ESTIMATING POWER DENSITY ABOVE RUNWAYS WITH COMPLEX CENTERLINE PROFILES

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I. INTRODUCTION

A method, which has special application to the Microwave Landing System, has been developed for estimating power density above runways with complex centerline profiles. The method uses a building block approach where the fundamental flat ground model is augmented with factors which account for the attenuation attributed to the particular centerline profile features. This paper is actually a sequel to the paper "Application of Wedge Diffraction Theory to Estimating Power Density at Airport Humped Runways" [1]. Application of a single wedge surface, as described in the above paper, proved to be adequate for estimating power density at several airport runways. However, at several other runways the centerline profile complexity was such that the single wedge surface proved to be inadequate.

II. THE WEDGE FACTOR METHOD

The above referenced paper has shown that if the receiver is near or in the shadow region then the power density can be expressed as a product of the flat ground power density and a wedge factor. For the case of multiple wedges, diffraction from the first wedge excites the second wedge which in turn excites the third wedge and so on. A simple method for estimating the power density in the shadow region is to compute the flat ground case and multiply the result by a factor for each applicable wedge. Figure 1. presents the basic concept. An example is given below for the case of Denver Runway 17R (see Fig. 2) with the receiver 10 ft above the threshold. The wedge factors 1,2 and 3 can be determined by locating the transmitter at heights of HT, 1 and 1 ft. above points 0, 1 and 2 and the receiver at heights of 1, 1 and 10 ft. above points 2, 3 and 4. respectively, and executing the Figure 4 program for the actual and flat ground cases for each of the three wedges.

		Transmitter MSL (ft)		
Factor	Units	5293	5295	5298
Transmitter power	dB W	13	13	13
Antenna gain	dB	8	8	8
$4\pi/\lambda^2$	dB $1/m^2$	35.5	35.5	35.5
$(HT/R)^2$	dB	-65.1	-63.0	-60.5
$(HR/R)^2$	dB	-62.1	-62.1	-62.1
Wedge No. 1	dB	-14.0	-13.0	-10.8
Wedge No. 2	dB	-11.9	-11.9	-11.9
Wedge No. 3	dB	12.0	12.0	12.0
Power density	dB W/m^2	-84.6	-81.5	-76.3

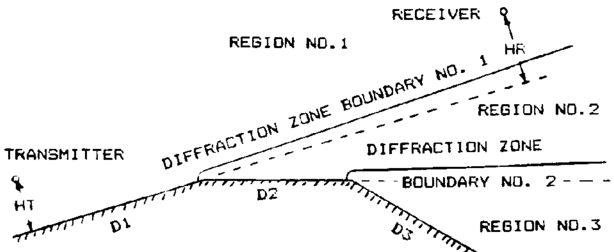
It should be noted in the table above that the Wedge No. 3 factor is positive. This is because the wedge angle is inverted (i.e. a concave surface). The computer program presented in [1] is modified as indicated in Figure 4 to handle this special case (lines with numbers that do not end with 0 are new; lines 590 and 600 have been changed). Continuous plots of power density versus height above threshold (see Figure 2) where obtained by locating a source above Point No.2 such that the power density was equal to the value computed for the receiver at the 10 ft height. This height was then used as input to the computer program (Figure 4) to generate the plots.

Measurements were made by a team of FAA and Hazeltine personnel at Denver during the period Dec. 7-11, 1987 [2]. A sample of the measurement results are shown in Figure 3. Included are estimated points based on the method presented above. Good agreement is observed.

REFERENCES:

1. A.R. Lopez, "Application of Wedge Diffraction Theory to Estimating Power Density at Airport Humped Runways", IEEE AP Trans., Vol. ap-35, No. 6, June 1987.

2. J.D. Jones, "MLS Signal Strength Measurements and MLS Mathematical Modeling of Runway 17R Hump at Denver Colorado Stapleton Airport", FAA Technical Center Report CT-140-88-9, May 1988.



REGION NO.	POWER DENSITY	
1	$P1 = P*G*(4\pi/\lambda^2)*(HT/R)^2*(HR/R)^2$	, $R=DI+D$
2	$P2 = P1*A1$	, $R=DI+D2+D$
3	$P3 = P1*A1*A2$	, $R=D1+D2+D3+D$

WHERE: P = TRANSMITTER POWER
G = TRANSMITTER GAIN
λ = FREE SPACE WAVELENGHT
D = DISTANCE ALONG EXTENDED WEDGE SURFACE'
A1 = WEDGE NO.1 ATTENUATION FACTOR
A2 = WEDGE NO.2 ATTENUATION FACTOR

FIGURE 1. ESTIMATING POWER DENSITY ABOVE RUNWAYS WITH COMPLEX RUNWAY CENTERLINES

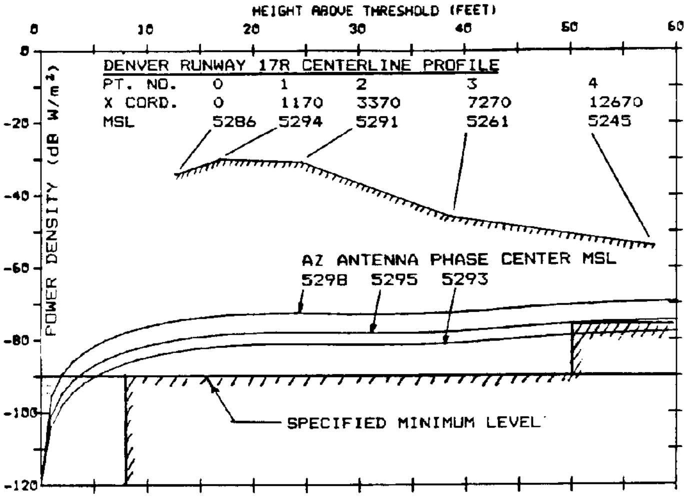


FIGURE 2. COMPUTED POWER DENSITY ABOVE THRESHOLD (POINT NO.4) OF DENVER RUNWAY 17R

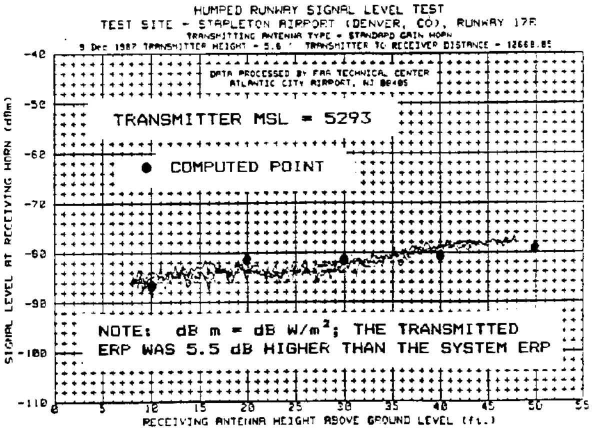


FIGURE 3. COMPARISON OF MEASUREMENTS AND COMPUTATIONS

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100 DATA 2,0,4000,10,8000,0,.2,13,8,1.215
110 READ ZT,Z1,X2,Z2,X3,Z3,WL,DBW,DBG,VPF
120 INPUT "RECEIVER COORDINATES X,Z = ";XR,ZR
130 PI=4*ATN(1)
140 THETA1=ATN((Z2-ZT)/X2)
150 D2=SQR((ZR-Z2)^2+(XR-X2)^2):D1=SQR((Z2-ZT)^2+X2^2)
160 D3=SQR((ZR-ZT)^2+XR^2)
170 ALPHA=ATN((Z2-Z1)/X2)-THETA1
180 BETA=ATN((Z2-Z3)/(X3-X2))+THETA1
190 ZI=Z2-D1*SIN(2*ALPHA+THETA1):XI=X2-D1*COS(2*ALPHA+THETA1)
200 ZI2=Z2+D1*SIN(2*BETA-THETA1):XI2=X2-D1*COS(2*BETA-THETA1)
203 ZI3=Z2+D1*SIN(2*BETA+2*ALPHA-THETA1):XI3=X2-D1*COS(2*BETA+2*ALPHA-THETA1)
210 D4=SQR((ZR-ZI)^2+(XR-XI)^2)
220 D5=SQR((ZR-ZI2)^2+(XR-XI2)^2)
224 D6=SQR((ZR-ZI3)^2+(XR-XI3)^2)
230 PHE=ATN((ZR-ZT)/XR)-THETA1
240 IF XR>X2 THEN GAMMA=ATN((ZR-Z2)/(XR-X2))
250 IF XR<X2 THEN GAMMA=ATN((ZR-Z2)/(XR-X2))+PI
260 IF XR=X2 THEN GAMMA=PI/2
270 THETA=GAMMA-THETA1
280 W=VPF*PHE*45/ATN(1):GOSUB 650:V1=1+.8*TANH
290 PHE2=ATN((ZR-ZI)/(XR-XI))-THETA1-2*ALPHA
300 PHE3=ATN((ZR-ZI2)/(XR-XI2))+2*BETA-THETA1
304 PHE4=ATN((ZR-ZI3)/(XR-XI3))+2*BETA+2*ALPHA-THETA1
310 W=VPF*PHE2*45/ATN(1):GOSUB 650:V2=1-.8*TANH
320 W=VPF*PHE3*45/ATN(1):GOSUB 650:V3=1-.8*TANH
324 W=VPF*PHE4*45/ATN(1):GOSUB 650:V4=1+.8*TANH
330 D3P=D1*2*(SIN(PHE/2))^2+D2*2*(SIN((THETA-PHE)/2))^2
