A Polarization Control for a Multi-beam DBS Receiving Antenna

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1. Introduction

Satellite broadcasting services are currently provided in Japan using four orbital positions. A number of satellites located in different orbital positions will provide in the future. We have performed a fundamental study on a multi-beam phased-array antenna that can simultaneously receive signals from a number of satellites in different orbital positions[1] (Fig.1 and Fig.2). To receive an arbitrary polarized wave, the multi-beam receiving antenna needs matching its polarization to that of incident waves.

This paper describes a study on a polarization-matching circuit for a reception of linearly polarized waves of an arbitrary angle, and also presents measured results of an experimental antenna.

2. Polarization-matching circuit

2-1. Basic concepts

The antenna receives the incident wave as two orthogonal components to match its polarization to the incident wave. Figure 3 shows coordinates of polarization. V_0 (H_0) is vertical (horizontal) polarization of the incident wave and V_A (H_A) is the vertical (horizontal) component of the antenna. θ is a polarization angle of the incident wave relative to V_A. The polarization of the antenna is matched to the polarization of the incident wave by rotating axes θ degrees. Figure 4 shows a block diagram of a polarization-matching circuit. To match the polarization of the antenna to the polarization of the incident wave, the amplitude of the components is set to $\sin\theta$ and $\cos\theta$ as shown in Figure 4.

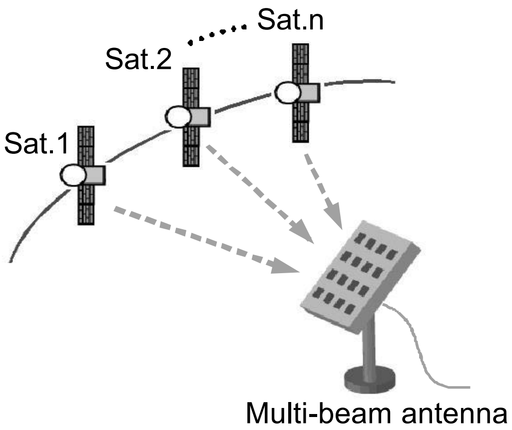

Figure 1 Multi-beam receiving antenna

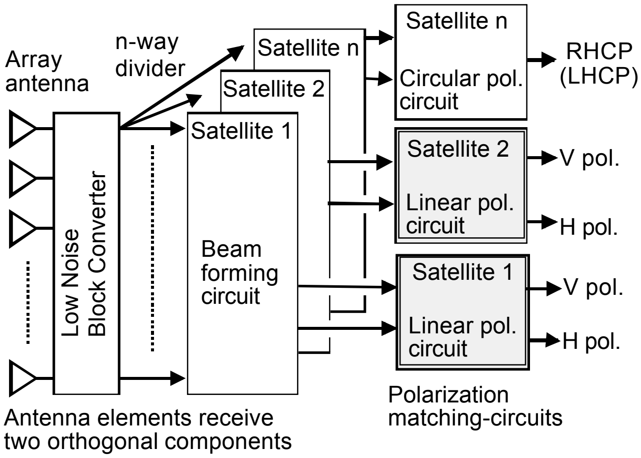

Figure 2 Brock diagram of multi-beam receiving antenna

2-2. Tolerance of amplitude and phase error

Cross-polarization characteristic is one of the major factors in estimating a performance of the polarization-matching circuit. Figure 5 shows calculated cross-polarization levels of the polarization-matching circuit with amplitude and phase errors. The cross-polarization levels rise with the increased errors. It is found from Figure 5 that tolerance of the amplitude error is about ±1 dB and tolerance of the phase error is about ±5 degrees, respectively, to keep the cross-polarization level below –25 dB[2].

