EVLA Front-End CDR

EVLA
Q-Band (40-50 GHz)
Receiver
EVLA Q-Band Receiver Overview

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   - New Upgraded EVLA Block Diagram

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6) EVLA Q-Band Interim Receivers

7) Test Results
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   - Swept LO1 vs. Block Converter Mode
EVLA Q-Band Receiver
Existing VLA Configuration

**RCP IF Out**

- 7.7-9.1 GHz
- 16-19.5 GHz

**LCP IF Out**

- 7.7-9.1 GHz

**LO Ref**

- 40-50 GHz
- 16-19.5 GHz
- 7.5-12.5 GHz

**Dewar**

- Old
- Integrated
- New
- Remove

**Pol**

- 40-50 GHz

**LCP**

- 16-19.5 GHz

**Dewar**

- Integrated
- New
- Remove

**RCP**

- 40-50 GHz

**LCP**

- 16-19.5 GHz

**Pol**

- 40-50 GHz

---

**Integrated**

**Remove**

**Old**

**New**
**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

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<th>Component</th>
<th>Old</th>
<th>New</th>
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<td>Dewar</td>
<td>Dorado 4IWC45-1</td>
<td>NRAO CDL</td>
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<tr>
<td>Pol</td>
<td>Atlantic Microwave AMC 1233 Septum Polarizer &amp; Cal Coupler</td>
<td>Post-Amp Module Caltech 3XM45-8.4-0.1L/R RF=40-50 GHz</td>
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<td>Post-Amp Module Caltech 3XM45-8.4-0.1L/R RF=40-50 GHz</td>
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<td>Magic-T MDL 22TH128</td>
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<td>DC-Block</td>
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### Notes:
- The new configuration includes upgrades to the LO Ref, RCP IF Out, and LCP IF Out sections.
- The new configuration also involves changes to the Tripler/Mixer Assembly and the DC-Block components.
- The variable attenuator and Magic-T MDL are new additions.
- The limiting LO amplifier and PA8207-2F are used to limit the input signal to 18 dBm.

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R. Hayward
EVLA Front-End CDR – EVLA Q-Band Receiver
24 April 2006
Q-Band Block Conversion

Frequency Diagram

- Translation of 40-50 GHz down to 8-18 GHz
- LO Ref 19.333 GHz × 3 = 58 GHz
  - Closest L301 Lock Point is actually 19.238 GHz
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.
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<th>P (1dB)</th>
<th>P (1%)</th>
<th>Temp</th>
<th>NF/C</th>
<th>Loss/Gain</th>
<th>Loss/Gain</th>
<th>Delta T</th>
<th>Trx</th>
<th>BW</th>
<th>Pnoise</th>
<th>Pnoise</th>
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## Estimated EVLA Q-Band TRx, Output Power & Headroom

*With RF Post-Amps*

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For Tsky of 26.0 and as high as 68K
**EVLA Q-Band**

*Simulated Impact of new RF Post-Amps on Receiver Performance*

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**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

Bottom Block

Top Block

39-51 GHz Filter

MMIC Amplifier

Amp Bias Card

R. Hayward

EVLA Front-End CDR – EVLA Q-Band Receiver
24 April 2006
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)

Q-Band 40LN2 powered Amplifier Module:
Compression Performance (3 dBm 1 dB compression point)
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

**Graph:**
- **X-axis:** Frequency (GHz)
- **Y-axis:** Gain (dB) and Return Loss (dB)

**Legend:**
- **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.
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

**LCP**
- Swept LO1 Mode (QL176216.345)
- BC Mode 58 GHz (QL176216.478)
- LNA Noise Temperature (QM-75)

**RCP**
- Swept LO1 Mode (QR176215.646)
- BC Mode 58 GHz (QR176216.407)
- LNA Noise Temperature (QM-76)

The graphs show the receiver temperature and gain for both LCP and RCP modes in Swept LO1 and Block Converter modes, with frequency ranges from 40 to 50 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)

Normalized Gain
Frequency & Gain Slope Equalization
40-42 GHz with 0 dB
42-44 GHz with 0 dB
44-46 GHz with 0 dB
46-48 GHz with 0 dB
48-50 GHz with 0 dB

Frequency (GHz)
Normalized Gain (dB)
LCP (QL17626.478)
RCP (QR176216.407)
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
- $P_{\text{In}}$ (min): -6 dBm
- $P_{\text{In}}$ (max): +6 dBm
- $P_{\text{Out}}$ (min): +21.5 dBm
- $P_{\text{Out}}$ (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