Depolarization of Ku-band satellite signal in relation to rain attenuation for the tropical region

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Abstract

The phenomenon of depolarization has been studied by monitoring the co-polar and cross-polar component of a plane polarized satellite signal transmitted with low fade margin from the geostationary satellite in the Indian region. During a rain event, co-polar component attenuates and cross-polar component enhances. Correlation between the co-polar and cross-polar component is usually high during rain events but sometimes it decreases in presence of large rain drops of diameter greater than 2.5 mm when the cross-polar component becomes significant in spite of very small value of co-polar attenuation

1. Introduction

The recent development in new satellite services has caused an increasing demand of bandwidth thus pushing up the frequency for satellite communications and leading to more complex systems involving the frequency re-use scheme with cross-polarized channels. The performance of the dual-polarized system in these higher frequency bands is affected by attenuation and depolarization during precipitation and other meteorological events. It has been observed that the scenario of propagation measurements in the tropical region at these frequencies is not so much encouraging since the data coverage for this region is, so far, inadequate, particularly in view of the fact that this region has much more complex and varying climatic behaviour compared to the temperate region. The sparse of data are also present in the Indian region which may be a matter of concern, as in the near future the Indian satellites will carry Ka-band transponders to provide a variety of services.

The present paper reflects some of the results of experimental observation for propagation measurements carried out at the Institute of Radio Physics and Electronics, University of Calcutta. It is known that principal propagation limitations above 10 GHz are attenuation and depolarization due to atmospheric hydrometeors intersecting the earth-space propagation path. The varying mixtures of hydrometeors with diverse shape and size make a considerable impact on the depolarization even in the low attenuation range. In the present study, a simple experimental method was adopted where the co-polar and cross-polar component of the satellite signal from NSS-6 satellite and the ground based disdrometer and ORG data were considered. The phenomenon of depolarization of satellite downlink was studied and the relation between the co-polar and cross-polar component has been investigated from the correlation between two components during rain.

2. Experimental Set-Up

The Ku-band signal at 11.172 GHz transmitted with horizontal polarization from satellite NSS-6 (geostationary at 95° E) has been received at an elevation of 63° at Kolkata, India (22°34' N, 88°29' E), since June 2004 [1]. The Ku-band signal is down-converted to an L-band signal and is fed to a spectrum analyzer which is operated with zero time span at the peak frequency of the received spectrum and the output of the video filter of the spectrum analyzer is recorded with a data logger and stored in a PC. The calibration of the satellite signal is performed using a Ku-band signal generator and a rotary vane attenuator. The signal has a low fade margin and could be calibrated down to 20 dB level below which there is no discernible change with the increasing attenuation. The cross-polar component of the satellite signal is monitored using a separate receiving channel with the components that are identical to that used for the co-polar channel. The polarization of the receiving horn antennas of the two channels are orthogonally aligned so that the co-polar signal level reaches the maximum and the cross-polar level is at the minimum, the separation between the two channels being about 18 dB. Further, the rainfall rate at the satellite receiver site has been measured by an optical raingauge and recorded simultaneously with the satellite signal. The signal level and the rain rate are recorded with a sampling interval of 10 sec. Also, a Joss-type disdrometer, co-sited with the satellite receiver, has been operated to measure raindrop size with an integration time of 30 sec. The experimental setup is shown in Fig 1.

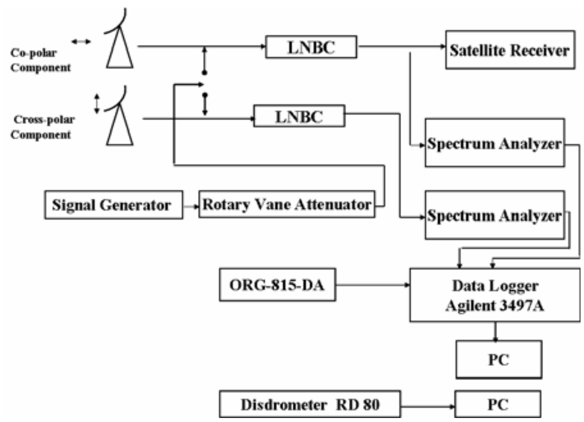

Fig 1. Experimental Set-Up for the Propagation Measurements at Ku-band

3. Results and Discussions

Fig 2. shows a typical variation of Ku band satellite signal in the co-polar and cross-polar channels along with the evolution of DSD during a rain event at Kolkata. The depolarization of the satellite signal is caused by the

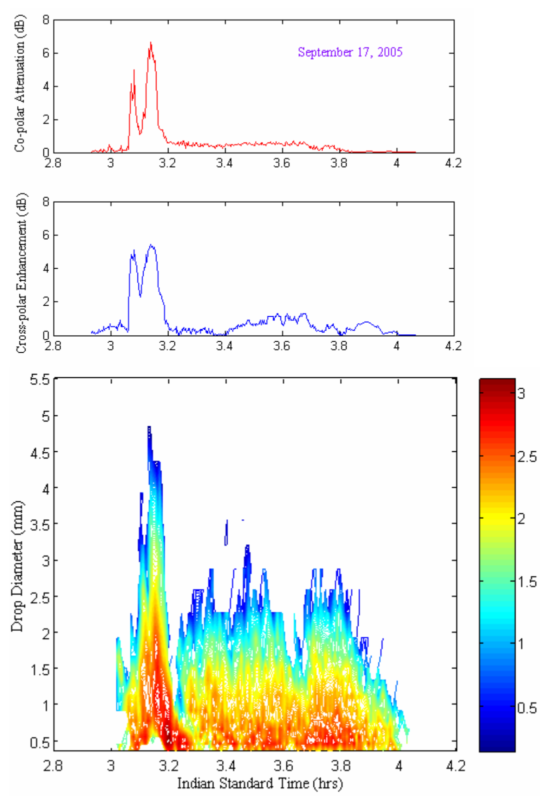

Fig 2. Temporal variation of Ku-band satellite signal and drop size distribution during a rain event

