# Surface Wave Propagation over a Rough Talus Slope at 160 MHz

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*Abstract*— **Field experiments of air surface wave propagation at 160 MHz were performed on a rough non-conductive dielectric talus slope of granite blocks, all of the same composition. Amplitudes for both vertical and cross polarization were measured meter by meter along linear transects 250 and 500 m long, along with GPS measurements of position and elevation. Attenuation rates for both polarizations were greater for smoother transects, with height standard deviation of about one third free space wavelength, than for rougher transects with up to one wavelength deviation. This unexpected finding resulted from the smoother dielectric surfaces permitting loss of energy into subsurface head waves, as evidenced by the nearly range-squared dependency of the surface waves. The results suggest direct point-to-point communications over rough terrain can be realized over multi-km distances.**

## I. Introduction

Point-to-point communications in rough terrain can take place via direct surface waves, indirect reflections from slopes, or by diffractions over ridges. Within wide valleys direct links may be the only viable channel, and may involve several intermediate links when there is no line of sight. If the surface roughness is much less than a free space wavelength, $\lambda_0$, then the ground wave amplitude attenuates as $1/R^2$, where $R$ is range. This dependency is approached within less than $2\lambda_0$ for vertical or horizontal broadside polarization, but not as quickly for radial endfire polarization [1–3]. As antenna height increases the range dependency approaches $1/R$. Here we report 160-MHz field experiments to find attenuation rates for propagation over a rough slope for which the elevation standard deviation from a mean ranges from $0.28\lambda_0$ to about $\lambda_0$. Thus we simulate communication by hand-held transceivers, with polarization varying from true vertical to true horizontal.

## II. Methods

Fig. 1 shows the setting for the transmit antenna (always vertical) and the insert shows the Yagi receive antenna. The talus slope is on the east side of Cannon Mountain in central New Hampshire, visible from highway Interstate 93 within Franconia Notch. The average slope is nearly uniform at 35° from horizontal. The rocks are granodiorite with a dielectric constant likely between 6 and 7. Avalanches are common from the overhanging sheet-fracture formation. We radiated at 160 MHz, commonly used world-wide with hand-held transceivers. We used both vertical and cross polarization, with amplitude measured every meter along two linear transects across slope and one down slope, and recorded GPS to about 10 cm precision. Vertical is absolute, and not with respect to the mean ground slope. Starting amplitudes were similar for all runs. Each profile took several days to record and so horizontal polarization or orienting the antennas perpendicular or parallel to slope were not tried, but the cross polarization results suggest they would be superfluous.

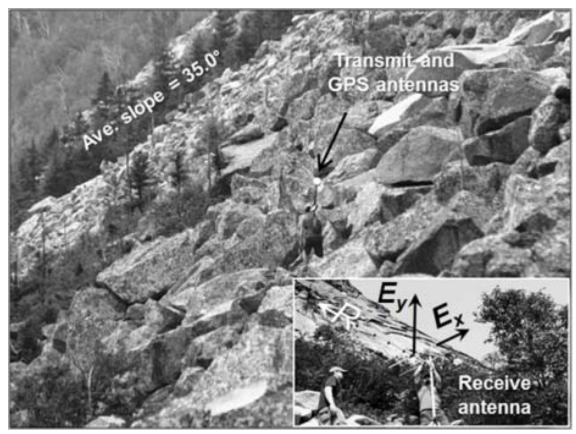


Fig. 1. The talus slope of angular boulders. Transmit and GPS antennas are carried along a linear across-slope transect. Insert shows receiver Yagi antenna and polarizations

## III. Results

Figs. 2 and 3 show the across-slope transects. The vertical polarization best fit $R$ exponent of 1.364 is intermediate between the extremes of 1.00 and 2.00. It applies to the first 424 m, beyond which elevation increased and the attenuation rates approached that of free space. The standard deviation (SD) from a best fit is 5.72 dB; SD of the elevation is 1.28 m, or 0.68 $\lambda_0$. The cross polarized best-fit exponent is 1.334 with SD = 5.00 dB, and elevation SD ≈ $\lambda_0$. Figs. 4 and 5 show the results for the down-slope transects. The vertical-to-vertical exponent is 1.579, and the vertical to horizontal exponent is 1.864, with SD = 3.74 and 5.08 dB, respectively. In the former case the transect elevation SD from a mean value = 0.52 m = 0.28 $\lambda_0$; for cross-polarized the elevation SD = 0.30 $\lambda_0$. A LiDAR survey from across the valley found SDs of 1.05 and 0.81 m for the across and down slope areas, respectively.

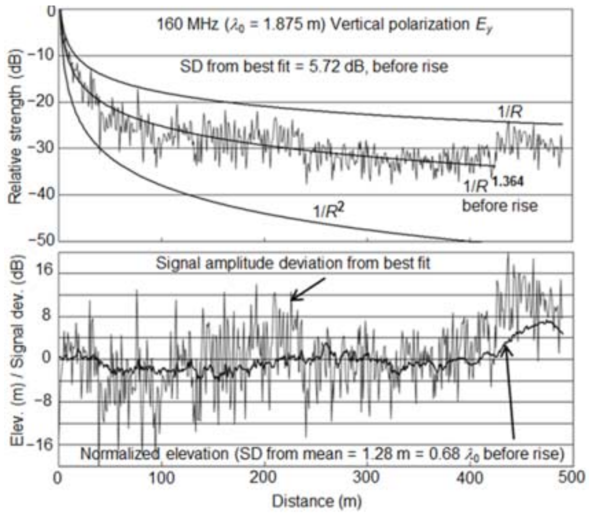


Fig. 2. Amplitude and elevation for the along-slope vertical polarization transect.

