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Safe introduction of in-hospital wireless LAN

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Abstract

Insufficient research on electromagnetic interference (EMI) with medical electronic equipment by the signals of wireless LAN has been done. Therefore, electromagnetic compatibility between medical electronic equipment and wireless LAN data communications was done (IEEE802.11a, b, and g).
First, to determine if medical electronic equipment is affected by EMI caused by radio waves, we irradiated radio waves to ten types of medical electronic equipment in an electromagnetic anechoic chamber. EMI were observed on three pieces of equipment. Next, to determine if the electromagnetic field emitted by the medical devices might interfere with wireless LAN communication, we measured the electric field intensity. Data analysis showed that the electromagnetic wave emitted by microwave ovens was at almost the same center frequency of the communication channel specified by the IEEE802.11b for wireless LAN.
Although the number of medical electronic equipment investigated in this study was small, hospital administrators should consider electromagnetic wave testing of all medical electronic equipment to be used in areas of common wireless LAN use when planning the installation of wireless LAN.

Keywords

Electromagnetic Interference, wireless LAN, medical electronic equipment.

Introduction

Because electronic medical record keeping is being introduced into Japanese hospitals, the necessity for bedside access to medical examination data is increasing. In order to realize this, installing bedside LAN cables or installing wireless communications is required. From the viewpoint of cost, wireless communication would be most attractive.

Due to fear of electromagnetic interference (EMI) with medical electronic equipment, the introducing wireless LAN with electromagnetic waves has been slow. As a result of investigations in 1994-1995, the Japanese Ministry of Public Management, Home Affairs, Posts and Telecommunications implemented a guideline that forbids the use of cellular phones in almost all areas of hospitals. Because of the guidelines, hospitals in Japan have been negative to the installation of radio communications, other than remote patient monitors. This guideline was also updated to apply to third generation cellular phones, such as W-CDMA, after investigations done in 2002 [1]. Only experimental results were released concerning wireless LAN, and the propriety of use was not shown in the results of these investigations. In many countries, electromagnetic waveÅ@emission in the hospitals is restricted [2-3].

In Japan, nurse call systems have adopted the mobile PHS (Personal Handy-phone System), for installation into many hospitals. PHS is a technology developed in Japan and the maximum output of the radio waves (1.9GHz band) emitted from a subscriber a feeble 0.08W. Therefore, use of PHS is allowed in larger areas than cellular phones under the Japanese guidelines [1]. After confirmation of the safety of medical electronic equipment in the presence of radio waves from PHS [4-5] PHS was widely embraced, not only by nurses but also by doctors in Japanese hospitals.

However, since the transmission speed and security of data communication on wireless LAN systems has improved, the expectations for wireless LAN in hospitals has grown [6-8]. Because the safety of wireless LAN on medical equipment has not been well documented, only a few hospitals have introduced wireless LAN as test cases. To test the safety limits of medical electronic equipment in the presence of radio wave data communication equipment, we irradiated a number of pieces of such equipment with radio waves emitted from wireless LAN apparatus.

Methods

Observation of wireless LAN interference with medical electronic equipment

In order to investigate if EMI by radio wave in the 2.4GHz band and 5.2GHz band on medical electronic equipment, as standardized by IEEE802.11 [9-10], we irradiates radio waves to a number of pieces of medical electronic equipment in an electromagnetic anechoic chamber (4m by 7m, and 3.5m in height, at ADOX Fukuoka, Nogata, Japan). Using the system shown in Figure 1 with the equipment shown in Table 1, irradiation was done with sine waves (2.45GHz and 5.2GHz) emitted from antennas located at the front, back, right side, left side, top and bottom of the medical electronic equipment. The output was 2.7W for 2.45GHz, and 2.9W for 5.2GHz. The output value was determined by the maximum power of the amplifier.

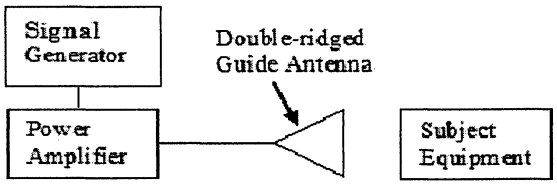

Figure 1 - Schematic diagram of the radio wave irradiation process

Table 1: Equipment used for radio wave irradiation

Equipment	Distributor	Types
Signal Generator	Hewlett-Packard	8341A
Power Amplifier	Hewlett-Packard	8349B
Double-ridged Guide Antenna	EMCO	#3115
Cable (10m)		5D2W

The equipment included one piece of hemodialysis equipment, two ventilators, one electric knife system, three infusion pumps, and three syringe pumps. Each piece of equipment requiring a liquid was made operational using water.

Radio waves were irradiated to each piece of equipment. The antenna was first set about 30cm from the equipment. If there was no malfunction, the antenna was brought closer until it touched the surface of the equipment. When a malfunction was observed while recording the phenomena, the distance from the medical equipment at the time of malfunction was observed.

Interference to the 2.4GHz band wireless LAN by electronic medical equipment

In order to determine if electromagnetic fields emitted by medical devices might interfere with wireless LAN communication, we measured the electric field intensity of equipment that is usually used in hospital wards. The measurement focused on the frequency band used by wireless LAN. The target devices were one remote patient monitor, one electric knife system, and two microwave ovens.

