Considerations of US Burst Marker Design and Performance

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Summary of Current Burst Marker Proposal

- Power based burst marker detection (T.D. #97)
- Burst Markers baseline proposal
  - rahman_syed_3bn_01_1113.pdf
- Other burst marker proposal and analysis
  - montreuil_3bn_02a_0114.pdf
  - montreuil_3bn_01a_0114.pdf

- This contribution provides more analysis of above proposals and suggest an means of designing the burst marker.

Summary of Requirement for Burst Marker

- Minimum SNR requirement: 10dB
- Target Packet Error Rate (including packet loss rate): 5e-5
- Miss detection rate: < 5e-6
- False Detection Rate: 1/100~1/1000 of PER.
- Assume pre-equalized channel
- Other impairments:
  - Narrowband ingress noise

Power Based Detection for 2-D Burst Marker

- Power based detection

$$P = \sum_{i=1}^{M} P_i \qquad N = \sum_{i=1}^{K} N_i$$

where Pi is the power of each position of ‘1’, and Ni is the power of each position of ‘0’

- Burst Marker Detected if

P>= Thd and N < Thd.

0	1	0	1
1	0	1	0
0	1	1	0
1	0	0	1

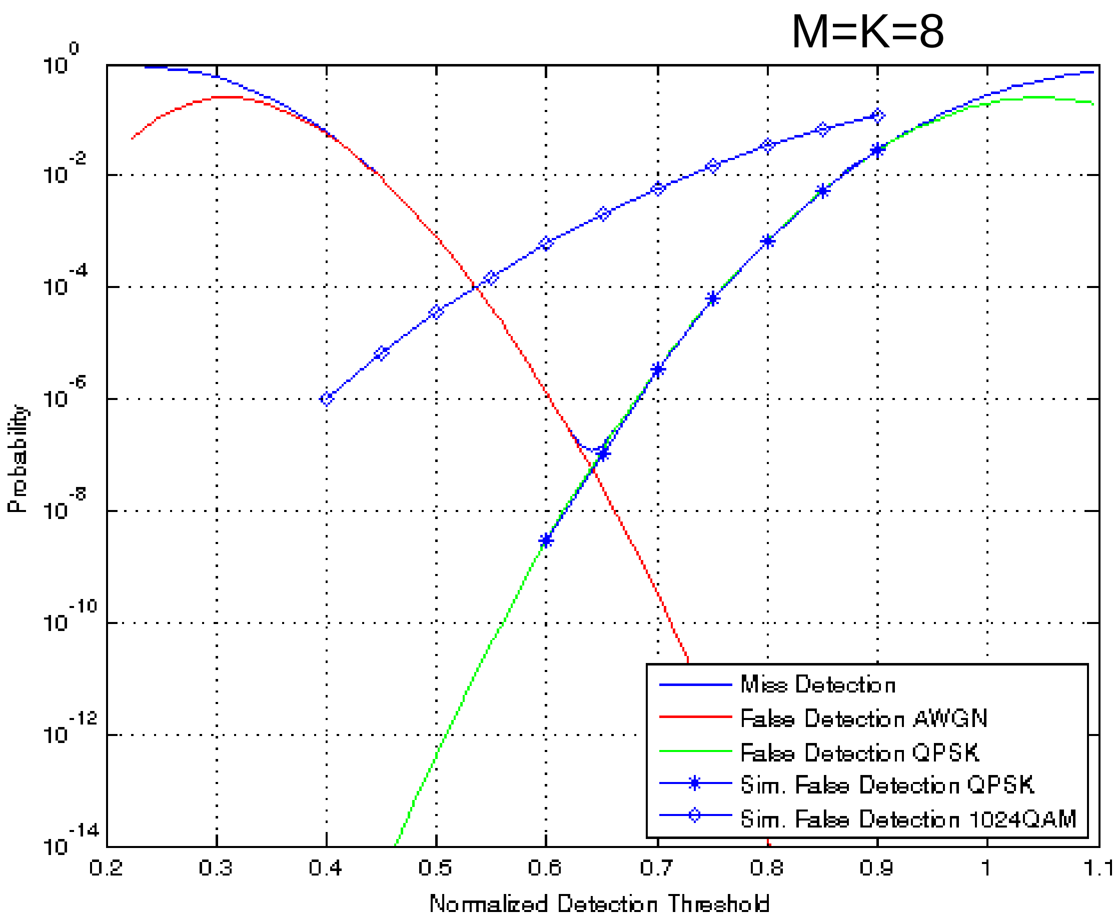
1: BPSK sequence with full power
0: No signal

Detection Error

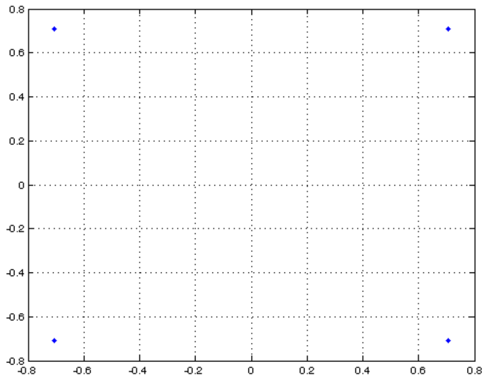
- Miss Detection:
  - Burst Marker present, but undetected
- Two types of false detection:
  - Only white noise present, but detect burst marker
  - US data present, but detect burst marker
- Example: 4x4 burst marker

