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Reduction of Signal Integrity Issues in Printed Circuit Board using Electromagnetics Bandgap Structure

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Abstract—***These day's electronic devices operate on the GHz frequency which requires a high speed circuit. Due to high speed data transfer there are lot of signal integrity issues induce in circuit.Electromagnetic Bandgap Structure is used to reduce the signal integrity issues. In this paper,two dimensional electro-magnetic bandgap structure is proposed for noise mitigation in printed circuit board.Results confirms the reliability of 2D EBG for noise mitigation and the upgrade in the signal quality.Results are interms of transmission parameter S21 -86.49 dB ,surface current Distribution and have the bandwidth of 1.48 GHz.***

Index Terms—**Printed Circuit Board (PCB), Signal Integrity (SI), Electromagnetic Band-Gap (EBG) Structure**

I. INTRODUCTION

The ever-growing clock frequencies and bit-rates and the demand for lower levels of voltage supply make the todays high-speed digital systems very sensitive to noise[1] [2] [3].Because of high speed signal transmission and compact PCB's many signal integrity issues are induced. Due to these issues signal quality and performance of the system gets decreases. By using electromagnetics bandgap structure signal integrity issues can be decreased. In high speed printed circuit board there are many problems occur like ringing, crosstalk, delay, distortion, ground bounce, signal loss, etc these are called signal integrity issues. We have to reduce these signal integrity issues or simultaneous switching noises to get the better performance of the system.EBG is nothing but aElectromagnetics Band-Gap structure.EBG is metallic periodic structure which restrict the electromagnetics wave ofparticular frequency.EBG is also called metamaterial. Ametamaterial (from the Greek word Meta, meaning "beyond") is a material designed to have a property that isn't found in normally happening materials. Data rate beyond 1 Gbps create the noises in the digital circuits [4] [5].In [1],the EBG structure is printed on a substrate with height 0.2mm with this wideband stopband is achived.But with 0.2mm substrate height the fabrication and handling for testing is too difficult. Therefore in this work we haveusegeneralizedsubstrateheighti.e.0.8mm. Fig. 1 describes signal integrity issues i.e. insertion loss, return loss, dispersion, cross talk,etc. Nowadays cross talk issues are very high because of compact traces and high-speed traces. Crosstalk is nothing but a signal propagating in one circuit can induce a signal in another circuit. Crosstalk occurs due to mutual coupling between traces because of this data is induced in victim trace .Crosstalk is usually thought of as occurring between two parallel traces running next to each other on the similar layer. Solutions for reduction of crosstalk are gap between traces is large, separate high-speed trace and low-speed trace, etc. Instead of that crosstalk is reduced by using EBG structure [6].Ringing is nothing but a oscillation of signal i.e. the oscillation is a reaction to a sudden change in the input signal. Ringing is caused by parasitic inductance and capacitance. A pulse or sudden change in the input makes the parasitic components to resonate at their characteristic frequency domain, creating the ringing effect in output. Ringing effects on system are increased electromagnetic interference, increased current flow, decreased performance and audible feedback. Distortion is nothing but a alteration of original signal in the circuit. Distortion is usually undesirable thus engineers attempt to eliminate or limit it.

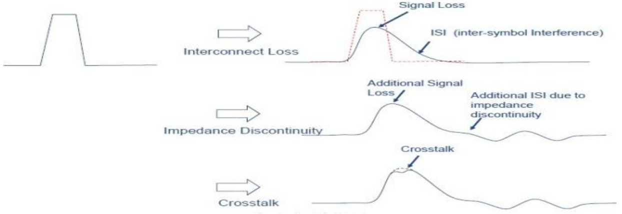

Fig. 1. Signal Integrity Consideration

II. PLANAR EBGBEHAVIOUR

The geometry of two dimensional EBG structure is shown in Fig. 2.It is made by 6 patches connected to eachother by using bridges which is rectangular in shape. The analysis of structure is done by using the transfer parameters(S- Parameters) between the ports. The bridges act as a dominant inductive and patch esactsasa dominant capacitive.

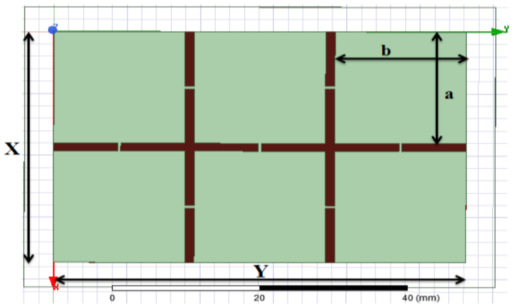

Fig. 2. Top View of 3X2 Planar EBG

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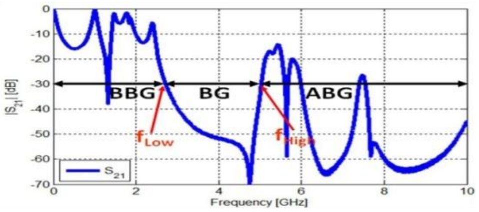

Fig. 3. Frequency Spectrum of S_{21} for planar EBG

The basic ideology of the two dimensional EBG behavior, the cavity created by the EBG plane and the solid one is excited by the resonance excitation. These cavity geometry resonances and their electrical properties enhance or restrict the propagation of a voltage between the planes[2].

