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Signal Integrity Issues Reduction In PCB Using Metamaterial

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Abstract

High-speed circuit design has become a very popular industry in the development of electronic technology. Data Transfer at high speed raises many signal integrity issues. Metamaterial (EBG) is used to reduce the signal integrity issues. In this paper, two-dimensional electro- magnetic bandgap structure is proposed to reduce the noises in printed circuit board. Results & validation checks the reliability of 2D EBG for noise mitigation and the upgrade in the signal quality. Evaluate result in the form of transmission parameter S21 -86.49 dB (Loss of signal), surface current Distribution and bandwidth of 1.48 GHz. Also proposed the design of multilayer printed circuit board with metamaterial.

Key Words:*Printed Circuit Board (PCB), Signal Integrity (SI), Electromagnetic Band-Gap (EBG) Structure*

1. INTRODUCTİON

High-speed circuit design has become a very popular industry in the fast development of electronic technology. The SI (signal integrity) and PI (power integrity) issues caused by high-speed circuit design are also becoming increasingly prominent. In the design process of electronic systems, the size of the system is getting smaller and smaller, and the number of integrated circuits is increasing. The components and traces on the printed circuit board are getting denser and denser. At the same time, the frequency of signals is getting more and more. High, the rising edge of the signal is steep, which in this case leads to serious electromagnetic compatibility caused by mutual inductance and mutual capacitance between the device and in the device. In the electronic system printed circuit board, including crosstalk, reflection, delay and synchronous switching noise, these problems not only affect the performance of the PCB, resulting in the signal cannot be correctly, effectively transmitted, or even distortion, will also affect the entire control of the PCB System performance. In this paper, we analyze the occurrence of crosstalk, reflection, and synchronous switching noise, and propose corresponding possible measures for these problems[1].

SI refers to the quality of the signal's transmission on the signal transmission line, which is reflected in the signal's ability to respond with the correct voltage, timing, and bandwidth in the circuit. In high-speed, high-density digital circuits, signal integrity issues are roughly expressed in the following areas: ringing, overshoot, undershoot, and delay. Signal integrity problems can cause significant distortion and timing turbulence of the signal, and can lead to data errors. There are many factors that cause signal integrity problems such as parameters of component, the layout of components on the PCB, the stacked structure, and the high-speed signal lines etc. How to route on the PCB is a key factor affecting SI. The main factors are crosstalk coupling, signal reflection and electromagnetic interference.

A **metamaterial** (from the Greek word Meta, meaning "beyond" and the Latin word *materia*, meaning "matter" or "material") is a material engineered to have a property that is not found in naturally occurring materials. Metamaterials are materials typically engineered with novel or artificial structures to produce electromagnetic properties that are unusual or difficult to obtain in nature. Because of their promise to provide engineerable permittivity, permeability, and index of refraction, metamaterials have drawn broad interest and have led to possible utilization in many electromagnetic applications from the microwave to

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optical regime, especially for the radiated-wave devices.

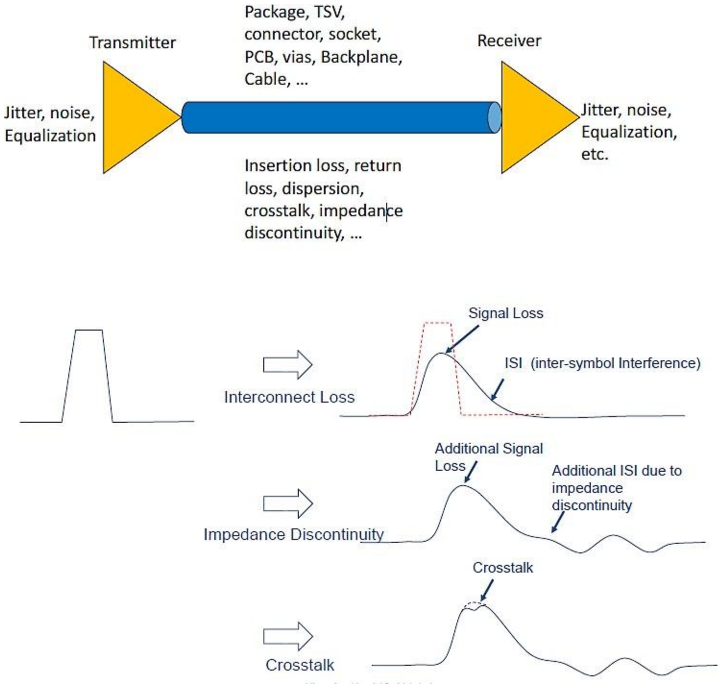

Fig 1 : Signal Integrity Issues

2. ABOUT EBG

The geometry of 2 dimensional EBG structure is shown in Fig. 2. It is made by 6 patches connected to all with bridges which is rectangular in shape. The study of structure or design is done by using the transfer parameters (S- Parameters) between the ports. The bridge act as a dominant inductive and patches acts as a dominant capacitive.

The basic phenomenon of the 2D EBG behavior, the cavity formed by the EBG plane and the solid one is excited by the resonance excitation. These cavity geometry resonances and their electrical properties improve or restrict the propagation of a voltage between the planes [2].

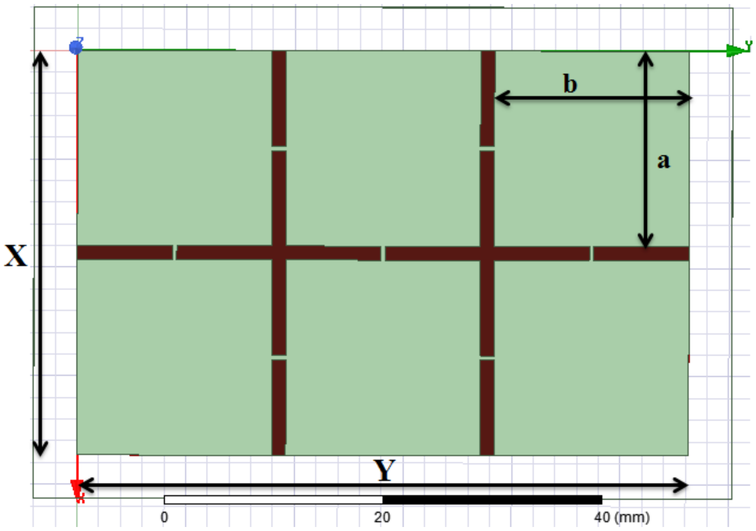

Fig 2 : Top View of 3X2 EBG Structure

“For 2-dimensional electromagnetics bandgap structure 3 regions 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). The regions are shown in the Fig. 3.”

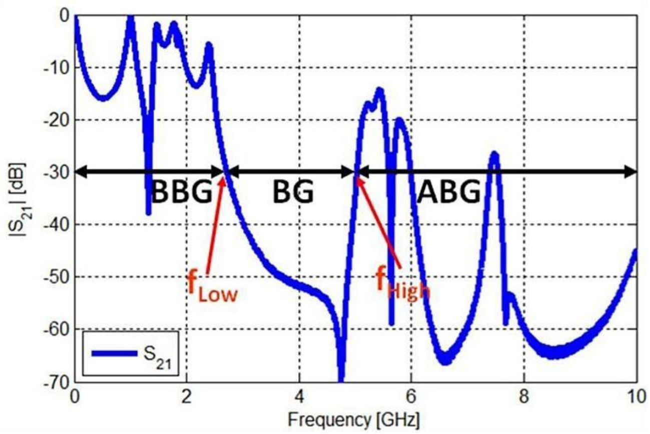

Fig 3: Frequency Spectrum of Planar EBG (S21)

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

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

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

$$F_{high} = \frac{c}{2b} \tag{2}$$

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 existing in the conductor passing through the bridges.

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-4 have 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=3 mm and y=3 mm for port 1,and at x=25.7 mm and y=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 wave-port excitation or probe-fed excitation.

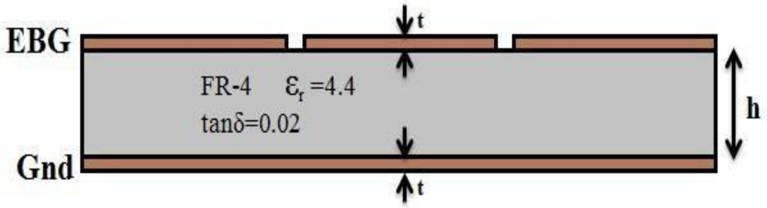

Fig 4: Side View of 3x2 Planar EBG

Table 1: Dimmensions of 3x2 Planar EBG

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 F_{low} 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 simulation of the design. 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.

