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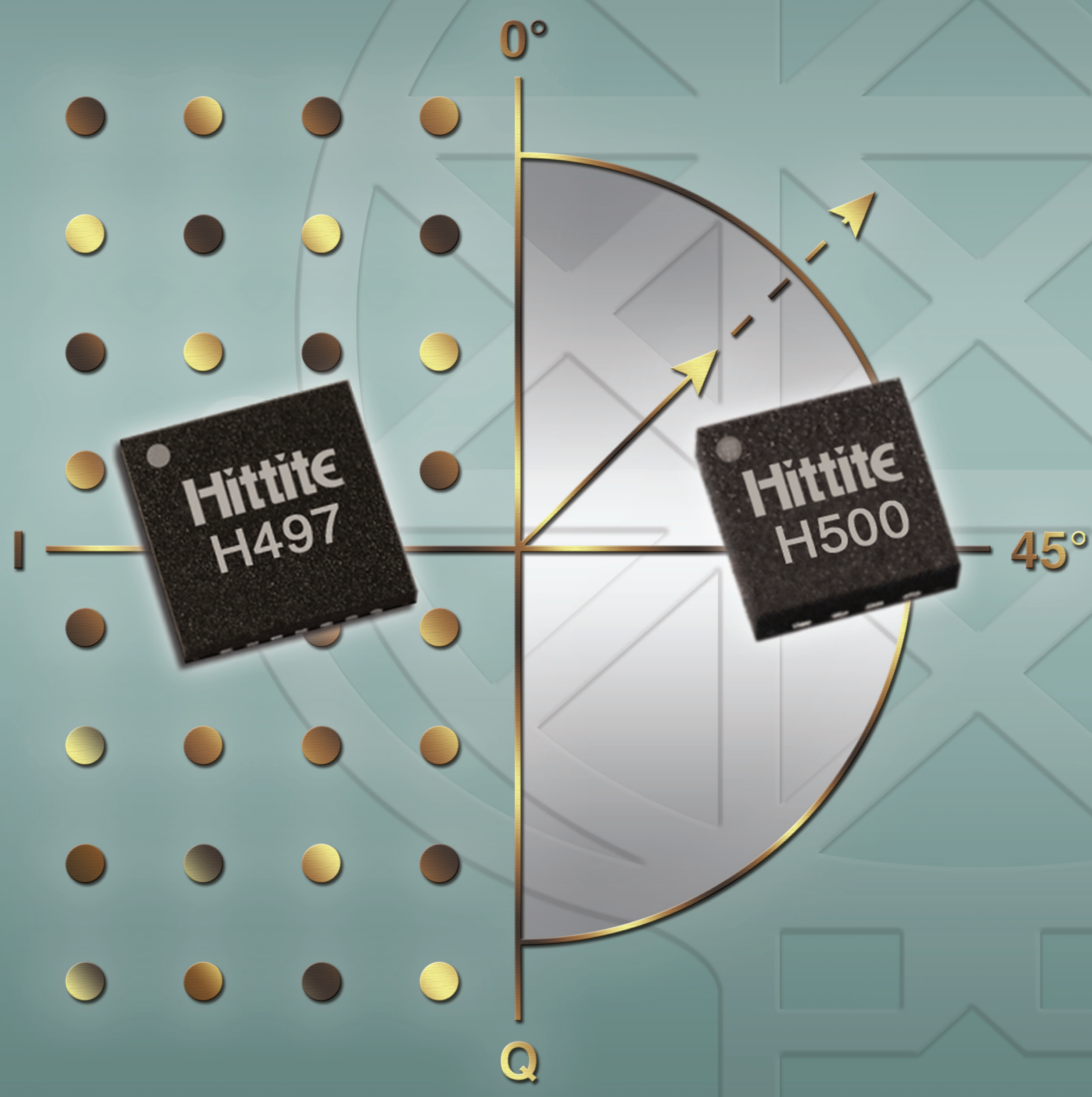

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cover story

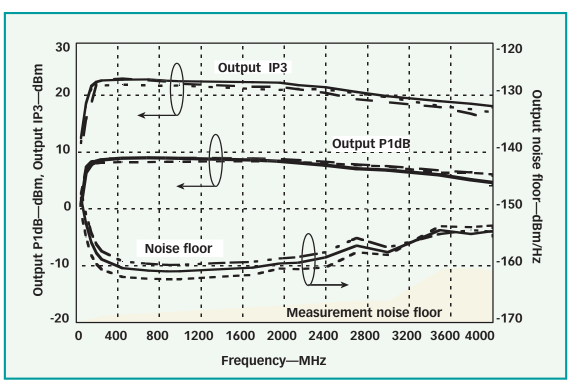
Modulators Direct Linear Gain And Phase

Broadband direct and vector modulators make the most of different semiconductor processes to provide linear, low-noise performance with precise control.

JACK BROWNE
Publisher/Editor

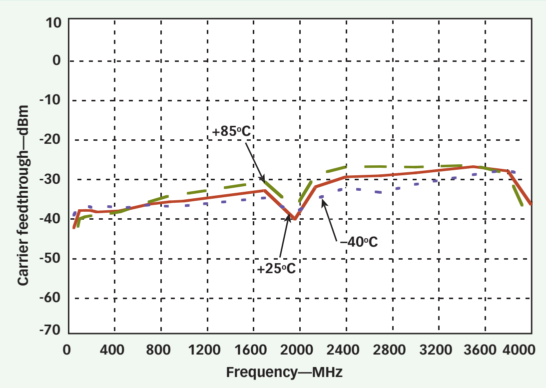
Modulators make wireless transmissions possible. Whether in fixed wireless links, wireless local loops (WLLs), or current and next-generation cellular systems, modulators enable the complex modulation formats that support modern, high-data-rate wireless communications. In support of a wide range of communications systems, Hittite Microwave Corp. (Chelmsford, MA) has launched both the wideband model HMC497LP4 100-to-4000-MHz direct quadrature modulator and the HMC500LP3 1800-to-2200-MHz vector modulator. The RF integrated circuits (RF ICs) offer excellent linearity with precise amplitude and phase control over temperature.

The two modulators (see front cover) differ in their process technologies as well as their functions. As a fabless semiconductor company, Hittite's engineers enjoy the freedom of matching the best semiconductor process to a given application. While exploring several options for the model HMC497LP4, several goals were set as improvements over the company's earlier model HMC495LP3 direct quadrature modulator (250 to 3800 MHz). These goals included enhanced broadband noise floor, increased output power, and better image sideband suppression. By evaluating several semiconductor processes, improving silicon- and GaAs-based technologies, the best combination of dynamic range and linearity was achieved with an advanced silicon-germanium (SiGe) process.



1. The HMC497LP4 direct quadrature modulator provides stable outputs and noise characteristics at measurement temperatures of –40, +25, and +85ºC.

Supporting a wide frequency range of 100 to 4000 MHz, the HMC497LP4 employs a local-oscillator (LO) input phase splitter to feed in-phase (I) and quadrature (Q) signals to a pair of mixers which, in turn, have their RF outputs combined in a wideband summer. The input phase splitter can be driven by wideband LO signals from 100 to 4000 MHz at levels from –6 to +6 dBm. The LO can be driven in either differential or single-ended mode. The RF output signals are available at a single-ended port matched to 50 Ω. The compact RF IC accepts wideband modulation input signals from DC to 700 MHz in support of a wide range of current wireless standards.



2. The HMC497LP4 delivers uncalibrated carrier feedthrough suppression that is stable with temperature.

End Results

The end results of careful circuit design and the benefits of the process include lower noise floor (–159 dBm/Hz) in the HMC497LP4 compared to the HMC495LP3 (–157 dBm/Hz), more output power at 1-dB compression in the HMC497LP4 (+9 dBm) compared to the HMC495LP3 (+1 dBm), and improved sideband suppression in the new modulator (–42 dBc for the HMC497LP4) compared to the older device (–36 dBc in the HMC495LP3). In fact, the combination of the HMC497LP4's low noise floor and high output power result in an outstanding dynamic range of 168 dB at 1960 MHz and 161 dB at 3500 MHz, currently high-water marks for a direct quadrature modulator. The modulator is well suited for use in software-defined radios (SDRs) where the upconversion circuitry must dynamically vary the modulator format depending upon changing requirements and operating conditions. The broadband modulator can be used for almost any analog or digital modulation format, including binary phase-

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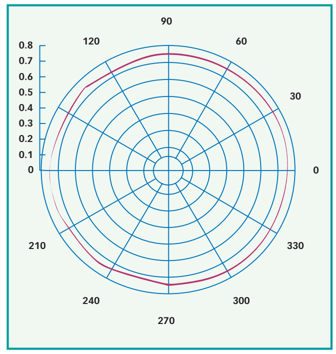
shift keying (BPSK), quadrature phase-shift keying (QPSK), orthogonal frequency-division multiplex (OFDM), and quadrature amplitude modulation (QAM). The RF IC can serve applications in the UHF band at 400 MHz as well as at RF frequencies through 2200 MHz and microwave frequencies through 4000 MHz.

The HMC497LP4 direct quadrature modulator is designed to provide stable and predictable broadband performance **(Fig. 1)** over a wide temperature range (–40 to +85°C). As the plot shows, output power remains flat across the wide frequency range, while the noise floor shows some slight rise at the higher-frequency limit, which may also be due in some part to the noise floor of the measurement equipment. The output power at 1-dB compression is +9 dBm from 1700 to 2200 MHz, +7 dBm from 2200 to 2700 MHz, and +6 dBm from 3400 to 4000 MHz, while the output noise floor is –161 dBm/Hz from 450 to 960 MHz, –159 dBm/Hz from 1700 to 2200 MHz, –157 dBm/Hz from 2200 to 2700 MHz, and –155 dBm/Hz from 3400 to 4000 MHz. Of note is the modulator's outstanding output third-order intercept point of +22 dBm from 450 to 960 MHz, +22 dBm from 1700 to 2200 MHz, +20 dBm from 2200 to 2700 MHz, and +17 dBm from 3400 to 4000 MHz.

The modulator's circuitry is configured to minimize carrier and sideband feedthrough at the RF output port. The typical uncalibrated carrier feedthrough suppression **(Fig. 2)** is –32 dBm from 450 to 960 MHz, –30 dBm from 1700 to 2200 MHz, –26 dBm from 2200 to 2700 MHz, and –24 dBm from 3400 to 4000 MHz. (With calibration, which involves manual adjustments of the I/Q port DC voltage offsets at +25°C, the measured carrier suppression shows an improvement of about 10 dB.) The typical uncalibrated sideband suppression is –43 dBc from 450 to 960 MHz, –42 dBc from 1700 to 2200 MHz, –33 dBc from



3. The HMC500LP3 vector modulator provides 360 deg. of continuous linear phase control range.

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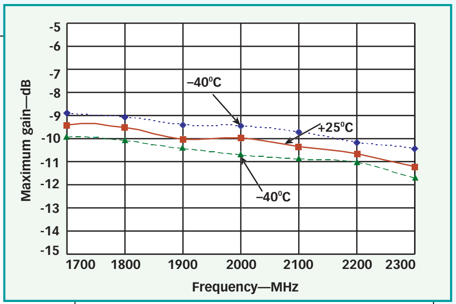
2200 to 2700 MHz, and –22 dBc from 3400 to 4000 MHz. The SiGe modulator typically requires a supply current of 168 mA at +5 VDC. The LO and RF port return loss is typically 15 dB. The direct quadrature modulator is supplied in a 4 × 4-mm QFN plastic surface-mount package.

Not to be outdone, the model HMC500LP3 vector modulator offers 360 deg. of continuous phase control from 1800 to 2200 MHz **(Fig. 3)** in combination with a typical gain control range of 40 dB. A vector modulator provides performance that is linear with respect to RF input signals compared to direct modulators which limit the input LO signal before applying the I/Q modulation signals to generate a modulated RF carrier. The vector modulator preserves the modulation already on the input RF waveform but enables additional arbitrary amplitude and phase control to be applied to the signal.



4. HMC500LP3 maximum gain over temperature.

In contrast to the direct modulator, the HMC500LP3 is fabricated with a GaAs heterojunction-bipolar-transistor (HBT) process that delivers excellent linearity from a single supply. With an input third-order intercept point of +33 dBm and input noise floor of –152 dBm at the maximum gain setting of –10 dB (the output noise floor remains flat across the full range of gain settings), the modulator boasts an input IP3/noise floor ratio of 185 dB.

The modulator –152 dB input noise floor at maximum gain is well suited for "correcting" distortion in high power amplifiers (HPAs) as part of a feedforward, predistortion, or feedbacklinearizer circuit. Digital and RF predistortion techniques attempt to correct the distortion before the input to the power amplifier. In such applications, a wide control bandwidth is critical for generating a "mirror-image" version of the distortion generated by the output amplifier. Feedback linearizers sample the output distortion and try to cancel it with sufficient loop gain. Feedforward techniques directly sample the amplifier's output distortion, amplify it, and then subtract it from the output.

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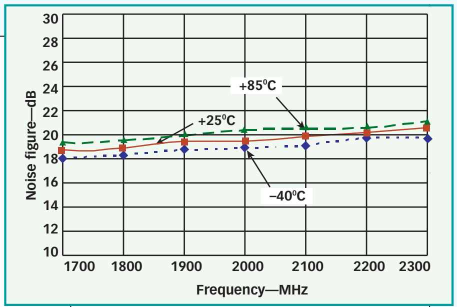
With input 1-dB compression of +16 dBm, the vector modulator can be used in phased-array systems, for analog and digital predistortion schemes, in HPA linearization circuits, and even as a limited-band electronic phase shifter. Like the direct modulator, the HMC500LP3 is designed to provide stable performance over temperature **(Figs. 4 and 5)**. It features gain flatness of 0.15 dB across any 60-MHz bandwidth and I/Q amplitude balance of ±1.5 dB. The input



5. HMC500LP3 noise figure over temperature.

return loss is 17 dB while the output return loss is 15 dB. The device operates with a control voltage range of +0.5 to +2.5 VDC and exhibits control port input –3 dB bandwidth of 150 MHz with an equivalent input noise level of 6 $nV/(Hz)^{0.5}$. The vector modulator draws 90 mA at +8 VDC and is supplied in a 3 × 3-mm QFN plastic surface-mount package.

Both modulators serve wireless and other high-frequency applications with performance that is designed for stability with variations in supply current and temperature. Each has been targeted for a specific semiconductor process to achieve optimum performance while maintaining the lowest-possible power consumption. **Hittite Microwave Corp., 20 Alpha Rd.., Chelmsford, MA 01824; (978) 250-3343, FAX: (978) 250-3373, Internet: www.hittite.com.**

Notes: