ELECTROMAGNETIC SHIELDING WITH THE TEXTILE STRUCTURES

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Abstract
The equipment and methods of measuring microwave electromagnetic field in textiles is presented. The results of measurement can help to optimize the textile structure for electromagnetic shield application. The assignment of textile structure resistance against electromagnetic smog is required. The main objective is searching for assessing of electromagnetic fields passing through textiles, especially in the microwave range.
Key words: microwave electromagnetic fields, electromagnetic smog, compatibility, shield, textile structures

1. Introduction

The electromagnetic smog is called undesirable electromagnetic fields and waves which arise particularly as a result of technical activities of human. These problematic fields and radiation are found wherever the electrical equipment is used or using electromagnetic waves for transfer energy (microwave own) or information (mobile communication). These fields have influence on electrical equipment, to humans as well. Everything must be adjusted by the standards and it is deal about absorbed or radiated electromagnetic energy.

2. Theory

The electromagnetic field is the vector field. Maxwell's equations together with the continuity equation, Lorenz equation of forces and material relations form are the basis of the theory of electromagnetic fields. We can derive all known phenomena in this field with their help. Range of electromagnetic waves is from long radio waves to gamma rays. Each frequency range has its own specifics and technical application. For example, microwaves have frequency range 300 MHz to 300 GHz. It corresponds with the wavelength of 1 mm to 1 m. This range is widely used in industrial applications. Here we present only some applications:

- Ground services - The information is transmitted between the transmitter and receiver using the directional beam of microwave energy.
- Satellite Communications - The transmission of information uses the transponder between the network stations. The geostationary satellite is used on orbit.
- Mobile phones - They operate at frequencies of 900 Hz or 1.8 GHz.
- Navigation - Radar works in the microwave band.
- Microwave sensors - They can be realized for measuring speed or changes. Sensors to detect movement in a specific area and sensors to measure humidity. It works on the principle of the Doppler Effect.
- Medical applications - The microwaves are used in many medical areas such as oncology, urology, cardiology, surgery, even a microwave scalpel.

Important parameters are frequency and material constants such as conductivity, permittivity and permeability. These parameters have influence on shielding. With these constants the character of electromagnetic field is changed. This environment can be divided into:

• Linear, nonlinear – The parameters ε, μ, σ are independent on the field intensities in the linear environment.
•Homogeneous and heterogeneous - Environment is homogeneous, if the parameters ε, μ, σ are the same in environment. It depends on coordinates.
• Isotropic, anisotropic - Isotropic environment has parameters ε, μ, σ independent on the direction vectors of electromagnetic field.
• Disperse, dispersive - The phase velocity depends on frequency waves in disperse environment.

3. Measure method

The ways to measure of electromagnetic shielding by textile structure are several.
The transfer power is in order μW and mW. Adverse effect of surrounding noise must be disregarded on the construction and measurement.
The problem is that this interference doesn't have constant power in time. We will try about maximum suppression of unwanted noise in the realization of equipment. The distance of antenna of analyzer and transmitter EM field must be adjusted to transmitter power because of overrunning the analyzer scope. Simulations are very convenient before the real building for the first basic idea of the electromagnetic field distribution in space. Thanks to these simulations, we can identify the dimensions of metal parts and adapted to the frequency.
Gigahertz RF Analyzer HF38B solution with log-periodic antenna was bought based on the available information. It works in 800 MHz to 2.5 GHz. (from 2.5GHz to 3.3GHz with reduced accuracy). This device is very sensitive. It works in the range from 0.01 μW / m² to 19.99 μW / m² or 0.01 mW / m² to 19.99 mW / m². The device displays an immediate signal value, RMS signal and maximum peak.
Another method of measurement is an indirect measurement. Results have qualitative character. This method shows us the absorption of electromagnetic energy in the material. These orientation measurements can be used only when the electromagnetic field interacts with material and generate heat. It is evaluated by thermo camera. This measurement tells us the distribution of electromagnetic field. Wave is more muted with increasing distance from the source, e.g. Fig. 1.

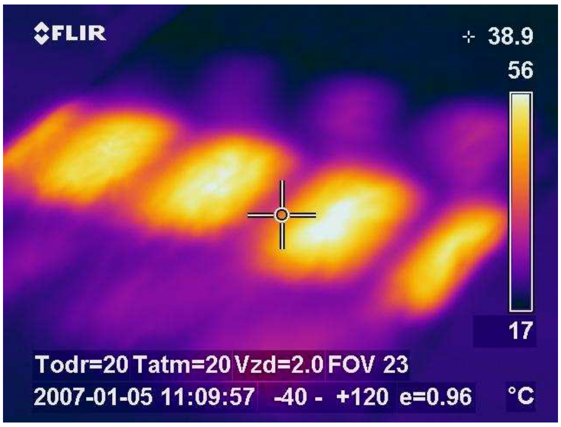

Figure 1. Distribution energy in waveguide

4. Simulations

The measurement by the waveguide which transmits electromagnetic energy was chosen.
We know the distribution of electromagnetic field inside the waveguide if the waveguide dimension is in relation to frequency. There is the high shielding of surrounding noise. The disadvantage is that one waveguide may be used only for specific frequency band. If the

waveguide is connected to the vector analyzer, we can measure S-parameters. The reflected and expired wave can be determined from it.

The following simple simulation on fig. 2 gives us an idea about the distribution of electric field intensity, where the textile material stands in the way of wave. As you can see, the amplitude of the electric field is reduced thanks to textile material (it depends on the properties of textile material).

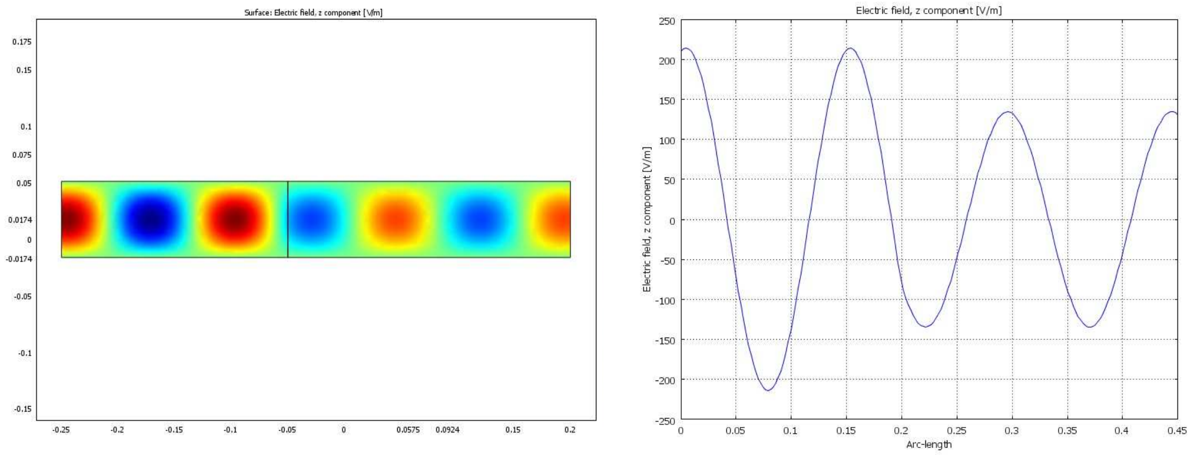

Figure 2. Simple 2D simulation

The following fig. 3 presents simulation real model. Electromagnetic wave is generated by an antenna which is located in front of the waveguide. Textile material stands in the way of electromagnetic wave. Some energy is reflected and absorbed. The important part is energy absorber, which it is located at the end of waveguide.

The problem arises at the interface of two materials at the end of the energy absorber and air, the opened end of waveguide as well. There is a reflection of electromagnetic wave back into the waveguide in these parts.

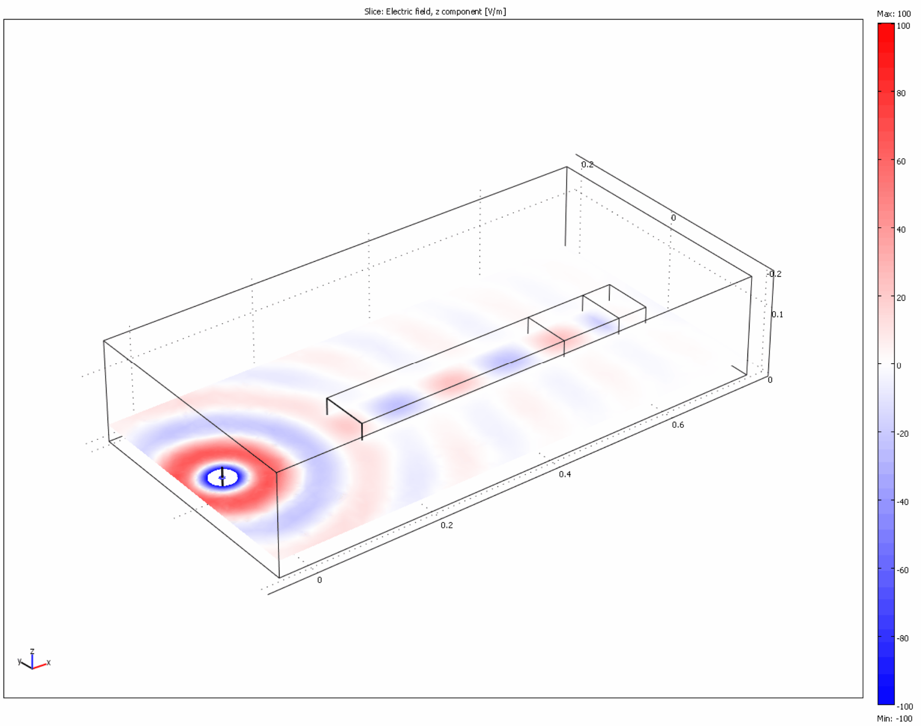

Figure 3 Real 3D model of waveguide

5. Measurement device

The whole device consists of two waveguides with the flanges. One part of the waveguide has measuring antenna where the Analyzer HF38B is connected. Textile material is placed on the input of waveguide. The end of the waveguide contains special foam with carbon for maximal absorption of energy. The textile material is oriented perpendicular to the wave. Transmitting antenna is located in an area near the input of waveguide. The ZigBee module is applied here like a source of EM field. The operation frequency is 2.4 GHz. The whole measurement device is shown on the fig. 4.

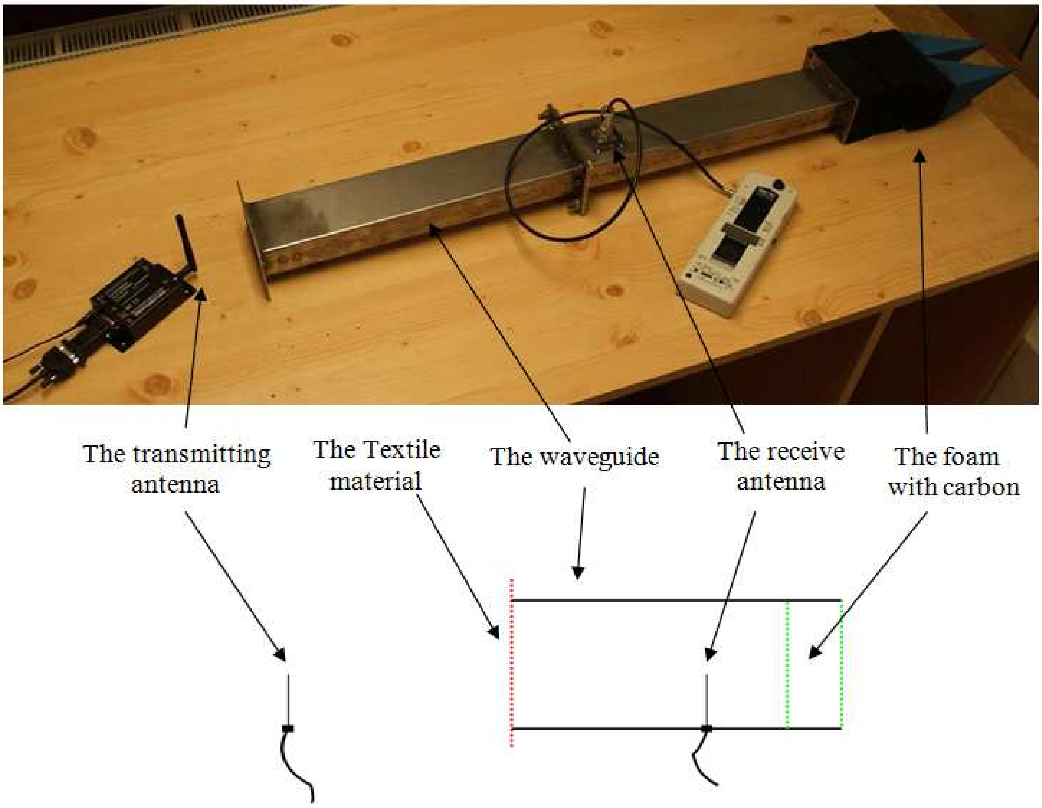

Figure 4 The measurement device

The measurement principle is based on two measured values.
The power density without the textile material is measured first. Then the power density is measured with covered input by textile material. The attenuation of EM fields is counted from these two values by formula

$$SE = 10 \log \frac{P_1}{P_2} \tag{1}$$

where P_1 is the power density with a textile material and P_2 is the power density without the textile material.
The following table 1 shows the measured values for some materials. The metal fibers have influence to shielding which they are contained in textile material. The advantage is that thin layer of metal fibers have a large EM reflection. The disadvantage is that these textile

materials with metal fiber are very expensive. We can use textile material with carbon if we want to absorb energy by material. But, the material thickness must be in several centimeters.
I would recommend finding the dependence of percentage of metal fibers in textile material on shielding.

Table 1. Measured data

Textile material	P_1 [W/m^2]	P_2 [W/m^2]	SE [dB]	[%]
99% PES, 1% metal	1,16E-03	1,28E-05	19,69	98,8991
99% PES, 5% metal	1,17E-03	5,99E-06	23,06	99,4872
non-woven fabrics with out metal	1,17E-03	8,91E-04	1,17	23,6439

6. Conclusion

The study shows the possibility of measuring attenuation of the electromagnetic field. We will try to refine the results and the usage of a vector analyzer for the measurement in the future. Most of the attention is devoted to method of measurement of electromagnetic waves in space. The measurement must be adapted to frequency band. Here is described one method of measurements, which is supported by simulations.

7. Acknowledgements

This work was supported by the student grant SGS 2010/7821 - Interactive mechatronic systems in technical cybernetics and funded by the project TIP - Fabrics with the increased comfort and resistant to electromagnetic radiation FR - TI1/122. The authors thank to Czech Grant Agency under grant 102/08/H081 for assistance in electromagnetic field modeling.

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