

60KW Solid-State Booster Amplifier

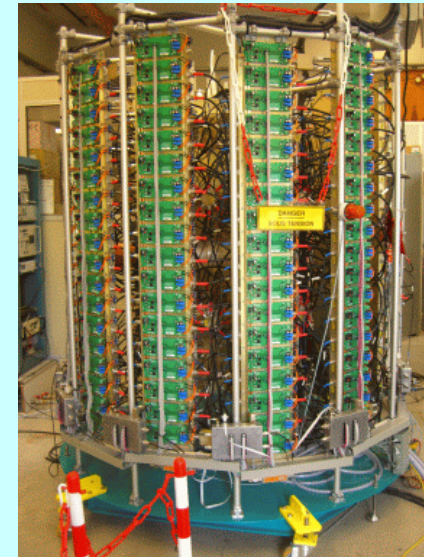
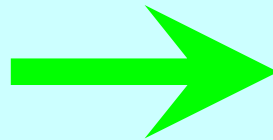
Development at PSI



Booster Klystron Amplifier



Test Stand



Booster Solid-State Amplifier



60KW Solid-State Amplifier

M. Gaspar, M. Pedrozzi

Target Specifications

Output Power: 60KW

Center Frequency: 499.652MHz

Efficiency: ~ 50%

Price: Cheaper than Klystron Amplifier

Lifetime: Longer than Klystron Amplifier

Maintenance: Easier, Hot Swap Possible

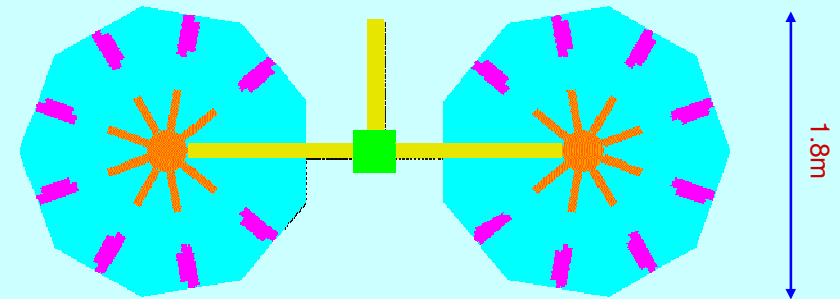
Construction: In House

Proposed Design Configurations

1- 2 Tours = 16 Bars = 256 times 250W Modules → $P_{out} = 64KW$ max

- Advantages:
- Extra Power to Compensate Losses
 - Uses Developed 250W Amplifier
 - Easier Maintenance
 - Only Half of the Amplifier may be used if needed

