Wireless Monsters
Group 3

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CHALMERS

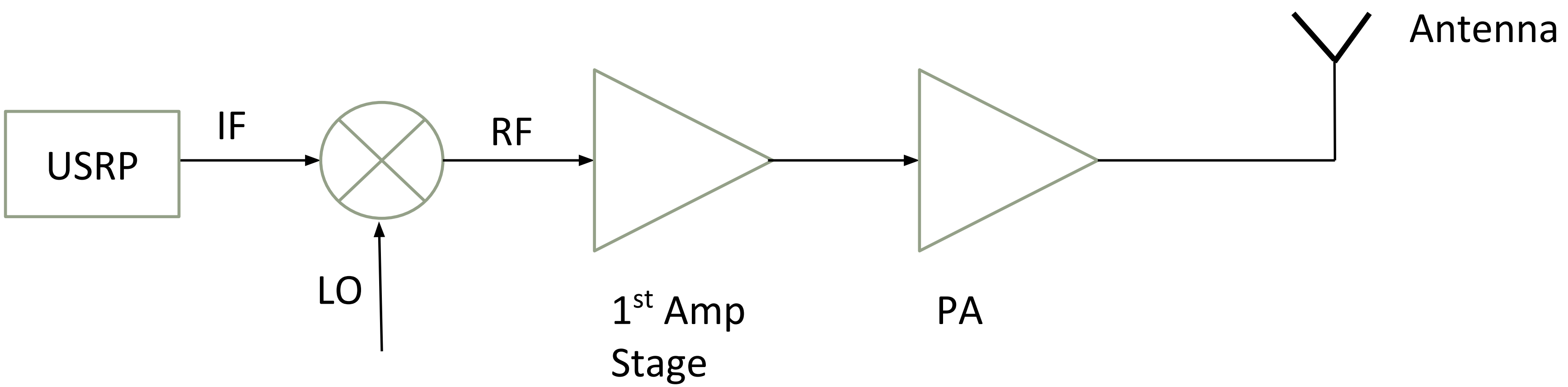
Design Approach

- Link budget
- Component selection
- Layout design
  - Transmitter
  - Receiver
- Software implementation
  - MATLAB Scripts
  - LABView Simulations

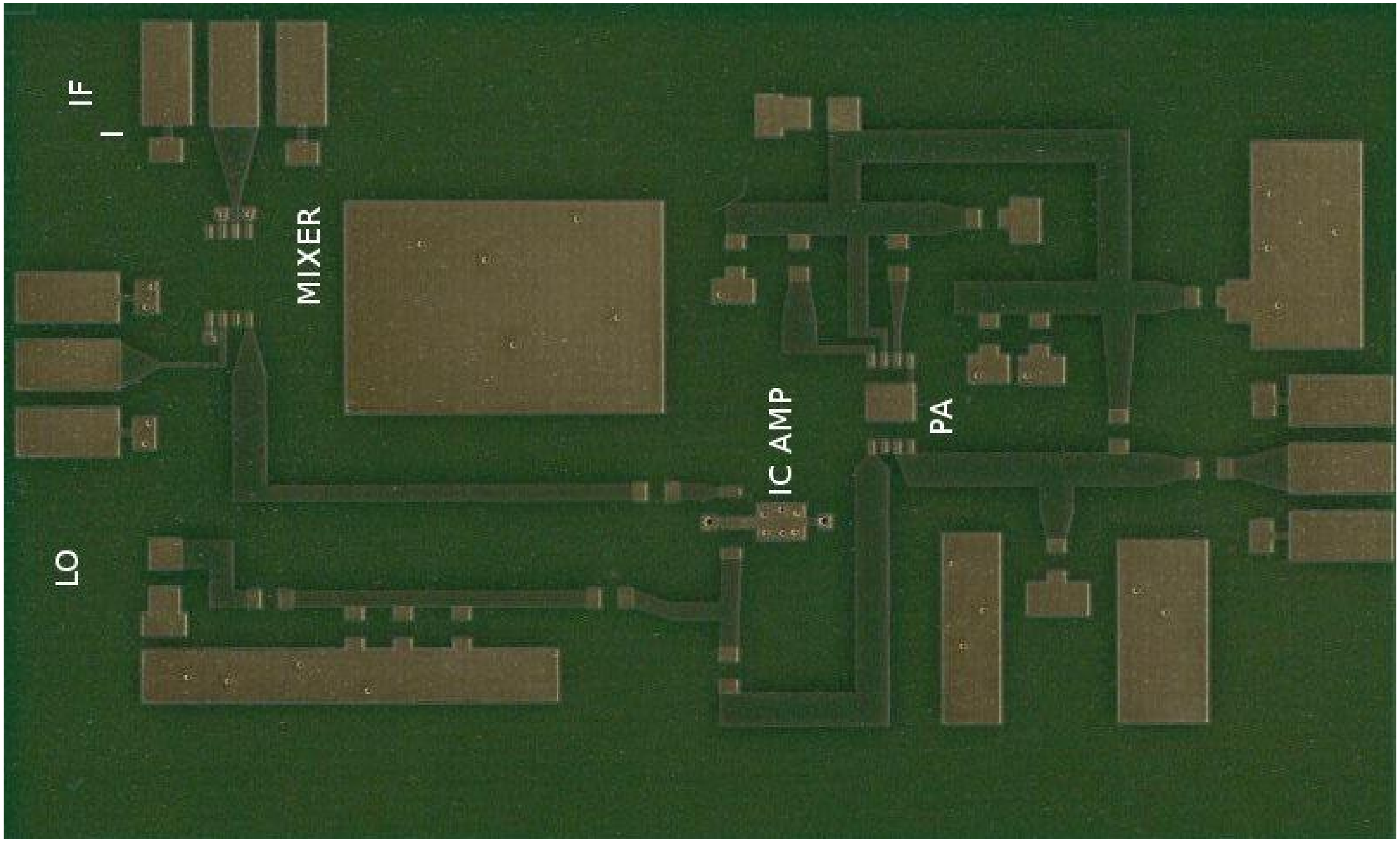
Link Budget

USRP output	P_{USRP} = -3 dBm
Gain (transmitter)	G_{TX} = 25 dB
Transmitted Power (before antenna)	P_t = 22 dBm
Path Loss	L_{path} = 84 dB
Received Power (input of receiver)	P_r = -56 dBm
Receiver's Noise Figure	F_{rec} = 4.6 dB
System's Noise Temperature	T_{sys} = 836.4 K
Noise Power (output of receiver)	N_{out} = -84 dBm
Signal Power (output of receiver)	P_{out} = -32.2 dBm

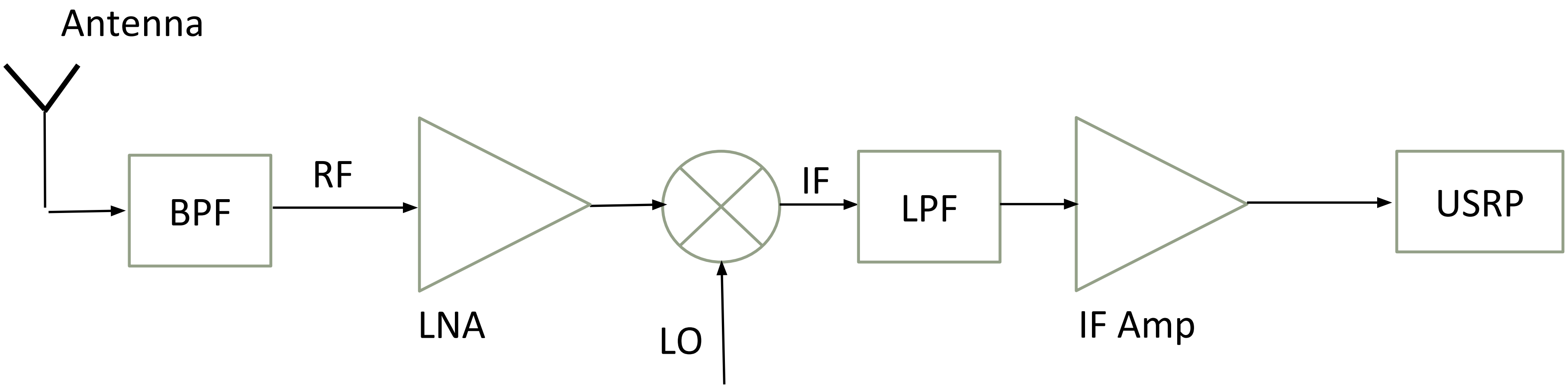
Transmitter Design (TX)



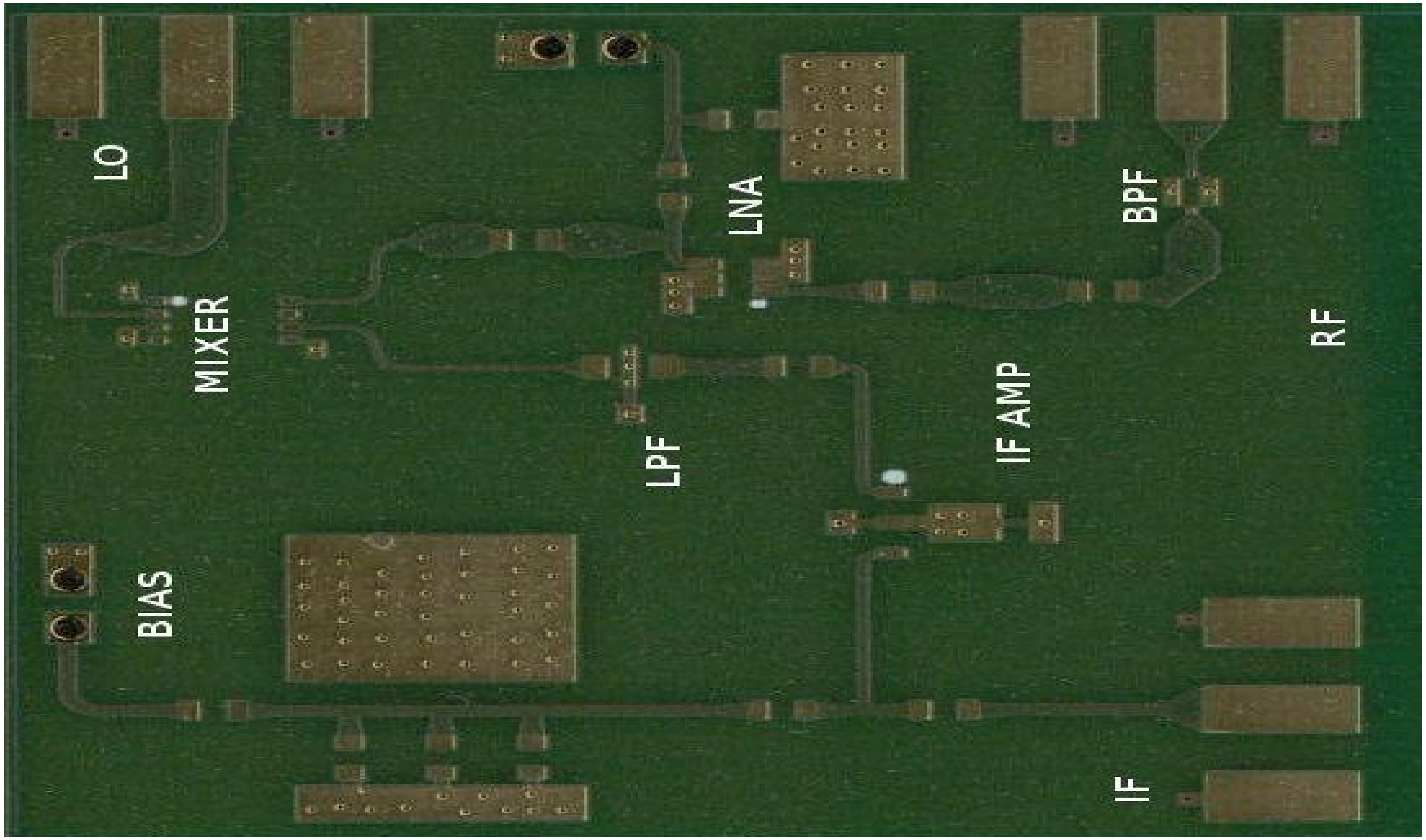
Transmitter PCB (TX)



Receiver Design (RX)



Receiver PCB (RX)

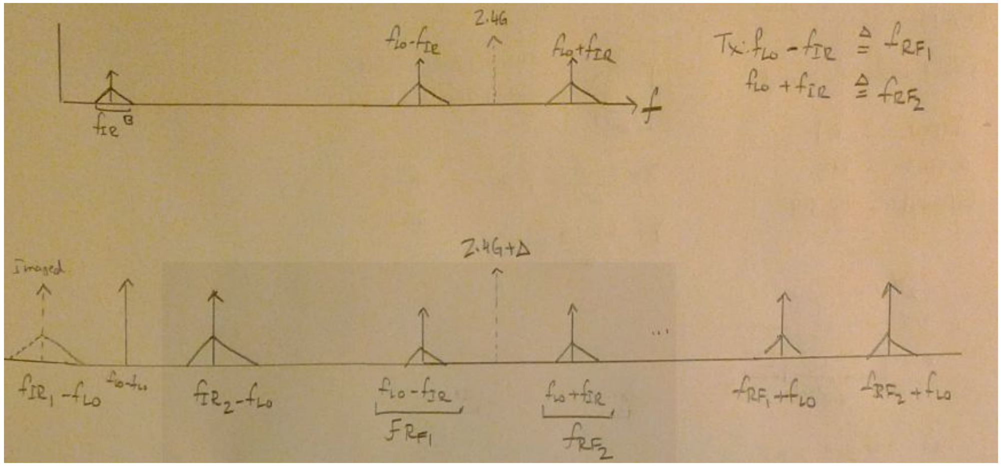


IF and Images

IF = 40MHz

LO_TX = 2.4GHz

LO_RX = 2.33GHz



1. F1 = 30MHz - Our signal
2. F2 = 110MHz - Filtered by LPF

Pulses and Bandwidth

1. Bandlimited signal B. Sampled at fs>2B

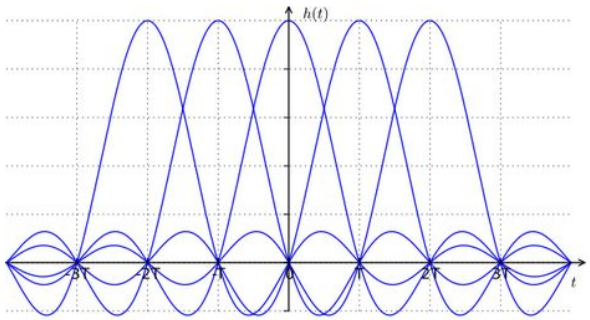
$$x(t) = \sum_{n=-\infty}^{\infty} x(nT) \cdot \mathrm{sinc}\left(\frac{t - nT}{T}\right)$$

2. Pulses: Sinc is infinite, not very practical.

3. Nyquist Criterion.

   (Eliminate ISI)

$$h(nT_s) = \begin{cases} 1; & n = 0 \\ 0; & n \neq 0 \end{cases}$$



4. Raised Cosine Pulse. Is a Nyquist pulse and it's not infinite!

5. Root Raised Cosine Pulse.

$$H_{rc}(f) = H_{rrc}(f) \cdot H_{rrc}(f)$$

Modulations

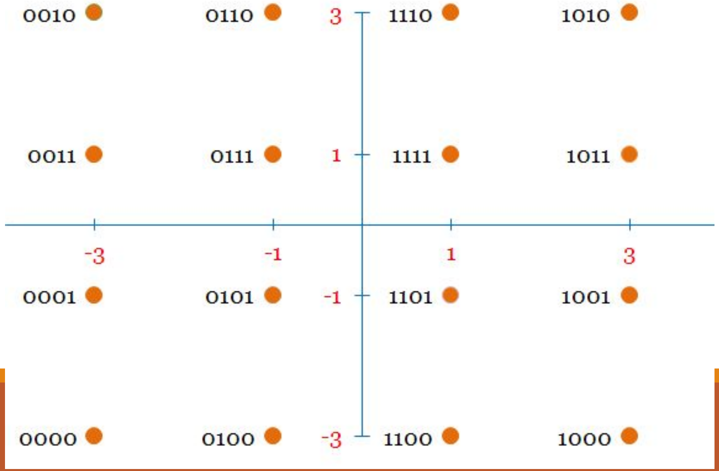
1. 16 QAM. Quadrature Amplitude Modulation.

2. 4 Amplitude scalings on 2 orthogonal carriers, make for 16 symbols

Transmitter:
$$s(t) = Re\left\{[I(t) + iQ(t)]\,e^{i2\pi f_0 t}\right\}$$
$$= I(t)\cos(2\pi f_0 t) - Q(t)\sin(2\pi f_0 t)$$

Receiver:
$$r(t) = s(t)\cos(2\pi f_0 t)$$
$$= I(t)\cos(2\pi f_0 t)\cos(2\pi f_0 t) - Q(t)\sin(2\pi f_0 t)\cos(2\pi f_0 t)$$
$$= \frac{1}{2}I(t) + \frac{1}{2}[I(t)\cos(4\pi f_0 t) - Q(t)\sin(4\pi f_0 t)]$$

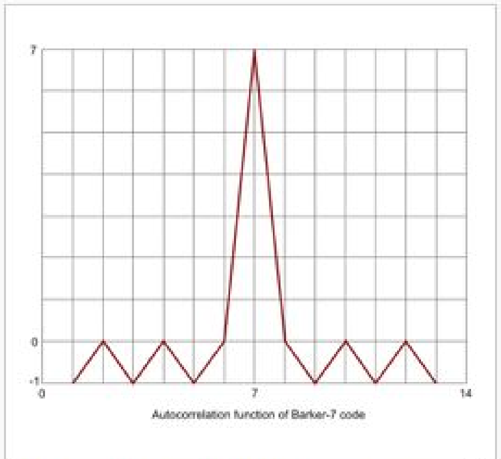
3. Gray Coded



Barker and BER Curve

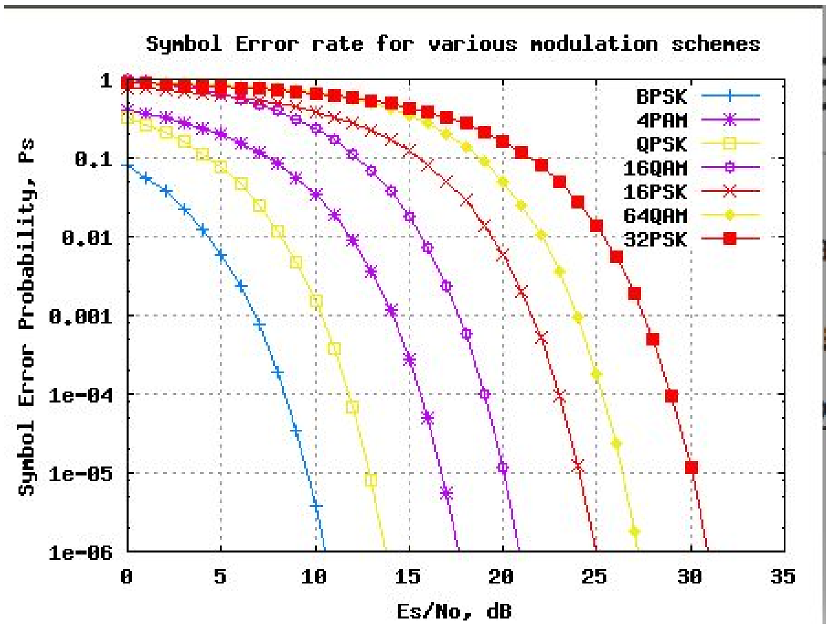
1. Barker Sequence. Non-main lobe coefficients are small. $|c_v| \leq 1$

2. Autocorrelation high peak to sidelobe ratio:



Autocorrelation function of a Barker-7 code

3. ~20 dB QAM, for BER = 10^-6.



Software - Transmitter

1. Convert bits to symbols. Decimal value of 2 (QPSK) or 4 (16-QAM) consecutive bits are used as an index in our constellation mapping.
2. 13 symbol barker sequence added to both I and Q channel for frame synchronization at receiver.
3. I and Q channels up-sampled and convolved with root-raised cosine.
4. I and Q channels moved to IF frequency and added (mixed)

