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Radiation Protection Dosimetry (2016), pp. 1–5
doi:10.1093/rpd/ncw095

THEORETICAL EVALUATION OF ELECTROMAGNETIC EMISSIONS FROM GSM900 MOBILE TELEPHONY BASE STATIONS IN THE WEST BANK AND GAZA STRIP—PALESTINE

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Theoretical assessments of power density in far-field conditions were used to evaluate the levels of environmental electromagnetic frequencies from selected GSM900 macrocell base stations in the West Bank and Gaza Strip. Assessments were based on calculating the power densities using commercially available software (RF-Map from Telstra Research Laboratories—Australia). Calculations were carried out for single base stations with multiantenna systems and also for multiple base stations with multiantenna systems at 1.7 m above the ground level. More than 100 power density levels were calculated at different locations around the investigated base stations. These locations include areas accessible to the general public (schools, parks, residential areas, streets and areas around kindergartens). The maximum calculated electromagnetic emission level resulted from a single site was 0.413 μW cm^{-2} and found at Hizma town near Jerusalem. Average maximum power density from all single sites was 0.16 μW cm^{-2}. The results of all calculated power density levels in 100 locations distributed over the West Bank and Gaza were nearly normally distributed with a peak value of ~0.01% of the International Commission on Non-Ionizing Radiation Protection's limit recommended for general public. Comparison between calculated and experimentally measured value of maximum power density from a base station showed that calculations overestimate the actual measured power density by ~27%.

INTRODUCTION

The widespread of mobile telephony base stations around the West Bank and Gaza Strip has increased the public concern about the possible health effects of electromagnetic radiation emitted from these base stations in the Palestinian environment. The public interest for having accessible and easy to understand information on the levels of electromagnetic radiation is an important demand. The West Bank and Gaza Strip are geographically separated regions. Researchers from the West Bank cannot travel to Gaza to perform experimental works. Therefore, a theoretical assessment of electromagnetic frequency (EMF) emission levels is considered as a useful and important tool for the study of current situation in Gaza. Gaza Strip has a small area (~365 km^2); therefore, most mobile telephony base stations are situated in highly populated areas. The calculation of electromagnetic emission level is possible by knowing the technical data of the mounted antennas and the position of the exposed individual. It is important to have an accurate base station configuration data, such as antenna pattern, mounting height, tilt, bearing, transmitter power and feeder losses[(1)].

Actual measurement of power density from mobile phone base stations requires sophisticated and expensive equipment. Such equipment is not always available for all laboratories, in addition to the presence of many other sources of radiofrequency radiation at a typical site[(2)]. Data about antennas are usually provided by the mobile telephony network operators. Different software tools have been developed for this purpose. They can provide quick and easy assessment of EMF levels in areas not accessible for the researcher.

The main purpose of this work is to provide data on the environmental EMF levels from GSM900 mobile telephony base stations in the West Bank and Gaza Strip and compare with the general public exposure limit provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards which are adopted by the Palestine Ministry of Environment.

MATERIALS AND METHODS

The RF-Map program

RF-Map is a software tool for the assessment of cumulative environmental EMF levels around single or multiple radio communications transmitter sites. The field calculations of power density in watts per square meter are carried out using the standard far-field formula[(3)]:

$$S = \frac{P \times G}{4 \times \pi \times d^2}, \tag{1}$$

where S is the power density (W m^{-2}), G the antenna power gain (absolute), P the antenna power (W) and d the distance to antenna (m).

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The program uses either a direct path or a two-ray propagation path. If the two-ray model is used, calculations then assume flat ground. The program calculates the correct ground reflection for vertical, horizontal or slant polarization. In this work, the two-ray path model was used. A relative dielectric constant of 15 and earth conductivity of 0.012 S m^{-1}[3] were assumed.

Data collection

A database has been established containing all the investigated sites necessary for field calculations of power density. The database includes site map, coordinates and technical parameters, namely antenna mounting configuration, number of sectors, antenna type for each sector, height of each antenna sector above the ground, mechanical tilt at each sector, direction of main lobe, number of carriers per sector and power output. All technical data about the investigated sites were obtained by the mobile phone network operator. All the GSM900 antennas used in Palestine are from Kathrein. The most frequently used type is K739635 panel. Most sites have three mounted sector panel antennas. Site maps used in this work are either aerial photo maps or street maps converted to a bitmap format and adjusted to an acceptable resolution for the RF-Map program. Maps were a limiting factor in our study because many of them are not available or available with a resolution which does not fit into the program.

