A tri-band cryogenic receiver for the RAEGE project antennas

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Tri-band receiver pros & cons

Main pros:

- S, X and Ka band simultaneously => Backward compatibility
- Feed horn cooled down to 20 K
- Simultaneous dual circular polarization
- Traditional cryo LNA designs (unbalanced LNA's)
- Easy NoiseCal and PhaseCal signal injection in front of the LNA's
- Less sensitive to RFI than broad-band receivers
- Ka-band receiver very useful during antenna commissioning
- Simultaneous X/Ka-band reception
- Compatibility with new TTW antennas

Main cons:

- 180º and 90º hybrid circuits are necessary => cooled low-loss design to reduce impact on overall Trx
- Not fully continuous coverage of 1-14GHz band

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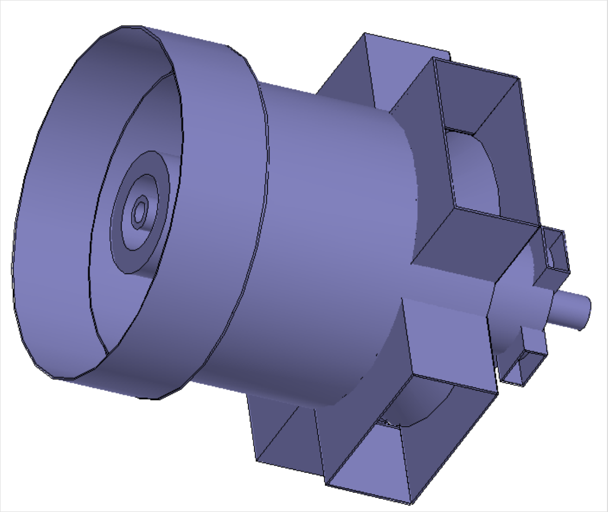
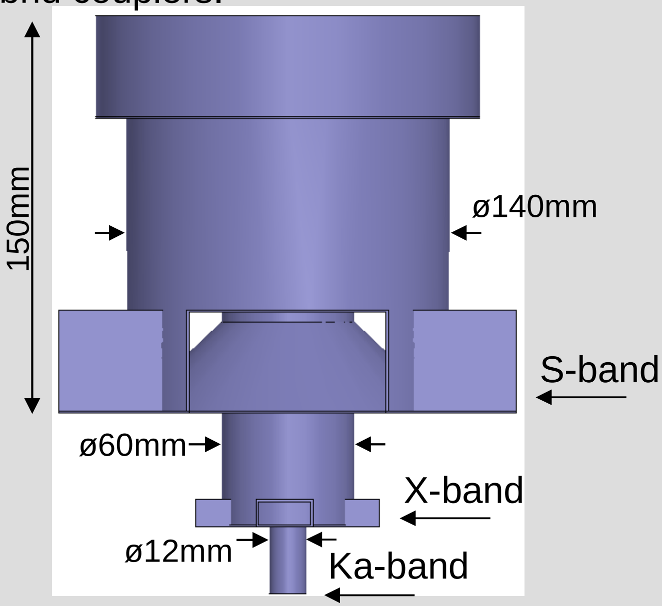
Tri-band feed design

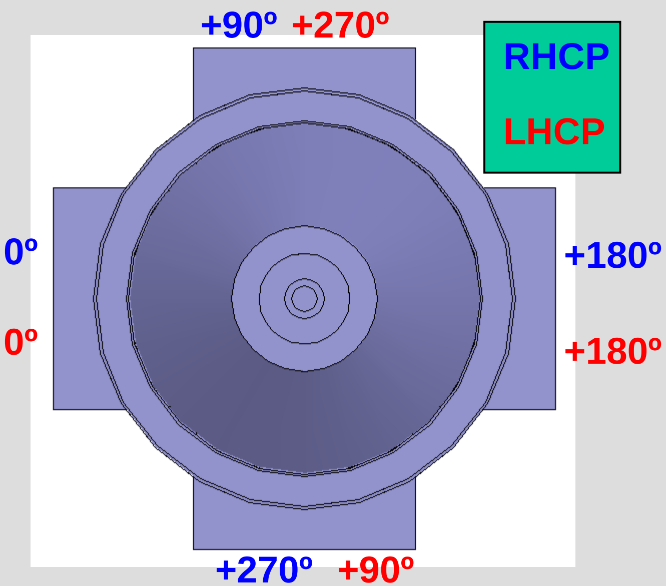


- Tri-band feed horn for future VLBI2010 radiotelescopes
- Three simultaneous frequency bands:

