

# Measurement System for Adjacent Electric Field and Magnetic Field Distributions on an IC Package.

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**Abstract** - We have developed an adjacent electromagnetic field distribution measurement system using a unique sensor and three-input phase-difference measurement technique that can simultaneously measure electric and magnetic field (magnitude and phase) distributions up to 3GHz. The system can measure vector electric and magnetic field distributions on an IC package with lead frame level resolution. These electromagnetic distributions are effective in evaluating the EMI from an integrated circuit.

## 1. INTRODUCTION

There is a demand for compact and lightweight mobile information equipment. However, as equipment becomes smaller and lighter, adjacent interference, such as coupling, becomes more problematic. For wireless communication equipment in particular, radio circuits are jammed by the harmonic frequencies of the digital ICs in the equipment, thus degrading reception sensitivity. For evaluating this problem, a high-frequency adjacent electromagnetic field distribution measurement is necessary. The evaluation of adjacent electromagnetic fields from an IC, which causes interference, is important in particular. However, conventional methods of measuring adjacent electromagnetic field distributions with electric or magnetic probes lack sufficient performance at higher frequencies.

To resolve this problem, we have developed a new method using a unique sensor with a simple structure [1] to accurately measure the adjacent electromagnetic field distributions. [2], [3].

Developed measurement system can measure electric and magnetic field distributions, simultaneously, with phase information [4]. The measured electric and magnetic field distributions on an IC package using the system are effective in evaluating EMI from an IC.

## 2. ELECTROMAGNETIC SENSOR

The sensing element of the electromagnetic sensor shown in Figure 1 consists of a simple wire loop, the ends of which are connected to outputs A and B via coaxial cable. The simplicity of the sensor's structure makes the device easy to reduce in size.

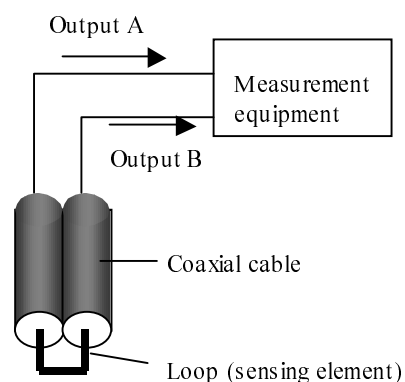


Figure 1. The structure of the sensor.

Figure 2 shows the equivalent circuit of the sensor and outputs and how the sensor measures electric and magnetic fields. The outputs from the sensor are generated by both electric and magnetic fields. The current from magnetic field  $I_m$  is generated by magnetic flux crossing the loop. Outputs from the magnetic field have the same magnitude but are opposite in direction at A and B. The current from electric field  $I_e$  is generated by the electric field at the sensing element. Outputs from the electric field also have the same magnitude and are in the same direction at A and B. Therefore, the outputs at A ( $O_a$ ) and B ( $O_b$ ) are

$$O_a = I_e - I_m. \quad (1)$$

$$O_b = I_e + I_m. \quad (2)$$

By calculating the vector sum and difference of these outputs, the output by magnetic field can be separated

from the output by electric field.

$$I_e = (O_a + O_b)/2. \quad (3)$$

$$I_m = -(O_a - O_b)/2. \quad (4)$$

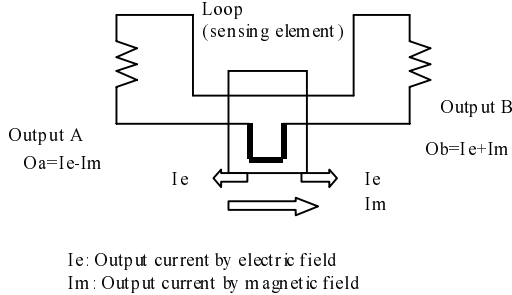


Figure 2. The equivalent circuits of the sensor and outputs.

Figure 3 shows an example of the sensor structure using a 3-layer printed circuit board. The sensor consists of a 0.2mm line formed in the center layer of the board, the outputs of which are connected to a measurement instrument and a termination via 50 Ohm strip lines.

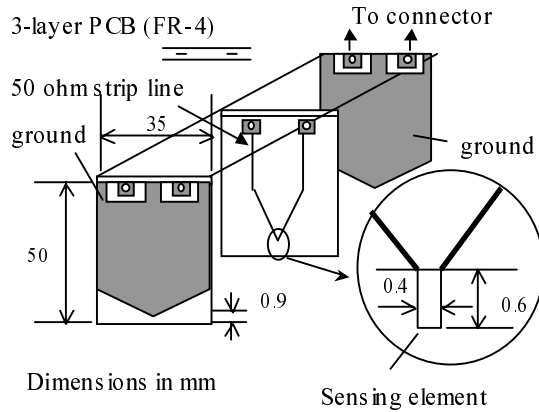


Figure 3. The PCB sensor structure.

