USRP RF calibration utilities and impairments correction techniques

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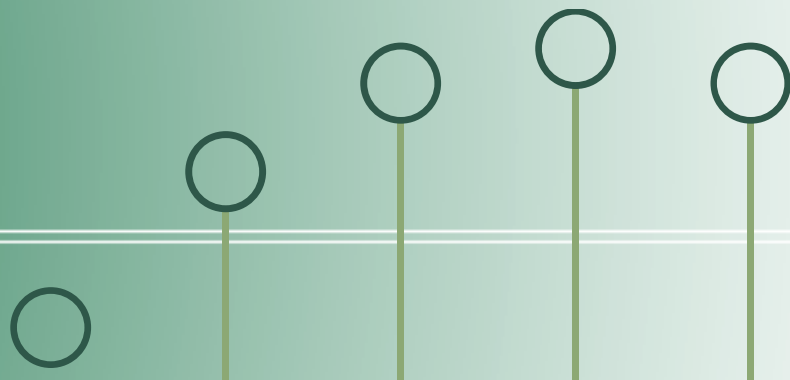
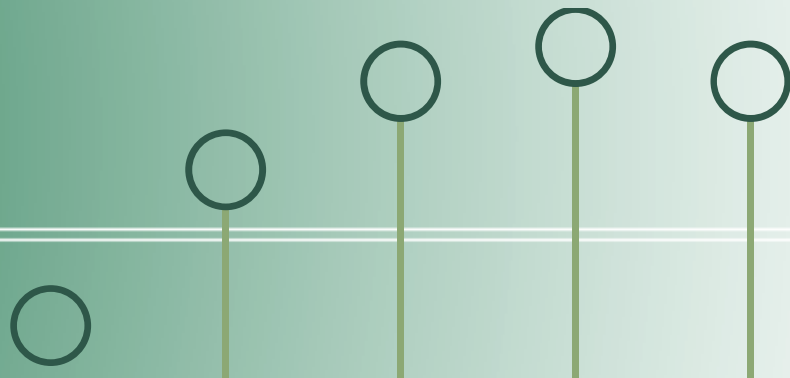


Let us discuss:

- Filter response
- IQ imbalance
- DC level
- Calibration utilities
- Two stage tuning