0	1	0	1
1	0	1	0
0	1	1	0
1	0	0	1

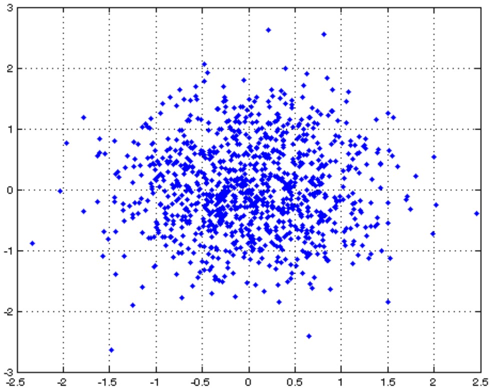
Error Probability



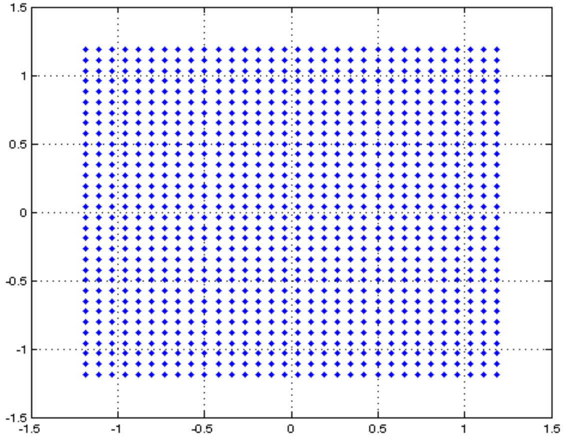
Different Data Symbol Statistics



QPSK



Gassian

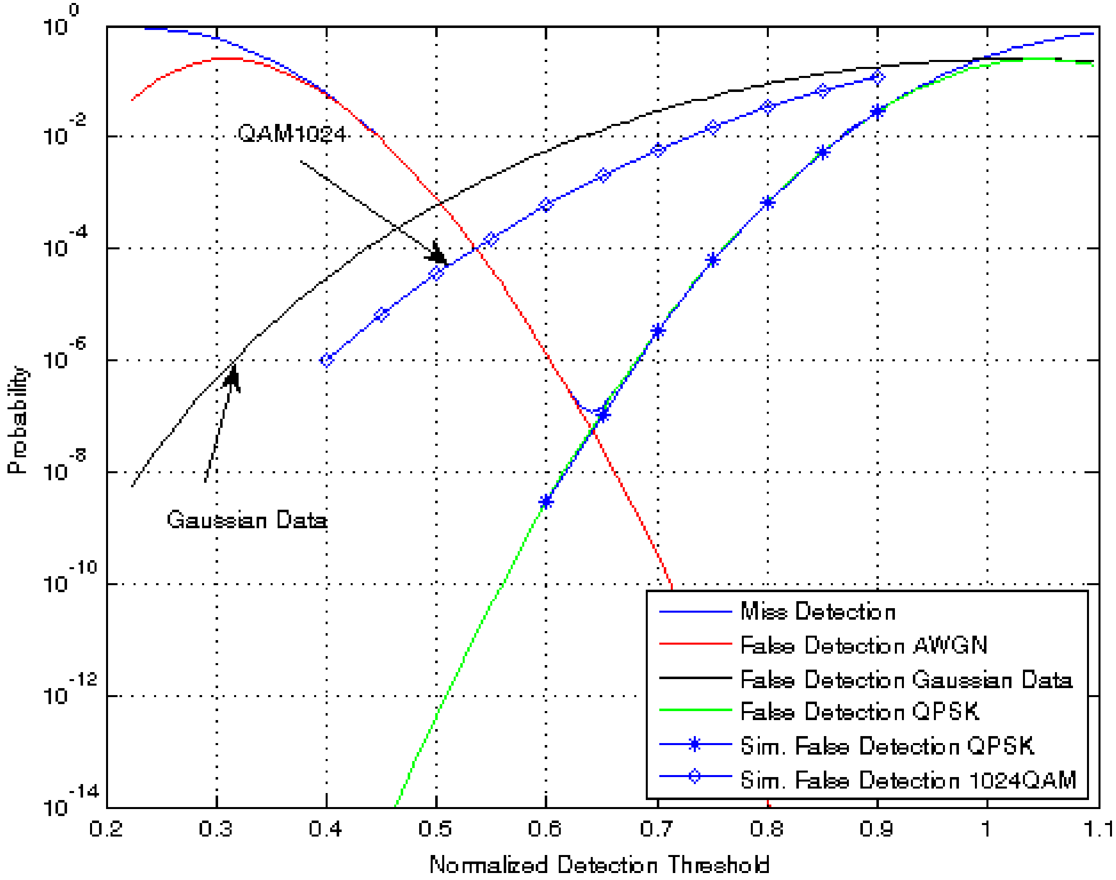


1024QAM

Use Gaussian Constellation
well approximate worst case

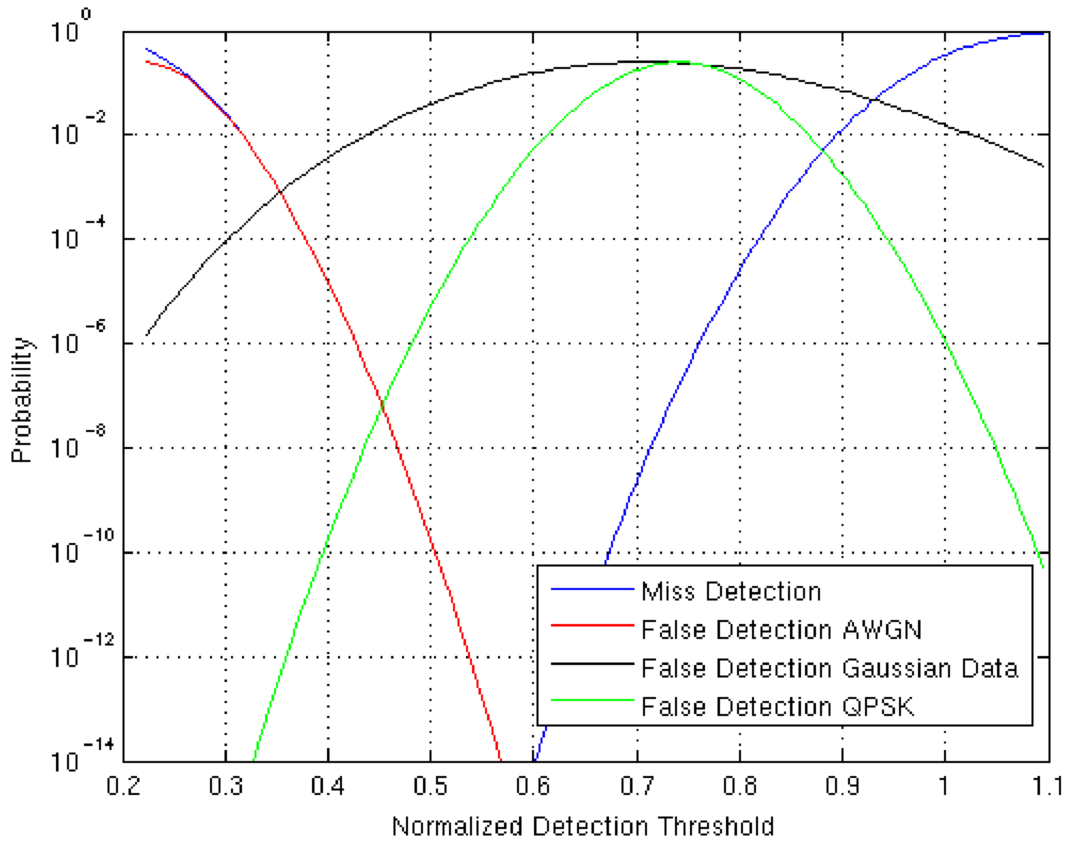
Error Probability---Gaussian Approximation

