radar Repair School. During an eighteen-month assignment in Tokyo, Japan I took night courses at the Army Education Program School. I received my discharge from the Signal Corps in 1949 and entered St. Lawrence University in Canton, New York that fall. Next came study under a combined plan—three years at St. Lawrence University and two years at the Massachusetts Institute of Technology. In 1954 I received two degrees, a BS in Physics from SLU and a BSEE in Electrical Engineering from MIT. During my college years I belonged to the physics and math societies Sigma Pi Sigma and Pi Mu Epsilon, as well as the scholastic society Phi Beta Kappa.

While I was at MIT, Professor Guillemi recommended me to Ned Spencer, who was at MIT to recruit engineers for Wheeler Laboratories. Through an interview with Ned, and later with Frank Williams at the offices in Great Neck, I was impressed with the state-of-the-art antennas and microwave components that Wheeler Lab engineers were designing and developing. I accepted the offer of a position at Wheeler Laboratories over ones from Raytheon and a government organization, and have always been pleased that I made that choice.

I began working at Wheeler Labs in mid-August 1954. One of my first challenges was to get through the traditional WL initiation of new engineers with my sports jacket intact. One afternoon I found my jacket with one sleeve inside the other, with an eight-inch long wooden block of 4x4 inside the inner sleeve. Neither sleeve could be pulled over the 4x4. I worked at it at home most of the evening and finally discovered how to remove it. I feared at times I would have to cut the jacket, as I later found out others had done.

My first work assignment involved the design of vehicular and base station communication antennas for Communication Products Company in New Jersey. These antennas operated in the VHF and UHF bands and required experimental adjustment of element lengths for proper matching. The work was under the direction of Ned Spencer with direct supervision by Bob Wengenroth, who had worked on these designs prior to my arrival.

These antennas were tested and adjusted on the roof of the WL building, a welcome change from working at my desk. There were a few logistic problems, however. It was necessary to run a long extension cord from the test equipment through a window to an electrical outlet in the office below. I had to drop the cord, run down to the office, open the window, fish the cord through and plug it in. Some working in the office decided it would be simpler if I just rapped the extension cord on the window and they would bring it inside and plug it in. That was a great advantage for me, but it soon became a distraction to those working in the office. One day I couldn't get any AC power on the roof and checked back in the office. Someone whose patience had worn thin had cut off the plug at the end of the extension cord!

Over the years we at WL designed a whole catalogue of high quality antennas for Communication Products (CP). Many were conventional skirt-dipole antennas, including two-element directional as well as single-dipole omnidirectional types. The lower frequency antennas required more space for testing than was available on the roof of the WL building in Great Neck. Consequently, these were tested at the New Jersey farm of the owner of Communication Products. We later greatly improved the antennas for CP. One such improvement was the coaxial-collinear array antenna, reinvented when Bill Bryson, Chief Engineer at CP came to Wheeler Labs to discuss future antenna design work. He had the idea of cutting gaps in the outer conductor of a coaxial line to allow current to flow to the outside and radiate. Mr. Wheeler explained why that wouldn't work and went on to suggest modifications that made it into a workable antenna. CP sold many thousands of these antennas. When they applied for a patent, however, they found that a man from Germany had invented it back in 1934. They were able to get an improvement patent for it, though, and this antenna is still widely used today at base stations.

Bill Bryson thought of another antenna idea that he said came to him while eating a plate of spaghetti. Many CP antennas consisted of a quarter-wave radiator over a ground plane of radial spokes. When the antennas were mounted on vehicles these spokes were hazardous. Bill's idea was to coil the spokes into a spiral similar to heating elements on a stove, making them compact and less dangerous to work around. Tests proved that the spirals worked, with only some reduction in bandwidth compared to straight spokes.

Two more antennas for CP are important to remember; both were suggested by Mr. Wheeler. The first was an antenna to compete with other suppliers of communication antennas. It consisted of a radiating wire several wavelengths long in which the out-of-phase portions of the wire were wound into a coil too small to produce significant radiation. In this way the in-phase portions radiated with just enough out-of-phase radiation to produce some super gain effect. CP sold many of these base station antennas and others market them today as well. As for patenting, this time it was an Englishman who had invented it in 1936.

The second antenna was for radio broadcasting in the FM band. CP needed a low-cost, simple antenna that would radiate circular polarization in all directions and provide as much gain as desired by stacking elements one above the other. The antenna devised was a horizontal open loop with one half bending down and the other up to look somewhat like the thread on a screw. This antenna worked quite well, was widely used, and is still marketed today.

Another project I worked on in my early days at Wheeler Labs was related to guidance antennas for the Hawk and the Sparrow III missiles. The work was for Raytheon, with Pete Hannan directing my efforts. The key feature of the antenna was a rotating disk spinner with three slots, which resulted in a narrow radiated beam that spun at three times the rate of the disk. Our goal was to improve the antenna performance by finding the optimum spinner shape. Many different configurations were tried. The tests were done on a range in the basement of the Great Neck building, where absorber panels were strategically located to prevent unwanted reflections. The spinner was turned by hand a few degrees at a time and the resulting signal on a detector across the room was recorded. The technician turning the spinner was behind an absorbing panel, and it was comical to see his arm appear periodically as if from nowhere to make each adjustment. Many hours were consumed in this operation, but no improved shapes were identified. Instead, a polarization filter was devised which absorbed the objectionable radiation generated by the spinner slots. (This is a good example of how the staff at Wheeler Labs often found alternative ways to achieve a desired result when the first approach was unfruitful.) The polarization filter consisted of conductive strips on a fiberglass sheet. These strips absorbed polarization parallel to them, but passed perpendicular polarization with no noticeable loss. The technique was used on later projects as well.

I was among those who transferred to the Smithtown laboratory when it first opened in 1957. This new facility had a pattern range to test precision tracking radar antennas. We also installed the roof-to-ground pattern range for CP communication antennas. Initially several of us carpooled together for the long drive from our homes near Great Neck to Smithtown, something none of us will forget because of the traffic on Route 25A. Later other roads were built and it became easier, but by that time we had all moved to the Smithtown area.

I became involved in one of the Nike-Zeus projects soon after transferring to Smithtown. My project was to design a new Missile Tracking Radar (MTR) antenna for the system. It was to be a precision tracking steerable parabolic antenna of the Cassegrain type, similar to the earlier Nike-Hercules antenna but only four feet in diameter. The work was done for the Bell Telephone Laboratories Murray Hill group. The design met specifications, but after it was completed a new multimode comparator was designed at Wheeler Labs that was incorporated into the MTR design, giving it added capabilities. The new comparator required the redesign of the antenna sub-reflector. Later the MTR design was used in other applications. I also designed a new sub-reflector for the Nike-Hercules antenna to enable it to function with the new comparator. This same design was then used on the Air Force Titan 107A-2 radar antenna that was used to guide NASA missiles during launch.

Shortly after the Nike work I was assigned to a Navy antenna project which became the SPG-55A. The purpose of the project, which was contracted through Raytheon, was to modify an existing Navy gun-laying radar antenna to give it missile-directing capability. A memorable part of this project was my trip to the Boston Navy Yards to see one of these antennas on a Navy destroyer. The design accomplished all goals despite the lack of precision on mounting surfaces of the old antennas being modified. (We even had to re-machine the mounting surfaces.) One distinctive feature of the antenna was its white nose cap that was very prominent. The antenna required some very careful study and design work as well as judicious use of absorber material to prevent holes in coverage that could lose a missile.

Two interesting events occurred following this project. The report on the SPG-55A antenna, which three of us on the project helped to write, was sent through Navy channels; I received a note from a Navy official that was very complimentary. He stated that by reading our report he understood for the first time how this type of Navy antenna really worked. That was a great encouragement, and I have always been grateful for the training in report writing I received at Wheeler Labs. The second event took place several months later when I received a phone call from the Philadelphia Navy Yard asking what was in the large crate stored there. The irony of this really hit me as I remembered how hard we had worked to meet a very urgent shipping schedule many months before.

The SPG-55A antenna was produced for many years. Since Wheeler Labs had done the design we were best equipped to certify the antenna's performance, so for several years we redesigned it for new manufacturers.

Another item developed at Wheeler Labs was a polarization-converting panel. I was assigned to one such project when an Army group from Langley, Virginia asked Wheeler Labs to design a panel to convert the radiation from the Nike-Ajax lens antenna to circular polarization. This was achieved by mounting a flat panel with a polarizing wire grid onto the front of the antenna. I remember this small project because some time later I saw one of the polarizing panels on a Nike-Ajax antenna when vacationing in the Outer Banks of North Carolina. One of the rewards of our work is to actually see our designs in use.

In the mid-1960s I was assigned to the Dazzle radar antenna project, which perhaps was my most adventurous. This was a parabolic reflector antenna 87 feet in diameter, operating in the VHF frequency band. The data-gathering channel for the system operated at a rather low frequency in the VHF band, and a monopulse tracking channel at about three times that frequency was used to steer the large dish. This had been built by another company but had failed to lock on and track targets. The feed system was a cluster of dipoles that proved to have so much interactive coupling that it failed. Wheeler Labs proposed to design a new antenna feed that would avoid the problems encountered with the original feed. The contract was for the Army Missile Command in Redstone Arsenal and Wheeler Labs subcontracted through Collins Radio. It was a very intricate system with special need to preserve symmetry. One key feature was the decoupling loops that were located to shield dipole ends from each other. The peak power levels also required special globes on the ends of dipoles to prevent corona, and in addition, some dipoles were angled in a slightly dogleg fashion to separate the ends adequately. When this feed was assembled over a circular ground plane and painted white it was rather spectacular.

It was on this project that I attended my first conference at the Pentagon in Washington, D.C. Collins and Wheeler Labs personnel presented a summary of the results and success of the project to that time, and we were proud of our achievements. However, representatives from another company were present hoping to sell their radar system, and they tried to cast doubt on the ultimate success of our project. The Pentagon official seemed inclined to believe them and complained that companies such as Wheeler Labs made a profit of 30%. Actually, Wheeler Labs never charged anything like that. Ultimately we were completely vindicated when the new feed worked perfectly as we had predicted, and the other company did not get their sale.

Not only did I go to the prestigious Pentagon, but as the Dazzle installation was at the Woomera Missile Range in South Australia, Harry Redlien, Fred Van Daavelar and I had the privilege of going there to help with the installation. We had opportunity to do some sightseeing in Adelaide and Sydney. The missile range was in the outback desert where the kangaroos run wild and the Australian national flower blooms. It was fun to climb up onto the giant antenna pedestal and install the feed and coaxial line system. One incident took place when I was high up in the structure preparing for the installation. I looked down to see a large group of Australians examining the newly assembled feed, and I wondered if they had spotted some problem we had failed to identify. I hurried down and asked if anything was wrong, but they simply replied, "It's pretty." I felt good about that and noted what a contrast it was to the original feed nearby.

One test technique developed on the Dazzle project was that of measuring the impedance of a single element in an array of active elements. I have used this technique many times since.

During the last half of the 1960s I led a project to develop an improved built-in antenna for battlefield intrusion detectors for use in the Vietnam War; Hazeltine produced these detectors. Many thousands were deployed in the jungles and gave warning of enemy troop movements. It was very satisfying to have a part in protecting our troops.

About the same time, Hazeltine and Wheeler Labs worked on a project for RCA to develop an alternative feed system for the array antenna for the Navy Aegis program, later called SPY-1. The phased array radar antenna for the system required a very complex feed system to divide the transmitter power between the hundreds of elements in the array. This feed system had to provide monopulse operation which utilized both sum and difference mode patterns, and the space available was very limited. The feed network consisted of two parallel sections of reduced height waveguide with cross-guide coupler branches leading to the array elements. Since the elements were closer together than the waveguide width, it was necessary to put the coupler branches on both the top and bottom walls of the waveguide in an overlapped arrangement. This proved to work quite well, although it had not been tried before. We were able to achieve a feed system that excited the elements with an excitation taper for very low sidelobes and independent control in both the sum and difference modes. Later the Aegis feed system was designed using stripline transmission line and couplers instead of waveguides. This project gave me experience that was very valuable when I worked on the design of the Navy's SPG-30 antenna after leaving Wheeler Labs.

The projects above were the most memorable ones I worked on, but there were many more. These included:

- The SEMTR monopulse Cassegrain antenna that improved on the Nike-Zeus MTR
- Special short-circuit choke joints for the petals of the Nike-Zeus target track radar antenna
- The study of, and solutions for, reflection problems in the HAPDAR phased array antenna feed chamber

- Design of array elements, feed chamber and transmitter feed for the Missile Site Radar phased array antenna
- Study of reflection effects and design of a personnel protection shield for the SAM-D phased array system
- Design of “invisible” radome support hoops for the Nike-Zeus and Titan radar antennas
- Analysis of captured Russian aircraft antennas to identify their operating bands and capabilities
- A number of electromagnetic countermeasure (ECM) antennas
- IFF antennas and add-on IFF antennas, both omnidirectional and unidirectional types, for airborne applications.

In addition, I designed many waveguide and coaxial line components such as directional couplers, hybrids, filters, mixers, dual and circular polarized devices, etc.

After working for Wheeler Labs I went on to ITT Gilfillan to work under a former Wheeler Labs colleague, Bob Hanratty. From there I went in a new direction that was unusual for an engineer. With my family I went to Costa Rica to study Spanish, and then we went to Quito, Ecuador for me to serve as an engineer with the pioneer missionary short wave radio station HCJB. Upon joining HCJB I learned that one of their technical officers knew about the excellent reputation of Wheeler Laboratories and judged antenna engineers trained by Mr. Wheeler to be the highest qualified of any in the world. That reinforced my conviction that working with Mr. Wheeler was indeed a privilege. Most valuable of all was to be taught how to achieve new, innovative designs. From a set of requirements, I learned to devise a simple, cost-effective design that would provide the desired performance.

While at HCJB I designed and supervised the construction of numerous curtain arrays and directional AM and FM antennas for radio broadcasting, and designed several short wave transmitters. After 15 years HCJB had no need for additional antennas, and I joined Kintronic Laboratories in Bristol, Tennessee. At the beginning of 1994 I retired, and am currently working as an electrical engineering consultant.

Joel Becker

When, in March 1955, a tall blond man walked up to me in the hallway outside my electronics class at Brooklyn Polytech and introduced himself as Frank Williams of Wheeler Laboratories, I was nonplussed. Based on a recommendation by my professor, I had been selected as an employment candidate by his company. To this Bronx boy, Long Island was close to the edge of the world. After much discussion with my family about the unusual nature of this recruiting approach and the uncertainties of working for a small, unknown company, I accepted the invitation for an interview, and subsequently, an employment offer. This proved to be a major milestone in my life.

After receiving the BEE degree from Poly in June 1955, I was employed at WL through 1970, during which period I worked on a good sampling of the wide variety of technical projects (microwave components and antennas) in which WL was involved. These included the Stationmaster base station antenna for Communications Products, an 80-foot pillbox antenna for the Nike-Zeus system (also a unique double-layer pillbox designed as a potential replacement at 1/10 scale), and a series of ground-reflection blocking fences for a number of different radar applications. I obtained my MEE at Poly in 1960 and subsequently took Industrial Management courses there.

I was promoted through the standard progression of engineering and project responsibility from development engineer to senior development engineer, and from project manager to engineering manager. In the last role I had responsibility for planning and implementing a company capability in microwave integrated circuits and solid state component development. My managerial functions at various times included service as Company Security Officer and Director of the recruiting effort. Eventually, I served as second-in-command to George Vaupel when he became chief engineer.

I left WL as part of a large layoff in late 1970; both GEV and I had tears in our eyes when he told me the news.

In the nine years following my time at WL, I worked for several companies in the areas of systems engineering and antenna design and consulting, including a stint at Hazeltine, where I worked as a systems engineer under Stu Litt (SPL) and Henry Redlien (HWR). However, I had never seriously contemplated leaving WL and, in the past, had found it hard to understand what motivated those who had resigned to pursue other opportunities. In retrospect, the finely tuned engineering environment at WL that nurtured and developed so many outstanding engineers also left some of us somewhat naive in some respects. I required additional education in the ways of the rest of the industry in order to survive. These lessons in "realism" were sometimes painful. While compromise was often necessary, I found that WL training did not dissipate. The WL engineering approach was always in the background, providing a model for the right way to solve problems.

In 1979, I was considering another change in employment (still pursuing the impossible dream), when an opportunity was presented to me by Sid Arnow. SA had been working as an independent consultant but was at that time involved with other ventures. Dick Flam (RPF), then head of the Antenna Department at AEL, had asked SA if he was available for a consulting assignment. I was suggested and accepted as a replacement, resigned from Sedco where I was employed at the time, and began a new career as an independent antenna consultant. Most of my initial consulting work (operating as DLW Technology Source, Inc.) was for companies in the defense industry; many jobs were the result of referrals by WL alumni.

During a consulting assignment, I occasionally have the opportunity to influence a younger engineer toward a thoughtful engineering approach and my WL background takes control. I do my best to discourage the generation of masses of computer data as a substitute to thinking out the fundamentals of a problem. (I often recall HAW's early resistance to the use of computers, for this reason.) Unfortunately, engineers who have been around for a few years often resist such retraining. It is a matter of "too little, too late." I regret that others can't have the benefit of the WL sustained training at the onset of their careers.

My career has been very strongly influenced by my 15 years at WL. The influences have been both technical and personal. I have many pleasant memories of that period and still maintain contact with a large number of friends and colleagues from WL.

Jerome D. Hanfling

I was born in Brooklyn, N. Y. on March 12, 1933. I received my elementary and secondary school education at P. S. 217 and Midwood High School. My aptitude in mathematics, as well as my desire to prepare myself for a paying job after graduation, led me to take the pre-engineering curriculum at Brooklyn College, and then to study electrical engineering at CCNY. I obtained a BSEE degree in 1955.

My interest in electromagnetics was piqued by the EM courses at CCNY. Also, during my summer vacations in 1953 and 1954, I obtained employment at Rome Air Development Center (RADC) at Griffiss AFB in Rome, N. Y. Part of the time was spent monitoring high-power tests of polarization-twist duplexers; this was my introduction to microwave hardware. It was at RADC that I met George Vaupel, who would later become an important contact for WL employment.

During my last year at CCNY in 1955, I became engaged to my future wife, Marcia. In order to permit her to finish her education at Brooklyn College, I focused my job hunting in the New York area. My recollection is that I sent a letter and résumé to WL. At my interview in Great Neck, I discussed (with prompts and questions by Hank Schwiebert) rectangular waveguides, and was able to apply boundary conditions to construct the electric and magnetic fields for the dominant mode; this was a real fun interview.

During my laboratory tour, I was impressed not by fancy microwave test setups but by how simple slotted-line setups with manually-tuned klystrons could be used to carry out sophisticated component designs. This was in contrast to my experience at RADC, which had lots of fancy test equipment but did not have the know-how of a WL to carry out advanced component designs.

My interview introduction to WL was with D. Dettinger, and G. Vaupel stopped by to say hello as well. Finally, I was marched upstairs to be introduced to H. A. Wheeler. The entire interview was very satisfying, and I made up my mind that this was the place to start my engineering career.

When I started work I did not have a car, but was prepared to take the LIRR from Brooklyn to Great Neck. Fortunately, there was room for me to travel to work as a passenger in the Brooklyn car pool, whose members included H. Bachman, G. Vaupel, D. Lerner, and I. Koffman. Between discussing technical problems from work and looking out for police so as to avoid speeding tickets, the rides were exciting.

My first assignment was working for Pat Loth on hybrid-T junctions. I sat in Lab 16 with R. Hanratty, J. Franklin and J. Campbell (a summer employee whom I ran into later on at Raytheon).

I spent five years at WL in Great Neck working on microwave hardware for the NIKE systems. The customer was Bell Telephone Laboratories; as such, many car trips to the BTL facility at Whippany, N. J. were required. These trips with Pat, Harry, Pete, etc. revealed another dimension of professional togetherness. Next came tasks for the U. S. ballistic missile program. I designed crystal detector mounts for the Titan radio inertial guidance system. Also, I developed the equations to predict the polarization loss between the NIKE-Hercules track radar and the Titan horn antenna polarizations as a function of the launch and flight dynamics. The polarization was mapped on a stereographic projection of the radiation hemisphere.

The work proceeded professionally, yet included a certain amount of hijinks such as open/closed window battles, rubber band fights, and practical jokes (involving missing desks and Jell-O, among other things). The participants included G. Vaupel, J. Becker, L. Appleman, and R. Tuminaro. Later on, I became a lab supervisor, with Paul Meier and Roger Segal among my charges.

Another aspect of the WL experience was continuing education. In the evenings, I took graduate courses at Brooklyn Poly, a revered center of microwave research. This was a sort of partnership between Poly and WL, in which Poly provided the theoretical foundation for solving the practical problems met at work. The Poly experience started with courses in Brooklyn at Jay Street, then on to Mineola High School, and finally with the opening of the graduate school at Farmingdale. I received my MEE in 1960. The formal education was supplemented by in-house seminars describing ongoing projects, and by the math club led by HAW.

The work experience at Great Neck was delightful, with lots of interaction with and among senior engineers P. Hannan, P. Loth, H. Bachman, F. Williams, D. Dettinger, etc., and insights and instruction from HAW. Wheeler instructed me on the use of low-frequency equivalent circuits to represent microwave resonators and waveguide discontinuities. I applied these techniques to the broadband matching of crystal detectors, phased array radiating elements, and to the design of microwave filters. Also, HAW introduced me to the stereographic projection that I used to map the three-dimensional polarization properties of fundamental radiating elements. This was the subject of my Master’s thesis; the idea was extended to present the electric fields in the aperture of paraboloidal reflectors.

In 1960, I joined the group comprising H. Redlien, N. Spencer, R. Hanratty, and S. Lieberman that began working in the Smithtown facility to carry out pattern measurements of antennas. Here I led a group including A. Lopez, R. Frazita, R. Giannini, G. Charlton, R. Lodwig, and S. David that was tasked to develop and test the discrimination radar variable beamwidth antenna for the Nike-Zeus system.

This Cassegrain antenna had a twist-reflecting grid on the main dish. I became aware that we had no solution to handle oblique incidence on the wire grid in the cardinal planes. The usual separation into TE and TM modes (E-field orthogonal and parallel to the plane of incidence) which occurs in the ±45° planes was not valid in the horizontal and vertical planes.

At Brooklyn Poly, I was introduced to a new set of orthogonal modes, E-type and H-type, which could be separated into E and H fields both normal and coincident with the grating. Equivalent circuits could now be applied to the twister design for all planes of incidence. This stimulated a course project report at Poly, and I co-authored an AP-S Transactions paper on the subject. Also on the project, HAW wrote a fundamental AP-S paper entitled, "Antenna Beam Patterns which Retain Shape with Defocusing." I researched the Fourier Transforms listed in Campbell and Foster for pairs that retain their functional shape under defocusing.

Following the discrimination radar job, we became a subsidiary of Hazeltine Corporation. My first job with Hazeltine was supervising the design of an IFF array containing full-wave dipoles fed by coplanar parallel strips, all printed on one side of a glass-filled Teflon substrate. During this program, Mr. Wheeler, working with R. Frazita, provided the community with a solution for the wave impedance of the co-planar feed by using conformal mapping techniques. We successfully designed, built, and tested this IFF antenna, which I understand became a product line at Hazeltine after I left WL.

My introduction to phased arrays came with the task responsibility to design the front-face radiating element for the missile site radar (MSR). The MSR group included H. Heinemann, R. Frazita, L. Botte, C. Schlotterhausen, and G. Charlton; the customer was Raytheon. The array face had to be designed to operate in rain, ice, and snow environments and had nuclear requirements. Two task forces were set up among the WL, Raytheon and BTL participants, requiring meetings at Raytheon in Bedford, MA every two weeks. We became Eastern Airlines shuttle regulars.

I worked with G. Knittel on array coverage studies that led to criteria for optimizing the element lattice and number of faces for a prescribed angular coverage. The front element design was optimized for wide-band, wide-angle performance. More than 10,000 elements were built for two systems, one in Meck Island and the other in North Dakota.

I left WL in 1967 to accept a job at Raytheon, where I spent twelve years working in their Missile Systems Division (MSD) and over 14 years in the Equipment Division. My WL experiences influenced and contributed greatly to my work at Raytheon.

For example, in my work involving various advanced phased array radiating elements, I have applied low frequency, double-tuned, coupled-circuit concepts and array mutual-coupling theory learned while at Wheeler Laboratories. I have used these in the development of novel radiating elements and array face configurations for various ground-based, space-based, and airborne phased array systems. These techniques were used to develop dielectrically loaded waveguide and slot radiators, and microstrip-patch radiators. These coupled-circuit matching networks were combined with the array face aperture-to-free space discontinuity including mutual coupling. The dimensions of the radiators and predictions of performance were determined by the use of theoretical calculations in combination with Wheeler waveguide simulator measurements. The designs were verified by small-array embedded element-pattern and mutual-coupling measurements.

