



Owens Valley, California

Instrumental Compatibility for the HSA & Global VLBI



Brewster, Washington

North Liberty, Iowa

Hancock, New Hampshire



Jonathan Romney
NRAO / Socorro

3rd International VLBI Technology
Workshop

2014 November 10 – 13

Maun

Los Alamos, New Mexico

Kitt Peak, Arizona

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Fort Davis, Texas

St. Croix, Virgin Islands



VLBA Sensitivity Upgrade

First Major Upgrade Since VLBA Inauguration in 1993.

Initial concepts developed 1999 – 2000.

Sensitivity Upgrade Memos #2 & #3

(science.nrao.edu/facilities/vlba/publications/memos/upgrade)

Many elements later cited in 2004 Taylor – Lonsdale report.

(www.vlba.nrao.edu/astro/VLBI_Future/future.pdf)

Project established 2007, with initial funding.

Decided *against* "VLBA2010" name.

Overall concept:

Replace everything downstream from IFs with modern technology.

Match limits of existing IF system; sample directly in IF.

All further processing digital.



Goals & Status

Initial Project Goal: “4 Gbps by 2011”.

Instrumentation designed and built for 4 Gbps throughput.

Budget limited recording system to 2 Gbps.

Estimated cost of new units and media for 4 Gbps operation: 0.9 – 1.2 M\$.

Initial, limited 2-Gbps operation began February 2012.

NOW FULLY OPERATIONAL

(... on the VLBA, + others detailed later.)

“Last bug” corrected more than four months ago.

You are the first audience to hear me say this in person.



Overview of New Instrumentation

RDBE = “ROACH Digital Backend”

ROACH = “Reconfigurable Open Architecture Computing Hardware”, developed by KAT / NRAO / CASPER collaboration.

RDBE includes CASPER samplers, NRAO ALC and synthesizer modules, and Haystack on-board control software.

FPGA firmware developed by Haystack / NRAO collaboration.

Mark 5C Recording System

Joint development by NRAO / Haystack / Conduant Corp.

Dual-module recording considered operationally unsustainable on the VLBA; maximum single-module recording rate is 2 Gbps.



Two Basic Functional Modes

PFB (Polyphase FilterBank)

Developed (primarily) by Haystack Observatory.

Operates in second Nyquist zone; fundamentally LSB.

Fixed **16 x 32-MHz** channel configuration; requantized to 2 bits.

Only 15 channels of usable data.

Fixed 2048 Mbps output data rate, in mark5b emulation format.

Channels selectable from **2 IF inputs**; placeable in 32-MHz steps.

Frequently used observing configurations:

Compact dual-polar: 8 contiguous channel pairs, centered in IFs.

Spanned single-polar: 16 contiguous channels spanning entire IF.

Workhorse for wideband continuum observations.

Currently only one mode supported per observation.



Two Basic Functional Modes

DDC (Digital DownConverter)

Developed by NRAO.

Full capabilities require dual-RDBE configuration.

“Last Bug” occurred in this mode.

Configurations

1,2,4,8* channels; equal bandwidths of 128* / 64 / 32 / ∞∞∞ / 1 MHz.

Channels selectable from 4* IF inputs.

* 8-channel or 4-IF modes require dual-RDBE hardware configuration; maximum 8-channel bandwidth: 64 MHz (i.e., 2-Gbps recording).

Limit of 4 channels per RDBE required for optimal filter shapes.

Frequencies settable in steps of 15.625 kHz.

But may not cross IF “zone boundaries” at 640 and 896 MHz.

Requantized to 2 bits, VDIF format; possible future upgrade to >2 bits.

Currently only one mode supported per observation.



Recent Developments

Full-Time RDBE Operations

Significant shift from DDC-4 to DDC-8 mode since July 2014.

Throughput in Aug-Sept-Oct quarter:

Total observing time: 1015 hours (46% of full time).

Total recorded data: 746 TB *per station* (108% of predicted media requirement!).

RDBE “Last Bugs”

Setup failures in DDC-8 mode: (mostly) fixed.

“4x4” IF switch setting failures: correction developed.

Bandwidth-dependent delays: fix designed, installation pending.

Other VLBA Issues

New first-LO synthesizer designed & verified.

Amplitude calibration issue identified; still under study.

New ‘track’ disk-module management system nearly ready.



Beyond the VLBA: the High Sensitivity Array (HSA)

HSA is a limited set of large-aperture radio telescopes, jointly scheduled with the VLBA, from a single observing proposal:

EVLA WIDAR correlator has operational RDBE-like modes; recording on a Mark 5C unit.

Currently only available in non-subarrayed "Y27" configuration.

GBT is completely implemented as a VLBA station.

Effelsberg has developed scripts to operate RDBE / Mark5C from the Field System.

All modes (PFB, DDC-4, DDC-8) operated correctly in a recent test.

Arecibo plans to adapt Effelsberg script approach.

Has previously operated successfully in PFB mode.



Beyond the VLBA: the Global cm-Wave Network

VLBA + EVN Stations, Proposed Jointly

Most EVN Stations Use DBBC-2 Units

Highly compatible with RDBE.

Differences in extremes of number of channels and bandwidth.

DBBC/PFB may produce 32 (or more) 32-MHz channels.

RDBE/PFB could also produce – but not record! – 32 channels.

DBBC/DDC supports 16 channels, but limited to 16-MHz channel BW.

Well-matched tuning quanta.

$1024 \text{ MHz} / 2^n$: $n = 32 \Rightarrow 238 \text{ mHz (DBBC)}$.

$n = 34 \Rightarrow 59.6 \text{ mHz (RDBE)}$.

In both cases, requirement for integral number of cycles in 1 second dictates practical quantum of 15.625 kHz (5^6 Hz ; $n=16$ above).

Also, if compatibility with legacy systems is required, both systems are limited to 250-kHz tuning steps.



Beyond the VLBA — the Global cm-Wave Network

“Hybrid Mode” May Resolve Most Mismatches

FX correlators can process different numbers of data channels spanning the same total bandwidth.

Frequency resolutions per spectral point must match in cross-multiplier.
Easier (probably) to implement in a software correlator.

Actually used in original VLBA correlator, for Mark 3(A) format.

Recently demonstrated in JIVE / SFXC and MPIfR / DiFX.

Concern about channel mapping of T_{sys} data in Socorro / DiFX.

Two user groups recently agreed to develop this capability.

Review of First-LO Standards May be Desirable

New, wider observing bandwidths may make current standards unfeasible or sub-optimal in some cases.



Of Course, Testing Will be Required :-)

Initial RDBE/DBBC Tests Already Successful

... at JIVE and MPIfR.

Specific VLBA-Based Tests may be Needed

... before including or referencing in NRAO Call for Proposals.

HSA observations prematurely scheduled in early 2013 failed, incurred substantial observing-time cost to re-observe.

Probably (hopefully) sufficient to include just one station with each type of digital signal processing.

Volunteers or suggestions invited.



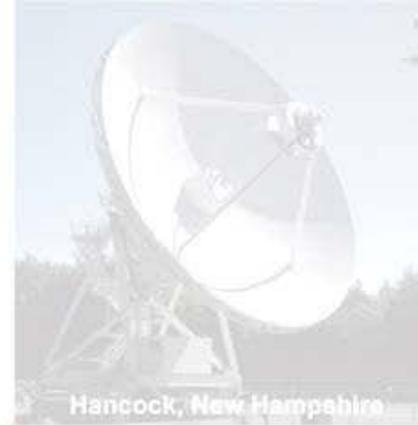
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North Liberty, Iowa



Hancock, New Hampshire



Maunakea, Hawaii



Thank you



Los Alamos, New Mexico

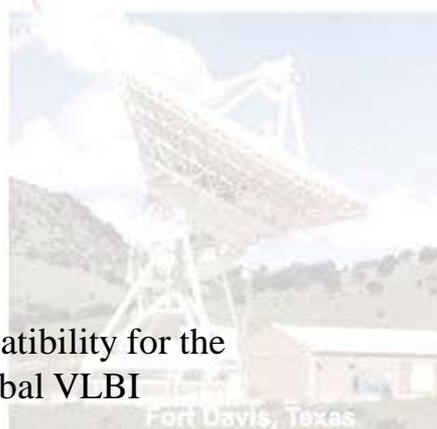


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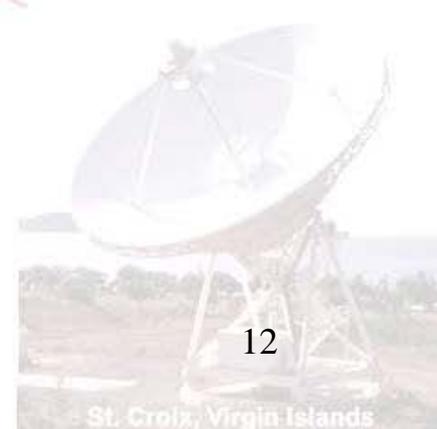
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