III-6 A HIGH POWER, Y JUNCTION, E-PLANE CIRCULATOR

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The need for a small, lightweight, high-power circulator for duplexer operation at 9375 MHz has led to the development of a symmetrical E plane, Y junction circulator capable of handling in excess of 1/2 MW peak and 650W average power. This does not represent the ultimate, however, since equipment limitations allow tests only up to these powers. The circulator will perform adequately in the frequency range of 9.0 to 9.6 GHz. Figure 1 is a plot of insertion loss as a function of frequency at low power levels. A resonant absorption peak appeared in the frequency range; however, this peak can be moved from one frequency to another with only a slight field adjustment.

The circulator test model shown in Figure 2 was constructed in two sections with the cut along the plane of zero current with respect to the rectangular waveguide. This type of construction increases the power handling capabilities of the circulator as far as the E fields are concerned. A circular hole 0.890" in diameter with a length equal to the broad dimension of the waveguide (1.122") forms the junction of the three ports. The diameter was determined from the formula for the resonant frequency of a right circular cylinder operating at 9375 MHz with a fixed length of 1.122". The field patterns in the junction are believed to be similar to those obtained in a cavity of the same length and diameter. The purpose for constructing the circular hole at the junction was to eliminate breakdown that was occuring between the ferrite discs and the sharp corners, which are formed by the junction of three rectangular waveguide ports.

Ferrite discs are mounted at the center of the junction along the narrow wall of the waveguide. The biasing field is applied along the axis of the discs. Early high-power tests proved very discouraging since breakdown and destruction of the material occurred at power levels well below the desired level. It was determined that this trouble was caused by the mounting technique. Discs were mounted using cement, which burned at high power levels and in so doing presented voids between the ferrite disc and the circulator wall. This problem was overcome by using epoxy, which was capably of withstanding much higher temperatures. The epoxy used was EPON 822 with curing agent D, manufactured by Shell. Using epoxy presented the problem of removing the discs when the tests were concluded. This was solved by constructing plugs that could be press-fitted in a hole drilled thru the junction. Two plugs are pictured in Figure 2 with ferrite discs mounted on them. These plugs can be removed from the circulator and others inserted when it is necessary to change the material. Another mounting technique that is not presently available is to metallize the discs to the plugs. This process should improve the heat transfer from the disc to the circulator wall since the epoxy being used has a poor thermal conductivity.

The materials tested to date are listed in Table I along with some of their physical properties:

TABLE I – MATERIAL PROPERTIES

Material	$4\pi M_s$(gauss)	ΔH(Oe)	Loss Tangent	g Factor	ϵ_r
Polycrystalline YIG	1780	45	<0.0001	2.00	16
2% Dy Doped YIG	1760	83	0.0004	1.99	16.1
4% Dy Doped YIG	1715	135	0.0005	1.96	16.1
8% Dy Doped YIG	1700	230	0.0002	1.96	15.9
4% Dy, 30% Gd Doped YIG	1200	230	<0.0001	1.95	16.0

The values of the various properties were obtained from Sperry Microwave Electronics Company.

Curves of insertion loss versus power for pure polycrystalline YIG and also for the 4% dy, 30% gd doped material are shown in Figure 3. It can be seen from this figure that both materials tested showed steps in insertion loss as the power increased. A curve of constant loss up to 500,000 W would be ideal provided this loss is not too high.

Curves of low-level insertion loss versus disc geometry are shown in Figure 4. The geometry used for all high-power tests has been a disc 0.450" in diameter and either 0.106" or 0.112" thick. The insertion loss at low levels seemed to be more dependent on thickness of the disc rather than diameter. The 0.450" dia. was chosen because of the convenience in having these cut and also because of the slightly lower insertion loss, although the loss difference is not as large as the allowable error in our measuring technique. It was also desirable to keep the absorbed loss as low as possible and although some disc sizes may have slightly lower insertion loss they showed high absorbed loss. This absorbed loss will produce high temperatures in the discs at high power levels and possible cause the material to crack or cease to operate properly. The size was therefore determined more from absorption rather than insertion loss as well as the convenience of cutting, which was mentioned above. All the materials listed in Table I operated satisfactorily at the high power levels. The applied field at high power levels was between 800 to 1000 gauss.