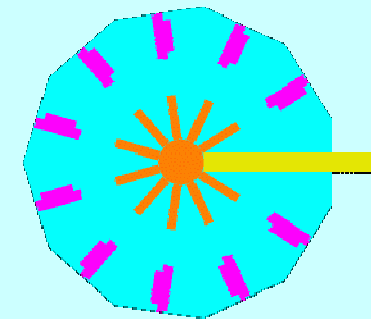
- Drawbacks
- Slightly Bigger Size



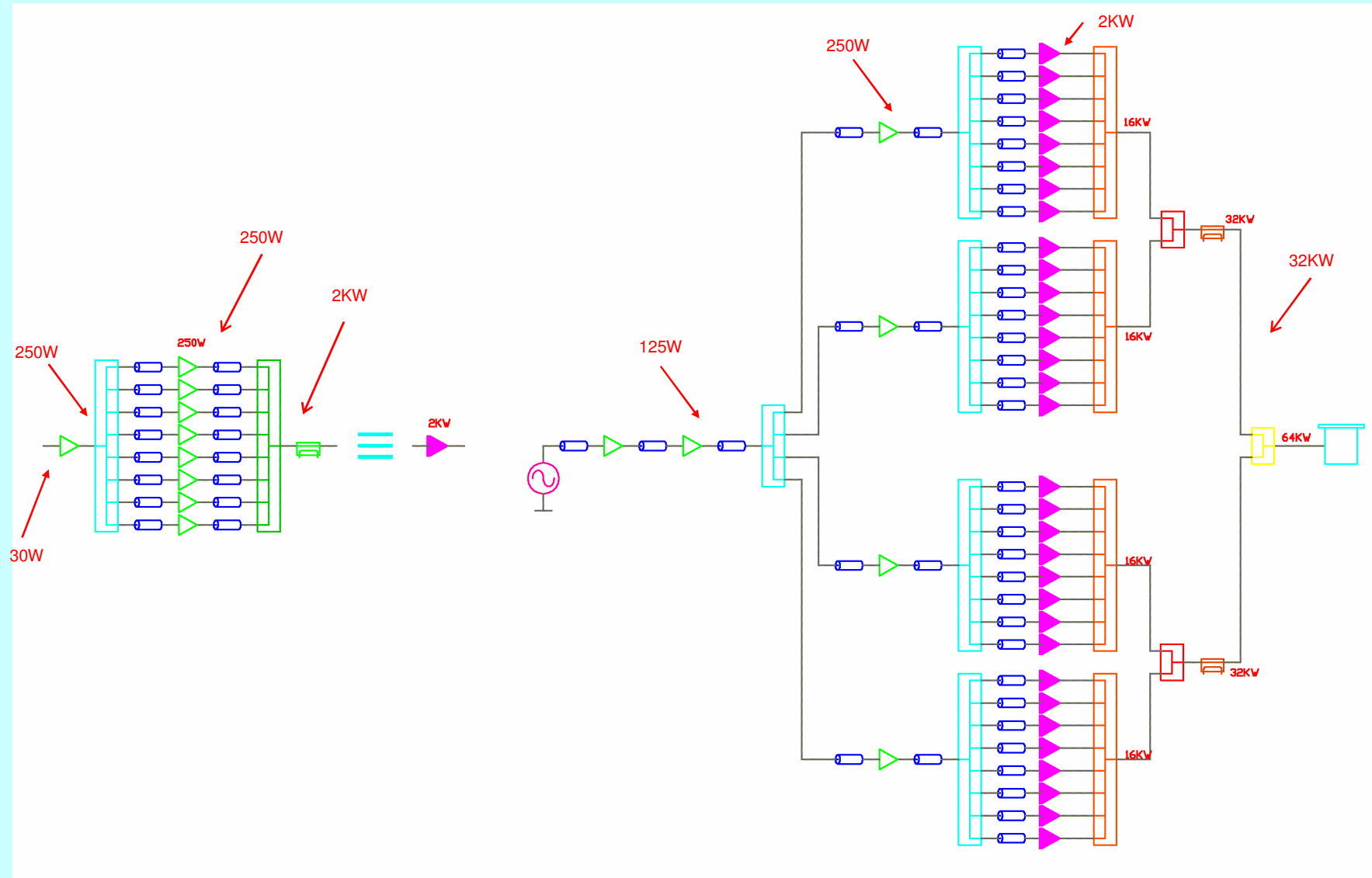
2- 1 Tour = 10 Bars = 160 times 250W Modules → $P_{out} = 40KW$ max

- Advantages:
- Lower price possible (may save 20%)
 - Smaller size

- Drawbacks
- Requires Higher Gain Amplifier (not yet available)
 - No extra Power to Compensate Losses
 - Too Compact, Worse Maintenance



60KW Amplifier Schematics



Components Available

Power Supply: 3 Different Models Commercially Available (Industry)

Power Splitter: 2 8-Way and 1 4-Way Prototypes working (PSI Design)

250W Amplifier Module: 2nd Prototype working (PSI Design)

Cooling Bar: Use Soleil Design (Should Keep Compatibility) (Industry)

Circulator + Load: Commercially Available (Industry) (Already Tested)

Components Under Development @ PSI

Control System: Local (Amplifier Module) and Main Controllers

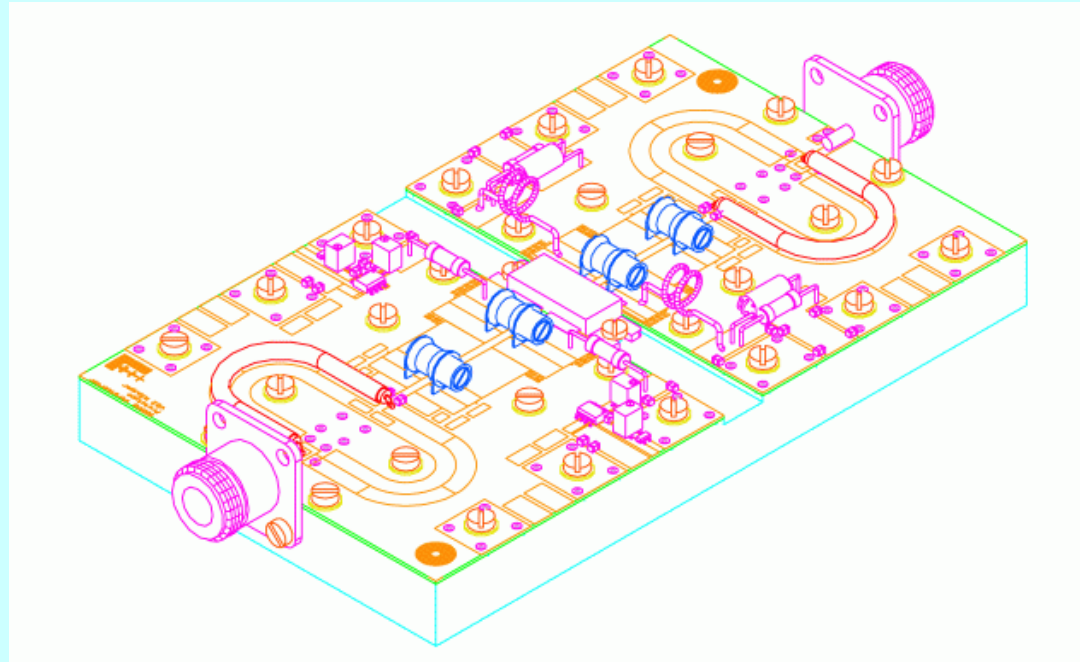
Power Splitter: 1 2-Way, 1 4-Way and 1 8-Way Low Loss High Isolation

