LOW CROSSTALK CHARACTERISTICS OF BURIED MICROSTRIP LINES

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ABSTRACT

This paper describes the extremely low crosstalk characteristics of a guided wave structure, Buried Microstrip Line. The analyses with the use of rectangular boundary division method and FDTD method have revealed that the line structure possesses much lower coupling coefficients than traditional microstrip lines, from -15 dB to -100 dB depending on their burial depth. This line structure is believed to be quite useful for realizing highly integrated microwave and millimeter-wave circuits.

I. INTRODUCTION

There have been increasing demands for downsizing microwave and millimeter wave components including MIC's and MMIC's because recent hand-carrying microwave apparatus such as personal mobile phones are required to be minimized in both weight and size. Despite such strong requirements, small sized or highly integrated microwave circuits have not been sufficiently developed. One of the reasons is that the high integration of MIC's and MMIC's forces us to make distances between interconnects in IC's and MMIC's extremely short, which can lead to serious crosstalk between circuits, degradation in circuit performances, and even reliability problems.

Several studies have been published in the past [1-2] on reducing coupling coefficients between two closely placed lines. However, it seems that guided wave structures which give satisfactorily low coupling coefficients and are readily applicable to MIC's/ MMIC's have not been reported.

In this paper, we investigate one variation of microstrip line structure, Buried Microstrip Line, (BMSL), which possibly meet the above requirements. As shown in Fig.1, dielectric media, through which electromagnetic waves propagate, are buried in a MICs' or MMICs' dielectric substrate such as alumina-ceramic, GaAs, and InP. Strip conductors are placed on the top of the buried dielectrics, and a ground conductor layer is formed to surround the buried dielectric. This type of structure has been studied as a single transmission line by Rozzi et al. [3-4]. To our knowledge, however, the crosstalk characterization of this structure has not been reported for the sake of realization of highly integrated microwave circuits.

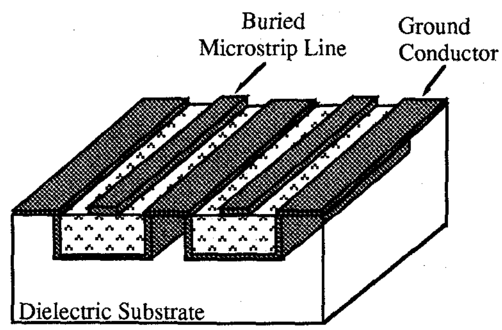

Fig.1 Schematic view of Buried Microstrip Line (BMSL)

Numerical analysis is conducted using a simple and practical method, Rectangular Boundary Division Method (RBD) [5] with the assumption of quasi-TEM wave approximation as the first step analysis and then the validity of the quasi-TEM wave analysis is confirmed by a full-wave analysis of Finite Difference Time Domain Method (FDTD) for the present dimensions.

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II. NUMERICAL ANALYSIS

(1) QUASI-TEM WAVE ANALYSIS WITH RECTANGULAR BOUNDARY DIVISION METHOD

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Figure 2(a) shows a cross-sectional view of the BMSL structure with size parameters.

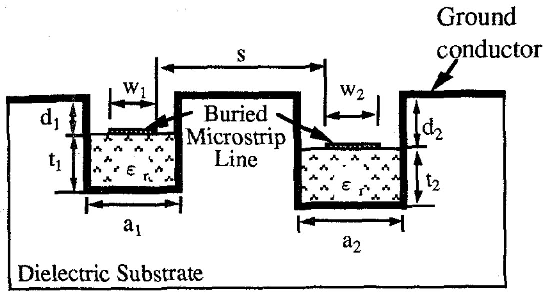

Fig.2(a) Cross-sectional view of BMSL

The reason of the utilization of the RBD method is that the total region considered here can be easily divided into rectangular subregions suited to this simple and efficient method. If the ground and strip conductors are considered to be perfect, an analytical model for the problem comes down to Fig.2(b) consisting of five regions.

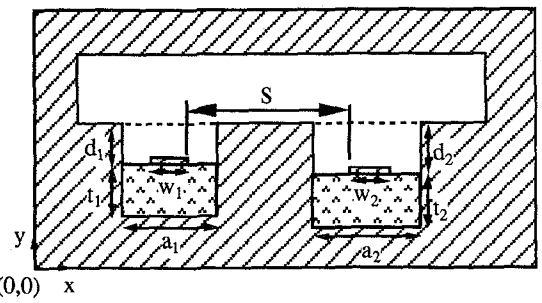

Fig.2(b) Analytical model of BMSL for rectangular boundary division method (RBD)

NUMERICAL RESULTS (RBD)

Figure 3(a) and 3(b) show calculated coupling coefficients, k of the BMSL's as a function of distance between the two lines, s for comparison with the coupling coefficients of microstrip lines. The results shown in Fig. 3(a) are for $a_1=a_2=3$ mm, $t_1=t_2=2$ mm, $d_1=d_2=0$, 1, 2, 3 mm, $w_1=w_2=1$ mm, and $\varepsilon_r=3.4$. Those shown in Fig.3(b) are for $a_1=a_2=2$ mm, $t_1=t_2=2$ mm, $d_1=d_2=0$, 1, 2, 3 mm, $w_1=w_2=1$mm, and $\varepsilon_r=3.4$. The coupling coefficient, k is defined as usual as follows:

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

where Zeven and Zodd are determined as

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

(v_0= light speed in vacuum, C_M=capacitance with dielectric, C_{M0}=capacitance without dielectric, M=mode (even or odd)).

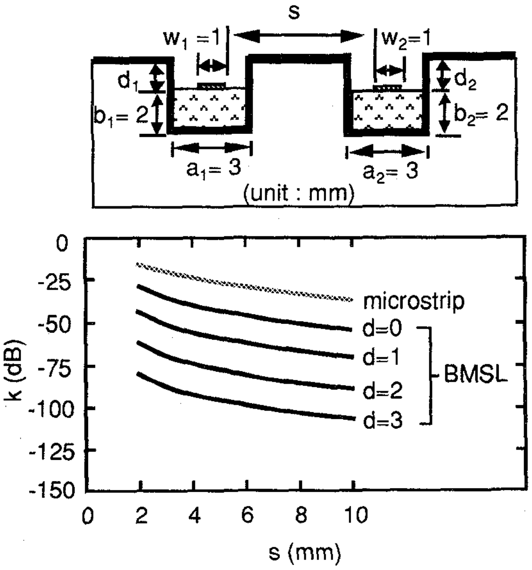

Fig.3(a) Relationship between coupling coefficient, k and distance of lines, s (a=3mm)

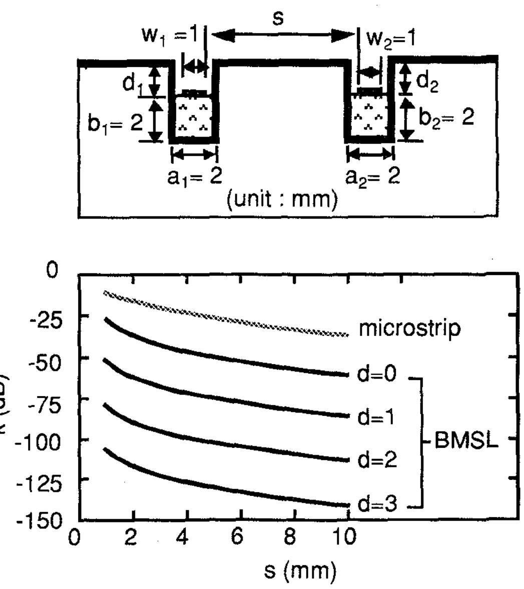

Fig.3(b) Relationship between coupling coefficient, k and distance of lines, s (a=2mm)

As seen in the figures, the BMSL possesses extremely low coupling coefficients compared with traditional microstrip lines, especially with the increase of burial depth, d. Comparison of Fig.3(a) with Fig.3(b) also indicates that the coupling coefficients become much smaller when the width of the buried dielectric becomes narrower because of the stronger containment effect of propagating waves. When the dimensions are chosen to be $a_1=a_2$=2mm and $d_1=d_2$=3 mm, the k values of BMSL become extremely low to -100 dB. From these results, we conclude that the BMSL structure is greatly useful in achieving high isolation transmission lines for microwave circuits such as MIC's and MMIC's.

(2)FINITE DIFFERENCE TIME DOMAIN METHOD (FDTD)

The above mentioned analysis using RBD is based on the quasi-TEM wave approximation. In this section, the validity of the approximation is checked by a full wave analysis, namely finite difference time domain method (FDTD) [6]. The analytical model adopted here is shown in Fig.4(a) and Fig.4(b). The model contains two parallel-coupled BMSL's (l=17.5 mm) and four termination resistors with resistance value same as the characteristic impedance of the lines. This method was reported in the literature [7], and it showed that reflected coefficients at the terminations are less than 10 percent for the frequencies under 10 GHz. The cell size is set to be Δx=0.5 mm, Δy=0.25 mm, and Δz=0.25 mm. The time step is Δt=0.4 ps, which are derived from the Courant condition [8]. The adopted absorbing boundary conditions are Mur's 1st and 2nd orders' [9]. The cell numbers are n_x=30, n_y=48, and n_z=130.

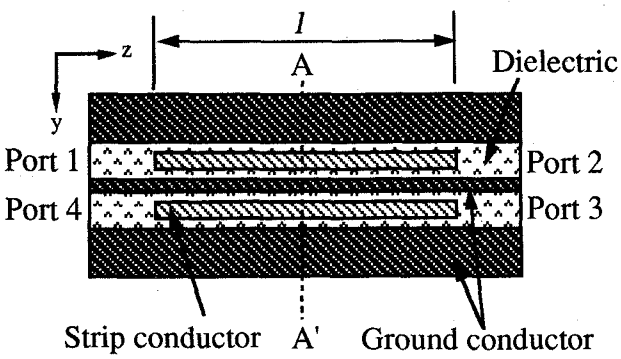

Fig.4(a) Top view of analytical model for parallel-coupled BMSL's for FDTD analysis

