X Band LNA with coaxial input matching, capacitive probe, and dielectric band pass filter

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Santa Clara, CA

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X band LNA’s performance, overview

Owner	made by	1st Stage	NF dB	Gain dB	Remarks
HB9BBD	HB9BBD	MGF4919G	0,727	25,89	incl. WG SMA adapter made by HB9BBD
F1OPA	F1OPA	NE3512S02	0,78	20,41	incl. WG SMA adapter owned by F1OPA
HB9BBD	DL3BCP	NE3512S02	0,743	27,49	incl. WG SMA adapter made by HB9BBD
OK1DFC	DB6NT	NE3511S02	0,826	25,39	incl. WG SMA adapter made by HB9BBD
OK1DFC	DL3BCP	NE3512S03	0,71	28,5	incl. WG SMA adapter made by HB9BBD
UA3AVR	UA3AVR & US4ICI	NE3210S01	0,89	22,1	incl. WG SMA adapter made by HB9BBD
SM3BYA	LNB SM3BYA	?	1,11	25,9	incl. WG SMA adapter made by HB9BB
HB9DUK	KUHNE	?	0,91	26,3	SMA INPUT SMA OUTPUT
HB9DUK	KUHNE COPY	?	0,97	24,2	SMA INPUT SMA OUTPUT
HB9DUK	KUHNE	?	0,974	22,36	incl. WG SMA adapter made by HB9BB
SM7GEP	DL3BCP	NE3512S03	0,715	28,42	incl. WG SMA adapter made by HB9BB
SM2CEW	SM2CEW	?	0,9	20,08	incl. WG SMA adapter made by HB9BB
PA2DW	DL3BCP	NE3512S03	0,704	29,33	incl. WG SMA adapter made by HB9BB

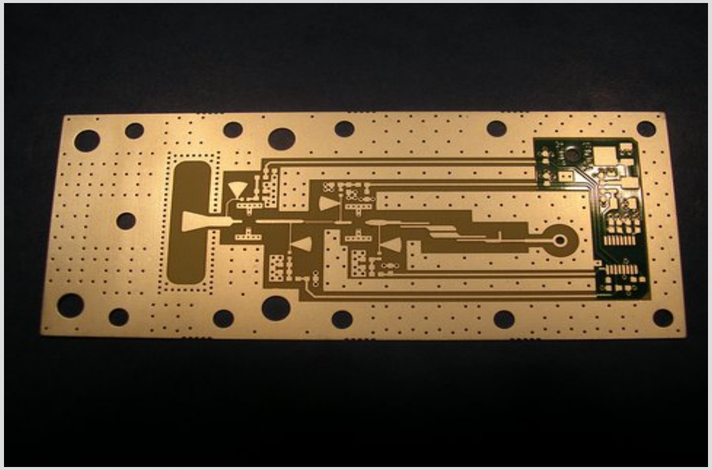
Table: NF measurments 10 GHz LNA at Örebro 2017, by HB9BBD - All LNAs have 2 stages e

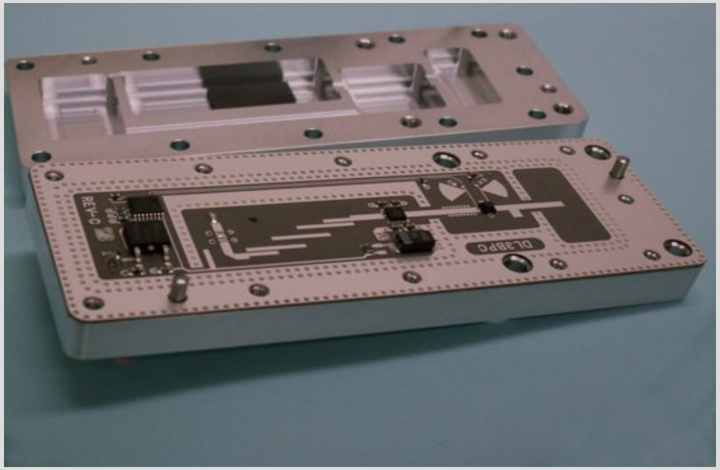
LNA's under test, result corrected for wg loss

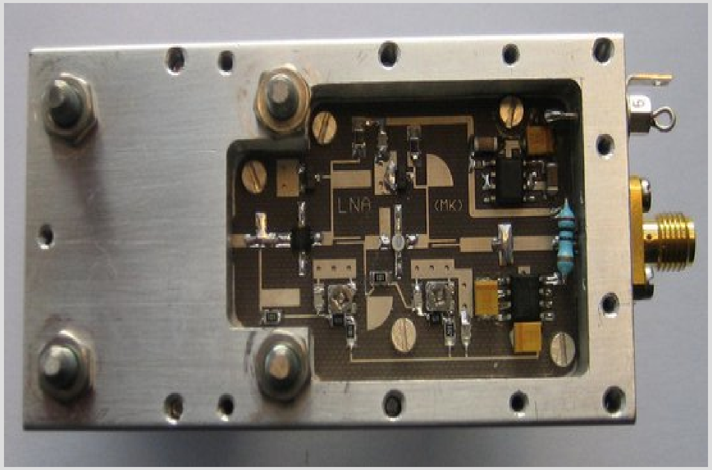
10368MHz 0.735dB 23.915dB

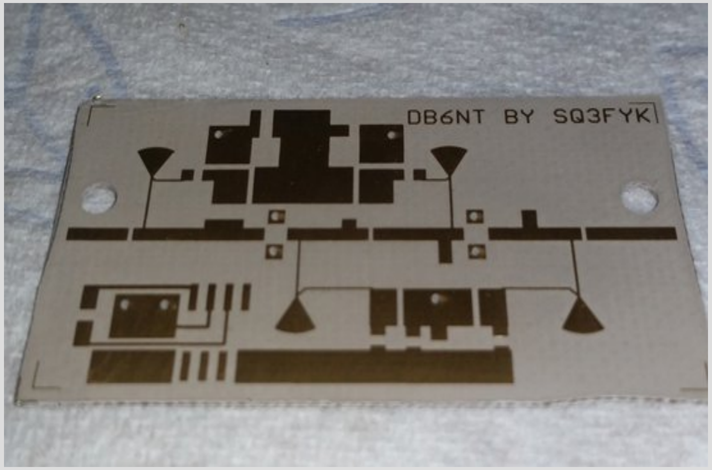
10368MHz 0.701dB 20.213dB

Some popular LNA’s



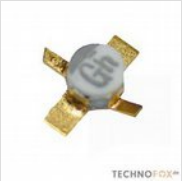






Frequently used GaAs Fet's, Nfmin at 12GHz

- NE32584C 0.45dB obsolete



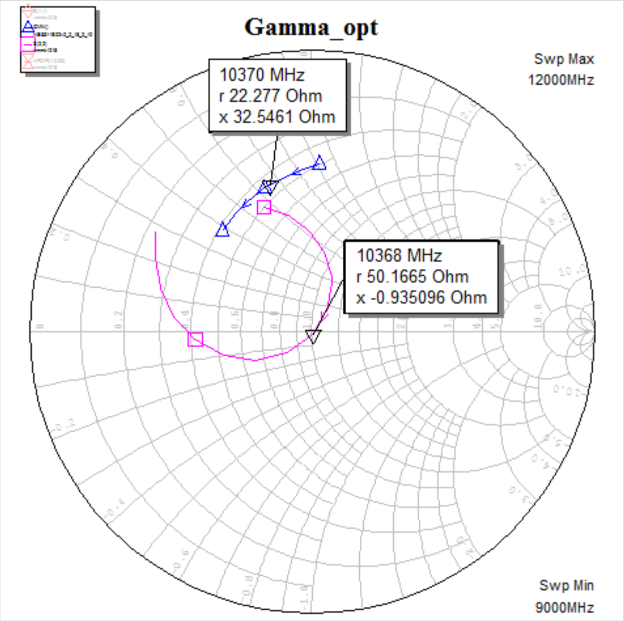
- NE3210S01 0.35dB obsolete
- NE3511S02 0.3dB   replacement CE3512K2
- NE3512S02 0.35dB replacement CE3512K2
- CE3514M4 0.42dB

