PREDICTION OF RAIN ATTENUATION ON EARTH-SPACE PATHS

H.J.Li and G.F.Zhang

Wuhan University, Peiole's Republic of China

1. INTRODUCTION

In order to obtain the semiempirical model which can be widely used in predicting rain attenuation along earth-space paths operating above 10GHz, it is necessary to study the spatial structure of rainfall and to analyse the experimental data of rain attenuation. On the basis of the property of rainfall obtained by using meteorology radar[1][2] and according to the experimental results of rain attenuation measured at the Radiowave propagation Laboratry of Wuhan University, we proposed the semiempirical model for prediction of rain attenuation along earth-space paths, called WTD model. Using WTD model and CCIR model respectively, we calculated the attenuation due to rainfall on eighteen earth-space links in Japan, the United states, France and Norway experimental results of which have been published in the report of CCIR[3] and two links in Wuhan China. The results of attenuation and the prediction accuracy are given in this paper.

2. SPATIAL DISTRIBUTION OF RAIN INTENSITY

On the basis of the results measured by rain gauge and radar, we suppose that the horizontal and vertical distributions of rain intensity are independent namely:

$$R(x,z) = R_0 f(x) g(z) \tag{1}$$

Where Ro is point rainfall rate at a station, f(x) is the function of horizontal distribution and g(z) is the function of vertical distribution.

Rain gauge and radar measurements indicate that rainfall is characterized by large areas of low rates with a number of smaller regions of high rates. Considering variation of the effective path average factor[4] with rain rate and the property of the Hogg's effective path length[5] the function of horizontal distribution is presented:

$$f(x) = e^{-x/t} \tag{2a}$$

$$t = \frac{t_0}{R_0 - 10} \tag{2b}$$

Where to is a parameter of rain cell and its appropriate value was found to be 280 in calculation.

The vertical structure of rainfall is relevent to the original altitude and distribution of rain intensity. After analysis of the data with radar and study of rain attenuation we get the function of vertical distribution of rain intensity:

$$g(z)=(1-z/H)\,e^{z/(H-H_m)} \tag{3}$$

where

$$H=H_R-H_g \tag{4}$$

$$H_R=5.1-2.15\log\left(1+10^{\left(\frac{\varphi-27}{25}\right)}\right)+0.1\sqrt{R_\circ} \tag{5}$$

Hg is the height of the station, and Hm is the height of the center of maximum rain intensity:

$$H_m=(0.36+0.25/e^{R_\circ/12})\cdot H \tag{6}$$

From the above analysis and discussion, we get the spatial distribution of rain intensity used for calculation of attenuation as follows:

$$R(x,z)=R_\circ(1-z/H)\,e^{(z/(H-H_m)-x/t)} \tag{7}$$

3. CALCULATION OF RAIN ATTENUATION AND ESTIMATION OF PREDICTION ACCURACY

The total attenuation due to rainfall along earth-space paths can be obtained by intergrating the specific attenuation along the path.

$$A=aR_\circ^b\frac{1}{\sin\theta}\int_0^H(1-z/H)^b\exp\left[b\cdot z\left(1/(H-H_m)-\cot\theta/t\right)\right]dz \tag{8}$$

The intergration in (8) can be obtained approximatly as b approchs 1. That is

$$A=aR_\circ^b\frac{H}{\sin\theta}\,\gamma \tag{9}$$

where $\gamma=(1-b+b/c)\,e^b/c+(1+b/c)/c$ (10)

$$c=bH\left(1/(H-H_m)-\cot\theta/t\right) \tag{11}$$

It is evident that $aR_\circ^b\frac{H}{\sin\theta}$ is the attenuation for uniform rainfall. and γ is the corrected factor which is the function of point rainfall rate and elevation angle of the path.

We calculated the rain attenuation on eighteen earth-space links in Japan, the United states, France and Norway as well as two links in China by WTD model and CCIR model.[6] The results are shown in Table 1. Table 2 gives the mean M, standard deviation S and rms deviation D of the percent error of predicted attenuation at fixed probabitity level 1%, 0.1%, 0.01% and 0.001% of the year.

4. CONCLUSTION

From the calculated results presented in the last section, we conclude that: the attenuation predicted by WTD model agrees well with the measurements and its results are much better than those obtained by CCIR model. Especially at the precentages of time, 1% and 0.001% of the year at which the attenuation is usually considered to be diffcult to predict, the WTD model can provide results in good agreement with the experimental data but the other model can not.

