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Electromagnetic compatibility of wireless medical telemetry systems and light-emitting diode (LED) lamps

Abstract. *Light-emitting diode (LED) lamps have been widely introduced in clinical settings for energy conservation and cost reduction However, LED lamps radiate electromagnetic noise and they cause poor reception of broadcasting and wireless communications. In this study, we investigated the effects of LED lamp use on the electromagnetic environment surrounding wireless medical telemetry systems and discuss the safe installation of LED lamps in a clinical settings.*

Streszczenie. *Oświetlenie LED jest szeroko stosowane w klinikach medycznych, pozwalając na oszczędność energii i redukcję kosztów. Źródła światła bazujące na diodach LED emitują szum elektromagnetyczny powodując pogorszenie komunikacji bezprzewodowej. Artykuł przedstawia badania wpływu lamp LED na elektromagnetyczne środowisko obejmujące bezprzewodowe systemy telemetrii medycznej i omawia zasady instalacji lamp LED w obiektach medycznych. (**Kompatybilność elektromagnetyczna medycznych systemów telemetrycznych i oświetlenia LED**).*

Keywords: wireless medical telemetry system; light-emitting diode lamps; electromagnetic noise.
Słowa kluczowe: system bezprzewodowej telemetrii medycznej, oświetlenie LED, szum elektromagnetyczny.

Introduction

In Japan, with the increasingly widespread use of light-emitting diodes (LEDs), electrical goods manufacturers have substantially downscaled traditional lighting, such as incandescent electric lamps and fluorescent light tubes. Additionally, the Japanese government has established policies to prohibit the manufacture and importation of traditional lighting by the end of 2020 [1]. Moreover, Baumgartner et al. predicted that LEDs will account for almost 70% of the general lighting market and over 70% of the outdoor and residential lighting markets by 2020 [2]. Therefore, hospitals will be entirely lit by LED lamps in the near future.

LED lamps have been widely introduced in clinical settings to save energy and reduction of cost. Until recently, LED lamps were more expensive than traditional lighting devices, but their prices have gradually decreased. Additionally, the introduction of LED lamps reduces the total operating cost. In hospitals, in addition to room lighting, LEDs are used for shadowless lamps, oral cavity lighting, and lighting goggles used in operations.

However, electromagnetic interference (EMI) by LED lamps has been reported. In 2010, poor reception of analogue television and radio broadcasting signals occurred after the installation of LED lamps along shopping streets in north-eastern Japan [3]. In hospitals, EMI with wireless medical telemetry systems may occur. Wireless medical telemetry systems are medical devices that transmit patient vital signs, such as electrocardiograms, respiratory waveforms, blood pressure, electromyograms, and oxygen saturation of arterial blood, to a patient monitor by radio waves. In Japan, the 420 to 450 MHz frequency band and 2.4 GHz band, commonly known as, Industrial, Science and Medical band, „ISM band" are assigned for such use. However, ISM bands are also used for various purposes, such as wireless local area network, microwave oven and cordless phone. To prevent interference with such devices, the 420 to 450 MHz frequency band are commonly used in many Japanease hospitals.

CISPR 15 ed.8.0 ("Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment") regulates electromagnetic field radiation by lighting and similar equipment to avoid EMI [4]. This standard regulates the limits of conduction and radiation noise from electrical lighting. However, the target frequency band of radiation noise is from 30 to 300 MHz. Moreover, it has been reported that some LED lamps also radiate higher frequency noise of over 300 MHz [5]. There are no regulations on the frequency band used by wireless medical telemetry systems. Poor reception of signals from wireless medical telemetry systems could cause serious medical problems, such as interference with cardiac monitoring. Determining the possibility and effect of EMI is a pressing task now that LED lamps are widely used in hospitals.

In this study, we investigate the effects of LED lamp use on the electromagnetic environment surrounding wireless medical telemetry systems and discuss the safe introduction of LED lamps.

Methods

Measurement of electromagnetic noise radiated from LED lamps

We collected target LED lamps from mass merchandisers and online shops for this measurement. They included 13 bulb-type lamps and four straight-tube-type lamps. The frequency distribution of the electric field intensity induced by each LED lamp was measured using a spectrum analyzer (MS2690A1 / Anritsu) and a near-field probe (Model 7405 / ETS-Lindgren) in an anechoic chamber. The frequency range was from 30 to 1,000 MHz. Both the resolution bandwidth (RBW) and video bandwidth (VBW) were 100 kHz. The distances between the near-field probe and the LED lamp were set at 1, 10, 30, and 50 cm. The strongest intensity for all measured frequencies was recorded using a maximum hold function for 30 seconds.

