MICROWAVE CIRCUIT DESIGN BY MEANS OF A SIMPLE SIMULATOR WITH AN ON-LINE MINICOMPUTER

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Abstract

A simple analogue simulator is used to define circuit topology with lumped and distributed elements, to vary circuit parameters and to continuously display the frequency response. Parameter sensitivity can also be tested. Applications are given.

Introduction

It is current practice when designing transistor amplifiers (with bipolars or FET's) or reflection-type amplifiers (with Gunn or avalanche diodes) to make use of computers to accurately measure the active devices with a network analyser[1] and to calculate the best circuit from measured parameters (usually in microstrip) that will give the required specification[2]. The circuit topology needs to be defined before this last calculation however and this definition is usually based on previous experience and a few general principles.

Many different circuits are frequently possible[3]. The usual analysis of this problem makes use of equivalent circuits with lumped elements which is however not capable of exploring all the possibilities, nor of foreseeing some unwanted responses outside the useful frequency band. It is theoretically possible to calculate all possible solutions by means of a computer but this becomes unwieldy when one tries to program suitable choice criteria. A much simpler and less costly method will be described in this paper. A circuit topology is first dictated by the operator and the machine continuously calculates its response as the parameters are varied. The topology can then be easily modified.

Hardware description

The simulator itself consists of two rows of potentiometers, each supplied by a constant current. The variable outputs are addressed by means of a multiplexer to an A/D converter connected to a Philips P 860 32 K-word memory minicomputer. This reads the received information either as characteristic impedances and electrical lengths or as lumped elements. The machine then calculates the impedance and displays it on a visugraph with a simplified Smith diagram. The impedance plot is renewed whenever a potentiometer is adjusted.

Definition of topology

Any series-parallel configuration of up to 20 elements is accepted. This can include lossy or lossless distributed lines, described by a characteristic impedance and a length normalized to the center frequency wavelength. Each line can be associated with any lumped element including shunt and series resonant dipoles.

The choice of each element, its position in the circuit and the address of its associated potentiometer on the front panel of the simulator are first described at the keyboard by means of a very simple language which requires no more than one line.

The computer tests the syntax and displays the topology by graphical representation as a control.

An example in Figure 1 shows 3 series lines and two parallel (open and short circuited) lines connected to a 50 ohms termination.

General processing procedure

After the topology description, the frequency range and the fixed parameters are read at keyboard. The computer then reads the values of the variable elements by addressing the relevant potentiometers. It calculates from the load L the reflection coefficient seen in the input plane G as a function of frequency and displays it on a simplified Smith chart (Figure 2). He can then adjust the value by changing the potentiometer setting and the new impedance is displayed. The operator can at any time ask for a tabulated listing of the impedances and other circuit parameters (Figure 3). As can be seen in Figure 4, the reading of the data, computation and display are placed in an automatic loop which is only interrupted by the keyboard operator. Calculation and display are suppressed if there is no significant change between two data readings.

Applications

The simulator can be used to predict passive circuit responses (filter analysis, matching discontinuities,...) or to synthetize circuits for matching active devices. In that case, it is particularly interesting to use the same computer for the device characterization as an automatic network analyzer and store the S-parameters data. The designer can thus display the target specification and adjust the simulator knobs until the displayed response is in good agreement with the target.

If necessary, the parameters can be optimized by the computer once the topology has been defined to finalize the design. The final structure can be tested again on the simulator to see the sensitivity to the parameters by slightly moving the knobs.

Design example

A wide band 7 - 11 GHz Gunn amplifier has been designed from the measured reflection coefficient of the diode. Constant 10 dB gain circles have been plotted on a Smith chart as a target. The final circuit topology which gave the proper phase variation versus frequency[2] is represented in Figure 5.

The sensitivity to the length variation of the series line number 3 can be seen in Figure 6. This was obtained by slightly adjusting the knob and seeing the sensitivity in the impedance plot that this produces.

Thus for a complete microwave amplifier design, the procedure can be summarized as follows :

1. Device parameters are measured on an automatic network analyser. The results are stored.

2. The same computer calculates the optimum circuit impedance for the desired specification (gain, VSWR, noise factor, temperature stability,...).

3. The optimum circuit impedance is displayed and the circuit simulator, which is described in this paper, helps to define the appropriate topology and tests sensitivity.

4. A final optimisation of circuit parameters is carried out by means of a simple optimisation routine. The circuit geometry is calculated.

5. The circuit is made.

Conclusion

The development of small and easily usable minicomputers makes it possible for flexible real time systems where the engineer can at any moment assess the value of a circuit according to its approach to the target specification. This is particularly suited to microwave circuit design where the use of large computers is time consuming.

