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Transmission System - Total Cost of Ownership

presented by:

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PowerSmart™

INTRODUCTION

- High interest among broadcasters / RF network operators to reduce overall transmission facility cost of ownership
- Total Cost of Ownership (TCO) includes more than initial cost, energy cost, and maintenance of transmission equipment
- Acquisition, maintenance, operating, training costs of all required systems in transmission facility including cooling and floor space, must be considered to arrive at lowest TCO

TOPICS TO BE COVERED

- Definition of “Total Cost of Ownership” (TCO)
- All elements that determine the real, long term,“Total Cost of Ownership”
- Besides the reduction in direct operating costs, the benefits of reduced (TCO) include a reduction of carbon footprint in support of green technology.
- Comprehensive analysis is required including:
  - Trade off’s between air and liquid cooling systems
  - Impact on the overall facility, floor space requirements, size, and the thermal efficiency of the transmitter building
- New evaluation process / analysis tool to design transmission facility for lowest (TCO) (work in progress)
- Example of the findings from a real world, transmission site (TCO) analysis

WHAT IS TOTAL COST OF OWNERSHIP?

- Acquisition cost of transmission equipment
- Installation cost of transmission equipment
- Operating cost of transmission equipment
- Maintenance cost of transmission equipment

- Acquisition cost of facility cooling system (HVAC, etc.)
- Installation cost of facility cooling system (HVAC, etc.)
- Operating cost of facility cooling system (HVAC, etc.)
- Maintenance cost of facility cooling system (HVAC, etc.)
- Periodic replacement cost for facility cooling system (HVAC, etc.)

- Acquisition or recurring lease cost of floor space required
- Training costs

OTHER FACTORS AFFECTING TCO

- Average outside air temperature at facility location
- Cost of energy at facility location
- Size, construction, and thermal efficiency of facility

TRANSMITTER SELECTION IMPACT ON TCO

- Physical size and foot print (FT^2)
- Power density of transmitter (Watts / FT^3)
- Type of cooling – air or liquid
- Operating efficiency (AC to RF) of the transmitter
- AC power requirements – (1) phase or (3) phase
  (polyphase may be more expensive to bring to some sites)
- AC input voltage and voltage regulation requirements
- Maintainability – hot swappable modules, air or liquid filter replacement, and all other maintenance tasks
- Commonality of transmitter types – spares sharing, common training, and operational requirements
- N+1 transmitter system architecture can reduce number of backup transmitters required

TRANSMITTER SELECTION IMPACT ON TCO

- Choice between air or liquid cooling of transmission equipment makes a significant difference in TCO
- Initial purchase cost of liquid cooled transmitter is typically higher than an equivalent air cooled transmitter
- Elimination of most air conditioning costs make breakeven period short and provide significant long term operational savings
- Typical air conditioning units require ongoing maintenance and replacement on a 5 to 8 year cycle
- Liquid cooled transmitters have significantly lower energy consumption than combined energy consumption of air cooled transmitter and required air conditioning

TRANSMITTER EFFICIENCY OPTIMIZATION

- 50v LDMOS power amplifier technology
- 95% efficient power supplies
- Advanced Real Time Adaptive Correction (RTAC)
- Advanced Crest Factor Reduction
- Variable speed cooling system – air or liquid
- Sharing liquid cooling across multiple transmitters

