Efforts toward EMC design (Ⅱ)

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Abstract

Automotive electronic devices, which have achieved high levels of performance and integration, now have the problem of requiring improved EMC performance year by year.

In response to this, Fujitsu Ten promotes improvement activities for EMC design quality, and in the previous article, we introduced the following five items:

① EMC regulations and requirements for Fujitsu Ten, ② Current situation of EMC design, ③ Necessity for EMC design incorporation, ④ Development of EMC elemental technology, ⑤ Successful examples of EMC design

For further improvement of EMC design quality, the development of EMC design skills by all designers is necessary in addition to five items mentioned above. As well, the promotion of elemental technology development or establishment of EDA tools with an eye to the future becomes important.

In this article (the last one), we introduce the following four items:

① Efforts for EMC design education, ② EMC elemental technology development for the future, ③ Development and utilization of EDA tools , ④ EMC design for devices

1 Introduction

We introduced the following five items in the previous article (FUJITSU TEN TECHNICAL JOURNAL No.30):

①EMC regulations and requirements for Fujitsu Ten
②Current condition of EMC design
③Necessity of EMC design incorporation
④Development of EMC elemental technology
⑤ Successful example of EMC design

And in this article, we introduce the following five items:

①Efforts for EMC design education
②EMC elemental technology development for the future
③Development and utilization of EDA tools
④Future efforts
⑤Successful example of EMC design-2

2 Efforts for EMC Design Education

2.1 Necessity of Education

In the previous article, we introduced practical design methods, elemental technology development, and design examples. To utilize the know-how in each product development, improvement of EMC design skills of each designer is necessary.

For this skill improvement, a systematic education with range from EMC basic knowledge to EMC design application and countermeasure for EMC is required, however it had not been sufficiently developed in Fujitsu Ten.

For example, in the previous education method of EMC design, a handing down of the experimental rules from experienced designers was a main method in each design department, and the systematic education for young engineers was not conducted.

As a result, when being directed to conduct EMC design or to take countermeasure for EMC, the young engineers blindly conducted design or took the countermeasure with insufficient theoretical understanding.

If they understand the basic EMC design theory, they can advance effective design or countermeasure without taking a wrong direction when designing products or taking countermeasures for defects.

As mentioned above, improvement of EMC design quality requires the systematized education with range from basic to application of EMC.

Fujitsu Ten holds EMC design seminars adapting to the practice in order to improve skill of each designer from young to experienced.

2.2 EMC Design Seminar

We hold EMC design seminars to deepen the theoretical understanding of EMC. **Table 1** shows a list of the seminars and **Fig. 1** shows a picture of the seminar.

Table 1 List of EMC Design Seminar

	EMC seminar	Applicable person	Content
①	Education for new employees	Technical new employees	EMC basic (EMC, EMC problem, overview of EMC design)
②	Basic technology course	Those who desire to learn the basic	EMC basic, noise, electromagnetic wave, basic calculation, overview of EMC design
③	Electrical design course	Engineers of electrical design	EMC concept, mechanism, circuit, pattern, countermeasure technique, case example of countermeasure, etc
④	Mechanism design course	Engineers of mechanism design	EMC concept, mechanism, countermeasure technique, case example of countermeasure, etc
⑤	CAD operation course	Electrical CAD operator	EMC basic education, circuit basis, pattern design method
⑥	Visiting course	Desiring department	From basic to design, entire countermeasures (meet the needs)

Fig.1 Picture of EMC Design Seminar

In this seminar, we start from the basic contents, what EMC is, and provide the fundamental knowledge of effective high frequency wave to improve EMC performance.

After that, we classify designers into circuit designers, printed board designers, and mechanical designers, and educate them on each category.

2.3 Educational Policy

Focusing on enhancing the contents of a seminar, we create a special textbook after clarifying the educational policy, and use the textbook in the seminar.

In the seminar, we give a theoretical explanation while minimizing mathematical formulas and give the following practical contents:

①Understand by image
②How to design specifically
③How to apply and take countermeasures

In the special textbook, the specific numeric values are given as much as possible, explaining the design method, and are established as a design guide. For example, in the printed board design, the recommended values of guard pattern width, fulfilling the purpose, are given. Also, in the mechanical design, shapes and dimensions, which should be selected for opening section to release the heat, are given (Refer to **Fig. 2** and **Fig. 3**).

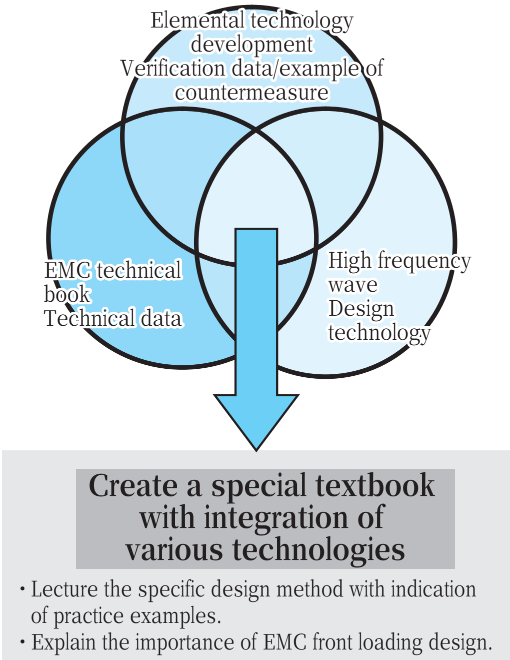


Fig.2 Creation and Utilization of Special Textbook

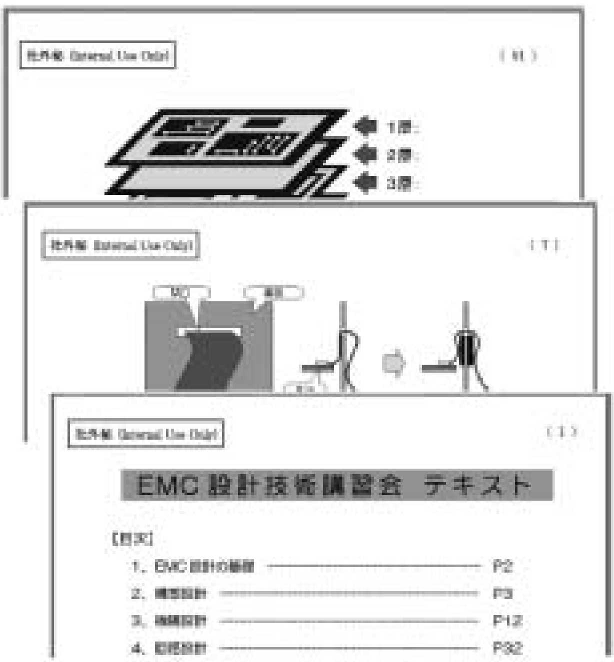


Fig.3 Extract from Special Textbook

With the educational policy mentioned above, we conduct education that improves practical understanding of the designers and that directly leads to product development.

For designers who desire to deepen their theoretical understandings, we support the further improvement of technical capabilities by recommending the participation in outside seminars, as well as giving a course individually.

2.4 Fostering of Authority Engineers

The challenge of education includes fostering of authority engineers of EMC design (hereinafter, referred to as EMC-AE).

EMC-AE refers to the engineers who have knowledge of EMC design and EMC defect countermeasure, and can point out the problems and issues during EMC-DR (EMC-Design Review) and elsewhere.

In this fostering education, EMC-AE candidates learn the basic knowledge and general applied technology in the seminar or by self-learning, and increase the practice through EMC design / countermeasure. It is essential that they acquire extensive knowledge participating in more EMC-DR.

At present, the number of EMC-AE is not enough, however we aim to put EMC-AE in each design department in the future.

Development of this staffing quality enables incorporation of effective EMC design widely in the company and leads to the further improvement of EMC design quality.

3 EMC Elemental Technology Development for Future

3.1 Future EMC Elemental Technology

We described the importance of education, however we must improve the content of our in-house education because the automotive electronic equipment will become more sophisticated and complicated.

Hence, the continuous development for the elemental technology to be used for EMC design is essential.

This development ranges from chassis, printed board or circuit to part. As an example of elemental technical development, we describe the development of high-speed transmission line below.