250W Amplifier Module: Closed Case and Test-bench Cooling Plate

Power Combiner: 8-Way and 2-Way Coax

Power Coupler: 2KW and 32 KW Types

250W Amplifier - The Key Component



3D-View of the 2nd Prototype

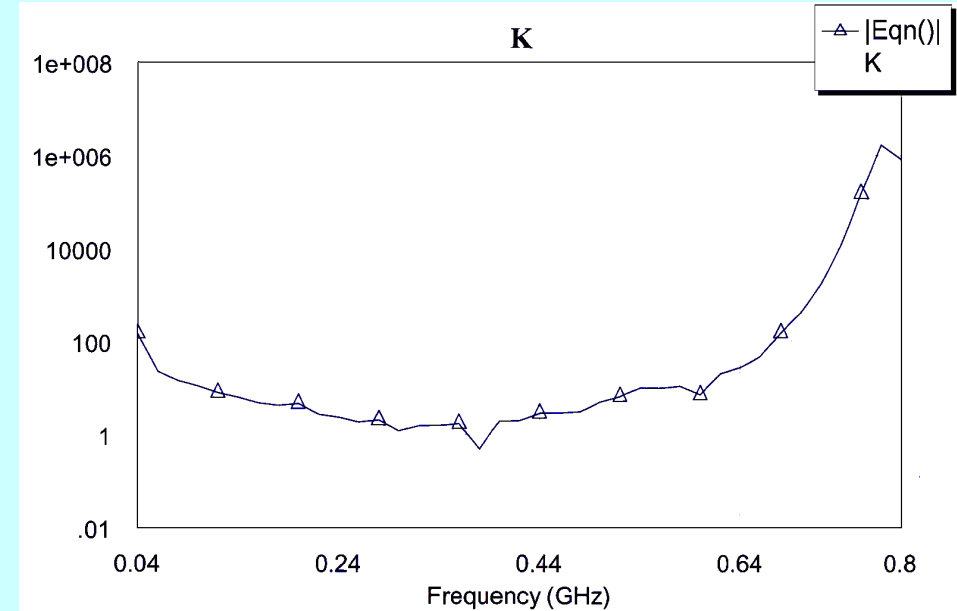
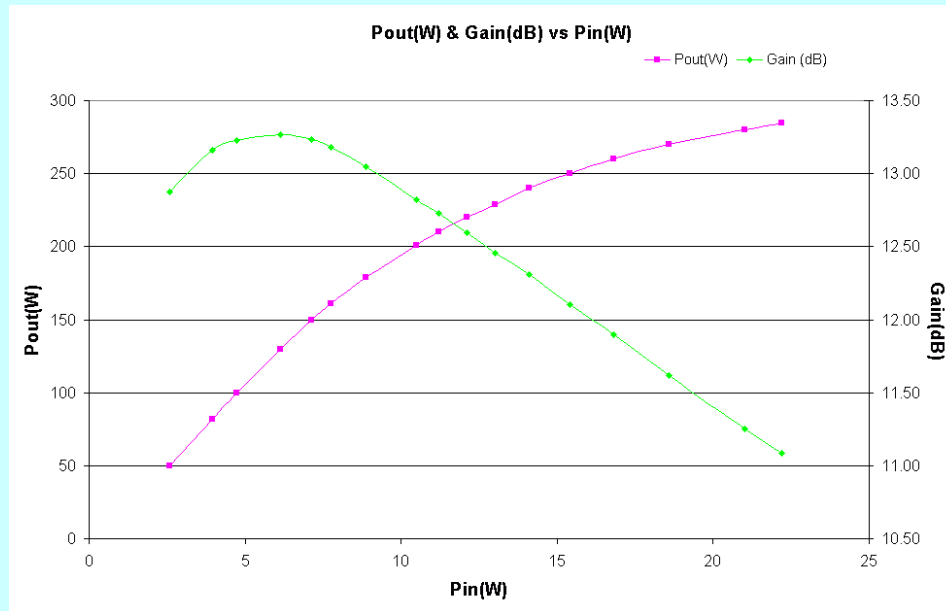
Key Performance Parameters

