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Research paper

Using rectangular trace to reduce the crosstalk of the coupled microstrip lines

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Abstract

New electronic products must have high-speed, small size and lower voltages supply. With such layout, signal integrity (SI) becomes an actual important issue because sensitive equipment is affected on electromagnetic interference (EMI). Crosstalk is a major factor in signal integrity (SI) of printed circuit boards (PCBs). Crosstalk noise is usually represented in terms of Near-End crosstalk (NEXT) and Far-End crosstalk (FEXT). Crosstalk is a common problem that degrades circuit performance. To reduce this problem, via hole-fences connected by guard trace between double microstrip lines are used, in this case the crosstalk will be reduce by 6 dB than use 3W rule, but when it replaced by rectangular metal the crosstalk was reduce by 7dB, is better than use via hole-fences by 1 dB. The simulation result was done by using FEKO 5.5 simulator.

Keywords: *FEXT; NEXT; SI; Via Fences*

1. Introduction

In microwave circuit, the microstrip line has many problems one of these problems are crosstalk (coupling). Coupling is an important problem for the circuits that have multi-lines, which is induced by the difference between the capacitive coupling ratio (Cm=CT) and inductive coupling ratio (Lm=LS) [1]. This problem is still very important due to the usage of the Very Large Scale Integration (VLSI) circuit's technology with extremely small dimensions of micron levels [2] [3]. The study shows that microstrip lines can be easily adapted to the small dimensions. The crosstalk problem is due to the close placement of the lines which can be reduced by some design techniques, which are discussed fully later. Crosstalk is one source of noise in PCBs and is of particular concern high-speed circuits, is one major source of noise to interfere with SI. In latest years, the crosstalk problem is getting worse because design density is increasing between connections of chips [4]. Crosstalk is generally known as Near-end crosstalk (NEXT) and Far-End crosstalk (FEXT). FEXT and is induced by the difference between the inductive coupling ratio L_m/L_S and capacitive coupling ratio (C_m/C_s), but in addition, it is relational to the length of the parallel microstrip lines and only occurs in heterogeneous environment. In a parallel-terminated of the microstrip lines, the NEXT is less problematic than FEXT so that it really affects the SI at the receiver side [3]. So, reduce Far-End crosstalk FEXT is one of the most important objectives in a PCB layout [3]. Coating microstrip lines with 3W rule [5] is used by PCB designers to comply with (PCB) design and signal integrity.
In this paper based on the mode of double parallel microstrip lines Fig. 1 the crosstalk problem between double microstrip lines will be analysis and under tow kind of designs to reduces crosstalk (FEXT and NEXT). The coat substrate in those designs was used to protect metal from external phenomenons.

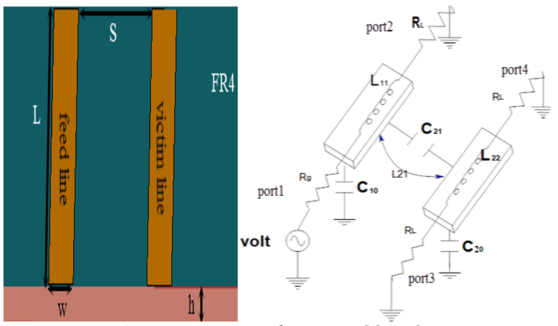

Fig. 1: Geometry of Step-Width Balun

2. Crosstalk equations

The voltage of the far-end crosstalk is motivated as a result of variation between coupled capacitive and inductive rate to multiple microstrip lines C_m/C_S & L_m/L_S where $C_{21}=C_m$, $L_{21}=L_m$ which are mutual capacitance and inductance respectively C_S and self-capacitance and inductance respectively. Where the total inductance and the total capacitance in this design are:

$$L=\begin{bmatrix} L_{11} & L_{12}=L_m \\ L_{21}=L_m & L_{22} \end{bmatrix} \text{nH/m} \tag{1a}$$

$$C=\begin{bmatrix} C_{11} & -C_{12}=-C_m \\ -C_{21}=-C_m & C_{22} \end{bmatrix} \text{pF/m} \tag{1b}$$

The voltage at the Far-end and Near-end are related to Cm, Cs, Lm and Ls was given by [11] as follow equations. For the FEXT voltage at port 4, far from source port is:

Let $K_a = \frac{C_m}{C_s}, K_b = \frac{L_m}{L_s}$

$$V_{FEXT} = \frac{1}{2}\left(K_a - K_b\right) * T_D * \frac{dV_{in}\left(t - T_D\right)}{dt} \quad (2)$$

For the port 3 which is close to port 1, in other words, near-end has voltage called near-end crosstalk voltage as shown in Equation given by [5].

