10 GHz Power Combiner

More elegant, omitting Magic-T's

Agenda

- Introduction
- Traditional Method: Band-Combiner with 50 Ohm Load
- Narrow Band Solution
- The Goal of this Project
- Practical Design of a 10 GHz Combiner
- Measurements with 4 Mini-PAs
- Measurements with 2 Mini PAs
- Measurements with 4x Kuhne MKU 3cm-46 dBm PAs
- New Setup – Echo Test
- Conclusions
- Appendix
- Coaxial - WG Adapter
- Source for Components

Introduction

- The concept of these combiners has been published as summary in Dubus 4/2017 and Dubus 1/2018
- Since, there are users of this new way of power generation accross the EME community
- High Power >50 dBm on 3cm is generated by TWTs
- BigGuns in EME use TWT Power Amplifiers
- Power Supplies for TWTs are pretty complex
- It is primarily obsolete military or commercial stuff in use
- Handling high voltages is delicate, especially outdoors

Example:
BigGun 10 GHz EME TX

SP6JLW

53 dBm

TH3947A

Introduction

- Semiconductors in the 45 dBm range are accessible now which triggered the idea of combining 2 or 4 solid state amplifiers
- The ambition to close the power gap to TWTs by SSPAs was born
- Combining power amplifiers with MagicTs or Hybrid couplers is lossy, heavy and bulky
- Several MagicTs cascade the losses by number
- Thus the efficiency is poor

Introduction

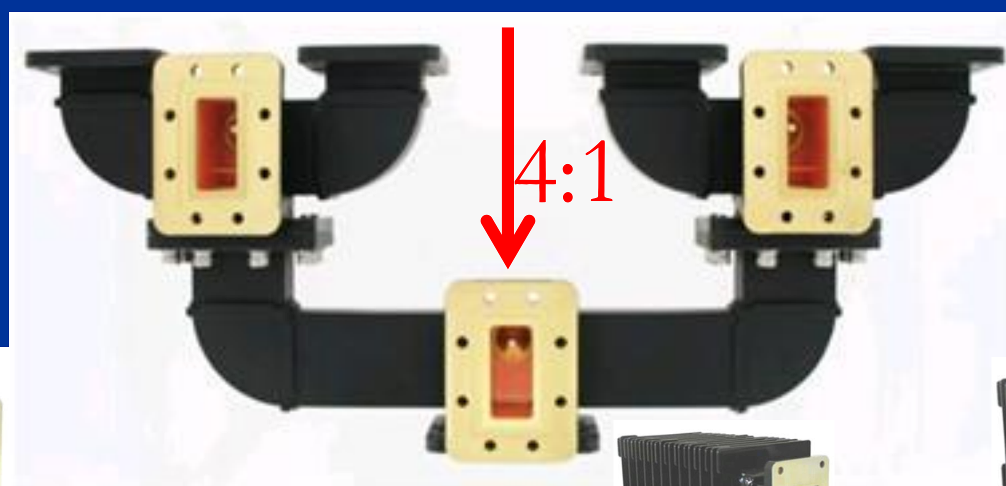
- The professional approach combines 2 amplifiers per stage.
- 4 amplifiers therefore require 3 MagicTs.
- All the cascaded losses of these reduce efficiency

Band-Coupler and Dummy-Loads

Input power divider
Power limit approx. 10W

1:4 DRIVE

PA-OUTPUT



Output power combiner, full band-with, power limit several KW

Introduction

- The desire to try high power with SSPAs becacme irresistible when my first 3cm EME QSO was made. I worked with 1m offset-dish, 46 dBm circular pol, CW RANDOM, no Internet, no chat, no sked and no fake.
- I could receive various stations easily with good signals.
- I wanted to close the power gap to TWTs because low power proved to be my major handicap

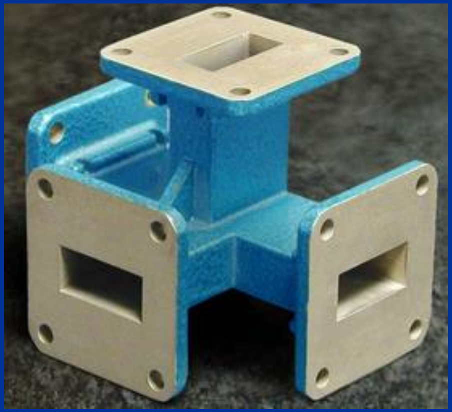
10 GHz EME QSO with OZ1LPR

NO INTERNET!
NO SKED, NO CHAT!
NO DIGITAL! No fake!
FULLY RANDOM!
PURE CW!

HB9BBD h.m. LNA
PA Kuhne, repeated calling, then „QRZ..
QSO took 40 Min. until RRR

Traditional (Band)Coupler

They carry the whole bandwith, e.g.
WR75 10-15 GHz

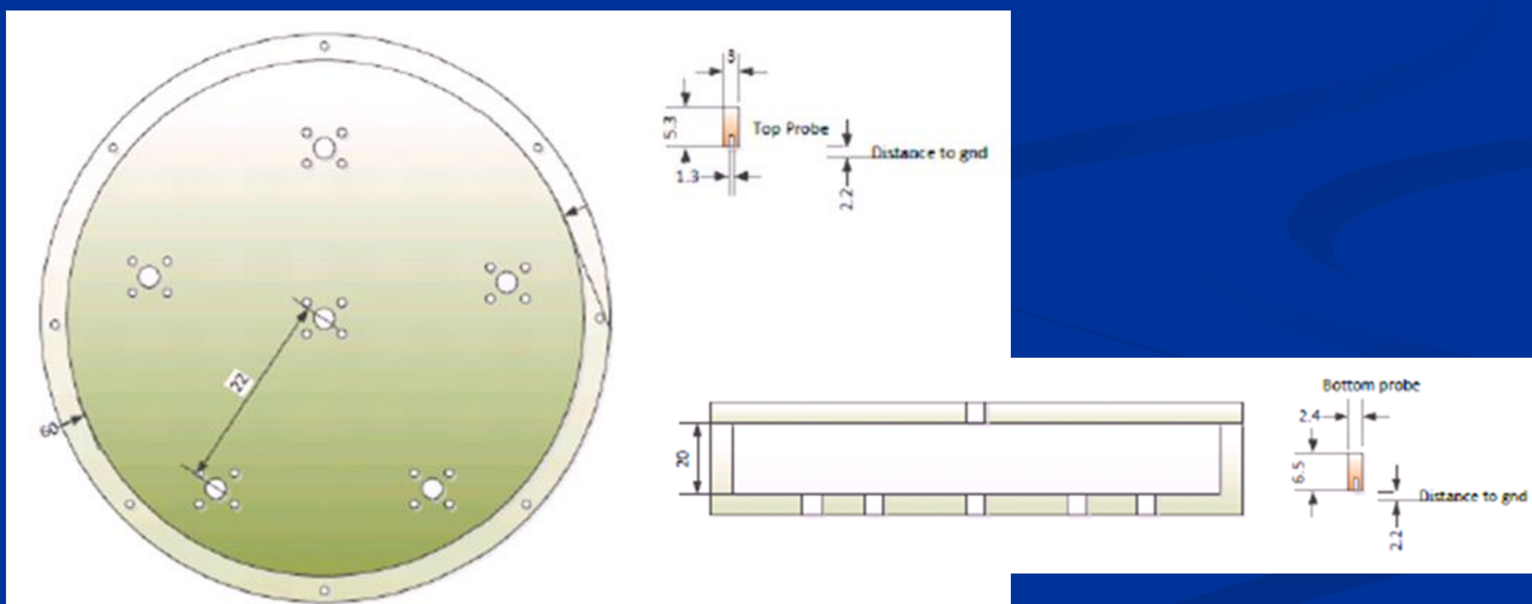


Outdoors with rubber sealing

Hams need just several 100 KHz

Narrow-Band Approach

On the occasion of the 2015 ÖREBRO EME Conference, Goran, AD6IW mentioned in the appendix to his presentation the idea to combine 5 power amplifiers



My Goal

Was to combine 4 PAs of same power level to one antenna. The losses of the whole combined power pack shall remain below -0.5dB

1 dB already would equal 20% loss of power. This would mean to loose almost 1 out of the 4 power amplifiers
and instead of 6dB I would get 4dB only ☹

This has a very negative thermal and an even more negative economical effect

By omitting Magic-T combiners all dummy loads become obsolete and efficient combining appeared feasible

My Goal

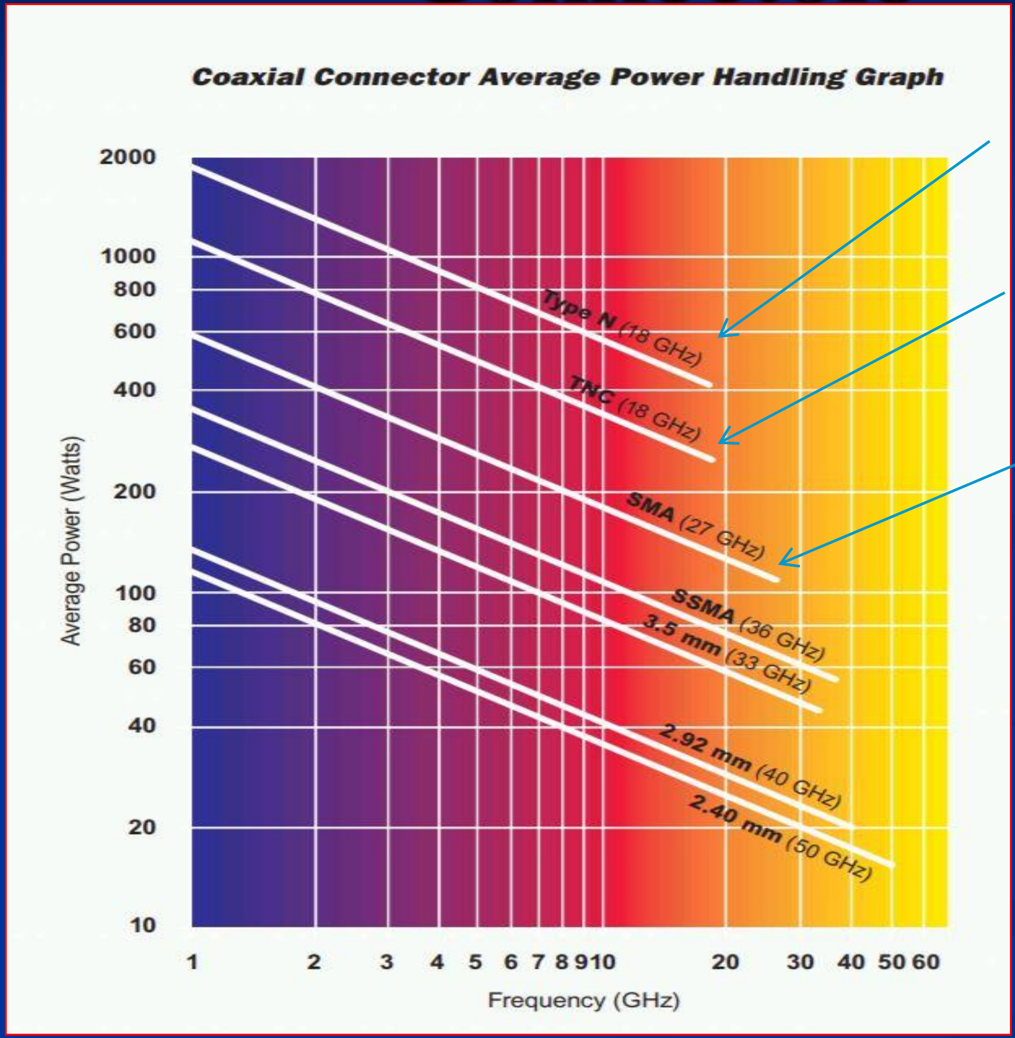
Broadband-
Coupler
3-stages

Very expensive >500 Eur
>2 dB losses = >40%
96 screws...

