Data Digitization & Transmission

Session Moderator: Chris Langley

Atacama Large Millimeter/submillimeter Array
Karl G. Jansky Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

Data Digitization & Transmission Overview and Issues

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NRAO

Session Considerations

- Requirements and parameter space for digitization and data transmission systems
- Scalability, and limitations, of current approaches
- Technical risks and issues
- Emerging technologies and opportunities
- Candidate architectures for ngVLA based on these discussions

Session Topics

- Jim Jackson: “Overview & current NRAO systems”
- Larry D'Addario: "Signal Organization for Long-distance Transfer with Wide-band Front Ends“
- Ron Beresford: "Radio Over Glass, Analog or Digital? Progress from Australia“
- Matt Morgan: "Integrated Digitization with Unformatted Serial Data Transfer“
- Frank Murden: "Analog Devices Ultra-wideband ADC Technology Roadmap"

NGVLA Current Thinking

- Antennas
  - 250+
  - 15 to 25m diameter
- Processed bandwidth
  - Up to 50 GHz
- Array configurations
  - Baseline plan is ~300km diameter circle centered on JVLA
  - Discussions of longer baselines to encompass all of NM, western TX, eastern AZ, southern CO, and northern MX
- Operating cost needs to be comparable to JVLA

NGVLA Proposed Frequency Coverage

- Three major bands
  - 1 to 8 GHz
    - Narrower BW, but likely greater bit depth than other bands
    - Key driver on physical size of receiver package
  - 8 to 50 GHz
    - May need to be broken into multiple bands
    - Performance of LNA's could require multiple receivers
    - Availability of wideband digitizers will affect LO/IF design
  - 70 to 115 GHz
    - Availability of wideband digitizers will affect LO/IF design

Current NRAO situation

- JVLA/ALMA
  - RF digitized in 1 to 2 GHz chunks
    - In antenna digitization
      - 4 Gsps / 3 bits (JVLA/ALMA)
        - » JVLA – ADC/Hittite HMC5831, Teledyne RAD004
        - » ALMA – custom device from Bordeaux
      - 2 Gsps / 8-Bits (EVLA)
        - » E2V TS83102G0B
  - Data Transmission
      - 12 In-house designed 10 Gbps psuedo-SONET links / antenna
      - 10+ year old design
      - Could be modernized and modified to fit into commercial networks

Current NRAO situation

- VLBA
  - RF digitized in 512 MHz chunks
    - RF over coax to station building
    - Digitized in RDBE
      - 1 Gsps / 8-Bits (EVLA)
        - » E2V AT84AD001B
    - Digital down-conversion for recording
  - Data transmission
    - Full bandwidth
      - Hard disk recorders (Mark 5B/C)
      - Local 10 Gig E interface from RDBE to recorders
    - Lower bandwidth on commercial networks at some stations

Current NRAO situation

- Smaller systems
  - Using Ethernet on smaller systems
    - VLITE/LOBO – 10 Gb Ethernet to correlator
      - VLA antennas to control building
      - Spare fiber pair
    - Other projects & VLBA real time testing
      - 1 Gsps or less / 8-bits
      - VLBA station to PVDSOC via internet

Functional Requirements

- Analog bandwidth, bit depth and sampling rate of digitizers
  - Bandwidth dependent on science requirements and maximum possible BW of receivers
  - Bit depth depends on predicted RFI environment for life of system
    - More crowded sky, new satcom bands
    - WiFi / internet systems (satellites, balloons, cellular, etc)
    - Vehicle radars
    - Future things we haven't even thought of yet!
    - High bit depth = high data rates or need for local data reduction
  - Where is industry heading?
- Analog vs. digital transmission or a combination of both
- Signal organization for long distance transfer of wideband signals

