RADIO WAVE METHODS OF MONITORING THE ELECTROMAGNETIC PARAMETERS OF RADIOABSORBENT MATERIALS

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An analysis of radio wave methods of monitoring electromagnetic parameters over a broad range of frequencies is given. The sensitive elements used in moderating systems are examined.

At the present time magnetodielectric and metallic coatings are widely used in various branches of industry for the screening and absorption of electromagnetic waves, particularly for the measurement and testing of radio engineering apparatus and the development of echoless chambers, microband UHF moduli for the removal of the electromagnetic resonances of chassis, etc. [1-3]. For these purposes ferromagnetic materials are used, the parameters of which must be monitored both during the production process and during the design of devices containing these materials.

Modern methods of monitoring and measuring the electromagnetic parameters (EMP) of radioabsorbent materials (RAM) can be classified in accordance with the various principles and devices that can serve as the basis of a measurement instrument, namely: the measurement circuit realized by the measurement instrument; the principle of display; the type of sensitive element used; and frequency range [4]. The wide use of radio wave methods of monitoring and measuring the EMP of RAM is preceded by determination of the functional link between the monitored parameters of the substance (dielectric and magnetic permeability, in the general case complex) and the characteristics of the sensitive elements used. Thus, monitoring of the EMP of RAM reduces to selection of a model of the electrodynamic measurement instrument to be used; to the establishment of the analytic link between the characteristics of the working wave type propagating in the measurement instrument and of the propagation constant; and to determination of the functional links between the propagation constant and the EMP of the substance to be determined.

According to the principle of display, measurement methods are divided into resonance, bridge, reflectometric, and quasioptical [5].

Resonance methods based on resonance phenomena in a sequential or parallel resonance circuit [6] are the most widely used. During measurements the circuit is tuned to resonance by varying the length of the transmission line or the oscillator frequency. The presence of the sample in the measurement system causes a shift in the resonance frequency and the Q-factor of the circuit, the variation in which is used to calculate the desired EMP. In the 1-100 MHz range a resonance method (circuit, oscillator, or radiointerference) based on oscillator circuits consisting of elements with concentrated or distributed parameters is used. The circuit and oscillator methods are the most prevalent. The main drawback of the circuit method is error in tuning to resonance (the presence of a linear section in the resonance curve, especially during measurement of loss). Measurement
error in the oscillator method is caused by error in the measurement of frequency or frequency drift, which is significantly higher than the resonance tuning error. Moreover, the oscillator method is more sensitive.

The problem of determining the complex permeabilities $\varepsilon, \mu$ of RAM includes solution of Maxwell’s equations for a given configuration of resonator electrodes, taking into account the effect on this field (usually by the perturbation method) of the structure of the sample placed in the resonator. Coaxial, rectangular, and cylindrical field resonators have become prevalent in this area. Torroidal resonators are used less frequently [7]. In these systems EMP can be measured both by the indirect method of measuring variation in the resonance frequency and by measuring variation in the geometrical dimensions of the resonator. In the first case the measured quantities are the resonance frequency and the Q-factor, while in the second case they are the resonance wave length and the width of the resonance curve. The sample should have a well-defined geometrical form (rod or disk) and partially or completely fill the resonator. When the volume of the resonator is completely filled by materials with small loss, simple relations for calculation of the complex permeabilities, the real part of which is expressed by the ratio of the fundamental resonance frequencies of the resonator when empty or filled, while the imaginary part is expressed by the variation in their Q-factors, are obtained [8].

The application of solid resonators in the investigation of RAM is limited by the narrow range of their frequency retuning ($\pm 25\%$). As a result, to cover the 100-1000 MHz range, it is necessary to create several unwieldy set-ups, which makes it impossible to perform measurements at large tangents of the angle of the dielectric loss characteristic of RAM measurements. More promising are resonators made of sections of coaxial or wave-guide lines of variable length or of delay systems that permit measurement over a broad range of frequencies [9-11]. The method of measurement in the majority of cases depends on the values of the parameters being measured: for RAM with small loss, the resonance frequency and Q-factor are measured, while for significant loss wave-guide methods, which nevertheless do not permit measurement of the parameters of materials with high conductivity in the centimeter wave region, are used.

Depending on the type of sensitive element (SE) (measurement cell) in which the RAM sample is placed, the standard methods of measurement are classified by frequency range.