DEPOLARIZATION MEASUREMENTS ON THE ATS-6 20 GHZ DOWNLINK:

A DESCRIPTION OF THE VPI&SU EXPERIMENT AND SOME INITIAL RESULTS*

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Abstract

This paper describes an experiment in which precipitation depolarization on the ATS-6 20 GHz downlink is measured. It presents some initial results for depolarization by snow.

Introduction

The VPI&SU ATS-6 experiment is primarily concerned with the depolarizing effects of precipitation at millimeter wavelengths. Since raindrops, snowflakes, and ice crystals are not spheres, they scatter electromagnetic waves anisotropically and cause the polarization of a wave to change as it propagates through rain. Because excessive depolarization will introduce crosstalk into communication systems which employ orthogonal polarization for frequency re-use, an understanding of atmospheric depolarization phenomena is necessary to the design of future earth-satellite communications systems. Several groups are studying or have studied depolarization in terrestrial millimeter wave radio systems and at least two mutually consistent theoretical models have been developed.[1,2] The predictions of these models agree well with experimental data taken on linearly polarized ground systems, but the extent to which the terrestrial models must be modified to describe satellite path depolarization is at present unknown.

Depolarization on a ground to satellite path may be different from rain depolarization on the ground for three reasons. These are (1) differences in size and shape distributions of the raindrops, (2) the presence of snow and ice in the freezing layer, and (3) the possible influence of cirrus cloud ice crystals.

Experiment Description

The ATS-6 satellite transmits a linearly polarized signal at 20 GHz; in our experiment we are measuring the incoming power in the co-polarized and cross-polarized components of the incident signal. The decibel ratio of the cross-polarized signal component to the co-polarized component is called the cross polarization ratio (CPR). Under clear weather conditions the CPR is small (-28 to -50 dB, depending upon antenna alignment); precipitation depolarization causes it to rise.

A block diagram of our experimental system appears in Figure 1. In addition to the CPR of the incoming signal it records attenuation and ground-level rain and wind data. A Ku band radar is used to probe the weather conditions along the satellite path. All of the equipment is under the real-time control of a dedicated Raytheon PB-440 digital computer which updates the antenna pointing at ten-minute intervals and performs initial data processing.

The receiver switches between the cross-polarized and co-polarized antenna feeds once every two seconds.

Snow Depolarization Observations

At the time of writing we have not had a sufficiently hard rain to produce significant depolarization, but a severe snowstorm lasting from 30 November-2 December, 1974, yielded what we think are the first snow depolarization data for a satellite path. Snow and occasional freezing rain fell during most of this time interval, but from time to time there was considerable variation in the ground precipitation rate. The net accumulation was 10 inches.

Since spacecraft operational restrictions prevented us from obtaining a continuous look at the signal from beginning to the end of the storm, we made a series of separate observations, each several hours in length. After the storm was over we made clear sky calibration runs on December 3 and 6 to aid in data analysis.

Figure 2 displays average measured values of attenuation and cross polarization ratio versus time for the data runs between November 30 and December 6, 1974. Breaks in the time axis emphasize that this figure is a collection of data from 5 different runs spread over 6 calendar days.

The θ variable in Figure 2 is the antenna polarization angle. Under clear weather conditions the incoming signal is polarized at $\theta = -19.5°$, but with this antenna polarization the cross-polarized component is below the receiver phaselock threshold. We normally operate the antenna at $\theta = -16.5°$; this provides a clear weather isolation of -28 dB and enables the receiver to work properly. However, on December 2 the snow depolarization was such that we were able to make measurements at $\theta = -19.5°$.

On November 30 and the early part of December 1 heavy snow was falling. During the second run on December 1 the ground snowfall rate was negligible, but heavy cloud cover remained and surprising attenuation and CPR values were measured. On December 2 the satellite was available during an intense snow shower. As the hour progressed the snow rate decreased and we saw corresponding changes in the attenuation and CPR. Unfortunately, we had to relinquish use of the satellite before the snow ended. Overall, our data indicate that ground precipitation and higher altitude phenomena both play a role in snow depolarization; the only sure way to separate the two is to compare data measured simultaneously on terrestrial and satellite paths.

Snow depolarization is somewhat more difficult to analyze than rain depolarization because at present a

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theoretical model is nonexistent and in addition we have no handy "snow rate" parameter analagous to rain rate. One approach is to plot attenuation versus CPR and examine the result. This is done in Figure 3 for all the data presented in 2.

The data in Figure 3 bear some resemblance to attenuation versus cross polarization isolation plots calculated for rain depolarization in terrestrial radio systems using non-ideal antennas. Figure 4 is a typical plot for a 19.3 GHz, 1 km, rain-filled path with 45° linear polarization and a variety of residual (clear weather) CPR values. This is <u>not</u> a theoretical model for our 20 GHz snow data for the satellite path; it is introduced to show the trend of these curves and the effect on them of the residual isolation.

