



Preliminary Experiments for the Assessment of V/W-band Links for Space-Earth Communications

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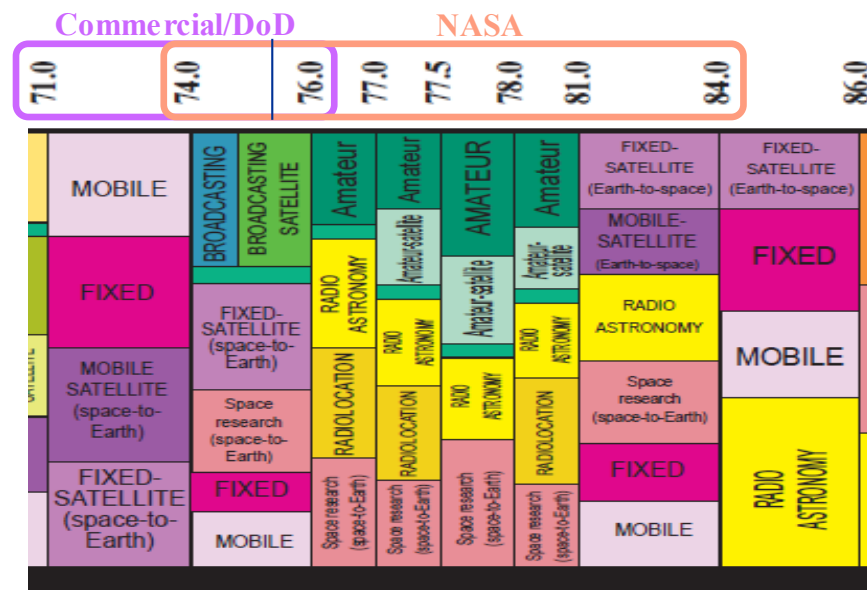
Motivation



Motivation

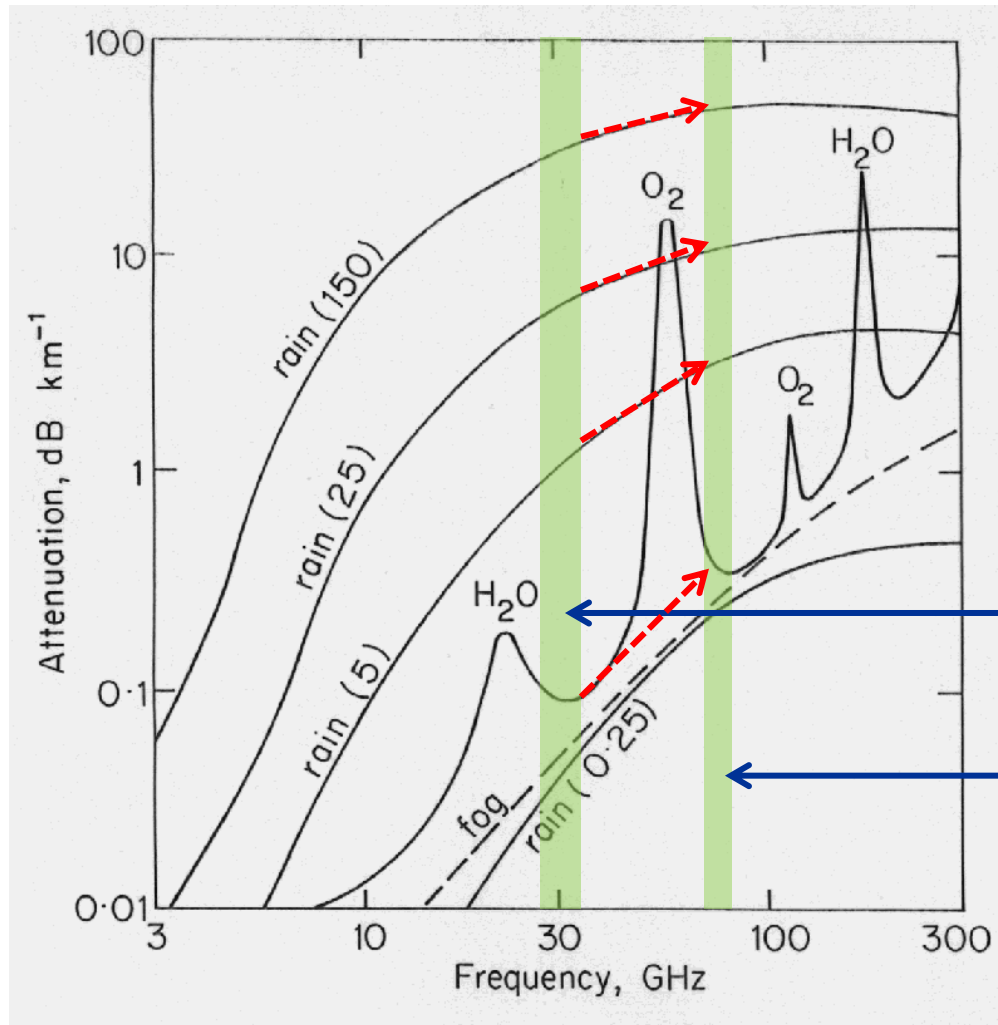
- As a result of spectrum crowding and the need for wideband, high data rate space communications systems becomes increasingly problematic within the confines of currently utilized spectrum allocations, a typical approach is to move to higher frequencies where these limitations are not yet realized.
- Two communications architectures hoping to achieve multi-Gbps data rates are being investigated concomitantly by NASA, via the next generation Space Based Relay (SBR), and by AFRL, via the future military satellite communications (MILSATCOM) system, for the potential use of V/W-band space-earth links (NASA: 74-84 GHz, AFRL: 71-76/81-86 GHz).
- However, several issues related to propagation through the Earth's atmosphere must be better understood before reliable communications systems can be designed at these frequencies. These issues include:

- **gaseous absorption, cloud attenuation (passive radiometry)**
- rain attenuation, scattering, scintillation, and signal depolarization. **(active beacon)**



Space-to-Earth Downlink Allocations [1]

Absorption Spectra of the Atmosphere



Current operational frequency band (Ka)

Frequency band of interest to NASA/DoD

Sea level specific attenuation spectra induced by the atmosphere as a function of frequency due to atmospheric gases and various rain rates [2].



Motivation (continuation)

- Ideally, a space-based beacon should be employed to characterize the full propagation path, but, in the absence of such an opportunity, a terrestrial link can provide valuable information which can be used to enhance passive radiometric measurements.
- In this paper, preliminary results of gaseous and cloud attenuation estimates in the V/W-band derived from a microwave profiling radiometer deployed at White Sands, NM, is presented as a first-order estimate of V/W-band communications system performance.

Measurement	Radiometer	Terrestrial Beacon	Space-based Beacon
Gaseous Attenuation	Green	Green	Green
Cloud Attenuation	Green	Red **	Green
Rain Attenuation	Red	Yellow	Green
Depolarization	Red	Yellow	Green
Scintillation	Red	Yellow	Green
Tropospheric Dispersion	Red	Yellow	Green
Ionospheric Dispersion	Red	Red	Green

Terrestrial experiment can provide first order estimates of these effects at substantial cost savings!

