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Problems and solutions in the introduction of wireless communication technology to the clinical medicine setting

Abstract. *The introduction of wireless communication technology into large Japanese hospitals is rapidly progressing. However, many hospitals are having problems, such as inadequate signal range, electromagnetic interference by waves generated inside/outside the hospital, or by devices carried in by the staff or patients, and some have problems with network security. Here we show illustrations of these problems and give solutions that might be considered.*

Streszczenie. *Wprowadzanie technologii komunikacji bezprzewodowej w dużych szpitalach w Japonii postępuje bardzo szybko. Jednak w wielu szpitalach występują problemy, takie jak niedostateczny poziom sygnału, zakłócenia w postaci fal elektromagnetycznych wytwarzanych wewnątrz i na zewnątrz szpitali lub generowanych przez urządzenia noszone przez personel lub pacjentów, a w niektórych przypadkach problemy z zabezpieczeniem sieci. W artykule zaprezentowano te problemy oraz zaproponowano rozwiązania, które mogą być zastosowane. (**Problemy i rozwiązania w związku z wprowadzeniem technologii komunikacji bezprzewodowej w jednostkach opieki medycznej**).*

Keywords: Electromagnetic environment; Electromagnetic Noise; Security.
Słowa kluczowe: środowisko elektromagnetyczne; szum elektromagnetyczny; bezpieczeństwo.

Introduction

The introduction of wireless communication technology by large Japanese hospitals is rapidly progressing and expanding. Typical examples of how wireless LAN data is currently used include communication between the servers and terminals of hospital information systems and voice communication between patients and nurses that uses a weak output mobile phone system (PHS, Personal Handy-phone System) as part of a nurse call system. Portable radiological imaging equipment that transmits images to a Picture Archive and Communication System (PACS) through wireless LAN has been commercialized and is widely equipped in wards. In Japan, the diffusion rate of mobile phones is close to 100%, of which smart phones exceed 40%. In this environment many inpatients wish to use in-room wireless LAN or mobile phones. The Japanese guidelines for the use of mobile phones in hospitals have recently been reformed, and areas in which they are permitted have been increased. In some hospitals, inpatients are permitted to use wireless LAN to connect to the Internet. The introduction of RFID systems is attracting attention. IC cards are used widely as a secure form of door key. There is also a movement to incorporate VoIP technology into nurse call systems.

However, many hospitals are having problems, as in the list below, and are being left behind in their efforts to employ safe, convenient, and economic wireless communication systems.

1. Inadequate signal range
2. Electromagnetic interference by waves generated outside the hospital
3. Electromagnetic interference by electromagnetic noise from sources inside the hospital
4. Electromagnetic interference by devices carried in by the staff or patients
5. Problems of security

Among the above, problems 1 to 4 are concerned with network availability. If availability is not secured, wireless communication cannot be done or would be difficult. In this paper, we show illustrations of these problems and give potential solutions, such as electromagnetic propagation simulation in the planning stage and appropriate shielding.

EMC and wireless LAN use in hospitals

When the installation wireless LAN is being planned, electromagnetic compatibility (EMC) both between the wireless LAN and medical devices and between the wireless LAN and people must be carefully considered.

In Japan, the output of wireless LAN apparatus is limited to under 10mW/MHz by the Radio Law. The bandwidth of a wireless LAN channel is 22MHz in IEEE802.11b and 20MHz in IEEE802.11g. Considering the envelope intensity, the summed output of the wireless LAN apparatus will be under 200mW. This output is lower than that of a Japanese cellular phone handset.

Therefore, at least in Japan, wireless LAN use is compatible with medical devices unless they are too close [1]. The maximum output from wireless LAN apparatus in Europe is limited, equal to or less than that of Japan.

Even if a wireless LAN apparatus emits the maximum output allowed in Japan, the electric intensity will not exceed the Japanese guidelines for human exposure unless the apparatus is affixed to the skin [2]. This means that the use of wireless LAN is quite safe, however, user education on keeping wireless LAN apparatus at a distance of at least several centimetres from medical devices or people is necessary before beginning use.

EMI between Japanese wireless LAN apparatus and medical devices or people has been well researched. If the output of wireless LAN apparatus is lower than that specified by Japanese Radio Law, EMC can be insured almost anywhere in the hospital.

Problems with hospital wireless LAN

A. Inadequate signal range

Inadequate signal range is often seen, mainly because the material used in the walls and doors causes the signal range to be smaller than what was assumed when the building was planned.

One example is Shimane University Hospital (hereafter, SUH) [3], where the corresponding author worked for over 12 years. SUH built a new hospital building in 2011. It has nine floors that are 51 m east to west and 31 m (the lower four floors are 51 m) north to south. The fifth to ninth floors are wards, and there is a staff station in the centre of each floor.

