Efforts toward EMC design (I)

Katsuji Hirabayashi
Hideo Hanamoto

Abstract

These days, in-vehicle electronic equipment have been rapidly enhancing their higher function, higher performance and higher integration, and their progress has been continuing. In addition, the utilization of electromagnetic waves such as with mobile telephones and wireless LAN has been exploding, thereby increasing the risk that they and the automotive electronics equipment will exert a harmful influence on each other.

Meanwhile, EMC (Electro Magnetic Compatibility) regulations in each country and EMC specifications required from customers have become more demanding, and the compatibility of equipment performance and EMC performance is required.

Consequently, a review of product design technique has become necessary and Fujitsu Ten has worked on the following improvement activities for EMC design quality:

① EMC front-loading design, ② EMC-DR (Design Review) and consulting activity, ③ EMC design elemental technology development, ④ EMC design education, ⑤ EMC rule checker introduction.

We introduce these improvement activities for EMC design quality in twice.

1 Introduction

We introduce Fujitsu Ten's "efforts toward EMC design" in 2 issues. We start with the EMC environment surrounding Fujitsu Ten, the necessity for EMC design and our efforts, development of EMC elemental technology and a successful example of EMC design.

2 What EMC Is

These days, the chance of hearing the term "EMC" or "noise" has increased for overall electronics equipment including home electronics, as well as automotive electronics equipment.

EMC (ELECTRO MAGNETIC COMPATIBILITY) indicates the resistance to system intervention so that the equipment does not create electromagnetic interference to everything, and the equipment will work satisfactorily even if the equipment is subject to electromagnetic interference (Refer to Figure 1).

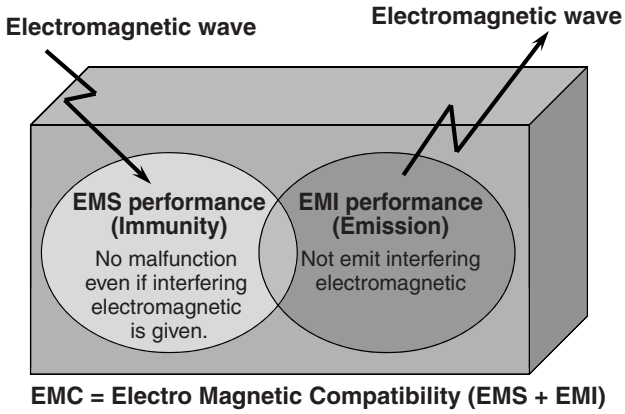


Fig.1 What EMC is

For example, the use of mobile phones is prohibited in the vicinity of priority seats on a train. This is out of consideration for people who use medical equipment such as pacemakers that can be adversely affected by EMC. This shows that EMC problems are a part of our lives.

Also, the "EMC problem" may be described as "a noise problem", however we use the term "EMC" throughout this article.

3 EMC Environment Surrounding Fujitsu Ten

3.1 Progress of Automotive Electronics Equipment

Automotive electronics equipment has been rapidly developing and increasing, and their applications are widespread in a vehicle. For example, more than one hundred ECU (electronic control unit) are installed in some luxury cars, and automotives cannot be done now without electronics equipment (Refer to Figure 2).

Furthermore, for example, improvement of PC-level high performance of the latest navigation as well as the numbers of installations creates an extremely sever environment for EMC.

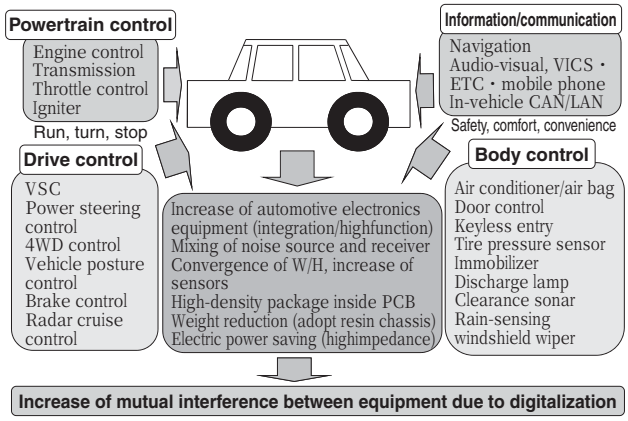


Fig.2 Automotive Electronics Equipment

3.2 Strengthening of EMC Regulations

EMC regulations are being strengthened in each country, and they will be enforced within a year or two even in Japan where there has been no EMC regulation for vehicles.

