V-5. A HIGH-POWER X-BAND LIMITER*

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The narrow ferrimagnetic linewidth exhibited by single crystal yttrium iron garnet forms the basis for several novel microwave devices. These may be divided into two main categories, namely, magnetically tunable filters and microwave limiters. Single crystal YIG spheres may be associated with additional microwave resonators to enhance one of these desired characteristics and to suppress the other.

In the present program, our task was to design a high-power X-band limiter with the following characteristics:

Center frequency:	9600 mc
Instantaneous bandwidth:	100 mc
Insertion loss:	0.5 ± 0.2 db for low level signals
Power handling capability:	50 kw peak; no catastrophic failure up to 250 kw peak
Power output:	Shall be sufficiently low so that a diode switch can provide the additional protection required in a typical radar system.

A three-resonator configuration was chosen. The configuration originally proposed by DeGrasse, in a stripline version, seemed the best starting point. The two outer cavities consist of conventional microwave resonators which are made a full wavelength long so that the YIG sphere may be placed at a convenient position of maximum r-f magnetic field. The two cavities are oriented at right angles to each other, with the YIG sphere located in a coupling hole; it thereby provides the required mutual coupling when it is biased to gyromagnetic resonance.

The bandwidth sets the desired value for the loaded Q of the outer resonators and the loaded Q of the middle YIG sphere resonator. Since the overall bandwidth is relatively wide, a rather large YIG sphere is required. Large spheres are notoriously susceptible to spurious mode excitation which results in serious distortion of the bandpass characteristic. The size of the YIG sphere may be reduced by designing the auxiliary cavities in reduced height waveguide. Both 0.100 by 0.900 inch and 0.150 by 0.900 inch cross-sectional dimensions were tried. For the smaller height, the insertion loss contributed by the outer resonators could no longer be considered negligible compared to the insertion loss contributed by the YIG spheres. The final version uses 0.150 by 0.900 inch cross-section resonators.

A second important consideration concerns the quality of the yttrium iron crystal available. The resonance linewidth of typical crystals used in this program is less than 0.25 oersted when measured at 5000 mc. This linewidth may be related to the unloaded Q of the YIG sphere and it assumes a

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value of approximately 6000. These measurements are based on a configuration where the sphere represents a slight perturbation of a microwave cavity, whereas in a limiter, a tightly coupled configuration is required. The effective Q of the YIG sphere is thereby reduced by a factor of 2. With a loaded Q of approximately 50 it contributes approximately 0.2 db insertion loss.

A narrow linewidth lithium ferrite sphere was substituted for the YIG sphere. It raised the overall device insertion loss to 3 db, in agreement with its relatively broader resonance linewidth.

The overall insertion loss, with a YIG sphere 0.090 inch diameter, is shown in Figure 1. It was 0.3 db at the band center, and 0.5 db at the edges of a 75 mc band.

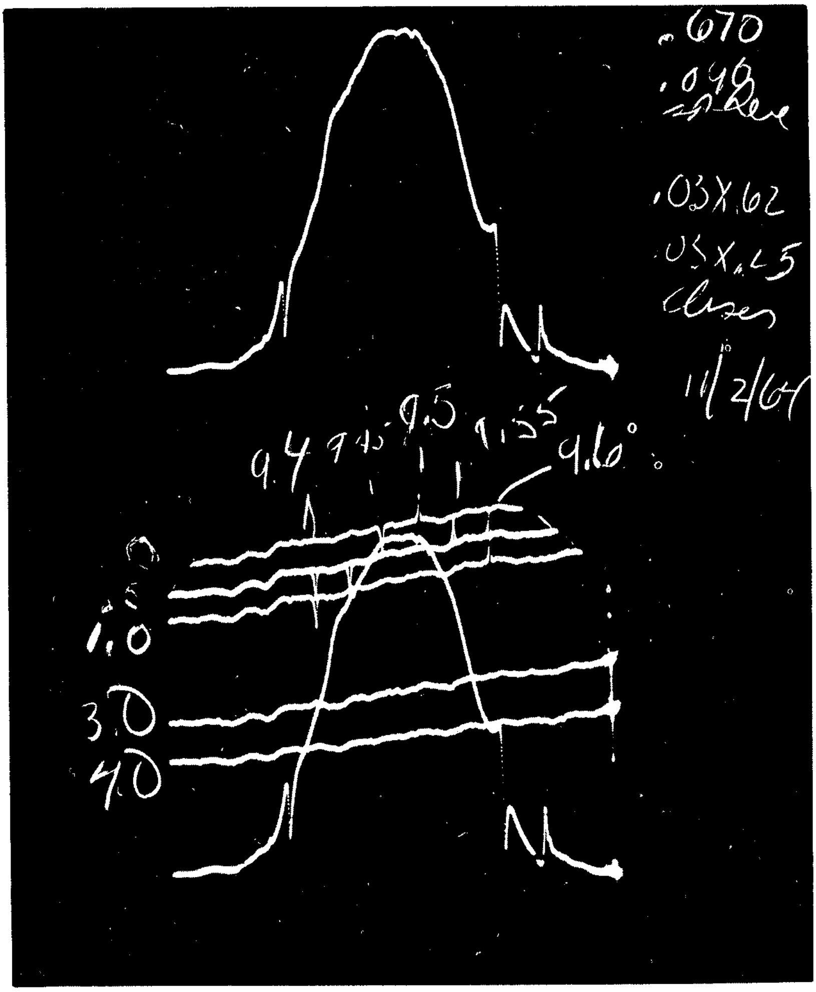

Figure 1.

The assembled device, including the biasing magnet, is shown in Figure 2.

Figure 3 shows a typical high power response curve. The lower trace represents a 50 kw peak pulse with one microsecond duration. The upper trace is taken under 100 times higher sensitivity. One may observe a short duration spike at the leading edge of the r-f pulse with flat leakage following during the r-f pulse interval.

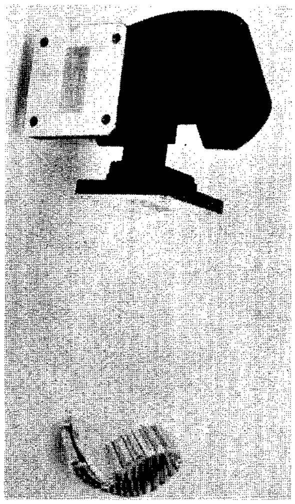

Figure 2.

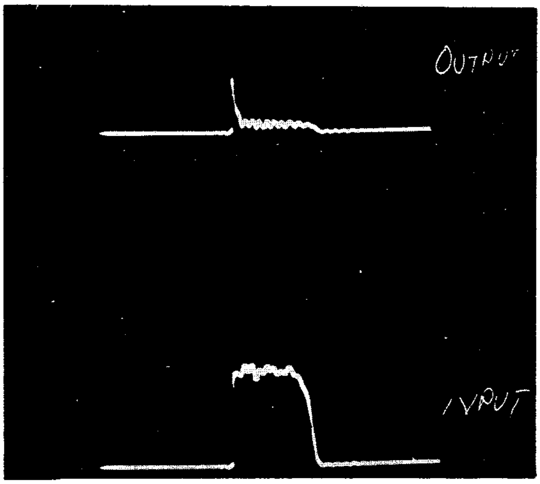

Figure 3.

Figure 4 shows a graph of output peak power versus input peak power. It may be seen that limiting occurs at approximately 50 watts peak. The slope of the output power curve is less than 2 db for a 30 db range of input power.

This device represents the first practical solid state replacement of conventional TR tubes. The leakage by the device has been reduced sufficiently to be handled by a semiconductor or switch to provide the total receiver protection required in a typical radar system.

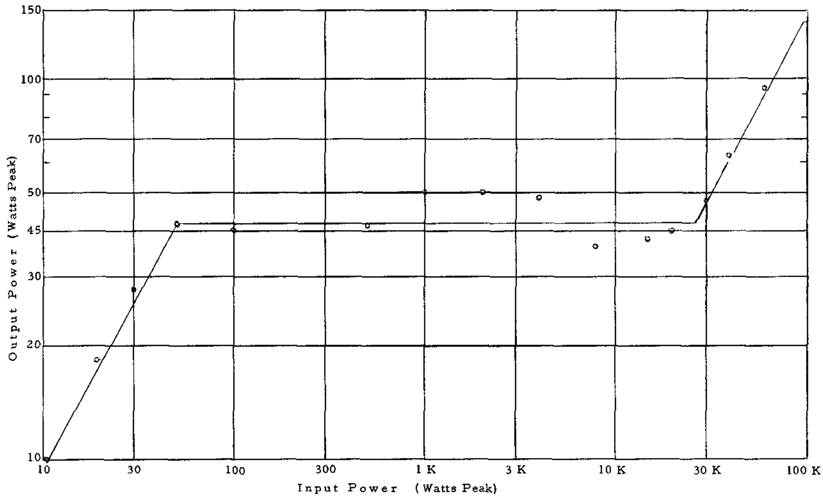

Figure 4. YIG Limiter Performance