Frequency Domain Eye Diagram for Orthogonal Frequency-Division Multiplexing

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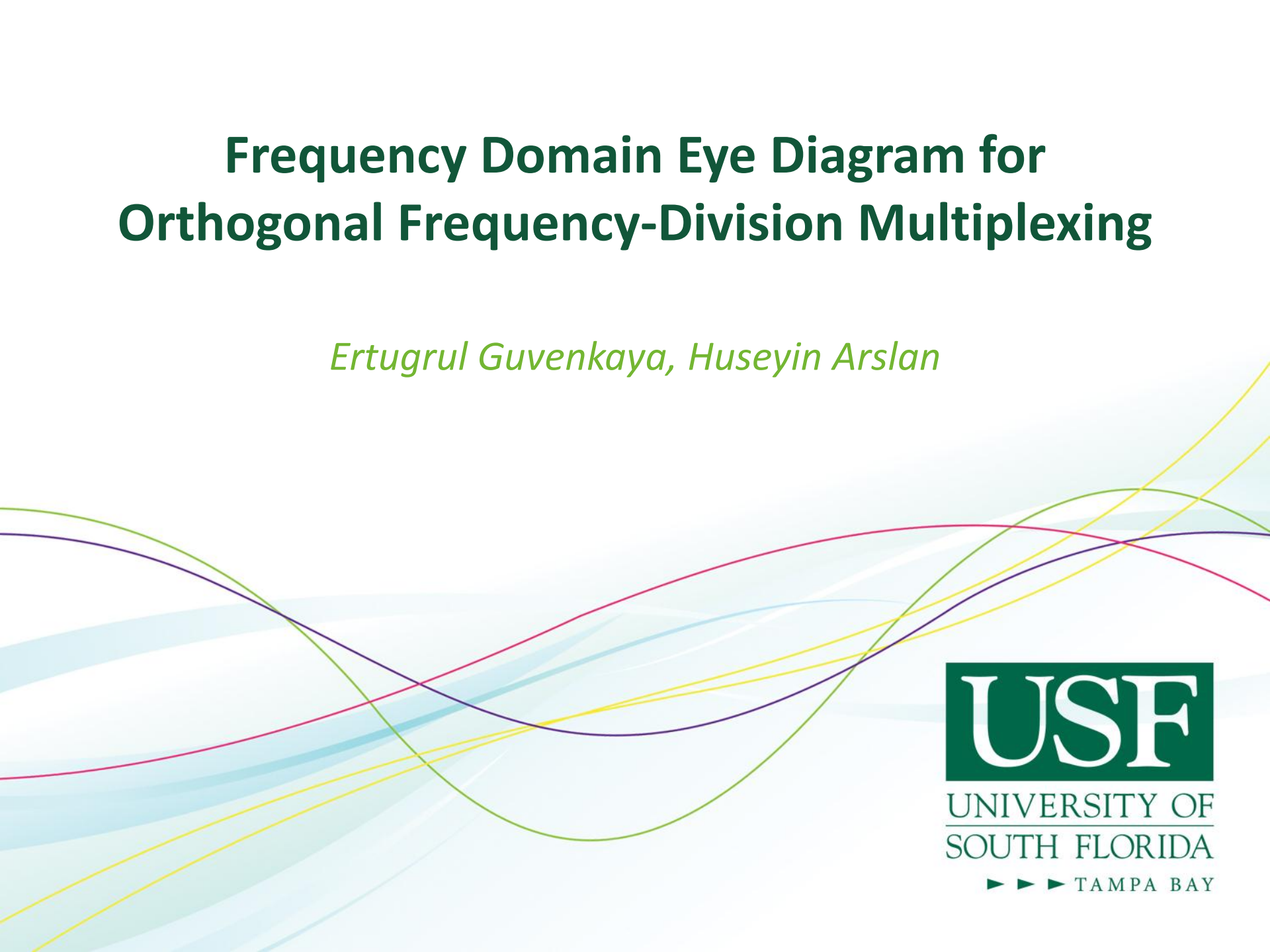


