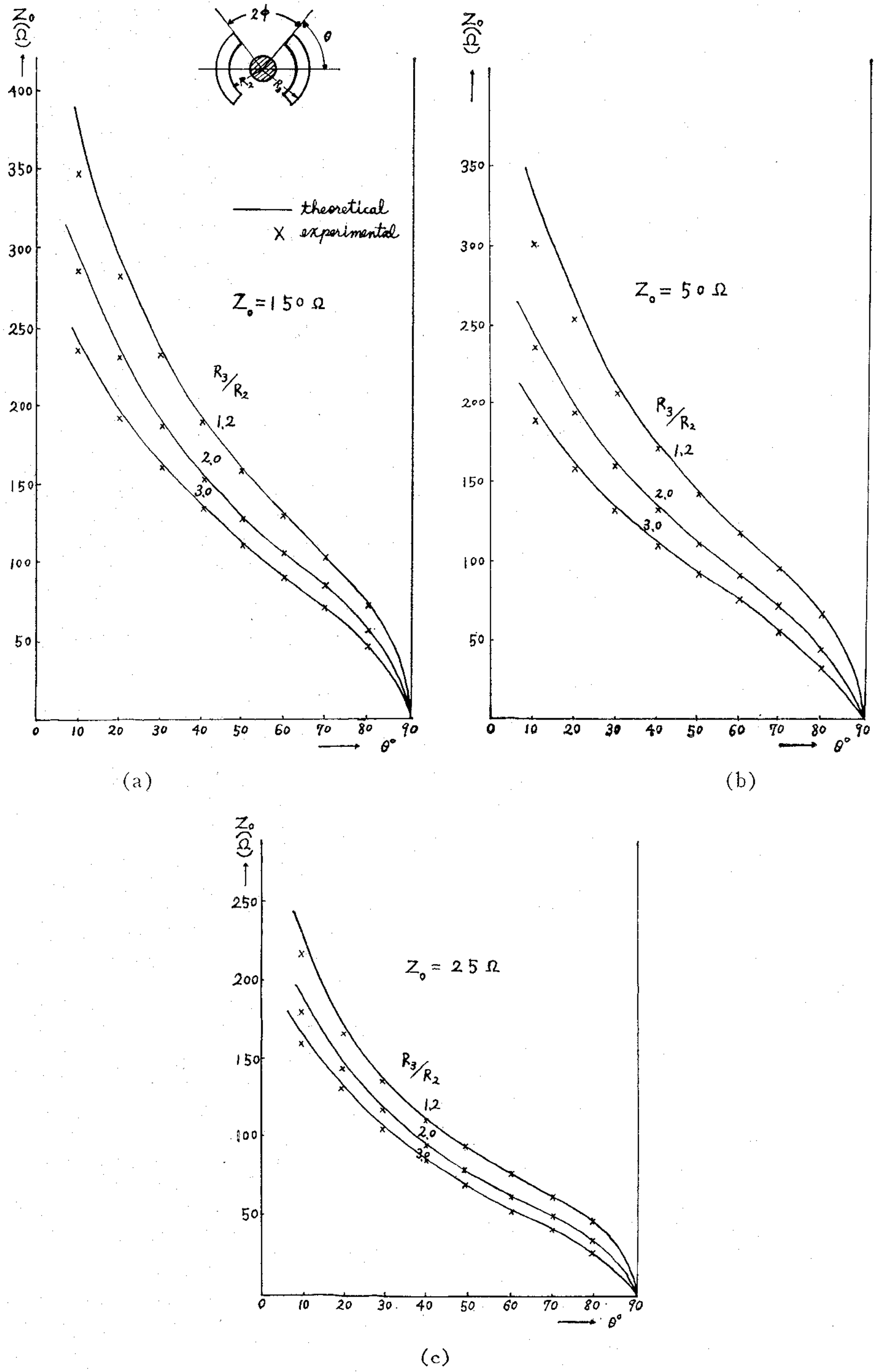

(a) (b)

(c)

Fig. 4—Characteristic impedance of Split coaxial line; (a) case of 150 ohms for the no slit, (b) case of 50 ohms for the no slit, and (c) case of 25 ohms for the no slit.

6) The variable range of the split width.
   - A) $2\phi = 10^\circ \sim 40^\circ$.
   - B) the whole range.

7) The split coaxial with the thickness of the wall in consideration.
   - A) This is proven[4] in reference to the split cylinder with the thickness of the wall.
   - B) Our treatise[2] which conducted almost the same problem in contrast with Bochenek[4] was already published.

8) Experiments.
   - A) None.
   - B) The results of the experiment of the water tank conform fully with the theory as shown in Fig. 4.

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[4] K. Bochenek, "Impedecja falowa linii wyslepujecej wjednym Z rodzajów symetryzatora," *Arch. Electrotech*, vol. 4, pp. 135–148; April, 1956.

A Method for Enhancing the Performance of Nonreciprocal Microwave Devices*

The performances of nonreciprocal microwave devices are as temperature dependent as the ferrimagnetic materials used to produce them. Hence, the operating characteristics vary markedly with incident power level and ambient temperature. In order to compensate for these temperature changes, special cooling techniques are frequently utilized. Since those are often inconvenient, devices are more usually designed to operate at a much broader frequency range than the specifications demand resulting in deterioration of performance in the specified band. In some cases, ferrites may be especially prepared to have a nearly constant saturation magnetization for a range of temperature, as illustrated in Fig. 1. Whereas both of these ferrites have the same saturation magnetization at room temperature, changing the temperature to 100°C causes a 25 per cent change in the $4\pi M_s$ of the commercially available ferrite, but only a 7 per cent variation in the especially designed one. Tailoring ferrites to the application is much too difficult to represent a solution to the problem.

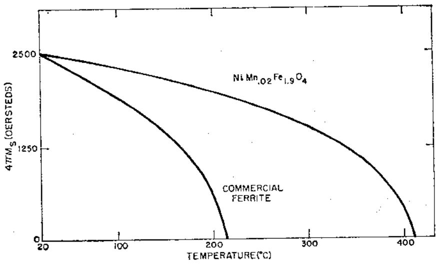

Fig. 1—Saturation magnetization curves for a simple, commercially available ferrite and for an especially designed ferrite having the same $4\pi M_s$ at room temperature.

A simpler solution may be to design devices for operation at the highest ambient temperature to be encountered, or the highest temperature developed because of high input power, and control the temperature of the ferrite to this level. Fig. 2 illustrates one method among many for accomplishing this. Alternatively, some design geometries would lend themselves to an adoption of the well-known technique used in ferromagnetic resonance research: The sample is heated directly through a metal post on which it is mounted in the resonant cavity. A very simple temperature control circuit is required, only regulating to ±10°C or more, since the saturation magnetization does not change very rapidly with temperature even in simple ferrites (Fig. 1). Operation of a nonreciprocal device at a constant elevated temperature results in optimum performance at all power levels and ambient

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* Received by the PGMTT, March 18, 1959. This work was done while the author was at the Microwave Physics Lab., Sylvania Elec. Products, Inc., Mountain View, Calif.

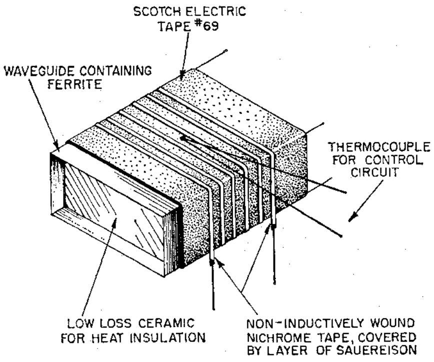

Fig. 2—Schematic diagram illustrating a method for maintaining an elevated constant operating temperature for a nonreciprocal device.

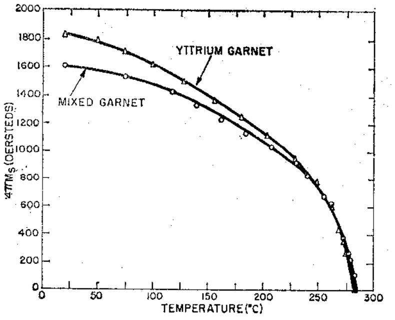

Fig. 3—Saturation magnetization as a function of temperature of yttrium iron garnet and a mixed garnet, $2.5\ Y_2O_3 \cdot 0.5\ Gd_2O_3 \cdot 5\ Fe_2O_3$.

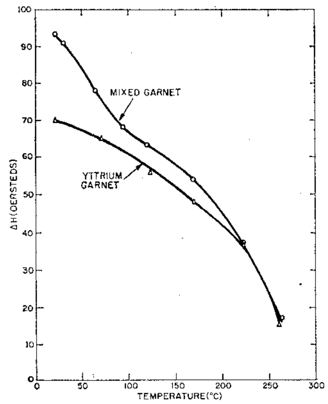

Fig. 4—Ferromagnetic resonance line width of yttrium iron garnet and the 2.5 Y to 0.5 Gd mixed garnet as a function of temperature.

temperatures over the required frequency band.

The design of very low microwave frequency nonreciprocal devices is also significantly enhanced by this method. Essential for the design of such devices are ferromagnetic materials with both narrow resonance line width and small saturation magnetization. Narrow line width materials are required for avoiding the overlap between the inevitable low magnetic field losses, which are reciprocal, and the desired nonreciprocal resonance losses. A small saturation magnetization is highly desirable to ensure stability of operation through definite saturation of the material at the small applied fields required for operating devices at low frequencies ($\omega = \gamma H$). To date, the materials most nearly fulfilling these requirements are mixed garnets in which the *c* sites are shared by yttrium and gadolinium ions.[1] However, as Figs. 3 and 4 show, the desired reduction in saturation magnetization is accompanied by an increase in the line width. Hence, mixed garnets represent, at best, only a compromise solution.

