Preliminary Mid-Band Troposcatter Measurement Results using Different High-Gain Receiver Antennas

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***Abstract*— This article provides initial results of measurements made to assess the influence that different antenna patterns have on the received signal level of a mid-band troposcatter radio link. Measurements were performed at 3.475 GHz over a 185 km troposcatter link in Colorado with two vertically polarized receiver antennas: standard gain horn and parabolic dish. Median values of basic transmission loss (BTL) are compared for the two antennas. Cumulative distribution functions (CDFs) of hourly median BTL are plotted against predictions from the Institute for Telecommunications Sciences' Irregular Terrain Model (ITM). BTL measurements with the standard gain horn (219.77 dB median and 8.73 dB standard deviation) show better comparison with ITM predictions (214 dB median, and approximately 7.8 dB standard deviation) than BTL measurements made with the parabolic dish (228.21 dB median and 8.67 dB standard deviation). Further measurements and modeling are needed to explain these differences.**

Keywords—antennas, propagation modeling, measurement design, test and validation

I. Introduction

The Institute for Telecommunications Sciences (ITS) is conducting a multi-year Mid-Band Propagation Model Study program funded by the Department of Defense Chief Information Office with the goal of establishing an improved and community-accepted mid-band (i.e., 3.1–4.2 GHz) radio frequency propagation model framework to predict basic transmission loss (BTL) for a diverse range of link geometries, e.g., clutter, terrain, air/ground, over-water, and trans-horizon. Propagation models are powerful tools used to predict signal characteristics in a complex environment. These models must make assumptions about the environment and radio system to be useful and effective. One common assumption is to describe terminals as isotropic, which are convenient theoretical constructs. However real-world antennas focus energy (as described by the antenna gain and radiation pattern), which can cause discrepancies in predictions if not accounted for properly.

This article focuses on the troposcatter link geometry with the theory and predictive models developed from first principles by Dalke [1]. Dalke describes electromagnetic wave interactions with the troposphere through the common volume shared by a transmitter and receiver located along a path over the horizon. Dalke develops and describes the integral involved in calculating the scattering energy within this volume and the relationship that antenna gains and atmospheric refractivity have on predicted outcomes. Models that utilize the common volume integral, such as the Irregular Terrain Model (ITM) [2], assume that the antennas are isotropic, which makes the integral easier to solve. In the real world, isotropic antennas do not exist, with the closest equivalent being omnidirectional antennas. Such antennas are infrequently used to transmit over trans-horizon paths.

In this paper, preliminary mid-band troposcatter measurement results are provided for two different vertically polarized receiver antennas to assess the influence that antenna patterns have on the received signal level.

II. Measurement Description

In August of 2022, ITS deployed a 3.475 GHz continuous-wave (CW) fixed location transmitter (TX) mounted on a tower in Sterling, CO, and a fixed location receiver (RX) installed at the Table Mountain Radio Quiet Zone and Open-Air Test Facility [3]. Fig. 1 shows a simple diagram of the measurement system configuration and components. Measurement parameters are summarized in Table 1.

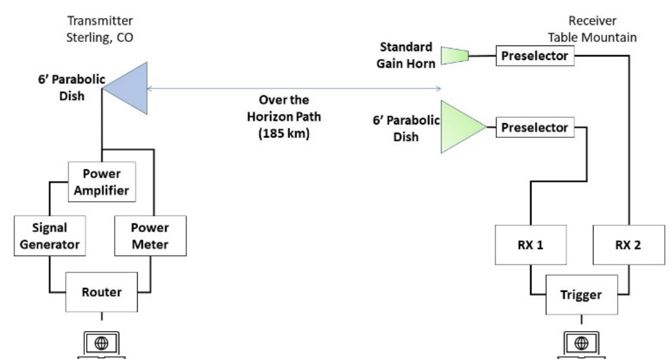

Fig. 1. Diagram of 3.475 GHz troposcatter measurement system deployed at Sterling, CO, and Building T2 at Table Mountain, Boulder, CO.

Table 1: Relevant Measurement Parameters

System Component	*Value*
6′ Parabolic Dish Antenna	3 dB Beam Width: 3.3° Gain: 33.5 dBi Polarization: Vertical
Standard Gain Horn Antenna	3 dB Beam Width: 18° Gain: 20 dBi Polarization: Vertical
Transmitter	Center Frequency: 3.475 GHz Mean Power: 44.8 dBm
Receiver (with Preselector)	Noise Figure: 4.6 dB Gain: 24 dB Equivalent Noise Bandwidth: 1 kHz

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At Sterling, a CW signal was generated as input to the 6′ parabolic dish for the duration of the experiment. Each antenna (at the TX and RX sites) utilized a precision path alignment kit to ensure the center beam for each was directed at the common volume crossover point. This point is defined as the lowest point where the common volume intersects and is calculated using the geometry of the site locations and the connecting path's terrain profile.

