EFFECT OF THE INTRINSIC MAGNETIC FIELD OF A VOLUME RESONATOR ON THE SECONDARY ELECTRON DISCHARGE IN IT

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The magnetic high-frequency (hf) field of a volume resonator which increases away from the axis can reach values which affect the properties of the secondary electron hf discharge (a multipactor). Conditions can arise under which the particles participating in the discharge are displaced in the radial direction both towards and away from the resonator axis.

One can treat the phenomenon as a variant of the Z-pinch with the distinctive feature that the electric and magnetic fields are shifted by 90° in phase.

We will consider the secondary electron hf discharge [1, 2] in a toroidal resonator with the E_{010} type of oscillations. We will write the expressions for the electric and magnetic fields in the form

$$E_z = \alpha E_0 \sin \omega t; \tag{1}$$

$$B_\varphi = \gamma B_0 \cos \omega t, \tag{2}$$

where ω is the oscillation frequency, αE_0 and γB_0 are the amplitudes of the fields, and α and γ specify the dependence on the radius. In particular, α and γ are expressed in terms of Bessel functions for a cylindrical resonator when $h = 0$ (see Fig. 1).

We will assume that during the flight between the walls the radial shift is small, so that α and γ vary little during a single flight. We will restrict the discussion to the region in which there is no radial electric field; as a rule, a multipactor develops in such regions. The remaining approximations are the same as in the usual multipactor theory [1].

The equation of motion in the crossed fields (1) and (2) is of the form

$$e(E_z + \dot{r}B_\varphi) = m\ddot{z}, \; e\dot{z}B_\varphi = -m\ddot{r}, \tag{3}$$

where e and m are the charge and mass of an electron; the dot denotes differentiation with respect to the time.

The solution of the system (3) is [3]

$$z = \frac{1}{\omega}\int y(\theta)\,d\theta + C_3; \tag{4}$$

$$r = \frac{1}{\omega}\int x(\theta)\,d\theta + D_3, \tag{5}$$

where

$$y = y_0 + C_1 y_1 + C_2 y_2; \; x = x_0 + D_1 x_1 + D_2 x_2;$$

$$x_1 = y_1 = -\sin(q \sin\theta); \; x_2 = y_2 = \cos(q \sin\theta);$$

$$x_0 = p\left(x_1 \int x_2 \sin\theta d\theta - x_2 \int x_1 \sin\theta d\theta\right);$$

$$y_0 = \frac{p}{q}\left(y_2 \int \frac{y_1}{\cos^2\theta}\,d\theta - y_1 \int \frac{y_2}{\cos^2\theta}\,d\theta\right);$$

$$p = \frac{e}{m}\frac{\alpha E_0}{\omega}; \quad q = \frac{e}{m}\frac{\gamma B_0}{\omega} = \frac{\gamma\omega_c}{\omega}; \quad \theta = \omega t.$$

Usually the magnetic field is small and $q \ll 1$. One can show that in this case Eq. (4) changes into the usual equation of multipactor theory [1], and we obtain from Eq. (5) an expression for the shift during a single flight

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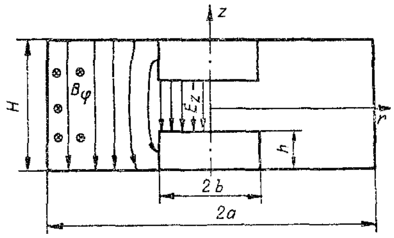

Fig. 1

$$\Delta r = -(pq/\omega)\Phi_n(\theta_1),$$

where $\Phi_n = \frac{3}{2}\pi(2n-1)\sin\theta_1\cos\theta_1 + 6\cos^2\theta_1 - \frac{(2n-1)^2\pi^2}{4}$; n is the order of the multipactor, and θ_1 is the equilibrium angle of the discharge; the ratio of the rate of incidence of electrons on the wall to the initial velocity of the secondary electrons is taken equal to three.

When $n \geq 2$, the value $\Phi_n < 0$; therefore the particles which take part in the discharge will drift away from the center. When n = 1, the sign of the shift depends on the equilibrium angle of the discharge: $\Phi_1 > 0$ for $\theta_1 > -30°$ and $\Phi_1 < 0$ for $\theta_1 < -30°$.

The experiments which have been conducted [4] have shown that the electron current of the discharge appears earlier near the cylindrical wall of the resonator than the voltage in the given region which is necessary for the existence of the discharge is attained. The current density exceeds by two orders of magnitude that which is attained in the central part of the gap. The measured energy with which the electrons are incident on the walls amounts to less than 20 eV, i.e., too low for maintaining a self-maintained discharge. The voltages which were attained in the experiment correspond to no less than a third-order multipactor in the large gap. These facts confirm the existence of a radial shift of electrons in a resonant hf discharge caused by the intrinsic magnetic field of the resonator.

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