Digital Modulation Primer using GNU Radio

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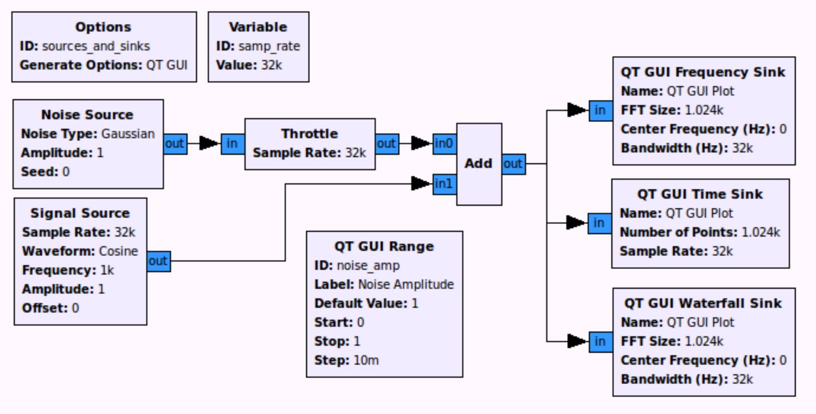
Download Materials

- http://www.trondeau.com/gr-tutorial
    - Use examples for version 3.7
- Presentation PDF
- Case Study materials
    - GNU Radio apps to run examples.
    - Links to source code for analysis.
    - Data file for first case study.
    - Images of expected output.
    - Exercises.

Sources and Sinks (quick review)

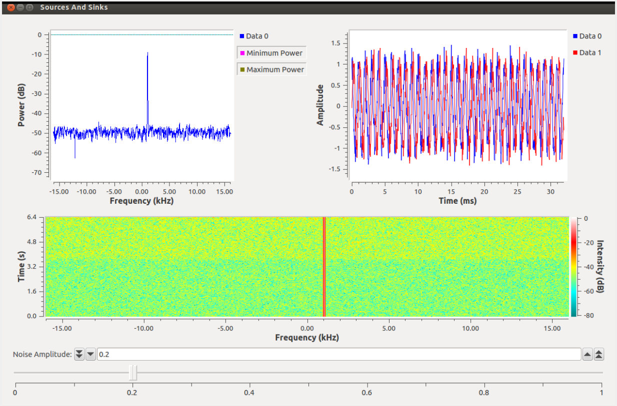
- sources_and_sinks.grc



- Demonstration of using multiple sources to create a noisy sine wave and multiple sinks to view it in different domains.

Sources and Sinks (quick review)

- sources_and_sinks.grc - Output

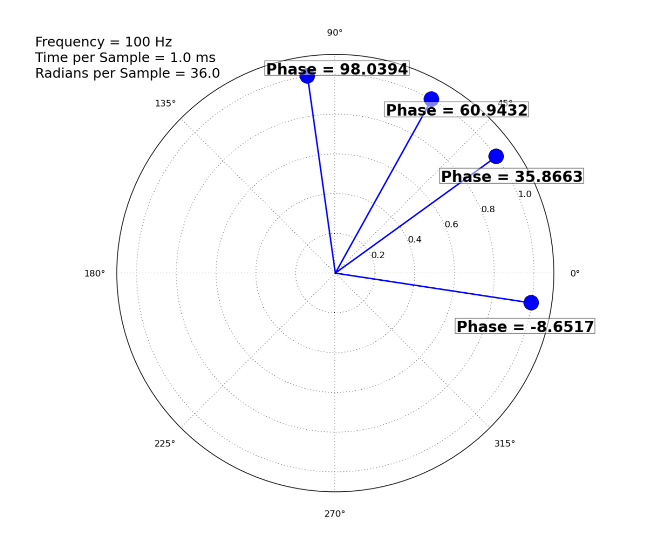


- Showing PSD, spectrogram, and time domain of the noisy signal.