Identification of radiation source from LED lamps

It has been reported that the radiation noise from LED lamps is typically generated by the power circuit of a switching supply [6]. To determine this phenomenon, we disassembled an LED lamp and reconnected the power circuit and light-emitting component using a long electrical cable (Fig. 1). We measured their electric field intensities at very short distances using a near-field probe to find the source of radiation (Fig. 2).

Examination of the effect of noise radiated from an LED lamp on a wireless medical telemetry system

We observed the effect of radiated noise when an LED lamp was set close to a receiving antenna or a leaky coaxial cable attached to a wireless medical telemetry system. We used a patient monitor (BSM-2401, Nihon Kohden, Co., Ltd.) and a wireless medical telemetry transmitter (ZS-910P, Nihon Kohden, Co., Ltd.). The transmitter was connected to a vital sign simulator, which sends normal electrocardiogram signal to the patient monitor. The specifications of the transmitter are shown in Table 1.

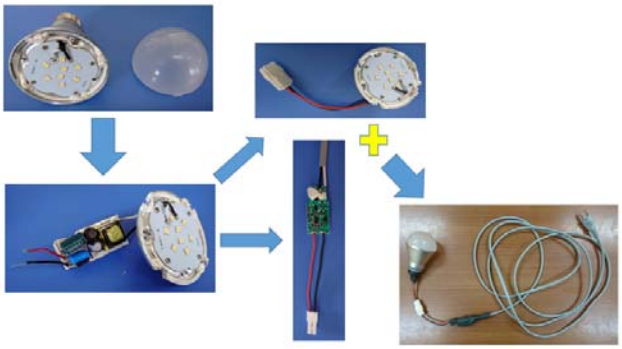

Fig.1. Process of disassembling and recconection of an LED lamp

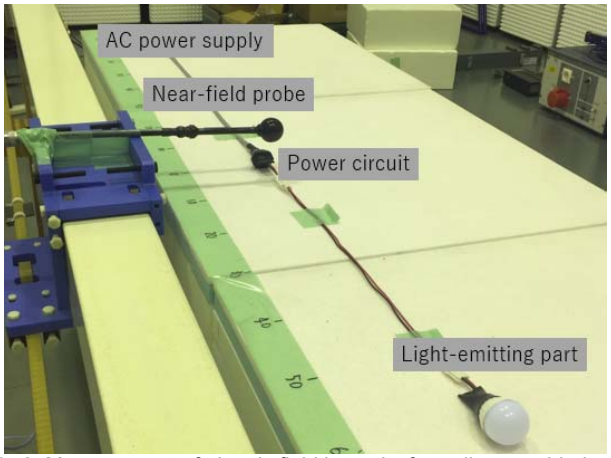

Fig.2. Measurement of electric field intensity from disassembled LED circuit

Table 1. Specifications of wireless medical telemetry transmitter

Modulation method	Frequency shift keying (FSK)
Type of radio wave	F7D
Center frequency	444.7625 MHz
Occupied bandwidth	8.5 kHz
Transmitting antenna	Electrode lead
Output power	1 mW

We placed an LED lamp near the antenna of a patient monitor and observed the effects of radiation noise superimposed on the vital signal (Fig. 3). In addition, we measured the electric field intensity under this condition using a spectrum analyzer.

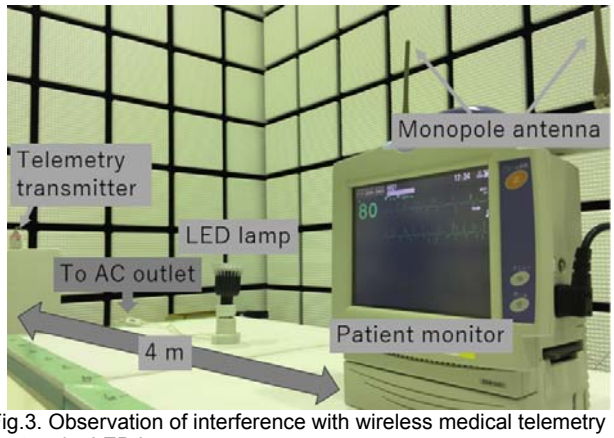

Fig.3. Observation of interference with wireless medical telemetry system by LED lamp

Results

Measurement of electromagnetic noise radiated from LED lamps

As an exapmle, some of the measured intensities and frequency characteristics of the electric field emitted from four bulb-type LED lamps are shown in Fig. 4. The maximum electric field intensity in the measured frequency band at a distance of 1 cm was 99.5 dBμV/m (at 50.5 MHz) and that in the wireless medical telemeter frequency band (420 to 450 MHz) was 71.5 dBμV/m (at 435 MHz) indueced by LED A. LED A radiated extremely strong noise in a wide frequency band. The differences in the electric field intensity between LED A and the background noise were 41.8 dB at a distance of 1 cm, 38.8 dB at 10 cm, 28.6 dB at 30 cm, and 21.2 dB at 50 cm.

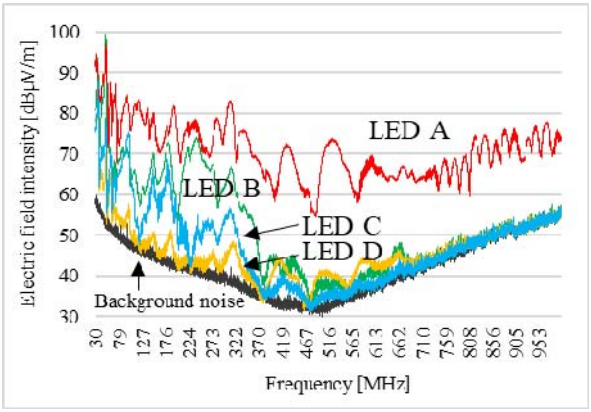

Fig.4. Electric field intensity induced by four bulb-type LED lamps at a distance of 1 cm

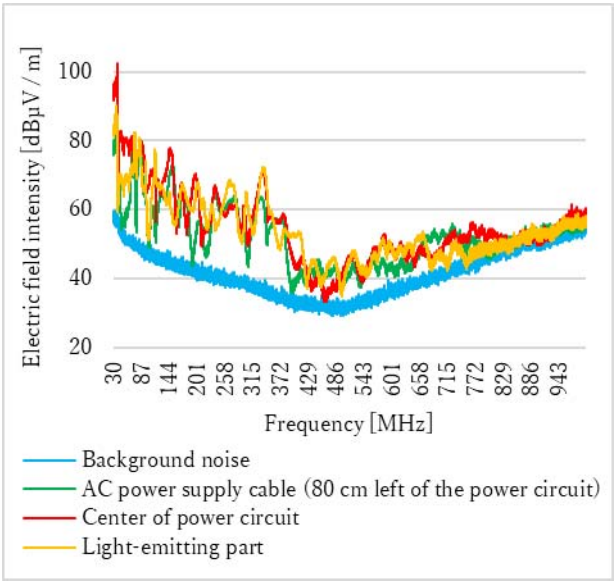

Fig.5. Electric field intensity induced by one disassembled bulb-type LED lamp (30 MHz to 1 GHz)

Identification of radiation source from LED lamps

The measured intensities and frequency distribution of the electric field for each component of one bulb-type LED lamp are shown in Fig. 5. The electric field intensities from the AC power supply cable, power circuit, and light-emitting component were also larger than the background noise, but they seem to be similar for each component. The measured electric field intensity and frequency distribution at 420 to 450 MHz for each component of one straight-tube type LED lamp are shown in Fig. 6. In particular, the electric field intensities of the AC power supply cable and power circuit were larger than that of the light-emitting component.

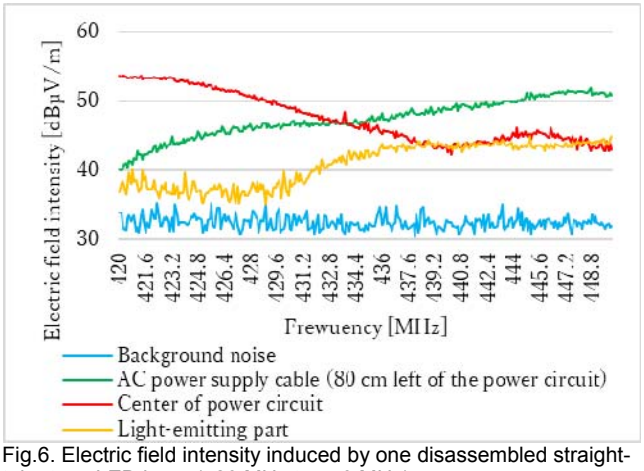

Fig.6. Electric field intensity induced by one disassembled straight-tube type LED lamp (420 MHz to 450 MHz)

Examination of the effect of noise radiated from an LED lamp on a wireless medical telemetry system

The patient monitor shows normal electrocardiogram, commonly known as „sinus" and displays number of heart rate. However, artifact noise was observed on an electrocardiogram and incorrect heart rate was displayed when an LED lamp was placed close to the patient monitor (Fig. 7). Then, the patient monitor did not show electrocardiogram, and become disconnected (Fig. 8). This effect was observed when the transmitter and receiving antenna were located at a distance of approximately 5 m (generally, the monitor normally has good reception).

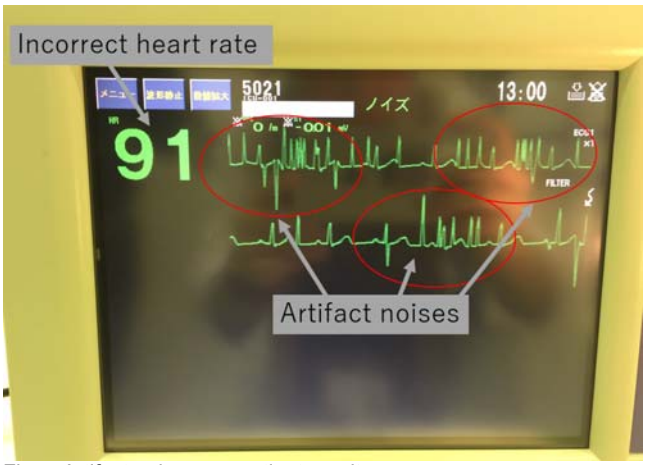

Fig.7. Artifact noise on a patient monitor

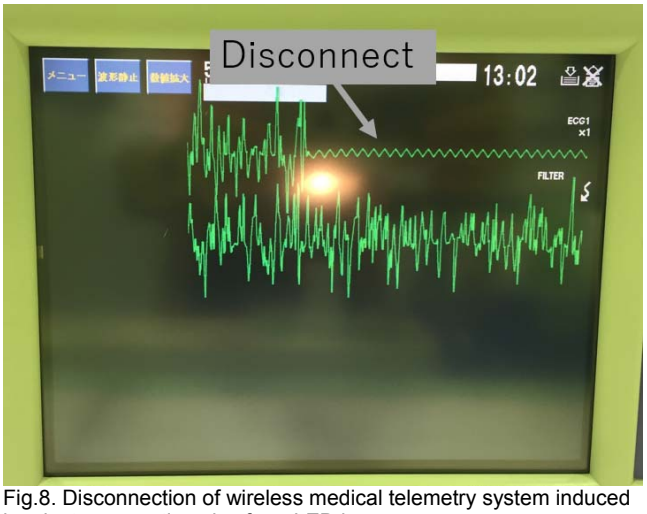

Fig.8. Disconnection of wireless medical telemetry system induced by electromagnetic noise from LED lamp

When the LED lamp was lit near the patient monitor, the noise level increased, and the wireless telemetry signal was buried in the noise (Fig. 9). As viewed from the prespective of time domain, the electromagnetic noise superimposed on the wireless telemetry signals (fig. 10).

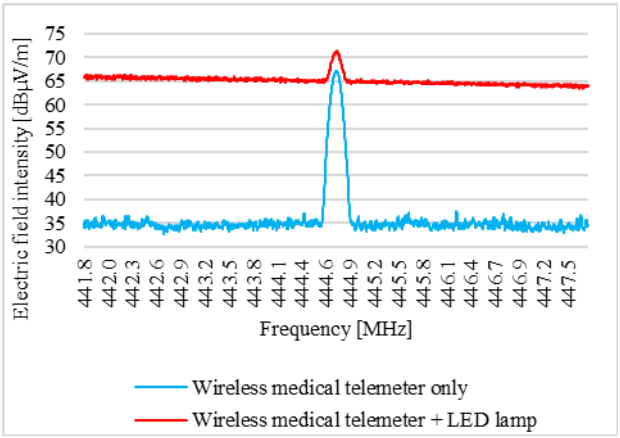

Fig.9. Reduction of signal-to-noise ratio when the LED lamp was lit next to the patient monitor

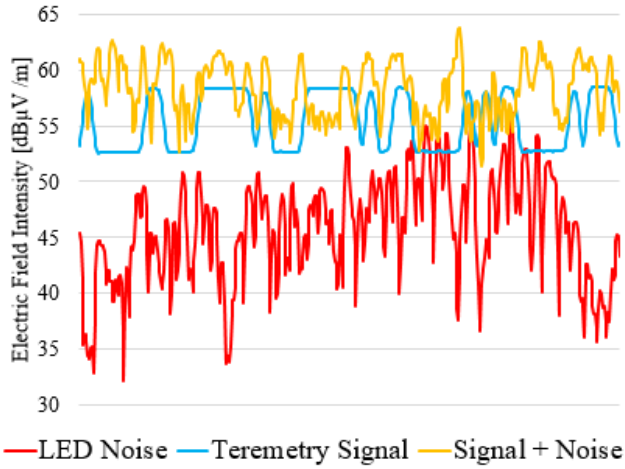

Fig.10. The electromagnetic noise superimposed on the wireless telemetry signals (time domain measurement)

Discussion

To receive signals satisfactorily for patient monitors, a signal-to-noise (S/N) ratio of at least 30 to 40 dB is required [7]. Our results showed that LED lamps increased the noise level and considerably decreased the S/N ratio. Generally, the S/N ratio of a wireless medical telemetry system is high when the transmitter and receiver are very close. When an LED lamp was lit near the receiving antenna of a patient monitor, even if it was at a distance at which good reception is normally obtained, the S/N ratio fell and noise was superimposed on the vital signal.

According to our results, both the AC power supply cable and the power circuit radiated noise in the 420 to 450 MHz band. Wireless medical telemetry systems consist of a receiving antenna (monopole antenna or leaky coaxial cable are often used in Japan), an amplifier, and coaxial cables in order to provide a good receiving environment throughout wards. Commonly, monopole antennas hang from the ceiling, but leaky coaxial cables are set in the ceiling. They are generally installed in the ceiling of hospital wards and corridors. Of course, AC power supply cables for LED lamps generally run through the ceiling. At many hospitals, various transmission cables, including leaky coaxial cables, are installed in this space. Therefore, leaky coaxial cables also pick up radiated noise and thus could be

subjected to interference from the AC supply cables of LED lamps. Moreover, LED lamps generate impulse noise via the power circuit of a switching supply [6]. The body of an LED lamp that is mounted on the power circuit may interfere with monopole antennas. Both the power circuit and the AC power supply are potential EMI sources and may cause poor reception in wireless medical telemetry systems with monopole antennas and leaky coaxial cables.

To prevent EMI with wireless medical telemetry systems, it is desirable to take the following measures: choose low-noise LEDs and maintain a sufficient distance between the LED lamps and the monopole antennas and leaky coaxial cables.

As we mentioned above, CISPR 15 ed.8.0 regulates the radiation noise level from electric lighting and similar equipment, but the target frequency range is limited. Additionally, the distance between the target device and the receiving antenna is set to 3 to 10 m to determine the noise level. However, EMI with wireless medical telemetry systems by LED lamps is caused when they are extremely near, such as in the ceiling or under the ceiling. In our results, the near-field electric field intensities (distances of about 1 to 50 cm) of several LED lamps were very high. Therefore, maintaining the electromagnetic compatibility of hospital lighting, especially to avoid interference with wireless medical telemetry systems by LED lamps, should be carried out by an approach different from CISPR 15. To provide safe and high-quality medical care, the electric field intensity measurements of 420 to 450 MHz should be disclosed when installing LED lamps in hospitals. Guidelines to promote the safe introduction of LED lamps at hospitals are required. One of the future issues for the establishment of highly viable guidelines is the quantitative evaluation of the degradation of reception in telemeter systems subjected to interference and the statistical evaluation of LED emissions.

Conclusion

We investigated the radiation noise from LED lamps and the possibility of interference with wireless medical telemetry systems. We confirmed that several LED lamps radiated an electric field at 420 to 450 MHz with high strength at the very near field. EMI with a wireless medical telemetry systems by LED lamps has the potential to occur at the extremely near field, i.e., in or under a hospital ceiling.

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