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SHIELDING EFFECTIVENESS OF SOME CONDUCTIVE TEXTILES AND THEIR CAPABILITY TO REDUCE THE MOBILE PHONES RADIATION

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***Abstract**: An analysis of the shielding effectiveness by the method of dual transversal electromagnetic cell is proposed for a set of conductive materials of the type wire-inserted textiles. Based on the experimental results, some of the materials are further on used to test their capability to effectively reduce the specific absorption rate of energy deposition in the head due to mobile phone, when they are covering the surface of the handset. It is demonstrated that both reducing and increasing the radiation that penetrates the head may appear, and this depends on both the material structure, its position and orientation relative to the device and to the frequency band the phone is emitting.*

Keywords: electromagnetic shielding, DTEM cell, SAR, radiofrequency dosimetry, radiation protection

1. Introduction

Mobile phones radiation, denoted generally by the specific absorption rate (SAR) of non-ionizing energy deposition in the head, was classified by the World Health Organization's International Agency for Research on Cancer as 'possibly carcinogenic to humans' in May 2011.

Even before SAR measurement standardization, researchers were interested in developing methods and materials to offer the user a better protection to the handset emitted radiation.

Immediately after the year 2000 a series of shields - particularly near the earpiece of the phone, conductive meshed-materials, conductive fabrics, conductive foams, wire-mesh screens, multi-layer designs have entered the market, but without being scientifically and systematically characterized [1]. SAR reduction of mobile phone handsets was an important objective but no quantification of the shielding effectiveness had been carried out at that time.

In 2003, in a first article [1], six commercially available products and six shielding materials were characterized against two mobile phone models. The results showed that a SAR reduction could

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be obtained in a quota of maximum 10% and that shielding effectiveness was dependent on the position of the material relative to the phone and on the handset type (antenna). Later on, the same group published a second paper in 2005 [2], in which they analyzed SAR reduction effectiveness by using a conductive material (aluminum) attached on four models of GSM900 handsets – 2nd generation (2G). A pre-compliance SAR measurement system was used while changing the position of the material relative to the handset surface was the variable of the test. The authors concluded that a SAR reduction of as high as 63% could be achieved in one case, while there also appeared cases when SAR was increased by the material's presence, depending on its location in relation to the phone. The SAR distribution was also investigated, with and without the shielding metal. A new approach was published later in 2005, when reducing SAR was proposed by using a magnetic material based on the idea that magnetic near-field had the major contribution to SAR value [3]. The ferrite sheet conducted to a reduction of the spatial peak SAR of 13%. Authors of [4] studied in 2008 the effect of nickel–zinc spinel ferrite shields of various shapes and sizes and concluded that a reduction factor of SAR of a maximum 52% could be obtained. In 2010 the use of resistive sheets was proposed for shielding [5], while both numerically and experimentally was demonstrated that a peak SAR reduction of over 60% was possible. Later on, the same year, a retrospective about the subject of shielding used for mobile phone radiation attenuation was also published [6].

SAR reduction in a slotted PIFA antenna mobile handset working in dual band was analyzed in 2012 by simulation only [7] with the presence of a metal sheet for screening. A peak SAR reduction of 10-12% was obtained.

In 2014 a metamaterial was proposed for shielding purposes of the phone radiation [8], and also ferrite shields were tested [9], [10]. Both simulation and measurements were provided and the experiments made use of the COMOSAR system that will be used in present experimental approach as well. By such approach a more refined analysis of shielding possibilities and effects were available in specific cases.

Some commercial shielding products were also investigated in 2014 [11] for the 3rd generation of mobile phones (3G) by using a specialized SAR measurements system. The reported results underlined either shielding capabilities, with efficiencies of almost 60%, but also amplification capabilities, with a SAR increase of 11%. Once more it was proved that a strong dependence exists between SAR factor reduction (or enlargement) and the position or the dimension of the shield.

Under such circumstances, it became interesting to develop our own procedure enabling original testing of shielding materials on the market. Therefore, present experimental approach aimed at applying preliminary experimental checking of the SAR reduction capabilities of two knitted fabrics containing copper (Cu) or silver (Ag) yarns, fabrics that had no previous characterization regarding shielding effectiveness (SE).

In a first stage we addressed the problem of shielding effectiveness determination of the materials, by using a dual transversal electromagnetic (DTEM) cell method [12], [13]. In the second stage, SAR measurements of mobile phone were made, without and with conductive textile materials covering the face of the handset. The standardized SAR measurement procedure recommended in [14] was applied during the use of COMOSAR dosimetric system existent in the Electromagnetic Compatibility Laboratory from Prejmer, Romania.

The SAR tests were made on a mobile phone model Nokia C5 communicating wirelessly with the base station simulator which provided

alternatively both communication standards: second and third generation (2G and 3G), respectively.

Promising results were obtained during tests, indicating that the procedure may be further applied for developing shielding effectiveness measurements by our group.

2. Methodology applied for determination of SE and SAR reduction in sample sheets of conductive textiles

Shielding effectiveness of planar sheets of material was measured by a DTEM cell from TESEO, Italy. We followed the methodology explained in [12] and [13]. The planar thin (1-2mm) sheets of materials, 10x10cm dimensions, were inserted one by one in the DTEM cell and covered the rectangular slot, as recommended in [14].

At two ports of the DTEM cell a spectrum analyzer with tracking generator model FSH3 from Rohde&Schwarz was connected: at the input port testing signals covering the range 500MHz-1GHz were provided, at an incident power level of 10dBm, while at the output port of the DTEM cell, the transmitted signal was captured and displayed on the analyzer which was set in channel power mode. At the other two ports of the DTEM cell, 50 ohm impedances were mounted. The set-up of the SE measurement stand is presented in Figure 1.

The settings of the spectrum analyzer, used in channel power mode, were: resolution bandwidth RBW=100Hz, video bandwidth VBW=1kHz, sweep time SWT=1s, Span=4kHz, channel bandwidth Ch Bw =2kHz. Measurements of SE were made in the range with a step of 10MHz.

After SE characterization of the textile conductive samples, just two of them were extracted for further tests in the SAR laboratory. They were used to cover the surface of the phone in contact to the human phantom cheek, in order to shield the radiation coming to the head.

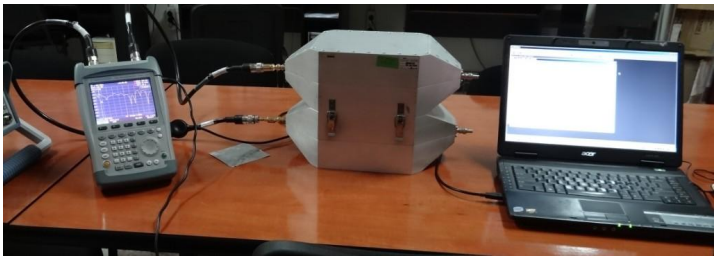


Figure 1: DTEM cell connected to the spectrum analyzer equipped with tracking generator for shielding effectiveness measurements of rectangular thin sheets of materials

The preparation of the human phantom along with settings of the base station simulator and positioning of the mobile phone in cheek position as in standard [15] are described separately, in [16]. SAR determination was made on a phone model Nokia C5 set in 2G (897MHz) and then in 3G (1950MHz) communication standard. Two different positions of each shielding material were provided for each measurement case (rotated one to another with 90 degrees), while the spatial maximum average SAR (SAR_{avg}) and the peak SAR (SAR_{peak}) were measured inside the liquid filled phantom head. Comparisons of SAR values obtained when no material and with the presence of material on the phone surface, followed.

3. Shielding effectiveness determined at DTEM cell tests and SAR reduction factors of the covered mobile phone

3.1. SE of metal-wires inserted textiles.

A set of 6 different sub-millimetric wired textiles containing copper (Cu) and a

second set of 6 different sub-millimetric wired textiles containing silver (Ag) were characterized with the DTEM cell method. SE of the materials is represented as a function of frequency for the two sets in Figure 2. As observed, in the frequency range of the 2G (GSM) uplink band of mobile phones (890-915 MHz), some materials are shielding better than others. A reference for SE values in case of copper is given, by using a sheet of solid copper 1.5 mm thick (denoted Cu_solid) – for comparison, whose SE is 20-30 dB larger than that of copper-wires textiles.

Based on these results, we selected for further SAR tests just two copper containing materials, with SE between (-26…-30)dB, denoted as Cu_2 and Cu_6 and two silver materials, with SE between (-22…-25)dB, denoted as Ag_1 and Ag_3).