Outline

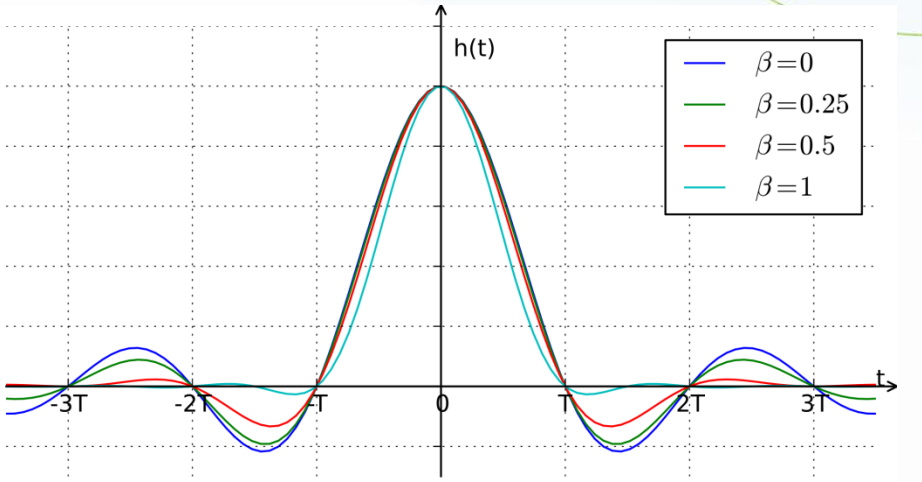
- Time – Frequency duality
- Time varying impairments
- Frequency Domain Eye Diagram
- Conclusions

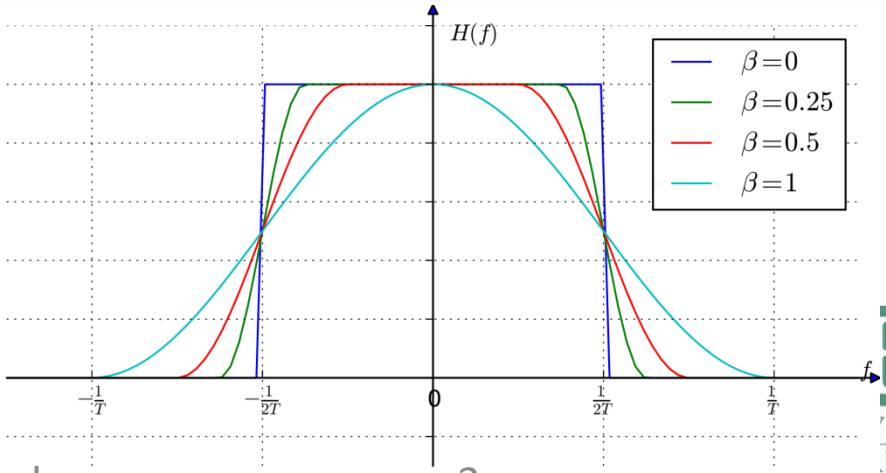
Single Carrier with Nyquist pulse

- Zero crossings at symbol spacing;

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

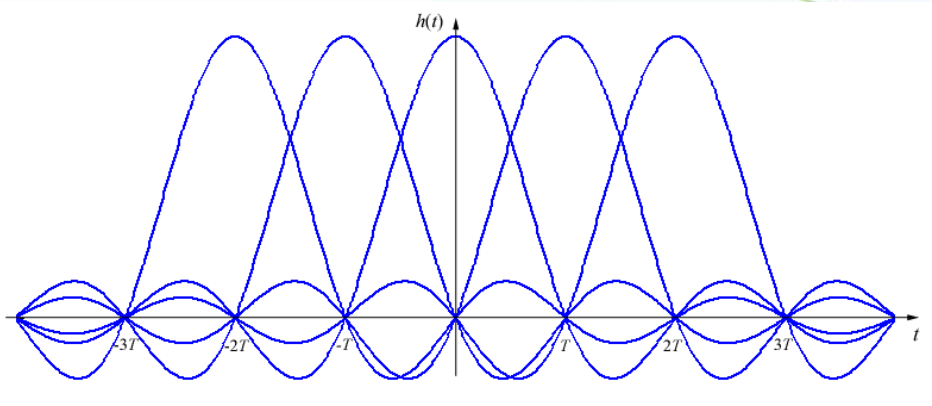
- This is also referred as Nyquist zero-ISI criterion.
- E.g.; raised cosine pulses are widely used in single carrier systems like EDGE, HSPA and UMTS.

