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Design of Delineator System for Remote Vehicle Entry Detection and Notification

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Abstract. In this paper, a design of a delineator system for remote vehicle entry detection and notification is studied. A delineator is a gaze guidance device on roads that helps prevent accidents from veering off the road by providing information on the alignment of the road ahead to the driver at night by retro-reflecting the light from the vehicle's headlamp in a direction close to the incident direction. The proposed delineator system consists of a delineator, an Arduino Uno board, a frequency-modulated continuous wave (FMCW) radar, and a short-range wireless communication module. The FMCW radar is used to detect vehicles approaching in front, whereas the short-range wireless communication module is used to wirelessly inform the vehicle entering information to the opposite lane. The Arduino Uno board is used to control and power radar sensors and short-range communication modules. After installing the proposed delineator system on the road, the initial recognition distance of an entering vehicle and the vehicle entrance notification using a short-range wireless communication module were successfully tested.

Keywords; delineator, vehicle entry detection, notification, radar, wireless communication

1. Introduction

In Korea, more than 70% of the country is made up of mountains, so there are more curved roads compared to other countries [1]. For curved roads in which the road alignment changes rapidly, gaze guidance and visibility enhancement safety facilities such as delineaters, seagull signs, road studs, and roller guard rails should be installed to induce driver's attention and prevent traffic accidents, in accordance with the ministry of land, infrastructure and transport's road safety facility installation and management guidelines [2]. However, these existing road safety facilities induce defensive driving through the driver's voluntary attention rather than notifying the presence of an oncoming vehicle in advance.

A delineator is a gaze guidance device on roads that helps prevent accidents from veering off the road by providing information on the alignment of the road ahead to the driver at night by retro-reflecting the light from the vehicle's headlamp in a direction close to the incident direction. It should be installed not only in sections in which the road alignment changes rapidly, such as curved roads, but also in sections with a design speed of 50 km/h or more, where it is difficult to recognize the road alignment, and in sections where the number of lanes or roadway width changes.

Fig 1. Examples of delineators.

Research on ways to increase the effect of preventing traffic accidents by adding wireless communication and LED color change functions to the delineator has been actively conducted. A smart delineator has been developed that adds the function of expressing different colors according to the risk level to the passive retro-reflecting delineator [3]. The road hazard grades were divided into five levels (green, yellow, orange, red, and red (blink)), and deceleration rates were determined for each level. A patent for a delineator module control system for the secondary accident prevention is applied [4]. When a shock is detected in the event of an accident or an emergency situation is detected according to a user's operation, an emergency notification message is provided to the delineator group management device that manages the group to which the user belongs, and the emergency status is under the control of the delineator group management device. Deliwave, a smart emergency warning device to prevent secondary traffic accidents, has been developed [5]. With a built-in wireless communication technology and a shock sensor in the existing delineator, it detects when the guardrail receives an impact in the event of an accident and turns on the lights when the red high-brightness LED lamps are sequentially relayed to notify the driver more than 1 km from the rear. However, a delineator system that provides vehicle entry information obtained based on a radar sensor to a vehicle in the opposite lane, which may be a potential target of a traffic accident, has not been developed.

In this paper, a delineator system combined with an Arduino Uno board, a frequency-modulated continuous wave (FMCW) radar, and a short-range wireless communication module is proposed for remote vehicle entry detection and notification.

2. Design of Delineator System

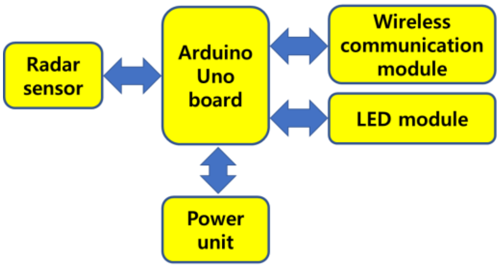


Fig 2. Block diagram of proposed delineator system.

Fig. 2 shows the block diagram of the proposed delineator system. An Arduino Uno board is used to integrate a radar sensor, a wireless communication module, a LED module, and a power unit. An FM24-NP100 from Chongqing Yanwu Tcchnology Co., Ltd., China is used as a radar sensor [6]. It is a 24 GHz FMCW radar, which can recognize a vehicle up to 20 m away with a transmit power of 6 dB. A 4×1 microstrip patch array antenna with a horizontal beam width of 78 degrees and a vertical beam width of 23 degrees was used as the transmit/receive antenna, respectively.

