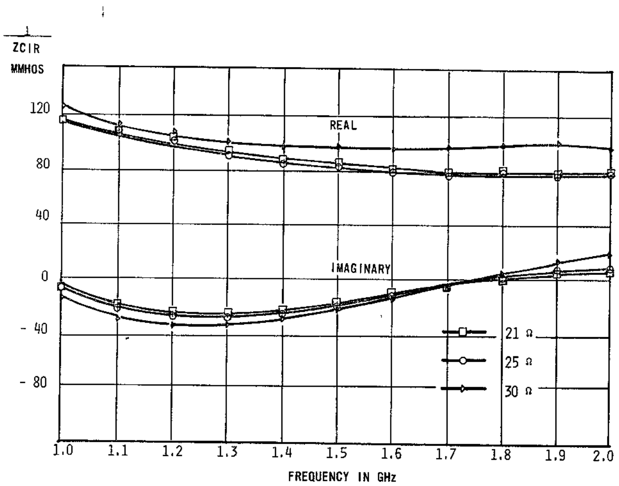

Fig. 3. Measured Z_{cir} for ferrite puck biased below resonance using different line couplings.

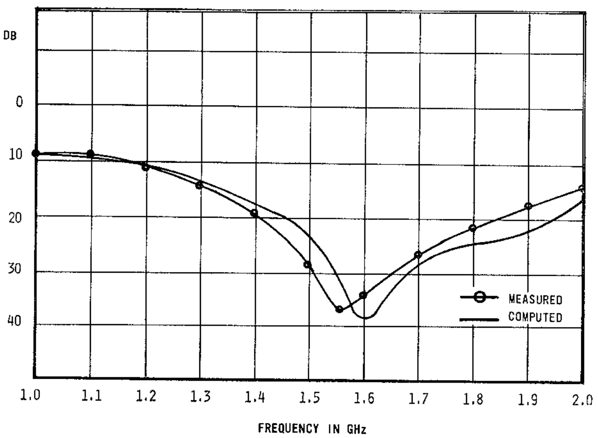

Fig. 4. Computed and measured isolation of stripline circulator.

Besides providing an accurate circulator synthesis technique, this procedure should give a means of more direct evaluation of theoretical boundary value solutions for junction circulators.

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A Compact Subsidiary-Resonance Limiter

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***Abstract*—A compact subsidiary-resonance limiter with a dynamic range of greater than 200 kW is described. The structure consists of a multilayer ferrite–dielectric "sandwich" placed on the narrow wall of a reduced-height reduced-width rectangular waveguide. Below-the-threshold insertion loss is less than 0.5 dB over the 5.4–5.9-GHz band, and the threshold level is about 20 W.**

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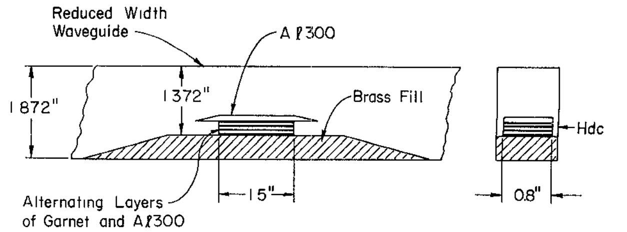

Fig. 1. Cross section of a multilayer limiter. The thicknesses of the layers, beginning with the garnet layer adjacent to the brass fill, are 0.030, 0.050, 0.030, 0.030, 0.070, 0.030, 0.030, and 0.125 in, respectively.

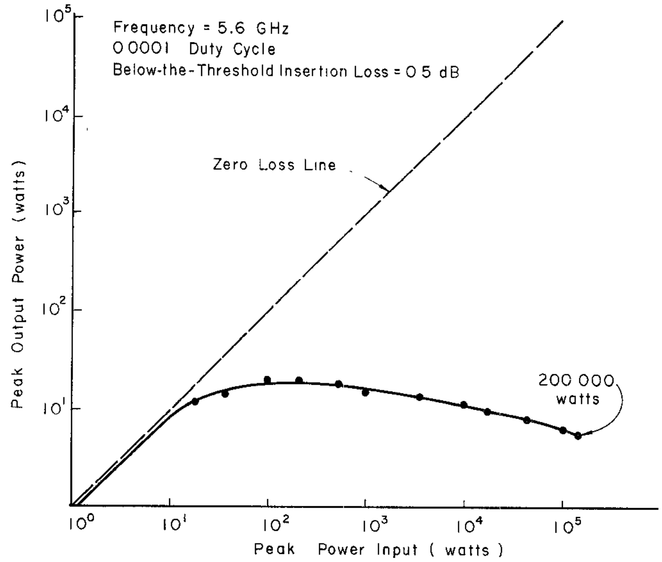

Fig. 2. High-power characteristics for the multilayer subsidiary-resonance limiter.

Subsidiary-resonance limiters have been studied extensively [1]–[4] for application in duplexing circuits. A recent paper by Carter *et al.* [5] describes a laminar limiter structure consisting of a cascade of rectangular rods of ferrite and dielectric along the narrow wall of a rectangular waveguide. The laminar structure has the distinct advantage that its threshold power level can be very low (2.8 W). The dynamic range of the laminar limiter is controlled by the number (and size) of the ferrite rods. Dynamic range of a conventional single-slab type of limiter is controlled by the length of the ferrite slab. In both cases obtaining wide dynamic range necessarily requires a relatively large structure with a long magnet. The purpose of this correspondence is to describe a multilayer loading technique that permits a wide dynamic range and a low threshold to be obtained with a physically small structure and a short magnet.

Cross-sectional views of a typical multilayer limiter structure are given in Fig. 1. This structure consists of four slabs of YIG interleaved with four slabs of Al-300 dielectric placed on the narrow wall of a reduced-height reduced-width rectangular waveguide. The ferrite and dielectric slabs are of various thicknesses selected experimentally to obtain maximum dynamic range. The ferrite slabs are only $1\frac{1}{2}$ in long. Thicknesses and other pertinent data are provided in the diagram. This multilayer limiter has a below-the-threshold insertion loss of less than 0.5 dB in the 5.4–5.9-GHz frequency band. The threshold power level is about 20 W and the dynamic range is greater than 200 kW. Characteristics of the limiter were essentially constant over the frequency range of the magnetron, 5.4–5.9 GHz. A plot of output versus input power is given in Fig. 2. Notice that the limit of the dynamic range has not been reached at a peak power input of 200 kW, which was the maximum power available from the magnetron. The finite excitation time of the nonlinear effect permits the leading edge of the input pulse to "leak through" essentially unattenuated. This is referred to as the spike leakage and its amplitude very nearly follows the zero loss line shown in Fig. 2. The width of the leakage spike

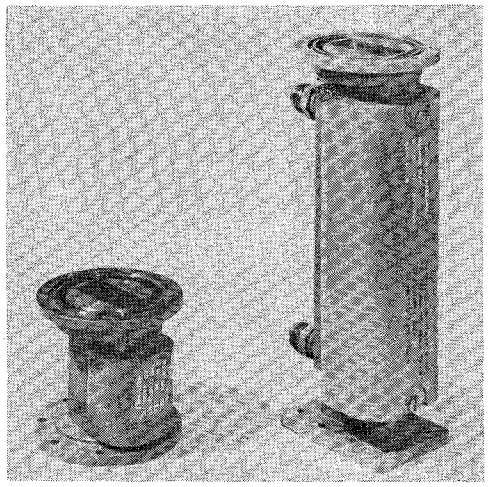

Fig. 3. Comparison of a multilayer limiter with a single-slab limiter of comparable dynamic range.

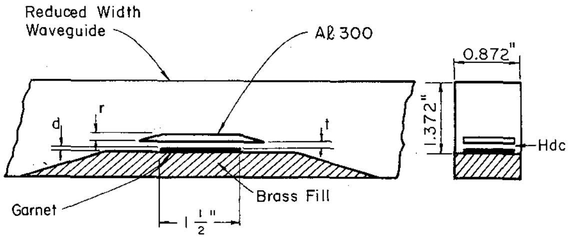

Fig. 4. Single-slab limiter.

was about 30 ns. A single-slab limiter with roughly the same peak power characteristic (40-W threshold, greater than 200-kW dynamic range) is compared with the multilayer limiter in Fig. 3. The length of the ferrite slab in the single-slab limiter is 7 in.

The multilayer limiter as described above is suitable for low average power operation. Higher average power capability can be achieved by using high thermal conductivity dielectrics, such as beryllium oxide or boron nitride, as the dielectric layers in the ferrite–dielectric "sandwich." Fins and liquid cooling channels may also be utilized to boost the average power capabilities.

For comparison with the multilayer configuration, the characteristics of the single-slab structure shown in Fig. 4 were measured for a large number of combinations of dielectric and ferrite thickness and interslab spacings. The length of the ferrite was the same as that in the multilayer structure. Some of the combinations had very low threshold levels (about 10 W) but none of the single-slab configurations exhibited a wide dynamic range. Best results were obtained with a YIG, Al-300 structure having $t=0.170$ in, $r=0.125$ in, and $d=0.40$ in. This combination had a threshold of 150 W and a dynamic range of 10 kW.

Although conclusive evidence is not available, the wide dynamic range of the multilayer structure is apparently obtained through control of the RF field intensity profile. The ferrite slabs nearest the center of the waveguide begin to limit for a lower input power level than those near the waveguide wall. As the input power is increased, the ferrite slabs nearest the waveguide axis reach a saturation value of limiting but the slabs further from the axis begin to limit maintaining the output power level approximately constant. This process continues until all slabs approach their saturation limiting value, at which time the output power begins to increase with additional increase in input power and the structure is considered to have reached the limits of its dynamic range. To maintain a constant output level the slab arrangement must be such that each additional slab begins to limit at just the right input power level to provide smooth transition.

In conclusion, a multilayer loading technique has been described for subsidiary-resonance limiters which permits a wide dynamic range and a low threshold power level to be obtained with a physically small structure and a short magnet.

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