

# 2-D Marker Sequences

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# Introduction

- Burst Markers (BM) indicate start and end of an upstream OFDMA burst.
- Usage:
  - Length of burst
  - Number of LDPC codeword and type (long, medium, short)
  - Profiles

# Assumptions

- BM are transmitted after ranging and are pre-equalized
- First element of BM is time aligned with RB. BM search is in frequency direction, down to the RB.
- RB are 1, 4 or 8 subcarriers by M symbols.  $M \geq 4$
- BM can span across multiple RB (to allow BM larger than one RB).
- BM can span across OFDMA frame (needed when BM is larger than one RB).
- End and Start BM are usually separated by one or more RB of silence (idle)
  - Not for BM detection but to prevent collision from time granularity of the 1-D to 2-D mapping
  - BM detection must not be impaired by idle

# 2-D Marker Sequences Properties

- Exploit the 2-D structure of OFDMA
  - K subcarriers by L symbols
- Ternary signaling,  $P = -1$  or  $1$ ,  $N = 0$ 
  - Ease the differentiation of BM from data
  - N in the BM allow boosting of P without increasing total output power
- Good auto-correlation and cross-correlation for a large set of sequences

# 2-D Marker Sequences Properties

- Detection is by power averaging of “P” and “N” at the assumed locations
- Additional information can be carried by the BPSK “P” symbols like:
  - Start
  - End
  - Profile
- Idle RB between BM could be used to differentiate between Start and End BM at RX
- Square BM:  $K = L$ , where  $K$  is an even integer
  - $K/2$  Nulls RE in each row and column

# 2-D Marker Sequences Properties

- Non square BM:  $K = L-1$ , where  $K$  is an odd integer
  - $(K+1)/2$  Nulls in each row
  - $(K-1)/2$  or  $(K+1)/2$  Nulls in each column
- Logical NOT ( $P \rightarrow N, N \rightarrow P$ ) of a sequence is an orthogonal sequence to the original sequence.
- Many sequences with good auto-correlation to choose from:
  - $4 \times 4 \rightarrow 8$  sequences
  - $5 \times 6 \rightarrow 10080$  sequences
  - $6 \times 6 \rightarrow 64$  sequences
  - $8 \times 8 \rightarrow 256$  sequences

# Interleaving

- 2-D Burst Marker sequences can be interleaved with the data if the 2-D structure is kept intact
- Examples of 4x4 BM interleaving:

0	DP	1	DP	0	DP	1	DP
DP	1	DP	0	DP	1	DP	0
0	DP	1	DP	1	DP	0	DP
DP	1	DP	0	DP	0	DP	1
DP	DP	DP	DP	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP

Time

0	DP	1	DP	0	DP	1	DP
DP	DP	DP	DP	DP	DP	DP	DP
DP	1	DP	0	DP	1	DP	0
DP	DP	DP	DP	DP	DP	DP	DP
0	DP	1	DP	1	DP	0	DP
DP	DP	DP	DP	DP	DP	DP	DP
DP	1	DP	0	DP	0	DP	1
DP	DP	DP	DP	DP	DP	DP	DP

Time & Frequency

0	1	0	1	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP
1	0	1	0	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP
0	1	1	0	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP
1	0	0	1	DP	DP	DP	DP
DP	DP	DP	DP	DP	DP	DP	DP

Frequency

“1” is location of BPSK (P), “0” is location of Nulls (N), “DP” is Data or Pilot  
 RB are shown with lowest frequency at top, highest at bottom



# **2-D BURST MARKER SEQUENCE EXAMPLES AND CORRELATION**

# 2-D 4X4 Sequences

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

BM4x4\_1

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

BM4x4\_2

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

BM4x4\_3

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

BM4x4\_4

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

BM4x4\_5

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

BM4x4\_6

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

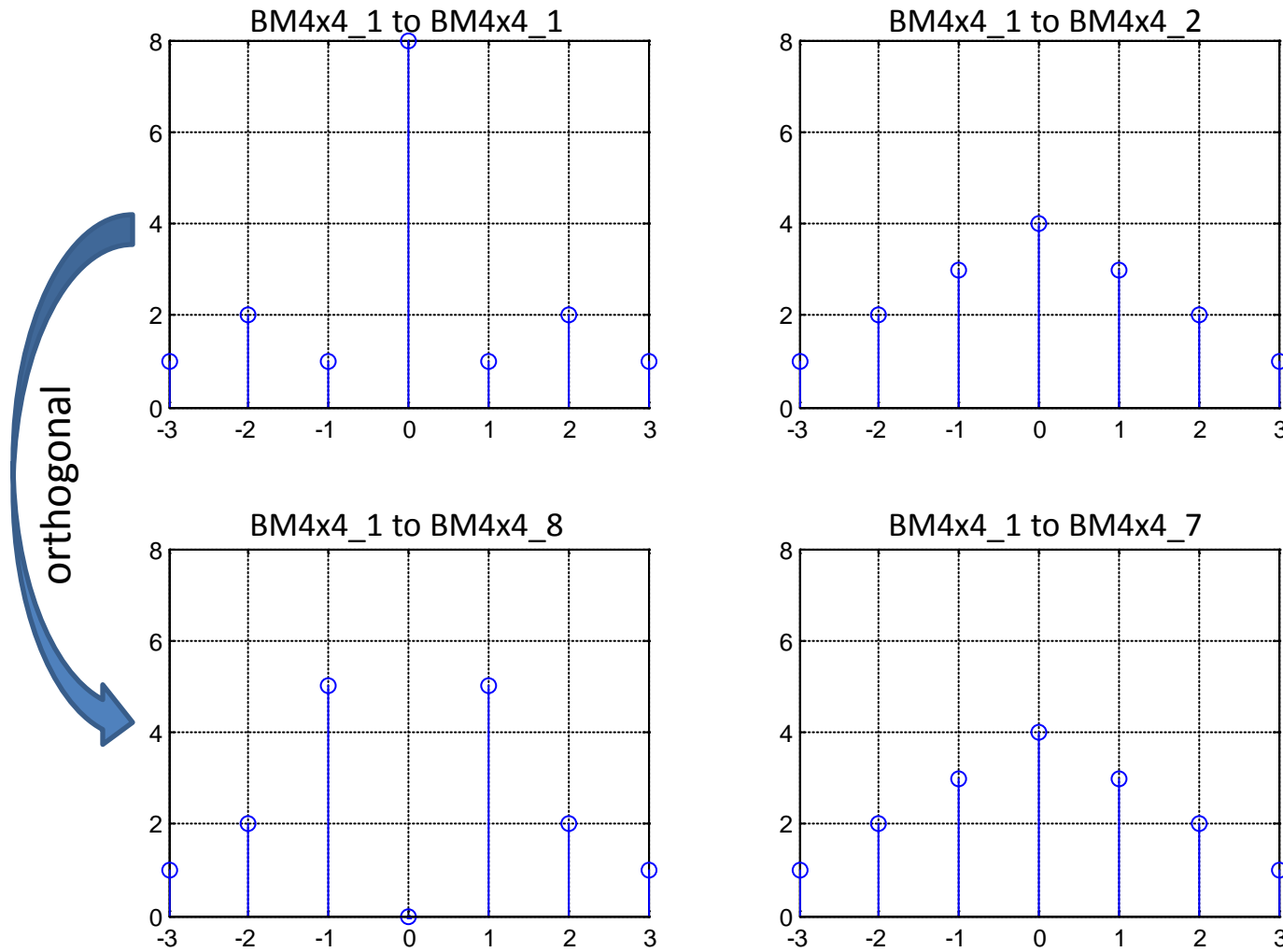
BM4x4\_7

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

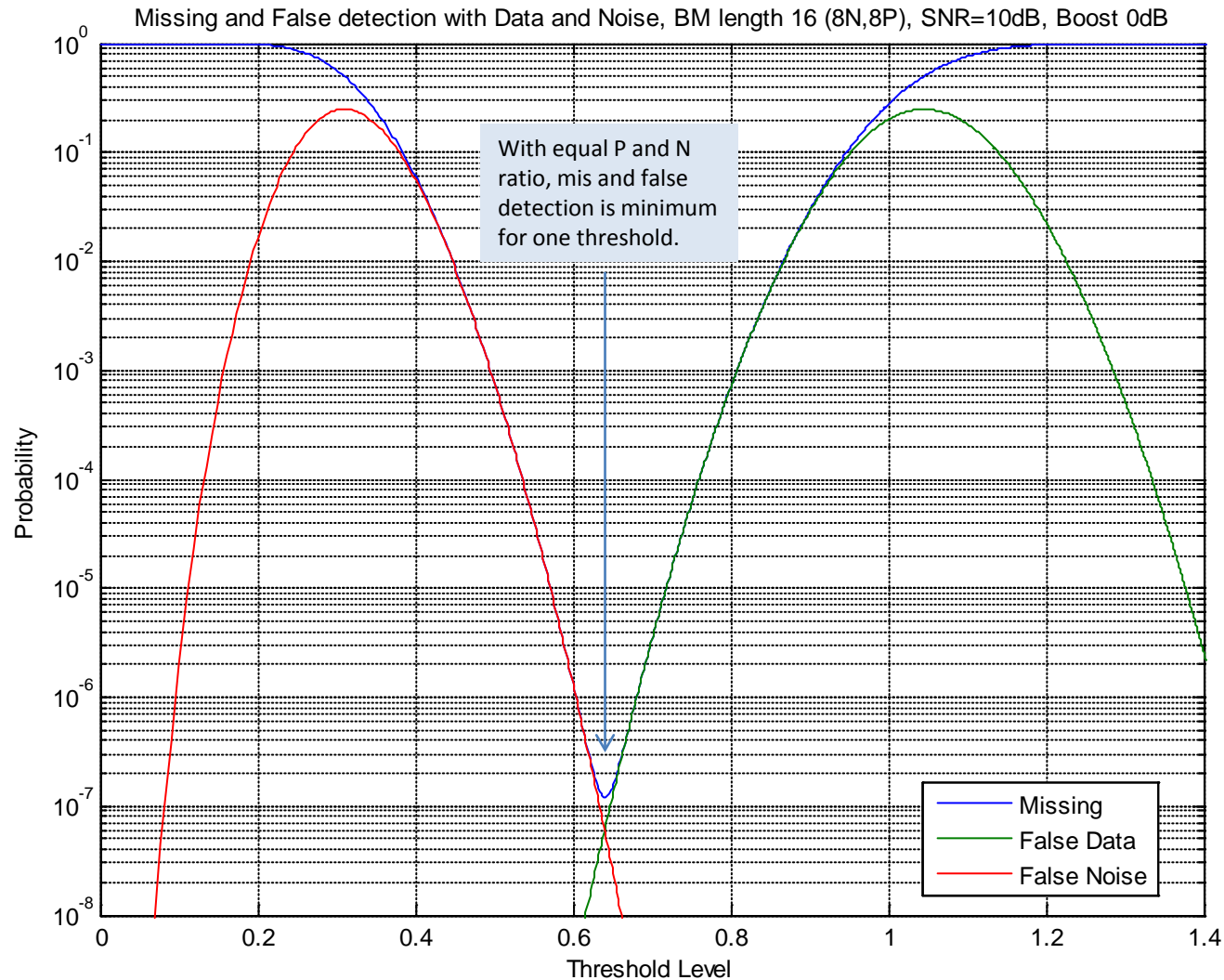
BM4x4\_8

“1” is location of BPSK (P), “0” is location of Nulls (N)

