SIMULTANEOUS DUAL-POLARIZATION FERRITE PHASE SHIFTER

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ABSTRACT

Radar system needs exist for antennas capable of forming simultaneous orthogonally polarized congruent agile beams. For a phased array system this implies that the phase shifters must be capable of transmitting and receiving any arbitrary polarization. This paper describes the performance of a latching reciprocal ferrite shifter at X-band frequencies which provides polarization-independent performance at moderate power levels and with low insertion loss.

INTRODUCTION

The simultaneous dual-polarization ferrite phase shifter uses two dual-mode phase shifters[1] latched to one another as shown in Fig. 1. This eliminates the external magnetic yokes and provides two parallel paths for the r-f energy. The flux levels existing in each path have the same amplitude but opposite direction. Reversing the sense of circular polarization in one path with respect to the other causes r-f signals propagating in the parallel paths to receive the same amount of differential phase shift. Thus, two phase shift channels may be provided, one for each orthogonal sense of input polarization. If the input polarization is separated into two orthogonal channels, each channel may be phase shifted by the same amount and the pair recombined at the output port to achieve dual polarization operation. This device using orthogonal mode transducers rather than septum polarizers was first described in 1969[2].

THE SEPTUM POLARIZER

The septum polarizer is a four-port waveguide device shown in Fig. 2. The square waveguide at one end constitutes two ports since it may support two orthogonal modes. The stepped septum divides the square waveguide into two rectangular waveguides sharing a common wall. If one of the rectangular waveguide ports is excited, the signal is transformed into a circularly polarized signal at the square waveguide. Exciting the other rectangular port results in the opposite sense of circular polarization at the square port. The operation of the septum polarizer is illustrated also in Fig. 2. Assume the square port is excited with an electric field parallel to the septum. This signal transforms into two odd-mode signals at the rectangular ports. An electric field perpendicular to the spetum transforms into two even-mode signals as shown. If both input

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components exist simultaneously, cancellation at one or the other rectangular port occurs if the amplitudes are identical and the phase difference is either 0 degrees or 180 degrees. If the septum is designed to provide 90 degrees of differential phase shift, isolation will occur for circularly polarized input signals.

PHASE SHIFTER DATA

A dual-polarization phase shifter was physically realized using air-filled septum polarizers and dielectric matching transformers between the ferrite rod and the rectangular ports of the septum polarizer. The phase shifter was electronically stepped through the various phase states while the r-f frequency was slowly varied from f_{low} to f_{high} (an 11 percent bandwidth at X-band). The input polarization was linear, either parallel to the septum or perpendicular to the septum. Data for the insertion loss, the return loss, the phase shift and the cross-polarization is given in Figs. 3 through 7. Note that with linear input polarizations both legs of the phase shifter carry energy, while circularly polarized inputs would result in energy in one path or the other depending upon the sense of the circular polarization.

INSERTION PHASE AND CROSS-POLARIZATION

Variations in the insertion phase of the two ferrite rods used to construct the unit will have two effects:

(a) Variation in insertion phase of the device, and

(b) Generation of an unwanted cross-polarized signal.

Let the input be linearly polarized parallel to the septum. The output of each phase shifter before recombination in the output septum polarizer is

$$E_1 = (A_o + A_1)e^{j(\phi_o + \phi_1)}$$
$$E_2 = (A_o + A_2)e^{j(\phi_o + \phi_2)}$$

where ϕ_o is the desired phase shift, A_1, A_2 and ϕ_1, ϕ_2 represent amplitude and phase errors introduced by channels 1 and 2 respectively. Now, for convenience, let $A_1 = A_2$. After recombination, the desired signal is

$$E = 2\,(A_o + A_1)\cos(\phi_2 - \phi_1)\, e^{j\left(\frac{\phi_2 - \phi_1}{2}\right)}$$

While the cross-polarized signal is

$$E = 2\,(A_o + A_1)\sin\left(\frac{\phi_2 - \phi_1}{2}\right) e^{j\left(\frac{\phi_2 - \phi_1 - \pi}{2}\right)}$$

Thus, the cross-polarized signal can be controlled fairly easily by phase matching the two rods used to construct the phase shifter. Although this sounds difficult, in practice it may be accomplished easily and inexpensively.

