Electromagnetic Interference with Medical Devices from Third Generation Mobile Phone Including LTE

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***Abstract*—This paper describes Electromagnetic Interference (EMI) with medical devices used in hospitals from third generation mobile phone. Transmission power, frequency, radiation mode, and radiation sources are considered to investigate the relationship with EMI. Long Term Evolution (LTE), High Speed Packet Access (HSPA), and Wideband Code Division Multiple Access (W-CDMA) are selected as the transmission method because they are widely spread over the world. Thirty-two different medical devices, which are mainly used in the operating room or Intensive Care Unit, are used in this evaluation. The results show that 12 medical-device models (37.5%) incurred EMI. The results also clearly show that the EMI strongly depends on the transmission power and the distance between the mobile phone and medical device. For example, when transmission power at 800 MHz is the nominal maximum and 10 dBm, the maximum EMI distances are approximately 70 and 10 cm, respectively. Based on this, the nominal maximum power test is important for conservative evaluation. On the other hand, the results do not show that EMI is dependent on the frequency band. Therefore, evaluations must consider all mobile phone frequency bands so that EMI can be property detected. Furthermore, the electromagnetic field emitted by a half-wave dipole antenna causes higher levels of EMI than that by a mobile phone. Since characteristics of a half-wave dipole antenna are well known, reliable and reproducible evaluations are expected. One possible EMI test procedure is to use a half-wave dipole antenna in order to determine the evaluation conditions for actual mobile phones. Finally, in terms of the radiation mode, we show that discontinuous radiation might cause higher levels of EMI than those for continuous radiation.**

Keywords*— Electromagnetic Interference (EMI); Medical Device; Mobile Phone; Long Term Evolution (LTE); High Speed Packet Access (HSPA)

I. Introduction

During the 1990s when mobile phones proliferated widely, there was anxiety regarding Electromagnetic Interference (EMI) with medical devices from mobile phones. Therefore, many evaluations were conducted and reported on this topic [1-12]. In 1997, the Electromagnetic Compatibility Conference Japan (EMCC) published an investigation report regarding EMI with medical devices from mobile phones and guidelines for the use of mobile phones in hospitals [1]. This investigation was conducted based on 727 medical devices using the Personal Handy-phone System (PHS) [13] and Personal Digital Cellular (PDC; Japanese second generation system) [14] as examples of the transmission method. Subsequently, the Ministry of Internal Affairs and Communications (MIC) of Japan published an investigatory report including the results of mobile phones using the Wideband Code Division Multiple Access (W-CDMA) technique in 2002 and recognized the reasonability of the guidelines published by the EMCC [2]. These investigations were conducted with a half-wave dipole antenna and an actual mobile phone as radiation sources. The transmission power of the source was set to the nominal maximum. In addition to continuous radiation, discontinuous radiation with a period of approximately 1 s was used in a conservative test. The results showed that, for example regarding W-CDMA, the maximum EMI distance was 60 cm. There were also some investigations performed outside Japan regarding EMI with medical devices from mobile phones. For example, Tri *et al.* reported results of EMI tests in 2001 [3], 2005 [4], and 2007 [5]. They conducted EMI evaluations with respect to Time Division Multiple Access (TDMA), CDMA, Integrated Digital Enhanced Network (iDEN), Global System for Mobile Communications (GSM), and the analog mobile phone system. Commercial mobile phones were used as the radiation source. The maximum EMI distance was 84 in. (approximately 2 m). In these tests, transmission powers of the mobile phones were not fixed at the maximum. In 2006, Calcagnini *et al.* [6] also conducted EMI tests using GSM mobile phones. Transmission powers of the mobile phones were at the maximum and the maximum EMI distance was 30 cm. In 2007, van Lieshout *et al.* [7] reported EMI for 61 medical devices from General Packet Radio Service (GPRS) and Universal Mobile Telecommunications System (UMTS) mobile phones. In their study, mobile phone signals were generated using a signal generator and radiated from an electrically balanced handheld antenna. The maximum EMI distance was 5 m for the nominal maximum of the transmission power. In these tests conducted outside Japan, evaluation conditions were not clearly considered, especially the transmission power and radiation source. Recently, mobile phones using High Speed Packet Access (HSPA) and Long Term Evolution (LTE) [15, 16] have proliferated worldwide. However, there was no reported evaluation of the EMI from HSPA and LTE mobile phones to medical devices used in hospitals. Therefore, in [17] we conducted an evaluation of the EMI from these types of mobile phones. The maximum EMI distance for HSPA and LTE was 80 cm. The Peak to Average Power Ratio (PAPR) was focused on this evaluation because recent technologies could generate higher PAPR. The results showed the differences among LTE, HSPA, and W-CDMA do not have significant effect on the EMI. In this paper, transmission power, frequency, radiation mode, and radiation sources are considered to investigate the relationship with EMI.

