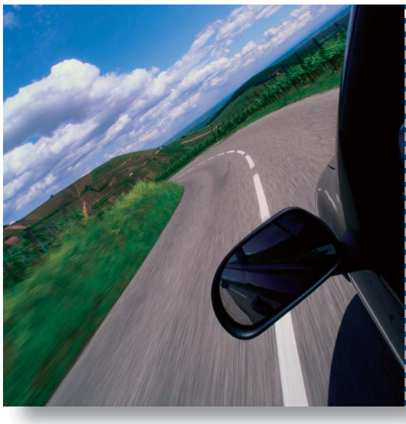
ISSN 1345-3041

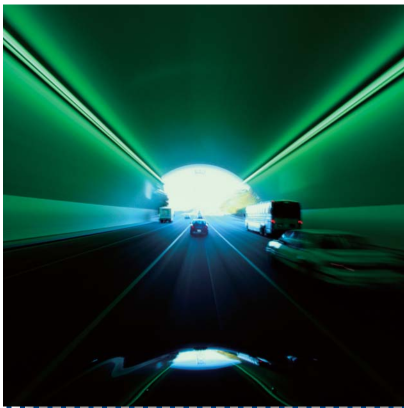
MITSUBISHI ELECTRIC

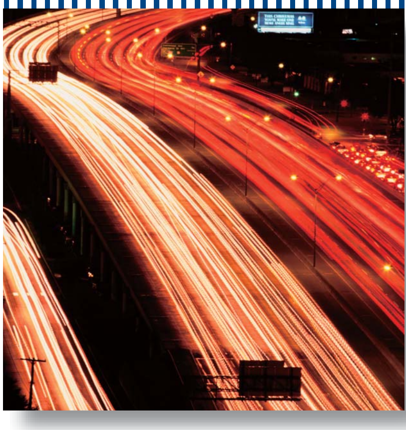
Dec. 2004／Vol.108

ADVANCE

Leading-edge Technologies Underpinning Motorized Society







MITSUBISHI ELECTRIC

Changes for the Better

Dec. 2004 / Vol. 108

MITSUBISHI ELECTRIC ADVANCE

Leading-edge Technologies Underpinning Motorized Society

Cover Story

Feeling the breeze with the entire senses while enjoying the passing scenery is a pleasure enjoyed not only by children, but also by adults. Automobiles have been giving such pleasure to the adults for more than a century.

The center photo emblematizes our wish for continual progress in motorized society and culture that allows such experience. The four surrounding pictures symbolize the target that technology must point to in order to realize a new level of motorized society. They are, from clockwise from upper left, "the environment," "safety," "information and entertainment," and "security."

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Mitsubishi Electric Advance is published on line quarterly (in March, June, September, and December) by Mitsubishi Electric Corporation.

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Technical Reports

Overview

Author: *Takahiko Kondo**

Nearly 120 years have elapsed since the gasoline engine car was invented in the latter part of the 19th century. The principle of basic operation remaining unchanged during this long period of time, automobiles are now indispensable in our daily life as an excellent means for mobility and of transport for users.

Mitsubishi Electric Corporation has contributed to the innovation of automobiles by pioneering the application of various new technologies of electronics like microcomputers, IC's and other semiconductors as well as the use of various high-performance sensors and compact lightweight actuators.

Automobiles in the 21st century should be earth-friendly, human-friendly and with driving pleasure. "Environment", "safety & security" and "information & entertainment", these are the buzzwords for such automobiles.

To materialize this, a wide range of versatile and sophisticated research and development of technologies is required, viz. not only miniaturizing and electronic control technologies but also other areas of technologies associated with communications, information processing and space/artificial satellites.

Mitsubishi Electric Corporation, with excellent records and capabilities in these areas of technology development, will aggressively carry out the development of leading-edge technologies that underpin the motorized society and foster a new automobile culture in the 21st century, whereby we will contribute to the economic society where we live.

* *Senior Vice President & Group President – Automotive Equipment*

Development of Transmission Built-In Type IPU

Authors: *Akinori Akazawa** and *Takuya Michinaka**

In order to meet a variety of needs, we have developed an IPU (Integrated intelligent Power drive Unit) that offers high vibration compatibility and high thermal cycling compatibility. This was achieved through the development of ingenious geometry and construction for its various components.

This report focuses on our ability to enhance vibration compatibility and thermal cycling compatibility as key technologies.

1. Enhancement of Vibration Compatibility

In installation environments, conventional IPUs are mounted in the interiors of vehicles. Unlike those IPUs, ours is intended to be mounted directly on motors and built inside transmissions, where vibration is far more severe. Therefore, high vibration compatibility is demanded of it.

1.1 Challenges

Figure 1 shows the construction of the IPU. The power chips (i.e. insulated gate bipolar transistors and free-wheel diodes, or IGBT's and FWDi's for short, respectively) are connected with the insert bus bar inside the IPU casing by means of wire bonding, and a silicon gel is poured onto them. In Fig. 1, wire (1) is a control signal connection to the IGBT chip; wire (2) is a connection between the IGBT chip and the FWDi chip; and wire (3) is a connection between the FWDi chip and the intra-IPU insert bus bar. When the IPU experiences vibration, so shakes the silicon gel inside, causing stress on the wires. If the IPU is installed in a place where there is wild vibration such as on a motor or inside a transmission, the problem arises of wires being broken by the stress.

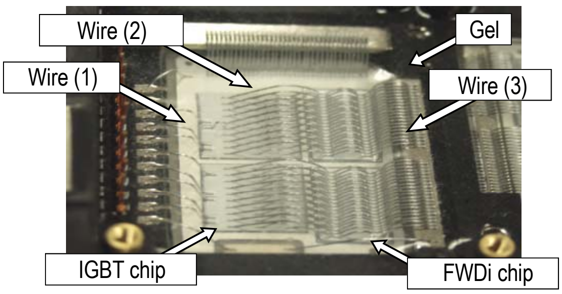


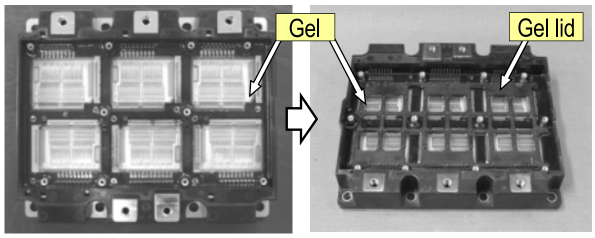
Fig. 1 Structure of IPU

1.2 Measures

Since the vibration of the gel is the cause of the wire-breakage problem, we have devised a way of suppressing the vibration of the gel.

As shown in Fig. 2, a part called "gel lid" is placed on top of the gel.

Of the wires shown in Fig. 1, wire (1) is most vulnerable to vibration, thus, we focused on this wire and performed analysis. The relationship between the displacement of the gel and the wire with/without the lid placed on top of the gel is shown in Fig. 3. On a cross-section parallel with wires (1) to (3) inside the IPU shown in Fig. 1, the displacements of the gel are represented by the contour lines. When the maximum gel displacement without the gel lid is normalized to 1.0, the gel displacement at the location of wire (1) stood at 0.29 with the gel lid in contrast to 0.79 without the gel lid, meaning that the placement of the gel lid has made it possible to reduce gel displacements to about one third. As such, we have ascertained that the placement of the gel lid is effective in suppressing the vibration of the gel, and it has thus become possible for us to secure high vibration compatibility.



a) Conventional structure b) Vibration-proofed structure

Fig. 2 Countermeasure for suppressing vibration

2. Enhancement of Thermal Cycling Compatibility

For greater thermal cycling compatibility, we have improved the thermal fatigue life of solder joints in the IPU power module. These are shown schematically in Fig. 4. Since these solder joints constitute heat-dissipating paths for power devices and are directly linked to the deterioration of performance and heat-dissipating capability, they represent important parts of the module.

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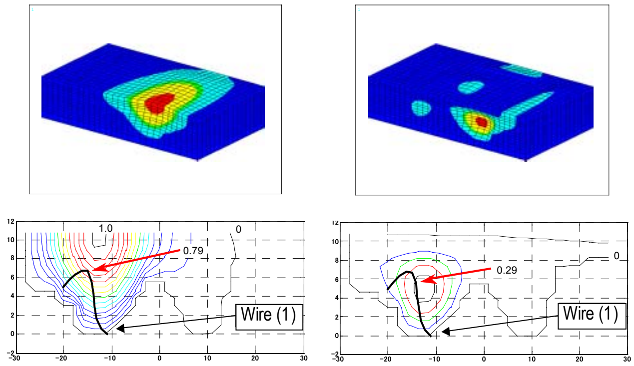


a) Without gel lid b) With gel lid

Fig. 3 Relations between wires and gel's displacement

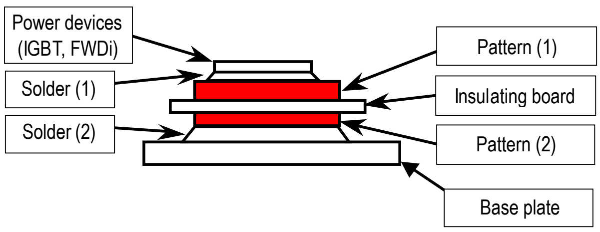


Fig. 4 Structure of the power module

As for installation on actual wheeled vehicles, the base plate of the IPU is fixed onto a vehicle-side heatsink, such as the housing of a motor or a transmission, using screws. The base plate, being restrained to the heatsink, undergoes deformation from mutual thermal expansion and thermal contraction, accelerating the deterioration of the solder joints.

Figure 5a) shows in schematic form how the power module portion of the IPU itself undergoes heat-caused deformation when the IPU is not mounted. However, when the IPU is mounted on the heatsink as shown in Fig. 5b), the base plate gets restrained in the direction that its heat-caused deformation (warpage) becomes suppressed. As a result, the amount of distortion/stress in the solder joints increases to a greater degree than when the IPU is not mounted, and deterioration is accelerated.

As discussed, it is necessary not only to achieve greater thermal cycling compatibility as a product itself, but also to take into consideration the circumstances in which the IPU is mounted on a heatsink in order to secure reliability.

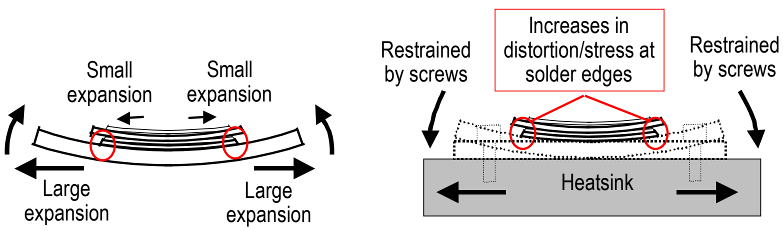
As one measure against the problem, in order to alleviate the distortion/stress that occurs in the solder joints, we have carried out two studies. Taking a look at Fig. 4 here, since Solder (2) is greater than Solder (1) in terms of distortion/stress caused by structural thermal expansion differences, we have implemented measures by focusing on Solder (2).

Firstly, the curvature radius R of the corners of the conductor pattern (2), as shown in Fig. 6 on the insulating board has been increased to diffuse the concentration of distortion/stress.

Secondly, the distortion/stress in the solder joints caused by heat-induced deformation has been reduced through the optimization of the thickness of Pattern (1) and Pattern (2), as shown in Fig. 4.

Fig. 7 shows the results of thermal cycling testing performed on a power module incorporating the above remedies and installed on a heatsink mimicking the real thing. Assuming the degree of deterioration of solder joints before the furnishing of remedies equal 1, the degree of deterioration has been reduced by the remedies to approximately 0.5 at the cycle count set for the purpose of making assessments, so low a level that no problem would arise in actual applications.