340 D4P=D1*2*(SIN(PHE2/2))^2+D2*2*(SIN((THETA-2*ALPHA-PHE2)/2))^2
350 D5P=D1*2*(SIN(PHE3/2))^2+D2*2*(SIN((THETA+2*BETA-PHE3)/2))^2
354 D6P=D1*2*(SIN(PHE4/2))^2+D2*2*(SIN((THETA+2*BETA+2*ALPHA-PHE4)/2))^2
360 SN1=SGN(THETA):IF SN1=0 THEN SN1=1
370 SN2=SGN(THETA-2*ALPHA):IF SN2=0 THEN SN2=1
380 SN3=SGN(-THETA-2*BETA):IF SN3=0 THEN SN3=1
390 SN4=SGN(-THETA-2*ALPHA-2*BETA):IF SN4=0 THEN SN4=1
400 E1R=(D1+D2)*V1*(.5+.5*SN1)*COS(2*PI*D3P/WL)/D3
410 E1I=(D1+D2)*V1*(.5+.5*SN1)*SIN(2*PI*D3P/WL)/D3
420 E2R=(D1+D2)*V2*(.5+.5*SN2)*COS(2*PI*D4P/WL)/D4
430 E2I=(D1+D2)*V2*(.5+.5*SN2)*SIN(2*PI*D4P/WL)/D4
440 E3R=(D1+D2)*V3*(.5+.5*SN3)*COS(2*PI*D5P/WL)/D5
450 E3I=(D1+D2)*V3*(.5+.5*SN3)*SIN(2*PI*D5P/WL)/D5
452 E4R=(D1+D2)*V4*(.5+.5*SN4)*COS(2*PI*D6P/WL)/D6
454 E4I=(D1+D2)*V4*(.5+.5*SN4)*SIN(2*PI*D6P/WL)/D6
460 D=D1*D2/(D1+D2)
470 FOR K= 1 TO 4
480 IF K=1 THEN THET=THETA:SN=SN1:GOTO 520
490 IF K=2 THEN THET=THETA-2*ALPHA:SN=SN2:GOTO 520
500 IF K=3 THEN THET=-THETA-2*BETA:SN=SN3:GOTO 520
510 IF K=4 THEN THET=-THETA-2*ALPHA-2*BETA:SN=SN4
520 V=2*PI*SQR(D/WL)*SIN(THET/2):V=ABS(V)
530 IF V=0 THEN E3R(K)=.5:E3I(K)=0:GOTO 580
540 W=V:GOSUB 650:TANH1=TANH
550 W=V/2.4:GOSUB 650:TANH2=TANH
554 IF V<.00001 THEN E3R(K)=.5*SN*COS(PI*TANH2/4):GOTO 564
560 E3R(K)=(TANH1/2/V-V*EXP(-1.5*V)/4)*SN*COS(PI*TANH2/4)
564 IF V<.00001 THEN E3I(K)=.5*SN*SIN(PI*TANH2/4):GOTO 580
570 E3I(K)=(TANH1/2/V-V*EXP(-1.5*V)/4)*SN*SIN(-PI*TANH2/4)
580 NEXT K
590 ER=E1R-E2R-E3R+E4R-E3R(1)+E3R(2)+E3R(3)-E3R(4)
600 EI=E1I-E2I-E3I+E4I-E3I(1)+E3I(2)+E3I(3)-E3I(4)
610 P=(ER^2+EI^2)/4/PI/(D1+D2)^2
620 IF P=0 THEN DBP=-1000 ELSE DBP=10*LOG(P)/LOG(10)
630 DBWM2=DBP+DBW+DBG+10.3
640 PRINT "X = "XR,"Z = "ZR,"DB W/M^2 = "DBWM2:END
650 IF W>10 THEN TANH=1:GOTO 680
660 IF W<-10 THEN TANH=-1:GOTO 680
670 TANH=(EXP(W)-EXP(-W))/(EXP(W)+EXP(-W))
680 RETURN
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FIGURE 4. REVISED HUMPRWY PROGRAM, INVERTED HUMP CAPABILITY