A Technology for Evaluating LSI Radiated Immunity using Stripline Method

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Abstract— The technology for evaluating LSI radiated immunity was developed by using our original stripline cell(SL-Cell) as an alternative to the conventional TEM-Cell. This enabled us to carry out LSI radiated immunity tests at up to 7400 V/m with low power consumption (10 W). The developed system for testing the LSI radiated immunity can share its main body with the LSI conducted immunity test system using DPI method.

Key words: EMS, Radiated Immunity, Stripline, Measurement

1. Introduction

Recently, there has been increasing demand for the immunity of LSI particularly those in automobile microcomputers. To meet this demand, we have already developed a technology for evaluating the LSI conducted immunity using the direct power injection method (hereafter, DPI).[1],[2] Then, as for the next target, aiming at the realization of a simple and high-accuracy evaluation method, a technology for evaluating LSI radiated immunity was developed, in which a radiated electromagnetic field generator that uses the stripline method (hereafter, SL-Cell) as an alternative to the conventional TEM-Cell is used.[3]

2. Basic Structure and principle of SL-Cell

A transverse electromagnetic cell (hereafter, TEM-Cell) has a sealed structure in which ground layers are placed above and below a center conductor, whereas a SL-Cell has a parallel-plate structure. Therefore, it is possible to generate an electric field of arbitrary intensity by changing the height of the active conductor (septum) (Fig. 1).

3. Basic Design of SL-Cell

According to transmission line theory, the characteristic impedance of the SL-Cell is uniquely determined by the shape of the active conductor (septum ratio: W/h). Dimensions of the septum of the SL-Cell must have a fixed ratio of W/h=5.0 in order to obtain a characteristic impedance of 50 Ω (Fig. 2). Therefore, the septum height was adjusted to 3–7 mm (a width of 15–35 mm), in line with the shape of practical septums.

4. Fabrication of Prototype SL-Cells

On the basis of the proposed design, five prototype SL-Cells with different septum shapes (SLC-3 (h=3mm) – SLC-7 (h=7mm)) were fabricated (Fig. 3). Moreover, the compatibility with general-purpose small TEM-Cells was ensured regarding the structure used for mounting on a test board and the shape of each connector (Figs. 4 and 5).

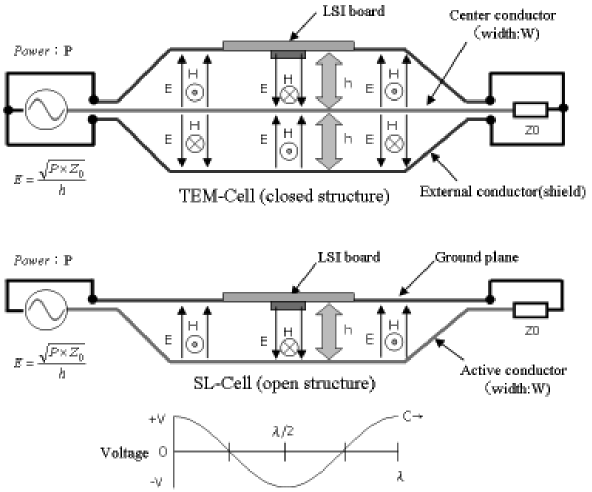

Fig. 1 Comparison of basic principles of TEM-Cell and SL-Cell

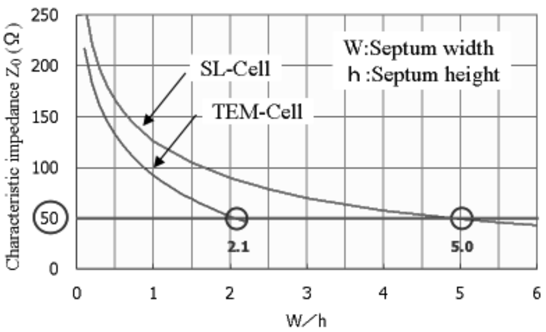

Fig. 2 Relationship between septum ratio and characteristic impedance.