Functional Requirements

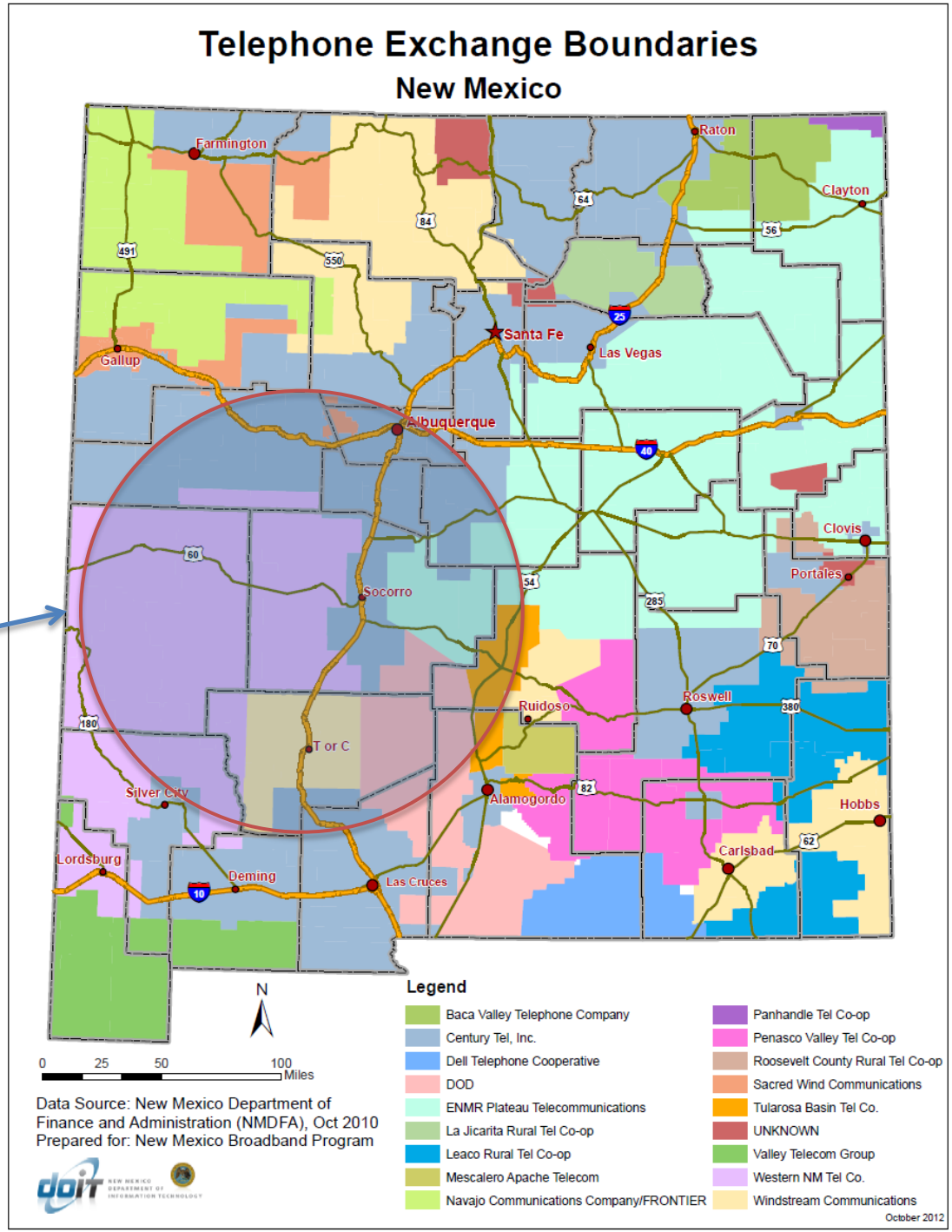
- Transmission medium:
  - Owned fiber,
  - Leased dark fiber,
  - Commercial network bandwidth
  - Probably will require combination of all of the above!
- Integrated electronics design considerations
  - LO/IF, ADC, DTS in small RFI tight, enclosure(s)
  - Easily swapped for replacement
  - High reliability
  - Good stability with minimum heating / cooling requirements
  - Potentially cheap enough to be non-repairable, throw-away items

Fiber Constraints / Assumptions

- Due to the expected scale of the array (300km+), may have a mixed fiber optic system
  - NRAO owned fiber (array center, last mile), leased fiber (where available), and leased bandwidth on long hauls
- Leased bandwidth introduces issues with timestamping of data
  - Systems needs to deal with packets arriving out of order and provide for the padding of lost packets
- For RF over fiber
  - Cannot assume that all fiber is buried or thermally stabilized.
  - May need to leverage existing utility easements from telecom and rural electric coops
- May have more than one solution in the proposed architecture, with different approaches for the center of the array vs. the extents.

Interaction with multiple telecom operators is expected…

r=150km



Trends & Opportunities

- Full RF bandwidth analog over fiber would eliminate the need for reference distribution to the antenna
  - Analog transceivers are approaching bandwidths of 100GHz.
  - Unclear if there is sufficient total power to remain linear while preserving SNR
  - Creates new concerns, such as the dispersion in velocity, jitter in the transmitter, etc
  - Still need to monitor the optical length of the fiber system to maintain phase coherence
- Digital systems
  - 10 Gb Ethernet / Infiniband / SONET– now commodity products
  - 40 &100 Gb Ethernet & Infiniband – becoming available but $$$$
  - 400 Gb or Terabit Ethernet – being thought about!

Desirable Outcomes from this Session:

- A better understanding of:
  - The requirements and parameter space for digitization and data transmission systems
  - Limitations and scalability of current approaches
  - Technical risks and issues to be addressed
  - Emerging technologies that may provide construction and/or operations cost savings, while meeting performance specifications
  - Possible architectures for ngVLA

Questions?