Analysis of Interfered Noise for Sound Systems over LTE Mobile Phones

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Abstract— **As the LTE is deployed commercially, the effect of interference of LTE mobile phone is issued. The paper presents an interference analysis of LTE mobile phone in the sound systems. Three LTE mobile phones from different manufacturer's brands are used for measuring interference and three GSM phones are tested for the relative comparison with the LTE phones. A speaker and a wire telephone are applied as sound systems which are affected by LTE phone. The output spectra exposed to the LTE phones are presented and the interfered noise levels in sound systems are experimented at various distances from the LTE phones, and also at various powers of the LTE phones. The experimental results show that LTE mobile phones generate an interfered noise in sound systems up to the distance of 30~40cm. Also, the interfered noise is generated at over the power of 0dBm.**

Keywords- LTE; interference; sound system.

I. INTRODUCTION

Evolution of wireless technology has been achieved in phase during a remarkably short time. The first generation (1G) has fulfilled the basic mobile voice, while the second generation (2G) has introduced capacity and coverage. This is followed by the third generation (3G), which has opened the gates for higher speed mobile broadband. The significant expansion seen in mobile and cellular technologies is a result of the increasing demand for high-data-rate transmissions [1], [2]. As the fourth generation (4G) cellular networks, which offers high performance and capacity, the long term evolution (LTE) has been proposed by 3rd generation partnership project (3GPP) [3].

Tens of countries already provide LTE mobile phone service and many others are preparing to start the service. Accordingly, the number of LTE user is expected to grow steeply. As the usage of LTE mobile phones is increased, the study on interference issue of LTE cellular phone with the sound systems is necessary.

LTE has adopted orthogonal frequency division multiple access (OFDMA) for downlink and single carrier frequency division multiple access (SC-FDMA) for uplink as the communication method [4]. In these methods, both of time and frequency division multiple access are employed to support multiple users. Therefore, the interference problem which causes the noise to sound systems can be emerged in LTE system as similar to a global system for mobile communication (GSM). Cellular telephone such as GSM is already known to cause electromagnetic interference with sound systems because of the pulsed nature of the signal of the time division multiple access (TDMA).

The interfered effect of GSM is investigated in many researches and applied to standards. In [5] and [6], the frequency spectra from several mobile phones including GSM and code division multiple access (CDMA) services are measured and compared. In [7], GSM modulation signal is suggested for the immunity test of sound and television broadcast receivers and associated equipment.

On the other hand, the interfered effect of LTE has not been investigated even though the need of interference analysis of LTE is growing. This paper focuses on interference analysis of LTE mobile phone in sound systems such as a speaker or a wire telephone, based on the measurement. LTE mobile phones from three different companies are used to investigate for the purpose. Additionally, three GSM mobile phones from identical companies are tested for the relative comparison with the results of LTE mobile phones.

The paper is organized as follows: Time domain structure of LTE system is described in Section II. Measurement methods are shown in Section III. Then, experimental results are presented in Section IV. Discussion is given consecutively in Section V. Finally, conclusions are followed in Section VI.

II. CHARACTERISTICS OF LTE SIGNAL

LTE supports two radio frame structures for frequency division duplex (FDD) and time division duplex (TDD) modes [8]. In the FDD mode, uplink and downlink transmission are separated in the frequency domain. In the TDD mode, uplink-downlink configurations with both 5ms and 10ms downlink-to-uplink switch-point periodicity are supported.

In this paper, we test LTE mobile phones which operate in the FDD mode, which has been deployed commercially. As shown in Fig. 1, the generic radio frame of LTE in FDD mode has time duration of 10ms in the time domain. A frame is divided into 20 slots of each 0.5ms. Each slot consists of a number of symbols. Although one slot composes the smallest resource block, the basic time-domain unit for scheduling in LTE is one sub-frame. Two consecutive slots form a sub-frame of 1ms duration. The

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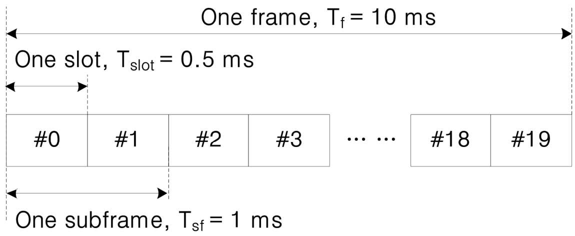

Figure 1. Frame structure of LTE

fundamental frequency associated with the LTE frame rate of 100 Hz and several of the harmonics fall in the audible frequency region. Therefore, they can cause interfered noises to sound systems.

