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Crosspolarisation Measurements at 13 GHz on a Slant Terrestrial Path: Comparison between Circular and Linear Horizontal Polarisation

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1 Introduction

To decide whether linear or circular polarisation should be used in a satellite communication system based on frequency re-use by polarisation discrimination is a rather complex problem. Among the most important parameters that may play a role in the decision process, we simply point out: antenna design problems, precision of the attitude control of the satellite, distribution of earth station locations within the coverage area, effects of the propagation medium. The purpose of this paper is to describe the effects that are to be expected due to atmospheric precipitations in the 11/14 GHz frequency band, neglecting the other aspects of the problem for the time being.

To measure these effects, the Swiss PTT, under contract to ESA, established an experimental link between their microwave radio-relay station of the Jungfraujoch (3690 m) and a lower site located in Isenfluh (1090 m). The frequency used was 13 GHz. The elevation angle was 14° for a total path length of 10 km; the clearance of this path was ideal for those propagation tests to be performed. Nearly three years of measurements have been obtained over this link, including three summer seasons. Two of them provided data for circular polarisation and one for linear horizontal polarisation. Although the data for circular and linear polarisation were not obtained simultaneously, i.e. during the same summer season, we may try to compare the effects that were observed in presence of the same amount of copolar attenuation. (In practice, there is also a slight difference in attenuation for the two types of polarisation.)

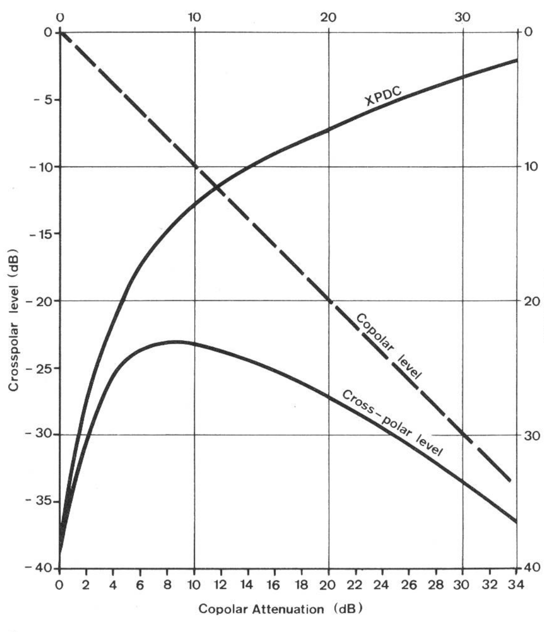

Fig. 1
13 GHz – circular polarisation – (theoretical)

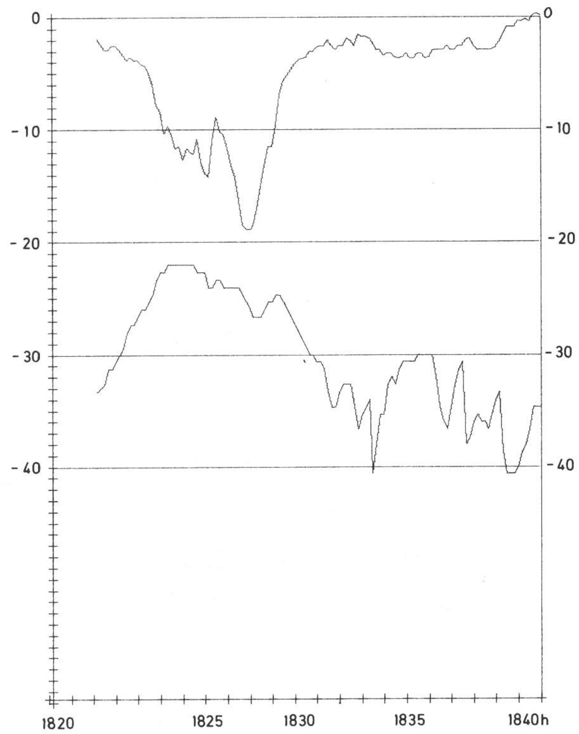

Fig. 2
Circular polarisation: thunderstorm of August 4, 1974, 1830 h

2 Effects on circular polarisation

According to theory [1, 2, 3] when rain is present on an earth-satellite path, some energy is transferred into the orthogonal polarisation mode, causing degradation of the overall polarisation discrimination factor XPD. The amount of energy transferred starts increasing rapidly as a function of the rain intensity present over the path, which is also proportional to the attenuation of the copolar signal (*Fig. 1*). When the copolar attenuation reaches about 10 dB, irrespective of path length, the depolarised component begins to be attenuated in turn, but less rapidly than the copolar component does. This results in a steadily decaying cross-polar discrimination ratio with increasing copolar attenuation.