Instruments

Experimental measurements were performed around one base station to check the validity of theoretical calculations with a Narda SRM-3000 selective radiation meter (Narda Safety Test Solutions). This instrument is a portable spectrum analyzer that covers the frequency range from 75 MHz to 3 GHz with high sensitivity (~87 μV m^{-1}), equipped with an isotropic antenna with an uncertainty of ~±2.1 dB at 900 MHz. The instrument is designed to give immediate on-site results. The spectrum analysis mode provides an overview of all frequency components with their field strengths. The spectrum is clearly displayed and determines maximum values measured directly onsite.

Study area

More than 100 power density levels were calculated using RF-Map software in different locations around 34 selected macrocell base stations over the West Bank and Gaza Strip. Figure 1 shows the distribution of base stations and the number of investigated sites across the West Bank. Only four base stations in Gaza Strip were investigated. The majority of investigated base stations are located in the central and southern parts of the West Bank. The reason for investigating the majority of sites in the West Bank was the availability of required maps for these sites. Surveying points are generally taken at 1.7 m height above the ground.

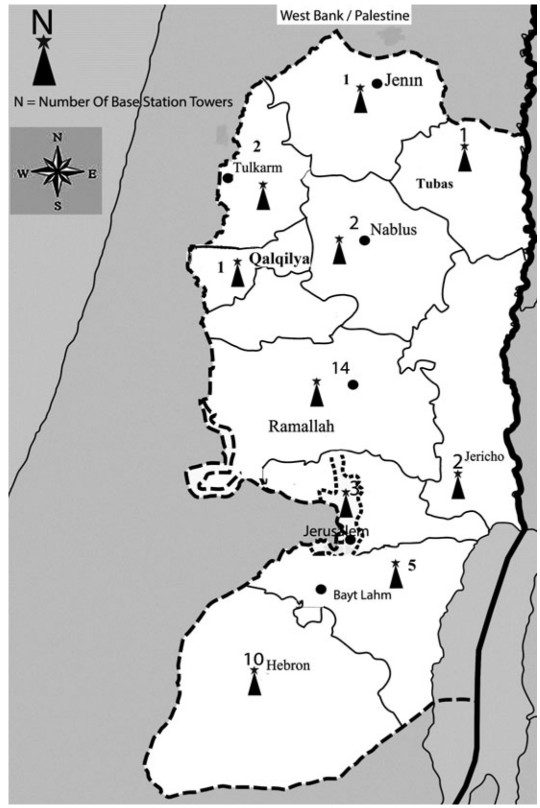

Figure 1. Investigated sites in the West Bank, Palestine.

RESULTS AND DISCUSSION

The power density emerging from the emission of a base station depends on the type of the antennas and their characteristics such as antenna gain, emitted power, height, mechanical tilt and antenna directivity. Theoretical assessments and experimental measurements of EMF levels were performed first for one selected base station with three sector antennas in Halhoul city near Hebron to compare. The site consists of three sector panel antennas (two of the type Kathrein 739635, one K739624), which are mounted at a height of 27 m. Each antenna has four radiofrequency carriers with a nominal frequency of 960 MHz and a maximum operating power of 47 dBm. Bearing of the antennas to true north are 50, 180 and 310°. The K739635 antenna gain is 2 × 17 dBi. It was assumed that the three antennas operate with the maximum power. The radiation map of this base

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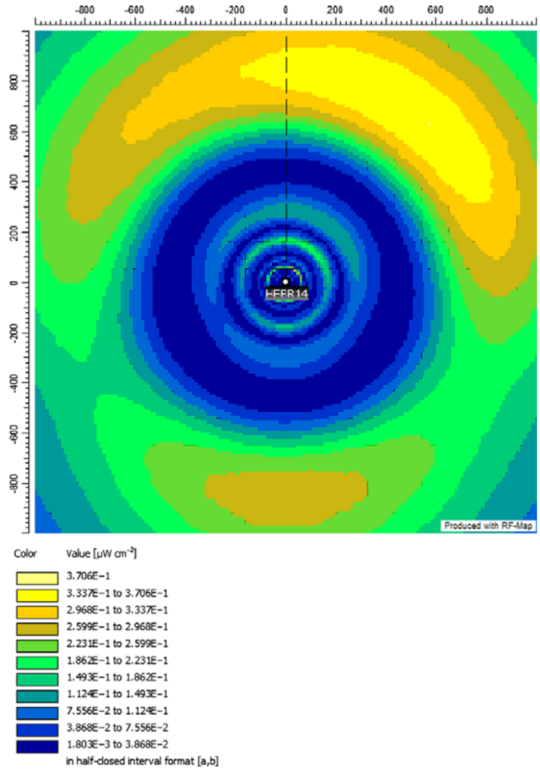

Figure 2. Estimated levels of EMF emitted from the mobile phone base station at Halhul city (plain view).

