# UHF Mountain Propagation: Measurements and Modelling

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***Abstract*— The White Mountains in New Hampshire provide a location where UHF non-line of sight (NLOS) paths become important. Because line of sight (LOS) paths are often blocked, reflections from adjacent tree covered slopes, visible to both transmitter and receiver, provide a bistatic propagation path with sufficient intensity. The question of the reflection mechanism will be discussed using broad band measurements and forest models.**

***Keywords—NLOS links; wide-band measurements forest models, diffuse scatter***

## I. Introduction

The NLOS radio-frequency (RF) channel for ground communications in mountainous terrain exhibits multipath and delayed behavior, causing intersymbol interference and equalization issues at the receiver [1-2]. Bistatic travel time between a transmitter and receiver is often tens of micro-seconds and can exceed 100 $\mu$ sec in mountainous terrain [3-4].

Streeter, Breton and Corgan [5] have built a portable channel sounder and measured these effects at 437 MHz in several locations in the White Mountains of New Hampshire. Their results show power-delay plots with delay spreads of up to 80 $\mu$ sec. Using Digital Elevation Maps (DEM) of the regions under test, they can locate the mountain side areas where both the transmitter and the receiver are visible (co-visibility regions) and calculate the location of bistatic delay contours, thus relating measured channel characteristics to specific scattering locations in the surrounding environment.

Assuming there are several co-visible paths from the transmitter to the receiver, the received power can be given

$$\mathrm{P_r} = \frac{\lambda^2}{(4\pi)^3}\sum_{n=1}^{N}\frac{\sigma_n^0 \mathrm{A}_n P_{tn}}{\mathrm{r}_{TSn}^2 \mathrm{r}_{SRn}^2} \tag{1}$$

where $P_{tn}$ is the power incident on the n^th^ co-visibility region of area $\mathrm{A}_n$, $r_{TSn}$ and $r_{SRn}$ are the distances from the transmitter and receiver to the n$^{th}$ co-visibility region $A_n$ and $\lambda$ is the wavelength. All quantities in (1) can be calculated from geometric considerations except the bistatic scattering cross section, $\sigma_n^0$ of the n$^{th}$ mountainside region. In this paper the forested mountainside will be modeled and the bistatic cross section will be computed in an attempt to understand the source of the reflection.

## II. Channel and Forest Measurements

Measurements using the channel sounder at 437 MHz were conducted in September/October, 2018 in the Mount Washington region of the White Mountains in New Hampshire. The experimental site is shown in Fig. 1. Here the Mount

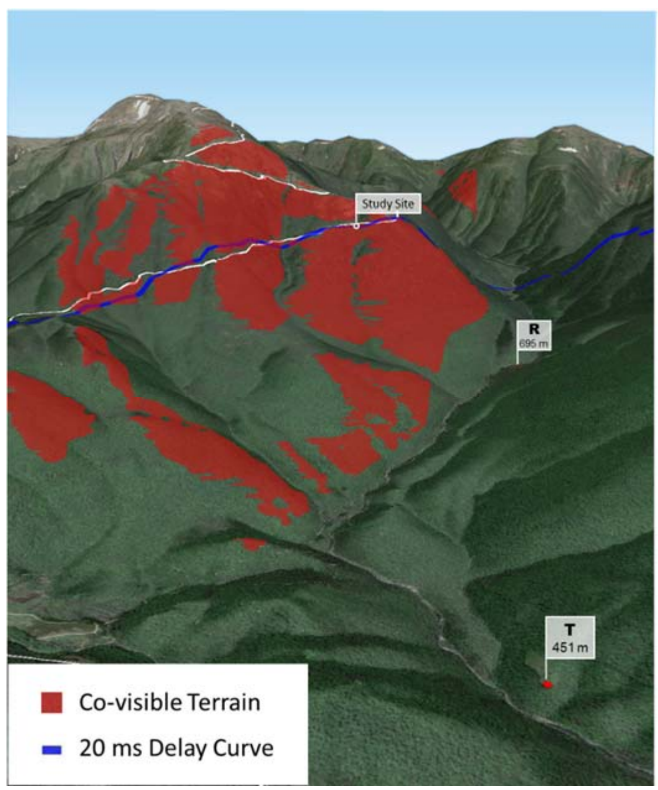

Fig. 1: Experiment site

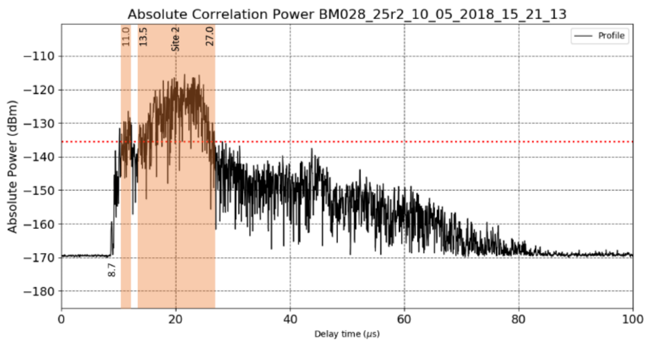


Fig. 2: Power-delay profile

Washington Auto Road to the peak is shown by the gradually ascending white line. This road was used to access sites where ground truth measurements were made.

The transmitter antenna T (see Fig. 1) was a vertically polarized corner reflector fed by a dipole, located 3 m above ground level. The antenna had a beam width of 60° and the antenna azimuth was aligned with the region of interest. The receiving antenna was a vertical dipole located 2.5m above ground level. There was no direct line of sight path between the transmitter and the receiver. The regions of co-visibility are shown in Fig. 1 by the red colored regions.

A graph of the measured power vs delay is shown in Fig. 2. The maximum power received occurs in the region around 20 $\mu$sec. In Fig. 1 a purple line (close to the road) indicates the place where the bistatic delay from transmitter to receiver is 20 $\mu$sec.

Vegetation maps indicate that forests of spruce and fir trees inhabit this region. The team made measurements at three sites close to the road. One of those sites is particularly close to the 20 $\mu$sec delay line as indicated in Fig. 1. This site is occupied by a dense growth of spruce trees. The slope of the region is about 30 deg. from the horizontal. The team has measured the dbh (diameter at breast height) of about 150 trees that is used to construct a dbh distribution as a function of tree diameter. The average tree height is about 10 m. Several profiles of the surface are taken by measuring the distance from a taut line.

## III. Calculation of $\sigma^o_{vv}(\theta_i,\phi_i;\theta_s,\phi_s)$

The George Washington University has developed a forest model for the UHF frequency range [6-7]. The forest is considered to be a collection of discrete scatterers. Tree trunks, branches and needles are modeled by lossy dielectric cylinders and leaves by lossy dielectric disks. The distorted Born approximation is used to compute the bistatic scatter taking into account the reflection and scatter from the underlying rough surface. Presently the model is being adopted to an inclined rough surface. Initial estimates indicate that at P band frequencies the bistatic scattering cross section will be impacted by the presence of the underlying rough surface.

## IV. Conclusions

An experiment involving multipath measurements and forest modeling has been initiated. A site close to the region of maximum scatter is in the process of being modeled. Since only one site along the 20 $\mu$sec delay curve has been investigated other sites must also be studied, however a methodology has been established.

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