Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 1 Issue 3, October - 2014

Comparison Of The Impact Of Rain On Receiver G/T For The Horizontal, Vertical And Circular Polarization

Isaac A. Ezenugu
Department of Electrical/Electronic Engineering,, Imo State University (IMSU), Owerri, Nigeria
isaac.ezenugu@yahoo.com

***Abstract*— In this paper, comparison of the impact of rain on receiver G/T for the horizontal, vertical and circular polarized satellite signal at different operating frequencies is presented. The study used International Telecommunication Union (ITU) rain attenuation model to determine the rain attenuation on satellite communication LINK for three different polarization categories, namely horizontal, vertical and circular polarization. Then, rain attenuation was used to determine the antenna noise temperature and the corresponding system noise temperature and receiver G/T value. Numerical computation was conducted for a region with $R_{0.01}$ of 95 mm/hr and for a satellite link with elevation angle of 30°. The results of the rain attenuation computation show that the horizontal polarization has the highest rain attenuation in all the frequencies considered while the vertical polarization has the least rain attenuation. Also, the results of the computation of receiver G/T for different frequencies and polarizations show that from the frequency of 1 GHz to 10 GHz, there is a sharp drop in G/T due to rain from 17.705 dB at clear sky to 13.5 dB at frequencies above 10 GHz. In addition, from the frequency of 1 GHz to 10 GHz, there is a sharp drop in variation in G/T due to rain, with a value of 0.035 dB at 1 GHz to 4.175 dB at frequencies above 10 GHz. In all, the results show that frequencies from 10 GHz and above are significantly affected by rain attenuation. Hence, when planning for satellite link in such frequencies, adequate provision must be made for rain fading.**

Keywords*— *Rain Attenuation, Receiver Figure Of Merit, Polarization, Rain Rate, Specific Rain Attenuation, Rain Height

1. INTRODUCTION

In the communication industry, efforts are always made to account for the effect of rain on wireless signals in the Ku-Band frequencies and above [1,2,3,4,5,6,7]. At such high frequency of 10 GHz and above, the effect of rain is significant. In one hand, rain introduces attenuation of the signal strength. In another hand, the rain attenuation increases the antenna noise temperature [8,9,10,11,12,13]. The increase in the antenna noise temperature then affect the receiver antenna gain to noise temperature (G/T) ratio.

Studies have shown that the rain attenuation increases with increase in frequency [14,15,16,17]. In this paper, the study focuses on the impact of rain on satellite signal in the frequencies of 1 GHz to 100 GHz. The study examined the effect of rain on satellite signal with vertical polarization, horizontal polarization and circular polarization. Elaborate mathematical model based on International Telecommunication Union (ITU) rain attenuation model is used to determine the rain attenuation for the frequencies studied [18,19,20]. Then, antenna noise temperature and the overall receiver system temperature are determined with respect to rain and clear sky conditions. The reduction in the G/T from the clear sky condition to the rain condition for the various frequencies studied is determined. The study presents idea that is relevant for the power control unit of satellite communication link and for performance analysis of the satellite link at design time.

2. METHODOLOGY

2.1 Computation of Rain Attenuation

The specific rain attenuation, γ_R is given as a function of rain rate in mm/hr along with the frequency and polarization dependent parameters, k and α [19,20];

$$\gamma_R = k(R^{\alpha}) \tag{1}$$

Where k_v and α_v apply to the vertically polarized, k_h and α_h apply to the horizontally polarized, and k_c and α_c apply to the circularly polarized case. The values of k_v , α_v , k_h and α_h are provided by ITU whereas, k_c and α_c are computed as follows;

$$k_c = \frac{k_h + k_v}{2} \tag{2}$$

$$\alpha_c = \frac{(k_h)\alpha_h + (k_v)\alpha_v}{2k_c} \tag{3}$$

Rain attenuation, A_R for an effective rain path length, D_{Rain} is given as;

$$A_R = (\gamma_R) D_{Rain} \tag{4}$$

The effective rain path length, D_{Rain} is given in terms of rain height, H_R , antenna height, H_A and the elevation angle, θ as follows;

$$D_R = \left(\frac{H_R - H_A}{\sin(\theta)}\right) \tag{5}$$

$$D_o = \begin{cases} 35e^{-0.015(R_{0.01})} & \text{for } R_{0.01} < 100 \\ 35e^{-0.015(100)} & \text{for } R_{0.01} \geq 100 \end{cases} \tag{6}$$