# 2-D 4x4 Sequence Correlation



# Mis and False Detection vs Threshold, BM 4x4 (8N,8P), SNR=10dB



# 2-D 6X6 Sequences (5 out of 64)

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

BM6x6\_1

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

BM6x6\_64

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

BM6x6\_25

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

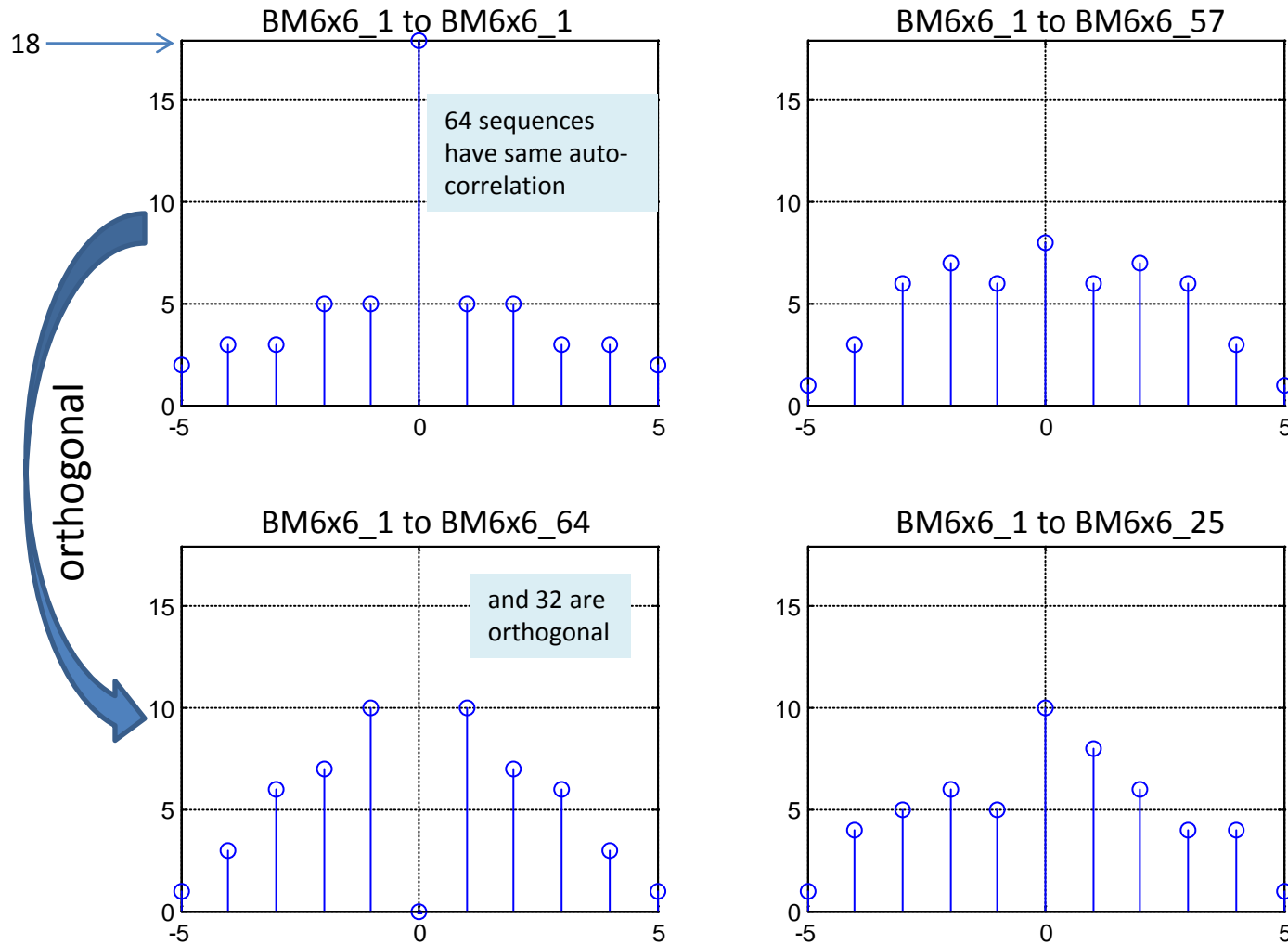
BM6x6\_38

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

BM6x6\_57

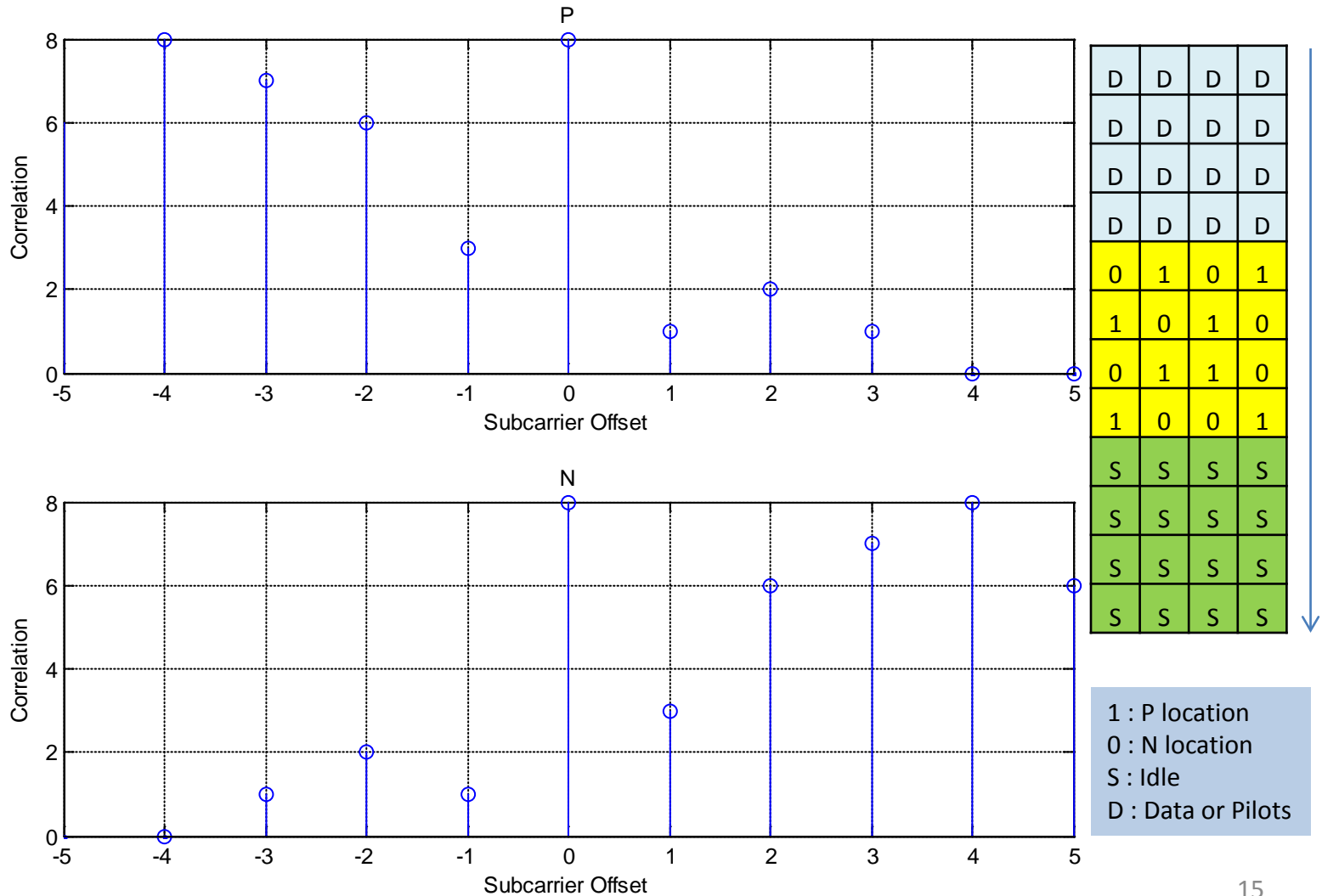
“1” is location of BPSK (P), “0” is location of Nulls (N)

