V-4. ADVANCED FERRITE DUPLEXING-LIMITING TECHNIQUES*

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Recent advances in the field of high power ferrite devices have permitted the use of microwave duplexing techniques providing reliability and fail-safe protection previously impractical or impossible.

The objective of the work reported here was to develop a C-band, all solid state radar front-end utilizing high quality state-of-the-art ferrite devices, completely passive in nature, and serving as a (fail-safe) duplexer-limiter with the option of frequency preselection.

The basic arrangements of components are shown in the block diagram of Figure 1. The single junction four-port circulator performs the task of routing power from transmitter to antenna, and antenna to receiver. Power flow is always from any one port to one adjacent port with maximum isolation to the remaining two. The high power termination of the fourth port provides isolation for the transmitter, and prevents recirculation or "ringing" by absorbing energy reflected from the receiver.

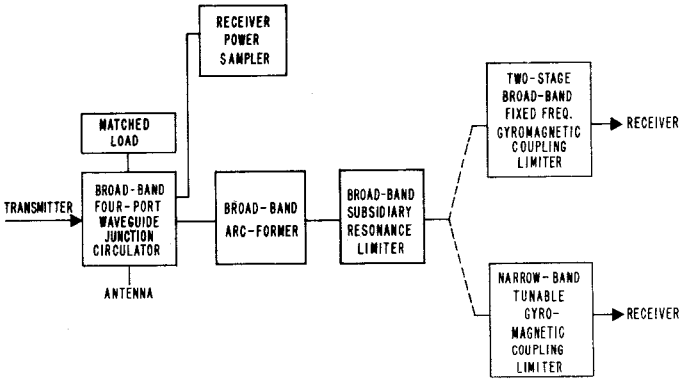

Figure 1. Block Diagram of Possible Duplexer Configurations

Microwave power entering the receiver port may originate from several sources: transmitter leakage power through the circulator, reflected power from a poorly matched antenna, or received power through the antenna. In all cases the received signal is limited to a maximum of 100 milliwatts by a broadband, three stage, cascaded limiter consisting of a subsidiary resonance limiter, a second-order gyromagnetic coupling limiter, and a first-order gyromagnetic coupling limiter. Figure 2 depicts the power threshold and dynamic range of the three units individually and collectively.

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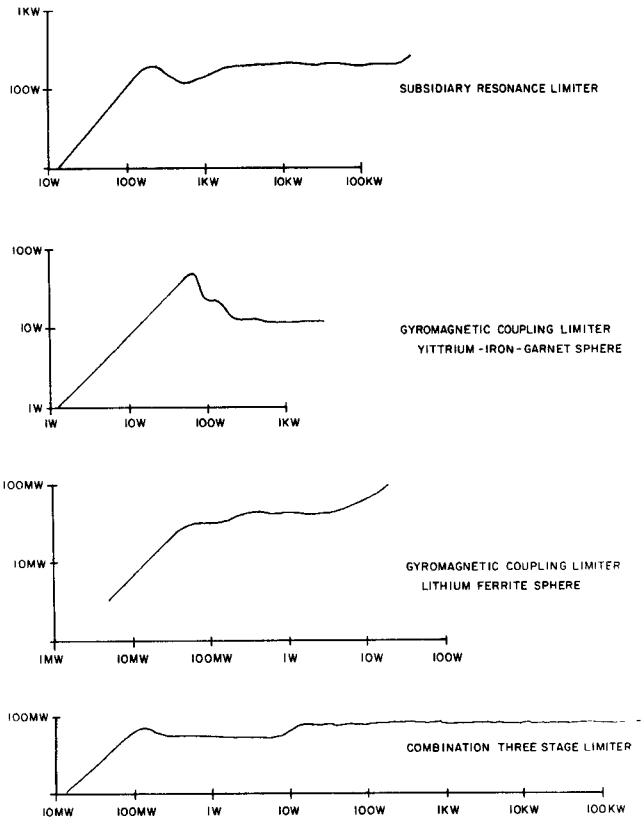

Figure 2. Limiting Characteristics of the Various Units Individually and Combined

The gyromagnetic coupling limiters consisting of high-Q resonators may be designed for broad-band, fixed tuned operation or as a narrow-band, electronically tunable limiter-preselector.

