

We can write (3) in the form

$$\Gamma' = \frac{\Gamma \cosh \psi e^{i\phi_a} + \sinh \psi e^{-i\phi_c}}{\Gamma \sinh \psi e^{i\phi_a} + \cosh \psi e^{-i\phi_c}}, \quad (5)$$

where  $\psi$ ,  $\phi_a$ , and  $\phi_c$  can easily be expressed in  $a'$ ,  $b'$ ,  $c''$ , and  $d'$ .

The isometric circles of (5) are given by

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

Eq. (5) has recently been used as a basis for an elementary study of impedance transformations through bilateral, lossless two-port networks.<sup>3</sup> 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.<sup>4</sup> Similarly, bilateral, lossy two-port networks have been studied by means of the Cayley-Klein model of the three-dimensional hyperbolic space.<sup>5</sup>

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<sup>3</sup> 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.

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

<sup>5</sup> —, "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.

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, primar-

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

## 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

ily at the test frequency of 9375 mc under the established JAN conditions.<sup>1</sup> 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  $\pm$  30 mc) and determining the increase in output power.

<sup>1</sup> 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.

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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