The floor plan of the new building is shown in the upper part of Figure 1. Wireless LAN use was available at the opening of this building. The designer planned six access points (AP) to cover one floor. The planning focused on computers placed on desks and did not consider the material of the walls and doors or that the floor of the target

space was built using a slab construction method that included steel rods imbedded in concrete. The door of each patient room is made of lightweight steel. The door of the pipe space (corridor side) for the toilets in the patient rooms is made of iron. The glass does not have any special electromagnetic shielding capacity, and most of the walls between patient rooms are made of gypsum board with steel frames.

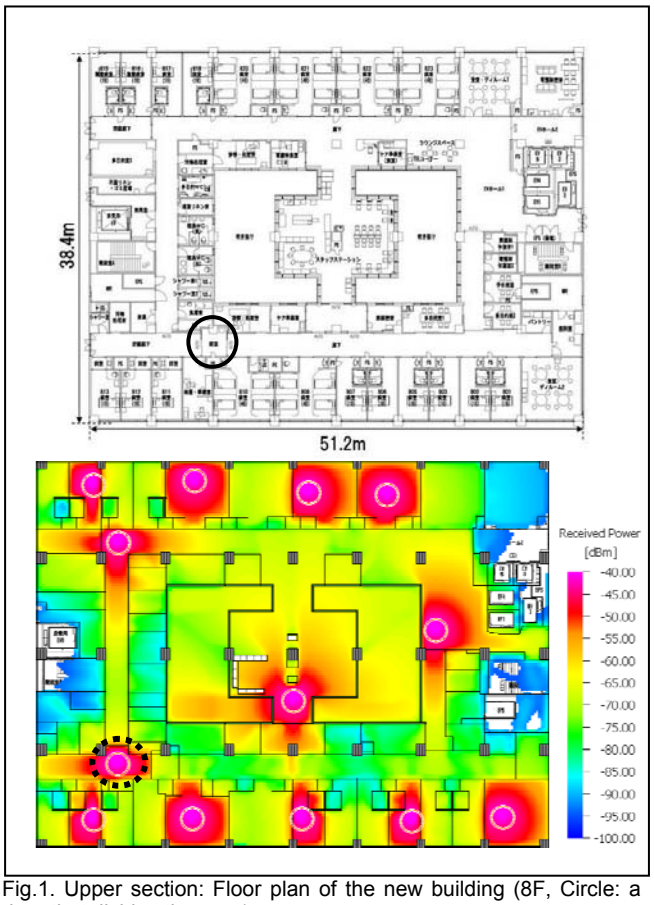

Fig.1. Upper section: Floor plan of the new building (8F, Circle: a door that divides the area)
Lower section: Simulation results (white circle is the recommended position of the APs. The dotted circle is an extra AP)

We did an electromagnetic field propagation simulation using the Lay-tracing method, with the goal of obtaining a bit rate of 10 or more Mbps at bedside in all of the wards. Based on the results of the simulation (shown in the lower part of Figure 1), 13 sets of APs were installed on this floor. On other ward floors, the average number of APs was 12. Especially on this floor, doors (shown as a circle in the upper section of Figure 1) are set in the corridor. Because this floor is a ward for serious cancer patients, doors are used to divide the area by the air cleanliness class. The material of the door was not known at the time of our simulation. We performed the simulation under the assumption that the door was made by metal. As a result, one extra AP, shown in the lower section of Figure 1, was required on this floor. The total number of APs needed to be increased by about 1.5 times what was included in the original plan.

B. Electromagnetic interference by waves generated outside the hospital

The spread of wireless LAN to homes and offices has been remarkable, and these outside wireless LAN signals can invade a hospital, which can cause interference with the waves generated by the hospital wireless LAN. Even when the signals from an AP reach the intended terminal, communication failure can occur if the signal received from other AP(s) is stronger. To insure the effectiveness of the Wi-Fi environment, it is imperative that signals reach the required area at intensity greater than the threshold.

When the service set identifiers (SSID) of APs in different systems are the same, terminals will have difficulty determining with which AP to communicate. Thus, we felt it important to investigate the possibility of signals from outside the hospital that might interfere with the efficient operation of our system. To accomplish this, we investigated the IEEE802.11a and 11g signals coming from outside the new SUH building [3]. No signals that might have an effect on our wireless LAN communication were detected in 11a, but there were three in 11g. Other detected signals were of weak intensity.

For these three strong 11g signals, the signal intensity distribution was investigated in detail, and the most powerful signal detected was that on the northeast corner of the second floor. The received signal intensity was approximately -50dB. The SSID of this signal source was initially thought to be an institution located in a neighbourhood to the west. The results of more precise analysis showed that the signal was probably not from this institution, but rather from an AP installed in a section of SUH on the second floor of the building immediately to the north. This should not be a problem because the room where the strongest intensity was recorded is a space only for staff, and the users of the room did not intend to use HIS terminals connected to the wireless LAN. On other floors, there was no invasion of this intensity. For these reasons, the results of the investigation showed that we did not need to change the planned locations of the APs for the new building, and we concluded that the installation of electromagnetic shielding was unnecessary.

C. Electromagnetic interference by electromagnetic noise from sources inside the hospital

The use of medical devices and electronic products that use the same frequency as wireless LAN can interfere with the waves generated by the hospital wireless LAN.

The use of wireless LAN AP installed without the permission of the LAN manager (out-of-control AP) will affect the existing LAN. In addition, electromagnetic noise sources that can block wireless LAN communication in the 2.4GHz band, which is used by IEEE802.11b/g/n, may exist in a hospital. A well-known example is a microwave oven, and the possibility has also recently been shown for game machines with a communication facility. In addition, some medical devices also emit electromagnetic noise in the 2.4GHz band.

Our previous investigation found electromagnetic waves that had leaked from a microwave oven [4], with electromagnetic fields observed equivalent to the centre frequencies of channels 11 and 13 of IEEE802.11b.

Wireless LAN and game machine communications may also be influenced. Some of them use a 2.4GHz band signal. Our observation found a remarkable reduction of the transmission rate of wireless LAN when there was communication between two game machines [5].

One example of a medical device as a source of an electromagnetic field is microwave therapy equipment (Figure 2). Such equipment permitted in Japan has a maximum output of 250W and is often used for warming treatment at clinics, nursing homes, and ordinary homes. Standardization is by the Japan Industrial Standard (JIS T0601-2-6 [6]). It is problematic that microwave therapy equipment can irradiate strong 2.4GHz band electromagnetic waves.

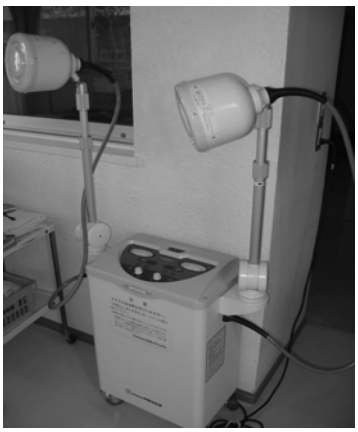

Fig. 2. Microwave therapy equipment

The authors observed the influence of microwave therapy equipment on wireless LAN communication in a hospital and measured the electric field intensity in an electromagnetic anechoic chamber [7]. Wireless LAN signals were not observed when the equipment was switched on. In addition, four invading signals were observed when the equipment was switched off. The maximum electric field intensity of 49 V/m was measured at three meters from the front of the equipment. This value exceeds the radiated electric field value permitted in the presence of life sustaining equipment.

D. Electromagnetic interference by devices carried in by the staff or patients

Recently, staff members have been allowed to carry in their personal communication devices. This is being called “bring your own device”, BYOD. The use of BYOD may bring about security problems, as described in section E, with the instrument itself serving as a source of electromagnetic noise. Measures are necessary to avoid situations in which BYOD leads to the transfer of sensitive information from the hospital system to personal devices.

The waves generated by tablets, smart phones, and game machines that personnel or patients carry in and use for private purposes can interfere with the hospital wireless LAN. In addition, a patient could carry in a radio router (tethering instrument) for private communication. This could bring about the same problems as the above-mentioned out-of-control AP installation.

E. Problems of security

If the security setup is not well planned and executed, many kinds of problems may arise. For example, an unauthorized person could access the hospital wireless LAN to monitor communications or to access, alter, or destroy patient data. Also, unapproved information disclosure and availability problems are examples of security matters that must be considered when planning and using wireless LAN in a hospital. Network managers need to protect against information leaks through wireless LAN connected terminals, even if the terminal is accessed correctly. If information can be saved in a terminal, the possibility exists that the information can be downloaded and taken outside the hospital. Also, disturbances of availability can be caused by electromagnetic noise, as above-mentioned.

The security policy of SUH is as below. Initially, the wireless LAN communication infrastructure of SUH was for staff use only. MAC Address filtering was used in the AP to prevent unauthorized connection. Also, the setup of the SSID refuses connection with the value "Any", and the value is different for each floor to prevent unauthorized connection and to prevent terminals from being moved from their assigned floor. Data encryption using OCB AES (128 bits) is used to prevent the interception of information. In addition, communication logs are stored for a year and managed by the network administrators. Although the input of an ID and password is unnecessary at the time of connection to the network, authentication with an ID and password is necessary at the time of login to a destination system.

The IEEE802.11a and IEEE802.11g specifications are both used in the new system. Communication with HIS terminals is mainly done with 11a, and other uses are assigned 11g. The purpose of this separation is to keep the influence of other systems on the HIS at a minimum, for example by portable radiological equipment that transmits a massive amount of data.

In SUH, the use of HIS terminals other than those installed by the hospital is forbidden. However, a medical model has come to be used in which medical teams are a blend of staff from the traditional clinical divisions. This means that staff members may move to work in multiple wards. To solve the challenges this creates, we adopted Dynamic VLAN technology and enabled selection of a connection destination by setting up SSIDs for use in a single floor unit or for the whole building. The setting up of SSID terminals is restricted to the system administrators, and change by a user is not permitted.

Although the cipher system was changed to WAP2-PKI, MAC address filtering and communication log management are carried out as before.

In addition, BYOD may be a source of information leaks. Devices such as personal computers and USB memory sticks can be used to save information from the hospital information system (HIS) servers and the device can be carried out of the hospital. This type of "taking information out of hospital" should be forbidden. Also, all staff members must be careful to avoid the loss or theft of the devices in their care.

Fundamental solutions to the above threads

Proper management of the wireless LAN system and keeping it user-friendly are the most important things for solving the problems discussed above. Security problems related to wireless communication have been discussed for decades, and methods to control access to terminals, authenticate users, and for the cyphering of data are widely available. User education is also important.

On the other hand, electromagnetic problems are not yet being well managed. In this paper, we described the electromagnetic noise found in the frequency band for IEE802.11 series wireless LAN. Unfortunately, there are many noise sources in hospitals [8]. In order to insure electromagnetic compatibility (EMC) between wireless communication systems and medical devices, we recommend careful consideration of the electromagnetic environment, including the materials of walls, floors, and windows. Interdisciplinary collaboration with construction and materials engineers is essential [9]. With knowledge of the building materials used, we can stimulate the propagation of wireless LAN signals.

Conclusion

SUH, where the first author worked for 12 years, has realized an environment in which access to and the sharing of information are possible “anytime, anywhere". The system has been used safely for more than 10 years. Before the construction of the new hospital building, electromagnetic field propagation simulation was done to insure that wireless LAN could be safely used.

Wireless communication use in hospitals will continue to expand. The installation of VoIP and a system that extensively uses RFID tags are being developed.

Because security countermeasures are indispensable when introducing wireless communications to a clinical setting, the above proposed security countermeasures must be carefully considered.

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REFERENCES

[1] E. Hanada, Y. Hoshino, H. Oyama, Y. Watanabe, Y, Nose Negligible electromagnetic interaction between medical electronic equipment and 2.4 GHz band wireless LAN. Journal of Medical Systems 26 (2002), No.4, 301-308

[2] Telecommunications Bureau of the Ministry of Internal Affairs and Communications (Japan) Telecommunications Technology Council Report No. 89 "Radio-Radiation Protection Guidelines for Human Exposure to Electromagnetic Fields". 1997 (Available from Webpage http://www.tele.soumu.go.jp/e/sys/ele/index.htm, Accessed on Oct. 9, 2015)

[3] E. Hanada, T. Kudou, and S. Tsumoto, “Installation of Secure, Always Available Wireless LAN Systems as a Component of the Hospital Communication Infrastructure,” Journal of Medical Systems, 37 (2013), No.3, Article 9939 http://dx.doi.org/10.1007/s10916-013-9939-2

[4] E. Hanada, and T. Kudou, “Electromagnetic noise in the clinical environment,” Proc. ISMICT2009 (The 3rd International Symposium on Medical Information and Communication Technology) (2009), 2D04, Montreal.

[5] K. Ishida, D. Watanabe, K. Fujiwara, and M. Hirose, “Study of Electromagnetic Interference with Wireless LAN by Wi-Fi Devices,” (in Japanese) Proc. The 34th Joint Conference on Medical Informatics (2014), 660-663.

[6] Japan Industrial Standard, “JIS T0601-2-6:2015, Medical electrical equipment-Part 2-6: Particular requirements for the basic safety and essential performance of microwave therapy equipment,” Japanese Industrial Standards Committee, 2015.

[7] E. Hanada, S. Itoga, H. Tamai, Y. Nagae, H. Kurosawa, T. Meguro, T. Kano, and T. Kudou, “Unnecessary” Electromagnetic Field Radiated From Medical Devices,” Proc. ISMICT2010 (The 4th International Symposium on Medical Information and Communication Technology) (2010), A1-5

[8] E. Hanada, “The electromagnetic environment of hospitals: How it is affected by the strength of electromagnetic fields generated both inside and outside the hospital,” Ann Ist Super Sanita, 43 (2007), no.3, 208-217

[9] E. Hanada, “The necessity of interdisciplinary collaboration for the improvement of the electromagnetic environment in medical settings,” Journal of Electrical & Electronic Systems, 3 (2014), 122. http://dx.doi.org/10.4172/2332-0796.1000122