Transmit power measurement results of configured-maximum-transmit-power-controlled mobile phones in hospital

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Abstract: Reducing the transmit power of mobile phones is effective in preventing electromagnetic interference (EMI) with medical devices in hospitals. However, to our best knowledge, no study has shown transmit power measurement results of mobile phones for which the configured-maximum-transmit-power was controlled by specific base station (BS) parameters. This letter shows transmit power measurement results from a mobile phone for which the configured-maximum-transmit-power is experimentally controlled by indoor BSs in a hospital. Reduction in the mobile phone transmit power and the issue of preventing EMI with medical devices are discussed based on the measurement results.

Keywords: Mobile phone, Transmit power, EMI, Hospital

Classification: Electromagnetic compatibility (EMC)

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1 Introduction

Using mobile phones in the vicinity of medical devices incurs the risk of electromagnetic interference (EMI) to these medical devices [1]. In 2014, the Electromagnetic Compatibility Conference Japan (EMCC) updated guidelines for using mobile phones and other devices in hospitals [2]. The guidelines allow the use of mobile phones if rules in hospitals for using mobile phones without EMI between mobile phones and medical devices are established and enforced [2]. Furthermore, in establishing these rules, the separation distance of 1 m was recommended to be secured between mobile phones and medical devices in the guidelines. This separation distance was based on the results of EMI tests and an electromagnetic immunity for medical devices by complying with JIS T 0601-1-2: 2012 based on IEC 60601-1-2: 2001, Amd.1: 2004. The latest standard applicable to electromagnetic immunity for medical devices are JIS T 0601-1-2: 2018 based on IEC 60601-1-2: 2014. However, this letter refers to JIS T 0601-1-2: 2012 in accordance with the guidelines [2].

This separation distance is based on the maximum transmit power of a mobile phone. Since a lower maximum transmit power would enable a shorter separation distance, reducing the transmit power of a mobile phone can result in expanding the area in which mobile phones can be used without imparting EMI to medical devices (hereinafter referred to as the mobile phone usable area).

In the long term evolution (LTE), the transmit power of a mobile phone was defined as the input power at the antenna connector of the mobile phone, the maximum transmit power of mobile phone is 23 dBm [3]. LTE specifies the configured-maximum-transmit-power of a mobile phone (Pcmax) which controls the maximum mobile phone transmit power to maintain a value lower than the set parameter value in a base station (BS). Therefore, BSs utilizing Pcmax can expand the mobile phone usable area in a hospital. However, to the best of our knowledge, no study has shown transmit power measurement results for a Pcmax controlled mobile phone in hospitals.

This letter shows the measurement results of the transmit power for a Pcmax controlled mobile phone in an operating room and a patient room of a hospital. A Pcmax value lower than 23 dBm was experimentally applied to several indoor BSs. The transmit power reduction due to the Pcmax controlled mobile phone and the issue of preventing EMI with medical devices are discussed based on the measurement results.

2 Measurement method

2.1 Measurement environment

The mobile phone transmit power was measured in the Kanazawa University Hospital. The service area of the employed cellular system in the hospital is composed of outdoor and indoor BSs. Indoor BSs of the LTE and W-CDMA systems using the 2-GHz band were installed on the ceilings of hallways and operating rooms in the hospital. The Pcmax of outdoor and indoor BSs are generally set to 23 dBm. In this letter, the Pcmax value for a part of the indoor BSs
was experimentally set to limit the maximum transmit power of mobile phones to less than 10 dBm. This Pmax value is the same power level as the mean transmit power of the personal handy-phone system which has been used as extension telephones in hospitals before the update of the guidelines in 2014. These indoor BSs are referred to as lower Pmax indoor BSs. The other indoor and outdoor BSs are referred to as default Pmax indoor and outdoor BSs, respectively.

The mobile phone transmit power was measured in an operating room and a patient room in the hospital. In the operating room, the service area consisted of only lower Pmax indoor BSs. On the other hand, in the patient room, the service area consisted of lower Pmax indoor BSs and default Pmax outdoor BSs. Mobile phones can connect to either BS depending on the received power from the BS. Therefore, the effect of lower Pmax indoor BSs on the maximum transmit power of mobile phone may differ in the both rooms.

2.2 Measurement configuration
The mobile phone transmit power was measured using a mobile phone application (Sigma-ML, Meritech). This mobile phone application records the transmit power at each sub-frame in the physical uplink shared channel (PUSCH) and the connected BS information. The transmit power of the mobile phone, $P_t$ [dBm], in the PUSCH is defined in the LTE specifications [4] by the following equation.

$$P_t = \min\{P_{c,max}, P'_t\},$$

where $P_{c,max}$ is the Pmax parameter in the BS, and $P'_t$ is calculated by the mobile phone with the number of resource blocks, path loss between the mobile phone and BS, and so on. During this measurement, the mobile phone sent user datagram protocol (UDP) packets to the specified server to measure the PUSCH transmit power.

In order to measure efficiently the maximum mobile phone transmit power in each room, the measurement procedure was determined based on preliminary measurements considering three-dimensional (3D) space and time-dimension aspects.