3.2 Development of High-Speed Transmission Line with Cable

The transmission system of image data starts to change with the advancement of hi-vision of television screen.

LVDS system [※1], one of the differential transmission systems that transmits data at high speed, is beginning to be adopted in the field of the automotive electronic equipment as well.

Fig. 4 shows the trend of the differential transmission system.

※1 LVDS system: Refer to the differential transmission system with which transmission speed of 100Mbps or more is available. In the future, this system will become mainstream in image data transmission of automotive electronic equipment.

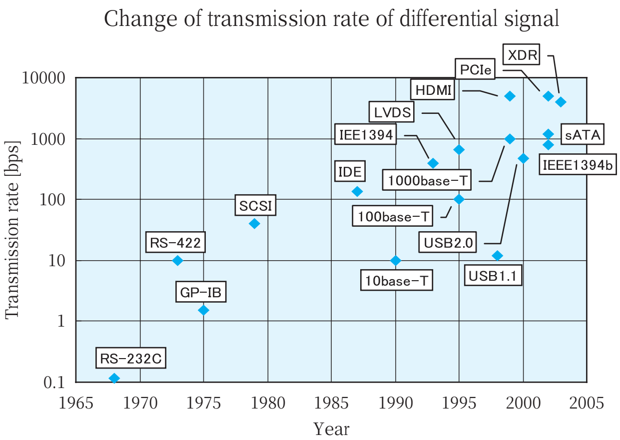


Fig.4 Transmission Rate of Differential Transmission System

Examination case of high-speed data communication media is shown below.

In most cases, a body and display section of the automotive electronic equipment is connected by FPC (flexible cable). However, using FPC causes deterioration of transmission quality such as waveform turbulence or causes EMC problems such as the generation of emission noise from the cable.

As one of the proposed measures, adoption of a narrow line coaxial cable is considered, however there is a fear that the cost is increased significantly. Therefore, we conducted the comparative discussion of the FPC and the narrow line coaxial cable.

One EMC evaluation method for the differential signal line is the characteristics impedance.

The narrow line coaxial cable can have stable characteristics impedance, but FPC, not having the coaxial structure, has possibility of unstable characteristics. Therefore we selected the FPC and the narrow line coaxial cable as an object to be compared.

Here, we introduce the result of study of TDR[※2], the characteristics impedance of the transmission line.

Turbulence of TDR performance should be minimized because it directly leads to the emission increase.

Fig. 5 shows the prototype of the narrow line coaxial and FPC, and **Fig. 6** and **Fig. 7** shows the measurement result of the characteristics impedance by TDR.

While the normal FPC (one layer board) has significant turbulence of the characteristics impedance of signal line, the narrow line coaxial cable has stable impedance. This finds that the narrow line coaxial cable is competitive in performance and EMC (**Fig. 6**).

However, we confirmed that even FPC can obtain the similar characteristics impedance to the narrow line coaxial cable if FPC incorporates EMC design and strengths GND (**Fig. 7**).

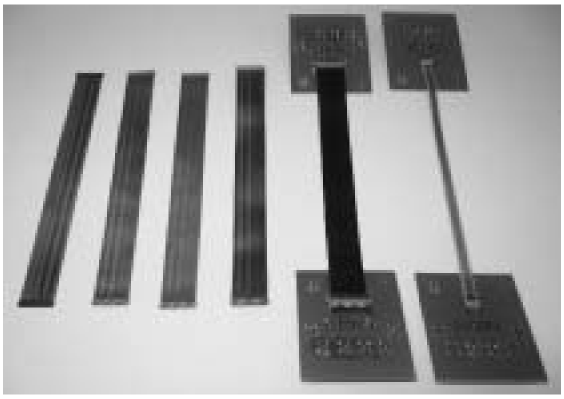


Fig.5 FPC (5 types), Narrow Line Coaxial Prototype, and Printed Board for Evaluation

