# EPoC Burst Marker Proposal for EPoC 802.3bn

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# Supporters

# 2-D Burst Marker Design (1)
# 2-D “B” and “N” sequence

- Burst Marker size is $N_f$ x $N_s$. Size determine performance for false and misdetection
- 1:1 ratio of BPSK “B” to Nulls “N” is best performance
- $N_f$ (frequency direction size) should be even, allowing boosting the power of “B” subcarriers by 2 without increasing total output power
- $N_s$ (time direction size) can be a odd or even

# 2-D Burst Marker Design (2)
# 2-D “B” and “N” sequence

- Best 2-D auto-correlation sequence is selected (by exhaustive search)
- BM can be interspersed with the data and pilots to improve robustness
- Stop marker is the complement of the Start sequence:
  - “B” → “N” and “N” → “B”

# 2-D Burst Marker Design (3)
# 1-D "B" sequence

- "B" sequence is 1-D BPSK of length $(N_f \times N_s)/2$
  - No position ambiguity, set by the 2-D sequence.
- Sequence boosted by 2 (3 dB) for robustness.
- Best 1-D auto-correlation sequence selected (by exhaustive search). Some circular shifts of a sequence are mutually orthogonal.
- Profile encoded on BPSK sequence. Each profile has its own circular shift of the base sequence. Examples:
  - BM 4x4 BPSK profile 0 (no shift) : S0 = [-1 1 1 1 1 -1 1 -1];
  - BM 4x4 BPSK profile 1 (shift +1) : S1 = [-1 -1 1 1 1 1 -1 1];
  - BM 4x4 BPSK profile 4 (shift -3) : S4 = [1 1 -1 1 -1 - 1 1 1 ];

# Proposed 2-D Burst Marker, Profile 0

4x4 Start BM

| | | | |
|---|---|---|---|
| 0 | -1 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 0 | 1 | -1 | 0 |
| 1 | 0 | 0 | -1 |

Frequency

Symbol

4x6 Start BM

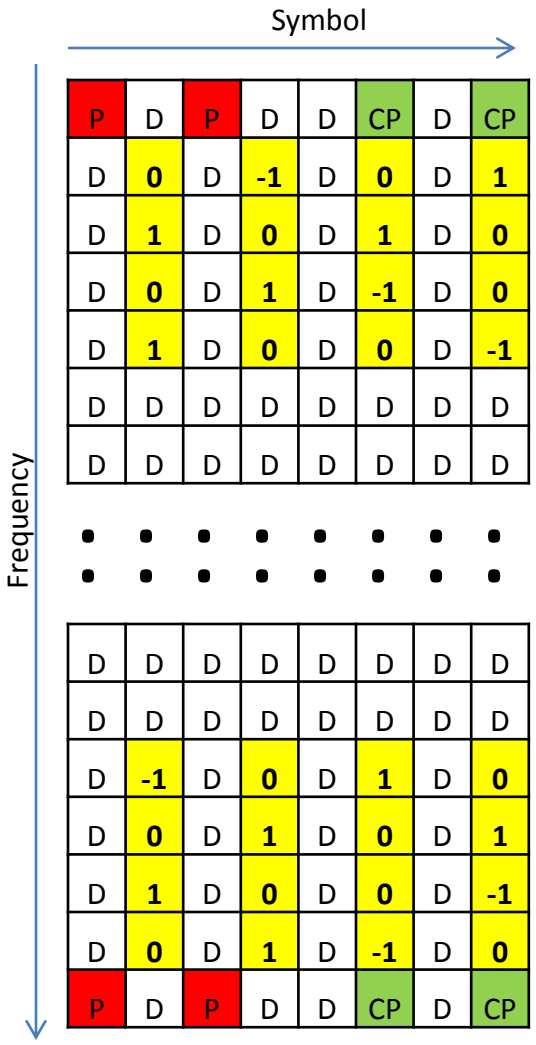
| | | | | | |
|---|---|---|---|---|---|
| 0 | -1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 |
| 0 | -1 | -1 | 0 | 0 | 1 |
| 1 | 0 | 0 | -1 | 1 | 0 |

4x8 Start BM

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | -1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 | -1 | 1 |
| -1 | 0 | 1 | 0 | 1 | 0 | 0 | -1 |
| 0 | -1 | 0 | -1 | 0 | 1 | -1 | 0 |

- 4x4 BM "B" sequence: **S0 = [-1 1 1 1 1 -1 1 -1]**
  - **7** mutually orthogonal sequences by circular shift of [0,1,2,3,-3,-2,-1]
- 4x6 BM "B" sequence : **S0 = [-1 1 1 1 1 1 -1 -1 1 1 -1 1]**
  - **11** mutually orthogonal sequences by circular shift of [0,1,2,3,4,5,-5,-4,-3,-2,-1]
- 4x8 or 8x4 BM "B" sequence : **S0 = [-1 1 1 1 1 1 -1 1 -1 1 1 -1 -1 -1 1 -1]**
  - **13** mutually orthogonal sequences by circular shift of [0,1,…,6,-6,-5,…,-1]
- Stop marker is complementary to Start marker, **"B" → "N" , "N" → "B"**
- Profile sequence is on Start and Stop marker. First element is top left corner, then left to right and top to bottom.
- Start BM is preceded by one subcarrier carrying Pilots and Data. Stop BM is followed by one subcarrier carrying Pilots and Data (see examples).

