Optical AM Wireless Communication System Using LEDs

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ABSTRACT

Recently the light emitting diodes (LEDs) have been used for the traffic light systems because of their features such as low power consumption, long life and low temperature generation. If we can distribute information for positioning and security with the traffic lights, it is expected to apply it to Pedestrian Intelligent Transport Systems (PITS) for elder and/or handicapped people. In attempt to realize such a system at low cost, this technical paper proposes an optical wireless communication system in which the light wave intensity-modulated with amplitude-modulated (AM) signals in the medium frequency-band is transmitted and received with PIN photo-diode and a commercially available radio receiver for the AM broadcast, and the performance measured with an actual traffic lights as well as with an experimental LED set are shown.

TECHNICAL PAPERS

1. Introduction

In accordance with the technological progress in the light emitting diode (LED), its applications are evolved over wide spread areas. As an example, the traffic lights using LEDs have been gradually introduced in Japan, because LED has their features such as low power consuming, long life and low temperature generation. In addition, visible light communications using LEDs have been attract great attentions as being potential to a new type of communication, and many researches are in progress [1]. Associated with these trends around the LED, if an additional function of the optical communications making use of the high-speed responding capability of LED can be implemented, we will be able to distribute various kinds of information such as positioning, security and so on. In other words, a new type of Pedestrian Intelligent Transport Systems (PITS) may be realized for the purpose of welfare for elder and/or handicapped people. Several researches concerned with such Traffic Light Communications (TRC) have been conducted [2]-[4].

From this point of view, we have also studied on TRC aiming at realizing a simple and low cost system and developed an optical wireless communication system using an existing radio receiver for the AM broadcast signals shown in Fig.1. In this system, the information is carried on the light wave intensity-modulated with amplitude-modulated (AM) signals in the medium frequency-band, which is detected by a PIN-photo diode, and the AM signals are applied to an existing AM radio receiver.

We have conducted a preliminary test to evaluate the performance using an experimental system with small scale, and have measured some characteristics using a set of actual traffic lights. In this Technical Paper, we first describe a basic configuration of the developed system, and then show the results of the preliminary evaluation and measured results of the performance for an actual traffic light.

