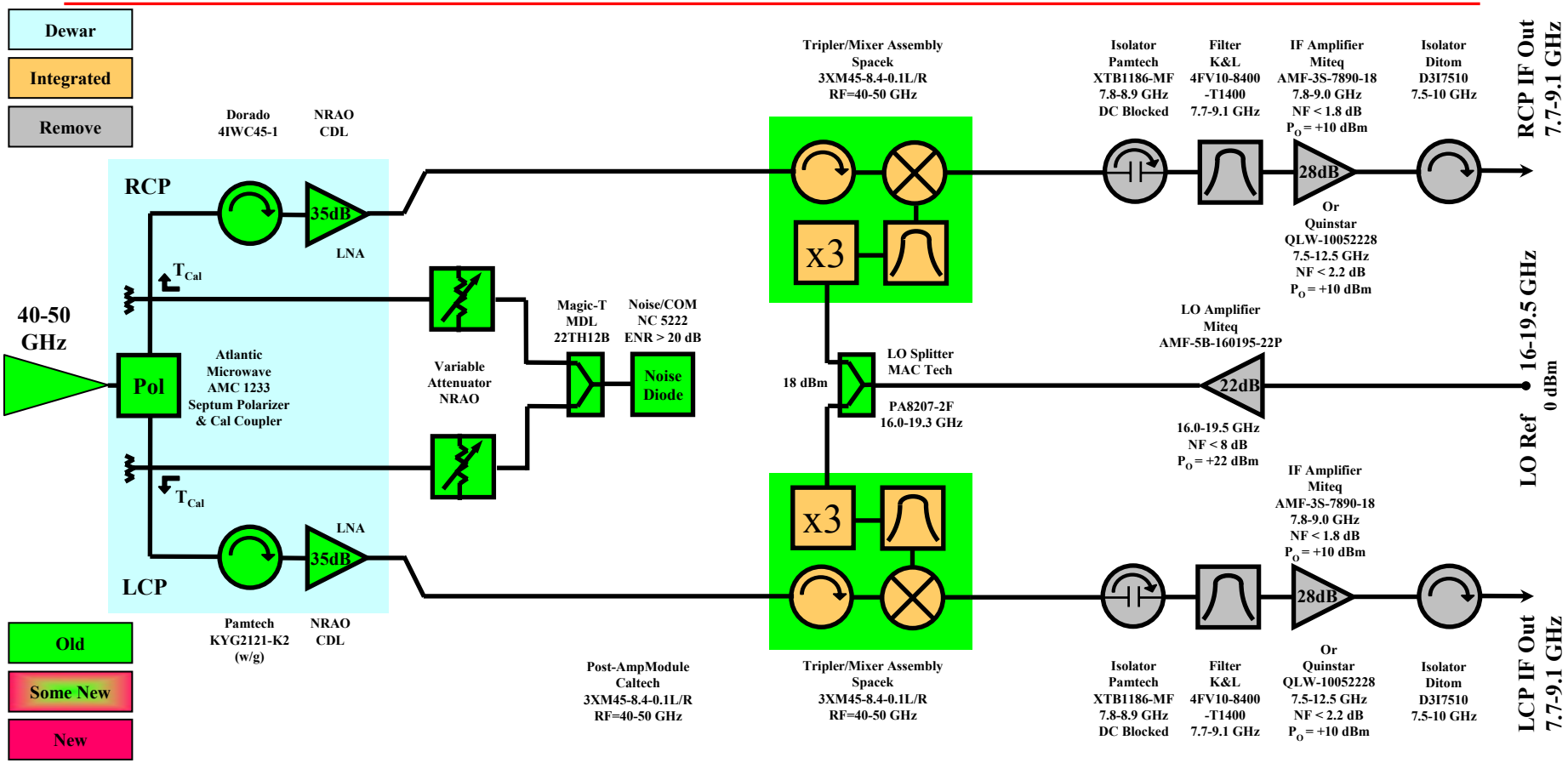
EVLA Front-End CDR

EVLA
Q-Band (40-50 GHz)
Receiver

EVLA Q-Band Receiver Overview

1) **EVLA Upgrade**
   - **Existing VLA Configuration**
   - **Required Modifications**
   - **New Upgraded EVLA Block Diagram**
2) **Block Converter Scheme**
3) **Noise & Headroom Model**
4) **Performance Improvement Simulations**
5) **MMIC Post-Amp Module**
6) **EVLA Q-Band Interim Receivers**
7) **Test Results**
   - **RF vs. IF Post-Amps**
   - **Swept LO1 vs. Block Converter Mode**

EVLA Q-Band Receiver
Existing VLA Configuration



EVLA Q-Band Receiver
VLA to EVLA Modifications
LO & IF Chain

- Adopt Block Converter Scheme (40-50 → 18-8GHz)
  - **Retain Spacek Tripler/Mixer Assemblies. Although original VLA spec for IF was 8400"100 MHz, the units work at 1-18 GHz.**
  - **Remove all narrowband 8.4 GHz IF components, including**
    - **Isolators, Filters and Post-amps**
  - **Replace with wideband DC-Blocks and 8-18 GHz Isolators**
  - **IF & LO bulkhead SMA connectors are replaced with 2.9mm**
- Replace Current LO Ref Amp with Limiting version
  - **Leveled Output = 21.5 ± 0.5 dBm over ± 6 dBm input range**
  - **Add Input Isolator**

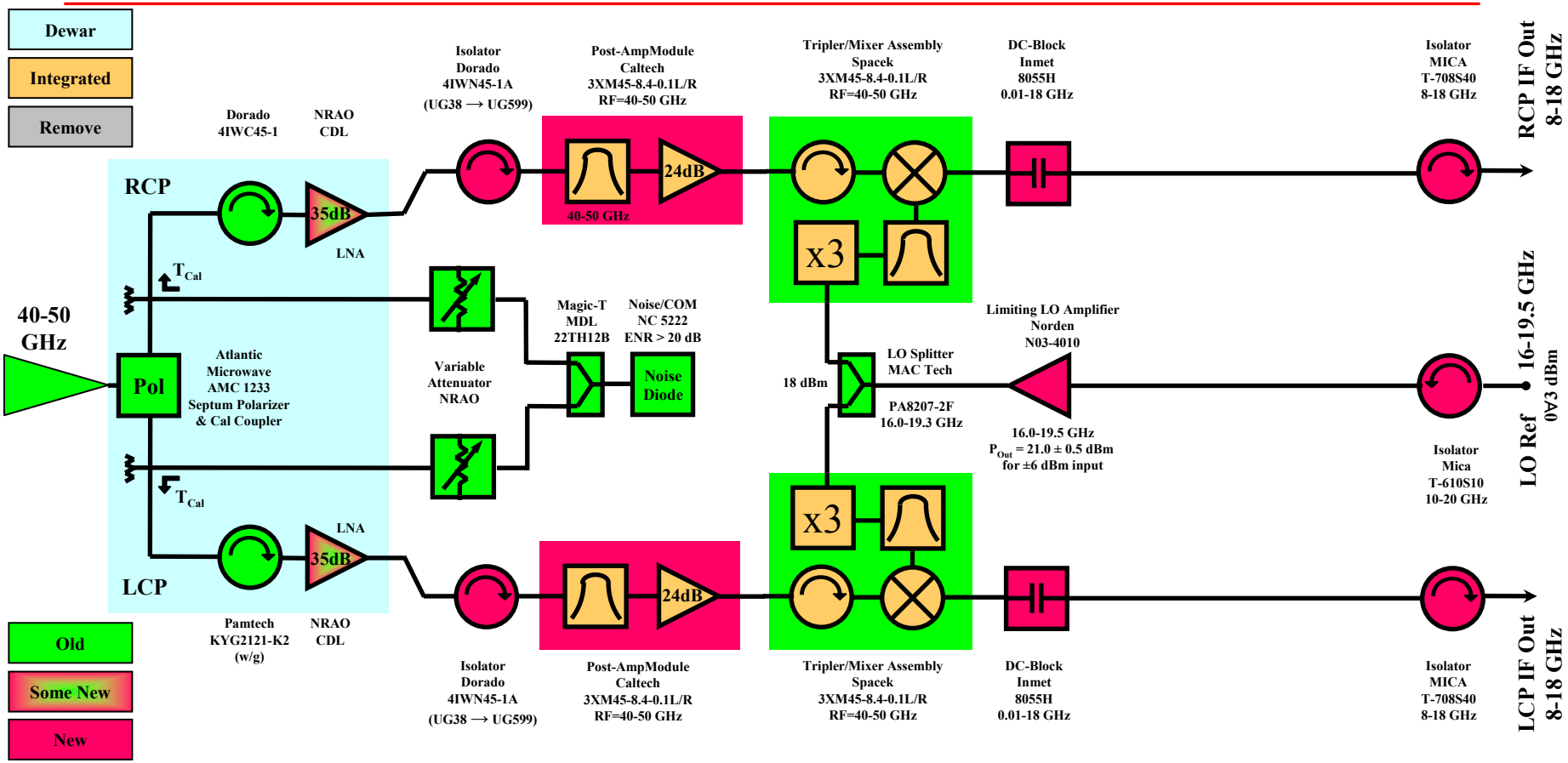
EVLA Q-Band Receiver
VLA to EVLA Modifications
RF Chain

- Add new Q-Band Post-Amp Module (QPAM)
  - **Caltech-designed, NRAO-built MMIC-based amplifier**
  - **Has 39-51 GHz input filter to improve Headroom**
  - **23 dB gain in front of mixer improves T_{Rx} by up to 5-10°K**
- Add RF Isolator before Q-PAM unit to reduce ripple
  - **Custom Dorado unit with circular input & square output flanges**
- Bench evaluation tests carried out on each receiver to improve the match between the various circular waveguide components
- Brackets to eliminate microphonics

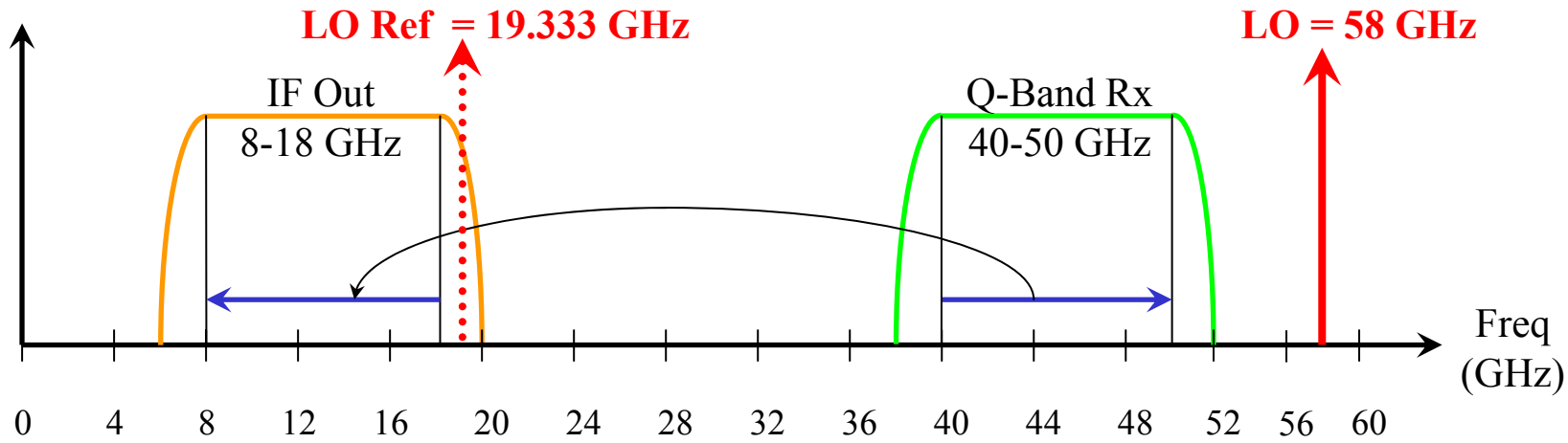
EVLA Q-Band Receiver
VLA to EVLA Modifications
Other Changes

- Replace Old Card Cage with new design
  - **Mount underneath; new extended legs required**
  - **Add new AC Box**
  - **Add Noise Diode Interface Box (includes ±15V & ±5V regulators)**
- Receiver rotated 180° from current VLA orientation
  - **Cold-head now points to the rear of the receiver**
  - **New front connector panel required**
- New mounting tower allows for a Dry Air system to encompass the feed-horn & eliminate moisture buildup as well as provide RFI shielding

EVLA Q-Band Receiver
New Upgraded Configuration



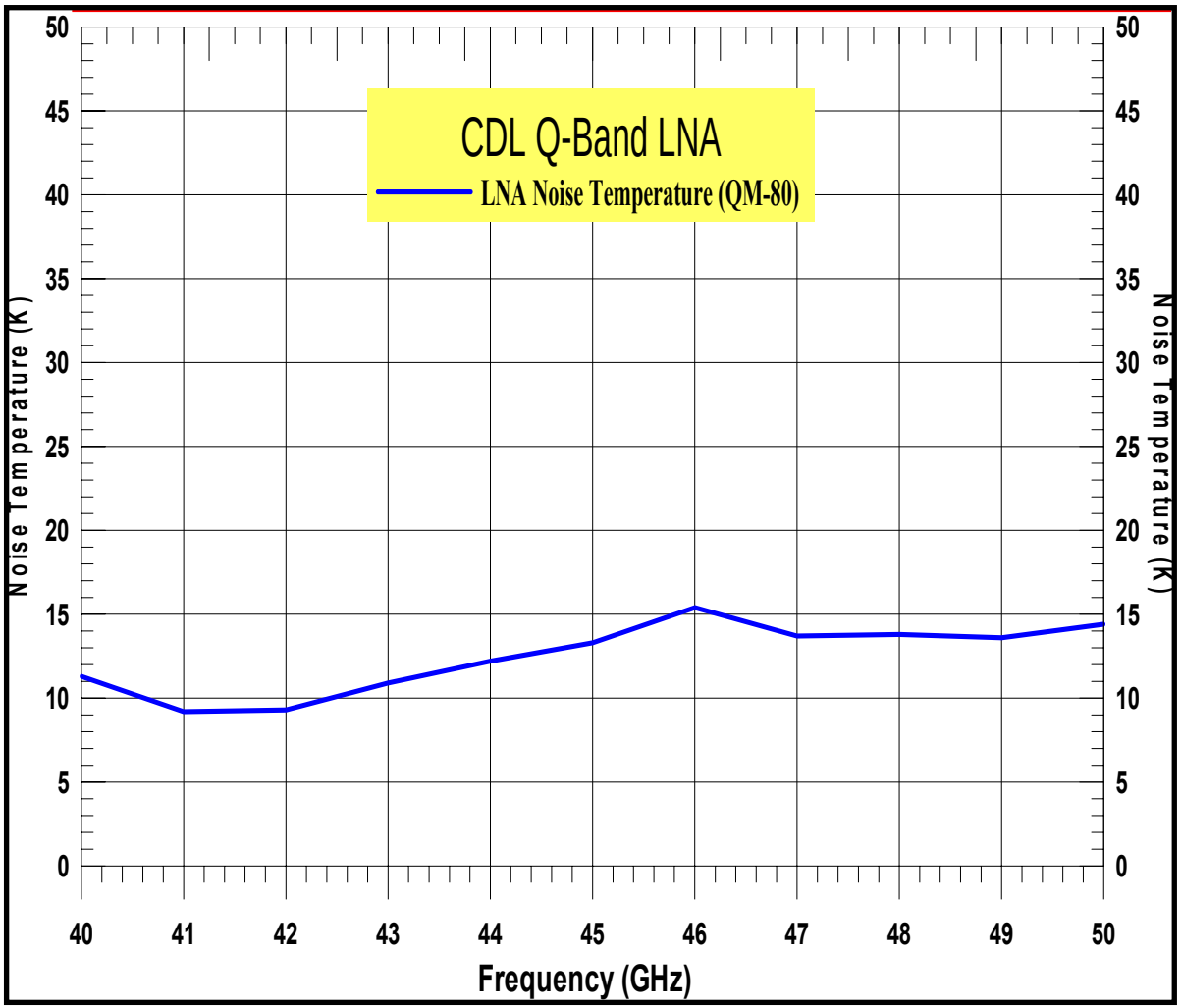
Q-Band Block Conversion Frequency Diagram



- Translation of 40-50 GHz down to 8-18 GHz
- LO Ref 19.333 GHz x 3 = 58 GHz
  - **Closest L301 Lock Point is actually 19.238 GHz**

CDL Q-Band LNA Performance

Cryo-3 Device in 1st Stage



Replace all old 5-stage GaAsFET's with new MAP-style InP units, as well as several existing MAP units which have inferior performance.

24 new LNA's

Upgrade existing 4-stage MAP amps by returning them to CDL for substitution of Cryo-3 device in the 1st stage.

35 upgraded LNA's

Original MAP amplifier designed for 35-46 GHz bandwidth. A new 4-stage Cryo-3 design under development to improve gain flatness & sensitivity at the high-end.

Estimated EVLA Q-Band T_{Rx}, Output Power & Headroom

With IF Post-Amps

EVLA Q-Band Rx (RHH : 28 March 2006)	P (1dB) (dBm)	P (1%) (dBm)	Temp (K)	NF/C (dB)	Loss/Gain (dB)	Loss/Gain (linear)	Delta T (K)	Trx (K)	BW (MHz)	Pnoise (dBm) for Tsky of 26.0 (K)	Pnoise dBm/GHz	Headroom (dB)
									14000	-83.0	-94.5	
Weather Window			300		-0.05	0.9886	3.474			-82.5		
Feed Horn			300		-0.05	0.9886	3.514			-82.1		
Vacuum Window			300		-0.01	0.9977	0.708			-82.0		
Septum Polarizer			18		-0.3	0.9333	1.320			-82.1		
Waveguide			18		-0.1	0.9772	0.461			-82.2		
Cal Coupler (IL)			18		-0.2	0.9550	0.954			-82.2		
Cal Coupler (Branch)			300	-30	0	1.0000	0.300			-82.2		
Isolator			18		-0.5	0.8913	2.586			-82.4		
LNA	-10	-22	25		35	3162.2777	33.032			-44.8		22.8
Flexguide			18		-2	0.6310	0.004			-46.8		
Stainless Steel W/G			159		-2	0.6310	0.062	46.42		-48.8		
Waveguide			300		0	1.0000	0.000			-48.8		
Isolator			300		-0.5	0.8913	0.038			-49.2		
Mixer	-2	-14	300		-8	0.1585	1.876			-57.1		35.2
DC Block			300		-0.5	0.8913	0.272			-57.6		
Isolator			300		-0.5	0.8913	0.305		10000	-59.6		
IF Post-Amp	10	-2	446.0	4	25	316.2278	4.172			-34.3		32.3
Isolator			300		-0.5	0.8913	0.001	53.08		-34.8		

Estimated EVLA Q-Band T_{Rx}, Output Power & Headroom

With RF Post-Amps

EVLA Q-Band Rx	P (1dB)	P (1%)	Temp	NF/C	Loss/Gain	Loss/Gain	Delta T	Trx	BW	Pnoise	Pnoise	Headroom
RHH : 28 March 2006	(dBm)	(dBm)	(K)	(dB)	(dB)	(linear)	(K)	(K)	(MHz)	(dBm)	dBm/GHz	(dB)
										for Tsky of		
										26.0	and as high as 68K	
										(K)		
									10000	-84.5	-94.5	
Weather Window			300		-0.05	0.9886	3.474			-84.0		
Feed Horn			300		-0.05	0.9886	3.514			-83.5		
Vacuum Window			300		-0.01	0.9977	0.708			-83.4		
Septum Polarizer			18		-0.3	0.9333	1.320			-83.6		
Waveguide			18		-0.1	0.9772	0.461			-83.6		
Cal Coupler (IL)			18		-0.2	0.9550	0.954			-83.7		
Cal Coupler (Branch)			300	-30	0	1.0000	0.300			-83.7		
Isolator			18		-0.5	0.8913	2.586			-83.9		
LNA	-10	-22	25		35	3162.2777	33.032			-46.2		24.2
Flexguide			18		-2	0.6310	0.004			-48.2		
Stainless Steel W/G			159		-2	0.6310	0.062	46.42		-50.2		
Vacuum Window			300		-0.2	0.9550	0.015			-50.4		
Waveguide			300		-1	0.7943	0.085			-51.4		
Isolator			300		-1	0.7943	0.107			-51.6	-62.4	
Filter (39-51 GHz)			300		-1	0.7943	0.135		12000	-52.6		
RF Post-Amp	5	-7	751.7	5.5	24	251.1886	1.648			-28.5		21.5
Isolator			300		-1	0.7943	0.001			-29.5		
Mixer	-2	-14	300		-8	0.1585	0.018			-37.5		15.5
DC-Block			300		-0.5	0.8913	0.003			-38.0		
Isolator			300		-0.5	0.8913	0.003	48.43		-38.5		

EVLA Q-Band

Simulated Impact of new RF Post-Amps on Receiver Performance

Expanded Very Large Array

Simulation Parameters

T_{LNA} : 10 → 30°K

LNA Gain : 35 → 25 dB

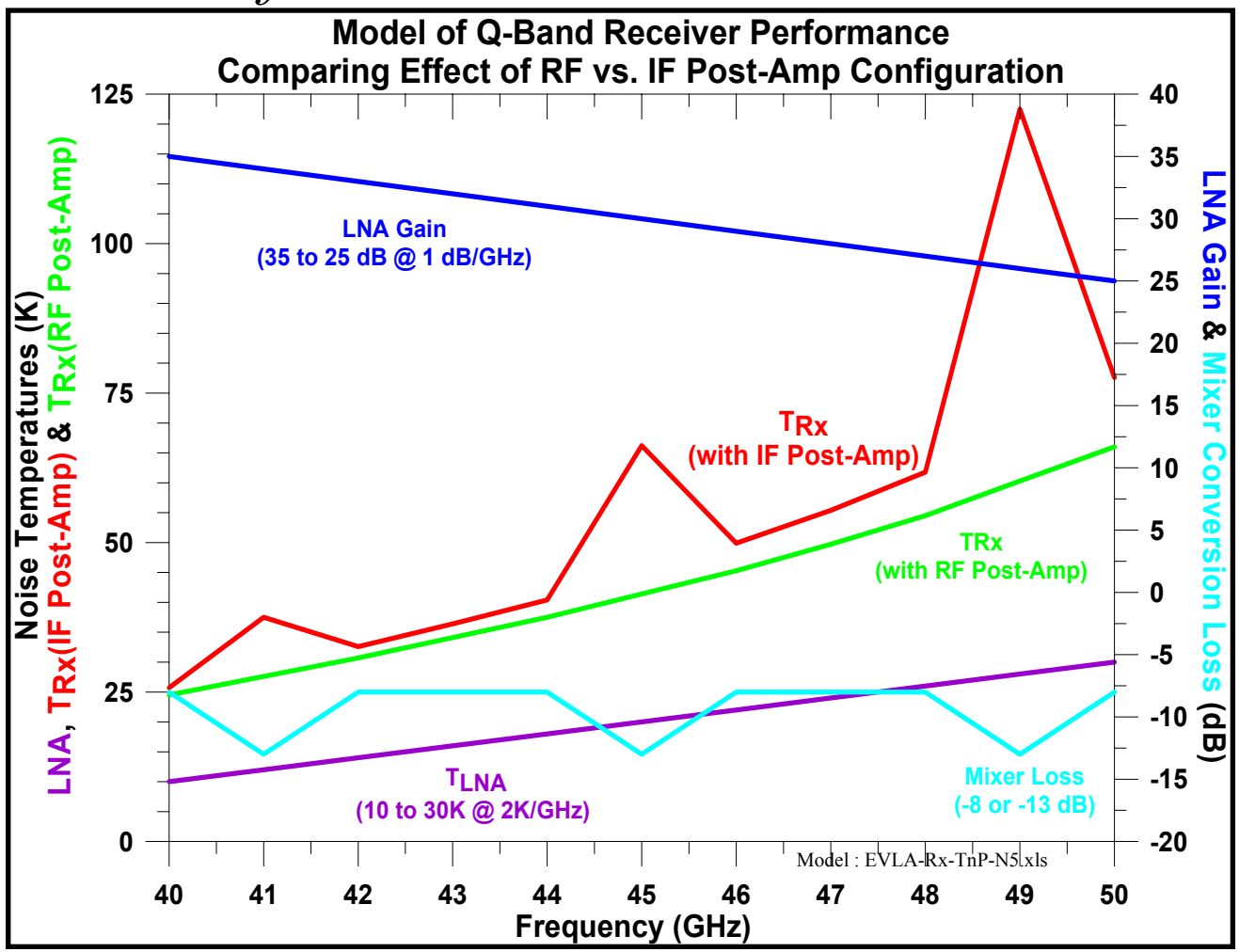
Mixer Loss : -8 or -13 dB

IF Post-Amp Scheme

* Moderately affected by LNA Gain roll-off
* Strongly affected by Mixer Conversion Loss

RF Post-Amp Scheme

* T_{Rx} Affected less by LNA Gain roll-off
* Negligible affect from Mixer Conversion Loss

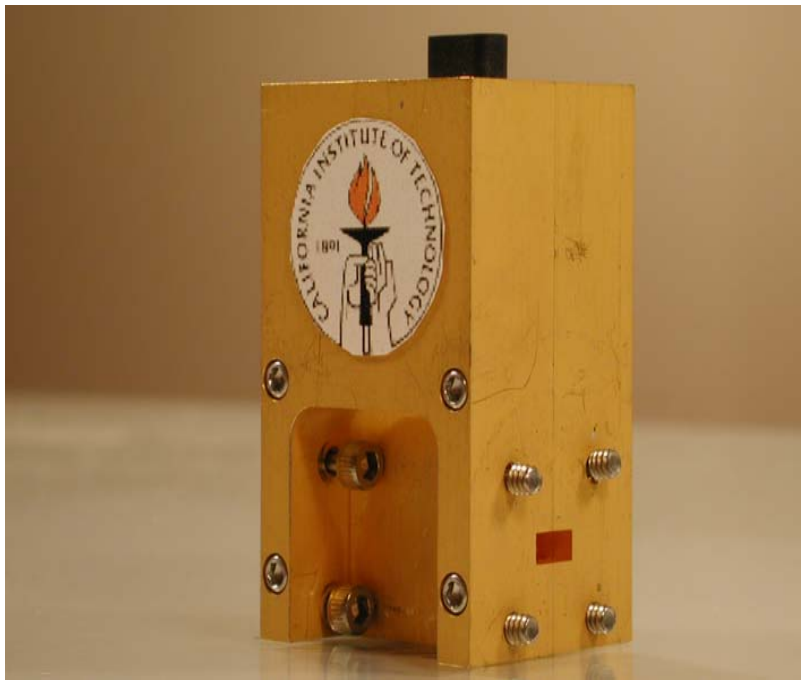


EVLA Q-Band

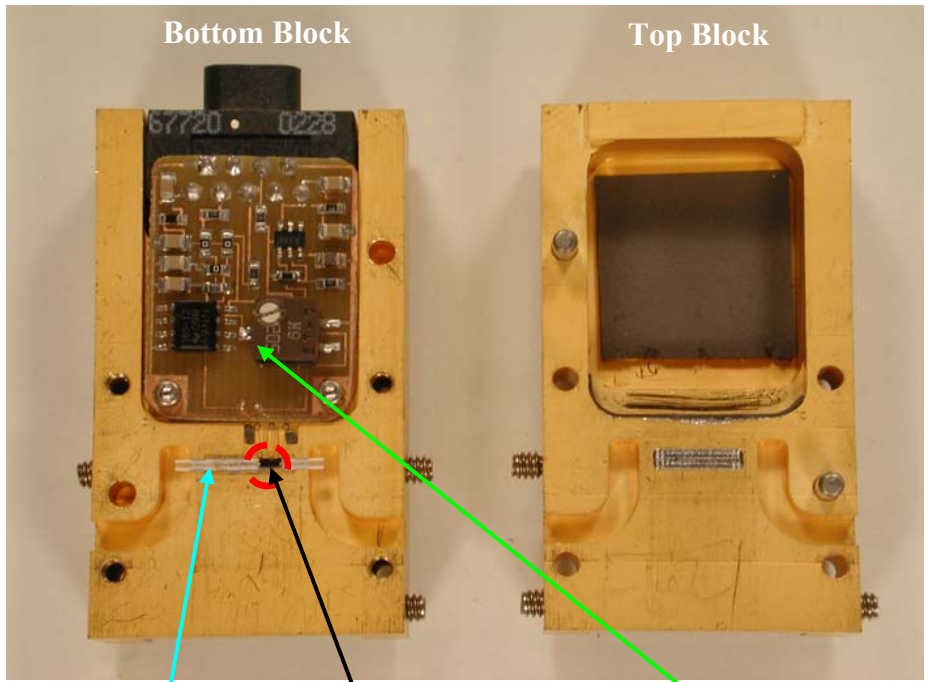
Q-Band Post-Amp Module (Q-PAM)

(Prototype units designed & built at Caltech)

Assembled Module

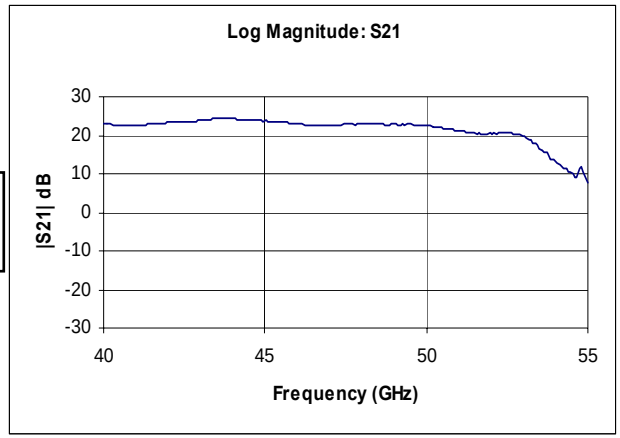


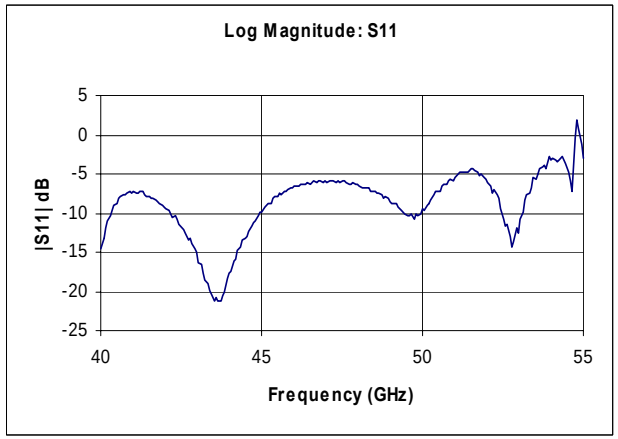
Disassembled Module



EVLA Q-Band
Q-PAM Prototype
(Test Results courtesy of Patrick Cesarano, Caltech)

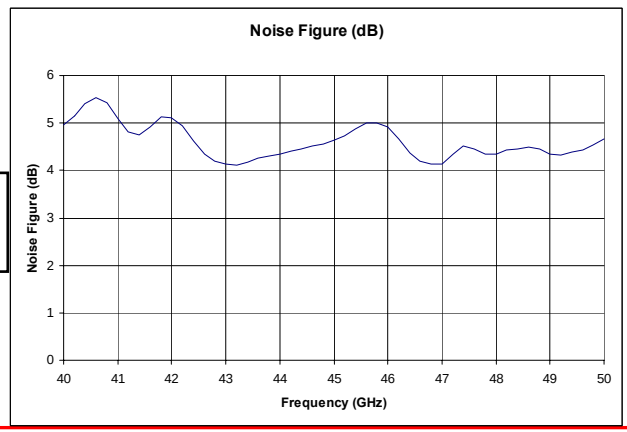
Gain
24 ± 1 dB

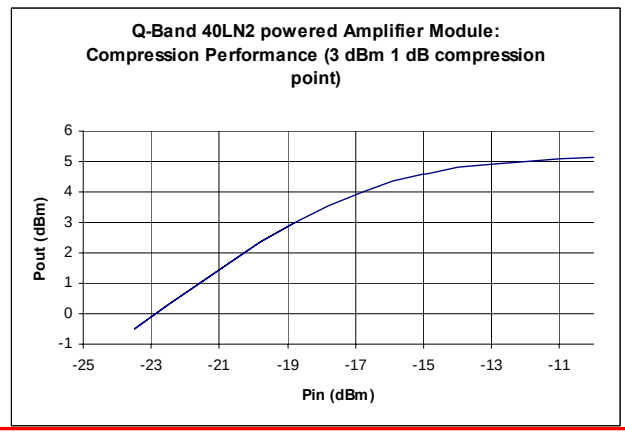




Input Return Loss < -5 dB (will need an Isolator)

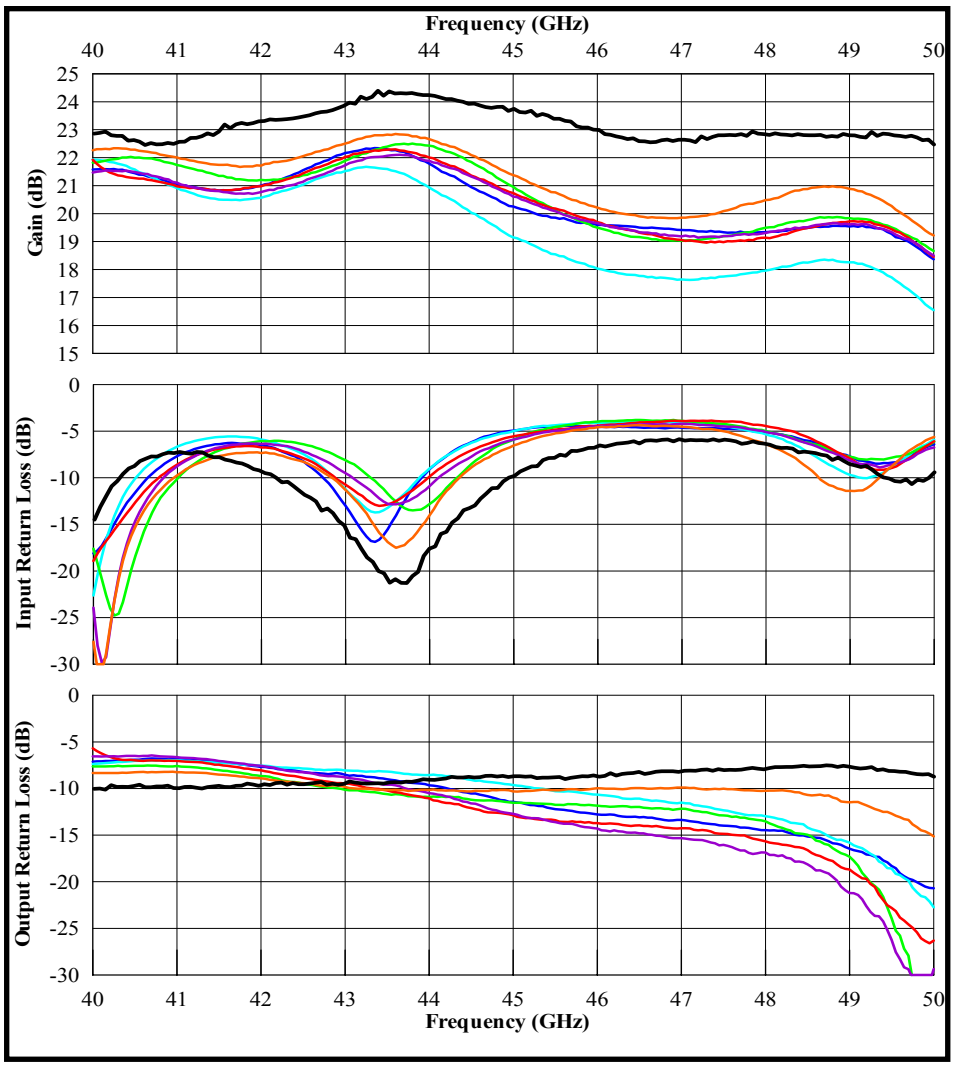
Noise Figure < 6 dB





Compression Point > +3 dBm (spec was -5 dBm)

First NRAO Production Batch of 6 Units



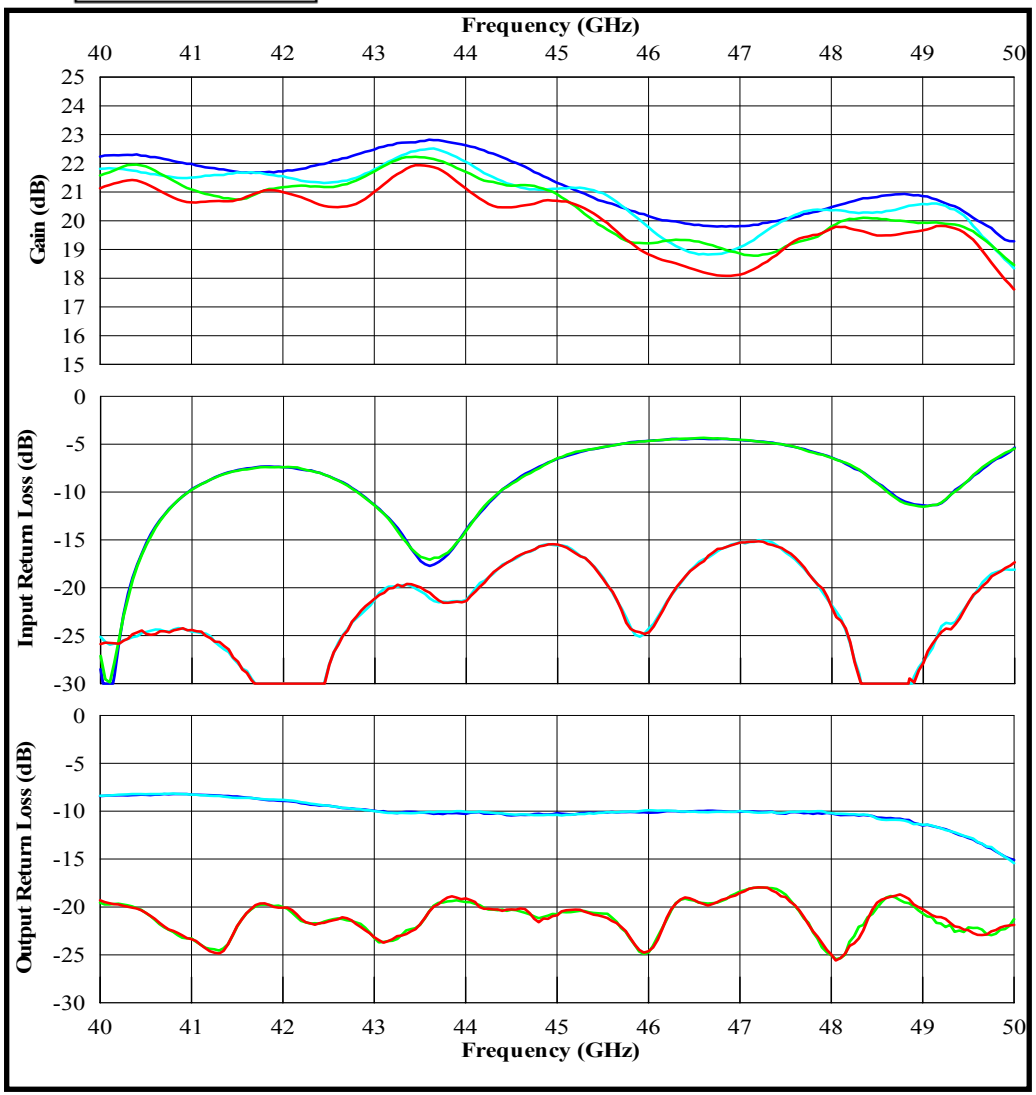
Q-Band Post-Amplifier Modules (QPAM) - No Isolators
27 Jan 2006

- QPAM SN001 with V(Gate) = -0.385V
- QPAM SN002 with V(Gate) = -0.382V
- QPAM SN003 with V(Gate) = -0.384V
- QPAM SN004 with V(Gate) = -0.383V
- QPAM SN005 with V(Gate) = -0.385V
- QPAM SN006 with V(Gate) = -0.361V
- Caltech SN001

Gain roll off at high-end likely due to devices in the Raytheon wafer (they made 3 attempts to meet the standard DC spec's.

Performance improvement still very attractive.

QPAM's with Isolators



Q-Band Post-Amplifier Modules (QPAM) SN006
27 Jan 2006

- QPAM with No Isolators
- QPAM with Input Isolator
- QPAM with Output Isolator
- QPAM with Input & Output Isolators

QPAM Unit Cost

- Assumes minimum of 66 QPAM units
- Direct Cost = $1,000
- Indirect Cost = $3,800
  - if include pro-rated costs (with KaDCM) of
    - Caltech contract
    - Wafers
    - 50 GHz test equipment
    - Wire bonder & accessories, etc.

EVLA Q-Band

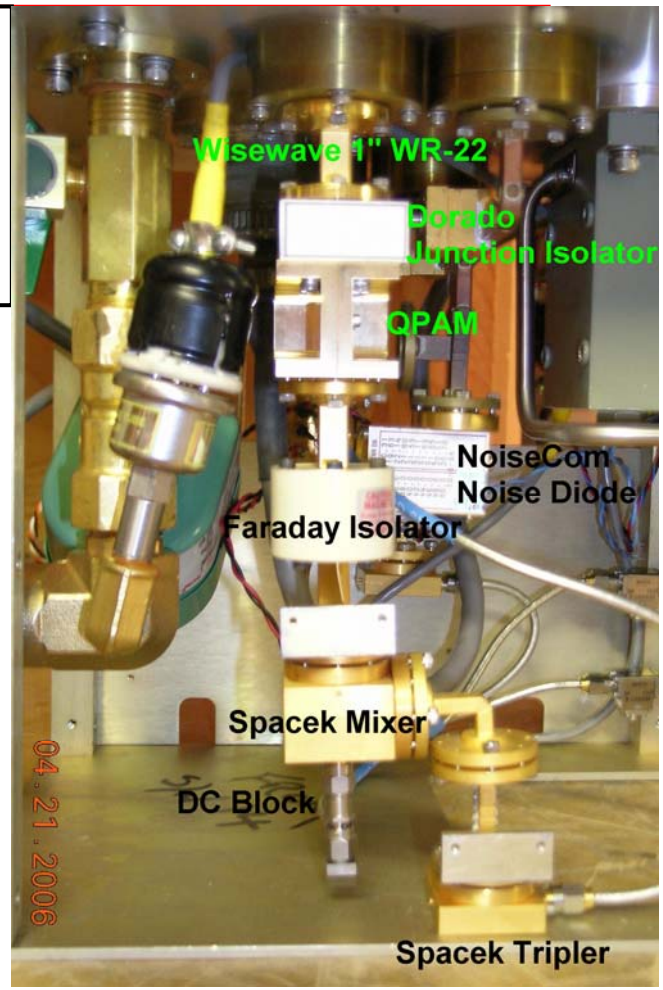
First EVLA Q-Band - Q#30

View of Interim Receiver ←

Close-Up View of QPAM →

Interim receivers will eventually be returned to the lab for further modifications, including:

- new Card Cage
- new AC Box
- new VR/Cal Box
- new Front Panel



Q-Band SN 17 - Third EVLA Interim Receiver

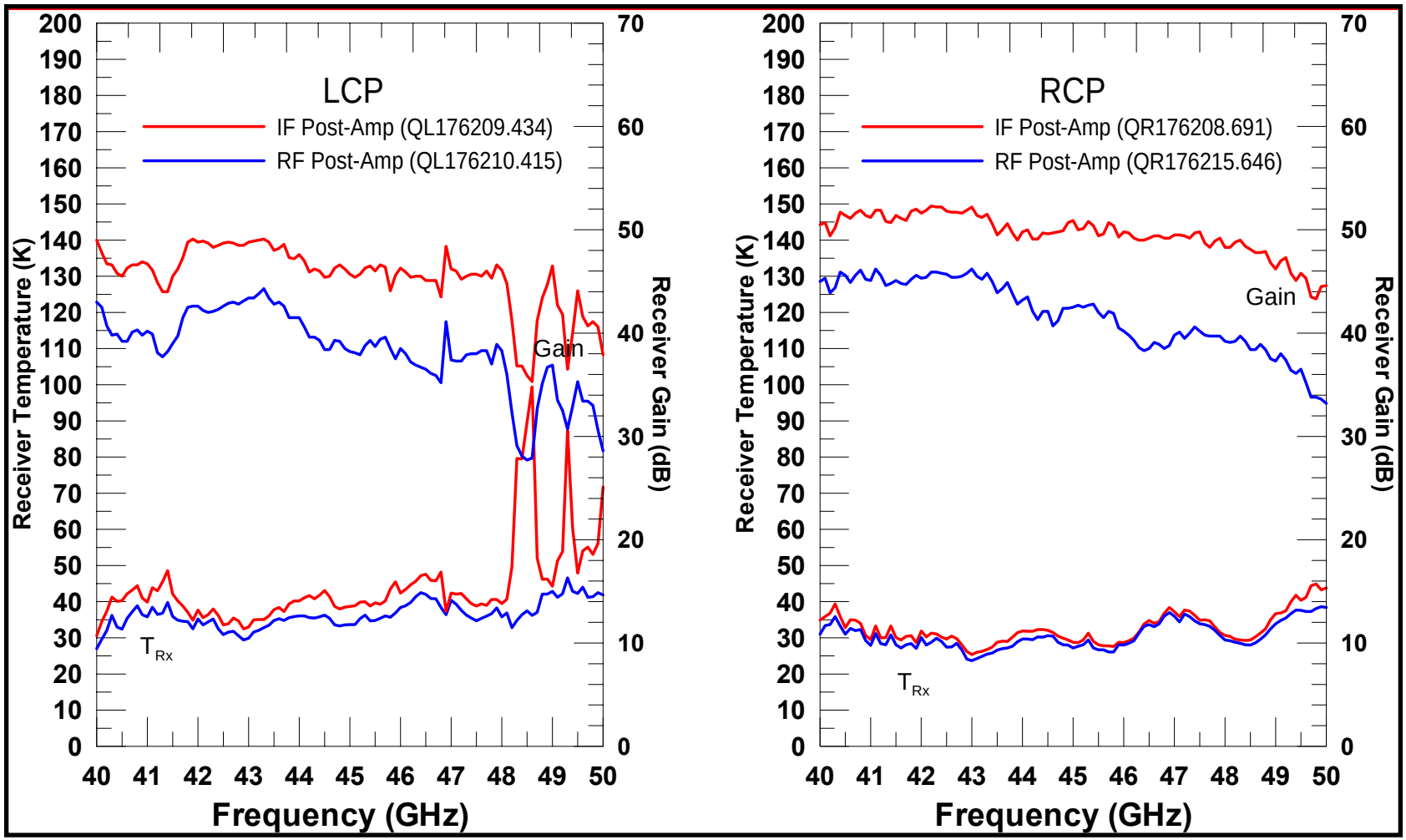
IF vs. RF Post-Amps with "Poor" LCP Spacek Mixer (9D22)

24 Feb 2006

Using Swept LO1 Mode (with 8.4/1.4 GHz IF filter):

Old style VLA configuration with IF Post-Amps

EVLA configuration with NRAO RF Post-Amps & Dorado Isolators



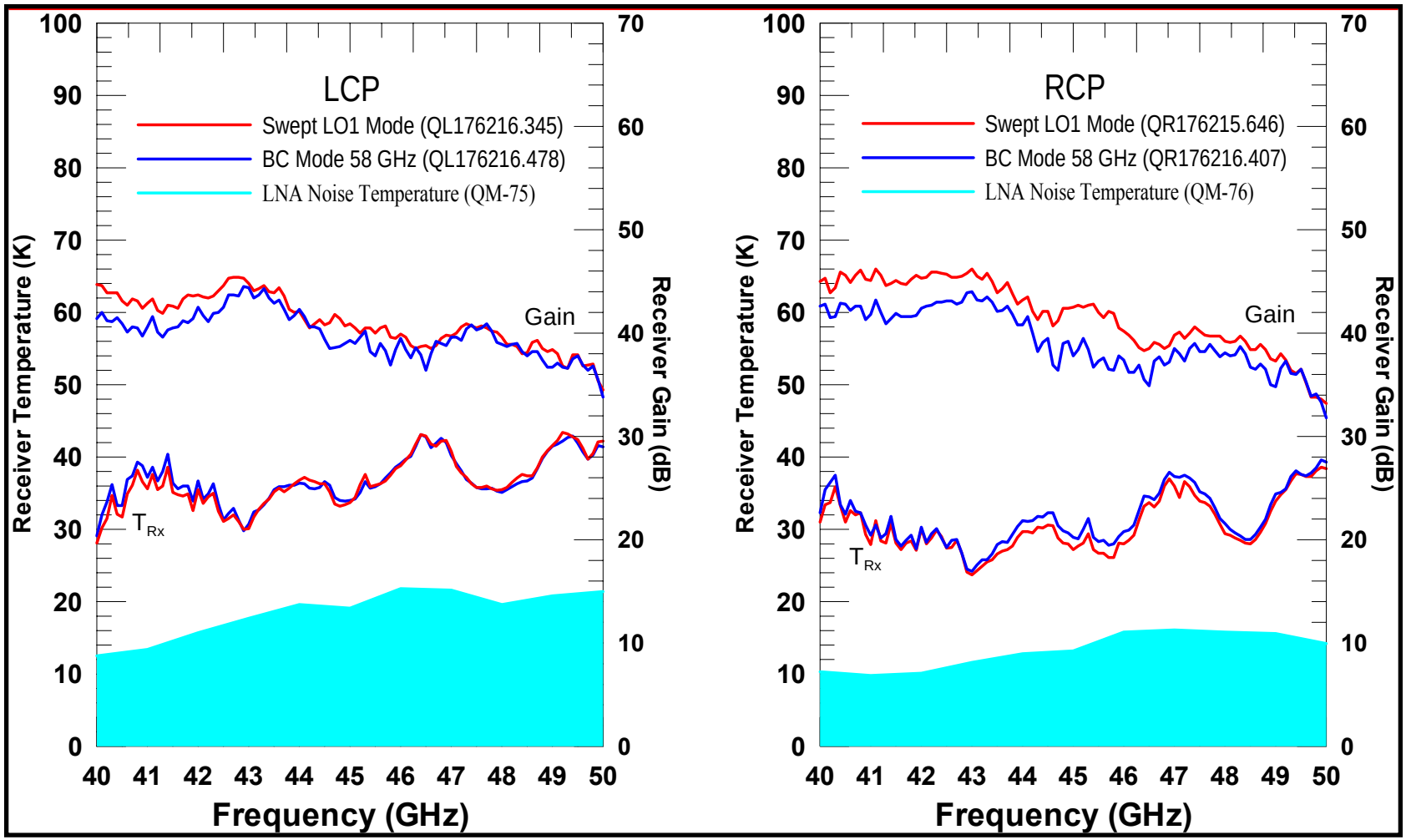
Q-Band SN 17 - Third EVLA Interim Receiver

Swept LO1 vs. Block Converter Mode

23 Feb 2006

Swept LO 1 Mode : LO1 = 48.4 to 58.4 GHz, LO2 = 8.4 GHz

Block Converter Mode : LO1 = 58.0 GHz, LO2 = 18.0 to 8.0 GHz

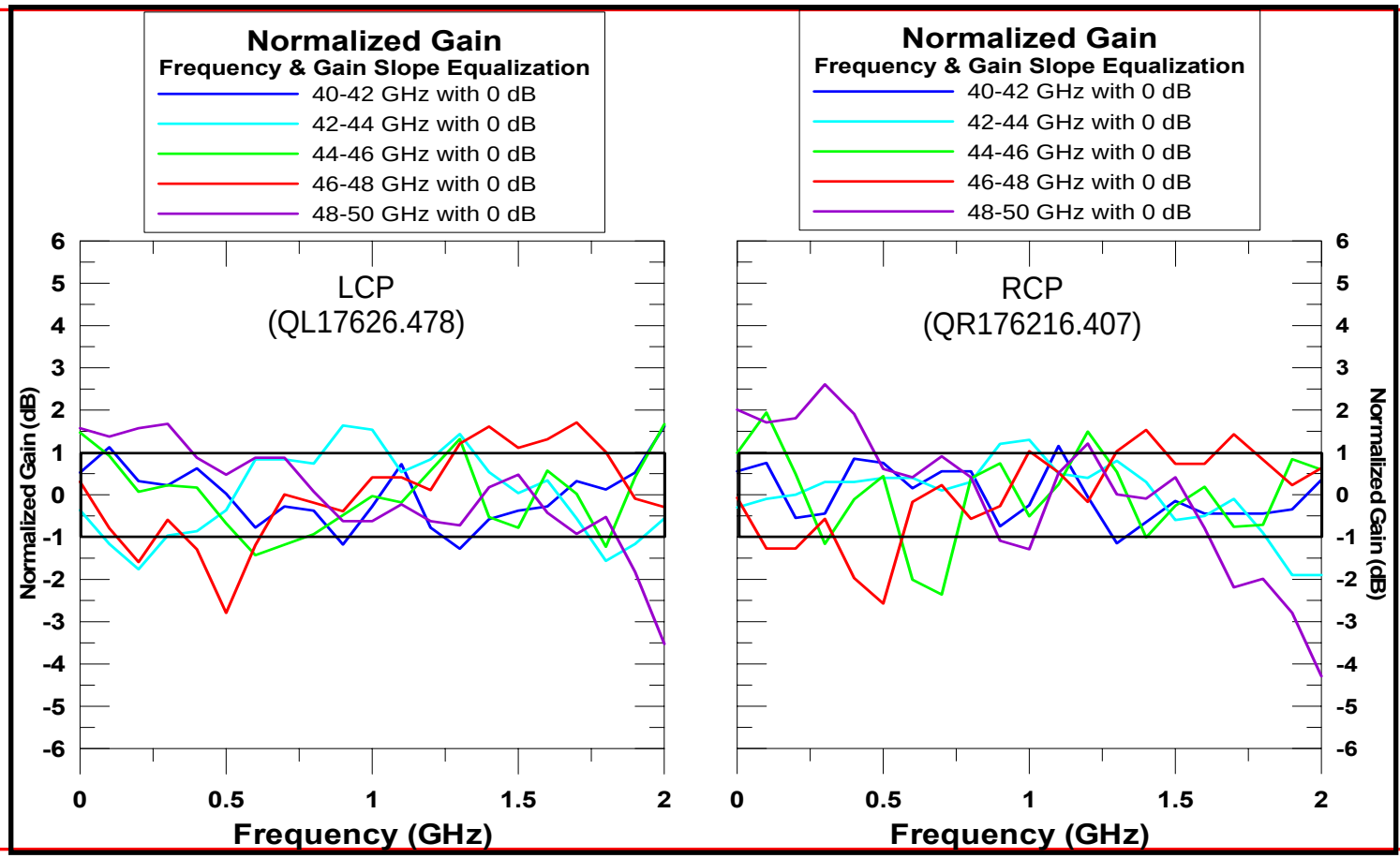


Q-Band SN 17 – 3rd EVLA Interim Rx

Gain Flatness in 2 GHz Bandwidths - No Equalization

Block Converter Mode - (LO1 = 58, LO2 = 18-8 GHz)

(23 Feb 2006)

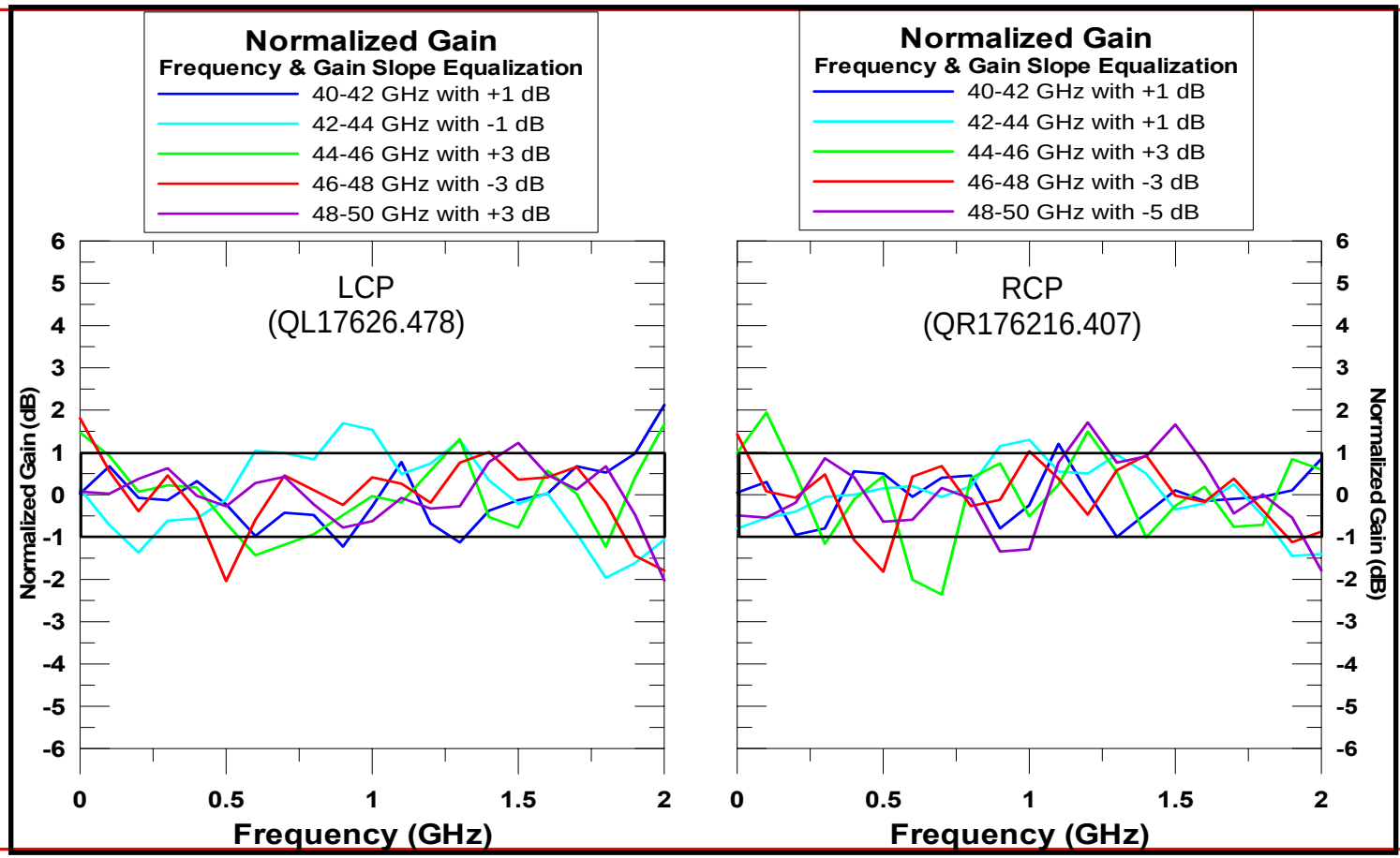


Q-Band SN 17 – 3rd EVLA Interim Rx

Gain Flatness in 2 GHz Bandwidths - Best Equalization

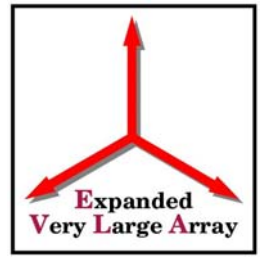
Block Converter Mode - (LO1 = 58, LO2 = 18-8 GHz)

(23 Feb 2006)

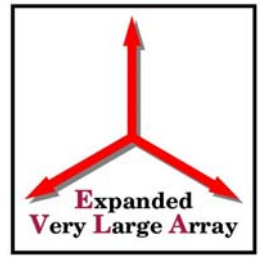


EVLA Q-Band Summary

- Incremental upgrade to an existing VLA receiver band
- EVLA design improves sensitivity and broadband performance
- New/upgraded LNA's will provide even more improvement
- M&S Budget - $109.1K already spent out of $254.7K allotment
  - **Remaining large ticket items**
    - **QPAM production**
    - **LNA's**
    - **Cables**
    - **New Card Cages**
- To keep within the EVLA Project spend profile, it was felt that the upgraded design was low risk and that we could confidently proceed with mass production
- **We hope the FE CDR Panel agrees…**



Questions ?



Backup Slides

VLA/EVLA
Q-Band (40-50 GHz)
Receiver

- VLA is currently outfitted with 30 Q-Band receiver systems:
  - **Mexico provided initial -$1M funding in the mid 1990's to build the first 10 receivers.**
  - **NRAO built the next 15 receivers from RE funding.**
  - **EVLA provided funds to build the final 5 receivers, later compensated by Mexican EVLA funding.**
- EVLA will upgrade existing VLA systems.

Limiting LO Amp

ALC Microwave ALA04-0028

• Input Frequency	16-19.5 GHz
• P_{In} (min)	-6 dBm
• P_{In} (max)	+6 dBm
• P_{Out} (min)	+21.5 dBm
• P_{Out} (max)	+22.5 dBm
• O/P Variation over I/P Drive (max)	"0.5 dB
• Power Flatness with Freq (max)	"0.5 dB
• Max Input No Damage	+20 dBm

Desirable to protect the Spacek Tripler/Mixer assemblies from being blown by excursions in LO Ref power.

Q-Band Dewar Innards