ANTENNA MODELLING FOR FIELD CALCULATION IN THE VICINITY OF A RADIO BASE STATION

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Abstract :

Thousands of base station antennas (BSA) have been installed to support the development of mobile telephony. In the same time there is a public concern about the electromagnetic fields induced by these antennas and there is, in the vicinity of these antennas, a need for estimation and visualization of electromagnetic. Far field gain of the antenna is easy to use but inaccurate in the near field. In this area, the antenna model is often complex and involves full wave analysis. We developed a method able in a simple and fast way to estimate the field strength in the vicinity of the antenna the field.

Introduction :

To support the development of the second generation of mobile telephony thousands of base station antennas (BSA) have been installed. The development of UMTS will increase this number. In the same time there is a public concern about the Electromagnetic Fields induced by these BSA. To protect general public and workers from electromagnetic field hazards international committee such as International Committee on Non Ionising Radio Protection (ICNIRP) output guidelines[1]. Since the questions are important in Europe, in 1999 the European Council output recommendations[2] based on these ICNIRP guidelines. In this context general public as well as local authorities are looking for information on the radio frequency exposure level. The need for estimation and visualization of electromagnetic fields have growth last years in particular in the vicinity of the BSA.

The analysis of the field radiated by the antennas has been studied for a long time [3]. It is well known that the far field gain allows a simple and accurate approach to calculate the electromagnetic field strength far from the antenna. This approach is valid out of the "near field zone" which is given by $2D^2/\lambda$ from the antenna, where D is its characteristic dimension, λ the wavelength. For instance, with a typical GSM outdoor antenna operating at 900 MHz this distance is above 20m. On the other hand, in the close vicinity of the antenna, such simple approach did not exist. Near field analysis has been intensively used in antenna design and in this domain, because of accuracy, full wave analysis is often requested. Since the accuracy is not the same and since we need to take into account the environment, we developed a method able in a simple and fast way to estimate the field strength in the vicinity of the antenna the field.

Base stations antenna modelling

Base station antenna are often composed of array of dipoles or patch antennas and the proposed approach takes advantage of that. Moreover back reflector and horizontal separators reduce the coupling between the elements and in particular, between any element and the image of the adjacent element. Therefore, the radiated near field of the entire antenna can be considered as the superposition of the fields radiated by one sub antenna shifted in space. The main advantage of this approach is to allow the estimation of the near field of the entire antenna using the far field gain of the sub-antennas may be used to estimate the near field of the entire antenna. This approach is valid in the far field of each sub antenna which is very close to the large antenna, with typical GSM antenna the characteristic dimension of a sub-antenna is about one wavelength, so the far field gain of the sub antenna is valid id the distance to the antenna is above 2λ. Since the input power distribution (in phase and amplitude) has a large influence on the near and far field emitted by the total field is given by the summation of all the contributions weighted by their own input power. At the end the total field emitted is given by:

$$E(r,\theta,\varphi) = \sum_{i}^{Ncell} \sqrt{\alpha_i^2 P_{in}} \sqrt{\frac{30\, G_{cell}(r,\theta,\varphi)}{r_i}}\; e^{jkr_i}$$

with r_i the distance between the observation point and reference point of sub antenna #i; G_{cell} is the gain of sub antenna relative to an isotropic antenna and α_i is the complex weighting coefficient of sub antenna "i". The power conservation impose that these coefficients must verify the following relation: $\sum_i |\alpha|_i^2 = 1$

The input power distribution is often not known. For a given antenna the objective is to design the sub antenna and to determine the complex weighting coefficients. The sub antenna gain is determine using full wave analysis and after that an optimization, based on genetic algorithm, of the power distribution according to the measured BS far field vertical diagram is carried out. This process has been applied to commercial antennas and as shown on Fig.1 and Fig.2 the results are good.

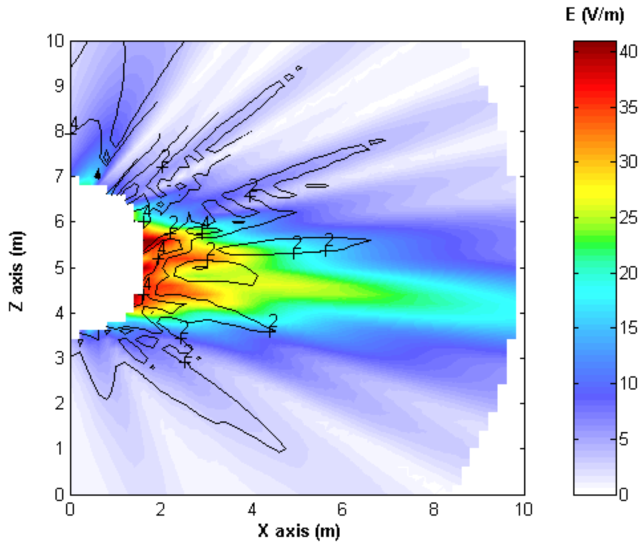

Fig. 1: Absolute error contours for the near radiated field for an optimized distribution.

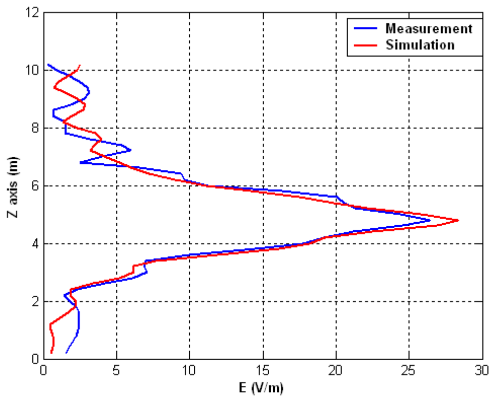

Fig.2: E-field evaluated at 5m in front of the antenna

Environment modelling

Using sub antenna description, the antenna model is valid in the near and far field of the entire antenna. Because of possible reflections and transmissions, the environment should have an influence on the field strength. To take into account this possible scattering, the estimation of the field in the vicinity of the antenna is carried out using the image theory. The sources are the sub antennas so the ray tracing method can be used in the far field of these sub antennas. Reflections (see Fig.3) and transmissions are evaluated using well known optic theory.

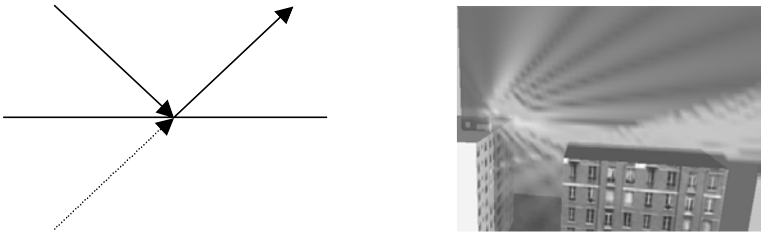

Fig3. : Principle of reflection and electrical image

Field visualization

Using a 3D software, the vicinity of the antenna is modeled; buildings, roofs, walls and ceilings are localized and visualized. Using this 3D model, the software determines the images of each sub-antenna related to these reflectors. Using all these sources, the total field is computed by summation of all the contributions which are calculated using the far field gain of the sub antenna and the dielectric properties of the scatter. This approach allows the determination of compliance boundaries as well as the estimation of the field strength in the vicinity of the antenna.

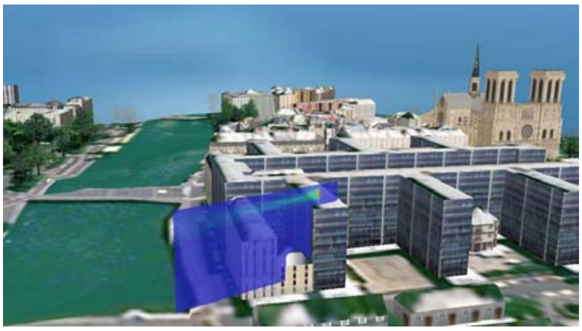

Fig.4: Visualization of the field in the vicinity of the antenna

Conclusion

The method described allows, in a simple and fast way, to estimate the field strength in the vicinity of the antenna the field. Valid beyond about 2 wavelength of usual radio base station, the method is accurate and can be used to estimate compliance boundaries around the antennas. Combined with ray tracing method, this approach allows also to estimate the RF exposure linked to RF antenna.

[1]. ICNIRP Guidelines – "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)" - Health Physics April 1998 Volume 74 Number 4

[2]. Council Recommendation - 1999/519/EC - 12 July 1999 - on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (Official Journal L 197 of 30 July 1999).

[3]. C. A. Balanis, “Antenna Theory, Analysis and Design”, John Wiley & Sons, 1982.