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Forward Obstacle Warning System - Laser Alarm -

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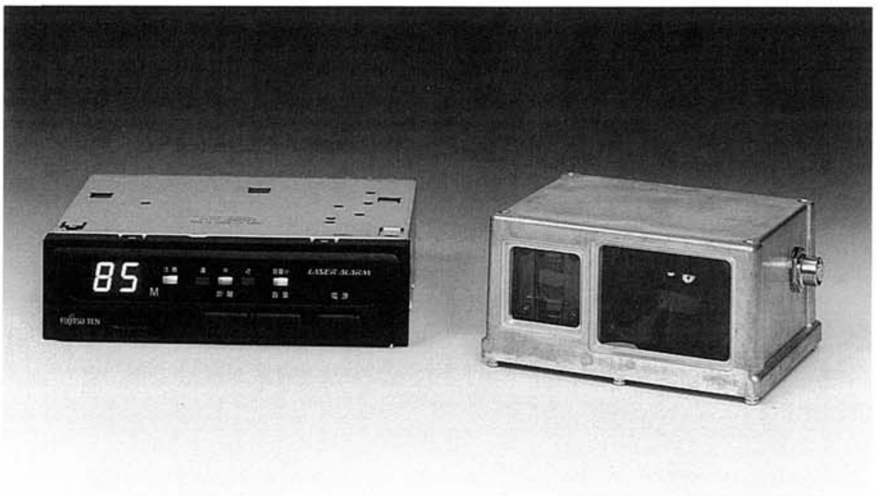

To help prevent truck and bus collisions, we have developed the "Laser Alarm," a forward obstacle warning system equipped with an infrared laser radar.

Using the laser radar, the Laser Alarm measures the distance and relative velocity of forward obstacle, with respect to the vehicle. This system automatically calculates the safety distance by measuring the distance, relative velocity and vehicle velocity-to warn the driver if a collision is imminent.

We incorporated new optical and signal processing mechanisms to make the system compact, light-weight, and even affordable. We also developed a unique logic technique to prevent unwanted warnings at road curves. This logic further enhanced the system reliability.

1. Introduction

Vehicles are an important means of transportation for society, allowing for a wide range of social activities. However, the increasing rate of traffic accidents year by year are posing a social problem.

People expect safer cars to help avoid collisions or protect drivers from collisions.

We added the "Laser Alarm" to our line-up of safety devices, such as anti-lock brake systems (ABS) and air bags, in the fall of 1994. This forward obstacle warning system for trucks and buses helps prevent vehicle collisions using a laser radar system.

This paper outlines the system design and introduces the system functions and performance.

2. Development background

When the causes of traffic accidents on expressways were analyzed, careless driving accounted for about 40% (Figure 1).

If a system can warn absent-minded drivers of forward obstacles, the number of careless collisions will decrease significantly.

The demand for this kind of safety system is especially high for long-distance drivers, such as truck-drivers and highway bus drivers. To satisfy this demand, we developed the Laser Alarm. The system is compact for easy installation in a vehicle and low priced.

3. System qutline

The Laser Alarm measures the distance and relative velocity between the vehicle and a forward obstacle using laser radar and generates a warning sound if a collision is imminent.

This chapter describes the system configuration, the radar and display unit performance, and the logic system for the warning generation.

3.1 System Configuration

As shown in Figure 2, the system consists of a laser radar unit, a display unit, and a vehicle speed sensor. These components are installed in a vehicle as shown in Figure 3.

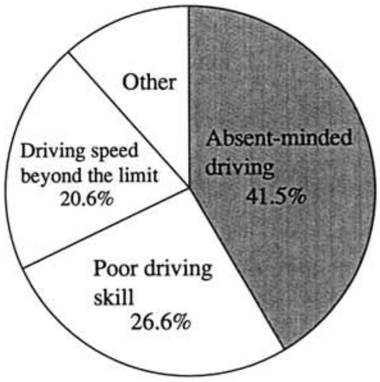

Figure 1. Causes of traffic accidents on expressways

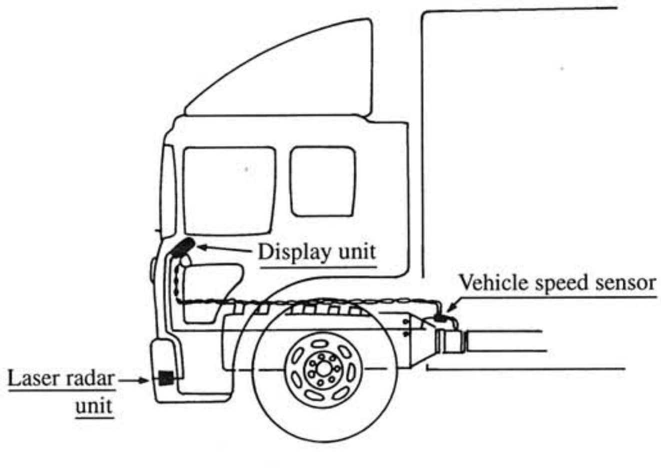

Figure 3. Installing devices in the vehicle

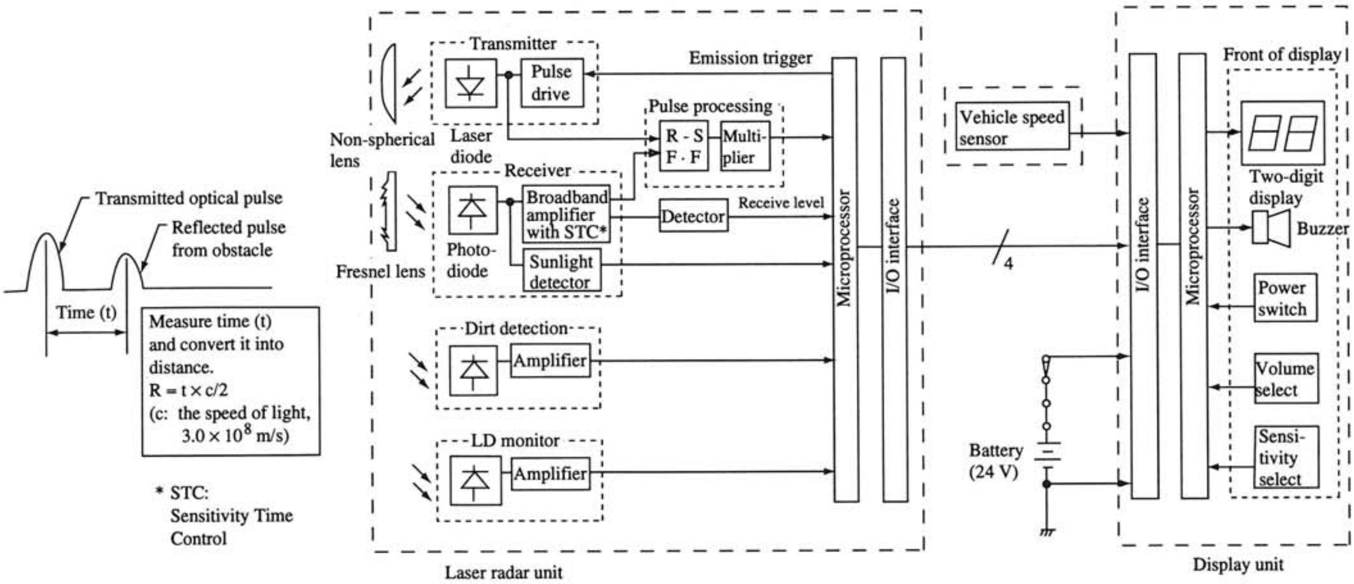

Figure 2. System block diagram

This system uses laser pulses for measurement. By measuring the time difference (t) between a transmitted pulse and a received pulse reflected from an obstacle, the distance (R) to the target is calculated as follows:

$$R = t \times c/2 \quad (1)$$

c: Speed of light (3.0×10^8 m/s)

The distance value is transmitted to the display unit as pulse-width modulated (PWM) data. The system calculates the relative velocity with the obstacle. The system then, judging from the self velocity, generates a warning if this relative velocity is over the threshold.

3.2 Laser Radar Unit

Table 1 lists the main specifications of the radar.

Table 1 Radar unit

Detection distance	0 to about 80 m (when a reflex reflector of 51 mm dia. is used as a target for detection)
Detection angle	About 5° horizontal × 2° vertical
Distance measurement error	± 1 m or less
Emission pulse duration and power	40ns, 20W
Outside dimensions	140 (W) × 70 (H) × 105 (D) mm
Weight	About 1 kg or less
Operating temperature range	-30 to +75 °C

3.2.1 Construction

Figure 4 shows the construction of the radar unit.

To scale-down our prototype device, we reduced the parts count, simplified the construction, and adopted a Fresnel lens with a short focal distance for receiver. To reduce the system weight, we use one-piece optical frame made of resin.

The dirt sensor (to detect dirt on the front of the unit) and the photodiode (to monitor the emission power of the laser diode) are built into the optical frame to simplify radar unit assembly.

3.2.2 Obstacle detection area

The obstacle detection area of the laser radar must be set to one lane-width (about 3.5 m). The radar can then accurately detect a vehicle moving in from an adjacent lane but not vehicles running in adjacent lanes on a straight road.

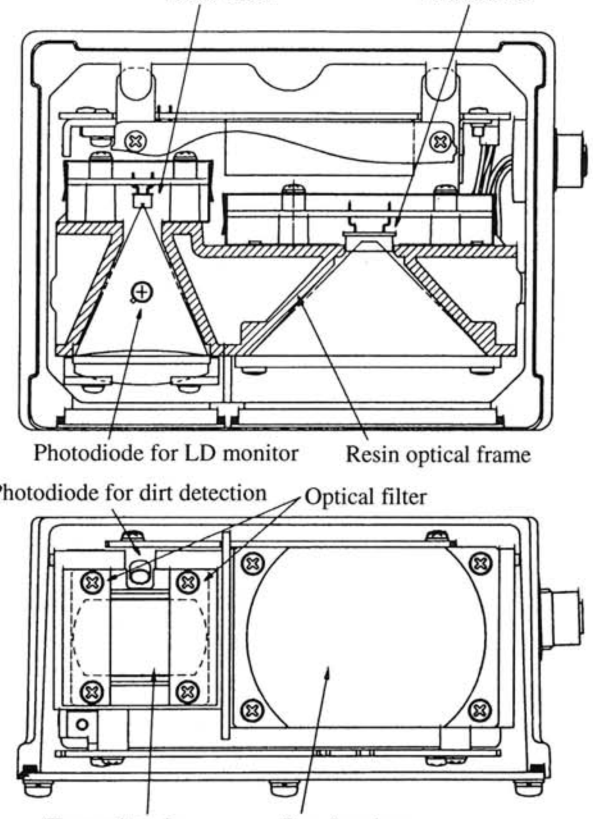

Figure 4. Construction of the radar unit

This requisite is generally satisfied with one of two approaches. One method is to use three laser diodes. The other is to use two or more photodiodes to cover the detection area.

However, our approach uses one laser diode and one photodiode. As shown in Figure 4, we attached optical filters before the transmitter lens of the Laser Alarm to vary the transmittance, thus maintaining sufficient detection area.

Figure 5 shows the obstacle detection area when a reflex reflector of 51 mm dia. is used as a target for detection.

3.2.3 Maximum detection distance

A laser radar receives reflected light from a forward obstacle to measure the distance to the obstacle. The Laser Alarm uses laser radar to receive light reflected from the high transmitter reflex reflector on the back of a vehicle.

As shown in Figure 6, the system detected about 90% of the vehicles running at least 80 m ahead in our experiments.

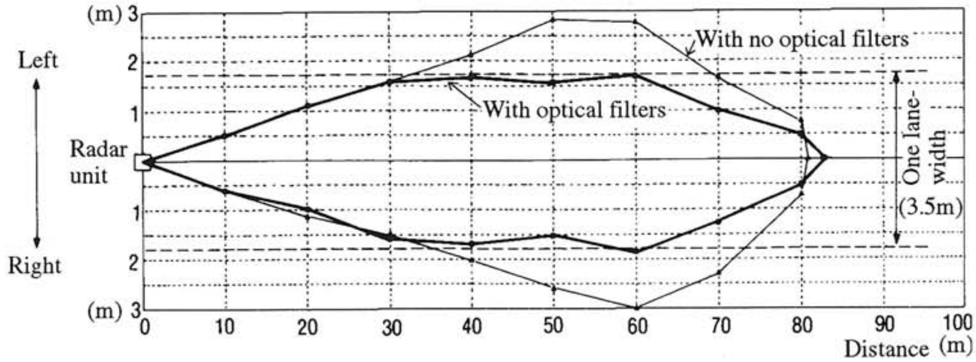

Figure 5. Obstacle detection area

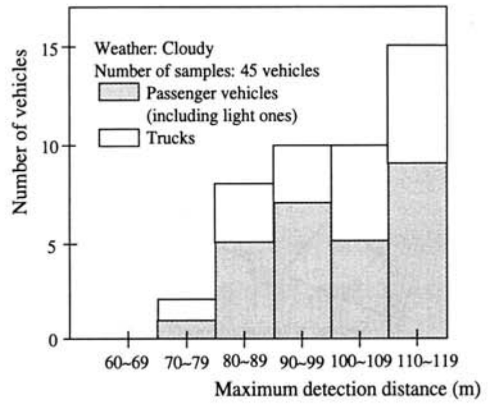

Figure 6. Maximum detection distance on the road

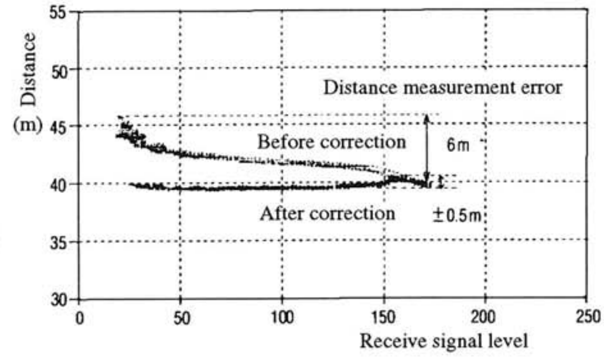

Figure 8. Correction of distance measurement error

3.2.4 Distance measurement error

In pulse-type radar, the timing when the signal exceeds the threshold varies depending on the strength of the received signal. This characteristic causes a distance measurement error. By correlating the receive signal level with the distance measurement error, we adopted a correction mechanism to reduce the error. The mechanism successively reads the receive signal level into the microprocessor to correct the distance. As shown in Figure 8, this mechanism reduced the detection distance error to ±1 m or less.

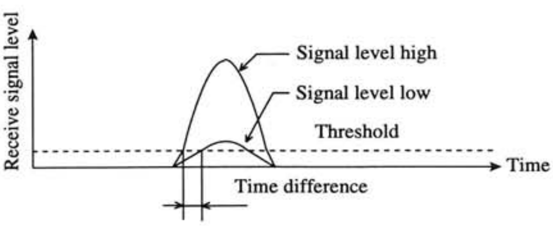

Figure 7. Cause of distance measurement error

3.3 Display unit and self diagnosis

Table 2 lists the main specifications of the display unit.

When the ignition switch is turned on, the Laser Alarm is activated automatically and starts its self diagnosis on the buzzer, display unit, and other sections.

Table 2. Display unit specifications

Display items	• Distance from 0 to 99 m in 1-m steps when the vehicle is running • "– –" when the vehicle is not running • Fault code when there is a system error
Warning	• Two-level output: First (caution), second (danger) • Detection range selection: Three levels • Volume selection: Two levels
Power supply	24 VDC, 0.8 A max. (including the supply current to the radar unit)
Outside dimensions	180 (W) × 50 (H) × 154 (D) mm (1 DIN size)
Weight	About 0.8 kg max.
Operating temperature	-30 to +75 °C

If the system is abnormal, the self-diagnostic function outputs a fault code (Table 3) to the display unit and sounds the buzzer for a warning.

Table 3. Self-diagnostic fault codes

Code	Fault	Main cause
A0	Data communication error	The cable is broken.
A1	Laser diode malfunction	The emission power of the diode is low.
A2	Transmitter malfunction	The transmit processing circuit is malfunctioning.
A3	Sensor circuit malfunction	The receive processing circuit is malfunctioning.
A4	Dirt detected	The front panel of the radar unit is dirty.

3.4 Obstacle alarm

3.4.1 Logic of warning generation

To prevent a collision, for example when the vehicle ahead quickly brakes to stop, the minimum safety distance must be maintained. This distance must include the idle time for the driver's reaction delay. The minimum safety distance can be calculated by

$Dn=(2Vs-Vr) \times Vr/2\alpha+Vs \times TR$. ... (2)
Dn (m) : Minimum safety distance
Vs (m/s) : Vehicle velocity
Vr (m/s) : Relative velocity with the forward obstacle
α (m/s^2) : Deceleration of won vehicle
TR (s) : Idle time

Using the formula for the minimum safety distance, we created a warning generation map. The system is designed to output two types of warnings according to the level of danger, starting from distance Dt.

First level (caution): $Dt \leq Dn$
Second level (danger): $Dt \leq Dn \times K$
(K: Coefficient <1)

Figure 9 shows the warning generation map when the vehicle is approaching a forward obstacle at the relative velocity of 30 km/h.

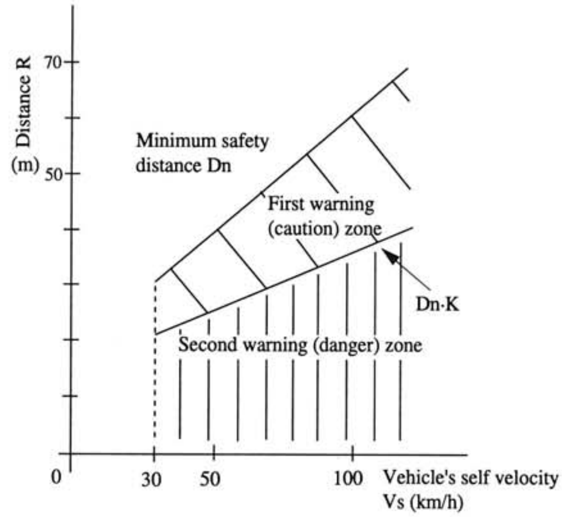

Figure 9. Warning generation map

3.4.2 Vehicle test

Figure 10 shows the on-load test data when the vehicle is approaching a static obstacle at the speed of 60 km/h.

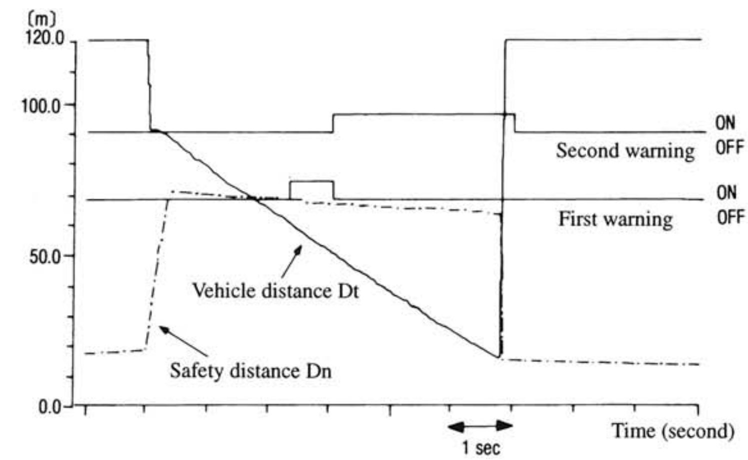

Figure 10. Generation of warnings when approaching a static obstacle

The system generated the first warning 60 m before the obstacle and the second warning 50 m before, to ensure safe braking.

We monitored where drivers braked their vehicles when driving on expressways at the relative velocity (Vr) of about 5 km/h without this system. Then we plotted the braking points and confirmed that they almost matched the warning generation map (Figure 11).

However, since driving methods differ between drivers, the warning generation timing can be set to "Far," "Intermediate," or "Near" with the detection range switch. This allows the user to adjust the sensor to match both the traffic status and the user's driving style.

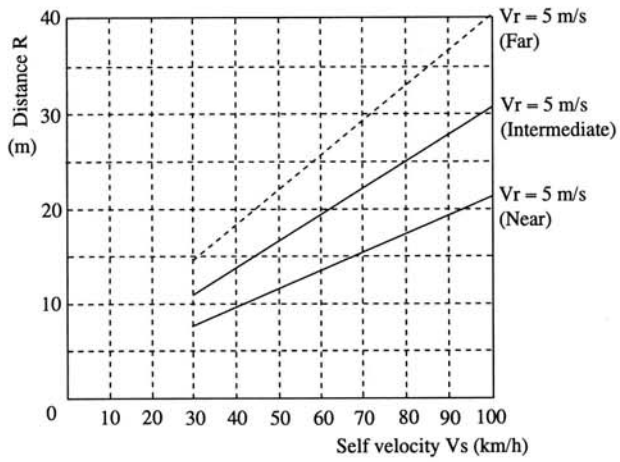

Figure 11. Braking point monitor result

3.4.3 Suppression of unwanted warning

Unwanted alarms make the driver nervous, and reduce the driver's confidence in the system. Therefore, this system is designed not to generate a warning under the following conditions:

① The self velocity is 30 km/h or less. (The traffic is congested.)

② The forward obstacle is moving away. (There is a little danger of collision.)

③ The vehicle is going around a curve which has a line of reflectors along the shoulder. (The system generates a warning until it detects the reflectors.)

If a curved road has reflectors installed along the shoulder of each curved section, the relationship between the detection distance and time will be as shown in Figure 12.

The system stores the changes in the detection distance. If the distance change pattern is the same as the previously detected one, the system does not generate a warning. By this logic, the system sounds the buzzer for several seconds only at the beginning of a curve to warn the driver of the curve. The system suppresses warning generation in the middle of a road having continuous curves, like an S-shaped road.

4. Conclusion

Forward obstacle warning systems have already been developed and released by several manufacturers as commercial products and are helping to promote safe driving.

We could make the Laser Alarm compact, lightweight, and low-priced while keeping the same performance as the conventional products.

We expect this kind of system will be used widely in many type of vehicles to help prevent traffic accidents. To satisfy market needs, we intend to develop even better products.

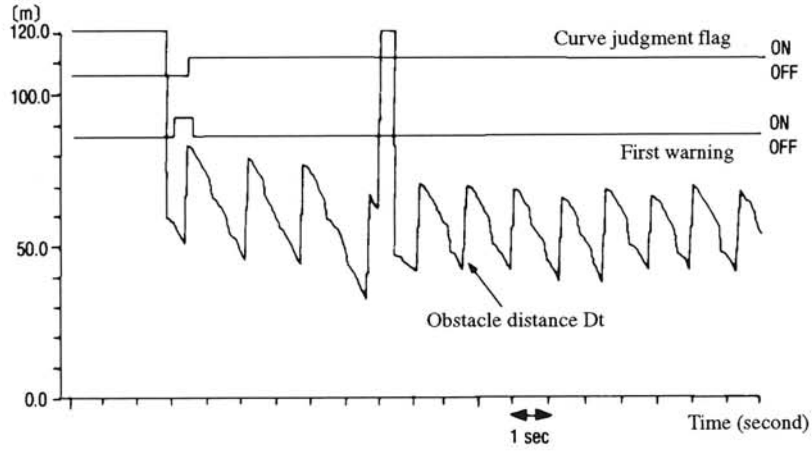

Figure 12. Suppression of warning in a curved road

Acknowledgments

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