Terrestrial Link Rain Attenuation Measurements at 84 GHz

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***Abstract*—We present 560 m terrestrial link rain attenuation measurements at 84 GHz in Albuquerque, New Mexico. Both empirical and theoretical rain attenuation models such as ITU-R, Mie and Rayleigh will be examined with the measurements. This study will contribute to the understanding of signal propagation phenomena and the utilization of the W/V-bands for satellite communication.**

I. INTRODUCTION

Radio frequency (RF) satellite communication has expanded to higher frequency spectrums in order to exploit additional bandwidth for data transmission. Gigabit per second data transfer rates are expected to be achieved at millimeter waves (30-300 GHz) [1]. Portions of the V-band (40-75 GHz) and W-band (75-110 GHz) are reserved for future satellite communication bands and the Q-band (33-50 GHz) has started to yield practical uses [2]. One of the main concerns for utilizing W/V-band in a satellite communication system is the lack of understanding of atmospheric attenuation effects. Therefore, it is essential to perform comprehensive research to experimentally quantify atmospheric attenuation effects in this band.

Rain is known as the dominant impairment of W/V-band among the various atmospheric attenuation constituents. Raindrops can be comparable to the size of the wavelengths in this band and make the rain attenuation effect significant. There is a need to experimentally validate existing rain attenuation and scattering models.

The W/V-band Terrestrial Link Experiment (WTLE) is a ground-based long distance atmospheric propagation research experiment in Albuquerque, New Mexico [3]–[5]. In this study, we utilize the receiver system of WTLE and conduct a 560 m short distance link experiment (i.e., short-link WTLE) for the rain attenuation measurement. We examine rain attenuation models such as ITU-R, Mie, and Rayleigh with the short-link WTLE that provide nearly homogeneous rain attenuation across the path and minimum of other atmospheric attenuation effects.

II. RAIN ATTENUATION MODELS

In general, there are two types of rain attenuation models: empirical and theoretical models. The most well-known and utilized empirical model is ITU-R. ITU-R p838 gives recommendations for calculating the rain attenuation with a simple functional form $\gamma = kR^{\alpha}$, where γ is the specific attenuation (dB/km), R is the rain rate (mm/hr), and k and α are the frequency dependent coefficients [6]. This model has proven to be reliable in various frequency ranges but remains incomplete for millimeter waves. Indeed, the ITU-R model did not match well with the measurements in several experiments involving millimeter waves [7]. This was mainly due to the fact that the coefficients k and α were not obtained for millimeter waves but extrapolated from lower frequencies.

Among many theoretical rain attenuation models, Mie and Rayleigh scattering models are based on fundamental electromagnetic theories of Maxwell's equations. Mie scattering model is based on the solutions of Maxwell's equations for the scattering of electromagnetic waves by a spherical particle [8]. The model works at the wavelengths similar to the size of the particle.

The Rayleigh scattering model is for the case when the size of the particle is much smaller than the wavelength [9]. The dielectric particle will act like a dipole and radiates in-phase with the incident wave. The radiation increases as D^3/λ, where D is the diameter of the particle, and λ is the wavelength of the incident wave. Due to the wide spectrum of the raindrop size, we may need to use Mie and Rayleigh models simultaneously to represent the measurements.

III. EXPERIMENTAL SETUP

In this research, we temporarily re-purpose the 84 GHz receiver from the 23.6 km WTLE link to support the 560 m short-link WTLE. An unmodulated right-hand circular polarized signal is transmitted while the receiver collects vertically and horizontally polarized signal in separate channels. This short-link WTLE will operate during the desert monsoon season of 2016 (approximately 3 months) in order to focus on the rain attenuation effect. Two disdrometers located at the transmitter and receiver site provide accurately measured rain rate and raindrop size distribution (i.e., DSD). A system diagram is shown in Fig. 1.

The experimental configuration is an attempt at isolating attenuation due to rain by minimizing contributions from other atmospheric phenomena such as clouds and turbulence. From the short-link WTLE, we gather essential rain attenuation data with reliable information about the rain across the link.