II. Evaluation Method

International Electrotechnical Commission (IEC) 61000-4-3 [18] describes an EMI evaluation method for electrical devices, including medical devices, exposed to a far-field radiated Radio Frequency (RF) electromagnetic field. However, mobile phones can come into direct contact with medical devices. In other words, electric circuits of medical devices and mobile phone antennas might have direct interaction in a near electromagnetic field region. Therefore, in this study, we employ an evaluation scheme that is based on two methods: the method used in the investigation by EMCC and MIC [2], and that described in American National Standards Institute (ANSI) C63.18 [19]. These methods consider and provide a way to evaluate direct coupling in a near electromagnetic field. The medical devices except for floor standing devices are placed on an 80-cm high wood table as described in ANSI C63.18 [19]. Clinical engineers judge whether or not EMI occurs.

The evaluation procedure is described below. First, the medical device is set under normal operating conditions with appropriate simulators. Second, an RF electromagnetic wave radiation sources, i.e., a half-wave dipole antenna or a mobile phone are scanned while in direct contact with each surface of the medical device. When the source is scanned, elements of the half-wave dipole antenna or the long side of the mobile phone is set perpendicular and parallel to the long side of each face of a virtual cuboid that covers each medical device. The back surface of the mobile phone is set facing the medical device because stronger radio waves are emitted from the back surface than screen surface of the phone. If EMI is detected, the abnormal responses due to EMI, e.g., alarms or noises, and the point that EMI becomes the most significant are recorded. Then, the radiation source is moved away from the point that EMI becomes the most significant, and the distance at which the EMI disappears is recorded.

LTE, HSPA, and W-CDMA are selected as the transmission methods for the mobile phones. The evaluation parameters are determined referring to the uplink specifications published by the 3GPP [15, 16]. The evaluation parameters for each transmission method are given in Table I. In this study, basically a half-wave dipole antenna is used as a typical radiation source. The reason that half-wave dipole antennas are used is that they have very well-known characteristics and the radiation gain is generally higher than that for mobile phones. Commercial mobile phones that mount internal antenna are employed only for medical devices in which EMI occurs when using the dipole antenna. Since no commercial mobile phone for LTE at 800 MHz or 1.5 GHz was available, no evaluation of this type of mobile phone was performed. Also, since no mobile phone that can communicate using all the transmission method shown in Table I exists, two mobile phones were used for the test. One is for HSPA and W-CDMA tests, and the other is for LTE test. In this paper, the transmission power represents the time averaged input power to the radiation sources. The nominal maximum power and 10 dBm are selected for the transmission power. The nominal maximum power for LTE is 23 dBm, and those for HSPA and W-CDMA are 24 dBm. MIC [2] used the value of 10 dBm in the their investigation and it is the same as the average PHS transmission power. Two radiation modes are used in the evaluation: discontinuous and continuous. The discontinuous period is 1 s. This means that the radiation source repeats a cycle emitting 0.5 s of radiation and 0.5 s of no radiation. The electronic circuits of some medical devices are operated in order to detect biological rhythms such as breathing and heartbeat, which have similar cycles. Discontinuous radiation could cause higher levels of EMI than those by continuous radiation [2, 20]. Therefore, only when EMI occurs in discontinuous tests, continuous tests are conducted.

The EMI evaluation is conducted using 32 different medical device models. These devices are mainly used in the operating room or Intensive Care Unit (ICU) in a hospital such as electrical medical devices used in operations and external blood circulation devices.

