TABLE I

RESULTS OF SENSITIVITY MEASUREMENTS (f = 70.8 Gc).

Use	Measurement	Typical results	Best results	Selected 1N 53*
Video detector in conventional waveguide	Voltage sensitivity (mv./mw.)	300 to 500	640	230
	Tangential sensitivity (dbm.)	−48 to −51	−58	−44
Mixer in conventional waveguide	Tangential sensitivity (dbm.)	−78 to −80	−85	−77
Mixer in reflecting beam waveguide	Tangential sensitivity (dbm.)	−75 to −81	−85	—

* Selected from 12 available cartridges. Mounted in DE MORNAY BONARDI mount type DBA-313.

herently wide band although this has been demonstrated experimentally only for frequencies from 71 to 75 Gc. Only a few detectors were constructed and it is hoped with improved fabrication and/or other crystal materials, still further increases in sensitivity and performance could be expected.

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Some Experimental Results on the X-Band Junction Circulator

The general trend in the development of junction circulators is to provide a 20 dB isolation over the widest possible frequency band. However, in some special applications, ferrite circulators with higher isolation and low insertion loss are required for narrow bandwidth operation. An example of this is a circulator operating in connection with a parametric amplifier or maser, where the circulator insertion loss should be held small to decrease the inevitable noise. Also, in some systems diplexing signals of different frequency, high isolation of the neighboring channels in a relatively narrow frequency band is a ferrite circulator fundamental feature. These and other problems lead UNIPAN-Scientific Instruments Corp. towards some conceptions in junction circulator design.

Following reports of other authors [1], [2] experiments with ferrite inserts in a symmetrical waveguide H-plane Y junction have been carried out. Prism inserts with a triangular base were tested. When studying the circulation effect the prism height h and the base side a were changed and various external magnetic fields were applied along the Y axis—see Fig. 1. No additional reactive matching elements were introduced into any one of the branches.

When testing the circulation for a fixed ferrite configuration, while altering the frequency and the magnetic field strength, curves similar to that given in Fig. 2 were obtained. It was found, that for inserts with different side length of triangle and height h equal to that of the standard WR 90 waveguide, maximum isolation values between port 1 and 3 in Fig. 1 exist at frequencies which can be predicted. It was further found, that points which correspond to maximum isolation constitute a straight line, with a slope of $a/\lambda = 0.287$, as in Fig. 3. The result is similar to that of Aitken and McLean [2] for cylindrical rods.

The confirmation of the curve in Fig. 3 allows circulator design for any desired frequency. The following characteristics could be obtained with such circulators: maximum isolation 50 dB at any frequency, isolation better than 20 dB over band ±150 Mc/s around center frequency, VSWR below 1.20, and insertion loss below 0.2 dB—without additional reactive elements.

Looking for broadbanding it was assumed that perfect matching of the Y comprising the magnetized ferrite insert is the only necessary condition which should be satisfied to obtain circulation. It is seen from Fig. 2, that the introduction of a ferrite into Y will produce narrow-band matching. Introduction of matching elements requires the ferrite prism to be lowered, and results in increase of demagnetization coefficients, in and the application of higher magnetic field strength which, in turn, will improve the circulator stability when operating in external stray magnetic fields.

Input admittance measurements have been carried out on Y's comprising longitudinally magnetized ferrite prisms of various dimensions. A reverse mode of cir-

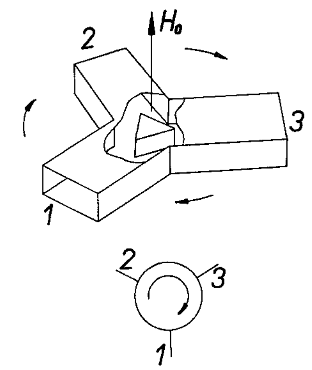

Fig. 1. Three-port junction ferrite circulator.