# 2-D 6x6 Sequence Correlation

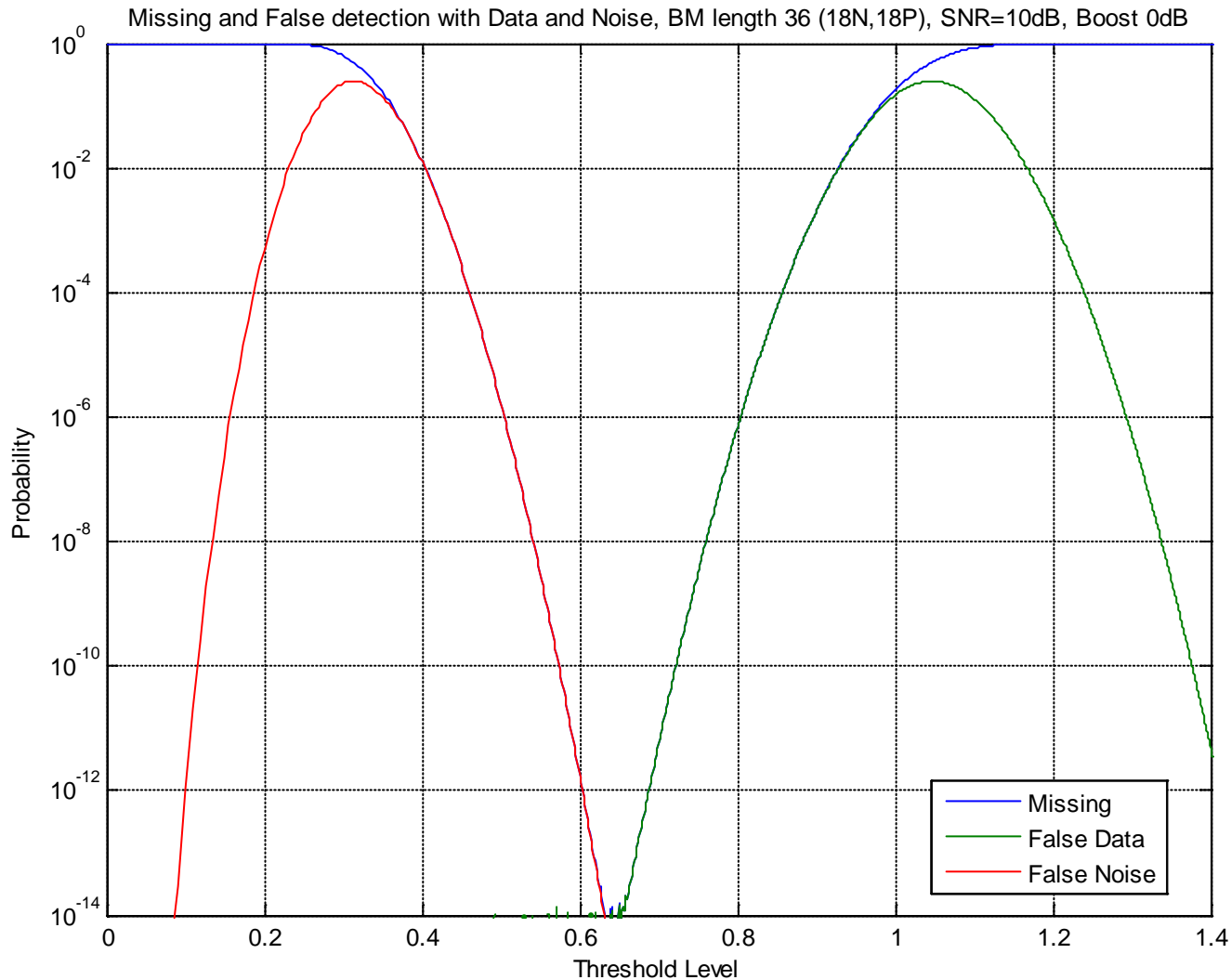


# BM 4x3

## Data and Idle prior and after BM



# Mis and False Detection vs Threshold, BM 6x6 (18N,18P), SNR=10dB





# 2-D 8X8 Sequences (5 out of 256)

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

BM8x8\_1

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

BM8x8\_64