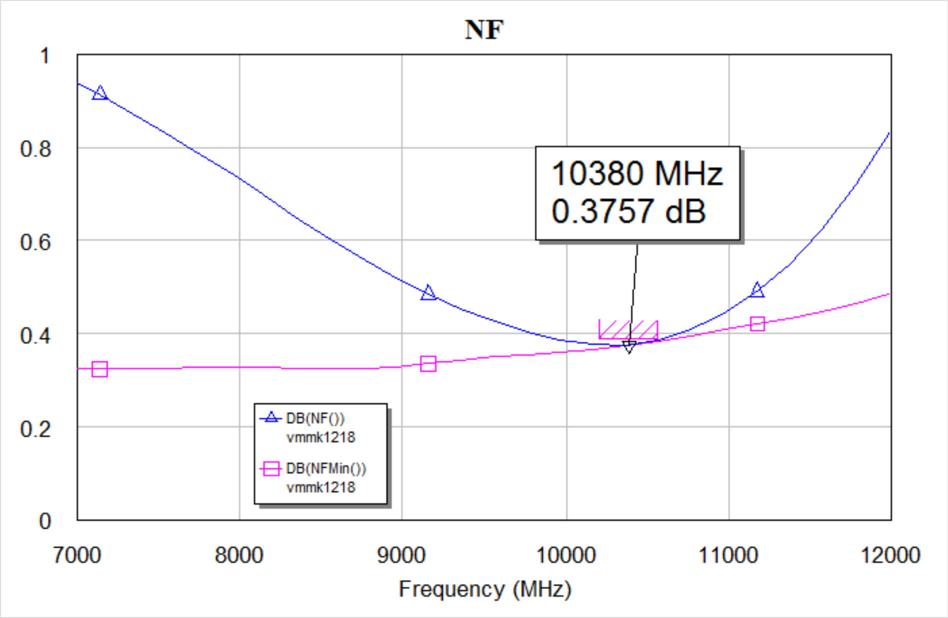
- NE3515S02 0.35dB obsolete
- MGF4919G 0.45dB
- Very limited selection of X band GaAs Fet's ?

Is 0.7dB NF barrier for 10GHz LNA?

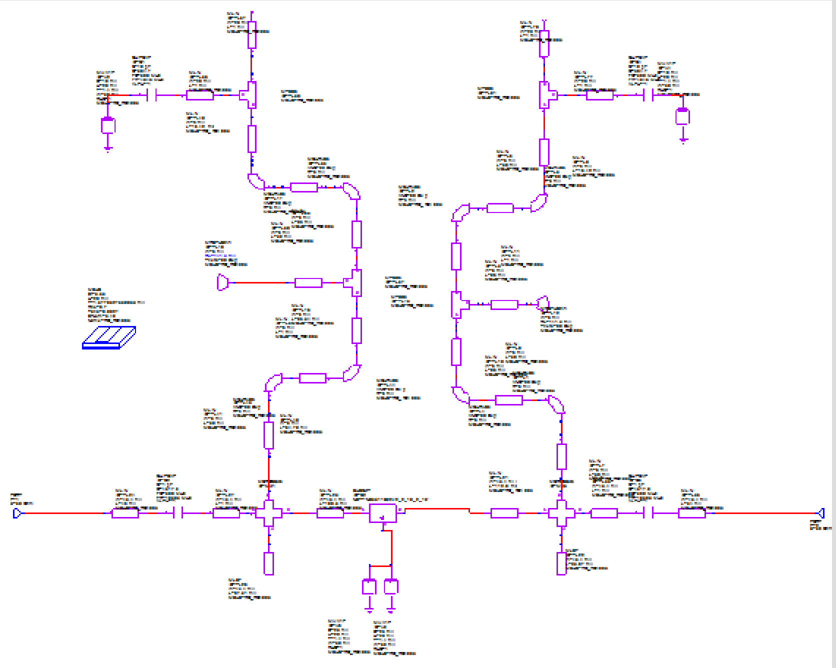
- Specified Nfmin. for GaAs Fet’s:
  between 0.3 dB and 0.45 dB at 12 GHz.
- What cause additional losses, higher NF?
- Is it possible to improve LNA design, and get lower NF with existing GaAs Fets ?
- Most LNA’s looks the same, copies
  or slightly modified DB6NT LNA design.

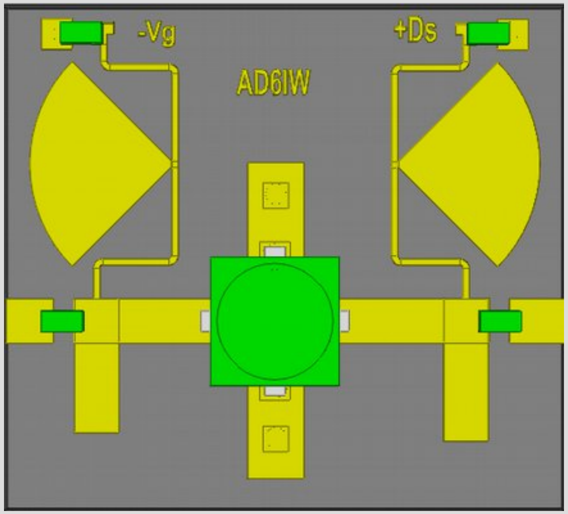
Linear LNA Simulation





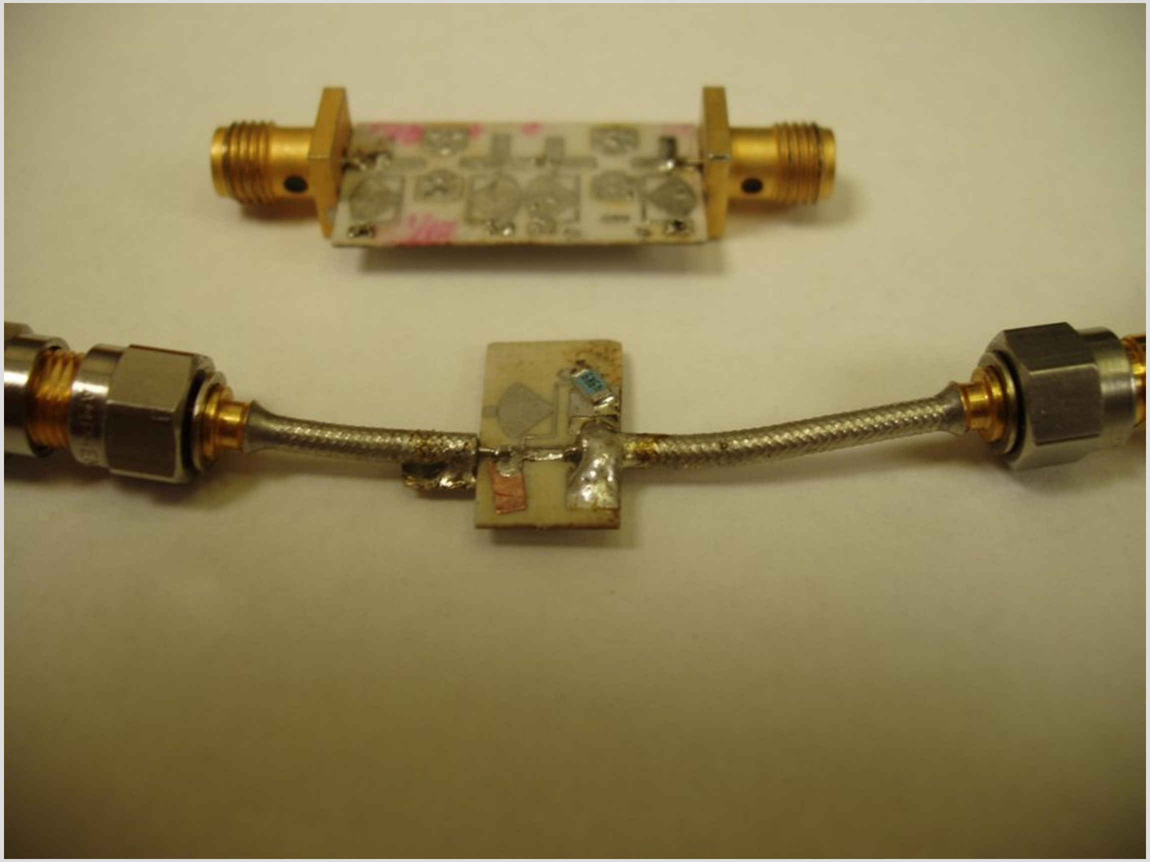
Simple X band LNA design, with real parts