M=K=8



Error Probability---Gaussian Approximation 3dB Boost

M=K=8

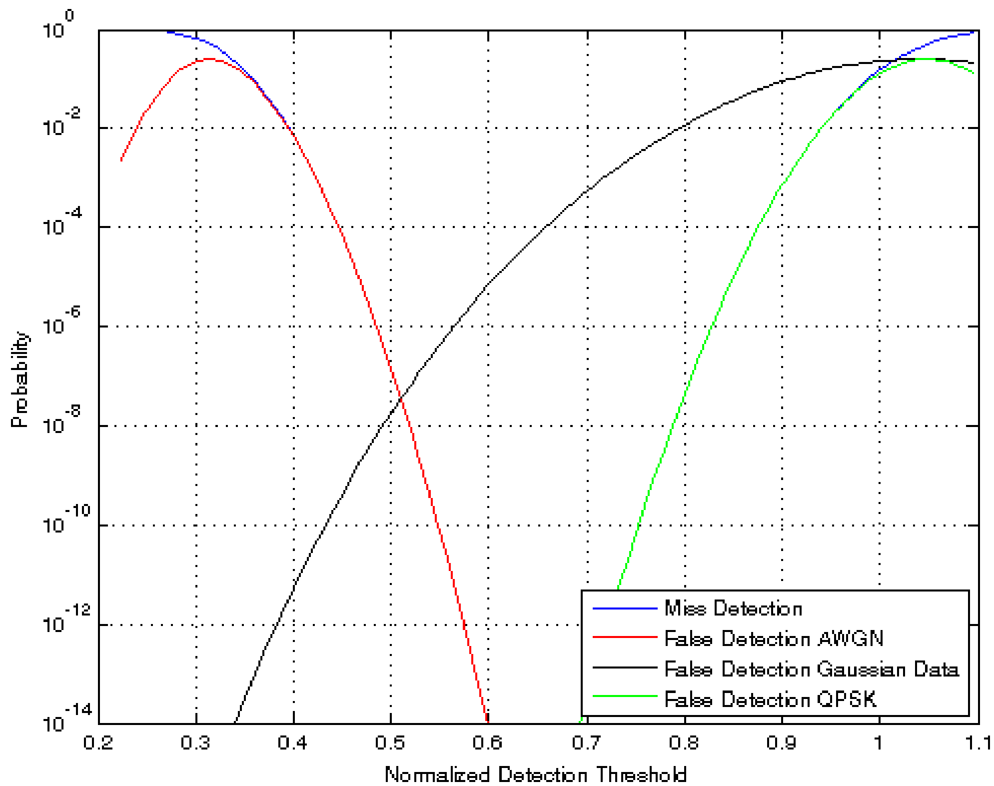


How Large Does the Burst Marker Need To Be for Current Proposal

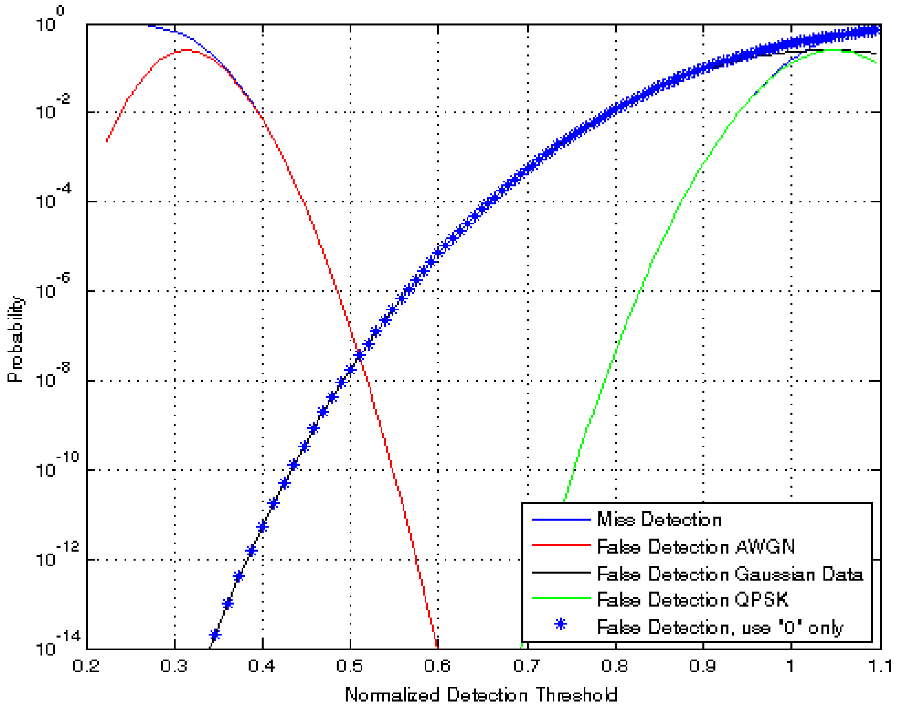
- False Probability < 1e-8, and Miss probability < 1e-6
- M=K=22,

i.e. 22 “1”s and

22 “0”s



"1"s In the Burst Marker Does Not Help on False Probability of Data



- In case of false probability of data

Prob{P>= Thd}~1

- Prob_false = Prob{N < Thd}

Power Ratio Detector

- Compute the power of “1”s and “0”s as P and N

$$P = \sum_{i=1}^{M} P_i \qquad N = \sum_{i=1}^{K} N_i$$

- Radio Detector
  - Burst Detect: P/N>Th
- Error Performance
  - Miss Detection: Burst Marker present, but not detect

P~ noncentral chi-square of 2M degree of freedom

noncentral parameter=2M*SNR

N~ chi-square of 2K degree of freedom

P/N: non-central F distribution

Power Ratio Detector

- False Detection due to AWGN

  P and N are both chi-square of 2K degree of freedom

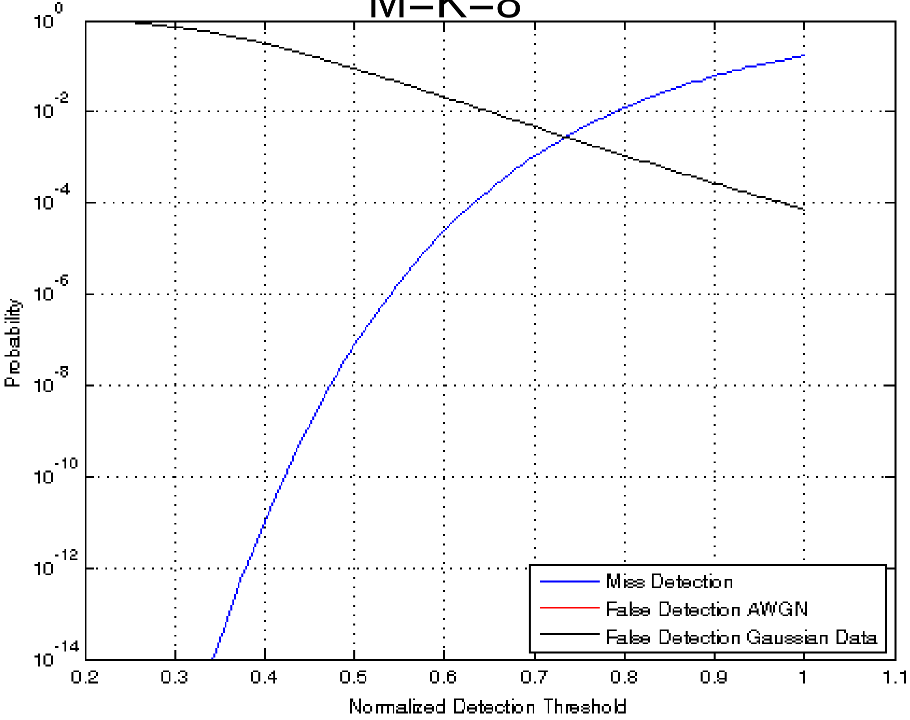
- False Detection due to Gaussian Data

  P and N are both chi-square of 2K degree of freedom

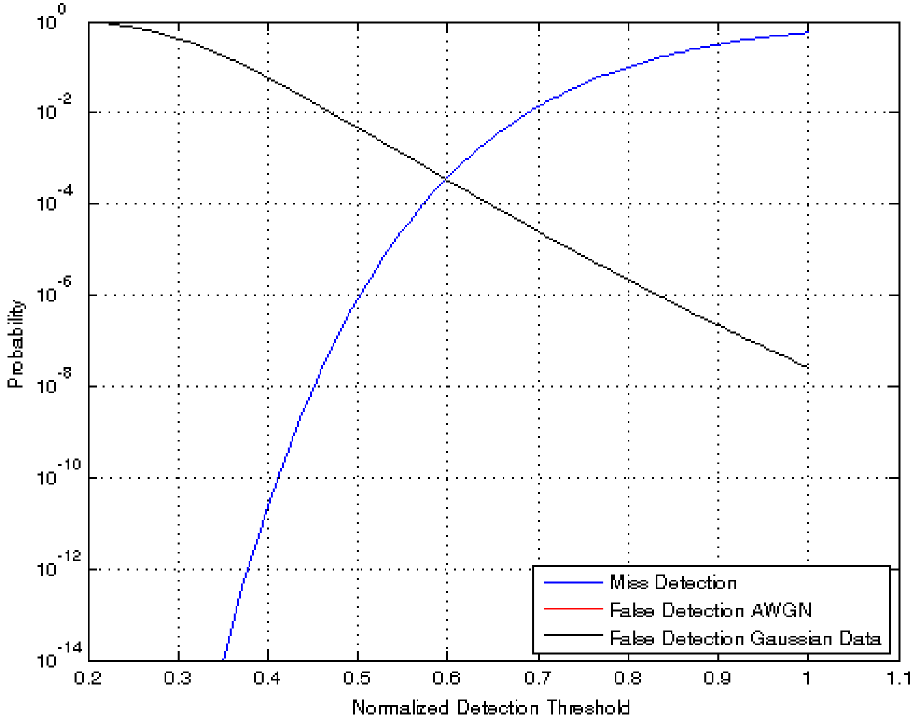
- For power ratio detector, the false detection rate due to AWGN is the same as that due to Gaussian data.

Error Performance of Power Ratio Detector

M=K=8

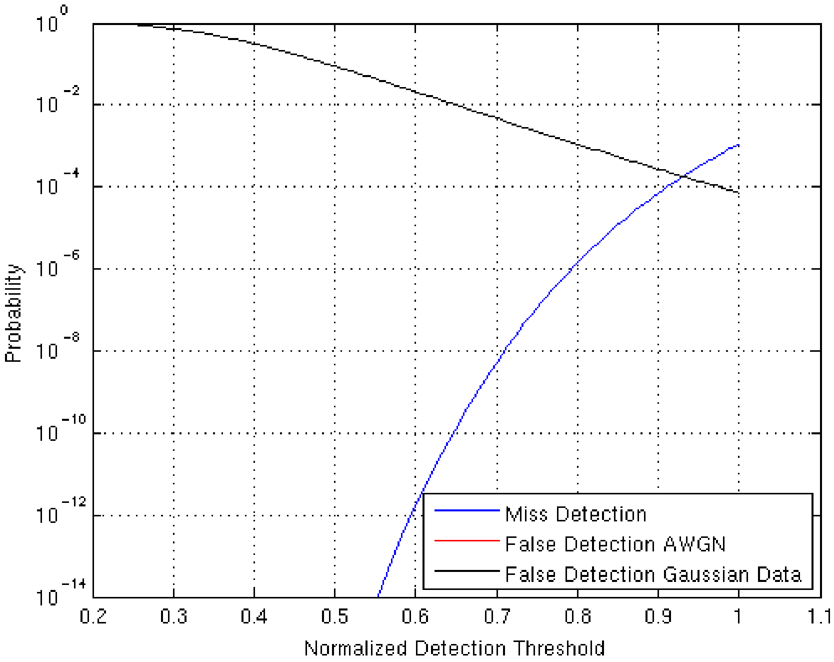


M=K=12

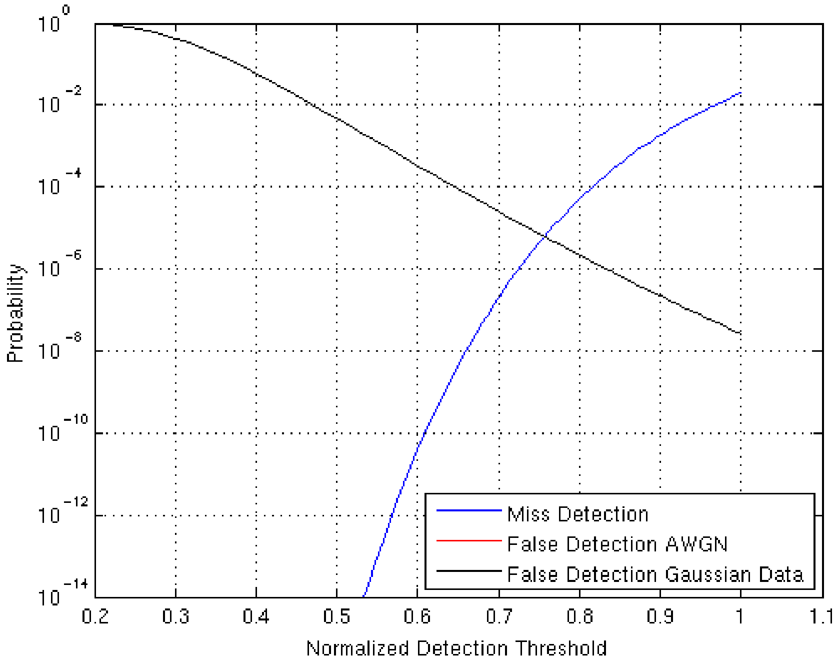


Error Performance of Power Ratio Detector – With 3dB power boost

M=K=8



M=K=12



Considerations

- Consider the power threshold detector
- In the proposed burst marker, false probability of data is dominant of false probability.
- ‘1’s in the burst marker do not help on the false probability of data. Only ‘0’s can help.
- ‘1’s in the burst marker only help in the detection over AWGN.
- Decouple the detection of “0”s and “1”s
  - Provide flexibility of burst marker design
  - The number of “0”s and “1”s can be designed separately.
- Propose two-step detection
  - First step: detect “0”s within burst marker
  - Second Step: detect “1”s within the burst marker

First Detector

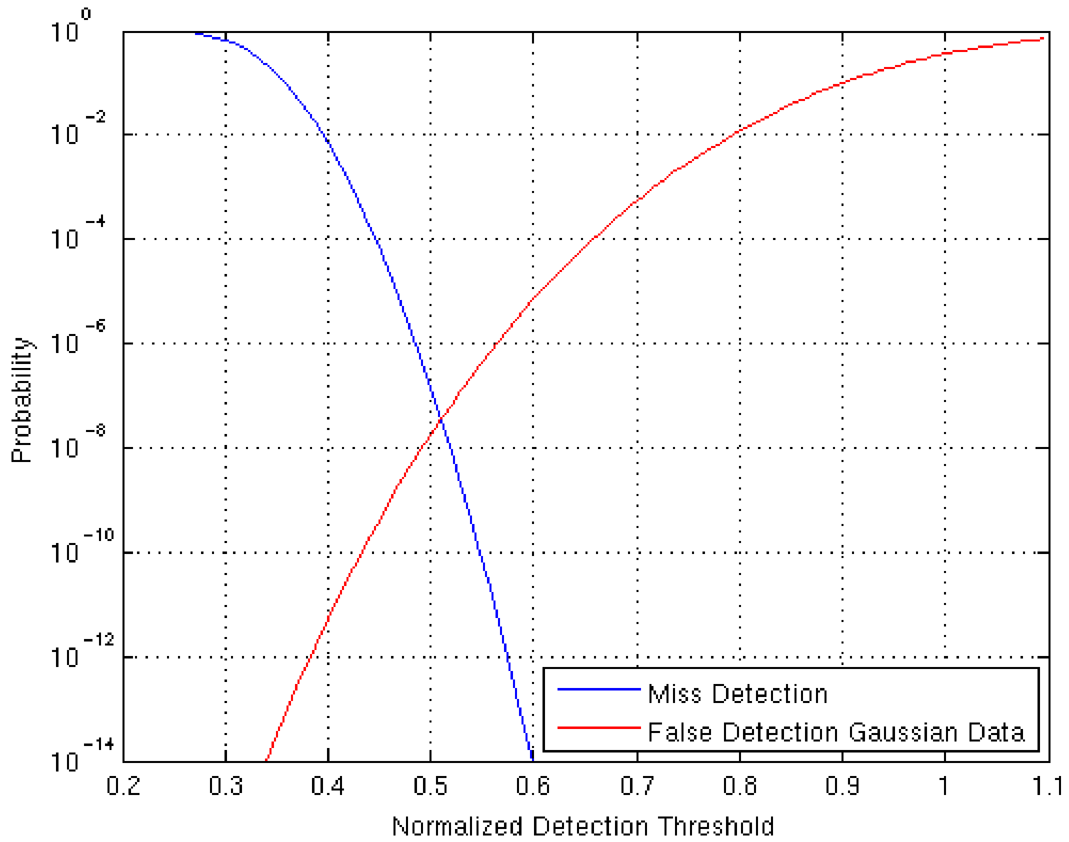
- Assume K zeros are defined in the burst marker, Ni, i=1,,,K, as power of each “0”

