Tim Shroyer
Chief Technology Officer
General Dynamics SATCOM Technologies

ModuMAX High Power Amplifier Advancements

Figure 1 ModuMAX High Power Amplifier

ModuMAX - Over 15 Years of Exceptional Reliability

General Dynamics SATCOM Technologies' ModuMAX High Power Amplifiers have provided exceptional reliability with the simplest plug-and-play, fully hot-swappable designs available in satellite uplink service for more than 15 years. The patented ModuMAX modular design keeps carriers on the air even during maintenance or module degradation. This remarkable field performance is backed up by hundreds of thousands of hours of operation for many of the world's largest satellite uplinkers. Since the first ModuMAX HPAs were fielded, General Dynamics SATCOM Technologies has worked to take advantage of the best available RF, digital, and semiconductor technology to enhance the already superior ModuMAX performance.

General Dynamics SATCOM Technologies is making ModuMAX even better with optimized new developments. Improvements to the field-proven, true hot-swappable ModuMAX design means satellite uplink service will be even more reliable, without the need to install multiple redundant amplifiers for even the most demanding applications. Results are demonstrated by actual uplink amplifier performance in the field, and while the design advantages are clear to a careful analysis, ModuMAX reliability is proven by signals staying on the air, in every conceivable condition, all day, all month, and for years to come.

New ModuMax Features Currently Being Developed

- Higher power, reliable GaN FET Technology
- More efficient, more reliable power supply
- Color touch screen for local control
- Embedded web browser with remote monitor & control, remote software upgrade, and factory monitoring and assistance capability

ModuMAX Design

The key to ModuMax's reliable performance is its patented true, hot-swappable architecture. At its core, the ModuMAX uses multiple, passively-combined Solid State Power Amplifier (SSPA) modules to achieve sustained, linear RF output power with exceptionally low-loss waveguide combining on the output -- all within the ModuMAX chassis. This passive combining technique ensures that problems with any individual ModuMAX module, whether a Solid State Power Amplifier, a power supply, or a fan, does not interrupt the ModuMAX linear RF output power. Maximum output power capability to overcome the worst rain fades may be reduced by an SSPA module failure but since HPAs normally operate below that maximum level, the ModuMAX Monitor & Control can maintain output power for critical, glitch-free digital transmission.

