A Joint Modulation Identification and Frequency Offset Correction Algorithm for QAM Systems

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Outline

- Introduction
- Modulation Identification
- Frequency and Phase Offset Estimation and Correction
- Simulation Results
- Conclusions
- Questions

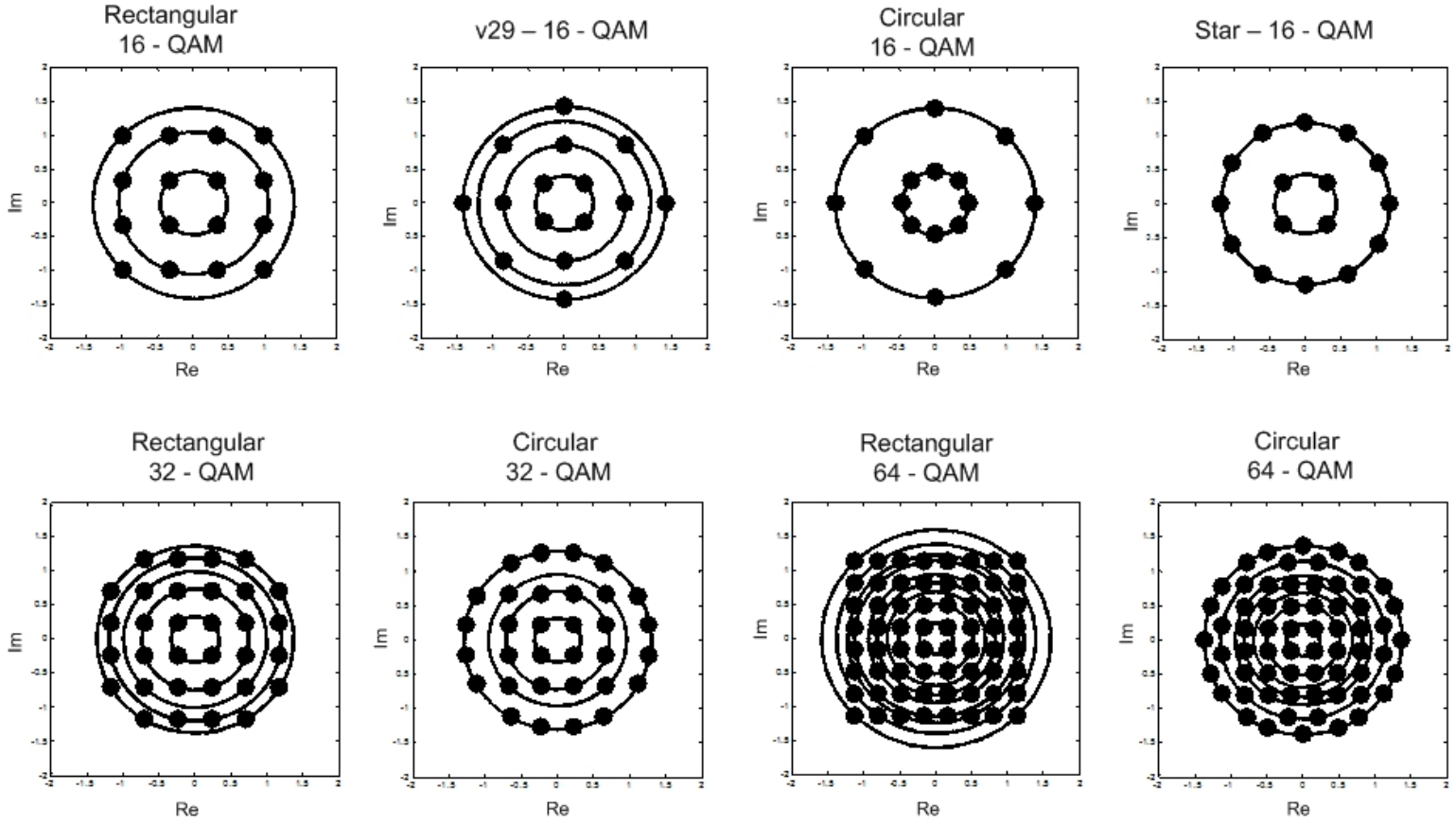
Introduction

- Blind receivers
- Blind frequency offset estimation and modulation identification algorithms
- Frequency offset due to the oscillator mismatches
  - Assumes that the modulation is known
- Modulation order depends on the source system
  - Assumes that there is no frequency offset
- Benefits for SDR?