3.2. SAR reduction in presence of Copper and Silver sheet textiles used to shield 2G and 3G frequency bands radiation.

In Table 1 it is shown an example of results obtained for average SAR values in the phantom head for 2G emission of the phone, without and with shielding materials present on the handset surface. There are cases when the material is decreasing SAR but also cases when it increases it. Similar results where obtained for all materials and also for 3G communication band. The main outcome is that the orientation of the wires and the position relative to phone antenna are of crucial importance for SAR reduction impact.

Table 1. SAR values in the head with and without a shielding material

Shielding material	SAR_{avg} (W/kg)	
	Normal position	Rotated position
Without material	0.558	0.558
Cu_6	0.506	0.339
Ag_3	0.606	0.327

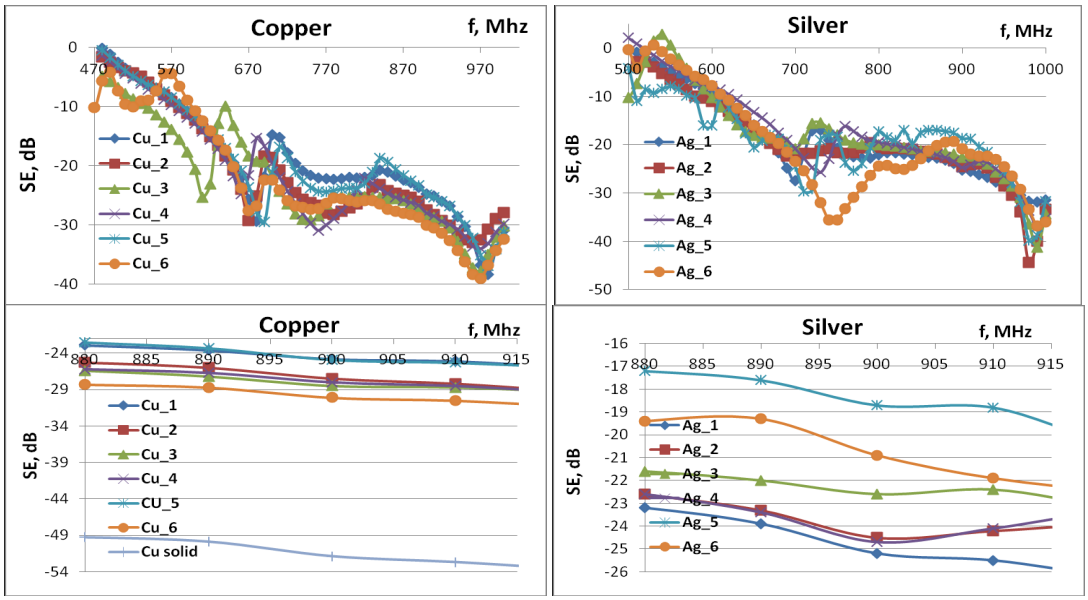


Figure 2: Shielding effectiveness of samples of planar thin sheets of conductive textiles in a large frequency band (up) and restricted just in GSM-2G frequency band of mobile phones (down)

In Figure 3 it is emphasized the variation of the internal electric field strength (E_int) induced inside the phantom head, as the points of measurement go deeper (27 points where used on a spatial axis entering inside the head, distanced at 4mm). One can observe that the shielding impact is different with depth for each material and its position relative to the handset body.

In Figure 4 the curves of SAR reduction with depth in the head are

represented for the shielding materials covering the handset while communicating in 2G and 3G uplink bands. For GSM uplink case, all materials except Ag_3 with normal position of the yarns, have shielding properties for all depths. For 3G uplink case however, a very different situation is encountered. Practically all the conductive materials present between the handset and the cheek are amplifying the radiation instead of shielding it. Very large amplification of radiation is noticed, conducting to local SAR values at the heat surface as large as 6.7 W/kg, practically tripling the SAR value in case when no material is interposed for "protection".

Figure 5 presents a set of two-dimensional maps of 3G-SAR distribution in the head, and underlines how hot spot is moving and how SAR is spreading different, depending on situation.

