Occupational and Public EMF Exposure – Textiles Shields as a Modern Approach for Protection

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Abstract
Apart from the existing standards and hygienic guidelines, technical and organizational methods are applied in people's protection against EMF. Two groups of people are specified: people employed at application and supervision of EMF equipments (occupational exposure), and people who live, work, or study near EMF devices and installations (public exposure). The analysis of own studies results concerning the choice of work-places exposed to strong EMF in different branches of economy proved the need to lower the exposure to those fields: in industry, medicine, radiocommunication and broadcasting in special conditions. Shielding is one of the methods of EMF protection. Shields made of metal are expensive, heavy, not always handy or sometimes even not suitable for practical usage. Flexible materials (textile fabrics) shielding against EMF are more and more frequently applied in practice, e.g. to cover walls of rooms or devices' coverings to decrease emission.They are a modern approach to protect against EMF. This study presents results of measurements of EMF intensities in occupational and naturall environment the most popular sources of EMF and effectiveness electroconductive textile attenuation. Designed shields have been used in physiotherapy surgeries with shortwave and microwave diathermy in two Polish hospitals. An advantage of shields made of electroconductive textiles is their lightness and considerably lower cost in comparison with shields made of metal sheets and wire mesh.

1. Introduction

Legally established level of electromagnetic fields (EMF) maximum admissible intensity values in working and municipal environment obligates the owner of devices (EMF sources) to monitor EMF levels and ensure appropriate protection against their harmful health effects [1-2]. Apart from the existing standards and hygienic guidelines, technical and organizational methods, and health protection are applied in people's protection against EMF. Two groups of people are specified: people employed at application and supervision of sources (occupational exposure), and people who live, work, or study near EMF sources (public exposure). The analysis of own studies results concerning the choice of work-places exposed to strong EMF in different branches of economy proved the need to lower the exposure to those fields: in industry, medicine, radiocommunication and broadcasting in special conditions [3-5]. And for exemple EMF occurring in physiotherapy room penetrates to the neighbouring room as consulting rooms, other rooms for rehabilitation or corridors (waiting – rooms). Shielding is one of the protection methods against EMF. There is a possibility of applying different forms of shielding. Shields made of metal are expensive, heavy, not always handy or sometimes even not suitable for practical usage. There are investigations on new shielding materials, e.g. special loaded plastics, multilayer films or textile fabrics. Flexible materials (textile fabrics) shielding EMF are more and more frequently applied in practice, e.g. to cover walls of rooms or devices' coverings to decrease emission. They are a modern approach to protection against EMF [6-9]. The technology of electrically conductive fibres production has been worked out at the Textile Research Institute (Łódź, Poland) which has patent protection in Europe and USA [10]. Measurements of shielding effectiveness (SE) of fabrics from these fibers proved a possibility of their application as electromagnetic shields. Designed shields have been used in physiotherapy surgeries with shortwave and microwave diathermy in two Polish hospitals. Results of the EMF measurements proved that the protective zones outside each of the rooms with operating diathermies could be eliminated [11]. This study presents results of measurements of EMF intensities in occupational and municipal environment, the most popular sources of EMF as well as the above mentioned electroconductive textiles attenuation effectiveness.

An advantage of shields made of electroconductive textiles is their lightness and considerably lower cost in comparison with shields made of metal sheets and wire mesh.

2. Presentation of the own results of EMF exposure examination

Natural electromagnetic environment has been disturbed by electromagnetic fields (EMF) created by a large number of radio, television, and satellite stations, radiolocation and radionavigation devices, land mobile radiocommunication base stations as well as electromagnetic devices for distributing electric energy (transformer-distribution stations and electric power lines). Each device powered by electric current is an EMF source which propagates into the surrounding space. Thus, EM fields are everywhere around us. They are produced by devices used at home, e.g.: hairdryers, shavers, TV receivers, computer screens, cordless phones or cell phones.

Depending on the purpose of an EMF source, frequency range, and transmitter power, different groups of general population undergo a different exposure to EMF. The level of exposure depends on the state of industrialization of a given country area or region, and it is on average higher for inhabitants of big cities in comparison with rural areas.

