A–7–1 THE USE OF DEEP COOLING FOR IMPROVING ANTENNA PARAMETERS.

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The report deals with the application of quantum effects of superconducting state of the material (i.e.negligible Joule losses, the Meissner and Josephson effects and magnetic flow quantization) to construct small-sized high efficient antenna devices. The general information about possibilities of deep cooling application and superconducting phenomena to decrease the threshold of sensitivity, to provide selective properties and to improve efficiency of antennas consistent with receiving-amplifying links are given in this work.

For receiving antennas the relative efficiency on cooling increases with decreasing their electrical dimensions [I–4]. Relative gain factor G_r and quality factor Q_r of the device with superconducting vibrators of the operative length l_e depend on the following parameters: electrical dimensions ($u = \lambda/2\pi D$ for a magnetic vibrator with a diameter D, $\alpha = I$, – solid lines; $u = \lambda/4l$ for an electrical one with a length l, $\alpha = 0$, – dotted lines, see fig.I); tuning quality Q_t (see fig.2), taking account of the losses in tuning units R_t; isolation R_i with the capacity C_i. To determine G_r and Q_r we used the estimates of the ratio of radiation resistance to the total loss in the radiator, namely

$$R_l/R_\Sigma = 0.86\cdot IO^{-4} l d^{-I} R_s L_\alpha$$

and in the antenna circuit, namely

$$R_j/R_\Sigma \simeq 2.5\cdot IO^{-4} \, |X_{a\alpha}|^{j+I} L_\alpha \, (\omega C_i)^j Q_j$$

Here $L_\alpha = (2N^2)^\alpha (\lambda/l)^{2\alpha+2}$; N – the number of frame vibrator coils, $X_{a\alpha}$ – reactive input resistance, Q_j – quality factor of circuit elements, $Q_j = Q_t$ with $j=0$; $Q_j = Q_i$ with $j=I$, $\lambda = c/\omega$. The experimental data for G_r and Q_r (fig.I) are obtained in the laboratory using lead superconducting radiators.

The combination of quantum effects opens the possibility of further decreasing thermodynamic fluctuations in the superconducting system with the transformation of field induction changes ΔB of the signal into current changes ΔI according to the relation

$$\Delta I = \Delta B S_I / L_a$$

($L_a = L_I + L_0$ – frame inductance with the area S_I). The simultaneous increase of S_I and the decrease of L_a are achieved by the parallel inclusion of frames [5]. For measuring ΔI it is reasonable to use the superconducting quantum interferometer SQUID coupled with the frame. The response of such a system to the field is not difficult to estimate from the relation

$$\Delta B_a = 2\Delta\Phi / kS (L_0/L_a)^{I/2},$$

where $\Delta\Phi$ – magnetic flow resolution of the SQUID, k – the coupling factor of the receiving frame with the SQUID, L_0–quantization circuit inductance.

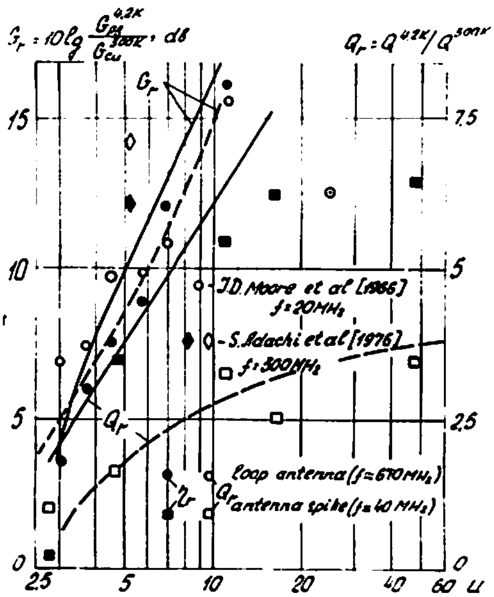

Fig.I

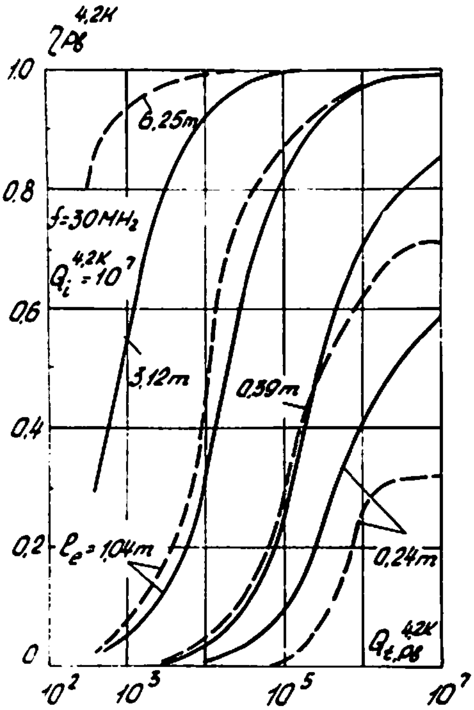

Fig.2

The consideration of fluctuation reasons and sources in the system of this type, when hysteresis is present, which was carried out in [6], showed the reality of attaining field sensitivity of the order of 10^{-12} erg/Hz$^{1/2}$ with $S \approx 10^{-2}$ m^2 in the wide frequency band, while energy sensitivity is about 10^{-30} Joule/sec [7]. The introduction of the volumetric structure of normal metal or (and) resistive insertion into receiving frame area (Fig.3) allows to form amplitude-frequency characteristics of the system inherent in a low-pass filter. Besides, it is possible to use resonance frames to ensure selective properties of the system.

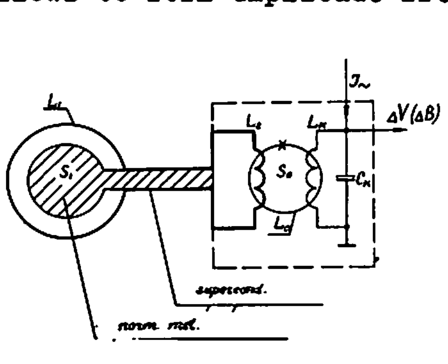

Fig.3

When the system operates in the analogue regime and in a wide frequency band it is difficult to ensure dynamic amplitude range of more than 30÷40db due to peculiarities of SQUID characteristics. And only the use of analogue-digital regime, when magnetic flow quantum numbers due to signal field are counted, allows to extend the dynamic range considerably. However, this possibility requires considerable increasing of frame areas.

The use of deep cooling is probably the only principal possibility of considerable improving antenna parameters of the size much less than operating wave length. Practical applicability of cryogenic device, however, requires the solution of a technical problem of maintenance of the cryogenic system under operating conditions.

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