Modulation Identification

- The modulation type is QAM.
  - Assuming the orders are 16, 32 and 64.
- Each modulation order have more than one mapping
- When frequency offset is present, we will be facing with rings which differ in number in most of the cases; but in some modulation orders, number of the rings are the same.

Modulation Order Identification

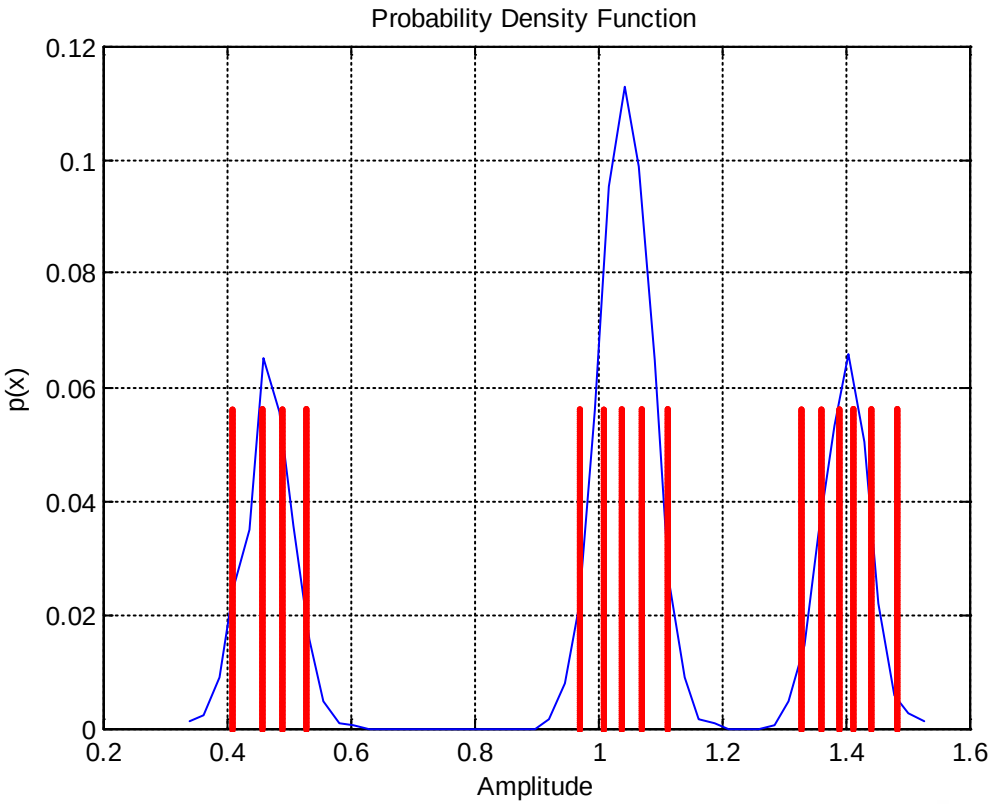


Modulation Order Identification

- Problem:
  - Estimating the modulation order
- Solution:
  - Identifying the number of rings
  - Clustering
    - Not enough!
  - Density information

Modulation Identification

- Solution:
  - 15 clusters
  - Close clusters are grouped together
  - At each cluster the density is obtained and compared to other densities



Frequency and Phase Offset Estimation and Correction

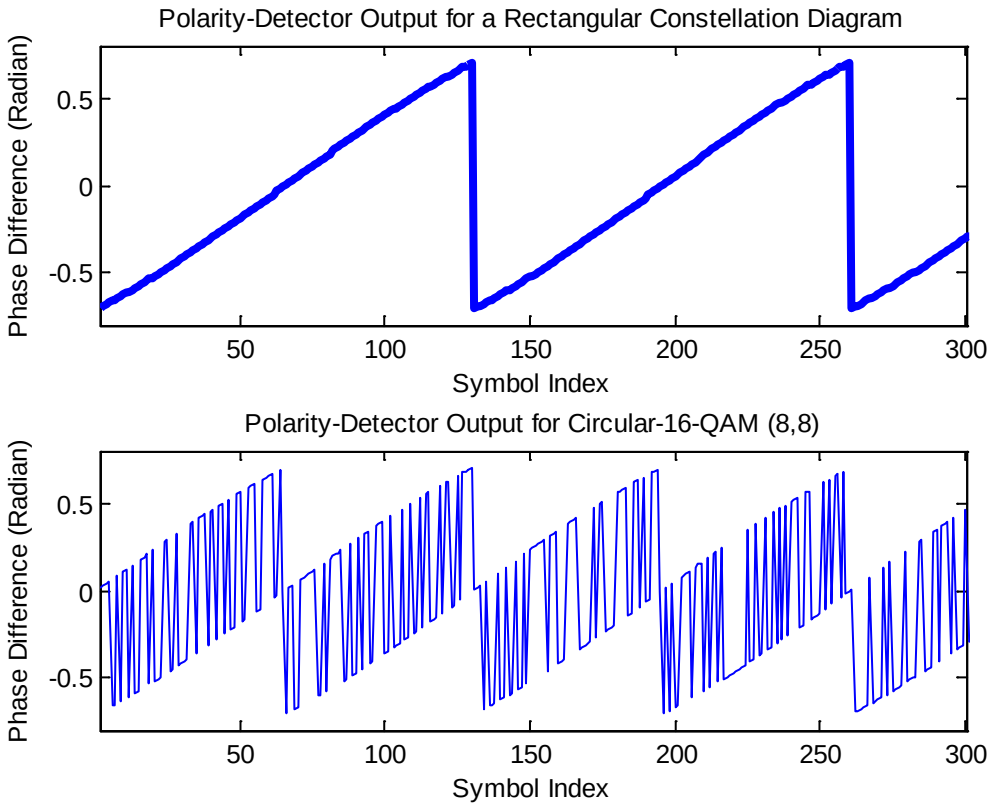
- Circular Constellation Diagrams
  - Star-16-QAM (4,12)
  - Circular-16-QAM (8,8)
  - V.29-16-QAM
  - Circular-32-QAM
  - Circular-64-QAM
- Rectangular Constellation Diagrams
  - Rectangular-16-QAM (Square)
  - Rectangular-32-QAM (Non-Square)
  - Rectangular-64-QAM (Square)

Frequency and Phase Offset Estimation and Correction

- Circular Constellation Diagrams
  - The focus is on outer circle which behaves like PSK signals
- Polarity Detection
  - Decision symbol
    - $d(n) = A(n)[\cos(\arg(d(n))) + j\sin(\arg(d(n)))]$
  - Phase Difference
    - $p(n) = \mathrm{Im}[r(n)/d(n)]$

Frequency and Phase Offset Estimation and Correction

- Circular Constellation Diagrams
  - Polarity detector can not track the offset
  - Identifying new decision symbols, *d(n)*, for each case