Complex Numbers

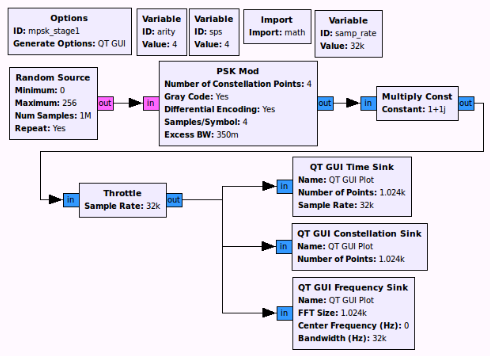
- $z(t) = x(t)cos(2\pi f(t)t + \phi(t)) + jy(t)sin(2\pi f(t)t + \phi(t))$
- $z(t) = c(t)e^{-j2\pi f(t)t+\phi(t)}$
- Information can be encoded in $c(t)$, $f(t)$, and $\phi(t)$.

Complex Numbers: Polar Plots



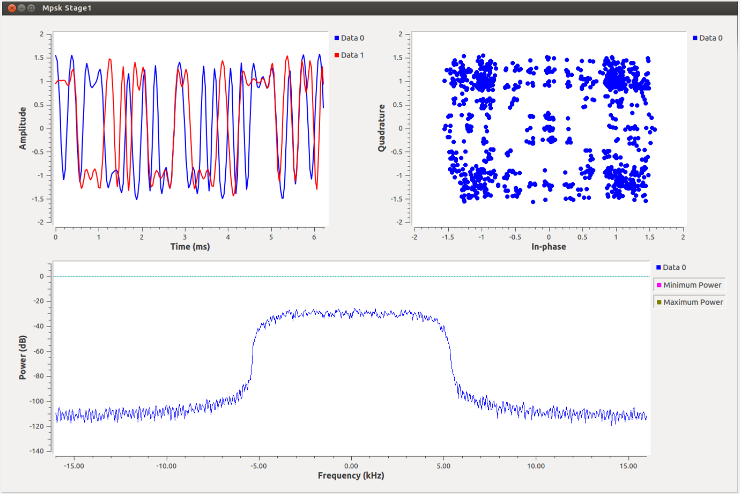
Modulating & Transmitting a Signal

- mpsk_stage1.grc



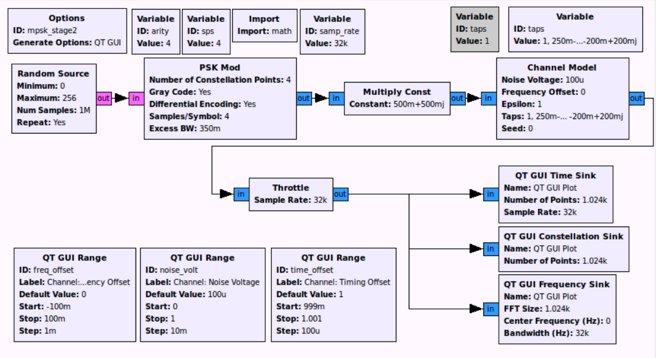
- Using a pre-build PSK modulator block from GNU Radio.

