V-2. BROADBAND STRIP TRANSMISSION LINE UHF CIRCULATORS*

J. W. Simon

Sperry Microwave Electronics Company, Clearwater, Florida

The recent need for compact nonreciprocal devices in the UHF region has focused much attention on the three-port junction circulator. This device when polarized above the resonant magnetic field, can be constructed into a compact configuration capable of an electrical performance and size advantage heretofore unattainable with ferrite isolators, duplexers, etc

A method for the design of this device was developed utilizing the recent theoretical advances and extensive experimental work. These designs are applicable for circulators having bandwidths of 1 to 40 percent. Designs are described for use in the 200 to 300, 300 to 400, 400 to 600 and 600 to 800 mc regions. Curves are provided which allow frequency scaling to be employed for centering the operating band at any convenient point between 200 to 800 mc. Typical operating characteristics for 40 percent bandwidth circulators are 17 db isolation, 1.0 db insertion loss and a maximum VSWR of 1.40.

The basic approach used in developing these circulators was based on the fact that the bandwidth can be extended by impedance matching the ferrite loaded junction to the characteristics impedance of the transmission line (Reference 1). By plotting (on a Smith Chart) the input impedance of the circulator, it is possible to determine the bandwidth and to ascertain what improvements are derived when the junction parameters are experimentally adjusted. In this way useful experiments can be conducted to study the effects of various parameters such as magnetic field, $4\pi M_s$, linewidth and transmission line geometry.

In general, the type of impedance characteristics desired is one which is relatively constant with frequency (a small group of points when plotted on a Smith Chart) and as near the line impedance as possible. This type of response can be matched using simple elements such as impedance transformers, lumped reactances, etc.

Tests were performed in the manner specified above in the frequency bands 200 to 800 mc In general, the following trends were found to exist:

1 In attempting to group the impedance characteristics of the above resonance circulator, little if any, benefit was derived for a variation of $4\pi M_s$ over a particular range of values. This is in contrast to results reported on below resonance circulators (Reference 1) where the magnetization of the material used was found to be of great importance.

2 Of the materials tested, the tightest grouped impedance characteristics were obtained using materials with narrow linewidths and biased as near resonance as loss permits.

3 The geometry of the ferrite material appeared to have little effect on the shape of the impedance characteristics. This was also found to be the case in below resonance circulators (Reference 1).

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4 In obtaining a tight grouping of the impedance characteristics, considerable assistance was derived by optimizing the center conductor geometries. The optimum geometry appears to be a simple round center disc joined by three legs.

5 When using a center conductor geometry, as shown in Figure 1, the optimum ratio of ferrite radius, R_f, to center conductor radius, R_c, appears to be between 1.75 and 1.85. It was found that for this ratio, no external matching was required in general.

6 It is possible to scale a design in the UHF region if the material, ground-plane-spacing, strip-width, strip-thickness and R_f/R_c ratio are held constant while the disc diameter and magnetic field are the adjustable factors.

Taking these factors into account, a standard design was arrived at which was used as a basis for the UHF bands. The material selected for this design was a yttrium iron garnet. The geometry of this material and the microwave structure are illustrated in Figure 2. In Figure 3, is shown a curve depicting the relation between diameter and frequency for these designs. Data representative of these designs are shown in Figures 4 and 5.

