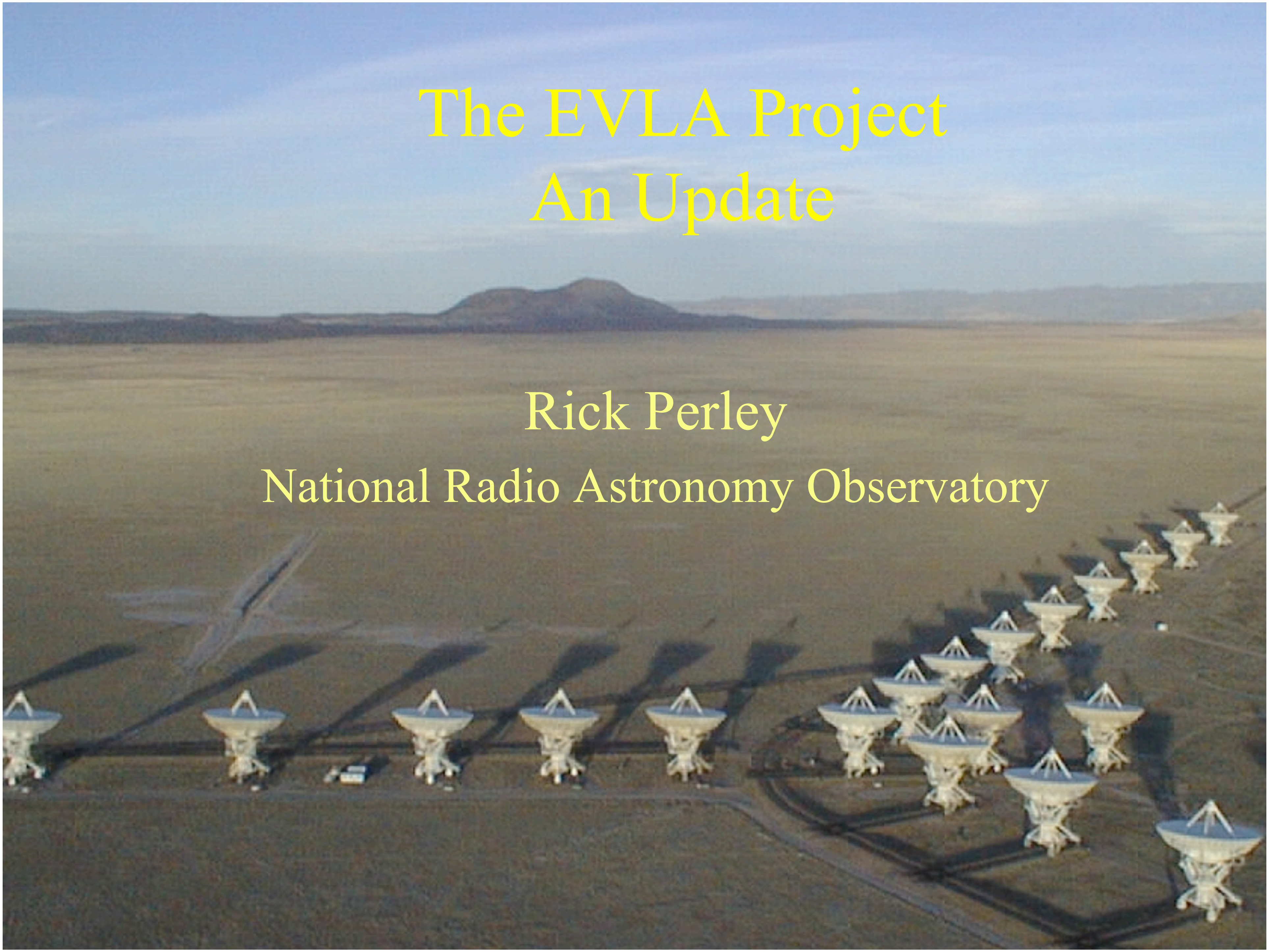
The EVLA Project
An Update
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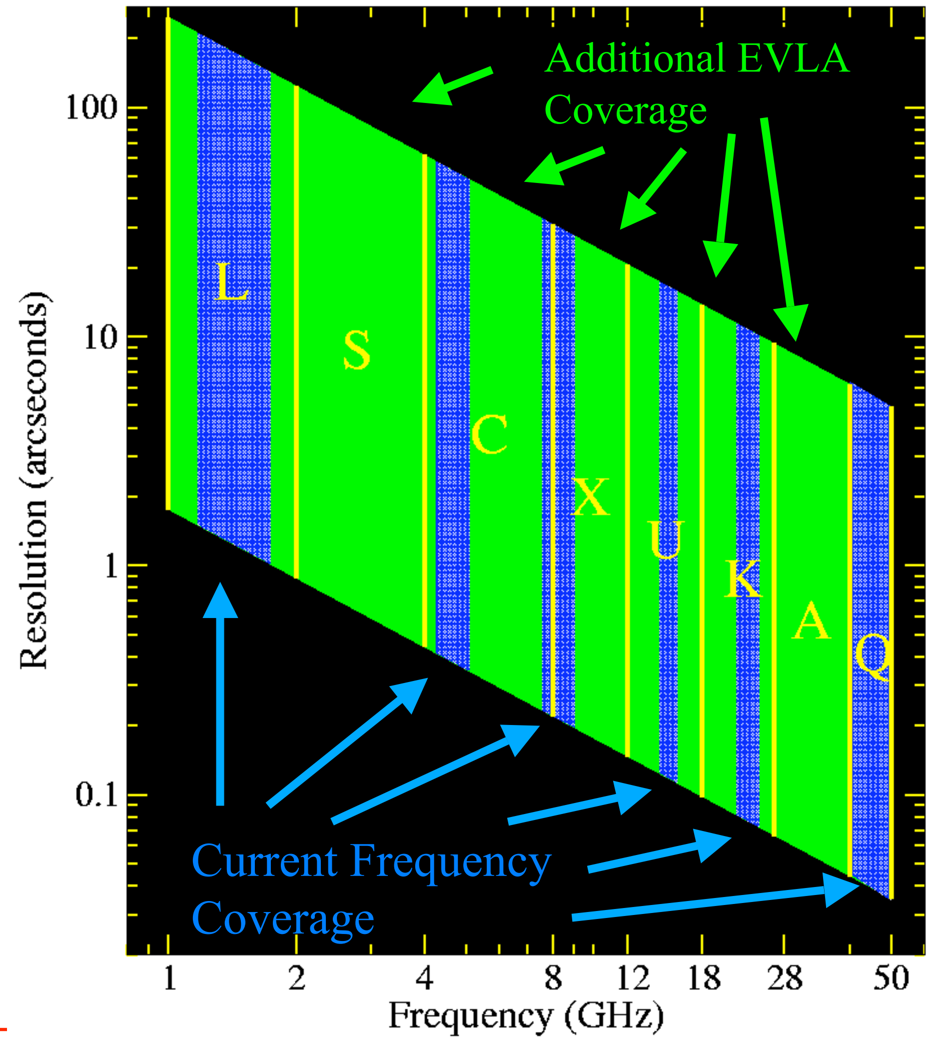
EVLA Project Goals

- Fundamental Goal: By building on the existing infrastructure, multiply ten-fold the VLA's observational capabilities.
- Full frequency coverage from 1 to 50 GHz.
  - 8 frequency bands with cryogenic receivers.
  - Two intermediate frequency (IF) pairs – with no restrictions on their tuning (unlike current VLA).
- 1 μJy point-source continuum sensitivity (most bands)
- New correlator with 8 GHz/polarization capability
  - 16384 minimum channels/baseline
  - Full recirculation capability
  - 128 independently tunable frequency slots.
- Noise-limited full-beam imaging in all Stokes parameters
- Completion by 2012.

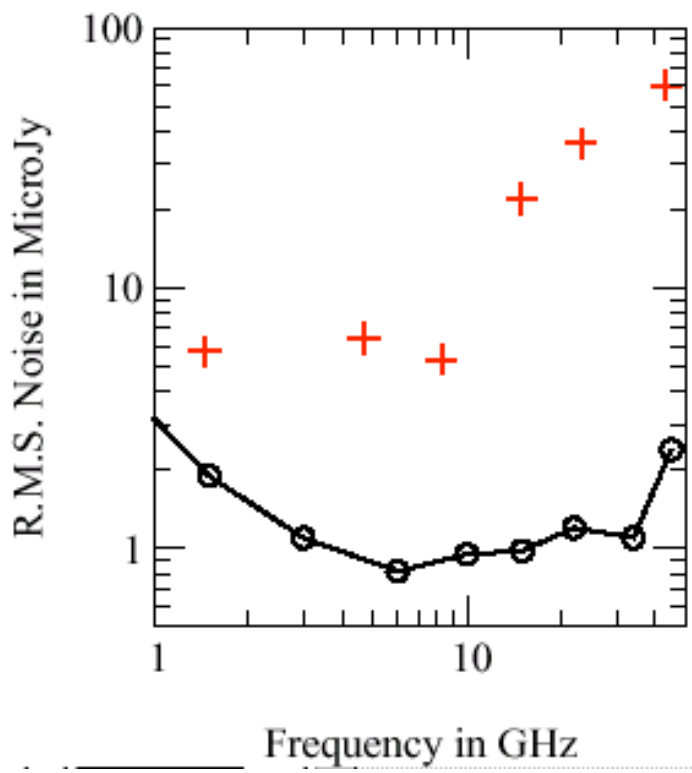
Frequency - Resolution Coverage

- A key EVLA requirement is continuous frequency coverage from 1 to 50 GHz.
- This will be met with 8 frequency bands:
  - Two existing (K, Q)
  - Four replaced (L, C, X, U)
  - Two new (S, A)
- Existing meter-wavelength bands (P, 4) retained with no changes.
- Blue areas show existing coverage.
- Green areas show new coverage.
- The two IF pairs can be tuned *anywhere* in the selected band.

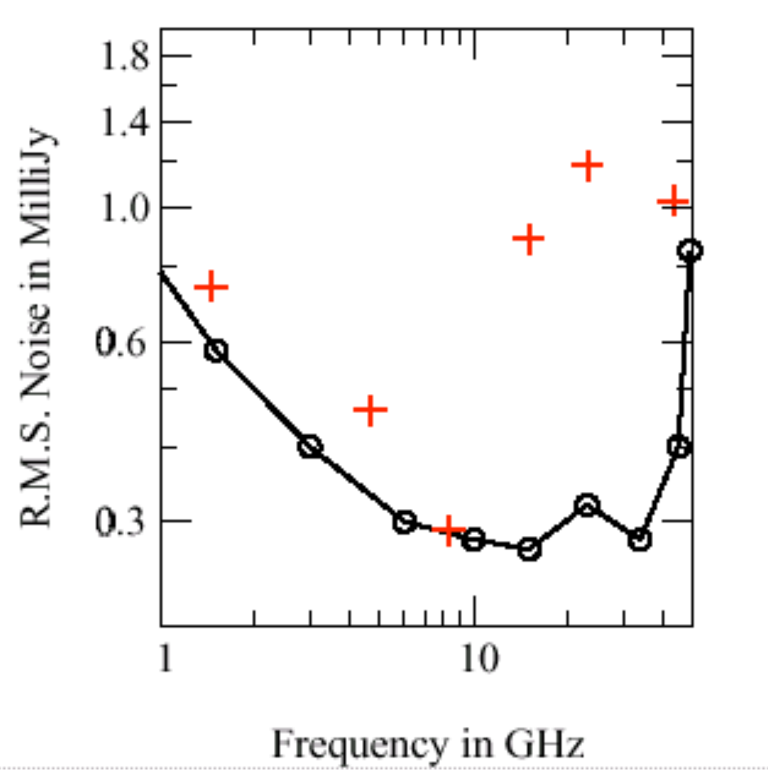


Sensitivity Improvement
1-σ, 12 hours

Continuum Sensitivity



Spectral Line Sensitivity



Red: Current VLA, Black: EVLA Goals

EVLA-I Performance Goals

The EVLA's performance is vastly better than the VLA's:

Parameter	VLA	EVLA	Factor
Point Source Sensitivity (1-σ, 12 hours)	10 µJy	1 µJy	10
Maximum BW in each polarization	0.1 GHz	8 GHz	80
# of frequency channels at max. bandwidth	16	16,384	1024
Maximum number of frequency channels	512	4,194,304	8192
Coarsest frequency resolution	50 MHz	2 MHz	25
Finest frequency resolution	381 Hz	0.12 Hz	3180
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	5

The cost to the NSF for this >10-fold improvement is $57M – about 1/3 the cost of the original VLA.

What is the EVLA Not Doing? (or, what happened to Phase II?)

- Expanding to provide 10 times the current best resolution (the New Mexico Array).
  - Lost: A ~few Kelvin brightness sensitivity at milliarcsecond resolution capability provided by the full EVLA.
- A super-compact configuration, for low surface brightness imaging (the ‘E’ configuration).
  - This ~$6M component could easily and quickly be done as a standalone project. (Lost: 10 μK brightness sensitivity on 12 arcsecond scale at 34 GHz).
- A sub-1 GHz facility. The VLA’s optics system makes it very difficult to implement an efficient wide-band low-frequency capability.
  - All proposed methods to do this require extensive design and development – for which we have no budget.

The Eight Frequency Bands

Band (GHz)	System Temp (K)	Aperture Effic. (%)	IF BW (GHz)	Digitization
1-2	28	.43	2x1	2 x 2GS/s x 8bits
2-4	25	.60	2x2	4 x 2 x 8
4-8	24	.60	2x4	4 x 4 x 3
8-12	34	.65	2x4	4 x 4 x 3
12-18	35	.65	2x6	6 x 4 x 3
18-26.5	45	.55	2x8	8 x 4 x 3
26.5-40	50	.45	2x8	8 x 4 x 3
40-50	60 - 95	.30	2x8	8 x 4 x 3

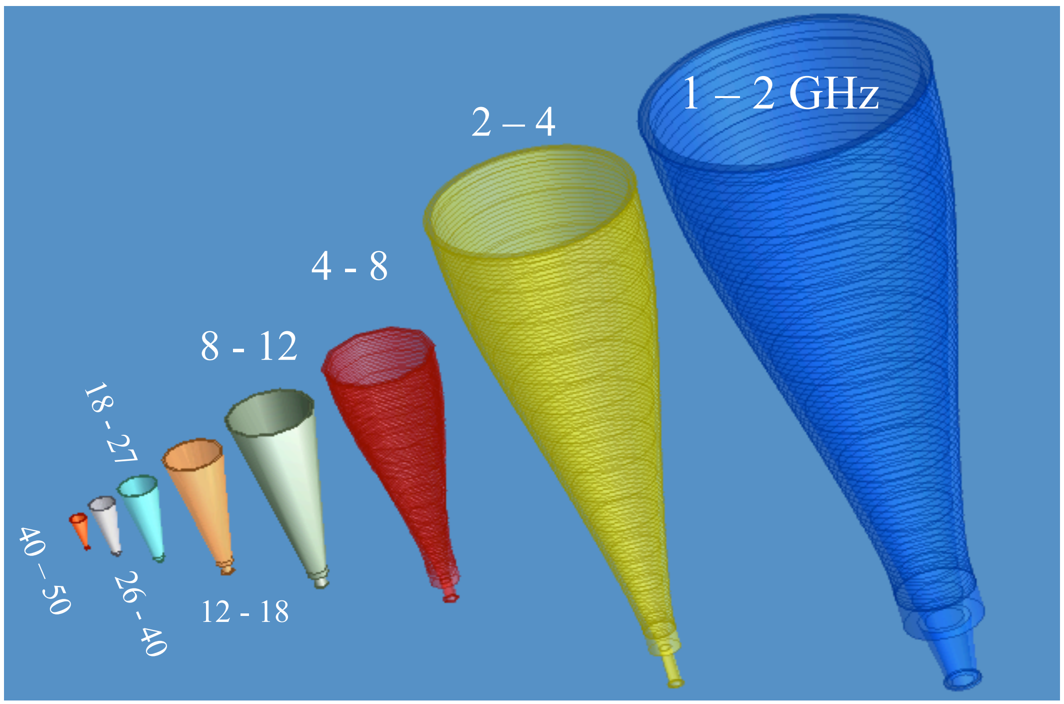
Blue = System tested and in place, or under installation.

Green = Prototypes to be tested in 2007 or 2008.

Red = Deferred to end of project

EVLA Feed System

All eight Cassegrain feeds are compact or linear taper corrugated horns with ring loaded mode converters



Today's EVLA Status!

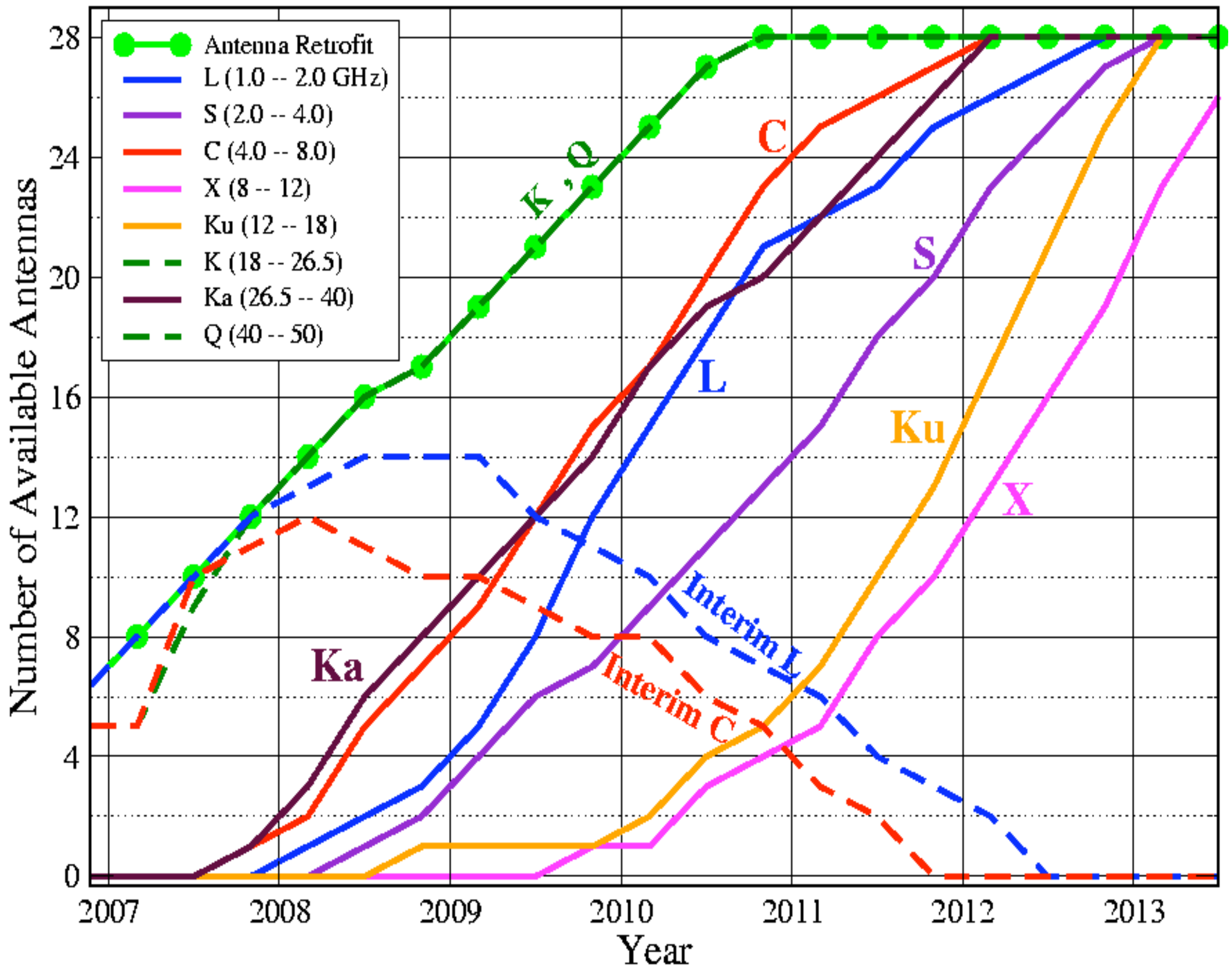
- Ten antennas now converted to EVLA standards

- Eight of these are back in the array for regular observing.
- Antennas will be upgraded at a rate of 6/year, completing in 2010.
- Nearly all technical issues resolved.
- (n) = receiver to be installed within the next month.

Ant.	.3 - .34	1 - 2	4 - 8	8 – 8.8	18 – 27	40 - 50
13		L	C	X	K	Q
14	P	L	C	X	K	Q
16		L	C	X	K	Q
18	(P)	L	C	X	K	Q
17	P	L	C	X	K	(Q)
24	(P)	L	C	X	K	Q
23	P	L	(C)	X	K	(Q)
26	(P)	L	C	X	K	Q
21	(P)	L	(C)	X	K	
19		(L)	(C)	(X)		

New Capabilities Timescale

- The old correlator will be employed until the WIDAR correlator achieves full 27-antenna capability – mid 2009.
- Old correlator's limitations remain:
  - 50 MHz BW
  - 16 to 512 channels
- Full band tuning available now, on schedule shown here.



4 and P Bands
(73.0 – 74.6, 300 – 340 MHz)

- No change in tuning or antenna sensitivity.
- The n*100 kHz comb lines are gone!
- All other internally generated combs are gone (we think!)
- Deployment of these bands were delayed for some time by design issues which are now resolved.
- Outfitting will catch up by summer, ready for A-configuration.

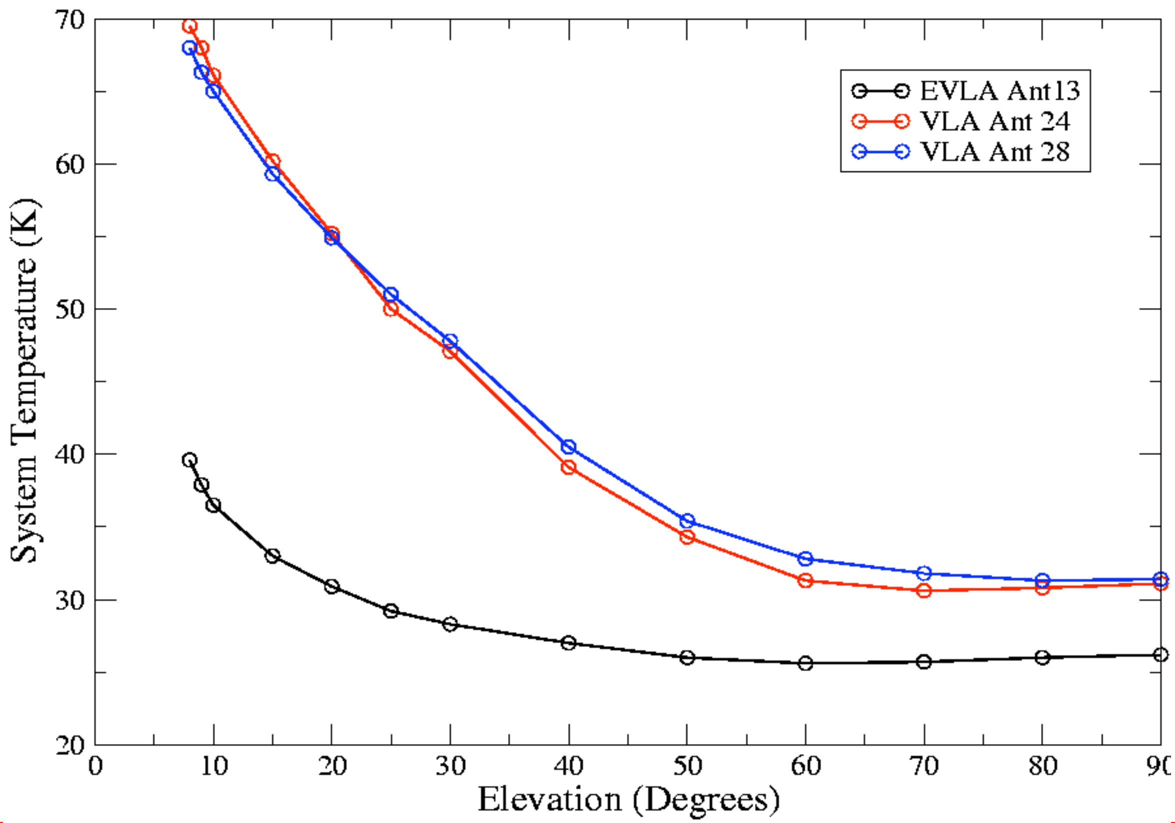
L-Band

1.0 – 2.0 GHz

- Currently deploying an ‘interim receiver’, providing 1.2 – 2.0 GHz tuning.
- Final system (full 1.0 – 2.0 GHz) awaits final testing and production of the new OMT.
- Unexpected good news: Virtually no RFI in newly available spectral zone: 1740 – 2000 MHz.
- Efficiency of new system 40 – 46%.
  - Compared to ~50% for VLA L-band feed.
- Tsys below 30K.
- Spillover contribution much reduced at low elevation.

EVLA and VLA Tsys at L-Band

This shows the great improvement in spillover performance Of the new L-band feed.



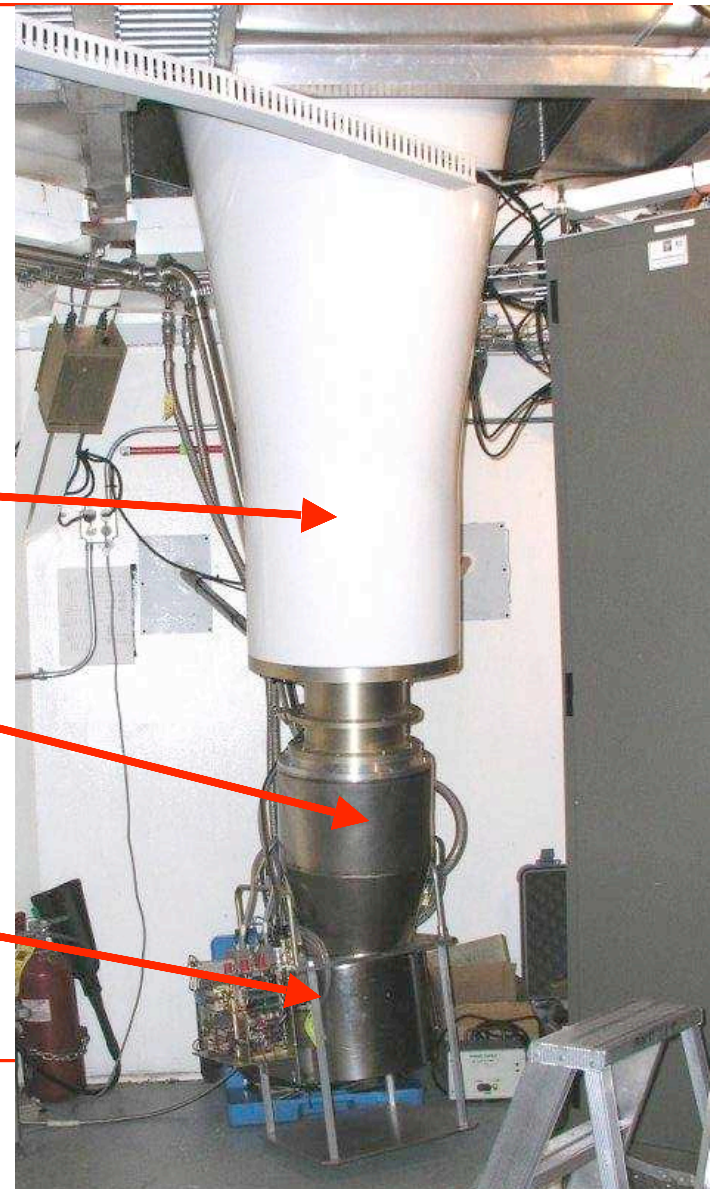
L-Band OMT

- New L-Band Horn/OMT now installed on antenna 14.
- Designed to give 1 – 2 GHz high efficiency, good polarization.

Horn

OMT (inside cryo)

Receiver



S-Band
2 – 4 GHz

- A brand new band, opening a new spectral window.
- Full size horn, offering excellent efficiency (>60%), and low system temperature (<30K).
- Double the BW of L-band => could be the band of choice for non-thermal emission sources.
- Prototype horn now being assembled. Feed tests begin this summer, deployment on antenna for testing near end of year.
- Implementation slowed by physical size.

