NEAR FIELD EVALUATION FOR MOBILE COMMUNICATION ANTENNAS

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ABSTRACT

Because of the growing development of mobile communication systems, transmission antennas tend to be installed on top of small towers and close to people. Therefore, it is necessary to perform the analysis of the electromagnetic field behavior, to prevent the electromagnetic radiation from reaching the people with intensity levels above the ones permitted by governmental standards. This work presents the results of near field antenna measurements as a comparison and consequent validation of developments proposed in previous papers.

1. INTRODUCTION

With the increasing demand for communications services, specially for cellular networks, the transmission antennas tend to be installed close to people, *e.g*. when mounted over building roofs as in Fig 1, making important the verification of the electromagnetic field levels present in the near field region, particularly along the axis of maximum irradiation.

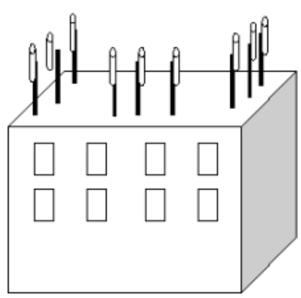

Figure 1. Example of antennas installed in urban areas.

Descriptions of the electromagnetic field behavior in the near field for apertures can be found at [1,2,3,4,5,6,7,8], in which the equations present input parameters different from those used by antenna suppliers, such as power and gain. Reference [8] introduces new equations for the electric field in the near and far field area, where antennas are approximated as apertures. This is summarized in section 2.

Section 3 presents the results of measurements performed by CPqD Research Center, in the near field of antennas used for mobile communications in the 800 MHz range, with a comparison to the equations proposed for the near and far field areas in Section 2. A brief description of the software developed for the verification of field levels of antennas is presented in Section 4.

2. NEAR AND FAR FIELD PROPAGATION

Let a transmitter radiate an output power P_t watts from an isotropic radiator. Assume that this isotropic radiator is placed in free space, a homogeneous, non-absorbing medium of dielectric constant unit. Suppose also that the receiver is situated at a distance *r* meters from the transmitter. The equation that relates the electric field and the power applied to the transmitter is, in V/m [9]

$$E_{rms}(r) = \frac{\sqrt{30 P_t g_t}}{r}, \tag{1}$$

where g_t is the gain of the antenna, given by

$$g_t = 10^{\frac{G_t}{10}}, \tag{2}$$

showing how many times the power applied to the isotropic transmitter must be increased to produce the same field as the given antenna, where G_t represents the characteristic gain of the antenna in dBi. This equation can be applied only in the far field region. Equation (1) is used in [8] to establish an association between the electric field and the power applied to apertures.

Thus, using (1) and the equations found in [2,3,6] for the electric field of apertures, reference [8] provides new formulations that can be applied for either the near or far field of some types of apertures. With the intention of comparing the results of measurements performed in panel antennas, to be showed in the next section, one can use the equation proposed for rectangular apertures along the direction of maximum propagation, given by Equation (3), where L_x and L_y ($L_x > L_y$) are the sides of the aperture and *C* and *S* are the Fresnel cosine and sine, respectively.

$$E_{rms}(r) = \frac{\lambda\sqrt{30 P_t g_t}}{2\left(L_x^2 + L_y^2\right)} \cdot \left[C^2\left(\frac{L_x}{2\sqrt{L_x^2 + L_y^2}}\right) + S^2\left(\frac{L_x}{2\sqrt{L_x^2 + L_y^2}}\right)\right]^{-\frac{1}{2}}$$

$$\cdot\left[C^2\left(\frac{L_y}{2\sqrt{L_x^2+L_y^2}}\right)+S^2\left(\frac{L_y}{2\sqrt{L_x^2+L_y^2}}\right)\right]^{-\frac{1}{2}}$$

$$\cdot\left[C^2\left(\frac{L_x}{\sqrt{2\lambda r}}\right)+S^2\left(\frac{L_x}{\sqrt{2\lambda r}}\right)\right]^{\frac{1}{2}}$$

$$\cdot\left[C^2\left(\frac{L_y}{\sqrt{2\lambda r}}\right)+S^2\left(\frac{L_y}{\sqrt{2\lambda r}}\right)\right]^{\frac{1}{2}} \quad (3)$$

3. THE MEASUREMENT SET AND THE RESULTS

The experimental verification of (3) through the measurement of commercial antennas was developed according to the scheme shown in Fig.2, at the CPqD laboratories, Campinas, Brazil. Table 1 describes the items used for the measurement system.

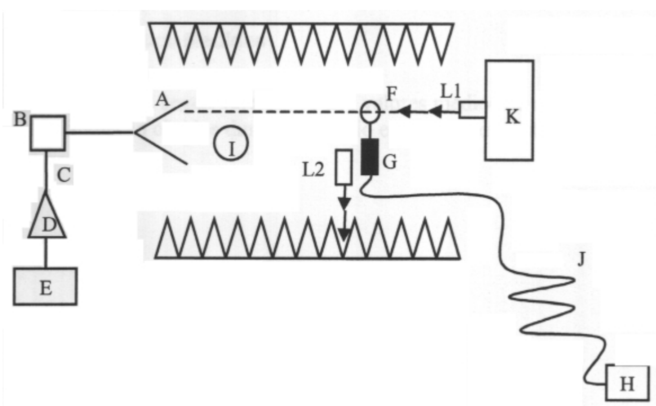

Figure 2. The set used for the measurements.

ITEM	DESCRIPTION	DETAIL
A	Antenna under test	See Table 2
B	Transition guide/cable	DIN 7/16 (m) / N (f)
C	Cables for TX and RX	Microwave Cable HP 85381-C
D	Signal amplifier	HP 83017A
E	Transmission system	HP 8340B
F	Antenna probe	Electric field probe WG (Wandel & Goltermann) E-Field Type 8.2 2244/90.21 G-0008 RS:0.984 Frequency: 100KHz ~ 3GHz
G	Radiation meter	EM Radiation Meter WG (Wandel & Goltermann) EMR-300 BN-2244/31 I-0046
H	Lap Top	Digital T530G
I	Anechoic Chamber	RANTEC 65393
J	Serial bus cable	Kit EMR-300
K	Scanner + Alignment base	Scientific Atlanta 5906
L1	Antenna axis alignment	Laser
L2	Distance signalizing	Laser

Table 1. Items of the apparatus.

The antennas under test are described in Table 2.

SUPPLIER	MODEL	GAIN (dBi)	Dimensions (cm)
Cell Wave	AP906513-1	15	99.5 x 26 x 12.5
EMS	FV651510NA2	16.8	243.8 x 30.5 x 17.8

Table 2. Antennas under test.

Regarding the results, a brief analysis of the accuracy of the measurement equipment, described in Table 3, is performed.

ITEM	DESCRIPTION	VALUE
G	Display resolution	0.01 V/m
F	Absolute error at 27.5V/m and 27.12MHz	± 1.0dB
F	Linearity referred to 27.5V/m and 27.12MHz	± 1.0dB (2.5~800V/m) ± 3.0dB (1~2.5V/m)
F	Frequency response	± 2.4dB (100MHz~3GHz)
F	Isotropy deviation	± 1.0 dB (f>1MHz)
F	Calibration Factor	0.98 (824 MHz) 0.99 (806 MHz)

Table 3. Accuracy of the equipments.

The probe has systematic errors that require some analysis: it shows a frequency response within ± 2,4dB of the nominal value, ± 1.0 for the isotropy deviation, and ± 1.0dB (2.5~800V/m) / ± 3.0dB (1~2.5V/m) for the linearity referred to 27.5V/m and 27.12MHz. Adding all errors yields an inaccuracy of ±4.4dB for levels above 2.5 V/m and ± 6.4dB for levels under 2.5V/m, which results in:

$$20\log\left(\frac{E_{meas}}{E}\right)=\pm 4.4 \quad (4)$$

for levels above 2.5 V/m and

$$20\log\left(\frac{E_{meas}}{E}\right)=\pm 6.4 \quad (5)$$

for levels under 2.5V/m. Finally, the final electric field is

$$\left[E^{-} = \frac{E_{meas}}{1.66}, E^{+} = \frac{E_{meas}}{0.6}\right]_{>2.5V/m}, \quad (6)$$

$$\left[E^{-} = \frac{E_{meas}}{2.09}, E^{+} = \frac{E_{meas}}{0.48}\right]_{<2.5V/m}. \quad (7)$$

Fig. 3 shows the measurement performed for the antenna model AP906513-1, both for the near and far field, where a power of 0.03162W has been applied, and the curve obtained from (3). It can be seen that the curve levels are within the values observed in (6) and (7).

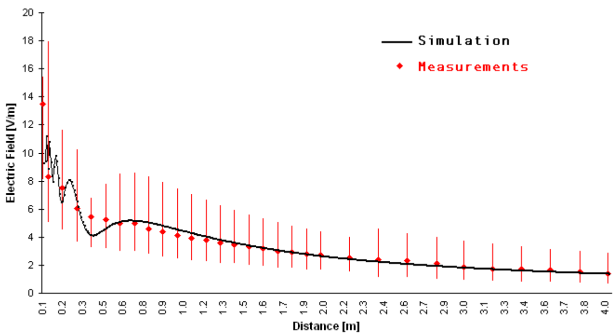

Figure 3. Measurement results of the antenna AP906513-1

4. SOFTWARE FOR SIMULATION

A software for prediction of the electric field behavior in the areas that are close and far from the antennas has been developed from the equations presented in [8] along with the results obtained in the measurements of the electric field, shown in the previous section.

The user has the option of choosing the type of aperture for the simulation of the antenna, as seen in Fig.4. The panel antenna is the default. The input parameters are: size of the antenna, radiation pattern, gain, applied power, frequency, and the distance considered in the analysis. Then, the user chooses the option "Matrix Generation", which generates a matrix that will contain the data to plot the curves and predict the electric field behavior.

As an output, the user has two options. One is the plotting of the electric field and power density for an input angle, according to the antenna pattern diagram, as seen in Fig.5.

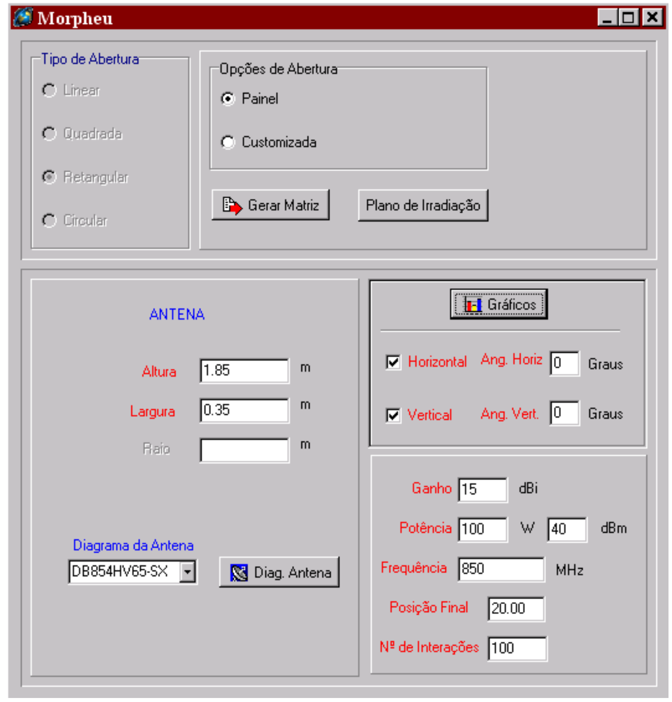

Figure 4. Software developed for electric field prediction.

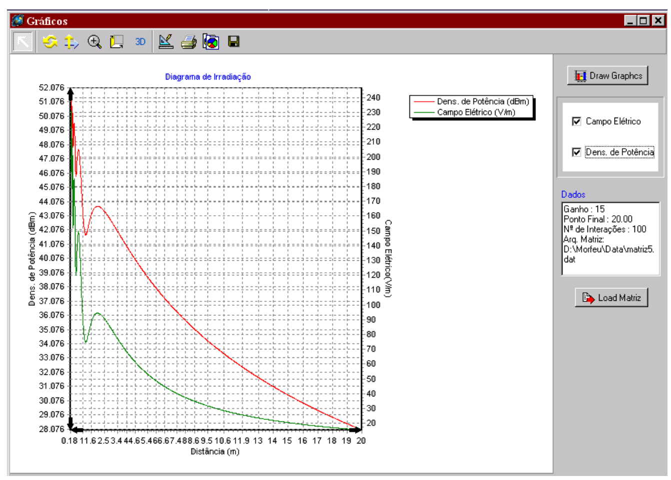

Figure 5. Plotting of the electric field and power density for an input angle.

The other option is to perform a prediction for the electrical field levels in the irradiation region of the chosen antenna, as shown in Fig.6.

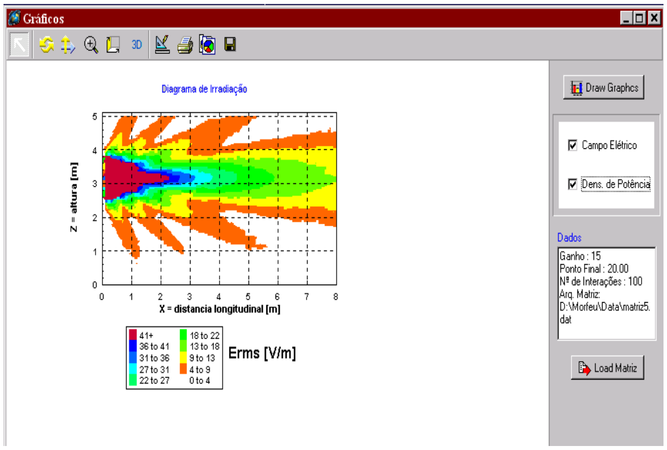

Figure 6. A prediction for the electrical field levels

This software is an important tool for the electric field levels analysis and the verification of the directives presented in [10].

5. SUMMARY

The measurements performed in the 800 MHz band for different antenna models has shown that (3) has an accurate result for the entire range of panel antennas with

$$\frac{L_y}{L_x} > 0.2 \qquad (8)$$

as observed in Fig.3. Otherwise, (3) presents a good accuracy only after a certain distance from the antenna, close to the lower limit of the Fresnel region, given by [11]

$$\sqrt[3]{\frac{\left(Lx^2+Ly^2\right)^{\frac{1}{2}}}{2\lambda}\,\frac{\left(Lx^2+Ly^2\right)^{\frac{1}{2}}}{2}}. \qquad (9)$$

For the far field, Equation (3) presented, as expected, the same result as Equation (1), making it useful for any region of the electromagnetic field.

The software presented in this article is in its beta version. It is still necessary a verification for different frequencies, *e.g.* the 1800 MHz band, and the measurement of other types of antennas to fully confirm its results. However, it is indeed a valuable tool to predict if the installation of antennas in crowded areas comply with the standards for electromagnetic compatibility.

6. REFERENCES

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