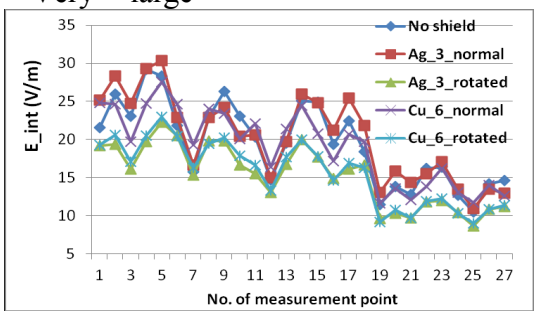


Figure 3: Shielding materials impact on induced electric field distribution in the depth of the phantom head for GSM-2G radiation

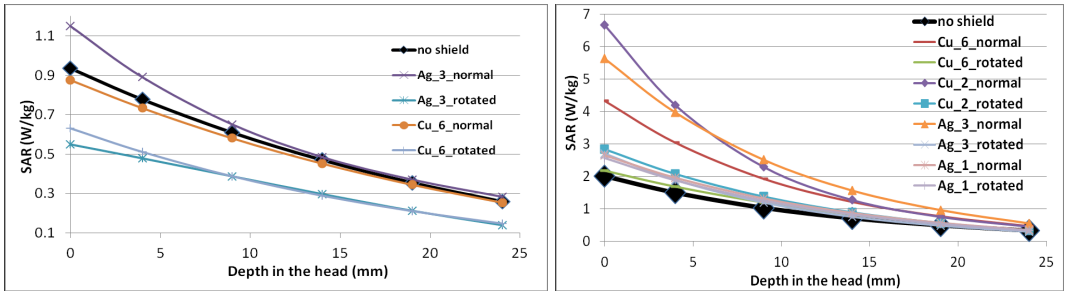


Figure 4: SAR variation in the depth of the head without and with shielding materials, when used in 2G frequency band (left) and 3G frequency band (right)

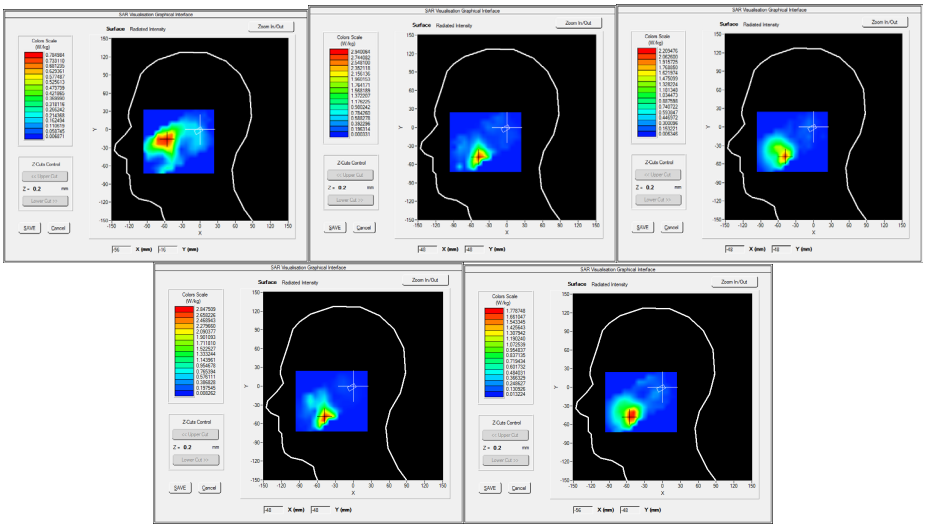


Figure 5: SAR distribution in the head with 3G phone by the ear (first left: without material; 2nd and 3rd – with copper material, normal and rotated; 4th and 5th - with silver material, normal and rotated.

4. Conclusions

Shielding effectiveness is not the proper predictor of capability of materials to reduce the radiation penetrating the head of mobile phone users. This latter characteristic depends very much on the type of material – the wires dimensions, their relative orientation to the handset antenna, etc. As near-field scattering sources, the conductive-wires textiles are modifying in fact the radiation pattern of the mobile phone antenna. Both decreasing and increasing SAR levels of mobile phone is possible when using "shielding" materials, and for the same phone, protection is not guaranteed for all operating frequencies. Shielding capabilities of such materials need very careful study further on.

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