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N94-16046

COMPARISON OF OLYMPUS BEACON AND RADIOMETRIC ATTENUATION MEASUREMENTS AT BLACKSBURG, VIRGINIA

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Abstract - Measurements of attenuation of the 20 and 30 GHz beacons on board the OLYMPUS satellite are compared to simultaneous observations of atmospheric attenuation by a multichannel microwave radiometer along the same path. Departures from high correlation between the two measurements are believed to be related to differences in antenna beamwidths. Mean equivalent zenith attenuations derived from the slant path data are compared to zenith observations made at previous locations.

I. Introduction

The availability of the OLYMPUS satellite with beacons operating near 12.5, 20, and 30 GHz offers an opportunity for high frequency propagation measurements in the eastern United States. In cooperation with the NASA Propagation Program, The Satellite Communications Group at Virginia Polytechnic Institute and State University (Virginia Tech) at Blacksburg, VA, has constructed receivers and is performing a one year period of measurements of the beacon signal levels. In addition, the receivers are equipped with microwave radiometers to permit the measurement of low values of attenuation by the clear atmosphere and liquid-bearing clouds. The radiometric measurements also allow determination of a clear sky reference level for the beacon measurements. The Virginia Tech OLYMPUS propagation study program and receiver/radiometer design is discussed in more detail by Stutzman (1990) and McKeeman (1990).

The Virginia Tech radiometers employ the same antennnas and share some of the RF circuitry in the beacon receivers. As the antennas are designed for fixed angle operation, it is not possible to employ "tipping curve" calibrations which inherently include calibration of the antenna and front-end losses. For this reason, the National Oceanic and Atmospheric Administration/Wave Propagation Laboratory (NOAA/WPL) steerable beam, multichannel radiometer (20.6, 31.65, and 90.0 GHz), was employed to assist in the calibration of the Virginia Tech radiometers operating near 20 and 30 GHz. In addition, the WPL radiometer was used to obtain attenuation statistics at 20, 31, and 90 GHz for Blacksburg, VA to add to the database begun in 1987 at San Nicolas Island (Snider et al., 1989).

2. Experimental Plan and Instrument Configuration

The NOAA/WPL transportable radiometer with steerable antenna (Hogg et al., 1983) was moved to Blacksburg, VA where it was operated from 8 August to 13 September 1990. The separation between the WPL radiometer and the three beacon receivers was about 20 m. Antennas were directed along the slant path to the OLYMPUS satellite (13.9 deg elevation, 109.4 deg azimuth). Thus, all instruments viewed approximately the same region of the sky. However, because of the different antenna sizes employed by the various instruments (see Table I), each instrument observed slightly different fields of view. The antennas of the NOAA/WPL radiometer are designed to produce approximately equal 2.5 deg beamwidths at each frequency (Hogg, et al., 1983). Further details of the WPL radiometer have been discussed at previous NAPEX meetings and will not be repeated here. However, it should be noted that the NOAA/WPL radiometers are calibrated using the "tipping curve" method which includes the effects of the antenna.

Radiometers in the OLYMPUS beacon receivers are total power systems that measure atmospheric emission in a 25 MHz bandwidth within a few tens of MHz from the beacon operating frequencies. The radiometers are operated in temperature controlled enclosures to maintain a constant gain without switching. Components ahead of the input to the radiometers include the antenna, low noise amplifier, and bandpass filter. The antennas used with the beacon receivers are not capable of being moved over a sufficient range of elevation angles to perform tipping curve calibrations. Instead, initial calibrations were performed using cold (~80 K) loads and hot loads (273-303 K). This technique does not allow for calibration of the antenna system. In addition, uncertainties about the emissivity of the cold and hot loads reduce the absolute accuracy of the calibration to about ±1 K. One objective of the participation by NOAA was to help reduce the uncertainty in calibration of the 19.77 and 29.65 GHz radiometer channels.

Table I. Characteristics of Microwave Radiometers Employed in OLYMPUS Propagation Observations at Blacksburg, VA.