Thus, the thermal cycling resistance-related life has extended approximately twofold and the IPU has reached a point where it can offer satisfactory lifespans for its applications in such environments as being mounted directly on motors and embedded in transmissions. This high-reliability IPU is thus expected to expand flexibility in vehicle layout.



a) Power module in isolation (with temperature being raised)

b) When the power module is restrained to the heatsink (with temperature being raised)

Fig. 5 Thermal transformation of the IPU power module

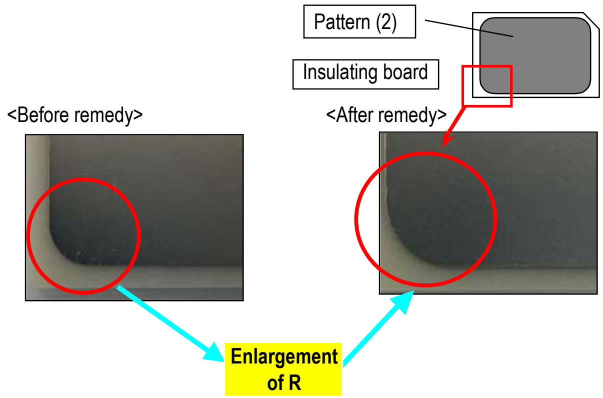


Fig. 6 Pattern on the insulating board

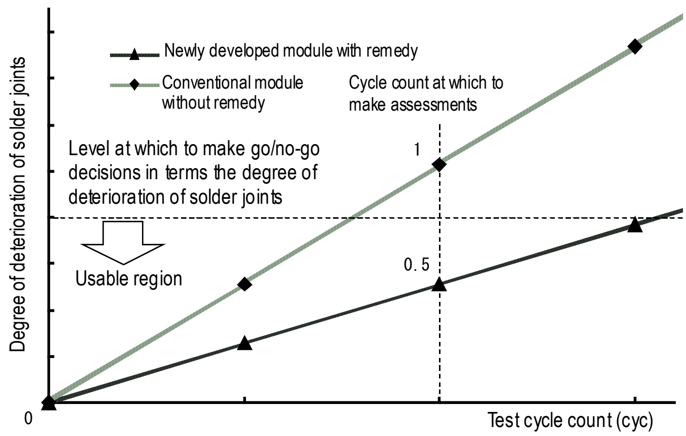


Fig. 7 Thermal cycling test result of the IPU with heat-sink (-40°C to 125°C)

Development for Brushless EPS System

Authors: *Seiki Kodama** and *Kazumichi Tsutsumi**

1. Foreword

Electronic power steering (EPS), compared with hydraulic power steering (HPS), is advantageous in terms of improved fuel efficiency and enhanced ease of installation, and is rapidly being applied to subcompact and compact cars. To meet the demand for higher power motors, which are necessary for expansion of its application to medium size and large cars, Mitsubishi Electric Corporation has developed a brushless EPS system. Its system configuration is the motor-ECU combined type, which aims to achieve improving ease of mounting and higher efficiency by reducing losses in wiring.

This report presents the features and an overview of the motor-ECU combined brushless EPS system.

2. Challenges to Achieving Higher Output Power

The EPS system causes the motor to generate torque appropriate to the driving conditions on the basis of a steering torque signal and a vehicle speed signal to augment the steering force of the steering system. Therefore, fluctuations in the motor's output torque are transferred directly to the steering system, leading to deteriorated maneuverability. Since the absolute values of torque fluctuations generally increase with increasing output, it is necessary to reduce torque fluctuations by such means as the optimization of the electromagnetic motor's design and the enhancement of control precision.

3. Features of the Motor

For the stator of the motor, we have adopted a linear bridged core, which is our proprietary technology. Since the linear bridged core allows wire winding in its linear state and thus is less subjected to constraints for the diameter of the coil wire, and the dimension of the winding tool by virtue of the slot openings between teeth, it has the advantage of greater flexibility in teeth geometry design, a governing factor of torque fluctuations. With a combination of this linear bridged core and a ring magnet with skewed magnetization, we have developed and produced a brushless motor with low-cogging and low-torque ripples.

4. Features of Control

The EPS generates steering assistant torque using the motor, commensurate with the driving conditions based on the steering torque signal and the vehicle speed signal.

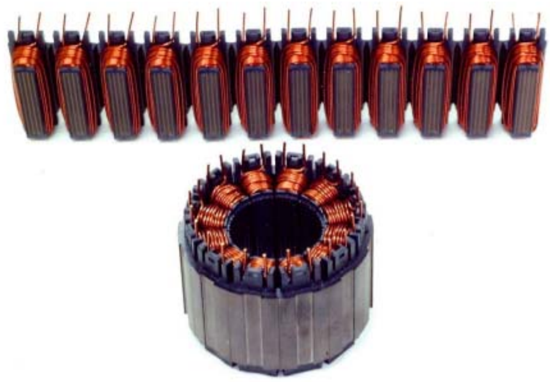


Fig. 1 Linear bridged core

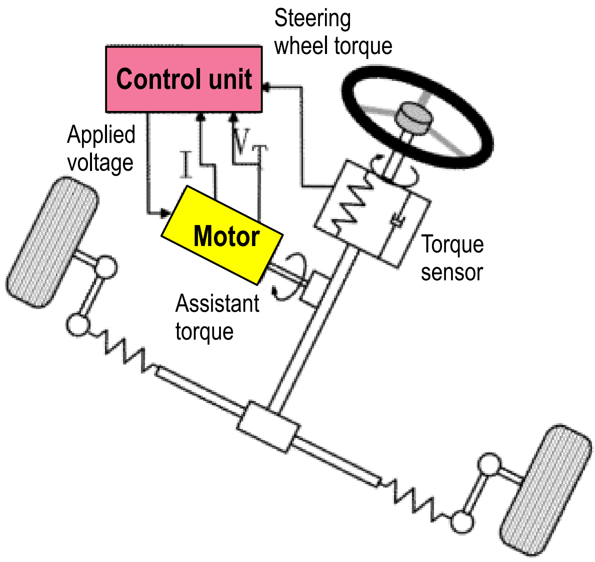


Fig. 2 Structure of EPS system

The motor to be controlled is a Surface Permanent Magnet Synchronous Motor (SPMSM), which has permanent magnets arranged on the surface of its rotor and undergoes torque control by means of vector control.

Under vector control, a three-phase motor current is coordinate-transformed (d-q transformation) to a rectangular coordinate system comprising an excitation current component (d-axis current) and a torque current component (q-axis current) so that the excitation current and the torque current can be controlled independently of each other.

Since the output torque of the SPMSM is propor-

*Himeji Works

tional to the q-axis current in theory, the steering assistant torque characteristic is set as a q-axis current that corresponds to the steering torque and the vehicle speed. While at the same time, in order to ensure stability when driving at high speeds, the q-axis current value is reduced according to the vehicle speed (Fig. 3). The d-axis current, which does not contribute to torque, is controlled to zero.

Since the SPMSM is a synchronous motor, it is absolutely necessary to detect the position of the rotor. The motor for the EPS is connected directly to the steering system via a steering gear, and its rotation is halted when in a steering hold state even if torque is being generated. In order that the motor current can be converted to a sine wave in relation to the rotor position, even in a state of ultra-low-speed rotation including a pose state, the motor position is detected with high resolution with the help of a resolver.

The EPS operates on battery voltage. To produce three-phase AC from this DC voltage, motor drive circuitry is configured in three-phase voltage-fed inverter form and driven by PWM (Pulse Width Modulation).

Figure 4 shows a control block diagram of the EPS. The motor current is controlled in such a way that the q-axis target current (Iq*) and the d-axis target current (Id*), both for generating steering assistant torque, agree with the torque current component (Iq) and the excitation current component (Id) respectively, as calculated from the detected motor current.

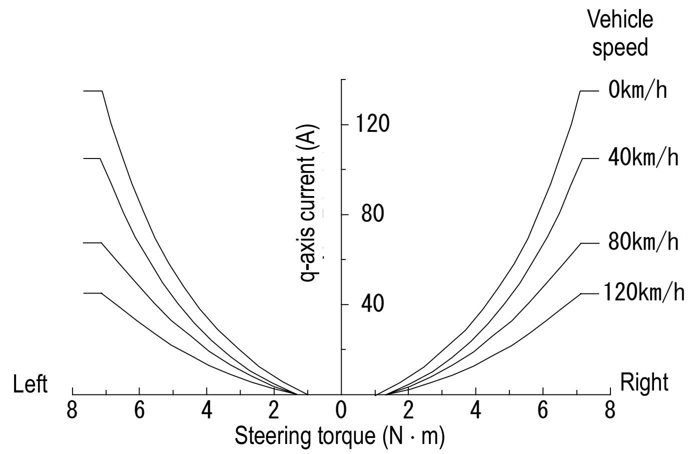


Fig. 3 Steering torque - q-axis current

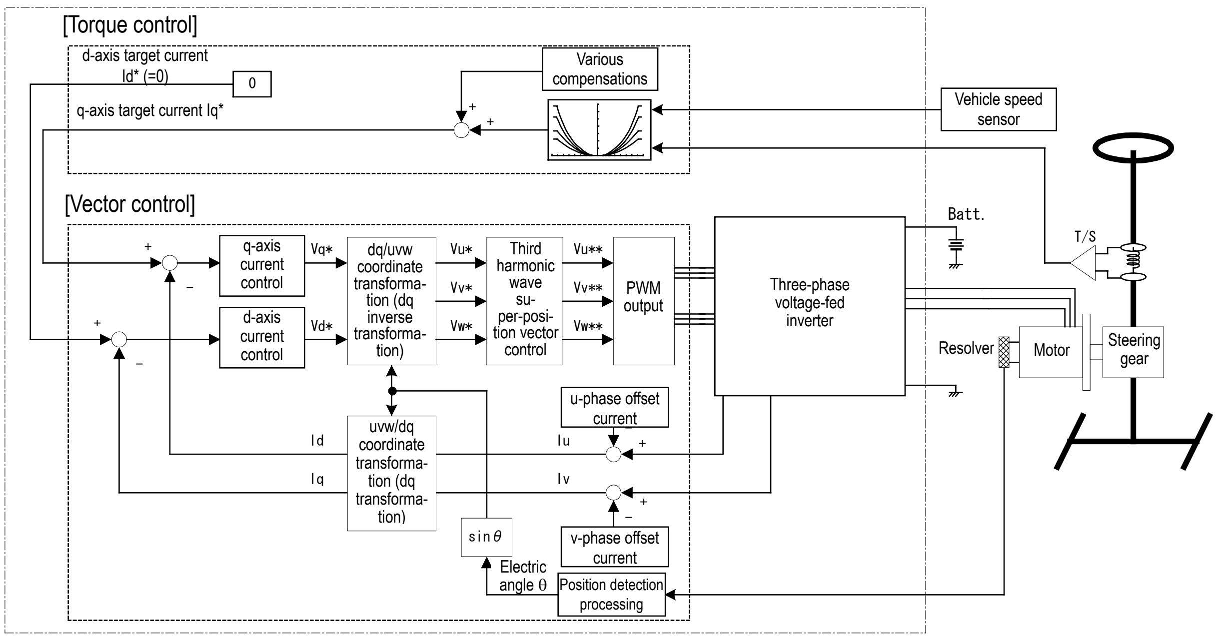


Fig. 4 EPS control block diagram

5. Integral Structure

Figure 5 shows a product example of the motor-ECU combined structure. Advantages of integrating the ECU and the motor include:

(1) Improved efficiency by virtue of reduced resistance of connecting wires between the motor and the ECU
(2) Reduced number of steps required for installation onto vehicles and improved ease of installation.
(3) Improved output precision by managing motor output characteristics while handling the motor and ECU as a pair.

Fig. 5 Motor-ECU combined structure

6. Conclusion

As has been discussed above, through the optimization of the electromagnetic motor's design and the enhancement of control precision, we were able to develop a high-output EPS system that can be used for medium-size to large cars. We would like to pursue further downsizing and achieve even higher precision and efficiency in the future.

Engine Management System for Motorcycle

Authors: *Wataru Fukui** and *Hiroshi Okuda**

At a time when efforts are underway to produce low-emission motorcycles that are friendly to the Earth's environment, the method of fuel injection has been moving away from conventional mechanical means to microcomputer-based electronic control. Since 1996, Mitsubishi Electric Corporation has been involved in the development of volume-production of engine management systems for motorcycles. The company has since been playing a part in the reduction of exhaust emissions from motorcycles.

