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Effects of Rain on Vertical and Horizontal Polarized Ku-Band Radio Propagation in Tropical Region

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ABSTRACT

Moisture in the atmosphere takes many forms, some of which play a significant role in attenuating electromagnetic waves. The effects are, of course frequency-dependent. Although fog, clouds, snow and dust particles affect the propagation of signals but when frequencies higher than 10 GHz are transmitted and received in a heavy rain fall area, a Noticeable degradation occurs. The knowledge of rain attenuation statistics for vertical and horizontal polarized Ku-band radio propagation through satellite earth-links in tropical region is very useful for Budget link planning for end-viewer Television (TV) reception. In this work, the effect of rain on vertical and horizontal polarized Ku-band was investigated to deploy an appropriate link budget strategy when designing the satellite network and allocating a higher power consumption to overcome rain fade loss.

Keywords: *- Ku-band satellite system, polarization, link budget, Rain Attenuation, Rain Rate.*

I. INTRODUCTION

Scattering of the radio signal into different direction by the rain droplets is known as rain scattering. This rain scattering is a function of the wavelength of the radio wave and the size of the scattering particle [1]. Rain drops are not truly spherical, which results in differently polarized waves to suffer different attenuation (scattering & absorption by rain drops). Hence, rain scattering depends on the polarization of the radio waves. A horizontally polarized wave would be scattered forward or backward, in case of forward scattering the propagation range increases by 800 km. But vertically polarized wave suffers sideways scattering [2]. Satellite communication system like other systems has some impairments at both, the transmitting and receiving equipment; polarization mismatch losses, di-pointing losses and free space losses[3]. The first three impairments can be improved and overcome their effects is not impossible, but the last one needs some technical and special methods to reduce not to overcome but to reduce its effects. Free space losses in clear sky exists and affects the signal, and this loss increases in case of rain, snow, heavy clouds, specially, the regions with heavy rain suffers the loss of signal during rain[4]. This paper is an attempt to investigate the extent to which rain attenuation will affect vertical and horizontal signals at Ku-band. At the same time to suggest the possible means of having better reception during this natural phenomenon.

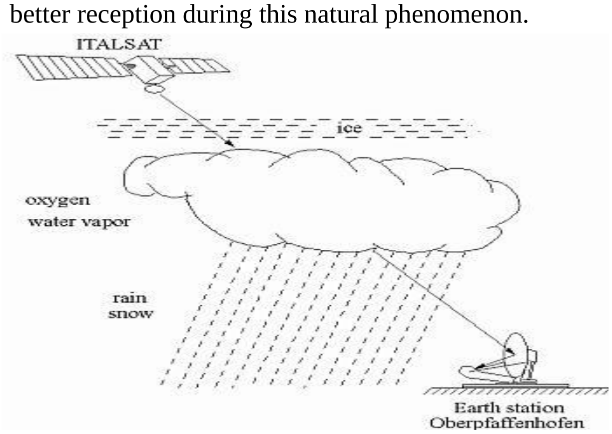

Fig 1. Rain Effect on Satellite System (down-link)

II. METHODS

The satellite earth station was set up using offset parabolic dish of 90 cm in diameter in tandem with field strength meter as shown in Fig 1. The operating frequencies were 10 and 12 GHz to obtain experimental values for vertical and horizontal attenuation. The automatic weather station (AWS) was synchronized with the experimental set up; rain-rate data obtained were substituted into International Telecommunication Union Recommendation Model (ITU-R) to compute vertically and horizontally attenuation.

The specific attenuation Y_R (dB/km) is obtained from the rain R (mm/h) using the power-law relationship [4]-[8].

$$Y_R = kR^{\alpha} \quad (1)$$

Values for the coefficients k and α are determined as functions of frequency, f (GHz), in the range of 1 GHz to THz, from the following equations, which have been developed from curve-fitting to power-law coefficients derived from scattering calculations:

$$\log_{10}{}^{k} = \sum_{j=1}^{4} a_j \exp\left[\left(-\frac{\log_{10} f - b_j}{c_j}\right)^2\right] + m_k \log_{10} f + C_k \quad (2)$$

and

$$\alpha = \sum_{j=1}^{5} a_j \exp\left[\left(-\frac{\log_{10} f - b_j}{c_j}\right)^2\right] + m_\alpha \log_{10} f + C_\alpha \quad (3)$$

where f is the frequency in GHz, m_k= -0.18961, C_k = 0.71147, m_a = -0.05374, C_a =0.83433 and the values for the constants a_j, b_j and c_j are given in table 1.

