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SHIELDING PROPERTIES OF TEXTILES AGAINST ELECTROMAGNETIC RADIATION

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***Abstract**: Being at home or pursueing our profession in our workplace, we are continuously exposed to electromagnetic radiation. The term "electrosmog" includes all the types of radiations surrounding us, coused by the magnetic field of the Earth, high voltage transmission lines, electric equipments working close to us, even cellphones too. The frequencies, intensities of theses radiations and fields are different, as well as their character (electric, magnetic or coming from large distance), and the electrosmog created by them has various effects.*

Aim of our research work is to develop textile products for clothing that are able in some degree to filter the electromagnetic radiation reducing its eventual harmful effect. We wanted to develop woven fabrics that could be used in making fashionable garments as materials of certain components (e.g. inlays) having this advantageous feature.

To test the radiation filtering ability we developed a measuring method adapted to an instrument basically available for measuring of electrosmog.

***Keywords**: Electro smog, shielding capacity against electromagnetic radiation, protecting textiles*

1 INTRODUCTION

Importance of protective everyday clothing is continuously increasing since environmental risks have come to the fore. Growing of environmental risks caused by electro smog is our day-by-day problem. Number of pieces of high frequency equipment is increasing and, though the manufacturers do their best to decrease electromagnetic radiation, it is not yet undoubtedly proved that this radiation is not harmful to health.

Research works and tests have not yet proved undoubtedly either the direct effect of electro smog to health or that of its harmlessness. Therefore it is understandable that people want to use all equipment that can reduce the eventual negative effect of this radiation. A group of such equipments consist of textiles that are able to shield electromagnetic radiation to a certain degree.

2 MEASURING OF PROTECTING EFFECT OF TEXTILES AGAINST ELECTROMAGNETIC RADIATION

Our aim was, first of all, to develop inlay fabrics that are able to offer a certain protection against electromagnetic radiation (for example against that of produced by mobile phones), and also to develop a proper method for measuring of the effectiveness of shielding.

2.1 Method for measuring of shielding effect (on basis of IEEE-STD 299/MIL-STD 285)

Measuring of effectiveness of shielding used for textile fabrics has been implemented by the method shown in Fig. 1. The radiation detector was placed in a shielded chamber covered by aluminium foil, only the display could be seen. This chamber contained the antenna and most parts of the receiving unit. An opening of 160×160 millimetre has been cut on one side of the chamber (taking the 125 mm wave length of the generated radiation into consideration) for the guided measuring of the radiation produced by the emitting antenna. This opening was covered by the piece of fabric to be tested which transmits the radiation in a grade depending on its shielding capacity. In the succeeding measurements the specimens were turned by 90 grades to test the differences in shielding effect according to the direction of warps and wefts.

2.2 The measuring set-up and the measuring environment

To create induced electromagnetic field in the discrete frequency range of 2,4 GHz we used a 10 dB high gain antenna with guided radiation. Type of the radiation detector is HF 58B; it is available to perform measurements in the range of 800 MHz to 1,5 GHz. This range includes all frequencies which are produced by the usual pieces of equipment like mobile phones, microwave ovens, Bluetooth, wireless telephones, etc., the radiation from which might be harmful for the human organism.

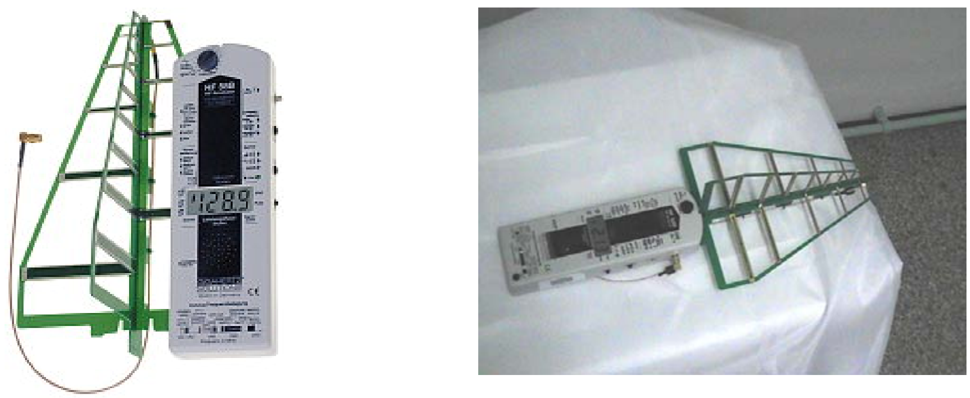


Figure 1: HF 58B Electro smog measuring set-up

This instrument has a logarithmic-periodic antenna. High frequency radiations are usually polarized, i.e. the plane of the waves is vertical or horizontal. Measuring in both planes is possible by changing the antenna position.

Radiation is produced by an oscillator. Electric polarization of the electromagnetic field is vertical.

Intensity of the radiation is measured by a high frequency radiation measuring unit (it measures the power density). Measuring range in the 800 to 2500 MHz frequency range is 2 to 2000 $\mu W/m^2$. The instrument is available to measure power density S in mW/m^2 or $\mu W/m^2$. Not only the mean but also the peak values can be read on the digital display.

The measured values mean radiation performances according to the given frequency, relating to a theoretical area created by the dipole.

The properly large distance of the emitting and the receiving antennas takes the distortion problems of „close ranges" into consideration so we can count on near real expansion. Position and polarization of the emitting and receiving antennas were tuned and unchanged during the measuring process.

Power density S_o of the source of electromagnetic radiation in the environment of the radiation source could be measured in $\mu W/m^2$. Power density S_1 of the radiation that comes through the fabric put between the radiation source and the measuring antenna can be measured and it depends on the damping effect.

2.3 Evaluation

Shielding effectiveness (*SE*) against electromagnetic radiation can be described by the shielding or damping factor given in dB. Damping factor SE_i can be calculated from the ratio of power density measured without shielding ($S_{i\ without\ fabric}$) and that with shielding produced by the tested fabric covering the opening of the chamber ($S_{i\ with\ fabric}$):

$$SE_i = 10\lg\left(\frac{S_{i\,without}}{S_{i\,with}}\right)[dB]$$

Damping factor *SE* of the tested fabric is the mean of the momentary values:

$$SE = \frac{1}{n}\sum_{i=1}^{n} SE_i\,[dB]$$

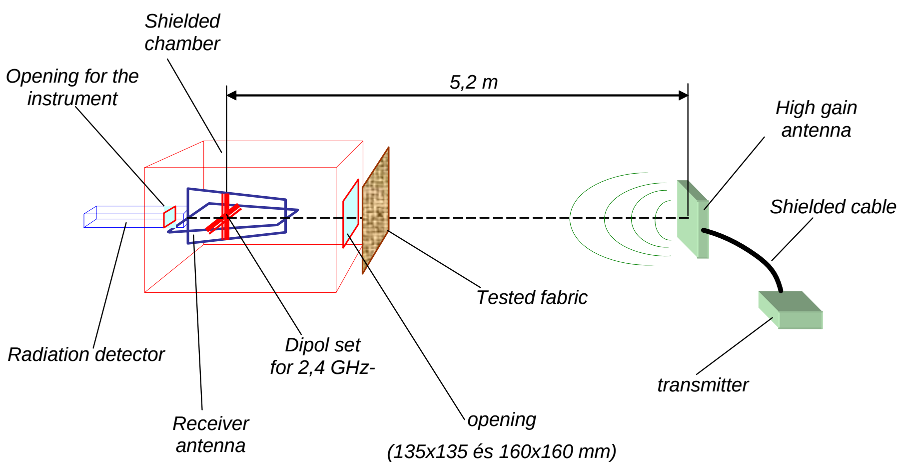


Figure 2: Sketch of the measuring set-up

2.4 Noises burdening the measuring processes and their handle

In order to minimize electromagnetic and other background noises during the measuring processes we implemented the following measures:

- There were only very few mobile radiation sources (mobile phones, computers, etc.) in the building in the late afternoon.
- Measurements were carried on in a ground-floor room which was separated from the street with several walls.
- It was not possible to eliminate radiation sources like light-sources and the transformers of the emitting and receiving units but the noise generated by them was, concerning their intensity and spectrum, static and their frequency was far from the measuring range.
- The transmitting antenna was placed in that way that there was no reflecting surface in the direction of and near the supposed radiation cone, so the antennas could be well positioned.
- Sizes of the chamber were relatively small (600×350×350 mm) but phenomena of near ranges created by inner reflections did not influence significantly the measured values.

- The two persons who carried out the tests could not be concerned as completely static damping medium. Their dielectric properties did not change during repeated measurements and produced only little changes between measurement series, though we tried to control it. However, their position and movement were out of the measuring area of radiation transmission thus their influence can be neglected.
- After switching on the measuring system we waited at least half an hour to give time for warming up and to achieve stable and reproducible state.
- During each measurement we waited 5 seconds before reading the values in order to give time the system t becoming stable.
- Task of the two operators was always the same: they covered the opening by the test fabric always in the same method and they read the display again always in the same way which was not very easy because the values varied and this could be a significant source of error.
- Before the tests fabrics were conditioned in order to have the same humidity. This was important because results can be influenced by the dielectric behaviour of the test fabrics and we want to minimise this effect.

2.5 Analysis of the measuring system, tests of repeatability and reproducibility (R&R)

Because the principle of these tests is quite new there are presumably no earlier analyses carried on to estimate the uncertainties of such systems (instrument, operator, object, environment, method). In implementation of the tests we took care of quantification of uncertainty components following the principles of R&R method known in the automotive industry. To analyse the measuring system we carried on test series of ten tests each, similarly to the real tests. In addition to the immediately repeated tests we set up and used the system at three different times, in order to be able to take the smaller differences in preparation and implementation of the tests (the long term components of fluctuations) into consideration

2.5.1 Examination of reproducibility

First the fluctuation components of repeated tests has been estimated. This is the standard deviation coming from data of short test series carried on in unchanged circumstances:

$$\hat{\sigma}_{re} = \frac{\overline{\overline{R}}}{d_2}, \quad \text{thus} \quad \sigma_{repeatability} = \mathbf{1{,}88}\ \boldsymbol{\mu W/m^2}$$

(d_2 is a statistical constant for estimation of standard deviation, depending on the number of the repeated measurements.)

2.5.2 Examination of repeatability

Here the uncertainties are quantified the origins of which are the effects coming from smaller deviations in set-up of the measuring system (change of operator, noise structure in the environment, some different in reading strategy, smaller changes in placing, not identified synergy effects, etc.).

$$\hat{\sigma}_{rp} = \frac{\overline{R_{\bar{x}}}}{d_2}, \quad \text{thus } \mathbf{2{,}106}\ \boldsymbol{\mu W/m^2}$$

(d_2 is here a statistical constant for estimation of standard deviation, depending on the test series carried on at various times and their means.)

2.5.3 *Calculation of R&R value*

The R&R value can be calculated from the two variances mentioned above:

$$R\,\&\,R = \sqrt{\sigma_{re}^2 + \sigma_{rp}^2}\ \text{, thus } \mathbf{2{,}22\ \mu W/m^2}$$

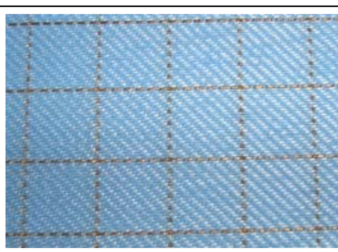
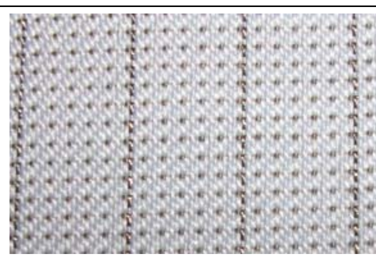
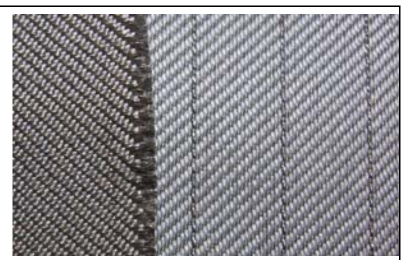
3 TESTED FABRIC SAMPLES AND THEIR RESULTS

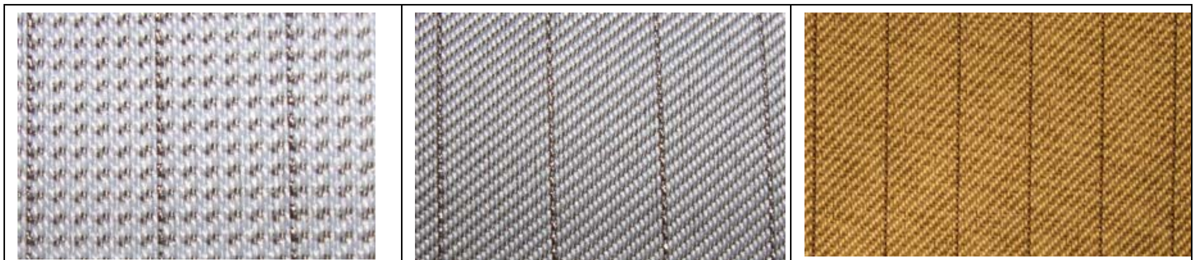
Using the above presented method we wanted to determine how and at which value the shielding effect of various textile fabrics against electromagnetic radiation is influenced by metallized yarns placed into the fabric structure.

The test fabric was a striped woven fabric, made basically from polyester but first having metallized yarns in both the warp and the weft system in certain distances (1 metallized yarn followed by 24 polyester yarns). Thus, it was a symmetric checked fabric. For further tests we changed the distances of metallized yarns in the weft: they were used in each 2nd or 4th weft insertion and also we used 2/2 weft insertion as well.

Table 1: Data of tested fabrics

Sample No.	Warp	Weft
0.	100% PES	100% PES
1. (checked)	24 times PES/ 1 metallized yarn	110 dtex PES (sequence: 24/1)
2.	24 times PES/ 1 metallized yarn	3 times 110 dtex PES FTF One 78/18 dtex metallized yarn
3.	24 times PES/ 1 metallized yarn	Each weft yarn: 78 dtex f18 metallized yarn
4.	24 times PES/ 1 metallized yarn	2 times 110 dtex PES FTF 2 times 78 dtex f18 metallized yarn
5.	24 times PES/ 1 metallized yarn	One 110 dtex PES FTF One 78 dtex f18 metallized yarn
6.	24 times PES/ 1 metallized yarn	Each weft yarn: 160 dtex twist
Basic warp:	74 dtex PES	-
Metallized yarn:	78 dtex f18 PA 6.6 with silver coating	-
Basic weft:	-	110 dtex PES

		
1. sample	2. sample	3. sample



4. sample	5. sample	6. sample

Figure 3: Photos of the test fabrics

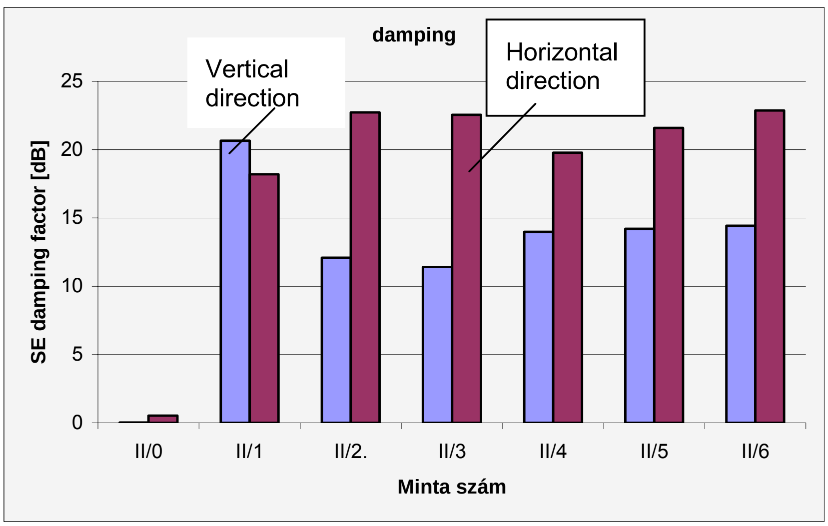


Figure 4: Electromagnetic damping factors measured on the samples

The following connection is valid between the shielding (values in dB) and the shielding effect (given in %) [2]:

Table 2: Shielding levels

Shielding dB	Power density after shielding %	Ratio of absorbed radiation %
0	100	0
10	10	90
20	1	99
30	0,1	99,9
40	0,01	99,99
50	0,001	99,999
60	0,0001	99,9999

Two levels of electromagnetic field and shielding can be distinguished [2]:

- professional level: > 30 dB
- general level: < 30 dB

According to the test results, fabrics containing metallized yarns in the warp (one metallized yarn followed by 24 polyester yarn, the distance between the metallized yarns is 7 mm) present a shielding effect of 99 % comparing with fabrics made of 100 % polyester yarns. Fabrics with additional metallized yarns in the weft placed in the same set-up (7 mm distance between them) produce balanced shielding effect. The fabrics reach the 20 dB damping level and it meets the requirement of general work-clothes but not enough for effective protection against continuous and strong radiation in such work places like, for instance, antenna installation. This shielding level is acceptable for protection against electromagnetic radiations being present at home or in an office, in such environment it protects the human organism against the eventual harmful electro smog.

Shielding effect does not increase when the distance between metallized yarns is smaller than 7 mm. Further examination should be carried on with various radiation frequencies to determine the optimum density of metallized yarns (i. e. their number in 10 mm), their technical and economic parameters as well as the metallized yarn containing fabric construction in order to achieve optimal polarization when wearing the garment.

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