GTE LENKURT

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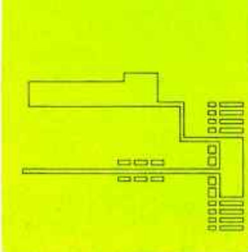
MICROSTRIP TECHNOLOGY



Microstrip transmission lines may be incorporated into microwave equipment design to achieve a compact, integrated unit of lower cost and greater reliability than those composed entirely of discrete components.

The microstrip transmission line is one of several mediums by which electromagnetic waves, traveling at microwave frequencies, can be conveyed from one circuit to another. They may, for example, tie together the stages of the transmit power amplifier in a microwave transmitter. Or, they may be used to connect the circuit elements of mixers and local oscillators in microwave receivers (see Figure 1).

Microstrip transmission line evolved from strip transmission line, which in turn evolved from coaxial transmission line. Like coaxial line and strip line, microstrip line usually operates in the principal or TEM (transverse electromagnetic) mode of transmission. (See the September, 1972 issue of the *Demodulator* for a discussion on principles and applications of strip transmission lines.)

Strip and Microstrip Lines

Strip and microstrip transmission lines are markedly different from each other in construction and material composition. Strip line utilizes a conducting strip between two ground planes and microstrip has a conductor above a single ground plane (see Figure 2). The dielectric constant of a material is an important factor in microstrip operation. It is the degree to which a dielectric material can store electrostatic energy, as compared to air. Only a single ground plane is needed in microstrip because the dielectric constant of the substrate material is much higher than that used for strip line. The concentration of electromagnetic fields between the conducting strip and the dielectric material increases as the dielectric constant of the material is increased, thus allowing less radiation into the air. The high concentration of fields in microstrip circuits permits a more compact overall design than does strip transmission line. But, why use microstrip at all? Isn't it simply another way of doing something that has previously been accomplished by coaxial line, waveguide, or strip line? Part of the answer to these questions is affirmative, but microstrip circuits also have other characteristics which make them particularly desirable in certain applications.

At 1 GHz and higher, microstrip transmission line offers a new approach to microwave circuitry, at a lower cost. Microstrip also provides circuit compactness and greater ease of production than either coaxial or waveguide components. Probably the greatest single advantage of microstrip circuits, from an engineering point of view, is the convenience with which active devices and discrete components can be mounted on the microstrip line. Since the line is open at the top, it is

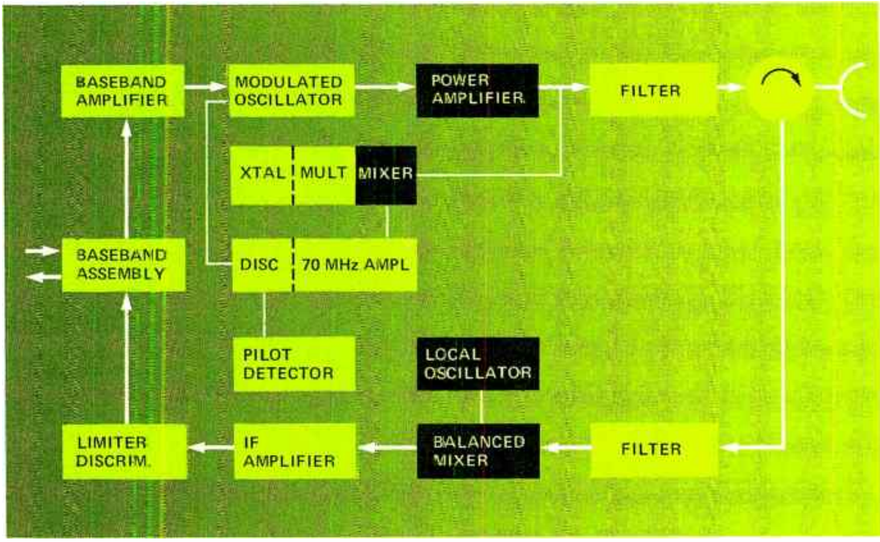


Figure 1. Microstrip circuitry is used to great advantage in some microwave power amplifiers, mixers, and local oscillators.

easily accessible and highly conducive to the mounting of discrete components for both production and experimental purposes.

