The Calibration of the Geometry and Antenna delay in Askaryan Radio Array Station 4 and 5

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INTRODUCTION

The Askaryan Radio Array (ARA) experiment at the South Pole is designed to detect the ultra high energy neutrino-induced radio signals in ice. There are 5 autonomous ARA stations (A1-A5). Each station comprises 16 antennas, 8 HPol and 8 VPol, deployed at the bottom of four 200 m deep vertical holes. Each station also has 4 calibration antennas, 2 HPol and 2 VPol, for in-situ calibration of geometry and timing.

ARA STATION LAYOUT

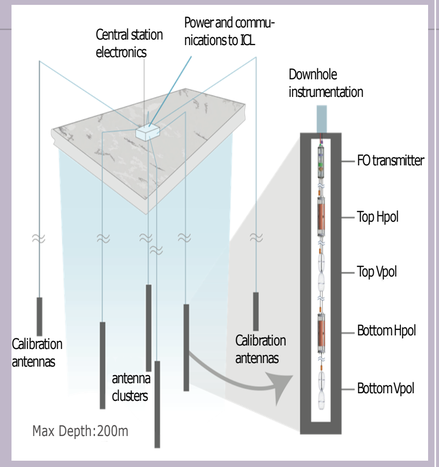


FIG. 1: Layout of an ARA station. All stations are equipped with both vertically and horizontally polarized measurement antennas and calibration antennas.

ARA DIGITIZATION SYSTEM

- ARA DAQ system comprises 4 digitisers (DDA) per station.
- IRS2 chips are mounted on the DDA.
- IRS2 samples input data at (~3.2 GS/s) speed.
- Each chip has 8 channels.
- 4 channels / chip digitize input RF signals.
- We calibrated all IRS2 chips in stations A4 and A5.
- Each channel of the chip has 128 sampling capacitors.
- There are 32,768 storage sample/channel.

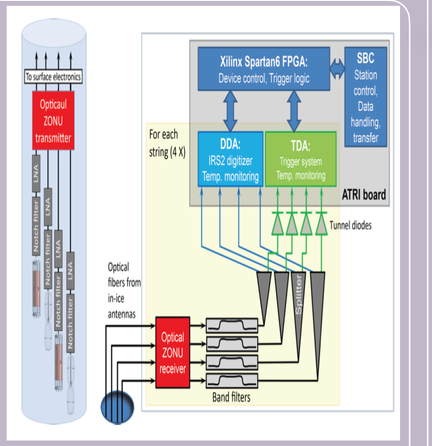


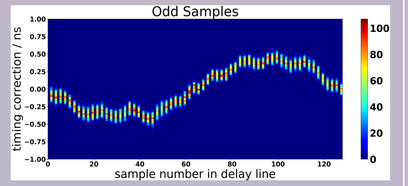
FIG. 2: ARA DAQ system

DIGITIZER CALIBRATION : A4 & A5

A. TIMING CORRECTION

- The IRS2 chip stores the input signal via Switched Capacitor Array (SCA) .
- SCA consists of 128 sampling capacitors / per channel, 64 odd+64 even samples on 2 delay lines.
- 128 finely tuned delay elements samples input data.
- Delay elements have offset (jitter) (Fig 3, top) that we correct.
- Sine waves (f=218 MHz) used as calibration data, fed to digitisers.
- We achieved a timing correction precision of <0.08 ns in the delay elements (Fig 3, bottom).

Before Calibration



After Calibration

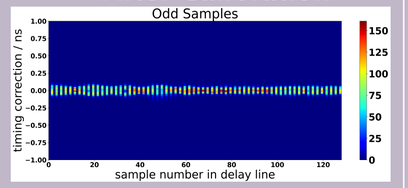
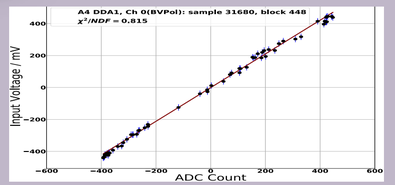


Fig 3: Top: timing jitter histogram of uncalibrated odd samples in chan 0, A4 Bottom: timing jitter histogram of timing calibrated odd samples in chan 0, A4

B. ADC-to-Voltage Conversion

- Each channel of a digitiser chip has 32768 storage samples.
- We apply amplitude calibration on time-corrected sine waveform.
- We find ADC-to-voltage conversion factor for all samples/channel of the chip in A4 using a linear fit.
- The individual error per sample is included in the linear fit.
- For A5, we apply a cubic broken fit to convert ADC to voltage (mV)
- We calibrated all 16 antennas in A4 & A5 stations.



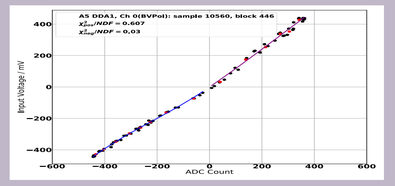
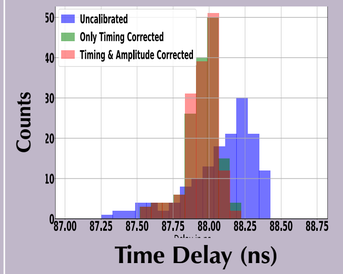


Fig. 4 Top: , ADC-to-voltage conversion of a sample, A4 Bottom: ADC-to-voltage conversion of a sample, A5

VALIDATE CALIBRATION WITH DATA

Using the calibration RF signals in all 16 channels of the chip, we find the inter-channel time delay in A4 and A5 with < 0.1 ns precision.



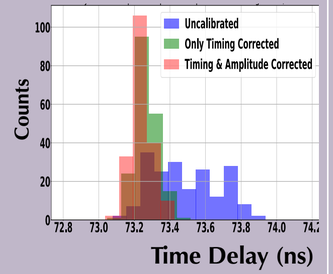


Fig5, left: Inter-channel time delay in A4, Right: inter-channel time delay in A5

STATION GEOMETRY & ANTENNA POSITIONING

Calibration is essential for proper data analysis. A5 antenna location in the ice is determined with ~5 cm precision

For A4, station geometry calibration is in progress.

REFERENCES AND ACKNOWLEDGEMENTS

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