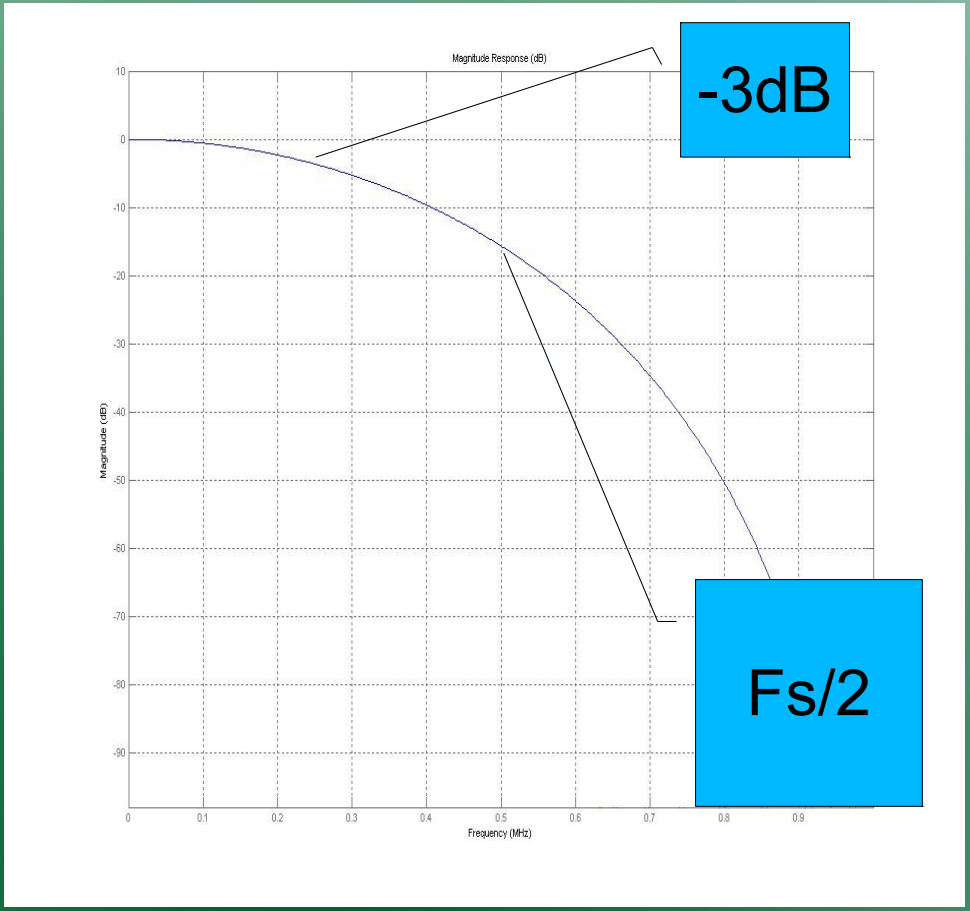


RX and TX DSP chain config

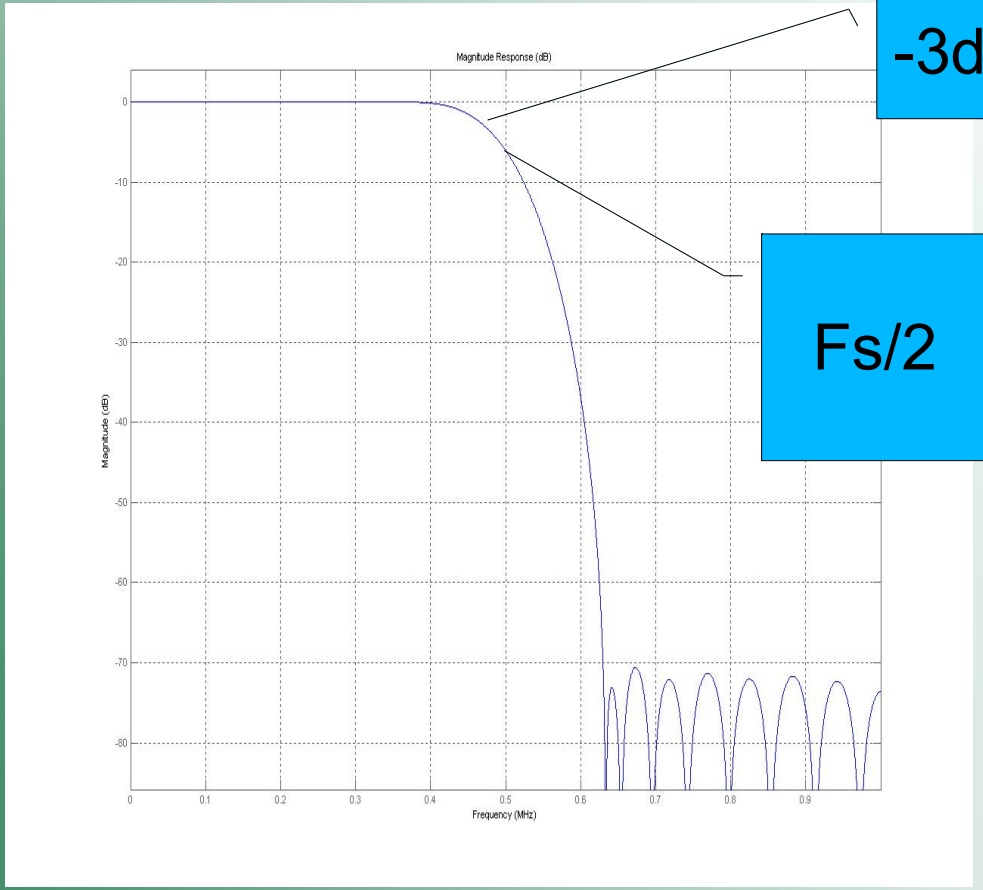
- Decimation = FPGA DSP rate/sample rate
- Rate determines bypassing...
- Decimation % 2 = 1 → 0 HB, CIC only
- Decimation % 2 = 0 → 1 HB in chain
- Decimation % 4 = 0 → 2 HB in chain

- Interpolation = FPGA DSP rate/sample rate
- Rate determines bypassing...
- Interpolation % 2 = 1 → 0 HB, CIC only
- Interpolation % 2 = 0 → 1 HB in chain
- Interpolation % 4 = 0 → 2 HB in chain

Filter Response



CIC

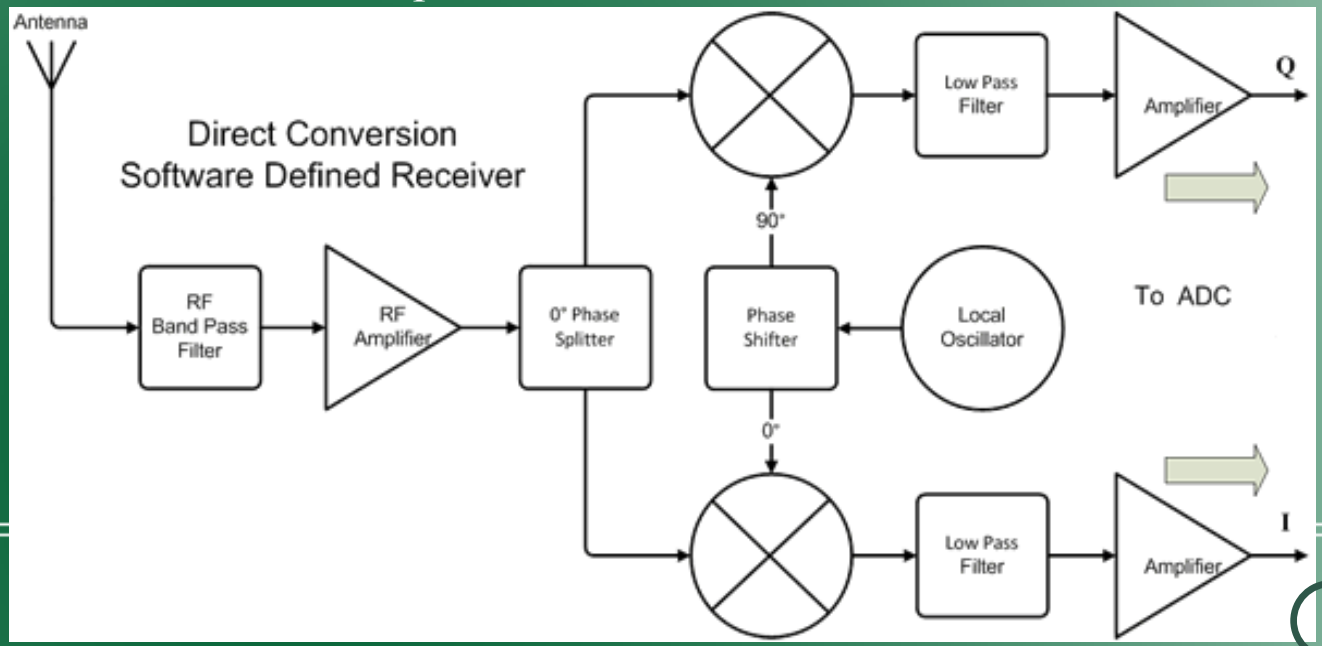


HB

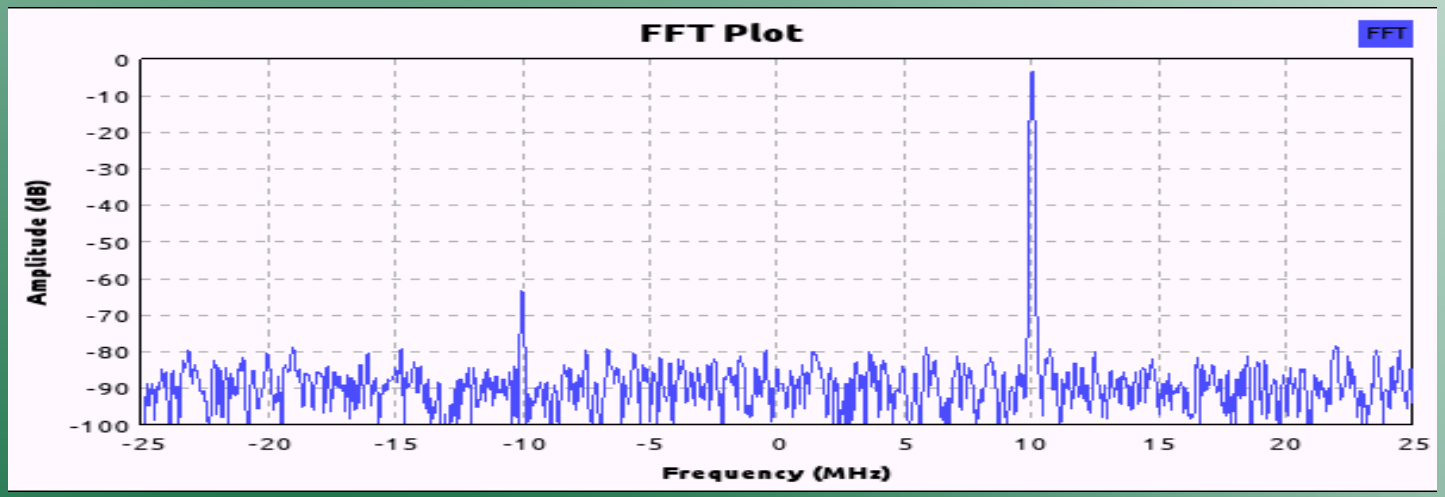
IQ Imbalance distortion

- Magnitude imbalance caused by...
  - Mismatch in amplitude between I and Q
- Phase imbalance caused by...
  - 90 degrees + epsilon phase between I and Q mixer
  - Possible filter group delay mismatch
- See Matt's Impairments Presentation for more...