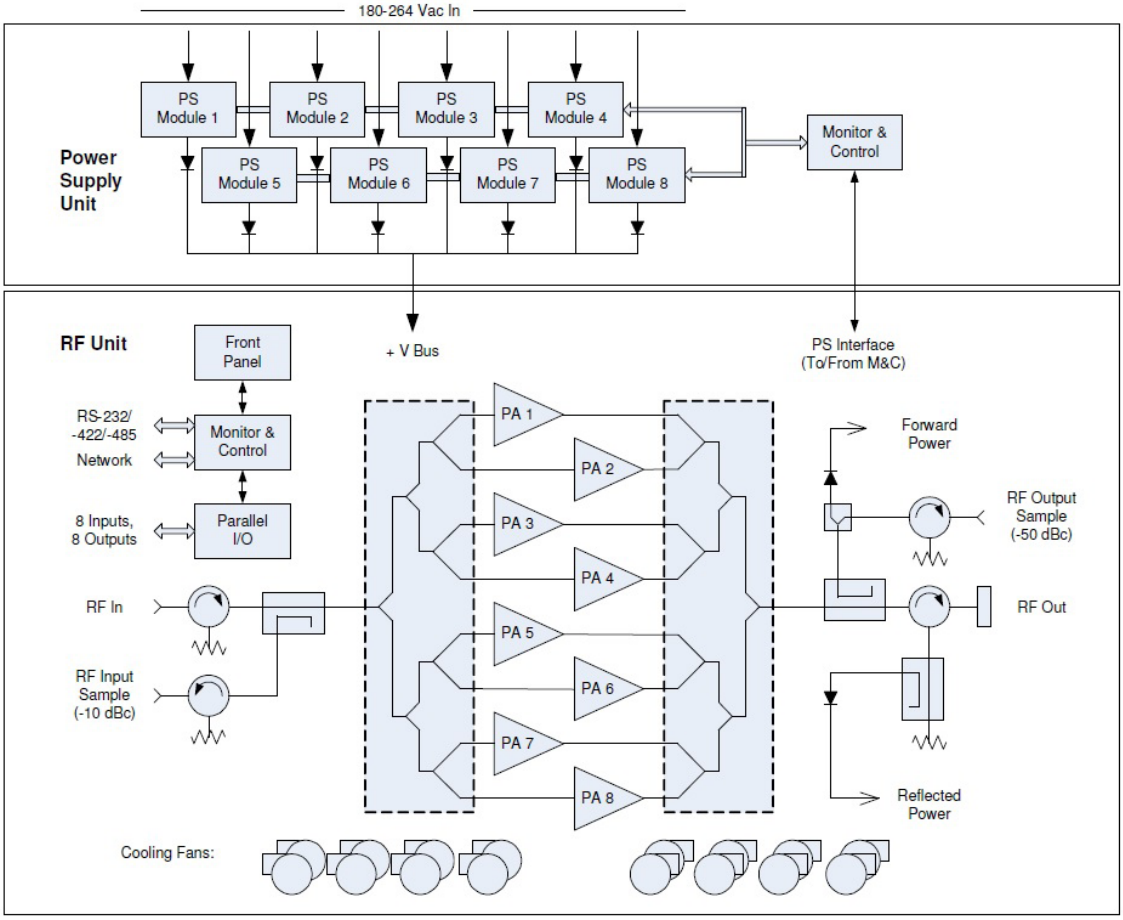

Figure 2 ModuMAX Block Diagram

Figure 2 illustrates the Block Diagram of the ModuMAX. It highlights the modularity and passive combining architecture which make the ModuMAX the amplifier of choice. All active components within the ModuMAX are hot-swappable without removal of power. The true, hot-swappable capability for all major components in General Dynamics SATCOM Technologies' ModuMAX SSPAs sets the standard for amplifier reliability.

Patented Modular Architecture

The major modules in ModuMAX consist of eight separate Solid State Power Amplifiers (SSPAs), six to sixteen separate power supply modules, and eight separate fan assemblies. The input RF power to the amplifier is passively divided to drive each of the SSPA modules. In turn, the RF output power from each SSPA is passively combined in a low-loss waveguide to produce the desired level of linear RF output power. Each of these modules can be removed and replaced while the amplifier is continuously on the air without the need to turn off the power. In fact, all major system components: power supply modules, fans, logic board, parallel I/O board, and front panel touch screen display module, are hot-swappable. The individual ModuMAX modules have exceptionally high Mean Time Between Failure (MTBF) performance individually, however this design enables the amplifier to stay on the air continuously, even if individual modules experience problems. To make this possible General Dynamics SATCOM Technologies has incorporated some industry-unique capabilities in each of the modules as well as the ModuMAX as a system.

RF Plug-In Modules

ModuMAX SSPAs utilize eight identical and fully interchangeable RF plug-in modules. Significant technology advancements have been incorporated into these latest RF modules. They provide excellent linearity under higher output power conditions through an optimal mix of the latest in GaAs and GaN technology. While some manufacturers simply claim GaN "is the latest thing" and has to be used for everything, the ModuMAX RF modules use GaN to its best advantage in the later amplifier stages to provide higher levels of RF output power at higher temperature levels. The first version of the new generation GaN ModuMAX can support 1080 Watts of Ku-Band output power. Future enhancements are under development for higher power and additional frequency bands. Through the use of a unique linearization technology, General Dynamics SATCOM Technologies has designed the RF drive stages to electronically correct the RF power roll-off and signal distortion GaN devices alone would otherwise suffer. The result is higher power in smaller volume, with more power efficiency. With that improvement, the latest generation ModuMAX RF modules are more rugged, more powerful and more capable than previouse [SSPAs].

