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RAIN DEPOLARIZATION COMPENSATION SYSTEM (RDC SYSTEM) USING BEACON SIGNAL FOR C-BAND SATELLITE COMMUNICATIONS

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1. Introduction

As is well known, rain media between the earth station and the satellite degrades overall cross polarization discrimination (XPD) in satellite communication systems. Accordingly, compensation systems for rain depolarization at earth stations have been studied at many organizations, and some of them have already been operated for practical use. (1) - (3)

These existing compensation systems are divided into two types with respect to the up-link compensation method.

One method is "closed-loop control method" using looped-back pilot signals, which shows high compensation performance especially in the up-link. (3) However, this method requires a complicated system and transmission of pilot signals only for this purpose.

The other method is "open-loop control method" monitoring only down-link signal, where the up-link compensation is based on the correlation between the up- and down-link rain depolarization. (2) (3) This method enables polarization compensation with a comparably downsized system. In addition, this method has another important advantage that it does not require the transmission of pilot signals if the satellite beacon is utilized as the monitored down-link signal. However, if the beacon XPD is low, this method using the satellite beacon does not show optimum compensation performance for communication carriers, because the compensation according to the satellite beacon compensates not only rain depolarization but also the beacon cross-polarization that the satellite itself has.

This report introduces the Rain Depolarization Compensation System (RDC System) which has been developed for the C-band satellite communications in dual circular polarization. Although its compensation operation is based on the satellite beacon signal, the method described here is able to eliminate the effect of the beacon XPD, so that the compensation for up- and down-link communication carriers can be optimum. This report describes the configuration, the basic algorithm, and the experimental results of the RDC System.

2. Operation

(1) Configuration

Figure 1 shows the block diagram of the developed RDC system, which compensates up- and down-link carriers depolarized by differential phase shift (DPS) due to ellipsoidal shape of rain drops.

The polarization restoration in RF is based on the function of the rotary π and $\pi/2$ polarizer assembly. These four polarizers (π and $\pi/2$ for 4GHz and 6GHz) are individually rotated by the respective Pol. Rotators which are driven by the Motor Controls. The Motor Controls and all the other components such as the Down Converter, the Demodulator, etc. are monitored and controlled by the RDC Control.

(2) Beacon Signal Flow

The received beacon signal from the satellite, which is depolarized by the rain path, are transferred to the 4GHz OMT after compensated by the 4GHz rotary π and $\pi/2$ polarizers. By the 4GHz OMT, the signal is divided into two polarization components, that is, RHCP and LHCP (one is co-polarization and the other is residual cross-polarization), and supplied to the LNAs. Then, these two polarization signals are extracted by the couplers and supplied to the Demodulator as 70MHz signals via the Down Converter. By the Demodulator, these 70MHz signals are transformed to DC voltage signals indicating the residual cross-polarization level in complex number, and sent to the RDC Control. In this report, the above complex cross-polarization level is expressed as "x-pol. vector (e_x, e_y)" , where e_x is co-phased component with the co-polarization while e_y is 90 degree phase shifted component.

(3) Down-link Compensation

The down-link compensation is based on the closed-loop control method using beacon signal from the satellite; the RDC Control rotates the 4GHz π and $\pi/2$ polarizers monitoring the detected beacon x-pol. vector. However, the developed system does not minimize the beacon x-pol. vector for the following reason.

The cross-polarization received by the earth station antenna is composition of two factors; one is the cross-polarization that the satellite itself inherently has, and the other is depolarization due to rain. Therefore, if the 4GHz polarizer assembly was controlled so that the beacon x-pol. vector would be minimized, the polarizer assembly would compensate not only the cross-polarization due to precipitation but also that of satellite beacon. However, the cross-polarization characteristic of the satellite beacon is sometimes much lower than that of communication carriers. Accordingly, such operation that minimizes the beacon x-pol. vector may degrade the XPD for communications carriers on the contrary, when the rain depolarization is small.

Instead, the RDC Control rotates the 4GHz π and $\pi/2$ polarizers so that the detected beacon x-pol. vector may approximately coincide with "the offset vector (e_{x0}, e_{y0})".

$$-10\cdot\log\{(e_x-e_{x0})^2+(e_y-e_{y0})^2\} \geqq XPD_{th} \qquad (1)$$

where XPD_{th} : Threshold XPD Value

The offset vector corresponds to the cross-polarization which the satellite beacon inherently has, and is calculated from the beacon cross-polarization characteristic measured under a clear sky in advance.

$$\begin{aligned} e_{x0} &= e_0\cos(2\beta_0+2\theta_{qd0}-4\theta_{hd0}) \\ e_{y0} &= e_0\sin(2\beta_0+2\theta_{qd0}-4\theta_{hd0}) \end{aligned} \qquad (2)$$

where $\theta_{hd0}, \theta_{qd0}$: 4GHz π and $\pi/2$ polarizer angular positions when the beacon XPD was pre-measured under a clear sky

e_0 : Beacon cross-polarization level under a clear sky

β_0 : Beacon tilt angle (TA) under a clear sky

In order to satisfy eq.(1), the RDC Control calculates the angle error of the 4 GHz polarizers ($\Delta\theta_{hd}$, $\Delta\theta_{qd}$), which can be approximated as follows.

