V-8 COMPUTER ANALYSIS OF MICRO-WAVE INTEGRATED SWITCHES

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The circuit analysis of microwave networks composed of distributed transmission lines and lumped circuit elements soon become complex when the transmission lines employed have significant loss that must be considered. The many possible combinations of lumped circuit parameters and the use of shorted and open stubs to form resonant circuits useful for the control of microwave energy make it very necessary to use the computer to do the complex calculations for circuit analysis. Such a program must contain the possibility then for the user to specify not only the network numerical values but the way in which these network components are connected. In general the characteristics of a network can be computed from its ABCD matrix.(1) The specification of a network is then broken down into its simplest form called a SECTION, each SECTION being specified by eleven parameter values or circuit TYPE designations. When each SECTION is so specified the computer calculates the transfer ABCD matrix for this section of the network and combines this matrix to the preceding SECTIONS by matrix multiplication before considering the next section of the network. A Flow Diagram for the computer program is shown in Fig. 1. After the first data card containing a name and number for indentification is read the input data for the first case or problem is read. The computer then prints out the titles and input data so specified for the user to check the PARAMETER values and control TYPE numbers given in the data. The specified PARAMETER changes are made in the SECTIONS designated and a set of changes called the VARIABLE is made to the network. The VARIABLE becomes the horizontal axis for plotting the characteristics of the network and the PARAMETER changes generate a family of curves for the network analysis. After each change in the VARIABLE the ABCD matrix is calculated and/or stored in core for later plotting. After all changes in the VARIABLE and PARAMETER are complete, a tape is generated to control the plotting of the network characteristics by the High Speed Microfilm Recorder SC-4020.

MATRIX ANALYSIS OF NETWORKS

When the final section has been added to the network chain of sections the properties of the ABCD matrix are determined. The formulas(1) used for these calculations are listed in Fig. 2. To obtain the output characteristics of the network the values of A and D are interchanged and the output reflection properties calculated. This is equivalent to an interchange of the generator and load. The transmission characteristics of a network are not affected by this interchange. The return loss and VSWR are computed from the reflection coefficient. The input/output impedance or admittance of the network are simple ratios of the terms of the ABCD matrix as given in Fig. 2.

The design of a SPDT switch using diodes in shunt as shorting devices requires a "T" center section. Shunting diodes as switching elements form a quarter-wave stub to present an open at the center of the "T". The optimum line impedance for the arms and stem of the "T" section given in Fig. 3 can be calculated with a few restrictions. The arms of the "T" must be equal for a symmetrical switch design. To form a broadband shorted stub from this "T" section requires that the impedance on each side of the stub be equal resulting in equal impedance sections of line forming the "T" junction. The equation for a maximally flat broadband quarter-wave stub shown in Fig. 3 is:

$$2Y'^{3}_{1} - 2Y'_{1} = Y'_{2}$$

where Y'_1 is the normalized admittance of the transforming quarter-wave sections on each side of the stub.

Y'_2 is the normalized admittance of the quarter-wave stub. Using the restriction of $Y'_1 = Y'_2$ results in:

$$Y'_1 = \sqrt{3/2} = 1.224$$

For a 50-ohm transmission line design the optimum impedance for the "T" line is 40.83 ohms.

Calculations using the computer analysis program are shown in Fig. 4. The impedance of the lines forming the "T" were varied from 50 to 35 ohms. The maximum VSWR at the band width limits is given in Fig. 5. From this curve it is shown that the improvement of bandwidth beyond 75% increases the VSWR maximum rapidly above 1.10 reaching a bandwidth of 92% at a VSWR limit of 1.2

The effect of the optimum "T" impedance on the isolation through the shorting diode switch was computed and synthesized by the diode equivalent resistance when biased "short." The isolation, at mid-band, is not affected by the "T" junction impedance and degrades less than 10% at the octave band edges.

