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Subharmonically pumped SIS mixer.

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SIS harmonic mixer based on quasioptical structure with equiangular planar spiral antenna was investigated. SIS junction capacitance was resonated out by integrated circuit elements. LO frequencies were 1/2, 1/3 and 1/8 of signal frequency 75 GHz.

The most impotant SIS mixer advanteges are conversion gain, low intrinsic noise and low sufficient LO power. But single junction SIS mixer has 30 dB input signal power range only [1] and it may decrease at high frequencies more than 200 GHz due to Josephson and "switching" noise rise [2].

Our experiments show that subhurmonically pumped SIS mixer may have improved saturation power and reduced noise at high frequencies in some operation modes. The problem of stray LO power modulation may be solved by using simple filter rejector because of considerable difference LO and signal frequencies. In addition loss costly, low frequency sources may be combined with SIS harmonic mixer to provide LO power.

In experiments we used signal frequency 75 GHz whereas LO frequency was 37.5 GHz for the second harmonic operation and 25 GHz for the third one. To provide this frequency range experimental device included oversize circular waveguide 15 mm in diameter and two lenzes coupling scheme similar to [3]. Quasioptical planar structure consisted of equiangular spiral antenna and $Nb\text{-}Al_xO_y\text{-}Nb$ SIS junction with integrated cicuit elements was maded on fuzed quartz substrate (fig.1) . SIS junctions performance and fabrication technology were reported in [4,5]. IF amplifier had 30-300 MHz band and 110 K noise temperature. In the case of the eighth LO frequency hurmonic operation (9.5 GHz) IF coaxial cable was used for LO power guiding to SIS junction.

Because of dramatic difference LO and signal frequencies for subharmonically pumped SIS mixer there are three different regimes of mixer operation: I) quantum both for signal and LO frequensies, II)quantum for signal frequency but nonquantum for LO one, III) nonquantum for both ones. The experiments show there is no large difference for I) in conversion losses between usual and harmonic operation (see Fig.2) - the ratio of conversion losses for ordinary and the second and third LO frequency harmonics were $L_{21}/L_{11} = 0.82 \pm 0.15$ and $L_{31}/L_{11} = 0.67 \pm 0.15$. Optimum bias voltage for the second harmonic operation is V_g - gap voltage of SIS junction and $\alpha_{opt} = 2.4$ thus it gives the possibility to avoid rising SIS mixer noise at high frequencies. In addition the bias point is stable for different signal and LO frequencies and double width current step at the gap voltage for LO frequency gives the same saturation power as nonharmonic SIS mixer operated at the first subgap step bias point.

LO voltage level which must be applied to SIS junction for good conversion conditions is $\alpha_{opt} = eV_{LO}/hf_{LO}$ and for ordinary operation $\alpha_{opt} \cong 1$. It was found that n-harmonic SIS mixer operation needs $\alpha_{optn} \cong n \cdot \alpha_{opt1}$ and it corresponds to the same LO power as for non-

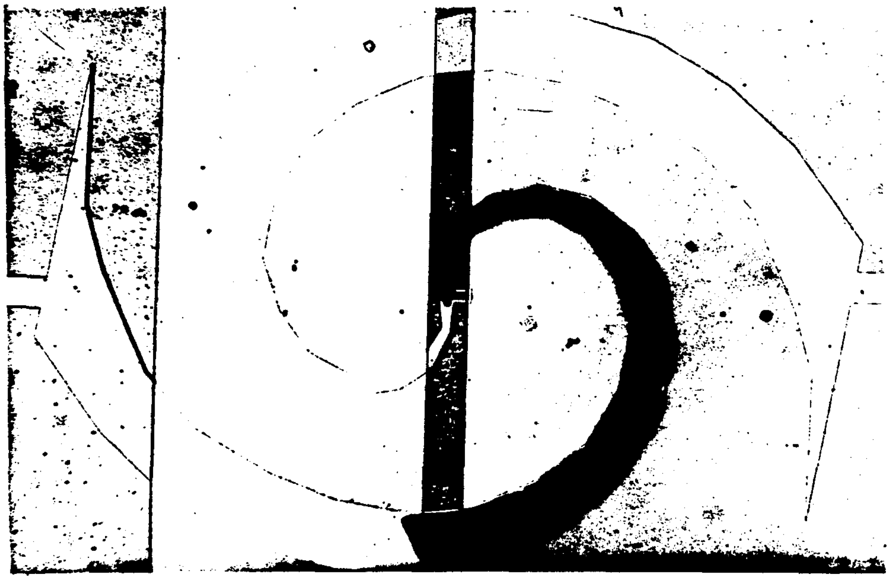

Fig.1 Quasioptical planar SIS mixer structure.

harmonic mixer:

$$P_{LO} \sim V_{LO}^2 \sim (\alpha_{optn} \cdot hf_{LOn}/e)^2 \approx (n \cdot \alpha_{opt1} \cdot hf_{LO1}/e \cdot n)^2$$

Nonquantum LO and quantum signal harmonic mixer conditions are $hf_{LO} / e < \delta V_g < hf_{signal} / e$, where δV_g is voltage range of I_{dc} rising at energy-gap voltage V_g.In this case there is some deformation of pumped SIS junction I-V curve step stracture with increasing the steps width. Fig.3 shows I-V curves with and without (1) LO power for the second (2) and the third (3) harmonic modes and SIS junction with δV_g=250 μV. For LO frequency 37.5 GHz IF responce is "semiquantum": there is quantum IF signal peak at the gap voltage, but classic mixing at subgap bias voltages.

For LO frequency 25 GHz we have classic nonquantum junction responce whereas for f_{LO}=75 GHz we have strong quantum one. The ratios of conversion losses for ordinary and harmonic operation were L_{21}/L_{11}= -3 ± 0.3dB and L_{31}/L_{11}= -5.7 ± 1.5dB.

High oder LO frequency harmonic mixer may be very intreresting for short MM and subMM wavelengths because of solving LO sourses problem.Our experiments show conversion losses strong dependence on I-V SIS junctions quality. Thus choosing LO frequency 70-90 GHz leads to strong quantum I-V SIS junction responce and better conversion losses for signal frequency more than 200 GHz without large difference from harmonic and ordinary mixing.

Input signal power range was also measured for nonquantum LO and quantum signal frequency mixer operation. As mentioned in [6] IF mixer load may drive SIS mixer saturation power. Table 1 shows measured normalized saturation power lewels for two different IF mixer loads and different LO frequency harmonics.

SIS junction noise experiments show no additional noise in presence of incident RF power besides shot noise rising due to bias current increase. Considerable incident RF power magnitude may lead to SIS junction heating and thus rising Nyquist noise.

Table 1

IF load	Psat11	Psat21	Psat31
4 Ohm	0.04	0.04	0.24
95 Ohm	0.025	0.02	0.11

Based on this results one may suppose the extending input signal power range because of increased saturation power but less bias current shot noise rising.

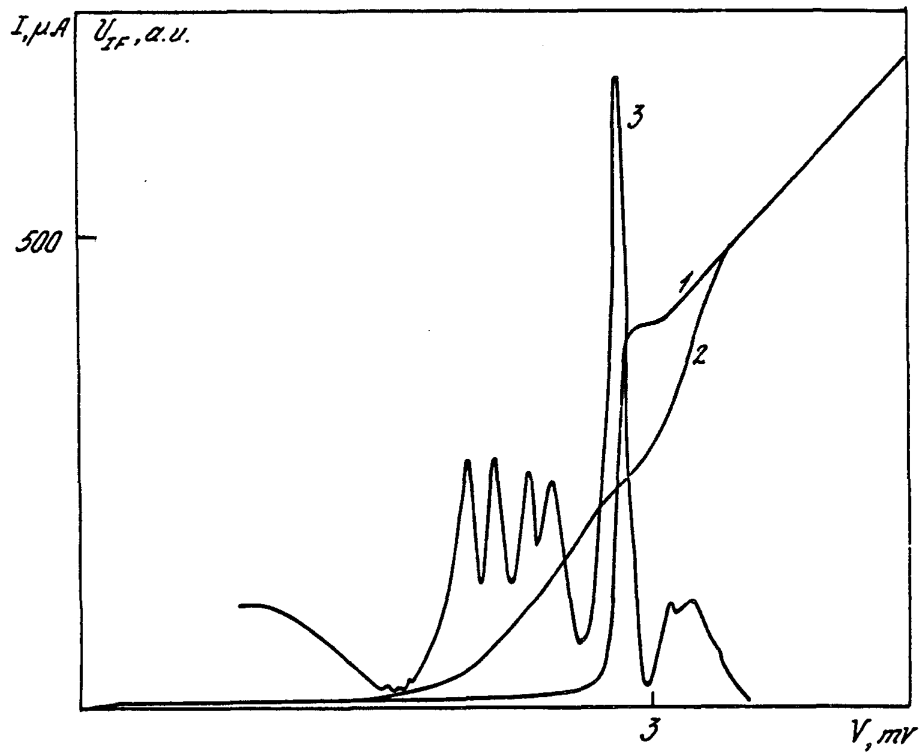

Fig.2 Quantum for LO and signal frequencies SIS mixer operating mode. IF signal (3), I-V SIS junction curves with (2) and without (1) LO power (the second harmonic).

Thus subharmonically pumped SIS mixer have some advantages and gives additional chance for SIS mixer using. Short MM and subMM wavelengths SIS mixer harmonic operation solves LO sorses problem without increasing sufficient LO power.Simple filter may be used to avoid stray LO power modulation because of considerable LO and signal frequencies difference.

Quantum both for signal and LO freqencies n-harmonic mixer conversion losses increase as $n^{-1/2}$only. Double LO frequency SIS mixer operation optimum bias voltage equal gap voltage. The bias point is universal for all LO and signal frequencies and gives a possibility to avoid at high frequencies additional Josephson and switching noise. High order harmonic SIS mixer should have good performance at

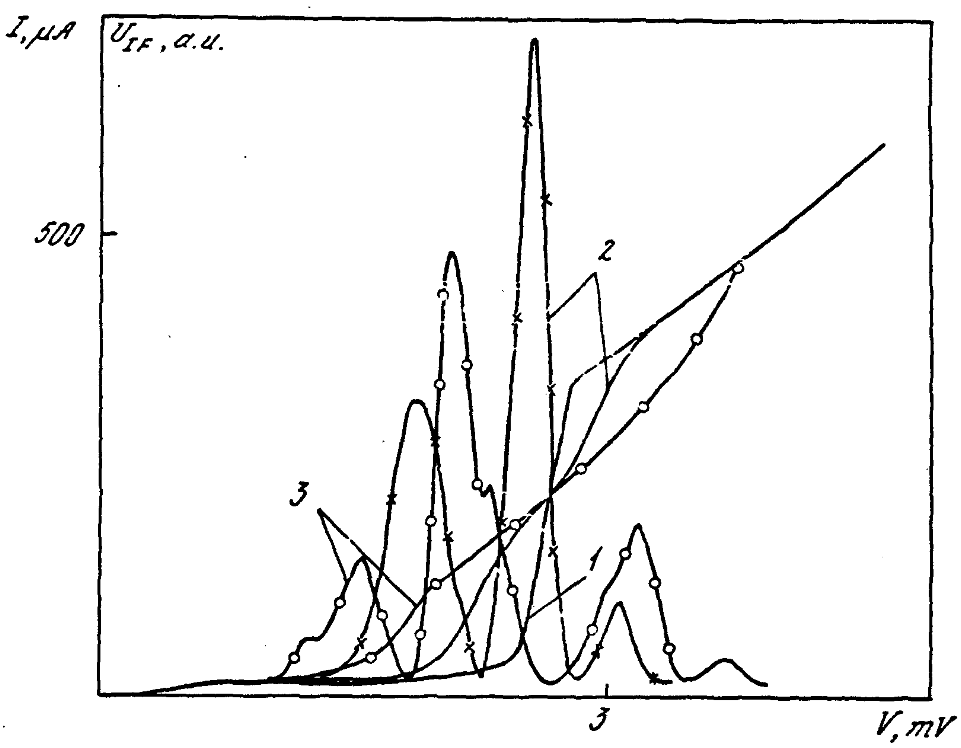

Fig.3 Nonquantum for LO and quantum for signal frequencies operating mode. I-V curve (1), IF signal and pumped I-V curve for the second (2) and the third (3) LO frequency harmonic operation.

high frequencies in the case of strong quantum LO frequency SIS junction responce.

Nonquantum LO frequency and quantum signal frequency harmonic mixer extends signal dynamic range because of 8 dB rising saturation power with 5 dB increasing convertion losses.

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