STUDY ELECTROMAGNETIC FIELD ATTENUATION IN NANOMATERIALS

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Abstract: *This paper presents number of measurement systems and experimental methods for the investigation of nanomaterials behavior inside electromagnetic field (EMF). The measurements systems and methods presented in this paper were developed in order to investigate nanomaterials behavior relative to the influence of electromagnetic fields of different frequencies within a wide spectrum ranging from several tens of MHz up to tens / hundreds of GHz. This paper was written in the framework of the 429/2006 CNCSIS project " Study of the shielding properties of materials obtained by nanotechnologies and nanoprocessing in order to ensure their integration in electrical and electronic systems aimed at improving environment quality".*

Keywords: *nanomaterials, nanotechnologies, electromagnetic field, microwave systems.*

1. INTRODUCTION

The presence of perturbing electromagneting fields in homes and workplaces is the cause of many equipment malfunctions with negative consequences on operating accuracy and safety of electronic circuits.

At present most of the electromagnetic field (EMF) is generated in the microwave range, witch corresponds to the operating frequency range receiving systems. The regulations and standards established by international organization [1,2] include measures reducing the perturbing influence of electromagnetic fields generated by the great variety of equipments so as to comply with electromagnetic compatibility requirements. The regulations include both electromagnetic radiation sources as well as equipments, systems, that cam be affected by the energy of radiating or leakage electromagnetic fields.

Modern science has developed a new class of materials – nanomaterials – resulting from a mixture of material particles with different electrical properties. Nanomaterials, along with materials having determined properties such, as conductors and insulators, are offering new solution in a variety of application a therefore of great interest for scientists and industry researchers. By their structure, the properties of nanomaterials can be characterized by extreme values of electrical conductivity and permittivity which can be determined by controlling their internal composition.

With the rapid development of radio-electronic systems operating on the 10 MHz to 100 GHz frequency range, the electromagnetic field energy attenuation and absorption characteristics of insulating materials and especially of nanomaterials should be measured and determined with accuracy.

2. MEASUREMENT METHODS

During the experimental investigation, several methods were verified for determining the microwave field attenuation produced by the tester material samples.

Following methods were verified:

- the method of microwave field power measurement, using a thermistor bridge;
- the radiofrequency substitution method;
- the detection method of microwave field power measurement;
- the microwave radiation method, using a horn antenna;

- the microwave field power measurement method using the spectrum analyzer;
- the measurement method using the TEM – cell.

By comparing the measurement results from identical samples, using various techniques the most appropriate method of determining material effects could be selected. Thu, the “method of measuring microwave power by radiofrequency detection” is very good method for determining the attenuation of electromagnetic field in nanomaterials. This method, which must be adapted in accordance with the measured while eliminating the influence of perturbing fields and the energy, required in the measuring process. In addition, the results obtained by using the selected measurement method should be in concordance with the results obtained by employing alternative measurement methods and even with computer simulations.

The measurement of microwave field power by radiofrequency detection involves amplitude modulation of the microwave signal using a 10 kHz rectangular wave signal. This will result in amplitude rectangular pulls modulated radiofrequency signal with a 50 % duty cycle. A point-contact diode detector ensures radiofrequency energy detection and applies a voltage signal to the power meter given by [4]:

$$U = \sqrt{P \cdot R_s} \tag{1}$$

where: U – is the detector voltage output;
P – is the power of the detected signal;
R_s – is the detector load resistance.

The utilized power meter displays the input signal power in dBmW, according to the relation:

$$P[dBm] = 10\lg\frac{P[mW]}{1mW} \tag{2}$$

As results of measuring procedure provides a first measurements of the microwave power P1 in absence of the test sample. Next, after inserting the material sample in the waveguide, power P2 is determined for the signal. The difference of powers P1 – P2 represents the attenuation introduced by sample under test and can be expressed as dBm or dB relationship the instrument scale (see Fig. 1).

Different types and categories of materials were used during the experimental investigations. These samples were of different thickness and formed of two more layers of identical different materials.

3. MEASUREMENT SYSTEMS

For the relatively broad frequency band, ranging between 10 MHz and 100 GHz, which includes metric, decimeter and centimeter wavelengths, it was necessary to develop measurement setups including radiofrequency generators, transmission lines with adequate connectors, appropriate sample stands, instruments for measuring the power in accordance with the selected method.
The paper presents measuring system that is organized so as to extend over to frequency range, from 10 MHz to 1 GHz and from 1 GHz to 100 GHz respectively.

3.1. 10MHZ TO 1GHZ MEASUREMENT SYSTEM

Using the frequency – wavelength conversion, that is:

$$\lambda_{[m]} = \frac{300}{f_{[MHz]}} \tag{3}$$

The wavelength interval corresponding with the measurement frequency range is determined between 30 m and 0.3 m (30 cm). for this case, the measurements are performed especially on the metric band. This allows for the use of TEM-cells, where the test samples are placed, and of coaxial cable to interconnect the elements of the measurements system (see Fig. 1).

The measuring system for the 10MHz ÷ 1GHz frequency band includes the following equipments:

- RF signal generator, in the 10 MHz ÷ 1000 MHz band;
- spectrum analyzer in the 10 MHz ÷ 1100 MHz band;
- TEM-cell;
- digital storage oscilloscope (DSO);
- connecting elements for the metric and decimeter band (coaxial cables, signal distributor, connectors).

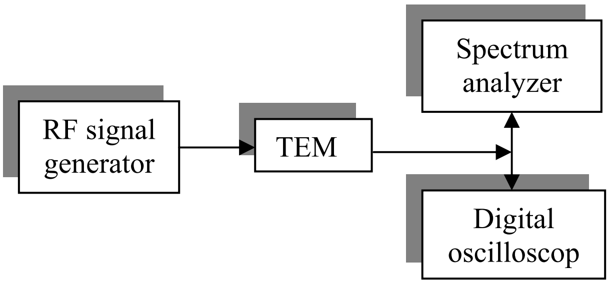

Fig. 1 Measurement setup for the 10 MHz ÷ 1000 MHz frequency interval

Measurement of the attenuation levels produced by each nanomaterials sample at different frequencies on the 10 MHz ÷ 1000 MHz range includes the following steps:

- instrument calibration and interconnecting in accordance with Figure 1;
- successive adjustment of the selected frequencies using the RF generator;
- for each selected frequency value, two values of electromagnetic field power, P_1 - are determined in the absence of the material sample inside the TEM-cell and another two values P_2 – are determined with the material sample placed inside the TEM-cell;
- the attenuation for each frequency value and sample type is calculated using the relation:

$$a_{[dB]} = 10 \cdot \lg \frac{P_2}{P_1} \tag{4}$$

- the attenuation versus frequency characteristic is drawn for each material type, between 10 MHz and 1000 MHz.

The test sample is placed inside the TEM-cell between the central conductors, perpendicularly to these, so as to completely cover cross-sectional area of the cell [3].

3.2. 1GHZ TO 100GHZ MEASURING SYSTEM

In accordance with the conversion relation (1) the 1 GHz to 100 GHz band corresponds to the wavelengths from 30 cm to 3 cm, which places the measurements in the centimeter band.

The measurement setup must be capable of generating and transmitting electromagnetic microwave energy. For the proposed measurements the microwave generator should be connected with the measuring equipment via waveguides.

The composing elements of a such experimental setup are presented in Figure 2:

- microwave generator;
- adjustable power supply;
- waveguide lune;
- calibrated variable attenuator;
- power meter (SWR – meter);
- digital oscilloscope;
- field detector with high- frequency diode.

Depending on the method applied in measuring the microwave field power, the high – frequency diode can be replaced with a termistor in a balanced whetstone bridge. In this case the measured power is determined using an adequate power meter. The presented system can be arranged around a waveguide and a LABVOLT microwave generator with Gunn oscillator.

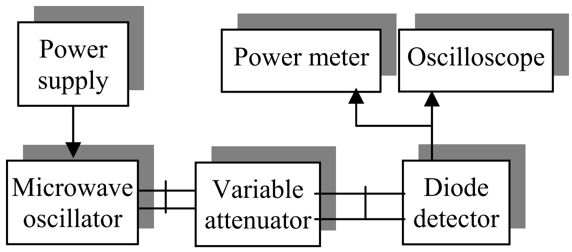

Fig. 2 Measurement setup for microwave field attenuation

Measurement of the attenuation levels of the electromagnetic field produced by nanomaterials levels on the 1 GHz ÷ 100 GHz range includes the following steps:

- instrument calibration and interconnecting in accordance with Figure 2;
- the variable attenuator is set at maximum attenuation;

At the selected frequency values, two dB measurements are performed using the power meter. Firstly, P1 is measured in the absence of the test sample. Then, after having inserted the sample in the waveguide perpendicular to the propagation direction, P2 is measured;

The attenuation produced by the presence of the nanomaterials sample is calculated as the relation:

$$a_{[dB]} = P_{2\,[dB]} - P_{1\,[dB]} \tag{5}$$

- the attenuation versus frequency characteristic is draw for each material type, between 1 GHz and 100 GHz.

The described methodology allows for directly determining the power in dB using diode detector and the power meter on the dB scale. When using a thermistor in a balanced Wheastone bridge, the power can be determined from the peak-to peak modulated voltage displayed on an oscilloscope screen. Thus, the relation gives the average power dissipated in the thermistor:

$$P = \frac{V_{pp}^2}{8R} \quad (6)$$

were: R = 8 Ω and is the resistance of the thermistor as specified for the LABVOLT equipment.

Figures 3 and 4 illustrate the measurement setups described in this section.

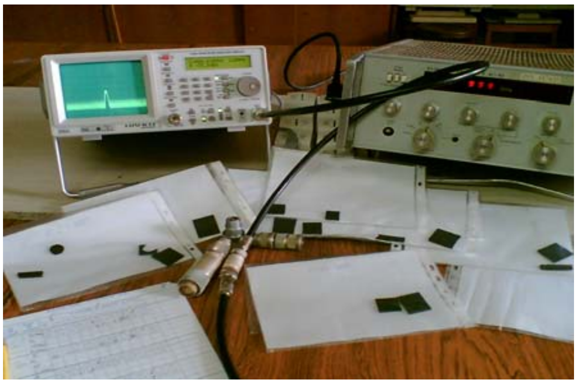

Fig. 3 Measurement setup for the m an dm band

Fig. 4 Measurement setup for the cm band

4. CONCLUSIONS

Experimental investigations for determining the new material characteristics require the use of providing the highest accuracy. The described systems were verified by carrying out test measurements on known material sample for which the results have confirmed the validity and accuracy of the measurements.

The employed techniques and procedures are closely related with the technical specification of the measuring instruments and equipments included in the experimental setups and also with the characteristics of the electromagnetic field propagation in different media and transmission lines.

In the microwave region, the most accurate measurement results were obtained by using a measurement setup which includes RF signal generators, microwave transmission equipments, radiofrequency diode detectors and a dedicate power meter.

Measurement system and method verifications were carried out on material samples with known parameter values and have demonstrated that these are capable to perform the measurement of the desired parameters with a good accuracy.

Experimental investigations should be carried out for a variety of the cases and situation depending on the specific application areas, which calls for a broader spectrum of measuring procedures and techniques.

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