
Google
Search, or say Google
Pacifica Airlines flight 2340
Status: Delayed
Depart San Francisco
SFO 7:09pm
Terminal 4, Gate A3
Arrive Taipei
TPE 10:32pm
Terminal 2, Gate 50
Navigate to SFO / 34 min
Showtimes today
Smart Shoot
People
Nokia City Len
9:41 AM
Messages
Calendar
Photos
Camera
Videos
Maps
Weather
Passbook
Notes
Reminders
Clock
Stocks
Newsstand
iTunes
App Store
Game Center
Settings
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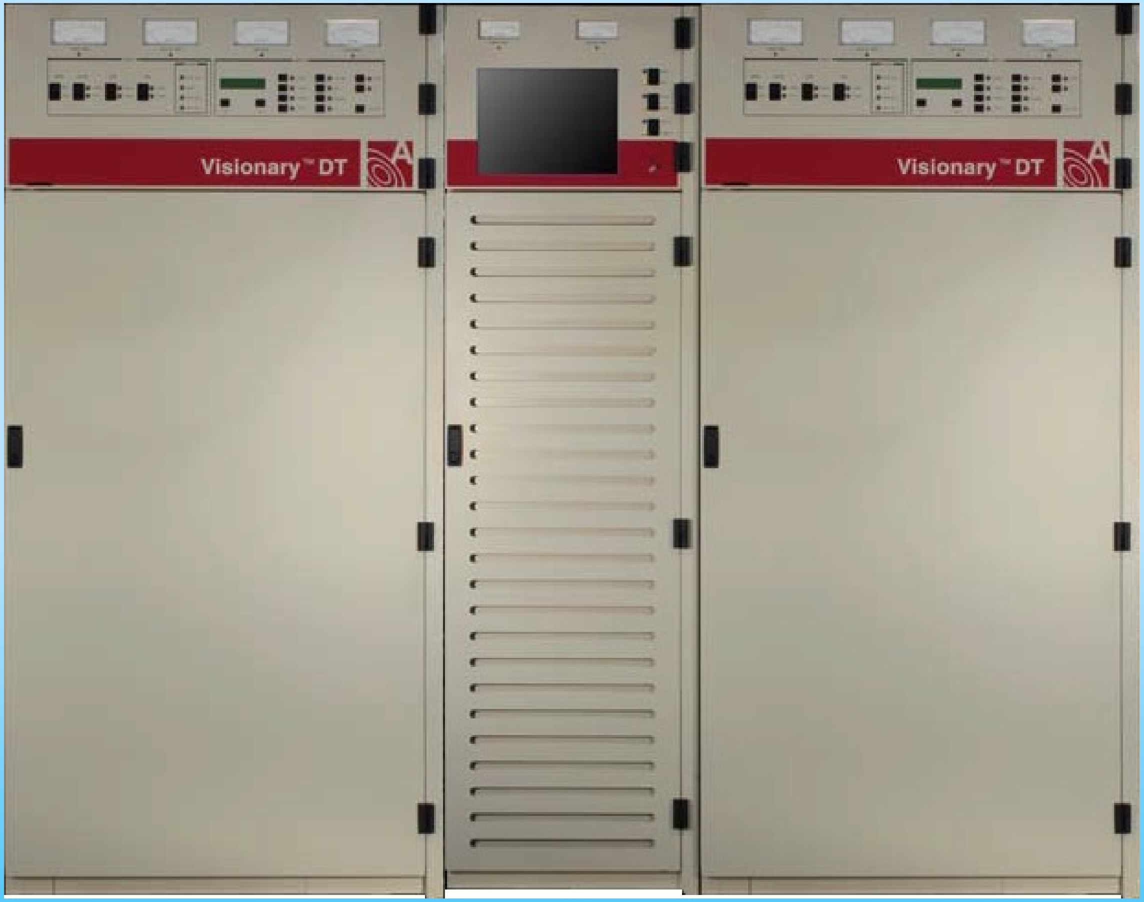

Visionary™ DT
Visionary™ DT

Key Points

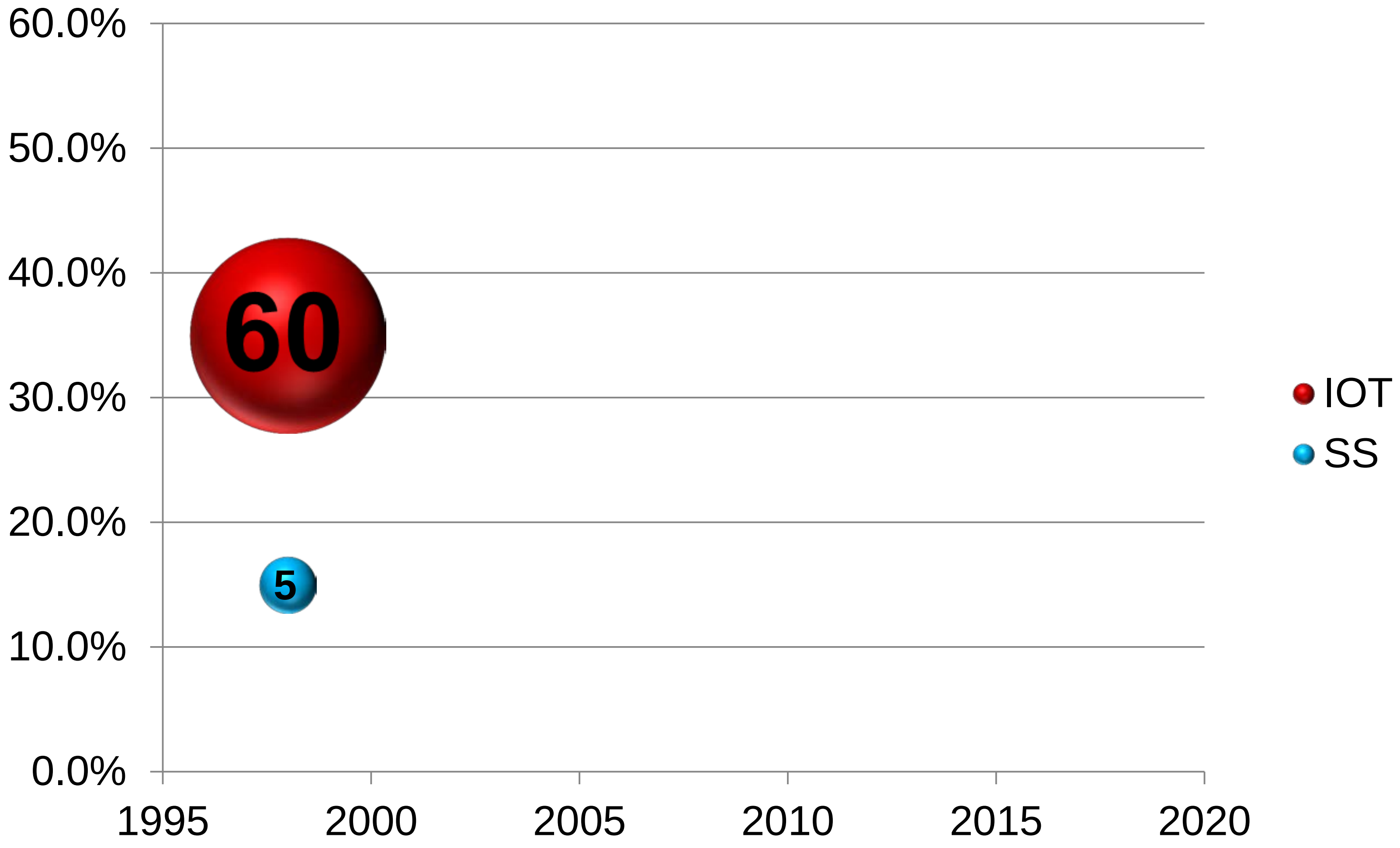
Power

Performance

Payback

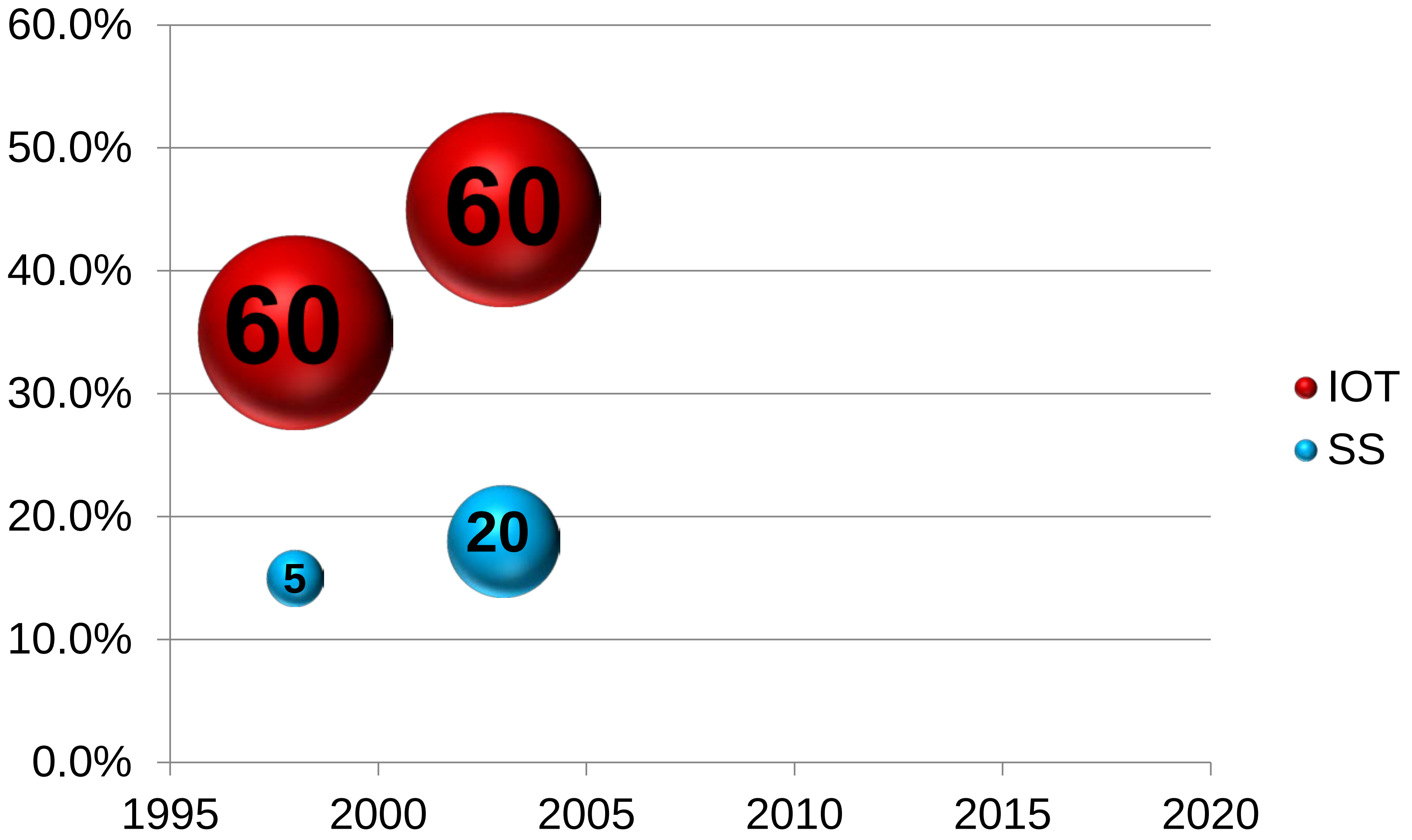
ROHDE&SCHWARZ

1998 – Beginning of DTV Transition

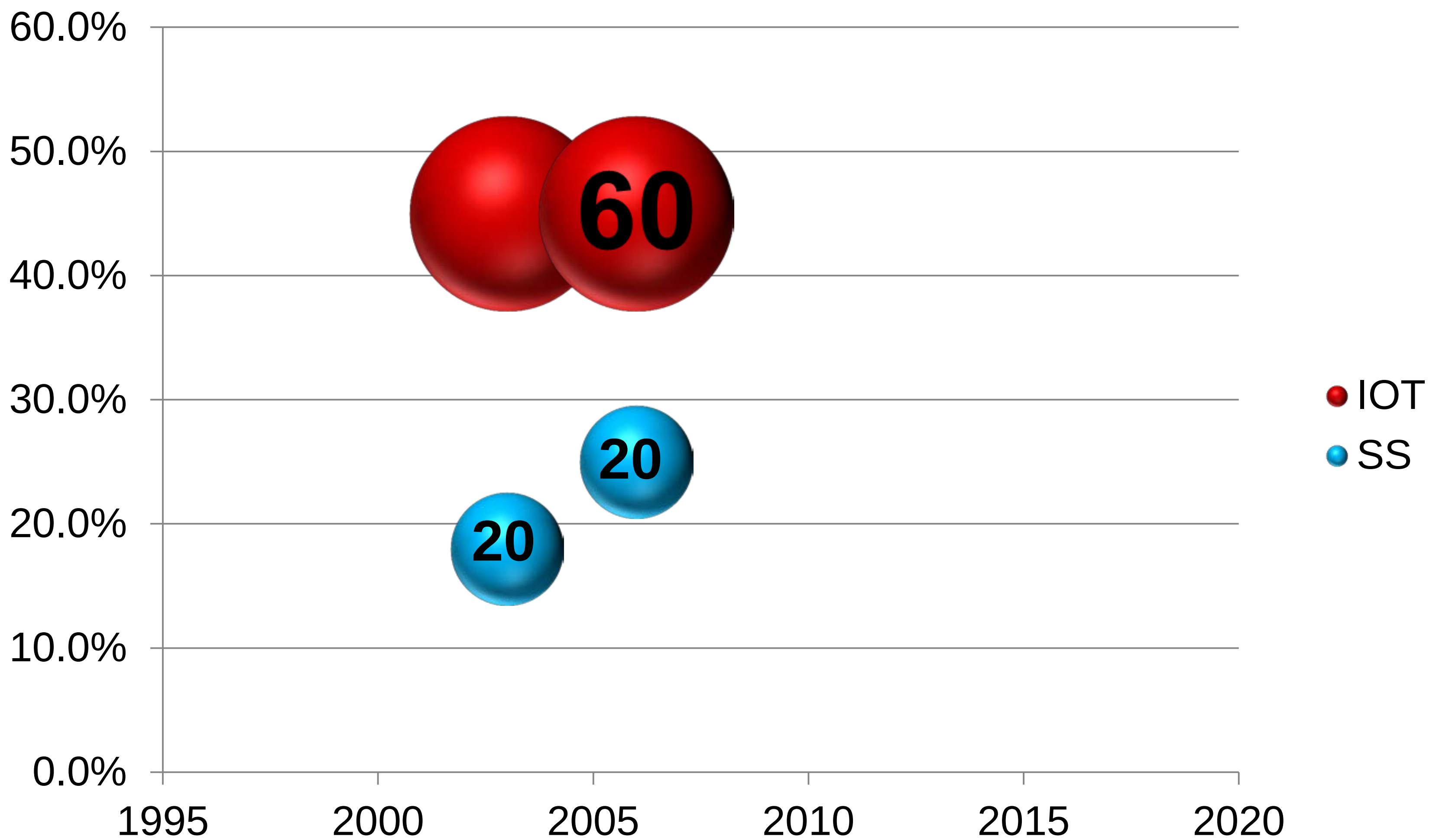


ROHDE&SCHWARZ

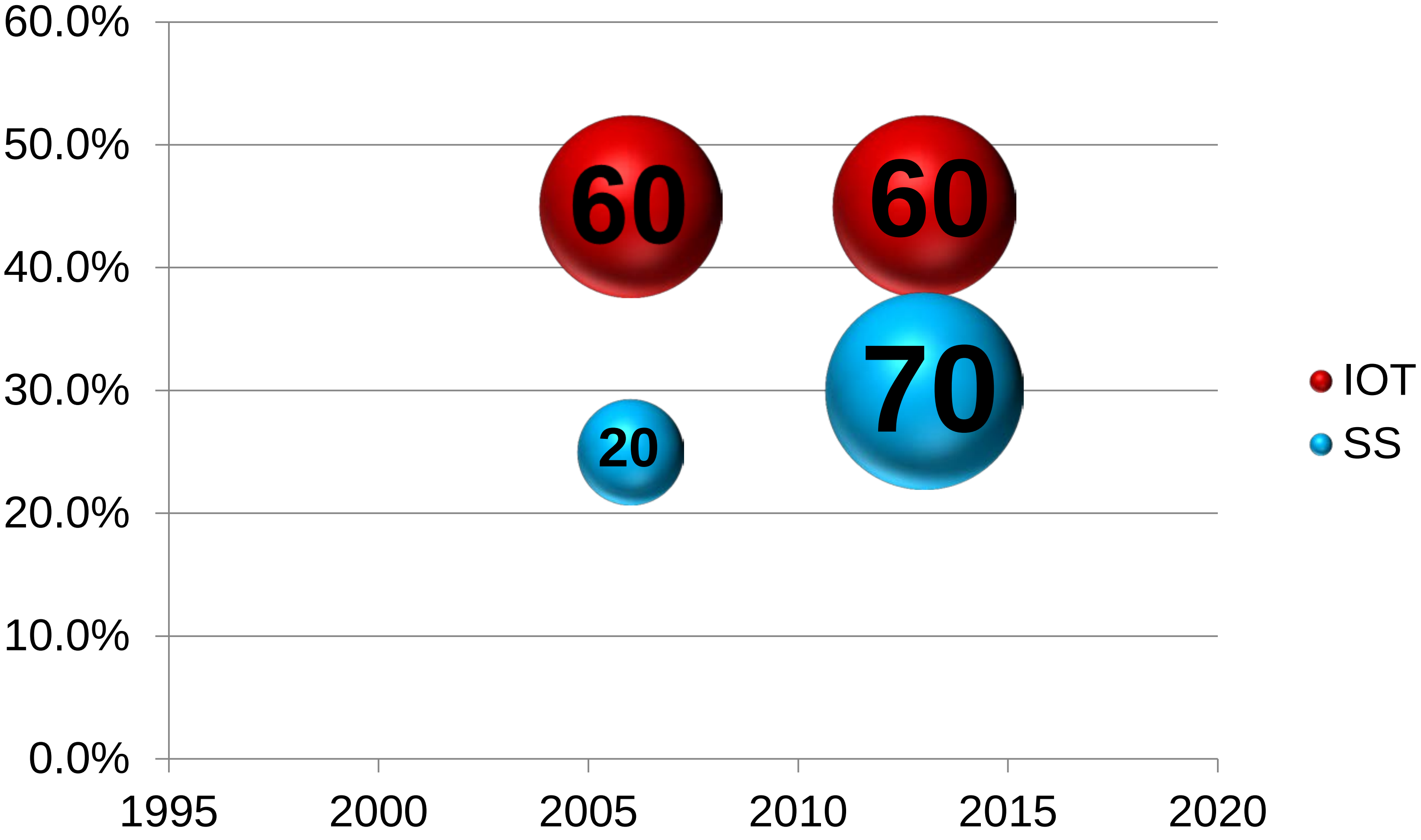
2003 – Increased SS Power & IOT Efficiency



2006 – Increased SS Efficiency due to Design



2013 – Improved Design and Transistors



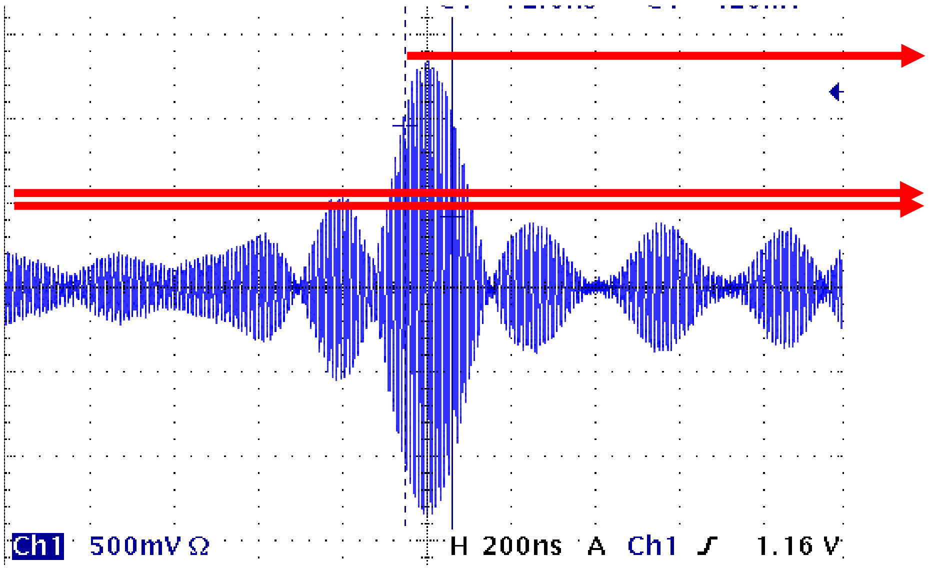
Key Points

Power ✓

Performance

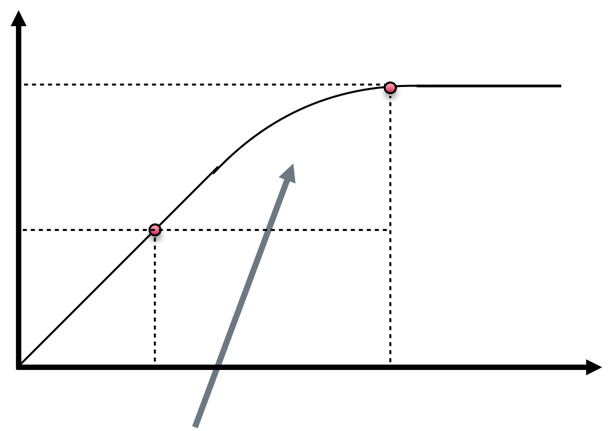
Efficiency Enhancement technologies

Basics for amplifying ATSC signals



High peaks

Average power – 78% efficiency

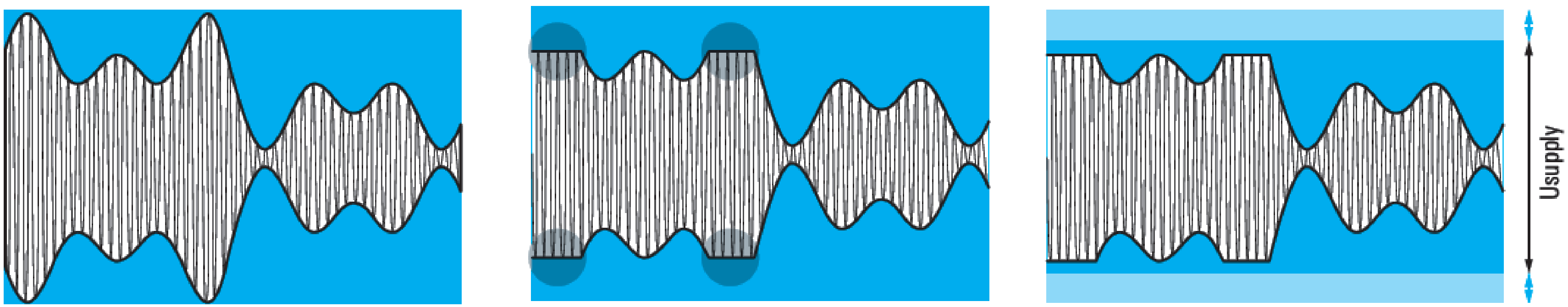


$$\textbf{Crest Factor} = \frac{\text{Peak value}}{\text{Ave value}}$$

Signal manipulation
Crest factor reduction

- Reduce Crest Factor without reducing signal quality

Without CFR | With CFR | Lower supply voltage

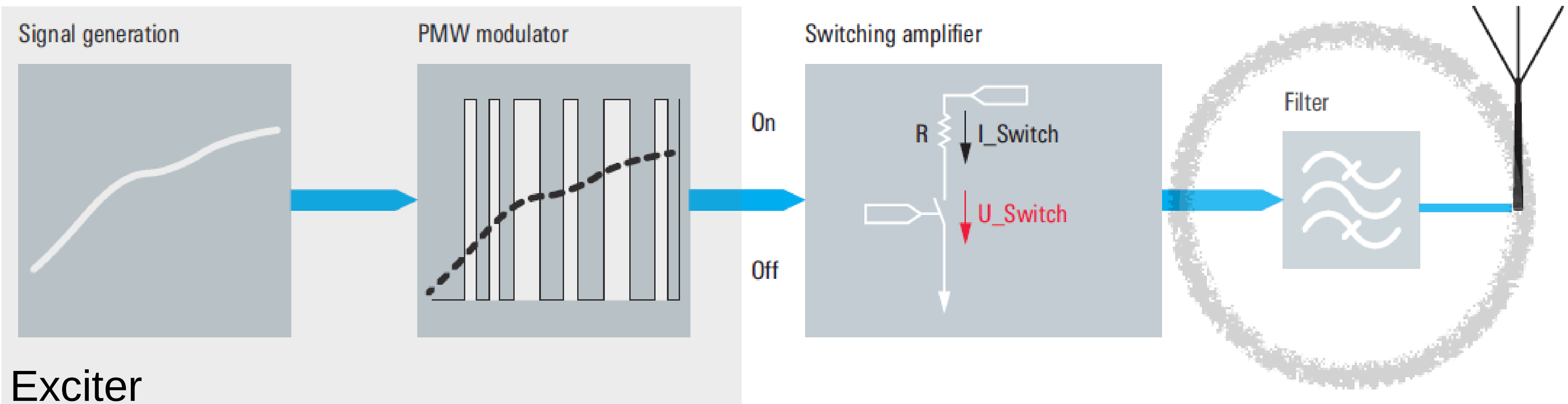


Crest Factor Reduction, e.g. R&S method for all OFDM standards

Wasted energy

Power Supply Manipulation
Switched mode power amplification SMPA

- Transistors work in switched mode: 100 % ON or 100 % OFF
- Amplitude modulated signal is transferred to pulse width modulation

