# LDMOS Power Amplifiers for 23 cm – 150 W to 1 kW

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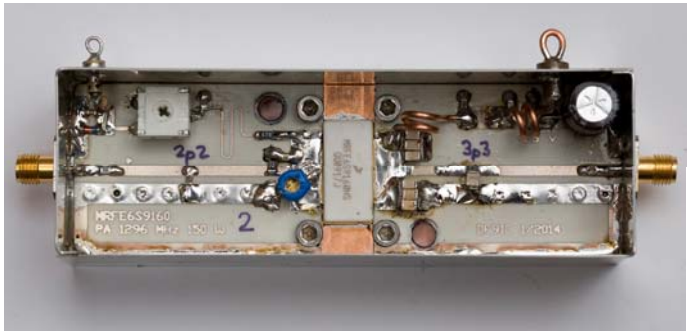


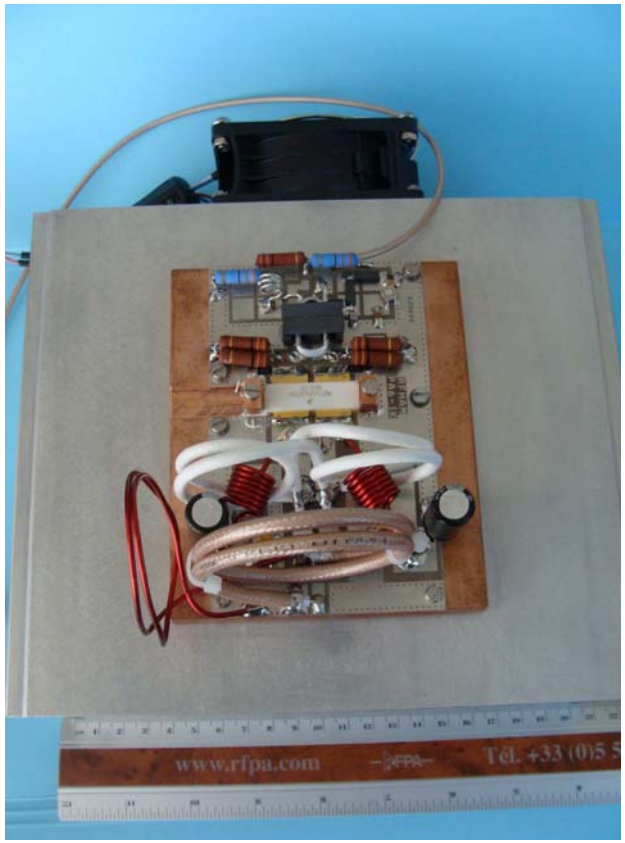
# LDMOS: „full legal power“ ?

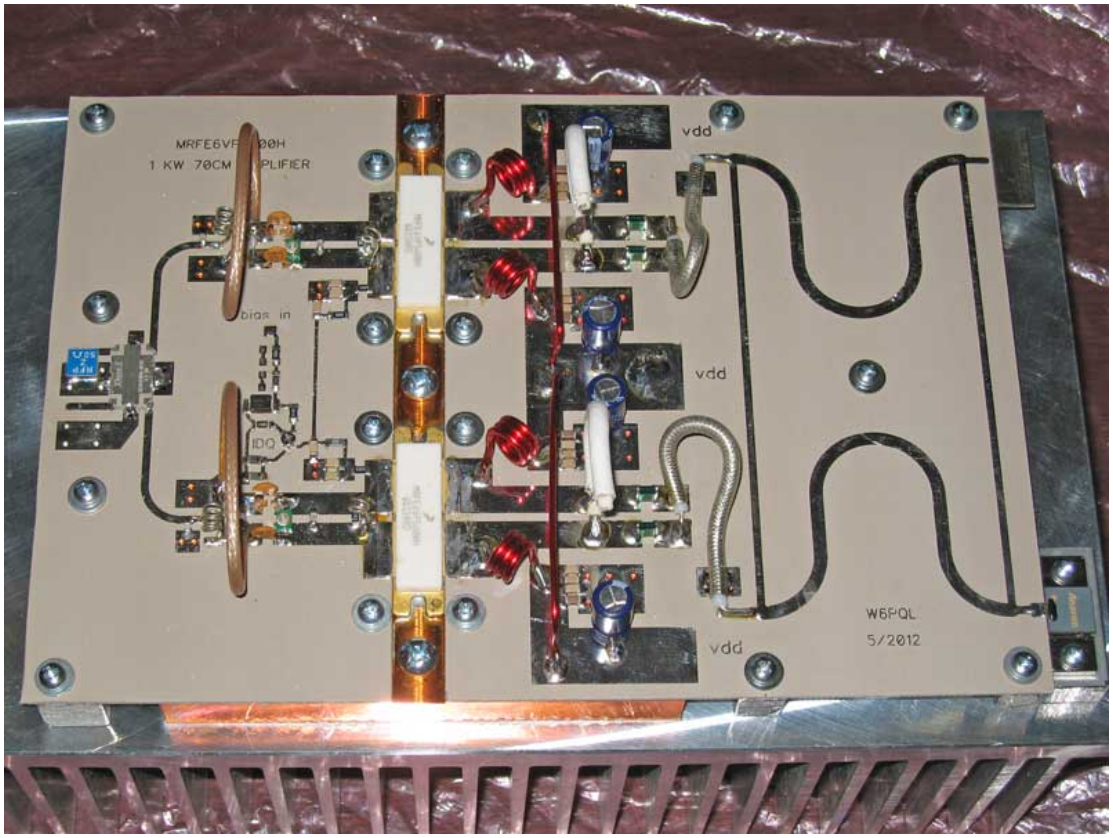
- Popular LDMOS amplifier modules (pallets):

- 144 MHz: 1 kW LDMOS MRFE6VP61K25
- 432 MHz: 500 W MRFE6VP5600
- 1296 MHz: 150 W 2 x MRF286

# Pallets without a shielding box

- OK for a prototype – but not for a product



# PAs based on such pallets

- Imperfectly shielded outer enclosures


# Module concept

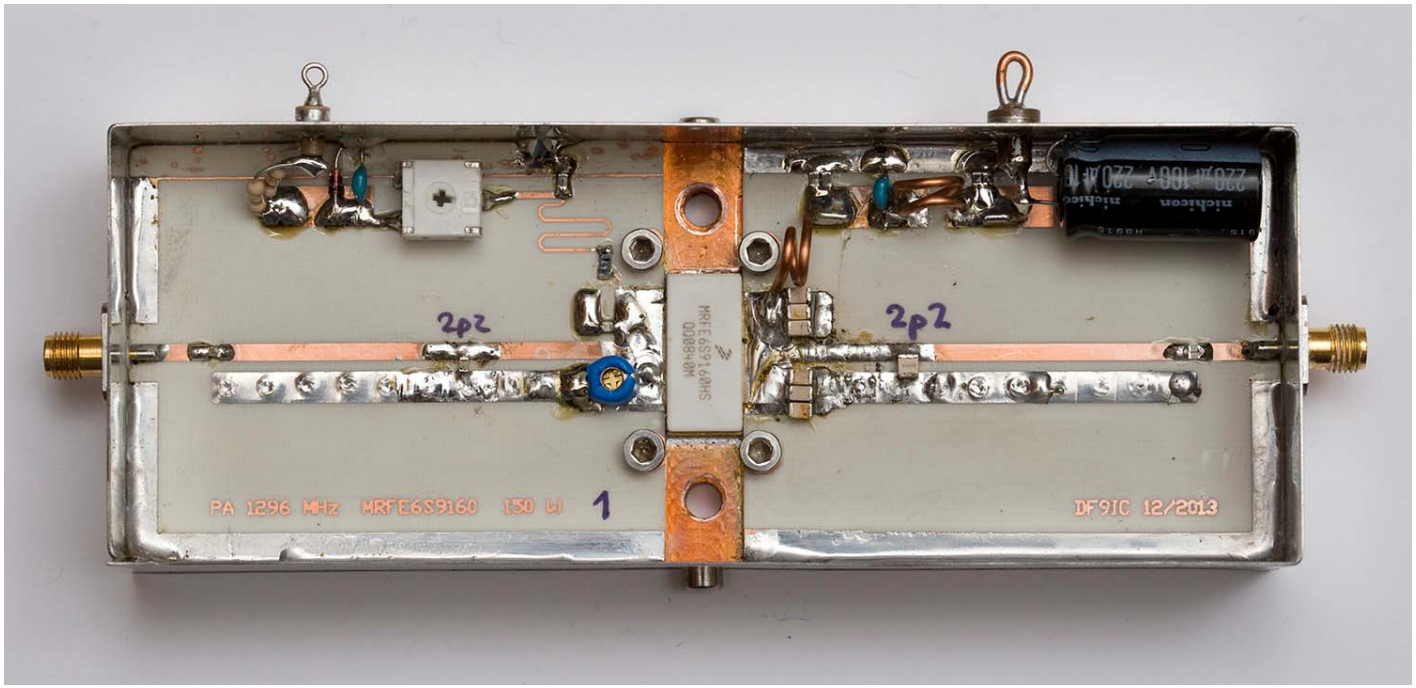
- Use of a cheap shielding box, to be integrated with a large heat spreader
- Low cost LDMOS surplus transistors (from cellular, not broadcast market)
- Expensive components only where really needed (but reliable design nevertheless)

# Concept of the box

- Transistor is installed on a copper heat spreader
- Frame and cover from tin plated material (possibly joint with the heat spreader)
- PCB fixed with screws to the copper and soldered to the tin plate frame

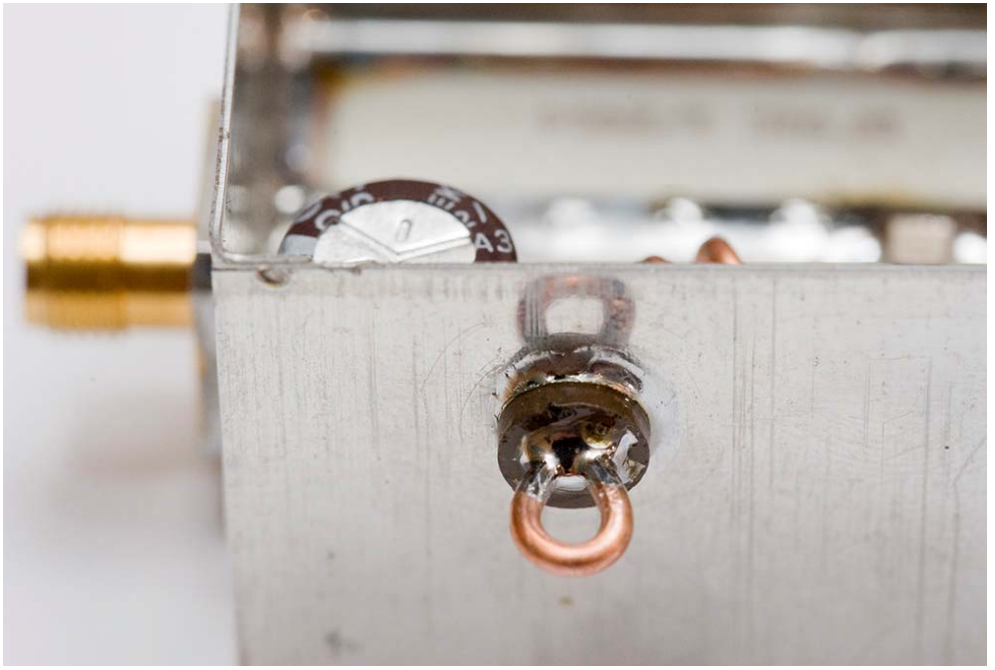
# Concept of the box

- Two separate PCBs for input and output circuits
- As few through-holes as possible



# High-current feedthrough

- Feedthrough capacitors for 10-25 A



# Which transistors for 1296 MHz?

- Cellular transistors for 900 MHz 60 W:
  MFR9060, MRF6S9060, MRF286 etc.
  (without internal pre-matching)
- Broadcast/ISM transistors for 1300/1400 MHz
  (internally pre-matched):
  PTF141501E 150 W 28 V
  BLF6G13L-250P 250 W 50 V
- Cellular transistors for 900 MHz 125...160 W:
  MRFE6S9125, MRFE6S9135, MRFE6S9160
  (only pre-matched at the input)

# My prefered 23 cm PA transistor

**Freescale Semiconductor**
Technical Data

Document Number: MRFE6S9160H
Rev. 1, 12/2008

RoHS

## RF Power Field Effect Transistors

N-Channel Enhancement-Mode Lateral MOSFETs

Designed for N-CDMA, GSM and GSM EDGE base station applications with frequencies from 865 to 960 MHz. Suitable for multicarrier amplifier applications.

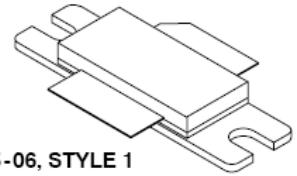
- Typical Single-Carrier N-CDMA. Performance @ 880 MHz: $V_{DD}$ = 28 Volts, $I_{DQ}$ = 1200 mA, $P_{out}$ = 35 Watts Avg., IS-95 CDMA (Pilot, Sync, Paging, Traffic Codes 8 Through 13) Channel Bandwidth = 1.2288 MHz. PAR = 9.8 dB @ 0.01% Probability on CCDF.
  - Power Gain — 21 dB
  - Drain Efficiency — 31%
  - ACPR @ 750 kHz Offset — -46.8 dBc in 30 kHz Bandwidth
- Capable of Handling 10:1 VSWR, @ 32 Vdc, 880 MHz, 3 dB Overdrive, Designed for Enhanced Ruggedness.

**Features**

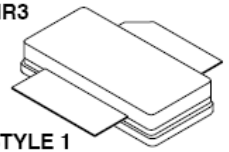
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Internally Matched for Ease of Use
- Qualified Up to a Maximum of 32 $V_{DD}$ Operation
- Integrated ESD Protection
- RoHS Compliant
- In Tape and Reel. R3 Suffix = 250 Units per 56 mm, 13 inch Reel.

**MRFE6S9160HR3**
**MRFE6S9160HSR3**

**880 MHz, 35 W AVG., 28 V**
**SINGLE N-CDMA**
**LATERAL N-CHANNEL**
**RF POWER MOSFETs**

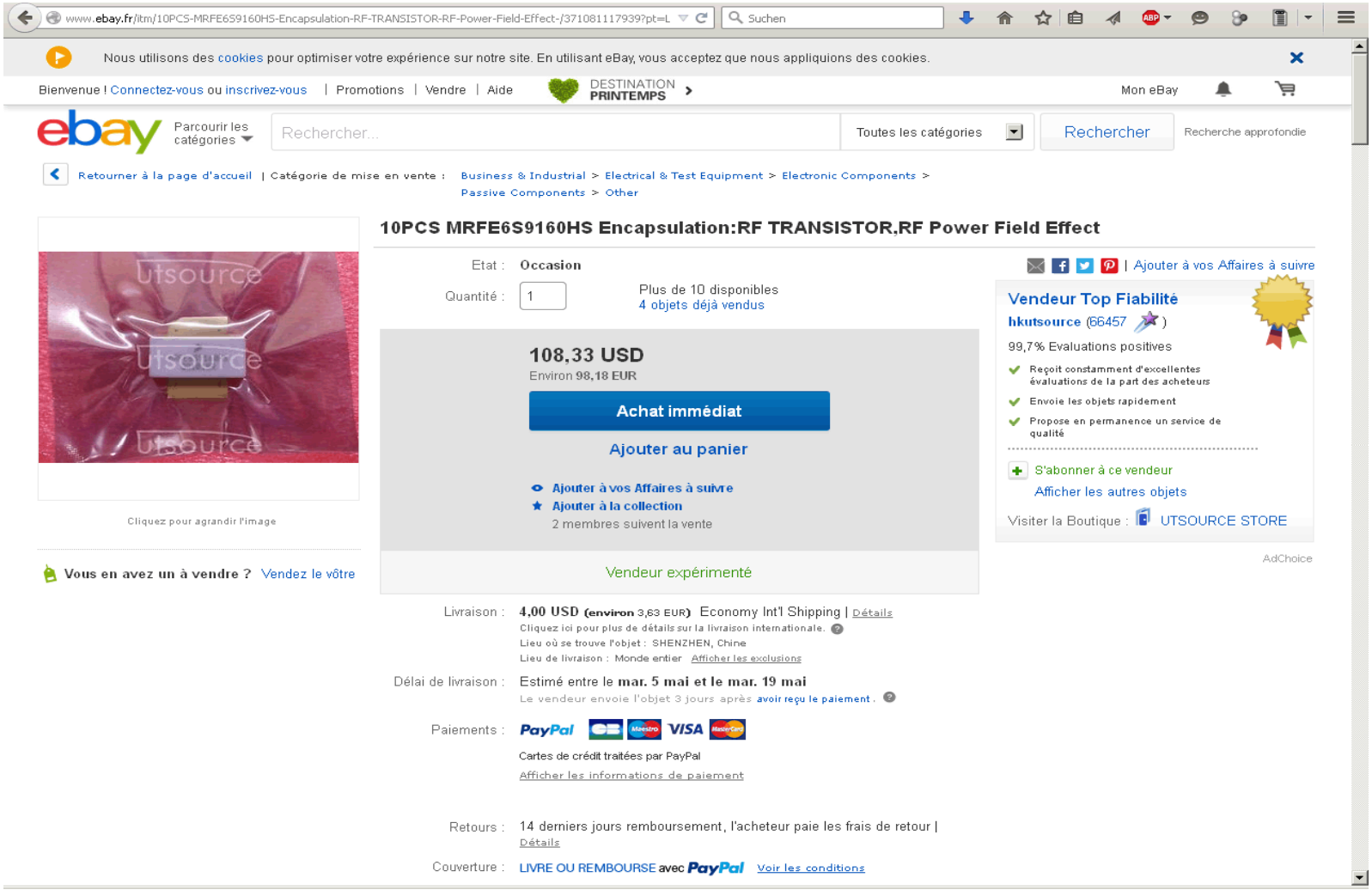


**CASE 465-06, STYLE 1**
**NI-780**
**MRFE6S9160HR3**



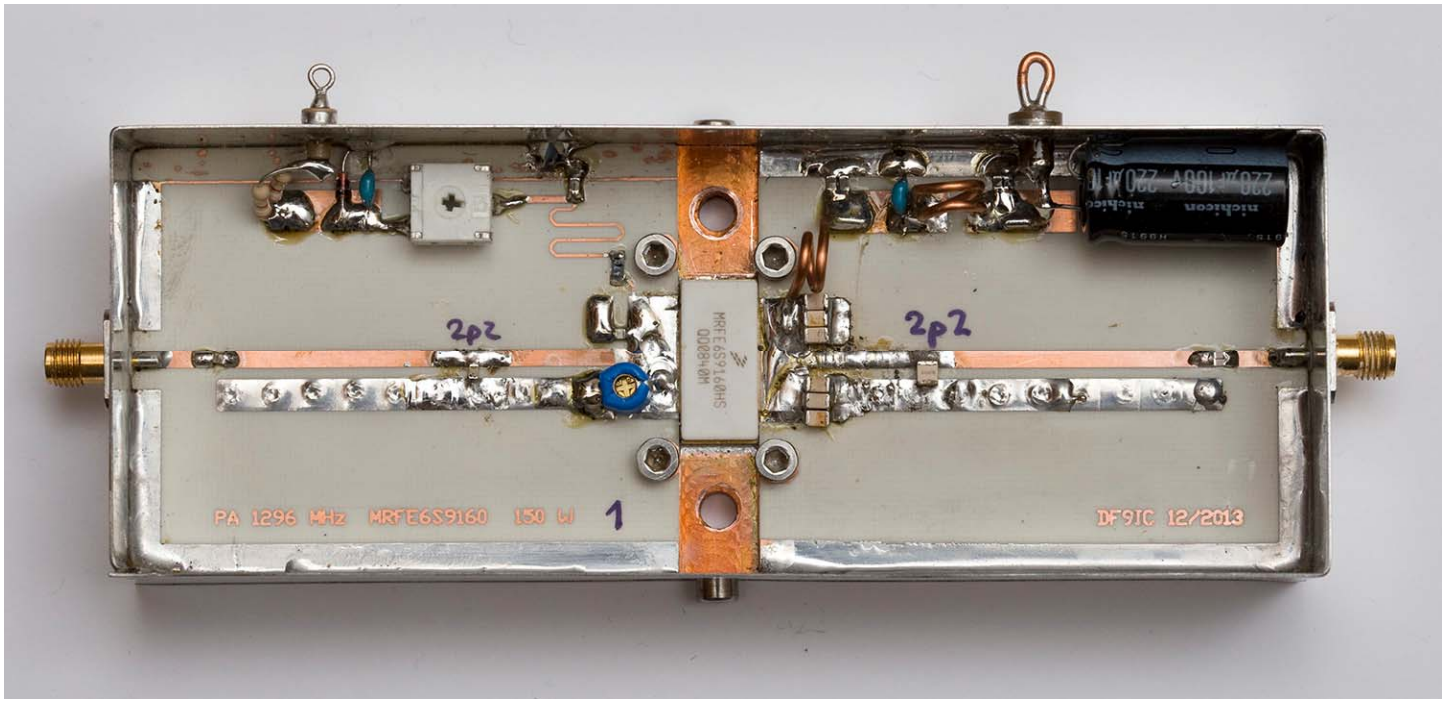
**CASE 465A-06, STYLE 1**
**NI-780S**
**MRFE6S9160HSR3**

# MRFE6S9160HS – 10 EUR



# PA 1296 MHz: the prototype

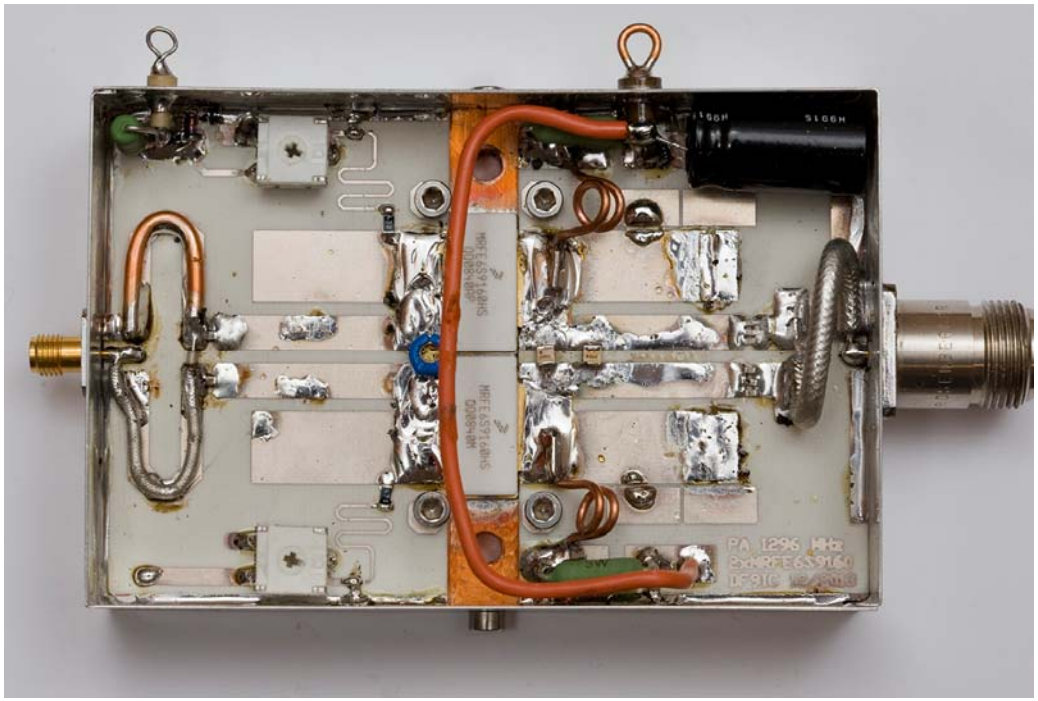
- Let‘s try it !




With sucess: 150 W output power at 19...20 dB gain

# PA 1296 MHz: push-pull ?

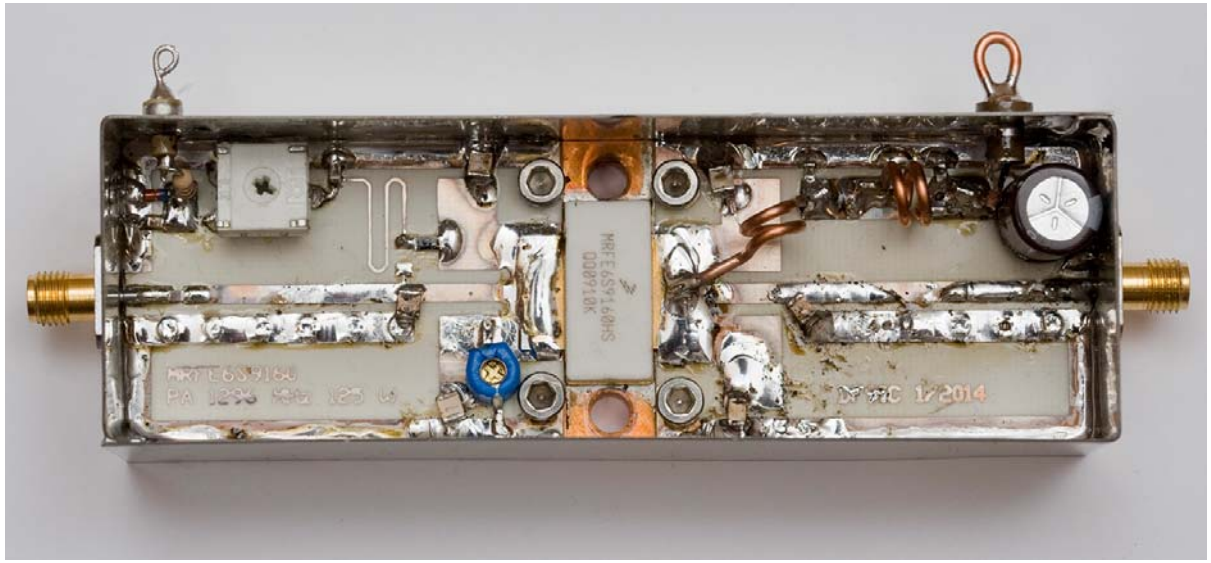
- Experiment of a push-pull amplifier:



Poor result: assymetric behaviour, low efficiency.

# PA 1296 MHz: MRFE6S9160

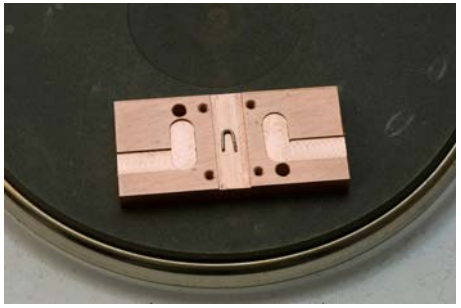
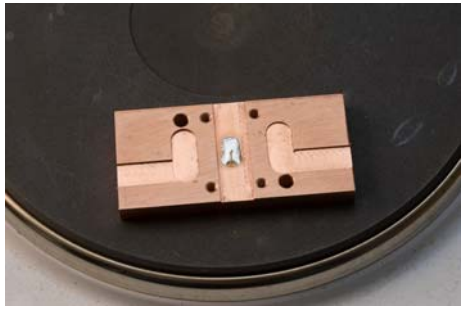
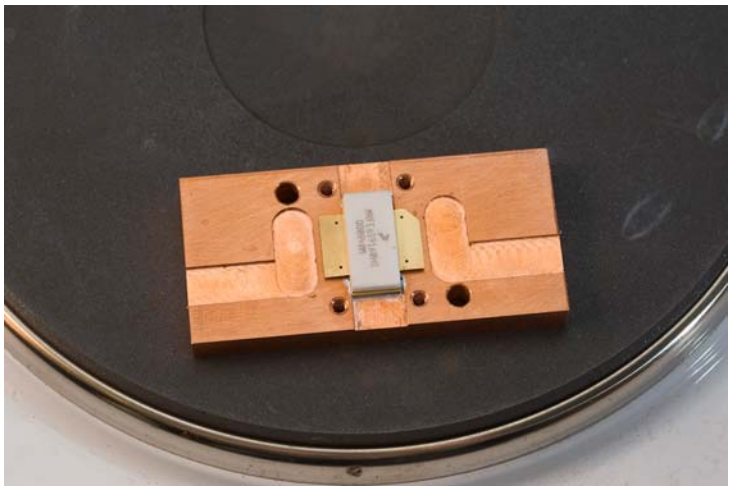
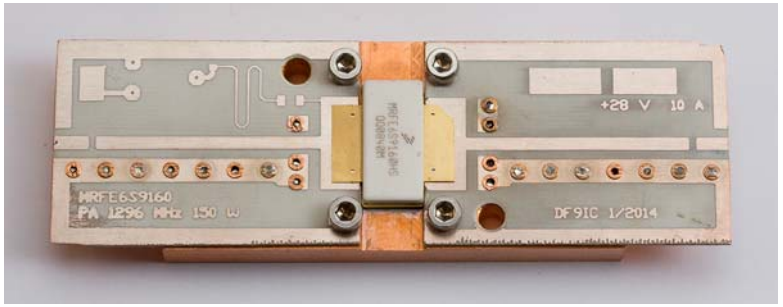
- Design of an amplifier without through-holes close to the transistor:



Result: similar to the first prototype, but critical contacts at the PCB edges

# PA 1296 MHz: MRFE6S9160

- Soldering of the transistor to the heat spreader: first trials with tin-lead solder

# PA 1296 MHz: MRFE6S9160

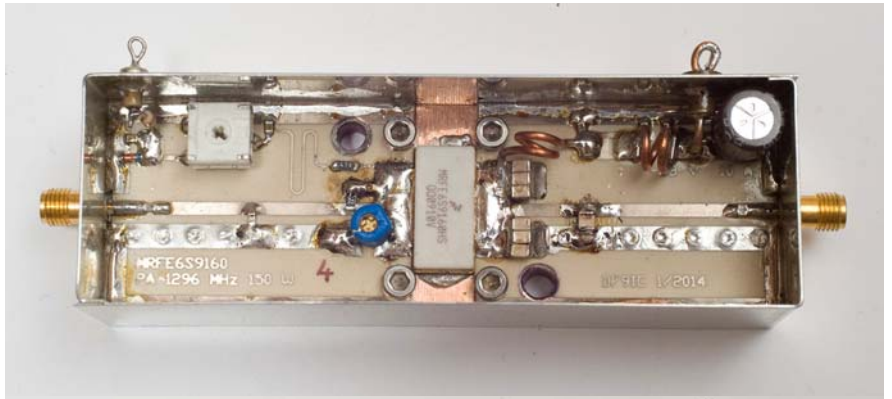
- Result: this process was working, but caused several failures too (transistors had reduced transconductance)
- Then: use of a low temperature SMD solder paste - 138°C – Edsyn CR11 Sn42Bi58 (tin – bismuth)

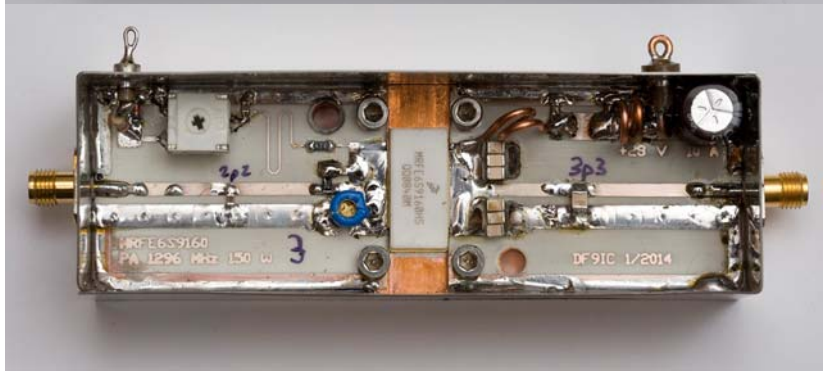

- Slowly heating and cooling the pallets

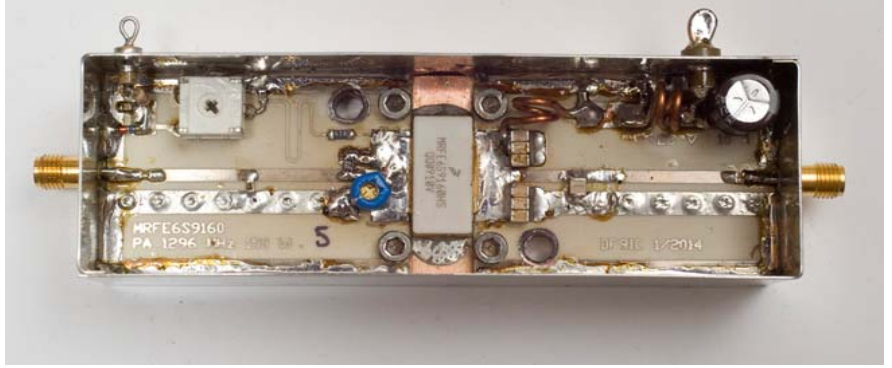
  => no more failures (from 20 transistors)!

# PA 1 x MRFE6S9160 RO4003

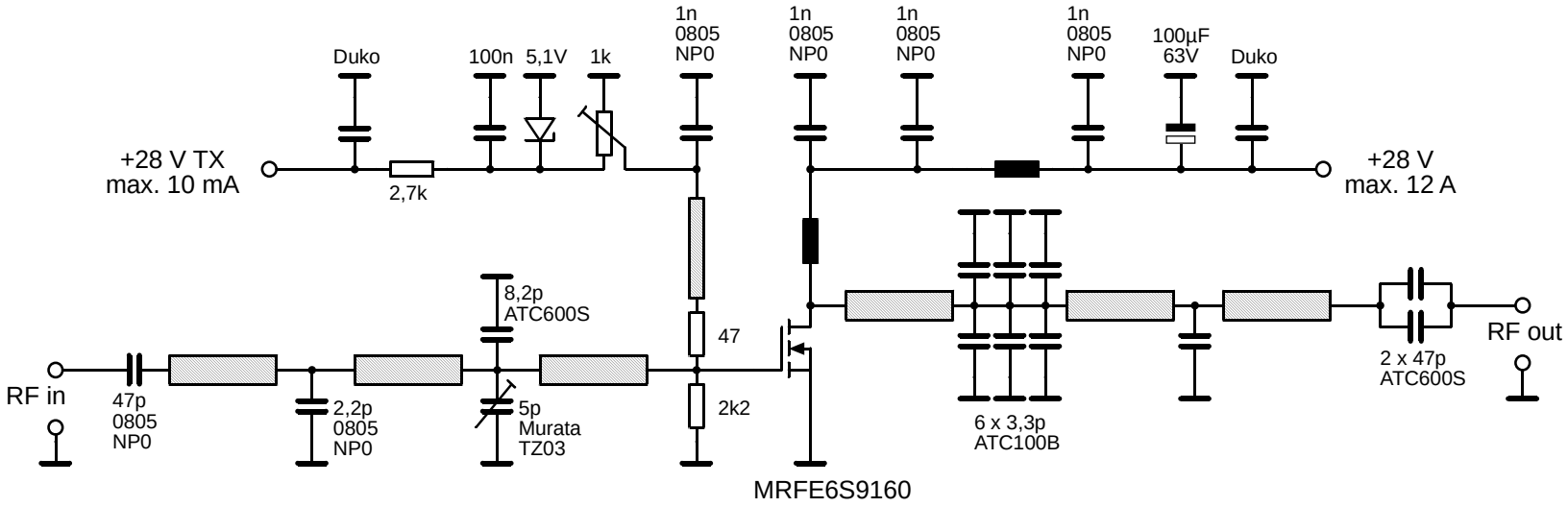
- Design verification with 4 new prototypes – all achieve >150 W at 28 V

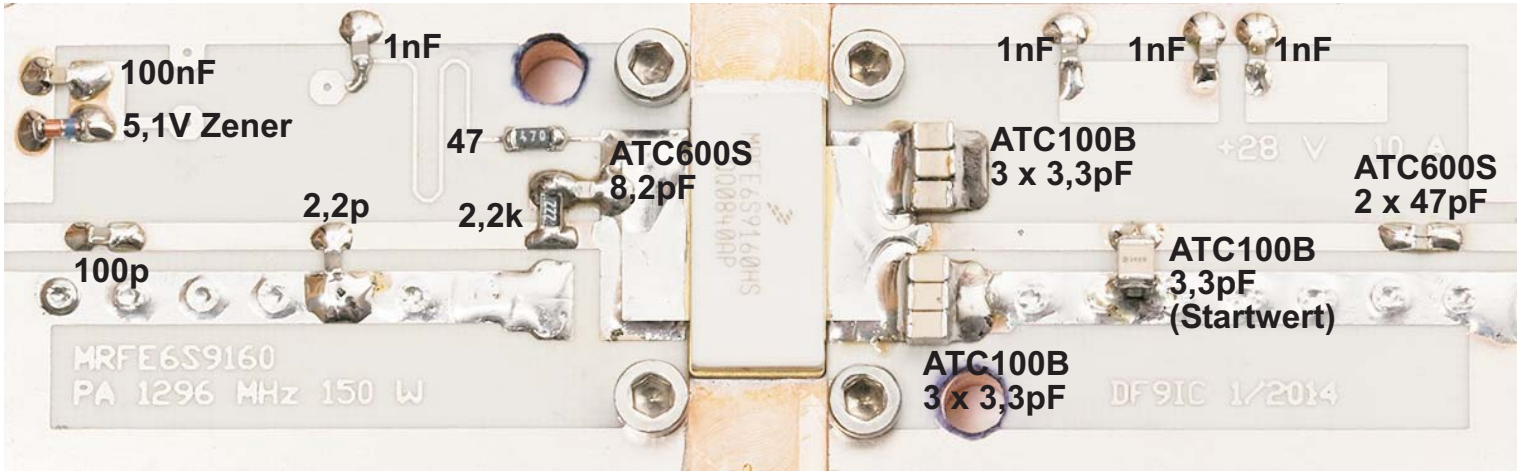



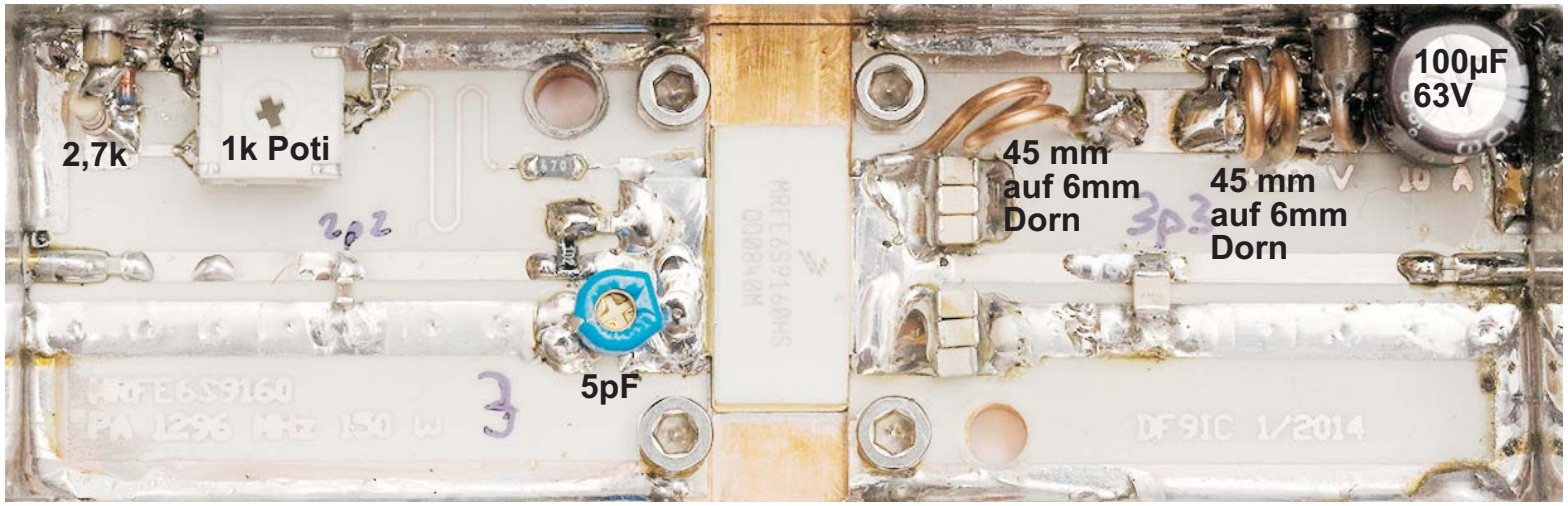



# PA 1 x MRFE6S9160 RO4003

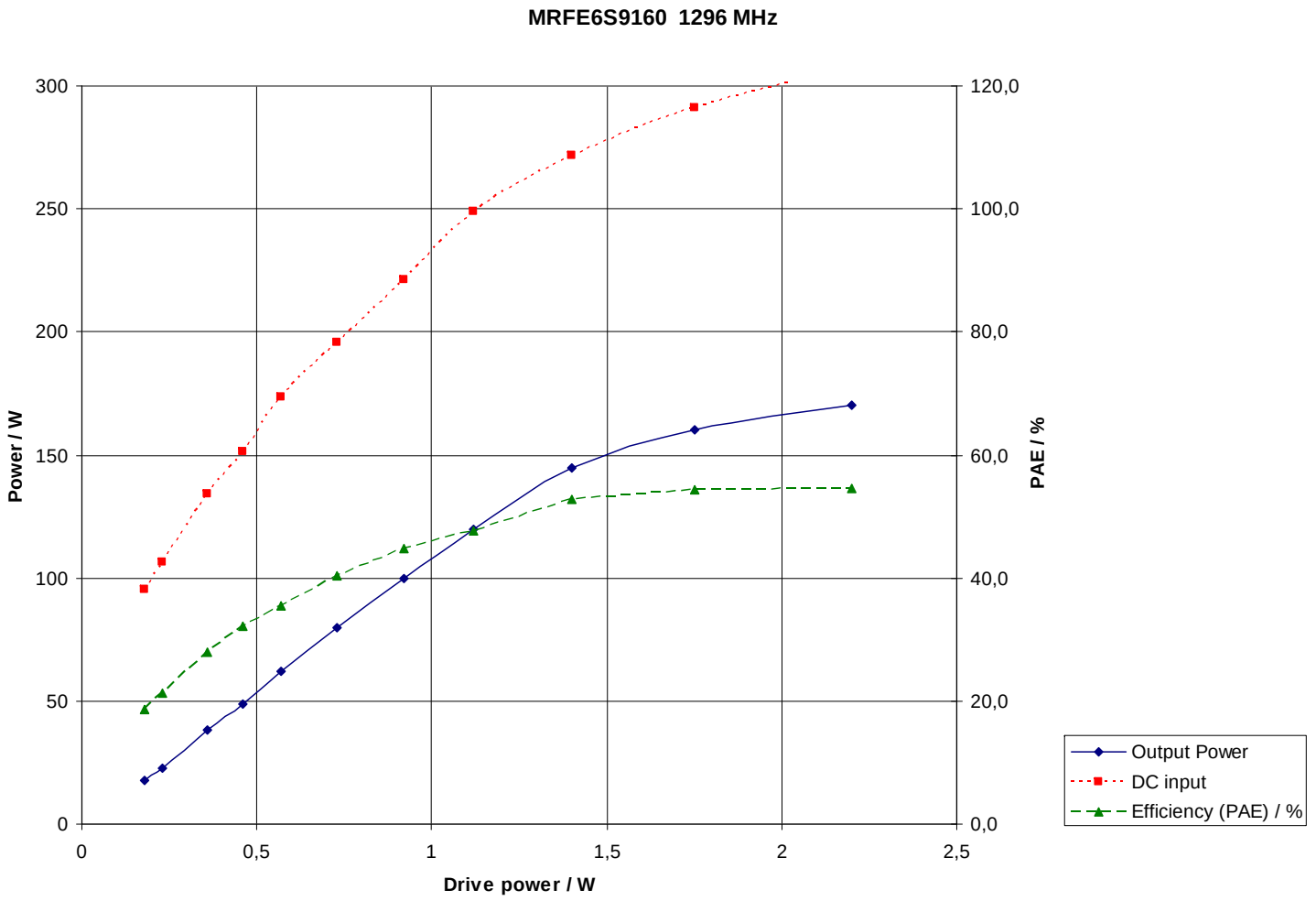


# PA 1 x MRFE6S9160 RO4003



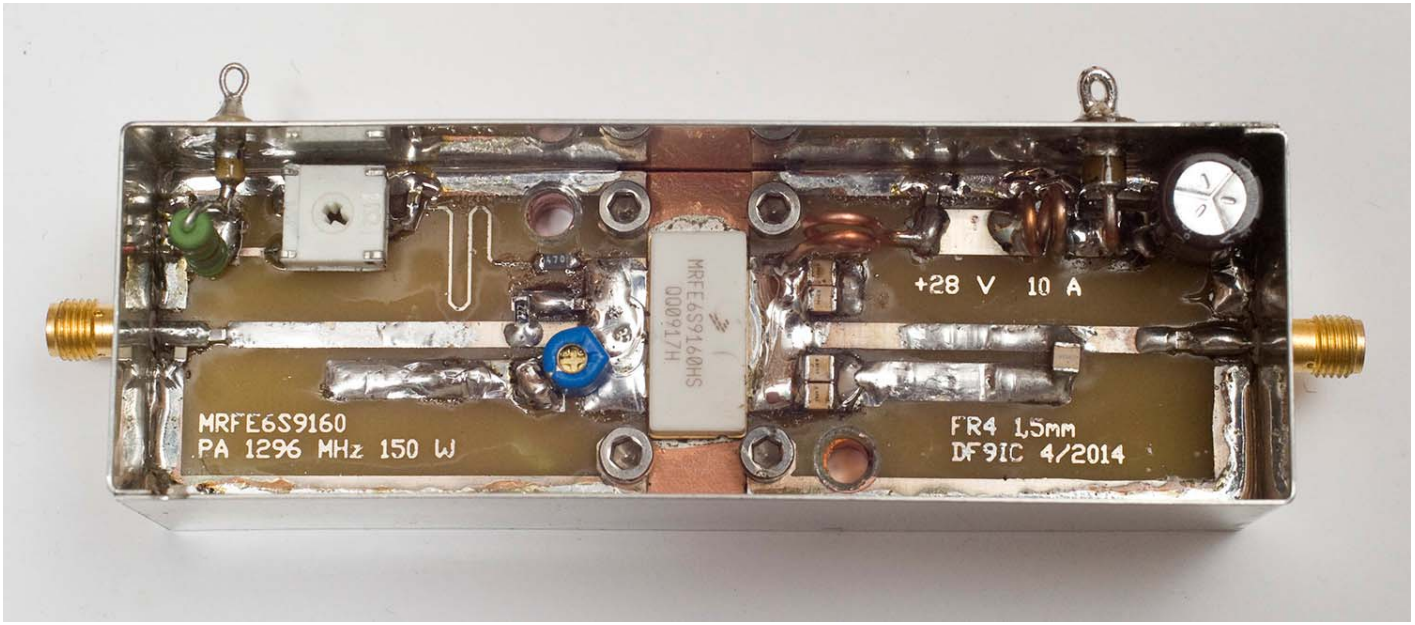



# PA 1 x MRFE6S9160 RO4003



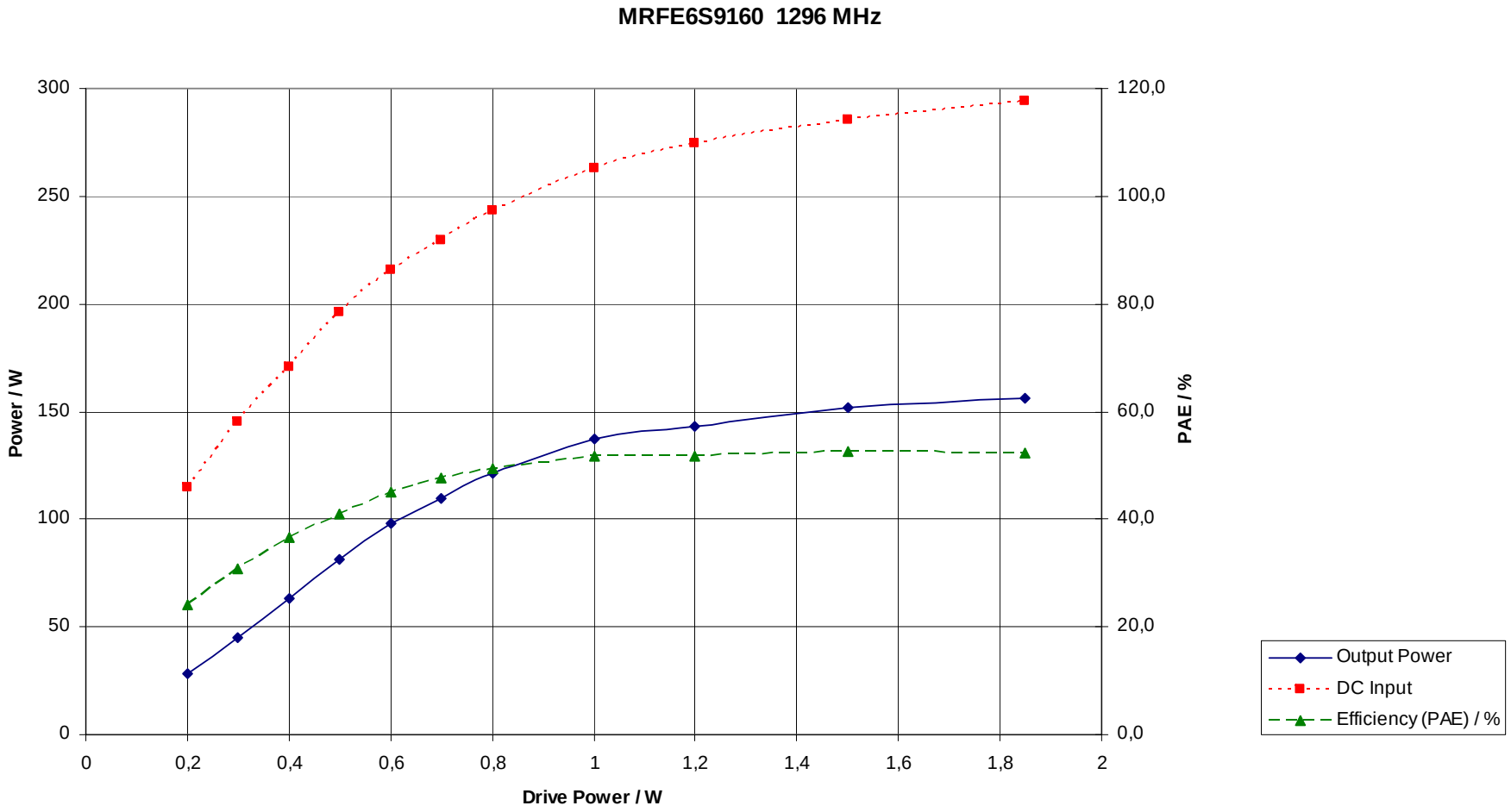
# PA 1 x MRFE6S9160 FR4

- Another experiment on 1.5 mm FR4 substrate, as RO4003 is difficult to buy in small quantities



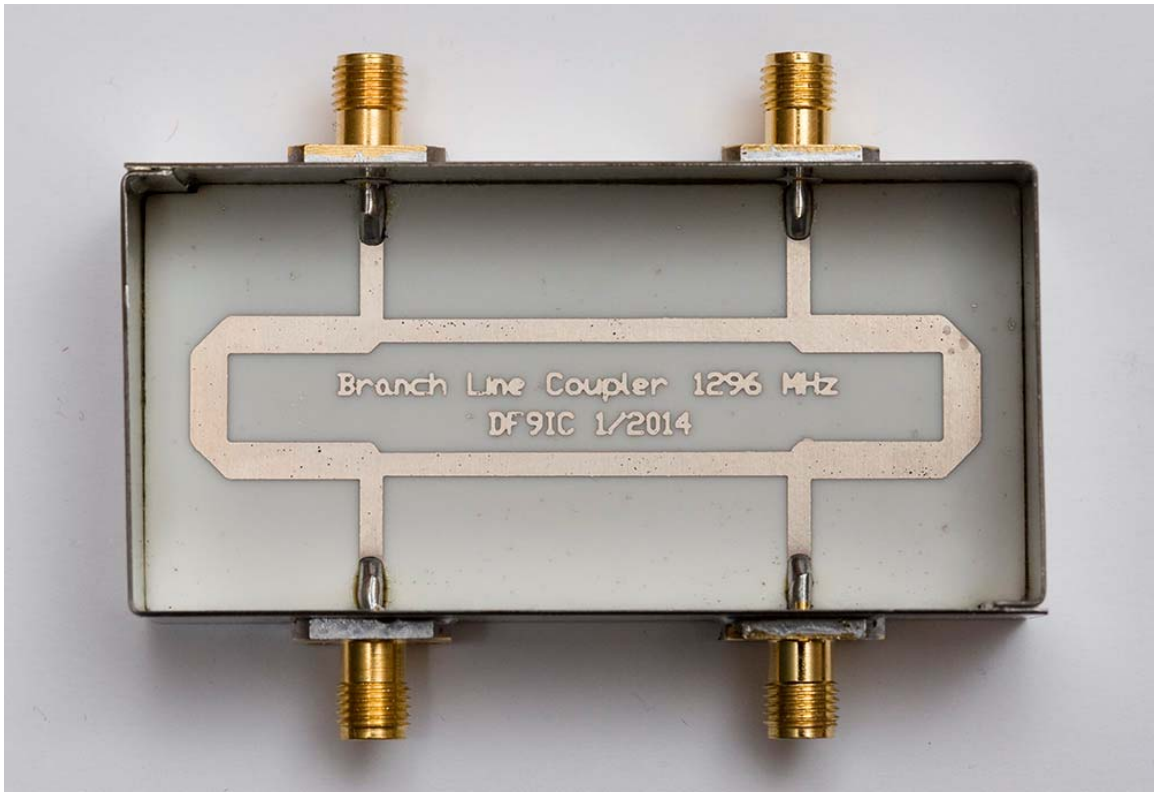

- The result is lower output power and reduced efficiency

# PA 1 x MRFE6S9160 FR4



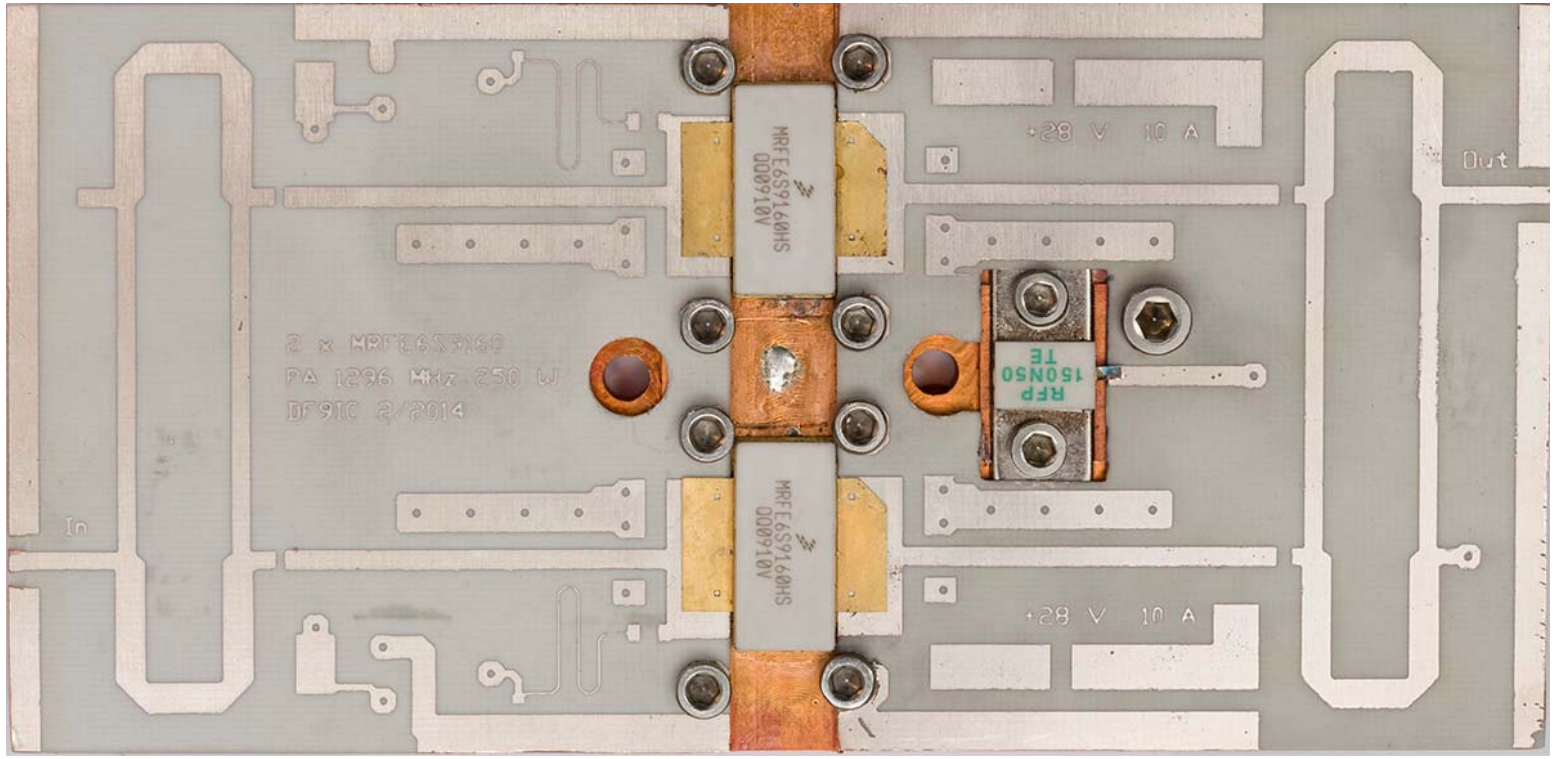
# PA 2 x MRFE6S9160 RO4003

- Next stage: coupling of two amplifiers

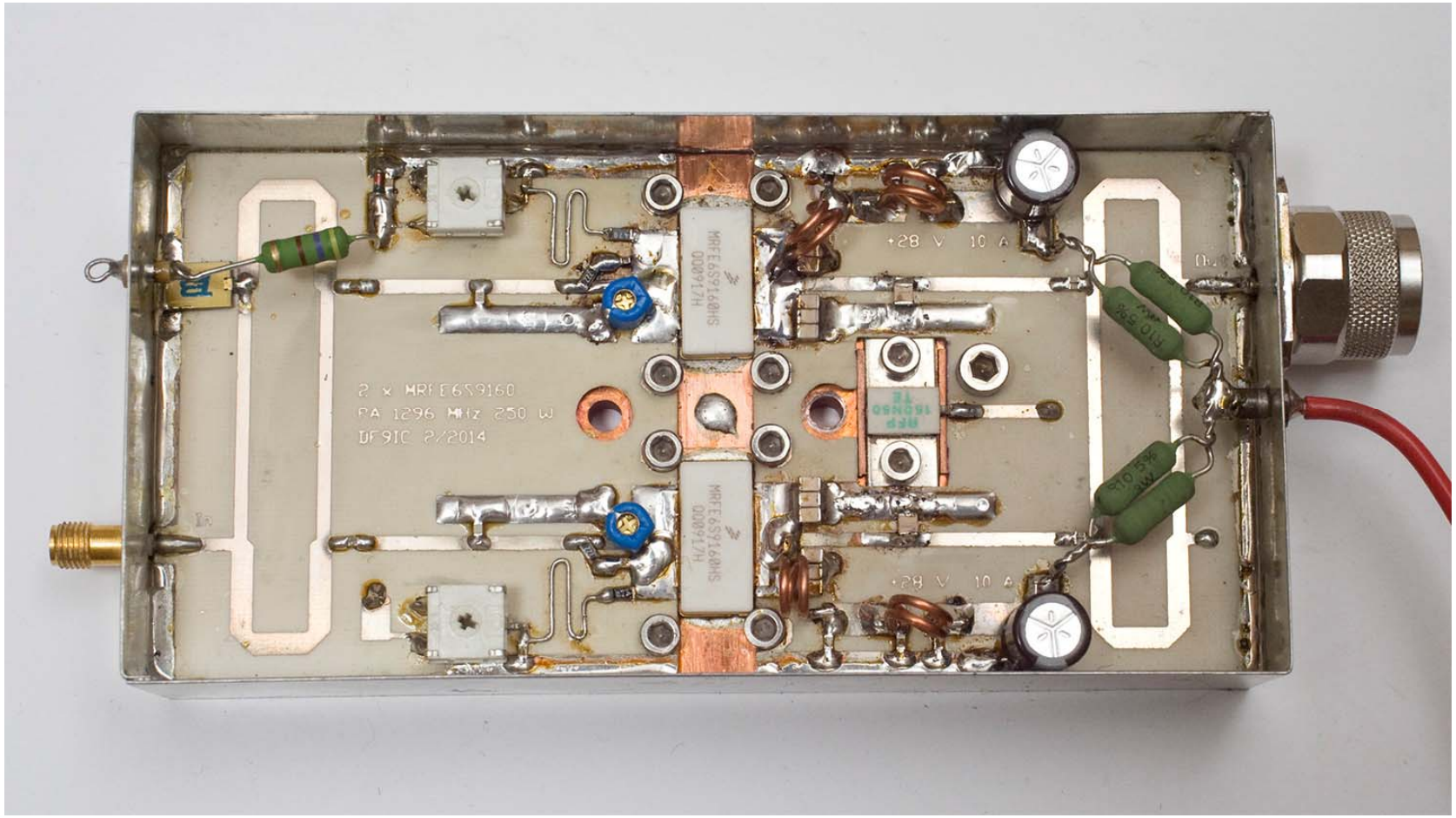


# PA 1296 MHz: 2 x MRFE6S9160

- Prototype of the twin amplifier



# PA 1296 MHz: 2 x MRFE6S9160

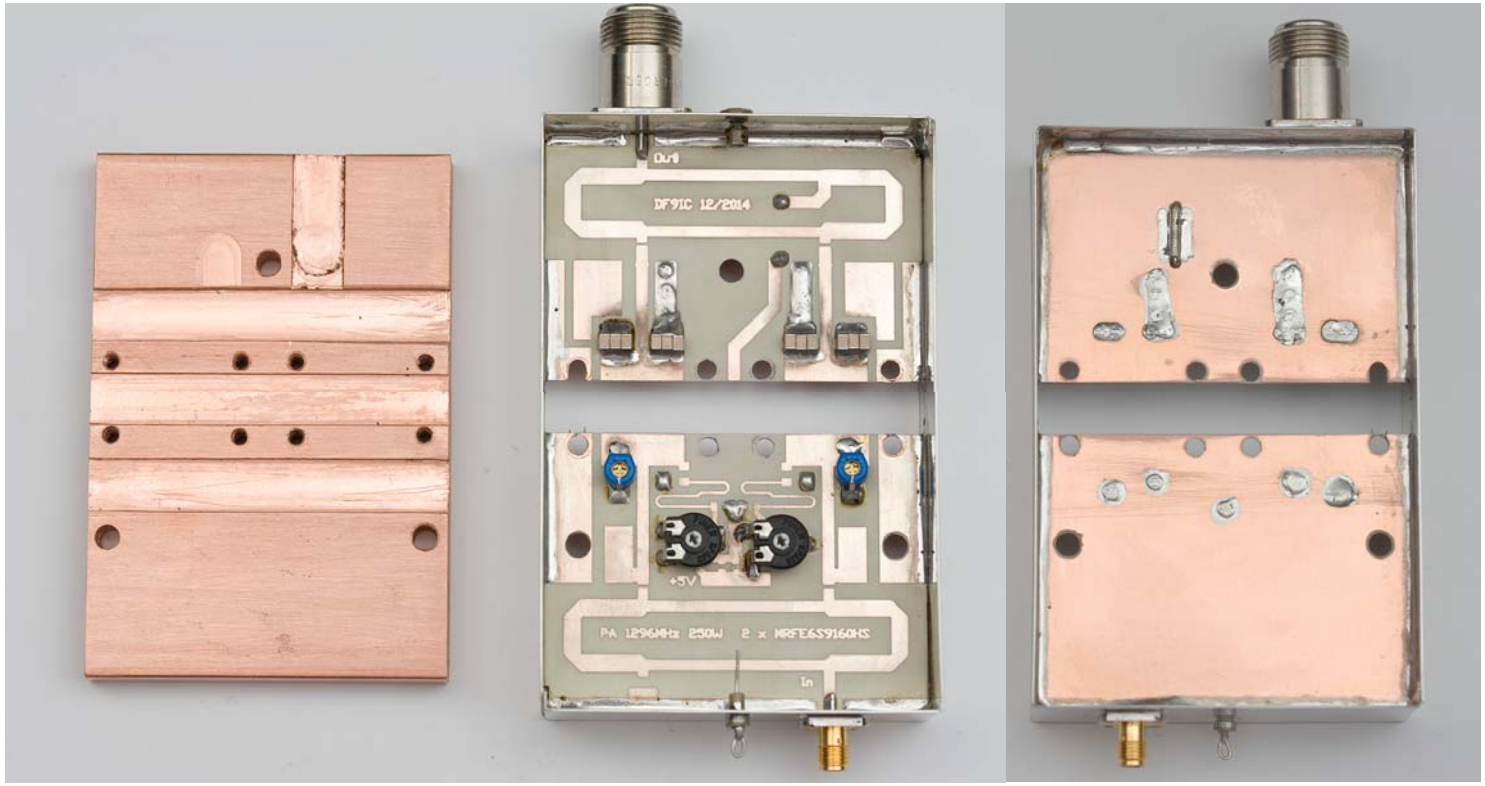


# PA 1296 MHz: 2 x MRFE6S9160

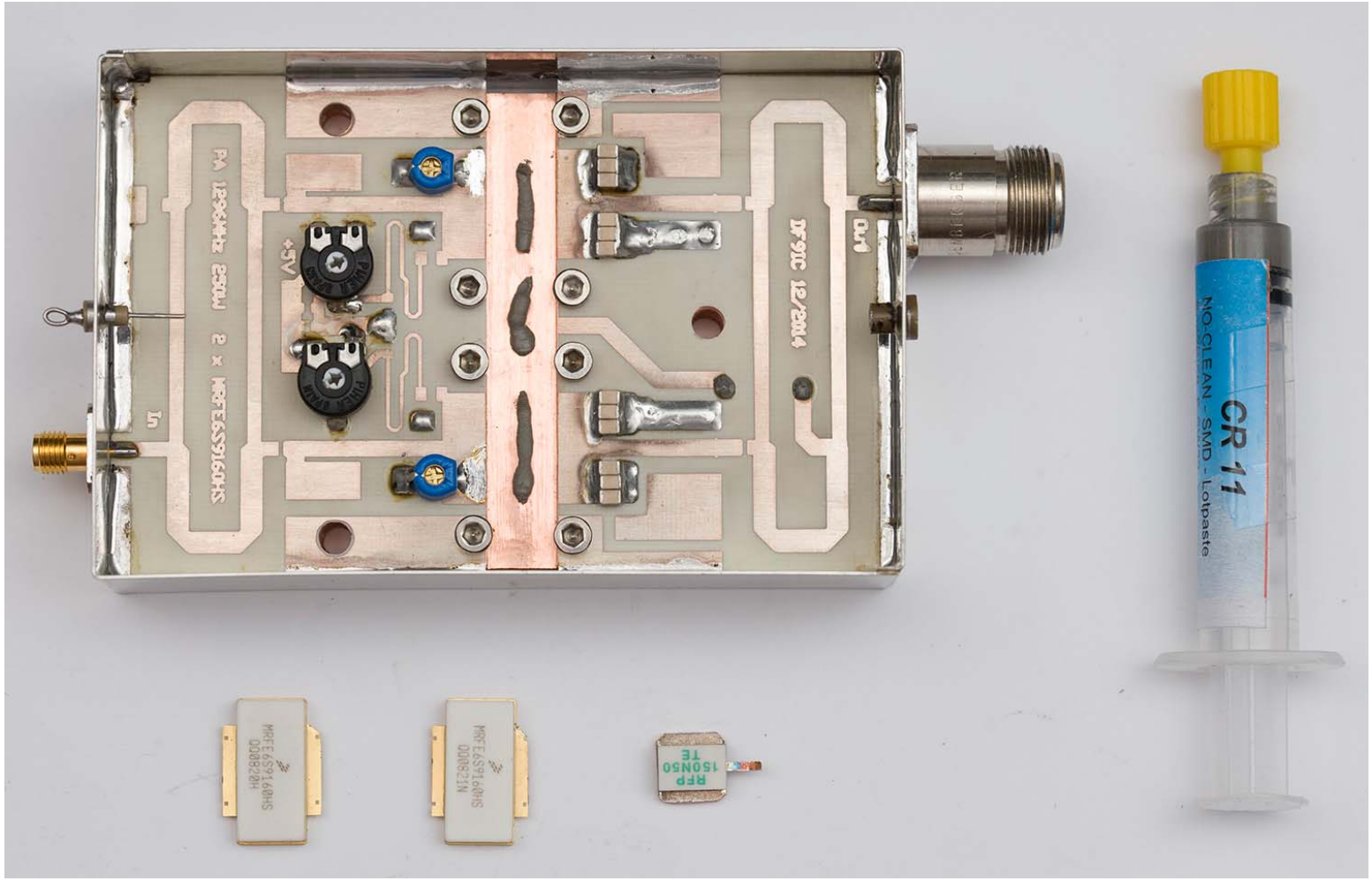
- Result: success, nearly 300 W at 28 V, efficiency and gain bit lower than for the single amplifier
