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Impact of Elevation Angle on Rain Attenuation in Satellite Communications

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Abstract: Satellite communications is also known as distance-insensitive communication system [1]. It is one of the important methods to provide global connectivity and broadcasting facilities. In addition to providing many benefits, satellite communication link faces many issues due to frequency selectivity and transmission through ionosphere. In this paper, the impact of elevation angle on rain attenuation component is investigated. Simulation results verify the notion of reduced attenuation on increasing elevation angle.

Keywords: Rain Fall Rate, Rain Attenuation, Elevation Angle

I. INTRODUCTION

The Spectrum congestion issue poses a critical challenge in wireless communications. It is due to the bandwidth-hungry application-requirements of end user and development of new standards and technologies. It can be solved through the use of opportunistic or secondary use of RF spectrum in cellular bands., while the same issue can be solved for satellite communications through opportunistic communications and migration from C to Ka band [2]. Various authors recommend the use of opportunistic cognitive driven schemes for satellite communications [3-5]. Another method to facilitate the users with larger bandwidth requirements is the use of frequencies greater than 10 GHz. The major cause of concern that deteriorates the performance of transmission over higher bands (i.e. f_c >10 GHz) is rain attenuation [6]. Rain attenuation depends on carrier frequency, operating climate and elevation angle [7-9]. Hence, the results show the impact of elevation angle is significant on rain attenuation. In this paper, we compute the impact of elevation angle on rain attenuation. Furthermore, several authors have presented experimental studies on rain attenuation and signal degradation under different climates. To elaborate the impact of rain attenuation, ITU-R has introduced a channel model [10]. Furthermore, various authors have also recommended extensions to the ITU-R model as well as computed the impact of various parameters on rain attenuation. In [11], authors proposed a model for rain attenuation under tropical climates. The real time measurements were carried out in Singapore using two satellites i.e. WINDS and GE 23 at frequency of 18.9 GHz and 12.75 GHz respectively. The results of the proposed model follow the ITU-R model. Furthermore, it is also claimed that the proposed model outperforms the other rain attenuation models. In [2] authors recommend an improved rain attenuation prediction model working under tropical regions. This model gives better extrapolation characteristics. The experimental measured data is taken at 15 GHZ in Malaysia with tropical climate considerations. It is shown that the proposed rain attenuation model performs better than ITU-R model under specific conditions. Besides, other models that perform better under specific country or specific conditions are recommended by [12-14] .

Thus, it is essential to compute key parameters that significantly contribute towards degradation of signal quality over 10 GHz and above. In this paper, the impact of elevation angle is computed on rain attenuation at 20 GHz. The computations will be useful to predict rain attenuation over a broad range of frequencies. The simulation results validate the notion of using higher elevation angle for satellite transmissions because that result in lesser rain attenuation. The rest of the paper is organized as follows: Computation of Rain attenuation is presented in Section II. Simulation results are presented in Section III. Section IV concludes the paper.

II. Impact of Elevation Angle on Rain Attenuation

In this section, the procedure to compute the impact of elevation angle on total rain attenuation is presented.
Rain attenuation can be calculated by using equation (1) [1]:

$$A = \alpha L \quad (1)$$

In above equation, A shows the attenuation due to rain impact, α represents the specific attenuation and L shows the effective length of signal through rain. The specific attenuation is the function of rain rate.

Step 1: Compute Specific attenuation using equation (2):

$$\alpha = aR_p^b \quad (2)$$

In the above equation, a and b are regression coefficients that can be referenced from the tables in [1]. R_p represents rain rate that is measured in mm/hr.

The regression coefficients depend on polarization of transmitted signal waveform, hence for circular polarization, these are given by:

$$a_c = \frac{a_h + a_v}{2} \quad (3)$$

$$b_c = \frac{a_h b_h + a_v b_v}{2a_c} \quad (4)$$

Step 2: Calculate Slant Length

The Slant Length can be calculated by using equation (5), for elevation > 5^0

$$L_s(km) = \frac{h_R - h_S}{\sin(Elevation)} \quad (5)$$

For Elevation $\leq 5^0$ [15]

$$L_s = \left[\frac{2(h_R - h_S)}{\sin 2(elevation) + \frac{2(h_R - h_S)}{R_e}} \right]^{1/2} + \sin(elevation) \quad (6)$$

Step 3: Calculate Horizontal component of Slant Length using the formula [1]:

$$L_G = L_s Cos(Elevation) \quad (7)$$

Step 4: Calculate effective path length

$$L = L_s r_p$$

Thus, total attenuation can be calculated using equation (1). In the next section, the numerical computed results are presented.

III. Numerical Results

In this section, results of the proposed investigation are presented. The following parameters are assumed for calculating the impact of elevation angle on rain attenuation. Rain Rate is assumed to be 10 mm/hr exceeded for 0.1% of the year, rain height is assumed 2 km, carrier frequency is assumed to be 20 GHz and the polarization is assumed to be right hand circular.

By using the above model and values of the parameters the calculated rain attenuations at different elevation angles as shown in Figure 1. The results show a relation between transmitted frequency and rain attenuation. The decrease in rain attenuation to less than 2.5 dB for elevation angle of 90^0 clearly suggests the use of higher elevation angle for satellite communications to result in lower signal degradations.

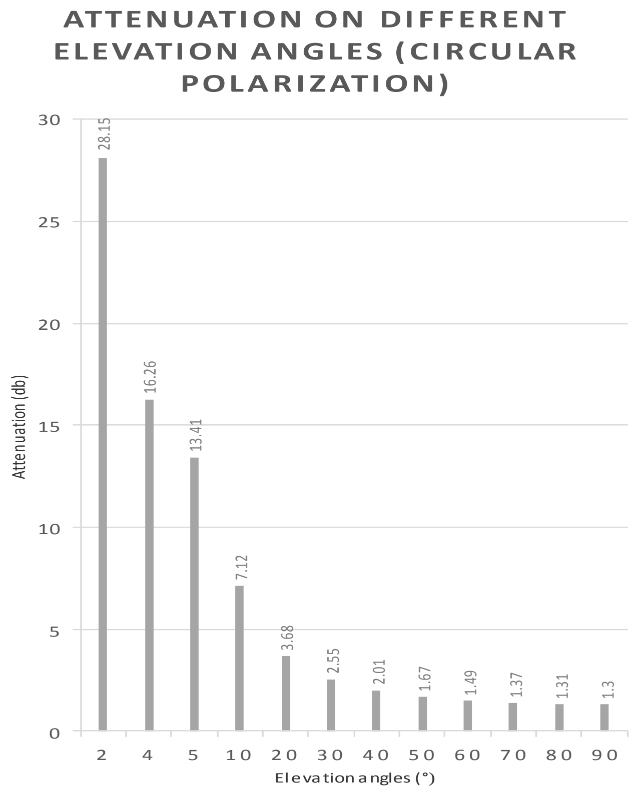

Figure 1. Shows the relation between Elevation Angle and Attenuation

IV. Conclusion

In this paper, relation between rain attenuation and elevation angle is studied, simulated and investigate. The results recommend the use of higher elevation angle for superior performance.

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V. References

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