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DEDICATED RELIABLE CREATIVE

ELENOS World Broadcast Experience · itelco BROADCAST · BE · PRO TELEVISION TECHNOLOGIES

Elenos Group World Broadcast

Doherty Technology for Broadcast Transmitters – a technical discussion

Innovation lives here

Webinar Schedule

1. Elenos Group
2. William H. Doherty
3. AM transmitters / TV transmitters
4. Amplitude modulated amplifiers
5. Conventional Class AB
6. Envelope Average Modulation Tracking
7. Kahn EER Amplifier
8. Average Power Tracking
9. Doherty Power Amplifier
10. Doherty Power Amplifier choices
11. Summary

Your host:
Chuck Kelly
VP Market Development

Special Guest:
Perry Priestley
COO / CSO Broadcast Electronics

elenos group

DEDICATED RELIABLE CREATIVE

60,000 Installations

130 Countries

90 Years of Experience

Elenos Group

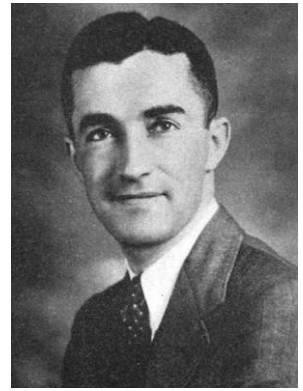
Elenos
- Founded in 1977 in Ferrara, Italy

Itelco
- Broadcast began in **1962** in Orvieto, Italy

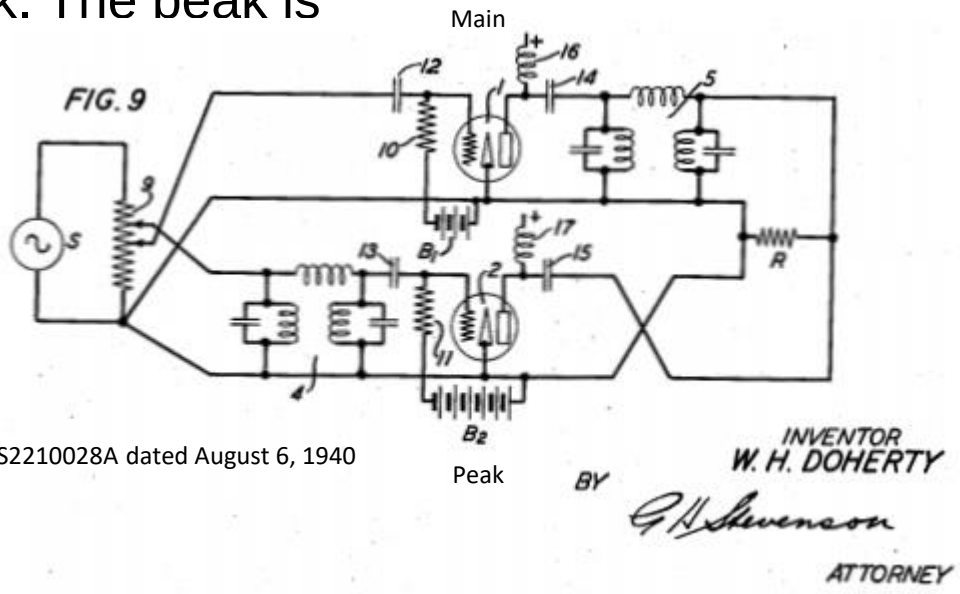
BE
- Established in Quincy, Illinois in **1959**

PROTELEVISION TECHNOLOGIES
- Established in Denmark, over **50** years of experience

William H. Doherty (1907 – 2000)



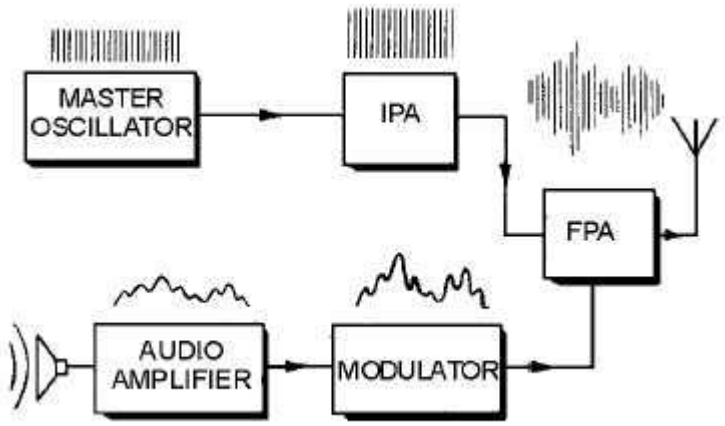
- Graduated with BSEE and MSEE from Harvard
- Invented concept in 1936, patented in 1940 (80 years ago next month)
- First used by Western Electric in AM transmitters
- Further developments by Continental Electronics in 50kW AM transmitters
- Works by combining two amplifiers, the main and the peak. The peak is only active when needed, saving energy.



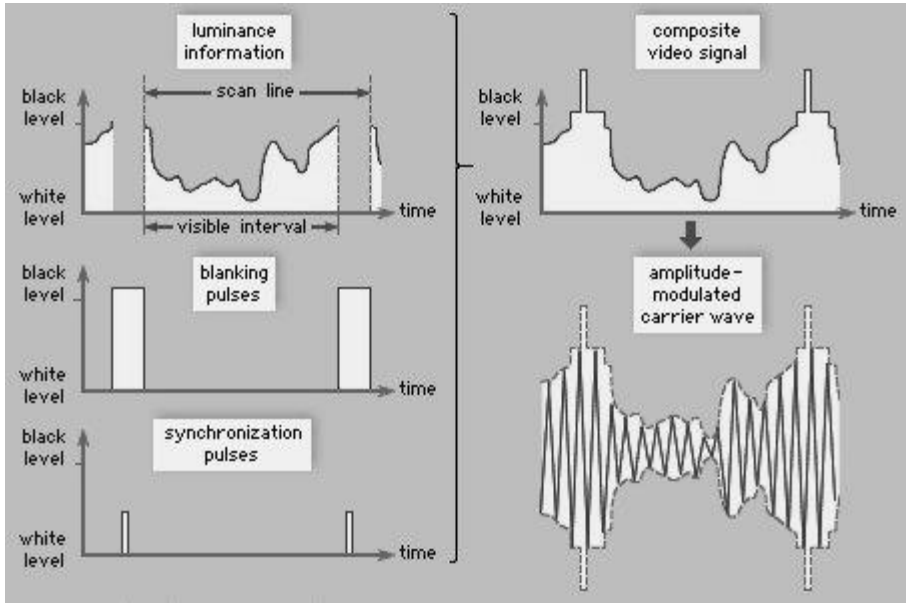
From the US patent application US2210028A dated August 6, 1940

Analog TV has a lot in common with AM transmission

- Both require high linearity and have dynamic amplitude
- The need for high linearity typically requires class AB amplification
- Class AB is typically very low efficiency