Narrowband
Combiner
Loss < 0,5dB

inexpensive, 47 Euro

Practical Solution Connectors



N

TNC

SMA

Source: Southwest Microwave: Frequency/Power Graph of connectors

Practical Solution Connectors

Power beyond > 53 dBm exceeds SMA capacity. This is why I choose TNC for this project. N is also capable to do this job



TNC Connectors can handle up to 56 dBm on 3cm. They have the advantage of smaller size than N.

SMA connectors of good quality can handle up to 53 dBm. Minor quality SMA connectors vaporize at 47 dBm already after seconds!!

Practical Solution
Coaxial Cable

Sucoform141 by Suhner is
Specified up to 53 dBm on 10 GHz

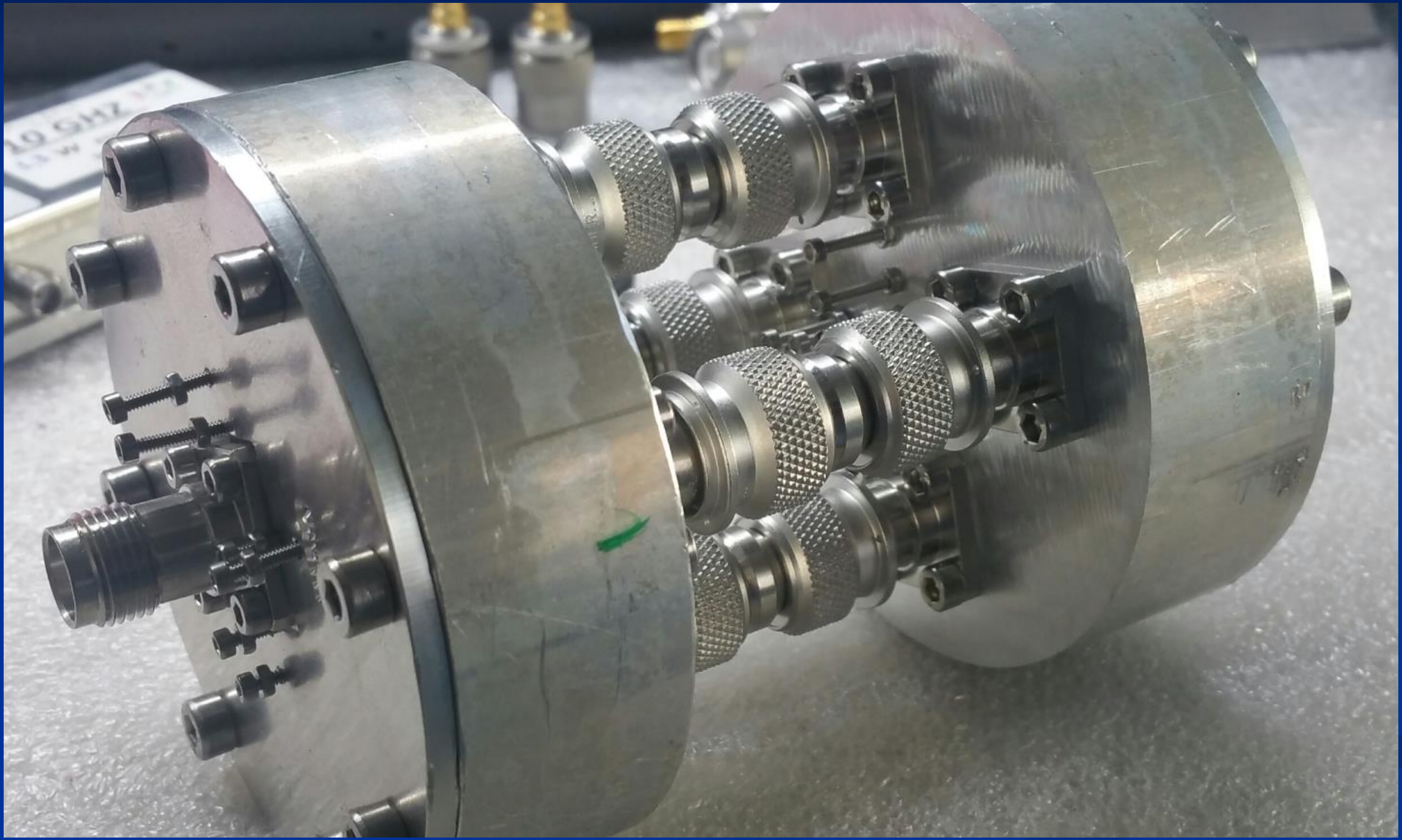
Is it feasible?..

In the beginning of this project its positive outcome was at risk
It is not modest to regard a new approach as to be smarter as proven solutions by professionals

Measurements of a single of such 4:1 combiner requires a network analyzer with 5 ports which I don‘t have
I took the challenge and milled 1 1:4 divider and one 1:4 combiner, so I could measure the two at once

Practical Solution Combiner

Measurement with NWA (S12/S21 2 ports)



Practical Solution
Combiner

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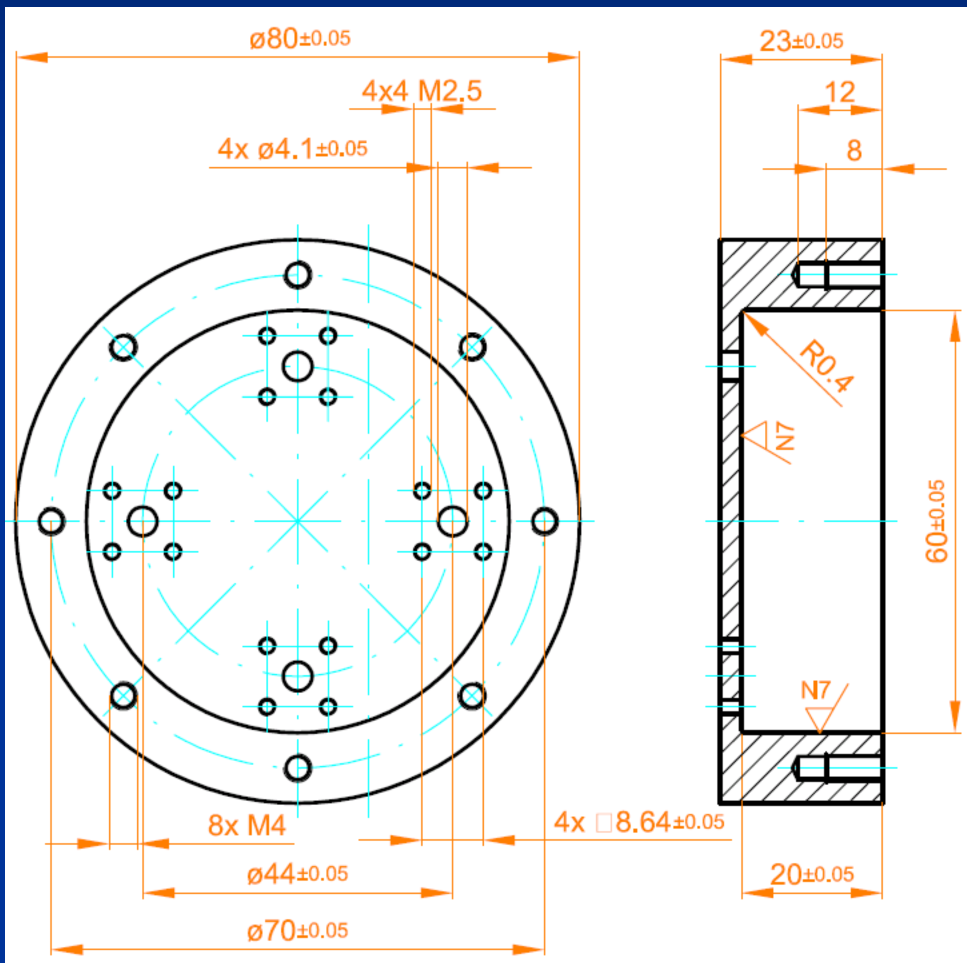
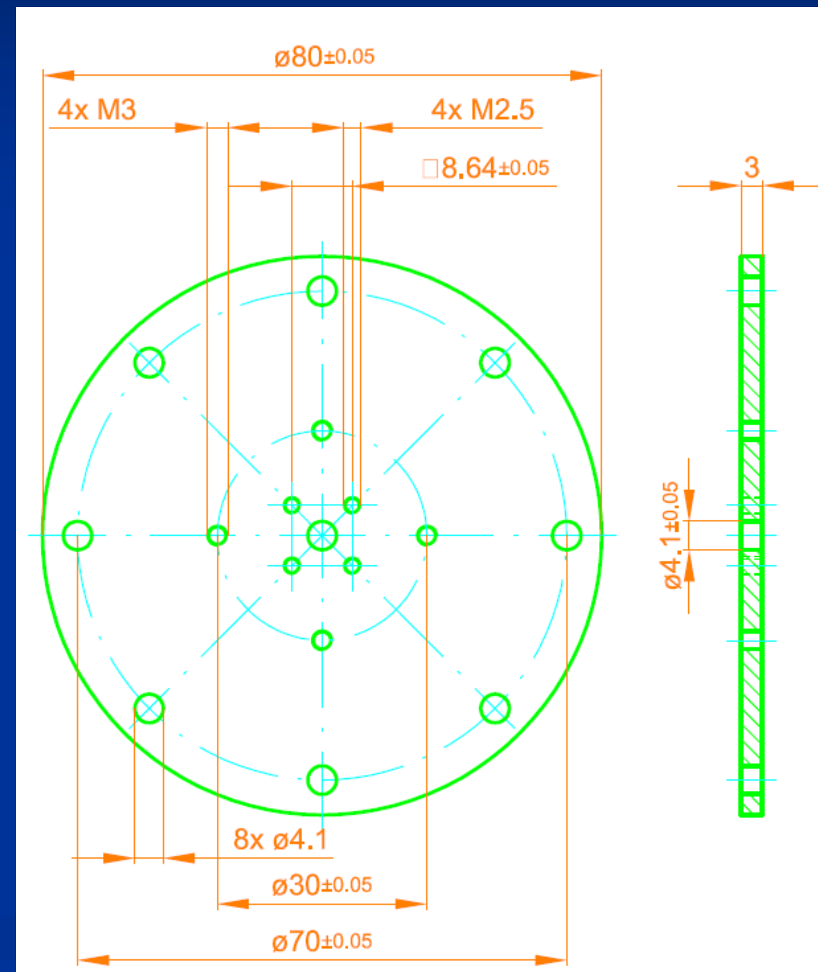
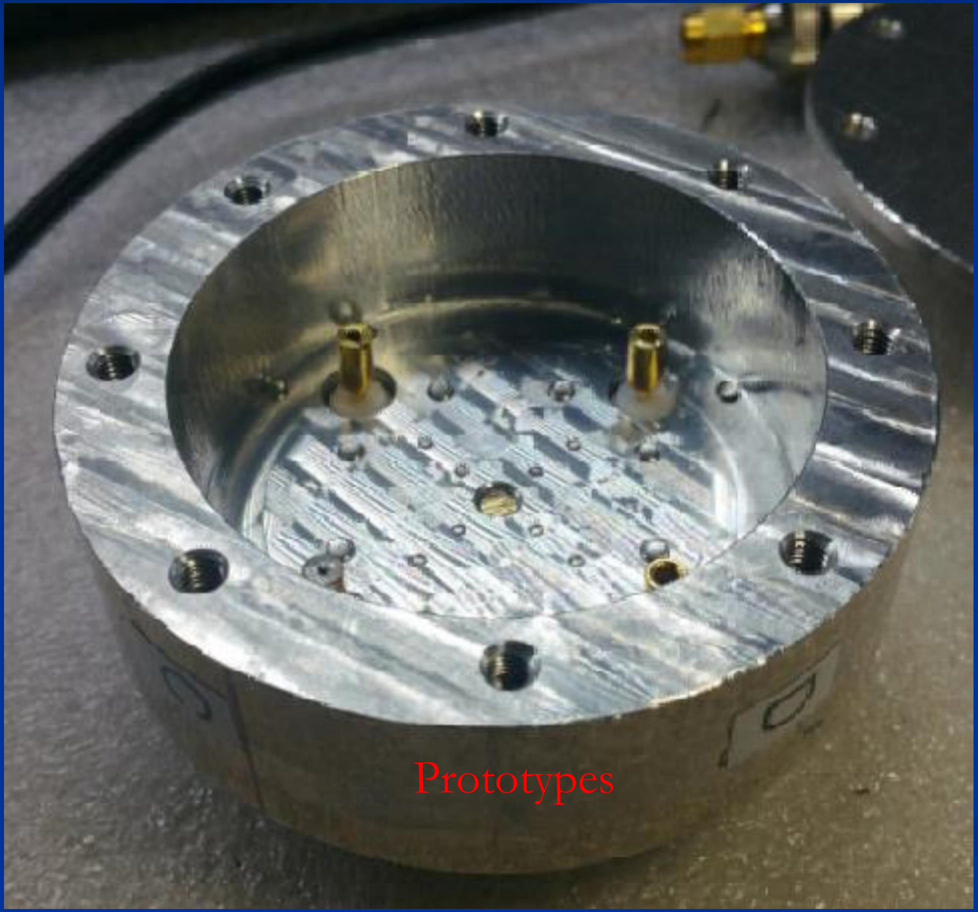
Prototypes