- Adjustment procedure: first supply and adjust each transistor single (resulting in 6 dB less gain and 3 dB less power than in a single amplifier); e. g. 5 W to 70 W
- then only minor fine adjustment necessary for the joint operation (expect 5 W to 280 W then, according to the above example)

- Next step: try to make PCB smaller and module simplier to build

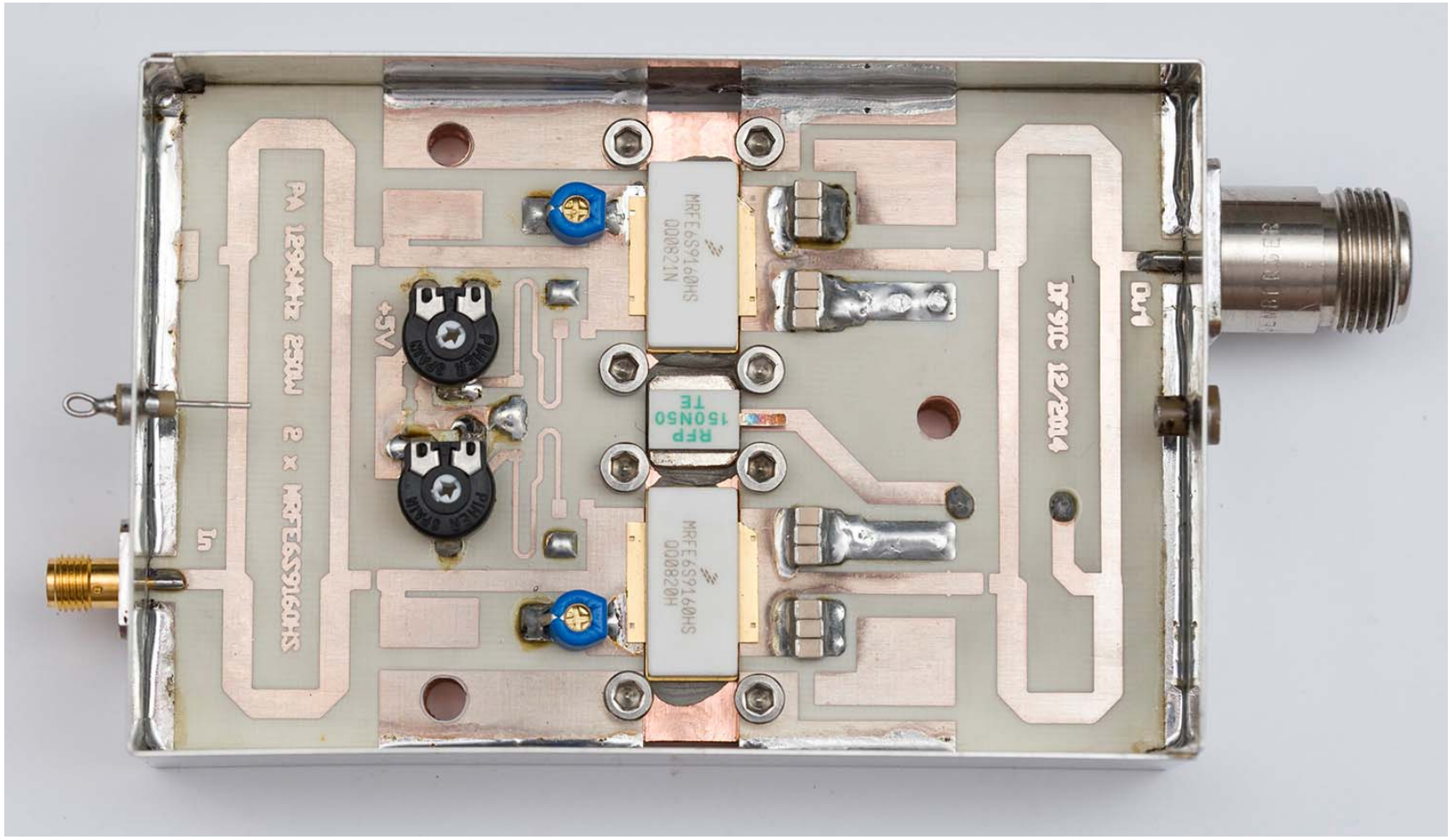
# PA 1296 MHz: 2 x MRFE6S9160



# PA 1296 MHz: 2 x MRFE6S9160



# PA 1296 MHz: 2 x MRFE6S9160



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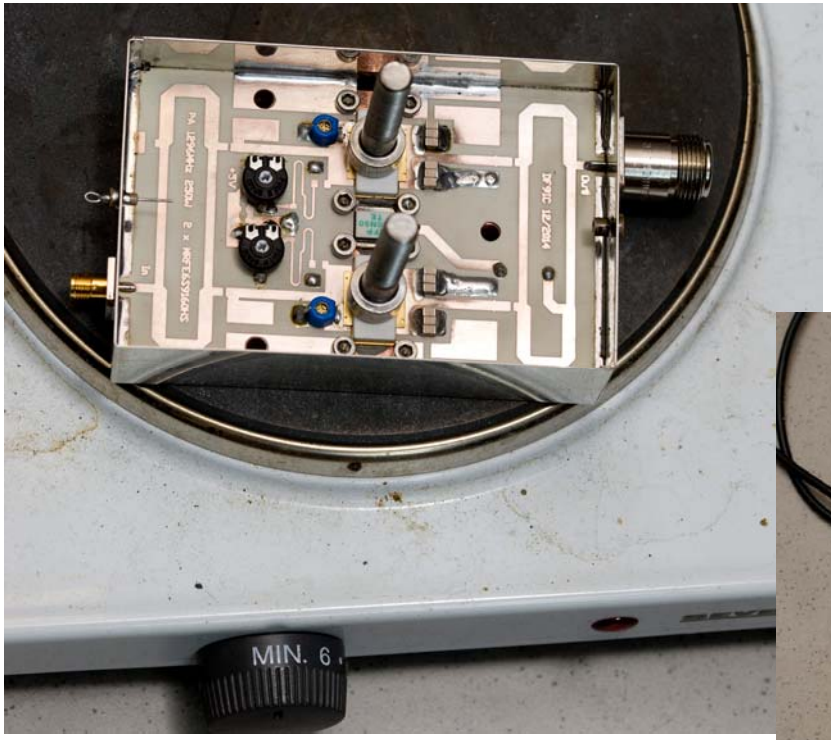