$$N = \sum_{i=1}^{K} N_i$$

- Detect: N<Thd
- Error Event:
  - False probability due to data: Pf1
  - Miss detection probability: Pm1

Error Performance of First Detector

K=22



Second Detector

- Assume M “1”s in the burst marker.
- pi, i=1,…,M is taken from {-1,1} as PRBS sequence.
- ri, i=1,…,M as the received value at the output of FFT.
- Coherent correlator

$$P = \sum_{i=1}^{M} r_i p_i$$

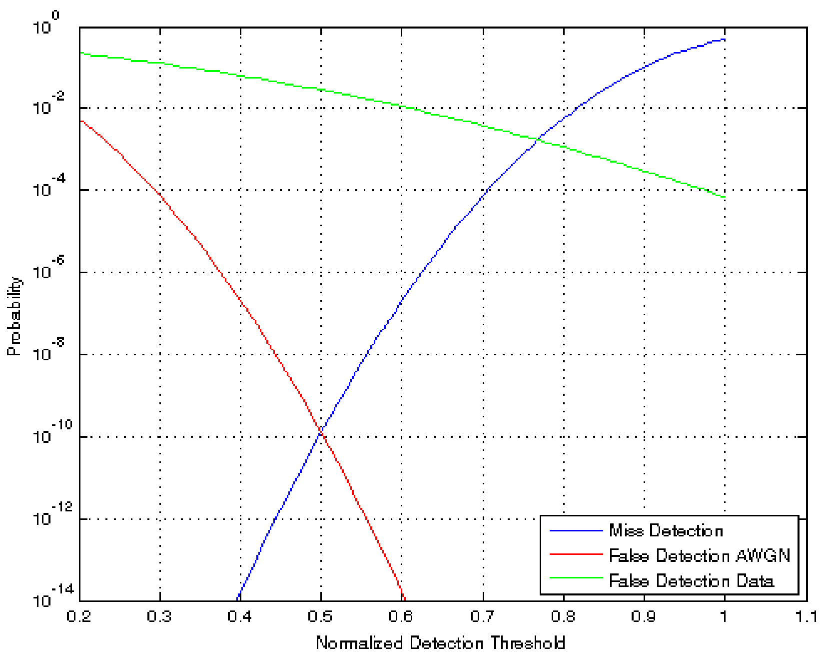
- Non-coherent correlator

$$P = \left| \sum_{i=1}^{M} r_i p_i \right|$$

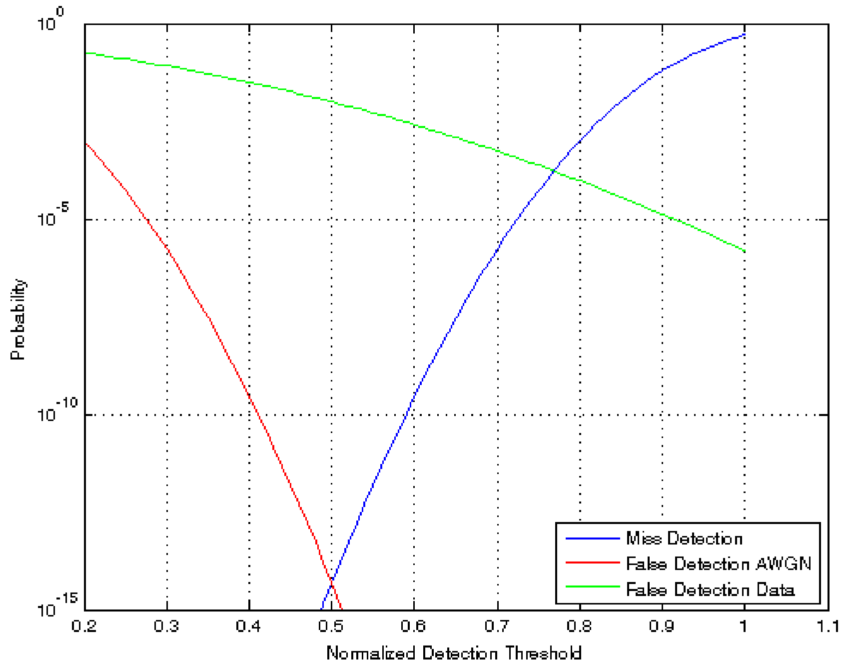
- Detect: P>Thd
- Error Event
  - Miss detection Pm2
  - False detection due to noise Pf2
  - False detection due to data: Pf2_data