References

1. S.F. Adam, "A new precision automatic microwave measuring system", IEEE Trans. Inst. Meas., IM-17, 4, Dec. 1968.

2. J. Magarshack, "Design and applications of solid state amplifiers", Eu. M.C.-5, Hambourg, Sept. 1975

3. H.H. Ku, A.F. Podell, "Microwave Octave-band GaAs FET amplifiers", IEEE-MTT-S conference, p. 69, 1975.

DESCRIPTION DE LA TOPOLOGIE

1,(2),3,(4.0),5.1,

ERREUR=Q

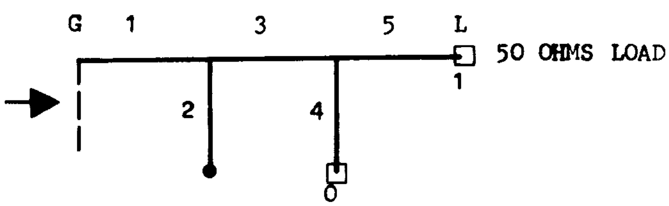

Fig. 1-Circuit topology display showing 3 series lines (1, 3, 5) with two stubs, one open circuit (2), one short circuit (4) and the load (1)

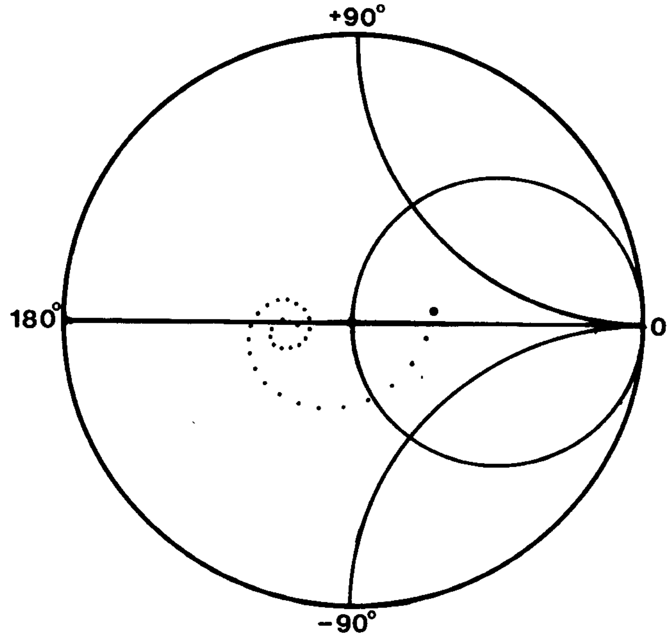

Fig. 2-Frequency response for one setting of the parameters. Frequency varies from 4 to 7 GHz in steps of 100 MHz

F(MHZ)	RO(DB)	RO(LIN)	PHI(DEG)
4000	-10.90	.285	9.0
4400	-11.16	.277	-78.4
4800	-8.96	.356	-134.3
5200	-8.79	.364	-170.1
5600	-11.27	.273	165.5
6000	-16.35	.152	177.0
6400	-12.63	.234	-156.1
6800	-10.97	.283	-174.2

FINAL VALUES OF PARAMETERS

DISTRIBUTED LINES			LUMPED ELEMENTS		
I	ZO	L/LO	R(OHMS)	L(NH)	C(PF)
1	50.085	.001			
2	100.000	.541	OPEN CIRCUIT		
3	46.032	.174			
4	64.493	.293	SHORT CIRCUIT		
5	71.013	.917	50.0		

Fig. 3-Tabulated form of final results giving frequency, return loss in dB and linear, and in degrees, the VSWR and the real and imaginary parts of the reduced impedance (R, X) normalized to 50 ohms. The circuit parameters are listed according to their location (Fig. 1) with their characteristic impedance Z (Ω) and electrical length (normalized to λ at the centre frequency)

