Preliminary Results from the AFRL-NASA W/V-Band Terrestrial Link Experiment in Albuquerque, NM

Wave Propagation in Terrestrial, Oceanic and Atmospheric Environments

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Presentation Overview

1. Motivation & Experiment Goals
2. Site of Study
3. Receiver Site (COSMIAC)
4. Transmitter Site (Sandia Crest)
5. Instrumentation
6. Preliminary Results
7. Solar Influence
8. Concluding Remarks

Wireframe schematic of the WTLE receiver front end electronics.
Motivation & Goals

Experiment Motivation & Goals

- To **assess the impact** of atmospheric effects on links operating in the V and W-band (rain attenuation, scintillation, depolarization, etc.).
- To **develop physical models** to improve predictions of atmospheric attenuation within the V/W-band.
- To provide a **testbed** for RF propagation measurement instruments & techniques.
- To assess **optical link** performance with a side-by-side link in tandem with the existing RF link.

*WTLE transmitter front end electronics and lens antennas.*
## Site of Study

### Receiver
- **Site**: UNM / COSMIAC (Roof)
- **Latitude**: 35.054031° N
- **Longitude**: 106.619443° W
- **Altitude**: 1.596 km
- **Installation Date**: September 2015

### Transmitter
- **Site**: Sandia Crest
- **Latitude**: 35.215128° N
- **Longitude**: 106.451245° W
- **Altitude**: 3.239 km
- **Beacon Freqs.**: 72 GHz, 84 GHz
- **Installation Date**: September 2015

### Path
- **Azimuth**: 40.444°
- **Elevation**: 3.984°
- **Path Length**: 23.55 km

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COSMIAC (University of New Mexico)  
(Photograph: Google Earth)

Sandia Crest  
(Photograph: Google Earth)
Receiver Site (COSMIAC)
Transmitter Site (Sandia Crest)
Instrumentation

Beacon Receivers

- **Antenna Gain**: 45.6 dBi (V / W-band)
- **Dynamic Range**: 70 dB (V) / 68 dB (W)
- **Co/Cross-Polarization Isolation**: 13 dB (V) / 20 dB (W)
- **Polarization**: LHCP
- **Sampling Period**: 0.1 sec (10 Hz)

Weather Instrumentation

- **Anemometer**: Young 05178A
- **Temperature/Humidity Sensor**: Young 41382VC
- **Pressure Sensor**: Young BPV3000
- **Tipping Bucket**: Young 52203
- **Laser Disdrometer**: Thies Clima 5.4110
Block Diagram
Under normal operating conditions, the V and W-band receivers track their respective beacon signals using a modified Quinn-Fernandes frequency estimation algorithm. The cross-polarization signal is tracked from the current co-polarization frequency.

When attenuation approaches the noise floor (below a given power threshold), the frequency estimate is replaced by an average of the frequency estimate prior to the fade. This allows for a slight improvement in dynamic range during the beginning and end of deep fades.

Signal lock is immediately regained when the signal reappears above the noise floor.
Clear Sky Day (2015-09-30)

Diurnal variations in atmospheric gaseous absorption (AGA) observed in timeseries attenuation on clear-sky days.
Deep Rain Fade (2015-11-04)

Strong rain event exceeds dynamic range of receiver on all channels.

Photo Credit: Albuquerque Journal
Rain at receiver subsides while rain fade continues, indicating continued rain along the path.
Strong depolarizing effects observed on both V and W-band channels during solid precipitation (snow) event.

Photo Credit: Albuquerque Journal
Cloud Event (2016-01-09)

Strong fluctuations on both V and W-band channels with no precipitation while clouds obscure the peak of Sandia Crest.
Measurement Spectral Density

Channel Power (dBm)
Time (UTC)

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Channel Power (dBm)
Time (UTC)

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Attenuation Statistics

Large month-to-month variability, up to 35.8 dB (V) and 39.8 dB (W) between the best and worst months.
Rain Rate Statistics

In total, rain was observed 1.05% of the time over the 7 month period (approx. 61.48 hours).

99.9% of the 7 month period, the rain rate was less than 3.513 mm/hr.

In other words, the rain rate was less than 3.513 mm/hr for 90.48% of times when rain was measured.
Daily co/x power disturbances were observed, particularly on the W-band, and correlated with solar position. This was remedied by replacing the transmitter radome with a more suitable $\varepsilon_r=1$ dielectric.
Concluding Remarks & Future Work

Conclusions

• The WTLE terminal has been operational since October 2015, collecting attenuation, scintillation, and depolarization data across a 26 km link in Albuquerque, NM. As of this presentation, **nearly nine months of data have been collected**.
• For **99% of the time, the observed attenuation was less than 16.845 dB (V) and 22.065 dB (W)**. The worst months in terms of the attenuation were October (V) and November (W), while the best month for both was March (V and W).
• Large monthly variability was observed, with a difference of up to **35.8 dB (V) and 39.8 dB (W)** month-to-month.
• Rain was observed **1.05%** of the time over the analyzed 7 months (61.5 hrs). The rain rate only exceeded 3.5 mm/hr for **5.8 hrs** over the 7 months.

Future Work

• Weather station along the path is currently being installed to assess weather conditions along the link.
• Tandem optical link is planned for the near future to characterize optical propagation with concurrent RF data.
Thank You!
Appendix Charts
Contact Information

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Tx Air & Plate Temperatures and PWM Output
Power Detector Variance & PWM Outputs
Receiver Software
Tx Power vs. Rx Power (2015-09-29 0600 - 1200)

TLE Transmitter Power Detectors

2015-09-29

Receiver Power (dB)

Transmitter Power Detector (dBm)

ΔTx = 0.7896 dB
ΔRx = 1.815 dB

y_Co = 1.1894x + -32.8114

ΔTx = 0.7896 dB
ΔRx = 1.446 dB

y_X = 0.44256x + -39.1026