V-6 ALL GARNET MICROSTRIP CIRCULATORS FOR INTEGRATED CIRCUITS

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In a recent report[1] by the author results were presented for an X-band 3-port microstrip* circulator. A YIG disc was embedded in a ceramic substrate and copper lines, disc, and ground plane were deposited on this composite substrate. Figure 1 is a photograph of a typical microstrip circulator. Unfortunately, cementing a YIG disc into a ceramic substrate is not an ideal approach to integrated microwave circuits. Ideally, an all garnet substrate would be more practical by combining simplicity of design with ease of fabrication. This paper reports the results obtained with all garnet substrate 3-port microstrip circulators. Results are reported using an electromagnet and a small permanent magnet. In addition, a latched version of a microstrip circulator was built and successfully tested. The latched version lends itself to simple mass production techniques.

Copper transmission lines, disc, and ground plane were evaporated onto a garnet substrate after a chrome flash. Figure 2 is a photograph of a Trans-Tech G-1200 substrate. This substrate is mounted in a holder identical with that of Fig. 1 for testing purposes. The garnet material and copper disc diameter are important parameters in determining the frequency band of operation. Circulator action is possible because the microwave energy is concentrated in the neighborhood of the copper disc and ground plane. Figures 3 and 4 show graphically the data obtained on two such substrates, with a copper disc diameter of 0.23" and transmission line widths of 0.027" and 0.025" respectively. The data of Fig. 3 was obtained with an electromagnet while that of Fig. 4 was obtained with a small Indox VI permanent magnet, 0.15" high, 0.3" diameter, and located near the ground plane of the substrate. In Fig. 4 data was not taken below 7.6 GHz because of instrumentation limitations. In both figures the insertion loss is slightly greater than the circulators fabricated in ceramic substrates. However, the bandwidth defined for isolation greater than 20 dB, is significantly larger.

Following these studies which established the usefulness of magnetic insulating substrates, a feasibility test of a latched microstrip circulator was carried out. Figure 5 is a photograph of the latched device. The two pictures on the left-hand side of Fig. 5 portray both halves of the circulator while the picture on the far right is the assembled result. The white annulus visible in the photograph is a dielectric ring of magnesium titanate, 0.025" thick. It has been used for convenience only and is not strictly necessary. An air gap would have served as well. This dielectric material matches the dielectric constant of the garnet, Trans-Tech G-1600, circulator. The garnet inside the dielectric annulus is 0.22" in diameter and 0.25" thick. The overall height of the entire latched circulator is 0.135". In this crude fashion preliminary latching results were obtained. These results are shown in Fig. 6. The insertion loss is rather high for two reasons. First, the evaporated copper transmission lines and disc did not adhere to the surface of the garnet because of contamination in the initial chrome flash.

Consequently, it was necessary to glue the copper lines and disc with Duco cement. In previous work with YIG discs cemented into ceramic substrates such gluing techniques were used at times and the insertion loss was two to ten times higher than that obtained with good adhering evaporated lines. Second, this thicker microstrip circulator has a higher impedance. Consequently, higher impedance transmission lines are necessary. Such high impedance, or narrower width lines, were not used because there were no evaporation masks available. Masks are being prepared now and the latched circulators will be retested shortly with the new transmission lines. The insertion loss should drop significantly with proper line width and well bonded copper evaporations.

Fabrication of the above latched circulator in one piece is possible using the same techniques that are employed in fabricating laminated ferrite memory sheets. Fabrication is simple and inexpensive and the latching wire is automatically embedded in place. All that remains is the evaporation of the copper lines, disc, and ground plane. This laminated approach will be tested very shortly. Elimination of the two separate pieces for the latched device should provide an improved closed flux path and remove any possibility of microwave loss arising from the crack between the two pieces.

