

Radiation Noise Reduction Effect using Capacitor with Resistor on Double-Layer Board

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Abstract— The purpose of this study is to estimate the radiation noise reduction effect by using the capacitor with resistor on a Double-Layer board. In the most application the power distribution of the multi-layer printed circuit board is realised by double-layer board. In many cases, the radiation peaks are radiated from the power-ground layer appears at the layer resonance frequencies. As one of the methods to suppress such radiation, the capacitor with series resistor was investigated in this study. The resistor is able to dump the resonance, however, it makes the impedance higher. From some experiments, it is known that the capacitors with resistor which one mounted at the corners of the board reduce the resonance and also suppress the radiation from the Double-Layer board. And it is also known that the reduction effect of the radiation is related to the number of the capacitors.

Key words: decoupling capacitor with resistor, radiated noise reduction, power ground plane, multi-layer printed circuit board

I. INTRODUCTION

Since the radiation noise from the electronic equipment is regulated in many countries, the effective techniques of radiated noise reduction is needed in the design and manufacturing fields of the equipment. It is well known that the radiated emission from the electronic equipment is often dominated by the radiation from the power-ground line or plane. In many cases the power-ground plane is oscillated by the rush current flow or voltage fluctuation by the IC switching, and the oscillation yields the radiation from the plane especially at the resonant frequencies of the plane. The well-known counter measure is to attach a decoupling capacitor (bypass capacitor) between power and ground plane close to the IC. The decoupling capacitor reduces the voltage fluctuation and noise current which are sources of the radiation.

One of the alternative reduction methods for radiated noise is to reduce the radiant efficiency of the power ground plane. Because the resistive device is effective to reduce the radiant efficiency, the lossy inductor such as ferrite bead or ferrite sheet is often used. Authors are studying the radiated noise reduction effect using decoupling capacitor with resistor. The technique to insert the resistance serial to capacitance is designed to decrease the anti-resonant peak [1]-[3]. From

some experiments under micro-strip line as a power-ground line, though attaching the resistor to the capacitor makes the impedance increase, the radiation from the line was reduced.

In this paper, the radiated noise suppression effect of the capacitor with resistor used in Double-Layer board is investigated.

II. CAPACITOR WITH RESISTOR ON THE POWER GROUND LINE

The capacitor is often used to reduce and decouple the power-ground switching noise by mean of its low impedance. As is well-known like in Fig.1 (a), the capacitor has the small lead inductance that increases the impedance as the frequency increases. This inductance and other reactance circuit such as a power-ground line make resonances which causes the increase of radiation noise.

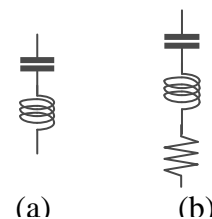


Fig.1 Equivalent circuits of capacitor and capacitor with resistor.

In this case it is expected that the resistor attached to the capacitor, as shown Fig.1 (b), would suppress the resonance and radiation of the power-ground line. In the previous work, it is known that the radiation peak was reduced by attaching the resistor to the decoupling capacitor mounted on the micro-strip line as a power-ground line.

The radiation from the power-ground line was reduced by capacitor with resistor, however, the impedance of the capacitor with resistor was increased. The high impedance decoupling capacitor induces malfunction of the IC because the enough current supply to the IC is not guaranteed.

In order to supply current enough to the IC and to suppress the line resonance the decoupling capacitor was mounted near the noise source and the capacitor with resistor was mounted at the terminal of the line because the maximum voltage

presents at the line terminal. From some experiments it is known that the radiation from the line can be reduced by the capacitor with resistor. [4]-[5]

These results were studied by using the line model, however, a parallel planes are often used as a power-ground line in multi layer printed circuit board. Thus the reduction effect of the radiation from Double-Layer board by using capacitor with resistor was investigated in this study.

III. MODEL

A. Double-Layer Board

A rectangle shape two layers board was used. The photograph of the board is shown Fig.2. The geometries are 250 (length) x 200 (width) x 1.6 (thickness) mm. The bulk capacitance of the board is about 1.4 nF. The insulator of the board is glass epoxy with relative permittivity 4.7.

A SMA connector for signal input as a noise source was mounted at the center of the short side of the board. This position is chosen to reduce the resonance mode to make analysis be easy.

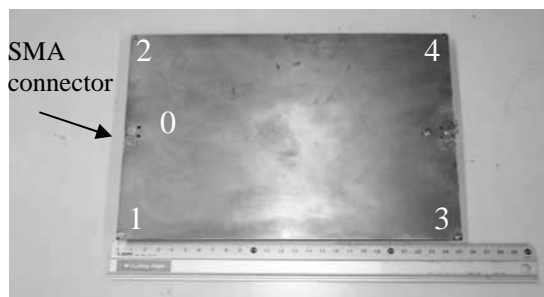


Fig.2 The double-layer board.

B. Position of the Capacitor

The radiated noise suppression effect was investigated in the cases of (1) a capacitor with series resistor is mounted near the signal input (Fig.2, position 0) and (2) some capacitors with series resistor are mounted at the corners of the board (Fig.2, position 1 to 4). In the case (1) the noise suppression effect of the capacitor with resistor as a decoupling capacitor against the normal decoupling capacitor is investigated. And in the case (2) the suppression effect of the board resonance by the capacitor with resistor is studied. The mount points of the capacitors are selected at the corners because the anti node of the standing wave on the board appears there.

C. Measurement Method

The input impedance and the radiation were measured and evaluated. The input impedance was measured from the SMA connector. The scattering parameter S11 was measured by network analyzer Anritsu MS2024A and transformed to the input impedance.

The sinusoidal wave of the signal generator was inputted to the board through the SMA connector and the far field radiation was measured in 3m anechoic chamber. The board was stand on its longer edge on the table and horizontal polarized radiation was measured by bi-log antenna.

IV. MEASUREMENT

A. Capacitor with series resistor alternative to decoupling capacitor

Generally the decoupling capacitor is mounted near the noise source to reduce the power-ground noise or radiation. In this case a capacitor or the capacitor with resistor was mounted between two layers of the model board near the signal input which plays a roll of power-ground noise source, and the input impedance and the radiation was measured. The capacitance of the all capacitors is 0.1 μ F and a resistor 1, 4.7, 10 or 22 Ω was attached to the capacitor in series. The input impedance and the radiation are shown Fig.3 and Fig.4 respectively.

In Fig.3, the input impedance of the board with decoupling capacitor or the capacitor with small value of resistor (1 or 4.7 Ω) has a main resonance at 5 MHz due to the capacitor and lead inductance, while the cases of without capacitor or the capacitor with large resistor (10 or 22 Ω) the resonance due to the capacitor did not appear. From this result it is understand that large value of resistor prevents the current flow of the capacitor and effect of the resistor is not expected.

Above this main resonant frequency, the impedance increases as depending on the frequency increases, and the sets of peak and dip have appeared at resonant frequencies of Double-Layer board.

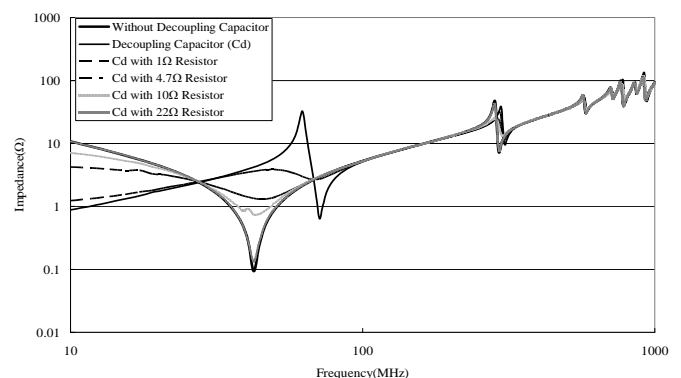


Fig. 3 Frequency dependence of input impedance of double-layer board with decoupling capacitor mounted near the signal input

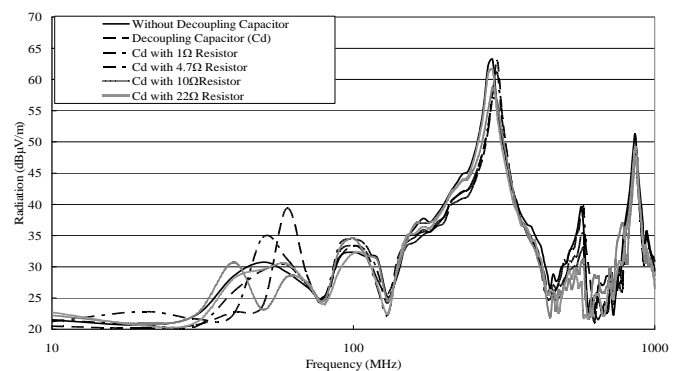


Fig.4 The radiation spectrum of double-layer board with decoupling capacitor mounted near the signal input

From a comparison of Fig.3 and 4, the large radiation peaks appear at about 300 MHz and higher frequencies. These are the resonance modes of the board. In this model the characteristic impedance is small to the signal source. Thus the peak of the radiation is observed at the frequency according to the peak of the input impedance.

The radiations from the board with capacitor with different value of resistor are not so different each other without 30 – 50 MHz. It is considered that the radiation from the board is dominated of the resonance of the board because the board has wide area and low impedance. In this case the suppression of the resonance of the board may be effective.

B. Capacitor with resistor mounted on the corner of the board

Noise reduction effect can not be expected so much on Double-Layer board by capacitor with series resistor alternative to the decoupling capacitor near the noise source. Furthermore the impedance of the decoupling capacitor expected to be as low as possible to guarantee the IC operation.

Thus the capacitor with resistor was employed to suppress the board resonance in this case. A decoupling capacitor was mounted near the signal input and the capacitor with resistor was added at the corner of the board. The corner of the board was chosen because the anti node of the resonance of all modes appears at the corner. It is convenience for suppress the resonance of the board.

In order to evaluate the effect of the capacitor with resistor, the number and position were changed as following cases.

- (a) A capacitor with resistor at each corner (indicated as position 1, 2, 3 or 4 in Fig.2).
- (b) Two capacitors with resistor at a pair of positions.
- (c) Four capacitors with resistor at all positions.

A 0.1 μF chip capacitor and a 4.7 Ω chip resistor were used for all capacitors and attached resistor.

First, the case (a) was investigated. A capacitor with resistor was mounted on one of the 4 corners as shown in Fig.5. The input impedance and the radiation in this case are shown in Fig.6 and 7, respectively.

In Fig.6 and 7, the input impedance is reduced at 300MHz (board resonance) and radiation peak is also reduced 3.5dB in the case of with the capacitor with resistor. In the higher modes of the resonance, such as 570MHz or 870MHz, the radiation peak is not reduced so much.

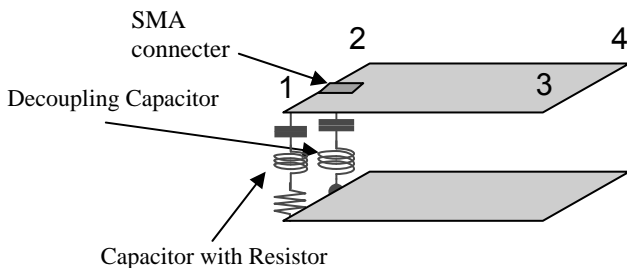


Fig.5 The board with a capacitor resistor at one of the corners

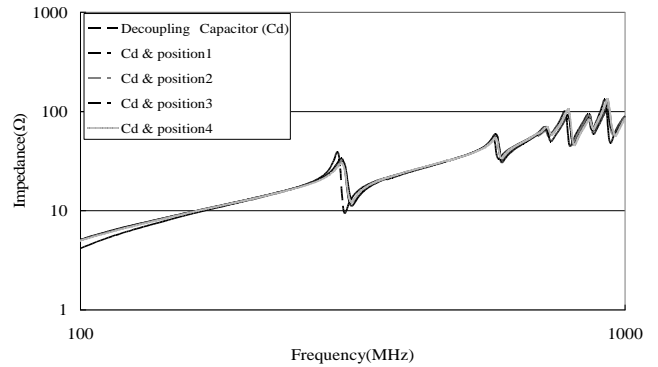


Fig.6 The input impedance of the board with a capacitor with resistor

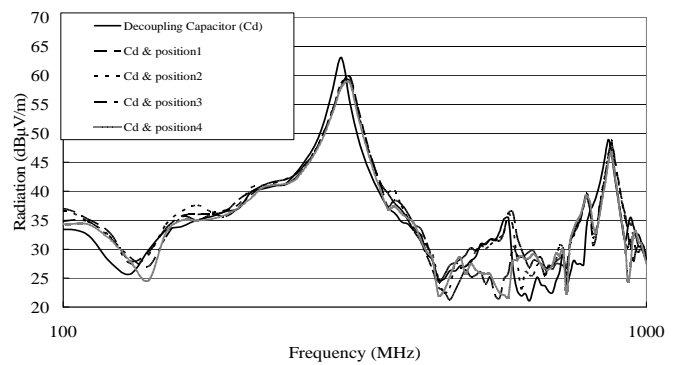


Fig.7 The radiation from the board with a capacitor with resistor

Next, for the case (b) two capacitors with resistor were mounted at a pair of 4 positions, 1-2, 1-3, 1-4, 2-3, 2-4 and 3-4 as shown in Fig.8. The input impedance and the radiation in this case are shown in Fig.9 and 10, respectively.

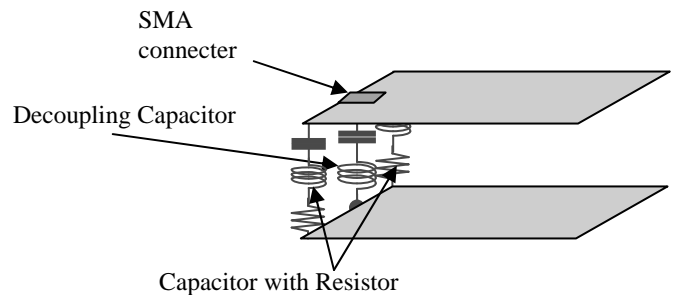


Fig.8 The board with two capacitors with resistor at position 1 and 2.

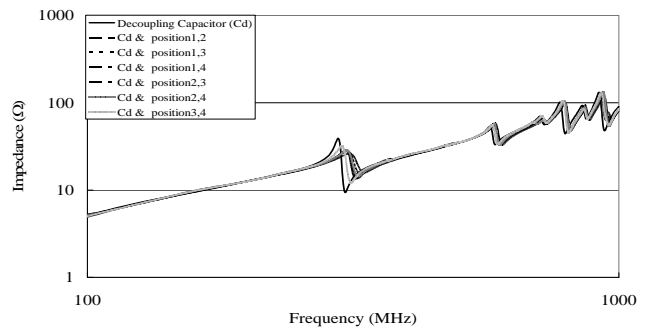


Fig.9 The input impedance of the board with two capacitors with resistor

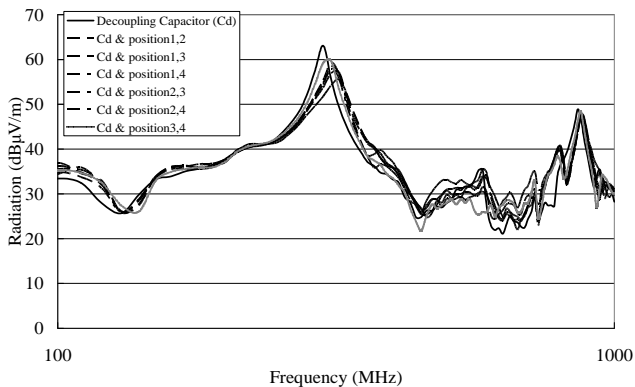


Fig.10 The radiation from the board with two capacitors with resistor

From Fig.9 and 10, input impedance is reduced at 300MHz and radiation peak is reduced about 7dB. The radiation peak at 570MHz is also reduced.

