Didelės skvarbos medžiagų matavimų metodika mikrobangų intervale

Determinination the $\varepsilon`, \varepsilon``$ of materials with hight permitivity values in microwave range

Olga Suvorova[1], Alexander Barannik[2], Irina Protsenko[2], Artem Plyuchsh[1], Juras Banys[1]
[1]Vilnius University, Faculty of Physics, Saulėtekio av. 9, III bld., Vilnius, LT-10222
[2]Institute for Radiophysics and Electronics, Akademika Proskury st., 12, Kharkiv, 61085
o.a.suvorova@gmail.com

Advantages in computer science and mathematical methods bring us a family of electromagnetic software able to analyze the behavior of many electronic components. The aim of this communication is to verify how commercial solvers can extract dielectric permittivity of a sample of high permittivity materials, e.g., ferroelectric materials. For measurements we applied two methods.

The first type of measurements is the following: a sample of ferroelectrics of appropriate size were placed in rectangular waveguide, then we measured set of S - parameters by network analyzer. Then by digital model designed in Ansys HFSS or Comsol Multyphysics, we calculated S - parameters which are corresponded to measured ones.

For exact extraction of $\varepsilon`, \varepsilon``$ from S parameters, we start the iterative process of tuning of every simulated $S(\varepsilon`, \varepsilon``)$ to a measured S – parameter in a way that

$$\left\|S_{\mathrm{ij}}^{\mathrm{measured}} - S_{\mathrm{ij}}^{\mathrm{calculated}}\right\| \leq \mathrm{tolerance} \qquad (1)$$

We found, that in many cases due to the oscillating behavior of functions $S(\varepsilon`, \varepsilon``)$ direct methods of tuning, ex. Newton- Raphson method, Simplex method does not work. Instead of that we look for local minimums of

$$\min \left\|S_{\mathrm{ij}}^{\mathrm{measured}} - S_{\mathrm{ij}}^{\mathrm{calculated}}\right\|_{\mathrm{L2}} \qquad (2)$$

by methods without derivative, e.g. search based ones [1].

The approach has been tested, and then it has been used for extracion of $\varepsilon`, \varepsilon``$ of samples with unknown permittivity. We extracted $\varepsilon`, \varepsilon``$ of a sample of material BT-0.1CF (Table 1). Reflection |R| and transmission |T| coefficients were measured in 25-40 GHz band.

Table 1. Extracted from |R| and |T| coefficients $\varepsilon`, \varepsilon``$ values of and its error. Sample sizes are 0.08x0.11 mm.

F(GHz)	ε'	ε''	*error*(%)
26.53	447	234	4
27.68	442	233	3
29.74	432	210	4.1
30.64	415	206	4.5
31.58	401	168	5
33.02	378	155	0.9
35.35	314	99	1.7

In the second approach we put a sample in close proximity of sapphire semi-optical resonator, where the sample can perturb EM field radiated by resonator [2]. Earlier this method was applied for determination of complex permittivity of liquids and graphene films [2-3]. Resonator has been made from synthetic sapphire. Material NBT-0.3BT had the form of thin cylinder with diameter 17.6 mm and high 3.2 mm. We measured the resonance response of empty resonator, then we determined frequency shift ΔF and value of quality factor ΔQ of resonator loaded by sample. These parameters were measured at chosen frequency 30.32 GHz at H_{911} mode. By tuning of simulated ΔF and ΔQ to measured ones we estimated the $\varepsilon`, \varepsilon``$ of the sample.

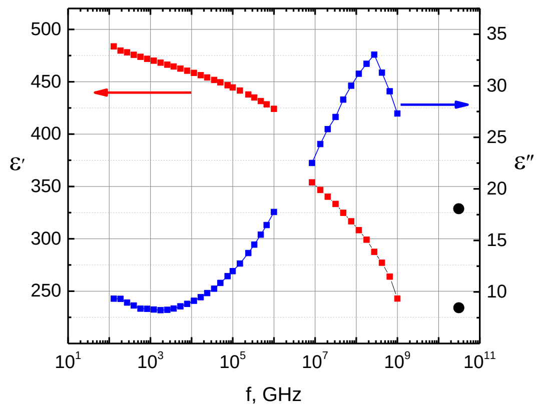

Fig.1. Extracted $\varepsilon`, \varepsilon``$ values from measured parameters by waveguide (curves, [4]) and by sapphire resonator (black points, $\varepsilon` = 234$ $\varepsilon`` = 18$).

Key words: dielectric permittivity, numerical simulation, ferroelectrics.

Literature

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