MEASUREMENTS OF THE ELECTROMAGNETIC RADIATION FROM A BTS FOR RADIATION HAZARD PURPOSES

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Abstract

In this work we present the procedure and the results of the measurements that we have carried out in the vicinity of two GSM 900 Base Transceiver Stations (BTS). The results have shown that the power density levels measured are below the reference values of international guidelines and similar to the levels found in the literature. However, contrary to what is often reported for the urban environment, it was estimated from the measurements that the exposure levels due to the GSM spectrum are lower than those arising from FM radio broadcasting stations.

1. INTRODUCTION

The rapid introduction of new technologies into everyday life and in the area of mobile telecommunications has created a public concern about the possible health effects of the used equipment and the electromagnetic radiation. The increase of cellular phone subscribers has called for an expansion of the existing cellular networks in the urban environment of several countries, which involved the construction of more and densely situated Base Transceiver Stations (BTS), known also as base stations.

Although the public is concerned with the possible health effects of the electromagnetic radiation coming from the cellular phones, it appears that its main concern remains the location of base stations and the processes by which they are authorized [1]. In the literature, however, the reports on the electromagnetic radiation emitted from base stations either for auditing purposes or for radiation hazard surveys are rather sparse [2-4]. Even less are the reports on the contribution of these parts of a cellular phone network into the total electromagnetic environment [3, 4].

In this work we give an account of the instrumentation and the procedure we used for conducting measurements in the area around two base stations. The estimated power density arising from the base station is compared with that from FM radio broadcasting.

2. MATERIALS AND METHODS

2.1. Description of the measurement sites

The cases of the two base stations examined in this work are chosen because of the interest they presented. The first base station was located on top of a block of flats in the center of the city of Thessaloniki (Fig. 1a), consisting of nine floors. The antennas of the BTS were located on the top (9th) floor of the building, which was open and contained no housing space. The residents of the flats below the antennas became concerned and asked for an assessment of the power density levels in the building.

(a)

(b)

Figure 1. Photos of the two base stations considered in this study.

The second base station was located in the south-east suburbs of the city. It was a macrocell base station with a high (25m) antenna tower (Fig. 1b) covering three sectors. This base station had created concern not only to the residents of the blocks of flats opposite to it, but, as is often the case and is reported in [1], also to the parents of the pupils attending the two schools (one private and one public) in the vicinity of the base station (Fig. 2).

2.2. Description of the measurement equipment

The measurement equipment consisted of the following:

- Broadband radiation survey system: electromagnetic monitor Narda 8716 and isotropic probe Narda 8760 (max. rated power density 0.2W/m^2 and frequency range 300kHz–1000MHz)
- Spectrum analyzer HP 8590D.
- Polaroid camera HP 197B.
- Mangellan GPS Trailblazer.
- KVH Datascope for measuring distances.
- Monopole antenna for the GSM frequency range, where its Z_{input} is ≈50Ohm. Measurements of the corresponding VSWR are shown in Fig. 3 (points with squares). The gain of this antenna was 3.4dBi.
- Cavity-Backed Spiral (CBS) antenna with ≈50Ohm Z_{input}, in the GSM frequency range. The measured VSWR of the antenna is shown in Fig. 3 (points with circles). This antenna has a circular polarization; its measured gain for vertical and horizontal polarization was found to be 1.8dB and 2.8dB higher than the monopole respectively.
- AMC dipole antenna for the FM band. The antenna is well characterized from the manufacturer.
- Cables (RG214/U) and N-type connectors, the total attenuation of which has been measured to be 1.8dB/5m.

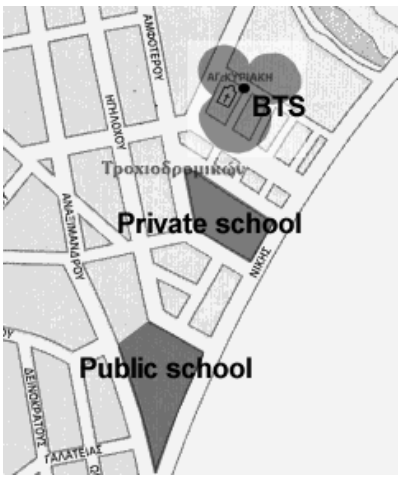

Figure 2. Location of the second BTS with respect to the two schools.

