LiFi

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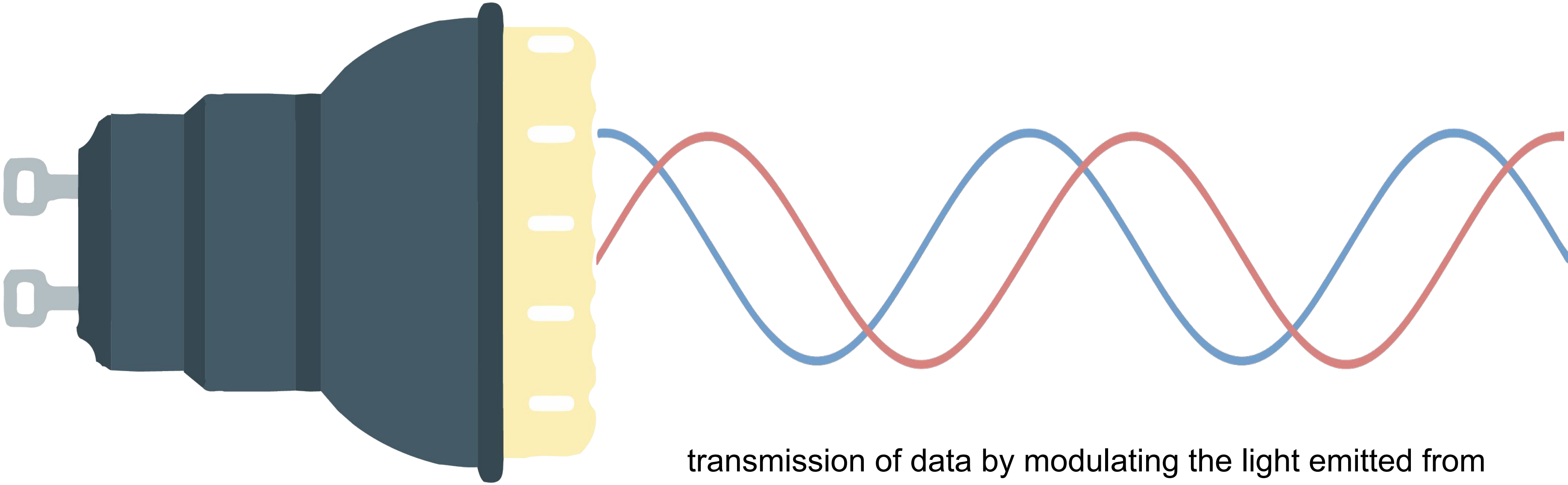
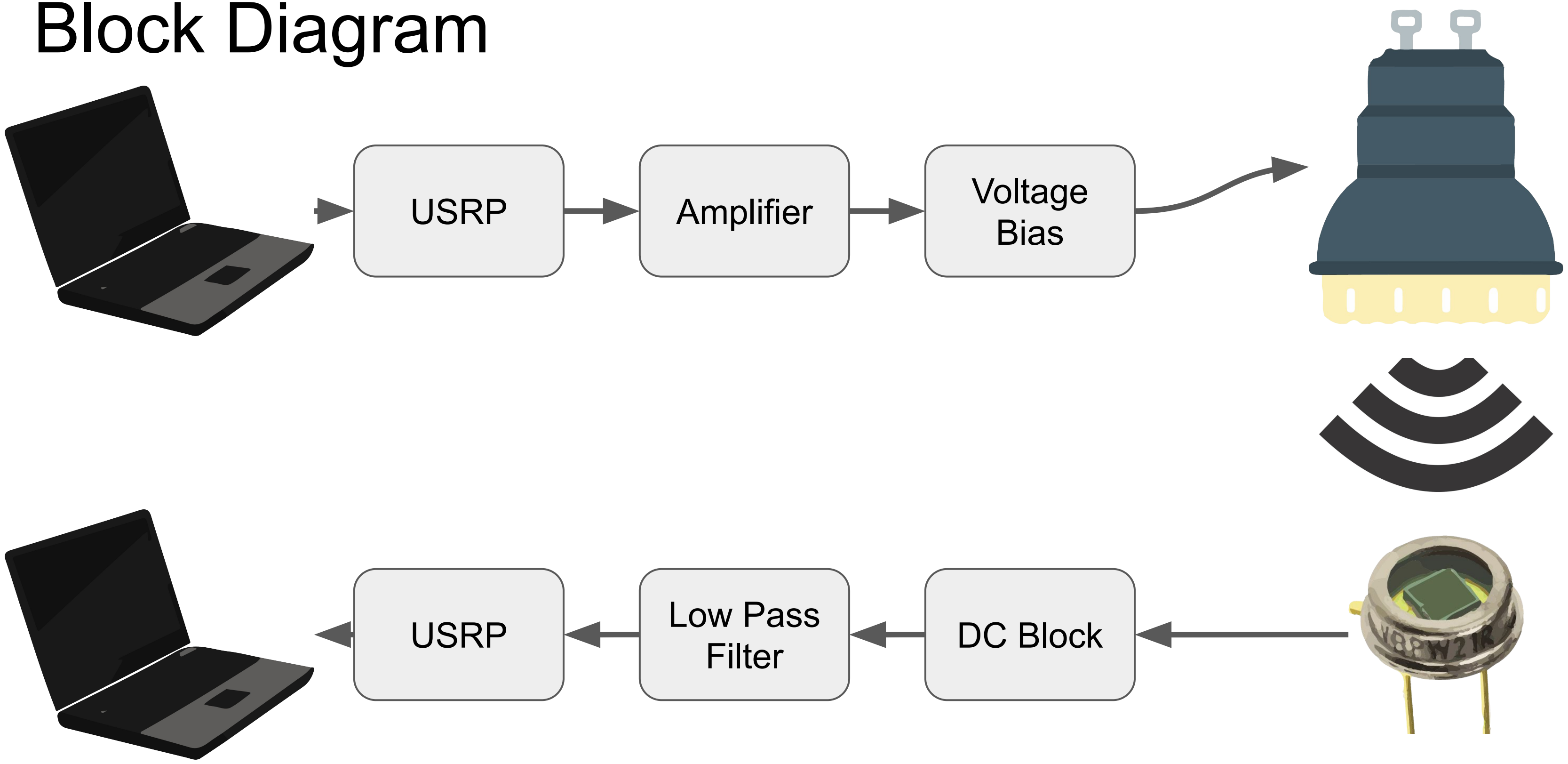
What is Lifi?