The predictions of the theoretical model have been verified for several thunderstorm events (*Fig. 2*). In fact, for circular polarisation, the correlation coefficient between copolar attenuation and polarisation discrimination was always found to be larger than 0.7 for thunderstorm precipitations. A best fit linear regression performed over 15 events gave the relation:

$$XPD = 34 - 20 \log A_p \quad (1) \text{ [thunderstorm]}$$

[1] Paper presented at a colloquium, held in Berne by the European Space Agency (ESA) and the Swiss PTT, on June 24–25, 1976

where

XPD polarisation discrimination (dB)
A_p copolar attenuation due to rain (dB)

which is in good agreement with the theoretical model. Dry snowfalls were found to have a stronger depolarisation effect than thunderstorm precipitations; however, in this case, the copolar attenuation was much less (*Fig. 3*). The relation:

$$XPD = 32 - 30 \log A_p \quad (2) \text{ [snow]}$$

best describes the degradation of the discrimination due to dry snowfall.

Other types of precipitation had less marked effects. Further information on this subject may be found in [4].

3 Effects on linear horizontal polarisation

The effects of rain on a linear horizontal polarised electromagnetic wave are much weaker than those exerted on a circularly polarised wave. This is in agreement with prediction by the theoretical models. Actually, since the clearweather level of the polarisation discrimination was only around 35 dB in our link, it was difficult to observe any marked increase of the crosspolar level in the presence of rain attenuation (*Fig. 4*). Thus, most of the degradation of the crosspolar discrimination is due to the fade of the copolar component. A clear-weather isolation better than 45 dB would be necessary to observe propagation effects separately, as we did for the circular polarisation. However, since in a real system the clear-weather discrimination level would not be much better than the one we had over our link, we nevertheless present those results as representative of a real case situation.