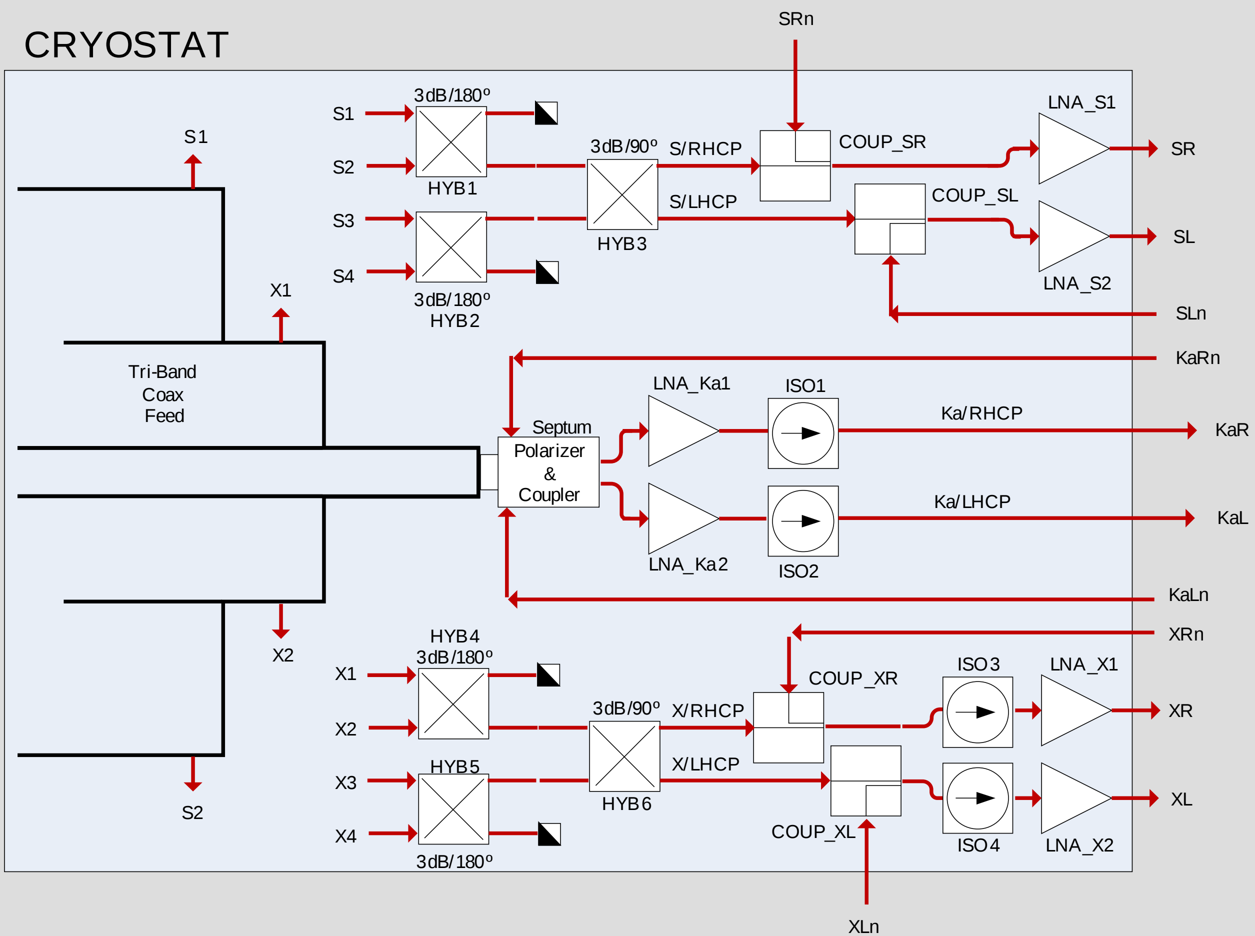
  S (2.2-2.7 GHz)   X (7-9.5 GHz)   Ka (28-33 GHz)

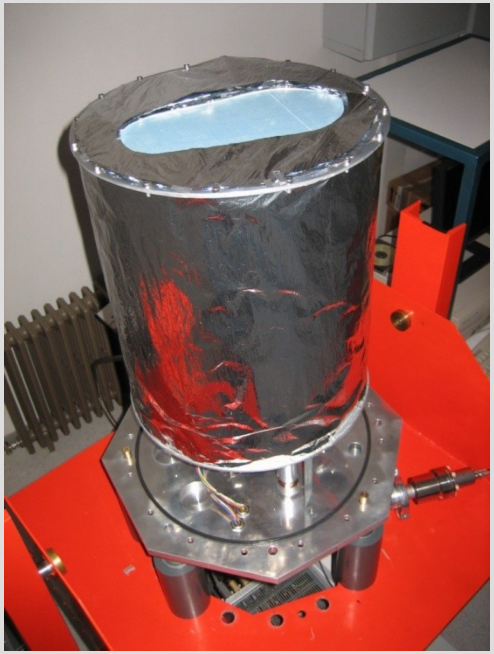
- Coaxial feed for S and X bands and a conventional conical feed (Ka band), all working in the TE_{11} mode.
- 4-port excitation needed to generate the TE_{11} mode (broadside radiation) in the coaxial waveguides. The desired phase shifts for RHCP/LHCP operation are performed by 180º and 90º cryogenic hybrid couplers.



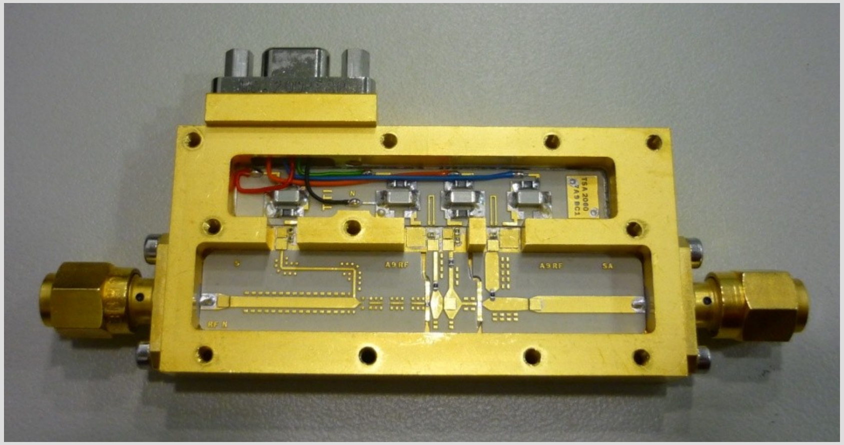


Cryostat content





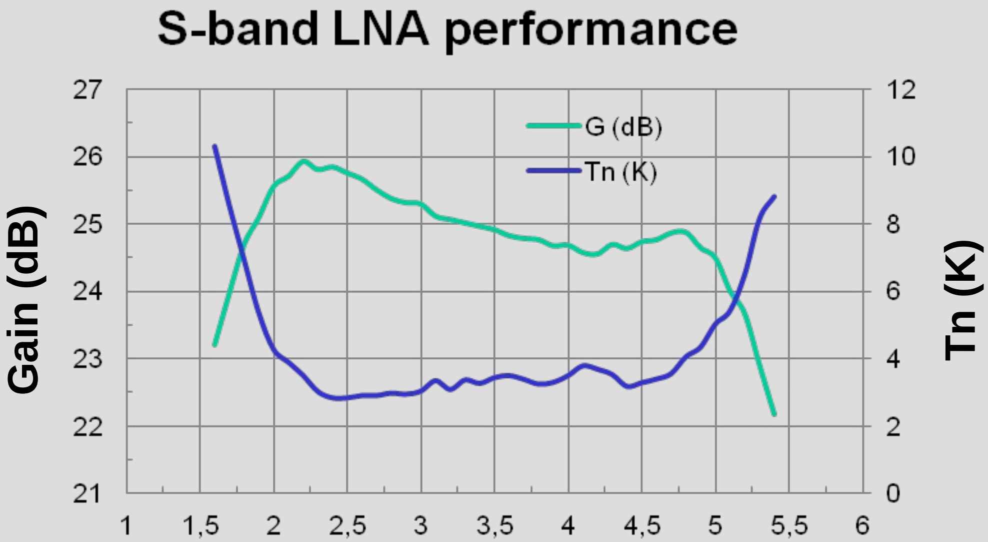
S-band LNA’s



Hybrid design

Measured performance:

- Freq: 2 .. 4.8 GHz
- Tn < 4 Kelvin
- G > 24.5 dB
- IRL = -13.4 dB
- ORL = -17.4 dB



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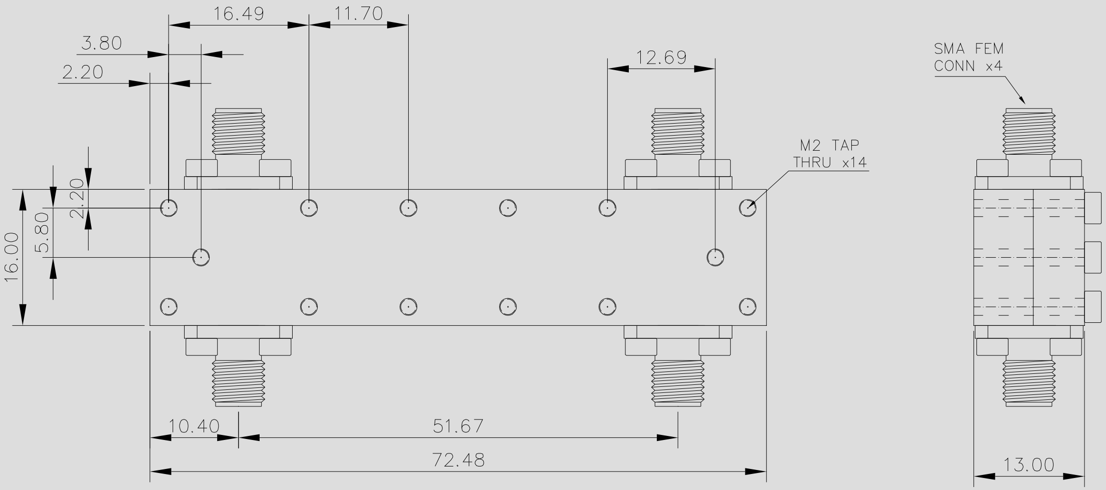
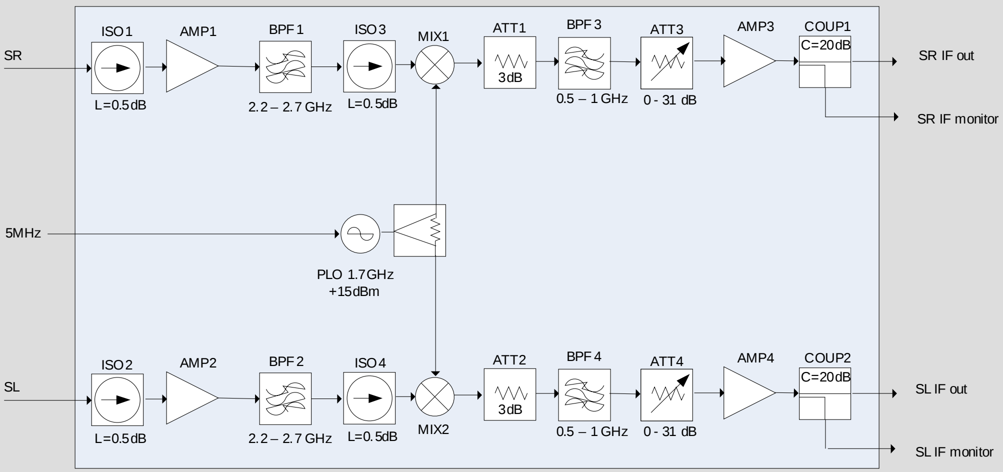
S-band hybrids

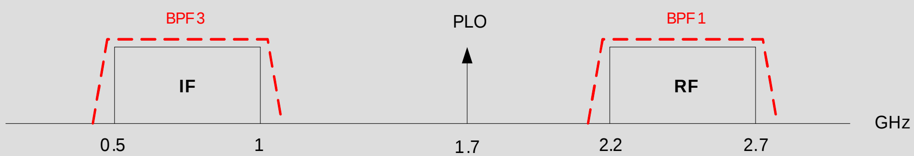
Serial Number	**YH90S 1003**	
Description	**3dB 90º cryogenic hybrid**	
Frequency Band	1.1 – 4.5 GHz	
Nominal Coupling	3 dB	
Connector	SMA female, sliding pin	
Weight (typ.)	56 g (1.97 oz)	
Temperature	*297 K*	*20 K*
A. E. Insertion Loss dB (max.)[*1]	0.53 dB	0.26 dB
Return Loss (max. any port)	-21.2 dB	-19.2 dB
Amplitude Unbalance (max.)	± 0.3 dB	± 0.35 dB
Phase Unbalance (max.)	± 3.7º	± 4º

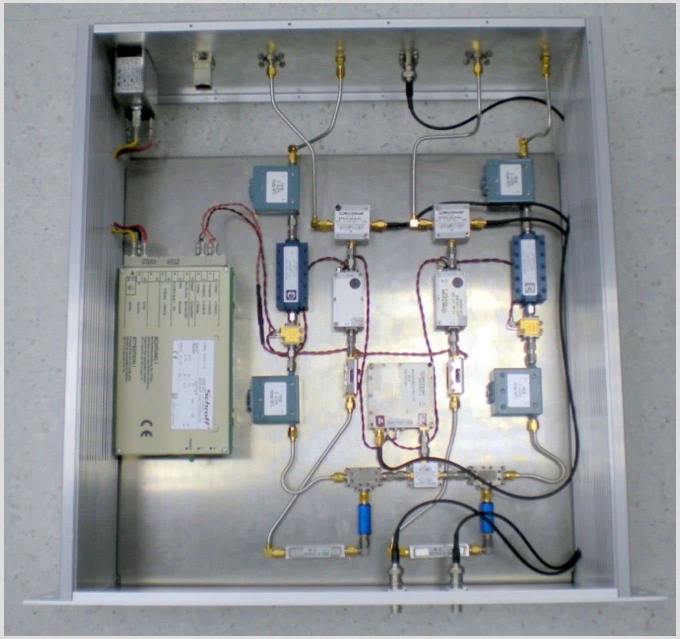
**1: Average Equivalent Insertion Loss (dB),* $L_{eq}=10\log_{10}(|s_{11}|^2+|s_{12}|^2+|s_{13}|^2+|s_{14}|^2)$



S-band downconverter module







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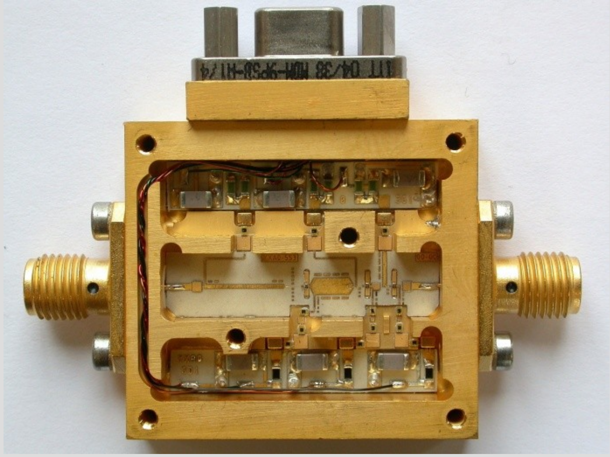
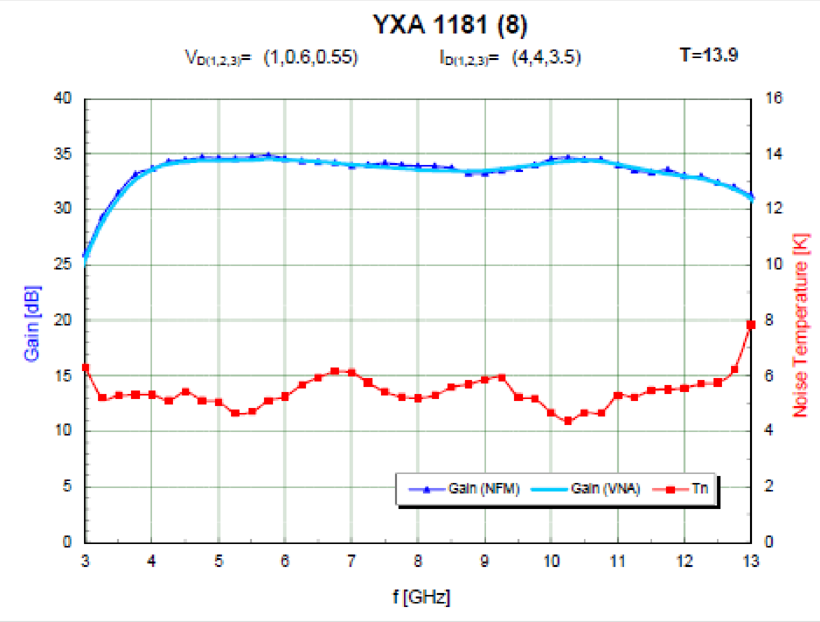
X-band LNA’s

Hybrid InP design

Measured performance:

- Freq: 4 .. 12 GHz
- Tn = 5.3 Kelvin
- G = 34 dB
- IRL = -3 dB
- ORL = -12.5 dB





Notes:
•Same LNA as those provided for ALMA Band 9
•IRL to be improved with cryogenic isolator

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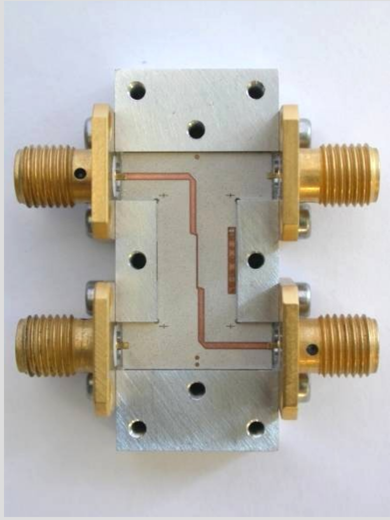
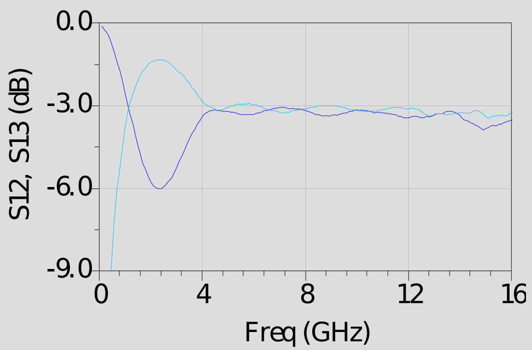
X-band hybrids

Serial Number	**YH90X 1005**	
Description	**3dB 90º cryogenic hybrid**	
Frequency Band	4 - 13 GHz	
Nominal Coupling	3 dB	
Connector	SMA female, sliding pin	
Weight (typ.)	36 g (1.27 oz)	
Temperature	*297 K*	*20 K*
A. E. Insertion Loss dB (max.)*1	0.6 dB	0.3 dB
Return Loss (max. any port)	-20 dB	-20 dB
Amplitude Unbalance (max.)	± 0.25 dB	± 0.3 dB
Phase Unbalance (max.)	± 1º	± 2º

**1: Average Equivalent Insertion Loss (dB),* $L_{eq}=10\log_{10}(|s_{11}|^2+|s_{12}|^2+|s_{13}|^2+|s_{14}|^2)$



Nominal Coupling	**3 dB /180º**	
Temperature	*297 K*	***16.5 K***
A. E. Insertion Loss dB (max.)	0.45 dB	**0.17 dB**
Return Loss (max. any port)	-19 dB	**-18.5 dB**
Amplitude Unbalance (max.)	± 0.3 dB	**± 0.18 dB**
Phase Unbalance (max.)	± 4.7º	**± 3.1º**



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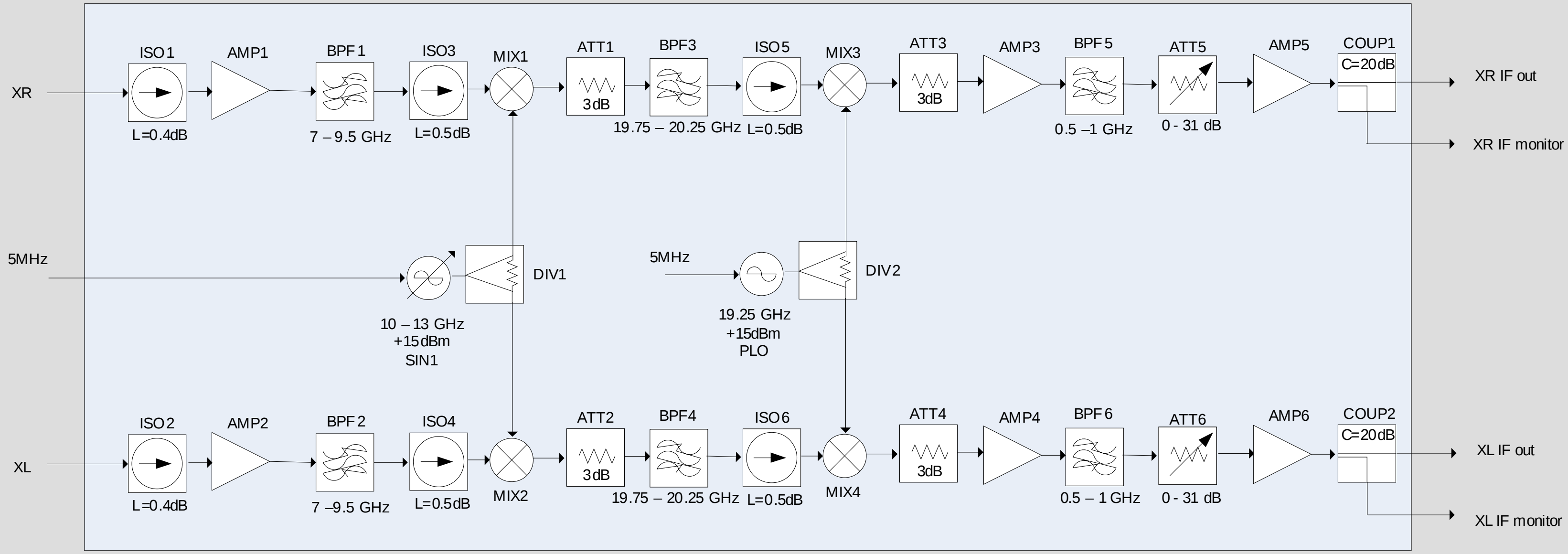
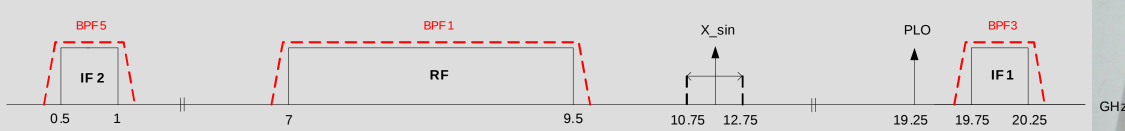
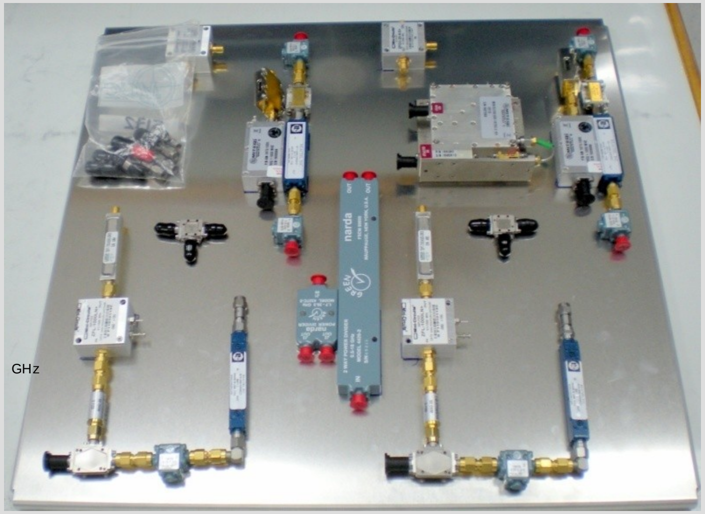
X-band downconverter module







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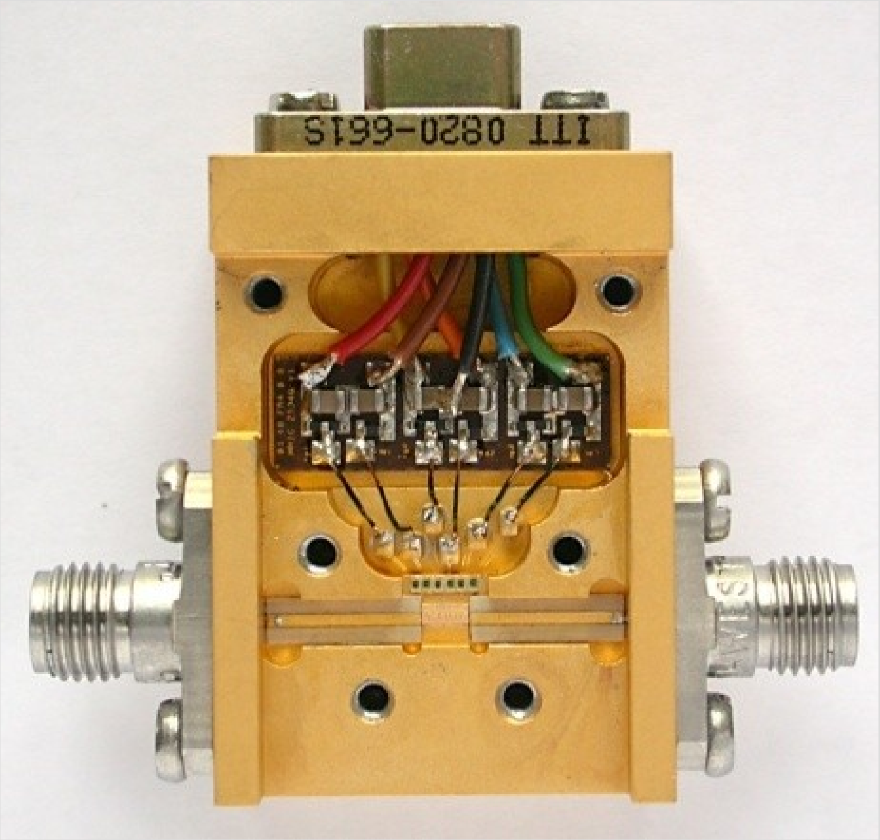
Ka-band LNA's

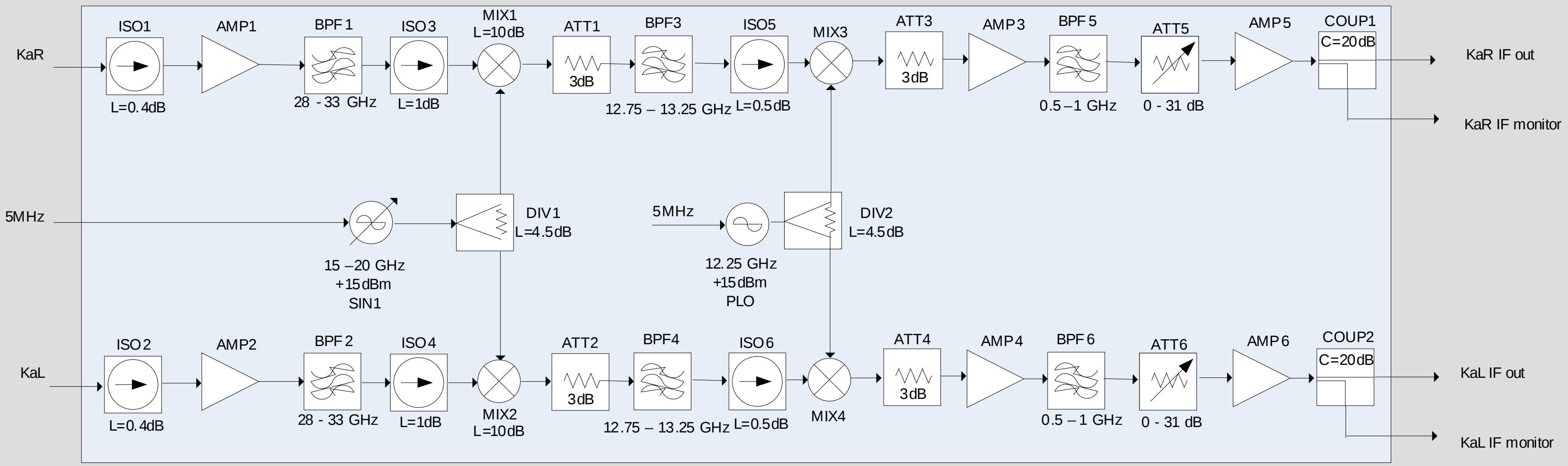
MMIC design

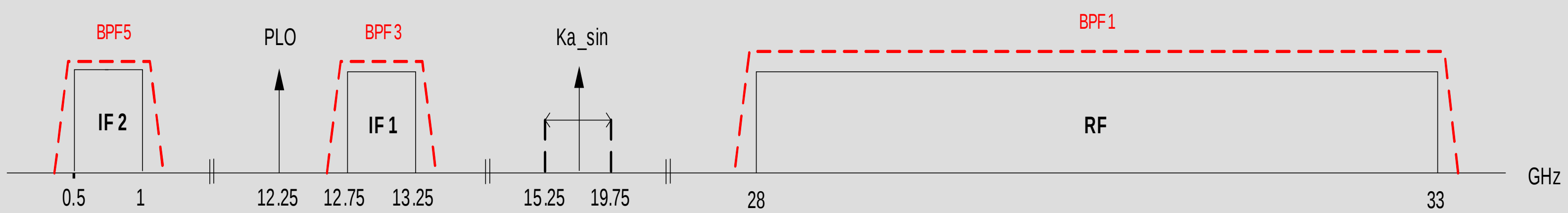
Expected parameters:

- Freq: 25 .. 35 GHz
- Tn = 15 .. 16 Kelvin
- G > 24 dB +/- 1dB
- RL < -10dB

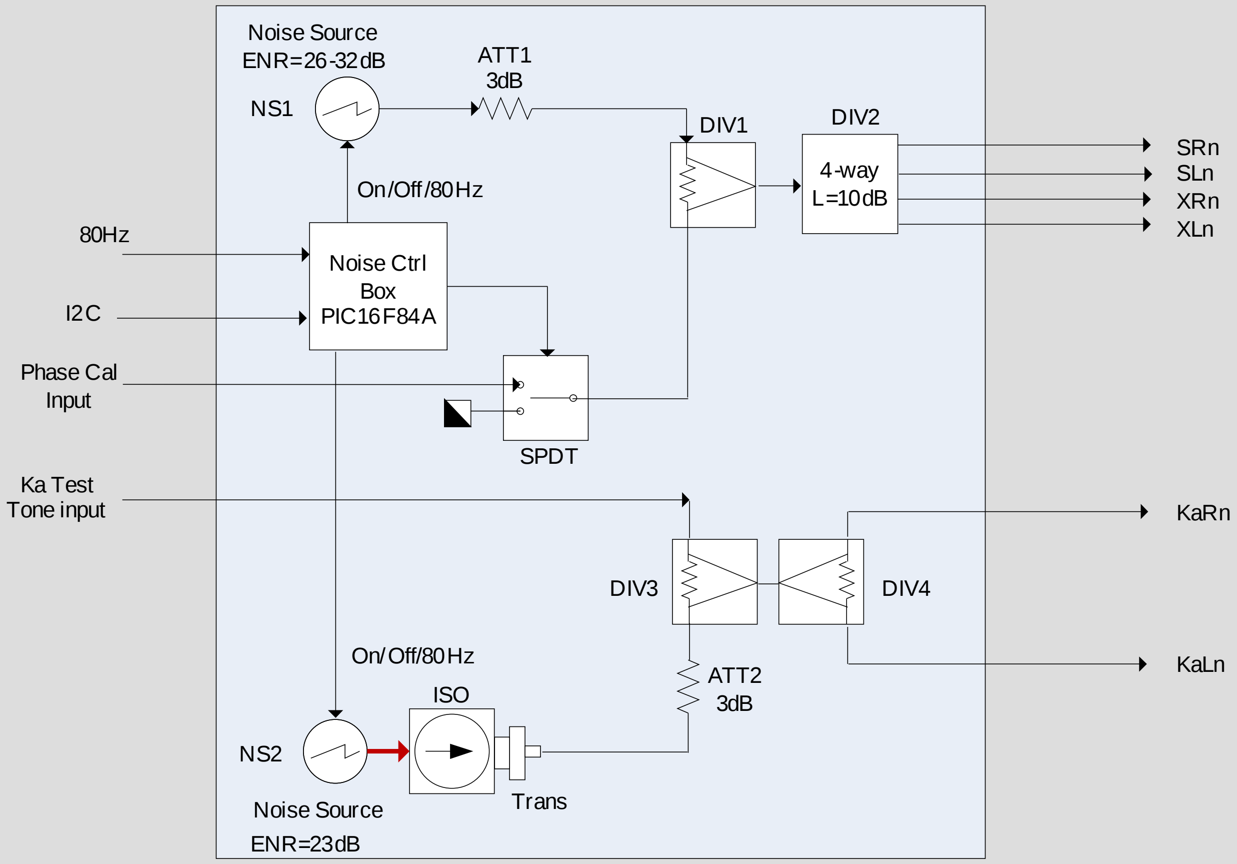


Ka-band downconverter module





NoiseCal module



Estimated receiver performance

Band	Range (GHz)	Trx (Kelvin)	Rx gain (dB)	Inst. BW (MHz)
S	2.2 – 2.7	13	58 .. 89	500
X	7 – 9.5	18	53 .. 84	500
Ka	28 - 33	25	57 .. 88	500

Future work

- Tri-band feed tests
- Integration of X and Ka-band downconverters
- Integration of NoiseCal module
- Dewar design, construction and assembly
- Cryostat integration and tests
- Monitor/Control software
- Receiver lab tests

Deadline: September ’ 2012

Thank you for your attention

Picture by F. Moreno.