Microwave Integrated Circuits

When active and passive components are added to a microstrip transmission line, it comes under the general category of a microwave integrated circuit (MIC). The microstrip MIC has a unique geometry for each application because the lengths of microstrip line are of critical importance to its overall function. MIC's are usually of two types – hybrid or monolithic. Hybrid circuits may be constructed by using standard printed circuit photoetching, and thin or thick-film techniques. The passive components in hybrid circuits, such as resistors, capacitors, and inductors, are manifested in the form of metallic patterns along the conducting strip or soldered on as discrete elements. Active components, such as transistors and diodes, are connected to the passive components in discrete form, thus totally incorporating microstrip transmission line, and active and passive components into one compact package.

Monolithic MIC's contain all active and passive components within the semiconductor substrate itself. To date, the uses for these circuits are somewhat limited in their applications by power restrictions, losses in the substrate, and by difficulties encountered in obtaining a satisfactory yield per production run.

Hybrid Microstrip Circuits

GTE Lenkurt builds hybrid microstrip circuits using the thin-film process, in which passive components are achieved by application of silver, gold, and glass-filled resistive inks. These hybrid circuits often have an alumina dielectric for the substrate, which is a ceramic material with a dielectric constant of approximately 9. The dielectric material decreases the velocity

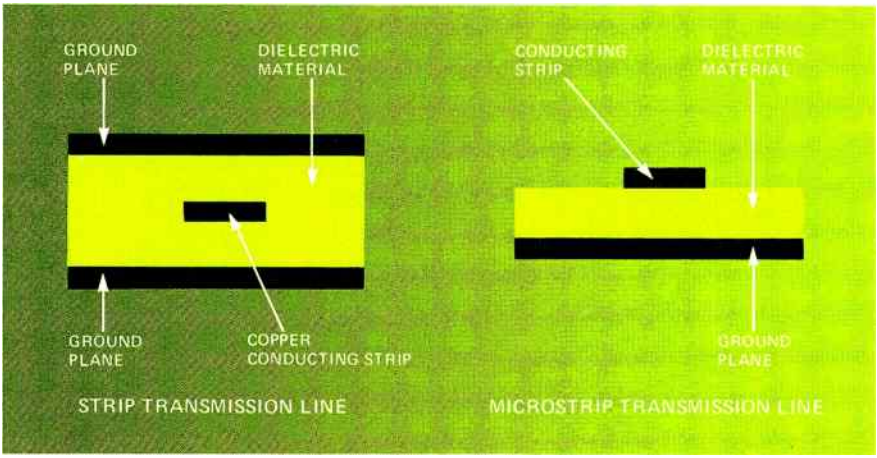


Figure 2. Microstrip transmission lines differ from strip transmission lines in construction as well as in size and type of material.

with which an electromagnetic wave propagates along the microstrip transmission line. This effect reduces or compresses the wavelength to a quantity which is equal to the length of the wave in free space, divided by the square root of the dielectric constant of the substrate material. This is how microstrip circuitry can reduce the physical size of microwave equipment. An alumina substrate, for example, which has a dielectric constant of 9, will reduce the wavelength within the substrate by one-third (wavelength/$\sqrt{9}$).

It is vitally important that the dielectric constant of the substrate material be rigidly maintained during production, since even a slight deviation will cause a change in the electrical properties of the final microstrip circuit. The high dielectric constant and low loss of the alumina substrate permit high-frequency circuits to be metallized on the microstrip transmission line, and at the same time maintain a low loss characteristic. Other materials used for substrates include industrial diamond and sapphire. Diamond is used for high-heat applications, where heat must be transmitted through the substrate and away from the electronic components. Sapphire substrates can be highly polished, which permits very fine lines to be etched on the substrate. This allows the lines to be placed closer together when a high degree of coupling is required in a circuit design. The higher the dielectric constant, the higher the concentration of lines of force within the substrate, and consequently, the more circuits which can be positioned next to each other without danger of interference by radiation. Still, except for military purposes, such as in aircraft equipment, compactness is not the greatest advantage of microstrip circuits. Their greatest economic advantage is in the ease with which they can be mass produced once the correct dimensional and electronic design has been determined.

