SIMPLE AND LOW-COST METHOD OF FAR-END CROSSTALK REDUCTION IN COUPLED MICROSTRIP LINES

Talgat GAZIZOV, Nyurgun LEONTIEV, Olga KUZNETSOVA-TADJIBAEVA
Tomsk State University of Control Systems and Radioelectronics,
Lenin Ave., 40, Tomsk, Russia, 634050, E-mail: talgat@tu.tusur.ru

1. Introduction

The far-end crosstalk reduction problem becomes one of the most important signal integrity and internal EMC problems being an obstruction for development of high-speed and high-density electronic equipment. Particularly, the problem is actual for electrically long interconnects in nonhomogeneous dielectric filling.

The far-end crosstalk may be reduced by wider separation of coupled interconnects or by placing the additional grounded traces, but at the expense of decreasing the density of interconnects. A number of useful possibilities for reduction of high-speed signal distortions in high-density interconnects of the double-layered dielectric PCB are shown in [1]. Moreover, some additional possibilities for reduction of far-end crosstalk in cascaded sections of the board's interconnects have been presented recently [2]. Particularly, the property of capacitive coupling coefficient of two coupled suspended or inverted microstrip lines to be more than inductive coupling coefficient is used in these improvements. Unfortunately, this property is not inherent to usual microstrip lines used widely for high-speed signals' transmission in various applications, for example, in ultra wideband radar systems with microstrip antennas.

The aim of this paper is to investigate the method of far-end crosstalk reduction in two coupled microstrip lines by means of the covering dielectric layer.

2. The proposed method

We consider here a case of two coupled lines only, assuming for simplicity that the influence of other conductors is negligible. The main idea of the method is very simple and consists in the following.

As shown in [3, 4], the capacitive coupling of suspended or inverted microstrip lines may be more than, less than or equal to the inductive coupling in accordance with parameters of the lines. Therefore, the far-end crosstalk being approximately proportional to the difference of capacitive and inductive couplings will have positive or negative polarity or will be canceled in accordance with parameters and type of the lines. It is well known that the capacitive coupling of usual microstrip line is always less than the inductive coupling for any parameters of the line. However, a simple addition of the covering dielectric layer over the usual microstrips transforms the ones to lines similar to inverted microstrip lines (Fig.1). Therefore, some new properties absent in usual microstrip lines may appear in the covered microstrip lines and may be used in single section or cascaded sections of the coupled lines. Particularly, if the difference of capacitive and inductive couplings in one section has a sign, which is opposite to the difference of capacitive and inductive couplings in other section, the partial or complete compensation of far-end crosstalk is possible. To test this assumption the calculation of lines' parameters and simulation of waveforms would be done.

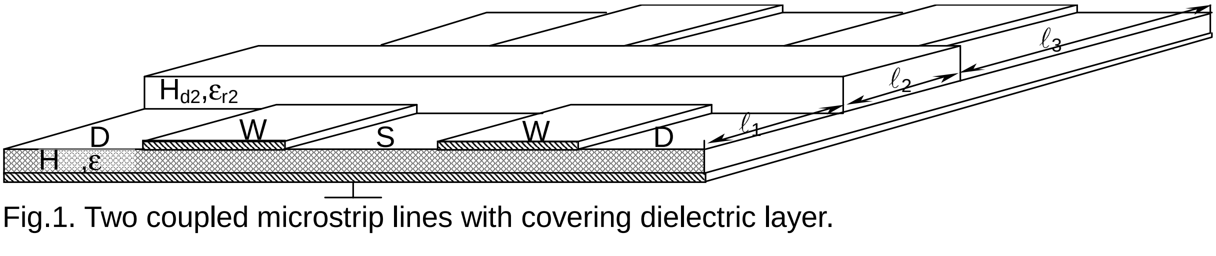


Fig.1. Two coupled microstrip lines with covering dielectric layer.