| | Operation | Max |
|-----------------------------------|-----------|-------|
| Output Power (with Circulator) | 250W | 290W |
| Gain | 12dB | 11dB |
| Efficiency | ~ 50% | ~ 50% |

250W Amplifier - Measurement Results

Pulsed Mode – Gate-width=400μs f=2Hz Rise-time>10μs

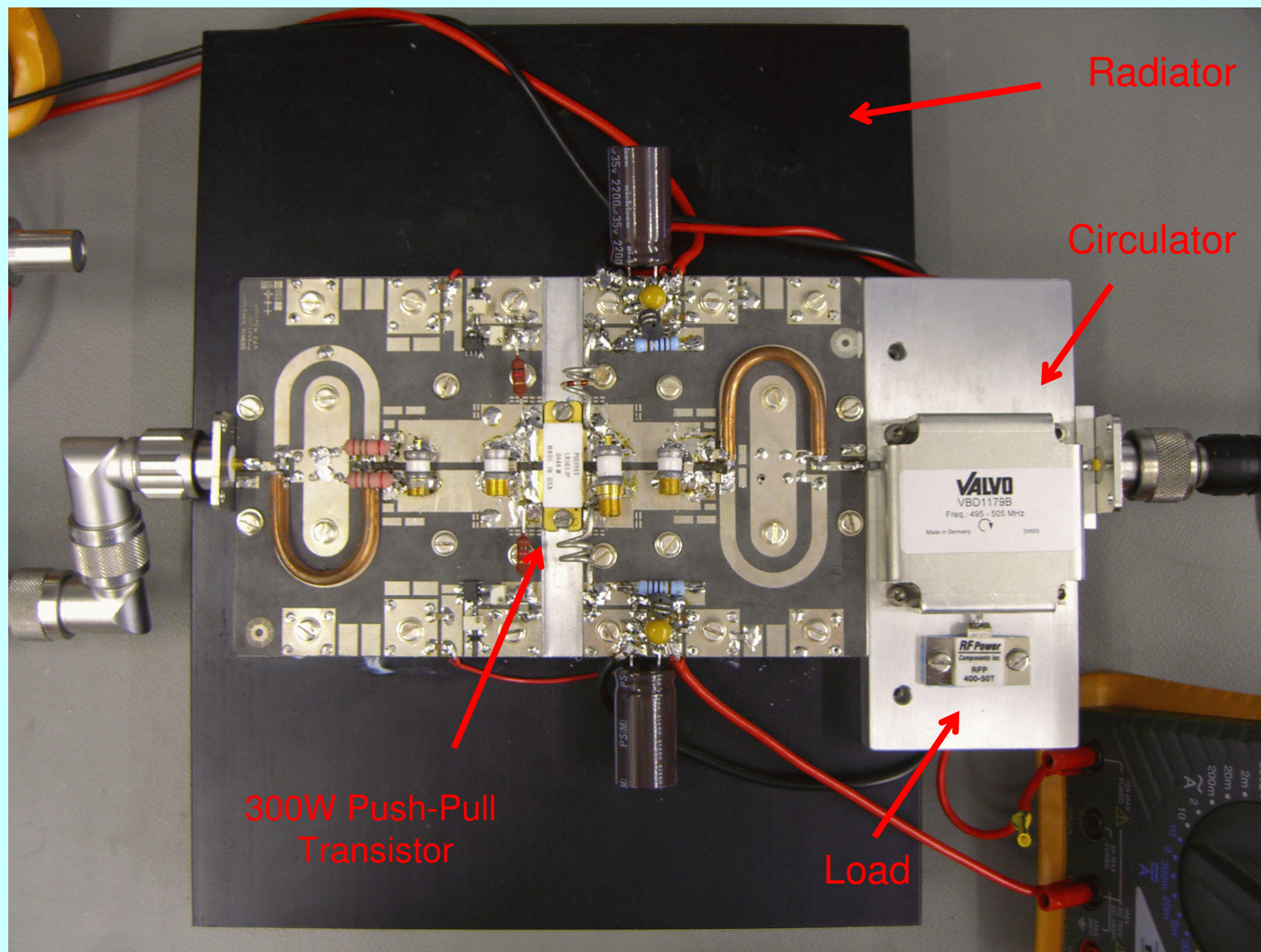
Stability Factor K



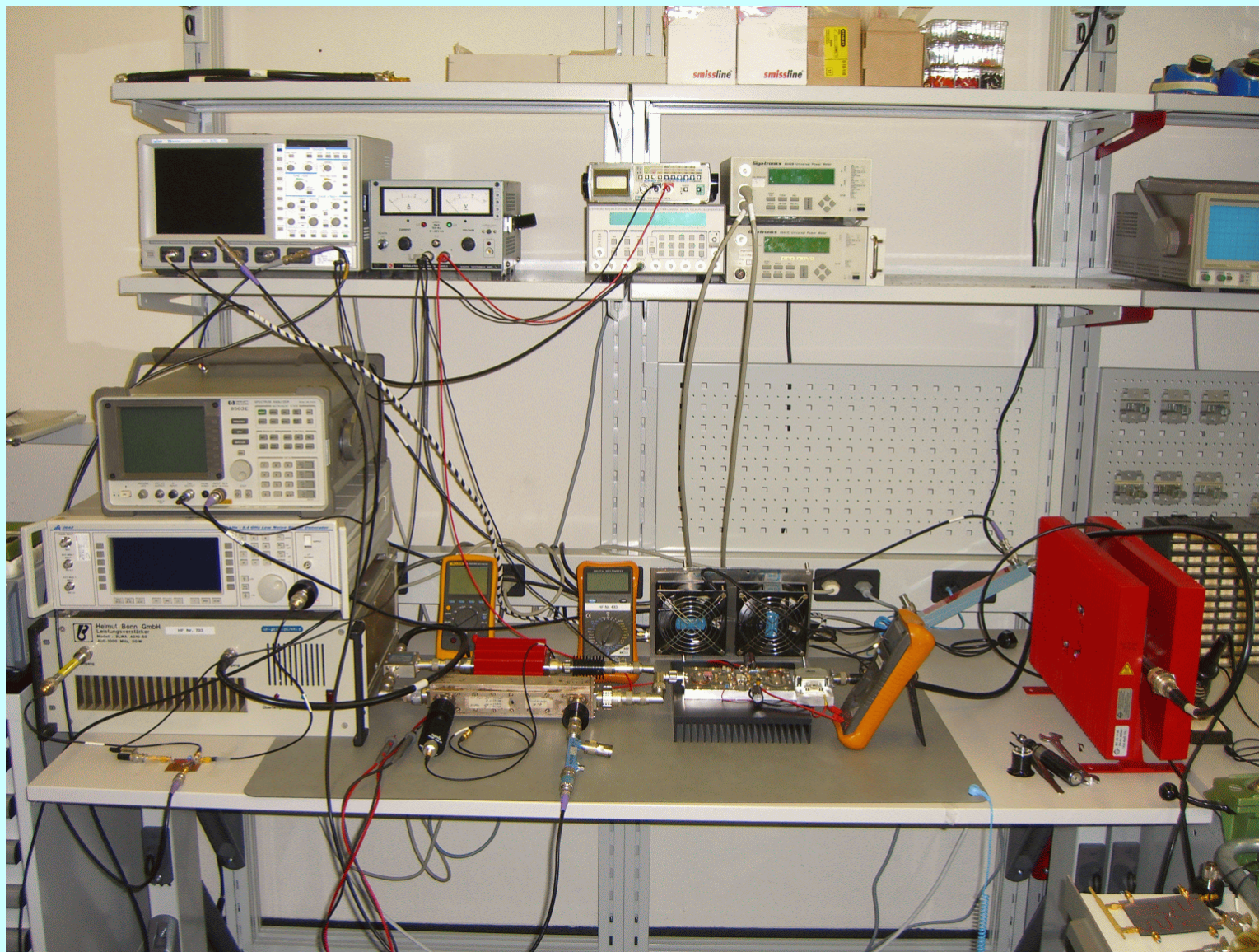
$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} \quad K > 1$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \quad |\Delta| < 1$$

