177-207 GHz Radiometer Front End, Single-Side-Band Measurements

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ABSTRACT: *Twenty years of progress in 200 GHz receivers for spaceborne remote sensing has yielded a 180-220 GHz technology with maturing characteristics. The maturing characteristics are evident by increasing hardware availability —supply side—that parallels further refinement in receiver front-end (RFE) performance requirements—demand side—at this important spectrum band. The 177-207 GHz super-heterodyne receiver, for the Earth observing system (EOS) microwave limb sounder (MLS), effectively illustrates such technology developments. This MLS receiver simultaneously detects six different signals, located at side-bands below and above its 191.95 GHz local-oscillator (LO) frequency.*

The paper describes the MLS 177-207 GHz RFE, and provides measured data for its lower and upper side bands. Side-band ratio data is provided as a function of intermediate frequency (IF), at different LO power drive, and for variation in the ambient temperature.

INTRODUCTION

The 191.95±15 GHz receiver of the MLS employs a sub-harmonic (x2) mixer simultaneously producing (Table 1) six IF outputs, three of which originate at the lower RF side-band (191.95-15 GHz) and the other three at the upper RF side-band (191.95+15 GHz).

RF [GHz]		LO [GHz]	IM [GHz]		IF [GHz]
LOWER $[RF_-]$ BAND	177.265	191.95	206.635	@ RF_+ BAND	14.685
	181.599		202.301		10.351
	183.314		200.586		8.636
UPPER $[RF_+]$ BAND	200.980	191.95	182.920	@ RF_- BAND	9.030
	204.357		179.543		12.407
	206.137		177.763		14.187

Table 1. MLS 191.95 GHz Receiver Spectrum Characteristics

As Table 1 illustrates, each one of the 191.95 GHz MLS side bands contain RF inputs and image (IM) inputs; therefore, IM rejection with a filter is not a practical option. In effect, this MLS receiver relies on the availability of a double-side-band (DSB) mixer with superior single-side-band (SSB) sensitivity—i.e., mixers yielding extremely low-noise-temperature and a side-band ratio, which approximates unity, over an RF band spanning 30 GHz.

A mixer is the prime determinant of the RF side-band characteristics of a super-heterodyne receiver—especially at high millimeter-wave (MMW) frequencies, where a low-noise MMW amplifier is not available to precede the mixer. The DSB inputs, i.e., upper/lower RF_+/RF_- side band respectively, down converts simultaneously to the same output IF band, following the relation $f_{IF} = |f_{LO}-f_{RF\pm}|$. Mixers employing non-linear resistive devices exhibit theoretically identical RF-to-IF power conversion loss [1], for $f_{RF\pm}$ inputs symmetrically paired $2\mathrm{x}f_{IF}$ apart relative to the frequency f_{LO} of the local-oscillator.

Practically, DSB mixer operation is spectrum bounded: high-end bound, by the bandwidth of the mixer's circuit and the parasitic elements associated with a non-linear resistive device; and low-end bound, by the frequency stability of the LO.

Progress at Aerojet in subharmonic (x2) mixer's RF and IF circuit design [2] and improvements at University of Virginia in mixer Schottky diode technology [3] are the prime facilitators of the MLS 191.95±15 GHz RF side band's characteristics reported in this paper.

SINGLE-SIDE-BAND TESTS SET-UP

Single-side-band (SSB) measurements have been performed at JPL, on this MLS RFE, in the 177-207 GHz input RF band and 8-15 GHz output IF band. The test set-up is based on a parallel two-grid Fabry-Perot interferometer (FPI) configuration previously described [4]. This test set-up was originally constructed for measuring RFE conversion-loss at each side-band, for IF frequencies up to about 12 GHz. A minimum grid spacing of about 2900 μm accommodated such test capabilities, and also determined the orders of resonance of the parallel grid. The MLS higher IF frequency requires an FPI with reduced grid spacing and lower orders of resonance, to ensure avoidance of aliasing of the lower and upper side-bands between consecutive resonance orders of the grids. Reduction in grid spacing—modified FPI achieves a minimum grid spacing of less than 1000 μm—required installing a shim on the step micrometer shaft driving the slide assembly holding one of the grids. The variable differential transformer reference was then readjusted to indicate positions to the controlling computer, consistent with the modified minimum grid spacing.

This test set-up facilitates relative measurements of RFE conversion-loss at the lower side-band (L_-) and the upper side-band (L_+), for which the mixer is assumed the sole determinant. The specific spectrum of a SSB application determines the relations between RF_-; RF_+, and RF; IM respectively, to yield a side-band ratio L_{RF}/L_{IM}. This ratio enables the calculation of the receiver's SSB noise-temperature (T_R(SSB)) from measured receiver DSB noise-temperature (T_R(DSB)).

The relation between SSB and DSB receiver noise-temperature

$$T_R(SSB) = T_R(DSB) x (1+(L_{RF}/L_{IM}))$$

$T_R(DSB)$ is measured by the Y-factor ("Hot" and "Cold" loads) method

$$T_R(DSB) = (T(RF_{Hot})-YxT(RF_{Cold}))/(Y-1)$$

SINGLE-SIDE-BAND MIXER MEASURED PERFORMANCE

The MLS 191.95 GHz RFE is designed to exhibit $T_R(DSB) \approx 1000$ K over an IF of 8-15 GHz, yielding $T_R(SSB) \leq 3000$ K (side-bands imbalance (≤ 2) is accommodated) over the 177-207 GHz RF band. Figure 1 summarizes MLS receiver DSB and SSB measurements at nominal operation conditions of base temperature 22.5°C, and an optimum 91.95 GHz LO power drive (+5 dBm). Figure 1 shows measured $T_R(SSB)$ data in comparison with measured $T_R(DSB)$ data. The measured DSB data is converted in the figure to a SSB receiver yielding "ideal" side-band balanced $<T_R(SSB)> = 2xT_R(DSB)$. Hence, the difference between $T_R(SSB)$ and $<T_R(SSB)>$ in the figure illustrates L_{RF}/L_{IM} deviation from perfect balance.

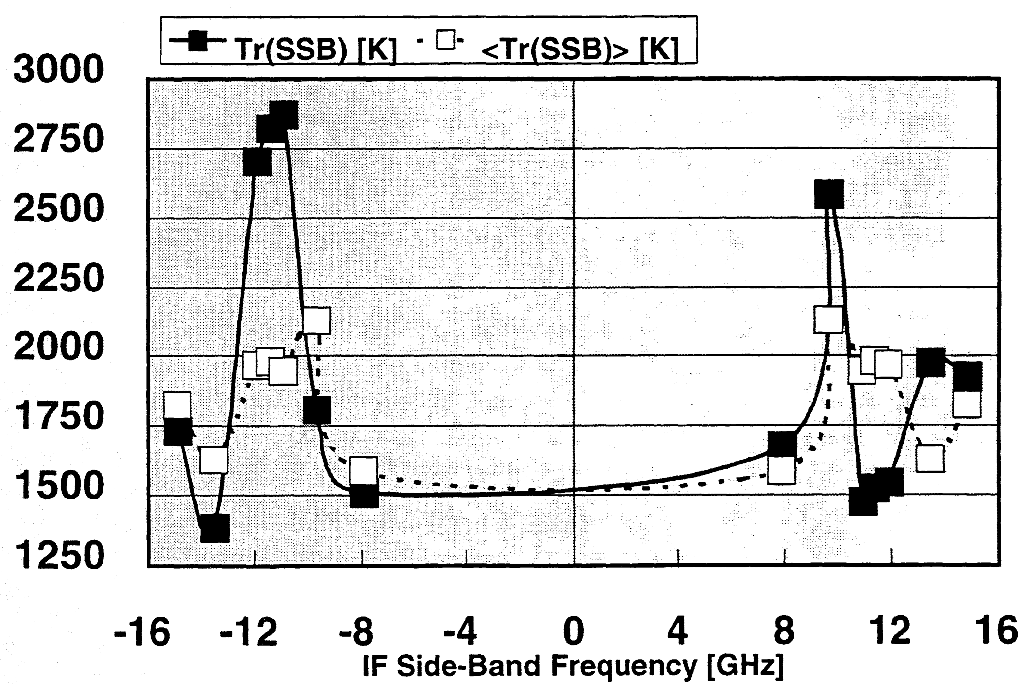

Figure 1. Measured $T_R(SSB)$ Data Compared to Measured $T_R(DSB)$.

($<T_R(SSB)>$ is for an "Ideal" Mixer with Balanced Side bands).

Table 2 depicts the percent variation in side-band balance, relative to the nominal operation conditions, for changes in the receiver's ambient temperature (22.5°C±17.5°C) and variation in LO power drive (+5dBm±1.5dBm).

	SIDE-BAND-RATIO % CHANGE (Relative to:LO=+5dBm; $T_{AMBIENT}$=22.5°C)		
IF [GHz]	**7.9**	**11.4**	**14.9**
LO=+5dBm $T_{AMBIENT}$=40°C	**+6%**	**-8%**	**0%**
LO=+6.5dBm $T_{AMBIENT}$=22.5°C	**+17%**	**-11%**	**-11%**
LO=+5dBm $T_{AMBIENT}$=22.5°C	**Side-Band-Ratio 0.90**	**Side-Band-Ratio 1.85**	**Side-Band-Ratio 0.90**
LO=+3.5dBm $T_{AMBIENT}$=22.5°C	**0%**	**+3%**	**0%**
LO=+5dBm $T_{AMBIENT}$=4°C	**-11%**	**0%**	**0%**

Table 2. The Percentage Variation in Side-Band Balance for Different Ambient Temperatures and LO Power Drives, Within The MLS IF Band.

REFERENCES

[1] C. H. Page, "Frequency Conversion With Positive Nonlinear Resistors", Journal Research National Bureau Standards, Volume 56, April 1956.
[2] I. Galin, "A Mixer Up To 300 GHz With Whiskerless Schottky Diodes For Spaceborne Radiometers", The 7th International Symposium on Space Terahertz Technology, Charlottesville VA, 1996.
[3] P. H. Ostdiek, et al, "Integration Of An Anti-Parallel Pair Of Schottky Barrier Diodes In MMW Mixers", The 15th International Conference on IR and MM-Waves, December 1990.
[4] R. J. Dengler, A. Hanpachern, P. H. Siegel, "A Fully Automated High Accuracy RF/IF Test System for Millimeter- and Submillimeter-Wave Mixers", 1998 IEEE MTT-S International Microwave Symposium Digest, pp. 1719-1722.