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A BAND-PASS MICROWAVE FILTER IN HIGH-TEMPERATURE SUPERCONDUCTING FILMS

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The paper discloses advantages of usage of films made of high-temperature superconductors for creating various microwave devices. The quality factor of an asymmetric strip resonator of film design is estimated at frequency 2 GHz and at 77 K (liquid nitrogen temperature). Frequency responses of a nine-resonator band-pass filter designed with the use of films are included. The advantages of application of high-temperature superconducting films for new generations of microwave devices are outlined.

A band-pass filter, which performs the signal selection function, must have a minimum of loss in the pass-band and high selectivity outside the band. Usually, the main part of such filters represents strip copper resonators arranged on a polycore substrate. For example, in the range of frequencies up to 2 GHz and at room temperature the quality factor of such filters may take values up to 160–300 (depending on its topology). However, in the present-day maintenance conditions of such microwave devices this quality may be insufficient. Particularly, as the number of users of mobile telephones in large cities increases, there arises a serious problem of mutual impact of neighboring channels on communication quality — because of insufficient suppression of a powerful signal penetrating from outside the reception band, and of intensive industrial interference. As a result, we have to raise the transmission power of the telephone itself. On the other hand, as shown by numerous medical inquiries, it may become dangerous for the user health. In this case, the availability (at the basic station) of a receiver equipped with filter, allowing for little loss in the reception band and having steep slopes at the band edges, could resolve these problems radically. All this necessitates selective systems with high quality factor, and the only way is to diminish the loss in the strip resonator by means of its cooling. It leads to growth of resonator's quality due to lowering the wire resistivity. But even this decision cannot ensure large gain in the microwave range, although the resistivity ρ (of copper, for instance) falls rapidly with temperature T ($\rho \sim T^5$).

As can be seen from calculations, in this case the surface resistance R_s must decrease in proportion with $\sqrt{\rho}$. However, this fact has not been confirmed by experiments. For example, a copper half-wave strip resonator on a polycore substrate 0.5 mm thick and wave resistance $Z_w = 50\ \Omega$ (with copper strip 5 μm thick) at frequency 2 GHz has the quality $Q \cong 200$ at room temperature, and $Q \cong 600$ at 77 K (the liquid nitrogen temperature), although in this case ρ decreases substantially. Theoretical inquiries in this phenomenon show that the reason consists in the abnormal skin-effect in metals at low temperatures [1]: as the temperature lowers, the surface resistance somewhat decreases at first, and then remains almost constant, despite a considerable lowering of temperature down to 4.2 K. A good decision here is to apply in microwave devices some superconducting materials able to provide a considerable increase in resonator's quality factor. The high-temperature superconductors (HTSC) discovered in 1986 have the temperature of transition into superconducting state close to 91 K. This property permits to use them in liquid nitrogen (77 K), which is much more practical than maintenance of classical superconductors operating at the temperature of liquid helium (4.2 K).

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