Local Oscillator Systems for (sub)millimetre Spectroscopy

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ABSTRACT

One of the most critical subsystems in a (sub)millimetre heterodyne radiometry instrument is the Local Oscillator (LO) system, especially for high resolution spectroscopy. For space applications, requirements such as low power consumption, compactness and reliability concerns add an additional dimension to the system design issues.

Design aspects of a complete LO system will be described below. This includes trade-offs between phase noise characteristics of Gunn oscillators and harmonic reference oscillators, bandwidth requirements of tuning ports as well as power supply filtering and general protection of various components. As an example, the complete LO system of the ODIN satellite will be described, a system with very high resolution requirements, and for SMILES.

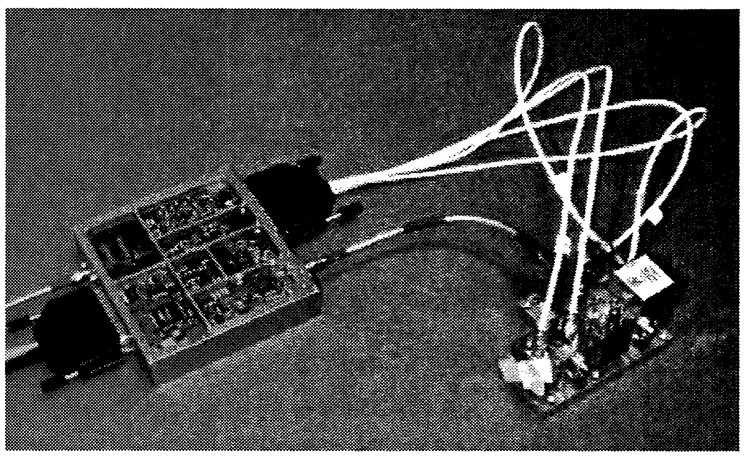

Figure 1. Breadboard of the SMILES phaselock and control system.

SYSTEM COMPONENTS

Harmonic reference oscillator (HRO). The harmonic reference oscillator is a low phase-noise frequency synthesizer in the 2-10 GHz band. This signal is mixed harmonically with the Gunn oscillator in order to produce a low IF frequency. The harmonic IF is then used for the phase-locking of the Gunn oscillator.

PLL reference oscillator (PRO). This synthesizer is used to create a signal in the 50-500 MHz range. This signal is used in the main PLL as a reference for the phase detector. The PRO will typically set the system frequency step size.

Main PLL. The main PLL consists of a high performance phase- frequency discriminator feeding the main active loop filter. PLL requirements are dependent on the quality of the Gunn oscillator and the receiver phase-noise specification. Loop bandwidths can range from 100 kHz to 10 MHz.

Main reference source. This reference is usually an OCXO or a TCXO with stability in the order of 10^8 or better.

Biasing and monitoring. The biasing system of a front-end controller is often over-looked. In a typical receiver, bias shall be provided to Gunn oscillators, harmonic mixers, multipliers, cryogenic mixers and cryogenic IF amplifiers. Bias points on all these units should be monitored together with temperatures. 30 bias and 50 monitor channels are used in ODIN.

The most critical elements of the LO system is the HRO and the PLL loop filter. Given a typical gunn oscillator, these units limit the maximum resolution of the receiver. In order to analyze how different noise contributors affects the overall phase-noise performance of an LO system, a MatLab simulation program has been developed. The program simulates a large number of noise sources and transforms the result to the operating frequency. Performance is evaluated and compared with the specification.

THE ODIN SYSTEM

The ODIN satellite is a joint aeronomy and astronomy mission. The main payload consist of four tunable heterodyne schottky receivers in the frequency range 480-570 GHz and one fixed tuned 119 GHz heterodyne system.

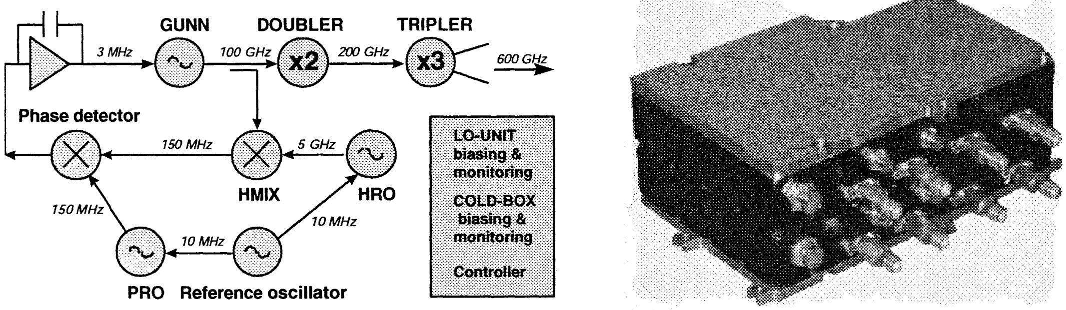

FIGURE 3. Block diagram for the ODIN control system. The box on the right incorporates four complete phase-lock and control systems.

SMILES

Based on the experience from the ODIN satellite, a phase-lock and control system for the Japanese SMILES experiment, scheduled for operation on the International Space Station has been developed. Although the basic design is similar to the ODIN version, it differs in frequencies, interfaces as well as specification.

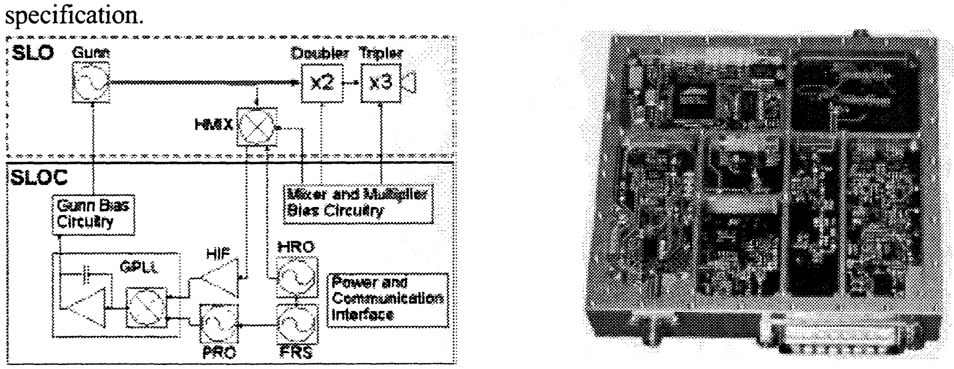

Figure 4. Block diagram of the phase lock and bias system for the SMILES LO to the left, and top view of the physical realization to the right.

6. CONCLUSION

When designing a controller for a (sub)millimetre front-end, one must realize that this is a complex system. One of the most over-looked issues is the great number of biasing and monitoring circuits needed. These circuits play an important roll for the phase-noise budget. They also serve as protection circuits for the very sensitive front-end components such as multipliers and mixers.

In order to transform the resolution requirements of the receiver to specifications at component level, a MatLab program has been developed. This program takes into account many sources of noise and different filter functions through out the system.