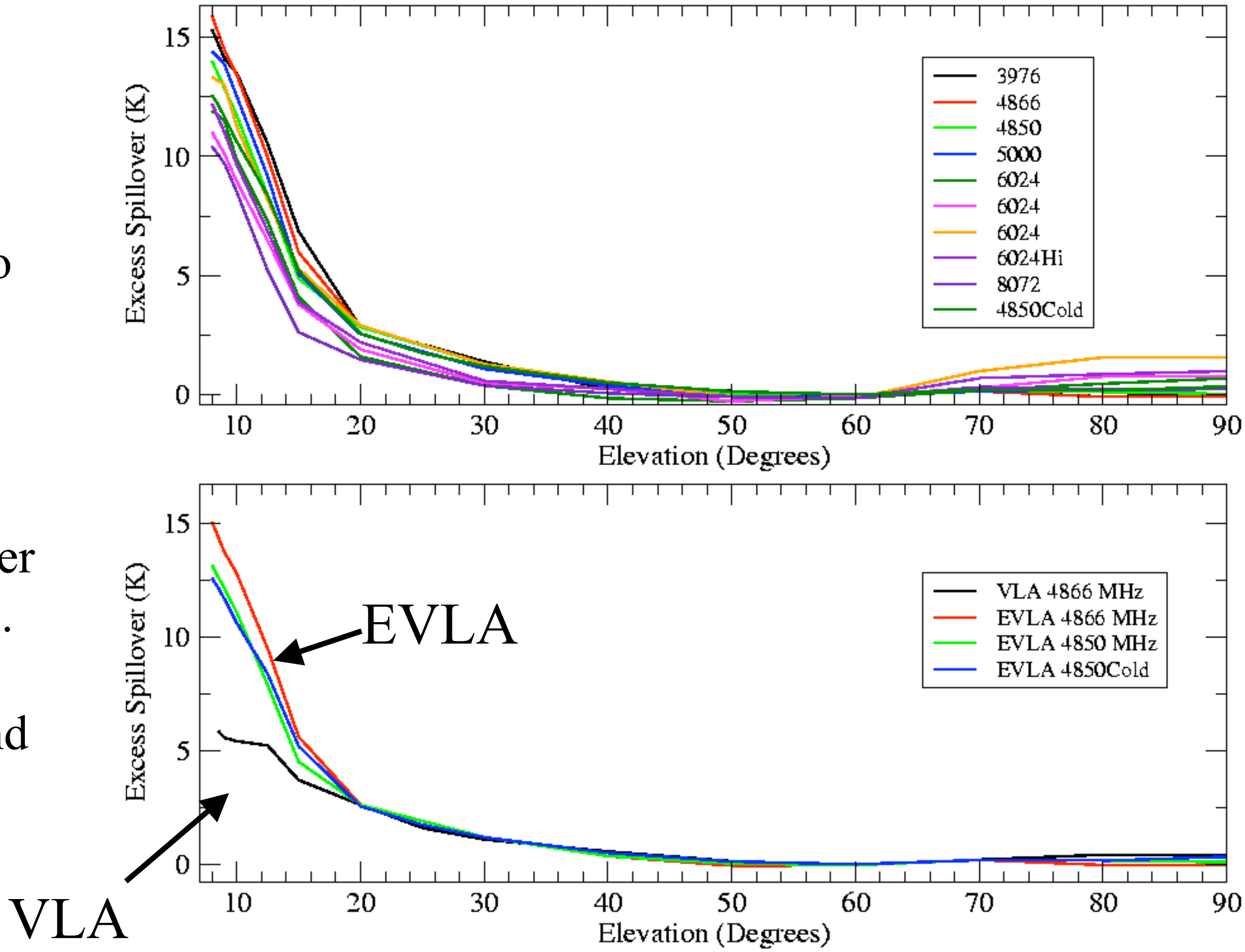
C-Band
4 – 8 GHz

- Systems currently being installed are interim – OMT design is still under development.
- Current systems using narrow-band OMT.
- Tuning range remarkably wide: 4.25 – 7.75 GHz, with excellent performance (except for some resonances).
- Polarization performance outside the 4.5 – 5.0 GHz range is very poor.
- Final system will have Tsys ~ 25K, Efficiency > 60%.

Variation with Elevation
C-Band

• At C-band, the feed shows excellent performance from 4 to 8 GHz.

• Some excess spillover at very low elevations. This is the price to be paid for such wideband feeds.



X-Band
8 – 12 GHz

- This will be the last band to be outfitted, starting in 2010, with completion in 2013. (Also, the first band to be jettisoned, in case of funding shortfall).
- Until 2010, the old (JPL) receivers (8.0 – 8.8 GHz, with Tsys ~35K) are being reinstalled.
- OMT design here is uncertain – scale up the Boifot K-band design, or scale down the quad-ridge L-band design.
- Work to resolve this issue now beginning.

U-Band

12 – 18 GHz

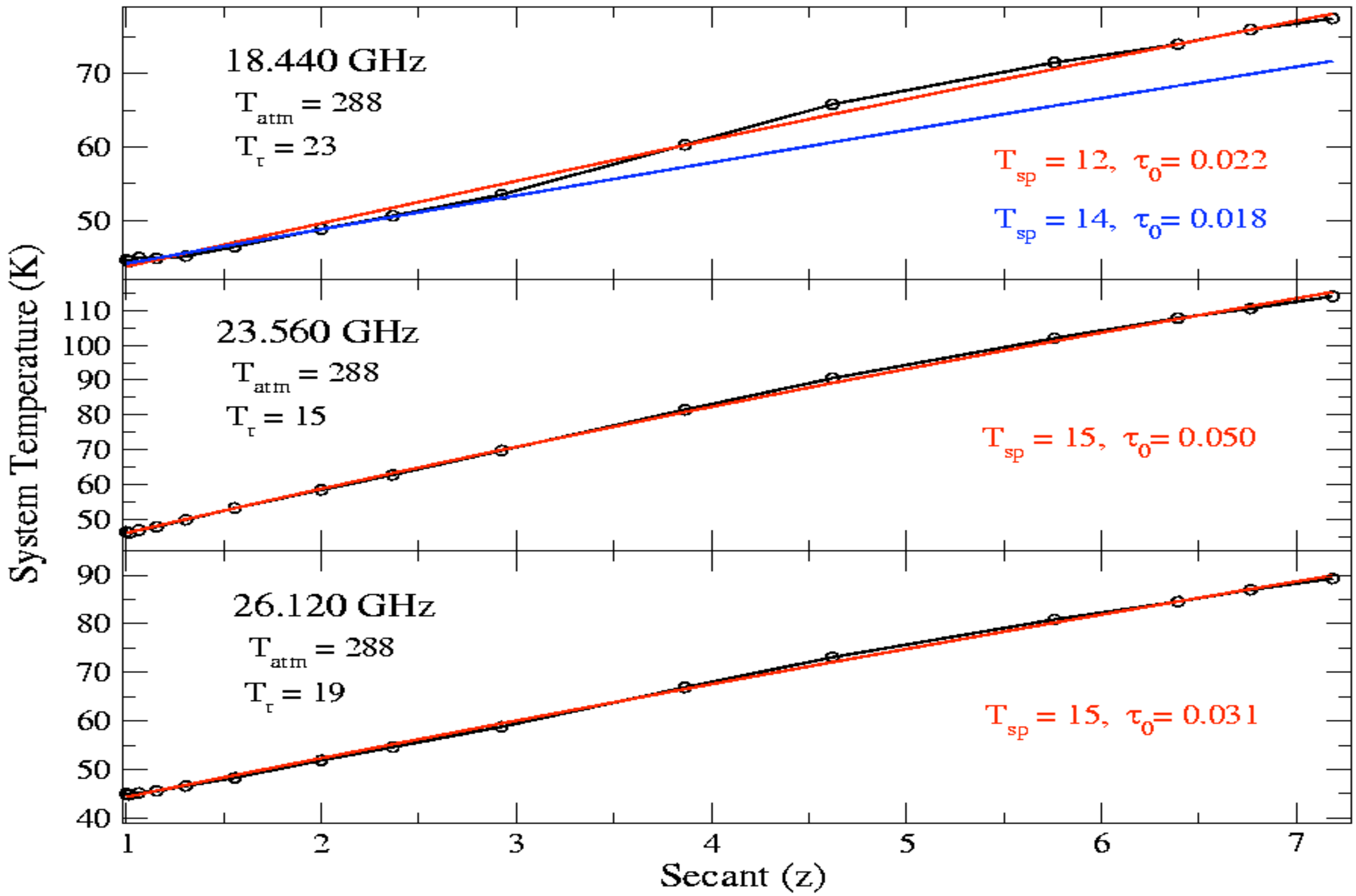
- Not possible to re-install these (very old and very poor) receivers following antenna retrofit.
- The EVLA antennas will have no U-band capability until 2009.
- New systems begin installation in 2009, completing at the end of 2012.

K-Band

18 – 26.5 GHz

- These receivers are the same as the (recently upgraded) VLA receivers.
- New electronics allows full tuning range (VLA could not do this).
- Excellent performance, with Tsys ~ 45K, Efficiency about 50%.
- Available now!

K-Band Sky Dips



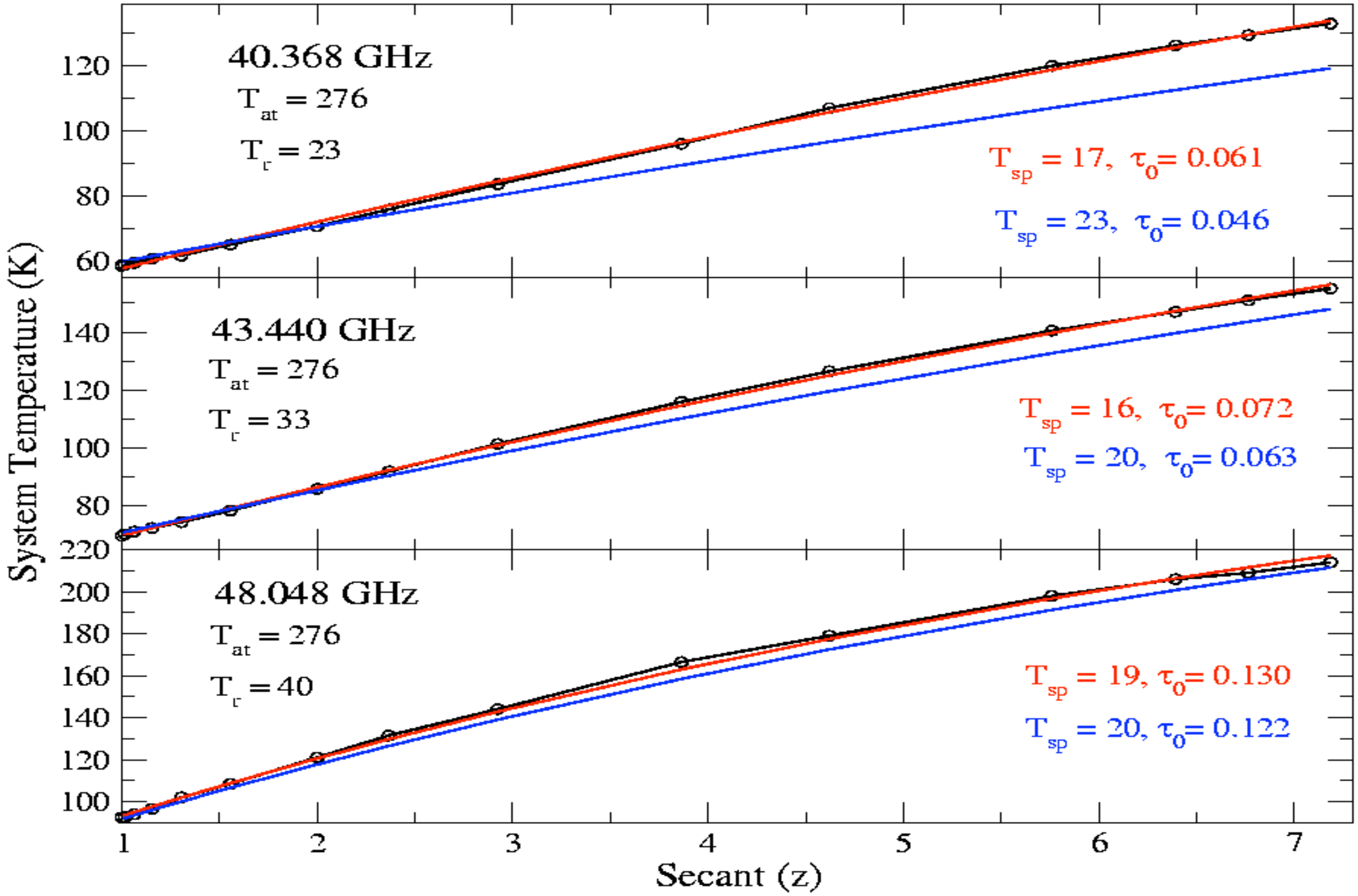
A-Band
26.5 – 40 GHz

- Prototype receiver now under construction.
- On-sky testing should begin this summer or fall.
- Our first ‘new’ band, with superb performance:
  - Tsys < 60K, Efficiency ~ 50%.
- Expect this band to be heavily used for thermal science.

Q-Band
40 – 50 GHz

- Old VLA systems being recycled.
- Sensitivity improved somewhat by IF improvements.
- Full tuning separation now enabled.

Q-Band Sky Dips



EVLA and VLA M&C

- The two arrays run by different M&C systems:
  - VLA: the venerable Modcomps
  - EVLA: Linux-based Executor
- The two systems are only 'loosely coupled', and numerous synchronization issues have resulted.
  - These have affected all observing, especially pointing, holography, and sky survey modes.
- Modcomps to be decommissioned June 27, and the EVLA Executor will run both the VLA and EVLA.
- Much work involved in transferring all critical capabilities and observing modes.
- Not all modes will work on June 28:
  - Solar modes missing for sure. (A-config – no solar useage).
  - VLBI modes maybe.
  - Raster modes, planet tracking, possibly absent.

Party!!!

- Want to come to a good party?
- June 27, 2007 is *THE DAY* we turn off the Modcomps for good.
- An appropriate celebration (along with a well-deserved plaque and citation) is being planned.

What works, and what doesn't?

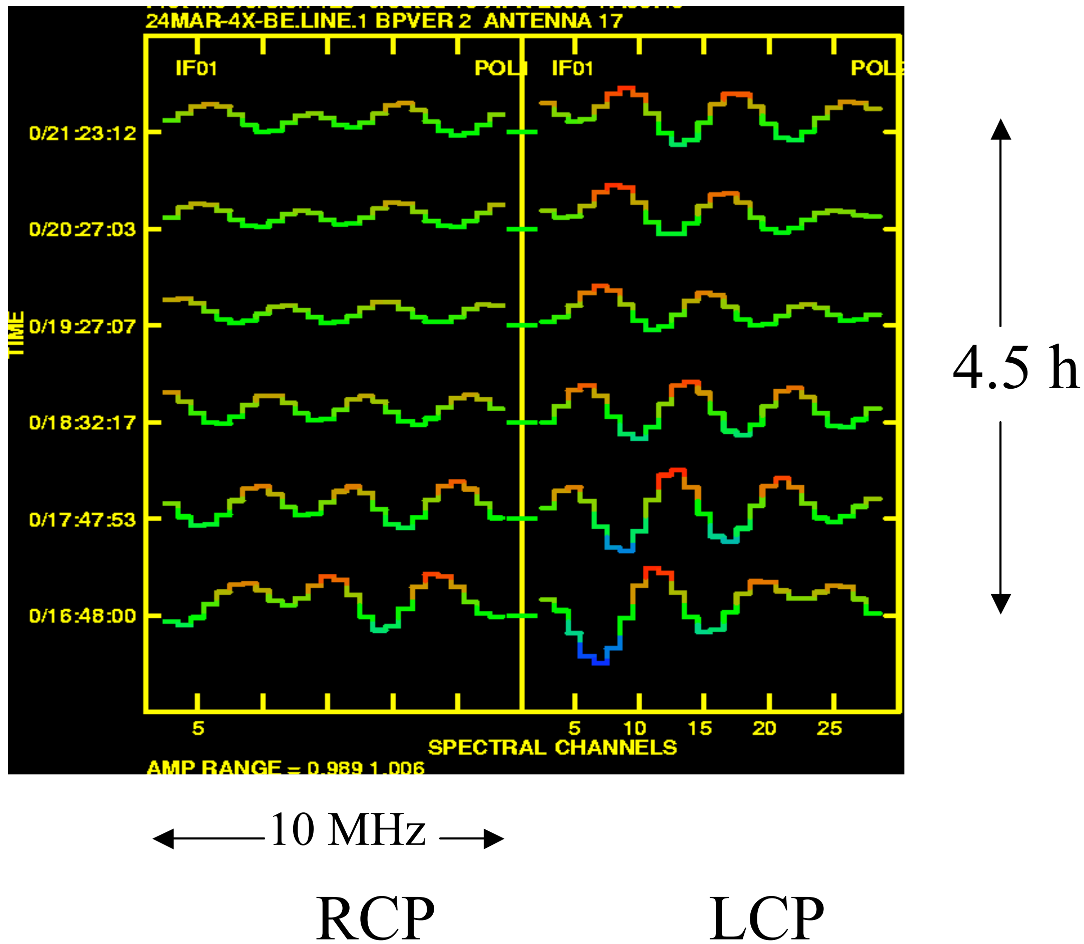
- Phase stability:
  - We believe ALL short-term EVLA phase stability issues are resolved.
  - Some peculiar problems still exist, are being tracked down.
  - RT phase now applied on most antennas – affects long-term phase stability. Performance being checked.
  - Three modules show temperature sensitivity – now under study. No quick resolution.
  - VLA now known to be responsible for phase jumps on VLA x EVLA baselines, when frequencies change.
  - There is no fix for this. Calibrate when you change frequency.
- Amplitude stability:
  - Occasional drop-outs (1% of data, very brief (< 410 msec), very small (~10% amplitude)) still occur.
  - One remaining large-scale, rare, phenomenon still being chased down.

Current issues, cont.

- Antenna pointing, etc.
  - Pointing fine, referenced pointing modes work (usually).
  - EVLA antennas often late on source – due to wrap condition not known to Executor.
- Bandpass issues
  - EVLA bandpass does not have the ~180 degree 'hook' in the bottom 2 MHz of baseband that is on the VLA.
  - Continuum observations on VLA x EVLA baselines are significantly degraded – a 'closure' error.
  - Can repair via baseline calibration (but SNR lost for good).
  - Can avoid via spectral line observations.
  - EVLA bandpass MUCH more stable than VLA – no standing wave.

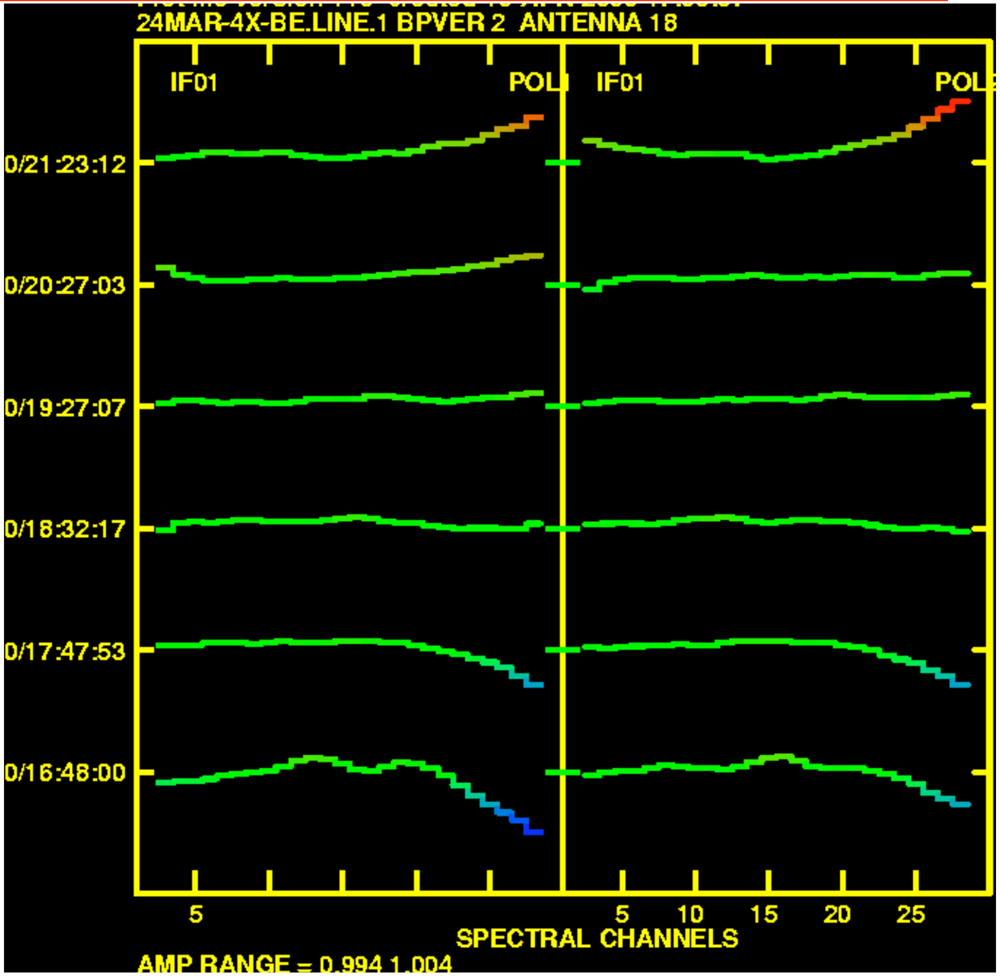
VLA Bandpass Amplitude Differential Hourly Snapshots

- VLA antenna 17 amplitude, X-Band
- 4 MHz Ripple due to waveguide reflections.
- Magnitude ~ 0.5%
  - (50 times too high)
- Typical for all VLA antennas.



EVLA Antenna 18 Amplitude Results

- Amplitude stability excellent.
- No sign of VLA's 3 MHz ripple.
- Full range is 0.4%.
- Away from baseband edge, range is ~.05%.
- Variation likely due to VLA baseband filter.



Issues, cont.

- Doppler Tracking
  - algorithm between Modcomps and Executor not identical.
  - VLA x EVLA will not give sensible data with Doppler tracking.
  - Must do spectral line with fixed frequency, and use off-line processing to make doppler adjustments.
  - This problem will end after June 27, 2007!

Correlator

- Design and construction of correlator ‘sub-contracted’ to DRAO correlator group (Penticton, BC, Canada).
- All costs covered by Canadian NRC.
- Their design is an extraordinarily flexible machine, with an ‘XF’ architecture
- A 32 station correlator, but more than 32 antennas can be input, with bandwidth reduction.
- Recirculation provided for increased frequency resolution.
- Vast number of ways to share resources internally, trading inputs, or sub-correlators, or polarization, for more channels.
- Full polarization, pulsar modes, phased array, VLBI-ready, extensive subarraying, etc.

Software!

- We have major work ahead in software:
  - Correlator modes and operation.
  - Telescope scheduling, archiving, default image generation.
  - Calibration of 2:1 BWR data.
  - Imaging
    - 2:1 BWR ratio imaging
    - Polarization (removal of beam polarization)
    - RFI excision
    - Multiple-direction self-calibration
    - Management of non-coplanar imaging
    - Management of spectral line cubes.
- The EVLA proposal underestimated software costs (if we knew then what we know now …)
- Remaining contingency will be reserved for hardware.
- Assistance from NRAO headquarters will be needed to meet the software requirements.

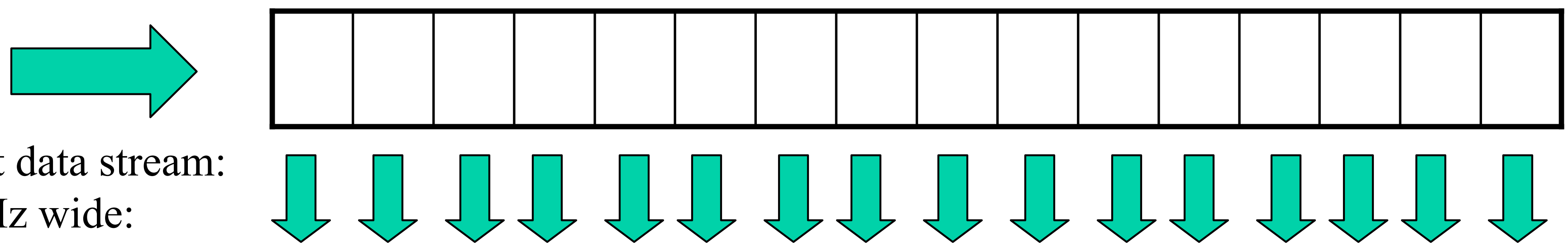
Major Future Milestones

- Modcomp control computers turned off — June 27, 2007
- Test prototype correlator on the sky — Apr – Aug 2008
  - Four antenna test and verification system
  - Not available for science
- Full Correlator Implementation — Jun ’09 – May ‘10
- VLA’s correlator turned off — late 2009 ?
  - New correlator capabilities will be much greater
  - About 6 VLA antennas will not be useable (temporarily)
- Last antenna retrofitted — Sept. 2010
- Last receiver installed — Sept. 2013

Correlator – FIR Filter

- Each of 8 inputs, each 2.048 GHz wide, is digitally divided into 16 sub-bands.

16-port FIR filter

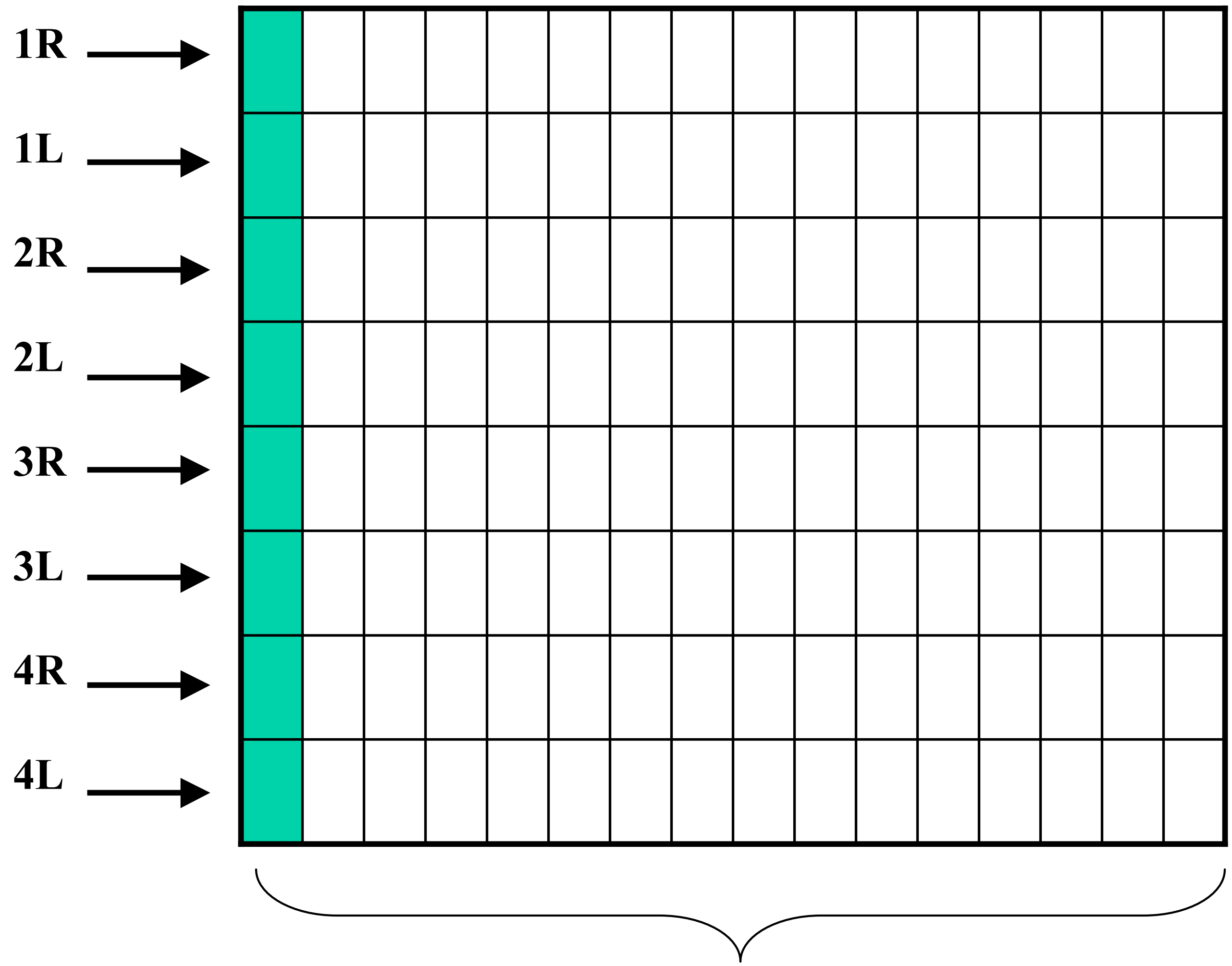


Input data stream:
2 GHz wide:
4096 Gsamp/sec x
3 bits

- Each output data stream is variable in width and frequency.
- Width can be 128, 64, 32, … ,03125 MHz.
- Frequency can be anywhere within 2 GHz input.
- Each output goes to a separate sub-correlator, providing 1024 spectral channels.

16 Sub-Correlators each process one sub-band output from all eight inputs

Eight 2 GHz Inputs in Four Pairs



Each subband, for each IF input, individually tunable in width and placement.

Each column processed by one sub-correlator, each with 1024 channels

Correlator Flexibility

- Resources from any sub-correlator can be given to any other sub-correlator.
  - Doing so doubles the spectral resolution of the recipient sub-correlator
  - 15 sub-correlators can be given to one – improving spectral resolution 16-fold.
- Resources from any input IF channel can be given to any other input IF channel.
  - Increases resolution for one channel up to 16-fold.
- Both tradeoffs can be done simultaneously!
  - Increases resolution up to 256-fold.
- If this is still not enough resolution, recirculation is available on four IFs, providing up to 4 million total channels/baseline.

Correlator Status

- Detailed design nearly complete.
- Breconridge (the contract manufacturer) has delivered a fully populated baseline board for detailed testing in Penticton.
- Baseline board is large: 51 x 41 cm, 28 layers, 85000 connections, 95000 vias, 1.2 km trace length, 11802 parts.
- Station board also populated and in testing in Penticton.
- Phasing board design delayed. All other boards completed.
- ASIC correlator chip passed (yesterday!) all 30 tests at full speed! All FPGAs are ready, including the filter.
- Prototype correlator (4 stations) expected for on-sky testing in June 2008.