Modulating & Transmitting a Signal



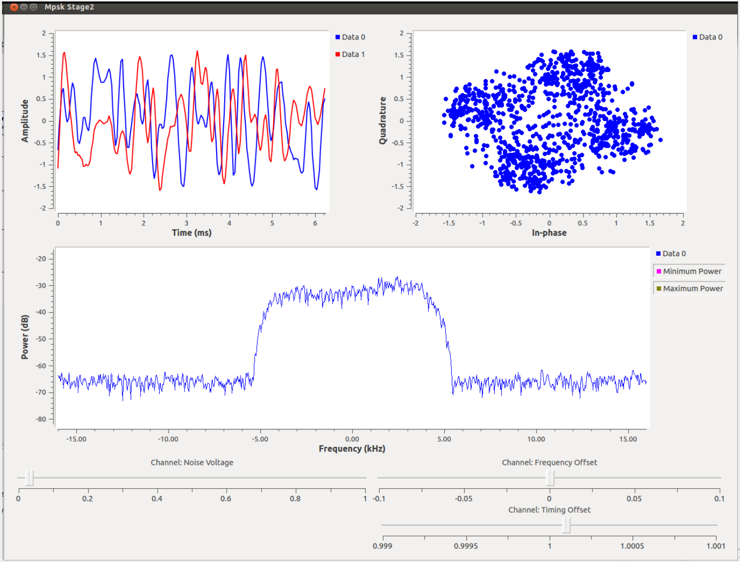
The Received Signal

- mpsk_stage2.grc



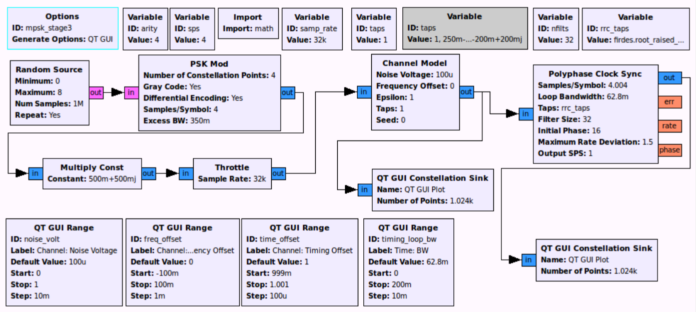
- We can simulate a channel model with noise, frequency and timing offsets, and multipath.

The Received Signal



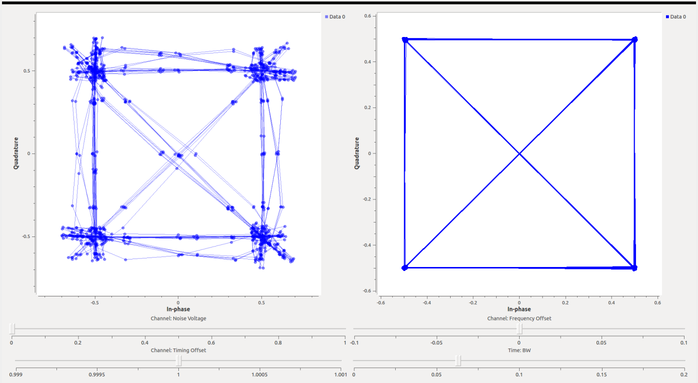
After Timing Recovery

- mpsk_stage3.grc



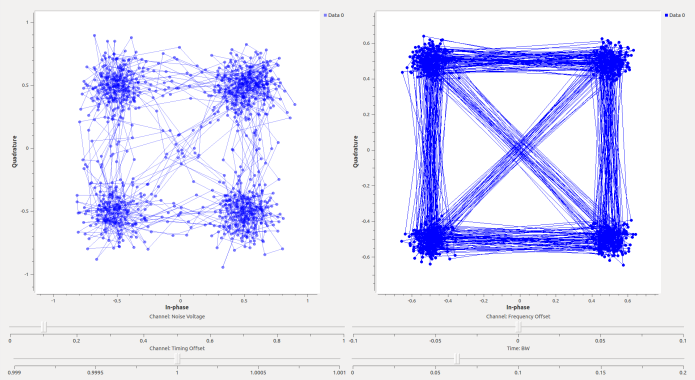
- We use a control loop algorithm to find the right sampling time to fix clock mismatches between the transmitter and receiver.

After Timing Recovery



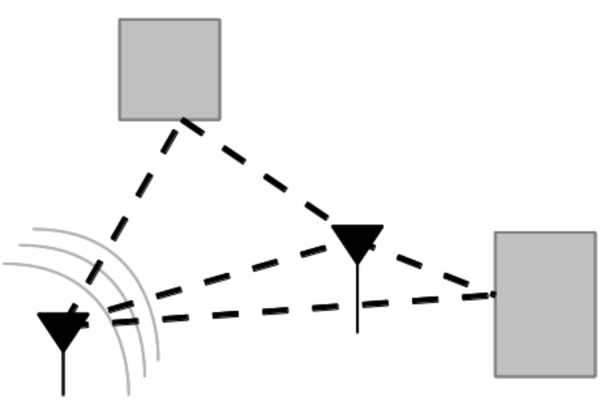
- Showing a no-noise situation to illustrate ISI (self-interference) issues in the received signal before timing recovery and matched filtering.

After Timing Recovery - With Noise



- Even with noise, we can still recover the proper timing.

