iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** II **Month of publication:** February 2018

DOI: http://doi.org/10.22214/ijraset.2018.2271

Analysis of PCB to find Trace Impedance by Method of Moment and Cross-talk Interference

Avali Ghosh[1], Sisir Kumar Das[2], Annapurna Das[3]
[1, 2, 3] ECE Department, MAKAUT, GNIT, Kolkata

***Abstract**: In this paper the impedance of PCB trace is calculated from the charge distribution on microstrip line using method of moment. The parasitic element values are computed to find the crosstalk interference in PCB. The results of theoretical analysis are obtained by using MATLAB. The crosstalk interference also found using modeling and simulation with Ansoft HFSS tool. These results are compared with the experimental results and found good agreement.*
Keywords: *Crosstalk, Multi-conductor PCB traces, Near - end crosstalk, Far - end crosstalk, Method of Moment.*

I. INTRODUCTION

Double layer printed circuit board consists of multi-conductor microstrip traces. In dense PCB designs, crosstalk interference occurs due to electromagnetic coupling between signal traces through mutual inductances and mutual capacitances. Several authors analyses coss-talk in PCB[1-10]. In this paper the line parameters such as capacitances and characteristic impedance are calculated from the charge distribution on the trace by method of moment. The parasitic element values are computed to find the crosstalk interference in PCB. The crosstalk interference also found using modeling and simulation with Ansoft HFSS tool. These results are compared with the experimental results and found good agreement.

II. LINE IMPEDANCE USING METHOD OF MOMENT

In high-speed systems, control of the electrical characteristics of the transmission lines is crucial. The basic electrical characteristics that define a transmission line are its characteristic impedance and its propagation velocity. In this analysis the PCB traces of equal width w above a FR-4 dielectric substrate of thickness h and dielectric constant $\varepsilon_r = 4.4$ are considered above a ground plane. The line impedance of the trace can be obtained using empirical formula [11]. These formulae was derived using some assumptions and depend on trace width/substrate thickness. The traces are designed in this paper very accurately for 50 ohm using Method of Moment as described below

A. MOM Segmentation

For surface charge distribution, the microstrip section is divided into N sections as shown in Fig. 1.

$$n = 1,2,3,\ldots\ldots\ldots, M \text{ on the strip} \tag{1a}$$

$$n = M+1, M+2, M+3,\ldots.., N \text{ on the ground plane} \tag{1b}$$

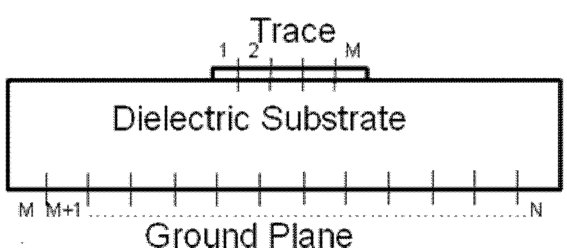


Fig. 1 Cross-sectional view of Microstrip section

Charge density ρ is constant on each segment ΔS_n

$$\rho = \sum_{n=1}^{N} \alpha_n f_n \,; \tag{2}$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor : 6.887
Volume 6 Issue II, February 2018- Available at www.ijraset.com

where $f_n = 1$ on ΔS_n

$= 0$ elsewhere

$\alpha_n =$ constant coefficient corresponding to ΔS_n

$=$ charge per unit length and unit width of element ΔS_n

The characteristic impedance of the line is

$$Z_0 = \frac{1}{vC} \tag{2a}$$

where $v =$ Velocity of wave inside the hybrid medium

$C =$ Capacitance of the line / length

$$C = \frac{\int_{S_1} \rho(x, y) ds}{V_0} = \frac{Q}{V_0} = \frac{\sum \alpha_n f_n}{V_0} \tag{3}$$

The charge distribution on the strip $\rho(x', y')$ is determined by method of moment using Poisson's equation:

$$\nabla^2 V = \frac{\rho}{\varepsilon_0 \varepsilon_r} \tag{4}$$

Therefore electric potential inside the substrate between strips and ground plane is

$$V(x, y) = \frac{1}{\varepsilon_0 \varepsilon_r} \int_{S_1 + S_2} G(x, y \mid x', y') \rho(x', y') ds' \tag{5}$$

Since $\rho = 0$ in the substrate between S_1 and S_2, integration is performed are the strip and ground surfaces.

$G(x, y \mid x', y') e(x', y') ds' = \frac{1}{4\pi\varepsilon r}$ is the Green's function for the line.

$V(x, y)$ satisfies boundary conditions

$V(x, y) = 0$ on the ground plane at $y = 0$ (6a)

$= V_0$ on the strip at $y = h$ (6b)

Substituting equation 2 to equation 5

$$V(x, y) = \frac{1}{\varepsilon_0 \varepsilon_r} \sum_{n=1}^{N} \int_S G(x, y \mid x', y') \alpha_n f_n ds' \tag{7}$$

For unit pulse function $f_n = 1$ on ΔS_n

$= 0$ elsewhere

Equation 7 reduces to

$$V(x_m, y_m) = \frac{1}{\varepsilon_0 \varepsilon_r} \sum_{n=1}^{N} \alpha_n (x_n, y_n) \int_{\Delta S_n} G(x_m, y_m \mid x_n, y_n) \alpha_n f_n dS_n \tag{8}$$

$x_m, y_m \rightarrow$ observation point on the conductor

$x_n, y_n \rightarrow$ source point on the conductor

Equation 8 can be written for all points in matrix form

$$[V]=\frac{1}{\varepsilon_0\varepsilon_r}[G_{mn}][\alpha_n] \quad (9)$$

Therefore unknown coefficients can be determined

$$[\alpha_n]=\varepsilon_0\varepsilon_r[G_{mn}]^{-1}[V] \quad (10)$$

where $V=V_0$ for $n=1,2,3,\dots\dots\dots,M$

$=0$ for $n=M+1,\dots\dots,N$

(m,n) the element

$$G_{mn}=\int_{\Delta S_n}G(x_m,y_m\,|\,x_n,y_n)dS_n \quad (11)$$

Capacitance is expressed in terms of total charge on one of the conductors,

$$C=\frac{\sum_{n=1}^{M}\alpha_n\Delta S_n}{V_0} \quad (12)$$

The line impedance is computed using eqns. 2a and 12.

B. Line Parasitic elements and Crosstalk

The derived empirical equations on the electrical parameters of the microstrip line in the inhomogeneous medium with one side exposed to air are as follows [5]:-

$$\frac{C_t}{\varepsilon}=\left[1.15\left(\frac{w}{h}\right)^{0.963}+1.07\left(\frac{t}{h}\right)^{0.049}\right]+\exp\left(-3.52*\frac{s}{h}\right)*\left[0.75\left(\frac{w}{h}\right)^{0.25}+2.7\left(\frac{t}{h}\right)^{1.36}\right] \quad (13)$$

$$\frac{C_m}{\varepsilon}=1.17\left(\frac{w}{h}\right)^{0.083}*\left(\frac{s}{h}+0.402\right)^{-0.78}+\left(\frac{s}{h}+1.32\right)^{-0.8}*\left\{-1.36\left(\frac{w}{h}\right)^{-0.037}+0.227\left(\frac{t}{h}\right)^{0.98}\right\} \quad (14)$$

$$\frac{L_S}{\mu_O}=3.71\left(\frac{h}{w}\right)^{0.041}+0.018\left(\frac{h}{w}\right)^{-0.73}-3.39\left(\frac{h}{t}\right)^{-0.0006}+\exp\left(-1.89*\frac{s}{h}\right)*\left\{0.75\left(\frac{h}{w}\right)^{-0.0052}-0.84\left(\frac{h}{t}\right)^{-0.026}\right\} \quad (15)$$

$$\frac{L_m}{\mu_O}=\left\{-0.415\left(\frac{h}{w}\right)^{-0.16}-2.38\left(\frac{t}{w}\right)^{1.18}\right\}*\left(\frac{s}{h}*1.07\right)^{-2.6}+\left(\frac{s}{h}+0.89\right)^{-2.03}*\left\{0.418\left(\frac{h}{w}\right)^{0.13}+1.37\left(\frac{t}{w}\right)^{1.09}\right\} \quad (16)$$

