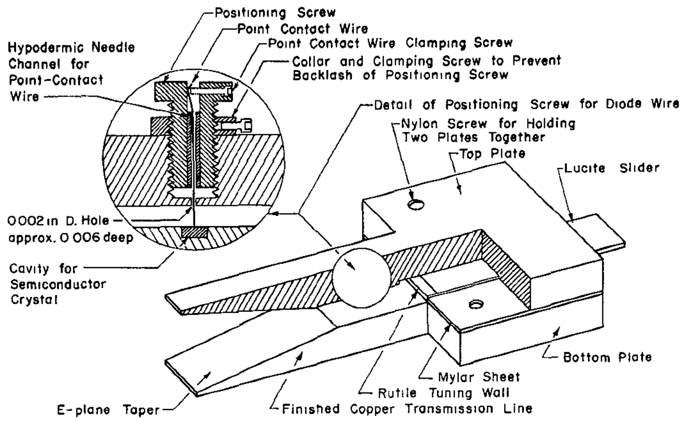


Fig. 1. Parallel-strip transmission line diode mount.

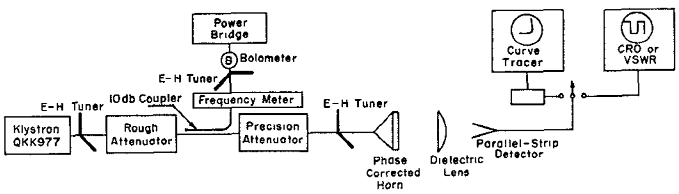


Fig. 2. Block diagram of experimental setup for video detection at $\lambda=3.3$ mm.

TABLE I

SENSITIVITIES OF DIODE DETECTORS AT $\lambda=3.3$ MM

| Diode Type | Semiconductor | Wire | NDS* (dBm) | TSS† (dBm) |
|---|---|---|---|---|
| Point-contact diode | Si from 1N53 | Tungsten | −36 | −41 |
| Point-contact diode | GaAs (Se doped) $\rho=7.10^{-4}$ ohm-cm. | Phosphor-bronze | −29 | −39 |
| Point-contact tunnel diode | GaAs (Se doped) $\rho$ is unknown [5] | Zinc | −42 | −22 |
| Point-contact back diode | GaAs (Se doped) $\rho=7.10^{-4}$ ohm-cm | Zinc | −32 | −30 |
| 1N53 Cartridge | Si | Tungsten | −17 | −29 |

* Video amplifier: HP 415B VSWR Meter (200-ohm input impedance, ~30 c/s bandwidth).
† Video amplifier: Textronix Type E Preamplifier (10 Megohm input impedance, 50 $\mu$V/cm sensitivity, 0.2 c/s to 20 kc/s bandwidth).

TABLE II

RELATIVE SENSITIVITIES OF DIODE DETECTORS AT $\lambda=2.1$ MM

| Diode Type | Semiconductor | Wire | *Relative Sensitivity |
|---|---|---|---|
| FXR wafer with point-contact diode | Si | Tungsten | 0.0 dB |
| Point-contact diode | Si | Tungsten | 6.0 dB |
| Point-contact tunnel-diode | GaAs | Zinc | 2.5 dB |
| Point-contact diode | GaAs | Phosphor-bronze | <0.0 dB |

* Sensitivity relative to FXR diode mount.
* Video Amplifier: Narda 441B VSWR Meter (200-ohm input impedance).

result of the impedance match between the particular diodes and the input of the diode amplifier. While less sensitive, gallium arsenide diodes and the gallium arsenide back-diodes gave improved performance when compared with a 1N53.

At $\lambda=2.1$ mm, a comparison was made between the strip mount with different diodes and a silicon-tungsten in-guide mounted diode (FXR model 6638A) which was available in the laboratory. This waveguide mount does not represent an absolute standard because of the wide variation of performance which is common to point-contact diodes, but it did serve as a reference to indicate the performance of the new mount. The results are shown in Table II. No quantitative measurements were taken at $\lambda=0.84$ mm but for detectors in the parallel-strip mount, silicon-tungsten diodes were more sensitive than the tunnel-diodes tested.

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## A 150 Mc/s Circulator

The below-resonance operation of strip-line circulators at lower frequencies is not of interest as the low magnetic loss region is quite narrow on the magnetic field axis. Kittle's equation for resonance frequency is

$$f=\gamma\sqrt{[H_A-(N_Z-N_X)M][H_A-(N_Z-N_Y)M]} \quad (1)$$

$$N_X+N_Y+N_Z=4\pi \quad (2)$$

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where $N$ is the demagnetization factor, $\gamma$ is 2.8 Mc/oersted, $M$ is the magnetization, and $H_A$ is the applied field. The demagnetization factor is negligible in the direction that the ferrite is relatively thick and the surface is small. Therefore, for a thin ferrite disc, $N_X$ and $N_Y$ are zero then

$$H_A = \frac{f}{\gamma} + 4\pi M. \tag{3}$$

Below-resonance circulators with low insertion loss can be built for frequencies as low as about 750 Mc/s using available materials with a saturation magnetization of approximately 300 gauss.

For frequencies below 750 Mc/s, the above resonance operation is utilized for low insertion loss circulators.

