IX-1. A FAST MILLIMETER FERRITE LATCHING SWITCH

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During the past few years considerable interest has been generated in remanent latching ferrite phase shifters, especially the non-reciprocal type as conceived by Silber,[1] for phased array antennas. By utilizing the square loop properties of ferrites and operating them in the two remanent states, differential phase shift is obtained. These phase shifters possess the virtue of extreme compactness, ability to sustain high peak and average powers, are self-latching, that is required no holding power in either state, and can be switched rapidly with low energy.

The initial step in arriving at an efficient latching ferrite phase shifter design was to determine the optimum physical dimensions of the ferrite toroid. The objective was to find a geometry which would yield a maximum phase shift and minimum insertion loss per unit length. Several toroidal configurations were examined. The effects of dielectrically loading the center of the toroid were also investigated. Three ferrite materials were considered, Mg Mn (TT-390), NiZn and Lithium. A summary of the results obtained with these materials is as follows:

Material	t - inch	D - inch	Dielec Loading	Degrees/ inch	Degrees/ db
TT-390	.024	.060	None	28	37
"	.024	.060	k = 9	64	64
"	.010	.050	None	55	104
"	.010	.050	k = 9	64	160
"	.010	.050	k = 13	70	140
"	.010	.050	k = 16	78	143
"	.010	.045	None	49	66
NiZn	.010	.050	None	Too much loss	
"	.010	.050	k = 13	135	270
"	.010	.045	k = 13	131	300
"	.010	.050	k = 16	151	251
Li	.010	.050	k = 13	87	174

t = width of slot
D = width of toroid
The height of all the test toroids was 0.140"
Switching wire AWG #33 lacquer coated

The resultant basic phase shift element is shown in Figure 1 and represents the optimum configuration which yielded the best results with regard to phase shift and insertion loss while simultaneously avoiding undesirable moding effects. The material chosen for the final model was the nickel zinc because of its high figure of merit. The ferrite toroid slot was dielectrically loaded with a material of K = 13 whose dimensions were 0.008" X .060". Figure 2 illustrates the characteristics of the 90° bit.

A single pole double throw switch was then fabricated around two 90° phase shift elements as shown in Figure 3. The design was patterned after the differential phase shift switchable circulator approach. Switching pulses were supplied to the switch by dual R-C discharge circuits which supplied current pulses of alternate polarity at a peak current of 6 amps. The switch was reversed in 1.3 usec. with approximately 21 microjoules of energy across the ferrite. Figure 4 illustrates the insertion loss, isolation and VSWR characteristics of the switch over the frequency range of 35.9 - 37.0 Gc. The insertion loss is 0.75 db max. at both outputs and the isolation exceeds 26 db. By adjusting the pulsing wire, the operating frequency was extended to 33.8 - 36 Gc with a slight increase in insertion loss and decrease in isolation. Figure 5 illustrates the insertion loss, isolation and VSWR characteristics of the switch with the broader operating bandwidth. In this case the insertion loss is 1.0 db max. and the isolation 20 db min.

The switch was also tested at 36 Gc with a 1.0 usec pulse, 0.001 duty cycle and 50 kw of peak power. The insertion loss did not increase at this power level. Since no more power was available for test, the peak power at which nonlinear effects would be present could not be determined.

ACKNOWLEDGMENT

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REFERENCE

1. Levey, Land, Silber, "A Fast Switching X-Band Circulator Utilizing Ferrite Toroids," IRE Wescon Convention Record, Part 1, pp. 11 - 20, (1960).

