Calibration from the perspective of near surface technologies

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Calibration Tasks in Radio Neutrino Detectors

- Ice propagation
- Antenna response within the inhomogeneous, mostly ice medium
- Channel response (time offsets, amp and digitizing)
- System response (e.g., channel thresholds, level 0 triggers (majority logic), trigger type, higher level triggers – realtime thermal noise suppression)

Ice Propagation - challenges

- Ice properties are anisotropic and inhomogeneous
  - To varying extent, correlated with ice flow
  - Depth dependent and striated
  - Discontinuous density variations near the surface
- Radio paths are long – up to 5km – which sample a large variation in ice properties
- Birefringence and scattering
- Large discontinuity of index of refraction at the firn-air surface

Ice Propagation - questions

- What extent of campaign is required to gather sufficient information on the anisotropic and inhomogeneous nature of the ice
  - How expensive and how many people?
- What do we know enough about?
  - Attenuation vs depth
  - Attenuation vs frequency
  - Average density variation with depth in the firn for mostly Vpol
- What do we need more information on?
  - Birefringence depth dependence, directional dependence
  - Scattering direction and polarization
    - by dust layers
    - by density variation in firn
    - By surface sastrugi

Ice Propagation - recommendation

- Plan robust campaign, utilizing both existing and special purpose calibration campaigns
  - Put 4 or more surface stations around SPice hole at 500m as soon as possible
    - Well calibrated TRX, with Hpol and Vpol options
    - Variable amplitude to stay within the linear response of the surface detector
    - Study azimuthal dependence of birefringence for more vertical propagation
  - Run SPice tests over consecutive years to measure LPDA response vs snow depth and different surface roughness
    - Maybe run early after station opening to get rough surface
  - Install calibration station, as suggested by Dave Besson, in RNOG and then during first year deployment of Phase 2

Antenna Response-challenges

- Embedded in a non-air medium, making simple lab calibrations (in air) less certain
- Non-air medium geometry may be difference from antenna to antenna
  - Distance and angular position with respect to hole wall
  - Slot wall may prevent a uniform filling of snow for LPDA. Drifting snow tends to cover, not fill in.

Antenna Response-questions

- In my option, we know enough about the LPDA response (for symmetric geometry) and Vpol antennas.
  - We learned from parallel antenna LPDA that it is difficult to get every wiggle in the waveform understood
  - Fortunately, with this geometry, it is not necessary. Errors in Antenna response and ice propagation cancel out in reconstruction direction
- Not really my topic, but "How do we establish the absolute in-ice response of Hpol"? "What level of absolute calibration of Hpol is required to reach 3 deg polarization accuracy or better?"

Antenna Response-recommendation

- Similar recommendation as ice properties – use pulsers in SPice hole and Greenland hole
- For upward facing LPDA – drones; to improve the response for Cosmic Rays (see upcoming slide)

Channel Calibration-challenges

- Most relevant amp and digitizer properties can be measured in the lab as a function of temp, so no major challenges

Channel Calibration-recommendation

- Amp temps immediately deployment can be quite different from steady state, so plan on setting thresholds to (1) establish reasonable immediate operation, (2) adjust until rate of temp variation slows
  - Little if any snow overburden at first
  - Ambient temp is warmer than typical

- System noise for upward facing LPDA can vary with time due to galaxy

System calibration - challenges

- Must understand trigger threshold to <0.3 sigma
- Trigger thresholds and/or rates change with time, so need to continuously monitor, and occasionally adjust
- Multiple triggers create additional complexity
  - Phased, majority logic on surface, CR trigger, combined elements (surface and deep, station to station)
  - Higher level triggers to identify and deprioritize thermal noise events

System calibration - questions

- Do we control on global trigger rates or on channel thermal noise raises
  - ARIANNA stations monitored single channel rates, and adjusted thresholds periodically
  - For CR trigger, did not do anything special for galactic noise, but rate variation was considerable
- What fraction of total bandwidth will each trigger type consume?

System calibration - recommendation

- Develop automated calibration based on thermal noise on a channel by channel basis
  - Monitor and record channel trigger rates
  - Include feedback to maintain channel rates to within a specified tolerance
  - High wind periods will generate additional triggers in surface component − may not want to adjust thresholds

Cosmic rays

- The surface component can utilize the large data set from cosmic rays
  - Same LPDA with same symmetry, embedded in snow
- Polarization can be measured and response confirmed with hundreds of CRs per station per year.
  - Study station to station variation in high level response due to local ice, installation differences
  - Accuracy or predicted polarization angle limited by unknown location of station on CR radio footprint (<10 deg) due to competing geomagnetic and Askaryan components.
  - Uncertainty reduced for large zenith angle events (subselect large zenith angle > 70 deg)
  - Footprint location can be estimated from two or more stations observing same CR event.

Non-conventional calibration sources

- Airplane emission, balloon pulsers, etc
  - My sense is that all of these are useful as exploratory or confirmation tools, but not something that will provide reliable, authoritative and fully extensive information. It is time to get serious about calibration

Final Comments

- The surface component was designed to minimize the need for absolute calibration of propagation, antenna response and impacts of local ice effects
  - Parallel LPDA
  - Both DNR signals with the same dipole gives sub-100ps timing accuracy
- Campaigns to understand the absolute antenna response and propagation effects such as birefringence are time consuming, highly iterative, and expensive
  - mixed-media lab measurements of Hpol are too problematic at the moment.
  - It remains to be seen if in-situ antenna calibrations can be done in an expeditious way with adequate precision