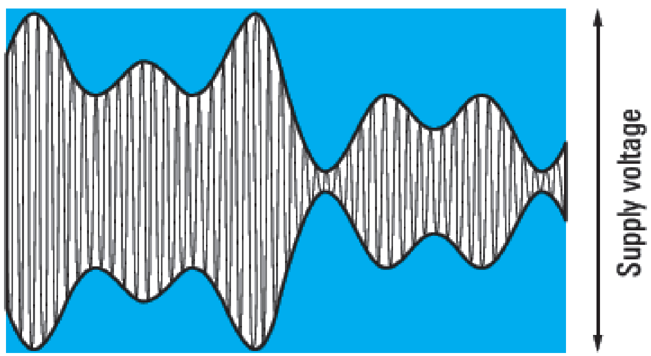


- Requires specific development in exciter and amplifier
- Requires specific transistors

Power supply manipulation
Envelope tracking

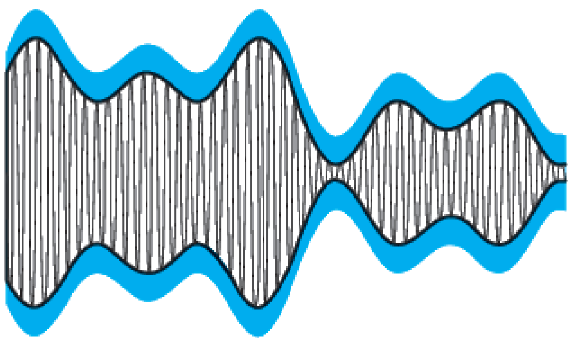
- Modulate supply voltage of transistors with signal envelope

w/o ET



Static Supply voltage

with ET

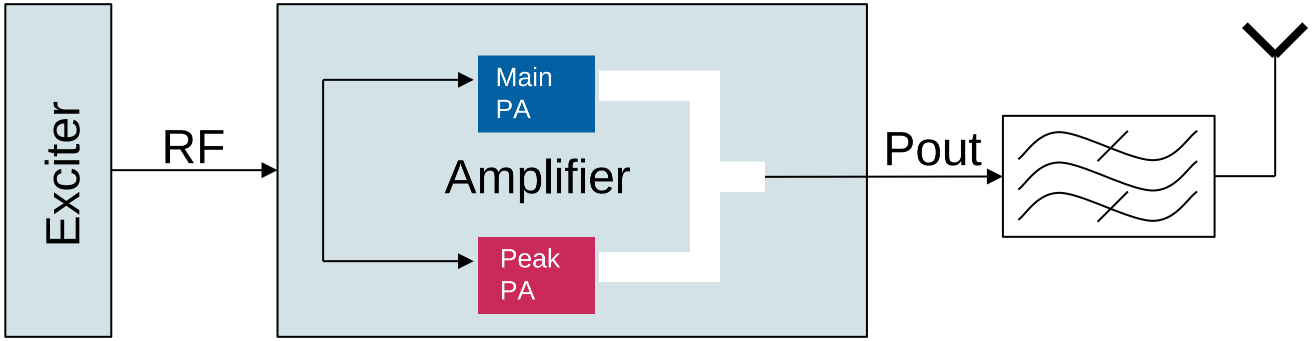


Dynamic Supply voltage

Wasted energy  Envelope

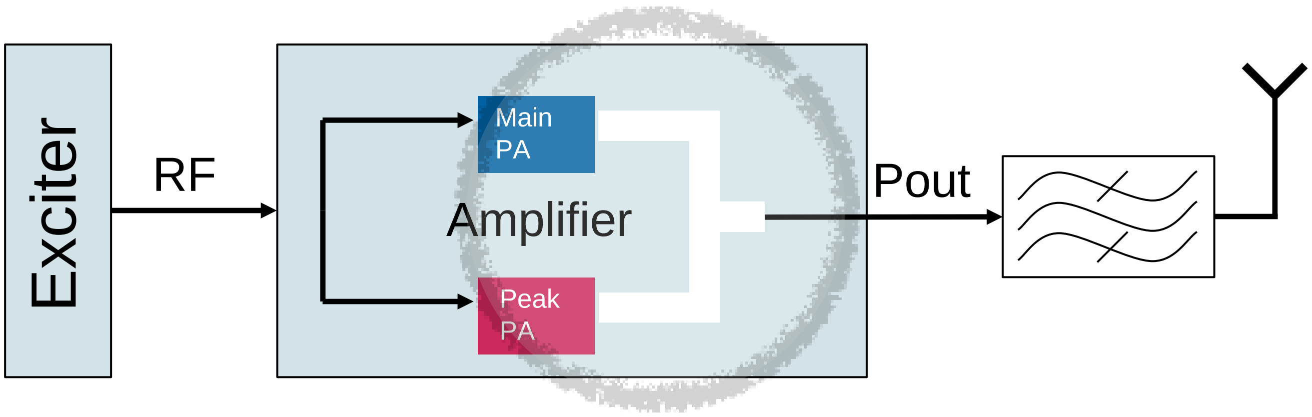
Amplifier manipulation
Doherty amplifier

- **Amplification for main and peak signals is separated**
  - Main amplifier amplifies average signals (class A/B)
  - Peak amplifier amplifies peak signals (class C)
  - ➉ lower headroom in main amplifier required
  - ➉ No energy required in peak amplifier as long no peaks are in the signal



Amplifier manipulation
Doherty amplifier

- **Main and peak signals are amplified separately**
  - This has historically required in a narrow band design



Amplifier manipulation
Doherty amplifier

Pro's

- **Proven technology**
- **Low complexity**
- **Transistors available**
- **High return, +10-15%**

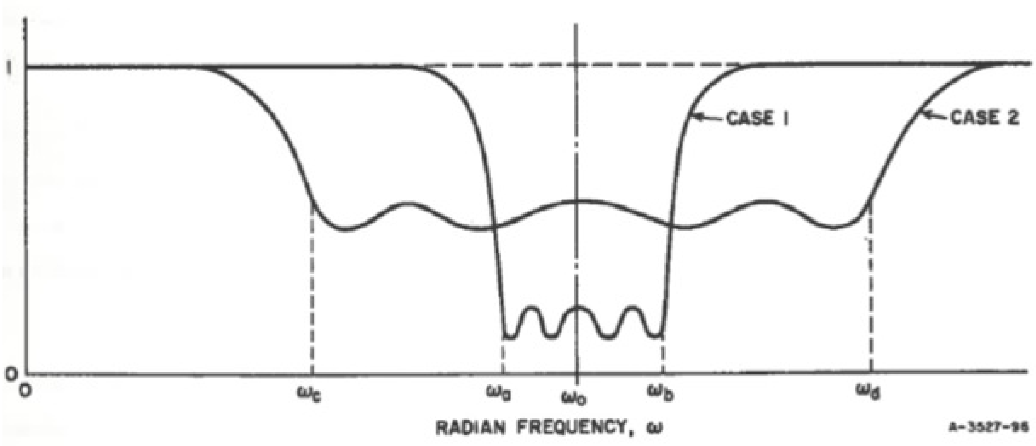
Con's

- **Narrow band design required for highest efficiency return**

Doherty Amplifier
Why is it narrowband?

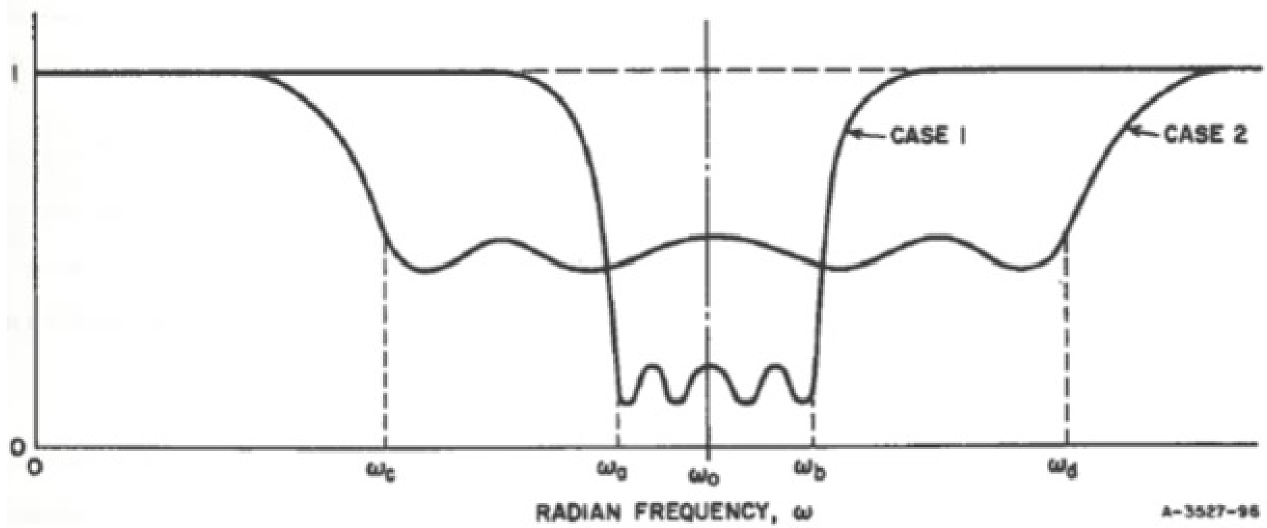
- **It all boils down to the fundamental limits of the match bandwidth as defined by the Bode Fano Limit**

$$\int_{\omega_u}^{\omega_o} ln\left|\frac{1}{r}\right| d\omega = \frac{\pi}{RC}$$



Doherty Amplifier
Why is it narrowband?

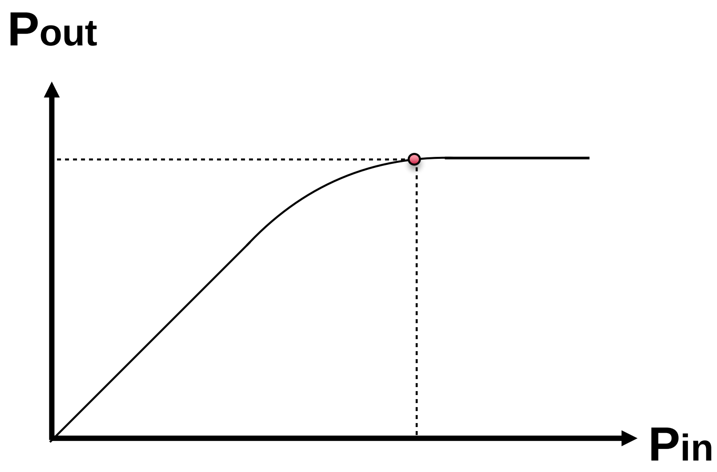
- **For brilliant efficiency you need brilliant matching**
- **Broadband design means worse matching, and less efficiency**



- **A narrow band design gives you brilliant matching therefore brilliant efficiency**

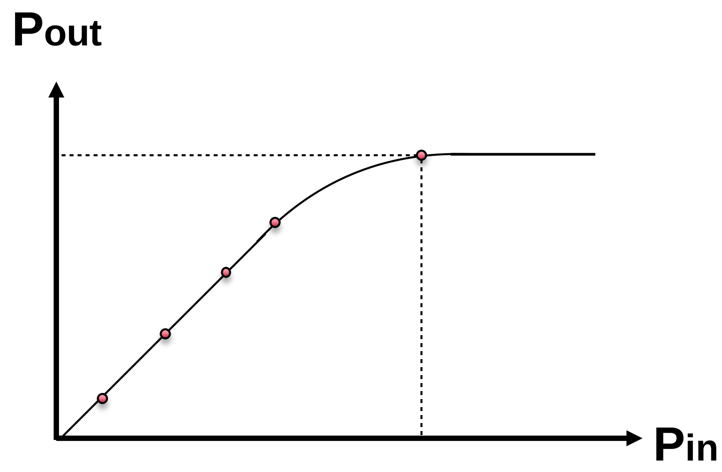
Doherty Amplifier
Why is it narrowband?

- **The best efficiency is achieved when the transistor is in saturation, or at its peak power.**



Doherty Amplifier
How do we achieve high efficiency?

- **This requires as close to a constant load impedance as possible (matching network)**
- **But.... the input power continuously changes**
- **So.... the best efficiency can't be achieved over a wide modulation range with a constant load impedance**



Doherty Amplifier
How can we maintain high efficiency?