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

BM8x8\_16

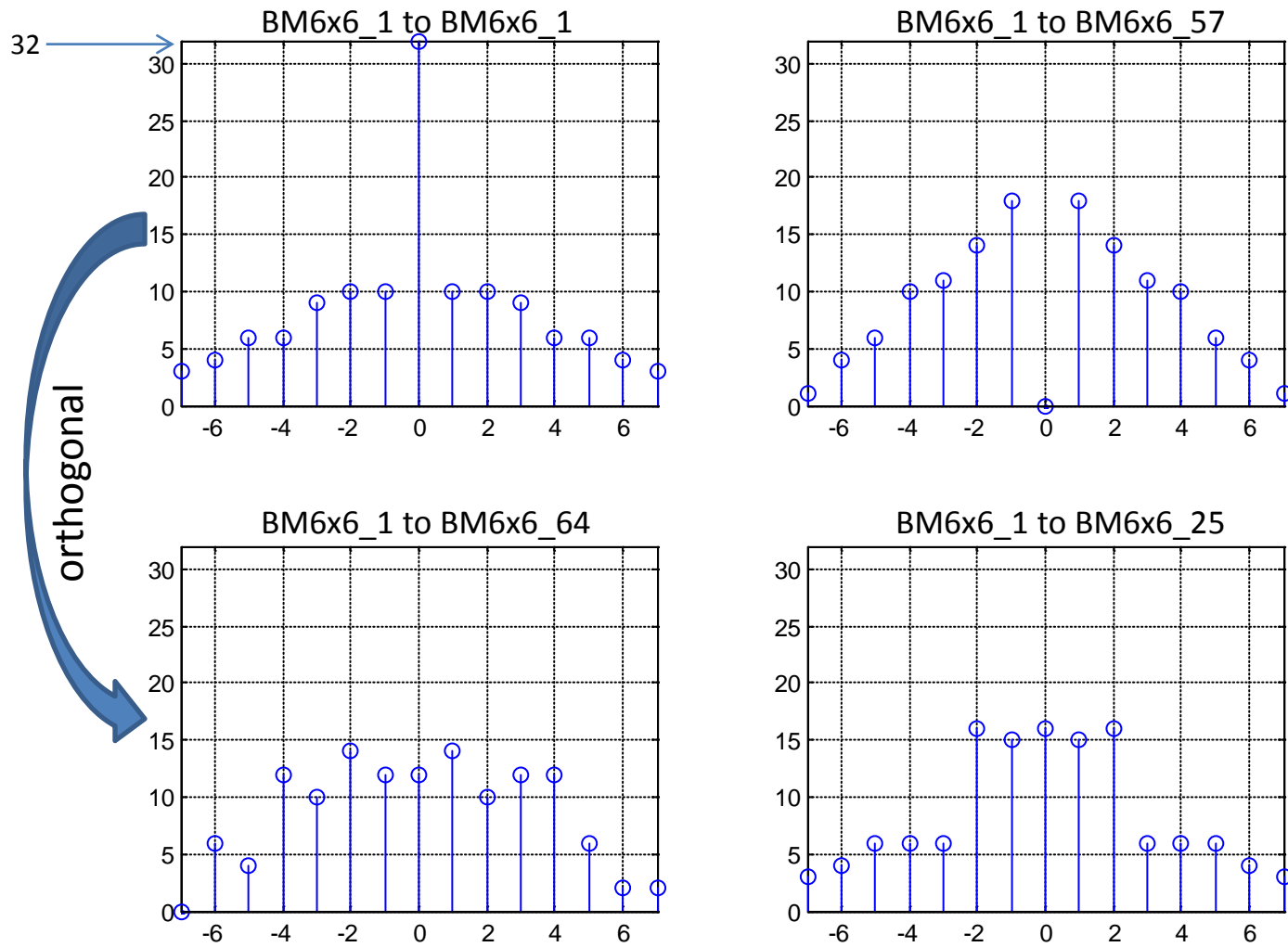
0	1	1	0	0	1	0	1
1	0	0	1	1	0	0	1
1	0	0	1	0	1	1	0
0	1	1	0	1	0	1	0
0	1	0	1	1	0	1	0
1	0	1	0	0	0	1	1
0	0	1	1	1	1	0	0
1	1	0	0	0	1	0	1

BM8x9\_28

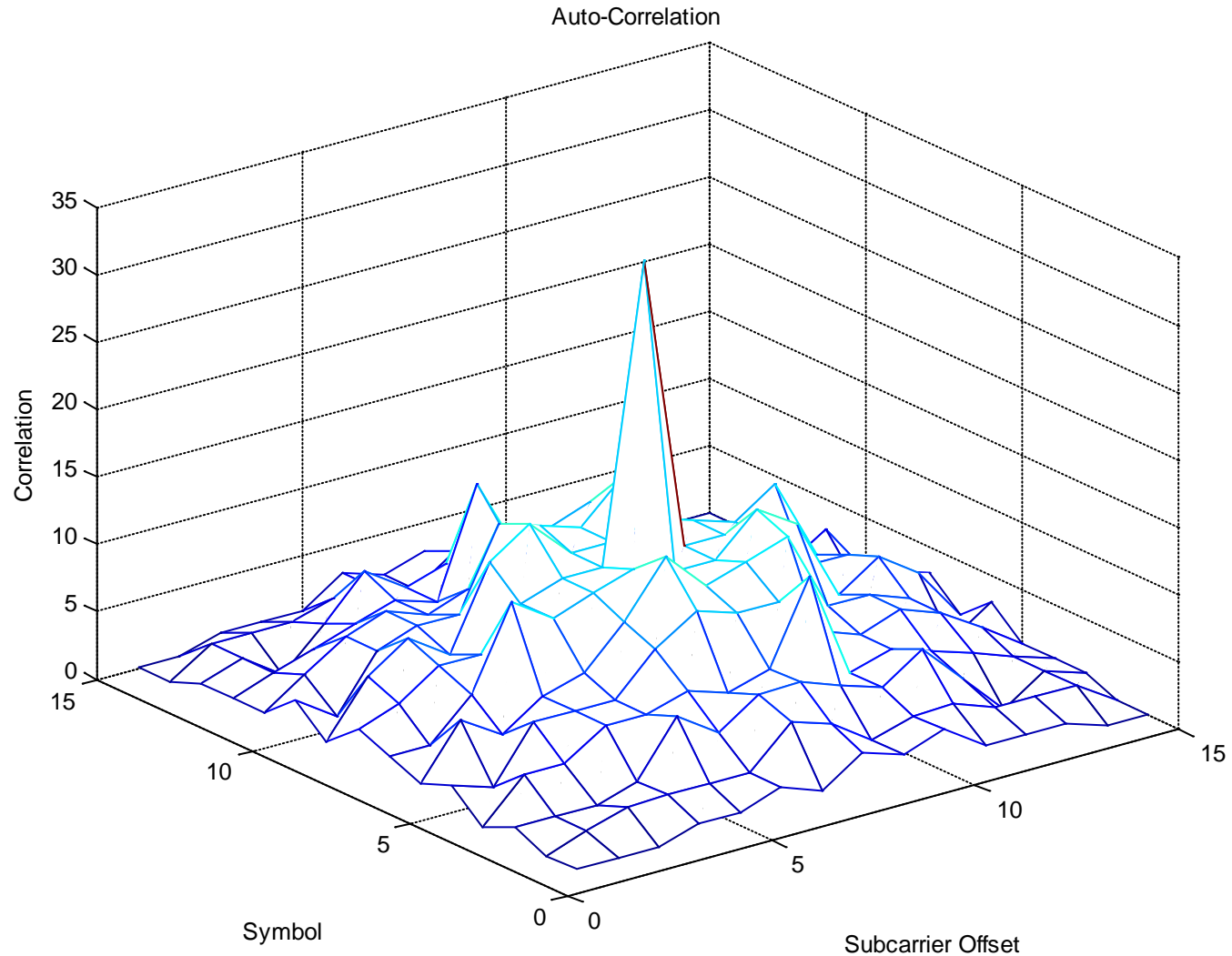
1	0	0	1	0	1	0	1
0	1	1	0	0	1	1	0
0	1	1	0	1	0	0	1
1	0	0	1	1	0	1	0
0	0	1	1	1	0	1	0
1	1	0	0	0	0	1	1
0	1	0	1	1	1	0	0
1	0	1	0	0	1	0	1

