MIT Haystack / NASA
VGOS Signal Chain

10th IVS TOW Workshop
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Agenda

• Overview of Signal Chain
• Frontend Systems
• Backend Systems
• Calibration Systems
• Monitor and Control
• Command / Control Architecture
• Documentation Highlights
Overview

• Three versions of MHO Signal Chain
  • Developmental (Non-VGOS compliant – 512MHz bands)
    • 2.2 – 12 GHz (GGAO)
  • First generation (Non-VGOS compliant – 512MHz bands)
    • 2.2-14 GHz (Kokee, McDonald)
    • Operational consistent between sites
  • Second generation (VGOS compliant – 1024 MHz bands)
    • 2.2 – 14 GHz (Westford)
    • Roll out to other NASA sites expected 2020

• A complete signal chain consists of mechanical / network electrical distribution / instrumentation
Detail Block Diagram

ANTENNA

20K dewar

V-pol

H-pol

LNA

HIGH

LOW

RF distributor

V-pol

H-pol

LOW

HIGH

CONTROL ROOM

CDMS ground unit

H-maser

Mark6

UDC

RDBE

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Frontend Block Diagram
Receiver Payload

• 2-14 GHz Cryogenically cooled receiver
  • FE noise temperature of 40K max

• QRFH Feed
  • Efficiency > 50%

• Dual linear H/V polarization
  • Low band 2 – 5GHz
  • High band 4 - 14 GHz

• Supports
  • Pre-LNA instrumental phase / amplitude monitoring
  • Operational servicing
  • Operational control / monitoring
Signal Chain Calibration Subsystem

• Covered as a complete system for the VGOS signal chain
• Injection of phase / noise pre LNA
Frontend Payload Power Distribution Subsystem

- DC Breakout Board
  - Evolved from lessons learned during the KPGO12m FE troubleshooting
    - Short resulted in loss of FE subsystems
  - Power distribution / monitoring capabilities
  - Environmental monitoring
  - Accelerometer and Gyro monitoring
Monitor and Control Subsystem

• Frontend centralized monitor / control of the payload and antenna hub
  • 81 Monitor Control Points (MCP)
• Monitor subsystems
  • Environmental (temperature / humidity / pressure)
  • DC Voltage ( -5V, +5V, +15V)
  • DC Current
  • RF Power
  • Alarms (e.g. Compressor)
  • Linear Displacement (positioning system)
• Control
  • Variable Attenuators
  • Compressor functions
  • DC Power (Pre-amplifies, Calibrator, Compressor)
Monitor and Control Architecture

- Accessible to
  - PCFS
  - Grafana/infuseddb
- Information accessed
  - Ethernet
  - USB
  - RS232
- Nodes defined
  - Configuration files
- Data is logged
Frontend System
UpDown Converter (UDC)

- UDC’s support a 2-14GHz RF to IF frequency conversion
- Two versions exist:
  - 2.0 with KPGO/MGO
    - IF Output 512-1024MHz
    - Tuning range 2-12 GHz. 400 kHz resolution
  - 2.1 at Wf
    - IF output 512-1536MHz
    - Tuning range 2-16 GHz. 40 Hz resolution
    - Upgrade plan for NASA stations 2020
- Require 4 UDCs for VGOS signal chain
  - 1 low band (2.3 – 5 GHz)
  - 3 high band (4 -14 GHz)
- Configurable via Ethernet, e.g. PCFS, or front panel (manually)
- Variable attenuation 0-31.5dB
Roach Digital Backend (DBE)

- Roach DBEs supports 512 or 2 GHz IF BW to digital conversion output on 10 Gbps Ethernet Interface
- Two versions exist:
  - Roach1 (RDBE-G) at KPGO/MGO / Yj
    • 512 MHz band IF Input
    • Polyphase filter band (PFB) FPGA personality
    • 16 Channels complex data at 2Gbps
  - Roach2 (R2DBE-G) at Wf and Yj
    • 2 GHz band IF Input
    • Polyphase filter band (PFB) FPGA personality
    • 16/32/64 Channels complex data at 2/4/8 Gbps, respectively
- Upgrade plan for NASA stations 2020
- Outputs 10-100 MHz diode control for noise calibration system
- Require 4 DBEs for VGOS signal chain
Mark6

• 16Gbps data recorder (2013)
  • Astronomy / Geodesy dual use
• Records data to disk module
  • 4 Gbps guaranteed / module
  • Data can be shipped or e-transferred from system to correlator
  • Supports 8-80 TB disk modules
• NASA sites have 2 systems / site
  • Spare
• Software
  • control-plane / data-plane
• OS distribution is presently Debian
  • Future version will be a RedHat derivative (CentOS)
VGOS Calibration System

- Calibration Antenna Unit
  - Phase calibration injection
  - Noise calibration injection (sourced from one RDBE-G Unit – 10-100MHz)
  - Cable Delay Measurement System - AU

- CDMS Ground Unit
  - Cable Delay Measurement System – Gnd
  - Calibration PC - recorder
Calibration Antenna Unit
CDMS  Ground Unit

CDMS - Calibration PC (CDMS-CPC)

- CDMS VSI-S Server
- Delay Calculation
- Software Phase Comparator

1G Ethernet

VSI-S Interface

CDMS-GU

Cable Delay Measurement Subsystem - Ground (CDMS-GND)

- Directional Coupler
- Directional Coupler
- Dual Channel Software Defined Radio Embedded System
Command and Control - PCFS

Key
--- IF (Analog)
--- Digital Data (10G Ethernet)
--- Command and Control (1G / 100M Ethernet)
--- POE (private subnet – non routable)
Documentation

• For all systems
  • Users Manuals
  • Verification and Validation methods and results
  • Interface control documents
  • Installation procedures
    • Required for NASA safety
  • Safety analysis
  • Spare(s) guidelines
  • Maintenance procedures
  • Version control of all documents and systems
Questions?