ing in additional noise. We must await the noise measurements.

The ferrite device is capable of higher output powers than the maser and operates at room temperature. At the present stage the solid-state masers are low temperature devices.

Mr. Anderson: Could we get some suggestions for nomenclatures for these devices, three-level maser, two-level maser, the ferrite or garnet amplifier, so that maybe we could start using a common name?

Dr. Scovil: I believe the term "maser" should be restricted to devices utilizing a population inversion or negative temperature and that the various masers should be differentiated perhaps by a prefix indicating their method of operation; *e.g.*, ammonia beam maser, two-level maser, three-level maser, etc.

I think that the christening of the ferrite device is best left to Drs. Suhl and Weiss who have produced it. It does not fall in the category of negative temperature devices.

Dr. R. W. Damon (General Electric Co.): The principal reason for the great interest in resonance amplification devices lies in their potentiality as low noise amplifiers. Usually the term "noise" refers only to a fluctuating output observed in the absence of a signal, but, under some conditions, random variations in amplifier gain also should be considered. In this respect, the ferromagnetic amplifier might be at some disadvantage compared to the three-level paramagnetic device. The paramagnetic amplifier uses the driving oscillator only to create a saturation condition for a pair of energy levels. If the driving power is sufficiently large, fluctuations in the driving level have little effect on the degree of saturation and the gain is thus independent of small variations in driving power. The ferromagnetic amplifier, on the other hand, operates as a negative resistance device, obtained by driving a nonlinear reactance with power level above a certain instability threshold, and fluctuations in power level of the driving source will lead to fluctuations in gain.

Dr. Hogan: Well I have just been informed that in about 3 minutes the lights in this auditorium will be turned out, so I suggest we start on our way.

Correspondence

Note on Impedance Transformations by the Isometric Circle Method*

The isometric circle method is a graphical method of transforming a complex quantity by the linear fractional transformation. It has recently been applied to impedance transformations through bilateral two-port networks.[1] The purpose of this note is to show the connection between the isometric circle method and another graphical method called the "triangular" method, and also to present a useful formula for reflection-coefficient transformations through bilateral, lossless two-port networks.

The triangular method is described in an unpublished paper by Mason.[2] In this method it is assumed that one pair of corresponding values $Z_a \rightarrow Z_a'$ is known for the linear fractional transformation

$$Z' = \frac{aZ + b}{cZ + d}, \quad ad - bc = 1 \tag{1}$$

where, for a fixed frequency, a, b, c, and d are complex constants. The values $Z' = O_i = a/c$ for $Z = \infty$, and $Z' = \infty$ for $Z = O_d = -d/c$ are known also. For an arbitrary impedance Z, the transformed impedance Z' is constructed by drawing the similar triangles O_dZ_aZ and $O_iZ'Z_a'$ in the complex impedance plane. See Fig. 1. The connection between the triangular method and the isometric circle method is shown in Fig. 1. In Fig. 1, the different operations of the isometric circle method (marked by arrows) are indicated by the points Z_1, Z_2, and Z', and the angle $-2 \arg (a+d)$ is denoted by θ.

Impedance transformations through bilateral, lossless two-port networks can be performed by the equation

$$Z' = \frac{a'Z + jb''}{jc''Z + d'}, \quad a'd' + b''c'' = 1, \tag{2}$$

where $a' = \text{Re } a$, $b'' = \text{Im } b$, $c'' = \text{Im } c$, and $d' = \text{Re } d$. Expressed in reflection coefficients,

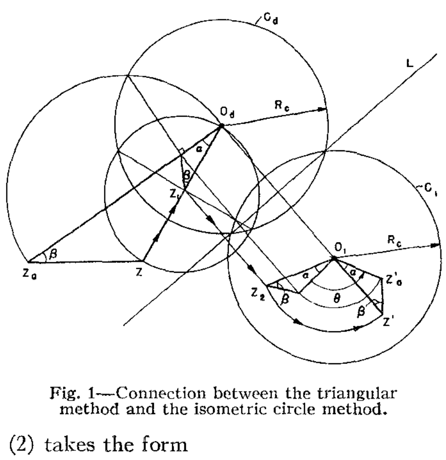

Fig. 1—Connection between the triangular method and the isometric circle method.

(2) takes the form

$$\Gamma' = \frac{A\Gamma + C^*}{C\Gamma + A^*}, \quad |A|^2 - |C|^2 = 1, \tag{3}$$

where

$$A = (a' + d')/2 - j(b'' + c'')/2$$
$$C = (a' - d')/2 - j(b'' - c'')/2. \tag{4}$$

A star indicates a complex conjugate quantity.

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[1] E. F. Bolinder, "Impedance and polarization-ratio transformations by a graphical method using the isometric circles," IRE Trans., vol. MTT-4, pp. 176–180; July, 1956.

[2] S. J. Mason, "A Simple Approach to Circle Diagrams"; 1954.

We can write (3) in the form

$$\Gamma' = \frac{\Gamma \cosh \psi e^{j\phi_a} + \sinh \psi e^{-j\phi_c}}{\Gamma \sinh \psi e^{j\phi_c} + \cosh \psi e^{-j\phi_a}}, \tag{5}$$

where ψ, ϕ_a, and ϕ_c can easily be expressed in a', b'', c'', and d'.

The isometric circles of (5) are given by

$$\left.\begin{aligned} O_d &= -\coth \psi e^{-j(\phi_a+\phi_c)} \\ O_i &= \coth \psi e^{j(\phi_a-\phi_c)} \\ R_c &= 1/|\sinh \psi| \end{aligned}\right\}. \tag{6}$$

Eq. (5) has recently been used as a basis for an elementary study of impedance transformations through bilateral, lossless two-port networks.[3] A somewhat more complicated study of the same type of network has been performed by means of non-Euclidean hyperbolic geometry in the two-dimensional Cayley-Klein diagram.[4] Similarly, bilateral, lossy two-port networks have been studied by means of the Cayley-Klein model of the three-dimensional hyperbolic space[5].