anisotropy of the propagation medium contributed by rain, ice and turbulence of the atmosphere. In our case, the depolarization is measured in terms of enhancement of cross-polar component of the received signal. On analyzing Fig 2. it is evident that the cross-polar component is higher relative to the co-polar component at the first peak of the variation than at the second one. Some large drops of diameter 3 to 4 mm were recorded by the disdrometer during the first peak, which caused the enhancement of cross-polar component more prominently than affecting the co-polar attenuation in this region. With the progress of rain, the sizes of all the drops have increased resulting in simultaneous rise of co-polar and cross-polar component at the second peak. During the decaying phase of the event, the cross-polar signal continued to have a value greater than 1 dB even if the attenuation decreases substantially. This is again due to the presence of some large drops of diameter 2.5 mm and above as indicated by the disdrometer measurements which causes noticeable depolarization but no significant attenuation.

Fig 3. depicts the correlation coefficient that exists between the co-polar and cross-polar component of the signal for another rain event. A good correlation, the coefficient exceeding 0.8 is obtained between the two

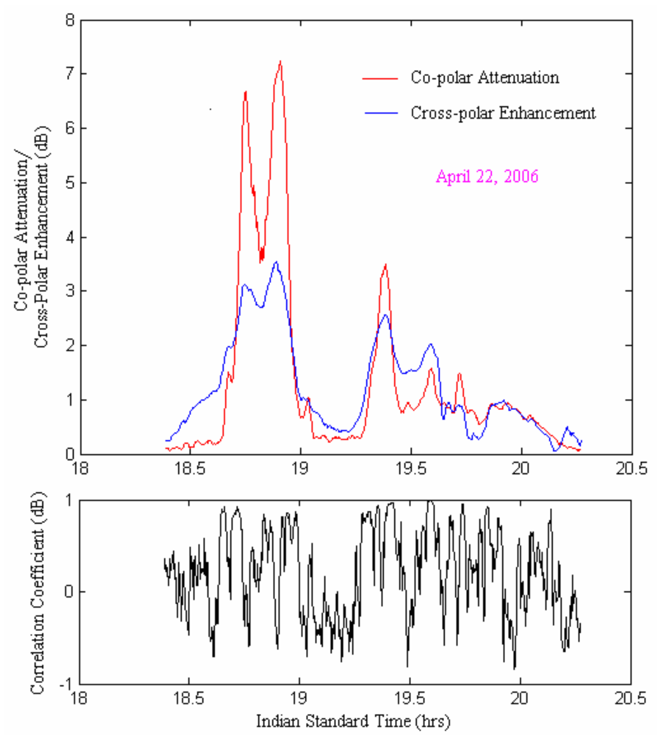

Fig 3. Time variation of co-polar and cross-polar signal and the correlation coefficient between the two

orthogonal signals for the larger part of the rain event. However, the correlation falls sometimes even becomes negative during some parts of the rain event. In these regions, the depolarization remains significant even if the attenuation decreases to lower values. As already mentioned, the combined effect of the hydrometeors with diverse shape, size and thermodynamic phase attributes for this sharp dip in the correlation. It is to be noted that, smaller number of large drops along with ice particles can reduce the correlation between the co-polar and cross-polar components, whereas the role of large number of smaller drops is less significant [2].

Fig 4. depicts the relation between the co-polar and cross-polar data of the signal as obtained from the measurement for the year 2006. Two distinct clusters are noticed from the above figure, which gives an indication that the cross-polar enhancements are larger in one region than in the other for the same co-polar attenuation. As already mentioned, the presence of large rain drops are responsible for differing cross-polar enhancement, the upper clustering of the scatter plot is caused by the presence of comparatively greater number of larger drops.

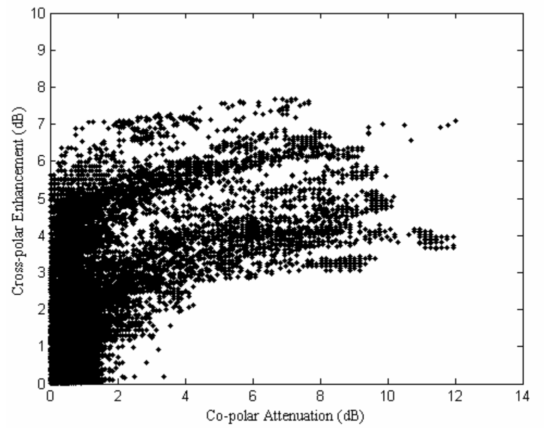

Fig 4. Variation of cross-polar enhancement against the co-polar attenuation

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4. Conclusions

The paper presents a technique of sensing the depolarization effect of a low fade margin satellite signal by employing a simple experimental system. The effect of drop-size distribution of rain on the satellite downlink signal of frequency 10 GHz and above has been investigated. It has been found that, during rain, large drops with prominent oblateness have a greater impact on the cross-polar component than on the co-polar one. At the same time, the decrease of correlation of the two orthogonal signals is also controlled by the drop size distribution during the raining events.

5. Acknowledgement

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6. References

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