AM



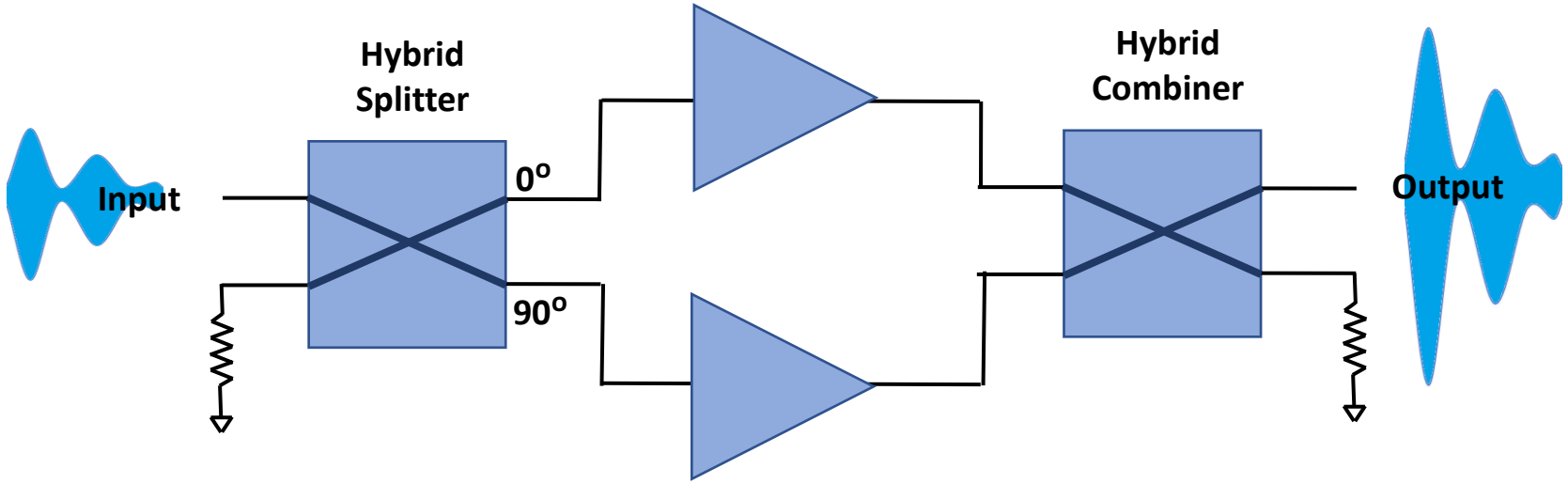
TV

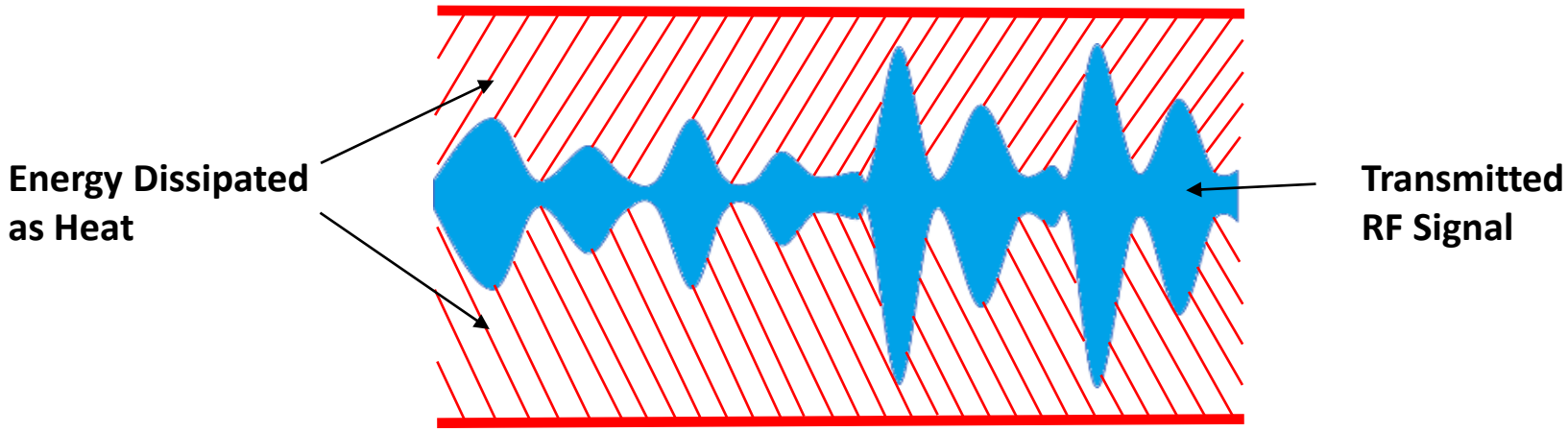
Amplitude modulated amplifier design choices

- Conventional class AB amplification:
  - ✓ Very low efficiency but high linearity
- Envelope average modulation tracking
  - ✓ Improved efficiency, high RF bandwidth, low modulation bandwidth
- Kahn Envelope Elimination and Restoration amplification (Class C):
  - ✓ High efficiency, but low modulation bandwidth – good for audio, not video
- Average Power Tracking with AB amplifier:
  - ✓ Medium efficiency, high RF bandwidth, low modulation bandwidth
- Doherty amplification:
  - ✓ High efficiency, low RF bandwidth

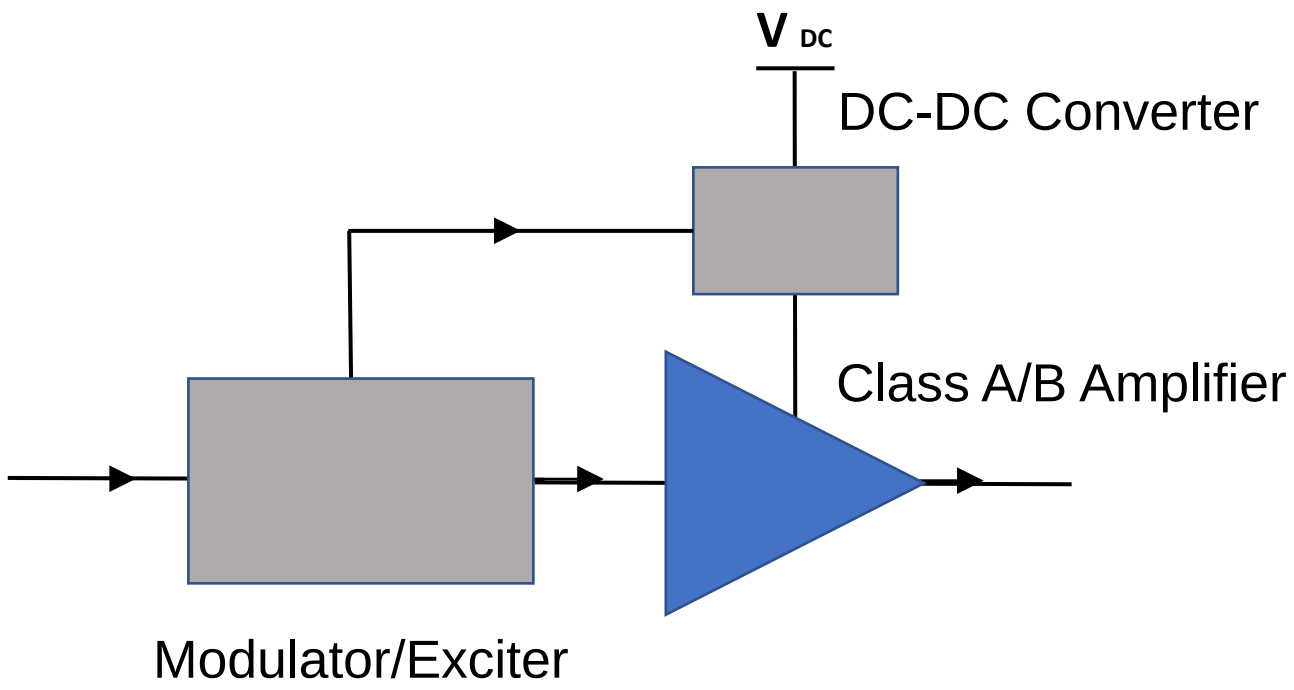
Conventional Push-Pull class AB amplifier – AM modulated

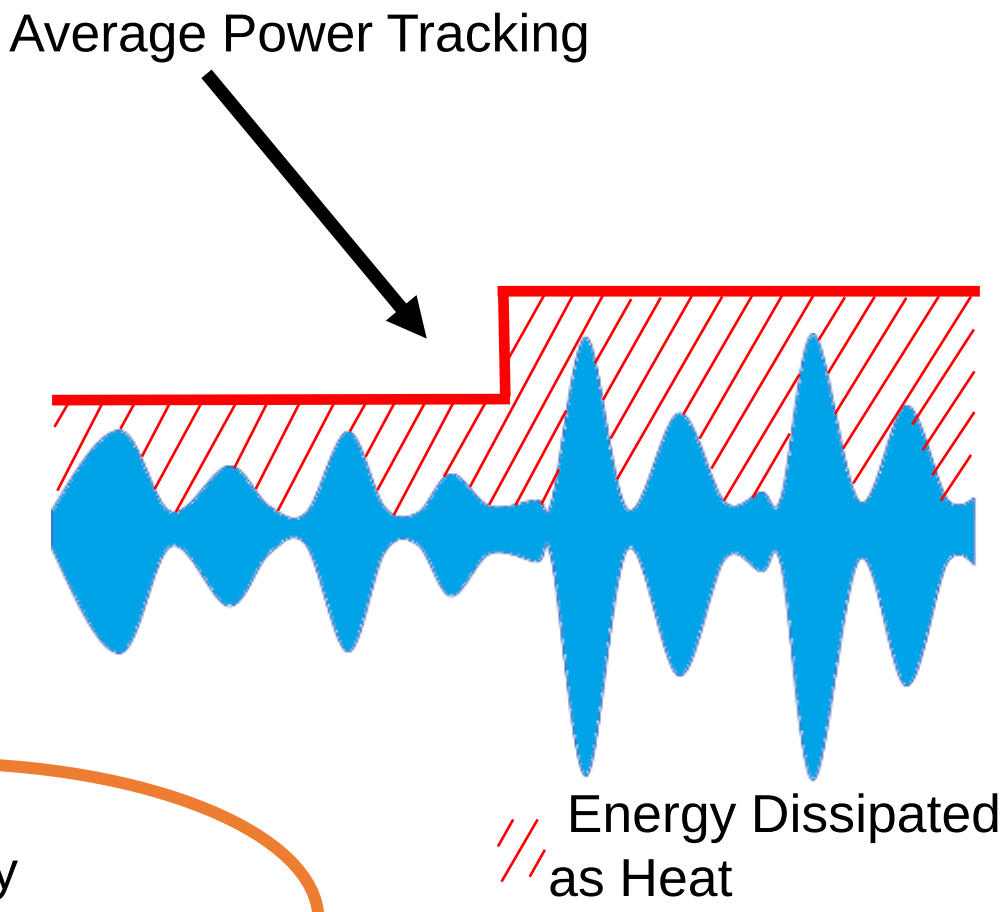
- Class A/B typically used for RF amplifiers provides relatively linear amplification at a reasonable efficiency.
- Typically up to 30% transistor efficiency is obtained.