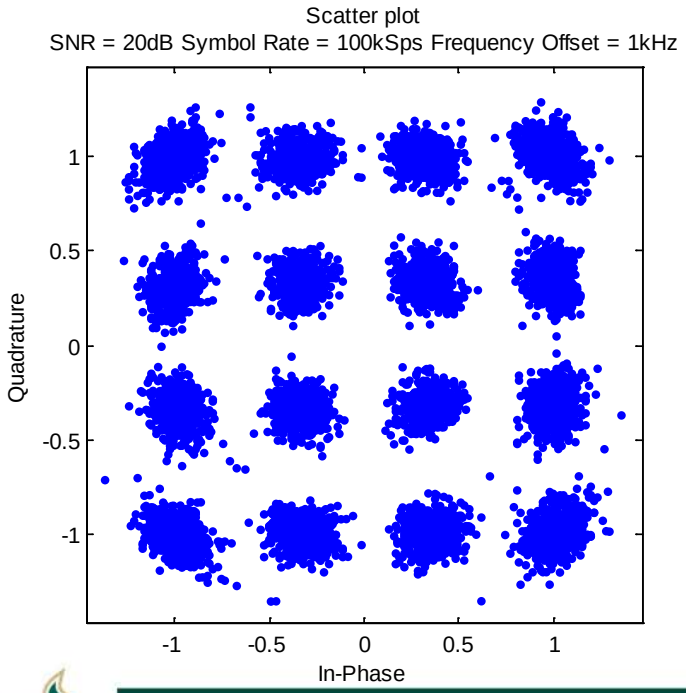


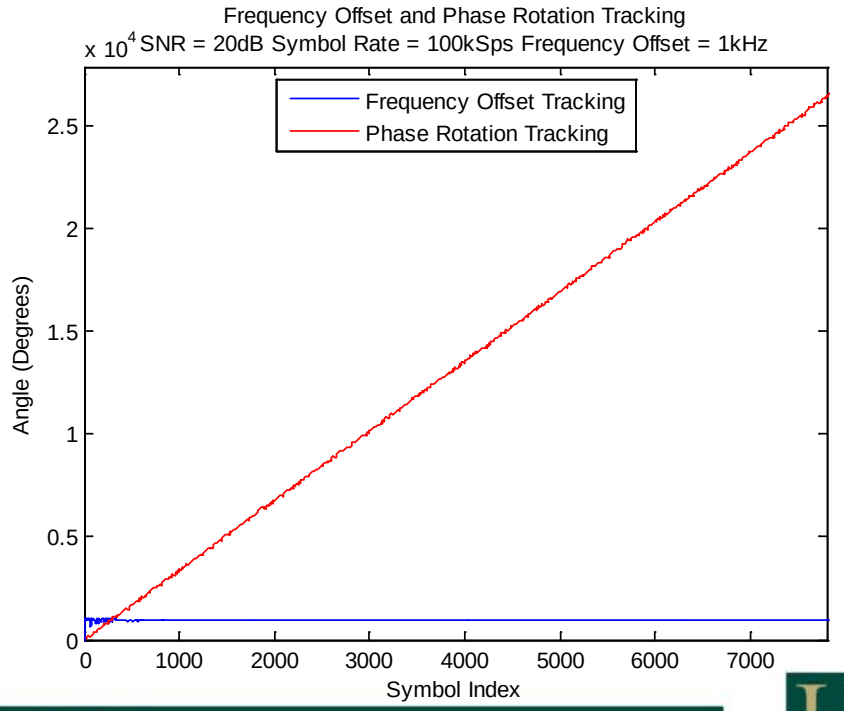
Frequency and Phase Offset Estimation and Correction

- Rectangular Constellation Diagrams
  - The focus is on constellation points having the longest radii, i.e. highest SNR
- Polarity Detection
  - Phase Difference
    - $p(n) = \mathrm{Im}[r(n)/d(n)]$

Frequency and Phase Offset Estimation and Correction

- Rectangular Constellation Diagrams





Simulation Results

- Modulation Identification
  - False Alarm Rates
    - A false alarm is misdetection of the modulation order and mapping.
    - But for 16QAM, detecting it as 64QAM is not a false alarm since the frequency offset correction methods are the same and vice versa.

Simulation Results

- Modulation Identification
  - False Alarm Rates

Modulation Type	False Alarm Rate
Rectangular-16-QAM	0%
Circular-16-QAM	0%
v29-16-QAM	0%
Star-16-QAM	0%
Rectangular-32-QAM	0%
Circular-32-QAM	0%
Rectangular-64-QAM	1%
Circular-64-QAM	3%

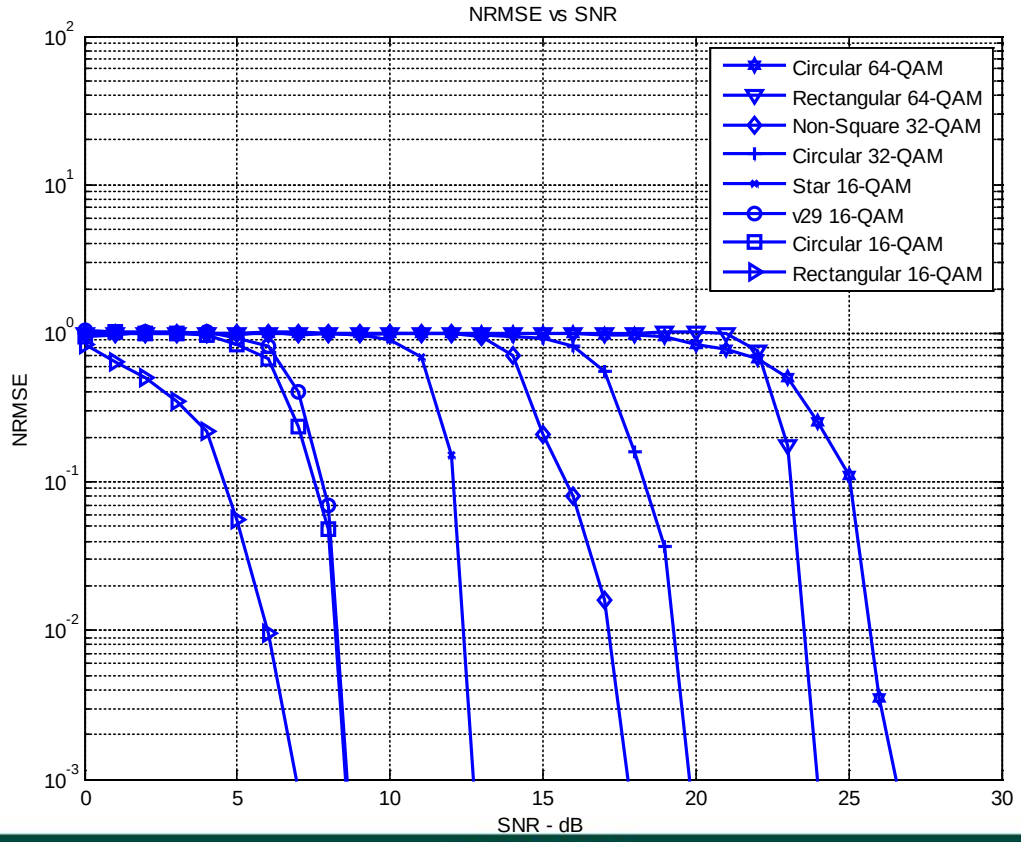
Simulation Results

- Frequency Offset Estimation
  - Normalized Root Mean Square Error(NRMSE)

$$NRMSE = \sqrt{E[(1 - f'_o/f_o)^2]}$$

Simulation Results

- Frequency Offset Estimation



Conclusion

- Despite the techniques in the literature for discretely treating the modulation identification and frequency offset problem, a technique which treats both as a single problem is proposed.
- According to the simulation results the technique is effective in single tap channels.
- Can be applied to the front end of the SDR systems.

Questions?

Thank You!