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Semiconductor Advances Propel High-Power Amps

Solid-state power amplifier designers have a wide range of emerging transistor technologies to choose from for next-generation commercial and military platforms.

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Improved linearity is one of the requirements for an effective wireless commuications transition from 2G series to 3G/4G systems, and high-performance RF transistors are vital to the amplifiers in these newer systems. As network operators transition from 2G services to 3G/4G systems, the role of highly efficient, highly linear RF transistors with higher operating voltages in base station amplifier designs become critical. Consequently, the technology that was well suited for 2G system amplifiers is inadequate for the nextgeneration platforms. To ensure that gallium arsenide (GaAs)-based RF power transistors are in the race for sockets in high-power amplifier designs for 3G/4G infrastructure applications, TriQuint Semiconductor has developed highvoltage heterojunction bipolar transistors (HV-HBTs). Launched late last year, the first members of this new GaAs HV-HBT amplifier family were tested in a Doherty configuration commonly used by base station amplifier manufacturers. According to the manufacturer, the HV-HBT devices delivered an efficiency level of 57 percent, surpassing the efficiencies available using competing technologies like laterally diffused metal oxide semiconductor (LDMOS) transistors or more- expensive gallium nitride (GaN) devices.

Since the HV-HBTs are designed for the output stages of the base station amplifier, the company has also readied low-power HBT pre-drivers and drivers for these devices, which were unveiled at the recent IEEE MTT-S International Microwave Symposium. Combining the HBT drivers with HV-HBTs, the company has developed a complete RF high-power amplifier (HPA) solution for the 3G/4G infrastructure applications.

In fact, using these HBTs in a three-stage configuration (predriver, driver, and output stage), the supplier demonstrated a symmetrical Doherty amplifier reference design that was capable of delivering 200 W P1dB or 50 W average WCDMA output power with an overall power-added efficiency (PAE) of 42 percent and 40 dB gain (*Fig.1*). The two-output stage HV-HBTs in this Doherty design included the new 2.14 GHz 100 W (P1dB) TG1H214100-FL, which the company is sampling to key customers and is slated to go into pre-production in the fourth quarter. The 50 W P1dB driver used in this reference is the new TG1H214050-FL, preceded by the new HBT pre-driver.

The new HBT pre-drivers integrate two stages in a single package. This allows designers to reduce the number of discrete amplifier components in a system. When used in a typical base station HPA design, a 25 percent cost reduction and a PCB area savings of 12 cm^2 can be achieved compared to designs using two separate discrete amplifier stages, states Doug Slansky, TriQuint's product marketing manager. The new amplifiers' high linearity minimizes additional signal distortion for repeater applications when used in final amplifier stages, and reduces back-off power requirements to minimize distortion from high peak-to-average ratio (PAR) signals in 3G/4G mobile base stations. This translates into reduced overall system costs and improved efficiency, which can lower HPA power consumption and improve operational expenditures (OpEx) for multicarrier 3G mobile infrastructures, notes Slansky. The new high-dynamic range 2-stage 28 V HBT amplifier drivers AP631 (4 W) and AP632 (7 W) are available now.

In addition, for WCDMA or multicarrier GSM designers, the manufacturer is also sampling the 1842.5 MHz 100 W (P1dB) TG1H184100-FL part to key users. Meanwhile, the supplier is also developing second-generation versions with almost twice the output power capability. Plus, a 2650-MHz, 100-W (output at P1dB) version is also in the works for WiMAX and LTE applications, according to TriQuint.

BROADBAND HPA

To extend the reach of solid-state amplifiers into the power levels of traveling- wave-tube (TWT) and vacuum electron device (VED) domain, CAP Wireless is exploiting the attributes of spatial combination. Using spatial power combining techniques, the developer has given solid-state amplifiers in general, and GaAs MMICs in particular, the needed boost. In this scheme, output signals from multiple low-power devices are coherently combined, typically in a constrained, guided wave environment, to provide high output power without incurring the losses associated with printed circuit combiners.

Thus, taking a total of 16 1.5-W GaAs MMIC amplifiers with reasonable efficiencies and combining their individual

outputs via spatial combining technology, CAP has crafted a 10-W instrumentation-grade amplifier with a bandwidth of 2 to 20 GHz. According to the manufacturer, the 2-to-20-GHz, 10-W amplifier, labeled GT-1000A, provides the bandwidth and output power of a TWT amplifier but with the reliability of solid-state electronics, safe low-voltage operation, minimal aging characteristics, and excellent fault tolerance. By offering the 2-to-20-GHz bandwidth in one unit and eliminating the band switching typical of multiple amplifiers from older technology, the new rack-mount broadband amplifier saves cost and time and increases reliability. The amplifier also features high linearity, a noise figure of better than 8 dB, lower than -30 dBc harmonics, and less than -60 dBc spurious content.

Interestingly, test equipment supplier Giga-tronics has incorporated the GT- 1000A amplifier into its broadband frequency synthesizers to achieve 10 W of leveled output test-signal power over a wide frequency range. In fact, the GT-1000A microwave power amplifier has been paired with Giga-tronics 2400B or 2500A frequency synthesizer to deliver +40 dBm of leveled output power from 2 to 20 GHz. It provides all the power needed for overcoming cable and switching loss to a device under test (DUT) and for providing the power levels needed for pulsed test applications, according to CAP.

Aimed at EMI/EMC testing, the GT- 1000A is tailored as a general-purpose R&D lab amplifier, as an exciter for high-power transmitters, and can be rack mounted for ATE and system integration for manufacturing test, the developer said. The broadband microwave power amplifier with Spatium technology was demonstrated at last month's IEEE International Microwave Symposium in Atlanta, GA. The company has dubbed the proprietary spatial-combining technology Spatium.

Another solid-state proponent expanding into the TWT turf is RF Micro Devices, Inc. The device supplier has unwrapped a 400-W HPA that exploits the attributes of internally developed GaN-on-silicon-carbide high electron mobility transistors (HEMTs). According to RFMD, the 400-W gallium nitride (GaN) HPAs are designed for air traffic control radar and shipborne or ground-based pulsed S-band surveillance radar applications. The 400-W HPAs operate over a frequency range of 2.9 to 3.5 GHz, from a 65-V supply delivering 10.5-dB gain. Placed in a thermally efficient, ceramic hermetic package measuring only 24 x 17.4 mm, the 400-W GaN HPAs deliver power density and size advantages over competing silicon bipolar technologies, asserts RFMD. The drain efficiency of the GaN transistor is 50 percent across the band.

In S-band radar applications, the HPAs are combined in larger 2.5-kW "pallet" amplifier assemblies with as many as eight or more HPAs in each pallet. TWT technology, traditionally used in these applications, is prone to reliability issues resulting in field failures and expensive replacement costs. With a mean-time-to-failure (MTTF) goal of 1E6 hours at a 200 degrees C junction temperature, RFMD's GaN-on-SiC technology will deliver superior reliability, resulting in a considerably lower total cost of ownership for customers, asserted RFMD.

GAN RF POWER TRANSISTORS

Concurrently, rapid improvements in performance, reliability and manufacturing is attracting HPA designers toward GaN RF power transistors. For instance, Merrimac Industries, Inc. recently inked a development agreement with Nitronex Corporation to develop highly integrated power amplifiers using Merrimac's proprietary Multi-Mix multilayer circuit technology and high-power density GaN-on-silicon transistors.

Similarly, UK's RF power efficiency specialist Nujira is collaborating with Nitronex to create a power amplifier reference design for WiMAX base stations. Combining 28-V 90-W (Psat) GaN devices (NPT25100) from Nitronex with high-accuracy-tracking (HAT) technology from Nujira and conventional digital predistortion (DPD) techniques, the partners have been able to realize more than +44 dBm of linear power with 45 percent efficiency at a linearity of –55 dBc using a four-channel WCDMA waveform. Under a demanding WiMAX waveform with 20-MHz video bandwidth and 8.2-dB peak-to-average power ratio (PAPR), the same solution demonstrated +43.2-dBm linear power with 43-percent power-added efficiency, according to the developers.

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