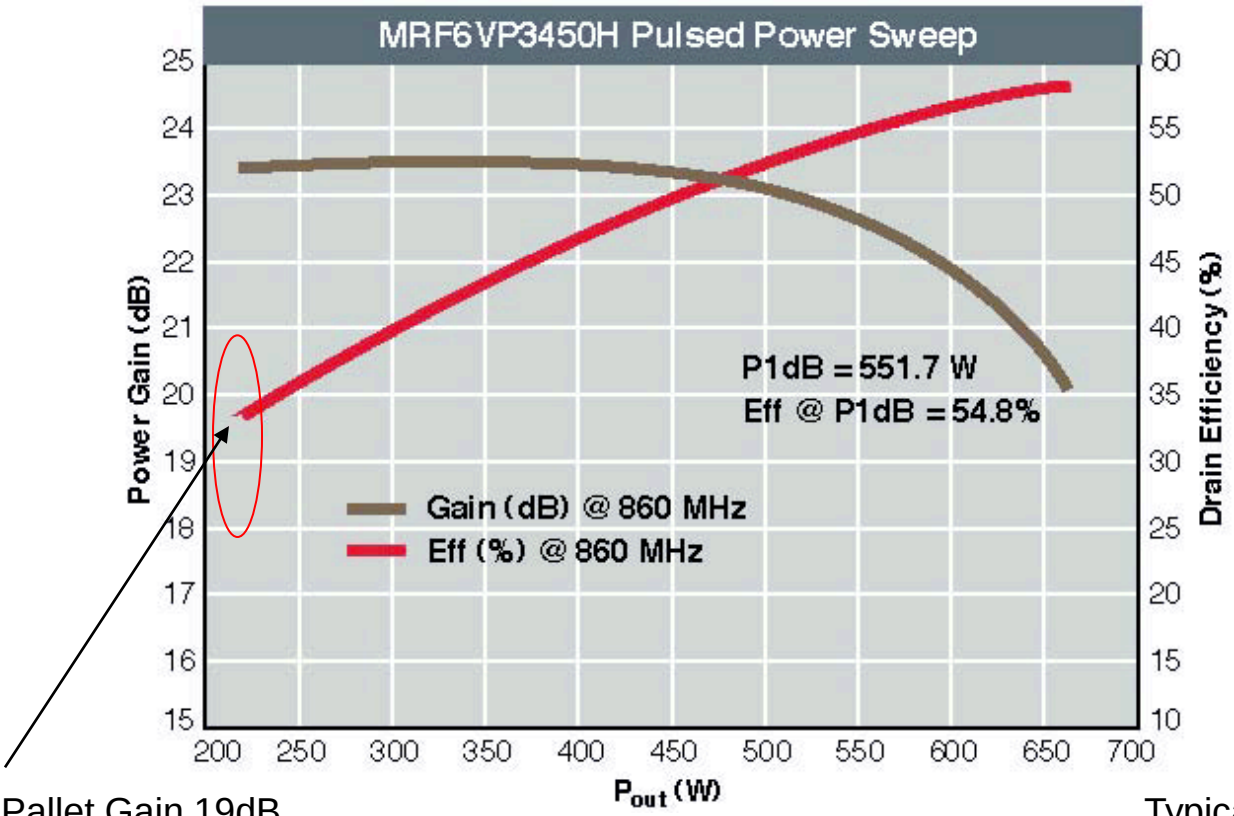
FET TECHNOLOGY COMPARISON

Attribute		Si VMOS	28V RF-LDMOS	50V RF-LDMOS
CW eff. at P1dB		3	5	5
Power Gain		3	5	5
Thermal resistance		3	4	5
CW Packaged Power Density		3	3	4
High Intrinsic Zin / Zout (wideband)		3	3	4
On-Die Passives Integration		2	4	4
Variability / Performance spread		2	4	4
Technology Maturity		5	5	4
Reliability		4	5	5

Comparison of RF Power Attributes vs. Technology

Red = Poor
Yellow = Neutral
Green = Strength
(Scale 1 to 5)

FET TECHNOLOGY COMPARISON



Practical Pallet Gain 19dB in digital DVB-T operation and 21dB in FM operation

Typical efficiency of over 28% in DVB-T operation and 84% in FM operation

* Ref. Freescale Semiconductor White Paper: "*50 Volt LDMOS – An Ideal RF Power Technology for ISM, Broadcast and Radar Applications*"

TCO ANALYSIS TOOL

- Harris has developed prototype tool to analyze and calculate TCO for a broadcast transmission facility
- Visited Riverview ATC site to test tool
- Consider all elements in power consumption budget
- Transmitter make / model
- Transmitter cooling – air vs. liquid
- Cooling system percent of total cost
- Transmitter percent of total cost
- Payback period (OPx vs. CAPx)

TCO ANALYSIS TOOL

Transmitter	Model		Total Transmitter Acquisition Cost	HVAC Acquisition Cost	HVAC Installation Cost	Annual HVAC Maintenance (Per Ton)	Heat Is Ducted?	HVAC SEER Level	Annual Rental Fee		Annual Preventative Maintenance No. of Visits	per visit Rate for Preventative Maintenance	First Year Training Cost
									Price:	Per:			
Maxiva ULX ATSC	ULX-2400ATi		$153,600.00	$500.00	$2,500.00	$150.00	No	12	$0.00	ft2	4	$400.00	$2,000.00
	Television	Installation	$22,400.00			$150 per ton is industry standard							
		Commisioning	$11,200.00										
		Unit Cost	$120,000.00										

Region	Country/State
USA	Texas
Price Per kW/h:	$0.065

Source - IEA "Electricity Information 2010"

Product Desription
Liquid-Cooled UHF Multimedia TV Transmitter

First Year TCO (includes acquistition costs & training)	Annual OPEX	Five Year TCO	Ten Year TCO	Fifteen Year TCO	Twenty Year TCO	Lifetime Total Cost of Ownership
$165,890.32	$7,290.32	$195,051.60	$231,503.21	$267,954.81	$304,406.41	