Many people are familiar with Raytheon's work on the PATRIOT. What they may not know is that Wheeler Labs made very significant contributions to the PATRIOT (SAM-D) phased array system. WL worked on the proposal and was subcontracted to do the feed and comparator. Pat, working with Len Steffek and Richie Kumpfbeck, did the electrical design of the radar main array feed system; WL also did the transmit feed, shown in the photo on page 26.

I was the lead engineer responsible for all of the phased arrays in PATRIOT, including the radar main array, the auxiliary arrays and the IFF phased array, which was probably the first IFF phased array ever. What was unique about my participation was that I was able to use the experience garnered at Wheeler Labs on the discrimination radar, the missile site radar, and on IFF and apply it to this complex system. In particular, I was able to apply the lessons taught to me by HAW on coupled circuits, Q's, and the grating lobe series, etc. to the design of the radar array front and rear radiating elements, the IFF radiating element, and the overall array face design. Four patents were issued to me for designs that are now embodied in the PATRIOT hardware. The Wheeler Lab experience enabled me to carry forward this array system successfully.

At Wheeler Laboratories, I was trained in the subtleties and disciplines of microwave and antenna engineering. Here we were not only dedicated to doing a good job, we were encouraged to get involved in our electrical engineering profession. I joined the IEEE and became active in the professional societies. I am a past chairman of the Boston Chapter of the Antennas and Propagation Society and a PACE representative for the Society. I was elected a Fellow of the IEEE for contributions to the design and testing of passive and active phased-array antenna systems. I have lectured for short courses on phased array antennas and antenna measurements.

Currently, I live with my wife, Marcia, in Framingham, Massachusetts. We have a son, Edward, who is employed at MITRE Corp., and a daughter, Merle, working at the Lahey Clinic. This family remembers, and appreciates, the WL experience.

Murray Novick

After graduating from Brooklyn Technical High School on 450620, I took (and passed) the U.S. Navy Eddy test. This qualified me for 10 months of training as an electronics technician, and eventually a rating of Electronics Technician 1/c. School was followed by one year of service aboard an aircraft carrier, the USS Wright. I was then assigned to the electronics school at Great Lakes, IL where I served as an electronics instructor until my discharge on 480505.

In 1948 electronics was not very profitable, so I went to work in the family business managing a corset shop. The Korean War created a shortage of electronic technicians, and in 1951 the Navy recalled me to serve aboard the USS Missouri for a year. In 1952 electronics looked more like a growth industry and I decided to become an electronic engineer. With the aid of the GI Bill I attended the Polytechnic Institute of Brooklyn, graduating with a BEE in 1956. At Poly I had good grades and two of my professors suggested that if I could qualify, Wheeler Labs would be a good place to maximize my skills.

My interview at WL was conducted first by Dave Dettinger, then by Ned Spencer. During Dave's interview I mentioned that I was worried that my math skills might not be adequate for WL. Dave said not to worry, and when he passed me on to Ned, told him I was weak in math and that he should question me in other areas. Ha!

My work at WL consisted of two phases—WL Great Neck and WL Smithtown. At Great Neck I designed miscellaneous Ku-band waveguide components for the Nike-Hercules radar; at Smithtown I did antenna design for Communications Products Company.

Ku-Band Components

The Ku-band components incorporated several innovations and are described below:

- A 2-hole crossguide coupler in which a second hole was added to enhance directivity. A single-hole coupler normally has directivity equal to its coupling. The improved coupler made tighter couplings practical.
- A topwall coupler in which the coupling array consisted of two rows of holes arranged symmetrically around the centerline.
- A non-contacting waveguide shutter.
- A rectangular choke waveguide flange.
- A fixed attenuator consisting of a block of lossy material mounted to the broad wall of the waveguide.
- A variable attenuator in which in which a fiberglass vane coated with a lossy metalization, and supported by two metal rods in the narrow wall of the waveguide, could be positioned from flush with the narrow wall to the center of the waveguide. The design problem was to maintain impedance match as the vane was moved to vary the attenuation.

- A high power termination in which the design problem was to keep the termination short and to distribute the attenuation to achieve uniform power dissipation and not burn the leading edge.
- A waveguide pressure window consisting of a sheet of Kapton that was impedance matched by painting a conductive iris on it.
- A high power sidewall coupler with flat coupling (approximately ±0.l dB) over more than l GHz. The flat coupling was achieved by narrowing the width of the secondary waveguide to modify the propagation velocity of the coupled wave.

Stationmaster Antenna-Based Designs

Wheeler Labs had already designed the Stationmaster antenna (an omnidirectional, 6-dB gain antenna consisting of a collinear array of half-wavelength coaxial lines with inner and outer conductors interchanged every half-wavelength) before I was assigned to Smithtown, but this was the basis for three of my designs. These included:

- A broadside bi-directional array at 460 MHz. This array utilized two Stationmaster antennas spaced 0.625 wavelength and provided a 4-dB gain improvement. Sidelobe suppression was 8-dB and bandwidth was 7 MHz.
- A cardioid array consisting of two antennas spaced one-quarter wavelength apart.
- A 956 MHz Stationmaster design. The design effort was to determine the dimensions that resonated one gap, and then to parallel enough gaps to obtain 50 ohms.

Powermaster Antenna

The Powermaster antenna (shown in the upper right-hand photo on page 29) was a 1 kW, 460 MHz, 10-dB omnidirectional gain antenna with 5% bandwidth. It was based upon the Stationmaster design, that is, a standing wave was generated along a transmission line and alternate radiating elements (surrounding the line) were connected to alternate sides of the line at half-wavelength intervals, but it was center-fed to broaden the pattern bandwidth. The electrical dimensions of the antenna are illustrated in figure 4-7. Physically, it was massive; over twenty feet long, with three-inch diameter radiating cylinders, and the internal transmission line which excited the radiators consisted of two 7/8-inch diameter copper pipes shorted at the ends. One of the pipes served as the outer conductor of a feedline to the center of the antenna, where the pipe was pierced and the center conductor brought out and connected to the second pipe.

My contribution to this antenna was to build the test fixture that simulated a radiating section of the antenna, and to take the data that were used to design the complete antenna. As shown in figure 4-8, the desired radiating mode had a short circuit plane of symmetry at the gaps but there was a possible parasitic mode that had an open circuit plane of symmetry at the gap. A key

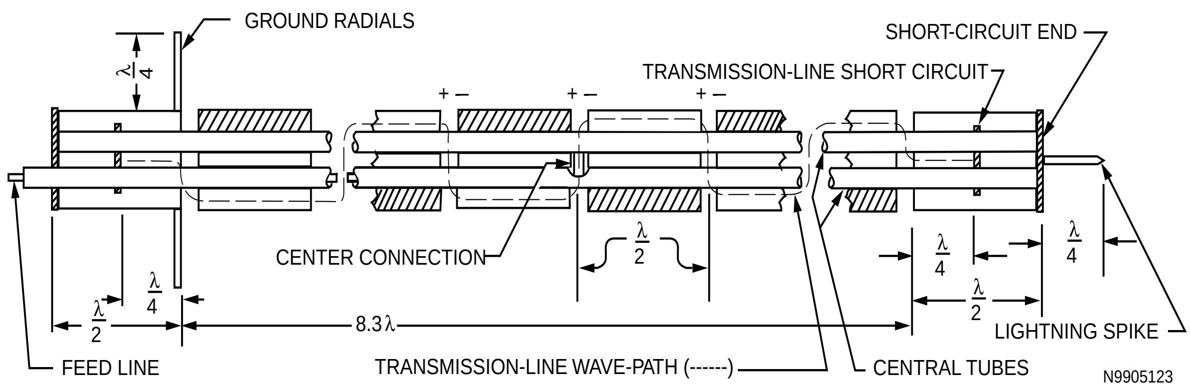

Figure 4-7. Powermaster Antenna, Electrical Dimensions

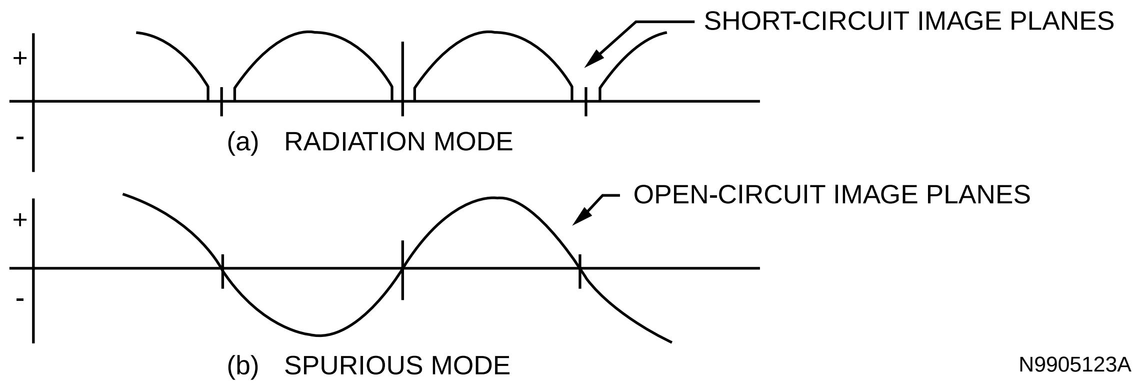

Figure 4-8. Current Modes of the Powermaster Antenna

feature of the design was the three-quarter wavelength, non-radiating end section that suppressed the parasitic mode. The first completed prototype did not have the desired gain or impedance and was difficult to analyze, but I think my suggestion to cut the antenna in half so that measurements could be made at the in-phase (0° beam tilt) frequency helped shorten the design time.

Parallel-Plate Simulator

Communication antennas must often be mounted off the side of a support tower. The effect of this mounting upon the radiation pattern is a function of both the tower diameter and the spacing of the antenna from the tower. By simulating a two-dimensional slice of space a parallel-plate simulator (shown in the photo on page 33) was used to measure this effect. Frequencies as high as 9.6 GHz were used to scale the tower diameters to reasonable dimensions. The simulated tower and antenna were mounted within a rotating center section and a remote probe measured the pattern as the center rotated. A choke joint insured electrical continuity across the gap introduced by the center section. The outer circumference of the simulator was terminated with carbon vanes to minimize the effect of reflections upon the pattern.

Wheeler Labs was my first job as an engineer and although I didn't realize it when I started, I had many bad work habits. The reports I had to write did much to minimize the bad habits and give me some good habits. Probably the most important of these was the idea that I should run my jobs in a manner that would allow me to write a report that I would be proud of. This made it necessary to treat my engineering notebook as a close friend that was interested in my thoughts and all job activities. In 1988 the FBI made a sweeping investigation of many defense companies for possible time card fraud. It was nice having a close friend to protect both my company and myself.

As a group, WL was the smartest, most congenial group of people I have ever worked with. They worked hard and they played hard, especially at skiing and ping-pong. From the way we fought at the ping-pong table you would never know that we were really friends. And the skiing I was introduced to by fanatics such as Dave Lerner and George Vaupel has resulted in my buying a retirement house near a large ski slope that offers senior citizen discounts.

Irwin Koffman

I was born in Brooklyn, NY on May 4, 1932, attended PS-131 elementary school in Brooklyn, and graduated from Brooklyn Technical High School, which at that time was regarded as one of New York's "elite" schools, in 1950. At the time I graduated from high school my family's economics were poor, so I opted to first go to work rather than directly to college so that I could save some money. I worked for three years, then entered the City College of New York in 1953, and was awarded a Bachelor's degree in Electrical Engineering in 1956. While working at

Wheeler Labs I attended evening classes at Polytechnic Institute of Brooklyn and received a Master's Degree in Electrophysics in 1961.

It was a practice at CCNY to invite representatives from industry to deliver a talk relating to various advanced technical topics of their choosing. One afternoon I noticed that Mr. Wheeler of Wheeler Labs, Great Neck, NY was scheduled to visit CCNY to deliver a talk in connection with tracking antennas. I attended the talk and demo given by Mr. Wheeler and assisted by Frank Williams. I found the subject fascinating, particularly the portion that dwelt with monopulse tracking techniques, and as a result I wrote Wheeler Labs to express my desire to work at WL.

As a result, I was invited to visit and tour WL, was interviewed by Henry Bachman and Frank Williams, and was introduced to Harold Wheeler and Dave Dettinger. I received an offer in the spring of 1956 to join WL. At that time I had offers from IBM, Kearfott, and Raytheon, but accepted the offer from Wheeler Labs because I felt WL was an elite technical organization, felt comfortable amongst their cadre of young engineers, and was excited (and bewildered) by the type and diversity of projects in progress.

I started work at WL, Great Neck on June 13, 1956 and departed in November 1970. This was a period when science, technology and engineering were of great importance, and of considerable urgency to the nation. We were in the midst of the "cold war," Sputnik was launched, we endured the missile gap and won the missile race, and we initiated a national effort to put satellites, and then men, into space. It was clear that the nation's security demanded that technology command the nation's interest and support, and it did.

Upon arrival at Wheeler Labs I was assigned to a desk (opposite Murray Novick, who had started work a week earlier) located in a Lab that was under the administrative supervision of a senior engineer, Herb Rickert. It was practice to divide up the Great Neck facility into a group of large lab rooms within which were gathered the desks of typically six to ten engineers, commingled amongst the lab benches and associated microwave test equipment.

Led by Dave Dettinger, Ned Spencer, and Frank Williams, indoctrination of the new engineers began early. It included the receipt of a set of tools (a pair of screwdrivers, a 6-inch steel scale, a pair of needle-nose pliers, a small file, etc.), which was meant to convey the message that microwave/antenna engineering at WL was a down-to-earth, hands-on, do-it-yourself skill. In addition, each new engineering recruit was given a solidly bound notebook and encouraged to maintain a neat, detailed record of design work and test data and to adopt Wheeler's logical date/time code. Further, recruits were instructed in the use of the modified "Smith Chart" (now referred to as the "Wheeler Chart") to graphically represent the impedance or reflection locus of a microwave structure, how to prepare shop drawings and shop work orders that would not be bounced back by the then shop supervisor, Al Paskevich, and how to prepare WL technical reports.

My very first assignment was to assist Don Hastings, a senior engineer, in measuring the retro-directive spatial response of a solid spherical Luneberg lens whose surface was partially coated with a reflecting coating. We set up a small test range in the basement of the Great Neck facility. I didn't contribute much to the task at hand but I asked a lot of questions and fortunately, Don was very patient.

One of my earliest assignments was working for Henry Bachman to develop a "non-reflecting," high-power microwave waveguide filter that would suppress spurious radiation from a military radar system. At the time this was a serious problem, since the spurious radiation was interfering with AT&T's microwave communication links that straddled the country, and which in one instance interfered with the transmission of the Rose Bowl football game. With Mr. Wheeler's guidance in establishing the theoretical filter parameters, and after considerable breadboard design and test, several working models were fabricated. However, full-scale implementation was never accomplished, since eventually the offending signal source was successfully "cleaned up." Nonetheless, this project was significant to me since development of the filter was the subject of a Wheeler Lab seminar that I delivered to the staff.

In the 50s and 60s Wheeler Labs played an important role as a subcontractor to Bell Labs in developing key antenna portions of the Nike anti-aircraft and then the Nike anti-missile systems. These tasks involved the efforts of a major portion of the staff; particularly notable was the innovative work of Pete Hannan in applying Cassegrain concepts to the design of microwave antennas and the application of multi-mode feedhorns, and Patricia Loth in managing the development of key waveguide "plumbing" assemblies. I had the pleasure of working for, and learning from, both of these fine engineers.

My involvement in this effort included participation in the design and test of the polarization-twisting surfaces of the Nike-Zeus target track radar antenna, participation in the design and test of its multi-mode feedhorn, and design of several radiators used with a large image-plane Luneberg lens, switched-beam surveillance radar antenna.

As an outgrowth of some of my work with polarization-twisting surfaces, I submitted to Polytechnic Institute of Brooklyn a Master's thesis that established the relationship between the eccentricity of conic surfaces and the polarization characteristics of the feeding antenna. This thesis was published in PTGAP, and was selected for inclusion in a book entitled "Reflector Antennas," published by IEEE Press and edited by A.W. Love.

One of the amusing incidents that occurred during the design of the multi-mode feed was the discovery of an anomalous discontinuity in the measured electric field intensity within the feedhorn. After much time and analysis, no satisfying explanation for the anomaly could be found until it was finally discovered that a yellow-jacket hornet had taken up residence at a particular location within the feedhorn, and was slowly building its nest. When the hornet's nest was removed, electromagnetic theory was again on solid footing.

One of the most satisfying accomplishments with which I was associated was the development and supply of the ground-based tracking antenna used to track the Telstar communications satellite, so as to provide an initial prediction as to the satellite's orbital path. Under subcontract to Bell Telephone Laboratories, WL was charged with redesigning the Nike-Hercules tracking antenna so that it would track a beacon at another frequency on the satellite. I was assigned as the project leader and, working with Richard Giannini and Don Yenoli as well as with BTL personnel, we delivered in a timely fashion two Telstar tracking antennas, one to a site in Andover, Maine and the other to a site in Plemour-Budeau, France. Happily and proudly, the trackers performed flawlessly.

Shown on page 29 is a photo of the Telstar tracking antenna mounted on a rotatable pedestal, located on the roof of WL's antenna test site at the Smithtown, Long Island facility. Atop the antenna is the author of this narrative, engaged in the adjustment of a standard gain horn.

I was fortunate to be involved with many other interesting and challenging projects, including development of blast-hardened antennas for Troposcatter communications, development of a series of antenna systems to accomplish detection of non-metallic mines, and demonstration of a non-contacting, non-radiating, continuous-access communications transmission assembly for use by high-speed trains.

Starting in the early 60s, support from our principal customer, Bell Telephone Laboratories, began to decline dramatically and even though our parent, Hazeltine Corporation, relied on WL to a greater extent, it was evident that the capture of new business from a broader range of clients was a high priority. As a result, starting in 1967 until I departed in 1970, I devoted most of my time to marketing the expertise of Wheeler Laboratories.

After I left WL and joined other organizations, I was struck by the perception of a heightened sense of competition both internal and external, as compared to WL. As a consequence, cooperation and information sharing were more grudgingly offered. In addition, engineers and technologists were more often treated as necessary expenses rather than as valued resources, as was the case at Wheeler Labs.

My recollections of Wheeler Labs are filled with much pleasure, and a proud sense of being part of a unique organization. I am indebted to the learning opportunities afforded me and to the association with many outstanding colleagues.

Robert E. Puttre

I was born on 360313 in Brooklyn, NY and attended Brooklyn Technical High School, followed by one semester at City College of New York and four years at Cooper Union in Manhattan. I graduated from Cooper Union in 1958 with a BEE. (Dean's List, TBP).

At Brooklyn Tech, I chose their electrical course, and together with a dozen or so students, was selected to specialize in broadcasting. This course included both RF communication theory and practical radio station operation. Sid Arnow was one of the other students in the class and we both obtained our FCC first-class radio-telephone licenses.

The one semester at CCNY bridged a winter graduation from high school and a September start at Cooper. During this period, I joined the N.Y. Air National Guard as a radio operator in a communications group. This provided me with both the technical satisfaction of being in radio equipment surroundings and a draft deferment during an uncertain period. After basic training and six years of monthly weekend assignments, I was discharged just months before my unit was activated into service to Europe.

George Vaupel, a Cooper graduate, recruited my junior class for summer employment at WL. During the technical interview in Great Neck, I steered the discussion to resonant organ pipes, drawing an analogy between audio and RF standing waves, open and short circuits, etc. I also described an electronic gunshot sound-effects generator I built for WNYE-FM at high school.

My summer assignment was in Great Neck, reporting to Herb Rickert, and to some degree, Pat Loth. A Nike target-track comparator was experiencing occasional high-power misfiring. I made SWR measurements of the comparator and transmit circuit waveguide, with both unfired and simulated-fired TR and ATR tubes, starting at the operating X-band and going up in frequency as high as possible to try to find any above-band resonances. This was my first experience of performing a test to study something that no one had ever done before, and I loved it. Unfortunately, that experience changed my attitude toward schoolwork when I returned for my senior year. Lab experiments and class problems seemed less challenging because I felt the work was not original or unique. The answers or solutions were already known by a myriad of previous students. Happiness was returning to WL after graduation, not to mention receiving the highest starting salary of the whole class.

Full-time employment began 5806 in Lab 16, reporting to Pat; Joel Becker, Irwin Koffman, Dick Peritz and Hal Guthart were also in the group. My assignment was to develop a waveguide device that would launch a particular ratio of TE-30 and TE-10 modes at the wide waveguide throat of the Nike-Zeus target-track radar feedhorn. Pete Hannan's optimum feed for a monopulse antenna required a shaped sum-mode illumination at the feedhorn aperture. The two modes propagating through the feedhorn and arriving at the aperture, in-phase and at the correct relative amplitudes, would create his required RF illumination. It is difficult to describe the satisfaction I received, seeing my very first technical development integrated with my teammates' components in a final production system.

Dave Lerner, George Vaupel and Ed Bruns belonged to a YMCA social group called Intercollegiate Alumni. For Labor Day weekend, 1959, George invited me to attend an IA trip to Lake Sebago, Harriman Park, NY and he asked me to provide transportation for another member, Claire Devoy, who lived near me. I complied and from that weekend on, Claire and I were inseparable. We married nearly four years later. Thank you, George.

One attitude that was prevalent at WL that unfortunately I never saw at any subsequent company was the unselfish cooperation amongst the technical staff. For example, after the collated copies of the weekly progress reports (the fruits of our Friday afternoon chore) were distributed, engineers reading about work being done in other projects were often eager to call to share their experiences or to make sincere suggestions to help others. Cross-fertilization and cooperation were the norm and, depending on the circumstances, everyone was willing to be either a teacher or a student. There never seemed to be concern that someone else's success would diminish the chance of your own. Instead, we gained satisfaction in helping each other.

Something at WL helped to create a fraternal-like bond among the staff. People who were mutually employed at other companies after leaving WL continued to communicate and cooperate in the special way they did at WL.

There was one particular piece of advice I remember learning from Mr. Wheeler that has helped me a number of times. It was simply that the first thing a person should do when trying to troubleshoot a malfunctioning device is to do a thorough visual inspection, and to avoid the initial urge to immediately perform a test with some sort of test equipment. A visual inspection always takes much less time than the simplest of tests, and often results in a clue as to the cause of the problem or, short of that, to the best test to perform.

When the second floor of the Great Neck lab was expanded to add more conference rooms and a library, two additional rest rooms were installed. Mr. Wheeler requested Pat Loth, the resident artist, to sketch something on the doors to indicate male and female. Pat did not want to just repeat the two stylized stick figures that were on the first-floor rooms. At my suggestion, she sketched a slide rule for the men and a typewriter for the women. Although that solution was appropriate for the 1960s, it certainly would be "politically incorrect" today. Some embarrassment also resulted when two male auditors who were visiting us did not recognize what a slide rule was, and confused the typewriter for an adding machine.

During my seven years at WL, in addition to working with waveguide components and antennas, I was also involved in a variety of developments in the UHF and lower frequency bands. These in part included:

- An antenna for an instrumented decelerometer that was designed to remotely investigate the load-bearing qualities of the moon's surface prior to the astronauts' landing
- A collinear pair of linear omnidirectional arrays for a tactical military communications system
- A dual-band antenna for a buoy-mounted submarine detection system.

This background gave me the knowledge and confidence that I brought to my subsequent positions after WL. For three years, I was the antenna-system designer for a number of UHF airborne military systems developed and built at Technical Research Group in Melville, NY, a subsidiary of Control Data Corp. Later, after a 9-year hiatus working for New York Telephone where I was involved with voice-frequency circuits and switching machines, I returned to radio frequency work. The telephone companies were in the initial stages of implementing the 800-MHz cellular telephone systems developed by Bell Laboratories. I joined a small group from various East Coast telephone companies to develop practical planning techniques to put the AT&T cellular telephone theories and equipment to use. Based on RF propagation estimates, we chose the detailed search areas for the initial cell sites in each of the service areas from Boston to Virginia. Here again, the systematic problem-solving techniques learned at WL were put to good use.

Later, I helped coordinate the New York Telephone microwave-link frequencies to minimize cross-interference. Finally, I joined the Wireless Communications Laboratory within NYNEX Science and Technology, where again I'm involved with the RF portion of current and new wireless communication systems.

Ron Rudish

My recollections of Wheeler Labs are misted by elapsed time, but some barnacle-encrusted events are still recognizable and a few stand out sharply. I will try to present my recollections accurately, although I claim poetic license for those that may be colored by my imagination.

