Crosstalk reduction using nonuniform transmission lines

Conference Paper · September 2015

DOI: 10.1109/SOFTCOM.2015.7314081

Mnaouer Kachout
École Supérieure des Communications de Tunis

Fethi Choubani
École Supérieure des Communications de Tunis

Crosstalk Reduction Using Nonuniform Transmission Lines

Mnaouer KACHOUT*, Jamel BEL HADJ TAHAR and Fethi CHOUBANI

Innov'COM, Sup'Com,
Carthage University, Tunis, Tunisia
mnaouer.kachout@supcom.rnu.tn

***Abstract*— In this paper, a crosstalk reduction technique is proposed which utilizes nonuniform transmission lines. We investigate the effect of the nonuniform transmission line on the crosstalk reduction by simulation. We also present a comparison between coupled lines with uniform and nonuniform structures. Results show that using nonuniform guard line reduces crosstalk by more than 10db.**

Keywords—guard line; nonuniform line; crosstalk

I. INTRODUCTION

With the advances in integrated circuit technologies, printed circuit boards (PCBs) with highly dense interconnects are commonly used. To accommodate a number of line traces in a small area, multi-layer PCBs with tens of layers are widely adopted despite the high cost of fabrication. The density of signal transmission lines on a layer is mainly limited by the crosstalk levels between adjacent line traces. The conventional design guide states that the clearance of the line traces is kept larger than three times the width of line traces [1]. To overcome the density limitation, various crosstalk reduction schemes are devised like serpentine line traces [2], via fences [3], or corrugated lines [4]. In most approaches, efforts are made to decrease the crosstalk levels by equalizing the magnitudes of coupling voltages due to capacitive and inductive mechanisms so that they cancel each other such as inserpentine line or via fences [5].

Interest in cross-talk on transmission lines and microstrip circuits has spurred a lot of interest in recent years, and thus there are many aspects and approaches to cross-talk prediction published in the literature. Modal decomposition, a technique that decouples the lines by finding the propagating modes on the lines, can be used to find an exact solution of the transmission-line equations. Modal analysis can be used both in the frequency domain [6], and in the time domain [7].

This technique is easily implemented into SPICE circuits using the uncoupled line model and linear dependent sources. Other techniques provide approximate solutions by solving the equations using time-stepping, fast Fourier transforms, convolutions, and discrete lumped-element circuits.

In this paper, the cross-talk between two parallel transmission lines on the PCB is reduced by inserting a third line between the interfering lines. This third line is called guard line. Nonuniform guard line is adopted to decrease crosstalk levels.

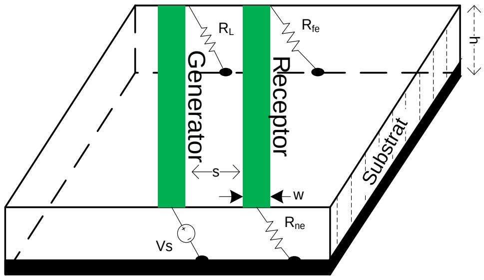

Fig. 1: Three-conductor transmission lines illustrating crosstalk

In the following sections, reduction of crosstalk levels is investigated. This paper is organized as follows. Section 2 presents a brief background on formulating multiconductor transmission lines. In Section 3 we study the effect of uniform and nonuniform guard lines between the two transmission lines on crosstalk reduction.

II. CALCULATION OF CROSSTALK

A three-micro strip transmission lines structure is sketched in Fig. 1, an equivalent model is depicted in Fig. 2.

A voltage source $V_S(t)$, with internal resistance R_S, is connected to a load R_L via both a generator conductor and reference conductor. A receptor circuit shares the same reference conductor and connects two terminations R_{NE} and R_{FE} by a receptor conductor.