It is assumed that products cannot be sold if the compliance with EMC related regulations is not performed. Therefore the products to be developed are required to pay attention to EMC regulations.

The establishment and strengthening of major EMC regulations in Europe and North America and elsewhere are shown in Figure 3.

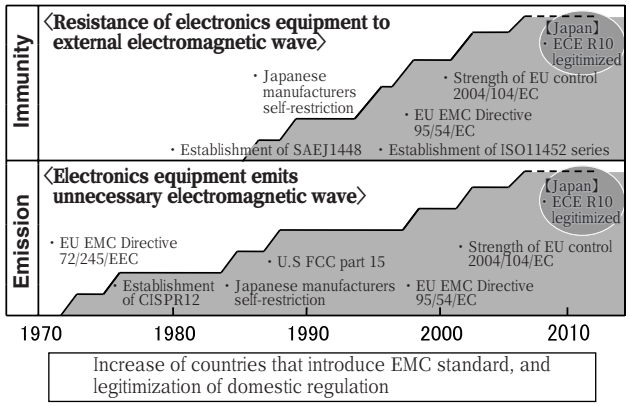


Fig.3 EMC Regulation for In-Vehicle Equipment

The automotive electronics equipment manufacturers including Fujitsu Ten are required by their customers to fulfill EMC performance. Because this customer demand is revised conforming to EMC regulations of each country, more stringent revision and nonconventional test will be added.

Therefore, the automotive electronics equipment manufacturers need to continue to respond to the various EMC regulations of each country.

4 Current Situation of EMC Design

4.1 Trend around the World

In major manufacturing industry, it is now common to divide electric work into circuit design and printed board design. Therefore, many young circuit designers do not experience the printed board design, and do not have enough know-how about the printed board design.

Also, designers at the manager level have little work experience of EMC countermeasures because of the greater complexity and high-speed digital technology in today's products. Hence they cannot give correct advice to the young designers.

There are great differences in the mechanical design depending upon the business category. For example, EMC regulations are strict and EMC design is progressing in a field where the most-advanced hardware is developed such as PC, the latest game machine, digital information home appliance, and others. On the other hand, EMC design is not conducted very often in the other fields as a whole.

4.2 Current Situation of Fujitsu Ten

In Fujitsu Ten, the department where dividing work into the circuit design and printed board design is advancing, and the department where the circuit designers conduct the printed board design by themselves actively are mixed.

Consequently, differences of EMC design quality between departments and variation of awareness of EMC design result.

Also, since the strength, heat release and ease of assembly are emphasized in mechanical design, the efforts toward EMC design are hardly adequate.

This is because the circuit designer's request or explanation to the mechanical designer is not adequate, and the mechanical designer's knowledge of EMC design and awareness of importance level are lacking.

Fujitsu Ten has taken steps towards the improvement of EMC design quality based on resolving these problems. We explain this activity.

5 Necessity of Incorporation of EMC Design

5.1 Responding to Change of Times

As described so far, product design responding both to the enhancement of high speed or high integration of the automotive electronics equipment and to the tightening of EMC regulations is required.

Therefore, the printed board or chassis design will be changed significantly from the conventional design method, and this can be said as a reformation of the design method. We explain this design method giving some examples.

5.2 Specific Example of Design Reformation

The design reformation includes the circuit, printed board, mechanism and others. We explain a layer structure of printed board as one example here.

In the conventional concept of 4-layer printed board, the second layer was selected for GND plane layer and the third layer was selected power supply plane layer reduction between power supply and GND, as shown in Figure 4 (left).

However, a concept of current digital printed board with high speed differs from the conventional one. As a result of evaluation in Fujitsu Ten, we confirmed that the layer structure shown in Figure 4 (right) is effective for EMC because the radiation from the wiring is converged in the GND plane layer. This concept is shown in the latest literature.

