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INCREASING SENSITIVITY OF PONDEROMOTOR WATTMETERS USING FERROMAGNETIC RESONANCE

As shown in [1], microwave wattmeters based on the principle of ponderomotive action of electromagnetic waves have a number of important advantages over other wattmeter systems. These advantages include the ability to create absolute high-precision power meters.

In particular, for the construction of ponderomotive wattmeters, registration is used by the mechanical moment of forces acting on the sample upon absorption of electromagnetic waves [1]. The magnitude of the moment of forces is determined by the formula

$$N = P|\omega, \quad (1)$$

where P — absorbed power; ω — vibration frequency.

The disadvantages of ponderomotive wattmeters include low sensitivity for low power levels. Increasing the sensitivity of ponderomotive wattmeters can be achieved using ferromagnetic resonance.

Let's find an expression for the moment of forces [2]

$$\boldsymbol{N} = \int [\boldsymbol{M} \times \boldsymbol{H}]\, dV, \quad (2)$$

acting on an isotropic single-shift spherical ferrite sample at resonance (here M — the magnetization vector, H — magnetic field strength). From the Bloch equation [3,4]

$$\partial \boldsymbol{M}|\partial t = -\gamma[\boldsymbol{M} \times \boldsymbol{H}] - \omega_r(\boldsymbol{M} - \boldsymbol{M}_0), \quad (3)$$

where γ — gyromagnetic ratio; ω_r — relaxation frequency; M_0 — equilibrium static magnetization; $\boldsymbol{H}=(H_1\, cos\, \omega_t - \frac{4\pi}{3}\, M_x, H_1 \sin\omega_t - \frac{4\pi}{3}\, M_y, H_0 - \frac{4\pi}{3}\, M_z)$ — field inside the sample (in the magnetostatic approximation), we have

$$\overline{N}|_{t=2\pi/\omega} = -\frac{\omega_r}{\gamma}(M_z - M_0)\, i_z, \quad (4)$$

When obtaining (4), it was taken into account that at resonance $(\omega \approx \gamma H_0)$ $M_{x,y} \sim cos\omega_t$, $\sin\omega_t$[3]. Используя решение для M_z [3], finally we have

$$\overline{N} = \omega_r\gamma H_1^2 M_0\, V\, /\, [\omega_r^2 + \gamma^2 H_1^2 + (\omega - \gamma H_0)^2]. \quad (5)$$

Accordingly, the formula for measuring the amplitude of the high-frequency power will take the form $\left(H \ll \frac{\omega_r}{\gamma}, \omega = \gamma H_0\right)$:

$$H_1 = [(\overline{N}_{\omega_r})/(M_0 V_\gamma)]^{1/2}. \quad (6)$$

Let us estimate the minimum possible value of the recorded power using ferromagnetic resonance. From (6) for $\omega_r/\gamma \approx 1\, E$, $M_0 \approx 100\, Gs$, $V \approx 10^{-3}$ cm^3 и $N_{min} \approx 10^{-11}$ din·cm[5] we get $H_1 \approx 10^{-5}$ E. For a wave of the H_{10} type in the waveguide, respectively, we have $P \approx 10^{-6}$ W. The sensitivity of the best (conventional type) ponderomotive wattmeters ~ 10^{-3} W.

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