It was a spring day in 1957, my junior year at Cooper Union. I had just completed an interview for a summer job. I had met with George Vaupel, an engineer from Wheeler Laboratories (WL), a place which did not exist in my limited knowledge prior to the interview. This meeting differed from other interviews. Whereas other companies' representatives probed my knowledge of the technology in *their* businesses, George probed my understanding of *my* endeavors. I learned later that this unusual interviewing technique was characteristic of the way all WLers were taught to interview because it provided a better measure of intelligence and potential.

Much to my amazement, soon after that interview I received an invitation to report to 122 Cutter Mill Road to work at the Labs for the summer. My recollections of that summer have faded into unspecific impressions, but one event is still crystal clear.

I was tuning Bob Wengenroth's multi-resonator filter manifold while it was mounted in a lengthy waveguide test setup that included a reflex klystron, wavemeter, attenuator and other equipment. The entire setup was perched precariously on waveguide support posts which elevated it nearly a foot above the workbench. Somehow I managed to topple it. Red-faced and quivering with expectation of dismissal, I recovered the pieces from the lab floor. Bob graciously assumed part of the blame for setting up without safeguards against clumsy hands, and so I finished the summer without retribution.

To my amazement considering the mishap, I was invited to join the staff at the newly opened Smithtown Laboratory when I graduated. Even more amazing, it was reportedly the best offer in the senior class. To this city-dweller, Smithtown seemed like an exciting outpost in the backwoods, and this newfangled antenna technology fascinated me. So I accepted.

That first year at Smithtown was a learning experience. I found that rookie engineers learned engineering by first learning how to be technicians. I observed that everyone called everyone else by their first name except for the boss, whom they called “Mr. Wheeler” (HAW); I learned that this was out of genuine respect for his complete command of engineering, as much as for his position in the organization. I also learned that at WL everything was engineered to perfection; even the date was specified by logical rather than common form. When the newspaper was dated July 14, 1958, WLers dated their correspondence 580714. The date of the WL annual dinner dance was always selected as the date on which daylight savings time declared a one-hour sleep dividend as it reverted to standard time.

I was eager to attend my first annual dinner dance until I learned that we were assigned to sit at the same table as Mr. Wheeler. I was totally intimidated. Perhaps it was my tender age of 20; I viewed HAW in awe as a scientist of towering stature, a stereotypical image that rendered him both formal and well above “ordinary talk.” But he was also the boss, a role that must require him to be cold and calculating, I thought. Would he use even this opportunity to evaluate his employees? How could we enjoy an evening if we had to watch every word and mannerism? Nevertheless, we attended and sat at that table. Much to our pleasant surprise, we learned that this leader and wizard was also a warm and friendly human being with a good sense of humor. Our trepidation was unfounded. He made it easy for us to relax as we informally chatted with him. We were quite happy that we had the opportunity to dispel the imagined caricature.

HAW left a special mark on my memory, but it was also his employees that made WL a very special place. I remember them as a free-spirited group that worked hard and played hard. They formed a tightly knit team with strong camaraderie. Yet each had distinguishing individual traits which remain embossed in my memory.

Dave Dettinger was still Chief Engineer when I joined WL. I had heard many stories about the practical jokes in which Dave was alternately the instigator or the recipient. I will defer to the first-hand witnesses to tell the stories about events that were before my time at WL. I remember Dave for his emphasis on perfection of written communication. Dave told me that the engineering report was WL’s principal product. This justified his formalization of the report writing process. Perfect results were guaranteed because authors used checklists to ensure that each preordained step had been completed before proceeding to the next, and submitted their reports to editorial reviews by both an assigned “critic” and a “reviewer” at critical report stages. I was not the only one to note Dave’s attention to grammatical detail. At a luncheon on the occasion of his departure for a position at MITRE, Dave was given a saltshaker full of punctuation symbols so that he could sprinkle them liberally on documents to suit his taste.

Ned Spencer was Chief Engineer during a significant part of my tenure at WL. I remember Ned as a gifted leader with an unusually effective style. If Ned wanted me to do something, he would rarely give me a direct order to do it. Instead, he skillfully managed to make me think it was my idea and that it was something that I had wanted to do for the longest time.

Then there was Fred Van Davelaar, WL’s mechanical engineer, plant engineer and principal raconteur. I was fascinated by his World War II episodes in which he starred as a James Bond protégé. I also realized that Fred was a member of the practical joke team when other team members used the large davit that Fred designed to transport Dave’s small European car to the roof of the Smithtown laboratory, perching it on top of an antenna rotator mount.

I recall Murray Novick as another grand storyteller and perhaps the principal comedian of WL. Typical of his impromptu one-liners was the toast that he offered at a luncheon for a secretary named Mary, who was leaving WL to give birth. He paraphrased the nursery rhyme with a wry grin, “Mary, Mary, quite contrary...or was she?”

Many stamped my memory as much for their extra-curricular, as for their technical, specialties. Dave Lerner, my supervisor during my early years at WL, was expert at polarizer, feed and lens design but at lunchtime he became the quintessential bridge player. When four weren’t available you would find Dave displaying his skill at ping-pong. At times, Warren Elliott was Mr. Airborne IFF, but at lunchtime, he was Mr. Fours-No-Trump. At other times, he would leave the world of radome design to play softball with Bill Meserole, George Knittel, Bob Hanratty, et al. I remember Bill for his work on the Zeus transmit antenna, George for his work on arrays, and Bob for his work on missile antennas and power breakdown. I also remember Bob for his tennis matches with Harry Redlein, whom I remember as the “father of monopulse.” I remember that Al Lopez, one of the first at WL to apply the geometrical theory of diffraction to antenna design, was one of WL’s most serious cyclists. Joel Becker and Jean-Claude Sureau were also diffraction buffs when they weren’t buffing their sports cars. When Pete Hannan wasn’t configuring Cassegrain antennas he set sails or hiked trails.

The emphasis on engineering excellence at WL was exceeded only by the emphasis on the education of engineers. I took advantage of WL’s liberal tuition reimbursement policy to attend graduate classes at “Poly.” I thought that the frequent staff seminars were a great fringe benefit until I was invited to present one of them. I lacked confidence in my ability to tell my colleagues, some of the country’s leading experts in antenna technology, information that they didn’t already know.

My career as an engineer at WL started with the design of the feed for the Zeus acquisition radar under the direction of Dave Lerner. Later I assisted in the development of an airborne “source” antenna to measure the patterns and polarization of the Zeus MAR array antenna. These projects gave me the opportunity to meet and work with some of the best of Bell Labs’ microwave and antenna engineers, both at Whippany, NJ and at White Sands, NM. This group included Phil Smith, the man who published that infamous reflection chart on which impedance loci rotated in the “wrong” direction (opposite to the Wheeler Chart, of course). Subsequently, I worked on numerous projects involving miniature antennas, multi-frequency band antennas, retro-directive antennas, precision-tracking antennas and phased arrays. Among the designs carried out under my supervision was the ground based interrogator antenna system used by the U.S. Air Force for Identification, Friend-or-Foe (IFF) and Air Traffic Control (ATC). The WL chapter of my career closed at the end of 1970, when WL ceased to exist as a separate entity. At that time, my position was Engineering Manager for company operations in IFF/ATC, communications, satellite navigation and laser applications.

During the WL part of my career, I learned many of the principles of the technology, principles that were discovered first or expressed clearly first by Wheeler, such as force feed, paired echoes, and the volume versus efficiency limitations of small antennas.

Besides learning technology at WL, I learned how to be an effective engineer. I learned to take notes in a notebook, which is good engineering practice, but which isn't industry practice. I learned how to write. Most importantly, I learned how to think about a problem in a way in which the problem is reduced to its essentials; this allows me to concentrate on the critical issues, bypassing the chaff. Also I learned to look for fundamental limitations so that I would not waste effort at trying to do the impossible. This is the most important lesson that I have retained from my education at WL.

I am convinced that these lessons have advanced my post-WL career dramatically. I am now a Principal Staff Engineer at AIL Systems, Inc. where I have worked exclusively since leaving WL. In this role, I provide technical leadership for the Antenna Technology department, and consultation to AIL's RF and Receivers department, their Electro-Optics department and to several major program offices. I have authored or co-authored 18 U.S. patents and six papers, including one which received a Best of Year award from IEEE. I received the IEEE's Hirsch award "for innovative contributions to microwave antennas and receivers and particularly the invention of the FASCAN System." Many thanks for an excellent education at the "Wheeler School of Engineering."

Alfred R. Lopez

New York City and 1930 were the place and year of my birth. The schools I attended as a youth were St. Rose of Lime Parochial School and Brooklyn Technical High School. After high school I spent a few years learning and practicing automotive mechanics. During the Korean War (1951-1953) I enlisted in the U.S. Air Force and spent two years in the Philippine Islands as a member of the 600th Air Force Band. After discharge from the service the first order of business was my marriage to my lovely wife Mary. I then enrolled in Manhattan College and, after graduating in 1958 with a BEE, I joined Wheeler Laboratories. In 1963, I received a MSEE from Polytechnic University.

I first heard of Wheeler Laboratories from Bob Borman, a fellow classmate at Manhattan College, who had worked at Wheeler Laboratories in the summer of 1957. I recall my interview at 122 Cutter Mill Road, Great Neck, NY. Dave Dettinger, who was Chief Engineer at the time, greeted me and briefed me on the activities of the laboratories. He then introduced me to Herb Rickert, who took me off to a room on the second floor and offered me the opportunity to discuss a technical topic of my choice. I recall that I chose to talk about some elementary mathematical relationship. Following my discussion with Herb, Jerry Hanfling gave me a tour of the facility. I was very much impressed with the character of the laboratories; it seemed so professional and well organized. I recall saying to myself as I drove away, "They'll never make me an offer."

When I started at Wheeler Laboratories, Henry Bachman was my supervisor. My first job was J-377; I recall Mr. Wheeler commenting on the significance of the number 377. I had never known that free space had impedance. We were developing for AIL a sum and difference turnstile antenna system for a satellite application. My specific task was to design and build a breadboard 3-dB backward-wave directional coupler. The work environment was ideal, as Henry and I shared a laboratory/office with Frank Williams and Bob Kaplan.

In 1959 I transferred to the new antenna range facility in Smithtown, N.Y. At that time Smithtown was on the crest of a building wave that was sweeping Long Island. My wife and I bought a home in Commack, which was within reasonable bicycling distance of both Smithtown and Great Neck. Ned Spencer was in charge of the antenna facility. Being somewhat removed from Great Neck, we relied on him for guidance and direction. He had a talent for stimulating and motivating the Smithtown staff.

My first project at the Smithtown Lab was designing a feedhorn for the Nike-Zeus discrimination radar antenna, working under the supervision of Harry Redlien. This work, along with work done on the Sprint missile antenna, was done for Bell Laboratories.

In 1963 I developed a basic new technique for obtaining cancellation of ground clutter in airborne radar antennas. Displacement of the antenna phase center along the antenna aperture to achieve clutter cancellation was a prior technology that was effective for side-looking radars. We developed a method for phase center displacement along the boresight of the antenna (see figure 4-9). This provided clutter cancellation capability for airborne radars in the forward and rear looking directions. This work is the subject matter of section 16.7, “Platform-Motion Compensation, Forward Directions” in the second edition of M. Skolnik’s “Radar Handbook.”

During this same period of time I was completing my Master’s thesis at Polytechnic University. My advisor, Professor Leopold B. Felsen, gave me insight into the geometrical theory of diffraction. This theory was, for the most part, relegated to academia. After receiving my Master’s degree I decided to write a paper that reduced some of the geometrical diffraction concepts to a simple form. I was motivated to do so by my training at Wheeler Laboratories. In 1966 I published the paper “The Geometrical Theory of Diffraction Applied to Antenna Pattern and Impedance Calculations” in the IEEE Transaction on Antennas and Propagation. This paper included a diagram which showed the far-field teardrop radiation patterns for diffraction components (see figure 4-10).

During the mid-1960s The Wheeler Laboratories group was heavily involved with the development of phased array theory and practice. I was part of a team that was supporting Raytheon in their phased array activities. During this time I developed a simple form of monopulse feed network for an array antenna which allowed complete independence of the sum and difference excitations, with ideally zero dissipative loss (see figure 4-11, from Chapter 4 of D. K. Barton’s book “Modern Radar System Analysis” Artech House, 1988).

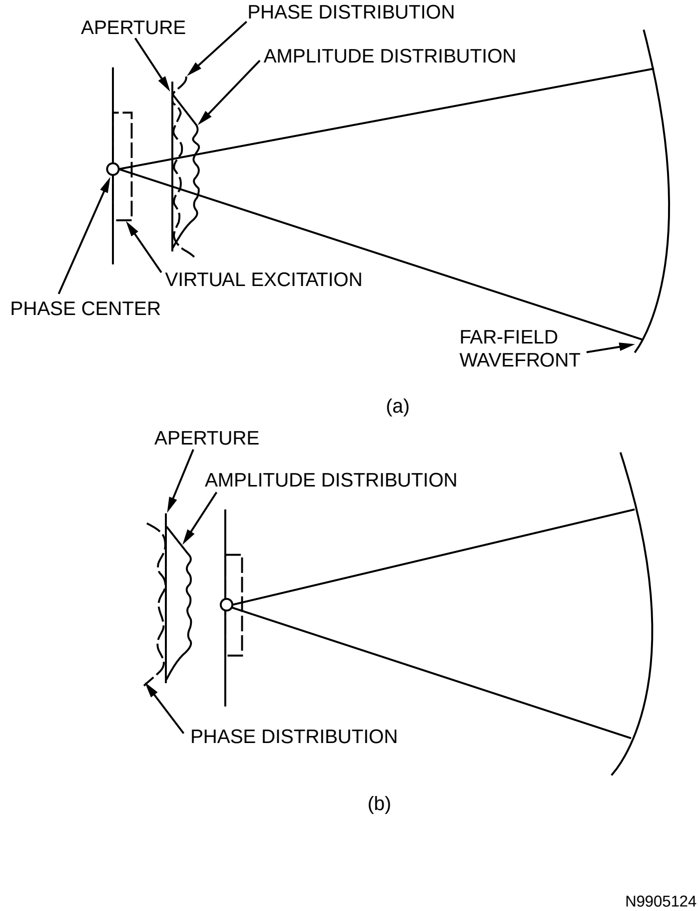

Figure 4-9. CPCT Concept Showing Displacement of the Phase Center (a) Behind the Physical Aperture and (b) Ahead of the Physical Aperture

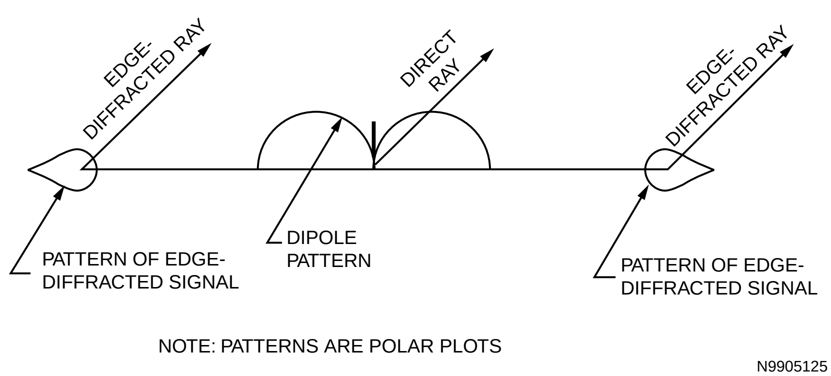

Figure 4-10. Patterns and Relative Orientation and Location of three Sources Contributing to the Total Field

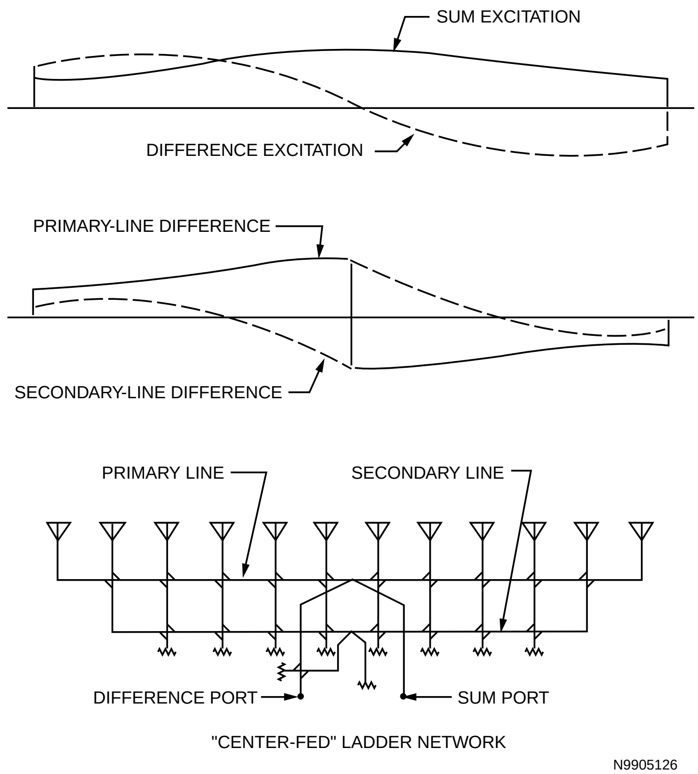

Figure 4-11. The Lopez Feed: A Dual-Ladder Network for Separate Optimization of Σ and Δ Excitation of a Linear Array

At the end of 1969 our group got involved with the development of the Microwave Landing System (MLS). My involvement with this program spanned my entire career from that point in time. Dick Frazita and I had a chemistry that produced many ideas, and a driving intensity that would not allow us to give up on MLS. Our efforts resulted in the FAA awarding the first production MLS contract to Hazeltine in January of 1984.

In retrospect, Wheeler Laboratories provided a pleasant environment where learning and discovery were continuous, never-ending processes. The only limitations were those that were imposed by the boundaries of the individual's own capabilities and resourcefulness.

(Editor's Note: On June 8, 1988 Alfred R. Lopez was presented with the H. A. Wheeler Application Prize Paper Award for his paper "Application of Wedge Diffraction Theory to Estimating Power Density at Airport Humped Runways." Reproduced below is an excerpt from his acceptance remarks, which provides insight into the kind of relationship that existed between Mr. Wheeler and the engineers with whom he worked.)

> I am honored and thrilled to receive this award. Harold A. Wheeler has been a colleague and a good friend of mine for 30 years. If I may, I would like to share with you a thought regarding Harold Wheeler.

Throughout the years that I have known him I've tried to understand what makes him so very special. There is no question that Mr. Wheeler is a scientist; he has great facility with the principles and application of the body of truths related to physics and mathematics. I believe the unique characteristic that sets him apart from most other scientists is that he is truly an artistic scientist. He is gifted with the talent for reducing complex scientific principles to simple forms that are aesthetically pleasing and universally helpful to theoreticians and practitioners. This, along with his compassion for his fellow man, makes him a very special person.

I thank you, Mr. Wheeler, for your teachings and for your help.

Peter Lubell

I came upon the scene at Wheeler Labs in 1958, fresh from exciting years spent at The Cooper Union, which had followed an equally rich and varied technical education at Brooklyn Technical High School.

During each of the two previous summers, I had been privileged to be employed in a technical capacity, most recently at Polarad Electronics. Prior to that, during my sophomore break I had worked in the Engineering Department of Consolidated Edison, a power company.

These two experiences had focused my attention on joining Wheeler, rather than on employment offers from much larger companies such as Philco and Sperry. The distinctly different environments provided me with an opportunity to choose between working in a small, tightly knit group, or in a larger, more highly structured situation.

This choice was made, with a reasonable degree of confidence, after I had interviewed with all the parties involved. I chose not to return to Polarad, since the opening that they offered was as part of a larger team, working in an entirely different area of electronics, rather than in the group I had worked for over the summer.

The Wheeler offer, which involved working in a small group on projects addressing the then "cutting-edge" of communications technology—microwave transmission—was very exciting.

At Wheeler, we worked in small groups of five or six people and we were never far removed from technical reality. This "reality check" was accomplished by our making our own measurements and by our design of jigs and fixtures to support our own experiments.

A close working partnership was encouraged with both the master shop mechanics who fabricated the devices, and with the professional draftsmen who helped create our physical designs. These attitudes were highly important in the microwave technology of that period since much of the circuitry was realized as mechanical structures, as opposed to the solid-state realization that is common today.

Although I was only at Wheeler for about a year, my experiences formed a basic foundation for my engineering career in the following thirty-odd years. The approach of not jumping to conclusions and maintaining a critical attitude toward unusually positive results has stood me in good stead for many years, in a variety of situations.

Another characteristic of the Wheeler experience which I value highly was the ease of access to highly experienced "mentors," even to Mr. Wheeler himself. Also of great value was the use of the excellent on-premise technical library. Throughout my education and even in everyday life, when faced with a problem I have always said, "Let's read the literature and see what others have done and said."

To me, this "literature search" is the very essence of "engineering" as opposed to "pure science." My personal view of engineering is that it is a concrete application of technology, built brick-by-brick, on a firm foundation, rather than the more abstract, breakthrough approach of "pure science."

For the past 20 years of my career I have focused on activities in the areas of satellite transmission and cable television. Within these areas my technical responsibilities have been to produce successful system applications, often using technology developed by others.

Even following this aspect of engineering, I still find that the critical process, first learned at Wheeler, is invaluable to me in working out the bugs of a system. It is also extremely helpful in the understanding of the problems faced by the technical people who have to live with, and operate, a system.

Lastly, in my recollections of my Wheeler experience, I value the many friendships which I made in those days, and which have endured up to the present time, over 30 years later. I am still pleased to list among my friends Lou Appleman, who "sold" me my Wheeler tool kit; Joel Becker, who provided many rides to and from the office (and in doing so, was a great motivator to my getting my own car); Paul Meier, with whom I worked again when we both employed by AIL; Bob Puttre, my link to the telephone company over many years; and Ron Rudish, who also worked again with me at AIL.

I continue to be indebted to Dave Dettinger, Frank Williams, and Henry Bachman for their enlightened and stimulating supervision and their encouragement of my ongoing IEEE activities. Add to these, my friendship with the late Henry Jasik through involvement in both the technical and professional (IEEE) areas. And I'd like to acknowledge Harold Wheeler's contribution as well, in all of these aspects of my professional life.

George Herman Knittel

I was born into this world on 23 February 1934 and had the benefit of a strong, responsible father and a gentle, helpful mother. My father was an electrician, and that was the dominant influence in my choosing electrical engineering as a career. I graduated from the Polytechnic Institute of Brooklyn in 1955 with a BEE degree and immediately entered the U.S. Army as a second lieutenant through the ROTC program.

In those days the Army didn't pay much attention to one's technical qualifications, so I was assigned as a combat engineer platoon leader, stationed in Germany. Although this did little or nothing to develop my electrical engineering expertise, it did help me to grow up—and I got to see much of the European world. The German mark was valued at 4.2 per dollar at that time, a bargain by today's standard. All in all, it was a good experience for a young man fresh out of college.

Having decided in 1957 that two years of growing up in the Army was sufficient, I found myself rusty in my chosen profession and unwilling to ask an employer to hire me in that condition. The obvious thing to do was to go back to school, which I did, graduating with an MEE degree from Brooklyn Polytech in 1958.

Somehow I came to apply for employment at Wheeler Laboratories and was interviewed about the spring of 1958. The interview process was careful, thorough, and efficient for both company and applicant. I remember that Henry Bachman was my technical interviewer and I even remember some of the probing questions he asked. He made me think, and reason my way to answers. I slipped through the interview process (probably the only interviewee ever to do that), was made an offer, and accepted it. In retrospect, I perceive three reasons for my accepting the job offer:

- Impression of the company and its people. One got the impression of a well-run organization doing interesting, state-of-the-art microwave work. The people were competent, dedicated, and friendly. There was time to learn, and to do a job well. The small size made everyone accessible, and everyone important.

- The mystery of electromagnetics. In both undergraduate and graduate school, I found electromagnetics to be a profound mystery. (I still do today, but in a different way.) Wheeler Laboratories was actually developing microwave antennas and components, and I saw this as the opportunity to finally understand what it was all about. In addition, they were willing to pay me to do so. Wow!

- I needed a job. I had only two offers of employment, the other from a large manufacturing company. The starting salary of this one was 10% higher, and the decision was easy.

While I was being introduced to Wheeler Laboratories, my heavenly Father also introduced me to the beautiful Mary O'Shea, whom I wooed and wed. Upon leaving the Army, I had decided that it was time to get married and so began interviewing candidates at various dances and social functions in Nassau and Suffolk counties. After most candidates failed to pass the first filter, and the few that did failed the second filter, I was starting to become discouraged. It was then that I was led to her, at the Irish-American Center in Mineola. Our marriage on 5 September 1959 coincided with my move to the Smithtown laboratory, which made possible the purchase of a 3-bedroom house in Smithtown for $14,200—quite feasible on a salary of about $8,000.

It has been said that there was no better place for a young engineer to learn and grow than at Wheeler Laboratories. Indeed! Learn, I did. And grow, I did. For eight fascinating and interesting years, I gave all that I could give, and received all that I was capable of receiving.

My first supervisor, Herb Rickert, taught me well and whetted my appetite for microwave antennas. We were developing the SPG-55A dual-frequency dish antenna for Sperry Gyroscope company. My job was to design and test the various dielectric surfaces. I spent a lot of time making designs, and reviewing their calculated performance with Herb, Pete Hannan, and Mr. Wheeler. Later, I spent many a happy day in the basement of the Great Neck laboratory, building a test setup, qualifying it, and using it to test panels of the designs.

The next supervisor, George Vaupel, continued my training. He placed emphasis on writing excellent reports. One time when we were reviewing a draft of a report I had written, he indicated that I had misused a particular word. I said that I would take care of it later, but he would have none of that. He pulled out a dictionary, looked up the word, and made me understand there and then what it meant and why it was not the best word for my intended communication.

Later on, I got to work on VHF communications antennas with Ned Spencer, and on phased array antennas with Pete Hannan and Mr. Wheeler. The evolution of technology in the 1960s to where large phased arrays were feasible led to a substantial theoretical and experimental research effort in the antenna community. Wheeler Laboratories was right in the midst of this work with Pete's "element gain paradox" paper and Mr. Wheeler's invention of the phased array waveguide simulator. I managed to publish my first paper in the AP Transactions on the number of planar-array faces needed for hemispheric scan coverage. These were exciting times.

Periodic reviews of each project with Mr. Wheeler were most valuable. He had remarkable insight, always able to dispense with trivia, to ask the most important questions, and to give the most significant advice. Perhaps his greatest gift was to be able to take a complex system, identify its few key components, and develop a simple model useful for understanding the system, designing it, and estimating its performance. At times, his reasoning was so far above mine that I felt the need of an interpreter. Fortunately, Pete and Ned often filled this role for me and others, and the work received maximum benefit from Mr. Wheeler's comments.

One of my most treasured lessons at Wheeler Laboratories came during the time I was supervising two summer students. We were at a review of the project with Mr. Wheeler, and one of the students had an idea about how to proceed: "Why don't we just..." he began. Having been at Wheeler Laboratories for a few years, I knew exactly why we don't just..., and I proceeded to tell him with gusto. In two minutes I demolished his idea and made him feel stupid. As I finished my discourse, I glanced at Mr. Wheeler. He was looking at me with a hard-to-describe look, but he said nothing. He didn't have to; the communication was very clear. "George, I'm older and wiser than you, and I don't do that to your ideas. Why do you do it to others'?" The point went straight to my heart, and I resolved from then on to work at respecting others' ideas and humbling myself. It was the beginning of a lifelong effort, which is still underway today.

One of the most amusing incidents occurred with the same two students. We had an SPG-55A antenna on the test range and were measuring its patterns. It was late afternoon, and there was trouble with leakage from some waveguide joints interfering with sensitive measurements of null depths. I instructed the students to go out to the antenna and metal tape certain joints. Next morning, we turned on the test setup and got no signal. After spending the better part of the morning diagnosing the problem, we discovered that what they had done was to take the waveguide apart, place metal tape across the waveguide opening, and put it back together again. Electromagnetics, it seemed, was still a great mystery to undergraduates.

I thoroughly enjoyed my years at WL and participating in the many technical and social activities. Especially memorable were the softball games to which all the players looked forward. We didn't win much, but we had lots of spirit and lots of good times.

About 1966, I began to have the feeling that "there was something more that I could be." I went to Mr. Wheeler and told him that I wanted to go back to school for my doctorate. He understood, and supported my decision.

The period 1966-1968 was most challenging and interesting for Mary and me. We had three small children, ages 5, 6, and 7. I gave up my job and returned to Polytech full time for a doctorate in Electrophysics. Financial support came from the GI bill, a fellowship from the school, generous parents, and the grace of God. The training received and the maturity developed at WL enabled me to finish the doctoral requirements in 1968, after which I joined the faculty as an assistant professor.

Once I had my doctorate, I decided that it was time to call Mr. Wheeler "Harold." Dave Dettinger would regard that as heresy, but I felt differently and I made myself do it. The result was predictable. Harold graciously accepted my daring new approach, and we continued in a friendly, supportive professional relationship.

Practical experience from WL, together with theoretical expertise acquired from other giants in the field such as Art Oliner and Alex Hessel, put me into an excellent position to contribute to the profession. During my tenure at Polytech (1968-1972), I was party to many papers, two books, and several consulting arrangements. One of my great joys was to be able to help students understand the mystery of electromagnetics. I served as associate editor for array antennas for the AP Transactions. The government of Israel brought me to the Technion in Haifa to lecture for two weeks on phased array antennas. I was able to take Mary and our (by then) four children with me.

In 1972, I joined MIT Lincoln Laboratory, where I have been happily employed for the past 21 years. The superb preparation I received at WL served me well during these years, being a major factor in my election, in 1987, to the position of president of the IEEE Antennas and Propagation Society.

In retrospect, I could not have done better than to begin my professional career at Wheeler Laboratories. The training in problem solving, teamwork, the excellence in speaking and writing, and other learned skills were capabilities beyond price in my professional life. Wheeler Laboratories' reputation and its high regard by so many of my colleagues and associates, even into the 1990s, continues to amaze and please me, and to make me grateful.

Vince Mazzola

I was born in Brooklyn, New York on 380517, and attended The Cooper Union School of Engineering, where I received the degree of Bachelor of Electrical Engineering in 1960. During my employment at Wheeler Labs, I also received the degree of Master of Electrical Engineering in 1964 from the Polytechnic Institute of Brooklyn, now known as Polytechnic University. In 1974, I received a Master of Science degree in Accounting from Long Island University and, in 1977, became a CPA.

I first became aware of Wheeler Labs (WL) while at Cooper Union. The company had an extraordinary reputation among the staff and students and I had become increasingly fascinated by the field of microwaves and radiation. WL had already employed Robert Puttre and Donald Yenoli, my fraternity brothers at Cooper Union; Bob had accepted full-time employment and Don had worked at WL as a summer intern. As they related their wonderfully pleasant experiences to me, I was impressed by the professional approach taken by the company's management toward its staff. The competition was keen and therefore I considered the prospect of an offer of employment to be very remote.

Much to my surprise, however, I received an invitation to visit WL, where I was interviewed by Dave Dettinger, Robert Wengenroth and Robert Kaplan. Dave Dettinger gave me an overview of WL. I concluded that this was a place where my contributions would be recognized and work could really be "fun." Robert Wengenroth was my technical interviewer, and I chose to discuss the negative resistance amplifier. His questions were very good, and I struggled to explain the operation of this device. However, I enjoyed our conversation and the approach to the problem that we developed during the interview. Robert Kaplan gave me the WL tour and I must say that I used this tour to try to impress upon him my interest in microwaves. The interviewing process left a strong impression on me; I knew that if WL offered employment, I would accept without reservation.

I began my employment 600615 under the tutelage of Joel Becker and Ned Spencer, and was assigned to the Nike-Zeus pillbox antenna project. Joel explained to me that I would be designing a two-dimensional zero-dB coupler. The concept, which originated with Mr. Wheeler, was fascinating to me. Eventually Joel Becker and I co-authored a paper on the subject, and I applied the idea to my Master's thesis at Polytechnic Institute of Brooklyn as well. The Nike-Zeus project also gave me the opportunity to work with Mr. Wheeler.

All of those early experiences left an impression on me. Until I began my own practice as a CPA, WL was the only place where I was able to conduct myself as a truly professional person. WL provided professional training and knowledge that was not available in any other place. That knowledge is still with me and I use it every day in the practice of my current profession. The opportunity for me, as a novice, to work with the founder and head of such a company and to make a contribution has greatly influenced me. In both careers, I have enjoyed working with young people, respecting their opinions and encouraging them to make a contribution to the project at hand.

The support staffs at WL, including office, shop, maintenance and others were truly outstanding. The WL family accomplished work on a true team basis. There have been several reunions of the WL family since the first one was held in 1977. The reunions have always been well attended even though great distances now separate some of us.

Although now a CPA and no longer a practicing engineer, my experiences at WL continue to influence me in my conduct and approach in my current profession. This includes communicating my ideas to others both orally and in writing, and in my use of the WL analytical approach to assist clients in the operation of their businesses. I try to motivate the clients' personnel to think objectively and consider them to be equal participants. As such, I respect their opinions and listen to their suggestions. I encourage employers to improve their working relationships with their staff using the WL ideas.

Perhaps in the long term, the most valuable contribution of WL will be noted not in technical, but in humanistic terms.

Richard F. Frazita

I was born on August 1, 1938 in Brooklyn, New York. I went to St. Michael's grammar school for a few terms. Our family moved around a bit, as was pretty common then, though I clearly remember Richmond Hill in Queens. From there we moved to the Ridgewood section in Brooklyn, where I was schooled at St. Brigidt's. After graduating from St. Brigidt's, and thanks to the good Brothers and the efforts of my father, I was given a scholarship to Bishop Loughlin Memorial High School in downtown Brooklyn. Our educators were the Christian Brothers and they schooled us for academic excellence and higher education. I did well in this environment and the Brothers selected me to receive a partial scholarship to Manhattan College in Riverdale near Van Cortland Park in the Bronx. Again, I was taught by the Christian Brothers. I graduated in 1960 with a BSEE degree and what I feel was a solid grounding in fundamentals. In 1965, I earned an MSEE degree from the Farmingdale branch of Brooklyn Poly. Professor Griemsman was my Thesis advisor.

My first contact with Wheeler Labs was an interview by Al Lopez, who was also a Manhattan man and who had been sent there to recruit his Alma Mater. My friendship with Al has lasted through all the years since and I have great respect for him. At that interview, Al made a real impression on me as he enthusiastically introduced the notion of microwaves, which sounded mysterious and profound; in addition, I discovered that we shared a common liking for mathematics and modeling complex behavior. He invited me to the Labs for a follow-up interview, at which I remember meeting with George Vaupel and Joel Becker. Somehow I was given an offer (you guys really blew it) which I weighed against offers from Norden's radar division and from Western Electric, which had more of a manufacturing flavor to it. Western wanted to me to develop some sophisticated special test equipment for a production run that was cranking up in Allentown, Pennsylvania. As a city boy, Allentown just did not impress me; I was impressed, however, by the people I met at the Labs that day in Great Neck. Also, the demonstration I had seen of an open waveguide intrigued me to no end. I liked the Wheeler offer because microwaves sounded like a new, cutting-edge challenge.

I married Eileen just after graduation in 1960 and we moved to Great Neck for about a year. My aunt owned a home in Great Neck near Allenwood Park. She put us up there until we had our own place built in Deer Park a year later, just in time for our first son Richard Edward, and then for our second son Stephen. We were close to the Smithtown antenna range where I was subsequently transferred.

My first microwave project at Great Neck was scaling the design of a balanced mixer and some hybrid junctions from X-band to Ku-band for the Nike radar extension. One part of the design that didn't scale was the waveguide-to-diode transition. To do this, I measured the reflections from a "bag" of diodes and plotted a scatter chart to find the design center. This was a good introduction to the art and science of microwaves. Lou Appleman and Saul Lieberman were my first supervisors.

Great Neck was a fun place and all the people were pleasant, intelligent and just a little different, well, maybe even a little strange. I think this was one of the distinguishing characteristics of Wheeler Labs, that the people were all a bit out of the ordinary; they were intelligent, innovative, adventuresome and outspoken on a variety of subjects—potential leaders. To me, coming from a conservative, slightly sheltered Catholic environment, the Labs seemed a little far-out, like the Rive Gauche. A quality I think was endemic was that the Lab management was never afraid to take a technical risk on a promising idea. Looking back, the track history of the Wheeler alumni speaks for itself.

My first antenna project was the development of the variable beamwidth antenna for the discrimination radar, under Jerry Hanfling. This project was a real eye-opener for me, having all the appeal a fledgling engineer could ever want—theoretical challenge and practical, big structure/tight tolerance physical implementation with such good stuff as polarization twist reflectors, Cassegrain optics with a movable subdish for beam broadening, and off-axis tracking monopulse with Pat's multimode feed. Jerry's team built the scale model DR antenna, and this was my introduction to antenna measurements including a short range. Jerry and I went to White Sands Missile Range to review some difficulties they were having with the full-scale antenna and to check on a metal plate lens design of ours for boresighting the antenna on a pole a short distance away. The trip offered great exposure for me both technically, and to life south of the border in Juarez. In fact, it was my first airplane trip. Jerry was a darn good supervisor and I was sorry to see him go to Raytheon; he brought a lot of expertise to them.

I remember looking for a table of complex Fourier transforms for a truncated odd and even form of the probability function to represent the DR antenna sum and difference illuminations. We were trying to baseline the edge effects on the pattern shapes and the off-axis tracking linearity as a function of sub-dish motion (10:1 beamwidth change). Harry Redlien computed some defocused patterns but the computational power at that time was minimal so I found a Russian text that tabulated the transform relationships we were looking for. But when Mr. Wheeler developed his theory of defocused apertures using the symmetric and antisymmetric forms of the Gaussian transform of infinite extent, he demonstrated his approach to modeling problems. This was a classic work and a prime example of his approach to problem solving, Wheeler style, which emphasized modeling the fundamental behavior of a system, using elegantly simple mathematical and physical relationships. The trick is, you need to have an intuitive sense and a rich imagination in order to define the right model. It is an art that Wheeler perfected to a high form, and which was the cornerstone of the Labs, in my opinion.

Another example of modeling with which I had personal experience was the grating lobe series. While Bell Labs was publishing papers with pages and pages of integral expressions, Wheeler and his team presented a more insightful and practical view of array behavior. I was fortunate to work on the MSR phased array and made a small contribution to his original concept by adding the modeling of surface wave behavior using the grating lobe series as a starting point. I also worked with Jerry on the array simulation using multimodes to measure polarization characteristics and impedance in other than the normal E and H planes. We didn't seem to get credit for that effort, but years later Jerry and I jointly published this work.

The Labs decided to develop an expertise in phase shifting devices for our array work. I recall working on the design of wide-band, wide temperature range, latching ferrite phase shifters under the direction of Dr. Ernie Wantuch of Fairleigh Dickinson University and Pat Loth. Dick Giannini worked on diode phase shifters. By this time I was beginning to catch on to the modeling approach, and so I had an insight into the switching behavior of the ferrite in a waveguide. I envisioned an expanding shell boundary separating equal but oppositely magnetized material, with the boundary determined by the flux applied to the drive wire and the previous state of the flux reversal boundary. This enabled a very simple and accurate model for determining microwave phase shift versus drive and temperature. The load impedance of the ferrite core was also determined for the electronic driver from the model.

In my opinion, this approach to problem recognition and modeling set the Labs apart from the academic circles, and was perhaps the key enabler for the technical contributions made by the Labs. Certainly the approach was distinctive. If I learned one thing, it is that a solution isn't possible until you can define the real problem, and do it on a single sheet with pictures or a diagram. The method should be taught in school, and it need not be limited to engineering.

My Master's thesis was influenced by Wheeler's work on conformal mapping to describe the transmission line behavior of metal strips in the presence of mixed, inhomogeneous dielectric. Wheeler treated the case of parallel lines with a sheet between the conductors. My case was for parallel lines on the same side of the dielectric sheet (coplanar). Mr. Wheeler was my mentor and gave me the direction to work the problems through. The result from modeling the wave behavior this way was a simple closed cell with metal strips on top and bottom, open circuit boundaries on the sides and the space partially filled with parallel and series components of dielectric. The effect on phase velocity and impedance was estimated by bounding the solution of this simple geometry between a low-K and a high-K solution with rules for interpolating in between. High-K ignored the series air capacitor while low-K took the series capacitor into account by an area rule. The approach worked well experimentally and I found out a few years later that an engineer at Bell Labs who was developing microwave semiconductors acknowledged the PIB thesis report in an article.

As we all recall, the Labs was heavily involved in developing the most unusual phased array antennas that encoded space with frequency by cyclic phase shifting. These were the Doppler antennas for the Microwave Landing System (MLS). This subject is a whole book in itself and, as Al Lopez always says, it should be written sometime in the future—maybe. The early team of Wheeler, Hannan, Redlien, Lopez, Zeltser and I had a ball in the conceptual phase. Ideas were rich and freely flowing; I can't remember a more creative period at the Labs. The implementation of Doppler beamport antennas and the modal circular array were contributions that deserved international recognition, but because the United States finally selected a different system technique, they were soon forgotten. The development team led by Ron Schineller, Dick Gianinni and Dick Flam was outstanding; to this day I have never seen so competent and professional a team. I certainly feel good about the role we played in supporting our nation's defense back in the 60s and 70s.

I can honestly say I never met anyone from Wheeler I didn't like. Ned Spencer once gave me a piece of advice in a performance appraisal that I'll always remember: stick your neck out because that's what it's for. The nicest gentleman I ever met was at the Labs—Don Hastings. It was a real pleasure to be around him, and I hope he is well and happy in his mission. I have good memories of the Wheeler Class of '60, my entry year, which I believe included the largest group of recruits in any one year. Above all, the meetings with Mr. Wheeler over the years will always be a lasting memory and a priceless experience.

Personally, I think I've grown both professionally and individually because of the opportunities afforded me over my thirty years at Wheeler/Hazeltine. I made a few inventions and for a short spell, I was head of the Labs after George Vaupel's watch, but I was still infatuated with MLS so I felt compelled to move on to the Air Traffic Control Product Line. Today, I'm still involved in

MLS through my consulting practice, but now, the technology is forcing a newer solution to landing aircraft based on satellites rather than ground-based transmitters.

I left the company in 1990 and, as alluded to above, started my own consulting office. I have a lot to be thankful for and wouldn't change a thing, except I regret that I didn't publish nearly enough. Though in retrospect I had lots of good subjects, much of my energy and spare time over the years was absorbed instead by my involvement, with my wife, in the youth soccer movement.

E. Ronald Schineller

I was born on February 8, 1938 in Brooklyn N.Y. I attended Holy Child Jesus elementary school in Richmond Hill, N.Y. and Bishop Loughlin Memorial High School in Brooklyn. In 1960, I graduated from Manhattan College, Riverdale, N.Y. with the degree of Bachelor of Electrical Engineering. After starting my employment at Wheeler Laboratories in 1960, I attended the Polytechnic Institute of Brooklyn part time, and was awarded the degree of Master of Science in Electrical Engineering in 1964.

I was interviewed in the spring of 1960 for employment at WL at the Great Neck Laboratory. It seems hard to believe, but I can still remember the interview rather vividly. There was a welcome and introduction by Dave Dettinger, and then the famous (or infamous) technical interview, given in my case by Bob Hanratty. I recall going in with trepidation, and trying to explain that I knew nothing about microwaves! I really didn't; in fact I knew almost nothing about electromagnetic waves, since my instructor at Manhattan College had decided to teach us tensor analysis, rather than Maxwell's equations. Fortunately for me, WL was looking for people with potential, rather than with prior training in microwaves. So Bob Hanratty and I discussed transient behavior of circuits, and a filter project that I was doing for Eta Kappa Nu. Apparently I did all right, since I subsequently received an offer of employment.

After some soul searching (I still wasn't sure I wanted to work with microwaves), I accepted the offer and started work at WL in September of 1960. I had decided to take my last summer off, and work on my uncle's farm in the Catskills, as I had done in previous years. I remember my surprise when I came to work the day after Labor Day and was told that I would be paid for the holiday even though it had occurred before I had actually started work! But that was the kind of place that WL was.

My first supervisor was Henry Bachman, and my first assignment was to work on the missile beacon antennas for the Nike-Zeus missile. The basic requirement was to provide circular polarization with an isotropic radiation pattern, that is, 0-dbI gain over all space. Without any knowledge of antennas, it didn't seem very difficult, but how quickly I learned. I worked very closely with Bob Kaplan, from whom I learned a great deal; Bob was a natural teacher, and spent many hours teaching me about polarization charts, Smith Charts, and of course Wheeler Charts.

Bob was later to become my supervisor, when we embarked on a brand new project at WL—lasers. In another example of Mr. Wheeler's great foresight, he realized that lasers were like microwaves, only at a higher frequency. And, he reasoned, they would derive the same benefits as did microwaves from waveguide propagation. Hence we embarked on a project to develop a "single-mode optical waveguide." This was a very exciting phase of my employment, probably the closest to real research that I have ever done. The work did eventually lead to two patents that I would receive—the first, a technique for using proton irradiation to form optical waveguides and the second, a unique optical filter based on optical waveguide principles. This work really was a forerunner of the optical fibers of today which are revolutionizing transmission of telephone signals around the world, and which will, in a few years, play a key role in the new era of personal communication.

I remember my first "marketing" experience. Bob Kaplan, John Strong of Hazeltine and I visited a NASA office in Washington D.C., where we described our concept of the macroscopic optical waveguide to a Mr. Roland Chase. Things were different in those days; Mr. Chase was so impressed with the idea that he invited us to submit an unsolicited proposal, and we were awarded a contract within a few months. I believe the amount was $35,000, which in 1963 was a substantial sum of money for a research and development study contract.

My first three years at WL were spent in Great Neck; in 1964, I made the move to Smithtown. Around this time, Bob Kaplan left WL for a position as one of the founders of a new laser company, Quantronix Corp., and I was put in charge of the laser group. Being relatively young and inexperienced, this was quite a challenge. However, I was very fortunate to be able to obtain guidance from both Mr. Wheeler and Harry Redlien; they helped me to apply some of the basic principles of antennas to the laser work.

One interesting concept was optical simulation of microwave antenna patterns. We built a model of the antenna about an inch in size, and illuminated it with a laser beam. One could then either view the far field pattern directly, or scan it with a small optical detector to obtain a measured pattern.

I believe we did some real pioneering work in the field of optical waveguides, but when the concepts and advantages started to become more widely known and appreciated by the likes of Bell Laboratories, they started to apply a great deal of money and manpower to this work. We were no match for the resources they were able to apply and so, no longer able to compete, our work ceased.

The technical work at WL was very interesting, enjoyable and rewarding, but as all of us who worked there know, that was only a part of it; WL was truly a second family, where you got to know people and do things together much beyond the work experience. As most of the Wheeler gang knows, I was always a sports enthusiast, and still enjoy many different sports and I think we played just about all of them at WL. The lunchtime activity was the sport in season—softball, football, basketball, hockey or tennis, and after work (or before) there was golf. I remember the softball league where I believe we always came in last, but enjoyed it just the same. I recall George Knittel on the mound (occasionally spelled by me), Warren Elliot trying to teach us the theory of the game, and Brian Cullen always hustling and generally playing better than the rest of us. (I did manage to hit my share of home runs some years.)

I remember the lunchtime football and basketball and the rivalry between Brian and me; he was a natural athlete, but my height was a great equalizer. I remember Vic Milligan and I (and later John Pedersen at HC) setting out to play golf at 5:30 a.m., before the course had officially opened, and getting to work by 9 a.m. for a day's work. Those were the days! I've sometimes referred to them as Camelot—a few brief shining moments through the years.

My years at WL had a great impact on my personal life as well as my professional development. It was at the 1962 Wheeler dinner dance where I had my first date with Mona, who was to become my wife less than a year later. We bought a home in Huntington, shortly before I was transferred to the Smithtown laboratory. My first two children, Lisa and Lynn, were born while living there, in 1964 and 1966. There were many other young couples at WL at the time, and we made many friends with whom we shared our experiences with both the joys and the challenges of raising children. We commiserated often on our parenting problems with Brian and Barbara Cullen, George and Sandy Scherer, Dick and Ann Flam and many others. As the family grew, we followed the trend of the time, and in 1968, moved to a larger home in Dix Hills. My third daughter Karen and my son Ronny were born there.

We all remember the dark days of 1970 when due to one of the cycles in the defense industry, WL was unable to continue with business as usual, and there was a major layoff of staff, myself included. I was fortunate to quickly land a job with the N.Y. Telephone Company in New York City, but after only six months, decided to return to the defense industry with a position at AIL in a small group doing laser work.

After two good years at AIL I returned to the Wheeler fold by accepting an offer to join the Wheeler group at Hazeltine Corp. in Greenlawn. Working initially under George Vaupel and subsequently under Dick Frazita, I got back into the antenna field, working on the microwave landing system (MLS). I was responsible for the "modal antenna," a large cylindrical array whose function was to provide azimuth information for the landing aircraft. I recall spending many long hours working with Vic Milligan and John Pedersen to phase-trim the 270 coaxial cables which drove the slotted waveguide antenna elements. After the usual "fun" testing on the Smithtown range (I believe this may have been the heaviest antenna ever tested there—including even Dave Dettinger's Fiat), the antenna was shipped to Wallops Station, Virginia for MLS flight tests. This was another memorable experience, often working many hours into the night to get ready for a flight test the next day, battling swarms of mosquitoes as well as the technical problems with the antenna.

It was at Hazeltine in the late seventies that I first started working with solid-state amplifiers. My first circuit was an L-band oscillator/amplifier for use in the transponder of the Mark XII IFF system. This was a great learning experience, since I had the opportunity to work directly with Mr. Wheeler. It always amazed me how he could recall something he had done many years earlier, perhaps with a vacuum tube, and apply it to the problem I was working on, which involved a transistor amplifier. This work was a forerunner of my primary area of expertise today, namely monolithic microwave integrated circuits, or MMIC technology.

I left Hazeltine in 1978 to join ITT in New Jersey. I became heavily involved in various IR&D projects at ITT, many associated with new and advanced technologies. Eventually this led to a leadership role at ITT in the development of MMICs, the field to which I have devoted most of my energies for the past twelve years.

The change in microwave technology, since my start at Wheeler Laboratories in 1960, has been remarkable! I have seen the transition from heavy brass waveguides of many inches in size and weighing several pounds that were used just to carry signals, to complete microwave integrated circuits formed on a single piece of gallium arsenide measuring a few millimeters. The reductions in size, weight and cost afforded by MMIC technology are so great as to open up entirely new market opportunities. These range from active aperture phased arrays used in the defense sector to hand-held cellular phones and GPS receivers in the commercial area. The equipment needed to fabricate these MMICs, as well as the CAD tools to design them, did not exist in the days at WL. However, many of the fundamental concepts remain the same, and these were learned early at WL.

In my position managing the Microwave Design department at ITT, I try to instill many of the same thought processes that we learned at WL in the younger engineers. MMIC design relies heavily on computer-aided design for simulation and optimization—there is now a much greater premium on getting the design right the first time (first pass success) because of the considerable expense and time required to produce a MMIC chip. But I always try to get the engineers to think before turning to the computer to solve a problem, and frequently encourage the use of the Smith Chart for visualizing what is happening in a circuit.

Engineering writing continues to be a very important part of my job, and again I owe a great deal of credit to my early training at WL. The procedures we had to utilize—the outlines, drafts, and multiple reviews, instilled a discipline and a thought process that has helped me immeasurably through the years. And it's a process I try to teach young engineers today.

In conclusion, I owe a tremendous debt to Wheeler Laboratories and to Mr. Wheeler personally for where I am today. WL played a major role in both my career development and my personal life, and for this I am forever grateful. Thank you, Mr. Wheeler!

Vic Milligan

I came to work at "The Labs" about three weeks after discharge from the Navy in the spring of 1961. I was 22 years old and married, with a son just a year old. My father had worked for Grumman most of his adult life and I had been accepted there for employment. I was told I would begin work in two weeks, but when that time had passed and I called, they said there was some sort of mix-up and that it would be another two weeks. I was a little anxious, being a young husband and father, so I looked at the afternoon want ads in the newspaper and noticed a small ad for a technician. I called and they said to come down right away. I was interviewed by Bob Hanratty, Ned Spencer and Carmine Cocozzelli, and told I could start on the following Monday. Needless to say, I was impressed with the speed in which they made their decision.

My years spent at Wheeler Labs were happy and rewarding years. I think the reason for this was the working environment that existed at Wheeler Labs during those early years, which was conducive to learning and improving one's skills. I experienced a working atmosphere in which my efforts were appreciated by my supervisors and co-workers. No matter how insignificant the task, it was viewed as an important part of the overall project. This kind of interaction with my co-workers gave me the incentive to do more, and I always felt a part of the Wheeler Lab family. I use the term family because personally, that is how I felt in those early days.

The first supervisor I worked for was Carmine Cocozzelli. He was about 10 years older than I was, and had spent many years as a Chief Radio Officer in the Merchant Marines. He was very knowledgeable about the variety of test equipment that the technicians had to operate, repair and calibrate. He was, as I recall, intensely loyal and honest. Over the years I never had anything but the greatest love and respect for him.

I pursued my career by attending school at night and worked my way up the engineering ladder when Wheeler Lab became part of Hazeltine Corporation in the early 1970s. I spent all but two years of my working life first with Wheeler Labs, and later with Hazeltine. I was truly blessed to have worked with Mr. Wheeler when he was Chief Scientist at Hazeltine in the late 70s and 80s. During that time I was involved in the design of a number of electrically small antennas, a field in which he was considered an expert; I benefited greatly from his teaching.

Sidney Arnow

I started work in the summer of 1961. During my daylong interview I had been treated so royally, as if I was really important, that even though I had seven other offers I had no real choice—I *had* to work at WL. A surprise was that one of my interviewers, Bob Puttre, had been with me at Brooklyn Technical High School, though he had gone directly to college while I worked in industry for two years before starting college at Brooklyn Poly. As a result, he started his engineering career two years earlier than I did. Bob took me to lunch at Patricia Murphy's and, over a drink, told me how much he was enjoying work at WL. Each one of my interviewers really impressed me not only with their brightness, but also with their sincere commitment to, and interest in, their work at WL. This was a group that was in a different class when compared to the employees at the other companies that had interviewed me; by comparison, the other companies, and some of them were big names, all seemed to be "schlock" outfits.

WL started me, as they did all new engineers, on the bench, a practice that was unique. My very first project was to impedance-match the feedhorns of an X-band MMML comparator feed. This was an important and very valuable experience—I later learned that most engineers never got any bench experience. As a result, they never really learned how to take data, or how to evaluate whether the data they might be called upon to review was any good. Later, I worked to develop the MAR polarizer in a dielectric-disc-loaded waveguide. Then, I was introduced to the amazing world of simulation of phased arrays in waveguides.

Absolutely, my own highlight at WL was the people who worked there. To a person, they comprised the most wonderful group I ever met. I learned so much from them, both about engineering and about life. They helped me so much to grow up, and to give me a "can do" attitude. The best way to describe them is to say that they had class. Many of them became, and are still, my most important lifelong friends. What a pleasure it is for me to be counted among this group.

One of the most unique WL management concepts was the idea that employees could be trusted. Each employee was issued his own key to the building and was taught how to operate the security system, so that he could come in and work during off hours, or even to use the "lab" for his own project, day or night. Many WL'ers came in out-of-hours to perform repair work on their cars. It was amazing to me that this was not only permitted, but encouraged. Management today is just beginning to realize that mutual trust between employees and management is not only possible, but also extremely important. Wheeler knew this 40 or more years ago.

There were some very special people at WL, such as Rocco Mangione, a member of the maintenance staff. He was near 80, I think, and had spent most of his younger working life in the fresh fruit and vegetable field. What a delightful, wise, and intelligent gentleman he was; it was such a pleasure to be instructed about life by him. And the pride he took in his work was a model display of the pursuit of excellence. I have never seen floors, bathrooms, or desktops maintained with such pride and care. A much sought-after reward for each engineer was to have his grey linoleum desktop restored to better than new by Rocco. An engineer could give nothing short of his best work after such a restoration was bestowed by Rocco.

Singular, of course, was Mr. Wheeler. His lessons and training were legend, even then. Either he was the source of the concepts that guided the labs, or he created the world that gave birth to them. Technically, he was a guru's guru, but he was an accessible guru, and we all tried to emulate his way of thinking and working to whatever extent we were able. We all wrote the date his way, and though we laughed about it, we all used 3x5-inch index card reminders. We all recorded our notes in 1/4-inch per box graph paper notebooks. We all tried to sketch "to scale" in our notebooks. Of course, we all used Wheeler Charts, instead of Smith Charts. And when each of us moved on we took these habits, and more importantly the thinking that went behind them with us, much to our individual benefit.

Quotes—real or imagined? I really don't know. When asked why WL'ers flew first-class while all other engineers sat in coach, Wheeler is reported to have said, "If *we* don't travel first class, who *should?*" (Remember, this was in the early 60s.) Accurately quoted or not, this kind of thinking made each of us feel that we, and our individual contributions, were important, and helped to give each of us an attitude of success.

Though I am untrained in managing people, it is my opinion that Wheeler, either through instinct or prior experience, clearly understood how to put together a capable group, and how to motivate all of the people within the group to perform their best work. It was my very deep pleasure to have known, and to have been touched by, Mr. Harold Wheeler.

Stuart P. Litt

In 1961 when I was in my third year at Cooper Union, I received a letter from Dave Dettinger, inviting me to interview for a summer position at WL. Up to that time, I had not engaged in remunerative technical work of any kind, and I had supposed that I would spend another summer in upstate New York working as a waiter in a resort hotel.

I grew up in New York City and was always interested in math and all branches of science. I particularly liked explaining science to others, sorely testing the patience of my relatives. An uncle used to give me his old copies of “Popular Science” and “Popular Mechanics,” to which I became addicted at the age of seven. My parents were of very modest means, and from the time I got my first job delivering newspapers in the seventh grade I made my own spending money.

I went to the Bronx High School of Science in its heyday and was exposed to a curriculum built around the premise that learning was a delight, not a chore. My favorite subject was, and remained later, physics, in which I found I could generally absorb concepts with about the same effort as reading a novel. I did not study very much, and worked about 30 hours a week in a neighborhood drugstore. I chose engineering as a career over the desires of my folks, who wanted me to be a physician.

I was fortunate to be admitted to The Cooper Union, which as a small, private 100% scholarship school in Manhattan, was ideal for people without the means to go to a tuition college. To apply to Cooper Union in those days, the prospective undergraduate had not merely to choose engineering exclusively but also, irrevocably, to choose his engineering specialty. The admissions test, a full-day affair that required concentration to the point of exhaustion, was good preparation for the WL interview.

At Great Neck I was first met by Frank Williams. I don’t remember who toured me through the laboratory but I surely remember my technical interview by Pete Hannan. He asked me to derive the “capacitance of a sphere” and, with a few helpful hints from Pete, I was able to figure it out, much to my own amazement.

Pete asked me to talk about a project I particularly liked. Instead of a school project, I chose an idea I had been thinking about for an automated identification system to keep track of clothing in a dry cleaning plant. I got the inspiration for it a few years earlier while working in my father's plant. Pete, who was of course unfamiliar with the operational requirements, absorbed it all and asked his usual penetrating questions. I answered as best I could, refining my concepts as we went along. I was picked over several other Cooper students whom I respected. My summer employment, on an annualized basis, made me the highest paid member of my family.

Smithtown was a wonderful learning experience. George Scherer and I reported to Fred Van Davelaar and were assigned to test a scale model of the Nike-Zeus acquisition transmitter antenna that was under construction at Kwajelein. The scale model of this folded pillbox was about eight feet long and had been designed at Great Neck under Joel Becker. Irwin Koffman was in the process of moving out to Smithtown and became our technical overseer.

The pillbox operated in the waveguide mode so the plate spacing was critical. I had the job of measuring the spacing with a set of go/no-go gauges mounted on long rods. As my first technical writing assignment Fred asked me to draft the letter to Bell Labs. I wrote this big thesis which Irwin helped me edit down to the one page the subject deserved.

One learns the most when things are not working right, and it so happened that the pillbox had a design flaw in the coupling region which slightly defocused it. Thus the experience of setting up and performing the testing, which was certainly educational, was expanded to afford an understanding of how the antenna worked, both by intent and in fact. Reconstruction of the model to eliminate the flaw was too expensive and time consuming, so a first-order fix was devised by moving the feed (preceding the Hubbel telescope by a few years).

I also had an object lesson in the meaning of handling equipment carefully. We used a 1-inch remote oscilloscope to peak the power from the klystron signal source. One day I left the scope sitting on the antenna mount gearbox and went back into the lab to work the mount controller. When I tried to bring the antenna down to zero elevation, the angle indicator refused to go the last few degrees. After a few moments I suspected what had happened, and confirmed it when I went back onto the roof. There was the little remote scope, crushed between the mount and the gearbox. Was I about to be ejected from my first job? Horrified, I went to Fred, who remained calm and told me to get a replacement from the technician staff. So I said to Carmine Cocozzelli, proffering the hopelessly smashed instrument, "I think there is a malfunction in this scope." Deadpan, he replied "We'll troubleshoot it for you. Meanwhile, here's a temporary replacement." As I walked away with relief, he added "Watch where you put it."

Despite this incident, I was invited back for full-time work at Great Neck in June of 1962. The number of new employees, which I think was a record, more than filled the work assignments available. Ned Spencer brought in a job from Communications Products to double-tune their Stationmaster antenna, which had been designed at WL some years before. For my first assignment, with Ned's help, I devised an LC tuning circuit which unfortunately was too lossy to be effective. But Ned showed me the power factor practicalities in tuned circuit design.

After helping Sid Arnow test a new cast monopulse comparator that had been designed by Pat (Burgmyer) Loth, I eventually joined what was to become the largest project at Great Neck, the electrical design of the Nike-X phased arrays.

Odd-shaped waveguide simulators were a hallmark of Mr. Wheeler's work in phased array theory. One simulator used a triangular guide, and for impedance measurements we used a specially constructed slotted line which, for symmetry, had a slot in each wall. The readings from it made no sense, and I traced the problem to the fact that the presence of more than one slot caused otherwise evanescent waveguide modes to excite unwanted TEM modes in the slotted line. At this point I felt that in addition to learning, I was beginning to contribute creatively as well.

I then had the job under Vince Mazzola of developing a low-power wave launcher for the disc-loaded waveguide receiver elements. This was my first opportunity to work directly with Mr. Wheeler on a design project. Each meeting with him was exhausting and transforming. One could work for two weeks on an hour of guidance. Despite my very junior position, our meetings always seemed to be a two-way learning experience, and I was always left with the feeling that I retained responsibility for the project's success or failure. And so Mr. Wheeler was ahead of his time in the area of the participative management style.

During the first few years at WL, we new recruits fell under the influence of our seniors, even in things not directly related to the work at hand, the greatest on me personally being in the area of automobiles. The prevailing ideal was that a good engineer never let anyone else, especially anyone associated with a commercial garage, tinker with his automobile. Saturday mornings saw a swarm of cars parked in back near the machine shop, with their owners scurrying to and fro and crawling underneath. For a city boy that never had a car until he started working, this new world was both compelling and frightening. So I learned, despite my disinclination, a degree of mechanical self-reliance, accomplishing such high tasks as rocker-arm repair, water pump replacement and the like, although Richie Metrick once told me I came down a few pegs in his estimation when he observed me in the greatest of confusion changing a set of brakes.

As a small company, each of us had special support assignments that broadened our experience. One of mine was the purchase of test equipment for the Great Neck labs. We bought a newfangled desktop-computing device called the LOCI which, remarkably, could instantaneously compute the natural logarithm and antilogarithm of any number, as well as add and subtract numbers. It was great fun to use; with an 80-hole punch card one could program it to calculate a trigonometric function. It was the first computing product of a startup outfit called Wang Laboratories. Thus have our careers spanned the spectacular rise and fall of a technology giant.

I was assigned to help Pete Hannan develop his idea for a new kind of capacitive ground plane as a means of providing extended scan range for a phased array. The project involved extensive calculations, for which Frank Williams arranged for me to use the new IBM 1131 computer at the Hazeltine Research Labs (HRL) in Plainview. Weeks of work (which one could now undoubtedly do in about five minutes on a home computer) produced performance plots which

Pete and I incorporated into a paper, which was the subject of my first professional presentation at the A&P symposium that year. Pete and Harry Redlien had the task of making me into an acceptable presenter, which took a little work, my previous stage experience having been limited to amateur standup comedy at a summer resort in my college days. The project also gave me an introduction to the HRL staff, and I was subsequently loaned out to them often for special projects.

This was an entrepreneurial time at WL; the Bell Labs work was tapering off and many of us were assigned to new business development tasks. Also, Hazeltine wanted to make wider use of WL technology in its own business. Working with Hazeltine's marketing organization, Irwin Koffman identified an opportunity for improved commercial satellite communications antennas. Pete Hannan came up with several unique ideas including a torus antenna (which was later developed by Comsat Corporation but was never widely adopted because of its cost) that could, with multiple feed positions, cover a number of satellites in equatorial orbit.

Richie Kumpfbeck and I performed extensive performance studies in support of Pete's ideas. Also, with some Hazeltine engineers I visited a number of large-antenna fabricators in search of a team member. The project did not progress to contract work, but it gave me a taste of new business development, as well as systems analysis, and I enjoyed it tremendously.

Towards the end of WL's time as a separate entity I joined an effort by Ron Rudish and Jim Maune to develop a line of airborne satellite communications antennas. John Wartti of HRL taught us the essentials of technical marketing, taking us to the relevant Government laboratories where our visits became known as "seminars." To the lab people we were really eggheads! Eventually we competed for and won several development contracts for new-type UHF and microwave satcom antennas devised by the team. The largest one came just as WL was merged into HRL.

My work on the satcom team tapered off during the last year of WL as I joined a fledgling radio navigation product line, staffed by both WL and Hazeltine design engineers and led by Henry Bachman. Although we did not develop a long-term business, in a sense we set a precedent for the subsequent integration of many talented WL engineers into the Hazeltine organization.

I stayed on at Hazeltine another sixteen years before leaving to join several other smaller companies. Throughout that time I witnessed the profound effect the small number of WL people had on the fortunes of this venerable company, including some truly superhuman efforts in the face of daunting odds. These stories, however, are for another time.

The Microwave Landing System (MLS) project, however, is especially relevant to the WL story because of the extent to which WL-trained talent permeated this effort and the stream of innovations that were created in a short period of time. From 1970 to 1974, HC and five other companies, each larger and better resourced than HC, vied to develop a new aircraft landing system for worldwide use. Each competitor had total systems responsibility, from analysis of operational requirements to equipment design and testing. Hazeltine chose to back the Doppler scanning system, a promising technology but a substantial underdog because of political pressures to adopt its conventional scanning beam rivals.

The Hazeltine program, headed by Harry Redlien, included many WL engineers at all levels teamed with many other fine Hazeltine people. The development of the antennas for this system became the principal goal for WL, which was now part of HRL. One of Doppler's reputed weaknesses was the supposed inability to realize certain antenna characteristics such as planar beams and 360° azimuth scanning. In each case WL engineers, led by Dick Frazita, determined to produce the very antennas that were deemed impossible.

Hazeltine progressed to become a finalist in this competition. While the demonstration equipment was being constructed and tested, it was my job to lead the preparation of an extensive proposal to develop the production versions of the system, and then to be the chief representative of Hazeltine during a four-month FAA evaluation in Washington—a process involving four U. S. companies plus several foreign ones and hordes of government officials and consultants. Mr. Wheeler, who had guided the fundamental technical concepts throughout the system development, spent a few days each week in Washington, and in a sense worked for me on the Doppler team. And a team player he was, putting up with some pretty awful politics at times.

It was a pleasure to represent the Doppler system because Hazeltine (with the ITT Gilfillan team which was led by another WL alumnus, Jeff Nemit) had developed and fielded, in a two-year period, a system that was superior to its competition in almost every respect, including cost, performance, documentation and overall refinement. All except one—it was not a conventional scanning beam system, and so in the end it was not chosen.

MLS at Hazeltine had several later reincarnations and flourishments, but ended unfortunately some years after I left the company. However, the Doppler program was the most unforgettable experience of my technical career. It was the last time I know of that so many Wheeler-trained people worked together, and it produced a body of work of exceptional originality and quality.

Robert E. Millet

I was born just a few miles from the Little Neck headquarters of Hazeltine Corporation in the year that Germany invaded Poland. Although I was insulated by age from the tribulations of World War II, my career has been significantly affected by the Cold War that followed. From the research and development driven by concern about nuclear war with the former Soviet Union, to the real war in the Gulf involving battles between Soviet-made SCUD ballistic missiles and the Patriot air defense system developed and manufactured by my current employer, Raytheon Company, my career has been inexorably entwined with the Soviet Union as enemy. I now look forward to a world in which Russia is an ally.

Like so many of my colleagues at Wheeler Laboratories, I graduated from the Polytechnic Institute of Brooklyn, now Polytechnic University, in 1961. In those days, it was a seller's market, and it was not uncommon for a senior with good grades to receive as many as five job offers. I had two at the time I decided to accept the Wheeler offer. The other was from IBM, in a new field called telecommunications. Looking back, it now seems remarkable that I didn't even know what the word meant, and perhaps part of the reason that I accepted the WL offer was that the IBM interviewer didn't seem to, either. Certainly an important consideration was the excellent reports about the professional standards at WL that I received from summer hires of the previous year. It was a pivotal decision; much later, I would understand how poorly a Baccalaureate degree prepares a person for a productive career in engineering. The education that I received at WL was probably as important to my future as was the one at Polytechnic.

I don't remember much about interviews associated with the hiring process. I do remember being interviewed by Harry Redlein. The only question I remember him asking was whether I played golf; I didn't. Fortunately, Harry didn't hold this against me, and I was hired on. If I ever got an explanation for such a perfunctory interview, I've forgotten it. I like to think it was part of an explicit policy that emphasized the hiring of good prospects based on academic performance, on the premise that anyone who could get good grades at a good school could be taught to be a good engineer by the exceptional staff at WL.

The irony of refusing the IBM offer to work in the embryonic field of telecommunications is that my first assignment at WL was at the forefront of this endeavor. When I joined the staff in July 1961, George Knittel and a summer hire were just beginning a program for Bell Labs, Murray Hill to design a telemetry antenna for AT&T's TELSTAR communications satellite. If I may be forgiven a bit of conceit, I believe the successful launching of TELSTAR heralded the beginning of the telecommunications age. Although AT&T did not get to capitalize directly on this pioneering effort, others took this first small step to new heights (22,800 miles more or less). Today such satellites are so commonplace that we are unconscious of their existence unless we are directly involved in their manufacture or launch. In 1961, TELSTAR was an ambitious undertaking and its newness is illustrated by one anecdote.

The design for this telemetry antenna was based on a concept, the normal mode helix, recommended by Harold Wheeler. He had worked out the basic theory and written it up years earlier. The requirement was for an omnidirectionally radiating, circularly polarized antenna. Wheeler had shown that this is physically unrealizable, but the normal mode helix came close, at least in theory. The only difficulty was that its favorable properties only applied in isolation; in the TELSTAR application, it would be in the proximity of the satellite itself. It was thought that if the helix was placed on a short mast with radials to isolate the helix and mast, then good polarization properties would be preserved.

Unfortunately, at 140 MHz, where the antenna was to operate, "short" meant about one meter (half a wavelength). Operation at such a low frequency also made testing difficult. The other challenge was impedance matching, which was complicated by three factors: 1) the normal mode helix, being end-fed, had a very high impedance; 2) the antenna had to operate at two widely-spaced transmit and receive frequencies; and 3) the on-board telemetry transmitter was severely power-limited so the match had to be very good, and be accomplished with very low-loss components.

Naturally, we thought that we at WL were doing all the hard work, but at Bell Labs there was a team of mechanical engineers agonizing over the moment of inertia budgets for the developing satellite. For them, testing wasn't difficult, it was impossible. The problem was that TELSTAR was spin-stabilized; it became well known to all of us that unless the moment of inertia about the spin axis was much higher than any other axis, the satellite could start to tumble. The real problem was, how much was "much higher"? This was 1961, only four years after Sputnik. We at WL struggled to approach Harold Wheeler's near-ideal, almost-omnidirectional, circularly-polarized telemetry. Meanwhile, the Bell Labs engineers were constantly trading off the risk of the satellite tumbling against the risk that telemetry would be lost, owing to a cross-polarized condition if the antenna were not extended away from the satellite by a one-meter mast. The highlight of our efforts was the demonstration of antenna deployment by George Knittel at one of the monthly WL seminars. The antenna, fabricated from exotic, elastic beryllium was successfully deployed, radials oscillating to equilibrium, on a telescoping mast, using a small pyrotechnic device. The lowlight of the program occurred when Bell Labs management told us that the mechanical engineers had convinced them not to deploy the antenna, but to leave it in close proximity to the satellite body. We scrambled to ascertain that our much-loved helix would perform adequately as a monopole; it did.

Although I worked on many other interesting projects at WL in the six years I was there, none stand out so distinctly as this first. What does stand out vividly is the extremely wide diversity of my projects, even over the relatively few years that I worked at WL. They covered the frequency spectrum from 150 MHz to 95 GHz, antenna types from very short wires to large phased arrays, and applications from communications to ballistic missile defense. A significant fraction of that time was spent on microwave structures other than antennas, most notably radar fences for such purposes as sidelobe clutter suppression and personnel protection. On many of these projects, my responsibilities included conceptual design, detailed design, supervision of model construction, testing, and of course, preparing a written report of the work. This cradle-to-grave involvement in a diversity of projects was an educational opportunity that probably had no equal then or now, and that I find useful to this day.