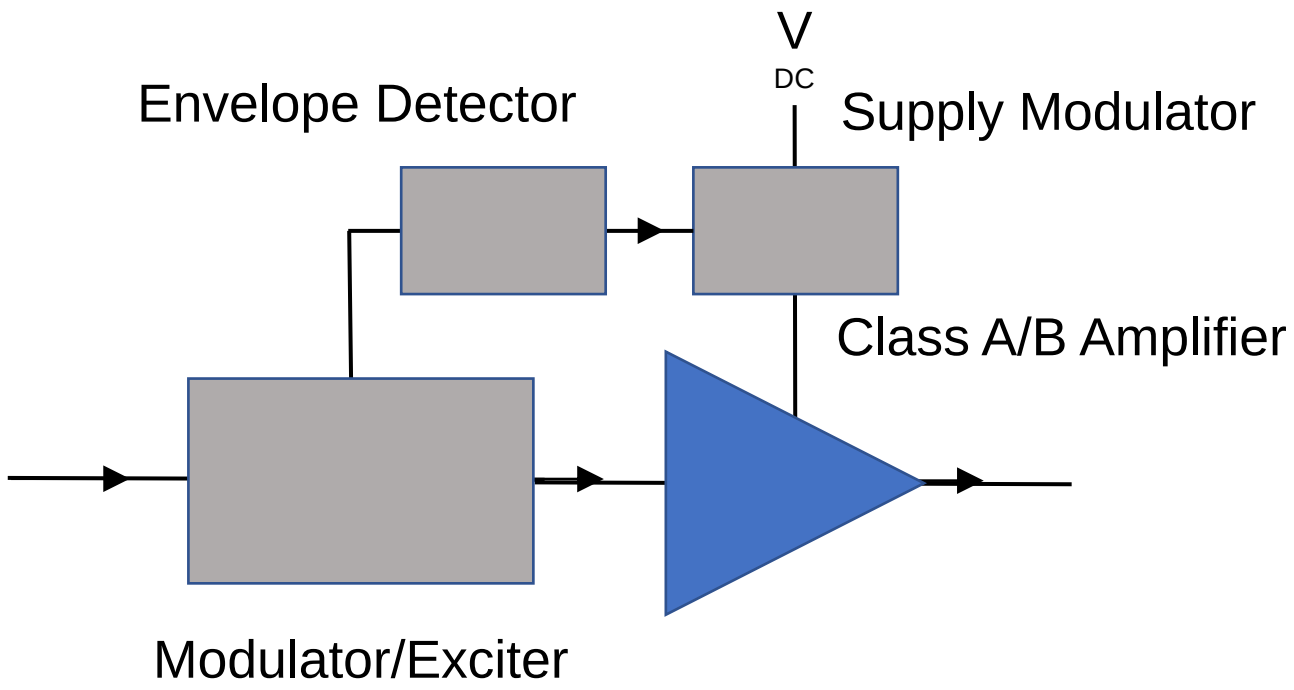
Envelope Average Modulation Tracking



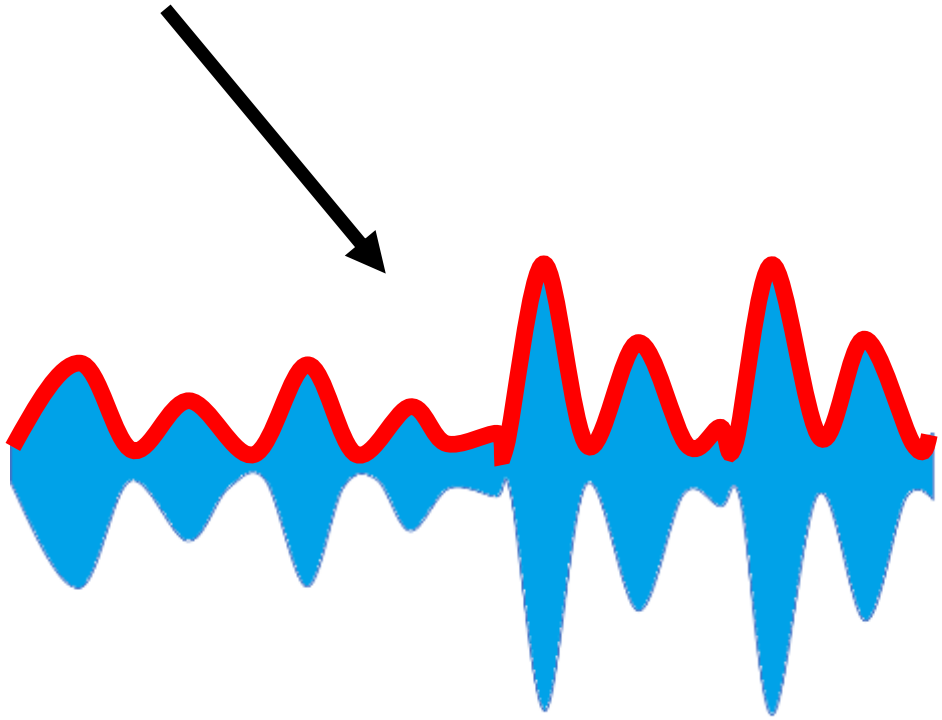


~ 35% Efficiency
65% Wasted energy as heat

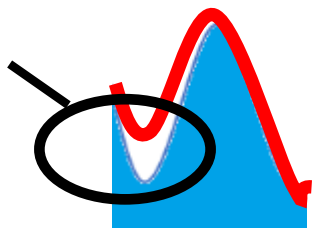
Envelope Power Tracking



Envelope Power Tracking

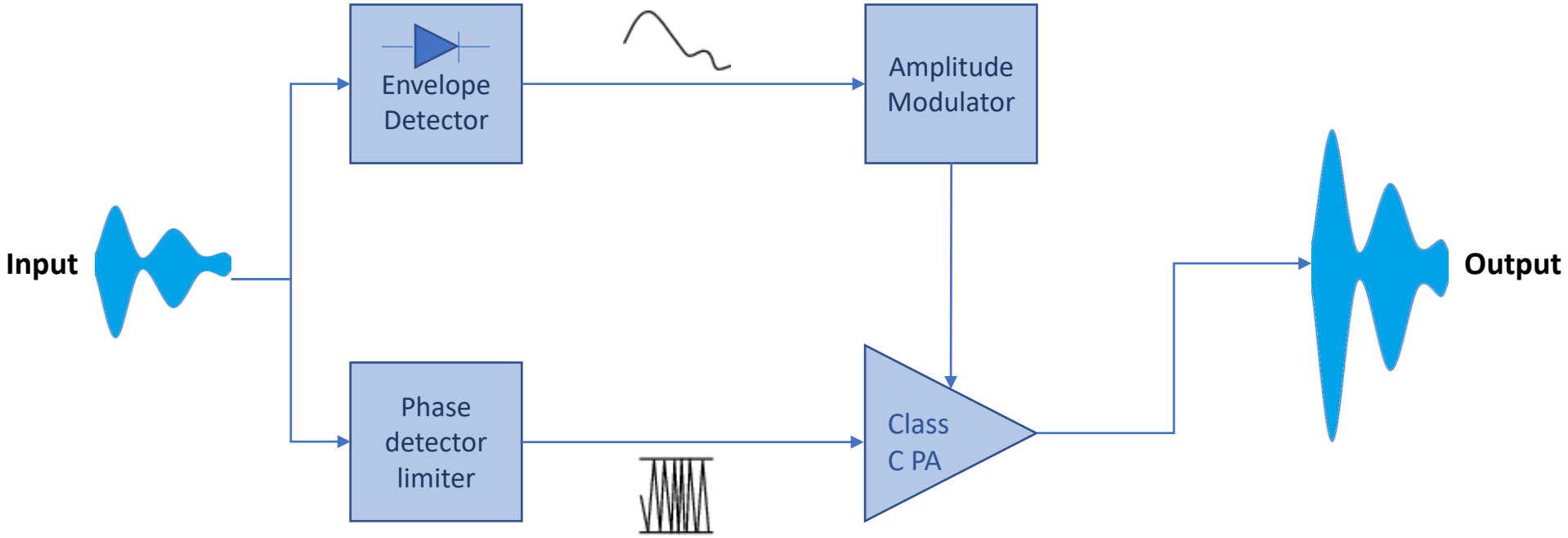


Envelope doesn't track to zero



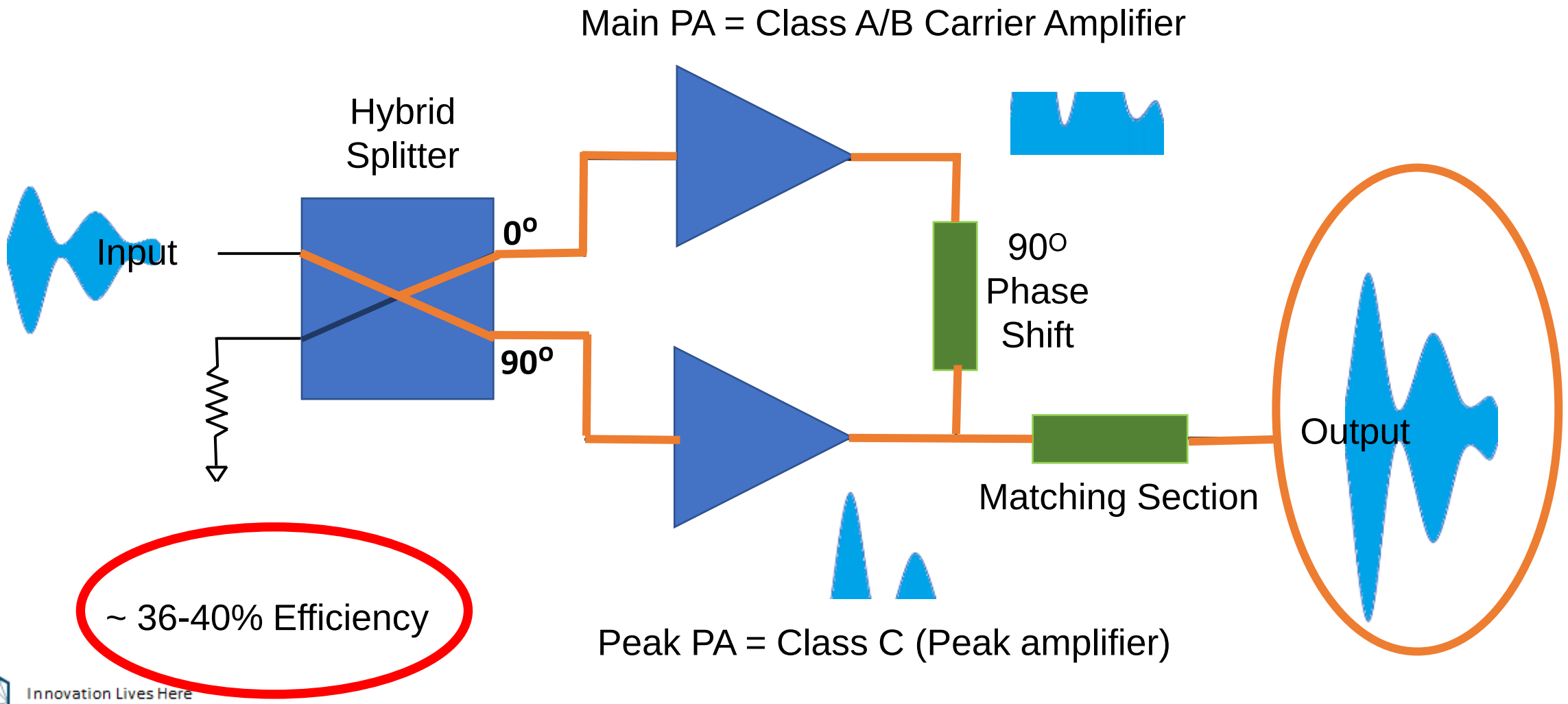
~ 40% Efficiency
60% Wasted energy as heat