CONCLUSION

A reciprocal, latching ferrite phase shifter which is capable of operation with simultaneous orthogonally polarized signals has been described. Experimental data demonstrated satisfactory operation over a ten percent bandwidth at X-band. The device provides excellent control of the cross-polarized signal.

ACKNOWLEDGEMENT

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REFERENCES

1. C. R. Boyd, Jr., "A Dual-Mode Latching Reciprocal Ferrite Phase Shifter," IEEE Transactions on Microwave Theory and Techniques, 1970 International Symposium Issue, Vol. MTT-18, pp 1119-1124, Dec. 1970.
2. W. E. Hord and J. A. Benet, "Polarization Insensitive Reciprocal Latching Phase Shifter," U. S. Patent No. 3626335, Dec. 1971.

FIGURE 1

DUAL-CHANNEL, DUAL-MODE PHASE SHIFTER

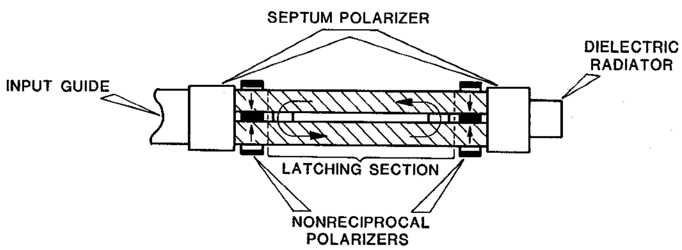
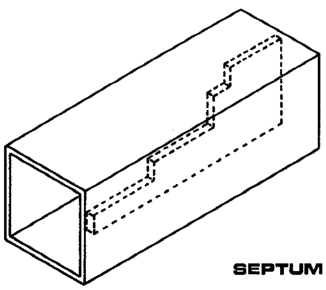