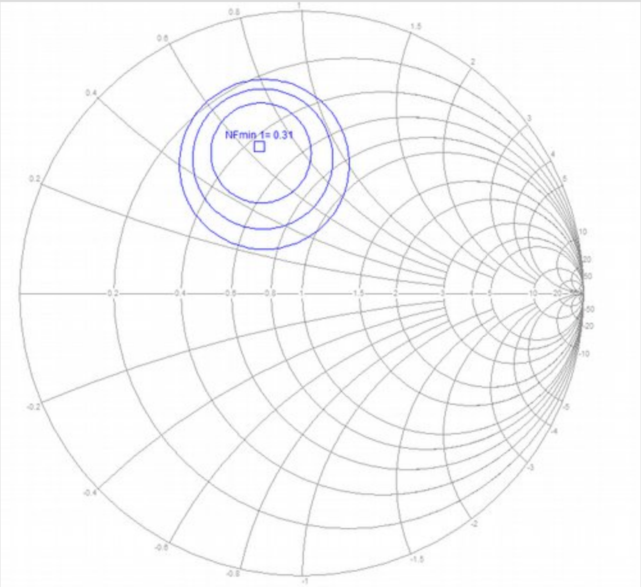


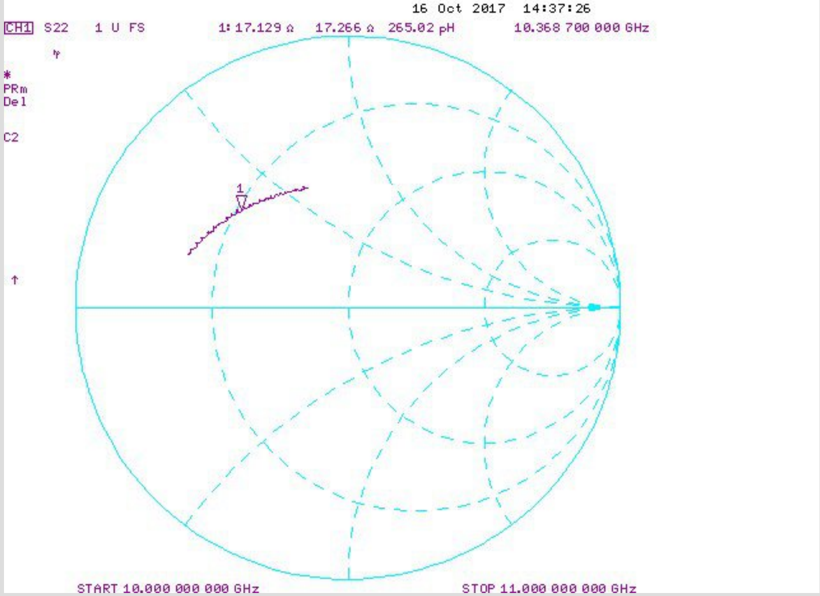
RO4003C 20mils

VNA matching setup, simulations – measurements, correlation



Input matching simulation and measurement

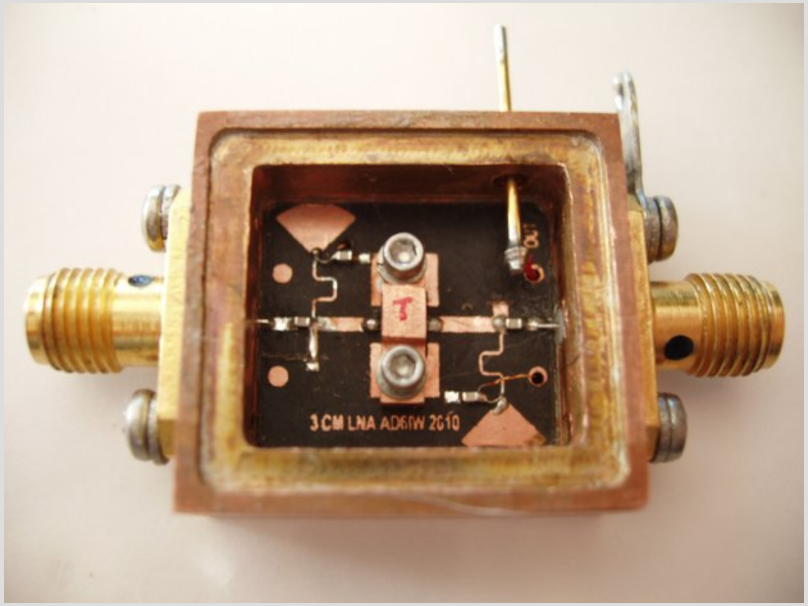




NE3511S02 2V 10 mA
NF circle, radius 0.05 dB
Nf_min 0.31 dB to 0.325 dB

Implementation and performance

- NE3511S02
- 10 mils Duroid 5880
- NF 0.75dB
- Gain 13.8dB
- IRL –6.7dB
- ORL –19dB
- Same LNA on 20mils R4003, ~ 0.1dB higher NF
- Unconditional stable

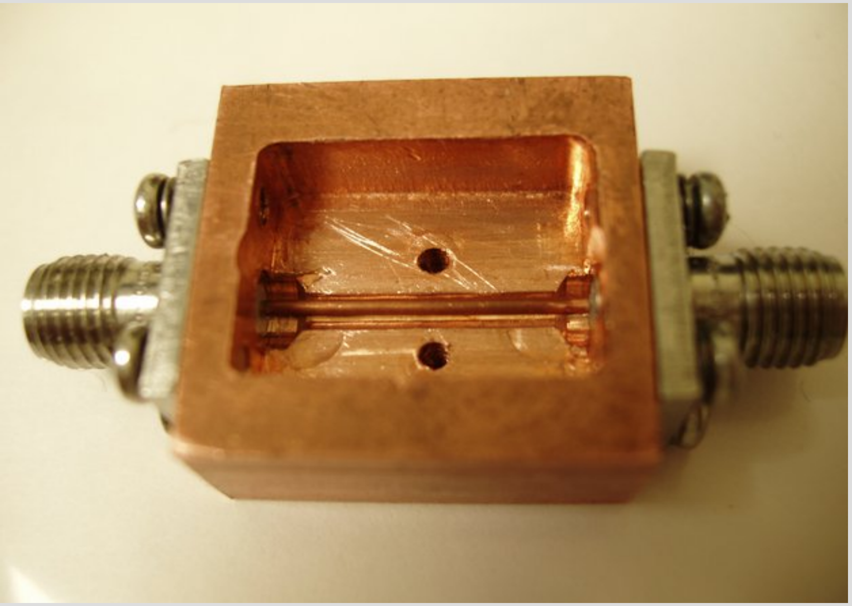


Critical design points

- Connector VSWR, enclosure size, cover height
- Coaxial to micro strip transition - hard to design properly w/o EM simulations.
- Grounding, vias, metal structure, geometry, conductivity and surface roughness.
- Input TL matching, bias tee, coupling capacitor
- Micro strip - quasi TEM, combination of dialectic loss, cooper loss, radiation loss, lossy media.
- Substrate thickness - trade off between cooper/dialectic/radiation loss

Coaxial Transmission Line with capacitive probe, experiment

- 0.1dB of insertion loss including SMA connectors, TL and two capacitive probes.
- IRL / ORL > 30dB
- Z0 50 +/-1 Ohms
- Flat frequency response.
- Critical probe length.



Real TEM Mode

Basic Coax calculations

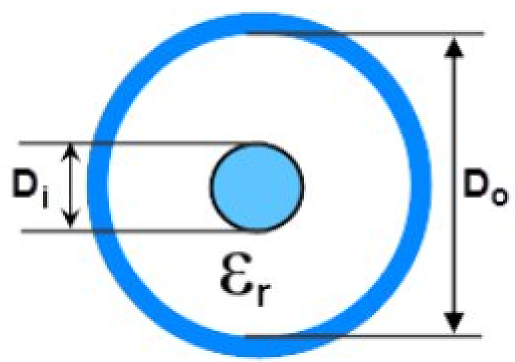
<u>**Formulas for Coaxial Cable Calculations**</u>

$$Z_o(Ohms) = \frac{138 \times log_{10}\left(\frac{D}{d}\right)}{\sqrt{\varepsilon_r}}$$

$$C\ (pF) = \frac{7.354 \times \varepsilon_r}{log_{10}\left(\frac{D}{d}\right)}$$

$$L\ (Inductace)nH = 140.4 \times log_{10}\left(\frac{D}{d}\right)$$

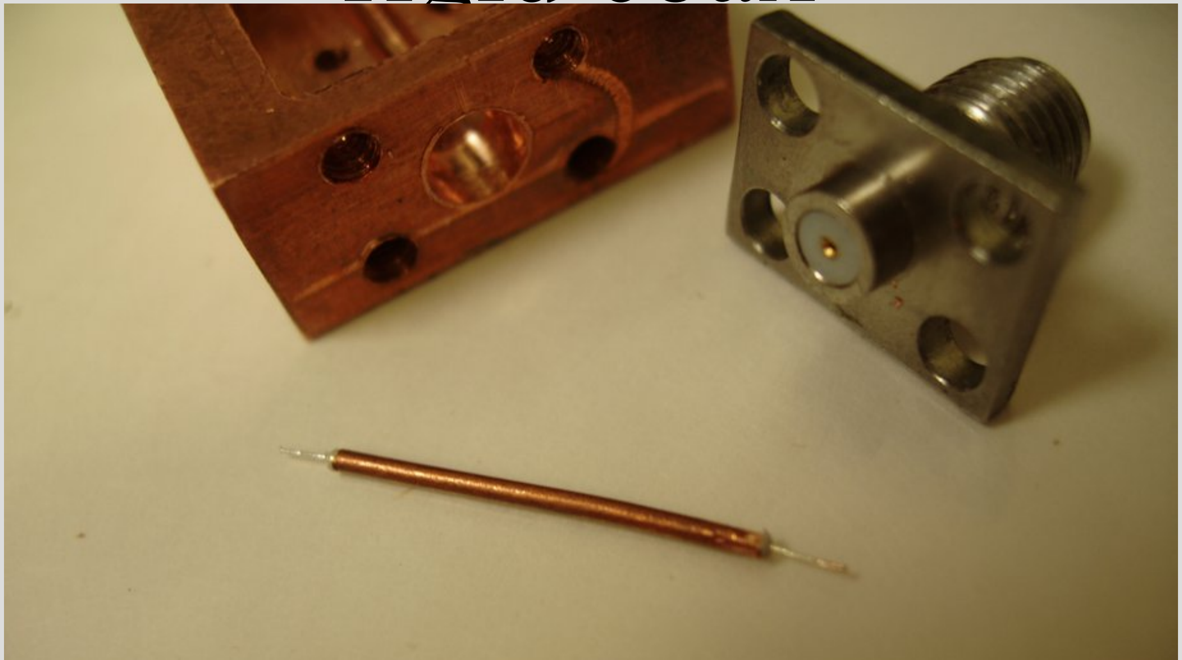
$$\text{Cutoff Frequency (GHz)} = \frac{11.8}{\sqrt{\varepsilon_r} \times \pi \times \left(\frac{D+d}{2}\right)}$$



Coaxial Cable Cross-section

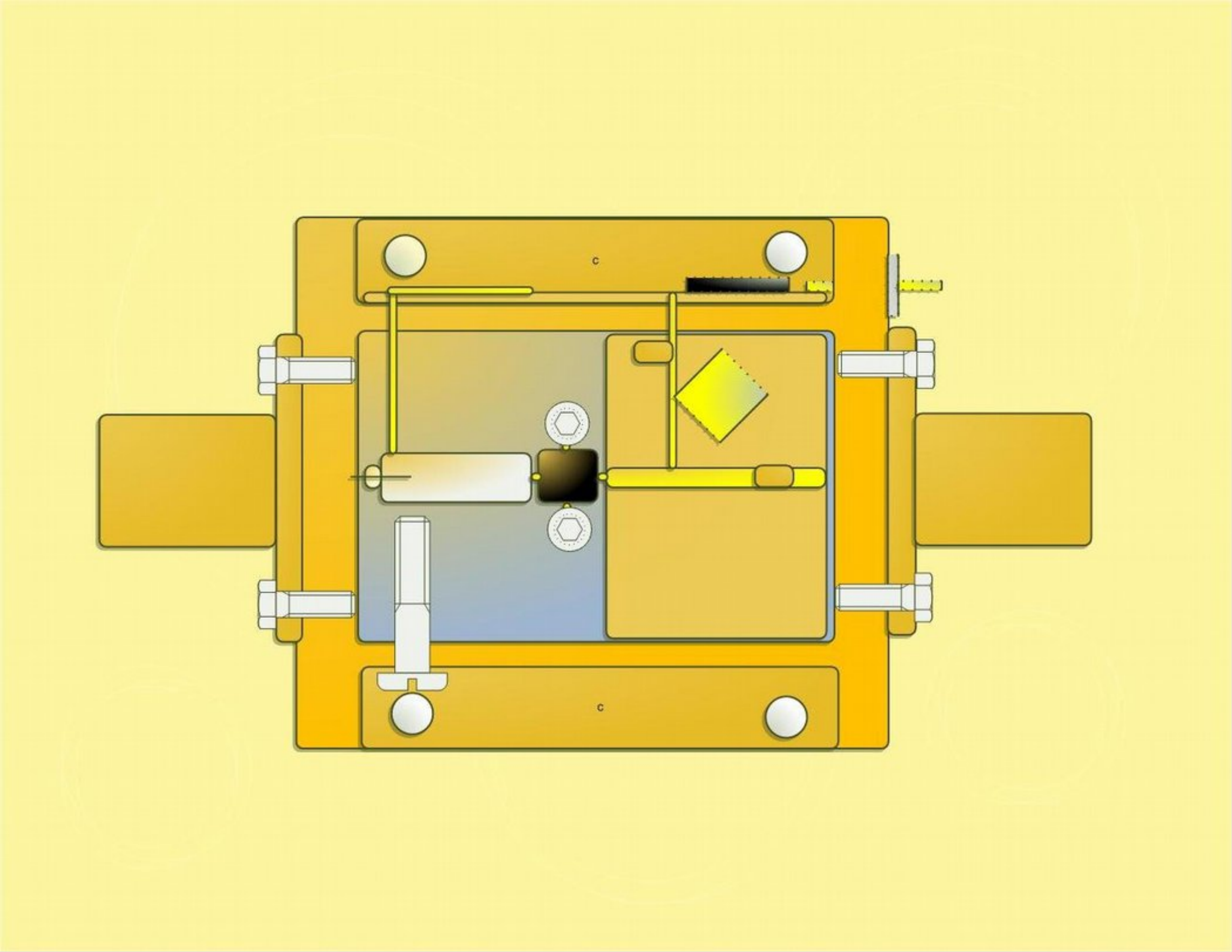
50 Ohms (D / d) = 2.303
C = 29 pF / Feet
3 mm probe ~ 0.3pF

TL details, UT-034 cooper semi rigid coax



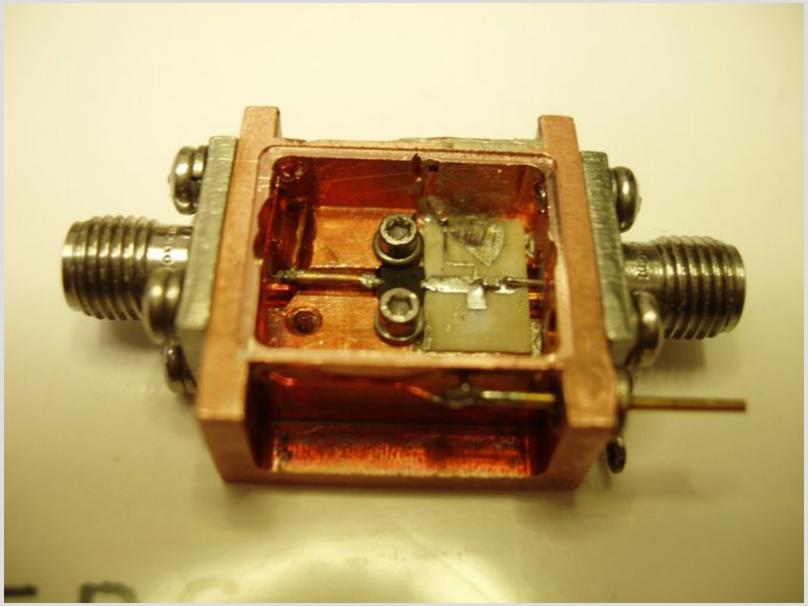
Probes are inserted 2.5 mm deep in coax.
Cooper semi rigid coax OD 0.034” 29 pF/Ft
Coupling capacitance ~ 0.25 – 0.3 pF

Coaxial input matching LNA, sketch

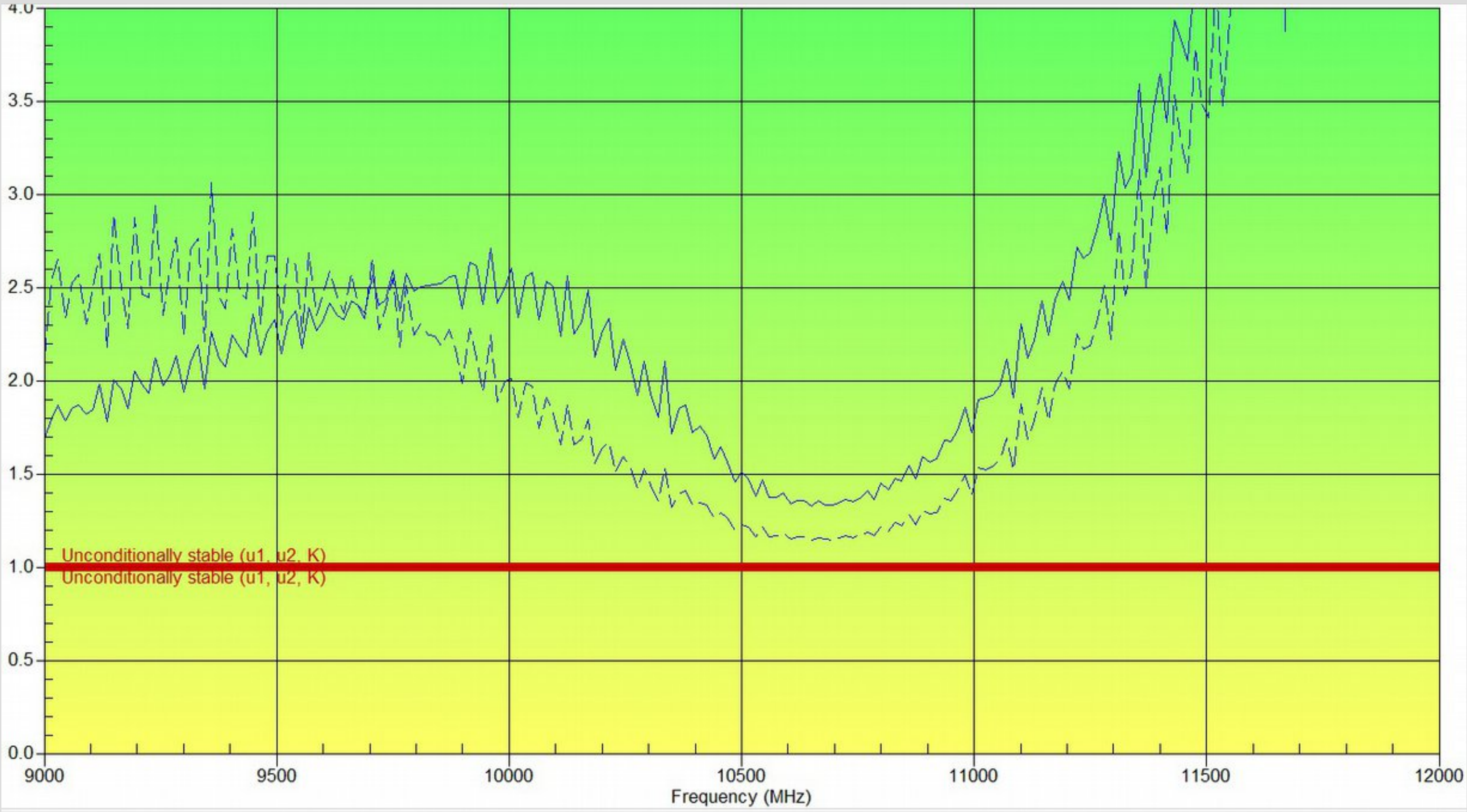


First prototype realization and performance

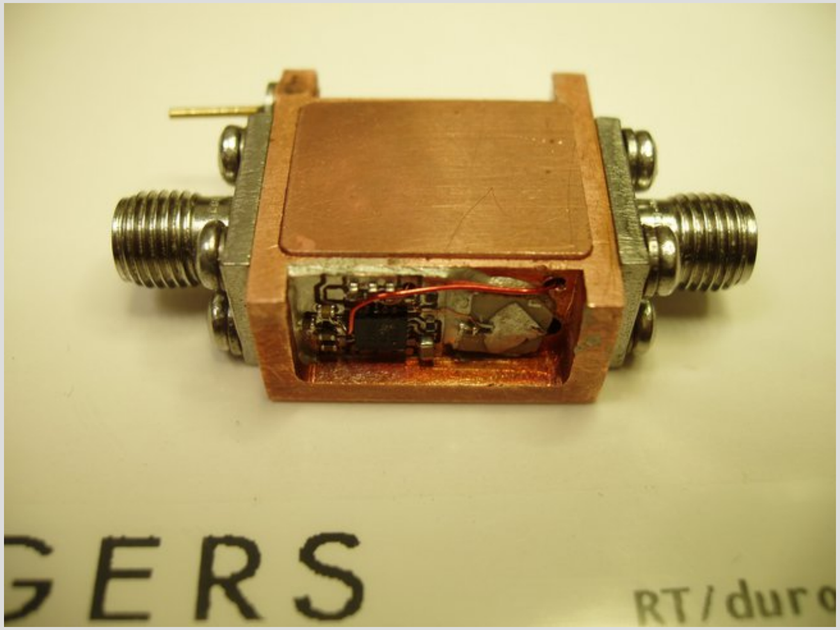
- NF 0.65dB
- Gain 13.7dB

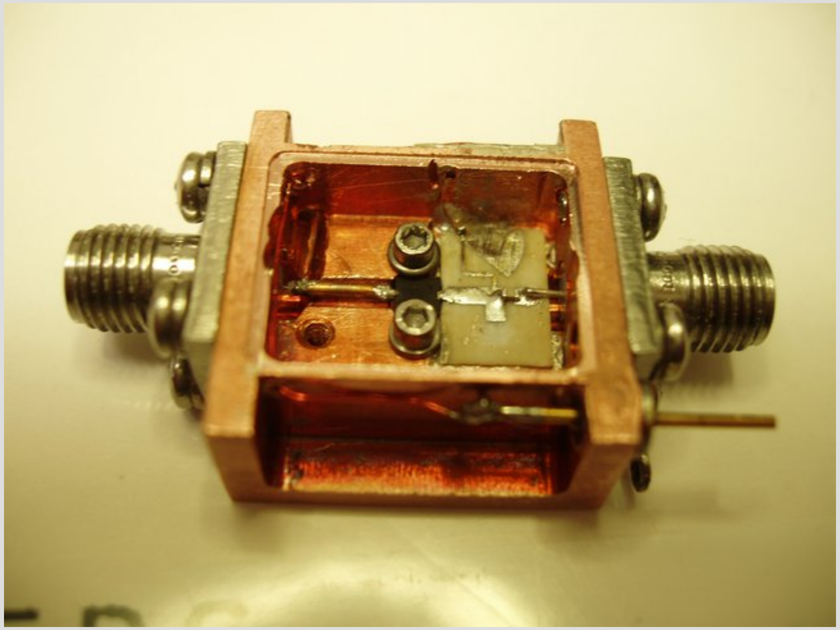


LNA stability plot, measured



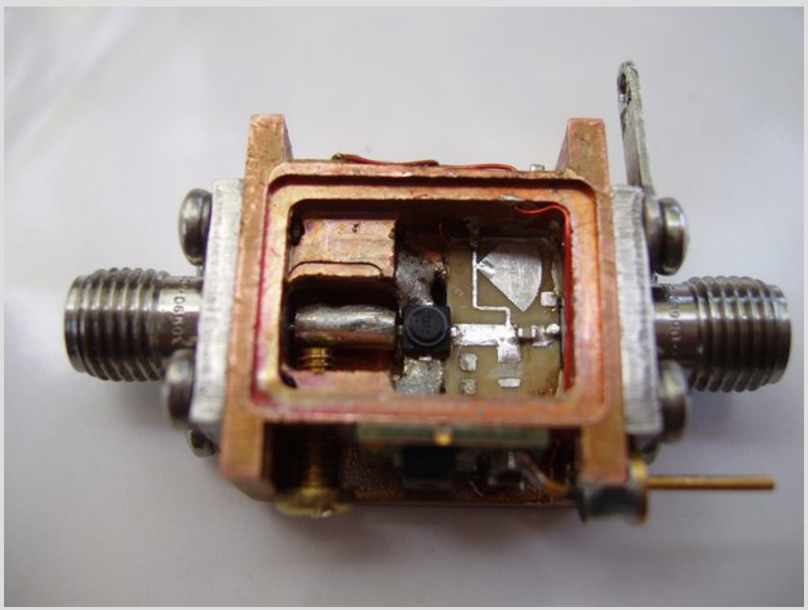
Bias board and some details





ZABG4003 Fet LNA Bias Controller, 5V max. input Voltage

Slightly better but not good enough, modified new design



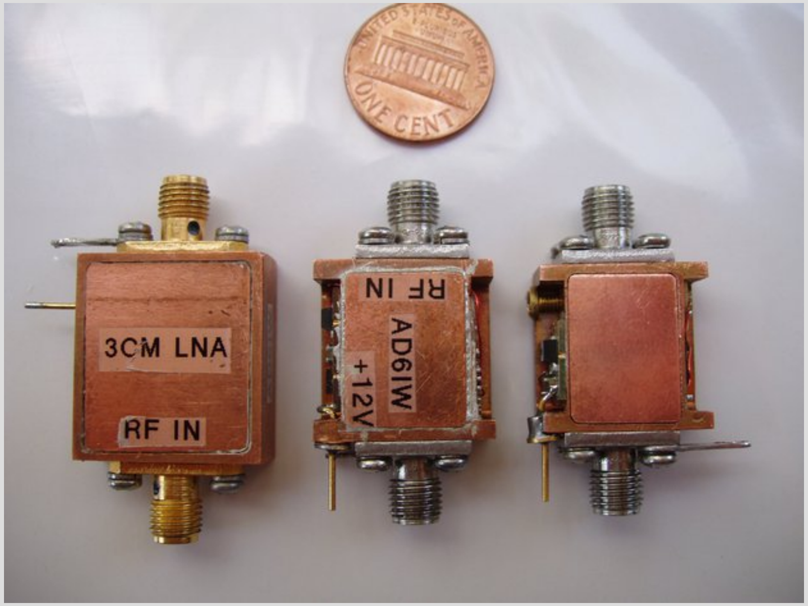
- Increased diameter of coaxial line to 0.086”,

  two times lower IL
- Added tuning screw
- Finally NF < 0.6 dB !
- Gain 13 dB
- IRL –5.1 dB, ORL –22 dB
- Some NF and Gain are traded for stability, and S12 and S11 requirements.
- Second stage amplifier, better stability and higher gain.

Conclusion and future work

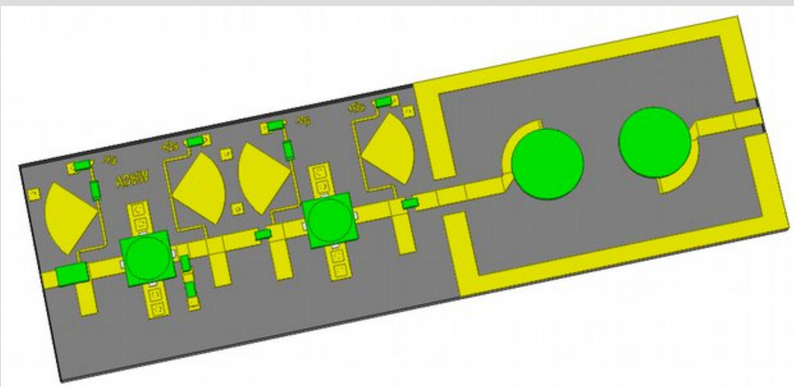
- Coaxial matching with cap. probe demonstrated lower IL, and NF.
- There is still room for improvements, lower NF.
- Quarter lambda capacitive probe, larger diameter TL
- Wave guide, two stage LNA is in development, with probably lower NF.
- Commercial LNA's will be available soon.

Prototype X band LNA's.



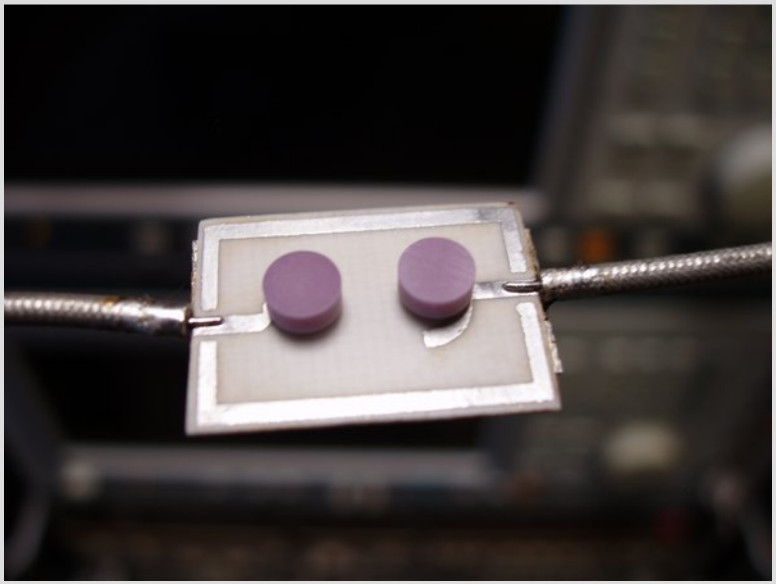
NF: 0.75dB 0.65dB 0.6dB

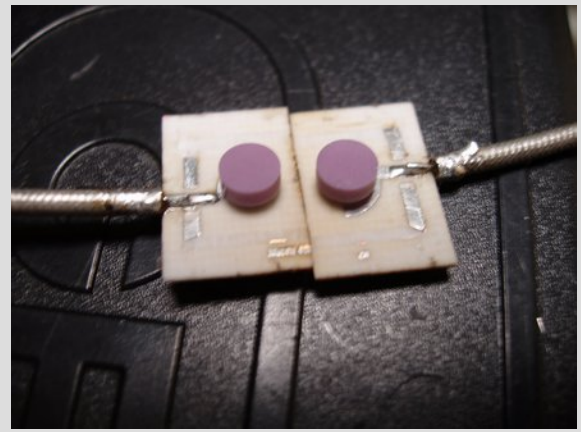
10 GHz Dielectric band pass Filters

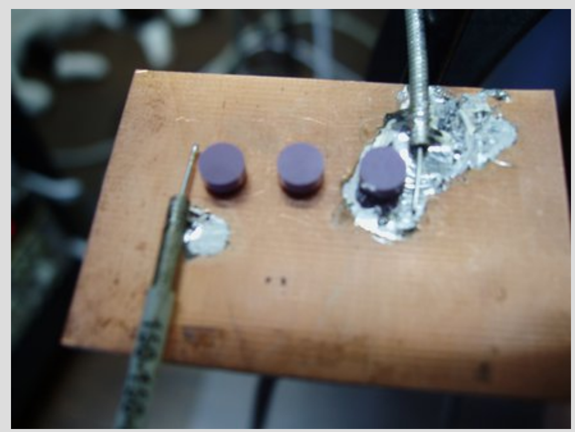


- Small size, nice for SMD board design
- Good image rejection, high Q
- Low Insertion loss < 1dB
- Narrow BW 50 – 150MHz
- SMA, SMD versions
- Easy to made
- Low cost
- DR puck source, Ebay
- Buy puck with spacer ring

VNA Dialectic resonator test

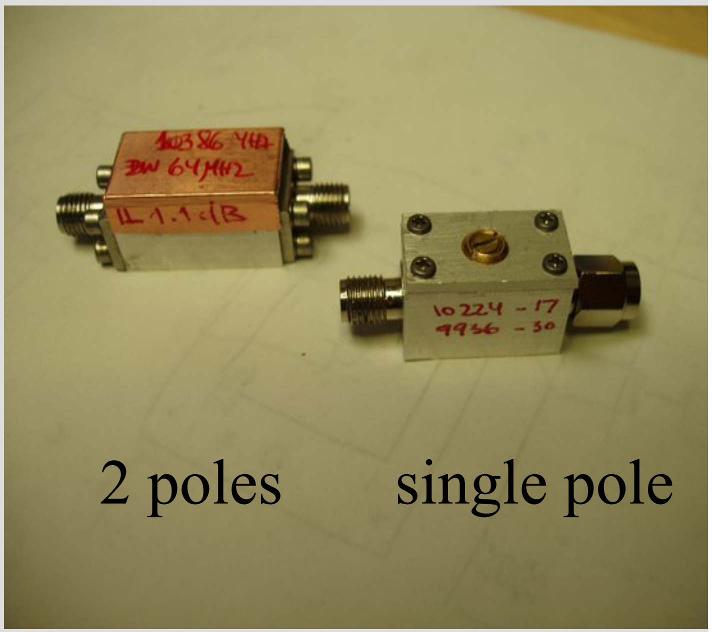


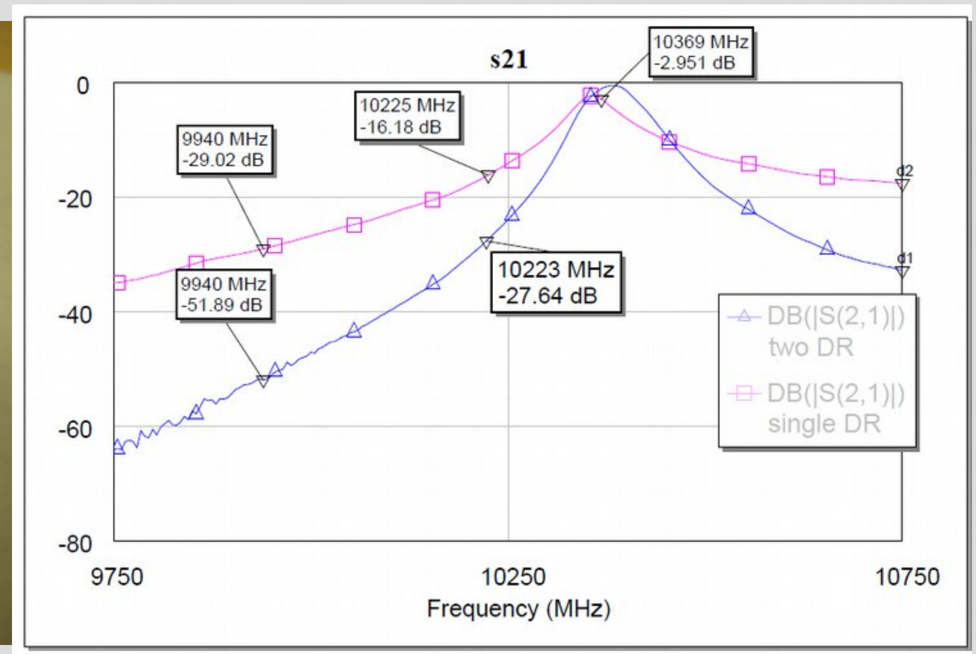




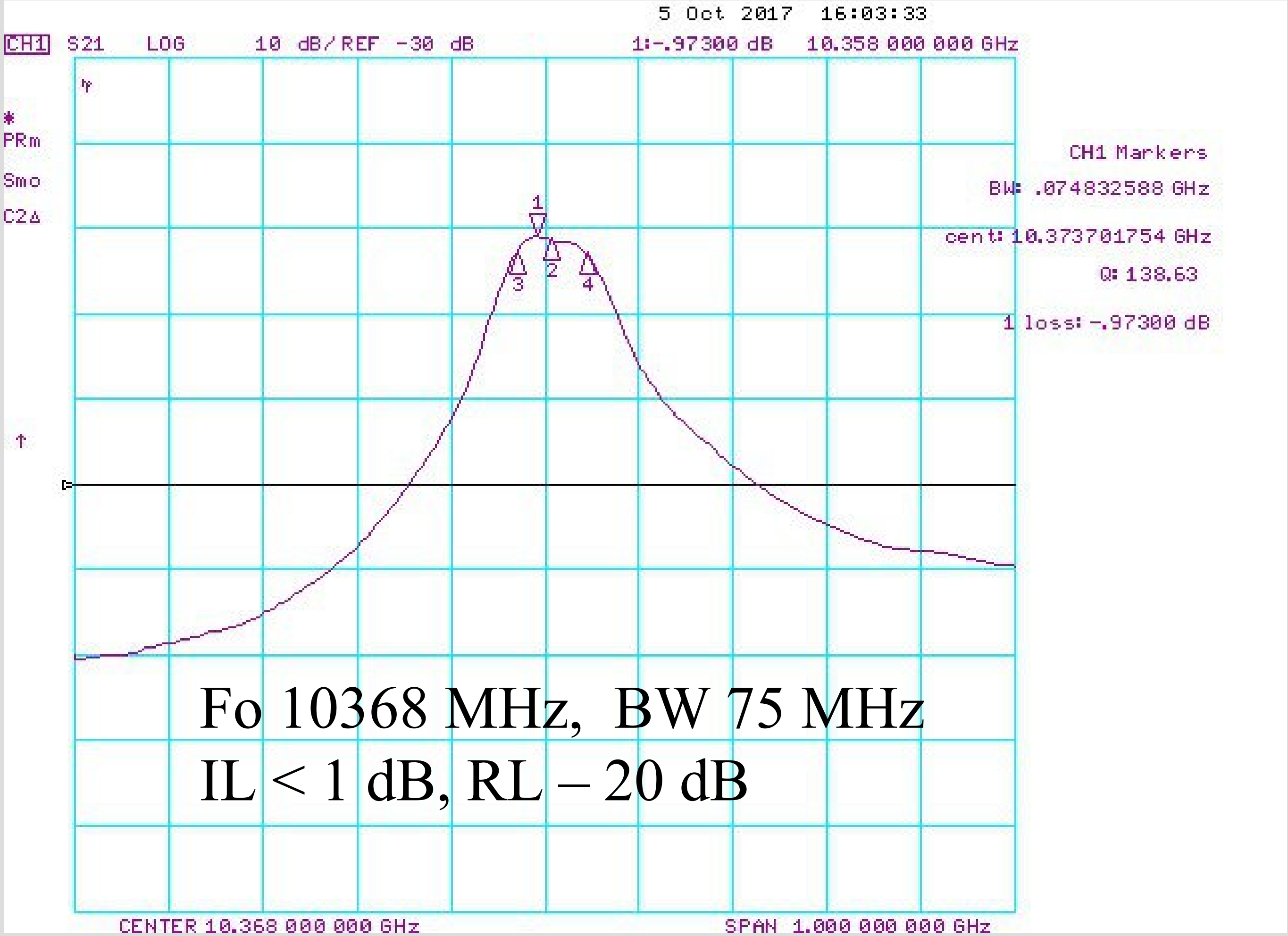
Puck res. frequency 10.24 GHz
Critical coupling, test
Frequency Pushing << 5%
Metal shield should be 3 times of the puck radius, away.

10.368 GHz SMA DR Filters



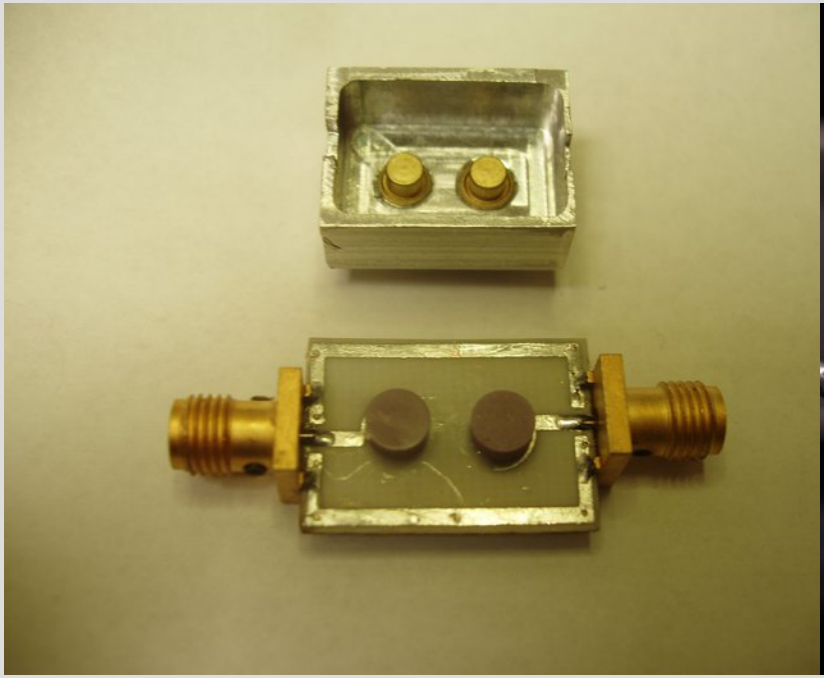


Two DR SMA Filter response, measurement

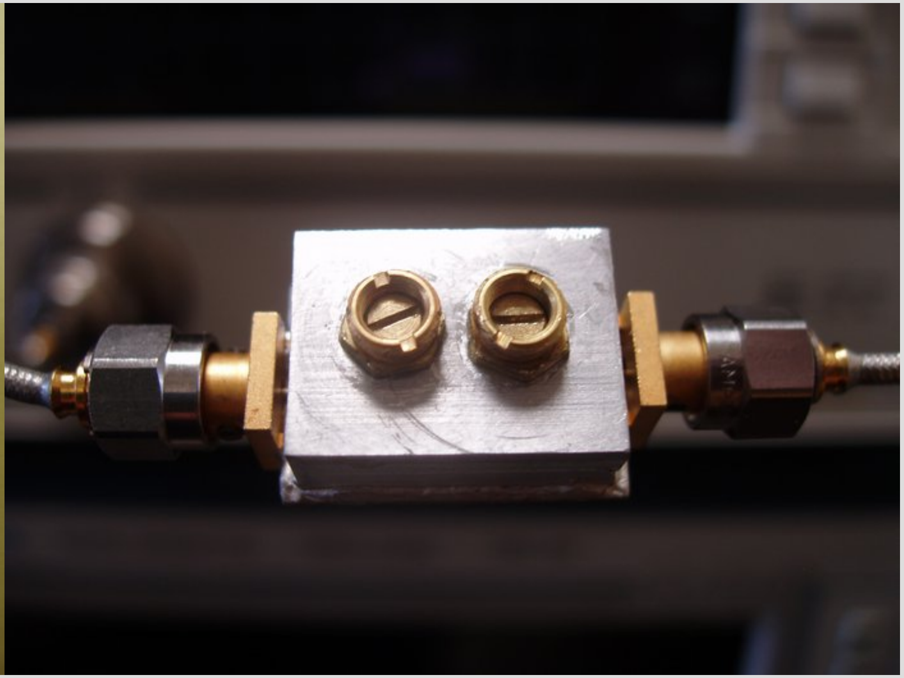


Fo 10368 MHz, BW 75 MHz
IL < 1 dB, RL – 20 dB

SMD Dielectric filter, with tuning screws

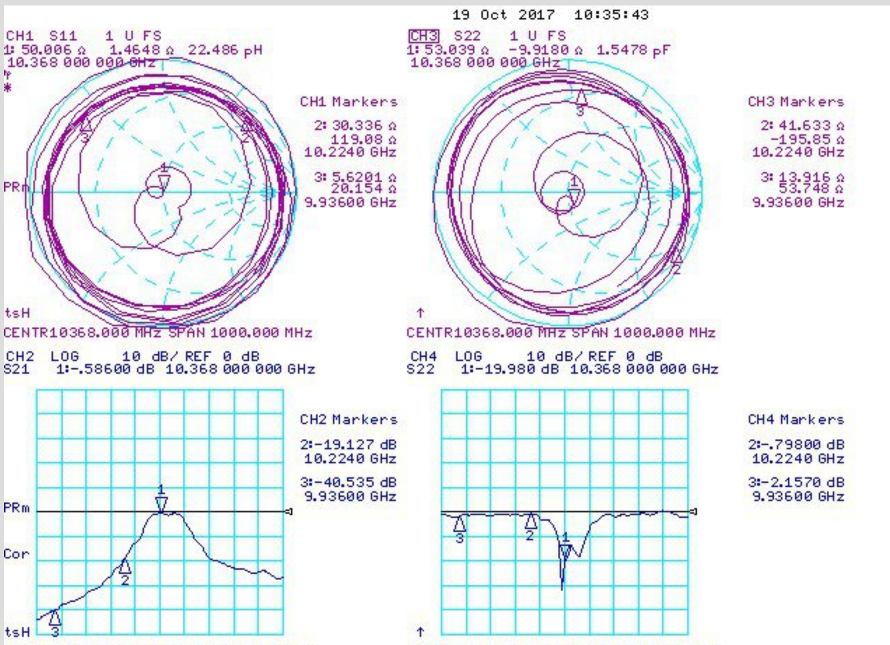


Test Fixture

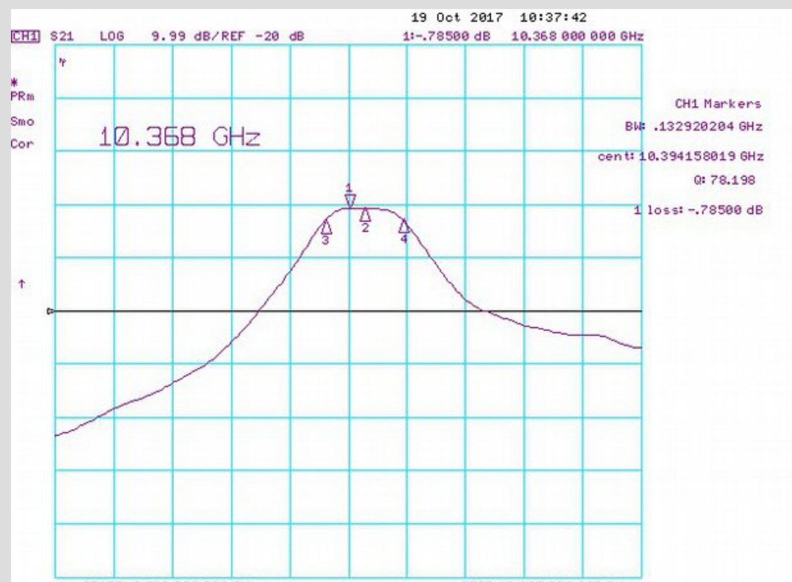


Filter size: 0.78” x 0.58” x 0.3”

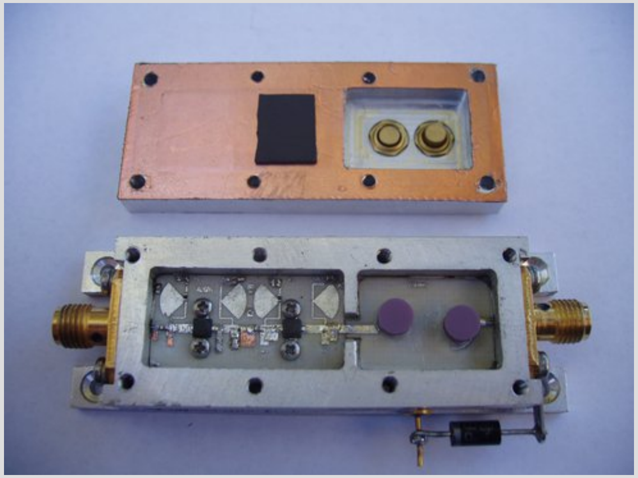
10.4 GHz SMD Filter performance

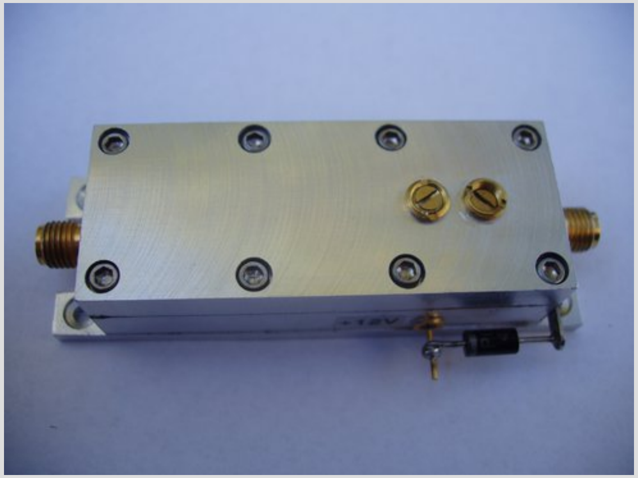


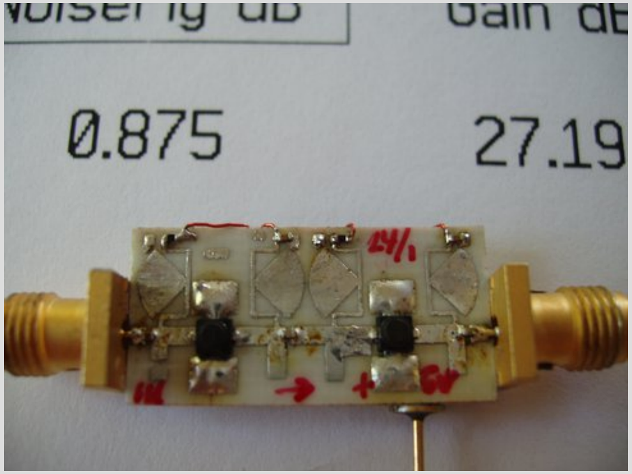
BW ~ 100 MHz
IL 0.8 dB
RL – 20 dB
9936 MHz, > 40 dB rejection



10 GHz front end with incorporated DR filter







Thank You
Questions?

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