Transmitter	Model	TX Power Output Before Filter	TX Typical Power Consumption	Typical Efficiency	Model Specifications
Maxiva ULX ATSC	ULX-2400ATi	2,500 W	9,617 W	26.00%	

Total Heat Output	Heat Output Indoors	Annual Air Cooling Requirement (kW-Hr)	Total Cooling Needed (BTU/H)	Total Cooling Needed (Tons)	Annual HVAC Maintenance Costs	Annual Cooling Costs (100% AC)	Annual Cooling Costs (var. AC)	Air Cooling
0 W	0 W	0 kW-Hr	0.00	0.00	$0.00	$0.00	$0.00	

	Total Heat Output	Heat Output Indoors	Annual Cooling Requirement Liquid +HVAC	Annual Cooling Costs	Total Cooling Needed (BTU/H)	Total Cooling Needed (Tons)	Annual HVAC Maintenance Costs	Liquid Cooling
4	7,117 W	550 W	3,210 kW-Hr	$207.98	1,876.68	0.16	$23.46	

Annual Total Electrical Usage	Annual Carbon Emissions (tons)	How Many Cars on the Road	Annual Transmitter Consumption Cost	Annual Electricity Costs (100% AC)	Annual Electricity Costs (var. AC)	Consumption
87,452 kW-Hr	52.47	9.9	$5,458.88	$5,666.86	$5,458.88	

Height (RU)		Height	Width	Depth	Volume (m^3/ft^3)	Efficient Volume (m^3/ft^3)	Power Density (KW per m^3/ft^3)	Footprint (m^2/ft^2)	Dimensions
450.3	cm	2004.0	648.0	1194.0	1550.52	403.08	0.00	77.37	
	in	1145.1	370.3	682.3	167424.6	43524.58	0.00	1754.45	

MTBF	Rental Costs	Annual Service & Maintenance Costs	Service
125548	$0.00	$1,600.00	

TCO COMPARISON TOOL

	Harris #1	Harris #2	Competitor A	Competitor B
	Transmitter	Transmitter	RF Output Before Filter	RF Output Before Filter
	Maxiva UAX Digital	Maxiva ULX ATSC	2,500 W	2,500 W
	Model	Model	Power Consumption	Power Consumption
	UAX-2000	ULX-2400ATi	13,820 W	14,000 W
Transmitter Installed Cost	$135,000.00	$155,600.00	$130,000.00	$125,000.00
HVAC Acquisition Cost	$5,200.00	$500.00	$3,657.71	$3,715.87
HVAC Install Cost	$7,500.00	$2,500.00	$7,500.00	$7,500.00
Heat Ducted?	No	No	No	No
Cooling Method?	Air	Liquid	Air	Air
Annual Rental cost	$0.00	$0.00	$0.00	$0.00
Annual TX Maintenance Cost	$1,600.00	$1,600.00	$1,600.00	$1,600.00
Annual HVAC Maintenance per ton	$150.00	$150.00	$150.00	$150.00

