



TWT vs a Modern SSPA Architecture for Very High Power

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Topics

- › Expertise Overview
- › Evolution into the Modern Architecture
- › Modern Architecture – High Level Description
- › Major System Elements
 - The RF Drawer - aka Booster
 - Digital Features in the Amplifier
 - Combining Considerations
- › Scalability
- › Availability
- › Effective MTBF
- › Total Cost of Ownership
 - With a model
- › Concluding Remarks and Q & A Session

SCALABLE Liquid and Air Cooled SSPA's

Established RF Architecture
Supporting Mission Critical Applications from
HF to X-band
CW & Pulse
COTS & Custom

90 kW
NEW!
Scalable liquid cooled hot swapping for applications requiring tens or hundreds of kilowatts, CW or Pulsed

8 kW Pulsed

2 kW CW
in 8U chassis

1 kW CW
in 5U chassis

500 W CW
in 3U chassis

Rack Mount System Amplifiers

- ☑ CW, Pulse, and Long Duty Cycle Pulse
- ☑ High Efficiency and High MTTF's
- ☑ Scalable in Power – Liquid Cooled Models
- ☑ Hot Swapping – Liquid Cooled Models

RF and Microwave Modules

- ☑ New 48V Modules Available!
- ☑ Analog or Digital Control
- ☑ Feature Rich



Expertise Overview



- › Pulse and CW SSPAs
- › HF to X Band

- › EW
- › Radar
- › Product Testing
- › Communications

- › Modules
- › Air cooled Systems
- › Liquid Cooled Transmitters

RF POWER AMPLIFIERS
HF to X-Band * Air & Liquid Cooled * Software Definable * Hot Swappable * Multi-Function

Atlanta 2021

IMS
Booth 1225

EMPOWER
RF SYSTEMS, INC.

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1(310)412-8100



Evolution – The Multi-mode and Interoperable Power Amplifier



- › Today's topic is the result of planned roadmap of technology implementation
- › The first generation of Solid State Multi-mode and Interoperable Power Amplifier is mature As seen in our Next Gen family of air cooled system amplifiers
 - **Multimode** Power Amplifier is an amplifier that can operate in all modes required for its application
 - **Interoperable** Power Amplifier is an amplifier that requires no change in hardware to operate in any mode
 - **Why do we care?** A single unit is capable of Multi-Domain applications. Designed to stay ahead of the increasing complexities of the signals environment.

SATCOM TRANSMITTER

SSPA's from Empower

Space Available

When you modernize an older uplink system with an SSPA from Empower RF, what will you do with the free space?

- 2X Improvement in SWaP
- Higher Efficiency
- Higher MTBF's
- Waveform Flexibility
- Rugged for Mobile Deployment
- Remote Monitoring and Control
- Active RF Device Redundancy – Graceful Degradation

Model 2176
1.75 to 2.12 GHz
4000 Watts

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ADVANCED GaN on SiC AMPLIFIERS

For Next Generation Multi-Function Radar

SKU	Frequency (MHz)	Pout	Size
2210	150 - 450	1.2 KW Pulse 20%	R19U
2234	400 - 450	1.80 KW Pulse 10%	R80U
2211	2700 - 3100	1.2 KW Pulse 20%	R3U
2229	2900 - 3500	2.5 KW Pulse 20%	R5U
2214	2900 - 3500	8 KW Pulse 20%	R19U
2217	5200 - 5900	8 KW Pulse 20%	R17U
2225	5200 - 5900	90 KW Pulse 20%	R34Ux2
2221	9000 - 10200	8 KW Pulse 20%	R17U

Solid state, scalable architecture designs for CW and pulse applications requiring hundreds of kilowatts of RF output power.

Call for an engineering assessment of your systems requirements.

Scalable Solid State Power is a Better Choice

- High Reliability (MTBF) and Low Mean Time to Repair (MTTR)
- Redundant Architecture to Maximize "On Air" Power
- Long Duty Cycle and Pulse Width Performance
- Pulse Systems can be Operated in CW with Reduced Power

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AMPLIFIER TECHNOLOGY

for Domination of the ELECTROMAGNETIC BATTLESPACE

	SKU	Frequency (MHz)	Pout(Watt)	Size
CW	2203	1 - 30	1000	R5U
	2162	20 - 1000	1000	R5U
	2180	1000 - 2500	2000	R8U
	2170	1000 - 3000	1000	R5U
	2223	600 - 6000	150	R5U
	2215	1900 - 6000	200	R5U
Pulse	2210	150 - 450	12000 Pulse 20%	R19U
	2211	2700 - 3100	1200 Pulse 20%	R3U
	2217	5200 - 5900	8000 Pulse 20%	R17U
	2225	5200 - 5900	90000 Pulse 20%	R34Ux2
	2221	9000 - 10200	8000 Pulse 20%	R17U