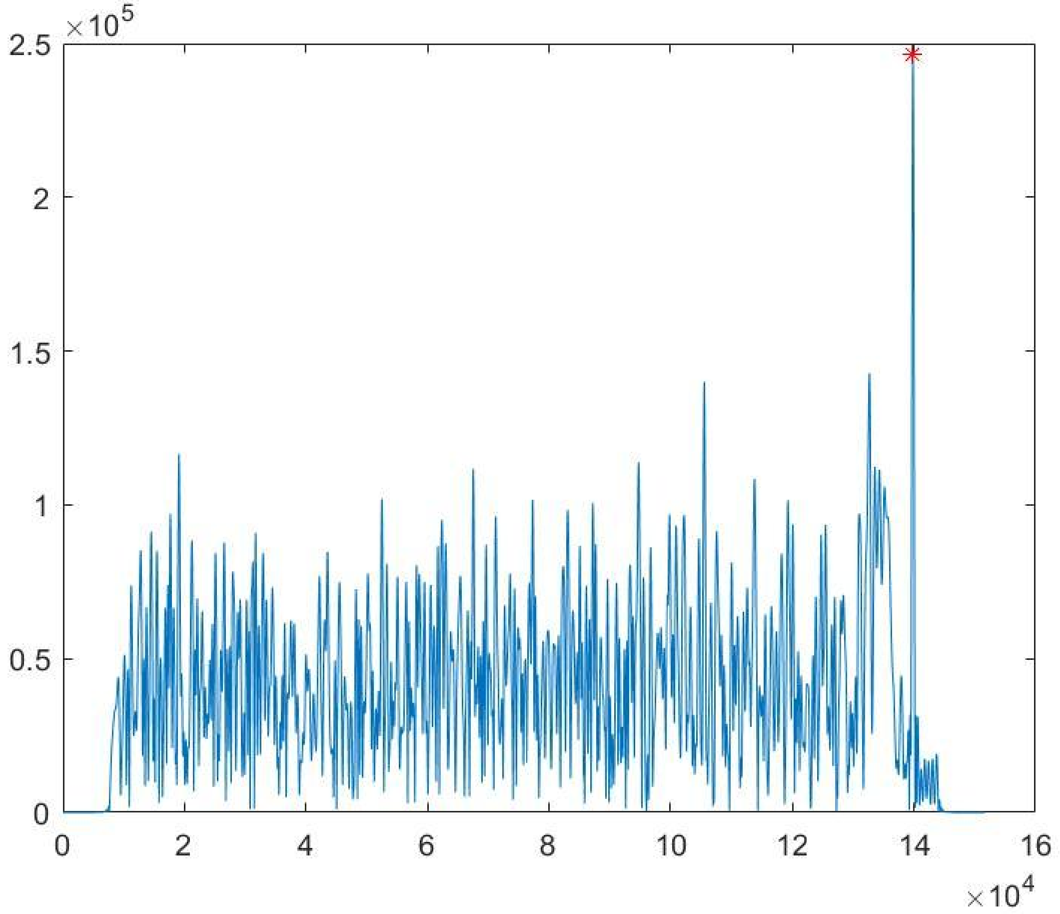
Software - Receiver

1. While no frame has been found:
    a. Continuously acquire a frame
    b. Move signal from IF to baseband
    c. Match filter the signal
    d. Check for Barker sequence by correlating the Barker sequence with the frame, if the correlation has a max value above a set threshold we assume that a message has been detected and we move to step 2 (We keep the IF signal for future use). Otherwise we repeat step 1.
2. Find the index where the maximum correlation occurred and use for frame synchronization.
3. Use the first symbol of the Barker sequence to determine phase offset

Software - Receiver cont.

4. Using the IF signal we again move the signal from IF to baseband but with the addition of phase correction. We assume that the phase shift will be similar over the complete received frame.
5. Matched filter the baseband signal and remove tails of filter.
6. Downsample signal.
7. Use the symbols in the Barker sequence to scale the received symbols to match constellation points. (Equalization)
8. Apply a Maximum-Likelihood (ML) detector (Optimal detector).
    a. For each received symbol we subtract the scaled received symbol value from the constellation values.
    b. The minimum absolute value and its index in the constellation vector corresponds to the decimal value of the detected symbol.
    c. Convert decimal index to bits and output demodulated bitstream.

