MEANDER-LINE AND HYBRID MEANDER-LINE TRANSFORMERS

by

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Abstract

A new application of meander lines to impedance transformers is proposed and developed. Meander-line transformers are shown to have less bandwidth than stepped-impedance transformers for a given passband VSWR, but can have greatly preferred shape factors in stripline and MIC realizations. Hybrid meander-line transformers allow circuit designers greatly increased flexibility in choosing transformer shape factors, while allowing (basically) the same electrical performance as with either stepped-impedance or meander-line transformers. Experimental confirmations are presented.

Introduction

Transformers are very often required in microwave components and systems. Coupled-transmission-line geometries, such as interdigital and/or combline, are often used for purposes of obtaining impedance transformations.[1] However, in many applications these structures are quite unsatisfactory for a variety of reasons: (1) The required coupling between lines may not be practically realized; (2) One or more of the coupled lines may require grounding, which is difficult in stripline and microwave-integrated-circuit (MIC) realizations; (3) in addition to ideal transformers, the equivalent circuit for these (and other coupled-line geometries) contain shunt or series reactances that limit the bandwidth over which the transformer may be used.

The stepped impedance transformer,[2,3,4] consisting of a cascade of unit-elements[5] (UE), is also commonly used. The stepped-impedance transformer can transform widely differing impedances (resistances, to be strictly correct) over narrow to very wide bandwidths, and they can be constructed readily in air-line, stripline and MIC. However, each section of a stepped-impedance transformer is a quarter-wavelength long at band center.** Consequently, the length of a multisection transformer can be quite large. An idealized solution to this problem would be to fold the stepped-impedance-transformer accordian fashion. In order to preserve the electrical characteristics of the circuit, shielding between the folded lines would be needed. Conceptually, this technique is satisfactory but in practice the required shielding would be impractical. On the other hand, if the shields were removed, there would be significant coupling between lines that would seriously degrade the transformer performance.

Figures 1(a) and (b) depict conventional meander-line geometries in stripline and MIC. We note that these structures may be considered as folded, coupled-line, stepped-impedance lines. Thus, from this perspective the meander line might be considered as comprising a class of generalized coupled-line transformers within which the stepped-impedance-transformer is merely a special case for which coupling between turns is negligible. From this point of view, an extension of meander-line transformers to hybrid meader-line transformers is quite natural. A hybrid meander-line transformer is one in which coupling between some adjacent turns is negligible, whereas for other adjacent turns it is significant. Several examples of hybrid meander-line transformers are illustrated schematically in Figures 2(a), (b), and (c). Each commensurate-length line is generally a different characteristic impedance. Theoretically, the number of hybrid configurations is $2^{(N-1)}$, where N is the order of the transformer and the number of commensurate-length lines. Hybrid geometries allow the circuit designer much greater flexibility in the physical layout of the transformer than he would otherwise have with only meander-line and stepped-impedance transformers.

Figure 3 presents theoretical data of maximum VSWR versus bandwidth (BW) with the number of meander-line turns as a parameter. Also plotted is the corresponding data for stepped-impedance transformers. The data is for an impedance transformation ratio of 2:1 and coupling between meander-line turns of 10 to 16 dB. However, the data is typical of the general case. The data shows the superiority of the stepped-impedance transformer with regard to electrical performance. However, equivalent or better performance is always possible with meander-line transformers by adding additional turns. Again, it is emphasized that the principal advantage of meander-line and hybrid meander-line transformers is the reduction in overall length and the increased flexibility in obtaining suitable shape factors for the stripline or MIC transformers being considered.

Experimental Results

A three-turn meander-line transformer was designed to match 25 to 50 ohms over a 60 percent bandwidth (BW = 1.857). It was constructed in stripline using 1 oz. copper clad Rexolite 1422, and a ground plane spacing of 0.250 inch. The nominal center frequency was 1 GHz. The interconnections between meander-line turns were mitered experimentally for a satisfactory VSWR. Four 1/8 watt, 100-ohm carbon resistors connected in parallel were used for the 25-ohm load. A photograph of the final design is given in Figure 4. The measured and computed VSWR's are shown in Figure 5. Note that although the center frequency of the transformer is slightly high, and although there is some degradation in the response near the upper band edge, generally speaking, there is excellent agreement between the two curves.

Experimental confirmation of the design procedure for hybrid meander-line transformers was also obtained. An N = 4 hybrid 2:1 impedance transformer, shown in Fig. 6, was constructed in stripline and tested. Its theoretical bandwidth and VSWR were 4:1 and 1.14, respectively. Its measured maximum VSWR in the passband was 1.2, while the mean VSWR was about 1.15.

Conclusions

An extensive table of meander-line transformers having 2 to 6 turns, impedance transformation ratios of from 1.1 to 20, and bandwidth ratios of from 1.5:1 to 10:1 has been

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** Excepting the short-step transformer.[6]

compiled and will be presented in the full paper. The transformer responses are, for all practical purposes, equal-ripple responses. For a given ripple, the bandwidth of meander-line transformers is less than what can be obtained with stepped-impedance transformers of the same degree. The principal advantage of meander-line transformers is their compactness.

The concept of hybrid meander-line transformers was introduced. Hybrid meander-line transformers permit circuit designers considerable flexibility in choosing the geometrical shape of the transformer design. The bandwidth of hybrid transformers lies between that of meander-line and stepped-impedance designs for the same passband VSWR. Several examples of hybrid transformers were illustrated in the text.

Experimental three-turn meander-line and N = 4 hybrid meander-line transformers were designed and constructed in stripline. The experimental data agreed extremely well with the theoretically computed responses.

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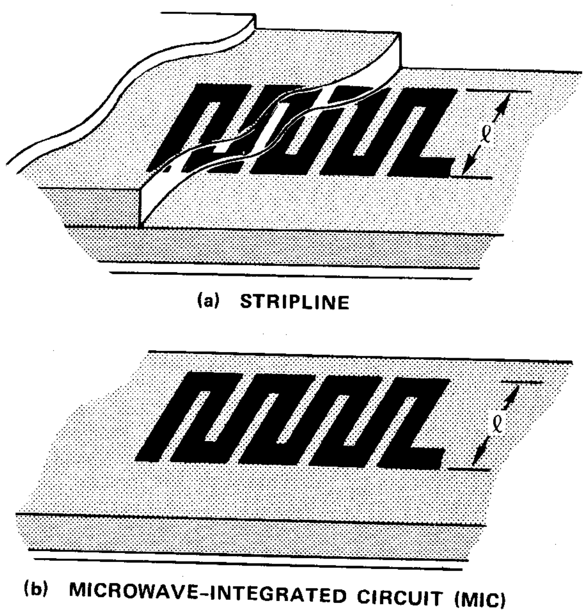

