EVLA Front-End CDR

Laboratory
Receiver
Testing

EVLA Ka-Band Receiver Overview

1) Rx Characterization
- **SOIDA Rack**
- **EVERETT Rack**

2) PNA Measurements
- **OMT Tweaking**
- **Phase Matching**

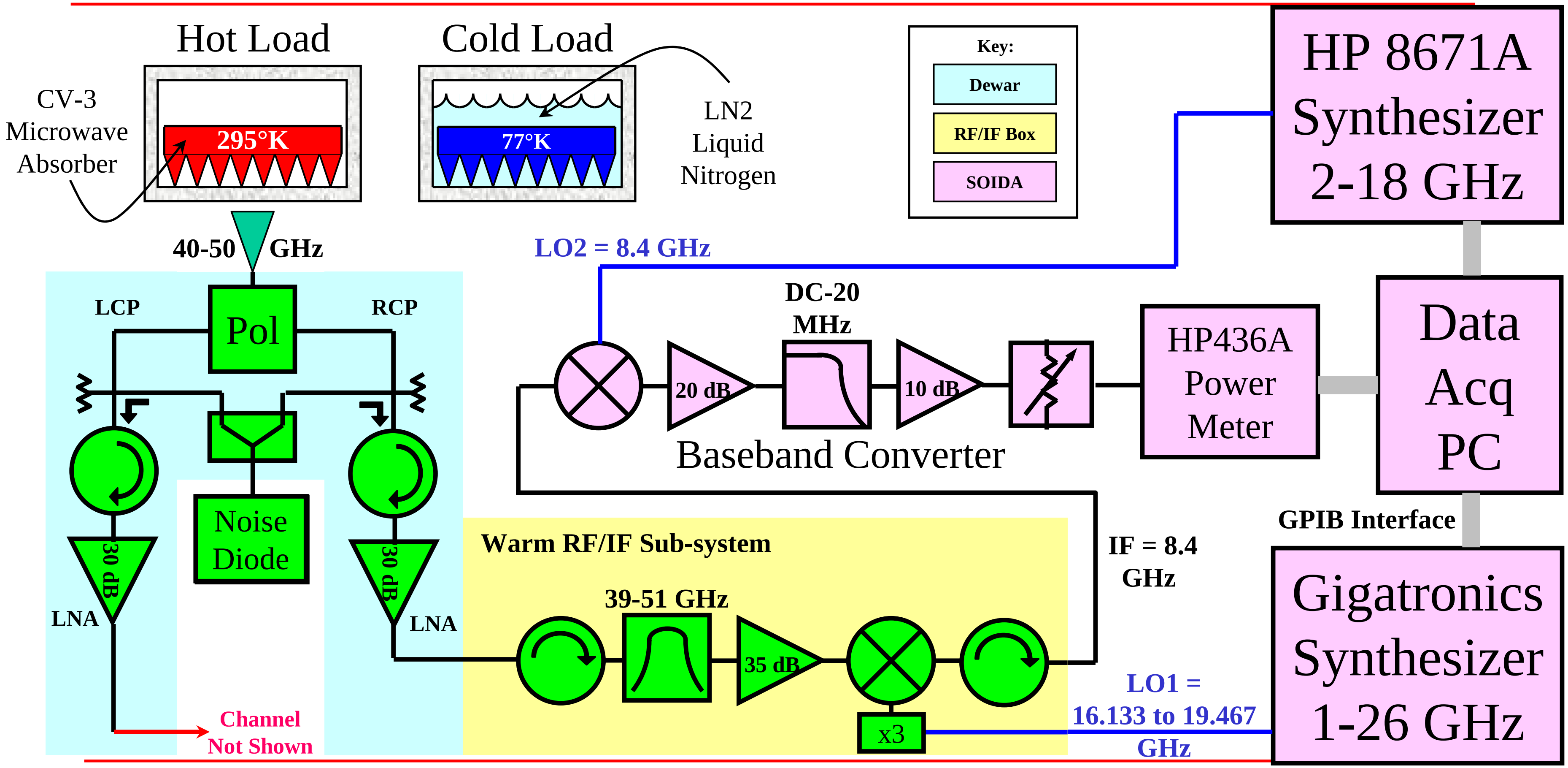
3) SNA Measurements
- **General Purpose Measurements**
- **Sensitivity (Y-Factor)**
- **Axial Ratio**
- **Total Power Stability**

The SOIDA Rack

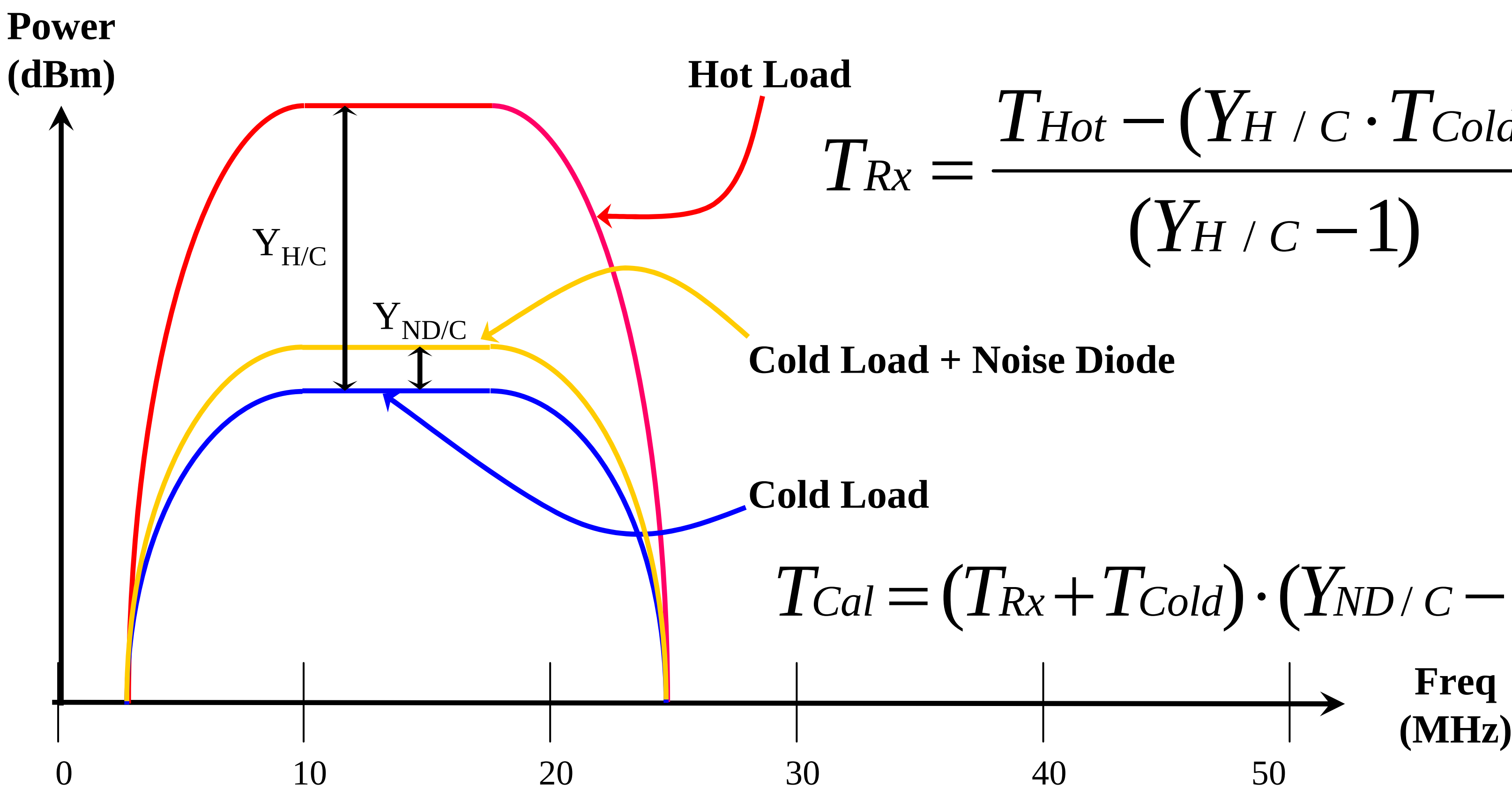
SOIDA Testing Q-Band Rx

- The SOIDA Rack consists of a data acquisition PC, two commercial frequency synthesizers, a power meter plus a custom designed Baseband Converter (BBC) unit.
- The system is designed to:
  - **Measure the receiver sensitivity (i.e., T_{Rx}) vs. frequency**
  - **Measure the noise diode calibration (i.e., T_{Cal}) vs. frequency**
- We also have a 2nd test rack which is affectionately known as the SOS Rack, for "Son of SOIDA"

"SOIDA" Hot/Cold Load EVLA Q-Band - Swept LO1 Characterization



What SOIDA Sees



$$T_{Rx} = \frac{T_{Hot} - (Y_{H/C} \cdot T_{Cold})}{(Y_{H/C} - 1)}$$

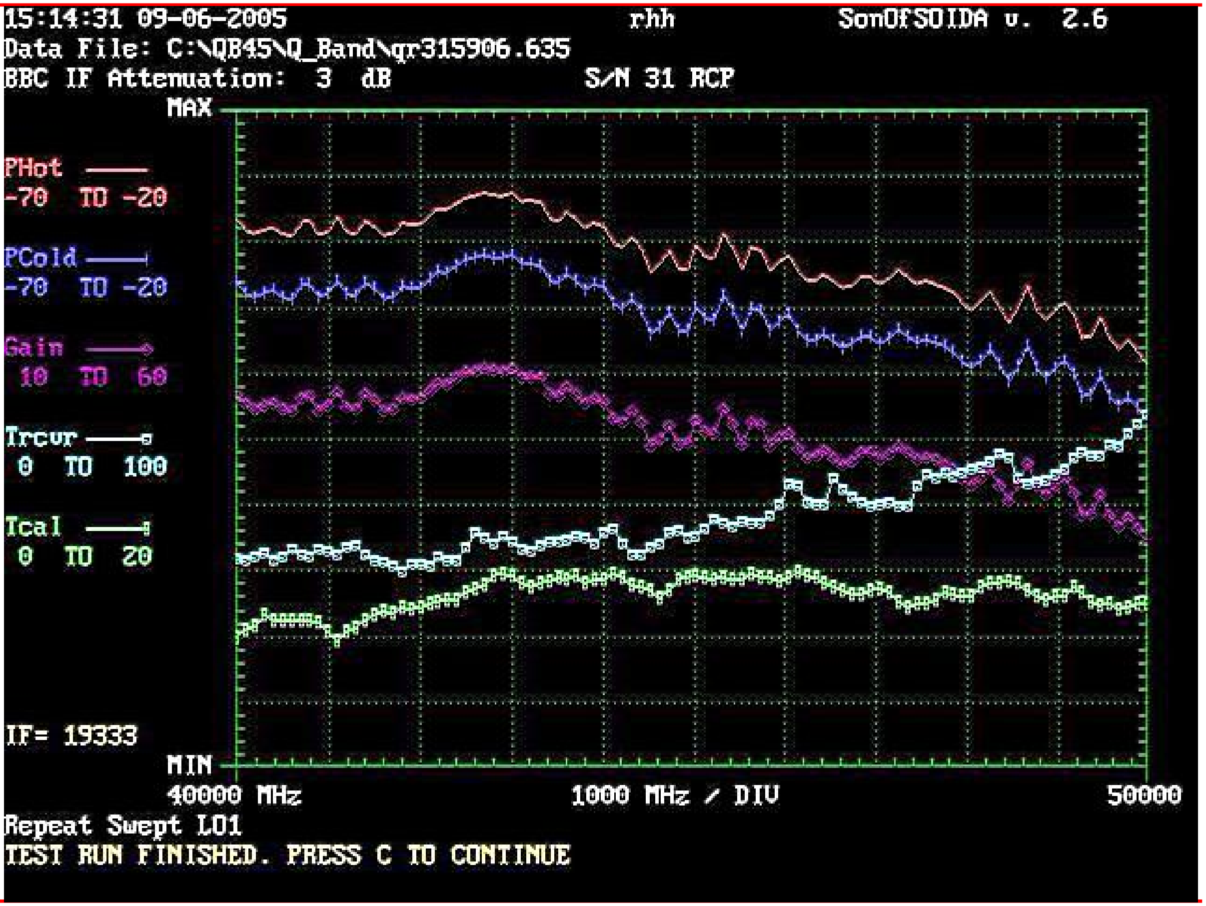
$$T_{Cal} = (T_{Rx} + T_{Cold}) \cdot (Y_{ND/C} - 1)$$

A Typical SOIDA Plot

EVLA Q-Band Receiver

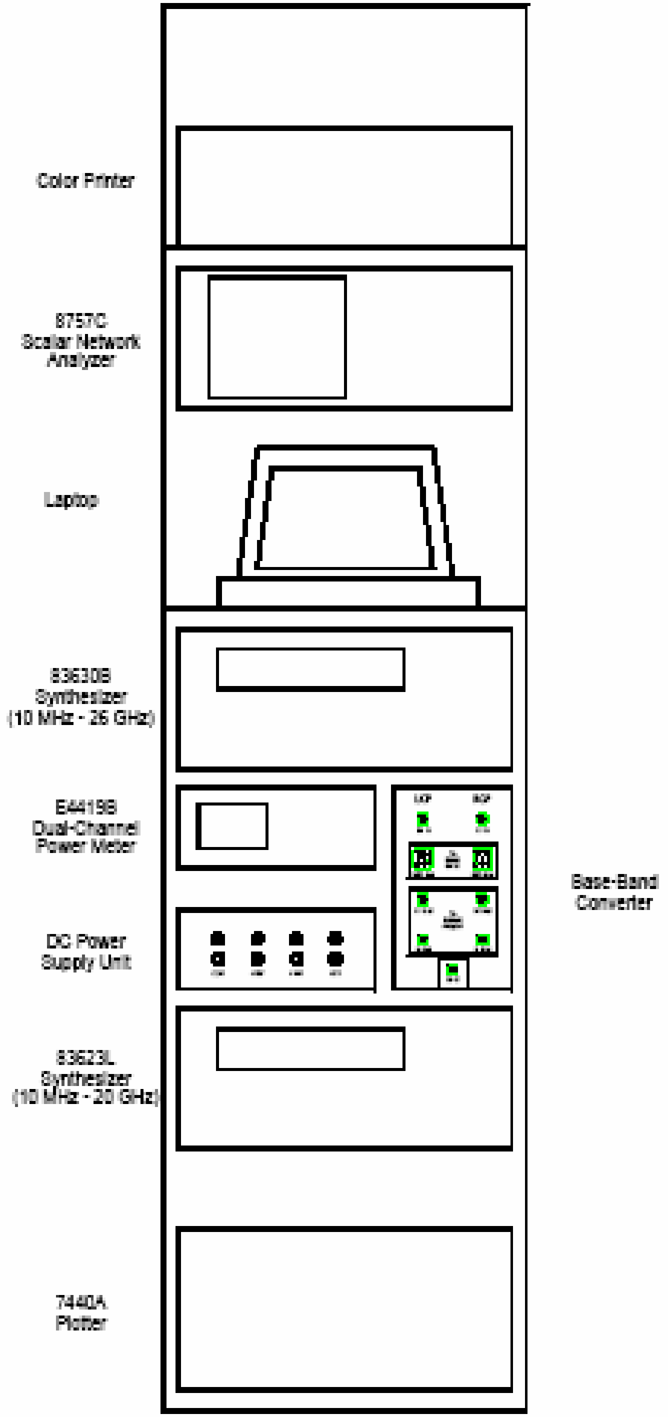
The SOIDA plot is designed to display the following information:

P_{Hot}
P_{Cold}
Gain
T_{Rx}
T_{Cal}
(S_{Cal})



The Next Generation Test Rack

- EVLA requires 240 upgraded or new receivers.
- Both SOIDA & SOS use obsolete test equipment - synthesizers & power meters.
- The PC's are ancient 33 MHz machines.
- Only able to do one channel at a time.
- Takes ~1½ hour to do a single W-Band channel.
- Developing a new dual-channel replacement rack which uses a modern laptop, E4119B power meter, 83630B/24L synthesizers and a new broadband dual-channel BBC.
  - Cost $90K each
- EVERETT++ = "**Expanded Vla Enhanced Receiver Evaluation & Test Terminal**".
- Plan on 2 EVERETT Racks as well as 1 (or 2) SOIDA Racks (depending on longevity).



E8364B Precision Network Analyzer (PNA)

- Agilent's newest generation of Vector Network Analyzer
  - **DC – 50 GHz**
- Electronic Calibration Unit (to 50 GHz)
- Mechanical Cal kits
  - **Coaxial - 3.5 mm**
  - **Waveguide - WR-42, WR-28 & WR-22**
- Frequency Translation Option
- Higher Dynamic Range and faster than the 8510 VNA
- Windows Platform
- Bought to facilitate Ka & Q-Band MMIC-based modules
- Cost - $150K

Precision Network Analyzer
EVLA Related Measurements

PNA measuring Return Loss on 2nd L-Band OMT

- Return Loss measurements of OMT during tweaking
- Phase Balancing of Cables between OMT & Hybrid
- Measurement of MMIC device and multi-function module S-Parameters using Wafer Probe Station
- Numerous General Purpose Measurements of RF & microwave components and sub-systems

Scalar Network Analyzer

- Coaxial SNA = 8757C + 83630B Synthesizer

  10 MHz to 26.5 GHz

- W/G SNA = 8757E + 83623A Synthesizer

  2 to 20 GHz

  Plus Source Modules at

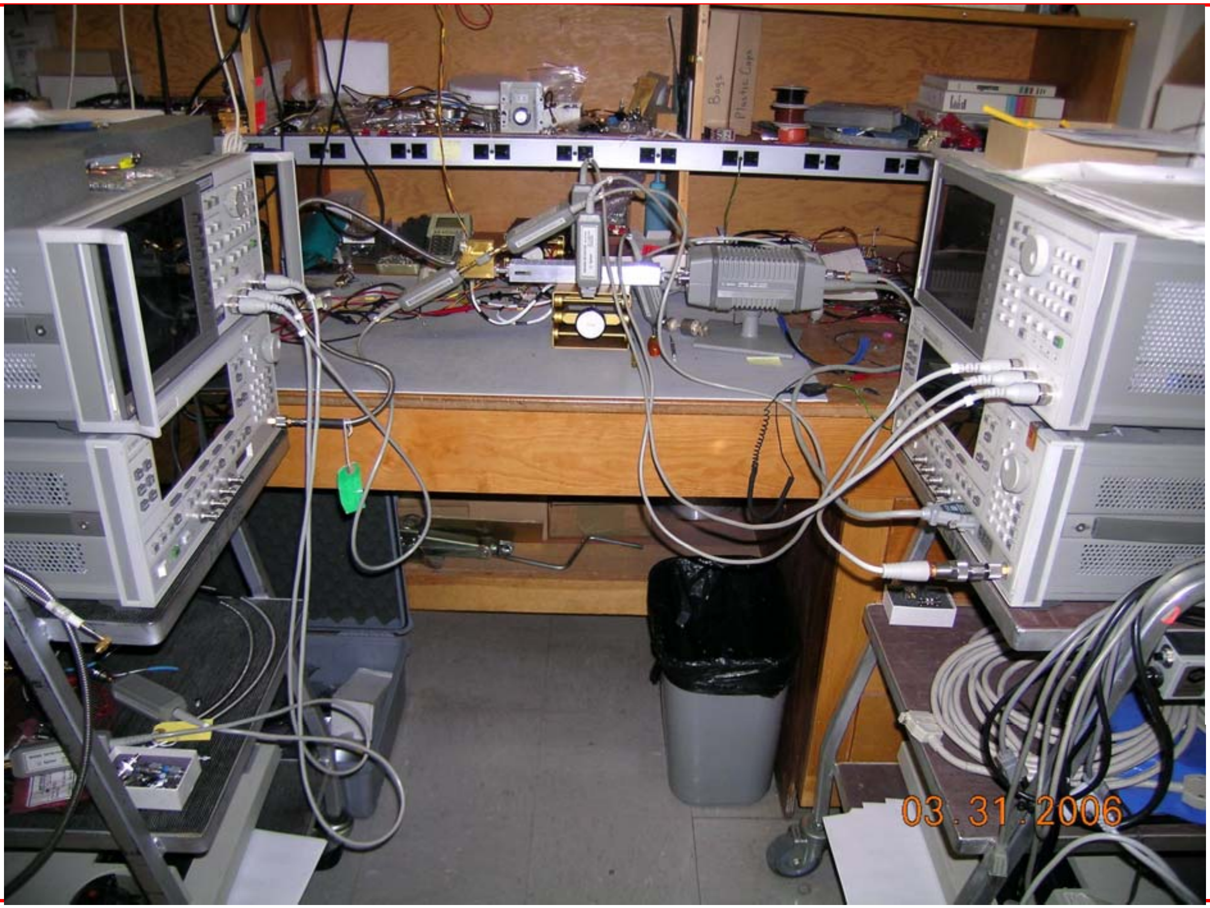
  Ka, Q & W-Band

Acquired enough surplus 8757C's to build one into the new EVERETT Racks as well.

SNA GP Measurements

Frequency Response
Ka-Band Down-converter

Coaxial SNA



Waveguide SNA

SNA GP Measurements

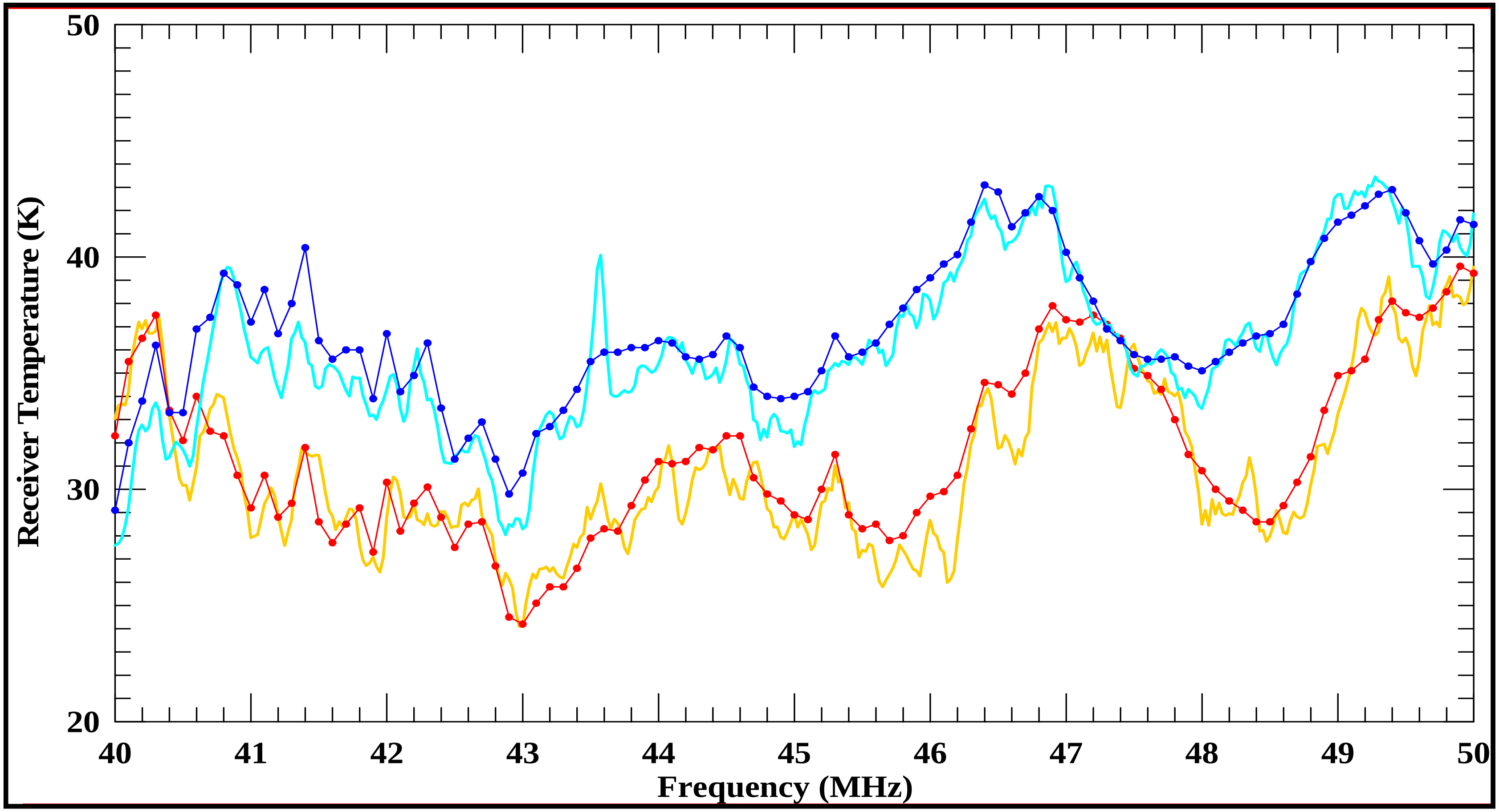
KaDCM Frequency Response
Close up

Y-Factor Measurement with SNA

- SNA's can be configured to measurement Y-Factor sensitivity essentially in real-time
  - **1 minute vs. 15 to 90 minutes on SOIDA**
  - **Dual channels simultaneously**
- For Lower Frequency Rx's with no internal frequency conversion or for the EVLA Block Converter Mode receivers, use with the BBC on the SOIDA Rack.
- For Higher Frequency Rx's with internal mixers, use a narrow filter and post-amp n the IF output.
  - **8400, 11000, 14200 MHz filters with 100 MHz bandwidth**
- Not always as accurate as SOIDA but allows quick comparison measurements (T_{Rx} vs. LO Power, bias settings, cpt changes, etc.)

SOIDA & SNA Measurement Comparison of Receiver Temperature
Block Converter Mode on Receiver Q#17

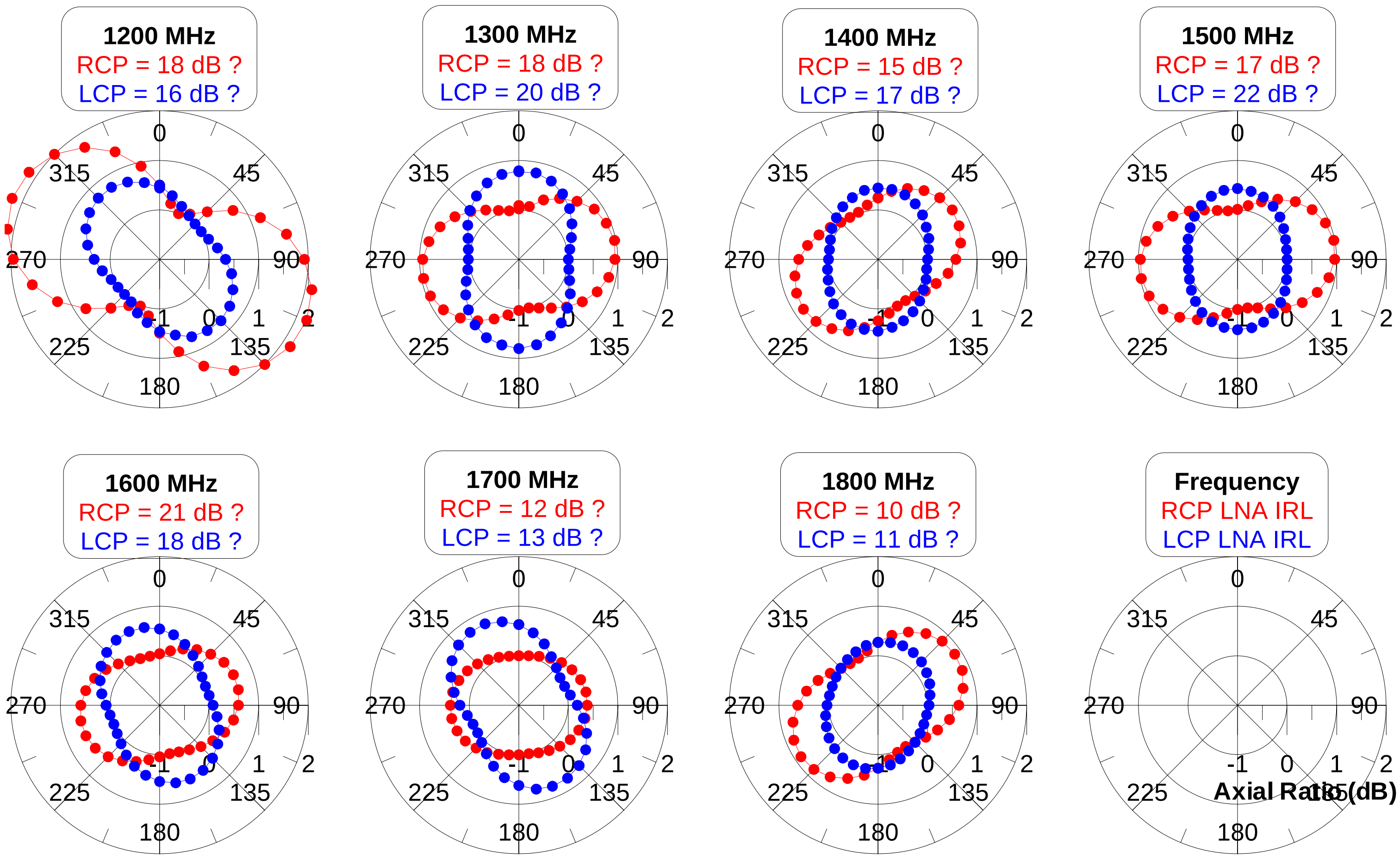
LCP - SOIDA 100 MHz Step Size, 40 MHz Filter Bandwidth & 32 Sample Average
LCP - SNA 25 MHz Step Size. 40 MHz Filter Bandwidth & 8 Sweep Average
RCP - SOIDA 100 MHz Step Size, 40 MHz Filter Bandwidth & 32 Sample Average
LCP - SNA 25 MHz Step Size, 40 MHz Filter Bandwidth & 8 Sweep Average



Lab Measurements of Circular Polarization

- Attempt to measure the response of the receiver to a linearly polarized signal rotated through 360E by injecting it into the receiver and detecting the LCP & RCP output power.
  - **If the polarizer is perfect, we should see no variation.**
  - **If the polarizer has a 1 dB axial ratio, we should see the output power change by 1 dB.**
- Best done on an antenna test range
  - **Would be a pain at L-Band with its 16 ft feed**
- So lab measurements done using a circular waveguide test fixture that gives us both a linear polarized signal and a rotary joint.
- Initially measurements were taken with a power meter at each Position Angle (typically every 10 to 20E) for a fixed frequency.
- Polarization plotted up in Polar Plots (i.e., "Peanuts")

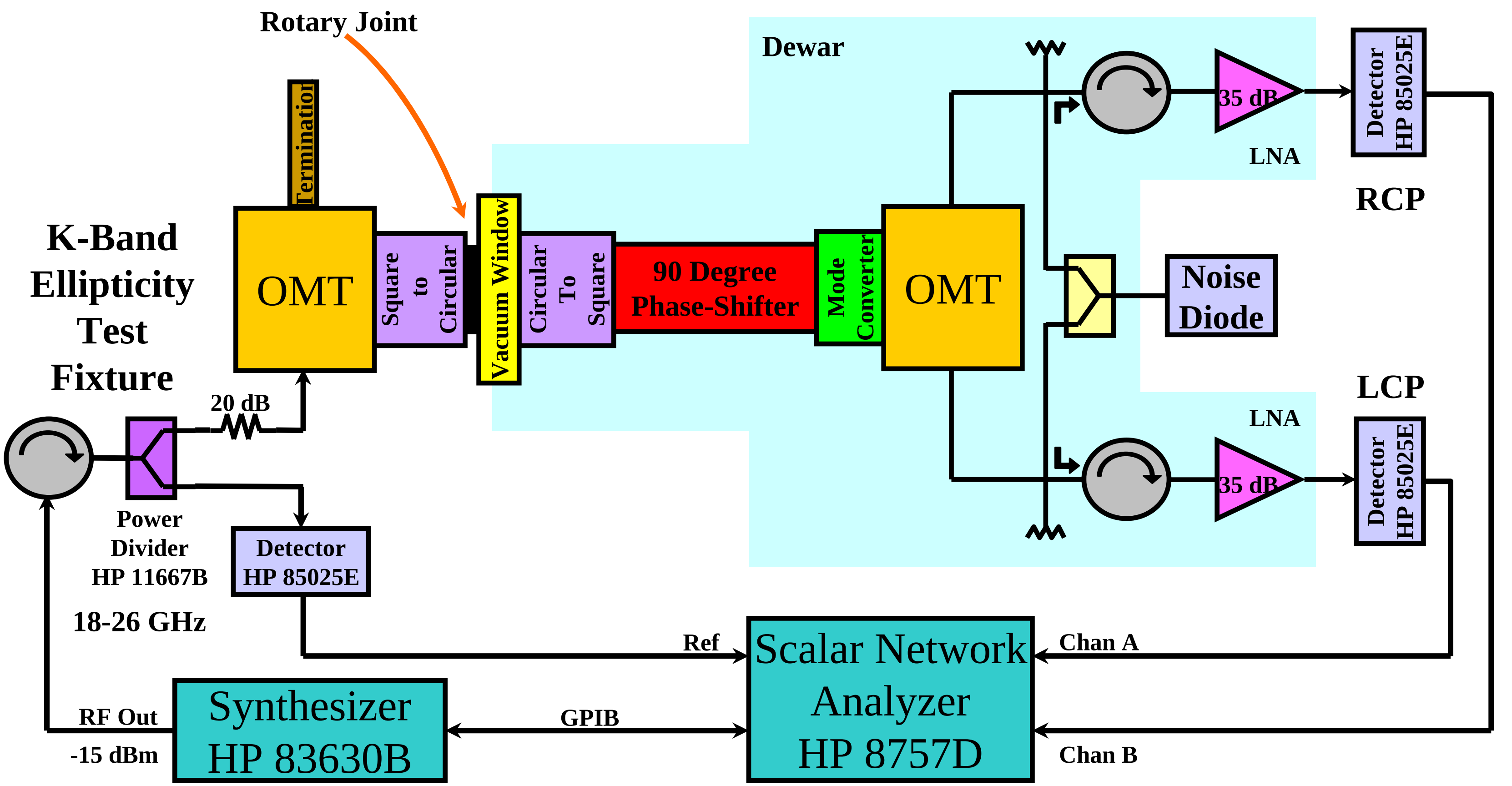
L-Band S/N 02
Axial Ratio (dB) and Position Angle of Major Axis versus Frequency
Cold Receiver with Bradley Prototype Balanced Amplifiers
Drain Voltages & Currents Tweaked to Eliminate LNA Oscillations
(28 Jan 2004)