1. Trends in Motorcycle Emission Control

Reductions in exhaust emissions from gasoline engines on four-wheeled vehicles have made significant strides in the past 30 years, contributing greatly to the reduction of air pollutants.

However, where motorcycles are concerned, emission control has been making progress and been stepped up on account of regulations that have been devised and put into effect in the past 10 years. In Japan, target values representing significant emission reductions are set in place, to take effect from 2006. Also in the EU (European Union), a similar step-up of emission control is planned to go into effect around the same time. Table 1 shows motorcycle emission control values in Japan and the European Union. When compared with four-wheeled vehicles, motorcycles are particularly worthy of note for their high HC emissions. This is partly because motorcycle engines are required to achieve high-response engine characteristics similar to those of motorcycle racing engines, and there are layout constraints that come from the necessity to fit the engine into the body compactly.

2. Engine Management System

Electronic fuel injection began making its way into motorcycles in 1998 in earnest. The carburetor (mechanical fuel-spraying device), which used to be the only one means of injecting fuel, is still being widely used on mass-produced wheeled vehicles. Compared with four-wheeled vehicles, motorcycles are characterized by their broad engine rev ranges. Some sports motorcycles exceed 13,000 revs/min. in maximum engine speed. Furthermore, a well-thought-out arrangement is used in which each of the engine cylinders is equipped with its own air intake system so that the required air can be suctioned into the cylinders responsively. This specification is similar to its counterpart for Formula racing engines found on four-wheeled racing machines. On an auto racetrack, such an engine reaches a maximum engine speed (of 13,000 RPM) from an idling speed (of 1,000 RPM) in a short period of time. Therefore, variation in the amount of air being suctioned in per unit time is large, and it is necessary and important to squirt gas in the correct amounts in such a transient state. Since the carburetor is capable of determining the amount of fuel commensurate with the intake air pressure generated in relation to incoming air by virtue of its principle of squirting fuel (on the principle of water spraying), it features excellent response in regulating the amount of fuel to be injected in a transient state. The carburetor having this characteristic has undergone evolution up until today in terms of characteristics geared to motorcycles. As far as current emission control values are concerned, motorcycles each equipped with a conventional carburetor can meet them with the combined employment of a catalyst and a

Table 1 Regulation of exhaust gas

ZONE	YEAR		CO (g/km)	HC (g/km)	NOX (g/km)	REMARK
JAPAN	1999		13.0	2.0	0.3	4STROKE ENGINE
	2006 (TARGET)		2.0	0.5	0.15	
EU	2003	UNDER 150CC	5.5	1.2	0.3	
		OVER 150CC	5.5	1.0	0.3	
	2006 (DRAFT)	UNDER 150CC	2.0	0.8	0.15	
		OVER 150CC	2.0	0.3	0.15	
JAPAN FOUR-WHEELED VEHICLE	2000		0.67	0.08	0.08	10·15MODE

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fuel-cutting solenoid which protects the catalyst at the time of deceleration by preventing unnecessary fuel from being injected. However, in order to satisfy more stringent future exhaust emission control values, it becomes necessary to inject fuel in the minimum required appropriate amount at optimum timing in each of the following modes: cold startup mode, acceleration/deceleration drive mode, and high-speed drive mode. The limits of the fuel injection control capability of the carburetor, which is a mechanical injection device, come into view here.

In a bid to cope with future stepped-up exhaust emission control, efforts have been afoot to develop an engine management system for installation on motorcycles. In recent years, engines equipped with two throttle valves (double throttle control) have made their debuts. Upstream of a throttle valve (primary throttle valve) which is opened/closed by the operator's throttle operation, an electric throttle valve (secondary throttle valve) is provided. The electric (secondary) throttle valve is opened/closed under the control of the engine management system which determines an optimum degree of opening in relation to engine conditions such as the engine speed, the degree of opening of the primary throttle valve, and the gear position. By virtue of the adoption of this double throttle arrangement, the velocity of the incoming air is optimized in the individual revolution ranges of the engine, making it possible not only to achieve efficient combustion from the low to high revolution ranges, but also to secure the responsive driving performance of a motorcycle. Figure 1 shows the engine management system. In order that the fuel amount can be optimally controlled relative to the engine's operating condition, the control unit (ECU) processes data about the pressure of the air streaming into the engine, the degrees of throttle valve openings, and air temperature, along with other engine information, in real time to detect the amount of the incoming air. Then, on the basis of the detected incoming air amount, the ECU issues an injection-drive (time) instruction to the injector that corresponds to the required amount of fuel injection in such a manner that the target air/fuel ratio may be achieved. The controlled air/fuel mixture condition is detected by the O_2 sensor installed on the exhaust pipe, and the sensor output is fed back to achieve the target air-fuel ratio.

As discussed, fuel injection control that is optimally suited to driving conditions is implemented, contributing to reductions in the amount of tailpipe emissions.

3. Overview of the Evolution of Microcomputer Performance

The performance of microcomputers inside engine management units has been improving sharply in recent years as shown in Fig. 2. In 1990, the computers of ignition units incorporated in fuel injection systems for carburetors were 8-bit chips. The amount of ROM was approximately 16kB. As a significant departure from these figures, the microcomputers of ECUs manufactured in 2003 for electronic fuel injection were 32-bit high-performance chips. The amount of ROM has increased by far to 512kB. This sophistication is for the purpose of achieving the mutually incompatible objectives of addressing emission controls and securing

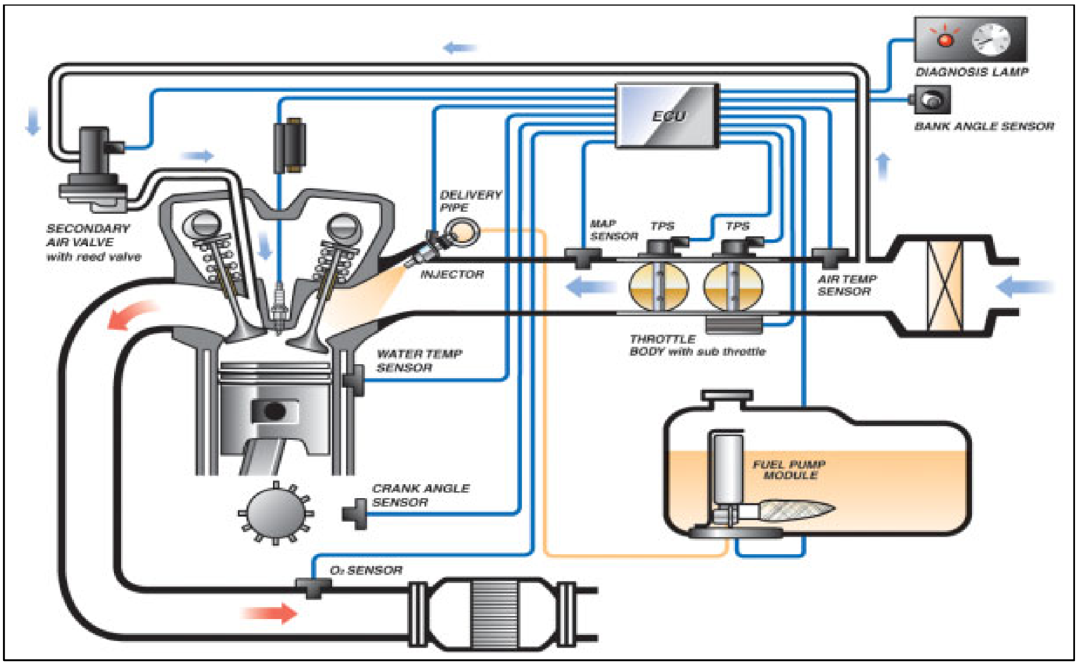

Fig. 1 Motorcycle engine management system

responsive driving performance as expected from motorcycles. Also down the road, the need to process various kinds of engine information in real time will grow and the sophistication of microcomputers will proceed in order to inject fuel in the proper amounts while the engine is in a transient state. On the other hand, challenges for sophistication, cost reduction, and package downsizing represent important factors for motorcycles. As a measure to protect the Earth's environment, it is extremely important to reduce tailpipe emissions in the fast-growing Asian region. Electronic fuel injection systems largely on medium- to large-sized motorcycles are composed of large numbers of parts, leading to increases in cost.

In order to achieve reductions in the amount of fumes from the tailpipes of small-sized vehicles, that are expected to climb up sales charts in the Asian region, it can be said that mass production of inexpensive electronic fuel injection systems is mandatory. From now on, we will make stepped-up efforts at developing low-cost, high-performance engine management systems for motorcycles, and thereby strive to offer products that are friendly to the global environment.

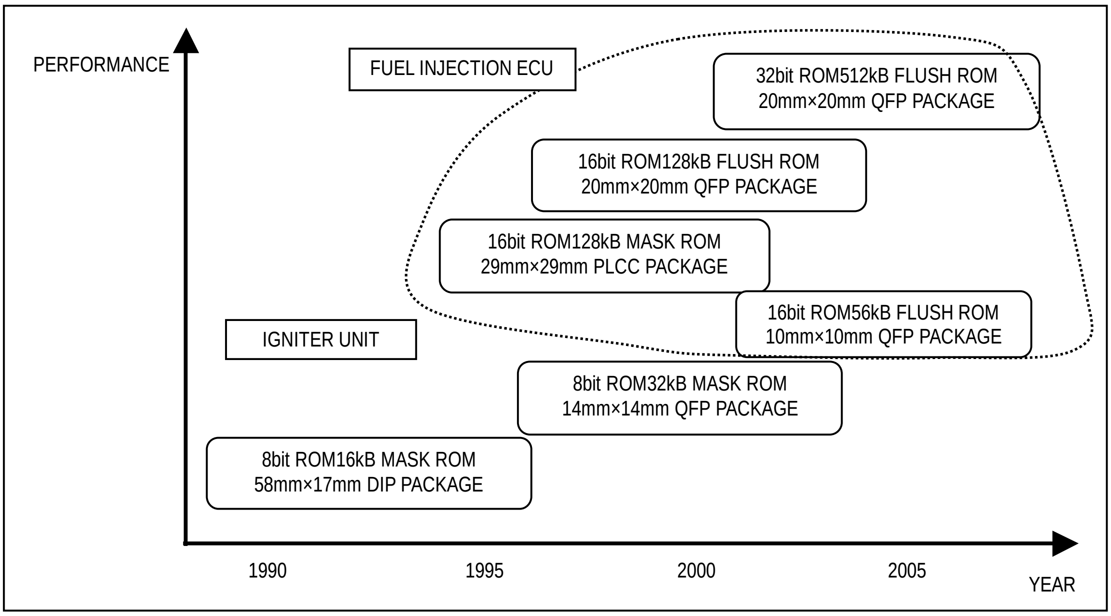

Fig. 2 Trend of micro controller for motorcycle

Miniaturization of Sensor for Engine Control

Authors: *Hiroshi Nakamura** and *Koji Tanimoto**

In recent years, automobiles have been evolving in terms of emission control, improved fuel efficiency/economy, and reduction in price. Against this backdrop, improvement in precision, downsizing, and reduction in weight and cost are demanded of sensors. This report describes our new-generation small-sized pressure sensor and plug-in type micro-air-flow sensor that have been designed to address these challenges. (Fig. 1)

1. Small-sized Pressure Sensor

These days, the use of pressure sensors for automobiles has been increasing for such purposes as intake-air quantity detection and atmospheric pressure detection. Ever since production of semiconductor pressure sensors began in 1980, we at Mitsubishi Electric Corporation have been making various improvements.