Frequency(GHz)	Antenna Aperture (m)	Antenna Beamwidth (deg)	Bandwidth (MHz)	Approximate Sensitivity (K)	Integration Time (s)
Virginia Tech					
12.50	4.0	0.44	25	≤ 1.0	1-3
19.77	1.5	0.72	25	≤ 1.0	1-3
29.65	1.2	0.60	25	≤ 1.0	1-3
NOAA/WPL					
20.60	0.51	2.50	500	≤ 0.3	1
31.65	0.51	2.50	500	≤ 0.3	1
90.00	0.15	2.50	500	≤ 0.4	1

3.0 Initial Results

It had been planned to present a preliminary comparison of brightness temperatures measured by the NOAA and Virginia Tech radiometers at NAPEX XV. However, as the Virginia Tech radiometric data are not yet available, we shall instead discuss observations of attenuation made by the two instruments during August and September 1990.

3.1 Comparison of Beacon and Radiometric Attenuation Observations

Examples of beacon fade data and simultaneous observations of attenuation at 20 and 31 GHz by the WPL radiometers are shown in Figs. 1 and 2. The relative values of the radiometric attenuation data have been adjusted with a constant offset in order to match approximately the beacon levels during clear weather. Excellent correlation between the beacon and radiometer is found up to an attenuation of about 15 dB. Higher values of radiometric attenuation were not calculated due to uncertainties in the brightness measurement and the mean radiating temperature of the atmosphere. In general, the beacon and radiometer attenuation measurements of Fig. 1 vary in synchronism during a fade. However, Fig. 2 reveals several cases where radiometer and beacon attenuations do not track closely. These instances are believed to be caused by regions of attenuation by clouds or precipitation on relatively small spatial scales which do not simultaneously fill the different antenna beamwidths of the various instruments. Attenuation measured by the radiometers in the beacon receivers would be expected to track more closely with the beacon level since common antennas are used. We will determine if the latter expectation is the case when the Virginia Tech radiometer data become available.

3.2 Attenuation Statistics

Cumulative distributions of attenuation at 20, 30, and 90 GHz derived from the WPL radiometer are shown in Figs. 3-5. Although the data were measured along a slant path, they have been normalized to equivalent zenith values for comparison with previous measurements at other geographic locations. The distributions appear to have the same shape as seen previously. Mean attenuation data at Blacksburg and mean values for locations previously examined are shown in Table II. Note that the values include both clear and cloudy data. The greater mean equivalent zenith attenuation at Blacksburg may be due to measurements being made along a slant path with frequent rain showers present. Future analyses shall compare only the clear sky attenuation data to determine the relative background attenuations at the different locations.

Table II. Comparison of Mean Attenuation Observed at 20.6, 31.65, and 90.0 GHz for Locations Examined to Date. Clear and Cloudy Data Combined.

	Mean Zenith Attenuation (dB)		
Location	20.6 GHz	31.65 GHz	90.0 GHz
San Nicolas Island			
July 1987	0.398	0.321	1.128
Denver, Colorado			
December	0.159	0.158	0.411
August	0.497	0.278	1.190
Wallops Island, Virginia			
April/May	0.428	0.398	1.239
Blacksburg, Virginia*			
August/September	0.661	0.444	1.711

*Blacksburg data are normalized to zenith from 13.9 deg slant path

4.0 Summary

In general, excellent correlation was observed between direct measurements of OLYMPUS satellite attenuation by the Virginia Tech beacon receivers and radiometric attenuation observations by the NOAA/WPL multichannel microwave radiometer. Occasional differences are likely to be the result of different antenna beamwidths employed by the two measurement systems. Equivalent zenith attenuation values observed at Blacksburg are greater than seen at previous locations. This result may be due to observations being made on a slant rather than a vertical path.

