to quantitative terms. Table I shows a remarkable agreement between the true quarter wavelength in each ridge-guide section and the sum of the length of that section and half the height of the previous step.

TABLE I

Section No.	1	2	3
λ_c	5.15 cm	7.9	12.6
$\lambda/4$ at 9 kMc	1.091 cm	0.915	0.863
Actual length +half step height	1.092 cm	0.938	0.863

The agreement seems too good to be fortuitous and it would be interesting to find out for what range of ridge width and height it holds.

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Pulse-Operated Circulator Switch*

One of the major disadvantages of employing a ferrite circulator as a microwave switch is the holding current required to maintain the circulator in the switched position. One solution to this problem, reported by Levey and Silber,[1] is the utilization of ferrite tubes as the differential phase shift element in a circulator. Switching is accomplished with a single pulse of current which reverses the magnetization in the closed ferrite tubes, and by virtue of the closed magnetic path, remains permanently magnetized in this new state. Using this technique, microsecond switching speeds have been obtained. This approach requires a ferrite that has both the requisite microwave and dc magnetic characteristics which all too often are unattainable in a commercially available material and necessitates the development of a special material.

For many applications in which microsecond switching speeds are of no consequence, but it is mandatory that the holding current be eliminated, another approach may be followed; the best microwave material for the frequency and application of interest is used in the microwave circuit and a switchable magnetic material, external to the microwave circuit, is used to supply the bias field requirements. This arrangement provides greater flexibility in the realization of pulse actuated ferrite switches. The coercive force of the switchable magnetic material must be such that the remanent magnetization may be reversed with a current pulse of reasonable magnitude and yet retain the proper amount of magnetization at the conclusion of the current pulse. The coercive force required depends on the magnetic circuit, a greater coercive force being required when air gaps are introduced.

Using this technique, a stripline symmetrical junction circulator was converted to a pulse-operated switch. The low bias field requirement of 200 gauss[2] was obtained from a commercial steel (SAE 4130) whose composition is similar to that of a chromium permanent magnet steel. This material was used as the core of an electromagnet consisting of 30 turns of wire, located in each ground plane over the ferrite loaded junction; a soft iron, U-shaped bracket completed the magnetic circuit. Fig. 1 is a photograph of the switch.

Fig. 2 is a photograph of an oscilloscope trace showing the pulse actuated switching action. The top trace shows the train of dc current pulses of opposite polarity that causes reversal of the magnetic bias; the bottom trace is the rectified output of one port showing the switching action. The output drops from 0.5-db insertion loss to 20 db down at an operating frequency of 2050 Mc. In this configuration, 5-ampere current pulses are required to reverse the magnetization and place the "open circuit" magnetic field at 200 gauss. Pulse widths of 140 msec were used because they were readily available in the laboratory, but since the switching time is approximately 5 msec, pulse widths of 10 msec should suffice to produce the switching action for this unit.

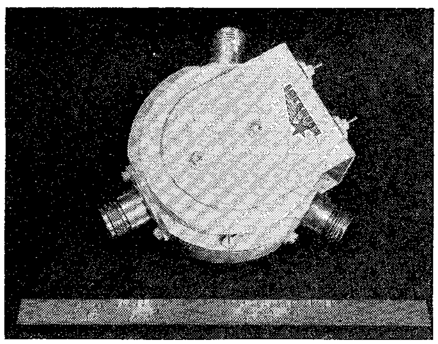

Fig. 1—Model of pulse-actuated ferrite switch.

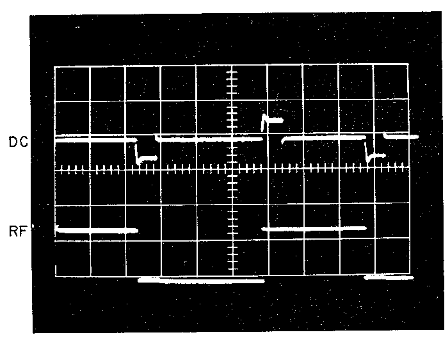

Fig. 2—Oscillograph showing pulse-actuated switching action, 200 msec/cm.

Faster switching times could be obtained by reducing the number of turns in the electromagnet. Fig. 3 shows the characteristics of the circulator-switch biased only by the remanent magnetization of the steel; after 24 hours at room temperature in this state, no changes in these characteristics were noted.

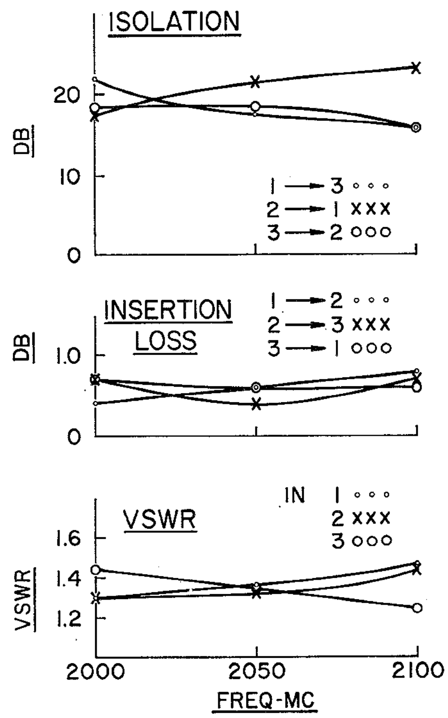

Fig. 3—Characteristics of ferrite circulator-switch.

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* Received by the PGMTT, February 21, 1961.

[1] L. Levey and L. M. Silber, "A fast-switching X-band circulator utilizing ferrite toroids," 1960 IRE WESCON Convention Record, pt. 1, pp. 11–20.

[2] L. Freiberg, "Lightweight Y-junction strip-line circulator," IRE Trans. on Microwave Theory and Techniques, vol. MTT-8, (Correspondence), p. 672; November, 1960.

Polishing Technique for Garnet Spheres*

A new technique using a motor-driven polishing head intended primarily for the final stages of polishing yttrium-iron-garnet spheres has been developed. This method has produced several fractional oersted linewidth crystals including a matched pair of 0.060-inch diameter spheres ground simultaneously.

The polishing device shown in Fig. 1 uses a 200-rpm motor with a $\frac{5}{8}$-inch-diameter

* Received by the PGMTT, March 1, 1961.