Kahn EER amplifier – AM modulated



- Provides excellent (up to 90%) efficiency for AM broadcast
- Modulation bandwidth not suitable for television

Doherty Amplification



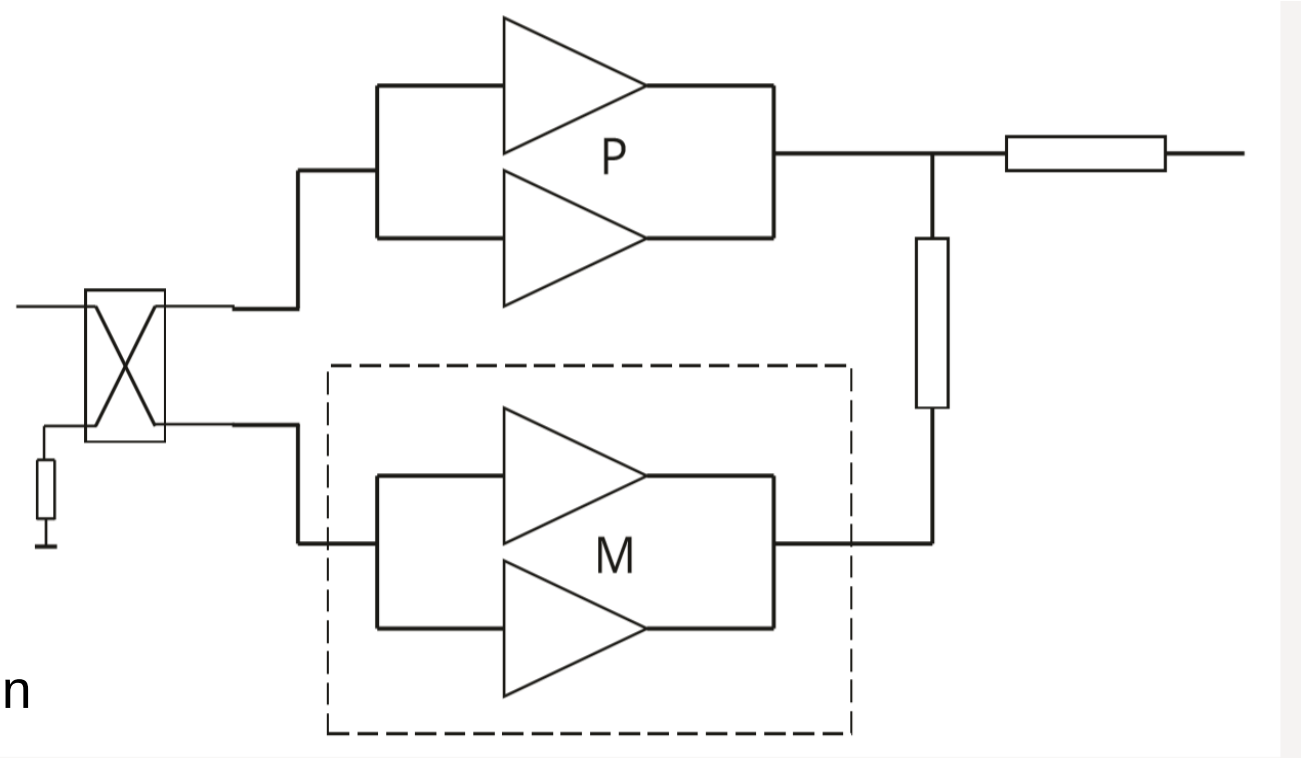
Amplifier Designs – Classical 2-Way Doherty Architecture

Benefits

- Small size
- High power (240 W in a Pallet)
- Balun (cancellation of 2nd harmonic)
- Low cost
- Standard Pallet configuration

Disadvantages

- Narrowband
- Limited power in broadband amplifier design



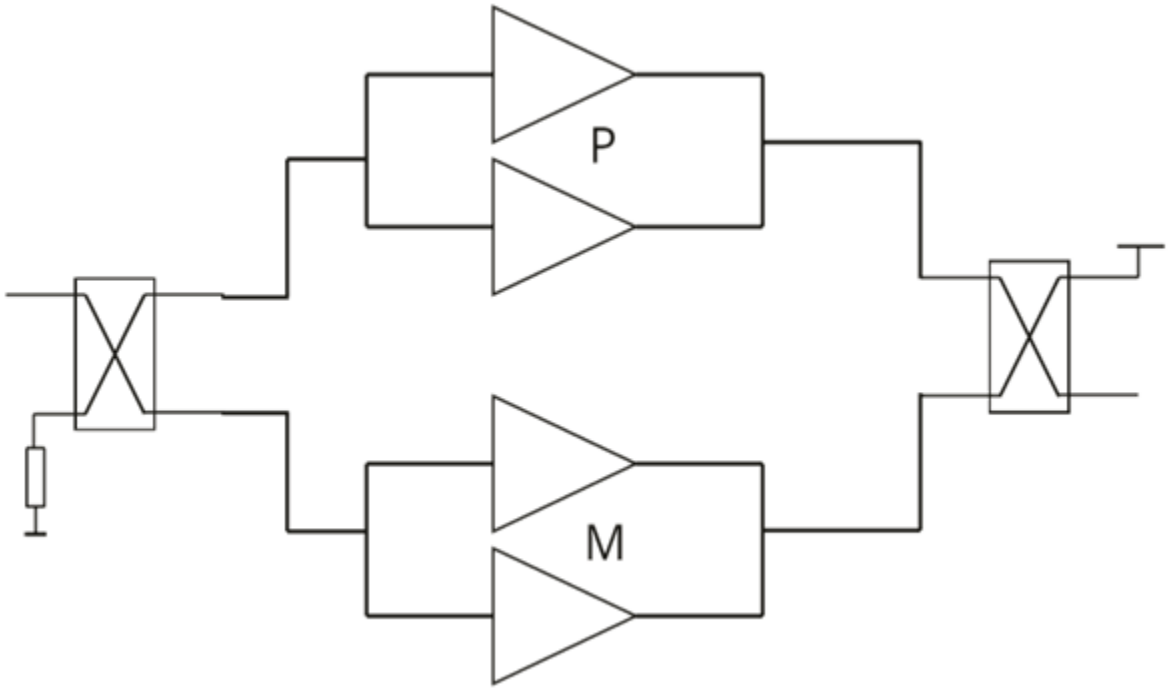
Amplifier Designs – Classical (a)-symmetric 2-Way Doherty, hybrid variant (Variant with input and output hybrids)

Benefits

- Compact implementation (normally used in a balanced class AB pallet).
- Output hybrid has a zero ohm or infinite load to realize the correct Doherty transformations

Disadvantages

- Narrowband behavior is because of the phase shift already introduced in the broadband amplifiers
- Limitation in power when using full broadband amplifiers. A too high of a power level will reduce the impedance level at the transistor lead and this results in an unpractical broadband design



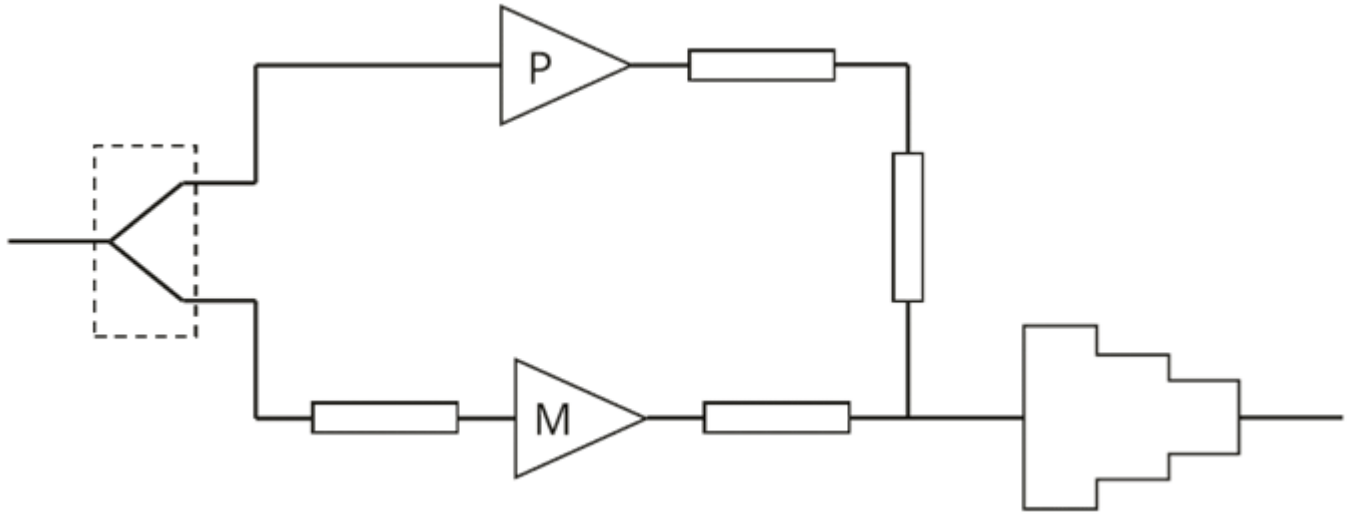
Amplifier Designs – Wideband 2-Way (a)-symmetric Doherty

Benefits

- Broadband (full band solution is feasible)
- High power (115-150 W designs)
- Efficiency > 50%

Disadvantages

- Use of 10 mm PCB
- Larger size
- No balun



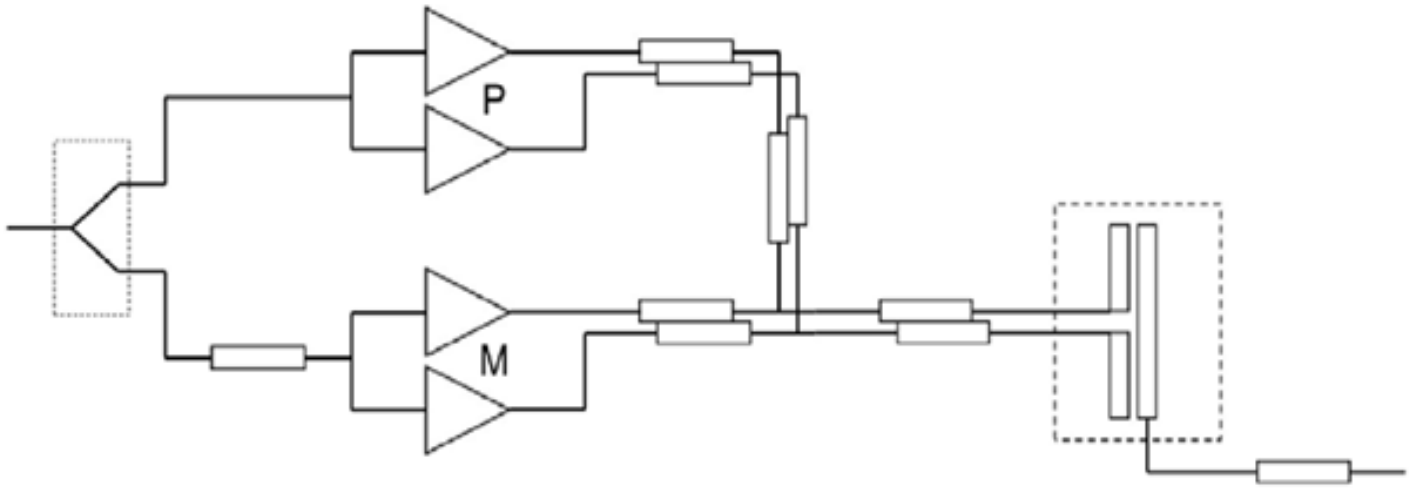
Amplifier Designs – Odd-Mode Wideband (a)-symmetric Doherty

Benefits

- Broadband (full band feasible)
- High power (250 W in pallet)
- Efficiency > 50%
- Balun (no 2nd harmonic influence)

Disadvantages

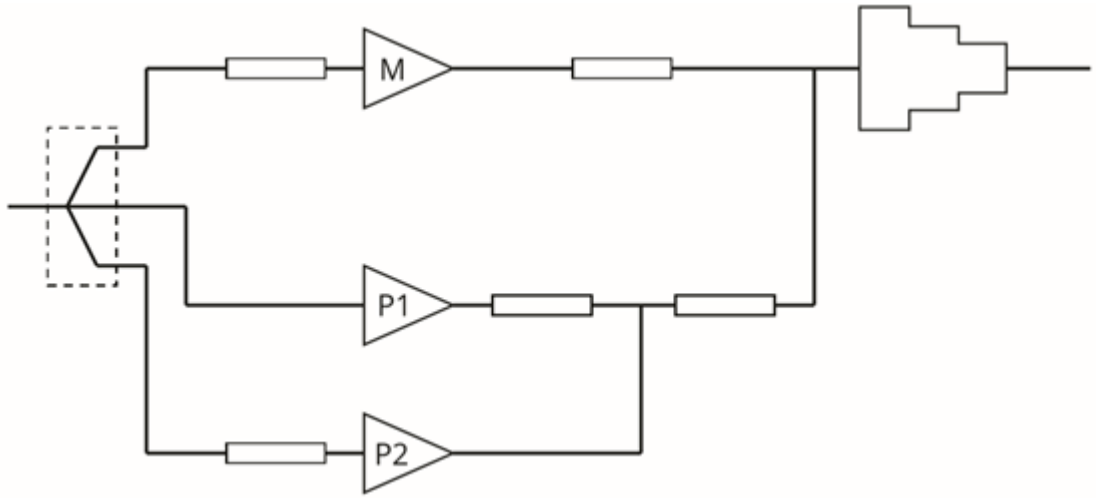
- Use of 10 mm PCB
- Higher cost (multilayer PCB)
- Complexity
- Thermal measures needed
- No tuning of broadside coupled line



Amplifier Designs – 3-Way Doherty

Benefits
- High power
- Best efficiency
- Optimum in DVB-T and ATSC

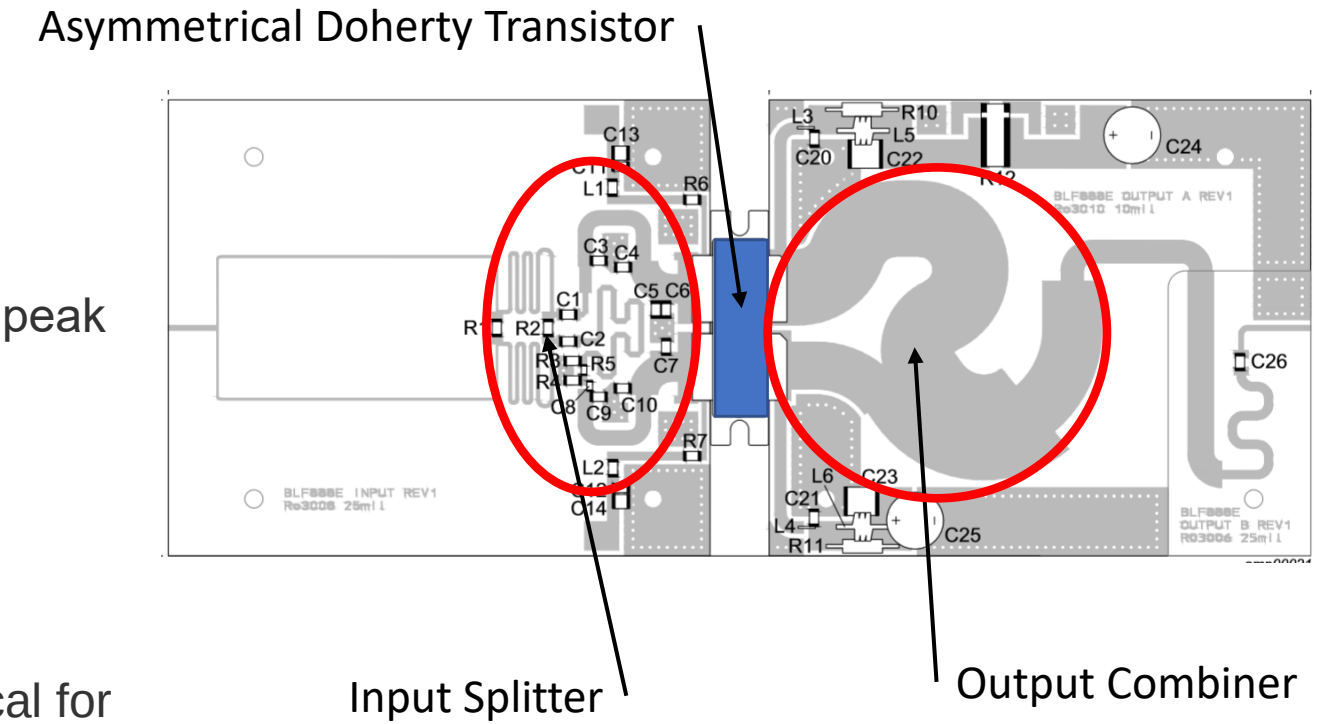
Disadvantages
- Bandwidth
- Complexity
- Stronger adaptive correction needed
- No balun



Amplifier Designs – Wideband 2-Way (a)-symmetric Doherty

Key design aspects:

- Input relatively simple to ensure correct phase/amplitude
- Signals out of phase by 90° ¼ λ line
- No isolation so “main” transistor “load pulls” the peak transistor causing phase shift and impedance differences
- Splitters and combiners are bandwidth limited
- Conclusion
  - Good design of the output combiner is critical for optimum impedance matching, linearity maintenance and maximum operating bandwidth