Crosstalk due to electromagnetic coupling between signal traces through mutual inductance and stray/mutual capacitance between two or more conducting traces or interconnect can be expressed as follows [6]

$$\frac{V_{ne}}{V_S}=j\omega\left(\frac{R_{ne}}{R_{ne}+R_{fe}}*\frac{L_{12}}{R_S+R_L}+\frac{R_{ne}R_{fe}}{R_{ne}+R_{fe}}*\frac{R_LC_{12}}{R_S+R_L}\right) \quad (17)$$

$$\frac{V_{ne}}{V_S}=j\omega\left(-\frac{R_{fe}}{R_{ne}+R_{fe}}*\frac{L_{12}}{R_S+R_L}+\frac{R_{ne}R_{fe}}{R_{ne}+R_{fe}}*\frac{R_LC_{12}}{R_S+R_L}\right) \quad (18)$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor : 6.887
Volume 6 Issue II, February 2018- Available at www.ijraset.com

III.RESULTS AND DISCUSSION

A. Theoretical Result

Self capacitance has been calculated with the method of moment to design the PCB for 50 ohm trace impedance. The results for charge distribution on the trace and impedance versus w/h are shown Fig. 2.

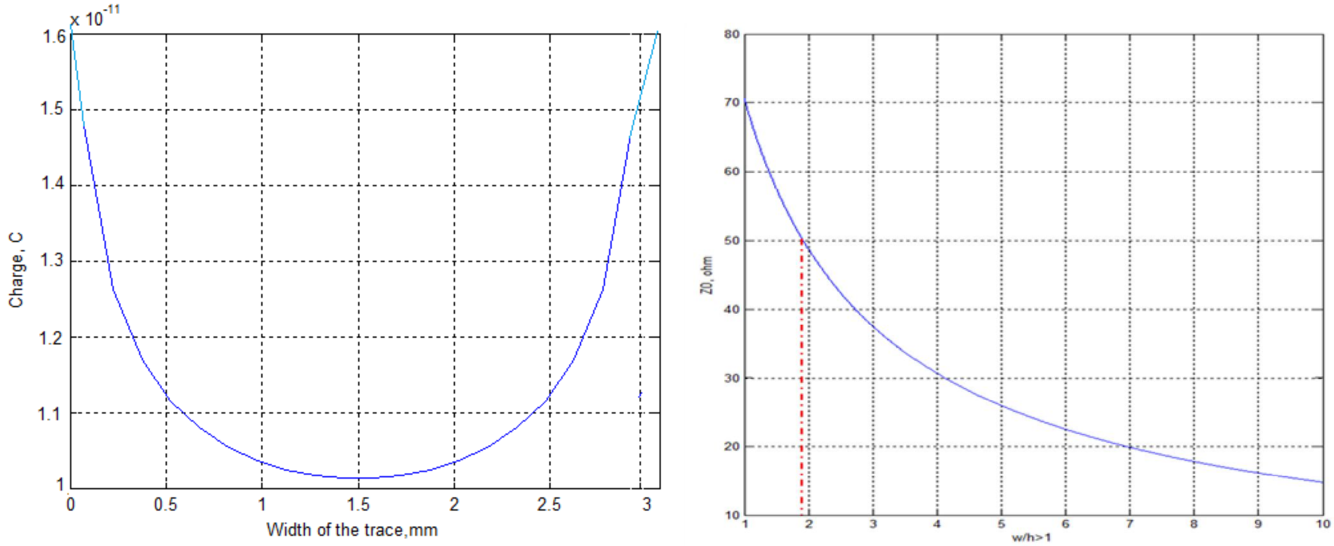


Fig. 2 a) Charge distribution Vs Width of the trace by using MOM

b) Z_0 Vs $w/h>1$ of microstrip line

In this PCB design two parallel traces of 50 ohm are on the top surface above the dielectric substrate and copper plane is at the bottom is considered as shown in Fig. 3. A PCB was made with FR4 material, height of substrate, h = 1.6mm. The thickness of the copper trace t is assumed negligible i.e. t = 0.001mm and trace width w = 3.1mm, spacing between two traces is s = 6.2mm.

