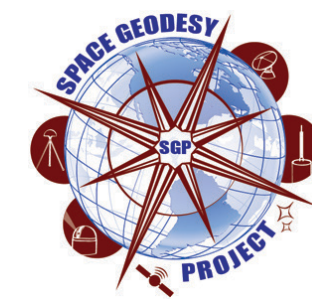# Rolling out the MIT/NASA Next-Generation VLBI Broadband Signal Chain

C. Ruszczyk, G. Rajagopalan, R. McWhirter, C. Eckert, P. Elosegui, R. Wilcox, J. SooHoo, A. Burns, K. Wilson, P. Bolis, D. Sousa, M. Titus, J. Byford, M. Goodrich, M. Derome

VGOS, the next-generation broadband signal chain for VLBI Geodesy by MIT/NASA, incorporates a number of technology novelties such as the Calibration Delay Measurement System (CDMS) and the ROACH2-based digital backend (R2DBE). The former is a key component for accurate estimation of instrumental delays; the latter supports 1-GHz bandwidth sampling capability. The CDMS adds active picosecond-level cable delay measurement capabilities to the MIT Haystack calibrator to correct for cable delays, signal phase, and amplitude across the full VGOS band. The R2DBE is currently undergoing zero-baseline testing at the Westford VLBI station.
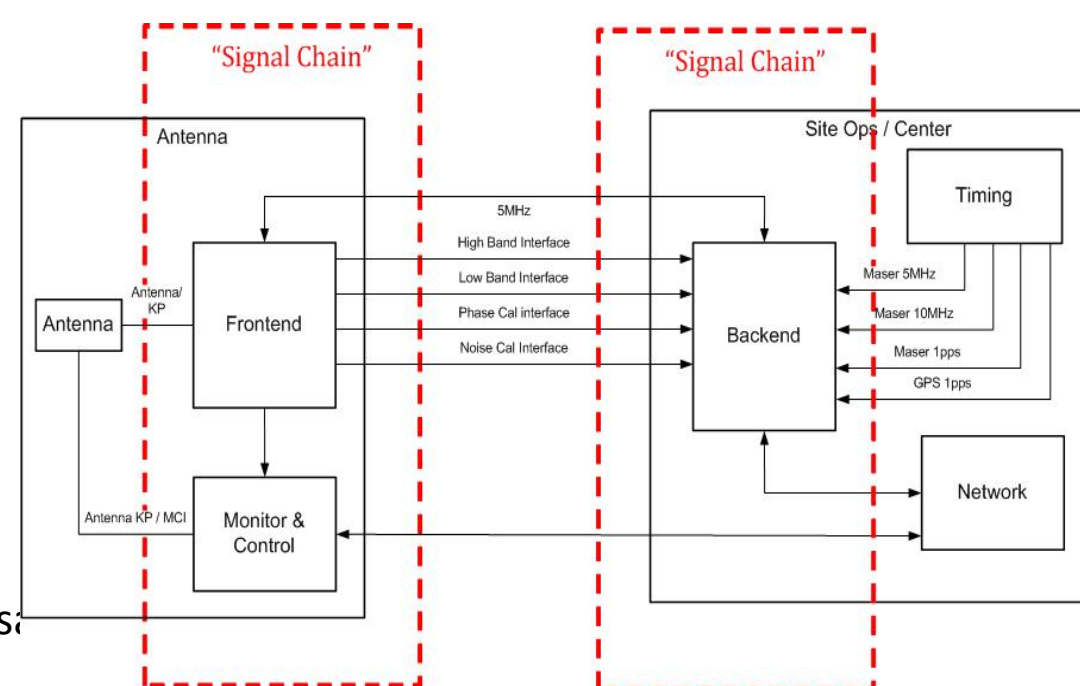
VGOS VLBI Signal Chain Frontend

- Frontend noise temperature 40K over 2-14 GHz (max – excluding atmosphere)
- Feed efficiency > 50%
- Aperture efficiency ~ 70% over 2-14GHz
- Spur free dynamic range 90dB in 1Hz bandwidth (min)
- Dual linear H/V polarization with -20dB isolation
- Support for pre-LNA instrumental phase and amplitude monitoring

VGOS VLBI Signal Chain (SC) Backend

- Supports the Frontend receiver signal to independently to 4 tunable IF conversion sub bands (RF Distributor v. 2.0)
- Supports 2-14GHz RF down conversion to 2GHz baseband output (UDCs v 2.0)
- Digitizes 512MHz IF bandwidth into 16x32 MHz complex signals into 2bit VDIF format (RDBE-G v. 3.0)
- Records data to disk modules at data rates up to 16Gbps (Mark6)
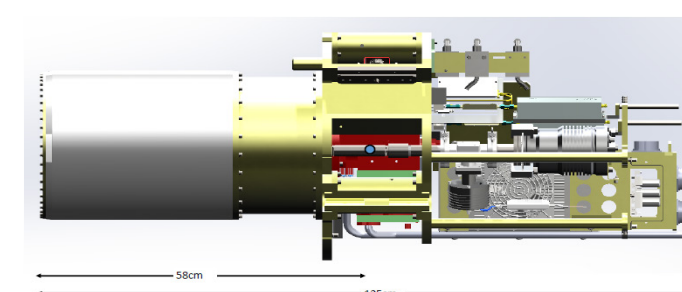
Calibration

- Provides calibration system for determining instrumental delays in VGOS system (cable delays, signal phase, and signal amplitude)
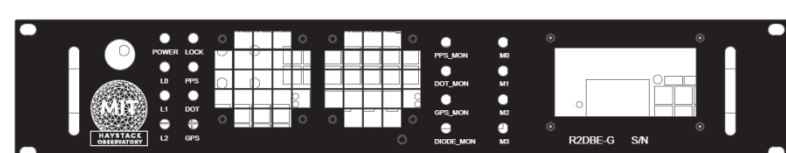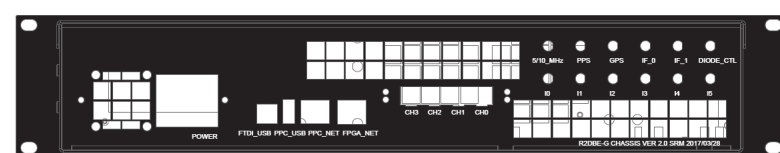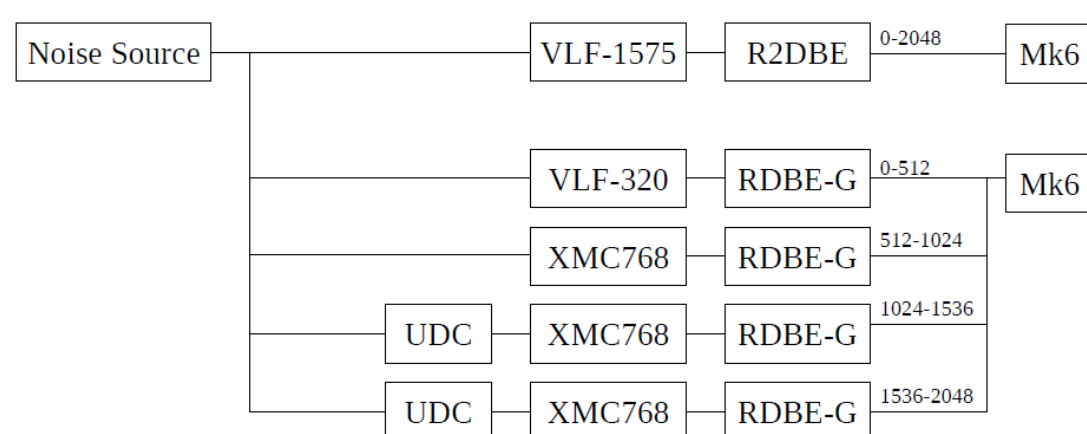

VGOS VLBI SC architecture

VGOS VLBI SC frontend

VGOS VLBI SC Backend at KPGO

RDBE-G Front Panel

RDBE-G Back Panel

RDBE-G / R2DBE Testing

R2DBE-G v. 4.0

MHO's 4th-generation digital backend, based upon the Roach2 and Virtex 6 FPGA, is 100% VGOS compliant.

- Supports a 2 IF x 2048 GHz (H&V-pols) IF bandwidth digitized into 64x32 MHz complex signals into 2 bit VDIF format.
- ASAIA 5 G sps ADC (2,4,8,16 Gbps)
- Form factor (2U) is same as RDBE-G, with updated configuration
- Four 10G optical SFP+ interfaces
- Command Set is backward compatible with v3.0
- Extended multicast capabilities for monitoring (PCAL, TSYS)

Testing

- The polyphase filter bank (PFB) FPGA personality, v4.0, verified thru simulation and a zero baseline bench test with existing RDBE-G v3.0.
- Zero-baseline testing continues with RDBE-G v3.0 PFB personality over both 1024 and 2048 GHz bandwidth.
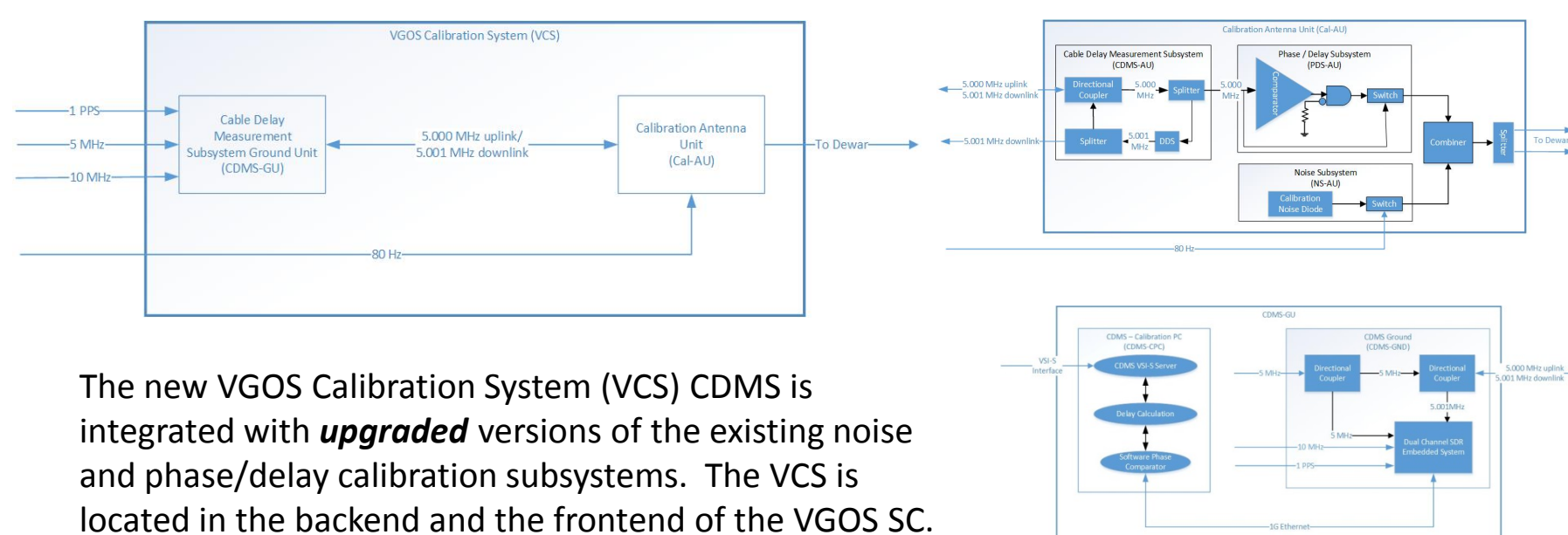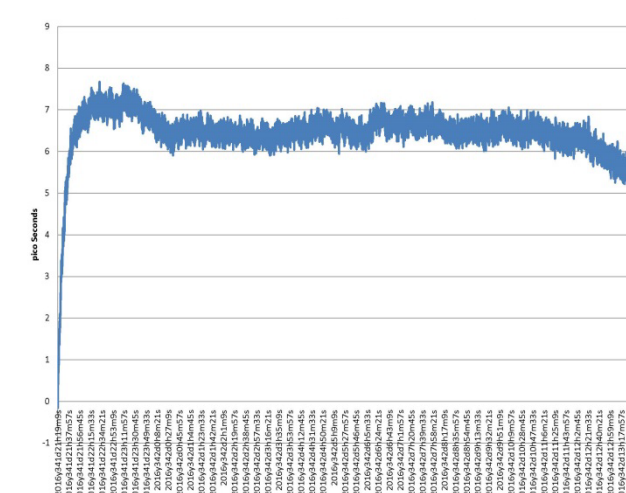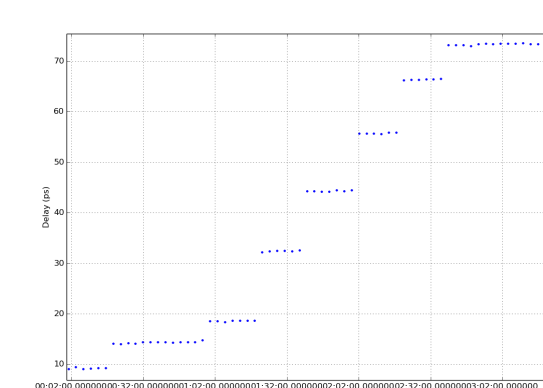
Calibration: CDMS

- CDMS involves monitoring the electrical length of the signal-carrying cables to enable corrections for cable length variations induced by mechanical, thermal, and any other effects with an RMS accuracy of ≤1 picosecond.
- CDMS delay stability is designed to exceed the following standards (Allan standard deviations): 1.8e-14 at 30 s, 5.5e-15 at 100 s, 9.0e-16 at 600 s and 1.0e-16 at 50 min.
- The default cable for delay calibrations is assumed to be an LMR400 coaxial cable; fiber optic cable support may be requested.

The new VGOS Calibration System (VCS) CDMS is integrated with *upgraded* versions of the existing noise and phase/delay calibration subsystems. The VCS is located in the backend and the frontend of the VGOS SC.

Stability tests are executed and the Allan standard deviations verified against requirements.

A trombone is inserted into the link to verify that the CDMS is measuring proper length changes with the results shown.