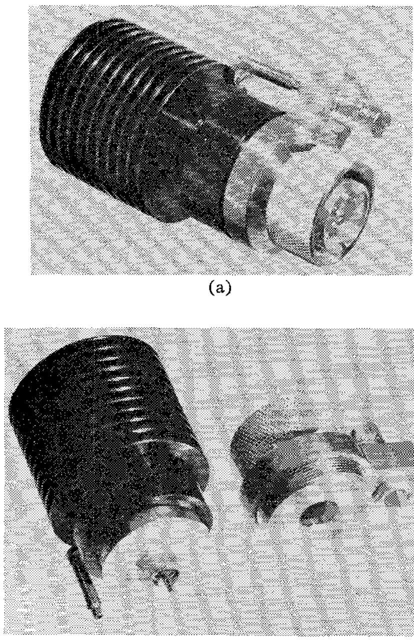

Fig. 2—(a) mounted diode switch with connector for the triggering. (b) Diode switch screwed off, showing the mounted semiconductor diode in the cooling cylinder.

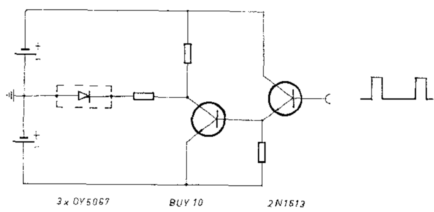

Fig. 3—Principal circuit of the trigger unit.

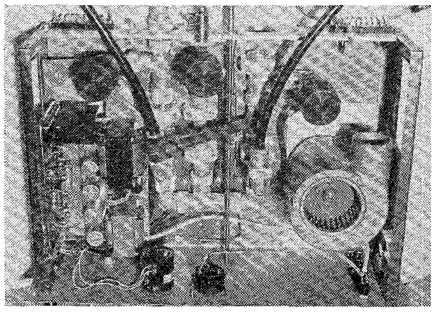

Fig. 4—The apparatus, showing the trigger unit and the 3 semiconductor diode switches without cooling channel.

variable line *VL* we can obtain any amount of phase jump.

The most critical parts of the shifter are the diode switches. They limit the switching time as well as the switched energy. They also determine how far we approach the ideal short or open circuit. We built selected semiconductor diodes OY 5067 in a coaxial element (Fig. 2), compensating the stray capacitance as much as possible.

Care has been taken to conduct the terminal energy from the diodes by a blackened brass cylinder which is forced air cooled. So we are able to shift an energy of 150 w in less than 1.5 μsec. A diode element itself has an open to closed ratio of 25 db. With special RF diodes we hope to reach better switching times.

The diodes will be triggered in parallel by the power stage shown in Fig. 3, having a rise time of less than 200 nsec. The apparatus itself is seen in Fig. 4.

In a similar way this switching principle could be used in switching from one transmitter to two different loads or from two different transmitters to the same receiver. We think that it would be possible to build similar switches for rectangular waveguide systems.

H. Gerke
A. Paulin
Deutschen Elektronen-Synchrotron
Hamburg, Germany

Recent Linewidth Measurements with a Cross-Guide Coupler

The continued interest in both narrow and broad linewidth ferromagnets for microwave applications motivates studies directed toward measuring their pertinent parameters. Two of the more important parameters are the linewidth and the effective g factor. These quantities are ordinarily measured in a resonant cavity where quite often it is necessary to use two different cavities for materials whose line widths differ by several orders of magnitude. Although the procedure for using this method is unnecessarily involved when one desires to measure only the linewidth and the g factor, the cavity technique is considered the standard.

The purpose of this communication is to present measurements that show that the cross-guide coupler technique is satisfactory for both narrow and broad linewidth materials using the same coupler and that it is also possible to perform these measurements over a wide frequency range. The theory and operation of the cross-guide coupler method has been presented before[1] so only some of the more recent results will be given here.

Since it was suggested that the coupler method might not be satisfactory for extremely narrow linewidth samples,[2] it was of interest to determine experimentally whether such a supposition were true. Initially, attempts were made to polish several YIG single crystals using the method described by Carter, *et al.*[3] Linewidths as narrow as 1.5 Oe at X-band[4] were obtained in this manner although it was found necessary to line the tube constraining the ferrite above the grinding wheel with a plastic insert in order to avoid chipping the surface of the sphere during its random bouncing. Because of the difficulties encountered in polishing spheres and obtaining one without inclusions, it was decided to purchase a polished sphere from Microwave Chemicals Lab., Inc., New York, N. Y. The linewidth and g factor of this sphere were measured over the frequency range from 2–17 Gc.[5] Two cross-guide couplers constructed from $\frac{7}{8}$ inch and $\frac{5}{8}$ inch coax were used for frequencies to 6 Gc and 9 Gc, respectively, and ordinary X-band and K_u-band waveguides were used for the other two couplers. The behavior of the linewidth as a function of the normalized field for resonance is shown in Fig. 1. Since the g factor was constant at a value of 2, the abscissa may be converted to frequency in Gc by multiplying by 5. The increase in linewidth at the lower frequencies is caused by the sample becoming unsaturated whereas the increase in linewidth at frequencies near 3 Gc is caused by the uniform mode entering the spin wave manifold. A considerable scattering of points occurred for frequencies above 8 Gc with some frequency bands from 100–500 Mc wide where the uniform mode did not possess a clean resonance but was coupled to various magnetostatic modes. Since the linewidth and the coupled power were very sensitive to the incident power level, sufficient attenuation was always inserted in the primary line to produce the minimum linewidth. A comparison of our data with that reported by Masters, *et al.*,[2] Douthett and Kaufman,[6] and Microwave Chemicals[7] is also noted in Fig. 1. It is interesting to observe that the linewidth is less than 0.5 Oe over the entire frequency range from 3.4–6 Gc with the narrowest linewidth of about 0.2 Oe at 4.38 Gc. However, no attempt was made to obtain either extreme accuracy or to seek a minimum linewidth since our interest was in the general behavior of the linewidth as a function of frequency. Two linewidth values taken at different times at a frequency of 10 Gc are shown in Fig. 1 with a vertical dotted line between them to give an idea of the repeatability of the measurements. The accuracy in measuring linewidths was estimated at ±15 per cent for linewidths of 1 Oe. It was found necessary to add several turns of wire to the yoke of the magnet[2] in order to measure linewidths below 2 Oe. The YIG sample was not glued in the coupling hole but was placed in a hollow cylindrical cavity in a dielectric rod and the rod was glued in the coupling hole. The axes of the coupling hole, the dielectric rod, and the cylindrical cavity were all parallel. However, considerable difficulty was experienced with the YIG sample moving about in the coupling hole. This problem was solved by placing the sphere in a cylindrical cavity whose axis was perpendicular to the axis of the dielectric rod.

The linewidth behavior of the single crystal YIG sphere in Fig. 1 was typical of

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[1] D. C. Stinson, "Ferrite linewidth measurements in a cross-guide coupler," IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 446–450; October, 1958.

[2] J. I. Masters, B. R. Capone, and P. D. Gianino, "Measurement technique for narrow line width ferromagnets," IRE Trans. on Microwave Theory and Techniques, vol. MTT-8, pp. 565–566; September, 1960.

[3] J. L. Carter, E. V. Edwards, Jr., I. Reingold, and D. L. Fresh, "Ferrite sphere grinding technique," *Rev. Sci. Instr.*, vol. 30, pp. 946–947; October, 1959.

[4] M. W. Niemann, M.S. thesis, Elect. Engrg. Dept., The University of Arizona, Tucson, Ariz., 1961.

[5] T. McGregor, M.S. thesis, Elect. Engrg. Dept., The University of Arizona, Tucson, Ariz., 1962.

[6] D. Douthett and I. Kaufman, "The unloaded Q of a YIG resonator from X-band to 4 millimeters," IRE Trans. on Microwave Theory and Techniques, vol. MTT-9, pp. 261–262; May, 1961.

[7] Microwave Chemicals Lab., Inc., New York, reports a linewidth of 0.55±0.15 Oe at 5.656 Gc.

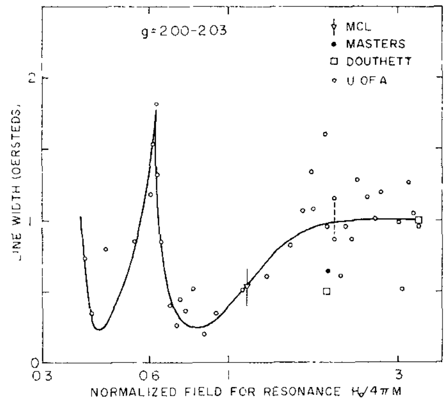

Fig. 1—Linewidth vs normalized field for resonance for 0.020 inch diameter sphere of Microwave Chemicals Lab. polished single-crystal YIG. Multiply the abscissa by 5 to convert to frequency in Gc.

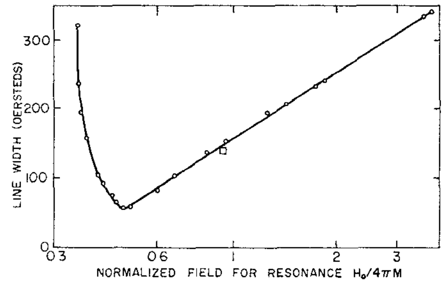

Fig. 2—Linewidth vs normalized field for resonance for sphere of Motorola M-052 polycrystalline spinel. Multiply the abscissa by 10 to convert to frequency in Gc.

other commercial polycrystal and single crystal YIG and substituted YIG materials. However, magnetostatic modes were noticed only in the single crystal materials. One notable feature of the curves for these materials is the fact that the linewidth remains fairly constant after the frequency becomes larger than 2.8 ($4\pi M$) Mc. These results are in disagreement with Douthett and Kaufman[6] who find a linear increase in linewidth with frequency. We have also determined experimentally that the sample size does not have an appreciable effect as frequency is changed, *i.e.*, it is not necessary to keep the ratio of sphere diameter to wavelength constant. However, the linewidth is very dependent upon the surface finish, especially with narrow linewidth materials. Consequently, it is important to improve the surface finish as the frequency increases.

The linewidth behavior of a polycrystal spinel is shown in Fig. 2 as a function of the normalized field for resonance. The material is M-052, a Motorola nickel cobalt ferrite, for which the manufacturer reports a saturation magnetization of 3150 gauss, a linewidth of 140 Oe (at 9.3 Gc), and a g factor of 2.27. The manufacturer's linewidth value is shown on Fig. 2 by a square. The abscissa in Fig. 2 may be converted to frequency in Gc by multiplying by 10. It is interesting to note that the linewidth drops to less than half of its X-band value when $H_0/4\pi M$ is equal to about one half and that the linewidth continually increases with frequency after the uniform mode enters the spin wave manifold. This behavior is typical of spinels and is considerably different from that displayed by the garnets.

A more recent material that is of considerable interest possesses a hexagonal crystal structure[8] and is designated $\text{Zn}_{1.5}\text{Mn}_{0.5}\text{Y}$ ($\text{Ba}_2\text{Zn}_{1.5}\text{Mn}_{0.5}\text{Fe}_{12}\text{O}_{22}$). The linewidth of a single crystal sphere of this material was measured at X-band and its linewidth increased from 16–20 Oe as the frequency increased from 8.2–12.4 Gc. The sample was 0.055 inch in diameter and had a 600 grit (40 micron) finish. These measurements were performed with a magnetostatic field and the microwave magnetic field in the easy plane and perpendicular to each other. The linewidth is slightly larger when the microwave magnetic field is perpendicular to the easy plane but is considerably larger when the magnetostatic field approaches a direction perpendicular to the easy plane.

Donald C. Stinson
Dept. of Elec. Engrg.
University of Arizona
Tucson, Ariz.

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[8] Supplied through the courtesy of A. Tauber, U. S. Army Signal Res. and Dev. Lab., Ft. Monmouth, N. J.