5.0 Future Plans

Future analysis will include comparison of NOAA and Virginia Tech brightness temperature observations to determine if systematic differences exist. Based upon these comparisons, the feasibility of calibrating the beacon receiver radiometers with an independent radiometer will be evaluated. Finally, the radiometric attenuation statistics recorded during clear weather will be analyzed to determine the variability of the background attenuation as a function of path-integrated water vapor.

References:

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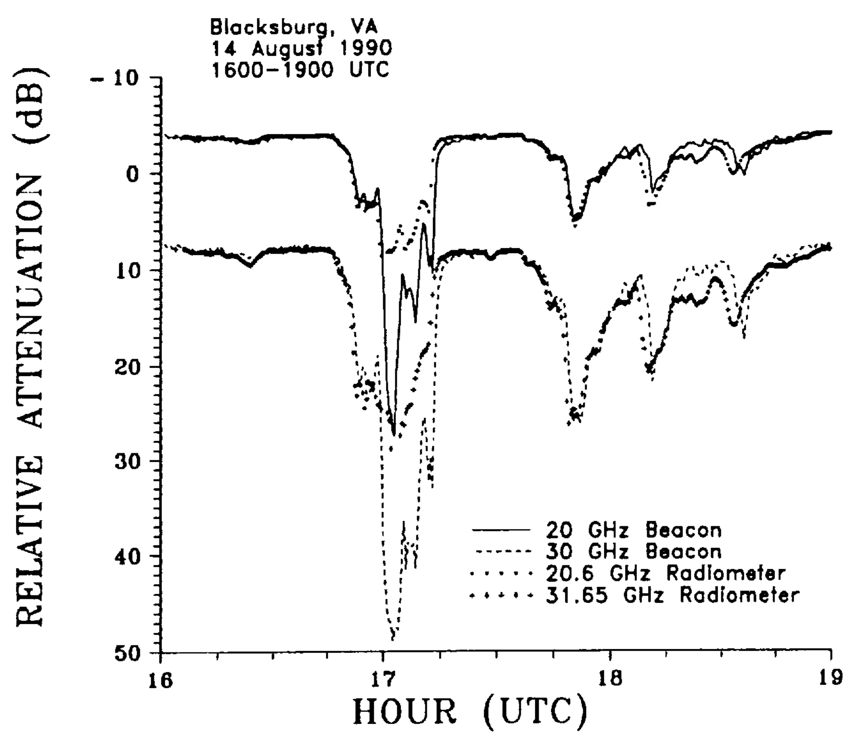

Figure 1. Comparison of attenuation of OLYMPUS satellite beacons measured by Virginia Tech receivers and by NOAA/WPL microwave radiometer on 14 August 1990 during periods of clear skies, clouds, and precipitation.

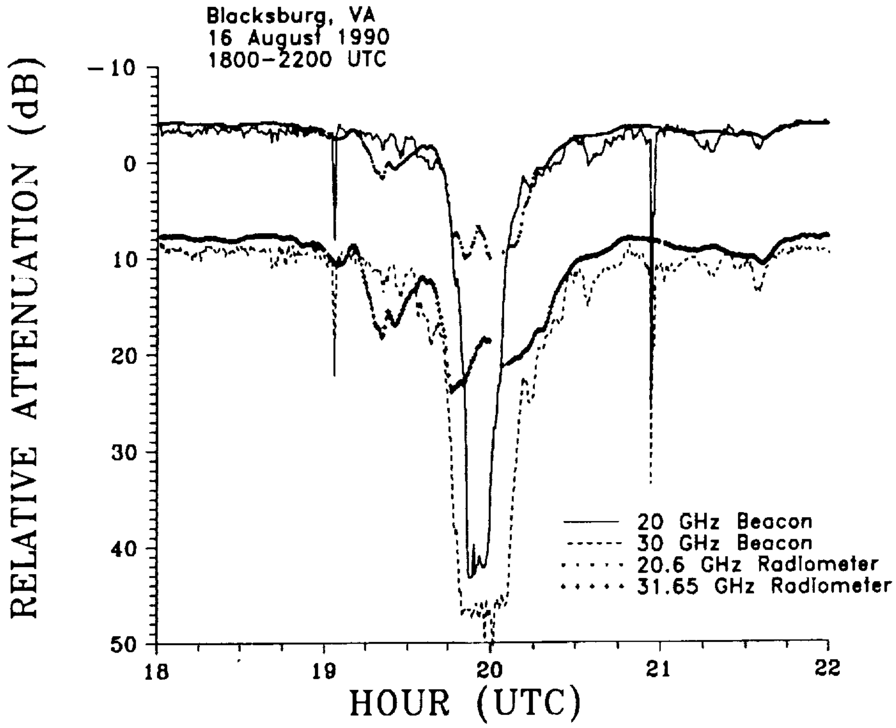

Figure 2. Comparison of attenuation of OLYMPUS satellite beacons measured by Virginia Tech receivers and by NOAA/WPL microwave radiometer on 16 August 1990 during periods of clear skies, clouds, and precipitation.

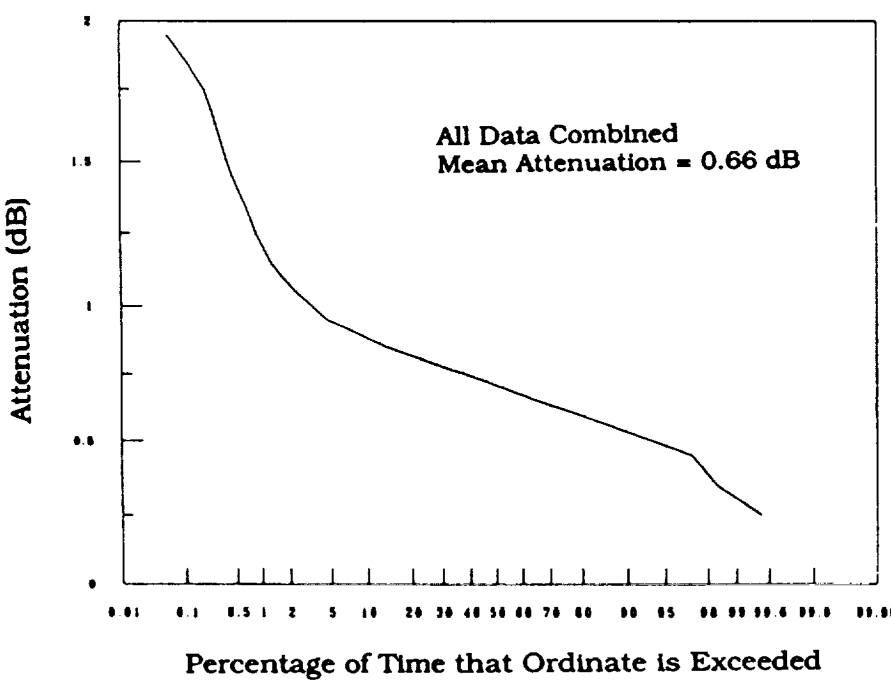

Figure 3. Cumulative distribution of zenith-normalized attenuation at 20.6 GHz measured by NOAA/WPL microwave radiometer during both clear and cloudy weather at Blacksburg, VA, 7 August - 12 September 1990.