Two types of imbalance: magnitude and phase

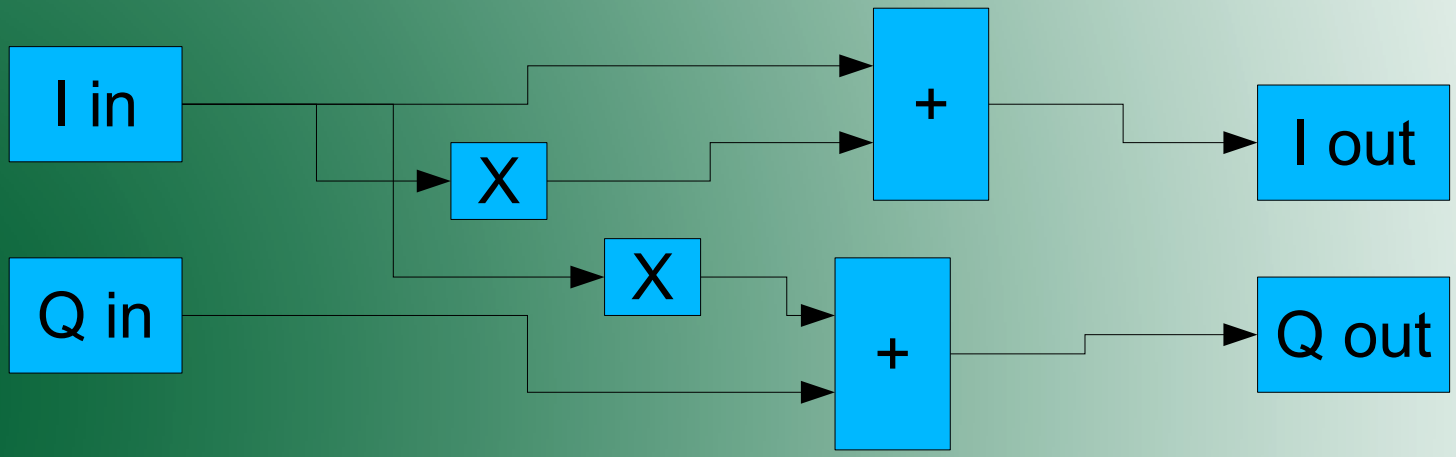


IQ Imbalance and correction



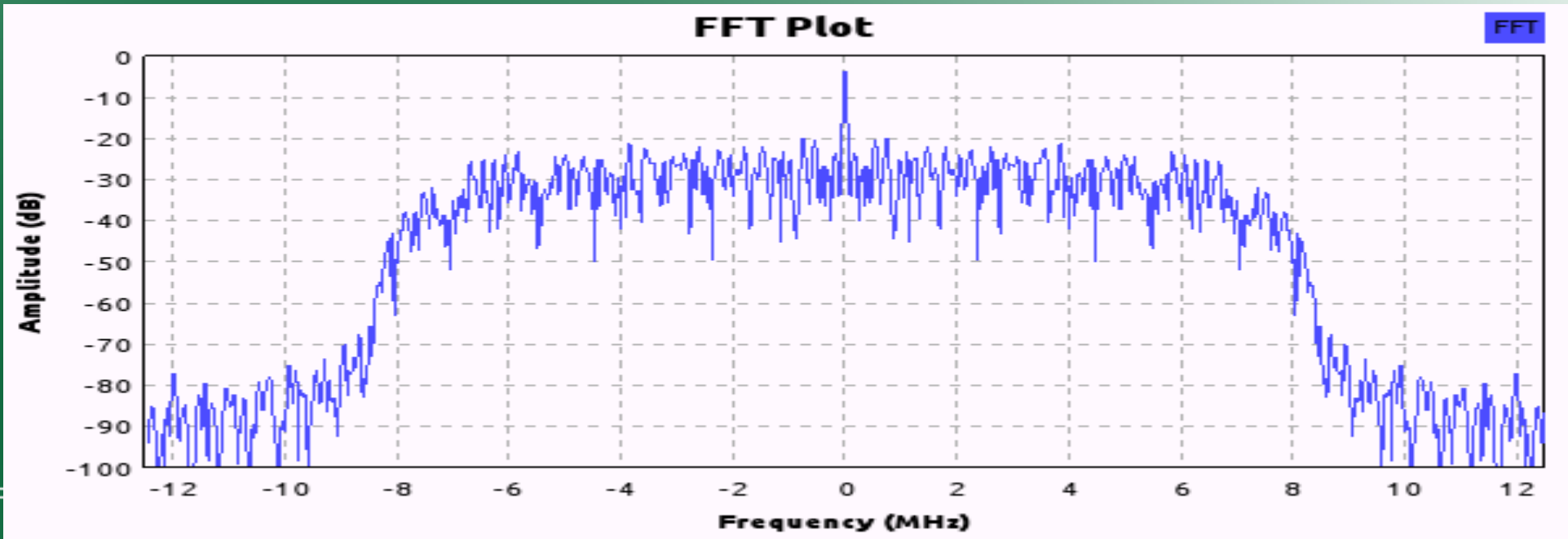
IQ imbalance – single test tone

