Field Test Results of Intelligent Delineator System

Intelligent Transport System Technology Research and Development for Winter Traffic

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The intelligent delineator system is a light-emitting delineator incorporating a pole-type visibility meter and a car halt surveillance radar. When visibility is reduced it emits light to warn drivers, and it detects stopped cars to warn followers. The development of this system was begun in 1993. Initially a pole-type visibility meter was developed for this system, and its performance was examined in field tests in winter 1993–1994. The light-emitting delineator with this pole-type visibility meter was installed at a median strip on a national highway near Sapporo, Japan, in winter 1994–1995 for the on-site test. It was found that the pole-type visibility meter has sufficient accuracy and stability in operation. A car halt surveillance radar, which uses milliwave technology to detect stopped cars in blowing snow conditions, also was developed. Its performance was examined in field tests and on the same highway in winter 1995–1996. The car halt surveillance radar and the total system have shown enough possibility for further practical development. The Hokkaido Development Bureau is now developing a special research plan focusing on intelligent transport system (ITS) technology research and development for winter traffic, called the ITS/Win Research Program. The development and the field test results of the intelligent delineator system are reported, and research-and-development challenges for the ITS technology for winter traffic in Hokkaido are addressed.

Reduced visibility caused by blowing snow on highways has been a key issue for winter traffic safety in Hokkaido, Japan. In recent years, high-grade trunk roads have expanded in Hokkaido and many multi-vehicle winter collisions have occurred. Following drivers must know immediately when a car is stopped because of an accident or difficulty in driving under reduced visibility conditions. Lack of warning may be a cause of multiple-vehicle collisions. In fact, on March 17, 1992, the largest accident in Japan occurred under reduced visibility conditions in snow on the expressway near Sapporo. It involved 186 vehicles.

Development of the intelligent delineator system was begun in 1993 (*1*). The system is a light-emitting delineator incorporating a pole-type visibility meter and a car halt surveillance radar (CHSR) using milliwave technology. When visibility is reduced because of blowing snow or other causes, the system emits light to warn drivers, and it detects halted vehicles and warns the followers. Figure 1 (*1*) shows the composition of the intelligent delineator system. Figure 2 (*1*) shows the concept of the intelligent delineator system installed on a median strip. The CHSR detecting an accident in reduced visibility conditions is shown.

Pole-Type Visibility Meter

The pole-type visibility meter was specially developed for the intelligent delineator system. Because it is used in combination with a light-emitting delineator, the measuring part is in the shape of a vertical pole with a diameter as small as possible. Figure 3 shows the block diagram of the pole-type visibility meter. It emits near-infrared rays. The measuring area is formed by crossing light-receiving

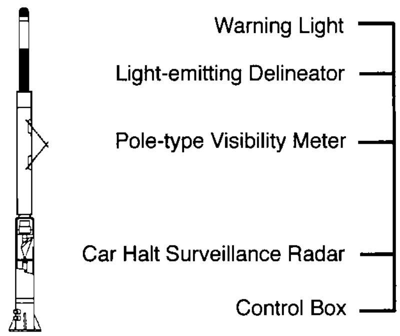


FIGURE 1 Composition of intelligent delineator system.

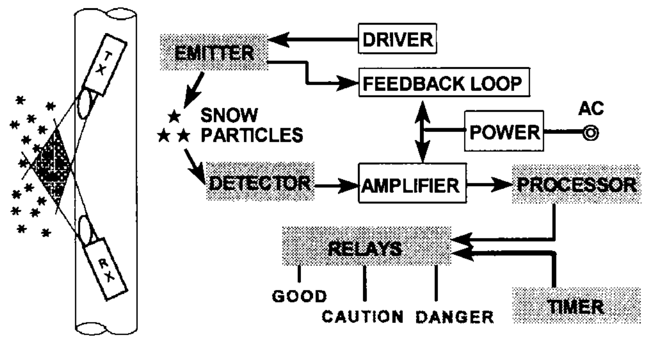


FIGURE 3 Pole-type visibility meter.

beams only in a sampling zone. The projected rays are scattered to the front or diagonally to the front by particles of snow flying into this zone, and the intensity of scattered rays is measured by the detector. The received signals are then processed by an amplifier, a signal discriminator, and an output discriminator, and reduced visibility signals are generated. In signal processing, background light is removed by high-speed modulation, and a feedback function to automatically stabilize light sources is performed. Output signals are obtained based on the visibility categories of "Good," "Caution," and "Danger" with a timer (1 to 999 sec).

Figure 4 (*1*) shows the calibration curve of this device and visibility during the daytime. From the field observations in winter for 3 years and comparative experiments in a smoke test room, the practicality of this new pole-type visibility meter has been proved.

CHSR

The CHSR is a milliwave (59.5 GHz, 70 mW) FM-CW radar. It measures the direction and distance of the target object by using rotating horizontal pencil beams approximately 80 cm above the ground. It judges the existence of halted vehicles by referring to the calibration data collected when there were no halted vehicles. Whereas the maximum detection distance of the system used in the test in the winter of 1994–1995 was 60 m, it was extended to 110 m in the winter of 1995–1996. This was achieved by improvement of software to limit the measurement area on the road.

Figure 5 shows the block diagram of the CHSR. An offset parabolic antenna rotates once every 2 to 3 sec in a cylindrical frame. This causes the transmission of sharp waves of beams sweeping continuously and horizontally at about 80 cm above the road surface. Because reflected waves are received every 4° between the angles of 0° and 90°, a total of 23 steps of signal can be obtained. Analog-to-digital conversion and fast Fourier transformation (FFT) processing of these signals yield a total of 128 power spectra. By representing the frequency on the abscissa axis and the intensity of signal on the ordinate axis of a bar graph, spectral arrays are obtained.

Figure 6(*a*) shows the monitor screen at the evaluation of the CHSR. The upper part shows the received waves (beat signals) and the lower part is the spectrum diagram after FFT processing. On the monitor screen in Figure 6(*b*), the horizontal axis represents the distance and the vertical axis represents the angle. The angle was measured every 4° starting from 0°, and the height of the wave represents the level of received waves. As the measurement area was limited on the road by 23 sweeping beams, the signals are hyperbolically interrupted.

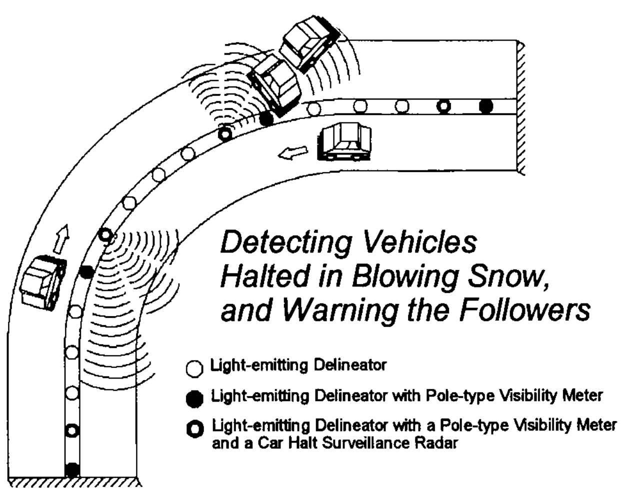


FIGURE 2 Concept of intelligent delineator system.

Field Tests of CHSR in Winter 1994–1995

A test to detect halted cars on a winter road was conducted in February 1995. The test was conducted in light snowfall and in heavy snowfall artificially made by using a rotary snowplow. Snow was blown to a height of about 20 m and a stable snowstorm and reduced visibility conditions throughout the test site were created.

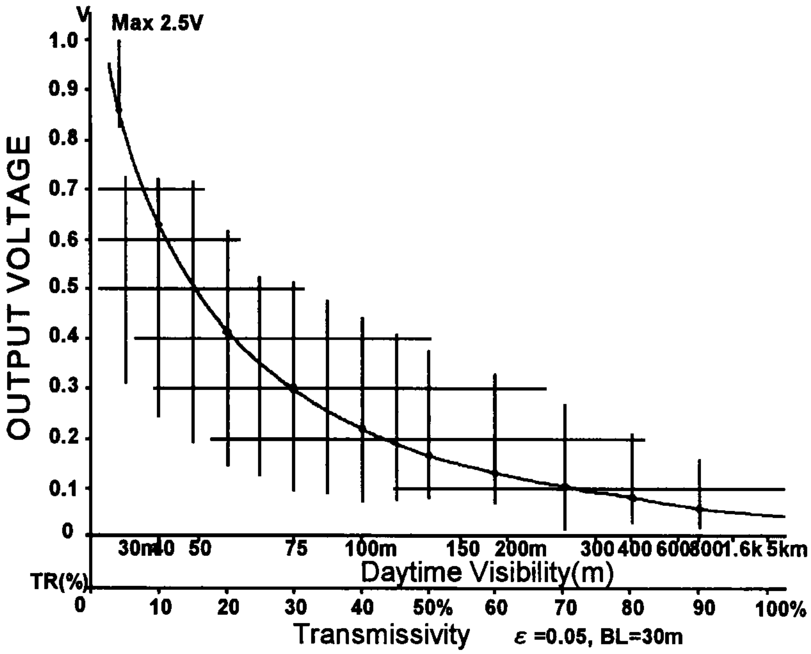


FIGURE 4 Visibility conversion curve.

Figure 7 shows the field test of the CHSR in the winter of 1994–1995. The detection results were satisfactory. A small vehicle about 40 m away could be detected without fail even when the visibility was as low as 10 m. The presence or absence of snowstorm conditions makes almost no difference in the figure. Moreover, a warning signal to indicate the existence of a halted car was sent out even when the car was buried under snow.

Field Tests of CHSR in Winter 1995–1996

On the basis of improvements to the system that were produced experimentally in the winter of 1994–1995, fields tests were conducted in the winter of 1995–1996 to detect vehicles in reduced visibility conditions caused by snowstorms. The maximum detection distance was confirmed and the response time was verified. The tests

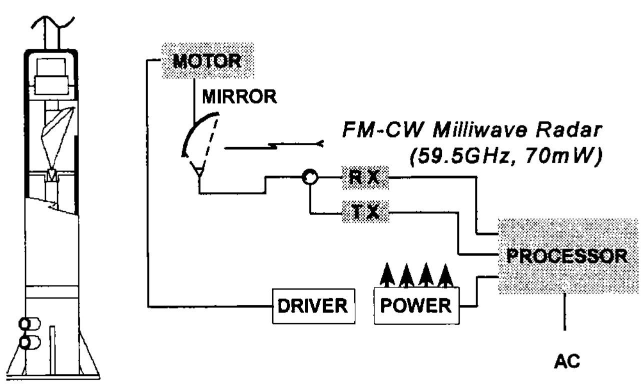
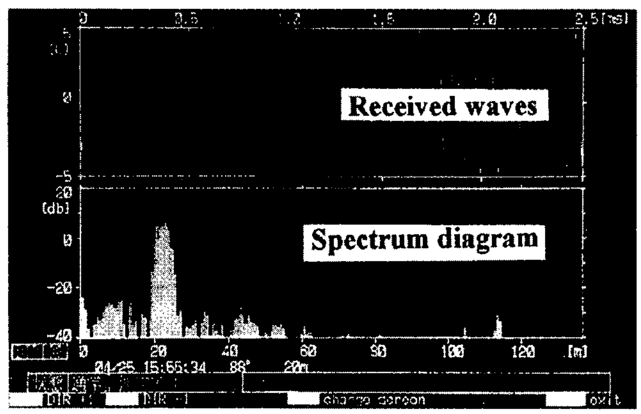
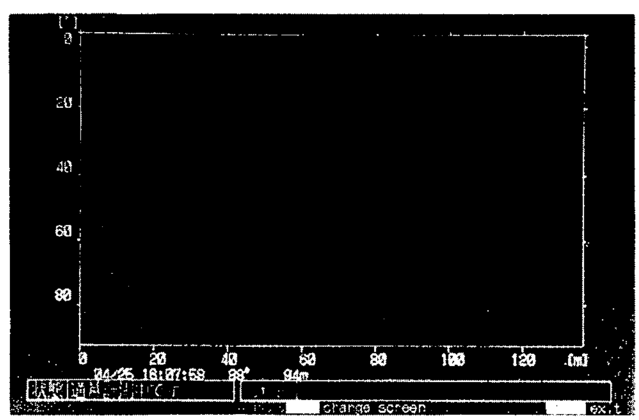


FIGURE 5 Car halt surveillance radar.



(a)



(b)

FIGURE 6 Monitor screen at evaluation of car halt surveillance radar.

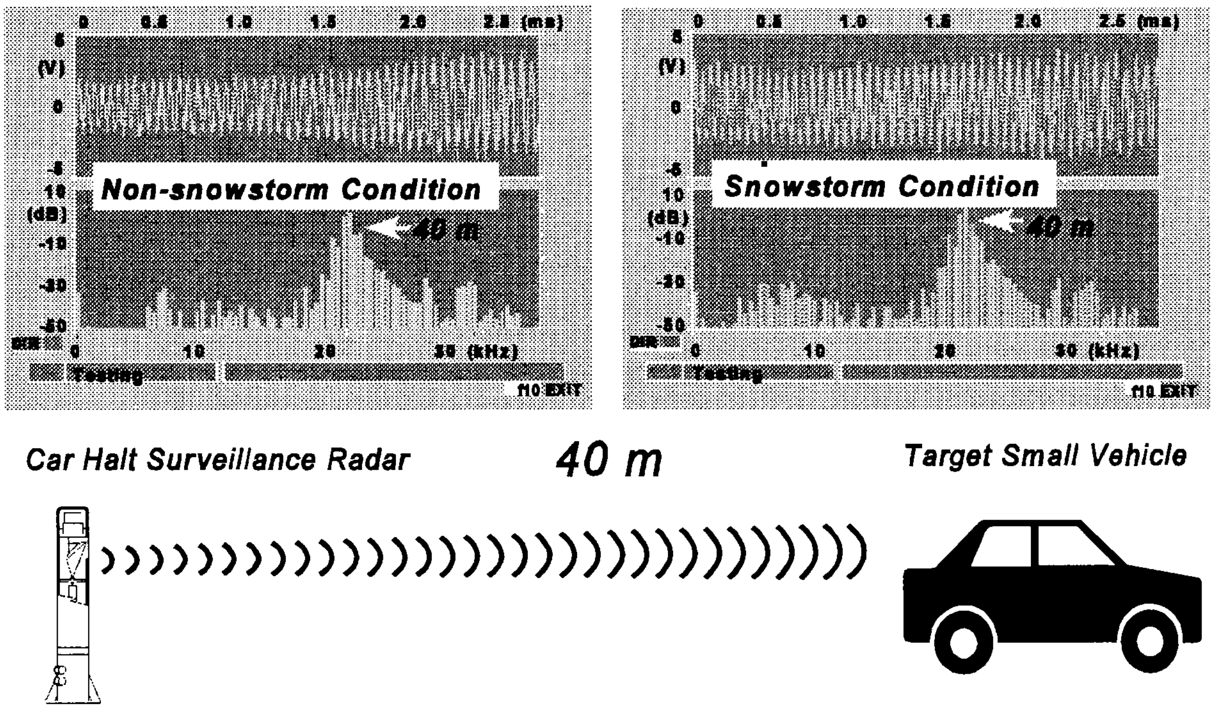


FIGURE 7 Field test of car halt surveillance radar in winter 1994–1995.

were conducted twice at the Ishikari Blowing Snow Test Field, on January 18 and March 22, 1996, and once on the Ebetsu section of National Route 12 on February 22.

Tests were conducted using four types of vehicles—a mini, a subcompact, a recreational vehicle, and a bus—to simulate actual driving conditions. Figure 8 shows the CHSR and a test condition in which the CHSR was placed at the 0-m point on a 10-m-wide, 120-m-long test road to detect cars every 20 m (Figure 9).

Tests on January 18, 1996

On January 18, 1996, a northwesterly wind was blowing at speeds of 5 to 8 m/sec, the temperature was –11°C, and visibility was 20 to 100 m. Four types of vehicles were stopped at intervals of 20 m, and the confirmation of detection and measurement of response time were done at the same time. The measurement was conducted at each interval for each car type. Although all the cars were detected, the response time was 15 to 30 sec and stable results could not be obtained. The area-setting and automatic measurement programs used in the test were still under development.

FIGURE 8 Car halt surveillance radar and field test in winter 1995–1996.

Tests on March 22, 1996

On March 22, 1996, a northwesterly wind was blowing at speeds of 5 to 6 m/sec, the temperature was –2°C, visibility was 100 to 200 m, and there was snowfall. The test was conducted for four types of vehicles on the same road setting as for the previous test, and the improved area-setting and automatic measurement programs were used. Vehicles up to 110 m away could be detected without fail. The response time, which was thought to be a problem on January 18, was 6 sec at all points (at this stage, the rotation speed was 2 sec per rotation and detection was made for three rotations) and stable detection was confirmed. To verify the detection, the measured data were recorded on the hard disk of a personal computer and lighting of the red lamp was checked visually. The test results are shown in Table 1. Although the milliwave has been proved to be an all-weather sensor that is not affected by snow, fog, or other weather conditions, the detection of all types of vehicles in the

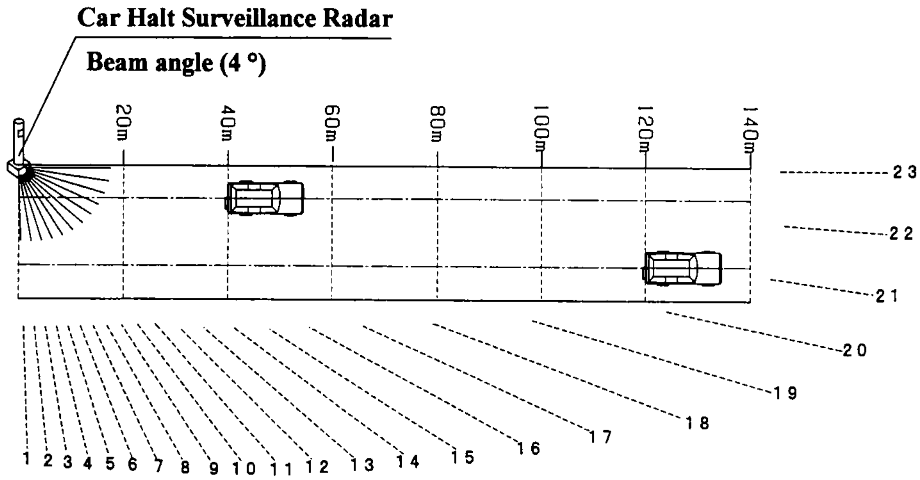


FIGURE 9 Field test layout of car halt surveillance radar in winter 1995–1996.

heavy snowstorm with visibility of 100 m was considered significant.

Field Test of CHSR on National Highway Route 12

The CHSR was installed at the side of National Highway Route 12 (Ebetsu Section). It has been working automatically without an operator since January 1996. Its performance has been checked by manual test (Figure 10) and by using images from an ITV camera installed near the system. ITV camera images showed that the CHSR could detect snowplows and other halted vehicles.

ITS/Win Research Program

The development of technologies for the intelligent transport system (ITS) has been under way nationwide in Japan. Through advancement of information communication technologies and the development of vehicle and highway intelligence technologies, the system will allow the unified functioning of people, vehicles, and highways. It will also lead to the improvement of traffic safety and efficiency, amelioration of the environment, a more enjoyable driving experience, and the founding of new industries. The Hokkaido Development Bureau (HDB) has established the Committee of Intelligent Transport Systems within the bureau to consider the application of ITS technology. The committee is developing the ITS/Win Research Program, which focuses on ITS technology research and development for winter traffic. It includes 17 research projects, such as the development of the intelligent delineator system, the intelligent ITV camera, and a highway information system using Internet technologies (i.e., Intranet technology).

The program is categorized by three concepts: (*a*) directly avoiding danger by introducing intelligent ancillary road facilities (the Intelligent Winter Highway System); (*b*) indirectly reducing accidents via advanced highway information systems, thereby decreasing anticipated dangers (the Winter Highway Information System for Traffic Safety and Efficiency of the 21st Century); and (*c*) building a comprehensive highway disaster prevention information system. The goals of the ITS/Win Research Program are to (*a*) formulate solutions to traffic problems specific to Hokkaido winters; (*b*) increase efficiency of snow removal and road surface maintenance and management during winters; (*c*) create sophisticated response systems for disasters such as large-scale earthquakes; (*d*) resolve the year-round traffic safety problem in Hokkaido; and (*e*) provide improved road service specially tailored for Hokkaido.

The intelligent ITV camera has been developed to detect unexpected phenomena through image processing and to transmit messages widely and efficiently on the computer network in conjunction with the e-mail and

TABLE 1 Detection Results for Different Types of Vehicles

Car Type	Direction	20 m	40 m	60 m	80 m	100 m	110 m	120 m
Mini	Rear	**D**[a]	**D**	**D**	**D**	**D**	**D**	**ND**[c]
Sub-compact	Rear	**D**	**D**	**D**	**D**	**D**	**D**	**ND**
Recreational Vehicle	Rear	**D**	**D**	**D**	**D**	**D**	**D**	**UD**[b]
Bus	Rear	**D**	**D**	**D**	**D**	**D**	**D**	**UD**

[a]**D**: Detection [b]**UD**: Unstable Detection [c]**ND**: No Detection

FIGURE 10 Field test of car halt surveillance radar on National Highway Route 12.

World Wide Web server systems. Digitized image information will be transmitted in various forms and will change the ITV camera from a simple monitoring tool to a part of a monitoring network with an operator. HDB has long been aware of the potential for using Internet technologies in highway information systems. The Internet's multimedia, on-demand, and interactive functions could be useful to the system. In fact, a system that provides real-time images of mountain passes where there are severe weather conditions during the winter is being built on the Internet. The Civil Engineering Research Institute of HDB opened an Internet homepage called Northern Roads (http://www2.ceri.go.jp/eng/index.htm), which introduced research and development activities including the ITS/Win Research Program in Hokkaido. HDB, in conjunction with the World Road Association's World Interchange Network program, is hoping to exchange information about the ITS/Win Research Program with all snowy, cold countries and regions that have similar problems with winter traffic safety and efficiency.

Conclusions

The intelligent delineator system is a light-emitting delineator incorporating a pole-type visibility meter and a CHSR. When visibility is reduced, the system emits light to warn drivers, and it detects halted vehicles and warns the followers. Evaluation tests were conducted on the pole-type visibility meter in the winter of 1993–1994 and on the CHSR by using milliwave technology in the winter of 1994–1995 and 1995–1996. It was confirmed that the pole-type visibility meter had sufficient accuracy and stability in operation. As for the CHSR, in the test of the winter of 1994–1995, a subcompact car could be detected from about 40 m away without fail in about 10-m visibility conditions, which were created artificially by a rotary snowplow. In the 1995–1996 winter, three tests were conducted from January to March; a mini, a sub compact, a recreational vehicle, and a bus all could be detected from 110 m away without fail in 100- to 200-m visibility conditions caused by natural blowing snow. The authors are convinced that the system is feasible for further development toward future field use. The milliwave is not affected by snowfall and it is strongly expected to be basic ITS technology indispensable for a winter driving support system.

Winter driving conditions are severe because of slippery road surfaces and reduced visibility conditions caused by snow. However, these conditions may be alleviated by ITS, which has the potential to significantly increase safety by supporting winter driving. The ITS/Win Research Program, which HDB is currently developing, is expected to make a large contribution to the improvement of winter traffic safety.

Acknowledgments

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Reference

1. Kajiya, Y., Y. Fukuzawa, and K. Ishimoto. Development of Intelligent Delineator System. *Proc., 2nd World Congress on Intelligent Transport Systems*, Yokohama, Japan, October 1995, Vol. III, pp. 1193–1198.