CROSSTALK REDUCTION IN MULTI-CONDUCTOR TRANSMISSION LINES USING PERIODIC STRUCTURES OF COMPLEMENTARY SPLIT-RING RESONATORS

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Abstract

Crosstalk is a major concern in the printed circuit boards which degrades the operating performance of the system. Now-a-days the transmission lines are routed close to each other due to the technology advancement and miniaturisation in the physical sizes of the board. When these transmission lines are in close proximity energy couples to the neighboring lines to initiate the crosstalk. Crosstalk increases with the increase in the frequency. The two types of crosstalk are near-end crosstalk and far-end crosstalk. This article addresses the issues caused due to the crosstalk phenomena in the multi-conductor transmission lines and the way to reduce the crosstalk using periodic structures of metamaterial based complementary split-ring resonators (CSRRs). The CSRRs are etched in the ground plane beneath the transmission lines to reduce the crosstalk. S-parameters are simulated to measure the crosstalk parameters. Comparative measurements are carried out with solid ground plane, single unit cell of CSRR at centre, three and five unit cells of CSRRs for the frequency range of 5 to 10 GHz.

Index Terms: Near-end crosstalk, far-end crosstalk, transmission lines, CSRRs, printed circuit boards.

I. INTRODUCTION

Crosstalk is an electromagnetic interference phenomenon which occurs in a coupled parallel transmission lines when they are in close proximity to each other. Energy is coupled from one line adjacent line by means of mutual capacitance (C_M) and mutual inductance (L_M) exists among the lines which lead affects the performance the system. The two types of crosstalk are termed as near-end crosstalk (NEXT) and far-end crosstalk (FEXT). S-parameters are used to measure the NEXT and FEXT between the lines. Usually for a two conductor transmission lines S_{31} indicates the NEXT and S_{41} gives the FEXT. The crosstalk measured at near-end to the source is called as NEXT and far from the source end is termed as FEXT. The FEXT is a major concern in the PCBs which creates signal integrity problems. NEXT and FEXT are dependant on the frequency and increases with the increase in the frequency. Different methods have been proposed to reduce the crosstalk. Providing more spacing between the lines reduces the crosstalk but this leads to increase in the physical sizes of the board. Grounded vias and guard traces are placed in between the parallel lines to reduce the crosstalk. Addition of these materials complicates the design strategy and increases the cost. So a trades-off is needed between the crosstalk, design methods and physical sizes of the board.

Recently metamaterials are used to control the electromagnetic properties of the electronics a system operating on micrwave frequency. Metamaterials are created artificially to exhibit controllable electromagnetic properties not found in naturally available materials. They are frequency selective surfaces and possible to get defined properties by varying its physical dimensions. Being the presence of inductance and capacitance between them they are treated as resonators. This article proposes a method to reduce the crosstalk between the lines using metamaterial based complementary split–ring resonators.

Additional crosstalk noise was produced to eliminate the initial crosstalk noise thereby cancelling the FEXT and NEXT effects [1]. An idle conductor bar terminated at both ends which is equal to the width of line was inserted between the transmission lines. Grounded vias were placed between the lines and makes the crosstalk potential to zero [2]. Metal filled via holes were inserted in between the Transmission lines to reduce the crosstalk phenomena and measurements were taken by varying the number of via holes [3]. Grounded vias were inserted in between the transmission lines of the board reduce the crosstalk [4].The concept of split rings to get desired performance in microwave regime was introduced. By varying the physical structures of the resonators the performance of the system can be modified [6] and CSRRs were introduced in the ground plane to minimize the NEXT and FEXT effects. The crosstalk reduction was also achieved when single and multiple combinations of CSRRs were designed in ground plane [7]. CSRRs can be etched by conventional etching technique and fabricated easily. So, introduction of metamaterial based CSRRs produces the necessary field in the ground plane to reduce the NEXT and FEXT effects by cancelling the electric and magnetic field produced by the transmission lines. In this paper the crosstalk effects were reduced by designing ring shaped CSRRs in the ground plane with outer diameter of 8mm and inner diameter of 5mm with a capacitive gap of 0.5mm.

II. CROSSTALK

Now-a-days electronics systems are operating on very high frequency interms of several GHz.In a coupled parallel line if one of the conductors is connected with a driver which operates on very high speed, digital pulses makes its variation and making change in the self and mutual impedance parameters. Electromagnetic energy is coupled from one of the line to other because these lines are in close proximity.

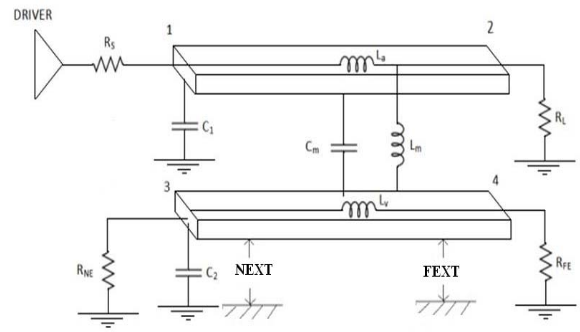


Fig.1 Concept of NEXT and FEXT

NEXT is measured at the near-end of the source and FEXT is measured at the far-end of the source as shown in Fig.1. In a three conductor transmission line the two values of NEXT are represented by S_{31} and S_{51} whereas FEXT are represented as S_{41} and S_{61}. All the ends of the multi conductor transmission lines are terminated with 50 ohms.

III CSRR

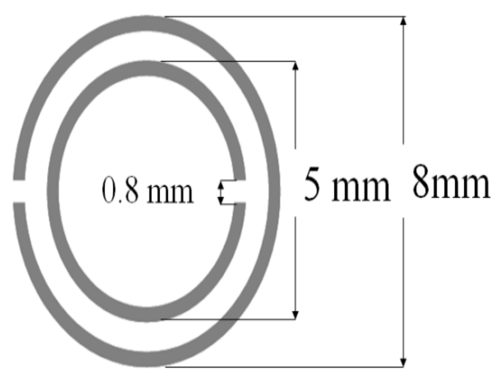
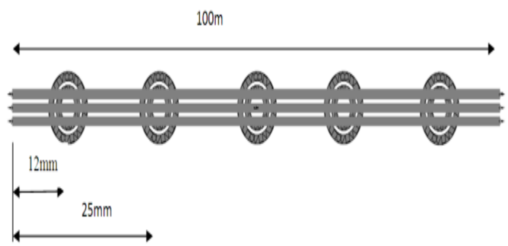


Fig.2 Physical Dimensions of CSRR

Metamaterials are artificial structures and can be tuned to any frequency to get desired performance. Split-ring resonators (SRRs) are one of the metamaterial structures to get the better response in high frequency region. The dual part of SRRs is complementary split-ring resonator which is created by etching the SRRs. The Fig.2 shows the design structure of CSRRs with the specifications which is used to reduce the crosstalk effects in the ground plane. The Fig.3 shows the five numbers of CSRRs in the ground plane and transmission lines in the conductor plane. The total length of the transmission line is taken as 100mm and five numbers of unit cells of CSRRs were placed with the following dimensions: 1st unit cell of CSRR is placed at 12mm from the starting end and succeeding CSRR are placed with a distance of 25mm and 50mm.

Fig.3 Multi-conductor transmission lines



loaded with 5CSRRs

The simulations are carried out for the solid ground and with 1 CSRR placed at the centre, 3 CSRRs and 5 CSRRs.

IV. Measurement Analysis

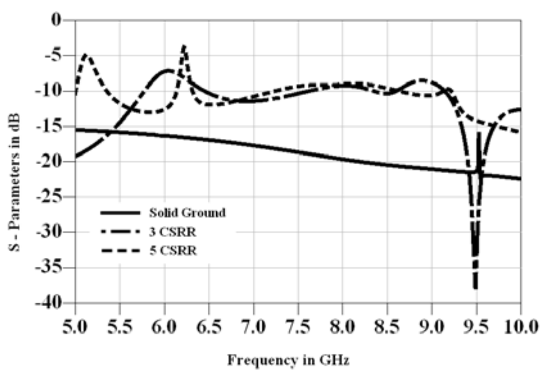


Fig.4 Near-end crosstalk – S (3, 1)

The Fig.4 shows the NEXT values measured at the near-end of the second conductor. By using solid ground plane the NEXT value is – 20 dB at 9.5 GHz and the NEXT were achieved as -38 dB by using 3 CSRRs in the ground plane which is -20 dB reduction compared with solid ground plane.