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Fielded and Proven

- Threat Simulation Emitters
- CW and Pulse Radars
- Broadband Communications
- Jammers

EMPOWER'S AMPLIFIERS are tactically deployed and operating on multiple levels in support of DoD missions

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TWT Killer

No single point of RF failure

Performance monitoring down to the packet level

Ease of maintenance and no high voltage power supply

Every combined booster is digitally set for phase and gain

Scalable upgrade in power

Higher MTTF's

System will remain operational and "on the air" with graceful power degradation

Pulsed models offer 100nsec to 500nsec widths and 20% duty cycle

Not swapping on liquid cooled models available

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Air Cooled Evolution

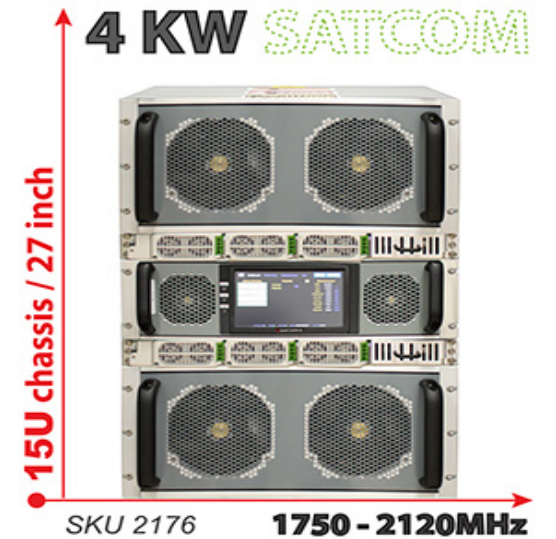


A Smart, User Configurable, Scalable Power Amplifier Architecture for Fielding More Advanced, Future Proof, Multi-Domain EW, Radar, Satcom, and Communications Systems.



150 MHz to 450 MHz, 12 KW Pulse
 2.9 GHz to 3.5 GHz, 8 & 10 KW Pulse
 5.2 GHz to 5.9 GHz, 8 KW Pulse
 9.2 GHz to 10 GHz, 8 KW Pulse

scalable power
 "system of systems"



Threat Simulation Network Amplifiers - 2 MHz to 6 GHz coverage

Central Node



17.5" x 21" x 22"

2 MHz – 3 GHz Switch Filters
 Central Controller

1 – 3 GHz 250W PA
 2 – 6 GHz 25W PA + Switch Filter

Power Supplies

2 – 30 MHz 250W PA
 30 – 1000 MHz 250W PA

Unmanned Remote Nodes



17.5" x 12.25" x 22"

2 MHz – 1 GHz Switch Filters
 Central Controller

Power Supplies

2 – 30 MHz & 30 to 1000 MHz 25W PA's
 1 – 3 GHz & 3 – 6 GHz 25W PA's
 Switch Filters

BEYOND GAN

BEYOND OPERATING CLASS

THE ARCHITECTURE
MATTERS

Contemporary SSPA manufacturers have not taken advantages of the newest technology

- High speed ADC & DACs
- RF silicon integrated into FPGA fabric
- Fiber Optics
- DSP

Advantages across multiple dimensions – Additional benefits vs traditional SSPA architecture

Reliability/Availability

Fidelity

Wave Form Flexibility

- Long Pulse Widths and Duty Cycles

Total Lifetime Cost of Ownership

Integration Features

- Web API for M2M

Scalability

Additional Operational Capabilities

- Precise Control with Short Latencies
- Accurate Complex Waveform Power Management
- Broader Instantaneous Detection Bandwidth
- Faster Frequency Hopping
- “On the Fly” Mode and Operational Profile changes

What's on your Radar?

high power AMPLIFIERS

Rugged Efficient Compact

High Efficiency, Best in Class SWaP

Extensive Self Protection and Redundant Amplifier Architecture to Maximize “On Air” Power

AC, 400 Hz, and DC Power Available

Easy Integration of Filters and T/R Switches

Key Performance Parameters Controlled Locally or Remotely

Flexible Operating Modes Ideal for Radar and Related Research, Product Testing, Threat Simulation



BANDS

C

S

L

UHF

VHF

HF


Land


Mobile

Shipboard

Airborne

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Solid State TWT Replacement
L-band - 10 kW Pulse - 9U chassis

Evolution Commonality - “Platform-driven” Approach



Our recurring and consistent RF deck architecture, along with common power supplies, is used across all platforms.

