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Research paper

Effect of electromagnetic interference shield on package and PCB

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Abstract

In this work, the effect of metal shield of ball grid array package on electromagnetic coupling is analysed. To compare the electromagnetic coupling between the packages on a printed circuit board, two test vehicles are presented. All vehicles have a metal shield overall surface of their package with the exception of their bottom side. One vehicle connects the metal shield to the ground plane. However, the other does not connect between those. Electromagnetic coupling simulations for two test vehicles are performed with frequency range from 10 MHz to 15 GHz. Electrical field distributions of the test vehicles are also calculated. From the calculation results, the metal shield structure in this work can reduce effectively the electromagnetic coupling between the packages from the frequency range of 11 GHz to 15 GHz. Connecting the metal shield on the package to the ground plane provides better electromagnetic interference between the packages.

Keywords: *Electromagnetic Interference; Coupling; Metal Shield; Package; S-Parameter.*

1. Introduction

Recently, high-speed electronic devices such as smart phones, tablets and notebooks are being developed with multi-function, high-performance, high-speed operation and miniaturization. In particular, a small ball grid array (BGA) package is required to realize various functions. It can provide operating at a high-frequency in a limited area such as a smart phone. As multiple BGA packages are highly integrated into a printed circuit board (PCB), a noise from each chip may affect adjacent packages [1]. In addition, it can result in the electromagnetic interference (EMI) between the different BGA packages [2].

A metal lid on top of the BGA package has been widely used to prevent the electrical radiation from a chip. Effect of a grounded lid structure on package level EMI shielding was recently reported [3]. However, the size of the BGA package increases due to the solder pads for lid shield attachment. Recently, the electromagnetic shielding has been realized through a metal coating in BGA package [4-6]. Several previous studies have been investigated on a silver shielding coating sprayed on the top and the sides of the package [4-5] and a copper metal sputtered on the surface of the package with a thickness from 1 μm to 15 μm [6]. Metallization technique to plate a thin metal layer or coat a conductive adhesive around the package are also an emerging method to prevent EMI [7]. For suppression of EMI, an electromagnetic bandgap structure that consists of periodic metallic patterns in a multilayered PCB was introduced in [8]. These metal shields provide a material and structure that can reflect EMI and then can solve an electromagnetic coupling that occurs on a high-speed PCB.

New analysis technique and design methodology have been studied to reduce the electromagnetic emission between the BGA packages [9-10]. However, in this paper, the influence of metal shield is analysed by calculating electromagnetic coupling and its field distribution between BGA packages on PCB. Effect of connecting metal shield to ground plane in the PCB is also analysed using electromagnetic simulation.

Table 1: Dimensions for BGA Package and PCB

Parameter	Value
Package size	5.0×5.0 mm^2
Package thickness	1.0 mm
Separation between packages	0.5 mm
Chip size	3.5×3.5 mm^2
Trace width	80 μm
Trace thickness	18 μm
Reference plane thickness	18 μm
Dielectric thickness	45 μm
Ball pitch	0.8 mm
Ball diameter	0.5 mm
PCB thickness	1.0 mm

2. BGA package structure and its arrangement on PCB

In order to analyse the electromagnetic coupling between the package and the PCB, two BGA packages are arranged on PCB. Fig. 1 shows the BGA package structure and its arrangement on PCB for the electromagnetic coupling calculation. The BGA package has a size of 5 × 5 mm^2 as shown in Fig. 1.

There are a chip and trace inside the packages. Each trace in the BGA package is designed using a microstrip structure with a characteristic impedance of 50 Ω. However, the traces have a limited reference plane area because of small package area. It has a width of 80 μm and a length of 3.0 mm. The ball pitch and the ball diameter are set to 0.8 mm and 0.5 mm, respectively. The BGA package thickness is 1.0 mm and both packages are spaced 0.5 mm apart. PCB thickness is designed as 1.0 mm. Dimensions for BGA package and PCB are summarized in Table 1. These parameters are determined to consider the actual BGA package design and its placement on the board.