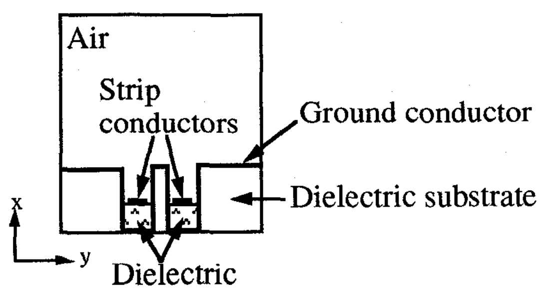

Fig.4(b) Cross-sectional view at A-A' in Fig.4(a)

NUMERICAL RESULTS (COMPARISON OF RBD WITH FDTD)

Figure 5(a) and 5(b) show examples of the calculated s-parameters for the case of $a_1=a_2$=2 mm, $t_1=t_2$= 2 mm, $d_1=d_2$=3mm, $w_1=w_2$=1 mm, s=1.5 mm, and ε_r=3.4 to compare the results from RBD and from FDTD. The s-parameters from RBD are calculated using a method introduced by Yamamoto et al. [10]. In the method electric or magnetic fields for each port are obtained as

$$c_1=(\Gamma e+\Gamma o)/2$$
$$c_2=(Te+To)/2$$
$$c_3=(Te-To)/2$$
$$c_4=(\Gamma e-\Gamma o)/2.$$

Where, c_1-c_4 are electric or magnetic fields, and Te, To, Γe, and Γo are a transmission coefficient for the even mode, a transmission coefficient for the odd mode, a reflection coefficient for the even mode, and a reflection coefficient for the odd mode, respectively. This method is especially adequate for crosstalk analysis because it can provide s-parameters for the isolation port also, while traditional methods do not [11].

Figure 5(a) shows the s-parameters for the isolation port (port 3) and Fig 5(b) shows those for the coupling port (port 4). These figures clearly indicate good agreement of the results based on RBD with those on FDTD, therefore verify that quasi-TEM mode assumption is valid for BMSL structure of the present dimensions. This fact is considered to make design of MIC's and MMIC's containing BMSL's quite simple. From Fig.5(a) and Fig. 5(b), it is also revealed that FDTD can handle such small signal power levels, which corresponds to a calculation dynamic range as much as 140 dB.

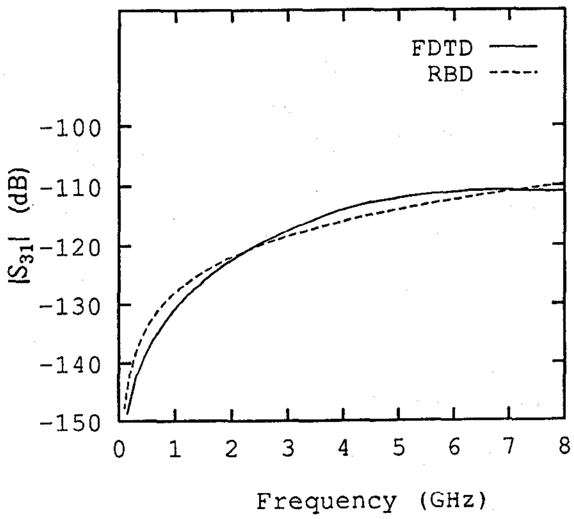

Fig.5(a) Comparison of s-parameters ($|S_{31}|$) between RBD and FDTD.

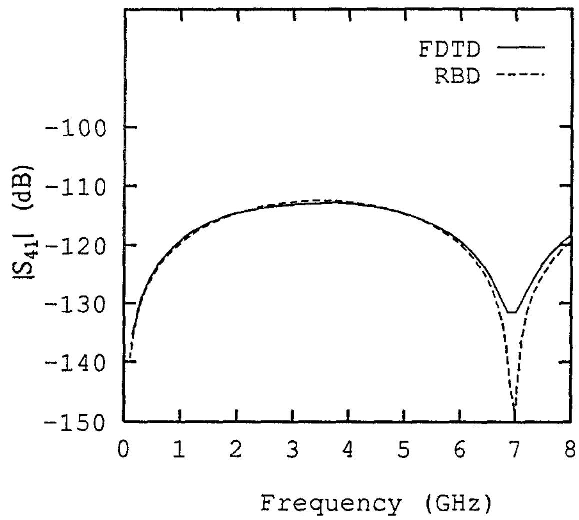

Fig.5(b) Comparison of s-parameters ($|S_{41}|$) between RBD and FDTD.

III. CONCLUSION

The crosstalk characteristics of BMSL structure have been analyzed and compared with those of traditional microstrip lines with the use of RBD and FDTD methods. It has been revealed that the structure possesses extremely low coupling coefficients compared with those of microstrip lines from -15 to -100 dB for the given dimensions. The FDTD analysis verified that the quasi-TEM assumption is valid for the structure of the present dimensions, showing that design of MIC's and MMIC's of BMSL's is quite simple by using quasi-TEM parameters. The BMSL structure is expected to be utilized in MIC's and MMIC's requiring low cross-talk characteristics.

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