$$V_{NEXT} = \frac{1}{4}(K_a + K_b)[V_{in}(t) - V_{in}(t - T_D)] \quad (3)$$

It is clear that K_a must be equal to K_b for zero V_{FEXT}. In this thesis, we carried out a study to reduce the V_{FEXT} i.e. to achieve $K_a \approx K_b$. Where T_D the propagation time is over the transmission line and $\frac{dV_{in}(t - T_D)}{dt}$ is changing for the applied voltage at the aggressor line as the ratio of time. The crosstalk in the double microstrip line is due to the mutual inductance and the mutual capacitance between the lines which are given by following equations [1]:

$$v = L_m * \frac{d_i}{d_t} \quad (4a)$$

$$i = C_m * \frac{d_v}{d_t} \quad (4b)$$

Where v, and i represent voltage and current drop respectively in the victim trace, di/dt is the time varying current and dv/dt time varying voltage in the feed line. (L_m and C_m) are mutual capacitance and inductance the coupling equations are shown below [1]:

$$\left|S_{21}\right| = *\left|\cos\left[\frac{(\Delta\beta)L}{2}\right]\right| \quad (5a)$$

$$\text{Or } |S_{21}| = 20\log\frac{V_2}{V_1} \quad (5b)$$

$$|S_{41}| = \left|\sin\left[\frac{(\Delta\beta)L}{2}\right]\right| \quad (5c)$$

$$\text{Or } |S_{41}| = 20\log\frac{V_4}{V_1} \quad (5d)$$

Where $\Delta\beta = \beta_e - \beta_o$; β_e and β_o are even and odd mode propagation constant respectively. The scattering parameters for the backword coupling are direct couple S_{21}, NEXT S_{31} and S_{41}. But the refflection coefficient S_{11} and S_{41} are zero.

$$S_{21} = \frac{\sqrt{1 + D^2}}{\sqrt{1 - D^2}\cos\theta + j\sin\theta} \quad (6a)$$

$$S_{31} = \frac{jD\sin\theta}{\sqrt{1 - D^2}\cos\theta + j\sin\theta} \quad (6b)$$

$$\text{Or } |S_{31}| = 20\log\frac{V_3}{V_1} \quad (6c)$$

Where θ is the phase coupling or electrical length of the coupling microstrip lines where if the length of the coupled line increases, the lead to the phase of signal will increase as shown in equation from [1]:

$$\theta = \beta L = w\sqrt{\mu\varepsilon}L = \frac{2\pi fL}{u} \quad (6d)$$

And the coupling parametar D is:

$$D = \frac{Z_{0e} - Z_{0o}}{Z_{0e} + Z_{0o}} \quad (6e)$$

Where L is the physical coupling length of the line, V_2 is the direct coupling voltage or reflected voltage from port 2, V_4 is the Far-End crosstalk voltage, V_1 is the input voltage (source voltage) and V_3 is near-end crosstalk voltage; Z_{0e} and Z_{0o} are even and odd mode charecterstic impedances respectively of the coupled lines where the characteristic impedance of line $Z_0 = \sqrt{Z_{0e} * Z_{0o}}$.

3. FEKO simulation for crosstalk

The impact factors of the crosstalk between parallel microstrip lines in PCB are various, for example, spacing between lines, effective relative permittivity of the substrate, and length of line, frequency and thickness of substrate. One of the simulation methods used those factors to reduce crosstalk. in this paper, There are tow methods also help us to reduce the crosstalk between lines like via fence and rectangular metal placed between lines.

4. Rectangular trace

In this section, new proposed method will be used to reduce the crosstalk between double microstrip lines with good results and the lowest cost than used via fences Fig 2. In this case the rectangular trace will be placed Instead of the via fences between double microstrip lines as shown in the Fig 3 with dimensions shown in Table.1 below. It is achieved high direct couples but closely; and less FEXT compared with the previous methods (3W spacing rule and with use via fences) by 7dB and 1dB respectively. Figs. 4, 5 demonstrate direct coupling, (FEXT) between lines respectively. The lines have characteristic impedance of 50Ω matched by same impedance load.

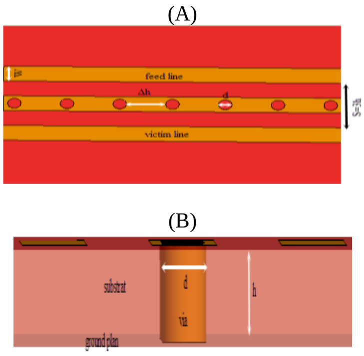

Fig. 2: Used Via Fence (A) Top View (B) Side View

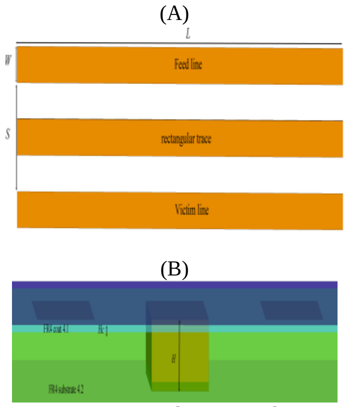

Fig. 3: Double Microstrip Lines With Rectangular Trace (A) Tope View (B) Side View

