Rain Attenuation Prediction For Higher Frequencies in Microwave Communication Using Frequency Scaling Technique

U. Kesavan
Electrical Engineering Department
Polytechnic Sultan Haji Ahmad Shah Malaysia
Kuantan, Pahang, Malaysia

Md. Rafiqul Islam, Khaizuran Abdullah
Faculty of Engineering,
International Islamic University Malaysia
Jalan Gombak, 53100 Kuala Lumpur, Malaysia
*rafiq@iium.edu.my

Tharek A. R.
Wireless Communication Centre, Faculty of Electrical Engineering
University of Technology Malaysia
Skudai, Johor, Malaysia

***Abstract*—At a frequency range above 5 GHz, rainfall becomes a serious and major source of attenuation for microwave communication. Atmospheric effects play a major role in designing terrestrial or satellite-to-earth links operating at frequencies above 5 GHz. Raindrops absorb and scatter radio waves, leading to signal attenuation and reduction of the systems availability and reliability. Rain attenuation is very critical in tropical region compare to temperate region due to the geographical location. There are many techniques to predict the rain attenuation. In this research paper frequency scaling technique has been considered and discussed. In this research, three pair of frequencies, 5.8 GHz, 15 GHz and 26 GHz was compared and analyzed. All the measured data of rain attenuation for the above operating frequencies are presented. The equation of power n value for all percentage of time at certain operating frequency was identified. The results show that the proposed new power n =1.57 closely agreed with the predicted and measured rain attenuation for all the three frequency range (5.8, 15 and 26 GHz). This data will be very useful for any researcher and mobile operators in this region for designing their microwave communication links.**

Keywords- Rain attenuation, Received signal strength, Frequency scaling, Terrestrial link.

I. INTRODUCTION

Frequencies below 5 GHz, excess attenuation due to rainfall and atmospheric gaseous, frozen particles such as snow, ice crystals is very small and can be neglected in radio system design. However at frequencies above 5 GHz rain drops causes absorption and scattering and contributes to transmission losses severely [1-3].The attenuation due to rain on any path depends on Specific Attenuation in dB/Km, Frequency, Polarization, Temperature, Path length and latitude [4-5]. The rainfall causes reduction of the receive signal level because of absorption and scattering of radio waves. There are many method to identify the rain attenuation, one of the technique is by using the frequency scaling technique. Frequency scaling models of those available in the literature were found to be inadequate to predict rain attenuation measurements in Malaysia. Therefore, an evaluation of the power law model can be written as equation (1).

$$RAS_n = \frac{A(f_U)}{A(f_L)} = \left(\frac{f_U}{f_L}\right)^n \qquad (1)$$

Values of n are computed for the 15 GHz / 5.8 GHz, 26 GHz / 5.8 GHz and 26 GHz / 15 GHz frequency pairs. Statistical Ratio of Attenuation, RAS, is defined as follows [5]

$$RAS(f_L, f_U, \%p) = \frac{Rain\,Attenuation\,Statistics\,(f_U, \%p)}{Rain\,Attenuation\,Statistics\,(f_L, \%p)} \qquad (2)$$

where the rain attenuation statistics at upper and lower frequencies are considered at the same percentage of time occurrence, p. The common data base for each pair is used, which means the data used only at instants attenuation pairs (A_U / A_L) are valid. Based on the statistical analysis carried out for the Rain Attenuation Statistics (RAS) and Rain Attenuation (RA) in the previous research work, reported at the same location at Universiti Teknologi Malaysia, Skudai, Malaysia in the year 2000 by Rafiqul [6], the analysis of annual attenuation ratio statistics as well as individual raining event indicated that an average attenuation ratio can be used to scale attenuation at measured frequency to any desired frequency.

In this research, three pair of frequencies, 5.8 GHz, 15 GHz and 26 GHz was compared and analyzed. All the measured data of rain attenuation for the above operating frequencies are presented in Table 2. The rain attenuation data for 5.8 GHz and 26 GHz are measured via the experiment test bed. whereas for the 15 GHz the data was taken from Rafiqul's work [6] in 2000, and is used as an intermediate data between the 5.8 GHz and 26 GHz. The set-up by Rafiqul is almost the same except on the path length, which was 300m. Therefore, an assumption was made by taking into consideration the path length of 1 km with rain being distributed uniformly.

