VLBA Upgrade: Scientific, Observational, and Technical Requirements

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This memorandum re-issues slides originally presented at an NRAO Long-Range Planning Retreat in Socorro on 2000 September 20. This presentation concentrates on the technical requirements abstracted from the science drivers originally presented at the preceding Planning Retreat. It is re-issued in the Sensitivity Upgrade Memo Series as background material, to demonstrate both the continuity of the current effort, and the contrast in some important details.

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Short-Term Enhancements (Already Under Way)

3-mm Observing Band

- Receivers: 3 old + 2 new + 1 hybrid operational by December.
- Receivers: 2 more new operational in 2001.
- Main- and sub-reflector holography system: first test next week.
- Pointing: several new features operational, or about to become.

512-Mbps Recording Capability

- Installed at 7 VLBA stations; "all modes" test recorded last week.
- To become operational by first or second quarter of 2001.

Short-Term Enhancements

Incorporate GBT and Arecibo Into VLBA Operations

- GBT already has VLBA Data Acquisition System.
  - Built as part of VLBA project, used at 140-Foot for several years.
  - Could be integrated and tested once IF system is ready.
- Arecibo is buying VLBA-compatible DAS.
  - First tests whenever they are ready.

Phase Stability and Coherence

- Improved measurement-based modelling of ionosphere (GPS) and troposphere (WVRs).

Long-Range VLBA Upgrade

Scientific Requirements

Reviewed in detail at least Retreat (99/4/23).

Major Research Areas ---

- Studies of AGN “jet launching regions”.
- Blazars with gamma-ray flares.
- Location and velocity of gamma-ray burst blast waves.
- Mapping ionized gas in AGN cores.
- Studies of Galactic “microquasars”.
- Line absorption against compact continuum sources.
- Cosmological distance scale.
- Astrometry, parallax and proper motion of galactic objects.
- Extragalactic astrometry.

Observational Requirements

Greater Continuum Sensitivity

Greater Spectroscopic Sensitivity

Greater Low-Brightness Sensitivity

Greater Spatial Resolution

Continuous Frequency Coverage

Technical Requirements (in Descending Priority)

1. Expanded Bandwidth
   … through IF / Baseband / Recorder / Correlator subsystems.
2. Additional Antennas Close to VLA
3. Additional Distant Antennas
4. New or Expanded Frequency Ranges
5. 22-GHz Receiver Upgrade
   … to EVLA design with WVR capability.

Expanded Bandwidth --- 1
Upgrade VLBA Recording System

Expansion Path to 1 Gbps Designed into Existing System

- Hardware requirements studied; cost estimate 3 M$.
- Requires no expansion of IF/BB capacity, nor of correlator.
- BUT: *Operationally unsustainable* beyond small fraction of time, under current operations scheme. Must either ---
  - Operate VLBA stations on staggered shifts, or
  - Increase operations budget to hire part-time tape changers.

Fundamentally, Substantial Increase in Recorded Bits/Day

- … REQUIRES AUTOMATED TAPE CHANGING, i.e.:
- New, cassette-based recording system.

Expanded Bandwidth --- 2a
NEW Recording System: 1 Gbps

"S3" System

Crestech, York University, Toronto.
Based on modified commercial digital VCR from JVC.
Commercial changer from Tiltrac, capacity 60 hours at 1Gbps.
Status: Development of recorder and changer well advanced.
Estimated Availability*: 2002 -- 03.
Estimated Cost*: 75 -- 90 K$ per station.

* Rough estimates based on current market conditions.

Requires:

New VLBA correlator playback interface.

Expanded Bandwidth --- 2b
NEW Recording System: 1 Gbps

"MOTS" System

Haystack Observatory.

Based on off-the-shelf 'LTO' (future-generation DLT) drives.

Only special-purpose VLBI hardware is standard VSI module.

Status: Conceptual study.

Estimated Availability*: 2002 -- 03.

Estimated Cost*: 96 K$ per station.

* Rough estimates based on current market conditions.

Requires:

New VLBA correlator playback interface.

Expanded Bandwidth --- 3a
NEW Recording System: *8* Gbps

"S4" System

Further development of S3 system.

Status: Conceptual study.

Estimated Availability: TBD.

Estimated Cost: TBD.

Requires:

Expansion of IF/BB electronics.

Entirely new correlator -- or VLBI capabilities in EVLA correlator.

Expanded Bandwidth --- 3b
NEW Recording System: *8* Gbps

"MOTS" System

Further development of 1 Gbps system.

Status: Conceptual study.

Estimated Availability*: 2007.

Estimated Cost*: 108 K$ per station.

* Tenuous extrapolation from current market conditions.

Requires:

Expansion of IF/BB electronics.

Entirely new correlator -- or VLBI capabilities in EVLA correlator.

Expanded Bandwidth --- 4
Real-Time Transmission Systems

Recording System has always been Achilles' Heel of VLBI.

- Is technology ready yet to switch to (near) real-time, wideband transmission system at reasonable bandwidth?
- *Unfortunately, can't answer this question at present.*
- Consensus at recent URSI Global VLBI WG meeting: will need one more magnetic recording generation.

Real-Time Transmission Systems

Will have to Decide for EVLA New Mexico Array

- Magnetic recording would be awkward for NMA (+VLA), but not impossible.
- Dedicated fiber link (like VLA-PT) probably not feasible for real-time transmission for entire NMA.
- Would have to use public packet-switched networks.
- Already demonstrated for similarly short-range VLBI in Japan.

Public Network Only Option for VLBA Distances

- Feasibility, current and expected future bandwidth unknown.
- Under discussion in Europe.
- Study not yet started in U.S.

Additional Antennas

Close to VLA

… for increased spectroscopic sensitivity.

… and for increased low-brightness sensitivity.

Identical to EVLA Phase 2 New Mexico Array.

Beyond Outer VLBA Stations

… for increased angular resolution.

Would have to be located beyond US territory.

South American sites (possibly including ALMA site) would enhance N-S coverage and visibility of southern sources.

Other “new” antennas might include closer operational connections to dedicated VLBI stations in Europe.

Frequency Ranges and Receiver Upgrade

Particular Frequency Ranges of Interest

… from Scientific Requirements:

300 -- 1200 MHz	Redshifted HI lines.
800 -- 2300 MHz	Ionospheric calibration for astrometry.
6 GHz	OH and methanol maser lines.
20 -- 50 GHz	Redshifted molecular lines.

Additional Dual-Frequency Pairs Also Valuable

22-GHz Receiver Upgrade

WVR capability of EVLA design important for phase stability.

RECOMMENDATIONS

Establish working relationship with, and monitor progress of, both university groups developing new recording systems.

Start combined feasibility study of real-time data transmission, for both NMA and VLBA. (Could also address SKA needs.)

Study VLBA symbiosis in EVLA correlator.

Study array configuration for “EVLBA”.

QUESTIONS

What bandwidth capacities and costs can we realistically anticipate, both for magnetic recording and for real-time transmis-sion over NM/US/global distances, 5 -- 15 years in the future?

Should we aim at a 1-GHz “interim” capability, or go straight to the 8-GHz option?

Can the EVLA correlator (i.e., the DRAO “WIDAR” design) accommodate VLBA correlation as well, at reasonable cost?

What maximum bandwidth is optimal for such a solution?