

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

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

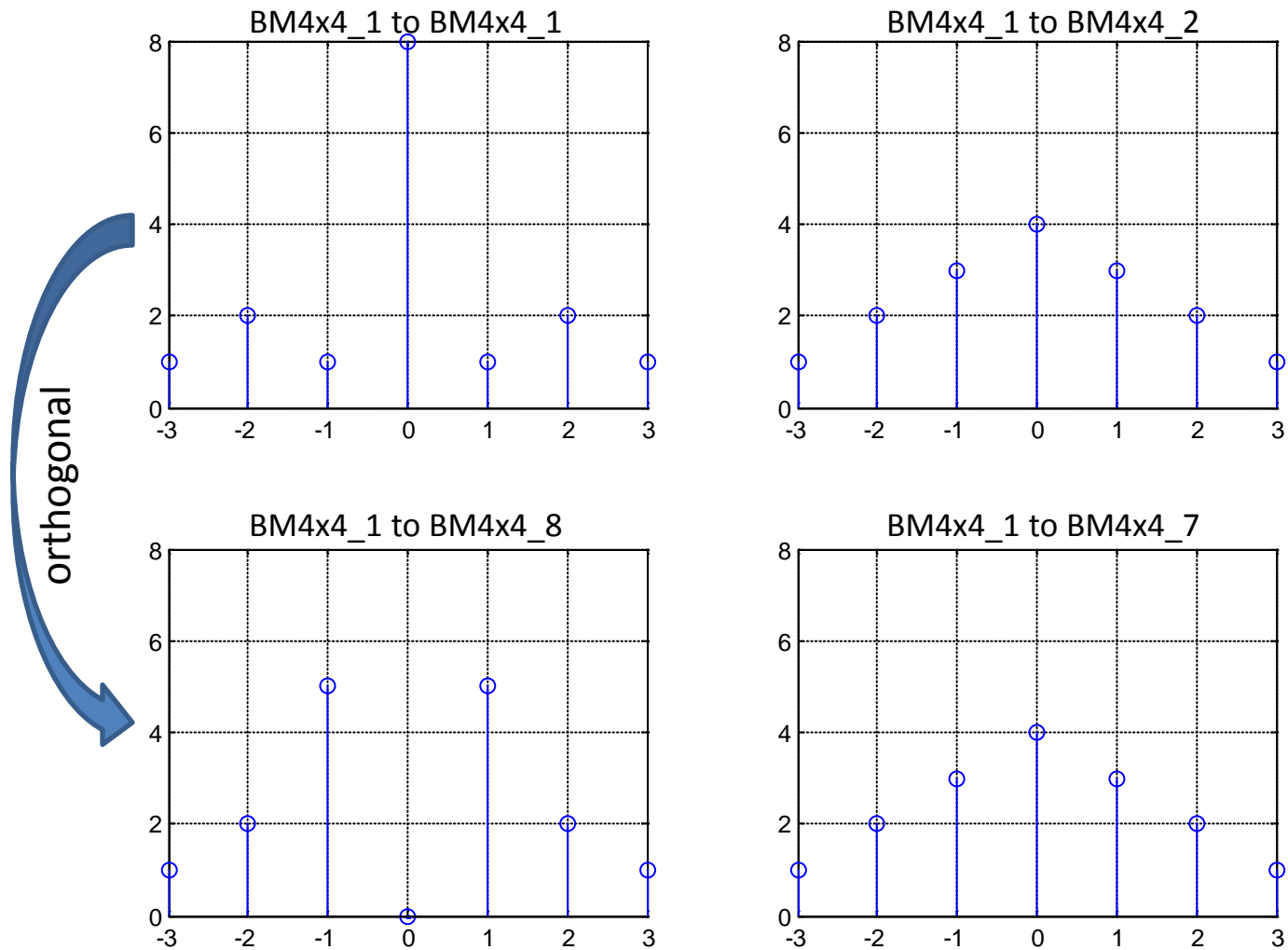