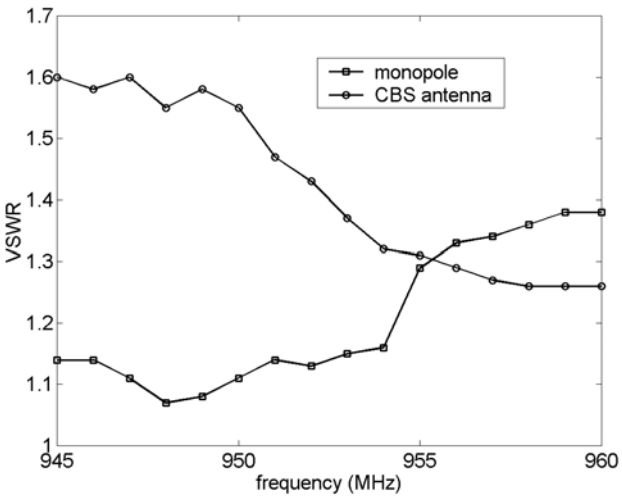

Figure 3. VSWR of the two antennas.

2.3. Description of the measurement procedure

The measurement procedure included two steps. Initially the radiation survey system was used, in order to determine the spots of high power density. At a second stage the spectrum analyzer was used with the two antennas to obtain measurements in the frequency domain. The measurements were conducted at several heights. The sweep time of the spectrum analyzer varied between 46.7msec and 83.3msec and the total measurement time was more than 6 minutes. The mode of operation was chosen to register the peak values (MAX HOLD), so that the measurements corresponded to the "worst-case". The several spectra were stored and later processed in the laboratory for the estimation of the power density. Only the frequencies with the ten largest power measurements were considered. Measurements were also performed for the FM spectrum, in order to evaluate the power density of the radio broadcasting stations.

According to Annex IV of [5], in situations where simultaneous exposure to electromagnetic fields of different frequencies occurs, the possibility that these exposures will be additive in their effects must be considered. Taking into account that the frequencies under investigation are above 10MHz and following the above principle we introduce the Safety Index (SI). This is the sum of the ratios of the measured power density at a frequency to the respective power density reference level at this frequency, for all frequencies considered, i.e.

$$SI = \sum_{f_i} \frac{S_{f_i}^{measured}}{S_{f_i}^{reference\ level}} \qquad (1)$$

It is clear that, in order for a location to be in compliance with the exposure guidelines specified in [2] and [3] for the general public, it must be $SI \leq 1$ for this location.

3. RESULTS AND DISCUSSION

The calculation of the power density from the stored spectra was carried out by taking into account the effective aperture, the gain and the VSWR of the receiving antennas at each frequency, as well as the total attenuation (cables and connectors) of the receiving path.

3.1. The Polarization Ratio (PR)

A point of interest for the calculations is the depolarization of the electromagnetic radiation. Although the radiation from the BTS was vertically polarized, measurements with the above antennas have shown that the polarization ratio (PR), i.e. the power density of the horizontal polarization to the power density of the vertical polarization, should be taken into account for the estimation of the power density. The median value of PR, used also in the calculations, was 0.09. However, inside the buildings, as expected, this value was measured to be as high as 0.19, due to multiple reflection and diffraction. In the case of the second BTS, there were some measurement points inside the two schools, where the PR had a very large value, i.e. 2.7, for the frequencies used in the other two sectors covered by the BTS and not in the one that contained the schools (Fig. 2). Therefore, these large values were not significant with regard to safety, because they correspond to the back and side lobes of the antenna, for which the power is very low.

3.2. BTS on top of a residential building

It is important to distinguish between the power density of the electromagnetic radiation as a result of the operation of mobile telecommunications and that which arises due to the presence of a specific BTS. Fig. 4 shows clearly the frequency ranges, which have to be considered for the estimation of the power density levels that the BTS under consideration creates. Although Fig. 4 contains all the measurements that were conducted inside the building and on top of it, the same pattern is repeated, if we draw the respective diagram for each floor separately.