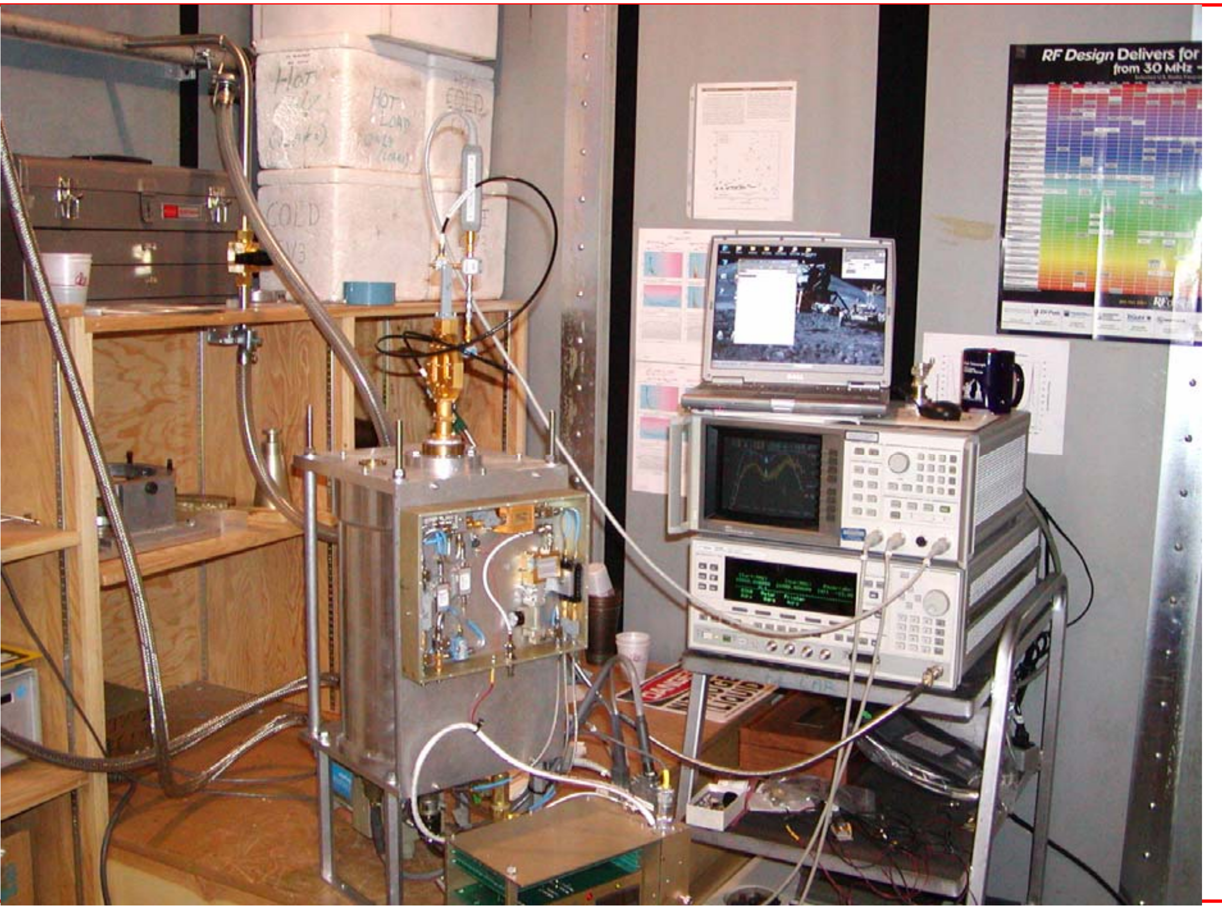
SNA Ellipticity Measurements

- Power Meter measurements truly painful and we were under sampling the frequency response
- Developed new test procedure using the SNA
  - Full frequency sweep taken at each Position Angle
  - SNA Reference channel eliminates power variations from RF cable being twisted.
  - SNA data “grabbed” by laptop & written to Excel file
  - Super spreadsheet imports the -100,000 data points and then calculates the axial ratio for each frequency point
    - 2.5 MHz @ L-Band or 20 MHz at K-Band
  - Scheme also allows smoothing of data before AR calculated so effect of freq ripple in the test setup can be reduced.

Scalar Network Analyzer
Axial Ratio vs. Freq Measurements
K-Band Ellipticity Test Setup

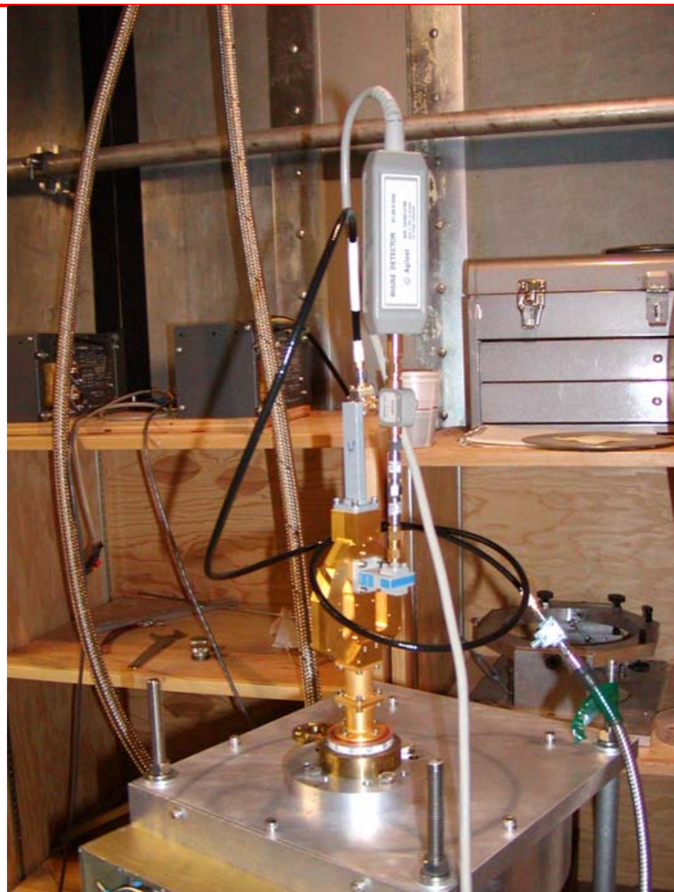


K-Band S/N 28
Under Test



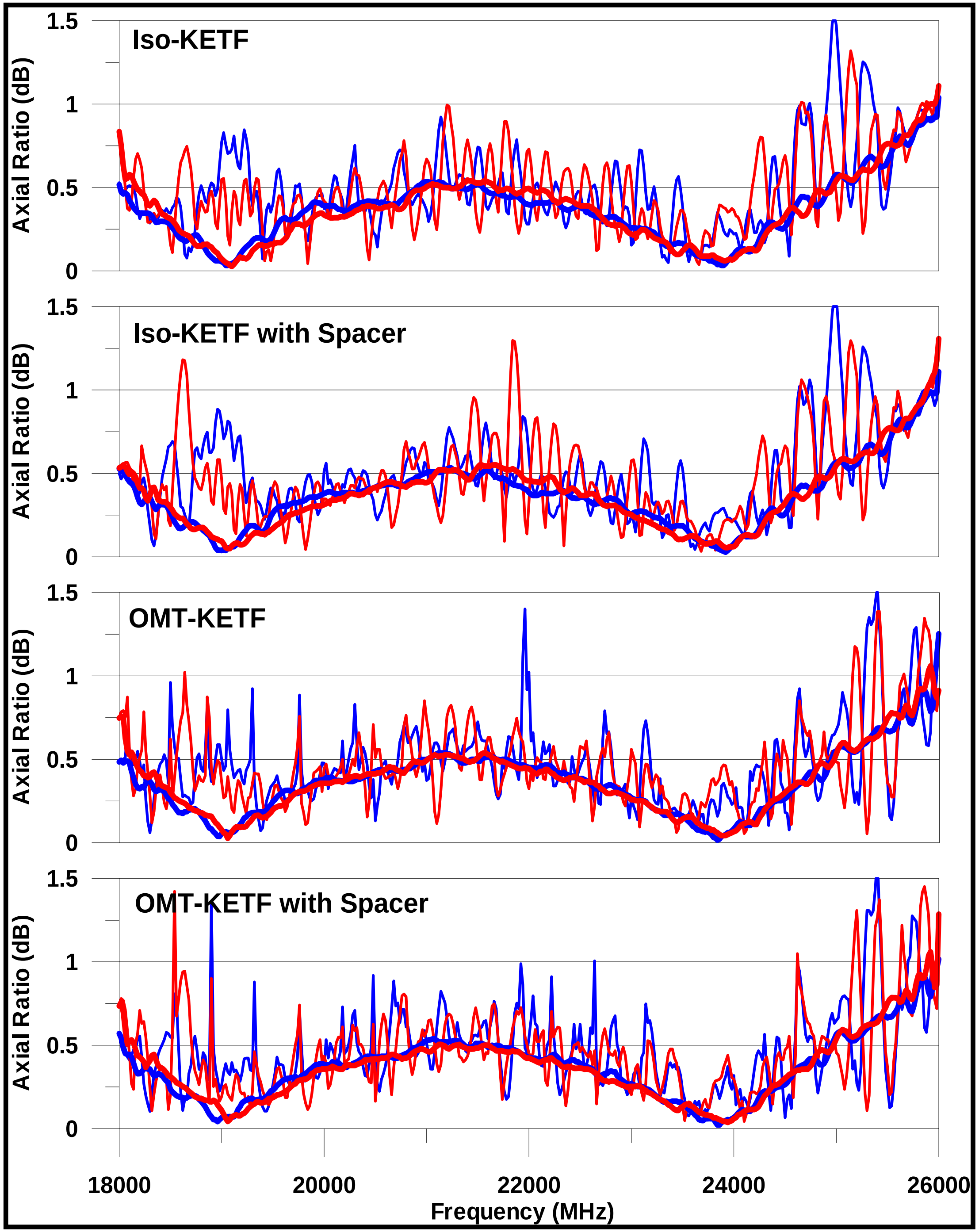
K-Band Ellipticity Test Fixtures (KETF's)

OMT KETF uses spare Wollack OMT



Isolator KETF uses Faraday Isolator

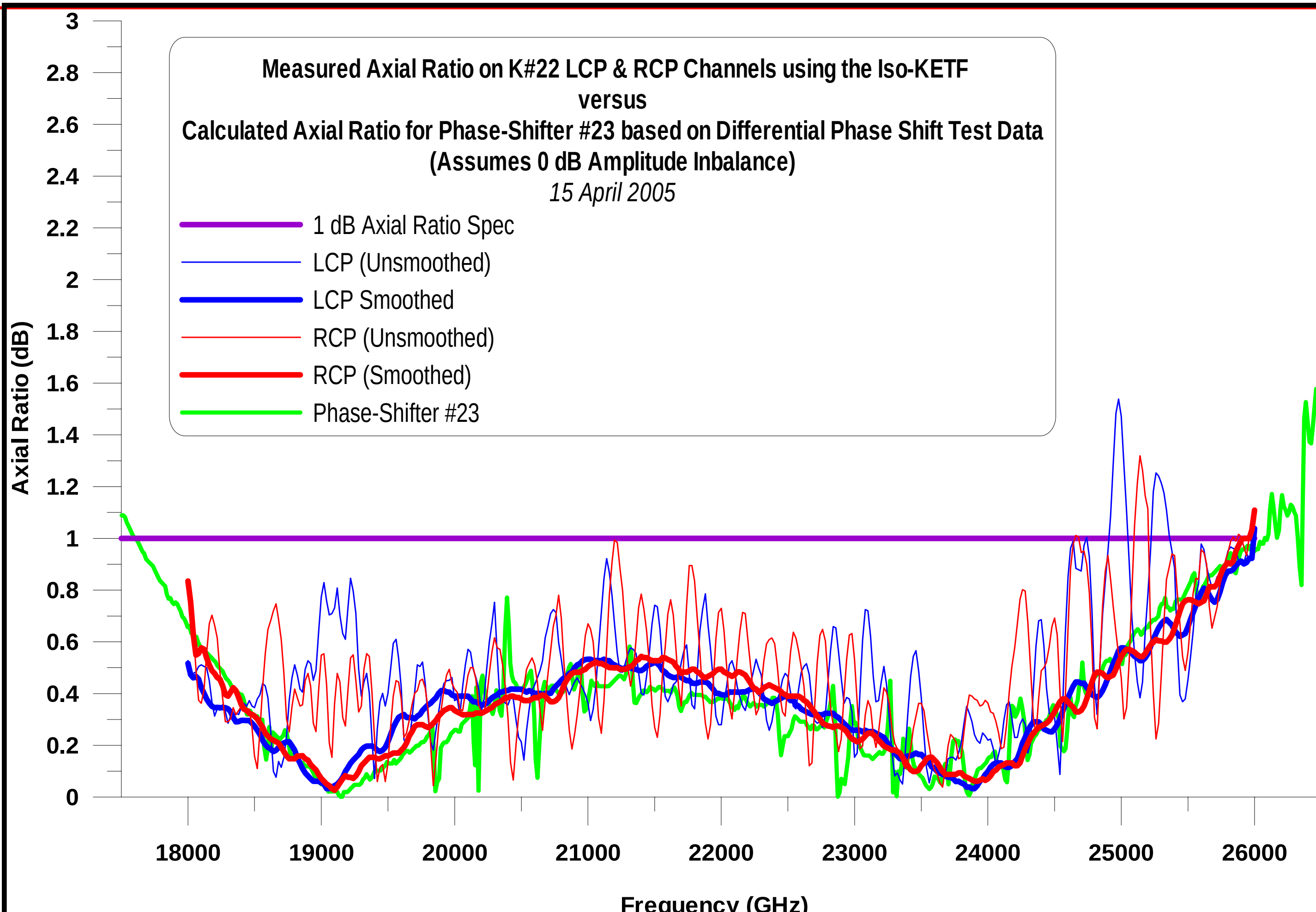
High Resolution SNA Axial Ratio Scan



K#22 Axial Ratio for Various K-Band Ellipticity Test Fixtures
LCP & RCP
(15 April 2005)

