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Microwave Transmitters Rise to Radar Systems' High-Power Challenge

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Microwave transmitters are one of the most critical elements affecting the overall performance of a radar system. To reach the output power levels required by radars, the high power transmitters must amplify the radar waveform without distortion. The higher the required power level, the more challenging the task for the transmitter designer.

dB-4121 Microwave Power Module

For radar transmitters, the ratio of RF output power to prime power input – the true measure of efficiency – must be high. Efficiency of the transmitter affects not only the prime power consumption and thermal dissipation, but also the reliability, size and weight. To achieve high power levels and high efficiency, many transmitters use a single power-amplifying device such as a high-power vacuum electron device (microwave tube). A typical block diagram of a microwave transmitter is shown in **Figure 1.** While the diagram illustrates amplification using a traveling wave tube (TWT), this same configuration is used by the majority of amplifying-type microwave tubes. Basically, a pulsed signal from a radar waveform generator is applied to an amplifier that uses RF power transistors to produce an output to drive the TWT. This device amplifies the drive signal to the required level.

The output sections of many transmitters have components similar to those shown in **Figure 1.** In addition, very-high-power transmitters include an arc detector to sense any breakdown in the waveguide and turn off the RF power before it can damage the TWT.

Achieve Higher Power by Combining Devices

Multiple power sources can be combined to achieve higher power levels than those that can be obtained from a single device. For example, 1-10 Watts of output power can be produced by combining the output of multiple milliwatt solid state amplifiers using passive components. These components can be integrated on a substrate. However, each solid state amplifier generates heat, adds weight and requires more real estate – three areas that designers strive to decrease for applications where minimal payloads are essential, such as onboard unmanned aircraft.

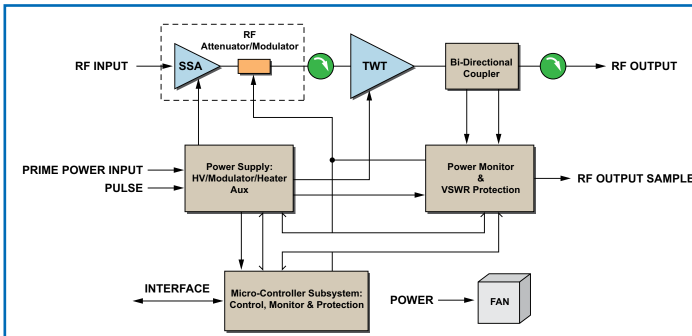

Figure 1: Block diagram of transmitter using TWT

When power requirements jump up to the megawatt level, there simply isn't enough physical area or heat removal to accommodate large blocks of solid state components. For these applications, the best solution is to combine the power of multiple TWTs. **Figure 2** illustrates the basic principle of a power-combined TWT amplifier. Even though multiple TWTs are employed, a power-combined amplifier has a single RF input and output. An RF signal from the host system is amplified by the solid state amplifier to between 27 dBm and 33 dBm, depending on the TWT. This output is split into two equal-amplitude signals of appropriate phase relationship and sent to the inputs of the two TWTs. A line stretcher or adjustable phase trimmer is added in one or both of the signal paths for fine tuning the phase difference between the two signals.

Depending on the frequency range and power level, the amplified RF outputs from the TWTs can be combined in a hybrid junction or Waveguide Magic Tee to produce the final RF output. To avoid combining losses, the two signals must have the same frequency, the correct phase relationship and be equal in amplitude.

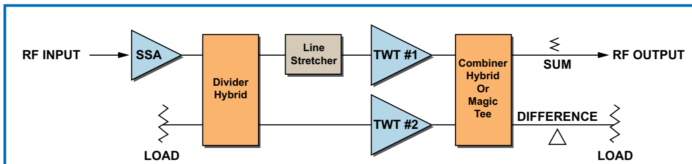

Figure 2: Basic principle of power-combined TWT amplifier

Besides providing higher output power, power combining TWTs improves reliability by providing graceful degradation. In other words, the failure of one amplifying device will not bring down the entire transmitter. Reliability improvements also result from lower operating voltages, modularization, better thermal management, and reduced stress levels on components.

dB Control, a TWT amplifier manufacturer located in Fremont, California, combines up to four wideband, periodic permanent magnet (PPM)-focused, conduction-cooled high-power TWTs to amplify continuous wave, AM, FM or pulse-modulated signals. Compared to using a single TWT, these power-combined TWTs provide higher saturated output power and improved harmonic performance. To ensure superior reliability, all high-voltage transformers, magnetics and dielectrics are designed and manufactured in-house. The company also utilizes proprietary transformer fabrication, encapsulation and high-voltage component potting techniques specifically designed for demanding military applications. As a result, dB Control's power-combined amplifiers are currently used for a wide variety of applications such as radars, electronic counter measure (ECM) systems and electronic warfare (EW) simulation, test and measurement and RFI/EMI/EMC testing.

MPMs Provide More Power over Wider Bandwidth

As microwave tubes and solid state amplifiers each have their own particular advantages, the Microwave Power Module (MPM) utilizes a synergistic combination of both devices. As illustrated in **Figure 3**, the RF signal path consists of a solid state driver amplifier and a short-length TWT (typically about seven inches long) specifically designed for use with a lower-voltage power supply (up to 8 kV). The gain reduction that occurs from shortening the TWT helix length is compensated by the driver amplifier, and the RF chain gain is maintained. The power handling capability, bandwidth, efficiency and heat-tolerant capacity of the TWT is fully utilized in this design.

A wide array of MPMs is available for S- to W-band applications in both continuous wave and pulsed configurations. With RF outputs from 20 Watts to more than 2 kW, MPMs are widely used as transmitters for radar, ECM, and any application where the platform resources (prime power, size and weight) are limited, and long, failure-free operation is essential. For instance, on board every Predator unmanned aircraft, the LYNX I and II Synthetic Aperture Radars (SAR) designed by Sandia Laboratories and manufactured by General Atomics are powered by

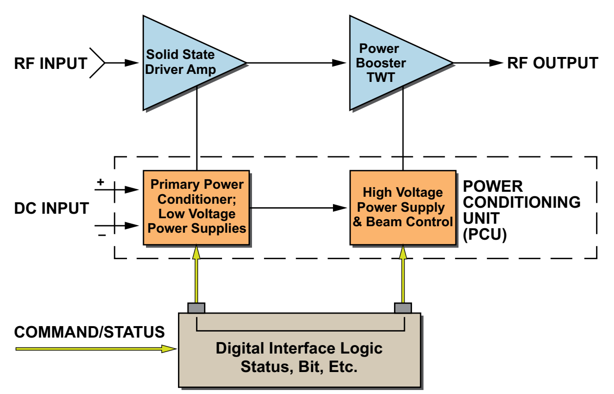

Figure 3: Microwave Power Module (MPM) block diagram

a dB Control MPM. Designed for the harsh conditions encountered in airborne environments, these MPMs can withstand high altitudes, gunfire vibration, shock acceleration, explosive atmospheres, rain, and humidity. The devices operate at temperatures up to +100°C for short periods and are compliant with MIL-STD461E standards.

The MPM was first developed in the early 1990s. A Tri-Service Program funded by the U.S. Army, Navy, and Air Force produced small, high-power amplifier modules in a common form factor that operated from low-voltage DC power supplies. The idea was to use a solid-state driver-amplifier based on MMICs or discrete RF power transistors to drive a mini-TWT, and combine the devices with a power supply and control circuits in a very compact enclosure.

MPMs now serve as transmitters for advanced radar, ECM and communication systems. In many types of radar, these MPMs have to faithfully amplify complex waveforms with multiple modulation schemes, pulse patterns, pulse bursts, and counter-jamming capabilities. As

Device	Peak Power Limit	Frequency Limit	Bandwidth	Platforms
Helix TWT/ Mini-TWT	15 kW	40 GHz	Octave or more	Ground, mobile, ship and airborne
Coupled Cavity TWT	250 kW	95 GHz	5%	Ground, mobile, ship and some airborne
Ring Bar/Ring Loop	20 kW	18 GHz	5 to 10%	Ground, ship and airborne
Klystron	10 MW	40 GHz	1 to 2%	Primarily ground, ship and large aircraft
Extended Interaction Klystron (EIK)	2 kW	220 GHz	1%	Ground and Special
Crossed Field Amplifier (CFA)	1 MW	18 GHz	1 to 5 %	Ground, mobile and ship
Gyrotron	1 MW	100 GHz	3 to 5%	Ground

Figure 4: Microwave tubes for radar transmitters

waveforms become more exotic, threats continue to increase in volume, and cross sections of targets decrease due to the use of stealth technologies, radar systems will require high stability of transmitted waveform, spectral purity and higher power over a wider bandwidth.

Even though some solid state devices have achieved a frequency range of 2-18 GHz, the output power of these devices usually maxes out at about 20 Watts. In comparison, an MPM providing 125 Watts of continuous wave RF power over a frequency range of 4.5 - 18 GHz will be introduced this month by dB Control at the AOC 47th Annual International Symposium and Convention in Atlanta, Georgia. Specifically designed to meet the power requirements of today's radars, ECM transmitters, and EW threat simulators, the new dB-4121 MPM enables radars to use advanced functions such as frequency hopping and other deception-jamming techniques.

Selecting a Radar Transmitter

When selecting a high-power transmitter, both the application and the platform must be considered. If the application requires multiple functions and the radar must provide time-shared roles for each function, this requires a special type of transmitter. Or if the transmitter will be used in multiple roles, for example, for countermeasures and data links, it must provide RF power management capability and have a wide bandwidth to enable multi-band frequency agility.

The installation platform is also an important consideration because of the size, weight and thermal limitations that could be imposed on the transmitter. Plus, some platforms test the transmitter's reliability by exposing it to harsh environmental conditions, such as extreme temperature, high altitude, dust, humidity, and vibration.

Figure 4 lists various radar transmitter installation platforms and the types of microwave tubes best suited for each application. As shown in the table, ground-based long-range surveillance radar requires either a high-power klystron or TWT, while a lower-power helix TWT is better suited for airborne multimode radar. The type of device used for power amplification may also be determined by the transmitter's size and weight. For instance, a transmitter using a helix TWT to achieve output power levels of 10 kW is relatively smaller and lighter than a transmitter using a 100 kW klystron or coupled-cavity TWT.

Both solid state devices and vacuum tube amplifiers have risen to the challenge of producing higher power while reducing size and weight and increasing efficiency and reliability. Wideband gap semiconductor devices are being introduced with improved thermal performance. Active Electronically Scanned Antenna (AESA) radar systems are using solid state technology, and many other exciting developments are taking place in this field. The bandwidth and power of TWT amplifiers and other vacuum electron devices continue to increase, even as size and weight decreases. The ongoing improvement in the performance and efficiency of both of these types of devices ensures that microwave transmitters will continue to meet the challenges of advanced radar systems for years to come.

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www.dbcontrol.com