A linear correction for the imbalance

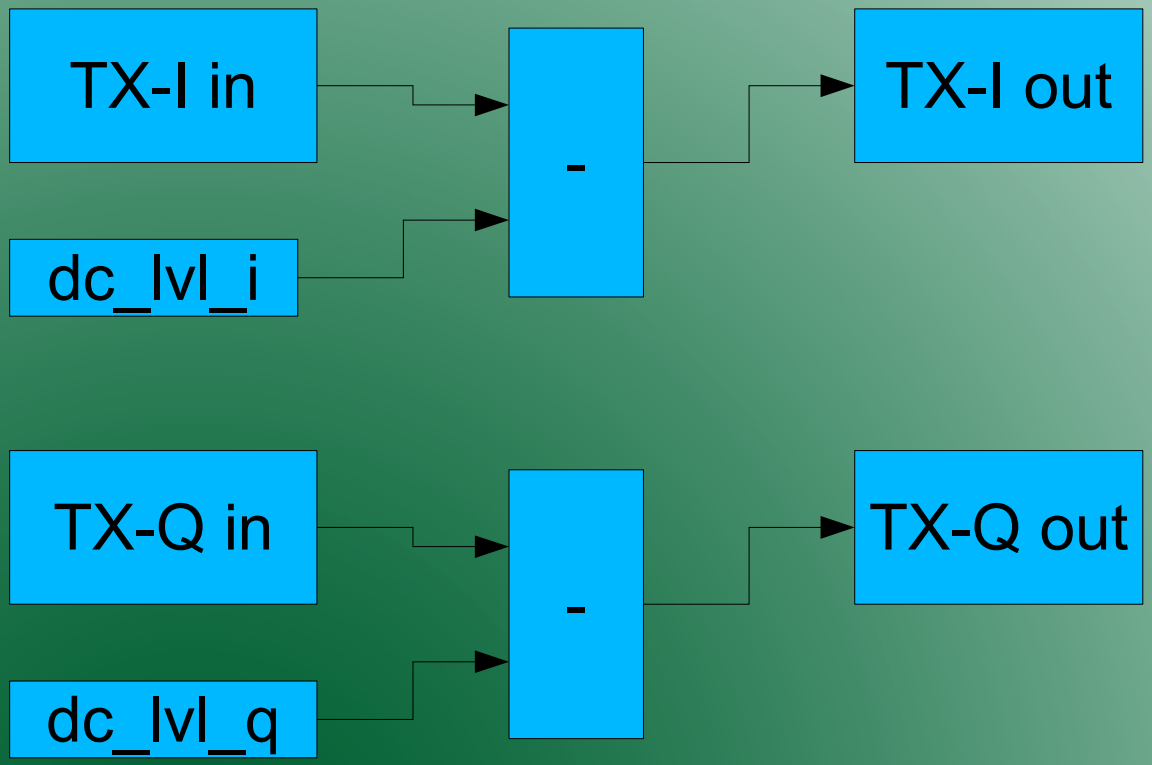


DC level distortion

- Some DC level at the mixer, causes...
  - LO in the spectrum, (darn)
- See Matt's Impairments Presentation for more...