Table 2: Equipment used for radio wave measurement

Equipment	Distributor	Types
Spectrum Analyzer	Hewlett-Packard	8566 B
Double-ridged Guide Antenna	EMCO	#3115
Cable (5m)		5D2 W

Measurement was done in an electromagnetic anechoic chamber (10m by 30m, and 10m in height, Nippon Sheet Glass, Ibaraki, Japan) using the system shown in Figure 2 with the equipment shown in Table 2. The radiated electric field was once received using a dipole antenna and was analyzed with a spectrum analyzer. When the frequency was high, the receiving antenna was changed to a double-ridged guide antenna and measured again. The receiving antenna position was fixed at 3m from the object equipment. Since it was thought that the radiation of the patient monitor and the electric knife did not have directivity, the position was set only in front. The microwave oven was measured with the antenna to the front, right, left, and back.

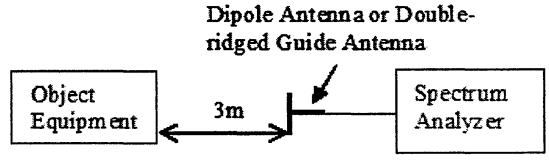

Figure 2 - Schematic diagram of the radio wave measurement process

Results

Experiment 1

For 2.45GHz radio waves, malfunctions were observed in two models of syringe pumps and one ventilator. For 5.2GHz radio waves, malfunction was observed in one of the three models of syringe pump. Details are shown in Table 3.

Experiment 2

The center frequencies of the electromagnetic wave emitted from the electronic devices and electric field intensities are shown in Table 4. Although the electromagnetic waves emitted from the patient monitor and the electric knife was comparatively strong in center frequency, the intensity at frequencies 10% or more separated from the center frequency were very weak. The center frequency of the electromagnetic wave that leaks from a microwave oven may be the same as the frequency of the channel defined by the IEEE802.11b standard [9], as shown in Table 4. Moreover, from some of the microwave ovenÅ@directions, strong electric field intensity was observed even in the ranges 20% separated from the center frequency.

Discussion

In this observation, EMI with medical electronic equipment irradiation by radio waves with strengthened output were observed. This shows that EMI may occur even if the frequency of the irradiated radio wave is the same as the one used by wireless LAN, much higher than the one used in cellular phone systems. However, in this experiment, the power of the irradiated radio waves was several times or more stronger than the maximum output of the actual wireless LAN apparatus permitted by the laws of Japan, 10mW / MHz [11], and the United States, 1W [9]. Therefore, it cannot be said with certainty that EMI occurs when using wireless LAN in an actual clinical setting.

In analysis of the electromagnetic waves emitted by electronic devices, there were cases where the frequency of the electromagnetic wave, which a microwave oven emits, was almost the same as the center frequency of the communication channel specified by the IEEE802.11b for wireless LAN. Some apparatus based on the IEEE802.11b specifications have the terminal or the access point constantly supervising the field intensity or the S/N ratio of the received signals.

Table 3: Type of malfunction of irridiated medical electronic equipment

a) 2.45GHz

Equipment	Position of the antenna	Malfunctions	Maximum Distance
Ventilator B	Gap on front	Incorrect numerical display on the ventilation amount sensor (lower)	10cm
Syringe Pump B	Bottom	Incorrect lighting of the extension tube occlusion status indicator	40cm
		Equipment stopped with incorrect warning of the extension tube occlusion	10cm
	Back	Incorrect lighting of the extension tube occlusion status indicator	12cm
		Equipment stopped with incorrect warning of the extension tube occlusion	6cm
Syringe Pump C	Bottom	Equipment stopped with incorrect warning of the extension tube occlusion	3cm

b) 5.2GHz

Equipment	Position of the antenna	Malfunctions	Maximum Distance
Syringe Pump B	Bottom	Equipment stopped with incorrect warning of the extension tube occlusion	6cm

Table 4: Observed electromagnetic-waves emitted from the tested electronic device

Equipment	**Function**	**Center frequency of emitted electric field**	**Maximum Electric Intensity**	**Equivalent Channel Number (IEEE802.11b)**
Remote Patient Monitor (Transmitter)		**441.3MHz**	**86.8 V/m**	-
Electric Knife	**Mono-polar**	**500kHz**	**97.4 V/m**	-
	Bi-polar	**461.8kHz**	**104.5 V/m**	-
	Argon Beam Coagulator	**620kHz**	**91.1 V/m**	-
Microwave Oven A		**2.465GHz**	**121.3 V/m**	**11ch.**
Microwave Oven B		**2.472GHz**	**117.2 V/m**	**13ch.**

When the value of field strength or the S/N ratio is below the fixed one, these apparatus change their own settings in many cases, such as automatic transmission speed reduction or changes in the method of performing more positive communication. From this result, when a microwave oven and an access point are near, it is suggested that the electromagnetic waves leaked from the microwave oven will mix in the receiving antenna of an access point, with the possibility that transmission speed will be influenced as a result. Not installing an access point near a microwave oven would be recommended.

The radio wave frequency band used by the IEEE802.11b and IEEE802.11g standard is 2.4000 GHzÅ`2.4835 GHz. This band is called the ISM band (Industrial, Scientific and Medical band) and has a wide range of applications. For radio data communication, a de-facto standard called Bluetooth [12] uses this ISM band. Bluetooth data communication equipment for short-range communication between household electrical appliances is inexpensively marketed. If the introduction of wireless LAN is haphazard, the possibility exists for interference with communication between Bluetooth equipment and IEEE802.11b or IEEE802.11g equipment.

Conclusion

Because the number of medical electronic equipment investigated this study was small, the director of a hospital should consider electromagnetic wave irradiation testing of all the medical electronic equipment used in any area where wireless LAN is planned. Since a stronger output of emission by wireless data

communication equipment is accepted in Europe and America than that in Japan [9], the need for irradiation testing is high.

Wireless LAN systems in the future with even higher-speed data communication are expected to be put on the market. It would seem prudent to check the safety of any new wireless LAN transmitters based on new specifications that appear on the market.

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