Propagation measurements due to rain and ice using the OTS satellite over the period January 1979 - May 1980

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Abstract

In this paper, we summarize propagation measurements along a slant path to the Orbital Test Satellite, OTS. Measurements were made using the circularly polarized beacon at 11.786 GHz. We present possible explanations for some of the measured propagation activity using a theoretical model incorporating rain, ice and a segmented rain and ice path. We also discuss measurements made with two electric field probes. Lastly the effect of a rain event on a glass-fibre radome is illustrated and compared to the same event received via a co-located radome-less antenna.

Key words : Wave propagation, Centimeter wave, Satellite communication, Experimental study, Hydrometeor, Wave attenuation, Wave depolarization.

I. INTRODUCTION

The experimental programme at the University of Essex, Colchester, Essex, UK, comprises measurements using the OTS circularly polarized beacon transmission at 11.786 GHz. Since the BO/B1 beacon became operational in June 1978 we have been recording copolar and cross-polar signals, together with their relative phase. Uninterrupted transmissions have been available since January 1979 and the data presented here relate to propagation activity from that date. We include cumulative statistics of attenuation and cross-polar discrimination for the calendar year 1979. In addition we present several interesting individual events. These events, occurring during (i) rainfall (ii) rainfall and ice, and (iii) ice, are analyzed using a theoretical model [1] incorporating rainfall scattering assuming a standard drop size distribution, ice scattering assuming negligible attenuation, and a segmented ice-rainfall model along the slant path. The theoretical model also incorporates the effects of horizontal wind shear on hydrometeor canting, which is shown to be of significance when predicting XPD and phase activity. The station is also equipped with two point discharge, electric field probes, data from these probes is presented to show the localized nature of the field from rain cells together with simultaneous comparison of cross-polarization and phase along the OTS propagation path.

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II. EQUIPMENT DESCRIPTION

We record the copolar and cross-polar signal components from the OTS B0/B1 circularly-polarized beacon, together with their relative (not absolute) phase via a 2.1 m Cassegranean antenna at an elevation angle of 30°. The antenna is equipped with a low pressure air-blown feeder system to prevent the accumulation of water on the feed window and is steered by a pre-programmed, microprocessor controlled, servo-system. The receiver consists of two microwave mixers, fed from the ports of an orthomode transducer, and two double conversion superheterodyne receivers equipped with coherent detectors. The cross-polar signal is detected in quadrature, the two components so produced are used to derive the amplitude of the cross-polar signal and the relative phase between the copolar and cross-polar. A rotatable dielectric polarizer precedes the omt. The receiver is calibrated by injecting a known amplitude signal source, at 11.786 GHz, into the receiver chains. Both the outdoor down-converters and the main I.F. receivers, housed in the laboratory, are in temperature controlled environments to improve their stability.

In addition to the 2.1 m dish, we have been recording B1 beacon signals via a 1 m diameter Cassegranean antenna covered in a glass fibre radome. This antenna is mounted on a moveable trolley, which provides vertical and horizontal diversity. The diversity receiver uses the same mixing scheme as the main receiver and thus, using common local oscillator sources, uses the same mixing scheme as the main receiver chains. A rotatable dielectric polarizer precedes the omt. The receiver is calibrated by injecting a known amplitude signal source, at 11.786 GHz, into the receiver chains. Both the outdoor down-converters and the main I.F. receivers, housed in the laboratory, are in temperature controlled environments to improve their stability.

To assist with analysis we simultaneously record a number of meteorological parameters. Most notable are two point discharge electric field probes, one on site and one 5 km down the slant path towards OTS. The phase and amplitude of the two propagation paths may be compared.

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To assist with analysis we simultaneously record a number of meteorological parameters. Most notable are two point discharge electric field probes, one on site and one 5 km down the slant path towards OTS which we use to record the vertical point discharge current activity. An X-band plan position radar (ppi) is also being used in conjunction with the field probes to provide identification and direction information of rain cells in the propagation path. We also record the 'on-site' wind speed and direction at a height of 30 m above ground level.

III. INDIVIDUAL EVENTS

III.1. Snow.

During the winter months of 1979 we experienced several heavy snowfall events. Accumulation of wet snow on the main reflector resulted in 'attenuations' of ~7 dB and corresponding xpd's of ~17 dB. Wet snow accumulation has been found to produce severe antenna de-pointing such as to produce a 'null' on axis, indeed we removed the majority of accumulated wet-snow from the reflector and found the 'attenuation' to return to ~1 dB from ~7 dB and xpd from ~17 dB to ~38 dB [2] (see cumulative statistics). Dry snow has not been found to produce significant attenuation.

III.2. Rainfall.

The rainfall event shown in Figure 1 produced ~3 dB copolar attenuation and a corresponding 18 dB xpd. An interesting observation during this event is the varying phase during the peak activity which is followed by a steady response.

We now consider the phase responses of events shown in Figures 1 and 2 with respect to a theoretical model [1]. This model allows raindrop canting in planes parallel and perpendicular to the direction of propagation, corresponding to horizontal and vertical wind shear, respectively.

The model was used to produce Figure 3. Here we employ a 4° deterministic raindrop canting angle model. The slant path is assumed to be 6 km. This is not a sensitive parameter and was chosen to allow low xpd levels to be plotted. An 11.6° polarization tilt angle and a 30° elevation angle is chosen to be appropriate to our site. The horizontal wind direction is also a deterministic quantity and the phase versus xpd is plotted using various wind directions. In Figure 3, it can be seen that for a deterministic canting angle model it is the wind direction only which exhibits an effect on the phase response for a given xpd level. In Figure 4, we employ a distribution of canting angles. Using data from a terrestrial link [6] we have shown that a truncated Gaussian distribution of canting angles with a variance of 43° (mean 8.5°) fits our measured data [4] and it is therefore used to generate the data in Figure 4. (Note that on