Simulation of Shielding Effectiveness of Materials using CST Studio

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Abstract: - Recently, the development of electronic and electric devices has caused an increase in the level of electromagnetic radiation; therefore, the demand for protection against this danger has increased. There are many ways how to ensure the protection of device against electromagnetic interference; however, this paper is devoted just one of the ways, the shielding. The paper is focused on calculation of shielding effectiveness of material used to protect facilities. The results of the experiment are made by using of CST simulation software. The findings presented in this study serve to find suitable shielding material.

Key-Words: - Shielding effectiveness, CST Studio Suite, electromagnetic interference, electromagnetic susceptibility, attenuation, shielding material, electromagnetic simulation

1 Introduction

Electromagnetic interference has become the serious problem for all electronic and electrical devices; that is why the demand for protection of devices against this danger has increased. This paper describes one of the ways how to ensure the electromagnetic immunity of device against radiated electromagnetic emissions. This way is meant the using of shielding material. Calculation of the shielding effectiveness of these materials was performed by using CST Studio Suite simulation software, which is the suitable tool for this experimental attempt. The research is focused on obtaining information about the properties of shielding materials.

Electromagnetic interference and susceptibility are two parts of the term called electromagnetic compatibility. This term means nothing more than an electronic and electrical device or system is able to resist to the impact of electromagnetic interference, and at the same time, this device or system can not affect other devices in its electromagnetic environment. The definition includes two basic areas which characterize the terms electromagnetic interference and immunity.

Electromagnetic interference is a process wherein the signal generated by the source of interference is transmitted via electromagnetic constraints to disturbed systems. EMI is concerned with identifying causes of disturbance. [1] To achieve adequate levels of electromagnetic interference is necessary to pay attention to all components and shielding during the development of the facility. [2]

Conversely, electromagnetic susceptibility is defined as the ability of device or system to operate without a fault or with strictly defined permissible influence in the electromagnetic environment. The aim of electromagnetic susceptibility is to increase the electromagnetic immunity of interfered equipment by technical means. EMS mainly studies the elimination of the consequences of interference than identifying its causes. [3]

Electromagnetic interference can be limited in three main areas, namely at the source of the disturbance, at the receiver and in the transmission route. For the purpose of this work, it is necessary to restrict noise coming into the receiver because there are many interference sources and it is not possible to eliminate all of them. Depending on the method of interference propagation, the means to reduce unwanted noise fall into two categories, namely disturbance by conduction and radiation. In the case of conducted interference, the device is equipped with EMI filters, chokes, capacitors; it is also possible to change the transmission medium or arrangement of circuits. Radiated interference is reduced by selecting a suitable shielding. [4]

Shielding can be defined as a structural means to reduce interfering electromagnetic fields within a defined area. In other words, it protects the devices against unwanted external electromagnetic interference and simultaneously it prevents leakage of electromagnetic disturbance from the device. [4]

2 Shielding Effectiveness

The significant parameter in this area is shielding effectiveness that describes how the material eliminates the effects of electromagnetic radiation from the interference source. [4] According to [5], shielding effectiveness is defined as a ratio of the received signal from the transmitter without shielding to the received signal inside of shield. In other words, it represents the insertion loss when the shielding material is placed between the transmitting and the receiving antenna. [5] According to [5], there is also defined the term known as shielding enclosure. The shielding enclosure represents a structure protecting its interior against the effect of an exterior electric or magnetic field, and at the same time, it protects the environment of the structure against the effect of an interior electric or magnetic field. A high-performance shielding enclosure is able to reduce the impact of electric and magnetic field strengths by to seven orders of magnitude depending on current frequency. The shielding structure is mostly created by the metal material with continuous electrical contact between adjoining panels, including doors. [5] As can be seen, the definition is similarly the one defining the electromagnetic compatibility mentioned in the introduction of this paper.

According to [6] and [7], this parameter can be described by the following equation.

$$SE = 10 \cdot \log \frac{P_1}{P_2} [dB] \tag{1}$$

Individual characters indicate:
P_1 – power generated by interference source;
P_2 - power passing through the shielding material.

This equation is also shown in the publication [5], which describes mathematical shielding relationships depends on frequency. These mathematical relationships are following:

- 9kHz – 20MHz

$$SH = 20 \cdot \log \frac{H_1}{H_2} [dB] \tag{2}$$

$$SH = 20 \cdot \log \frac{V_1}{V_2} [dB] \tag{3}$$

- 20MHz – 300MHz

$$SE = 20 \cdot \log \frac{E_1}{E_2} [dB] \tag{4}$$

- 1.7GHz – 18GHz

The mathematical relationship for this frequency range is the same as (1).

The equation (1) can be adjusted into a form which better corresponds to the physical mechanisms of the shielding effect. [4] This adjustment is described in publications [6] and [7].

$$SE = R + A + M [dB] \tag{5}$$

Individual characters indicate:
R - attenuation by reflection;
A - absorbent attenuation;
M - attenuation caused by multiplied reflection.

2.1 Attenuation by Reflection

This type of attenuation indicates how much energy is reflected at the interface between the dielectric with the impedance of Z_0 and the metal barrier with the impedance of Z_M. The same situation occurs on the output between the metal barrier and the dielectric. [4] According to [6] and [7], the attenuation can be written as follows.

$$R = 20 \cdot \log \left| \frac{Z_0 + Z_M}{2Z_M} \cdot \frac{Z_0 + Z_M}{2Z_0} \right| [dB] \tag{6}$$

$$R = R_1 + R_2 [dB] \tag{7}$$

Individual characters indicate:
Z_0 – impedance of environment (dielectric);
Z_M – impedance of material.

2.2 Absorbent Attenuation

This type of attenuation occurs by absorption of energy by the shielding material due to heat losses. [4] According to [6] and [7], the equations can be written as follows.

$$A = 20 \cdot \log e^{\frac{t}{\delta}} [dB] \tag{8}$$

$$\delta = \sqrt{\frac{2}{\varpi \mu \sigma}} \tag{9}$$

Individual characters indicate:
t – material thickness;
δ – intrusion depth;
σ - conductivity;
μ - permeability;
ω – wave frequency.

2.3 Attenuation Caused by Multiplied Reflection

In the case, when the electromagnetic wave passes through the shielding material, then there are multiple reflections on the interfaces between environments. If ($t >> \delta$), the impact of multiple reflections is negligible; conversely, if ($t << \delta$) then the attenuation is negative and shielding effectiveness decreases. According to the information given in publications [6] and [7], the attenuation may be described by the following equation. [4]

$$M = 20 \cdot \log \left| 1 - \left(\frac{Z_0 - Z_M}{Z_0 + Z_M} \right)^2 \cdot e^{-\frac{2t}{\delta}} \cdot e^{-j\frac{2t}{\delta}} \right| [dB] \quad (10)$$

Individual characters indicate:
Z_0 – impedance of environment (dielectric);
Z_M – impedance of material;
δ – intrusion depth.

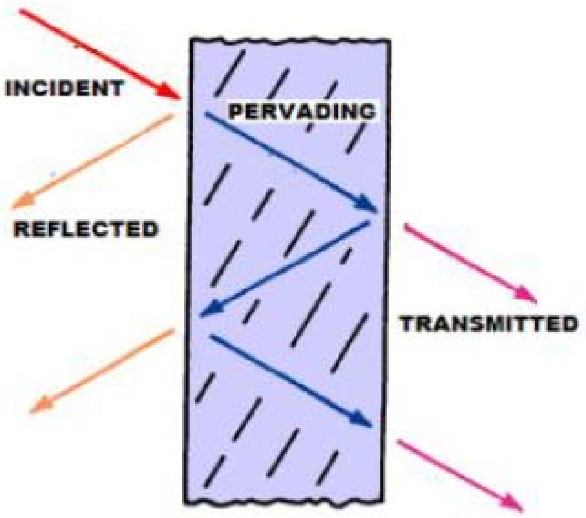

Fig. 1. Attenuation by Multiplied Reflection. [7]

3 CST Studio Suite

The whole process of calculation of shielding effectiveness was performed using CST Studio Suite simulation software. CST Studio Suite software represents a comprehensive simulation tool to deal more tasks than just electromagnetic simulation. It can be used also to solve the issue such as circuit simulation, shielding effectiveness, mechanical stress or temperature of components. The simulation software contains several simulation algorithms based on time, frequency or integral domain including:

- Finite Integration Technique (FIT)
- Transmission Line Matrix (TLM) method
- Finite Element Method (FEM) [8]

Solver use is dependent upon required task; however, all these solvers can be used to solve one problem without having to create new objects. CST Studio Suite allows to couple more tasks into a single complex task which can combine a circuit, cable, shielding, mechanical stress or thermal simulation. [8]

It leads to another advantage of this simulation software the opportunity to combine circuit and 3D elements into one project. The electrical connections between single elements can be set and placed in a 3D layout. The designer is able to watch multiple simulation tasks at the same time such as drawing and behavior of designed object. [9]

4 Experiment

The software is suitable for this experiment because it includes a wide database of materials. As representatives of shielding materials, steel and aluminum were selected. These materials are readily available and suitable for use with security devices. In addition, both materials are relatively cheap.

The process of simulation began by modelling the shielding material whose dimensions are 1x1m and thickness is 1mm. The receiver and transmitter are located facing each other on both sides of the material. The distance of transmitter and receiver from the material under test is 0.5m. The plane wave serves the source of the electromagnetic field and the probe receives the intensity of field penetrated through the shielding material. For an idea, Fig. 2 illustrates the process of testing where TX antenna replaces the source of the field and the RX antenna substitutes the probe.

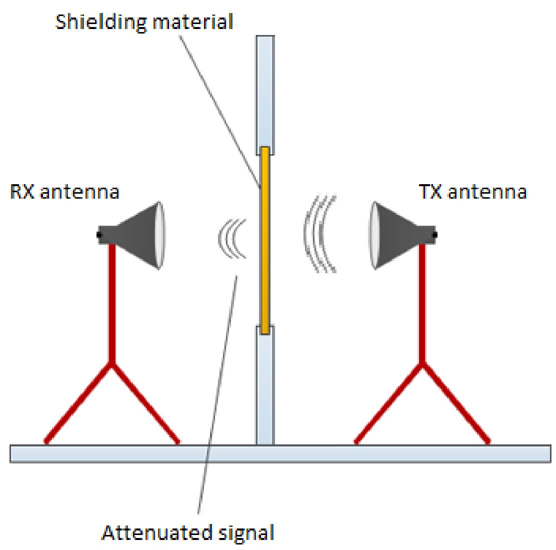

Fig. 2. Testing of Shielding Effectiveness. [10]

4.1 Shielding materials

The shielding material is one of the most famous ways of the device to protect the device against radiated electromagnetic interference. Shielding material can eliminate the level of disturbance and at the same time, it does not require intervention into the electronics of the device. As mentioned above, this paper describes only several representatives of potential materials for shielding purpose. Because CST Studio software includes a large number of materials, the paper describes the properties of selected materials in Tab. 1 and 2. It is necessary to remark that the data is taken from the software database.

Table 1. Parameters of Aluminum

Name	**Value**	**Unit**
Type	Lossy metal	-
Mue	1	-
Electrical conductivity	3.56e+007	S/m
Rho	2700	Kg/m^3
Thermal conductivity	237	W/(mK)
Heat capacity	0.9	kJ/(kgK)
Diffusivity	9.75309e-005	m^2/s
Young's modulus	69	kN/mm^2
Poisson's ratio	0.33	-
Thermal expansion	23	1e-6/K

Table 2. Parameters of Steel

Name	**Value**	**Unit**
Type	Lossy metal	-
Mue	1	-
Electrical conductivity	6.993e+006	S/m
Rho	7870	Kg/m^3
Thermal conductivity	65.2	W/(mK)
Heat capacity	0.45	kJ/(kgK)
Diffusivity	1.84103e-005	m^2/s
Young's modulus	205	kN/mm^2
Poisson's ratio	0.29	-
Thermal expansion	13.V	1e-6/K

5 Results of Simulation

This section describes the results of the electromagnetic simulation which was created by CST Studio software. A number of shielding materials for the purposes of this research is huge; despite this fact, this paper includes only several representatives. Results in this section depict attenuation of the electromagnetic field through the shielding material and it helps to create an idea which material is the suitable choice for increasing of electromagnetic immunity.

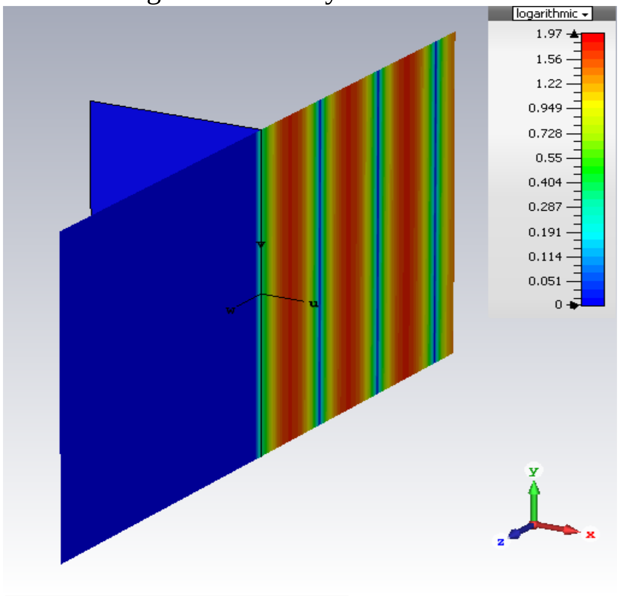

Fig. 3. Shielding Effectiveness of Steel.

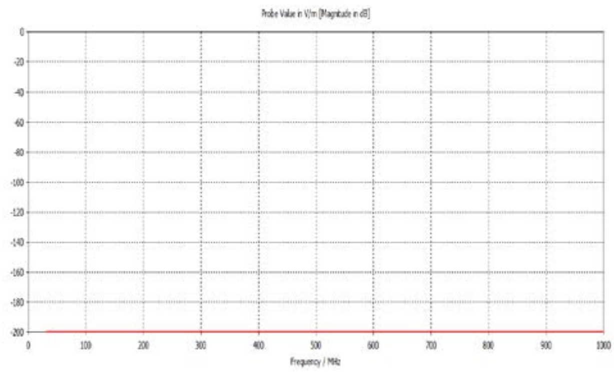

Fig. 4. Shielding Effectiveness of Steel Material. [4]

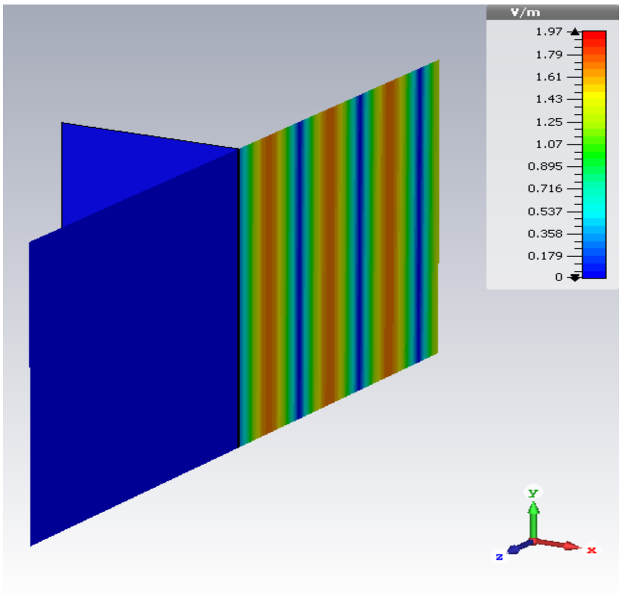

Fig. 5. Shielding Effectiveness of Aluminum. [4]

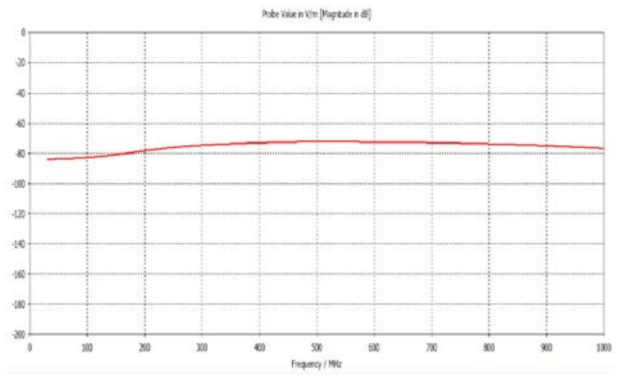

Fig. 6. Shielding Effectiveness of Aluminum Material. [4]

To ensure all functions of devices, cabling should be lead throughout the shielding material for transferring data or to supply power to the device. Therefore, copper wire with a diameter about 1mm is lead throughout the material. The results of shielding effectiveness can be affected by selected wire. It includes the shape, diameter or load of wire.

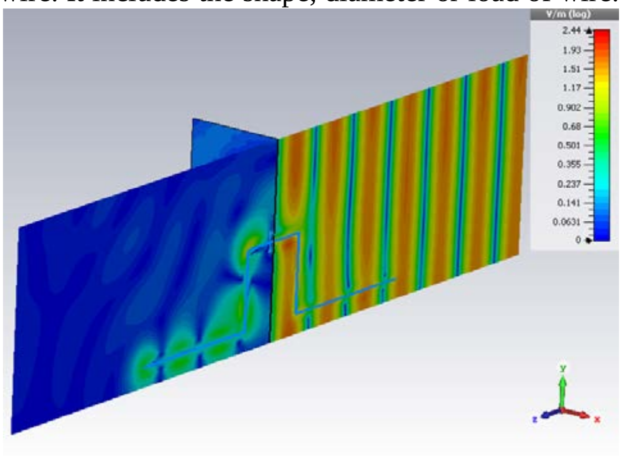

Fig. 7. Shielding Effectiveness of Aluminum when Copper Wire Passing through Material.

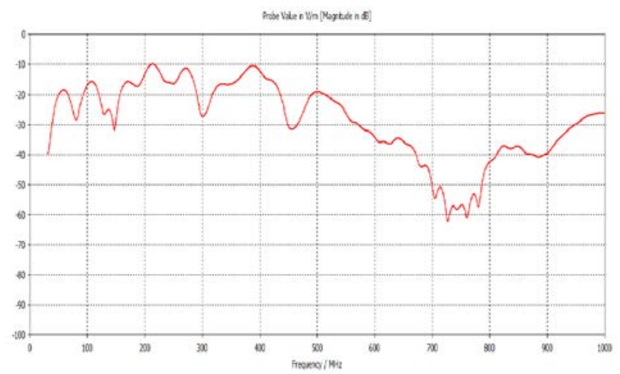

Fig. 8. Shielding Effectiveness of Steel Material through Which Passing Copper Wire. [4]

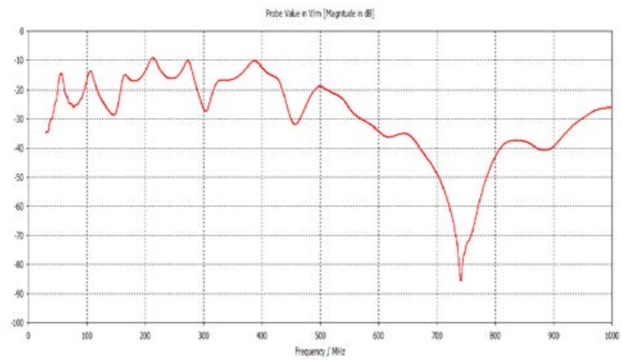

Fig. 9. Shielding Effectiveness of Aluminum Material through Which Passing Copper Wire. [4]

6 Conclusion

The information described in this paper is focused on the calculation of shielding effectiveness of the material. The reason why the paper is devoted to shielding is the topicality of the issue because the reliability represents the most important factor of all devices, the great emphasis must be placed on the electromagnetic immunity. This article summarizes one of the ways how to protect the electronic and electric device or system against electromagnetic interference.

The results of the experiment show that the chosen materials are presented with diametrically different shading properties. Steel appears to be a better choice to protect the device up to frequency 1GHz than aluminum because it is able to resist the effect of the electromagnetic field. In the case of aluminum, the field penetrates with certain attenuation. This information is not immediately clear when looking at a 3D model; therefore, there are also 2D graphs which clarify the situation.

CST Studio Suite software represents a suitable way to experiment with shielding material. One of this experiment is described in the section of results where a simple unshielded copper wire was led throughout the shielding material. In this case, the field can couple to the wire and pass through a sealed material.

The main purpose of this paper is to expand the existing knowledge of shielding materials for electrical and electronic devices. This article will serve as a basis for future research in this research field. Future work can be enriched by a combination of different kind of shielding materials working in the frequency range 80MHz up to 1GHz as the European electromagnetic compatibility standards specify.

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