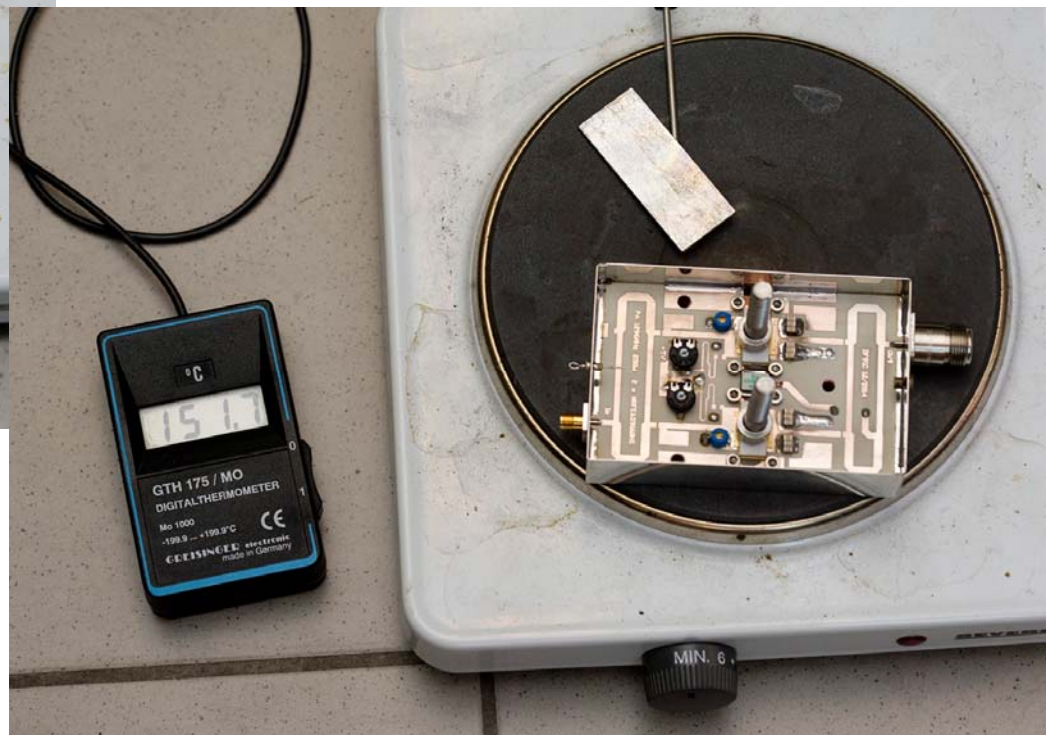

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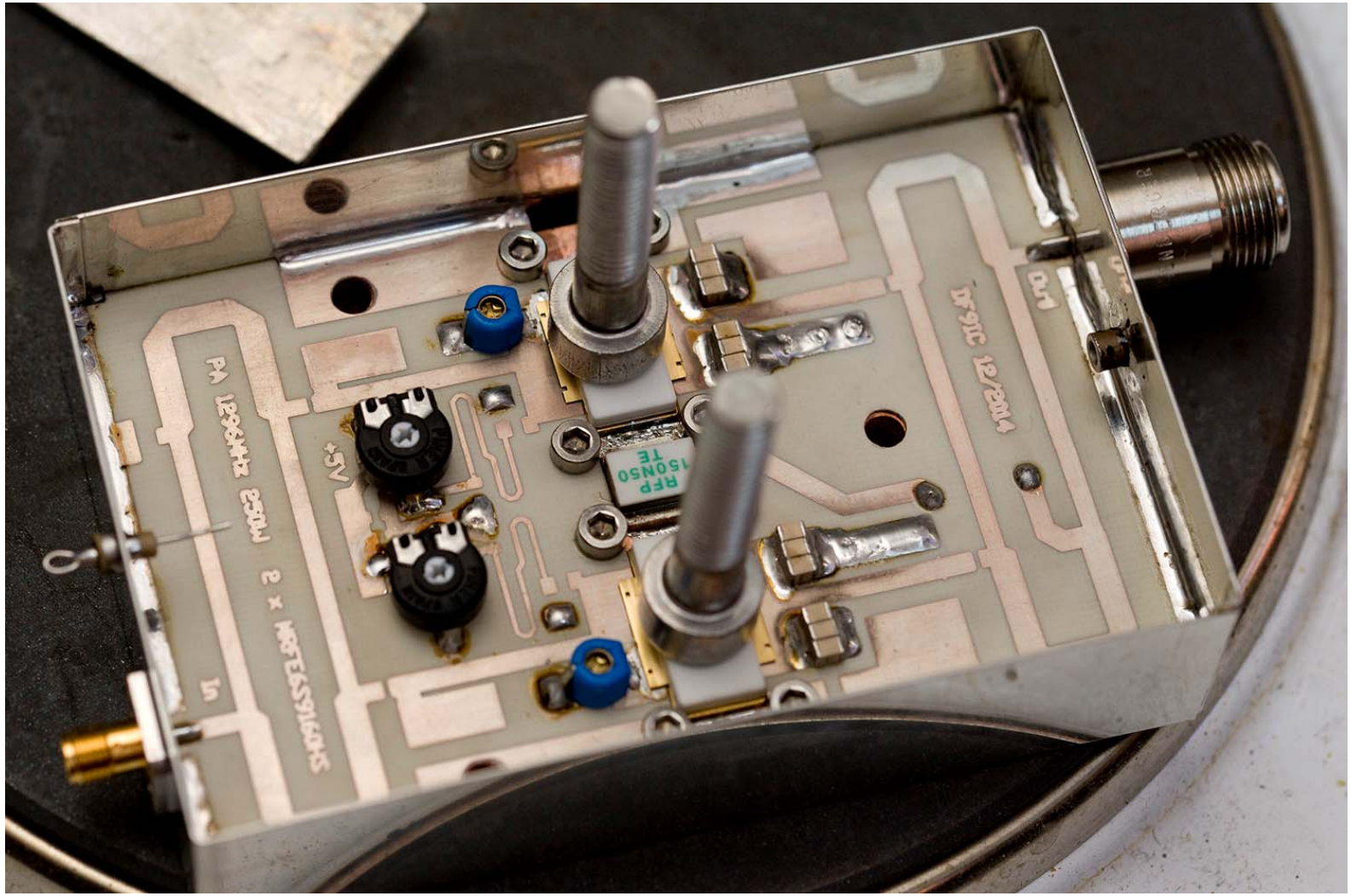

# PA 1296 MHz: 2 x MRFE6S9160

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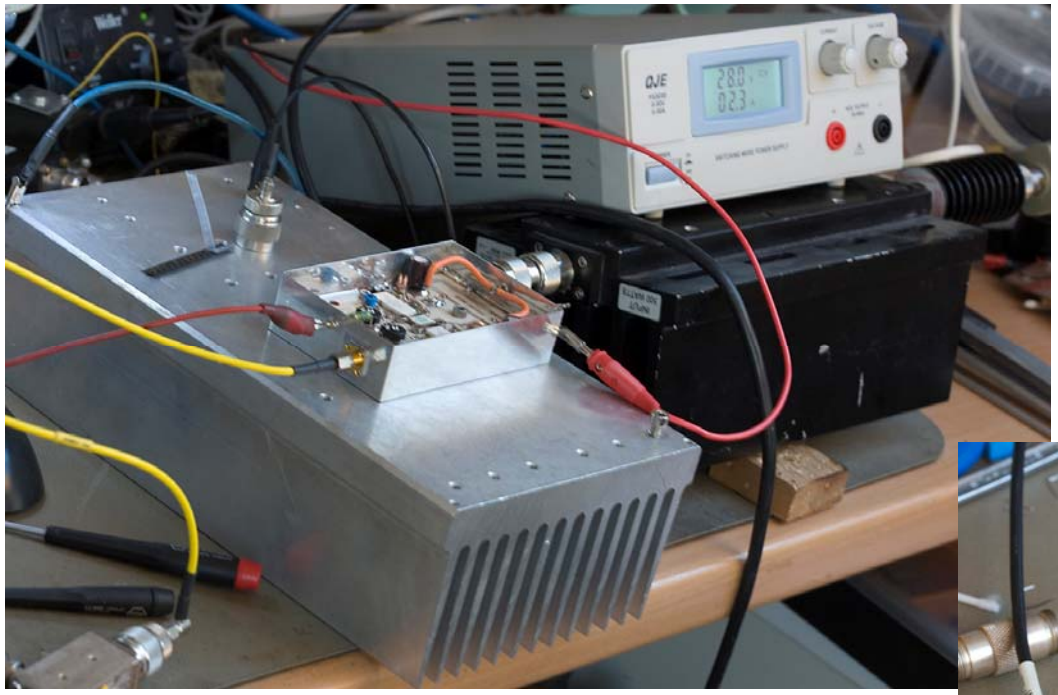
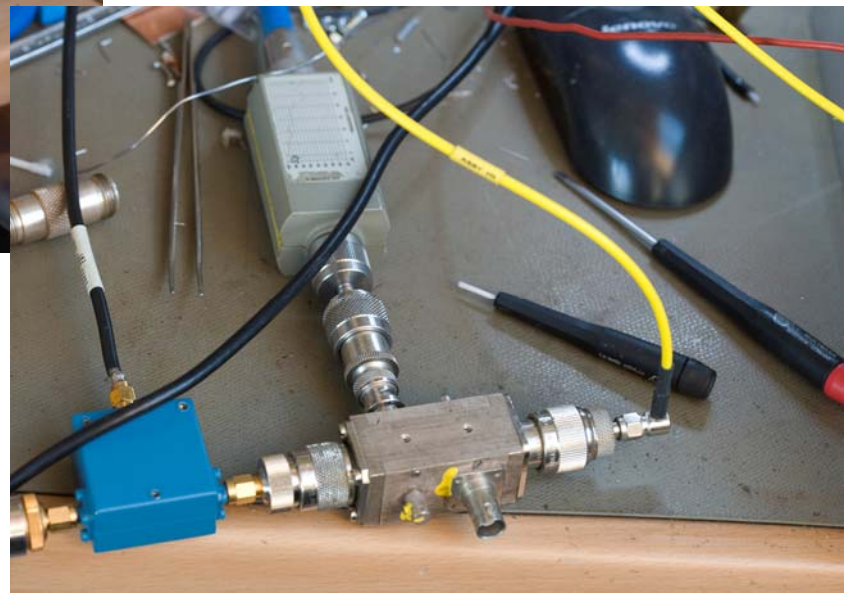
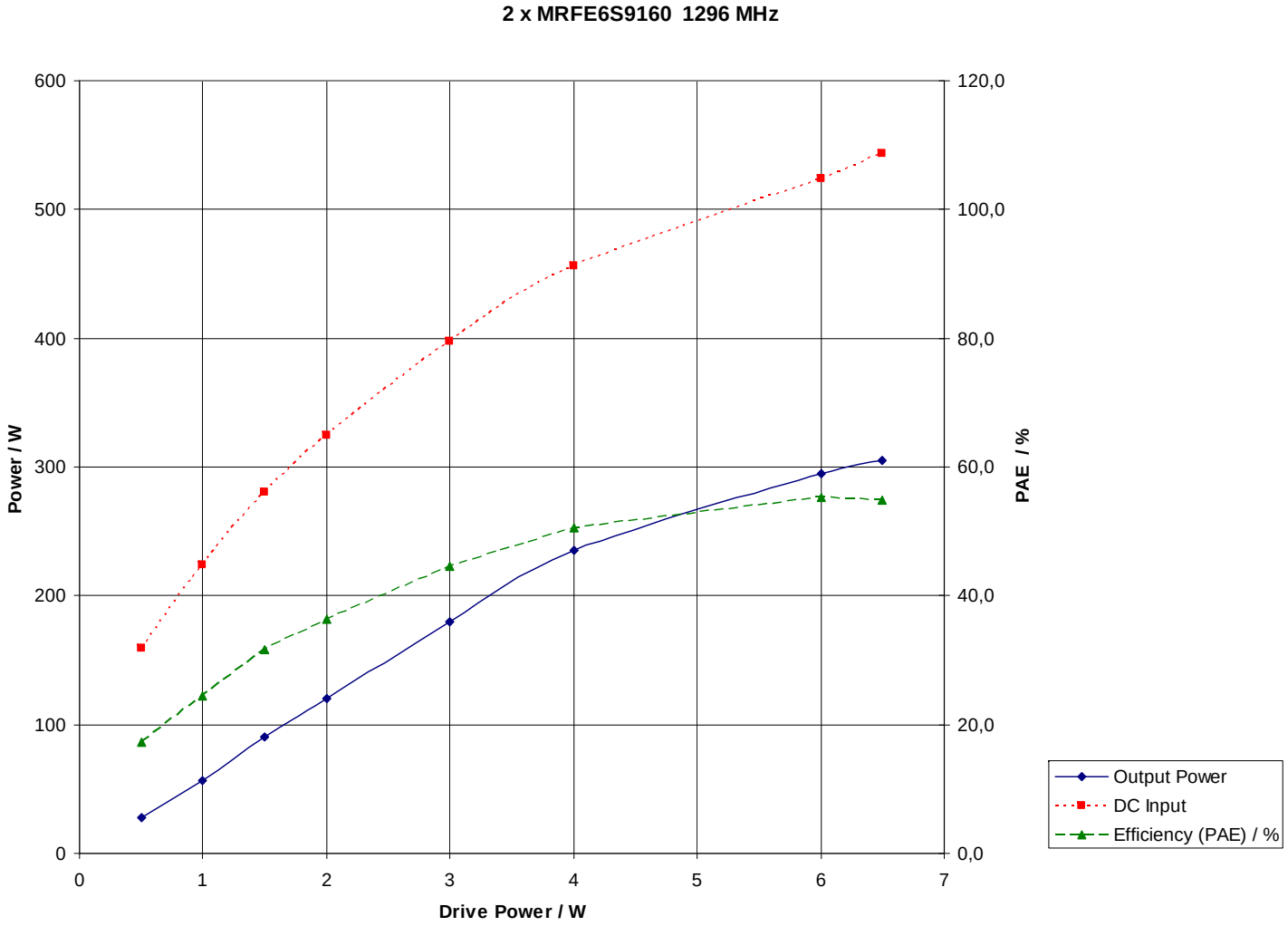


