

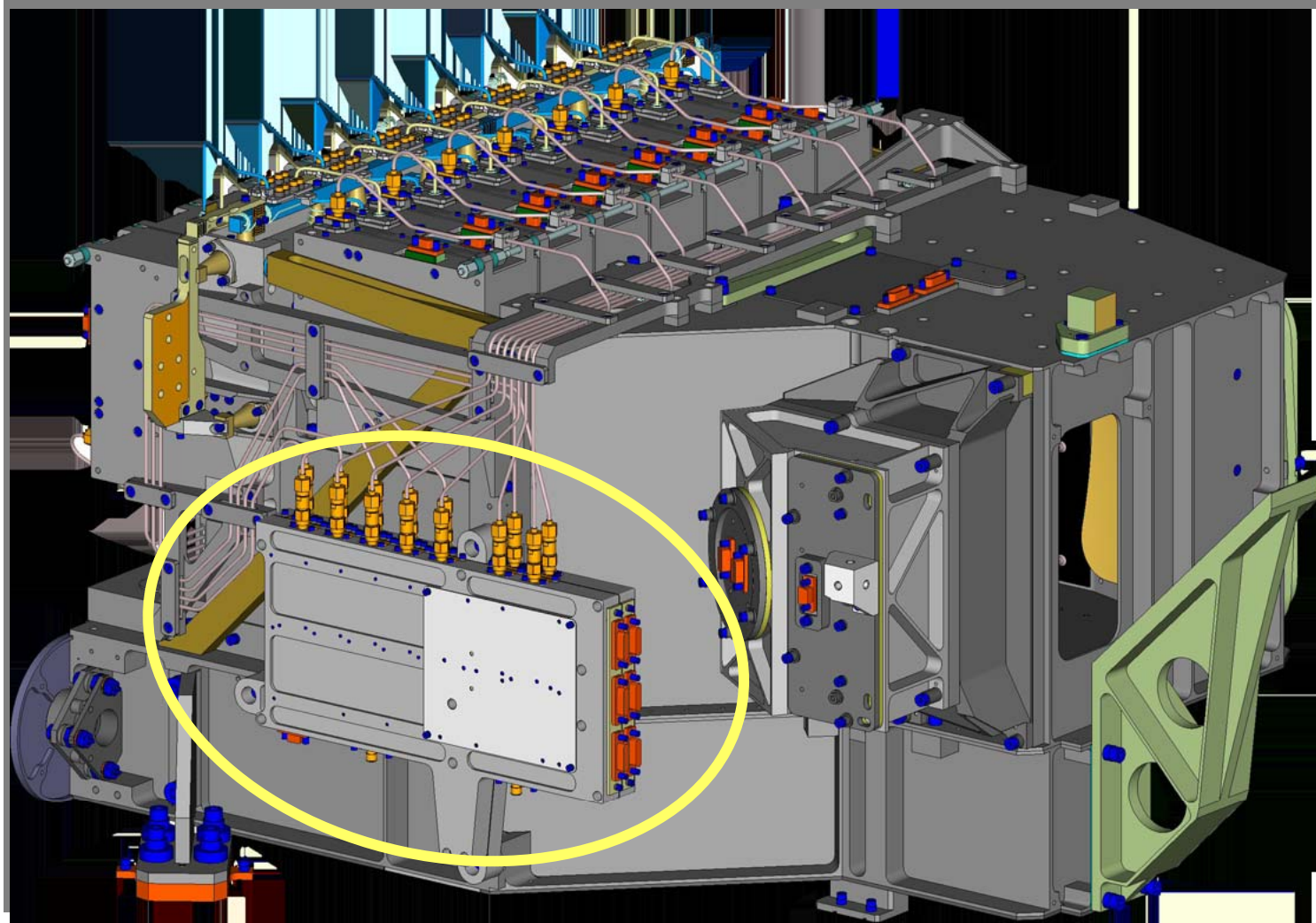
IF-2: the Intermediate Frequency Amplifier for HIFI