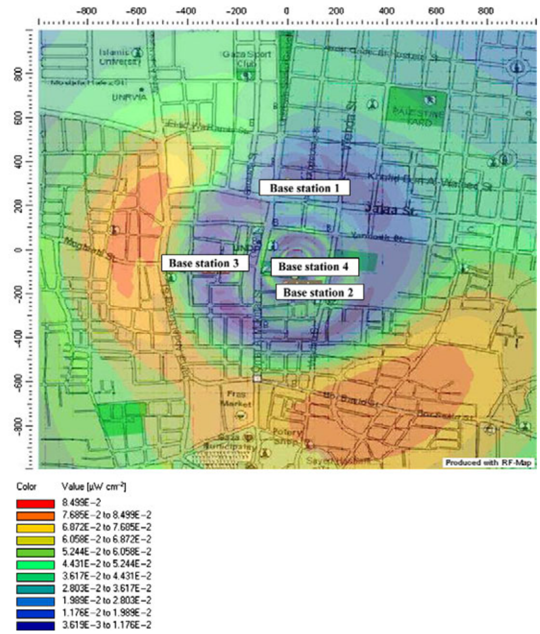

Figure 3. Cumulative electromagnetic radiation levels estimated from four base stations in Gaza city center.

station was generated for an area of 4 km^2 and is shown in Figure 2. The value of the maximum EMF level evaluated at a height of 1.7 m was 0.37 $\mu W\,cm^{-2}$. The actual measured power density in the area of calculated maximum EMF level was 0.27 $\mu W\,cm^{-2}$. The calculated value overestimates the actual measured value of power density by 27%. Because the attenuation of GSM900 signals in surrounding buildings is not considered in calculations, the calculated maximum power density can be considered as the upper bound for public exposure from the investigated base station. Therefore, theoretical assessments can provide acceptable results of EMF levels, and could be a reliable tool for evaluating exposure in areas not accessible for researchers.

Figure 3 illustrates a street map overly of cumulative EMF levels estimated from four mobile telephony base stations in Gaza city center. The maximum power density level resulted from these four base stations was ~0.085 $\mu W\,cm^{-2}$. Higher values of power densities were found across the most two crowded streets in the area: Port Said and Aljala streets.

Figure 4 shows the relationship between power density and the distance from a single base station. In this case, the maximum EMF level was found at a distance ~200 m from the base station. In most cases, the maximum EMF levels for single sites were found at distances between 400 and 800 m away from the base station. In general, at the beginning of setting up a new mobile telephony base stations in the country, there was a public rejection for setting up these stations close to residential areas due to public concerns about the possible health effects from radiofrequency radiation emitted from these stations. This is why the maximum power densities were found at relatively far distances from the base station. In the case of the base station radiation map shown in Figure 2, the distance of maximum level from the base station is ~860 m.

In fact, the possible effect would be higher in this case because the people who use mobile phones are exposed to more electromagnetic energy from the hand set itself, which emits more radiation when it is used at far distances from the base station. This situation caused problems for the mobile phone network operators in setting up their base stations near residential areas. It is known theoretically that at the far field of the antenna, radiation intensity decreases according to the inverse square low. Typically, radiation from GSM antennas reaches the ground level at a distance between 50 and 300 m[2].

In some areas, street map surveys were performed. Figure 5 presents the results of power density survey along two of the most crowded streets in Gaza city. The manner in which power density will change along

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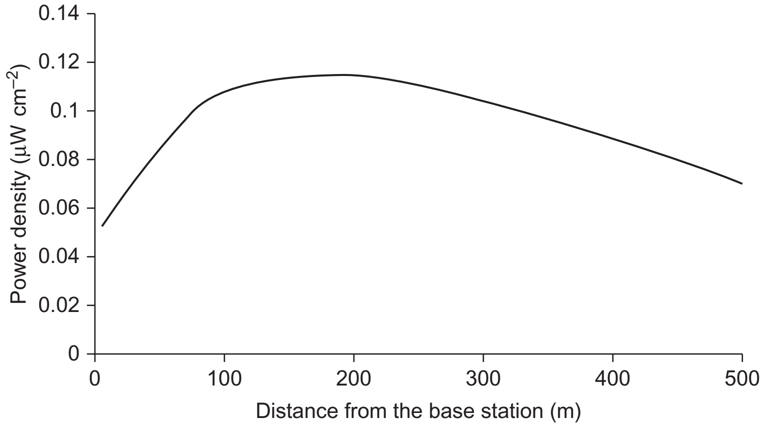

Figure 4. Power density as a function of the distance from the base station.

