Medium Power S-Band Rotary Field Ferrite Phase Shifters

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Reciprocal rotary field phase shifters have been developed at S-band frequencies with peak power capacity of 40 kW, average power of 600 W and switching times of 100 microseconds. Data is presented on a production lot of these devices showing the statistical properties of the peak and RMS phase error and the peak and average insertion loss.

I. INTRODUCTION

The rotary field ferrite phase shifter achieves excellent phase accuracy by controlling the amplitude of drive currents applied to two orthogonal windings. The unit is generally used in single-axis scanning applications where moderate power handling ability and good phase accuracy are required. Reciprocal units have been developed at S-Band with peak power capacity of 40 kW, average power of 600 W and switching times of 100 microseconds. Several hundred of these devices have now been produced and data on a production lot is presented.

II. PHASE SHIFTER DESIGN

The basic rotary-field phase shifter design is shown in Figure 1. Linearly polarized energy at either the transmitter/receiver port or the antenna port is converted to circular polarization by the quarter-wave plates. The circular polarization impinges on the ferrite rotatable half-wave plate where variable insertion phase is imparted the wave depending upon the rotational angle of the magnetic bias field. Each degree of rotation of the bias field results in two degrees electrical phase shift [1]. A more detailed description of the rotary field phase shifter is available in the literature [2, 3]. Cross-polarized energy resulting from deviations from the design values for the quarter-wave plates and the half-wave plate is absorbed either by the thin film absorber at the T/R port or the coaxial load at the antenna port.

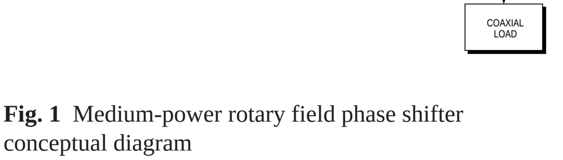

Fig. 1 Medium-power rotary field phase shifter conceptual diagram

The phase shifter is fabricated from a round ferrite-ceramic rod. The rod is coated with a thin metallic layer to form the r-f circuit. An external yoke to provide the variable bias field is registered with the half-wave plate.

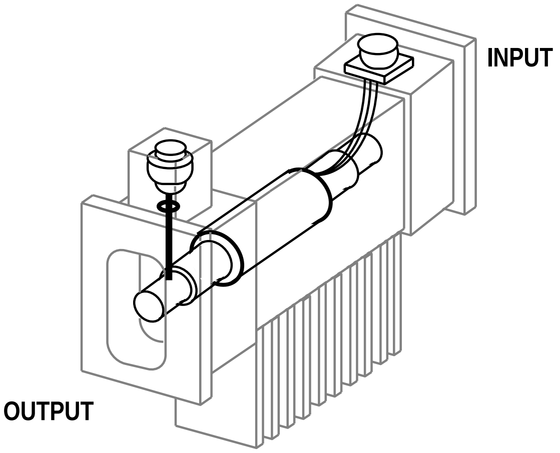

Fig. 2 S-band medium power rotary-field phase shifter

This subassembly is located within a metal housing as shown in Figure 2. Input and output ports are waveguides.

The design of the external yoke and control windings is crucial in obtaining good phase control accuracy. The number of slots in the yoke and the number of turns per slot are adjusted to provide the necessary quadrupole field pattern which may be rotated smoothly as the coil currents are varied. The number of turns is kept as small as possible to ensure fast switching speeds. The yokes are fabricated using a stack of metal laminations as the magnetic core. The optimum sine and cosine coil distributions are wound by hand in accordance with computer generated wiring tables.

