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EFFECTS OF ELECTROMAGNETIC FIELD OVER A HUMAN BODY, SAR SIMULATION WITH AND WITHOUT NANOTEXTILE IN THE FREQUENCY RANGE 0.9—1.8 GHZ

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Within only the last decade, usage of mobile phones and many other electronic devices with high speed wireless RF connection is rapidly increasing. Modern life requires reliable, quick and high-quality information connections, which explains the widely spreading craze for electronic mobile devices of various types. The vast technological advances we are witnessing in electronics, electro-optics, and computer science have profoundly affected our everyday lives.

Meanwhile, safety concerns regarding the biological effects of electromagnetic (EM) radiation have been raised, in particular at a low level of exposure which we everyday experience. A variety of waves and signals have to be considered such as different sine waves, digital signals used in radio, television, mobile phone systems and other information transfer systems. The field around us has become rather complicated and the "air space is getting more and more dense with RF. The establishing of safety recommendations, law norms and rules augmented by adequate measurements is very important and requires quite an expertise.

But as many scientific researches suggest, what we are currently witnessing is very likely to generate a great public danger and a bad influence over the human body. There are many health organisations warning the public for possible development of cancer, mental and physical disorders etc [7, 8]. These suggestions are quite serious and should not be neglected by the official bodies and the test laboratories.

In the following work, the effects of electromagnetic field over a virtual model of a human head have been simulated in the frequency range from 900 MHz to 1800 MHz (commonly created in the real life by mobile GSM system) with the help of the program MEFiSTo 2D Classic [1]. The created virtual models using the 2D simulation&computation software proved that the use of new high tech nanotextile materials for shielding layers around the human body can reduce the effects of EM fields dramatically if chosen properly according to the area of application.

K e y w o r d s: specific absorption rate, SAR testing

1 INTRODUCTION

The problems that occur with EM fields leads to the must-do need of testing the devices' level of RF energy with which they "pollute the environment around them. And here comes the term SAR (specific absorption rate) which is very important to be distinguished and paid attention by customers when buying electronic devices [3, 4].

So what is SAR testing? Specific Absorption Rate (SAR) testing is the radiofrequency (RF) dosimetry quantification of the magnitude and distribution of absorbed electromagnetic energy within biological objects that are exposed to RF fields. In other words this means SAR is a measure of the rate at which energy is absorbed by the body when exposed to a radio frequency (RF) electromagnetic field. SAR is usually averaged either over the whole body, or over a small sample volume (typically 1 g or 10 g of tissue) [2, 9]. In the case of our research only partial SAR levels are calculated. SAR can be calculated as

$$\mathrm{SAR} = \frac{\sigma |E|^2}{\rho} \tag{1}$$

where
$\sigma =$ conductivity of the tissue (S/m);
$\rho =$ mass density of the tissue (kg/m^3);
$E =$ rms electric field strength (V/m).

Fig. 1. Phantom model for SAR testing and determining radiation levels [10, 12]

The levels of absorbed energy are expressed as watts per kilogram (W/kg) for cell phone verification by the

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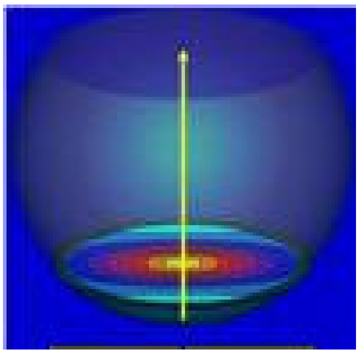

Fig. 2. Spherical phantom [12]

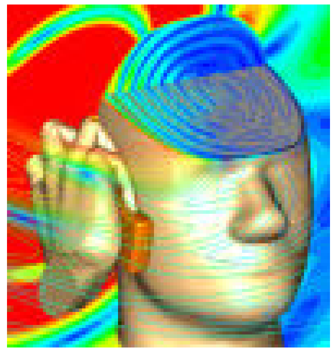

Fig. 3. Complexed phantom [12]