These preliminary results using garnet substrates suggests another area of investigation for integrated microwave circuits. Recent work at RCA Laboratories on ferromagnetic insulators (chalcogenides)[2] have shown that these materials can be locally doped to yield semiconductor magnetic materials with high mobilities. It may be possible to prepare substrates of these materials, dope them locally to provide active devices such as amplifiers and oscillators, and use the undoped portion of the substrate for passive nonreciprocal (and reciprocal) devices such as nonreciprocal phaseshifters[3] and circulators. Operation either latched or with a permanent magnet is feasible. Present advances in both materials and devices make the prospect of microwave systems on magnetic substrates a distinct possibility.

References

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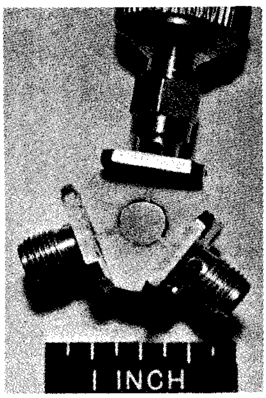

FIG. 1 - Photograph of X-Band Microstrip Circulator (YIG disc cemented into ceramic substrate)

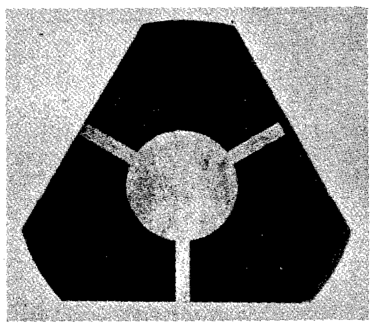

FIG. 2 - Photograph of a Garnet Substrate Microstrip Circulator

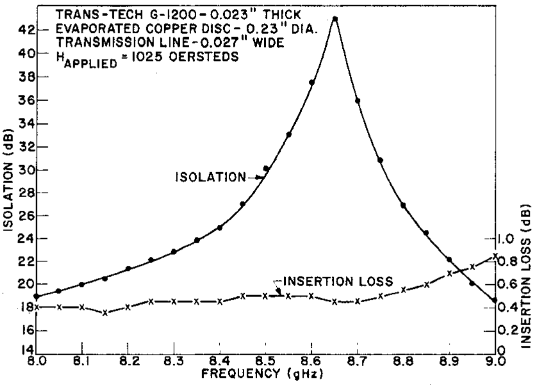

FIG. 3 - Garnet Substrate Microstrip Circulator Characteristics (electromagnet)

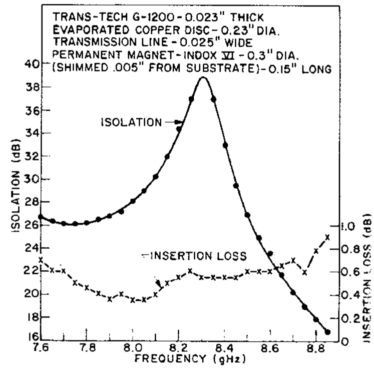

FIG. 4 - Garnet Substrate Microstrip Circulator Characteristics (permanent magnet)

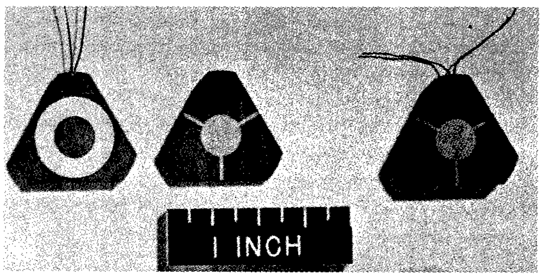

FIG. 5 - Photograph of a Latched Microstrip Circulator (right side of a photograph is assembled circulator)

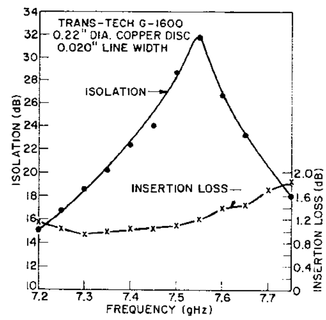

FIG. 6 - Characteristics of a Latched Garnet Microstrip Circulator