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(Paper published in Hermes Symposium Proceedings.) (Vol 2, p. 111) Queen

Experiment F-1-1

"Propagation"

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INTRODUCTION

To design a satellite communications system using frequencies above several gigahertz, it is necessary to evaluate the attenuation of microwave signals by liquid water in the earth's atmosphere. For those satellites which use orthogonal polarizations to increase their capacity, it is also necessary to evaluate the depolarization of signals by non-spherical raindrops, ice particles in clouds, and snow. Since the characteristics of precipitation vary widely across Canada, it is insufficient to study attenuation and depolarization in only one location.

This paper describes a joint experiment being conducted by the Communications Research Centre of the Department of Communications and Bell-Northern Research to measure the characteristics of depolarization and attenuation at several locations across Canada using the signal received from the 11.7 GHz beacon of CTS. Initial results obtained at Ottawa are summarized.

BACKGROUND

Measurements of depolarization and attenuation of the CTS beacon have been made at Ottawa since July 1976. With support from the Trans-Canada Tele-

* formerly at Bell-Northern Research.

phone System and the Department of Communications, this experiment has recently been extended to several locations which are believed to be representative of the various climatic areas of Canada. Equipment was installed at the telephone toll offices in Winnipeg, Toronto, Halifax and St. John's in August and September 1977. The equipment at Winnipeg will be moved to Vancouver in January 1978.

Since earth stations operating in the 12 and 14 GHz bands can be located within cities, the depolarization and attenuation data will be directly applicable to the design of future satellite communications systems. The combined measurements of depolarization and attenuation will also assist in understanding the significant depolarization mechanisms in the 12 and 14 GHz bands and their relation to various meteorological quantities. Predictions of depolarization statistics may then be made from existing statistics of other propagation or meteorological quantities. When rain is the dominant depolarization mechanism, a technique has been developed for predicting depolarization statistics from rain attenuation statistics [1]. Since rain attenuation statistics, particularly those obtained with radiometers, are more widely available than depolarization statistics, it is important to evaluate this technique. The measurements provide a means of not only evaluating this technique but also obtaining the effective parameters of the raindrop canting-angle distribution (i.e., distribution of orientations) which are also required by the prediction technique. At some sites, the combination of depolarization and rainrate measurements will allow the evaluation of techniques for predicting rain depolarization statistics from rainrate statistics [2].

EXPERIMENTAL TECHNIQUES

Attenuation and depolarization data are obtained from measurements of the linear orthogonal components of the circularly-polarized signal from the CTS beacon. At Ottawa, a 3.7 m antenna is employed; 1.9 m antennas are used at the other sites. The amplitude and phase of the two orthogonal linearly-polarized components (nominally horizontal and vertical) are coherently detected by a special phase-lock receiver whose block diagram is given in Fig. 1. The differential attenuation ΔA (in dB) and differential phase Δβ (in radians) between these orthogonal components are calculated from the demodulator outputs, Q and I, using

$$\Delta A = 10 \log \left[\frac{(Q-Q_0)^2 + (I-I_0)^2}{(Q_{cs}-Q_0)^2 + (I_{cs}-I_0)^2} \right] \qquad \text{(dB)}$$

$$\Delta\beta = \tan^{-1} \left(\frac{I-I_0}{Q-Q_0} \right) - \tan^{-1} \left(\frac{I_{cs}-I_0}{Q_{cs}-Q_0} \right) \qquad \text{(radians)}$$

where Q_{cs} and I_{cs} are the clear sky values of Q and I, and Q_0 and I_0 are the values of Q and I obtained during that part of the receiver calibration in which the H signal is removed. The cross-polarization discrimination (XPD) and co-polar attenuation (CPA) are then calculated using the approximate relations

$$XPD \simeq -10 \log \left\{ [(\Delta A/8.686)^2 + (\Delta\beta)^2]/4 \right\} \qquad \text{(dB)}$$

$$CPA \simeq A_V + \Delta A/2 \qquad \text{(dB)}$$

The theoretical basis of these relations is discussed in [1].