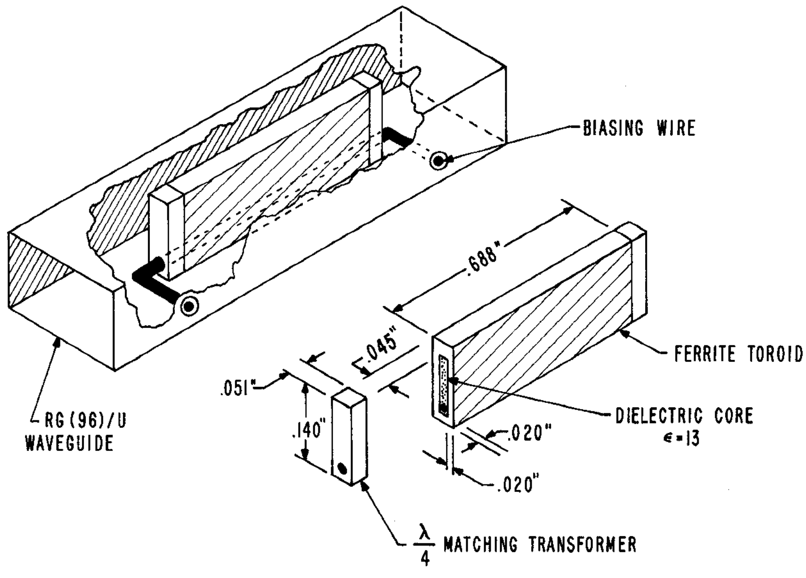

FIG. 1. PHASE SHIFTER CONFIGURATION

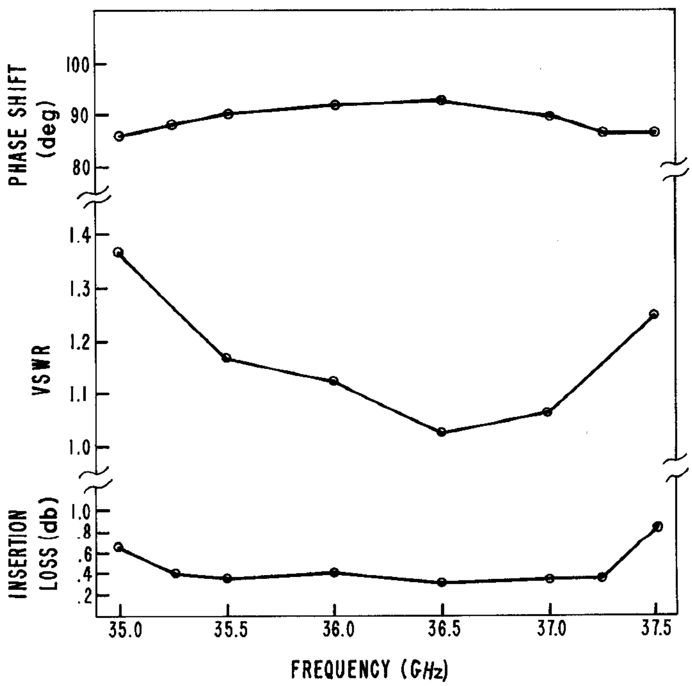

FIG. 2. PHASE SHIFTER CHARACTERISTICS

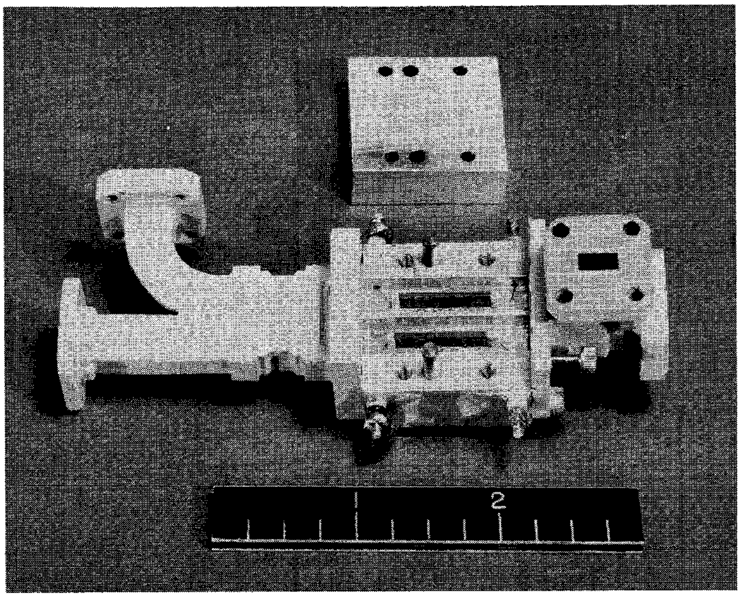

FIG. 3. SWITCH CONFIGURATION

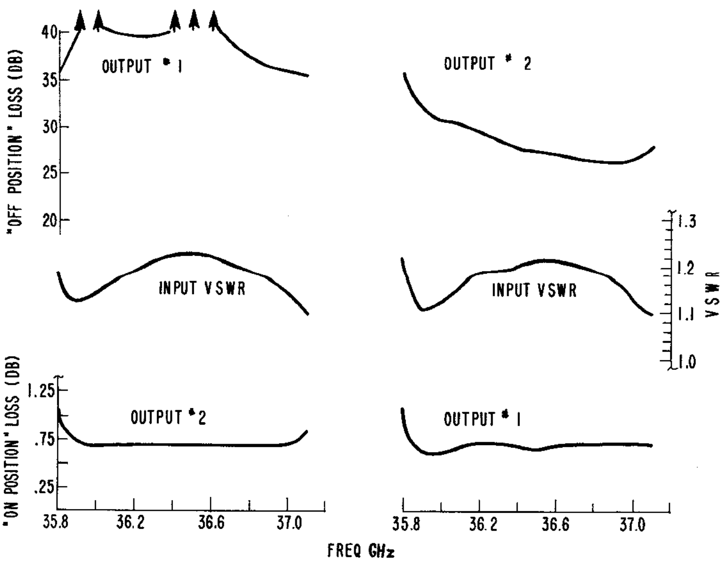

FIG. 4. SWITCH OPERATING CHARACTERISTICS

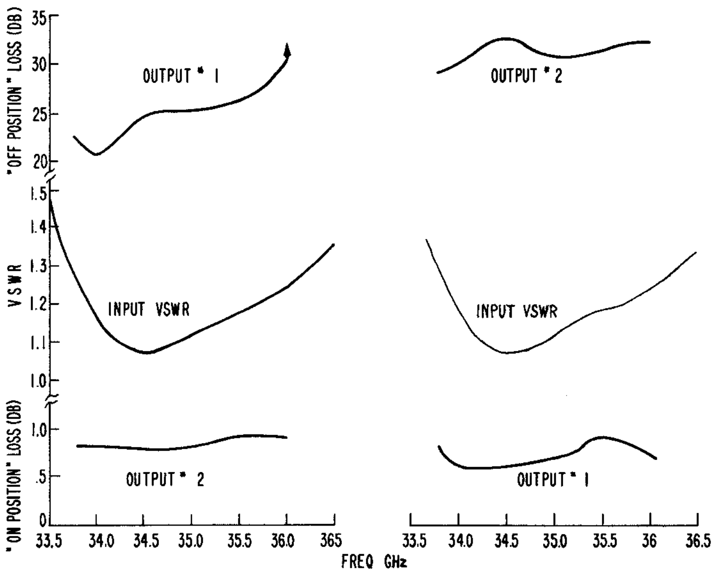

FIG. 5. BROADBANDED SWITCH CHARACTERISTICS