Microwave Absorbing Materials for Protection from Electromagnetic Radiation

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Abstract – **Elastomer-based microwave absorbers, intended for varied applications, especially for human protection from adverse influence of electromagnetic radiation, were developed. The influence of chemical character of the polymer matrix and chemical nature and concentration of some fillers with high values of the imaginary part of the complex dielectric permittivity and magnetic permeability on the microwave properties of the absorbers is investigated. Some more important microwave parameters of the absorbers as function of frequency and composition (mass ratio filler/rubber) are measured.**

Keywords - **Microwave absorber, Electromagnetic radiation Absorption active filler**

I. Introduction

As is well known radiofrequency (RF) and microwave (MW) radiation are electromagnetic radiation in the frequency ranges 3 kHz - 300 MHz, and 300 MHz - 300 GHz, respectively.

Electric and magnetic fields are complex physical agents whose potential health effects are the subject of much research [1-4]. Particularly controversial are the biophysical mechanisms by which these RF and MW fields may affect biological systems. General health effects reviews explore possible carcinogenic, reproductive and neurological effects. Health effects by exposure source are noted in radar traffic devices, wireless communications, broadcast communications, and industrial processes.

Spreading industrialization and increasingly powerful equipment raise issues about the health risks firstly to workers, then to the general public. At the same time, rapid technological advances in electronics, electro-optics and computer science have set the stage for an unprecedented drive towards improving existing medical devices and developing new ones. In particular, advances in RF/MW technology and computation techniques have paved the way for new treatments and diagnostic methods.

Today, more and more manufacturers are using microwave absorbing materials to enhance shielding performance at higher frequencies.

Microwave absorbers are specifically designed to attenuate or absorb microwave energy, and act as coatings with modified electrical or magnetic properties that allow absorption of microwave energy at discrete or broadband frequencies. Absorbers are used for radar cross section (RCS) reduction, electromagnetic interference (EMI) reduction, suppression of surface waves, and transmission line applications, as well as for radome lining and antenna side lobe reduction. On the other hand microwave absorbers are used or under study for protection of the environment and people from adverse influence of high frequency electromagnetic radiation.

Most of the contemporary microwave absorbers are produced of dielectric polymer matrix and specific functional fillers with high values of the imaginary part of the complex dielectric permittivity and magnetic permeability that absorb high frequency energy.

Since the single-layer absorber cannot own simultaneously a combination of broad-band and strong-absorption in the gigahertz (GHz) frequency band, multi-layer absorbing structures are employed to obtain effective microwave absorbers [5-7].

The aim of the paper is to present the results of our investigation on elastomer-based composites with different absorbing fillers developed for production of microwave absorbers, intended mainly for human protection from adverse influence of electromagnetic radiation.

II. Sample preparation and testing

Nitrile butadiene rubber (**NBR**) and chloroprene rubber (**CR**) were used as elastomeric matrix. Acetylene carbon black, carbonyl iron and natural magnetite were used as absorption active fillers. These fillers are accessible, inexpensive and very effective in a broad frequency range, as our investigations showed. The rubber-fillers mass ratio was shown in Table I.

TABLE I
BASIC COMPONENTS OF THE SAMPLES IN PHR

Basic components	**Polysorb Fe**	**Polysorb Fe - C**	**Polysorb MB/S-MB**
NBR	100	100	50
CR	-	-	50
Carbonyl iron	100; 300; 500	50; 100; 150; 300; 500	-
Acetylene carbon black	-	40	15; 55; 90
Natural magnetite	-	-	15; 110; 170

The fillers were compounded with rubber and the other obligatory ingredients in various proportions in a two-roll mill

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for samples **Polysorb Fe**, **Polysorb Fe-C** and **Polysorb MB** (Table I). Vulcanization was carried out by heating at 160°C for 10 min, using an electrically heated hydraulic press at a pressure of 10 MPa.

The material **Polysorb S-MB** is a liquid microwave absorber for elastic coatings. Acetone was used as dissolvent and the ratio dry mixture : dissolvent was 1:5. The vulcanization was going on at room temperature. These coatings were spreaded with a spraying pistol or with a brush, according to the circumstances.

The materials **Polysorb Fe - O** and **Polysorb Fe - W** are liquid microwave absorbers. **Polysorb Fe – W** is 40 % water dispersion of styrene acrylate copolymer and **Polysorb Fe – O** is based on an acrylate copolymer dissolved in a mixture of organic dissolvents (toluene and xylene). Carbonyl iron was used as an absorption active filler. These absorbers were prepared in two varieties:

Polysorb Fe – O – 15 **Polysorb Fe – W – 15**
Polysorb Fe – O – 30 **Polysorb Fe – W – 30,**

where the filler-polymer mass ratio was 15 phr and 30 phr respectively. It is possible to obtain coatings on the concentration gradient principle using these varieties in common.

Test specimens in different sizes according to the frequency of measurements were obtained. Some more important microwave parameters – absorption or attenuation, voltage standing wave ratio (VSWR) of the obtained rubber composites as function of frequency were measured using standard methods.

The waveguide measurements and the free-field measurements are very important for a comparative evaluation of the different absorbing materials. The measurement's methods were discussed in detail in our previous paper [8].

III. Results and Discussion

Our investigations indicated that the chemical nature of the elastomeric matrix had significant influence on the interaction between the electromagnetic waves and the absorbing composite (Fig. 1). Natural magnetite in concentration 100 phr was used as filler in all composites.

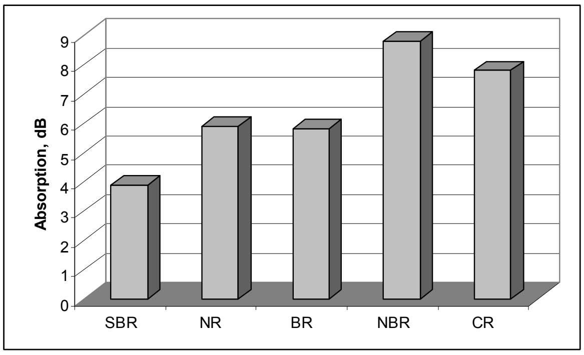

Fig. 1. Influence of the chemical nature of the elastomeric matrix on the absorption of electromagnetic waves at frequency 9, 4 GHz.

According to the obtained results the elastomers with polar functional groups or bonds (NBR, CR) determine better microwave properties of the absorbers.

Microwave absorbers intended for human protection from adverse influence of high frequency electromagnetic radiation have to absorb entirely electromagnetic energy. This is almost impossible to achieve with single-layer composite material. For that reason our investigations were directed mainly to develop multi-layer protective elastomeric coatings. In most cases the measurements were carried out in the frequency band 1-4 GHz, that is biologically significant.

Polysorb Fe and **Polysorb Fe – C** are flat, one-, two- and tree-layered materials made on gradient principle in respect to filler's concentration. The results of reflection coefficient measuring for tree different frequencies – 2, 3 and 4 GHz, are shown on Fig. 2.

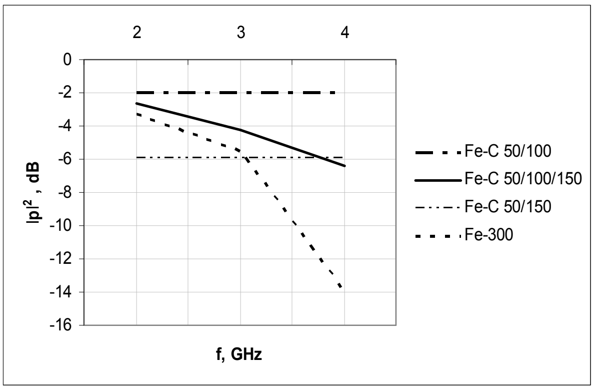

Fig. 2. Reflection coefficient frequency dependence for Polysorb Fe and Polysorb Fe – C

It is evident, that the best results for reflection coefficient are obtained for the material **Polysorb Fe – C 50 / 150** (constant value -5, 9 dB). Also good results showed **Polysorb Fe – 300 –** reflection coefficient -14 dB for the frequency 4 GHz, where as absorption active filler carbonyl iron was used. The filler – polymer mass ratio was 300 phr, but this filler is Bulgarian production and it did not raise the cost of material as a whole.

This group microwave absorbers are convenient to cover metal or nonmetal surfaces and rooms in order to decrease reflection of electromagnetic waves.

Microwave absorbers **Polysorb MB** are two- and multi-layered. An advantage for these absorbers is that the fillers (natural magnetite and acetylene carbon black) are accessible and inexpensive.

It is observed frequency dependence of the reflection coefficient for the 2-4 GHz band (Fig. 3). At 9,4 GHz the samples show reflection 88%, that means they are suitable for protective shields on metal and nonmetal surfaces.

Microwave absorbers **Polysorb MB** are fire safety (self-extinguishing) and they have good compatibility with decorative paints. The shield effect improves when using combinations of coatings (**Polysorb MB 170/90** as base and **Polysorb MB 110/55** on it).

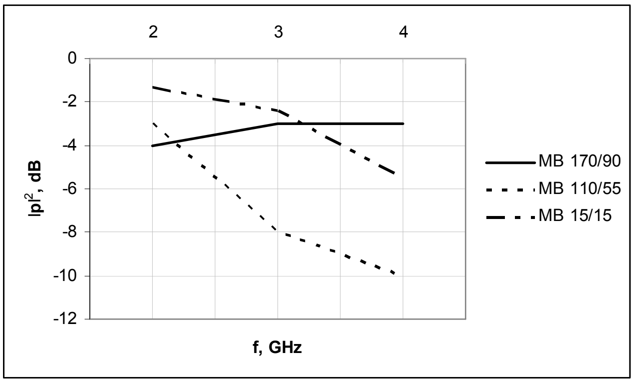

Fig. 3. Reflection coefficient frequency dependence for Polysorb MB

Rather effective broadband microwave absorber for frequency range 8-16 GHz is a multi-layered optimized structure on the base of **Polysorb MB** with concentration gradient of fillers (Fig. 4).

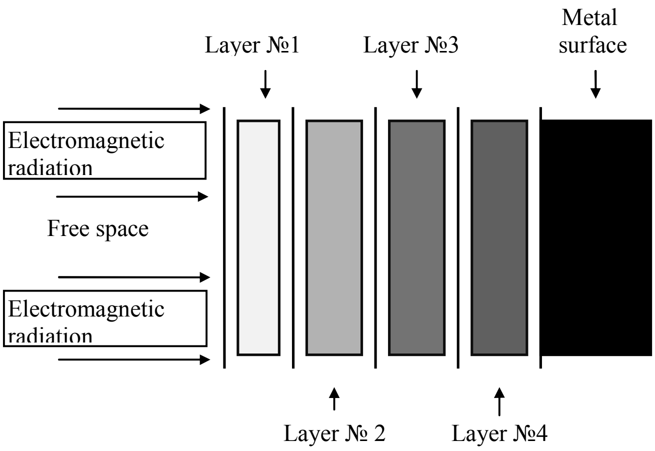

Fig.4. Multi-layered optimized structure on the base of **Polysorb MB**

Layer № 1 – 1,5 mm thick, **Polysorb MB** 15/15
Layer № 2 – 1,5 mm thick, **Polysorb MB** 110/55
Layer № 3 – 1,0 mm thick, **Polysorb MB** 170/90
Layer № 4 – 3,0-6,0 mm thick, **Polysorb MB** 15/15

This multi-layered optimized microwave absorber was measured at 7, 8 and 9,4 GHz. The total thickness of the structure was 7,35 mm. In Table II the results of voltage standing wave ratio (VSWR) and the reflection coefficient are given.

TABLE II
VSWR AND REFLECTION COEFFICIENT OF A MULTI-LAYERED STRUCTURE

f ,GHz	VSWR	$\|p\|^2$, %	$\|p\|^2$, dB	$\|p\|^2$, dB/mm
7	2,5	18	-7,36	0,5
8	1,8	8	-10,88	0,74
9,4	3,5	31	-5,11	0,35

The coatings **Polysorb S-MB** possess high adhesion to metal surfaces, they have water-proofing and anticorrosive effect. These coatings are elastic, weather-proof and their working temperature is from -45 ^{o}C to 110 ^{o}C.

To achieve the necessary thickness (1,5-2,0 mm) of the coatings **Polysorb S-MB,** as well as a gradient of filler's concentration, 3 – 7 layers from developed varieties of composites were used.

Free–field measurement at frequency 9,4 GHz of 0,5 mm thick sample was carried out. In Table III the results of this measurement are given.

TABLE III
RESULTS FROM FREE-FIELD MEASUREMENT OF POLYSORB S-MB SAMPLE

θ, deg	10	20	30	40	50	60
P_1, mW	22	22,8	23	11,7	10	10,8
P_2, mW	25	26,6	27,3	15,5	16	17,6
$R_{\varphi,\theta}$ dB	-0,56	-0,67	-0,74	-1,22	-2,04	-2,12

Very important distinctive feature of the liquid absorbing materials **Polysorb S – MB** is the possibility to soak-up fabrics (polyamide, polyester) and then to use them for individual protective clothing to shield workers from dangerous levels of electromagnetic radiation.

The results from measurement of **Polysorb Fe - O** and **Polysorb Fe – W** samples at frequencies 9 and 9,4 GHz are given in Table IV.

Advantage of microwave absorber **Polysorb Fe – O 30** is its low reflection of electromagnetic waves (at 9,4 GHz), when it is coated on metal surface. This means that it is convenient for antiradar camouflage coatings. Absorption coefficient is better for **Polysorb Fe – O 15/30** sample (Table IV), that is very important when the materials are coated on nonmetal surfaces.

TABLE IV
RESULTS FROM MEASUREMENT OF
POLYSORB FE-O AND FE-W SAMPLES

	Polysorb Fe – O 30	**Polysorb Fe – W 30**	**Polysorb Fe – O 15/30**	**Polysorb Fe – W 15/30**
f , GHz	9	9	9,4	9,4
VSWR	3,5	10	9	8
$\mid p \mid^2$, %	31	67	64	60
$\mid p \mid^2$, dB	-5,11	-1,74	-1,94	-2,18
$\mid p \mid^2$, dB/mm	1,28	0,44	0,28	0,27
α , dB	7	7	7,5	5,5

Microwave absorbers **Polysorb Fe – W** are convenient to use as protective shields when they are coated on metals. The compositions **Polysorb Fe – O** are suitable to coat on every solid surfaces, while **Polysorb Fe – W** are preferred to coat on walls and ceilings indoors.

V. CONCLUSION

The nitrile butadiene rubber would be the most suitable as dielectric matrix in preparation of elastomer based microwave absorbers, due to the highly polar nitrile group – C ≡ N in its macromolecules.

The effectiveness of some fillers with high dielectric or magnetic losses and their combinations was studied at different frequencies.

The two- and multi-layered microwave absorbers that contain combination of carbonyl iron and acetylene carbon black and combination of natural magnetite and acetylene carbon black are broadband and they ensure more effective protection of the human beings and environment from adverse influence of electromagnetic radiation.

REFERENCES

[1] "Health effects from radiofrequency electromagnetic fields", AGNR report, Doc. NRPB, vol. 14, no. 2, pp.1-177, 2003

[2] Review of the scientific evidence for limiting exposure to electromagnetic fields (0-300 GHz), Doc. NRPB, vol. 15, no. 3, pp.1-224, 2004

[3] J.C.Lin, "Human and environmental protection from electromagnetic emissions", IEEE Microwave Magazine, vol. 6, no.1, pp. 30-34, 2005

[4] *Radio-Frequency and Microwave Radiation*, Third Edition, American Industrial Hygiene Association (AIHA), 2004

[5] Y.He, R.Gong, X.Li, X.Wang, Q.Hu, "Design, fabrication and characteristic of two-layer microwave absorbers composed of magnetic micropowder – rubber composites in X-band frequency range", Europhysics Letters, vol. 77, no. 6, 2007

[6] Y.B.Feng, T.Qiu, C.Y.Shen, "Microwave Absorbing Materials", Journal of magnetism and magnetic materials", vol. 318, no. 1-2, pp. 8-13, 2007

[7] A.W.Guy, C.Chung-Kwang, J.A.McDougall, C.Sorensen, Measurement of shielding Effectiveness of Microwave Protective Suits", IEEE Trans., Microwave Theory and Techniques, vol. 35, no. 11, pp. 984-994, 1987

[8] R.I.Shtarkova, I.V.Petrova, N.T.Dishovsky, G.I.Krunev, "Magnetic Field Influence on Some Microwave Characteristics of Rubber Based Thin Films", ICEST'04, Conference Proceedings, pp. 225-228, Bitola, Macedonia, 2004