V-14. A Mono-Control Microwave Semiconductor Switch

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The circuit shown in Fig. 1 has the useful property that the impedance looking into the input remains matched if the two outputs are terminated in matched loads regardless of the value of Z, whether it be reactive, real or even negative. This statement is conditional on the requirement that the value of Z be identical in two locations. The division of power to the two outputs is not independent of Z but is controlled by it. Obviously, if Z is reduced to zero, output #1 will be shorted out and no power will appear at that port. In the converse, if Z is infinite, output #2 is shorted out by the open-circuited quarter-wavelength stub.

Knowing the properties of quarter-wavelength lines and considering the special cases of Z being zero and infinite impedance, it can be easily reasoned that the input is matched and all power is transferred to one port or the other. For any in-between values of Z, it can be shown analytically that the input remains matched and the power is divided between Z and the two outputs, with the division being dependent on the value of Z.

As mentioned before, the input remains matched for any complex value of Z; but if for simplicity only, real positive values of Z are considered, the attenuation to the two outputs is given by:

$$\alpha_1 = 10 \log \left(\frac{Z_o}{R} + 1\right)^2 \text{ db} \tag{1}$$

$$\alpha_2 = 10 \log \frac{\left(\frac{Z_o}{R} + 1\right)^2}{\left(\frac{Z_o}{R}\right)^2} \text{ db,} \tag{2}$$

where Z_o = characteristic impedance and $R = Z$.

Equations (1) and (2) are plotted in Fig. 2. As an example, if R/Z_o is varied from 0.1 to 10, a *SPDT* switching would be obtained with 0.8 db in-

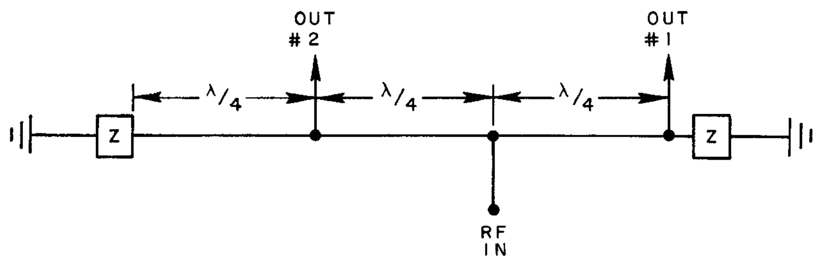

Fig. 1 Mono-control switch equivalent circuit.

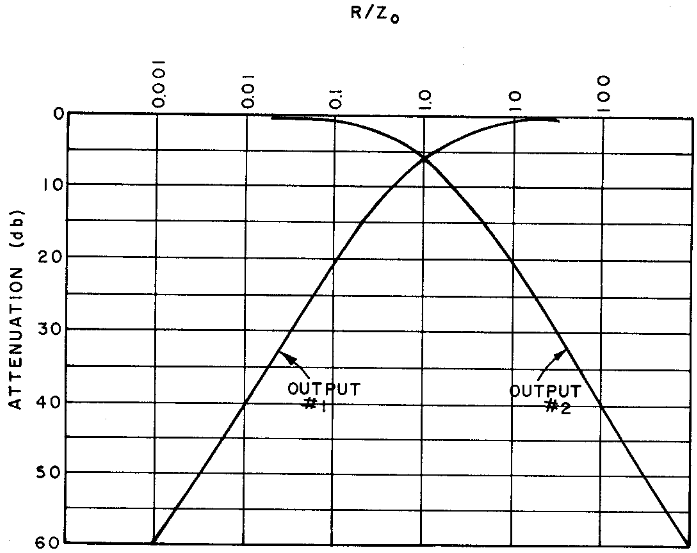

Fig. 2 Computer power division as a function of normalized diode impedance.

sertion loss and 20.8 db isolation. Varactors or *PIN* diodes provide a means of obtaining an impedance that can be varied by means of a bias over such a dynamic range. A semiconductor switch is then made by providing a structure with the necessary quarter-wavelength lines and control (biasing) circuit with the diodes providing the Z's of Fig. 1. The diodes must be reasonably identical and are connected to the same control terminal. The diodes need not be tuned for the input of the switch to be matched. A wider dynamic range or impedance can be obtained by tuning the diodes, which will result in improved isolation and insertion loss, as shown by Fig. 2. If the diodes provide a sufficient variation without tuning, as is often the case with *PIN* diodes, there is no need for tuning and the structure can thus be simplified.

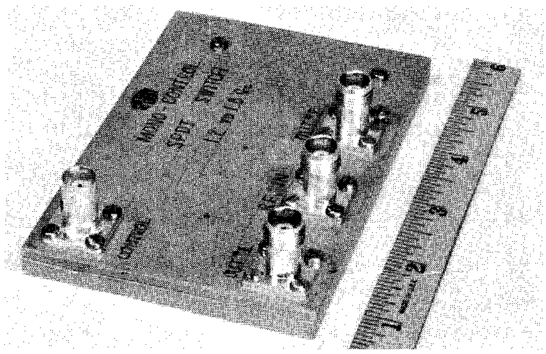

Fig. 3 Experimental mono-control switch.

An experimental switch was designed using this structure for a center frequency of 1500 Mc. The switch is in strip transmission line and uses two simpler pig-tail lead *PIN* diodes directly soldered into the circuit. A photograph of the switch is shown in Fig. 3. The use of the pig-tail lead diodes and no tuning provisions reduces to the minimum the number of machined parts required, making the switch readily producible; the mono-control feature makes system utilization equally simple.