Except at Ottawa, each receiving terminal is complemented by a standard Canadian tipping-bucket raingauge and a 13 GHz radiometer [3] to measure the sky noise temperature. Radiometers and receivers are calibrated daily. All data are recorded at one-second intervals on digital magnetic tape, and the tapes are sent to Ottawa each week for analysis.

INITIAL RESULTS

The initial results are best illustrated by the scatter plot in Fig. 2 of XPD versus log (CPA), based on eight rain events at Ottawa, including two convective storms, during July and August 1976. Each data point represents a 10 s sample of XPD and CPA. For the six light to moderate rain events observed, the CPA never exceeded 3 dB. Although the values of XPD show considerable scatter, the minimum value was 20 dB. For the two convective storms, however, the XPD reached a minimum of 14 dB for a CPA of 10 dB. The relationship between XPD and CPA is better defined for these heavier rain events.

Several theoretical curves have been included in Fig. 2 to help explain the experimental results. These curves are based on the dropsize distributions of Laws and Parsons (LP) [4] and Joss *et al.* [5] (J-T and J-D), the forward-scattering amplitudes of Oguchi [6] for Pruppacher-Pitter-form raindrops, and effective standard deviations of the raindrop canting-angle distribution of $\sigma = 0°$ and $40°$ [1]. As discussed in more detail elsewhere [7], a comparison of the experimental and theoretical curves results in the following conclusions:

(i) The scatter in the experimental data for a given attenuation is due much more to variations in the canting-angle distribution than to variations in the dropsize distribution. Thus, an extensively tested dropsize distribution, such as that of Laws and Parsons, can be adopted for all rain depolarization predictions.

(ii) At least for the events analyzed, rain depolarization at 11.7 GHz seems to be more significant than depolarization due to other hydrometerors along the path. Thus, depolarization predictions based only on rain effects may be valid in the 12 and 14 GHz bands. However, additional measurements are required, particularly for other climates, before a more definite conclusion can be drawn.

(iii) The relationship between XPD and log(CPA) for rain is approximately linear as suggested by theory. Thus, XPD statistics can be predicted from known CPA statistics. For the frequency and elevation angle of the experiment, a suitable prediction equation is XPD = 35 - 20 log(CPA). Similar relations can be obtained for other frequencies and elevation angles using the effective standard deviation of the canting-angle distribution of $\sigma = 25°$ [1] which this relationship implies. A possible dependence of σ on climate will be obtained from the additional measurements at other locations.

CONCLUSIONS

Theoretical calculations show that XPD is approximately linearly related to log(CPA) and suggest that depolarization statistics can be predicted from rain attenuation statistics. This is confirmed by initial results from measurements at Ottawa. Measurements at other Canadian locations will allow a more extensive evaluation of theory and provide the necessary information on the effective canting-angle distribution of the raindrops. The direct attenuation measurements will provide a means of evaluating calculations based on radiometric measurements of sky noise temperature.

REFERENCES

1. W.L. Nowland, R.L. Olsen and I.P. Shkarofsky, "Theoretical relationship between rain depolarization and attenuation", Electron. Lett., 27 October 1977, 13, pp. 676-678.

2. C.C.I.R. DOC. 5/206 (Canada), [1974-1978]. "Techniques for the prediction of rain depolarization statistics at microwave and millimetre wavelengths", 20 May 1977.

3. J.I. Strickland, "The measurement of slant path attenuation using radar, radiometers and a satellite beacon", J. Recherches Atmosphériques, January-June 1974, 8, pp. 347-358.

4. J.O. Laws and D.A. Parsons, "The relation of raindrop-size to intensity", Trans. Am. Geophys. Union, 1943, 24, pp. 452-460.

5. J. Joss, J.C. Thams and A. Waldvogel, "The variation of raindrop size distributions at Locarno", Proc. of the International Conference on Cloud Physics, 1968, Toronto, Canada, pp. 369-373.