TX DC level correction



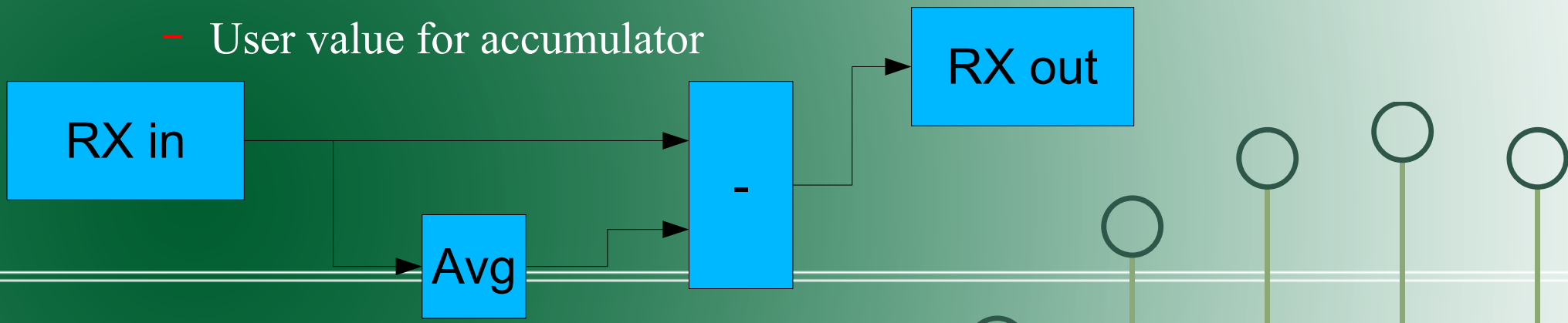
Simple constant subtraction for I and Q

RX DC level correction

- No self calibration utility
  - Tune the frontend
  - Accumulator settles
  - Freeze the accumulator
- Other options
  - Disable the accumulator
  - Accumulator always runs
  - User value for accumulator

```
void set_auto_dc_offset(
        const bool enb,
        size_t chan = 0)
```

```
void set_dc_offset(
        const std::complex<double> &offset,
        size_t chan = 0)
```

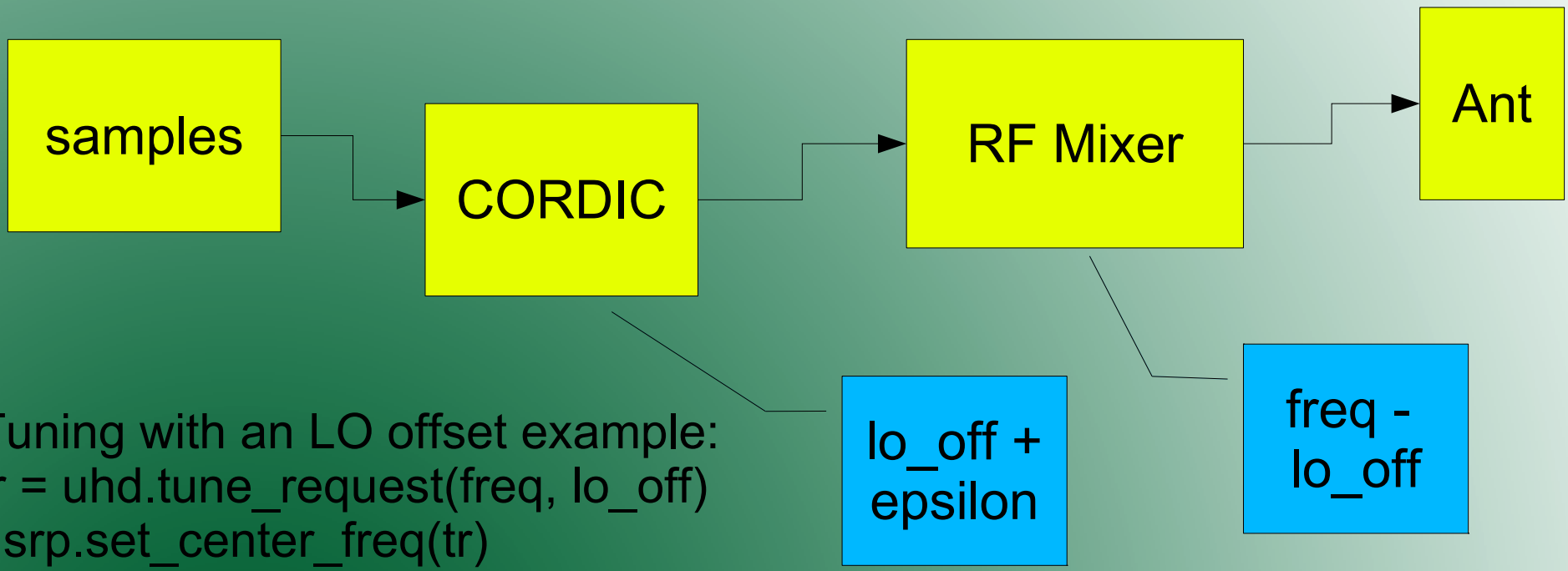


The calibration utilities

- The cal utilities use leakage on a transceiver daughter-board to perform self-calibration
- The following utilities sweep across frequency:
  - Calibrate for RX IQ imbalance
  - Calibrate for TX IQ imbalance
  - Calibrate for TX DC level
- Calibration saved in a csv and loaded at runtime

http://files.ettus.com/uhd_docs/manual/html/calibration.html

Using an IF to mitigate distortions



Tuning with an LO offset example:
tr = uhd.tune_request(freq, lo_off)
usrp.set_center_freq(tr)