For 2 dimensional electromagnetics band gap structure 3 parts can be defined in the frequency spectrum: region Below Band-Gap (BBG), Band-Gap region (BG) which is -30 dB, region Above Band-Gap (ABG).These regions are shown in the Fig. 3.

The starting frequency i.e.F_{low} of the band gap which is occures at -30 dB bandgap is as follows [7].

$$F_{low} = \frac{1}{\pi\sqrt{(\frac{b2}{c2}) + (2k1\varepsilon\frac{g}{td}b2) + (k1gCpln(\frac{td}{w}))}} \qquad (1)$$

The ending frequency of the bandgap i.e. F_{high} is as follows

$$F_{high} = \frac{c}{2b} \qquad (2)$$

The starting frequency i.e.F_{low} of the band gap which is occures at -30 dB bandgap is as follows [7].

Electromagnetics BandGap Structure plane modify the distribution of the field at the resonances because of the gaps and the slots in the design which is normal to the plane.The link among the patches is caused by the current which is exist in theconductorpassingthroughthebridges.

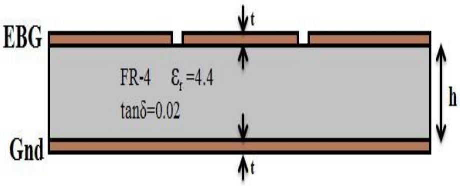

Fig. 4. Side View of 3x2 2D EBG

The side view of the planar EBG is shown in Fig. 4.It is the 3X2 EBG structure used in the design.The substrate used in design is FR-4 which is epoxy laminate material.FR-4have relative permittivity i.e. ε_r=4.4 and dielectric loss tangent i.e. tan(δ)=0.02 and have relative permeability(μ) is 1.The ports for determination of the insertion loss (S_{21}) are situated at x=3mmandy=3mmforport1,andatx=25.7mmandy= 40.7 mm for port 2.The ports are characterized as vertical excitations from the base PEC wall to the top PEC (Perfect Electric Conductor) that is waveport excitation or probe-fed excitation.

TABLE I PARAMETER DIMENSION

Description	Parameters	Values
Substrate Length	X	28.7 mm
Substrate Width	Y	43.7 mm
Patch Length	a	13.7 mm
Patch Width	b	13.7 mm
Bridge Length	l	1.3 mm
Bridge Width	w	0.4 mm
Substrate Height	h	0.8 mm
Substrate Permittivity	εr	4.4
Thickness of metal layer	t	17 um

The limits of the and F_{high} of bandgap are measured at threshold level of the -30dB i.e. S_{21}=-30 dB. ANSYS High Frequency Structure Simulator(HFSS) v.17 is used for simu- lation of the design.

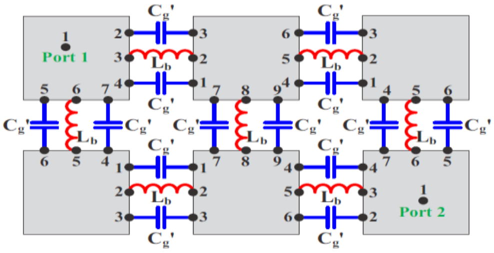

Fig. 5. Equivalent Circuit Model [7]

Fig. 5 shows the equivalent circuit model of the 3x2 planar electromagnetics bandgap structure.Capacitors and inductors are formed in this design are shown in this Fig.5.Where C_g’ is acapacitancebetweenthepatchesand$L_b$islumpedinductance of thebridge.

III. DESIGNPROCEDURE

First design the solid plane which have dimension 28.7 mm on X-axis and 43.7 mm on Y-Axis.Then create ports between ground and sollid plane.Port 1 is situated at (3,3) mm and Port 2 is situated at (25.7,40.7) mm.FR-4 substrate heightis0.8mm. Design of the solid plane is given in Fig.6.

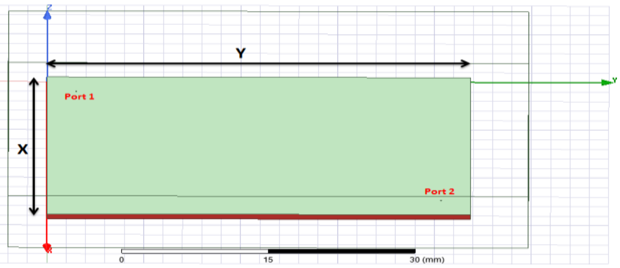

Fig. 6. Design of solid plane

Then make new design of the 3X2 EBG structure for signal integrity analysis is as follows. First create the substrate of material FR-4.Substrate have dimension 28.7 mm on the X- axis and 43.7 mm on the Y-axis and height of the substrate is 0.8 mm. Then after creating substrate create ground plane on the bottom of the substrate having dimension 28.7 mm on the X-axis and 43.7 mm on the Y-axis.

Then create the electromagnetics bandgap structure on the top side of the substrate.Create patches having dimesnsion a=13.7 mm on X-axis and b=13.7 mm on Y-axis.Then create Bridges having widht 0.4 mm and length 1.3 mm. Then apply boundary condition to the ground and EBG plane.Then create Ports between ground and EBG plane.Port 1 is situated at (3,3) mm and Port 2 is situated at (25.7,40.7) mm shown in Fig. 7.

Fig. 7. Ports Excitation

Then apply the excitations on the ports.Set the solution frequency at the 3.5 GHz. After that simulate the design for the results. Evaluate the S-parameters and surface current distributions.

IV. RESULTS

This design achieves the reflection coefficient i.e. S_{21} is -86.49 dB. And we get the bandwidth of 1.48GHz.Proposed design having F_{low} at 3.38 GHz and F_{high} at 4.87 GHz as shown in Fig. 8. Red graph shows the S_{21} Parameter of the solid plane. Blue graph shows the S_{21} parameter of PCB with 3x2 2D Planar EBG structure.S_{21} describe the insertion loss in the design.

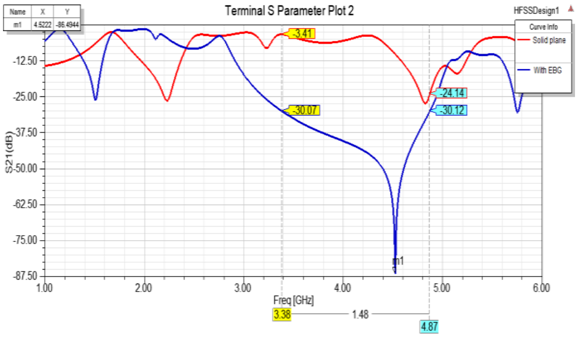

Fig. 8. Signal Integrity analysis Using Scattering Parameter S21.

In the geometry of the 3x2 EBG structure there are many capacitors and inductors are formed shown in Fig. 5. Due to this LC circuit EBG structure acts as a stop band filter.EBG structure has a property which acts as a band pass filter always. So noises which have frequency in below -30 dB range get restricted and we get the optimized result. This valley(3.38 GHz - 4.87GHz) represent the frequency range at which design reflects the least amount of power.

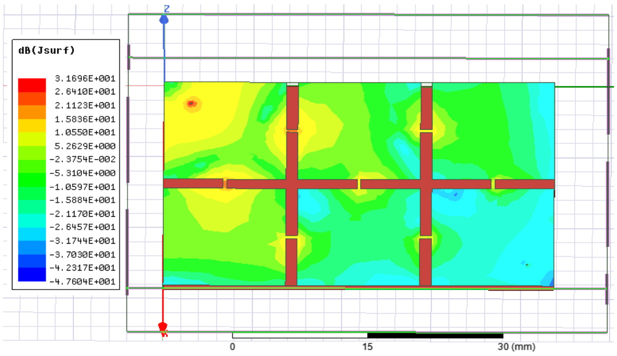

Fig. 9. Surface Current Distribution of 3x2 2D Planar EBG structure

Fig. 9 shows the current distribution of 3X2 2D planar EBG structure.Current distribution shows the current flowing in the electromagnetics bandgap structure layer.At port 1 more current distribute because of port 1 is the feeding port.Current is more at the bridges than the patches bacause this current is confined within the bridges which have a larger inductance than a fullplane.

V.CONCLUSION AND FUTUREWORK

In this paper 3x2 two dimensional EBG is proposed to reduce the signal integrity issues.Compare and analyze the results of printed circuit board without EBG structure (design of solid plane) and printed circuit board with EBG structure.AnalyzetheresultintermsoftheS-ParameterS_{21} i.e. insertion loss in the design,and also shows the current distribution or field distribution in the proposed design. This design is for the single layer.EBG structure technology can be used for the multilayer printed circuit boards.In multi-layer PCB there are compactness having more signal integrity issues,by using Electromagnetics Bandgap structure we can reduce the signal integrity issues and increase the performance of the system.

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