The effect of varying our antenna polarization angle θ is to change the residual CPR. At θ = -16.5° the clear weather CPR is -28 dB; the measured data at θ = -16.5° bear some resemblance to the -30 dB theoretical curve for rain.

References

1. P.H. Wiley, W.L. Stutzman, and C.W. Bostian, "A new model for rain depolarization," Journal de Recherches Atmospheriques (France), Vol. 8, pp. 147-153, January-June, 1974.

2. P. Watson and M. Arbabi, "Rainfall cross polarization at microwave frequencies," Proc. IEE (London), Vol. 120, pp. 413-418, April, 1973.

Acknowledgement

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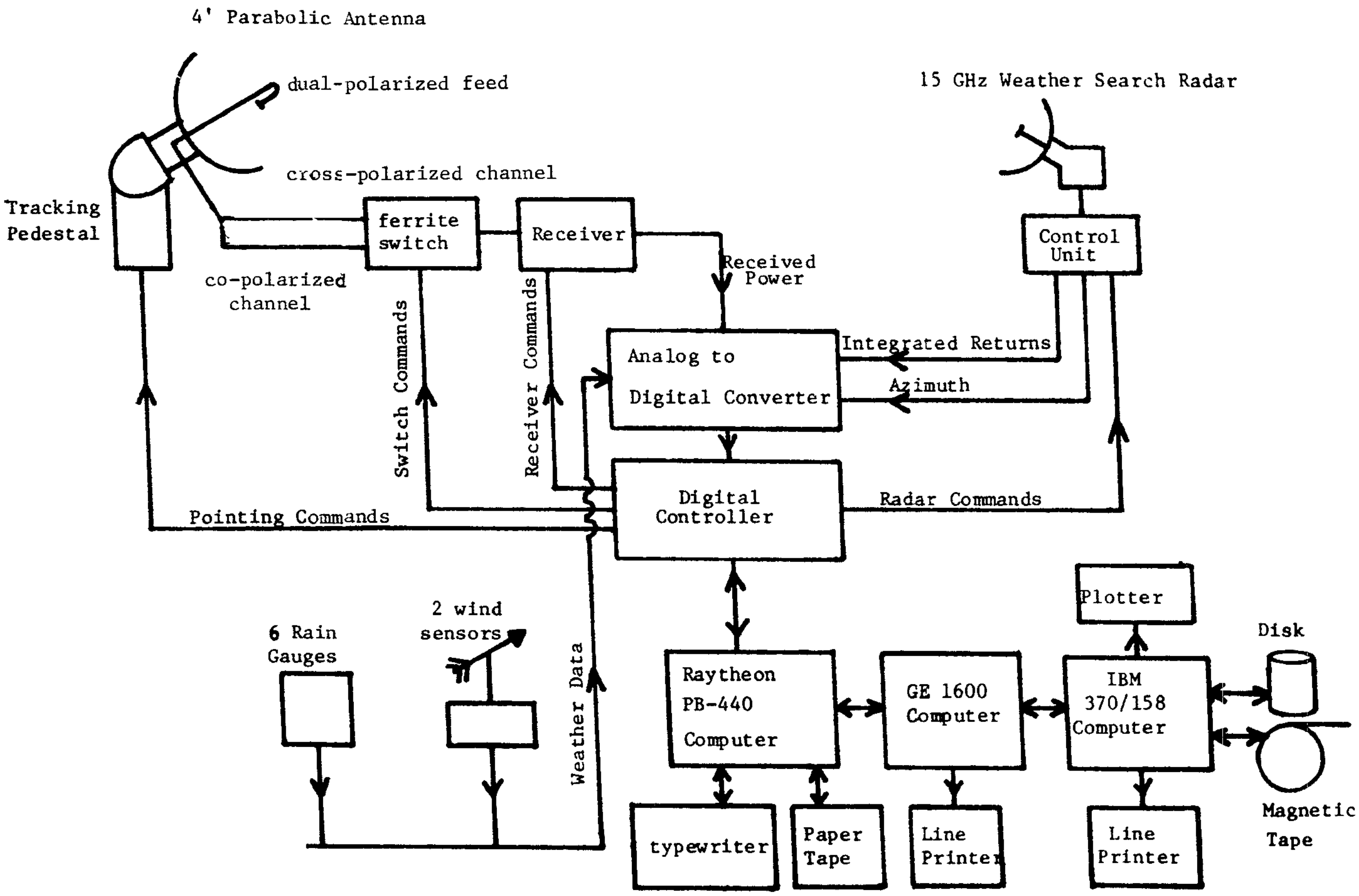

