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Investigation of Woven Characteristics on Electromagnetic Shielding Behaviour

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Abstract. Textiles have been highly applied for electromagnetic shielding purposes due to the increasing concern about health issues caused by human exposure to radiation. Properties of conductive yarn, fabric structure, and garment design have extreme effects on the electromagnetic behaviour and comfort of the final product. Lots of electromagnetic shielding textiles are made of metallic yarns regarding their high electrical conductivity. Therefore, some researchers have worked on electromagnetic shielding textiles made of metals. For example; the shielding effectiveness of woven fabrics made of hybrid yarns containing stainless steel wire was investigated. As discussed earlier, the fabric structure has significant effects on electromagnetic protection. Consequently, woven samples were produced using two different commercial electroconductive yarns (PA12 coated with Ag and Inox) to investigate the effects of the fabric structure. The main purpose was to define the best pattern among three basic woven patterns leads to the highest electromagnetic shielding. Moreover, the different weft yarn densities were applied to examine the effects of yarn density on the level of electromagnetic shielding. The electromagnetic shielding effectiveness of all the 2-layer samples was evaluated in the frequency range from 0.8 to10 GHz in an anechoic chamber. The woven sample with higher yarn density of PA12 coated with Ag yarns shows higher protection against radiation. To conclude, the results show that the yarn properties play the main role in shielding as well as yarn density and fabric pattern.

1. Introduction

These days, electrical devices such as mobile cell phones, microwave ovens, televisions and etc. are used all around the world. These electrical devices emit non-ionizing electromagnetic waves into our living environment. The range of electromagnetic waves shows in Figure 1. There are two main categories for electromagnetic waves based on frequencies (ionizing and non-ionizing). Although the detrimental effects of non-ionizing radiation are less than ionizing radiation, it is a source of some health problems on a human body for example: raised body temperature, vertigo, headache, and fatigue and weight loss for both mother and fetus during pregnancy period. This work has focused on waves are emitted by microwave ovens and cell phones which belong to non-ionizing radiation category (1-10 GHz) as it can be seen in Figure 1 [1].

Textiles have been extremely considered in applications of electromagnetic interface shielding [2]. The electrically conductive materials which can generate and transport free charges lead to electromagnetic shielding effectiveness and higher conductive products generally have better electromagnetic shielding effectiveness behavior. This is the reason that metals have been applied to improve the electromagnetic shielding effectiveness of textiles. For instance, the shielding effectiveness of woven fabrics made of hybrid yarns was investigated [3]. Hybrid yarns containing stainless steel wire were produced and then eight different fabric patterns were manufactured using them. The shielding effectiveness measurements of these fabrics have been done in the frequency range of 30 MHz-9.93 GHz and it showed that the shielding effectiveness was affected by fabric structure, yarn directions, density and settlement type of conductive hybrid yarn in the fabric.

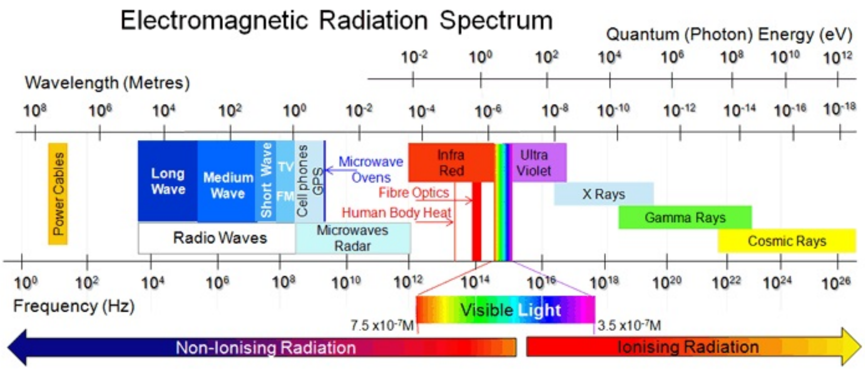

Figure 1. Electromagnetic radiation spectrum [1].

2. Experimental procedures

2.1. Electromagnetic shielding effectiveness tests

The method of determining the level of electromagnetic waves reduction for a medium often varies according to the particular shielding application. Some of the common techniques for testing shielding effectiveness for textiles are listed as below [4-7].

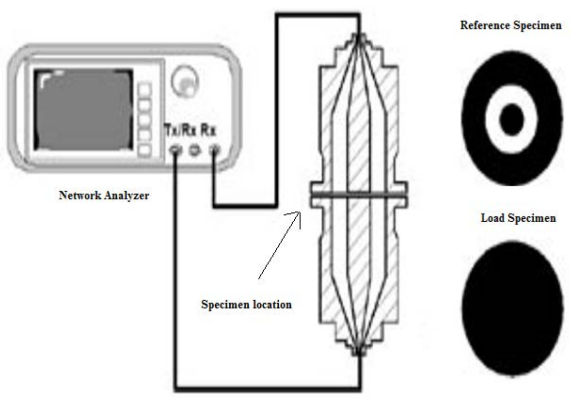

Figure 2. Measurement test setup for a method act in accordance with ASTM D4935-99 [6].

Coaxial transmission line test: This test method is used to define the shielding effectiveness of planar materials which measures plane-wave field electromagnetic wave radiation. A reference testing device is located in a holding unit and the voltage receives at a specific frequency is recorded. Then, the subject is replaced by a load device, which experiences the same test under the same conditions. A comparison between the reference and the load devices launches the ratio between power received with and without a shielding material. This test is based on ASTM D4935-10, 99 and the setup is shown in Figure 2 [6].

The results obtained in different laboratories with this method are comparable and it is considered the main benefit of this method. Also, this method can be used to resolve the records into reflection, absorption and transmission components. The main drawback of this method is that the procedure should be repeated at different frequencies. Obviously, this approach is time-consuming and takes several hours to make a spectrum [6].

Shielded box test: an anechoic chamber with a cutout portion is employed for shielded box test as it can be seen in Figure 3. A conductive coated shielding unit is positioned on the box’s opening and transmitted and received radiations are measured. The electromagnetic signals from both inside and outside the box are recorded and the shielding effectiveness of specimen is defined using the ratio of signals in equation (1). This method has been applied to evaluate shielding effectiveness of textile products [6].

This method is used for comparative tests in order to compare the shielding effectiveness of different specimens. The main problems of this method are that a sufficient electrical contact between test specimen and the shielded box is challenging to achieve and the frequency range is limited. Also, it is possible to put all the outside facilities in another room while the specimen is located in the opening between two rooms to achieve more accurate results. This approach is known as shielded room method which has been developed to overcome the limitations of the shielded box method considering the frequency range and accuracy [7].

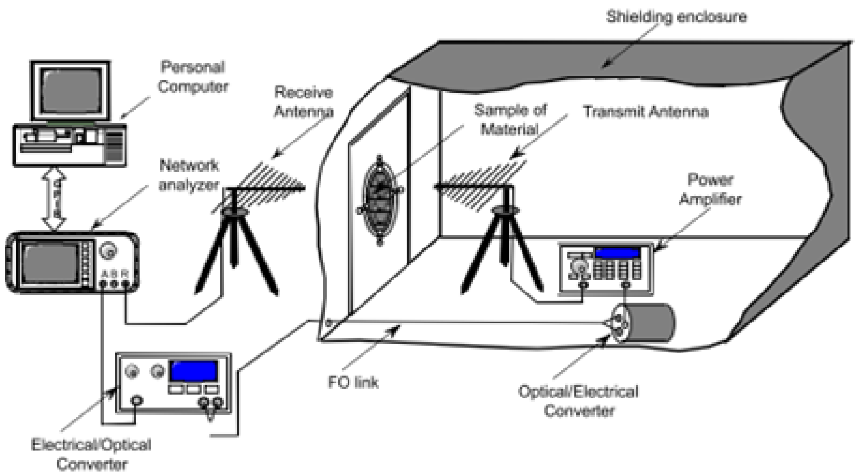

Figure 3. Adaptation of shielding effectiveness measurement method using the shielded box [6].

2.2. Experimental

The fabric structure and properties have significant effects on electromagnetic protection value. To investigate these effects, seven different woven samples have been made using two different commercial electroconductive yarns. The main purpose was to define the best pattern among three basic woven patterns to achieve the highest electromagnetic shielding. Also, the different weft yarn densities were applied to investigate the effects of yarn density on the level of electromagnetic shielding. Table 1 represents the characteristics of the samples. The shielding effectiveness of all the samples was evaluated using anechoic chamber in the frequency range (0.8-10 GHz).

The shielding effectiveness of 2-layer samples were measured since it is required to have conductive yarn in both horizontal and vertical direction to gain the shielding effectiveness.

Table 1. Different fabric samples properties.

Weft yarn**	Sample number	Pattern	Weft density (yarn/cm)	Areal density (g/m2)	Thickness (mm)	Volume Electrical conductivity (S/m)
PA12 coated with Ag	S1	Plain	16	102	0.58	18 ±2
	S2	Plain	8	121	0.46	250 ±24
	S3	Twill 2:2	16	105	0.68	310 ±30
	S4	Twill 2:2	8	118	0.54	428 ±13
Inox	S5	Plain	8	503	0.75	12 ±1
	S6	Twill 2:2	8	520	0.95	146 ±35
	S7	Satin 5	8	516	0.89	121 ±20

** Warp yarn is wool for all the samples

3. Results and discussions

As results display samples with Twill and Plain patterns and weft density (16/cm) shows the highest shielding effectiveness through all the samples. It is noted that the weft yarn for these samples was PA coated with Silver. It means that the higher yarn density leads to higher protection against radiation since sample S1 and S3 showed higher protection compared to S2 and S4.

To compare the pattern effects on shielding effectiveness, S5, S6 and S7 were compared and the results confirm that sample with Plain pattern shows higher protection followed by Twill pattern and the minimum shielding belongs to satin pattern.

Samples S4 and S6 were compared to see the effect of yarn properties on shielding. Although the results were really closed to each other, the shielding effectiveness of sample with PA coated with Ag as weft yarn showed higher shielding effectiveness. It is noted that the shielding effectiveness was between 40-50 dB for all the samples.

4. Conclusions

Textiles have been highly applied for electromagnetic shielding purposes due to the increasing concern about health issues caused by human exposure to radiation. The fabric structure has significant effects on shielding effectiveness. As a result, woven samples were produced using two different electroconductive yarns (PA12 coated with Ag and Inox). The main purpose was to define the best pattern among three basic woven patterns leads to the highest electromagnetic shielding. Also, the different weft yarn densities were applied to examine the effects of yarn density on the level of electromagnetic shielding. The electromagnetic shielding effectiveness of all the 2-layer samples was evaluated using anechoic chamber. The woven sample with higher yarn density shows higher protection against radiation. In addition to, the woven pattern and electrical conductivity of the yarn have influences on shielding effectiveness of the woven fabric. To conclude, the results show that the yarn properties, as well as yarn density, play the main role in shielding effectiveness of the final products.

5. References

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