"The latest generation ModuMAX RF modules are more rugged, more powerful, and more capable than previous [SSPAs] ."

GENERAL DYNAMICS
SATCOM Technologies

Figure 3 ModuMAX RF Plug-In Modules

RF Plug-In Module Key Differentiators

- Unique blind mate waveguide, RF, power and control interface
- No cable, front-panel hot-swappable
- Optimal gain and phase matching for module interchangeability
- Optimal linearization of the output GaN amplifier stages

The ModuMAX RF modules use a unique blind mate interface so they can be completely hot-swapped from the front panel of the amplifier, without removing power, connectors, or any cabling. The RF output of the RF modules employs a custom designed self-sealing waveguide flange design that ensures maximum efficiency for RF output power combining while also ensuring operator safety. RF input, primary power and control signals all interface to the RF modules via a custom connector on the rear of the modules so no other connections are required. Due to General Dynamics SATCOM Technologies' unique design, the modules are aligned in the factory to ensure repeatable, optimal gain and phase matching in each module making them 100% interchangeable. General Dynamics SATCOM Technologies' module gain and phase stability offers a critical advantage for maintenance, enabling a single module to serve as a spare for any of the different amplifiers employed in multiple ModuMAX installations.

"General Dynamics SATCOM Technologies' module gain and phase stability offers a critical advantage for maintenance, enabling a single module to serve as a spare for any of the different amplifiers employed in multiple ModuMAX installations."

ModuMAX SSPAs have more internal performance measurement capabilities than any other SSPA. In addition to the usual input and output RF power measurements, each RF module reports many internal stage-by-stage temperatures, voltages, and currents to the ModuMAX internal monitor and control system. This multiple reporting capability not only ensures peak operation, but also enables internal logging of the parameters. The access via the remote interface permits careful performance analysis and, if desired, remote factory assistance.

One of the biggest factors in the reliability of any SSPA, especially large, high power SSPAs, is the thermal design employed to keep the FET channel temperatures at an acceptable level. Cooler FETs run longer but over blown cooling systems can become too large, expensive, and difficult to install. General Dynamics SATCOM Technologies' many years of building high power SSPAs has given us tremendous expertise in optimal SSPA thermal design and management. That experience has been fully leveraged in the latest ModuMAX RF modules. Optimized electrical design of the amplifier circuitry, the thermal mechanical design and heat flow, as well as monitor and control, ensures ModuMAX SSPAs run reliably and cool for decades.

Modular Power Supply

The ModuMAX makes use of eight identical 48-volt DC power supply modules which share the total SSPA power load in an "N+1" configuration. The individual power supply modules are a standard telecom industry-proven design with hundreds of thousands of units currently in the field. Margin is designed into the system so that a loss of a single module will not affect operation and any module can be hot-swapped without any impact to performance.

Power Supply Module Key Differentiators

- Eight identical redundant, high reliability power supply modules in each enclosure
- Full operation even in the presence of one removed module
- Safe, fast and reliable replacement with keyed quick-connect

Power supply module replacement is safe, fast, and reliable with keyed, quick-connect, self-securing connectors on each module. Power supply operational parameters such as temperature, current, and voltage are continuously monitored and logged by the ModuMAX monitor and control system to confirm operation and to optimize maintenance activities.

Figure 4 ModuMAX Power Supply Modules

GENERAL DYNAMICS
SATCOM Technologies

Cooling System

The ModuMAX employs an integral forced-air cooling system offering fault-tolerant redundancy which minimizes RF module temperature. General Dynamics SATCOM Technologies has decades of experience in the design of large, high power SATCOM uplink power amplifiers as well as electronics used by militaries around the world in the harshest, most extreme environments. All that expertise is leveraged in the state-of-the-art thermal management design of the ModuMAX. Eight identical, redundant cooling fan assemblies are used in the cooling system with sufficient capacity to support continued full operation with the loss of one fan. Careful design has been incorporated to simplify installation, whether using open air ventilation or with optional full ducting. Internal temperatures are continuously monitored as is the rotational speed of each fan. Degradations are indicated on the control panel display and via the remote Monitor & Control interfaces.

ModuMAX Non-Stop Performance

The ModuMAX provides the industry's best non-stop uplink reliability. The patented true hot-swappable architecture means that redundancy is within the ModuMAX itself so there is no need to install expensive redundant amplifiers. While each of the modules described here clearly contribute to the ModuMAX performance, the real proof is its performance as a high power amplifier system.

The ModuMAX uses a powerful internal Monitor & Control system to ensure peak performance. All of the critical amplifier voltages, currents, temperatures and RF levels are monitored continuously and reported via the color touch screen for local control as well as via Ethernet and serial remote interfaces. The M&C embedded web browser provides excellent remote monitoring and control. In continuous operation the ModuMAX Monitor & Control system ensures that RF levels, temperatures, voltages, and currents are optimized for best linear operation. The high level of internal redundancy means that several potential problems that might take other SSPAs off the air have no impact on the ModuMAX .

One of the most significant features of the ModuMAX is its ability to maintain RF output power levels even if a module fails. This capability is key to ModuMax SSPAs' continuous performance success and is made possible because ModuMAX utilizes internal redundant power supplies, fans, and RF amplifier modules. Since the input RF signal is passively divided to each of the amplifier modules and then passively combined, in a high-efficiency waveguide on the output, there is no switching required which could cause the signal to be interrupted. The power supply modules share the amplifier power load in an "N+1" configuration using diode summing, again without any switching, so no possibility of power interruption exists. The cooling system uses eight redundant cooling fans, optimally sized so that the failure of one fan does not interrupt amplifier operation—even at extreme temperatures.

The high efficiency waveguide passive RF combining technique ensures that the RF power from each module is used most effectively. The loss of RF output power from one plug-in RF module reduces the total output power capability of the ModuMAX by 1.2 dB. However, it is important to note that this is a loss of output power capability and not operating RF output power. The reason this is possible is because the ModuMAX internal Monitor & Control system can maintain output RF power level, within the capabilities of the amplifier.

Consider the case of normal satellite uplink operation: High Power Amplifiers need to be able to achieve output power levels sufficient to meet the uplink power requirements for all the carriers being transmitted through the amplifier during peak rain fade conditions. However, rain fades are intermittent and worst case conditions are rather infrequent meaning the HPA usually operates at significantly lower RF output power levels. As long as the actual RF output power level is 1.2 dB or more below the maximum rated output power level, the ModuMAX can be configured to maintain output power level, glitch-free, until module replacement can be completed. All transmission analysis and corrections happen on-line, while transmitting, with no interruption of even high order digital modulation links, and without removing power from the amplifier.

Described Another Way:

- Even a module failure does not interrupt the RF output power level from a ModuMAX as long as that operating level is 1.2 dB below the maximum output power capability
- Module failure or hot-swap module replacement, while on the air and operating at normal output power, are invisible to even high order digital uplink signals
- If a module fails, the only thing that is lost is the maximum rain fade uplink margin capability until maintenance is performed

Obviously, many of the ModuMAX enhancements are powerful features that offer significant advantages for satellite uplinks, but non-stop, glitch-free operation is only possible with a ModuMAX. Even more expensive fully-redundant amplifier pairs experience a switching interruption while the redundancy kicks in. Those redundant amplifiers are not only more expensive but take more prime power than a single ModuMAX.

Linear Output and How Much Power is "Enough"?

In the days of wideband FM on satellite uplinks, transmit power could be measured as "saturated" power since the constant-envelope modulation format did not require "linear" power amplification. Digital modulation formats like BPSK, QPSK, and higher orders of modulation changed all that because uplink non-linearities cause digital inter-symbol interference, making the quality of the signal being transmitted suffer, as well as spectral regrowth which can generate interference to adjacent signals on the same satellite. With higher orders of digital modulation the requirement for linearity in transmit power is even more important.

