gate loses due to parasitic modes (the ground plane is etched on the bottom of this layer due to the topology of the double-Y balun).

The double-Y balun transitioning from an unbalanced microstrip line to a balanced coplanar strip (CPS) line does not provide inherent impedance transformation; hence, Klopfenstein impedance tapers were synthesized to transition from 50 to 77 Ω in the microstrip section and from 77 to 110 Ω in the CPS section. At the balun junction, the CPS stub lengths were chosen such that the λ/8 resonance is pushed outside the bandwidth of operation. Also, the smallest allowable conductor width and gap spacing were chosen to meet acceptable manufacturing tolerances.

The microstrip-to-waveguide transition has been analyzed numerically using a commercial 3D finite-element electromagnetic solver. The WR-90 waveguide (10.16×22.86×25.56 mm) was modeled as an air box. The 6010 and ULTRALAM substrates were modeled to account for dielectric losses. The microstrip section of the waveguide feed was excited using a 50-Ω lumped port; the output face of the waveguide was modeled as a wave port. The waveguide achieves maximum insertion loss of 0.84 dB, and a minimum insertion loss of 0.32 dB from 8.0 to 12.4 GHz with the ULTRALAM substrate and additional ground. The resulting insertion loss at the band edges is significantly lower. Further improvement in the insertion loss of the waveguide feed can potentially be obtained with continued numerical optimization.

This work was done by Jaikrishna Venkatesan of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42667

Thin-Film Ferroelectric-Coupled Microstripline Phase Shifters With Reduced Device Hysteresis

These are useful for electronically steerable ferroelectric reflectarray antennas.

John H. Glenn Research Center, Cleveland, Ohio

This work deals with the performance of coupled microstripline phase shifters (CMPS) fabricated using $Ba_xSr_{1-x}TiO_3$ (BST) ferroelectric thin films. The CMPS were fabricated using commercially available pulsed laser deposition BST films with Ba:Sr ratios of 30:70 and 20:80. Microwave characterization of these CMPS was performed at upper Ku-band frequencies, particularly at frequencies near 16 and 18 GHz. X-ray diffraction studies indicate that the 30:70 films exhibit almost a 1:1 ratio between the in-plane and out-of-plane lattice parameters, suggesting that their cubics create strain-free films suitable for producing CMPS devices with reduced hysteresis in the paraelectric state.

The quality of performance of the CMPS was studied based on their relative phase shift ($\Delta\phi = \phi_{nV} - \phi_{0V}$, where $n = 0$ to 400 volts DC) and insertion loss within the DC bias range of 0 to 400 V (i.e., E-field ranges within 0 to 53 V/μm). The performance of the CMPS was tested as a function of temperature to investigate their operation in the paraelectric, as well as in the ferroelectric, state (i.e., above and below the Curie temperature, respectively). The novel behavior discussed here is based on the experimental observation of the CMPS. Remarkably, these devices were hysteresis-free in the paraelectric state, and only showed Δϕ hysteresis while performing in the ferroelectric state. This behavior, observed for the aforementioned cation ratio, highlights the relevance of good crystalline structure for high-quality CMPS.

Elimination of Δϕ hysteresis is essential for practical microwave applications such as voltage-controlled oscillators and beam-steerable devices, particularly electronically steerable phased array antennas, which require accurate phase shift versus tuning voltage profiles for reliable operation. Accordingly, the optimization of the interplay among film microstructure, Ba content, and dielectric constant is critical for reliable CMPS devices. The origin of hysteresis is most likely related to fixed charges and ferroelectric domain phenomena in the ferroelectric state, as well as remnant ferroelectric domains in the paraelectric state. Consequently, to achieve minimum device hysteresis in the paraelectric domain, the BST films selected for the CMPS devices should be of optimal film composition [i.e., FWHM (full width at half maximum) < 0.05°], with minimum film strain (i.e., in-plane to out-of-plane lattice parameters ratio as close as possible to 1), and moderate values of dielectric constant (≈800 at $V = 0$) to enable acceptable tunability at manageable insertion losses.

This work was done by Félix A. Miranda and Robert Romanofsky of Glenn Research Center, Carl H. Mueller of Qinetiq North America, and Frederick Van Keuls of Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18370-1.

Two-Stage, 90-GHz, Low-Noise Amplifier

NASA's Jet Propulsion Laboratory, Pasadena, California

A device has been developed for coherent detection of the polarization of the cosmic microwave background (CMB). A two-stage amplifier has been designed that covers 75–110 GHz. The device uses the emerging 35-nm InP HEMT technology recently developed at Northrop Grumman Corporation primarily for use at higher frequencies. The amplifier has more than 18 dB gain and less than 35 K noise figure across the band.

These devices have noise less than 30 K at 100 GHz. The development started with design activities at JPL, as well as characterization of multichip modules using existing InP. Following processing, a test campaign was carried out using single-chip modules at 100 GHz. Successful development of the chips will lead to development of multichip modules, with simultaneous Q and U Stokes parameter detection.

This MMIC (monolithic microwave integrated circuit) amplifier takes advantage of performance improvements intended for higher frequencies, but in this innovation are applied at 90 GHz. The large amount of available gain ultimately leads to lower possible noise performance at 90 GHz.

This work was done by Lorene A. Samoska, Todd C. Gaier, Stephanie Xenos, Mary M. Soria, Pekka P. Kangaslahti, and Kieran A. Cleary of Caltech; and Linda Ferreira, Richard Lai and Xiaobing Mei of Northrop Grumman Corporation for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46627

A 311-GHz Fundamental Oscillator Using InP HBT Technology

This is the first fundamental HBT oscillator operating above 300 GHz.

NASA's Jet Propulsion Laboratory, Pasadena, California

This oscillator uses a single-emitter 0.3-µm InP heterojunction bipolar transistor (HBT) device with maximum frequency of oscillation (f_{max}) greater than 500 GHz. Due to high conductor and substrate losses at submillimeter-wave frequencies, a primary challenge is to efficiently use the intrinsic device gain. This was done by using a suitable transmission-line media and circuit topology. The passive components of the oscillator are realized in a two-metal process with benzocyclobutene (BCB) used as the primary transmission line dielectric. The circuit was designed using microstrip transmission lines.

The oscillator is implemented in a common-base topology due to its inherent instability, and the design includes an on-chip resonator, output-matching circuitry, and an injection-locking port, the port being used to demonstrate the injection-locking principle. A free-running frequency of 311.6 GHz has been measured by down-converting the signal. Additionally, injection locking has been successfully demonstrated with up to 17.8 dB of injection-locking gain. The injection-locking reference signal is generated using a 2–20 GHz frequency synthesizer, followed by a doubler, active tripler, a W-band amplifier, and then a passive tripler. Therefore, the source frequency is multiplied 18 times to obtain a signal above 300 GHz that can be used to injection lock the oscillator. Measurement shows that injection locking has improved the phase noise of the oscillator and can be also used for synchronizing a series of oscillators.

A signal conductor is implemented near the BCP-InP interface and the topside of the BCB layer is fully metallized as a signal ground. Because the fields are primarily constrained in the lower permittivity BCB region, this type of transmission line is referred to as an inverted microstrip. In addition, both common-emitter and common-base circuits were investigated to determine optimum topology for oscillator design. The common-base topology required smaller amount of feedback than the common-emitter design, therefore preserving device gain, and was chosen for the oscillator design.

The submillimeter-wave region offers several advantages for sensors and communication systems, such as high resolution and all-weather imaging due to the short-wavelength, and improved communication speeds by access to greater frequency bandwidth. This oscillator circuit is a prototype of the first HBT oscillator operating above 300 GHz. Additional development is necessary to increase the output power of the circuit for radar and imaging applications.

This work was done by Todd Gaier, King Man Fung, and Lorene Samoska of Caltech and Vesna Radisic, Donald Sawdai, Dennis Scott, and W.R. Deal of Northrop Grumman Corporation for NASA's Jet Propulsion Laboratory. This work was partially supported by the DARPA SWIFT Program and Army Research Laboratory. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Electronics/Computers category.*** NPO-44968

FPGA Coprocessor Design for an Onboard Multi-angle Spectro-Polarimetric Imager

NASA's Jet Propulsion Laboratory, Pasadena, California

A multi-angle spectro-polarimetric imager (MSPI) is an advanced camera system currently under development at JPL for possible future consideration on a satellite-based Aerosol-Cloud-Environment (ACE) interaction study. The light in the optical system is subjected to a complex modulation designed to make the overall system robust against many instrumental artifacts that have plagued such measurements in the past. This scheme involves two photoelastic modulators that are beating in a carefully selected pattern against each other. In order to properly sample this modulation pattern, each of the proposed nine cameras in the system needs to read out its imager array about 1,000 times per second. The onboard processing required to compress this data involves least-squares fits (LSFs) of Bessel functions to data from every pixel in real-time, thus requiring an onboard computing system with advanced data processing capabilities in excess of those commonly available for space flight.

As a potential solution to meet the MSPI onboard processing requirements, an LSF algorithm was developed on the Xilinx Virtex-4FX60 field programmable