Numerical and theoretical modeling of a heterodyne noise injection radiometer system

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***Abstract* — This paper presents a theoretical and numerical model of a radiometer noise injection system based on a heterodyne generation of the noise signal. The coupled 3D EM and nonlinear circuit simulation is performed at 600 GHz using the subharmonic mixers developed at LERMA and C2N.**

Keywords—Heterodyne, Noise Source, ENR, Sub-harmonic, Calibration, Sub-millimeter

I. Introduction

Noise signals for radiometer calibration are generated directly at the RF frequency using noise diodes up to 220 GHz [1]. At submillimeter wavelength, they can be generated by electrical or optical heterodyning [1], [2]. We present a simulation model of a 600 GHz radiometer noise injection system featuring a sub-harmonic mixer that up-converts the noise signal. The mixers used in the simulation were developed at LERMA and C2N [3].

II. Results

At submillimeter wavelength, radiometer calibration is made using two well calibrated blackbodies at physical temperatures below and above the nominal value of the equivalent brightness temperature of the scene to be detected (typically 4 K and 300 K). In case of noise injection, the injected noise signal effectively increases the T_{sys}. If one can verify that the radiometer output power, during the noise injection, is comparable to its predicted by an equivalent increase of $T_{ant,hot}$, the noise injection system can be used for hot calibration.

The simplified ADS simulation schematic of the system is shown in the Figure 1. The noise source is modelled by an IF resistor at the upconverting mixer with variable physical temperature. The bandwidth of the noise source is limited by an ideal filter. The LO, RF and IF frequencies are 290, 584 and 4 GHz, respectively.

When IF noise with temperature $T_{N,IF}$ is upconverted by a mixer with conversion loss L_{cnv}, the temperature at the output $T_{N,RF}$ is reduced according to the attenuator model – Eq. (1).

$$(1)\quad T_{N,RF} = L_{cnv} T_{N,IF} + (1 - L_{cnv}) \times T_{phys}$$

The input noise temperature of a system is dependent on the $T_{N,RF}$, coupler's loss, noise temperature, coupling factor (G_C, T_C, C) and noise temperature of the receiving mixer T_{mix}. The system noise temperature as a function of $T_{N,RF}$ can be expressed by Eq. (2).

$$(2)\quad T_{sys} = \left[T_C + (T_{N,RF} - 290)\frac{C}{G_c}\right] + \frac{T_{mix}}{G_C}$$

The comparison of the theoretically calculated with Eq. (2) and Keysight Advanced Design System Harmonic Balance (ADS HB) simulated T_{sys} is given in the Figure 2. The coupler is assumed to be lossless and with -10 dB coupling. The T_{sys} value at ENR of 0 dB corresponds to the circuit consisting of a coupler followed by a mixer. As the level of the IF noise increases, the effective system temperature increases too: an increase of the T_{sys} by 300K corresponds to the required ENR at the IF input of the first mixer of around 20 dB. The small discrepancy between the two curves is due to the finite number of harmonics in HB which affects the absolute value of the calculated noise.

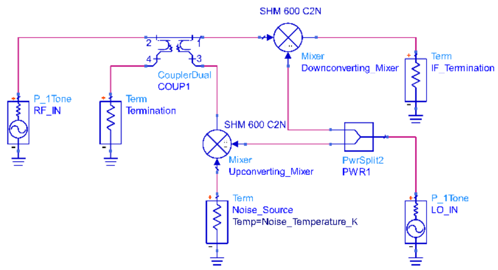

Figure 1 Simplified schematic of the simulated noise-injection system

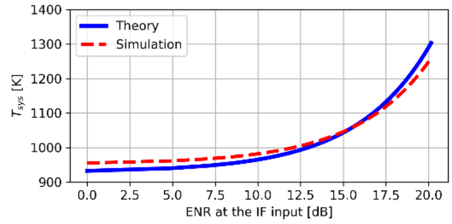

Figure 2, System noise temperature as a function of the IF noise level

References

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