Polarization of Received Signals for Wideband Wireless Communications in a Heavy Rainfall Region

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***Abstract*—Wireless fixed network access offers many advantages such as scalability and ease of deployment in low population density areas. However, its coverage is greatly affected by rainfall. In this letter, we study the effects of rain attenuation on radio channel in a heavy rainfall region for wideband signals in the 10–40-GHz frequency range. We conclude that although a lower frequency of <10 GHz is more affected by multipath due to a longer wavelength, it is still optimal in a heavy rainfall region due to high losses associated with higher frequency signals. In addition, for a path of over 1.5 km, the difference in horizontal and vertical polarization becomes significant.**

***Index Terms*—Attenuation, polarization, rain.**

I. Introduction

WIRELESS fixed network access offers a number of advantages, such as ease of adding subscribers and reaching remote areas with low population densities. However, the practical coverage range is limited by multipath effects, and, more significantly, rain fading. This letter presents results of extensive measurements conducted for polarization diversity reception in an outdoor base station local multipoint distribution system (LMDS). We study the effects of rain attenuation on the radio channel in accordance with ITU (International Telecommunications Union) Rain Region P where 99.99% availability is targeted for rain rate at 145 mm/h [1]. The channel reliability is quantified by its link availability as it measures the percentage of time that the link between transmitter and receiver can be established. Heavy rain severely affects the link availability as raindrops degrade the channel's SNR. In our scenario, the link is disabled by rainfall for no more than 52 min per year.

II. Experimental Details

An LMDS is set up with a fixed outdoor radio transmitter and a mobile receiver is used to measure the received signal to determine the effects of channel mitigation by analyzing the data under severe weather conditions. The received data is captured and stored in a notebook computer for analysis. The raw data is measured for the attenuation with respect to free space. The base station radio unit (BRU) with an integral 90-degree sector antenna converts the intermediate frequency signal from the base station into a carrier frequency ranging from 10 to 40 GHz for transmission over the wireless channel. The subscriber system is composed of an indoor Subscriber Terminal Unit and a Subscriber Radio Unit (SRU) mounted on the roof. The customer equipment, which in this case is a notebook computer for analysis, is placed very close to the subscriber system at 2 m apart to minimize any signal loss.

An assumption that variations of readings taken on different days under different environmental conditions does not exceed 2 dB [2] has been made. The transmitting antenna with gain 18 dBi is placed at the edge of a building at 50 m above ground and an line-of-sight (LOS) is established between the BRU and SRU. QPSK is chosen as the modulation scheme for this experiment to reduce the effects of cell to cell interference. Interference becomes most severe when two components of the same frequency and same polarization overlap. The operative path length d' as a result of rain attenuation is given by

$$d' = \frac{d}{1 + \frac{d}{d_0}} \tag{1}$$

where $d_0 = 35.e^{-1.5\times10^{-2}R}$.

R is the rate of rainfall in mm/hr and d is the path length (km) that the signal can cover for $\mathrm{BER} > 10^{-6}$ in free space. The carrier frequency is varied with a 90-degree base station antenna. The result of difference in rainfall attenuation between horizontal and vertical polarization in decibels per kilometer as a function of frequency is shown in Fig. 1. The difference in attenuation increases at a more substantial rate between 15–25 GHz since water vapor emission is dominated by a molecular resonance in this range with a local maximum at around 22 GHz. From 25 GHz, the attenuation due to rain varies approximately linearly with increasing frequency. Further, we also found this relationship to be independent of drop size distribution. It is also noted that the signal attenuation increases with increasing frequency [3].

