SAGE Committee Meeting – December 19 & 20, 2008

EVLA Goals, Progress, Status, and Projections

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Top-Level Project Goals

- Key goal: Improve the observational capabilities of the VLA (except for angular resolution) by a factor of ten or more.
- Provide a new monitor and control system, which must allow operation of EVLA and VLA antennas in transition.
  - This goal partially due to requirement that EVLA antennas be returned to service for continued VLA operations.
- Perform careful astronomical observations to verify that EVLA hardware and software function properly.
- Provide new data management software, including data post processing, for better access to array data products (effort distributed across divisions of NRAO)

Key EVLA Deliverables

- Full frequency coverage from 1 to 50 GHz.
  - 8 frequency bands with cryogenic receivers.
  - Two separately-tunable polarization pairs of up to 8 GHz BW
- Unmatched sensitivity:
  - 1 μJy/beam in full bandwidth continuum (1-σ, 9 hr).
  - 1 mJy/beam line sensitivity (1 km/sec, 1-σ, 9hr)
- New correlator with 8 GHz/polarization capability
  - 16384 minimum channels/baseline with full polarization
  - Spectral resolution varying from 0.1 Hz to 2 MHz.
  - 64 independently tuned sub-band pairs.
  - Recirculation capability and flexible correlator resource allocation to match correlator capabilities to science requirements.
  - Full range of special modes: sub-arrays, pulsar gating and pulsar binning, VLBI-enabled, phased array.
- Complete all hardware components by end of CY2012.

Overall EVLA Performance Goals

The EVLA's performance will be vastly better than the VLA's:

Parameter	VLA	EVLA	Factor
Continuum Sensitivity (1-σ, 9 hr.)	10 μJy	1 μJy	**10**
Maximum BW in each polarization	0.1 GHz	8 GHz	**80**
# of frequency channels at max. BW	16	16,384	**1024**
Maximum number of freq. channels	512	4,194,304	**8192**
Coarsest frequency resolution	50 MHz	2 MHz	**25**
Finest frequency resolution	381 Hz	0.12 Hz	**3180**
# of full-polarization sub-correlators	2	64	**32**
(Log) Frequency Coverage (1 – 50 GHz)	22%	100%	**5**

EVLA Sensitivity Goals

Band GHz	Band Code	S_E (req.) Jy	S_E (actual) Jy	Cont. Sens. 1-σ, 9 Hr., full BW μJy	Line Sens. 1-σ, 1 km/sec, 9 Hr mJy
1 -- 2	L	325	335	1.6	0.5
2 -- 4	S	235	TBD	TBD	TBD
4 -- 8	C	245	250	0.5	0.2
8 -- 12	X	300	TBD	TBD	TBD
12 -- 18	Ku	385	TBD	TBD	TBD
18 - 26.5	K	650	450	0.6	0.2
26.5 - 40	Ka	760	675	0.85	0.2
40 -- 50	Q	1200	1400	1.8	0.4

Black: Final systems

Blue: Interim systems

Red: Under Design

Purple: Prototype

$$S_E = 5.62 \frac{T_{sys}}{\varepsilon}$$

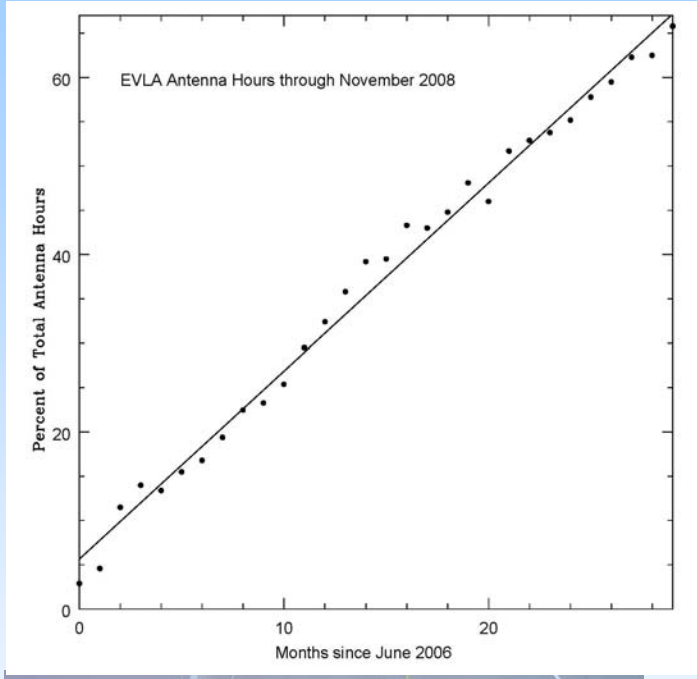
$$\sigma \sim \frac{0.01 S_E}{\sqrt{B_{GHz} T_{Hr}}} \quad \mu Jy$$

Snapshot of Project Status

- Project is going well
- Budget: Financial health of the project is good
  - Project contingency remains at historically high levels.
  - No plans to reduce scope of project
- Technical issues largely resolved
- Project is on schedule:
  - Antenna retrofits will be complete in Q3 2010
  - Receiver installation complete in late 2012
  - Correlator scheduled for completion in Q1 2010
  - Software development on track to support commissioning and early science

Antenna Conversion Progress

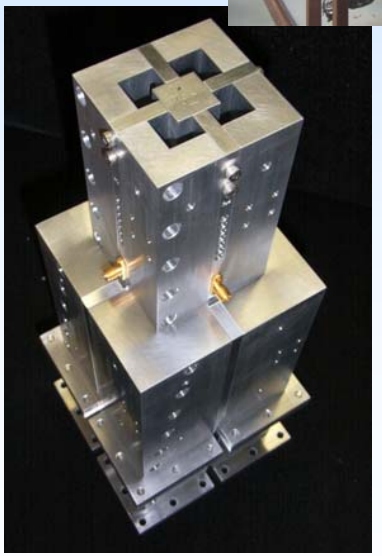
- Antenna conversions on track for completion in Q3 2010
  - Antennas placed in operation immediately after conversion is complete
    - 18 EVLA antennas now in use
    - Electronics outfitting of 19th antenna is nearly complete
    - Mechanical overhaul of 20th antenna is well underway
  - Proceeding at desired rate of about 6 per year



Receiver Progress

- Excellent progress on feed horn fabrication
  - All horns fabricated for L, C, and Ka-bands
  - Fabrication of S-band horns underway
- Full production of Ka-band receivers underway
  - First fringes on single baseline on Aug 8, 2008
  - 6 receivers installed in array now
- Design and fabrication issues with OMTs resolved
  - L, C, and S-band OMTs meeting specifications

L-band horns

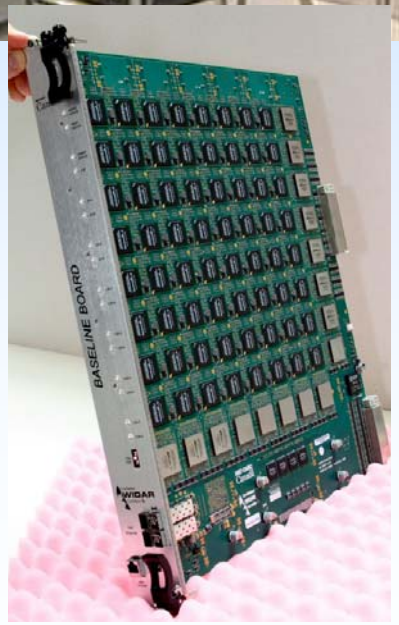


S-band OMT

WIDAR Correlator Progress

- Custom chips (12,000) received in Apr 2008
- High speed data cables and all 16 racks installed in Jun-Aug 2008
- On-the-sky tests of prototype began in Jul 2008
- First fringes with prototype on Aug 7
- Production review of printed circuit boards successfully completed on Dec 2-3
- Full production of boards to start in Mar 2009

Rack installation



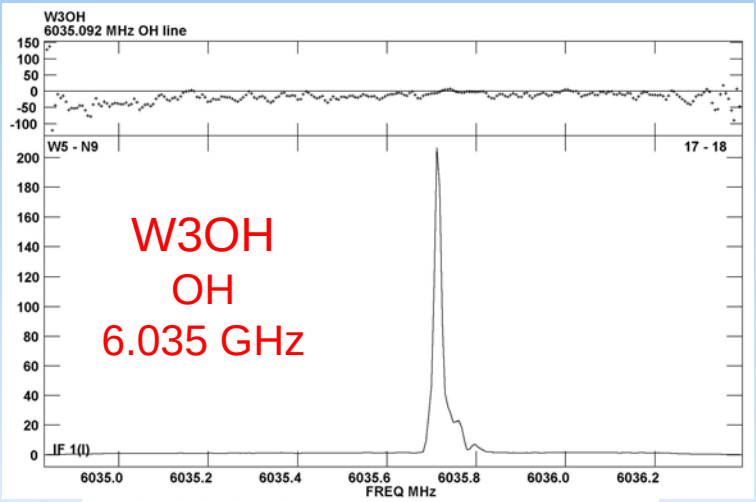
Baseline board

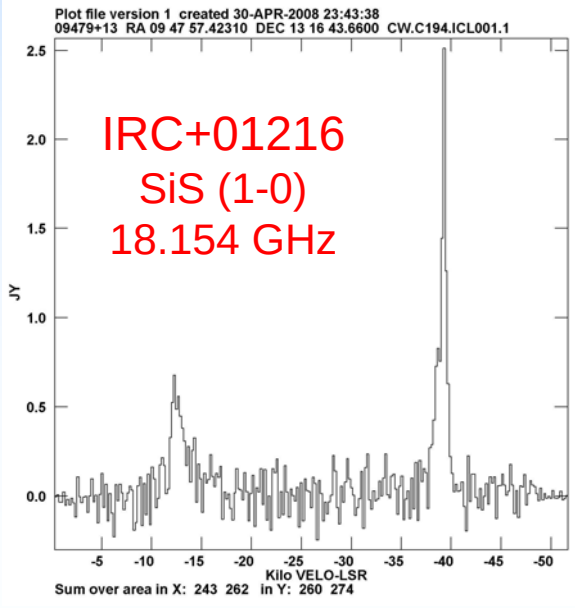
Additional Progress

- Wideband upgrade to LO/IF system started in June 2008
  - Production order of 3-bit, 4Gsps digitizers received
- Fiber infrastructure completed
  - Provides flexibility in locating antennas on the array
- Achieved goal of retiring VLA Modcomp control computers in Jun 2007.
  - 30 years worth of VLA M&C software replicated in new suite of EVLA M&C software
- Completed joint ALMA/EVLA definition of binary data format for visibilities
- Support for Ka-band observing with VLA correlator built into Observation Preparation Tool

New EVLA Science: C-Band and K-Band Results

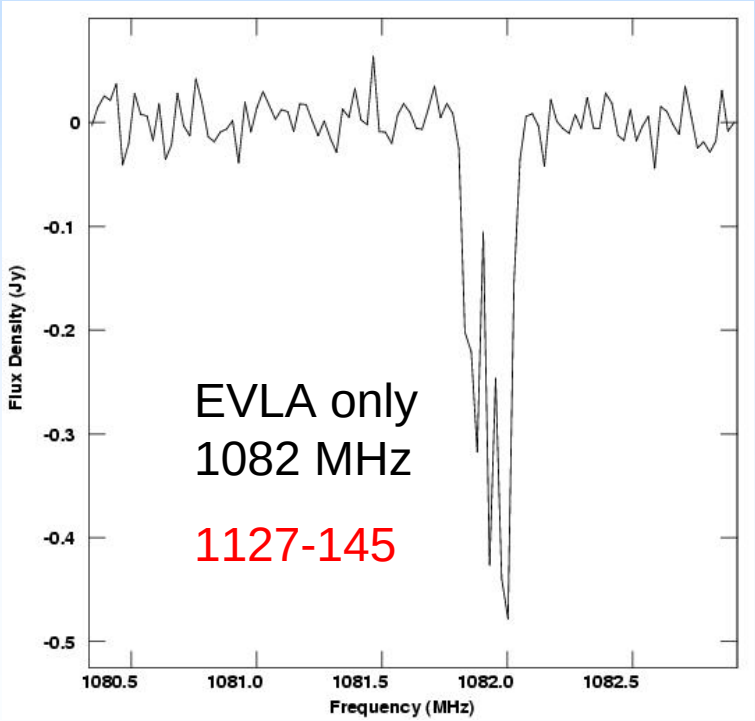
- C-band:
  - Traditional band is 4.5-5 GHz
  - Transition band is 4.2-7.7 GHz
  - First EVLA-only science: OH masers
    - AU Gem & NML Cyg: Sjouwerman et al. (2007, ApJL 666, 101)
    - ON1: Fish (2008, ApJL 669, 8)
- K-Band:
  - Traditional VLA K-band: 21.2 - 25.2 GHz
  - EVLA band: 18.0 - 26.5 GHz
  - First interferometric detection of SiS (1-0) at 18.154 GHz
    - IRC+10216 (CW Leo)
    - Claussen & Wooten

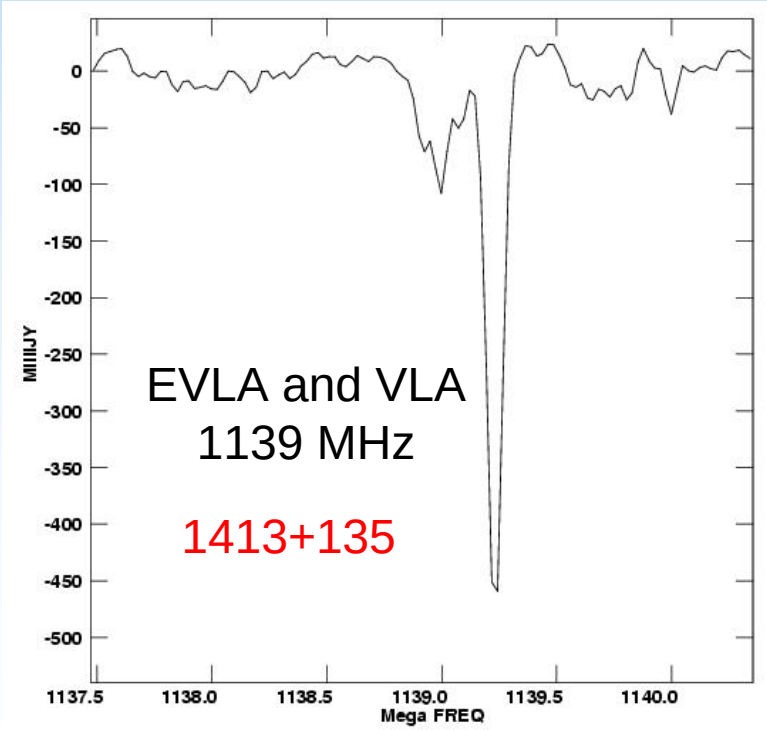




EVLA Imaging of HI Absorption at 1082 and 1139 MHz

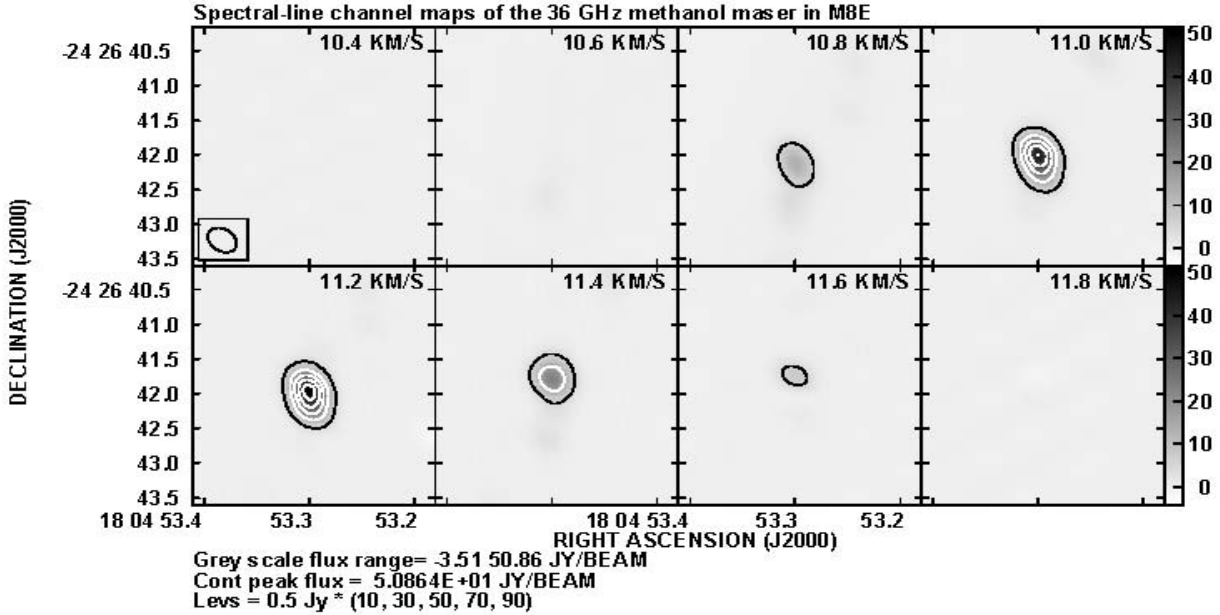
- Emmanuel Momjian observed two redshifted absorption lines with transition system, in D-configuration, in daytime.
- Frequencies used lie in aircraft ‘DME’ bands.
- About 25% of data flagged for RFI of some sort.
- Sensitivity will increase dramatically with new OMT.

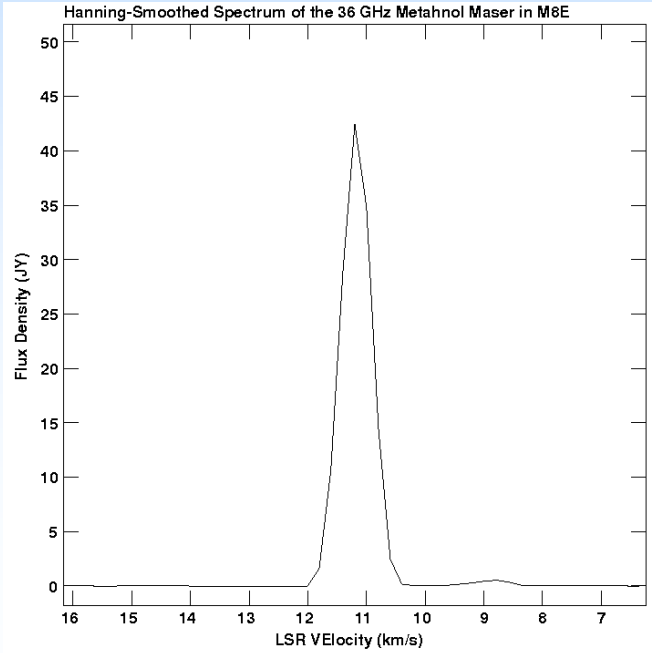




EVLA Science: Ka-band Spectroscopy

- Six new Ka-band (27 – 40 GHz) antennas now available.
- Ten available by March 2009 --- good for new science.
- As part of commissioning tests, Emmanuel Momjian has made imagines of the 36 GHz methanol maser in M8E.





Other Unique EVLA Projects Now Scheduled

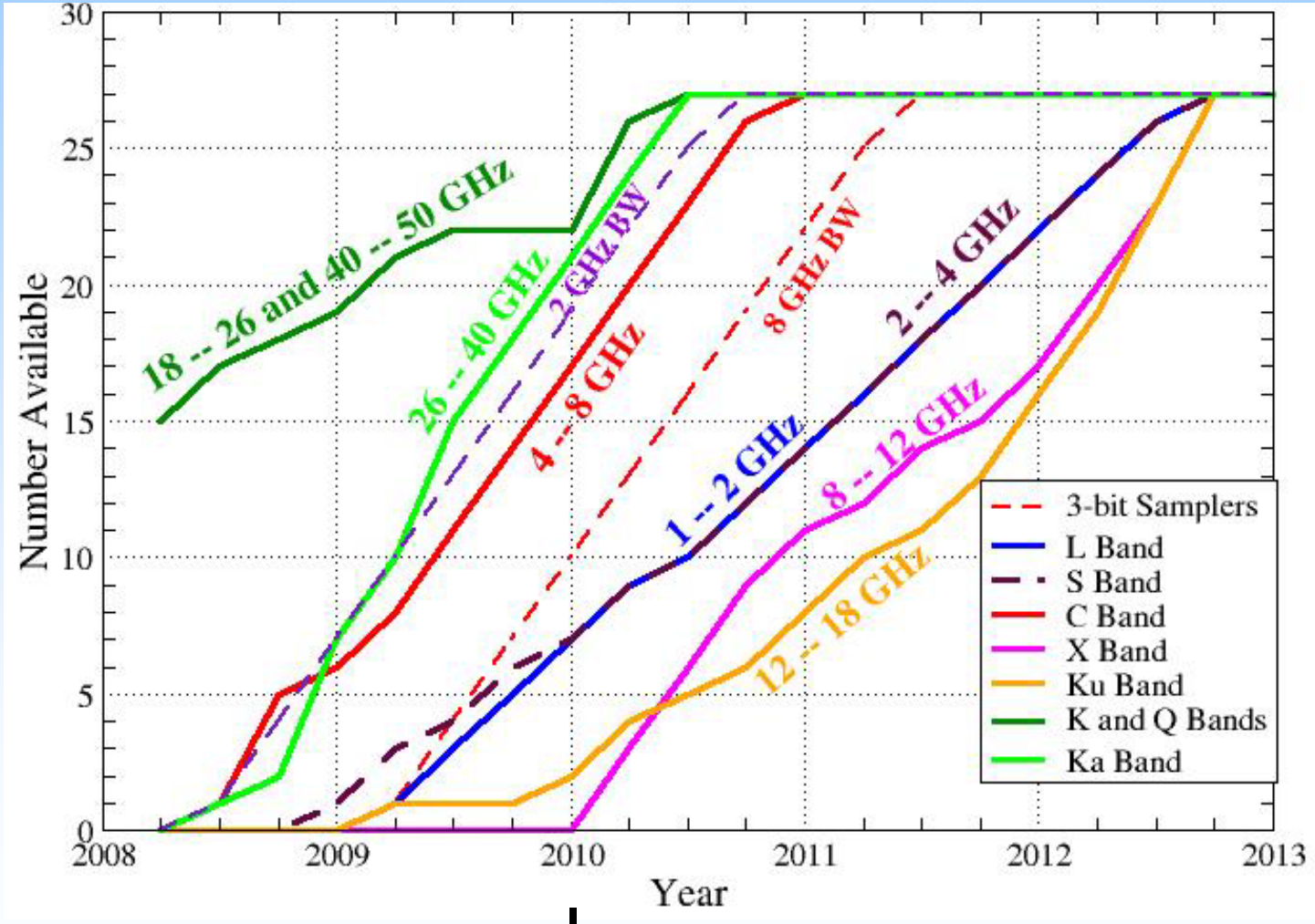
- Users have noted the increased frequency access:
  - 32 proposals accepted for C-band frequencies outside the VLA 4.5 – 5.0 GHz window.
    - Galactic science proposals involve methanol, excited OH, and formaldehyde masers in star forming regions.
    - Extragalactic science involves H_2O masers near z = 2.
  - 9 proposals accepted for expanded K-band coverage.
    - Science goals mostly involving high-redshift (z ~ 2 – 5) molecular emission from young galaxies.
- With more frequencies opening up, the interest in observing in these new bands will increase.
  - Most significant new capability in 2009 will be availability of Ka-band (26.5 – 40 GHz)

Antenna and Wideband Receiver Availability

- VLA antennas are being converted to EVLA antennas at a rate of 6/year.
  - 18 now converted. Conversion completed mid 2010.
- Upon conversion, EVLA antennas are outfitted with:
  - available wideband receivers (K, Q initially, now C, K, Ka, Q),
  - An existing VLA narrowband receiver, (X)
  - An ‘interim’ EVLA receiver – full tuning range, but limited sensitivity and polarization (C, L initially, now only L),
  - No receiver (Ku, S)
- New receivers will be outfitted on EVLA antennas in the field, as designs are finalized, and production enables.
- Three bands still to be designed/tested: S, X, Ku
- All receiver outfitting/retrofitting will be completed by end of 2012.

Wideband Availability Timescale

- When will full wideband tuning capability be available?

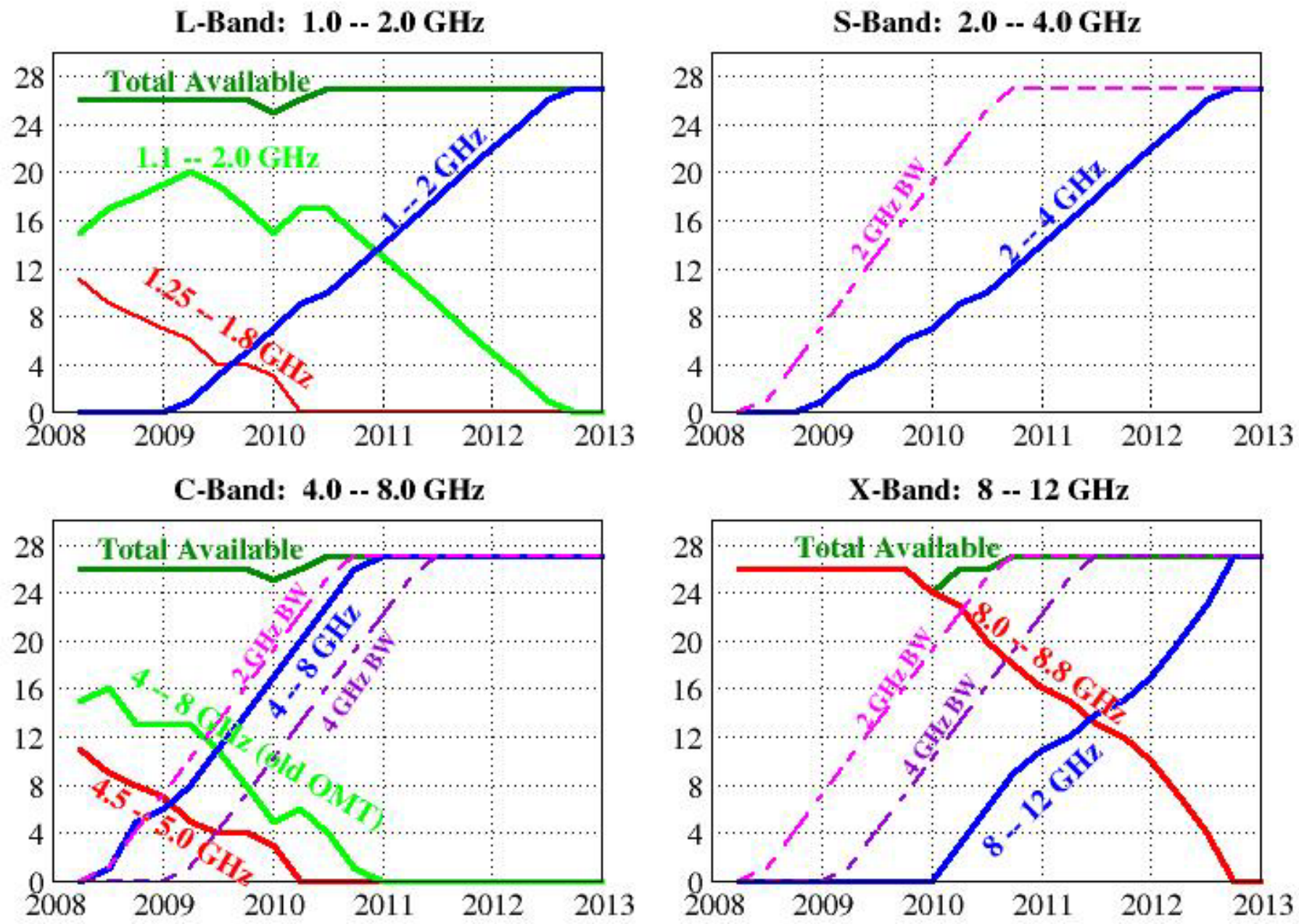


VLA Correlator | WIDAR Correlator

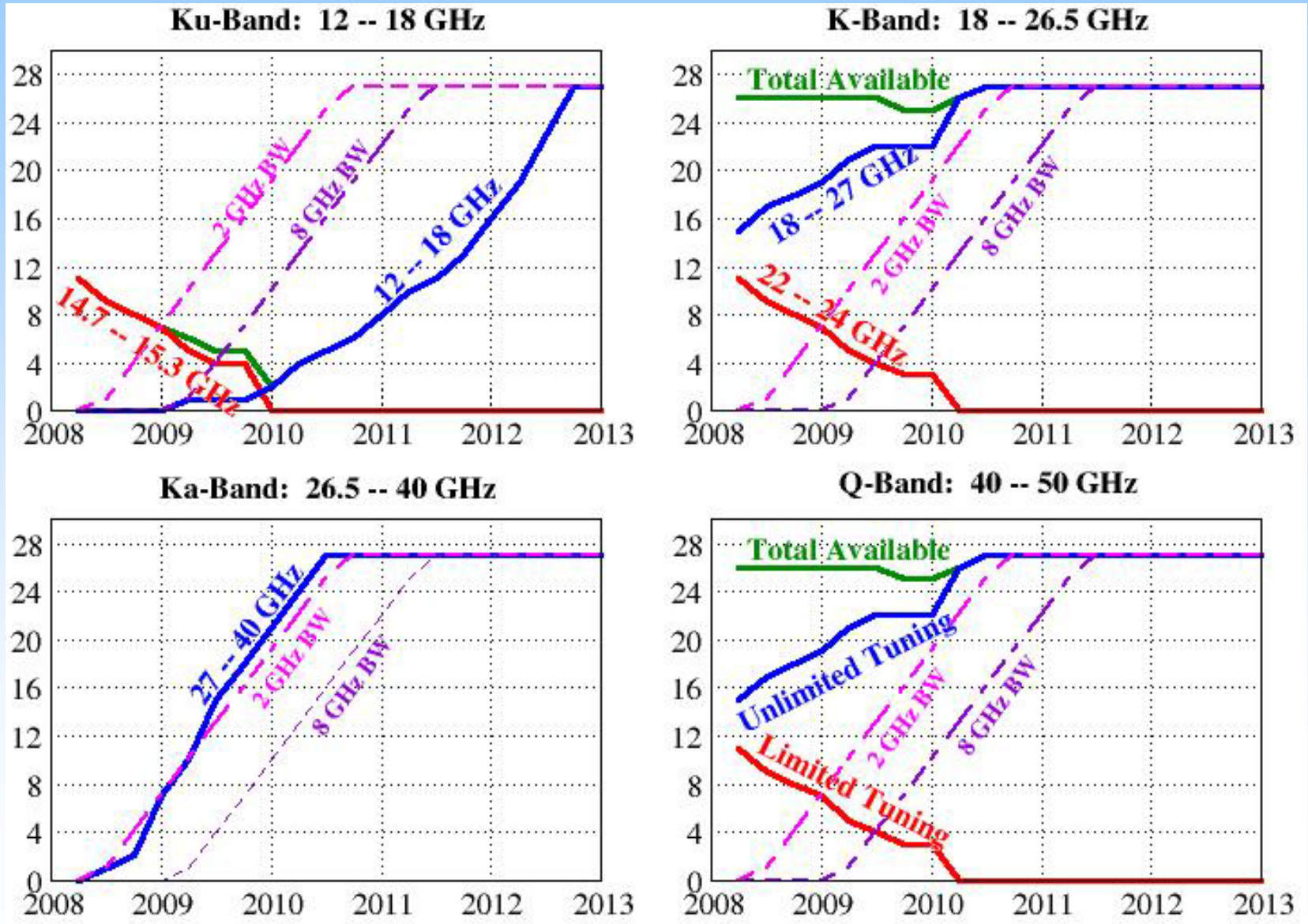
It’s Better Than It Looks!

- Wideband availability plot does not include capabilities of VLA antennas and ‘interim’ EVLA bands.
- Next two slides detail the capabilities growth for each band.

Low Frequency Bands Capability Growth



High Frequency Bands Capabilities Growth



Notes for the Previous Slides

- To describe the evolution of frequency access, we must define three kinds of receivers/antennas:
  - Old VLA – the old narrowband receivers, and the < 400 MHz frequency separation restriction between the two IF pairs.
  - Interim EVLA: (C, L bands) Full tuning range, no restriction on IF pair frequency separation, but great degradation in sensitivity and polarization outside the traditional VLA bands.
  - Final EVLA: Full bandwidths, no tuning restrictions.
- With this, the growth in **tuning** capability **using the VLA correlator** can be described fairly simply.
  - Still two IF pairs, maximum 50 MHz BW, maximum 512 channels.
  - A maximum of 22 EVLA antennas will be available to the VLA correlator.
  - Hence, after August 2009, the total number of antennas available will decrease with time, until WIDAR is on-line.
- In January 2010, remaining (~3) VLA antennas will be turned off when WIDAR correlator is brought on-line.

Increasing the Bandwidth

- Obtaining wider bandwidths and more channels requires the WIDAR correlator.
- The switchover to WIDAR cannot be a ‘1-step’ process.
- New hardware needed to enable wider BW: a second LO pair, a second downconverter pair, and the 3-bit samplers.
  - All EVLA antennas provide 1 GHz BW now.
  - 5 EVLA antennas can provide 2 GHz BW now, rising at 1/month.
  - Full 8 GHz BW upgrade starts early next year, completed by mid 2011.
- WIDAR station boards, baseline boards.
- New software – both within WIDAR and in post-processing -- needed to manage the dataflow and increased flexibility.

The Growth of WIDAR

- Critical on-sky tests (just completed) with 4-station WIDAR prototype.
- Initial implementation of the final WIDAR will be a 10-station system for further testing (known as WIDAR-0).
  - Planned to begin February, 2009.
  - Not available for science!
- In January 2010, WIDAR-0 will expand to handle all available EVLA antennas in a ‘VLA Emulation’ mode.
- What is this?

‘VLA Emulation Mode’

- We plan to replace the existing VLA correlator with WIDAR in mid-January, 2010.
- The initial WIDAR setup will provide, for all EVLA antennas, two basic modes:
  1. Two independent sub-band pairs of 128 MHz each, with full polarization, and 64 channels/correlation.
  2. One sub-band pair, RR and LL polarizations, 128 MHz BW, 256 channels per correlation.
- For both modes, the bandwidth can be divided by powers of two while keeping the number of channels fixed.
- We will remain in this state for some time to ensure reliability and stability.

OSRO WIDAR modes (1)

- Continuum applications and spectro-polarimetry
  - Two independently-tunable sub-bands (IFs), full polarization, each with bandwidth $128/2^n$ MHz (n=0,..,12), 64 channels

Sub-band BW (MHz)	Number of poln. products	Number of channels/poln product	Channel width (kHz)	Channel width (kms^{-1} at 1 GHz)	Total velocity coverage (kms^{-1} at 1 GHz)
128	4	64	2000	600/ν(GHz)	38,400/ν(GHz)
64	4	64	1000	300	19,200
32	4	64	500	150	9,600
16	4	64	250	75	4,800
8	4	64	125	37.5	2,400
4	4	64	62.5	19	1,200
2	4	64	31.25	9.4	600
1	4	64	15.625	4.7	300
0.5	4	64	7.813	2.3	150
0.25	4	64	3.906	1.2	75
0.125	4	64	1.953	0.59	37.5
0.0625	4	64	0.977	0.29	18.75
0.03125	4	64	0.488	0.15	9.375

OSRO WIDAR modes (2)

- Spectral line applications
  - One tunable sub-band (IF), dual polarization, with bandwidth $128/2^n$ MHz (n=0,..,12), 256 channels

Sub-band BW (MHz)	Number of poln. products	Number of channels/poln product	Channel width (kHz)	Channel width (kms^{-1} at 1 GHz)	Total velocity coverage (kms^{-1} at 1 GHz)
128	2	256	500	150/ν(GHz)	38,400/ν(GHz)
64	2	256	250	75	19,200
32	2	256	125	37.5	9,600
16	2	256	62.5	19	4,800
8	2	256	31.25	9.4	2,400
4	2	256	15.625	4.7	1,200
2	2	256	7.813	2.3	600
1	2	256	3.906	1.2	300
0.5	2	256	1.953	0.59	150
0.25	2	256	0.977	0.29	75
0.125	2	256	0.488	0.15	37.5
0.0625	2	256	0.244	0.073	18.75
0.03125	2	256	0.122	0.037	9.375

WIDAR Science, 2010 and Beyond

- All WIDAR hardware components will be here by December 2009.
- Expanded WIDAR observational capabilities will be commissioned through 2011. (Is earlier possible?)
  - Growth path not finalized.
  - Most likely path is to maximize bandwidth quickly, with limited flexibility.
  - Expanded capabilities to be made available to RSRO participants.
- More complicated and flexible modes to be added later – timescales set by availability of resources.
  - Increased number of channels
  - Greatly increased frequency resolution
  - Flexible correlator resource allocation
  - Pulsar mode observing
  - Phased array mode observing

Major Future Milestones

- Test 4-station prototype correlator on the sky — July ’08 – Feb. ‘09
  - Four antenna test and verification system
- Testing of 10-station correlator: — Feb. ’09 – Jan. ‘10
- Full Correlator Installation — May ’09 – Dec. ’09
- VLA’s correlator turned off — Jan. 2010
  - WIDAR correlator capabilities will be much greater
  - About 25 EVLA antennas will be available.
- Shared Risk Observing Begins — Jan. 2010
- Last antenna retrofitted — Sept. 2010
- Last receiver installed — Sept. 2012