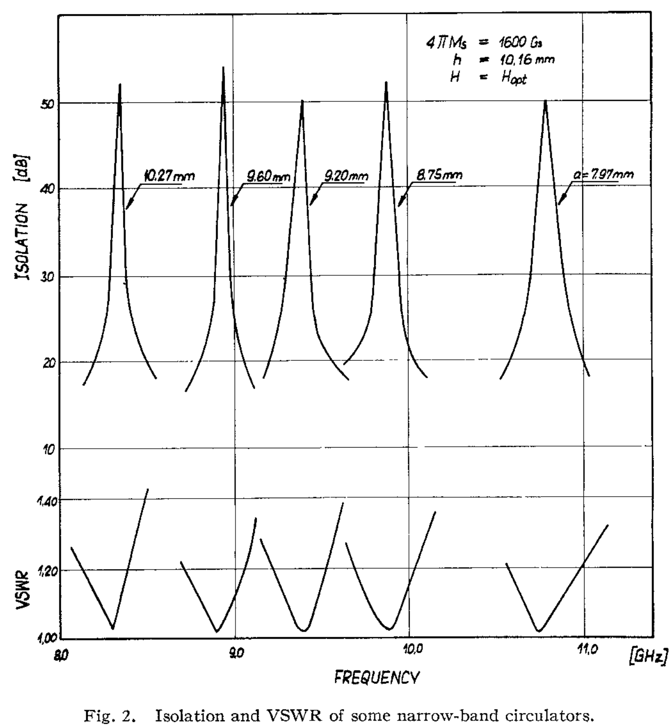

Fig. 2. Isolation and VSWR of some narrow-band circulators.

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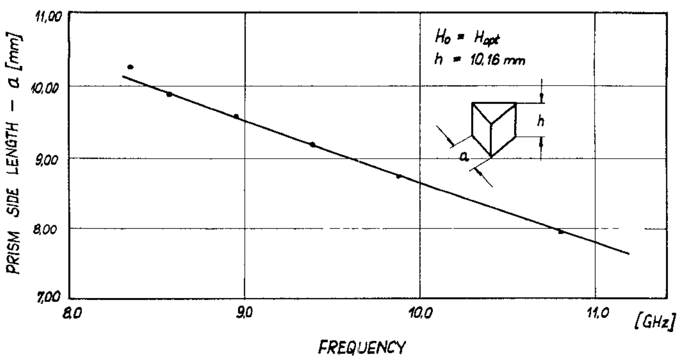

Fig. 3. Resonant frequency vs. ferrite prism side length.

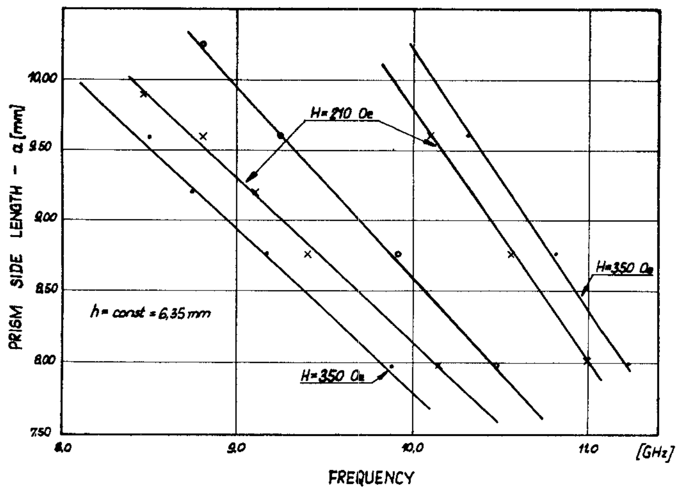

Fig. 4. Frequency for optimum circulation vs. ferrite prism side length.

