ISSN: 2348 - 2117

International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Volume 3; Issue 2; Page No. 129-134

Total Radiation Emission of a GSM Phone

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Abstract:
The mobile phone produce quite a significant level of electric and magnetic field around itself as seen in interference with other electronic devices. Carrying out test and measurement is a necessary step to determine the field levels produced and to ascertain compliance with regulations and standards on emission of electromagnetic radiation. The GTEM cell which is widely accepted as a sufficient tool in electromagnetic compatibility for both radiated susceptibility tests and radiated emission tests was used to determine the emission radiation of the phone. The measured peak E-fields in various regimes of the operation were -27.29dB (mV/m) for conversation and -27.20dB (mV/m) for ringing. This is intended to provide necessary data for correlation between measurements and open-area test site for on-going research.

Keywords: GTEM, GSM, Radiation, emission, polarization, correlation

Introduction

Electromagnetic pollution in urban and suburban areas is attributed to the intensive deployment of the mobile and fixed radio communication systems and networks in places with high population density. The popularity of cell phones and the need for effective network coverage has resulted in a proliferation of cell towers. At the same time, there are concerns over the electromagnetic radiation and the health risks associated with cell phones. Various studies have been carried out on limits [1-7]. Carrying out test and measurement is a necessary step to determine the field levels that exist in the vicinity of communication devices and to ascertain compliance with regulations and standards on emission of electromagnetic radiation.

The mobile phone, while emitting in use can produce quite a significant level of electric and magnetic field around itself. Sensitive electronic equipment such as control systems, medical and data processing equipment as well as communication networks can be affected by radiations produced by GSM signals [8-10]. The resulting interference with other electronic devices or systems in the vicinity of the mobile phone, and the other effect can be health concern for the users during conversations. The emission testing of GSM phones is therefore necessary to measure the emission levels of mobile phones in different situations (stand-by, communication, connecting call). These measurements can he conducted in various facilities such as Open Area Test Site, Anechoic and Semi-anechoic chambers and TEM and GTEM-cell [11]. Direct estimation of total intensity of set of EMF in some observation point at a ground surface, as a rule, represents extremely difficult and intricate problem connected with calculation of levels of EMF in the considered point generated by all radio transmitters located in a zone of radio visibility. Expected uncertainty of transmitters spatial allocation and parameters of EMR in most cases impede of its correct performance [12-13]. In this work the power emitted from the phone was measured in GTEM with attention for periods of ringing and conversation. GTEM cell has been widely accepted as a sufficient tool in electromagnetic compatibility for both radiated susceptibility tests and radiated emission tests[14]. The GTEM cell consists of a tapered section of rectangular 50 Ω transmission line loaded with an offset septum plate for increased working space to accommodate larger equipment under test (EUT). The septum is offset and tapered in such a way that 50Ω impedance is maintained along the length of the GTEM cell. Its termination is obtained by means of resistive 50 Ω elements between the septum and the cell wall at low frequencies and by means of RF absorbers across the cell end wall at higher frequencies. The input of the GTEM cell starts with a 50Ω type N coaxial connector and is gradually transformed to the tapered rectangular transmission line through a precision crafted apex [15].

GSM SIGNALS

GSM uses several frequency channels (carriers) spaced 200 kHz apart. A combination of frequency division multiple access (FDMA) and time division multiple access (TDMA) is used to achieve this structure. Each of these frequency channels contains eight timeslots (or time

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channels) with each timeslot carrying just one voice channel, so each carrier can handle up to eight subscribers in one direction – uplink or downlink. For the uplink the frequency band 876–915 MHz is allocated, whereas the downlink uses the band 921–960 MHz for the 900MHz band; 1710-1785MHz and 1805-1880MHz for the 1800MHz band. The GSM bands available for GSM services are shown in Table 1[16].

Table 1: The GSM bands

GSM 850 (America)	824 – 849 MHz (uplink), 869 – 894 MHz (downlink)
GSM 900 incl. GSM-R (Railway)	876 – 915 MHz (uplink), 921 – 960 MHz (downlink)
GSM 1800	1710 – 1785 MHz (uplink), 1805 – 1880 MHz (downlink)
GSM 1900 (PCS 1900; America)	1850 – 1910 MHz (uplink), 1930 – 1990 MHz (downlink)
Carrier spacing	200 kHz
Channels per carrier	8 timeslots (channels) per TDMA frame (4.615 ms)
Modulation	GMSK (Gaussian Minimum Shift Keying)
Access type	TDMA (Time-Division Multiple Access)
Power control	in 2 dB steps over a 30 dB range

As a result, different subscribers can transmit signal using same frequency, but at different time. A 25 MHz frequency band is divided into one way carrier frequencies using an FDMA scheme. Each base station is assigned one or more carriers to use in its cell. Normally, the 25 MHz band is divisible into 125 carrier frequencies but in GSM, the last carrier frequency is used as a guard band between GSM and other services that might be working on lower frequencies. The GSM frequency band is divided into 124 uplink/downlink carriers. Each carrier is divided in time into 8 time slots to allow at least 7 users to access the network using the same carrier[17]. Table I gives the parameters of GSM system. Each base station provides a base channel with information about the network and the base station itself. This channel occupies a specific frequency band and is called the Broadcast Control Channel (BCCH). It is transmitted at practically constant field strength [17]. One or more frequency channels, called traffic channels (TCH) are added to this for transmitting voice and data signals. The field strength of these channels varies with the load. Most measurements are generally more concerned with the area close to the transmitter site, and hence with the downlink field strength which predominates in this region. The worst case field strength, i.e. the maximum field strength when all TCHs are fully loaded, can be calculated from the practically constant field strength of the BCCH.

POWER CONTROL IN GSM

In order to contain the radiated power within acceptable limits, and at the same time providing reliable service, power control schemes are employed for GSM signals. As the mobile moves around the cell, its transmitter power needs to be varied; in the vicinity of the base station, power levels are set low to reduce the interference to other users. When the mobile is further from the base station, its power level is increased to overcome the increased path loss. However, if too much power is used, the user's battery will run down too quickly. All GSM mobiles are able to control their output power in 2dB steps [18]. The power control in GSM ensures that the mobile station uses only the minimum power level necessary for reliable communication with the base station. The lower transmitted power conserves the battery energy allowing the mobile terminal (the portable) to be lighter and stay on the air longer. Furthermore, recent concerns about health hazards caused by the portable's electromagnetic emissions are also alleviated. Another task for the power control in GSM is to provide smooth ramp-on and ramp-off of the TDMA bursts since too steep slopes would cause spurious frequency emissions. GSM defines eight classes of base stations and five classes of mobiles according to their power output (Table2).

Table 2 GSM Transmitter Classes

Power class	BS power (W)	MS power (W)
1	320	20
2	160	8
3	80	5
4	40	2
5	20	0.8
6	10	
7	5	
8	2.5	

The transmitted power at the base station is controlled, nominally in 2-dB steps. The adjustment of the transmitted power reduces the intercell interference and, thus, increases the frequency reuse factor and capacity. The transmitted power at the base station may be decremented to a minimum of 13 dBm [18].

The power control of the mobile station is a closed-loop system controlled from the base station. The power control at the mobile sets the transmitted power to one of 15 transmission power levels spaced by 2 dB. Any change can be made only in steps of 2 dB during each time slot.

The two schemes employed in the power control include the open and close loop power controls. The open-loop power control action is predicated on the estimation of the channel state. In the uplink (reverse link) it estimates the channel by measuring the received power level of the pilot from the base station in the downlink (forward link) and sets the transmitted power level inversely proportional to it. Estimating the power of pilot is, in general, more reliable than estimating the power of the voice (or data) channel since the pilot is usually transmitted at higher power levels. Using the estimated value for setting the transmitted power ensures that the average power level received from the mobile at the base station remains constant irrespective of the channel variations. The approach assumes that the signal strengths in the up/down links are closely correlated.

In the closed-loop power control system the decision is based on an actual communication link performance metric, like, received signal power level, received signal-to-noise ratio, received bit-error rate, or received frame-error rate, or a combination of them. In the case of the reverse link power control, this metric may be forwarded to the mobile as a base for an autonomous power control decision, or the metric may be evaluated at the base station and only a power control adjustment command is transmitted to the mobile. If the reverse link power control decision is made at the base station, it may be based on the additional knowledge of the particular mobile's performance and/or a group of mobiles' performance (such as mobiles in a sector, cell, or even in a cluster of cells).

In principle, the same categorization may be used for the power control in the forward link except that in the reverse link pilots from the mobiles are usually unavailable and only closed-loop power control is applied.

ESTABLISHING A CALL

The successful procedure for establishing a call that originates from the mobile station is outlined in fig. 1. The mobile initiates the procedure by transmitting a request on the random-access channel.

Since this channel is shared by all users in range of the base station, a random access protocol, like the ALOHA protocol, has to be employed to resolve possible collisions [19]. Once the base station has received the mobile's request, it responds with an immediate assignment message that directs the mobile to tune to a dedicated control channel for the ensuing call setup. Upon completion of the call setup negotiation, a traffic channel, i.e., a frequency in FDMA systems or a time slot in TDMA systems is assigned by the base station and all future communication takes place on that channel. Usually, the full available transmit power is necessary for the initial access and for a short duration after call establishment. For the rest of the call, both downlink and uplink transmit powers can be reduced to a level necessary to maintain a good link quality. The overall improvement in radio interference in the network thus obtained is helpful for the reduction of cluster size. In the case of a mobile-terminating call request, the sequence of events is preceded by a paging message alerting the base station of the call request. Figure 1 is the call setup procedure between the base station and the mobile station.

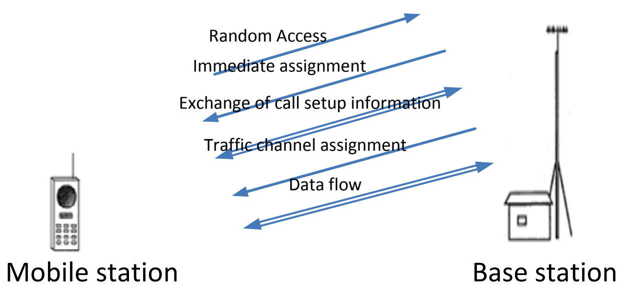


Fig. 1 Call setup procedure

MEASUREMENTS

The GTEM (model-5407) and Spectrum Analyzers and a horn antenna were used for the measurements. The mobile phone is battery powered, therefore, no external power supply is necessary and no cables which might disturb the fields and modify the results. The setup is therefore simple and is shown in Figure 2.

A grid was positioned on the floor of the cell and on this grid: the x-axis is horizontal and transverse or across the cell, with the origin located in the center of the cell, the y-axis is vertical and transverse to the cell, with the origin located at the floor of the cell, and the z-axis is longitudinal or along the cell from apex to base, with the positive axis towards the base of the cell. The z-axis origin is located at the longitudinal measurement position. This is usually placed far enough back in the cell to provide ample distance between the septum and the floor of the cell in which to place the EUT. The EUT is the rotated after each measurement for the three axes. Measurements are taken for each axis during mobile phones ringing and talking sessions.

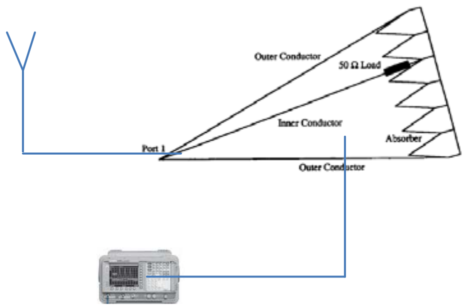


Fig.2 GTEM measurement setup

Fig. 3 The mobile station under test in the x- axis position in the GTEM. (GGIEMR, Nottingham University)

RESULTS AND DISCUSSION

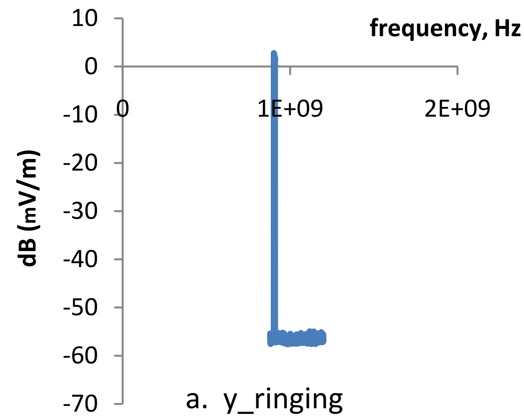
Table 3: E-fields during ringing

position	Peak Voltage dB (mV/m)	Minimum Voltage dB (mV/m)
x	-43.14	-57.28
y	-27.20	-57.26
z	-48.82	-57.87

Table 4: E-fields during conversation

position	Peak Voltage dB (mV/m)	Minimum Voltage dB (mV/m)
x	-42.56	-58.39
y	-27.29	-58.03
z	-52.41	-58.64

Fig.4(a) and (b) is a plot of the voltage in dB (mV/m) against frequency as displayed on the spectrum analyser for ringing and talking sessions for the vertical polarization.



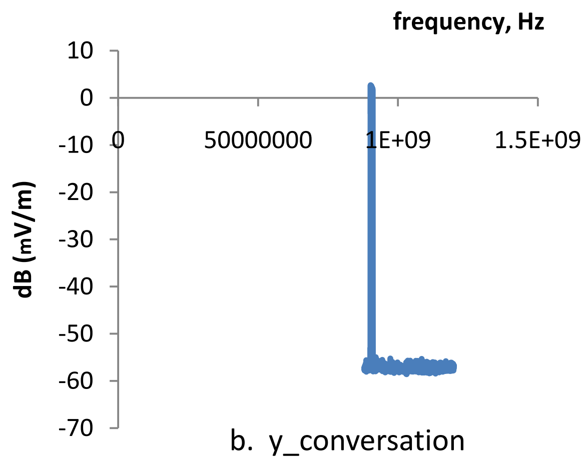


Fig. 4 (a) vertical field during ringing and (b) vertical field during conversation.

The free space field from a handset can determined approximately from the equation.

$$E = k\frac{\sqrt{P}}{d} \quad (1)$$

The far field from handsets can be estimated if the output power of the handset is known using equation (1) where E is electric field (V/m), P, the output power of the transmitter (W), d is distance (m) from the handset antenna, and k is a constant in the range 0.45 to 7, dependent on the antenna[10]. The emitted RF energy is much reduced if the mobile phone is used in a good signal area (near the base-station), while their use in a poor signal area like inside an elevator or a tunnel will result in the phone using a much higher power. The measured field in the GTEM is presented in components as the EUT was rotated in the x-, y- and z- directions.

Correlating TEM waveguide voltages to E-field data

Emission testing using TEM waveguides requires a TEM waveguide validation for EUTs in order to demonstrate the suitability of the TEM waveguide being used [20-21]. This procedure is intended to establish an alternative to open-area test site (OATS) emissions test methods. The TEM waveguide results are converted to equivalent OATS *E*-field data. The algorithm is based on the assumption that the radiated power as measured by a TEM waveguide will be radiated by a dipole positioned above a perfectly conducting ground plane.

This work is continued with the determination of the field factor (to be determined experimentally) and used in the correlation algorithm. The field factor is used in the algorithm for correlating OATS and GTEM measurements.

CONCLUSION

The cell phone was subjected to vertically and horizontally polarised fields, and was rotated in the horizontal plane so that each of its sides was exposed to the test field. Usually, the full available transmit power is necessary for the initial access and for a short duration after call establishment. For the rest of the call, both downlink and uplink transmit powers can be reduced to a level necessary to maintain a good link quality. As can be seen from the plots, Fig.4(a&b) after the initial access the rest of the call record a low field strength of -57dBm. A higher radiated field was observed when establishing connections but drops momentarily once connections are established both for the ringing or talking times. The result is presented component-wise with the y-component vertical polarisation having the highest field emission of -27.20dBm during ringing and -27.26dBm during conversation. However, these peak values are within acceptable levels for 2W class of GSM transmitters. Although only one mobile phone was tested, the principle of the work is the same for all models and more measurements are being conducted for correlation with OATS.

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