Eisuke HANADA[1], Kai ISHIDA[2], Takato KUDOU[3]

Saga University (1), National Institute of Information and Communications Technology (2), Oita University (3)

doi:10.15199/48.2018.02.06

Newly identified electromagnetic problems with medical telemetry systems

Abstract. *The current telemetry systems have enabled continuous monitoring of inpatient vital signs, but have the potential of being affected by electromagnetic noise or inappropriate signal range, which can impact patient safety. Herein, we report on newly identified problems associated with telemetry systems. We propose ways to solve these problems through information sharing among workers who construct and design hospitals, those who manage the medical devices used in hospitals, and those who deal with wireless communications.*

Streszczenie. *Obecne systemy telemetryczne pozwalają na ciągły monitoring funkcji życiowych pacjentów, ale jednocześnie są narażone na szum elektromagnetyczny i problemy z zasięgiem, co może wpływać na bezpieczeństwo pacjentów. Artykuł dotyczy nowo zidentyfikowanych problemów związanych z systemami telemetrycznymi i proponuje metody ich rozwiązania poprzez współpracę z projektantami szpitali, zarządcami urządzeń medycznych oraz specjalistami komunikacji bezprzewodowej. (**Nowo zidentyfikowane problemy w medycznych systemach telemetrycznych**).*

Keywords: medical telemetry system; wireless communication; building structure; electromagnetic noise; LED
Słowa kluczowe: medyczny system telemetryczny, komunikacja bezprzewodowa, struktura budynków, szum elektromagnetyczny, LED

Introduction

In Japan, "wireless medical telemetry systems" have been developed that continuously monitor inpatient vital signs, including heart rate with cardiac waveform, blood pressure, respiration rate, oxygen saturation rate in blood, and others. These systems consist of a monitor at the patient's bedside (bedside monitor) or affixed to the patient (patient monitor) that gathers vital signs and communicates them wirelessly to a monitor located in the staff station (central monitor). The Japanese government assigned the 420 MHz to 450 MHz frequency band for such use in 1989. If the output power does not exceed 1 mW, under the rules of the Japanese Radio Law, hospital staff can use the device without a license.

The wireless communications of almost all medical telemetry systems used in Japan are divided into frequency band "channels." Systems can be configured with a variety of bandwidths per channel, but a maximum of 480 channels can be used. Each bedside and patient monitor is assigned a unique channel; thus, 480 bedside monitors can be used in one area.

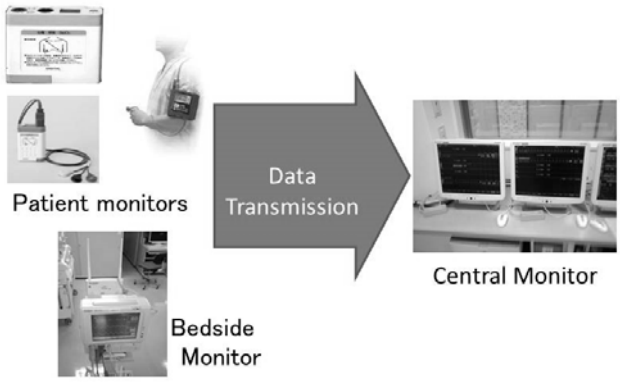

Fig.1. Medical Telemetry System

In other countries, the assigned frequencies differ. Some countries have assigned a band for MBAN (Medical Body Area Network), and some systems use the same frequency as wireless LAN. At present, almost all Japanese hospitals have adopted telemetry systems that use analogue signal communication.

The functions of the first medical telemetry system were continuous measurement and a warning system. For functions other than communication, the systematization of telemetry systems has progressed and more advanced functions have been added. Current telemetry systems connect to the hospital information system (HIS) and can send data to it to be stored. In addition, they have a function that can show a series of numerical values or cardiac waveforms for several seconds, including before and after a warning is sent.

Although wireless medical telemetry system use in hospitals that provide advanced care is spreading, various problems have appeared. For example, accidents caused by signals from patient monitors that did not reach the central monitor due to poor signal reception have been reported [1]. There were a variety of reasons for them. Some involved the battery of the patient monitor and others were caused by signal reflection from the doors, walls, or floors. Electromagnetic noise in the same band as a medical telemetry system can interfere with signals from the patient monitor, causing them not to reach the central monitor.

Any situation in which a signal does not reach its destination creates danger to a patient's life. Hospital directors should recognize and take steps to solve these problems. Here, we show examples of problems that have occurred in recent years and how to solve them.

Current problems with medical telemetry use

Problems common to wireless communication instruments include lack of the necessary access range and electromagnetic noise. In recent years, modernizations of medical devices and hospital construction have introduced factors that cause degradation of the communication environment.

Crosstalk is also a serious problem. Managing channels is one of the most important measures that can be taken to prevent these accidents. Almost 40 % of Japanese hospitals that adopt medical telemeters do not manage channels by themselves [1]. Because this is not a problem concerned with the electromagnetic environment, we do not discuss crosstalk between telemetry systems in this paper.

Change of the access range by changes to the building components

Not only the design but the structure of hospital buildings and the materials used in their construction have changed with the times [2].

In the case of Japan, major factors include the installation of shock-absorbing structures to meet improved

earthquake standards, remodelling, and the introduction of barrier-free designs to meet the requirements of patients with special needs.

A quake-absorbing structure reduces the influence of seismic waves on the building structure by supporting the building on springs and/or rubber pads that act as a damper. For best effect, the weight of the building must be reduced. To accomplish this, the amount of concrete used is reduced and deck plates are used for floor construction (Fig. 2), which means that wireless communication signals cannot penetrate the floor.

The walls between patient rooms in many modern hospitals are built with a steel frame and drywall. An acoustic absorber is put on the reverse side of the board leaving a space that enables easy repair and allows pipes to be set in the wall. Signals can more easily penetrate this type of wall than they can with a concrete wall. Also, when a room is divided, steel/aluminium partition panels are sometimes used that reflect wireless communication signals [3]. Cabinets made of steel also reflect wireless communication signals. When remodelling, a number of cabinets may be newly installed or moved, which can change the access range.

Fig.2. A floor made of steel deck plates (taken under construction)

The structure of doors and the composition of their materials have evolved along with the movement to enable a barrier-free environment. Examples include the use of sliding doors that reduce the chance of collisions and hanging doors that prevent falls by patients who might otherwise stumble over a door rail. The materials used for doors often include light metal panels to save weight, but metal doors reflect wireless communication signals.

Fig.3. Barrier-free doors of a patient room and a toilet (in a ward for children)

Sometimes telemetry antennas are set in a corridor. If the doors are made of metal, signals from a bedside monitor might not reach the antenna when the door is closed.

We regret that, at present, information about problems related to these construction methods is not being well communicated to the managers of the sections of the hospital responsible for managing medical telemetry systems: in many Japanese hospitals a clinical engineer.

Location of the antennas should be determined before construction and with precise planning. For example, electromagnetic propagation simulations should be done.

The best location for medical telemetry antennas is in each room. Sometimes the wall between the corridor and patient rooms is made of concrete. After construction, it is difficult to penetrate them to install cables for the antennas. In addition, when changes are made to the walls and doors at the time of hospital repairs or renovation, few hospitals do tests before construction that insure that the necessary wave access range can be maintained.

LED (Light Emitting Diode) lamps as a new noise source

The use of LED lamps is spreading quickly. LED lamps have a long life and can save energy. In Japan, electric bulbs are no longer manufactured and the production of fluorescent lighting is being reduced.

Recent reports on the introduction of LED lamps indicate that they can be the source of electromagnetic noise. Because a LED lamp is illuminated by the use of DC, it includes a rectifier circuit. In addition, the light-emitting device itself has a circuit. CISPR15 regulates electromagnetic field radiation by lighting apparatus. However, the upper limit of the target frequency is 300 MHz, and there is no regulation of the frequency band used by medical telemetry systems.

Studies of the relation between poor signal reception by medical telemetry systems and the electromagnetic field that a LED lamp emits are in progress, and reports have begun to appear [4, 5]. Because of insufficient information sharing, the antennas of medical telemetry system are often set too close to the ceiling lamps. In addition, lamps close to the antenna are sometimes replaced with LED. An example is shown in Fig. 4. In this situation, because the output of a bedside or patient monitor is weak, signals will be buried in the noise emitted from the LED lamp, in which case the central monitor cannot receive the signal correctly. If alarms are not received by the staff, patient safety suffers.

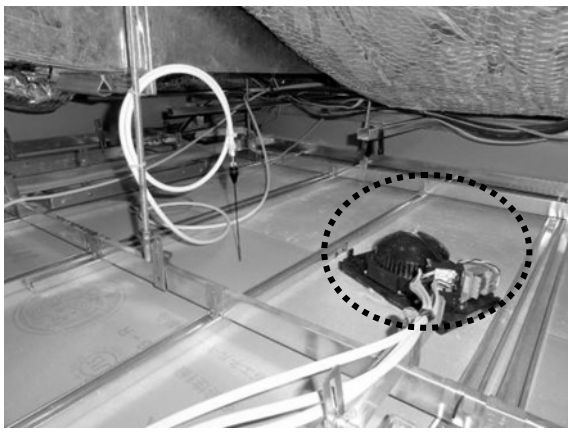

Fig.4. An antenna of a telemetry system (pole-type) and a LED socket (hatched circle) in the ceiling

There are no standards for the structure of LED lamps, and the structure of the circuits of the various products currently on the market is not unified. For this reason, the frequency distribution of the induced electromagnetic field differs for each.

Other ICT devices and medical devices

Some Information and Communication Technology (ICT) devices other than LED lamps, such as the I/O units and liquid crystal displays (LCD) of some nurse call systems or the access points of wireless LAN, may also emit or leak an electromagnetic field [4]. Basically, depending on the structure / device used in the electric circuit, every circuit emits an electromagnetic field, as mentioned above. The frequency differs with the structure of the circuit. In the case of the access point of wireless LAN, the communication signals emitted do not interfere due to the frequency difference. The inside of the circuit may emit an electromagnetic field with a frequency in the 400 MHz band [4]. Also, if the antenna of a wireless communication system is set too close to the unit, the antenna may not be able to receive signals correctly.

Non-invasive blood-pressure monitors and cardiotocomonitors (labour and fetal heart monitor) are categorized as medical telemetry systems, and the Japanese government has assigned the 429 MHz band to them. These medical devices are usually managed by other sections than the one that deals with medical telemetry systems. These situations may bring about crosstalk, or affect each other during wireless communication.

The Japanese government also assigned the 429 MHz band to remote-control systems, including signals for controlling cranes used in building construction. This means that there would be interference with medical telemetry systems only when the crane is working.

Some sensor systems designed to detect a patient leaving bed are also assigned the 429 MHz band. Along with the aging population, the number of patients who wander away from their beds is increasing. The demand for these systems is also increasing because of difficulty in recruiting sufficient staff for hospitals. Because of the increased number of these systems, the danger of interference has greatly increases.

Medical telemetry systems other than in Japan

As mentioned above, frequency bands assigned for medical telemetry systems in other countries differ from those in Japan. The lowest of the three bands designated by the FCC is from 608 to 614 MHz [6]. Other bands are above 1GHz. The results of our research showed that some LEDs with high power emit noise in this band [5]. This means that in many countries LED lamps might interfere with medical telemetry systems. Because we did not measure the higher frequency band, we are planning further studies.

Some medical telemetry systems use wireless LAN in their infrastructure. Some medical devices are known to emit strong electromagnetic fields of the same frequency as wireless LAN [7, 8], and thus may be noise sources. Microwave therapy systems are known to emit a strong 2.45GHz band electromagnetic field [8]. The maximum output power regulated in JIS T 0601-2-6:2015 is 250 W, but it was 100 W in the older version of the same JIS.

Measures that can be taken

To solve the problem of insufficient information sharing between the construction section and the section that deals with wireless communications, the Electromagnetic Compatibility Conference Japan has published guidelines and presented approaches that can be taken [1]. One of the authors, EH, participated in making the guidelines. Electromagnetic field propagation simulation is a useful tool for determining the necessary strength and reach of electromagnetic signals. Also, many types of materials/techniques for electromagnetic shielding have been invented for the management of electromagnetic fields.

In the near future, many kinds of wireless communication systems will be introduced, many specific to or that can be modified for hospital use. This means that different frequency bands will be required, in which case the desired reachable area of each wireless communication device may differ. As examples, it is important that wireless LAN signals not have such long reach that patient information cannot be protected but, at the same time, cellular phone signals from outside must be accessible in the hospital building. Some electromagnetic shielding techniques can block some frequency bands. Materials have been developed that provide shielding from electromagnetic fields while maintaining good transparency to visible light to keep the necessary brightness [9].

In regard to the problem of insufficient information about the emission of electromagnetic fields by LED lamps, we are in the process of doing studies through which we hope to shed light on the magnitude of the problem and to give concrete solutions to problems that are emerging with this new technology.

As we are finding solutions to the above problems, new technologies will be developed and incorporated in hospitals and the technology used in LED lighting will continue to advance. Therefore, it will be necessary for people who design and construct medical telemetry systems to keep these things in mind. A simple solution is for antennas to be installed a safe distance from noise sources, with the distance set according to the results of scientific study. Because many of the cables and antennas used by medical telemetry systems pass through hospital walls and the ceiling, it is important that the equipment management and facility management sections collaborate in these investigations.

Medical telemetry systems as IoT systems

A medical telemetry system is based on the same concept as an IoT (Internet of things) system, which consists of mobile terminals with sensors, network, and servers that collect data from the sensors. Because many IoT systems have adopted wireless communication, electromagnetic noise can cause interference. Disturbance of the sensor functions by an electromagnetic field (EMD for sensors) occurs rarely, but poor signal reception is often seen.

For IoT systems, wireless communication systems using the ISM (Industry Science Medicine) band are often used. A microwave therapy system, for example, might be a problematic noise source for IoT systems. Developers and the manager of a hospital IoT system should search for and eliminate noise sources from the area in which an IoT system will be used. Even if the IoT system uses the 5 GHz band wireless LAN, there are some restrictions. In Japan, the W52 and W53 bands are limited to indoor use because they duplicate the band used in satellite communication.

IoT systems are beginning to be used for the monitoring of biomedical information. This will be indispensable for physicians and nurses who treat serious patients. To insure patient safety, wireless communication must be a secure part of the infrastructure. Wireless communication is available in any area that the signals can reach. Improvement is needed in the management of the electromagnetic environment of most hospitals.

Conclusion

The use of radio wave based communication systems and electric waves in hospitals will rapidly progress. To insure safe and reliable communication, the range of access must be maintained appropriately and electromagnetic noise sources must be eliminated. Situations in which communication is stopped or the desired transmission speed is not obtained may be caused by various factors other than those shown here.

We hope that hospital directors and their staff will seriously consider the benefits of wireless communication and take an interest in maintaining a good electromagnetic environment and take the measures necessary to eliminate noise, which will require educational programs and information sharing.

Acknowledgments

The authors wish to deeply thank Mr. Yoshiya Muraki of Tokai Univ. for his precious information about medical telemetry systems.

This work was supported by JSPS "KAKENHI" grants Nos. 15K21461 and 15H04794.

***Authors**: Prof. Eisuke Hanada, Dr Eng., Saga Univ. Graduate School of Engineering and Science, Department of Information Science, Honjo-machi 1, Saga, 840-8502, Japan, E-mail: hanada@cc.saga-u.ac.jp; Dr. Kai Ishida, CE., National Institute of Information and Communications Technology, Applied Electromagnetic Research Institute, 4-2-1, Nukui-Kitamachi, Koganei, Tokyo 184-8795, Japan E-mail: gishikai@nict.go.jp; Prof.. Takato Kudou, Dr Eng., Dept. of Innovative Engineering,Division of Electrical and Electronic Engineering, Dannoharu Oita, 870-1192, Japan E-mail: tkudou@oita-u.ac.jp*

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