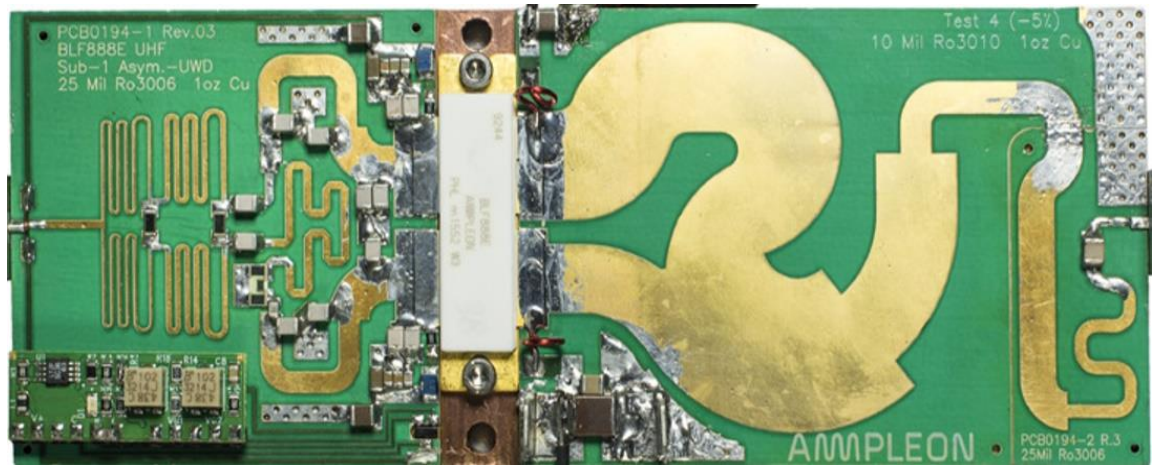


Information from Ampleon

Amplifier Designs – Wideband 2-Way asymmetric Doherty

Key Features*

- Bandwidth 470-610 MHz
- Efficiency > 50%
- 150 W DVB-T / ATSC 3.0
- Gain 17 dB
- Shoulders < -38 dBc (w/o correction)
- Size: 147 x 56 mm



- Band 1: 470 - 610 MHz
- Band 2: 600 - 700 MHz
- Band 3: 650 - 800 MHz

* Information from Ampleon

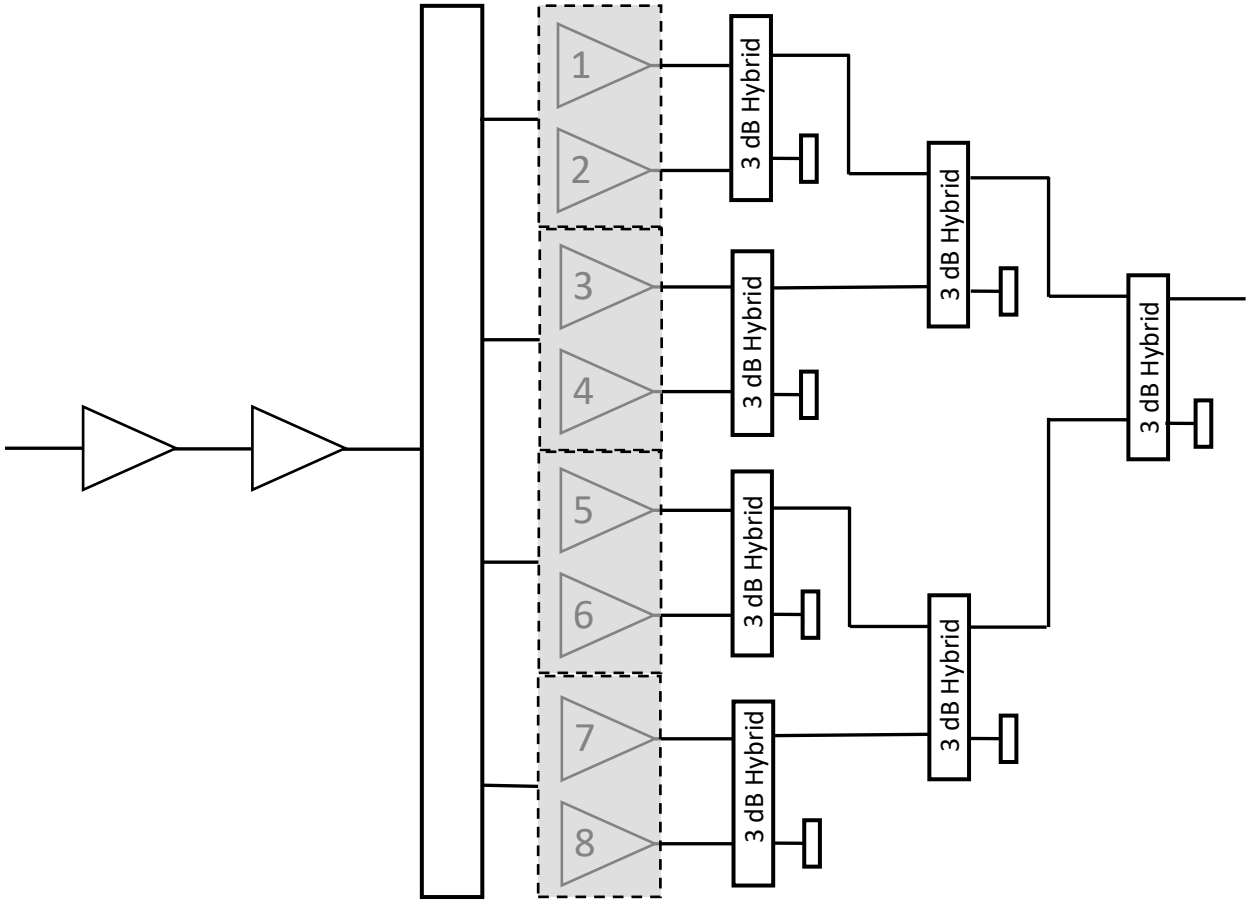
Transmitter Designs – 7 combiner system

Benefits

- Highest power – 1200W
- Symmetrical
- Optimum design
- Equal amount of 2nd harmonic power in ballast resistors (loads)

Disadvantages

- Does not fit inside 19” chassis
- Higher 2nd harmonics



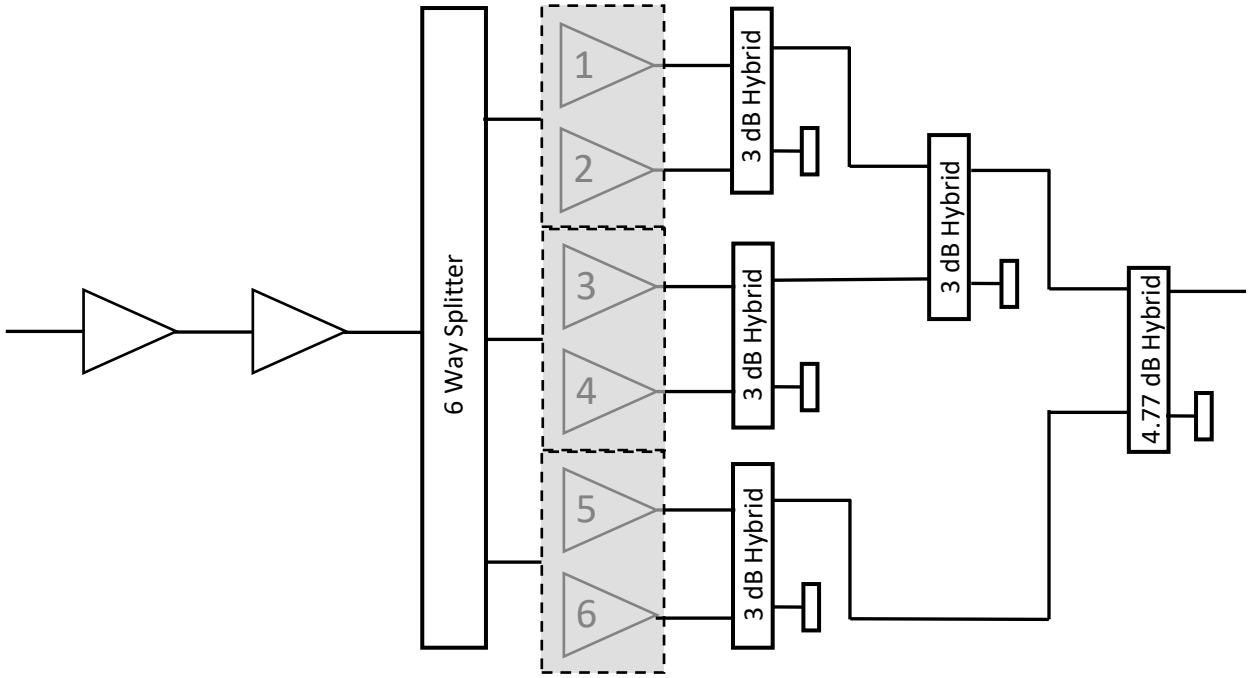
Transmitter Designs – 5 combiner

Benefits

- Fits inside 19” chassis
- Better “system” design
- Lower lost in event of failure
- Lower 2nd harmonic

Disadvantages

- Lower output per chassis (800W)
- 5 hybrids
- Non-symmetrical hybrid (4.77dB)