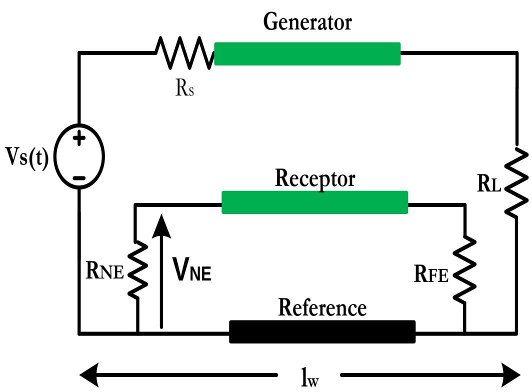

Fig.2: Coupled transmission line

This section aims to address crosstalk between conductors. The near-end crosstalk can be viewed as a transfer function between the input $V_S(t)$ and the outputs V_{NE} [8]. This can be determined by factoring out $V_S(t)$ to give:

$$\frac{\hat{V}_{NE}}{\hat{V}_s} = j\omega(M_{NE}^{IND} + M_{NE}^{CAP}) + M_{NE}^{CI} \quad (1)$$

where ω = 2πf

Where inductive coupling M_{NE}^{IND} in the near-end crosstalk is given by:

$$M_{NE}^{IND} = \frac{R_{NE}}{R_{NE}+R_{FE}} * \frac{l_m * l_w}{R_S+R_L} \quad (2)$$

M_{NE}^{CAP} *is* Capacitive coupling in the near-end crosstalk is determined by:

$$M_{NE}^{CAP} = \frac{R_{NE}*R_{FE}}{R_{NE}+R_{FE}} * \frac{R_L*c_m*l_w}{R_S+R_L} \quad (3)$$

Is the Common impedance coupling in the near-end M_{NE}^{CI} crosstalk can be evaluated using:

$$M_{NE}^{CI} = \frac{R_{NE}}{R_{NE}+R_{FE}} * \frac{R_0}{R_S+R_L} \quad (4)$$

The far-end crosstalk is determined by:

$$\frac{\hat{V}_{FE}}{\hat{V}_s} = j\omega(M_{FE}^{IND} + M_{FE}^{CAP}) + M_{FE}^{CI} \quad (5)$$

The far-end crosstalk inductive coupling M_{FE}^{IN} and capacitive coupling M_{FE}^{CAP} are given in (6) and (7), respectively.

$$M_{FE}^{IN} = -\frac{R_{FE}}{R_{NE}+R_{FE}} * \frac{l_m * l_w}{R_S+R_L} \quad (6)$$

$$M_{FE}^{CAP} = \frac{R_{NE}*R_{FE}}{R_{NE}+R_{FE}} * \frac{R_L*c_m*l_w}{R_S+R_L} \quad (7)$$

Common impedance coupling in the far-end crosstalk can be evaluated using:

$$M_{FE}^{CI} = \frac{R_{NE}}{R_{NE}+R_{FE}} * \frac{R_0}{R_S+R_L} \quad (8)$$

In our case, microstrip transmission lines structure shown in Fig.1 is assumed to be immersed in an inhomogeneous medium, where *w=2mm*, *s=8mm*, *h=1.6mm*, and ε_r*=4,7*(glass epoxy).

The per-unit length capacitance parameter matrix is:

$$C = \begin{bmatrix} C_g + C_m & -C_m \\ -C_m & C_r + C_m \end{bmatrix} \quad (9)$$

Using the aforementioned constitutive parameters of glass epoxy, one finds:

$$C = \begin{bmatrix} 115.5 & -4.92 \\ -4.92 & 115.5 \end{bmatrix} pF/m \quad (10)$$

The per-unit length inductance parameter matrix is:

$$L = \begin{bmatrix} l_r & l_m \\ l_m & l_g \end{bmatrix} \quad (11)$$

Using the relation between the per-unit length capacitance and inductance parameters, this yield:

$$L = \begin{bmatrix} 335.3 & 37.5 \\ 37.5 & 335.3 \end{bmatrix} nH/m \quad (12)$$

In Fig.3 we compare theoretical with simulation data.

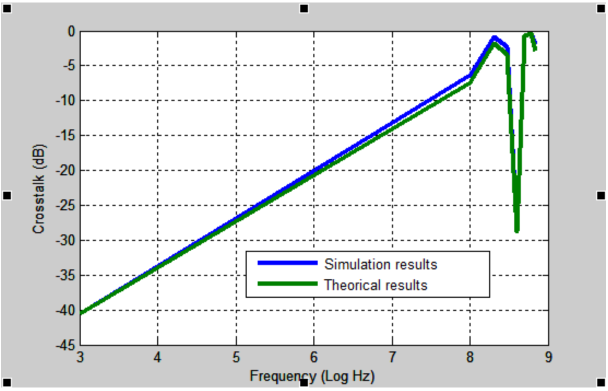

Fig.3 :Crosstalk:simulation vs theoretical results

Fig.3 shows that the coupling increases gradually with frequency. Maximum crosstalk is achieved at a frequency of *800MHz*.We can see that theoretical and simulations results agree well the foregoing has assumed a lossless line (perfect conductors) and a lossless medium. The assumption of a lossless medium is usually a reasonable assumption for frequencies below the GHz range. However, imperfect conductors can produce significant crosstalk at the lower frequencies. This is referred to as common impedance coupling.