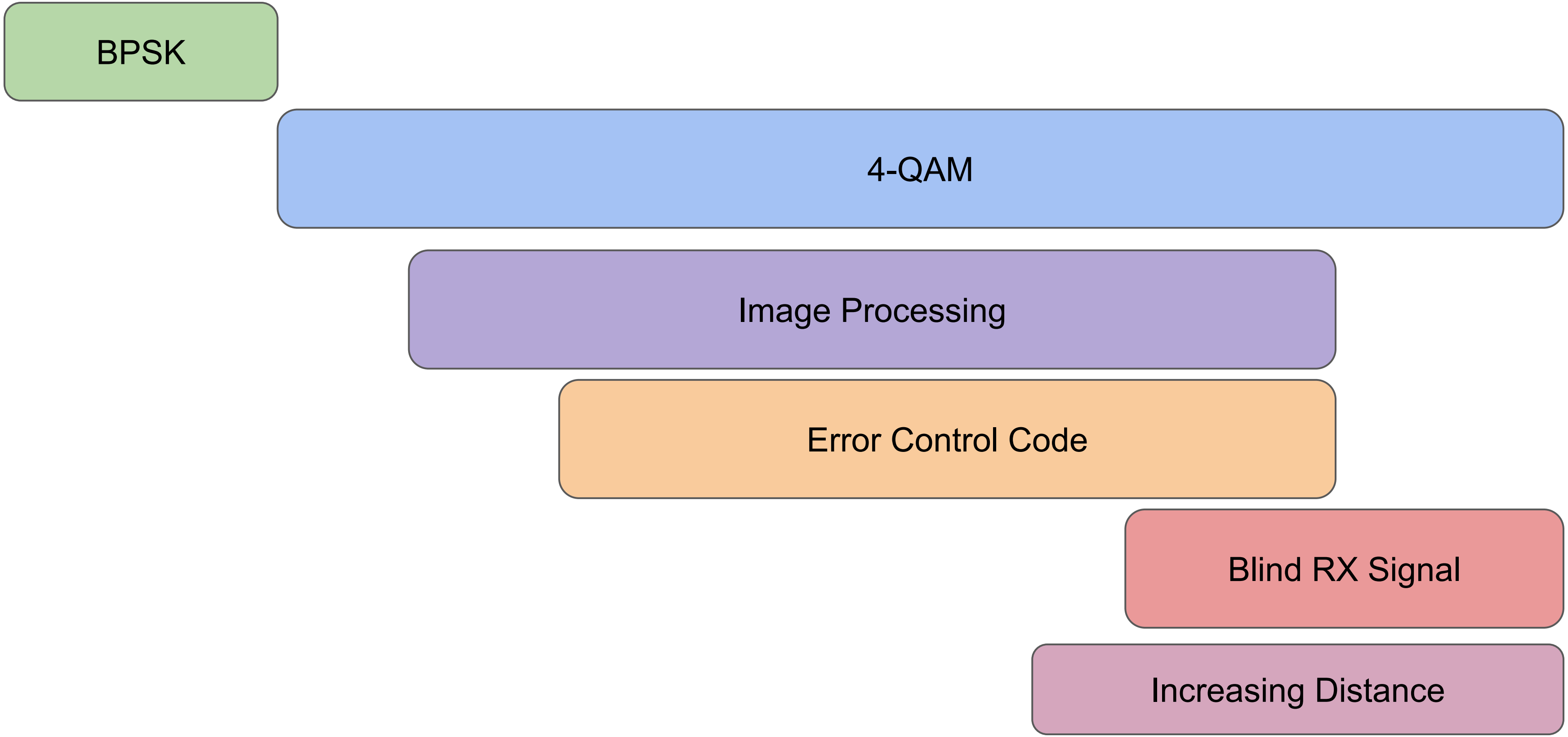


transmission of data by modulating the light emitted from a led bulb.

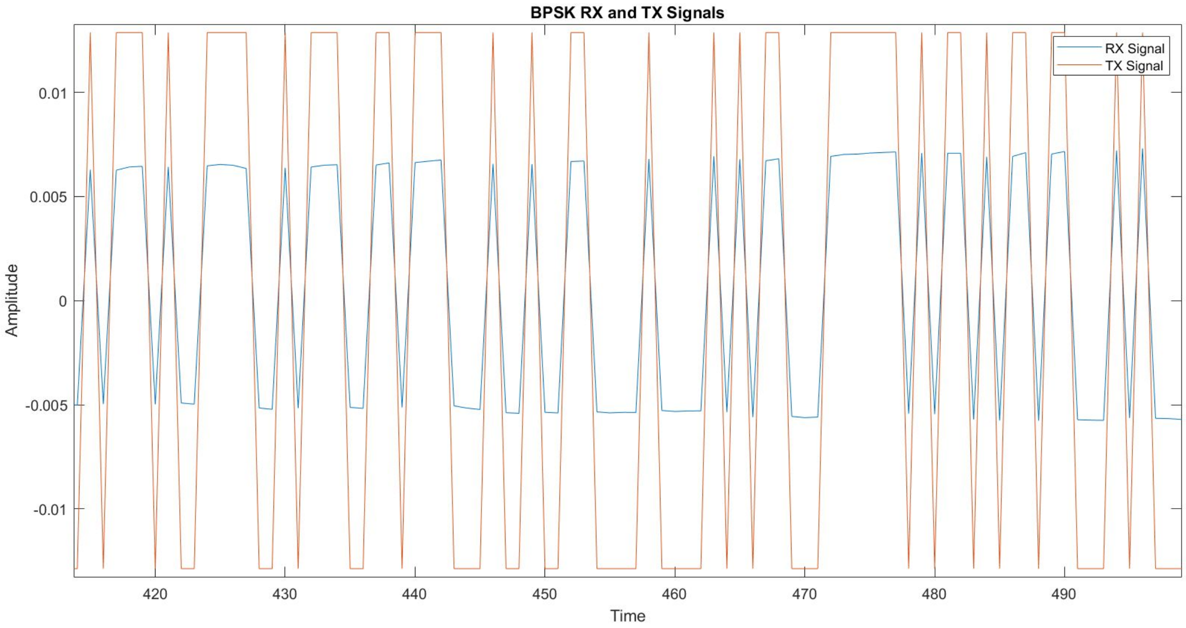
Block Diagram



Project Timeline



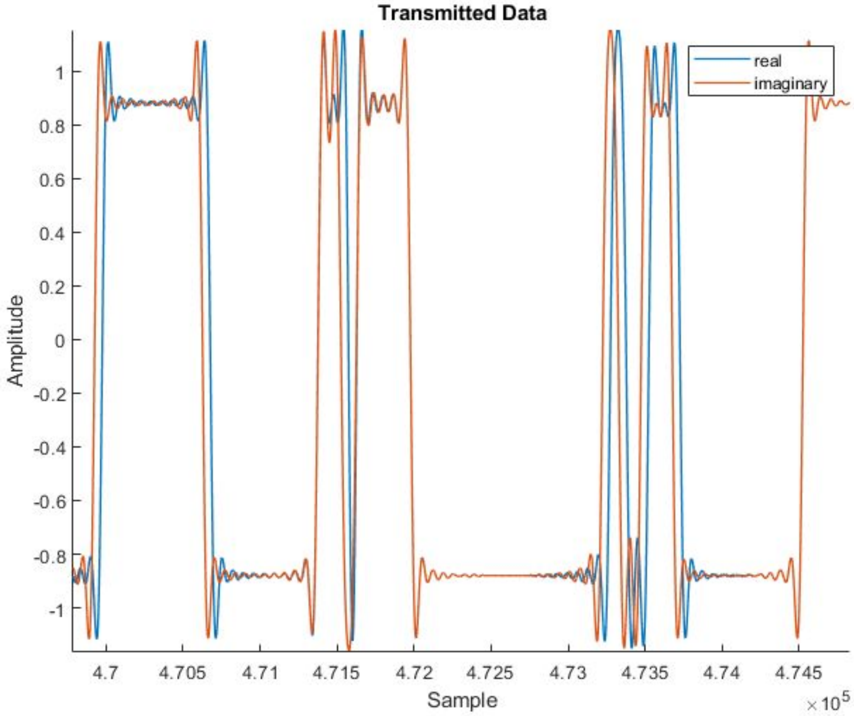
BPSK



3.5 inches
20 kbits/s
0% Error

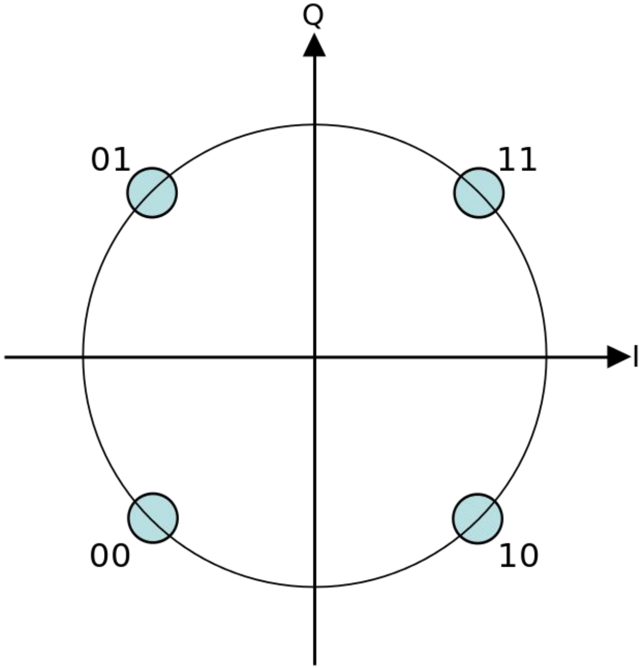
4-QAM Signal Structure

- 4-QAM QPSK
- Carrier Frequency of 150k
- Sample Rate of 2 Mbits/sec
- **R**oot **R**aised **C**osine Pulse
    - Pulse width of 50
    - RRC F(f)
- 200,000 bits per packet
- 80 kbits/sec data rate

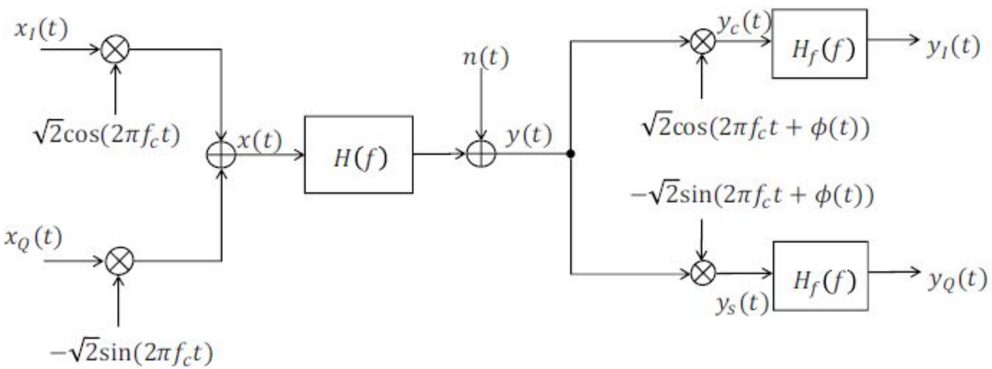


4-QAM

2 bits/symbol

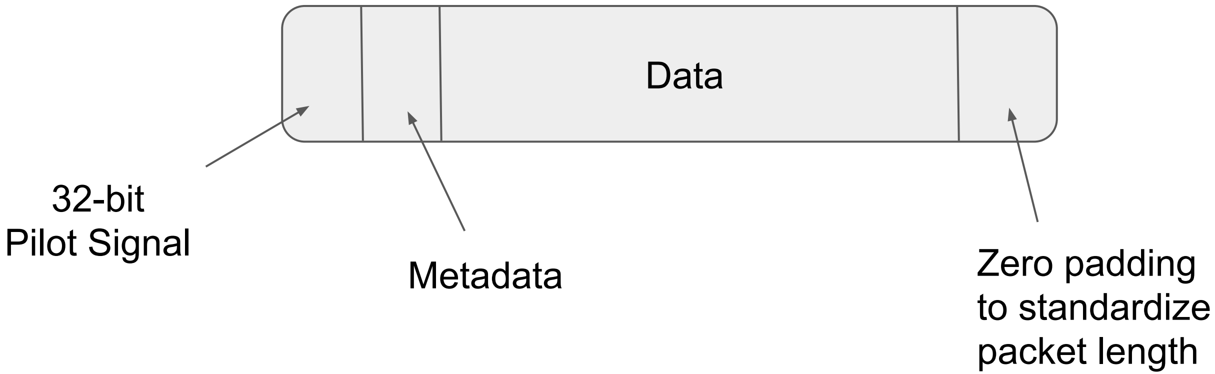


The 2 bits are transmitted 90 degrees offset from each other.



Packet Structure

- Sending black and white images
  - Including length and width metadata
- Hamming Correction Code (7,4)
  - Corrects 1 error in every 7-bits of data
  - Increases code size by ~7/4



Pilot Signal

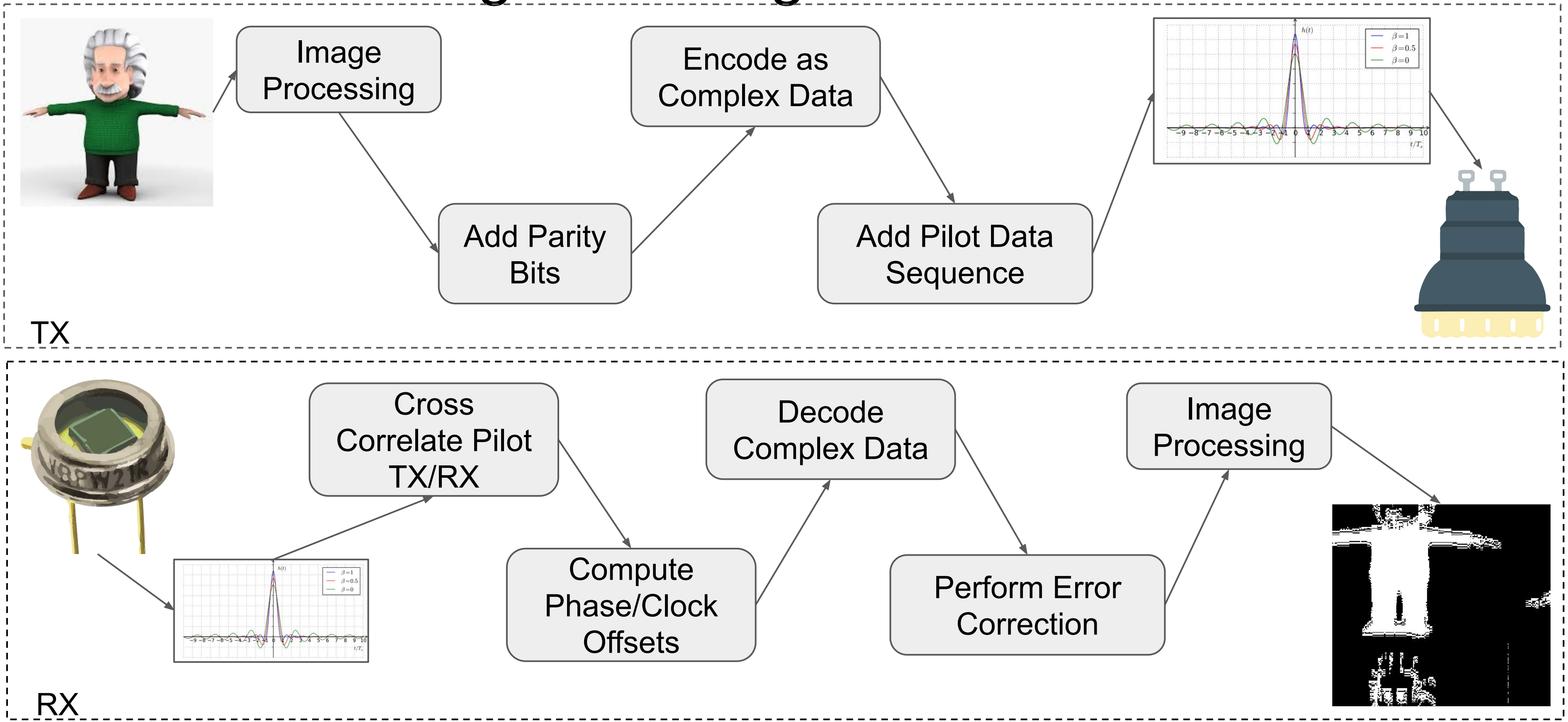
- Allow us to precisely find the start sequence of our data
  - Cross Correlation of Rx data with with starting sequence to determine location
- Random composition to reduce chance of start sequence showing up in the data