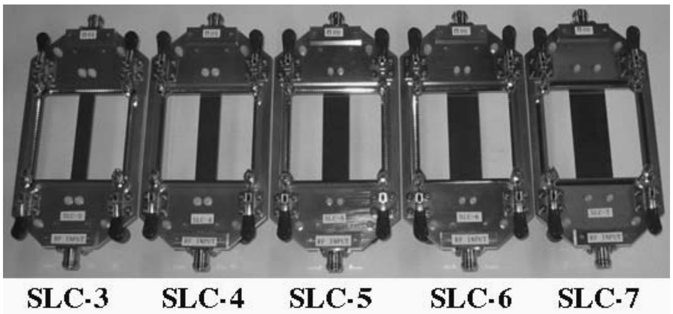

Fig. 3 Prototype SL-Cells.

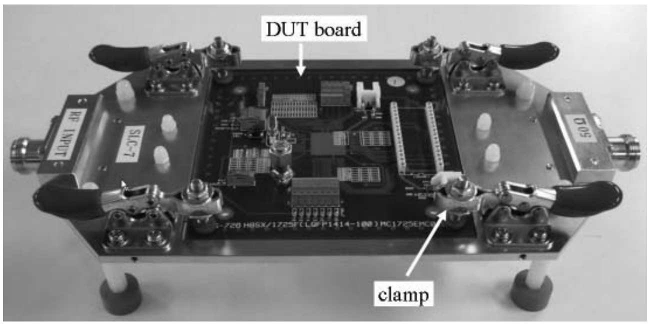

Fig. 4 Top view of prototype SL-Cell (SLC-7).

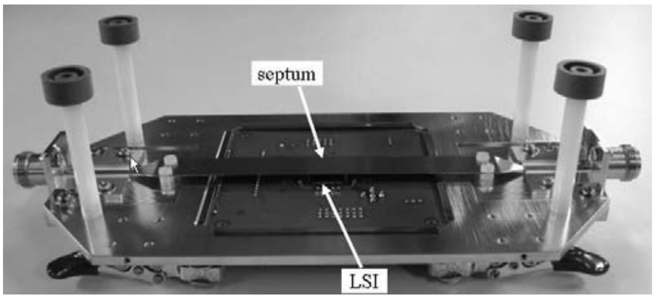

Fig. 5 Bottom view of prototype SL-Cell (SLC-3).

5. *Demonstration of Performance of SL-Cells*

5.1 *Transmission characteristics of SL-Cells*

The transmission characteristics of each prototype SL-Cell were measured by using a board on which a standard microcomputer (QFP100Pin, 15×15×h1.5 mm) was mounted. As a result, it was confirmed that the SL-Cells maintained a high accuracy of –0.35 dB at 1 GHz for the minimum septum height (3 mm), although their transmission characteristics deteriorated with decreasing septum height (Fig. 6).

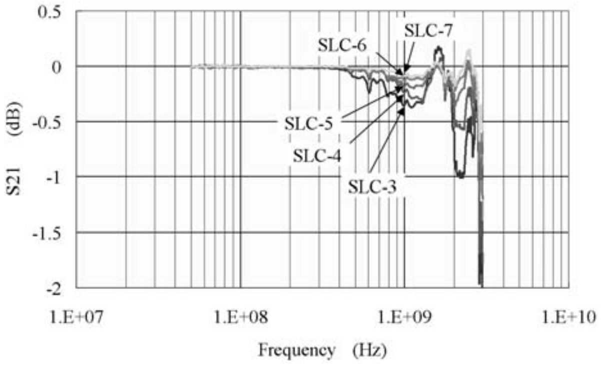

Fig. 6 Dependence of transmission characteristics on septum height of SL-Cell.

5.2 *Electric field detection characteristics*

To demonstrate the electric field performance of the prototype SL-Cells, several types of electric field calibration boards specially designed for SL-Cells, in which parallel-plate electric field sensors (E-10, E-20 and E-30) and a loop antenna magnetic field sensor (H-30) were installed, was prepared (Fig. 7). The electric length of each sensor mounting position was corrected by using a variable-length co-axial tube, and the impedance of each sensor was measured by using a impedance analyzer (Fig. 8).