Three principles of conducting a project stand out. First, the scientific method was always rigorously applied, although I don't recall anyone referring to it that way. That is, it was important to establish theoretically what was expected of the antenna or other device being designed, then to confirm that theory with a carefully designed experiment. Secondly, it was imperative that the theory be such that useful results be obtained by simple means such as a slide rule. This was sometimes painful to us younger engineers who saw the frontier of large-scale computing beckoning, but it forced the engineer to think through his problem as thoroughly as possible before proceeding with laborious, and possibly misleading, computations. Third, it was mandatory that each project be described in a final report that met the highest standards of technical writing. I still have a few WL reports to which I refer from time to time; I probably would have more if I had understood at the time how enduringly useful some of them would be.

It had to end sometime, though I did not leave WL willingly. Our major benefactor, Bell Laboratories, decided they would be better served by an in-house antenna design capability. Leaving school for the real world is often painful, as it was in this case, but a good education provides a solid foundation for a rewarding career; WL at least as much as Polytechnic University gave me this education. Fortunately, things were pretty busy at our parent company, Hazeltine, and I was able to find a job there. The applicability of antenna theory, that is, Fourier Transform theory, to radar waveform design and analysis allowed me to get up to speed in this area fairly quickly. Later, when the bottom fell out at Hazeltine, I was able to present myself as a radar systems engineer at Raytheon, where I have spent the last 22 years reaping the rewards of my WL education. I will illustrate the value of that education with a few anecdotes.

As I achieved greater seniority, I have found that it is more important to evaluate the work of others than to do original work myself. As I do so, I try to apply the three principles first learned at WL.

Failure to apply the scientific method may account for more inferior efforts than any other single cause. Asking an engineer either what theory he has to explain an empirical result, or what data he has to support some theory, can lead to the most interesting conversations. We humans all have selective memories. I can not in all honesty say I distinctly remember always applying the scientific method myself; however, I do find it a very effective filter for other people's work.

The value of insisting on the development of a simple theory with which to explain one's expectations may best be illustrated by telling a story about myself. A few years after joining Hazeltine, I was able to transfer to the Research Labs where radar signal processing research on a par with WL's antenna and microwave work was being done. My first assignment was to develop a method of precisely estimating the instantaneous range separation among radar scattering centers on an object in space (a satellite, for example). Partly because my supervisor was predisposed in a certain way and partly because the contract's statement of work was written that way, I set out to evaluate the concept using a Monte Carlo simulation, taking advantage of the availability of large-scale computing. I tried to develop a simple formula to predict the results of what was in effect a computer-based experiment. Unfortunately, my supervisor considered himself a mathematician, and approximations were anathema to him. At his urging, I dropped the attempt to derive a model and proceeded with the simulations. After some time, we proudly reviewed the results with the lab manager. Fortunately, he must have had some WL in him because he immediately saw that the results did not square with simple theory. (The lab manager was Randy Cope, who later became a Hazeltine vice president, undoubtedly because he had learned the three principles of good engineering even though he never worked at WL).

He sent me back with instructions to devise a simple theoretical model, which I did. My "empirical" results were almost completely uncorrelated with this model. Once I found the coding error, the revised results coincided so perfectly with the predictions of this simple theory that it seemed as though I had fudged the results. I now frequently make a nuisance of myself by asking engineers to compare their simulation results with a simple theory. It is frightening to see how frequently computer-generated results are accepted by even experienced engineers, simply because they are computer-generated.

The third lesson, documenting a project with a written report, has paid off innumerable times over the years. I think the most telling has been in the preparation of technical proposals. It is difficult to prepare a written report of a completed project, but writing about a proposed project is a true challenge. I have been involved in the preparation of several large proposals requiring the combined efforts of many engineers, as both writer and reviewer. It is remarkable how many engineers have difficulty producing their contribution, both in terms of timeliness and of quality. Proposal preparation is the time when the need to create quality technical writing within a tight schedule becomes most evident. Having the confidence to write quality technical material, built up from years of writing reports in the unique WL method, has often made the job a little easier.

I will always appreciate the continuing education I received at the hands of Harold Wheeler and his associates. There are many things I miss about working at WL, but two stand out. First, I have never since experienced the openness, in which any question was greeted with intellectual curiosity and a genuine desire to help. I cannot forget the shock I felt the first time after leaving WL that I asked a technical question of an associate and received the response "You don't have a need to know." Secondly, I have not had the same opportunity since leaving WL to work with craftsmen of the same caliber as the technicians, designers, and machinists whose contributions complemented the engineering work. Perhaps it was because they were able to convert my ideas into reality much better than I could have that it was such a pleasure to work with these men.

Bob Grossbach

Many years after I had left Wheeler Labs, I became friendly with a moody Frenchman at Eaton Corporation, where I worked as a job shopper on the B-1B program. The Frenchman was nearly always in trouble with management, and one day he said to me, "You and I, we are a lot alike, we both 'ave a cheep on our shouldair." I thought that this was probably true, although in my case, I could never understand exactly why.

I used to imagine that it was a result of having observed my father, a dental technician who was overworked, underpaid, and otherwise exploited all his life, but I have since come to regard this as too facile an explanation. I now believe that it's simply a personality trait, one of those mysteries from deep inside the double helix, a tiny section of coiled amino acid that is coded for "cheeps on the shouldair." It's hard to imagine what, if any, survival value this confers, but—and I apologize for the long-windedness—I certainly had one when I worked at Wheeler Labs, and of course, this colored my experience there.

I started at WL in 1962, having graduated from Cooper Union in June of that year. Almost from the beginning, I established a subconscious mental line, drawn at just the (lack of) effort level where one is fired. My focus became to float one epsilon above that line, no less, no more. I was not a mean-spirited employee but a childish one, never doing bad work but never really dedicating myself, not so much participating as observing, and always ready for entertainment.

Interestingly, many of my colleagues would occasionally themselves depart from serious attention to the job at hand and, in contrast to any technical triumphs, these are the times and the people that remain in my thoughts. So herein lie a few random access memories of my years at WL.

Jar Tightening

One of a series of contests, frequently held in Bob Puttre's lab. It began as a challenge among the engineers and techs—can you open this jar cover I just tightened? Any jar was okay; it could be the rubber cement, the silver paint, or the peanut butter you brought for lunch. But an interesting phenomenon was soon discovered: it is much easier to open a jar than to close it. It got so nearly anyone could undo a cover someone else had tightened, and it was quickly agreed we needed a new measure.

The one that evolved was based on the observation that as a cover was twisted past the point of simple contact closure, it gave off a series of clicks, probably as the result of material deformation and strain release. The number of clicks was proportional to the force one exerted, and this index soon became the gauge of prowess. The winner, incidentally, was always Nick Roschak, whose combination of wiry strength and the ability to maintain friction with his dry, bony hands made him outstanding.

Small Writing

Sid Arnow introduced me to this craft, advising me that on a prior job he used to inscribe words so tiny on a corner of the page, they were illegible to the naked eye. I quickly appreciated the skill's utility; one could write dirty sayings on official documents, denouncements of the boss, jokes—why, the possibilities were endless!

My competitive juices stimulated, I set forth to make myself the best small-writer in the lab. Several weeks hence, using a number six pencil sharpened after every stroke and working through a ten-power jeweler's loop on especially smooth paper (yes, the graininess of ordinary paper was a limitation), I succeeded in writing the word "skill" in letters just over ten mils high. In my subsequent life, I have not really used this capability as much as I'd anticipated, but I am comforted that it's there should I need it. (Some time after I'd left WL, I heard a rumor that Gerry Dorman had broken my smallness record. The rumormonger did mention, however, that Dorman used a microscope and wrote on a polished alumina disk. If this is true, I believe his achievement should go into the record books with an asterisk, albeit a very small one.)

Club Day

Any time that the WL upper management team went to visit Bell Labs, a certain individual in George Vaupel's Lab (name withheld to protect the guilty, but you know who you are) would bang an imaginary Chinese gong and declare "Club Day," a seven-hour period of general fooling around and no work. As is always the case, there were those who carried on as if nothing had changed, those who participated to a limited extent, and one or two like myself— childish, irresponsible, immoral slackers—who shamelessly exploited it to the hilt.

Interestingly, a fair amount of time was expended on intellectual challenges brought in by various club members: deduce the numerical value of chess piece symbols used in a long division example; determine whether a particular complex figure could be drawn without lifting pencil from paper; and (my own favorite), determine the probability that a triangle made by connecting three randomly placed dots is acute.

<u>World's Greatest Pain</u>

In George Vaupel's lab, I sat for a time facing Richie Metrick. Metrick's existence seemed to have a kind of larger-than-life quality (certainly larger than my life), a kind of soap opera-ish aura of being at center stage, with everyone else waiting in the wings. His work on aperture matching was the most crucially important and mind-bending of any job, he was secretly going to law school four nights a week, and he was doing all this despite being shorted several feet of large intestine. One day, observing his face covered by more than the usual sheen of perspiration and his vast single eyebrow furrowed nearly to his nose, I inquired if he was okay. "Right now," he replied, "I am in more pain than anyone has ever suffered in his entire life." At that moment, I felt privileged to be in his company.

<u>Loose Ends</u>

The first I remember was that of Bob Smith, a genial fellow who usually disappeared into the men's room about 10 a.m. carrying The New York Times and reappeared around noon. One day, he simply disappeared forever. Then there was Phil Avruch, a man noted for his eerie simulation of a submarine Klaxon. Returning from a summons upstairs (in the Great Neck facility), Phil marched to the nameplates on the door of Puttre's lab, removed his own and, with the solemnity of Churchill failing to win re-election after the war announced, "Gentlemen ... I'm out."

And then, inevitably, there came my own departure. I knew something unusual was going on when I was ordered to report to Frank Williams's office and given an Army manual to read. The title of the manual was "How to Listen", and it instructed recruits with attention deficits on how to get themselves in the frame of mind to follow instructions. When I returned, Frank advised me that we would not discuss the past, only the future. I imagined I was there because of my insistence during the previous eight weeks that Ed Pinck ask me five times before I would turn in my time card, but I had such a thoroughly checkered history that I could never be sure. The net result was that, for the next three months, I was to write up a daily progress report on my accomplishments.

Of course, no sooner did I hit the ground floor than I begin looking for a new job, which I found at Loral two weeks later. Frank seemed genuinely dismayed when I gave him the news, particularly since "I'd made excellent progress."

Well, the sad truth was I hadn't made any, never did, never have. Years later, however, I became an independent consultant and finally worked for a boss who knew all my tricks. And one schizophrenic day the two of us came to a kind of détente understanding: most times, it's harder to maintain that old chip-on-the shoulder, minimum-effort line than it is to just do the work and ignore it. And so, chastened but no wiser, I went (and have since gone) about my business.

Gerald C. Dorman

Imagine, if you will, that you're watching a videotaped program in full color of an engineer sitting at his 66-Mhz 486 computer, writing a chapter for a book about a company he used to work for. Imagine he is thinking "Gee, it seems like only yesterday that..." Now imagine the scene fading into a gentle blur and then, as the blur fades back into focus, you are looking at a streaky old hand-held 16-millimeter movie of two people sitting at a table eating sandwiches and talking to each other. I say to Richie Metrick, "You mean that vectors and matrices are not really equal but isomorphic?" He replies, "Yes, I think that is a better way to describe their similarity..." Now, in a series of flashbacks and flash forwards, we reminisce of times gone by...

June 13, 1962 came and went, leaving me as an electrical engineer. I had just graduated from The Brooklyn Polytechnic Institute (now Polytechnic Institute of NY) and to my surprise had received an unsolicited request to interview for a job from a company in Great Neck called Wheeler Labs, Inc., which I shall refer to as the Labs. I had never heard of them—so how did they come to know about me?

Asking about this at school, I found that the Labs contacted teachers at various technical schools in the area, asking for the names and addresses of students who fit a particular profile (more on this later) which, by past criteria, described a type suitable to become a microwave engineer. I immediately returned the interview request and within a few days was scheduled for an interview. In typical Lab fashion (although I did not know it at the time), the interview had been completely programmed in advance. The procedure consisted of a tour of the labs, meetings with several engineers, a test (yes, a real quiz), and a free lunch at Peter Luger's restaurant. Also there was a brief description of the Smithtown antenna range facility, which was somewhere out east on the island ("turn left at the bull" was given as the main direction). I met Patricia Loth, Leonard Steffek, Henry Bachman, Frank Williams and of course, Mr. Wheeler on my tour. I explained to my main interviewer that I knew nothing about microwaves. Apparently in 1962 I was not alone. The Labs were looking for people who, in addition to being an engineer, showed interest in learning new technical material, and who had a strong aptitude for mathematics. I believe we hired people with electrical, mechanical and other similar degrees.

I returned home after the interview not knowing how I fared, but having a strong desire to work at the Labs. The atmosphere there was difficult to describe; it bore a relaxed air and yet, at the same time, a strong technical dedication which I had seen occasionally in school. Everyone I had seen wore the classic 1960s style of engineering clothing, including jacket, white shirt and tie. In spite of this formal look, I noticed that air of freedom that comes with working on projects that one actually enjoys. I also walked through the lunch area, which included a ping-pong table; there were people playing as I passed by. In addition to ping-pong, I noticed several people playing a card game which I later found out was Hearts, a very popular lunchtime game. I asked other engineers whom I knew what they had heard about Wheeler Labs. Several told me that it was considered a "country club" by people they knew and that a lot of hush-hush military work was being done there.

Since I am writing this chapter, it is obvious that I received a job offer and accepted it. I remember that there was a lot of paperwork to be completed, fingerprints to be taken, people to meet, and finally I was assigned to a project. Now, the Labs were very much structured as an elementary school. This is not to disparage the Labs, in fact, the structure was perfectly suited to the tasks performed at the Labs. There were many rooms, each with a supervisor in charge of the room. You were assigned a project and a supervisor who might not be your "homeroom" supervisor. In this case, one would check in at the homeroom and then proceed to the room where work on the project was being conducted. Attendance (and tardiness) was observed at the homeroom. Paradoxically, this tight structure allowed a large amount of freedom, which I shall describe later.

My first assignment was building a cross-guide coupler. The process included designing, building, testing and verifying the original design criteria of the device. My supervisor was Len Steffek, nicknamed Len Steptwist, after the microwave device. I put to use all of the skills and learning I had received not only from college, but from high school. I had to calculate the size, shape and locations of little "X" shaped holes in a pair of brass waveguides. This involved mechanical design, mathematical computations and a lot of both intuitive and common sense thinking. Amazingly, when the coupler was returned to me from the shop it looked exactly like the piece I had designed. I then was shown how to make microwave measurements using things called slotted-lines, tuning probes, halometers, klystrons, terminations, and a chart referred to as a Wheeler Chart, upon which all measurements met their fate. The plots consisted of little curly lines, always moving counter-clockwise (or was it clockwise?) with increasing frequency.

My first challenge having been successfully met, I was then required to write a classified report to Bell Labs reporting on the results of my work. This was not a skill which I learned in school, but once again the Labs had a formula which, when applied to the writing of a report, made it very easy. The reports were generated by the engineer and then reviewed and graded by several supervisors. Revisions were made until the report was "optimum." Richard Peritz was one of my toughest critics, observing the subtle differences among the words "due to," "because" and "since." When my report was completed, it resembled all of the hundreds of other Wheeler Lab reports, all individuality having been purged during the review process. In the course of my stay at the Labs, I wrote two or three such reports. The second report amazingly required very little correction from the reviewers, showing that the process did work.

I was the last out of the Labs on Tuesday, November 9, 1965, when at precisely 5:17 p.m. the northeast power failure occurred. At the Labs, whoever was last to leave was responsible for locking up the building and setting the ADT alarm system, and I happened to be last on that fateful day. I remember setting the alarm and then hurrying out the door so it would close before the alarm delay time elapsed. It is true that in that small period of time the power failed and, for whatever reason, the alarm was triggered. My initial reaction was that I had made an error, so I went back into the Labs and called ADT and then Frank Williams, who had the ADT password. I remember being told to just lock up again after resetting the system. I did not realize the massiveness of the failure until on my way home I turned on the car radio and got static on most of the usual stations. I finally got a station tuned in and I was shocked to hear that the power in the entire northeast was out. My first thoughts were of sabotage (remember, these were the ‘60s). That was a day I will never forget for many reasons, but I always think of the Labs when I hear of that power failure.

Another of my challenges was designing an antenna and taking its patterns. There were rooms in the basement of the Labs where such patterns could be taken. Walls were lined with absorber, chart recorders were connected to amplifiers that in turn were connected to bolometers, antennas were mounted on pedestals and, if all went right, a pattern was recorded which resembled the theoretical one. For the particular antenna I had designed, I had to design a unique device to move the antenna around a fixed source. Normally, one rotates the test antenna but, for reasons unknown to me, the source was fixed at the center of the chamber and the test antenna had to be driven in an arc around the source. I designed a motorized wooden structure with a 6-foot boom extending out from the source. The motor was coupled to the floor by a rubber wheel and was remote controlled from a power supply outside the range. Again, these projects required much intuition and many skills and aptitudes not acquired in school.

As a result of my motorized antenna mover, or perhaps in spite of it, I was then given a rather large project to head. We were making very high-power devices for a radar system and these components had to be tested in a facility with the capability of actually causing a non-destructive (we hoped) electrical breakdown of the components. It turned out that the nearest such facility was operated by Raytheon (for whom I later worked) in Wayland, Massachusetts. It also was necessary to subject the devices under test to an exotic beam of radioactive energy in order to increase the probability of breakdown to a level whereby we would not have to wait an unduly long time for it to occur. I was responsible for the purchase of the material and the design of a shuttered, remote-controlled lead container which would, on command, open an aperture and irradiate the device under test only when necessary. We were required to wear radioactivity badges that were occasionally tested to see how much of a dosage we received. The facility was a huge resonant ring capable of sustaining two to three times more power than we needed for our testing.

Each week, Don Bond and I, and occasionally some other engineers, would set out in the late afternoon for the drive to LaGuardia airport. Carrying the components and our attaché cases, we would board the Boston shuttle. I think the fare in those days was $14, one way. At Logan airport, we would rent a car and drive to Wayland, perhaps an hour away, and check into the motel, ready to get an early start the next morning. Now, there is a pair of tunnels going in and out of the airport—the Callahan and the Sumner. Since we exited the airport via the Sumner tunnel, on our first trip, when we returned to the airport we spent a lot of time looking for signs to the Sumner tunnel. There were none because the Callahan tunnel is used for the trip to the airport! The tunnels were one way devices, one from the airport, one to the airport. A lesson in non-reciprocity well learned.

But, back to the testing. A technician named Howie actually ran the facility, while Don and I connected our components into the ring at the appropriate points. We always installed our test parts between two special right-angle bends which had special glass windows located in such a way that we could actually see the arc when it occurred. The ring had the capability of being pressurized to increase its high power capability, and when an arc occurred, the noise was quite startling—as if someone had used a hammer on the waveguide. We successfully designed high power pressure windows, various waveguide tuning circuits and many other waveguide components.

A resonant ring, by the way, is quite a magical device; it is the traveling wave equivalent of a standing wave cavity. Energy is injected into the ring via a special variable coupler and a phase shifter. The length of the ring is adjusted with the phase shifter so the injected energy is in phase with the energy traveling in the ring, thus adding to the power. The coupler effectively sets the "Q" of the ring. Until breakdown, the power in the ring is very real, but as soon as some loss is incurred, the power settles down to the actual read input power. The ring was probably 30 feet in circumference, and the power buildup was not instantaneous. One could almost imagine each wave running around the ring and being joined by the next wave as it passed the coupler—much like pushing someone on a swing.

The power levels we achieved are probably still classified, but they were enormous. The results of our testing formed the basis of several monographs and reports on high power testing, including the effects of radioactive sources in the vicinity of the breakdown region.

Sometimes Richie Metrick, George Vaupel or Nick Roschak would accompany us on one of these trips. After work we would drive into Boston proper and have a fine meal at one of the area's haute cuisine restaurants. We visited the Charter House on the Charles River and Trader Vic's in Chinatown quite frequently. The prime ribs at the Charter House were magnificent.

One eventful airplane trip that Don and I took out of LaGuardia one evening was on an old DC-6 that has four old-fashioned piston engines with propellers. About halfway to Logan Airport, Don noticed something unusual—one of the port engines had stopped! The pilot came on the PA system and said that a red indicator light had come on, indicating overheating, but that we would continue the trip on the remaining three engines. We tensed for the landing, but it was quite uneventful after all. The DC-6 was a very good aircraft, and in the rear was a large semicircular lounge that we frequented on the evening trips back from Logan. Those days were wonderful in an indescribable way—we were a bunch of youngsters having a lot of fun enjoying the work we were doing and getting paid for it. I guess we should have felt guilty, but we didn't; we didn't even think about it.

Wheeler Labs purchased a Wang desktop computer sometime in the mid-'60s, perhaps 1965. Prior to having a computer, and even subsequently, we would perform most of our computations using a slide rule, a pencil and a notebook (always a notebook). I believe we were the first technically oriented company on Long Island to have a mini-computer. The unit was only about as big as a present-day PC and much less powerful. We wrote programs and debugged them by entering the code on special paper cards. It was extremely useful for solving transcendental equations and performing waveguide calculations, some of which would previously have taken hours instead of minutes. After leaving the Labs, I did not see another desktop computer until nearly 10 years later! We certainly were on the cutting edge at the Labs.

In addition to engineers being able to write good reports, Mr. Wheeler demanded that his engineers be comfortable giving lectures and presentations. So every once in a while, the Great Neck and Smithtown groups would meet, alternating between the two locations, and someone would present a seminar on a topic of immediate interest. We would all take notes and observe carefully, for it would not be too long before one of us would be the person on the platform, giving a technical dissertation to the group.

Once every year, usually at one of these joint seminars, we would have group photos taken, to be saved for posterity. Again, the analogy with school (graduation pictures) comes to mind. These pictures and other memorabilia are exhibited whenever we hold one of our irregularly occurring Wheeler Lab reunions. At these reunions, alumni come from all of the country to be together for a brief several hours, reminiscing of old times, talking of new times, wondering where so-and-so is and what he is doing now, and in general having a great time. Awards may be given out and sometimes gifts are presented to people for various accomplishments, but for the most part, people talk about the Labs and how belonging to that unique “club” has improved their lives and their job skills, and had played an important role in forging their futures.

I indicated at the beginning of this chapter that there was some sort of a “Wheeler Labs” profile that was used as a basis for the selection of candidate engineers. There was indeed a very special type of person who was selected, and who then chose to work at Wheeler Labs. In addition to being very bright and mathematically and technically inclined, most of us were very talented practical jokers. There was a sort of initiation new engineers would be put through, beginning with finding a large wooden block somehow entrapped in their jacket sleeves in the fashion of a three-dimensional Moebius strip. This would invariably occur at the end of the day, when it was customary to put on one’s jacket. Many would put the jacket under their arms, leave and figure out the puzzle at home, returning the next day with a Cheshire cat-like grin and a large wooden block in tow. One person, who shall be left unnamed, physically removed the sleeve and threatened to bill us for the tailor charges to repair the jacket (he kept the block).

Then there was the string on the pencil gag, whereby an adept manipulator would hook this pencil through a buttonhole on someone’s jacket while they were watching. It was amusing to see the person then attempt to remove the pencil, which seemed impossible, except that he had seen it put on in front of him. Some of the gags were quite extraordinary, such as putting Dave Dettinger’s Fiat on a pedestal on the roof of the Smithtown facility (I never saw this, but I believe it happened). Once, an engineer (Dave again) took a leave to get married and when he returned to his apartment found the bathtub filled with Jell-O! Another time, we went into Manhattan for a bachelor party for one of the engineers. Walter Mohuchy was with us on that trip. We wound up in a belly-dancing establishment after traveling all around the city. I mention this because it might seem out of character for typical ‘60s engineers, but not at all for us.

One of the engineers used to regulate his life by a large clock in front of his homeroom. When we discovered this trait, I successfully got the clock to run from a Hewlett-Packard audio generator that had a 70-volt output level. We ran the clock all morning long at 40 Hz, causing the clock-watching engineer to wonder why he was so hungry when it was only 10:30. Then we raised the frequency to 80 Hz so that when it reached noon, it would be on time again. The unnamed engineer was very embarrassed when he discovered the trick we had played on him, but we did manage to break him of his habit. Years later, when I read both of Richard Feinman’s books, I saw the similarity between his exploits (such as playing bongos at a local bistro, or cracking open his boss’s secret safe) and those of many of the people at the Labs. Apparently people who are near to the genius level require some sort of divertissement in order to remain sane—or something like that. The people who were involved in these practical jokes were the very same people who were responsible for the design of very complex, state-of-the-art radar systems.