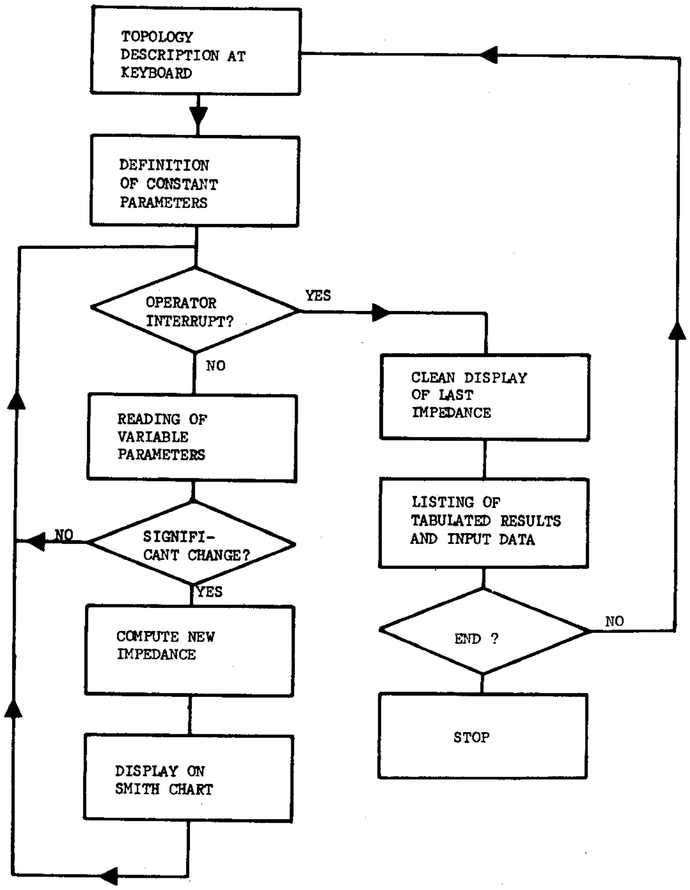

Fig. 4-Simplified block diagram of the simulator software

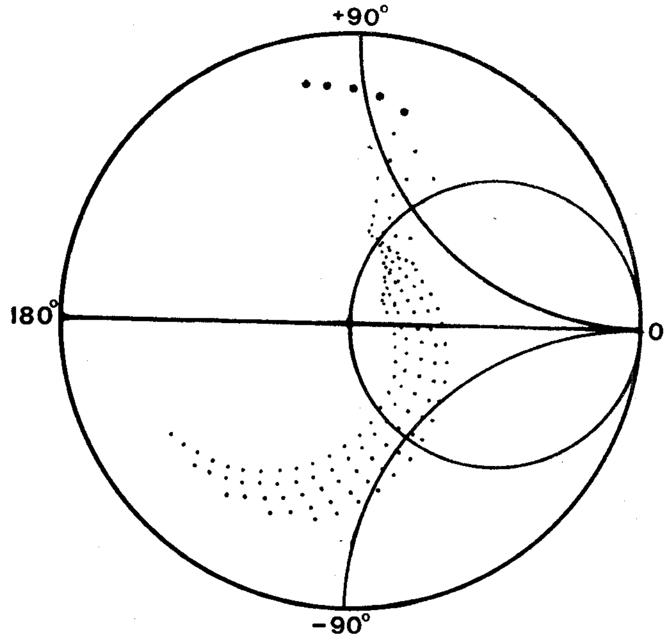

Fig. 6-Sensitivity of the circuit response to the length variation of line 3 in Fig. 5 : frequency varies from 7 to 13 GHz in steps of 200 MHz

DESCRIPTION DE LA TOPOLOGIE

1,(2),3,(4),5,(6),7.2,

ERREUR=0

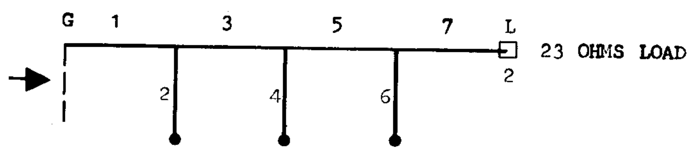

Fig. 5-Circuit topology of a 7 - 11 GHz Gunn amplifier circuit

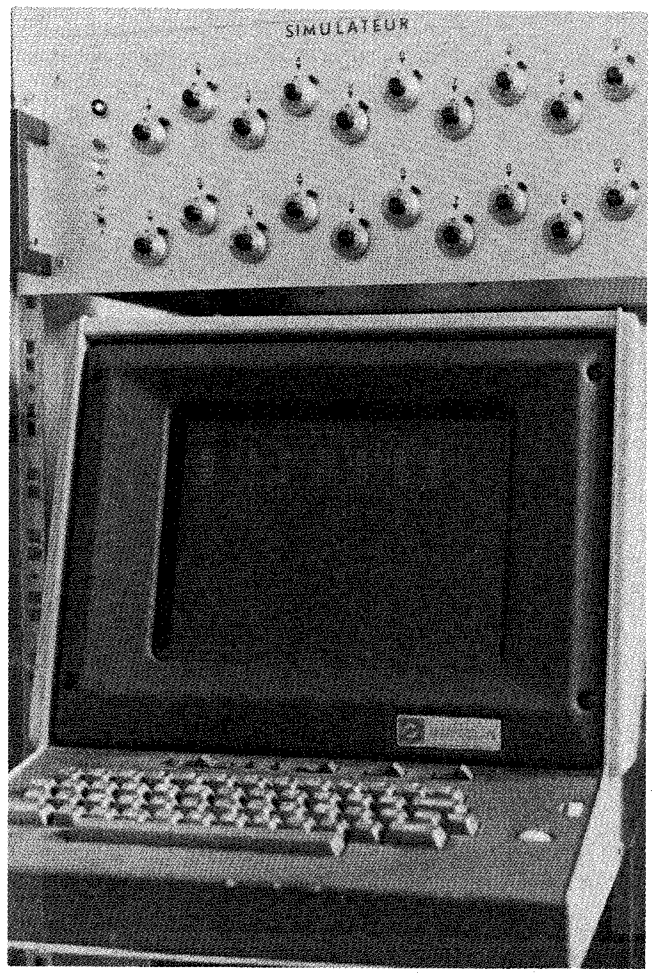

Fig. 7-Photograph of the simulator