PowerMAX Systems

Available in S, C, X and Ku Bands

Soft-fail Redundancy
Modular, Hot-swap Assemblies
Indoor and Outdoor Packages

TELEDYNE PARADISE DATACOM Everywhereyoulook™

The PowerMAX Advantage

Modular amplifier systems have been used in communication systems for over 40 years. Broadcast FM transmitters were among some of the first modular amplifier systems. As cellular base stations emerged these systems also utilized multiple RF amplifier modules.

Microwave amplifier systems were slow to adopt modular techniques. This was primarily due to the fact that Traveling Wave Tube Amplifiers (TWTAs) and Klystrons dominated high power amplifier applications. TWT operating voltages, as well as physical and thermal constraints make it extremely difficult to realize modular system architectures. As Solid State Power Amplifer (SSPA) technology evolved, it became possible to realize modular amplifier systems in the microwave frequency bands.

In the mid-1990s the first modular amplifier systems operating in C-Band emerged. These amplifiers represented a tremendous breakthrough for the Satellite Communications industry which has always placed an emphasis on reliability. These systems were comprised of a parallel set of RF modules that were passively phase combined to achieve higher output power.

In these early pioneer systems, only the RF modules were parallel redundant. Other active component assemblies such as fans, embedded controllers, DC/DC converters, and other ancillary passive components were not parallel redundant and existed as single points of failure.

As microwave semiconductors became more reliable it became obvious that the RF module is not the only assembly within an amplifier system that requires redundancy. The need for full parallel redundancy of all critical assemblies within an amplifier system quickly became apparent.

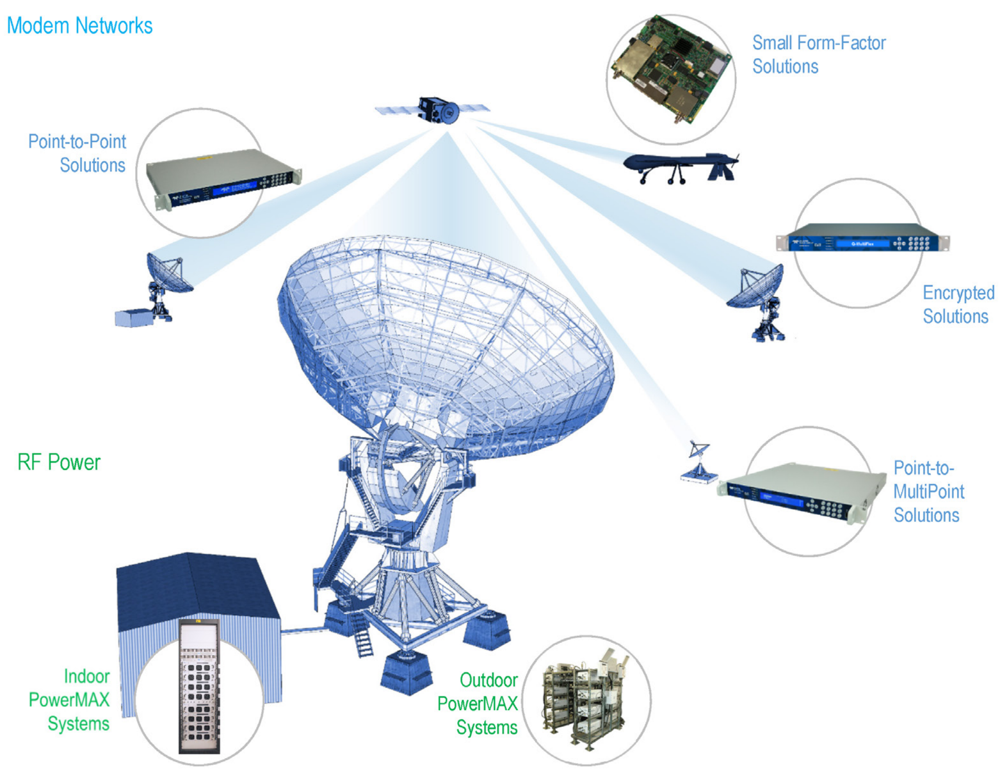
Another emerging need in Satellite and Military Communications was that of ever increasing output power levels. The early modular SSPA systems were limited to relatively modest RF output power levels. This was due to the power density of an SSPA brick and the number of bricks that could be packaged in a single chassis.

