NEWS

Generators Deliver Vector Modulation

By combining wideband I/Q modulators and advanced DSP techniques, these instruments offer the power and flexibility needed to produce complex communications waveforms.

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Vector signals, with their in-phase (I) and quadrature (Q) signal components, are used to emulate the complex modulation formats found in modern communications systems. Although test-signal generators have been a part of the high-frequency industry from the days of vacuum tubes, vector-signal generators are relatively new tools that are available from only a select handful of suppliers. The key to selecting a vector-signal generator lies in understanding the pertinent specifications and their meaning for specific applications.

Modern communications systems employ complex digitally modulated signals based on I/Q or vector modulation. In modulation formats such as binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), and quadrature-amplitude modulation (QAM), different phase and amplitude states are used to represent digital bits, supporting the transmission of bandwidth-efficient modulation over relatively narrow channel bandwidths.

Many commercial vector-signal generators include a sophisticated blend of hardware and software. The CS2010VSG vector-signal generator from L3 Communications, Celerity Systems Digital Broadband Test (Cupertino, CA), for example, is almost a cross between a personal computer (PC) and a traditional high-frequency signal generator **(see figure)**. It provides operators with a 1-dB channel bandwidth of 30 MHz that can be tuned across a total frequency range (in bands) of 685 to 2200 MHz. Initially designed to generate second-generation (2G) cellular signals, the vector-signal generator now includes a large signal set supporting intermediate-generation (2.5G) and third-generation (3G) testing, including Enhanced Data rates for Global Evolution (EDGE) cdma2000 1X and wideband-code-division-multiple-access (WCDMA) signals. It is also possible to add additive white Gaussian noise (AWGN) to the entire 30-MHz band or only specific portions of the 30-MHz band.

The instrument features direct-to-intermediate-frequency (IF) conversion to produce the desired modulation in software, rather than using the control of higher-frequency I and Q signal components to create the digital modulation. Due to inherent imperfections in the hardware I/Q modulators and baseband I and Q pulse-shaping filters, instruments based on traditional I and Q modulation have a tendency to suffer I versus Q timing errors, I versus Q relative-gain errors, and I versus Q offset errors. The software implementation of the CS2010VSG supports precise control

The CS2010VSG vector-signal generator is a cross between a PC and a traditional high-frequency signal generator. [Photo courtesy of L3 Communications, Celerity Digital Broadband Test (Cupertino, CA).]

over I and Q generation.

The CS2010VSG can generate up to 256 carriers, and can be fitted with a variety of output filters, including a Global System for Mobile Communications (GSM) filter for 880 to 960 MHz and a digital-communications-services (DCS) 1800 filter for 1805 to 1880 MHz. The instrument, which is based on a Pentium processor and Windows NT. It includes a file import facility to use existing or newly created I and Q files. These files are converted into direct-to-IF-based signals within the vector signal. Deep arbitrary-waveform-generation (AWG) memory provides up to 23 s (4 GB or 2 GSamples) of a 30-MHz-wide modulation bandwidth.

Along the lines of more traditional "rack-and-stack" test instruments, the SMIQ series of vector-signal generators from Rohde & Schwarz (Munich, Germany) [and available in North America from Tektronix, Inc. (Beaverton, OR, www.tektronix.com)] provide frequency coverage through 6.6 GHz. The vector-signal-generator line currently includes four models with bandwidths accommodating most wireless applications: SMIQ02B (300 kHz to 2.2 GHz), SMIQ03B (300 kHz to 3.3 GHz), SMIQ04B (300 kHz to 4.4 GHz), and SMIQ06B (300 kHz to 6.6 GHz). The SMIQ series instruments share a high-performance I/Q modulator and powerful digital-signal-processing (DSP) technology to generate analog and digital modulation formats. The instruments can generate amplitude modulation (AM) and frequency modulation (FM) as well as an assortment of digital modulation formats, from amplitude shift keying (ASK) to 256-state QAM. Digital filters enable the definition of approximately any type of baseband filtering, and symbol rates to 18 Msymbols/s are available.

The SMIQ vector-signal generators offer a fast settling time of less than 3 ms for frequency and less than 2.5 ms for amplitude. The generators support frequency hopping at rates of 500 μs, and provide users with control of frequency and level sweeps. Signal spectral purity is outstanding, with single-sideband (SSB) phase noise of –126 dBc/Hz offset 20 kHz from a 1-GHz carrier. The level accuracy is ±0.5 dB for output levels to +13 dBm (to +16 dBm in over-range mode). The generators are supported by a wide range of options, including an option for a noise generator and distortion simulator with noise bandwidths that are selectable from 10 kHz to 10 MHz, an option for fading simulation capability (six-path simulation or two generators can be linked for form a 12-path simulation) with selectable path attenuation and delay characteristics and calibrated RF levels from –140 to –5 dBm.

In addition to the vector-signal generators, the company also offers the AMIQ series of I/Q modulation gen-

erators. Offering as much as 16-b resolution at sample rates to 100 MHz, these modulation sources can be used along with an RF generator to create digitally modulated test waveforms.

The E4438C ESG vector-signal generator series from Agilent Technologies (Palo Alto, CA) now offers five frequency ranges, from 250 kHz to 1 GHz, 2 GHz, 3 GHz, 4 GHz, or 6 GHz. The generators feature 160 MB (32 MSamples) baseband memory for waveform playback and 6 GB (1.2 GSamples) of nonvolatile memory for storing waveforms and instrument settings.

The E4438C switches frequency in less than 14 ms and amplitude in less than 19 ms. It delivers +17-dBm output power at 1 GHz with level accuracy of ±0.5 dB. Using external sources with its I and Q input ports, the E4438C supports an RF modulation bandwidth of 160 MHz. With its internal baseband generator, the RF modulation bandwidth is 80 MHz.

The MG3672A digital-modulation signal generator from Anritsu Co. (Morgan Hill, CA) operates at carrier frequencies up to 2.75 GHz. It also features wide-range external I/Q input ports (a 3-dB bandwidth of 30 MHz) for generating a wide range of digitally modulated signals.

A vector-signal-generator solution from Nova Engineering (Cincinnati, OH) uses a programmable-logic-device (PLD) architecture to generate complex modulation by playing back high-resolution digital samples. The generator combines the company's Constellation PLD development board with its numerically controlled oscillator (NCO) intellectual-property (IP) core. Frequency resolution is 32 b, while phase offset can be set to 16-b resolution. The output frequency and resolution are a function of the clock frequency. So, for a 50-MHz clock frequency, the output frequency is approximately 20 MHz and the resolution is $50\ \text{MHz}/2^{32} - 0.012$ Hz.

Finally, for those unwilling to trade in their older signal generators, the model 2029 vector modulator for IFR Systems (Wichita, KS) converts an analog-signal generator into a vector-signal generator with frequency range of 800 to 2510 MHz. The instrument offers a 14-b internal arbitrary-waveform generator and an I/Q modulation bandwidth of 10 MHz that can be used to achieve an effective RF modulation bandwidth of 20 MHz.

These instruments represent a sampling of the vector-signal generators currently on the market. Those interested in a more comprehensive listing are invited to visit the *Microwaves & RF* Product Data Directory website at www.m-rf.com. MRF