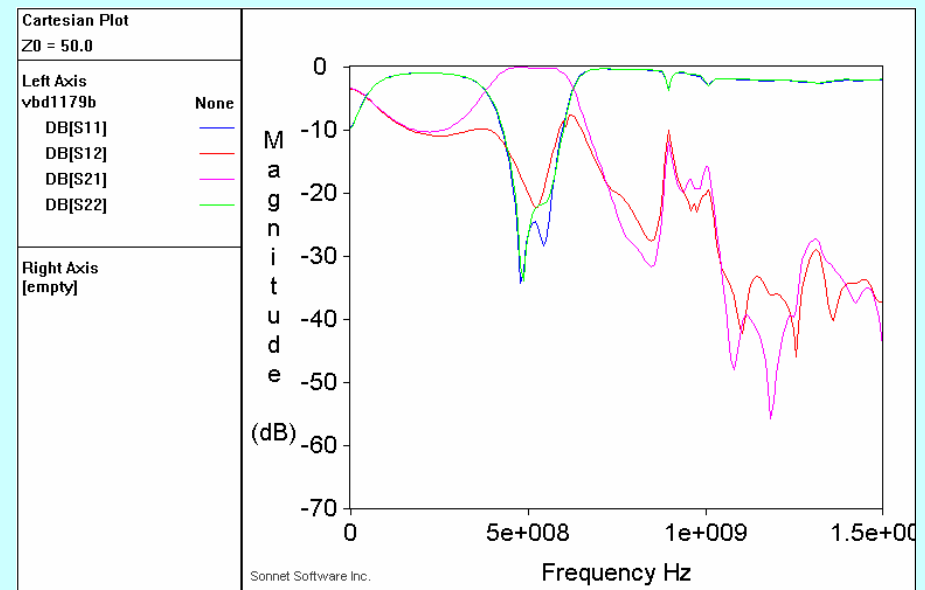
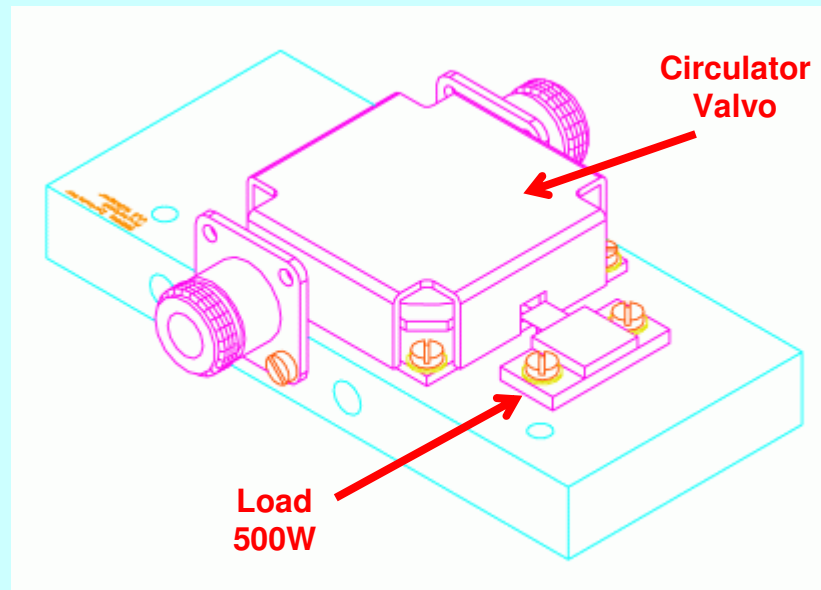
250W Amplifier - Working Prototype



250W Amplifier - Test-setup



Circulator



Key Performance Parameters

$$S_{21}BW_{0.2\text{dB}} = 60\text{MHz}$$

$$S_{11}BW_{<-20\text{dB}} = 100\text{MHz}$$

$$S_{12}BW_{<-20\text{dB}} = 50\text{MHz}$$

$$IL = -0.14\text{dB @ } 500\text{MHz}$$

$$RL = -27\text{dB @ } 500\text{MHz}$$

$$\Delta\Phi = -1\text{ }^\circ/\text{MHz @ } 500\text{MHz}$$

Power Splitter

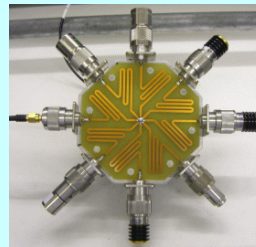
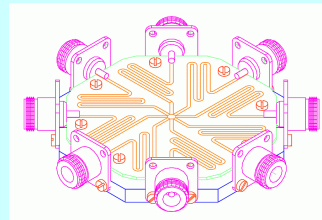
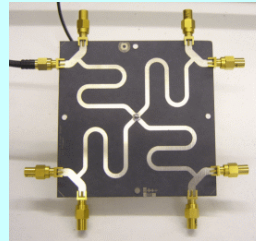
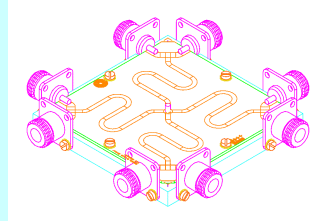
3 Configurations Available