Important to understand the intentionality of evolution. The RF Deck for our new Scalable, Hot Swappable, Liquid Cooled architecture is unchanged.



Air Cooled RF Deck

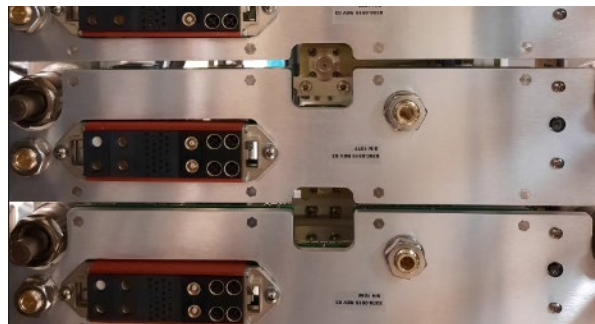
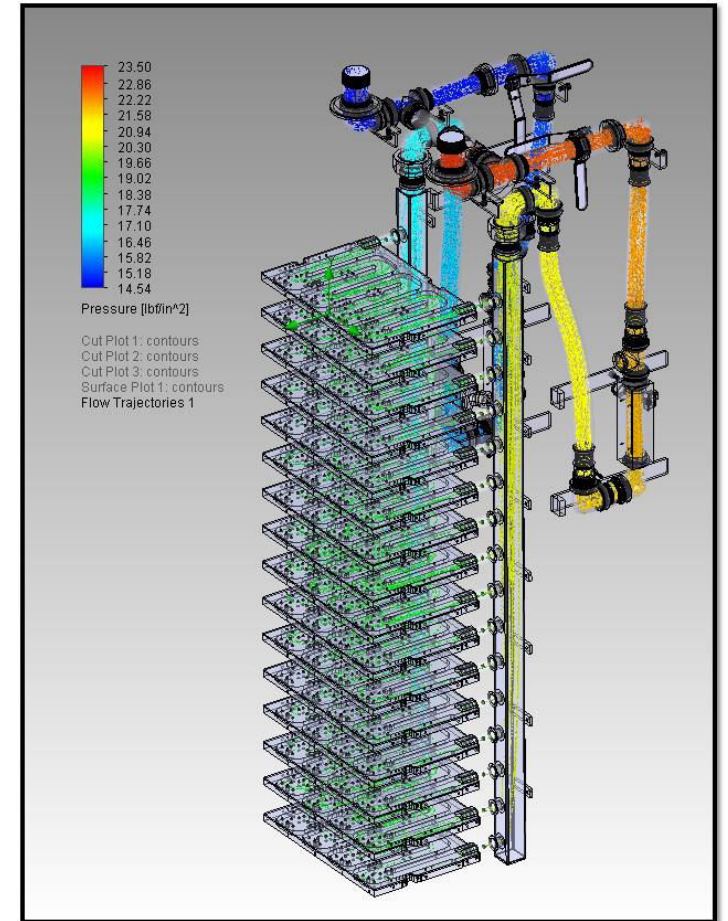


Liquid Cooled RF Deck



A Modern Architecture – High Level Description

Scalable, Liquid Cooled, Hot Swapping



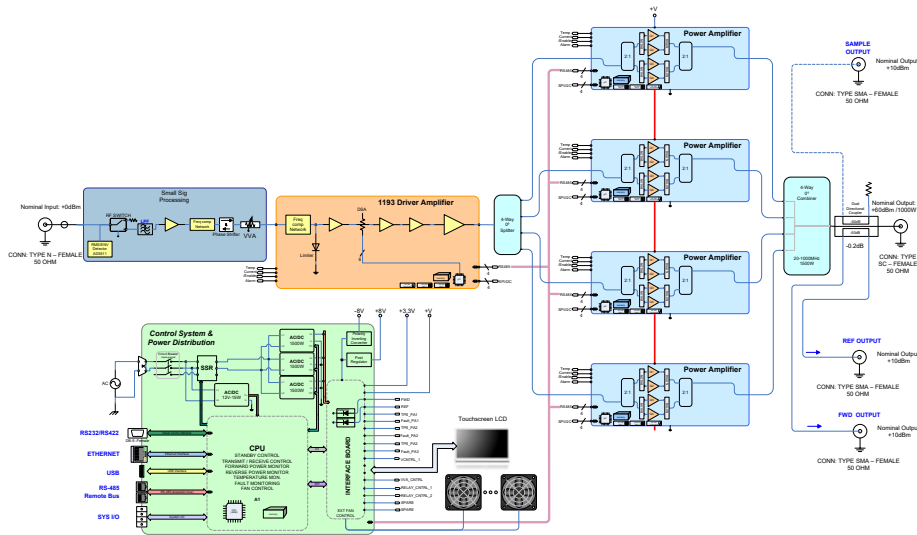
MAJOR SYSTEM ELEMENTS

- Fully integrated, liquid cooled SSPA amplifier building block
- System Controller
- Backplane Implementation, No External Cabling
- Waveguide Combiner
- Liquid Cooling Manifolds
- Optical Fiber Data Bus