Where $R_{0.01}$ is the rain rate in mm/hr for 0.01% exceedence time .

$$D_{Rain} = \frac{D_R}{1 + \left(\frac{D_R}{D_o}\right)} \tag{7}$$

2.2 Computation of Receiver System Temperature

The receiver system temperature T_{sys} is a function of antenna noise temperature, T_{ant} and the noise temperature due to other receiver components, T_{rec} , where [20];

$$T_{sys} = T_{ant} + T_{rec} \tag{8}$$

$$T_{ant} = T_m\left(1 - 10^{-A/10}\right) + T_s\left(10^{-A/10}\right) \quad (9)$$

2.3 Computation of Receiver G/T

The G/T performance of receiver in the face of rain is given as ;

$$\frac{G}{T} = \frac{G}{T_{sys}} = \frac{G}{T_{ant} + T_{rec}} \quad (10)$$

3. RESULTS AND DISCUSSION

The analytical expressions presented are used to evaluate the impact of rain on the G/T of the receiver. The input parameters used for the evaluation of the effect of rain on the receiver G/T are given in Table 1. The analysis is for a region with $R_{0.01}$ of 95 mm/hr and for a satellite link with elevation angle of 30°. The results of the rain attenuation computation for different frequencies and polarization are shown in Figure 1. According to Figure 1, the horizontal polarization has the highest rain attenuation in all the frequencies considered while the vertical polarization has the least rain attenuation.

Also, the results of the computation of receiver G/T for different frequencies and polarizations are shown in Figure 2 and Table 2. The results in Figure 2 and Table 2 show that from the frequency of 1 GHz to 10 GHz, there is a sharp drop in G/T due to rain from 17.705 dB at clear sky to 13.5 dB at frequencies from 10 GHz and above.

In addition, the results of the computation of the reduction in receiver G/T from its clear sky value for different frequencies and polarizations are shown in Figure 3 and Table 3. The results in Figure 3 and Table 3 show that from the frequency of 1 GHz to 10 GHz, there is a sharp drop in G/T due to rain, with a value of 0.035 dB at 1 GHz to 4.175 dB at frequencies above 10 GHz.

In all, the results show that signals at frequencies from 10 GHz and above are significantly affected by rain attenuation. Hence, when planning for satellite link in such frequencies, adequate provision must be made for rain fading.

Table 1 The input parameters used for the evaluation of the effect of rain on the receiver G/T

S/N	Parameter Description	Parameter Unit	Parameter Value
1	Rain rate, $R_{0.01}$ for 0.01 % exceeded time	Mm/hr	95
2	Rain Height, H_R	km	4.8
3	Antenna Height, H_A	km	0.05
4	Noise temperature due to cloud and rain, Tm	K	275
5	Sky Noise Temperature, Ts	K	210
6	Antenna Gain, G	dB	38.2
7	**Frequency, f**	GHz	1 to 100
8	**Elevation Angle, θ**	degree	30

