# Cellular Mobile Base Station Radiation at Baghdad

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## Abstract

Growing demand for mobile communication services results in a continuous increase in the number of base stations over a limited area, accompanied by public concern about the possible health and ecological effect of these systems. The main contribution of this paper is the usage of an empirical radio wave propagation model based on practical measurements in some ASIACELL sites in the city of Baghdad to measure the received signal power at the ground level in the vicinity of base stations and to determine the power- distance gradient value. The extracted power gradient value was used to examine the electromagnetic energy levels due to the base station transmitters. The calculated values of the power density levels in the vicinity of base stations were compared with the widely employed safety guidelines to ensure compliance with these standards. It was found that the exposure levels produced by the base station are too low compared with the exposure standards.

**Keywords:** Cellular Mobile Radiation Effects, Mobile Channel Modeling, RF safety limits.

## الاشعاع المنبعث من محطات الأجهزة الخلوية عند مدينة بغداد

عضيد حسن سلومي

**خلاصة**

أدى الطلب المتزايد على خدمات الاتصالات المتنقلة إلى زيادة مستمرة في عدد المحطات الرئيسية في منطقة محددة وقد ازداد معها القلق الشعبي من الآثار الصحية والبيئية المحتملة لتلك المنظومات. إن الإسهام الرئيسي لهذا البحث هو استخدام نموذج تجريبي لانتشار الموجات الراديوية اعتمدت فيه القياسات العملية في بعض مواقع شركة آسيا سيل ضمن مدينة بغداد كنموذج لقياس قدرة الإشارة المستلمة على الأرض قرب المحطات الرئيسية ولحساب مقدار اضمحلال الطاقة مع المسافة. تم استعمال مقدار اضمحلال الطاقة مع المسافة لغرض فحص مستوى الطاقة الكهرومغناطيسية المنبعثة من مرسلات المحطات الرئيسية. تمت مقارنة مستويات كثافة القدرة المحسوبة قرب المحطات الرئيسة مع معايير الأمان الراديوي الأكثر استخداما للتأكد من تطابقها مع تلك المعايير. وجد بان مقدار التعرض للإشعاع أقل بكثير من المعايير المحددة.

**الكلمات المفتاحية:** التأثيرا ت الاشعاعية للموبايل الخلوي، نماذج قنوات الموبايل، حدود سلامة RF

## I. Introduction

Electromagnetic radiation can be described as waves of electric and magnetic energy moving together through propagation mediums. Electromagnetic waves are classified into ionizing, and non-ionizing radiations depending on their frequencies.

Ionizing radiations are Extremely High Frequency (EHF) electromagnetic waves that have enough energy to produce ionization and break the atomic bonds, such as X-rays and gamma rays. Non-ionizing radiations are electromagnetic waves that have weak photon energies to result in ionization, such as the radio waves that are used for providing various types of communication at radio frequencies (RF) [1, 2].

As the population continues to grow and so does the number of people using mobile phones(subscribers), more and more base stations are going to be installed. The large number of base stations in areas where people live and work, has raised the public concern regarding the probable effects due to exposure to the radiation emitted by base stations [3]. At the same time, there is less concern over the mobile phones themselves, although the (RF) exposures from these phones are greater as the common position of use (the head of the user), receives the highest exposure [2].

In order to avoid any probable biological and health effects from short- and long-term exposure to RF radiation, several guidelines and standards have been issued by many national and international organizations. These guidelines are expressed in terms of field intensities, the power density in the far-field zone of the radiation source, or in terms of the energy absorbed by an element of biological body mass, i.e., called the specific absorption rate (SAR) [4, 5].

This paper is composed of four sections: section II provides a brief review of the cellular communication systems including a description of the based geometry for power density calculations at the ground levels. In section III the most widely- employed RF safety limits specified by the international health organizations are summarized. Section IV presents the power exponent radio wave propagation model that is applied to evaluate the power- distance gradient and power density levels to assess compliance with the maximum permissible exposure limits. The final section provides a summary and conclusion.

## II. Cellular Telephone Network Radiations

Cellular mobile communication networks were developed by replacing a single high power transmitter that is located to achieve a large coverage area in radio-TV broadcasting systems with a single, low-power transmitter. In order to increase the number of simultaneous calls in cellular mobile communication networks, a large area is divided into a large number of small areas (cells), that is covered by a single base station, and the frequency of a cell is reused to another cell after skipping several cells.

Base stations are connected to one another by the Mobile Switching Center (MSC), which is connected to the fixed communication system i.e., the Public Switched Telephone Network (PSTN). From the MSC the calls can be terminated into other cellular phones or conventional land-line phone.

To evaluate the power density at any location, it is necessary to understand how signals propagate in the particular environment.

In free space, at the far-field regions, the power density (S) from an isotropic point source may be thought of as the effective isotropic radiated power (EIRP) divided by the surface area of a sphere with radius r. In practice, Effective Radiated Power (ERP) is used instead of EIRP to denote the maximum radiated power due to radiation of $P_t$ watts by a distant antenna with a gain of $G_t$ . It can be given as [6, 7].

$$S = \frac{ERP}{4\pi r^2} = \frac{P_t G_t}{4\pi r^2} \qquad (1)$$

Eq.1, implies that the power density from a transmitting antenna is inversely proportional to the second power of distance ($S \propto 1/r^2$), where r is the distance between the radiation center of the antenna and the exposure point in the far-field zone.

In urban environments, the Line of Sight (LOS) path between the base station and the mobile units is mostly blocked as the height of the mobile unit antennas may be smaller than the surrounding structures. The received signal and the power density is inversely proportional to the power of the distance, which varies depending on the propagation medium. Such relationships take the form $S \propto (1/r^{\gamma})$, where $\gamma$ is the path loss exponent value which is typically between 2 and 6[8]. Larger values of power exponent correspond to faster decrease in power density as the distance becomes larger.

At ground level, RF exposure is inversely proportional with the distance measured from the antenna to the point at which the power density exists. Eq.1, computes the main beam (on-axis) power density at the free-space conditions, and the off-axis power density will be considerably less.

The power density at the ground level can be determined in terms of the effective radiated power, the heights of the transmitting antenna and exposure point, and the horizontal distance from the tower to the point of exposure(d), using the geometry shown in Fig.1. The power density can be given as[4]

$$S = \frac{P_t G_t}{4\pi r^2} = \frac{P_t G_t}{4\pi \left\{ \sqrt{(h_b - h_m)^2 + d^2} \right\}^{\gamma}} \quad (2)$$

where $h_b$ denotes the height of the base station antenna above the ground, and $h_m$ is the exposure point height.

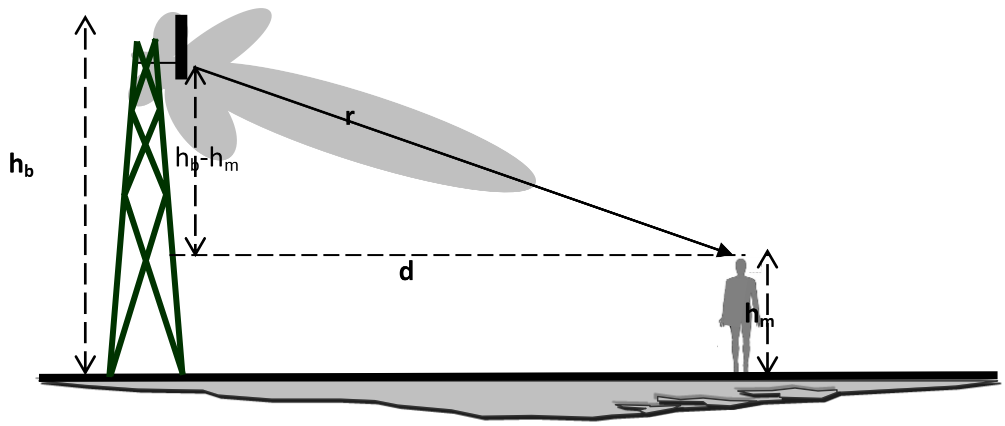



**Figure 1. Power Density Calculation at Ground Level**

## III. RF Safety Standards

Many international authorities provide the Maximum Permissible Exposure (MPE) levels that protect the public from RF radiations. These safety limits are usually given in terms of the maximum possible exposure of electric and magnetic fields, or power density. The most widely respected standard levels of (RF) radiation are those recommended by the American National Standards Institute and the Institute of Electrical and Electronics Engineers (ANSI/IEEE), and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ANSI/IEEE standard is recognized as an American National Standard, while the exposure standards recommended by ICNIRP has been adopted by more than 80 countries. These guidelines cover a wide range of RF frequencies as shown in Table 1 [2, 7, 9].

**Table 1. ANSI/IEEE - ICNIRP Exposure Limits [2] [7] [9].**

| Frequency f (MHz) | Electric Field E (V/m) | Magnetic Field H (A/m) | Power Density S ($mW/cm^2$) |
|---|---|---|---|
| ANSI/IEEE GULDE LINES | | | |
| 100-300 | 27.5 | 0.0729 | 0.2 |
| 300-3000 | -- | -- | f(MHz)/1500 |
| ICNIRP GULDE LINES | | | |
| 400-2000 | $1.375\sqrt{f}$ | $0.0037\sqrt{f}$ | f(MHz)/ 2000 |
| 2000-300000 | 61 | 0.16 | 10 |

The authority who is responsible for the most RF telecommunications services in the United States is the Federal Communications Commission (FCC). The FCC guidelines include standards for mobile base stations antennas are the same as the (ANSI/IEEE) guidelines[2].

The Global System for Mobile Communication (GSM) is the most popular system for mobile communications in the world. The GSM systems operate in either the 900 MHz or 1800 MHz band[4]. ASIACELL utilizes the GSM-900 to provide cellular communication services in Iraq, and the base stations transmitted RF signals are within the frequency band of 900MHz. Therefore, the Maximum Permissible Exposure (MPE) limits are between 0.45-0.6 $mW/cm^2$ based on ICNIRP and ANSI/IEEE guidelines respectively.

## IV. Propagation Channel Modeling

The propagation channel is the main contributor to many of the problems and limitations that be set mobile radio systems. RF engineers use mobile radio channel models to predict the mean signal strength and the level of RF energy that will be emitted by the base station at any point in the coverage area.

The complexity of signal propagation in urban areas makes it difficult to obtain a single model that characterizes the power level accurately across a range of different environments. Accurate radio wave propagation models can be obtained from empirical measurements. The power exponent model (Log-Distance model) is an empirical model that is widely used to predict the power transfer between a transmitter and a receiver depending practical measurements of the received power at different distances from the base station transmitting antenna in cellular system. It takes into account the decrease in energy density due to the radio wave spreading, as well as the energy loss in terms of an empirical path loss exponent (γ)[10][6].

The received signal power at any distance, i.e., $P_r(d)$ is proportional to the distance between transmitter and receiver d, raised to a certain exponent(γ), which is referred to as the power exponent value or the distance-power gradient; that is,

$$P_r(d) = P_r(d_o).\left(\frac{d_o}{d}\right)^{\gamma} \qquad for \quad d > d_o$$

Where $P_r(d_o)$ is the received power at a reference distance $d_o$.

As this model depends on real measurements, it can be used to derive empirical relationships for signal propagation and the effect of cellular mobile base station radiation can be examined by using this model.

**Power Exponent Model Application**

The received power measurements had been done at different distances from the base station transmitter in three different sites in the City of Baghdad by using the Cell Track software that has been installed in a cellular mobile phone. The received power has been measured by using this program, then the least squares approach is applied to calculate the accurate power exponent value. For each site (base station), N number of measurements had been taken. Least mean square error (LMS) as a numerical optimization schemes is applied to minimize the error in power exponent value calculation. The problem is formulated as finding the minimum of [6][10],

$$F(\gamma)=\sum_{i=1}^{N}(e_i)^2=\sum_{i=1}^{N}\left[Measured\ P_r(d_i)-Calculated\ P_r(d_i)\right]^2$$

$$F(\gamma)=\sum_{i=1}^{N}(e_i)^2=\sum_{i=1}^{N}\left[p_{ri}-\left(p_r(d_o)-10\,\gamma\,Log_{10}\left(\frac{d_i}{d_o}\right)\right)\right]^2 \qquad (4)$$

where $e_i$ is the error between the measured and calculated values of the received signal power, and $P_{ri}$ is the received power as measured in i-th measurement at the distance $d_i$.

Table 2, shows the obtained measurements at different distances from the base station of three sites in the city of Baghdad. Fig.2, shows one of the tested sites.

Applying eq.4, using the obtained measurements for the first site,

$$F(\gamma)=\sum_{i=1}^{N}(e_i)^2=[-51+51+0]^2+[-54.37+51+1.249\gamma]^2+[-55.65+51+2.218\gamma]^2+[-59+51+3.679\gamma]^2+[-63+51+4.259\gamma]^2+[-63.88+51+4.7712\gamma]^2+[-65.64+51+5.228\gamma]^2+[-67.97+51+6.02\gamma]^2$$

Differentiating F(γ) relative to γ and setting it to zero yields

$$\frac{dF}{d\gamma}=670.4254+248.987\,\gamma=0$$

$$\gamma=2.692709$$

The values of γ for the other two sites were calculated by the same method to be 2.758, and 2.754. The average value of the power exponent value was calculated to be 2.735.

**Table 2. Empirical Data for Three Sites (Practical Measurements)**

| **Distance (d) m** | **Received Power (Pr (d)) d Bm** | **Distance (d) m** | **Received Power (Pr(d)) dBm** | **Distance (d) m** | **Received Power (Pr(d)) dBm** |
|---|---|---|---|---|---|
| **SITE-1** | | **SITE-2** | | **SITE-3** | |
| do = 60 | Pr( do ) = -51.00 | do = 40 | Pr( do ) = -50 | do = 50 | Pr( do ) = -51.6 |
| 80 | -54.37 | 120 | -63.2 | 100 | -60 |
| 100 | -55.65 | 160 | -66.33 | 150 | -64.1 |
| 140 | -59.00 | 200 | -68.65 | 200 | -68 |
| 160 | -63.00 | 220 | -70 | 300 | -72.3 |
| 180 | -63.88 | - | - | 350 | -76 |
| 200 | -65.64 | - | - | | - |
| 240 | -67.97 | - | - | | - |

By using the extracted value of γ, the power density caused by a transmitting antenna of 20W, with a gain of 18dBi was calculated at a point of 1.5 m height. The calculated power density values were 0.00119 $mW/cm^2$, 0.0032 $mW/cm^2$, 0.001215 $mW/cm^2$, 0.000325 $mW/cm^2$, at 20m, 40 m, 60 m and 100 m away from the base station respectively. It can be noticed that the exposure levels produced by the base station is too low compared with the exposure limits even in close proximity to the antennas, because the mobile phone base stations are low power system. Unsafe power density levels can be reached due to high transmitter power, high antenna gain, very close proximity to the transmitting antenna.

In cases where exposure levels might pose a problem, there are various techniques can be applied to avoid excessive radiated power density absorbed by the general public who are exposed to the electromagnetic radiation emitted by cellular base stations.

Figure 3, shows that increasing the base station antenna height ($h_b$), results in radiation exposure reduction as the signal path to the exposure point will be increased. In Figure 4, the power density against the transmitting antenna height is drawn for a point 1.5 m above the ground, 50 m away from the base station. From the Fig., it can be noticed that the power density can be significantly reduced by increasing the transmitting antenna height.

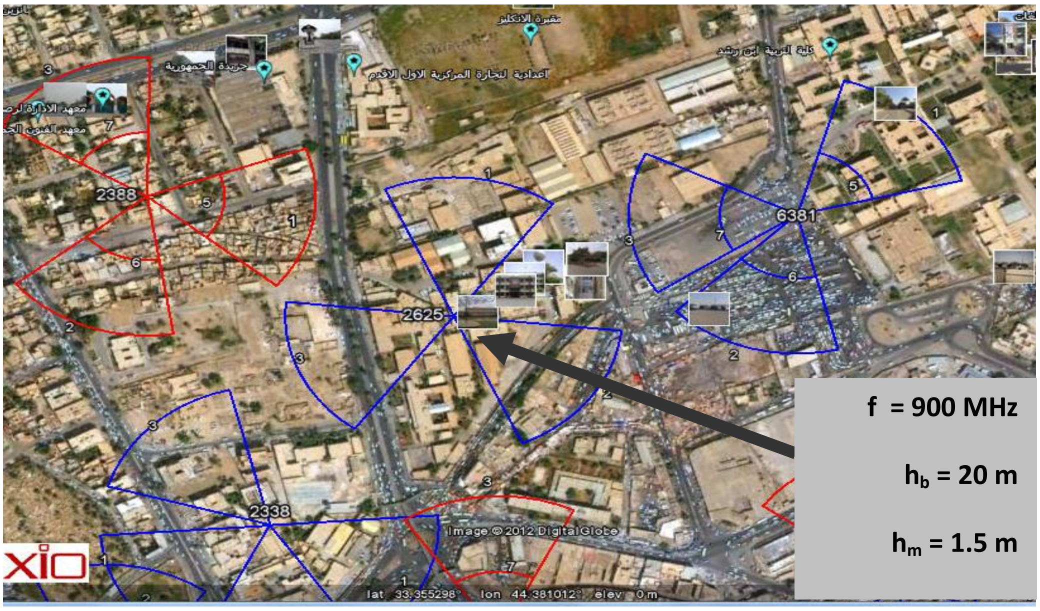
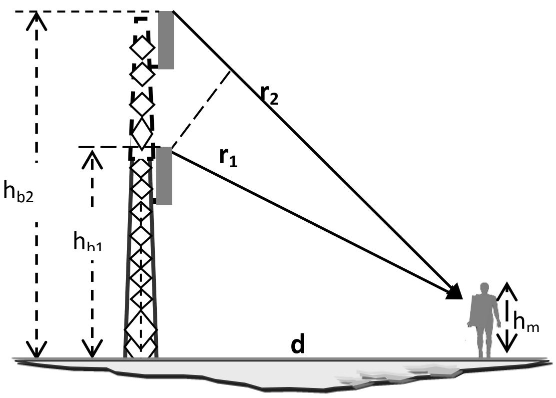



**Figure 2. Site No. 1 in the City of Baghdad**



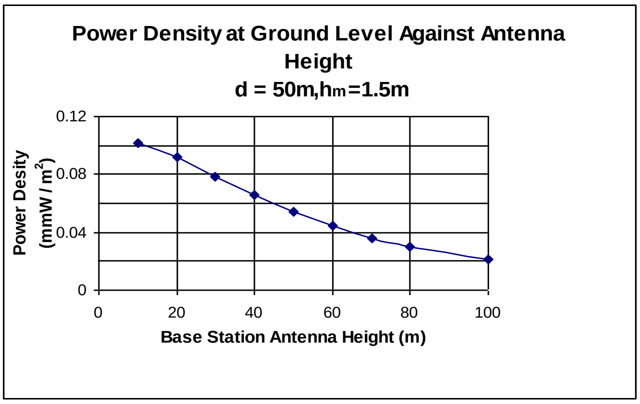




**Figure 3. Effect of Antenna Height**

**Figure 4. Power Density-Antenna Height Relation**

## Conclusions

Cellular base stations are one of the main sources of RF radiation that may affect the public health. Depending on empirical measurements taken in some sites in the city of Baghdad, the power exponent value was found to be 2.735 without line of sight between transmitter and receiver.

The power density levels calculated in the examined ASIACELL sites located in Baghdad are much lower than the exposure limit recommended by ANSI/IEEE and ICNIRP that are 0.6 $mW/cm^2$ and 0.45 $mW/cm^2$ respectively.

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