MPD MICROWAVE PRODUCT DIGEST
21st ANNIVERSARY

Modern EW Systems Require Efficient RF Power Management

January 2011

By Joe Hajduk, CEO, dB Control

One aspect of electronic warfare (EW) that is a constant challenge is keeping up with the ever-increasing sophistication and persistence of threat radars. For example, today's threat radar detection systems must quickly determine whether or not the target is real or has been created by a digital RF memory. DRFMs can be used to capture a signal, digitize it, reconvert it to analog, modify it, and then rebroadcast it. Using a library of known emitters, the DRFM can alter a target's radar cross section, range, speed, angle of arrival and direction, and even create false targets behind the target (reactive jamming) or ahead of it (predictive jamming). When these techniques are successful, the threat radar detection system may mislocate or misidentify a target.

High-power components play an important part in helping radar detection systems combat these threats. Electronic countermeasure systems, EW threat simulators and multi-band communication systems all use complex radar waveforms with multiple modulation schemes, pulse patterns and pulse bursts. These systems must convert received analog signals into digital form with the highest resolution and at the highest speed possible. To accomplish this, they need high-power components providing a high level of RF input power with a wide bandwidth in the range of 2 to 18 GHz, an RF pulse width of 1 microseconds to milliseconds, pulse burst at MHz ranges, a high dynamic range, extremely low phase noise, excellent amplitude and phase stability.

To achieve high power, some designers turn to solid-state amplifiers because they are smaller and lighter than TWT amplifiers. But even the most impressive gallium nitride (GaN), silicon LDMOS, or GaAs RF power transistors produce at most just over one kilowatt of RF power, and then only at comparatively low frequencies. Although some solid state devices have achieved a wide frequency range of 2 to 18 GHz, their output power maxes out at about 20W. In comparison, traveling wave tube amplifiers (TWTAs) have no problem meeting requirements for high microwave frequencies of up to 100 GHz and very high power levels over a broad bandwidth.

Compact, High-Power Alternatives to TWTAs

When size and weight of the high-power components is a concern, the ideal solution is to exploit the inherent advantages of both solid state and tube technologies by specifying a microwave power module (MPM). An MPM contains small, high-power amplifier components in a common form factor that operates from low-voltage DC power supplies. It uses a solid-state driver amplifier based on MMICs or discrete RF power transistors to drive a mini-TWT. With RF outputs up to about 300W continuous wave (2 kW pulsed), and at frequencies as high as 50 GHz, high-power MPMs are used extensively in ECM, radar, and satellite communications systems.

MPMs manufactured by dB Control (Fremont, Calif.) power the Lynx SAR/GMTI radar system onboard General Atomics Aeronautical Systems' Predator B unmanned aircraft systems. This enables the UAV to transmit near real-time, full-motion images of objects on the ground, with resolutions as fine as four inches. (See Figure 1) These images can be captured from 6 miles above, in total darkness, through clouds and rain. Equipped with advanced sensors and cameras, the UAV can remain in the air for up to 35 hours and detect a moving person from

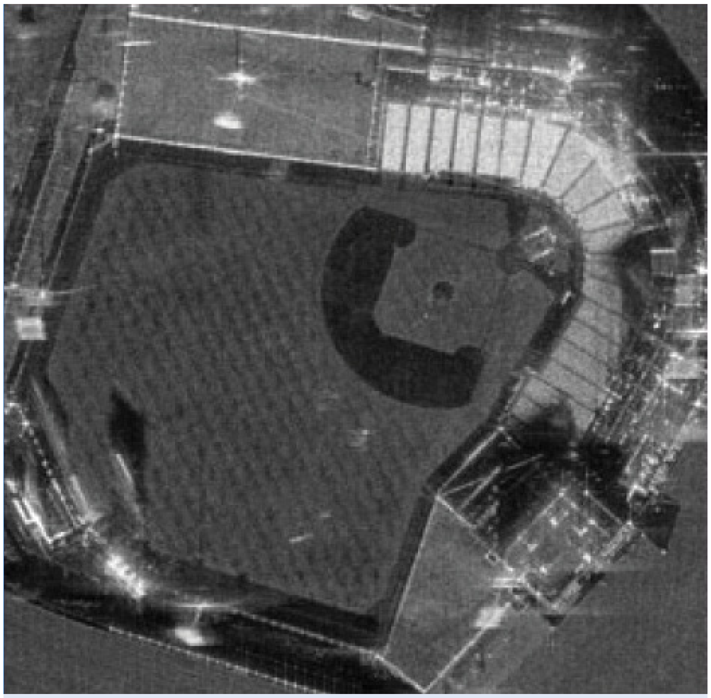


Figure 1: Synthetic Aperture Radar (SAR) image captured from General Atomics Predator UAV

32,000 feet above ground. UAVs have become such reliable and safe imaging systems that USAF Chief of Staff Gen. Norton A. Schwarz projected that the Air Force will increase its fleet of 250 UAVs to 450 or more over the next several years.

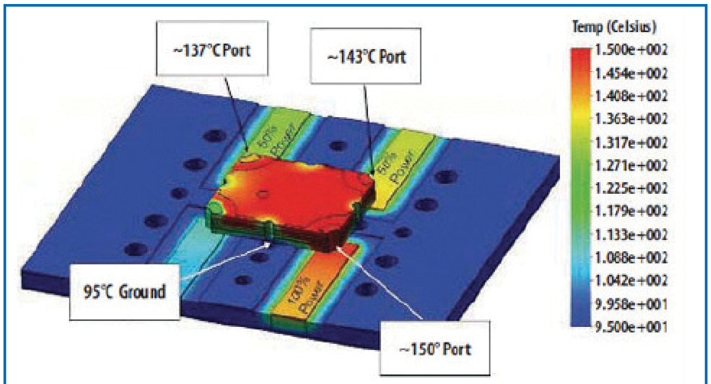
UAVs are also being used for commercial applications. For example, the Department of Homeland Security uses Predators to patrol the U.S./Mexican and US/Canadian border to help stem the flow of drugs, immigrants and terrorists. The Department of Energy is said to be testing UAVs for the detection of potential nuclear reactor accidents. NASA uses UAVs to monitor pollution and measure ozone levels. Massachusetts Institute of Technology (MIT) is developing GPS and video camera guidance systems to enable UAVs to locate and identify toxic substances. In addition, two ex-USAF Global Hawk UAVs are stationed at NASA's Dryden Research Center on Edwards Air Force Base in California to be used as airborne science research platforms.

While it's apparent from the increased need for more sophisticated radar and the growth of UAVs that there will continue to be a demand for high-power components, simply providing high power is not enough. The future belongs to devices that can effectively dissipate heat and provide the highest power over the widest bandwidth.

Higher Power Increases Heat

Both solid state and TWT amplifiers face the challenge of how to dissipate the heat generated by providing higher power. Excessive heat not only adversely affects the operation of nearby components, but is also an issue for compact environments, such as in aircraft and in communications systems in a ship's control room.

Because of the small size of high-power, high-frequency passive components such as hybrid couplers, dissipating heat can become a major issue even at tens of Watts. For example, the newest generation of Xinger passive components from Anaren Microwave (Syracuse, N.Y.) includes hybrid couplers measuring just 0.25 x 0.20 in., with models capable of handling more than 180W CW power at 1 GHz. These components are tested and modeled with thermal analysis tools (See Figure 2) to study the thermal flow through the components. In these studies, it was found that using plated viaholes made a significant difference in lowering temperatures at high power levels.



Thermal modeling was a key part of predicting temperature rises for a given input power level in the new Xinger-III passive components.

Figure 2: Thermal modeling of Anaren Microwave's Xinger III passive components.

TWT amplifier manufacturers address thermal management in a completely different way. Excess heat must be drawn away from the transistors and a safe operating temperature must be maintained for semiconductors and other solid state components. To accomplish this, most TWTs feature large-area heat sinks and forced-air cooling fans. For example, dB Control uses solid copper heat sinks under the TWT collector blocks to reduce thermal stress and increase the life of the TWT. Although copper heat sinks are more expensive than the more commonly used aluminum heat sinks, the manufacturer is willing to absorb the extra cost to guarantee reliability – a requirement for high-power components integrated into EW systems on which lives can depend.

In addition to adequate heat dissipation, high-power components need to have a wide bandwidth to handle a multitude of secure modulation formats and enable the use of advanced functions such as frequency hopping and other deception jamming techniques. To meet this challenge, dB Control introduced a compact, conduction-cooled MPM providing 125W of continuous wave RF power over a frequency range of 4.5 to 18 GHz. Weighing just six pounds, the new dB-4121 MPM (See Figure 3) is designed for use onboard manned and unmanned aircraft at altitudes of up to 50,000 feet. Other MPMs and MPM-based transmitters for X- and Ku Bands featuring 300 to 1000W peak power, a 20 to 40 percent duty cycle, a 100-400 microseconds pulse width, and variable PRF are also available.

High power components are also required to enable radar systems to use additional modes of operation and new frequency bands and/or spectrums so that U.S. military groups can communicate with our allies in times of war and with the Department of Homeland Security during a national emergency. Fortunately, there has been considerable progress on the design of systems that can operate at the upper end of the millimeter-wave spectrum.

Advancing to Terahertz Requirements

DARPA, the Defense Advanced Research Projects Agency of the U.S. Department of Defense responsible for the development of new military technology, has a high-frequency integrated vacuum electronics (hiFIVE) program focused on the development of a 5 to 220 GHz, 50W high power component with greater than five percent efficiency. A first-stage MMIC driver circuit will be integrated into the overall amplifier, along with cathode, electron-beam, interaction and collection structures. Since these structures are incredibly tiny, the device will be produced using microfabrication technologies such as reactive ion etching, along with advances in material, device, and circuit technologies. This high-power component is predicted to be able to operate without degradation for more than 100 hours in a high-bandwidth tactical communications link and provide throughput comparable to optical fiber – a very appealing feature for tomorrow's extremely small unmanned aircraft.

Figure 3: dB Control's dB-4121 Microwave Power Module provides 125W CW over 4.5 - 18 GHz.

In addition, the development of several new high-power components was announced at the 2010 International Vacuum Electronics Conference (IVEC), including a compact, lightweight 220 GHz, 50W sheet electron beam amplifier that uses nanoparticle cathodes and a compact, three-beam 220-GHz, 73W serpentine TWT amplifier with a saturated gain of 42 dB over an instantaneous bandwidth of 50 GHz (23 percent) when powered by three 100 mA, 20 kV, well-focused electron beams. The developers predict that this performance can be achieved in a very compact circuit length of only 1.5 cm. This is a significant advantage for electron beam devices, where issues of fabrication tolerances, beam alignment, and electron interception are critical.

The essential element in each of these applications is a high-power component. Considering the intense research and development being invested to extend power levels and frequency range while reducing the size and weight of these devices, it's safe to assume that even as the electronic warfare and commercial environments change, high-power components will be able to adapt.

For more information, please visit our website.
www.dbcontrol.com