wSMA – Wideband IF Development

Smithsonian Astrophysical Observatory

Edward Tong, Lingzhen Zeng, Raymond Blundell and Paul Grimes

Introduction to wSMA Wideband IF Development

At present, the majority of SIS mixer based receivers operate with an IF of 4 – 8 GHz, while an increasing number offer a wider IF band of 4 – 12 GHz. There are many factors which would put a limit on the IF bandwidth of an SIS mixer. In order to deliver up to 20 GHz of IF bandwidth, we have based our SIS mixer design on a three-junction series array connected to a wideband cryogenic isolator. Special considerations are given to the grounding of the mixer chip, which can introduce significant grounding inductance. We present the test results for the prototype wSMA 240 GHz receiver. Low noise operation has been confirmed over the IF range of 3.5 – 19 GHz, for Local Oscillator frequencies between 210 and 270 GHz.

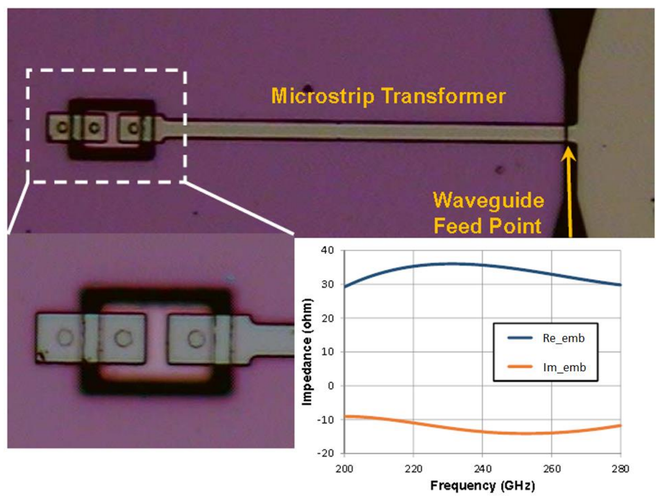
Three-Junction SIS Array

The 3-dB IF bandwidth of an SIS mixer is given by:

$$F_{3\mathrm{dB}} = \frac{1}{2\pi(R_{\mathrm{out}}//R_L) * (C_j + C_{\mathrm{tune}})}$$

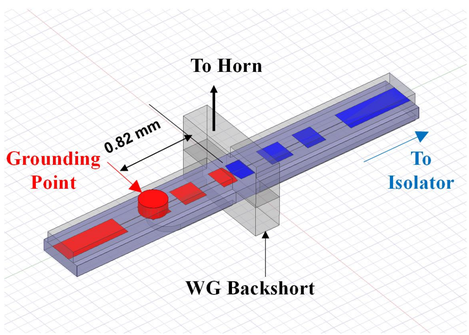
where C_j and C_{tune} are the capacitances of the junction and the tuning circuit respectively, and R_L is the load resistance of the mixer, which is typically 50 Ω for wideband IF system; and R_{out} is the output resistance of the mixer, which is in parallel with R_L.

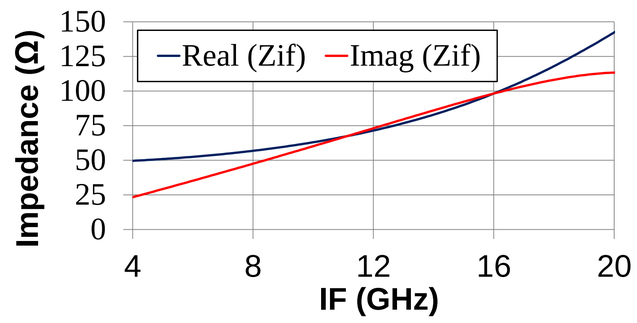
In order to reduce the junction capacitance C_j, we have chosen to use series junction arrays with relatively large dimensions, which can be reproduced reliably using optical lithography. For the wSMA 240 GHz mixer, C_j and C_{tune} are both designed to be ~58 fF. The theoretical value for $F_{3\mathrm{dB}}$ is ~27 GHz.



Grounding of Mixer chip

The grounding point of wSMA mixers is located behind the RF choke filter. This arrangement introduces a grounding inductance to the IF embedding impedance. The simulated IF impedance shows that the reactive part of this embedding impedance increases linearly with frequencies, corresponding to an added grounding inductance of L_{gnd} ~10 nH.



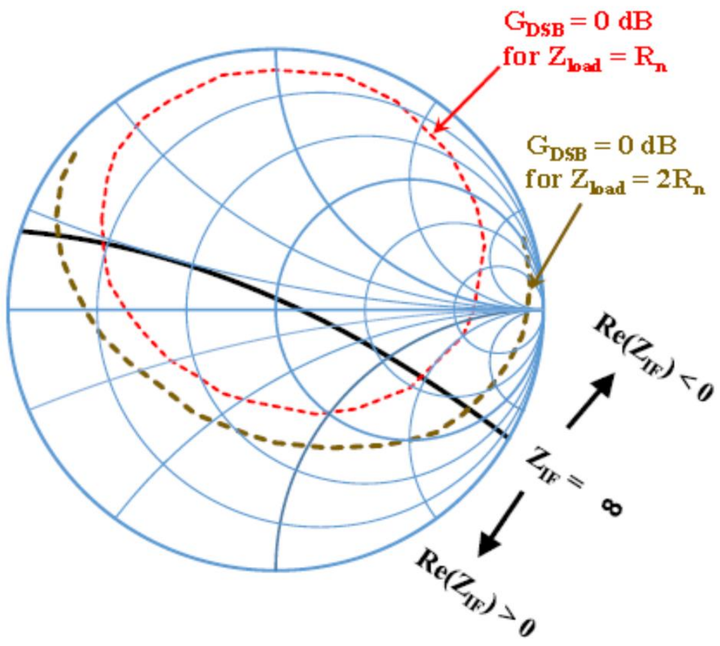


This grounding inductance interacts with the mixer capacitance: (C_j+C_{tune}) to provide a stronger conversion mixer gain at high IF, up to the resonant frequency of this L-C circuit:

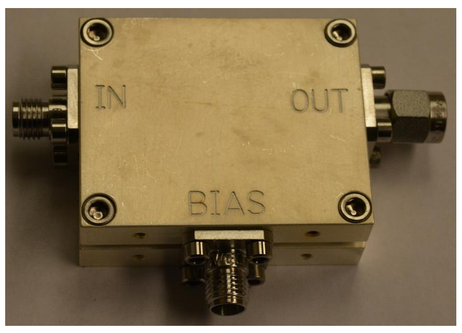
$$f_R = \frac{1}{2\pi\sqrt{L_{\mathrm{gnd}}(C_j + C_{\mathrm{tune}})}}$$

Wideband Cryogenic Isolator

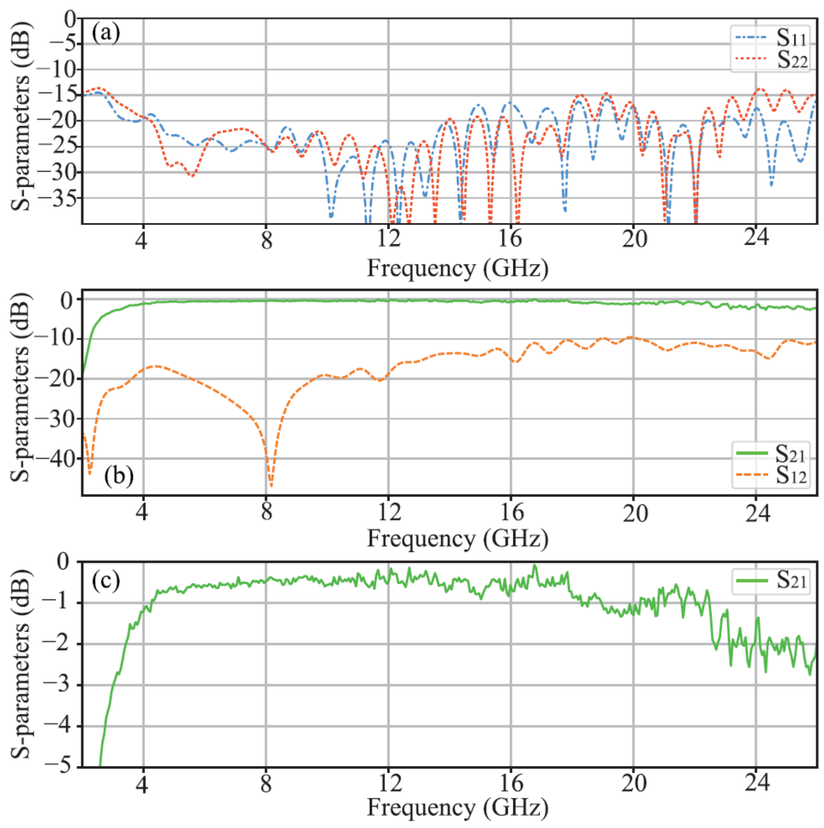
The figure below presents the result of a calculation based on Tucker's theory of quantum mixing. The region of the Smith chart above this solid contour yields negative output impedance, while the region below yields positive output impedance. The output impedance is independent of the IF load impedance. Unity conversion gain contours are plotted in dotted lines for the cases of an IF load impedances of R_n and $2R_n$.



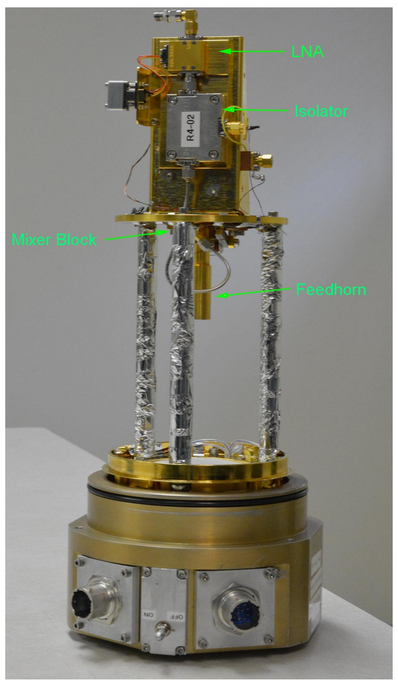
By employing an isolator at the IF port of the mixer, one can tolerate an infinite output impedance or even have the mixer operating slightly into the negative impedance region, without sacrificing stability.



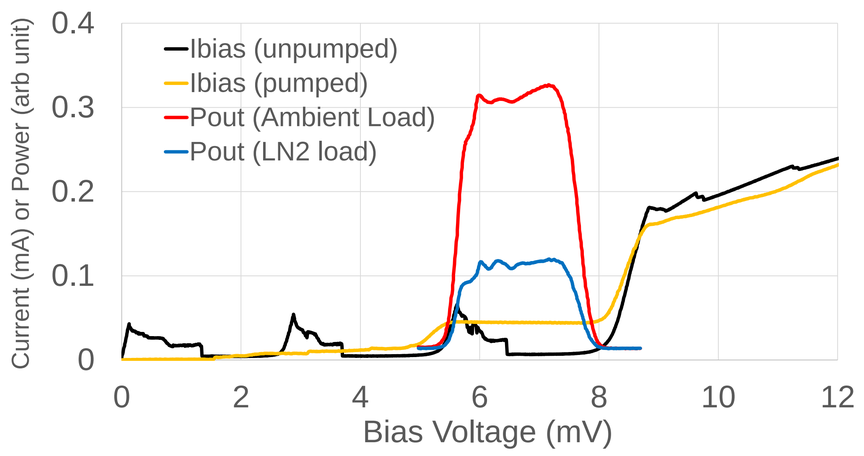
We have developed a cryogenic edge-mode isolator which is usable between 4 and 22 GHz. Its insertion loss is better than 1 dB from 4 to 17 GHz, rising to 1 – 1.5 dB from 17 to 22 GHz. The input return loss is about −15 dB from 4 to 22 GHz, and the isolation is better than 15 dB from 4 to 13 GHz, degrading to about 10 dB above 13 GHz.



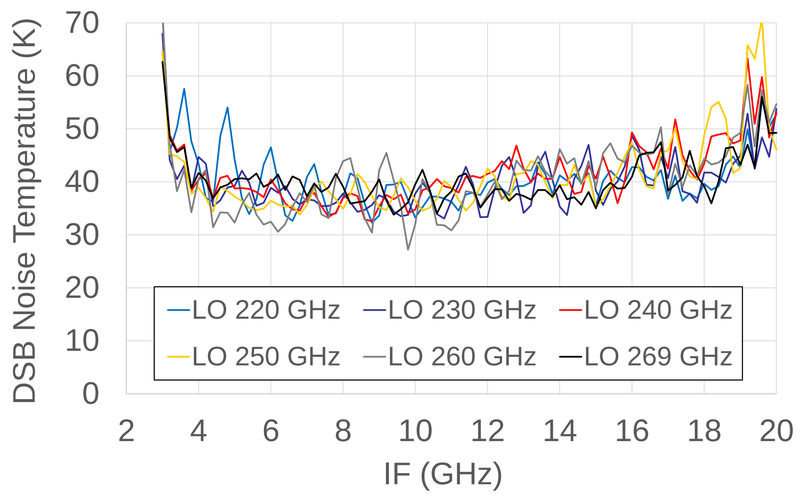
SMA Wideband IF Performance



SMA 240 GHz insert incorporating wSMA mixer



Current Vs Voltage (I-V) and output Power Vs Voltage (P-V) curve of the wSMA-240 mixer when the mixer was pumped at an LO frequency of 250 GHz. The output power was measured at an IF of 9 GHz through a 30 MHz bandpass filter. A maximum Y-factor of 2.93 was obtained at 7.5 mV bias.



Measured DSB receiver noise temperature of wSMA-240 mixer