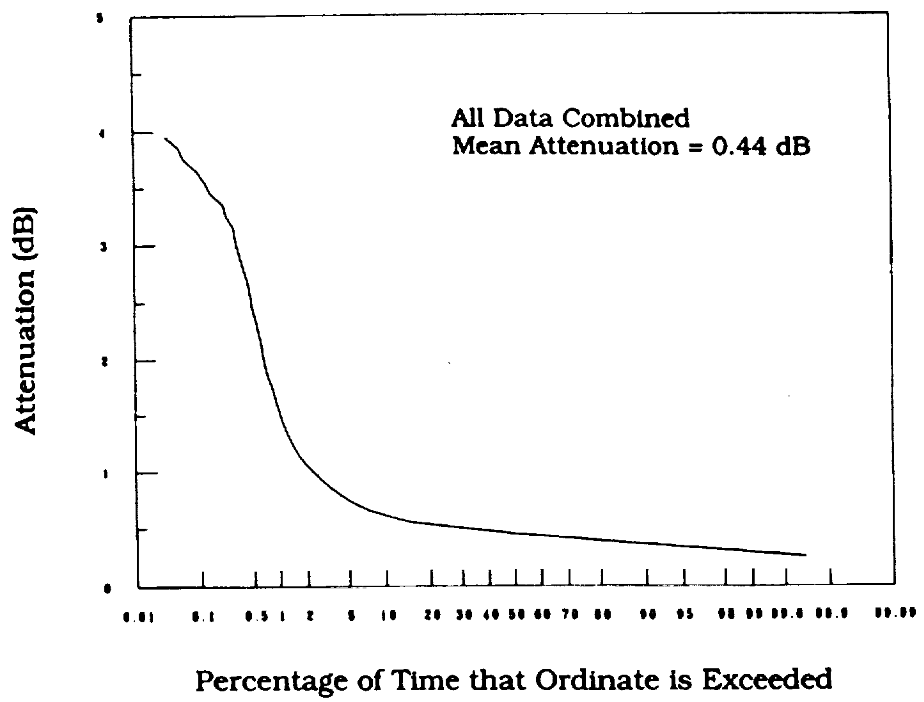

Figure 4. Cumulative distribution of zenith-normalized attenuation at 31.65 GHz measured by NOAA/WPL microwave radiometer during both clear and cloudy weather at Blacksburg, VA, 7 August - 12 September 1990.

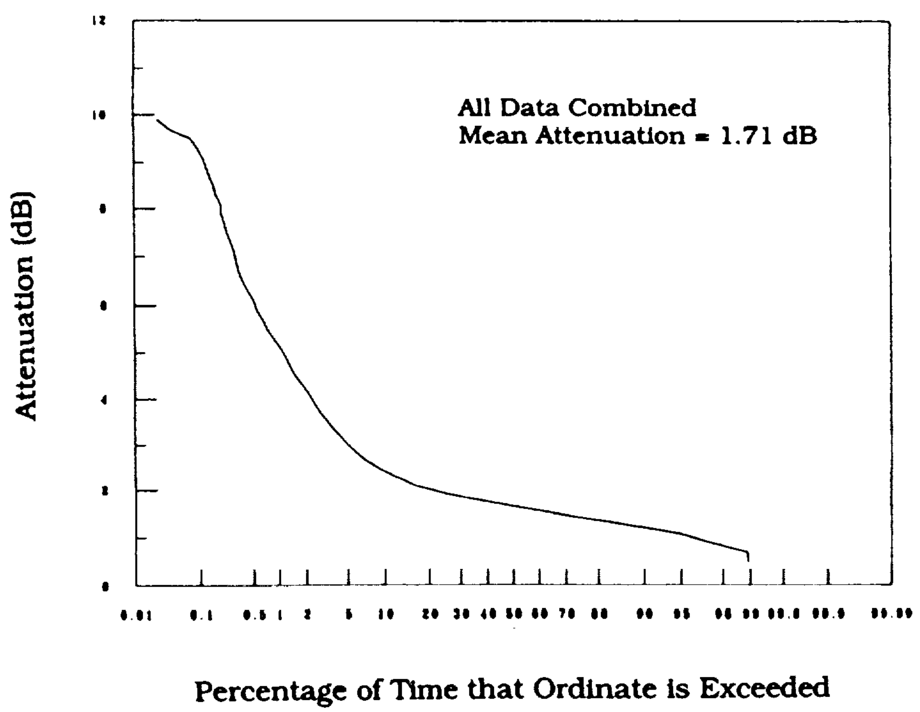

Figure 5. Cumulative distribution of zenith-normalized attenuation at 90.0 GHz measured by NOAA/WPL microwave radiometer during both clear and cloudy weather at Blacksburg, VA, 7 August - 12 September 1990.