Experimental Results on Buried Microstrip Lines for Constructing High-Density Microwave Integrated Circuits

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***Abstract*—This letter describes the characterization and some experimental results of a buried microstrip line (BMSL), a guided-wave structure considered to be promising for constructing high-density microwave and millimeter-wave integrated circuits because of its high isolation characteristics. The BMSL structure is characterized practically by the rectangular boundary division (RBD) method and rigorously by the finite difference time domain (FDTD) method. The analyzed results reveal that the BMSL structure possesses much lower coupling level than the conventional microstrip line does, from −15 to −100 dB depending on their burial depth. Experimental data show good agreement with numerical results.**

I. Introduction

In this letter, we describe the buried microstrip line (BMSL), which prossesses high isolation characteristics suited to high-density microwave integrated circuits. Fig. 1 shows a schematical view of BMSL whose dielectric medium, through which most electromagnetic waves propagate, is buried in the substrate. A strip conductor is placed on the top of the buried dielectric and conductor walls are formed to surround the buried dielectric. A similar structure has been studied for a single line by Rozzi *et al.* [1]. To our knowledge, however, the crosstalk characteristics of the structure have not been reported focusing on its application to microwave integrated circuits. The numerical analysis of the BMSL was conducted using the rectangular boundary division (RBD) method [2] based on the quasi-TEM approximation and the finite difference time domain (FDTD) method, which is based on the full wave analysis [3].

II. Calculation of Coupling Coefficients of Buried Microstrip Lines with Rectangular Boundary Division Method

The RBD method is employed for the analysis because the total region considered here can be easily divided into rectangular subregions suited to this simple and efficient method. The coupling level of two parallel BMSL's and those of two parallel microstrip lines are calculated and compared.

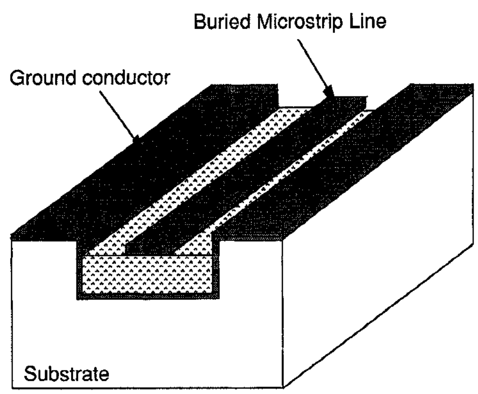

Fig. 1. Buried microstrip line (BMSL), which consists of a buried dielectric material, a strip conductor, and a ground conductor surrounding the buried dielectric material.

The coupling level, k, is defined as usual as follows:

$$k = \frac{Z_{\text{even}} - Z_{\text{odd}}}{Z_{\text{even}} + Z_{\text{odd}}} \tag{1}$$

where Z_{even} and Z_{odd} are determined as

$$Z_M = \frac{1}{v_0\sqrt{C_M C_{0M}}}. \tag{2}$$

[v_0 = light velocity in vacuum, C_M = capacitance with dielectric materials, C_{M0} = capacitance without dielectric materials, and M = mode designation (even or odd)].

Fig. 2 shows the calculated coupling levels, k, of the BMSL's as a function of distance between the two lines, s, in comparison with the k values of microstrip lines having the same dielectric thickness, dielectric constant, and strip conductor width. The calculated results are for $a_1 = a_2 = 100$ μm, $t_1 = t_2 = 100$ μm, $d_1 = d_2 =$ 0, 50, 100, 150 μm, $w_1 = w_2 = 50$ μm, and $\varepsilon_r = 3.4$. As can be seen in the figure, the BMSL possesses extremely low coupling levels compared with conventional microstrip lines, especially in the case of deeper burial depths d. When dimensions are chosen as $a_1 = a_2 = 100$ μm and $d_1 = d_2 = 150$ μm, the k values of the BMSL's become extremely low, such as −100 dB [4].