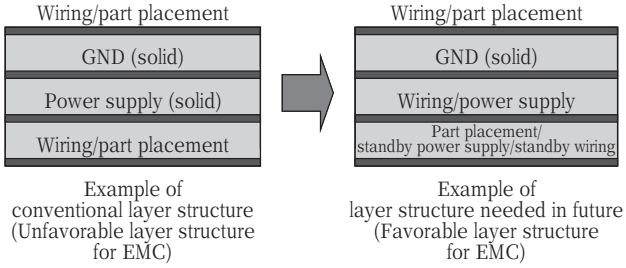


Fig.4 Example of EMC-Resistant Layer Structure
(cross sectional view of 4-layer printed board)

In the printed board with 2-layer or 6-layer or more, the effective design method is being established with the same concept, and good effects are achieved in many products.

Also in mechanical design, the effective design method is being established, and we will explain the details later.

5.3 Importance of Front Loading Design

If the incorporation of EMC design know-how is not conducted at a concept design step, good effects cannot be achieved. Also, there are many design know-how points that cannot be incorporated after a prototype step proceeds, as shown in the example of printed board layer structure in the previous section.

Therefore, it is important to incorporate EMC design know-how at as early a stage as possible.

This situation is shown in Figure 5.

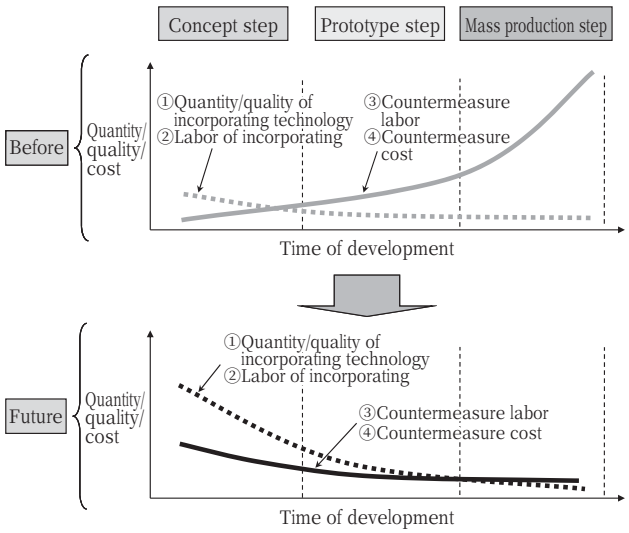


Fig.5 Importance of EMC Front Loading Design

- If the development is progressed, type and quantity of EMC design technology to be incorporated are reduced, and cost and manpower are increased rapidly.
- Incorporating the technology at the beginning of the development reduces cost and manpower at the stage where the development is proceeding.

5.4 EMC-DR

Implementing EMC-DR (EMC-Design Review) at the concept design step is the most effective in order to realize EMC front loading design.

This EMC-DR means that DR specialized for EMC is implemented at each design step such as circuit, printed board, structure and others. We confirmed that a dramatic effect is achieved by conducting this EMC-DR at the concept step, and promote an action for practice in-house.

EMC-DR is conducted categorizing into following three types as needed.

①EMC concept DR (EMC-DR at concept scheme step)
②EMC design DR (EMC-DR at design prototype step)
③EMC countermeasure DR (EMC-DR when countermeasure is needed after prototype)

Transition of EMC-DR achievement is shown in Figure 6. Implementation of EMC-DR at the concept step is becoming widespread.

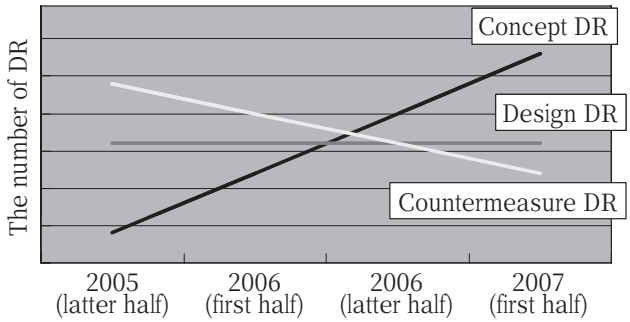


Fig.6 Implementation Transition of DR Type

Participation of AE (Authority Engineer) is the other important point to implement EMC-DR.

This purpose is that proper indication and directionality are extracted by the participation of members with knowledge of EMC in EMC-DR. The structure of EMC-DR is shown in Figure 7.