3D space
The height of the measured mobile phone was set to 1.5 m assuming that a medical staff member uses the mobile phone for voice calls. In the horizontal direction in 3D space, the floor of a room was divided into 60 cm × 60 cm meshes for measurement. The mobile phone used in the measurement was moved over meshes that do not have equipment installed, such as patient bed. Each mesh is referred to as a measurement point.

Time-dimension
Measurement of the mobile phone transmit power was conducted by 10 seconds and 100 seconds. The 10 seconds measurement was conducted to obtain the distribution of the transmit power in each room. The 100 seconds measurement was conducted to obtain the maximum transmit power in each room.
Measurement procedure

The measurement procedure was composed of two steps. In step 1, the transmit power was measured for 10 seconds at each measurement point to obtain the distribution of the transmit power in each room. In step 2, the mobile phone transmit power was measured for 100 seconds at some measurement points where the maximum transmit power was the highest or higher in step 1.

3 Measurement results

Fig. 1 shows the maximum transmit powers expressed as a heat map at each measurement point in the operating room and patient room. Shapes of markers in Fig. 1 mean the BSs connected by mobile phone at each measurement point. In operating room, mobile phone connected to the lower Pcmax indoor BS in Fig. 1 (a). As shown in Fig. 1 (b), mobile phone connected to the lower Pcmax indoor BS near the hallway in patient room. On the other hand, mobile phone connected to the default Pcmax outdoor BS near the window in patient room.

Fig. 2 shows the complementary cumulative distribution functions (CCDFs) of the transmit powers including all measurement points in the two rooms in step 1. These CCDF curves show the transmit power of mobile phone connecting to the lower Pcmax indoor BSs and the default Pcmax outdoor BSs regardless of the operating room and patient room. As shown from Fig. 2, the transmit power of mobile phone connecting to the lower Pcmax indoor BSs was lower than that of mobile phone connecting to the default Pcmax outdoor BSs. Based on a comparison at CCDF = 0.1 in Fig. 1, the transmit power of mobile phone connecting to the lower Pcmax indoor BSs is approximately 1 dBm.

Table I gives the mean and maximum transmit powers from steps 1 and 2. The mean transmit power was calculated by the transmit powers at all subframe when mobile phone was sending UDP packets. As shown in Table I, the maximum and mean transmit powers from step 1 were 10 dBm and -4.9 dBm, respectively in the operating room. In contrast, the maximum and mean transmit powers were 23 dBm and 17.4 dBm, respectively in the patient room. These transmit powers are higher than Pcmax value. Therefore, the reduction in the transmit power by controlling the BS Pcmax parameter is not always effective in an environment where the mobile phone can connect to a default Pcmax indoor/outdoor BS. In order to reduce a transmit power of mobile phones by controlling Pcmax parameter in a hospital, a connection of mobile phones is needed to be restricted to the lower Pcmax BSs only.

As indicated by Table I, the maximum transmit power is the same in steps 1 and 2 in the patient room. This is due to the specified maximum transmit power in LTE. In JIS T 0601-1-2: 2012 [5], the recommended separation distance, \( d \) [m], for life-support devices is calculated based on the equation below.

\[
d = \frac{23}{E} \sqrt{P},
\]

where \( E \) [V/m] is the compliance of electromagnetic immunity and \( P \) [W] is the maximum transmit power with a relative antenna gain of -2 dB [6]. In LTE, the
safe separation distance is 0.82 m at the specified maximum transmit power of 23 dBm such as the patient room. Based on the measurement results in the operating room, the safe separation distance considering a Pcmax BS is 0.18 m. Therefore, a lower Pcmax indoor BS expands the mobile phone usable area in the operating room. In contrast, the mobile phone can connect to default Pcmax indoor/outdoor BSs in patient rooms. Densely deployed lower Pcmax indoor BSs and an electromagnetic shielding from outside the hospital are needed to reduce the maximum mobile phone transmit power throughout the entire hospital.

Fig. 1. The maximum transmit power expressed as heat map in operating room and patient room.

Fig. 2. The transmit power and CCDF.
Table 1. The mean and maximum transmit power

| Environments     | Mean | Maximum |
|------------------|------|---------|
|                  | Step 1 | Step 2 | Step 1 | Step 2 |
| Operating room   | -4.9  | -0.3    | 10.0   | 10.0   |
| Patient room     | 17.4  | 19.9    | 23.0   | 23.0   |

4 Conclusion

This letter presented measurement results of the transmit power from a Pcmax controlled mobile phone in a hospital. The measurement results clarified the effect of the lower Pcmax parameter on reducing the mobile phone transmit power in a specific environment where mobile phones connect to only lower Pcmax indoor BSs. In the operating room, the maximum transmit power was 10 dBm, and the mean transmit power was -0.3 dBm. Based on a comparison of the results in the operating room and the patient room, this letter experimentally confirms a reduction in the mobile phone transmit power due to BS control of the lower Pcmax parameter.

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