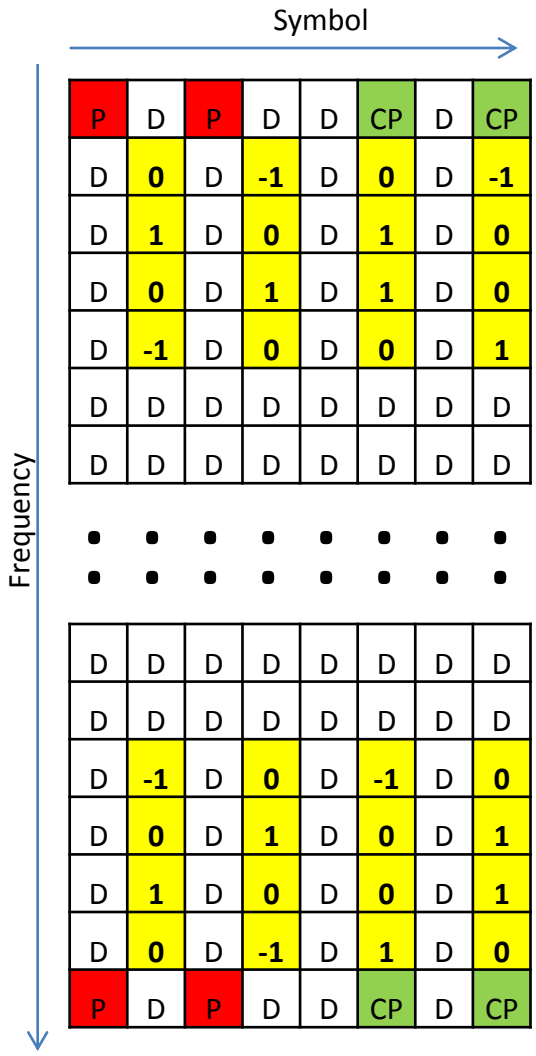
# Examples of BM 4x4 in 8 symbols RB




Start BM S0

Stop BM S0

Note: Power is constant versus time

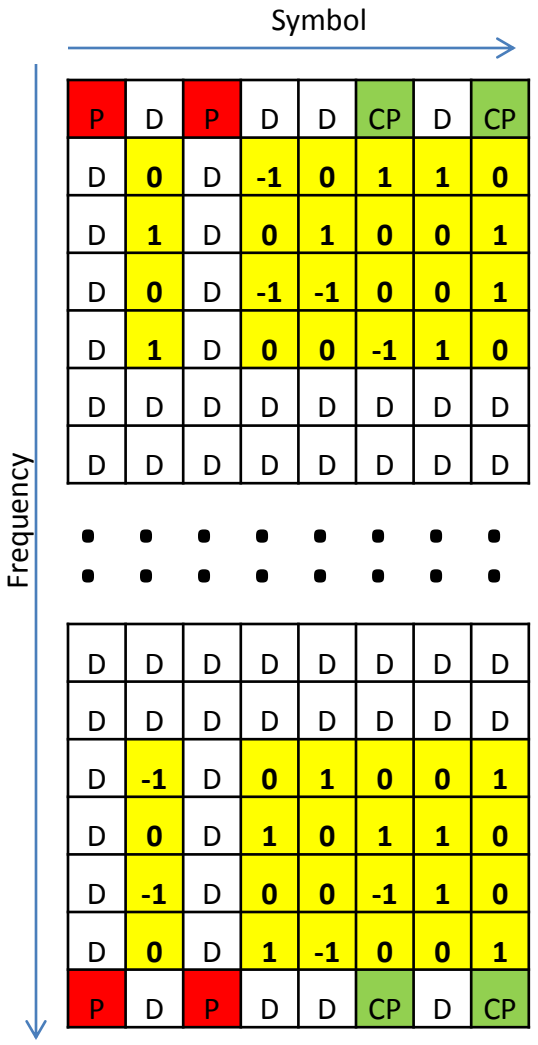



Start BM S1

Stop BM S1

**Legend**
+/-1 : BM "B"
0 : BM "N"
D : Data
P : Pilot
CP : C. Pilot

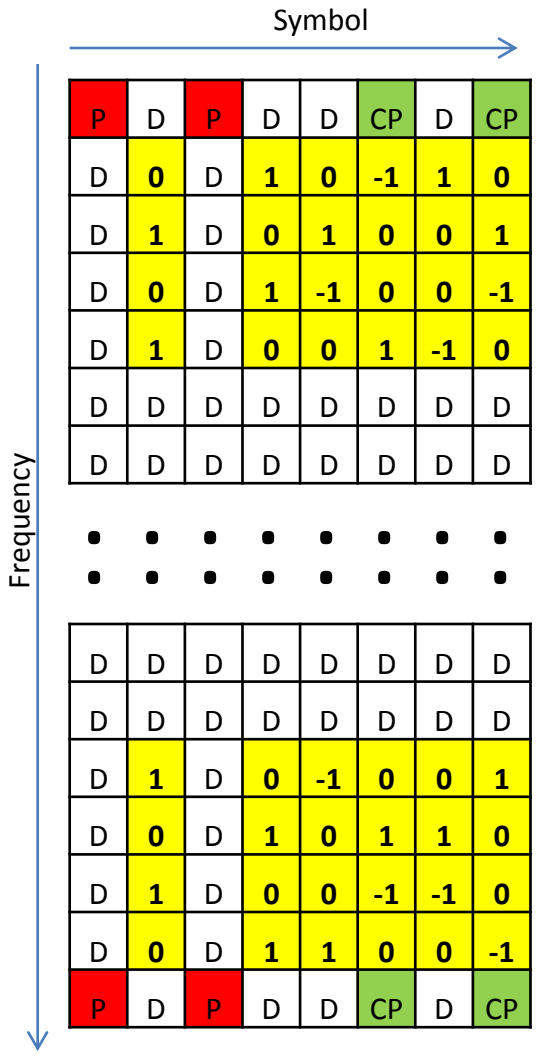
# Examples of BM 4x6 in 8 symbols RB




Start BM S0

Stop BM S0

Note: Power is constant versus time

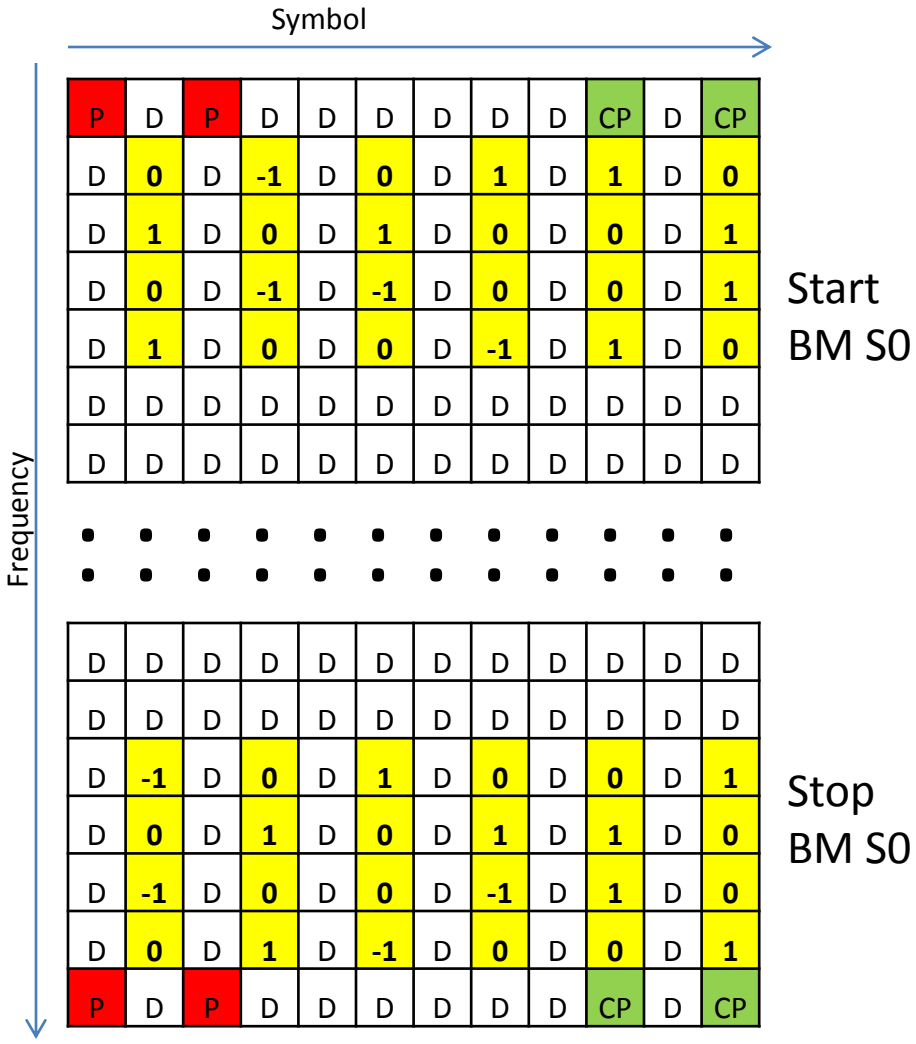



Start BM S1