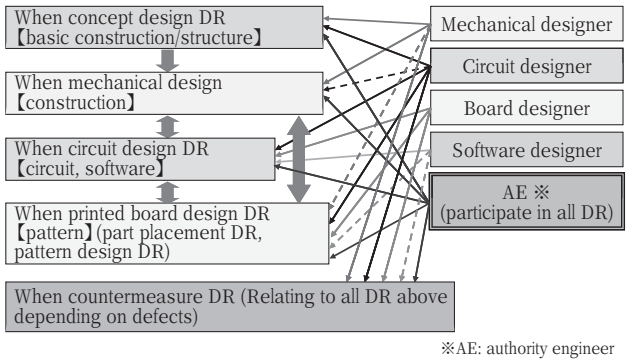


Fig.7 Member Recommended to Participate in EMC-DR

5.5 Effective Consulting Activity

There are some consulting companies that contract for EMC design and countermeasures, however this is expensive and good results may not be attained.

We started EMC consulting activities in the last fiscal year by ourselves.

In consulting activity, we conduct planning and give an advice about design / countermeasure in which information of design know-how gained from EMC elemental technology development and lateral deployment of effective EMC design / countermeasure case obtained inside / outside company are included.

In consulting, we can collect information of each department, therefore we can store know-how and give accurate advice gradually.

Also consulting responds to all of concept, design, and countermeasure, and the utilization of this consulting has increased rapidly including repeater.

- Latter half of 2006: 93 cases ⇒ First half of 2007: 150 cases

6 Development of Elemental Technology

6.1 Necessity of Elemental Technology

The elemental technology relating to EMC needs to be incorporated at each design step in order to improve the EMC performance of the product.

Therefore, the elemental technology development in EMC design is essential, and we progress the development selecting a theme.

The development theme notes a circuit and pattern that have been used without awareness of the elemental technology development, as well as a new circuit.

For example, there is a case of gaining significant EMC improvement effect by using even a simple filter circuit correctly, so we select the development theme widely.

6.2 Example of Elemental Technology Development

In the elemental technology development, we consider following four items as essential technologies, and conduct a verification experiment and simulation respectively:

①printed board pattern elemental technology, ②circuit elemental technology, ③EMC part utilization technology, ④mechanical design technology.

We store the results as design know-how, and provide them to each design department through EMC-DR, EMC design workshop and others.

①Printed board pattern elemental technology

The designers tend to rely on their experience and intuition to wire pattern. However, we design multiple patterns actually and evaluate effects in order to recognize good patterns quantitatively.

As an example, we give a validation example of guard pattern.

The guard pattern design had varied depending on the departments or designers and its criteria and effects had been unclear.

In order to recognize more pertinent guard pattern, we designed multiple printed boards and measured guard effect, and then studied the effective design method.We have stored and provided the guard patterns as the design know-how obtained from the result.

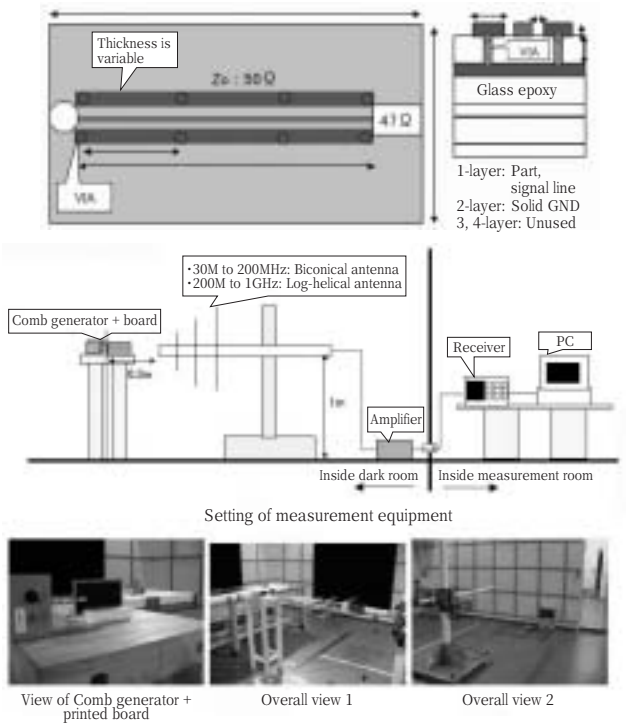


Fig.8 Elemental Technology Verification
(example of guard pattern verification)

②Circuit elemental technology

We give a validation example of DC/DC converter becoming a problem because of low-frequency noise. First, we decided a basic circuit and basic pattern. Then we designed about ten kinds of circuits and printed board patterns changed partially.