Table 1: Dimensional Parameter for Using Rectangular Trace Technique

W	H	H_c	L	S	W_R	ε_{r1}	ε_{r2}	D_v	
0.396 mm	0.2 mm	0.02 mm	50 mm	3W	0.396 mm	4.2	4.1	W	1.1855 mm

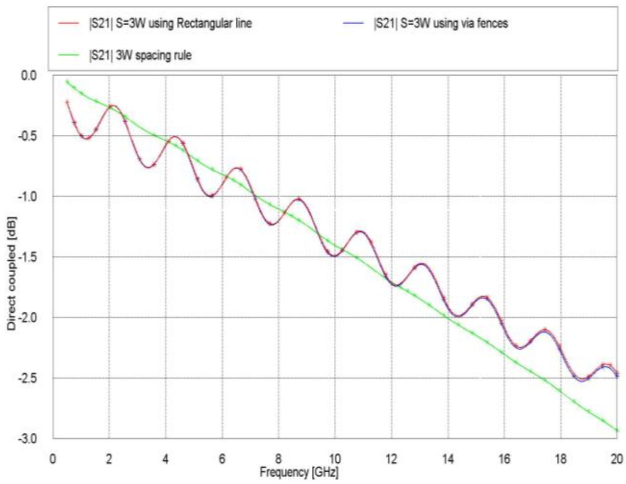

Fig. 4: Compare the Direct Coupling S11 Among Use Rectangular Trace, Use Via Fences and with 3W Rule, with S=3W

FEXT S_{41} when the rectangular trace was used with the spacing is 3W and comparing it with via fence and 3W rule manner shown in Fig. 5:

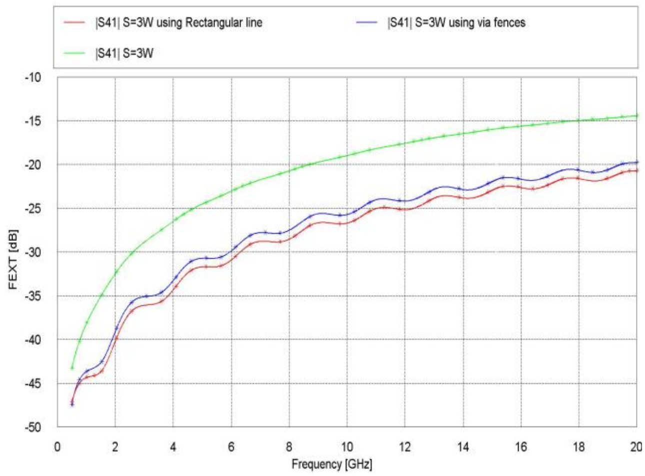

Fig. 5: Description of FEXT Among Use Rectangular Trace, Use Via Fences and with 3W Rule, with S=3W

The electromagnetic field when the rectangular trace was used between microstrip lines shown in Fig. 6 at frequency 10GHz.

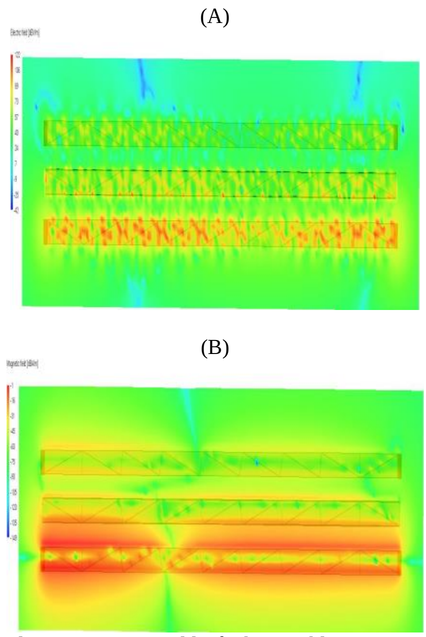

Fig. 6: The Electromagnetic Field of The Double Microstrip Lines with Rectangular Trace (A) Electric Field (B) Magnetic Field

5. Conclusion

In this paper changing and reduce the crosstalk between double microstrip lines was under compared three techniques, using rectangular trace between microstrip lines new method compared it with other two methods (3W rule and using via fence) all have same dimensions. The crosstalk problem between double microstrip lines is analysis and simulated by using FEKO 5.5 simulation software. With several previous methods used, we accommodate new way to reduction crosstalk by using novel geometry, e.g. using rectangular trace between microstrip lines, helped us to get better results for (FEXT); we compared with the past methods to solve this problem; and discover improvement in our results nearly by 7dB by using rectangular trace, if it's compared with the result of the design of the spacing rule for S= 3W, and 1dB if it's compared with the design that used via fence. But for NEXT, it reduces but slightly ranged because the NEXT is less effective than FEXT on signal integrity (SI) at the receiver.

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