Fig. 1 The exterior of pressure sensor and micro air flow sensor

As for the detection principle of the semiconductor pressure sensor, a diaphragm is formed by wet etching one side of a silicon chip. A pair of strain-gauge resistors is placed on the surface of the silicon chip, which is located at the other side of the diaphragm-formed side. As a pressure difference develops across the front side and the back side of the diaphragm, the diaphragm becomes deformed, thus causing a resistance value variation of ΔR in the value of the strain gauge resistance R on the surface. As a result, an electrical output of Vo as shown in the following equation can be obtained.

$$V_o = (\Delta R/R) \bullet E$$

Let us describe the structure of our latest generation of pressure sensor next.

As described above, the sensing element is bonded by anodic bonding to a glass die. By making use of the space created when the sensing element's diaphragm was formed through etching as a vacuum chamber, the use of components only for the purpose of forming a vacuum chamber has been eliminated, allowing a reduction in parts count. (Fig. 2a)

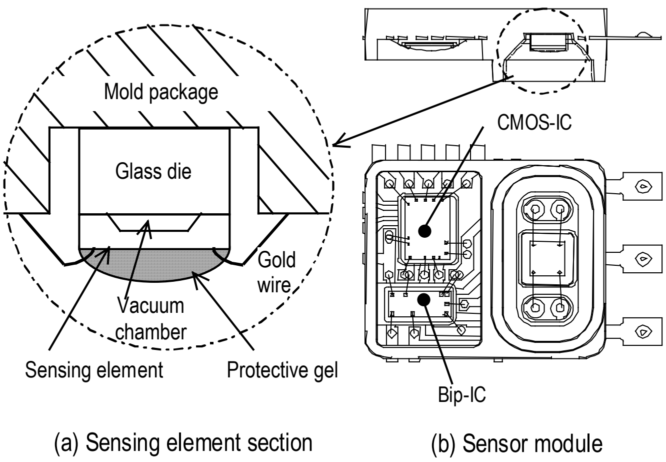

Fig. 2a Sensing element and sensor module

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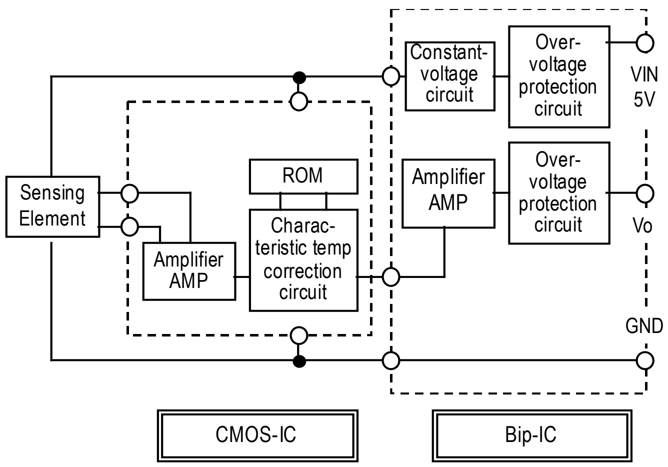

Fig. 2b The circuit diagram of pressure sensor

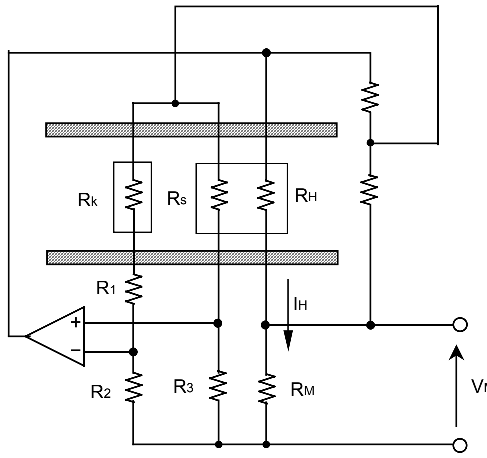

Fig. 3 The electronic circuit of micro air flow sensor

Since measurement pressure is applied from the strain gauge resistance side, the surface of the sensing element is protected against contaminants contained in the medium to be measured by means of the coating and gel.

The internal circuitry of the sensor consists of three sections: (1) A sensing element section that transforms pressure to electrical output; (2) A CMOS-IC that amplifies the output from the sensing element and performs temperature correction on the output; and (3) A bipolar IC that protects the CMOS-IC from inputted overvoltage. The entire circuitry consists of these three sections alone (Fig. 2b and Fig. 3). All of these ICs are being manufactured in general-purpose IC processes so that both reliability and cost-efficiency, which are demanded for use on automobiles, can be ensured.

The features of the sensor module are as follows:

(1) Reduction in volume and weight to 60% has been achieved by implementing necessary functional components in IC form.

(2) The use of solder has been eliminated (so that no lead is used) for bonding portions by using gold wire for making electrical connections with ICs, along with the adoption of welding for other electrical connections. This way, the sensing module has been designed with the environment-friendliness and enhanced reliability.

(3) By making the sensing elements capable of sensing pressure on their front surfaces, deterioration of pressure sensitivity due to deposited contaminants or trapped liquid is prevented.

(4) The CMOS-IC stores data on the intrinsic properties of the sensing elements in its on-chip ROM. This data is used for making temperature corrections. By using the ROM, higher precision and greater productivity can be achieved.

(5) The incorporation of filter circuitry in the bipolar IC ensures EMI resistance and surge resistance. Thus eliminating components for EMI measure.

As per the above listed features, our latest small-sized pressure sensor module has achieved improvement in precision as well as reduction in size, weight, and cost.

2. Micro-air-flow Sensor

In order to meet the demand for higher-precision, smaller-sized, lighter-weight, and easier-to-install AFSs (air flow sensors), we have developed a highly-responsive micro-air-flow sensor (micro AFS) using sensing elements to which micro-machining technology has been applied. The micro-air-flow sensor is of the small-sized plug-in type that can be easily installed by insertion into the tube coming out of the output port of an air cleaner.

The micro AFS utilizes the fact that, when electric current is passed through a heating element that has been formed on the sensing element for heating purposes, the amount of heat transfer from the heating element to the air flow depends on the flow rate. In the constant-temperature control circuit shown in Fig. 4, the air flow temperature is detected with an air flow temperature sensor, and the heating current being passed through the heating element is controlled in such a way that the temperature of the heating element stays higher than that of the air flow temperature by a given amount. Thus, the amount of flow can be detected from the heating current I_H.

Part of the sensing element, which is made of part of a silicon substrate, assumes a diaphragm structure formed by etching that has a thickness of several μm. On that diaphragm structure, the heating element (RH) and the heating temperature sensor (R_s) are formed in

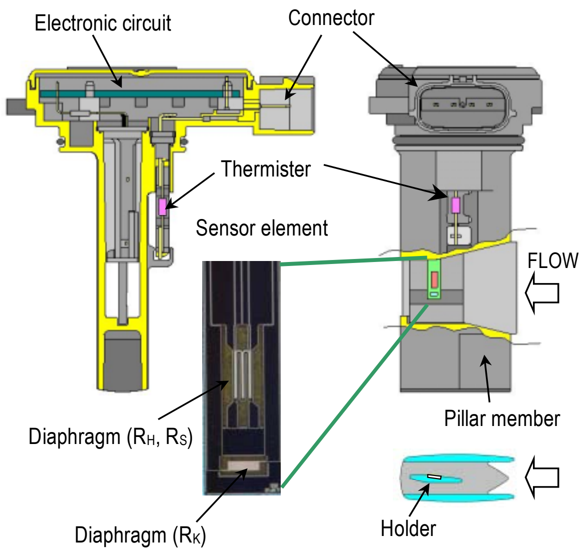

Fig. 4 The sectional structure of micro air flow sensor

the form of thin platinum films. Adoption of a thin diaphragm structure to the heating element has made it possible to significantly reduce the heat capacity of the heating element, and, at the same time, to thermally insulate the heating element from the silicone substrate, achieving low power consumption and high responsiveness as a result.

While a thinner diaphragm is preferable from the viewpoint of flow rate sensitivity and responsiveness, strength is demanded of the diaphragm at the same time so that it may not be damaged by the pressure of the air flow or collision of some of dust that may pass through an air cleaner. We have defined the thickness and width of the diaphragm from the viewpoint of mechanical strength, and then set the width of the heating element to half the width of the diaphragm to obtain flow-rate sensitivity that meets the required specifications.

In a conventional AFS, stabilization of flow is performed by placing a grid on the upstream side of the sensing element so that flow rate distribution becomes uniform. For a plug-in type, however, it is necessary to impart this stabilizing function to the sensing flow tube itself. In the case of the micro AFS, pillar members are placed on the support side and the tip side along the sensing flow path, and the flow on the upper-stream side of the AFS is split and attenuated. Then the pressure distribution across the diameter in the tube is made uniform so that the impact of flow rate distribution may be reduced. In addition, to ensure that a stable flow rate characteristic can be obtained, the wall on the entry of the sensing flow tube has a rather flat shape that is slightly protruding toward the upstream side so that the main stream smoothly flows into the sensing flow path.

Features are as follows:

- By adopting the plug-in configuration and making the electronic circuitry and the sensing flow tube smaller, downsizing to 1/5 the weight has been attained as compared with conventional types equipped with tubing.
- With the use of the microsensor as the sensing element, high-speed responsiveness that is faster by an order of magnitude than its conventional counterparts in response time after powering on - 1/3 or smaller in response time with respect to flow-rate changes - has been attained.
- Through the optimization of the shape of the sensing flow tube, unevenness-of-flow-distribution characteristics that are equivalent to or better than conventional ones with a grid have been obtained and the pressure loss has been reduced to 1/3 of what it used to be.

As has been described above, our small-sized pressure sensor and micro-air-flow sensor have achieved greater precision and reduction in size, weight, and price to meet the needs of customers. We are committed to continue developing and releasing customer-satisfying sensors.

Electromagnetic Field Analysis for Smart Entry Systems

Authors: *Kiyoshi Yoda** and *Hiroaki Yamamoto***

Automobile security is increasingly the concern of drivers. Smart entry systems serve to unlock the doors and start the engine with greater security and convenience. When the driver pushes a button on the door handle, an identification card in his pocket or bag receives a low frequency (LF, 132 kHz) magnetic induction signal from the vehicle and if the card recognizes the signal correctly an ultra high frequency (UHF, 315 MHz) signal is transmitted back to the vehicle thereby unlocking the door. Once inside the car, the identification card and the vehicle constantly communicate to verify the card location. If the vehicle detects the card inside the car, the driver can activate the engine by pushing a start button.

To efficiently design the smart entry systems, in-vehicle LF transmitting antenna locations must be determined so that a minimum number of antennas assure communication everywhere inside the car. It is highly desirable to optimize the antenna locations without experiments because the optimal positions should be determined in an early design stage before the car actually exists. To solve this layout problem, we need to calculate magnetic field distributions generated by the in-vehicle LF antennas since the identification card requires sufficiently strong magnetic field signals.

This article describes a simple simulation algorithm we have developed for calculating the magnetic field distributions that considers the vehicle structure. Preliminary results are also shown to confirm the validity of the algorithm.

1. Magnetic Induction Field Analysis Model

We need to calculate the low frequency magnetic fields generated by in-vehicle LF antennas taking into account the vehicle structure. The primary magnetic field generated by the antenna causes eddy currents on the vehicle's metal body thereby resulting in additional magnetic fields. The frequency of the magnetic fields is 132 kHz and its skin depth is sufficiently small for the vehicle's metal body. Consequently, we can assume that the eddy currents flow on a perfect electric conductor sheet.

Figure 1 shows a simple model including a current carrying coil and a perfect electric conductor sheet. The coil generates magnetic induction fields, leading to eddy currents on the conductor sheet. The eddy currents generate additional magnetic fields, and therefore, the total magnetic fields in the space are the summation of the original fields generated by the coil and the additional fields caused by the eddy currents. If we know the eddy current distribution on the conductor sheet, we can calculate the total magnetic fields.

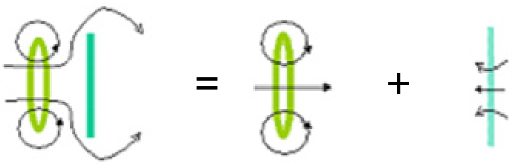

Fig. 1 A magnetic field analysis model

2. Formulation of Governing Equation

The wavelength of the low frequency magnetic field is much larger than the vehicle size. This means that we can ignore displacement currents. In other words, the eddy currents can be accurately modeled by divergence-free loop currents shown in Fig. 2.

