VII-4 HIGH POWER, OCTAVE BAND-WIDTH, SPDT MICROWAVE SWITCHES

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Previously, broadband SPDT switches used, principally, diodes in series with the transmission line -- sacrificing high power performance because of the difficulty with removal of the diodes' heat and compromising switching performance due to the inconvenience in tuning to maximize the isolation. Means for broad-banding the "on" state have been suggested[1], but hitherto undemonstrated is the effectiveness of the approach as well as the availability of a counterpart solution to the problem of broadbanding the "off", or isolation behaviour of a practical switch in which some parasitic series inductance is found.

This paper presents:

1) data for a 1-2 Ghz, SPDT, 1.2 db max. loss and 40 db min. isolation, switch tested to 6 kw pk power at 1 μsec. pulse length and 0.001 duty cycle
2) a design method to permit use of large diode capacity
3) a method for evaluating the effect of parasitic inductance on the "on" state
4) a criterion for minimizing diode ohmic losses
5) tuning requirements to achieve high isolation over broad bandwidths.

CIRCUIT MODELLING

The equivalent circuit is given in Fig. 1. As shown, the diode and an inductive shorted stub are used to simulate a quarter wavelength stub as appropriate to some particular filter design. Fisher suggested a simulation which matches the filter stub's susceptance and its frequency derivative at the switch's arithmetic center frequency. In the case where the largest allowed diode capacity is to be used -- as desired in a high power switch -- the tuner reduces to a lumped inductor, as shown in Fig. 2. But a slightly larger capacitor may be employed if, instead, the susceptance is matched at the band edges, $f_{1,2}$. This is also shown in Fig. 2. An added advantage of the band-edge match occurs for maximally flat loss designs, because the simulation is best where the reflective loss is greatest.

The parasitic inductance of the diode and mount should be kept to a minimum and then series resonated using the bypass capacitor. The resulting circuit branch can be treated as a frequency-variable, effective capacitor as shown in Fig. 3. By placing a bound on the tolerable degree of capacity variation -- either by analysis of the filter design or by intuition -- the bound on f_o/f_R, which is related to L, can be determined. For example, for $< \pm 10\%$ variation over an octave band keep $f_o/f_R < 0.3$.

Figure 4 shows an equivalent circuit useful for estimating the RF dissipation in the diodes. The total dissipation is the sum of the contributions from the forward and reverse biased diodes, given approximately by:

$$\text{I. L.} = \frac{P_{(dissipated)}}{P_{(available)}} = \frac{f}{f_c}\left[\frac{R_F}{R_R}\cdot\frac{X}{Z_o} + (n+1)\cdot\frac{Z_o}{X}\right]$$

where X is $1/\omega C$. A minimum value is achieved by choosing,

$$Z_o = X\sqrt{\frac{R_F}{R_R'(n+1)}}$$

Turning to the "off" arm of the switch, the isolation is given approximately by

$$\text{Isolation} \approx \left(\frac{Z_o}{2\pi f_1}\right)^4 \cdot \left(\frac{F}{L_1 L_2}\right)^2$$

provided the normalized susceptance of the switching elements exceeds 10 and their spacing is between 60 and 120 electrical degrees. This analysis neglects the diodes' resistances and so is valid only away from the resonances $f_{A,B}$. The usefulness arises in determining the minimum values of isolation to be obtained within the band. Using this expression it is possible to show that the minimum isolation to be obtained in the band is maximized by "stagger tuning" the series resonant switching elements at frequencies $f_{A,B}$ so as to satisfy:

$$f_A f_B = f_1 f_2$$

$$f_A^4 - \tfrac{1}{2}(f_1+f_2)^2 f_A^2 + (f_1 f_2)^2 = 0$$

$$f_1 < f_A < \sqrt{f_1 f_2} < f_B < f_2$$

This produces the minimum isolation at $f = f_1$, f_2, and $\sqrt{f_1 f_2}$. The isolation expressions are developed using the model in Fig. 5.

EXPERIMENTAL MODEL

A switch model was constructed based upon Mumford's tabulated[2] 5 stub filter design for a 0.6 db maximum reflective loss across an octave band. The resultant switching performance is shown in Fig. 6. P-I-N diodes of 1.0 pf capacity were used. A total of 6 were employed, i.e. $n \simeq 2$ in reference to Fig. 4. The capacity was much less than the maximum allowed and so Fisher's simulation method was used, which simplified tuning because of the presence of the adjustable stub.

Bias values of −150 volts and +100 ma. per diode were employed. A high power test performed at 1200 mhz with 1 microsecond pulses and a 0.001 duty cycle yielded burnout levels of up to 6 kilowatts peak power. This is about the reverse breakdown limit that should be expected[3] for the 800 to 1000 volt diodes when installed in the 50 ohm impedance switch.

ACKNOWLEDGEMENTS

The authors wish to thank Microwave Associates for whom they performed the study and the Navy who sponsored the project via contract NObsr-93266. Appreciation is also extended to many individual contributors, especially H. Griffin who constructed and tested the switch.

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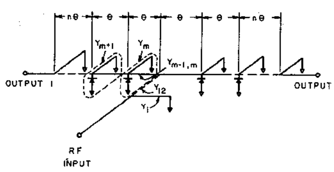

where

Y_m = characteristic admittance of the m^{th} stub,

$Y_{m-1,m}$ = characteristic admittance of the transmission line joining the Y_m and Y_{m-1} stubs.

FIG. 1 - Equivalent Circuit

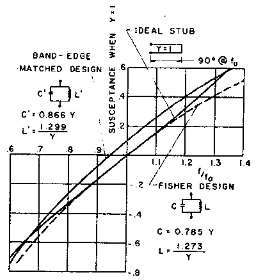

FIG. 2

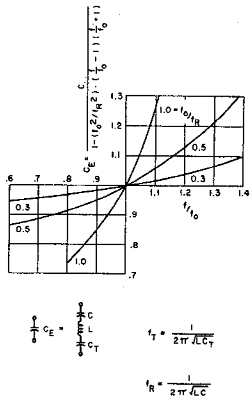

FIG. 3

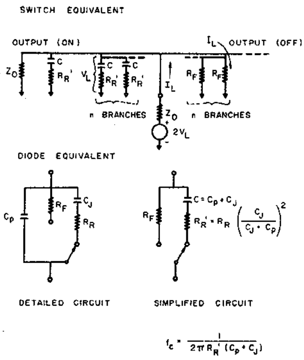

FIG. 4 - Equivalent Circuit

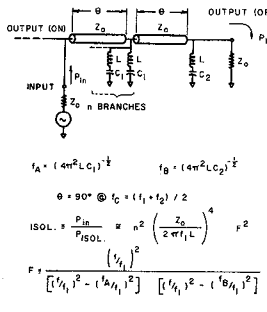

FIG. 5

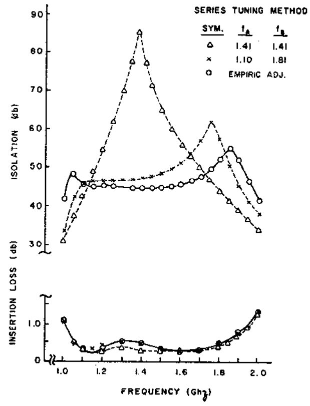

FIG. 6 - Switching Performance

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S.S. Tunnel Diode & Mixer-Preamp-Converters-Attenuators-Duplexers-Modulators-Limiters-Switches-Sources-Multipliers-Levelers-Phase Shifters-Diodes-Materials