2-3. Experimental model of polarization-matching circuit

Figure 6 shows an experimental model of a polarization-matching circuit working in 1-GHz band. A 180°-hybrid coupler serves as a 2-way power divider and a 90° phase shifter. The signal at -90° output terminal has a 180° phase difference relative to the +90° output terminal. By using these two signals, we can obtain V_0 without the inverter circuit shown in Figure 4. To adjust both amplitude and phase of the signal within the tolerance above, we used variable attenuators with a 0.2 dB-step and variable phase shifters. Figure 7 shows a measured cross-polarization levels of the experimental circuit when a common signal is fed to both V_A and H_A. The cross-polarization level less than –25 dB was obtained over a frequency range between 1 and 2 GHz.

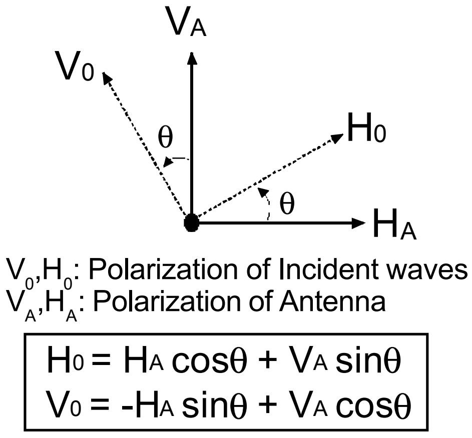

Figure 3 Coordinates of polarization

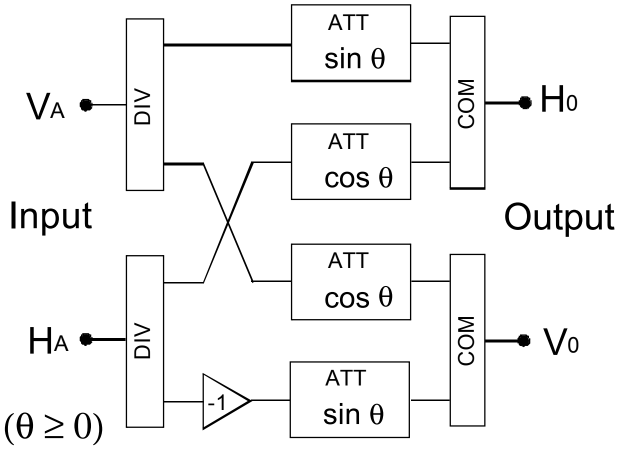

Figure 4 Block diagram of polarization-matching circuit

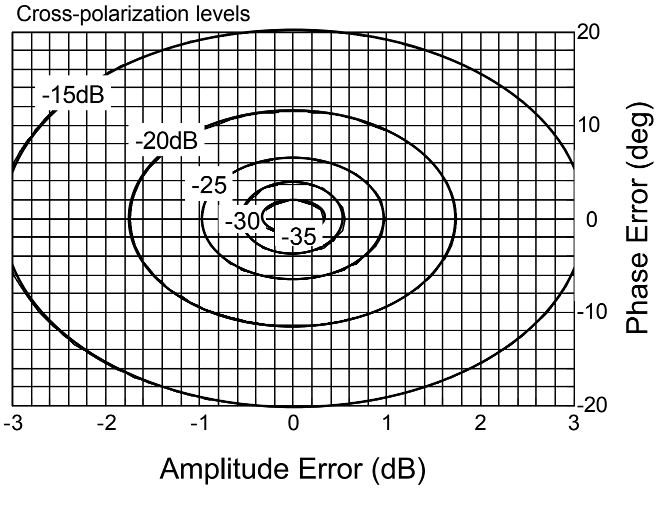

Figure 5 Cross-polarization levels of polarization-matching circuit with amplitude and phase errors

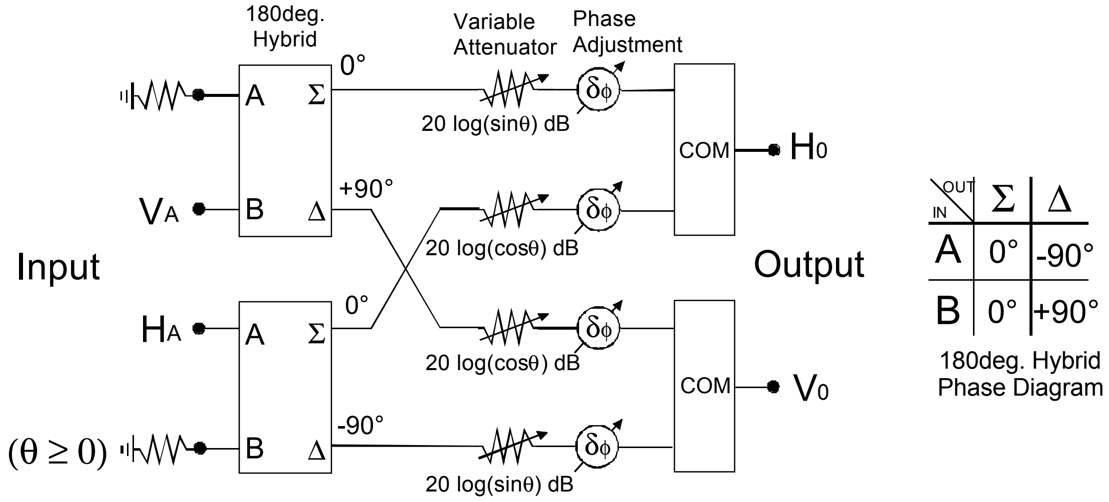

Figure 6 Experimental model of polarization-matching circuit

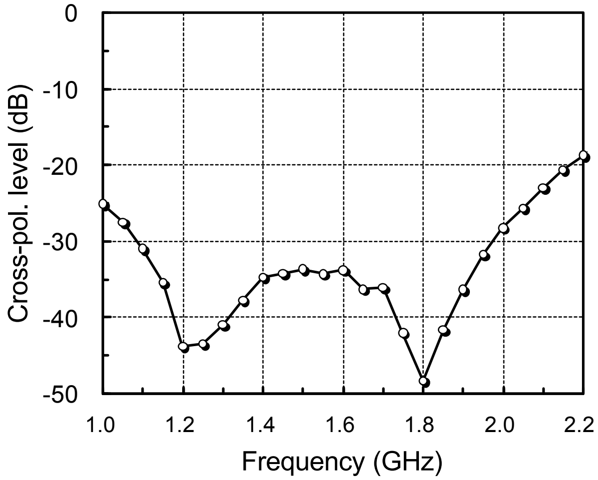

Figure 7 Measured cross-polarization levels of experimental model of polarization-matching circuit

3. Measured results on experimental antenna

3-1. Configuration of experimental antenna

Figure 8 shows a configuration of an experimental antenna that receives linearly polarized waves of arbitrary angles. The antenna consists of 48 microstrip patch elements for 12-GHz band (0.76 mm thick PTFE substrate, ε_r=2.17). Each element has two output ports (V_A, H_A) for the reception of orthogonal wave components. Signals of orthogonal wave components are down-converted to 1-GHz band, and they are input to the polarization-matching circuit.

3-2. Cross-polarization characteristics

Figure 9 shows measured cross-polarization levels of the experimental antenna when the azimuth angle ϕ is zero (normal direction) and the polarization angle θ is changed. Figure 10 shows the cross-polarization pattern (θ = 45 degrees) measured at 12.2 GHz and 12.5 GHz. In the measurements, the polarization-matching circuit was adjusted at 12.5 GHz (1.82 GHz in 1-GHz band). The cross-polarization levels of less than –20 dB was obtained over a frequency range of 500 MHz, while they are larger compared with that of the polarization-matching circuit due to the amplitude and/or phase difference between V_A and H_A of the antenna elements.