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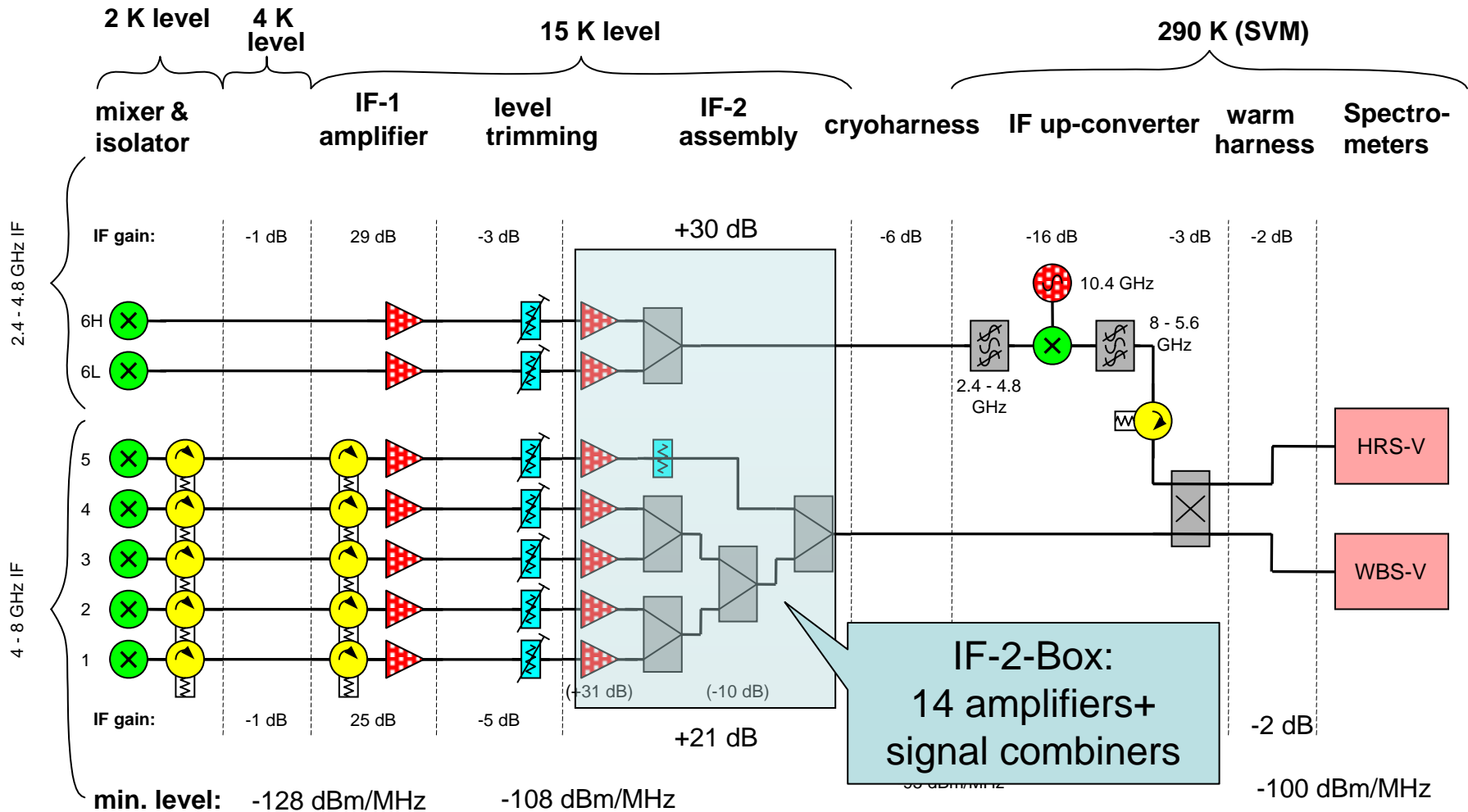
- Introduction: the HIFI-Receiver System
- The IF-2 Amplifier System
- The InP – HEMT: a low noise microwave amplifier device
- Cryo-cooled amplifier
- From the (academic) prototype to the (industrial) flight model
- Conclusions

IF-2: a part in the Herschel HIFI Receiver Chain

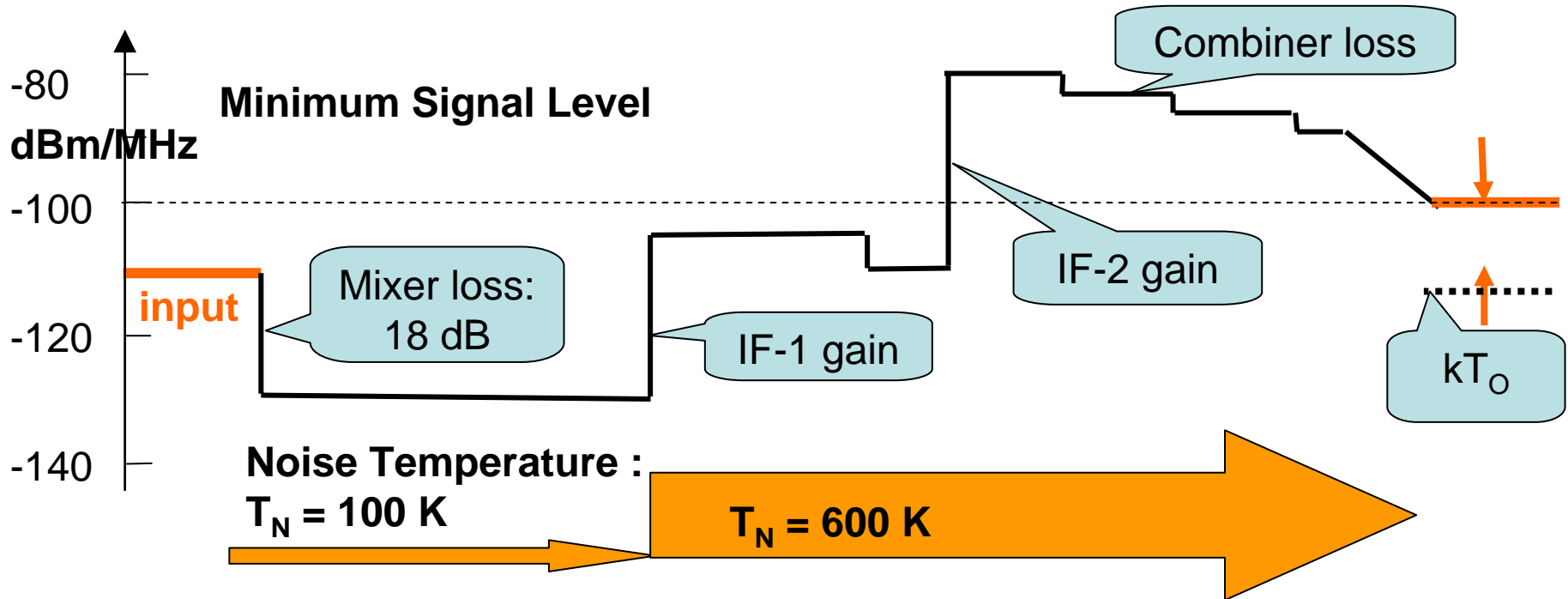
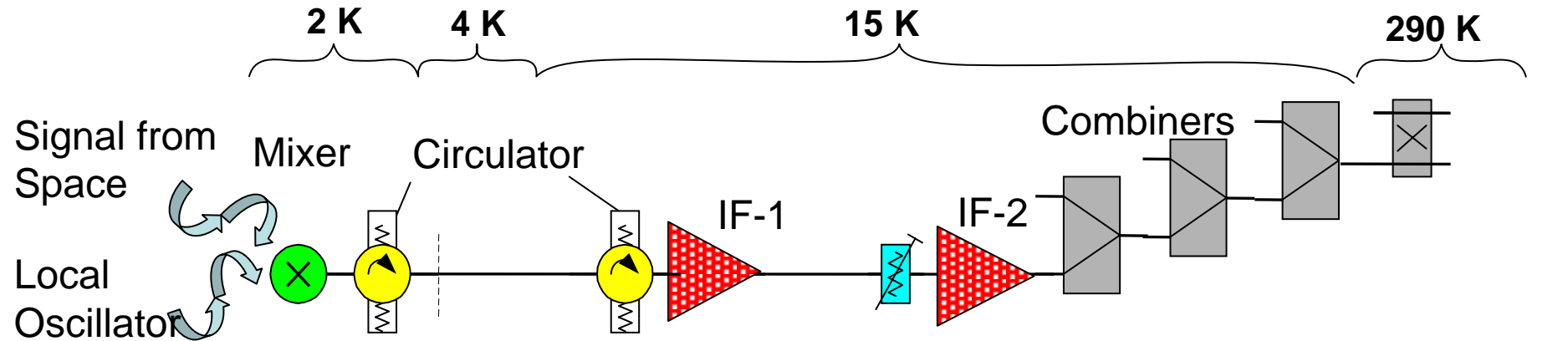


HIFI System Design: SRON Netherlands Institute for Space Research

HIFI Dual IF System - one polarization (Identical diagram for the orthogonal polarization).

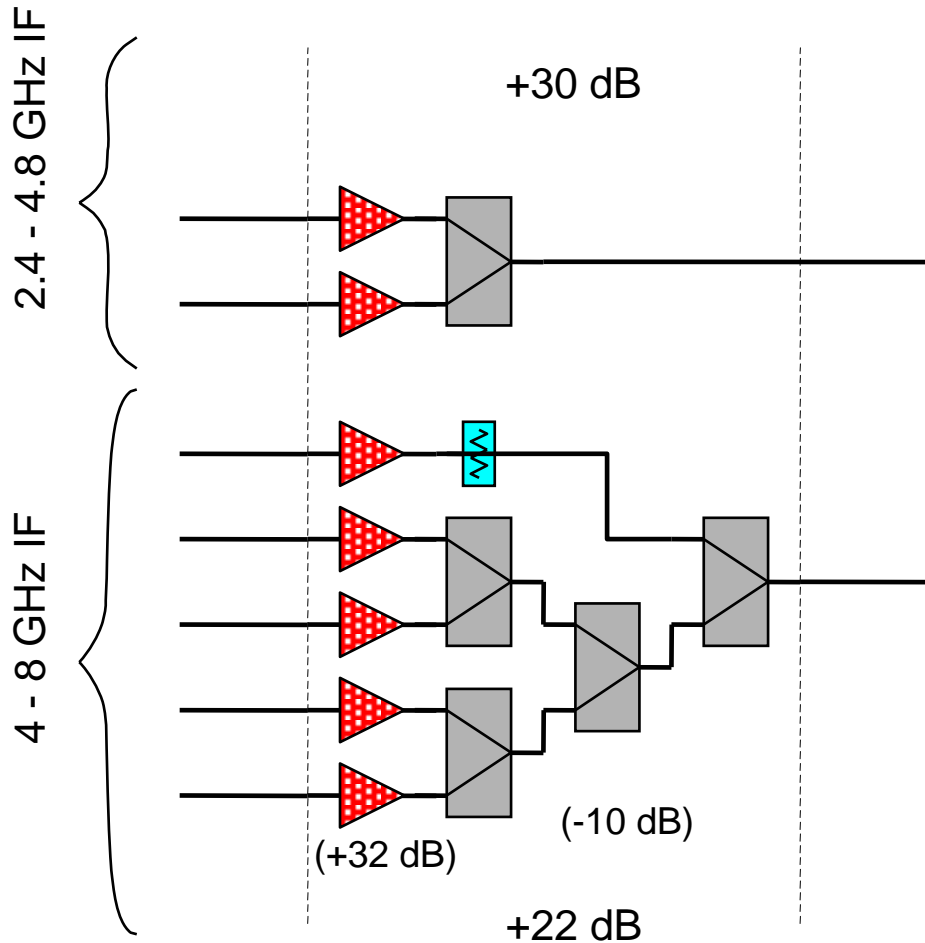


HIFI Receiver: Gain and Noise (Channel 1; 480 – 640 GHz)



HIFI IF-2 Assembly - one polarization

N. D. Whyborn,



(Identical diagram for the orthogonal polarization)

Two amplifier types:

- Bands 1–5 (4 – 8 GHz)
- Bands 6H&L (2.4 – 4.8 GHz)

Amplifier Specifications:

Comment/Challenge

Octave Bandwidths: 2.4 – 4.8 and 4 – 8 GHz	+ (ultimate bandwidth for hybrid technology)
Power Gain: 32 dB	0 (3 stage ampl.)
Operation at T = 15K	0 (III/V devices requ.)
Low noise temperature: < 50K	0 (HEMTs requ.)
Input return loss: > 10 dB,	+ (large bandwidth)
Output return loss: > 10 dB	+ (large bandwidth)
Power dissipation \leq 6 mW	0 (HEMTs requ.)

+: challenging 0: manageable -: no problem)

Required semiconductor amplifier device:

Low noise – low power – high gain - small input/output capacitance

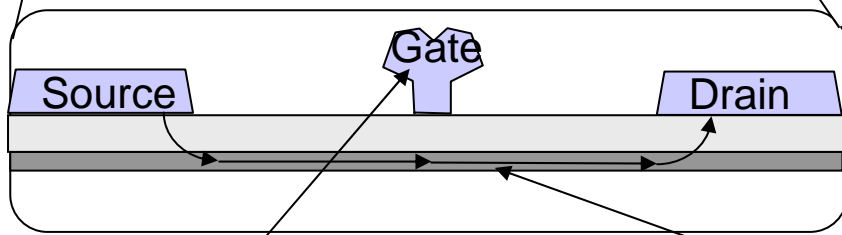
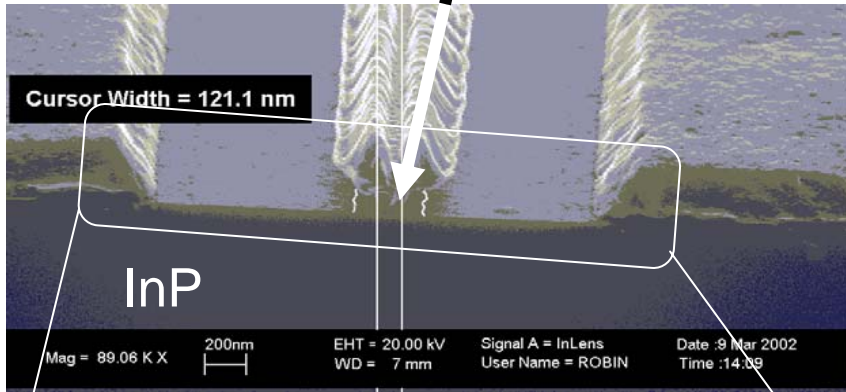
→ InP-HEMT (high electron mobility transistor)

(World wide one space qualified device: TRW CRYO7)

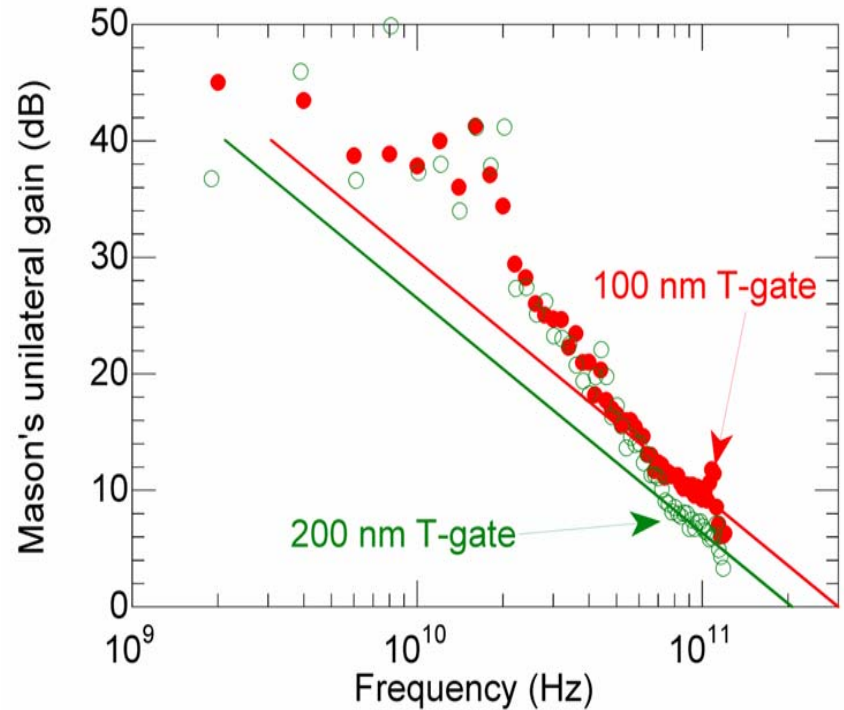
InP HEMT: A Field-Effect Transistor for the mm-Wave Range

InGaAs/InAlAs HEMT on InP


Key Parameter: Gate-Length: 0.2 μm 0.1 μm .
 Max. Oscillation Frequency f_{max} : 200 GHz 300 GHz



Gate voltage controls electron current in GaInAs-channel from source to drain

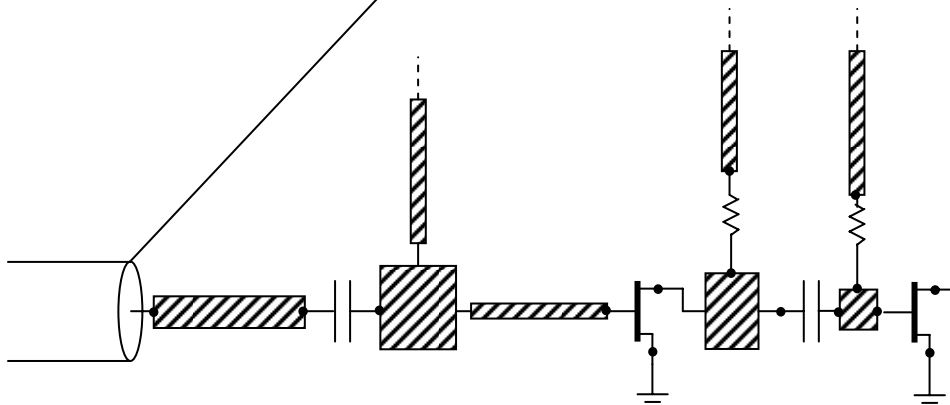
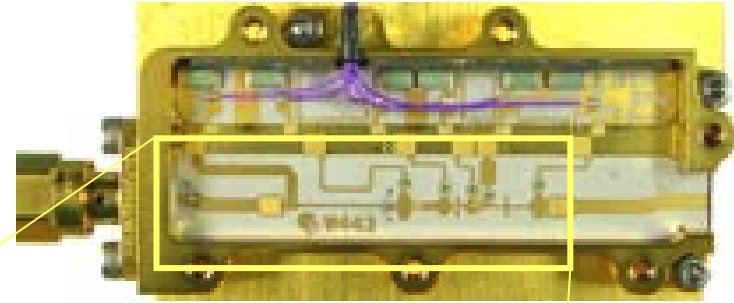


HEMT Noise Properties

- The InP HEMT shows best microwave noise performance of all semiconductor devices.
- The HEMT noise sources are mostly **thermal** noise sources.
  the HEMT noise temperature scales with ambient temperature
- Typical: HEMT operating temperature 300 K 15 K
 HEMT noise temperature 60 K 6 K
 at $f = 6$ GHz
- **Cryo-cooled InP HEMT microwave amplifiers are world champions in noise temperatures**

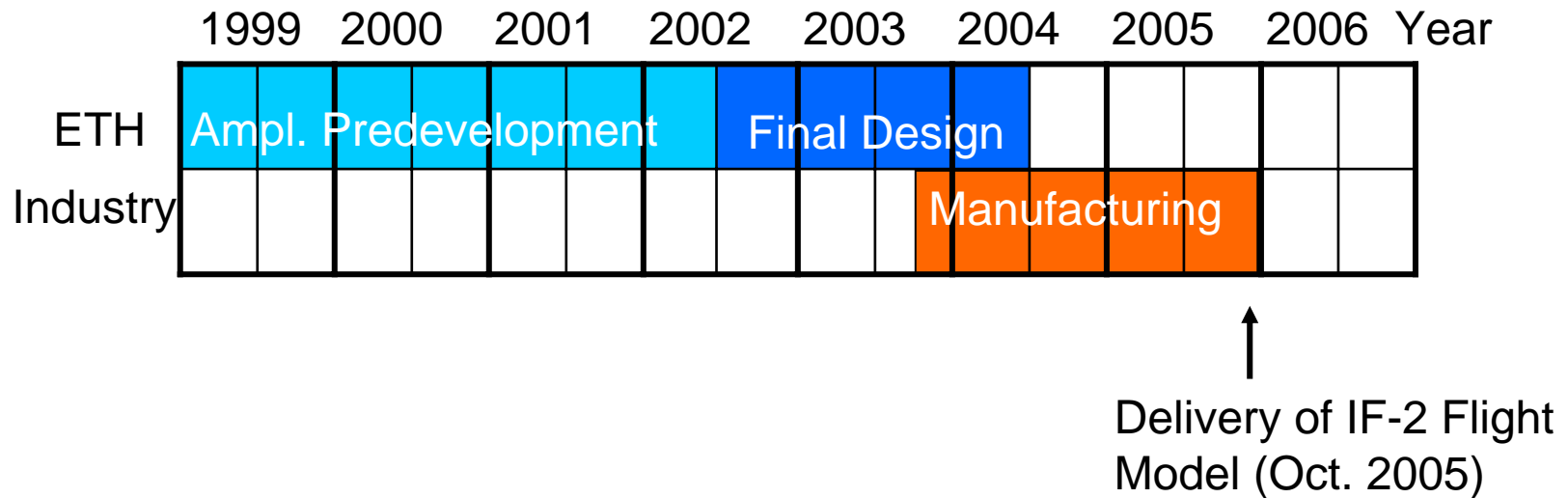
Amplifier Design and Manufacturing:

Hybrid technology (MIC)
(Monolithic would be
preferable – no
space qualified
process available)



Complex mounting and
bonding technology for
HEMTs, line elements,
passive lumped devices

IF-2 Development



Transfer to the Industry

Prime Contractor, management

product assurance, measurements: **Contraves** | Space

Mechanical construction:



Electronics: **Baumer electric**

Low temperature microwave measurements: **ETH**

Development of the amplifiers at the ETH prior to selection of the industrial partner → **no info available of space qualified mounting and bonding processes of the industry**

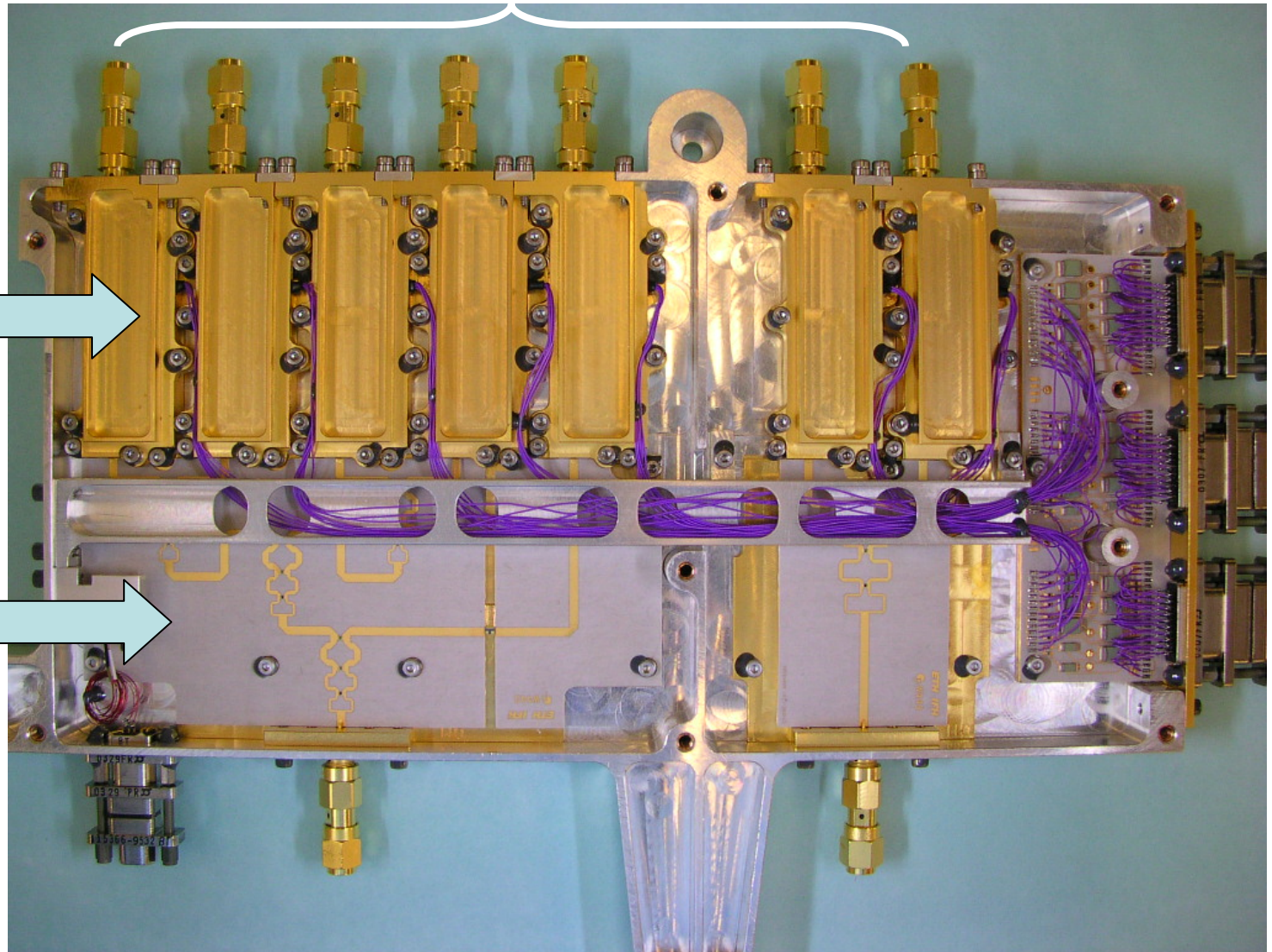
→ Significant and time consuming modifications and adaptations:
Mounting and bonding processes for passive devices and HEMTs

IF-2 Amplifier Box

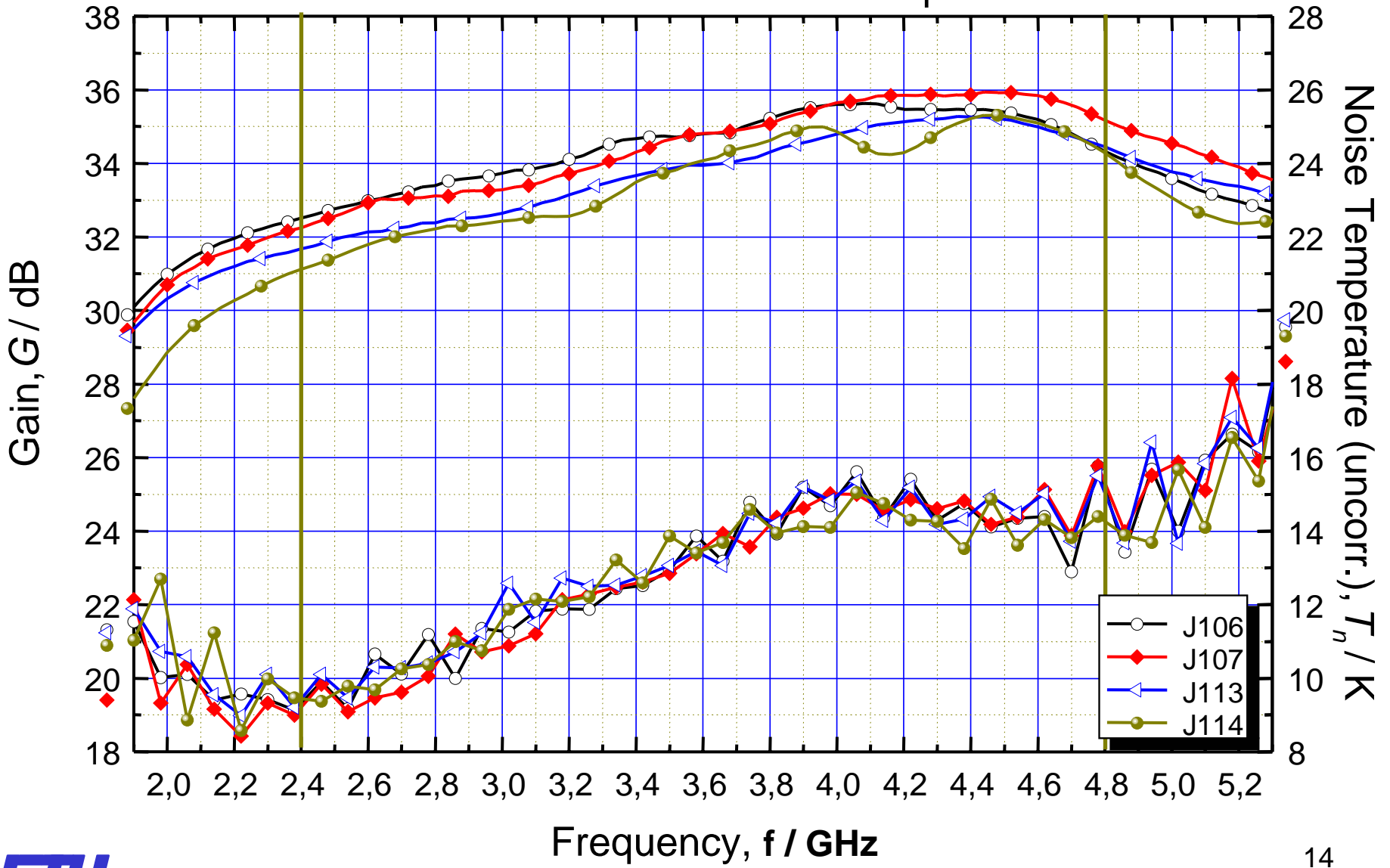
2 x 7 Inputs

2 x 7
Amplifiers

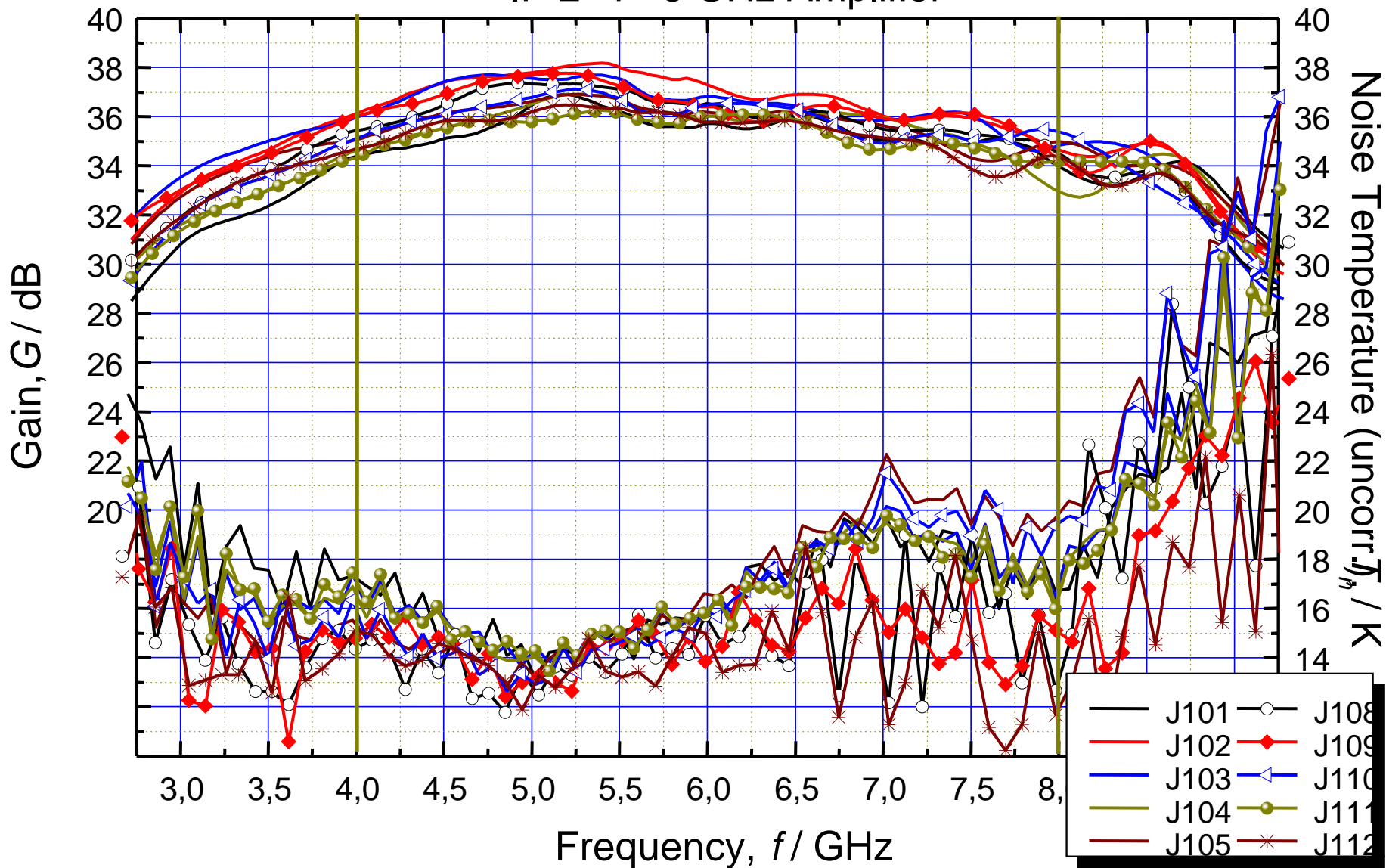
Output
combiner
network



IF-2 2.4 – 4.8 GHz Amplifier



IF-2 4 - 8 GHz Amplifier



Summary of Measurements

	2.4 – 4.8 GHz Ampl.	4 – 8 GHz Ampl.	
Power Gain	31-35	33 – 36	dB
Gain Ripple	± 1	± 1.2	dB
Input Reflection	< -8	< -8	dB
Output Reflection	< - 10	< -10	dB
Mean Noise Temp	13 (uncorrected)	17 (uncorrected)	K
Power Consumption	<6	< 6	mW/Ampl.

Conclusions

- A University Lab can design but cannot manufacture a space qualified device.
- The specifications for a system like HIFI are moving targets. The design takes longer (much longer) than expected.
- The cooperation with the industry was smooth, but required more time than expected.
- Our thanks go to



Baumer electric

SRON
Netherlands Institute for Space Research

Contraves | Space



Swiss Space Office