A COMPUTER AIDED DESIGN OF L-BAND TRANSISTOR POWER AMPLIFIERS

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Abstract

A computer aided design procedure is formulated for L-band transistor power amplifiers. The procedure incorporates a precision measurement technique for transistor impedances, a model for large step discontinuities in microstrip and an optimization routine for the direct realization of broadband matching circuits.

Introduction

In recent years, considerable effort has been extended in the area of the design of Class C microwave transistor power amplifiers. The material contained herein details a procedure for the specification, optimization and realization of the microstrip matching circuits associated with transistor power amplifiers. The procedure incorporates a precision measurement technique for transistor impedances, a model for large step discontinuities in microstrip, and an optimization routine for the direct realization of broadband matching circuits. The final computer outputs are the physical dimensions for microstrip transmission line matching sections.

Measurements

The impedance measurements are performed with a Hewlett-Packard Manual Network Analyzer. Because the impedances associated with microwave power transistors are on the order of 1 ohm, the inaccuracy of the Network Analyzer often masks the actual values. To account for these inherent errors, an errorless instrument was assumed in conjunction with an error network as shown in the signal flowgraph of Fig.1. The errors are minimized in a manner similar to that presented by Hand.[1] The Network Analyzer is calibrated using an SMA-type short placed at the face of the test port. Three offset shorts, of known lengths, are connected and the values of S_{11} are recorded. From analysis of the error network of Fig.1, the measured value, M_R, of S_{11} is given by

$$M_R = e_{oo} - \frac{e_{o1}\, e^{-j2\beta\ell}}{1 + e_{11}\, e^{-j2\beta\ell}} \quad . \tag{1}$$

The three signals, e_{oo}, e_{o1}, and e_{11} are determined at each frequency of interest from the measured values M_R.

These values are used in the inverse equation,

$$S_{11} = \frac{S_R - e_{oo}}{S_R\, e_{11} + e_{o1} - e_{oo}\, e_{11}} \quad , \tag{2}$$

to correct the measured value, S_R, of the reflection coefficient for the unknown impedance. An estimated accuracy of the measurements of reflection coefficient in the area of unity is $\pm.005$ and $\pm1^{o}$.

Microstrip Impedance Steps

The impedance matching networks that are used during the construction of the transistor amplifiers consisted of several transmission line sections, of varying characteristic impedance and length, in microstrip. It was found that accurate matching networks could not be constructed without accounting for the discontinuity effects of the very large impedance steps that were encountered during the design procedure.

Some earlier papers have considered the problem of small step discontinuities, however, the results are found not to be applicable to very large steps.[2] Several circuits similar to that shown in Fig.2 have been constructed, and impedance measurements have been made in the one to two gigahertz region. A lossy line section was chosen as the junction model, and the attenuation, characteristic impedance and line length are determined from the measured impedances with the use of a computer optimization routine. The results are shown in Fig.3. As a test of the junction model, measurements have been performed on an arbitrary circuit and compared with the calculated values. The results, shown in Fig.4, were in good agreement.

The junction model presented above is for a 25 mil alumina substrate with a relative dielectric constant of 10.4 and has been determined to be accurate in the one to two gigahertz region.

Transistor Impedances

Several factors must be considered during the measurement of the transistor impedance, for example output power, junction temperature, gain, efficiency and others. Device and circuit limitations have been considered in a recent article presented by Pitzalis and Gilson.[3] The amplifier designer is free to choose any set of single frequency impedances which satisfy a particular amplifier requirement, and to incorporate them into this optimization routine.

The transistor impedances used during this design procedure have been measured by a circuit substitution method. The transistors are configured as common base, Class C amplifiers and have been installed in a transistor test ficture. The test fixture consists of a transistor mounting section and two alumina substrates with 50 ohm transmission lines. Bias is applied through low resistance coils, independent of the microstrip networks.

The 50 ohm line sections are overlayed with conductive tape as matching sections at several discrete frequencies. The overlays are adjusted until the desired performance characteristics are obtained at a single frequency, the test fixture is then disassembled, and the circuit impedance measured. The procedure is repeated for several frequencies in the band of interest.