Over the years, HPA producers have generated a number of different ways to describe the output power capabilities of satellite uplink high power amplifiers. Unfortunately there is some confusion in the marketplace on this topic that require SATCOM uplink providers to be very careful to understand the real specifications of the HPAs they are considering to get the HPA they need rather than one that can't quite meet their requirements.

The most common output power specification for Electron Tube amplifiers is "Saturated" power, but it is often described simply as "output power" if there is no other clarification. The most common output power specification for GaAs Solid State Amplifiers is "P1dB", or the output power level at which the output is compressed by 1 dB compared to a linear amplification of the input signal. The most common output power specification for GaN Solid State Amplifiers is "P3dB", or the output power level at which the output is compressed by 3 dB compared to a linear amplification of the input signal.

The P3dB specification for GaN SSPAs lets manufacturers claim higher output power levels, so it looks more attractive on datasheets. But with digital modulation formats used today, that higher power level can't actually be used. The output power specification which is most important for real-world digital satellite uplinks is Linear Output Power.

Increasingly, specifications for very high order digital modulations drive a new requirement specifying output power level under a particular Noise Power Ratio, or NPR. Higher orders of modulation tend to have higher Peak-to-Average-Power-Ratio, placing higher demands on the linearity of the uplink HPA so maximum performance requires better amplifier linearity.

General Dynamics SATCOM Technologies utilizes a very sophisticated linearization design in the ModuMAX to ensure optimal linear output power under all signal output conditions. This can be seen in the performance of the amplifiers on the air, at all possible output power levels from Maximum Linear Output Power to further levels of back-off. Unfortunately, HPA output power specifications are difficult to interpret by even seasoned satellite systems engineers. Some manufacturers optimize their HPAs at an arbitrarily high level, which looks good in written specifications but actually makes linearity worse at a few dB farther back-off—where most HPAs should exhibit improved linearity. General Dynamics SATCOM Technologies' ModuMAX SSPAs provide excellent linearity at all power levels from Maximum Linear Output Power down. ModuMAX SSPAs are rated both at Saturated Output Power and Linear Output Power in our specifications but when comparing SSPA performance users should be diligent to ensure they are comparing the actual performance needed rather that the power levels that don't match the actual operating mix of signals.

"When comparing SSPA performance users should be diligent to ensure they are comparing the actual performance needed rather than power levels that don't match the actual operating mix of signals."

General Dynamics SATCOM Technologies has developed a number of tools to ensure that ModuMAX SSPAs satisfy real user needs rather than just datasheet specifications. Contact us with your specific operating requirements in terms of frequencies, modulation type, and linearity range and we will help you select the optimal solution for your SATCOM transmission needs.

Where Does ModuMAX Go From Here?

General Dynamics SATCOM Technologies' ModuMAX SSPAs have demonstrated the highest reliability and availability of any satellite uplink power amplifier in actual field operation around the world. ModuMAX's patented hot-swappable architecture ensures non-stop satellite uplink under the most demanding conditions. RF power semiconductors are experiencing significant new development. While most of these advances are at lower frequency applications than SATCOM, and often lower power levels, higher power devices are becoming more cost-effective and ever more powerful in higher SATCOM frequency bands. As described, the latest advancements in GaN semiconductor devices and power supply design are making ModuMAX even more capable. General Dynamics SATCOM Technologies is leveraging those developments in even higher power ModuMAX RF modules and for other SATCOM frequency bands. Those developments can be seen in new General Dynamics SATCOM Technologies' product releases, making ModuMAX the high reliability satellite uplink power amplifier of choice for decades to come.

Contact Us

Please contact us if you would like more information.

customercare@gd-ms.com

1-770-689-2040

www.gdsatcom.com

GENERAL DYNAMICS
SATCOM Technologies