

## Effects of Ferrite Strip Mounting Positions on Millimeter Wave Isolator Characteristics\*

The position of the ferrite strip in a field displacement type isolator is an important problem. If  $x$  and  $L$  are defined as the mounting position of the ferrite strip and the width of the rectangular waveguide, respectively, as shown in Fig. 1, then, according to Soohoo,<sup>1</sup> Lax,<sup>2</sup> Fox, *et al.*,<sup>3</sup> and Button,<sup>4</sup> the optimum value of  $x$  ranges from  $0.095L$  to  $0.27L$ . The sign of the directivity (backward to forward ratio of attenuation) for very thin ferrite strip is the same if  $x < L/2$ .

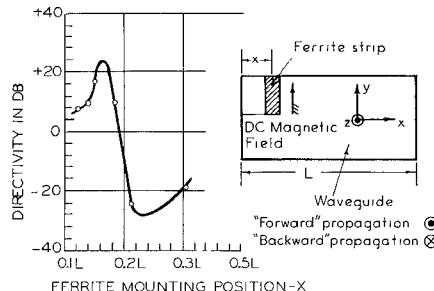


Fig. 1—Directivity and mounting position of ferrite strip.

The ferrite strip which the authors investigated was mounted on a polystyrene strip and was placed in RG-98/U waveguide as shown in Fig. 1. No attenuator film was coated on the ferrite strip in this case. The dimensions of the ferrite strip were 0.0117 inch  $\times$  0.0325 inch  $\times$  0.133 inch. The ferrite strip, made from a single crystal type sample LRR-1<sup>5</sup> (BaFe<sub>12</sub>O<sub>19</sub>, anisotropy field 18.4 koe, apparent density 5.13 g/cm<sup>3</sup>) was magnetized in the direction of easy magnetization. External dc magnetic field was applied in this direction as shown in Fig. 1, and the isolator was tested at frequency of 58.3 kMc.

The optimum position of the ferrite strip in this case was  $x = 0.16L$ , which agreed with the results reported in the literature, but different results were obtained for directivity. The sign of directivity changed at  $x = 0.19L$ . This is considerably smaller than  $x = L/2$  reported in the literature. The experimental results obtained are shown in Fig. 1. The optimum values of backward to forward ratio of attenuation are plotted against the mounting position  $x$ . The results can be interpreted as a selective resonance of the ferrite structure against coun-

bined spatial harmonics as indicated by an arbitrary scale in Fig. 2.

When the applied dc magnetic flux density was changed, many peaks appeared in the attenuation curve as shown in Fig. 3. Several examples near the transition region of the directivities are shown in the figure. For each position of the ferrite strip, almost the same numbers of peaks were detected for backward attenuation. All the peaks were found at approximately the same magnetic flux density, even though the heights of the peaks were different. It can be considered that the peaks are due to complicated selective structural resonance of ferrite and spatial harmonics. In a certain mounting position, some peaks were ac-

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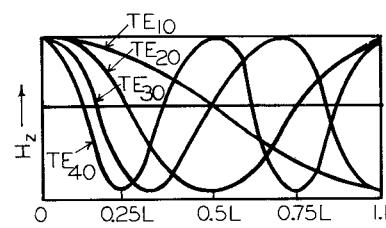
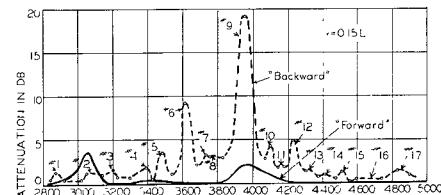
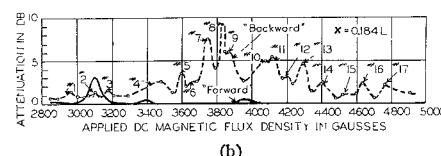


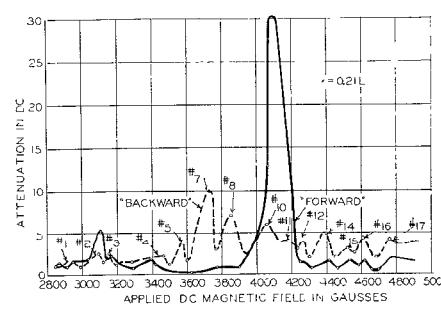
Fig. 2—Spatial harmonics in ferrite-loaded waveguide (arbitrary scale).



(a)



(b)



(c)

Fig. 3—Magnetic resonance characteristics.

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<sup>1</sup> R. F. Soohoo, "Theory and Application of Ferrites," Prentice-Hall, Inc., Englewood Cliffs, N. J.; 1960.

<sup>2</sup> B. Lax, "Frequency and loss characteristics of microwave ferrite devices," PROC. IRE, vol. 44, pp. 1368-1386; October, 1956.

<sup>3</sup> A. G. Fox, S. E. Miller and M. T. Weiss, "Behavior and applications of ferrites in the microwave region," Bell Sys. Tech. J., vol. 34, pp. 5-103; January, 1955.

<sup>4</sup> K. J. Button, "Theoretical analysis of the operation of the field displacement ferrite isolator," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 303-308; July, 1958.

<sup>5</sup> Supplied by A. O. Smith Corp.

centuated and others were reduced. The sign of directivity corresponding to peak No. 2 did not change over the range of  $x = 0.109L$  to  $0.303L$ . It is thought that this is due to the local resonance with the  $TE_{10}$  mode. It is interesting to note that at the position where the directivity vanishes, most of the forward attenuation peaks are reduced as shown in Fig. 3(b).

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## An L-Band Loop-Type Coupler\*

The design of loop couplers for various loop length has been reported by Lombardini, Schwartz and Kelly.<sup>1</sup> This device is useful for many applications as the over-all length can be held to about 6 inches, whereas a comparable multihole coupler must be on the order of several feet long. The loop-type device couples a  $TE_{10}$  waveguide mode from a RG-69/U to a TEM mode in a  $\frac{3}{8}$ -inch coaxial line. A comb-type coupler, for coupling a coaxial line to  $TE_{10}$  waveguide, was reported by Lombardini and Schwartz.<sup>2</sup> This device made use of a multiple-capacitive probe situated in a longitudinal slot in the top wall of the waveguide.

The scattering matrix of the four-port device of Fig. 1 is

$$S = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}. \quad (1)$$

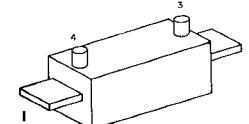


Fig. 1—A four-port device.

For matched ports, the principal diagonal elements of (1) will become zero:

$$S_{11} = S_{22} = S_{33} = S_{44} = 0.$$

The energy coupled to the loop will travel in the direction opposite to that of the incident energy, therefore,

$$S_{13} = S_{24} = S_{31} = S_{42} = 0.$$

For a lossless symmetrical network the uni-

\* Received by the PGMTT, April 11, 1961.

<sup>1</sup> P. P. Lombardini, R. F. Schwartz and P. J. Kelly, "Criteria for the design of loop-type directional couplers for the L band," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-4, pp. 234-239; October, 1956.

<sup>2</sup> P. P. Lombardini and R. F. Schwartz, "A new type of directional coupler for coupling coaxial line to  $TE_{10}$  waveguide," 1957 IRE WESCON CONVENTION RECORD, pt. 1, pp. 22-29.