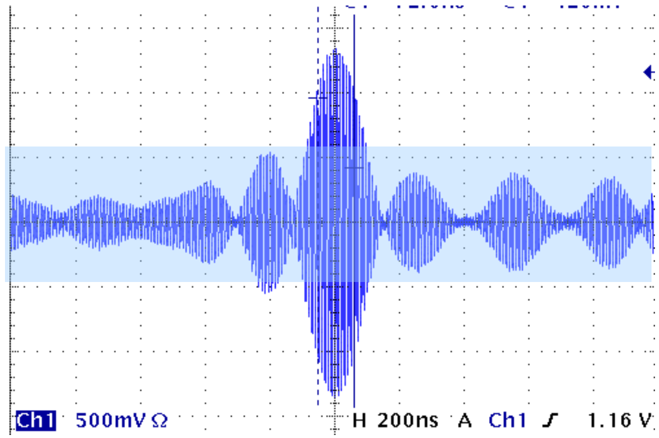
- **Since the compression point is in inverse proportion to the impedance**

$$P = \frac{V_d^{\,2}}{2 \cdot R_L}$$

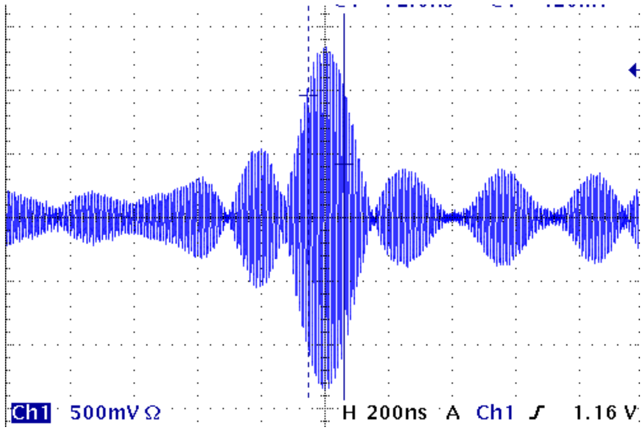
50 Ohm → 100W
100 Ohm→ 50W

- **The solution to this is to dynamically adjust the impedance of the load of the low power amplifier**
- **This is called load impedance modulation or "load pull"**

Doherty Amplifier
How does load pull work



Amp ON

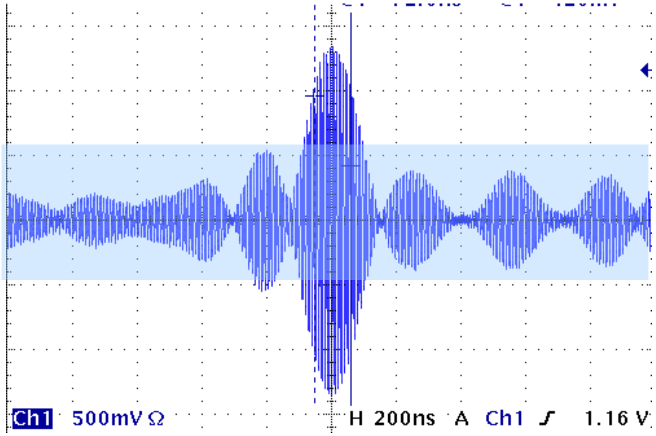


Main amplifier - lower headroom required

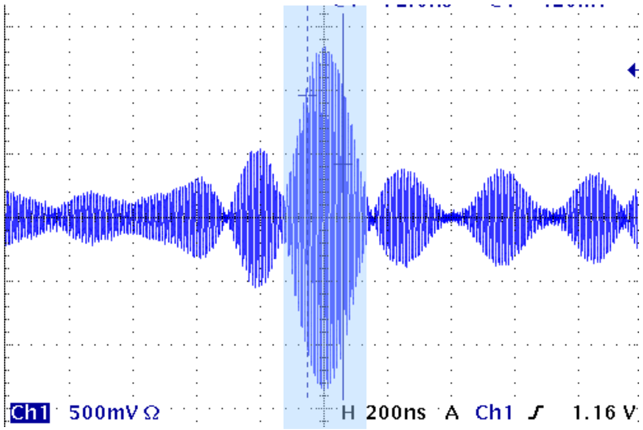
Peak amplifier – works only for signal peaks

- **Low power signal - power below -6db**
- **Main transmitter has a load of 2 x RL and reaches saturation**
- **The peak transistor is off**

Doherty Amplifier
How does load pull work



Amp ON

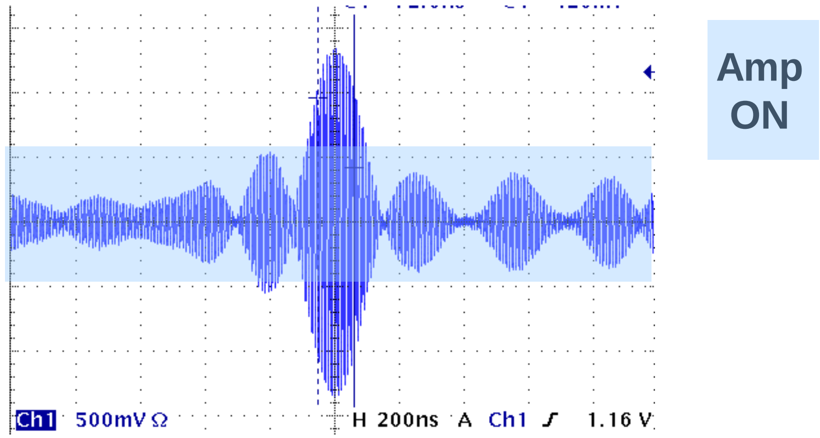


Main amplifier - lower headroom required

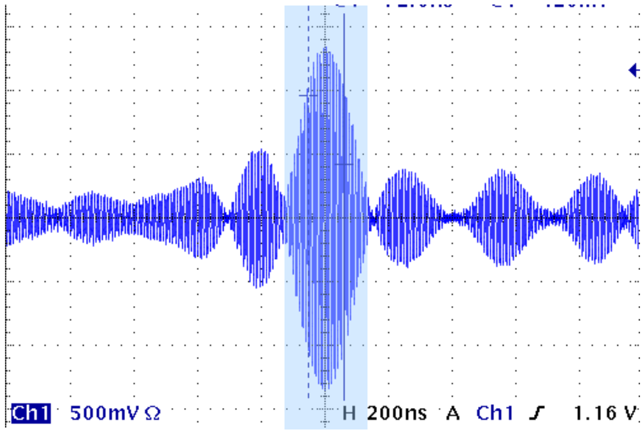
Peak amplifier – works only for signal peaks

- **Signal reaches -6db of peak - peak amplifier turns on**
- **Its current reduces the load impedance of the main amp**
- **The power of the main and peak amplifiers are combined**

Doherty Amplifier
How does load pull work



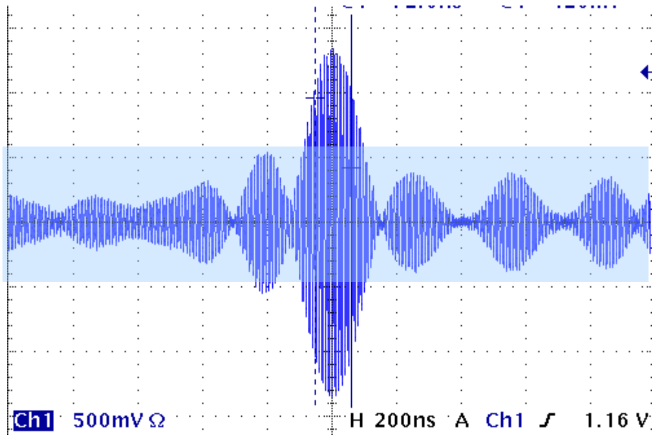
Main amplifier - lower headroom required



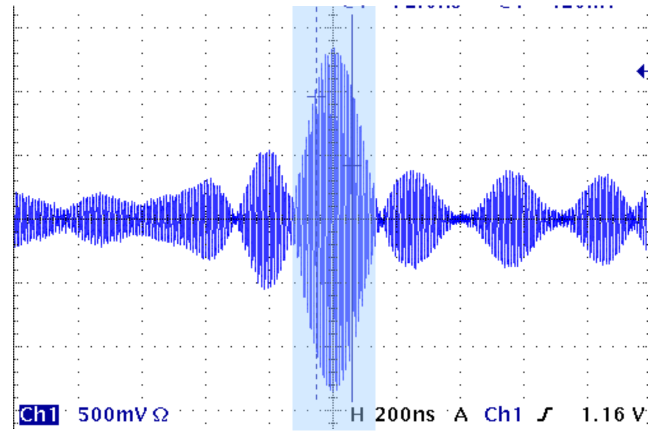
Peak amplifier – works only for signal peaks

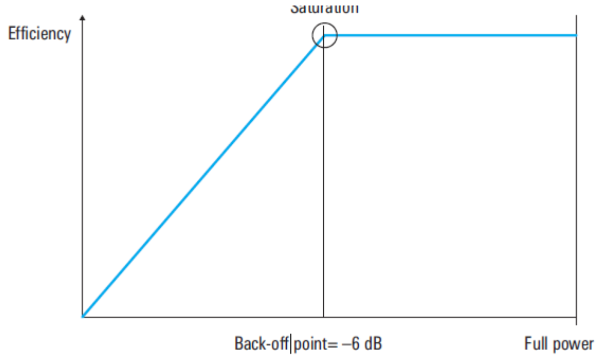
- **Signal reaches 0db, or max power**
- **Main and peak amplifiers each deliver half of full power**
- **Both amplifiers operate at optimum efficiency at 50 ohm**

Doherty Amplifier
Doherty combiner



Amp ON





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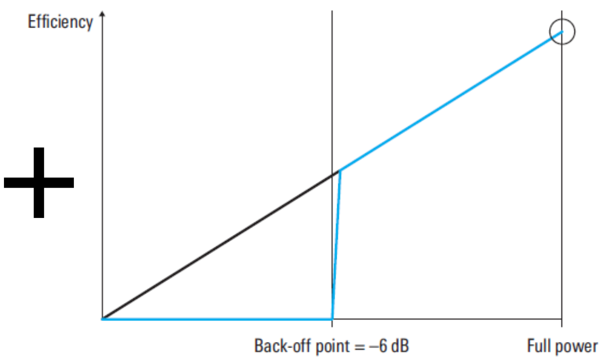

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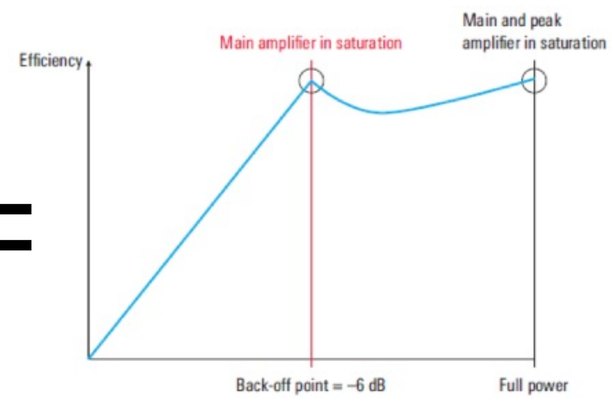
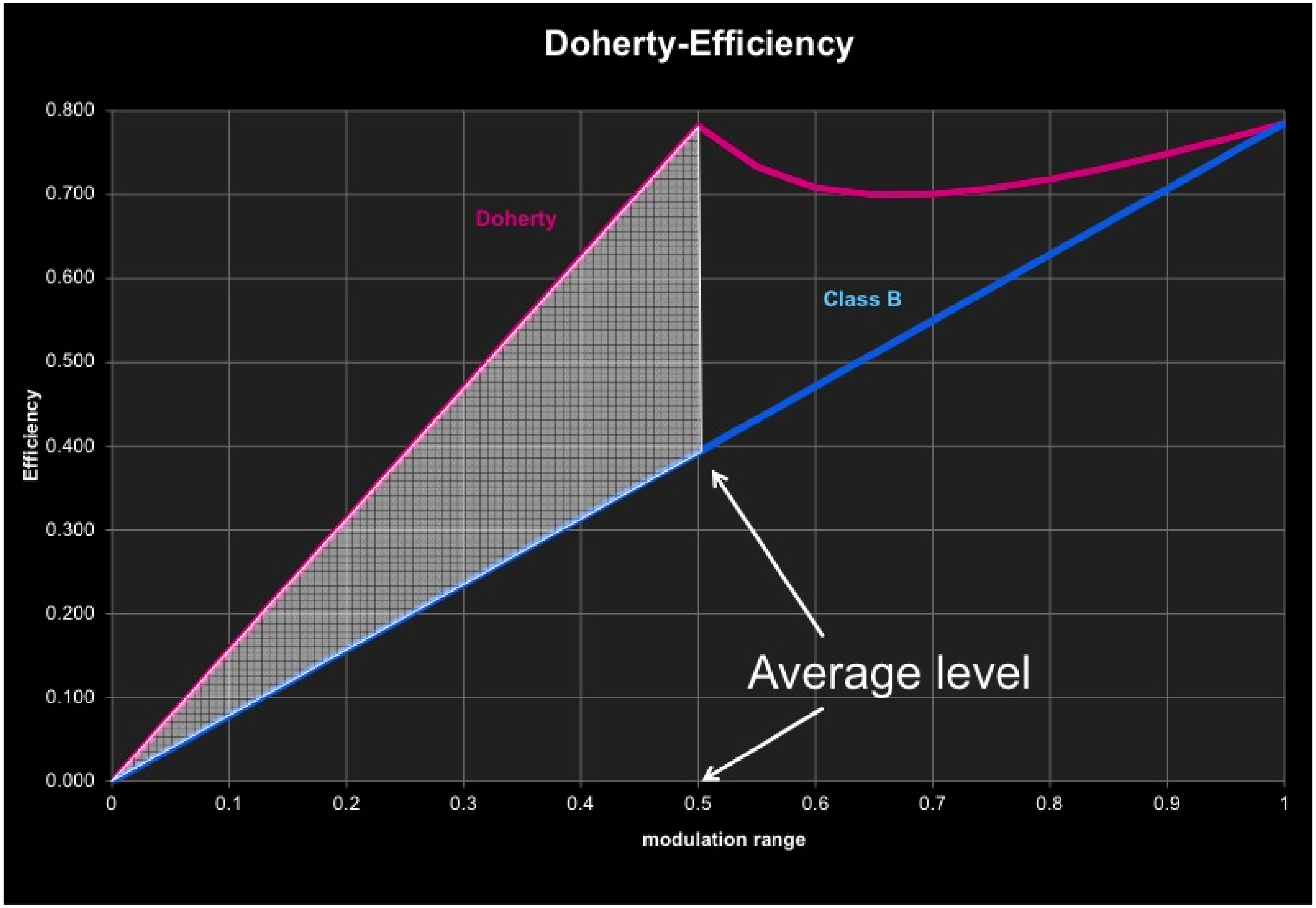


Class A/B

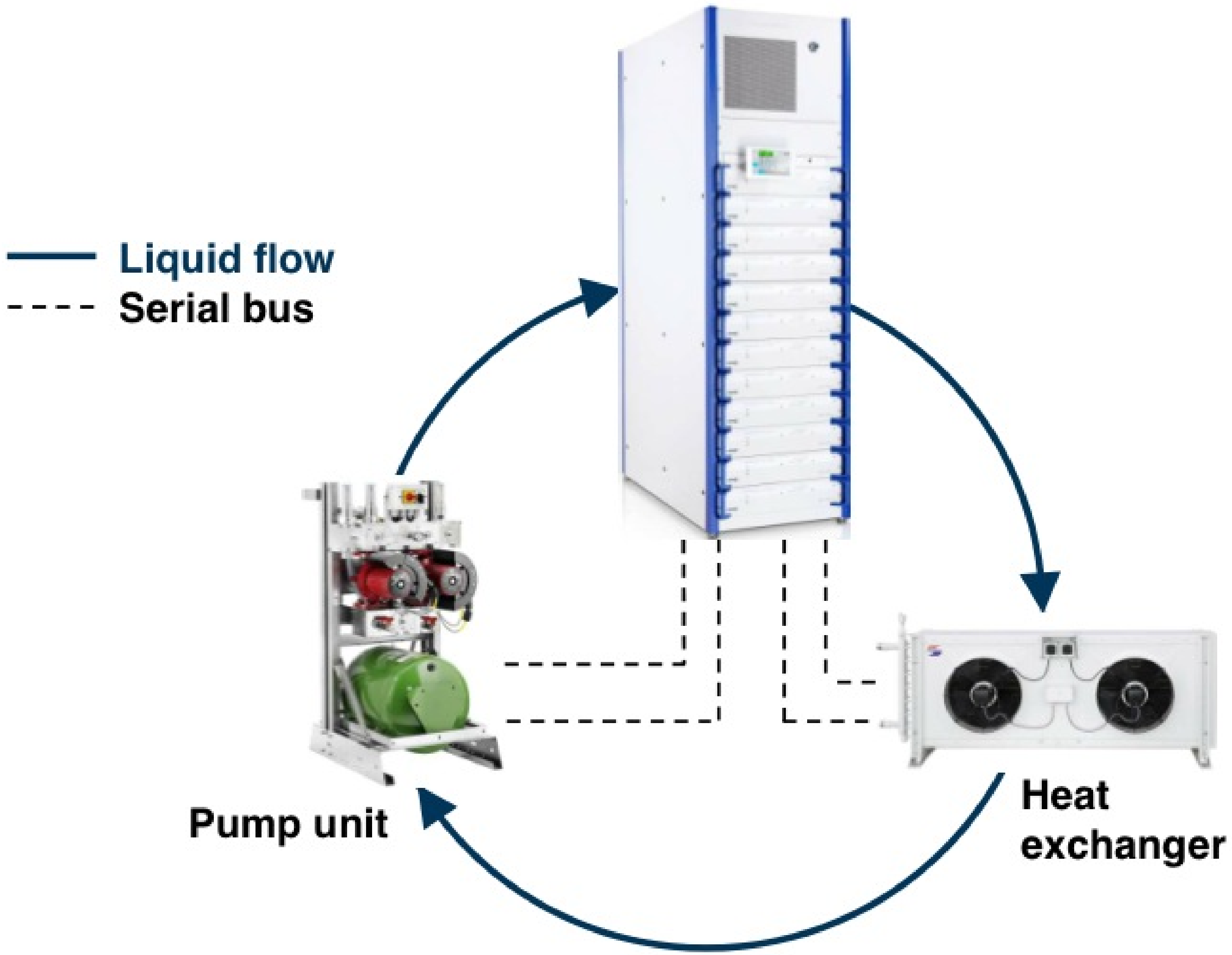
Class C

Doherty Amplifier
Combined signals



ROHDE&SCHWARZ

Additional Sources of Efficiency

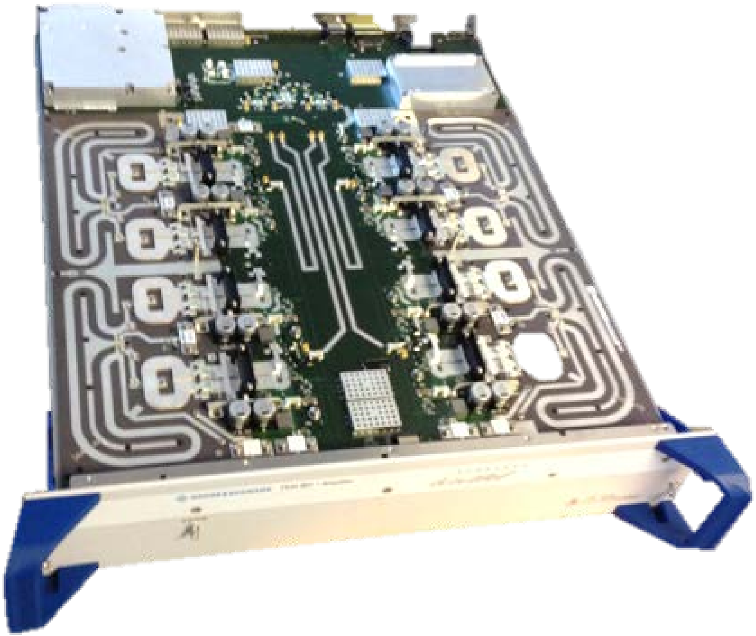


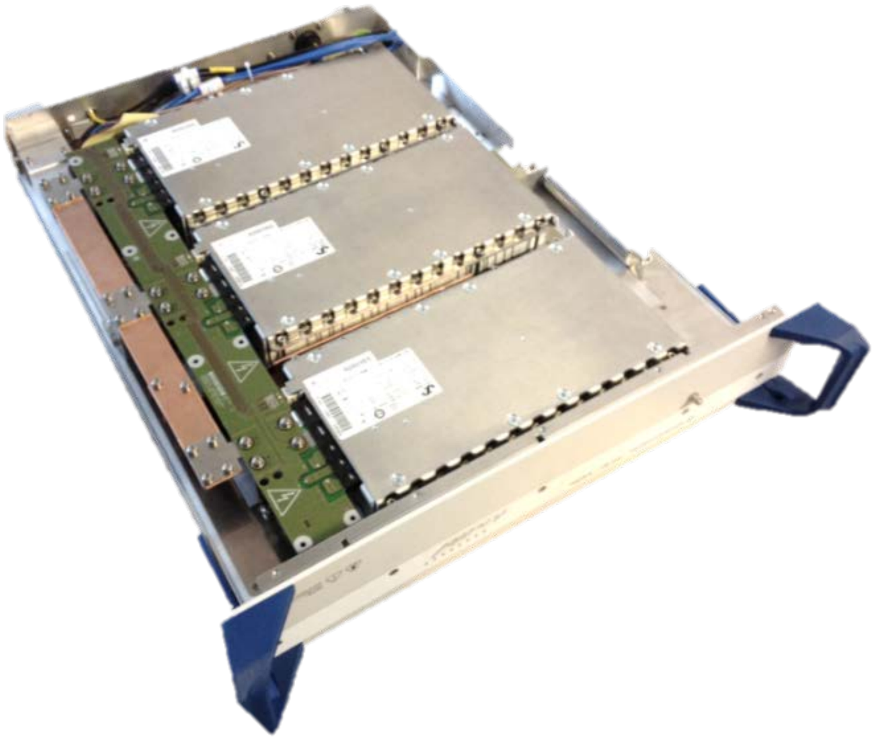
Efficient Cooling System
Custom pump and heat exchanger

- **Custom designed pump system**
- **Variable speed pumps**
- **High efficiency heat exchanger**
- **Variable speed fans**

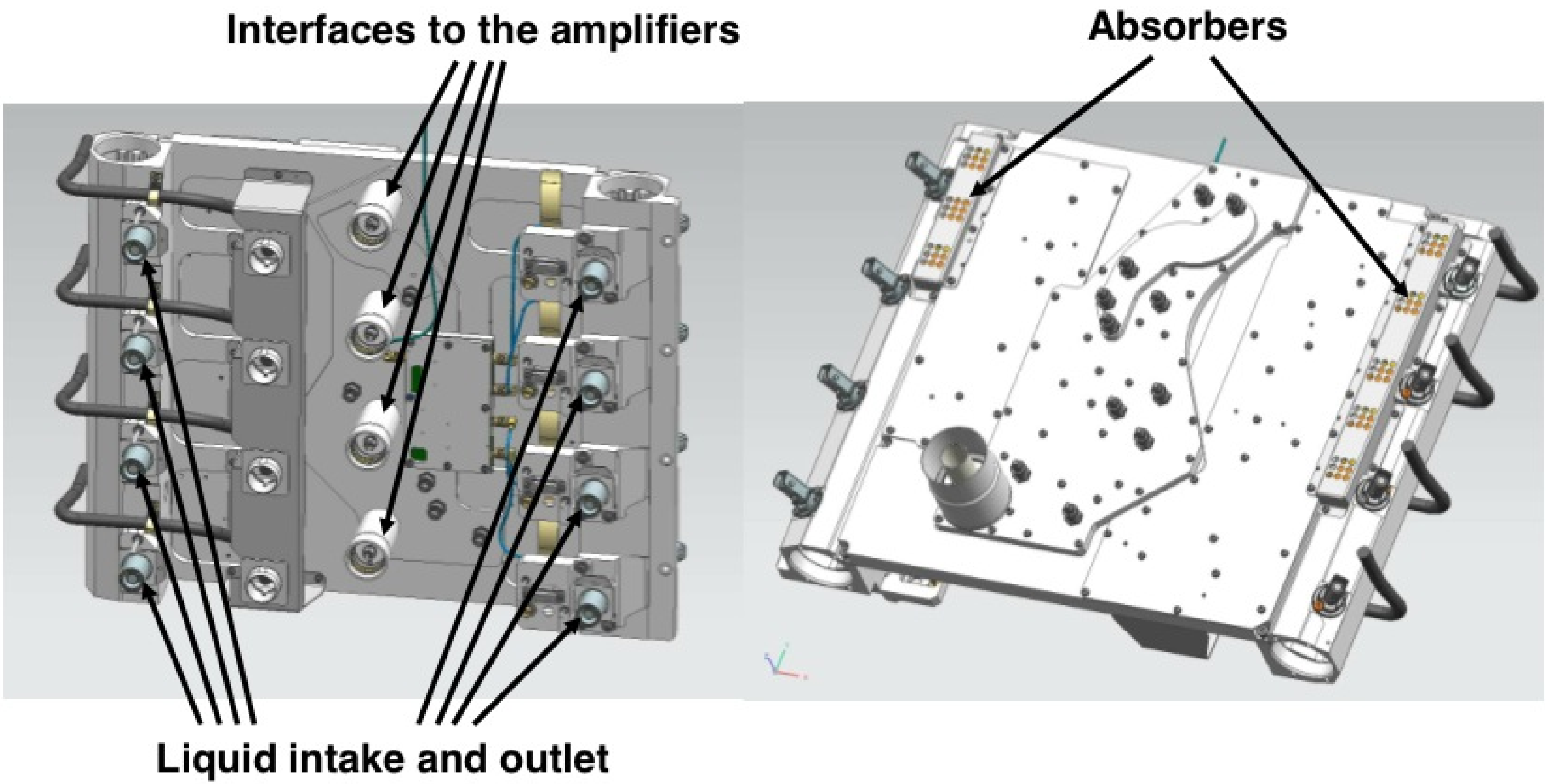
Efficient Cooling System

- **Power supplies and Power Amplifiers Liquid Cooled**
- **Liquid cooling provides for maximum removal of heat from room**
- **Reducing AC Requirement**



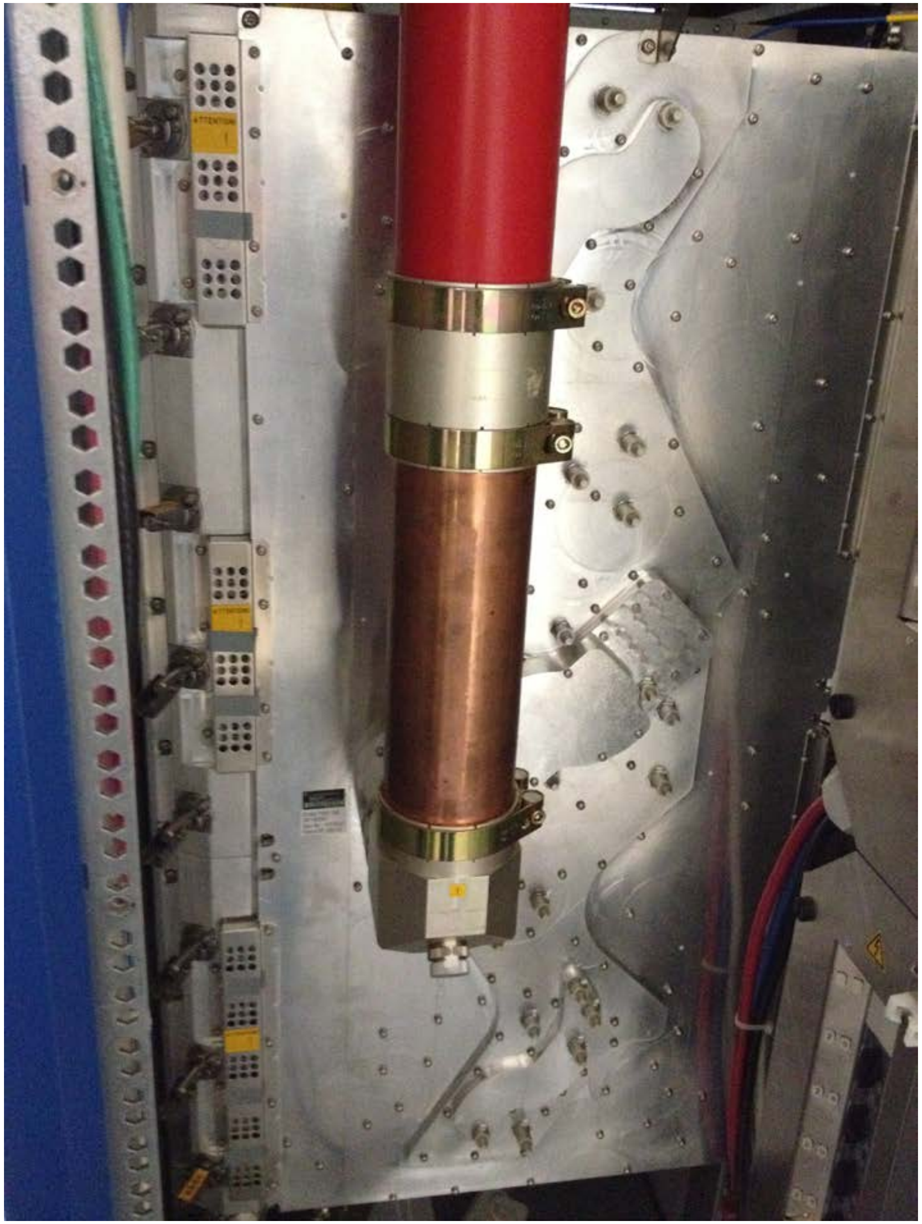


Efficient Combiner Designs

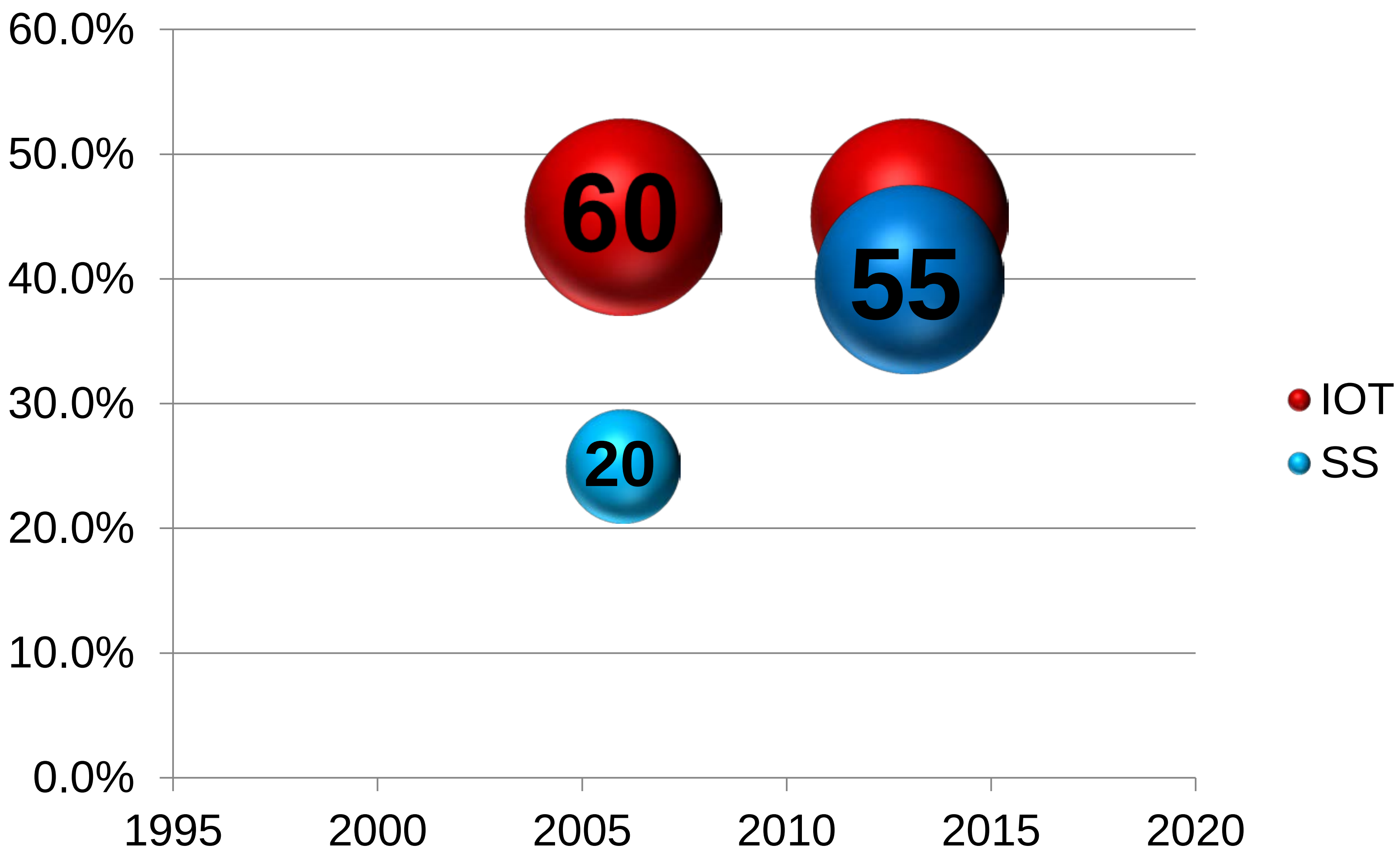


Efficient Combiner Design

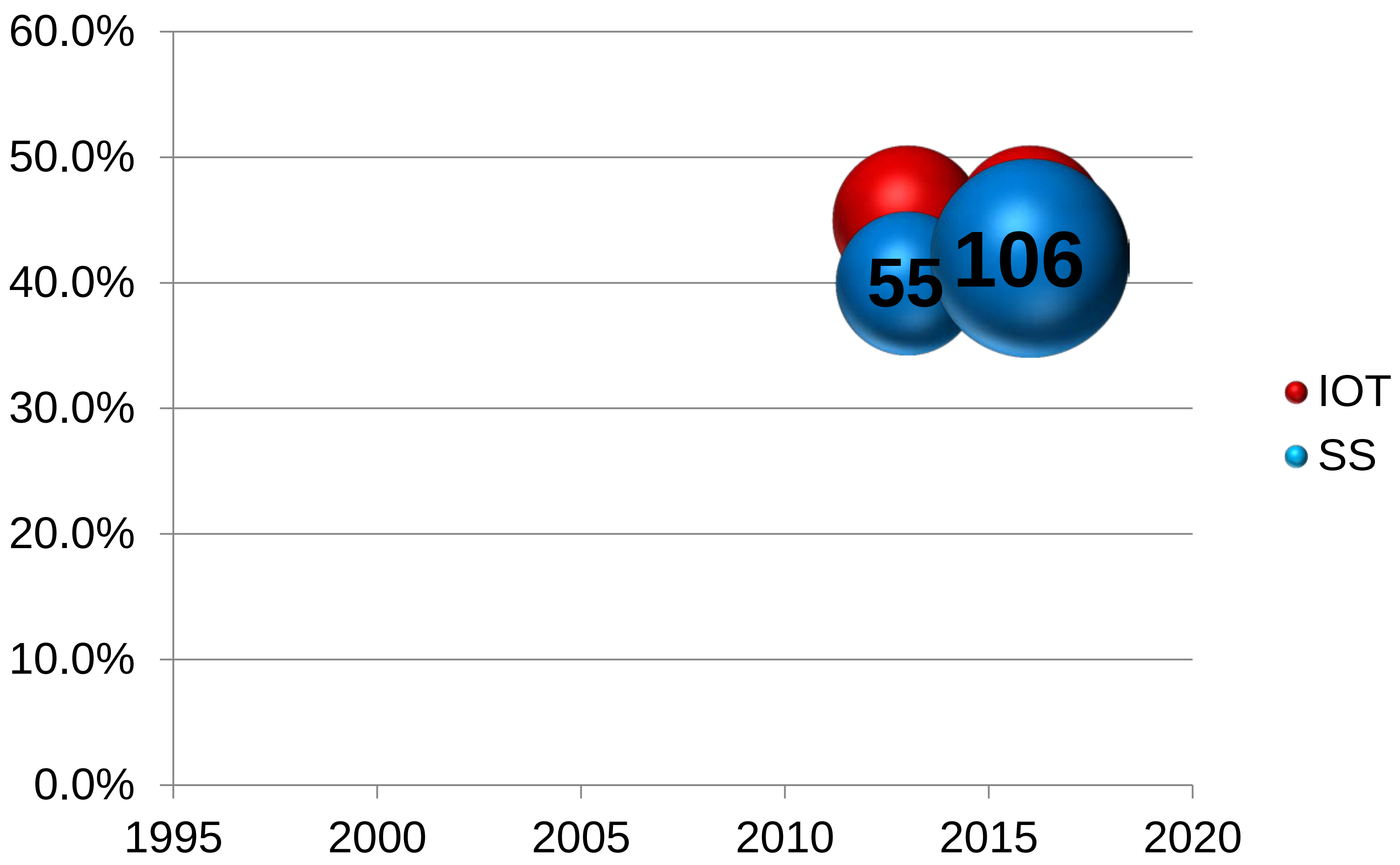
- No cables
- No hoses



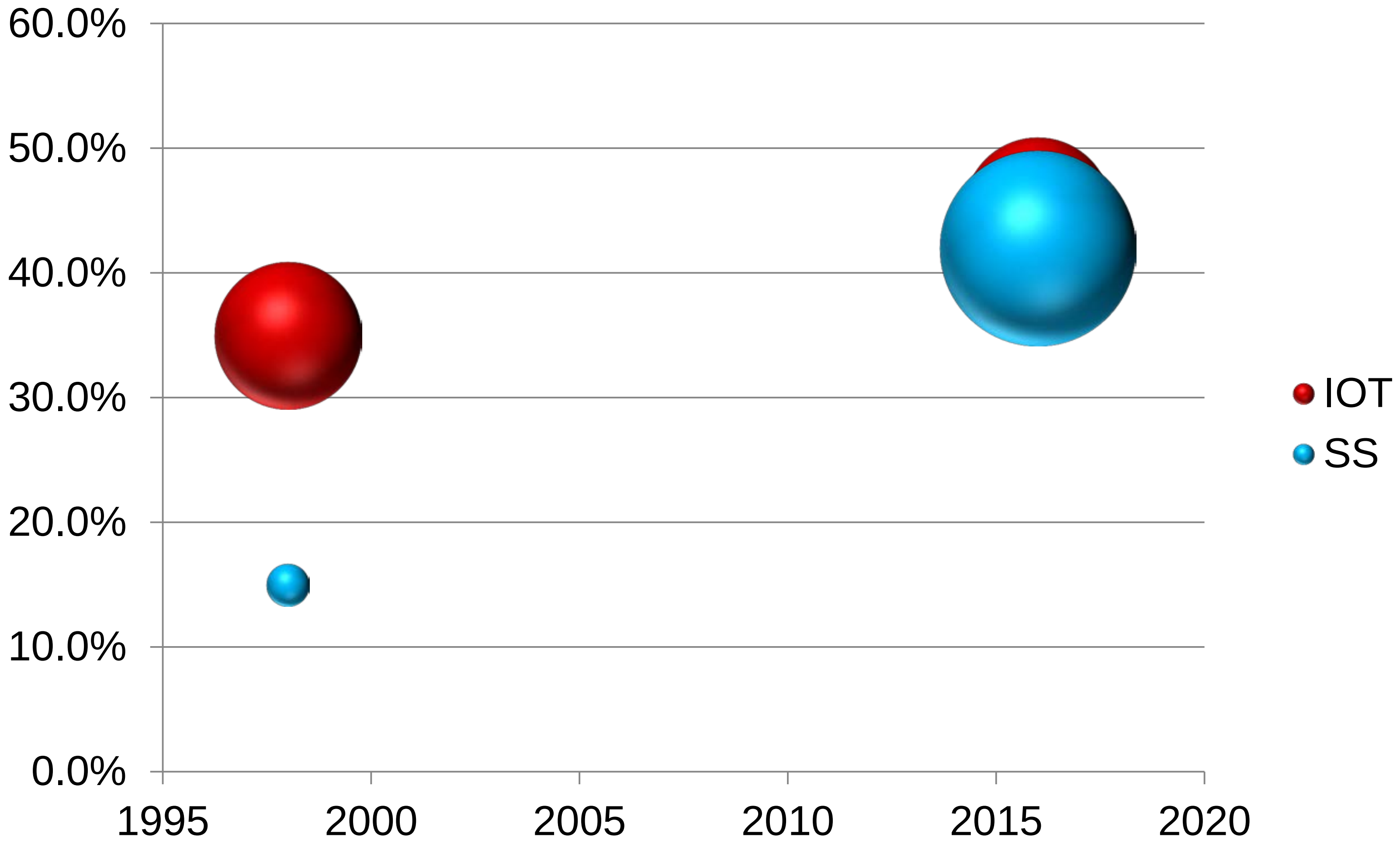
2013 - Introduction of Doherty



2016 – Current Modern Design



1998 – 2016 Evolution over 20 years



Key Points

Power

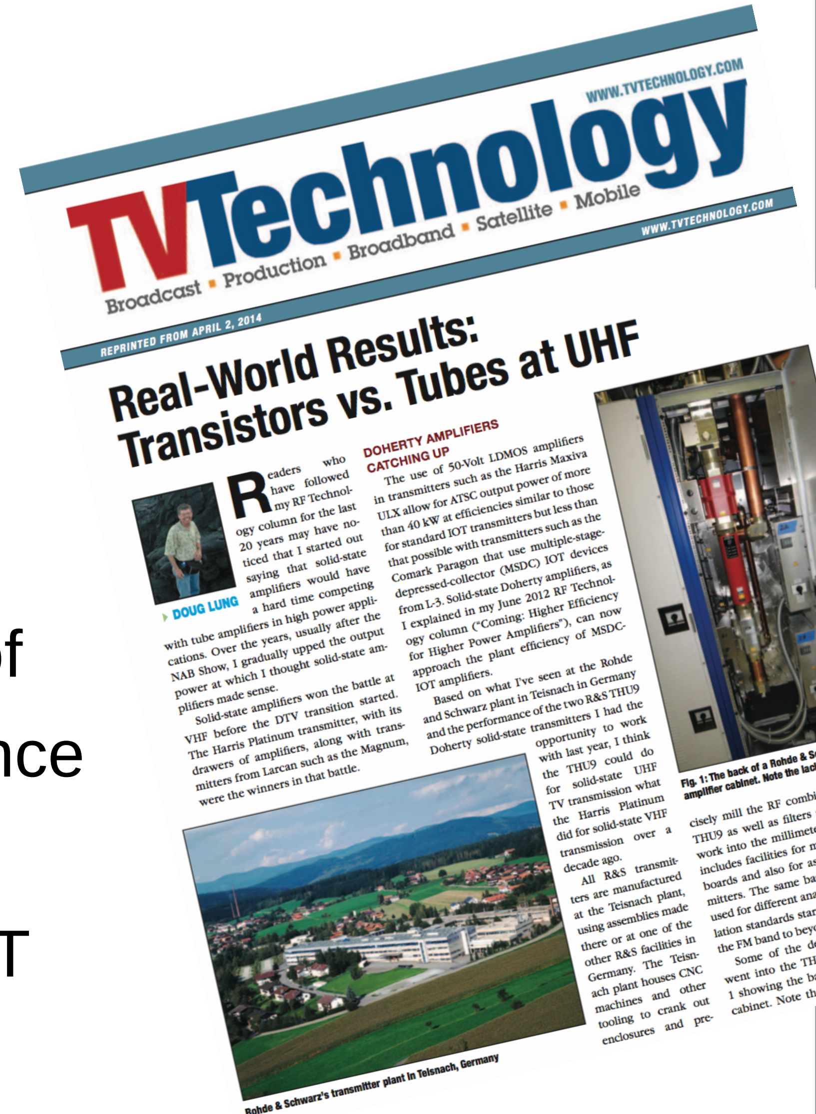
Performance

Payback

Case Study- 40kW SS vs MSDC IOT

WWSI 40kW Replacement

- Article compared SS Doherty VS High Efficiency IOT
- SS approaches plant efficiency of MSDC IOT, less than 2% difference
- Installation easy compared to IOT



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Real-World Results: Transistors vs. Tubes at UHF

DOUG LUNG

Readers who have followed my RF Technology column for the last 20 years may have noticed that I started out saying that solid-state amplifiers would have a hard time competing with tube amplifiers in high power applications. Over the years, usually after the NAB Show, I gradually upped the output power at which I thought solid-state amplifiers made sense.

Solid-state amplifiers won the battle at VHF before the DTV transition started. The Harris Platinum transmitter, with its drawers of amplifiers, along with transmitters from Larcan such as the Magnum, were the winners in that battle.

DOHERTY AMPLIFIERS CATCHING UP

The use of 50-Volt LDMOS amplifiers in transmitters such as the Harris Maxiva ULX allow for ATSC output power of more than 40 kW at efficiencies similar to those for standard IOT transmitters but less than that possible with transmitters such as the Comark Paragon that use multiple-stage-depressed-collector (MSDC) IOT devices from L-3. Solid-state Doherty amplifiers, as I explained in my June 2012 RF Technology column ("Coming: Higher Efficiency for Higher Power Amplifiers"), can now approach the plant efficiency of MSDC-IOT amplifiers.

Based on what I've seen at the Rohde and Schwarz plant in Teisnach in Germany and the performance of the two R&S THU9 Doherty solid-state transmitters I had the opportunity to work with last year, I think the THU9 could do for solid-state UHF TV transmission what the Harris Platinum did for solid-state VHF transmission over a decade ago.

All R&S transmitters are manufactured at the Teisnach plant, using assemblies made there or at one of the other R&S facilities in Germany. The Teisnach plant houses CNC machines and other tooling to crank out enclosures and pre-

Rohde & Schwarz's transmitter plant in Teisnach, Germany

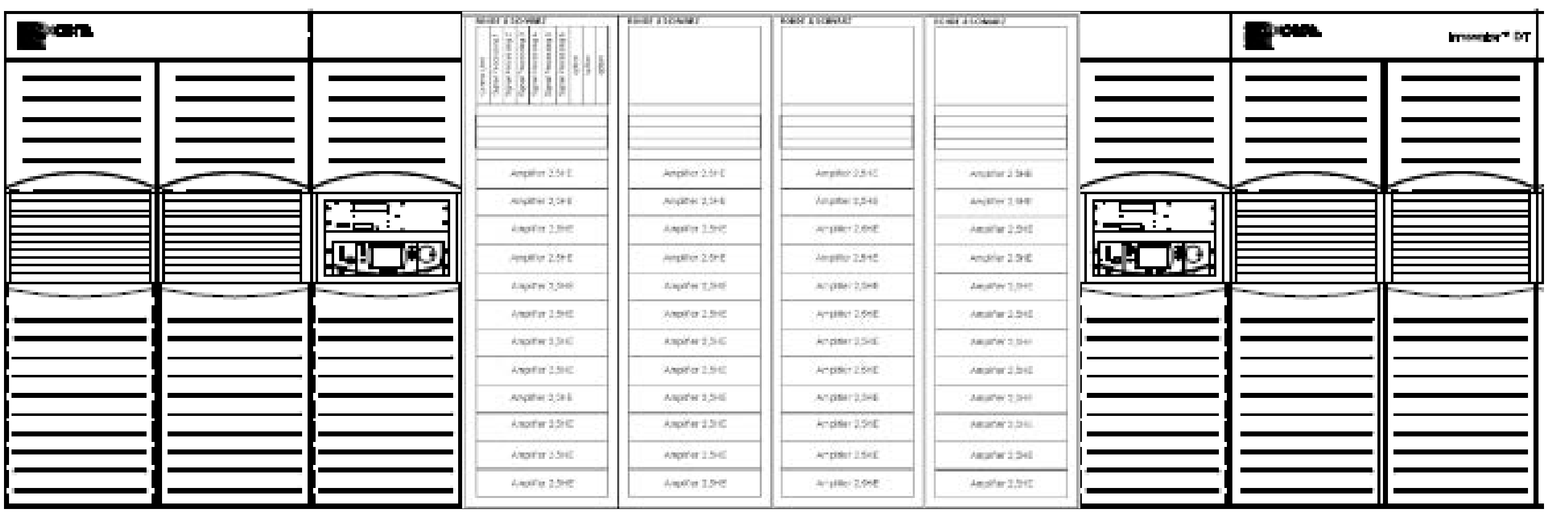
Fig. 1: The back of a Rohde & S
amplifier cabinet. Note the lac

cisely mill the RF combi
THU9 as well as filters
work into the millimete
includes facilities for m
boards and also for as
mitters. The same ba
used for different ana
lation standards star
the FM band to beyo
Some of the de
went into the TH
1 showing the ba
cabinet. Note th

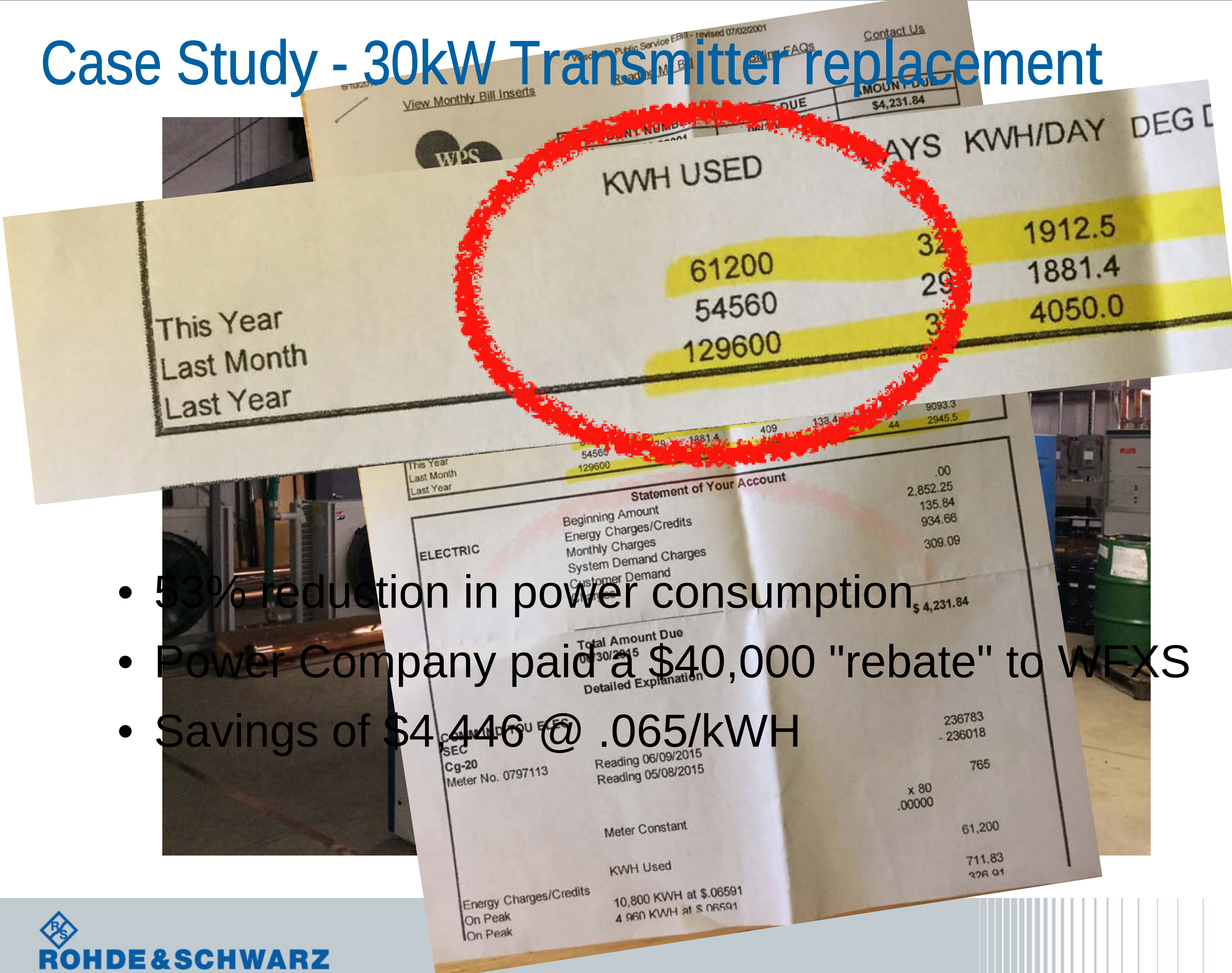
Case Study - Replace 15yr old 30kW SS

KERA (Dallas PBS) 50kW TPO Required

	Legacy SS	THU9-48	Difference
Transmitter length ……….	20ft	8 ft	52 sq ft
Output power ……………	30kW	50kW	20kW More!
Efficiency …………………	18%	40%	More than 2x Eff
Estimated operating … cost @ $.09 Kw/hr	$131,400/yr	$98,550/yr	**$32,850/yr**



Case Study - 30kW Transmitter replacement



- 53% reduction in power consumption
- Power Company paid a $40,000 "rebate" to WFXS
- Savings of $4,446 @ .065/kWH

Case Study – 7kW VHF in PR

iPad 12:34 PM 69%

Spreadsheets Undo **Transmitter Cost of Ownership**

Transmitter Comparison | Graph | Cash Flow Diagram

Transmitter Comparison

Replace the **bold** values in the Transmitter Comparison table with your own values by taping the cell and moving the sliders. The other values are calculated for you.

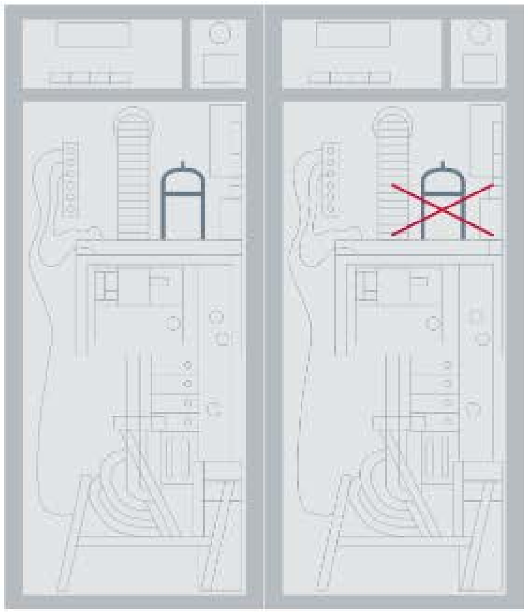
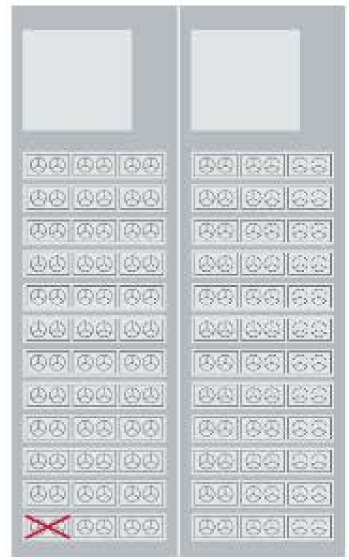
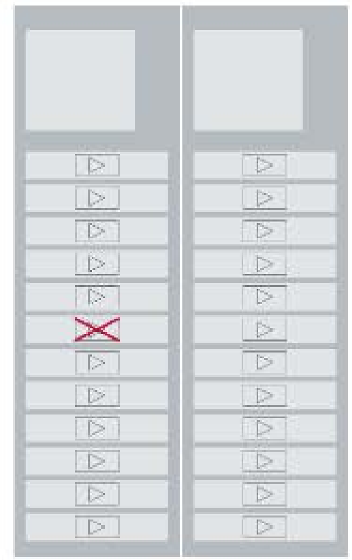
Transmitter Details

	THU9	SS	Dual IOT
Transmitter life (Years)		15	
Electricity rate (Kw/hr)		$0.26	
Transmitter power (Kw)	7	7	0
Efficiency	50%	17%	10%
Power consumption of cooling, drivers, heater, focus supply etc. (Kw)	Included	0	0
Tube replacement cost		N/A	$0
Tube life (years)	N/A	N/A	1
Maintenance cost ($/yr) parts & labor	$0	$0	$0
Purchase price	$0	$0	$0

Cost of Ownership

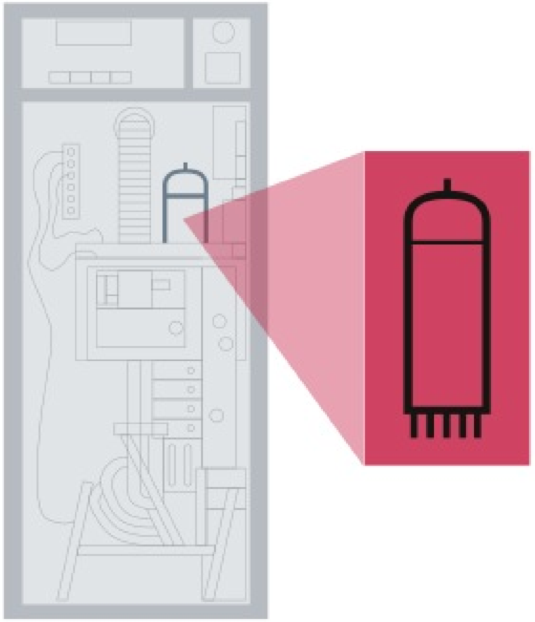
Transmitter/ Year	THU9	SS	IOT
1	$31,886	$93,784	$0
2	$63,773	$187,567	$0
3	$95,659	$281,351	$0
4	$127,546	$375,134	$0
5	$159,432	$468,918	$0
6	$191,318	$562,701	$0
7	$223,205	$656,485	$0
8	$255,091	$750,268	$0
9	$286,978	$844,052	$0
10	$318,864	$937,835	$0
11	$350,750	$1,031,619	$0
12	$382,637	$1,125,402	$0
13	$414,523	$1,219,186	$0
14	$446,410	$1,312,969	$0
15	$478,296	$1,406,753	$0

Redundancy advantage

Redundancy elements	2 tubes	Dozens of supplies	12 power amplifiers per rack
			
Remaining output power	50 %	100 %	92 %

Difference in size and cost of components

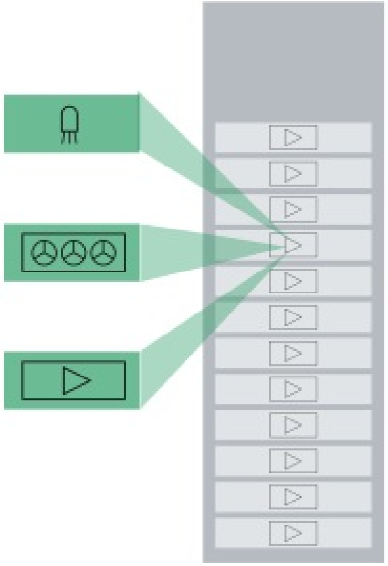
IOT technology



- Expensive component
- Grid-Re-Adjustment needed
- – 3 dB loss when serviced

Big tube to be replaced regularly

Solid state technology



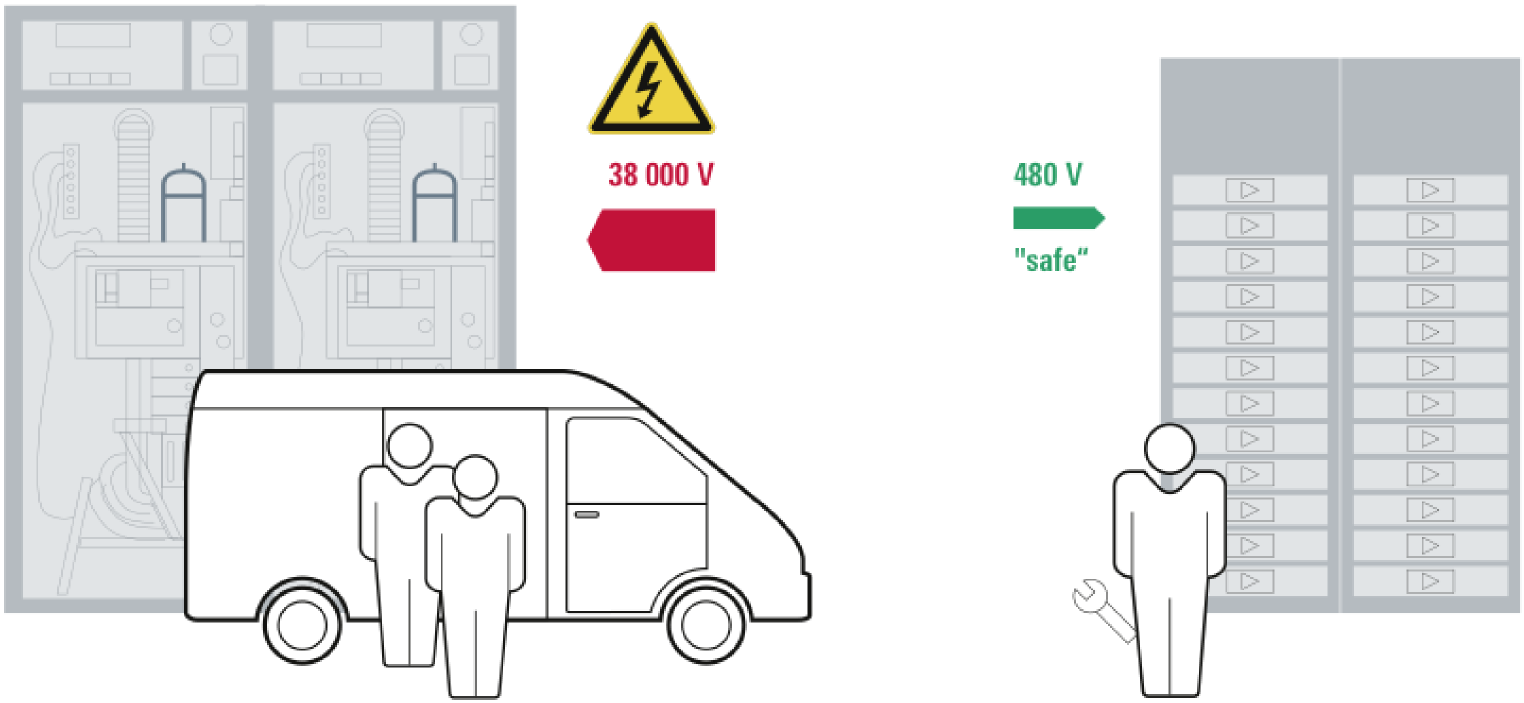
- Small components
- Minor effect when failure
- Only small loss when serviced

Small components as spare parts

Difference in handling

IOT technology

Solid state technology



Complex special equipment

IOT: Complex & dangerous

Simple service tools

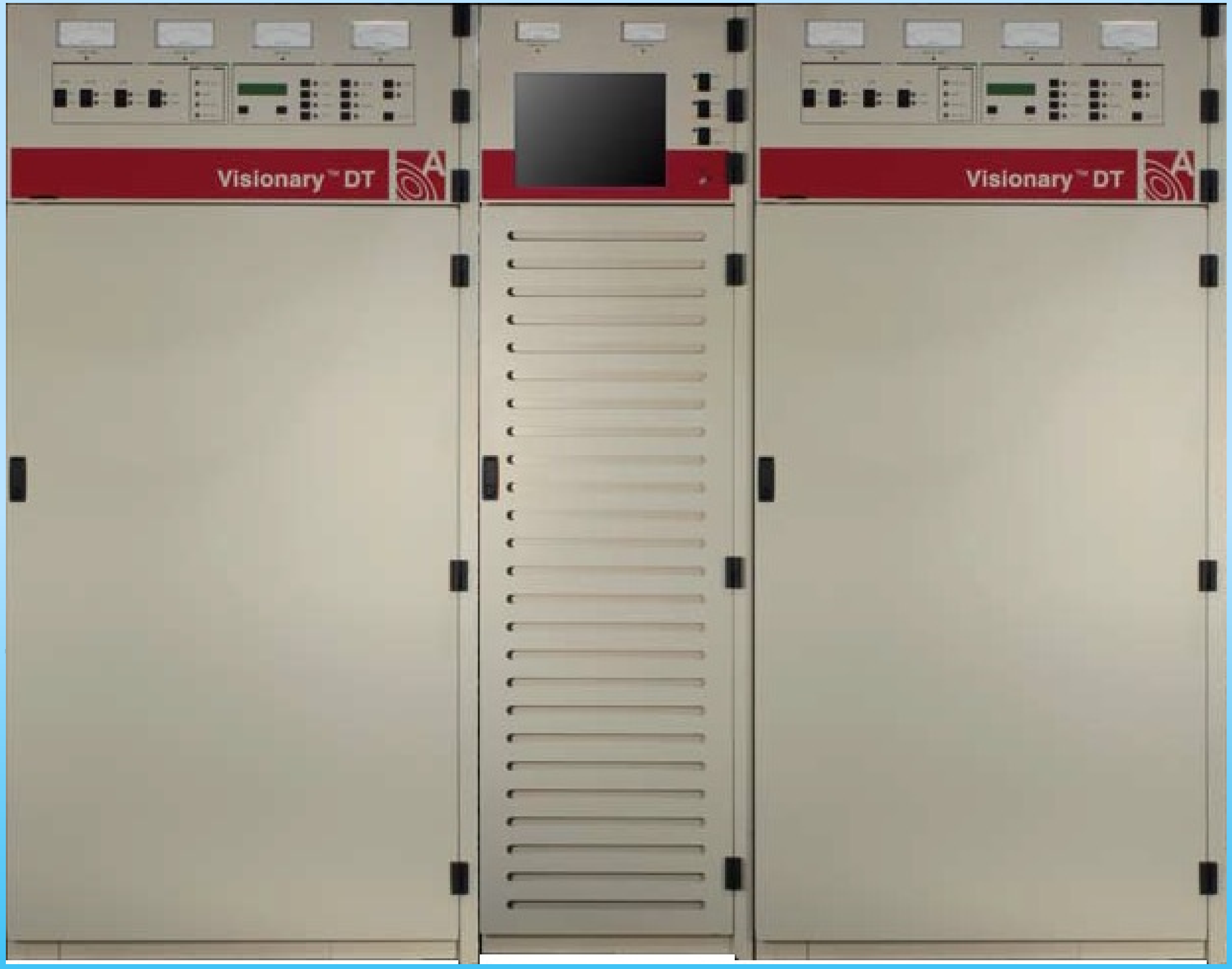
Simple & Safe

Key Points

Power ✓

Performance ✓

Payback ✓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Thank You!