Digitization in LFAA

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Outline

- Quantization effects in LFAA
- Quantization nonlinearities and dynamic range
- Optimal input amplitude in presence of RFI
- RFI management in LFAA beamformer

Quantization effects for a Gaussian noise

Good:

- Quantization noise very similar to receiver noise

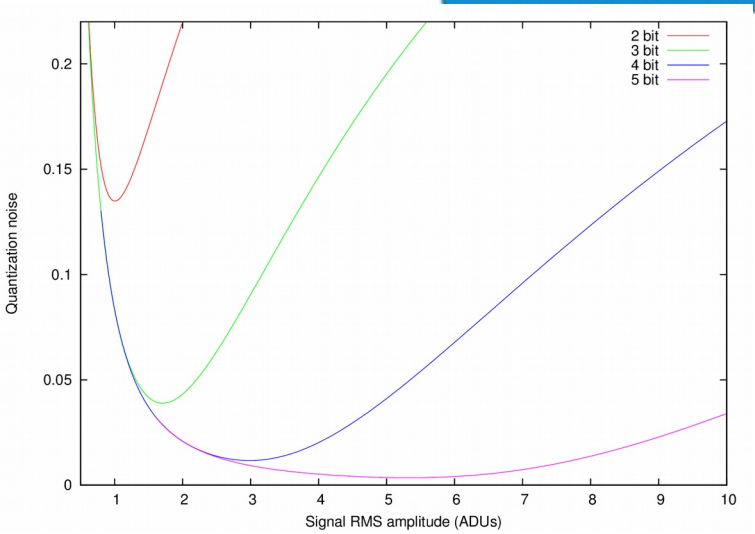
  → Modest degradation of SNR
- Dithering: SFDR increases dramatically

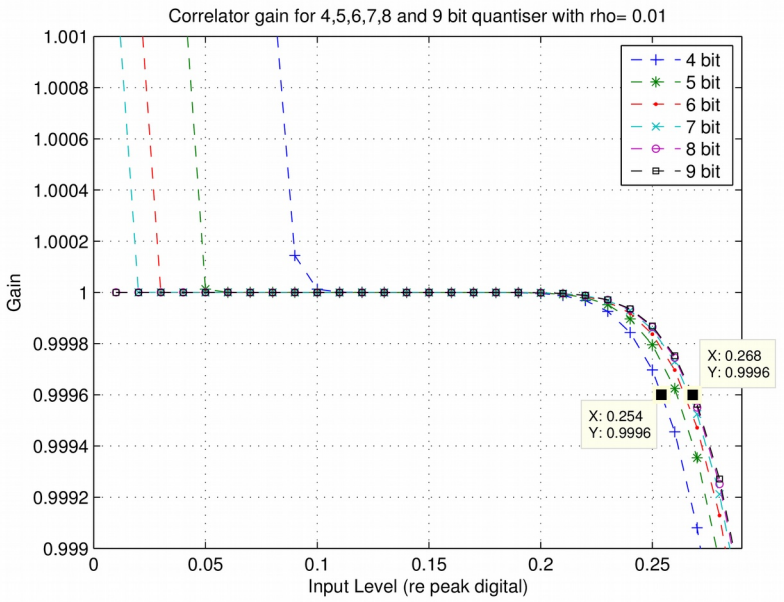
  → RFI tends to be confined to affected channels, no large harmonics

Bad:

- Gain variation with signal amplitude
- Nonlinear effects

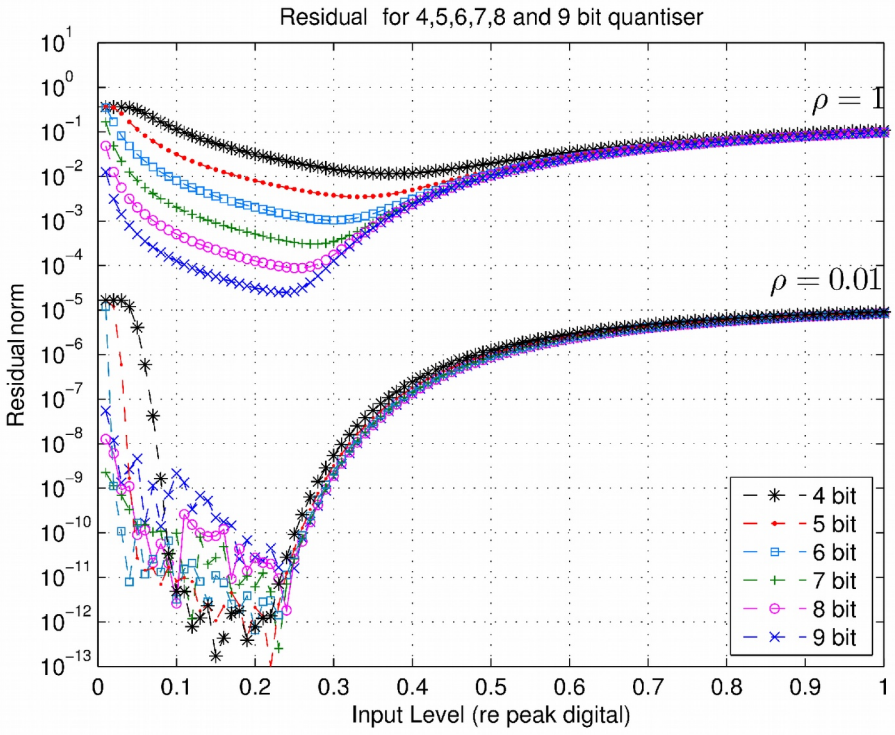
  Both can be corrected **if signal amplitude and spectrum are known**
- With at least 4 bits, response can be kept linear, but at a cost of extra noise





Quantization effects and RFI

- Linear range: adding RFI reduces the available range
- Nonlinearities: Introduce harmonics → spurious RFI and image ghosts
- In an interferometer, nonlinearities introduce ghost images of strong sources



A 10% RFI could introduce a -40 dB 3rd harmonics if signal level not optimal

IP3 for an ADC

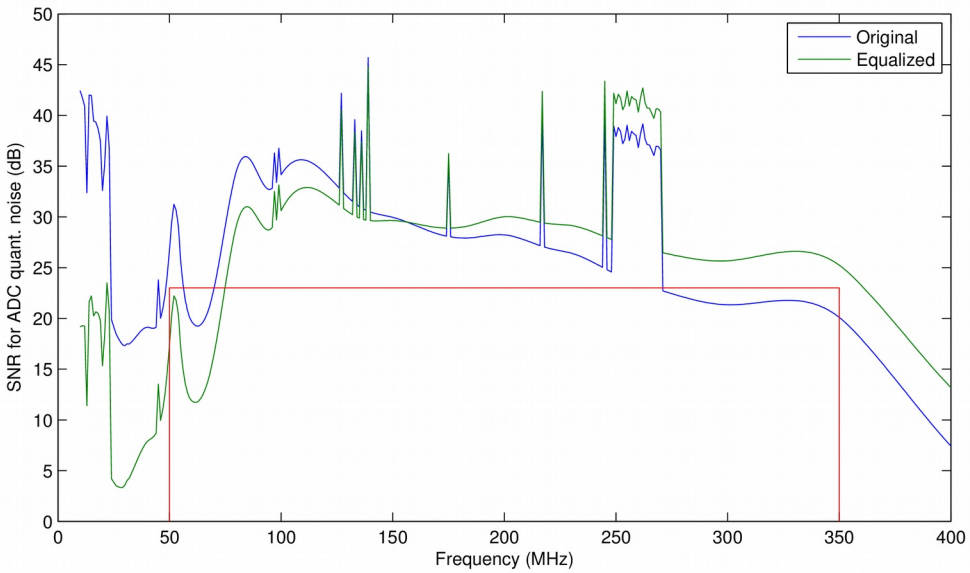
If operated at > 0.4 times clipping level: ~3 dB above clipping level

If operated < 0.25 clippling level: 30-40 dB above clipping level

LFAA input level

Bounds

- Low: signal SNR > 200 at any frequency
  Depends on input bandshape (including RFI)
- High: signal should never exceed 25% of clipping level
  Added RFI & Time variable RFI included