3. Calculation of capacitive and inductive couplings

First of all, the per unit length matrixes of capacitive coefficients [C] and inductive coefficients [L] are calculated for coupled microstrip lines with covering dielectric layer by program based on two-dimensional method of moments and described in [3,4]. Then, using the calculated elements of matrixes [C] and [L] a capacitive coupling ($K_C=-C_{2,1}/C_{1,1}$) and an inductive coupling ($K_L=L_{2,1}/L_{1,1}$) are obtained. An external dielectric is air. The relative permeabilities of all dielectrics are equal to unit. All strips have the same thickness (T) and the same width (W) such that T/W=0.1. The relative distance from external sides of strips accounted for in calculations D/W=3, while the relative separation of lines S/W=1. The calculations are performed for relative permittivity of the first dielectric layer $\varepsilon_{r1}=3$ and the relative height $H_{d1}/W=0.5$ for various parameters of covering dielectric layer $\varepsilon_{r2}=1\text{-}5$ and $H_{d2}/W=0\ldots0.8$. The calculated difference of capacitive and inductive couplings (K_C-K_L) as a function of H_{d2}/W is shown in Fig.2. Note that the possibility of (K_C-K_L) to be equal to zero or more than zero is seen clearly for coupled microstrip lines with the covering dielectric layer (while it is impossible for coupled microstrip lines without the covering dielectric layer, when $H_{d2}=0$). Moreover, it is seen that the condition $\varepsilon_{r2}>\varepsilon_{r1}$ is necessary for this phenomenon.

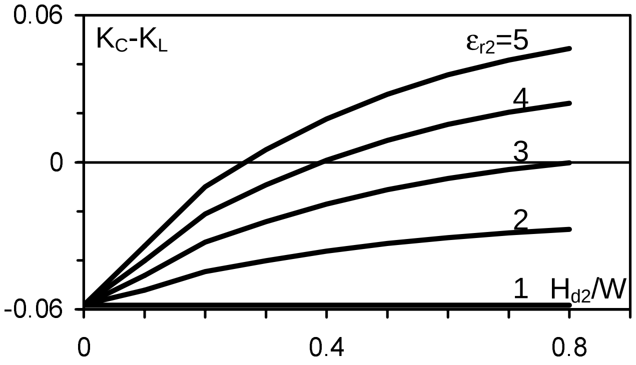
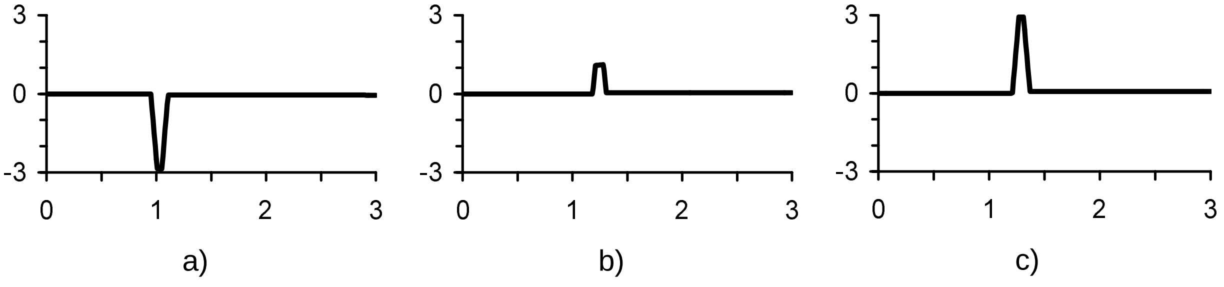


Fig.2. Dependence of difference of capacitive and inductive couplings (K_C-K_L) of two coupled microstrip lines with covering dielectric layer on height of the layer H_{d2}/W for various relative permittivities of the layer $\varepsilon_{r2}=1\text{-}5$. $H_{d1}/W=0.5$, $\varepsilon_{r1}=3$, D/W=3, S/W=1.