Fully characterizable
 Partially characterizable
 Cannot characterize

** Could potentially characterize if transmitter placed above cloud layer



Experiments

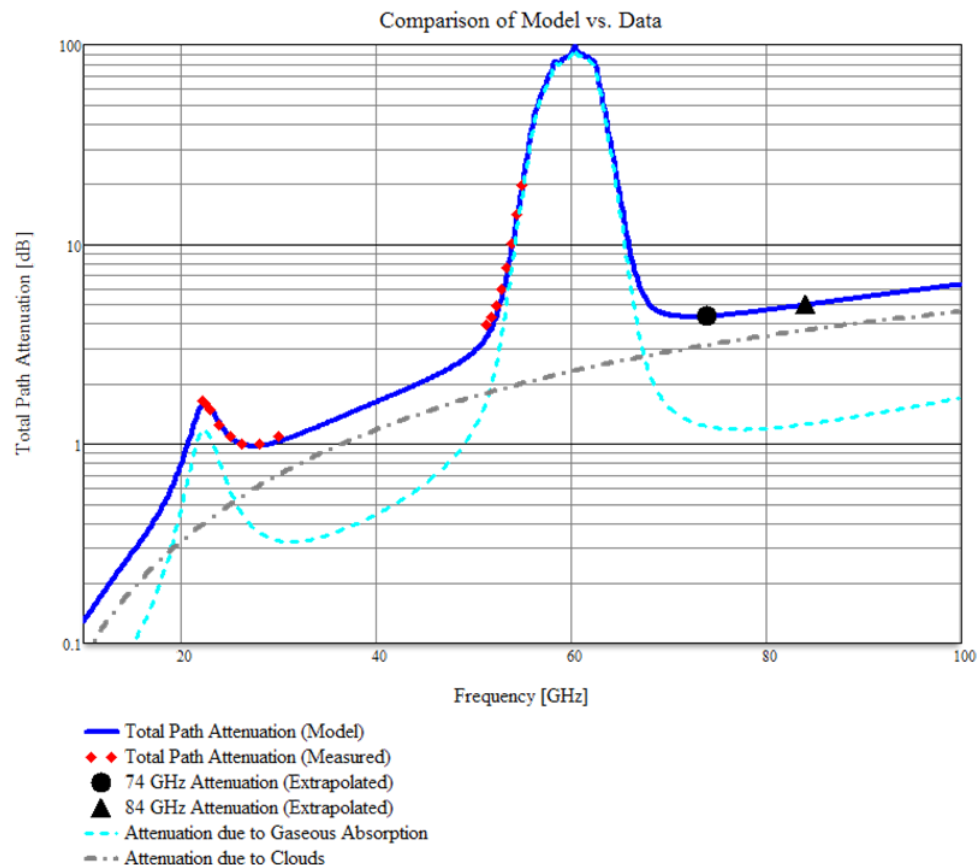


Overview of Past Terrestrial Millimeter Wave Experiments

Experimenters	Link Length	Frequency (GHz)	Duration	Main Results
Ho, et. al. [2]	4.1 km	36, 110	2 years	Measured scaling factor between 36/110 GHz rain attenuation and found it to fit ratio curve computed using Laws-Parson drop size distribution. Measured scintillation effects on the order of 3 dB on 110 GHz path.
Weibel, et. al. [3]	2 km	90.5	1 year	Showed significant deviation in range of attenuation due to rain dependent on drop size distribution for specific rain events, rain rates.
Buys, et. al. [4]	935 m	94	4 months	Showed good agreement between measurement and model for drop size > 0.6mm. Not the case for drizzle conditions.
Sander [5]	1 km	52, 90.8, 150	2 years	Measured rain attenuation coefficients as a function of rainfall rate. Statistical averages show moderate correlation with model.
Timms, et. al. [6]	250 m	60	1 year	Measurement of rain attenuation exceeds values predicted by ITU-R models.

Appears to be lack of terrestrial propagation data in the 70/80 GHz region of spectrum...

Radiometric Characterization of White Sands



- A Radiometrics MP-3000A Temperature, Humidity, and Liquid Profiler has been deployed at White Sands, NM, since September 1, 2012.
- From the 35 channel radiometric measurements and derived atmospheric profiles, estimates of the gaseous and cloud attenuation in the V/W-band can be made using existing models.



Radiometric Characterization of White Sands (cont)

- The Cumulative Distribution Function (CDF) of losses due to gaseous and cloud attenuation for six months of data collection in White Sands, NM, is shown in Figure 2.
- Radiometric data is for clear sky and cloud conditions only. Rain events were removed from data for CDF analysis.

Observations:

- Attenuation due to clouds can approach values in excess of 20 dB, which will limit system availability even without the presence of rain
- Cloud attenuation at V/W-band will play a significant role in future V/W-band communications system design and will require mitigation techniques (e.g., site diversity)

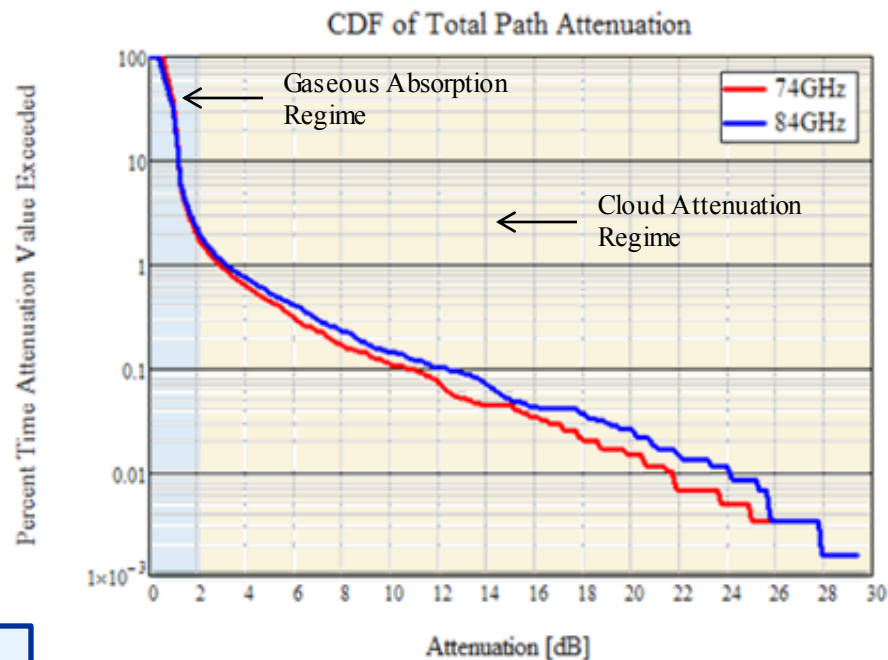
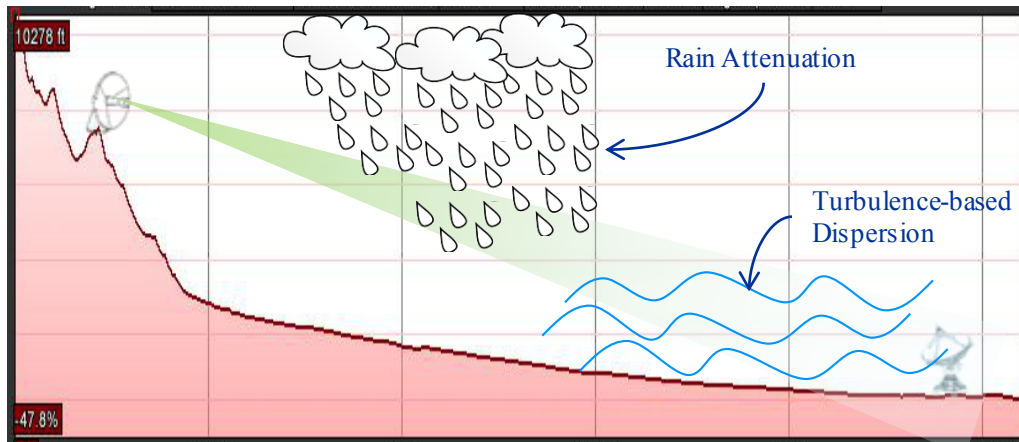


Figure 2. CDF of estimated total path attenuation at 74 and 84 GHz derived from radiometer data and models.

Proposed Terrestrial Link Experiment



Sandia Peak

UNM Campus

Goals:

- To collect preliminary propagation data to better define satellite-based beacon system experiment and obtain first order estimates of atmospheric effects
- To characterize wide bandwidth ($> 1\text{GHz}$) phase dispersion effects due to atmospheric turbulence

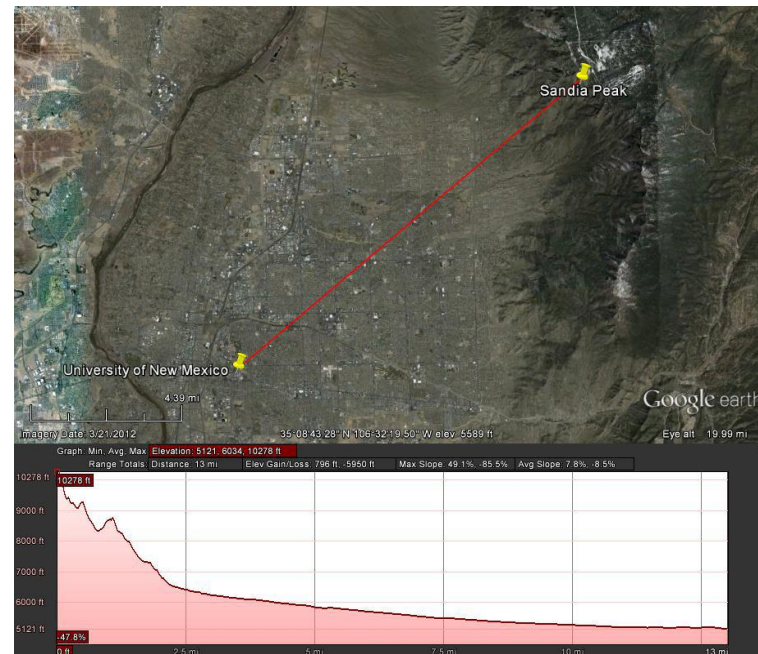
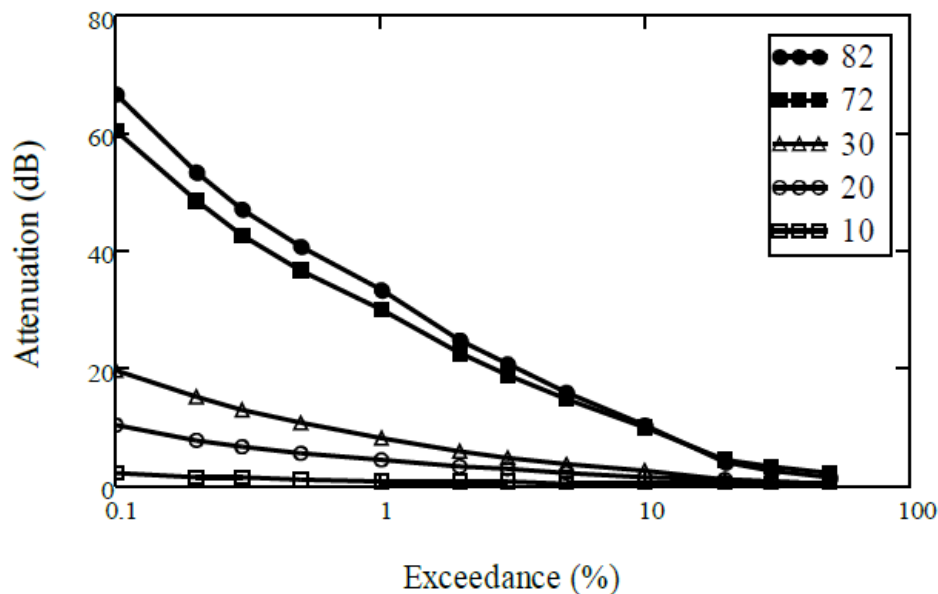


Figure 3. Top view and elevation profile for identified site in Albuquerque, NM, for terrestrial propagation experiment.



Proposed Terrestrial Link Experiment (Cont.)



CDF of Rain Attenuation Losses Predicted From ITU-R P.618-10 Model [11]

Table I. Experiment Design Specifications.

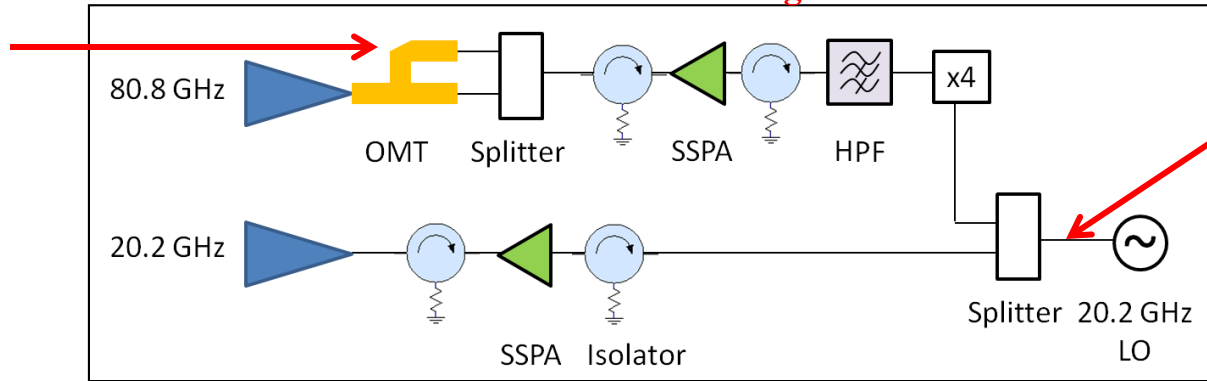
Experiment Parameter	Value
Slant Path Distance	20 km
Elevation Angle	5 deg
<i>Transmitter</i>	
Frequency	20.2, 80.8 GHz
EIRP	0 dBW
Polarization	Linear
Cross-Polarization Isolation	>25 dB
<i>Receiver</i>	
Antenna Aperture	0.6 m
System Temperature	1200 K
Sampling Rate	10 Hz
Dynamic Range	>50 dB

- From a mountain top position, a moderate elevation angle can be achieved along a slant path which can be used to characterize rain attenuation and scattering/depolarization effects.
- Dual frequency K (20.2 GHz) and W (80.8 GHz) band measurement will provide information on a scaling factor which can exploit existing K-band attenuation statistics to derive long term W-band statistics [10].
- Cross-polarization isolation >25 dB at the transmitter and receiver is required to effectively measure any depolarization effects, as this is the typical levels induced by atmospheric effects.
- Dynamic range >50 dB is required to characterize W-band attenuation statistics >99.9% of time.



Proposed Terrestrial Link Experiment (Cont.)

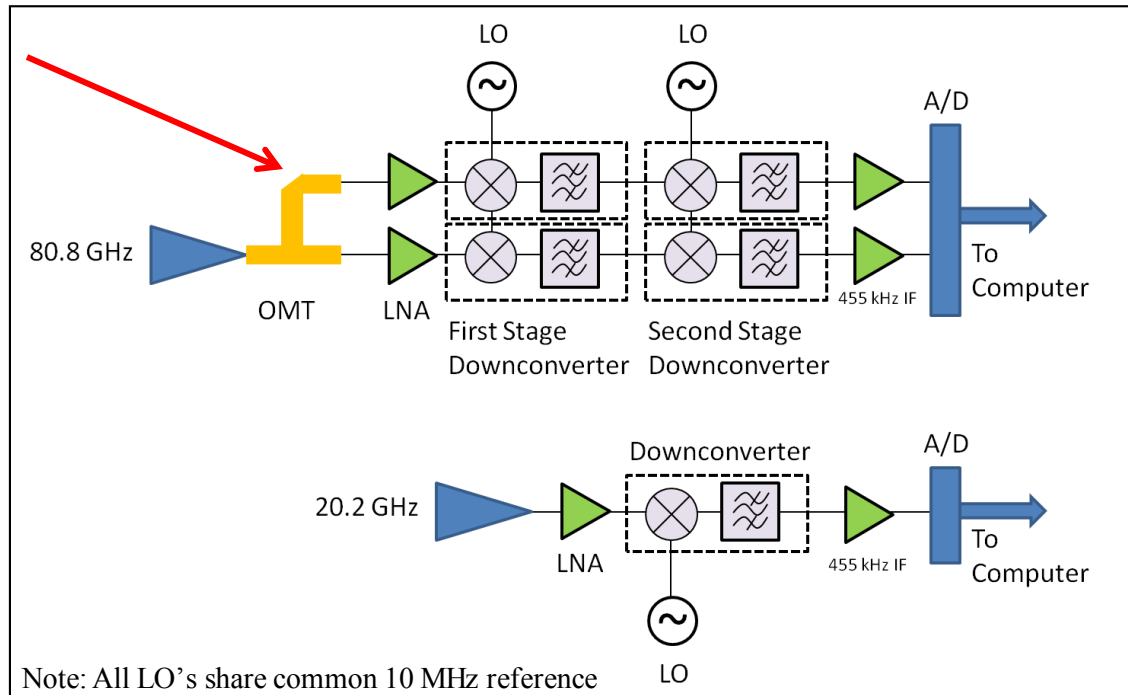
Transmitter Block Diagram



* Dual polarization coherent transmit

* Coherent 20/80 GHz frequencies for deep rain fade measurements

Receiver Block Diagram



* Dual polarization coherent receive for amplitude/phase decoherence measurement



Conclusions

- For six months, radiometer data have been collected at White Sands, NM, which have provided estimates of gaseous and cloud attenuation statistics in the V/W-band, indicating significant challenges exist even for non-rainy conditions.
- Full characterization of V/W-band link performance requires the additional characterization of the effects of rain attenuation for space-earth communications systems to be designed reliably.
- Through the conduction of the terrestrial link experiment, critical first-order information on rain attenuation, scintillation, depolarization, and dispersion at V/W-band can be gathered without the need for a costly space-based beacon source.
- A dedicated measurement campaign for a minimum of 5 years is required to develop models for system performance at the New Mexico site.



References

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