Equivalent Circuit Model of Crosstalk Reduction Parallel Transmission Lines with Defected Microstrip Structures

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***Abstract*—A defected microstrip structure (DMS) method is used for crosstalk reduction between parallel coupled pair transmission lines (CPTLs). To reduce the couplings from the adjacent transmission line, a new DMS is designed and etched on one of the transmission line. Additionally, equivalent circuit model is also studied to provide an effective analysis method for analyzing the crosstalk of DMS-CPTLs by considering the S-parameters, namely, S11, S12, S13 and S14. The proposed designs are verified by using HFSS based on FEM and the equivalent circuit is studied by using ADS. The results show that the far-end crosstalk and near-end crosstalk are reduced by about 30dB and the equivalent circuit simulation agrees well with the HFSS simulation.**

Keywords—Defected microstrip structure (DMS); far-end crosstalk; near-end crosstalk; coupled pair transmission lines (CPTLs); equivalent circuit

I. INTRODUCTION

With the development of high speed communications and the personal devices, many electronic devices are designed within a limited space, includes antennas, filters, transmission lines and so on. In the circuit system, coupled transmission lines are widely used in high speed printed circuit boards (PCBs) and integrated circuit. Crosstalk or coupling between two adjacent transmission lines is one of the most important issues for high speed signal integrity. Many design methods and rules have been proposed and established in the literatures to help suppress or reduce crosstalk between neighboring transmission lines [1-2], such as placing guard traces between the adjacent lines, reducing the coupling length, increasing the distance between nearby transmission lines. However, these methods increase the overall size of the system.

In this paper, a defected microstrip structure (DMS) method is used for crosstalk reduction between parallel coupled pair transmission lines (CPTLs). The equivalent circuit model is also presented and investigated. The coupled pair transmission lines with defected microstrip structure (DMS-CPTLs) are analyzed by using high-frequency structure simulator (HFSS) and their performance for near-end and far-end crosstalk reduction are compared. The equivalent circuit model of DMS-CPTLs is proposed and investigated by using Advance Design Systems (ADS). From the simulation results, the mutual coupling can be reduced by about 30dB for far- and near- ends.

II. CONFIGURATIONS AND EQUIVALENT CIRCUIT OF THE DMS-CPTLS

Based on the traditional coupling transmission lines and defected microstrip structure (DMS), a coupled pair transmission lines with DMS are proposed and its geometry with desired dimensions are illustrated in Fig. 1. The proposed DMS-CPTLs are designed on a substrate with relative dielectric constant of 4.4 and thickness of 1.6 mm.

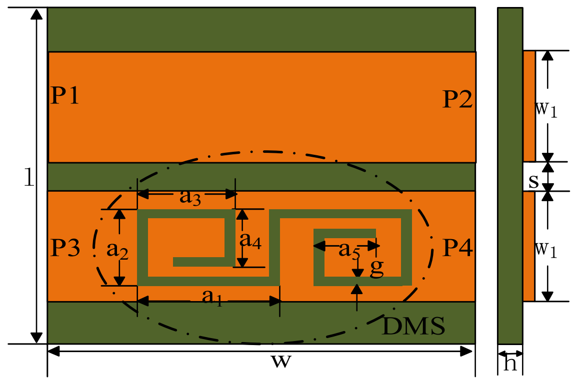

Fig. 1 Geometry of the proposed DMS-CPTLs. The optimal parameters are l=12.8, w=8, h=1.6, w_1=3, s=1, a_1=2.8, a_2=2.6, a_3=2.4, a_4=2, a_5=1.6, g=0.2 (all in millimeters)

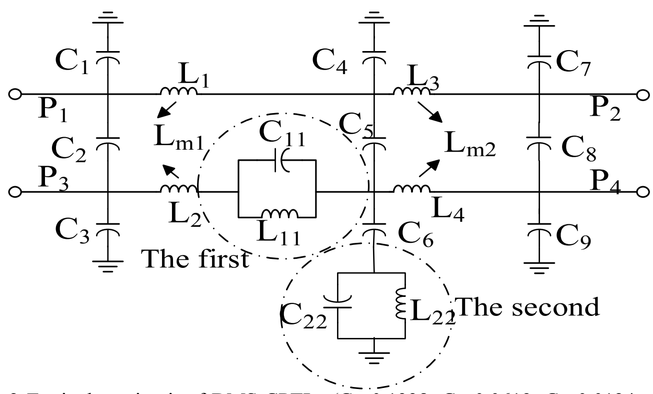

Fig. 2 Equivalent circuit of DMS-CPTLs (C_1=0.1338, C_2=0.0619, C_3=0.0124, C_4=0.2142, C_5=0.0834, C_6=0.3583, C_7=0.0728, C_8=0.0255, C_{11}=4.9976, C_{22}=4.9987 C_9=0.3762(all in picofarads); L_1=0.7629, L_2=1.4906, L_3=0.6164, L_4=3.3045, L_{11}=4.4002, L_{22}=4.4002, L_{m1}=0.1963, L_{m2}=0.32(all in nanohenrys)

The equivalent circuit model of the proposed DMS-CPTLs is depicted in Fig.2. In Fig.2, the first parallel inductance and capacitance, which series in a circuit, are the equivalent circuit of the DMS structure. The second parallel LC resonant circuit is used to filter the influence of DMS structure from the ground. This circuit model is obtained from the coupling transmission line and the circuit model of the defected microstrip structure [3-5]. The values equivalent circuit components of the DMS-CPTLs are extracted from the S-parameters.