The electric field calibration board (E-10, H-30) was mounted on the prototype SL-Cell. Then the output response (S21) of each sensor with respect to the signal input to the SL-Cell was measured by using a network analyzer, and the electric field characteristics of the SL-Cells were evaluated (Figs. 10 and 11). The electric field detection characteristics (theoretical value) can be determined from the basic electric characteristics (C and L) of each sensor determined from above measurement results of impedance and the dimensions of each sensor.

The electric field characteristics of each SL-Cell were determined by using the electric field sensor (E-10) or the magnetic field sensor (H-30), and compared with theoretical values. As a result, good electric field characteristics were demonstrated in the range up to approximately 1 GHz for all prototype SL-Cells. The measurement result of the conventional general-purpose small TEM-Cell (1 GHz type) is also shown (Figs. 10 and 11).

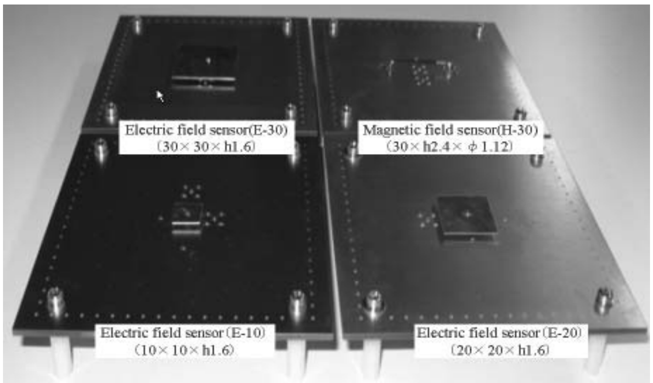

Fig. 7 Electric/magnetic field sensors for SL-Cell.

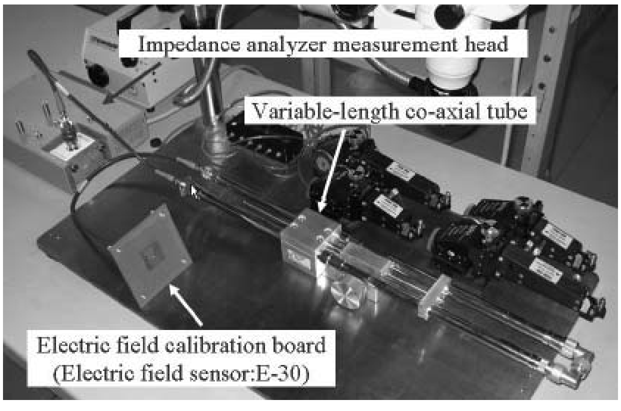

Fig. 8 Setup used for measuring impedance of an electric field calibration board.

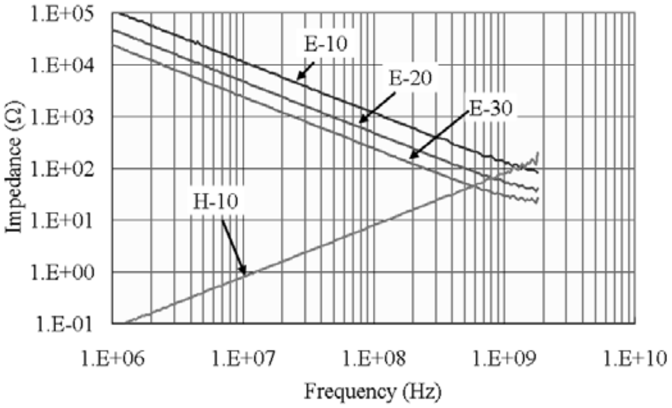

Fig. 9 Impedance characteristics of electromagnetic field sensors.

