"MICROGUIDE" A NEW MICROWAVE INTEGRATED CIRCUIT TRANSMISSION LINE

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Abstract

A new transmission line for microwave integrated circuit applications at frequencies above X band is described. Although physically similar to microstrip, its principal mode of propagation is a quasi-TE_{10} waveguide type mode. Preliminary measurements indicate low loss and reduced coupling between adjacent lines.

Introduction

Various types of transmission lines have been developed for use in microwave integrated circuits to miniaturize a variety of active solid-state as well as passive components. These lines include microstrip,[1-3] sandwich line,[4] suspended stripline,[5] inverted microstrip,[5] slot line,[6] coplanar line,[7,8] and dielectric waveguide.[9] A chart showing some of these lines and a qualitative assessment of their characteristics is contained in Fig. 1. Of these lines microstrip transmission lines have been used most extensively the past ten years in the frequency range from 1 to 10 GHz. Being a planar structure microstrip is easily fabricated, reproduced, and versatile. Semiconductor devices and other solid state circuit components are relatively easily bonded and integrated in microstrip circuits.

Slotline and coplanar lines have many of the advantages of microstrip but have not been used extensively because their losses and tendency to radiate are greater than microstrip. Sandwich line or stripline with high dielectric constant material has low loss and small radiation compared to microstrip particularly at frequencies above 10 GHz. However to prevent unbalanced modes from being excited and propagated, tight tolerances are required on the substrate surfaces. Another significant disadvantage of sandwich line is that solid state devices are not conveniently added on the structure. In addition, add-on devices are a source of undesired modes due to their asymmetry.

In this paper we describe a new "microstrip-type" of transmission line called "microguide." Microguide has all the desirable features of microstrip, such as planar geometry, ease of fabrication, reliability, ease of mounting add-on devices, plus the ability to handle higher power with lower loss and radiation. This new transmission line should be particularly well suited to operation at frequencies above 10 GHz because the coupling and interaction between components and lines should be significantly reduced from microstrip.

Microguide Line

A three-dimensional view of microguide is shown in Fig. 2. It is seen to consist of a wide strip of width, a, over a ground plane separated by a high-K material of thickness, b. The physical configuration of a microguide transmission line is similar to the physical configuration of a microstrip line, but the width is larger than the width of a microstrip line. The principal transmission mode in microguide is not a quasi-TEM mode as in microstrip but is more like a waveguide-type mode.

A sketch of the field configuration of the principal mode of microguide is shown in Fig. 3. Its electric field is antisymmetric with respect to the center of the guide. Its magnetic field is symmetric. A zero-order approximation for the fields in a microguide assumes that the fields are contained entirely within the region between the top conductor and the bottom ground plane. This is equivalent to assuming that microguide is a waveguide with magnetic side walls instead of electric side walls. Then the dominate mode in microguide is the TE_{10} mode. The quasi-TEM mode can also be excited on a microguide line and provision must be made to suppress this mode. One possible mode suppressor is shown in Fig. 4. Since the TEM mode of microstrip has even symmetry, the two modes are orthogonal to each other and do not couple under ordinary circumstances. Figure 5 shows some possible microstrip to microguide transitions that are based on the orthogonality of the TEM and TE_{10} modes.

Preliminary measurements of the unloaded Q of a microguide resonator indicate that microguide has low loss. A single resonator 1/2-inch wide and 1-1/2-inches long was fabricated on a 1/16-inch thick substrate, whose relative dielectric constant was approximately 10. The following values of unloaded Q were measured for the microguide line.

Frequency	Guide Wavelength	Q_u
4252 MHz	1.527 inches	118
5085 MHz	1.008 inches	312
6000 MHz	0.765 inches	605

The guide wavelength was computed by using an effective dielectric constant, effective resonator length, and effective resonator width obtained from measurement of three distinct resonances. The effective dielectric constant was found to be 9.93, the effective resonator length 1.526 inches and the effective resonator width 0.539 inch. The cut-off wavelength was then set equal to 1.08 inches and the guide

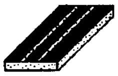
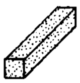
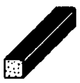
TYPE OF LINE	CONFIGURATION	CAREFUL TOP TO BOTTOM REGISTRATION REQUIRED	TRANSITION TO COAXIAL	SIMPLE ETCHING TECHNIQUE	COMPATIBLE WITH CHIPS IN CIRCUIT	EASY CIRCUIT ADJUSTMENT	ISOLATION	CONVENIENCE FOR USE WITH FERRIMAGNETIC DEVICES	PROPAGATION LOSS
μstrip		No	Easy	Yes	Yes	Yes	Moderate	Moderate	Moderate
Coplanar Waveguide		No	Easy	Yes	Yes	Yes	Better Than Slot Line	Slight	Moderate
Slot Line		No	Requires $\sim\lambda/4 \times \lambda/4$ of Area	Yes	Yes	Yes	Moderate to Poor	Good	Moderate
Strip Line		No	Easy	Yes	No Requires Machining or Special Substrates	No	Good	Slight	Moderate
Parallel Pair (planar)		No	Difficult	Yes	Yes	Yes	Good	Moderate	Moderate
Parallel Pair (suspended substrate)		Yes	Easy to Microstrip, Then Easy to Coaxial	Yes	Yes Heat Sinking a Problem	Yes	Good	Slight	Moderate to Low
Dielectric Surface Waveguide		No	Difficult	No	No	No	Poor	Good	Low
Dielectric Filled Waveguide		No	Difficult	No	No	No	Excellent	Good	Low
Microguide		No	Moderate	Yes	Yes	Yes	Good	Good	Moderate