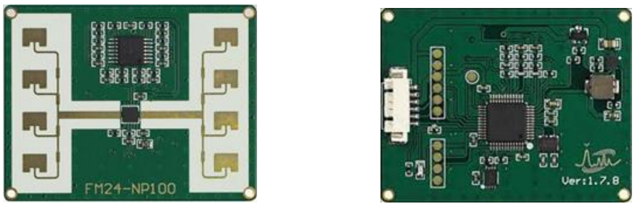
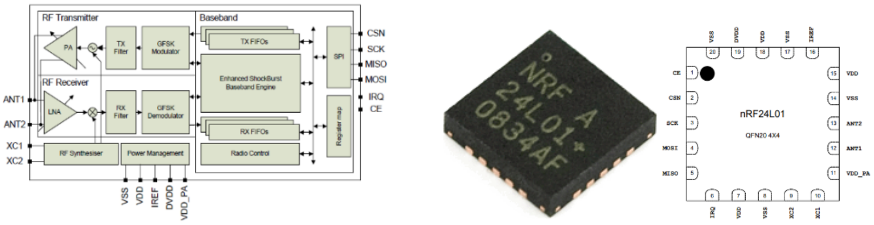


Fig 3. Photographs of FM24-NP100.

For a short-range wireless communication module, an nRF24L01+ module from Nordic semiconductor, Norway is chosen [7]. The nRF24L01+ is a cheap single chip radio transceiver operating in the global, license-free ISM (industrial, scientific, and medical) band at 2.400 – 2.4835 GHz. The nRF24L01+ consists of RF transmitter/receiver, RF synthesizer, Tx/Rx filter, GFSK (Gaussian frequency shift keying) modulator/demodulator, and baseband logic circuits. Available data rates are 250 kbps, 1Mbps, and 2 Mbps. RF channel bandwidth is 1 MHz for 250 kbps and 1

Mbps, whereas it is 2 MHz for 2 Mbps. In Tx mode, power amplifier (PA) control has four programmable steps, RF24_PA_MIN, RF24_PA_LOW, RF24_PA_HIGH, and RF24_PA_MAX



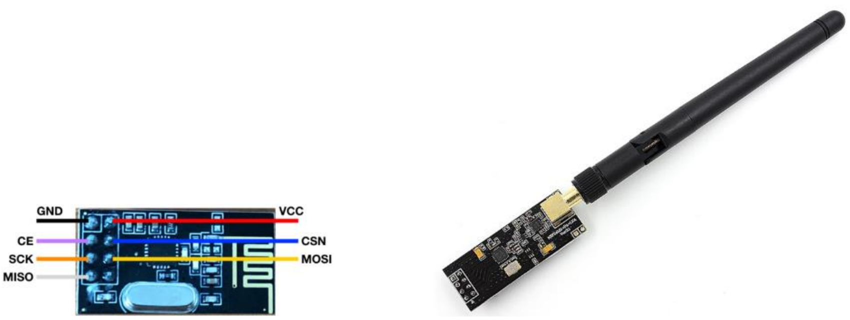
(a) (b)

Arduino Code	RF output power (dBm)	DC current Consumption (mA)
RF24_PA_MAX	0	11.3
RF24_PA_HIGH	-6	9.0
RF24_PA_LOW	-12	7.5
RF24_PA_MIN	-18	7.0

(c)

Fig 4. nRF24L01+ transceiver: (a) block diagram, (b) chip, and (c) RF output power setting.

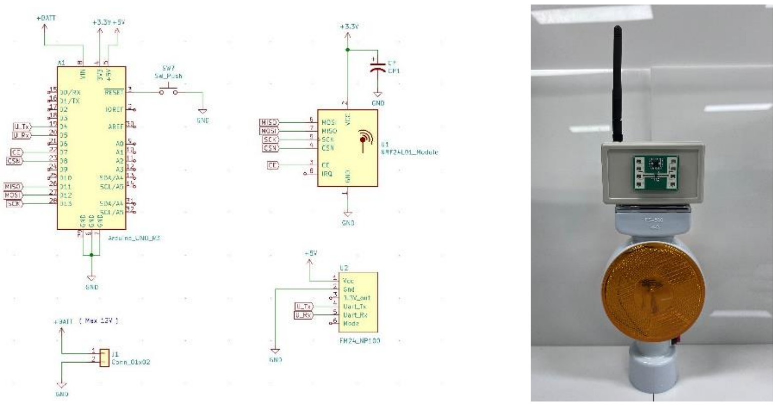
There exist two types of modules for the nRF24L01+ transceiver [8]. The built-in antenna module has a meander-line antenna combined on a PCB board. On the other hand, a power amplifier and a low noise amplifier are added for the external antenna module, and an external antenna is connected to increase the communication distance.