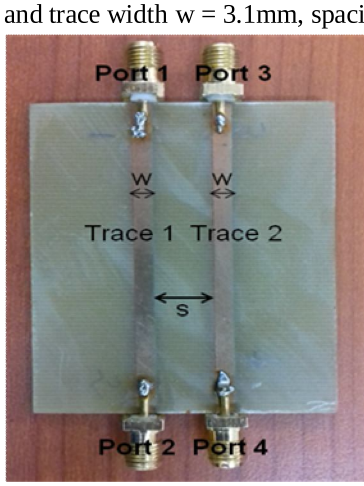


Fig. 3 PCB design

The mutual inductance and capacitance between two conducting traces are computed by using empirical formulae equation 14 and equation 16. Self capacitance and inductance has been calculated with the method of moment.

$$L_t = 3.3520 \times 10^{-09} \text{ H/m}$$

$$L_m = 1.1238 \times 10^{-09} \text{ H/m}$$

$$C_t = 1.1261 \times 10^{-12} \text{ F/m}$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor : 6.887
Volume 6 Issue II, February 2018- Available at www.ijraset.com

$$C_m = 1.6402 \times 10^{-12} \text{ F/m}$$

Crosstalk due to near-field / reactive field electromagnetic coupling between two conducting traces at 1GHz are

$$V_{next} = -29.6758 dB$$

$$V_{fext} = -34.5617 dB$$

Self capacitance and inductance has been calculated with the method of moment. The mutual inductance and capacitance between three conducting traces computed are

$$L_t = 4.5503 \times 10^{-09} \text{ H/m}$$

$$L_m = 8.18806 \times 10^{-09} \text{ H/m}$$

$$C_t = 1.0379 \times 10^{-12} \text{ F/m}$$

$$C_m = 1.9006 \times 10^{-12} \text{ F/m}$$

Crosstalk due to near-field / reactive field electromagnetic coupling between three conducting traces at 1GHz are

$$V_{next} = -7.8186 dB$$

$$V_{fext} = -19.3347 dB$$

B. Experimental Result

The experimental measurement of crosstalk is done by using Agilent PNA Series Network Analyzer E8363B (10 MHz – 40 GHz) in SAMEER, Kolkata. The coupling parameters S31 (Near-end) and S41 (Far-end) are measured. The experimental setup with network analyser are shown in Fig. 4.

Fig. 4 Experimental setup with network analyser

Theoretical results are obtained by using MATLAB and modelling and simulation results using Ansoft HFFS-12 software tool are compared with those obtained from experimental ones. The results obtained from analytical, HFSS and experimentation are compared and found in good agreement as shown in Fig. 5 and Fig. 6.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor : 6.887
Volume 6 Issue II, February 2018- Available at www.ijraset.com

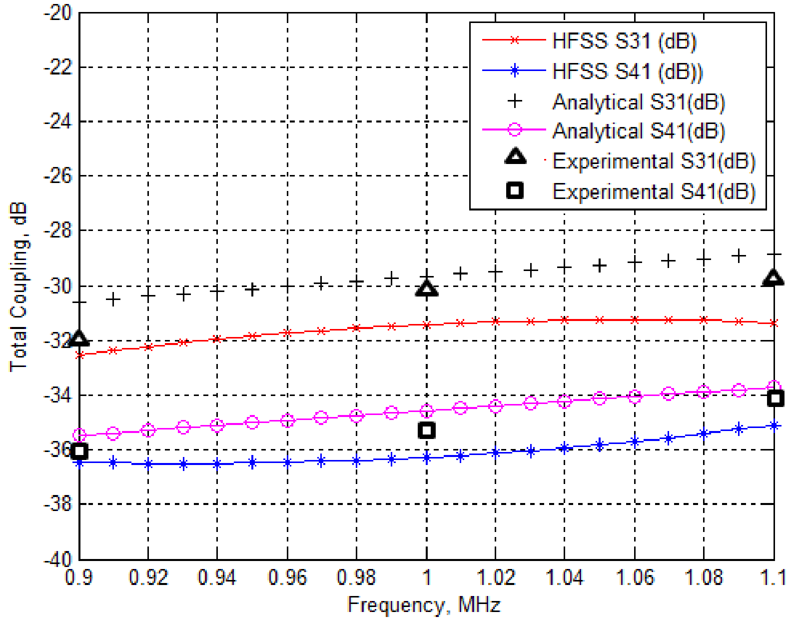


Fig. 5 Crosstalk Vs Frequency for Two adjacent traces (w=3.1mm, s=6.2mm, h=1.6mm, εr=4.4)