To calculate equations (3) and (4), outputs from the sensor ( $O_a$  and  $O_b$ ) must be vectored. A vector network analyzer is used to measure vector outputs from the sensor. Figure 4 shows the adjacent electromagnetic field distribution measurement system using a vector network analyzer and the sensor. The system can measure the adjacent electromagnetic field around a passive circuit, which is driven by the signal from port 1 of the vector network analyzer. The sensor outputs are connected to ports 2 and 3, respectively. The outputs from the electric field ( $O_e$ ) and magnetic field ( $O_m$ ) are

$$O_e = (S_{21} + S_{31})/2. \quad (5)$$

$$O_m = -(S_{21} - S_{31})/2. \quad (6)$$

Electric and magnetic field distributions can be measured by scanning the probe.

We investigated the output characteristics of the sensor by

using the measurement system.

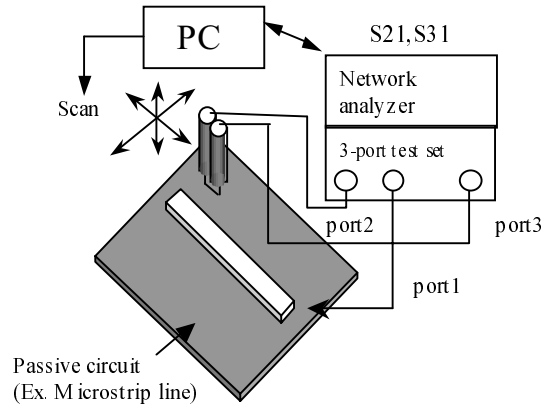


Figure 4. Electromagnetic field distribution measurement system using a vector network analyzer.

The output-versus-frequency characteristics of the sensor were measured by the system. The device under test was terminated 50 Ohm microstrip line. As shown in Figure 5, the electric and magnetic outputs from the sensor are proportional to frequencies over 1GHz in the figure. Therefore, the sensor can be used at high frequency.

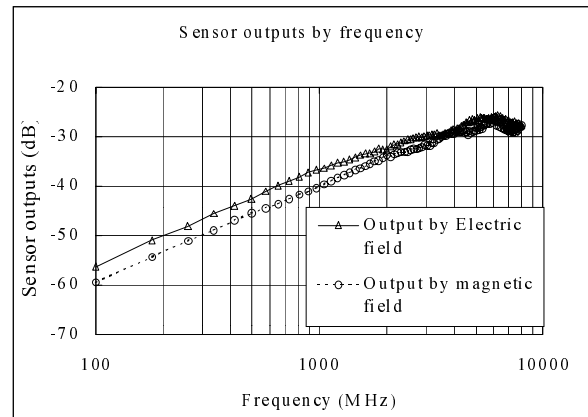


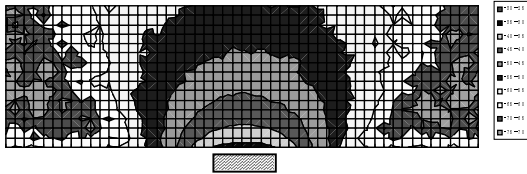
Figure 5. Output-versus-frequency characteristic of the sensor.

Figure 6 shows electric and magnetic field distributions above the microstrip line at 1.5 GHz the sensor was set parallel to the line, and scanning was done in 0.2 mm steps along the upper part of a cross section. Figure 7 shows electric and magnetic field distributions when the sensor was set at right angles with the line. The hatched squares in the figures show the width of the line.

The electric fields in both figures show almost same distributions. This shows that the electric field can measure without influence from the magnetic field. The magnetic field in figure 7 shows background level distribution without influence from electric field.

These distributions show that the sensor has about 40 dB separation ratio of the electric field to the magnetic field at 1.5 GHz.

Electric field

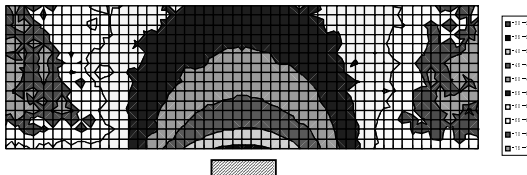


Magnetic field



Figure 6. Electric and magnetic field distributions above the microstrip line at 1.5 GHz (parallel to the line)

Electric field



Magnetic field

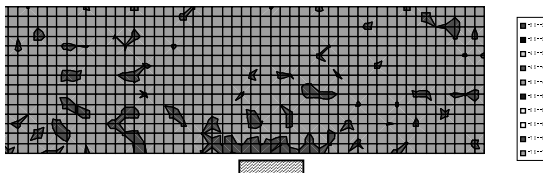


Figure 7. Electric and magnetic field distributions above the microstrip line at 1.5 GHz (at right angles to the line)

### 3. DISTRIBUTION MEASUREMENT SYSTEM FOR ACTIVE EQUIPMENT

Because the adjacent electromagnetic field measurement system with network analyzer can be used only for passive element measurements, the 3-input phase-difference measurement system must be used to measure active equipment.