FIG.1. CONVENTIONAL MEANDER-LINE GEOMETRIES

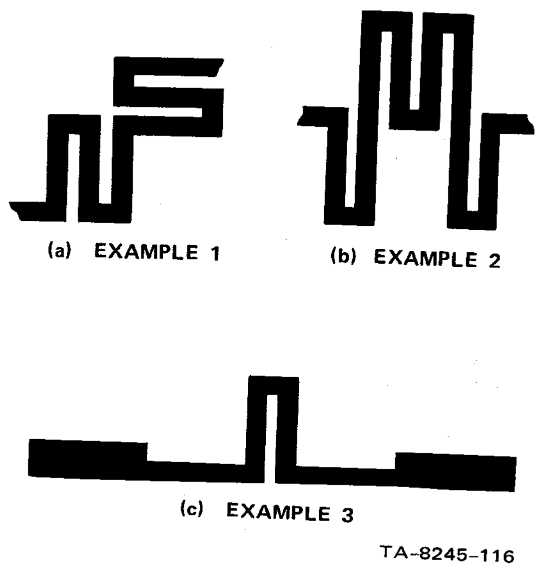

FIG.2. HYBRID MEANDER-LINE GEOMETRIES

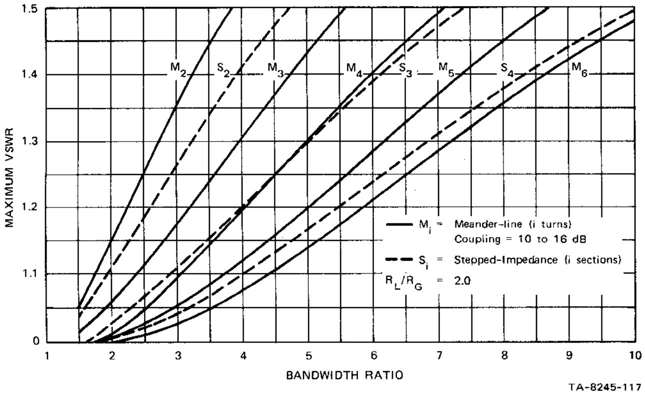

FIG. 3. CONVENTIONAL MEANDER-LINE GEOMETRIES

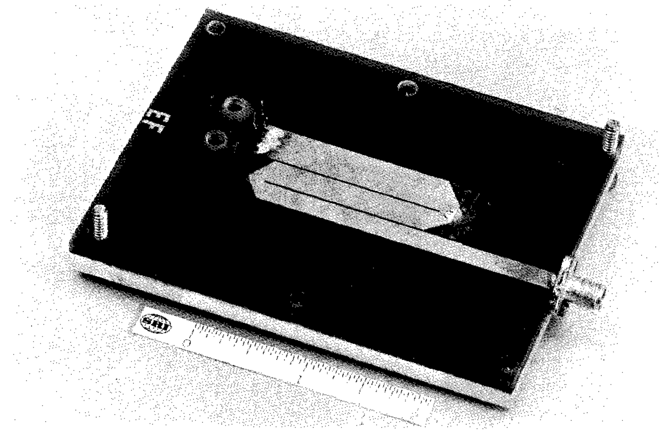

FIG. 4. EXPERIMENTAL THREE-TURN MEANDER TRANSFORMER

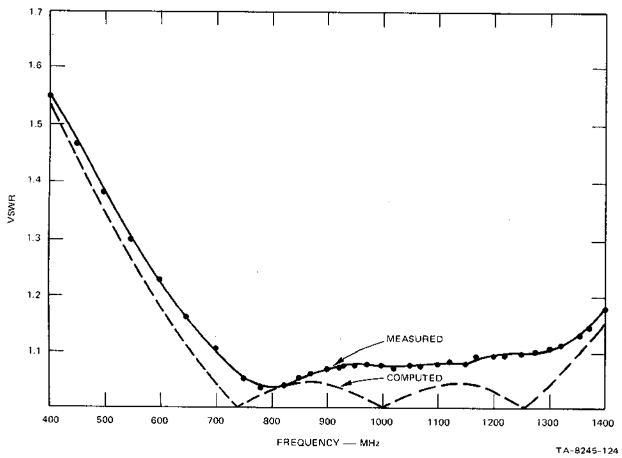

FIG. 5. MEASURED AND COMPUTED VSWR'S FOR EXPERIMENTAL THREE-TURN MEANDER-LINE TRANSFORMER

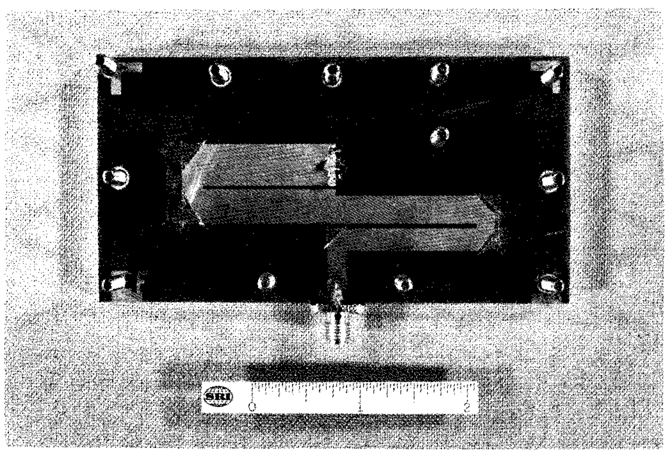

FIG. 6. EXPERIMENTAL (N=4) HYBRID MEANDER-LINE TRANSFORMER