7.1: FURTHER DEVELOPMENTS IN DIELECTRIC WAVEGUIDE DEVICES FOR MILLIMETER WAVELENGTHS

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An isolator and a variable attenuator having flat responses over the 50 to 60 Gc/s band were reported at the 1961 PGMTT Symposium. These devices utilized a broadband Faraday rotator which consisted of a solid rod of ferrite of sufficient diameter to function as a dielectric waveguide with characteristics approximating those of an infinite ferrite. Further development of this type of device has produced isolators with significant improvements in bandwidth and loss characteristics and a three-port circulator with broadband characteristics similar to the isolator. The characteristics of the isolator as functions of power and temperature have been studied in order to determine the limitations on the isolator's use.

The isolator previously reported had a maximum forward loss of ~ 1 db, minimum reverse loss of 30 db, and minimum return loss of ~ 20 db. This isolator was constructed of nickel-zinc ferrite ($4\pi M_s \approx 5000$ gauss) and Wesgo AL300 alumina. A magnesium-manganese-copper ferrite ($4\pi M_s \approx 1000$ gauss) has been found to be a more desirable material in spite of the slight increase in length required because it has lower dielectric loss and its lower dielectric constant more nearly matches that of the alumina. A further improvement in the dielectric mismatch may be had by using Coors AD-99 alumina, GE lucalox, or single crystal magnesium oxide, all of which have higher dielectric constants and lower loss tangents than AL300. A significant reduction in the loss at the low end of the band has been obtained by slightly increasing the inner diameter of the absorbing housing in the region of the alumina matching sections where the combination of lower dielectric constant and lower frequencies result in the greatest field extension.

Additional improvement in the reverse loss and the match have been obtained through new fabrication techniques including the evaporation of absorbing films directly upon the alumina. The results of these modifications as shown in Figure 1 are a maximum insertion loss of ~ .65 db, a minimum reverse loss of ~ 40 db, and a minimum return loss of ~ 22 db. The slight enlargement of the absorbing housing has extended the region of less than 1 db forward loss down to at least 46 Gc/s. Figure 2 illustrates the performance of another isolator over a 28 per cent band from 46 to 61 Gc/s. The forward, reverse, and return losses in this band are respectively 1 db max, 30 db min, and 20 db min.

In order to determine some of the limitations on the use of the isolator, a series of loss measurements have been made for various power levels and temperatures. These measurements indicate that the principal effect of higher reverse power, at least up to 250 mw, is a heating of the ferrite resulting in a reduction of $4\pi M$ and hence the rotation. As

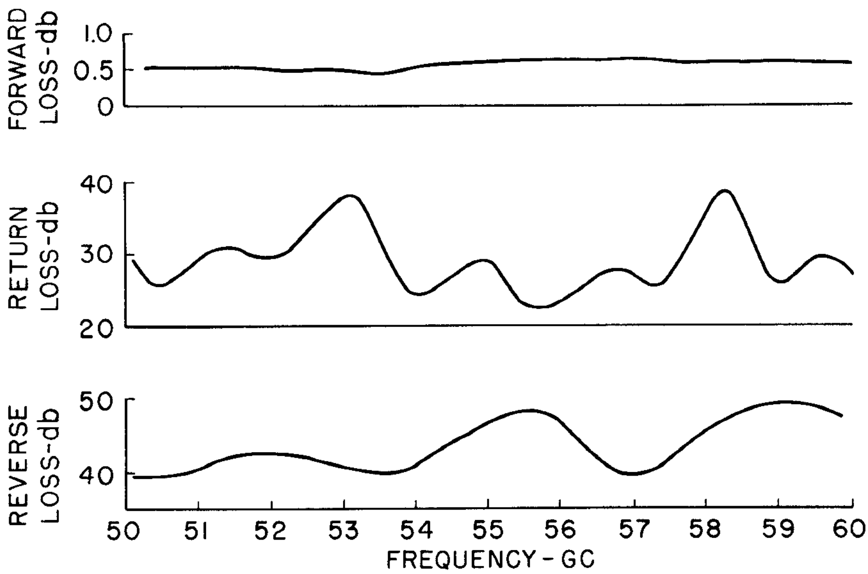

Fig. 1. Improved loss characteristics for 50 to 60 Gc/s dielectric waveguide isolator with constant biasing field.