Practical Solution
Combiner





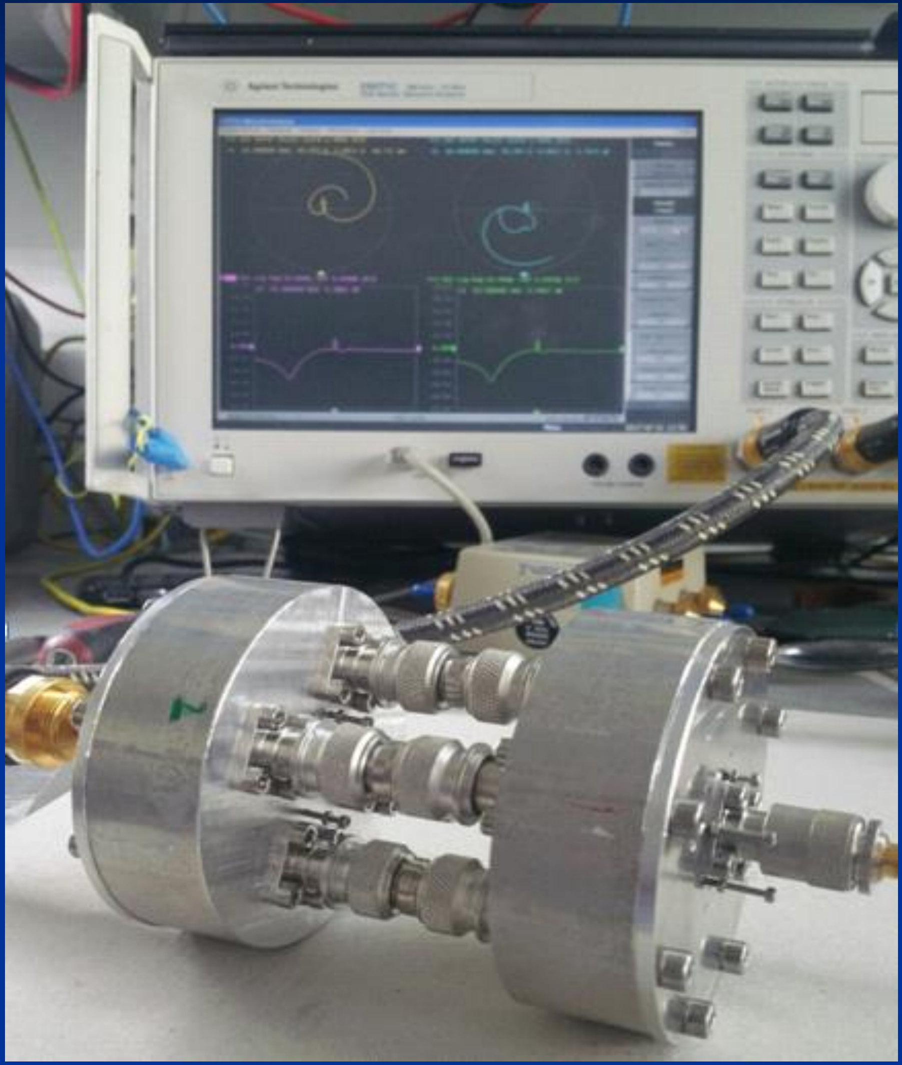
Practical Solution
Combiner (Prototype)



Antenna: L = 6,5mm
Diameter = 3mm
Distance to Body = 2mm

Tuning Screws on Cover
4xM3, 15mm from Center
Antenna on Cover L = 5,3mm

Measurements of Divider/Combiner

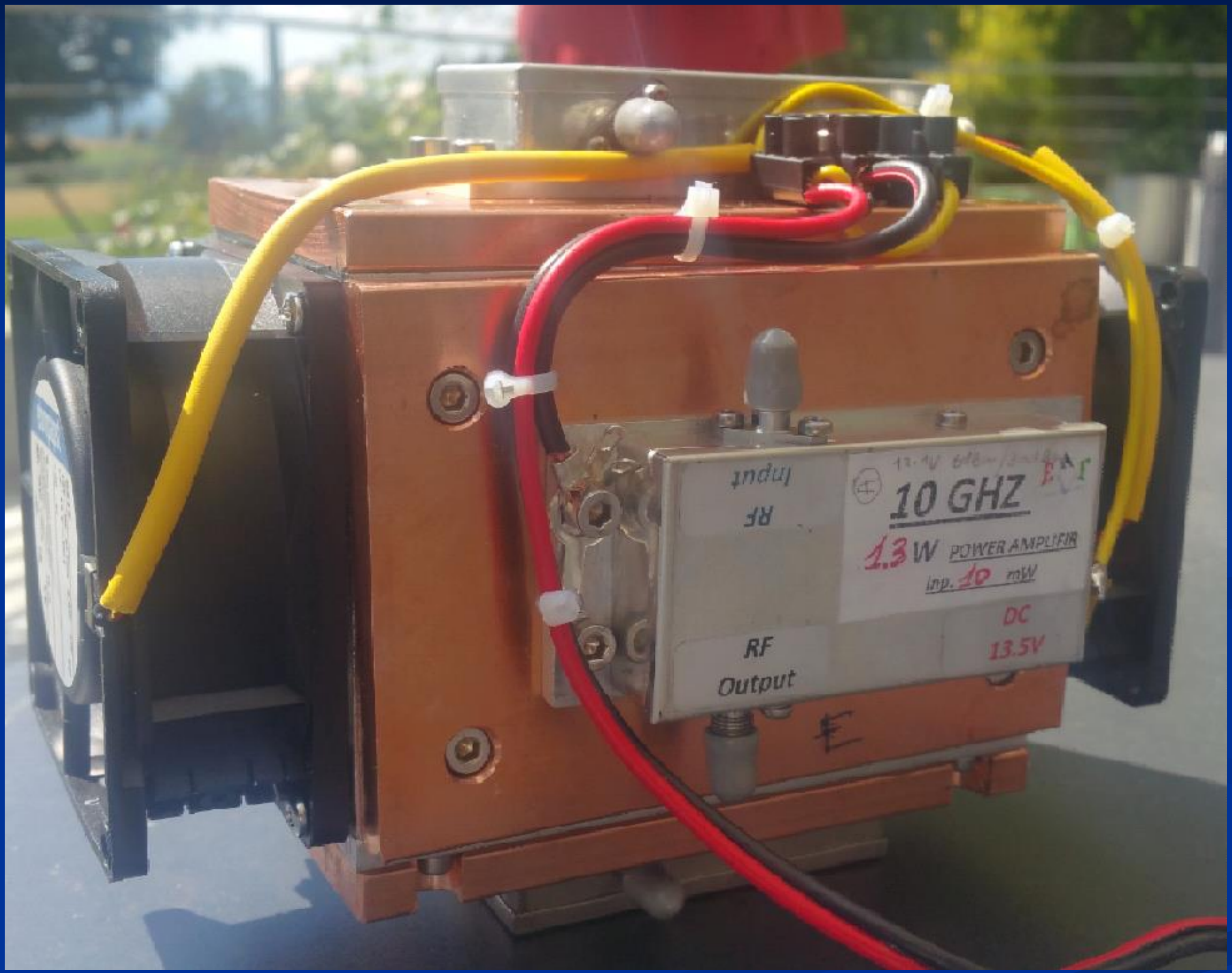


S11 54 Ohm,
S22 51.3Ohm
S21 -1.08 dB (inkl. TNC(+) - TNC(+)
S12 -1.06 dB inkl. TNC(+) - TNC(+)

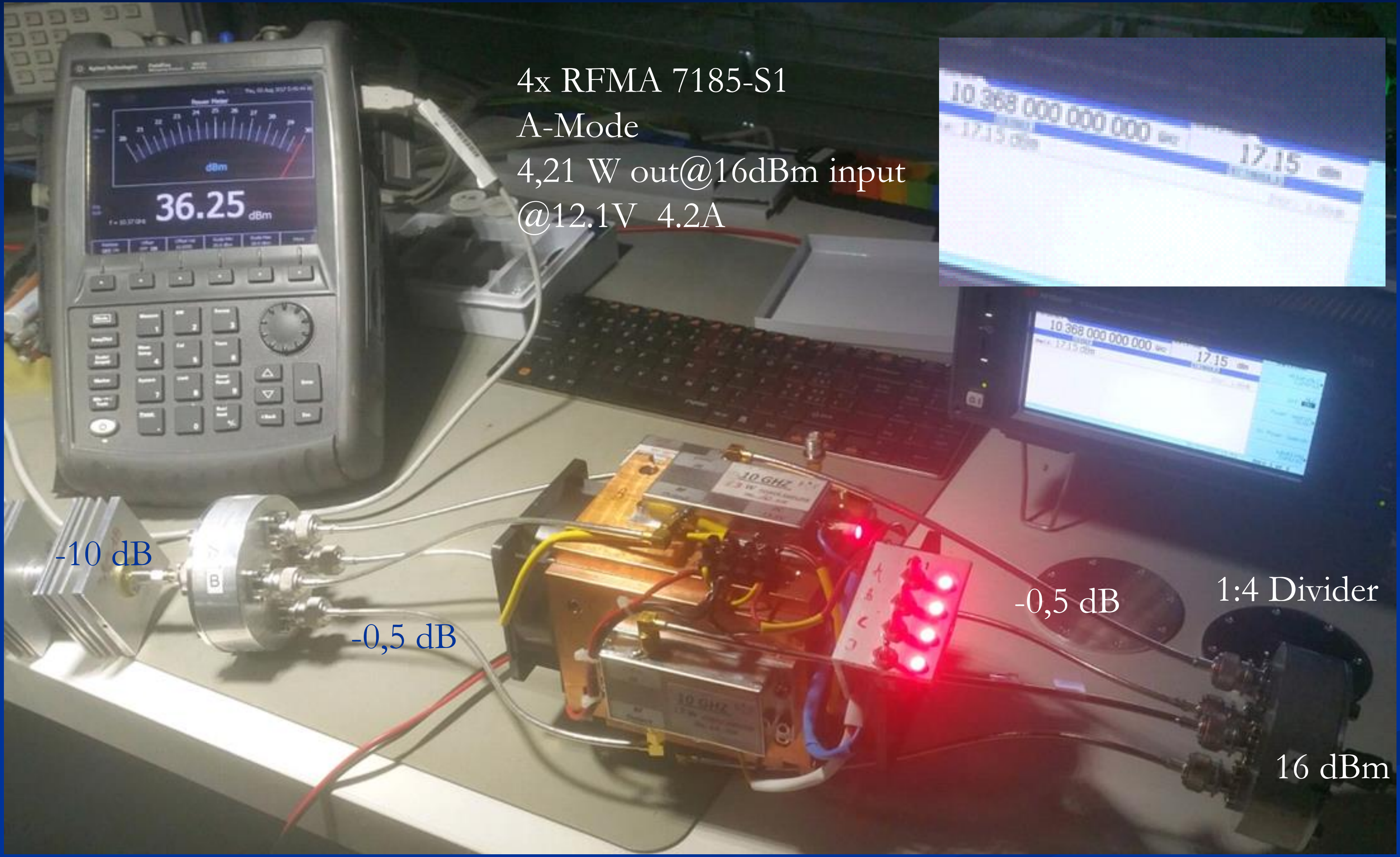
It seemed therefore feasible to achieve an insertion loss per coupler of less than 0.5dB


E5071C Network Analyzer
1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
Tr1 S11 Smith (R+jX) Scale 1.000U [F2]
>1 10.368000 GHz 54.022 Ω 1.9695 Ω 30.234 pH
54.022 Ω
Tr2 S22 Smith (R+jX) Scale 1.000U [F2]
>1 10.368000 GHz 51.281 Ω -4.0278 Ω 3.8111 pF
51.281 Ω
Tr3 S21 Log Mag 10.00dB/ Ref 0.000dB [F2]
>1 10.368000 GHz -1.0844 dB
-1.0844 dB
Tr4 S12 Log Mag 10.00dB/ Ref 0.000dB [F2]
>1 10.368000 GHz -1.0645 dB
-1.0645 dB
200 MHz

Measurements with 4 Mini-PAs



Measurements with 4 Mini-PAs



Measurements with 4 Mini-PAs

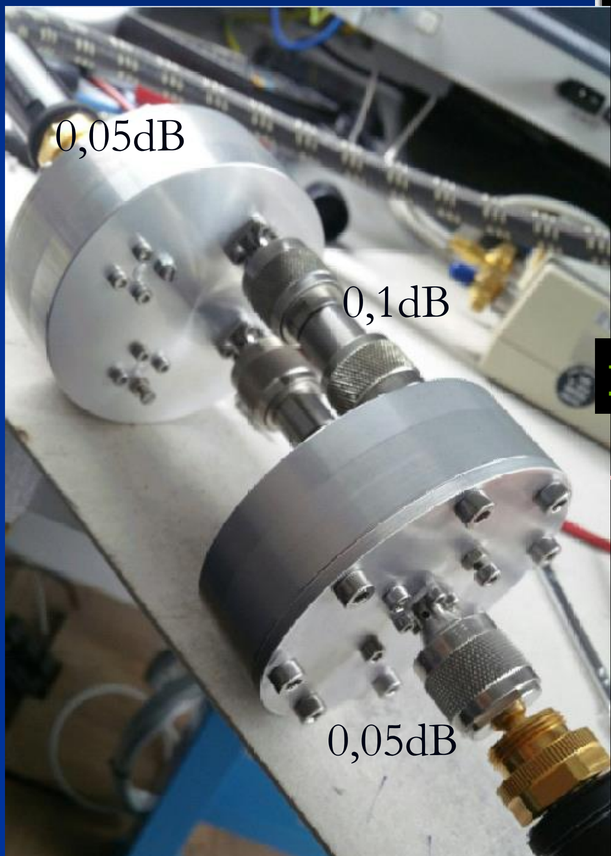
Power of 4 amplifiers each, and Sum

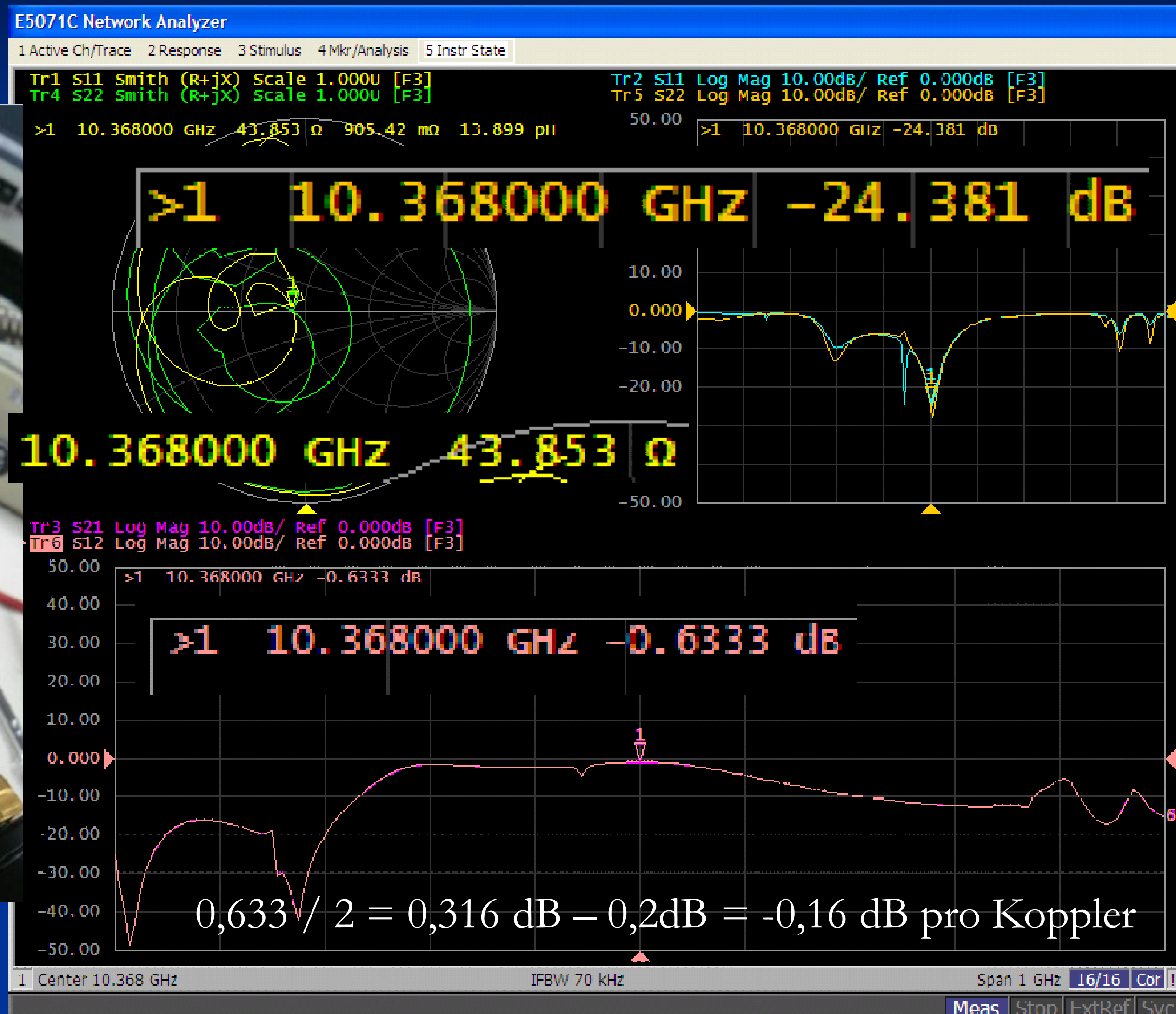
PA	dBm
A	27.8
B	30.69
C	31.2
D	30.64
Total	36.68

Measured power sum of 36,68 dBm compared to combined power of 36,25 dBm leads to attenuation of the Combiner of -0,43 dB

Measurements of 2 Mini-PA's only

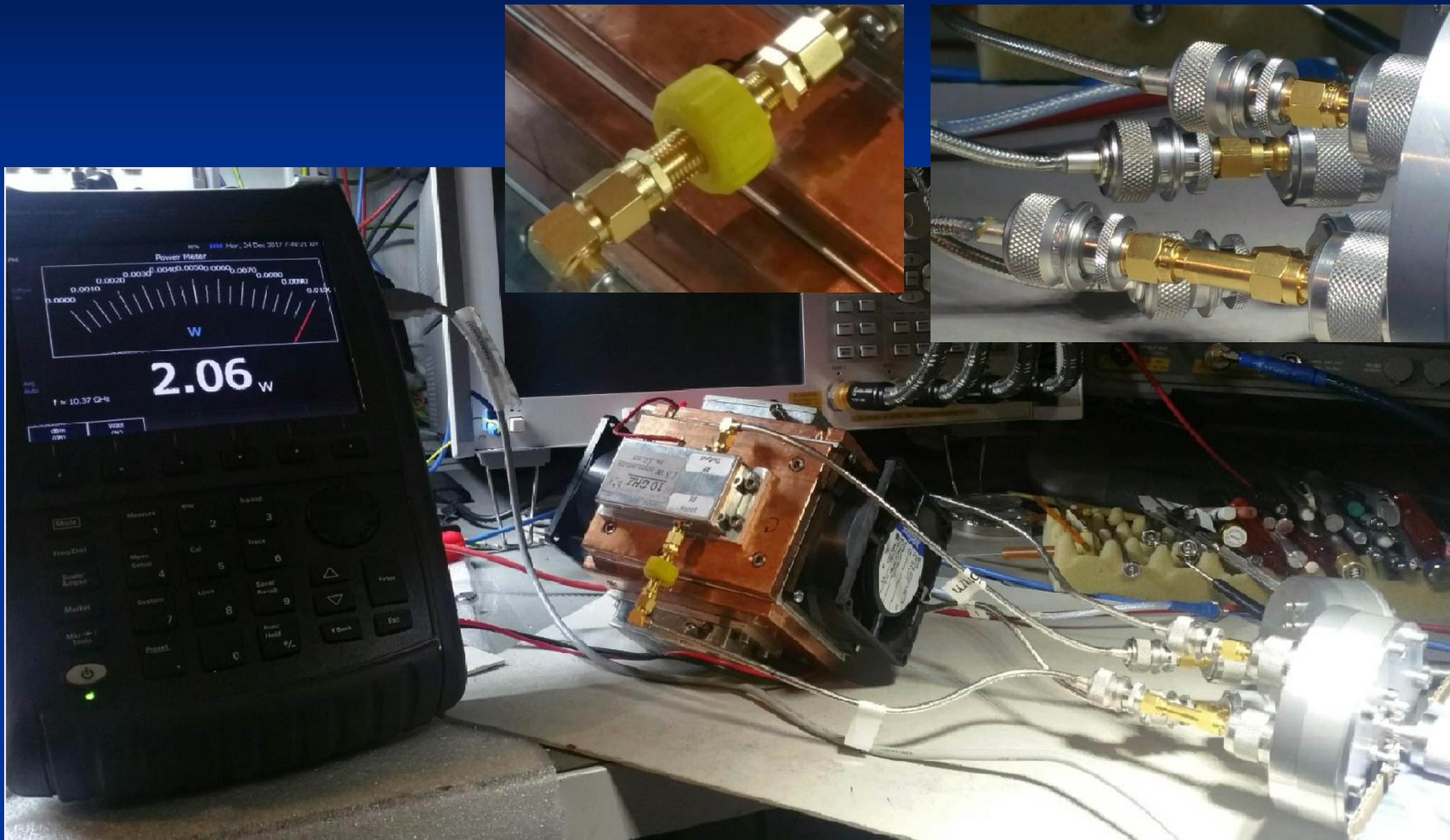
Match and insertion loss





0,633 / 2 = 0,316 dB – 0,2dB = -0,16 dB pro Koppler

Measurements of 2 Mini-PA's only



Measurements of 2 Mini-PA‘s only

2x RFMA 7185-S1
A-Mode
2,06 W out@13dBm input
@12.1V 2.1A

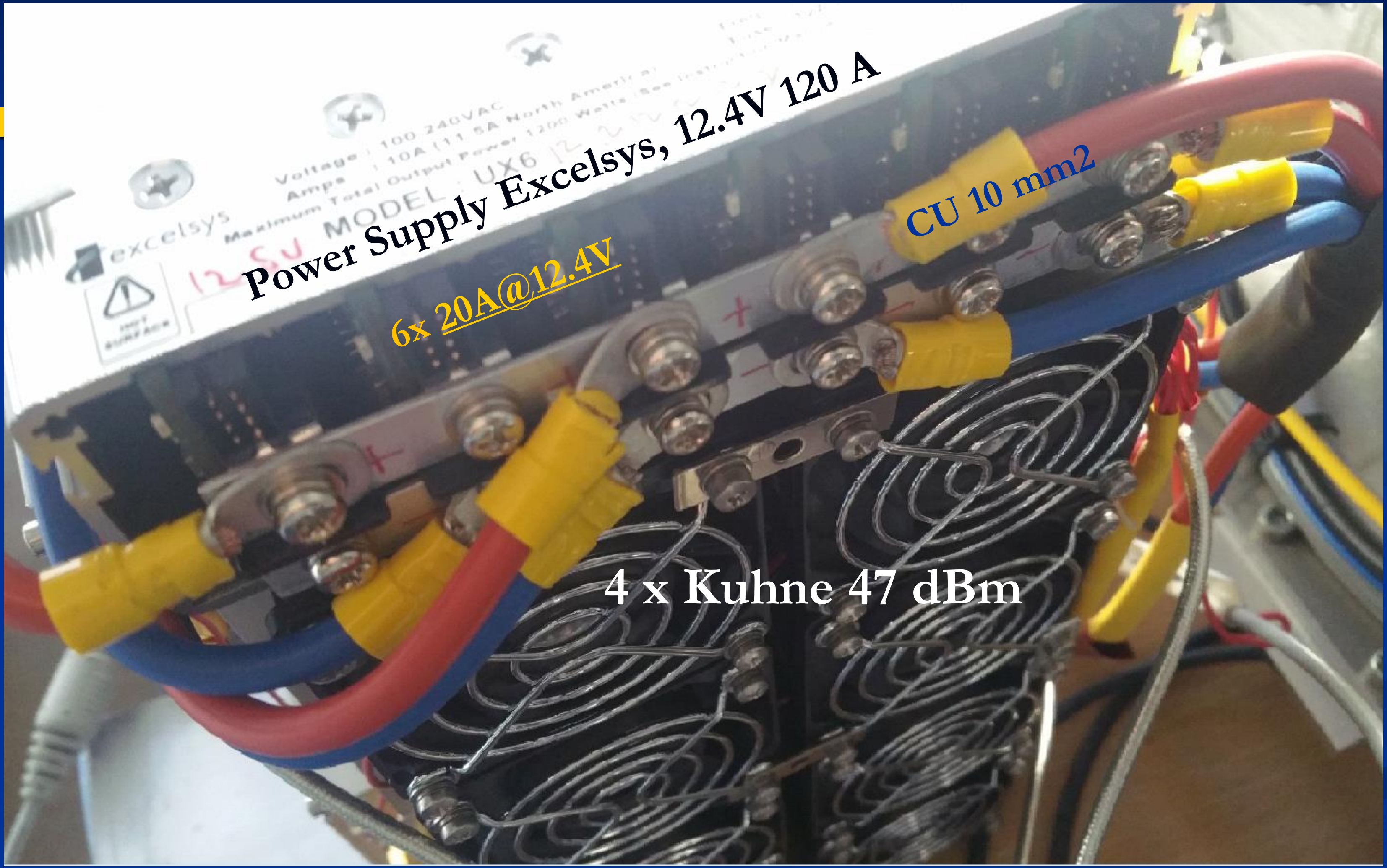
PA	dBm
A	27.8
C	31.2

2,33W = 100%
2,06W =   88,4%

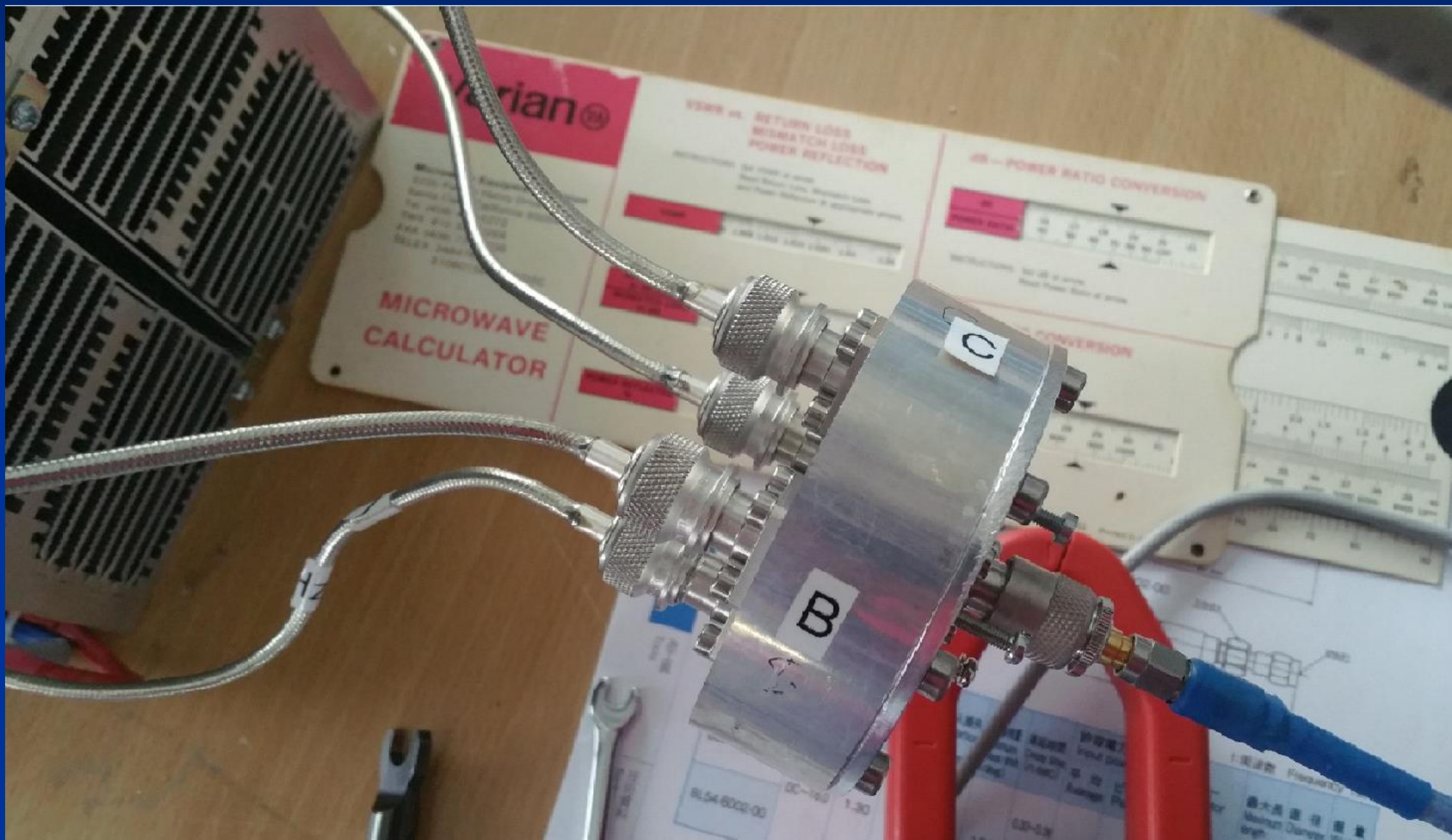
Tuning of 2 PA‘s takes more time than of 4 PAs

Asymmetric lay-out and thus Phase-Errors are more prominent and require correction

Measurements with 4 62W-PAs



Measurements with 4 x 47 dBm-PAs
The 1:4 Input Divider



Measurements with 4x47 dBm-PAs Phase-Shifter

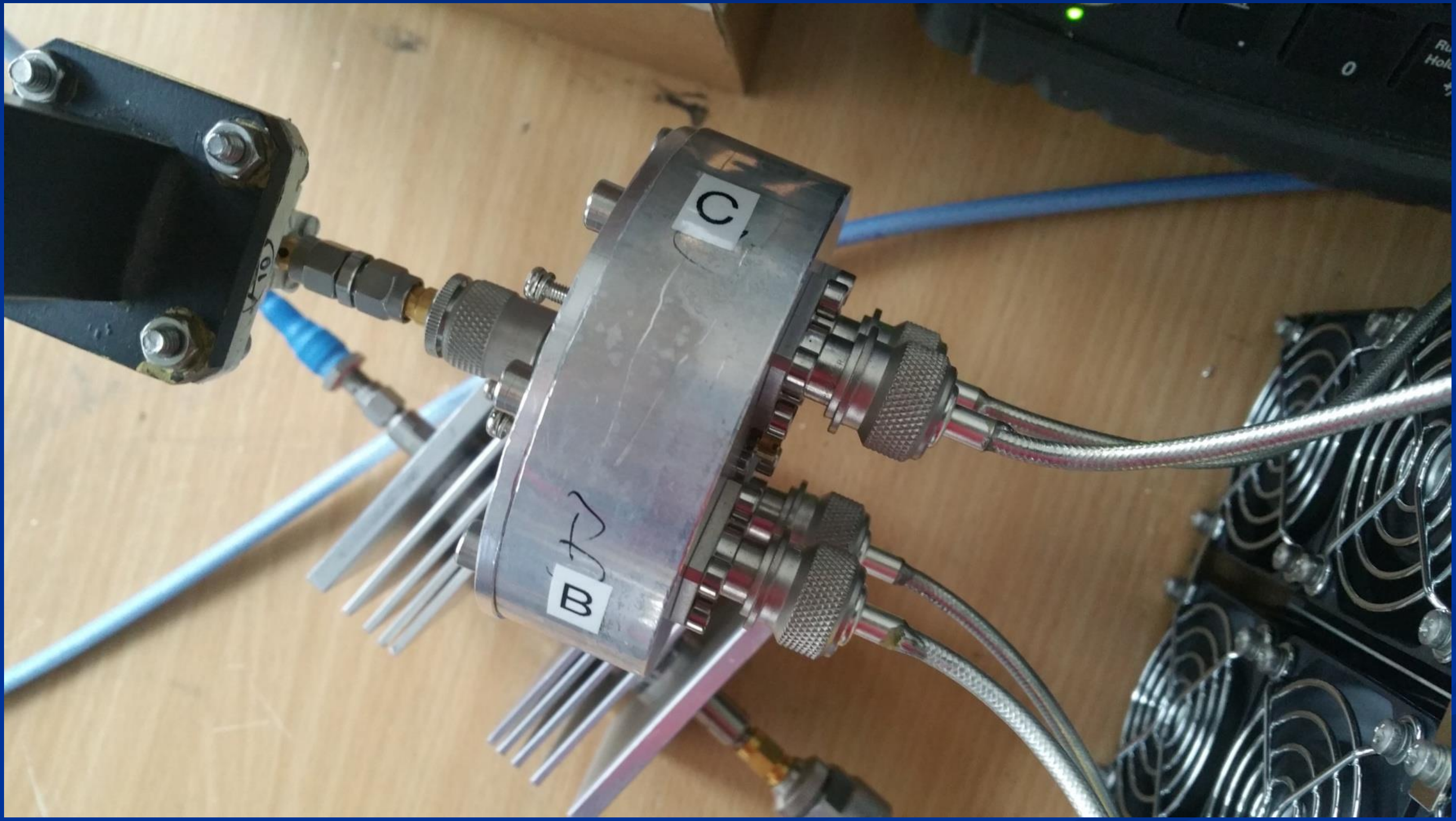
Up to 35 degree tuning @ 10 GHz

Multi-Stage amplifiers create more likely phase-errors. Mechanical tolerances, different amplification factors and thus different values in S-parameters are the major source of phase-differences

Measurements with 4x47 dBm-PAs

Phase-Shifters at the Input

Measurements with 4x47 dBm-PAs
4:1 Output Combiner



Measurement Set-up

Dummy-Load WR90 280W

Adapter WR75– WR90

Directional Coupler -50,5 dB

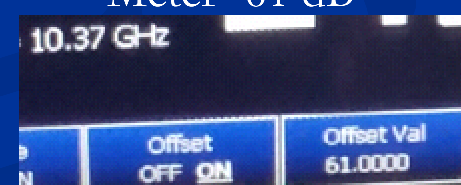
TNC-SMA + SMA-SMA-WG

Sucoflex 104 -0,5 dB

Attenuator -10 dB

Power Sensor Agilent U2000H

Offset-Korr. at Power Meter -61 dB



Measurements with 4 Kuhne

MKU PA 3cm-47 dBm

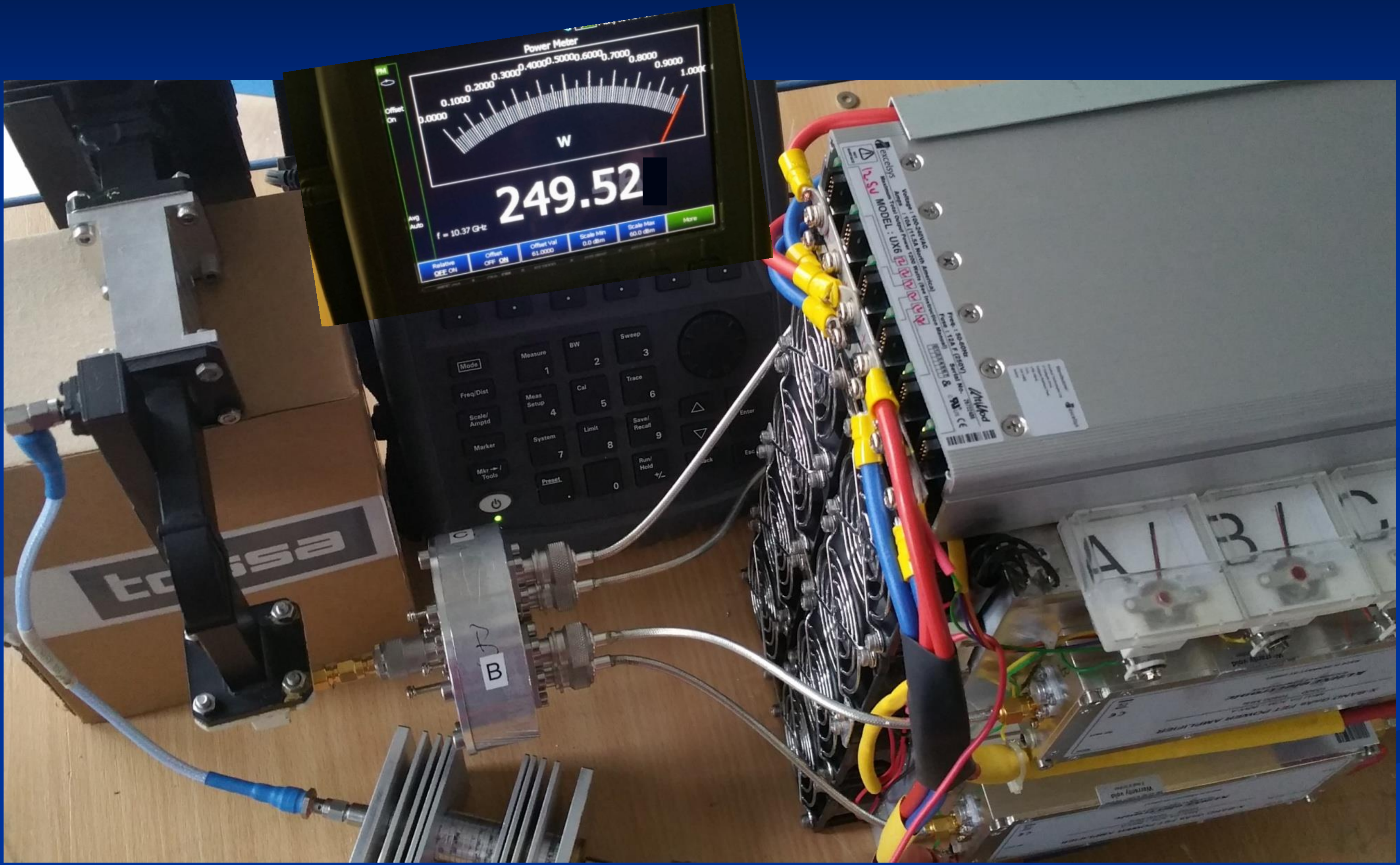
SMA-SMA Suhner Gold

SMA-SMA 3.5mm Steel warming up as „Dummy load“

Combiner remains at ambient temp.!

