Effect of Rain Attenuation on Millimeter Wave over Polarization

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Abstract: Millimeter wave has been used in radar applications for a long time, and is increasingly used in new fields, among which high data rate telecommunications is the most prominent. Short wavelength and unique propagation characteristics provide challenges and opportunities for design engineers working in these fields. Millimeter wave has become an indispensable part of 5G mobile communication field due to its excellent spectrum characteristics. In order to help the development of millimeter wave equipment, this paper mainly studies the millimeter wave rain attenuation phenomenon through the combination of theory and simulation. The effects of rainfall rate and polarization mode on millimeter wave propagation attenuation are compared and summarized. In addition, the total attenuation of millimeter wave communication path under different polarization rainfall characteristics is compared. Finally, the total loss of different frequency millimeter wave rainfall links is compared and analyzed. It provides a theoretical basis for the follow-up design and practical application of millimeter wave communication system.

Keywords: Millimeter Wave, Rain attenuation, Polarization.

1. Introduction

From the first generation (1G) cellular mobile communication system to the global deployment of the fourth generation network, mobile communication systems are developing at an amazing speed [1]. In 5G research, many countries in the world put the research of spectrum in a prominent position in 5G research [2]. ITU research group (WP5D) and relevant regional telecommunication organizations (ASMG, APT, CEPT, etc.) are actively carrying out research on 5G spectrum. According to the research results of many research institutions, the spectrum below 6GHz is the best spectrum resource in the near future [3]. But the spectrum resources below 6GHz have been basically exhausted, and relevant literature studies show that the available spectrum resources in the millimeter wave band (30GHz-300GHz) are quite abundant (about 60GHz), 200 times that in the low frequency band below 6GHz [4]. Therefore, many problems in the future 5g can be solved by using higher frequency millimeter wave communication technology [4] [5].This paper mainly analyzes the millimeter wave in the rainfall environment. The attenuation caused by rain differs because of parameters like geographic condition, rainfall capacity, the shape of raindrop particles (a flat sphere with a depression at the bottom) and path [6]. Although there exist many methods like Mie theory, matching method and so on, and mathematics models like SAM, DAH and MPM, this paper uses ITU-R, which is widely applied in the world especially in millimeter wave rainfall attenuation, to calculate rainfall attenuation.

2. The basic fundamental of millimeter wave

2.1 Millimeter wave rainfall attenuation

According to ITU-R P.838-3 and P.618-12, in this section, γ_R (dB/km), which contains random variables, is introduced, and it means the rate of rainfall attenuation. Here is a detailed explanation of some key formulas.

$$\gamma_R = kR^{\alpha} \tag{1}$$

R is the rainfall rate, and k,α are the two electromagnetic wave polarization factors.

$$k = [k_H + k_V + (k_H - k_V) \cos^2 \theta \cos 2\tau]/2 \quad (2)$$

$$\alpha = [k_H \alpha_H + k_V \alpha_V + (k_H \alpha_H - k_V \alpha_V) \cos^2 \theta \cos 2\tau]/2k \quad (3)$$

θ is inclination of propagation path, τ is the polarizable oblique angle. This paper only analyzes circular polarization(τ=45°), horizontal polarization(τ=0°)and vertical polarization(τ=90°).

2.2 Rainfall path loss of millimeter wave communication

Path loss refers to the power attenuation that occurs when a transmitted signal propagates from transmitting end to receiving end. When the signal propagation distance is increasing in free space, the power received by receiving device gradually decreases, and air will absorb energy of the radio wave. The radio wave will also interact with water molecules and impurities, and effects like reflect, refract, diffract and others will happen during the propagation process.This model, which describes one single direct path LoS (line of sight) in channel from receiver to transmitter, is the only model considered in this paper. The power of received signal is PR.

$$P_R = P_T G_T G_R \frac{\lambda^2}{4\pi D^2} \quad (4)$$

PT means the transmission power of millimeter wave antenna, GT and GR refer to gain of the transmitting antenna and receiving antenna. λ is the wavelength of the carrier wave, D means the distance from the transmitting end to the receiving end. The path loss index of free space propagation (the exponential constant of power with the transceiver) is usually taken as 2.In the millimeter wave link, the influence of atmosphere and rainfall on communication is considered, and the system received power PRX can be expressed as formula (5).

$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - A_{pl} - A_R \quad (5)$$

PTX refers to the transmit power, GTX represents the transmit antenna gain, GRX means the gain of receive antenna, AR and Apl mean the attenuation caused by rainfall and air when the path loss in free space

3. Results and Discussion

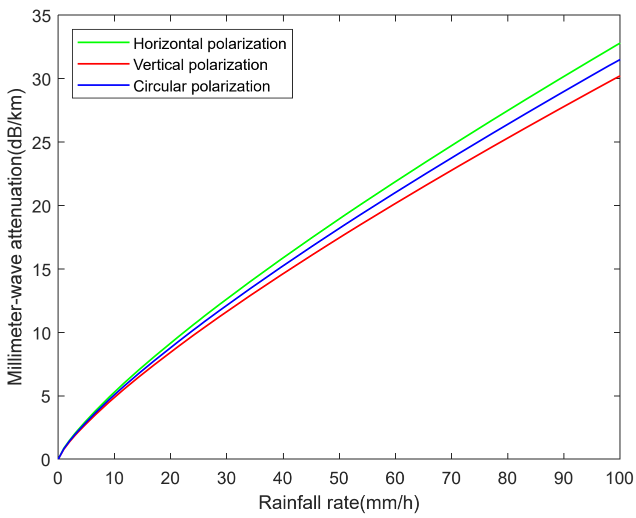

Figure 1. Rainfall attenuation of millimeter wave with three different polarizations

Set *f* as 70 GHz, the *r* as 20mm/h and the rainfall rate range is set as 0~100mm/h. In the Figure 1, the attenuation rate of millimeter wave increase with the increase of rainfall rate in the case of horizontal polarization attenuation, vertical polarization attenuation and circular polarization attenuation. Moreover, under the same rainfall rate, no matter which kind of polarization is, millimeter wave attenuation is similar. Among them, horizontal polarization has the largest impact on millimeter wave attenuation, circular polarization lies second, and vertical polarization has the smallest impact. In this way, in order to analyze total loss of rainfall link, gain of antenna is set as 27dbi. The formula of total link attenuation *g(R)* is (6).

$$g(R) = 92.4 + 20\,log\,f + 20\,log\,l + \gamma_R l - 27 - 27$$
$$= kR^{\alpha} l + 20\,log\,f + 20\,log\,l + 38.4 \tag{6}$$

When f is 70ghz, R is 20mm/h, link length L is from 0 to 10m, the total loss curve of the millimeter wave rainfall link under three different polarizations is simulated.

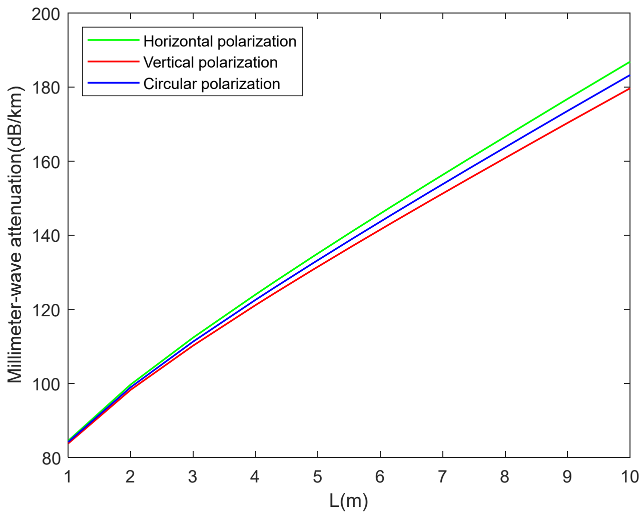

Figure 2. Total attenuation of three different polarization millimeter wave rainfall links

It can be seen from the total loss curve of the millimeter wave link in the rainfall environment in Figure 2 that, similar to Figure 1, the horizontal polarization has the largest impact on the millimeter wave attenuation. However, no matter which polarization, the millimeter wave attenuation is still under the same rainfall rate (20mm/h in Figure 1). Accordingly, f is selected as 30GHz, 70GHz and 300GHz respectively, L (receiving antenna to transmitting antenna) is set as 1m, the rainfall rate ranges 0~100mm/h. Under the horizontal polarization, the total loss of the millimeter wave link is Figure 3.

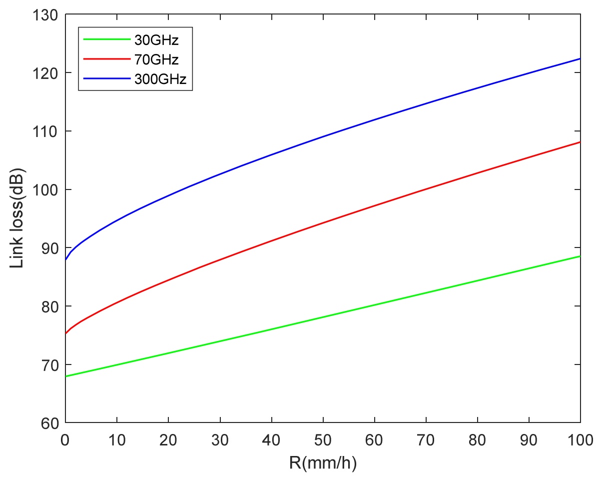

Figure 3. Millimeter wave path loss at different frequencies under horizontal polarization

The total path loss rises. According to the MATLAB work area, even when R is 1mm/h, the total path loss with the lowest frequency of 30ghz is still 67.9424dB. When R reaches 100mm/h, the total path loss reaches about 88.3309dB. The path loss with the highest f (300GHz) also increases from

87.9424dB to 122.3989dB in the range of *R* of 1~100mm/h. In practical application scenarios, the loss of 30GHz millimeter wave in rainfall environment is much smaller than that of 70GHz and 300GHz millimeter wave, which also means that in practical use, the attenuation problem of communication equipment using 30GHz millimeter wave is less than that of other communication equipment using two other types of millimeter wave.

4. Conclusions

This paper calculates the total attenuation of the millimeter wave communication path in the ideal environment, and simulates the influence of the attenuation of different polarization rainfall characteristics on the path loss of the millimeter wave communication system at the same frequency. Finally, under the condition of horizontal polarization, the influence curves of millimeter wave communication path loss under rainfall environment are compared and analyzed.That is to say, the influence of rainfall characteristic attenuation with different polarization on millimeter wave communication system is not very different. But when considering the millimeter wave frequency band, it is necessary to comprehensively consider the rainfall rate, millimeter wave link loss and communication system in the area where the transmitting and receiving devices are located, so as to minimize the impact of the rainfall environment on millimeter wave communication. This provides a theoretical basis for the subsequent design and practical application of millimeter wave communication system.This method is aimed at analyzing propagation characteristics of millimeter wave in precipitation environment, but it also plays a significant guiding role in the in-depth study and analysis of millimeter wave propagation and its propagation characteristics in various special climate environments such as snow and sand.

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