$$\begin{aligned} \Delta\theta_{hd} &= D_h\cdot(e_y-e_{y0}) && \text{(for } \pi \text{ polarizer)} \\ \Delta\theta_{qd} &= D_q\cdot(e_x-e_{x0}) && \text{(for } \pi/2 \text{ polarizer)} \end{aligned} \qquad (3)$$

where D_{hd}, D_{qd} : Drive coefficients for 4GHz π and $\pi/2$ polarizer

Then, the RDC Control rotates the 4GHz π and $\pi/2$ polarizers according to the above calculation. By choosing appropriate coefficients D_h and D_q, the polarizers are driven to the final position smoothly, and the x-pol. vector is pulled into the offset vector. Consequently, the XPD of the communication carriers are compensated nearly up to XPD_{th}.

(4) Up-link Compensation

The up-link compensation is based on the open-loop control method utilizing the correlation of rain depolarization between up- and down-link.(2)-(4)

The RDC Control firstly calculates DPS in the down-link (Φ_d) according to the angular position of the 4GHz π and $\pi/2$ polarizers. Then, the RDC Control estimates DPS in the up-link (Φ_u) according to the correlation between the up- and down-link described below.

$$\Phi_u = f(\Phi_d) \qquad (4)$$

The above function depends upon the elevation angle of the earth station antenna, and is normally approximated as a linear function as follows.(2)-(3)

$$\Phi_u = a\cdot\Phi_d + b \qquad (5)$$

Using the above correlation, the RDC Control rotates the 6GHz π and $\pi/2$ polarizers to the angle, where the polarizers pre-distort the polarization to compensate the up-link XPD.

$$\begin{aligned} \theta_{hu} &= \frac{1}{2}(\theta_{qu}+\theta_{qd})-\theta_{hd} && \text{(for } \pi \text{ polarizer)} \\ \theta_{qu} &= -a\cdot\theta_{qu}-\frac{b}{2} && \text{(for } \pi/2 \text{ polarizer)} \end{aligned} \qquad (6)$$

where θ_{hd}, θ_{qd} : 4GHz π and $\pi/2$ polarizer current positions

4. Experimental Evaluation

Figure 2 shows the test set-up for the RDC System. Feed A is the earth station antenna feed under test and Feed B is a dual circular polarization feed regarded as a satellite. To simulate low beacon XPD, pilot signal is input into Feed B from both the RHCP and LHCP port with an adequate ratio. Feed A and Feed B are connected with a "De-polarizer" which imitates DPS in the rain path. Using various De-polarizers, the RDC System was evaluated.

Figure 3 shows the time response of the compensation operation. This figure indicates that each polarizer was pulled into the final position smoothly and XPD was improved rapidly.

Figure 4 shows the measured compensation performance of the RDC System when the beacon XPD is 23dB. As shown in this figure, the system compensates the communication carrier effectively even if the beacon XPD is as low as 23dB.

5. Conclusion

The compensation system for rain depolarization has been developed and tested. The test result shows that the system operates effectively under low beacon XPD condition.

Field data which show the performance on the site are now being collected.

References

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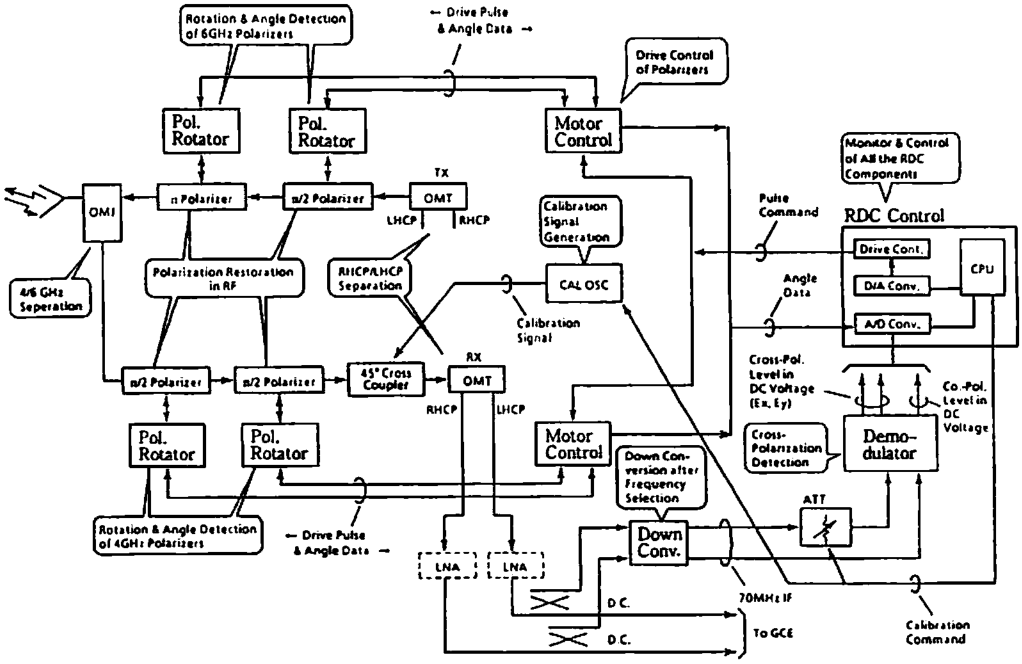

