Flexible RF Readout for Cross-cutting Heterodyne Imaging and Spectroscopy

Tilak Hewagama[1,2], Shahid Aslam[2], Hollis Jones[2], Theodor Kostiuk[2], Geronimo Villanueva[3,2], George Shaw[2], Timothy Livengood[1,2], John Allen[4], Nicolas Gorius[3,2], Michael Zimmerman[5], John Annen[2], & Don Jennings[2]
[1]University of Maryland; [2]NASA/Goddard Space Flight Cente, [3]Catholic University, [4]GSFC/Emiratus, [5]NPP/GSFC

Motivation

Infrared (5-12 µm) heterodyne-based devices for planetary missions are capable of

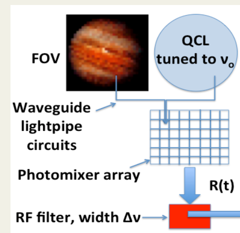
- Line shape characterization in the Doppler broadening limit,
- Resolving gas phase ro-vibrational transitions – composition,
- Eliminating parasitic contributions of other molecular species,
- Radiometry,
- Atmospheric thermometry,
- Atmospheric chemistry.

Development of Infrared heterodyne imaging and 3D (data cube) systems are constrained by

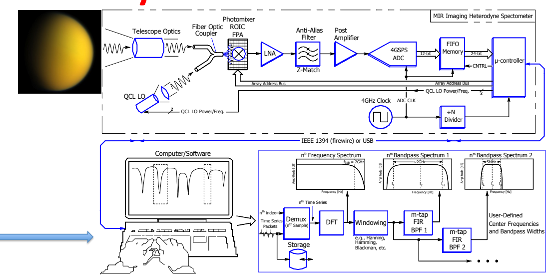
- Availability of high-speed 2-D format photomixer arrays,
- Broadly tunable, stable infrared local-oscillator sources,
- Adjustable readout system to route pixels of interest with user defined frequency band and resolution.

The first two devices are now becoming commercially available. We are developing a system to address the third aspect.

Readout System



[Top left] A schematic of the basic components. Mixing of the source and QCL signal results in a beat frequency down-converted to the microwave frequency domain. The compound signal detected by the sensor array, R(t), will be analyzed by the proposed RFSDR (top right figure).



[Top right] Functional block diagram of the spectrometer components. The telescope and QCL light signals are routed by waveguides, combined, and presented to the photomixer pixels. The difference frequency signals are multiplexed and amplified by the high-gain low noise amplifier (LNA) such that the system noise figure is commensurate with the spectroscopic bandwidth. The amplified time-series voltages are filtered, digitized, temporarily stored on an ultra-high speed FIFO memory, and routed to the spacecraft (or lab) computer. In software, the times-series data are de-multiplexed, transformed to the frequency domain, windowed, and filtered at spectral regions of interest. The post amplifier ensures that the RF signal, via gain or attenuation, fills the dynamic range of the ADC. The software filter block shows numerous multi-tap finite impulse response (FIR) bandpass filters to examine the spectral data—the center and bandwidth frequencies (5MHz to 1GHz) are user-selectable in which the amplitudes and group delays remain flat throughout the spectrum.

Heterodyne Background

Heterodyne system operation:

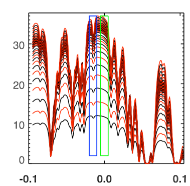
- Telescope beam is combined with a quantum cased laser source
- Signal is detected with a ultra-high speed detector
- Beat (difference) frequency contains the source spectrum
- The down-converted RF output stream is analyzed by RF software-defined readout techniques

Technologies

Quantum Cascade Lasers: room temperature (TE cooled room temperature tunable devices from Maxion Technologies, College Park, MD).

Waveguides as replacements for bulky free space optics.

Applications



Earth atmosphere in solar occultation (simulated). Each trace corresponds to a different tangent altitude in km. The blue and green boxes represent selected band-passes (width 300 MHz= 0.01 cm^{-1}) that isolate a unique O_3 line and wing region to study the molecular feature as a function of altitude. Although this example shows a ±0.1 cm^{-1} bandpass, the spectrometer can measure a variable bandpass or simply narrow spectral regions of interest.

References

Kostiuk T. (1994) *IR. Phys. Tech., 35,* 243.

Hutchinson, D. P., Richards, R. L., Simpson, M. L. (1998) *OSTI, **1998-03-01***.

Sonnabend G. *et al.* (2005) *A&A, 435,* 1181.

Villanueva G. L. *et al.* (2006) *IEEE, 54,* 1415-1424.

Acknowledgements

We gratefully acknowledge the support of NASA/Goddard Space Flight Center's Internal Research & Development Program for waveguide development and technical equipment funds.