The PowerMAX amplifier architecture developed by **Teledyne Paradise Datacom** in the early 2000s is a unique solution to redundant High Power Amplfier (HPA) systems that addresses both of these shortcomings.

The indoor PowerMAX system utilizes a complete 3RU chassis as the elemental 'module' of an SSPA system. Outdoor PowerMAX systems use either the popular Compact Outdoor SSPA or High Power Outdoor SSPA as the module component. This enables much higher RF power densities for an individual SSPA module. Because an entire SSPA chassis is the individual module, all other critical components including embedded controllers, fans, power supplies, etc., can now be made parallel redundant as well. This leads to a system architecture that is truly fault tolerant

A unique operating system firmware design allows such a complex system to be operated as though it were a simple single chassis amplifier. Now HPA systems can have the best of both worlds: the ability to achieve extremely high RF power levels and extremely high reliability levels simultaneously.

Teledyne's Indoor or Outdoor PowerMAX systems provide unmatched power for Earth Stations.



PowerMAX Redundancy

Because of the high level of redundancy in a parallel system, the PowerMAX is used as a self redundant system. That is to say that the minimum required output power is sized with one (n-1) chassis failure. The output combining network is entirely realized with passive waveguide combining networks that are optimized to have extremely low RF losses. Because there are no switches involved, there are no drops in the output carrier as experienced in traditional 1:1 and 1:2 redundant systems.

The system is typically configured in binary combinations of: 4, 8, or 16 modules. The PowerMAX architecture provides protection of initial investment in that it can be easily upgraded in the field. A system can be initially configured with 4 modules and be upgraded to 8 or 16 modules at a later time.

In terms of redundant (n-1) output power, the following table shows the reduction in output power for a system with 4, 8, or 16 modules. The 8- and 16-module configurations are best for self-redundancy as they experience relatively little maximum output power reduction with the failure of one module. The PowerMAX system is able to auto-correct the overall RF gain in the event of a module failure. Therefore systems that are operated with 3 dB or more back-off experience no change in output power with the failure of a module.

The PowerMAX system is able to maintain constant overall system gain with the loss of up to three RF modules.

Power Reduction with Loss of 1 RF Module

# of Modules	(n-1) Modules	RF Power Reduction
4	3	-2.5 dB
8	7	-1.2 dB
16	15	-0.6 dB

N+1 POWER SUPPLIES

- System design provides for one extra power supply module than necessary to power system.

N+1 SSPA MODULES

- System is designed such that the loss of one SSPA module will not affect required RF Output of system.

PowerMAX Maintainability

Removable Fan Tray for Fan Replacement
and Cooling System Maintenance

The Availability of a system is the ratio of actual service to required service for a given system. The Availability figure is useful for calculating the cost of service outages due to system failures. In reliability engineering, the Availability is defined by the following equation.

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

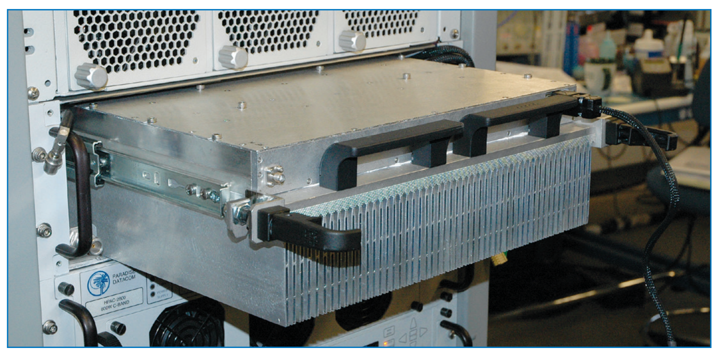
Where MTBF is the Mean Time Between Failure, and MTTR is the Mean Time To Repair