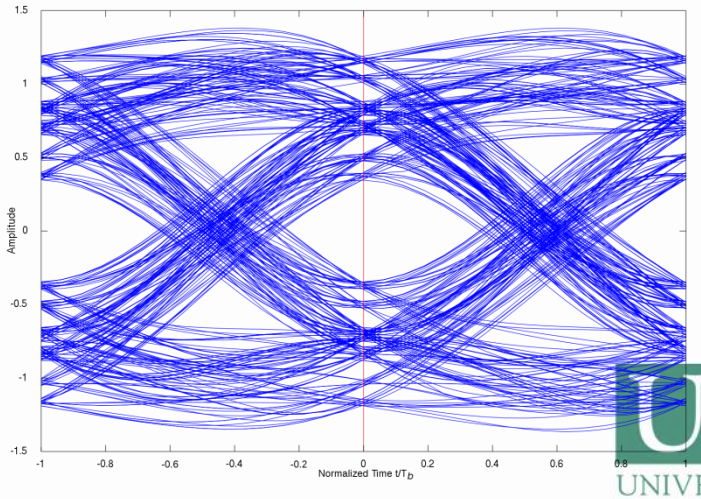




Single Carrier with Nyquist pulse

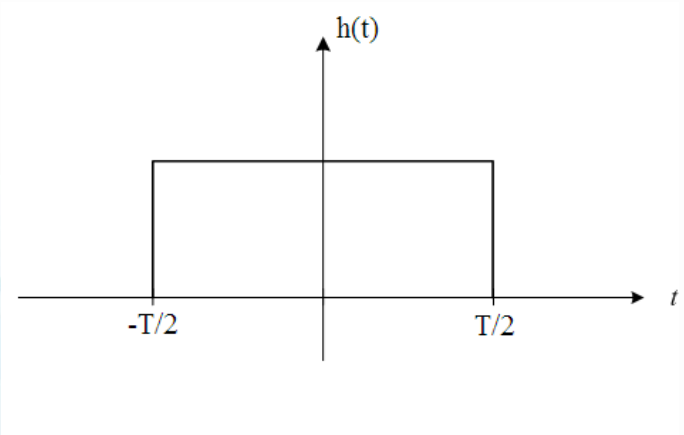
- Time spreading impairments in the system cause inter-symbol interference (ISI).
- Eye diagrams are used to observe the effects of these impairments in time domain.
- Timing jitter → shifted eye pattern
- Multipath delay spread → blurry eye openings.

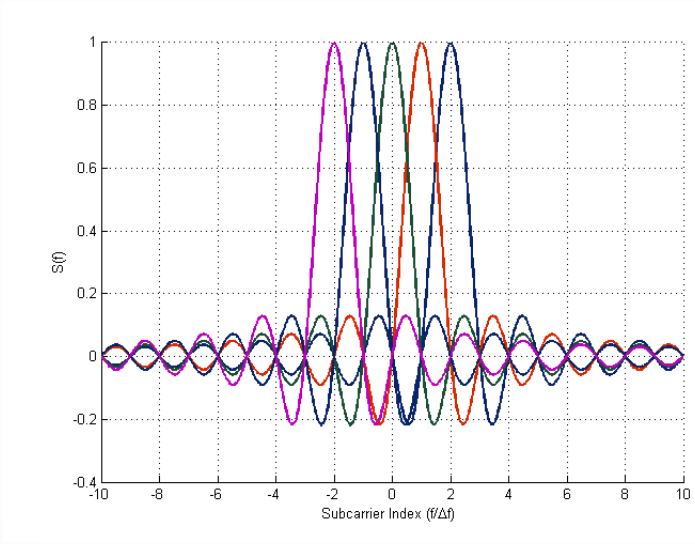




Time-frequency duality

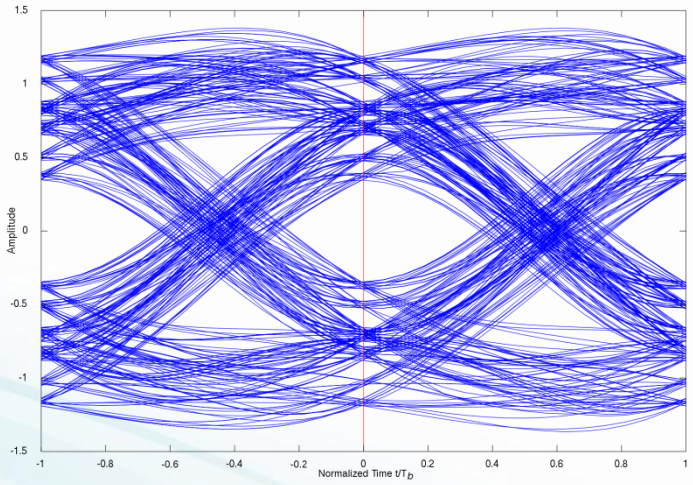
- In OFDM, subcarriers have sinc shapes because of rectangular pulse shaping in time.
- Single carrier systems: Time spreading and time offset → ISI
- OFDM systems: Doppler spread, carrier frequency offset →ICI





Time-frequency duality

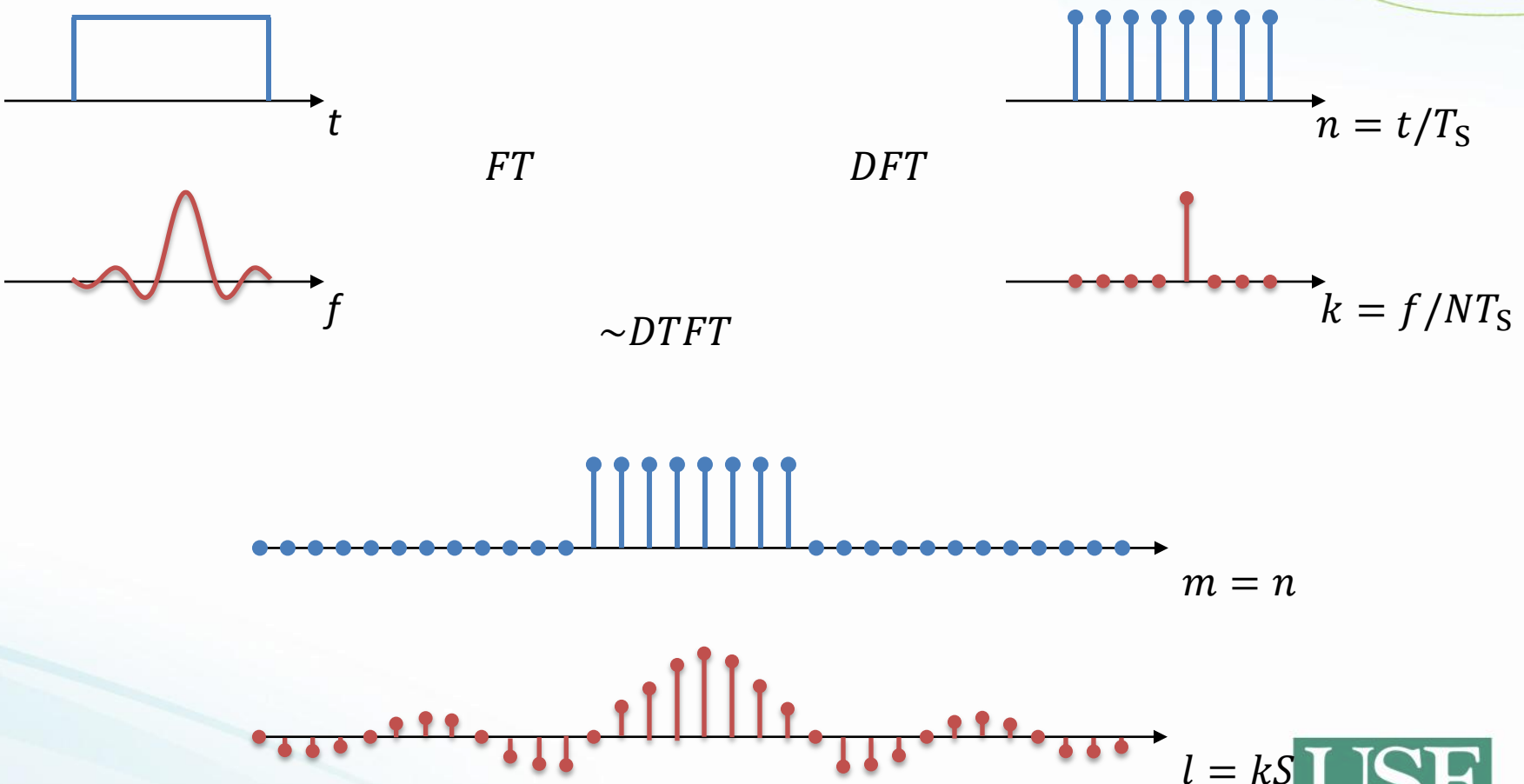
Impairments	Time	Frequency
Channel based	Delay spread	Doppler spread
Hardware based	Timing offset	Carrier frequency offset



