Signal Integrity Analysis of BGA Solder Joint

Shang Yuling[1,2], Shi Guangyao[2]

1. School of Mechanical Engineering, Jiangsu University,

Zhenjiang, 212013，China

2. School of Electronic Engineering And Automation, Guilin University of Electronic Technology, Guilin, 541004,China

Abstract

This paper analyzes Signal Integrity (SI) problems of BGA solder joint, which cannot be ignored in high-speed circuit design. Firstly, full-wave electromagnetic simulation software HFSS is employed to model BGA solder joint. And then, Scattering (S) parameters of BGA solder joint are obtained by simulating the solder joints under different shapes. The return loss of S parameters is analyzed to acquire the effects of BGA solder joint on SI. The results indicate that the influences of the port diameter of solder joint are obvious in the range of the entire simulation frequency, and the impacts of solder height and the maximum outer diameter on SI of solder joint increase rapidly as the frequency rises.

Key words: *BGA solder joint, Signal integrity, Return loss, Scattering parameter*

1. Introduction

The signal Integrity problem has become a problem with the development of modem electronic technology. A circuit system will not work better even can't work if there is no better signal integrity. And according to the circuit of high performance, high integration, BGA packaging technology has become the mainstream for high density packaging technology. So signal integrity problems of BGA solder joints have become a problem worth discussing. In this paper, aimed at the problems of signal integrity analysis of BGA solder joint, analysis of the solder joint height, diameter, effect of pad signal transmission of diameter and adjacent solder joints on BGA solder joint. 【1-3】

Signal Integrity is in high-speed circuit for signal transmission quality, how the electrical characteristic parameters that affect the performance of high-speed circuit which is mainly about the study of interconnection and digital signal interaction. Signal integrity problems can be attributed to the timing, noise, EMI of there, and the influence on the maximum for the noise problem. Noise problems are common reflection, crosstalk, ringing and switching noise, this paper selects the Return Loss of signal transmission of BGA solder joint is the reflection problem.

Return Loss is also called the reflection loss, is the parametric representation of signal reflection performance. Return Loss shows a portion of the incident signal is reflected back. Return Loss is caused by impedance mismatch on the transmission path. When the reflector is large enough, can cause signal distortion resulting circuit malfunction, signal transmission loss caused by the reflection of the signal is the Return Loss. 【4-7】

BGA solder connects BGA package and circuit board, all the signals need to be transmitted through the BGA solder joints, so to study Signal Integrity of BGA solder joint is very necessary. The solder joint of different forms of transmission performance of the signal will be what kind of impact and when two solder joints. Modeling and Simulation of the solder joint using the finite element tool, get the corresponding simulation results and based on the analysis of simulation results, the signal transmission performance of BGA solder joints can be predicted. 【8-10】

2. The establishment of the finite element model

This paper mainly analyzes the problem of signal transmission of single and two solder joints. In order to simplify the modeling process, the solder joints of upper and lower substrates and the pad adopts the same material and structure, the solder material is 63Sn-37Pb, pad materials is Cu and substrate material is FR4. At the same time, in order to facilitate the analysis, in this paper selects the standard of solder joint that the height of solder joint is 0.6mm, diameter of ports are 0.45mm, the largest diameter is 0.75mm. Setting the simulation frequency range is 0.5-10GHz.

Tab.1 Single solders joint geometry and material

Subassembly	*measurement （mm）*	*Material*
Substrate	*1×1×0.025*	*FR4*
BGA solder joint	*Diameter 0.75， Height 0.6*	*63Sn-37Pb*

Pad	***Diameter 0.6， Height 0.025***	***Cu***

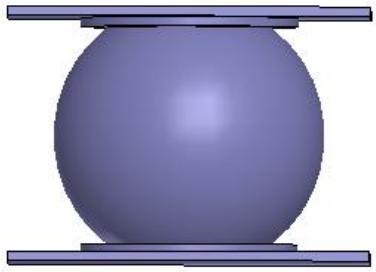

Fig.1 Single standard joint model

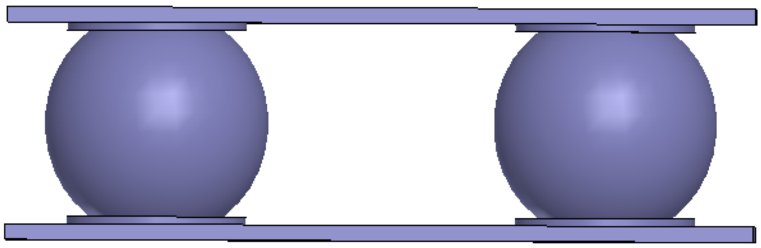

Fig.2 Two standard joint models

Two standard solder joinmodelsel of each part of the collection measurement and materials listed in T. B. 2，two standard solder joint mode is shownwn in Fig.2.

Tab.2 Two solder joint geometry and material

Subassembly	***measurement （mm）***	***Material***
Substrate	***1×1×0.025***	***FR4***
BGA solder joint	***Diameter 0.75，Height 0.6***	***63Sn-37Pb***
Pad	***Diameter 0.6， Height 0.025***	***Cu***
The two soldered dot center distance	***1.5***	

3. Simulation and analysis

Using the 3D simulation software HFSS, modeling and simulation analysis of BGA solder joints of different 3D parameters, get the S parameters of different models. Firstly, a single establishes a single solder joint model in HFSS, setting the boundary parameters of each part, then get the S parameter through simulation signal transmission. Finally, through the analysis of the S parameters of each model, get the signal transmission properties of different solder joints.

3.1 Simulation and analysis of single solder joint

Firstly, according to height, diameter and port diameter of modeling, analysis of Return Loss which is the main parameters effect of BGA solder joint signal transmission, get the influence of the signal transmission performance of BGA solder joint shape.

3.1.1 Influence of height on Return Loss

Firstly, we fixed the maximum outside diameter of the solder joint is 0.75mm, port diameter is 0.45mm, change the solder joint height, establish the model of the shoulder joint's height is 0.6mm, 0.55mm, 0.5mm, 0.45mm. Simulation of the model and get return loss of the solder joint. The results of the simulation are shown in Fig, 3 (Return Loss curve of 1, 2, 3, 4 corresponding to the solder joint height's 0.6mm, 0.55mm, 0.5mm, 0.45mm simulation results).

As it can be seen in Fig.3, return loss change obviously when solder joints' height is changing. With the decrease of solder joint's height, return loss following reduced, but decreased gradually slow down. From a single curve, with the rise of frequency the return loss to follow up and the shoulder joint's height is higher, the return loss rising faster. When the lower frequency, return loss more close.

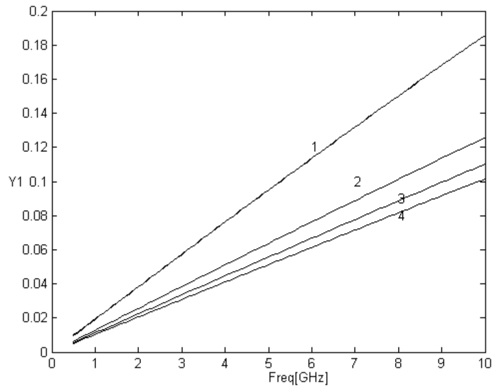

Fig.3 different height of solder joint RL

3.1.2 Influence of the maximum outside diameter on Return Loss

In order to obtain the influence of the maximum outside diameter on signal transmission performance, fixed the shoulder joint's height is 0.6mm solder joint, pot diameter is 0.45mm and changed the maximum outside diameter of solder joints. Establish the model of the shoulder joint's maximum outside diameter is 0.75mm, 0.7mm, 0.65mm, 0.6mm, 0.55mm, 0.5mm. Simulation of the model and get return loss of the solder joint. The results of the simulation are shown in Fig.4 (Return Loss curve of 1, 2, 3, 4, 5, 6 corresponding to the solder joint's maximum outside diameter 0.6mm, 0.55mm, 0.5mm, 0.45mm simulation results).

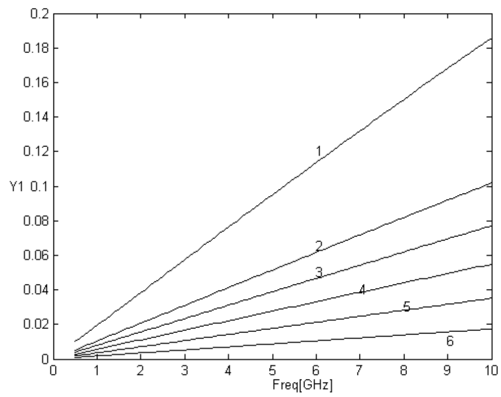

Fig.4 Different maximum outside diameter of solder joint RL

As it can be seen in Fig.3, return loss of each model in low frequency is close to and with the rise of frequency increases. Overall, the return loss of the solder joint with decreasing diameter solder joints decreased, but when the maximum outside diameter is 0.55mm and frequency is 10 GHz, the return loss is done not over the maximum outside diameter is 0.75mm and frequency is 1GHz. From a single curve, the return loss increased with the increase in frequency and the maximum outside diameter is a larger rise faster. Comparison with Fig.3 it can be seen, return loss of each solder joint model is not very different in the low frequency, but return loss rapid rise and the difference are more obvious with the increase of frequency.

3.1.3 Influence of solder joints' lower end diameter to the return wave loss

Fix the upper end diameter, height and maximum outside diameter of solder joints, change the lower port diameter of solder joints, establish the 3D simulation module to simulate and analysis the module. Fix the upper end diameter of solder joints in length of 0.45mm, height of 0.6mm, the maximum outer diameter is 0.75mm. The lower part of diameter are 0.7mm, 0.65 mm, 0.6mm, 0.55mm, 0.5mm. Simulation results are shown in figure 3. (Return loss curve 1, 2, 3, 4, 5 are the simulation results when the lower port diameter solder joints are 0.7mm, 0. 65 mm, 0. 6mm, 0.55mm, 0.5mm)

As it can be seen in figure 5, return loss change obviously when solder joints' lower port diameter is changing, and influence caused by this changing almost exceed from the change of frequency. As the ascent of the solder joints' lower end diameter, return wave loss increases sharply and it's wave curve tends to smooth. When the lower end diameter is 0.7mm, return loss almost unchanged in the range of whole simulation frequency, and maintain a high return loss. When the lower port diameter is 0.5mm, return loss curve is lower while the frequency is lower, but I will rise fast while the frequency arise. To sum up, solder joints' lower end diameter has an obvious effect to the return wave loss, return loss will increase when the solder joints' lower port diameter is increasing, and return loss change smaller in the range of frequency when solder joints' lower port diameter is tending to the maximum outside diameter.

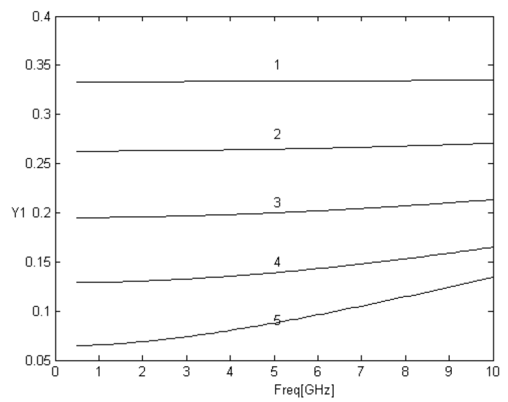

Fig.5 Different diameter of the lower port of solder joint RL

From the above simulation result we can see, the shape of BGA solder joint (height, maximum outside diameter and the lower port diameter) impact on solder joint signal transmission performance. The solder joint's height and maximum outside diameter have smaller effects on signal integrity in the low frequency, but this effect increase of frequency will be more and more obvious. In general, return loss increased with the rise of the solder joint's height and maximum outside diameter. The effect of solder joint's lower port diameter on the signal transmission performance is: the return loss of the solder joint is bigger with the maximum outside diameter rise and the return loss change smaller in the all simulation frequencies. Lower port diameter is small, the return loss of the solder joint is small and the return loss increased obvious with the rise in frequency.

3.2 Simulation and analysis of two solder joint

The above the analysis of a single solder joint's shape (height, maximum outside diameter and lower port diameter) impact on signal integrity. The analysis of two solder joint's shapes (maximum outside diameter and lower port diameter) impact on signal integrity. In order to facilitate the discussion, only change one of solder joint shape, selecting one solder joint as the standard solder joint, change another one's shape, then through analyzing the signal transmission of standard solder joint, get the influence of solder joint' shape on the adjacent joint signal integrity.

The two solder joint modeling, at first, fixed a solder joint's shape as the standard shape (maximum outside diameter is 0.75mm, height is 0.6mm, port diameter is 0.45mm), the center distance is 1.5mm, then change another solders joint's shape. Only changed the maximum outside diameter and port diameter at two solders joint simulation, at the same time the same parameter be selected for upper and lower port diameter.

