OFDM Transmitter and Receiver with Software Defined Radios

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Outline of the Presentation

Agenda

GNU Radio

GNU Radio

Open-source software development framework that provides signal processing functions for implementing software-defined radios. This framework also offers a graph design approach, namely GNU Radio Companion (GRC).

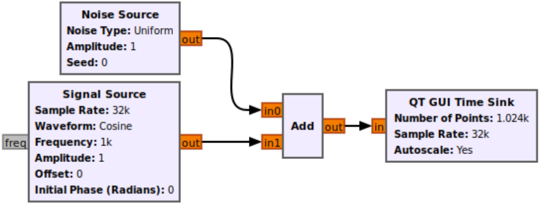


Figure: Simple flow-graph in GRC

Figure: Data types in GNU Radio

In-Phase and Quadrature (I/Q) Components of Signals

From the trigonometric identity:

$$\sin(\alpha + \beta) = \sin(\alpha)\cos(\beta) + \cos(\alpha)\sin(\beta)$$

every sinusoid can be expressed as the following:

$$\begin{aligned} x(t) &= A(t)\sin(\omega t + \phi) = A(t)\sin(\phi + \omega t) \\ &= [A(t)\sin(\phi)]\cos(\omega t) + [A(t)\cos(\phi)]\sin(\omega t) \\ &= \mathbf{I(t)}\cos(\omega t) + \mathbf{Q(t)}\sin(\omega t) \end{aligned}$$

GRC Example of Signal Generation with I/Q Components

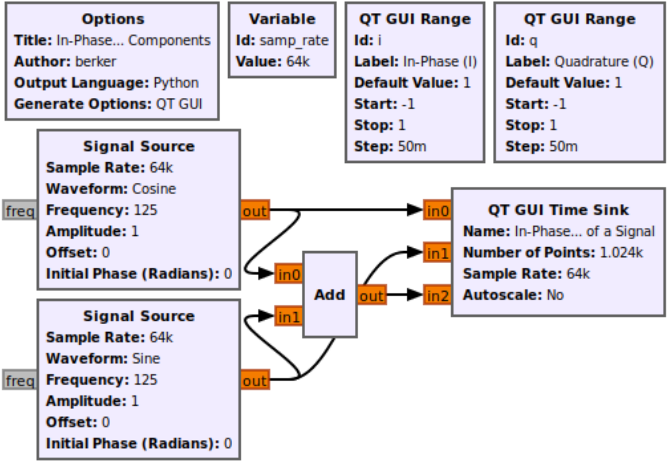


Figure: GRC flow-graph for generating I/Q signal

GRC Example of Signal Generation with I/Q Components

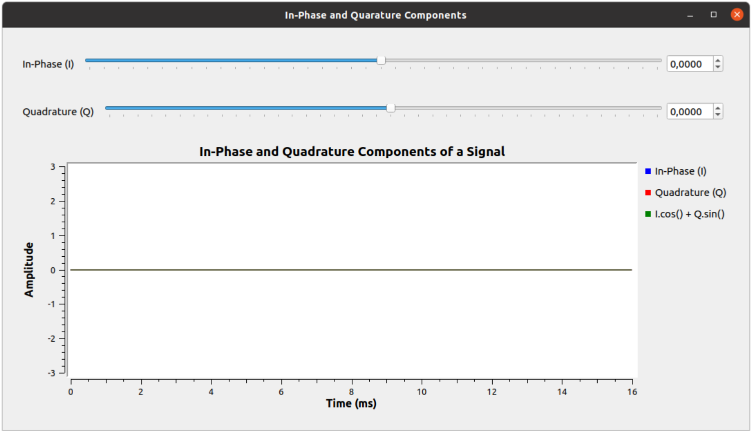


Figure: I = 0, Q = 0

GRC Example of Signal Generation with I/Q Components

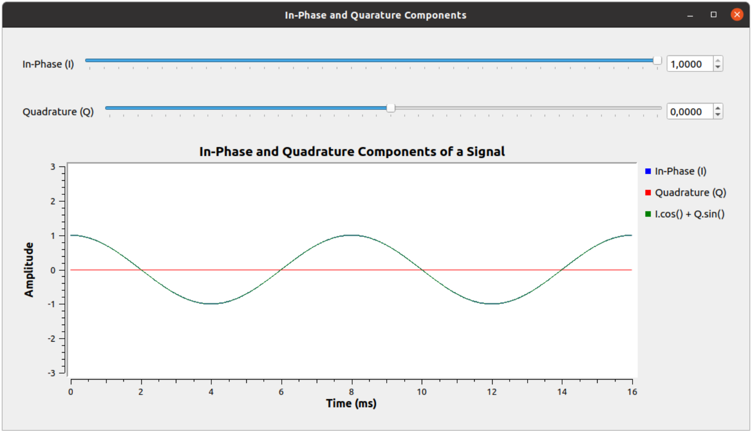


Figure: I = 1, Q = 0

GRC Example of Signal Generation with I/Q Components

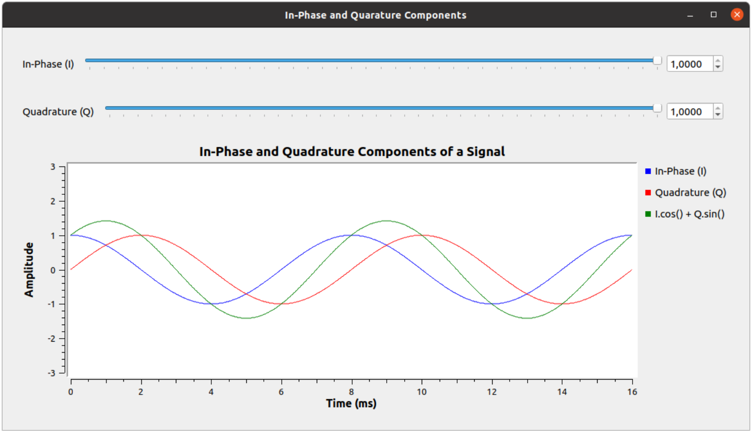


Figure: I = 1, Q = 1

Agenda

Variables

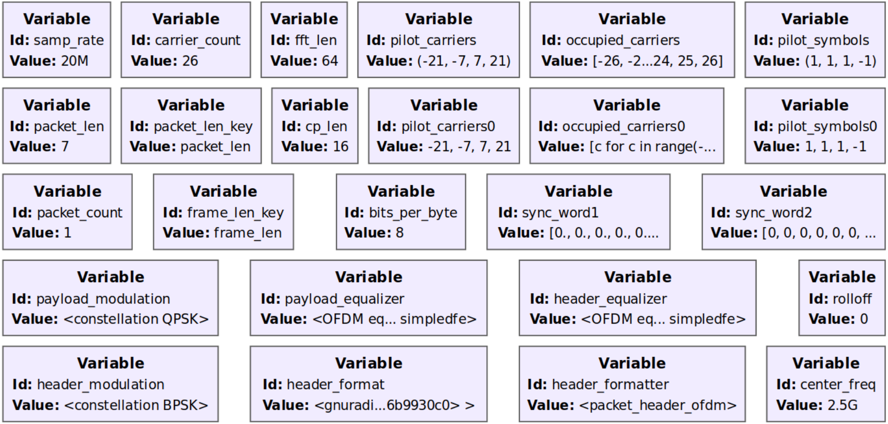


Figure: Variables used in OFDM Transmitter and Receiver

OFDM Transmitter

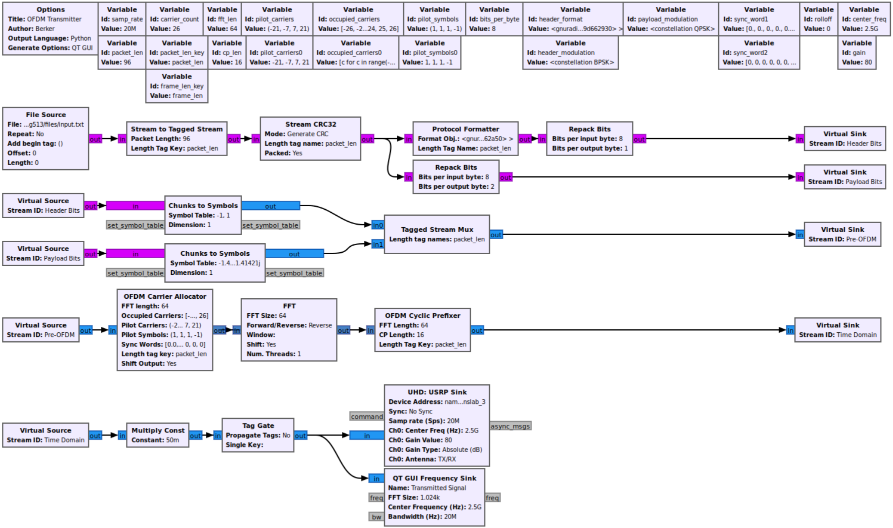


Figure: Complete GRC flow-graph of OFDM transmitter

OFDM Receiver

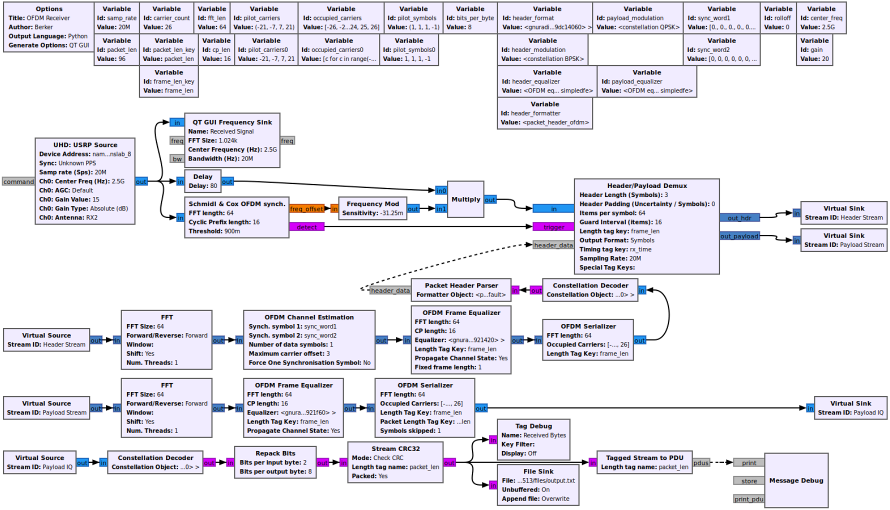


Figure: Complete GRC flow-graph of OFDM receiver

Agenda

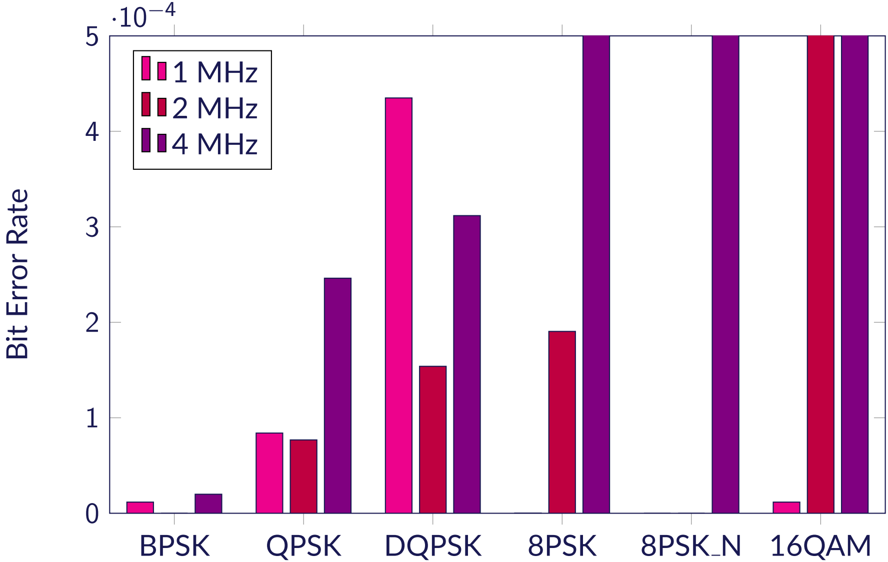
Test

Packet of size 96 bytes with known payload data is transmitted $N = 10000$ times. At the receiver side, received data and console output is written into files and these files are used for calculating:

1. **Bit Error Rate**
2. **Undetected Packet Count**
3. **Reception Time**

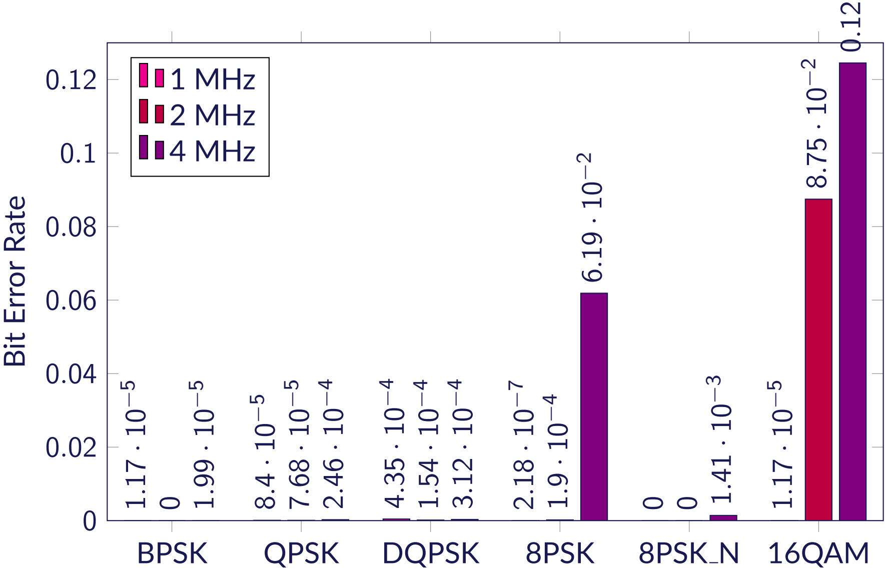
32-bit CRC is disabled for tests and the system is tested with different OFDM parameters: Bandwidth (1 MHz, 2 MHz, 4 MHz), Payload Modulation (BPSK, QPSK, DQPSK, 8PSK, natural 8PSK, 16QAM). Tests are run 3 times per configuration and the calculations are averaged. Also, all test are done with the same transmitter and receiver antennas gain values.

Results

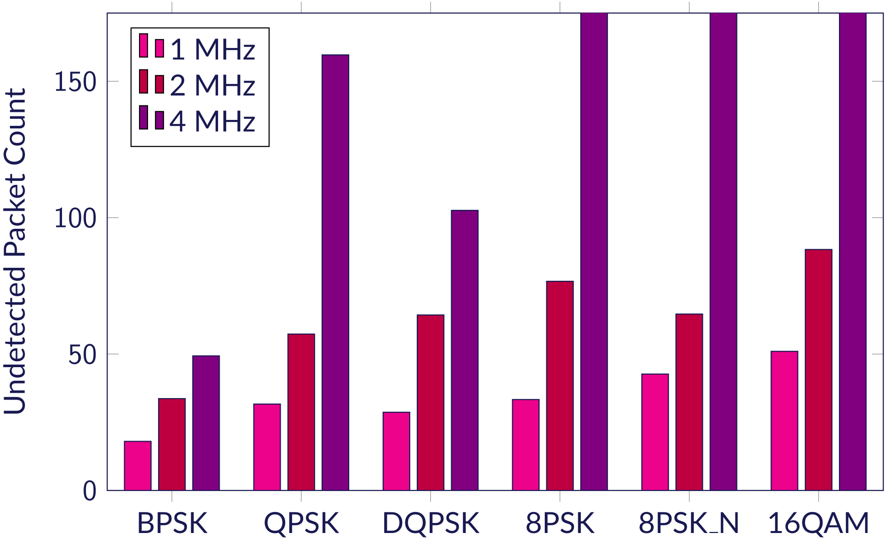


$\cdot 10^{-4}$
5
4
3
2
1
0
Bit Error Rate
1 MHz
2 MHz
4 MHz
BPSK
QPSK
DQPSK
8PSK
8PSK_N
16QAM