BM4x4_7

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

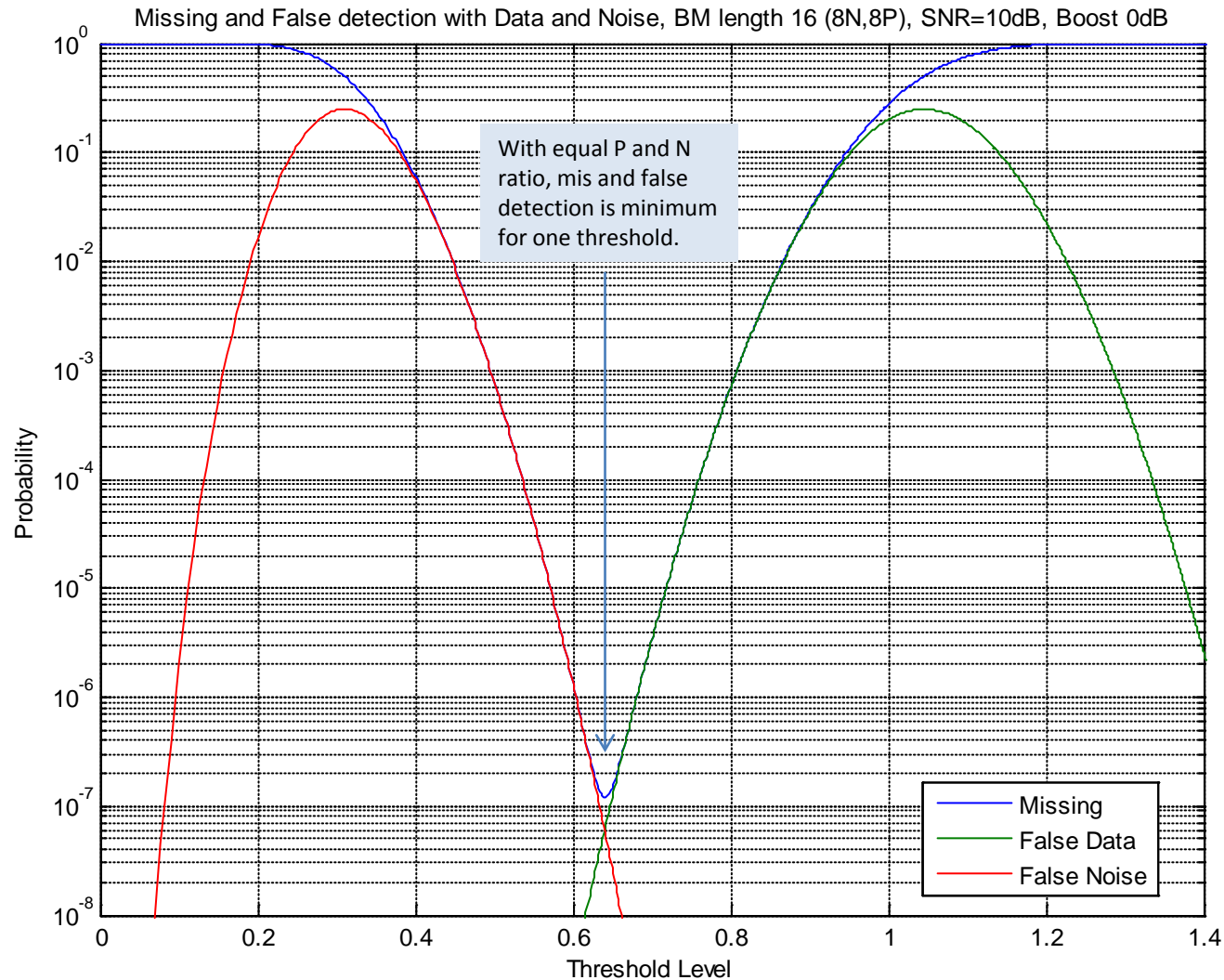
BM4x4_8