Finally, for the case (c) four capacitors with resistor was mounted at all corners of the board. Input impedance and radiation are shown in Fig.11 and 12.

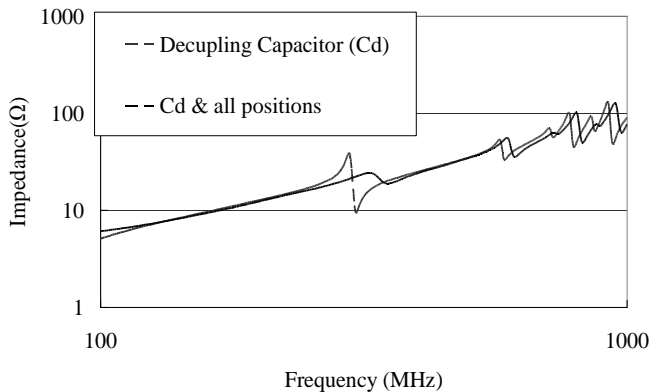


Fig.11 The input impedance of the board with four capacitors with resistor

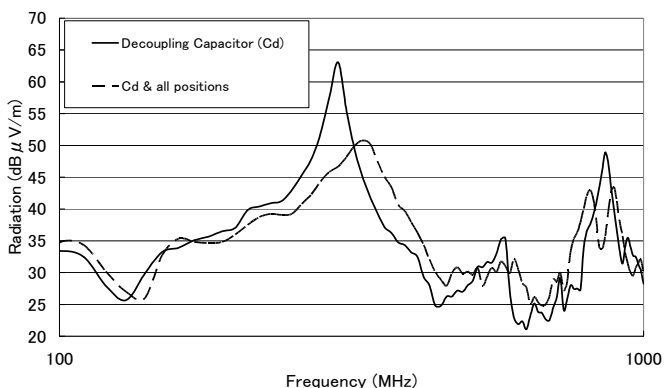


Fig.12 The radiation from the board with four capacitors with resistor

From Fig12, the radiation peak at 300MHz is reduced about 13dB. In addition radiation peak at 570MHz and 870MHz were also reduced.

V. DISCUSSION

In order to examine the suppression effect of the resonance by the capacitor with series resistor at the corner of the board, the voltage of the each corner was measured by oscilloscope. In the each case of (a), (b) and (c), the mean value of the measured voltage was calculated.

The mean voltage and the average of radiation reduction effect of each case are shown in Fig. 13. From the comparison, mean value of voltage reduction of four corners and the suppression of the radiation agree well. Thus the capacitor with series resistor is effective to dump the resonance of the board and suppress the radiation from the double-layer board.

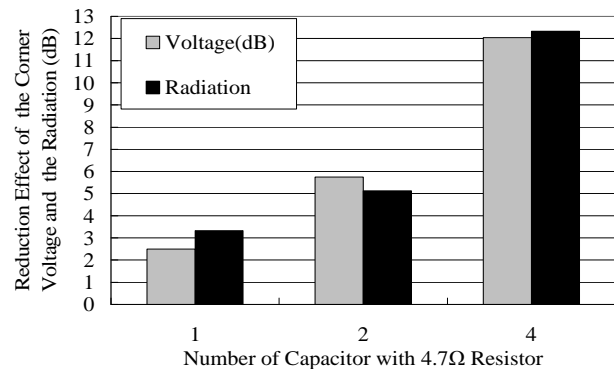


Fig.13 Reduction effect of the corner voltage and the radiation.

VI. CONCLUSIONS

From some experimental results, by using the capacitors with series resistor mounted on the corner of the double-layer board, the resonance and the radiation of the board is reduced according to the number of capacitors with resistor. This technique method is economic and easy to realize for many applications.

In the further works the appropriate value and mount position of the capacitor with resistor for effective noise suppression will be examined.

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