Circuit Design

An optimization routine has been formulated which incorporated the step discontinuity model and which requires the transistor impedances and starting

values for the line dimensions as input. The approximate starting values are selected using conventional transmission line matching circuit theory,[4] and the line dimensions are varied until the desired circuit impedances are obtained. The program produces the physical dimensions of the microstrip matching sections. A block diagram for the program is shown in Fig.5.

Results

The measured performance of an amplifier designed using the above procedure, and utilizing an MSC 2010 packaged transistor, is shown in Fig.6. The results are compared with several other amplifiers using the same transistor that have been designed by conventional experimental methods. The performance of the computer-aided-designed amplifier is that obtained with no experimental network adjustment. A photograph of the computer designed amplifier is shown in Fig.7.

The synthesis and realization of wideband matching circuits, derived from measured impedance functions, has been proven suitable for microwave transistor power amplifiers. High precision network measurement and realization methods are seen to be necessary. The same methods should be applicable to the one-port devices, differing only in the complexity of the networks necessary to provide the necessary impedance functions over several frequency ranges simultaneously.

References

1 B.P.Hand, "Developing Accuracy Specifications for Automatic Network Analyzer Systems," H.P.Journal, Vol.21, No.6, p.16, 1970

2 R.E.Neidert and G.T.O'Reilly, "Very Large Impedance Steps in Microstrip," Accepted for publication in IEEE Trans.Microwave Theory Tech.

3 O.Pitzalis, Jr., and R.A.Gilson, "Broad-Band Microwave Class C Transistor Amplifiers," IEEE Trans. Microwave Theory Tech., Vol.MTT-21, p.660,Nov.73

4 G.Matthaei, L.Young, E.M.T.Jones, Microwave Filters, Impedance-Matching Networks, and Coupling Structures, McGraw-Hill Book Co., New York 1964