“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

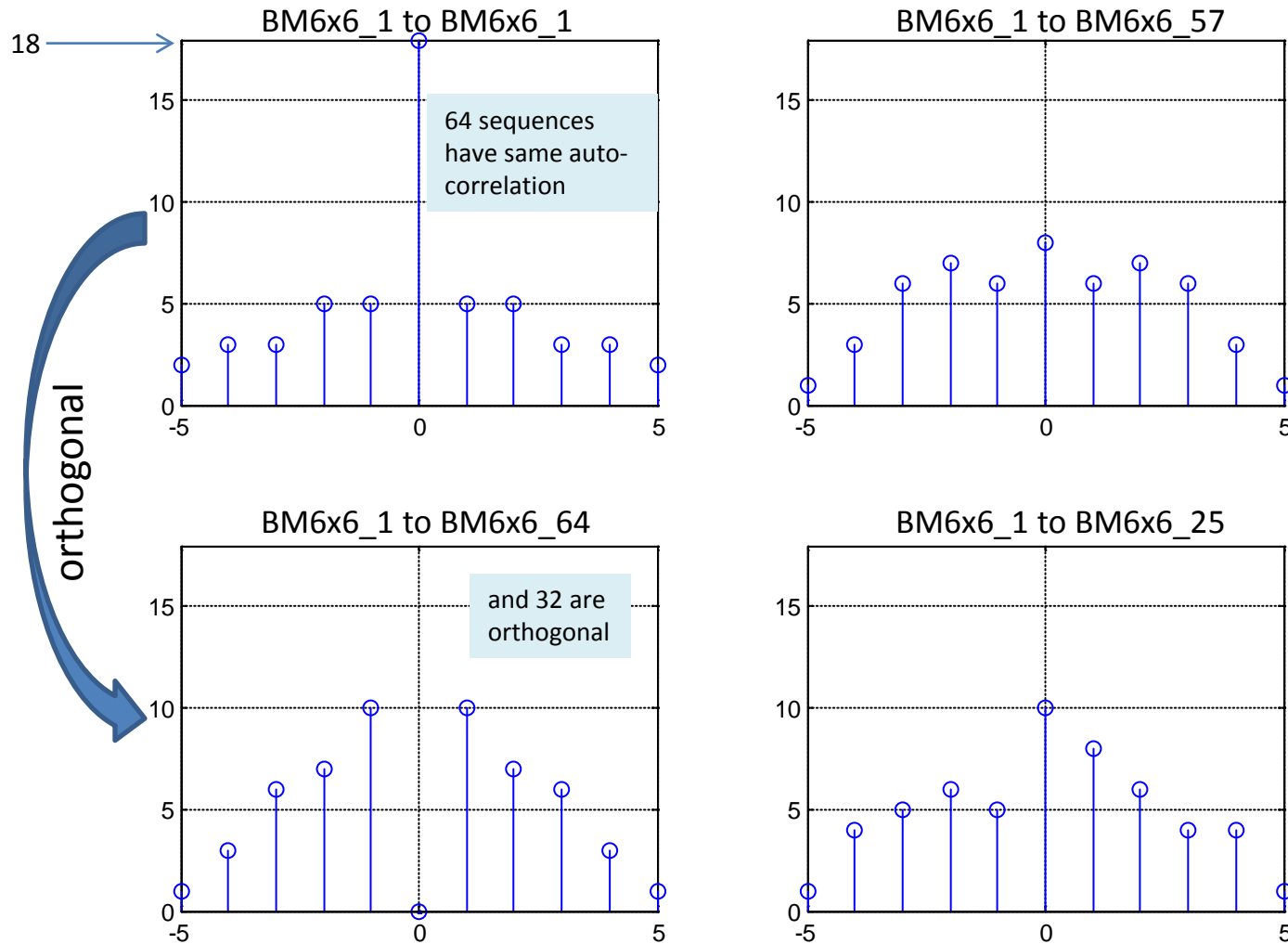
BM6x6_38

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