We can see that regardless of the MTBF, a high level of Availability can only be achieved when a system has a very low MTTR. Even a system with low MTBF can achieve high Availability with very low MTTR. However, the frequent need of repairs will have a bearing on the overall cost of operation. Therefore, amplifier systems operating in mission critical environments must have both high MTBF and low MTTR in order to maintain the highest Availability and lowest cost of operation.

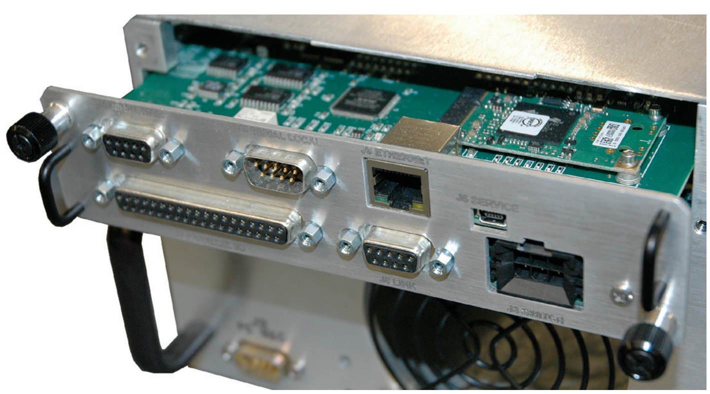
For an amplifier system to have low MTTR, it must be able to be quickly and easily repaired in the field. All of the active components of the PowerMAX system can be quickly and easily meaning that replacements can be made while the system is operational. There is never a need to schedule down time to perform a component swap.

Power supply modules are easily removable from the front panel. Likewise, the SSPA module and cooling system fans are also easily removable from the SSPA chassis front panel. The M&C embedded controller card is removable from the rear panel of the amplifier. This gives maintenance personnel the ability to easily make any necessary repairs on site. There is never a need to make expensive shipments of SSPA chassis to the factory or repair depot. The PowerMAX system is 100% maintainable in the field. Including fault diagnosis time, the MTTR of a PowerMAX system is typically less than 30 minutes.

Power Supply Modules Removable from Front Panel



SSPA Module Removal from Chassis Front Panel



Embedded Controller Cards
Removable from Rear Panel

PowerMAX Reliability

Reliability is defined as the probability of an amplifier to perform its function, resulting in no loss of service, for a specified period of time. Reliability is often confused with MTBF. The actual reliability of an amplifier is much less than the MTBF.

The MTBF figure assumes that a component can fail, be repaired, and then be put back into service. If the service life and MTBF were the same, then using the exponential distribution, the system would only have a 36.7% chance of operating to the MTBF without failure. A typical microwave amplifier system should be expected to have a 15 to 20 year service life.

$$Reliability = e^{-\left(\frac{Time}{MTBF}\right)}$$

It is interesting to compare the Reliability and output power among a single SSPA, a traditional 1:1 redundant system, and an 8-module PowerMAX system. Consider a single 800W SSPA chassis that has an MTBF of 200,000 hours. Obviously the single chassis has no redundant output power. That same chassis used in a traditional 1:1 redundant system now offers the benefit of full power redundancy and a modest increase in overall reliability.

When 8 of the 800W SSPA chassis are employed in a n-1, fault tolerant PowerMAX system the system reliability and availability increase dramatically. The RF output power of the system also increases dramatically. The (n-1) or redundant output power of the system is 3.4kW while the non-redundant output power becomes 4.5kW.

As the summary table below shows, utilizing a fault tolerant type of system such as PowerMAX enables tremendously high (5 nines) levels of system availability. The system has a 99.3% probability of operating without failure over a 15 year service life period.

These type of reliability figures are simply not possible with any other type of redundant system. The fault tolerant PowerMAX system architecture achieves extremely high reliability simultaneously with very high RF output power levels.

PowerMAX fault tolerant amplifier systems have changed the way in which engineers think about high power microwave amplifier systems. Multi-kilowatt amplifier systems can now be built to have extremely high system reliability and availability.

The convenience of being able to completely repair and maintain the system in the field offers tremendous cost savings to the end user.

Teledyne Paradise Datacom's PowerMAX systems are available with many options and add-ons including:

- L-Band Input Operation
- Ethernet Switch
- External Exhaust Adapters and Impeller Fans (indoor systems only)
- Single or Three Phase Prime Power
- Waveguide Arc Detection

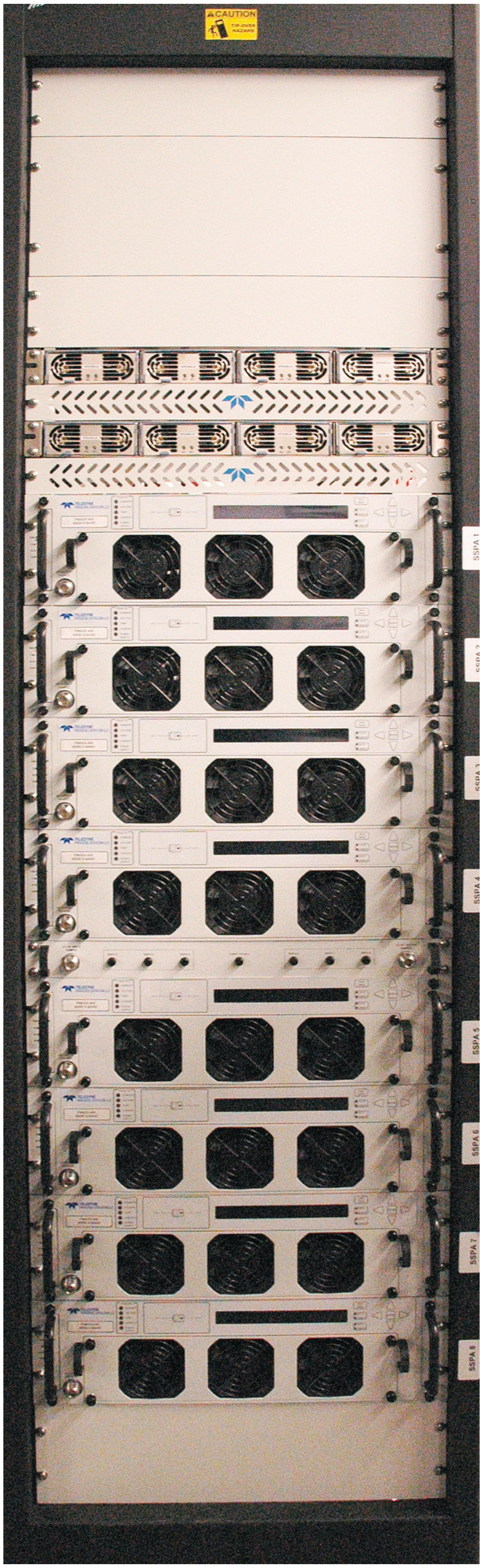
Summary, Reliability Among Single Chassis, 1:1 System and PowerMAX System

Parameter	Single Chassis	1:1 System	PowerMAX System
Max. RF Output Power	800 W	800 W	4.5 kW
Redundant RF Output Power	0 W	800 W	3.4 kW
MTTF	200k hours	516k hours	> 10^6 hours
MTTR	--	--	1 hour
System Availability	0.52000	0.758400	0.99998 (five nines)
System Reliability (15 years)	52%	77%	**99.3%**

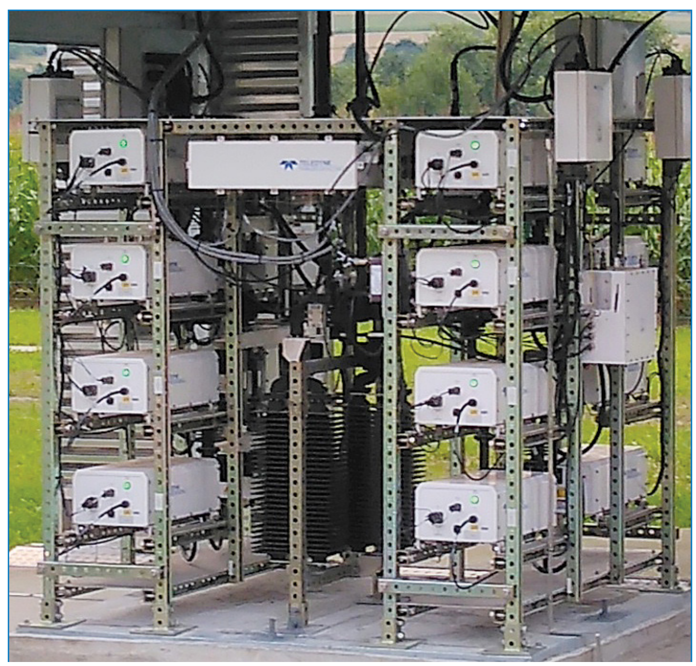
PowerMAX Configurations

PowerMAX systems are also available in outdoor configurations. Outdoor PowerMAX systems are used when it is desired to position the output power of the system closer to the antenna. The Outdoor system is also popular in installations where shelter design is difficult or prohibitively expensive.

All Outdoor PowerMAX systems are specified to operate over -40 °C to +55 °C ambient temperature environments. They are configurable using **Teledyne Paradise Datacom's** popular Compact Outdoor SSPA and the High Power Outdoor SSPA packages.



3 kW Ku-Band (8 Module) Outdoor PowerMAX System
Using 400W GaN High Power Outdoor SSPA Package



5 kW C-Band (16 Module) Outdoor PowerMAX System
Using 400W GaN Compact Outdoor SSPA Package

◄ 4 kW X-Band (8 Module)
Indoor PowerMAX System
Using 650W GaN 3RU SSPA Chassis

PowerMAX High RF Power

The chassis–module concept makes it possible to realize PowerMAX systems in a wide variety of frequency bands and output power levels. Systems can be designed from S-Band up through Ku-Band.

The following table shows some of the more popular GaN amplifier system output power levels. The table shows the various system (n) module output power and (n-1) or redundant output power level for a given SSPA module power level. Also shown is the linear output power, Plinear. Plinear is the linear power as defined by MIL-STD-188-164 for two tones separated by 5 MHz or $\leq$ -30 dBc spectral regrowth on a single OQPSK signal at 1.0x symbol rate.

Custom frequency bands and output power levels are available in both indoor and outdoor PowerMAX systems upon request.

Refer to the specification sheets listed in the PowerMAX section of our web site for output power and package availability.

