AUTEX 2022 Conference Proceedings 978-83-66741-75-1

DOI: 10.34658/9788366741751.84

KNITTED SHIELDS AGAINST ELECTROMAGNETIC WAVES

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ABSTRACT

The purpose of the research is to counteract the negative impact of electromagnetic waves on the human body by using knitted textile barriers. Four variants of knitted fabrics with plain weft stitches were designed and manufactured from electrically conductive yarns with resistance of 490 ohms. The variants of the knitted fabrics differed significantly in structural parameters, including loop density – varying from 15 to 0.9 thousand loops and fabric cover from 64 to 33%. The barrier properties against reflected waves at frequencies from 2 to 7 GHz ranged from 10 to 64 dB. It has been proven that shielding effectiveness SE depends on stitch geometry and structural parameters of the knitted fabric. It is a good starting point for further research on the optimization of the performance of knitted barriers against electromagnetic waves

KEYWORDS

Electromagnetic field EMF, knitted electromagnetic wave shields, shielding measurements and shielding effectiveness SE.

INTRODUCTION

Electromagnetic field is a natural phenomenon which people constantly experience in everyday life conditions. With the development of technology, apart from natural sources of radiation, new man-made artificial sources tend to appear, including X-ray generators, nuclear reactors, electrical devices, radio and telecommunication systems, and power installations [1,2]. Electromagnetic radiation can be divided into high-frequency ionizing radiation and non-ionizing radiation with relatively low wave energy. Over years medical research has emphasized negative impact of electromagnetic field on the human body [3]. Particular anxiety is caused by radiation from mobile telephony due to the application of new technologies based on higher frequencies, including 5G and 6G networks [4,5]. Speculations arise that electromagnetic waves used in telecommunications increase the risk of neoplastic diseases of the brain, head and neck area [6] and have a negative impact on fertility in both men and women [7–9]. It has been proven that radiation may disturb the speed of biochemical processes in cells of living organisms [10]. The International Agency for Research on Cancer (IARC) has developed a classification of carcinogenic agents and substances, which shows that radiation emitted by cellular telephony belongs to potentially dangerous factors. Various methods of attenuating electromagnetic fields are used to reduce the exposure, including shielding, which is the most common method of radiation protection. The briefly signaled evidence concerning negative impact of electromagnetic waves on the human body, inspired the authors to undertake research on the technology of knitted elastic electromagnetic shields which can be applied in clothing for people requiring special care, including newborns and children, pregnant women and seniors. The principal scientific goal of the presented research was to analyze the influence of structural and electrical properties of shielding fabrics on their effectiveness of electromagnetic wave attenuation.

MATERIALS AND METHODS

For research purposes, four variants of knitted fabrics with plain weft stitches were made from electrically conductive yarns. The yarn used was a multi-filament silver-plated thread from Shieldex company with a linear density of 150 dtex (Fig. 1a). Linear resistance of the thread over the length of 100 cm equalled 490 Ω. The produced knitted fabrics differed in structural parameters, including course and wale density, surface density, thickness, thread length in the loop, run-in ratio, linear, surface and volume fabric cover. Using the original Textil-Studio measuring system, surface porosity of the knitted fabric was measured with optoelectronic method, consisting in digital comparative analysis of the knitted fabric binary images and its actual view, using hysteresis function of the background pixels and knitting threads. The measured parameters of the knitted fabrics are summarized in Table 1, while Figures 1b and c present photographs of knitted fabrics differing in loop density. The four analysed variants of the knitted fabrics were produced on weft-knitting machines, variants 1 and 2 on a circular weft-knitting machine with needle gauge E14, and variants 3 and 4 on a flat machine with needle gauge E12. No difficulties were encountered while processing the metallized thread during the manufacturing process.

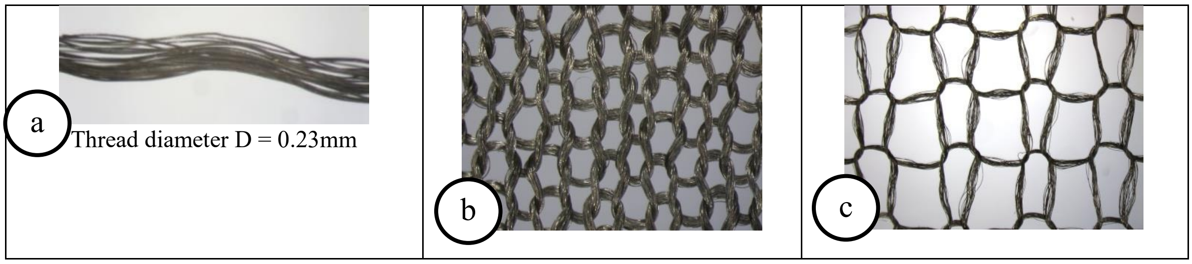

Figure 1. a –microscopic image of SHIELDEX thread, 150dtex b i c –fabric images variants 1 and 4, fabric face.

The produced knitted fabrics differ significantly in structural parameters- the first two variants are characterized by high loop density ranging from 15.6 thousand up to 11.7 thousand, surface density from 84.3 to 67.5 g/m^2 and fabric cover ranging from 64.3 to 59.6%. The structures of stitches in variants 3 and 4 are much "looser" and their loop density varies from 5.0 thousand. up to 0.93 thousand loops. Surface density is also lower- 47.5 and 15.5 g/m^2 and fabric cover equals 41.4 and 29.2%. It can be briefly concluded that the first two variants of knitted fabrics are characterized by quite "normal" properties typical for fabrics used in the clothing industry, while variants 3 and 4 are a-jour structures, also known as openwork fabrics.

Table 1a. Performance parameters of barrier knitted fabrics.

Fabric variant	Course density, Pr	Wale density Pk,	Loop density Prk,	Loop shape factor, C	Fabric thickness g	Thread length in the loop, lr	Wale take-up Wk
	course/10cm	wales/10cm	loops/1dm^2	-	mm	mm	-
1	151	103	15553	0.72	0.45	3.08	3.18
2	129	91	11739	0.73	0.40	3.78	3.44
3	74	68	5032	0.92	0.38	5.03	3.42
4	32	29	928	0.91	0.28	11.14	3.23

Table 1b. Performance parameters of barrier knitted fabrics.

Fabric variant	Course take-up Wr	Surface density Mp	Linear cover factor Zl	Surface cover factor Zp	Volume cover factor Zo	Surface porosity	Surface resistance
	-	g/m^2	loops/1dm^2	-	-	%	Ω
1	151	103	15553	0.72	0.45	3.08	3.18
2	129	91	11739	0.73	0.40	3.78	3.44
3	74	68	5032	0.92	0.38	5.03	3.42
4	32	29	928	0.91	0.28	11.14	3.23

In order to test barrier properties of the knitted fabrics, a measuring system was used, consisting of Rohde & Schwarz analyzer and basic TE 10 waveguide modes. In such type of waveguides the electric field is parallel to the shorter side and energy propagates along the shortest possible path (Fig. 2). The two-port vector circuit analyzer allows the measurements of vector networks with frequency ranging from 10 MHz to 14 GHz. The signal source is placed on one side of the device and the power meter is installed on the other.

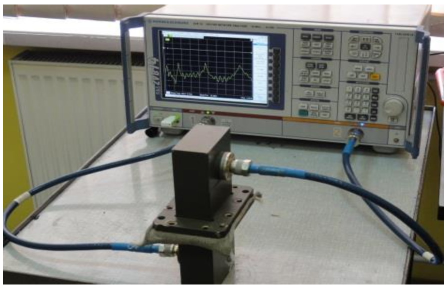

Figure 2a. Analyzer of electromagnetic waves attenuation.

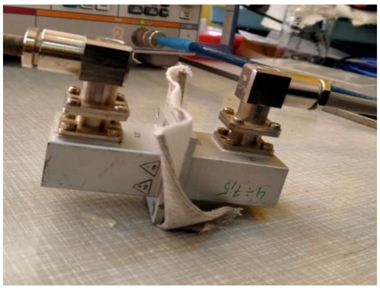

Figure 2b. Placing the sample in the measuring head.

Figure 2c. Waveguide 4 – 7GHz.

Two types of waveguides were used for the measurements, the first one with border frequencies from 2 to 4 GHz and the other from 4 to 7 GHz. For each variant of the knitted fabric, measurements were made in both frequency ranges, along the wales and courses.

The basic parameter describing shielding properties of a given material is its shielding efficiency (SE). It is attenuation indicator of electromagnetic field at a given point in space, which is caused by introducing a shielding material between that point and the source of electromagnetic field. For the tested knitted fabrics shielding efficiency was expressed in decibels (dB). This unit is mainly used in radio engineering and telecommunications.

RESULTS AND DISCUSSION

Significant differences can be noticed in the measurements results of barrier properties of the tested knitted fabrics, depending on their structural parameters, what showed the Figures 3, 4, 5 and 6.

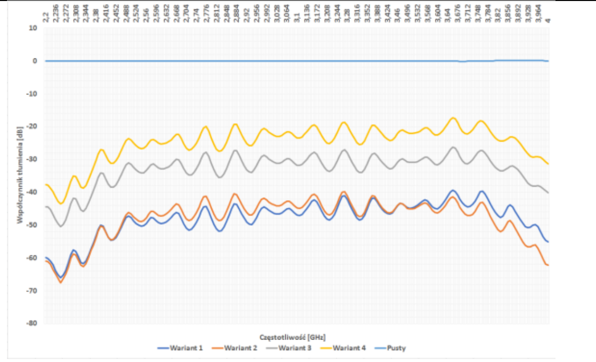

Figure 3. Attenuation along courses, frequency range 2–4 GHz.

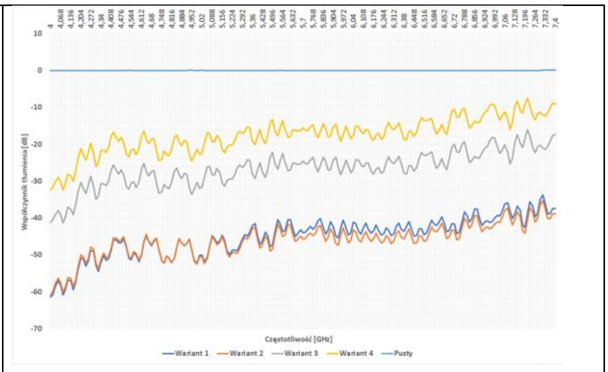

Figure 4. Attenuation along courses, frequency range 4 –7 GHz.

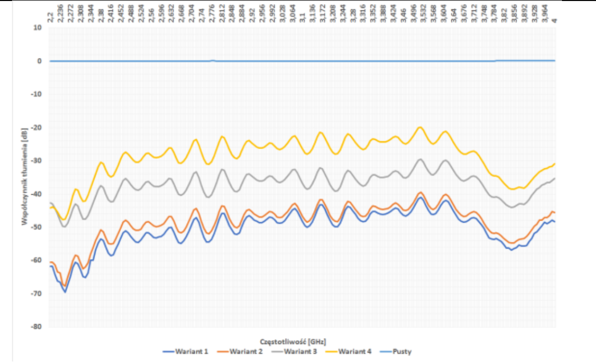

Figure 5. Attenuation along wales, frequency range 2–4 GHz.

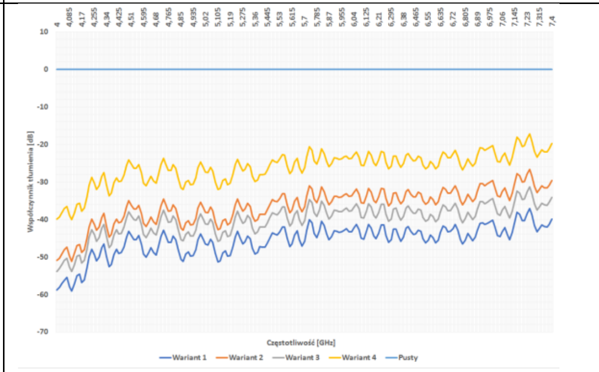

Figure 6. Attenuation along wales, frequency range 4–7 GHz.

The conducted attenuation measurements showed that in the whole range of tested frequencies, the selected variants of shielding fabrics are characterized by good attenuation properties. It was observed that the shielding effectiveness decreased slightly with the increasing wave frequency, which was especially apparent for high frequencies. These attenuation properties were also affected by the fabric direction in relation to the waveguides.

In case of measurements taken in full frequency range from 2 to 7 GHz, the best shielding properties were demonstrated by variants 1 and 2 (full cover) for which the SE indicator takes average values from 68 to 36 dB for electromagnetic wave attenuation along the courses, and from X to Y for attenuation along the wales. For a-jour fabrics (openwork structures), variants 3 and 4 the attenuation properties are much worse and in the direction of the courses SE equals from 50 to 11DB, while in the direction along the wales it is from 54 to 18DB. An interesting case which is worth a more thorough analysis is variant 3, which demonstrates good shielding effectiveness for high frequencies from 4 to 7GHz. These results are within the SE limits for knitted fabrics with high cover factor- variants 1 and 2. It can be explained by specific loop geometry, where the coefficient C = 0.92.

CONCLUSION

Based on the conducted research, it was found that:

- Variants with high loop density resulting in higher cover factor are characterised by about 44% better shielding efficiency against electromagnetic waves,
- The arrangement of courses and wales in relation to the radiation source has a significant impact on shielding effectiveness. Better shielding properties were observed for knitted fabrics arranged so that the direction of the courses was parallel to the shorter side of the waveguide,

- Generally, all the produced and tested knitted fabrics with plain stitches made of threads characterized by high electrical conductivity demonstrated good screening properties, and for low frequencies within 2 - 4GHz SE rates are very good (71 - 58db),
- -The obtained research results are quite promising and can be a good starting point for further design and modelling projects concerning optimization of barrier properties of knitted fabrics applied in protective clothing for people with special needs.

REFERENCES

[1] Lamża Ł., *Pole elektromagnetyczne a człowiek*, Ministerstwo cyfryzacji, Warszawa 2019, p. 131.

[2] Białoszewski P., *Pole elektromagnetyczne w środowisku – opis źródeł i wyniki badań*, Główny Inspektor Ochrony Środowiska, Warszawa 2007, p. 76.

[3] Rydzyński, K., *Oddziaływanie elektromagnetyczne fal milimetrowych na zdrowie pracowników projektowych sieci 5G i populacji generalnej*, Narodowy Program Zdrowia, Instytut Medycyny Pracy Łódź 2018, p. 112.

[4] Magiera A., Olecka I., *Telefonia komórkowa i jej wpływa na zdrowie ludzi*, Rocz. Państwowego Zakładu higieny, Wydawnictwo PZH 2019, no 3, pp. 225-235.

[5] Bortkiewicz A., *Badania skuteczności biologicznych działań PEM o częstotliwościach emitowanych przez telefony komórkowe*. Medycyna Pracy, 2001, no 2, pp. 101-106.

[6] Gherardini L, Ciuti G, Tognarelli S, Cinti C., *Searching for the perfect wave: The effect of radiofrequency electromagnetic fields on cells*, Int JMol Sci. 2014, vol.15, no 4, pp. 5366-5387.

[7] Adams J.A., Galloway T.S., Mondal D, Esteves S.C., Mathews F., *Effect of mobile telephones on sperm quality: A systematic review and meta-analysis*, Environ Int. Elsevier B.V. 2014, vol. 70, pp. 106-112.

[8] Wdowiak A., Mazurek P., *Wpływ pola elektromagnetycznego na rozród człowieka*, Przegląd elektrotechniczny 2016, no 1, pp. 124-127.

[9] Serdyńska M., Pawelczyk L., Jędrzejczak P., *Epidemiologia niepłodności* [in:] *Ginekologia*, Wyd. Lekarskie PZWL, Warszawa 2008, pp. 465-470.

[10] Żurawski P., Stryła.W., *Efekty biologiczne oddziaływania na człowieka pól elektromagnetycznych niskich częstotliwości*, Probl Hig epidemiol 2011, no 2, pp.167-172.