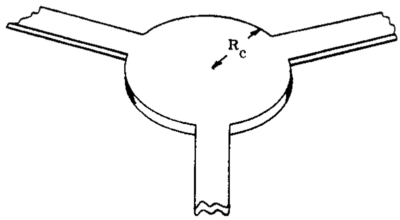

Figure 1. Center Conductor with Shielding Disc

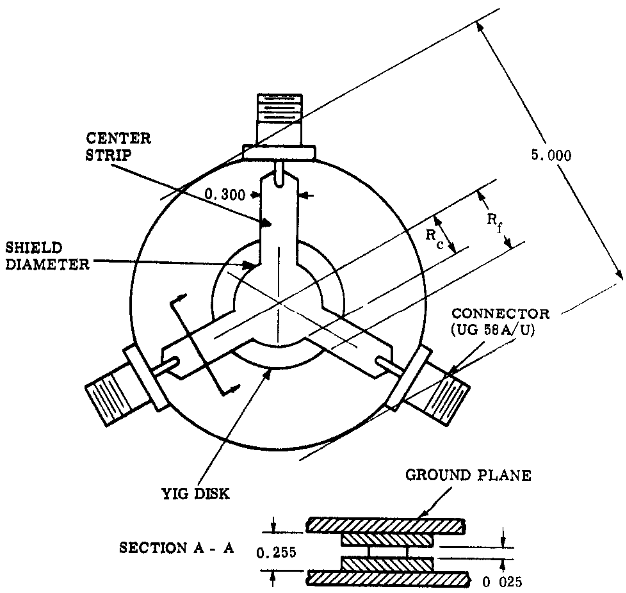

Figure 2. Strip Transmission Line Circulator Housing and Ferrite Configuration

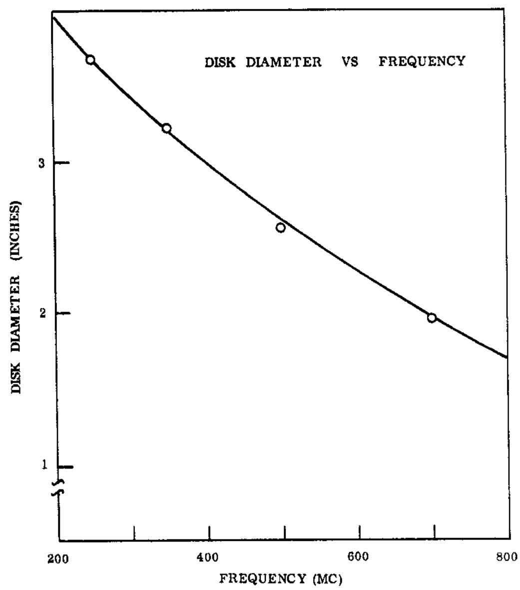

Figure 3. YIG Disc Diameter versus Frequency

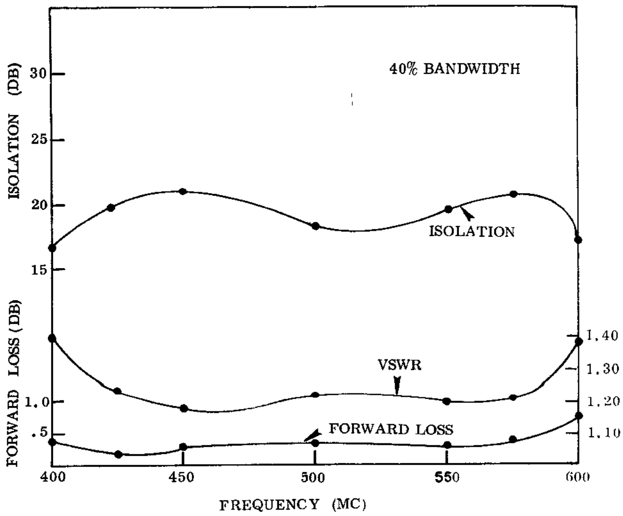

Figure 4. Typical Operating Characteristics of a 400 to 600 mc Circulator

A very simple method was arrived at to temperature stabilize these designs. It was found that the temperature characteristics could be considerably improved if the ratio of the saturation magnetization and the applied field ($4\pi M_s/H_a$) was held approximately constant for all temperatures. This was achieved by using barium ferrite magnets which have a magnetization versus temperature characteristic similar to that of the yttrium iron garnet. Figure 6 illustrates the operation of a temperature stabilized unit employing this technique.

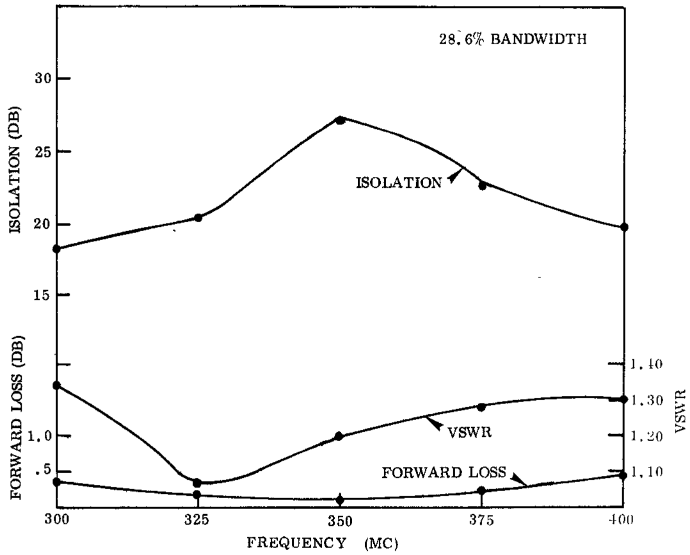

Figure 5. Typical Operating Characteristics of a 300 to 400 mc Circulator

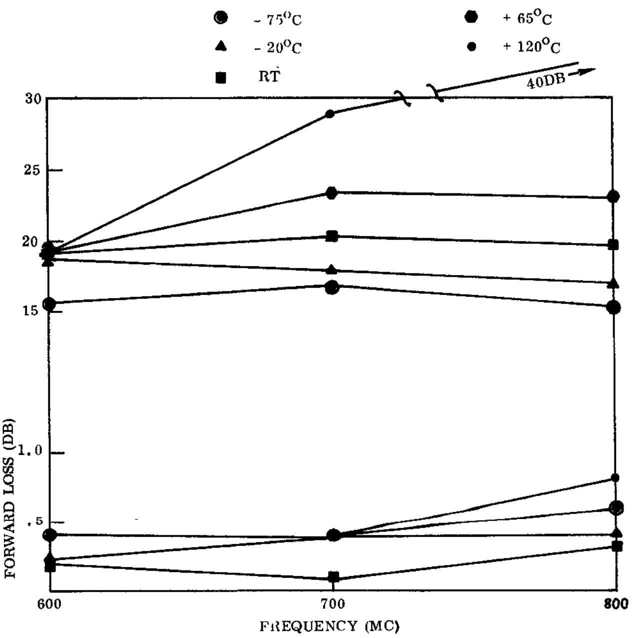

Figure 6. Temperature Characteristics of the 600 to 800 mc Circulator