Abstract

The performance of a statically hardware-compensated polarization measurement system is analysed, both, for linear and circular polarization. It is shown that such systems may affect the propagation measurements and hence their performance should be known prior to the evaluation of propagation data. With the results obtained, a propagation event recorded along the OTS propagation path is analysed in terms of the differential propagation parameters, i.e. differential attenuation and differential phase shift.

Key words: Wave propagation, Centimetric wave, Satellite communication, Isostatic compensation, Antenna, Experimental study.

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1. INTRODUCTION

Depolarization measurements on Earth-space links have become of major concern in present propagation studies since the economy of satellite communications is largely influenced by the degree to which dual-polarized systems can be utilized. Other than attenuation, the depolarization observed cannot necessarily be explained in terms of meteorological observables alone. This is because both the receiving and transmitting antennae contribute to the measured cross-polar signal and hence these residuals may mask or even dominate the propagation effect under study.

The main objective in the evaluation process of depolarization data, therefore, is to remove the antennae effects from the measured signals. There are several ways to meet this objective. The simplest, though not always possible, one is to make sure that the antennae residuals are small compared to the propagation effects of interest. With well designed antennae, this approach may be successful. However, in Earth-space communications, the axes of the satellite and ground station antennae in most cases make some, though small, angle, and hence considerable residual contributions to the cross-polar signal may occur. In addition, the satellite antenna undergoes significant temperature changes over a day,
which may cause severe degradations in the cross-polar pattern. Therefore, it becomes common practice to remove the residuals by either software or hardware cancellation techniques. This cancellation is possible for every cross-polar signal regardless of its magnitude and phase. In propagation studies, however, only static cancellation is used in contrast to communications systems where adaptive cancellation is desirable. The term “static” in this context refers to the fact that the residuals are cancelled by a properly adjusted signal being constant in magnitude and phase for considerable periods of time.

Depolarization measurements relying on this technique, however, may be corrupted by time-varying residuals due to temperature changes over the antennae or mechanical instabilities. Therefore, this paper analyzes this problem in some detail.

In section 2, it is assumed that a linearly-polarized carrier signal is transmitted by a satellite, while in section 3 circular polarization is dealt with. Section 4 is intended to serve as an example of the applicability of the methods outlined, in that a polarization event simultaneously observed with two different antennae along the same propagation path, i.e. the ots link, is analysed.

2. LINEAR POLARIZATION

It is assumed that a satellite transmits a nearly linearly-polarized signal, the field strength of which can be described by

\[ \begin{align*}
E_1 &= E_{x1} + E_{y1}, \\
E_{x1} &= E_{11} e^{i(\theta_1 - \pi / 2)} \hat{e}_1, \\
E_{y1} &= E_{21} e^{i(\theta_2)},
\end{align*} \]

(1)

where \( E_{11} \gg E_{21} \) and \( |E_{x1}|/|E_{y1}| \) is the polarization discrimination of the transmitted signal. \( \hat{e}_1 \) and \( \hat{e}_2 \) are two orthogonal unit vectors in a plane perpendicular to the direction of propagation. When travelling through the atmosphere, the components \( E_{x1} \) and \( E_{y1} \) may undergo different absorptions and propagation delays during special meteorological events. The predominant reason for this type of absorption and phase delay are nonspherical raindrops, but ice-clouds may cause considerable phase delay as well. Without loss of generality, the \( \hat{e}_1 \)-direction is chosen as that along which the additional attenuation (\( \Delta A \) dB) and phase shift \( \phi \) occur relative to the \( \hat{e}_2 \)-direction. Apart from a constant attenuation and phase-factor, the field strength of the wave becomes:

\[ \begin{align*}
\tilde{E}_1 &= \tilde{E}_{x1} + \tilde{E}_{y1}, \\
\tilde{E}_{x1} &= 10^{-\Delta A/10} e^{i(\theta_1 - \pi / 2) - \Delta A} E_{11} \hat{e}_1, \\
\tilde{E}_{y1} &= e^{\Delta A} E_{21} \hat{e}_2.
\end{align*} \]

(2)

When receiving this field strength, the receiving antenna, due to imperfections, cross-couples a fraction \( k_1 \) of the field strength \( \tilde{E}_{x1} \) into the \( y \)-channel and vice versa. \( k_1 \) is a measure of the polarization purity of the receiving antenna. In general, an additional phase shift, \( \chi_1, \) will be present. Hence, the field strengths in the \( x \)- and \( y \)-directions after being coupled out of the omr-system (polarization directions along the \( x \)- and \( y \)-axes) are

\[ \begin{align*}
\tilde{E}_{x1} &= \tilde{E}_{x1} + k_1 e^{i\chi_1} E_{11} + k_1 e^{i(\theta_1 + \chi_1)} E_{21} \hat{e}_1, \\
\tilde{E}_{y1} &= \tilde{E}_{y1} + k_1 e^{i(\theta_1 + \phi) - \Delta A} E_{11} + (1 - k_1 e^{i\chi_1}) e^{\Delta A} E_{21} \hat{e}_2.
\end{align*} \]

(3)

It is apparent from equation (3) that for certain values of \( k_1 \) and \( \chi_1 \) the field component in the \( y \)-direction may be diminished or even cancelled. In general, however, since \( k_1 \) and \( \chi_1 \) are parameters of the antenna system which cannot be changed, \( \tilde{E}_{y1} \) will be finite (see Fig. 1), even during clear sky conditions. To cancel the \( y \)-component of the field strength behind the receiving antenna, part of the field strength in the \( x \)-direction has to be added with phase \( \chi_1 \) to \( \tilde{E}_{y1} \) as is shown in Figure 2. The fraction of \( \tilde{E}_{y1} \) which is added with phase \( \chi_1 \) to \( \tilde{E}_{y1} \) is denoted by \( n_1 \). In principle, \( n_1 \) and \( \chi_1 \) can be adaptively adjusted so that at some instant \( t \) the resulting \( y \)-component vanishes even during unfavourable weather conditions.

FIG. 1. — Model describing polarization measurements in linear polarization.

Modèle décrit les mesures de polarisation effectuées en polarisation linéaire.

FIG. 2. — Cancellation network for linear polarization.

Réseau d'annulation de la composante croisée pour la polarisation linéaire.