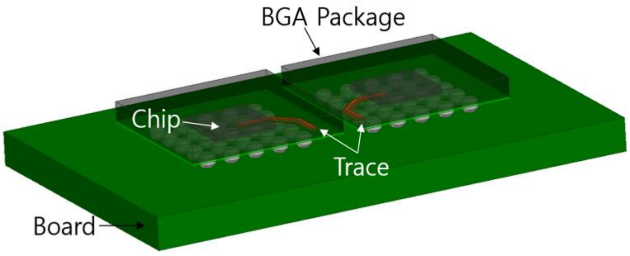
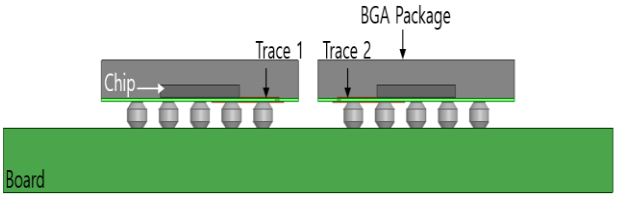


Fig. 1: BGA Package Structure and Its Arrangement on PCB for Electromagnetic Coupling Calculation.

3. Analysis of electromagnetic coupling

In this work, two test vehicles are presented to analyse and compare the effect of metal shield on electromagnetic coupling. Fig. 2 shows the two test vehicles on the board. The only difference between the two test vehicles is in the presence of a metal shield. The metal shield is covered on the epoxy mold compound (EMC) of the BGA package and has a thickness of 10 µm. As shown in Fig. 2 (b), the right BGA package have a metal shield on its whole surface with the exception of its bottom side. High-frequency signals between 10 MHz and 15 GHz are applied to each trace inside the BGA package. The EMI for two test vehicles is compared by analysing the electromagnetic coupling between the two traces. The electromagnetic simulation is performed using ANSYS HFSS. As shown in Fig. 2, the port 1 is designated to the trace 1 in the left package and the trace 2 in the right package is assigned as the port 2.

(A) Test Vehicle without Metal Shield



(B) Test Vehicle with Metal Shield

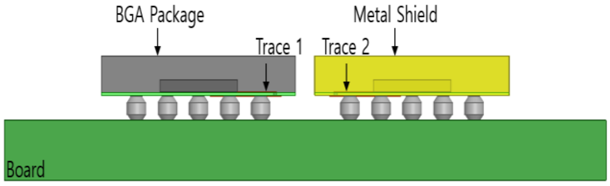


Fig. 2: Test Vehicles with and Without Metal Shield for Electromagnetic Interference Calculation.

Fig. 3 shows the electromagnetic coupling between two BGA packages. The electromagnetic coupling of the test vehicles shows almost the same results up to 5 GHz, but it is slightly different from 5 GHz to 11 GHz. In this frequency range, the electromagnetic coupling can’t be completely blocked by metal shield alone. Furthermore, the electromagnetic radiation of the test vehicle without metal shield increases significantly from 11 GHz. However, as shown in Fig. 3, the metal shield can reduce effectively the electromagnetic coupling above the frequency of 11 GHz.

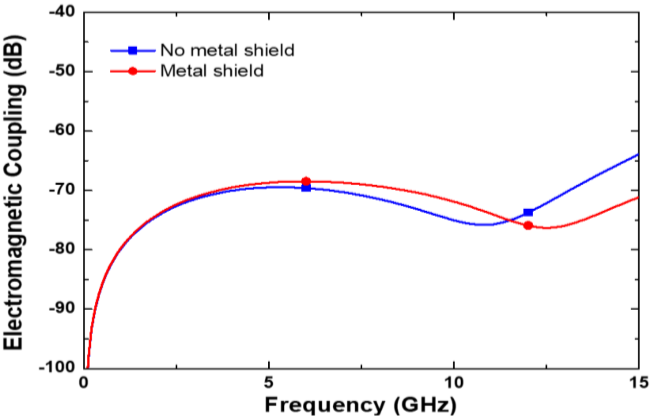
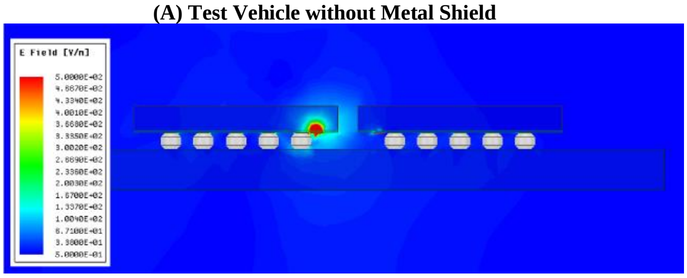


Fig. 3: Electromagnetic Coupling of Test Vehicles with and without Metal Shield.

The electrical field distributions of the test vehicles are calculated as shown in Fig. 4 and Fig. 5. The high-frequency signal with a frequency of 15 GHz is applied to the trace 1 inside the BGA package as shown in Fig. 2. Fig. 4 shows the sectional view of the electrical field distribution of the test vehicles. In the absence of the metal shield as shown in Fig. 4 (a), the electrical field generated by high-frequency driving in the left BGA package affects the adjacent right package and then causes the electromagnetic coupling between two packages. However, as shown in Fig. 4 (b), the electrical field has a relatively low effect on the interior of the left package with the metal shield.

(A) Test Vehicle without Metal Shield



(B) Test Vehicle with Metal Shield

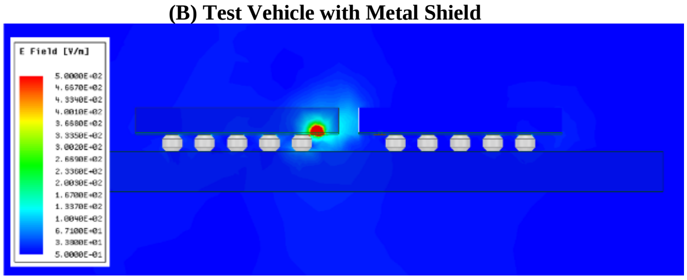
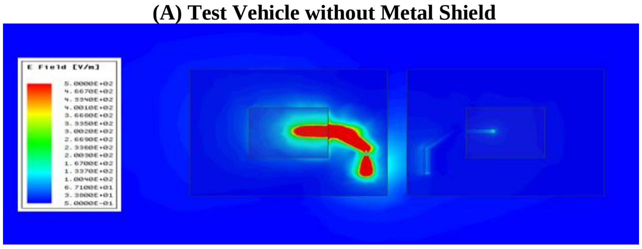


Fig. 4: Sectional View of Electrical Field Distribution of Test Vehicles at 15 GHz.

Fig. 5 shows the top view of the electrical field distribution of the test vehicle. As the separation between the traces is closer, the electrical field between the packages increases in both test vehicles. However, the test vehicle without the metal shield has higher electrical field. These results demonstrate that the metal shield on the package can reduce effectively the electrical coupling between the packages and the board at 15 GHz.

(A) Test Vehicle without Metal Shield



(B) Test Vehicle with Metal Shield

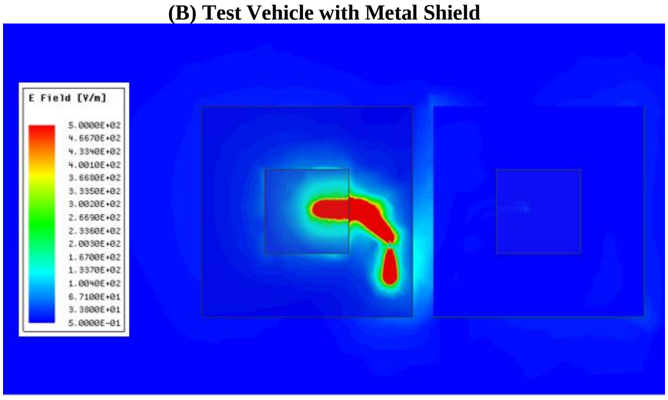
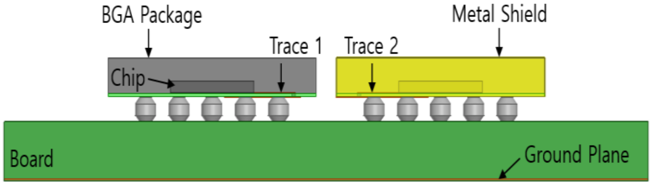


Fig. 5: Top View of Electrical Field Distribution of Test Vehicles at 15 GHz.

Effect of connecting a metal shield to a ground plane is investigated using the electromagnetic calculation. Fig. 6 shows two test vehicles with and without connecting the metal shield to the ground plane. The right BGA packages have the same metal shield with a thickness of 10 µm. The only difference between two test vehicles is whether the metal shield is connected to the ground plane of the PCB or not. As shown in Fig. 6 (b), two vias with a diameter of 0.16 mm connect the package to the ground plane. The right BGA package in Fig. 6 (a) has a structure in which a metal shield and a ground plane are not connected. On the other hand, the metal shield of the right package in Fig. (b) is connected to the ground plane using vias. By comparing the two structures, effect of the metal shield and the connection to the ground plane on EMI is analysed. High-frequency signals from 10 MHz to 15 GHz are applied to each trace inside the BGA package. The traces in the left package and in the right package are set to port 1 and port 2, respectively.

(A) Without Connecting Metal Shield to Ground Plane



(B) With Connecting Metal Shield to Ground Plane

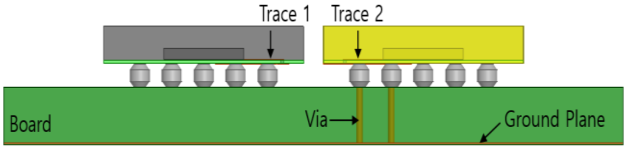


Fig. 6: Test Vehicles with and without Connecting Metal Shield to Ground Plane.

Fig. 7 shows the electromagnetic coupling between two BGA packages for two test vehicles. In all frequency ranges, the test vehicle with connecting the metal shield to the ground plane shows superior performance in electromagnetic coupling. The electrical field distributions on the PCB with and without connecting the metal shield to the ground plane are calculated and are shown in Fig. 8 and Fig. 9.

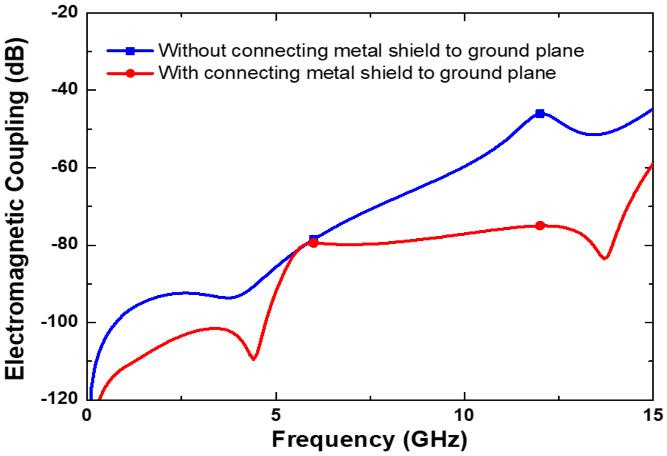
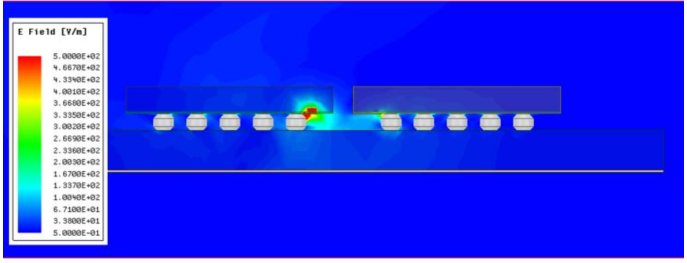


Fig. 7: Electromagnetic Coupling of Test Vehicles with and without Connecting Metal Shield to Ground Plane.

As shown in Fig. 6, the high-frequency signal with a frequency of 12 GHz is applied to the trace 1 inside the BGA package. Fig. 8 shows the sectional view of the electrical field distribution of the test vehicle. As shown in Fig. 8 (a), some areas near the trace 2 of the right package show a high electrical field distribution when the metal shield is not connected to the ground plane. An electrical field is also generated around the ball in the right package. Without a connecting metal shield to ground plane, a high-frequency driving of the left BGA package can cause the electrical coupling to adjacent package. However, as shown in Fig. 8 (b), a lower electrical field is distributed in the region near the trace 2 with connecting the metal shield to the ground plane. The strength of the electric field is also significantly reduced around the ball of the right package. Therefore, connecting the metal shield to the ground plane can reduce effectively the electrical coupling between the packages at 12 GHz. Fig. 9 shows the top view of the electrical field distribution of the test vehicle with and without connecting metal shield to ground plane. The field strength of the right package is higher for the test vehicle without connecting metal shield to ground plane. In other words, the right package has higher field strength in a wider area. In addition, the electrical field distribution also occurs around the outline of the right package. These results demonstrate that that connecting the metal shield to the ground plane in this work reduce the electrical coupling between the packages and then can be a solution to EMI.

(A) Without Connecting Metal Shield to Ground Plane



(B) With Connecting Metal Shield to Ground Plane

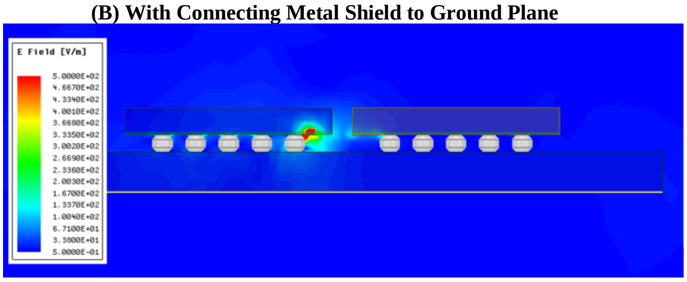
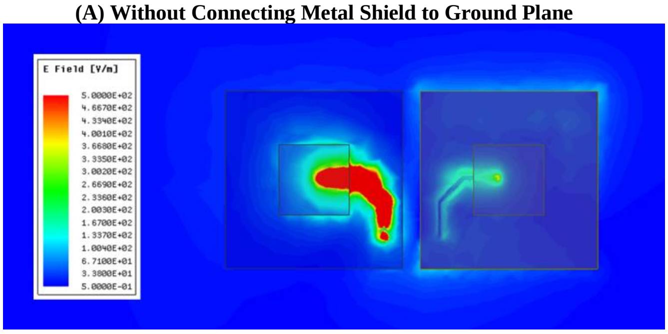


Fig. 8: Sectional View of Electrical Field Distribution of Test Vehicles at 12 GHz.

(A) Without Connecting Metal Shield to Ground Plane



(B) With Connecting Metal Shield to Ground Plane

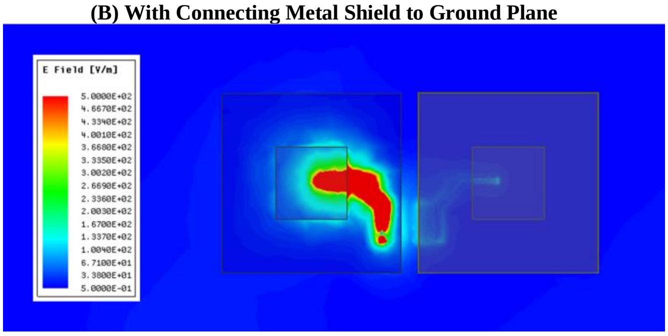


Fig. 9: Top View of Electrical Field Distribution of Test Vehicles at 12 GHz.

4. Conclusion

In this work, the effect of metal shield of BGA package on electromagnetic coupling is analyzed using electromagnetic calculation. From the results of the electromagnetic coupling, it demonstrates that the metal shield on the package can reduce the electrical coupling effectively from over the frequency of 11 GHz. The electrical field distributions also show that the electrical radiation does not have a significant effect on the inside of the package with the metal shield.

The effect of connecting the metal shield on the package to the ground plane in the PCB is also investigated by comparing the two test vehicles. In almost all frequency ranges, the package with connecting its metal shield to the ground plane shows superior performance in electromagnetic coupling. A lower electrical field is also distributed in the test vehicle with connecting the metal shield to the ground plane. These results demonstrate that connecting the metal shield to the ground plane can provide better EMI properties between the adjacent packages.

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