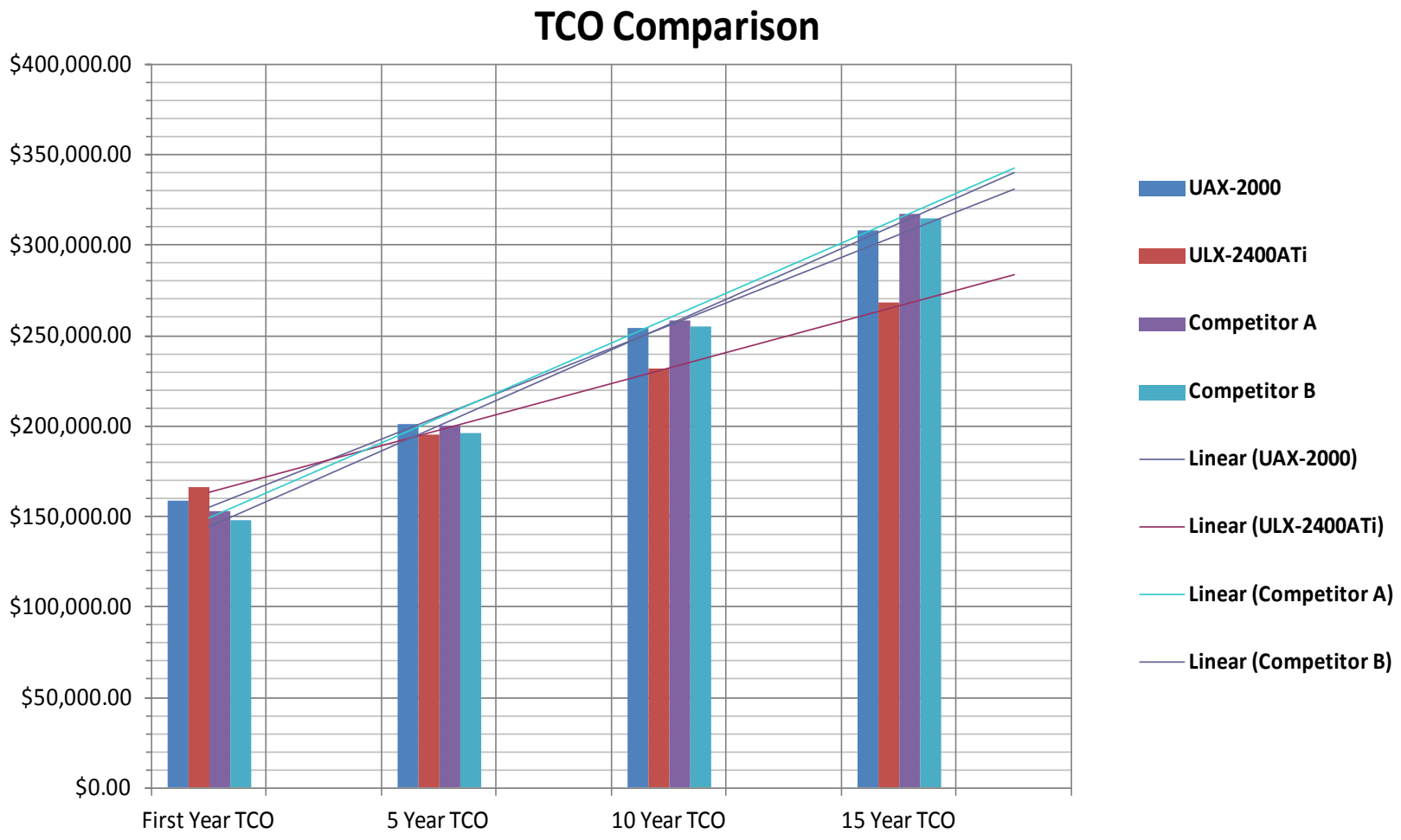
$150 per ton is industry standard

KWH Price:	$0.065
SEER Level	12

TCO COMPARISON TOOL

	Harris	Harris	Competitor A	Competitor B
RF Output Before Filter	2,500 W	2,500 W	2,500 W	2,500 W
TX Power Consumption	12,437 W	9,617 W	13,820 W	14,000 W
Annual Transmitter Consumption	108,948 kW-Hr	84,242 kW-Hr	121,063 kW-Hr	122,640 kW-Hr
Efficiency	20.1%	26.0%	18.1%	17.9%
Cooling Method	Air	Liquid	Air	Air
Ducted Heat Output	0 W	0 W	0 W	0 W
Heat Output Indoors	9,937 W	550 W	11,320 W	11,500 W
Liquid Cooling	0 kW-Hr	1,840 kW-Hr	0 kW-Hr	0 kW-Hr
# of PA	0	4	0	0
Air Cooling	24,752 kW-Hr	1,370 kW-Hr	28,197 kW-Hr	28,645 kW-Hr
Btu/H	33906	1877	38625	39240
Tons	2.83	0.16	3.22	3.27
HVAC Maintenance	$423.83	$23.46	$482.82	$490.50
Annual Cooling	24,752 kW-Hr	3,210 kW-Hr	28,197 kW-Hr	28,645 kW-Hr
Total Annual Power Consumption	133,700 kW-Hr	87,452 kW-Hr	149,260 kW-Hr	151,285 kW-Hr
Annual Cooling Costs	$1,603.91	$207.98	$1,827.14	$1,856.19
Carbon Emissions (Tons)	80.22	52.47	89.56	90.77
Annual Transmitter Consumption Costs	$7,059.84	$5,458.88	$7,844.90	$7,947.07
Annual OPEX	$10,687.58	$7,290.32	$11,754.85	$11,893.76
First Year TCO	$158,387.58	$165,890.32	$152,912.56	$148,109.63
5 Year TCO	$201,137.90	$195,051.60	$199,931.97	$195,684.67
10 Year TCO	$254,575.80	$231,503.21	$258,706.23	$255,153.46
15 Year TCO	$308,013.70	$267,954.81	$317,480.49	$314,622.26

TCO COMPARISON TOOL



HVAC – AIR COOLED TRANSMITTER

- Pros
  - Familiar technology
  - Simplicity - No concern about liquid spills

- Cons
  - Higher initial cost of A/C equipment
  - Higher total energy cost
  - Higher maintenance cost
  - High replacement cost of A/C equipment – shorter life cycle