As seen in Figs. 3 and 4, *both* the line widths and saturation magnetizations of rare earth garnets decrease with increasing temperature. By maintaining ordinary yttrium ion garnet at 150°C, a $4\pi M_s$ of 1300 oersteds and a ΔH of 50 oersteds may be easily obtained. Thus, by this relatively simple means, an improvement over the previously best material for nonreciprocal low microwave frequency applications of almost 20 per cent in saturation magnetization and 50 per cent in line width is achieved.

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[1] B. Ancker-Johnson and J. J. Rowley, "Mixed garnets for nonreciprocal devices at low microwave frequencies," Proc. IRE, vol. 46, pp. 1421–1422; July, 1958. See also M. H. Sirvetz and J. E. Zneimer, "Microwave properties of polycrystalline rate earth garnets," *J. Appl. Phys.*, vol. 29, pp. 431–433; March, 1958.

Characteristics of Argon Noise Source Tubes at S-Band*

During the design of equipment for applications in radio astronomy, various tests were performed on argon plasma noise source discharge tubes, with emphasis on the Bendix 6358/TD-12 which is Model A148 of Johnson and DeRemer.[1] In view of the wide use of these tubes as secondary standards of microwave noise power, a brief summary of the results obtained will be given. A description of the test equipment and experimental procedures used would be repetitive of much that has been reported by Sees[2] and Hughes,[3] but is available from the writer if desired.

An absolute calibration at 2885 mc was made on the TD-12, matched to its standard waveguide mount, and operating at the recommended discharge current of 250 ma. The value obtained for the effective noise temperature, T_D, was 10,700°K, with a probable error of 150°K. (T_D is defined by taking the available noise power equal to kT_Ddf, where *k* is Boltzmann's constant and DF is the frequency bandwidth.) In estimating the probable error, allowance was made for the fact that individual tubes are not precisely the same in noise emission. Relative measurements were made on a sample of twenty tubes consisting of twelve A148 (Bendix TD-12), and eight A147 (Bendix TD-10 and Philco L1306A) mounted and matched in *S*-band waveguide; the difference between any two was in most cases about 50° or less, with an extreme of 80° between the highest and lowest.

Hughes'[3] value of T_D for the British CV1881,[4] which is somewhat similar to the A147, was 11,140±130°K (frequency 2860 mc, discharge current 180 ma, 90° E-plane mount). Our tests on the CV1881 yielded a result of 10,900±160°K (frequency 2885 mc, discharge current 180 ma, 20° and 30° E-plane mounts).

Less accurate calibrations on the TD-12 were also taken at a few different frequencies between 2750 and 2910 mc. The results, although not very informative, were at least consistent with the theory that any variation of emission with frequency is small.[5]

The consistency of output of a single tube operating over a period of time is very good. Relative accuracies of one part in two or three thousand were obtained with the TD-12 (frequency 2885 mc) over selected two-hour periods; and one part in one thousand over fifteen-hour periods. For these particular tests, the discharge current was set at 300 ma. Although the emission is slightly higher and less critical to small changes in discharge current at the usual setting of 250 ma,. the audio frequency oscillations characteristic of these tubes[1] were more intense and irregular, with correspondingly poorer results as to consistency of output reading over a period of time. Whether the fault should be ascribed to the tube or the particular measuring equipment used, it is probably preferable to operate at 300 ma discharge current when extreme accuracy is desired. The A147 tubes gave satisfactory results at their recommended discharge current of 250 ma.

Whether this degree of consistency of output can be maintained over much longer periods of time has not been established. Several tubes were retested after intermittent operation, continuous operation, repeated on-off cycling, or shelf-life of several months; some of these appeared to have changed in emission by as much as 50°, but these changes were not clearly related to the history of the tube. On this basis, the relative accuracy to be expected from the operation of a single tube, either continuously or intermittently, over periods of months, may not be better than one part in two hundred.

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* Received by the PGMTT, April 10, 1959.

[1] H. Johnson and K. R. DeRemer, "Gaseous discharge super-high frequency noise source," Proc. IRE, vol. 39, pp. 908–914; August, 1951.

[2] J. E. Sees, "Fundamentals in Noise Source Calibrations at Microwave Frequencies," Naval Res. Lab. Rep. No. 5051; January, 1958.

[3] V. A. Hughes, "Absolute calibration of a standard temperature noise source for use with S-band radiometers," *Proc. IEE*, pt. B, vol. 103, pp. 669–672; September, 1956.

[4] N. Houlding and L. C. Miller, "Discharge tube noise sources," Radar Res. Est., Great Malvern, Worcs., Eng., T.R.E. Memo. No. 593; October, 1953.

[5] P. Parzen and L. Goldstein, "Current fluctuations in D.C. gas discharge plasma," *Phys. Rev.*, vol. 79, p. 190; July, 1950.