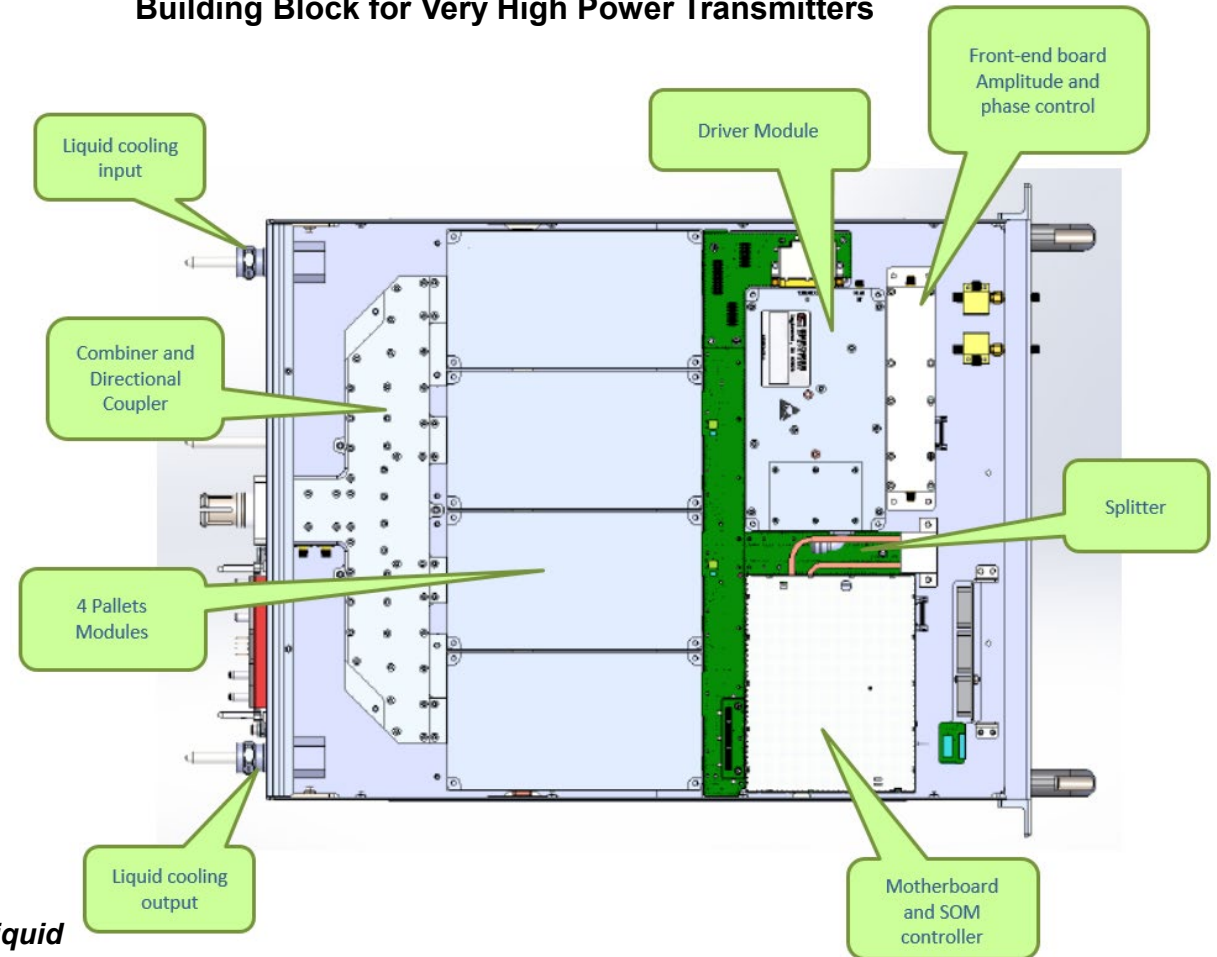


The RF Drawer - aka Booster

- › The basic building block is a fully integrated RF deck with power supply
- › Distributed RF and power supply design provides system redundancies and eliminates single points of failure



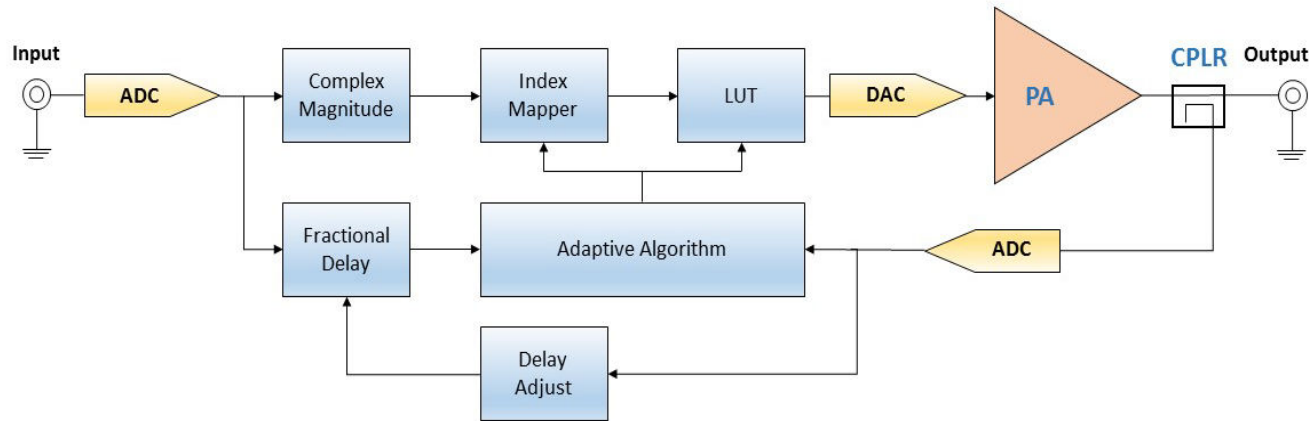
Liquid Cooled, 2U chassis Amplifier Drawer – The scalable Building Block for Very High Power Transmitters



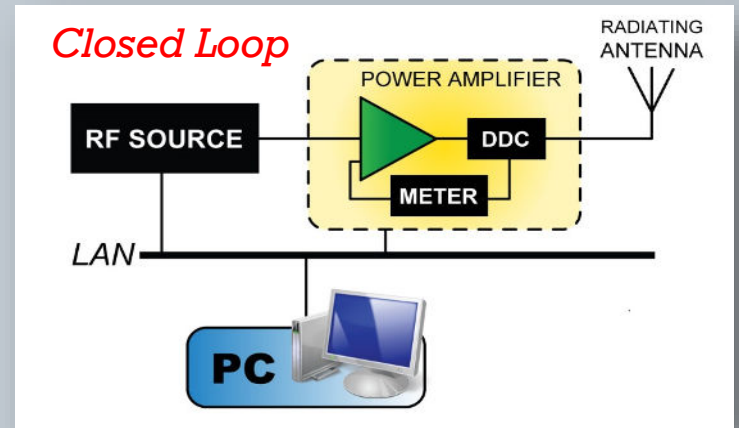
RF deck architecture is consistent across all liquid cooled scalable power transmitter designs.

Digital Features in the Transmitter

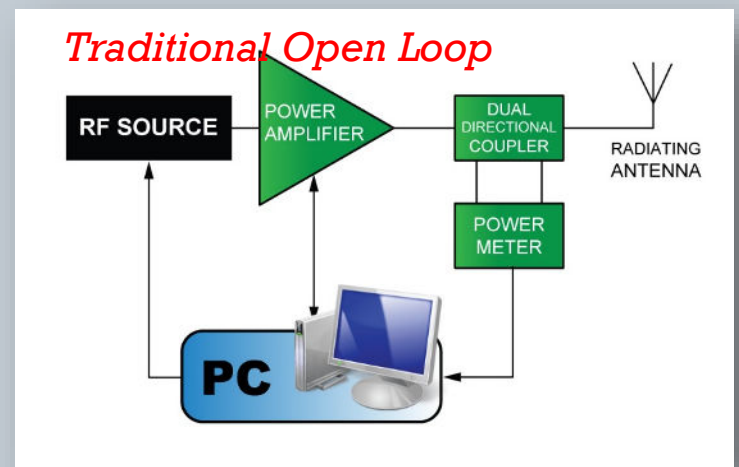
A Step Towards Closed Loop Inside the System Amplifier, Where it Belongs



- Digital Detection – What is it?
- Benefits of Digital Detection
- Fiber Optics – High Speed Data



How the Typical System Amplifier has Been Integrated for Decades



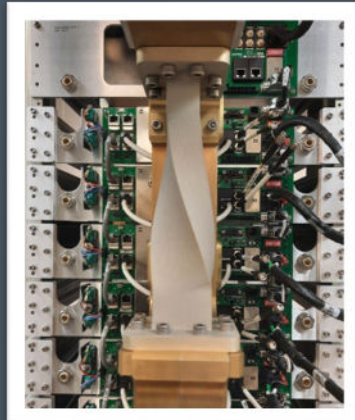
COMBINING CONSIDERATIONS

Reducing Insertion Loss

VSWR & Arcing

Isolated Loads

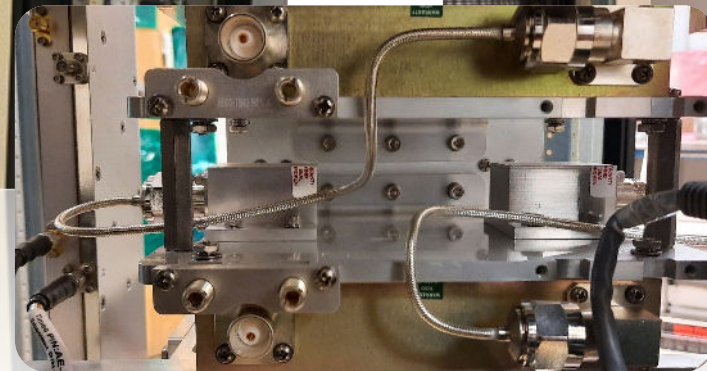
Adjustable Gain and Phase



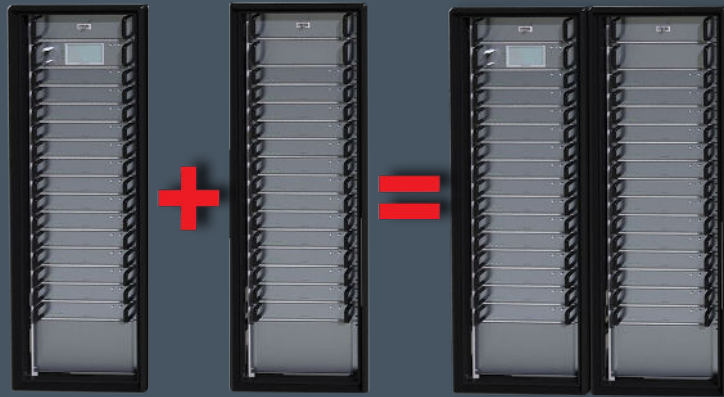
C Band



UHF



SCALABILITY



SSPA's and System Controller

Multiple SSPA's to be combined into a higher power configuration

Two or more racks integrated into a single, higher power configuration - control chassis in Rack #1 managing all amplifiers.