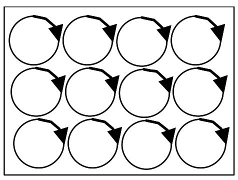

Fig. 2 An eddy current model on the vehicle metal body

Using the small loop current model in Fig. 2, we can simplify the problem, from solving unknown continuous eddy current distributions down to solving current amplitudes for all the given loops.

It is known that the alternating magnetic fields have no normal components on the surface of a perfect electric conductor. With this boundary condition in mind, we can derive the following equation:

$$B(r) \cdot n = B_0(r) \cdot n + \Sigma B(r', r) \cdot n = 0 \qquad (1)$$

where $B(r)$ is the total magnetic field at position r, $B_0(r)$ is the magnetic field generated by the in-vehicle antenna, $B(r', r)$ is the magnetic field at the position r caused by each current loop located at position r', and n is a unit vector perpendicular to the conductor surface.

If we define the loop current amplitude as $I(r')$, then the equation (1) reduces to the following:

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$$\Sigma (g(r', r) \cdot n) I(r') = - B_0 (r) \cdot n \qquad (2)$$

where g(r', r) is a magnetic field at position r caused by a unit loop current at position r'.

If the number of the loop currents is m, then we can evaluate the equation (2) at each center of the loop currents thereby obtaining m different equations. Because the number of equations equals the number of unknowns, we can solve the eddy current distributions. Note that all we need to do is to define small loops on the conductor sheet, and there is no need to divide air region into mesh unlike finite element methods. In a real vehicle structure, we can import CAD geometry data including triangular and quadrilateral meshes, and we can define a polygon loop current along each mesh edge.

3. Verification of the Algorithm

Before applying the algorithm to a vehicle structure, it is desirable to verify the algorithm using a simple conductor structure having an analytic solution.

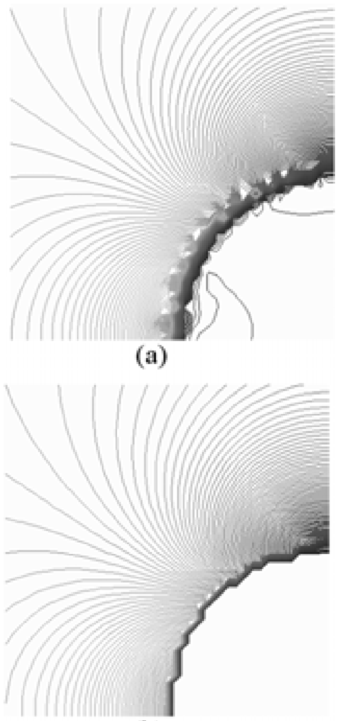
Figure 3(a) depicts calculated magnetic field contour plots using the proposed algorithm, whereas Fig. 3(b) shows analytically obtained field contours. In this calculation, a uniform vertically-directed magnetic field was applied to a conducting sphere shell having a radius of 1 m. The magnetic field contour plots in a quarter cross section are shown for viewing detailed distributions. The shell surface was divided into 1200 triangular elements. Except for proximity to the shell surface, the two contours are nearly identical.

Figure 4 compares calculated magnetic field lines with two different square mesh sizes using the present algorithm. In this calculation, an antenna coil is placed above a horizontally positioned square conductor sheet having an area of 1 m x 1 m at a distance of 4 cm. The square mesh sizes are (a) 2.5 cm and (b) 14.3 cm.

Figure 4 clearly demonstrates that the magnetic field lines fictitiously penetrate when using larger meshes. The proposed algorithm assures the magnetic field boundary condition on the conductor only at discrete points. This type of "point matching" technique does not consider magnetic fields at other intermediate points on the conductor surface. Consequently we need to decrease the mesh sizes until convergence is reached.

4. Magnetic Field Contour Outside the Vehicle

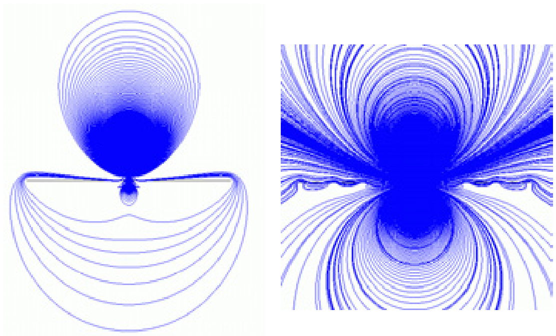
In the smart entry systems, the required communication distance between the card and the in-vehicle antenna is 1 m. Because the card has a minimum detectable magnetic field of 10 nT, we have evaluated 10 nT contour lines for a given antenna location and antenna driving current.



(a)

(b)

Fig. 3 Comparison of magnetic field contour plots (a) proposed algorithm (b) analytical solution



(a) (b)

Fig. 4 Comparison of calculated magnetic field lines with (a) 2.5 cm square mesh and (b) 14.3 cm square mesh. The antenna coil is placed above the horizontally positioned conductor sheet.

Figure 5 shows calculated 10 nT contour lines at heights of 0, 90, and 150 cm from the ground, whereas measured results are also indicated as dots. The data correspond to 0 cm, 150 cm, and 90 cm heights from left to right. In this case, the magnetic field is generated by an antenna installed inside the right hand side door.

We have confirmed that the calculated contour lines agree well with the measured results.

5. Time Domain UHF Antenna Analysis

We have also analyzed in-vehicle UHF receiving antenna characteristics using a commercial Finite Dif-

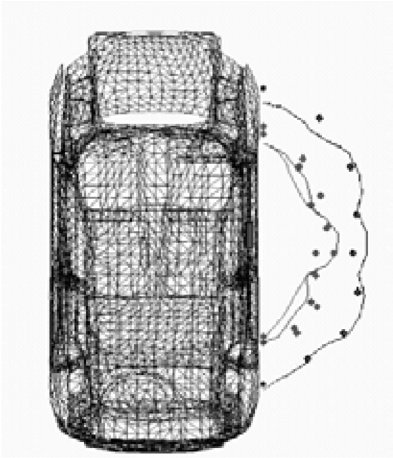


Fig. 5 10nT contour lines outside a vehicle. The data correspond to 0 cm, 150 cm, and 90 cm heights from left to right. Dots indicate measured results.

ference Time Domain (FDTD) code. To efficiently receive UHF signals from the identification card placed anywhere outside the vehicle, the antenna pattern should be as uniform as possible. Because the vehicle body highly affects the electromagnetic field pattern, it is important to analyze the pattern taking into account the vehicle structure.

Figure 6 shows electric field contours when the in-vehicle UHF antenna is excited by a 315 MHz sinusoidal voltage source. Due to antenna pattern reciprocity, transmitting and receiving patterns of an an- tenna are identical. The time interval is 0.7 nsec. We observe that the vehicle body affects electromagnetic wave propagation.

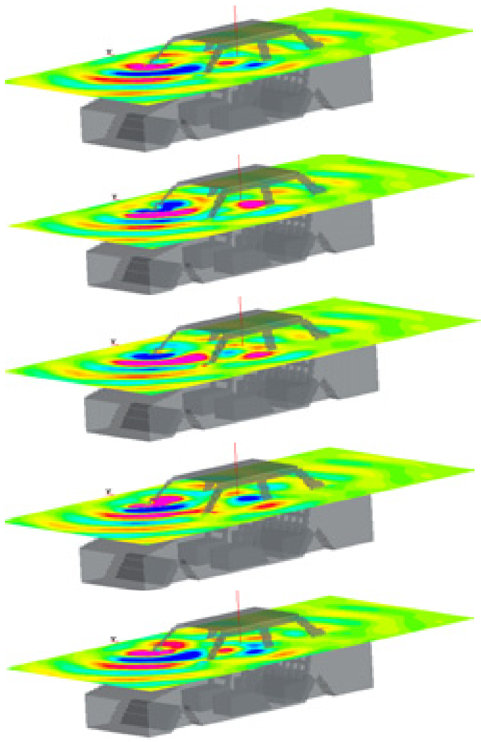


Fig. 6 Time domain UHF wave analysis. The electric field contours generated by an in-vehicle UHF receiving antenna is shown. Due to antenna pattern reciprocity, this calculation provides the receiving antenna pattern.

At present, work is proceeding on improving the algorithm for superior accuracy and speed. Our tentative result is very promising and we will report the details elsewhere in the very near future. With the improved calculation engine, antenna layout problems will be solved without tedious experiments.

In-Vehicle IT Design "OMNICAR"

Authors: *Shimon Okada* and *Kenta Kawahara*

Efforts made under such automobile-related themes as "Environment and Energy," "Safety," "Convenience," and "Comfort" are becoming requirements of society. We at the Industrial Design Center have been making suggestions through the implementation of our "in-vehicle multimedia concept and interface" research studies.

1. Three Features of Design-based Suggestion Activities

"An approach from the viewpoint of users" is a first feature. Users' sense of car values is undergoing a shift away from "running", "stopping", and "cornering" to "getting connected." In order to know what kinds of functionality users will demand of next-generation cars, it is necessary to assume their viewpoint.

"An approach with all-embracing viewpoints" is a second feature.

Being a development-based manufacturer of in-vehicle equipment, it is also important for us to crystallize concepts and ideas while striking a balance between the viewpoint of automakers and the viewpoint of suppliers.

"An approach that visualizes next-generation expectations" is a third feature.

We take advantage of our ability to integrate the development of concepts and images with our keen sense of perception in assessing the usage value of the latest technologies.

2. Ways of Implementing These Approaches

(1) Extracting problems (in a search for latent stress)

Settings where various kinds of information flood the cabin of your car, whether you like it or not, are growing in number. It is conceivable that this will become a greater stress on the driver and passengers.

(2) Setting a hypothesis about user needs and systematizing it

Through our group efforts, subliminal awareness and latent motives behind stress have been thoroughly explored. We have analyzed findings to determine that "stress may conversely reflect user needs", and we have set up the following hypothesis: "With the inundation of vast amounts of information, the act of sifting through it and extracting and organizing the required information for presentation to the driver and passengers in an easy-to-understand format leads to enhanced safety, convenience, and comfort."

The systematization of the hypothesis has been implemented in teamwork with other intra-company departments by factoring in such things as technological prospects and market trends. As a result, we have created a "technology roadmap" in order to illustrate the goal of the hypothesis.

(3) Generating ideas, structuring those ideas, and then expanding those ideas

Using sketches, contexts (usage scenes and profiles of users) concerning individual ideas was conceived of, and those ideas were shared by all members.

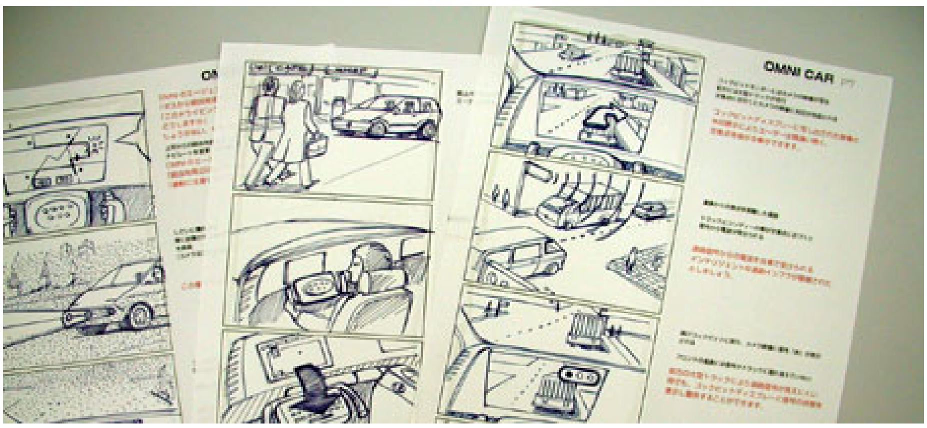


Fig. 1 OMNIC concept sheets

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(4) Preparing concept sheets (storyboarding)

We have put into scenario form what kinds of users would make use of our ideas. This piece of work is referred to as storyboarding. By virtue of this, the ideas were promoted to the level of applications (or functionality to be worked toward as a target). At the same time, as concept keywords, we have extracted "personalization", "seamless", "safety", and "security."