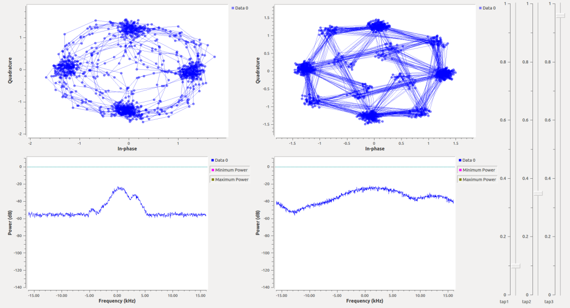
Multipath in Brief



- Multipath channels result from a signal bouncing off objects and hitting the receiver at different times and with different phases.

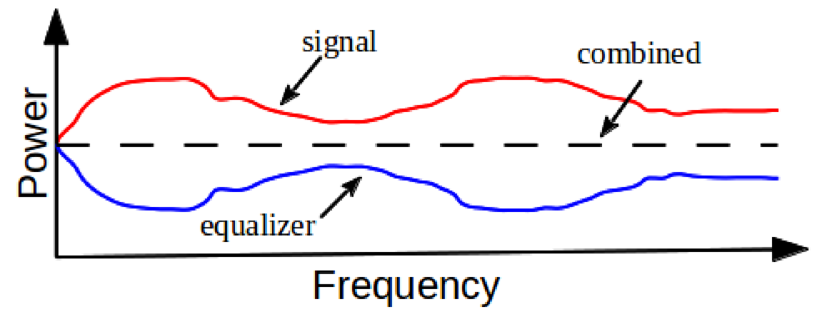
Effects of Multipath

- mpsk_multipath.grc



- This simulation allows us to adjust the multipath channel as though we are adjusting a stereo's equalizer. (SA: multipath_sim.grc)

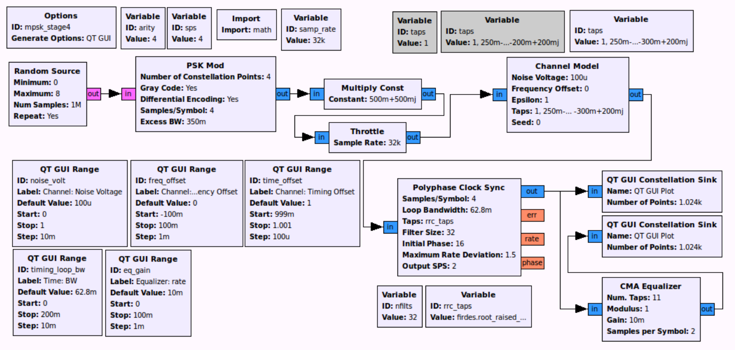
Equalizing Multipath



- Cartoon showing signal corrupted by multipath. Equalizer tries to invert the multipath so that the combination is a flat frequency response.

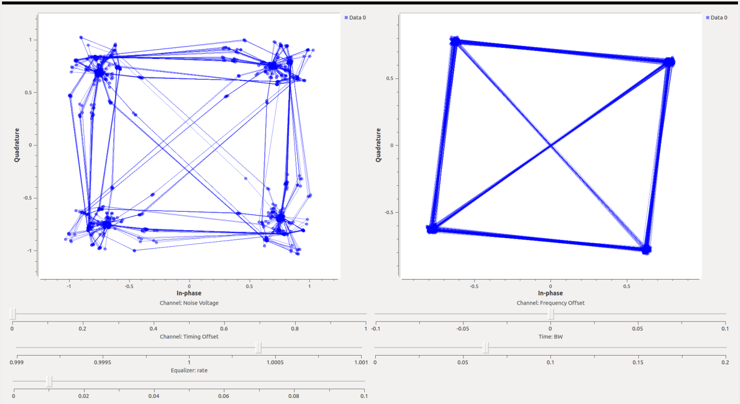
Equalizing Multipath

- mpsk_stage4.grc



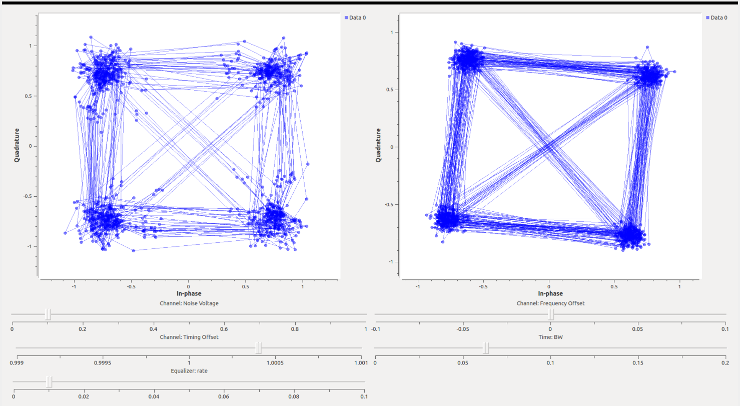
- Using the constant modulus algorithm (CMA) blind equalizer is used here to correct multipath distortion.