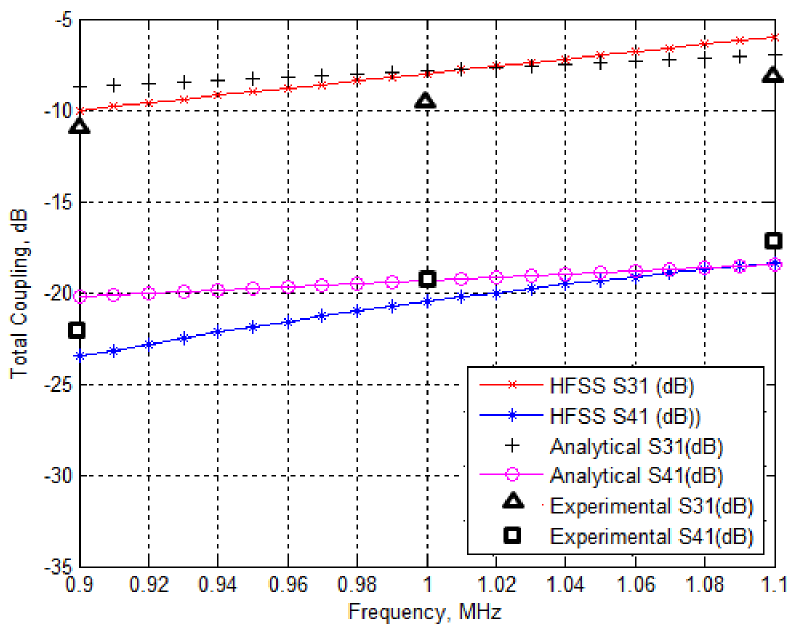


Fig. 6 Crosstalk Vs Frequency for Three adjacent traces (w=3.1mm,s=6.2mm, h=1.6mm, εr=4.4)

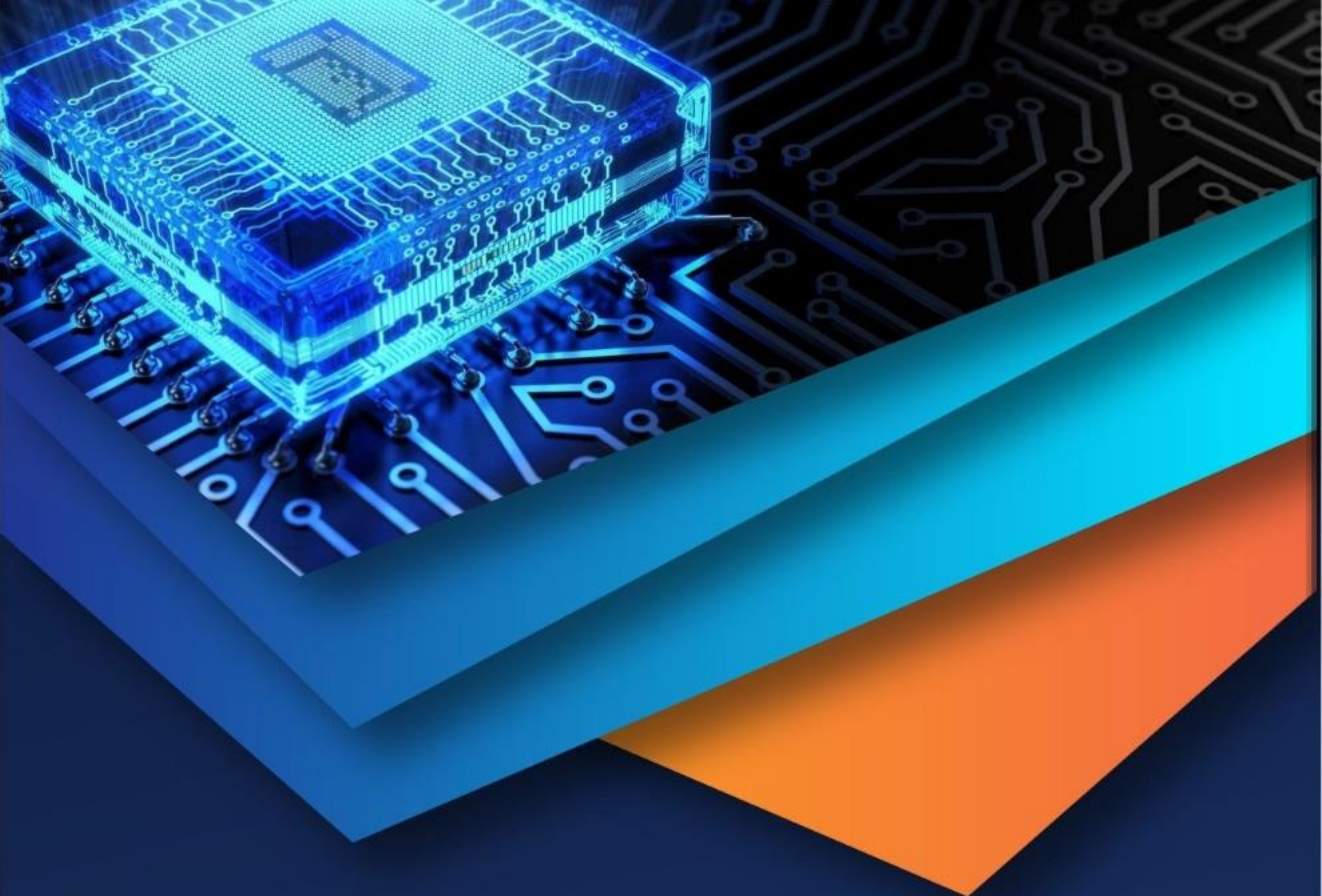
The discrepancies observed in these results are due to various assumptions made in the theory and also due to non ideal situations in the experimental setups.

