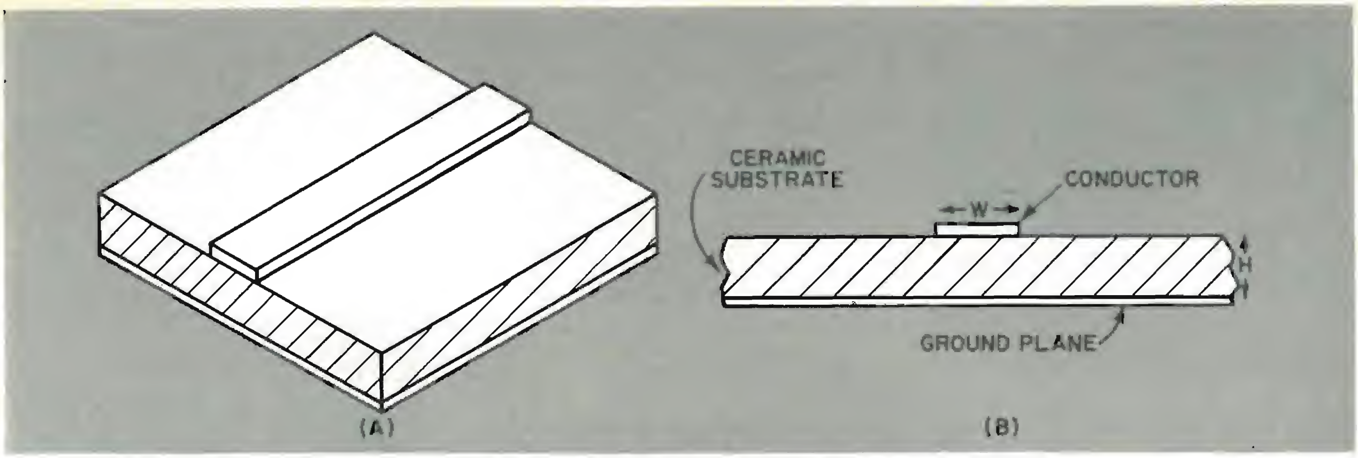



Fig. 1. Thin films of a flat, rectangular conductor strip deposited on side of a ceramic substrate with a conductive ground plane on the other side make up the microstripline circuit.

# Microstripline Parameters

By LEON SALES/ Lockheed Electronics Co.

*Having advantages of small size and light weight compared to microwave "plumbing," the microstripline technique is being widely used in airborne microwave and radar systems in conjunction with hybrid microelectronics.*

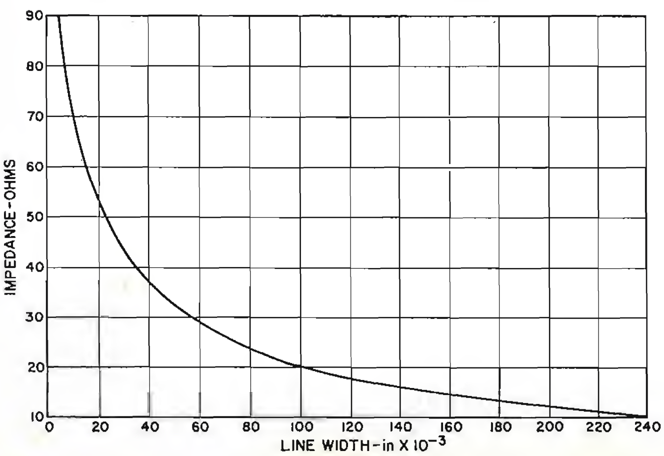
WITH hybrid integrated circuits expanding into microwaves, microstripline circuitry is rapidly assuming an important role, particularly in airborne phased-array radar systems.

In this article microstripline will be defined, its advantages and disadvantages assessed, and design techniques examined. These techniques are also applicable to the design of waveguide and coaxial components in microcircuitry, such as filters, transformers, couplers, and cavities.

### What is Microstripline?

Microstripline (Fig. 1) may be defined as a wire above a ground plane, being analogous to a two-wire line in which one of the wires is the ground-plane image of the actual wire. In practice, the wire that is employed, rather than being round, is actually rectangular in its shape and almost flat.