LCP
RCP

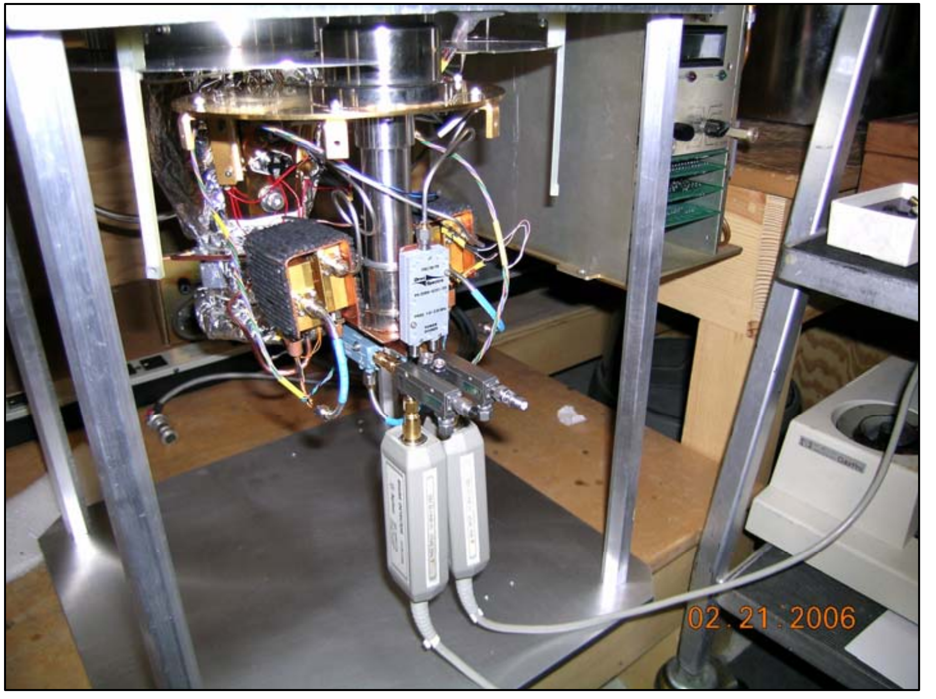
Typical K-Band Axial Ratio Measurement



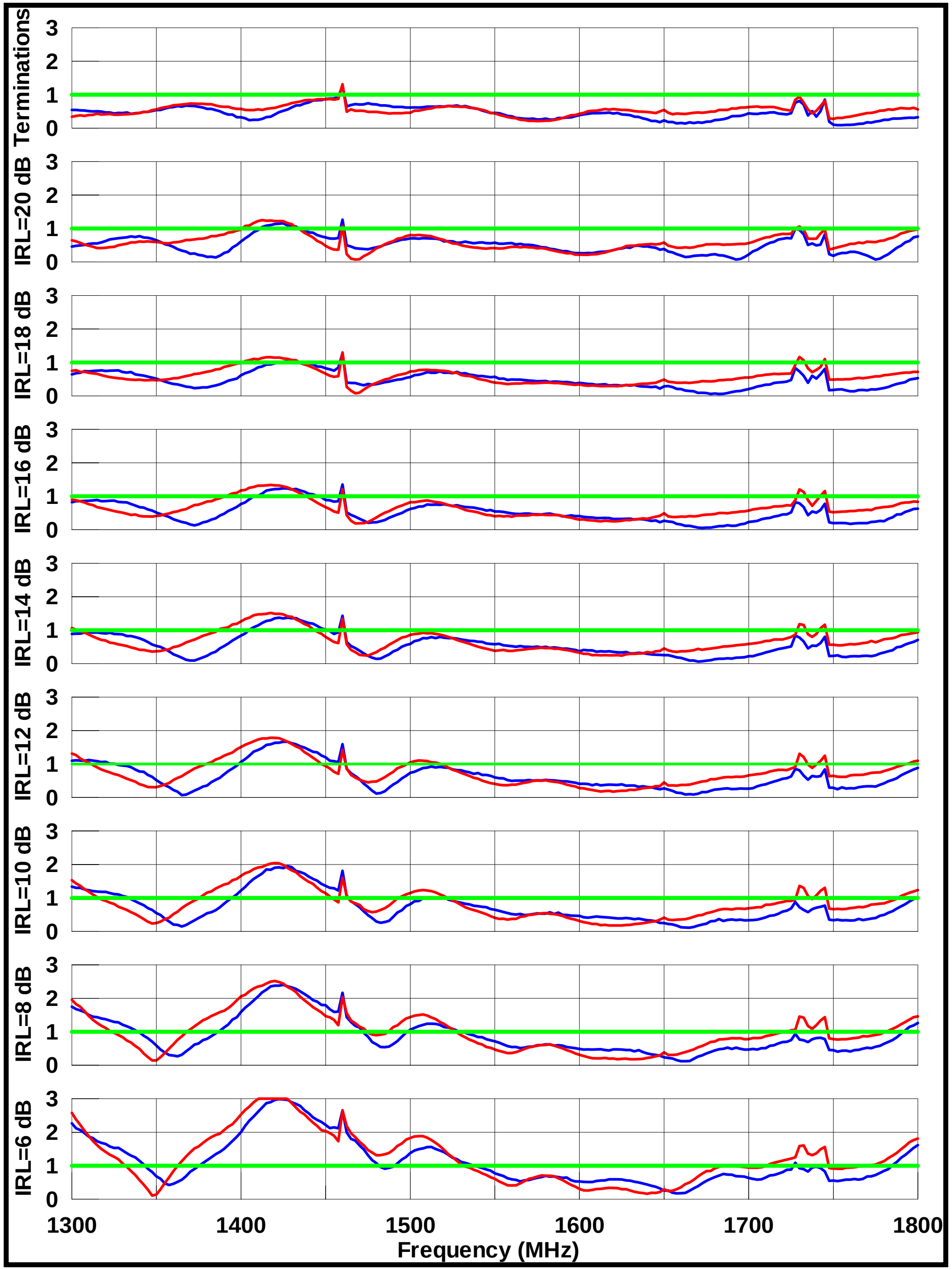
AR Test on L#21 using VLA-Style OMT

Simulated LNA Return Loss Measurements

Hybrid Coupler Polarizer in an EVLA Interim L-Band Rx (L#32)



Simulated LNA's using Terminations and/or Unterminated Pads (L#21)

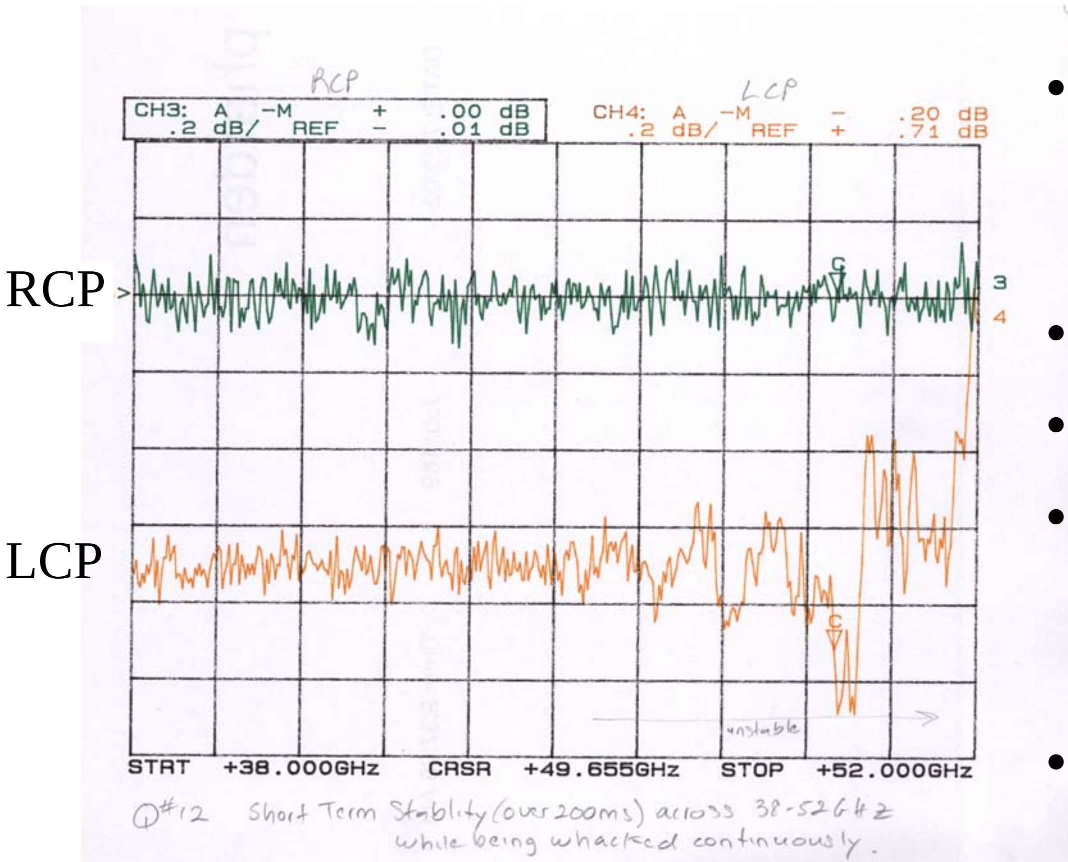


Simulated LNA Return Loss Measurements

L#21 Circular Polarizer - Quadridge OMT & Hybrid Coupler
Axial Ratio vs. Simulated LNA Input Return Loss
Axial Ratio Key = LCP , RCP & 1 dB Spec
(17 Feb 2006)

SNA Measurement of Total Power Stability

Q-Band S/N 12



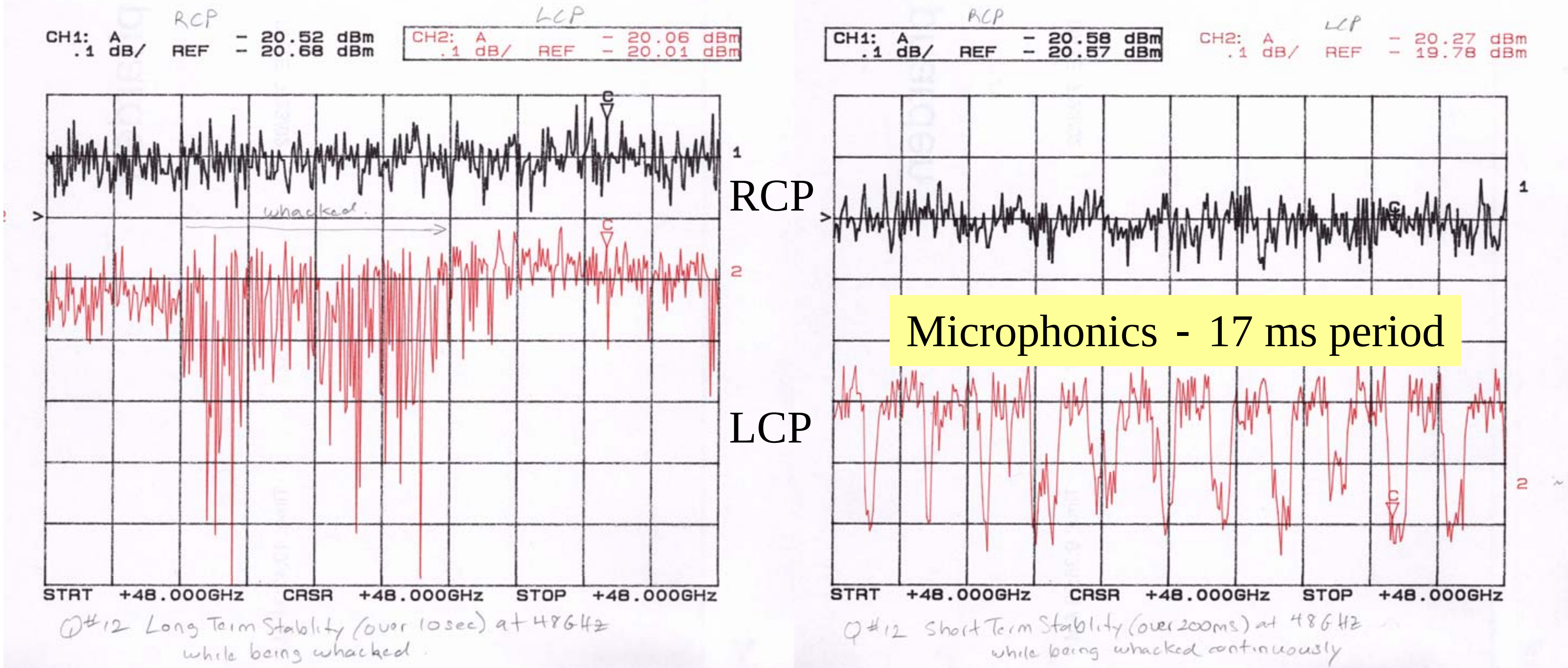
- Measure noise power (in 100 MHz BW) across Rx frequency response
- Save in Memory
- Look at “Meas-Mem”
- Microphonics will appear as deviations from a flat line
- Whack on dewar

Total Power Stability

Long & Short Term at 48 GHz

Q-Band S/N 12

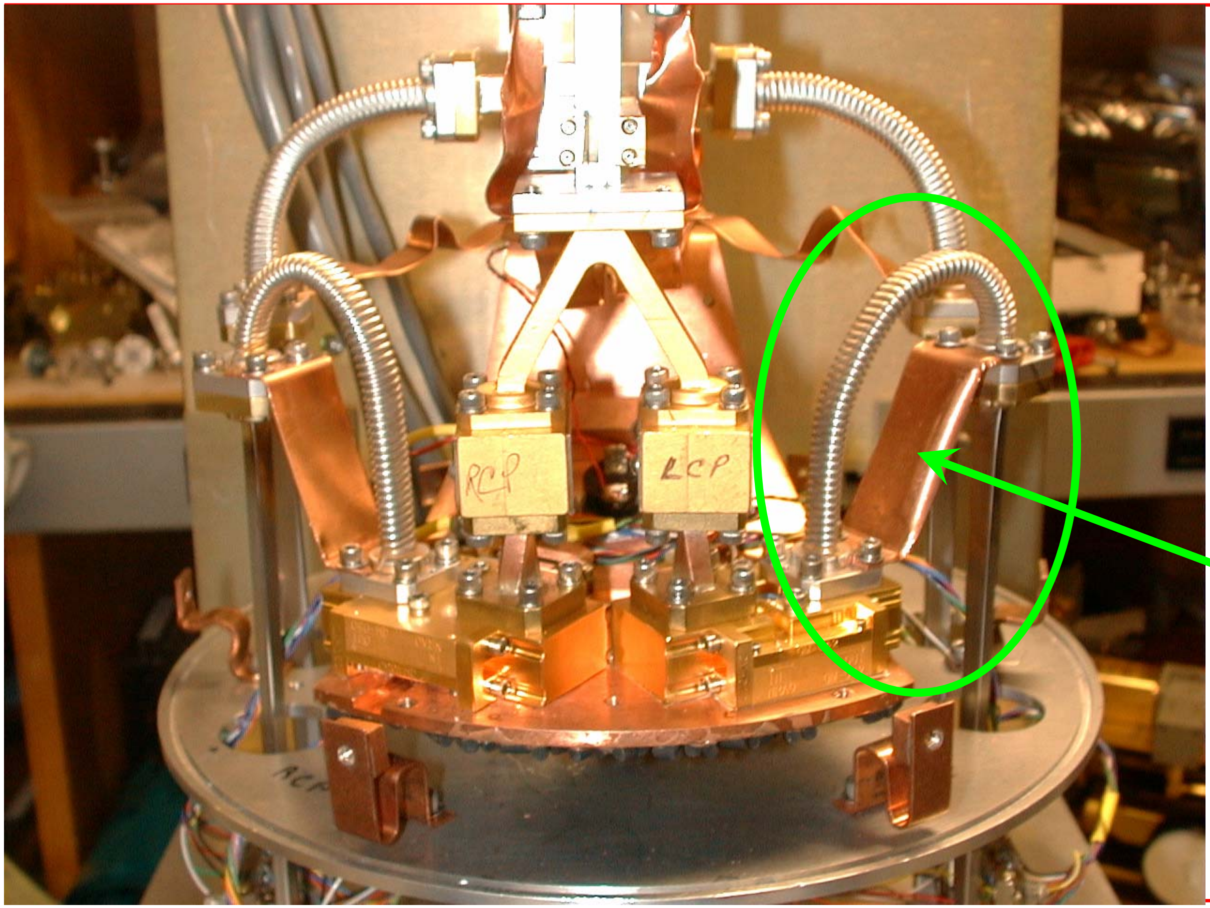
10 sec sweep | 200 ms sweep



Total Power Stability

Add Restraining Brackets across Output WR-22 Flexguide

Q-Band S/N 12

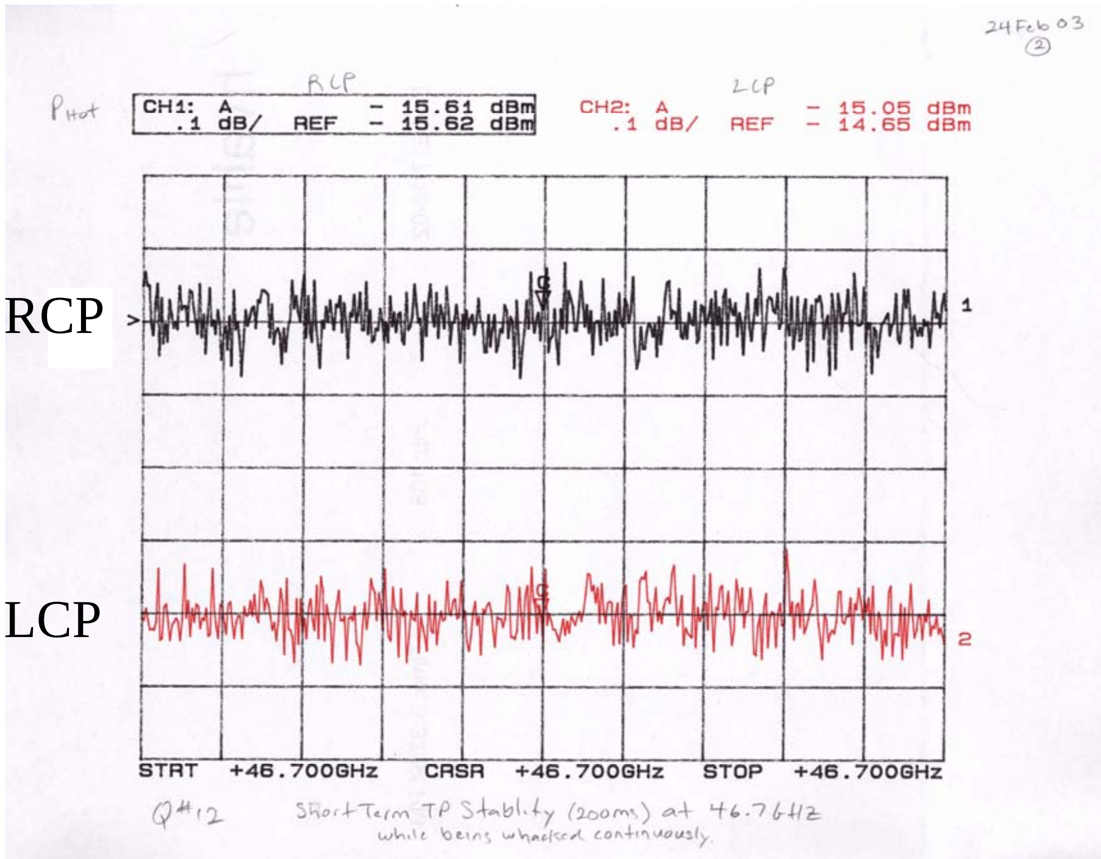


Restraining Bracket

Total Power Stability

Short Term after Fix

Q-Band S/N 12



Summary

- We believe we have the appropriate test equipment and have developed the requisite test techniques to characterize all of the EVLA receivers that will be built over the next 6 years.

Questions ?

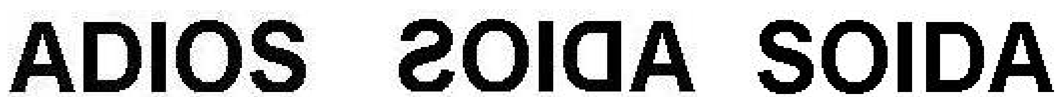
Backup Slides

Laboratory Receiver Characterization

- The first automated amplifier & receiver test measurement system built at the NRAO was designed by Sandy Weinreb at CDL in the late 70's & early '80's.
- This system used the foremost microcomputer of the day - the Apple II.
- The software for the system was written in BASIC by Sandy's son, Glenn.
- They gave it the name **ADIOS**, which stands for "Analog Digital Input Output System".

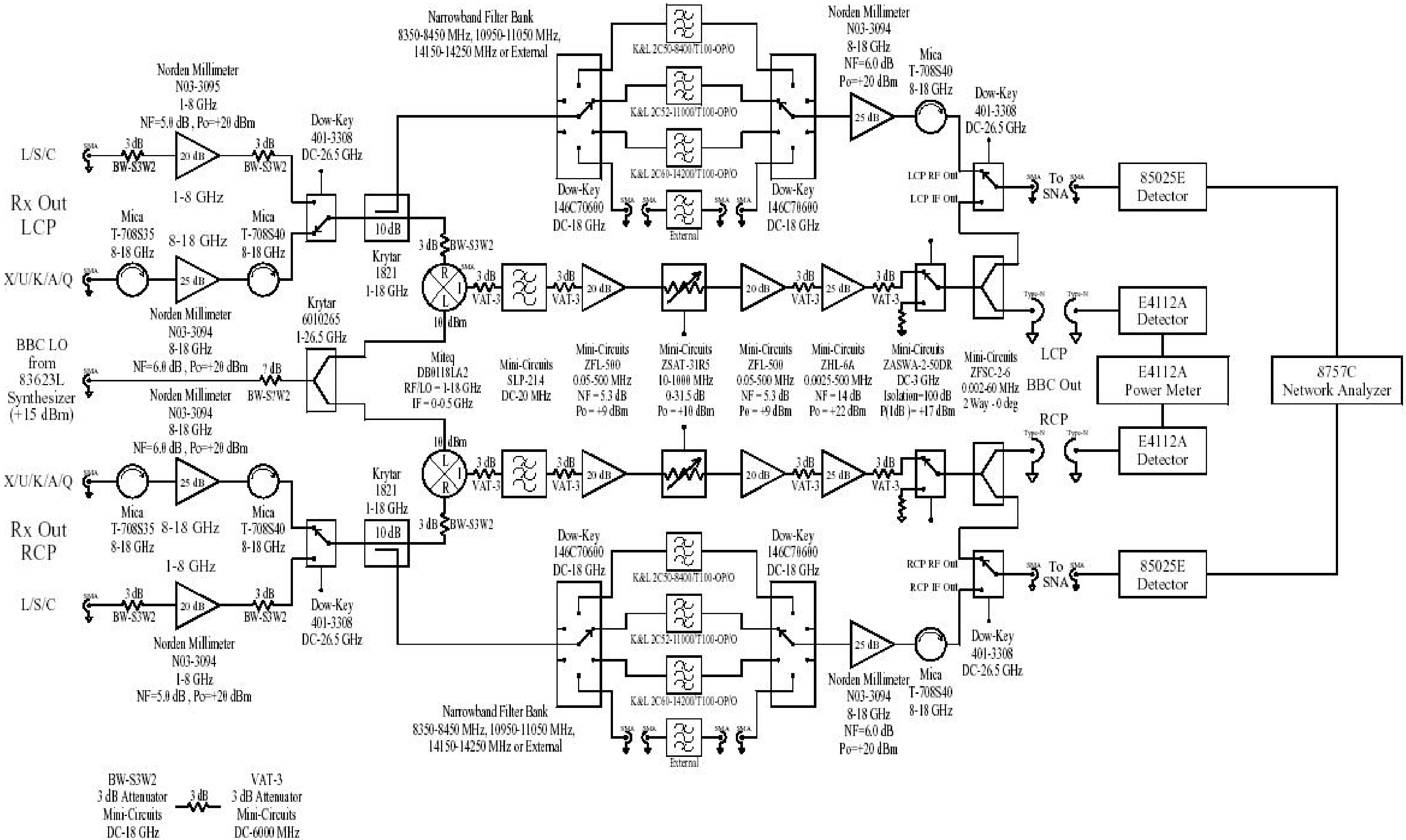
ADIOS, Amigos

- In the 1990’s, as the AOC took on an increasing role in VLA/VLBA receiver development & maintenance, Paul Lilie (former Head of the FE Group) designed a new PC-based test system.
- Ever one for a pun, he endowed it with a name that gave tribute to the original ADIOS system…



- The word SOIDA has become ubiquitous.
  - Adjective : “Did you do a SOIDA test on the receiver?”
  - Noun : “I did a SOIDA on it yesterday?”
  - Verb : “When will you SOIDA this receiver?”
  - Adverb : “I was SOIDA testing the receiver when it died?”

EVERETT++ Rack Baseband Converter



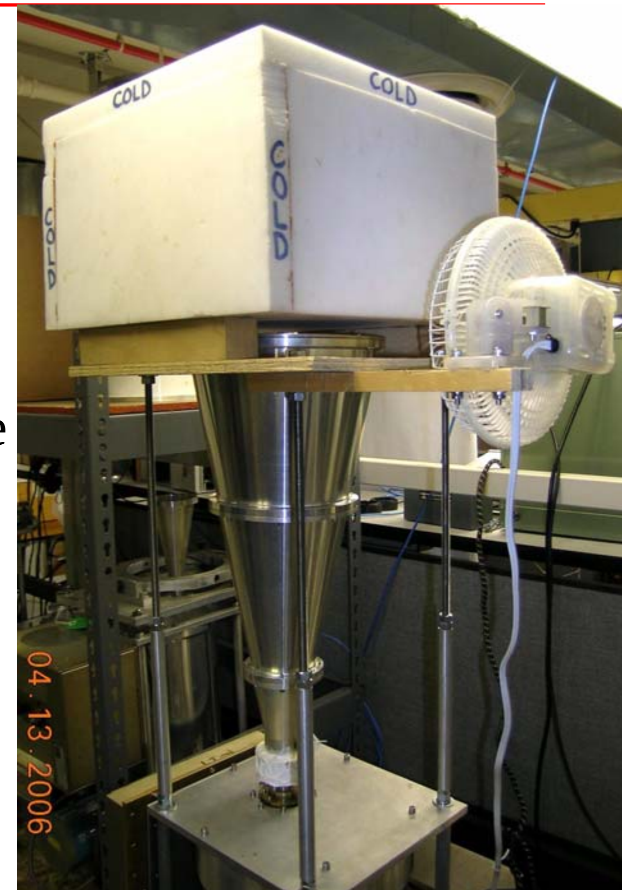
EVERETT++ = Expanded Vla Enhanced Receiver Evaluation and Test Terminal

R. Hayward
17 Dec 2003

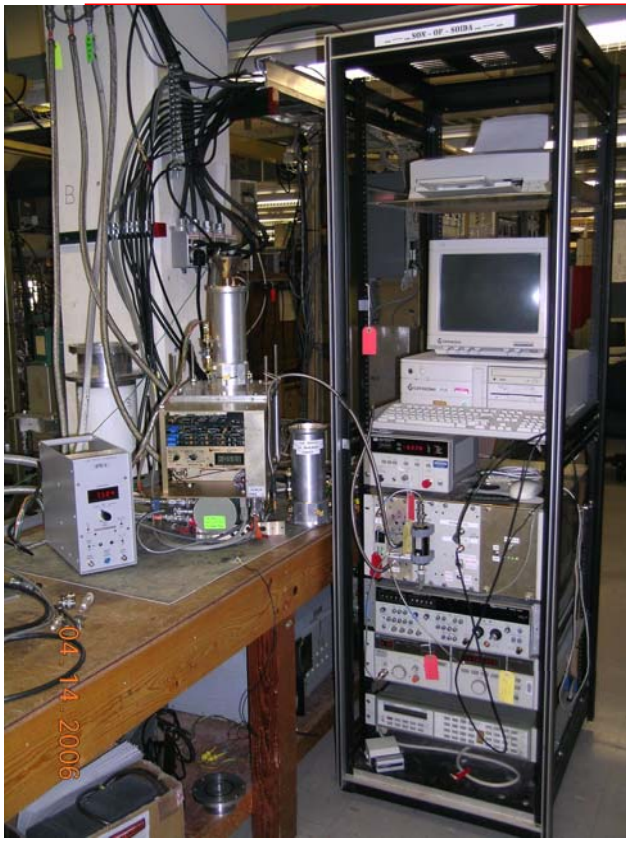
Hot/Cold Loads
High Frequency Rx's
Ku, K, Ka & Q-Band

K-Band Cold Load

- Feeds are considered to be part of the receiver.
- Hot/Cold Loads use CV-3 Absorber.
- Boxes made from Styrofoam or Zotefoam.
- K-Band has a metal plate to make Cold Load look "colder" (reduce leakage from 300K ambient).
- K-Band Cold Load elevated with fan to eliminate moisture build up on bottom surface.



Hot/Cold Loads
Lower Frequency Rx's
L, S, C & X-Band



SOS Testing a VLBA Ku-Band Rx

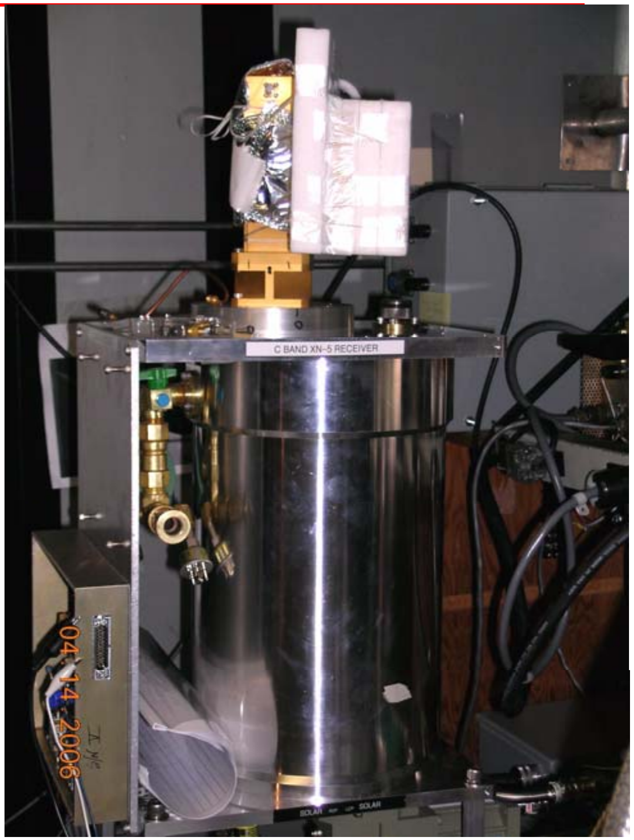
- The feeds for these receivers are built into the Vertex Cabin.
- So they need circular waveguide Hot/Cold Loads.
- Built from OMT's with coaxial terminations at ambient or immersed in LN2
- Old VLBA Hot/Cold Loads not broadband enough


L-Band Proto with 40" Section

Hot/Cold Loads
Lower Frequency Rx's
Examples

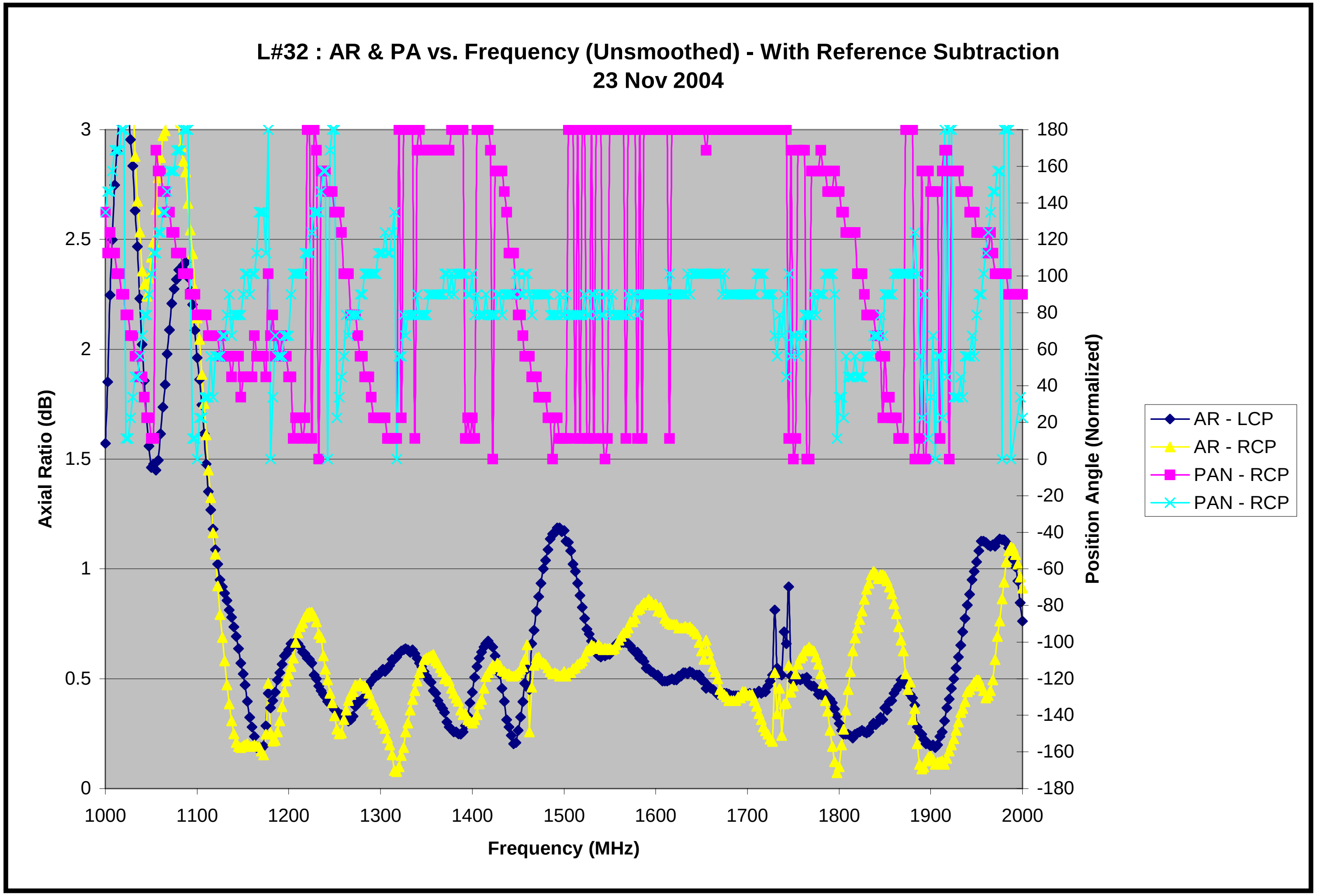
L-Band Hot/Cold Load

Lilie Noise Standard

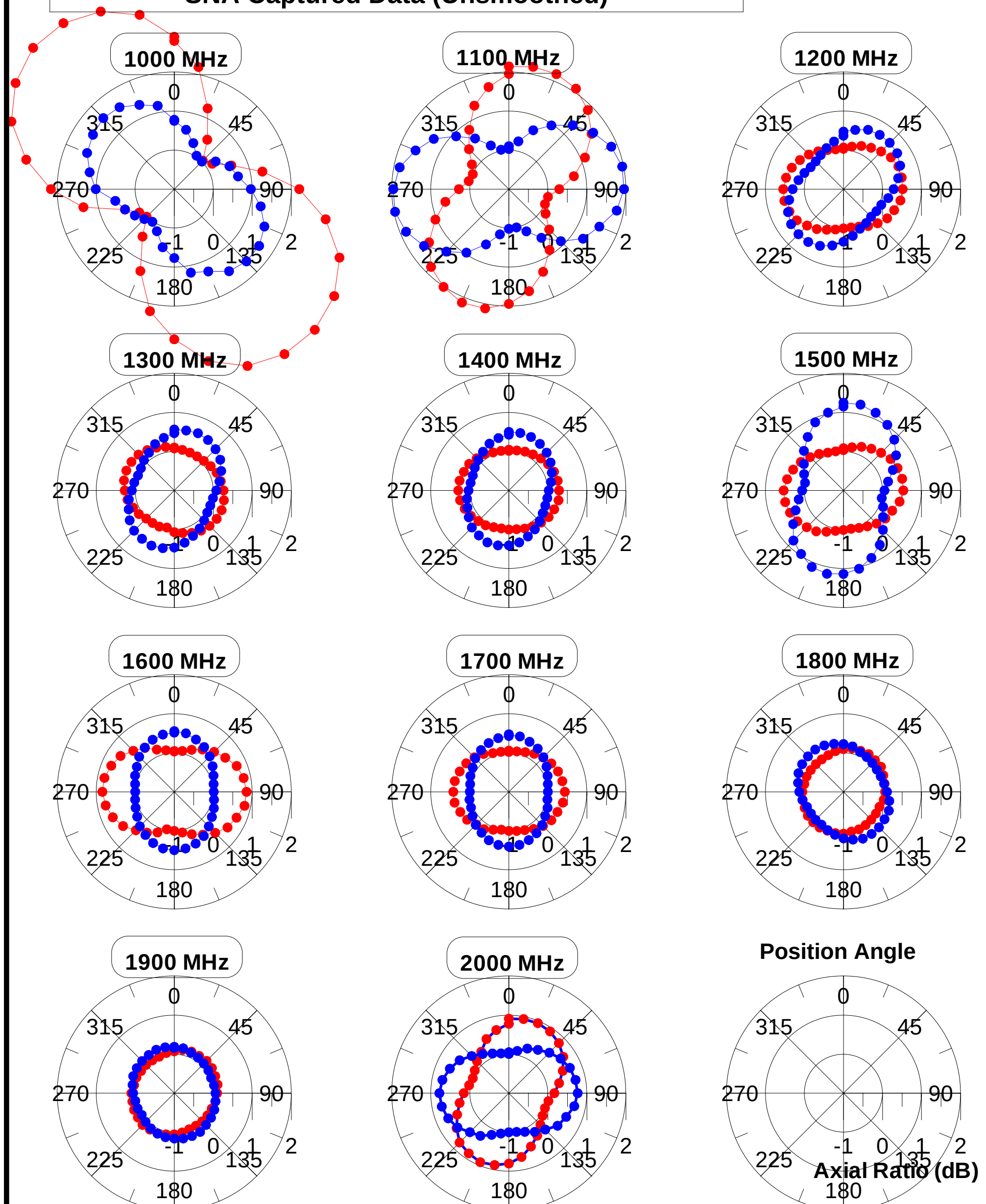


C-Band Hot/Cold Load

Typical L-Band Axial Ratio Measurement

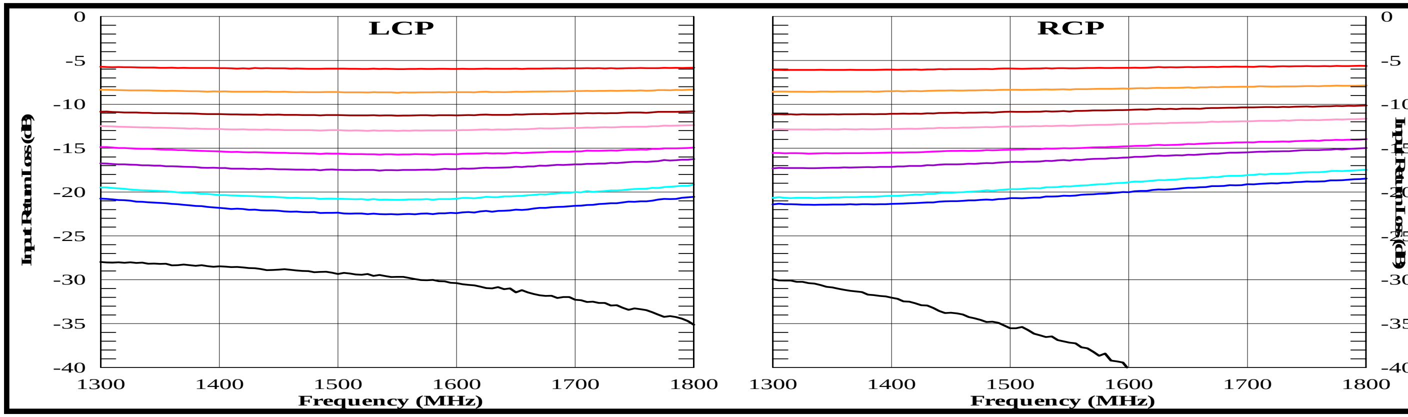


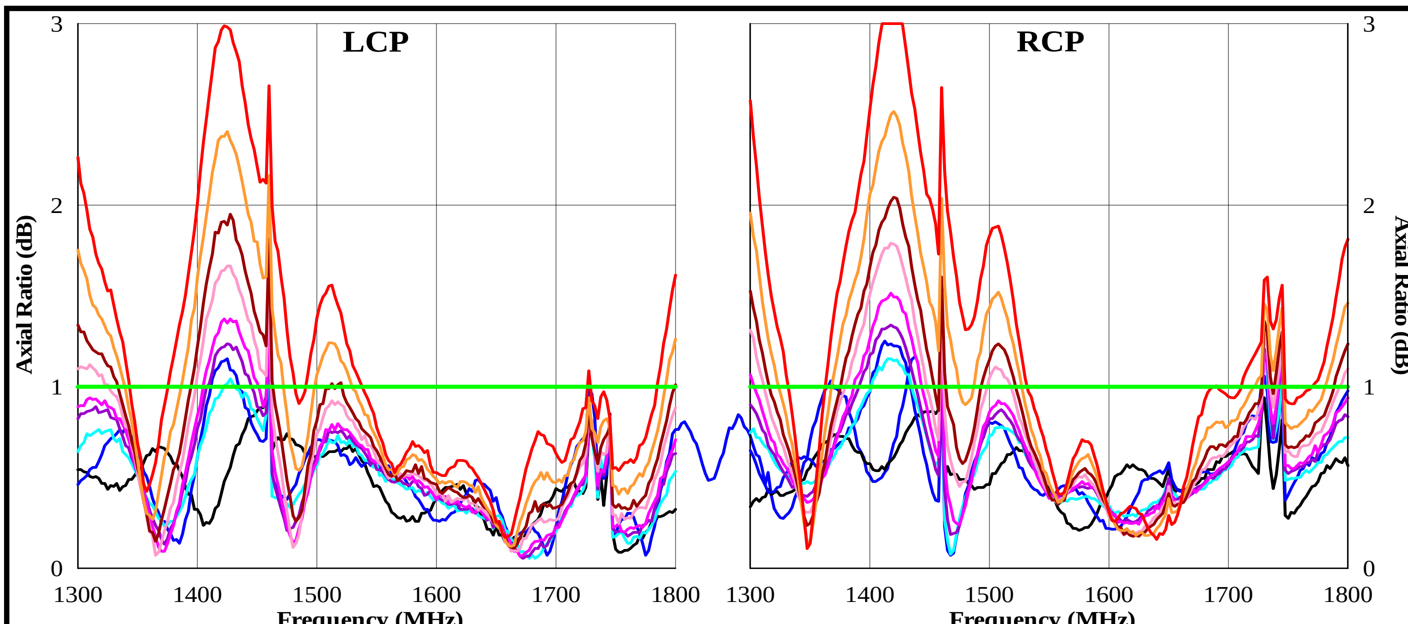
L-Band S/N 32 (23 Nov 2004) - With Ref Subtraction
Axial Ratio (dB) and Position Angle versus Frequency
Cold Receiver with Balanced LN+HP Gain Blocks
SNA Captured Data (Unsmoothed)



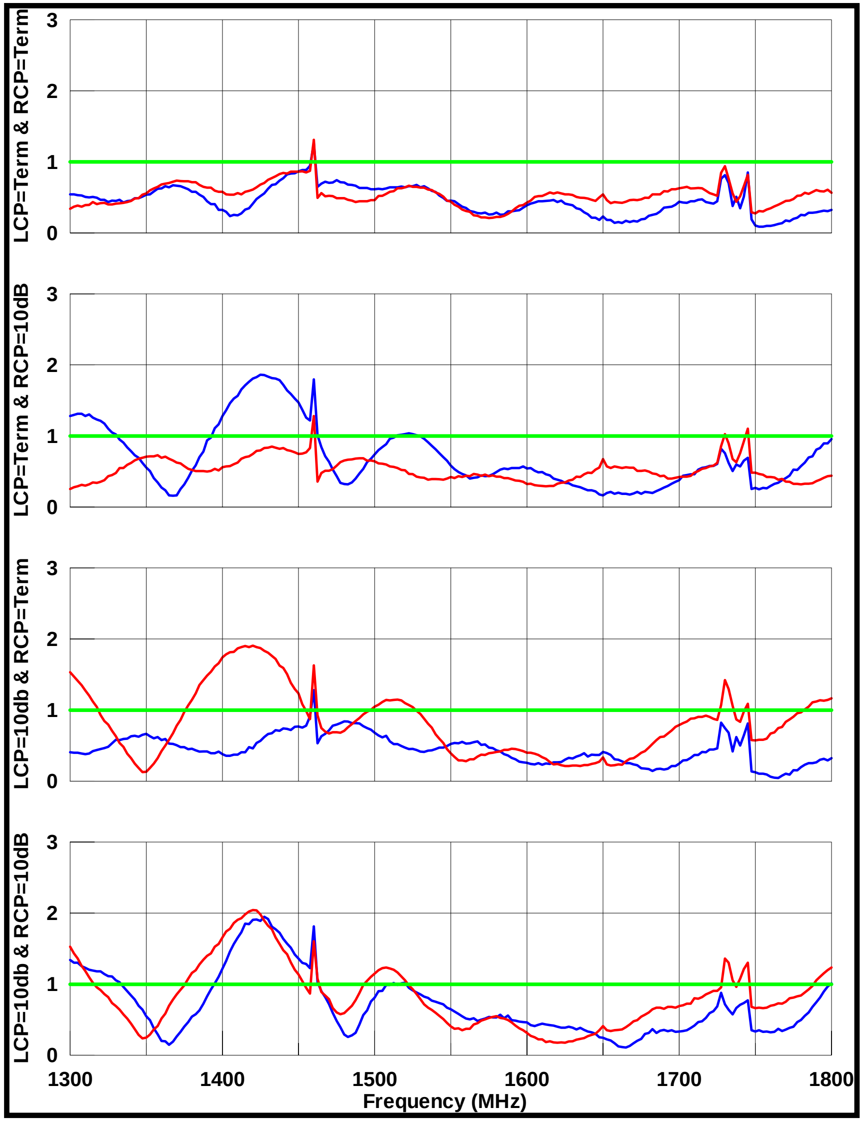
L#21 Circular Polarizer - Quadridge OMT & Hybrid Coupler
Axial Ratio vs. Simulated LNA Input Return Loss
(19 Feb 2006)

IRL = Terminations
IRL = 20 dB
IRL = 18 dB
IRL = 16 dB
IRL = 14 dB
IRL = 12 dB
IRL = 10 dB
IRL = 8 dB
IRL = 6 dB
Axial Ratio 1 dB Spec





L#21 Circular Polarizer - Quadridge OMT & Hybrid Coupler
Axial Ratio vs. Simulated LNA Input Return Loss
LCP & RCP IRL = Termination and/or IRL10 dB
Axial Ratio Key = LCP , RCP & 1 dB Spec
(17 Feb 2006)



General Purpose Test Equipment

- PNA DC-50 GHz (Agilent E8463B)
- Coaxial SNA DC-26 GHz (HP8757C + HP83630B)
- Waveguide SNA (HP8758E + HP83624A)
    - Ka, Q & W-Band Source Modules
- Spectrum Analyzer (Agilent 8563EC)
    - DC-26, 33-50, 75-110 GHz
- Power Meter (Agilent E4419B)
    - DC to 110 GHz
- SiteMasters (Anritsu S332B & S820A)