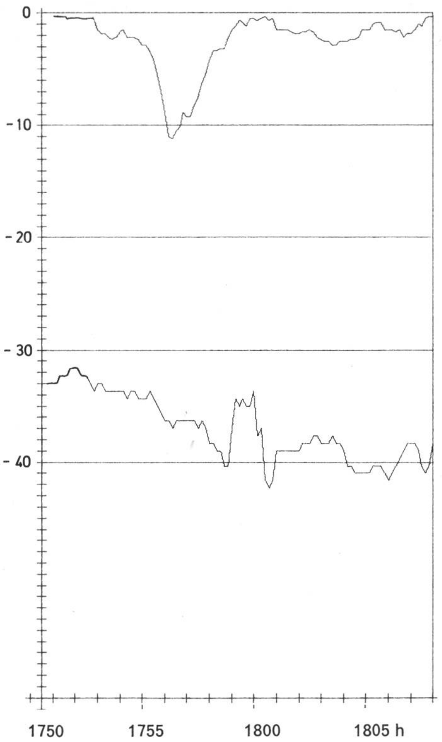

Fig. 4
Linear horizontal polarisation: thunderstorm of July 15, 1975

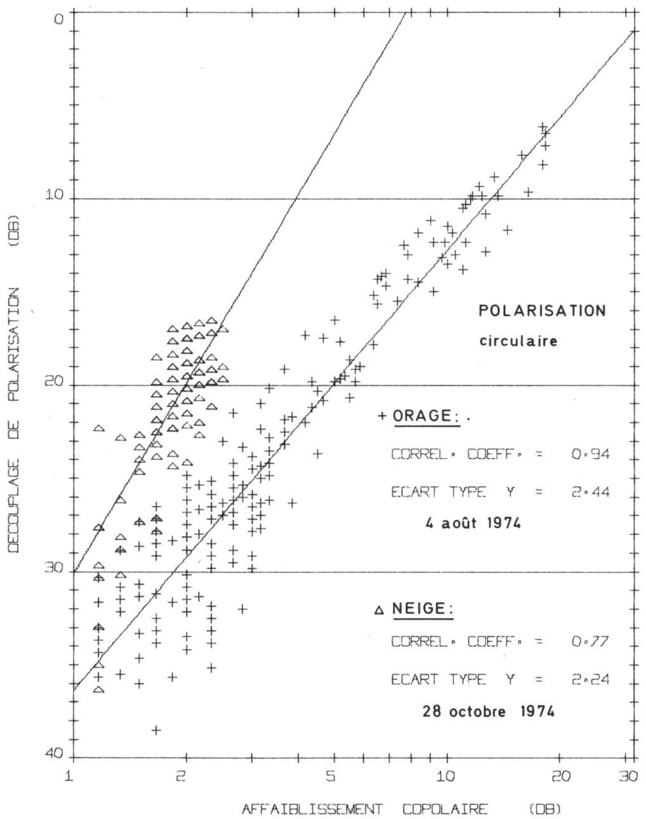

Fig. 3
Comparison between thunderstorm and snow precipitation for circular polarisation

Découplage de polarisation (dB) – Polarisation discrimination (dB)
Affaiblissement copolaire (dB) – Copolar attenuation (dB)
Polarisation circulaire – Circular polarisation
Orage – Thunderstorm
Coefficient de corrélation – Correlation coefficient
Ecart type – Standard deviation
4 août 1974 – August 4, 1974
Neige – Snow
28 octobre 1974 – October 28, 1974

Furthermore, there is an additional parameter which plays a role in the linear case, and did not in the circular one, namely the relative orientation of the electric field vector with respect to the axis of minimum anisotropy of the medium. This parameter is also called «canting angle» in the case of a single raindrop. Due to this, the correlation between polarisation discrimination and copolar attenuation is much weaker in the linear case than it was in the circular (*Fig. 5*). It seems that a relationship of the form:

$$XPD = 35 - 1.2\, A_p \quad (3) \quad (A_p < 15 \text{ dB})$$

best describes an upper-bound for the dependence between XPD and copolar attenuation in the case of linear horizontal polarisation.

Seven out of the nine thunderstorms considered had a best fit that was contained between this upper-bound and a lower-bound given by:

$$XPD = 43 - 1.4\, A_p \quad (4)$$

The effective angle between the electric field vector and the directions of minimum anisotropy of the medium must lay between 2° and 4° in order to explain such effects.

4 Conclusions

There is experimental evidence that from a simple propagation point of view linear horizontal (or vertical) polarisation would be preferable to circular for systems based on frequency re-use by polarisation discrimination. For thunderstorm precipitations, which certainly may be considered as the most detrimental atmospheric effect, polarisation discrimination can drop below 20 dB for a copolar fade of only 5 dB with circular polarisation, whereas it stays above 20 dB in the presence of fades as large as 15 dB with linear horizontal polarisation. However this might not be the case with linear polarisation for any orientation of the electric field vector in space, and it should be remembered that, in the case of the planned European system, the polarisation planes, being fixed with respect to the satellite, would be seen under tilt angles varying between 0 and 45 degrees, depending on the location of the earth station. Furthermore, this advantage becomes really significant only for A_p larger than 4 to 5 dB, as can be seen from (*Fig. 6*), which summarizes the situation.

Other points in the comparison between horizontal and circular polarisation are mentioned below:

a) The correlation between polarisation discrimination and copolar attenuation is much tighter for circular than for linear polarisation.
b) The effective canting angle for linear horizontal polarisation is of the order of 2° to 4°.