II. EXPERIMENTAL SET-UP

Two sets of radio links, of same path length 1.30 km were set up in Skudai, Johor Bahru, Malaysia. Both of transmitter and receiver operate at a frequency of 5.8 GHz and 26 GHz. The received signal level (RSS) was sampled

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every second. 12 months, June 2011 till May 2012 precipitation data was collected from two sets of tipping bucket rain gauges installed at microwave links site.

These data has been used to investigate the rain effects along the link. The weather station samples the relevant weather parameters every few seconds which can be used to further investigation. In every minute, it logs the average values of wind velocity, humidity and temperature parameters. The Davis rain gauge was used which is a tipping bucket type and size of 0.2mm sensitivity. Rain gauge records the rainfall rate occurring in each minute without recording non rainy events, therefore the rain rate is recorded as an integral multiple of 0.2mm/min or 12mm/h. The weather station was mounted on 10 meter high building and place in open area near the experimental sites. Table show the link specifications Measured signal and the rate data was collected in the same location for period of twelve months (June 2011 – May 2012). Fig. 1 and 2 shows the block diagram and the actual experimental set-up for measuring purpose. While Table I presented the specifications of links.

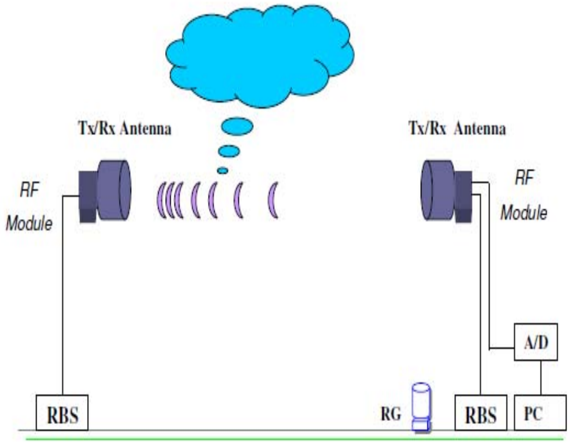

Figure 1. Block Diagrams of the experimental test bed.

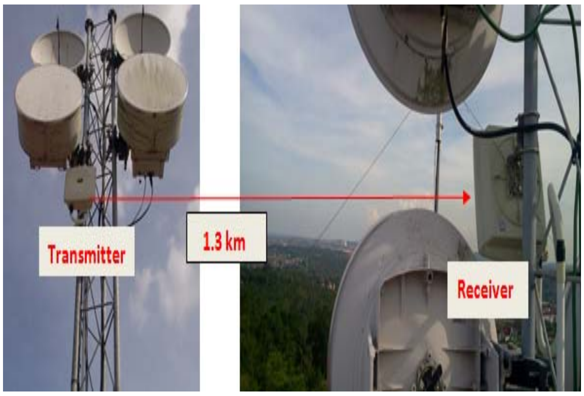

Figure 2. Experimental test bed.

III. RESULTS AND DISCUSSION

Table I and Table II show the typical measured attenuation using the frequency scaling technique and average power n value being applied at the frequency scaling method using the power law formula. The rain attenuation, using n power value at 5.8 GHz, 15 GHz and 26 GHz was recorded and compared. All the calculation for the rain attenuation was done using the rain attenuation equation (1) and Matlab software for analysis purposes.

TABLE I. SPECIFICATIONS OF THE 5.8 GHZ & 26 GHZ LINK

Link location	Hop length (km)	Freq GHz	Max Tx power (dBm)	10^{-6}BER (2X2 Mbps) received threshold	Antenna for both transmit and receive side	
					Size / m	Gain/ dBi
Johor Bahru	1.3	5.8	25.0	-97	0.2	40.0
		26	18.0	-83	0.6	20.0

TABLE II. MEASURED RAIN ATTENUATION VALUE AT 5.8, 15 AND 26 GHZ.