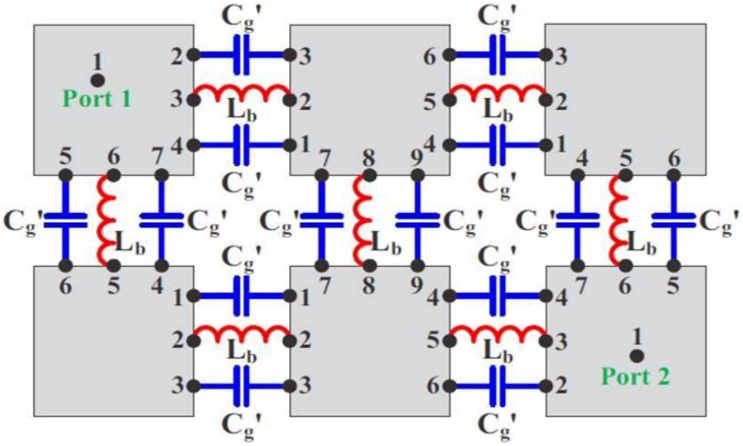

Fig. 5: Equivalent circuit of 3x2 EBG structure

Where C_g' is a capacitance between the patches and L_b is lumped inductance of the bridge.

3. DESIGN

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 solid plane. Port 1 is situated at (3,3) mm and Port 2 is situated at (25.7,40.7) mm.FR-4 substrate height is 0.8mm. Design of the solid plane is given in Fig.6.

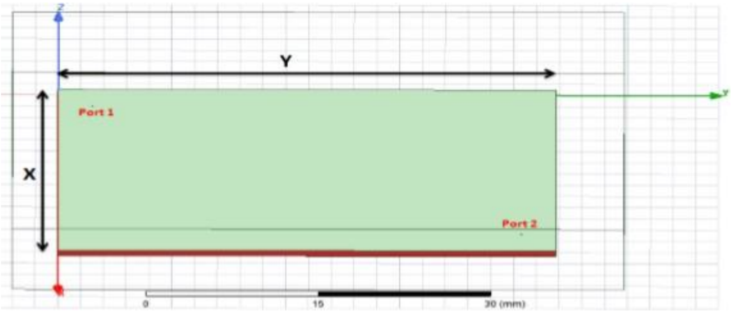

Fig 6. Design of Solid Plane

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 dimension a=13.7 mm on X-axis and b=13.7 mm on Y-axis. Then create Bridges having width 0.4 mm and length 1.3 mm. Then apply boundary condition to the ground and EBG plane. Then create Ports

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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.

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.

Fig 7. Port Excitation

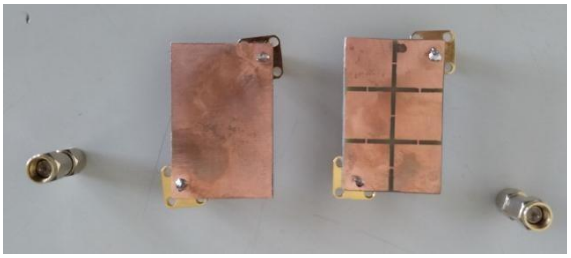

Fig. 8: Fabrication of solid plane and 3x2 EBG structure

Now design multilayer PCB which have dimension shown in table 2.

Table 2 : Dimensions of Multilayer PCB

Description	Parameters	Values
Substrate Length	X	80 mm
Substrate Width	Y	80 mm
Patch Length	A	5 mm
Patch Width	B	5 mm
Bridge Length	L	1.5 mm
Bridge Width	w	0.2 mm
Substrate Height	h	0.8 mm
Substrate Permittivity	εr	4.4
Thickness of metal layer	t	17 um

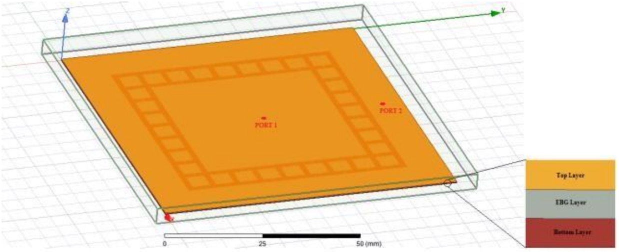

Fig. 9: Design of Multilayer PCB

4. RESULTS

This design achieves the reflection coefficient i.e. S_{21} is -86.49 dB. And we get the bandwidth of 1.48 GHz. Proposed design having F_{low} at 3.38 GHz and F_{high} at 4.87 GHz as shown in Fig. 10. 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.

