MEASUREMENT OF THE DISTRIBUTION OF ELECTROMAGNETIC FIELD FROM MULTISOURCES INSIDE A CAR.

Raquel A. A. Rodrigues [1], *Glauco Fontgalland* [2], *Raimundo C. S. Freire* [3]

[1] Department of Electrical Engineering, Federal University of Campina Grande (UFCG) - Campina Grande, PB, Brazil, raquel.rodrigues@ee.ufcg.edu.br
[2] Department of Electrical Engineering, Federal University of Campina Grande (UFCG) - Campina Grande, PB, Brazil, fontgalland@dee.ufcg.edu.br
[3] Department of Electrical Engineering, Federal University of Campina Grande (UFCG) - Campina Grande, PB, Brazil, freire@dee.ufcg.edu.br

***Abstract*— The goal of this paper is to plot the electromagnetic field behavior from multisources and calculate the density power inside a vehicle. It was done by measuring the electric field radiated by monopole antennas of λ/4, in frequency 2.045GHz. The Monopole antennas were positioned inside the vehicle to simulate the height of the mobile device in use by adults humans. The results show that the reflections of the microwave should be considered in risk assessments of EMF exposure in daily life.**

Keywords- Electromagnetic Field; Density Power; Multisource; Monopole antennas; Mobile phone.

I. INTRODUCTION

Given the growing use of mobile phones by population, has also grown the concerns of users, government authorities and the scientific community regarding the health risks that this technology can present. This concern is primarily motivated by the fact that, although known carcinogenic effects due to exposure to ionizing radiation and thermal effects, acute and short-lived due to exposure to non-ionizing radiation [1], there is still no agreement on non-thermal effects in the long run generated by non-ionizing radiation.

In 1988, published a study on the electric field distribution in a automobile body for an antenna system mounted inside the body performed by Masaoka Tanaka for the frequency range 3 to 5 GHz [6]. In 2006, Hondou has published a study on passive exposure to mobile phone in two rooms: in a container and an elevator to the frequency of 1.2 and 1.4 GHz [9]. In 2007, G. Anzaldi published a study by numerical computation of the electromagnetic field distribution inside a vehicle with radiation sources in the frequency of 835 MHz with the presence of human body [3].

Therefore, despite the numerous researches on this subject have yet to scientific uncertainties that motivate the development of new studies aiming to measure their exposure to electromagnetic fields (EMF) and investigate the possible health impacts.

The radiation emitted by mobile phones were classified as "possibly carcinogenic to humans" by the World Health Organization (WHO) on May 31 this is year. The agency lists the mobile phone use as a potential cause of cancer, the same category of lead, car engine exhaust and chloroform.

Inside the modern cars can be found various sources of non-ionizing electromagnetic waves such as mobile phones, iphones, bluetooth. Hence, in this closed space antennas behave as an arrangement of the reverberation occurring electromagnetic fields to form constructive and destructive combinations of fields, in addition to reflections due to the banks belonging to the car structure.

In this work, are reported the results of experimental measurement of electromagnetic field produced by monopole antennas of λ/4, used in mobile handsets, operating in the frequency of 2.045 GHz and also calculated the values of power density inside a car. In future work will be carried out numerical simulations to confirm the experimental results. Thus, this research aims to provide data to risk assessments of electromagnetic exposure, particularly in everyday situations and use of mass, because you can even avoid using the cell phone, but people can't avoid passive exposure to microwaves by the use of mobile for others.

II. MATERIAL AND METHODS

A. Electromagnetic Waves and Mechanisms of Interaction with the human body.

The electromagnetic waves used in mobile communications is the vehicle of energy transported through space in the form of electric and magnetic fields vary with time. Typical examples of electromagnetic waves include radio waves, TV signals, the radar beams and rays of light. All forms of EM waves share three main characteristics: they all travel at high speeds, to propagate, exhibit wave properties and they are radiated from a source without the need for a physical means of propagation [5].

With increasing frequency, electromagnetic wave energy becomes more concentrated, making it necessary to make a distinction between radio frequency waves that are in the range of non-ionizing radiation, and waves of higher frequencies, which are in the range of radiation ionizing.

The object of this paper is non-ionizing radiation in the range of radio frequencies used by mobile transceivers to transmit (in the far field region).

Electromagnetic waves when they interact with the human body, depending on the frequency and power, may produce some biological effect. This fact alone does not necessarily mean the existence of danger. A biological effect will become a security risk when a fault occurs in a person's health or their descendants [8].

The consequences of the mechanisms of interaction of non-ionizing electromagnetic waves with biological systems can be classified into two groups:

• Thermal effects: are caused by tissue heating as a result of absorption of part of the incident wave;

• Non-thermal Effects: are due to direct interaction of electromagnetic fieldsinduced in the body.

B. Technical Standards Adopted

The regulation adopted in Brazil by the National Telecommunications Agency - Anatel, resolution Nº 303 of July 2, 2002, for the assessment of human exposure to electromagnetic fields from radio, makes reference to the limits proposed by the International Commission for Protection Against Non-Ionizing Radiation - ICNIRP.

The exposure limits established in the regulations refer to occupational exposure and exposure of the general population CEMRF in the frequency range between 9 KHz and 300 GHz. As in this research study in the closed environment fits the scenario of exposure not controlled by the general population and the sources of EMF in the operating frequency of 2.045GHz, will be adopted as the threshold values for display only those presented in Table 1 [2].

TABLE 1 - LIMITS FOR EXPOSURE OF THE GENERAL PUBLIC IN A CEMRF WAVEBAND BETWEEN 2 GHz to 300 GHz (UNPERTURBED EFFECTIVE VALUES)

Frequency Range	Eletric Field E (V/M)	Magnetic Field M (A/M)	Equivalent Plane-wave Power Density S (W/m^2)
2 GHz to 300 GHz	61	0.16	10

C. Equipment Used

In the calibration procedures and measurement of the monopole antennas, measurement of losses in cables used in monopole antenna and receiver, measuring the impedance of the receiving antenna and power measurements inside the vehicle were used: a signal generator, Rohde & Schwarz 5M300 model coupled via coaxial cable (RG58 C / U of 1.45 m) at the base of each monopole antenna for SMA connector; an mesh analyzer Agilent model E5062A connected via coaxial cable (cable HFU2) to the receiving antenna log-periodic Rohde & Schwarz 12-144980 and an spectrum analyzer Agilent N1996A CSA, which was also connected to the receiving antenna.

D. EMF Sources

The Monopole antennas were modeled each by a metal rod of 37.5 mm (diameter 1.8 mm) and ground plane conductor compose of three rods of 25 mm separated 120° apart. In the next step we simulated the operation of the antenna with the software MS-CST.

The monopole antennas were positioned in vertical polarization, as well as the antenna measurement, a log periodic, polarizing the incident field to the maximum response of the antenna. Each monopole antenna was listed for identification, fed with power of 500 mW and individually calibrated and tested scattering parameters, standing wave ratio (SWR) and The Smith Chart, so that these could be considered approximately equal. We also measured the reception levels of monopole antennas and antenna measurement (log-periodic) for maximum 1.20m and minimum 81cm distances among those inside the car, these measurements were taken in the far field antenna measurement previously calculated.

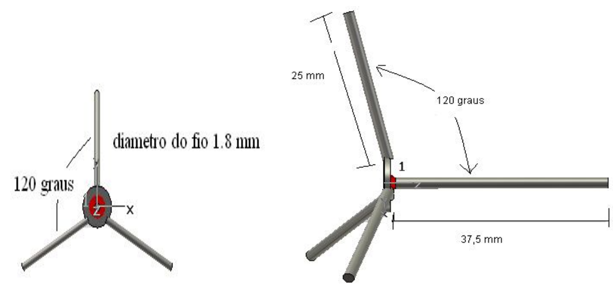
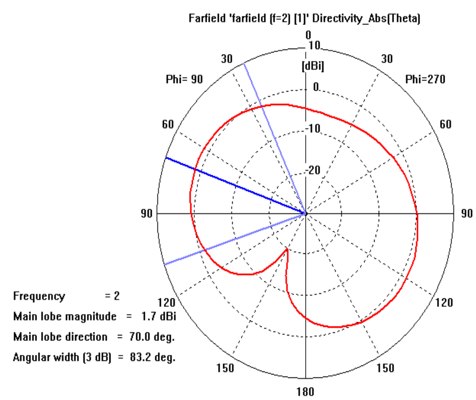


Fig. 1. Project monopole antenna for the frequency range from 1.8 to 2.1GHz: (a) top view and (b) side view.



(a)

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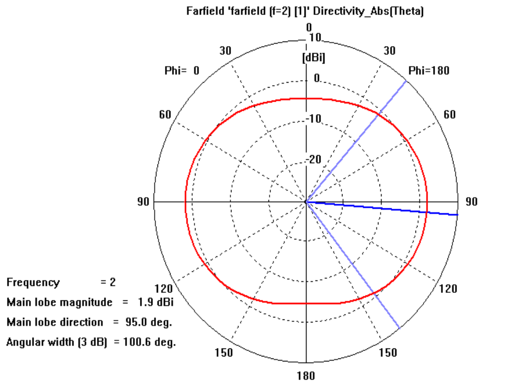

(b)

Fig 2. Diagrams irradiation 2D monopole antenna simulated in the computer software CST: (a) Vertical (b) Horizontal.

(a) (b)

Fig. 3- Diagrams 3D of radiation monopole antenna simulated in the software CST: (a) Vertical, (b) Horizontal

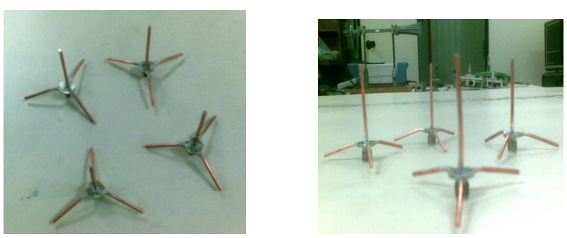

Fig 4- Photos of the monopole antennas built-in LEMA Laboratory of Applied Electromagnetics and Microwave-DEE / LEMA / UFCG.

E. The Far-field

The measures of this study were conducted in the region of the distant fields of antennas determined from the following conditions [7]:

$$r = \frac{2D^2}{\lambda}$$
$$r = 5D$$
$$r = 1,6\lambda \qquad (1)$$

Where: r = distance from the antenna to the far field [m]; D= dimension of the antenna elements [m], λ = wavelength in the operating frequency [m]. Substituting λ =0.15 and d = λ /4 = 0.0375m (at 2.045 GHz) comes to air = 24 cm.

F. Experiment Inside the Vehicle

The monopole antennas were positioned to simulate the height of the mobile device in use by an adult human being, one antenna on the front passenger seat and three on the back seat. We performed 16 measurements of power inside the vehicle (Fiat car/ model Uno Mille/2006) for the combinations of antennas in use or not. Then, it was calculated the distribution of electric field, magnetic field and power density taking into account parameters such as antenna factor and losses in the connecting cables.

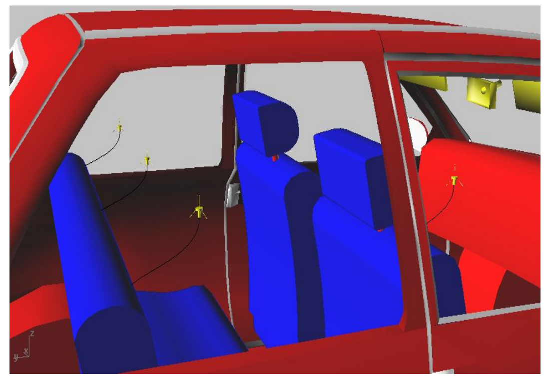

Fig. 5- Perspective within the Fiat car / model Uno Mille and positioning monopole antennas created in software Rhinoceros.

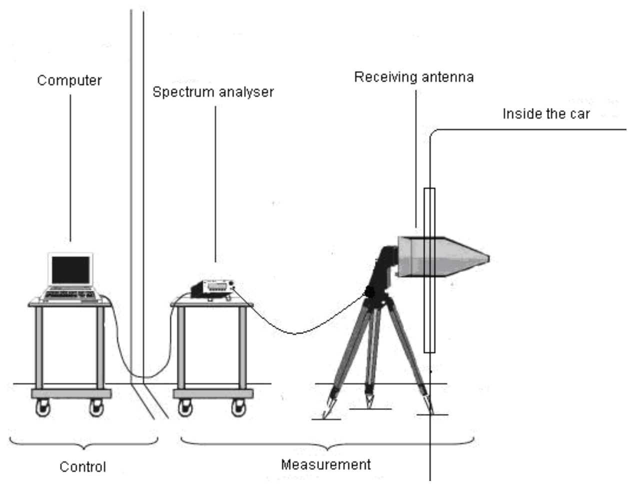

Fig. 6- Schematic layout of the receiving antenna, log periodic, and equipment for measuring the exterior of the car.

For the calculation level of electromagnetic radiation and equivalent plane-wave power density from each monopole and inside the vehicle should be considered the ohmic loss in the power cable used with the log-periodic antenna (2.54 dB) and input impedance of this antenna in the following expressions [4]:

$$P_{antenna} = 10^{-3} \text{ X } 10^{(P\ analyzer-\ P\ cable)} \qquad (2)$$

$$V_{antenna} = \sqrt{R_{antenna} \times P_{antenna}} \qquad (3)$$

$$E = V_{antenna} \times AF \quad (4)$$

$$H = E/377 \quad (5)$$

$$S = E^2/377 = H^2 X\ 377 \quad (6)$$

Where: $P_{antenna}$ = Power of the receiving antenna (W); $P_{analyzer}$= signal power measured with the analyzer (dBm); P_{cable}= ohmic loss in the cable (dB); $V_{antenna}$= Voltage at the terminals of the receiving antenna (V) ; $R_{antenna}$= 47Ω, input impedance of this antenna; E = electric field incident receiving antenna (V/m); AF = antenna factor of the receiving antenna (1/m); H = Magnetic Field incident (A/m) and value 377 is the impedance of free space in ohms; S= equivalent plane-wave power density (W/m^2).

III. RESULTS

The values of input impedance of monopole antennas in the frequency of 2.045 GHz measured with the analyser grids are shown in table 2. The figures 5 and 6 present the scattering parameters S11 and S21 measured with the analyzer grids for monopole antennas on the operating frequency of 2.045 GHz fabricated in the laboratory. You can see that the four monopole antennas resonate satisfactorily in the frequency of 2.045 GHz by S11 of the graphics and also the responses of S21, which at the same frequency, the antennas have a satisfactory level for the transmit power.

The tables 3 and 4 show the levels of approval for the monopole antenna operating frequency of 2.045 GHz, calculated at the terminals of the receiving antenna and the levels of electric, magnetic fields and equivalent plane-wave power density calculated from each of these two distances for monopole antenna reception inside the vehicle, 81cm and 1.20m respectively. The found values of the electromagnetic magnitudes in question were very similar in all four antennas.

The table 5 shows the numbers assigned to the various status settings of the antennas inside the vehicle during the measurements. The table 6 shows for each case the configuration of the antennas, the measured power with the analyzer and the calculated values of electric field, magnetic field and equivalent plane-wave power density.

TABLE 2- VALUES OF THE INPUT IMPEDANCE OF MONOPOLE IN FREQUENCY OF 2.045 GHz.

	Antenna 1	Antenna 2	Antenna 3	Antenna 4
Input Impedance	50 Ω	50 Ω	50 Ω	50 Ω

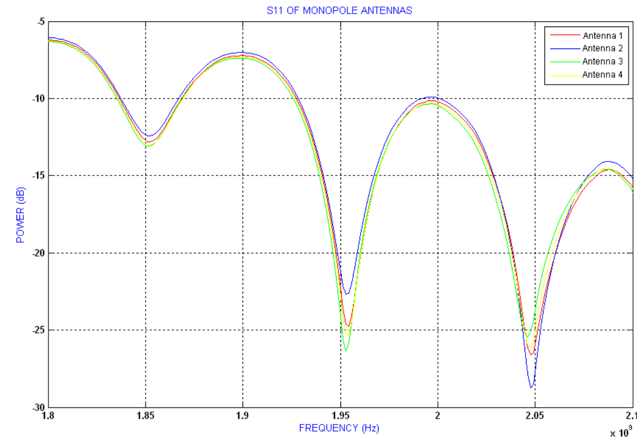

Fig. 7- Scattering parameter S11 of the four monopole antennas.

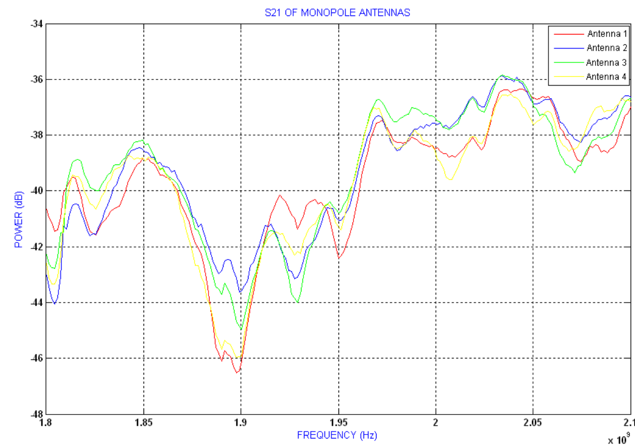

Fig. 8- Scattering parameter S21 of the four monopole antennas.

TABLE 3 – POWER, EMF AND POWER DENSITY FOR MONOPOLE OPERATING 2.045 GHZ: 81 CM DISTANCE MEASURING ANTENNA.

Antennas	Reception level at the terminals of log-periodic $P_{antenna}$ (μW)	Electric field from each monopole E (V/m)	Magnetic field from each monopole M (mA/m)	Equivalent plane-wave power density S (mW/m^2)
1	103.27	1.93	5.12	9.88
2	108.89	1.98	5.25	10.40
3	108.64	1.98	5.25	10.40
4	105.92	1.95	5.17	10.10

TABLE 4 – POWER, EMF AND POWER DENSITY FOR MONOPOLE OPERATING 2.045 GHZ: 1,20 M DISTANCE MEASURING ANTENNA.

Antennas	Reception level at the terminals of log-periodic $P_{antenna}$ (μW)	Electric field from each monopole E (V/m)	Magnetic field from each monopole M (mA/m)	Equivalent plane-wave power density S (mW/m^2)
1	45.92	1.29	3.41	4.41
2	46.99	1.30	3.45	4.48
3	38.81	1.18	3.14	3.69
4	43.05	1.25	3.30	2.89

TABLE 5 - NUMBER ASSIGNED TO THE VARIOUS SETTINGS STATUS OF ANTENNAS INSIDE THE CAR.

Configuration of the antennas inside the car.	Status of the antennas			
	Antenna 1	Antenna 2	Antenna 3	Antenna 4
1	Inactive	Inactive	Inactive	Inactive
2	Inactive	Inactive	Inactive	Active
3	Inactive	Inactive	Active	Inactive
4	Inactive	Inactive	Active	Active
5	Inactive	Active	Inactive	Inactive
6	Inactive	Active	Inactive	Active
7	Inactive	Active	Active	Inactive
8	Inactive	Active	Active	Active
9	Active	Inactive	Inactive	Inactive
10	Active	Inactive	Inactive	Active
11	Active	Inactive	Active	Inactive
12	Active	Inactive	Active	Active
13	Active	Active	Inactive	Inactive
14	Active	Active	Inactive	Active
15	Active	Active	Active	Inactive
16	Active	Active	Active	Active

TABLE 6 - MEASURED VALUES WITH ANALYZER AND CALCULATED VALUES OF ELECTRIC FIELD, MAGNETIC FIELD AND EQUIVALENT PLANE-WAVE POWER DENSITY INSIDE THE CAR.

Configuration of the antennas	**Reception level measured $P_{antenna}$ (μW)**	**Resultant eletric field E (V/m)**	**Resultant magnetic field M (mA/m)**	**Equivalent plane-wave power density S (mW/m²)**
1	0.047	0.041	0.10	0.0045
2	467.7	4.1	10.89	44.59
3	97.05	1.87	4.96	9.28
4	220.29	2.82	7.48	21.09
5	57.94	1.44	3.83	5.50
6	404.58	3.82	10.13	38.71
7	3.19	0.34	0.9	0.31
8	299.23	3.28	3.69	28.54
9	53.58	1.39	3.69	5.12
10	522.4	4.34	11.51	49.96
11	28.77	1.02	2.70	2.76
12	208.93	2.74	7.28	19.91
13	186.21	2.59	6.87	17.79
14	258.23	3.05	8.09	24.68
15	41.3	1.22	3.24	3.95
16	644.17	4.82	8.09	61.62

TABLE 7 - MEASURED VALUES WITH ANALYZER AND CALCULATED VALUES OF ELECTRIC FIELD, MAGNETIC FIELD AND EQUIVALENT PLANE-WAVE POWER DENSITY OUT OF THE CAR.

Antennas configuration #	**Measured** $P_{antenna}$ **(μW)**	**Calculated** ***E (V/m)***	**Calculated** ***H (mA/m)***	**Equivalent plane-wave** ***S (mW/m²)***
1	7.38	0.52	1.38	0.72
2	25.82	0.96	2.55	2.44
3	269.77	3.12	8.28	25.82
4	422.67	3.90	10.34	40.34
5	99.08	1.89	5.01	9.47
6	116.41	2.05	5.44	11.15
7	93.97	1.84	4.88	8.98
8	234.96	2.91	7.72	22.46
9	56.49	1.42	3.77	5.35
10	123.03	2.11	5.60	11.81
11	412.09	3.85	10.21	39.31
12	529.66	4.37	11.59	50.65
13	145.21	2.29	6.07	13.91
14	272.27	3.13	8.30	25.99
15	338.06	3.49	9.26	32.31
16	588.84	4.61	12.23	56.37

IV. CONCLUSION

Comparing the calculated values of the incident electric and magnetic fields inside the car with the exposure limits established by Anatel for the general population to CEMRF in the range of 2 GHz to 300 GHz, whereas the values of fields are not disturbed, ie values measured in the absence of exposed individuals and objects without introducing absorbers or reflectors CEMRF during the measurement process [2], we conclude that the calculated values do not exceed the values established by the regulation. However, it is known that public exposure to mobile phones can be enhanced by the reflection of microwaves in closed environments [9], thus motivating the continued study of the effect of reflection in these environments for the assessment of risk to health.

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