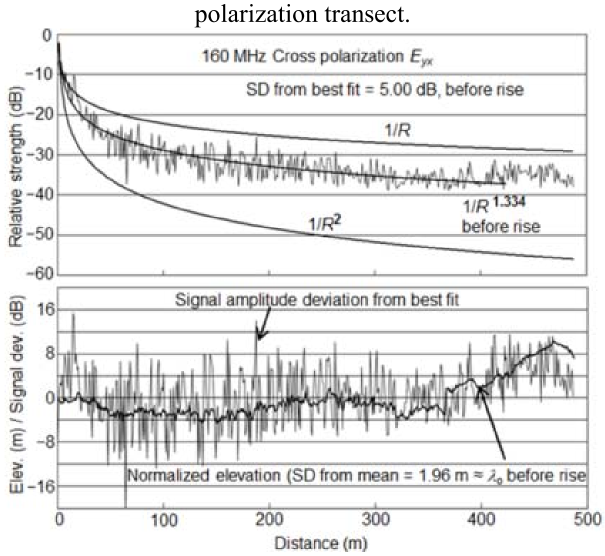


Fig. 3. Amplitude and elevation for the along-slope cross polarization transect.

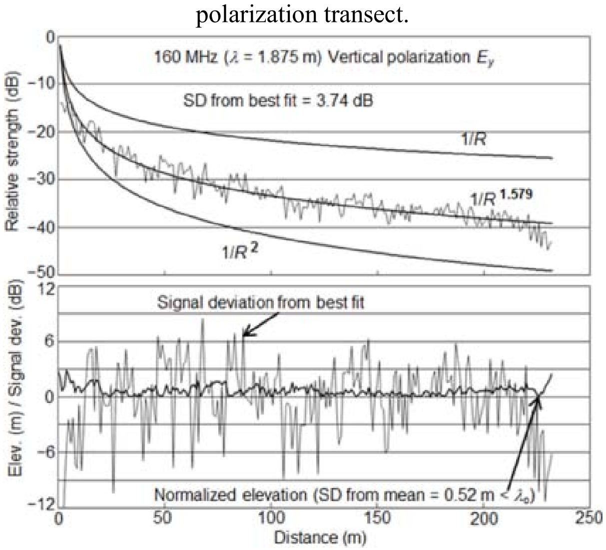


Fig. 4. Amplitude and elevation for the down-slope vertical polarization transect.

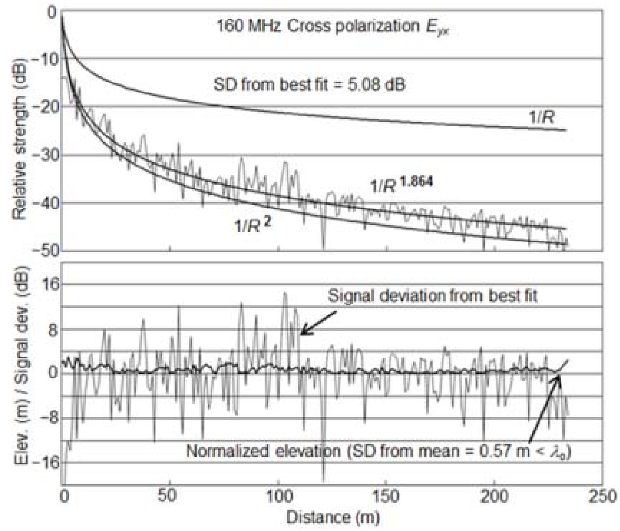


Fig. 5. Amplitude and elevation for the down-slope cross polarization transect.

## IV. Discussion and Conclusions

The attenuation rate was surprisingly greater for both polarization cases along the smoother down-slope transect, and approached the ground wave 2.00 rate for one run. We think this is because the smoother case allowed energy loss into the ground, as evidenced by the rate being near the ground wave $1/R^2$ case. This energy would be within a head wave (Fig. 6). The rougher ground prevented this type of loss, and the boulders caused sufficient forward scattering to bring the attenuation rates closer to the $1/R$ free space case. The exponent should greatly increase where all line-of-sight is lost.

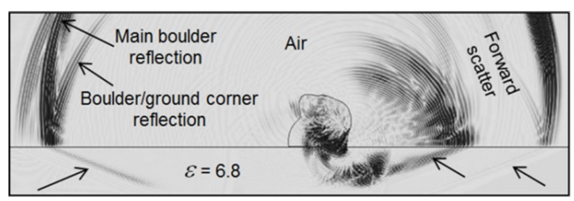


Fig. 6. 2-D simulation of pulse encountering a 7 $\lambda_0$ size dielectric ($\varepsilon = 6.8$) boulder. Arrows indicate forward and back head waves. Note strong forward boulder scatter.


## Acknowledgement

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