NONSTATIONARY PHENOMENA IN THE MIXED STATE OF SUPERCONDUCTORS OF THE SECOND KIND

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It is known that a sufficiently strong current perpendicular to the magnetic field produces in superconducting alloys that are in the mixed state [1] a potential difference, i.e, a voltage drop in the direction of current flow (see [2,3] and elsewhere). To explain this effect it is usually assumed that in the presence of an electric field the quantized magnetic-flux filaments (Abrikosov filaments) move under the influence of the Lorentz force in a direction perpendicular to the current and to the magnetic field. The velocity of this motion v is connected with the electric field intensity E by the relation

$$E = H(v/c). \tag{1}$$

The filament velocity (at a given current) is determined by the energy dissipation during their motion ("friction" of the filaments as they interact with defects [2,3], "creep" effects [4], "natural" relaxation of the filaments [5], normal resistance [6]). We shall show that, without specifying concretely the dissipation mechanism, some general conclusions can be drawn concerning the character of the phenomena accompanying such a motion.

If the Abrikosov structure has a period a in the direction of motion, then the density function of the "superconducting electrons" (the ordering parameter) can be expanded in a Fourier series

$$N_s(x) = \sum_{n=0}^{\infty} a_n \cos(2\pi nx/a), \tag{2}$$

i.e., it contains spatial harmonics with wave numbers $k_n = 2\pi n/a$. The motion of such a distribution gives rise to temporal harmonics with frequencies

$$\omega_n = k_n v, \tag{3}$$

where v is obtained from (1), i.e.,

$$\omega_n = (2\pi nc/a)\cdot(E/H) \tag{4}$$

Consequently, the density of the superconducting electrons will be at each point of space an oscillating function of the time, with the frequency of these oscillations given by (4).

These oscillations are similar to the oscillations of the superconducting Josephson current [7] in the presence of a potential difference between metals, whose frequency is given by

$$\hbar\omega = 2eV \tag{5}$$

(V is the potential difference between the superconductors).

Both the Josephson-current oscillations and the superconducting-electron density oscillations considered by us are "virtual" [7] in the sense that by themselves they do not cause the emission of real photons. The presence of interaction between the alternating superconducting current and the electromagnetic field should lead in both cases to radiation of electromagnetic energy at a frequency that is indeed determined by (5) or (4). A similar effect was observed experimentally for superconducting tunneling [8-10].

In our case there should likewise exist an analogous radiation effect accompanying the "resistive" effects in superconductors. Formula (4) is the analog of the Josephson frequency ratio for this case. However, to estimate the intensity of this radiation it is necessary to carry out calculations that start from a concrete energy-dissipation mechanism. Such calculations must take into consideration the exact boundary conditions at the sample boundaries.

It is clear that the bulk of the high-frequency energy will be dissipated inside the superconductor, and only a small fraction can emerge to the outside. The situation is similar in the Josephson effect (according to [10], the radiated power is $\sim 10^{-4} - 10^{-5}$ of the power released inside the superconducting tunnel structure).

Besides this effect, an inverse effect should exist, whereby irradiation of the superconducting sample with external high-frequency power leads, in the presence of energy dissipation, to a change in the form of the voltage-current curve J(E) and to the appearance on this curve of singularities at values of E connected with the irradiation frequency by a relation similar to (4). It is obvious that this phenomenon is perfectly analogous to the Shapiro effect for the Josephson superconducting tunnel current [11].

In conclusion, let us estimate the radiated frequency. For example, for the experimental data of [2] we have $H \sim 3 \times 10^3$ Oe, $E \sim 10^{-3}$ V/cm, from which we get in accord with (4) (assuming that $a \sim 10^{-4} - 10^{-5}$ cm)

$$\omega \sim 10^6 - 10^7 \text{ sec}^{-1}.$$

We note that the effect is highly sensitive to the regularity of the Abrikosov structure, i.e., the presence of regular periodicity in the arrangement of the filaments and constancy of their motion. Violation of the regularity will broaden the band of the radiated frequencies and reduce the radiation intensity in a given spectral interval. The effect can therefore become observable in sufficiently homogeneous conductors of kind II, which have no macroscopic defects (internal stresses, dislocation clusters, inclusions of a foreign phase, etc.).

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MEASUREMENT OF THE POLARIZATION OF COHERENT RADIO EMISSION OF EXTENSIVE AIR SHOWERS (EAS)

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The first measurement of coherent radio emission of EAS at 44 and 12.7 Mc, at amplifier bandwidths 4 and 2.6 Mc respectively, have been recently described [1-3]. These measurements confirmed the possibility of registering radio emission of EAS, predicted in papers [4,5] dealing with the search of coherent radio emission of the electron excess. The electron excess appears during the maximum development of the electron photon cascade in the EAS, and its emission is characterized by radial polarization and constitutes ordinary Cerenkov radiation.

It was indicated in [4] that V. I. Gol'danskii has proposed a mechanism whereby the charges in the EAS maximum are separated by the earth's constant magnetic field. This can give rise to synchrotron radiation, the power of which in the long-wave part of the spectrum will depend quadratically on the total number of electrons (positrons) in the EAS maximum. This radiation of the relativistically moving charges will be for the most part, but not completely, polarized in the plane of motion of the bunch, i.e., in the east-west direction.

To separate the radio emission polarized in the east-west direction from the usual Cerenkov radiation, an experiment was carried out at a wavelength 15.0 m with an amplifier bandwidth ~1.4 Mc.

A block diagram of the experiment is shown in Fig. 1. Signals from six dipoles (A_1 or A_2) were fed to a cascade preamplifier 1 and detector 2, and then through amplifier 3 and discriminator 4 to two coincidence circuits 5 and 6. The six dipoles A_1 were oriented east-west, and the other six dipoles A_2 north-south. The centers of the equilateral triangles O_1 and O_2, at the vertices of which were placed trays with Geiger-Muller counters (triggering setup), were at equal distance (36 m) from the centers of the corresponding rows of dipoles.

The simultaneous coincidences in the three circuits (5, 6, 7), corresponding, for example, to counters G_1 and the row of dipoles A_1 (see Fig. 1), were recorded for 17 out of every 24 hours. Every day between 10:00 and 17:00 false coincidences in all circuits (5, 6, 7) were monitored by gradually decreasing the total gain of the amplifier system to avoid amplitude overloading of the final amplifier 3.

The effective solid angle of antennas A_1 and A_2 was ~0.31 sr, and the physical areas of the antennas were ~100 m^2. The noise temperature of the preamplifier was 400°K, and the