TABLE I. EVALUATION PARAMETERS

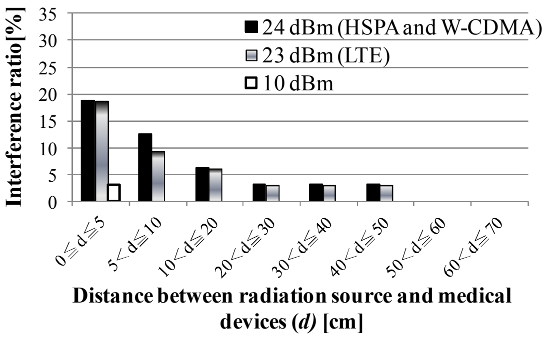
Items	Values		
	LTE	HSPA	W-CDMA
Radiation source	Half-wave dipole antenna, Mobile phone		
Transmission power [dBm]	23, 10	24, 10	
Frequency bands [MHz]	800, 1500, 2000	800, 1700, 2000	
Channel bandwidth [MHz]	10, 5	5	
Radiation mode	Discontinuous (period: 1 s), Continuous		

III. Evaluation Results

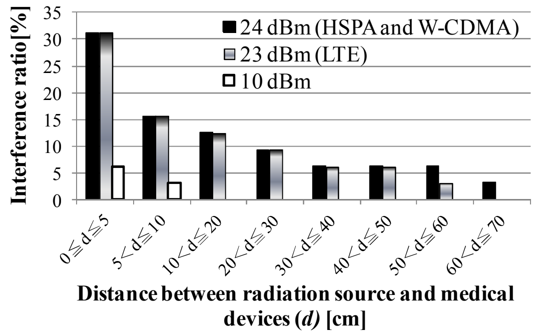
The evaluation results of the 32 models show that EMI was confirmed for 12 medical-device models. The maximum distance when EMI disappeared is 80 cm. The waveform of the electrocardiogram signal that is displayed on the ultrasonic echography monitor is distorted. The relationships among the EMI, power, frequency, radiation source, and radiation mode are discussed in this section.

A. Transmission Power and Distance Dependency

Fig. 1 shows the relationship between the distance from the medical device and the interference ratio. The interference ratio is the ratio of number of EMI occurred medical devices to the total number of evaluated medical devices (32). Figs. 1(a) and 1(b) show the results at 2 GHz and 800 MHz, respectively. These are common bands used in this evaluation for all transmission methods. The black, gray, and white bars show the results for the transmission power of 24 dBm (HSPA and W-CDMA), 23 dBm (LTE), and 10 dBm (LTE, HSPA, and W-CDMA), respectively.



(a) 2 GHz



(b) 800 MHz

Fig. 1. Distance and interference ratio.

The results for 24 dBm and 23 dBm are almost the same. For example, when the frequency band is 800 MHz, if the radiation source is placed within 5 cm of the medical device, the interference ratio is approximately 31% at both transmission power levels. When the distance is 60 or 70 cm, all EMI disappears. On the other hand, when the transmission power is 10 dBm, the interference ratio is approximately 5% even if the distance is within 5 cm. If the distance exceeds 10 cm, EMI disappeared for all medical devices evaluated in this study. These results show that the nominal maximum power test is important for a conservative evaluation. Not only the transmission power, but also the distance between the radiation source and medical devices has a great effect on the EMI. For example, when the frequency band is 800 MHz and the transmission power is 24 or 23 dBm, the interference ratio is 31% if the distance is within 5 cm. However, the interference ratio becomes approximately half when the distance exceeds 5 cm. If the distance exceeds 70 cm, there is no EMI.

B. *Frequency Dependency*

Fig. 2 shows an example of frequency dependency. The frequency bands used in this study are represented on the horizontal axis, and the furthest distance at which the EMI disappeared for each frequency band is represented on the vertical axis. Regarding medical device (A), the distance is 80 cm for the 1.7 GHz band, and no EMI was observed in the 800 MHz and 1.5 GHz bands. However, for medical device (B), the distance was under 10 cm for the 1.7 GHz band, and 59 cm for 1.5 GHz. In terms of medical device (C), EMI was only confirmed for 800 MHz. These results show that the frequency band that causes the most significant EMI is different depending on the medical device. Therefore, evaluations must consider all mobile phone frequency bands so that EMI can be property detected.