III. GUARD LINE EFFECT ON CROSSTALK REDUCTION

In this section we are interested in the study of the effect of guard line in crosstalk reduction. We start by using uniform guard line, and then we study the nonuniform one. Finally we make comparison between them in term of crosstalk reduction.

A. Uniform guard line

The crosstalk performances of coupled transmission line configurations shown in Fig. 4 are investigated in this section. The geometry comprises two microstrip lines with uniform guard line.

The effect of uniform guard line in terms of crosstalk is investigated. We used several widths w_u (2mm, 2.5mm and 3mm) of the guard line. From HFSS simulations, the S-parameters of these coupled structures are generated as presented in Fig.5.

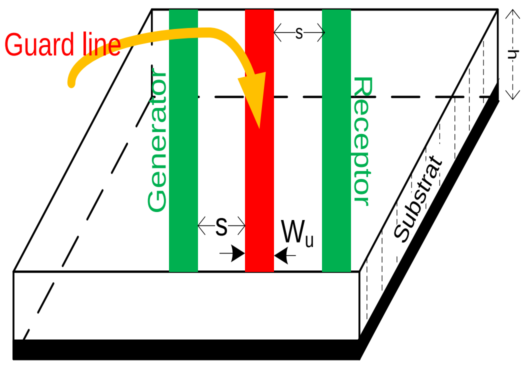

Fig.4 : uniform guard line

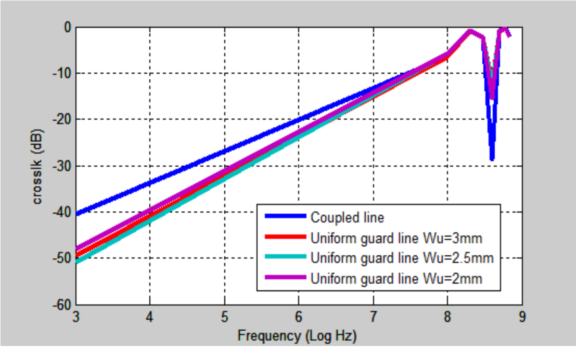

Fig.5: crosstalk effect of uniform guard line

The far end crosstalk levels obtained from the uniform guard line of 2mm width increases from -48dB at 1KHz to -7 dB at 100MHz. When the width of the guard line is increased to 2.5mm and 3mm the crosstalk decreases respectively to -51dB and -49dB at 1KHz. However at 100 MHz the crosstalk performance is the same for these different uniform guard line widths.

As can be seen, the proposed structure with uniform guard line provides significant reduction in crosstalk when compared with configuration without guard line over the same frequency span.

It can be observed that the crosstalk decreases when we use the uniform guard line. The best crosstalk reduction is achieved for a width guard line of 2.5mm.

B. Nonuniform guard line

To investigate the crosstalk reduction between adjacent lines by using a nonuniform line various test structures are studied. The nonuniform line structure is sketched in Fig 6.

We used different lengths w_n (2.5cm, 5cm, 7.5cm and 10cm) of the nonuniform structure. From HFSS simulations, the S-parameters of these coupled structures are represented in Fig.7.

Obtained results illustrate the crosstalk reduction effect, and give a comparison between crosstalk levels of structures with/without nonuniform guard line.

For 5cm w_n length the crosstalk increases from -54db at 1KHz to -7dB at 100MHz.Best performance in crosstalk reduction can be obtained with nonuniform guard trace with 2.5cm w_n length**.**

It is observed that the crosstalk decreases when we use nonuniform guard line. With Wn=2.5cm the crosstalk decreases by more than 10dB at a frequency of 1MHz.