(a) (b)

Fig 5. nRF24L01+ modules: (a) built-in antenna module and (b) external antenna module.

The circuit diagram and photograph of the Arduino Uno-based delineator system with the FM24-NP100 FMCW radar and the nRF24L01+ module are shown in Fig. 5.



(a) (b)

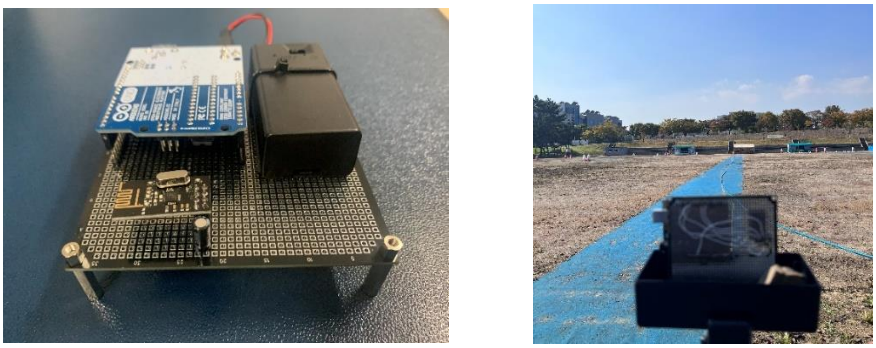
Fig 6. Circuit diagram and photograph of Arduino Uno-based intelligent delineator: (a) circuit diagram and (b) photograph.

3. Experiment Results

A. Communication Range Test for nRF24L01+ Transceiver

First, communication range tests are conducted using two Arduino-based radio systems with the nRF24L01+ transceiver in an open area, as shown in Fig. 7. Note that Two Arduino-based radio systems are installed at a position of 1 m above the ground using a tripod support.

The two Arduino-based radio systems with the nRF24L01+ transceiver are divided by the sending and the receiving systems for the communication range test. The sending system transmits data to the receiving system first, and after receiving the data, the receiving system must be transferred back to the sending system before it is judged that communication is complete. The sending system transmits once and sends data again after a predetermined delay time of 500 msec. The sending data consisting of a predetermined character data and an increased communication count is sent to the receiving system. After 100 transmissions, each communication test ends. When data is received from the sending system, the receiving system returns the predetermined character data and a count value by adding 100 to the number of the received transmission count. Success rate for each communication test is calculated by counting for the case when the sending system successfully received the returned data from the receiving system in 500 msec.



(a) (b)

Fig 7. (a) Photograph of the Arduino-based radio system with the nRF24L01+ transceiver and (b) communication range test setup.

Fig. 8 shows communication range test results for four different Tx power settings, RF24_PA_MIN, RF24_PA_LOW, RF24_PA_HIGH, and RF24_PA_MAX. Distance between the sending and the receiving systems is varied starting from 5 m to maximum communication range for each Tx power setting. Note that a total of three communication tests are conducted at each distance. It is observed from Figure 7 that maximum communication range for RF24_PA_MAX is the longest among the four settings. Communication success rate for RF24_PA_MAX remains around 100% until 75 m. It is slightly reduced to 70 m for RF24_PA_HIGH. For RF24_PA_LOW, it is further reduced to 30 m. The shortest communication range among the four settings is 10 m for RF24_PA_MIN.

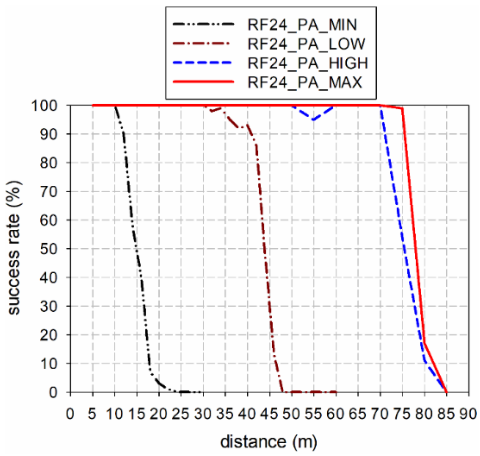
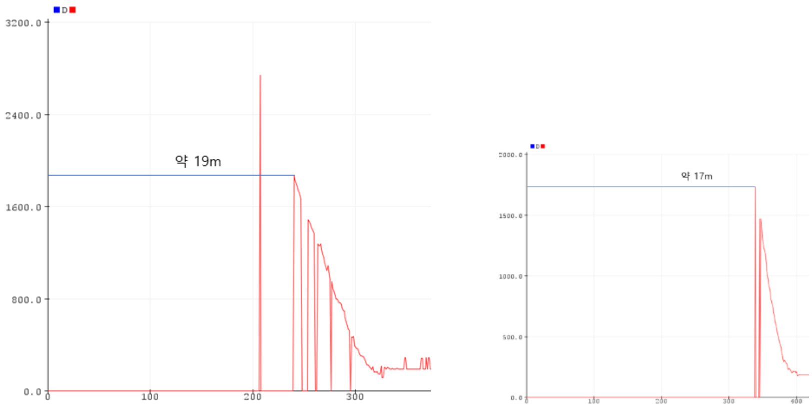


Fig 8. Photographs of FM24-NP100.

B. Vehicle Recognition Range Test for FM24-NP100 Radar

In order to install the delineator system on the road, it is necessary to know the maximum radar recognition distance. For this purpose, the maximum recognition distance test for the vehicle using FM24-NP100 FMCW radar is performed. The radar is placed on a tripod 1 m above the ground and installed in the center of the road to face the vehicle, and the maximum recognition distance is measured when the vehicle approaches at speeds of 15 km/h and 25 km/h. When the vehicle is approaching at 15 km/h, it is recognized for the first time at about 19 m, and when the vehicle speed further increases to 25 km/h, it is recognized for the first time at about 17 m, as shown Fig. 9.



(a) (b)

Fig 9. Maximum recognition distance of the radar: (a) 15 km/h and (b) 25 km/h.

C. Tests for Integrated Delineator System

Finally, after installing the proposed delineator system with FM24-NP100 FMCW radar and the nRF24L01+ transceiver on the road, the initial recognition distance of an entering vehicle and the vehicle entrance notification using a short-range wireless communication module are tested.

It recognizes the distance of an approaching vehicle using the radar. When the distance of the detected vehicle decreases, it is determined that the vehicle has entered and uses the nRF24L01+module to turn on the LED of the delineator in the opposite lane. Experiment results show that the vehicle is recognized at a distance of 8 m ~ 14 m, and the LED of the delineator in the opposite lane is turned on through the wireless communication, when the vehicle approaches at speeds of 15 km/h with total of 10 experiments.

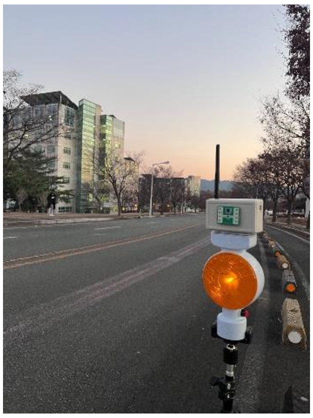


Fig 10. Expermint Setup.

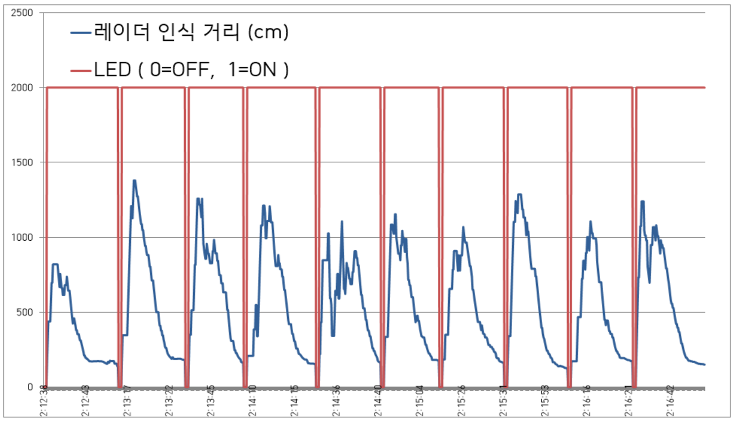


Fig 11. Radar recognition distance and LED status when the vehicle approaches at speeds of 15 km/h.

4. Conclusion

We have proposed a delineator system for remote vehicle entry detection and notification. An Arduino Uno board is used to integrate a radar sensor, a wireless communication module, a LED module, and a power unit.

The initial recognition distance of an entering vehicle using a radar and the vehicle entrance notification using a short-range wireless communication module are tested on a curved road. It was found that the initial vehicle recognition distance differs greatly depending on the speed and location of the approaching vehicle, and additional experiments to improve these problems will be conducted.

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