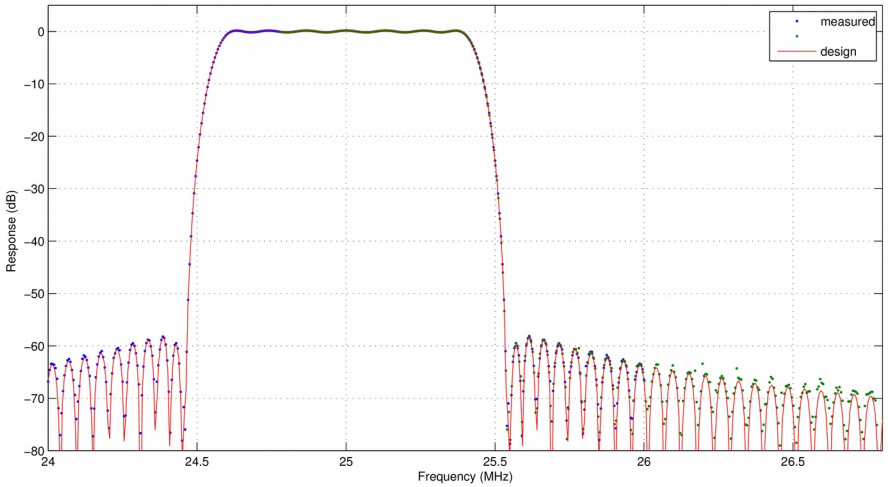
Assumptions:

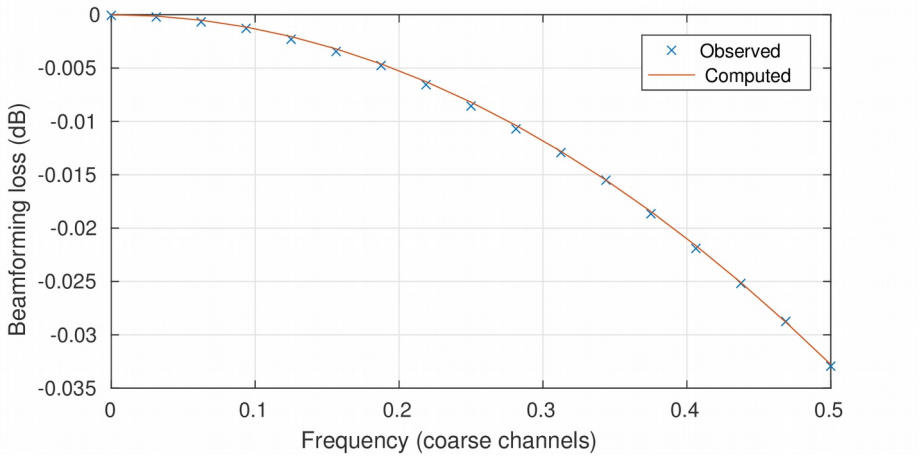
- Bandshape better than in the figure (old antenna)
- Good suppression of SW broadcast RFI
- RFI level from 2013 report
- Variable RFI could increase receiver power by factor of 2

16 < RMS(in) < 22
Assumed value: 17.5

LFAA channelizer/beamformer signal processing

- Polyphase channelizer
  - Oversampled (32/27 = 1.185x input rate)
  - 8 bit input, 20 bit output
  - Block scaling
- Calibration block
  - Per channel Jones matrix
  - bandpass correction
  - equalization
- Frequency domain beamformer
  - Dynamically computed phase (linear in time and frequency)
  - Final requantization to 8 bit for CSP
- Matlab model almost bit accurate for whole chain





LFAA channelizer/beamformer RFI management

- Continuous power monitoring for each antenna/polarization
- Compare power on short timeframe (~2 μs, fixed) to averaged power at longer timeframe (ms, programmable)

  Flagging threshold: 119% of average power
  Very simple stucture to minimize power consumption
- Flagging of data: irreversible (simple, no cost) vs reversible (requiries extra information to be transmitted & described)
- Internal dynamic range large enough to allow for single channel signal amplitude of 70 ADU. RFI spreading in more than 3 LFAA channels may reach saturation level without clipping in FFT
  - Variable block scaling to optimize requantization at FFT output
- Saturation of a LFAA channel in the FFT produces saturated or flagged data
  - Saturated for amplitude < 2x saturation
  - Flagged for amplitude > 2x saturation
- Beamformed channel flagged if one input flagged

Thank you