the octave range $60° < \theta < 120°$ are shown in Table I.

TABLE I

	Theoretical	Experimental
Isolation	>22 db	>18 db
Input Match	<1.5:1	<1.4:1

The performance figures observed from the four possible input terminals are similar over this frequency range.

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[1] General Electric Co. and E. M. Hicken, British Patent Application no. 20725/54.
[2] Mullard Ltd., S. J. Robinson, and N. E. Goddard, British Patent Application no. 770317.
[3] A. B. McNaughton, "A new broad-band coaxial hybrid ring," *Proc of the Internatl. Congress on Ultra High Frequency Circuits and Antennas*, Paris, France; October, 1957.

Lightweight Y-Junction Strip-Line Circulator*

In a recent issue, the practical realization of a Y-junction strip-line circulator was described[1] which used disks of yttrium iron garnet located at the junction of the Y, magnetically biased above resonance at approximately 2200 gauss. By using a material with a lower saturation magnetization (magnesium, manganese, aluminum ferrite, $4\pi M$, $=600$) we have reduced the bias field required to approximately 190 gauss for frequencies in the 2-kMc range and to approximately 800° gauss for frequencies in the 1-kMc range, thus reducing considerably the weight of the circulator. If the circulator is to be operated as a switch, the reduced field requirements permit faster switching times or, for a given switching time, a considerable reduction in power supply requirements.

Fig. 1 shows the results of a circulator operating at a fixed magnetic bias of 190 gauss. Although no attempt was made to determine the optimum ferrite diameter for this frequency range, it is felt that the performance of the circulator would be improved if a more optimum diameter were used.

Below 1400 Mc, the performance of the circulator was degraded at these low biasing fields, but by reversing the polarity of the magnetic field and biasing above resonance, good circulator action could again be obtained. Reversing the biasing field and biasing above resonance does not change the direction of circulation, as may be seen by referring to the equation below given by
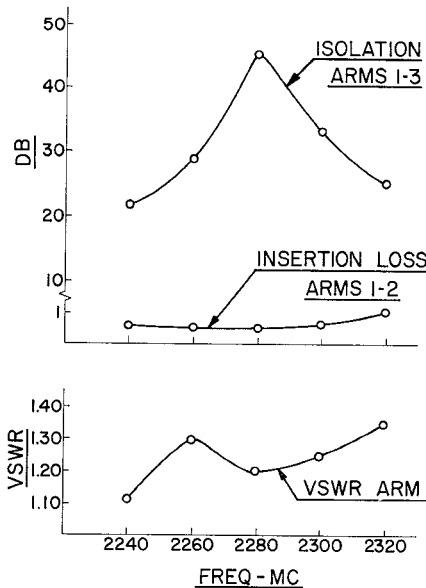
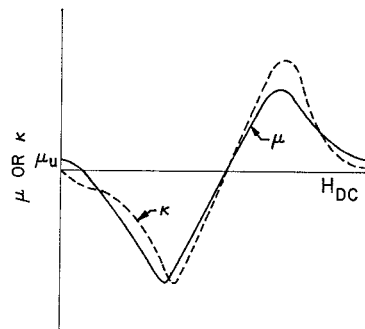Fig. 1—Circulator characteristics with fixed dc magnetic bias; $H_{DC} = 190$ gauss.

Fig. 2—Typical variations of real components of tensor permeability as a function of dc magnetic field.
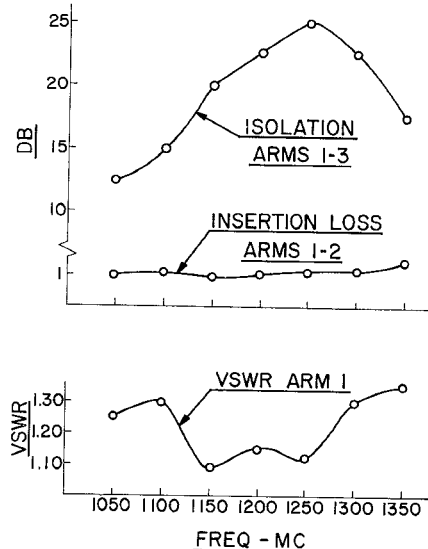

Fig. 3—Circulator characteristics with fixed dc magnetic bias; $H_{DC} = 820$ gauss.

Auld[2] for the change in the ath eigenvalue (δs_a) of the scattering matrix of the symmetrical Y-junction due to the application of the magnetic biasing field. The magnetic biasing field splits the reciprocity degeneracy of the eigenvalues to give circulator action:

$$\delta s_a = -j \frac{b}{2\omega\mu_u^2} \sum_{p=-\infty}^{\infty} A_{-p}^{(-a)} A_p^{(a)}$$

$$\cdot \left\{ (\mu - \mu_u) \int_0^R f_{-p}^{(-a)} \cdot f_p^{(a)} r dr \right.$$

$$\left. + j\kappa \int_0^R k \cdot f_{-p}^{(-a)} \times f_p^{(a)} r dr \right\} a \neq 0$$

where μ and κ are the components of the peameability tensor and the other symbols are as defined by Auld.[2]

A typical variation of μ and κ as a function of magnetic field is shown in Fig. 2. The magnetic biasing field is adjusted to make $\mu - \mu_u = 0$ either above or below resonance. Since κ reverses sign above resonance, there is a reversal in the direction of circulation, but by reversing the biasing field, the direction of circulation remains the same. Fig. 3 shows the characteristics of a circulator biased above resonance but still only requiring a magnetic field of 820 gauss. Here again it is felt that the performance would be improved if ferrites of optimum diameter were used. Thus by using a material with a lower saturation magnetization than yttrium iron garnet, bias field requirements are reduced with a consequent reduction in weight of the circulator.

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A Novel Broad-Band Balun*

Broad-band baluns have recently become the subject of renewed interest, particularly those suitable to couple spiral or planar log periodic antennas to the commonly used coaxial lines.[1-3]

To make such a balun capable of operating over the frequency band of 1000–4000 Mc and to take advantage of the strip transmission line techniques, the broad-band