Stop BM S1

**Legend**
+/-1 : BM "B"
0 : BM "N"
D : Data
P : Pilot
CP : C. Pilot

# Examples of BM 4x6 in 12 symbols RB




Start BM S0

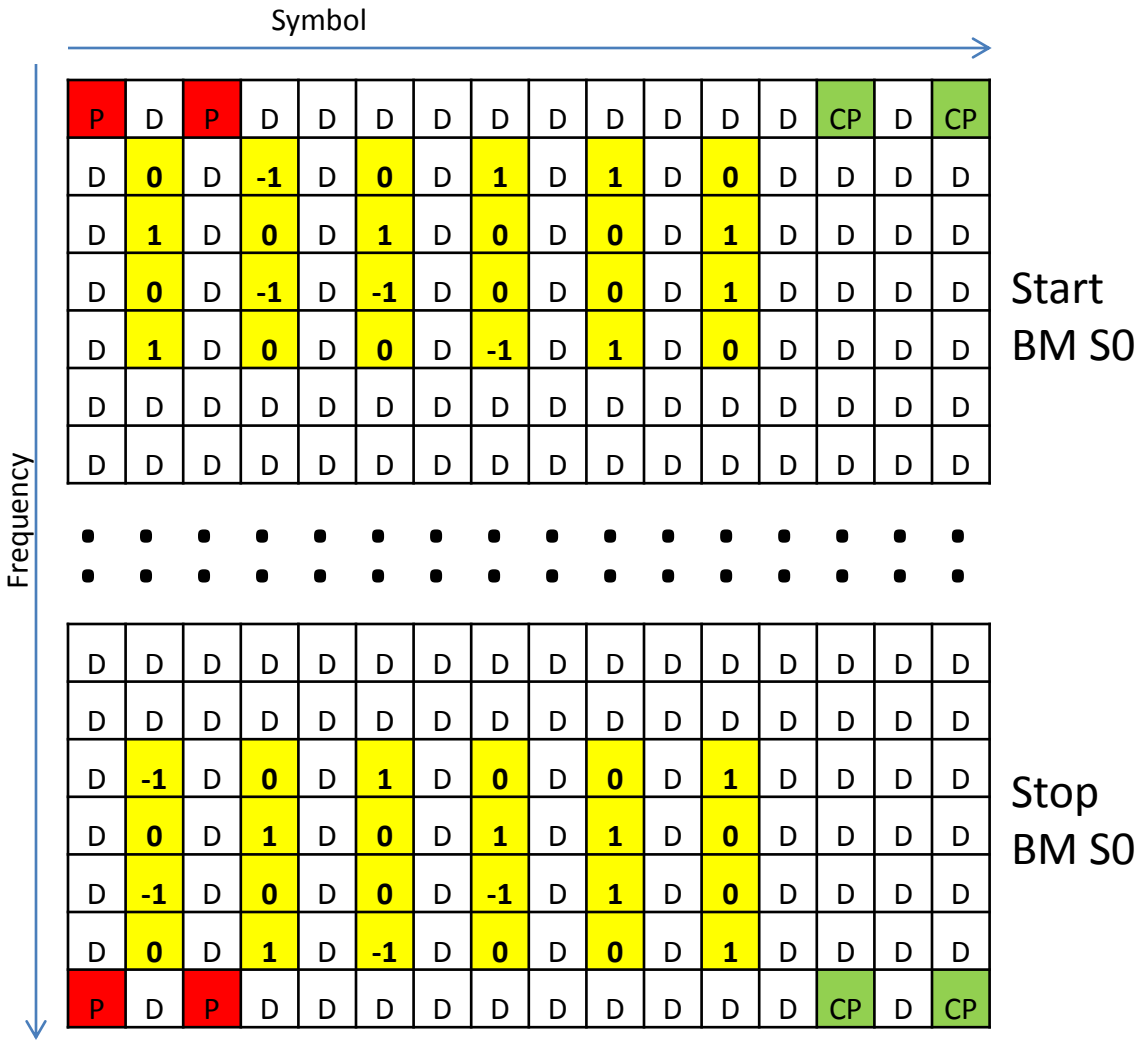
Stop BM S0

**Legend**

+/-1 : BM "B"
0 : BM "N"
D : Data
P : Pilot
CP : C. Pilot

Note: Power is constant versus time

# Examples of BM 4x6 in 16 symbols RB

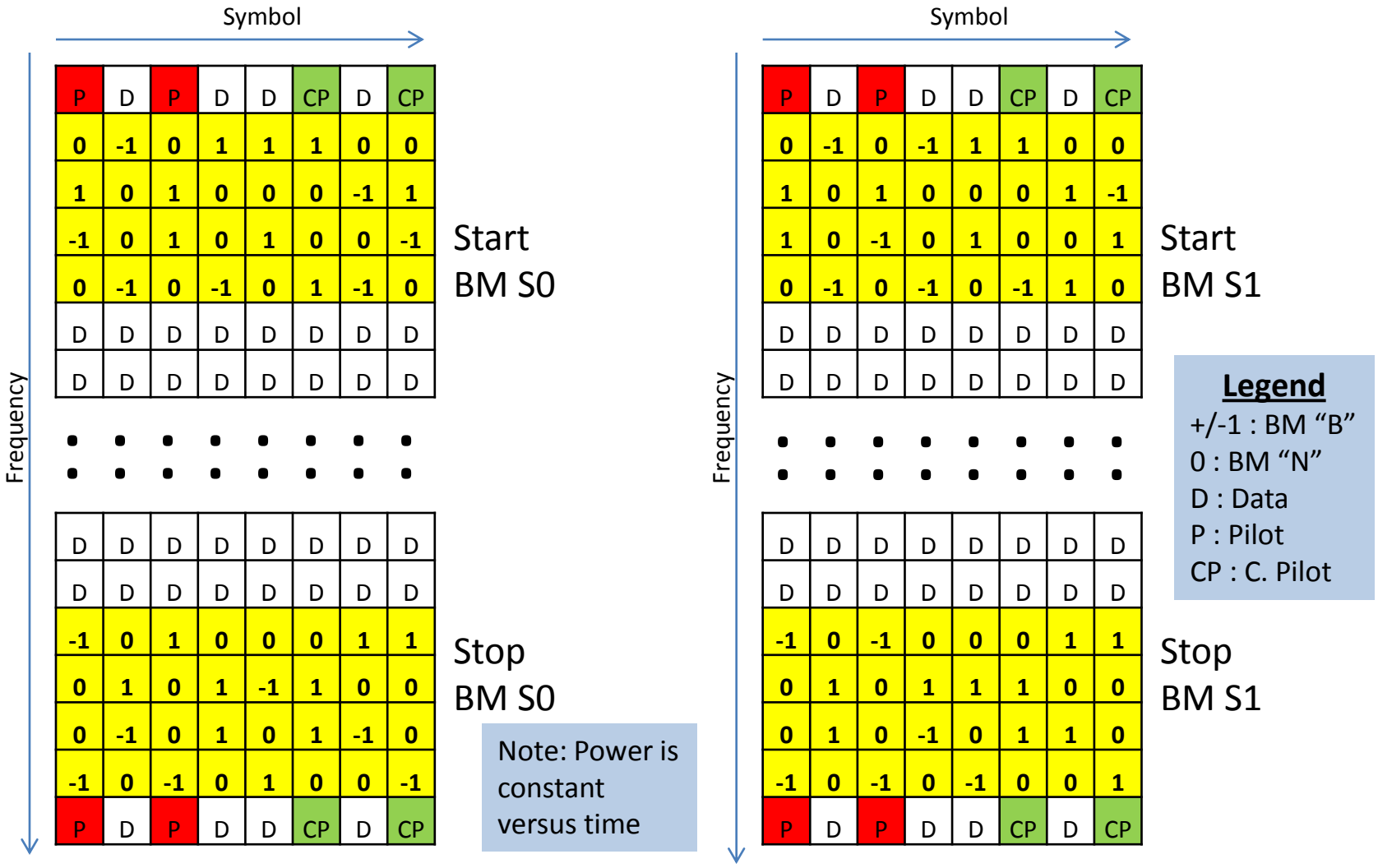



**Legend**

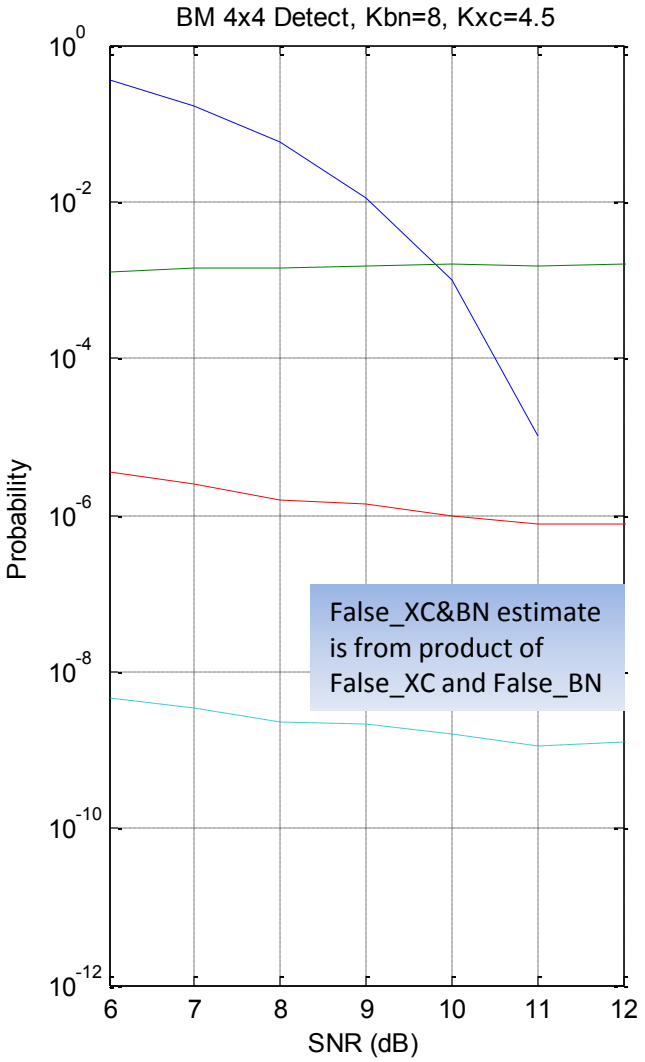
+/-1 : BM "B"
0 : BM "N"
D : Data
P : Pilot
CP : C. Pilot

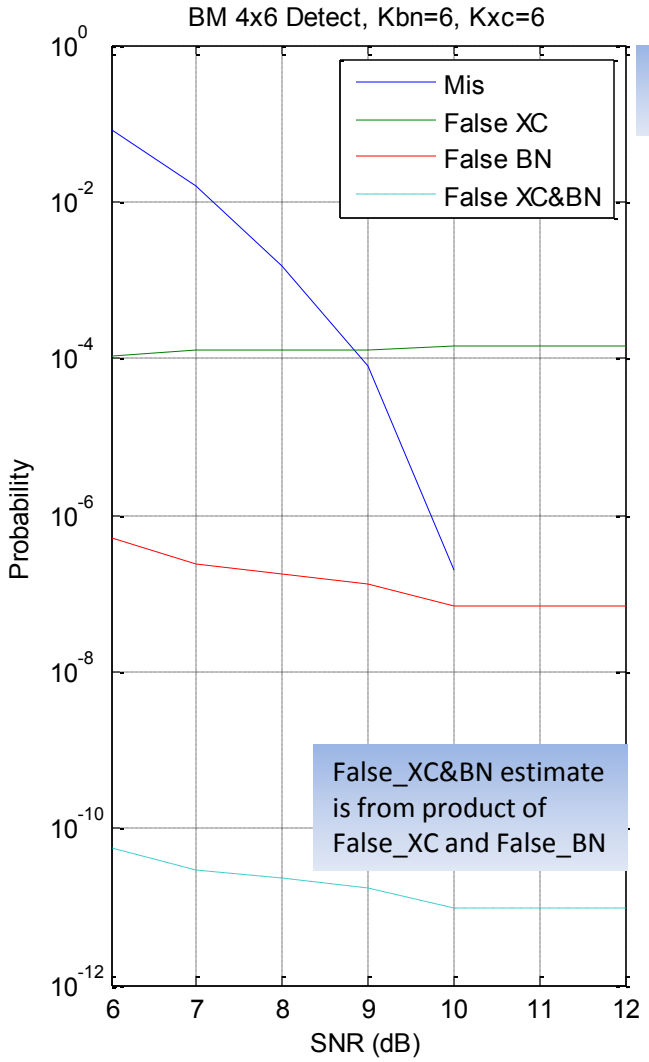
Note: Power is constant versus time

# Examples of BM 4x8 in 8 symbols RB



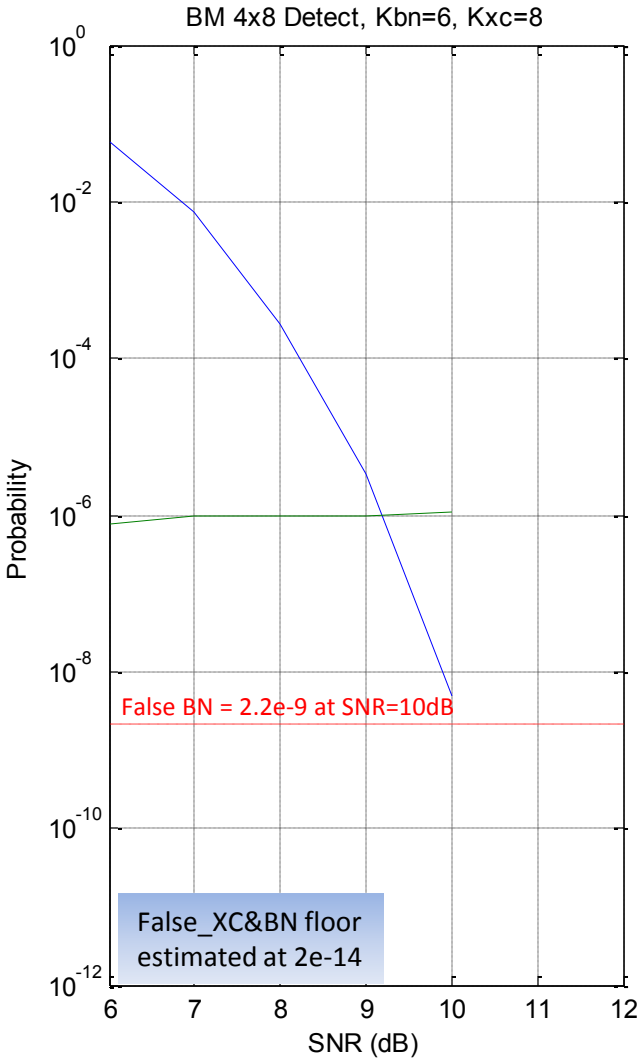
# Burst Marker False and Misdetection with Data

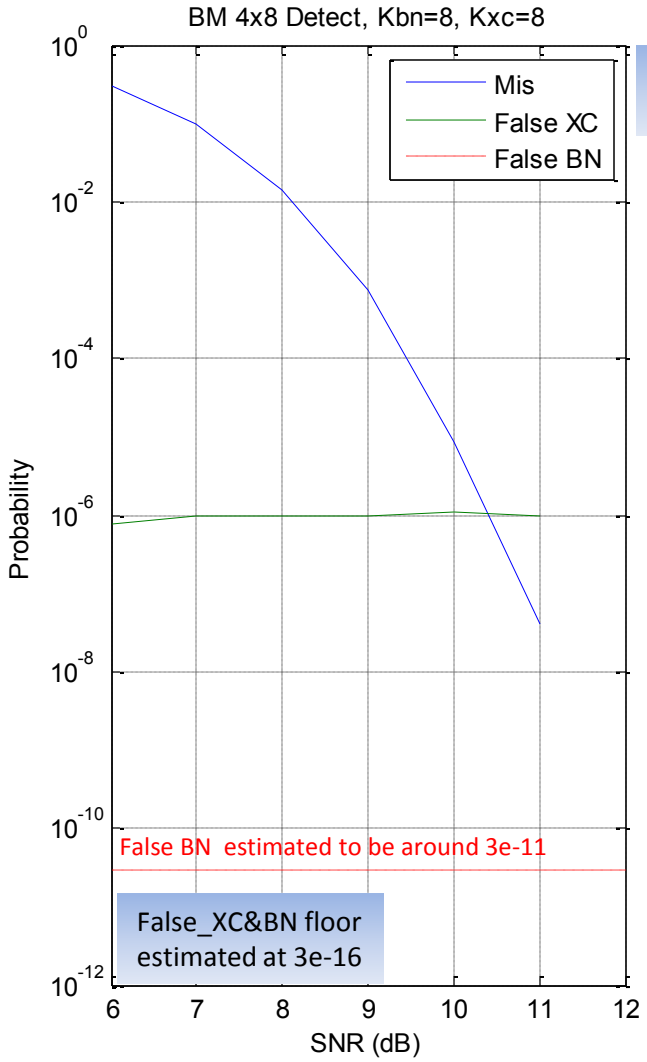



BM simulated in presence of 64-QAM

# Burst Marker False and Misdetection with Data




BM simulated in presence of 64-QAM

# BM Detector Simulation with Additive White Gaussian Noise only (no BM or Data)

- BM 4x4, $K_{bn} = 8$, $K_{xc} = 4.5$
  - False_BN = 7.5e-5, False_XC = 9.3e-4, False_XC&BN = 6.5e-8
- BM 4x6, $K_{bn} = 6$, $K_{xc} = 6$
  - False_BN = 2.2e-5, False_XC = 7.9e-5, False_XC&BN = 1.7e-9
- BM 4x8, $K_{bn} = 6$, $K_{xc} = 8$
  - False_BN = 1.1e-6, False_XC = 2.5e-6, False_XC&BN = 2.8e-12
- BM 4x8, $K_{bn} = 8$, $K_{xc} = 8$
  - False_BN = 4.2e-8, False_XC = 2.5e-6, False_XC&BN = 1.1e-13