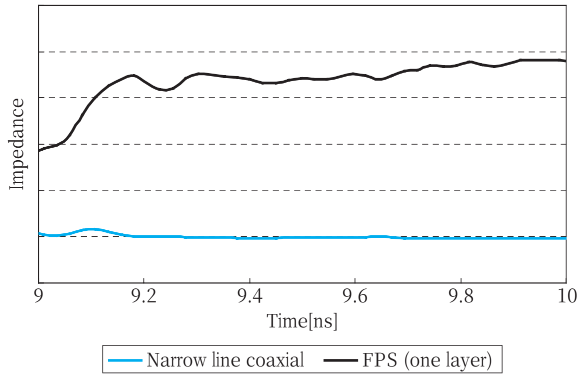


Fig.6 Characteristics Impedance of Narrow Line Coaxial and Normal FPC

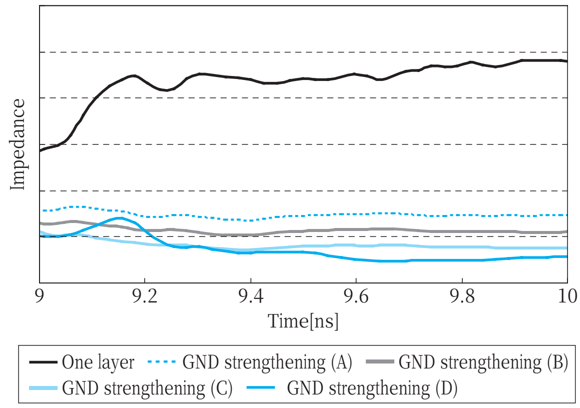


Fig.7 Characteristics Impedance of FPC (5 types)

※2 TDR: TDR (Time Domain Reflectometry): Measuring method of the characteristics impedance of transmission line by measuring and calculating the reflected wave with high-speed sampling oscilloscope after adding the high-speed pulse signal to the transmission line of measuring object. This impedance is found by the following formula. If the coefficient of reflection is set as ρ,

$$\rho = \frac{\text{Reflected voltage}}{\text{Incident voltage}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

・ZL: impedance of transmission line desired to obtain
・Z0: impedance of TDR measuring equipment

$$Z_L = Z_O \frac{1+\rho}{1-\rho}$$

As mentioned above, we examine the design technology aiming to achieve a good balance between EMC performance and cost, and deliver it to the design department sequentially.

3.3 SI Design and EMC Design

In previous section, we described the cable used in high-speed transmission line. However, devices in the printed board are often connected by high-speed transmission line, and EMC problems are caused.

In particular, recently, "SI design (Signal Integrity)", which had been unnecessary for in-vehicle equipment, becomes essential because the high-speed memory similar to PC is mounted in the decode printed board of the digital terrestrial broadcast.

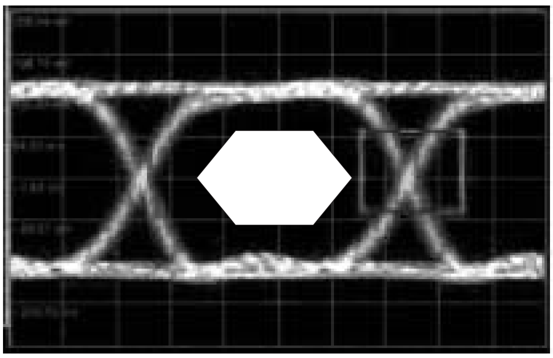
SI design refers to the proper design of line length or impedance in high-speed transmission line to control the reflection, and refers to the proper wiring design to produce the waveform without distortion, delay or ringing.

However, SI design may not go together with EMC design, therefore attention is required.

Specifically, when digital communication is conducted through the high-speed transmission line, emission noise is generated easily. To prevent this, damping resistor may be added to the signal line, however, there is a risk of deterioration of the waveform quality due to the distortion or delay of the waveform.

Fig. 8 shows the confirmation example of the waveform quality. For securement of the SI, the design should be conducted so that the diamond shape opens, however, if the damping resistor is added to the signal line in order to reduce the emission noise, the opening section of diamond shape may close.

As mentioned above, there is a trade-off between SI design and EMC design, and well-balanced design is required.



Measuring the signal eye pattern

- Diamond shape in the center indicates the standard. If the signal enters the diamond shape, it is judged as no-good. (declining aperture)
- If countermeasure against EMC (emission) is taken, the aperture declines and waveform quality deteriorates.