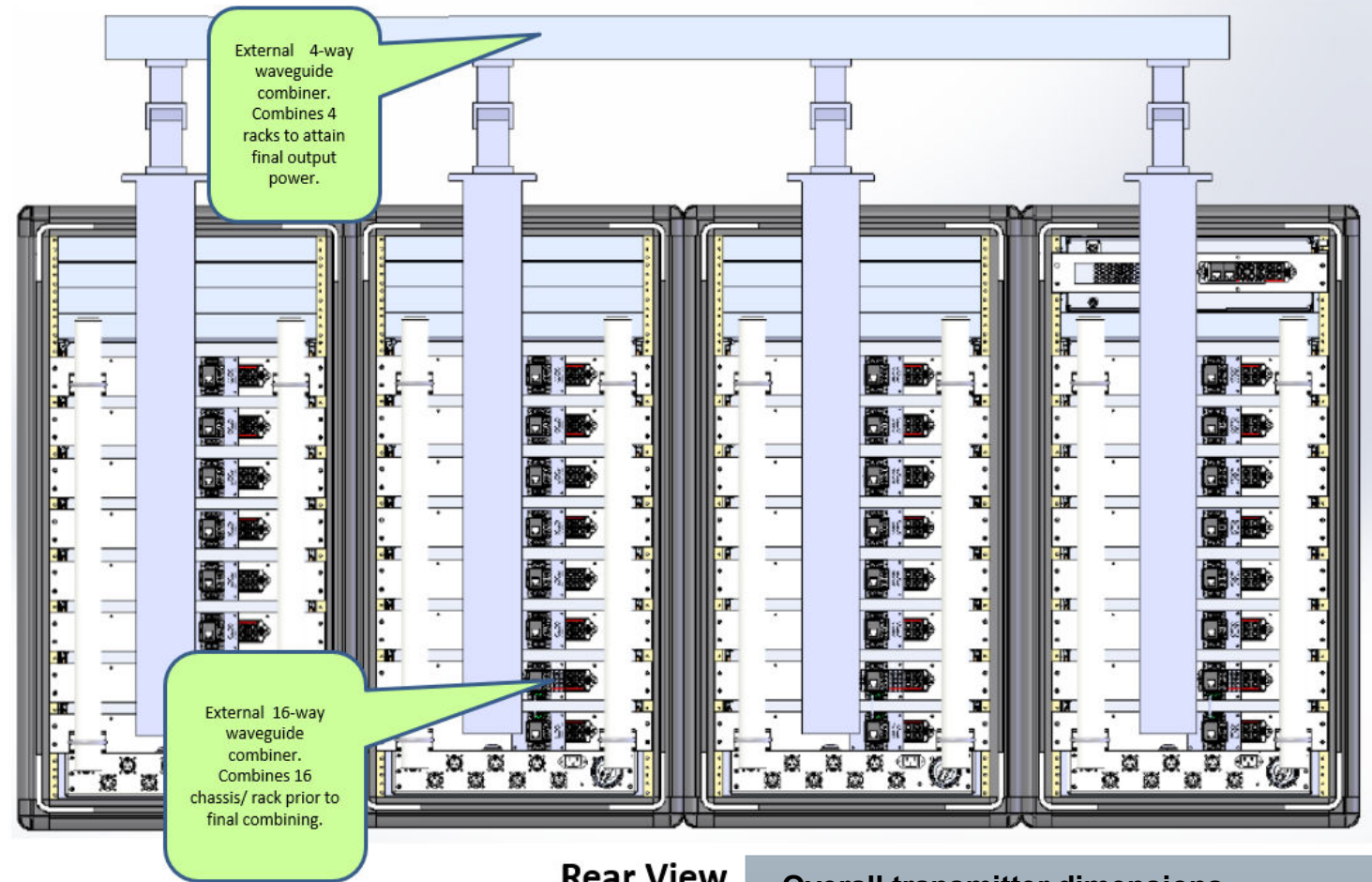
1. Scalability at the Rack Level

2. 2U Drawer Level

3. Longer PW & Duty cycle

Example

2.9 to 3,5 GHz, 310 KW peak, 16% duty cycle
PW 20 - 1000 μ sec, Rise / Fall time 10nS



Rear View

Overall transmitter dimensions
8' (wide) x 7' (high) x 4' (deep)
*additional clearance required for combiners
liquid cooling system housed separately*

Availability



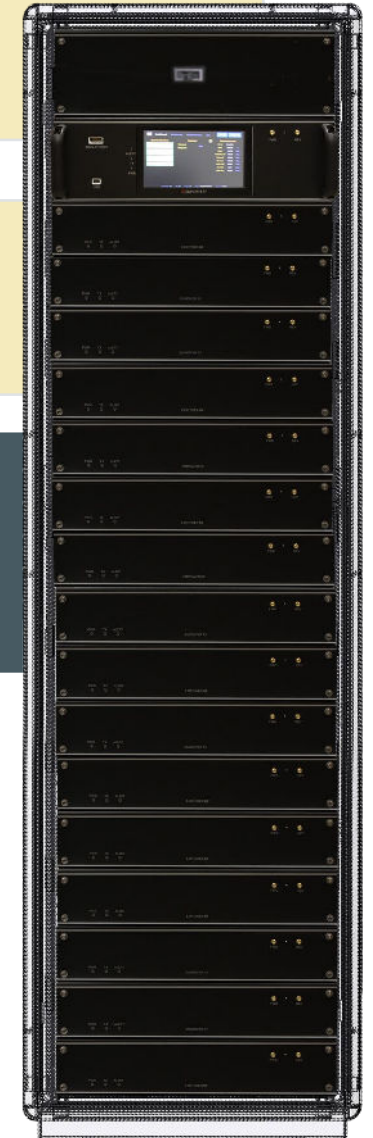
Mission Critical on Air Availability

- Reduced Points of Failure
- Distributed Architecture with Isolated Loads
- At the module Level, 2U Drawer level, and Rack Level
- Hot Swapping

The Amplifier Remains on Air

- At Reduced Output
- Component Failure, Drawer Failures, Cabinet Failure
- Exception is the Controller Failure. 15 minute MTTR

The Result: Traditional MTBF Definition Not Useful

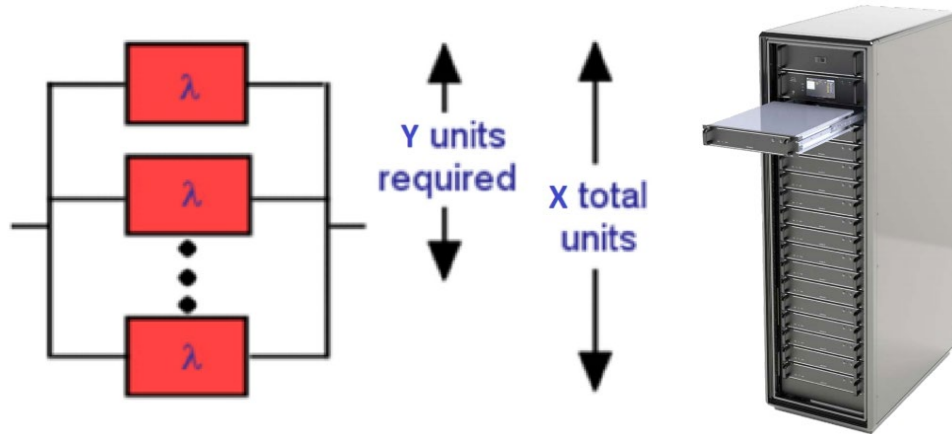


100KW Rack with 16 Drawers

# of Drawer Failures	Maximum Power Available (W)	dB Loss	Rated Power
1	93750	-0.280287236	
2	87500	-0.57991947	
3	81250	-0.901766303	
4	75000	-1.249387366	
5	68750	-1.627272975	
6	62500	-2.041199827	
7	56250	-2.498774732	
8	50000	-3.010299957	



Effective MTBF



Effective MTBF is based off effective failure rate of (X) parallel units which need (Y) operational for meeting application or mission success.

Subsystem	MTBF (note 1)	Failure Rate Per Million Hours (of booster)	MTRR	# Of Parallel Units	# That Can Fail	Effective Failure Rate of System Per Million Hours	Effective MTBF (note 2)
2U Booster	20,400	49	0.5	16	0	784	1,275
2U Booster	20,400	49	0.5	16	1	.14	6,900,000

(note 1) MTBF calculated with MIL-HDBK-217F, single 2U booster

(note 2) Exponential model

From the table it is obvious a type of redundancy is required for such a high power SSPA. But the surprising outcome is that with the proper architecture extremely high availability is intrinsic, literal redundancy is not required and therefore not an added cost. Only minimal fractional sparing is required.



Total Cost of Ownership (TCO)



Initial Amplifier Cost

- Typically higher for SSPA. Include cost of external hardware such as filters and isolators that may not be required for SSPA implementation. Some mission critical applications require redundant system with baseball switch.

Reliability MTBF

- TWT Failures within 2.5 years very common but varies with use case. Adjust with your use case data.

MTTR

- Effects spare strategy and quantities
- Mission down time
- Higher MTTR implies specialized Tech training

Maintenance Cost

- Includes rebuilds for cathode degradation
- ~60% of tube cost

Major Repair

- New Tube 70% of new amp cost
- How often? 1 to 5 years?

Annual Electrical Power Costs

- Need efficiency data related to power at antenna

Equipment Spares

- Use case showed 3X more spares required for TWT over SSPA for a non redundant SSPA
- Modular, distributed SSPA architecture allow “fractional” sparing, changing the TCO dramatically.



Intangibles

- Availability
- SWaP – in some cases
- Fidelity
- Technician Training
- Safety

Warning from two Major Tube Suppliers User Manuals

WARNING

HIGH VOLTAGE — VOLTAGES REQUIRED FOR OPERATION OF THIS DEVICE ARE EXTREMELY DANGEROUS TO LIFE; EQUIPMENT MUST BE DESIGNED WITH PROTECTIVE INTERLOCK CIRCUITS TO MAKE PHYSICAL CONTACT WITH THESE VOLTAGES IMPOSSIBLE. SEE “OPERATING HAZARDS” SECTION.

Lethal Voltages up to 15,000 Volts are present in this amplifier when it is operating. USE EXTREME CAUTION when inside the unit.



Concluding Remarks and Q & A Session



- › Lower Total Cost of Ownership than Non Modular Architectures
- › Always “On Air” Architecture
- › Extreme Effective MTBF
- › Upgradable
- › Pulse Fidelity, Random Pulse Width and Duty Cycle, High PRF’s
- › Waveform Flexibility
- › Signal Processing Functions on the Roadmap
- › SWaP Better in Many Cases
- › Integration Features
- › Plus a Long List of Intangible Benefits



More Questions? Send them to Sales@EmpowerRF.com