ASV-2 Safety Technology

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In establishing themes for the Phase 2 promotion Activities of the ASV (ASV-2) proposed by the Japanese Ministry of Land, Infrastructure, and Transport, we again analyzed traffic accident data as we did during phase one. More than half of all traffic deaths occur among those who are more vulnerable in traffic accidents, namely pedestrians, motorcycle riders and bicyclists, with most of these deaths resulting from being struck by automobiles. While a number of technologies have been developed and put into practical application in the areas of accident-avoidance assistance and injury risk reduction for automobile drivers, we also recognized the need to develop advanced technologies to help reduce accidents and injuries involving these more vulnerable parties. Accordingly, we defined the main theme of this phase as "protecting parties more vulnerable in traffic accidents." Additionally, we established "reducing automobile driver workload and fatigue" as a secondary theme, since reduced workload and fatigue allows automobile drivers to remain more attentive to surroundings and to interpret situations, make judgements, and/or perform control maneuvers more correctly, thereby contributing to the prevention of traffic accidents.

In the research, a fundamental principle is that "they must be systems that do not interfere with the driving operation," and the orientation is towards practicality.

Keywords: Driver assistance, Vision enhancement, ACC, Lane keep, Inter-vehicle communication, Night vision

1. Introduction

The Advanced Safety Vehicle (ASV-2) development promotion project, as proposed by the Japanese Ministry of Land, Infrastructure, and Transport, was a five-year plan implemented from 1996, with the participation of 13 Japanese manufacturers. In the ASV project, it is stated, "The aim is to carry out research and development for automobiles with far greater safety, by making vehicles more intelligent, through the utilization of new technologies, such as electronics technologies that have made rapid advances in recent years." In the six fields of (1) Prediction and Active Safety Technology, (2) Accident Evasion Technology, (3) Fully Automatic Driving Technology, (4) Collision Safety Technology, (5) Technology to Prevent the Secondary Effect from Collision, and (6) Automobile Infrastructure Technology, a total of 32 system technology items were specified, and each participating company was given a free hand in the development of the items they tackled. In the second phase, in addition to the passenger vehicles initiated in the first phase (carried out from 1991 to 1995) [1], trucks, buses, and motorcycles also became part of the projects. In addition, at the end of Y2000, joint proving tests (Smart Cruise 21) were carried out with the AHS (Advanced Cruise-Assist Highway Systems).

2. Background

In Honda's ASV-2, the starting points in carrying out safety research were "Tackling what sort of accidents would be effective?" and "What kind of technologies are important in avoiding accidents?" Fig. 1 shows the transition in the number of fatalities and casualties over the past ten years [2]. From this graph, the number of casualties has continually shown an increasing trend, and it can be predicted that future active safety research and development will be vitally important in the reduction in number of traffic accidents. Fig. 2 shows the percentage of accidents, according to the parties concerned. Among accidents with casualties, 50% were between two automobiles. Among fatal accidents, the percentage of those involving vulnerable road users – pedestrians, motorcycles, and bicycles – is also 50%. Making further detailed analysis, rear-end collision is the leading cause of accidents between vehicles at 30%. Among single vehicle accidents, many are due to errors in recognition and judgment, such as collisions with construction equipment or going off the road. In contrast, examining vulnerable road users fatalities, 70% are nighttime accidents, and among those, for pedestrians, those in a crossing are the most numerous. In addition, among motorcycle accidents, 70% are crossing collisions and collisions with a vehicle making a right-turn.
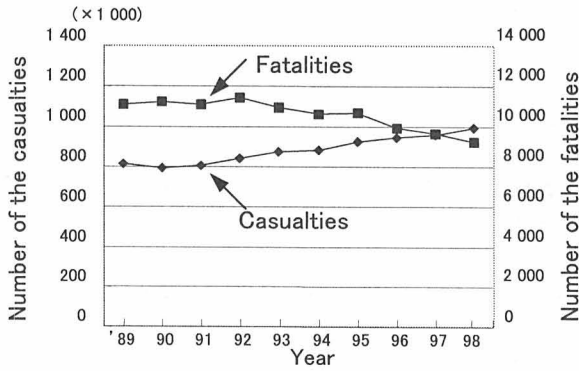
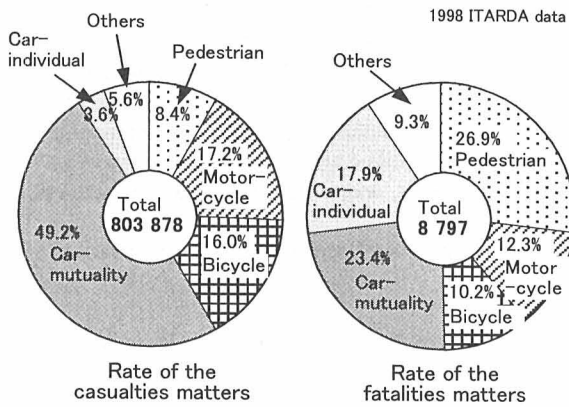**Fig. 1 Change of the number of the traffic accident people**