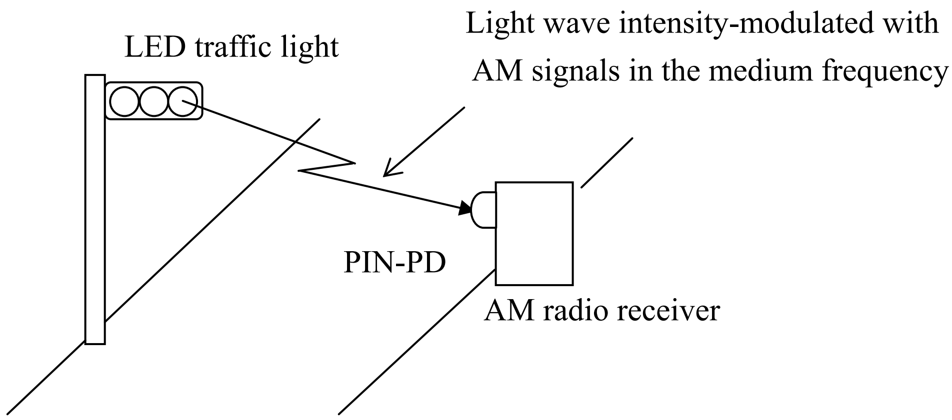

Fig.1. Optical AM wireless communication system using traffic lights

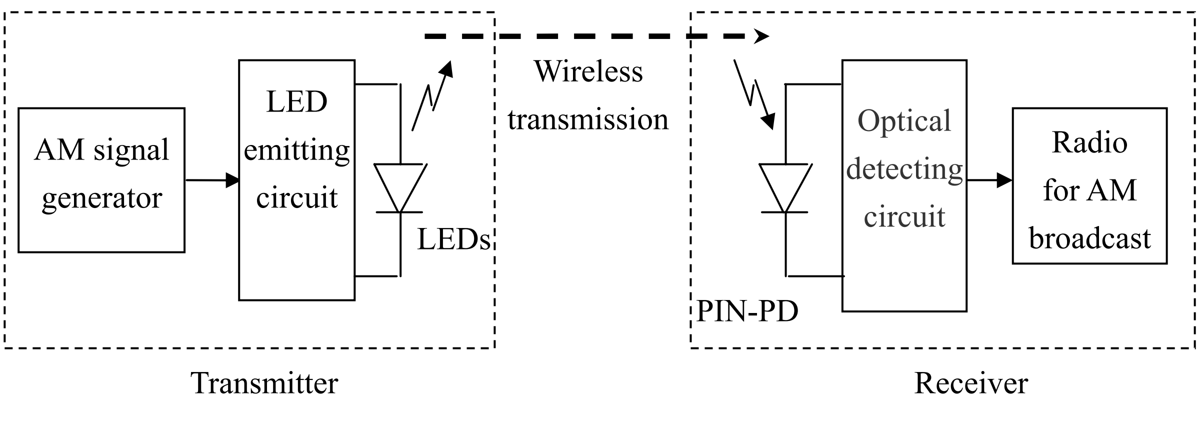

Fig.2. System configuration

2. Configuration of the optical AM wireless communication system

The basic configuration of an optical AM wireless communication system is shown in Fig.2. In this system, the information is carried on the light wave intensity-modulated with amplitude-modulated (AM) signals in the medium frequency-band, in which the low implementation cost and the frequency response of LEDs used for traffic lights are taken into account. As shown in Fig.2, the transmitter consists of an AM signal generator, an LED emitting circuit, and many LEDs. The receiver consists of a PIN-PD followed by a buffering amplifier and an AM radio set. These circuits are described in detail as follows.