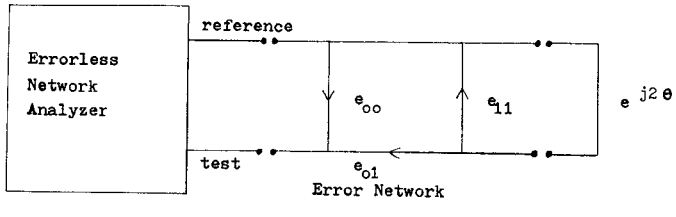

Fig. 1. Network Analyzer Error Correction Network

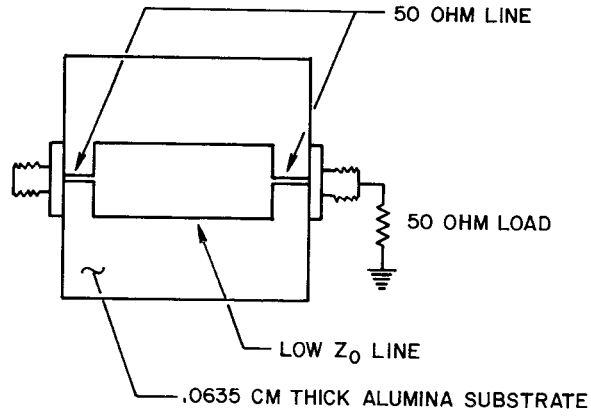

Fig. 2(a). Experimental Hardware

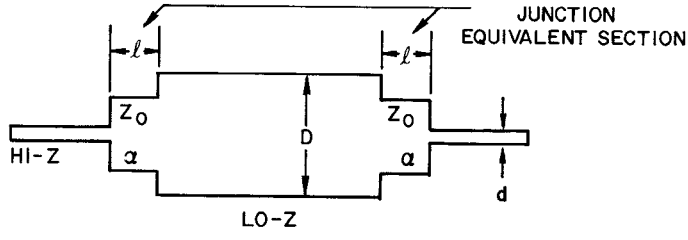

Fig. 2(b). Transmission Line Junction Model

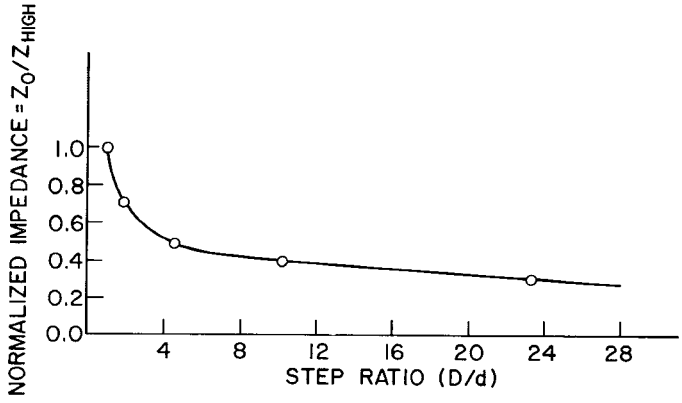

Fig. 3(a). Junction Model Transmission Line Impedance

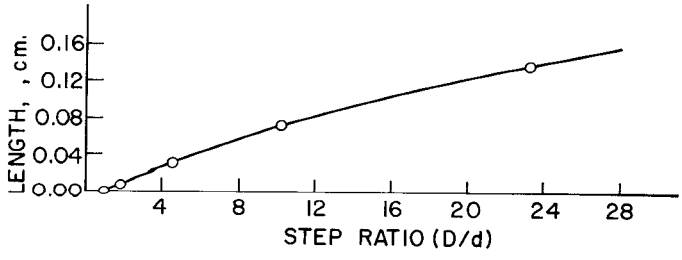

Fig. 3(b). Junction Model Transmission Line Length

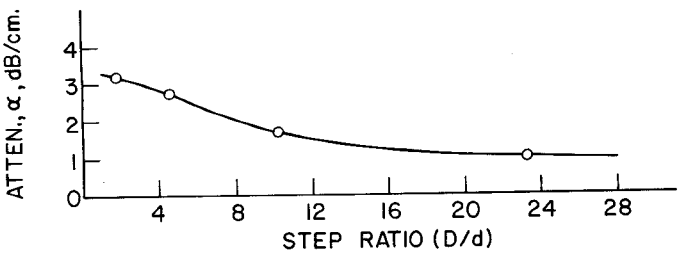