Equalizing Multipath



- Note the similarity between the time-synchronized and filtered output with multipath and the ISI of the signal before the matched filter with no multipath.

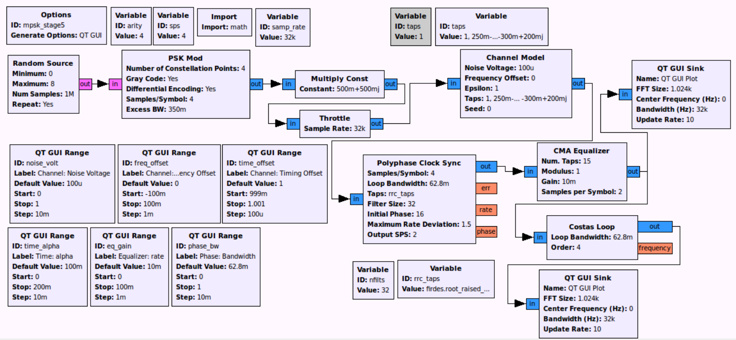
Equalizing Multipath



- Equalization working with noise.

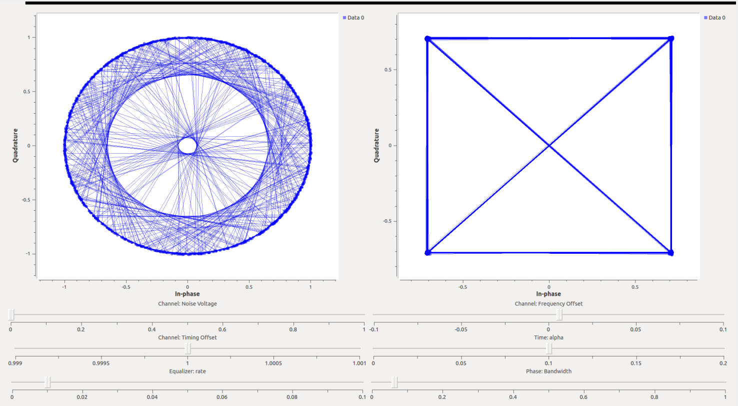
Phase Offset Correction

- mpsk_stage5.grc



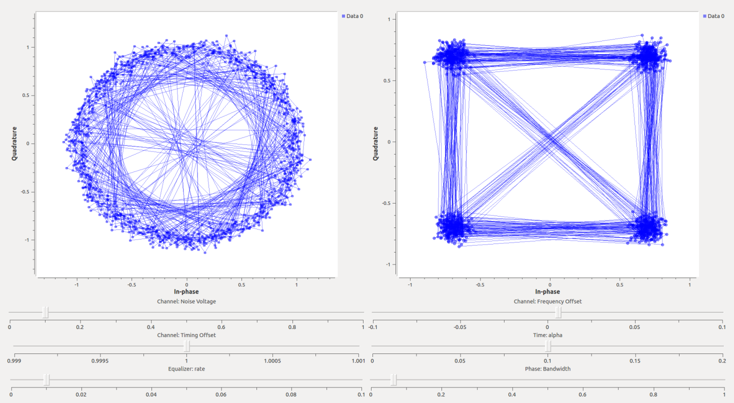
- The transmitter and receiver work off different clocks, so there will be a frequency and phase offset. We need to correct for any small frequency and phase offsets.

After Phase Offset Correction



- Left figure shows a rotate constellation. The Costas Loop block fixes the offset.

After Phase Offset Correction - With Noise



- Again, robust to AWGN.

Using captured DQPSK data

- mod01-intro/data/dqpsk_capture.32fc
- Symbol rate of 1 Msps
- Differential QPSK
- RRC filter with alpha=0.35
- Captured with ~100 kHz frequency offset
- Use scripts/rx_data.grc to experiment