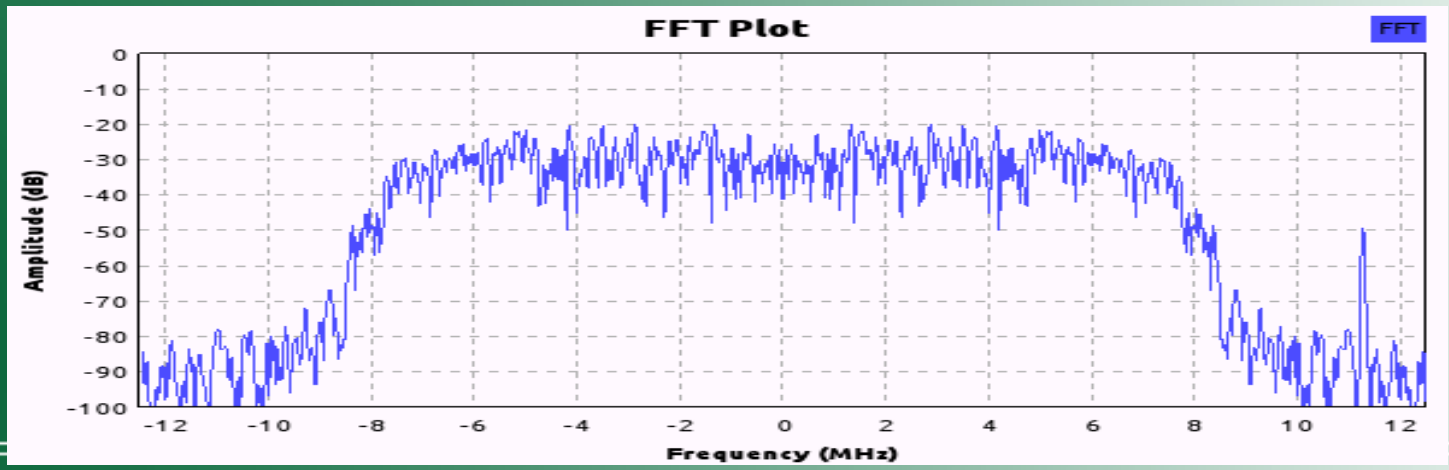
Put that tune request right into GRC!

Epsilon is a small error in frontend frequency approximation of target frequency

http://files.ettus.com/uhd_docs/manual/html/general.html

Disadvantages to IF

- Bandwidth issues
  - How far can the CORDIC tune? dsp_rate/2 – bw/2
  - How much analog baseband bandwidth?
- Transmitting out of band distortions
  - Calibration utils can still help here!
  - Mitigate w/ external frontend filters



FIN

- Conclusions
  - Impairments happen, but...
  - Multiple ways to mitigate
- Questions?