Paper

Evaluation of near field of the GSM base station antennas in urban environment

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Abstract — A simple and efficient method for evaluation of near field of the GSM base station antennas in urban environment is presented in this paper. The method is based on the replacement of panel antenna with a discrette linear array. Moreover, the geometrical optics approach is used to consider the influence of environment. The approximate results are found to be in excellent agreement with the results obtained by using the method of moments (MoM). Presented method can be successfully used for fast evaluation of exposure to electromagnetic fields emitted by the GSM base station antennas in urban environment.

Keywords — RF dosimetries, human exposure, radio base station, ray tracing.

1. Introduction

The rapid diffusion of wireless communication systems, specifically in cellular technology, has caused an increased concern for the potential detrimental effects on human health resulting from exposure to electromagnetic fields radiated by the antennas of these systems. This problem should be considered in two different aspects. The first one contains possible health hazards due to handheld phone devices. The second aspect, which this paper is devoted to, relates to EM fields emitted by the base station antennas.

Up to now, the exposure to the base station antennas has been studied in free space [6–9] and in urban environment in far field [10] only. Thus, the problem of exposure evaluation in near field in urban environment is still to be solved.

In the far-field region, which is defined as "the region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna" [1], the EM field can be relatively easily calculated, since all required information is the gain pattern of antenna and the radiated power. If the antenna has a maximum overall dimension D, the far field region is commonly taken to exist at radial distances from the source grater then $R = 2D^2/\lambda$, with λ denoting the wavelength. At distances less then R, in the near-field region, the EM fields usually have very complicated morphology, which is difficult to evaluate. For the typical GSM base station panel antennas ($D \approx 1.3$ m) the boundary between near- and far-field is located at the distance ~ 10 m and ~ 20 m for GSM 900 MHz and GSM 1800 MHz, respectively. Additionally, in urban environment the exposure conditions are quite different from those for free space, due to many scattering objects which are usually present in vicinity of antennas (trees, buildings, etc.).

The techniques of "rigorous" numerical modelling, as moment method (MoM) or Finite Differences Time-Domain method, are mostly used for studying the near field of antennas. The most common problem connected with application of these methods is knowledge of geometry of the base station antennas. Additionally, when exposure in urban environment is modelled, dimensions of the region to be studied can be huge compared with the wavelength, and consequently the time needed for analysis is unacceptably long. Thus, a simple and reliable calculation method for prediction of exposure to electromagnetic fields in urban environment is needed.

In this paper, a simple, accurate and computationally efficient method for evaluation of near field of the GSM base station antennas in urban environment is presented. The method is based on the replacement of panel antenna with a linear discrete array. Moreover, the geometrical optics approach is used to evaluate the influence of environment. In order to use geometrical optics the two-dimensional ray-tracing algorithm is employed. The approximate results are compared with those obtained by using the method of moments. Proposed method can be successfully used for fast evaluation of exposure to electromagnetic fields emitted by the GSM base station antennas.

2. Geometry of the base station antennas

Panel antennas seem to be the most popular for GSM 900 MHz as well as for GSM 1800 MHz base stations. The typical panel GSM 900 MHz antenna geometry is shown in Fig. 1. The geometry of the model is reasonably close to that of the 730370 antenna [12]. The antenna consists of an array of four collinear dipoles with horizontal separators placed in front of a reflector having the dimensions (height × width) 1280×240 mm. As it can be observed in Fig. 1 the antenna is made up of four identical "cells".

For this antenna, its catalogue data are as follows: $G = 14$ dBi (25.1 W/W), half power beamwidth in principal E- and H-plane 90° and 13°, respectively. The antenna is representative for the "Eurocell Panels" family of base station antennas for vertical polarization, commercially available in the frequency range from 870 to 960 MHz.

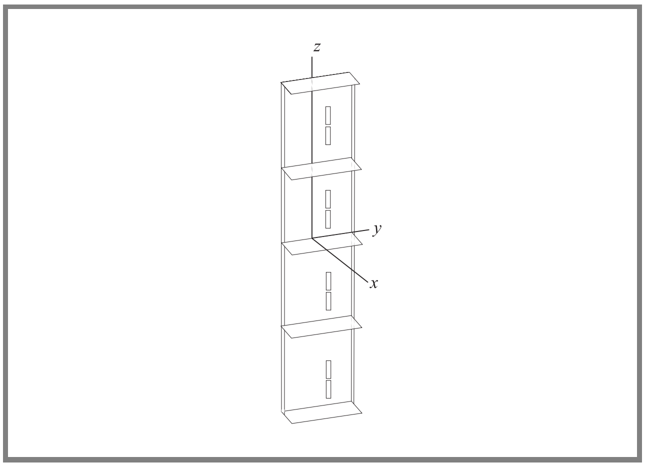

Fig. 1. Typical GSM base station panel antenna.