% of Time (p)	0.5	0.3	0.1	0.05	0.03	0.01	0.005
Rain(mm/h)	5	20	48	62	83	120	132
$A_{5.8}$ (dB)	0.2	1.5	2.5	2.7	2.9	3.5	3.7
A_{15} (dB)	0.8	6.0	10.0	11.0	12.0	15.0	16.0
A_{26} (dB)	0.5	4.0	16.0	22.0	28.0	34.0	39.0

From Table III, it was found that, when n = 1.57, the predicted rain attenuation is more closer with the measured rain attenuation, where the rest of all the other predicted rain attenuation is far different from the measured rain attenuation when using the predicted power n value. Further analysis was carried out to confirm the validation of the n power value with predicted results in the year 2000 by Rafiqul [6-8]. Rafiqul have suggested using different power n value based of the frequency range. Table IV shows the n power value and the predicted rain attenuation values.

From Table IV, the predicted power n value as suggested by Rafiqul [6-8] did not suit the predicted rain attenuation and measured rain attenuation. By using three different power n values, the predicted rain attenuation still did not match the measured rain attenuation value in this research. However, by using the current proposed power n value (n = 1.57) it comprised similar results at predicted and measured rain attenuation for frequency range from 5 GHz to 26 GHz. Using the percentage error equation (3) at 5.8, 15 and 26 GHz for predicted n = 1.2 compared to the proposed power n = 1.57 the predicted rain attenuation was 4.9 dB and 3.6 dB for 5.8 GHz, the percentage of error recorded was 36.1%. At 15 GHz, the predicted rain attenuation was 10.5 dB and 14.7 dB with percentage of error recorded at 28.6%. Whereby at 26 GHz, the predicted rain attenuation was 20.3 dB and 34.9 dB with percentage error recorded at 41.8%. The analysis clearly indicates that the predicted rain attenuation at certain operating frequency underestimates and also overestimates the predicted power n value. The proposed power n value will have a more consistent value at any range of frequency from 5 GHz to 26 GHz in a microwave system for tropical regions. Fig. 3 shows the comparison graph for the predicted rain attenuation using the proposed n power (n=1.57) and predicted n power value (n=1.2 and n=2.4) with the measured rain attenuation. The figure 3, it can clearly be seen that the proposed n power value follows closely the measured and predicted rain attenuation for all the three (5.8, 15 and 26 GHz) operating frequency ranges. This enhances the justification to propose a new power n value for predicting rain attenuation using frequency scaling method.

TABLE III. COMPARISON OF AVERAGE POWER N VALUE AT 5.8,15& 26 GHZ.

Value of n	***Rain attenuation (dB) at percentage of time (%)***						
	0.5	0.3	0.1	0.05	0.03	0.01	0.005
n =1.37							
$A_{5.8}$	0.2	1.7	2.8	3.1	3.4	4.3	4.6
A_{15}	0.7	5.3	8.8	9.5	10.2	12.3	12.9
A_{26}	1.8	13.3	22.2	23.9	25.7	31.1	32.8
n = 1.57							
$A_{5.8}$	0.1	1.4	2.4	2.6	2.8	3.6	3.8
A_{15}	0.8	6.3	10.5	11.4	12.2	14.7	15.5
A_{26}	1.9	14.9	24.9	26.9	28.9	34.9	36.9
n = 1.60							
$A_{5.8}$	0.8	.4	2.3	2.5	2.8	3.5	3.7
A_{15}	0.9	6.5	10.8	11.7	12.6	15.1	16.0
A_{26}	2.1	15.7	26.1	28.2	30.3	36.6	38.6

TABLE IV. PREDICTED RAIN ATTENUATION USING POWER n VALUE FROM PREVIOUS MEASUREMENT [6-7].