3.2.1 Changing the maximum external diameter

Keeping the selected standard solder joint unchangeable, simulations have been made respectively when the maximum outside diameter has changed (the maximum outside diameters were set 0.75mm, 0.65mm and 0.6mm, 0.55mm respectively). The simulation results are shown in Fig.6

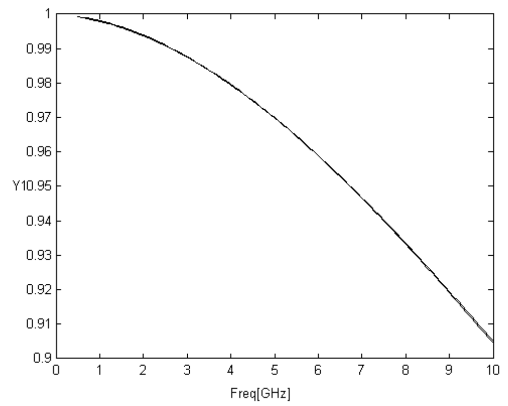

Fig.6 The maximum diameter change standard joint signal transmission diagram

From the Fig.6, we can get that the change of the shape of adjacent solder dots has little impact on the signal transmission performance of better standard solder dots. In the range of the whole simulation frequency, 4 curves almost coincide. As the signal frequency goes up, the transmission performance declines quickly. The decreasing speed increases with the frequency increasing. The change of the maximum external diameter of the known solder dots has an unobvious impact on the signal integrity of adjacent solder dots

3.2.2 Changing the diameter of adjacent solder dots

Keeping the selected standard solder joint unchangeable, simulations have been made respectively when the diameter of upper and lower port of adjacent solder dots has changed (the diameter of upper end were 0.75mm, 0.65;while the lower end's were 0.6mm, 0.55mm). The simulation results have shown in figure7. It found that the curves in figure7 and figure 6 are almost the same. The change of the diameter of upper and lower port of adjacent solder dots won't affect signal transmission performance of standard solder dots.

From the simulation, it can be known that when the shape (maximum outside diameter and solder port diameter) of BGA solder joints has changed, signal transmission performance of standard solder dots will hardly change. The simulation results from the two kinds of model are almost the same. From the above analysis, we can get that the change of the shape of the adjacent solder joint (maximum outside diameter and solder port diameter) won't influence the signal integrity of adjacent solder dots.

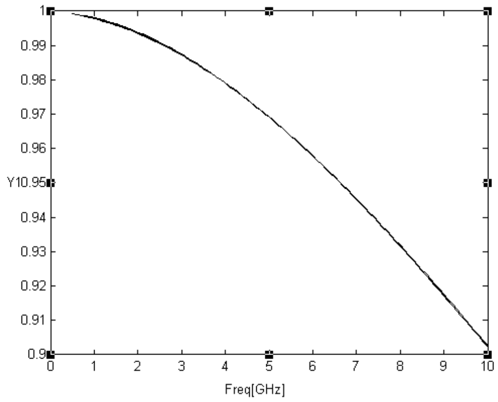

Fig.7 Solder joint port diameter changes standard solder joint signal transmission diagram

4. Conclusion

Analysis has been made in this paper, based on three factors of BGA solder joint shape (height, maximum outside diameter and solder port diameter) which have impact on signal integrity of solder joints. Then, it has been found that return loss will increase as the height and maximum outside diameter of solder joints do in the range of the whole simulation frequency. At low frequency, the height and maximum outside diameter of solder dot have little impact on return loss. However, with the frequency going up, the impact will increase quickly. And, the higher frequency is, the more impact it will have. The solder joint port diameter will affect the return loss of solder joints obviously in the range of the whole simulation frequency. The bigger the port diameter is, the larger the return loss is. On this occasion, the change of frequency has little impact on it. It will hardly change as the frequency did. And when the port diameter becomes bigger, the impact from the frequency is smaller. The three factors of solder dots have little impact on the signal integrity of adjacent solder joints. These conclusions have a certain reference value of technology and production of BGA solder joints.

5. Acknowledgments

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First Author： Shang Yuling(1977-) Associate Professor and Graduate student tutor
Research Direction: Singnal integrity testing of high-speed circuit

Second Author: Shi Guangyao (1986-)Master Degree Candidate
Research Direction: Singnal integrity testing of high-speed circuit