VLBI Digital Backend Program

Sheperd Doeleman
Haystack Observatory
Motivation for wideband DBE

• VLBI data rates up by only x4 since 1980’s.
• Modern FPGAs give increased performance at small fractions of Mark4/VLBA cost.
• For continuum obs. widebanding cost effective vs. larger dishes: 512Mb/s to 4Gb/s same as 42m VLBA dishes.
• DBE systems are portable.
• Wideband obs. important for key science.
• Industry driven growth path.
Current modes: 15 channels, each 32MHz, 2-bit = 1920Mb/s
15 channels, each 16MHz, 2-bit = 960Mb/s
DBE at Last Meeting

• Inputs:
  – Single 512 MHz IF
  – 1PPS (from GPS)
  – 1024MHz clock (clock board takes 5/10MHz)
  – Serial cable: arm 1PPS, set/read digital gains.

• Outputs:
  – Single VSI output.
  – 2Gb/s output – but only 1Gb/s recorded (sign).
Prototype DBE

Developed in collaboration with Berkeley Space Sciences Lab

Sampler boards

dBOB
Tests with last DBE Prototype

• X-band obs. between Westford-GGAO.
  – successful test with simultaneous Mark4/Mark5A and DBE/Mark5B recordings.
  – Excellent agreement between Mark4 and DBE fringes.
  – SBD and MBD for DBE fringes agree to within ambiguity: consequence of PFB.

• Field system running on Mark5B, channel gains set manually via serial link from Mark5B to DBE.
DBE X-band Fringes: 1Gb/s
Current DBE Status

• 2 x 512MHz IF inputs
• 2 VSI outputs, each 1.92 Gb/s
• State Counts
  – Determined from Mark5b data.
  – Digital gains set accordingly.
• 16 or 32MHz channels.
  – 32MHz: 8 tap filter.
  – 16MHz: 4 tap filter: VLBA/Mark4 compatible.
86GHz VLBI

SMTO-CARMA: 3C354.3 - 512Mb/s = 8 x 32Ms/s x 2bits/samp.
86GHz VLBI

VLBA_OV-CARMA: RCas (SiO maser)
230GHz VLBI

SMTO-CARMA: 3C273 - 1.92Gb/s = 15chan x 64Ms/s x 2bits/samp
230GHz VLBI

SMTO-CARMA: 3C273

Mk4 Fringe Plot

3C273.svpavm, 101-0740, SC
SMTO - CARMA, fgroup U, pol LL

multiband delay (μs)

delay rate (ns/s)

singleband delay (μs)

Avgd. Xpower Spectrum (MHz)

phase (deg)

amplitude
230GHz VLBI

SMTO-CARMA: 1749+096

Tcoh~20sec
230GHz VLBI

SMTO-JCMT: 1749+096 - 60uas fringe spacing. Tcoh~60sec
Near Term Plans

• Firmware:
  – Implement channel selector and VSI input on iBOB for Geodetic bandwidth synthesis: “daisy chain”.
  – 10GbE interface for burst-mode and COTS recorder.
  – 10GbE protocol.

• Observations:
  – 230GHz VLBI of Galactic Center and Quasars at 4Gb/s.
  – 5GHz observations of Gravitational Lens systems to search for central images.
  – Observations with VLBA, Arecibo on other projects.
1-2 Year Plans

• **Hardware:**
  - Re-design of DBE board (in collaboration with NRAO)
    - new 3Gs/s sampler
    - Xilinx Virtex5 FPGA
    - 10GbE output
  - IF processing front end: input is 100MHz to 15GHz IF, output is filtered 512MHz band. ($7.5-10K)

• **Firmware:**
  - State Count level correction on-board DBE; possibly done on Mark5B with serial feedback.
  - Optimize Filter shapes (increase FIR/Interpolator taps).
  - Pulsar gating capability.
  - Digital Downconverter implementation for spectral line applications.

• **Software:**
  - Control software integration.
  - Solution to DBE mode switching.
Flexible “Front-End Converter” for DBE

• Problem: Different systems need different IF frequency ranges
  – Even Mark 4 and VLBA systems use different IF ranges
  – Many modern RF/IF systems, particularly those at mm wavelengths, employ IF frequency ranges as high as 10-12 GHz
  – Often requires custom electronics at each such VLBI site

• Proposal is to couple a flexible dual-polarization IF frequency converter to the DBE for easy adaptability to almost any existing RF/IF system
Burst Mode

4 x 500MHz IF

Station 1PPS

H-maser 5/10MHz

4 x 500MHz IF

DBE

4Gbps bursts
10GigE
4Gbps bursts
10GigE

Buffer PC

10GigE NIC
32GB RAM

Buffer PC

10GigE NIC
32GB RAM

100 Mbps SATA2

4-disk SATA RAID

Station 1PPS

H-maser 5/10MHz

4 x 500MHz IF

Control PC

Completely COTS

Control

Pulsar-gating

Completely COTS