Fig. 2 Percentage of the traffic accident matters

From this information, the following five projects were selected as the research issues. [3][4]

1) Measures to reduce automobile driving load and rear-end collision damage reduction
2) Measures to improve recognition of vulnerable road users
3) Measures to improve motorcycle active safety
4) Motorcycle rider protection
5) Road infrastructure cooperation

In carrying out the research, one focus was "personal comfort reduces driving load", and in order to create practical measures, the following issues were noted.
a) Establishment of development guidance for new safety technology
b) Real-world tests
c) Verification of new system in use
d) Improved system reliability

3. Measures to Reduce Automobile Driving Load and Rear-end Collision Damage Reduction

3.1. System to assist in keeping in lane and lane departure warning (LKAS: Lane Keep Assistance System)

The lane mark is recognized through the use of CCD camera image processing [5], and with the center of that lane as the target, the steering assistance torque toward the target points is calculated from the difference between the target points specified on the target path and the vehicle's predicted position. Then, using the electric power steering (EPS) current control, lane-keeping assistance is carried out. In addition, lane departure warnings are simultaneously made.

3.1.1. Lane Keeping Control Algorithm.
As shown in the geometric model in Fig 3, the basic principle of lane keeping control is made up of two elements. The first element is Tf: Feed-forward torque, and its purpose is to work for vehicle stabilization in steady-state turning. According to R: road radius (curvature) determined by image processing, when driving on this road, the steering torque generating Cf: cornering force that is optimal for the centrifugal force is calculated, and steering angle is set. Thereby, it is possible to make the steady-state cornering. The second element is Tb: Feedback torque. When there is a deviation from the target path (Yd: lateral deviation and θ h: vehicle heading angle), it works for stabilization of target path keeping, by making the deviation zero.

The torque comprising these two elements is calculated as lane keeping torque Ta, making lane keeping possible. [6]

$$T_f = C_f \cdot \frac{V^2}{R} \tag{1}$$

$$T_b = Y_d \cdot K_a + \theta_h \cdot K_b + \frac{d}{dt} \cdot \theta_h \cdot K_c \tag{2}$$

$$T_a = (T_f + T_b) \cdot K_d \tag{3}$$

Yd: Lateral deviation from lane
θ_h: Vehicle heading angle
R : Road radius
Tf: Feedforward torque
Tb: Feedback torque
Ta: Assistance torque
V : vehicle velocity
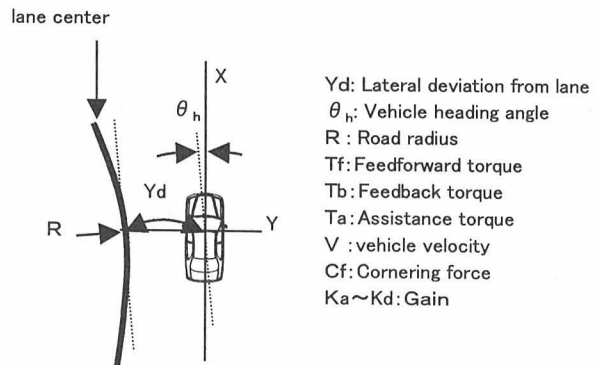Cf: Cornering force
Ka~Kd: Gain

Fig. 3 Geometric model

3.1.2. Evaluation of System Performance (steering torque and steering angle).

A comparison of steering characteristics was made between vehicles fitted with this system and those without this control (driving data from the lanes on the Tohoku Expressway, with a cruising speed of 100km/h, a travel distance of approximately 50 km). Fig. 4 shows a comparison of steering torque distribution. From these results, it is clear that in comparison with vehicles not having the control, those having LKAS have a greatly reduced steering torque.[7]
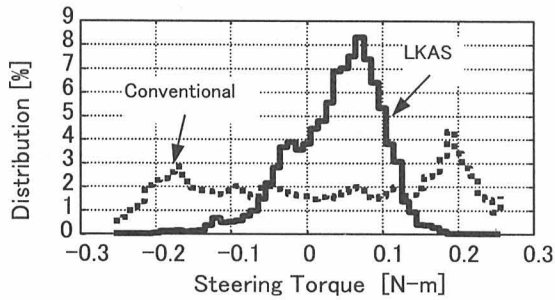
Fig. 4 Normalized Distribution of Steering Torque