Use an isolator in the input during test and optimization



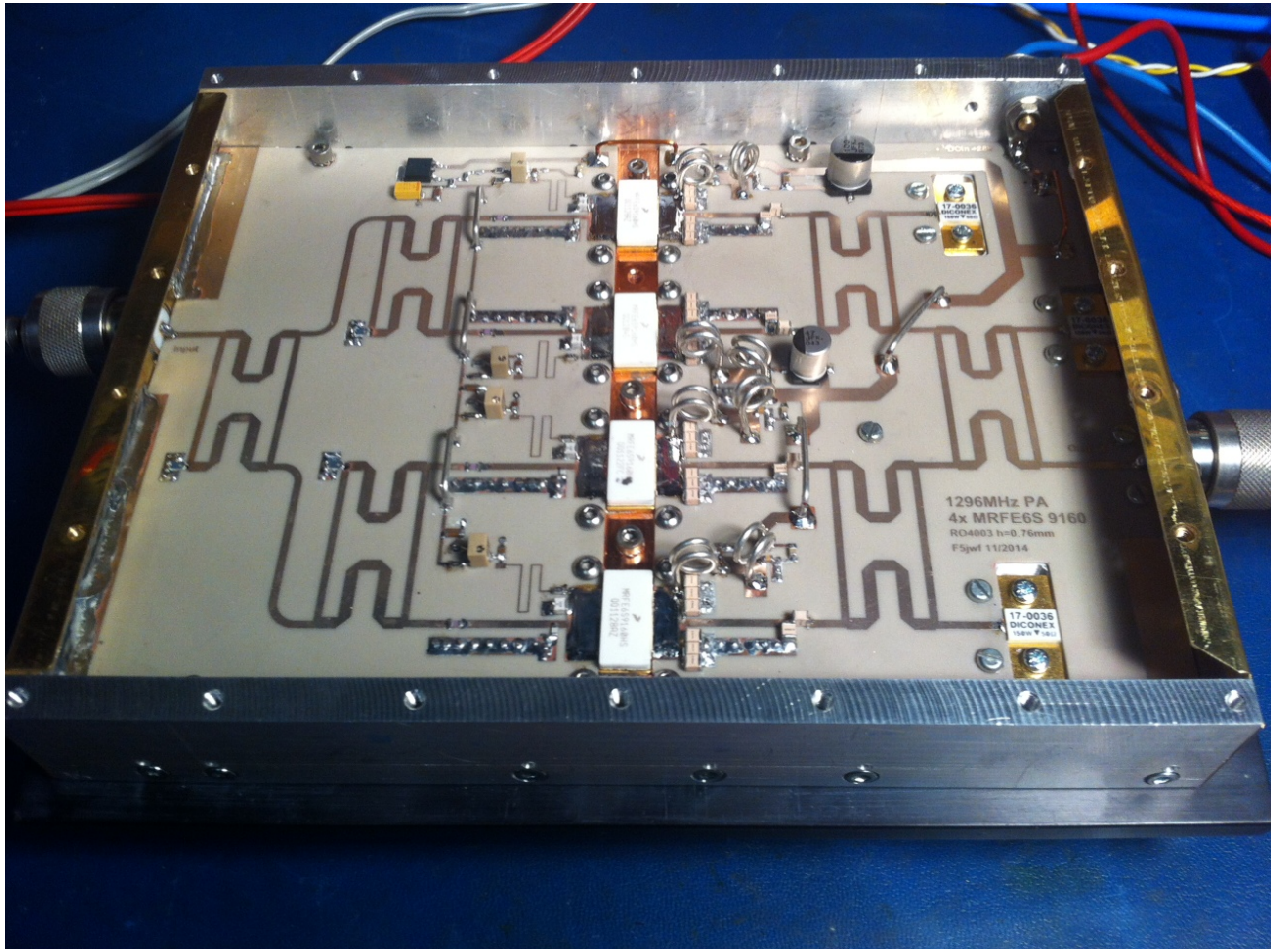
# PA 1296 MHz: 2 x MRFE6S9160



# PA 1296 MHz: 2 x MRFE6S9160

- Result:
  - Small high-power boxed amplifier module
  - 275 W at 26 V – 305 W at 28 V – 340 W at 30,6 V
  - 17 dB gain
  - >50% efficiency
- Adjustment more difficult than with single transistor module
- For bigger PAs I prefer to combine twin modules externally

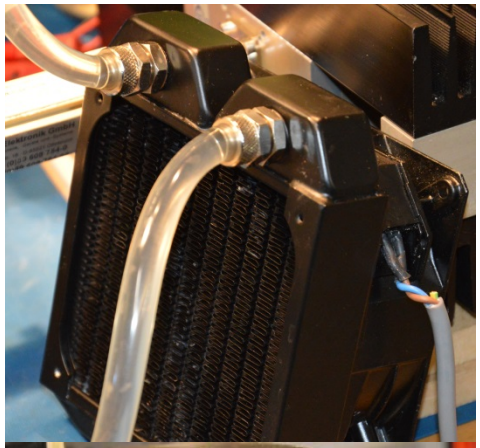
# F5JWF: 4 x MRFE6S9160

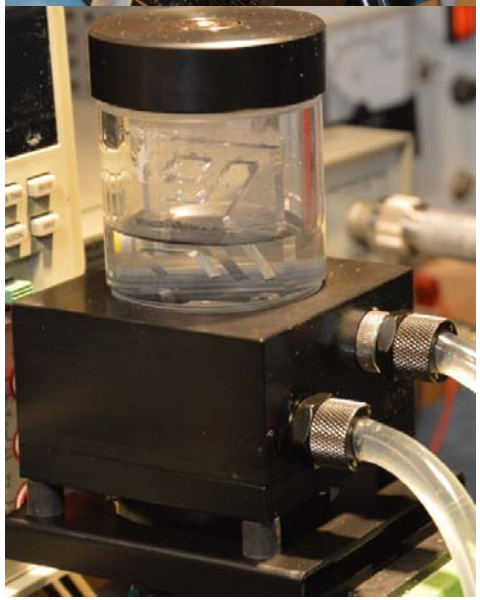



Based on the single transistor amp

Couplers and total design by Philippe F5JWF

# F5JWF: 4 x MRFE6S9160



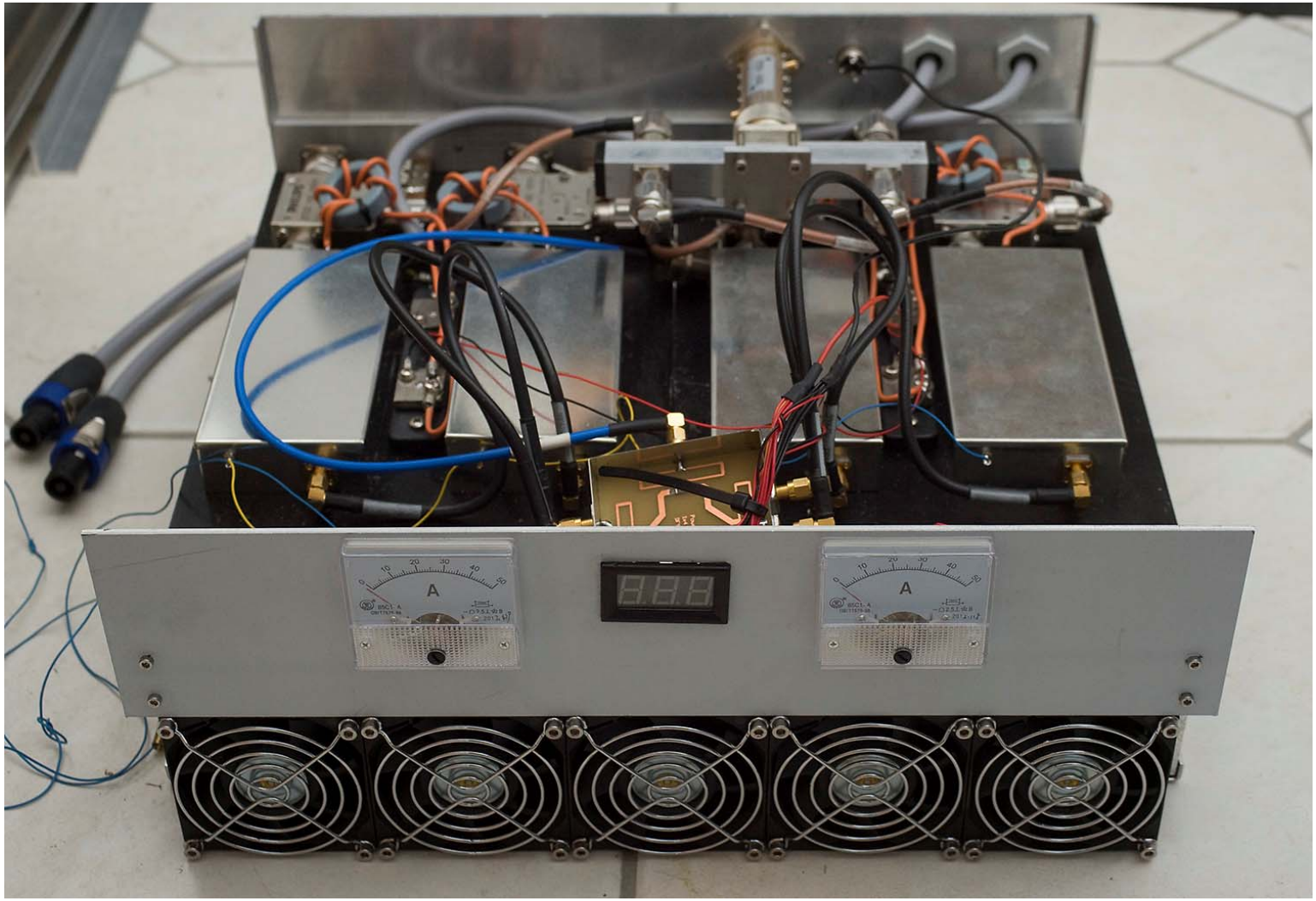


Efficient water cooling

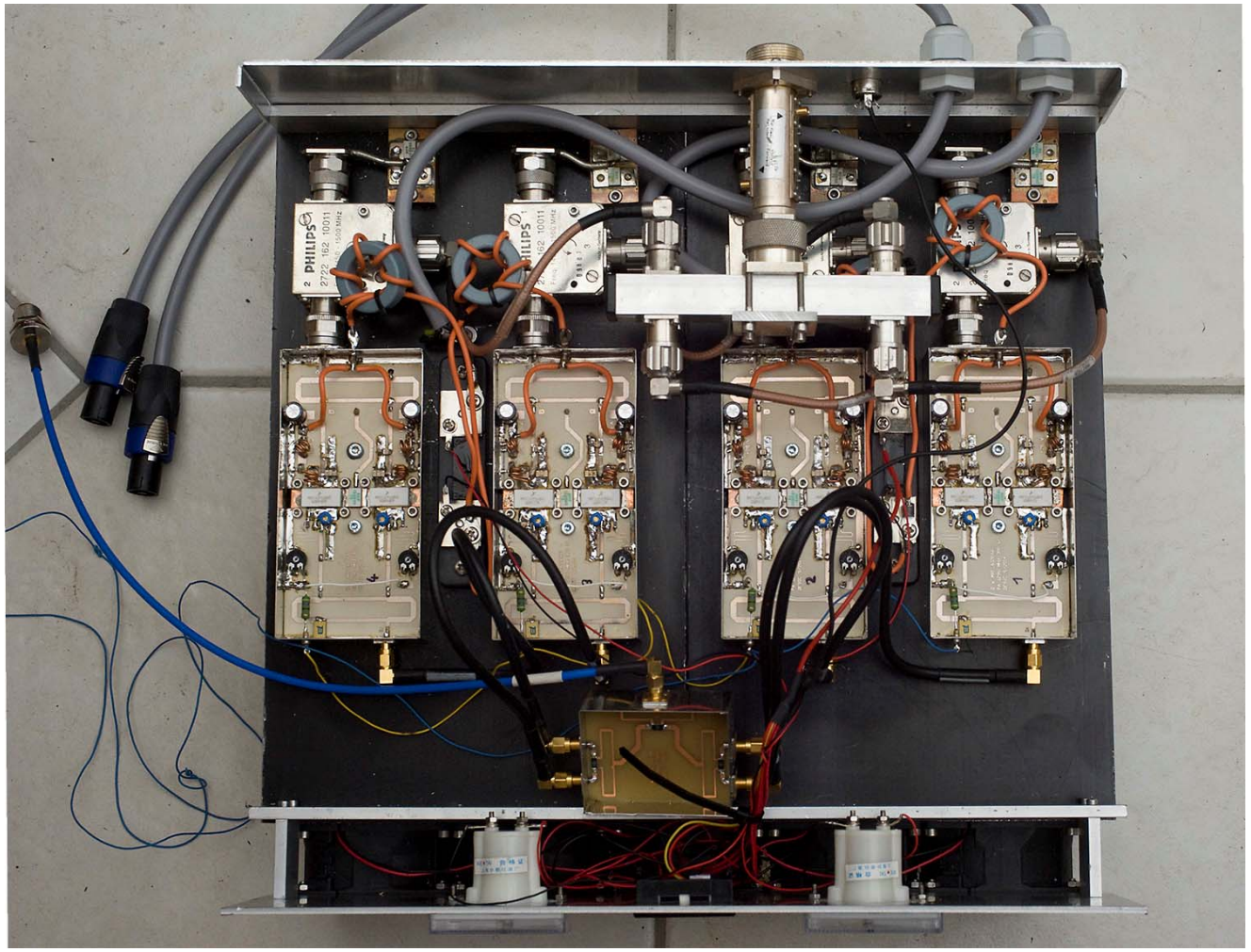
$P_{sat}$ >600 W

Philippe plans to mount two modules behind his dish feed for EME

# How to make 1 kW on 1296?



# PA 1296 MHz: 8 x MRFE6S9160




4 modules

Input:
Wilkinson
coupler
on FR4

Output:
isolators +
non-isolated
coupler
(antenna
combiner)

# PSU 28 V >100 A

- PSU and DC filtering has to be investigated

# Conclusion

- Concept of a 150 W 1296 MHz power amplifier module with a bill of material cost <30 GBP
- PA with 2 transistors in a box with printed couplers (min. 250 W for 60 GBP BOM)
- Higher power by combining multiple modules – 1 kW demonstrated