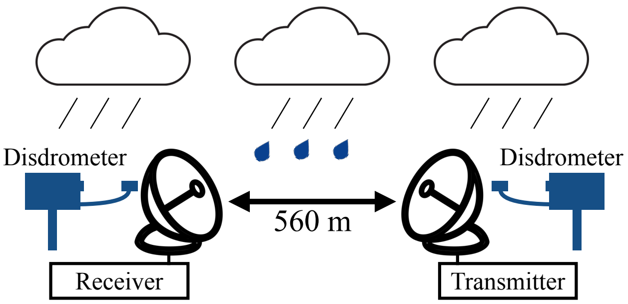

Fig. 1. Experiment diagram.

IV. PRELIMINARY RESULTS

We present the data that shows the change of received signal power during the rain events along with the measured rain rate in Fig. 2 and Fig. 3. Fig. 2 shows the observed signal power during the rain event on August 8, 2016 while Fig. 3 presents the rain rate for the corresponding rain event at the receiver and transmitter site. We will analyze data from rain events comparing measured attenuation with attenuation model estimates to evaluate the various models previously described.

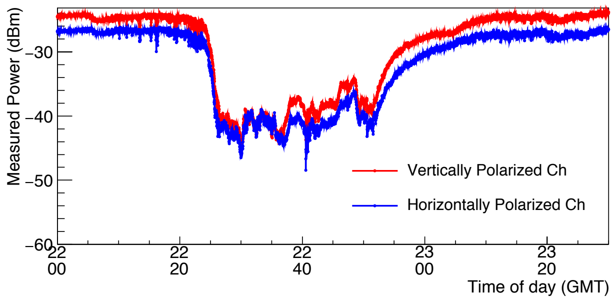

Fig. 2. Received signal power during the rain event on August 8, 2016.

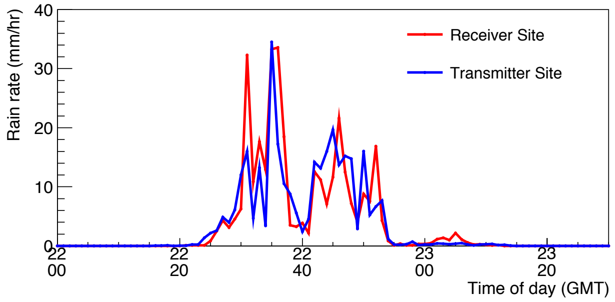

Fig. 3. Measured rain rate at the transmitter and receiver site during the rain event on August 8, 2016.

Fig. 4 shows the rain attenuation (dB) across the terrestrial link from 27 days of August 2016 data. During the period of data collection, there were 9 rain events including the one shown in Fig. 2 and Fig. 3. The experiment will be conducted through the end of October 2016 to capture more rain events.

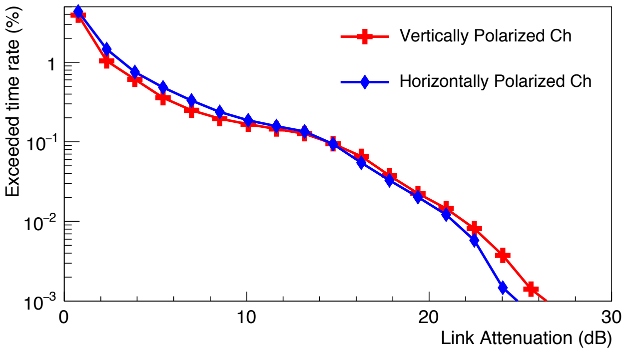

Fig. 4. Rain attenuation statistics from August 2016 data.

V. SUMMARY

We are measuring rain attenuation over a 560 m terrestrial link at 84 GHz. This short distance link experiment will provide measurements of attenuation due to rain effects nearly uncontaminated by other atmospheric effects. We will evaluate various rain attenuation models such as ITU-R and Mie to understand the limitation of each model. This research will contribute to the understanding of signal propagation phenomena and the utilization of the W/V-bands for satellite communication.

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