Electronics/Computers

Improvements in Speed and Functionality of a 670-GHz Imaging Radar

Image acquisition time has been reduced, enabling clearer images of contraband objects hidden underneath clothing.

NASA's Jet Propulsion Laboratory, Pasadena, California

Significant improvements have been made in the instrument originally described in a prior *NASA Tech Briefs* article: "Improved Speed and Functionality of a 580-GHz Imaging Radar" (NPO-45156), Vol. 34, No. 7 (July 2010), p. 51. First, the wideband YIG oscillator has been replaced with a JPL-designed and built phase-locked, low-noise chirp source. Second, further refinements to the data acquisition and signal processing software have been performed by moving critical code sections to C code, and compiling those sections to Windows DLLs, which are then invoked from the main LabVIEW executive.

This system is an active, single-pixel scanned imager operating at 670 GHz. The actual chirp signals for the RF and LO chains were generated by a pair of MITEQ 2.5–3.3 GHz chirp sources. Agilent benchtop synthesizers operating at fixed frequencies around 13 GHz were then used to up-convert the chirp sources to 15.5–16.3 GHz. The resulting signals were then multiplied 36 times by a combination of off-the-shelf millimeter-wave components, and JPL-built 200-GHz doublers and 300- and 600-GHz triplers. The power required to drive the submillimeter-wave multipliers was provided by JPL-built W-band amplifiers. The receive and transmit signal paths were combined using a thin, high-resistivity silicon wafer as a beam splitter.

While the results at present are encouraging, the system still lacks sufficient speed to be usable for practical applications in a contraband detection. Ideally, an image acquisition speed of ten seconds, or a factor of 30 improvement, is desired. However, the system improvements to date have resulted in a factor of five increase in signal acquisition speed, as well as enhanced signal-processing algorithms, permitting clearer imaging of contraband objects hidden underneath clothing. In particular, advances in three distinct areas have enabled these performance enhancements: base source phase noise reduction, chirp rate, and signal processing. Additionally, a second pixel was added, automatically reducing the imaging time by a factor of two. Although adding a second pixel to the system doubles the amount of submillimeter components required, some savings in microwave hardware can be realized by using a common low-noise source.

This work was done by Robert J. Dengler, Ken B. Cooper, Imran Mehdi, Peter H. Siegel, Jan A. Tarsala, and Tomas E. Bryllert of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-47180, volume and number of this NASA Tech Briefs *issue, and the page number.*

IONAC-Lite

A combination of energy and performance optimization is attained for high-speed Delay Tolerant Networking.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Interplanetary Overlay Networking Protocol Accelerator (IONAC) described previously in "The Interplanetary Overlay Networking Protocol Accelerator" (NPO-45584), *NASA Tech Briefs*, Vol. 32, No. 10, (October 2008) p. 106 (*http://www.techbriefs.com/component/content/article/3317*) provides functions that implement the Delay Tolerant Networking (DTN) bundle protocol. New missions that require high-speed downlink-only use of DTN can now be accommodated by the unidirectional IONAC-Lite to support high data rate downlink mission applications. Due to constrained energy resources, a conventional software implementation of the DTN protocol can provide only limited throughput for any given reasonable energy consumption rate. The IONAC-Lite DTN Protocol Accelerator is able to reduce this energy consumption by an order of magnitude and increase the throughput capability by two orders of magnitude. In addition, a conventional DTN implementation requires a bundle database with a considerable storage requirement. In very high downlink data-rate missions such as near-Earth radar science missions, the storage space utilization needs to be maximized for science data and minimized for communications protocol-related storage needs.

The IONAC-Lite DTN Protocol Accelerator is implemented in a reconfigurable hardware device to accomplish exactly what's needed for high-throughput DTN downlink-only scenarios.

The following are salient features of the IONAC-Lite implementation:

• An implementation of the Bundle Protocol for an environment that requires a very high rate bundle egress data rate. The C&DH (command and data handling) subsystem is also expected to be very constrained so the interaction with the C&DH processor and the temporary storage are minimized.

- Fully pipelined design so that bundle processing database is not required.
- Implements a lookup table-based approach to eliminate multi-pass processing requirement imposed by the Bundle Protocol header's length field structure and the SDNV (self-delimiting numeric value) data field formatting.
- 8-bit parallel datapath to support high data-rate missions.
- Reduced resource utilization implementation for missions that do not require custody transfer features. There was no known implementation of the DTN protocol in a field programmable gate array (FPGA) device prior to the current implementation.

The combination of energy and performance optimization that embodies this design makes the work novel.

This work was done by Jordan L. Torgerson, Loren P. Clare, and Jackson Pang of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact the JPL Innovative Technology Assets Management Office, 1-818-393-3421, and reference NPO-47344.

Large Ka-Band Slot Array for Digital Beam-Forming Applications

NASA's Jet Propulsion Laboratory, Pasadena, California

This work describes the development of a large Ka Band Slot Array for the Glacier and Land Ice Surface Topography Interferometer (GLISTIN), a proposed spaceborne interferometric synthetic aperture radar for topographic mapping of ice sheets and glaciers. GLISTIN will collect ice topography measurement data over a wide swath with sub-seasonal repeat intervals using a Ka-band digitally beamformed antenna.

For technology demonstration purpose a receive array of size 1×1 m, consisting of 160×160 radiating elements, was developed. The array is divided into 16 sticks, each stick consisting of 160×10 radiating elements, whose outputs are combined to produce 16 digital beams. A transmit array stick was also developed. The antenna arrays were designed using Elliott's design equations with the use of an infinite-array mutual-coupling model. A Floquet wave model was used to account for external coupling between radiating slots. Because of the use of uniform amplitude and phase distribution, the infinite array model yielded identical values for all radiating elements but for alternating offsets, and identical coupling elements but for alternating positive and negative tilts.

Waveguide-fed slot arrays are finding many applications in radar, remote sensing, and communications applications because of their desirable properties such as low mass, low volume, and ease of design, manufacture, and deployability. Although waveguide-fed slot arrays have been designed, built, and tested in the past, this work represents several advances to the state of the art. The use of the infinite array model for the radiating slots yielded a simple design process for radiating and coupling slots. Method of moments solution to the integral equations for alternating offset radiating slots in an infinite array environment was developed and validated using the commercial finite element code HFSS. For the analysis purpose, a method of moments code was developed for an infinite array of subarrays.

Overall the 1×1 m array was found to be successful in meeting the objectives of the GLISTIN demonstration antenna, especially with respect to the 0.042°, 1/10th of the beamwidth of each stick, relative beam alignment between sticks.

This work was done by Sembiam Rengarajan, Mark S. Zawadzki, and Richard E. Hodges of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47416

Development of a 150-GHz MMIC Module Prototype for Large-Scale CMB Radiation

NASA's Jet Propulsion Laboratory, Pasadena, California

HEMT-based receiver arrays with excellent noise and scalability are already starting to be manufactured at 100 GHz, but the advances in technology should make it possible to develop receiver modules with even greater operation frequency up to 200 GHz. A prototype heterodyne amplifier module has been developed for operation from 140 to 170 GHz using monolithic millimeter-wave integrated circuit (MMIC) low-noise InP high electron mobility transistor (HEMT) amplifiers.

The compact, scalable module is centered on the 150-GHz atmospheric window using components known to operate well at these frequencies. Arrays equipped with hundreds of these modules can be optimized for many different astrophysical measurement techniques, including spectroscopy and interferometry.

This module is a heterodyne receiver module that is extremely compact, and makes use of 35-nm InP HEMT technology, and which has been shown to have excellent noise temperatures when cooled cryogenically to 30 K. This reduction in system noise over prior art has been demonstrated in commercial mixers (uncooled) at frequencies of 160–180 GHz. The module is expected to achieve a system noise temperature of 60 K when cooled.

An MMIC amplifier module has been designed to demonstrate the feasibility of expanding heterodyne amplifier technology to the 140 to 170-GHz frequency range for astronomical observations. The miniaturization of many standard components and the refinement of RF interconnect technology have cleared the way to mass-production of heterodyne amplifier receivers, making it a feasible technology for many large-population arrays.