III. Experiments

In experiments, a BMSL coupler was fabricated for the evaluation of crosstalk characteristics. The line size in the cross-section is larger than those shown in Fig. 2 by a factor

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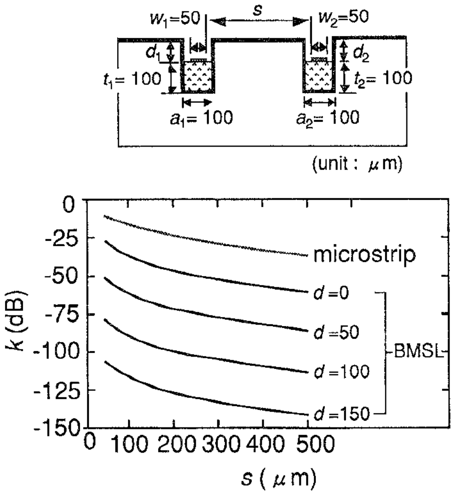

Fig. 2. Calculated coupling coefficients, k, of BMSL's as a function of the distance between the two lines, s, in comparison with the k values of microstrip lines of the same dielectric thickness, dielectric constant, and strip conductor width. Results are for $a_1 = a_2 = 100\ \mu$m, $t_1 = t_2 = 100\ \mu$m, $d_1 = d_2 = 0$, 50, 100, 150 μm, $w_1 = w_2 = 50\ \mu$m, and $\varepsilon_r = 3.4$.

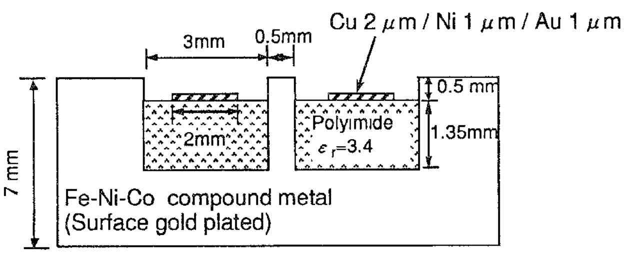

Fig. 3. Cross-sectional view of the fabricated BMSL. Covar is chosen as a substrate and polyimide is selected as buried dielectric material.

of about 20 for easier fabrication. Fig. 3 shows the cross-sectional view of the fabricated BMSL coupler. Polyimide was employed for the buried dielectric ($\varepsilon_r = 3.4$) and covar was chosen as the substrate material. The coupling length of the coupler is 35 mm and the coupling level was designed as -39.0 dB by the RBD method. S-parameters for the coupling port (S_{41}) were measured by an network analyzer HP8510B. The measured and calculated results with the RBD and the FDTD methods are shown in Fig. 4. As can be seen in the figure, these results show good agreement, indicating that the employed calculation methods are reasonable and that the quasi-TEM wave approximation can be practically applied to the proposed structure. The first local maximum value of the measured coupling level of the coupler is -39.5 dB, which is quite consistent with the designed value of -39 dB.

An extremely low coupling level such as -100 dB was not directly confirmed in this experiment because of the limitation of measurement. However, from the fact that the experimental

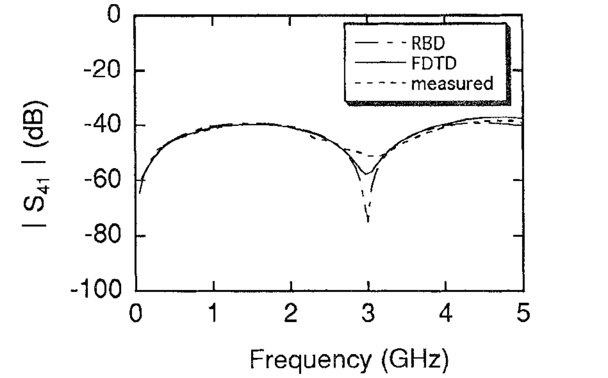

Fig. 4. Measured and calculated S-parameters with the RBD and with the FDTD methods for the coupling port (Port 4) These results show a good agreement, which supports the calculated results in Fig 2, and also demonstrates that the quasi-TEM wave approximation is valid for the proposed structure.

and measured results show good agreement we can conclude that BMSL's have superior low coupling levels as shown in Fig. 2.

IV. Conclusion

The buried microstrip line structure has been proposed for constructing high-density microwave integrated circuits. The stuructre possesses extremely low coupling levels compared with those of microstrip lines from -15 to -100 dB for the above dimensions. The agreement of experimental and calculated results on S-parameters clearly demonstrates that the employed calculation methods are reasonable. From the good agreement, we can conclude that BMSL should have extremely low coupling levels such as -100 dB and is expected to be utilized in high-density MIC's or MMIC's.

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