BM8x8\_33

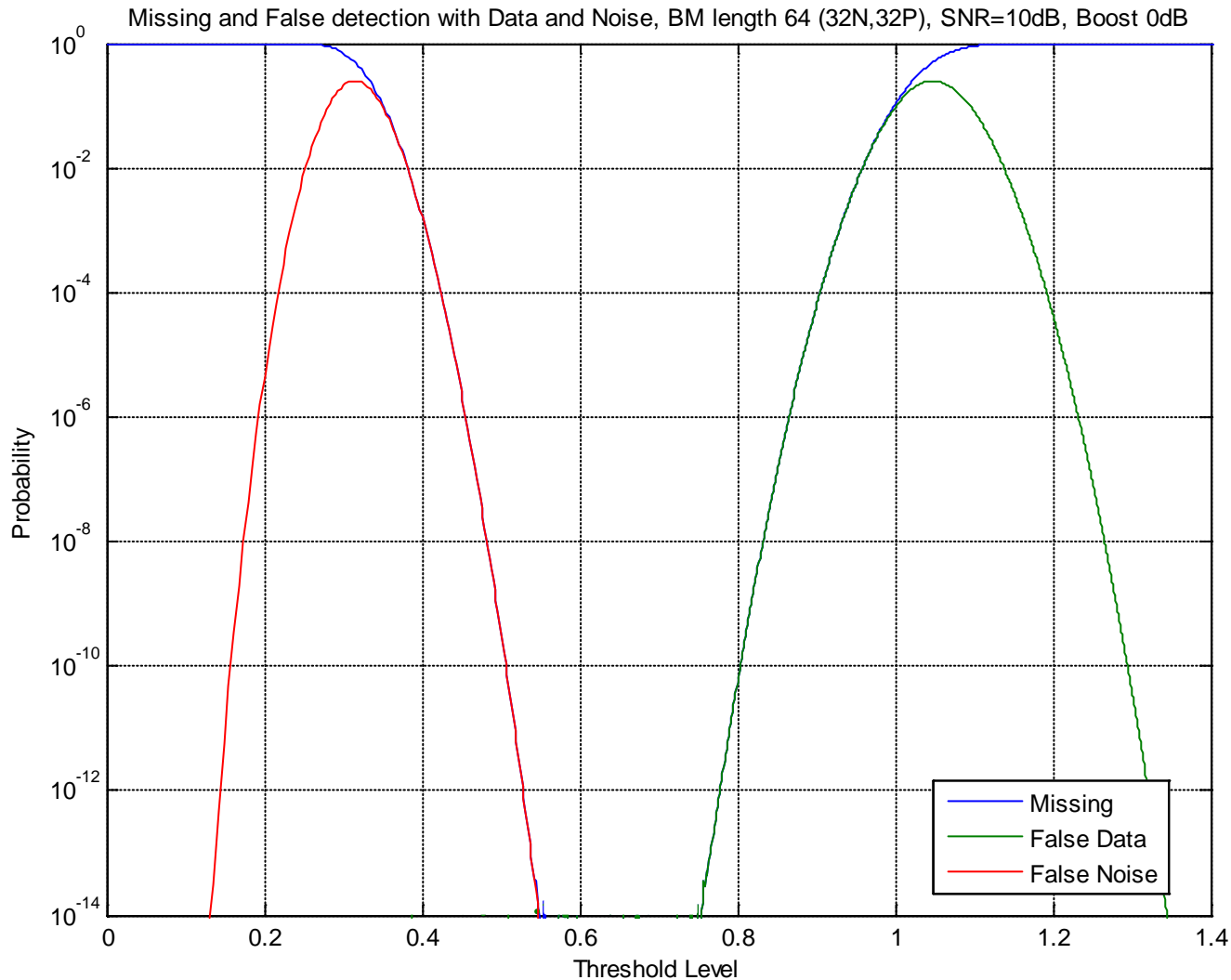
# 2-D 6x6 Sequence Correlation



# 8x8 2-D Auto-Correlation



# Mis and False Detection vs Threshold, BM 8x8 (32N,32P), SNR=10dB



# 2-D 5X6 Sequences (4 out of 10080)

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

BM5x6\_6004

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

BM5x6\_1590

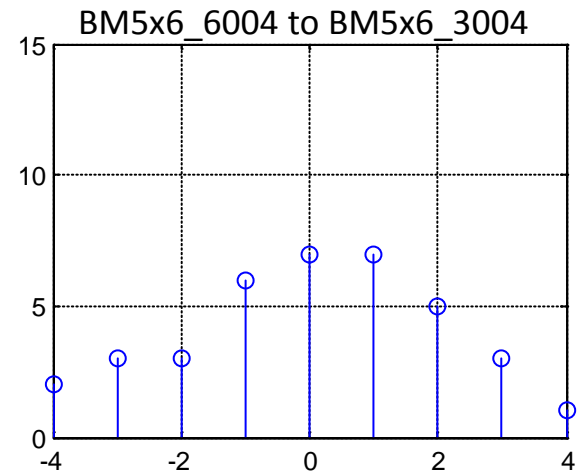
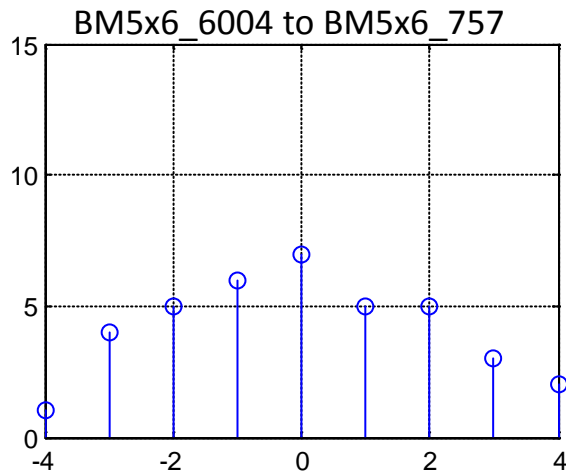
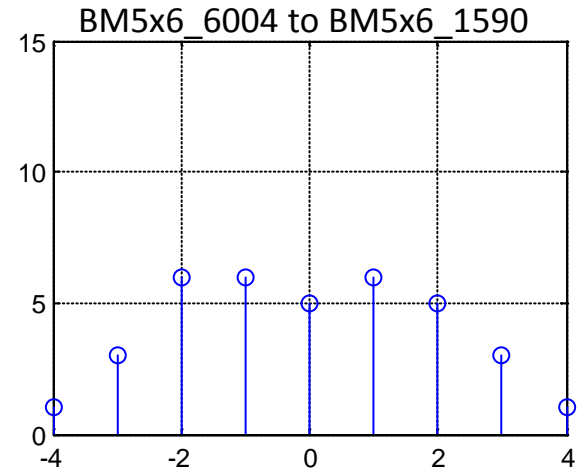
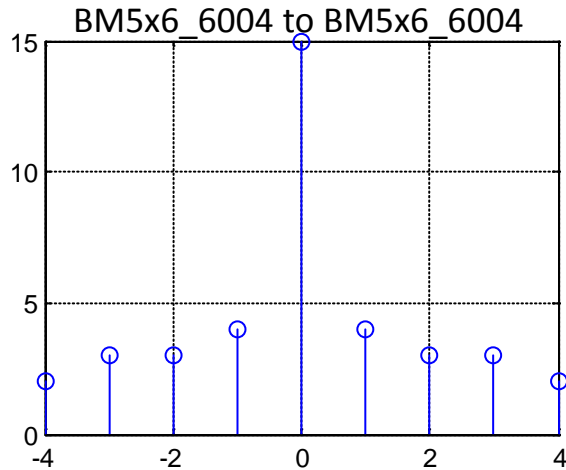
0	0	1	0	1	1
1	1	0	0	0	1
1	0	0	1	1	0
1	0	1	1	0	0
0	1	0	0	1	1

BM5x6\_757

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

BM5x6\_3004

# 2-D 5x6 Sequence Correlation



# Conclusion

- 2-D BM sequences exploit the 2-D OFDMA modulation structure to improve contrast for search of BM
- Equal number of P and N is optimal to minimize misdetection and false detection rate
- Equal number of P and N allow 3 dB boosting to further improve robustness
- 2-D BM sequences are suitable for RB of 1 subcarrier RB