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PREDICTION OF EXPOSURE CONDITIONS IN VICINITY OF UMTS BASE STATION ANTENNAS

Швидке впровадження безпровідного зв'язку впливає на те, що потенціальний ризик, якому підпадає здоров'я людини із-за пливу на неї електромагнітних полів, різко зріс. Стаття присвячена проблемам, які викликає сотова телефонія і які повинні бути розглянуті у двох різних аспектах: можлива небезпека здоров'ю із-за присутності кишенькових мобільних телефонів та розташування антен станцій. Для оцінки умов впливу антени станції універсальної мобільної телекомунікаційної системи (UMTS) запропоновано метод, який базується на заміні панелі антени дискретним лінійним масивом і який включає в себе елементи теорій геометричної оптики та дифракції.

Ввиду быстрого внедрения беспроводной связи потенциальный риск, которому подвергается здоровье человека из-за воздействия на него электромагнитных полей, резко возрос. Статья посвящена проблемам, вызываемым сотовой телефонией, которые должны быть рассмотрены в двух различных аспектах: возможная опасность здоровью из-за наличия карманных мобильных телефонов и размещения антенн станций. Для оценки условий влияния антенны станции универсальной мобильной телекоммуникационной системы (UMTS) предлагается метод, основанный на замене панели антенны дискретным линейным массивом и который включает в себя теорий геометрической оптики и дифракции.

The rapid diffusion of wireless telecommunications has focused attention on potential risks for human health due to the exposure to electromagnetic (EM) fields. In context of cellular telephony the problem should be considered in two different aspects: possible health hazard due to hand-held phone devices or due to base station antennas, which this paper will be devoted to. To evaluate exposure condition in vicinity of Universal Mobile Telecommunication System (UMTS) base station antenna, the method based on the replacement of panel antenna with a discrete linear array and combined with the geometrical optics and uniform theory of diffraction.

Introduction

To evaluate of exposure condition due to UMTS (Universal Mobile Telecommunication System) base station antenna, the knowledge of its field distribution is needed. Radiated field distribution is easy to evaluate in far-field region, where angular field distribution is essentially independent of the distance from the antenna [1]. In this case all data required for evaluation can be found in catalogues of the antenna, additionally the knowledge of supplied power is needed. If the antenna has maximum overall dimension D, it is usually assumed, that far-field region is commonly taken to exist at the radial distance from the source greater then

$$R = \frac{2D^2}{\lambda}, \tag{1}$$

where λ is the wavelength. For large base station antennas ($D \approx 2,6\,m$) the far field region starts with the distance of about 80 m for 2000 MHz. Simple calculations shows that for typical power level delivered to UMTS antennas the isolines of maximum permitted EM field intensity are located at near field region.

The near field distribution is difficult to evaluate, because it changes strongly with the distance from the source. Additionally, in urban environment, one must take under consideration the influence on the near-field distribution of scattering objects presented in vicinity of the antenna. Certainly, the near field can be successfully computed using full-wave methods, such method of moments or FDTD. However, full-wave methods are unpractical in routine procedure because of variety types of applied antennas, limited knowledge of their geometry. Additionally, for problem space dimensions considered in urban environment, time of computation by full-wave methods is unacceptably long. Thus a simple and reliable calculation method for prediction exposure conditions in urban environment is needed.

In UMTS base stations the most popular type of antennas are panel antennas. The typical panel antenna geometry is shown in Fig. 1. The geometry of the model is reasonably close to that of Kathrien antennas [4]. The antenna consists of an array of four collinear dipoles with horizontal separators placed in front of a reflector. As it can be observed, the antenna is made up of identical cells.

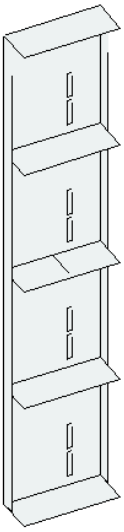

Fig. 1. Typical panel base-station antenna

In this paper, a simple and effective methods for evaluation of near field of typical UMTS base station panel antenna will be presented. The attention is focused at the method bases on the replacement the original antenna with discrete linear array. Total field in particular observation point located in near field of whole antenna is calculated as the sum of fields produced by each source of the array. Estimation of all needed parameters of the array from catalogue data of the antenna is discussed. Comparison of approximated results with those obtained by full-wave analysis shows, that the method can be successfully used for near field intensity evaluation. To evaluate the near field distribution in urban environment, the method based on the replacement of panel antenna with a discrete linear array is combined with the geometrical optics (GO) and uniform theory of diffraction (UTD). Some results of analysis of near field in practical situations will be presented. Obtained results will be related to recommendations on limitation of exposure to EM fields.

Simple methods

In simple near field intensity evaluations, far-field approximation is usually employed. Power density *S* at the distance *r* is given in [3]

$$S = \frac{PG}{4\pi r^2}, \tag{2}$$

where P is the input power and G – gain of the antenna under investigation. However, such approximation gives reliable results at the distance grater then R. Close to antenna far-field approximation usually overestimates the radiated power density.

Close to base station antenna, field intensity can be successfully evaluated by using of so-called cylindrical wave approximation. The method is recommended by FCC (Federal Communication Commission) as particularly useful for certain specialized antennas, such as UMTS panel antennas [5]. In cylindrical model it is assumed that in proximity of omnidirectional antennas (for example dipole antennas) power density has spherical symmetry. Consequently, inverse distance dependence for power density is obtained. If antenna under investigation has directional radiation pattern in horizontal plane it can be assumed, that in vicinity of the source power is radiated uniformly throw the portion of cylindrical surface corresponding to the half-power beamwidth of the antenna in azimuth plane [5]:

$$S = \frac{P}{\pi r D}\left(\frac{180}{\phi_{BW}}\right), \tag{3}$$

where ϕ_{BW} denotes the beamwidth in degrees.

Cylindrical-wave model leads to appropriate approximation of power density in vicinity of the antenna. However, the model fails if far field region because of inverse distance dependence. In contrast, in far field region spherical-wave model can be successfully employed. These two models can be combined in so called cylindrical-spherical wave model [3]:

$$S = \frac{PG}{4\pi r\sqrt{r^2 + r_0^2}}, \tag{4}$$

where r_0 is a constant. In far field region ($r > r_0$) reduces to spherical-wave approximation.

Close to antenna (4) leads to cylindrical-wave results if

$$r_0 = \frac{GD\phi_{BW}}{720}, \tag{5}$$

The model gives good approximation of average power density produced by panel antennas.

Discrete model of base-station antenna

For evaluation of near-field intensity of panel antennas, discrete model can be employed. Let r_d denotes the distance determining the boundary between near and far field region of separated cell of the antenna. If observation point is located at the distance greater then r_d, each cell can be replaced by source point. In this way discrete linear array as a model of antenna is obtained. For typical antennas, maximum dimension of separated cell is comparable to wavelength and r_d distance can be evaluated by (1) as equal to double wavelength.

Let us consider the array of N sources, as shown in Fig. 1. The fields emitted by every single source are calculated using far-field equations. The total EM field in a particular observation point is obtained as a sum of the fields radiated by individual sources. The phase shifts arisen from different distances between particular sources and the observation point are also included. Therefore, the total electric field is described by the following equation

$$E_{tot}(r)=\sqrt{\frac{30PG_m}{N}}\sum_{i=1}^{N}F(\theta_i,\phi_i)\frac{e^{-j(kr_i+\upsilon_i)}}{r_i}\mathbf{1}_{pi}, \quad (6)$$

where P is the radiated power, G_m and F – gain and radiation pattern of unit cell, respectively. Position vector associated with an observation point in the global co-ordinate system is denoted as r, and r_i, θ_i, ϕ_i fix observation point localisation in local spherical co-ordinate system centred at i-th element of the array. $\mathbf{1}_{pi}$ vector describes polarisation of the field radiated by i-th source.

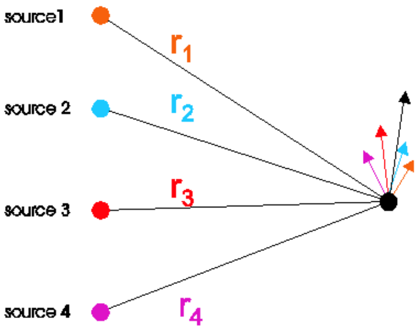

Fig. 2. Discrete model of panel antenna

It must be stressed that discrete model can be successfully employed in near-field analysis in urban environment. In fact, the model can be combined with geometrical optics and uniform theory of diffraction in order to taking into account influence of buildings located in vicinity of antennas under investigation. Another important advantage of discrete model is that it can be used both in near- and far-field of the antenna, because the model bases on the physics of specific antenna much more than spherical- or cylindrical-wave models.

Estimation of discrete array parameters

As has been shown in [2], all needed parameters of the array can be obtained from catalogue data of the antenna only. In this paper, improved method of model parameters estimations is presented. Introduced simplifications allow avoiding application of optimisation techniques, Fourier transform and filtration. Thereby, they make the method simpler in application then method proposed in [2]. At the same time, comparison of calculated field distributions with those obtained by full-wave analysis shows that excellent agreement can be obtained.