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[3] E. F. Bolinder, "Some applications of the isometric circle method to impedance transformations through lossless two-port networks," presented at the URSI-USA meeting in Washington, D. C.; May 22–25; 1957, and *Acta Polytech., Elec. Eng. Ser.*, to be published.

[4] ———, "Graphical methods for transforming impedances through lossless networks by the Cayley-Klein diagram," *Acta Polytech., Elec. Eng. Ser.*, vol. 7, no. 202; 1956.

[5] ———, "Impedance transformations by extension of the isometric circle method to the three-dimensional hyperbolic space," *J. Math. Phys.*, vol. 36, pp. 49–61; April, 1957.

On the Pressure Dependence of Microwave Crystal Rectifiers*

During the past couple of years, as a result of government interest, silicon microwave crystal rectifiers have not only decreased their noise figures but also have increased their resistance to adverse environments; *i.e.*, high burnout, high temperature, excessive humidity.

However, recent requirements have indicated a need for microwave crystal rectifiers which operate at low pressures; *i.e.*, high altitudes. Unfortunately, while there is no obvious reason to suspect any serious pressure dependence of any of the crystal parameters, there have been no quantitative operating measurements made as far as can be determined, except for the fact that radars do work in airplanes.

Therefore, in order that the current silicon microwave crystal rectifiers be characterized in so far as low pressure is concerned, a measurement of all the crystal parameters was performed in a reduced atmosphere.

All crystal measurements were made on a special test set which enables one to measure all the crystal parameters, primarily at the test frequency of 9375 mc under the established JAN conditions.[1] The conversion loss was measured by the usual modulation method. The noise temperature (ratio) was measured by comparing the noise power output of the crystal under test with the noise power output of a (equivalent) resistor. The vswr was measured with the standard slotted section, and the IF impedance by the use of an ac wheatstone-bridge type circuit operating at 1000 cps. The over-all noise figure of each crystal was measured by inserting a known amount of excess noise into the crystal at the signal frequency (9375 mc ±30 mc) and determining the increase in output power.

The crystal mixer (holder) was placed in a bell jar which could be evacuated by a nearby fore-pump. The reduced pressure was measured with the aid of an attached, calibrated altimeter. The crystal was initially measured in this holder at normal conditions, measured at the desired pressure, and remeasured at the standard (initial) conditions. The results of the measurements are shown in Table I.

TABLE I
Results of Measurements of Microwave Crystal Rectifiers At Standard and Reduced Pressures
Initial Readings—Standard Pressure

Number	Pressure (mm Hg)	Rectified Current (ma)	Conversion Loss (db)	Noise Temperature (times)	IF Impedance (ohms)	VSWR	Over-all Noise Figure (db) F_{IF}=3.2 db approx.
1	760	1.44	4.6	1.3	342	1.23	8.6
	15	1.28	4.9	1.3	361	1.39	8.4
	760	1.30	4.7	1.3	362	1.41	8.4
2	760	1.37	4.5	1.2	350	1.23	8.0
	15	1.33	4.6	1.2	359	1.28	8.2
	760	1.33	4.6	1.2	359	1.28	8.0
3	760	1.30	4.7	1.4	397	1.21	9.1
	15	1.30	4.7	1.4	399	1.22	9.0
	760	1.30	4.7	1.4	400	1.22	9.0
4	760	1.42	4.4	1.2	352	1.11	7.9
	15	1.39	4.5	1.2	356	1.16	8.0
	760	1.39	4.5	1.2	357	1.16	7.8
5	760	1.44	4.5	1.3	329	1.19	8.2
	15	1.44	4.6	1.3	331	1.19	8.2
	760	1.44	4.5	1.3	332	1.20	8.0
6	760	1.18	5.2	1.3	370	1.20	9.3
	15	1.16	5.5	1.3	375	1.20	9.1
	760	1.18	5.1	1.3	374	1.20	9.0
7	760	1.18	5.5	1.5	343	1.35	10.2
	15	1.14	6 0	1.5	346	1.36	10.2
	760	1.17	5.6	1.5	344	1.34	9.9
8	760	1.12	5.4	1.5	345	1.46	9.9
	15	1.12	5.5	1.6	349	1.47	10.1
	760	1.11	5.5	1.6	347	1.46	9.9
9	760	1.12	5.5	1.3	353	1.22	9.3
	15	1.12	5.6	1.3	357	1.22	9.3
	760	1.12	5.6	1.3	357	1.23	9.1
10	760	0.99	5.7	1.5	425	1.36	10.1
	15	1.00	5.8	1.5	424	1.37	10.2
	760	0.99	5.8	1.5	426	1.37	10.1

Table I shows that the crystal parameters were found to be essentially constant under reduced pressure and at standard pressure after the test when compared with initial measurements. Therefore, one can conclude that under the stated conditions (*i.e.*, MIL-E-1-C, JAN 1N23C, E or WE) up to an atmosphere of 85,000 feet (15 mm Hg) the cartridge type, JAN, silicon microwave crystal rectifiers show little or no degradation in performance due to a reduced pressure environment.

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[1] See 1N23C, E or WE Specifications issued by USASESA, Fort Monmouth, N.J.; also see Torrey and Whitmer, "Crystal Rectifiers," McGraw-Hill Book Co., Inc., New York, N. Y., ch. 9; 1948.

* Received by the PGMTT, October 14, 1957.