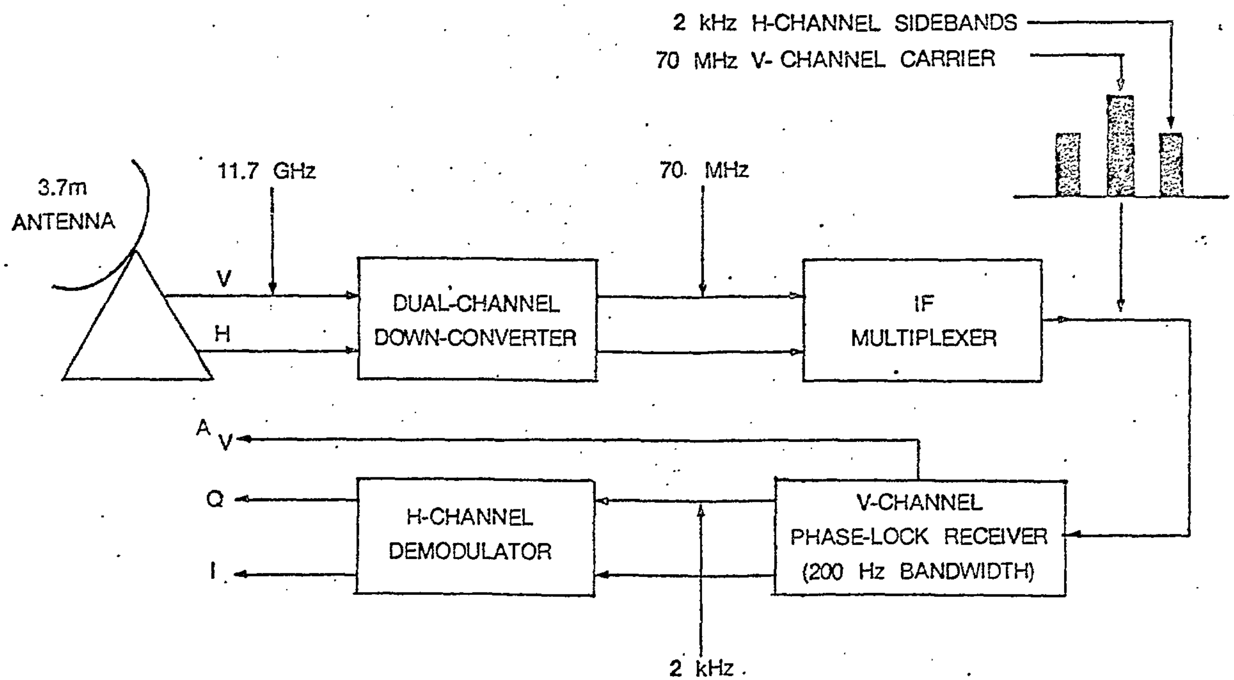
6. T. Oguchi, "Scattering properties of Pruppacher-and-Pitter form raindrops and cross polarization due to rain: Calculations at 11, 13, 19.3, and 34.8 GHz", Radio Sci., January-February 1977, 12, pp. 41-51.

7. W.L. Nowland, J.I. Strickland, J. Schlesak and R.L. Olsen, "Measurements of depolarization and attenuation at 11.7 GHz by using the Communications Technology Satellite", Electron, Lett., 24 November 1977, 13, pp. 750-751.

Legend To Figures

Fig. 1 *Block diagram of the CTS cross-polarisation receiving system.*

Fig. 2 *Comparison of 11.7 GHz experimental data and theoretical curves for XPD as functions of CPA. Circular polarisation, path elevation angle of 24.6°. —LP, — —J-T, and -----J-D dropsize distributions with an equi-oriented raindrop model. —o— LP dropsize distribution and random canting-angle model with σ = 40°. Data for the two convective storms are shown as crosses; the remaining data are shown as dots.*


2 kHz H-CHANNEL SIDEBANDS
70 MHz V- CHANNEL CARRIER
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V-CHANNEL
PHASE-LOCK RECEIVER
(200 Hz BANDWIDTH)
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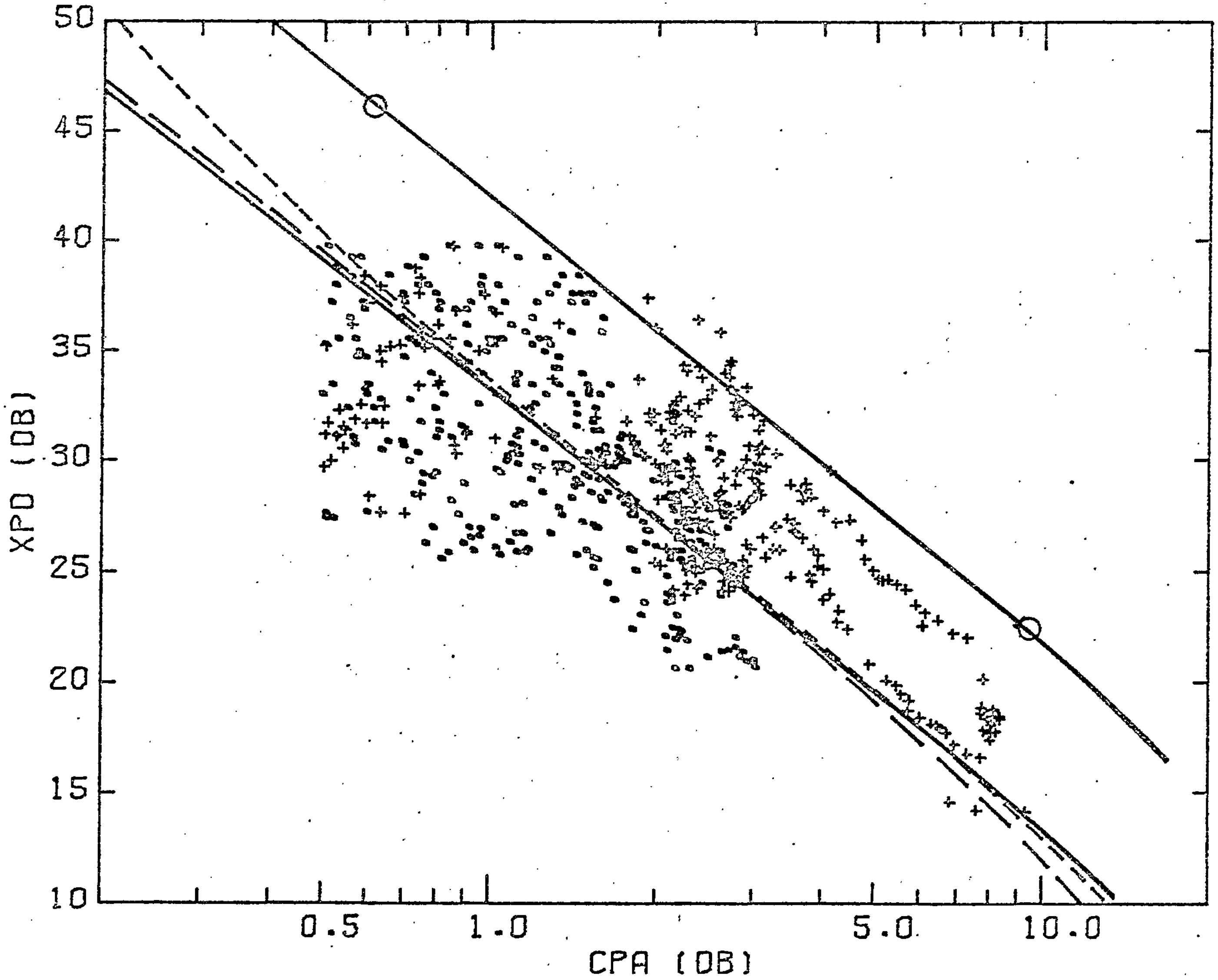
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