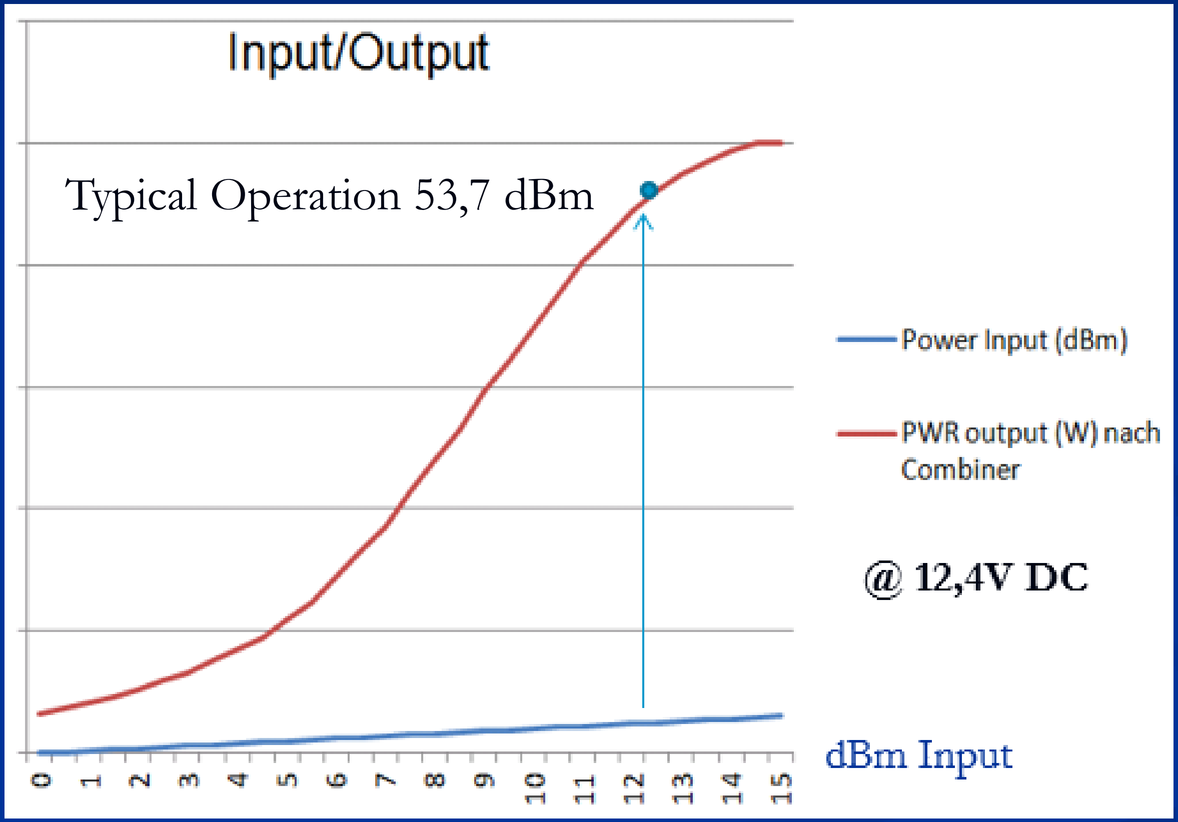
Measurements with 4 Kuhne

MKU PA 3cm-47 dBm



Power Graph

4x KUHNE MKU PA 3cm-47 dBm

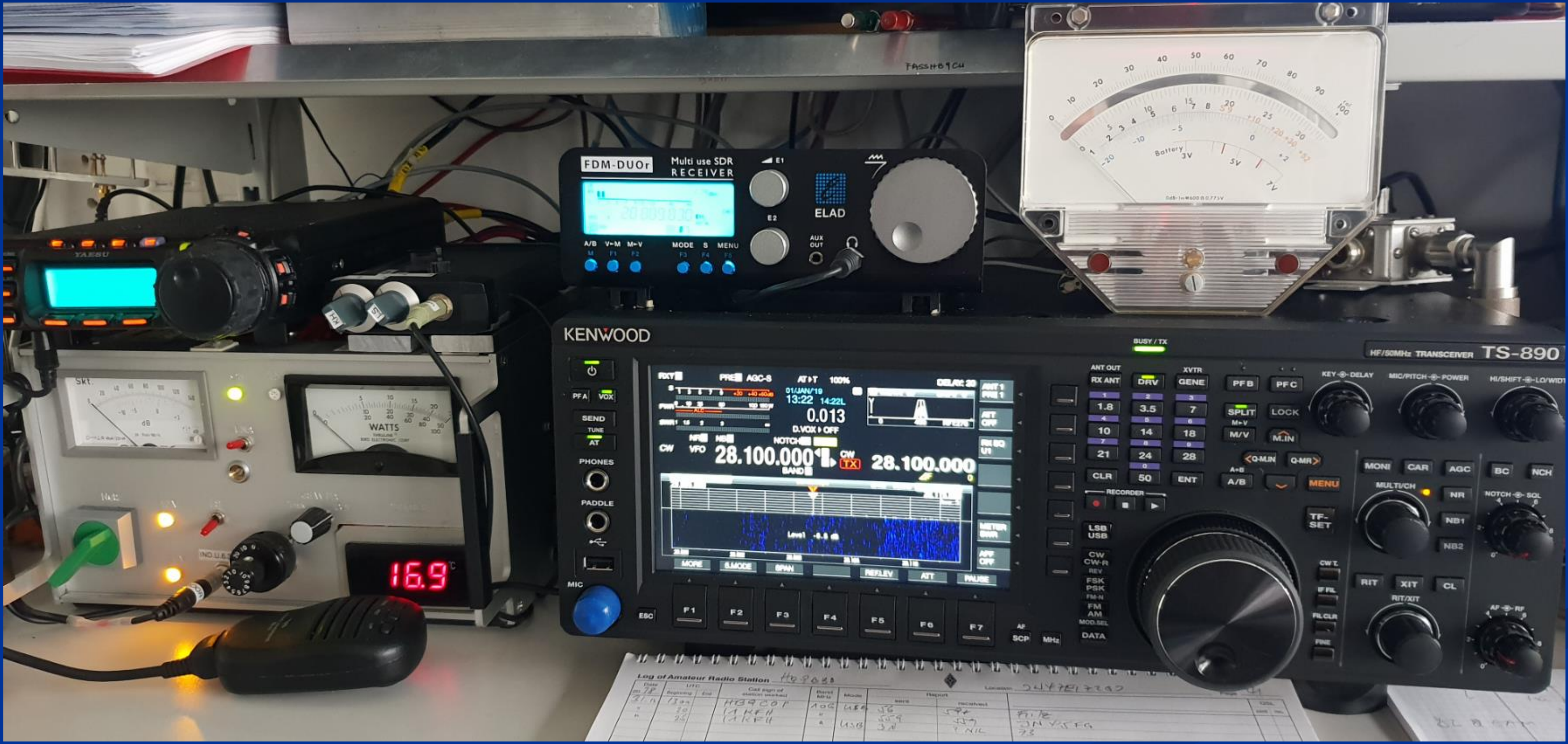


Efficiency

- DC Power input 12.4V @ 92A = 1.14 k
- RF input 24 mW > 40dB amplification
- RF output 54 dBm max Error +- 2%
- Sum of 4 amplifiers: 54 dBm, with Combiner same
- Efficiency 1.14W / 0,249k = 21,8%
- Insertion Loss by Combiner < 10W bzw. <2,5%

Practical Test

My new setup



My new Setup

1.8m Andrew Dish

My new Setup on the bench

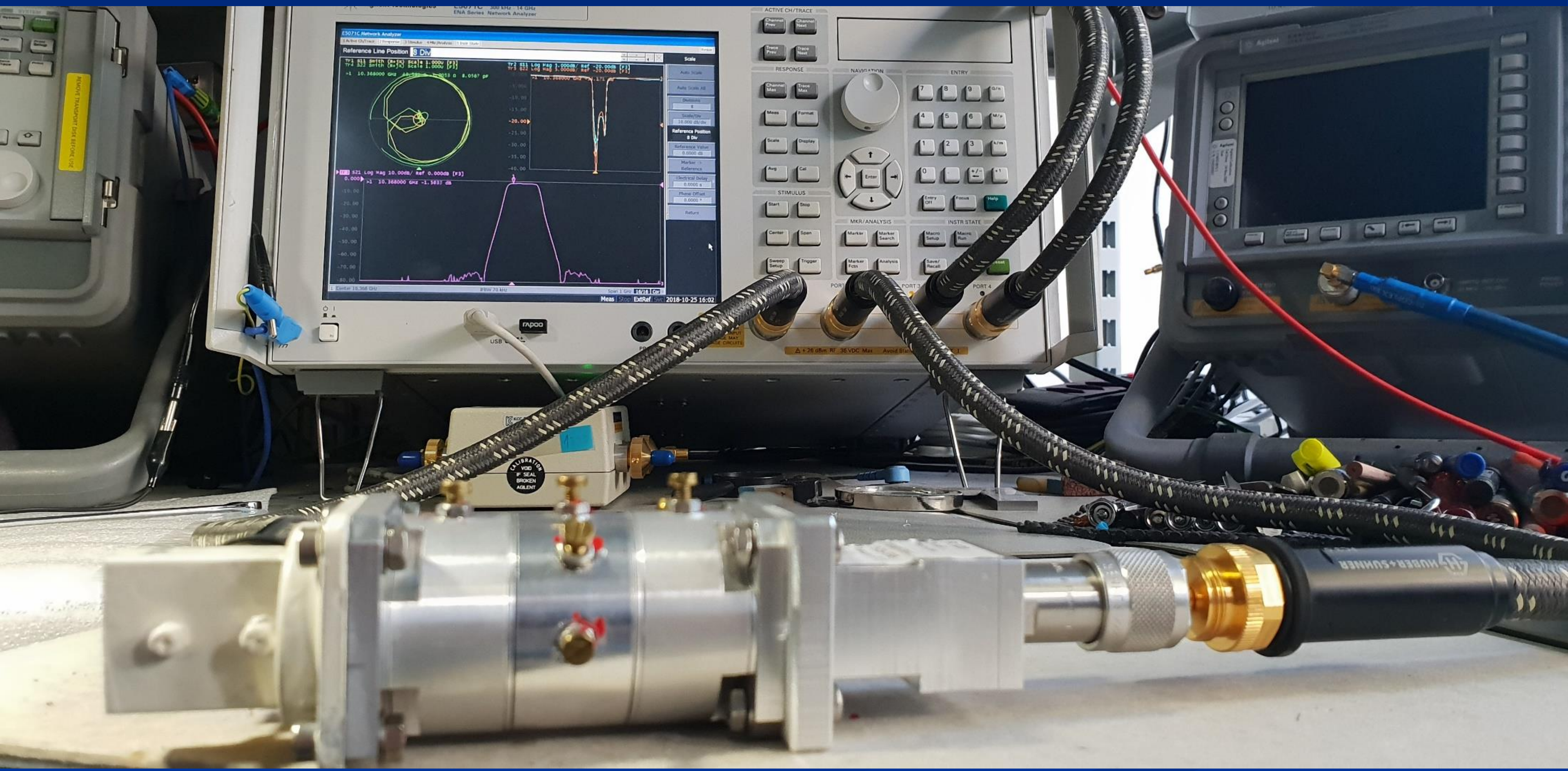
12.4 V Power supply
120 A

Combiner

Circulator with Dummy Load

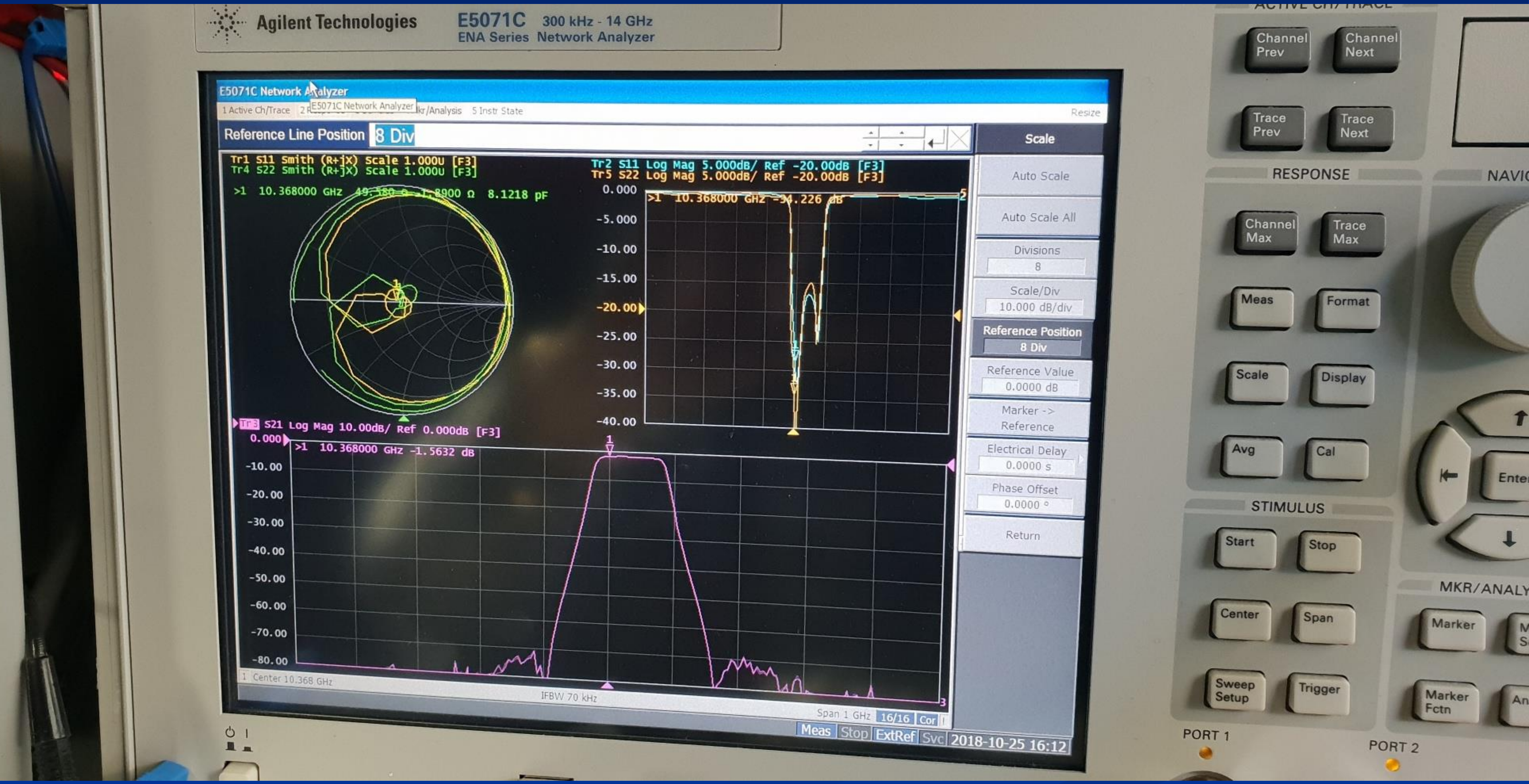
My new Setup

RF-Filter between Transverter and PA



My new Setup

RF-Filter between Transverter and PA



My new Setup

Ready for QSOs ;-)