III. RESUITS AND ANALYSIS OF THE DMS-CPTLS

The performance of the proposed DMS-CPTLs has been investigated by using HFSS. The S-parameters of the CPTLs with and without the decoupling (DMSs) are depicted in Fig.3. In Fig.4, the difference between near-end and far-end crosstalk is shown by subtracting the coupling of the CPTLs from the DMS-CPTLS. From the results, we can see that the far-end and near-end crosstalk are reduced by nearly 30dB.

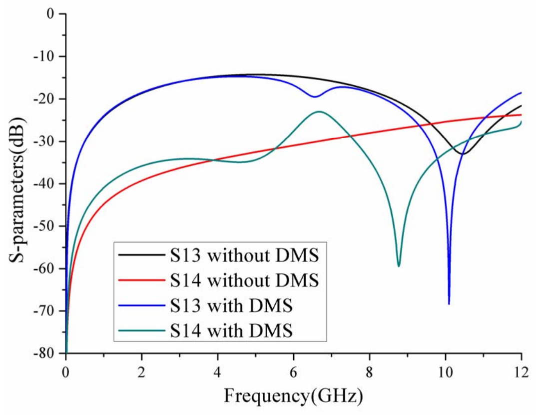

Fig.3 S-parameters of the CPTLs with/without the DMS

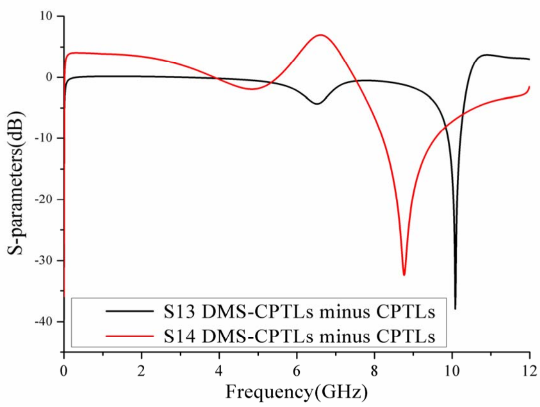

Fig.4 Different between near-end and far-end crosstalk of DMS-CPTLs compared with CPTLs

In order to further understand the effectiveness and the principle of the designed DMS-CPTLs, the equivalent circuit model of DMS-CPTLs are proposed and investigated by using ADS, and its performance is compared with the HFSS simulation. The comparison of the S-parameters for the DMS-CPTLs is illustrated in Fig.5. We can see that the simulation results of the equivalent circuit and the HFSS simulation are well agreed.

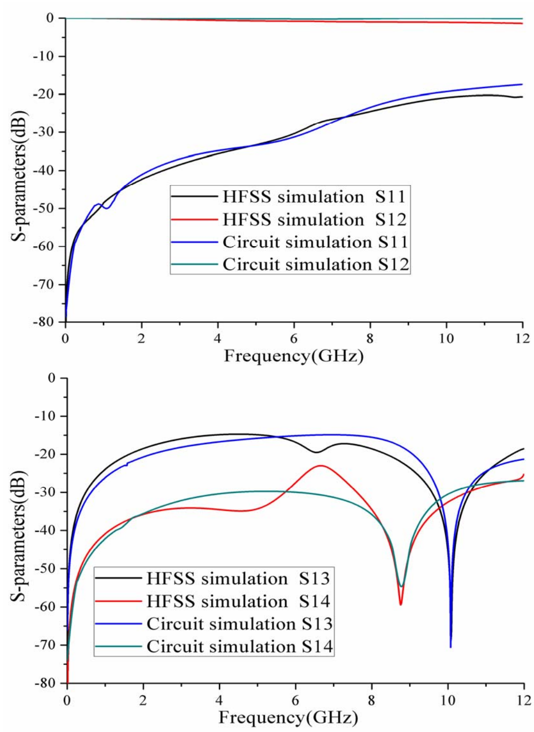

Fig. 5 Comparison of the S-parameter of DMS-CPTLs

IV. CONCLUSION

In this article, the DMS structure is used for reducing of near-end as well as far-end crosstalk in coupled pair transmission lines, and its performance has been verified by HFSS simulation and equivalent circuit models. The results proved that the proposed DMS-CPTLs can reduce the crosstalk of far-end and near-end by about 30dB.

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REFERENCES

[1] R. Mallahzadeh, A. H. Ghasemi, S. Akhlaghi, B. Rahmati and R. Bayderkhani, “Crosstalk Reduction Using Step Shaped Transmission Line,” Progress In Electromagnetic Research, vol. 12, 2010, pp.139-148.

[2] F. D. Mbairi, W. P. Siebert and H. Hesselbom, “High-Frequency Transmission Lines Crosstalk Reduction Using Spacing Rules,” IEEE Transanctions on Components and Packaging Technologies, vol. 31, No.3, pp. 601-610, Sept 2008.

[3] R. Mongia, I. Bahl and P. Bhartia, RF and Microwave Coupled-Line Circuits. Boston, MA: Artech House, 1999, pp. 123–180.

[4] T. Jiang, Y. Wang, and Y. Li. "Design and analysis of a triple stop-band filter using ratioed periodical defected microstrip structure," Frequenz, 2017, vol.71, pp. 341-347.

[5] Y. Li, W. Li, Q. Ye, A reconfigurable triple notch band antenna integrated with defected microstrip structure band-stop filter for ultra-wideband cognitive radio applications, International Journal of Antennas and Propagation, vol.2013, Article ID: 472645, pp.1-13.