Indonesian Journal of Electrical Engineering and Computer Science
Vol. 5, No. 3, March 2017, pp. 542 ~ 548
DOI: 10.11591/ijeecs.v5.i3.pp542-548

Evaluation of PCB Shielding Characteristic in Near Field

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Abstract

Wireless electronic devices nowadays always operate in high frequency while having small and compact form factor which led to electromagnetic interference among traces and components. PCB shielding is the common solution applied in electronic industry to mitigate electromagnetic interference. In this paper, PCB shielding characteristics such as shield's thickness, height, and ground via spacing in PCB boards were evaluated in near field. Test boards with various grounds via spacing were fabricated and evaluated by using 3D Electromagnetic scanner. On the other hand, shields with various thickness and height were modeled and evaluated through simulation. Results suggested that shielding effectiveness could be improved by having greater shield's height with smaller ground via spacing in shielding ground tracks. Shielding effectiveness can be improved by 1 dB with every step of 0.5 mm increase in shield's height. Besides that, approximately 0.5 dB improvement in shielding effectiveness with every step of 1 mm decrease in ground via spacing. Furthermore, greater shield's thickness can contribute better shielding effectiveness for operating frequency below 300 MHz.

Keywords*: PCB Shielding, Board Level Shielding, Near Field Shielding, Shielding Characteristic*

1. Introduction

There are two categories of shielding solution shown in Figure 1, which is enclosure level shielding and PCB (Printed Circuit Board) level shielding. Usually, to cover a whole circuit board or a system, enclosure shield is used to isolate its emission to external environment while avoiding interference from external. On the contrary, PCB level shield is made of small size metal cans, attached on a particular portion of a PCB board. By considering several wireless modules operate in a compact area, high potentially EMI (Electromagnetic Interference) coupling occurs between on-board digital circuits and on-board antennas [1]. PCB level shielding is capable of dealing with problems of the internal interference and regulatory emissions control at low-cost and providing ease of assembly compared to enclosure shielding. It becomes more effective when dealing with integration of close proximity wireless communication in a product through the isolation of the noisy transmitting or digital processing signal sources [2]. Several parameters are critical to impact shielding effectiveness, such as shield's thickness, height from the source, and most importantly number of apertures, aperture's size and location. Most of the study been conducted to date were relevant to the PCB shielding in far field. However, evaluation of shield's characteristic such as shield's thickness and height in near field are crucial as they are dominant factor in shielding effectiveness and usually electromagnetic radiation is hard to be predicted in close proximity. In this paper, results of the evaluation provided a guideline to improve shielding effectiveness through better design in terms of shield's thickness, height, and ground via spacing. If PCB level shielding able to provide promising radiation suppression, the requirement of the chasis enclosure with low cost material can be reduced, even possibly removes the need of enclosure shielding.

Received November 27, 2016; Revised February 2, 2017; Accepted February 19, 2017

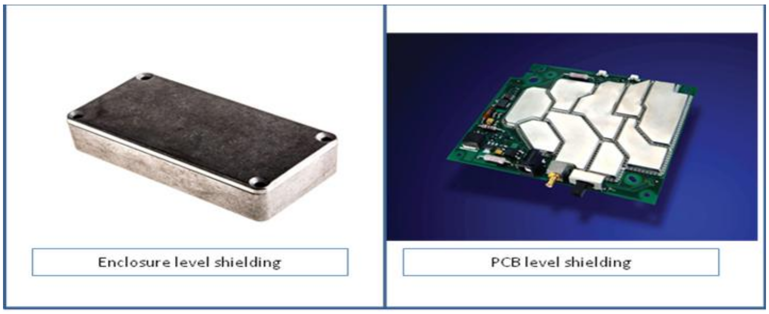

Figure 1. Enclosure level shielding and PCB level shielding

1.1. PCB Level Shielding Topology

Figure 2 depicts the structure of the PCB level shielding commonly applied in electronic devices. Five planes of the conductive shield cans known as shielding cover are made by the metal material, while the sixth bottom plane is the PCB itself which is the 0 V potential plane. Ground via provide connection between shielding cans and ground plane of the PCB. Consequently, space between ground vias along the ground track become free space or known as aperture potentially allows leakage of electromagnetic wave.