2.1. Occupational EMF exposure

In order to protect workers employed at devices and installations producing EMF, their environment is periodically measured for their EMF distribution. According to current national MAI’2001 guidelines, the EMF distribution is characterised by establishing protective zones: intermediate, dangerous, and hazardous. The analysis has been carried out using the information collected in the Central EMF Sources Database concerning about 8 thousand devices operating in the frequency range 0.1 MHz – 38 GHz, controlled up to 2002. Data on devices that are seen as EMF sources are collected in the above mentioned database according to their most important application areas, i.e.: medical applications, industry and energetics, radio and wire communication, and science. Analysis of the collected data proved the occurrence of protective zones in the vicinity of more than 53% controlled devices, including: hazardous zone in the vicinity of more than 6.7% of devices, no more than dangerous zone in the vicinity of about 32% of devices, and no more than intermediate zone for almost 15% of devices [3]. The highest measured intensity values of electric field in the workplaces (regular hours and shifts) were higher than 1000 V/m at spark – gap generators (6.4% of workplaces in dangerous zone), 220V/m at induction furnaces (6.9% of workplaces in hazardous zone), 1000 V/m at electrosurgery devices (35.5% of workplaces in hazardous zone), 200 V/m at short-wave diathermy (60% of workplaces in hazardous zone), 256 V/m at dielectric welders (4.8% of workplaces in hazardous zone). In radio and wire communication most devices work without servicing, therefore, a large group of workers employed at permanent or sporadic supervision of work of devices installed there does not undergo EMF exposure of values from protective zones. On the other hand, a specialised group of workers employed at assembly, disassembly, or removing damage of transmitting devices, may stay within the EMF range, for example, in close vicinity of transmitting antennas in special conditions of EMF extreme intensity values. Measured electric field intensity values on the mast’s girders of the multiprogram object, type RTCN, amounted to 180 V/m inside the ultra short-wave antenna system (powered by 16 kW transmitters, antenna gain 7.5 dB) and to 58 W/m^2 on a terrace under a TV antenna of IV/V range (powered by 80 kW transmitters, antenna gain 15 dB) [4]. Analysis of the collected data proved that EMF produced in the vicinity of about 16% of devices was higher than the EMF intensity values recommended by ICNIRP. The discussion on the possibilities of decreasing EMF exposure in occupational environment has shown that the desirable SE of screening materials should reach 10 - 40 dB (in the range of frequency 27 MHz, 90 –110 MHz, 400 – 800 MHz, 2450 MHz), depending on the shielding need and aims i.e. EMF attenuationup to admissible levels or’ to the lowest available levels.

2.2. Public/municipal EMF exposure

EMF measurement results obtained in the years 1995-2000 in the vicinity of: 5 objects RTC (Radio Transmitting Centre), including measurements for 2 short-wave, 14 RTTC objects (Radio-Television Transmitting Centre), 9 RTS objects (Retransmission Television Stations), 6 FM radio stations, as well as 15 base stations of mobile telecommunication were analysed. Measured values of field intensity around buildings and inside dwelling-houses in the vicinity of an object situated on the sparsely built terrain (I-III-story buildings) were contained in the range 0.6 – 1.9 V/m. They were below the Polish normative values, below ICNIRP'1998 recommendations [12] and they did not complay with very strict Swiss regulations of public protection [13]. Measurements of field intensity and power density were carried out for a big city with a RTTC object situated in its centre. The measurements proved that EMF level values in dwelling-houses and office buildings were contained in the range 0.5-6.0 V/m, but the highest values occurred in the vicinity of metal balcony rails and window-frames. The occurrence of measurable EMF values in air-conditioned buildings (metallized window panes) hasn't been observed. EMF measurements carried out for 15 base stations situated on the buildings' roofs (including 7 dwelling-houses) showed occurrence of power density values from the range from below 0.025 W/m^2 to 2 W/m^2 (higher than Polish normative values). The occurrence of measurable EMF values in containers with transmitting and navigating devices, or along cables distributing the radio signal from the container to antennas was not observed. Sporadically, occurrence of measurable EMF power density values on roofs and balconies of high buildings was observed. The discussion on the possibilities of decreasing EMF exposure in municipal environment has shown that the desirable SE of screening materials should reach 15 - 25 dB (in the range of frequency 90 –110 MHz, 900 MHz and 1800 MHz .)

3. Shielding properties of the electroconductive nonwovens

Shields are used either to isolate a space (room, apparatus, circuit etc.) from outside sources of electromagnetic radiation or to prevent undesired (unwanted) emission of electromagnetic energy radiated by internal sources. Traditionally they are based on of stiff metallic materials with well-known electromagnetic properties. Plastics with conductive coat or with metal fibres introduced during the moulding stage, other metallized non-conductive materials are more and more often applied. At the edge of the 80-ties and the 90-ties, following on the technique of metallizing textile fabrics on industrial scale, there appeared textile screens covered with metal, mainly according to chemical method. For metallization of textile fabrics the following products are most frequently used: copper, nickel, silver and their combinations [6-9]. Research works carried out up to now, confirmed that the products made of electroconductive fibres produced at Textile Research Institute Lodz, Poland are suitable for EMF shielding purposes.

3.1. Characteristics of nonwovens

The characteristics presented below concerns electrically conductive textiles which were tested for their application as electromagnetic shields. Polyacrylonitrile (PAC) fibres with metal salts have been produced under the trade name Nitril-Static at the Textile Research Institute for 15 years. Fibres 3.4 dtex/60mm are mainly subjected to modification process. Specific resistivity is the most important parameter of Nitril-Static fibres. Over 87% of modified fibres have specific resistivity in the range 1-5 Ω.cm. In use are electrically conductive fibres (EC) combined with other fibres. Two types of textiles have been examined for shielding effectiveness: WOM - E2001 – mass per unit area 108 g/m^2 and surface resistivity 1.5×10^4 Ω with 75% of EC- PAC textiles and 25% of polyester silk, and needled textile IGNS with 100% EC - fibres - mass per unit area 285 g/m^2 and surface resistivity 2.8×10^3 Ω. Both textiles are of olive-green colour. In practice, conductivity is not dependent on air temperature or humidity.

Measurements of shielding effectiveness of fabric from these fibres proved a possibility of their application as electromagnetic shields (Table I) [14].

Table I. Shielding effectiveness of nonwovens (results of measurements in EMC Testcenter Zurich according to MIL STD 285)

Frequency [MHz]	**Nonwoven IGNS**		**Nonwoven WOM-E**	
	E-field [dB]	**H-field [dB]**	**E-field [dB]**	**H-field dB]**
0.33 – 0.44	49,0	4.0	42,0	1
1.76	49,0	0.5	25,0	1
27.12	53,0	4.0	25,0	0
2450	24.5	-	-	-

3.2. Own examination of EMF attenuation of nonwovens

The basic parameter of shields is the characteristics of shielding effectiveness (SE) in the function of frequency. The measure of SE is attenuation which defines reduction of intensity of electric field and/or magnetic field after penetrating the shield. SE of a given shield with an established frequency depends on the shielding material, thickness of the shielding structure, and a distance between shielding surface and EMF source. Reflection losses, absorption losses, and multiple reflection losses in shields made of a thin layer of shielding material are factors contributing to the complete effectiveness value of shielding.
The Institute of Occupational Medicine in Lodz has carried out measurements of SE of more than 20 samples of the above mentioned textiles and their modifications in the GTEM chamber, in selected frequency ranges from 0.3 MHz to 30 MHz and 2450 MHz according to “small-size-samples” method [15]. This is a comparative method used in laboratory conditions to select proper material-having required SE values- for further tests. The highest SE values (depending on EMF frequency),which for WOM-E and IGNS were achieved - respectively ca. 28 dB for 27.12 MHz and ca. 17 dB for 2450 MHz).The pilot studies of a textile’s SE in frequency ranges used in UHF FM radio and TV stations prove SE of about 19 dB for 99 MHz, 23 dB for 215 MHz and 22 dB for 621 MHz. Within the range of the GSM’s work, this value was 27 dB.

3.3. Example of textile shields application

Practical application of textile shields is presented below for physiotherapy within shortwave and microwave diathermies. Measurements of EMF distribution in the vicinity of shortwave and microwave diathermies according to protective zones (see Polish limits) are presented in Figure 1. and Table II.
Shields in the form of wall laps and door curtains were designed in order to eliminate protective zones of EMF from the neighbouring rooms. For rooms with devices working in the frequency range 27.12 MHz, covering the walls with WOM E2001 textile was suggested, whereas for the room with a device working in the frequency range 2450 MHz - IG-NS textile was suggested. Door curtains were also made of WOM E2001 and IG-NS textiles. Designed shields have been earlier tested in laboratory conditions, with the use of shortwave and microwave diathermy as EMF source (microwave diathermy worked with a tube antenna).

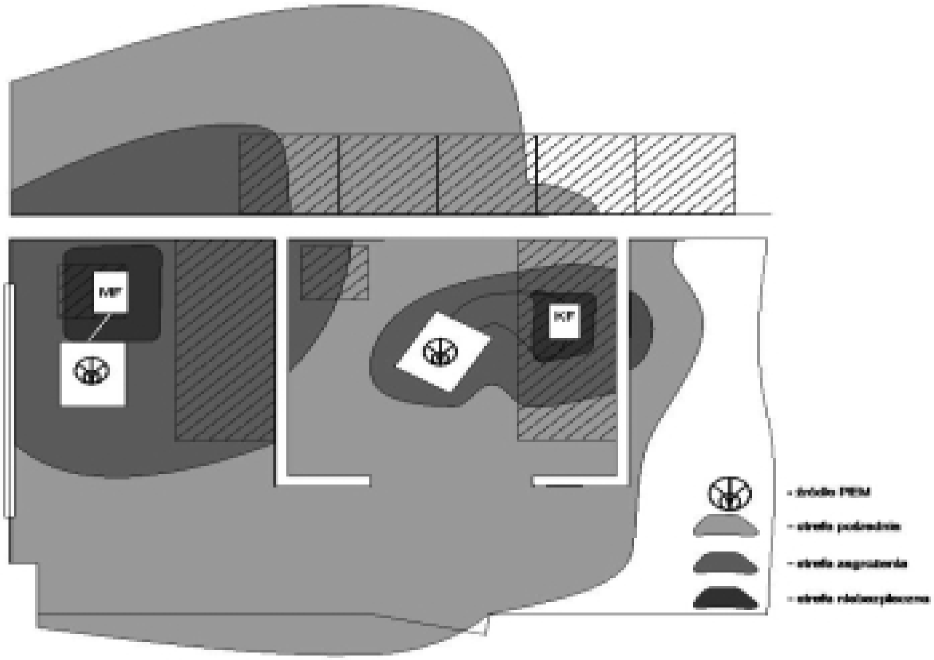

FIG.1. *Protective zones distribution -shortwave ad microwave diathermy operating (before shielding)*

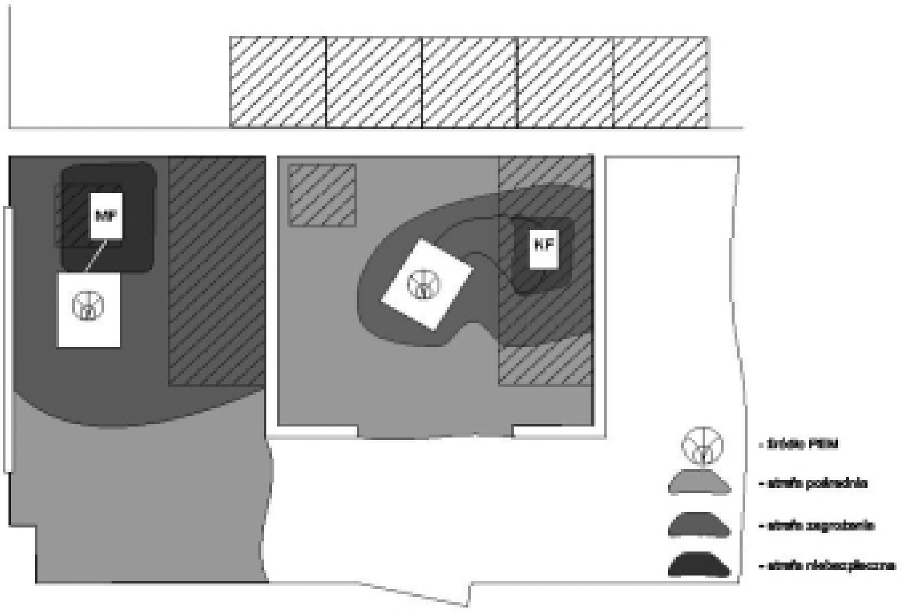

FIG. 2. *Protective zones distribution (after shielding)*

Figure 2. presents EMF distribution in rehabilitation rooms after applying shielding materials. This case describes the situation where two devices operate at different frequencies (most complicated case). If only one device is operating, then in the room with such a device a protective zone should be established (and respective EMF value limits)

Table.II. Measurements results of the EMF intensity before and after shielding cabin of hospital rehabilitation rooms (physiotherapy)

Shielding location	Radiation source		Protective zone / (intensity electric field/ microwave power density)	
			before shielding	**after shielding**
Cabins	cabin A microwave diathermy	Wall A1	*dangerous* 12.000 W/m^2	*safe* 0.022 W/m^2
		Wall A2	*intermediate* 0.280 W/m^2	*safe* 0.064 W/m^2
		Wall A3	*> intermediate* >0.200 W/m^2	*safe* 0.008 W/m^2
	cabin B shortwave diathermy	Wall B1	*intermediate* 19.0 V/m	*safe* 2.1 V/m
		Wall B2	*intermediate* 19.0 V/m	*safe* 3.0 V/m
		Wall B3	*dangerous* 24.0 V/m	*safe* 5.1 V/m

Periodic control of SE is necessary. Up to now wire mesh screens have been applied. Yet, such screens effective for shortwave diathermy are not suitable for microwave diathermy.

The project and their authors were distinguished with the prize of Polish Ministry of Labour and Social Politics.

4. Conclusions

Our research showed a possibility of application of electrically conductive textiles as electromagnetic shields in physiotherapy rooms. In case of operating rooms and surgery rooms, eliminating EMF of values according to protective zones from neighbouring rooms is not necessary, since their reach in the environment of electrosurgical units is limited to their vicinity. In this case, local shields may be recommended; for example in the form of screens or curtains covering sectors with sensitive electronic equipment (but not the patient-connected monitoring device) or sectors where attendant medical personnel stays. At this point of the research, it is not possible to limit EMF exposure of medical workers performing surgery procedures, since it is not possible to shield both electrodes' wires and electrodes themselves. Installation of shields requires special experience. Periodic control of shielding effectiveness is necessary.

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