One of the niceties of working at the Labs was the ability to take a personal day off. In today’s world, one would have to call in sick or fabricate some sort of story in order to take a day off, but at the Labs, you simply took a personal day—no explanation needed or required. I believe we charged J-102 for the day. It was not uncommon to see someone working on a personal project at the Labs on a day for which he had taken personal time. Dick Peritz and I were both interested in automobiles and automobile racing. We formed the Wheeler Labs racing team, bought a brand-new Alfa Romeo GTA race car and started a second career. We took many personal days and were found in the machine shop working on various parts of the car and the engine. I think many people thought we were crazy to spend thousands of dollars on a car, never register it, and immediately take it apart and start machining its internal workings. However, after the car was reassembled, Nick Roschak joined us as head of our pit crew and we proceeded to race the car at various tracks from Maryland to Montreal. At St. Jovite, Canada, we not only won our class, but returned with a large sum of money; we were no longer amateurs! After that, many Wheelerites would come to see us race, and they no longer thought we were crazy. We could not have done this had we not been working at the Labs, where we were supported not only by our peers, but also by management. The use of the model shop by engineers was unusual, to say the least, but we were encouraged to use it, and all but several machines were available for anyone to operate. It was expected that a microwave engineer should have a good working knowledge of the tools that would be used to build components he designed. This is another example of the Wheeler Labs philosophy, which urged each engineer to become a Renaissance person, an Everyman, so to speak.

I found this experience to be immeasurably important after I graduated from the Labs and went on to other pursuits. Wheeler produced “hands-on” engineers who not only designed the components, but could, if necessary, build them themselves. This talent is sorely needed in today’s generation of engineers. I look for these traits when I hire people to work for me, and enjoy working with people who are comfortable with all aspects of a project. There is a philosophy to which I subscribe, part of which states that you should never give someone something to do unless you can also do it. This I learned at the Labs.

Another group of which I was a member was the weekend ski group. It was an informal group of people, including at times George Vaupel, the late Harry Redlien, Herman Heinemann, Tom Dewey, Herman Bilenko, Dick Peritz, and Dave Lerner. We would work through lunch on Fridays in order to leave an hour early and get a head start on the traffic. George was unofficially in charge of the entire trip. We would assemble in the parking lot behind the Labs, where we would meet other skiers from various companies in the area. We were the central assembly point. At precisely 4:15, we would take off, usually headed for Stowe, Vermont, but occasionally somewhere else in Vermont, New Hampshire, upstate New York or Massachusetts. We usually arrived at our destination after 11 o'clock, but wouldn't get to bed until close to 1 a.m. Promptly at 7 a.m. the next morning, after breakfast, we were required by George to meet in the boot room where we laced up our Molitor leather ski boots and got our equipment together. We then departed for the slopes and skied Saturday until the lifts closed, usually at about 4:30 p.m. We rarely stopped for lunch—in fact, we rarely stopped skiing. Our après-ski activity would usually end at midnight, since that was the time Vermont closed on Saturday night. Sunday was a repeat of Saturday until 3 p.m., when we assembled in the parking lot, loaded our gear into the car and set off for Long Island. I usually arrived home after 11 p.m. and could not wait for Monday so I could get to work and rest up!

We made these trips every weekend during the winter, except for our winter vacations when we would spend two weeks in Vermont skiing. George met his wife-to-be on one of these trips, and at Christmastime, we would exchange presents at the ski lodge. I think that our working relationship was greatly strengthened by these weekend activities. One time we were stranded in Vermont by a snowstorm, and it was good to know my boss was with me, so I could verify my excuse when I got back. Of course, we skied that day—what else could we do?

I was probably the last Wheelerite to use the Smithtown facility for the purpose for which it was created. In the spring and summer of 1991, while working for Raytheon (SEDCO systems), I rented the Smithtown facility in order to take patterns of a circular array antenna we had developed for use with an RDF system in a Beechcraft airplane. The antenna operated from 20 to over 1000 MHz, so an outdoor range was necessary. For a brief two to three months the Smithtown facility was back in business, with an ex-Wheelerite at the helm. We used one of the large pedestals on the roof, the old Antlab controller, and the huge crane to mount and dismount the antenna system. Nothing had changed except we used a computer to record, store, and process the data, rather than using a chart recorder and then later performing tedious computations using slide rules. In spite of its age, all the equipment functioned flawlessly. In my spare time, I roamed the old halls and rooms, remembering of a time past. There were traces of the old days everywhere and filing cabinets full of old reports and group photos. There were original 3x5s, Wheeler Charts, and notebooks stored in cabinets. Most of these latter items have been moved to Hazeltine in Greenlawn for preservation.

The Smithtown model shop was in full operation with Rudi Trommer manning the machines. He recognized me when we met, and we spent some time reminiscing. I walked out to the source tower one day to look at it. It looked unchanged from 30 years ago, but it was locked and I returned to the main building. One day, we noticed a fire back by the railroad tracks and soon, we were surrounded by police and fire vehicles. It was a very exciting day. Not long after we completed our testing (successfully, I might add), the facility was closed and sold to the hospital next door. For a short time, though, the place was buzzing with activity, as in the old days.

As the streaky, black-and-white movie we have been watching fades into a blur and then returns to a sharply focused, full-color video, we once again see someone typing at a computer. If we look closely, we can see a contented smile on his face, almost as if he had relived that time again. It was a very magical and special time for all of us, those days at the Labs. We owe its founder, Mr. Wheeler, a great deal. He took us on a trip which none of us shall ever forget, because we lived it.

Alexander J. Kelly

I was born on March 25, 1941 in Brooklyn, New York and raised in eastern Queens, not far from the Hazeltine Little Neck plant. I attended Chaminade High School in Mineola, and graduated from Manhattan College in 1962 with a BEE. While working at Wheeler Labs, I attended Brooklyn Poly (now Polytechnic University) and graduated with an MSEE in 1964.

I was an example of a post-Sputnik engineering student who had no prior interest in, or experience with, electronics. Summer jobs with LILCO and the Port Authority gave me a sense of what I didn’t want to do rather than what I wanted to do. In my junior year, I interviewed unsuccessfully for a summer job at Wheeler Labs, but the tour that I was given left a strong positive impression.

I had the opportunity, during my senior year, to support Manhattan’s Civil Engineering department in a study of pollution of rivers and estuaries, using an analog computer. During my interview for a full-time position at Wheeler Labs, this project provided a good topic for discussion.

My initial interview in late 1961 was with Al Lopez, who was a Manhattan alumnus. During the interview at the Labs, Irwin Koffman was the technical interviewer, and Ray Tuminaro gave me the tour of the Smithtown Lab. This interview reinforced the positive impression that I had received the year before. The only other company that I interviewed with was Hazeltine, since my primary focus was on full-time graduate work. I had received an offer of a teaching assistantship from the Newark College of Engineering, and was pursuing a Hughes fellowship. My decision to accept the offer from Wheeler Labs, then, was based on a number of factors. I had no intention of pursuing a doctorate, and realized that I could pursue a Master’s degree at about the same pace with a full-time job as with a teaching assistantship. Having developed an interest in microwave technology, I was most impressed with the course offerings at Brooklyn

Poly. Finally, I was anxious to do “real work,” and had very positive feelings about what I had seen at Wheeler Labs, as well as about the people I had met during the interviews.

I started work in July 1962. When I arrived on the first day, I met Bob Weigand, a classmate at Manhattan. Bob had our drafting textbook with him, which took me aback; I had barely passed drafting, and one of the attractions of electrical engineering was that I thought I wouldn’t ever have to do drawings or sketches. However, over the ensuing months at Wheeler, I became a passable drafter. Ironically, during the fall of 1964, I became a part-time instructor at C.W. Post, and the first course that I taught was Drafting. This proved to be a source of great amusement to the machinists at Wheeler Labs. Over the years, the training in drawing and testing that I received at Wheeler Labs proved invaluable, as I became involved in designing microstrip and stripline subassemblies.

My first assignment at Wheeler Labs was to measure intercardinal patterns for a multi-mode, multi-horn monopulse feed. I was supervised by Ed Magill, and was assigned to Dick Peritz’ Lab.

One of my early assignments was to perform loss circle measurements on an X-band mixer. Although this was a brief assignment, the material that I studied in the “Wheeler Monographs” helped greatly ten years later when I was performing millimeter mixer research and development at LNR Communications.

Another early assignment that was interesting was the design of a sonobuoy antenna for Hazeltine. It was a simple design; a length of wire was attached to the top of a flotation balloon, which inflated after impact with the water. Henry Bachman supervised the design, and sat down with me and performed a calculation of the expected impedance, based on the monopole impedance and the transmission line properties of the structure between the input connector and the base of the monopole. The measured impedance proved to be in close agreement with Henry’s calculation. Henry gave me a schedule, a budget and general direction. Although it was a simple design, it stands out as my most interesting assignment and one that stayed with me in defining a methodology for approaching a design.

I was peripherally involved in phased array simulator projects, ultimately transferring to Smithtown in late 1964. I was assigned to Bob Hanratty’s Sprint missile antenna project. Although the overall project was interesting, my role was basically confined to performing measurements and at this point, I felt that I needed more challenging assignments to grow.

I left Wheeler Labs in April 1965 to go to work for a microwave component company, Ramcor. Although I was given the opportunity to finish the design of a space-borne switch and manage its qualification testing, I did not care for the overall atmosphere of the company. In the fall of 1965, I left to accept a position in the Radar department at AIL. This proved to be an excellent move, as it permitted me to build on the base of practical experience gained at Wheeler Labs, and take on a variety of design projects under minimal supervision.

In the fall of 1968, I accepted a position at Varian's LEL Division. Though I initially performed product development of microwave integrated circuits on alumina substrates, the position eventually led to management opportunities. Next I accepted a position at Cardion, and spent a couple of years designing integrated receivers and transmitters for IFF and ILS products. In 1973, I was approached by LNR Communications through Egan Hasforth, a Wheeler Labs alumnus. During four years at LNR, I worked on a variety of interesting research and development assignments that principally involved low conversion loss mixers for the high microwave and millimeter bands. Here the fundamentals learned at Wheeler Labs proved invaluable.

Late in 1976, I received a call from Dick Frazita, who was then the Laboratory Head for Wheeler Labs, which had been integrated into the Hazeltine Research Laboratories. I met with Dick and Al Lopez and discussed a position that would focus on business development. This was of interest to me for two reasons. First, I had already determined that this was the area that I wanted to pursue as a career path. Second, I had recognized that the advances being made in FETs would soon make the ability to design low-noise mixers the latter-day equivalent of buggy whip design.

I rejoined Hazeltine in early 1977 and worked with Dick, Al and Ron Schineller to pursue prime contract and major subcontract R&D. Early in 1979, I was promoted to Laboratory Head, and subsequently to Associate Director of Research. My principal contribution was to recognize the wealth of talent in Wheeler Labs and to provide the atmosphere and opportunities for the Wheeler Labs' staff to grow professionally.

In 1985, I left Hazeltine to accept a position of Vice President at Satellite Transmission Systems, a California Microwave subsidiary, where I have remained.

Dick Flam

As a senior majoring in physics at Rensselaer Polytechnic Institute in the spring of 1963, it was a foregone conclusion that I would go on to graduate school, and so I missed out on the joys of job interviews in my senior year. Talking to my classmates, many of whom were electrical engineers, I heard strange and wonderful stories of plant trips. Of these, the two that stood out as memorable experiences were plant interviews at Bell Laboratories (which took two entire days) and at Wheeler Laboratories (which no one had ever heard of). The WL interview process made a terrific impression on the undergraduates. In particular, the thorough interview process, and the interesting characters that carried it out, led to many stories in the dorm. Two years later, when I decided to take a one-year leave of absence from the graduate physics department at Rutgers University, I went to the placement office to see where I might interview for an interesting job near my home on Long Island. The name Wheeler Laboratories popped out at me and brought back recollections of the stories I had heard earlier, so I signed up for a campus interview. A few weeks later, Frank Williams showed up to interview me. It was interesting because I was the only student who had signed up for an interview; I guess Frank decided that he needed a day out of the office.

When I was offered a job at the Smithtown Laboratory a few months later, I asked that I be relocated to Great Neck, as this was much closer to my home. Frank Williams replied in no uncertain terms that he wanted me at Smithtown, and that was where I would have to go. This was my introduction to the WL management style, even before I walked in the door.

During my interviews I got my first exposure to the WL staff. I particularly remember a technical interview given by George Knittel during which he asked me to explain some of my work in solid-state physics. While discussing electron dispersion curves in lattices (a subject about which I can remember almost nothing), he asked me to explain a particular phenomenon, and I proceeded to do so in great detail. During the ride back from Smithtown to Great Neck it occurred to me that the answer I had given was completely incorrect. However, I had delivered this wrong answer with such authority and confidence that George assumed I knew what I was talking about. As the saying goes, "Often wrong but never in doubt."

When I got to Wheeler Labs in the summer of 1965 the labs was at its peak. There were over 100 engineers working in Great Neck and Smithtown, and the total staff exceeded 200 people. I believe this was the absolute zenith in the history of the labs. Over the past twenty years, I have tried to avoid the conclusion that the decline of the labs was correlated with my arrival. When I arrived I knew almost nothing about microwaves and antennas. My academic background had stressed solid-state physics, x-ray diffraction and crystallography. Fortunately, this gave me an excellent grounding in much of the mathematics related to antenna design and microwave circuits. The key factor, however, was my immediate tutelage by a number of really outstanding teachers.

My first supervisor, working on the design of a new antenna for the SPG-55A fire control radar was Don Hastings. He was supervising Fred Engelking and myself in a very elegant design. Don was extremely patient and generous in introducing me to the mysteries of the Smith Chart. Unfortunately, he failed to warn me of the personal preferences that Mr. Wheeler had when it came to impedance charts. In my first technical meeting with Mr. Wheeler, I proudly presented the results of my impedance matching of a high power X-band horn on the traditional red Smith Chart paper. With obvious irritation, Mr. Wheeler flipped the page over and examined the locus through the back of the paper so that its rotation would correspond to the preferred (and obviously superior) Wheeler Chart. That was a mistake I never made again.

As a young engineer starting a career at Wheeler Labs there were opportunities to learn many things from many people. I am particularly grateful to Harry Redlien, who taught me a great deal about arrays, Pat Loth, who knew more than I ever wanted to know about waveguides, and Al Paskevich, who taught me that you really do need tolerances on a drawing. I also particularly enjoyed learning from Fred Van Davelaar, who taught me the correct way to enjoy myself while on a business trip.

Obviously, Mr. Wheeler was in a class by himself as a teacher. In retrospect, I think I made a very wise decision early on, when I chose not to try and hide my ignorance from Mr. Wheeler. Both he and I knew that he was much smarter than I was and so whenever Mr. Wheeler would present one of his intuitively obvious formulas (which was not at all obvious to me), I would always stop the proceedings and ask for an explanation. Mr. Wheeler was always extremely gracious in explaining to me where the formula came from and, if possible, in doing a simple derivation. I am pleased to report that during my eleven years of working with Mr. Wheeler, these explanations were required less often as time went by. Even today I find myself using techniques for analysis that I learned at Mr. Wheeler's conference table.

I have come to believe that one of the things that set Wheeler Labs apart was its corporate culture. There are a number of adjectives that come to mind when trying to describe my perception of just what that corporate culture was: demanding, professional, elitist, and also open, friendly, cooperative.

Clearly, the thing that made it all come together was the singular group of people that comprised the Wheeler Lab staff. I will say more about them later, but it was certainly not the physical facilities, the equipment, or the management policies that made Wheeler Labs what it was. It was a group of extremely smart, highly motivated engineers, all of who were extremely competent and interesting, and most of who were very nice people. The combination of this group of working engineers (and I was among the most junior of them at the time), together with the atmosphere created by the labs managers, created an excellent learning opportunity. It was a great way to learn how to deal with your peers, your customers and your profession.

When I first started at Wheeler Labs I worked (for about 18 months) on a number of interesting antenna development projects. Perhaps the most interesting of these was the feed for the 86-foot parabolic reflector antenna located in Woomera, Australia that we designed for the Collins Radio Co. of Dallas, Texas. This 16-foot diameter feed was used with the very high power Dazzle radar for early re-entry signature studies. As the junior engineer in the group, I got to do much of the most interesting design and measurement work (some of it laying on my back underneath the feed in the backyard). Unfortunately, I was the only engineer on the team who didn't take the trip to Australia to install the feed (which turned into a round-the-world sight- seeing tour by Harry Redlien and Fred Van Davelaar). For several years I would look wistfully at Harry's slides of the exotic places they had been and wish that I had had just a little more seniority.

In 1967, at my request, I was put into the optical group on the second floor of the Smithtown Lab. There, together with Don Wilmot and Ron Schineller, we did pioneering work on the development of optical waveguides, which has since turned into a field called "integrated optics." It is interesting that the Wheeler Labs group had the foresight to see that this was going to be an important technology, one made possible by the earlier invention of the laser. It is unfortunate that business circumstances forced us to abandon this effort in 1970, just as large- scale development was beginning to get underway. In the mid-1980s while visiting an Army laboratory I was shown a clever way of fabricating integrated optical circuits. My guide to the Army lab was shocked when I casually informed him that I was one of the co-inventors who held a patent on the process they were using. His alarm was significantly reduced when I informed him that the patent would expire within about a year. Obviously, we were way ahead of our time in the optical group at Smithtown.

After returning to work on antennas and microwaves in the early 1970s, interesting projects continued. After the layoff of 1970, I was the only WL engineer left on the AEGIS program. This was a major development being done for RCA to design a radar feed network that would subsequently be manufactured by Hazeltine in Greenlawn. Being the sole survivor, I was quickly forced to learn a lot of new disciplines including customer relations in a very stressful time.

On a Friday afternoon in October of 1970, I returned home from a business trip to Boston to be greeted at the front door by my wife, Ann, who looked somewhat shocked. Rumors had been flying around the lab for several weeks and based on one of them I asked if the Wheeler Labs dinner dance had been cancelled. Ann's interesting reply was that she had received a call from the lab earlier in the day and that indeed, Wheeler Labs had been cancelled. However, I was one of the engineers chosen to stay on to form the new antenna lab at Hazeltine. I will always be grateful that I was out of town and missed the horrible experience of the announcement of the closing of the labs. The transfer to Hazeltine Corporation went reasonably smoothly, and those of us who survived did a good job of keeping the Wheeler corporate culture intact as we moved into the wilderness of the new corporation. After a few months of being outsiders at Greenlawn, people throughout the company came to understand that we could be extremely useful, and it was pretty smooth sailing within Hazeltine until I left in 1976.

In 1976 I left Hazeltine to join American Electronic Laboratories, Inc. of Colmar, PA. The move was motivated partly by a desire to leave Long Island, which was becoming increasingly oppressive in terms of traffic and population density. In addition, it had become clear to me that antennas, my chosen field of specialization, would never be a mainstream area within Hazeltine Corporation. Therefore, I accepted a position as division manager for the Antenna Development Division at AEL, a company producing an extremely wide range of antennas for military applications. In addition to working on a wide variety of antenna development programs, my division, which grew to 23 people while I was there, supported the antenna aspects of system work being done at AEL. We also supported an extensive catalogue of standard products and the production of military antennas totaling more than 12,000 antennas per year.

In the spring of 1980 Sam Russell, who was an old family friend, approached me. Sam had sold his chemical engineering company the previous year and wanted to begin a new engineering company in a different field. He approached me with an offer I couldn't refuse: he would provide financial backing and business acumen for a new engineering firm that I would run. I would be free to pursue any area I wished. At this point the lessons learned and the culture acquired during my years at Wheeler Labs came to the forefront. In establishing Flam & Russell, Inc. in the summer of 1980, many aspects of the company were modeled after Wheeler Labs. Some of these things were procedural and not very important (vacation and sick time accrual schemes, job numbering systems, etc.). The more important thing was the real emphasis on providing excellence in whatever it was we chose to do. Initially, we put together a small staff of specialists in electromagnetics and became consultants on the Wheeler Labs model. This was the basis for establishing a company, but never the ultimate objective. One of the things that the collapse of 1970 had taught me was that a company must have a product line that can carry it through times that would not support an engineering consultancy.

Therefore, we soon embarked upon the development of products aimed at improving the ability to do antenna measurements. Fortunately, we began to develop computer-based measurement systems just as the personal computer was coming into existence. Good timing, good fortune and good engineering have led us to a position where we now dominate this niche market. In the mid-1980s we were also in the right place at the right time when stealth technology began to bloom as a widespread application of electromagnetics. Our measurement systems could be readily adapted to the measurement of radar cross section (RCS), and after developing four generations of systems we now produce more RCS measurement equipment than anyone else in the world. In looking at where my company and I have come, the impact of my background at Wheeler Labs is evident. In fact, I think I can fairly say that my career and my company have been influenced most by two people: Samuel T. Russell and Harold A. Wheeler.

One of the pleasures of my present job is that it allows me to travel and meet with a wide variety of people around the world working in the areas of antenna and RCS measurement. It is always a pleasure to meet with Wheeler Labs alumni. Some of these people left the labs before I came, so I know them only by reputation. Others were my contemporaries, and it is always a pleasure to meet with them and swap war stories. The one theme that shines through is the incredibly high level of competence and achievement shown by the Wheeler Labs alumni. Wherever you find them, they are in extremely responsible positions and are doing great things for the companies that employ them.

The WL reunion held in honor of Mr. Wheeler’s ninetieth birthday was a singular pleasure. It is remarkable that such a large group of people would gather from far and near to meet with old friends and honor a company that closed its doors in 1970, and to pay tribute to the man who created it.

Richard S. Biondi

I joined WL in 1965, after graduating from the City College of New York with a Bachelor’s degree in Electrical Engineering. I worked for just under six years as an electrical engineer, with five of those years at WL, and one year at another small company called Jasik Laboratories. Although six years is a pretty short time in terms of a career, I remember many things that I learned, and people that I met, and these had a major effect on my life afterward.

I met a lot of very intelligent and interesting people at WL. In addition to Mr. Wheeler, I remember learning from people with a large variety of interests and intellects. I remember working in a lab with Jerry Dorman, Richard Metrick, Jim Maune, Sid Arnow, Vince Mazzola and others, and being ever impressed by the multitude of ideas and interesting thoughts that would emerge. It was a very stimulating and creative environment.

I learned a number of things that really helped me in my later career. One characteristic that I noticed about Mr. Wheeler was that he seemed very careful about details. Technical letters, for example, had to be written very carefully, with thought given to the selection of each word. I remember us spending what seemed to be inordinate amounts of time writing technical letters before we got them to communicate exactly what we meant. I think that this practice really helped me in my career afterward, when communication skills were perhaps even more important and my peers and competitors did not share the discipline and experience I learned from WL.

I really enjoyed doing the technical work at WL in the creative environment that existed there. We felt, perhaps correctly, that we were among the brightest, most creative people in America. The problem, of course, was that although our compensation seemed good, at least for recent college graduates, the long-term economic opportunities for engineers in America were, and still are, rather limited and insecure. I still ask myself why we weren't as well compensated as, say, lawyers and investment bankers if we were really as bright and creative, and as necessary to America, as it seemed that we were. During my time at WL, there were several layoffs and nobody felt secure. Salaries were good initially but they tended to plateau quickly, while for other professionals like accountants or lawyers, there seemed to be more opportunity.

I was laid off by WL in November of 1970. There were several other layoffs at WL before, and certainly many at other companies that I had heard about. I remember the horrible environment when everyone would worry that they would be called into their boss's office to be told the bad news. We would watch while the office doors were closed and our friends and associates were being given the bad news.

After I was laid off, I was very disillusioned with engineering. I did try to find another engineering job, and I did obtain an offer rather quickly, although the salary offered was below what I had been earning. This annoyed me and, rejecting that offer, I decided to change professions. A friend of mine had a job as an actuary, specializing in property-casualty insurance, and I spoke to him about the possibility of entering that profession.
With my friend's help I did manage to get a job as an actuary at the same company that he worked at, a fairly large firm called Insurance Services Office located in lower Manhattan in New York City. Insurance Services Office was a "Rating Bureau," which was an organization that collected and analyzed insurance data to compute insurance rates, which it published in rate manuals. It then sold these rate manuals to insurance companies.

The job as an actuary at Insurance Services Office was appealing to me because I had always been interested in math, and I thought I could succeed in any job that required a math background. In contrast to engineering where we were working on radar and other projects which appeared interesting, actuarial work seemed like it would be really boring, and for that reason I felt the competition would be much less keen as an actuary than as an engineer.

