MILLIMETER WAVE PROPAGATION MEASUREMENTS USING THE ATS 5 SATELLITE*

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The Applications Technology Satellite (ATS 5) Millimeter Wave Propagation Experiment is the first flight experiment in the GSFC Millimeter Wave Measurements Program for the determination of long- and short-term attenuation statistics of operational millimeter wavelength Earth-space links as a function of defined meteorological conditions. The ATS 5 experiment, launched August 12, 1969, is providing the first propagation data from an orbiting geosynchronous spacecraft in the 15-GHz (downlink) and 32-GHz (uplink) frequency bands. Several stations in the continental United States and Canada have been operating with the downlink transmission from the satellite since late September 1969. Figure 1 states the objectives of the Millimeter Wave Experiment and shows the locations of the participating ground stations.

The spacecraft transmitter is an all solid state phase-modulated unit that provides up to 250 mW of CW power at 15.3 GHz. The 31.65-GHz uplink signal is derived from a frequency stabilized klystron, varactor up-converter and 1000-W traveling wave tube amplifier. A multilevel computer processing program generates propagation statistics for attenuation as a function of rainfall rate, sky temperature, radar backscatter, and other meteorological variables.

The prime NASA station, located in Rosman, North Carolina, can both receive and transmit. The antenna system and radiometer and radar pedestals are shown in Figure 2. Downlink measurements made at Rosman show typical attenuations of 1 to 3 dB in light rains or dense fog, 3 to 7 dB in continuous rains (5 to 50 mm/hr), and a number of fades exceeding 12 dB in heavy thunderstorms. Uplink fades of up to 18 dB in heavy rains have been observed.

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*Paper delivered by J. Larry King.

Correlation of measured attenuation with ground measured rainfall rate was low for a single gauge but improved significantly with height averaging of 10 gauges. Correlation of measured attenuation with sky temperature recorded on a small aperture radiometer was very good for most storms. Valid predictions of attenuation from 16-GHz sky temperature measurements were observed for up to 15 dB of measured attenuation.

The uplink to downlink attenuation ratio varied with each precipitation event and often varied during a single storm. The ratio has ranged from 2:1 to 4:1 during heavy precipitation periods. Site diversity measurements at Columbus, Ohio, have demonstrated significant reductions in outage time rates with two stations placed 4 km apart.

The ATS 5 experiment results through the first 14 months of satellite operations are summarized in Table 1. Fifteen organizations with 19 ground stations are presently equipped to operate with the ATS 5 satellite, and experiment operations through June of 1971 are planned. A complete evaluation of propagation effects in the two frequency bands must await the reduction and analysis of the complete weather profile data from all participating stations. From the data reduced to date, however, it appears that both frequency bands exhibit an excellent potential for eventual utilization in reliable high-data-rate Earth-space communications systems.

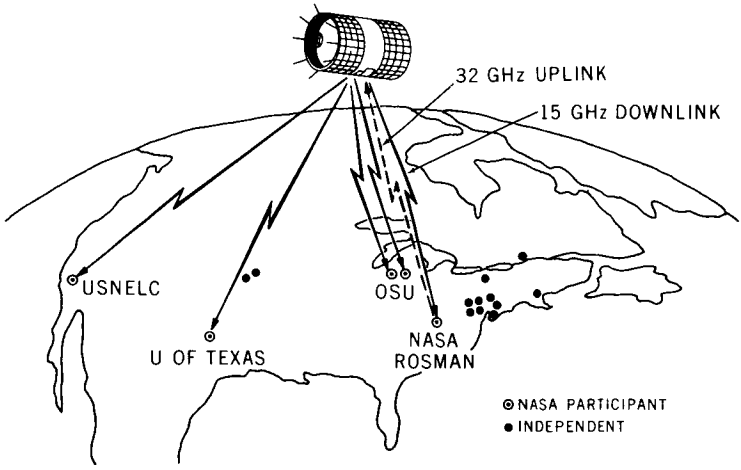

Figure 1—The ATS 5-millimeter wave experiment.

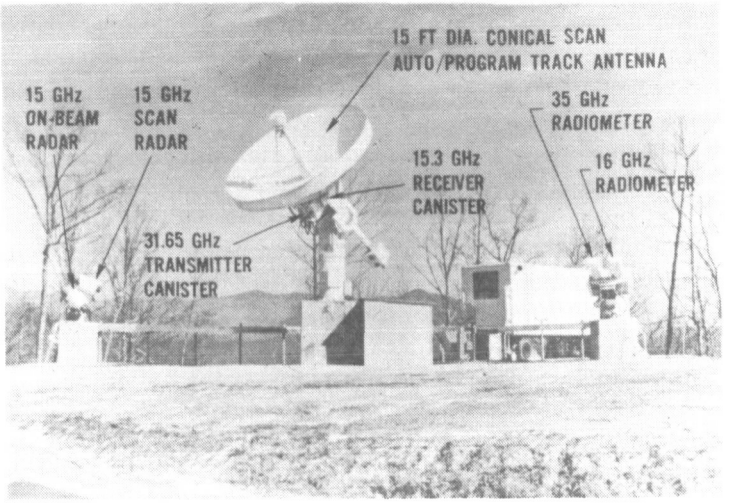

Figure 2—NASA Rosman, North Carolina, station.

Table 1—ATS 5 millimeter wave experiment summary (Oct. 1, 1969 – Dec. 31, 1970).

YEARLY OUTAGE TIME, ROSMAN STATION
- 15.3 GHz ATTENUATION EXCEEDED 15db FOR 1.7 HRS (0.02%)
- 31.65 GHz ATTENUATION EXCEEDED 18db FOR 13 HRS (0.15%)

BANDWIDTH COHERENCE
- NO MEASURABLE DECORRELATION ON EITHER LINK TO ± 50MHz

RAINFALL RATE CORRELATIONS (DOWNLINK)
- LOW FOR SINGLE GAUGE
- SIGNIFICANT IMPROVEMENT WITH HEIGHT AVERAGING

SMALL APERTURE SKY TEMPERATURE CORRELATIONS (DOWNLINK)
- VALID PREDICTIONS TO 15db OF ATTENUATION
- MEASURED ATTENUATION SLIGHTLY LOWER THAN PREDICTED

INTEGRATED K_U BACKSCATTER CORRELATION (DOWNLINK)
- LOW, RESPONSE VARIES WITH EACH STORM

UPLINK – DOWNLINK COMPARISON
- ATTENUATION RATIO STORM & TIME VARIABLE
- 2:1 TO 4:1 RANGE

SITE DIVERSITY
- TWO STATION (3 KM SEPARATION) IMPROVEMENT FACTOR OF 100