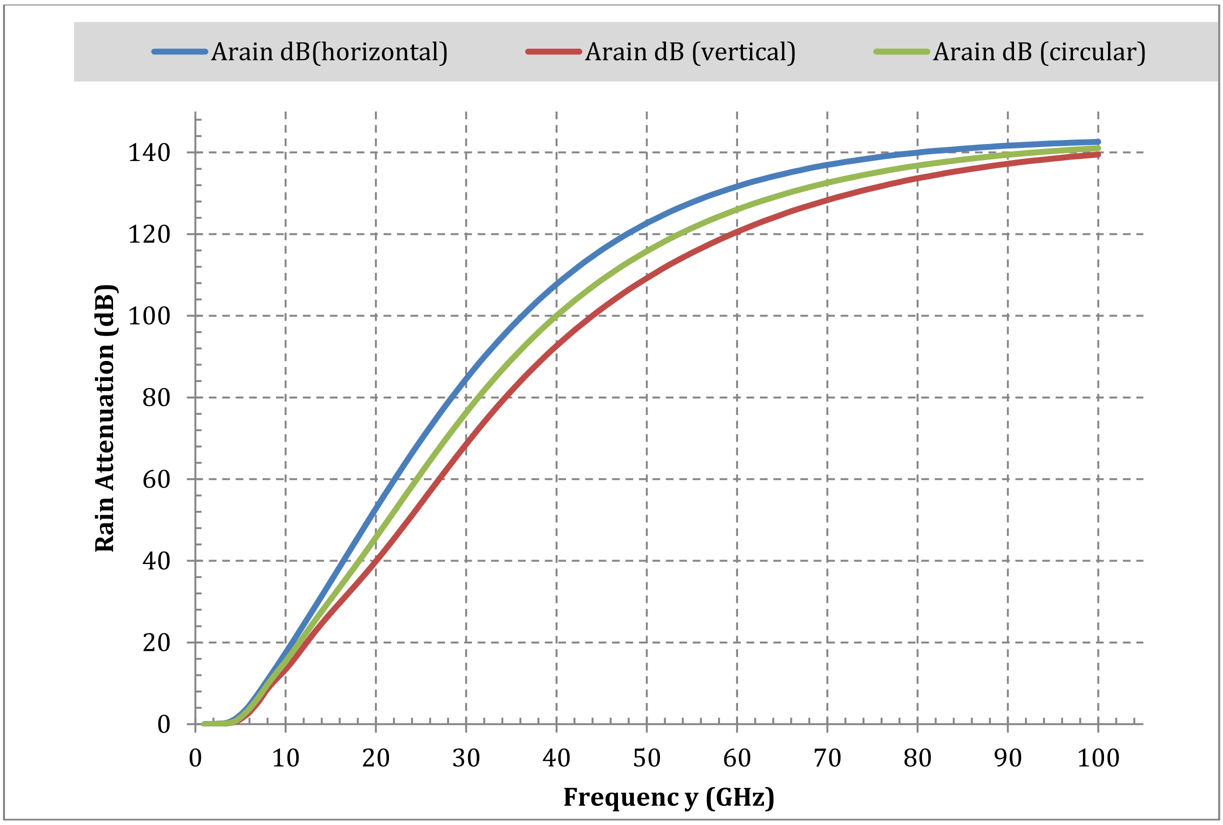

FIGURE 1 The results of the rain attenuation computation for different frequencies and polarizations.

Table 2 The results of the computation of the receiver G/T for different frequencies and polarizations.

Frequency (GHz)	TA(K) Horizontal	TA(K) Vertical	TA(K) Circular	Frequency (GHz)	TA(K) Horizontal	TA(K) Vertical	TA(K) Circular
1	10.6446	10.46486	10.53772	19	289.9967	289.9471	289.9846
1.5	11.37886	11.02198	11.1548	20	289.9985	289.9712	289.9925
2	13.26782	12.26	12.66819	21	289.9993	289.9846	289.9964
2.5	16.48932	14.31909	15.23462	22	289.9997	289.9919	289.9982
3	21.24532	17.50896	18.77165	23	289.9999	289.9958	289.9991
3.5	31.5407	22.39325	24.06643	24	289.9999	289.9978	289.9996
4	53.57004	30.96197	34.33503	25	290	289.9989	289.9998
4.5	87.65996	48.5001	58.33627	26	290	289.9994	289.9999
5	124.9686	78.44145	97.97515	27	290	289.9997	290
5.5	160.69	114.2052	138.3332	28	290	289.9999	290
6	193.1813	147.9681	172.6586	29	290	289.9999	290
7	241.5114	211.1103	228.1414	30	290	290	290
8	266.9067	251.7866	260.2736	31	290	290	290
9	279.1118	268.3858	274.5815	32	290	290	290
10	284.9722	277.2209	281.8571	33	290	290	290
11	287.7184	283.0972	285.9107	34	290	290	290
12	288.976	286.4756	288.0075	35	290	290	290
13	289.5412	288.192	289.024	36	290	290	290
14	289.7972	289.0365	289.5148	37	290	290	290
15	289.9104	289.4691	289.7552	38	290	290	290
16	289.9607	289.7011	289.8762	39	290	290	290
17	289.9828	289.8307	289.9377	40	290	290	290
18	289.9925	289.9047	289.9689	41	290	290	290

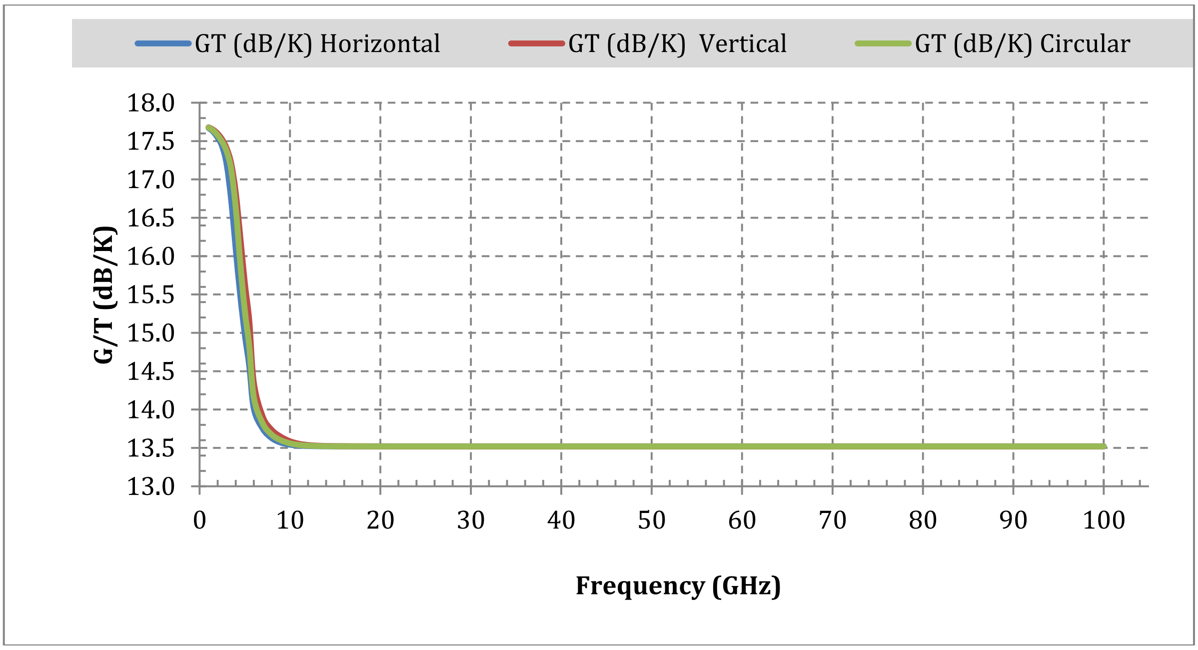

Figure 2 The results of the computation of the receiver G/T for different frequencies and polarizations.

Table 3 The results of the computation of the reduction in receiver G/T from its clear sky value for different frequencies and polarizations

Frequency (GHz)	ΔGT (dB/K) Horizontal	ΔGT (dB/K) Vertical	ΔGT (dB/K) Circular	Frequency (GHz)	ΔGT (dB/K) Horizontal	ΔGT (dB/K) Vertical	ΔGT (dB/K) Circular
1.0	0.035	0.026	0.029	11.0	4.175	4.151	4.166
1.5	0.081	0.056	0.067	12.0	4.181	4.168	4.176
2.0	0.160	0.107	0.130	13.0	4.183	4.176	4.180
2.5	0.274	0.185	0.215	14.0	4.184	4.180	4.183
3.0	0.510	0.301	0.340	15.0	4.185	4.182	4.184
3.5	0.977	0.498	0.573	16.0	4.185	4.184	4.185
4.0	1.613	0.874	1.072	17.0	4.185	4.184	4.185
4.5	2.216	1.450	1.788	18.0	4.185	4.185	4.185
5.0	2.724	2.050	2.413	19.0	4.185	4.185	4.185
5.5	3.140	2.550	2.882	20.0	4.185	4.185	4.185
6.0	3.693	3.354	3.547	21.0	4.185	4.185	4.185
7.0	3.958	3.802	3.890	22.0	4.185	4.185	4.185
8.0	4.079	3.973	4.035	23.0	4.185	4.185	4.185
9.0	4.137	4.061	4.106	24.0	4.185	4.185	4.185
10.0	4.163	4.118	4.146	25.0	4.185	4.185	4.185
11.0	4.175	4.151	4.166	26.0	4.185	4.185	4.185

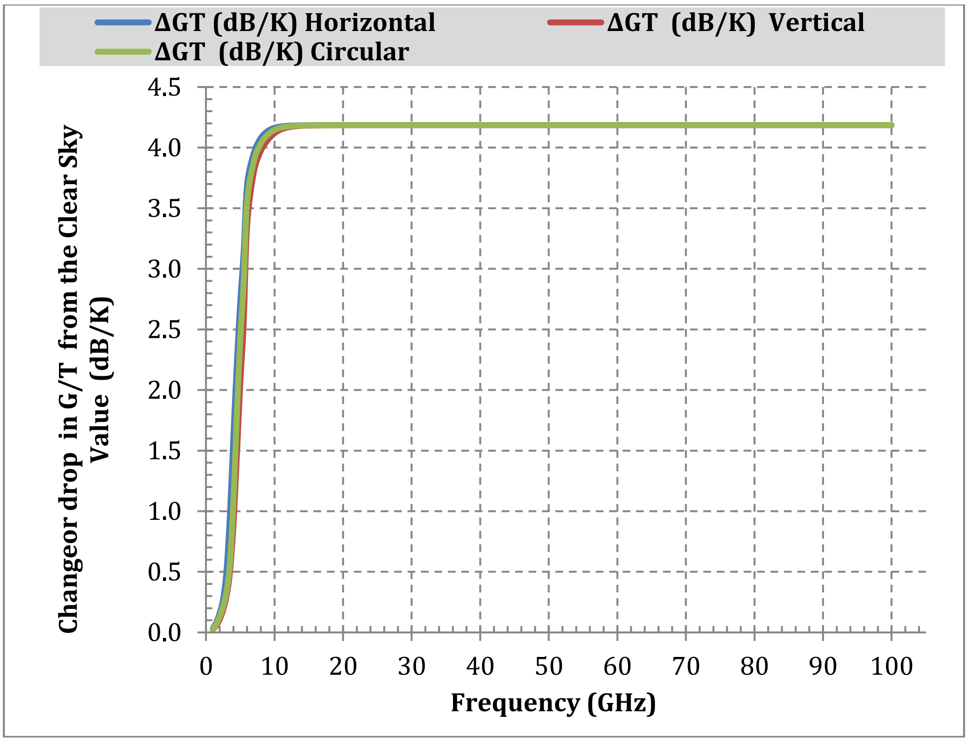

Figure 3 The results of the computation of the reduction in receiver G/T from its clear sky value for different frequencies and polarizations

4. CONCLUSION

The evaluation of the effect of rain on the antenna noise temperature and the receiver figure of merit (G/T) is presented. The evaluation also, examines the variation of the rain impact on G/T in the cases of horizontal, vertical and circular polarization. The results show that rain introduces rain attenuation which increases with frequency. Also, the antenna noise temperature is affected by the rain attenuation. The increase in rain attenuation and hence, the antenna noise temperature reduces the G/T value of a receiver. The horizontal polarization is the most affected while vertical polarization is the least affected. As such, for transmissions in regions with high rain incidence, it is better to use vertical polarization approach.

REFERENCES

1. AlYami, A. M. (2014). *Performance Analysis of Ku Band DVB-S2 VSAT System Under Dust and Sand Storms* (Doctoral dissertation, King Fahd University of Petroleum and Minerals (Saudi Arabia)).
2. Ghasemi, A., Abedi, A., & Ghasemi, F. (2012). *Propagation engineering in wireless communications* (pp. 247-249). New York, NY, USA:: Springer.
3. Prasad, A. A. (2009). *Investigation of the Effects of Cloud Cover on Ku-Band Satellite Link and Earth's Potential Gradient* (Doctoral dissertation, University of the South Pacific).
4. Jena, J. (2012). *Study of Rain Attenuation Calculation and Strategic Power Control for Ka-Band Satellite Communication in India* (Doctoral dissertation).
5. Aragon-Zavala, A. (2008). *Antennas and propagation for wireless communication systems*. John Wiley & Sons.
6. Smith, D. R. (2012). *Digital transmission systems*. Springer science & business media.
7. Adetan, O. (2014). *Modeling of raindrop size distribution and critical diameters for rainfall attenuation over microwave links in Southern Africa* (Doctoral dissertation).
8. Leijnse, H., Uijlenhoet, R., & Stricker, J. N. M. (2008). Microwave link rainfall estimation: Effects of link length and frequency, temporal sampling, power resolution, and wet antenna attenuation. *Advances in Water Resources*, *31*(11), 1481-1493.
9. Hirata, A., Yamaguchi, R., Takahashi, H., Kosugi, T., Murata, K., Kukutsu, N., & Kado, Y. (2009). Effect of rain attenuation for a 10-Gb/s 120-GHz-band millimeter-wave wireless link. *IEEE transactions on microwave theory and techniques*, *57*(12), 3099-3105.
10. Matricciani, E., & Riva, C. (2008). 18.7 GHz tropospheric scintillation and simultaneous rain attenuation measured at Spino d'Adda and Darmstadt with Italsat. *Radio Science*, *43*(01), 1-13.
11. Zinevich, A., Messer, H., & Alpert, P. (2010). Prediction of rainfall intensity measurement errors using commercial microwave communication links. *Atmospheric Measurement Techniques*, *3*(5), 1385.
12. Karmakar, P. K., Maiti, M., Bhattacharyya, K., Angelis, C. F., & Machado, L. A. T. (2011). Rain attenuation studies in the microwave band over southern latitude. *The Pacific Journal of Science and Technology*, *12*(2), 196-205.
13. Zinevich, A., Alpert, P., & Messer, H. (2008). Estimation of rainfall fields using commercial microwave communication networks of variable density. *Advances in water resources*, *31*(11), 1470-1480.
14. Marzuki, M., Kozu, T., Shimomai, T., Randeu, W. L., Hashiguchi, H., & Shibagaki, Y. (2009). Diurnal variation of rain attenuation obtained from measurement of raindrop size distribution in equatorial Indonesia. *IEEE Transactions on Antennas and Propagation*, *57*(4), 1191-1196.
15. Das, S., Maitra, A., & Shukla, A. K. (2010). Rain attenuation modeling in the 10-100 GHz frequency using drop size distributions for different climatic zones in tropical India. *Progress in Electromagnetics Research*, *25*, 211-224.
16. Abdulrahman, A. Y., Bin Abdulrahman, T., Bin Abdulrahim, S. K., & Kesavan, U. (2011). Comparison of measured rain attenuation and ITU-R predictions on experimental microwave links in Malaysia. *International Journal of Microwave and Wireless Technologies*, *3*(4), 477.
17. Chakravarty, K., & Maitra, A. (2010). Rain attenuation studies over an earth–space path at a tropical location. *Journal of Atmospheric and Solar-Terrestrial Physics*, *72*(1), 135-138.
18. Sridhar, M., Raju, K. P., & Rao, C. S. (2012). Estimation of rain attenuation based on ITU-R model in Guntur (AP), India. *International Journal on Communication*, *3*(2), 6.
19. Ojo, J. S., Ajewole, M. O., & Sarkar, S. K. (2008). Rain rate and rain attenuation prediction for satellite communication in Ku and Ka bands over Nigeria. *Progress in Electromagnetics Research*, *5*, 207-223.
20. Choi, D. Y., Pyun, J. Y., Noh, S. K., & Lee, S. W. (2012). Comparison of measured rain attenuation in the 12.25 GHz band with predictions by the ITU-R model. *International Journal of Antennas and Propagation*, *2012*.