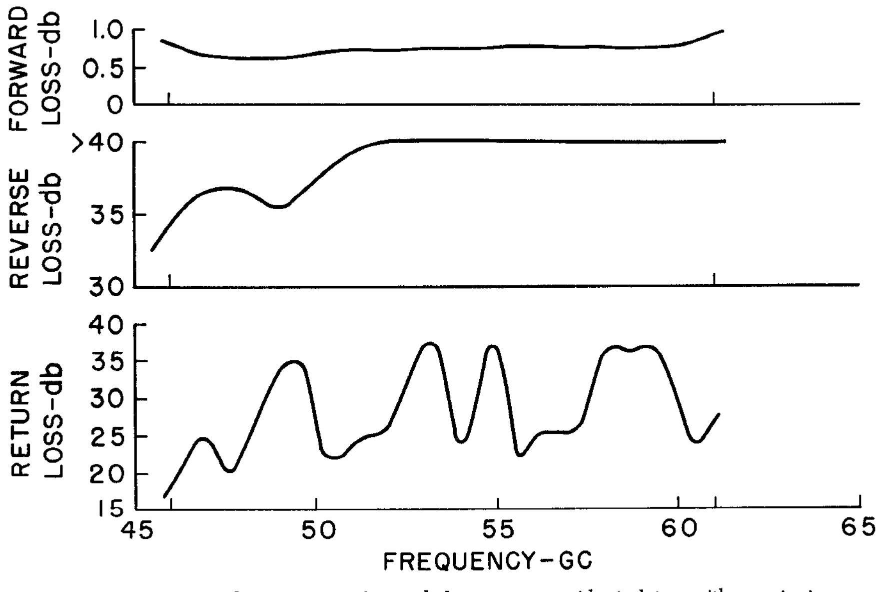

Fig. 2. Loss characteristics for a dielectric waveguide isolator with constant biasing field covering the 28% band from 46 to 61 Gc/s.

shown in Figure 3, the reverse loss of an isolator peaked at 1 mw is degraded to ~ 20 db at 250 mw reverse power, which is equivalent to a much higher forward power except in the presence of a very high reflection. The calculated increase in forward loss for this change in rotation

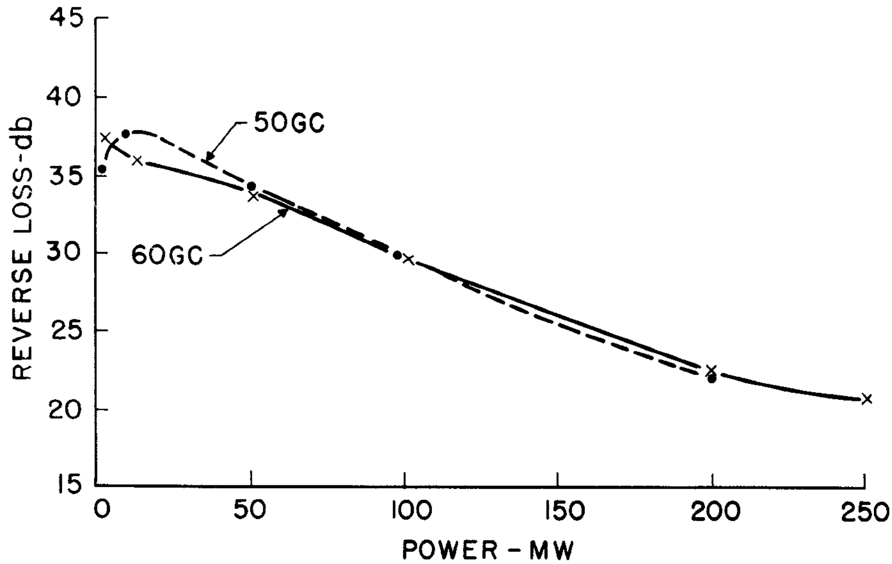

Fig. 3. Reverse loss of a dielectric waveguide isolator as a function of the reverse power in milliwatts. The isolator was biased for optimum operation between 1 and 10 milliwatts reverse power.

is ~ .04 db. The reverse loss may be peaked at any power level in the range measured so that one may compensate for expected dissipation. The result of peaking between 100 and 150 mw is shown in Figure 4.

Figure 5 shows the variation of the reverse loss as a function of temperature for an isolator peaked at 1 mw slightly above room temperature. The loss decreases from > 45 db to ~ 30 db at 185° F. This together with the power measurement indicates that the ferrite reaches rather high temperatures for moderate reverse powers. This situation may be improved in the future through the use of heat conducting supports or forced air cooling.

For higher power isolation where the return loss required is moderate one might better use a three-port circulator with one port terminated in a high power load. A three-port circulator using a 45° dielectric waveguide rotator and a polarization separator is in the early stages of development. Curves of typical per pass loss and isolation are shown in Figure 6. The insertion loss and isolation are respectively ~ 1 db and 20 db minimum over the 50 to 58 Gc/s band. The minimum return loss at Ports 1 and 2 is ~ 18 db and ~ 12 db at Port 3 which is the side arm of

