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The Effects of Rain on Millimeter Wave Communication for Tropical Region

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Abstract

The effects of rain on millimeter wave communication are investigated in the present study. Propagation of very short pulses at mm wave band has been discussed. Specific attenuation has been computed at different mm wave frequencies and its variation as a function of rain rate and frequencies have been assessed. The variation of rain attenuation over terrestrial link as a function of path length, frequency and rain rate has been examined. A comparison between rain attenuation along terrestrial path and earth space path has been made at mm wave band.

1. Introduction

Recent advances in related technology have expanded the scope of millimeter wave application in 5G cellular services, satellite communication, pulsed radar and high data rate digital communication link. For mm wave frequency range, there are several factors that affect propagation including (a) absorption due to gases or water vapor and (b) attenuation due to mist, fog, or rainfall. An assessment of these propagation effects is important so that sufficient design margin can be allocated to ensure the link's integrity under changing weather and atmospheric conditions. Rain is one of the main concern regarding mm wave propagation, since raindrops are roughly the same size as the radio wavelengths, and therefore cause scattering of the radio signals. In case of very short pulse propagation, rain causes broadening or compression of the pulses which causes transmitted symbol distortion. In [1-2], it has been shown that rain attenuation has a minimal impact on propagation for a small cell structure in temperate region for mm wave band. But this is not true for tropical region where heavy rain fall occurs. The tropical region experiences very high rain rates.The dynamics of tropical communication channel versus time is strongly influenced by the rainfall components. In the present study, we have discussed pulse broadening due to rain and examined the attenuation effects of rainfall on mm wave band signal propagation for tropical region.

2. Pulse Propagation through rain filled channel

When a pulse is propagated through rain filled medium, it becomes distorted due to scattering and absorption by raindrops. The pulse propagation in the rain-filled medium has been investigated by many researchers in past using numerical computations at different high frequency bands [3-6]. The propagation effects of pulsed signals have been assessed considering the Fourier transform of the pulsed signal and its modification by the transfer function of the raining atmosphere. The transfer function of the raining atmosphere has been derived from attenuation and phase-delay coefficients. It has been observed that the distortion of the pulse, in terms of broadening and a shift in the peak amplitude is quite larger at higher rain rates compared to lower rain rates. Also the pulse distortion significantly increases with path length. So, pulse broadening and hence transmitted symbol distortion is a major issue in the case of tropical rainfall.

3. Rain Attenuation Effects

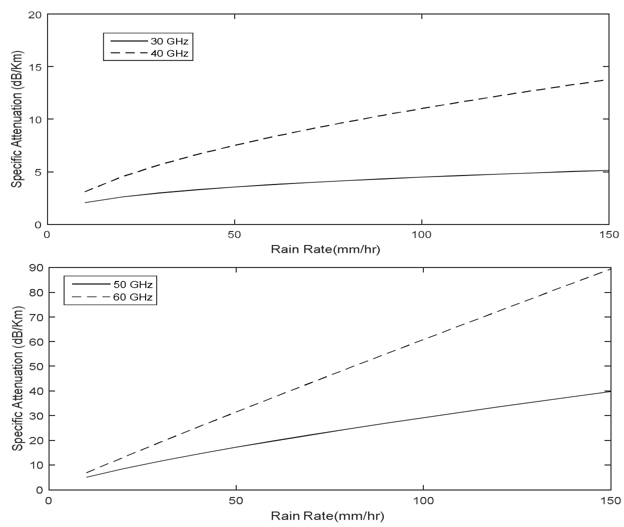

Figure.1 Variation of specific attenuation against rain rate for different frequencies 30, 40, 50 and 60 GHz.

Specific attenuation is computed from rain rate values using the technique described in [7] at different frequencies. Figure.1 gives the plotting of attenuation against rain rate for different frequencies 30, 40, 50 and 60 GHz. We see from the figure that as rain rate increases, specific attenuation increases. The increase of specific attenuation with respect to rain rate is smaller for 30 and 40 GHz. If we consider the graph for 30 GHz, we see that as rain rate varies from 50 to 100mm/hr, rain attenuation varies only 2 to 3 dB. But for 50 and 60 GHz, as rain rate increases, specific attenuation increases largely as is evident from Figure.1.

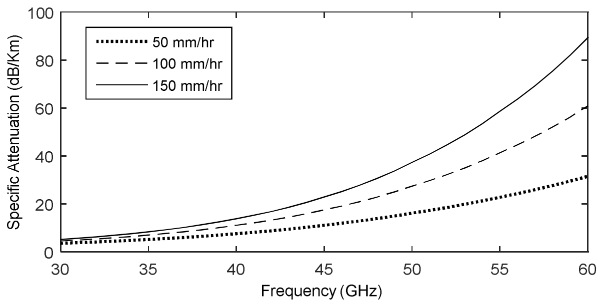

Figure. 2 Variation of specific attenuation against frequency for different rain rates.

Figure.2 shows specific attenuation as a function of frequency at different rain rates of 50, 100 and 150 mm/hr. The frequency dependence of specific attenuation from 30 to 60 GHz is investigated here. From the figure it is clearly seen that with the increase of frequency, specific attenuation increases slowly upto 40 GHz, but after that as we go for higher frequency, it increases rapidly. Also the variation of attenuation is much smaller upto 40 GHz as we move from rain rate 50mm/hr to 150 mm/hr. Above 40 GHz, with the increase of frequency, attenuation increases largely as we move from 50mm/hr to 150 mm/hr. Even for very large rain rate 150 mm/hr upto 40 GHz, specific attenuation is within 10 dB/km which can be mitigated using proper fade mitigation techniques. But if we observe the graph for 60 GHz, we see that even for 50 mm/hr rain rate , specific attenuation is above 20 dB/km which is very difficult to mitigate fully.

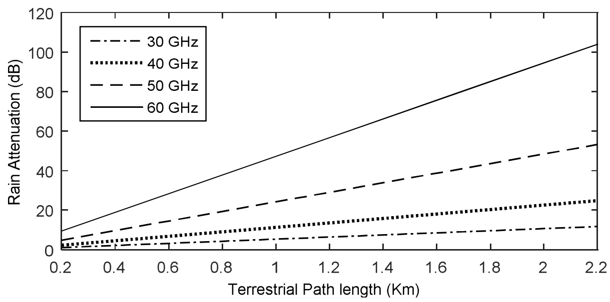

Figure. 3 Plotting of rain attenuation as a function of terrestrial path length for different frequencies 30, 40, 50 and 60 GHz.

Rain attenuation along terrestrial path has been calculated using the procedure described in [8] for different path lengths from 100 metre to 5 km and is plotted for frequencies of 30, 40, 50 and 60 GHz in Figure.3.We see from the figure that as path length increases, rain attenuation increases more rapidly for 50 and 60 GHz compared to 30 and 40 GHz. At 30 and 40 GHz, for 2 km path length, rain attenuation is 10 dB and 20 dB respectively. From the figure, it can be seen that above 1 km path length, rain attenuation is excessively large for 60 GHz. Even for 400 metre path length rain attenuation is above 20 dB. So as frequency increases, we have to reduce the link path length. From all the abovementioned figures it can be seen that for 50 and 60 GHz frequency bands, very high attenuation occur even for very small path length compared to 30-40 GHz frequency bands.The high attenuation in these band limit its practical use for longer terrestrial links and for Earth-space communication. The main application therefore is in dense urban environments where a high density of short links might be expected. For point-to-point links, one of the key advantages of the 50-60 GHz band is the relatively high directivity achievable from a physically small antenna. The narrow beam-widths and low side-lobe levels indicates that the signal power outside the narrow main lobe is very low. This is compounded by the high attenuation in the 50-60 GHz frequency band, which results in an even faster decrease of signal power outside the main beam. This high attenuation results in very short frequency-reuse distances making these bands extremely suited for high-link density deployments with minimum interference between the links.

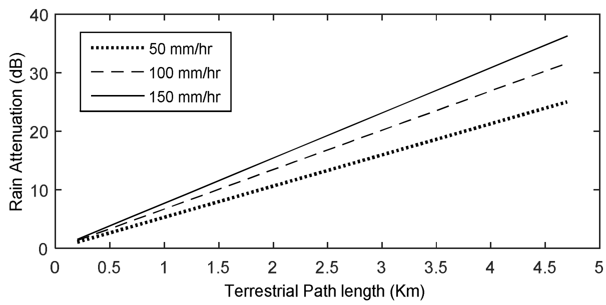

Figure. 4 Plotting of rain attenuation as a function of terrestrial path length for different rain rates 50, 100 and 150 mm/hr.

In Figure.4, rain attenuation has been plotted as a function of terrestrial path length for different rain rates at 30 GHz band. Here, we have seen that for path length upto 4 km, rain attenuation is within 30 dB even for a very large rain rate 150 mm/hr which is very rarely occurs throughout the complete path of 4 km length.

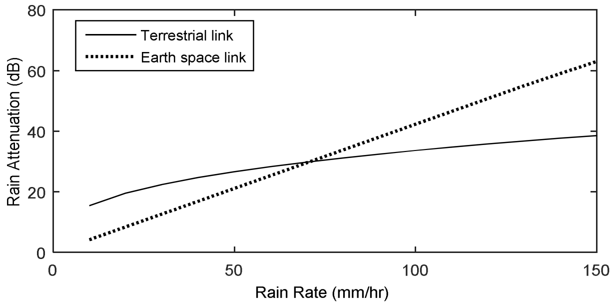

Figure. 5 Plotting of rain attenuation as a function of rain rate for terrestrial link and earth space link of 5km path length at 30 GHz.

Rain attenuation along earth space path is calculated from rain rates using ITU-R model [9] for different frequencies from 30 to 60 kHz at different path lengths. Plotting of rain attenuation at 30 GHz against rain rate along terrestrial path and earth space path of 5 km length is shown in the Figure.5. From Figure.5 we see that earth space attenuation is very low for lower rain rates, and as rain rate increases, it increases almost linearly. But terrestrial attenuation does not vary largely as we move from very low rain rates to high rain rates. From the Figure.5 it is evident that if rain rate is not very large, we can use 30 GHz band both for terrestrial link and earth space link of path length as large as 5 km with adequate fade margin.

4. Conclusion

The variation of mm wave signal propagation through rain filled medium has been examined. The tropical rain causes pulse broadening and hence symbol distortion, so the probability of symbol errors increases for mm wave communication system. Specific attenuation due to rain is not very large for the mm wave frequencies of 30 and 40 GHz, even for very high rain rate of the order of 150 mm/hr. If we increase frequency or path length, the attenuation increases significantly. For 50 or 60 GHz band rain attenuation is very large even for very low rain rates and these bands can be used only for very short distance communication.

5. References

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