Observation of an anomalous IF peak at high bias voltage in 660-GHz 
SIS Mixers

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Abstract

We have designed and fabricated 660GHz parallel-connected-twin-junction mixer for SMA. The receiver noise temperature, $T_{rx}$, is around 200K with a wire grid of 80% signal coupling. However, some mixers have poor performance when an anomalous IF peak beyond the junction’s gap voltage is observed. In this paper, we will discuss the origin and influence of this IF peak.

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We have designed and fabricated parallel-connected-twin-junction 660GHz SIS mixers. Typically the receiver noise of these mixers is near 200K[1]. However, some junctions have poor performance although their junction’s parameters are similar. The LO pumping of these mixers are difficult and the receiver noise temperature can be worse than 1000 K. It is important issue to understand the reason causing the poor performance for future design and fabrication.

Since the junction parameters are similar for good and poor performance mixers. Some important effects might be missing in regular measurement. Thus, we measured the junction’s I-V curve and mixer’s IF response to high bias voltage, up to 17mV, as shown in Figure 1(a). Anomalous IF peaks are observed, an indication of the non-linearity in junction’s I-V curve. The peak position shifts to higher voltage as the temperature decreases. Figure 1(b) shows the temperature dependence of corresponding current of IF peak. The data (solid square) can be fitted by a formula of $I_C \sim 1-(T/T_C)^{\alpha}$, where $T_C$ is 9.2 K and $\alpha$ is 4.6. In addition, not shown here, the IF peak position is modulated by an external magnetic field. Both temperature and magnetic field dependence indicate the existence of unintentional weak-link junctions in series with the SIS junctions.
To understand the origin of this unintentional junction, the cross section structure of junction with good and poor performance is studied by TEM. A regular contact between top and wiring Nb is observed in the junction with good performance, as shown in Figure 2(a). On the contrary, the contact area is small in the junction with poor performance, Figure 2(b). Most area on the top Nb seems filled by the fragments of insulating oxide. The contact area is estimated to be 0.15\(\mu\)m in diameter. This small contact behaves as an unintentional weak-link junction. The oxide fragments might fall into the contact hole during the oxide lift-off process.

![IF peak position vs. Temperature](image)

Figure 1 The anomalous IF peak beyond junction’s gap voltage, (a) IF peak at different temperature and (b) temperature dependence of corresponding current of IF peak.

We have found that the 660-GHz SIS junctions showing the IF-peak structure are usually difficult to be pumped by LO signals, thereby giving high receiver noise temperature. Obviously, such additional weak-link junctions might absorb a fraction of RF/LO signal power and result in poor mixer matching. As exhibited in Fig. 3(a), the

![Cross-sectional views](image)

Fig. 2 Cross-sectional views of (a) good contacting junction and (b) poor contacting junctions
testing result for a mixer demonstrates that the mixer performance (Y-factor) is dependent upon the magnetic field applied to the SIS junction, which changes the position of the IF peak correspondingly. Fig. 3 shows the receiver noise temperature of five mixer samples, which have different IF peak positions. Obviously, the receiver noise temperature is strongly dependent upon the position of the IF peak, differing from ~200K to >2000K. The higher voltage the IF peak occurs at, the lower receiver noise temperature the junction demonstrates.

In summary, an anomalous IF peak at high bias voltage region is observed in our 660-GHz SIS mixers when their performance is poor. The cross section structure of junction shows that some insulating oxide fragments might fall on the top Nb layer because of imperfect lift-off process. It reduces the contacting area between top and wiring Nb and an unintentional weak-link junction is formed. The existence of this unintentional weak-link junction will result in (1) the absorption of RF signal, and (2) the change of the mixer RF impedance. We have demonstrated the correlation between junction’s IF peak position and mixer’s performance. The performance becomes better when the IF peak is observed at higher bias voltage. In practical operation, the mixers with IF peak can be screened by checking the linearity of junction’s I-V curve at high bias voltage.

References: