

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 process-

ing 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 beam-formed antenna.

For technology demonstration purpose a receive array of size 1x1 m, consisting of 160x160 radiating elements, was developed. The array is divided into 16 sticks, each stick consisting of 160x10 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 1x1 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 Rengaranjan, 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 win-

dow 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.

This work furthers the recent research efforts in compact coherent receiver modules, including the development of the Q/U Imaging Experiment (QUIET) modules centered at 40 and 90 GHz, and the pro-

duction of heterodyne module prototypes at 90 GHz.

*This work was done by Pekka P. Kangaslahti, Lorene A. Samoska, Todd C. Gaier, and Mary M. Soria of Caltech; Patricia E. Voll, Sarah E. Church, Judy M. Lau, and*

*Matthew M. Sieth of Stanford University; and Daniel Van Winkle and Sami Tantawi of SLAC National Accelerator Laboratory for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47664*

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## Coupling Between Waveguide-Fed Slot Arrays

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Coupling between two waveguide-fed planar slot arrays has been investigated using full-wave analysis. The analysis employs the method-of-moments solution to the pertinent coupled integral equations for the aperture electric field of all slots. In order to compute coupling between two arrays, the input port of the first array is excited with a TE<sub>10</sub> mode wave while the second one is match-terminated. After solving the moment method matrix equations, the aperture fields of all slots are obtained and

thereby the TE<sub>10</sub> mode wave received at the input port of the second array is determined. Coupling between two arrays is the ratio of the wave amplitude arriving in the second array port to the incident wave amplitude at the first array port. The coupling mechanism has been studied as a function of spacing between arrays in different directions, e.g. the electric field plane, the magnetic field plane, and the diagonal plane. Computed coupling values are presented for different array geometries.

This work is novel since it provides a good understanding of coupling between waveguide-fed slot arrays as a function of spacing and orientation for different aperture distributions and array architectures. This serves as a useful tool for antenna design engineers and system engineers.

*This work was done by Sembiam Rengaranjan of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-47446*

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## PCB-Based Break-Out Box

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Break-out boxes (BOBs) are necessary for all electrical integration/cable checkouts and troubleshooting. Because the price of a BOB is high, and no work can be done without one, often the procedure stops, simply waiting for a BOB. A less expensive BOB would take less time in the integration, testing, and troubleshooting process.

The PCB-based BOB works and looks the same as a standard JPL BOB, called "Gold Boxes." The only differences between the old BOB and the new PCB-based BOB is that the new one has 80 percent of its circuitry in a printed circuit

board. This process reduces the time for fabrication, thus making the BOBs less expensive. Moreover, because of its unique design, the new BOBs can be easily assembled and fixed. About 80 percent of the new PCB-based BOB is in a \$22 (at the time of this reporting) custom-designed, yet commercially available PCB.

This device has been used successfully to verify that BOB cables were properly made. Also, upon completion, the BOB was beeped out via a multimeter to ensure that all sockets on the connectors were properly connected to the respective banana jack.

When compared to the Gold Box BOBs, the new BOB has many advantages. It is much more cost efficient, it delivers equal usability at substantially lower cost of the BOB, and the Gold Box is much heavier when compared to the new BOB. The new BOB is also a bit longer and much more versatile in that connectors are easily changeable and if a banana jack is broken, it can be replaced instead of throwing away an entire BOB.

*This work was done by Jason H. Lee of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46799*

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## Multiple-Beam Detection of Fast Transient Radio Sources

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A method has been designed for using multiple independent stations to discriminate fast transient radio sources from local anomalies, such as antenna noise or radio frequency interference (RFI). This can improve the sensitivity of

incoherent detection for geographically separated stations such as the very long baseline array (VLBA), the future square kilometer array (SKA), or any other coincident observations by multiple separated receivers.

The transients are short, broadband pulses of radio energy, often just a few milliseconds long, emitted by a variety of exotic astronomical phenomena. They generally represent rare, high-energy events making them of great