FIGURE 2



SEPTUM POLARIZER

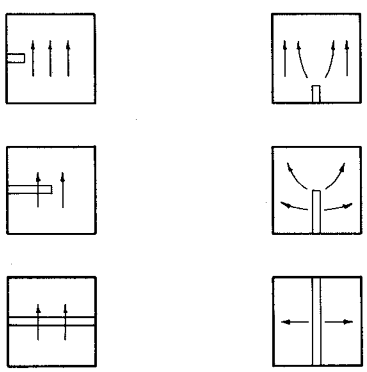


FIGURE 3

INSERTION LOSS AND RETURN LOSS VS. FREQUENCY

SIMULTANEOUS, DUAL POLARIZATION PHASE SHIFTER

INPUT POLARIZATION	HORIZONTAL LINEAR
FREQUENCY	X-BAND
BANDWIDTH	11.4%

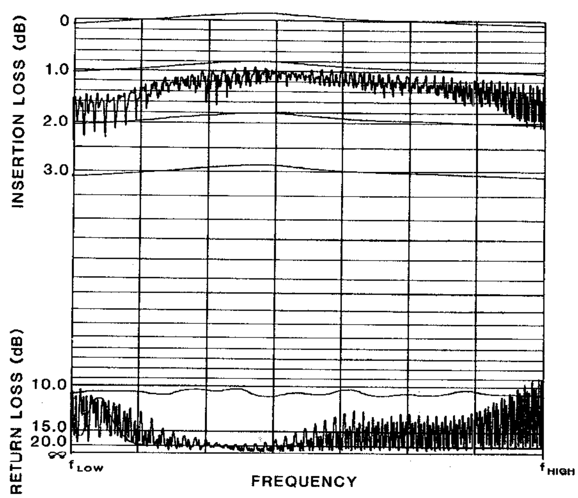


FIGURE 4

CROSS-POLARIZED COMPONENT VS. FREQUENCY

SIMULTANEOUS, DUAL POLARIZATION PHASE SHIFTER

INPUT POLARIZATION	HORIZONTAL LINEAR
FREQUENCY	X-BAND
BANDWIDTH	11.4%

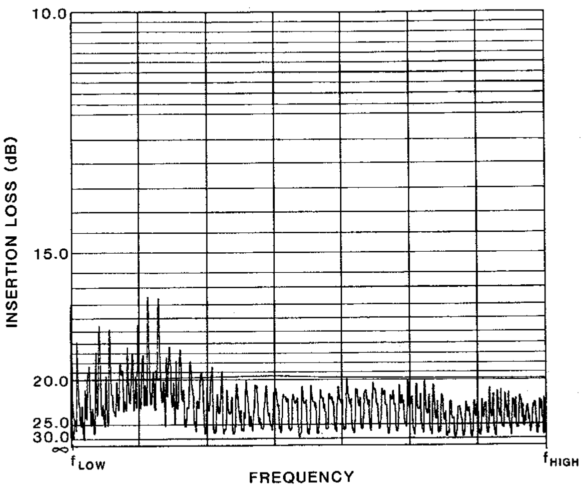


FIGURE 5

INSERTION LOSS AND RETURN LOSS VS. FREQUENCY

SIMULTANEOUS, DUAL POLARIZATION PHASE SHIFTER

INPUT POLARIZATION	VERTICAL LINEAR
FREQUENCY	X-BAND
BANDWIDTH	11.4%

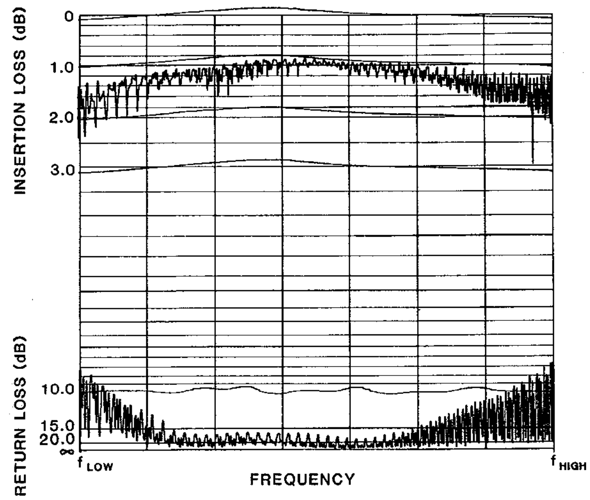


FIGURE 6

CROSS-POLARIZED COMPONENT VS. FREQUENCY

SIMULTANEOUS, DUAL POLARIZATION PHASE SHIFTER

INPUT POLARIZATION	VERTICAL LINEAR
FREQUENCY	X-BAND
BANDWIDTH	11.4%

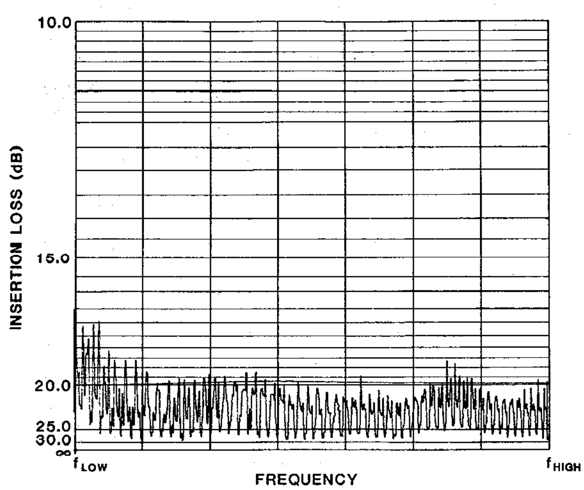


FIGURE 7

DIFFERENTIAL PHASE SHIFT VS. COMMAND STATE