Superconducting Terahertz Receivers and Oscillators

There are a number of practical applications where devices based on superconducting elements due to their quantum nature, unique set of parameters, and cryogenic operating temperatures significantly outperform devices based on traditional technologies. Superconducting elements offer an extremely high characteristic frequency and very strong nonlinearity. Superconductor-Insulator-Superconductor (SIS) mixers based on high-quality tunnel junctions are the key elements of the most sensitive sub-THz receivers; their operating frequency has reached 1 THz and noise temperature is restricted only by quantum limit. Many applications require a spectral resolution of $\Delta f/f \sim 10^6$; this can only be achieved with heterodyne receiving systems. The heterodyne mixer down-converts the weak input signal of interest to a lower intermediate frequency (IF) without loss of phase; the spectrum of IF signal is the same as the input one, but is shifted down in frequency by LO frequency. This report presents the results of the SIS receiver developments for the 211–275 GHz and 790–950 GHz frequency ranges with a noise temperature in the double sideband (DSB) mode of approximately 20 K and 200 K, respectively. These designs and achievements are implemented in the development of the receiving systems for the Russian Space Agency mission “Millimetron”, and for the ground-based APEX (Atacama Pathfinder EXperiment) telescope.

One of the most promising areas is the development of superconducting THz generators for integrated receiving systems. Such an application of the AC Josephson effect seems quite natural; however, many developments and studies conducted in dozens of major laboratories worldwide failed for a long time to create a generator with the required parameters. Until recently, it was possible to implement in one device both terahertz generation with the ability to tune the frequency in a wide range and a narrow emission line required for the most practical application only for systems based on long Josephson junctions (LJJ). The report presents the results of the development and study of an integrated local oscillator based on LJJ, conducted at the IREE in recent years, and also describes a new type of superconducting oscillator based on a one-dimensional array of Josephson junctions in a coplanar line.