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The method of material absorption measurement using the HPM generator

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Abstract

The paper presents the developed, original method of material absorption measurement based on the HPM (High Power Electromagnetic Pulse) generator and presents the results of measurements of the level of absorption (scattering) of electromagnetic waves for example absorbent materials. Additionally, the method of generating and measuring HPM impulses is discussed.

1. Introduction

Together with the increasing number of devices generating electromagnetic radiation, there is a need to protect devices and people against undesired electromagnetic radiation. The problem of protection against unwanted radiation is particularly important in the issues of electromagnetic compatibility. One way to protect against the effects of unwanted radiation is electromagnetic shields. In general, two ways of functioning of electromagnetic shields can be distinguished - by reflection of the incident electromagnetic wave or by the absorption of electromagnetic energy. Taking into account the effectiveness of shielding, the ideal electromagnetic shield should be characterized by low reflectivity and high absorption value of incident radiation.

Absorption is a process involving the penetration of molecules, atoms or ions into the interior of another substance that forms any continuous phase - (gas, liquid, solid, etc.). The absorption mechanism consists in the division of the absorbed component between the two volume phases (centers). Absorption is used on a massive scale in technological processes. A component absorbed by a solid is called absorbat, and an object used to absorb a particular ingredient is called an absorbent. In the presented paper there is absorption of electromagnetic radiation by using a solid throughout the volume of the absorbent [2, 5].

Currently, different methods of shielding in the microwave range and different in the low frequency range are used. Electromagnetic shielding in the microwave range are used graphite materials which also are formed as pyramidal pyramid. High efficiency of shielding in the low frequency range is achieved by using ferrite materials having additional magnetic properties [5].

In most cases the walls of the anechoic chambers are lined with two layers, one of which is composed of ferrite plates and the other one of graphite pyramids. However, such shielding methods are only suitable for use in anechoic chambers, since ferrite plates are very heavy and have a solid form, and graphite pyramids occupy a large size. Effective electromagnetic shields should have the following properties [3, 4, 6]:

- work in a specific frequency range or extremely broadband,
- have a solid or plastic form,
- have a specific reflection and absorption coefficient.

The article presents a developed, original method of material absorption measurement based on HPM (High Power Microwave) generator, which allows to learn the absorber properties and presents the results of measurements of the level of absorption (dissipation) of electromagnetic waves by exemplary absorbent materials.

2. High power electromagnetic pulse

High power microwave pulse called HPM is a very short duration pulse (the duration time is a few of nanoseconds) and high power (a few of gigawatts in pulse). The HPM impulse is also called the E bomb due to the possibility of causing irreparable damage to any electronic equipment within the range of such a pulse. Also, it should be noted that so far no harmful effects of such an impulse on living organisms have been found, thanks to which electromagnetic pulses have become known as humanitarian weapons. HPM pulses for the first time were observed as a side effect in outbreaks of atomic bombs, it was also found that the extent of such radiation greatly exceeds the means of destruction yet. Currently, several generation methods of HPM pulse were developed through dedicated generators of electromagnetic radiation.

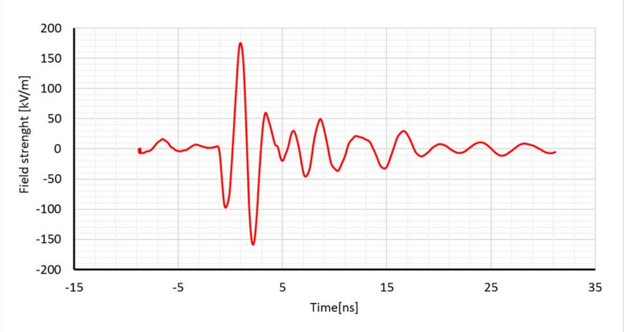

Figure 1. An example of time domain for sample HPM pulse [6]

Destructive action of E bombs depends on the destruction of all electronic equipment based on semiconductor technology, and in particular cases of destroying whole infrastructure of communications and power transmission [1]. Figure 1 shows an appearance of HPM pulse in the time domain, while Figure 2 shows the frequency spectrum of the pulse.

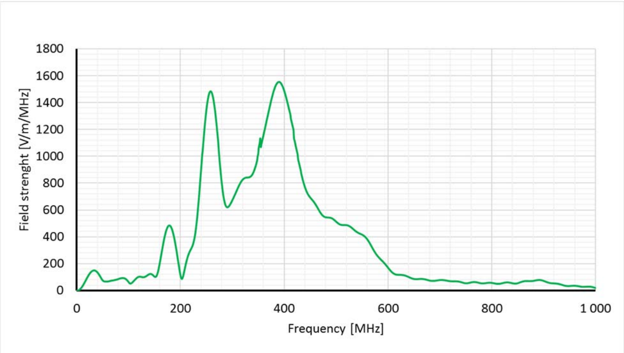

Figure 2. An example of frequency spectrum for sample HPM pulse [6]

3. Description of the method for measuring the absorption of materials

In order to measure the absorption value provided by the sample of the absorbing material to be measured, a measuring set consisting of a measuring signal transmitter (HPM generator) and an electromagnetic field strength meter (HPM pulse measurement system) are required.
Measurement of the absorption caused by the sample of the absorbing material is reduced to two HPM measurements at a specific distance from the material being tested. The first step is the reference measurement during which the impulse from the reference plate is measured, which is not covered by the absorbent material. At certain HPM generator parameters related to HPM pulse generation, the HPM pulse is measured at the field probe installation location. During the reference measurement, the HPM transmit antenna is directed to the reference plate and together with the probe the fields are aligned.
After the reference measurement, the basic measurement should be carried out during which the measurement of the impulse reflected from the plate with the absorbed material is carried out. The measurement conditions at this stage should be identical to the reference stage. The HPM generator parameters and the location of the HPM generator and field probe must be maintained.
Measured HPM pulses from two stages should be stored. In the developed measurement method as a measure of absorption of materials absorbing electromagnetic waves, a relative difference in the levels of frequency spectrum components obtained from the measured HPM pulses in the above two stages was proposed. After subtracting the calculated frequency amplitudes of the stored HPM impulses during the reference and basic measurements, we obtain a difference in levels, which is the value of the absorption brought by the sample material. In order to determine the absorption in a measure [dB], the difference in amplitudes obtained should be calculated as a decibel measure. In this way, the absorption characteristics of the tested material can be obtained as a function of frequency.
The block diagram of the laboratory stand for measuring the absorption of the tested material for the reference measurement is shown in Figure 3. While Figure 4 shows a block diagram of the laboratory stand for measuring the absorption of the material under test for basic measurement.

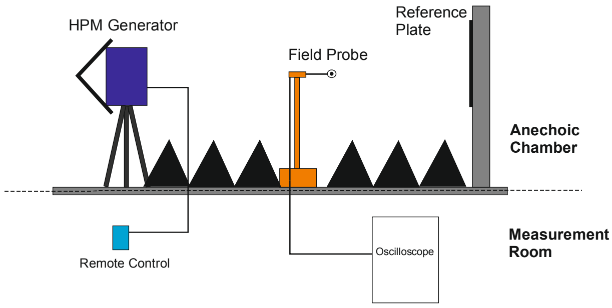

Figure 3. Block diagram of the laboratory stand for measuring the absorption of the tested material for the reference measurement

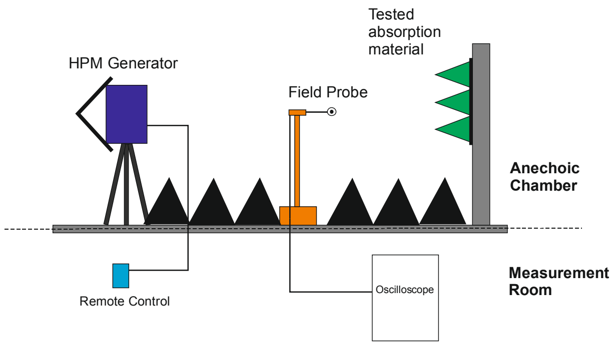

Figure 4. Block diagram of the laboratory stand for measuring the absorption of the tested material for the basic measurement

4. Description of the absorption material samples

The object of the measurement were two types of absorbers with dimensions (120 x 120) cm with applied absorbent material in the form of a sponge saturated with graphite compounds. The first absorptive material tested was the APM12 type absorber from Siepel, while the second absorbing material tested was the APM30 absorber from Siepel. As the reference material, when determining the absorption of individual materials, a metal plate was used without the absorbing material applied.

5. Measurement results

On the basis of the developed method for measuring absorption of absorbent materials using the HPM pulse generator, two absorbers from Siepel were tested. The results of measurements from the conducted research are presented below and step by step the stages realized during measurement and results development are discussed.

The first stage of the measurement process was the measurement of the generated and reflected HPM pulse from the metal reference plate. The results of the measured pulses are shown in Figure 5.

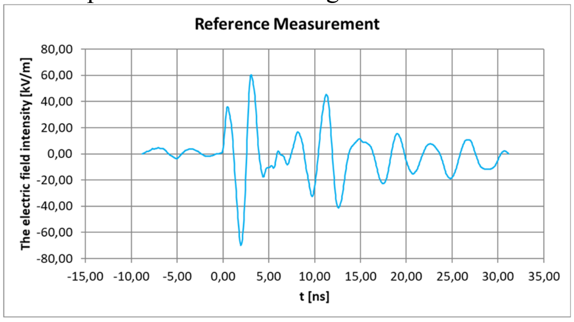

Figure 5. The HPM pulse generated directly from the generator and reflected from the reference plate in the reference measurement

The next stage of the measurement process was the measurement of the generated and reflected HPM impulse from the plate with the absorbing material applied. The results of the measured time and frequency pulses for the APM12 and APM30 absorbers are shown in Figure 6 and Figure 7 respectively.

a)

b)

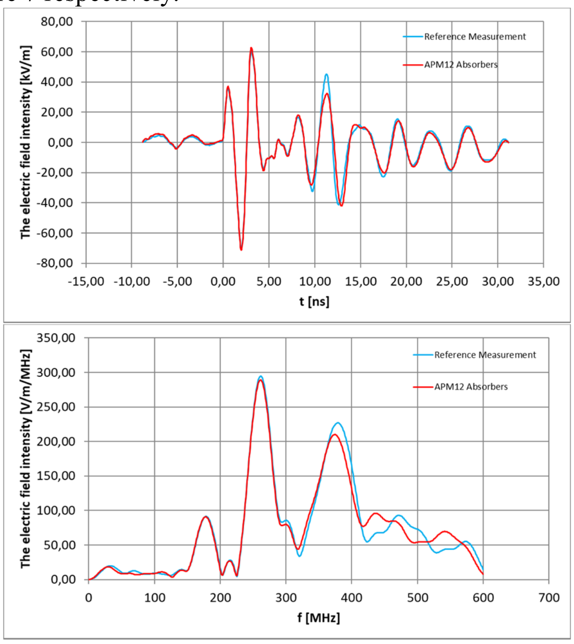

Figure 6. HPM pulse generated directly from the generator and reflected from the reference plate in the basic measurement for the APM12 absorber: a) in the time domain, b) in the frequency domain.

The next stage of the measurement process was the analytical isolation of the reflected HPM pulse from the reference plate and from the plate with the absorbing material applied. The results of the separated impulses reflected from the reference material and the material tested in the time and frequency domain for the APM12 and APM30 absorbers are shown in Figure 8 and Figure 9 respectively.

The last stage of the measurement process was the analytical calculation of the absorption value for the absorbing materials studied and the conversion of these values to a decibel measure. The results of the decibel absorption values for the APM12 and APM30 absorbers are presented in Figure 10 and Figure 11 respectively.

a)

b)

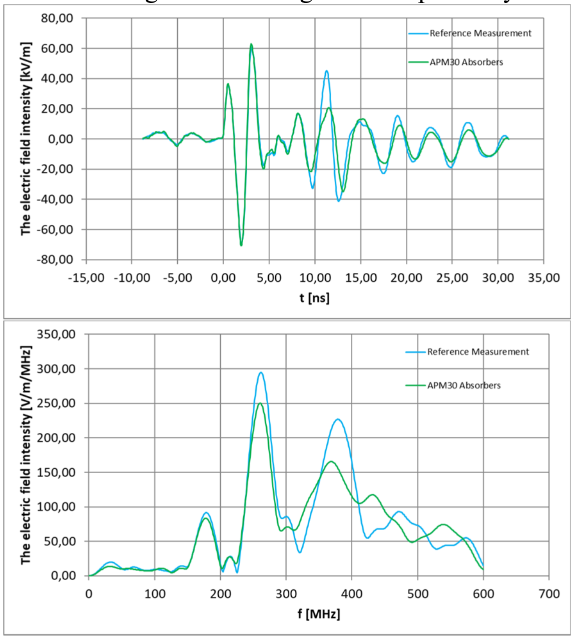

Figure 7. HPM pulse generated directly from the generator and reflected from the reference plate in the basic measurement for the APM30 absorber: a) in the time domain, b) in the frequency domain.

a)

b)

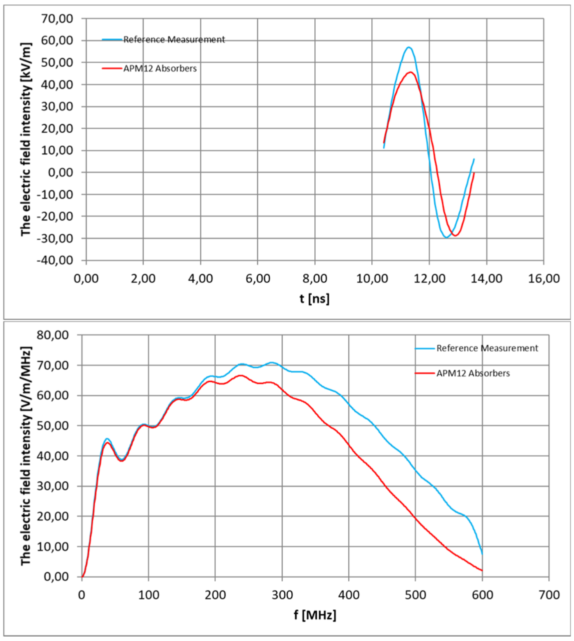

Figure 8. The HPM pulse reflected from the reference plate in the basic measurement of the APM12 absorber: a) in the time domain, b) in the frequency domain.

a)

b)

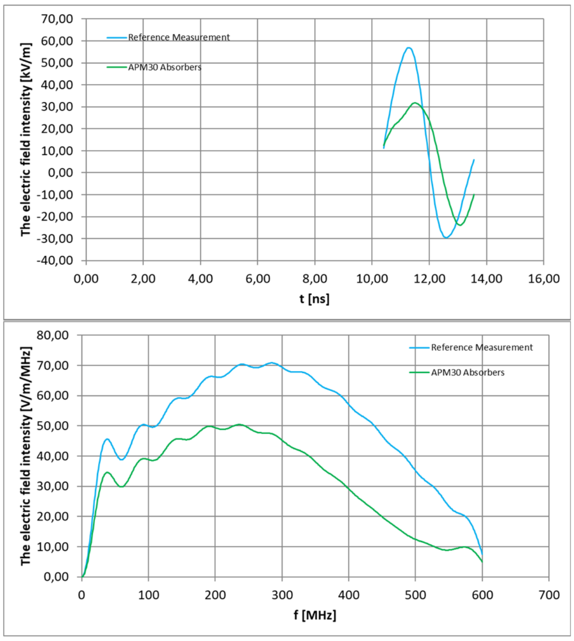

Figure 9. The HPM pulse reflected from the reference plate in the basic measurement of the APM30 absorber: a) in the time domain, b) in the frequency domain.

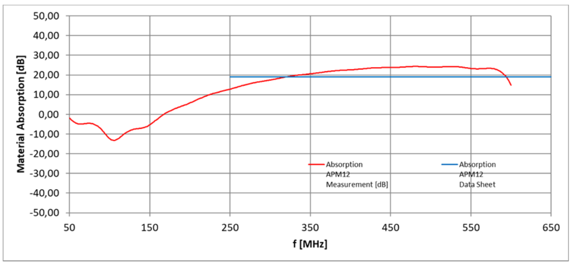

Figure 10. The absorption value as a function of frequency for the APM12 absorber

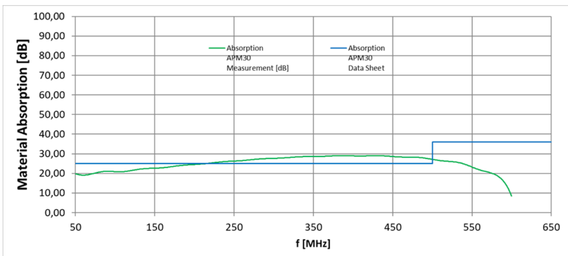

Figure 11. The absorption value as a function of frequency for the APM30 absorber

The results of absorption measurements of APM12 and APM30 absorbers are presented above. The red and green color in the graphs presents the results obtained from the measurements carried out in the anechoic chamber, while the blue color shows the absorption value from the Siepel catalog data. The laboratory stand for material absorption measurements described in the article based on measurements using the HPM generator can be successfully used for comparative studies on the absorption of various materials. The absorption values of these absorbers fully coincide with the catalog data from the Siepel catalogs.

7. Conclusions

The laboratory stand for material absorption measurements described in the article based on measurements using the HPM generator can be successfully used for comparative measurements on the absorption of various materials.

The absorption tests carried out for two types of absorption material as a function of frequency showed that the APM30 absorber is a material absorbing electromagnetic waves in the entire range of tested frequencies, while the APM12 absorber is a material absorbing electromagnetic waves in the frequency range of about 150 MHz. The properties of these absorbers fully coincide with the catalog data from the Siepel catalogs. The advantages of this method include very fast acquisition of the absorption value in the full range of the analyzed frequency and a large dynamic range of the absorption measurement. On the other hand, the disadvantages of the developed method are the relatively high price of the measuring equipment used and the limited frequency range in which we can test the absorption value of the tested materials (from about 50 MHz to about 600 MHz).

8. Literature

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