3.2. The Adaptive Cruise Control System with Stop & Go Control (ACC+Stop & Go)

This system is a driving load reduction system that assists in maintaining the distance between the vehicle concerned and the vehicle in front of it. The system carries out deceleration and automatic stopping in traffic jams, etc. and follows another vehicle across a wide range of speeds. Fig. 5 shows the control algorithm. Using a millimeter-wave radar sensor, the driving status of the vehicle in front is detected. The driving status of the vehicle fitted with the support system is detected with the vehicle speed sensor and yaw rate sensor, and in this way the system focuses on vehicles in front in the same lane. When the distance to the vehicle in front becomes short, there is deceleration through the throttle, and if that deceleration is insufficient, deceleration is carried out through the main brakes. In this way, an appropriate
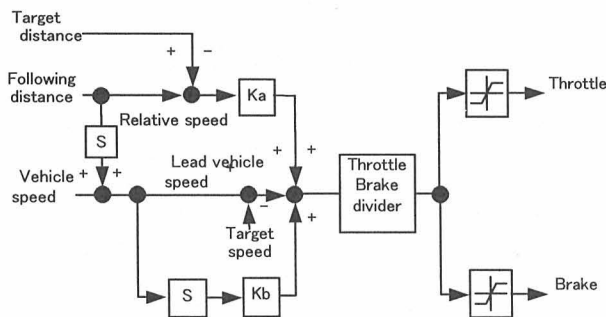
distance between the vehicles is maintained. At the same time, the driver is warned through the use of a warning device. Moreover, when the vehicle in front speeds up and the distance between the vehicles widens, the system functions as normal cruise control. The principle on the following control is to aim for ordinary driver operation characteristics and equivalent acceleration and deceleration. The means of achieving these characteristics is to fully consider a separate algorithm for appropriate acceleration and deceleration.

3.3. Rear-end Collision Velocity Reduction System (CVRS: Collision Velocity Reduction System)

When the distance to the vehicle in front becomes short, the driver is notified by a warning sound. If the driver does not respond and the distance to the car in front becomes so short as to be dangerous if nothing is done, the driver is prompted to avoid an accident by steering and braking, through a warning sound and braking. Furthermore, when it is judged that the rear-end collision is unavoidable, there is emergency braking to assist the driver's braking operation, causing the rear-end collision speed to drop, and reducing collision damage.

3.4. System Configuration

Fig. 6 shows a system configuration integrating the above three functions. Fig. 7 is the control block diagram. A CCD camera is fitted at the top of the windshield and a millimeter-wave radar device is inside the front bumper, detecting the lane mark and the vehicle in front. The system drives EPS, throttle actuator, and electronic control master power (E-M/P), etc., providing lane keeping and headway maintenance control.
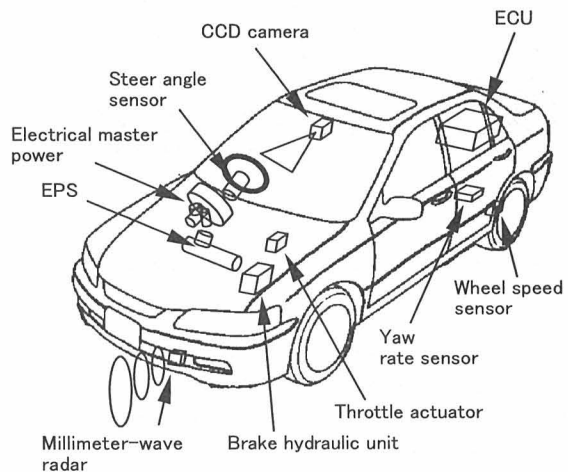

Fig. 5 Algorithm of ACC+Stop&Go

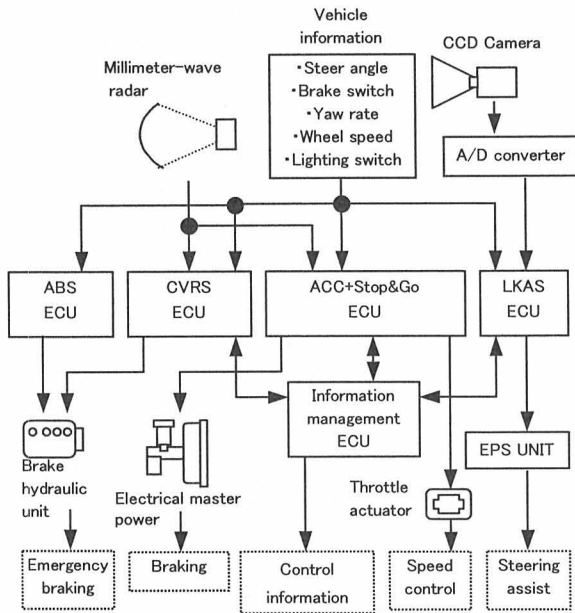**Fig. 6 Configuration of ASV-2 vehicle 1**

Fig. 7 Block diagram of ASV-2 vehicle 1

4. Measures to Improve Recognition of Vulnerable road users

4.1. Honda Night Vision System

This system works at night, informing the driver of pedestrians that are far from the headlight high intensity of illumination area and are difficult to see with the naked eye, with a voice guidance or highlighted image. It is a sense of sight support system. Fig. 8 shows the operation state when the system is providing information.
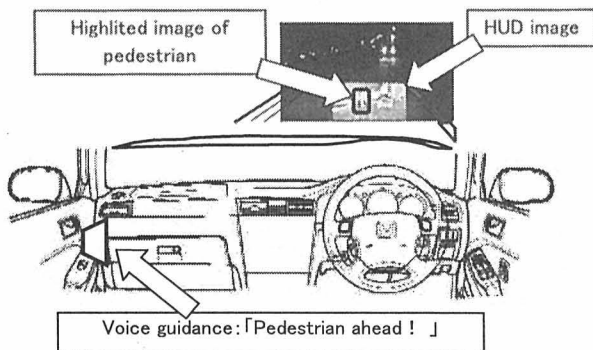

Fig. 8 Example of HUD image and voice guidance

4.1.1. Pedestrian Detection Method. As shown in Fig. 9, the distance to the pedestrian, the pedestrian's location, and size are calculated through stereo infrared camera image processing. Next, relative movement vectors are determined from the vehicle speed information and time change. Then, two areas are determined – approaching
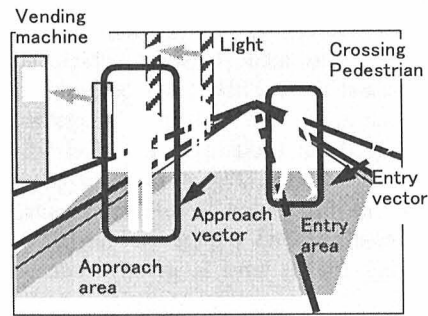

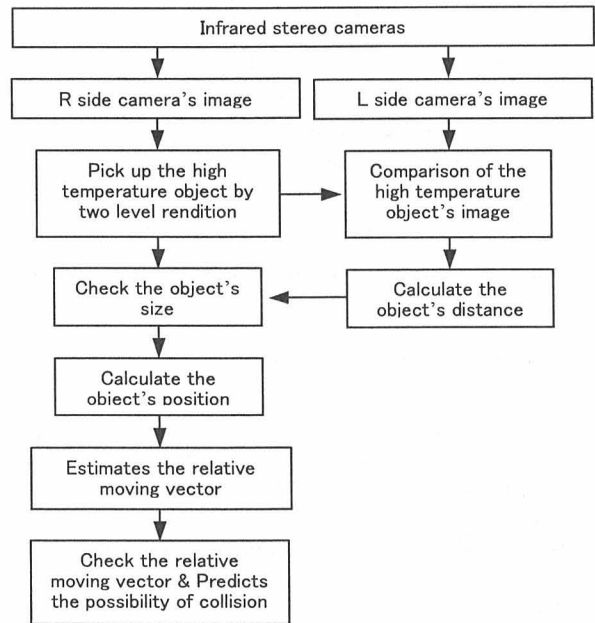**Fig. 9 Principle of pedestrian detection**

Fig. 10 Processing flow of pedestrian detection

and entry – and judgment is made about whether the subject enters these areas. Fig. 10 shows the processing flow. [8]

4.2. Active Headlight System

At intersections or curves, corresponding to steering wheel steering angle and vehicle speed, this system moves the upper reflector, giving light that matches road shape. Thanks to this, the road state is accurately understood and the driver's line of sight into the curves is effectively drawn, aiding in stable driving. This makes it possible to detect pedestrians in a timely manner. The internal structure and operation state are shown in Fig. 11. The upper reflector is moved by a stepping motor controlling light distribution. Fig. 12 compares the active headlights with conventional headlights in terms of light distribution.
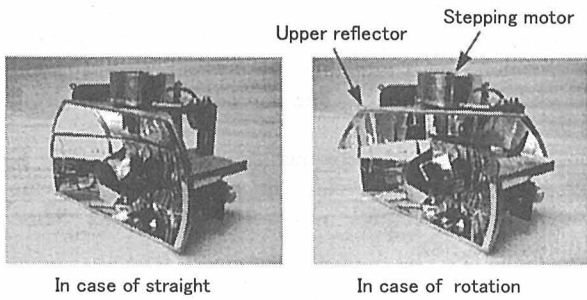
Upper reflector   Stepping motor

