

Figure 2. The Capacitance of the Electrically Variable Capacitor is changed or measured, depending on the position of the switch and the nature of the applied signal.

sistance of the capacitor. A pulse generator applies voltage pulses to change the capacitance. If desired, after each pulse, the capacitance and resistance can be measured by use of an inductance-capacitance-resistance multimeter or an impedance/gain analyzer. Also if desired, the DC resistance can be measured by applying a current of  $\approx 1 \mu\text{A}$  and measur-

ing the resulting voltage drop between the electrodes by use of a high-internal-resistance voltmeter. The magnitude of the AC test potential applied by the multimeter or analyzer and/or the magnitude of the DC test potential is kept below 50 mV — well below the threshold magnitude — so as not to change the capacitance unintentionally.

The threshold potential depends on a number of factors, including the composition and thickness of the perovskite film and the details of the process used to fabricate the device. The change in capacitance caused by a given pulse can be wholly or partly reversed by reversing the polarity of the pulse: that is, a pulse with one polarity causes the capacitance to decrease, and a pulse of the opposite polarity causes the capacitance to increase. The sign of the change in capacitance in relation to polarity of a pulse depends on the aforementioned factors and on additional factors, including the capacitance-change history of the device, the amplitude and duration of the pulse. After each change, the capacitance value is stable: It remains the same after repeated measurements using a signal much smaller than a capacitance-changing pulse.

*This work was done by Shangqing Liu, Naijuan Wu, Alex Ignatiev, and Jianren Li of the University of Houston for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31960-1*

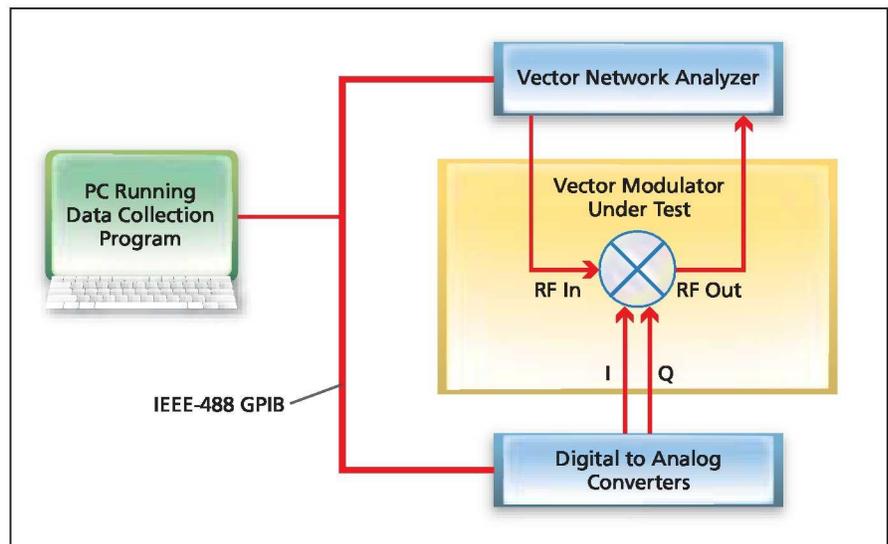
## System for Automated Calibration of Vector Modulators

**This test system helps create tabular or algorithmic functions to compensate for non-ideal behavior in vector modulators.**

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

Vector modulators are used to impose baseband modulation on RF signals, but non-ideal behavior limits the overall performance. The non-ideal behavior of the vector modulator is compensated using data collected with the use of an automated test system driven by a LabVIEW® program that systematically applies thousands of control-signal values to the device under test and collects RF measurement data.

The technology innovation automates several steps in the process. First, an automated test system, using computer-controlled digital-to-analog converters (DACs) and a computer-controlled vector network analyzer (VNA) systematically can apply different I and Q signals (which represent the complex number by which the RF signal is multiplied) to the vector modulator under test (VMUT), while measuring the RF per-



The Automated Test System uses computer-controlled digital-to-analog converters and a VNA to systematically apply I and Q signals to the VMUT, while measuring the RF performance.

formance — specifically, gain and phase (see figure). The automated test system uses the LabVIEW software to control the test equipment, collect the data, and write it to a file. The input to the LabVIEW program is either user-input for systematic variation, or is provided in a file containing specific test values that should be fed to the VMUT. The output file contains both the control signals and the measured data.

The second step is to post-process the file to determine the correction functions as needed. The result of the entire process is a tabular representation, which allows translation of a desired I/Q value to the required analog control signals to produce a particular RF behavior. In some applications, “corrected” perform-

ance is needed only for a limited range. If the vector modulator is being used as a phase shifter, there is only a need to correct I and Q values that represent points on a circle, not the entire plane.

This innovation has been used to calibrate 2-GHz MMIC (monolithic microwave integrated circuit) vector modulators in the High EIRP Cluster Array project (EIRP is high effective isotropic radiated power). These calibrations were then used to create correction tables to allow the commanding of the phase shift in each of four channels used as a phased array for beam steering of a Ka-band (32-GHz) signal.

The system also was the basis of a breadboard electronic beam steering system. In this breadboard, the goal was

not to make systematic measurements of the properties of a vector modulator, but to drive the breadboard with a series of test patterns varying in phase and amplitude. This is essentially the same calibration process, but with the difference that the data collection process is oriented toward collecting breadboard performance, rather than the measurement of output from a network analyzer.

*This work was done by James Lux, Amy Boas, and Samuel Li of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-44518.*

## Complementary Paired G<sup>4</sup>FETs as Voltage-Controlled NDR Device

G<sup>4</sup>FET-based NDR circuits are more versatile than their predecessors.

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It is possible to synthesize a voltage-controlled negative-differential-resistance (NDR) device or circuit by use of a pair of complementary G<sup>4</sup>FETs (four-gate field-effect transistors). [For more information about G<sup>4</sup>FETs, please see the immediately preceding article.] As shown in Figure 1, the present voltage-controlled NDR device or circuit is an updated version of a prior NDR device or circuit, known as a lambda diode, that contains a pair of complementary junction field-effect transistors (JFETs). (The lambda diode is so named because its current-versus-voltage plot bears some resemblance to an upper-case lambda.) The present version can be derived from the prior version by substituting G<sup>4</sup>FETs for the JFETs and connecting both JFET gates of each G<sup>4</sup>FET together. The front gate terminals

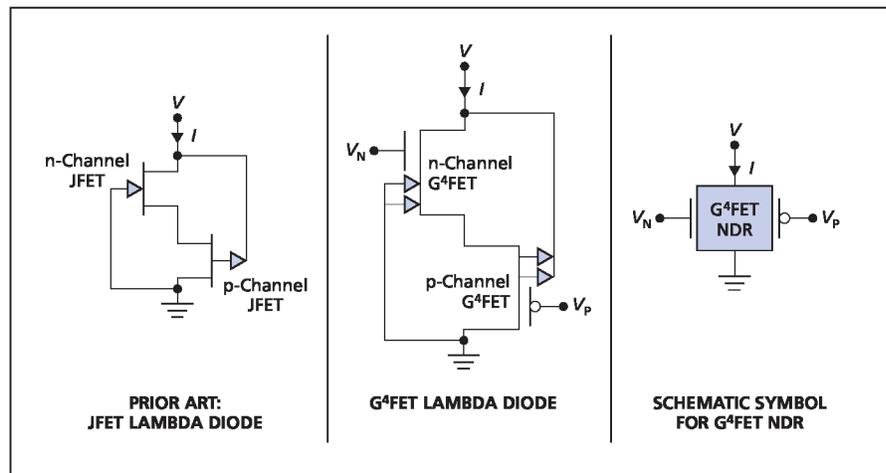


Figure 1. A Lambda Diode is a negative-resistance circuit or device, previously made from JFETs, and now made from G<sup>4</sup>FETs.

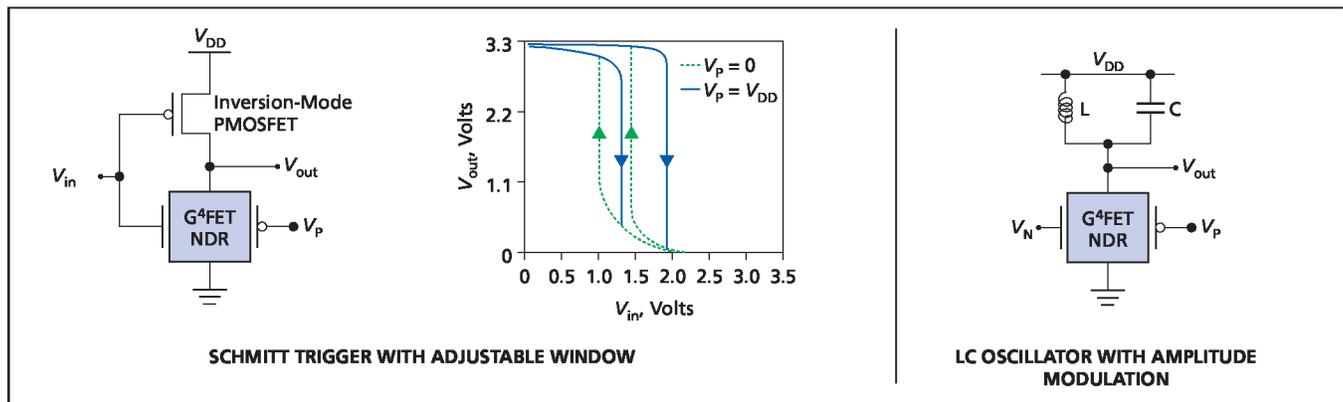


Figure 2. This LC Oscillator and Schmitt Trigger are examples of enhanced NDR circuits that can be made by use of G<sup>4</sup>FETs.