To apply discrete model of the antenna, knowledge of number of sources N, their arrangement, radiation pattern, and excitation coefficients is necessary. However, the model will be useful in practice, if only all of these parameters can be evaluated from catalogue data of the antenna under investigation. While typical panel antennas are analysed, sources of the discrete model form a uniform array: spacing between elements is the same, amplitudes of currents feeding particular sources are equal and each succeeding element has a υ progressive phase lead current excitation relative to the preceding one [1].

Number of cells of the antenna N is bounded with its height D and height of unit cell d. For typical base-station panel antennas, h is comparable to wavelength. Therefore, to evaluate number of source, the following relation can be used:

$$N\approx\frac{D}{\lambda}. \quad (7)$$

In far field region, total field of the array is equal to the field of a single source multiplied by array factor [1]

$$E_{tot}(r,\theta,\phi)=E(r,\theta,\phi)\times AF(\theta). \quad (8)$$

For typical panel antennas, maximum radiation occurs, when AF has its maximum value

$$\theta_m=\arccos\left(-\frac{\upsilon\lambda}{2\pi d}\right). \quad (9)$$

Nulls of radiation pattern appear for θ satisfying following relation

$$N\left(\frac{\pi d\cos\theta}{\lambda}+\frac{\upsilon}{2}\right)=\pm n\pi, \quad (10)$$

where $n=1,2,\dots$

It has been suggested in [2], that proper values of d and υ can be obtained using optimization techniques. As it will be shown in this paper, very reliable results are obtained, when d and υ are directly calculated from (6) and (7):

$$d=\frac{\lambda}{N(\cos\theta_0-\cos\theta_m)},$$

$$\upsilon=\frac{2\pi\cos\theta_m}{N(\cos\theta_0-\cos\theta_m)}, \quad (11)$$

when θ_0 denotes the nearest to θ_m null of radiation pattern ($\theta_0<\theta_m$).

Next, gain of unit source and its radiation pattern must be evaluated. Gain of unit cell can be evaluated as

$$G_m \approx \frac{G}{N}. \tag{12}$$

Of course, the smaller tilt is, the better is this evaluation. It can be assumed [2], that radiation pattern can be expressed as

$$F(\theta,\phi) \approx F_V(\theta) F_H(\phi)\,. \tag{13}$$

$F_V(\theta)$ and $F_H(\phi)$ are the radiation patterns of unit cell in vertical and horizontal plane, respectively. Array factor AF is not a function of ϕ. Thus, radiation pattern of unit cell in horizontal planes the same as known radiation pattern of whole antenna. However, $F_V(\theta)$ function can be successfully interpolated to obtain catalogue radiation patter of whole antenna in vertical plane [3].

Results

In order to examine the presented calculating methods typical base-station K742215 has been examined. Catalogue data of the antenna are as follows [4]:

- frequency range 1710-2200 MHz;
- gain 18 dBi;
- vertical half power beam width 6.5^{o};
- horizontal half power beam width 65^{o};
- electrical down-tilt 6^{o}.

Antenna is located at the building, close to roof edge. The nearest building was taken into account during the calculations. The building is located at the distance of 22 m and its roof is about 5 m under the centre of the antenna. It was assumed that antenna radiates power of 10 W.

Fig. 3 shows power density distribution in vicinity of the antenna, obtained by using of discrete model combined with high frequency techniques. Maximum power density allowed for general public in Poland is 0.1 W/m^2. From the picture it can be easily observed that actual power density excess limit value in main beam of the antenna only. Diffraction and refractions caused by the presence of the buildings do not disturb the field distribution significantly, that suggests that such phenomena do not play an important role in exposure condition evaluation.

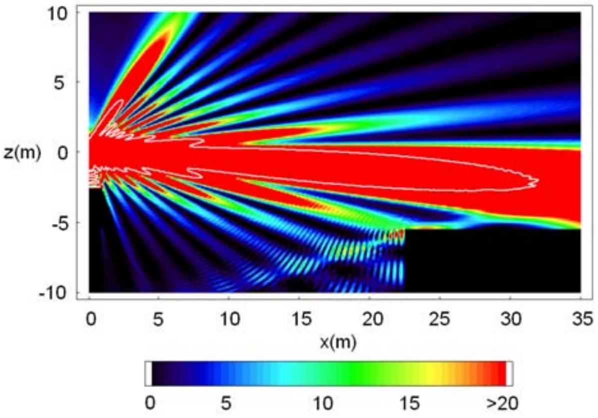

Fig. 3. Power density [mW/m2] in vicinity of 742215 antenna for 10 W radiated power

Conclusions

In this paper the methods of evaluation exposure conditions to EM fields in vicinity of UMTS base station antennas were presented. The method based on the replacement the original panel antenna with discrete linear array was the focus of the attention. Evaluation of the model parameters were discussed in details. As an example, the near field distribution in vicinity of typical antenna was calculated and presented.

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