We make those circuits and board patterns and weigh them after measuring. And then we specify a dominant factor of the low-frequency noise, and extract guidelines for noise reduction design.

③EMC part utilization technology

Currently, part manufacturers release many EMC components. They include parts to be mounted on the printed board and noise absorbent material to be used by attaching.

These EMC components have effects with the skill to utilize them fully, however they are not necessarily used fully. The reason is that a printed board design recommended by manufacturers cannot be conducted at Fujitsu Ten due to restrictions in manufacturing.

Here, we introduce an example of performance evaluation of EMC components using multiple printed board patterns.

The result was that the noise level was reduced by 24dB (from -64dBm to -88dBm), and we recognized that how important the using method of the pattern and others is, in addition to proper part selection.

This measurement result is shown in Figure 9.

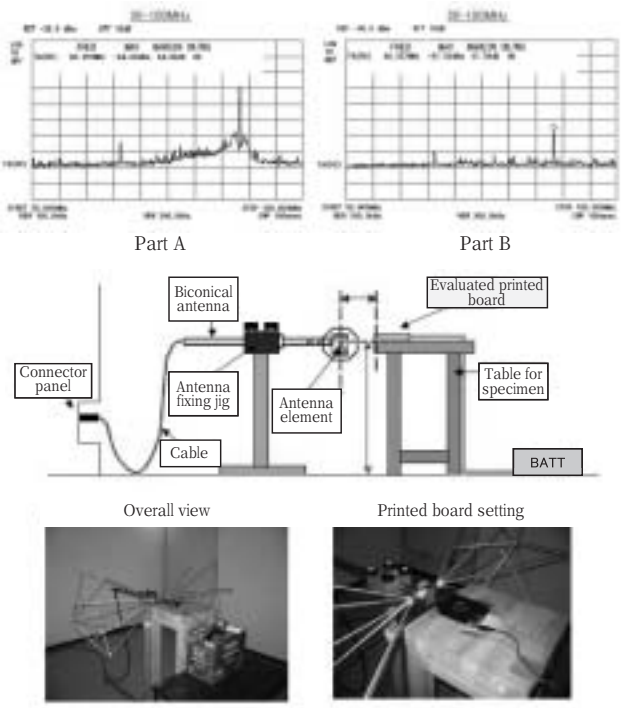


Fig.9 Elemental Technology Verification
(example of part utilization verification)

④Mechanical design technology

EMC performance varies greatly depending on a chassis or shield structure. In the mechanical design of Fujitsu Ten's products, we examined important points for designing, and procured / processed materials and measured the shield performance.

For example, an apertural area of heat release hole and chassis become an entrance / exit of noise. Especially a joint area of chassis becomes slit aperture and noise enters easily.

As for the shield effect by this slit shape, we evaluated both by actual measurement and we theoretically examined by electromagnetic field simulation.

Under a slit condition, the quantity of noise leakage is the same as when opened (OPEN), and under a condition, quantity of the noise leakage is suppressed to the same level as when closed (CLOSE).

The result of this electromagnetic field simulation is shown in Figure 10.

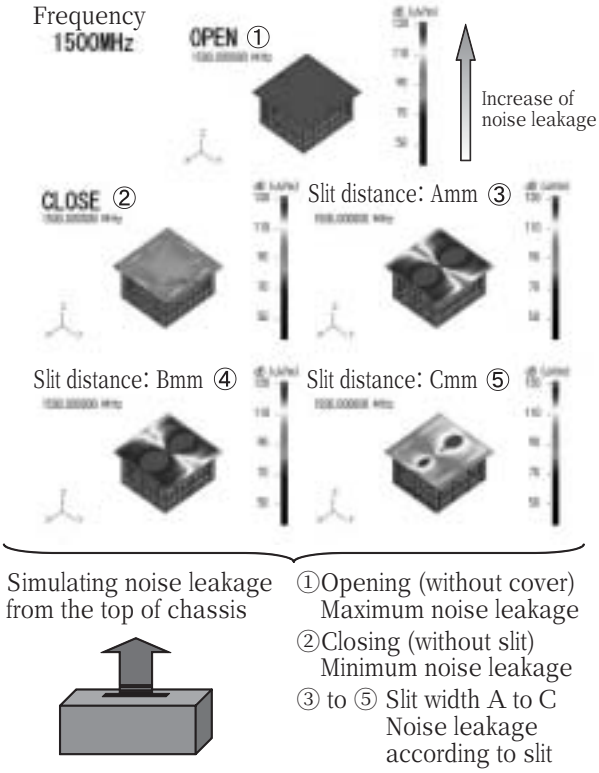


Fig.10 Noise Leakage from Slit
(result of electromagnetic field simulation)

Almost the same result was obtained in an actual equipment verification experiment as well, and we provide this slit design as design know-how to design departments and utilize it in actual design.