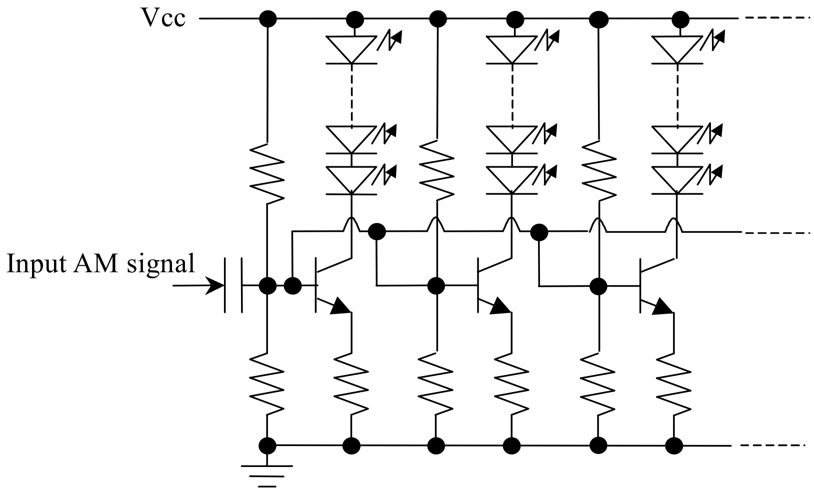

Fig.3. LED emitting cuircuit

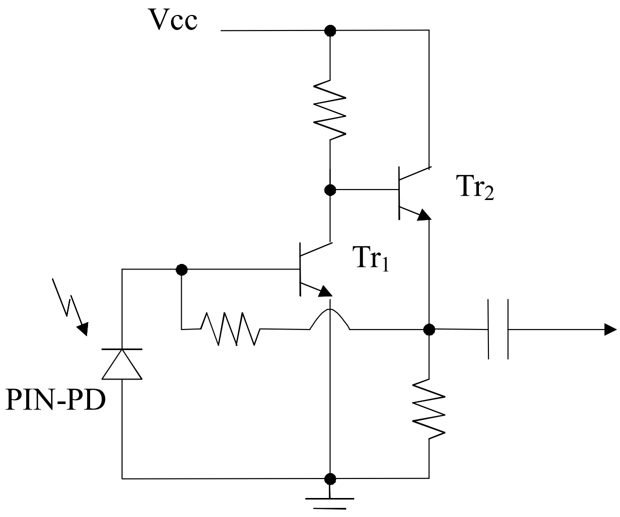

Fig.4. Optical detecting circuit

2-1. LED emitting circuit

In the LED emitting circuit, several LEDs are connected in series to the collector of a transistor. The number of LEDs connected in series has been determined so that the bias current necessary to drive each LED can be supplied with a reasonable value of collector voltage. Figure 3 shows the LED emitting circuit developed for experimental purpose. We designed this circuit such that the bias current supplied to each LED is set at 20mA for collector voltage Vcc of 12V. In order to drive many LEDs, we need a number of driving circuits connected in parallel as shown Fig.3.

2-2. Optical detecting circuit

In the optical detecting circuit shown in Fig.4, the light wave that is intensity-modulated with AM signals in the medium frequency-band is detected by PIN-PD, and converted into AM signals, which are amplified and output through the emitter follower, and applied to an AM radio receiver. The emitter follower plays a role of buffer to interface the circuit with the AM radio receiver. The output signal from the optical detecting circuit is applied to an antenna input terminal.

3. Preliminary experiment

We have developed an experimental system on reduced scale and conducted a preliminary experiment to evaluate the performance such as frequency response of the LED emitting circuit and transmission characteristics versus distance.

3-1. Frequency response of LED emitting circuit

The frequency response of the light emitting circuit as a parameter of the number of LED connected in series has been evaluated under following conditions.

Using red-colored LEDs, we have measured the level of light from LEDs with an optical level meter, which has the frequency response flat enough over the measured frequency range. The carrier frequency of AM signal was changed over the range 500 kHz to 1500 kHz, and the modulating frequency was 1 kHz with modulation degree of 80%.

The measured results are shown in Fig.5. The level in dB on the vertical axis in Fig.5 represents the level normalized by the value for the case where the carrier frequency is 500 kHz and the number of LEDs is 3. In this figure, the measured levels are slightly decreased with increase in the carrier frequency, and are of the almost same value for 3 and 4 LEDs. The measured levels in the case of 5 pieces, however, became very small. This is because the bias current was not enough in this case. From this result, we have selected four as the number of LEDs connected in series.

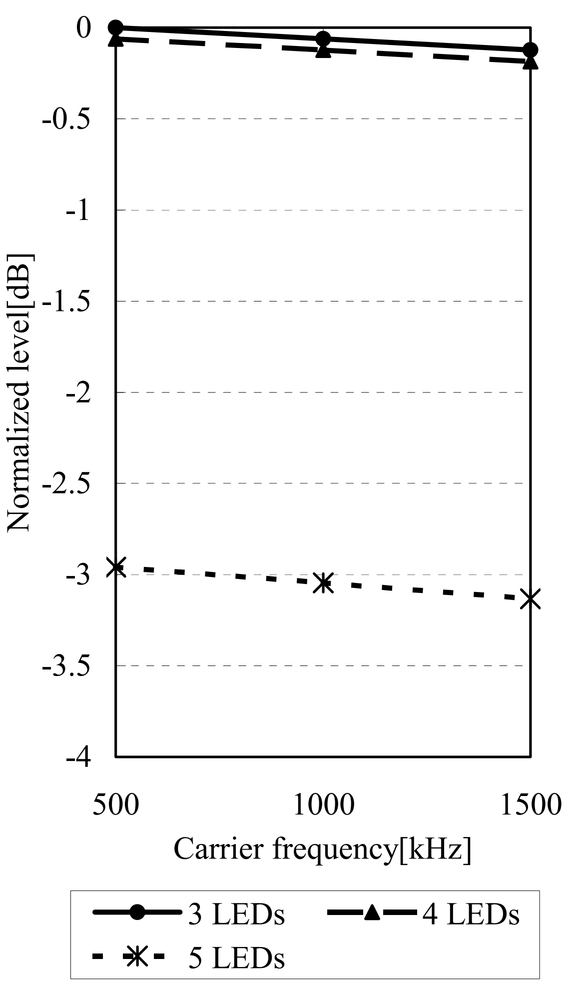

Fig.5. Normalized level vs. carrier frequency as a parameter of the number LEDs connected in series