In case of straight   In case of rotation

Fig. 11 Active head-light mechanism

Conventional   Active headlight
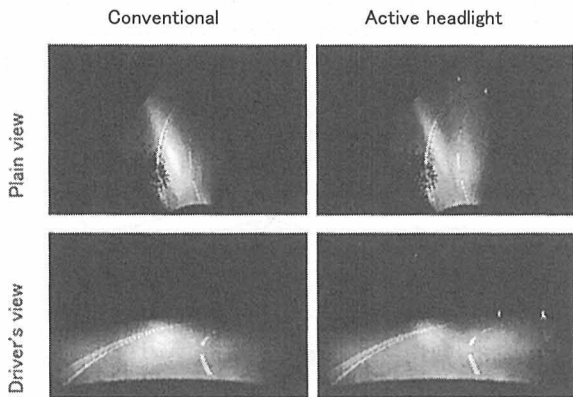

Plain view

Driver's view

**Fig. 12 Comparison due to the existence
of the control**

4.3. Motorcycle-Automobile Information Communication System
(IVCS: Inter-Vehicle Communication System)

As shown in Fig. 13, a typical accident between motorcycle and automobiles is a crossing collision or a right turn accident. The purpose of this system is to prevent these accidents in advance. Fig. 14 outlines the system. It is a system with both the motorcycle and the automobile having communication equipment, providing each other with the necessary information, and providing warnings of proximity through displays or voice messages. This system reduces overlooking the other vehicle or misjudging the approaching speed or distance.
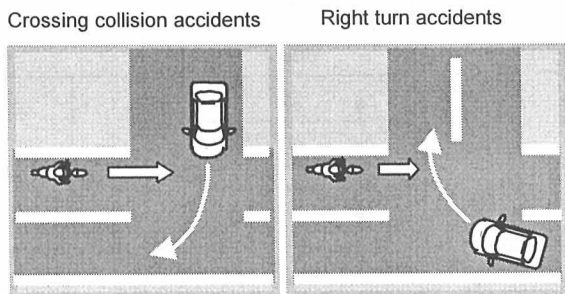
The recognition support system is composed of a

Crossing collision accidents   Right turn accidents

**Fig. 13 Typical traffic accidents
between automobile and motorcycle**
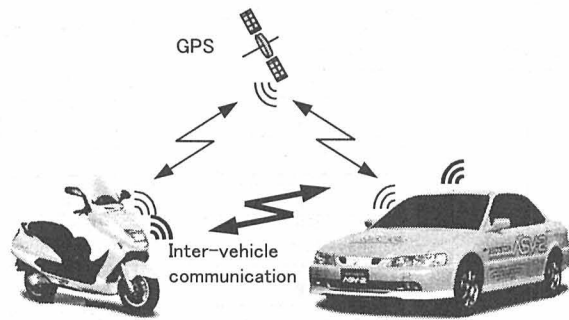

GPS

Inter-vehicle
communication

Fig.14 Inter-vehicle communication system

control ECU that controls vehicle information and communication, a range unit for inter-vehicle communication and an HMI (Human Machine Interface). Basically the same system is fitted to the motorcycles and automobiles.

4.3.1. System on the Automobiles. The system diagram is given in Fig. 15. A GPS and range communication modem, etc. as well as NAVI system are connected to the control ECU that processes vehicle information control and communication control. As shown in Fig. 16, the position of the motorcycle is shown on the NAVI display in real time. In addition, a symbol may be
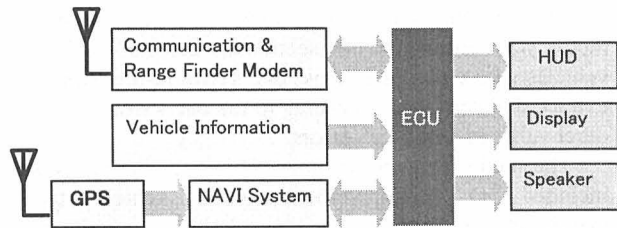

Communication &
Range Finder Modem

Vehicle Information

GPS   NAVI System

ECU

HUD

Display

Speaker

Fig. 15 Block diagram of Automobile System
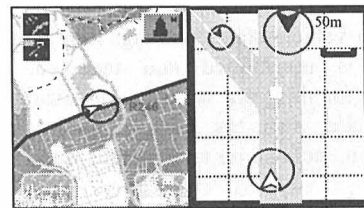

50m

Fig. 16 NAVI Display Information
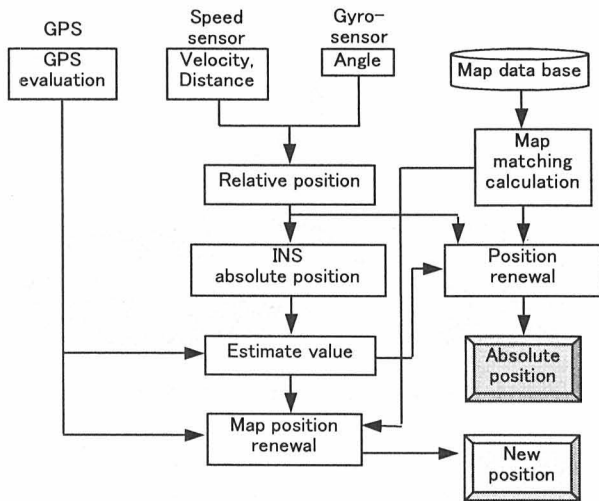

Fig. 17 HUD Caution Symbol

Fig. 18 Estimated positioning algorithm

projected onto the front window using a high luminance HUD (Head Up Display) in response to conditions, as shown in Fig. 17. Moreover, vocal cautionary information is provided.

Fig. 18 shows the control algorithm. As a result of developing an algorithm that assesses the latest car position from the position information provided by the GPS, vehicle speed, acceleration and deceleration, and the yaw rate, positioning errors are kept to a minimum, and position can be found in real time.

At approximately 200m before an intersection, motorcycles around the intersection are detected, and any vehicles whose path may cross one's own future path are extracted, determined according to the one's own and the other vehicles' cruising vectors.