III. SWITCHING CONSIDERATIONS

The switching speed of an R-L circuit is governed by the slope of the current at the instant of switching. This slope is equal to the applied voltage divided by the coil inductance. Faster speeds are obtained by increasing the drive voltage and decreasing coil inductance. However, sold state devices have practical limits on the voltages they may control and the number of turns must be sufficient to minimize the quantization error arising from the fact that the number of wires in a given slot must be an integer. Since high drive voltage is desirable for switching, but low voltage is mandated for sustaining the bias field, the electronic driver is designed to switch from the high voltage supply to the low voltage supply at the instant when the current reaches the desired value. Using this technique resulted in a switching time slightly less than 60 microseconds when either coil was switched from maximum negative current to maximum positive current. This allows 35 microseconds for backup angle which is necessary to remove hysteresis effects and allow random access of phase states.

IV. R-F PERFORMANCE

A plot of insertion loss versus phase state is shown in Figure 3. The modulation of the loss is approximately 0.1 dB. Figure 4 gives the phase error as a function of phase state for transmission in both directions through the phase shifter. The return loss versus phase state is shown in Figure 5 for both directions of propagation. Figure 6

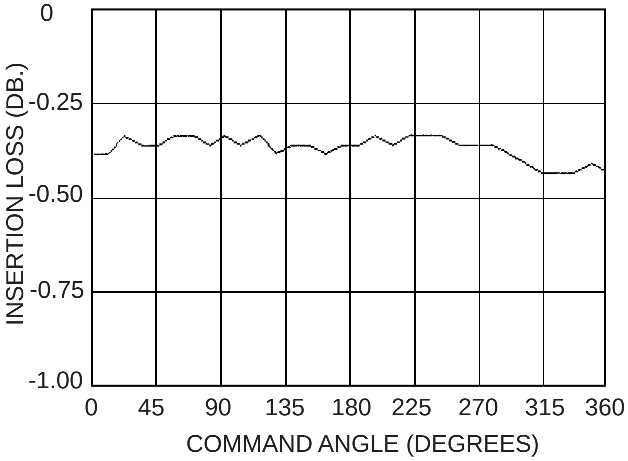

Fig. 3 Insertion loss vs. phase state

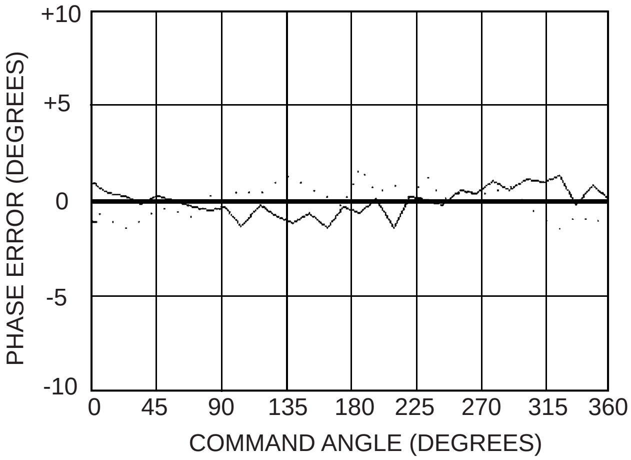

Fig. 4 Phase error

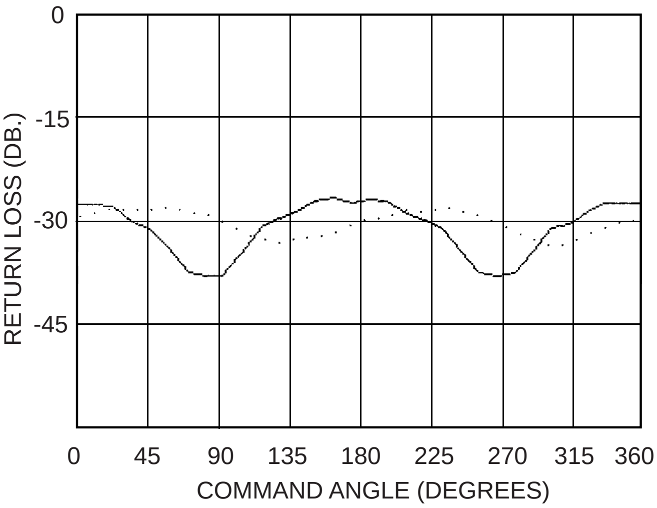

Fig. 5 Return loss vs. phase state

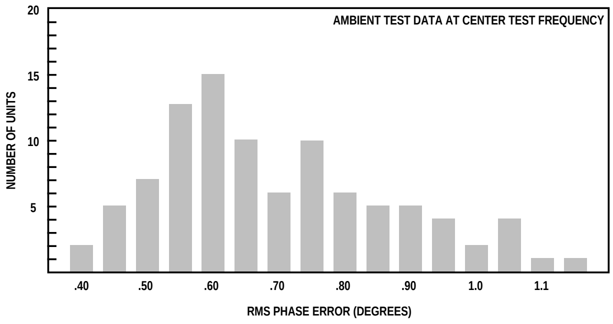

Fig. 6 RMS phase error

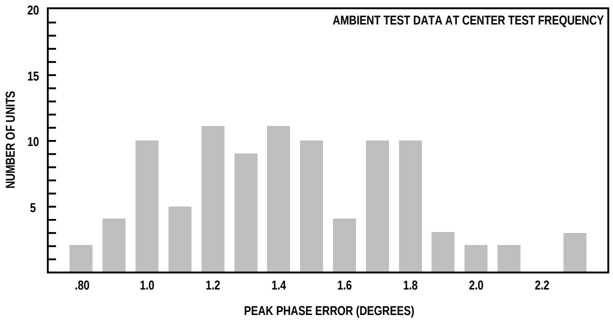

Fig. 7 Peak phase error

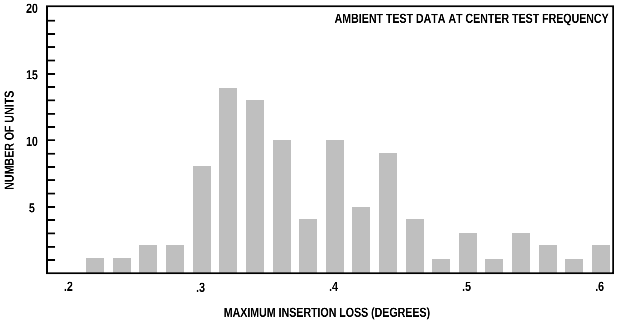

Fig. 8 Maximum insertion loss

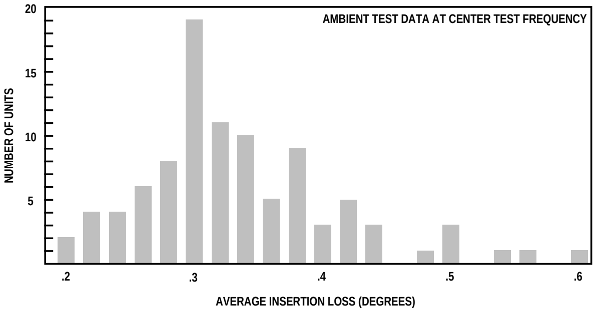

Fig. 9 Average insertion loss

and 7 are histograms of the RMS and peak phase error for a production lot of ninety-six units. Figures 8 and 9 present histograms of the peak and average insertion loss of the lot.

V. Conclusions

Data has been presented on a production lot of rotary field ferrite phase shifters. The air-cooled device is capable of controlling medium r-f power levels at S-band frequencies. Switching speeds for randomly accessed phase states are less than 100 microseconds with drive voltages of 40 volts.

VI. References

[1] A.G. Fox, “An Adjustable Waveguide Phase Changer”, Proc. IRE, Vol. 35, Dec. 1947, pp. 1489-1498.

[2] N. Karayiansis and J. C. Cacheris, “Birefringence of Ferrites in Circular Waveguide”, Proc. IRE, Vol. 44, Oct. 1956, pp. 1414-1421.

[3] A. G. Fox, S. E. Miller, M. T. Weiss, “Behavior and Application of Ferrites in Microwave Region”, Bell System Technical Journal, Jan. 1955, pp. 78-86 .