# BM Detector Threshold in Presence of CW Interference (1)

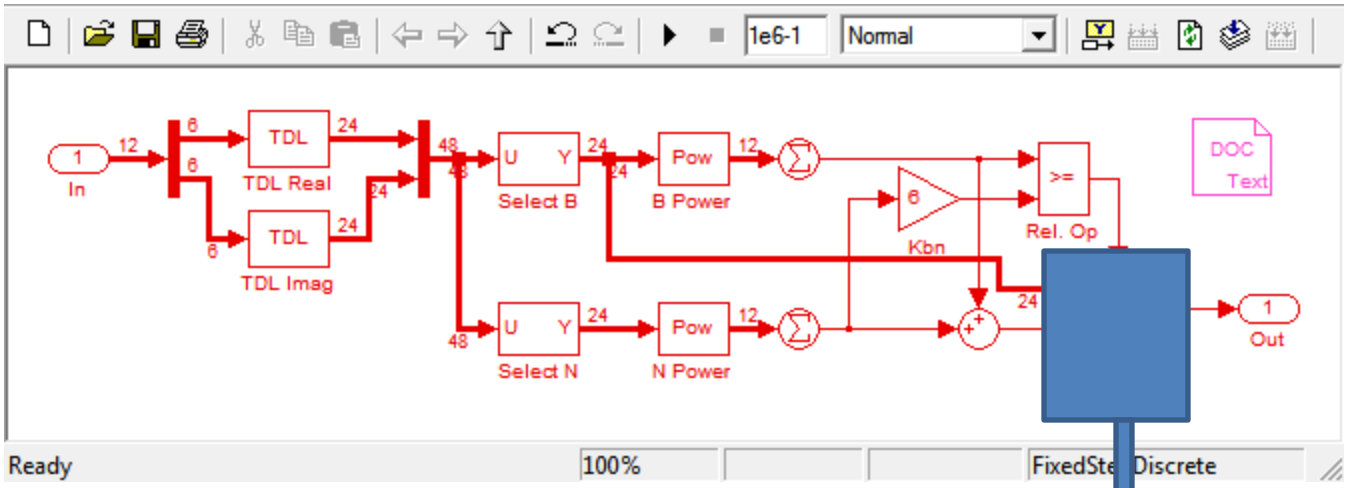
- CW interference (in noise free channel) prevents detection of BM. At threshold, Misdetection error rate 50%!
- Definitions:
  - $N_i$ is number of "N" RE corrupted by CW
  - $P_{cw}$ is power of CW (note: Data power is 1 and "B" is 2)
  - Kbn is scaling of sum of "N" RE power
- BM 4x4 threshold for: $N_i * P_{cw} * K_{bn} > N_B * 2$
  for $N_B = 8$ and $K_{bn} = 8$, then $P_{cw} > 2/N_i$
  - CW on one subcarrier : $N_i = 2 \rightarrow P_{cw}$ at 0 dB
  - CW on one symbol : $N_i = 2 \rightarrow P_{cw}$ at 0 dB

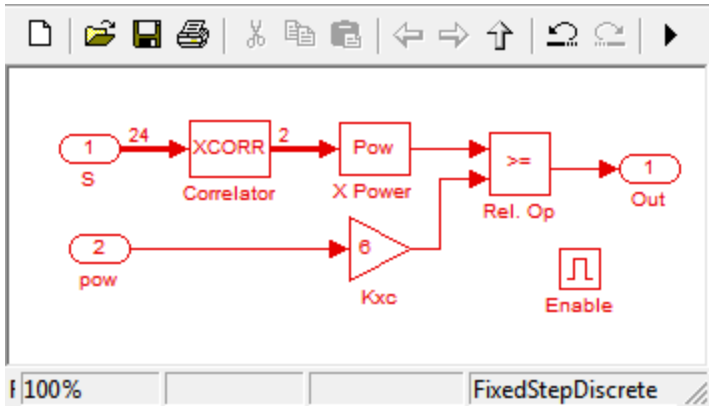
# BM Detector Threshold in Presence of CW Interference (2)

- BM 4x6 threshold for: $N_i * P_{cw} * K_{bn} > N_B * 2$
  for $N_B = 12$ and $K_{bn} = 6$, then $P_{cw} > 4/N_i$
  - CW on one subc. : $N_i = 3 \rightarrow P_{cw}$ at +1.25 dB
  - CW on one symbol : $N_i = 2 \rightarrow P_{cw}$ at +3 dB

- BM 4x8 threshold for: $N_i * P_{cw} * K_{bn} > N_B * 2$
  for $N_B = 16$ and $K_{bn} = 6$, then $P_{cw} > (32/6)/N_i$
  - CW on one subcarrier: $N_i = 4 \rightarrow P_{cw}$ at +1.25 dB
  - CW on one symbol : $N_i = 2 \rightarrow P_{cw}$ at +4.26 dB

# Simulink Model of BM 4x6 Detector and Correlator




$K_{bn} = 6$
$K_{xc} = 6$

Note: To find error floor, simulation up to 1e10 search.

# Remark

- With 16-QAM or higher data constellations, false detection error floor is:
  - BM 4x4: False detection floor ≈ 1e-9
  - BM 4x6: False detection floor ≈ 1e-11
  - BM 4x8: False detection floor ≈ 3e-16
- “B” & “N” sequence detection not affected for BM on non-contiguous spectrum or spanning across 2 frames for partially pre-equalized US.
- “B” BPSK sequence correlation may require pre-equalized upstream.
- BM 4x4 requires aggressive threshold for low error floor
  - not a lot of margin!

# Recommendation

- Use a single Burst Marker: BM 4x6 (slide 6)
  - Simplicity
  - Robust enough for low packet error rate
  - Minimal overhead
  - Up to 11 profiles for signaling
  - Low implementation complexity
  - Distinct Start and Stop Markers
  - Unity power

# PROPOSED MOTION #

- Adopt the 4x6 Burst Marker as described in Slide 6 as baseline for 802.3 EPoC (mapping in RB examples on slide 8-10)
  - Stop marker is the complement of “B’ & “N” Start Marker pattern
  - Non-nulls “B” boosted by a factor of 2 in power (3.01 dB)
  - Profile 0 encoded on “B” using S0 sequence
  - Orthogonal circular shifts of S0 sequence used for other profiles

- Moved by:
- Seconded by: