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Liquid-Cooled SSPA for Satcom Uplinks

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Engineered for demanding satcom uplink applications, the Empower RF Model 2253 solid-state power amplifier (SSPA), shown in ***Figure 1***, combines solid-state technology with a modular, liquid-cooled architecture. Operating from 1750 to 2120 MHz, the 2253 provides a 7 kW peak and 3.5 kW RMS of digitally-modulated output power. The 2253 is the latest member of Empower's standard liquid-cooled SSPAs built for critical applications requiring solid-state power and high availability. The 2253 system comprises a 6 ft. rack, eight 2U amplifier drawers, a built-in cooling distribution unit (CDU) and an external heat exchanger.

The architecture of the 2253 is distributed and modular, the latter allowing field replacement of amplifier drawers, the controller and CDU, as shown in ***Figure 2***. The distributed RF and power supply design eliminates single points of RF failure, delivering "always on air" operation and minimizing downtime. The distributed system design provides system redundancies, allowing continuous amplifier operation at maximum potential in the event of partial failures. Similar to N+1 configuration redundancy, the 2253 offers impressive effective mean time between failures.

The 2U amplifier drawer forms the essential foundation that enables the transmitter's superior availability. Each 2U chassis is a fully functioning, integrated amplifier with full gain and no external driver or external system power supply needed at the rack level. The phase and gain of the 2U amplifier are set digitally. The rear panel consists of blind-mate electrical and dripless liquid connectors, ensuring the unit is field serviceable.

The system controller for the transmitter incorporates a high speed embedded computing architecture to ensure control, monitoring and protection of the individual 2U amplifier drawers. The system controller is common across Empower's liquid-cooled family and can manage a single or scaled version of the 2253 system. When scaled up, one or more additional racks are added in parallel for higher power; however, the system controller manages the combinations as a single entity.

The amplifier system includes a range of features designed to enhance performance, reliability and ease of integration. The system offers instrument-grade measurement capabili-

Fig. 1 Empower RF Model 2253.

Fig. 2 The back and front panels of the CDU.

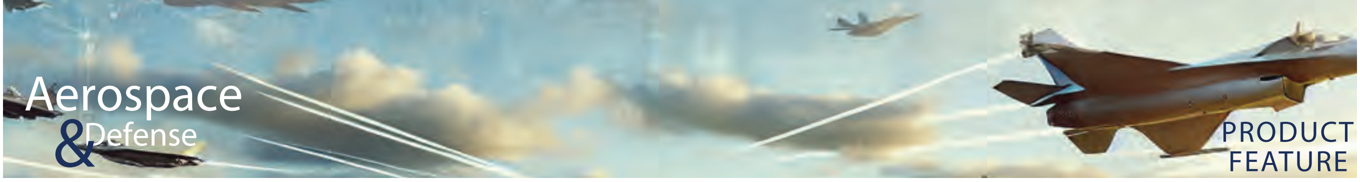

TABLE 1 SUMMARY OF SYSTEM BENEFITS

User Benefits	Description	Operational Impact
Reliability	Redundancy and distributed architecture, similar to N+1 with no single points of RF failure.	Operational hours (effective MTBF) with minimal downtime risks.
Mission-Critical Uptime	"Always On Air" operation in the event of component or amplifier drawer failure.	Continuous broadcast with high availability.
Low Total Cost of Ownership	Modular design reduces upfront costs and maintenance expenses.	Lower capital expenditure and lifecycle costs compared to non-modular systems.
Repairs	15-minute amplifier drawer swaps. No specialized training required.	Reduced repair time and labor costs for mission-critical environments.
Scalable Power	Add 2U amplifier blocks or entire racks. Combiner will need changing.	Flexible power expansion without system redesigns.
Waveform Flexibility	Latency adjustments and complex modulation support.	Signal agility for dynamic mission requirements.
Future-Ready Architecture	High speed processing and FPGA design allows DSP inside the amplifier.	Long-term adaptability to new waveforms and mode scenarios, plus a roadmap of signal processing functions.
Maintenance	No high-voltage supplies, intuitive diagnostics, common GUI across the family.	Reduced technician workload and error rates during servicing.
Fractional Sparing	One or two 2U amplifier blocks + one universal controller as backups.	Lower inventory costs while maintaining redundancy.
Broadband Agility	Faster frequency hopping and wider instantaneous bandwidth.	Adaptability to dynamic spectrum requirements in real-time operations.
Integration	Web API compatibility and standardized interfaces.	System integration with educed customization needs.

ties, delivering precise peak and RMS power readings. Granular performance monitoring is achieved through real-time tracking of current, voltage and temperature at pallet and device levels, enabling proactive maintenance and system optimization. The amplifier is integration-ready, featuring a Web API that supports communication and third-party system control. The system employs an internal network to connect to each amplifier drawer. To avoid multiple CAT6 cables and connection faults, the system uses a root switch and rapid spanning tree protocol to provide internal network redundancy and enhance operational reliability.

The architecture utilizes full backplane implementation, eliminating the need for cable or harness detachment during service. This simplifies maintenance and ensures compliance with EMI/RFI standards, reducing potential interference and improving overall system robustness. RF power is aggregated using in-house designed combiners, while a patented fiber-optic data bus provides noise-resistance and high data rates.

The benefits of this system architecture, summarized in Table 1, include its modular design, which enables fractional system sparing. This prevents users from needing a second identical system for backup, lowering the cost of ownership. For example, two 2U amplifier drawers and one controller represent a full system backup. The transmitter stays online while technicians service or replace individual amplifiers. Additionally, no specialized technician training is required and there are no dangerous high voltages to contend with. This significantly reduces maintenance and training expenses compared to TWT-based and non-modular solid-state systems.

The 2253 SSPA provides adaptability for evolving mission requirements through its waveform versatility, which supports modulations and frequency hopping to meet dynamic operational demands. Scalable power ensures seamless expansion via 2U amplifier drawers or full rack additions, enabling capacity growth without system redesign. Advanced waveform control delivers low-latency adjustments of complex digital modulation schemes and dynamic operational mode changes. Additionally, the future-ready architecture incorporates opportunities for signal processing enhancements aligned to a structured technology roadmap, ensuring performance and compatibility with emerging requirements. Together, these features position the system as a long-term, high-flexibility solution for advanced communication applications.

The significance of solid-state, high power transmitters for satcom, telemetry, tracking and command and space EW applications cannot be overstated. Increasingly complex waveforms, spectrum management requirements and multi-mission demands on ground-based infrastructure and deployed systems require intelligent amplifiers that combine high performance RF, thermal management and embedded computing control. Empower's 2253 SSPA and patented architecture support these demands.

VENDORVIEW

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