Laidžių medžiagų panaudojimas mikrobangių įtaisų miniatiurizavimui

Usage of conductive materials for microwave components miniaturization

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In the present work simple robust design of microwave components (such as effective microwave absorbers and compact matched loads) based on 3D-printable lossy nanocarbon-based composites with filler content above the percolation threshold is considered.

Usually, microwave components are based on a long wedge or pyramid placed in the center of the waveguide [1], and pyramid top is oriented to the incident wave source. Mentioned periodic pyramidal structures are already well known and used as broadband absorbers for the anechoic chambers [2,3]. However, all researches of this topic are devoted to pyramidal structures produced from non-conductive materials (usually polymers). The development of pyramidal structures based on lossy materials opens new possibilities in the field of electromagnetic interference (EMI) shielding applications. In particular, it allows to miniaturize microwave components.

As lossy material the DC-conductive (σ_{DC}=0.39 S/m) 3D-printable filament based on poly(lactic) acid filled with 12 wt.% of multiwalled carbon nanotubes was used. The electromagnetic properties of 3D-printed pyramidal regular structures were experimentally investigated and numerically simulated in 12–18 GHz (Ku-band) and 26-37 GHz (Ka-band) frequency ranges.

For the simulations of pyramidal structure electromagnetic properties and for the determination of optimal geometrical parameters of pyramids a multi-layered approach [4] developed in optics was used. In frame of this model the structures under study were considered as graded refractive index material. Then, knowing the complex dielectric permittivity ε^* of the bulk material (in case of filament used ε^*=16.74-*i*6.17 at 30 GHz), after the homogenization procedure, it was possible to find the relative amplitudes of reflected S_{11} and transmitted S_{21} through pyramid signals. The shielding efficiency SE is defined [5] as $SE_T = -20\log_{10} S_{21}$. Similarly, the efficiency due to reflectance is $SE_R = -20\log_{10} S_{11}$. The optimal geometrical parameters of pyramids correspond to the minimum parameters that satisfy the conditions: SE_T>20 dB and SE_R>20 dB (this is equivalent to the absorption of more than 99% of the power of incident wave). In the particular case of the filament used, the substrate thickness of 2 mm is optimal for both frequency ranges, while pyramid's height has to be 8−9 mm and 22 mm for Ka- and Ku-bands, respectively.

Experimentally tested components with optimal pyramid parameters demonstrate remarkable shielding efficiency (>20dB) within whole Ku- and Ka-bands as shown in Figure 1. It is possible due to the combination of high Ohmic losses within the material bulk and waves scattering due to the sample's geometry.

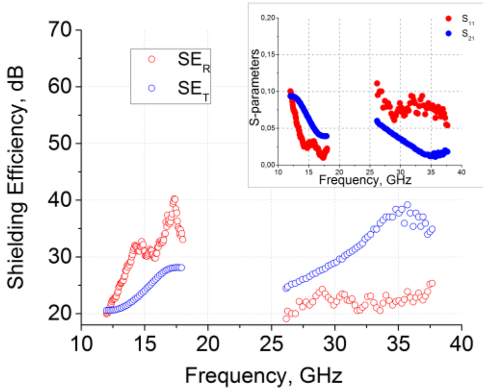

Fig. 1. Shielding efficiency and S-parameters (inset) of the 3D printed pyramidal samples in Ku- and Ka-bands

It means that these structures are suitable for practical application related to effective absorption of microwave radiation. The production of 3D-printable materials with controlled and predicted losses offers the possibility for miniaturization of 3D printed microwave components, such as absorbers and loads

Keywords: multiwalled carbon nanotubes, 3D printing, microwave absorbers, matched loads, shielding efficiency.

Literature

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