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Electromagnetic interference with medical devices from mobile phones using high-speed radio access technologies

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Abstract: This paper clarifies the Electromagnetic Interference (EMI) with medical devices from mobile phones that use high-speed radio access technologies including those in Release 8 specified by the 3rd Generation Partnership Project (3GPP) in a hospital environment. The Single Carrier Frequency Division Multiple Access (SC-FDMA) technique used in Release 8 has a higher Peak to Average Power Ratio (PAPR) than previous techniques such as Wideband Code Division Multiple Access (W-CDMA), and it may incur higher levels of EMI. The EMI is evaluated with respect to 32 medical devices that are typically used in hospitals. The evaluation results show that effect of increasing PAPR is not found significantly. The EMI strongly depends on the average transmission power of mobile phones. The maximum EMI distance is 80 and 8 cm when the average transmission power is the nominal maximum (23 or 24 dBm) and 10 dBm, respectively.

Keywords: electromagnetic interference (EMI), medical device, mobile phone, Peak to Average Power Ratio (PAPR), high speed radio access technology, Release 8

Classification: Electromagnetic Compatibility (EMC)

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1 Introduction

In the 1990s when mobile phones became widely spread, there was anxiety regarding the Electromagnetic Interference (EMI) with medical devices from mobile phones. In 1997 and 2002, the Electromagnetic Compatibility Conference Japan (EMCC) and the Ministry of Internal Affairs and Communications of Japan (MIC) [1] respectively published investigation reports regarding EMI with medical devices from mobile phones. A guideline for the use of mobile phones in hospitals was also published [2].

Subsequently, the 3rd Generation Partnership Project (3GPP) published the Release 8 specifications in 2008 [3] that specify Single Carrier Frequency Division Multiple Access (SC-FDMA) for the uplink. This multiple access technique has a higher Peak to Average Power Ratio (PAPR) than previous techniques such as Wideband Code Division Multiple Access (W-CDMA) specified in Releases 99 and 6 [3]. Previous papers describing the EMI incurred by medical devices from mobile phones focused on the time averaged transmission power of mobile phones [4, 5]. However, even if the time averaged power is the same, a higher PAPR may incur a higher level of EMI.

This paper evaluates the EMI with medical devices from mobile phones that use high-speed radio access technologies such as in Releases 99, 6, and 8 in order to clarify the effect on the EMI due to the change in the multiple access technique.

2 Evaluation method

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 environment. International Electrotechnical Commission (IEC) 61000-4-3 describes an EMI evaluation method for when medical devices are exposed to a far-field radiated Radio Frequency (RF) electromagnetic field. However, mobile phones can come in contact with medical devices, i.e., electric circuits of medical devices and mobile phone antennas

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Table I. Evaluation parameters (uplink) [3]

Items	Values		
	Release 99	Release 6	Release 8
Radiation Source	Half-Wave Dipole Antenna, Mobile Phones		
Transmission Power [dBm]	24, 10		23, 10
Frequency Band	800 MHz (Band VI) 1.7 GHz (Band IX) 2 GHz (Band I)		800 MHz (Band VI) 1.5 GHz (Band XXI) 2 GHz (Band I)
Channel Bandwidth [MHz]	5		10, 5
Radiation mode	Discontinuous (period: 1 s), Continuous		

can become directly coupled in a near electromagnetic field. Therefore, in this evaluation, the near field method is used. There are two near-field evaluation methods: the method used in the investigation by EMCC and MIC [1, 6] and the method described in American National Standards Institute (ANSI) C63.18 [7]. The method described in [1, 6] is used in the paper.

More specifically, the medical devices are set under normal operating conditions, and each parameter given in Table I is evaluated. The radiation source is placed in contact with the target medical device and moved along the front, left, back, right, and top surfaces of the device while rotating the antenna of the radiation source. If EMI is confirmed at a surface of the medical device, the radiation source is moved away from the position where the EMI level was the highest and the distance is recorded when there is no more EMI. In this paper, regarding a medical device, for all parameters, the furthest distance at which there is no more EMI is referred to as the EMI distance.

The evaluation parameters are determined referring to the uplink specifications described in 3GPP Releases 99, 6, and 8. The evaluation parameters for each Release are given in Table I.

As radiation sources, in addition to mobile phones, a half-wave dipole antenna is used. Half-wave dipole antennas have very familiar characteristics and enable repeatable evaluation. The transmission power represents the time averaged input power to the radiation sources in this paper. For evaluation, the nominal maximum power and 10 dBm are selected for the transmission power. For Releases 99 and 6, the nominal maximum power is 24 dBm, and for Release 8 the nominal maximum power is 23 dBm. The value of 10 dBm is used in the investigation by MIC [1], and it is the same as the average transmission power of the Personal Handy-phone System (PHS). Two radiation modes are used in the evaluation: discontinuous and continuous. The discontinuous period is approximately 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 constructed based on biological rhythms such as breathing and heartbeat, which have a similar cycle. As a result, the discontinuous radiation causes higher levels of

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EMI than continuous radiation [1, 6].

To confirm the effect of the PAPR on the EMI, the PAPR is measured. The results show that for the radio signals used in the evaluation, when comparing Release 99 to Releases 8 and 6, the PAPRs are approximately 4 and 1.5 dB higher, respectively. These PAPR values are for when the Complementary Cumulative Distribution Function (CCDF) is 0.0001%.