4. Simulation of far-end crosstalk waveforms

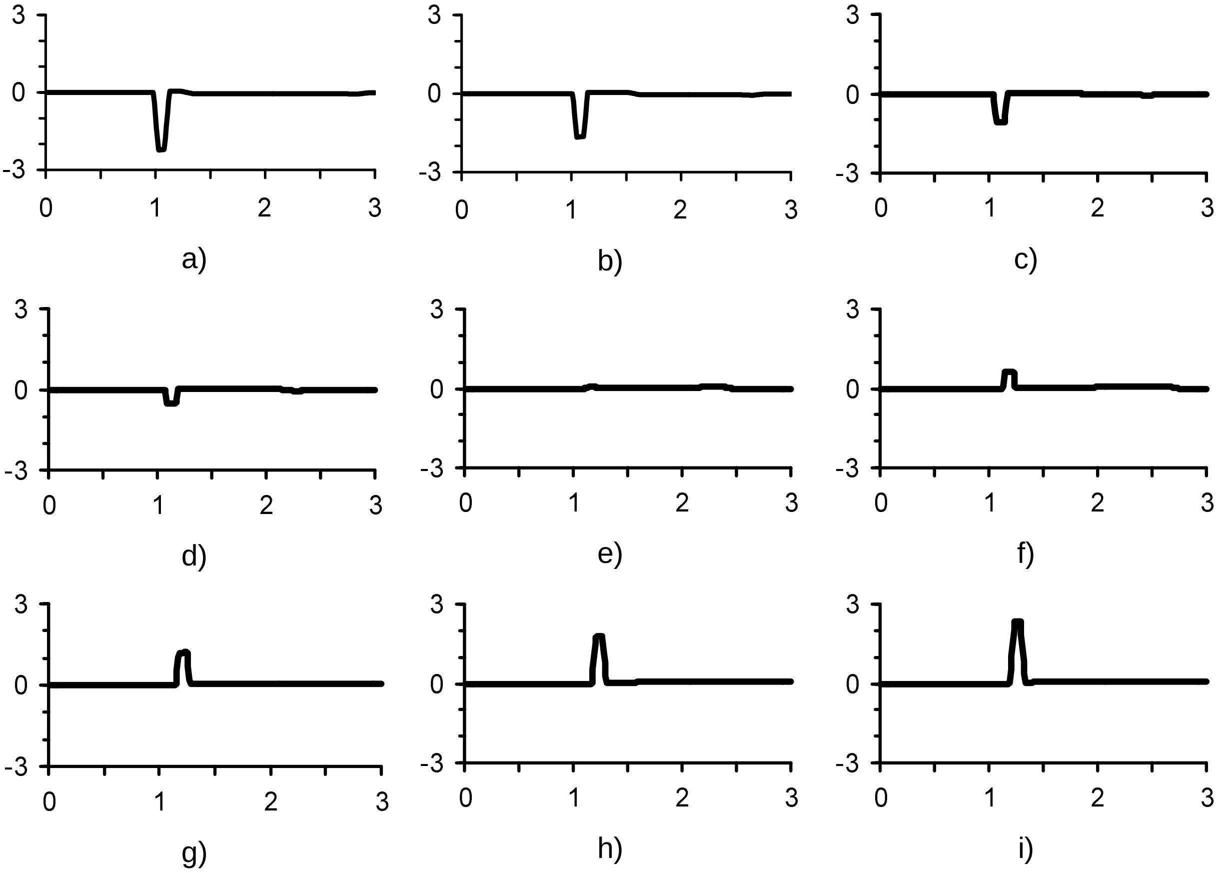
First, the far-end crosstalk waveforms have been calculated (assuming the lines to be without loss and without dispersion) for structure consisting of one section of coupled microstrip lines with covering dielectric layer ($\ell_1=0$, $\ell_2=20$ cm, $\ell_3=0$). Parameters of the lines are according to Fig.2 for $\varepsilon_{r2}=5$. All terminations of lines are equal to 50 Ohms and the ramp input signal with the magnitude $V_{in0}=10$ V and the rise time $t_r=100$ ps is applied at the beginning of active line. Three examples of far-end crosstalk waveforms calculated for $H_{d2}=0$, 0.4, 0.8 are shown on plots of Fig.3 (a,b,c, accordingly). It is seen clearly that far-end crosstalk changes significantly when increasing the height of the covering dielectric layer. Particularly, far-end crosstalk polarity may be changed and far-end crosstalk magnitude may be reduced considerably. It is seen also that for given value of ε_{r2} (when $\varepsilon_{r2}>\varepsilon_{r1}$) the according value H_{d2} may be chosen to minimize the far-end crosstalk.



a) b) c)

Fig.3. Far-end crosstalk waveforms (V, ns) calculated for $H_{d2}=0$(a), 0.4(b), 0.8(c).

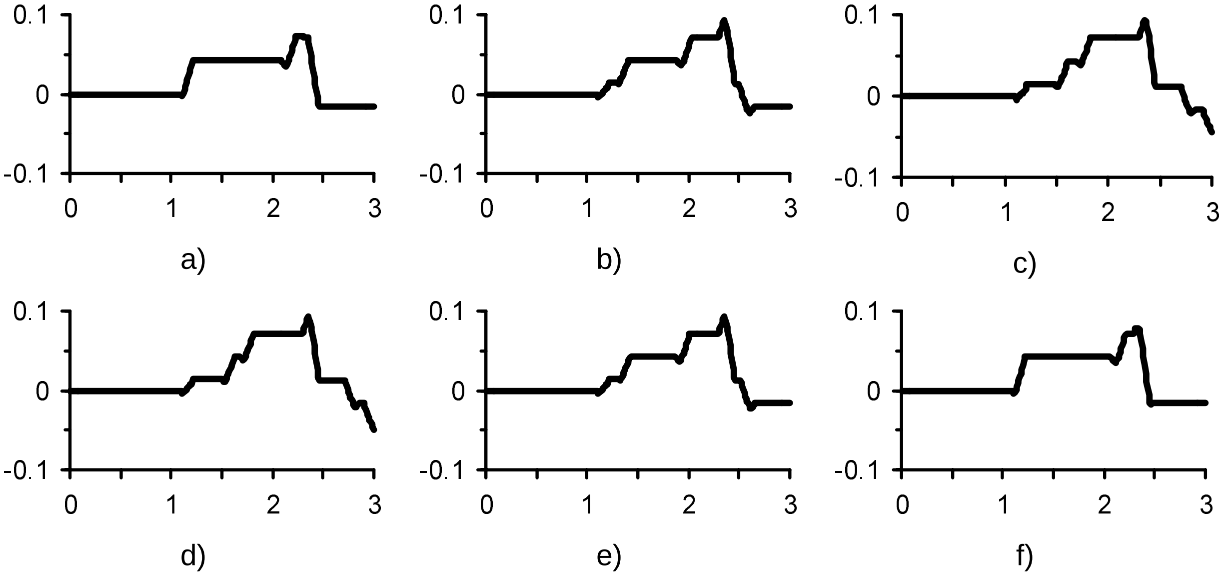
For more detailed investigation of the possibility of far-end crosstalk reduction a dependence of the waveform on the length of the covering dielectric layer was considered. For this aim the two-section structure ($\ell_1=0$) consisting of a section of coupled microstrip lines with covering dielectric and a section of coupled microstrip lines layer was analyzed. Analytical formulae used for calculation of far-end crosstalk waveforms in two-section structure with capacitance at junction of the sections have been presented in [5] and are omitted here. A strict accounting for the junction's discontinuity may be necessary, but it is not in the scope of this paper. Examples of far-end crosstalk waveforms calculated for cases when the length of the section of lines with covering dielectric layer was increasing (ℓ_2=2,4…18 cm), while the total length of two-section structure was constant ($\ell_2+\ell_3$=20 cm) are shown on nine plots of Fig.4 (a-i), accordingly. Parameters of the lines are according to Fig.2 for ε_{r2}=5, and H_{d2}/W=0.8. It is seen that far-end crosstalk magnitude may be reduced in this case similarly to the previous case. However, it is achieved by means of compensation of the negative far-end crosstalk of the second section by the positive far-end crosstalk of the fist section. Thus, in case of very thick covered dielectric layer the length of the layer would not be very long for complete compensation of far-end crosstalk.



a) b) c) d) e) f) g) h) i)

Fig.4. Far-end crosstalk waveforms (V, ns) calculated for increasing length (ℓ_2=2,4…18 cm) of the section with covering dielectric layer, while ℓ_1=0 and $\ell_2+\ell_3$=20 cm (plots a-i, accordingly).

At last, an influence of the covering dielectric layer's position on complete far-end crosstalk compensation was considered. For this aim, the length of the covering dielectric layer according to complete compensation of far-end crosstalk for structure of Fig.4 has been found (ℓ_2=9.84 cm). Then, the position ℓ_1 of this covering dielectric layer from the lines' beginning was increased (ℓ_1=0,2…10 cm), while the total length of this three-section structure was constant ($\ell_1+\ell_2+\ell_3$=20 cm). By analytic formulae proposed in [6] and extended by authors for lines of arbitrary lengths the according waveforms have been calculated and are shown (magnified 30 times) in Fig.5. It is seen that phenomenon of complete far-end crosstalk compensation is observed also in structure consisting of three sections of lines. Moreover, an influence of position of the covering dielectric layer on this phenomenon is negligible.



a) b) c)

d) e) f)

Fig.5. Waveforms (V, ns) of far-end crosstalk when increasing the position (ℓ_1=0,2…10 cm, plots a-f, accordingly) of the section with covering dielectric layer.

5. Conclusions

1. The method of far-end crosstalk reduction in coupled microstrip lines by covering dielectric layer has been presented and an influence of all main parameters of the covering layer (relative permittivity, height, length and position) on far-end crosstalk compensation has been investigated by modeling the parameters of lines and simulation of waveforms.
2. The method is very simple and low-cost because the covering dielectric layer may be implemented, for example, manually by attaching the layer of glue or dielectric plate.
3. The method may be used for improving of the directional couplers' directivity.
4. Moreover, the method may be useful, for example, for quick reduction of large far-end crosstalk detected suddenly in circuit boards having been traced and manufactured without proper modeling of interconnects.
5. Very small influence of the covering dielectric layer's position on complete far-end compensation simplifies considerably the usage of the method in practice.

6. References

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