Fig. 2. Microstripline impedance vs line width for a dielectric constant of 10.2 and for a ceramic thickness or height of 0.025 inch. Line widths are given in thousandths of an inch.




The insulation is alumina ceramic ($Al_2O_3$). Other insulating materials are available to the designer: crosslinked polystyrene, irradiated polyolefin, glass-reinforced PTFE, and others. The choice of alumina ceramic is a trade-off, a particularly good one since its dielectric constant, which is on the order of 10.2, allows for a reduced size of stripline. Other considerations are low losses, good reaction to thermal cycling, and ease of machining.

The ground plane, which covers the entire underside of the ceramic insulation (or substrate) and the conductor are deposited on the substrate by photoelectric forming. The deposition process consists of a thin initial layer of vacuum-deposited nichrome or chromium, then electroplating a layer of copper, followed by a layer of gold which acts as a protective coating. Another technique omits the copper layer and allows the gold to be plated directly on the nichrome or chromium. Thus, the principal conductor is gold rather than copper. This process may be considered a thin-film technique. Thick-film techniques are also employed.

### Producing Desired Impedance

Suppose a 50-ohm line is to be deposited on a ceramic substrate. The impedance ($Z_0$) of a microstripline is determined by the ratio of the width of the line ($W$) to the height of the dielectric ($H$) and the dielectric constant ($E_R$) of the insulating material.

Design equations employing the above parameters are complex and best handled by computer. However, a series of design curves derived by H. Caulton and H. Sobel's (of *RCA*) equations have been constructed. These curves are for a ceramic substrate, where $E_R = 10.2$, and where $H$ is 0.025 inch. Other curves for other heights of substrates and other dielectric materials can be derived.

From the curve of Fig. 2 the readout obtained shows that a 50-ohm line should have a width ($W$) of 0.023 inch. However, a correction factor is needed. The above readout applies to lines having zero thickness so that the horizontal axis really shows $W_{eff}$ rather than $W$. The need for a correction factor arises from the fact that a line of zero thickness exhibits a different $Z_0$ than a line possessing a finite thickness. This correction factor ($\Delta W$) must be applied to the parameter $W_{eff}$ obtained from the curve. In this case, with a 0.001-in line to be deposited, $\Delta W$ comes out to a value of about 0.001 in. Thus, the width of the line should be: $0.023 - 0.001 = 0.022$ inch.

If a line possessing a critical length (quarter-wave line, half-wave line, etc.) is to be deposited, a dielectric problem is encountered. A microstripline effectively exists in a two-dielectric media environment; the ceramic substrate and the air above it. This situation results in a complex effect on wave velocity.

To compensate for this phenomenon, a correction factor multiplier ($K$) is applied to the length of the line. Again, employing equations by Caulton and Sobol and resulting computer data, a curve has been derived from which $K$ may be found (Fig. 3). This correction factor is on the vertical axis and is shown as $\lambda/\lambda_{TEM}$, where $\lambda$ is the wavelength in air and $\lambda_{TEM}$ is the wavelength in the ceramic substrate that is being used as the example in this article. From the curve, $K$ has a value of 1.23 for a 50-ohm line. Thus, at 3.0 GHz, $\lambda = 10.0$ cm, and $\lambda/4 = 2.5$ cm. This quarter wavelength is then multiplied by $K$: $2.5 \times 1.23 = 3.075$ cm, which is the actual length of line deposited.

To calculate the attenuation of the stripline, another curve has been derived and plotted as loss *vs* impedance, Fig. 4. The attenuation is expressed algebraically as $\alpha_c F^{-1/2} \times 10^6 = L$, where $L$ is the value read on the vertical axis of the curve, $F$ is the frequency in Hz, and $\alpha_c$ is loss in dB/in.

For a line having a $Z_0$ of 50 ohms, $\alpha_c F^{-1/2} \times 10^6 = 2$. When this equation is simplified to:

$$\alpha_c = \frac{2}{(1/\sqrt{F}) \times 10^6}$$

and solved, $\alpha_c = 0.11$ dB/in at 3 GHz.