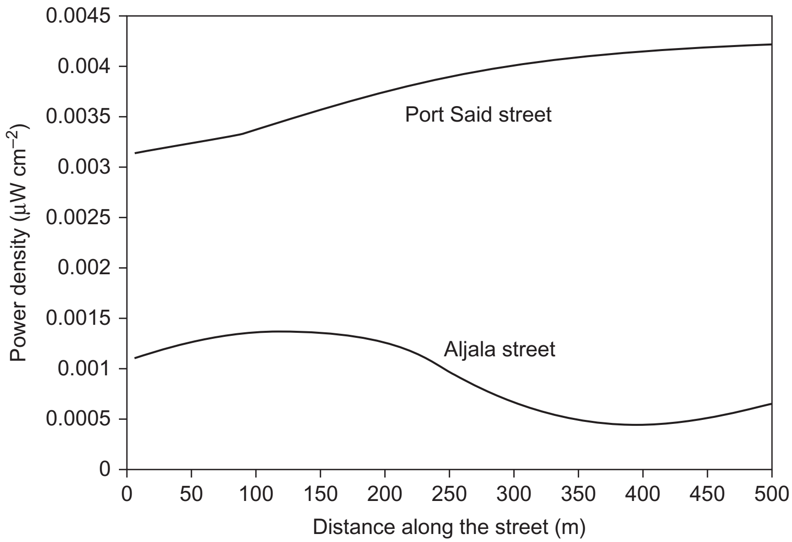

Figure 5. EMF levels resulted from four base stations estimated along two crowded streets in Gaza city: Port Said and Aljala streets.

the street is not predictable. In fact, it depends on the geometrical configuration of the four base stations in relation to the position along the street where the power density was calculated. These two streets are located close to the area where maximum fields are found.

The maximum estimated field at any location investigated in this study was 1.66 $\mu W\,cm^{-2}$ and is from a multisite configuration (13 base stations in the city of Ramallah). Ramallah is the political and commercial center of the West Bank with the largest number of mobile telephony base stations. This level is ~0.37% of the general public exposure limit of 450 $\mu W\,cm^{-2}$, as recommended by ICNIRP. The 'averaging times' in this limit are short (6–20 minutes) and reflect thermal considerations[4, 5]. The maximum in most occasions is less than 0.1% of ICNIRP standard. Figure 6 summarizes the results of all calculated power densities for various configurations and for all locations with a comparison to the ICNIRP guidelines recommended for general public.

CONCLUSION

Both measured and calculated values of power densities are well below the ICNIRP standards adopted in Palestine. Theoretical methods can be applied to evaluate the environmental radiofrequency radiation levels from mobile telephony base stations with an

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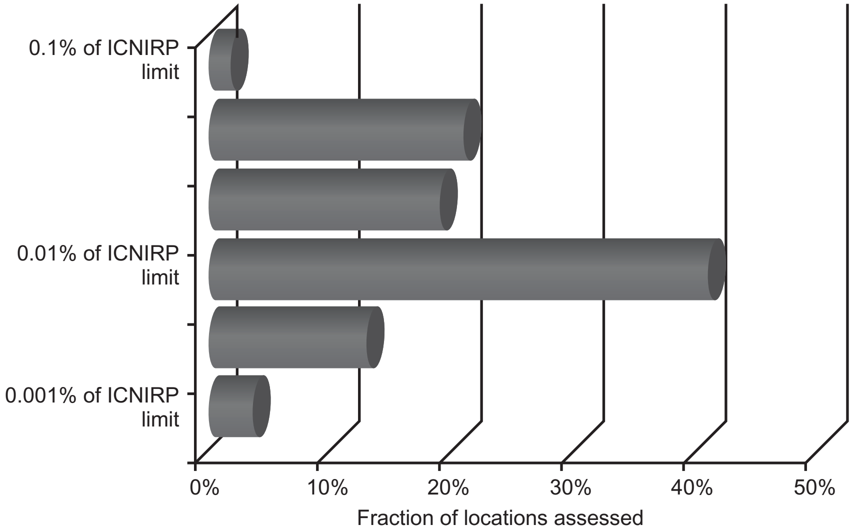

Figure 6. Radiofrequency radiation levels for all investigated locations over the West Bank and Gaza Strip in comparison to the ICNIRP limits recommended for the general public.

acceptable accuracy. Based on results, it can be concluded that the upper bound level of exposure due to GSM900 signals cannot contribute to adverse health effects caused by thermal effects of radiofrequency radiation. Further data will be needed for more detailed investigation of EMF levels from different sources of radiofrequency radiation. Based on thermal effects of GSM900 RF emissions, it can be considered that the Palestinian environment is safe.

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