I also considered the idea that even though actuarial work appeared boring to someone who didn't know anything about it, in reality it probably wasn't any more or less boring than many engineering jobs. I had come to realize that some engineering jobs could be boring also, even though they applied to interesting projects like large phased array antennas. I remembered engineers doing what appeared to be repetitive slotted line measurements, testing a multitude of geometric structures.

As it turned out, I was lucky to get the job at ISO. They were reluctant to hire ex-engineers, because they were concerned that I would return to engineering once the market improved. With my friend's help, plus a prospective boss who was Italian and wanted to hire someone with an Italian surname, I managed to get a job. I worked there just over 15 years and left as a manager of a department containing about 30 actuaries and technical support people. It took me nine years to pass all of the actuarial exams, although after two and one half years I was earning more than I had earned at WL.

In 1986, I left ISO to join a large actuarial consulting firm, which is where I work today. I recently became a full partner in the firm and I run my own practice providing actuarial consulting services to insurers and also to state regulatory authorities.

Looking back I see that in many ways, the work that I am doing as an actuary is not all that different from what I was doing as an engineer. (I even worked on a project several years ago evaluating the potential for liability insurance claims against radioactive waste disposal sites, in which I worked very closely with engineers.) The thought processes are similar, although the problems are different. There are some interesting differences between the two professions and I think that in some respects, engineers could learn from actuaries.

I really am a strong believer in the process whereby each actuary starts out as a student (after graduating from college with, typically, a Bachelor's degree in math) and must pass a set of actuarial examinations before that person is given professional accreditation. I think there are three advantages to this exam process. First, it fosters a tendency for actuaries to become generalists rather than narrow specialists, while engineers, at least while I was an engineer, are encouraged to become narrow specialists. The actuarial exams, while they all deal with insurance, deal with all aspects of the insurance business.

Electrical engineers, on the other hand, were (and perhaps still are) encouraged to specialize in one of the large number of sub-specialties within electrical engineering. Microwaves is one such specialty and I'll bet that there are many, perhaps hundreds, of sub-specialties within the purview of microwave engineers. I recall the IEEE as a very large organization with many subdivisions for each specialty.

The disadvantages of specialization to engineers from an economic perspective are obvious. It becomes extremely difficult for an engineer who has become expert in a technically challenging but obscure specialty to find another job if he is laid off. Such a person must worry also that his specialty will become obsolete, given the ever-changing technology. This is a serious problem that could, at least in part, be solved by providing broader formal training to engineers so that they could change roles more easily when the market demands it.

Another advantage of the system of formal actuarial exams to actuaries is that the exams provide accreditation to actuaries. Electrical engineers, at least when I was one, didn't have any formal accreditation other than a college degree and I heard of some so-called engineers who didn't even have college degrees (not at WL). There are a variety of tasks which actuaries perform, such as opining on the liabilities of insurance companies, which legally can only be done by a qualified actuary who has passed the actuarial exams. Thus, employers cannot save money by hiring less qualified people to do these tasks. This is helpful to all actuaries because (1) it keeps the profession from being flooded with less-qualified people and (2) it enhances the reputation and value of actuaries because people who hire actuaries with credentials know that they have had substantial formal training.

A third advantage of the actuarial exam system (and a main reason why I decided to become an actuary) was that a large measure of salary advancement and promotions are based on exam performance. This is good because it makes the selection process for promotions more objective, that is, less based on favoritism and office politics. It also guarantees, to people who can pass exams quickly, a minimum rate of salary advancement. Finally and perhaps most important, it guarantees that the people who become accredited actuaries after passing all of the exams have a minimum level of intelligence and competence. I believe that this guarantee of competence makes actuaries much more valuable to employers and clients than they would be without the exam system.

I don't know of any legally prescribed standards of professional conduct for electrical engineers. I also haven't heard of any mechanism whereby electronic engineers are ever disciplined for improper professional conduct. I have read of situations where important and expensive projects appear to have been badly engineered (e.g. telescope mirror in space station), yet I never heard of any engineers who were held accountable for these failures. It seems as if there should have been more professional accountability.

When I worked as an electrical engineer, we tended to focus on physical problems and interacted with other engineers and scientists, but not too much with other professionals such as lawyers, accountants, physicians, etc. As an actuary, especially as a consultant, I find that much more of my job involves interaction with these other professionals, since most of my client contacts are lawyers, accountants or physicians. Working with these different professionals adds a fascinating dimension to my work that didn't seem to be a part of my work as an engineer (although I suspect that some engineers work quite a bit with lawyers—perhaps more than they would wish to).

Perhaps it is true that engineers tend to define their role too narrowly, focusing on physical problems of interest to engineers. Many engineering problems have great social and political implications (e.g. designing weapons systems), yet the social and political issues are often considered to be the purview of other professionals.

Having worked in both the actuarial and engineering professions, I find it interesting to contrast the two. I may be way off base with respect to engineering, since I only worked as an engineer for a six-year period almost 25 years ago. It may be that I never really got a full perspective of what engineers do and/or things may have changed a great deal in the last 25 years; on the other hand, if my perceptions have any degree of validity, then perhaps these observations might be of some interest to the reader.

Richard J. Kumpfbeck

I started my professional career at Wheeler Laboratories (WL) in Great Neck, New York upon graduation from college in June 1966. I have been continuously employed since 1970 at Hazeltine Corporation, which in that year absorbed Wheeler Laboratories into its Research Laboratories (now called the Advanced Development Center); the Wheeler Laboratory name was preserved. Presently, my position is Laboratory Head, and the Wheeler Lab group now consists of 17 persons.

Though I began my professional career at WL in 1966, my first encounter with the Labs came many years earlier; here's the story...

I was born in New York City on June 25, 1944. My family moved several times before I was six years of age. In 1950, we moved from Queens to Great Neck, Long Island where, during my school-age years, we lived in three different homes, all within a few miles of one another. I mention this because it was in 1950 that I was first introduced to the name "Wheeler Laboratories." It turns out that our new home in 1950 was at 18 Ipswich Avenue, a dead-end residential street off Cutter Mill Road, just one block away from Wheeler Laboratories, at 122 Cutter Mill Road. During the summers of the early 1950s, my sister Nancy and I used to walk to summer camp, which was located not far south of where Cutter Mill Road crossed over the Long Island Railroad, and so we would walk directly in front of the Wheeler Laboratories building. I ask myself why I remember that and what it was that made such a lasting impression; it was the very green, consistently well-manicured front lawn!

Being an auto enthusiast even during my childhood, I remember well the Flying A gasoline and service station immediately adjacent to WL at which my grandfather always got his 1953 Chevrolet convertible serviced. In 1956 my family moved to another location in Great Neck, and I had virtually no further contact with, or thoughts of, WL until my senior year in college.

I attended St. Aloysius grade school and St. Mary's High School in Manhasset, the neighboring town, through 1962. My college of choice was Manhattan College, and I graduated in June 1966 with a BEE degree. After graduation I started work at WL and attended evening classes at the Farmingdale, Long Island campus of Brooklyn Polytechnic Institute, from which I received my MSEE in 1971.

During my senior year at Manhattan, I interviewed with several companies. Since I was near the top of my class, I could work wherever I chose. I received offers from Bell Laboratories, IBM, AIL (Airborne Instrument Laboratories), and WL. At the time Bell Laboratories had plans to move to the Chicago area, which I didn't favor. At IBM there was no military deferment possible, so I declined that opportunity. The offer that I received from AIL was quite a bit lower than from others at $6,750 per year, while Bell Labs and IBM offered $8,400; WL offered $9,000 per year.

My interview at WL was of the standard format—two technical interviews, lunch, and a tour of both the Great Neck and Smithtown facilities. My first interview was with Ned Spencer, and I remember that he seemed to be particularly interested in a new (to me) network stability analysis technique called "root locus," which I had recently studied in school; we discussed this for quite some time. Some time after the interview, I received an offer for employment. Before I accepted, I asked to revisit the Great Neck Laboratory to discuss in more detail the nature of work to which I would be assigned. Frank Williams invited me to discuss this issue, and we did; after that, I accepted the offer.

My first week of employment started the last week of June 1966, the week of my 22nd birthday, at the Great Neck Laboratory. I was assigned to work at this location until just before it closed in 1969. During those early years at Great Neck, I had the need to travel to the Smithtown Laboratory only on rare occasions. The Great Neck Laboratory made a lasting impression on me, as will be seen in the following paragraphs, which describe my recollections of the period between 1966 and 1968. I hope these will bring back fond memories for those of you who were there.

The Great Neck Laboratory at 122 Cutter Mill Road was a two-story masonry building with a full basement, approximately 80-foot square in size. The first floor contained a secretarial area in the front, and three moderately large rooms and one smaller room where most of the engineers had their desks. Each of the rooms was numbered; the three large rooms were called Labs 14, 15, and 16. The rest rooms and a copier machine were on the first floor as well. On the second floor in the front were the offices of Frank Williams, the Chief Engineer, and Harold Wheeler. The remaining area contained the accounting offices where August Belfiore and Alden Wheeler worked, a large conference room, and another lab. The basement, which was at ground level in the rear, contained Bob Mehling's model shop, Bill Zahn's maintenance area, Charlie W.'s photo lab, and an open area where antenna pattern measurements were performed. The rooftop also was used occasionally for antenna testing. It was serviced by an outside stairway on the north side of the building that was easily accessed through a doorway in Lab 16, adjacent to my desk.

On a few occasions, I used the rooftop for antenna impedance measurements. This was sort of interesting because from the roofs I could see the entire neighboring area, which was, of course, quite familiar to me. During those early years at Great Neck, I spent many, many days in the basement measuring antenna patterns. This indoor range was actually a reconfigurable anechoic chamber! The walls of the "chamber" were implemented using absorbing panels on wheels to allow custom antenna range configurations. Each panel consisted of a number of absorbers that fit into a wooden frame about 3 feet wide and 6 feet tall. I remember well carefully placing and tilting each individual panel to reduce specular reflections in order to achieve acceptable pattern range performance.

The rooms or labs, besides housing all of the engineers, also contained workbenches for test setups. Each lab had a room supervisor. I was assigned to Lab 16; Pat Burgmyer (formerly Loth) was the room supervisor. Lab 16 also housed the Drafting department, comprising two draftsmen. Others that I recall in Lab 16 were Len Steffek, my first mentor, Walter Mohuchy, Mario Napolitano, and Joel Carpet. Lab 15 had George Vaupel as room supervisor; the technician area was contained within this lab as well. Other engineers and room supervisors in that time period that I recall were Bob Puttre, Manny Balfour, Ed Pinck, Dick Peritz, Jerry Dorman, Herman Heinemann, Stu Litt, and Richie Metrick.

One thing that I learned in Lab 16 was how to write weekly progress reports. Each room supervisor required these hand-written reports at the end of each week. My fellow lab-mates told me to be sure that each report contained at least one English grammar mistake. You see, Pat Burgmyer, in addition to having a technical degree, also had expertise in English grammar. Therefore, a grammatical error or two would draw her attention and lessen her focus on the content of the report!

While thinking of humorous occasions in my early years in Great Neck, several always come to mind. The first involves the Lab 15 supervisor, George Vaupel. George had a habit of leaning way back in his chair when reading, such that when his phone rang, substantial body movement and repositioning was necessary to reach the telephone receiver. Upon observing this, one of the clever engineers implemented a switch on George's chair so that when he leaned way back, the switch would close and the phone would ring. Of course, when he reached for the phone, the ringing would stop, and no one was on the line. As I remember, this switch was remotely activated, and this practical joke was carried out many times before he caught on.

Another practical joke involved an engineer, whose name I can't recall, who always ate his lunch in a methodical manner over a certain time period during the lunch hour. He gauged the speed of his activity by occasionally glancing at the wall clock. Several of us decided to see if we could alter his timing by speeding up and slowing down the wall clock by his desk using other than 60-cycle ac power. We did this, and it worked; we could actually alter the speed at which he ate his lunch. He finally discovered something was wrong, and we all had a good laugh.

And of course, who could forget Herman Bilenko, who in those early days didn't have a car or a driver's license; he rode to work on his bicycle. In fact, he went everywhere on his bicycle. I remember that several times his project required travel to the Smithtown Laboratory. Yes, he rode his bicycle, a significant trip approaching 40 miles. On his travel expense reports he didn't include the customary and allowable mileage charge but did include an amount for food expenses; he argued, you see, that while cars need gas, he needed food to fuel his body for the trip. Herman was quite a character and a brilliant person.

My primary project in my early days in Great Neck was the development of a high power feedhorn for a large space-fed phased array. Len Steffek was my supervisor on the project. The feedhorn was used for a pressurized waveguide system and utilized a two-skin alumina window at the aperture. This effort required many diverse activities that included impedance matching, materials selection and evaluation, thermal considerations, radiation pattern measurements, and peak and average high-power testing. I learned a lot in a short time; the work was exciting and challenging.

The most memorable part of this project was the actual high-power testing. I performed high-peak-power testing at the Cornell Laboratories (CAL) in Buffalo, NY, and peak and average power testing at Raytheon in Wayland, MA. Both of these test activities involved air travel, a first for me. The tests at CAL used a very high-peak-power pulsed transmitter, with the test waveguide and feedhorn pressurized with sulfur hexafluoride. The waveguide ran through an opening in the building, and the feedhorn was outside, radiating into free space. We used a radioactive source positioned near the aperture to assure correct measurement of peak-power breakdown level.

The resonant ring testing at Raytheon was most exciting. I spent many weeks at Raytheon with Jim Makahon, a WL technician. The DC and RF power sources occupied a space equivalent to several large rooms; the resonant ring itself was in a large open area. The waveguide was all water-cooled. Peak power levels of nearly 100 MW and average power levels of over 2 MW were generated. After some design iterations, a successful design was achieved.

During my early days at WL, most development efforts included discussions with Mr. Wheeler both for technical guidance and to achieve a better theoretical understanding of the subject matter. Many times these discussions went off on several tangents; this was very useful and helped me broaden my understanding of related principles. I remember that many of the engineers, young and not-so-young alike, commented about the concise, and sometimes cryptic, style that Mr. Wheeler utilized to present or discuss most topics. One example of this is a report that I have and still use frequently. Every time I reference it, I'm amazed at its conciseness; I'm referring, of course, to WL Report 665, entitled "Impedance Tests of Single or Coupled Resonators," which is reprinted at the end of my recollection. Oh, don't worry, it's only two pages (four sides) long!

During 1968 and early 1969, the WL facilities were consolidated, and the Great Neck Laboratory was vacated. By 1969, all employees were at the Smithtown facility. To accommodate the extra personnel, a set of trailers was positioned adjacent to the building; this arrangement worked out fairly well. For me, the relocation to Smithtown was timely in that I moved from Great Neck to Huntington in April 1968. After about two very exciting years at Smithtown, defense business encountered a cyclical downturn; and in 1970, Wheeler Laboratories, as I had come to know it, ended. It was a sad day in November when two-thirds of the staff moved to Hazeltine's (then new) engineering building in Greenlawn, along with Hazeltine's Research Laboratories, which had also been recently relocated from Plainview.

I remained at Hazeltine during the long, hard years of the 1970s and the growth years of the 1980s. During that time, there were always challenging assignments, and I made a number of meaningful technical contributions. I also had the special honor of working closely with and obtaining guidance from Mr. Wheeler throughout all the years, up until his retirement in the late 1980s.

Throughout the 1970s and 1980s, we used the Smithtown facility as our antenna range; it was, of course, a key part of our capability. Hazeltine sold the Smithtown property in the late 1980s and vacated the antenna range in September 1992. In preparation for that divestiture, we designed and had constructed a new, modern antenna test facility that we called the Communications and Antenna Systems Laboratory (CASL). The new laboratory, which became operational in 1992, was dedicated to Mr. Wheeler in April 1993.

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IMPEDANCE TESTS OF SINGLE OR COUPLED RESONATORS

by Harold A. Wheeler

A line is terminated in a single resonator or a coupled pair of resonators. The terminal impedance locus is measured by SWR in the line and is plotted on a reflection chart. Certain points on the plot are identified and are used to compute the power factors of the resonators and of the line loading, and the coefficient of coupling. Any one of these may be found directly by observing certain frequencies on the locus.

p_1 = (unloaded) power factor of primary resonator
p_1' = loading power factor of primary resonator
p_1'' = $p_1' + p_1$ = loaded power factor of primary resonator
p_2 = power factor of secondary resonator
k = coefficient of coupling between primary and secondary resonators
k_x = apparent coefficient of coupling at crossover of loop in locus
g = normalized conductance (scale on axis of chart)

Each pair of points marked on a locus corresponds to a pair of frequencies (f_+ , f_-) such that

$$\text{the indicated } p \text{ or } k = \frac{f_+ - f_-}{f_o} \quad (1)$$

Relations for coupled circuits: (Fig. 3)

$$k^2 = k_x{}^2 + p_2{}^2; \quad (2)$$

$$(p_2 / k)^2 = \frac{g_x - g_1}{g_o - g_1} \quad ; \quad (k_x / k)^2 = \frac{g_o - g_x}{g_o - g_1} \quad (3)\ (4)$$

Determine p_2 directly by upper dotted circle.
Determine k directly by lower dotted circle, if there is a loop and crossover: $p_2{}^2 < k^2$.

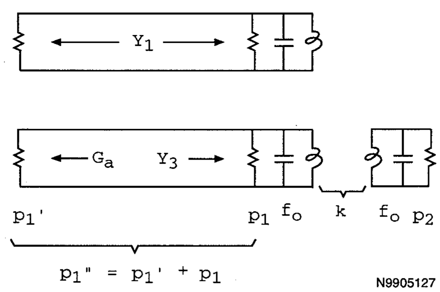

Fig. 1 - The circuit of a line and single or coupled resonators.

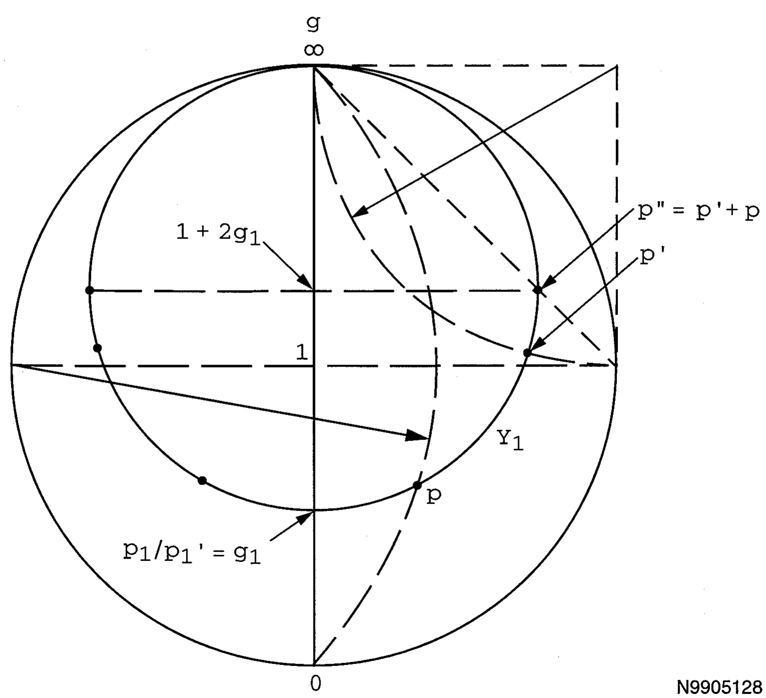

Fig. 2 - The reflection chart of single resonator.

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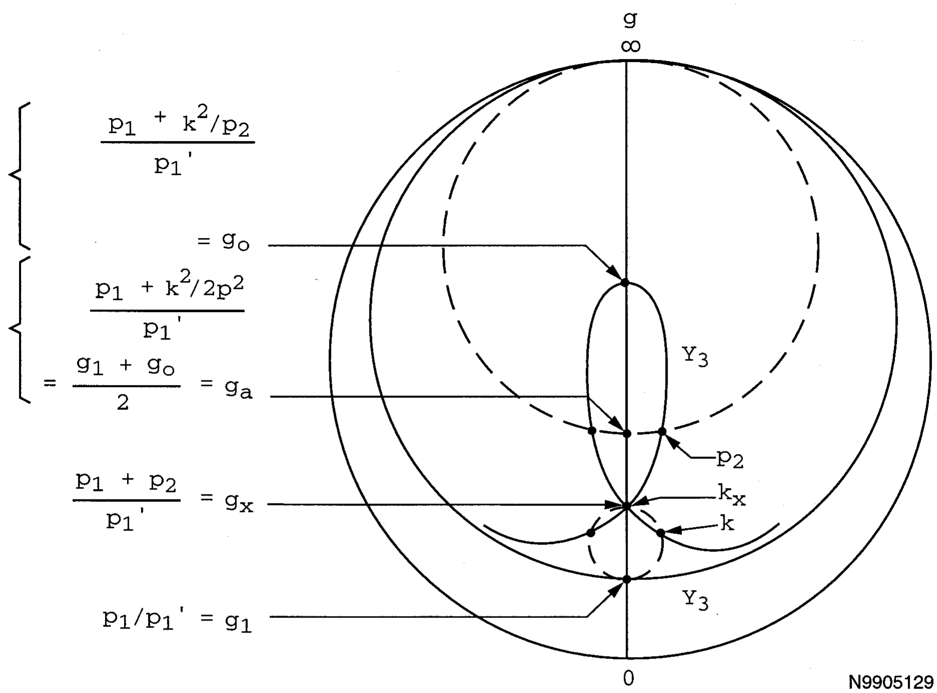

Fig. 3 - The reflection chart of coupled resonators.

Preferred procedures are as follows.

Weak coupling (no loop): $k^2 < p_2^2$.
Compute p_1' for primary.
Note g_1 and g_o ; draw dotted circle through g_a ; compute p_2 by (1);

$$k = \sqrt{p_1' p_2 (g_o - g_1)} \tag{5}$$

Moderate coupling (small loop): $p_2^2 < k^2 < 2p_2^2$
Evaluate p_2 as above.
Draw dotted circle through g_1 and g_x; compute k by (1).

Strong coupling (large loop): $2p_2^2 < k^2$
Compute p_1' for primary. Note g_1 and g_x ;

$$p_2 = p_1'(g_x - g_1) \tag{6}$$

At crossover, compute k_x by (1);

$$k = \sqrt{k_x^2 + p_2^2} = k_x \sqrt{\frac{g_o - g_1}{g_o - g_x}} \tag{7}$$

The latter formula for k does not require p_1' but does require g_o.

Instead of computing p_2 before k, the following procedure gives p_2 after k ; it is most useful if p_2 is so small it is difficult to measure directly: After determining k by lower dotted circle,

$$p_2 = \frac{k^2}{p_1'(g_o - g_1)} \tag{8}$$

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NB 68, p. 27-34. Also see J-323.
J-102
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John F. Pedersen

It's approaching 25 years since I first heard of the company Wheeler Laboratories. In 1969, I was in my last semester at CCNY, enrolled in a new microwave theory course being taught by the inspirational Professor Brown. He keyed my interest in microwaves. That spring, Wheeler Laboratories was one of the first companies to interview at CCNY, and I signed up for an interview after finding out their field of specialty; WL was to become my first interview. I recall that prior to the interview, one of the graduate students advised me that I was wasting my time since WL gave tough interviews and made very few, if any, job offers. I ignored the advice and went to the on-campus interview given by Sid David.

A week later I was at Great Neck, where R. Camisa gave a tour and sent me out to Smithtown. At Smithtown I was interviewed by Stu Litt. I went to lunch with Richie Kumpfbeck in his old Chevy; sprawled on the floor in front of the passenger seat were a load of car parts that I had to straddle. I was relieved that the interview was over and ready to enjoy my lunch when Richie told me that a second interview was planned for the afternoon. Al Lopez gave me the afternoon interview. Though I had mixed feelings about how well I answered the questions, about two weeks later I received a job offer that, incidentally, was higher than the offers my classmates were getting from other companies. I made up my mind on the spot to accept the offer, although I went to several other interviews for the experience.

I started work at Smithtown in June 1969. My first project was matching a horn and running computer cases for ARL used in the CPCT demonstration. My second assignment was the paper design of a radiation hazard monitor for the PAR site under H. Heinemann's direction. After a brief time working at Sperry, I returned to WL as part of Hazeltine's Research Lab. Since then I have worked on a variety of antenna projects, from MLS to the hybrid scan array antennas. Clearly, the diversity of the antenna assignments has been one of the many pluses of working at WL.

I'd like to express my gratitude to the senior technical staff at WL who had not only patience, but a keen understanding of how to teach new engineers. I can't imagine a better company to have spent my engineering career.