Materials For Protection Against High Power Electromagnetic Impact

Natallia Nasonova
Proton R&D Innovations
UAE, Abu Dhabi
info@proton-innovations.com

Abstract – A problem of development of shielding materials capable of protection of electronic equipment and systems against HPEM impact includes the tasks of effective HPEM shielding and the produced heat release. Composite and hybrid materials containing fillers of various types are investigated against the HPEM shielding efficiency and thermal behavior.

Key words: HPEM pulsed impact, composite materials, microwave absorption, heat distribution

I. INTRODUCTION

The impact of high power electromagnetic (HPEM) pulses (>100 V/m, duration upto 1.0 ns) on radio-electronic systems and equipment results in losses (distortion) of information, false alarms of security, fire and other alarm systems, equipment malfunctions, blocking of data transmission channels (both wired and wireless), faults and failures of electronic devices, etc. Shielding is an important element of an integrated approach to protect electronic equipment, systems and networks against the HPEM impact.

II. SHIELDING AND ABSORBING MATERIALS

A. *Components justification*

The present investigations cover a wide range of composite materials, containing conductive materials, including those with magnetic properties, such as carbon or metal particles, nickel and iron powders, ferrites, conducting polymers, liquid solutions, and their combinations and other fillers, dispersed in specific structural materials, such as elastic polymers, synthetic resins, concrete, mortars, etc (Figure). Particle size, concentration, distribution in the matrix, and shape (grains, fibers, flakes, etc.) play a significant role. Synthesis of composite, multilayered filler materials and hybrid structure designing increase the shielding efficiency of the shields and absorbers.

B. *EM power absorption requirements*

In general, the EM power absorbed per volume unit P_{loss} is determined by the frequency of the incident radiation f and the dielectric losses ε'' of the composite material:

$$P_{loss} = \omega\varepsilon_0\varepsilon''_r|E|^2 \approx 0{,}556 \cdot 10^{-12}\varepsilon''_r E^2 f, W/cm^2$$

An important problem for shields and microwave absorbers development is to develop a material, which is thermally stable for a long period of radiation exposure or quickly restore its properties after short-term heating without reducing the efficiency characteristics.

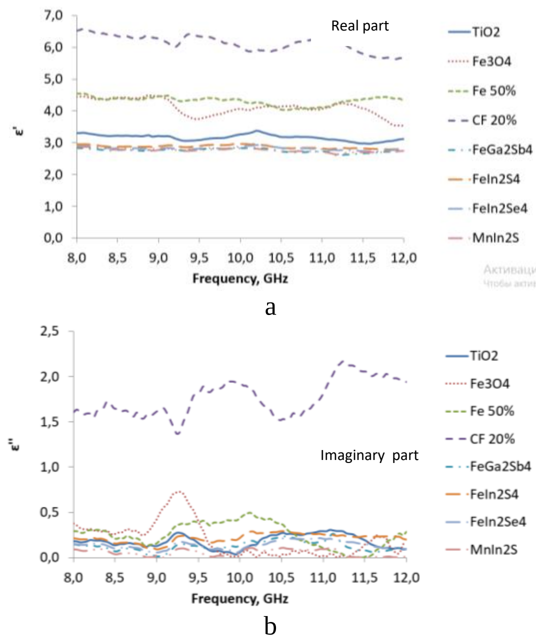

Figure. Complex permittivity for some of the developed polymer-based composites with various powder fillers in the frequency band of 8–12 GHz

The problem of HPEM shielding materials development includes the following aspects: 1. Analyze the application conditions; 2. Select the types of fillers and binders to achieve high shielding efficiency, as well as the workability of the resulting material; 3. Analyze the heat release processes in a composite material upon absorption of HPEM energy.

C. *Heat release analysis*

The impact of microwave electromagnetic radiation produces a temperature increase per dielectric volume unit:

$$\frac{dQ}{dt} = 8 \cdot 10^{-12} E^2 f \frac{\varepsilon''_r}{\gamma c}, deg/min$$

γ – is bulk density, g/cm^3; c – is a specific heat capacity, cal/g·deg. Since composite materials have a heterogeneous structure, there are losses due to thermal conductivity and radiation and the heat distribution process depends on multiple factors. The power P_h, which is required to heat a dielectric of weight G by ΔQ deg, can be approximately determined as follows:

$$P_h = 4{,}186 \cdot G \cdot c \cdot \Delta Q, \text{kW}$$

The measuring installation includes a pulse voltage generator PVG 50-1000 and an electric field digital indicator. The shielding efficiency regarding UWB electromagnetic pulses, averaged over the frequency range for their spectrum, is defined as the ratio of the electric field amplitudes measured before the shield was installed (E_1) and after it was installed (E_2):

$$\text{SE} = 20 \cdot \log\left(\frac{E_1}{E_2}\right), dB$$

A thermal portrait of a material while HPEM absorption in practice is obtained using a thermal imager.