

tors (pHEMTs), in the form of monolithic microwave integrated circuits (MMICs). Since the processing of HEMT amplifiers is quite different from that of Schottky diodes, use of Schottky mixers requires separate MMICs for the mixers and amplifiers. Fabrication of all the down-/up-conversion circuitry on single MMICs, using all-HEMT circuits, would constitute a major advance in circuit simplicity.

Three pHEMT-based subharmonic 670-GHz mixers were developed that are all subharmonically pumped at about 300 GHz, which greatly simplifies the local oscillator (LO) source, compared to a fundamentally pumped mixer requiring a 600-GHz source. The mixers use an active topology. Fundamentally, they are configured as a single-stage, grounded-source amplifier with a drain load controlled by the LO. The drain load is an additional transistor, or pair of transistors, switched by the LO signal.

This effectively samples the signal from the amplifier at the LO frequency, and passes the beat note on to the output terminal of the mixer.

In the down-converting mixer, the 670-GHz RF input is connected to the gate of the grounded source stage, whose drain is directly connected to the source or sources of the LO FETs (field-effect transistors). One version has only a single transistor in the drain load, and relies on the non-linearity of the FET plus the output tuning circuitry to block the RF and LO signals and passes only the IF to the output terminal.

The second down-converting mixer replaces the single LO FET with a pair having sources and drains connected together. The LO signal is fed to the two gates through a network that gives a 180° phase shift to one FET. Hence, the two FETs are switched on for alternating half-cycles of the 300-GHz LO, and the

drain FET pair acts like a sampler at twice the LO frequency. Simulations indicate about 6 dB of improvement in the conversion gain, from -6 dB for the two-FET design to around 0 dB for the three-FET design.

For the up-converting mixer, the circuit is similar to the three-FET down-converter, but with the IF input going to the gate of the grounded source stage, and the RF output taken from the drains of the LO transistors. The RF and IF matching networks are also modified to the correct frequency ranges. Simulations indicate a conversion gain of about 3 dB.

*This work was done by Erich T. Schlecht, Goutam Chattopadhyay, Robert H. Lin, and Seth Sin of Caltech; and William Deal, Bryan Rodriguez, Brian Bayuk, Kevin Leong, and Gerry Mei of Northrup Grumman for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48204*

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## Lidar Electro-Optic Beam Switch with a Liquid Crystal Variable Retarder

*Lyndon B. Johnson Space Center, Houston, Texas*

A document discusses a liquid crystal variable retarder, an electro-optic element that changes the polarization of an optical beam in response to a low-voltage electronic signal. This device can be fabricated so that the element creates, among other states, a half-wave of retardance that can be reduced to a very small retardance. When aligned to a po-

larized source, this can act to rotate the polarization by 90° in one state, but generate no rotation in the other state. If the beam is then incident on a polarization beam splitter, it will efficiently switch from one path to the other when the voltage is applied. The laser beam switching system has no moving parts, improving reliability over mechanical

switching. It is low cost, tolerant of high laser power density, and needs only simple drive electronics, minimizing the required system resources.

*This work was done by James Baer of Ball Aerospace & Technologies Corp. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-25113-1*

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## Feedback Augmented Sub-Ranging (FASR) Quantizer

**This device increases the accuracy of a switched capacitor amplifier, reduces the power and area of an integrated circuit, and reduces manufacturing cost.**

*Goddard Space Flight Center, Greenbelt, Maryland*

This innovation is intended to reduce the size, power, and complexity of pipeline analog-to-digital converters (ADCs) that require high resolution and speed along with low power. Digitizers are important components in any application where analog signals (such as light, sound, temperature, etc.) need to be digitally processed. The innovation implements amplification of a sampled residual voltage in a switched capacitor amplifier stage that does not

depend on charge redistribution. The result is less sensitive to capacitor mismatches that cause gain errors, which are the main limitation of such amplifiers in pipeline ADCs. The residual errors due to mismatch are reduced by at least a factor of 16, which is equivalent to at least 4 bits of improvement. The settling time is also faster because of a higher feedback factor.

In traditional switched capacitor residue amplifiers, closed-loop amplifi-

cation of a sampled and held residue signal is achieved by redistributing sampled charge onto a feedback capacitor around a high-gain transconductance amplifier. The residual charge that was sampled during the acquisition or sampling phase is stored on two or more capacitors, often equal in value or integral multiples of each other. During the hold or amplification phase, all of the charge is redistributed onto one capacitor in the feedback loop of the ampli-