Table 1. Values for the constants

J	a_j	b_j	c_j
1	-5.3398	-0.1001	1.1310
2	-0.3535	1.2697	0.4540
3	-0.2379	0.8604	0.1535
4	-0.9416	0.6455	0.1682

For linear and circular polarization, and for all path geometries, the coefficients in equation (1) can be calculated using the following equations:

$$k = \frac{k_H + k_V + (k_H + k_V)\cos^2\theta \cos 2\tau}{2} \quad (4)$$

$$\alpha = \frac{k_H\,\alpha_H + k_V\,\alpha_V + (k_H\,\alpha_H + k_V\,\alpha_V)\cos^2\theta \cos 2\tau}{2k} \quad (5)$$

Where θ is the path elevation angle and τ is the polarization tilt angle relative to the horizontal (45^0 for circular polarization).

Fig 2. Automatic Weather Station

Fig 3. Experimental set up

III. RESULT AND DISCUSSION

In this paper, the attenuation caused by rain is modeled for tropical region. Fig 4-7 presents attenuations comparison measured and calculated rain attenuation for horizontal and vertical polarization signals at 10 GHz and 12 GHz.

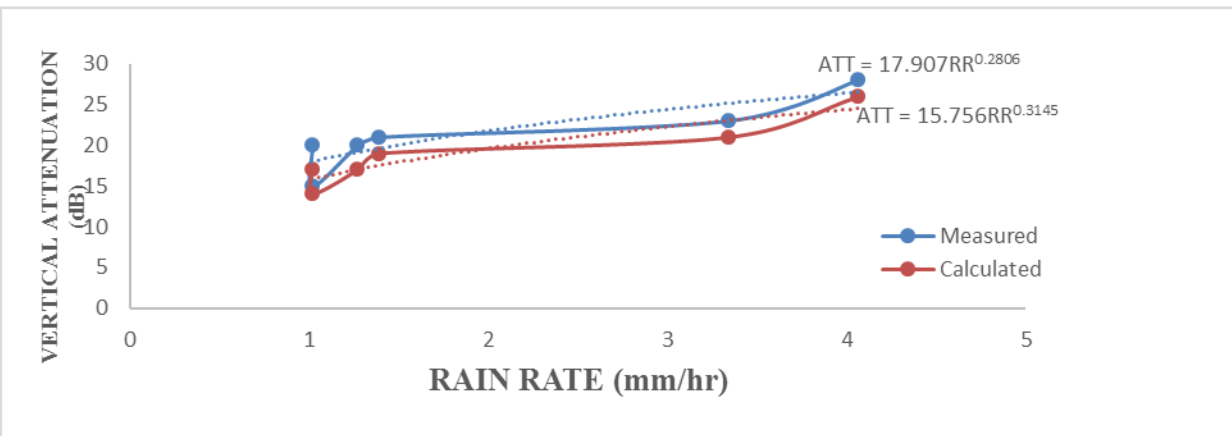

Figure 4: vertical attenuation against rain rate at 10 GHz

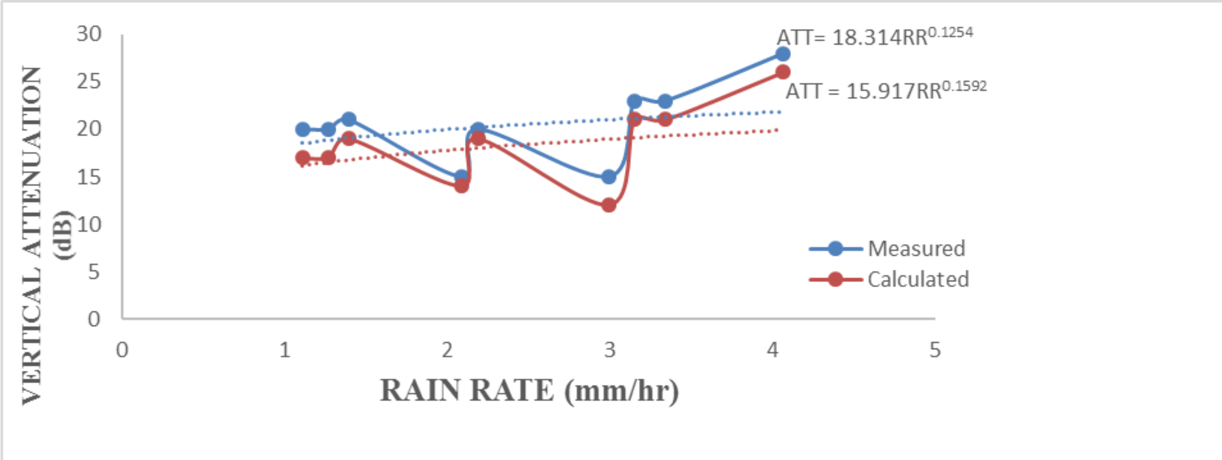

Fig 5: Vertical Attenuation against Rain Rate at 12 GHz

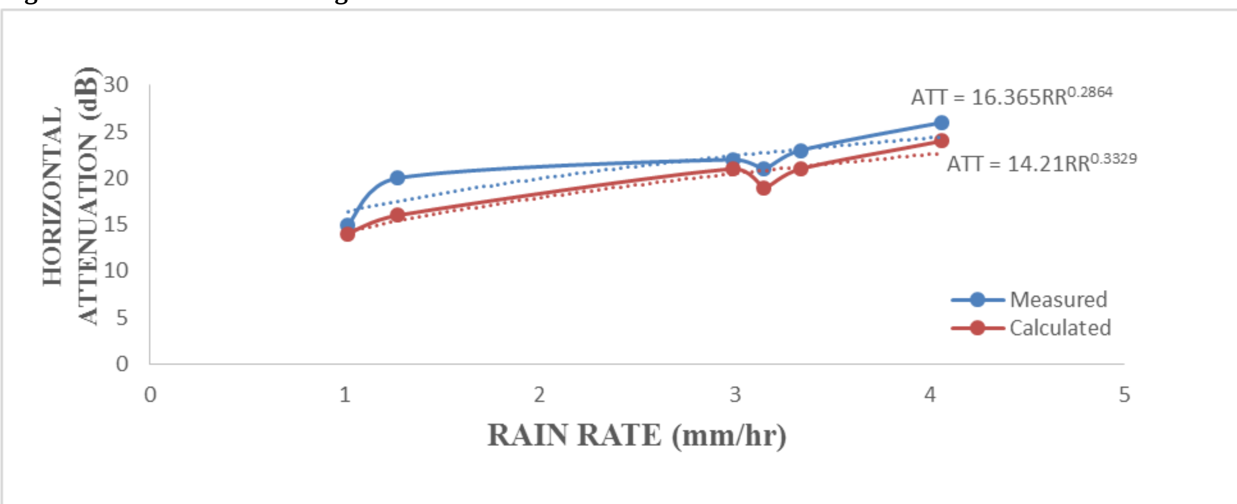

Fig 6. Horizontal Attenuation against Rain Rate 10 GHz

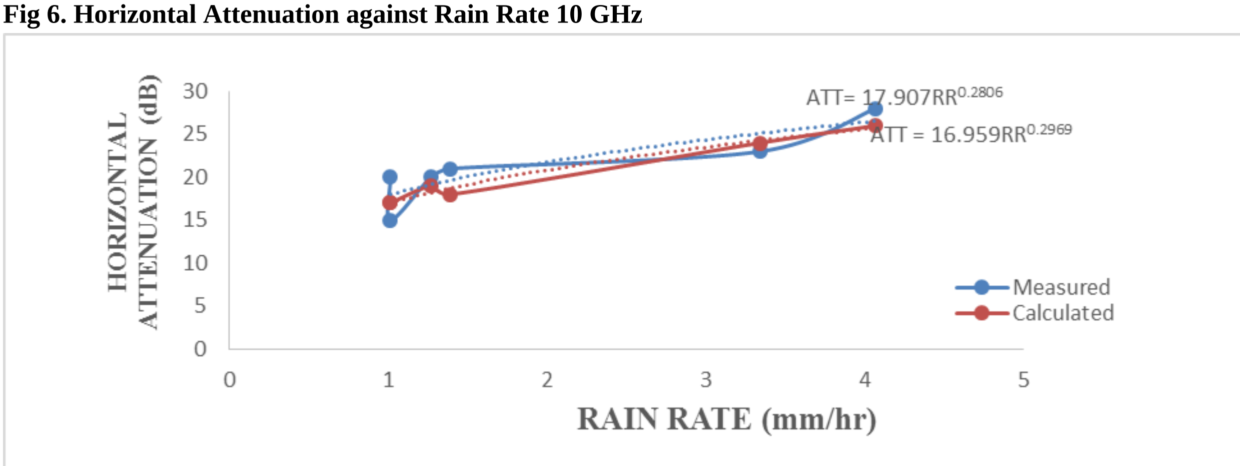

Fig 7. Horizontal Attenuation against Rain Rate at 12 GHz

From the results, it was observed that rain attenuates the received signal at Ku-band for both 10 GHz and 12 GHz frequencies downlink reception. From the findings, the horizontal polarized signals are affected by the rain and cause higher rain attenuation and higher decrease in the received signal strength than the vertical polarized signals.

IV.CONCLUSION

In this paper, the attenuation due to rain on vertical and horizontal polarization has been presented and modeled for tropical region. It is shown from the results that the horizontal polarized is affected greater than that of vertical polarized signal; also the approximately predicted amount of attenuation causes by rain is presented. Finally, some useful recommendations to minimize this attenuation and then improve the received signal has been presented.

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