3 Evaluation results

The evaluation results of the 32 models show that EMI was confirmed for 12 models. Table II shows the abnormal responses and EMI distances in regard to the 12 EMI-confirmed medical devices.

For all the medical devices, the discontinuous radiation mode exhibits a higher EMI probability and a longer maximum EMI distance compared to the continuous radiation mode. The EMI probability represents the percentage of medical devices exhibiting EMI from the evaluated medical devices.

Table II. Measured EMI distances

Medical Devices	Abnormal Responses	EMI Distances [cm]
Ultrasonic Echography (1)	Touch panel response occurs without touching panel	3.5
Ultrasonic Echography (2)	Waveform of electrocardiogram signals is distorted	80
Electrical Scalpel (1)	Noise is generated from speaker	29
Electrical Scalpel (2)	Noise is generated from speaker	0
Infusion Pump	Sensor falsely detects bubble	0
Flow Sensor for Percutaneous Cardiopulmonary Support Device	Falsely displays flow quantity change	9.5
Neural Stimulator for Electromyography	Waveform of stimulation signals is distorted and noise is generated from speaker	59
Electrocardiography	Error message “Confirm recording paper” is displayed	13
Harmonic Scalpel (Ultrasonic Surgical Knife)	Noise is generated from speaker	60
Transvenous Cardiac Pacemaker (1)	Pacing pulse is disabled	4
Transvenous Cardiac Pacemaker (2)	Pacing pulse is disabled	2.5
Transvenous Cardiac Pacemaker (3)	Pacing pulse is disabled and interval of pacing pulse is changed	30

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The maximum EMI distance represents the maximum EMI distance for the 12 medical device models. In the continuous radiation mode, the EMI probability and maximum EMI distance were 22% and 28 cm, respectively. They increased to 37% and 80 cm in the discontinuous radiation mode.

Among the medical devices in which EMI was detected, the maximum EMI distances when the radiation source was a half-wave dipole antenna were always longer than those when the radiation source was a mobile phone. Therefore, it was confirmed that the EMI evaluation using a half-wave dipole antenna yields a more conservative value than when using a mobile phone. As mentioned in Section 2, compared to Release 99, the PAPRs of Releases 8 and 6 are approximately 4 and 1.5 dB higher, respectively. Fig. 1 shows the relationship between the peak transmission power and maximum EMI distance. The Peak Transmission Power (P_{peak}) is calculated based on Eq. (1) using the transmission power (P_{t}) and PAPR.

$$P_{\text{peak}}\,[\text{dBm}] = P_{\text{t}}\,[\text{dBm}] + \text{PAPR}\,[\text{dB}] \tag{1}$$

In Fig. 1, "R." stands for "Release." The results are shown when the frequency band is 2 GHz and 800 MHz. These are common bands used in this evaluation for all the Releases.

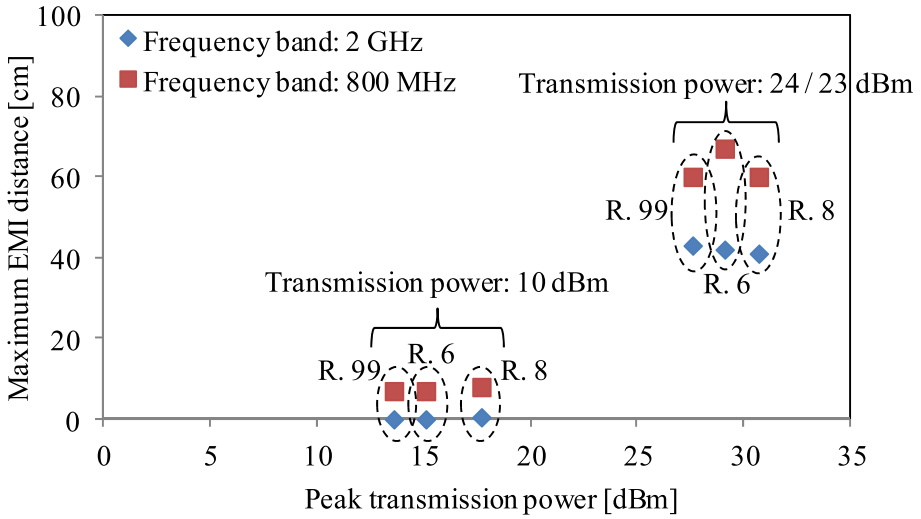

Fig. 1. Relationship between peak transmission power and maximum EMI distance

Fig. 1 shows that the difference in the PAPRs among the 3 Releases does not have a significant effect. The maximum EMI distance was longer when the frequency band is 800 MHz than for 2 GHz. The EMI strongly depends on the transmission power. For 800 MHz, the maximum EMI distance decreased from 67 to 8 cm when the transmission power changed from 24/23 to 10 dBm. For 2 GHz, the maximum EMI distance decreased from 43 to 0.5 cm when the transmission power changed from 24/23 to 10 dBm. With respect to all frequencies, the maximum EMI distance decreased from 80 to 8 cm when the transmission power changed from 24/23 to 10 dBm.

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4 Conclusion

This paper presented evaluation results of EMI with medical devices from mobile phones that use high-speed radio access technologies such as in Releases 99, 6, and 8. The evaluation results showed that the difference in PAPRs among the three Releases did not have a significant effect. The EMI strongly depends on the transmission power of the mobile phones. The maximum EMI distance decreased from 80 to 8 cm when the transmission power changed from 24/23 to 10 dBm.

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