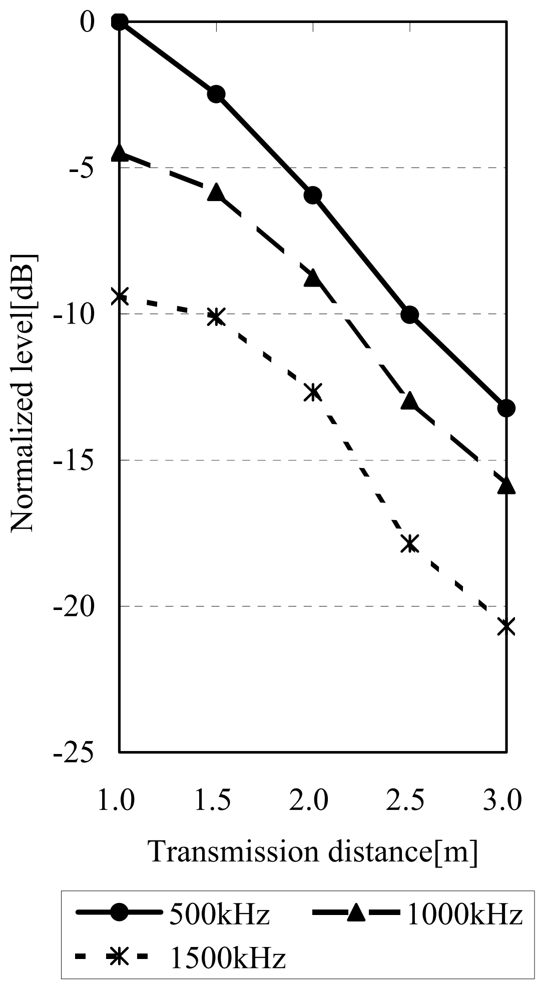

Fig.6. Normalized level vs. transmission distance as a parameter of carrier frequency

3-2. Characteristics of the receiver

As mentioned before, the receiver consists of an optical detecting circuit and an AM radio receiver. We measured the detected level of the optical detecting circuit as functions of the carrier frequency and propagation distance using the measurment set of circuits shown in Fig.7. As a light source we have used 80 red-colored LEDs, which were connected 4 in series for one transistor and 20 in parallel. The measured results of the received level normalized by the level for 500 kHz and 1.0 meter of distance are shown in Fig.6, in which the value 0dB corresponds to 422mv. As shown this figure, the level for the carrier frequency of 1500 kHz is about 7dB lower than that of 500 kHz, which indicates lower carrier frequency might be better to use.

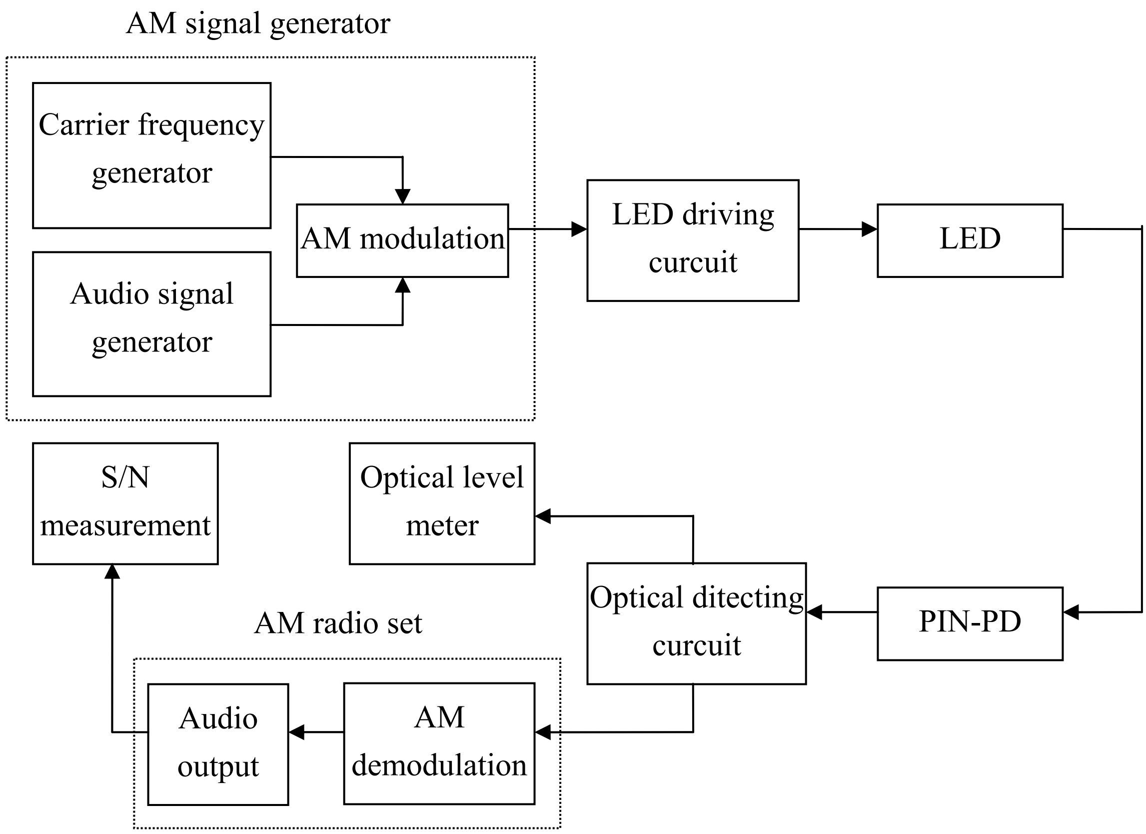

Fig.7 The block diagram for measuring characteristics of the receiver

4. Performance with an actual LED traffic light

4-1. Implementation of actual LED traffic lights

In order to ensure the feasibility of the developed concept, we applied it to an actual traffic light and evaluated the performance in terms of signal-to-noise ratio measured at the audio output of an AM radio receiver with the following arrangement.

The light emitting circuit using the actual LED traffic light for pedestrians is shown in Fig.8, in which 33 LEDs are connected in series and 6 groups in parallel (198 LEDs in total). Based on the knowledge obtained in the preliminary experiment and the condition of LED connection in the actual traffic light, all LEDs are driven with a single transistor. Assuming that the DC bias current of 20mA is supplied to each LED, the total current flowing into the collector becomes 120mA.

We have measured the level of light emitted from the circuit in Fig.8 with the optical level meter to obtain the frequency response of the circuit. The carrier frequency of AM signal was changed over the range 500 kHz to 2000 kHz, and the modulating frequency was set at 1 kHz with modulation degree of 80%. The measured results are shown in Fig.9. The levels in dB in this figure represent the values normalized by the level for the case where the carrier frequency is 500 kHz. The measured level for 1500 kHz decreases by about 0.6 dB compared with the value for 500 kH, which may not be so large.

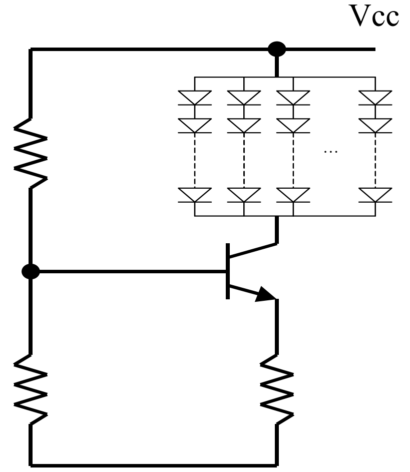

Fig.8. Connection of LEDs in the actual traffic lights

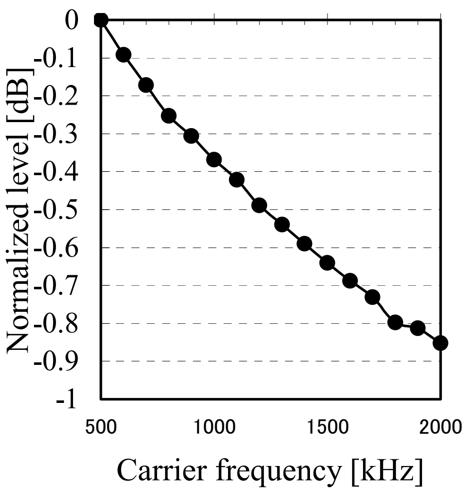

Fig.9. Normalized level of light versus carrier frequency

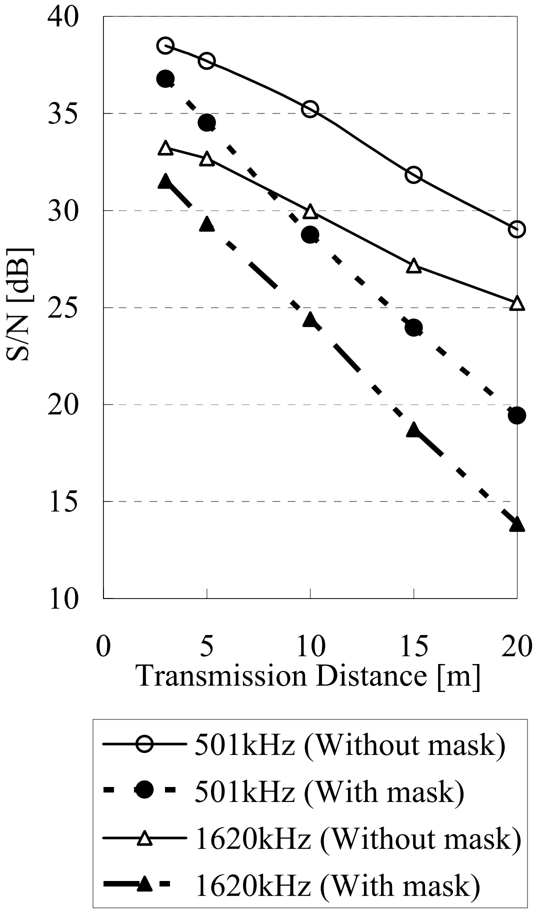

Fig.10. S/N at the audio output from AM radio receiver versus transmission distance

4-2. Measured results of the performance

Using the actual traffic light (red colored) for pedestrians, we have measured the signal-to-noise ratio (S/N) of the audio signal output from the AM radio receiver. The measurement was conducted with the carrier frequency of 501 kHz and 1620 kHz modulated by the audio frequency of 1 kHz. The measured results of S/N as a function of transmission distance are shown in Fig.10. The traffic lights for pedestrians are usually covered with the mask depicting the shape of pedestrian. The data shown in Fig.9 are the ones without or with the mask. The S/N with the mask is much lower than that without the mask, but the value of S/N suggests still being practical for voice information.

5. Conclusion

This paper describes a concept of communication system with the LED traffic lights, and also shows the measured results of the performance in terms of signal-to-noise ratio of the audio signal output from the AM radio receiver as a function of transmission distance. The measured results suggest feasibility of the system, but we need further study to ensure practicability of the system, the effect of background light will have to be clarified and an effort to increase S/N would be required. In this system, any way, we hope that users will be able to enjoy low cost communications with the traffic lights as a welfare ITS.

References

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1. Introduction

・Recently, the light emitting diodes (LEDs) have been used for the traffic light systems.

・If it is possible to distribute information for positioning and security through the traffic lights, we can expect to apply it to the Pedestrian Intelligent Transport Systems (PITS) for elder and/or handicapped people.

・Therefore, we have studied on Traffic Light Communications (TRC) aiming at realizing a simple and low cost system and developed an optical wireless communication system using an existing radio receiver for the AM broadcast signals shown in Fig.1

2. Optical AM wireless communication system

・In this system, the information is carried on the light wave intensity-modulated with amplitude-modulated (AM) signals in the medium frequency-band.

・The light wave is detected by a PIN-photo diode, and the AM signals are applied to an existing AM radio receiver.

3. Configuration of the optical AM wireless communication system

・The basic configuration of an optical AM wireless communication system is shown in Fig.2.

・In this system, the transmitter consists of an AM signal generator, an LED emitting circuit with many LEDs. The receiver consists of a PIN-PD followed by a buffering amplifier and a commercial AM radio set. .

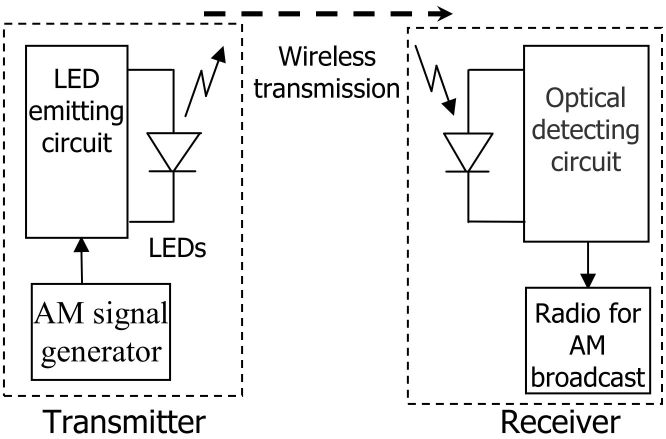

Fig.2. System configuration

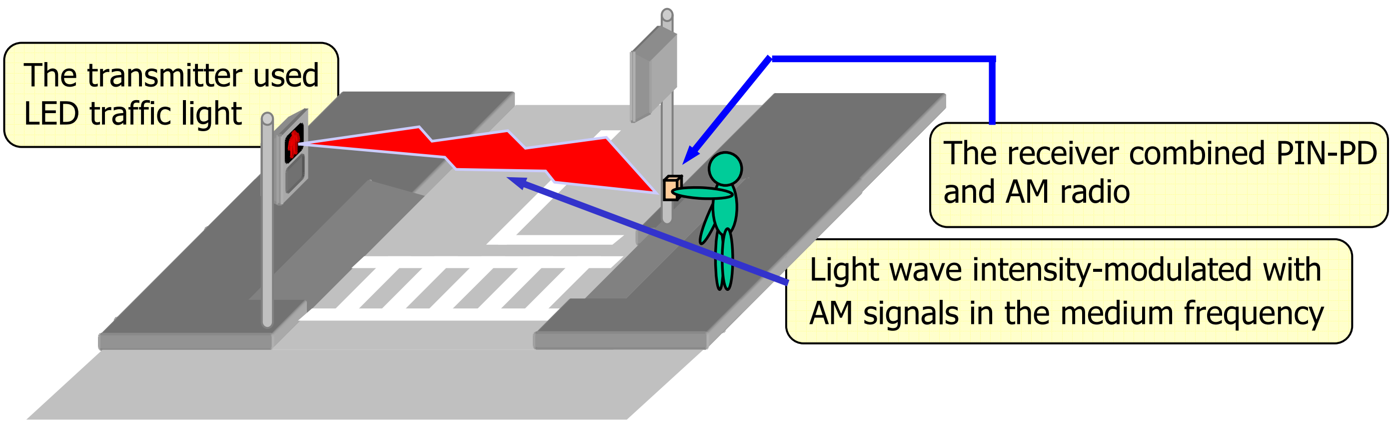

Fig.1 Optical AM wireless communication system using traffic lights

3-1. Transmitter

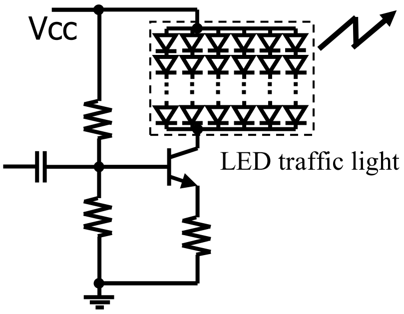

Fig.3 LED driving circuit

3-2. Receiver

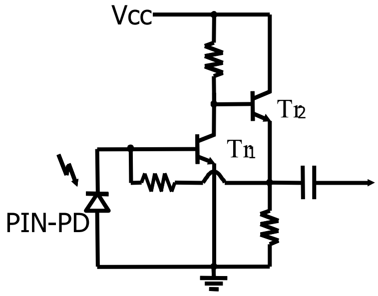

Fig.4 Optical detecting circuit

4. Performance with an actual LED traffic light

4-1. Experimental condition

- Red LEDs
- frequency : AM wave 500-1620 kHz
- Transmission distance : 3, 5, 10, 15, 20 meters