Fig.8 Waveform Quality of High-Speed Transmission Line

3.4 Future of Elemental Technology Development

We introduced the technical development of high-speed transmission cable or compatibility with SI design, however the development agenda of EMC elemental technology ranges from chassis, printed board or circuit to part.

Considering worldwide trends, the latest technology, used in PC, information appliance, or the latest game machine, has been applied in automotive electronic equipment, therefore we should focus on the technical problems such as PC, information appliance, and others.

We emphasize the elemental technology verification with actual equipment, and we also have to conduct the verification adopting electromagnetic field simulation to obtain the theoretical proof.

We introduce the verification of electromagnetic field simulation at the time of ESD (Electro Static Discharge) application.

Fig. 9 shows a model simulating the voltage fluctuation at a measurement point when the ESD is applied to one point.

In this example, the purpose is to utilize in selection of part for countermeasure and modification of printed board pattern while recognizing the voltage change due to ESD application and comparing with the verification result of actual equipment.

Fig. 10 shows the result of voltage fluctuation in simulation.

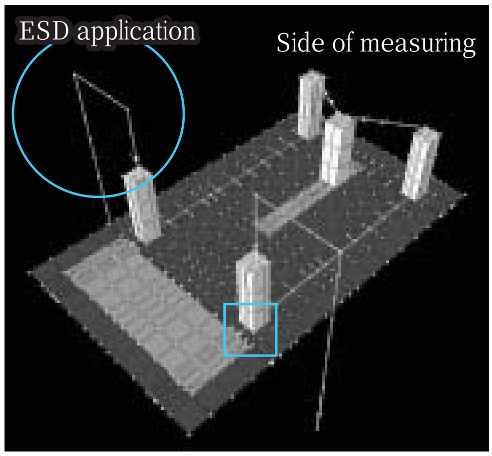


Fig.9 Electromagnetic Field Simulation Model for ESD Verification

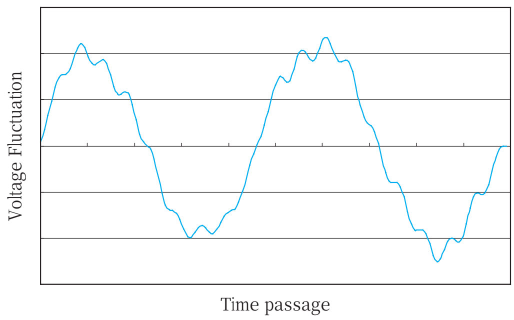


Fig.10 Result Example of Voltage Fluctuation in Simulation

As mentioned above, we verify the electromagnetic field simulation in parallel with verification using actual equipment, and promote the elemental technology development while confirming in both theory and fact.

4 Development and Utilization of EDA Tools

4.1 Introduction of EDA

Development of EDA (Electronic Design Automation) tools is effective in promoting the improvement activity of EMC design quality. EDA refers to a tool that automatically designs the electric circuit, printed board or others.

FUJITSU TEN LIMITED introduced EMC rule checker as the EDA tool.

EMC rule checker refers to a tool used in printed board pattern design, and it enables the pattern check of multilayer printed board with high integration and high density, for which visual inspection cannot be conducted.

4.2 Utilization of EMC Rule Checker

The introduced EMC rule checker shows the EMC improvements such as pattern design or part connection after inputting information of circuit and printed board and conducting analysis.

Table 2 shows a list of the checker functions.

Table 2 List of EMC Rule Checker Functions

	Rule	Outline
①	Interconnection length check	Length of signal wiring
②	Check of number of vias	Number of interlayer connection of signal wiring
③	Traces near plane edges	Signal wiring inside solid GND
④	GV plane crossing check	Capacitor nearby interlayer connection of signal wiring
⑤	Return path discontinuity check	Discontinuity of return path of signal wiring
⑥	SG pattern check	Guard pattern for signal wiring
⑦	Radiation electric field check	Radiation electric field strength of signal wiring
⑧	SG pattern via interval check	Via placement on guard pattern
⑨	Plane circumference check	Via position/numbers on solid GND
⑩	Filter check	Filter placement/position for connector signal line
⑪	Decoupling capacitor check	Capacitor between LSI power source and GND
⑫	Differential pair check	Difference of wiring length and parallelism of differential wiring
⑬	Crosstalk check	Clearance between wirings, and parallel wiring length

Thus, if the EMC rule checker is used as a tool to prevent the check omissions, we can expect the great effect.

On the other side of the coin, the EMC rule checker cannot point out the corrections of the whole printed board relating to conception design, therefore we firstly have to conduct the conception design sufficiently.

Also, each rule requires the setting of threshold values to determine acceptable/unacceptable, and this setting of values becomes know-how.

We promote the development considering the standardization of FUJITSU TEN's know-how and incorporation of it into the checker.

Fig. 11 shows the application process of EMC rule checker for mass production design, and **Fig. 12** shows the examples of check results.

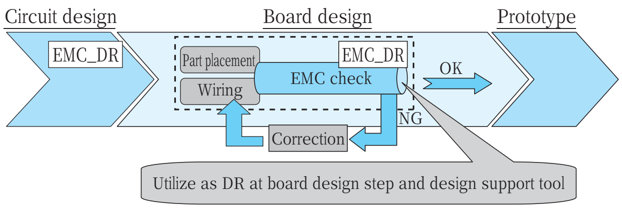


Fig.11 Usage Process of EMC Rule Checker

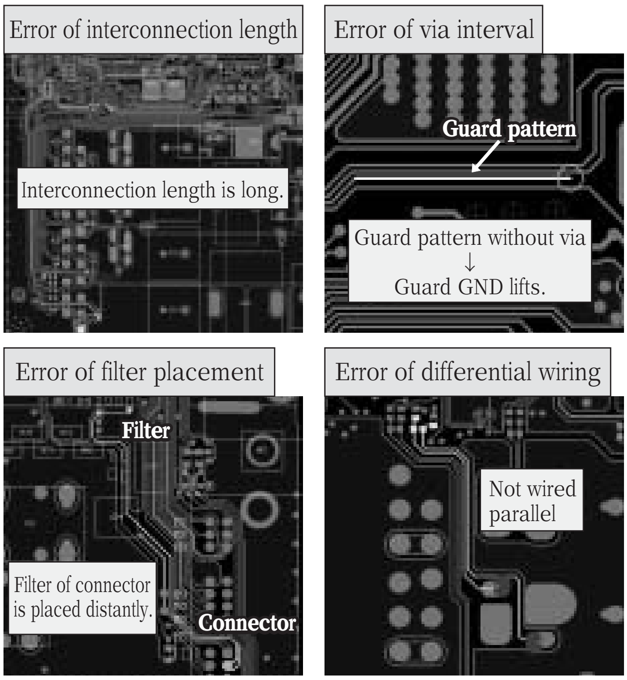


Fig.12 Implementation Example of EMC Rule Checker

5 EMC design for Devices

We described our efforts toward EMC design, however there are another problems remaining.

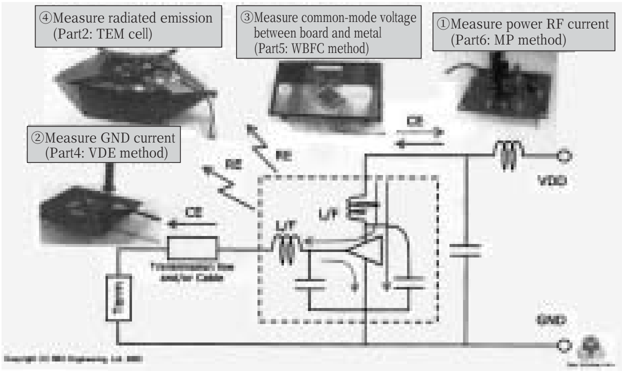
EMC performance of the device has a significant impact on the EMC performance of whole product, therefore we have to pay attention to the enhancement of function or speed of future devices.

5.1 EMC Performance of Devices

If EMC performance of the single electronic device is poor, EMC performance as a product cannot be obtained even if a good design is conducted for circuit, printed board, or structure.

Thus, device manufacturers consider an evaluation method for the single device, and some methods are proposed in the device industry.

Fig. 13 shows the EMC evaluation method of the single electronic device.

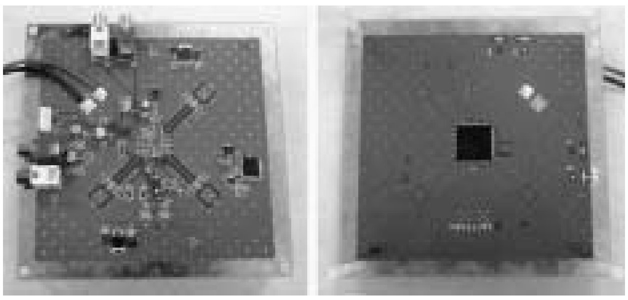


①MP method	Measure noise current flowing into power supply terminal of device.
②VDE method	Measure noise current flowing into GND terminal of device.
③WBFC method	Measure noise voltage between board and metal (chassis).
④TEM cell method	Measure radiated emission placing a test board in a cell.

Fig.13 EMC Evaluation Method of Electronic Device

FUJITSU TEN LIMITED selected a device with much noise and made a test printed board for evaluation of MP (Magnetic Prove) method.

Fig. 14 shows this printed board for evaluation.



Obverse side of printed board

Reverse side of printed board

Fig.14 Printed Board for MP Method Evaluation

Fig. 15 shows the measurement result of noise of the device using this printed board for evaluation of MP method and shows the EMC evaluation result when the same device is mounted on a prototype product.

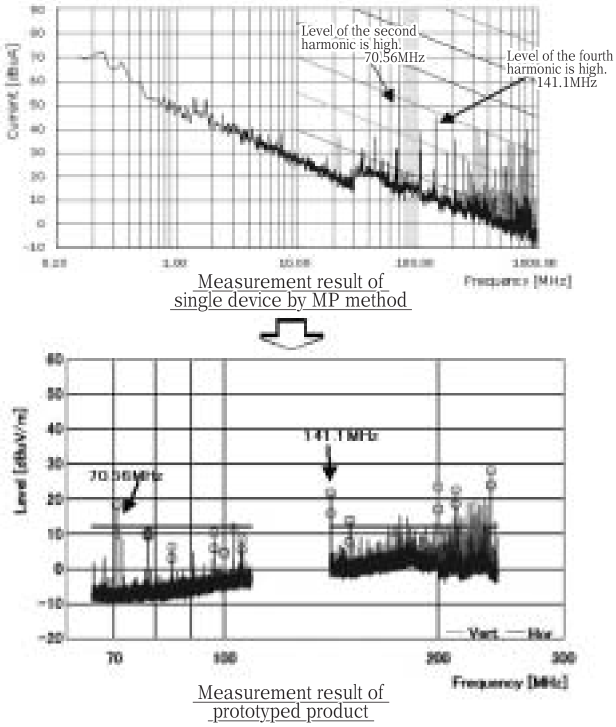


Fig.15 Comparison between Single Device and Finished Product

As a result, we confirmed the generation of the similar emission noise in the prototyped product at the same frequency as when the noise is generated in the single device.

In addition, we also confirmed that there is no correlation in the noise levels between the stand-alone device and the device built in the product.

In order to grasp the correlation, we will promote the accumulation of data by increasing the number of device to be evaluated, and study the EMC performance needed for the device.

We will also obtain / accumulate the single data for the multiple methods, adopted by each manufacturer, as well as for MP method, and will understand the correlation of emission noise between the single device and whole product.

6 Conclusion

We introduced our efforts toward EMC design in twice.

EMC (noise) is invisible and it is hard to understand its movement. Thus, it is difficult to conduct the efficient design or take the countermeasures against defects.

However, if the engineers have proper knowledge for EMC design, they can incorporate EMC design technology from conception phase of product design, and can advance the efficient product design acquired EMC performance.

To achieve this, we will improve the EMC technology by further advancing the company-wide efforts such as development of EDA tools or improvement of EMC performance of device, as well as continue the EMC elemental technology development responding to the new technology and continue our education activities such as seminars.

<References>

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Manufacturer "NEC Engineering, Ltd."

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