IV. CONCLUSIONS

In this paper the charge distribution on microstrip lines, self capacitance, and characteristic impedance are calculated by using method of moment. The line parasitic parameters are also calculated from empirical formulae. The crosstalk interference in PCB are computed. The results of theoretical analysis are obtained by using MATLAB. The crosstalk interference also computed using modeling and simulation with Ansoft HFSS software tool. These results are compared with the experimental results and found in good agreement with little discrepancies due to various assumptions made in the theory and also due to non ideal situations in the experimental setups.

REFERENCES

[1] Paul C. R., Introduction to Electromagnetic Compatibility , A Wiley- Interscience Publications, John Wiley & Sons, Inc, Newyork, 1987.
[2] Paul C. R., Analysis of Multi Conductor Transmission Lines, A Wiley- Interscience Publications, John Wiley & Sons, Inc, Newyork,, 1984.
[3] R.F. Harrington, Method of Moment, Wiley Publication.
[4] R. F. Harrington, Time - Harmonic Electromagnetic Fields, Donald G. Dudley, Series Editor, Wiley Publication.
[5] Young-Soo Sohn, Jeong-Cheol Lee, Hong-June Park and Soo-In Cho , ‘ Empirical Equations on Electrical Parameters of Coupled Microstrip Lines for Crosstalk Estimation in Printed Circuit Board’ , IEEE Transactions on Advanced Packaging, VOL. 24, NO. 4, November 2001.
[6] Stephen H. Hall and Howard L. Heck, Advanced Signal Integrity for high speed digital designs, A Wiley- Interscience Publications, John Wiley & Sons, Inc, USA, 2000.
[7] Charles Walker, Capacitance, Inductance and Crosstalk Analysis, Artech House, 1988.
[8] Grover. F. W., Inductance Calculations, Working Formulas and Tables, Drover Publications, Newyork, 1946.
[9] Paul C. R., Computation of Crosstalk in Multiconductor Transmission Lines’ , IEEE Transactions on EMC, VOL EMC-23, No-4, 1981.
[10] Clayton R. Paul, ‘Solution of the Transmission-Line Equations Under the Weak-Coupling Assumption’, IEEE Transactions on Electromagnetic Compatibility, VOL. 44, NO. 3, August 2002.
[11] Annapurna Das and Sisir Kumar Das, Microwave Engineering, Tata McGraw-Hill Education, 2000.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

TOGETHER WE REACH THE GOAL

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY