A microstripline design of a 50 mHz power amplifier
by Louis LeeGrande Barrett

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Electrical Engineering
Montana State University

Abstract:
Microstripline is a name given to the use of double-sided, copper-clad, circuit board for construction of very-high-frequency (VHF), ultra-high-frequency (UHF) and microwave transmission lines, inductors and capacitors. Microstripline differs from stripline construction in that stripline uses two ground-planes with a smaller main conductor sandwiched between them. Microstripline employs a single ground-plane. Microstripline is constructed by etching one side of the double-clad circuit board to a width corresponding to a desired characteristic impedance while the opposite, wider side acts as a ground-plane. If the width is narrow, the series inductance characteristic of the transmission line will dominate. Conversely, a wide width would cause the shunt capacitance of the line to dominate. By cascading microstripline sections of the proper widths, networks may be synthesized. This type of construction lends itself well for the application of VHF radio frequency amplifiers, where tab type transistors are used. Advantages of microstripline construction as contrasted with the use of all discrete components are improvements in amplifier performance, plus ease in design and fabrication of the amplifier. An amplifier for the 50 mHz region was designed, built, and tested using microstripline techniques and is described here. Methods of measuring circuit board parameters, criteria for amplifier network design, and results are given. The amplifier performed admirably. Results are discussed and analyzed and suggestions made for further study.

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Signature Louis L. Barrett

Date 25 May 1977

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ABSTRACT

Microstripline is a name given to the use of double-sided, copper-clad, circuit board for construction of very-high-frequency (VHF), ultra-high-frequency (UHF) and microwave transmission lines, inductors and capacitors. Microstripline differs from stripline construction in that stripline uses two ground-planes with a smaller main conductor sandwiched between them. Microstripline employs a single ground-plane. Microstripline is constructed by etching one side of the double-clad circuit board to a width corresponding to a desired characteristic impedance while the opposite, wider side acts as a ground-plane. If the width is narrow, the series inductance characteristic of the transmission line will dominate. Conversely, a wide width would cause the shunt capacitance of the line to dominate. By cascading microstripline sections of the proper widths, networks may be synthesized. This type of construction lends itself well for the application of VHF radio frequency amplifiers, where tab type transistors are used. Advantages of microstripline construction as contrasted with the use of all discrete components are improvements in amplifier performance, plus ease in design and fabrication of the amplifier. An amplifier for the 50 mHz region was designed, built, and tested using microstripline techniques and is described here. Methods of measuring circuit board parameters, criteria for amplifier network design, and results are given. The amplifier performed admirably. Results are discussed and analyzed and suggestions made for further study.

INTRODUCTION

Microstripline (MSL) is a method of realizing LC networks by cascading transmission line lengths of different characteristic impedance. The transmission line sections are made by etching a narrow conducting width on one side of a piece of double-sided, copper-clad, printed circuit board while the foil on the side directly opposite is either etched several times larger in width or left unetched. The wider side acts as a ground-plane for the other conductor.

MSL is a simplified version of "stripline" network synthesis. In stripline methods, two ground-planes are used with the narrowly etched center conductor sandwiched between them.

MSL is mostly applied in the microwave and ultra-high-frequency (UHF) regions (450 mHz and above) in either a complete network or commonly as part of a hybrid network also involving discrete components.

The purpose of the following study was to apply MSL to the design of a 50 mHz region, very-high-frequency (VHF) amplifier. The study was done to explore the feasibility of MSL at VHF and perfect design methods for use by experimenters who do not have expensive lab equipment.

The first part of this paper deals with methods used and data taken on several MSL widths. Once characteristic impedance and velocity data had been taken, it was tested for validity by building a low pass network also described.

The second part explains procedures used in the design and testing of a 52 mHz amplifier. This frequency was chosen because of availability of equipment to make measurements and test the amplifier.

G-10 epoxy-glass circuit board was used throughout with a dielectric thickness of 1 mm. The methods described in this study may be used to also establish line characteristics and design networks using other dielectrics and thicknesses.

An advantage to MSL is ease in constructing tuned networks using conventional printed circuit board methods. Once an accurate prototype is developed, it may be easily duplicated with no further tuning needed.

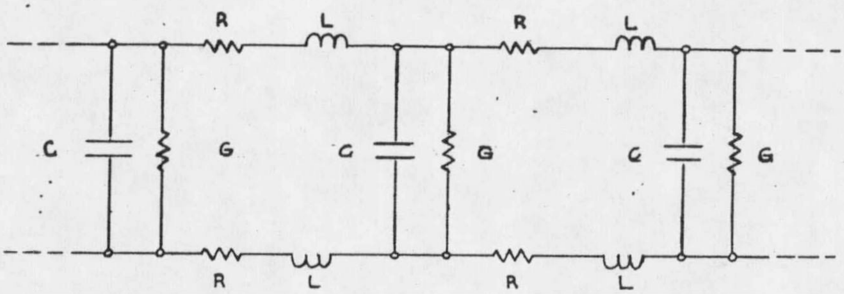
PROBLEM ANALYSIS

If MSL sections were to be used to synthesize networks, design equations had to be established. The logical place to begin was with the transmission line equations. Relationships were sought which would relate capacitance or inductance per unit length to measurable parameters. Such relationships would then lead to the design equations for the realization of networks.

MSL is similar to coaxial line in that the conductor surface is purposely smaller in width than its associated ground-plane. With that in mind, the coaxial transmission line model was used to begin the derivation of design equations. Figure 1a shows the general model for a parallel, balanced tranmission line (Potter and Fich 1963). The model is modified in Figure 1b to that of a coaxial, unbalanced line. The model consists of series inductance (L) and ac resistance (R) shunted by capacitance (C) and leakage conductance (G). If the line may be assumed lossless, the model may be simplified to that shown in Figure 1c. Only the series inductance and shunt capacitance comprise the line characteristics.

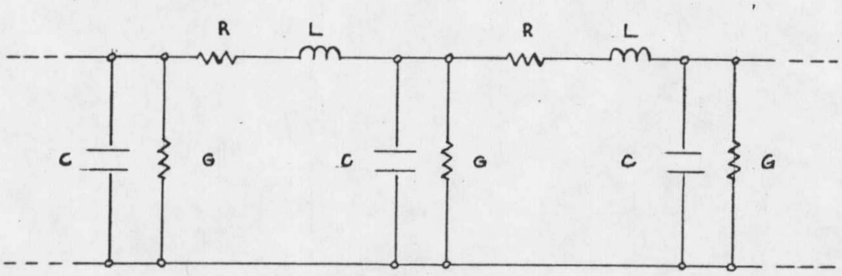
It was assumed the line was lossless initially. The lossless transmission line equations are then given by Potter and Fich (1963):

$$Z_0 = \sqrt{\frac{L}{C}} \qquad \text{(Ohms)} \qquad (1)$$



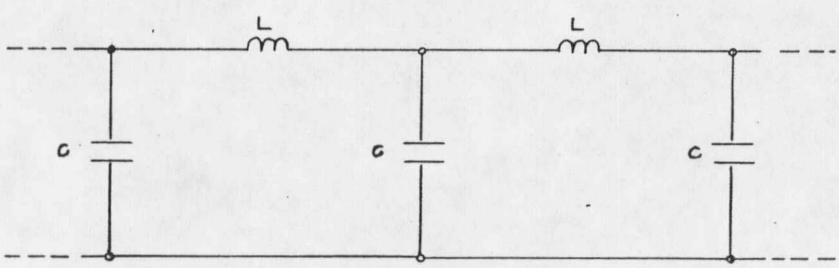
(a)

Parallel conductor transmission line with losses



(b)

Coaxial transmission line with losses



(c)

Lossless coaxial transmission line

Figure 1

Transmission Line Section Models

and

$$V = \frac{1}{\sqrt{LC}} \qquad \text{(meters/second)} \qquad (2)$$

where: L = Inductance per length (Henries/meter)

C = Capacitance per length (Farads/meter)

Z_o = Characteristic line impedance (Ohms)

V = Phase velocity through the line (meters/second)

Solving for L and then C from equation (1):

$$L = Z_o^2 C \qquad \text{(Henries/meter)} \qquad (3)$$

and

$$C = \frac{L}{Z_o^2} \qquad \text{(Farads/meter)} \qquad (4)$$

If equation (3) is substituted into equation (2), the capacitance per unit length becomes:

$$C = \frac{1}{Z_o V} \qquad \text{(Farads/meter)} \qquad (5)$$

Similarly, if equation (4) is substituted into equation (2), the inductance per unit length is:

$$L = \frac{Z_o}{V} \qquad \text{(Henries/meter)} \qquad (6)$$

As seen from equations (5) and (6), if the characteristic impedance (Z_o) and the phase velocity (V) could be established by experimental means, networks using series inductances and shunt capacitances could by synthesized by using the respective MSL lengths.