IV-2. A DIGITAL LATCHING FERRITE STRIP TRANSMISSION LINE PHASE SHIFTER

L. R. Whicker and R. R. Jones

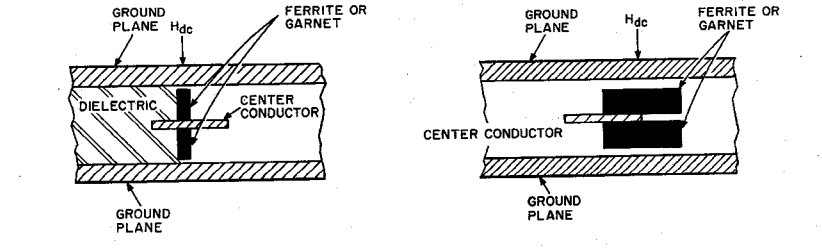
Westinghouse Electric Corporation, Baltimore, Maryland

This paper is concerned with the development of a new non-reciprocal, digital phase shifter which combines the rapid switching speeds offered by latching devices and the compactness of a strip transmission line structure. A four-bit, C-band model is described which offers a maximum of 3 percent phase deviation across an 8 percent frequency band with a corresponding figure of merit (degrees of phase shift/db loss) in excess of 500. In addition, the new phase shifter is much smaller than its waveguide counterpart, and is better suited for integration into a compact matrix which may contain many identical phase shifters.

Before the specific design of the phase shifter is considered, the properties of present latching ferrite phase shifters are reviewed. In particular, the switching mechanism for such devices is discussed, and the necessity of utilizing the microwave hysteresis characteristics of material toroids is indicated.

The evolvement of non-reciprocal TEM mode components is considered and Button's criteria for obtaining non-reciprocal action in such structures is discussed (Reference 1). It is pointed out that in such structures the TEM mode must be distorted in such a way as to produce a TE like mode having suitable planes of circular polarization.

Sketches of past strip transmission line structures are included for comparison (Figure 1) with those investigated here (References 2 and 3). In the new configurations (Figure 2), the arms of the toroids nearer the center conductor interact strongly with the microwave energy. In the far removed arms, the undesired interactions are small. The remaining arms complete the magnetic path and provide dielectric loading. Toroids made from both ferrite ($4\pi M_s$ = 1700 Gauss) and yittrium iron garnet ($4\pi M_s$ = 1600 Gauss) have been used in the investigation.



(a). REPORTED DESIGN OF STRIPLINE PHASE SHIFTER WITH DIELECTRIC LOADING.

(b). REPORTED DESIGN OF STRIPLINE ISOLATOR WITHOUT DIELECTRIC LOADING.

Figure 1. Reported Designs of Non-Reciprocal TEM Mode Devices

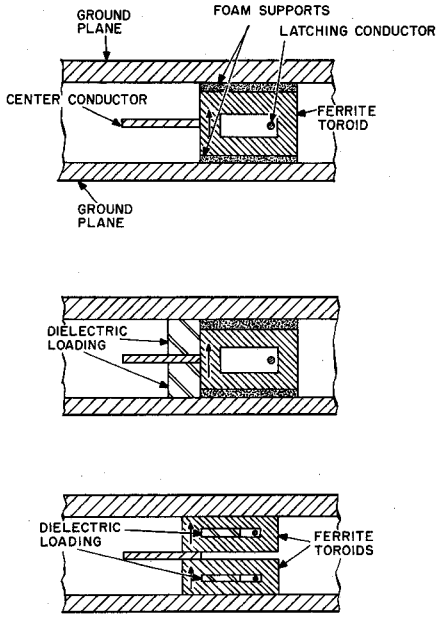


Figure 2. Configurations Which Have Been Investigated

Measured phase shift data are presented for both the one and two toroid models (Figures 3 and 4). In each case the toroid geometries have been optimized for the specified ground plane spacing. The frequency dependence on the phase shift data is correlated with Button's results for a coaxial structure (Reference 1). A figure of merit versus frequency plot is provided for the one-toroid model (Figure 5).