## Advantages and Disadvantages

The advantages of microstripline are very attractive to the designer. Two obvious ones are its weight and size. A 4-to-1 hybrid divider-combiner, a circuit effectively combining four amplifiers in parallel (solid-state amplifiers are inserted at the arrows), is shown in Fig. 5. The wider lines have a $Z_0$ of 50 ohms and the narrow lines a $Z_0$ of 70 ohms. These narrow lines are quarter-wave lines at $F = 3.3$ GHz. Note the circuit's size; it weighs only about 0.2 ounce including the connectors.

Another advantage simplifies quality-assurance problems. This is the accuracy of microstripline circuit reproduction in any quantity. Since it is "constructed" by a photoelectric process, once the initial circuit is processed additional circuits are as easily produced as "prints from a negative."

Microstripline may also be employed as a lumped two-plate capacitor. The mathematics are similar to that of the commonly used paralleled-plate capacitor. The ground plane is considered as one plate and the other plate is deposited on the substrate.

There is a serious limitation to the size of a capacitor that can be deposited in microstripline. It must be of small value; otherwise it would occupy a large area. If large values are mandatory, discrete components are employed. These are in the nature of capacitor chips that are soldered directly to the stripline.

It should be pointed out that soldering to gold is a vexing problem. Gold is easily and rapidly dissolved in tin-lead solders. It has been found that the use of indium solder circumvents this problem.

Inductances in the microwave region may also be made in stripline circuitry. These take the form of a shorted line less than a quarter-wavelength long at the operating frequency.

A difficulty arises in microstripline circuitry that is common to it and r.f. cable, particularly in the microwave region. This is that the bending of lines in sharp right-angle configurations is taboo. Two low-loss methods of bending microstripline employ a mitered 45° bend and a smooth round bend. Both have voltage standing-wave ratios of less than 1.1. The choice generally rests with the processing people as to which technique to employ, the criterion being the ease with which it fits into their particular process.

Microstripline has been on the electronic scene since the early 1950's. Its utilization, until just a few years ago, was limited. But its recent appearance in radar, coupled with the great strides made in microwave transistors, has generated a new boom in its use. ▲

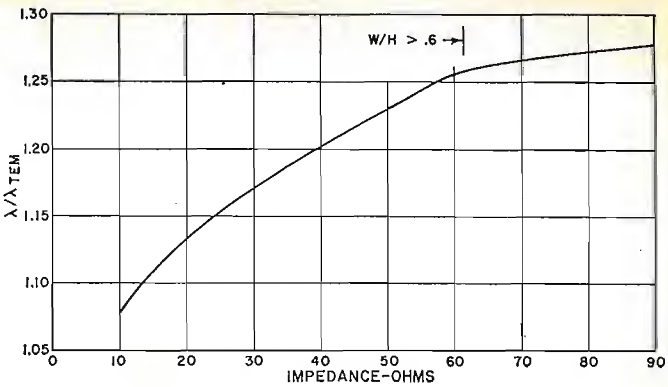



**Fig. 3. Actual wavelength of a given section of microstripline is greater than wavelength in free air as shown here.**

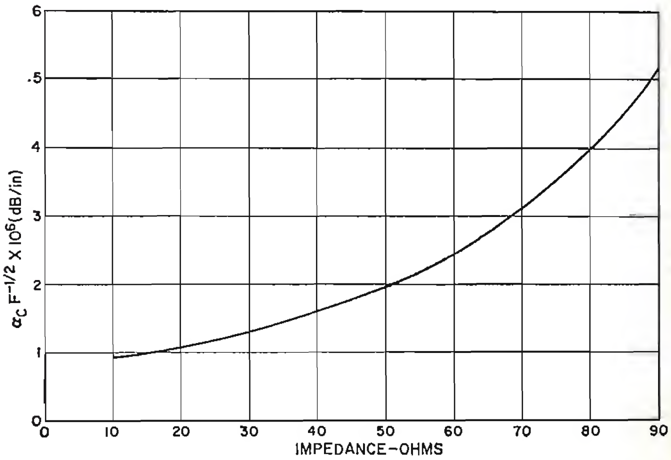



**Fig. 4. Attenuation for microstripline at various impedances.**

**Fig. 5. A 4-to-1 hybrid divider-combiner, which effectively combines four amplifiers (inserted at the arrows) in parallel. These amplifiers may simply be microwave transistors.**