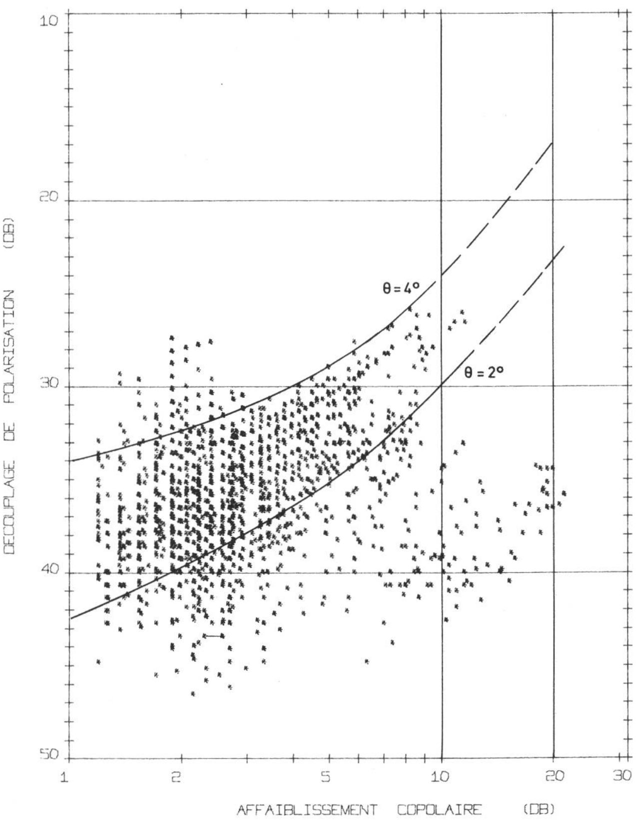

Fig. 5
Scattergram of 9 thunderstorm events of summer 1975 for linear polarisation
Découplage de polarisation (dB) – Polarisation discrimination (dB)
Affaiblissement copolaire (dB) – Copolar attenuation (dB)
Polarisation linéaire horizontale – Linear horizontal polarisation

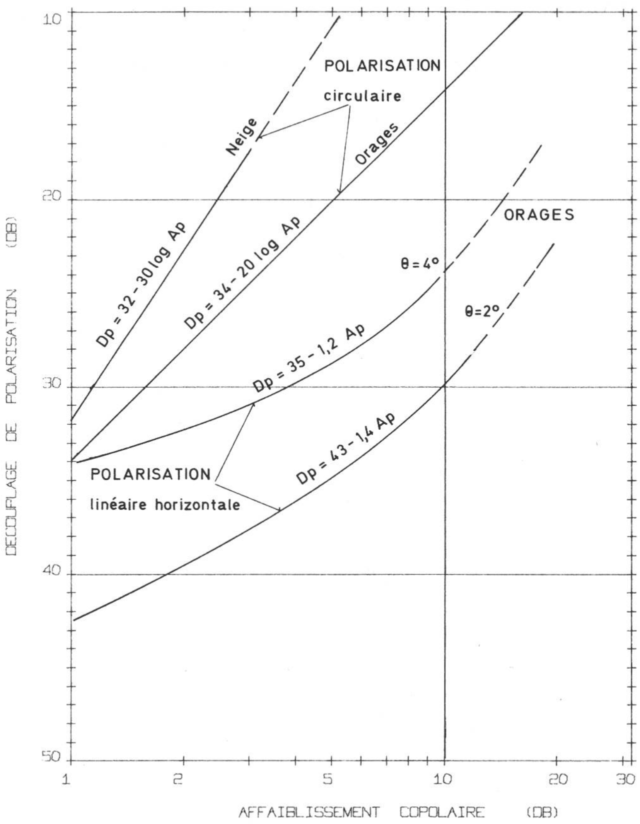

Fig. 6
Summary of the relationships between polarisation discrimination and copolar attenuation
Découplage de polarisation (dB) – Polarisation discrimination (dB)
Affaiblissement copolaire (dB) – Copolar attenuation (dB)
Polarisation circulaire - Circular polarisation
Neige – Snow
Orages – Thunderstorms
Polarisation linéaire horizontale – Linear horizontal polarisation
Comparaison entre polarisations circulaire et linéaire horizontale – Relationships between circular and linear horizontal polarisations

c) Snow has much more a depolarising rather than an absorbing effect.
d) The effect of the elevation angle can be taken into account by introducing a correction factor ($\sin^2\alpha$).
e) Relation [1] obtained at 13 GHz may be extrapolated in the 11/14 GHz band as follows:

$$11\ \text{GHz} : XPD = 32 - 20 \log A_p$$
$$14\ \text{GHz} : XPD = 34 - 20 \log A_p$$

for circular polarisation (worst case).

This work has been performed under ESTEC contract No 1672/72.

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