$$prob_{32} = \frac{1}{2^{32}}$$

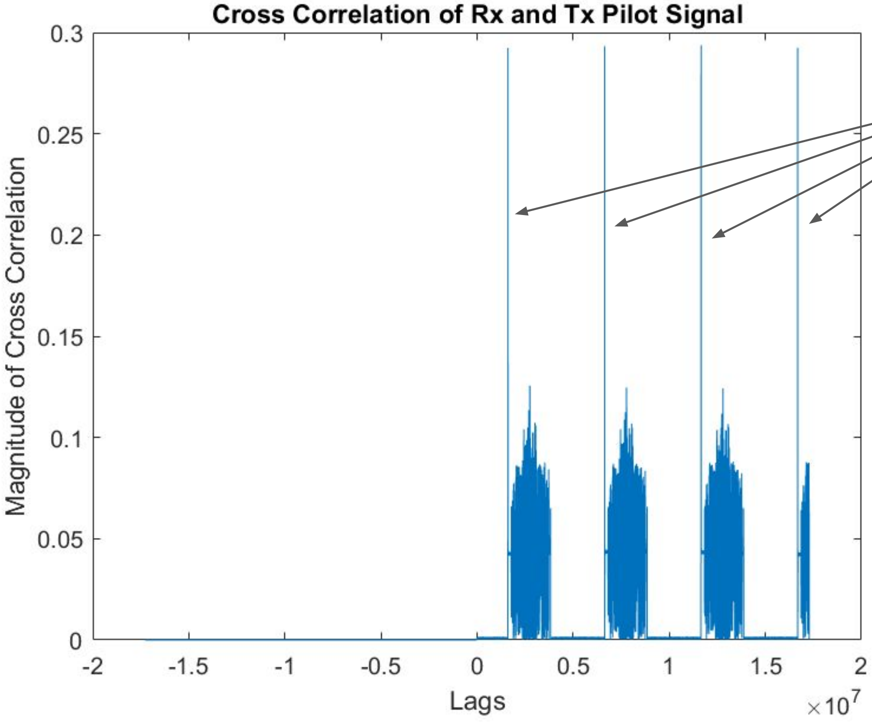
$$prob_{packet} = prob_{32} * (len - 32)$$

