IX-3. A SLOW WAVE DIGITAL FERRITE STRIP TRANSMISSION LINE PHASE SHIFTER

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During the past several years, microwave device development has been oriented toward the generation of compact, lightweight, rapid switching components. Devices which utilize toroidal or closed loop ferrimagnetic structures have proven invaluable in numerous phased array applications. However, such devices usually lack the compact size and lightweight characteristics desired.[1,2,3]

This paper is concerned with the development of a non-reciprocal, slow wave, digital phase shifter which combines the rapid switching speeds offered by latching devices and miniaturizing features of a slow wave strip transmission line structure. The slow-wave phase shifter described is smaller and more compact than conventional strip transmission line phase shifters. The diminuitive size (2 x 1 x 0.25 in., excluding connectors) along with low switching energy (less than 100 microjoules per 180° bit) and the sub-microsecond switching speeds make this device attractive for phased array applications. As a result of the nature of its construction, the device is restricted to low power applications.

It has been shown that the rf magnetic field components in the vicinity of various TEM slow wave circuits, and in particular the slow wave structure used in this device, are elliptically polarized.[4] The principle of operation of the new slow wave phase shifter is analagous to that of a twin slab waveguide non-reciprocal phase shifter.

The phase shifter design employs a slow-wave or tape structure, designed in this paper as a meander line* (see Fig. 1). The meander line is etched, using printed circuit techniques, on both sides of an 0.018-inch copperclad teflon slab and inserted into the bore of a ferrimagnetic toroid. The toroid is then placed between two copper ground planes as depicted in Fig. 2. This device has exhibited between 145° and 170° per inch of differential phase shift over a 5.0 to 5.4 GHz frequency range. The phase deviation for the slow wave phase shifter is ± 10% over this 8% band. (See Fig. 3.)

Impedance matching of the ferrite loaded slow wave line to a 50-ohm strip transmission line is accomplished with quarter wave transformers. Frequency-swept VSWR measurements for a single bit element reveal less than 1.5 : 1 over 5.0 to 5.7 GHz. (See Fig. 4.) Insertion loss values of 2.0 dB or less for a 180° bit have been recorded. The VSWR and insertion loss obtained to date, are not representative of an optimized device.

* The term "meander line" is used in a broad sense, i.e., because it resembles the meander line which is commonly used in TWT and filter applications.

It is possible to reduce the phase shift frequency dependence of this device by altering the dispersion associated with the ferrite slow wave structure. In particular, the adjustment of such parameters as tape line width, the line separation, and the ground line spacing, should effect a minimum frequency dependence. Techniques for reducing the insertion loss, such as changes in slow wave line geometry, are enumerated.

The proposed design may be extended to include multiple bit or element devices. A typical configuration which offers considerable promise is sketched in Fig. 5.

Possible applications include phased array antenna systems in which stacking and assembly space is extremely limited, or other microwave systems in which compact form factor is required.

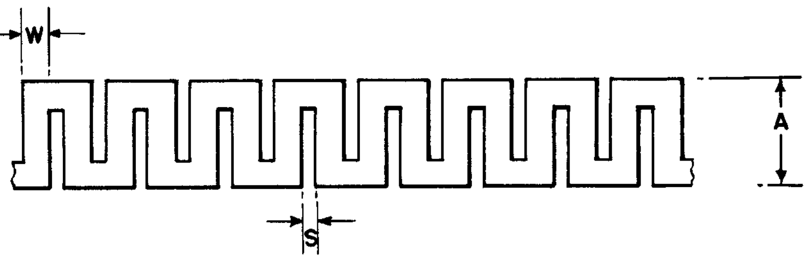

Figure 1. Meander Line Section

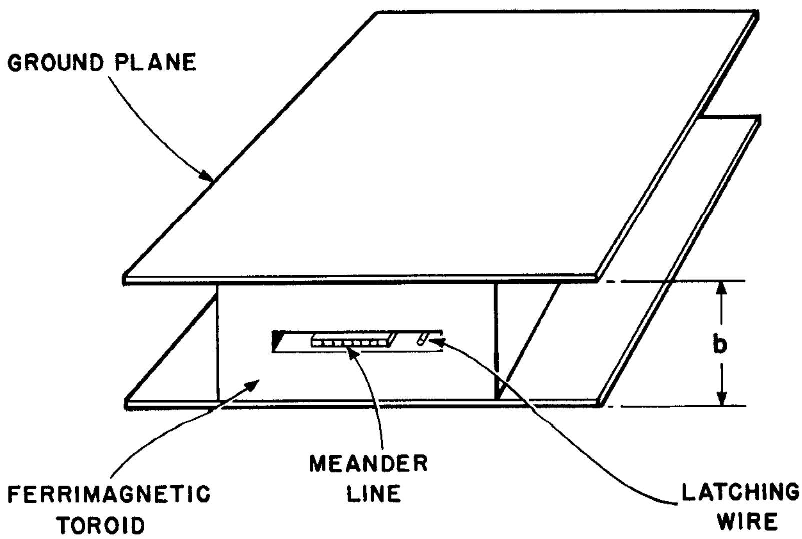

Figure 2. Non-Reciprocal "Slow Wave" Element

References.

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2. D. R. Taft, "Development of a Digital Phase Shifter Using Square Loop Garnet Materials," presented at 1964 Magnetism and Magnetic Materials Conference, November 1964.
3. L. R. Whicker and R. R. Jones, "A Digital Latching Ferrite Phase Shifter," IEEE Trans. MTT-13, pp 781-784; November 1965.
4. J. C. Cromack, "A Wide-Tuning Range S-Band Travelling-Wave Maser," Technical Report #155-5, Contract DA-36-039-SC-90839, Stanford Electronic Labs, April 1963.

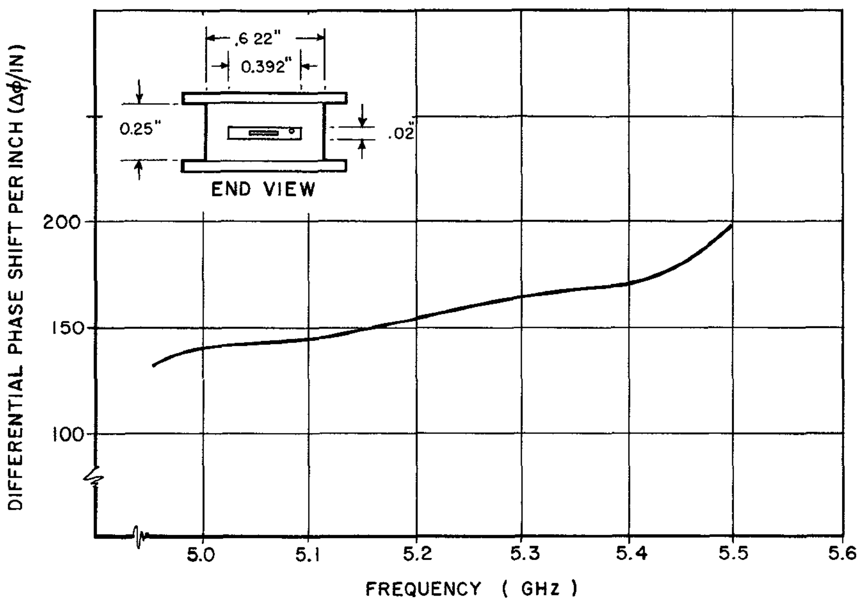

Figure 3. Differential Phase Shift per Inch vs. Frequency For Slow Wave Phase Shifter

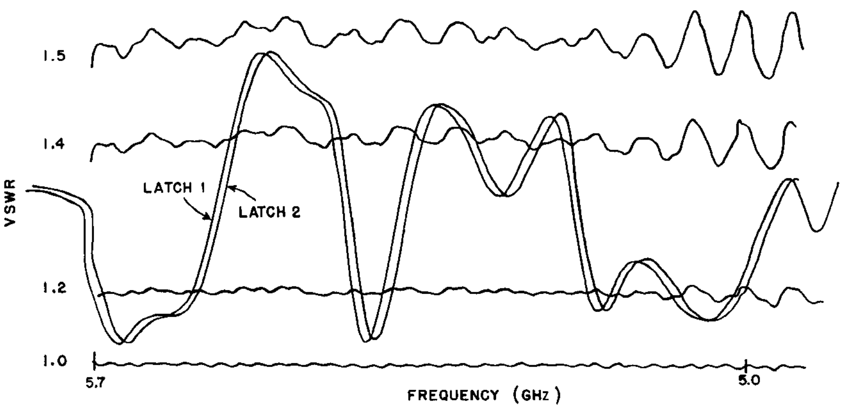

Figure 4. VSWR vs. Frequency for Ferrite Loaded Line

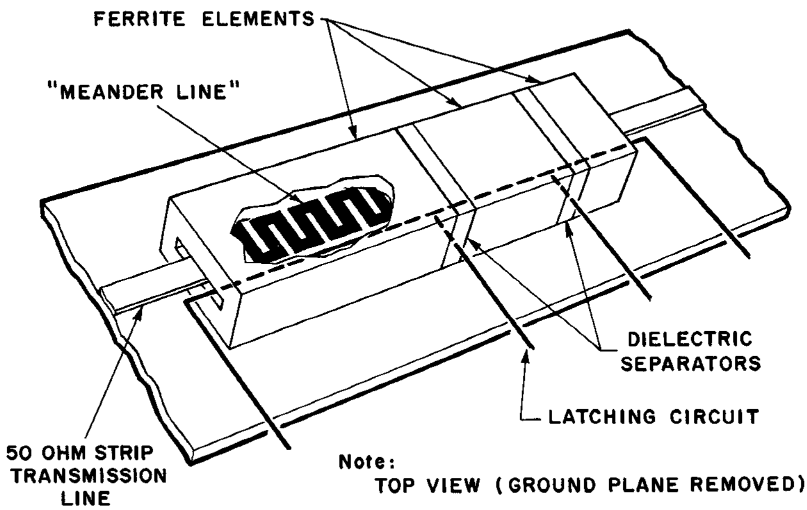

Figure 5. Typical Multi-Bit Phase Shifter Design