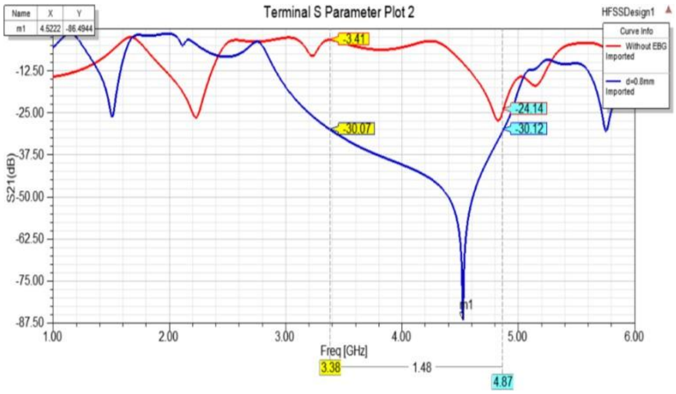

Fig. 10. Simulation Result of 3X2 2D EBG

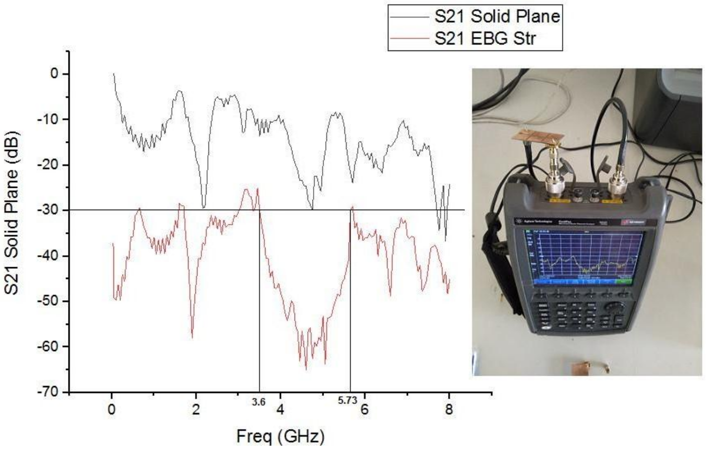

Fig. 11: Fabricated result on VNA

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 stopband filter. EBG structure has a property which acts as a bandpass 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) represents the frequency range at which design reflects the least amount of power. While Fig. 11 graph shows the fabricated result of PCB using VNA(Vector Network Analyzer).In fabricated result we get the valley at 3.6-5.73 Ghz. It is slightly different from the simulated result because of noises in the environment and results were not generated in the anechoic chamber.

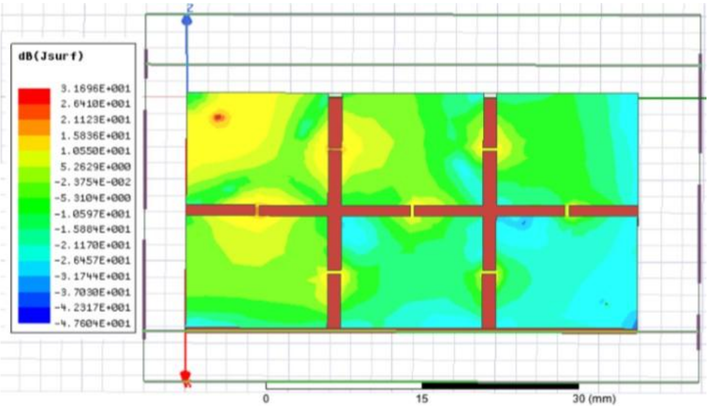

Fig 12. SCD of 3x2 EBG structure

Fig. 12 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 because this current is confined within the bridges which have a larger inductance than a full plane.

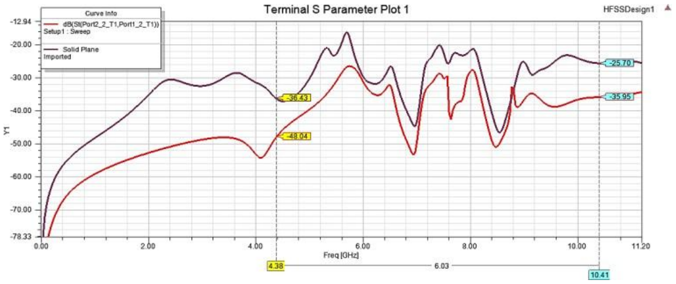

Fig. 13: Simulation result of Multilayer design

Result of SI of multilayer design shows in Fig. 13. Purple graph describes the reflection coefficient (S21 parameter) of solid plane while red graph shows the S21 parameter of the multilayer design with electromagnetics bandgap structure. We got the bandwidth of 6.03 GHz which is very good and also, we got less reflections in multilayer with EBG. And we got the reflection loss of -48dB.

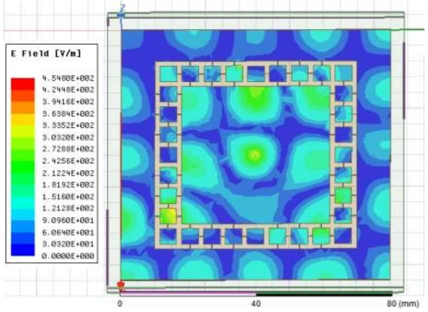

Fig. 14. E Field Distribution of Multilayer Design

Fig.14 shows the current distribution of the multilayer design. That represent the how current flows in the design.

5. CONCLUSİON

In this paper multilayer PCB and 3X2 2D EBG structure designed to reduce the signal integrity issues. Compare the results of printed circuit board without EBG structure (design of solid plane) and printed

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circuit board with EBG structure. We got the simulation and validation result of fabricated PCB in terms of the S_{21} i.e. insertion loss of the design, and also shows the current distribution or field distribution in the proposed design.

After single layer PCB we designed the multilayer PCB. EBG structure technology can be used for the multilayer printed circuit boards. In multilayer PCB there are more compactness have large SI issues, by using EBG structure we can reduce the signal integrity issues and increase the performance of the system. We got the BW of 6.03 GHz in multilayer design and S21=- 48dB.

References:

1. Fahad Bilal, Manisha Bansode, Pramod Bhavarthe, Dr. S.S. Rathod "Reduction of Signal Integrity Issues In Printed Circuit Board Using Electromagnetics Bandgap Structure", International Journal of Recent Technology and Engineering (IJRTE), vol. 8, Issue-9 , May 2019, pp. 3471–3474.
2. Pramod P.Bhavarthe,Surendra S.Rathod and Kuraparthi T.V. Reddy,"A compact Two-via Hammer Spanner Type Polarization Dependent EBG Structure",IEEE Microwave and Wireless Components Letters Volume :28,Issue:4,April 2018
3. Leo Raimondo,Francesco De Paulis,Antonio Orlandi,"A Simple and Eficient Design Procedure for Planar Electromagnetic Bandgap Structures on Printed Circuit Boards",IEEE Transactions on Electromagnetic Compatibility, Vol. 53, No. 2, May 2011
4. Francesco de Paulis,Leo Raimondo and Antonio Orlandi,"IR-DROP Analysis and Thermal Assessment of Planar Electromagnetic Bandgap Structures for Power Integrity Applications",IEEEE Transactions On Advanced Packaging,Vol.33,No.3,August 2010.
5. Vittorio Ricchiuti , Antonio Orlandi , James L. Drewniak and Francesco De Paulis,"Characterization of serial links at 5.5Gbps on FR4 backplanes", 2008 International Symposium on Electromagnetic Compatibility,Sept. 2008
6. Jun Fan, M. H. Nisanci, F. de Paulis A. Orlandi, "Practical EBG Application to Multilayer PCB: Impact on Signal Integrity", IEEE Electromagnetic Compatibility Magazine Volume 2,Issue 2,Page no 8287,2013
7. H. Nisanci,F. de Paulis, A. Orlandi, "Practical EBG Application to Multilayer PCB: Impact on Power Integrity",IEEE EMC Magazine, vol. 1, no. 3, Page No. 60-65, July 2012

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