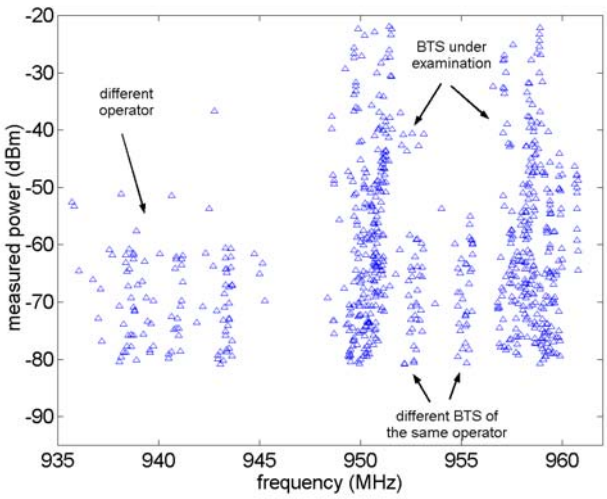

Figure 4. Distribution of the measured power with frequency for the BTS on top of the residential building.

On the top of the building, where the antenna is located, the maximum power density due to the electromagnetic radiation from it was 1.34W/m^2 (SI=0.28). This value was decreased by 50dB when the antenna was covered with aluminium foil.

The maximum power density at the GSM spectrum inside the building was observed on the eighth floor, i.e. one floor below the antenna. The total power density in the frequency range 935MH–960MHz was S_{GSM}=1.27×10^{-3}W/m^2 (SI_{GSM}=2.7×10^{-4}). This power density level can be attributed almost entirely (99.98%) to the radiation from the BTS antenna on top of the building. At the same location, where this maximum occurs, the FM spectrum was also measured. In the frequency range 88MHz–108MHz the power density was S_{FM}=1.55×10^{-3}W/m^2 (SI_{FM}=7.7×10^{-4}). It is worth noting that both the power density and the SI for the electromagnetic radiation from FM broadcasters is higher than that from the GSM BTS, although the antennas of the former are several kilometers away from the measurement site.

The power density inside the building does not reduce monotonously as we move to lower floors. Because of reflection and diffraction, the power density levels can vary significantly in space and this fact should always be considered when conducting similar measurements. In the case presented here, on one side of the building where the antenna is situated, there is no other building attached to it; the next building on that side is several meters away. We assume that this fact allows the radiation levels from the base station to present a second local maximum on the fourth floor, where it obtains the value of S_{GSM} =0.24×10^{-3}W/m^2 (SI=0.5×10^{-4}). The maximum of S_{GSM} on each floor was compared with the corresponding one resulting from a ray-tracing computer program, which was developed in our laboratory. This program calculates the received power at a point of a simple model of the two buildings, taking into account single and double reflection on walls and diffraction on edges. The theoretical calculations do not predict clearly the local maximum, but they present the least deviation from the measurements for the value of the fourth floor. It is understood from the above that the prediction of the radiation intensity in the vicinity of a BTS is not a simple task. Complex reflection and diffraction phenomena affect significantly the power density. Therefore, after a careful theoretical study, RF engineers should perform detailed measurements.

3.3. BTS in the neighborhood of schools

In the case of the second BTS, measurements have been performed at three different location, namely around the BTS tower, on the premises of a private school and at a public school (Fig. 2). The distribution of measured power with frequency for the second BTS is shown in Fig. 5. This figure concerns the site of the public school but the diagrams are similar for the other two sites as well.

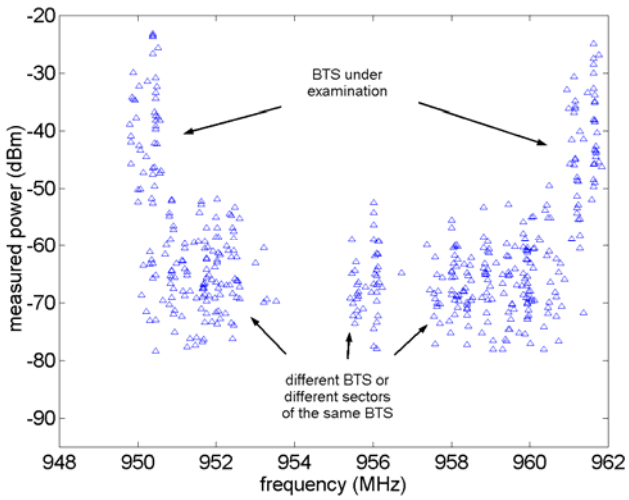

Figure 5. Distribution of the measured power with frequency for the site of the public school (second BTS).

The estimated maximum values of the power density and the SI for the GSM band at the three sites of measurement are given in Table 1. The respective values for the radiation originating from the particular BTS under examination comprised more than 98% of these values.

Site	max. S_{GSM} (W/m^2)	max. SI_{GSM}
Vicinity of BTS tower	0.28×10^{-3}	0.59×10^{-4}
Private School	0.24×10^{-3}	0.51×10^{-4}
Public school	0.47×10^{-3}	0.98×10^{-4}

Table 1. Estimated maximum values of power density and SI at the three sites of measurement.

It can be seen from Table 1 that, although the public school is more distant than the other two sites, the maximum power density is higher there. This can be attributed to the fact that the location, where this maximum appears on the second floor of the building, falls into the main beam of one of the BTS sectors, as it can be seen in Fig. 6. On the contrary, the blocks of flats opposite to the antennas present smaller values of power

densities, because they are aligned along a direction, which deviates significantly from that of any of the three sectors maximum.

Figure 6. Photo of the BTS, as seen from the location of maximum power density at the public school.

The values of Table 1 are in the same order of magnitude compared to the ones measured for the BTS on top of the residential building. The same holds also for the electromagnetic radiation arising from radio broadcasters. At one point of the public school playground, for example, the power density due to GSM was estimated at 0.02×10^{-3} W/m^2 ($SI_{GSM}=0.4\times10^{-5}$) and the power density of the FM band was 0.11×10^{-3} W/m^2 ($SI_{FM}=5.3\times10^{-5}$). All three measurement sites are again several kilometers away from the radio transmitters.

The results of our measurements were compared with values reported in the literature. It was found that the situation in other countries is different from that in Greece, where the power levels of the electromagnetic radiation in the FM spectrum are higher than those in the GSM 900 frequencies. Hamnerius and Uddmar have reported that in Sweden the contribution of the GSM 900 base stations to the total power density was up to 61% in city areas [3]. Although in the case of the city of the Hague reported by the Dutch Health Council [4] the percentage contribution of GSM 900 to the total power density was lower (about 32%), it was still clear that the radiation levels of FM broadcasting were significantly lower than those of wireless communications (GSM 900 and DCS 1800). On the contrary, we have found that the power density levels in these two frequency bands were comparable and in most cases the estimation for the FM range was higher than that for GSM 900. Bearing in mind the lower reference levels in

the guidelines [5, 6] for the FM frequency range, it was not surprising that the safety index for it was higher than for GSM 900.

4. CONCLUSIONS

The IEGMP report [1] has put forward many issues. In this work we have attempted to address only a few of them. Firstly, it should be noted that the measured values of power density were below the reference levels suggested by international guidelines [5, 6] even at the positions where maximum values were expected.

Another point to be considered, when reporting similar measurements, is the distinction between the sources of electromagnetic radiation. However, apart from reporting the evaluated power density levels, it is useful to compare them with the reference levels in the guidelines. It is clear from the literature and this work that every country presents a different situation and no general assumptions can be made. This fact can be useful to and should be considered by the experts working on risk management. Therefore, in order to be able to appreciate the contribution of different electromagnetic radiation sources the appropriate equipment should be used (e.g. spectrum analyzer). It is important for standardization bodies to specify a measurement methodology, which will take this, as well as other issues (e.g. measurement uncertainty, polarization ratio, averaging, search for maxima etc.) into account when evaluating human exposure.

Pertaining to the proximity of BTS to schools, it has been shown that the suggestion of the IEGMP to take into consideration schools during the GSM planning process is not without foundation. It was shown that at the grounds of a school in the main beam of the BTS antenna the power density levels where higher than at the residential areas in the vicinity of the BTS.

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