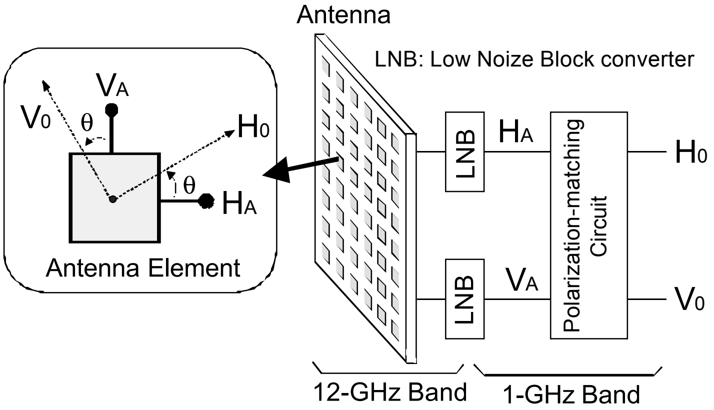

Figure 8 Experimental antenna

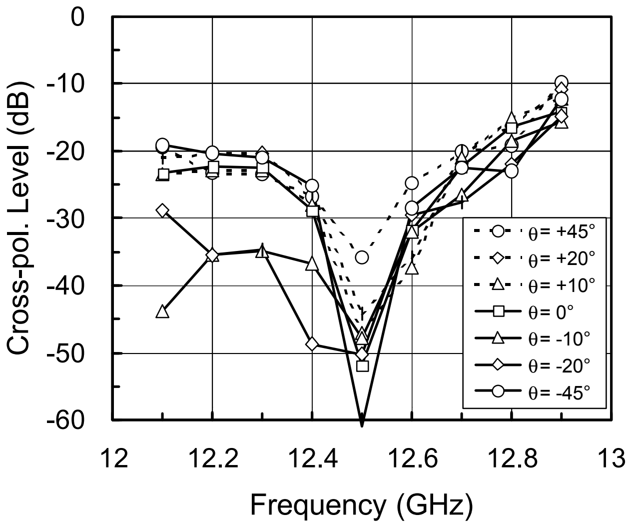

Figure 9 Measured cross-polarization levels of experimental antenna

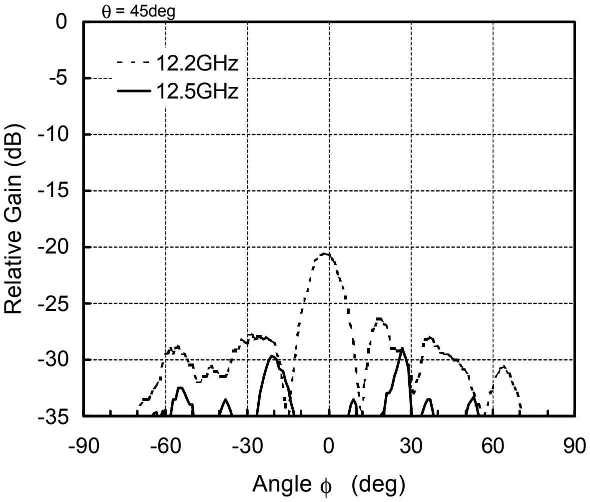

Figure 10 Measured cross-polarization patterns of experimental antenna (q=45deg.)

4. Conclusion

We performed a study on a phased-array antenna that can receive linearly polarized waves of arbitrary angle, and measured cross-polarization characteristics of the experimental antenna. The cross-polarization level of the antenna is below –20dB for any polarization angles and over a frequency range of 500 MHz. We will apply the polarization-matching circuit to a multi-beam receiving antenna for satellite broadcasting.

References

[1] M. FUJITA et al., "Experimental Results on Multi-beam Receiving Antenna for Satellite Broadcasting", IEEE International Conference on Phased Array Systems and Technology, May 2000

[2] Technical Report of Electric Industries Association of Japan, "Specifications and Performance Requirements on Receiving Antennas for Satellite Digital Broadcast Transmissions in the FSS Band", EIAJ CPR-5104