III. MEASUREMENT METHOD

For the analysing the effect of interference of LTE, the interfered noise levels in sound system are experimented according to various distances from the LTE phones and various powers of the LTE phones. Three LTE mobile phones from different manufacturer's brands are used for measuring audible interference. Additionally, three GSM phones from identical brands tested for the relative comparison with LTE phones. In order to ensure the confidence, the experiment is progressed in the anechoic chamber.

As shown in Fig. 2, a base station emulator and an antenna are used to control the LTE and GSM phones. The powers of the LTE and GSM phones are adjusted from 0 to 22dBm as the commands of base station emulator. A speaker and a wire telephone are investigated as sound systems at various distances from the LTE and GSM phones. The interference-induced sound pressure levels (SPL) are recorded by a sound pressure meter.

The spectra of interferences from the LTE mobile phones can be visualized by an oscilloscope. The interferences are measured in the time domain and then transferred to the frequency domain signal using the FFT function of the oscilloscope. However, the measurement of sound pressure levels is performed without the oscilloscope to prevent the driving sound of the oscilloscope from affecting the sound pressure meter.

IV. EXPERIMETAL RESSULTS

A. Reference noise levels

As listed in Table 1, initial sound levels of the sound systems are measured and the results are used as the reference interference levels for the following measurements. The reference levels are performed when the LTE and GSM phone are off and the each power of a speaker and a wire telephone are on. Because the wire phone is measured with the receiver picked up, the measured reference sound level of the wire phone is about 5dB louder than that of the speaker.

Sound systems	Reference sound levels
Speaker	42.2 dB
Wire telephone	47.2 dB

Table 1. Reference sound levels of sound systems

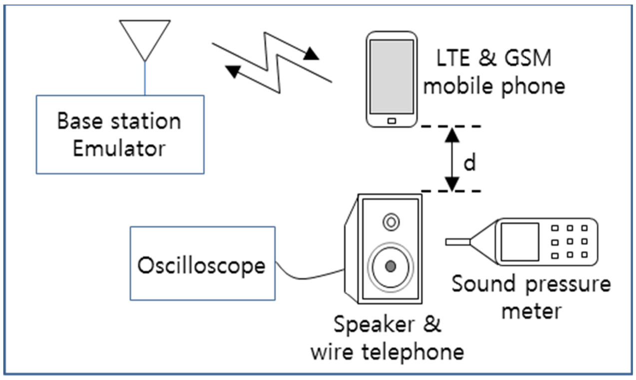

Figure 2. Measurement set-up

B. Spectra of interfered noise

The spectra of a speaker near to the LTE and GSM mobile phones are measured by wire connection from the output of speaker and the input of the oscilloscope.

Figs. 3 and 4 present the spectra of the interfered noise when the power of LTE and GSM mobile phones are 20dBm and the distance between each of LTE and GSM mobile phone and the speaker is 5cm. The interfered noise from LTE phone repeats at 10ms intervals and that from GSM phone repeats at 4.16ms intervals in the time domain. They match to the frame length of LTE and GSM. The peak voltage of the LTE phone is 1.19Vpp while that of GSM phone is 1.53Vpp.

Frequency spectra of Figs. 3 and 4 are presented from 0 to 20 kHz which is known as acoustic frequency range. The interference from LTE and GSM mobile phones reveals discrete peaks in the frequency domain. These peaks correspond to the frame rate and its harmonics. The type of interference produced by these technologies may be described as a buzzing sound in sound systems.

C. Interferences at the maximum power

The interfered noise levels of sound systems are examined when the power of the LTE phones is set to maximum value (22dBm) by the base station emulator to demonstrate the worst case of the interference scenario.

Plots of sound pressure levels of a speaker versus separated distance between the speaker and each LTE and GSM mobile phone at the maximum power are given in Fig. 5. The interfered effects of GSM mobile phones are tested for the purpose of relative comparison with LTE phones.

The initial distance between the speaker and each LTE and GSM mobile phone is set to 5cm, and then adjusted at intervals of 10 cm. Signs of A, B and C of Figs. 5 and 6 indicate the three brands of LTE and GSM phones. There are differences of measured sound levels among the LTE.