Error Performance-Coherent Correlator

M=8

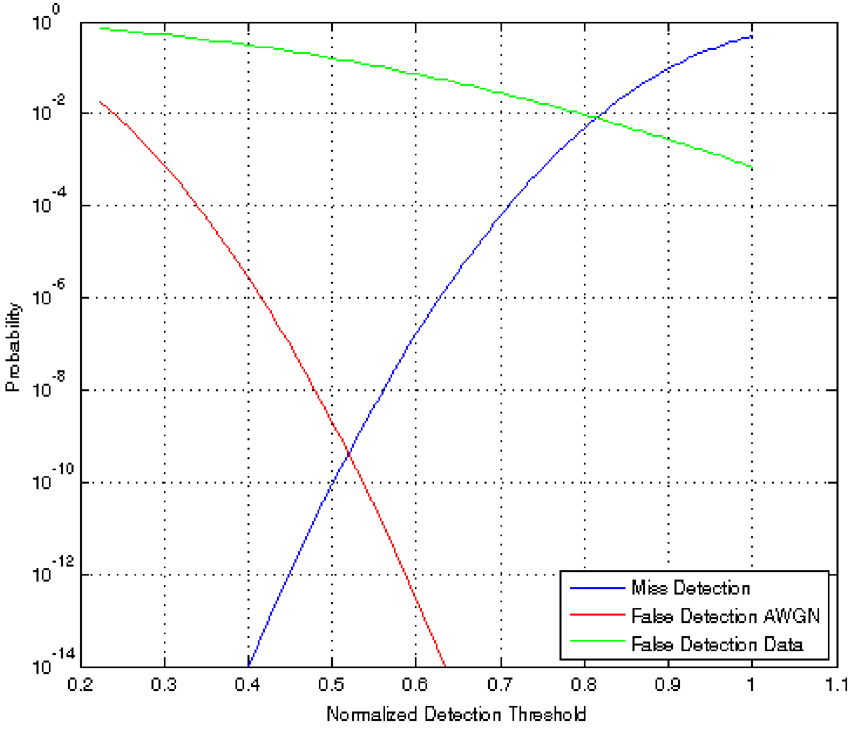


M=12

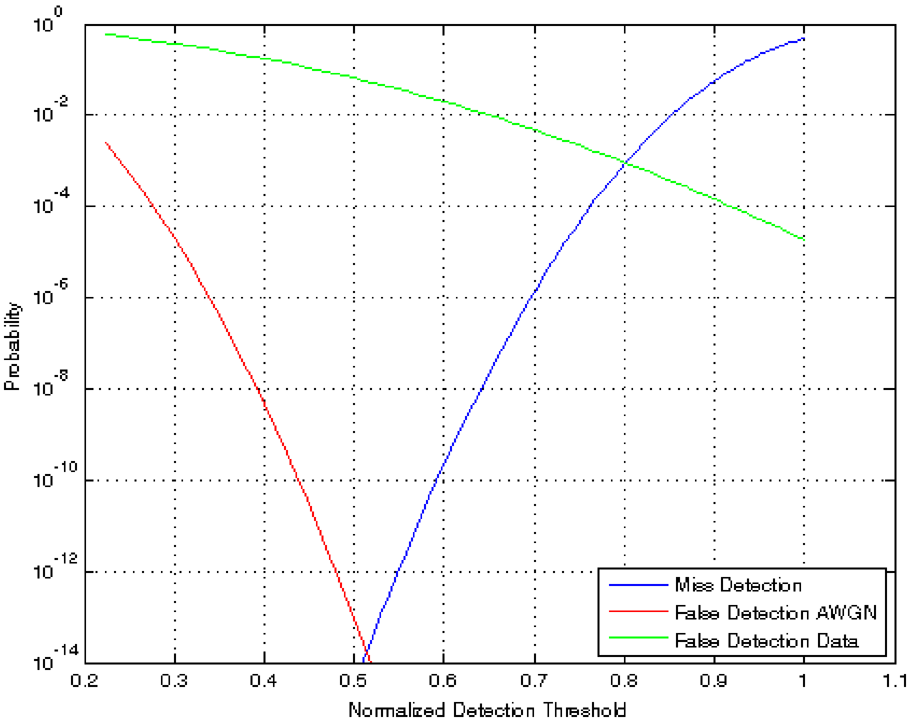


Error Performance - Noncoherent

M=8

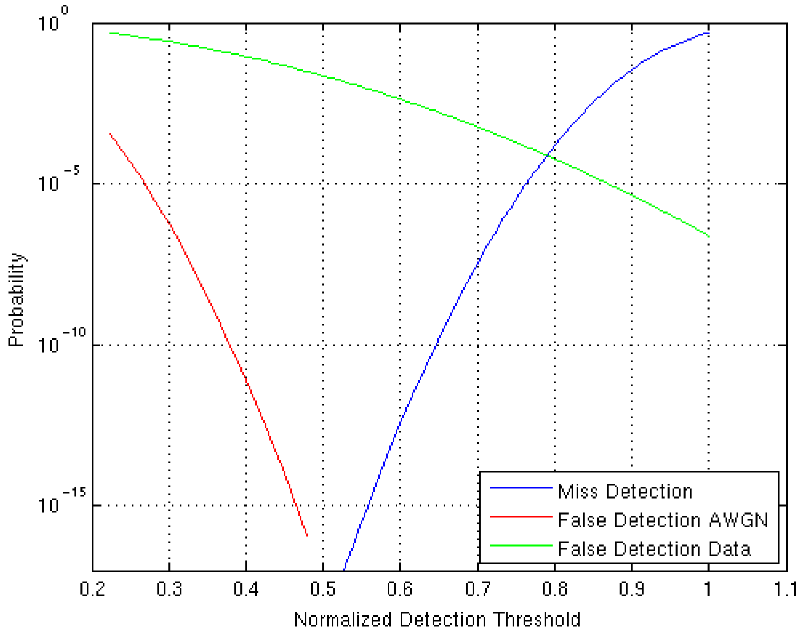


M=12

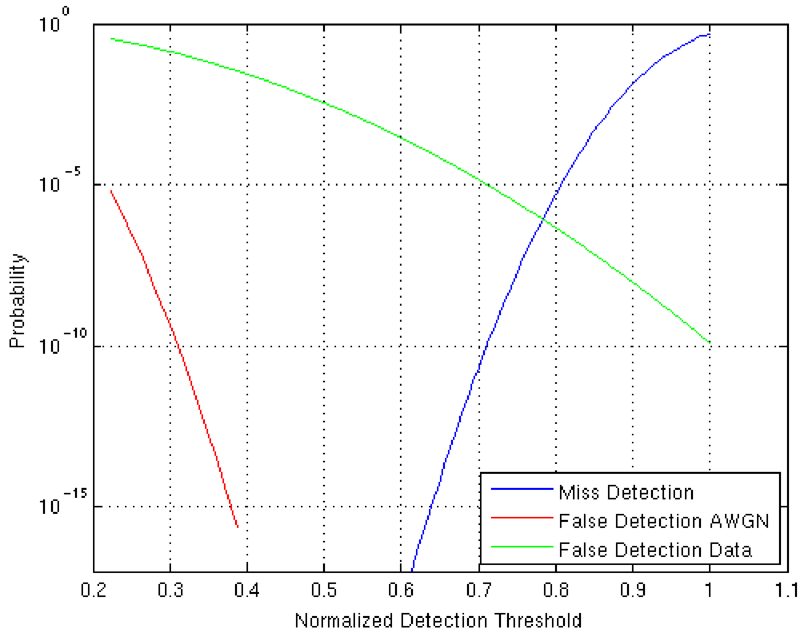


Error Performance – Noncoherent with 3dB Boost

M=8



M=12



Combined Error Performance for two Detectors

- Miss Detection
  - First detector miss, OR, second detector miss
    $Pm=Pm1 + (1-Pm1)*Pm2 \approx Pm1+Pm2 \approx Pm1$
    $(Pm2 << Pm1)$
- False Detection due to AWGN
  - First detector detect, AND second detector false detect
  $Pfawgn = (1-Pm1)*Pf2 \approx Pf2$
- False Detection due to Data
  - First detector false detect AND Second detector false detect due to data
  $Pfdata = Pf1*Pf2\_data$

Selection Rule for Burst Marker Length based on Two Step Detector

1. Select the number of “1”s M, such that miss detection < 1e-8, and false detection due to noise is less than 1e-10

   M>=8

2. Obtain Pf2_data given M and miss detection rate 1e-8.
3. Calculate the required Pf1 for first detector

   Pf1=1e-8/Pf2_data

4. Find the number of “0”s K, such that it meets Pm1<1e-6 given Pf1 obtained in step 3

Example

- M=8, when Pm2=1e-8, Pf2_data~0.1, the required Pf1=1e-8/0.1=1e-7.

  Find K such at Pm1<1e-6 when Pf1<=1e-7,

  K=20.

- M=12, when Pm2=1e-8, Pf2_data~1e-2, then, the required Pf1=1e-6

  Find K such that Pm1<1e-6 when Pf1<=1e-6,

  K=18.

Summary

- Two-step detection allows to choose M, K independently given false detection and miss detection requirement.
- The burst marker designed by the two-step detector has same error performance as square 2-D markers, but with reduced number of “1”s.
- The assumption of Gaussian constellation is only the worst case. Actual number K may be less if using the real constellation in simulation.
- If 3dB boosting of B symbols is used, we can expect less ‘1’s or less ‘0’s.

2-D Structure of Burst Marker(M,K)

- Current proposal uses scattered 2-D burst marker
- Resist narrowband interference??
  (Need to verify this)

0	1	0	1
1	0	1	0
0	1	1	0
1	0	0	1

- Sensitive to Inter-carrier Interference
  - AM hum 60Hz or 120Hz
  - Frequency offset (when search for burst marker, there may be uncorrected frequency offset.)
- Need to design 2-D structure to have good auto-correlation for both 0 and 1 positions.

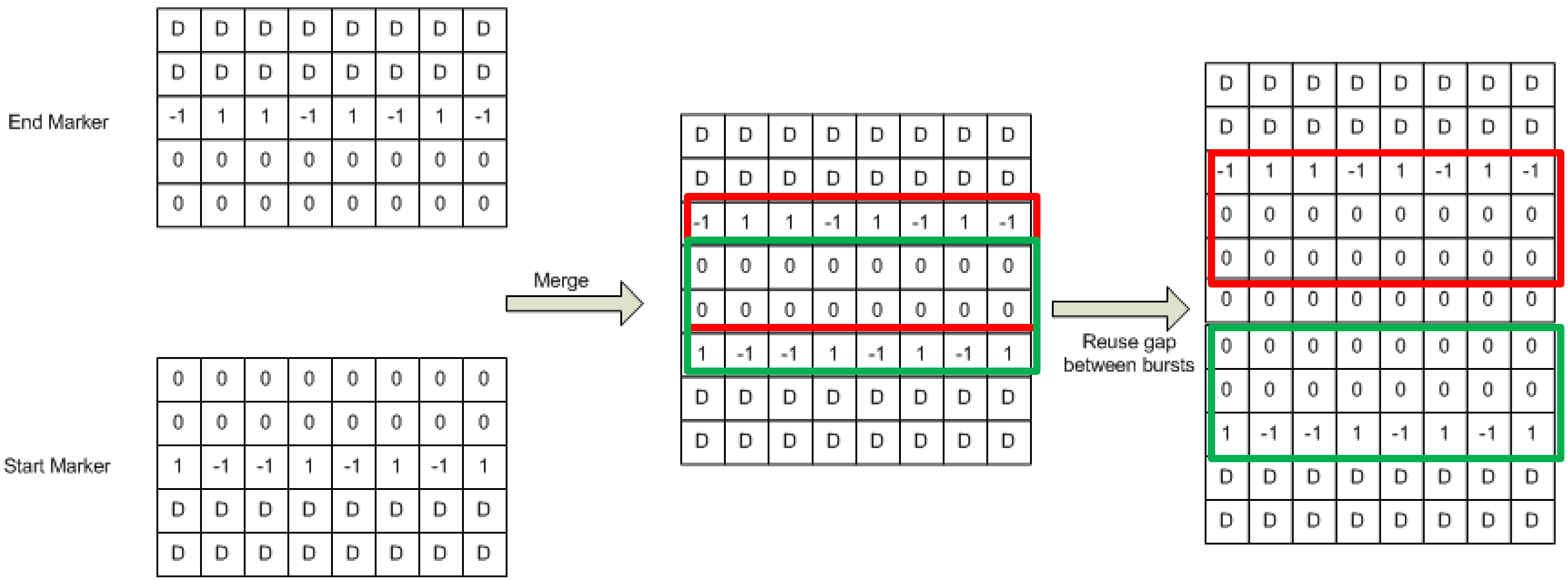
Alternative Structure with Isolated ‘0’s and ‘1’s

0	0	0	0
0	0	0	0
1	1	1	1
1	1	1	1

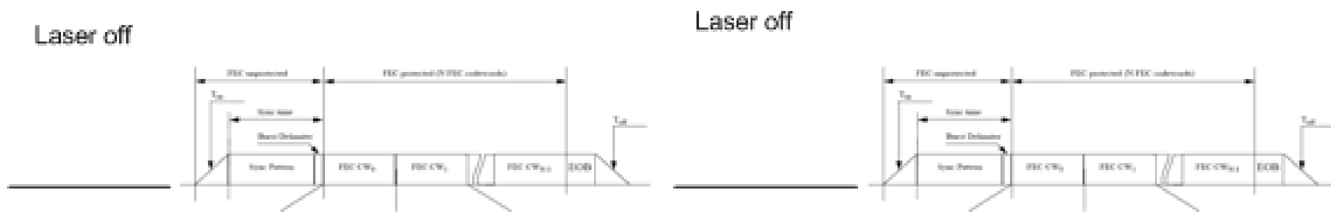
- Same Performance
- Less sensitive to ICI, esp. for start marker
  - Upon detection of the start marker, the residual frequency offset is not corrected yet. Frequency offset causes Inter-carrier interference(ICI)
- Narrow-band interference?
- Only need good auto-correlation for ‘1’.
  - Can use orthogonal sequence, such as walsh sequence