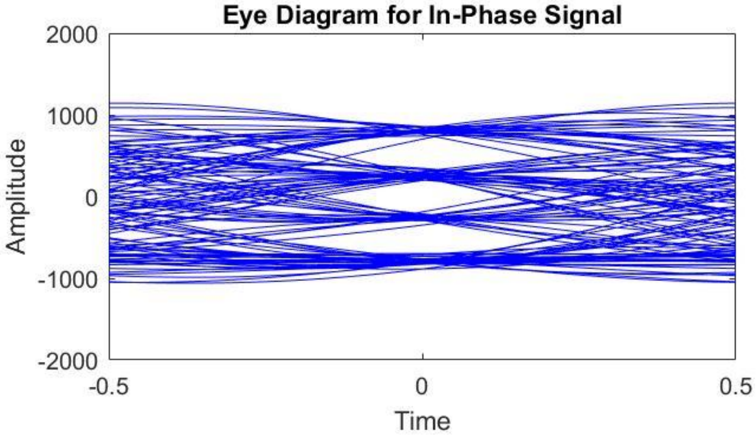
Frame synchronization

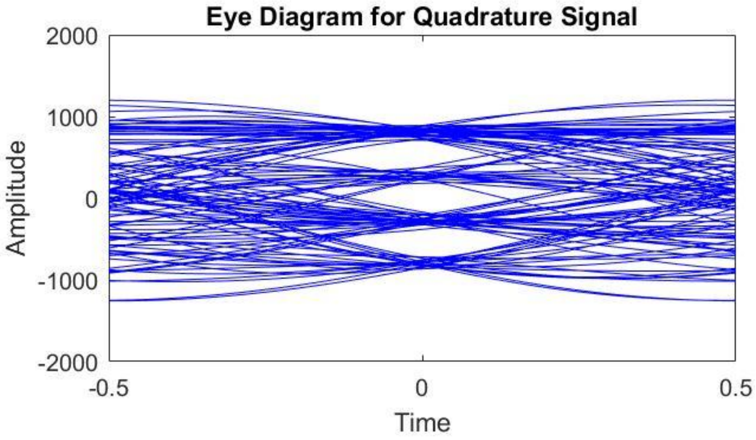


Eye Diagram

1. Eye Opening

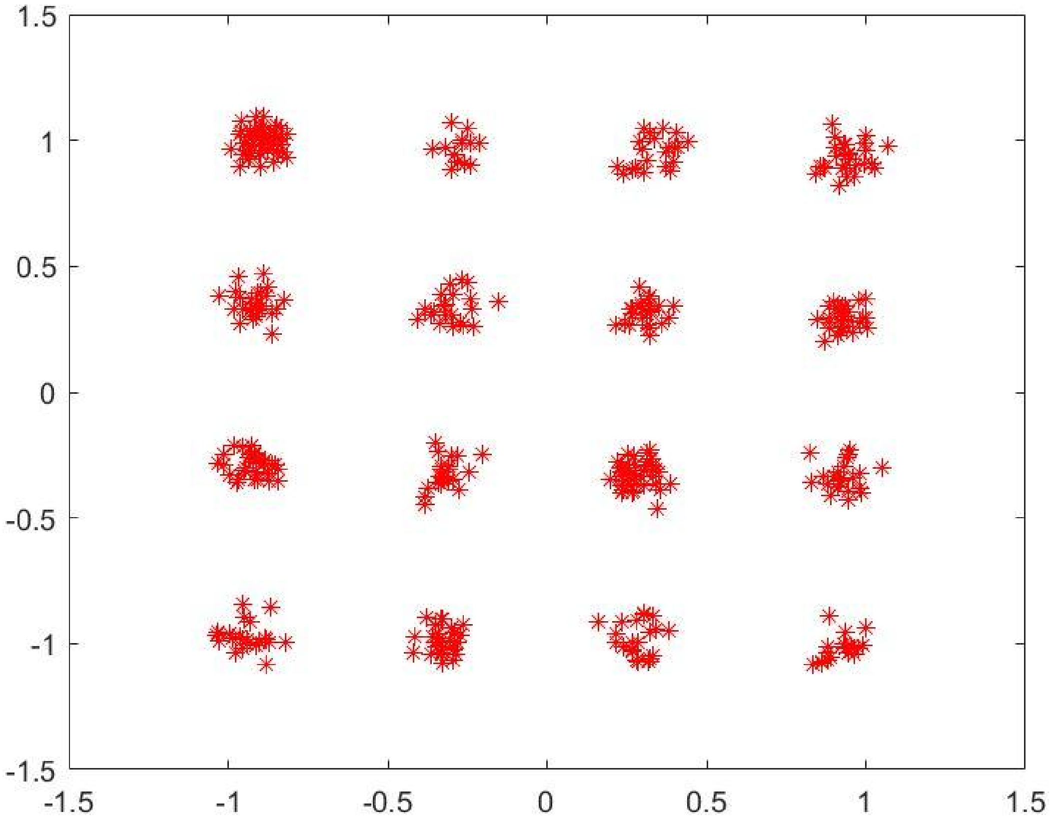
2. Synchronization Timing





Constellation @25 dB SNR and corrected 3PI/4 phase-offset

1. Phase offset
2. Frequency offset
3. Amplitude scale



Constellation @25 dB SNR and 3PI/4 phase offset without phase correction