The effects of polarized transmission have been studied for cell planning [4]. Under a similar environment, we investigate the fade margin of vertical and horizontal polarization. The fade margin measured is shown in Fig. 2. The y-axis represents the range of coverage by each of the polarized component. The relationship between fade margin α and rain attenuation γ is governed by

$$\gamma = k \cdot R^{\alpha} \tag{2}$$

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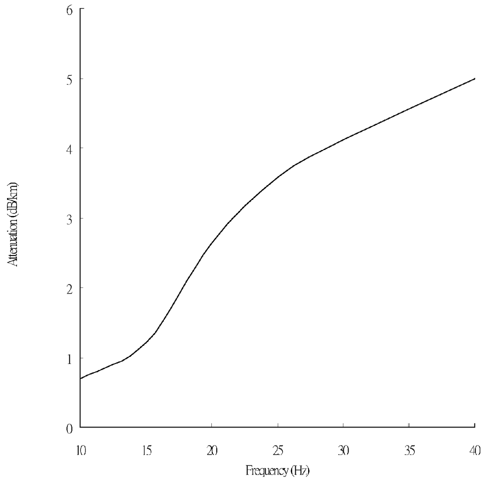

Fig. 1. Attenuation difference vs. frequency: ITU Rain Region-P.

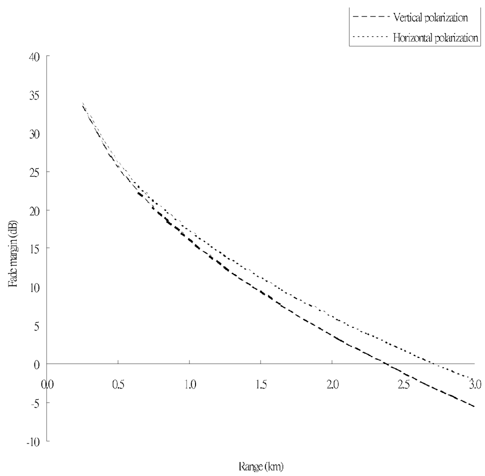

Fig. 2. Fade margin for QPSK, 99.99% link availability.

A lower carrier frequency can reduce depolarization due to rainfall.

The effects of depolarization between horizontal and vertical polarization are studied at 26 GHz. Fig. 2 also shows that the fade margin with horizontal polarization is higher than with vertical polarization and the margin increases with the range. While a lower frequency, namely <10 GHz, is less affected in this respect, it comes with a tradeoff of greater interference due to multipath.

The use of QAM has been studied because of higher cell to cell interference while offering higher data capacity. Fig. 3 shows a comparison between 16 and 64 QAM. With reference to QPSK, the relative fade margin of 16-QAM and 64-QAM is -8.7 and -16.6 dB, respectively.

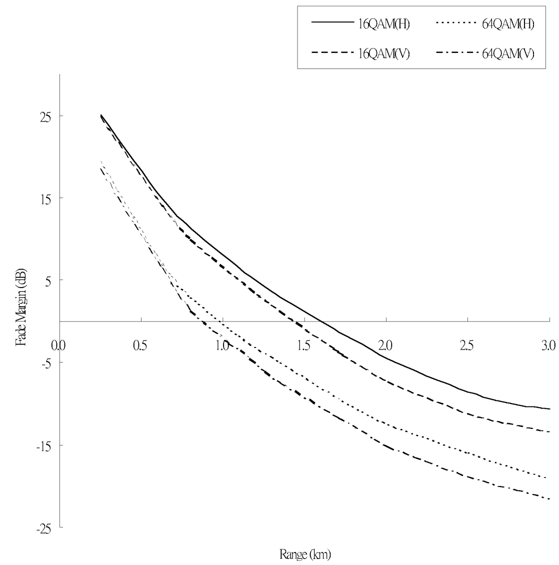

Fig. 3. Fade margin for QAM, 99.99% link availability.

III. Conclusions

A series of measures have been taken under heavy rainfall in Singapore, classified as Region P [1] of tropical climate with the effects of rain attenuation studied for wideband signals of frequency 10–40 GHz. Attenuation becomes more severe as the frequency increases where the rate of attenuation is greatest between 15–25 GHz. While a lower frequency of <10 GHz has much better performance with respect to rain attenuation, it is offset by multipath due to the longer path and the use of low gain antenna in the SRU. The difference in horizontal and vertical polarization becomes significant when the path length is over 1.5 km (the fade margin difference is 2 dB at 1.5 km). A reduction in range is resulted in changing the modulation scheme from QPSK to 16-QAM with the bandwidth efficiency doubled.

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