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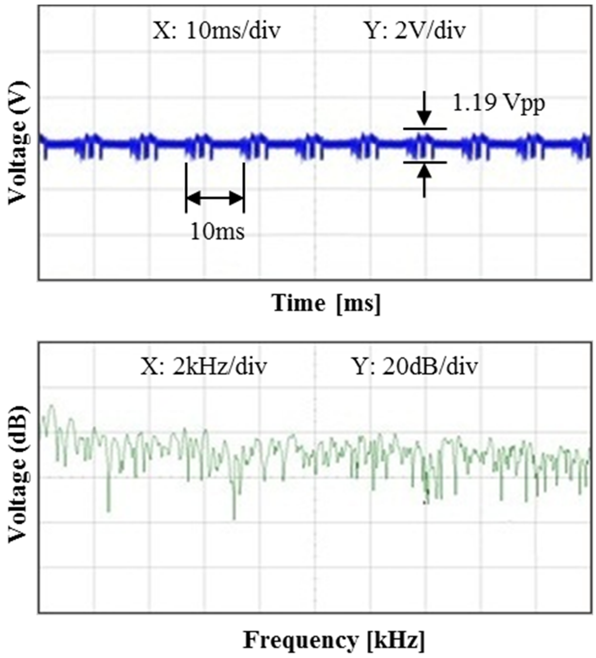

Figure 3. Spectra of interfered noise from LTE mobile phone

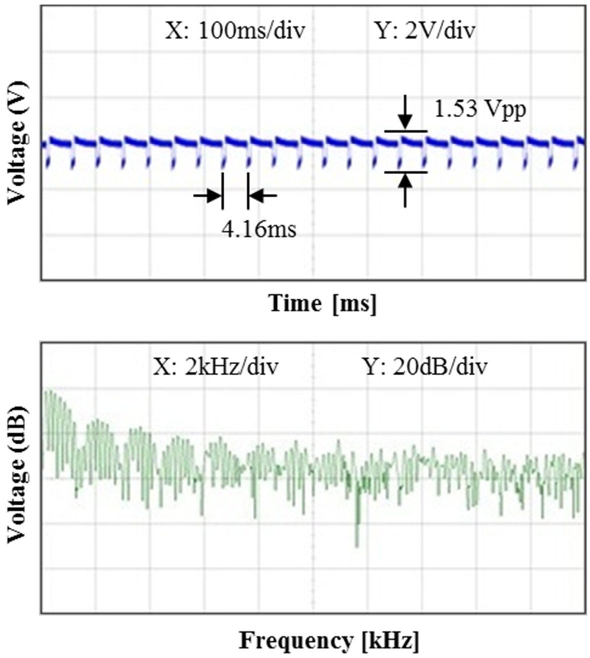

Figure 4. Spectra of interfered noise from GSM mobile phone

However, all of the interfered noises of the speaker from the LTE phones show the similar tendency. Even though the interfered noise levels from the LTE phones are lower than that from GSM phones, the interfered noises are detected up to a distance of about 25 cm. The interfered sound levels are approached to the reference value of Table 1 beyond 25cm.

The interferences of LTE mobile phones to a wire telephone at the maximum power (22dBm) are shown in Fig. 6. The initial distance between the speaker and each LTE and GSM mobile phone is set to 3cm, and also adjusted at intervals of 10 cm.

The interfered noise levels from the LTE phones are lower than that from GSM phones. While the interfered noises of GSM phones are detected up to a distance of over 63cm, the interferences of LTE phone diminishes and reaches to the reference value at a separation distance of almost 33 cm.

D. Interferences at various powers

The interfered noise levels of sound systems are investigated when the output powers of LTE mobile phones are varied from 22dBm to 0dBm for examining the effect of power.

Fig. 7 presents the plots of sound pressure levels of a speaker versus output powers of LTE mobile phones when the separation distance between a speaker and each LTE hone is fixed to 5cm. The interfered noise levels of the speaker decrease as the power of LTE phones declines. When the power reaches to 0dBm, the interfered sound levels are almost reaches to the reference values listed in Table 1.

Plots of sound pressure levels of a wire telephone versus output power of each LTE mobile phone are presented at Fig. 8 when the separation distance between wire telephone and LTE phones is fixed to 3cm. Although there are differences in the measured values among the LTE mobile phones, the interfered sound levels almost reach to the reference value at the power of 0dBm.

V. DISCUSSION

The audible frequency of human ear is generally known from the minimum 20Hz to the maximum 20 kHz. The experimental results show that LTE mobile phones apparently generate an interfered noise in the audible frequency region to sound systems such as a speaker and wire telephone, even though the interfered noise levels from the LTE phones are lower than that from GSM phones.

The interfered noise levels decrease as the distance between sound system and the LTE phone is increase. The interfered noise is almost vanished when the LTE mobile phone is about 30~40cm apart from the sound system. Therefore, a simple way to avoid the interfered sound noise is to place the LTE phone away from the sound system. But it cannot be a fundamental method for reducing the interfered noise.

The interfered noise levels also decrease as the power of LTE mobile phone declines. The output power of a LTE mobile phone in practical circumstance is determined by the distance from the base station and radio propagation environment. As the communication coverage of a base station is smaller, the output power of LTE mobile phone can be reduced. If the number of base stations is increased and the power of LTE mobile phone is reduced to less than

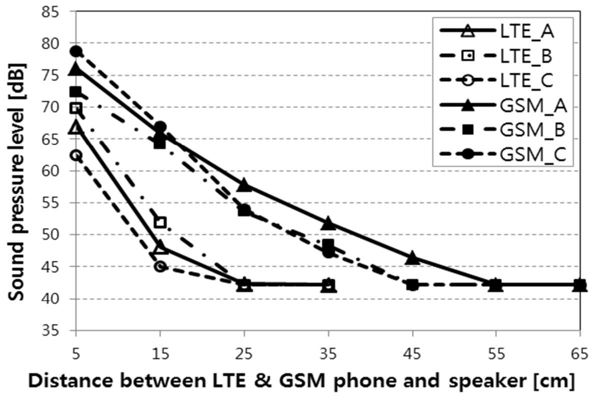

Figure 5. Interferences from LTE and GSM mobile phones for a speaker

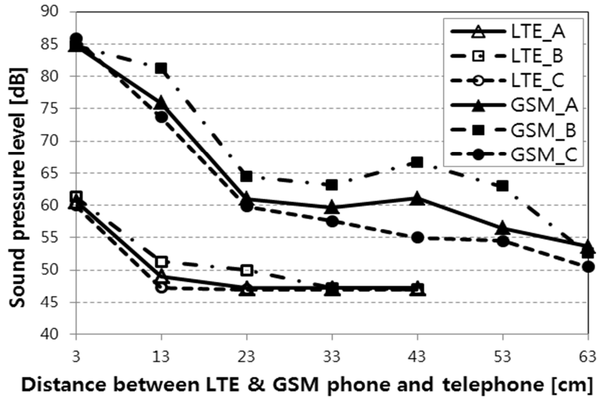

Figure 6. Interferences from LTE and GSM mobile phones for a wire telephone

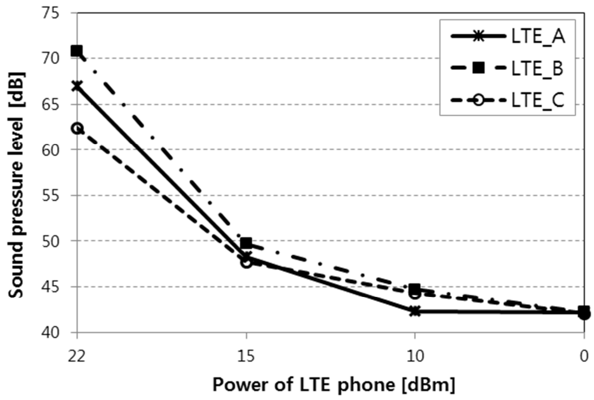

Figure 7. Interferences for speaker at various LTE powers

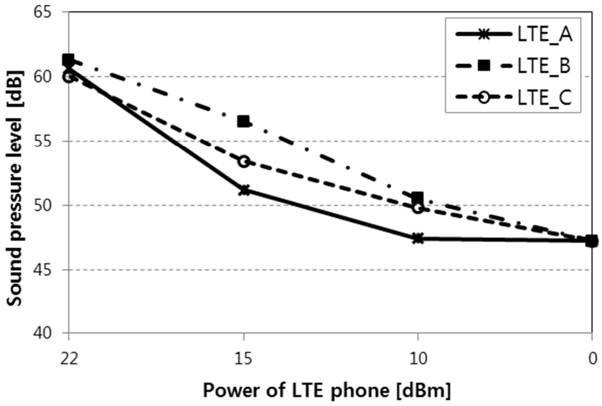

Figure 8. Interferences for wire telephones at various LTE powers

0dBm, the distance which the sound system is affected by a LTE mobile phone is expected to decrease to less than several centimetres.

VI. CONCLUSIONS

This paper presents an interference analysis of LTE mobile phone in the sound systems, based on the experiment. Three brands of LTE mobile phones investigated and a speaker and a wire telephone are applied as sound systems. The output spectra of interfered noise are presented in the time and frequency domain. Furthermore, the interfered noise levels in sound systems are measured at various distances from the LTE phones, and also at various powers of the LTE phones. The experimental results show that LTE mobile phones apparently generate an interfered noise to sound systems. Therefore, various efforts to reduce the interfered noises of LTE mobile phones such as separating from the sound systems or reducing the transmission power are necessary.

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