Time domain eye diagram

Frequency domain eye diagram

Interpolation in freq. domain



DFT vs. Centered DFT

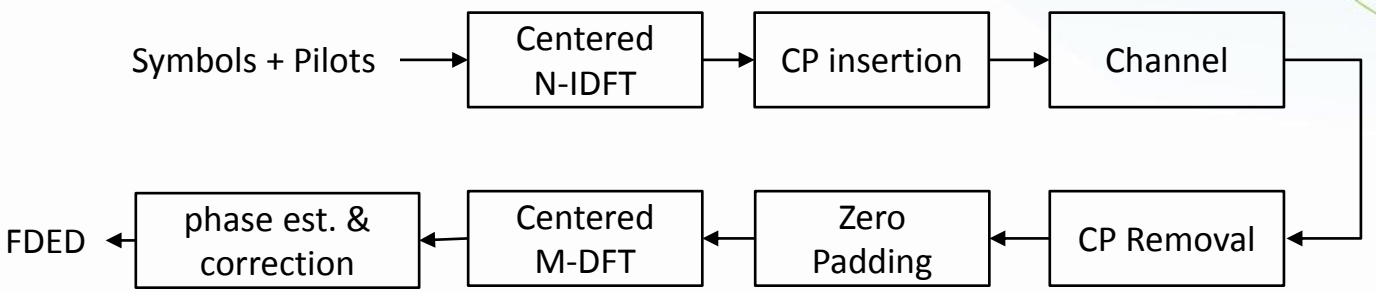
- Centered IDFT

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{j\frac{2\pi}{N}kn}, \qquad -\frac{N-1}{2} \leq n \leq \frac{N-1}{2}$$

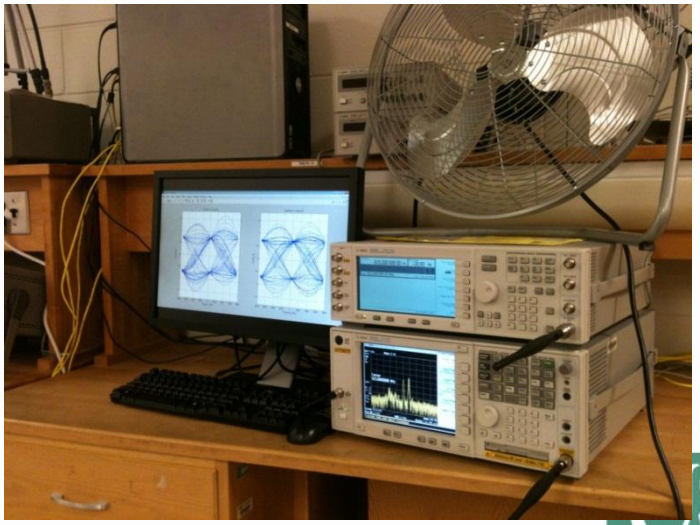
- Centered DFT

$$X(k) = \frac{1}{\sqrt{N}} \sum_{n=-\frac{N-1}{2}}^{\frac{N-1}{2}} x(n) e^{-j\frac{2\pi}{N}kn}, \qquad 0 \leq k \leq N-1$$

Diagram Construction

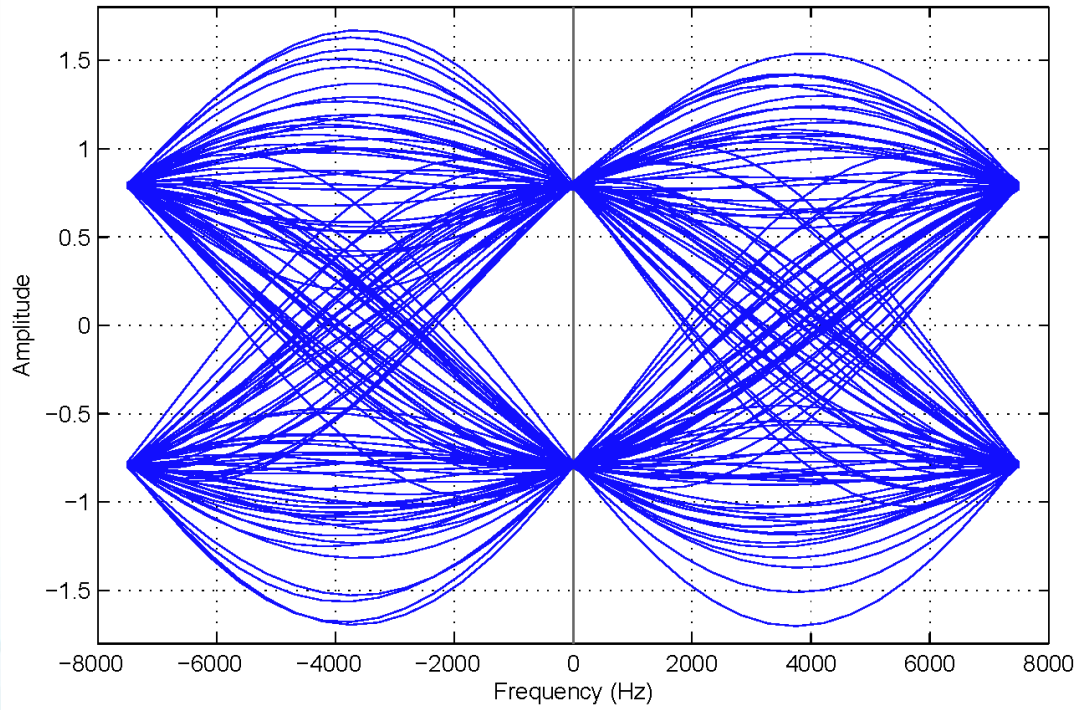


- Lab setup:
  - Artificially misaligned Local Oscillator for CFO
  - Rotating fan for time variation, i.e., frequency spread