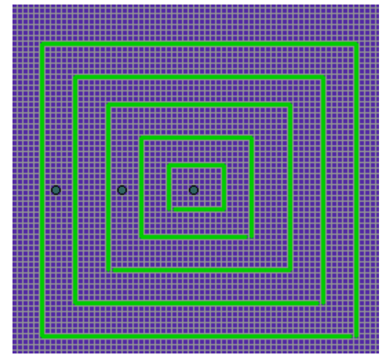

Fig. 4. A snapshot view of the used model of a head from MEFiSTo 2D Classic [1]

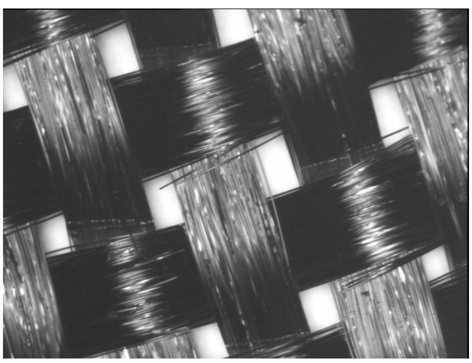

Fig. 5. Zoomed view of the textile's conductive carbon fibers [5]

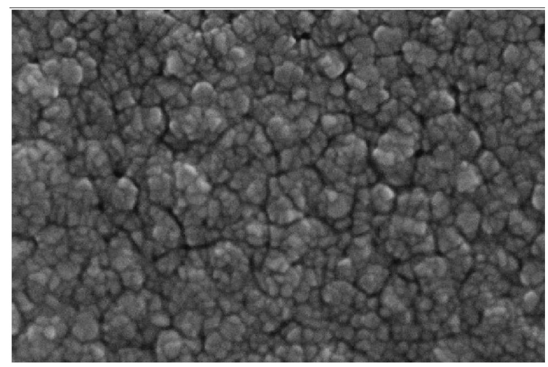

Fig. 6. SEM image of a rectangular sheet textile, layer thickness 1.2 microns, partictles' size up to 50 nm (Reference: IOM Leipzig)

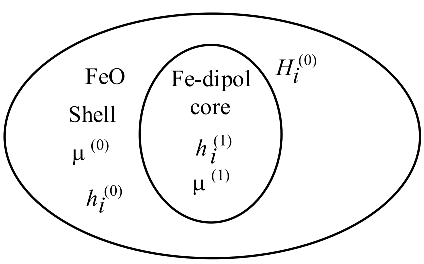

Fig. 7. Construction of a magnetic nanoparticle with magnetic fields acting [5], $h_i^{(1)}$ – dynamic magnetic field, $H_z^{(0)}$ – static magnetic field, $\mu^{(1)}$ – internal permeability, $\mu^{(0)}$ – external permeability

official bodies. International regulatory bodies are requiring SAR evaluations for most portable and mobile wireless technologies [6, 13]. Parameters that can affect SAR include:

- Types of radio service (cellular, PCS, LMR, WLAN, *etc*),
- Types of modulations (CDMA, GMSK, TDMA, AMPS, *etc*),
- Physical orientation to person (held-to-ear, held-to-face, belt-clip, lap-held, *etc*),
- RF power level (in Watts or mW),
- Changes to transmitter, antenna (extracted/retracted) or accessories (clips, batteries, *etc*).

The FCC classifies a wide range of standalone independently-operated portable transmitters as being potential candidates for SAR testing. Laptop computers, for example, may require SAR testing. Handsets, pagers, and other devices that are worn on a belt can also require SAR testing. When portable transmitter antennas and radiating structures are less than 20 cm from persons, except extremities (hands, wrist, feet and ankles), and depending on the devices frequency and threshold levels, SAR testing may be required [10–14].

A cell phone's SAR, or its Specific Absorption Rate, is a measure of the amount of radio frequency (RF) energy absorbed by the body when using the handset. All cell phones emit RF energy and the SAR varies by handset model. For a phone to receive *FCC certification* and be sold in the United States, its maximum SAR level must be less than 1.6 watts per kilogram. In Europe, the level is capped at 2 watts per kilogram, while Canada allows a maximum of 1.6 watts per kilogram [2, 13]

2 THEORY FOR THE SIMULATION SYSTEMS

There are two main methods to do SAR testing: experimental measurements (with dummies and phantoms of the human body) and simulations with RF FDTD computation software (modelling virtual phantoms of the human body). Both methods try to represent as realistic as possible the properties of the different kinds of tissues in the human body [11, 14].

Due to the fact that real measurement in true biological objects typically can not be carried out, SAR testing is commonly carried out using a standardized phantom model of a human body (Fig. 1). It is the most realistic way of representing the conditions which occur in real life [4, 12].

FTDT (Finite Difference Time Domain) computations are also a very good way of visualizing the magnetic radiation effects using software simulations. It has the advantage of being less expensive, quicker and more flexible in addition to the fact it also can show us visually the RF picture around the phantom [16]. The weak point here is that the virtual measurement in the simulation very much depend on the correct way of setting the simulation by the computer operator. Representing the properties of the materials in a natural and true way is also very hard to do with software. There are many unknown values and still unstudied facts about the human body which still have to be discovered. In Figs. 2, 3 are shown examples of usual simulation phantoms for SAR measurement.

In the case of our object of work presented in the article, SAR measurement using the simulation program MEFiSTo 2D Classic is presented in the current work [1]. A simplified square phantom, which is allowed by the capabilities of this simple program, is used for the needs of our computations.

3 DESCRIPTION OF THE SIMULATION TESTS, USED MATERIALS AND MODEL

Four cases are examined to evaluate the effect of high frequency electromagnetic field on a virtual model of a human head – the so called "phantom. In the cases examining the shield effect two different types of absorption materials are used in the simulation.

In the first case there is no shielding material used for protection of the phantom, in the other three cases there is simulated the usage of nanoferrite textile, carbon fiber textile and a combined shielding of both mentioned materials. The values for the resistivity of the used material are the following: Nanoferrite textile: $200\,\mathrm{M\Omega}$; Carbon fiber textile: $1.6\times10^{-3}\Omega$ [5]. The main point of the examination is to evaluate the effectiveness in the use of different shielding nano textiles (Figs. 4 ,5).

The material used is a piece of textile and adopted as the target prototype of clothing (sweaters). This textile equivalent of the microscopic image is shown in Fig. 5. On the contrary of the conventional materials such as ESD fabrics, these fabrics are composed from conventional carbon fibers [5].

The other kind of effective material are fabrics containing nanoparticles with a core of iron and a shell of oxidized iron is presented in Figs. 6, 7. Both materials have different magnetization of the nanoparticles.

The simulation area created with the 2D software, whose dielectric constant in our case is chosen to be 1, consists of a 241×139 cells mesh. The frequencies put under simulation tests are in the frequency range from 0.9 to 1.8 GHz.

In the process of simulation for all different cases, a multilayer square model of human head (phantom) was the object of computation and observation. It consist of one layer skin with resistivity value $1\,\mathrm{k\Omega}$, three layers of muscle&fat tissue with resistivity value $100\,\Omega$ for each separate layer and a "shell with resistivity value $12.3\,\mathrm{k\Omega}$ representing the human skull [8, 17].

The capabilities of MEFiSTo 2D Classic allow us to place up to three measuring probes to estimate the amount of RF radiation in the object of research. In our case, probe #1 is situated bellow the skin layer, probe #2 is placed bellow the 2nd muscle layer and probe #3 is situated inside the phantoms skull in the middle of the brain tissue. Representing objectively and realistically the properties of the actual human tissues is a very difficult and complicated task, we may just guess and simulate them. Because placing probes inside a real living human being is practically not possible, for the aims of SAR testing these kind of virtual models are used.

The virtual model or also called phantom put under test in our case gives us a general idea and relatively objective result for evaluation of the SAR.

Results from the different cases simulated are presented in graphs and images taken directly from the software product MEFiSTo 2D Classic. They are presented in the next pages of this work.

4 SIMULATION RESULTS

The values calculated for the levels of SAR have been normalised [17]

$$\mathrm{SAR_{norm}} = \mathrm{SAR_{sim}}/\mathrm{SAR_{max}}\,. \tag{2}$$

4.1 Basic case 1 without used shielding over the phantom

In this case the virtual model of a human head, the so called "phantom, is directly exposed to the influence of EM field created by the source visible in the left of Fig 8. This is the actual basic model used for comparison with other cases using shielding materials. The work cell mesh environment of MEFiSTo 2D is visible and the simulation area in all 4 cases consist of 241×139 cells mesh. The simulation data from the probes is presented in a graphical manner.

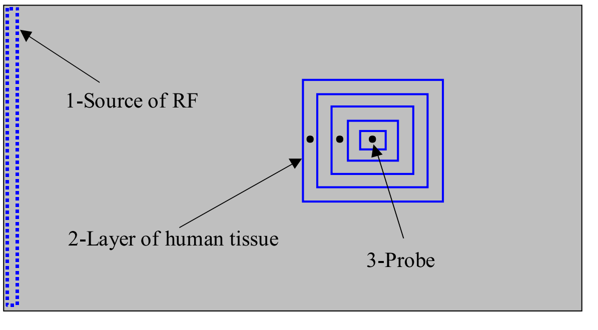

Fig. 8. View of the simulation area in case 1 – no shielding [1]

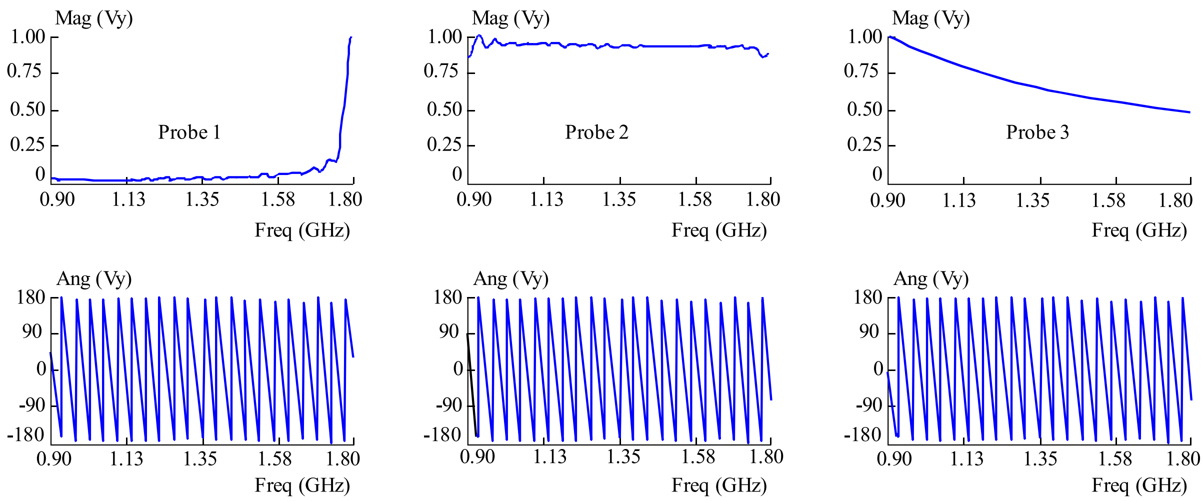

Fig. 9. Results for case 1 without shielding in graphs after the simulation [1]

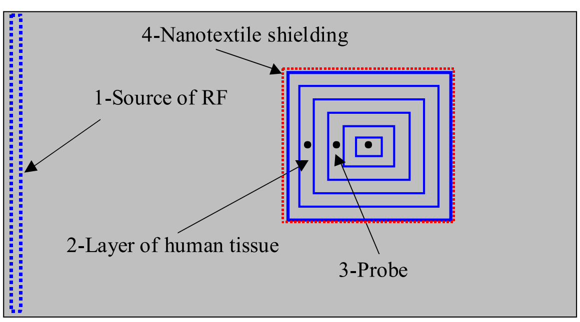

Fig. 10. View of the simulation area in the cases with shielding materials (enclosed shielding around the head) [1]

Simulation data for the case without shielding materials from the probes placed in the human head model (phantom) are in Fig 9.

4.2 Other case with use of nanoferrite and carbon fiber textiles

In comparison to the basic case (Fig. 10), here 3 other cases are presenting the use of shielding material over the model of a human head, the so called "phantom". Simulation data for the cases with shielding material from the probes placed in the human head model (phantom) are in Figs. 11–13.

5 CONCLUSION OF THE SIMULATION RESULTS

Results from the simulation tests are presented in diagrams (Fig. 14–17). The values from the simulation have an index character.

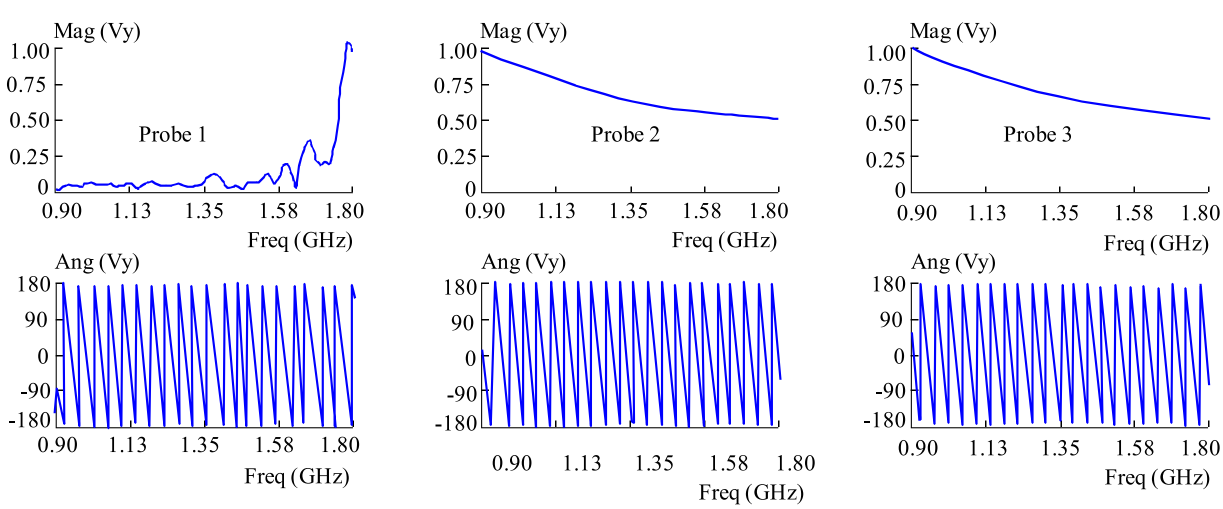

Fig. 11. Results for case 2 with nanoferrite textile shielding in graphs after the simulation [1]