Manufacture of Microstrip Circuits

GTE Lenkurt's hybrid microstrip circuits begin with an alumina substrate, coated on all six sides with a

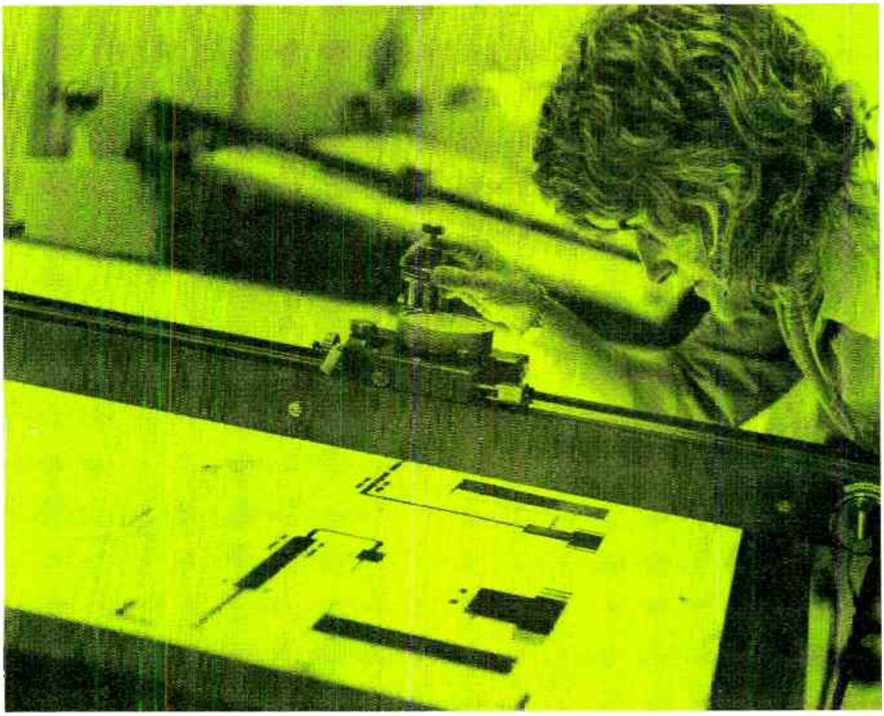


Figure 3. The first step in the construction of a microstrip circuit is the drawing of the dimensional pattern at ten times its normal size.

layer of chromium. The layer of chromium is covered by a layer of gold. The chromium layer serves as the adhesive base between the gold and the ceramic, since it has been found that chromium adheres to alumina better than most other materials. The first step in constructing a microstrip circuit is to draw the dimensional pattern of the circuit using a coordinatograph (see Figure 3). This machine is used to draw the circuit ten times its normal size, with a .001 inch tolerance. The drawing will serve to make the film negative which will be imprinted on the substrate. The microstrip circuit board is cleaned ultrasonically, and coated with a photoresistive chemical. The circuit image is then exposed and developed on the substrate. Immersing the substrate in an acid solution dissolves the unwanted gold and chromium, and leaves only the desired image, which has been protected by the photoresist. This process produces circuit boards such as those shown in Figure 4.

The various widths of the metallic strips perform certain electrical functions usually accomplished by passive components in lower frequency circuits. A thick line will produce a capacitive effect, while a thin line will look like an inductance. A gap in the strip functions as a filter, or may act as a coupling transformer. Inductors and capacitors are achieved by the classical approximation of certain lengths of transmission lines which are open or shorted at one end. A useful property of the microstrip method, then, is that many transmission characteristic impedances can be realized by choosing the correct metallic-strip width. Using the singular characteristics of microstrip transmission lines, the equivalent of lumped components can be achieved.

Soldering and Bonding

Active components are soldered to the circuit using low-temperature indium solder, which, while expensive, has excellent nonleaching properties. Conventional lead-tin solder will leach the gold from the circuit if too much heat is applied, thus changing the design characteristics of the circuit. Laboratory soldering is often done using a hydrogen-flame burner, which quickly heats the metallized surface, since alumina does not absorb infra-red heat. For large-volume production of microstrip circuits, all of the discrete components are soldered onto the substrate simultaneously.

Two relatively new devices used to bond discrete components to the microstrip circuit are the ultrasonic and thermocompression bonders. The ultrasonic bonder vibrates at 60 kHz, exciting the molecules on the leads of discrete components and on the microstrip line, thereby allowing them to merge and adhere to each other. The ultrasonic bonder operates on the principles of adhesion and cohesion. For example, when two highly polished surfaces are brought together, it is very difficult to pull them apart. The two surfaces remain together, not because of an existing vacuum, but because they are molecularly attracted to each other. The molecules are actually sharing their bond strength because of the surface excitation that has taken place during polishing. The 60-kHz vibration of the ultrasonic bonder uses this same principle to weld connections on microstrip circuits.

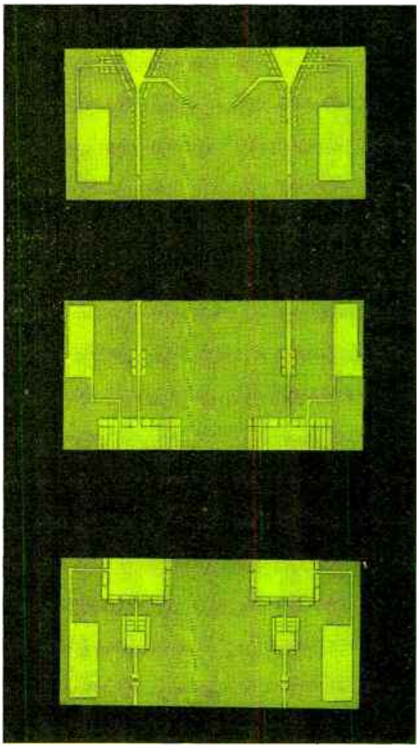


Figure 4. After etching, microstrip substrates are ready for the mounting of discrete components.

The thermocompression bonder heats the component leads and the gold circuitry, under pressure, until they are fused together. This process takes about half a second.

One disadvantage encountered in designing microstrip circuitry, is a certain loss in design time. The engineer cannot accurately construct the circuit in breadboard fashion to see if it will function properly. He cannot change the values of some components as easily as could be done in lower-frequency circuits. Each trial design must be painstakingly engineered and fabricated as if it were the final mold from which all other devices were to be cast. The cost in time, however, of design-

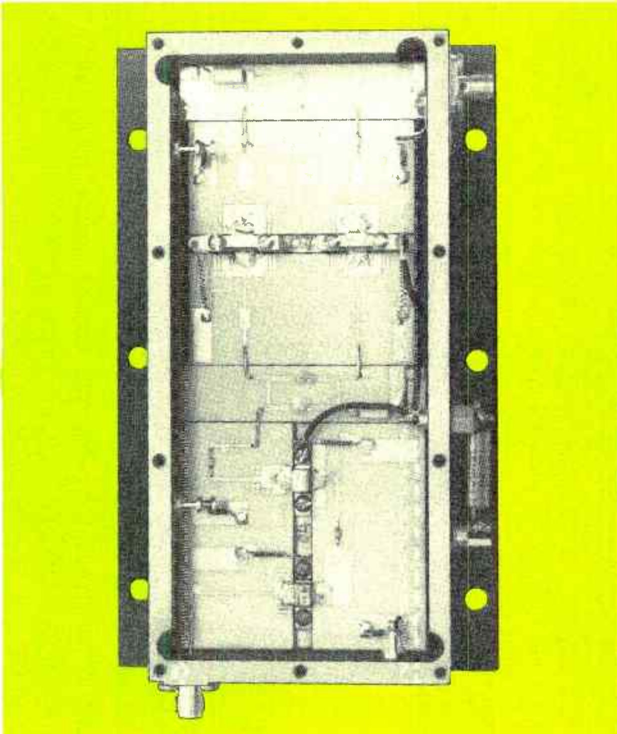


Figure 5. Hybrid microstrip circuits in a microwave power amplifier.

ing and building a microstrip circuit may be offset by the greater ease in manufacture and the higher reproducibility of the final product.

Microstrip circuitry is used only where it has a clear advantage over other transmission mediums. Figure 5 shows extensive use of microstrip circuitry in the 2-GHz power amplifier of a GTE Lenkurt 78C2 microwave radio. The tuning of such a circuit is performed by application or deletion of silver paint at certain areas along the substrate. This will alter the component value of the circuit, and give the amplifier the desired output characteristics.

Much experimental work still remains to be done with strip and microstrip transmission-line circuits, both in the development of monolithic and hybrid techniques, and in the extension of the use of microstrip circuitry to new electronic applications.

Microstrip circuitry should not be regarded as a panacea which will immediately solve all microwave transmission line problems. At this time, many transmission applications are more easily handled by using strip line, coaxial line or waveguide, and it is unlikely that microstrip will ever totally replace any of these mediums.

The telecommunications industry is well along in finding uses for microstrip circuitry, and it appears that future equipment will utilize an increasing amount of this circuitry, but only where it has definite advantages over other existing forms of transmission mediums.

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