- 4 Channels – FR4
- 8 Channels – Teflon
- 8 Channels – Suspended Substrate

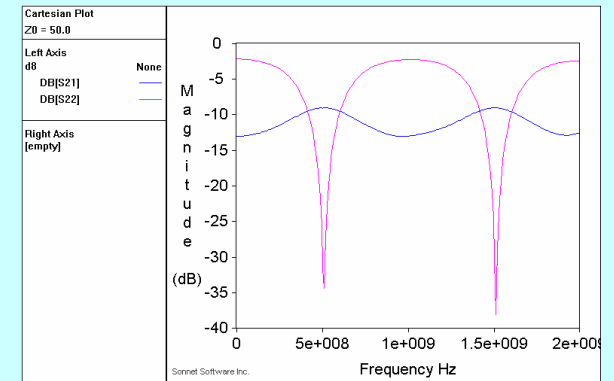
Designs in Progress

- 2 Channels – Teflon 3mm
- 8 Channels – Teflon 3mm improved isolation
- 4 Channels – Teflon 1.6mm

Prototypes



Measurement Results – 8-Channels Teflon



$$S_{21}BW_{-0.1\text{dB}} = 80\text{MHz}$$

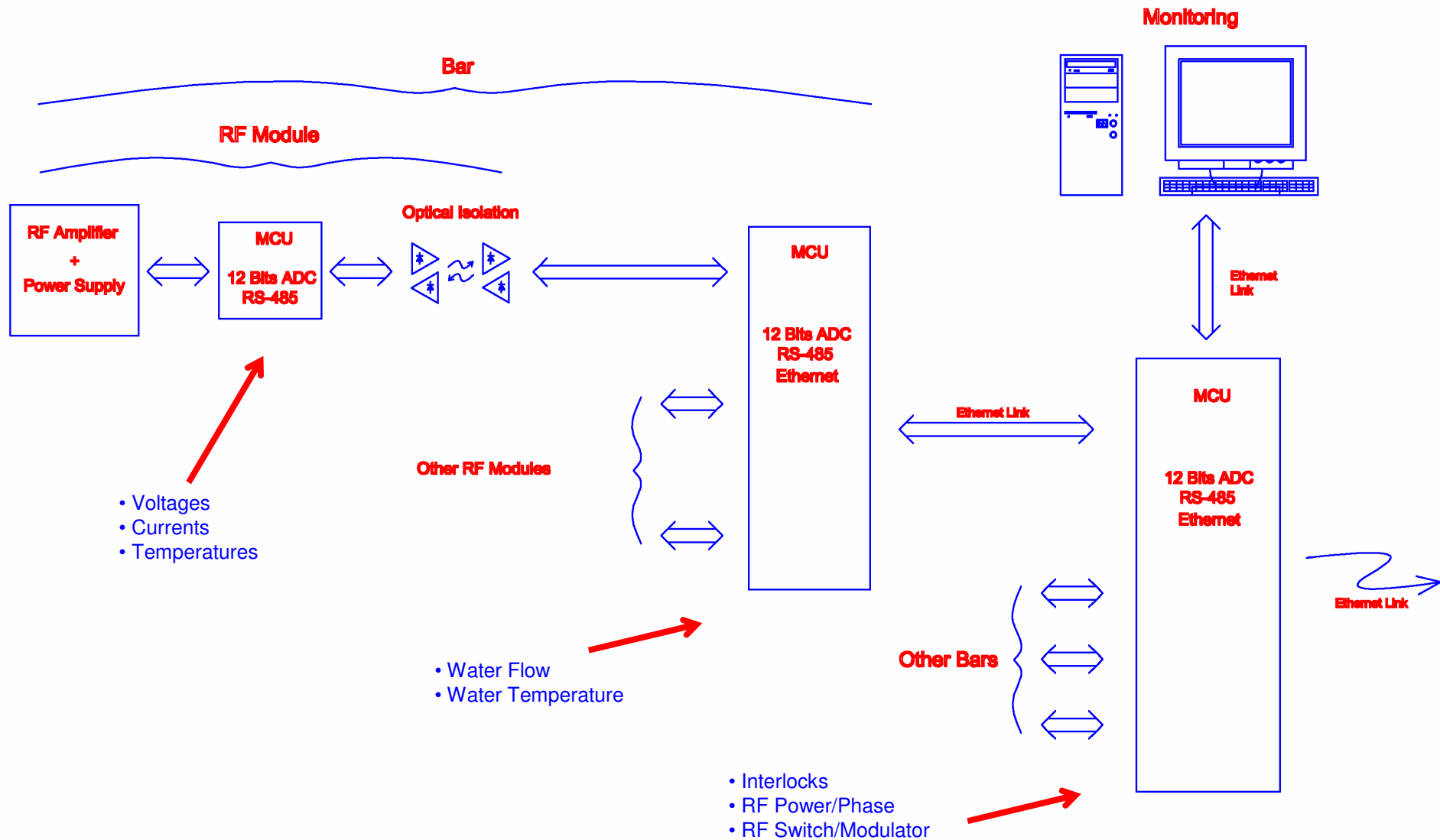
$$S_{11}BW_{<-20\text{dB}} = 100\text{MHz}$$

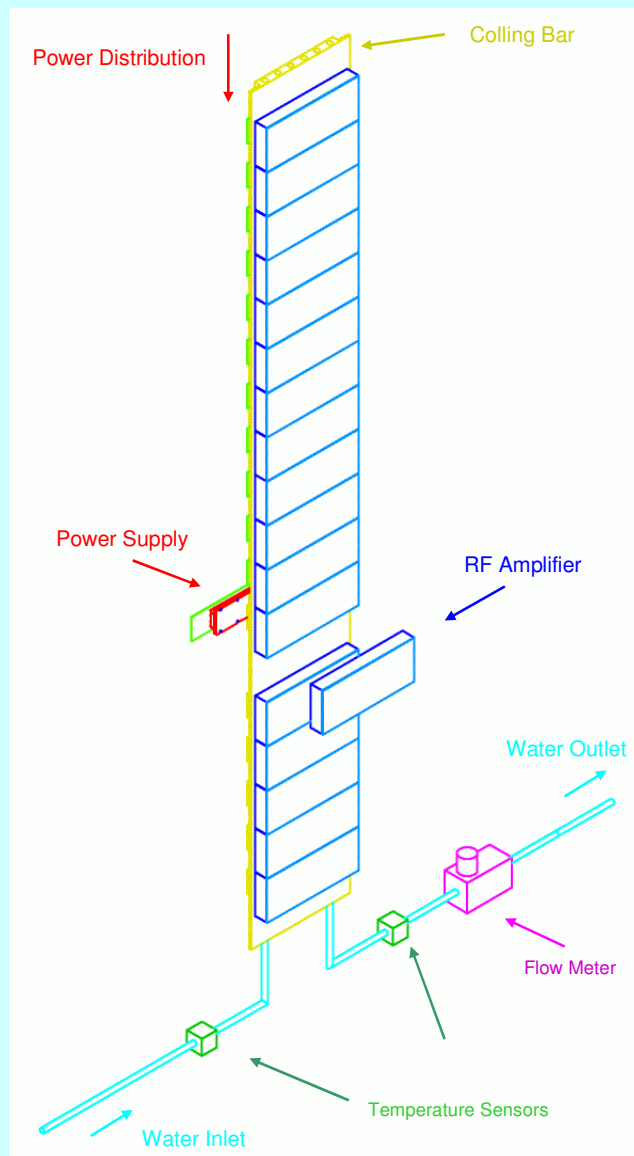
$$IL = -0.02\text{dB} @ 500\text{MHz}$$

$$RL = -29\text{dB} @ 500\text{MHz}$$

$$\Delta\Phi = -0.3\text{°/MHz} @ 500\text{MHz}$$

Supervision and Control





Cooling Bar - Fundamental Component

All Basic Requirements in One Component

- Mechanical Support
- Power Distribution
- Water Cooling
- Easy Maintenance and Accessibility

Cooling Requirements

$$P_{\text{total}} = 5800\text{W}$$



$$\text{Flux} = 10 \text{ l/min}$$



$$\Delta\Theta = 8.3^\circ\text{C}$$

High RF Power Density

$$\sim 0.2 \text{ W/cm}^3$$

Estimated Project Budget in CHF

| | |
|--------------------------|--------|
| Power Amplifier Modules: | 200000 |
| Power Supply: | 70000 |
| RF Cabling: | 10000 |
| General Assembly: | 30000 |
| Cooling System: | 30000 |
| Supervision and Control: | 10000 |

| | |
|------------------|--------|
| Estimated Total: | 350000 |
|------------------|--------|