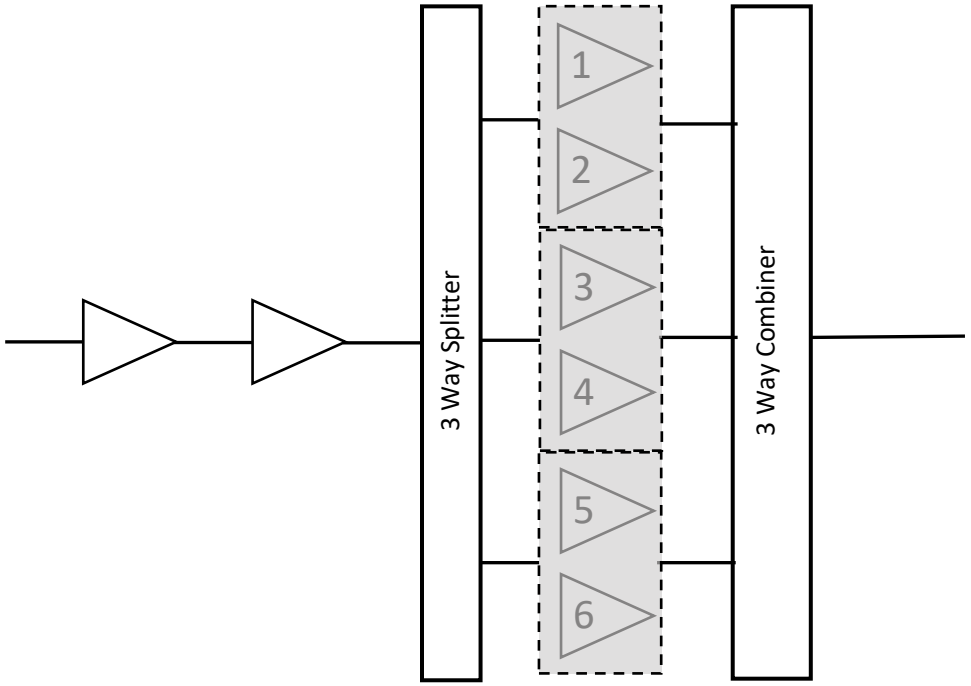
Elenos Group Innovation – 3-way splitter/combiner

Benefits

- Fits inside 19” chassis
- Better “system” design
- Fewer combiners
- Higher efficiency
- Lower loss in event of failure
- Lower 2nd harmonic
- Improved turnaround loss

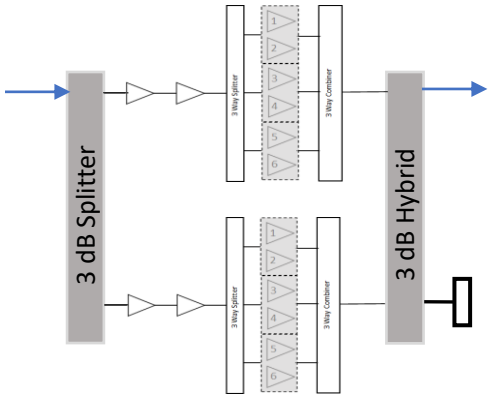
Disadvantages

- Lower output per chassis (800W)

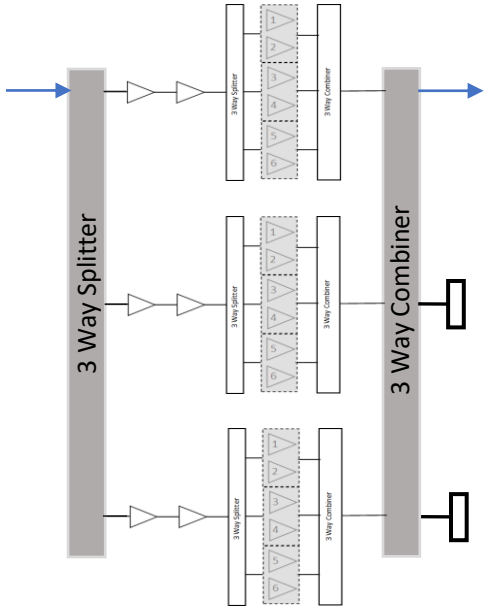


Elenos Group - transmitter design

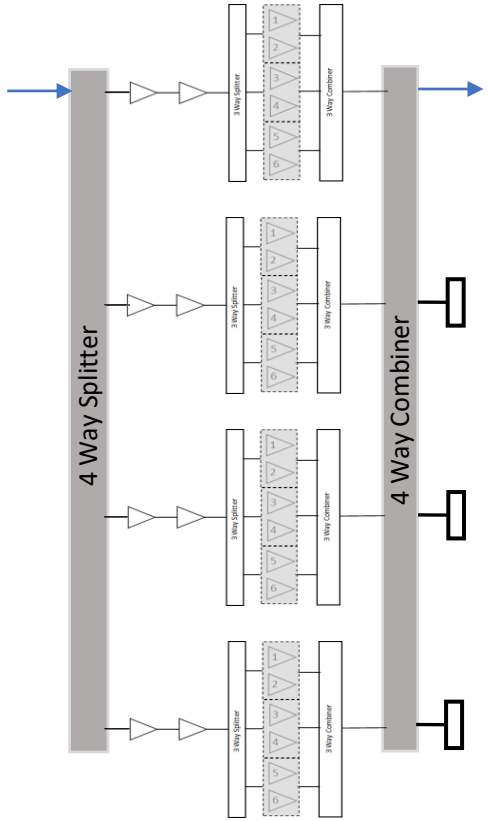
1200W*



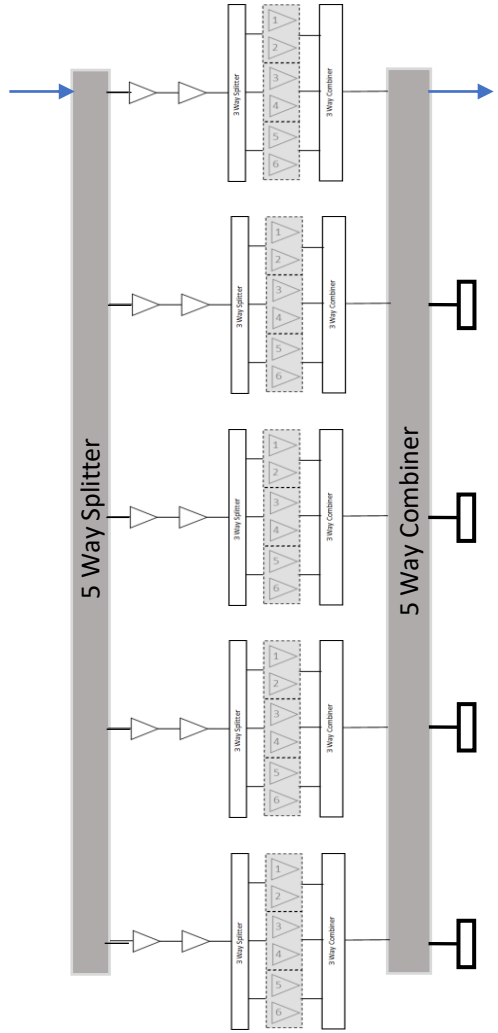
1800W*



2400W*



3000W*

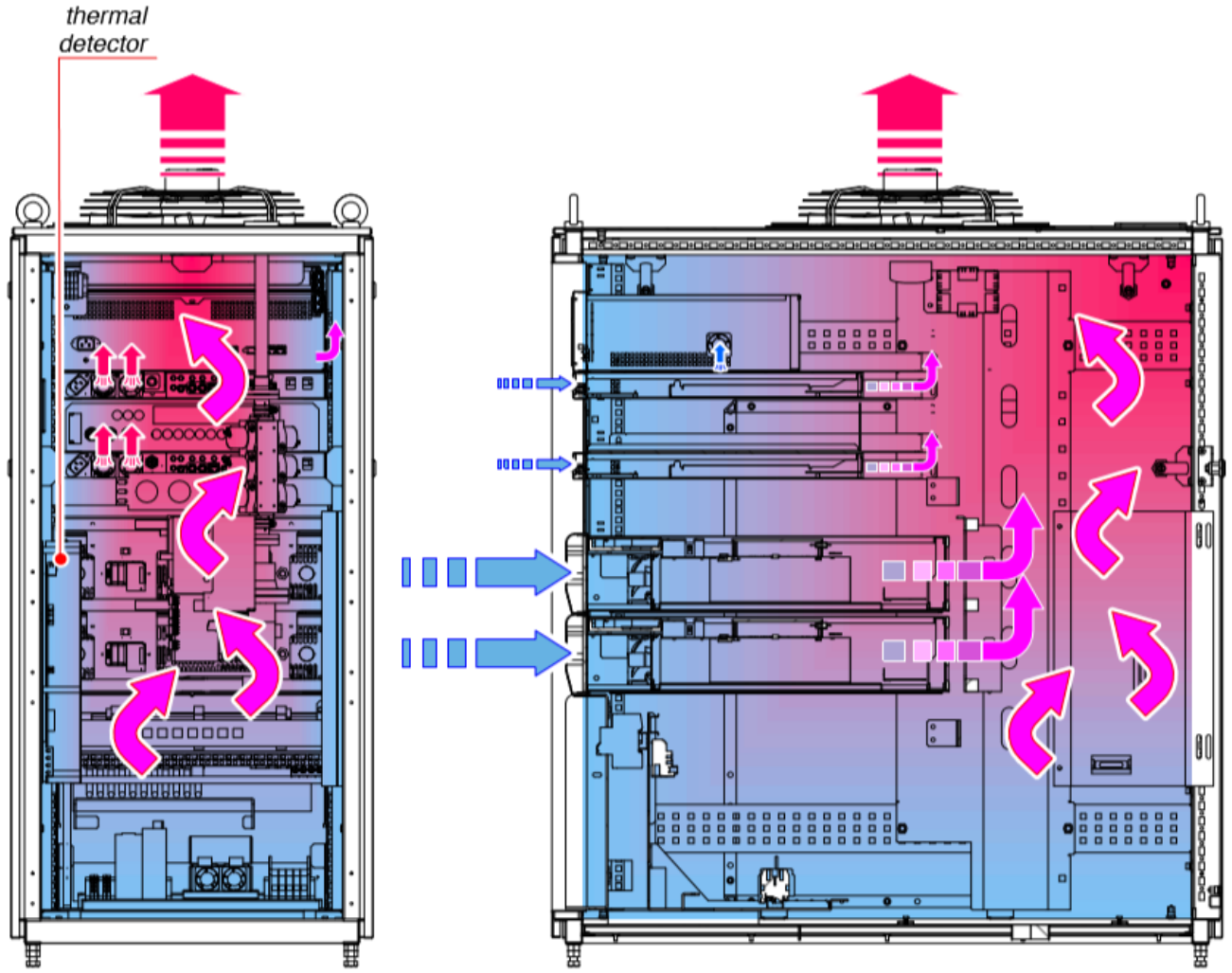


* OFDM standard (ATSC3.0, DVB-T, ISDB-T) measured before the output band pass filter) ATSC1 power 20% higher.

