

MEASUREMENT OF THE DEPENDENCE ON FREQUENCY OF THE RESIDUAL RESISTANCE OF SUPERCONDUCTING LAYERS OF LEAD

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1. Introduction

A number of residual resistance figures are given in the literature. All of them have been measured in RF resonators, but usually the surface of each resonator has been investigated for one frequency only. If these values are plotted versus frequency, the large scattering of the points does not permit their representation by a unique curve, to describe the frequency dependence.

For a more reliable determination of the frequency dependence the surface resistance of lead has been measured for the same resonator at various frequency and temperature values. This resonator was a coaxial one, excited in the TEM mode at the fundamental frequency and at its even harmonics.

The odd harmonics cause maximum currents to cross the midplane joints of cylinder and inner conductor. These may give rise to additional losses which could perturb the residual resistance measurements. Because of the unavoidable asymmetry of the resonator there remains some current crossing the joints for the even harmonics, too. To be sure that the measurements with these even harmonics were practically unaffected by extra losses, the layout of the resonator joints had been modified until a state was reached, where the differences between even and odd harmonic result nearly disappeared. Despite of this success the measurements were, nevertheless, restricted to even harmonics only.

2. Experimental set-up

The coaxial resonator, made of copper and electrolytically [4] lead plated (15–20 μ), was 400 mm long with inner and outer conductor diameters of 29 mm and 140 mm, resp.. It was evacuated and immersed in liquid helium in a cryostat.

A coaxial RF feed, conically widened at the resonator end, but with a constant characteristic impedance [5] and some pairs of holes in between this guide and the resonator formed the coupling system. The fields in the guide caused current to flow through the narrow bridges left in between the holes. The magnetic field surrounding the bridge currents coupled the coaxial line and resonator fields.

Two movable plungers in the coupling system allowed to set the coupling coefficient to desired values.

All elements of the coupling system were lead plated and superconducting during the measurements to avoid additional losses.

3. Results and Discussion

Usually the surface resistance is written as the sum of a superconducting term according the BCS theory [1], [2], [3] and of a residual resistance term for which, so far, no theory exists:

$$R_{\text{surf}} = R_{\text{sc}} + R_{\text{res}} = C \cdot \omega^\alpha \cdot \exp(-AT_c/T) + R_{\text{res}}$$

Plotting the surface resistance values versus $t = T_c/T$ at a fixed frequency and extrapolating $T \rightarrow 0^\circ$ K allows to determine the term R_{res} which is assumed to be independent of temperature and, furthermore, the constants C and A. (cf. Fig. 1).

The frequency range for each series of measurements with a new lead surface was 375 MHz to 5,000 MHz.

Fig. 2 shows the results obtained with surface IV. The surface resistance at $4,2^\circ$ K as well as the residual resistance are plotted versus frequency. Within the accuracy of the measurements ($\pm 10\%$) one obtains the same frequency dependence $\sim \omega^{-1.73}$ for both. The constant A turned out to be 2.04 in this case. Dashed lines in Fig. 2 indicate control measurements taken at odd harmonic resonances. They show slightly higher values and lead to the exponent $\alpha \approx 1,685$.

4. Conclusions

The measured frequency dependence $\sim \omega^{1.73}$ of the surface resistance is in agreement with the theory.

The same frequency dependence was found to hold for the residual resistance. Though without theoretical interpretation this result is of importance for applications of the RF superconductivity and will be taken into account. e. g. for linac and separator designs. It should, however, always be kept in mind, that these effects are dependent on the field configuration.

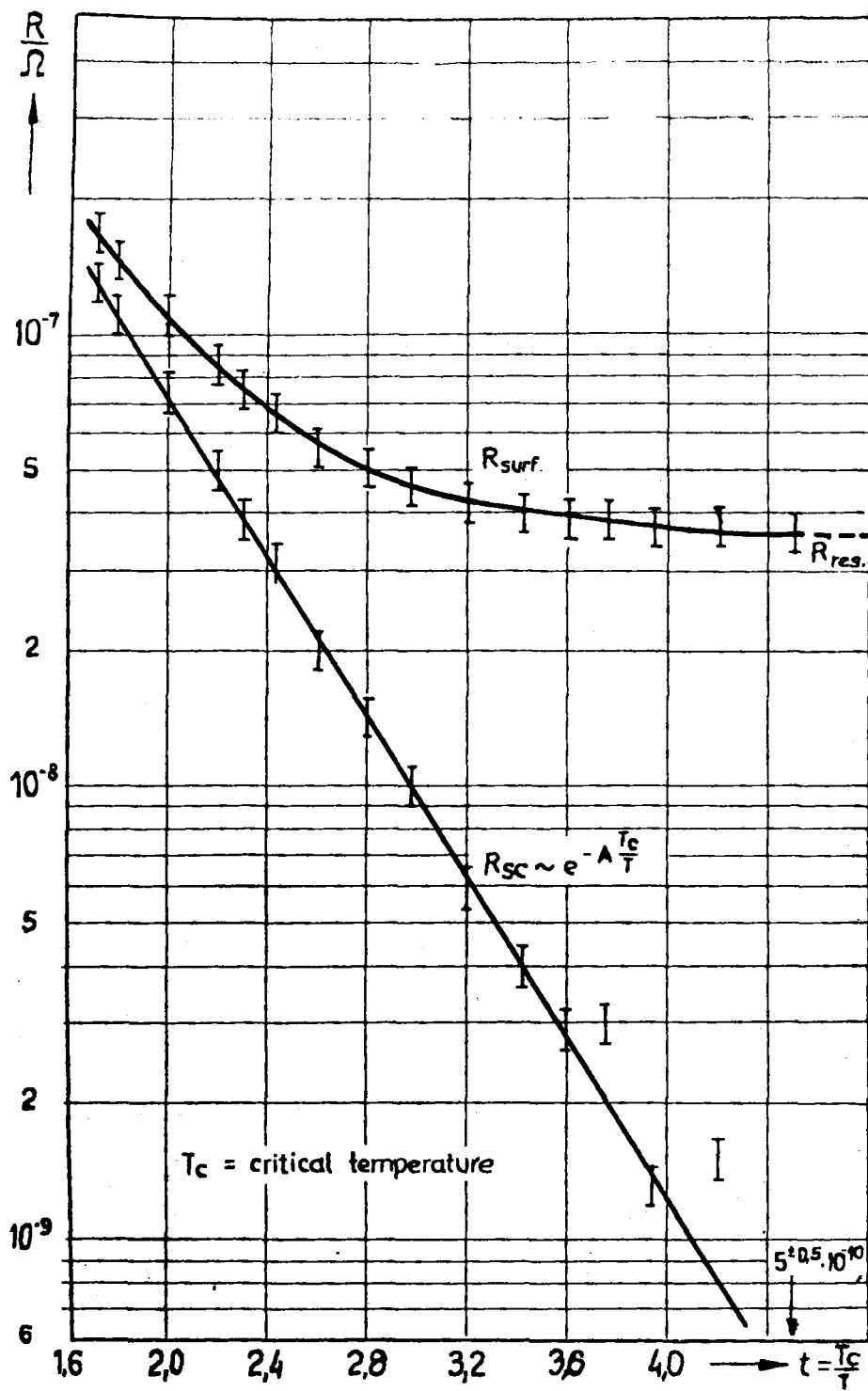


Fig. 1. Surface IV The temperature dependence of the surface resistance of lead at 376 MHz

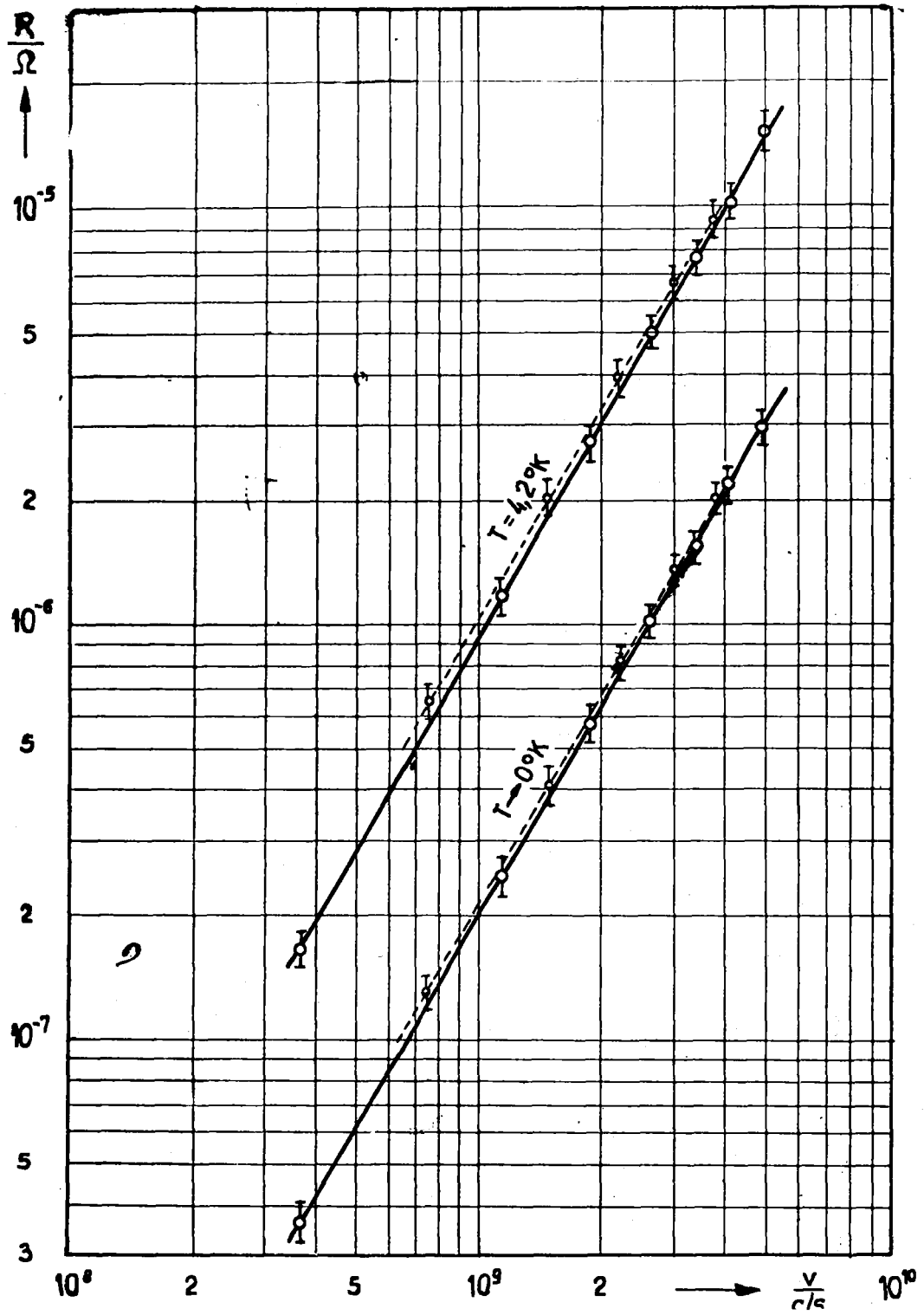


Fig. 2. Surface IV The frequency dependence for surface resistance of lead, measured for IEM configurations (dashed lines, odd harmonics)

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