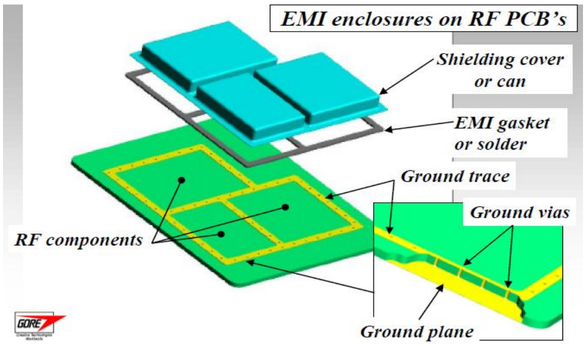

Figure 2. Structure of PCB level shielding [3]

In near field shielding, once the incident electromagnetic wave propagating towards shield, some of it are absorbed by metal and dissipated as heat, some of it reflected from the shield boundary, while the rest of it are transmitted out from the shield. Electromagnetic wave was attenuated based on field cancellation by opposite field generation, which is induced current on the shield's surface. Existence of apertures on shield's surface and formation within space between ground vias in PCB board may disrupt the flow of induced current, consequently degrade shielding effectiveness. Waveguide depth is another factor of shielding effectiveness, which is defined as distance to travel from radiation source to aperture on the outer surface of shield. For waveguide depth greater than maximum dimension of the aperture, increase in waveguide depth may contribute to better shielding effectiveness. Ability and capability of the shield cans to block external unwanted interference and avoid leakage of signal from the enclosure is defined as shielding effectiveness. Shielding effectiveness also can be described as the ratio between the received electric field intensity with and without shield assembled [4, 5].

$$SE\ (dB) = 20log_{10}\left[{}^{E_i}/_{E_o}\right] \quad (1)$$

Where,
E_i = Electric field intensity without shield assembled
E_o = Electric field intensity with shield assembled

Thus far, PCB level shielding effectiveness was evaluated in far field by several methods. Reverberation chamber was deployed by [6, 7] in PCB level shielding effectiveness measurement. Besides that, TEM (Transverse Electromagnetic) cell was the latest method applied by [8, 9] in component level shielding evaluation method. TEM cell ensures the establishment of uniform electromagnetic field in a shielded environment, simple and reliable compared to bulky setup of reverberation chamber, and applicable in lower operating frequencies. However, 3D Electromagnetic scanner was preferred in this paper to evaluate shielding effectiveness in near field precisely which was justified reliable in [10]. Compared to far field measurement, near field electric field measurement is more relevant as most of the electromagnetic interference issues in PCB are happened in near field region as the electronics components are small and placed compact on the board.

2. Research Method

Figure 3 describes the layout design and fabrication of test boards with various ground via spacing. In the layout design, it consists of a 10 mm long transmission line at the middle of the shield's ground track to act as a radiator. Each end of the transmission line was connected to the SMA connector live pin through the transmission line at the bottom layer. Bottom layer of the PCB as a ground plane to connect with shield can through ground via along the shield's ground track. All transmission line was characterized with 50 ohm characteristic impedance and insertion loss below 1 dB. Test boards "A" to "D" were fabricated with ground via spacing of 1 mm, 2 mm, 3 mm, and 4 mm respectively. Besides that, shield can with thickness of 0.3 mm, external height 3 mm, and three apertures on the top surface of the shield was used to be attached on all four test boards. Impact of aperture to shielding effectiveness was then evaluated.

