PHASE NOISE REQUIREMENTS IN INTERFEROMETRIC RADIOMETERS

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1. INTRODUCTION

This work has been conducted in the framework of a project devoted to assess the performance of the MIRAS (Microwave Imaging Radiometer with Aperture Synthesis) instrument [1], the single payload of the ESA-SMOS mission [2], as a preliminary **SMOSops (Operational SMOS) Receiver Technology Study.**

The MIRAS instrument is compounded of 63 receiver equally distributed in the arms of a "Y" shape array. Other 9 receivers are also used as reference real aperture radiometers and/or redundancy. Cross-correlation of the signals collected by each receiver pairs "k, j" give the samples of the so-called visibility function, V_{kj}, which develops into a brightness temperature map by means of a Fourier synthesis technique. Random or systematic phase errors in the visibility samples are directly translated into image errors through this Fourier synthesis process. Therefore, the performance of an interferometric radiometer such as the MIRAS may be degraded due to the phase instability of the signals used to demodulated the radiation collected by the antennas.

This work presents a comprehensive assessment on the impact of phase noise on the visibility errors the receivers that compound the interferometer:

- Correlation error due to phase noise
- Subsystem contribution to phase noise
- Typical phase noise requirements
- Phase drift constraints

2. CORRELATION ERROR DUE TO PHASE NOISE

In this section the basis for the analysis of phase noise impact on correlation errors is addressed. Phase noise is characterized by means of the spectral density of phase fluctuation $S_\phi\left(f_m\right)$ rad^2/Hz , where f_m is the so-called offset (modulating) frequency. However, phase noise specifications for local oscillators are usually expressed as single sideband phase noise £(f) in dBc/Hz. Local oscillator (LO) phase noise contaminates the signals collected by the antennas due to demodulation/downconversion process before sampling. If we take into account the correlation given between two receivers in the interferometer, the phase of every PLO (phase lock oscillator) $\phi_{LO}(t)$ can be split into a constant term ϕ_{LO} and a random term (phase noise) $\phi_n(t)$. Hence, taking into account the baseline corresponding to receivers "1" and "2", these phase terms can be written as:

$$\phi_{OL1}(t) = \phi_{OL1} + \phi_{n1}(t)$$
$$\phi_{OL2}(t) = \phi_{OL2} + \phi_{n2}(t)$$

Now, taking into account that the LO phase adds to the signal phase by means of the downconversion process, the equivalent signals at the antenna outputs $s_{a1,2}(t)$ can be written as:

$$s_{a1}(t) = S_1(t)\cos[\omega_o t + \phi_1(t) + \phi_{OL1} + \phi_{n1}(t)]$$
$$s_{a2}(t) = S_2(t)\cos[\omega_o t + \phi_2(t) + \phi_{OL2} + \phi_{n2}(t)]$$

where $S_{1,2}(t)$ and $\phi_{n1,2}(t)$ are the modulus and phase of the narrowband noise collected by the antennas. The complex correlation is now measured out of the analytic signals of $s_{a1,2}(t)$ as:

$$V_{12}^{meas} = E[S_{a1} S_{a2}^*] = E[S_1(t) S_2^*(t)] E[e^{j(\phi_1(t)-\phi_2(t))}] E[e^{j(\phi_{n1}(t)-\phi_{n2}(t))}] e^{j(\phi_{OL1}-\phi_{OL2})}]$$
$$V_{12}^{meas} = V_{12} E[e^{j(\phi_{n1}(t)-\phi_{n2}(t))}] e^{j(\phi_{OL1}-\phi_{OL2})}$$

This last expression allows to assess the impact of phase noise as a function of the offset frequency fm. It is shown that the impact of phase noise is related to the relation between the correlation (sampling) time t_s and the period of the phase noise component $t_m=1/f_m$.

3. PHASE NOISE CONTRIBUTION FROM PLO SUBSYSTEMS

In order to achieve coherent demodulation and good frequency stability, the local oscillator used to demodulate the signals collected by the antennas is designed as a phase lock oscillator (PLO). In this section, the noise contributions from each PLO subsystem to overall phase noise is analyzed. In order to set typical phase noise requirements, the correlated/uncorrelated nature of these noise contributions is taken into account as a function of the offset frequency f_m and the loop bandwidth.

5. PHASE DRIFT REQUIREMENTS

The analysis has shown that the main source of phase error comes from phase instability or drift with time periods t_m larger than the correlation (sampling) time t_s Since such errors are mainly driven by temperature drift, some preliminary specifications can be set according to the expected thermal drift along each orbit.

11. REFERENCES

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