3. Near field of isolated antenna

A simple and effective method for evaluation of the near field of the GSM base station antennas is presented in [3, 9]. The method is based on the replacement of antenna with a linear discrete array. Every single "cell" of the original panel antenna is modelled by one source of the array.
Consider the array of N sources, as shown in Fig. 2. The fields emitted by every single source are calculated using far-field equations. The total EM fields in a particular observation point are obtained as a sum of the fields radiated by individual sources. The phase shifts arisen from

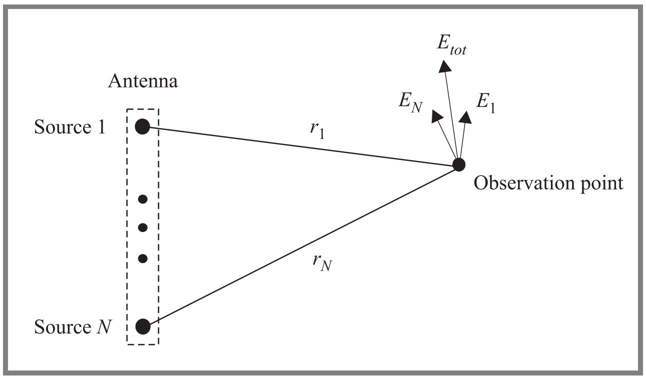

Fig. 2. Linear array as a model of base station antenna.

different distances between particular sources and the observation point are also included. Therefore, for a vertical polarization antenna, the total electric field is described by the following equation

$$\boldsymbol{E}_{tot}(\boldsymbol{r}) = \sqrt{\frac{30P}{N}} \sum_{i=1}^{N} \frac{\sqrt{G_s(\theta_i,\phi_i)}}{r_i} e^{-jkr_i} \mathbf{1}_{\theta_i}, \qquad (1)$$

where N is the number of "cells" of the antenna under investigation and at the same time it is the number of sources in its model; P is the radiated power and G_s is the gain pattern of unit cell. Distance between the source and the observation point is denoted as r_i, and $\boldsymbol{r}$ is a position vector associated with an observation point in the global coordinate system.
To apply Eq. (1), knowledge of the gain pattern of the unit cell of the antenna is necessary. It was found [9] that for the typical base station panel antennas sufficient approach of the gain pattern of the unit "cell" is function as follows

$$G_s(\theta,\phi) = \begin{cases} G_{\max}\sin^m(\theta)\cos^n(\frac{\phi}{2}) & -90 < \phi < 90 \\ 0 & \text{elsewhere.} \end{cases} \qquad (2)$$

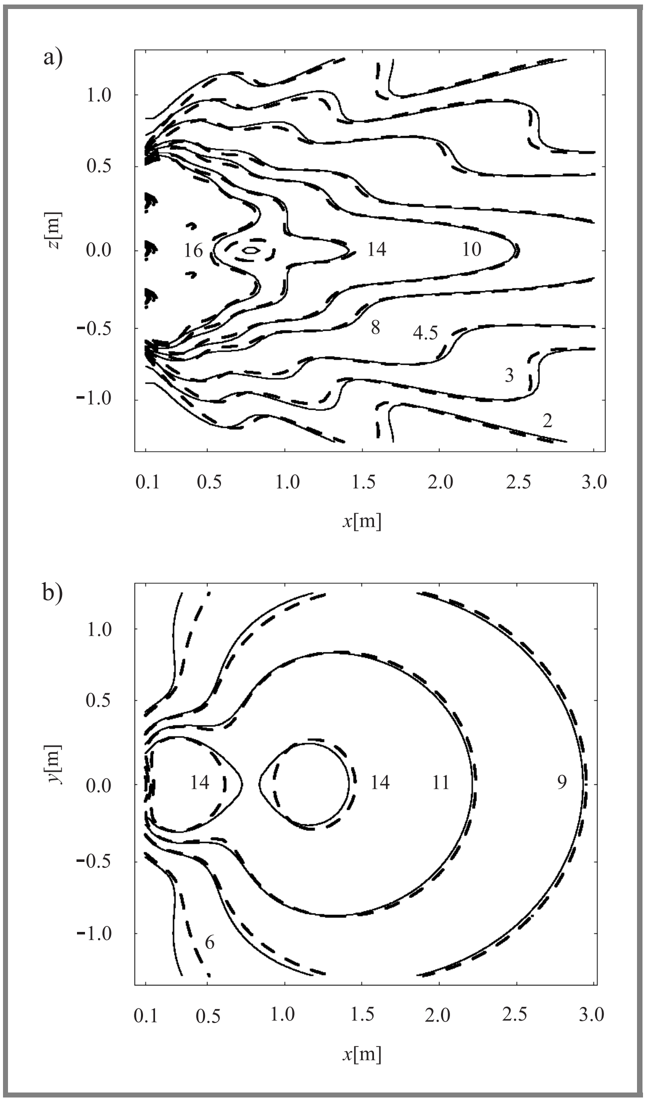

Fig. 3. Isolines of the electric field [V/m] in vicinity of 730370 antenna (radiated power 1 W) in principle E-plane (a) and H-plane (b), which were carried out using MoM (solid lines) and presented approach (dashed lines).

To obtain the appropriate half beamwidth of the antenna in principle E- and H-plain, values of respectively n and m should be calculated properly.
In order to examine the accuracy of presented calculating method, the approximated results are compared with the

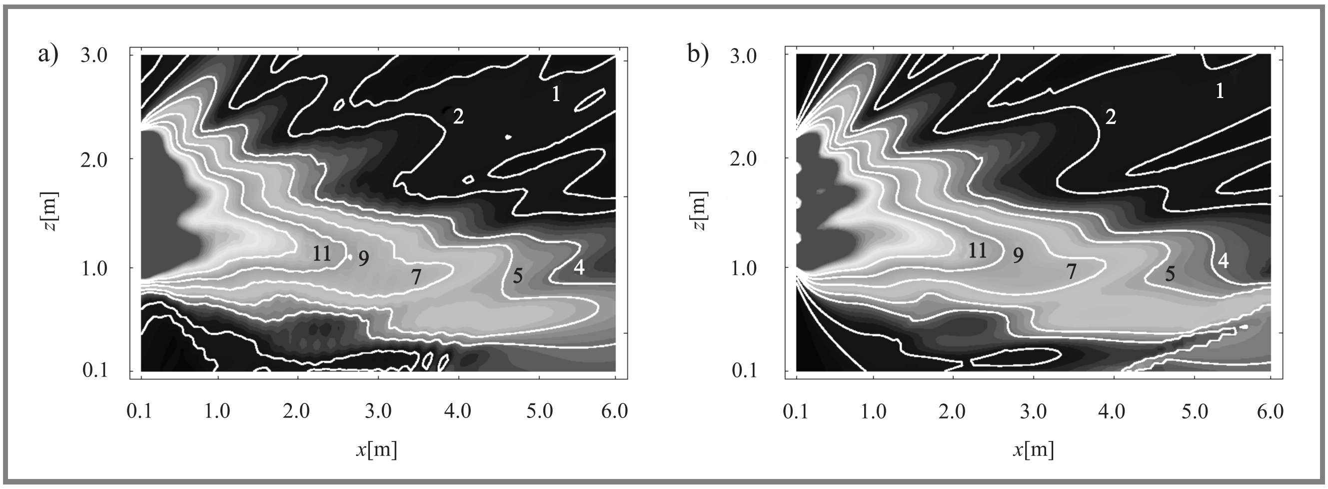

Fig. 4. Electric field [V/m] in vicinity of 730370 antenna (radiated power 1 W) placed 1m above and 1m in front of perfectly conducting plain, which were carried out using MoM (a) and ray-tracing approach (b).

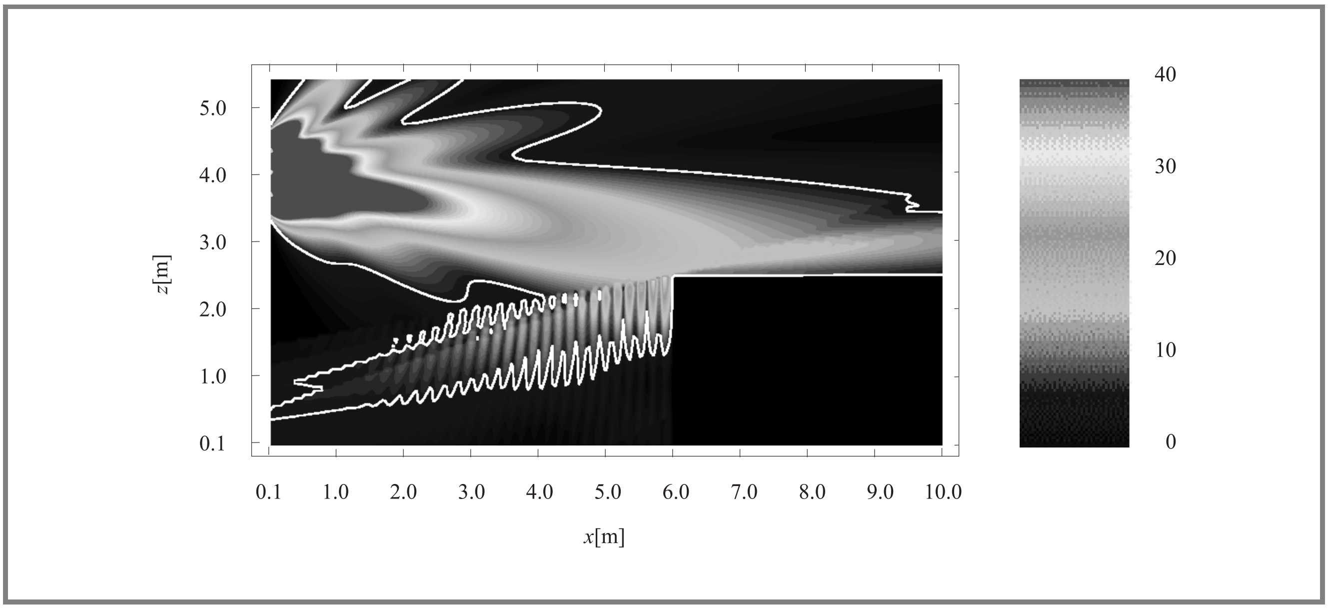

Fig. 5. The electric field [V/m] in vicinity of 730370 antenna (radiated power 15 W) placed in neighbourhood of a building.

results of numerical simulations, which were carried out using a customised, extended version of moment method based code MOMIC [2], which is specialized to wires and wire-grid structures. Isolines of the electric field in vicinity of 730370 antenna are shown in Fig. 3. One may notice that the approximated results are in excellent agreement with the full-wave analysis results.

4. Influence of the urban environment

To take under consideration the influence of scattering objects present in vicinity of antenna the geometrical optics approach has been used. Geometrical optics is a high-frequency asymptotic technique, which can be used to analyze objects large in comparison with the wavelength. Geometrical optics takes into consideration reflection and refraction mechanisms. Obviously, the edge diffraction mechanism also can play an important role in this case, which is omitted in presented approximations.

In order to use geometrical optics two-dimensional ray-tracing algorithm is employed. Recently, ray-tracing techniques have been widely used to predict radio propagation in indoor and outdoor environments [4, 5]. This approach has been also used to evaluate EM exposure level in the far field of the antenna in urban environment [10]. Ray-tracing gives reliable predictions of the EM field values only in the far-field region, where the antenna can be represented by the source point. However, if base station antenna can be replaced with linear array, ray-tracing approach will be reliable for calculating field close to antenna as well.

In Fig. 4, the electric field in vicinity of the antenna placed 1 m above and 1 m in front of the perfectly electrically conducting rectangular plane is shown. The dimensions of the plane are $(x \times y)$ 3 m $\times 1$ m. The antenna has $11°$ electric down-tilt and emits power of 1 W. However, practically such analysis is not very valuable, it allows to validate the presented method because this case can be easily analyzed using the moment method as well. As it can be easily seen the proposed approach shows a good accuracy.

Figure 5 describes the electric field morphology which appears in the surrounding of a building placed in vicinity of GSM base station antenna. The roof of the building is represented by perfectly conducting plane and the walls electrical parameters are $\varepsilon_r = 5$ and $\sigma = 0$ [4]. The building is located 1.5 m below antenna and 6 m in front of it. The antenna has $11°$ electric down-tilt and emits power of 15 W. As can be observed the field morphology is deformed by the building. There are reflections from the roof and wall, which causes the standing-wave in front of the building. In Fig. 5, an isoline of electric field intensity of 6.14 V/m is also marked. This value of electric field intensity corresponds in free space with power density of 0.1 W/m^2, which is maximum EM fields intensity permitted for general public by polish national recommendation on limitation of exposure to electromagnetic fields [11]. It is clearly seen that the shape of this isoline is quite different from the shape of appropriate isoline occurred in free space.

5. Conclusions

In this paper, a simple, accurate and computationally effective method for evaluation of near field of the GSM base station antennas in urban environment is presented. The method is based on the replacement of panel antenna with linear discrete array. Moreover, geometrical optics approach is used to evaluate the influence of environment. A number of comparisons between approximate results and full-wave analysis results carried out by author have proved that the proposed approach method is possible to estimate exposure to the near field of the GSM base station antenna in urban environment accurately.

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