The main content of inter-vehicle communication includes ID (motorcycle/automobile vehicle type identification), current position (latitude, longitude), vehicle speed, estimated position, location of next intersection, time until the next intersection is reached, number of vehicles from which signals are received, one's own vehicle state (braking, turn signal, etc.), and all data is transmitted and received. The update frequency for this data varies automatically in response to the state, such as vehicle speed, proximity to intersection, etc. and an autonomous distributed network is created.

4.3.2. Inter-vehicle Communication Range Modem
There are often occasions when accuracy of radio waves from a GPS satellite drops, due to being blocked between tall buildings or under an elevated bridge, etc., or due to multi-pass, etc. In this project, an SS (spread spectrum) communication range modem was developed, that makes it possible to measure direct relative distance during inter-vehicle communication under these kinds of conditions. The spread spectrum communication method has good multi-pass characteristics, and because it is

possible to measure the distance to the other communication party at the same time as transmitting information, by combining the system with a high-accuracy GPS without adding new equipment, the system is given redundancy.

This inter-vehicle communication range modem is fitted to both motorcycles and automobiles, and the communication control uses a CSMA (Carrier Sense Multiple Access).

4.4. System Configuration

The system installation diagram is shown in Fig. 19, and Fig. 20 is the control block diagram. Pedestrian detection is carried out by two infrared cameras placed
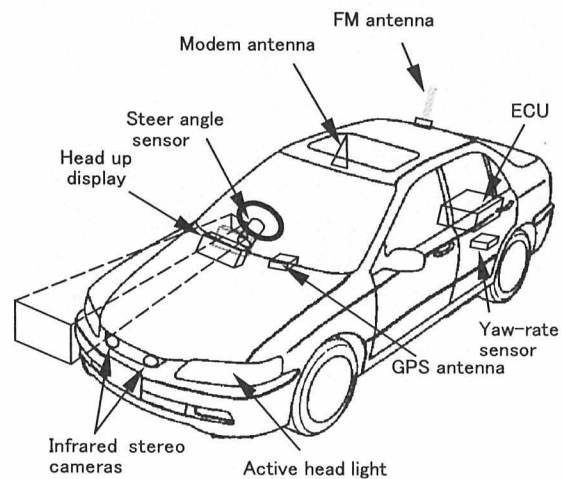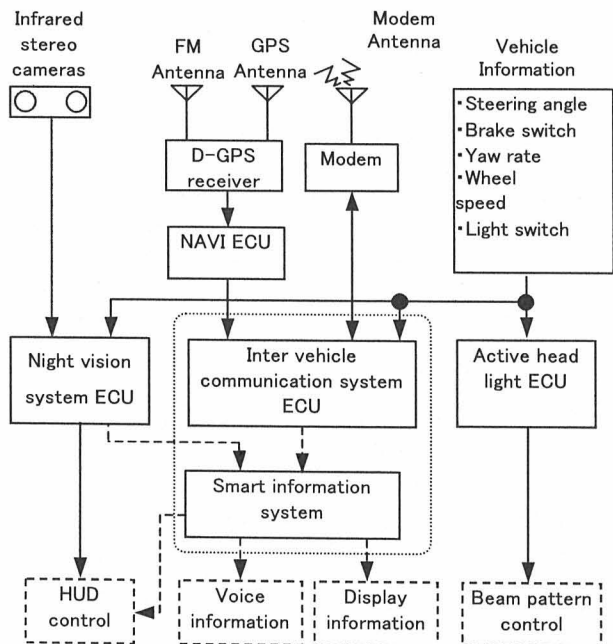

Fig. 19 Configuration of ASV-2 vehicle 2

Fig. 20 Block diagram of ASV-2 vehicle 2

inside the front grill. The active headlight light distribution control is linked to steering wheel angle. The motorcycle and automobile information communication system uses a communication modem antenna on the roof, carrying out communication with nearby motorcycles. Warning information is given by sound and image. The image is shown with both a head up display and on the navigation screen.

5. Measures to Improve Motorcycle Active Safety

5.1. Motorcycle-Automobile Information Communication System

5.1.1. System on the Motorcycles.
For motorcycles, which require lightweight and compact systems, information about the location of intersections is obtained from communication with the automobiles, rather than from map data displayed on a navigation system. A judgment is made about whether or not the future paths of the vehicles will meet, from the motorcycle's vector – calculated from its position and direction – and the vector of the automobile. Fig. 21 shows the system block diagram.