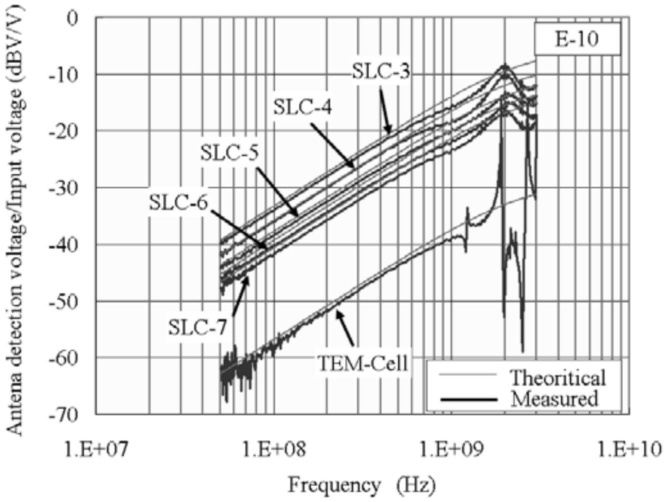

Fig. 10 Electric field detection characteristics of SL-Cell (Using Electric field sensor: E-10).

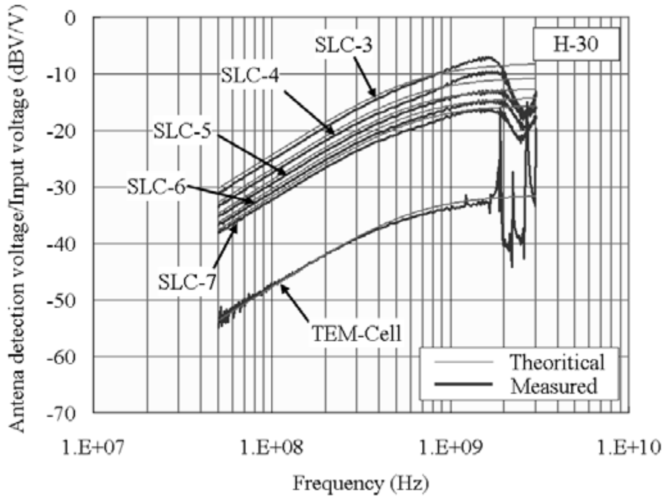

Fig. 11 Electric field detection characteristics of SL-Cell (Using Magnetic field sensor: H-30).

6. *LSI Radiated Immunity Test system*

The developed system for testing the LSI radiated immunity shares its main body with the LSI conducted immunity test system (10 W, 10 kHz – 1 GHz) (Fig. 12) using DPI method described in our previous report [1].

The RF injection line of the former test system is connected to the RF port of a SL-Cell, which enables the radiated immunity tests to be carried out (Fig. 13). The radiated immunity test is possible in the range of 3200V/m (SLC-7) – 7400 kV/m (SLC-3) by selecting an SL-Cell type that is appropriate for the DUT size.

During the test, the electric field strength at the DUT malfunction limit is automatically measured by increasing the injection power for each frequency while monitoring the DUT operational conditions.

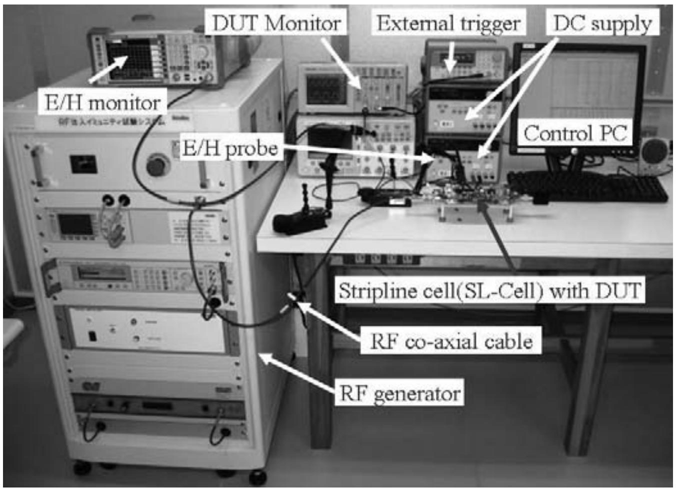

Fig. 12 Appearance of LSI radiated immunity test system.