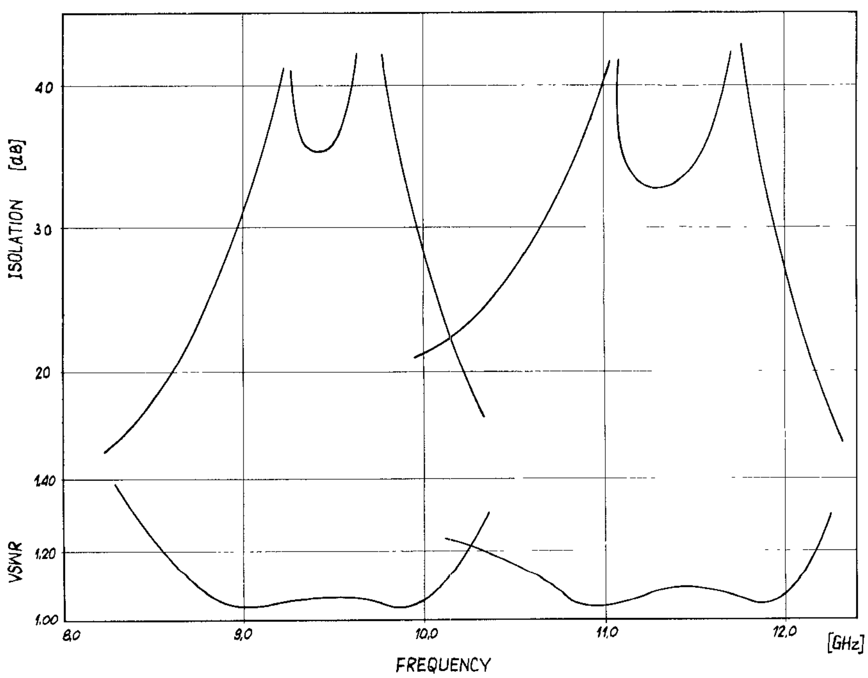

Fig. 5. Isolation and VSWR vs. frequency, for two broadband circulators.

culation was observed for 10.3 mm $>a>$ 7.5 mm and $h=6.35$ mm at higher frequencies. Figure 4 shows the frequency at which circulation exists in both senses as a function of the prism a dimension for two fixed magnetic field strengths. The reverse mode of circulation depends on ferrite dimensions and the value of the magnetic field applied. The slope of magnetic field strength vs. frequency at which the most effective circulation exists was observed to vary when altering the prism height. No satisfactory circulation at any point of the frequency band could be established for some peculiar prism height; this may confirm the Rowley-Sheehan model [3].

Next the input admittance of H-plane Y junction was tested, comprising a metal prism insert with triangular base and then a metal cylinder. Inserts like these alter the Y's characteristic admittance, thus providing a way for effective matching. It was seen that the susceptance varied with frequency more effectively in the case of the cylinder than in the case of the prism. For this reason, in the following experiments on broadband ferrite circulators, cylinders were left without further attention.

Probably a more systematic study of the input admittance in Y's comprising matching element and this, with various ferrite inserts magnetized by external fields, as well as an evaluation of the dependence of the Y's admittance on matching element size and field strength will establish a means for the successful design of any required ferrite circulator. It is because of this that we assume that to produce ideal circulation the sum of the Y's admittance and the admittance introduced by the magnetized ferrite and the matching element should be equal to unity. This approach to the junction circulator problems will be a future report.

Figure 5 shows the characteristics of an X-band waveguide junction circulator obtained as a result of an experiment. The characteristics are as follows: isolation above 30 dB within 12 per cent bandwidth, VSWR below 1.10, and insertion loss below 0.2 dB. It can be seen from Fig. 5, that by increasing slightly the magnetic field, a circulator can be obtained with isolation greater than 40 dB within 6 per cent bandwidth at VSWR below 1.05 and insertion loss below 0.1 dB.

Manganese-magnesium ferrite prepared by Dr. R. Wadas was used in all the above experiments; $4\pi M_s=1600$ Gs, $\Delta H=400$ Oe, $T_c=250°$C, and IPPT type M11. The material differs from these used by other authors [1] [2], but allows similar results however. This seems to confirm the assumption that proper matching is a more important factor in broadband circulator design than material quality.

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