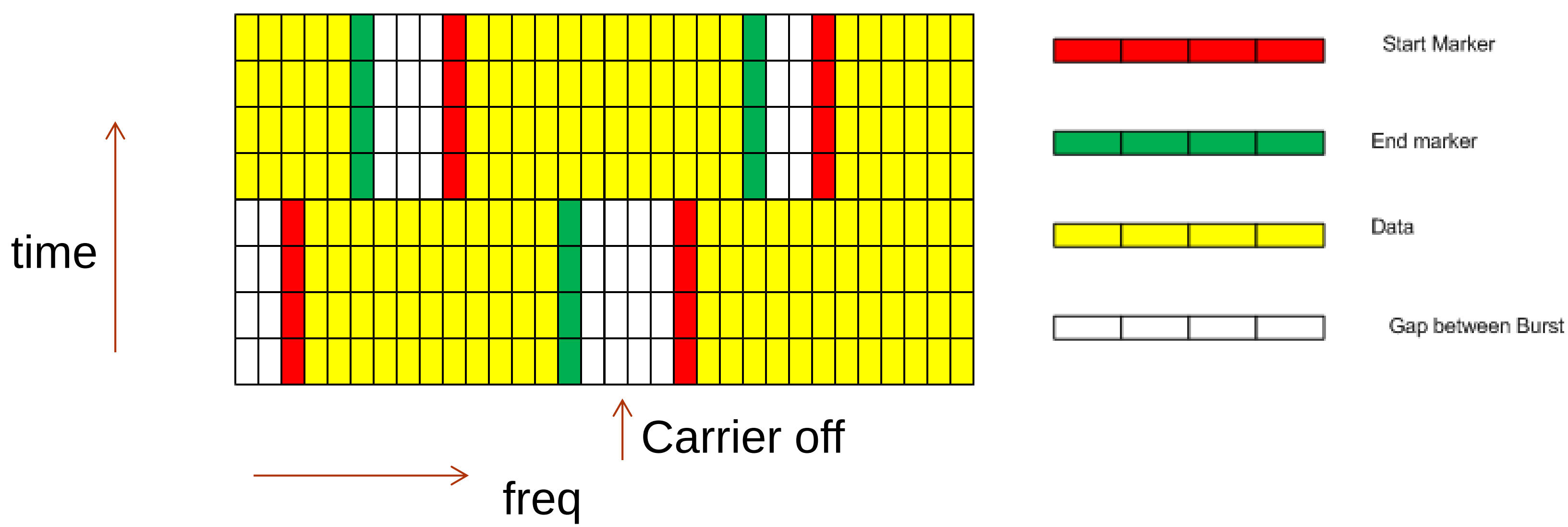
Example

- M=8, K=16



Similarity between EPON and EPoC Burst



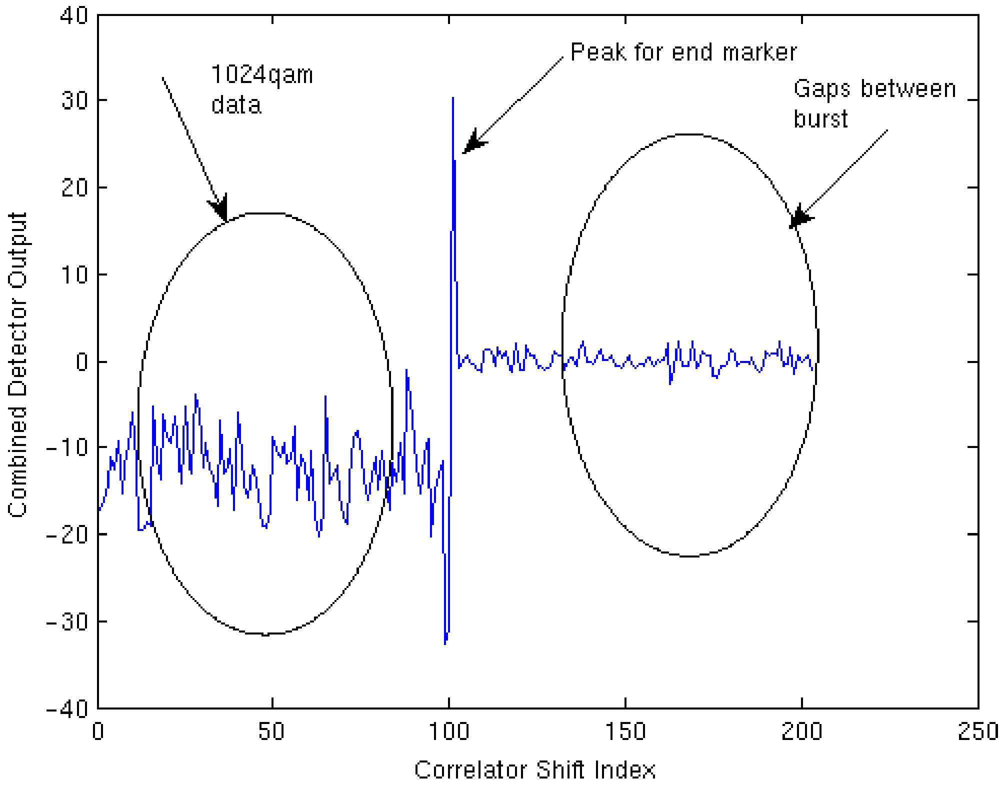


Further On Detector

- The two-step detector is used to derive the design rule, but it does not mean the best.
- Single receiver that combines both power detector and correlator:
  - First Detector $N = \sum_{i=1}^{K} N_i$
  - Second Detector $P = \left| \sum_{i=1}^{M} r_i p_i \right|$
  - Combined Detector: R = 2*P-N (Approximate Likelihood Ratio detector)

Example of Combined Detector

- M=8, K=16, 3dB boost of B symbol, 1024QAM, SNR=10dB (for data)



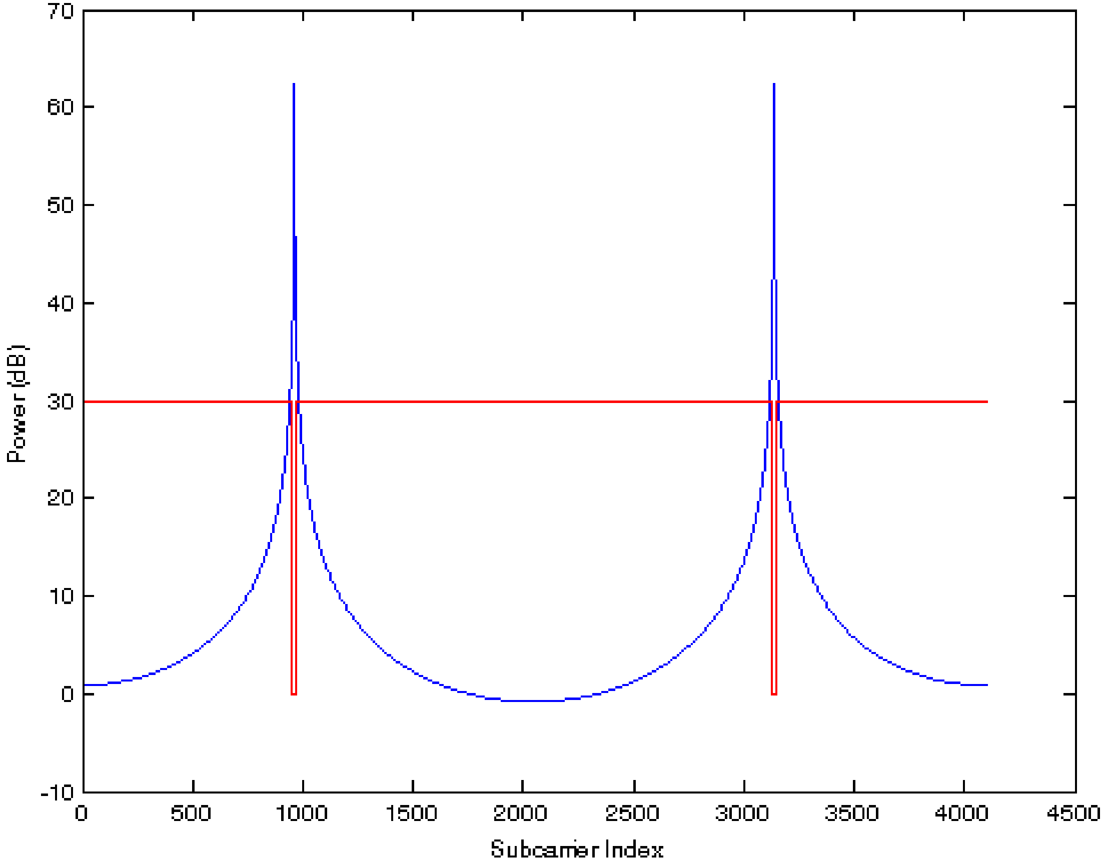
Summary

- With the isolated ‘0’s and ‘1’s, the start marker and end marker can share same ‘0’s, improve the efficiency.
- Any gap between bursts naturally becomes part of the ‘0’s and increase the reliability of detection.
- The two-step detector turns out to merely be a frequency domain “AGC”, i.e. first detect the power-off reset AGC and detection state machine, then detect the BPSK marker, similar to what EPON and other packet based systems do.
- There exists better one-step detector to combine the two steps and ease the burst marker detection.

Consideration for Narrow Band Interference

- Narrow-band interference generates power leakage because of rectangle windowing at RX
- If a strong NBI strikes start orend marker, it will most likely corrupt the detection any way.
- Narrow band interference is quasi-static.
- A better solution is to avoid the interfering subcarriers in the US bit-loading profile.
- When doing 1D-2D mapping, those subcarriers of poor C/I should be excluded.
- Quantitive requirement for rejection of narrow band interference needs to be established.

Leakage



70
60
50
40
30
20
10
0
-10
Power (dB)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Subcarrier Index