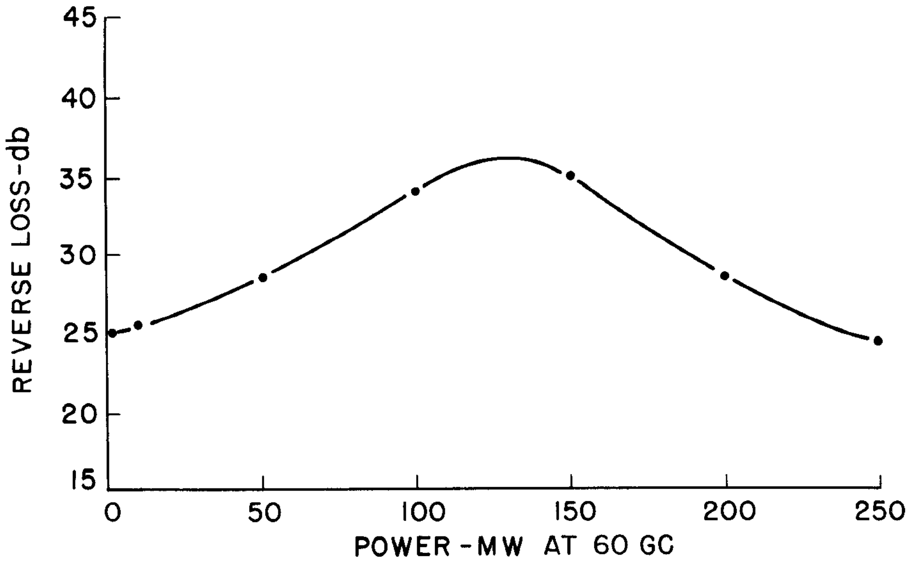

Fig. 4. Reverse loss of the isolator of Figure 3 biased foı optimum operation between 100 and 150 milliwatts reverse power.

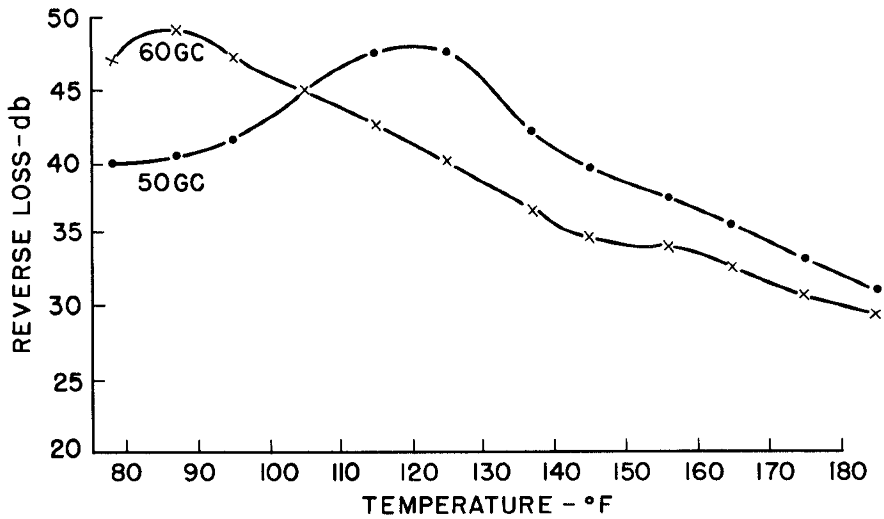

Fig. 5. Reverse loss of a dielectric waveguide isolator as a function of temperature with approximately 5 milliwatts reverse power.

the separator. The two peaks in the loss from Port 1 to 2 are resonances in the polarization separator which now limit the bandwidth and which should be eliminated with further development.

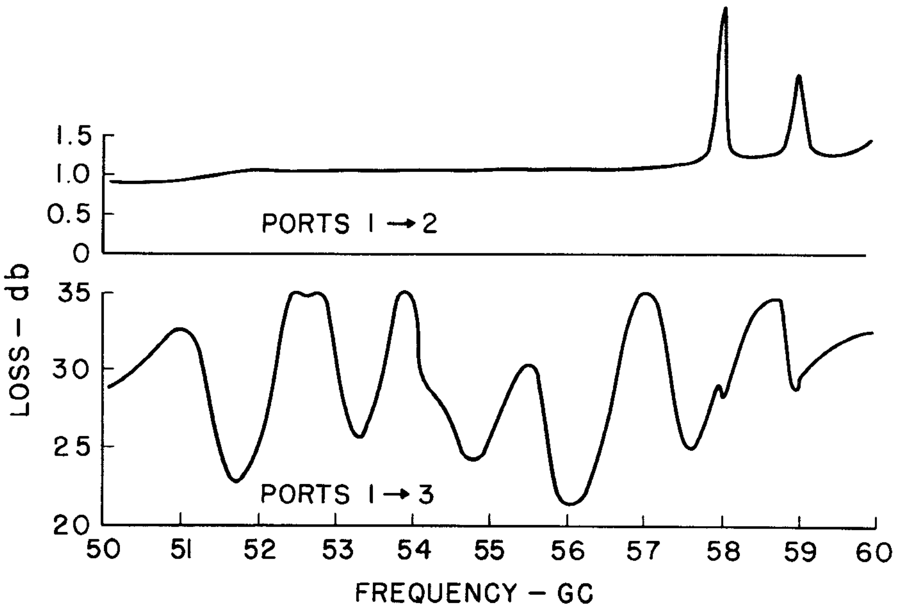

Fig. 6. Typical loss characteristics for a three port dielectric waveguide circulator with constant biasing field.

In addition to its use as a circulator or high power isolator, when supplied with a solenoid coil, this structure may be used as a three-port switch. The variable attenuator may be built either normally transmitting or normally absorbing and may be used for modulation or switching. Thus, the dielectric waveguide devices satisfy a wide variety of device needs with bandwidths never before achieved at millimeter wavelengths.