- Location : Indoor without background light

- The frequency response of the LED driving circuit
- Transmission distance using signal-to-noise ratio (S/N) at the audio output.

4-2. The block diagram for measuring characteristics

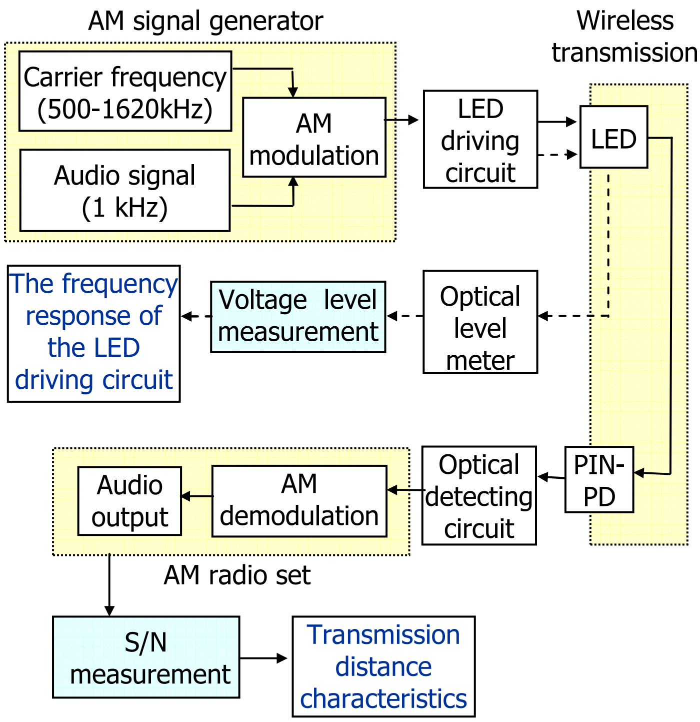

Fig.5 The block diagram for measuring characteristics

4-3. The frequency response of the LED driving circuit

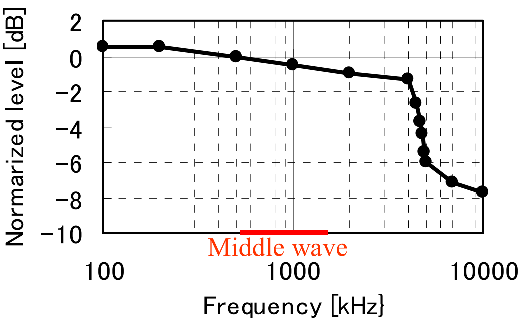

Fig.6 Normalized level of light versus carrier frequency

4-4. Transmission distance characteristics

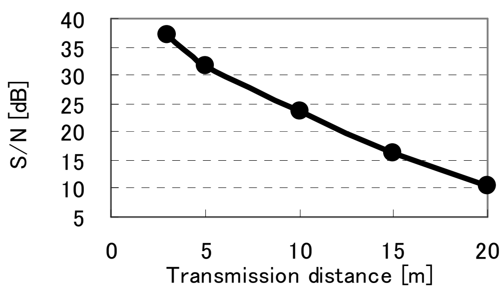

Fig.7 S/N at the audio output from AM radio receiver versus transmission distance

- The desired S/N on the radio is 20 dB.

5. Conclusion

- In this paper, we proposed the simple and low cost communication system with LED traffic lights.
- We have a prospect for practical use if the transmission distance is within about 10 meters.

This system is demonstrated at Meijo university booth.
Please have a look at our PITS !