Measured data shown in Fig. 3 indicate the design improvement of the switch by using a 40-ohm "T". A photo of the completed microstrip circuit is shown in Fig. 6. The drivers for the switches are mounted on small ceramic chips and located inside the switch housing.

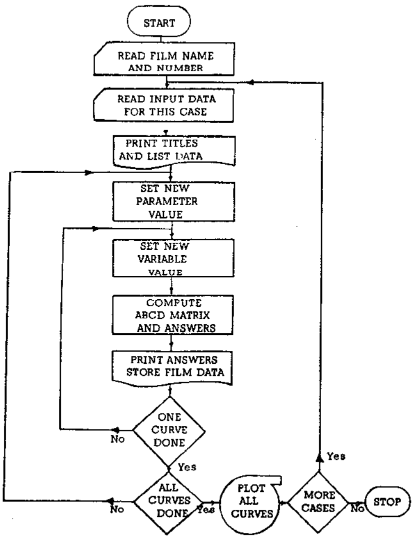
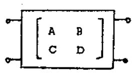


FIG. 1 - General Flow Diagram

Given ABCD Network



TRANSMISSION COEFFICIENT

$$T = \frac{2}{A+B+C+D} = T_1 + iT_2 = |T|\angle\theta$$

TRANSMISSION LOSS

$$T.L. = -20 \log_{10} (|T|)$$

REFLECTION COEFFICIENT

$$\Gamma = \frac{A+B-C-D}{A+B+C+D}$$

INTERCHANGE A and D FOR OUTPUT REFLECTION PROPERTIES

RETURN LOSS

$$R.L. = -20 \log_{10} |\Gamma|$$

INPUT VSWR

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

INPUT ADMITTANCE

$$Y_{in} = \frac{C+D}{A+B} \cdot Y_o$$

INTERCHANGE A AND D FOR Y_{out}

INPUT IMPEDANCE

$$Z_{in} = \frac{1}{Y_{in}}$$

ABSORBED POWER

$$\frac{P_{ABS}}{P_O} = 1 - |\Gamma|^2 - |T|^2$$

FIG. 2 - ABCD Matrix Analysis

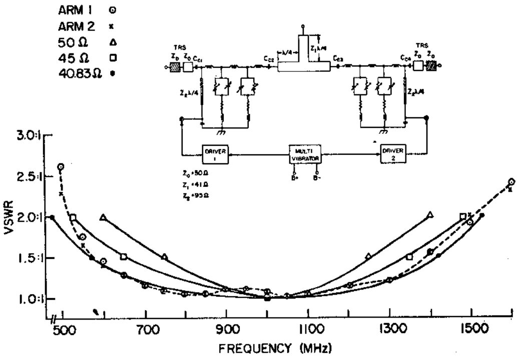


FIG. 3 - "T" SPDT Shunt Switch

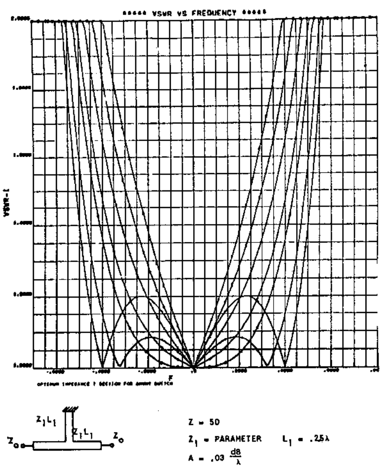


FIG. 4 - Computed VSWR of "T" Section of SPDT Switch

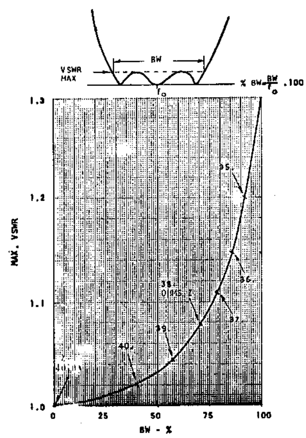


FIG. 5 - Max VSWR vs % Bandwidth for "T"