the pattern reverse with a frequency variation within 10 per cent. It is not necessary to use the ferrite below and above ferromagnetic resonance to achieve this reverse.

Fig. 4 shows the graphs of decoupling and forward loss of the two ports adjacent to the input for two typical cases. For a properly shaped ferroxcube 5D3 ($4\pi M_s \approx 2900$ gauss) a large separation of the two optimum frequencies for opposite circulation has been achieved whereas for ferroxcube 5A2 ($4\pi M_s \approx 1450$ gauss) with another shape and in another magnetic field the oppositely circulating frequencies have been brought close together. The cross decoupling was in all cases observed to be more than 15 db. It should be remarked that for the cross decoupling much higher db-values can be achieved if more attention is paid to the impedance matching.

Figs. 5 and 6 give the optimum working frequencies and the pertaining ratios of decoupling and forward losses as a function of the applied magnetic field and the height of the ferrite body, respectively. Fig. 7 gives the separation of the optimum frequencies for both senses of circulation for three different saturation magnetizations. Shape, applied field, and matching element are kept constant.

Finally it may be concluded that the described device—apart from some technical imperfections such as the poor cross decoupling—can be used as a quadruplexer if the power of the transmitters is not very much higher than that of the received signals. A proper design, such as used in the experiments described above, has two main advantages; namely, a normal polycrystalline ferrite can be used and the separation of the two oppositely circulating frequencies can be varied over a rather wide range because no absorption losses are limiting it.

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A Resonant Slope Amplifier Using A Microwave Pump Frequency*

Resonant slope (or resonant dielectric) amplifiers are of interest because of their high-input impedance and low-frequency capability.

The desire for a resonant slope amplifier, and the ready availability of microwave components in the Boeing Applied Physics Laboratory, led to the development of such an amplifier using a microwave pump frequency.

Fig. 1 shows a sketch of the amplifier system. The only nonstandard component used in the system is the cavity; the cavity is a section of X-band waveguide terminated at one end by an adjustable short, and at the other (input-output end) by a coupling iris. An MA 4296 varactor is mounted in the cavity at a position where the electric field is maximum (the cavity operates in the TE_{102} mode). Actually, a standard tunable detector mount such as the HPX485B could be used, with a coupling iris, for the cavity if the crystal mount were altered to provide a means for biasing the varactor.

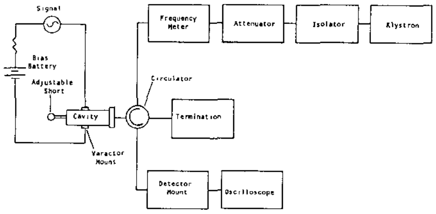

Fig. 1—Sketch of resonant slope amplifier system.

The principle of operation is virtually identical to that of the conventional lumped-circuit resonant slope amplifier. The varactor and the cavity form the resonant circuit. With no signal input, the adjustable short position and the klystron frequency are adjusted so that the circuit is slightly off resonance—the no-signal operating point is on the slope of the resonance curve. (A circulator is used, therefore resonance is indicated by a dip in the output; thus, the response curve of the circuit and circulator is inverted as compared to the response curve of the lumped, tuned circuit usually used.) The varactor is reverse-biased, and the signal is applied in series with the bias.

The signal varies the varactor capacitance which, in turn, varies the resonant frequency (or operating point) of the circuit. Thus, for small signals, the amplitude of the energy which is reflected by the cavity, and thus appears in the output of the circulator, follows that of the input signal. And, under proper conditions, the amplitude of the detected output signal can be much greater than that of the input.[1–4]

The power gain of our experimental amplifier at signal frequencies from dc through about 50 kc was constant at approximately 42 db. The pump frequency was 8.5 Gc. The input impedance, which is mainly a function of the varactor used, was about 2 megohms; impedances as high as 10^{10} ohms appear feasible.[5] The output impedance was about 1800 ohms.

The obvious disadvantage of the microwave version of the dielectric amplifier is its bulk. However, it is easily assembled from standard microwave components and comparatively large voltage gains are possible because of the high-Q microwave cavity.

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[1] L. A. Pipes, "A mathematical analysis of a dielectric amplifier," *J. Appl. Phys.*, vol. 23, pp. 818–824, August, 1952.

[2] G. W. Penney, J. R. Horsch, and E. A. Sack, "Dielectric amplifiers," *Trans. AIEE* (*Commun. and Electronics*), vol. 72, pp. 68–79, March, 1953.

[3] G. W. Penney, E. A. Sack, and E. R. Wingrove, "Frequency response of a resonant dielectric amplifier," *Trans. AIEE* (*Commun. and Electronics*), vol. 73, pp. 119–124; May, 1954.

[4] E. A. Sack and G. W. Penney, "Voltage gain of a resonant dielectric amplifier, *Trans. AIEE* (*Commun. and Electronics*), vol. 74, pp. 428–434; September, 1955.

[5] D. Roveti, "Diode amplifier has ten-gigohm input impedance," *Electronics*, pp. 38–40; December 22, 1961.

A Three-Port Network with Constant Phase Difference Properties*

I. Introduction

The 90° hybrid and the 180° TEM magic tee can, at least theoretically, be made to work over bandwidths of 10 to 1, and more. The device described is not limited to 90° or 180°. It provides a phase shift between its outputs that is not only constant with frequency, but also capable of being set at any value. In addition, the ratio of the powers delivered to the outputs may be set as desired.

II. Polarizing Element

There are classes of antennas in existence that have constant properties over very wide frequency ranges. One of the principal types is the arithmetic spiral. The arithmetic spiral is a circularly polarized element made up of two conductors winding in a flat plane (Fig. 1). The element is usually fed by means of a coaxial line connected between the two conductors at their center terminals. The bandwidth of the spiral is limited at the high end by the difficulty in winding the small central turns. No such difficulty is encountered at the low end, although in practice the circumference of the outer turns is kept less than 2λ at the highest operating frequency. Bandwidths of four to one and better are easily obtained with this type of element. The device described utilizes the wide-band polarization properties of arithmetic spirals to provide a constant phase difference between the outputs of a three-port network.[1] The network is frequency-

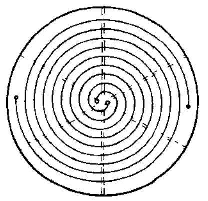

Fig. 1—The arithmetic spiral.

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* Received August 22, 1962.

[1] The arithmetic spiral is used in this discussion by way of illustration. Actually, any broad-band circularly polarized element may be used.