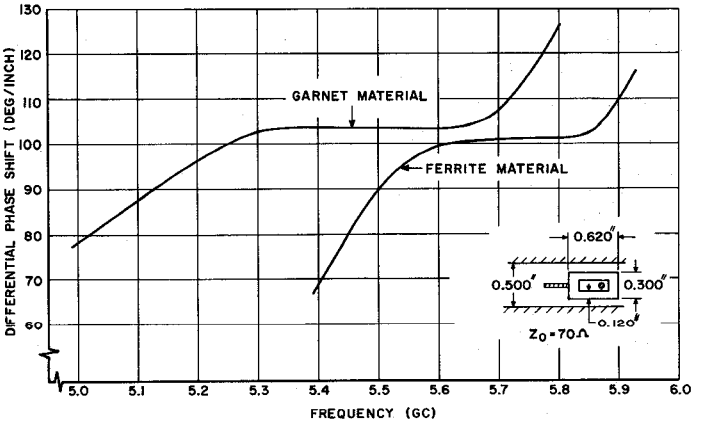


Figure 3. Measured Phase Shift Data for One Toroid Configuration

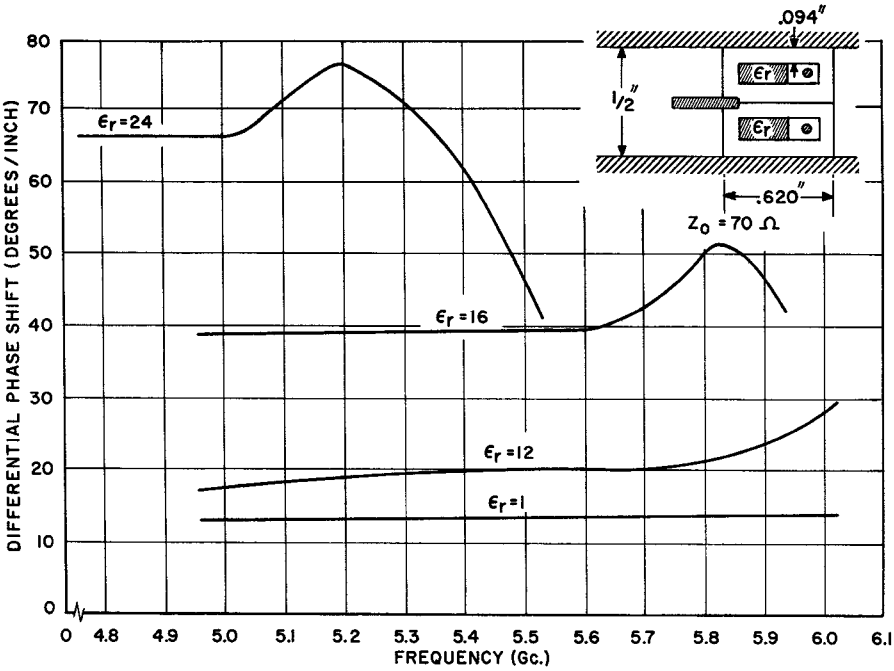


Figure 4. Measured Phase Shift Data for Two-Toroid Configuration

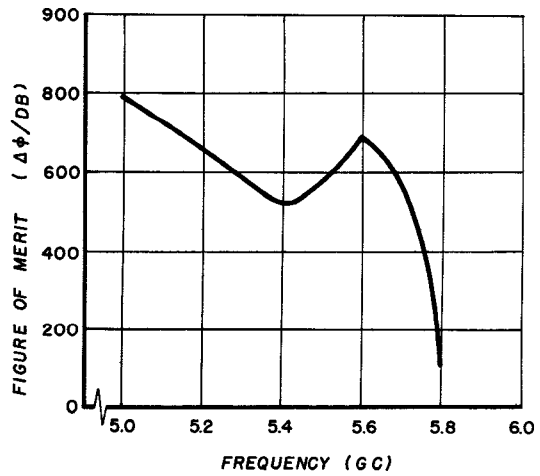


Figure 5. Figure of Merit Data for One-Toroid Model

After the advantages of both the one-toroid and two-toroid model are considered, the development of a four-bit, C-band phase shifter is described. In the design, the basic one-toroid model is utilized (Figure 6). As in a waveguide configuration, dielectric transformers and spacers are used for matching and for prevention of coupled demagnetizing effects respectively. Switching energy values are obtained and tabulated.

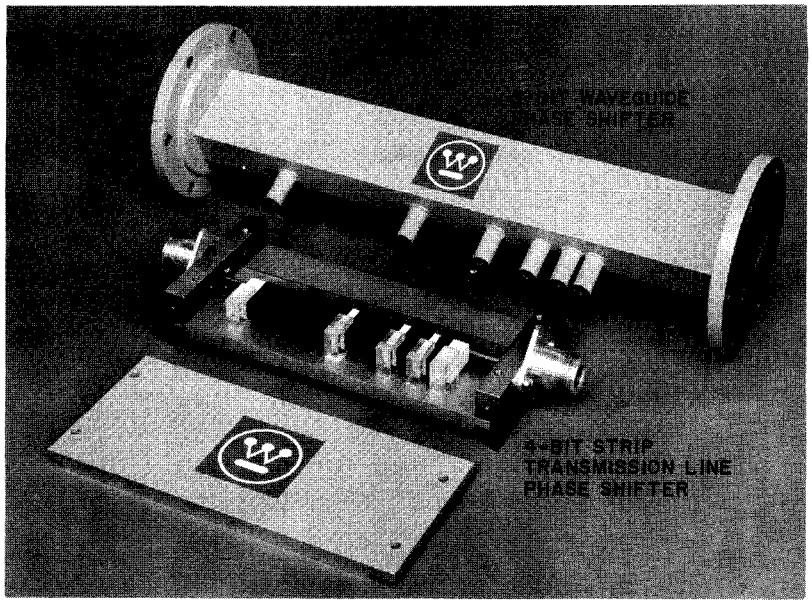


Figure 6. Five-Bit Waveguide and Four-Bit Strip Transmission Line Phase Shifters

Finally, it is pointed out that even though the new phase shifter offers many desirable features, additional optimization can result in wider bandwidth and further compactness. The possibility of using a single toroid with current controlled latching is indicated (Reference 4).

REFERENCES

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4. Whicker, L. R. and Jones, R. R., "A Digital Current Controlled Latching Ferrite Phase Shifter," submitted for presentation at the 1965 IEEE International Convention.