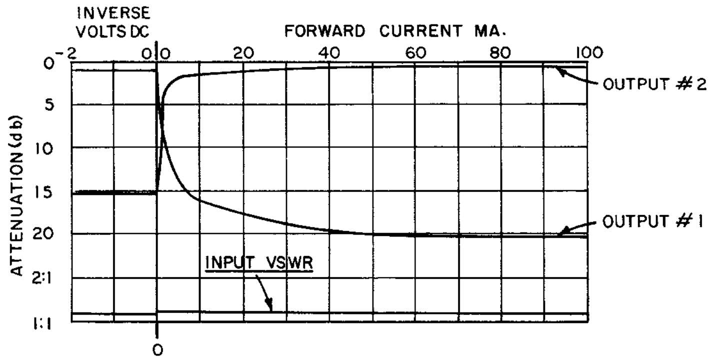

Fig. 4 Power division and VSWR vs mono-control signal. Frequency = 1500 Mc.

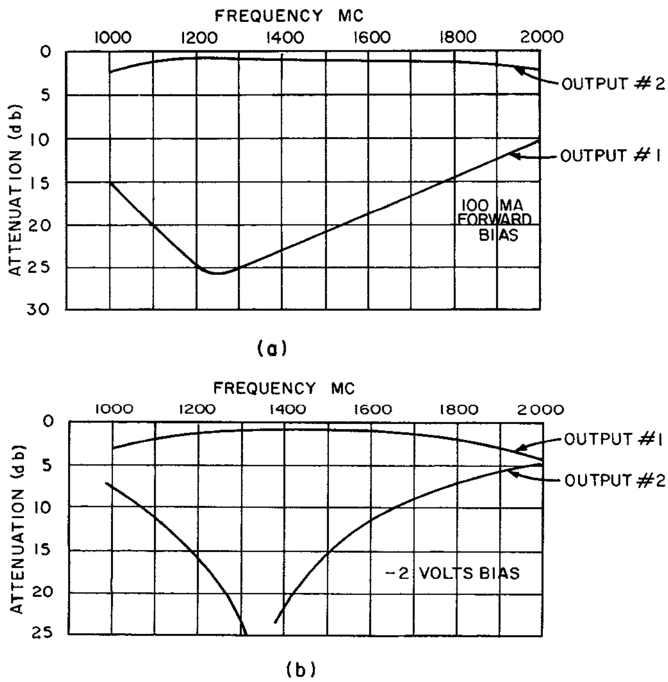

Fig. 5 (a) Frequency characteristics at inverse bias. (b) Frequency characteristics at forward bias.

Experimental data, measured with this switch, is presented in Fig. 4, 5 and 6. The effect of the mono-control signal on the division of power and *VSWR* is shown in Fig. 4. It is to be noted that most of the change occurs between zero and 5 ma of forward bias and, with further increases in the forward, or excursions into the inverse bias range, serve to give a slight improvement in isolation or insertion loss. This allows the switch to be overdriven to give a digital type response. The input is inherently matched during the switching interval, which is also confirmed experimentally by the data given by Fig. 4.

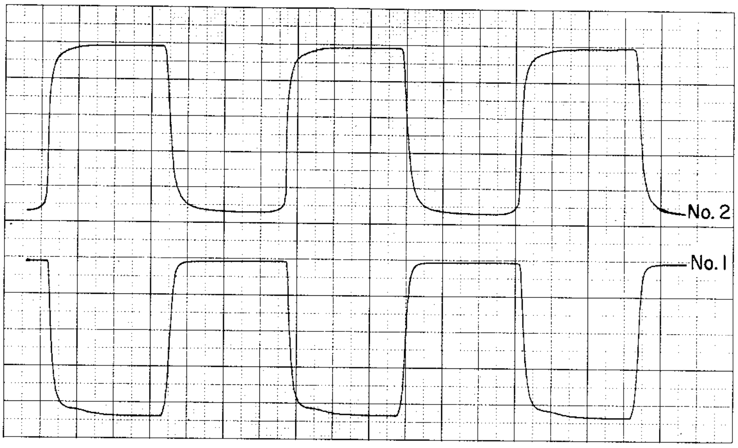

Fig. 6 Switch outputs when driven by 50 kc sine wave control signal. Frequency = 1500 Mc.

The frequency characteristics of the switch are shown in Figs. 5 (a) and 5 (b). Figure 5 (a) is for the inverse bias case, where the power is switched to output # 1, and Fig. 5 (b) is the forward bias case with the power switched to output # 2. The switch shows surprising bandwidth for a component that depends on quarter-wavelength lines, having less than 1 db insertion loss over a 400 Mc bandwidth. Though not explained in this summary, broadbanding techniques were incorporated in the design and will be explained in the presentation.

For a dynamic test, the switch was driven by a laboratory signal source supplying a 50 kc sine wave for the mono-control input, and the two rf outputs were detected and monitored by a dual channel sampling scope and recorded by means of a *X-Y* recorder. This recording is shown in Fig. 6. It can be noted that, even though the control signal was a sine wave, the rf outputs are square-wave modulated because of the digital response of the switch. The switching time, being a function of the diodes, was about 1 microsecond for the *PIN* diodes used. Varactors could reduce this switching time to the nanosecond range.

Work is progressing on miniaturized versions of the switch for *L* and uhf frequency bands. Progress and the means of miniaturization will be reported at the conference presentation.