Figure 1. Block Diagram of the RDC System

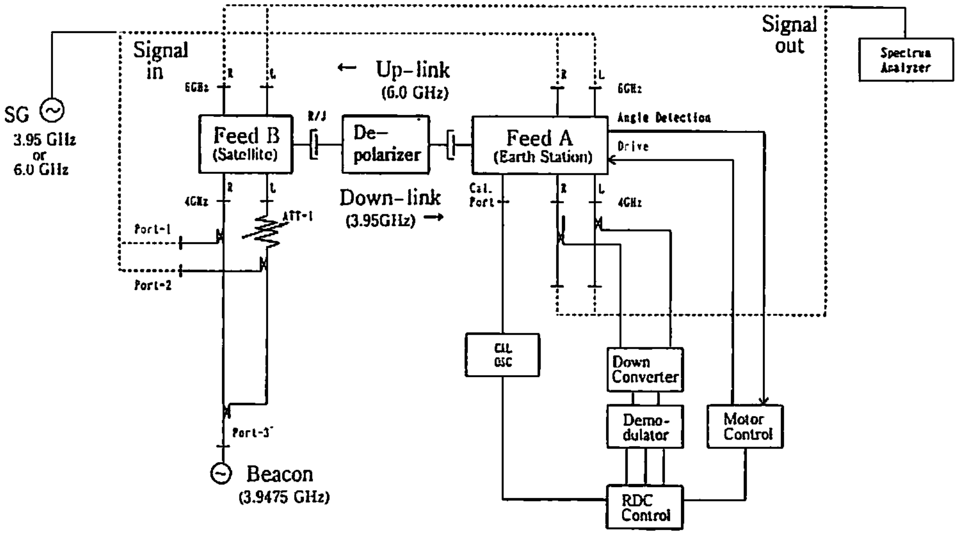

Figure 2. Test Set-up

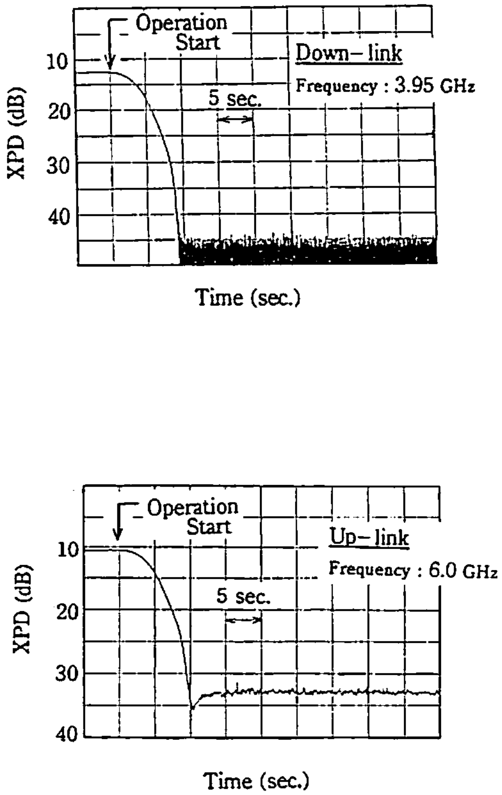

Figure 3. Measured Time Response

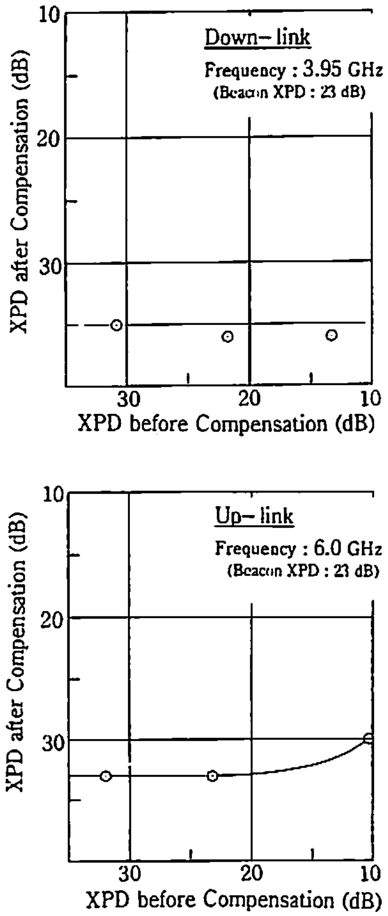

Figure 4. System Compensation Performance