Elenos Group - transmitter design

Benefits

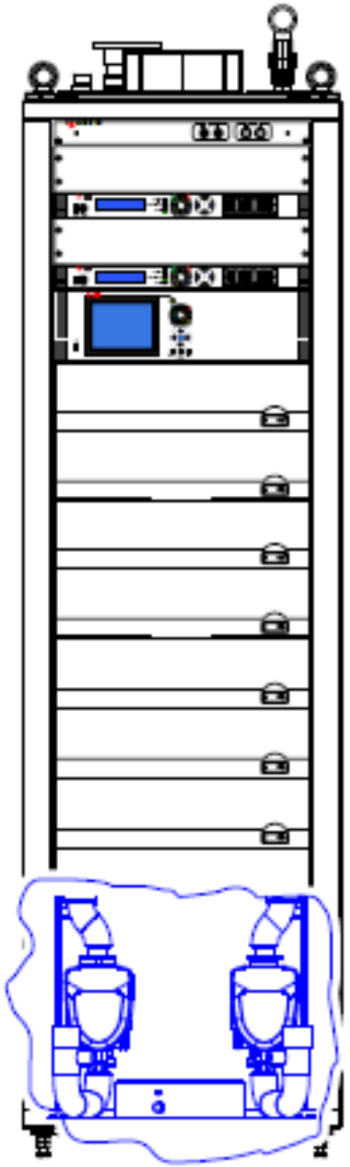
- Standard 19” chassis
- Less heat concentration
- More air flow – easier to remove heat from cabinet
- Reduces metal migration



Elenos Group - transmitter design

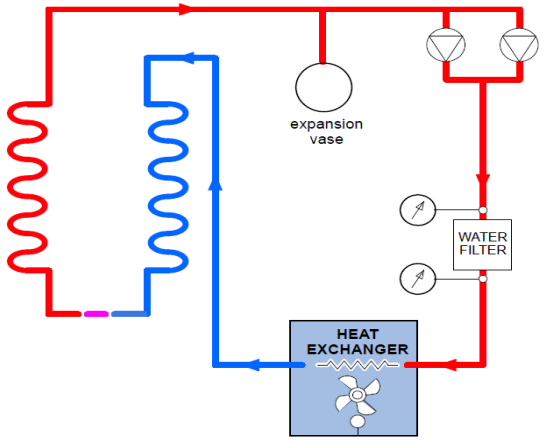
Liquid Cooling

- Not restricted by air flow demands
- Double sided system
- Six pallets instead of 3
- 1200W per chassis

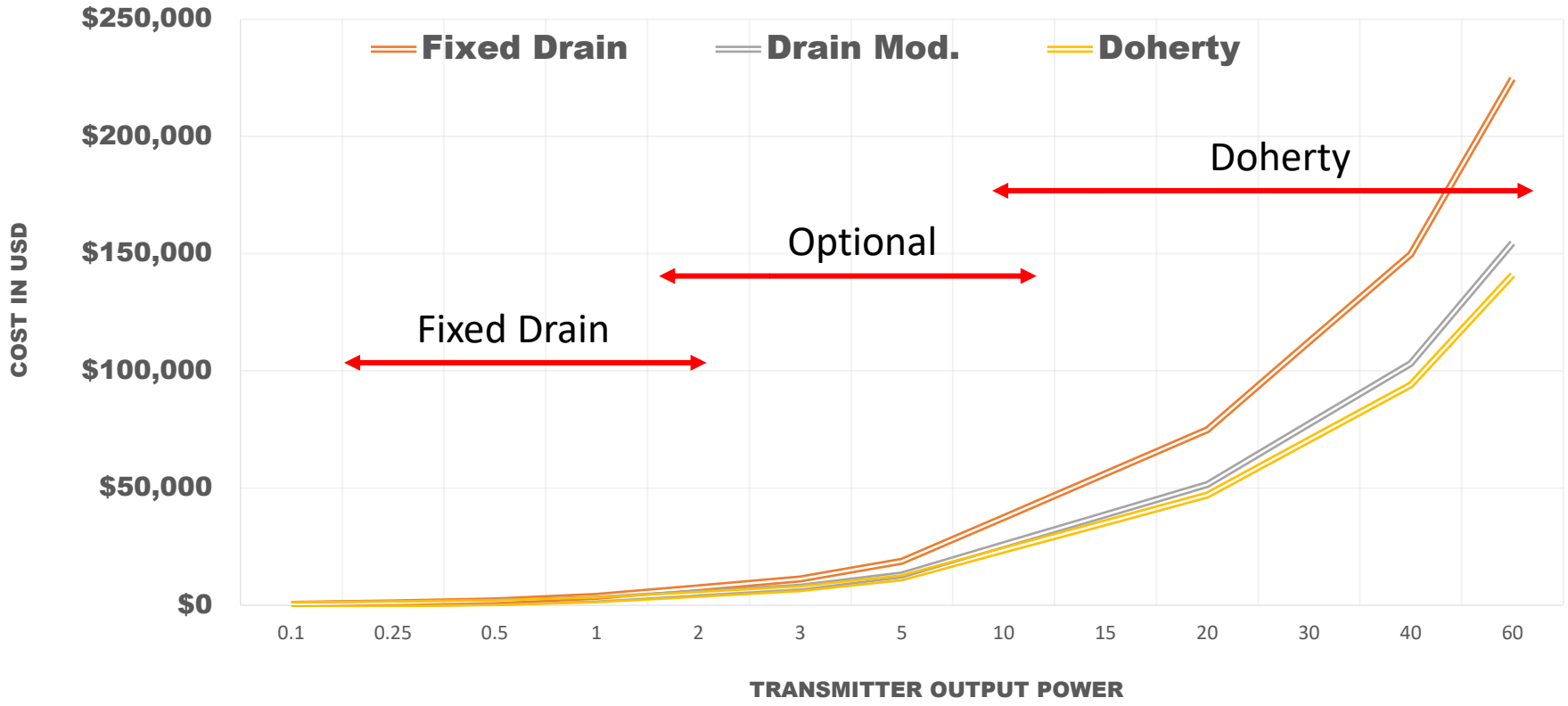


Power Levels of:

- 1200W
- 2400W
- 3600W
- 4800W
- 7200W
- 9600W



Operating cost analysis



Based on 24 hours 365 days per year operation, $0.1 KW/H electricity cost.

Elenos Group Doherty design - Summary

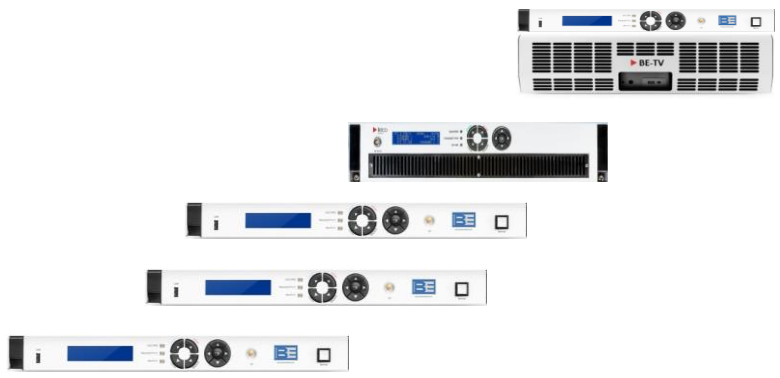
- Average Doherty amplifier efficiency versus conventional AB over UHF band
  - 50% versus 25% for standard Class AB (Drain)
- Total transmitter energy efficiency
  - 3kW transmitter efficiency > 45%
- Less heat dissipated on transistors
  - Higher MTBF and thus higher reliability
  - A reduction of 20 degrees C in junction temperature represents four times more in reliability
- Broadband through a new design by Ampelon that covers half of the entire UHF band (or all of the UHF band in North America)
- Extra savings due to simpler cooling system and less internal fans

Elenos Group TV Transmitters

Compact
VHF Band I
VHF Band III
UHF Band

VHF Band III
UHF Band

VHF Band III
UHF Band



1W 10W 100W 200W 600W 1200W 4800W 1200W 7200W

Summary

- Greater efficiency is required in broadcast transmitters.
- The Doherty topology the choice of almost all broadcast manufacturers due to its performance, reliability and simplicity.
- Several Doherty architectures have been examined so the tradeoffs can be weighed.
- BLF888E supports wideband Doherty and raises the amplifier efficiency to greater than 50% when configured in three UHF bands.
- The asymmetric variant provides higher efficiency and obtains higher output power than previous versions.
- There are possible future concepts that may provide greater efficiency such as the novel 3-Way Doherty, which could give an increase in efficiency but at the cost of a significant increase in complexity.
- Current BLF888E designs based on a three (2) pallet design are commonplace and provide a broadband solution with optimum in efficiency, reliability and ease of use.

Thank you

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