(5) Undergoing concept assessments

From the viewpoints of both future technologies in general and our own future technologies, assessments have been made by intra-company chairpersons who are directing in-vehicle equipment business out in the field. To our regret, as of this writing, clear-cut assessment criteria and assessment processes have yet to be established in terms of methodology, as they are still in trials.

(6) Visualizing concepts

In accordance with interface and hardware designs, a working prototype capable of operation has been constructed. At the same time, promotion visuals have been produced to demonstrate those aspects that cannot be presented using the prototype.

3. Track Record and Assessment of Suggestion-making Activities

Since 1999, we have been continually performing in-vehicle IT equipment-related design-suggestion activities targeted at major automakers and auto-related shows, both at home and abroad. We have also coined the pet name "OMNICAR Concept", under which our suggestions are made.

Automakers to whom we have made suggestions are providing us with feedback and comments of various kinds, both positive and negative. Opinions like these are making it possible for us to narrow down technology development themes and find directions we should take in the future.

4. Details of Suggestions

- OMNICAR 1 Creation of in-vehicle information space in sedan-type cars, with the media center, serving as a nucleus, designed to control multiple in-vehicle media in an integrated manner

(1) The media center is installed in a place where all persons in the car can operate it at the same time from the comfort of their seats.

(2) The large display housed in the media center enables back-seat passengers to enjoy a wide range of entertainment.

(3) The large portrait display for the driver offers an enhanced view while he/she is driving.

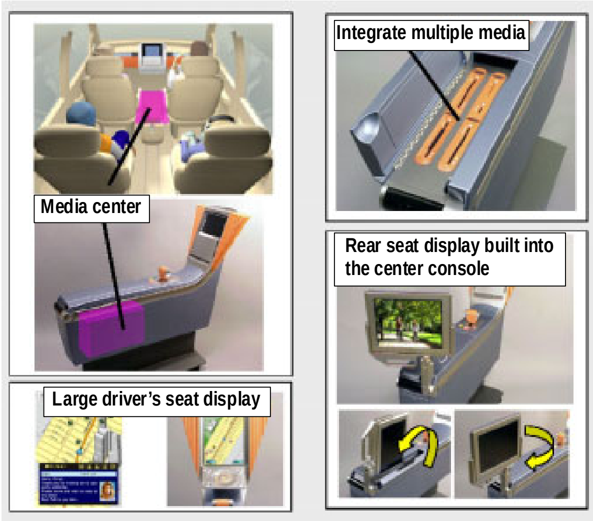

Fig. 2 Features of OMNICAR1

- OMNICAR 2 Creation of in-vehicle information space in minivan-type vehicles, with the media center, serving as a nucleus, designed to control multiple in-vehicle media in an integrated manner

(1) The media center is designed to move forward/backward by electromotion so that people in the vehicle can walk through the cabin.

(2) The retractable display incorporated in the media center may be accessed from the front passenger seat as well as the back seat, for example, to make an on-line transaction downloading media, and then watching that downloaded content.

(3) With the help of a personal digital assistant (PDA) equipped with the capability to perform personal identity verification, information security can be enhanced when making transactions such as above.

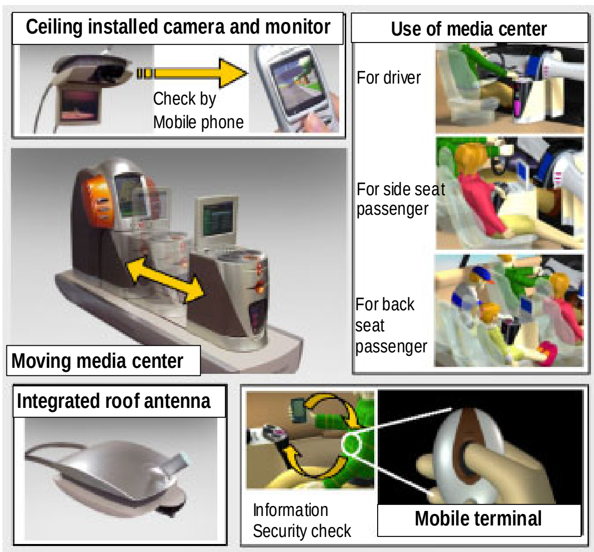

Fig. 3 Features of OMNICAR2

- OMNICAR 3 Creation of seamless in-vehicle information space via linkage between home information appliances or information generated by them and an in-vehicle information system

(1) Navigation route searching is possible via linkage between personal digital assistant and an in-vehicle information system.

(2) Navigation guidance with the superimposition of a route arrow display on actually shot imagery.

(3) The cabin of a vehicle can be turned into an office environment with the keyboard built in the steering wheel.

- OMNICAR 4 Creation of a new in-vehicle information equipment interface that allows the user to perform operations on various information with ease and safety while that interface responds to various changes in conditions resulting from running and stopping when the user is behind the wheel.

(1) The operation environment is optimized by a "situated interface," or a situation-adaptive interface, which is a combination of operation aids such as voice guidance and onscreen output that varies according to driving conditions. A "multi-modal" operation system that uses both a new, easy-to-operate device and a speech input system is also proposed.

(2) An "Agent-Based Interface" for the driver, which sorts, organizes, and outputs various information on the vehicle, is proposed.

5. Conclusion

It is important to establish criteria for the evaluation of concepts and a methodology for the implementation of evaluation processes in teamwork with other concerned organizational units in the future to pave the way for practical use.

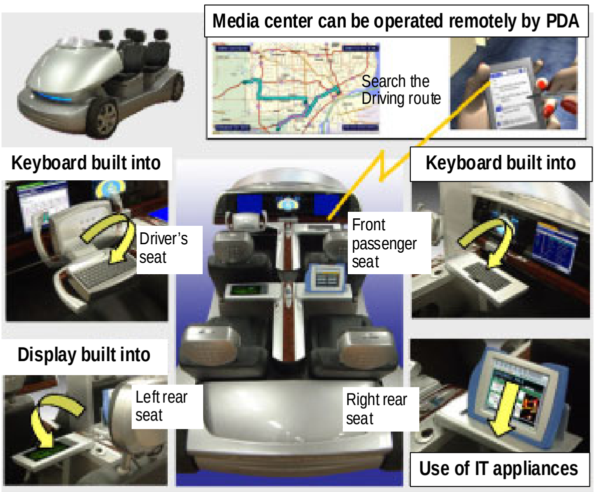

Fig. 4 Features of OMNICAR3

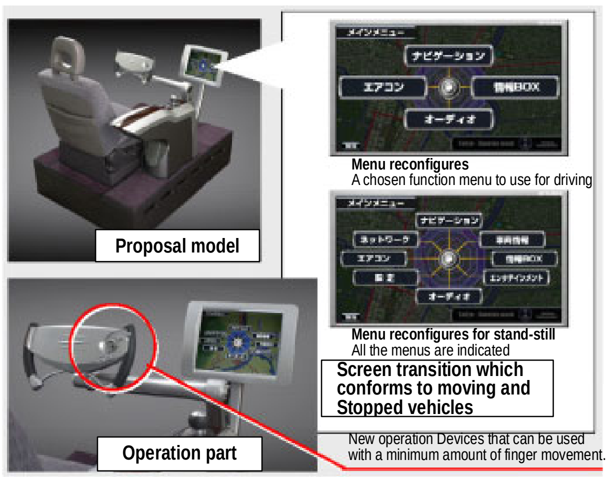

Fig. 5 Features of OMNICAR4

Voice Interface of Car Navigation System – Current Technologies and Future –

Authors: *Tomohiro Iwasaki*[*] and *Makoto Kosaka*[**]

We at Mitsubishi Electric Corporation have developed an HDD car navigation system, which has an improved voice interface, reflecting the results of usability assessments. This model incorporates a large-vocabulary speech recognition technology that allows you to search a database of 30-million addresses in Japan to pinpoint an address of interest by a single utterance, as well as a smart POI (point of interest) search function that enables you to find a point of interest by specifying only part of the name of interest.

1. Usability Assessments

The usability of the equipment cannot be measured only by evaluating the performance of the technology. To evaluate and improve usability, we at Mitsubishi Electric Corporation adopted an evaluation process which evaluates interface design from the user's point of view to improve specifications accordingly. In designing the voice interface this time, we have used the following methods:

(1) Questionnaire survey on the web for car navigation system users
(2) Heuristic evaluation conducted by evaluation staff
(3) User testing conducted with representative users

From the results of the above usability evaluations, a problem became evident that first-time users cannot use conventional voice interfaces because they do not know what to utter. In order to address this problem, we have constructed an interface that actively provides the user with explanations of recommended voice operation menu options via operation guide display. Also, we have set up a policy for the enhanced support of aliases, or alternative names, of POIs for places that are most frequently specified as destinations.

2. Speech Recognition Technology

It is necessary to recognize a variety of utterances for a user friendly voice interface. Thus, we have developed the large vocabulary speech recognition technology and the compiling technology of the "multiple words of POI" dictionary.

Already in our existing car navigation systems, we have been adopting a system of searching by address or by name of POI based on the large vocabulary speech recognition technology for setting the destination. This technology enables pinpoint search from among 30-million addresses and 80,000 POI names across Japan. So a user performs a basic operation by voice with a single utterance. For example, in address recognition, you can utter an address continuously from a prefecture name down to a house number such as "Tokyo-prefecture Chiyoda-ward Marunouchi 2-2-3."

Fig. 1 User test using driving simulator

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In addition, we have developed a technology of automatically generating a number of variations of a name of interest (multiple words of POI) for smart POI search. A dictionary for speech recognition is automatically generated from a huge database of POI names, that contain regular names. Conventionally, therefore, it has been necessary for the user to utter the regular name of the POI, which has been one of major reasons that a user feels difficulty.

To solve this problem, we have developed a new technology that automatically generates different variations of POI names. Figure 2 illustrates the process in which a "multiple words of POI" dictionary is automatically generated. A given POI name (regular name) is divided into appropriate units of morphemes (the smallest units of Japanese expressions), and then a set of variations is generated according to generation rules formulated for individual categories of POIs, taking omission, substitution, and synonyms into consideration. The generation rules are devised to prescribe, that while different variations be added, generation of unnecessary expressions and expressions of different meanings be suppressed.

Since an expression variation dictionary would expand fivefold conventionally generated terms, we have devised a new speech recognition engine, adopting efficient matching method, that reduces the amount of processing by bundling morphemes of partially common portions together.

3. Actual Examples of the Workings of the Voice Interface

This section describes the voice interface incorporated in the CU-H9000 HDD car navigation system (released in May, 2004) that adopts the above-mentioned design policy and speech recognition technology.

By making use of the above-mentioned "multiple words of POI" dictionary, we have realized the smart POI search function that enables the user to find the POI without knowing its regular name. Let's look into the workings of this function by taking as an example a search for "Nihon University Itabashi Hospital" by uttering "Nichidai Hospital in Tokyo." "Nichidai" is a popular name of "Nihon University", and "Itabashi" is a place name. When the system receives the expression "Nichidai Hospital in Tokyo", as a result of recognition, it repeats back the received expression "Nichidai Hospital in Tokyo" as it is, so that it will not be confusing to the user. Next, the system converts received expression to a regular name and searches POIs. As a result, it finds following 4 hits:

(1) Dental hospital affiliated to Nihon University School of Dentistry,
(2) Surugadai Nihon University Hospital,
(3) Nihon University Itabashi Hospital, and
(4) Nihon University Nerima Hikarigaoka Hospital.

And (1) is displayed on the screen as the first candidate (Fig. 3). "Surugadai" and "Nerima Hikarigaoka" are places names.

Fig. 3 Search result by utterance "Nichidai Hospital in Tokyo"

The user can select a candidate by uttering [Next] and [Back] commands. Also, the user can directly select (3) "Itabashi Hospital" by uttering the keyword "Itabashi" (Fig. 4).

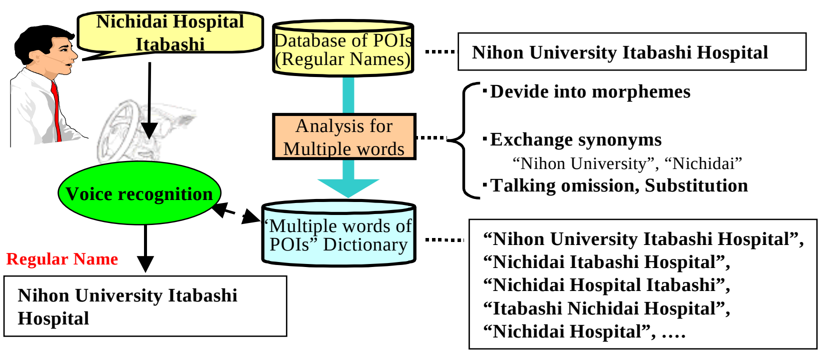

Fig. 2 Automatic dictionary generation method of multiple words

Fig. 4 Additional search result by utterance “Itabashi”

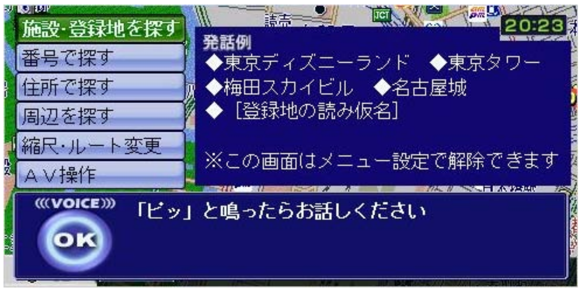

Fig. 5 Operation guide of voice interface

In addition, to make the voice interface easy to understand for first timers, its operation guide display has been enhanced. When the user presses the utterance key to start speech recognition, and if the car is at a standstill, operation guidance will fill the screen informing available voice operation functions (Fig. 5). On the left side of the screen, six operation menu items are listed, (1) Search by POI name, (2) Search by phone number, (3) Search by address, (4) Search nearest POI, (5) Change scale/route, (6) Play audio visual contents. They are selected as being more advantageous based on the function priority results of the usability evaluation. On the right, example utterances for the operation menu item being selected are shown. For operation menu items, we have chosen commands which can be executed by one-word or one-phrase utterances, and require less user operation compared with remote-control-accessed counterparts or the like. In addition, if the utterance key is pressed and then a long period of silence follows, utterance hints will appear.

4. Future Prospects

As each human being has his/her own personality, an optimum interface for each user may vary widely. Further, since the user himself/herself grows from a novice to a skilled user, a system is required that makes it possible to provide an optimum interface for each user, through selection among a number of options. For this reason, the following viewpoints are considered to be important:

(1) User-adaptive feature that records a history of frequently-used commands, destinations specified, music played back by the user, as well as the user's proficiency and preferences; (2) Driving status adaptive feature that responds to the current conditions (driving state, time of day, and location); and (3) Contents-adaptive feature that responds to the type of contents.

In addition, efforts are needed to accommodate even mental models of users, such as alleviating mental workload on the user, preventing the driver's distraction, and the like. Development of a technique to quantify usability is also an important challenge to be addressed.

Development of Car Use Indash 6 Discs DVD Changer Mechanism

Authors: *Kei Shirahata** and *Takashi Kuzuu**

DVD changer mechanisms that form the nuclei of backseat entertainment systems are required to become slimmer so that they can fit into single-height DIN-size chassis (German Industrial Standard: a height of 50 mm and a width of 180 mm). The latest changer mechanism we have developed has achieved a reduction in mechanism height by adopting our proprietary "Independent swing-out system" and "playback position offset system."

1. Basic Structure/Basic Operation of the DVX Mechanism

In recent years, demand is increasing for backseat entertainment systems that allow backseat passengers to watch video programs or enjoy games using a monitor for backseat viewing. In North America in particular, where people have frequent opportunities for long drives, DVD changers are in higher demand than single-disc DVD players because the changers eliminate the trouble of manually changing discs and are advantageous in terms of disk storage. Figure 1 shows how the changer that has just been developed is mounted for actual use on the car, as well as an oblique view of the changer mechanism. This paper describes the development of slimmed-down mechanical components for use in the multi-changer mechanism (hereafter called the DVX mechanism) which made placement into a single-height DIN chassis possible.

Figure 2 shows an oblique view of the entire DVX mechanism. A disc inserted from the front as shown in the figure is then pulled into the inside of the mechanism by means of the rollers in the roller unit, and held between the rear arm and the front arm, the latter of which is not shown in the figure. The disc being held is clamped by the playback base of the disc-playback floating deck and the clamp unit, and is moved to the playback position for reproduction. In addition, with the upper screw, which is not shown in the figure, and the lower screw passing through the center hole of the disc which is being held by the front and rear arms, a maximum of 6 discs can be loaded likewise by pinching them with the spacer engaged with the screws.

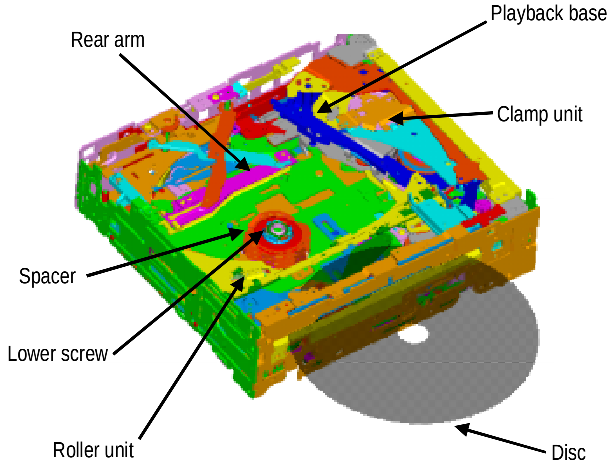

Fig. 2 Graphical overview of the DVX mechanism

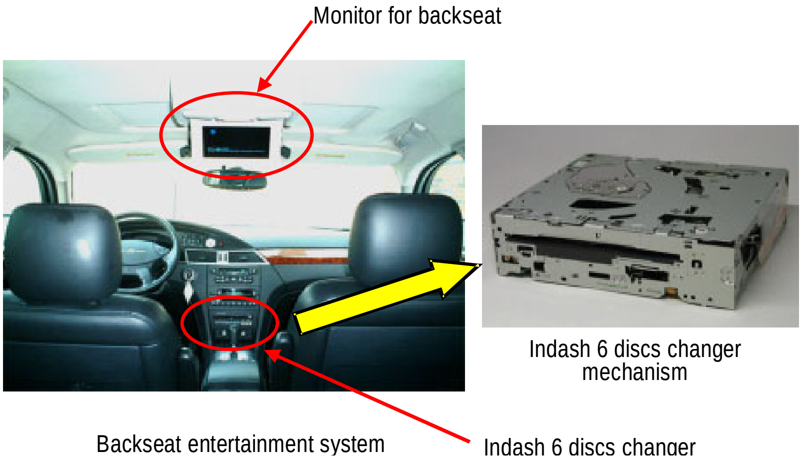

Fig. 1 Car use indash 6 discs DVD changer

*Sanda Works

In the DVX mechanism, a circuit board was placed on the bottom in such a manner as to fill the entire bottom surface area of the mechanism in order to secure the circuitry space required for DVD/CD reproduction. The board measured 6 mm thick. To realize the DVX mechanism, it was necessary to reduce the height of the mechanism section alone to 41 mm or smaller. The means we have devised to meet the above-mentioned size requirement are described in the paragraphs that follow.

2. Independent Swing-out System of the Playback Base and the Clamp Unit

In a conventional mechanism, the playback base and the clamp unit are arranged on the same axis, and when a disc is passed from the disc stocker to the disc-playback floating deck, the playback base and the clamp unit turn toward the disc stocker at the same time (under a concentric, simultaneous swing-out system).

In the case of the DVX mechanism, due to the clearance constraints imposed at the time of screw separation, the disc-playback floating deck would come into contact with stored disc(s) as it rotates if the concentric simultaneous swing-out system was adopted. Therefore, in order for discs to be put into a clamped state with a limited clearance, we have come up with the independent swing-out system in which the playback base and the clamp unit rotate independently of each other.

Figure 3 illustrates the arrangements of the concentric, simultaneous swing-out system and the independent swing-out system. The steps in which these two systems operate are as follows:

Concentric, simultaneous swing-out system

(1) Picks up a disk, (2) Swings out the playback base and the clamp unit at the same time, (3) Lowers the disc, (4) Clamps the disc, (5) Plays back the disc.

Independent swing-out system

(1) Picks up a disc, (2) Swings out the playback base, (3) Translate the playback base, (4) Lowers the disc, (5) Swings out the clamp unit, (6) Clamps the disc, (7) Translates the playback base and the clamp unit, (8) Plays back the disc.

The step (2) in the concentric simultaneous swing-out system is broken down into steps (2), (3), (5), and (7) in the independent swing-out system to make clearance compressed at the time of disc clamping.

In the concentric, simultaneous swing-out system, the playback base and the clamp unit together enter deep inside the mechanism. This arrangement necessitates clearance above and below the disc to prevent the disc from getting damaged by contacting any part of the mechanism. The thicknesses of the playback base and the clamp unit must also be considered.

In the independent swing-out system, the playback base alone enters into the mechanism first, thus eliminating the need for the thickness of the clamp unit which does not move at the moment. After completion of the descent of the disk in the next step, the clamp unit alone then enters into the mechanism, requiring no clearance below the disc. With the independent swing-out system, which rotates the playback base and the clamp unit independently, we have achieved a size reduction of approximately 2 mm, the clearance that was required below the disc in the concentric, simultaneous swing-out system. Figure 4 shows a side view of the floating deck with the clamp unit rotated to the position right above it.

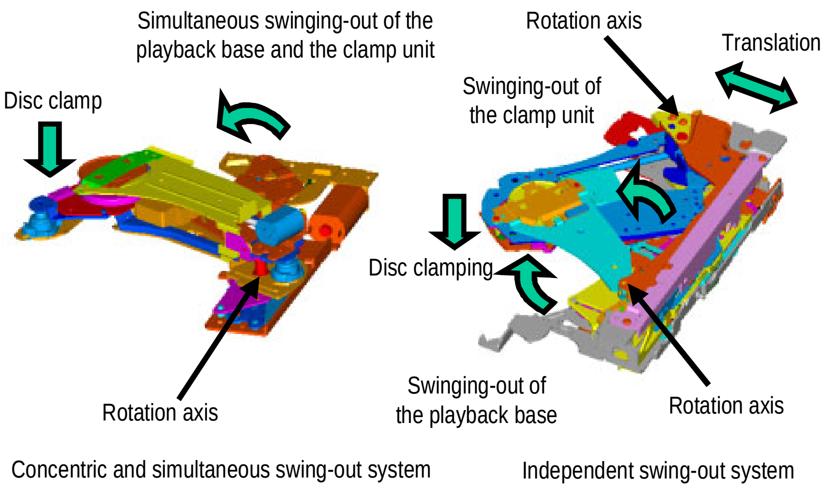

Fig. 3 Graphical views of concentric, simultaneous swing-out system and independent swing-out system

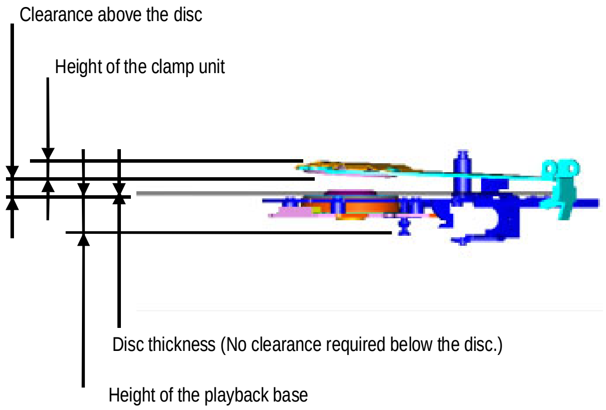

Fig. 4 Side view of the floating deck of the independent swing-out system

3. Playback Position Offset System

For a car-mounted set, a damper is used to protect against vibrations that reach the inside of the car. At the time of playing back a disc, since the disc-playback floating deck goes into a floating state, it becomes necessary to secure a space (shock proof clearance) to protect the floating deck from coming into contact with other parts. We have devised a structure in which the disc-playback floating deck moves away from the upper and lower screws and thereby a shock proof clearance is secured as shown in Fig. 5 when a disc is being played back.

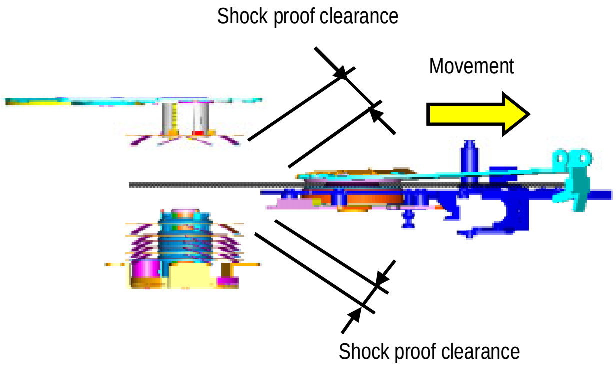

Fig. 5 Playback position offset system

4. Introduction into the Market

By using the above-mentioned mechanical arrangements, we have devised a way of slimming down the changer mechanism, and developed and succeeded in mass-producing a multi-disc changer mechanism that can fit into single-height DIN slots and is still capable of loading and playing back up to six DVD/CD discs, ahead of all our competition around the world. Currently, it is pre-mounted on two mini-van models from Daimler Chrysler as a back-seat-entertainment changer system.

World Trend of Digital Broadcasting for Mobile

Authors: *Kenji Miyashita** and *Kazuya Uryu***

Digital broadcasting has gone into service in Europe, North America, Japan, and other countries one after the other. Each broadcasting entity adopts a transmission system and a broadcast system by taking multipath interference, fading and the like into consideration. As for broadcasting targeted at mobile listeners, Europe's DAB (Digital Audio Broadcasting), North America's satellite-delivered XM (XM Satellite Radio) and Sirius (Sirius Satellite Radio) plus terrestrially-delivered HD Radio (High-Definition Radio), and Japan's ISDB-T (Integrated Service Digital Broadcasting - Terrestrial) have so far gone into service.

This paper provides an overview of individual broadcast systems and an ongoing commitment to ours at Mitsubishi Electric Corporation.

1. Overview of Digital Broadcasting for Mobile in Representative Countries

DAB, which was developed by the Eureka 147 project and has been put into practical use in Europe and Canada since 1995, is a terrestrial digital audio broadcast system.

As a transmission system, DAB was the first to employ OFDM (Orthogonal Frequency Division Multiplexing). The OFDM is a multicarrier transmission scheme. Increased resistance to multipath interference can be expected by added guard intervals and enhanced frequency utilization efficiency thanks to the use of an SFN (Single Frequency Network).

Sirius is a North American digital audio satellite broadcast system developed and operated by Sirius Satellite Radio. It went into service in July 2002 and offers 100 channels of programming for a monthly subscription fee of $12.95.

Since a fleet of three satellites (Fig. 1) orbiting the approximate center of the North American continent is used, the biggest advantage is that high elevation angles can be maintained even at high latitudes. In addition, gap fillers are used to cope with the deterioration of reception in urban areas due to the use of the S band (at 2.3 GHz).

XM is a North American digital audio satellite broadcast system developed and operated by XM Satellite Radio. It commenced transmissions in December 2001, offering approximately 100 channels of programming for a monthly subscription fee of $9.99.

To broadcast, two stationary satellites (Fig. 2) are deployed. Since they are located above the equator, the advantage is that fewer satellites are required than the Sirius system, although angles of elevation are lower at high latitudes. As with the Sirius system, gap fillers are used in conjunction.

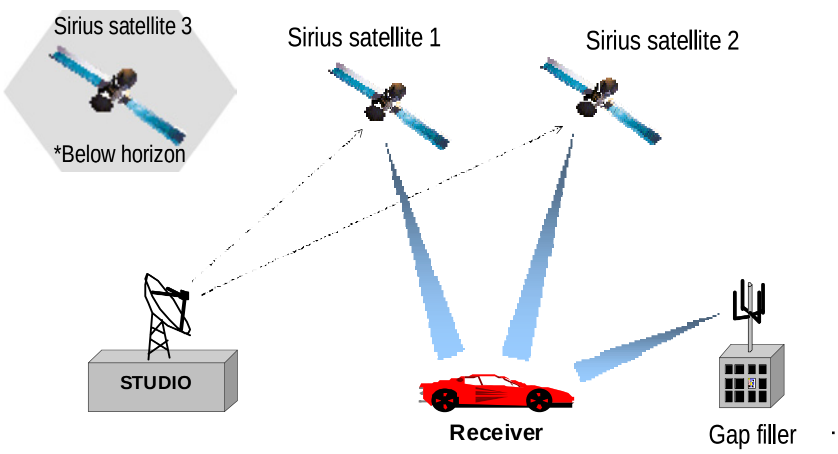

Fig. 1 Sirius broadcast system

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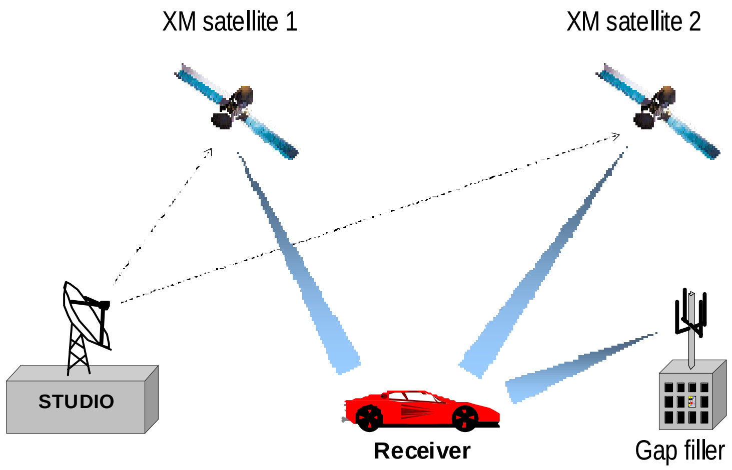

Fig. 2 XB broadcast system

HD Radio is digital audio broadcasting developed and operated by iBiquity Digital Corp. It went on the air in March 2003 using the already-existing AM/FM broadcast band.

Figure 3 shows the spectrum (FM Hybrid Mode) of HD Radio's broadcast wave. A conventional FM broadcast wave is located at the center of the band and OFDM (Orthogonal Frequency Division Multiplexing) is placed on both sides as a subcarrier. Since conventional broadcast equipment/facilities can be used, HD Radio has the advantages of being inexpensive in capital investment and being free of charge to its listeners.

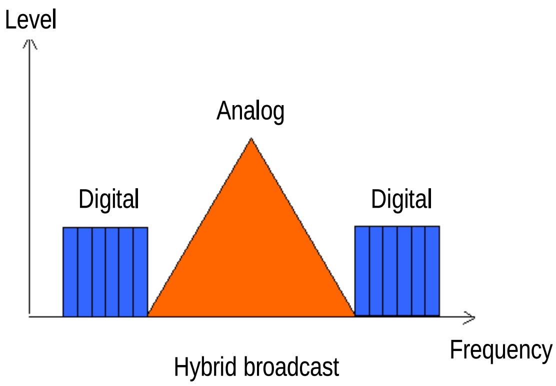

Fig. 3 Spectrum of an HD radio (FM)

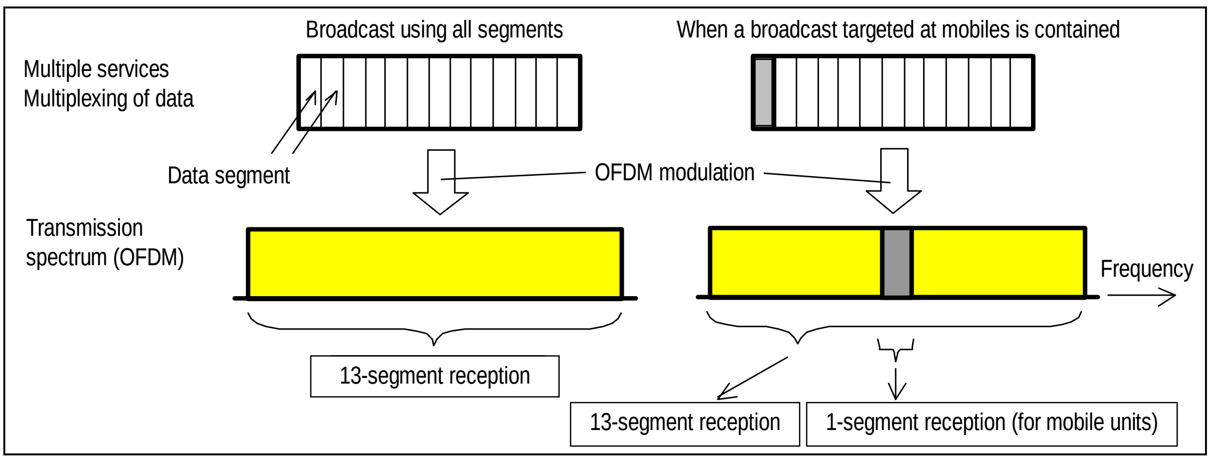

Fig. 4 Spectrum of an ISDB-T

ISDB-T is terrestrial digital broadcasting, which was launched in December 2003 in the three metropolitan areas of Japan, and is scheduled to be rolled out nationally by 2006. As a result, all conventional analog broadcasts will be taken off the air by 2011.

One major feature of it is that BST (Band Segmented Transmission)-OFDM is adopted as a modulation method. This is a Japan-specific scheme, and since a single channel is divided into 13 band segments under this scheme and a different modulation method can be assigned to different segments (Fig. 4), various kinds of services can be flexibly combined and transmitted.

Like other digital broadcasting systems, DVB-T (Digital Video Broadcasting - Terrestrial) is European terrestrial digital broadcasting and employs OFDM as its transmission system.

2. Mitsubishi Electric's Commitment

We at Mitsubishi Electric completed a product-level prototype of hideaway-type DAB receiver equipment in 2001. Since then, by capitalizing on know-how gained through the development of this receiver, we have so far developed receivers for Sirius, XM, ISBT-T, HD Radio and others.

As an example, we will introduce the results of a field test conducted on our Sirius receiver in Detroit, as well as others.

The spectrum of Sirius and the spectrum of XM are closely related to each other and act as interfering waves on each other. We have found that there are some areas where considerably large D/U (desired-to-undesired) signal ratios exist in the proximity of individual gap fillers. In early stages of our development, we encountered many spots where sound was momentarily interrupted a number of times. However, the number of such spots has significantly decreased by improvements we made to the AGC (Automatic Gain Control) circuit of the receiver, and the receiver has now reached practical levels of reception performance.

3. Conclusion

By virtue of the digitization of broadcasting, it has become possible for us to enjoy high-quality audio and beautiful and stable pictures even in cars.

What is more, digital broadcasting is not only limited to radio/TV broadcast services but also capable of transmitting large amounts of data to wide service areas at low cost. By taking advantage of this feature, digital broadcasting holds the promise of becoming a tool to bring information into closed spaces of wheeled vehicles. In the future, it will prove its worth more than ever before by making its way into applications such as VICSs (Vehicle Information and Communication Systems), each designed to be used in conjunction with a PLANETS (PLatform for Automotive infoNET System).

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