ELECTRONICS & TECHNOLOGY

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S Band RADAR Power Amplifier

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Outline

- ARELIS at a Glance
- Major Product Features
- Architecture
- Detailed Design
- Measurements
- Conclusions
ARELIS at a Glance

- Cons. turnover 2017: 17 M€
- Personnel: 135
  - R&D: 45
  - Production: 70

Fields of Expertise
- RF & Microwave
- Energy Conversion
- Aeronautics & Defense
- High-Technology fabrication
- Electronics & microelectronics

Detection
Interception

Communications
Transmission

Energy
Control & Conversion

Test & Measurement

NORMANDIE (55 p.)
LORRAINE (80 p.)

R&D  Production
Power amplifier module for pulsed RADAR application

Outputs of several amplifier modules will be combined for higher power levels (power scaling)

- 2 integrated amplifier channels, 1 common input
- Channel peak output power level 935 W min ... 1400 W max
- Pulse width 0.5 ... 150 µs, duty cycle ≤ 12%
- Frequency band 2700 ... 3100 MHz
- Pulse to pulse stability ≥ 68 dB
- Control of output spectrum emission
- Control of phase between the channels and between the modules
- Maintenance friendly (amplifier pallets, ventilator)
- Control RS485 and Ethernet
• 4 pallets per channel, graceful degradation, multiple transistors
  • Transistor choice: LDMOS stability known, mature technology, no negative voltage
  • 150W, 32V, NXP AFT31150N
• Combiner in suspended stripline (air stripline) for loss reduction
• Forced cooling by ventilation (50/60 Hz)
• Heatsink to spread and guide the heat

Junction temperature < 80°C
Heatsink is central element for common ground and thermal dissipation:

- Double sided mounting to accommodate all units
- Top side: power supply, control & command unit, LLA
- Bottom side: drivers, power splitters, HP pallets, combiners
The power supply is distributed over a busbar.

Pallet glides over power supply connector (RADSOK) and plugs into the combiner (P-SMP at pallet output and at combiner input).

Power supply connection established by the insertion of a pin.
Source / load pull measurement:
- Very low impedances expected
  → Impedance transformation
- Klopfenstein transformer
- TRL calibration kit

\[ Z_0 = 50 \, \Omega \quad Z_0' = 6.6 \, \Omega \]
Source / load pull results

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Gamma</th>
<th>Source</th>
<th>Gamma</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7</td>
<td>0.92</td>
<td>-170.2</td>
<td>0.85</td>
<td>-171.5</td>
</tr>
<tr>
<td>2.8</td>
<td>0.92</td>
<td>-170.0</td>
<td>0.87</td>
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<tr>
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<td>0.88</td>
<td>-167.0</td>
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<td>-172.4</td>
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<td>3.0</td>
<td>0.80</td>
<td>-170.0</td>
<td>0.87</td>
<td>-172.4</td>
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<td>3.1</td>
<td>0.81</td>
<td>-173.0</td>
<td>0.88</td>
<td>-172.0</td>
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</tbody>
</table>
Evaluation Board Development
Fabricated Pallets

HPA - Output Power @ $P_{IN} = 25\, \text{W}, V_{DD} = 32\, \text{V}$

HPA - Drain Efficiency @ $P_{IN} = 25\, \text{W}, V_{DD} = 32\, \text{V}$
RF envelope pulse shaping is necessary to reduce the occupied spectral bandwidth.

A programmable envelope signal circuit to modulate the gate voltage was designed to achieve optimization and adaptation to different situations.
Programmable pulse shaping signal allows

- Sector blanking
- Sector power reduction

e.g. interference problem
● Requirement: alignment of channel phase and module phase with closed lid (≤ ±10°)

● Phase variation of power pallets is not linear: phase shifter resolution better than 5° is needed

● COTS offer up to 6 bit phase shifters: 5.625°

● Implementation of a vector modulator programmed as phase shifter
Phase Shifter

Phase resolution with 12 bit DAC: 0.028°

\[ I'^2 + Q'^2 = 1 \]

\[ I' = \frac{1}{\sqrt{1 + (\tan \varphi)^2}} \]

\[ Q' = \sqrt{1 - I'^2} \]
Pulse to pulse stability and stability within the pulse

- Important that the power supply voltage level is highly repeatable from pulse to pulse and that it stays rather constant during the pulse

Synchronization of the power supply to the system clock

→ RF pulse start and stop are synchronized
→ high voltage repeatability

Voltage control is stopped during the pulse

- Low ESR capacitor bank delivers the necessary power during the pulse
→ no contamination of the drain supply and of the pulse
Measurements

100μs, 12%, 8 pulses

100μs, 10%

Frequency [GHz]

Power [W]

Stability [dB]
Measurements

\[ \Delta A = 0.2 \, \text{dB} \]

\[ \Delta \phi = 2^\circ \]
A high-power amplifier module in a 19" rackmount enclosure with the following features was developed:

- 2 output channels with pulsed peak output power of ≤ 1400 W
- Frequency band 2700 ... 3100 MHz
- Possibility of sector blanking and/or sector power reduction
- Highly stable and repeatable pulse form
- Control of output spectrum emission
- Control of phase between the channels and between the modules
- Maintenance: amplifier pallets and ventilator can be exchanged
- Control by RS485 (pulse control) and Ethernet (maintenance)