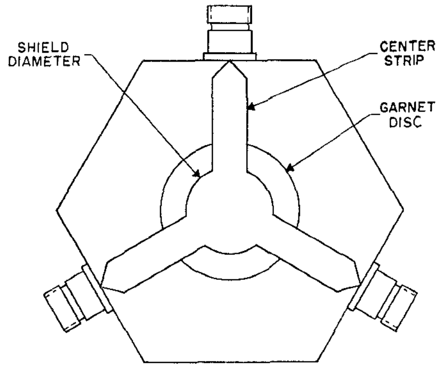


Fig. 1. Strip-line circulator at 150 Mc/s.

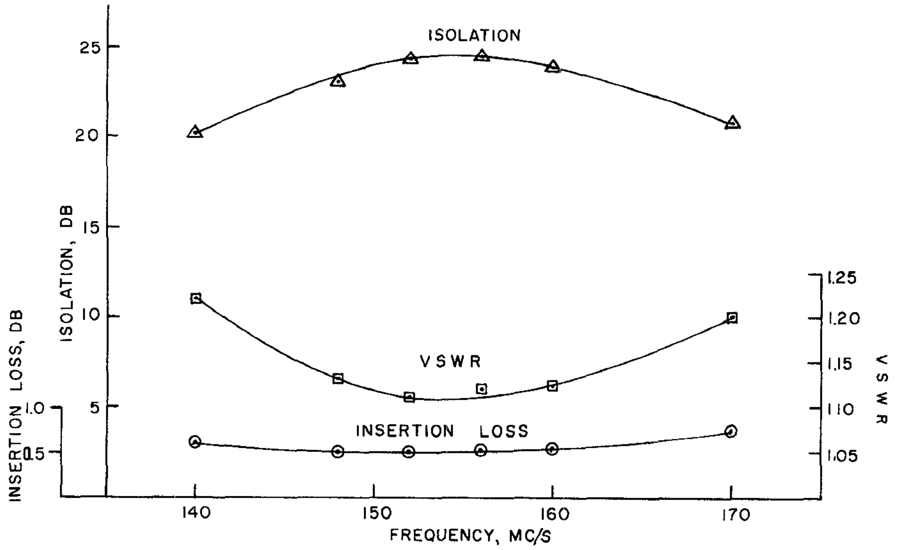


Fig. 2. Characteristics of 150 Mc/s circulator.

Buehler and Eikenberg[1] reported stripline circulators for the 100 to 400 Mc/s region utilizing a magnesium ferrite with a Curie temperature of 100°C. For high-temperature performance, garnet materials have demonstrated a more satisfactory performance.

For above-resonance low insertion loss circulators, the required applied field is

$$H_A = \frac{f}{\gamma} + 4\pi M + n\Delta H \tag{4}$$

for $n=2$ which is the biasing point at two line widths above resonance; losses are sufficiently low.

Figure 1 shows the structure of a 150 Mc/s strip-line circulator using an Airtron garnet material. It was found empirically that the characteristics of the circulator can be optimized for $D_f/D_s=1.8$ where $D_f$ is the ferrite diameter and $D_s$ is the shield diameter.

Figure 2 shows the characteristics of this circulator. An isolation greater than 20 dB and an insertion loss of less than 0.75 dB was achieved over a 20 percent band without use of a direct matching element.

The input impedance of the circulator plotted on a Smith chart indicated that a better match can be obtained by adding an inductive reactance before the ferrite disks. This inductive structure was introduced by reducing the width of the center conductor.

The characteristics of the circulator were improved and a return loss greater than 30 dB was measured, however; a reduction in bandwidth was observed. The high power requirement of the unit limited the type of matching structure which could be utilized.

*Temperature Consideration:* When the circulator is subjected to a high temperature environment, the saturation magnetization of the garnet will decrease. The change in saturation magnetization is much greater for the substituted magnesium manganese ferrites; nevertheless, to compensate for this reduction in saturation magnetization, (3) shows that the applied magnetic field should be reduced. In practice, this is achieved by using a compensating steel in series with the magnetic circuit. The permeability of the compensator reduces with an increase of temperature. This scheme is effective for low temperature as well.

For above-resonance circulators, the insertion loss increases rapidly with a reduction in temperature. Equation (3) shows that when $4\pi M$ is increased, the resonance frequency is shifted down, which would lower the insertion loss. However, the increase in insertion loss is due to broader line width.

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## Frequency Doublers Using Varactors Exhibiting "Punch-Through" Capacitance-Voltage Behavior

Recently, a number of authors[1–5] have given the analysis of the overdriven doubler for abrupt-junction, graded-junction, and stepwise-junction varactor doublers. All previous work has stimulated considerable interest in the prediction of power and efficiency of frequency doublers using varactors exhibiting a general nonlinearity. This discussion is concerned with the detailed analysis of the "punch-through" behavior varactor doubler to determine the conditions of optimum input and output resistances, maximum conversion efficiency, and power. The results will generally be determined by numerical techniques because of the algebraic complexity of the solutions. The analysis in this discussion asumes the varactor to be imbedded in a lossless tuned circuit.

Scarlett[1] and Rafuse[2] have made detailed analyses of the overdriven stepwise-junction varactor doubler and also point out that such an "ideal" diode will not multiply unless it is overdriven. In no case was a diode actually found to have such a stepwise-junction. However, varactors exhibiting "punch-through" capacitance-voltage behavior can usually be obtained. The broken line in Fig. 1 represents a stepwise-junction which has a constant elastance in the range of $0<q+q_\phi\leq Q_B+q_\phi$ and the solid curve

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