Figure 8 shows an outline of the three-input phase-difference measurement system. The system can measure signal magnitude and relative phase between three signals if the frequency and phase of the signals are unstable.

The measured input signal is down-converted to an IF frequency and digitized by an A/D converter. The signal magnitude, frequency and phase are derived by FFT (Fast Fourier Transform). All inputs are synchronized by using the same local oscillator and clock signal, which ensures that the relative phase information for all three inputs is maintained. By using the relative phase information, we can calculate vector sum and subtract the difference between inputs.

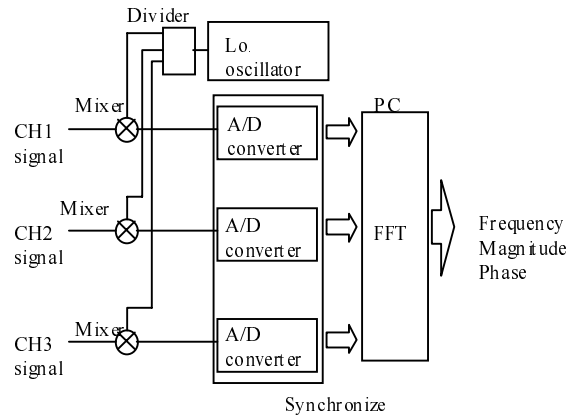


Figure 8. 3-input phase-difference measurement system.

The construction of the adjacent electromagnetic field distribution measurement system for active equipment using the 3-input phase-difference measurement system is shown in Figure 9. One input of the system is connected to a fixed probe, which is used as a reference for the phase measurement. The other two inputs are connected to the electromagnetic sensor to measure the electric and magnetic fields. The electromagnetic field distributions are measured by scanning and rotating the sensor under PC software control. Measured data stored as csv data. The system is shown in Figure 10.

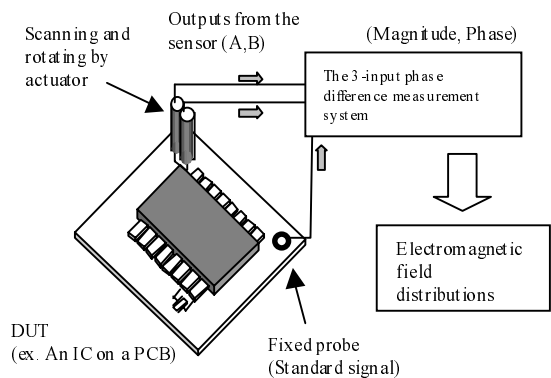


Figure 9. Construction of adjacent field distributions measurement system for active equipment.



Figure 10. The photograph of the adjacent field distributions measurement system.

The system can measure electric and magnetic field distributions of active equipment simultaneously with phase information at high frequency. By using the system, the electric and magnetic field distributions on IC package can be measured for surface scan method, which is used for evaluating the EMI of the IC.

Figure 11 are measured examples of the electric and magnetic field distribution on a 32 by 32 mm IC package at about 1GHz. The sensor was scanned at a 1mm interval 0.5mm above the plane of the package. The lines in magnetic field distribution are estimated current directions. The distributions show that the measured data has lead frame level resolution.

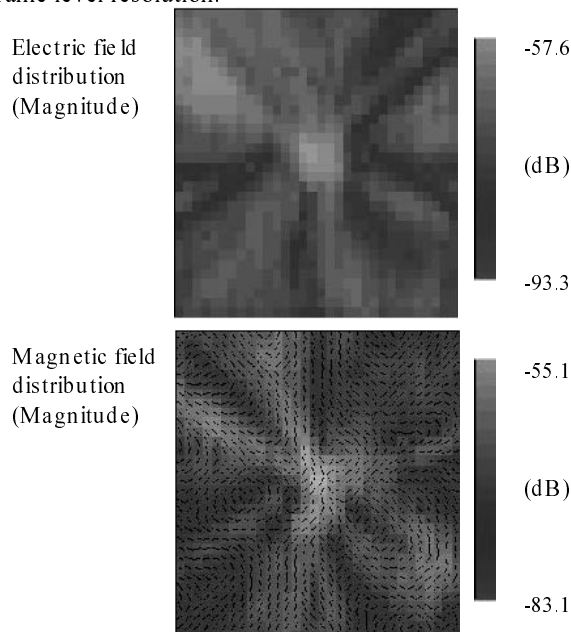


Figure 11. Adjacent electromagnetic field distributions on an IC package.

#### 4. CONCLUSION

The innovative electromagnetic sensor was designed for high- frequency, high-resolution operation, being able to simultaneously measure both electric and magnetic fields with phase information.

Adjacent electromagnetic field distribution measurement system for active equipment is developed with the sensor and three-input phase-difference measurement system. These systems provide simultaneous measurement of both electric and magnetic field distribution with phase information at high frequency, thus providing useful EMC information from these characteristics.

The measurement of electric and magnetic field distributions on an IC package by using the measurement system is one of effective evaluating methods for EMI from an IC.

#### 5. REFERENCES

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