A High Isolation/High Speed Microwave Modulator

The modulation technique shown in this communication is capable of converting a continuous wave X-band signal into nanosecond carrier pulses with measured (on to off state) isolation greater than 50 db. Fig. 1 illustrates the basic block diagram of the system.

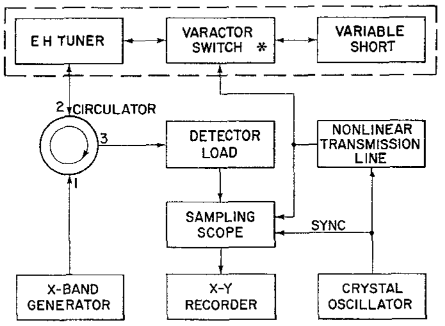

Fig. 1—Modulator block diagram. *Varactor diode mounted in an "in line" or tunable detector mount.

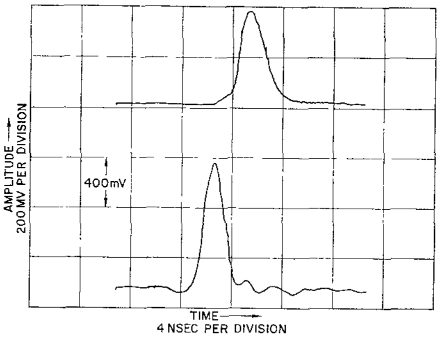

Fig. 2—Waveforms of modulating and detected pulse.

The theory of operation of this modulator is quite simple. Essentially, the CW signal from the X-band generator is circulated from port 1 to port 2 of the circulator; in the off state, the network formed by the E-H tuner, varactor switch and variable short form a nonreflecting load. Under these conditions no signal is circulated to 3. In the transmission state, a pulse is applied to the varactor switch which unbalances the network and allows a proportional pulse of microwave power to circulate to port 3.

It is interesting to note that a minimum balanced condition occurs if three of the four degrees of tuning freedom of the network are adjustable. This indicates that the network forms a pseudo microwave bridge. Two degrees of tuning freedom may be used if the reverse bias on the varactor diode is adjustable.

Under ideal conditions, *i.e.*, employing the use of a circulator of infinite isolation, it is felt that extremely high orders of transmission to off state isolation can be obtained by this technique. Since in these experiments the circulator isolation (port 1 to 3) was 35 db, some signal from the inadvertent detuning of the network at port 2 is used to cancel the leakage from port 1. This effect results in an increase in the normal insertion loss and a decrease in the measured isolation. The main contributions to the insertion loss are: 1) the incomplete unbalance of the network, 2) power dissipated in the diode, and 3) losses due to high VSWR in the network.

In the experiments, a 1 kc square wave and a 2 nsec pulse were used to trigger the diode. In the first case the trigger magnitude was sufficient to saturate the varactor diode, *i.e.*, no further significant increase in output for a change in magnitude could be obtained, whereupon the isolation was greater than 70 db and the insertion loss was 4.5 db. In the latter case the trigger magnitude was insufficient to saturate the diode; however, the isolation was greater than 50 db and the insertion loss was 10.6 db. Fig. 2 shows oscillographs of the 2 nsec trigger pulse (lower trace) and detected output video pulse (upper trace). Some smoothing of the pulse due to the finite bandwidth of the system is noted. The time delay between the trigger pulse and detected pulse is the delay time of the waveguide components.

The X-band power level used in these experiments was 263 milliwatts. The pulse repetition rate of the 2 nsec pulses was 97 nsec. An AEL 1033D (40 Gc cutoff) varactor diode was used as the switch and a 1N23B detector was used. The detector tangential sensitivity in the narrow pulse experiment was −43.5 dbm where in the 1 kc case the tangential sensitivity was −50 dbm both for a signal pulse noise-to-noise ratio of 1 db. In both cases the varactor diode was switched from zero volts to some reverse bias potential.

J. R. Alday
U. S. Naval Lab.
Corona, Calif.

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