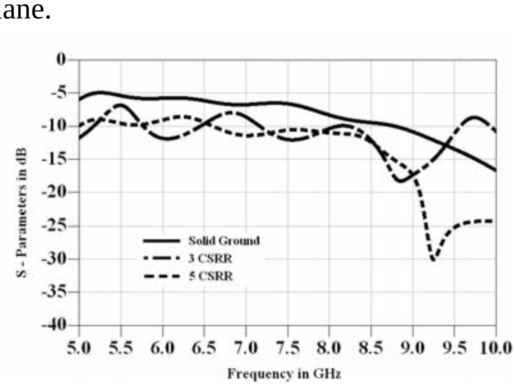


Fig.5 Far-end crosstalk – S (4.1)

Far-end crosstalk plays very important role in signal degradation due to its mutual inductance property. A strong magnetic mutual coupling is created between the transmission lines which enhance the FEXT especially in the high frequency of operation.The Fig.5 shows the FEXT for the solid ground plane, with 3 CSRRs and with 5 CSRRs. The S_{41} values are plotted for the frequency range of 5 to 10 GHz to the adjacent second conductor of the multiconductor lines and. The analysis is carried out for the three cases; first the solid ground gives -12 dB at 9.5 GHz and FEXT value improved for three CSRR configuration in which the 5 CSRRs in the ground plane gives a reduction of -30 dB. With the three CSRRs in the ground plane the FEXT is reduced -19 dB at a frequency of 8.75 GHz. The FEXT for the third conductor of the multi-conductor configuration is plotted in the Fig.6.

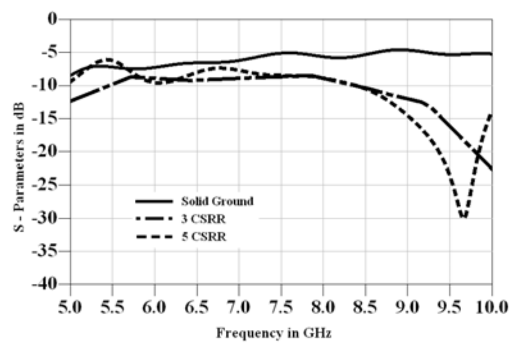


Fig.6 Far-end crosstalk – S (6, 1)

From the Fig.6, the FEXT value for the solid ground has an average of -5dB over the entire frequency range. The use of 3 CSRRs in the ground plane reduces the FEXT values to a of -25 dB at 10 GHz. The design of 5 CSRRs in the ground plane gives a reduction of -30 dB at 9.6 GHz. Based on the dimensions of CSRR the crosstalk value has been reduced to a determined value.

V. Conclusion

The behavior of two types of crosstalk for the solid ground, with 3 CSRRs and 5 CSRRs beneath the multiconductor lines configuration were analysed in this work. From the results the reduction of crosstalk parameters were achieved by designing the periodic structures of CSRRs in the ground plane.

REFERENCES

[1] Guang-Hwa Shiue, Jia-Hung Shiu & Po-Wei Chiu 2011, 'Analysis and design of crosstalk noise reduction for coupled striplines inserted guard trace with an open-stub on time-domain in high-speed digital circuits', IEEE Transactions On Components, Packing and Manufacturing Technology, vol. 1, no. 10, pp. 1573-1582.

[2] Kyoungho Lee, Hyun-Bae Lee, Hae-Kang Jung, Jae-Yoon Sim 2008, 'A serpentine guard trace to reduce the far-end crosstalk voltage and the crosstalk induced timing jitter of parallel microstrip lines', IEEE Transactions on Advanced Packaging, vol. 31, no. 4, pp. 809-817.

[3] Fengchao Xiao, Kimitoshi Murano & Yoshio Kami 2002, 'The use of via holes for controlling the crosstalk of non-parallel microstrip lines on PCBs', 0-7803-7264-6@IEEE.

[4] Asanee Suntives, Arash Khajooeizadeh & Ramesh Abhari 2006, 'Using via fences for crosstalk reduction in PCB circuits', 1-4244-0293-X@IEEE.

[5] Clayton Paul, R 2006, Introduction to Electromagnetic Compatability, John Wiley & Sons.

[6] Pendry, JB, Holden, AJ, Robbins, DJ & Stewart, WJ 1999, 'Magnetisn from conductors and enhanced nonlinear phenomena', IEEE Transactions on Microwave Theory and Techniques, vol. 47, no.11.

[7] Azhagumurugan, R & Indumathi, P 2014, 'A novel metamaterial structure to reduce far-end crosstalk in printed circuit boards', International Journal of Engineering and Technology, ISSN; 0975-4024, vol. 6, no. 2, pp. 588-591.