LIQUID COOLED TRANSMITTER

- Pros
  - Lower overall energy cost
  - Less floor space – higher power density
  - Lower initial cost of heat exchanger – no duct work
  - Lower maintenance cost – no air filters to clean
  - Less frequent replacement cost – longer life cycle
  - Much lower noise level
  - Ratio of heat transported by liquid vs. heat liberated into air
  - Can be integrated into facility cooling loop or geothermal cooling loop
  - Highly evolved and desired in DTV installations

- Cons
  - Less familiar technology to radio broadcasters
  - Higher initial cost of transmitter – quickly offset by power savings
  - Concern about liquid spills – unlikely with new technology

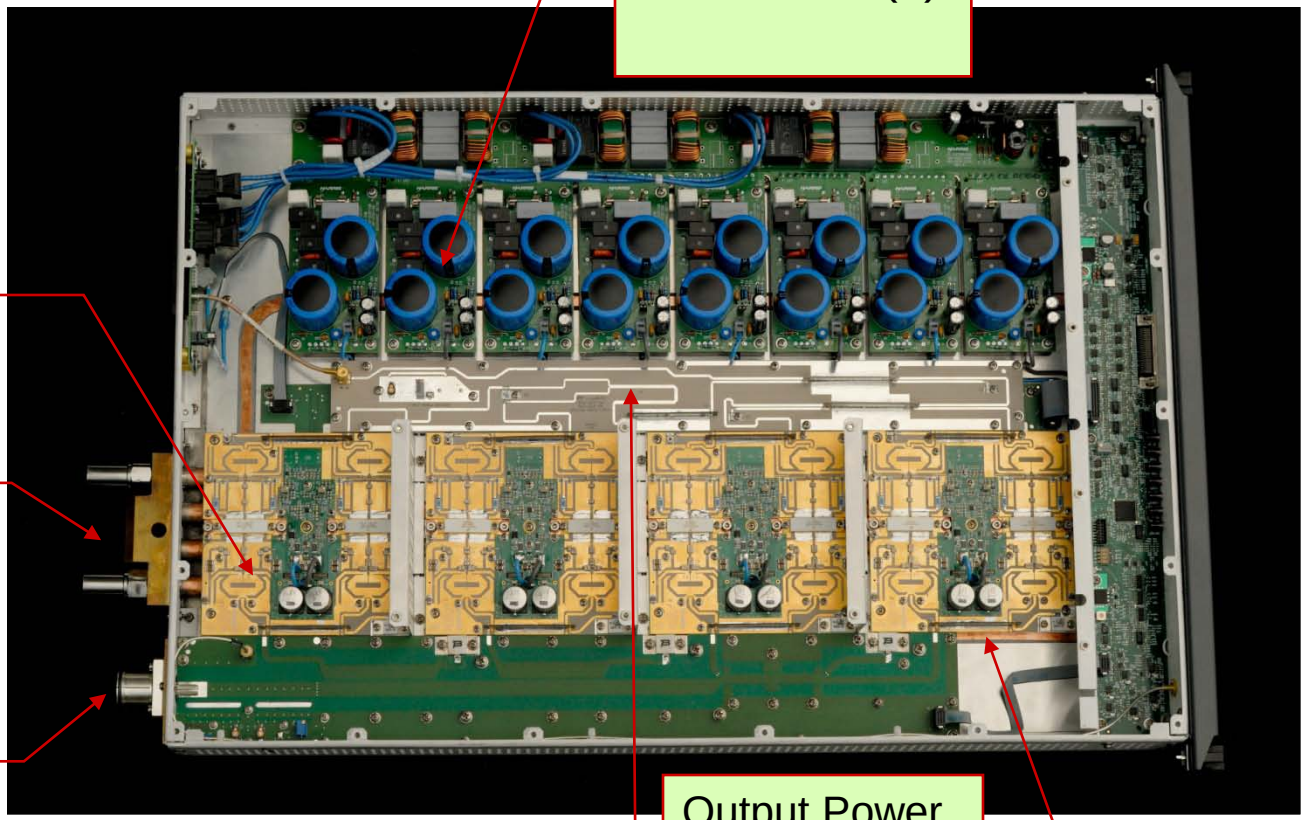
LIQUID COOLED UHF PA MODULE

Module weight < 20kg

RF Pallets (4)

Coolant blind mate connectors

Output RF Connector



AC-DC Converters (8)

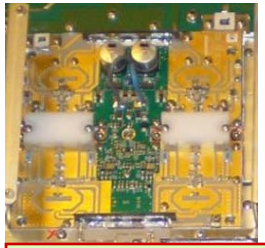
Output Power Combiner

Cold Plate

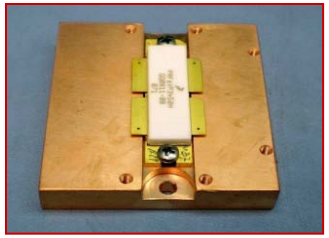
MAXIVA LIQUID COOLED UHF PA MODULE

User replaceable sub-assemblies shown

AC-DC Converter Module



RF Pallet

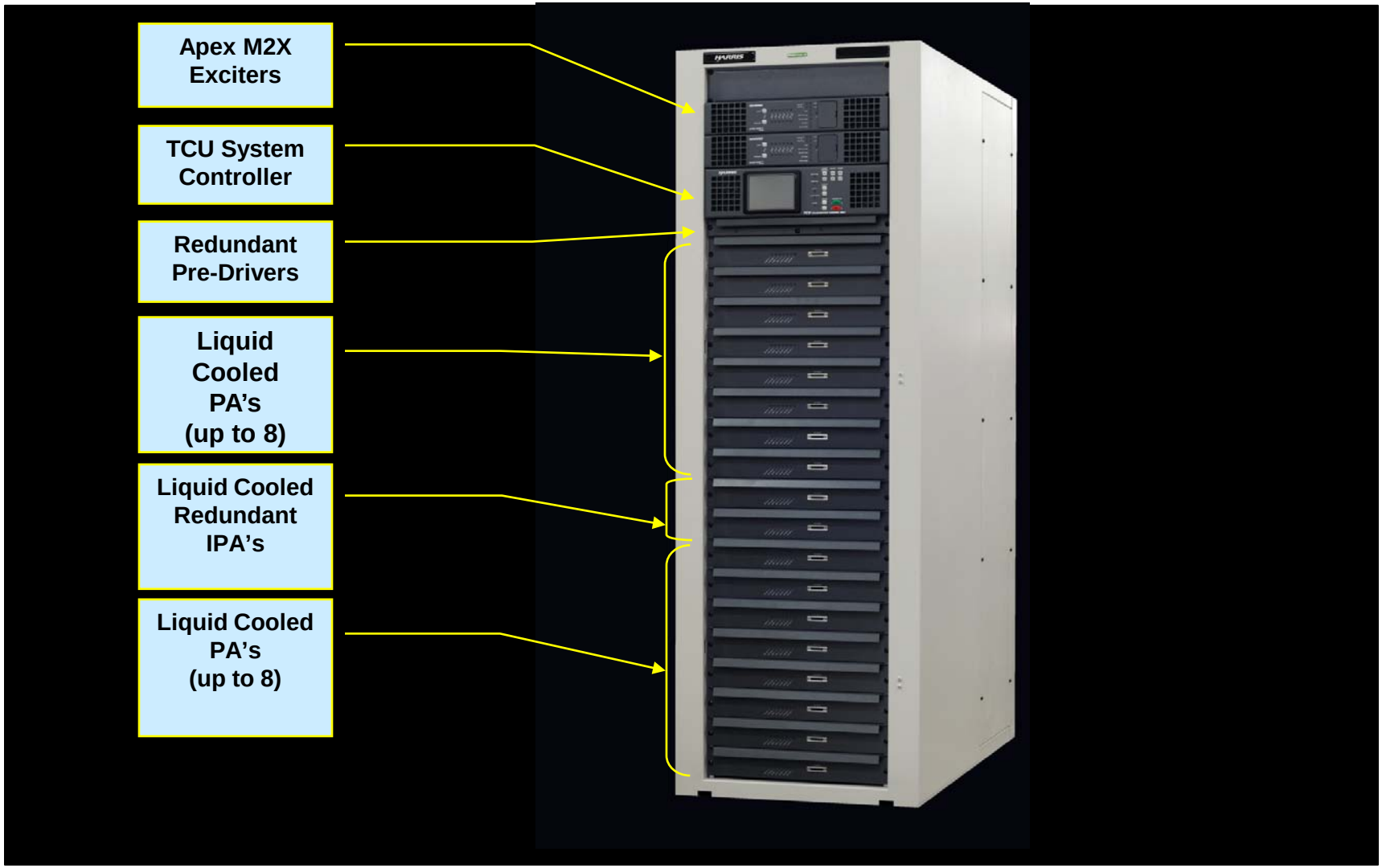


50V LDMOS Device with Heat Spreader

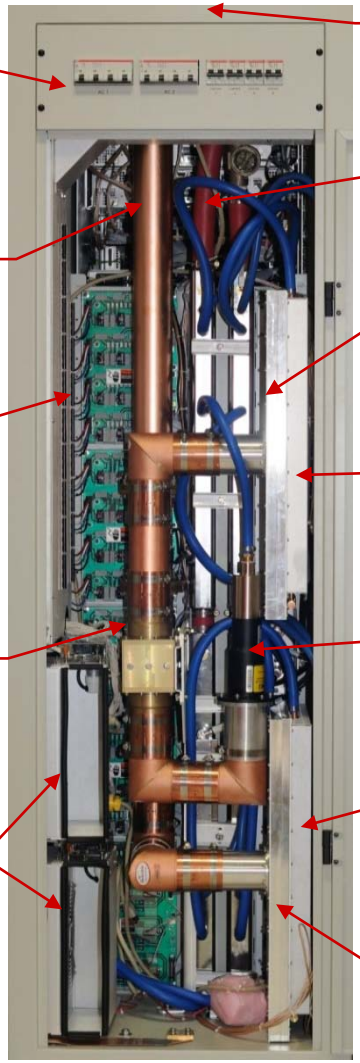
Diagnostic Port

Status LED's

MAXIVA ULX – FRONT VIEW



MAXIVA ULX – REAR VIEW



AC Distribution

RF Output Feeder

PA Circuit Breakers

2-Way Output Combiner

Redundant Cabinet Blowers (2)

I/O Panel (on top)

Coolant In/Out Hoses

Liquid Cooled Upper 8-way Combiner

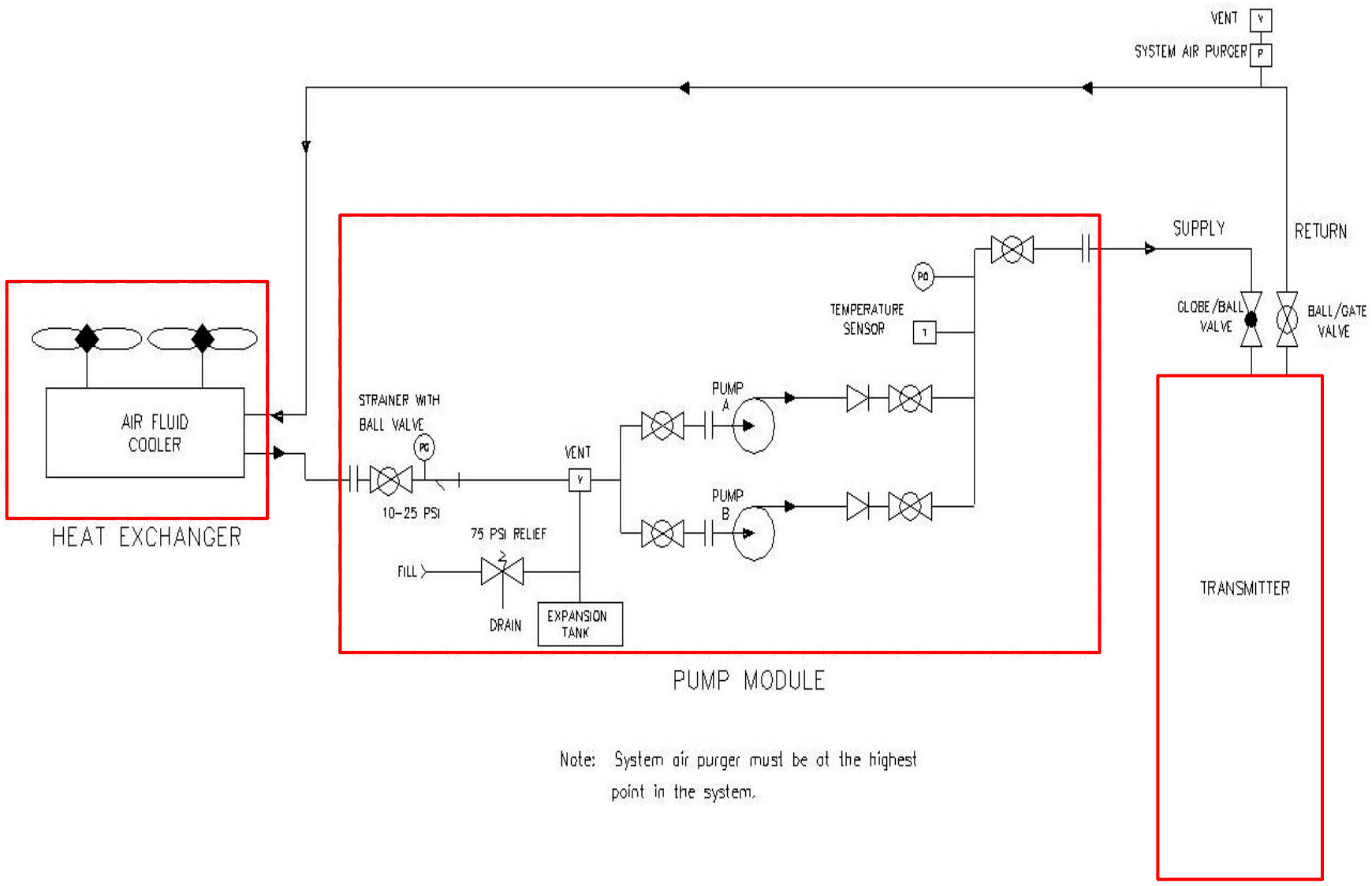
Liquid Cooled Upper 8-way Power Divider

Liquid Cooled Final Reject Load

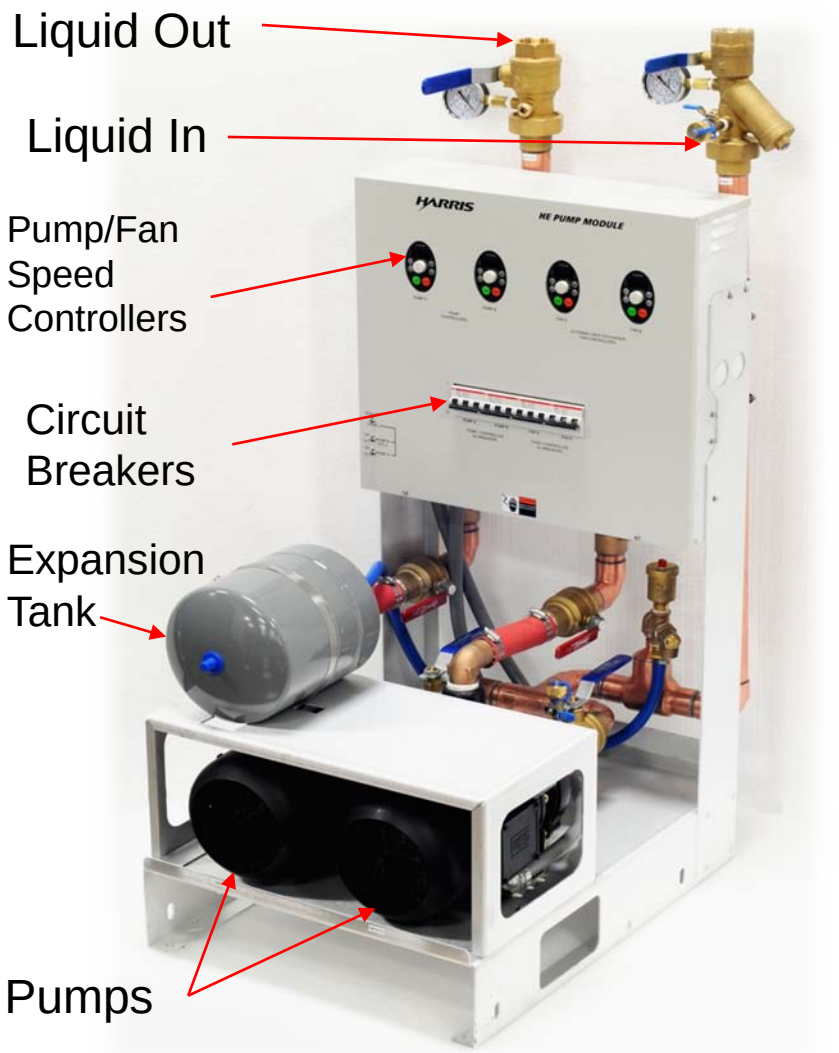
Liquid Cooled Lower 8-way Power Divider

Liquid Cooled Lower 8-way Combiner

COOLING SYSTEM BLOCK DIAGRAM



HIGH EFFICIENCY PUMP MODULE



LIQUID TO AIR HEAT EXCHANGER

- Compact size (Two sizes available, Tx dependent)
- Two Configurations – Horizontal or Vertical airflow
- Redundant variable speed fans

(50kW Dissipation unit shown, 12kW system is smaller)

Overall Dimensions:
1,989 mm Long
895 mm Wide
938 mm High

Overall Dimensions:
1,989 mm L
540 mm W
940 mm H

TCO - OPTIMIZATION SUMMARY

- Selection of transmission equipment
- Consider all acquisition, operating and maintenance costs
- Consider all elements in power consumption budget
- Cooling technology used in transmitter has large impact on TCO
- Volume and floor space of transmission equipment affects TCO
- Building efficiency

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Questions ?

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