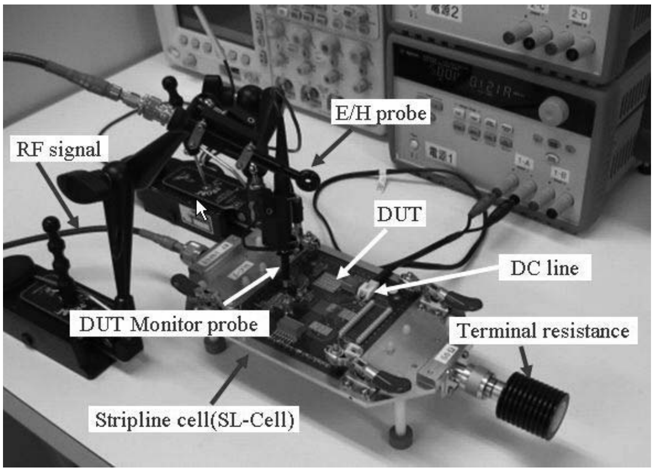

Fig. 13 DUT section of LSI radiated immunity test system using SL-Cell.

7. *Measurement of Radiated Immunity of Microcomputers*

Regardless of the type of SL-Cell, stable results were obtained in the measurement of the radiated immunity of microcomputers. Therefore, the measurement accuracy of this test method was verified (Fig. 14).

Regarding the radiated immunity of microcomputers, it was found that the frequency of lowest immunity level shifts slightly from 600 to 700 MHz depending on the measurement conditions of bypass capacitors and power circuits(Fig. 15).

This agrees well with the measurement result for high-frequency bands in the conducted immunity test by the DPI method on the same microcomputer under the same conditions (Fig. 16) .[1]

Therefore, it was shown that the conducted noise in the test using the DPI method acts as radiated noise in high-frequency bands.

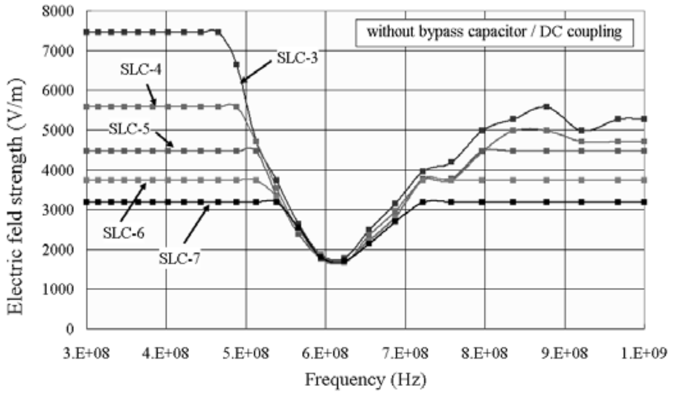

Fig. 14 Dependence of LSI radiated immunity on SL-Cell.

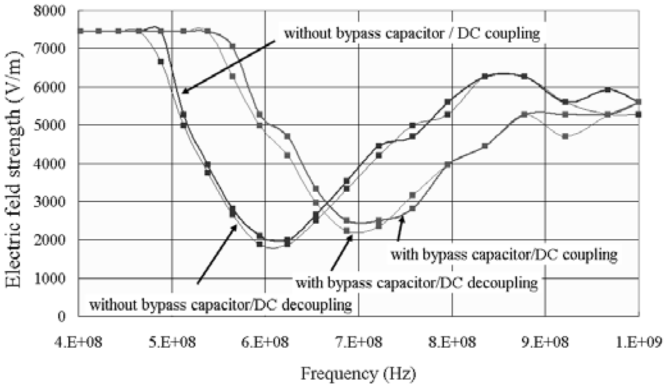

Fig. 15 Measurement of radiated immunity of LSI using SLC-3.

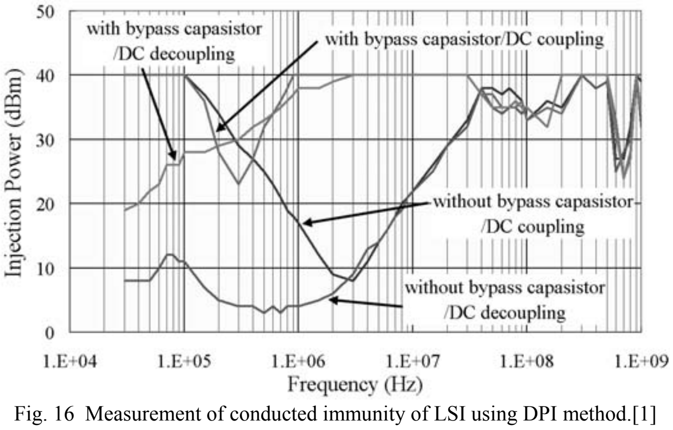

Fig. 16 Measurement of conducted immunity of LSI using DPI method.[1]

8. *Effects of Leakage Electric Field During Radiated Immunity Test*

The electric field attenuation is –40 dB in the vicinity of the device under test (DUT) (10 cm) during this test, and can be controlled to be –60 dB, which is within the safety standard (27.5 V/m), by installing shields at the sides of the SL-Cell (Figs. 17 and 18).

Therefore the electric field leakage around the main body of the system can be decreased to a level safe for human bodies by installing shields at the sides of the SL-Cell body.

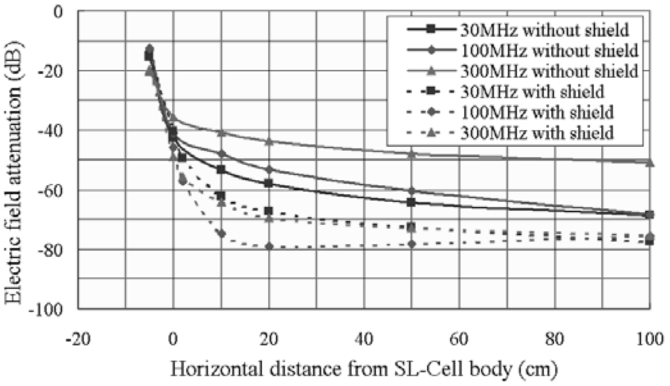

Fig. 17 Leakage electric field measured during radiated immunity test.

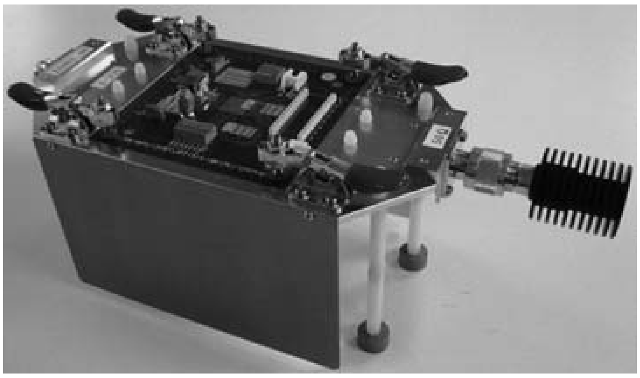

Fig. 18 Example of installation of electromagnetic shield for SL-Cell.

9. *Conclusion*

In this research, the following conclusions were obtained with respect to the utilization of stripline method for evaluating LSI radiated immunity.

(1) The technology for evaluating LSI radiated immunity was developed by using our original stripline cell(SL-Cell) as an alternative to the conventional TEM-Cell.
(2) This enabled us to carry out radiated immunity tests at up to 7400 V/m with low power consumption (10 W).
(3) The electric field characteristics of the developed test system (up to approximately 1 GHz) were determined by using our original electric field sensor for SL-Cells.
(4) It was revealed by a comparative test using an identical microcomputer that the conducted noise in the test by the DPI method acts as radiated noise in high-frequency bands.
(5) It was shown that the leakage electric field in the vicinity of the DUT was decreased by installing shields at the sides of the SL-Cell to satisfy the safety standard.

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[2] IEC62132-4: LSI Conducted Immunity Test Standards using DPI method.
[3] IEC62132-2: LSI Radiated Immunity Test Standards using TEM-Cell method (draft).