Single Module Power Level	8 of 8 Modules Psat (typical) dBm (W)	8 of 8 Modules Plinear (min.) dBm (W)	7 of 8 (n-1) Modules Psat (typical) dBm (W)	7 of 8 (n-1) Modules Plinear (min.) dBm (W)	16 of 16 Modules Psat (typical) dBm (W)	16 of 16 Modules Plinear (min.) dBm (W)	15 of 16 (n-1) Modules Psat (typical) dBm (W)	15 of 16 (n-1) Modules Plinear (min.) dBm (W)
S-Band								
300 W	62.3 (1,700)	59.3 (851)	61.1 (1,300)	58.1 (646)	64.8 (3,000)	61.8 (1,500)	64.2 (2,600)	61.2 (1,300)
400 W	63.5 (2,240)	60.5 (1,100)	62.3 (1,700)	59.3 (851)	66.0 (4,000)	63.0 (2,000)	65.4 (3,400)	62.4 (1,700)
500 W	64.5 (2,800)	61.5 (1,400)	63.3 (2,100)	60.3 (1,100)	67.0 (5,000)	64.0 (2,500)	66.4 (4,300)	63.4 (2,100)
600 W	65.5 (3,500)	62.5 (1,800)	64.3 (2,700)	61.3 (1,350)	68.0 (6,300)	65.0 (3,100)	67.4 (5,400)	64.4 (2,700)
800 W	66.5 (4,500)	63.5 (2,240)	65.3 (3,400)	62.3 (1,700)	69.0 (7,800)	66.0 (4,000)	68.4 (6,800)	65.4 (3,400)
1000 W	67.5 (5,600)	64.5 (2,800)	66.3 (4,300)	63.3 (2,100)	70.0 (10,000)	67.0 (5,000)	69.4 (8,600)	66.4 (4,300)
C-Band								
200 W	61.5 (1,413)	58.5 (708)	60.3 (1,072)	57.3 (537)	64.0 (2,512)	61.0 (1,259)	63.4 (2,188)	60.4 (1,096)
400 W	64.3 (2,692)	61.3 (1,349)	63.1 (2,042)	60.1 (1,023)	67.0 (5,012)	64.0 (2,512)	66.4 (4,365)	63.4 (2,188)
500 W	65.0 (3,200)	62.0 (1,600)	63.8 (2,400)	60.8 (1,200)	67.5 (5,625)	64.5 (2,820)	66.9 (4,900)	63.9 (2,450)
800 W	67.3 (5,370)	64.3 (2,692)	66.1 (4,074)	63.1 (2,042)	70.0 (10,000)	67.0 (5,012)	69.4 (8,710)	66.4 (4,365)
1000 W	68.0 (6,300)	65.0 (3,160)	66.8 (4,800)	63.8 (2,400)	70.5 (11,200)	67.5 (5,600)	69.9 (9,800)	66.9 (4,900)
X-Band								
300 W	63.0 (1,995)	60.0 (1,000)	61.8 (1,514)	58.8 (759)	65.6 (3,631)	62.6 (1,820)	65.0 (3,162)	62.0 (1,585)
400 W	64.2 (2,630)	61.2 (1,318)	63.0 (1,995)	60.0 (1,000)	66.9 (4,898)	63.9 (2,455)	66.3 (4,266)	63.3 (2,138)
650 W	66.3 (4,266)	63.3 (2,138)	65.1 (3,236)	62.1 (1,622)	69.0 (7,643)	66.0 (3,981)	68.4 (6,918)	65.4 (3,467)
800 W	67.2 (5,248)	64.2 (2,630)	66.0 (3,981)	63.0 (1,995)	70.0 (10,000)	67.0 (5,012)	69.3 (8,511)	66.3 (4,266)
Ku-Band								
200 W	61.0 (1,259)	58.0 (631)	59.8 (955)	56.8 (479)	63.6 (2,291)	60.6 (1,148)	63.0 (1,995)	60.0 (1,000)
250 W	62.0 (1,600)	59.0 (800)	60.8 (1,200)	57.8 (600)	64.7 (3,000)	61.7 (1,500)	64.1 (2,570)	61.1 (1,300)
400 W	64.0 (2,512)	61.0 (1,259)	62.8 (1,905)	59.8 (955)	66.6 (4,571)	63.6 (2,291)	66.0 (3,981)	63.0 (1,995)
500 W	65.0 (3,162)	62.0 (1,585)	63.8 (2,399)	60.8 (1,202)	67.6 (5,754)	64.6 (2,884)	67.0 (5,012)	64.0 (2,512)
600 W	65.8 (3,800)	62.8 (1,900)	64.6 (2,900)	61.6 (1,450)	68.5 (7,080)	65.5 (3,540)	67.9 (6,160)	64.9 (3,080)

Specifications are subject to change without notice. PowerMAX is covered by U.S. Patent Nos. 8,189,338 B2 and 8,411,447 B2.

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