$$= 4.6e - 5$$

Data Processing Flow Diagram



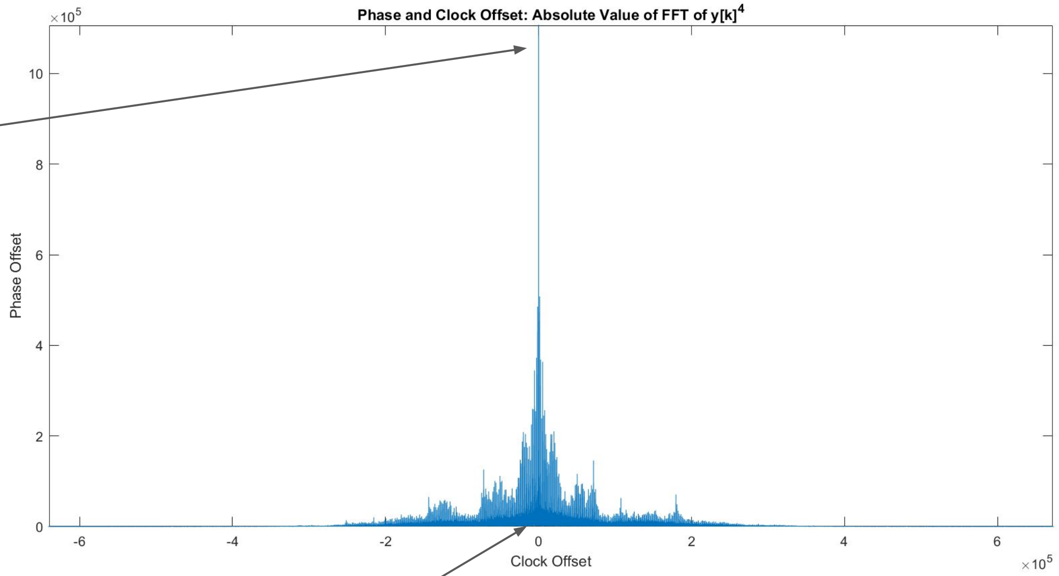
Find Start of Signal



Pilot Signal Starts

Phase Offset Correction Method 1: FFT / $y[k]^4$

$e^{j(4\varphi+\pi)}$



$4f_\Delta$

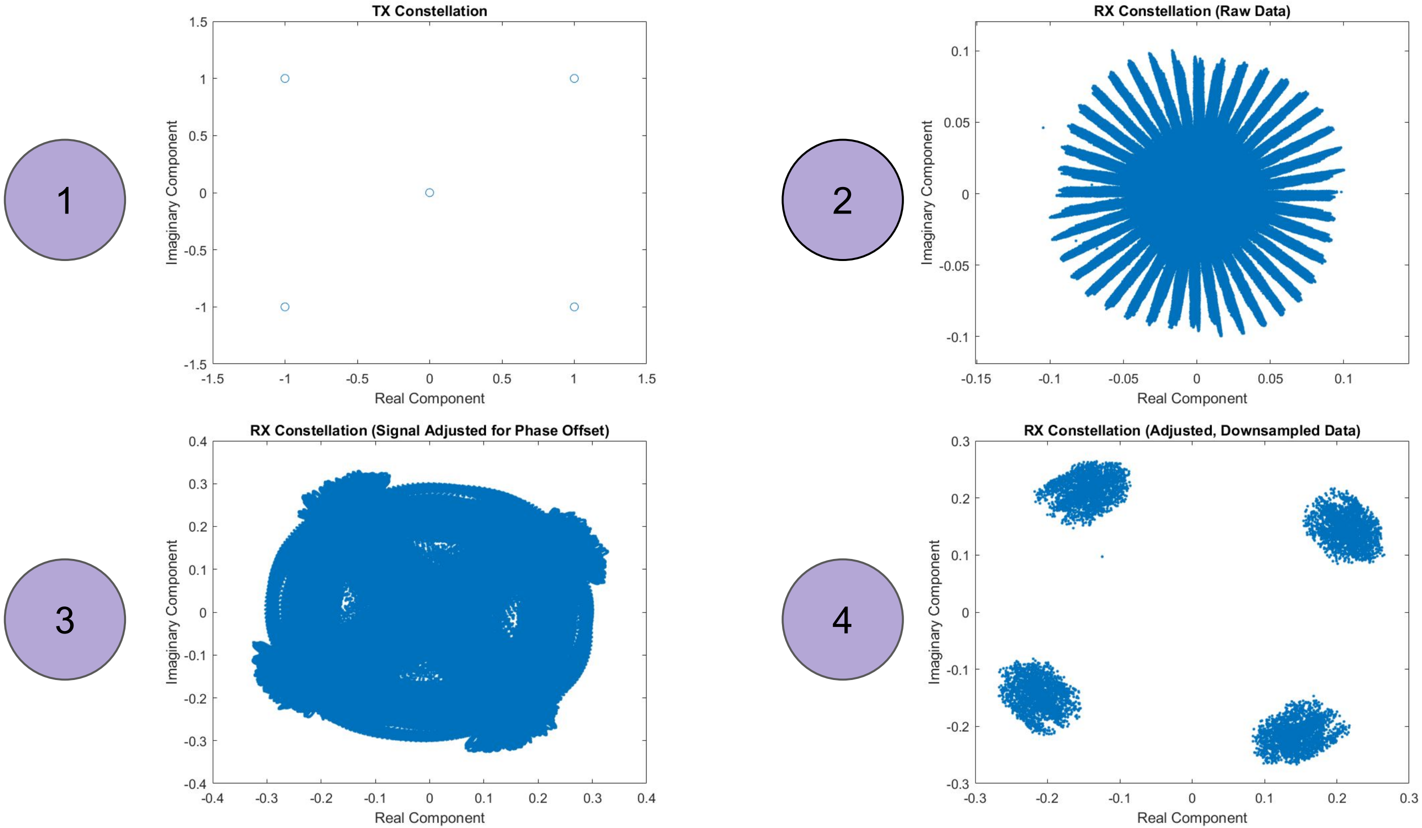
Pros

- Simple Implementation
- Minimum Error Rate Achieved ~2%

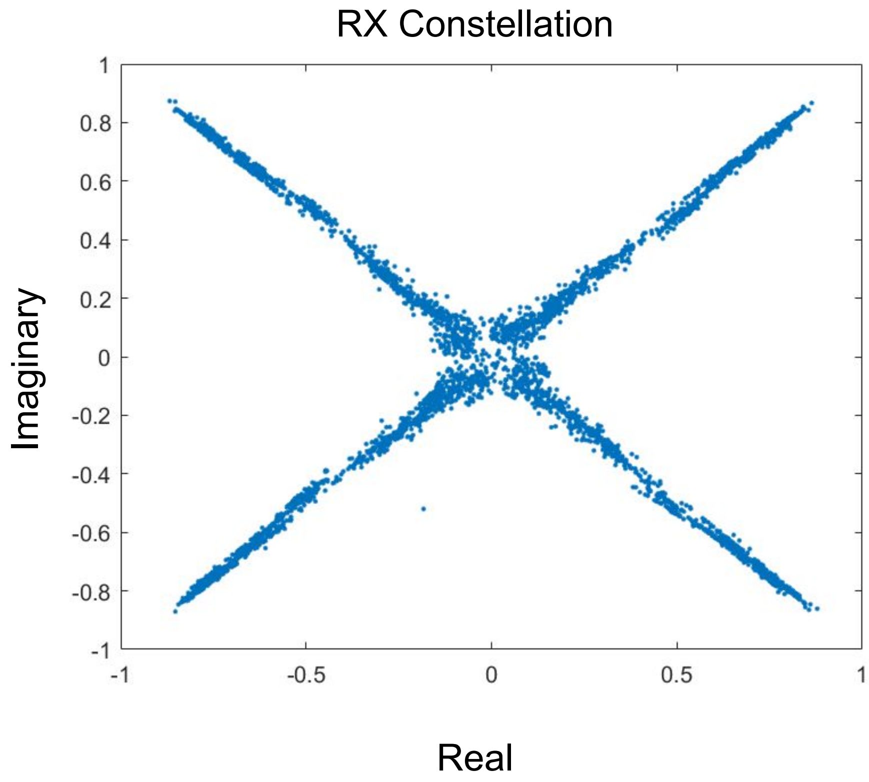
Cons

- More edge cases
- Commonly resulted in RX Constellation clusters centered on axes during development

Correcting Phase and Clock Offset



Phase Offset Correction Method 2: Costas Loop



Pros

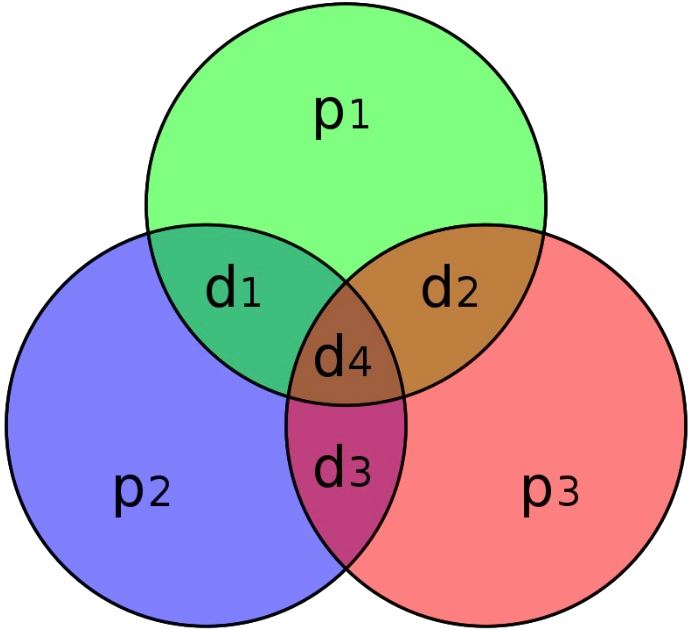
- Consistently reasonable RX Constellations

Cons

- Errors compounded too quickly
- Minimum Error Rate Achieved ~15-20%

```
for k = 1:length(rx)
    % Correct for phase offset
    x_hat(k) = y_bar(k).*exp(1i.*psi_hat);

    % Compute error e[k]
    e = -(1./sqrt(2)).*(sign(real(x_hat(k))).*imag(x_hat(k))) + (1./sqrt(2)).*(sign(imag(x_hat(k))).*real(x_hat(k)));
    e_sum = e_sum + e;

    % d[k]=Beta*e[k]+alpha*sum(l=0,k,e[l])
    d = (beta.*e) + (alpha.*e_sum);

    % psi_hat[k+1] = psi_hat[k]+d[k]
    psi_hat = psi_hat + d;

    % Wrap around psi_hat[k+1]
    if psi_hat < -pi
        psi_hat = psi_hat + 2.*pi;
    elseif psi_hat > pi
        psi_hat = psi_hat - 2.*pi;
    end

end
```

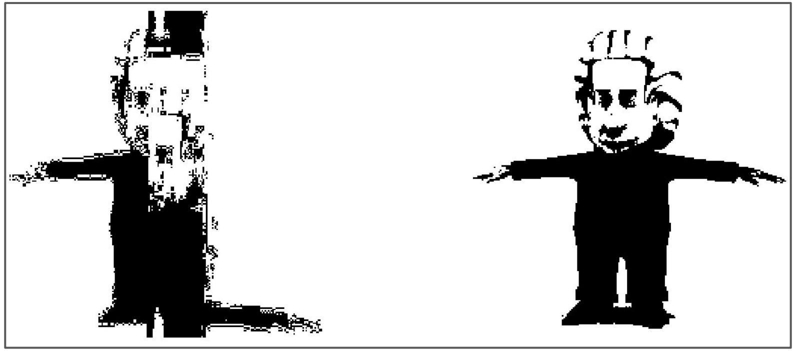
Error Correction Code: Hamming (7,4)



Sequence: [P1 D1 P2 D2 P3 D3 D4]

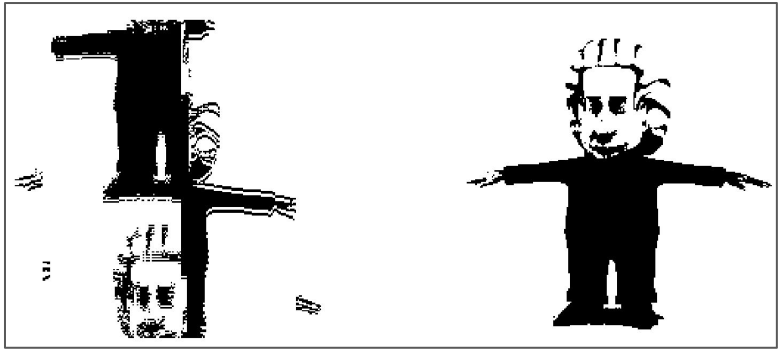
Error Correction Code

Hamming Code



25 inches
5% Error

No Hamming Code

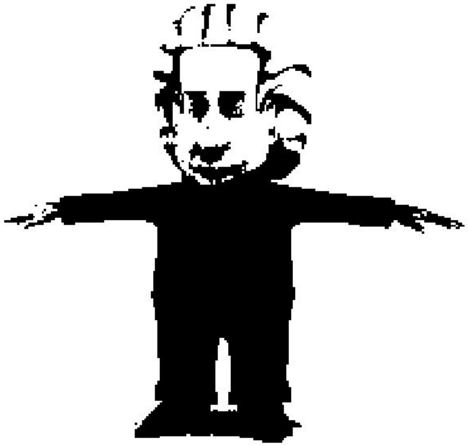


25 inches
10% Error

Best Results with Hamming

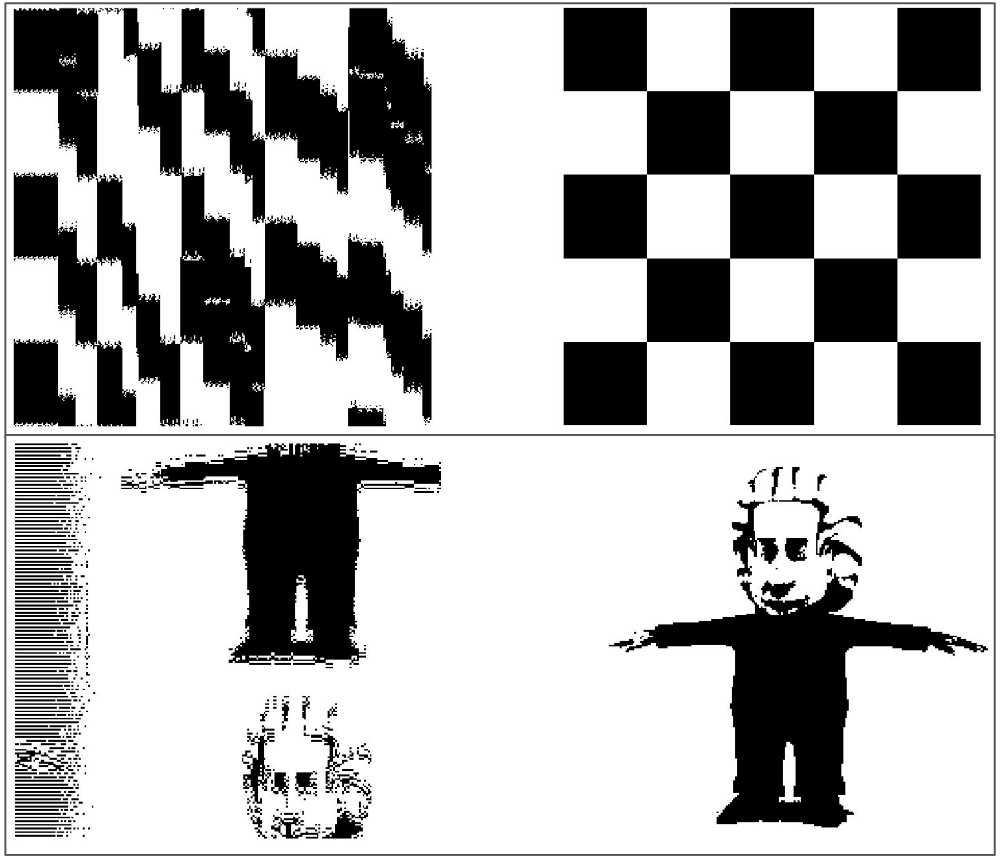
RX Image

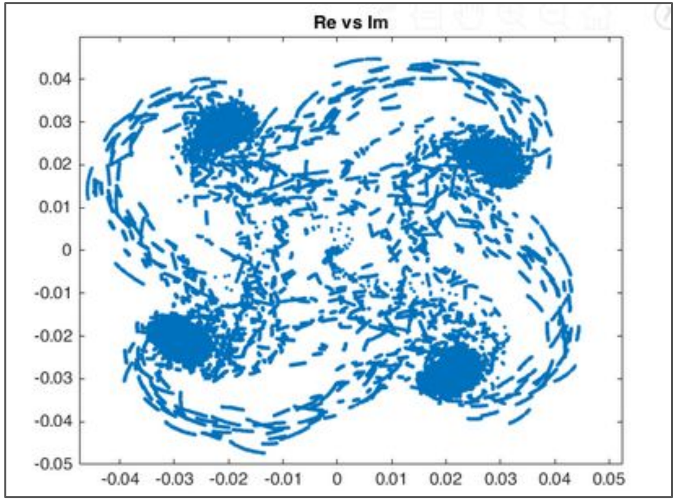
2% Error reduced from 3%
25 inches
Known File and Image Size



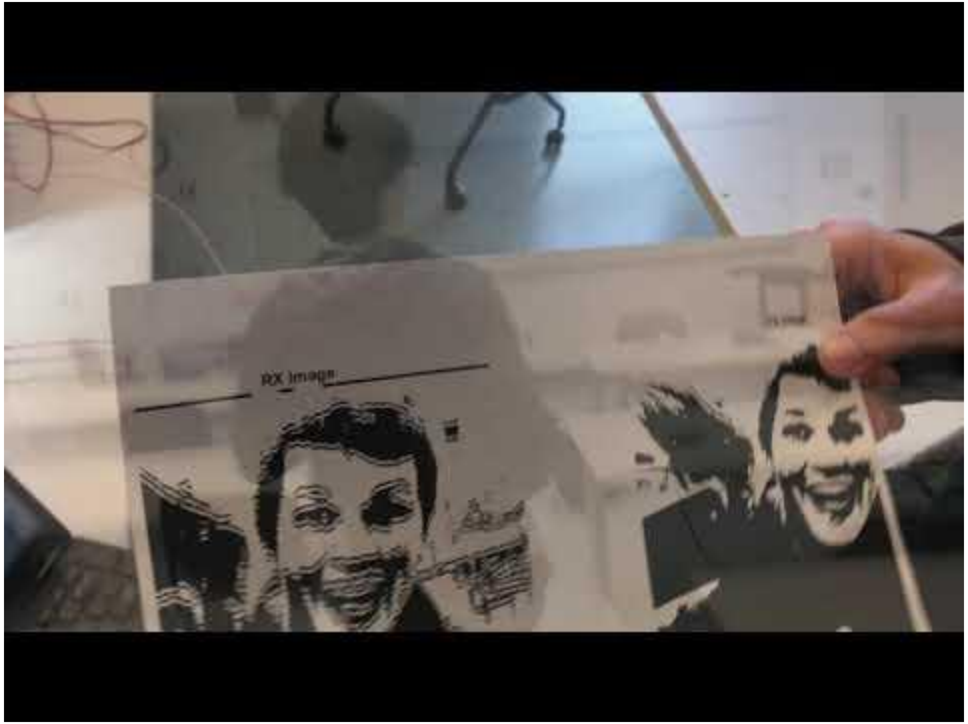
TX Image

Interesting Effects of Phase Offsets





Real World Application of LIFI



Conclusions

- Error due to distance of transmission increases rapidly with distance (1/d^4)
  - Inherent property of light
- Phase offsets remain a challenge for large data packets
  - Easy to perform perfect data reconstruction for packets containing <= 10k data points
  - Phase shifting affected error rate when data packets > 50,000 bits
  - Transmit data in smaller packets
- Adding a neural net to deduce whether the image was einstein or checkerboard would decrease our error rate to 0% but also decrease our data rate to 1bit/30mins

Questions?

Sent with  via light 12/11/2019