Fig. 22 gives an outline of system configuration. The HMI gives due consideration to motorcycle characteristics, and Fig. 23 shows HUI (Head Up Indicator) displayed, so that it is possible to confirm with the peripheral vision of the rider. Fig. 24 shows the structure of the speakers built into the helmet.
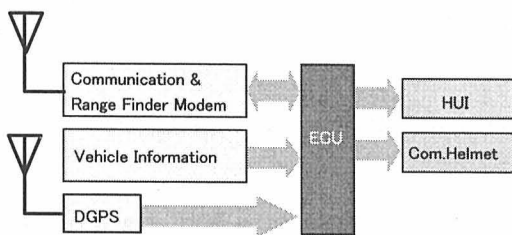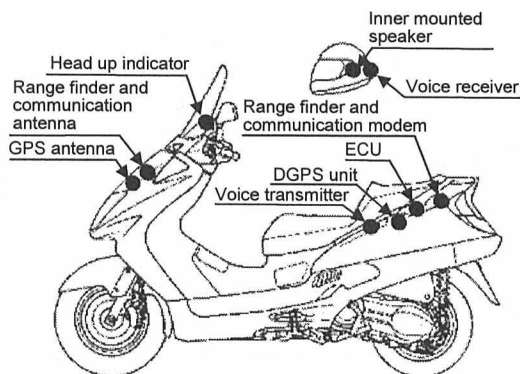

Fig. 21 Block Diagram of Motorcycle System

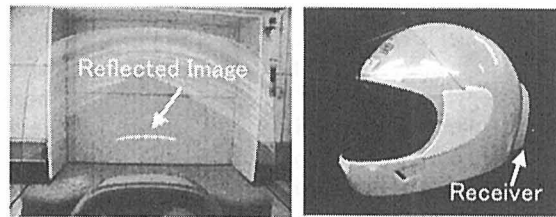
Fig.22 Outline of Motorcycle System

Fig. 23 Image of HUI   **Fig. 24 Communication Helmet**

5.2. Discharge Headlights for Motorcycles

With the adoption of discharge headlights on motorcycles, there are two technological issues unique to motorcycles.
(1) Because the light uses a high voltage of 20kV and the high voltage parts are near the rider, electric shock countermeasures are needed.
(2) The rider's eye point is higher than when in an automobile. In addition, the center area is brighter and it is more likely to sense the light and dark difference.
The first of these technological issues is dealt with by having the high voltage parts completely within the headlight housing, carrying out electric leakage treatment for each part, then a structure so that the rider does not receive an electrical shock even when immersed in water is created. The second technological issues is dealt with by taking the conventional halogen headlight, which makes it difficult to sense the light and dark difference, as the target, implementing a lens cut that makes brightness changes more gentle, and then light distribution that makes the sense of light and dark differences on a par with conventional lights is actualized. Fig. 25 gives an overview of this system.
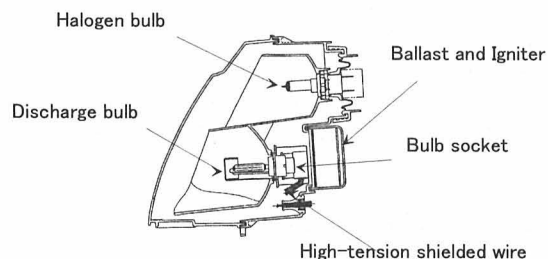
Fig. 25 Cross Section of Discharge Headlight

5.3. Development of the new tire

Because motorcycles drive on the road shoulder or in alleys more frequently than automobiles do, they often have flat tires. In addition, there is no spare tire fitted, so when there is a flat tire, it is not possible to continue driving. As shown in Fig. 26, the structure of this tire, namely TUFFUP tires has a double structure on the tire air chamber side, and the tread side chamber is filled

with 1.2mm of newly developed, special "air leak preventing gel". The gel is composed of a high viscosity material of various types of fibers and ceramic powder to which propylene glycol or an adhesive, etc. has been added. If there is a hole, the gel is pushed out due to internal pressure, and due to the tread rubber's elasticity the fibers in the gel, etc., are caught and the air leak is prevented.
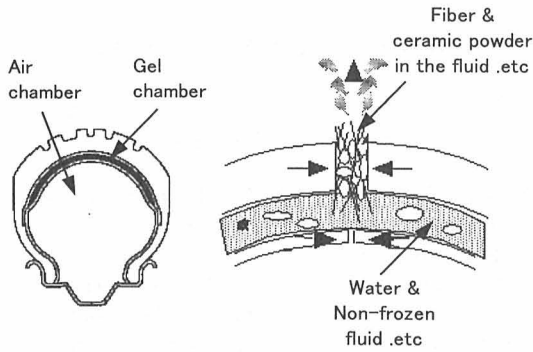

Fig. 26 A way of block in the puncture

5.4. Air Pressure Monitor

Air pressure drop prediction, when a motorcycle is being driven, has long been a strong desire. This system warns the driver when the air pressure drops. The structure is such that, integrated with the tire valve, air pressure and temperature sensors are inside the tire, and data is transmitted periodically using radio waves, using power from the built-in battery. Battery life is set at six years minimum. The radio waves are sent to the receiver in the body of the motorcycle, processed, and shown on the display parts. As for the control detail, the system calculates air pressure leak speed, the interval between transmissions becomes shorter in response to a leak, and the rider is informed at an early stage. In addition, by monitoring tire internal temperature, when it reaches an abnormal temperature of 100°C~150°C, there is a tire burst warning.