The experiment consisted of two trigger-controlled RXs for synchronous recordings. RX1 used a 6′ parabolic dish antenna with a gain of 33.5 dBi, followed by a preselector with a 50-MHz wide bandpass filter and low noise amplifier. The output of the preselector was connected to a laboratory-grade signal analyzer. RX2 is composed of an identical system to RX1 but substituting a 20 dBi standard gain horn antenna. Both antennas were installed on an observation platform approximately 5 m above ground level (AGL). A data capture consisted of the received signal sampled at 1.25 k samples per second for an hour. The system was then automatically calibrated before taking the next one-hour data capture. This process continued for 48 hours, resulting in 46 separate data files, with breaks for calibration and maintenance.

III. Results and Discussion

Each hourly data capture was processed to remove system influences (e.g., line losses, amplifier gains, or antenna gains) that resulted in the basic transmission loss (BTL), as described in [4], which is shown as plotted hourly median values in Fig. 2. The standard deviation from RX1 is 8.67 dB, which is very close to that recorded on RX2 at 8.73 dB, implying that the dynamic environmental conditions were observed equally.

The cumulative distribution functions (CDF) of the hourly medians of BTL for each RX show notable differences as illustrated in Fig. 3, which also shows predicted values from ITM. Observe that BTL measured by the standard gain horn antenna compares more favorably to the ITM predicted results than BTL measured by the parabolic dish. Specifically, the median BTL measured by the standard gain horn was 5.82 dB higher than that predicted by ITM, whereas the median BTL measured by the parabolic dish was 14.26 dB higher than that predicted by ITM.

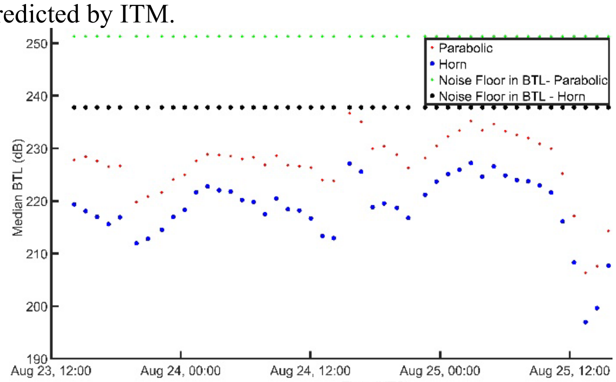

Fig. 2. Plotted hourly median of basic transmission loss (BTL) as recorded on RX1, with a parabolic dish antenna (red x) and on RX2, with a standard gain horn antenna (blue o). The approximate noise floor in BTL for each system is provided in green and black, respectively.

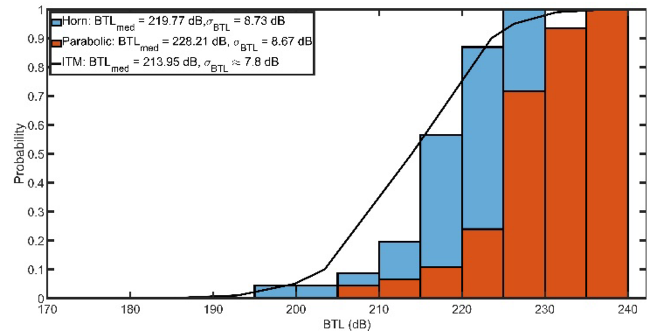

Fig. 3. Cumulative distribution function (CDF) of hourly median basic transmission loss from RX1, using a parabolic dish antenna (red) and RX2, using a standard gain horn antenna (blue). The CDF from ITM is plotted in black.

With two identical receivers with different antennas, we can observe the antenna effects on the received signal. The full scope of these effects warrants more investigation. This discrepancy could be attributed to the narrow beam of the parabolic antenna creating a smaller common volume, or, alternatively, the broad beam of the horn antenna being more receptive to the scattered energy of the propagated signal. Follow-on measurements with longer time duration and different antenna configurations are planned for next year.

IV. Conclusion

Antenna patterns must be considered to accurately predict signal characteristics in a propagation channel. Further measurements and modeling are needed to explain differences in BTL between those recorded with a parabolic dish and those made with the standard gain horn when compared to predictions from models such as ITM.

Acknowledgment

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