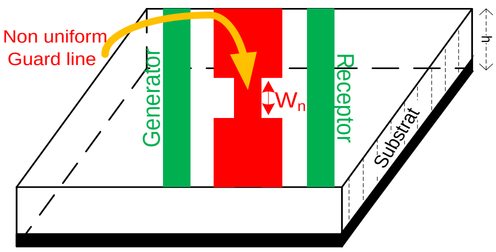

Fig.6: Nonuniform guard line

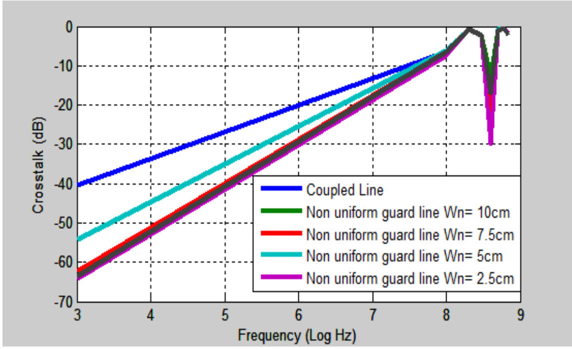

Fig.7: crosstalk effect of non uniform guard line

To illustrate the effect of nonuniform guard line in terms of crosstalk reduction, crosstalk levels of uniform guard line with w_u=2.5mm is compared with nonuniform guard line with w_n=2.5cm.

Fig.8 shows comparison between uniform and non uniform guard line. With uniform guard line the crosstalk level is reduced by 4dB at 1MHz. Maximum crosstalk performance reduction is obtained with nonuniform guard line (10dB at 1MHz). Obtained results show the advantages of using nonuniform guard lines for crosstalk reduction.

IV. Conclusion

In this paper, crosstalk reduction effect due to the nonuniform guard line is investigated. A simple numerical formulation is also presented to predict the crosstalk between uniform coupled lines. Comprehensive comparisons between the results which are obtained by using uniform guard line on one hand and those obtained by the non uniform guard line the other hand; have shown an excellent suprematy of the nonuniform guard line for crosstalk reduction.

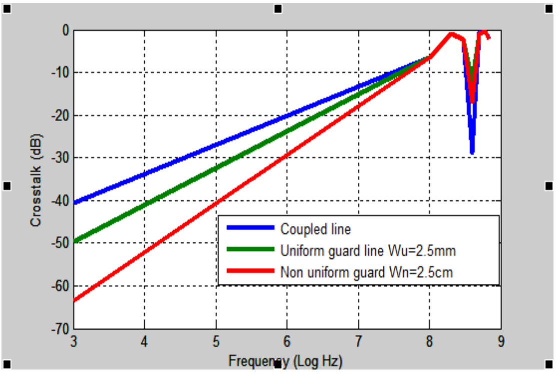

Fig.8: Uniform Vs nonuniform guard line

References

[1] Khalaj-Amirhosseini, M., ''Using linear sections instead of uniform ones to analyze the coupled nonuniform transmission lines,'' Int. J. RF and Microwave Computer-aided Eng., Vol. 19, No. 1, Jan. 2009.

[2] Huang, W.-T., C.-H. Lu, and D.-B. Lin, ''Suppression of crosstalk using serpentine ground trace vias, '' Progress In electromagnetic Research, Vol. 109, 2010

[3] Huang, W. T., C. H. Lu, and D. B. Lin, ''The optimal number and location of grounded vias to reduce crosstalk,'' Progress In Electromagnetics Research, Vol. 95, 241-266, 2009.

[4] Wu, J. J., ''Subwavelength microwave guiding by periodically corrugated strip line,'' Progress In Electromagnetics Research, Vol. 104, 113-123, 2010.

[5] Amirhosseini, M. K., ''Optimum design of microstrip interconnects using additional coupling capacitance,'' Journal of Electromagnetic Waves and Applications, Vol. 19, No. 7, 973-986, 2005.

[6] Khalaj-Amirhosseini, M., ''Analysis of coupled nonuniform transmission lines through analysis of uncoupled ones,'' Int. Symp. On Antennas and Prop. (ISAP'06), Singapore, Nov, 2006.

[7] Khalaj-Amirhosseini, M., ''Analysis of coupled nonuniform transmission lines using Taylor's series expansion,'' IEEE Trans. Electromagn. Compat., Aug. 2006.

[8] KACHOUT Mnaouer, BEL HADJ TAHER Jamel and CHOUBANI Fathi, ''Three Conductors Non uniform Transmission Lines: Electrical Equivalent Model and Crosstalk reduction'', International Conference on Multimedia Computing and Systems (icmcs'14), Marrakesh – Morocco, April 2014