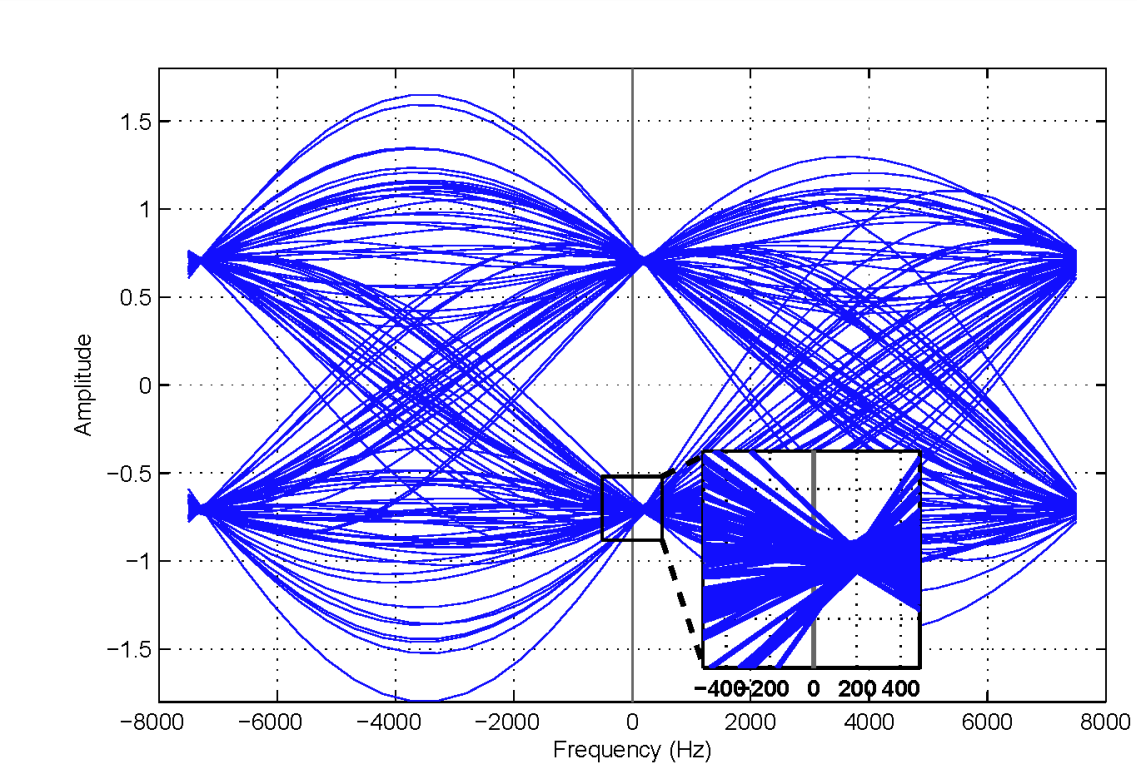
Eye Diagrams

Without any impairment, $\Delta f = 7.5\ \mathrm{kHz}$



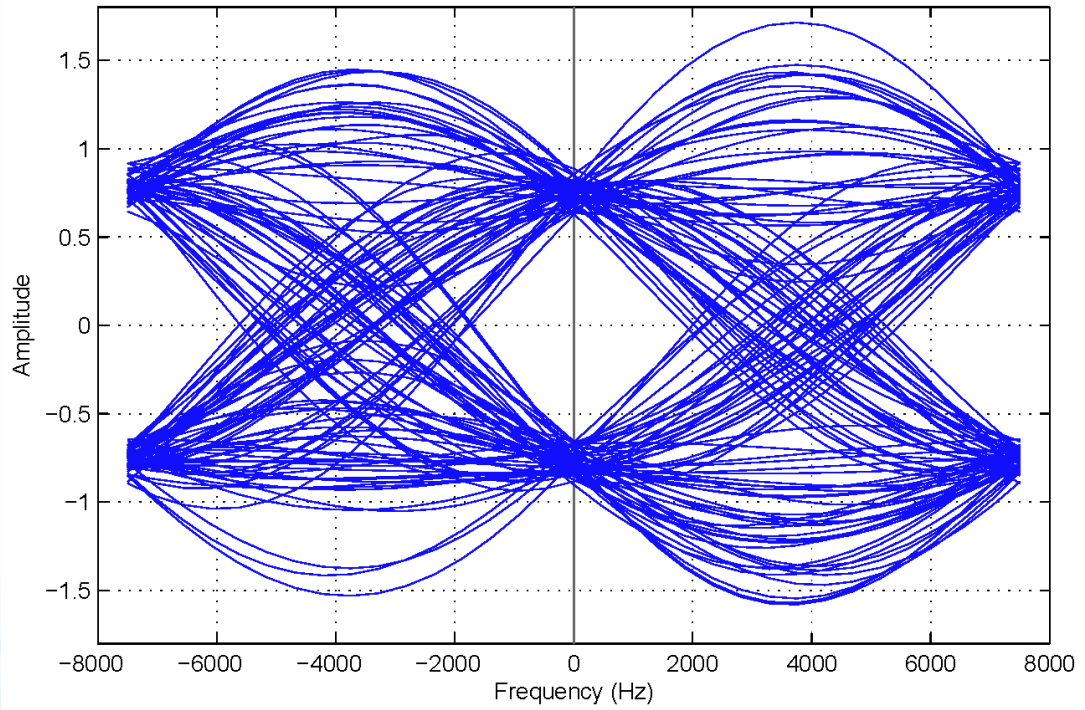
Eye Diagrams

With 200 Hz carrier frequency offset



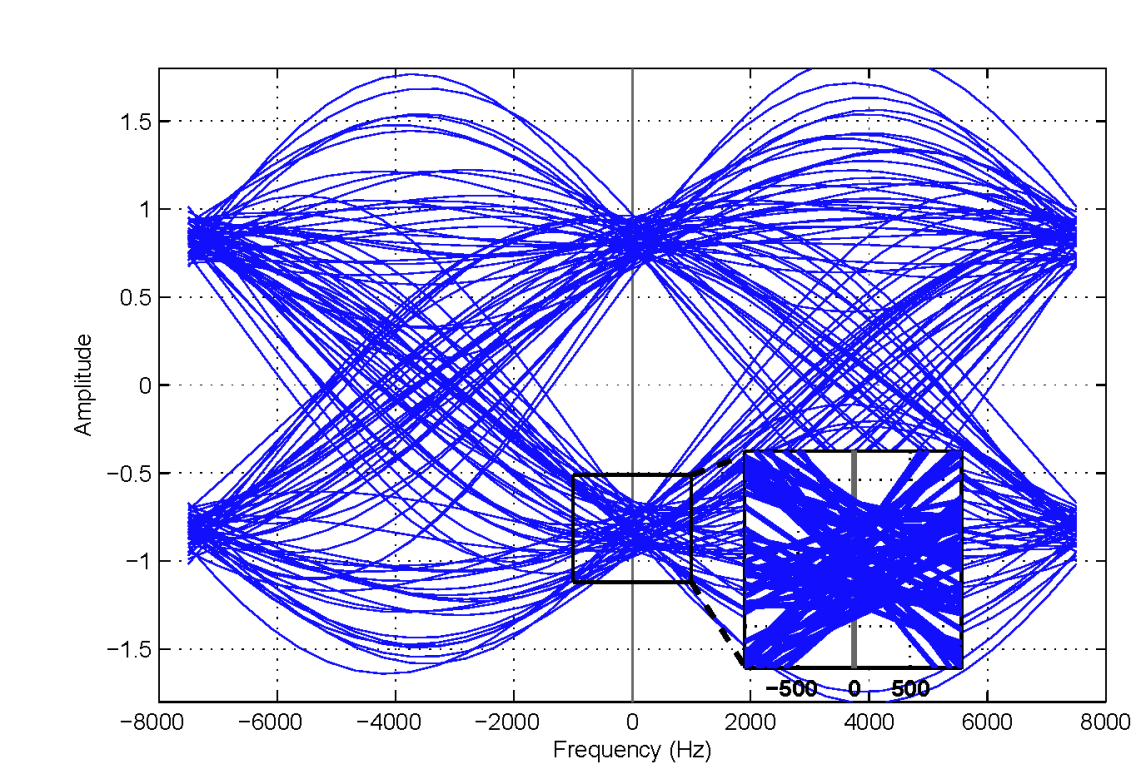
Eye Diagrams

With frequency spread, fan is ON