7 Effects of EMC Design

7.1 Practice / Successful Example

We have explained EMC design method and elemental technology development. We obtained good results by applying them, as shown in the examples.

For development of the 2007 model, the target of this product was to reduce to half size with the same circuit scale as the 2006 model. Also, further difficulties were anticipated in the 2007 model because we had struggled with EMC countermeasures in the 2006 model.

For starting of design, we conducted EMC-DR from the concept step and conducted EMC design.

The following items were incorporated as basic items for a printed board design at the prototype step:

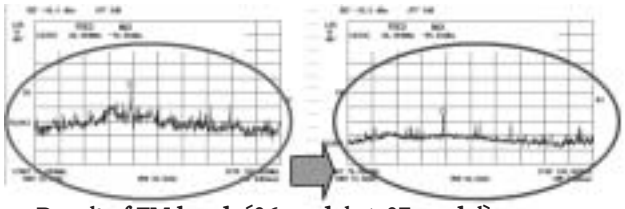
①Layer structure of printed board
②Effective utilization of solid GND
③Effective part placement for EMC
④Basic rules for pattern wiring
and others.

As a result, emission noise was improved by 10dB or more and EMC performance was significantly better than the 2006 model from primary prototype step.

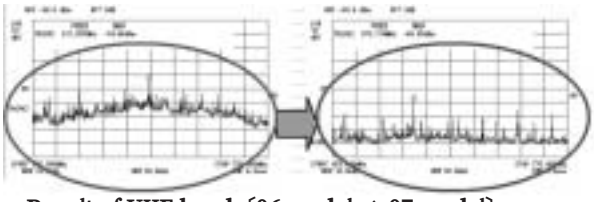
The comparison result of emission is shown in Figure 11.

Improved emission noise by 10dB or more

Appearance〔06 model ⇒ 07 model (1M)〕



Result of FM band〔06 model ⇒ 07 model〕



Result of UHF band〔06 model ⇒ 07 model〕

Fig.11 Successful Example of EMC Design

7.2 Factor of Success

The most significant factors of success are EMC-DR and incorporating EMC elemental technology with thorough Front Loading Design.

In particular, participation of members with much knowledge about EMC design in the concept step, circuit, printed board and mechanical design, and incorporation of EMC design know-how at the first step led to success.

Also, introduction of front loading enables us to confirm the EMC design effect from the first prototype step and to cut EMC improvement countermeasure time in half or less at downstream process.

As mentioned above, this is an example of confirming the effectiveness of front loading.

8 Conclusion

This time, we introduced the efforts toward EMC design, and product examples of obtaining significant improvement by incorporating EMC design.

Fujitsu Ten has worked on company-wide expanding of Front Loading Design with continuous elemental technology development.

Next time, we will introduce the efforts toward EMC design education, development / utilization of EDA environment, and future effort.

References

(1) Akira Okamura: "SI/EMC Countermeasure for Circuit Designers"
Publication office "Nikkan Kogyo Shimbun Ltd."
Reference page "Page 105"
Publication year "2007"
(2) (Material of seminar)
Katsuji Kobayashi (NEC Engineering, Ltd.):
Seminar title "Noise Measuring System by Magnetic Field Probe"
Manufacturer "NEC Engineering, Ltd."

Profiles of Writers

Katsuji Hirabayashi

Entered the company in 1986. Since then, has engaged in EMC elemental technology development and EMC design education by way of development of automotive wireless applications. Currently in the EMC Engineering Department, Research & Development Group.

Hideo Hanamoto

Entered the company in 1978. Since then, has engaged in business planning by way of automotive electronics equipment development, quality control and prototype. Currently the Department General Manager of the EMC Engineering Department, Research & Development Group and Nakatsugawa Technical Center.