Value of n	***Rain attenuation at percentage of time (dB)***						
	0.5	0.3	0.1	0.05	0.03	0.01	0.005
n=1.2							
$A_{5.8}$	0.2	1.9	3.3	3.7	3.9	4.9	5.3
A_{15}	0.6	4.5	7.5	8.1	8.7	10.5	11.1
A_{26}	1.1	8.7	14.5	15.7	16.8	20.3	21.5
n=2.4							
$A_{5.8}$	0.1	0.7	1.1	1.2	1.3	1.7	1.8
A_{15}	1.8	13.5	22.5	24.3	26.1	31.6	33.4
A_{26}	6.7	50.6	84.3	91.1	97.8	118.1	124.9
n=0.7							
A_{26}	0.6	4.2	6.9	7.5	8.1	9.7	10.3

From the above discussion and based on the measured data as given in Table IV, the power law model recommended for the 5 GHz to 26 GHz frequency range is,

$$R_{avg} = \left(\frac{f_U}{f_L} \right)^n \qquad (3)$$

whereby, $n = 1.57 \quad 5\text{ GHz} \leq f \leq 26\text{ GHz}$

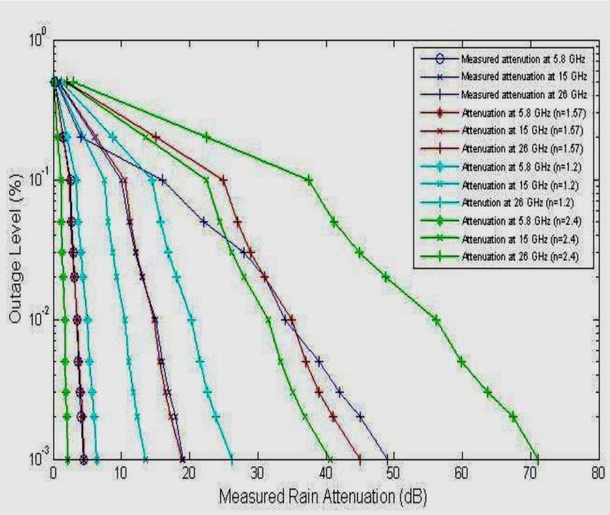

Figure 3. Comparison of the value of power n proposed and predicted for the rain attenuation.

IV. CONCLUSIONS

The analysis clearly indicates that the predicted rain attenuation at certain operating frequency underestimates and also overestimates the predicted power n value. The proposed power n value will have a more consistent value at any range of frequency from 5 GHz to 26 GHz in a microwave system for tropical regions. it can clearly be seen that the proposed n power value follows closely the measured and predicted rain attenuation for all the three (5.8, 15 and 26 GHz) operating frequency ranges. This enhances the justification to propose a new power n value for predicting rain attenuation using frequency scaling method. This research work will be useful for designing any microwave link especially for all the telecommunication operators in this region.

REFERENCES

[1]. Robert K. Crane, "Electromagnetic Wave Propagation Through Rain", John Wiley & Son Series,1996.

[2]. Robert K .Crane, "Prediction of Attenuation by Rain", IEEE Transaction On Communication, Vol Com28,No.9,September 1980.

[3]. D.Panagopoulos, Pantelis-Daniel M. Arapoglou, and Panayotis G.Cottis, "Satellite Communications at Ku, Ka and V Bands: Propagation Impairments and Mitigation Techniques", IEEE Communications Surveys and Tutorials,2004

[4]. John D.Kanellopoulos, and et al, "Rain Attenuation Problems Affecting The Performance Of Microwave Communication Systems", Ann Telecommun,45,n.7-8,1990.

[5]. Recommendation ITU-R P.530-14 , "Propagation data and prediction methods required for the design of terrestrial line of sight systems," February 2012.

[6] Final Reports on Rain Attenuation Studies for Communication Systems Operating in Tropical Regions, Wireless Communication Research Laboratory, Universiti Teknologi Malaysia, October 31, 2000.

[7] M.R. Islam, J. Chebil and A.R. Tharek, "Frequency Scaling of Rain Attenuation From 23- To 38-GHz Microwave Signals Measured In Malaysia", Proceedings of Asia Pacific Microwave Conference (APMC'99), vol. 3, pp. 793-796, Singapore, 30 Nov – 3 Dec, 1999.

[8] M.R. Islam & A. R. Tharek, "Measurement of Wet Antenna Effect On Microwave Propagation at 23, 26 and 38 GHz", Proceedings of 2000 IEEE Antenna and Propagation Society International Symposium, Vol. 4, pp.2094-2098, Salt Lake City, Utah, USA, July 16-21, 2000.