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Sizing Up Devices For Microwave Power Amplifiers

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Military requirements for RF/microwave power amplifiers continue to evolve with communications systems and other applications demanding increased bandwidth and more output power per device. Traditionally, vacuum electron devices (VEDs), such as traveling-wave tubes (TWTs), magnetrons, and klystrons, have been the devices of choice for high-power RF/microwave military requirements. But the technology has reached maturity in terms of performance and miniaturization limits, and is plagued by typically nonlinear performance and high noise. As a result, military system designers are seeking solid-state solutions for high-power RF/microwave amplification.

Semiconductor alternatives to VEDs include wide-bandgap transistors, such as silicon-carbide (SiC) and gallium-nitride (GaN) field-effect transistors (FETs). Such technologies exhibit higher power densities, high thermal conductivities, less capacitance-per-unit power, and higher breakdown voltages than devices made with earlier semiconductor processes, such as silicon bipolar and silicon laterally diffused metal oxide semiconductor (LDMOS), making them more viable for broadband, high-power RF/microwave amplifiers. They are also more linear, with lower thermal noise power than VEDs. Thermal dissipation is still an issue for solid-state devices, but improvements in packaging and heat-sink materials have helped remove heat and improve reliability.

Wide-bandgap transistors have been developed commercially and are available from a number of different suppliers, including Cree Microwave (www.cree.com), Nitronex Corp. (www.nitronex.com), and Eudyna Devices (www.eudyna.com). Research and development efforts are routinely published by a number of leading universities, and have also been sponsored by some of the larger semiconductor companies, such as Toshiba Corp. (www.toshiba.com).

In spite of the advances in solid-state devices, however, they offer limited output-power capability compared to VEDs. Devices capable of 1 kW output power at UHF are available from Freescale Semiconductor (www.freescale.com), while power levels to 200 W from a single device are available from several manufacturers. These devices operate to 4 GHz, with power levels to the tens of watts per device at X-/Ku-band.

Many novel amplifier architectures are now in development to meet the demands for higher levels of solid-state RF/microwave output power. One of these is spatial power combining, sometimes referred to as quasi-optical combining. With this technique, the output signals from multiple devices are combined coherently, typically in a guided-wave structure, for high output levels without the insertion loss associated with microstrip or stripline combiners. The approach has been demonstrated at 40 GHz and higher.

Spatial combining also protects against single-point failures, minimizing output losses due to a failed device by only 0.1 to 1 dB, depending upon the number of combined elements. While spatial combining is effective at typically 2 GHz and above, novel implementations of feedback and push-pull architectures are being developed for use below 2 GHz. Power amplifiers have been developed with 50 and 100 W output power and more than 2 decades bandwidth from 20 to 2500 MHz and beyond. Some take advantage of GaN or other wideband gap device characteristics, while others use multiple technologies.

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