Results of tests indicate that a high-power, symmetrical, Y junction, E plane circulator for duplexer application is possible. This circulator is small and lightweight. It is capable of handling 1/2 MW peak and 650W average power using ferrite discs 0.450" in diameter and 0.106" thick. These power levels do not represent the ultimate since equipment limitations prevent tests at high levels. Insertion loss from 0.6 db to 0.8 db and isolation of 15 to 16 db are easily obtained. Applied magnetic fields are on the order of 800 to 1000 gauss.

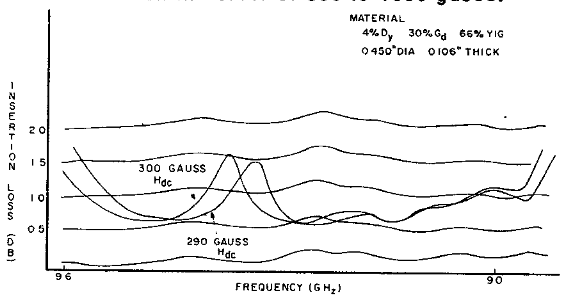

FIG. 1 - Insertion Loss as a Function of Frequency at Low Power Levels

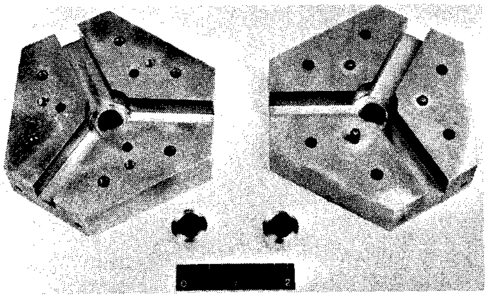

FIG. 2 - Symmetrical E Plane Y Junction Circulator with Plugs

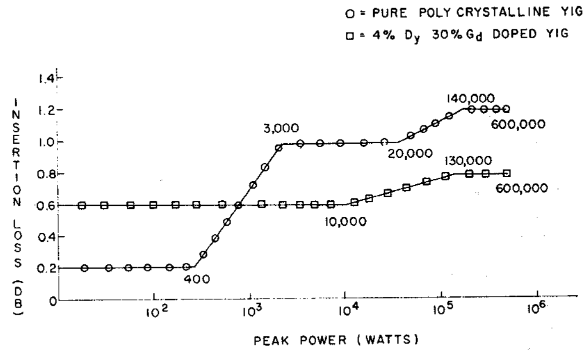

FIG. 3 - Insertion Loss Versus Peak Power

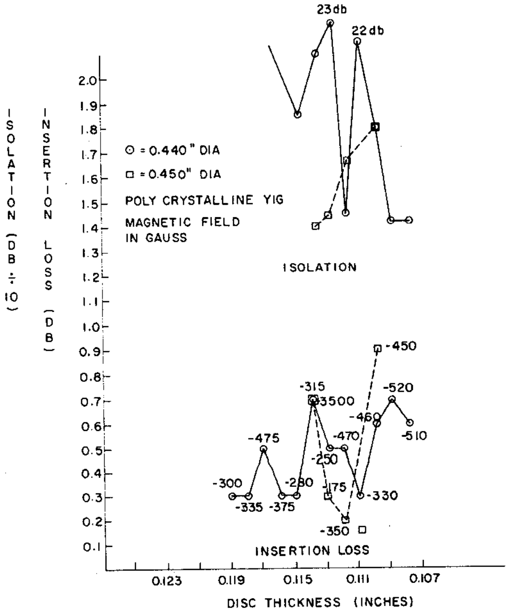

FIG. 4 - Low Level Insertion Loss Versus Disc Geometry