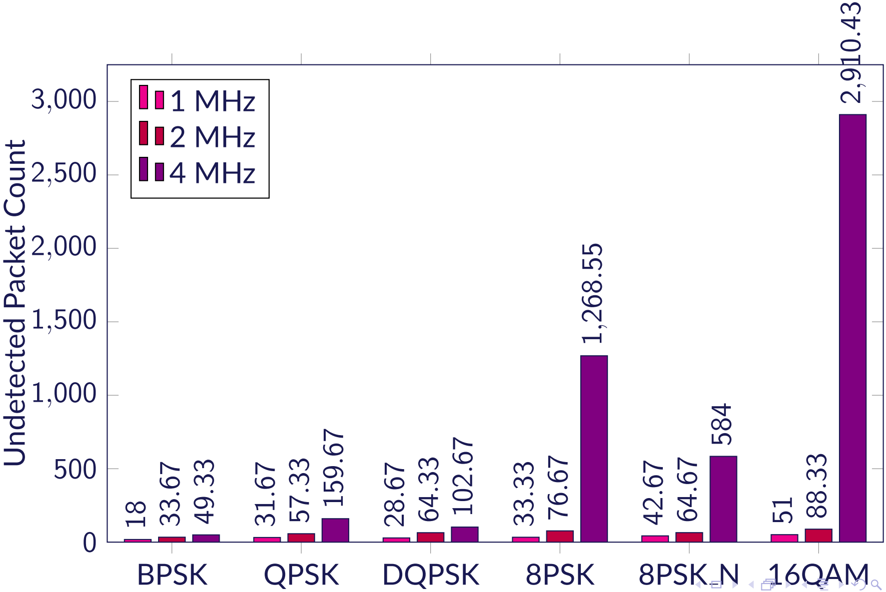
Results


1 MHz
2 MHz
4 MHz
Bit Error Rate
0
0.02
0.04
0.06
0.08
0.1
0.12
BPSK
QPSK
DQPSK
8PSK
8PSK_N
16QAM
1.17 · 10−5
0
1.99 · 10−5
8.4 · 10−5
7.68 · 10−5
2.46 · 10−4
4.35 · 10−4
1.54 · 10−4
3.12 · 10−4
2.18 · 10−7
1.9 · 10−4
6.19 · 10−2
0
0
1.41 · 10−3
1.17 · 10−5
8.75 · 10−2
0.12

Results


1 MHz
2 MHz
4 MHz
Undetected Packet Count
0
50
100
150
BPSK
QPSK
DQPSK
8PSK
8PSK_N
16QAM

Results


1 MHz
2 MHz
4 MHz
Undetected Packet Count
3,000
2,500
2,000
1,500
1,000
500
0
18
33.67
49.33
31.67
57.33
159.67
28.67
64.33
102.67
33.33
76.67
1,268.55
42.67
64.67
584
51
88.33
2,910.43
BPSK
QPSK
DQPSK
8PSK
8PSK_N
16QAM

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Discussion

- Increasing the bandwidth increases bit error rate and undetected packet count.
- Dense modulation schemes are more prone to bit errors and undetected packets.
- Transmitter and receiver might require fine-tuning for different configuration settings. For example, the transmitter and receiver system with current parameters cannot detect incoming frames when working with 20 MHz bandwidth.

Agenda

Future Work

- Reliable packet transmission with BEC and FEC mechanisms
- Testing the system with different OFDM parameters such as FFT length, CP length etc.
- Implementing self-adjusting system by controlling OFDM parameters such as modulation schemes, FFT length, CP length etc.
- Training a channel classification machine learning model from collected I/Q samples and deployment of the model

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Conclusion

- OFDM transmitter and receiver design in GNU Radio software
- Real-time data transmission using USRP SDRs
- Testing of the system with different OFDM parameters
- Possible future works on the project

Questions

THANK YOU

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presented by Berker Acır

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