Fig. 3(c). Junction Model Transmission Line Attenuation

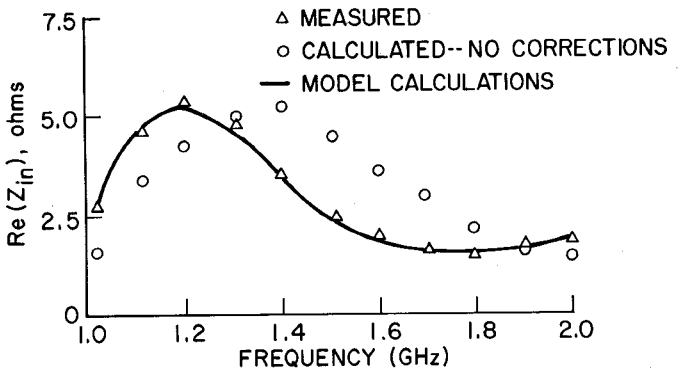

Fig. 4(a). Input Resistance

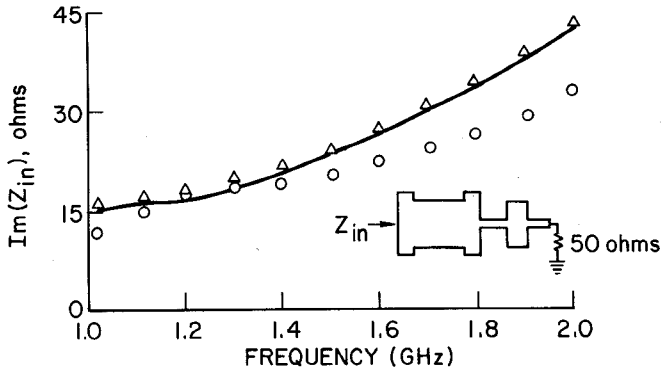

Fig. 4(b). Input Reactance

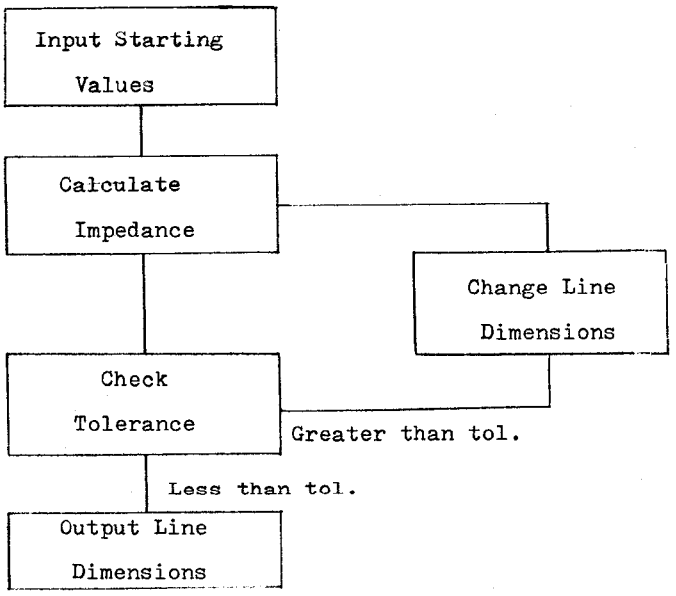

Fig. 5. Optimization Routine Block Diagram

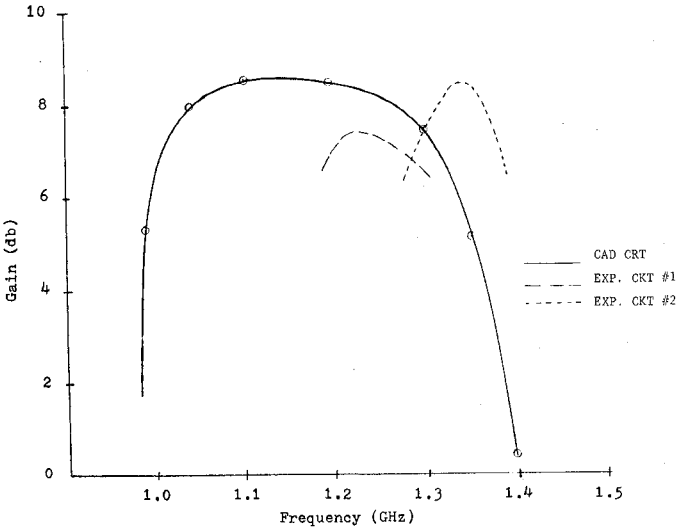

Fig. 6. Comparison Between Experimental and Computer Aided Designed Amplifiers

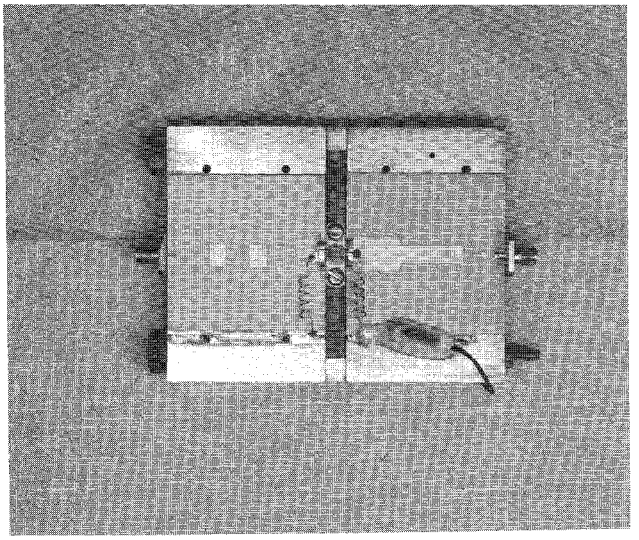

Fig. 7. Photograph of CAD Amplifier