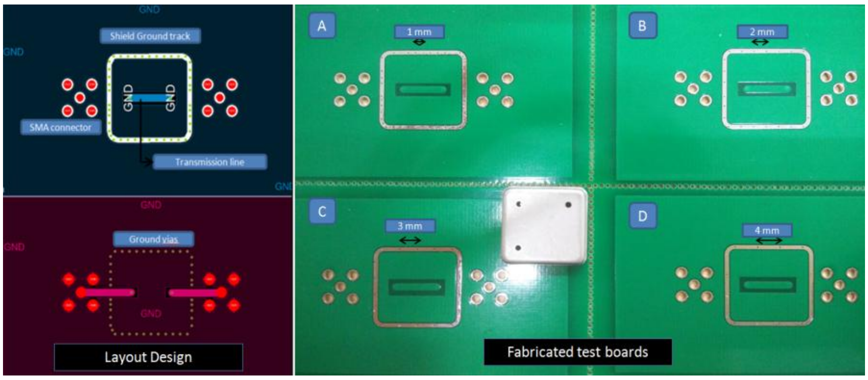

Figure 3. Layout design and fabrication of test boards with various grounds via spacing

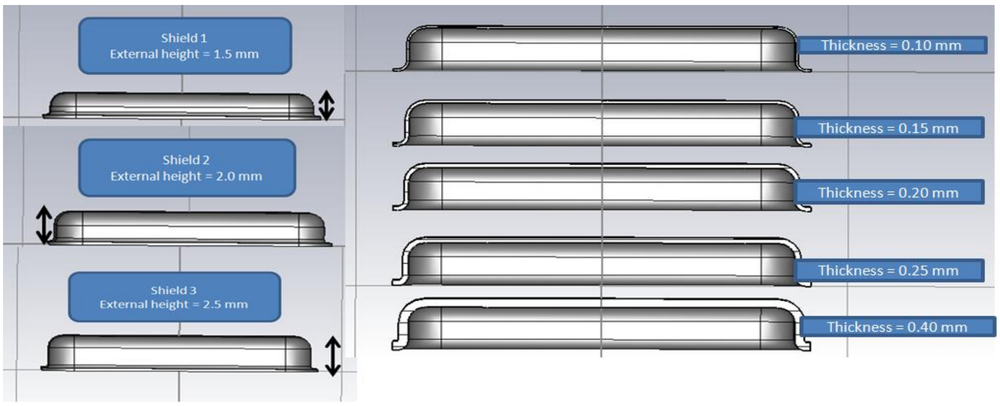

Figure 4. Shields modeled with various thickness and height

Figure 4 shows that the same shield was modified its dimension in thickness and height by using software tool into step files which were imported to CST (Computer Simulation Technology) for simulation. Spectral analysis of shielding evaluation was done by transient solver in CST simulation tool which is using hexahedral meshes with Finite Integration Technique and Perfect Boundary Approximation features. Shields with external height of 1.5 mm, 2.0 mm, and 2.5 mm, while thickness varied from 0.1 mm to 0.4 mm were evaluated its relation to shielding effectiveness in CST. Fabrication and measurement are excluded as there are several drawbacks. Even with tiny changes in geometry of the shield, tooling cost for the mould is very high in cost, while fabrication may expect variation occurred, especially the changes of variable is small. Besides that, simulation provide better environment with no interference and accurate result to evaluate the impact of the changes.

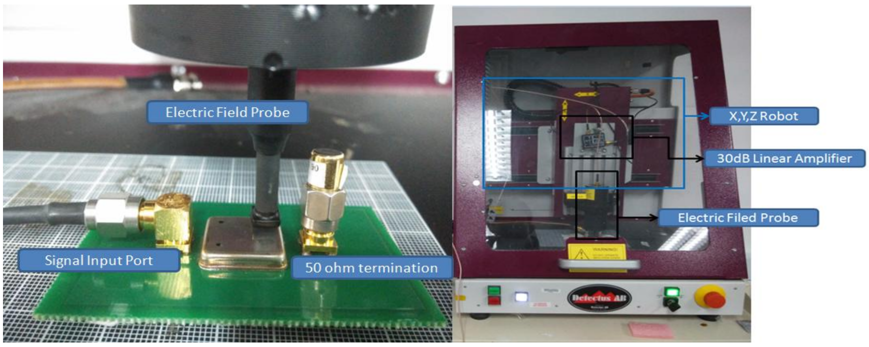

Figure 5. 3D Electromagnetic scanner structure and measurement setup

Figure 5 depicts the 3D Electromagnetic scanner consists of an X-Y-Z robot to alter the location of the electric field probe based on the coordinate, a 30 dB linear amplifier used to amplify the signal detected in case its too weak, and an electric field probe which support near field field intensity measurement. The scanner is capable to measure emission from components, traces, and intergrated circuit in near field with its advantage of good accuracy and precise electric field probe. In measurement, electric field probe was positioned 5 mm above the aperture on the top surface of the shield. One end of the transmission line was injected signal, while another end was terminated with 50 ohm load.

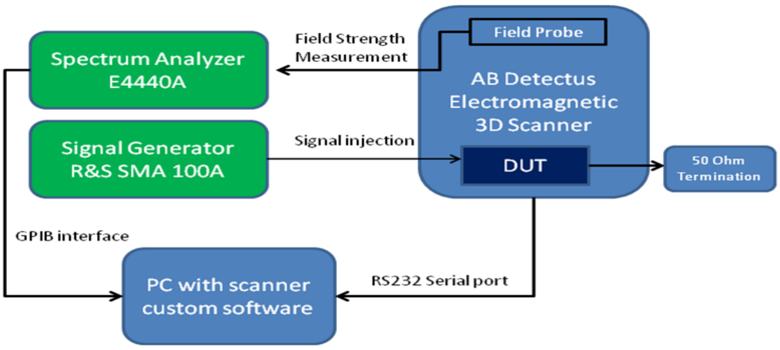

Figure 6. Block diagram of the measurement configuration

Figure 6 describes the measurement configuration and the communication interface protocol among each element of the setup. RS232 serial port was used to interface with PC to control and manipulate position of the electric field probe through custom software. On the other hand, electric field probe was connected to spectrum analyzer, while the results were retrieved into PC through GPIB interface. During measurement, signal generator was used to produce electromagnetic wave with 0 dBm, injected into port 1 of the test board. Port 2 was terminated with 50 ohm load to avoid huge reflection and radiation. Electric field intensity was sweeped from 10 MHz to 2.5 GHz in condition without shield attached on the test board at first, while repeated the measurement with shield attached. Shielding effectiveness was calculated by referring to equation (1).

3. Results and Analysis

In this section, results and analysis of shielding characteristics such as shield's height, thickness, and ground via spacing are discussed. All results presented are plotted in terms of shielding effectiveness calculated by ratio of electric field intensity without shield assembled to with shield assembled. Relation and impact of each shield's characteristic is discussed in such a way to achieve better shielding performance.

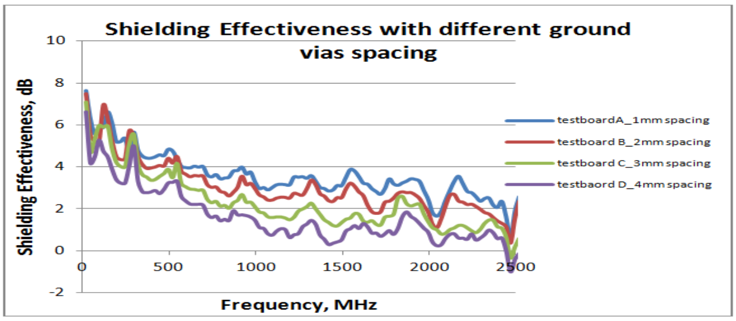

Figure 7. Shielding Effectiveness of shield with different ground via spacing

Figure 7 shows the plotted shielding effectiveness for four test boards with different ground via spacing. Across frequency up to 2.5 GHz, shielding effectiveness is reducing as wavelength of the electromagnetic wave getting shorter which allowed heavier radiation out from the aperture. Ground via served as joint to connect shield can and ground plane of the PCB to form an enclosure as a shielding solution to isolate particular part of the circuit. Thereby, spacing between grounds via, known as aperture inside PCB, play a main role to decide amount of electromagnetic wave radiation out from the enclosure. Result shows that shielding effectiveness is degraded as the ground via spacing getting larger due to bigger aperture in PCB allowed larger leakage of electromagnetic wave. Test board "D" with biggest ground via spacing 4 mm is having the worse performance. Shielding effectiveness is approximately 0.5 dB lower across frequency as the ground via spacing increases by 1 mm.

Shielding effectiveness of shields with different shield's height is shown in Figure 8. Shield's height is one of the critical parameter to decide shielding effectiveness as intereaction of the radiation source and aperture become sensitive in such a small space inside the shield. Result shows that shielding effectiveness is improved with greater shield's height as waveguide depth is increase, where the distance for electromagnetic wave to travel out from the aperture of shield is getting longer. The advantage of larger waveguide depth start reflect on better shielding performance when the maximum dimension of the aperture is comparable to waveguide depth. By having each 0.5 mm increase in distance for the electromagnetic wave to travel from the source to the aperture, shielding effectiveness improved by around 1 dB across frequency. Tiny adjustment in shield's heigh dimension can contribute to better shielding performance. However, the limit to have optimum height depends on the allowable scale of the product as devices nowadays require thinner experience.

Shielding effectiveness performance for shields with different thickness is presented in Figure 9. For thickness from 0.1 mm to 0.4 mm, shielding effectiveness was improved approximately 2 dB in operating frequency below 100 MHz, while around 1 dB improvement within frequency range from 100 to 300 MHz. On the other hand, shield's thickness has no impact to shielding performance for frequency higher than 300 MHz. Thicker shield have not much of impact to better shielding effectiveness as the increment in waveguide depth is too small which is only 0.3 mm different of thickness apart. With all these results and discussion, there is a guideline to be referred in early stage of shielding design. By considering several constraints in a particular application such as thickness, circuit complexity, and dimension of the device, shield is recommended to have lesser aperture on top surface, smaller dimension of aperture, smaller ground via spacing, larger height, and thicker shield for operating frequency below 300 MHz.

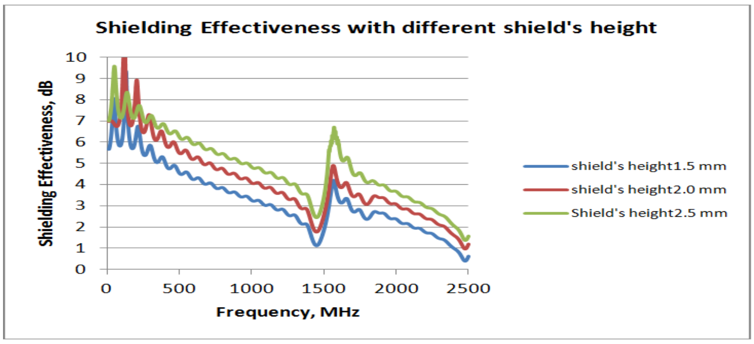

Figure 8. Shielding Effectiveness of shields with different height

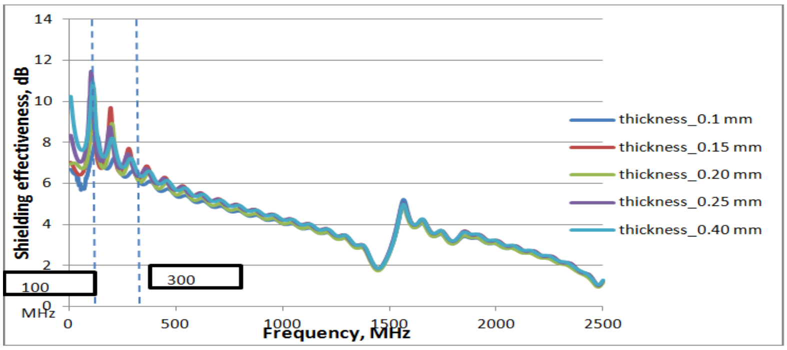

Figure 9. Shielding Effectiveness of shields with different thickness

4. Conclusion

PCB level shielding is a good solution in electromagnetic interference among components and circuits in electronic devices providing a good design of shield in the early stage of development. Results contribute to a good reference in shield characterization in terms of aperture dimension, shield's height, thickness, and ground via spacing. Several factors can help to achieve better shielding effectiveness: smaller ground via spacing improve shielding effectiveness by around 0.5 dB with every 1 mm step increase, and greater shield's height enhance shielding effectiveness by 1 dB with every 0.5 mm step increase. In conclusion, ground via spacing and shield's height are the main factors to be considered if the application is operating higher than 100 MHz. However, thickness of the shield has to be considered as well if the operating frequency is below 100 MHz.

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