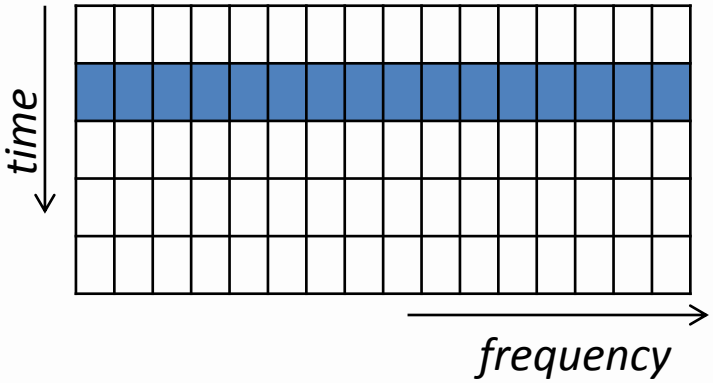


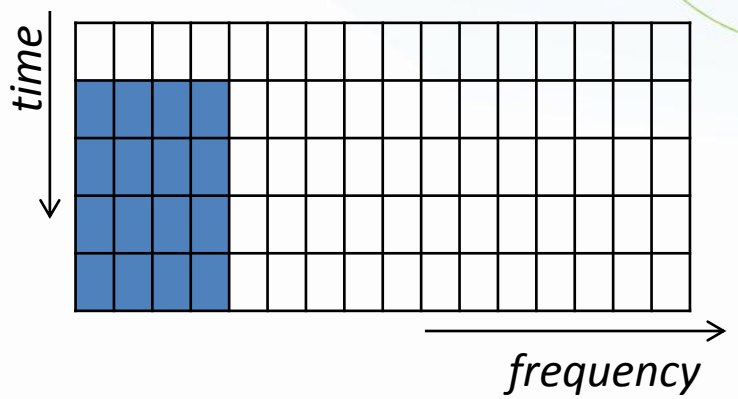
Eye Diagrams

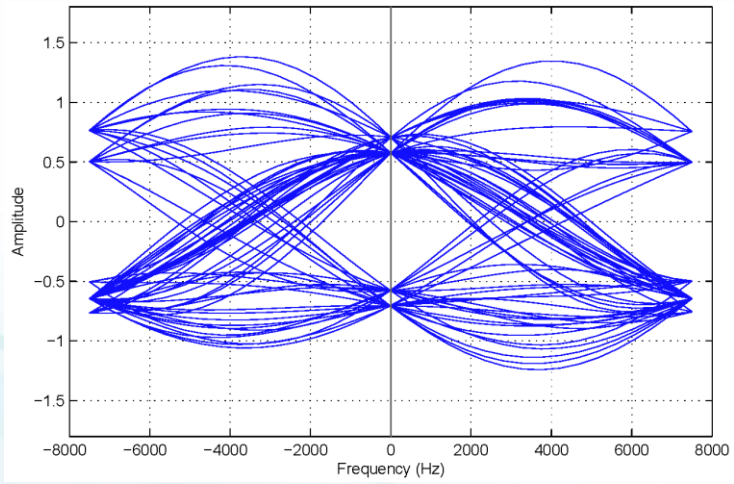
With both frequency offset and spread

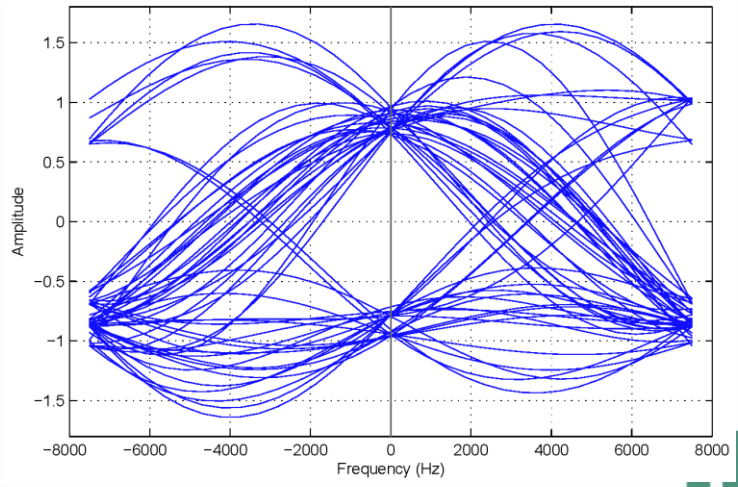


Frequency selectivity?









Conclusions

- Time varying impairments like
  - Frequency spread and
  - CFO

are visualized and identified from each other with eye patterns in frequency domain

- FDED can be utilized for
  - Interference identification
  - CFO estimation without preamble
  - Educational purposes.

Thank you..