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U.S. TECH

PRODUCTION

Vacuum Tubes: Still at Work

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For those of us old enough to remember, "tubes" ushered in the dawn of radio and were the guts of the first TVs. Today, traveling wave tubes (TWTs) and other vacuum electronic devices such as klystrons and crossed-field amplifiers are used by the military in radar, electronic warfare (EW) and electronic countermeasures (ECM) systems. It's safe to say that all EW or ECM systems now in service, and most of those on the drawing board, use or are being designed around, amplifiers based on tubes. Every Predator and Reaper Unmanned Aerial Vehicle (UAV) has a dB Control TWT Amplifier (TWTA) onboard, as do many of the Fire Scout and Global Hawk UAVs. There are also many other military and commercial applications for the TWT, including radar systems, electronic warfare or electronic countermeasures suites, communication satellite transponders, and instrumentation — EMI/EMC test equipment.

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While it's true that solid-state devices have a long life, can be inexpensively mass produced, and operate from low-voltage DC supplies, they are limited to providing relatively low RF output power over narrow bandwidths. A TWT, on the other hand, can deliver high levels of RF power over broad bandwidths at frequencies up to 100GHz or higher. Even the most impressive gallium nitride (GaN), silicon LDMOS, or GaAs RF power amplifiers produce at most just over 1 kW pulsed RF power, and then only at comparatively low frequencies. As for operating life, many TWTs now reach 100,000 hours, which means that they can reliably deliver their rated performance continuously for over a decade. This makes them well suited to the typical lifetime of a satellite communications system, and well beyond what is required in most commercial applications. And, when it's time, , a TWT can be easily replaced with another TWT in systems designed for this.

One of the greatest perceived disadvantages of tube-based amplifiers is their need for kilovolt power supplies, which increase size, weight, and system overhead. While this can be true for very-high-power systems, in most instances, it has rarely limited the TWT amplifier's usefulness. Besides, the power supplies used to accommodate solid-state amplifiers for these applications would be just as difficult, considering that they would need to provide the current to power-combine hundreds of transistors to produce the required RF output power.

MPMs: A Compact Alternative

Today there is even a product that exploits the inherent advantages of both solid state and tube technologies to deliver the best of both worlds. The Microwave Power Module (MPM) is a very compact enclosure that includes a solid-state amplifier that is used to drive a mini-TWT. dB Control's MPMs are available with RF outputs from 50 to 300 Watts continuous wave (1kW pulsed), and at frequencies as high as 50GHz.

These MPMs are extensively used in ECM, radar, and satellite communications systems. For example, dB Control's MPMs power the radar systems onboard the Predator drones that have proven so indispensable in Iraq and Afghanistan. The Predator's Lynx SAR/GMTI radar system transmits near real-time, full-motion images of objects on the ground with resolutions as fine as four inches. And even more amazing, these images can be captured from 16 miles above, in total darkness, through clouds and rain. Without dB Control's reliable

TWT amplifiers, images of this high quality and definition would not be possible.

In addition to protecting our troops overseas, UAVs are being used by the Department of Homeland Security to monitor the U.S. coastline and continental borders, by NASA to measure pollution and ozone levels and by the National Oceanic and Atmospheric Administration (NOAA) to monitor shoreline erosion. Future applications include using the UAV's radar images to determine the best response to disasters such as earthquakes, forest fires, nuclear reactor accidents and toxic spills.

Advanced Tubes for Terahertz Requirements

Looking over the development horizon, there is interesting research taking place to meet the needs of systems operating in the upper reaches of the millimeter-wave region. For example, DARPA's High Frequency Integrated Vacuum Electronics (HiFIVE) program is focused on an integrated, micro-fabricated tube-based power amplifier circuit that can deliver more than 50 Watts of RF power at greater than five percent efficiency over a bandwidth of five to 220GHz and higher.

This system will incorporate a first-stage monolithic memory driver circuit integrated into the amplifier, along with the cathode, electron-beam and interaction and collection structures. Since its structures are incredibly tiny, this device will be produced using microfabrication technologies such as reactive ion etching, along with advances in material, device, and circuit technologies. The program's grand finale will be an MPM that can operate without degradation for more than 100 hours in a high-bandwidth tactical communications link, with throughput comparable to optical fiber. This is obviously an appealing piece of hardware for tomorrow's extremely small UAVs.

So, even though solid-state devices may have chipped away at the lower-power applications, TWTs are moving upwards with unmatched RF output power.

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