6. Motorcycle Rider Protection

6.1. Airbags for Motorcycles

This system aims to reduce injury when the rider impacts the other vehicle, etc. after being thrown from the motorcycle, by absorbing the rider energy during the front collision using an airbag.

As shown in Fig. 27, the special features include the V shape of the airbag's back that comes into contact with the rider, and the connection support to the under-seat frame using the belt. The sensor system consists of acceleration sensors, attached to the left and right of the
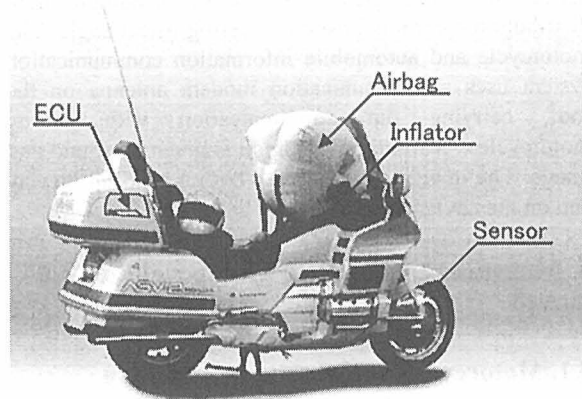

Fig.27 Airbag for Motorcycles

Table 1 Prototype Airbag Specifications

Volume (Liter)	120
Heightx width x length (mm)	630 × 500 × 615
Vent holes (mm)	Φ50 × 2 holes
Bag mounting point	1) module box 2) motorcycle frame, via 2 connecting belts
Inflator:	Pyrotechnic passenger car type 450kPa maximum pressure

front fork's bottom case, and an ECU unit. The airbag is deployed when one of sensors sense acceleration. The specification is given in Table 1. [9] [10]

7. Road Infrastructure Cooperation (Automobiles)

With an autonomous system, in a road environment where detection is difficult and outlook poor, obstacles (dropped items, vehicles, pedestrians) and road surface information (rain, snow, slippery conditions) are detected by the road infrastructure sensors, and that information is transmitted to the traveling vehicle through road-vehicle communication. This makes it possible to provide the driver with information and to make warnings or control the vehicle, etc. Honda has carried out proving tests for the following five systems.
· Forward Obstacle Collision Prevention Support System
· Intersection Stopping Support System
· Crossing Collision Prevention Advisory System
· Right Turn Collision Prevention Advisory System
· Crossing Pedestrian Collision Prevention Advisory System

8. Road Infrastructure Cooperation (Motorcycles)

For motorcycles, six proving tests have carried out including for the support systems in Section 6 and with the addition of the Curve Overshooting Prevention Support System.

9. Estimates of Accident Reduction Effect

For the systems developed (other than infrastructure cooperation), estimates were made of the benefits, based on the Japan Automobile Research Institute's accident reduction effect estimation method. The method of calculation is to take the number of incidents in statistics of accident situations related to the system being evaluated, multiply it by the relevant factor which corresponds to the system, and then multiply together the accident detection rate and safety operation rate. The results of these calculations are given in Table 2 and Table 3, and clearly show that accident reduction benefits can be expected.

Table 2 Ratio of the decrease prediction of the number of the traffic accident people

System of ASV vehicle 1	Fatalities	Casualties
Collision velocity reduction system	−2.1 %	−11.5 %
ACC with stop & go system	(−0.1 %)	(−0.4 %)
Lane-keep assistance system	−0.1 %	−0.1 %
Total	−2.2 %	−11.6 %

System of ASV vehicle 2	Fatalities	Casualties
HONDA night vision system	−6.1 %	−2.4 %
Active headlight system	−0.7 %	−0.3 %
Inter −vehicle communication system	−3.6 %	−5.1 %
Total	−10.4 %	−7.8 %

Table 3 Effect of motorcycle accident decrease rate

System of ASV vehicle 3	Fatalities	Casualties
Inter−vehicle communication system	−12.2 %	−8.9 %
Discharge headlight for motorcycles	−0.3 %	−0.03 %
TUFFUP tires	−0.3 %	−0.04 %
Air pressure monitor system	−0.5 %	−0.06 %
Total	−13.3 %	−9.0 %

System of ASV vehicle 4	Fatalities	Casualties
Airbag for motorcycles	−6.1 %	−7.6 %

10. Conclusion

In Phase 2 ASV, Honda established its projects "reducing driving load, protecting pedestrians and motorcycles, and reducing damage". As a result of Honda's research, the outlook for each system's functions and performance evaluations looks promising. In addition, benefit proving tests were carried out, and it was confirmed that the systems are effective in reducing accidents. Moreover, the lane keeping and lane departure warning system and the active headlight system have received certification from the Japanese Minister of Land, Infrastructure, and Transport, and were tested on public roads.

In the ASV project, this is the first time that motorcycles have been included. For some system, such as the airbags for motorcycles, the research is at a fundamental stage.

In the future, based on Honda's special strengths in handling both motorcycle and automobile products, Honda will work towards creating a traffic society where pedestrians, motorcycles, and automobiles can exist together in greater safety.

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