ACKNOWLEDGMENT

We are grateful to Prof. B.X.Liang, Associate Prof. C.Q.Zhang and R.S.Huang for their help.

TABLE 1 Comparisons of predicted and measured attenuations on earth-space paths

N	Location	f (GHz)	θ	Attenuation (db)											
				1%			0.1%			0.01%			0.001%		
				Am	Ap	Ac	Am	Ap	Ac	Am	Ap	Ac	Am	Ap	Ac
1	Wuhan, China	11.7	50°	1.3	0.7	0.4	4.9	4.5	4.2	14.5	14.6	22.1			
2	Kashima, Japan	11.7	37°	<1	0.8	0.5	2	2.7	2.1	7	6.7	6.9			
3	Kashima, Japan	11.5	47°	<1	0.8	0.5	2.5	2.9	2.4						
4	Gometz-la-ville, France	11.8	33.6°				2.5	1.5	1.1	5	3.7	3.2	10.5	8.1	9.1
5	Kjeller, Norway	11.6	22°	0.8	0.6	0.3	2.1	2.9	2.1	6.9	7.0	7.1	12.6	10.6	15.4
6	Kasennuma, Japan	12.1	34°	0.8	0.8	0.5	2.4	2.7	2.1	5.9	6.8	6.8	10.6	12.4	16.8
7	Osaka, Japan	12.1	41°	1.7	1.1	0.6	5.6	5.3	4.8	15.1	10.4	12.5			
8	Matsue, Japan	12.1	42°	1.3	1.0	0.6	4.3	4.3	3.8	13.3	9.8	11.3			
9	Ashizuyi Japan	12.1	45°	1.9	1.4	0.9	5.0	5.8	5.6	10.2	12.0	15.3	13.6	15.6	25.4
10	Minamidatio, Japan	12.1	52°	1.4	0.6	0.3	6	4.2	3.8	16.7	13.0	16.0	20	17.1	26.3
11	Yonaguni, Japan	12.1	58°	2.7	1.0	0.7	8.1	6.8	6.7	14.3	14.2	17.3	16.7	18.5	26.3
12	Waltham, USA	19	35.3°	2.1	1.7	1.0	7.5	8.6	7.1	18.1	20.8	22.7			
13	Blacksburg, USA	19.	45°				5.7	4.3	3.2	16.7	17.5	17.8	28	31.5	44.4
14	Kashima, Japan	19.5	48°	2	2.2	1.4	6	6.9	5.6	17	15.8	15.3			
15	Kashima, Japan	19.5	48°	2	2.2	1.4	6	7.4	6.1	16	17.7	17.7	31	30.3	37.7
16	Yokosuka, Japan	19.5	48°	3	2.7	1.8	7	7.8	6.5	27	23.7	26.1			
17	Yokohama, Japan	19.5	48°	4	2.7	1.8	8	8.3	6.9	16	21.0	22.1			
18	Sendai, Japan	19.5	45°	3	2.2	1.4	6	6.1	4.7	18	17.0	16.7			
19	Blacksburg, USA	28.6	45°				12.3	9.4	6.9	33	36.9	39.2			
20	Wuhan, China	35.3	50°	5	6.05	4									

Am: measured attenuations. Ap: WTD predicted attenuations. Ac: CCIR predicted attenuations.

TABLE 2. Percent error of predicted rain attenuations on earth-space paths

	1%		0.1%		0.01%		0.001%	
	WTD	CCIR	WTD	CCIR	WTD	CCIR	WTD	CCIR
E	-0.57	-25.29	-1.56	-11.56	-1.14	9.08	0.29	40.45
S	9.12	30.31	13.74	18.69	17.02	23.52	15.80	30.87
D	9.14	39.48	13.83	21.94	17.06	25.22	15.80	50.88

REFERENCE

1. H.J.Li and Z.W.Zhang ICAP 83 Conference Publication Number 219
2. Y.Furuhama,T.Ihara,H Inuki and N.Fugono THE TRANSACTIONS OF THE IECE OF JAPAN, vol. E63, No. 6JUNE 1980 437
3. CCIR Report 564-2.
4. Crane. IEEE Trans Vol com-28 p1717-1733 1980.
5. D.C.Hogg. Nature Vol 23 p337-338 1973.
6. CCIR Report 721.