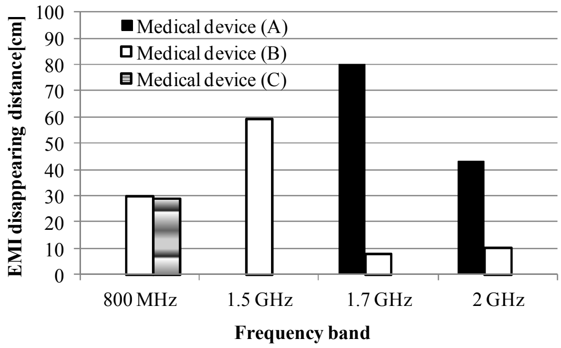


Fig. 2. Frequency dependency.

C. *Radiation Mode Dependency*

Similar to the results reported by MIC [2], our results showed that discontinuous radiation caused EMI to occur in a larger number of medical devices than continuous radiation. When the radiation mode is discontinuous and continuous, the number of medical devices in which EMI occurs is 12 and 7, and the maximum EMI distances are 80 and 28 cm, respectively. These results indicate that discontinuous radiation might cause higher levels of EMI than continuous radiation. The reason for this is that the electronic circuits of some medical devices are operated in order to detect biological rhythms such as breathing and heartbeat, and 1 s, the period of discontinuous radiation, is similar to these rhythms.

D. *Radiation Source Dependency*

Fig. 3 shows the results of radiation-source dependency. Each symbol represents a medical device in which EMI occurred when using both a dipole antenna and mobile phone. The furthest distance at which EMI disappeared when using the dipole antennas and mobile phones are represented on the horizontal and vertical axes, respectively.

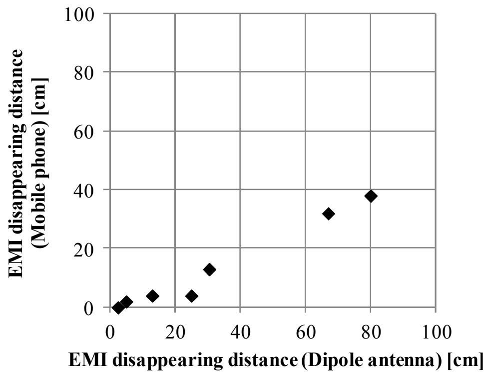


Fig. 3. Radiation source dependency.

The half-wave dipole antenna caused higher levels of EMI than the mobile phones in this study. The results show that EMI evaluation using half-wave dipole antennas is more conservative compared to that using mobile phones. Since the characteristics of a half-wave dipole antenna are well known, reliable and reproducible evaluation is expected. One possible EMI test procedure is to use a half-wave dipole antenna in order to determine the evaluation conditions for actual mobile phones.

IV. Conclusion

The aim of this study is to evaluate and clarify the EMI with medical devices used in hospitals from third generation mobile phones. LTE, HSPA, and W-CDMA were selected as the transmission method. Thirty-two different medical devices, which are mainly used in the operating room or ICU, are used in this evaluation. The evaluation scheme is based on two methods, one used in the evaluation conducted by MIC of Japan, and the other described in ANSI C63.18. It is found that of the 32 medical-device models tested, 12 (37.5%) exhibited EMI and that the EMI depends heavily on the transmission power and the distance between the mobile phone and medical device. For example, when the transmission power at 800 MHz is the nominal maximum and at 10 dBm, the maximum EMI distances are approximately 70 and 10 cm, respectively. These results show that the nominal maximum power test is important for conservative evaluation. On the other hand, the results do not show that EMI depends on the frequency band. Therefore, evaluations must consider all mobile phone frequency bands so that EMI can be property detected. Furthermore, the electromagnetic field emitted by a half-wave dipole antenna causes higher EMI levels than that by a mobile phone. Since characteristics of a half-wave dipole antenna are well known, reliable and reproducible evaluation is expected. One possible EMF test procedure is to use a half-wave dipole antenna in order to determine the evaluation conditions for actual mobile phones. Finally, in terms of the radiation mode, it is shown that discontinuous radiation might cause higher levels of EMI than those for continuous radiation.

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