Figure 1. Experimental Setup

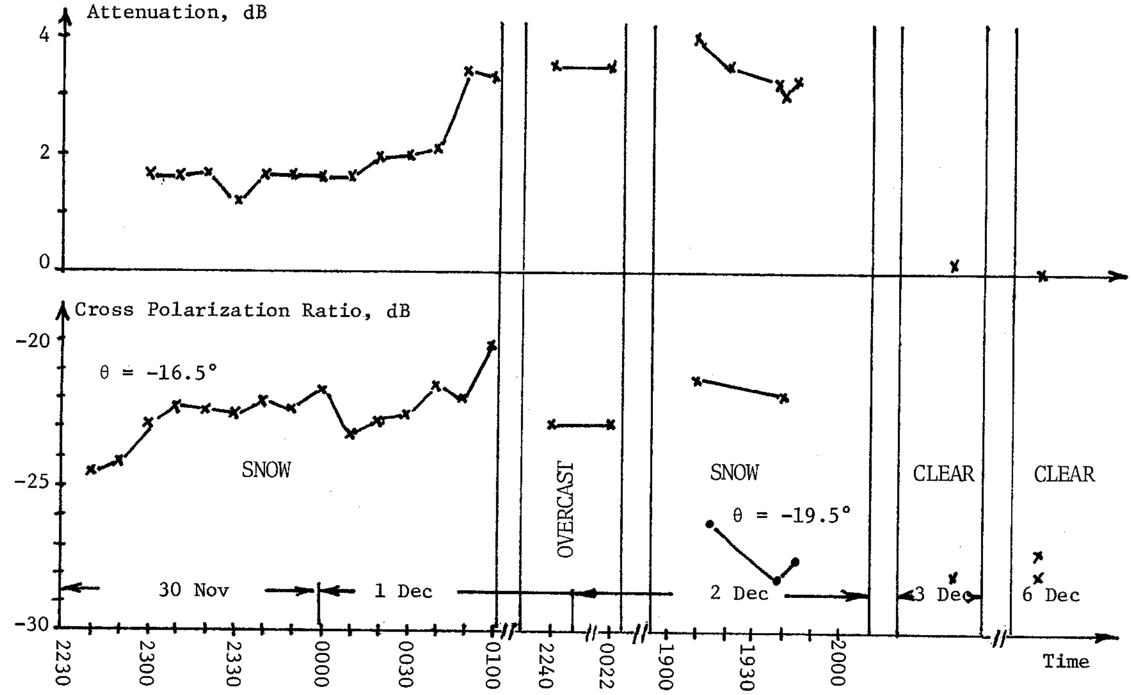

Figure 2. Attenuation and CPR data for the snowstorm of 30 November - 2 December, 1974.

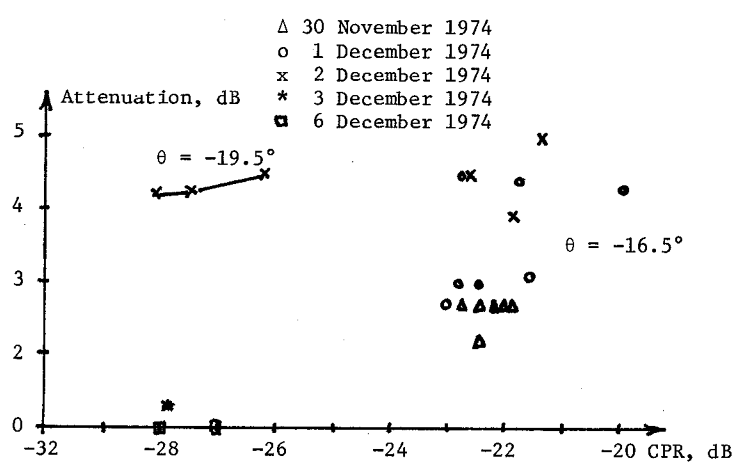

Figure 3. Attenuation versus CPR for the 30 November - 2 December, 1974, snowstorm and subsequent clear weather calibration periods.

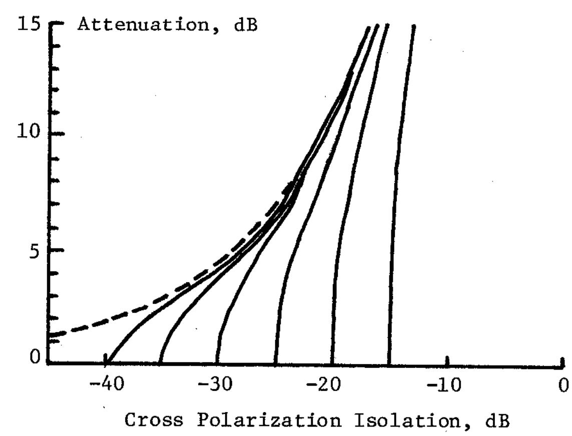

Figure 4. Rain induced attenuation versus cross polarization isolation (including antenna effects). The abscissa intercepts are the residual (clear weather) antenna isolations. The dashed curve is from the scattering model for no antenna effects. The frequency is 19.3 GHz, the path length is 1 km, and the antennas are linearly polarized at 45° with respect to the raindrop major axis.