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FIG. 1 COMPARISON OF MIC TRANSMISSION LINES

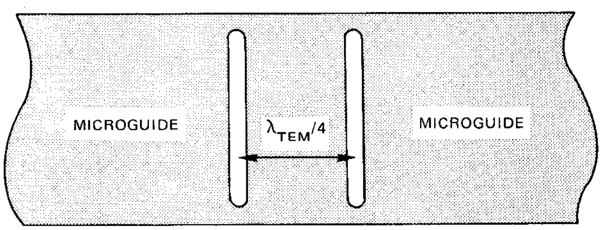

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FIG. 4 MODE TRAP (TEM ELIMINATOR)

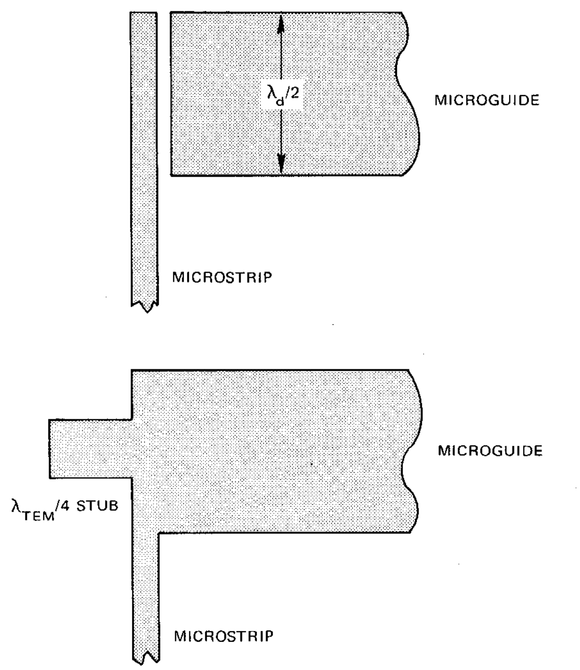

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FIG. 5 MICROSTRIP TO MICROGUIDE TRANSITIONS wavelength computed for each frequency.

Since the attenuation per guide wavelength in a waveguide is proportional to the square of the ratio of the guide wavelength to the wavelength in the dielectric, one would expect the unloaded Q to increase appreciably with increasing frequency as observed.

Microstrip quasi-TEM mode resonances were also observed on this resonator since no provisions were made to completely suppress this mode. The equivalent characteristic impedance of this microstrip line is about 10 ohms. Coupling for the TEM mode was such that measurement of unloaded Qs for various resonances in this mode were not possible except for one resonance at 4976 MHz. This resonance corresponded to a resonator whose electrical length was 2λ. The unloaded Q was measured to be 223.

Conclusion

A new type of transmission line for microwave integrated circuits has been described. Preliminary measurements indicate that the line has low loss and reduced coupling between adjacent lines. Filters in microguide appear to be very compact and practical. Since microguide is a type of balanced line, the design of magic T's using microguide should be very convenient. Microguide components become more practical as the frequency increases; therefore, microguide appears as an excellent alternative to microstrip in the upper microwave and millimeter-wave bands.

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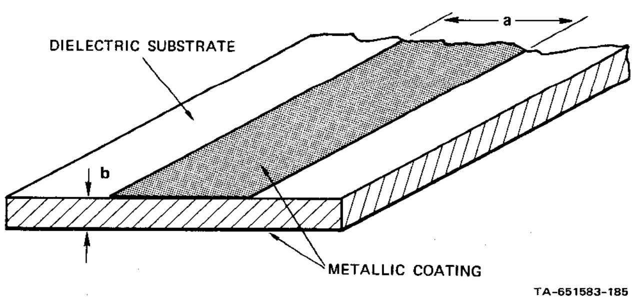

FIG. 2 MICROGUIDE AND PARAMETER DEFINITIONS

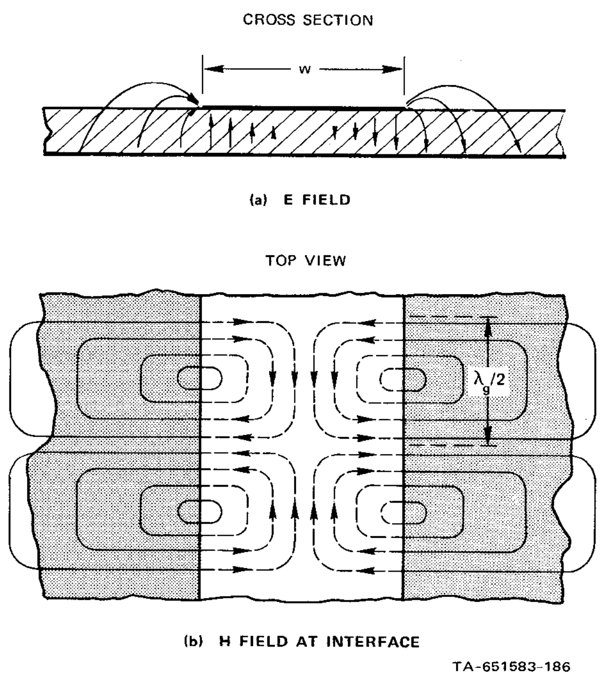

FIG. 3 APPROXIMATE FIELD DISTRIBUTIONS FOR MICROGUIDE