RAPID EVALUATION OF ELECTRIC AND MAGNETIC FIELD RADIATED BY BASE STATION ANTENNAS FOR CELLULAR COMMUNICATION

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ABSTRACT

A new technique to rapidly evaluate the safety perimeter of base station antennas is presented in this paper. The technique, based on near-field techniques, allows the determination of the electric and magnetic field almost everywhere around the antenna from a very limited set of measurement data. The reconstruction is achieved with an high level of accuracy. In this paper it is firstly shown that electric and magnetic field are not easily related in the near-field zone. The numerical validation of magnetic field reconstruction by the new approach is presented.

INTRODUCTION

In the last few years the rapid development of cellular communication has determined a great increase in the number of antennas installed. Fears of possible health hazard due to electromagnetic field exposure have grown consequently. In order to prevent these possible health risks, standards provide limits of exposition for human being to electromagnetic fields [1][2]. These limits, or sometimes more restrictive ones, have then been assumed as norms or recommendation in several countries [3][4][5]. In case of small coupling between the antenna and human body, as in the case of base station antennas, the limits are defined in terms of electric and magnetic field, called reference levels. Consequently, telecommunication operators are used to protect the area where the field overcome this limit by defining a safety perimeter around antennas (Fig.1).

The measurement of the field in the surrounding of the antenna could become a very difficult and time-consuming task. Firstly, the measurement of the field by means of a moving probe may take, typically, several hours per cubic meter of exploration.

Fig.1 Safety perimeter around a base station antenna for cellular communication

Moreover, in order to limit the interference of the environment, the test is generally conducted in an anechoic chamber, so that the physical dimension of the chamber limits the volume of exploration. These problems become more important in the case of very restrictive norms [4][5], for which safety distances extend to distances of tens of meters, well outside a typical anechoic chamber.
In the far-field region of an antenna, the magnetic and the electric field are proportional so that just one of the two fields shall be measured. On the contrary in the vicinity of the antenna (the near-field zone) the electric and magnetic field are not easily related. So, the procedure of compliance assessment of an antenna to these norms requires in general the measurement of both the electric and magnetic field, even if, usually, only electric field measurement are performed.
In this paper a new technique to rapidly evaluate both the electric and magnetic field of base station antennas is presented. The technique is based on near-field techniques, traditionally used to evaluate the radiation pattern of an antenna. The field is evaluated almost everywhere around the antenna from a very limited number of measurement. Only two components of the electric field are measured on a cylindrical surface around the antenna. Then, the six electric and magnetic field components are numerically evaluated almost everywhere. The measurement test lasts almost two hours with a single probe facility and less than one minute with a probe array system [6]. The reconstruction of the electric field by near-field techniques has been already numerically and experimentally validated [7][8][9]. In this paper the numerical validation for the evaluation of the magnetic field is presented.

NEAR-FIELD TO NEAR-FIELD TRANSFORMATION

Near-Field techniques allow evaluating the electric and magnetic field almost everywhere in the vicinity of the antenna, except in the reactive area where evanescent waves cannot be neglected. A general scheme of Near-Field to Near-Field (NF-NF) transformations in different measurement geometries is presented in Fig.2 [9]. Measurement data can be collected either on planar, cylindrical or spherical surfaces, in a Far-Field Range, or in a Compact Range.
A numerical post-processing is then applied to evaluate the field everywhere. Due to the elongated form of base station antennas for cellular communication, a cylindrical geometry seems the most appropriate for minimising the dimensions, and hence the cost, of the measurement facility. The NF-NF transformation used in this paper is shown in grey in Fig.1.
The two tangential components of the electric field are collected on a cylindrical surface. From this set of measurement, the cylindrical wave spectrum is evaluated by Fast Fourier Transform (FFT) and the far-field pattern is readily available [10]. The far-field is nothing but the plane wave spectrum [11]. By back-propagation of the plane wave spectrum, the electric and magnetic fields can be evaluated on planar surfaces, almost everywhere around the antenna (Fig.2).
In this way, one can reconstruct the field even inside the cylinder of measurement. Such a reconstruction would be more difficult in cylindrical coordinates due to the necessity of an accurate control of the number of retained cylindrical modes[12].

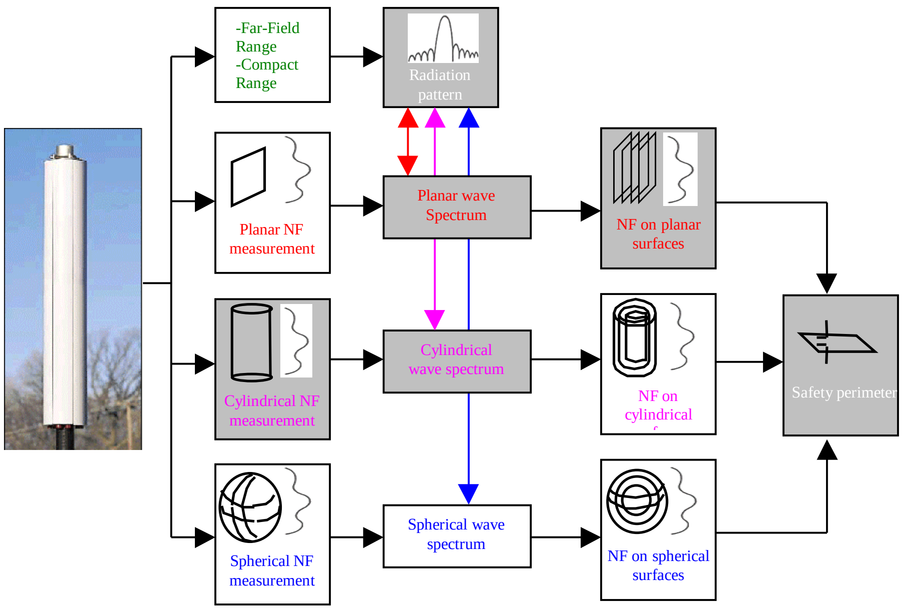

Fig.2:Near-Field to Near-Field transformation. The transformation used in this paper is in grey.

NUMERICAL VALIDATION

A base station antenna for cellular communication has been modelled as an array of dipoles on a reflector. The dimension of the antenna is 2.0 m per 20 cm. The operating frequency is 1800 MHz and the emitting power is 10 W. Firstly, it has been shown that the ratio between the electric field E and the magnetic field H is not equal to 377Ω in the vicinity of the antenna, as it happens in the far-field region. In Fig.3a the ratio between E and H is shown on an horizontal line in the direction of the main beam of the antenna. It is shown that the approximation is good just from a distance of 3 m from the antenna. Actually this ratio depends on the characteristic of the antenna. The approximation E/H=377Ω should be used just in the far field region, which, for this kind of antenna, is at about 50 m. Moreover for an horizontal line off the centre with respect to the main beam the approximation is even worse (Fig.3b).
If this approximation is used and the magnetic field H is evaluated from E/377, the mean square error on H in the vicinity of the antenna is 0.016 A/m, with an emitting power of 10 W. The limit level defined by ICNIRP[1] for the magnetic field at 1800 MHz is 0.16 A/m while the limit level defined by Italian norm[4] is 0.016 A/m. So, assuming 377O wave impedance in the near-field zone would induce an error on the magnetic field of 10% of the ICNIRP level and 100% of the Italian level. In Fig.4a the comparison between the reference magnetic field and the field evaluated by the approximation is presented on a vertical line at a distance of 30 cm from the antenna.
The magnetic field has been then evaluated by near-field techniques from electric field data on a cylindrical surface. The reconstructed magnetic field is compared to the reference in the vicinity of the antenna, in a volume of 2m per 2m, from 10 cm to 1 m in front of the antenna. The mean square error of the reconstructed magnetic field is 0.0016 A/m so that the error on the magnetic field is reduced to 1% of the ICNIRP level and 10% of the Italian level. In Fig.4b the comparison between the reference field and the field reconstructed by NF-NF transformation shows the high level of accuracy of the proposed method. In Fig.5a the safety perimeter for 0.16 A/m obtained from simulated data is presented. For comparison, in Fig.5b the safety perimeter from NF-NF reconstruction is shown. The reconstruction is obtained with an high level of accuracy.

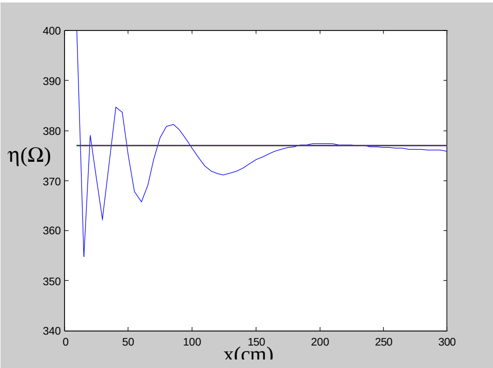

Fig.3a Impedance ζ=E/H at z=0.

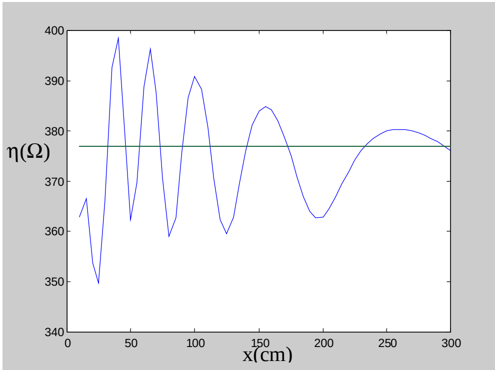

Fig.3b Impedance ζ=E/H at z=50 cm

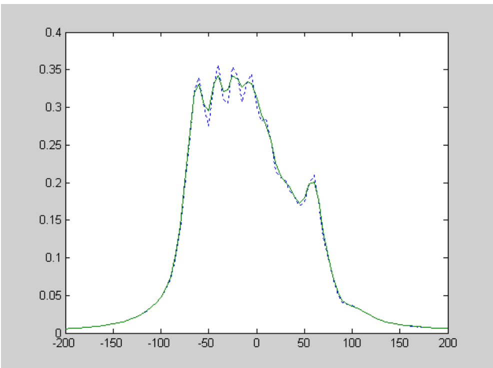

Fig.4a Comparison between direct magnetic field (solid) and field evaluated by approximation E/H=377Ω (dotted) at 30 cm from the antenna

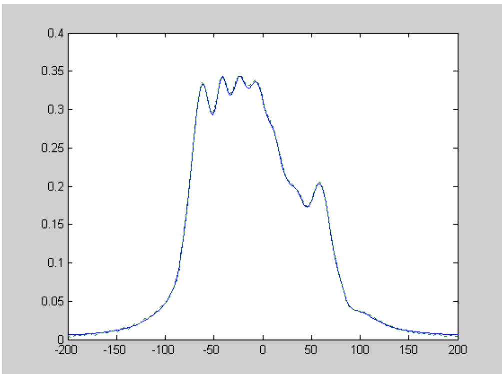

Fig.4b Comparison between direct magnetic field (solid) and field evaluated by NF-NF transformation (dotted) at 30 cm from the antenna

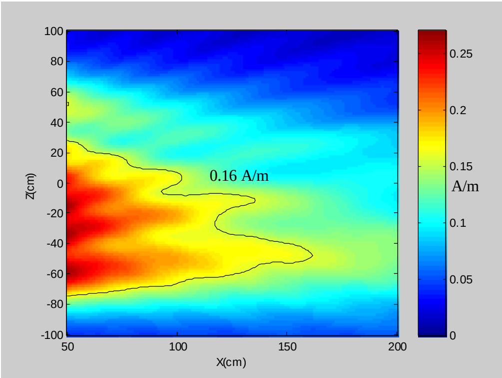

Fig.5a Safety perimeter from simulated data

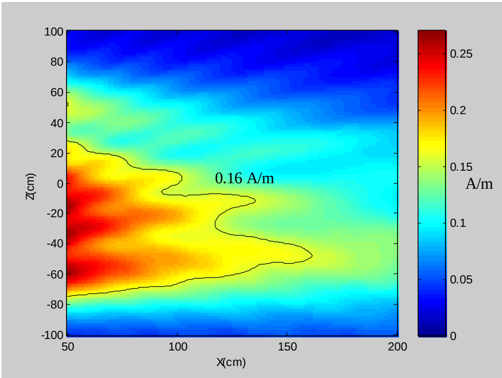

Fig.5b Safety perimeter from reconstruction

CONCLUSION

It has been shown that near-field techniques allows evaluating electric and magnetic field almost everywhere around the antenna, very rapidly from a very limited number of measurement. The reconstruction of the magnetic field is realised from the same set of electric NF measurement with a very high level of accuracy. Moreover the same measurement data used in the technique allows to evaluate the radiation pattern of the antenna, so that the evaluation of the near and far-field of the antenna is realised at the same time and from the same set of measurement.

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