The reliability and protective characteristic of the duplexer is further enhanced by providing a power sampler which will turn off the transmitter when the power in this port exceeds 100 kw peak. An arc former consisting of a resonant window arc gap is also included to present a short circuit in the receiver line during the finite time required to turn off the transmitter.

The two components of major interest are the four-port circulator and broadband gyromagnetic coupling limiters. Discussion of these devices in more detail follows.

The single junction, four-port, waveguide circulator (as shown in Figure 3) takes the form of a co-planar, 90 degree, WR-187 waveguide junction with axially magnetized ferrimagnetic discs placed at the center of the junction. A cylindrical metal post extending between the garnet discs functions as a matching device. The discs are kept thin with large surface areas in good thermal contact with the waveguide walls for maximum dissipation of heat.

The previous papers of P. J. Allen, B. A. Auld, L. E. Davis and H. Bozma have contributed to the theory of the single junction four-port circulator. Their theoretical analysis and design approach has been investigated and is discussed in this paper.

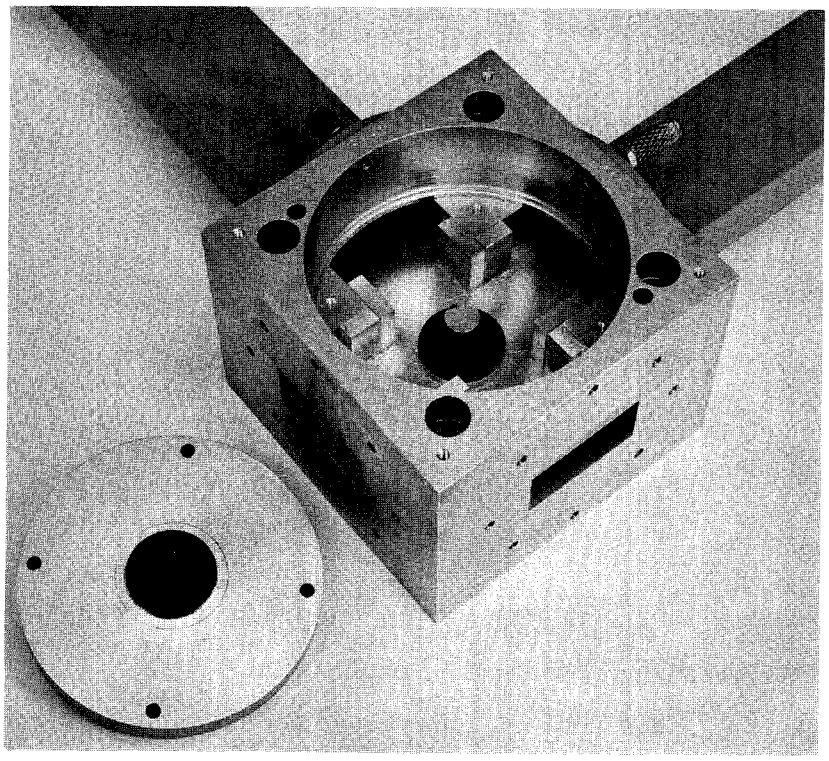

Figure 3. Four-Port, Single Junction Circulator with Broadband Matching

The electrical data for a single junction four-port circulator is shown in Figure 4. The unit has been successfully tested at 1 megawatt of peak power and 1.5 kilowatts of average power with 30 psi of pressurization.

Previous publications concerning gyromagnetic coupling limiters have reported a narrow-band response exhibiting a given limiting threshold and dynamic range dependent upon a single non-linear rf magnetization phenomena. This paper describes a dual sphere gyromagnetic coupling limiter with an instantaneous bandwidth of 10 percent that utilizes both the first and second order non-linear process to lower the limiting threshold and extend the dynamic limiting range.

As shown in Figure 5, the limiter is in the form of two co-planar cross-strip-line gyromagnetic couplers, the first of which utilizes a yttrium iron garnet sphere to provide second order limiting and the second a lithium ferrite sphere (to provide first order limiting). The different $4\pi M_s$ of the two materials permits the use of both limiting processes at C-band. The frequency response of the second order limiter is indicated in Figure 6.

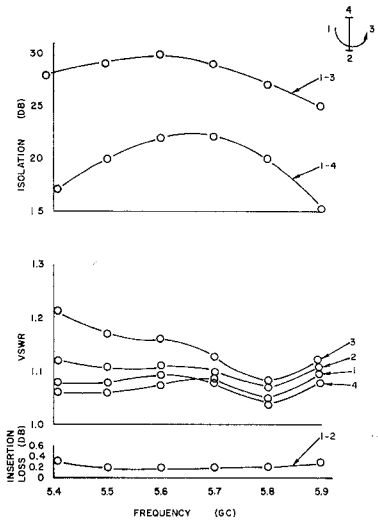

Figure 4. Electrical Data for the Four-Port, Single Junction Circulator

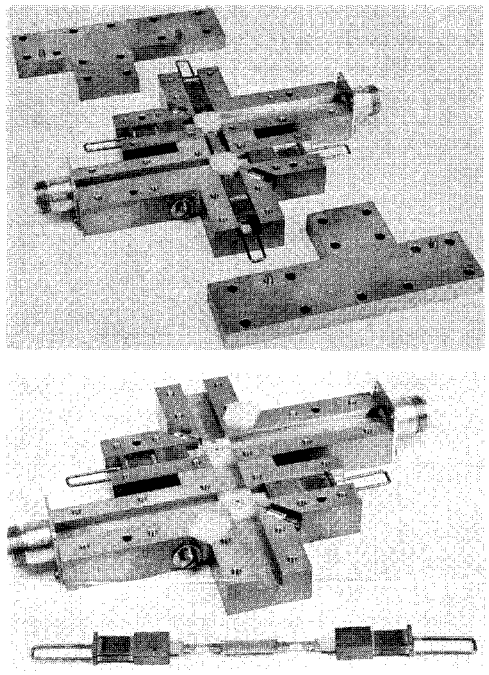

Figure 5. Broadband, Dual-Sphere Gyromagnetic Coupling Limiter

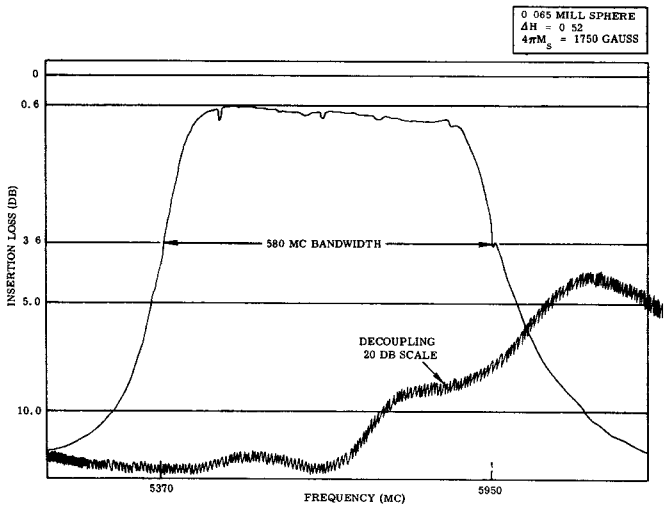

Figure 6. Bandpass and Loss Characteristics of the Second-Order Gyromagnetic Coupling Limiter

Combining the dual-sphere, low-level limiter with a subsidiary resonance limiter, such as described by J. Brown and J. Clark, and the four-port circulator provides an all solid state broadband duplexer-limiter with over 60 db dynamic range. Such a unit requires no support equipment, no tuning, no maintenance, and offers complete protection of the receiver.

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