Amplifiers play a vital role in satellite communications systems around the world, and have undergone major technology developments in recent decades, resulting in faster, more efficient products. As requirements from military and commercial entities alike have expanded, and demand for enhanced SWaP (size, weight and power) properties has grown, the leading amplifier manufacturers around the world have forged ahead with new product offerings. Douglas Slaton, Marketing Communications Manager of CPI Satcom Products, provides an overview of the development of amplifiers over the years, and outlines the latest products available on the market today.

The US military’s use of terminals for satellite communications is more widespread than ever before. Whether the need is to control unmanned aerial vehicles (UAVs), to strategically coordinate a vast array of assets or personnel during a mission, or simply to make it easier for service members to call home or improve their off-duty entertainment experience, the requirements for bandwidth are steadily increasing and show little sign of leveling off. In addition, militaries around the world have been working hard to improve the flexibility of their operations, particularly with regard to available uplink frequencies. No fighting force wants to face a situation where sophisticated battlefield software is unusable simply because satellite bandwidth cannot be found. The capability to uplink in multiple bands and, more importantly, the development of millimeter wave architecture, have provided a vital solution to the US military's bandwidth needs.

The changing requirements for amplifiers
Over the years, amplifier development has typically been able to keep up with the requirements the military has imposed, in terms of output power, frequency and power efficiency. The traveling wave tube (TWT) was conceived more than 25 years before Sputnik was launched in October 1957, as the control and manipulation of radio frequency (RF) waves had been a topic of interest for radar research since the...
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Amplifier Technology

Traveling Wave Tube Amplifiers

For medium and high power requirements, TWTAs are still the industry standard with regard to power efficiency and practical size. This is particularly true for the most common bands utilized by the military: X, Ku and Ka. In addition, the US Air Force has requirements for airborne TWTAs with liquid cooling, and manufacturers like CPI have made these products available. At least two of the leading TWT manufacturers, including CPI, offer most of these products and have considerable experience dealing with military prime contractors.

Douglas Slaton, Marketing Communications Manager of CPI Satcom Products

1920s. Andrei Haeff, a native Muscovite who emigrated to the United States in 1928 to study electrical and mechanical engineering at the California Institute of Technology, first began designing a prototype TWT in 1931, and was awarded a patent for it five years later. In 1943, Austrian Rudolph Kompfner utilized some aspects of Haeff’s work at the University of Birmingham to create a TWT that works much more like those used today. Kompfner is often credited with the invention of the modern TWT.

After the launch of Sputnik, the American military’s effort to develop satellites understandably became a top priority, and by 1968 they had begun operating the first communications constellation, the Defense Satellite Communications System (DSCS). For its larger, heavier terminals, DSCS II/III called for 700W X-band TWTAs, then 900W X-band TWTAs, and finally 2.5kW TWTAs. These requirements were reasonably straightforward for TWT companies, as well as for HPA manufacturers, since X-band products are not technologically much more difficult for manufacturers to develop than the C-band products that were already widely used in the commercial industry.

By the 1980s, the US military determined that a new satellite system would have to be developed to handle increasing bandwidth demands. The Wideband Global Satcom (WGS) constellation of satellites was therefore planned, utilizing both X and Ka-band frequencies. At the same time, the military contracted with various system integrators for multiband terminals, including multi-band HPAs, which could operate in either C-band or X-band, and often in Ku-band as well. This ‘quick fix’ enabled the military to contract for and use commercial capacity well beyond the capabilities of DSCS while the WGS system was being developed. These multiband amplifiers were typically developed under pre-COTS (Commercial off the Shelf) military procurement programs, which effectively required manufacturers to set up development and manufacturing programs that were parallel to the commercial ones they already had. Nevertheless, since government contracts often required very large quantities of amplifiers, these costly efforts were typically beneficial to the manufacturer in the long run.

In the 1990s, the government begin to switch to COTS procurement, and by the time serious requirements were identified in Ka-band, much of the TWT research and development (R&D) had already been done in commercial markets. Only in the solid state field has product development potentially lagged behind military demand, but that is now progressing at a rather quick pace.

Another challenge for manufacturers has been answering the need for mobile, tactical terminals and even miniature terminals that individual soldiers can carry. For these systems, the military has demanded more power, with less weight, better power efficiency, and smaller size. They even have an acronym for it: SWaP, for size, weight and power. While accommodating these often contradictory requirements can be a difficult assignment, industry manufacturers have answered the challenge with many product offerings, including the increased use of the latest solid state technology.

SuperLinear® and Peak Power TWTAs

SuperLinear TWTAs and Peak Power TWTAs are typically used in applications where a certain linear power is specified. SuperLinear TWTAs, which are exclusive to CPI, are highly power efficient and optimized for operation at linear output power. Peak power TWTAs are equally linear, but are not optimized for operating at lower power levels, and thus not as SWaP efficient.
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Mitsubishi Electric’s Ku-band 20W monolithic microwave integrated circuit (MMIC) amplifier for satellite earth stations, features the world’s first gallium nitride (GaN) high-electron mobility transistor (HEMT) MMIC with integrated linearizer to compensate for distortion. The MMIC GaN HEMT, has an output of 43dBm (20W) and linear gain of 20.0dB, will contribute to the downsizing, high-performance and faster development of power transmitters. Along with the company’s existing 50W and 80W GaN HEMTs the range enables power transmitters to be configured for a wide range of output power.

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**GaN-based solid state BUCs**

CPI also manufacturers GaN-based BUCs, which represent the latest solid state technology, and utilize Gallium Nitride FETs instead of the traditional Gallium Arsenide FETs. Historically, the frequency and bandwidth of SSPAs were dictated by the manufacturers of FETs, but in recent times, SSPA manufacturers have found manufacturers capable of producing FETs in just about all of the frequencies which interest the military. GaN BUCs are more efficient than GaAs BUCs, allowing for smaller footprints, lighter weight and higher practical power levels than the older technology.

**GaN-based transceivers**

The advent of GaN has resulted in some interesting lightweight products for individual use. Pictured below is a CPI 16 W X-band transceiver weighing only 4.1kg.

**MIL Standards explained**

Compliance standards for the military have been established by the US Department of Defense’s Defense Information Services Agency (DISA) for all satellite infrastructure, including high power amplifiers (HPAs). These standards were first established in the early 1970s and have been updated over time. The standards cover many aspects of each product, including signal linearity and noise performance; mechanical and environmental requirements such as shock, vibration, and resistance to salt air; and guidelines for qualification testing. The current version of DISA standards are called MIL-STD-188/164B.

New terminals that are intended for use with WGS satellites must also undergo a procedure commonly known as ARSTRAT testing. Individual components of terminals, such as HPAs and antennas, are not individually certified - only the entire terminals are. Thus, an HPA can be said to be approved for use in a particular ARSTRAT certified terminal, but it cannot be said to be ARSTRAT certified.

**Tri-Band TWTA s**

A number of manufacturers, including CPI, carry tri-band TWTA s in their catalogs. These amplifiers are typically able to produce signals in C-band, X-band and Ku-band.

**About CPI Satcom**

CPI’s Satcom Division (CPI Satcom) is a worldwide leader in uplink amplifier products and systems for satellite communications. The company has played a pivotal role in the satcom industry since its inception. The first satellite projects, including INTELSAT and CONUS, were supported by CPI, which was then part of Varian Associates, Inc.

Today, its scope and global reach is unmatched, having shipped over 40,000 high power amplifiers to uplink stations in over 150 countries. CPI Satcom products for satellite uplink and troposcatter applications are available in all standard frequencies.
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