Practical Echo-Test

Practical Echo-Test

Conclusions

- It is possible to efficiently combine 4 Power Amplifiers at 10 GHz
- The same is valid for 2 PAs only
- The major challenge is to achieve harmonic Phase
- All components have to carry the power level
- Increased temperature means lossy components or mismatch
- It is strongly advised to prudently handle all, also small power in X-Band

Conclusions

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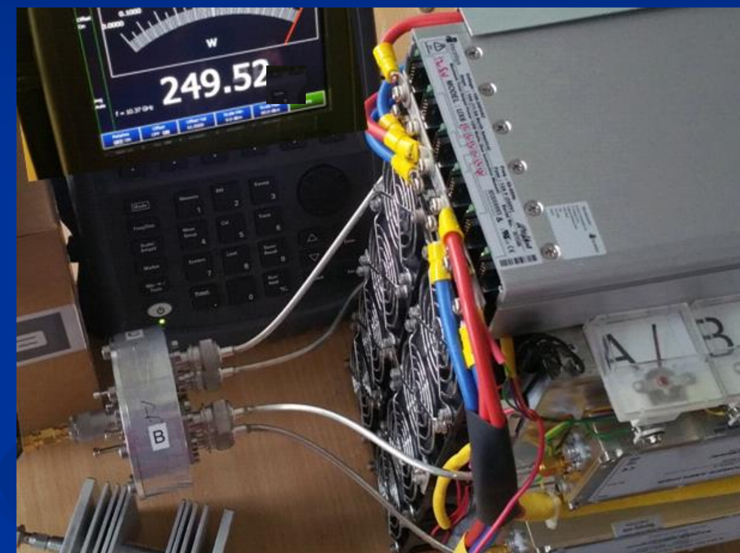
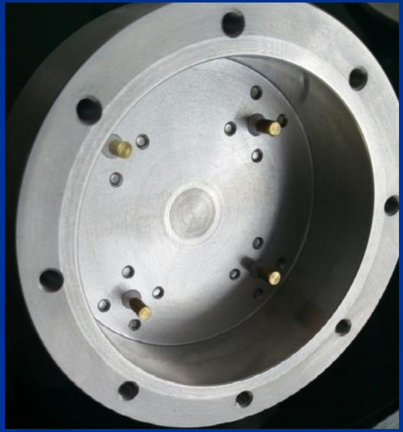


12 Kg, 54 dBm

90 Kg, 54 dBm

Source for Components

- Body and Cover 4:1 Coupler, finished to mount Connectors
  for SUHNER SMA or SUHNER N-Connectors (HB9BBD, Euro 47)



- Tuned with N-Connectors (HB9BBD Euro 145)

- Tuned with SMA-Connectors (HB9BBD Euro 145)

- Phase Shifter SMA-SMA (HB9BBD, Euro 53)
  (sorry, this is my cost-price)

Remarks and Questions?

Appendix

Thoughts and realization of better WG-Koax Adaptors

SMA-WG75 Adapter

Typical Specification: Match <20 dB is not sufficient

Datsheets:

Electrical Specifications

Frequency Range	8.2GHz - 12.4GHz
V.S.W.R	1.3 :1 (avg)
Radiation	Directional
Polarization	Vertical or Horizontal
Maximum Power	200 Watts

Configuration

Waveguide Size	WR-
Flange	Sq
RF Connector	SMA
Impedance	50 Ohms
Body Geometry	Right Angle

Electrical Specifications

Description	Min	Typ	Max	Units
Frequency Range	8.2		12.4	GHz
VSWR			1.25:1	

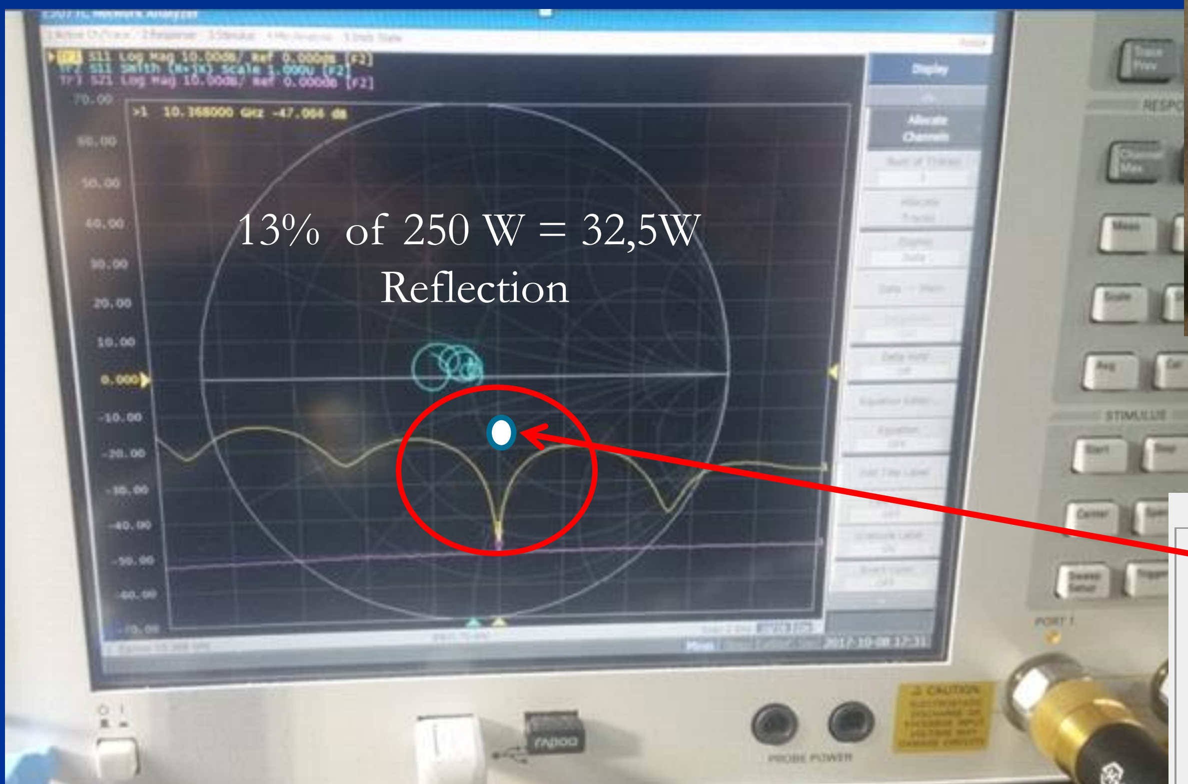
Electrical Specifications

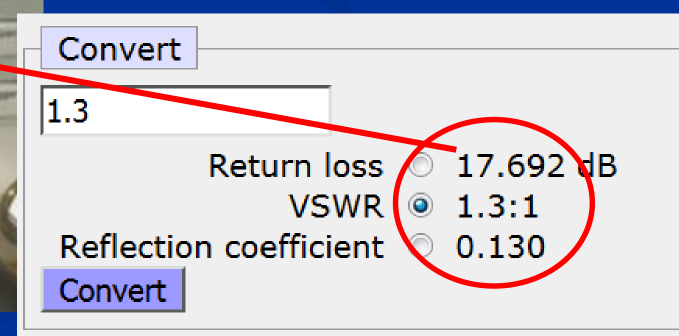
Description	Minimum	Typical	Maximum	Units
Frequency Range	8.2		12.4	GHz
VSWR			1.3:1	

1:1,3 = 13% Loss

SMA-WG75 Adapter

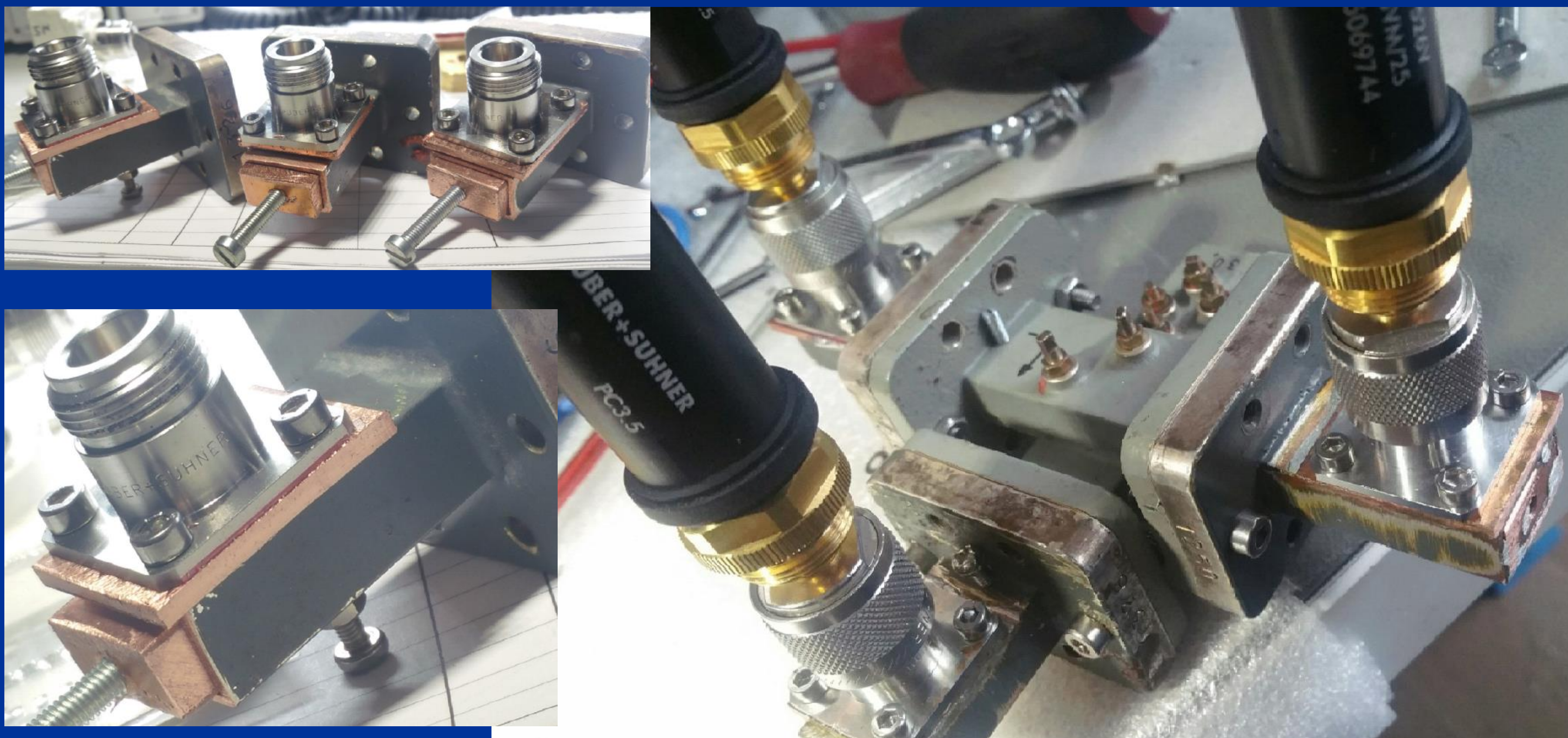
Self-Made or Re-Tuning on 10‘368 MHz





SMA-WG75 Adapter

It pays off to build Adapters by your own!



SMA-WG75 Adapter

Cross-Copler at 10'368 MHz with homebrew Couplers