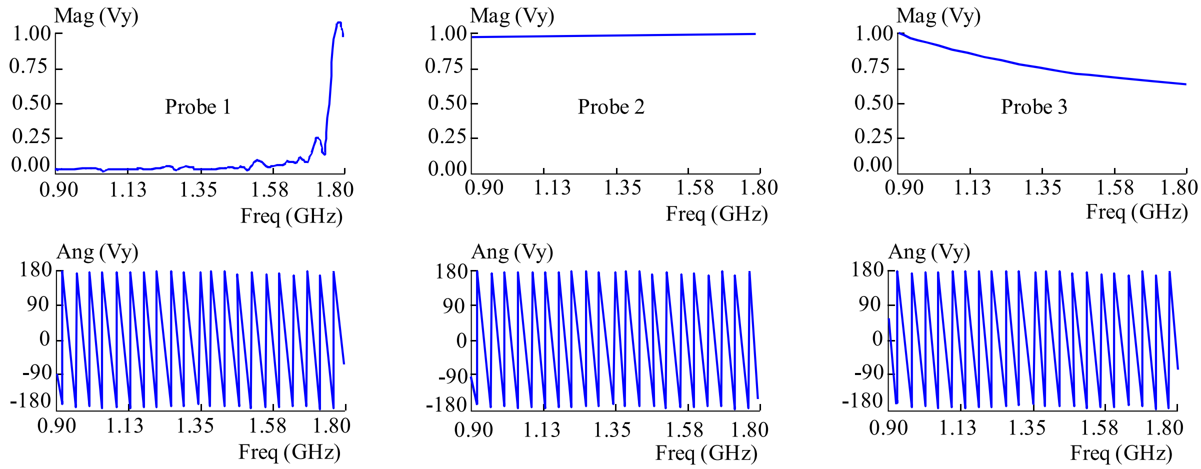

Fig. 12. Results for case 3 with carbon fiber textile shielding after the simulation [1]

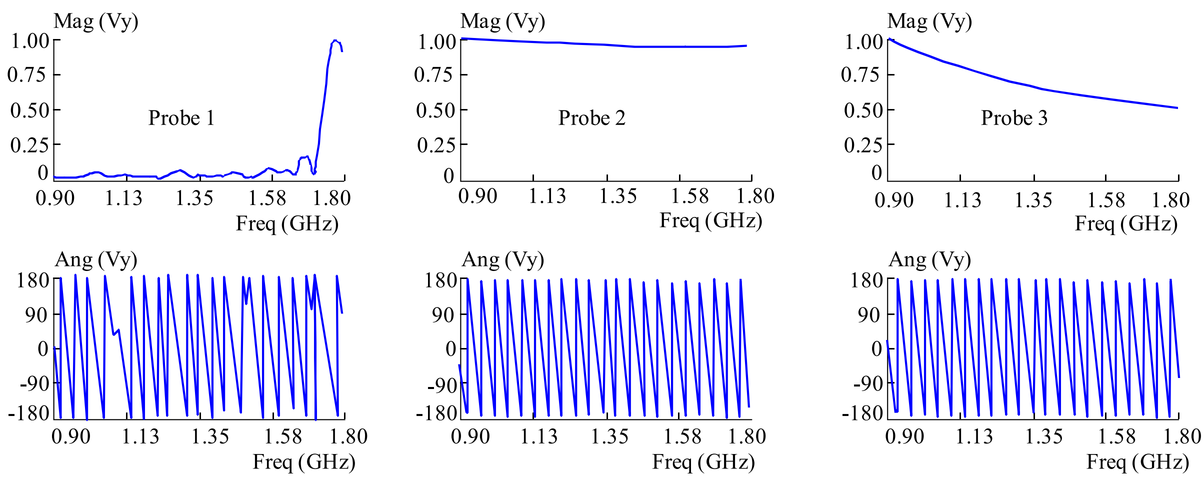

Fig. 13. Results for case 4 with both textile materials in graphs after the simulation [1]

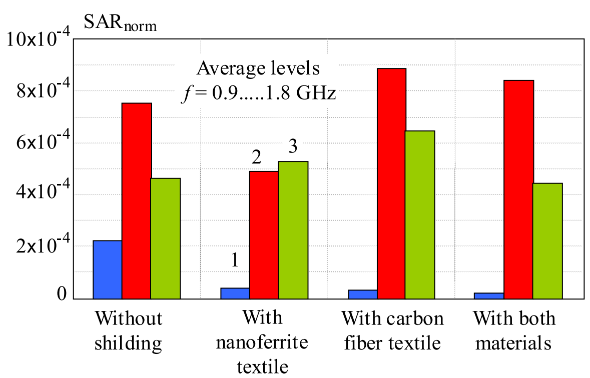

Fig. 14. Average levels of SAR_{norm} in frequency range $f = 0.9$ to 1.8 GHz: 1 probe under the skin, 2 probe under the muscle tissue, 3 probe inside the brain

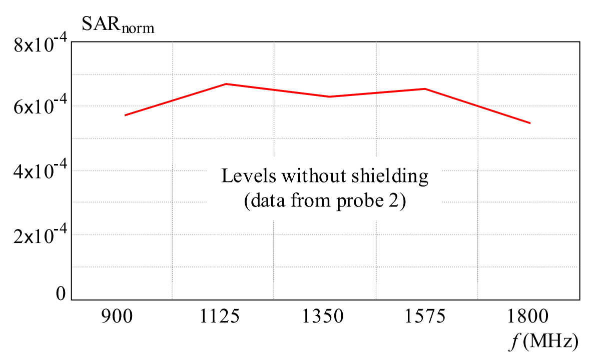

Fig. 15. Levels of SAR_{norm} in frequency range $f = 0.9$ to 1.8 GHz without shielding

After the simulation, the results from probe 1 are showing that the average SAR level with all kinds of shielding materials is $\geq 400\,\%$ lower then in the case without shielding (in the case with both shielding materials the reduction is > 300 times in the strength of the field).

Some reduction is noticed in probe 2 in the case of the usage of nanoferrite textile (around 30 %).

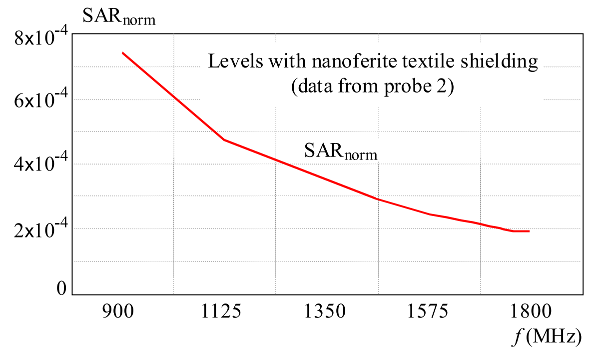

Fig. 16. Levels of SAR$_{norm}$ in frequency range $f = 0.9$ to 1.8 GHz with nanoferrite textile

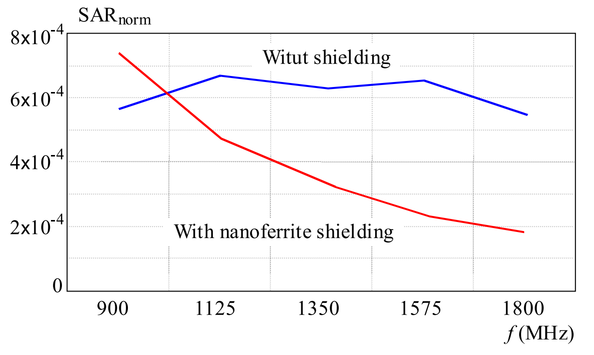

Fig. 17. Levels of SAR$_{norm}$ in frequency range $f = 0.9$ to 1.8 GHz with nanoferrite textile

Reduction of the SAR levels in the brain tissue is best noticed in the case of usage of both materials, as results from probe 3 show us (just around 10 %). A combined use of textiles with the right properties provide great possibilities for reduction of the RF effects over the human body.

Table 1. Calculation of SAR$_{norm}$ using formulae (1),(2); 1 – probe under the skin, 2 – probe under the muscle tissue, 3 – probe inside the brain

	Simulation field data			
	Without shielding	With nanoferrite textile	With carbon fiber textile	With both materials
1	22.41×10^{-6}	3.27×10^{-6}	2.96×10^{-6}	0.74×10^{-6}
2	75.00×10^{-6}	4.85×10^{-6}	88.93×10^{-6}	83.57×10^{-6}
3	46.33×10^{-6}	52.81×10^{-6}	64.56×10^{-6}	44.26×10^{-6}

The practical implementation of shielding materials is to achieve good results in a real life environment and is strongly recommended especially in environments with high levels of RF energy (electrical substations, hospitals, electronic factories etc). A great scientific relief is that some present and future developments in the nano technology are very likely to help us deal with the danger of electromagnetic fields.

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