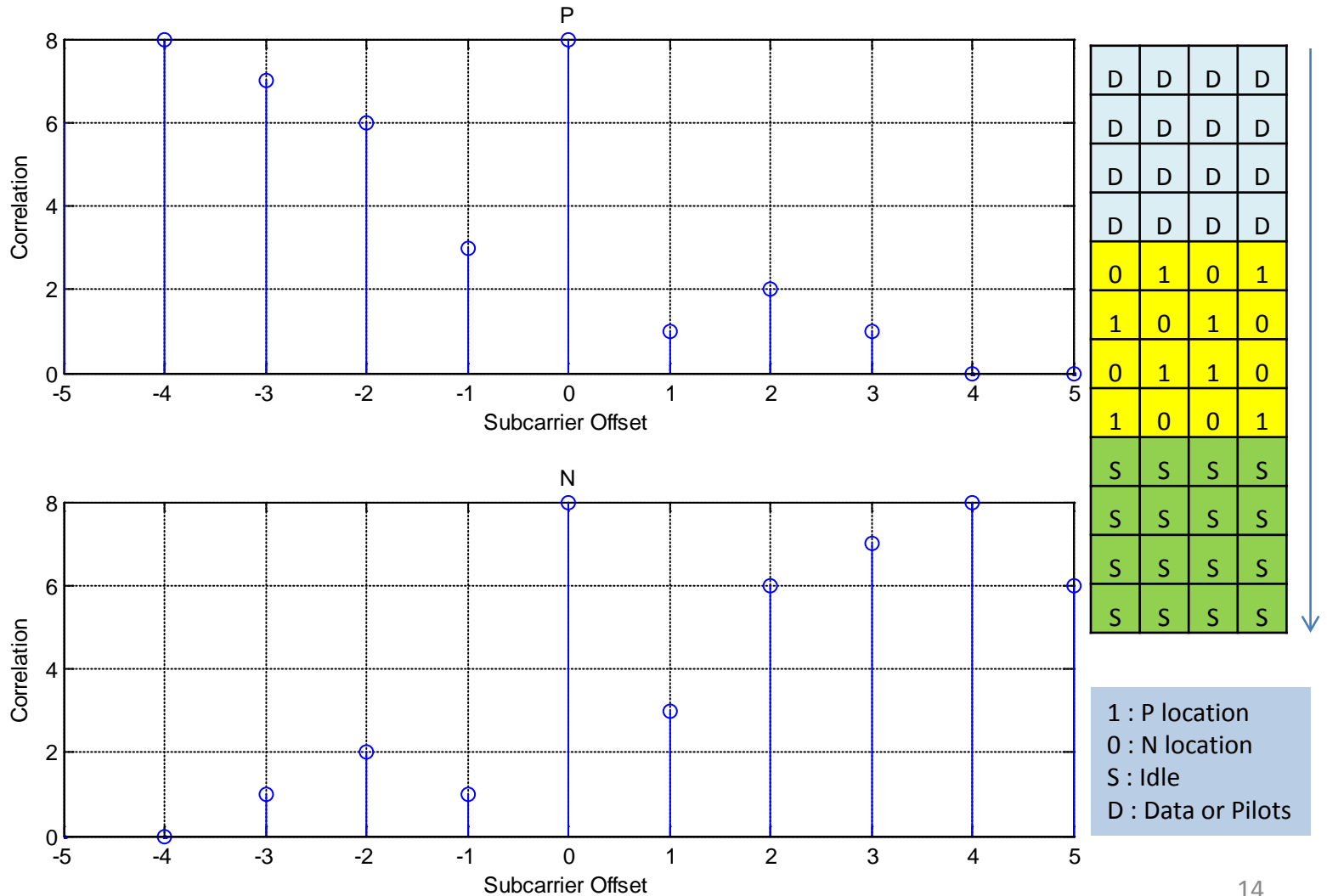
“1” is location of BPSK (P), “0” is location of Nulls (N)

2-D 6x6 Sequence Correlation

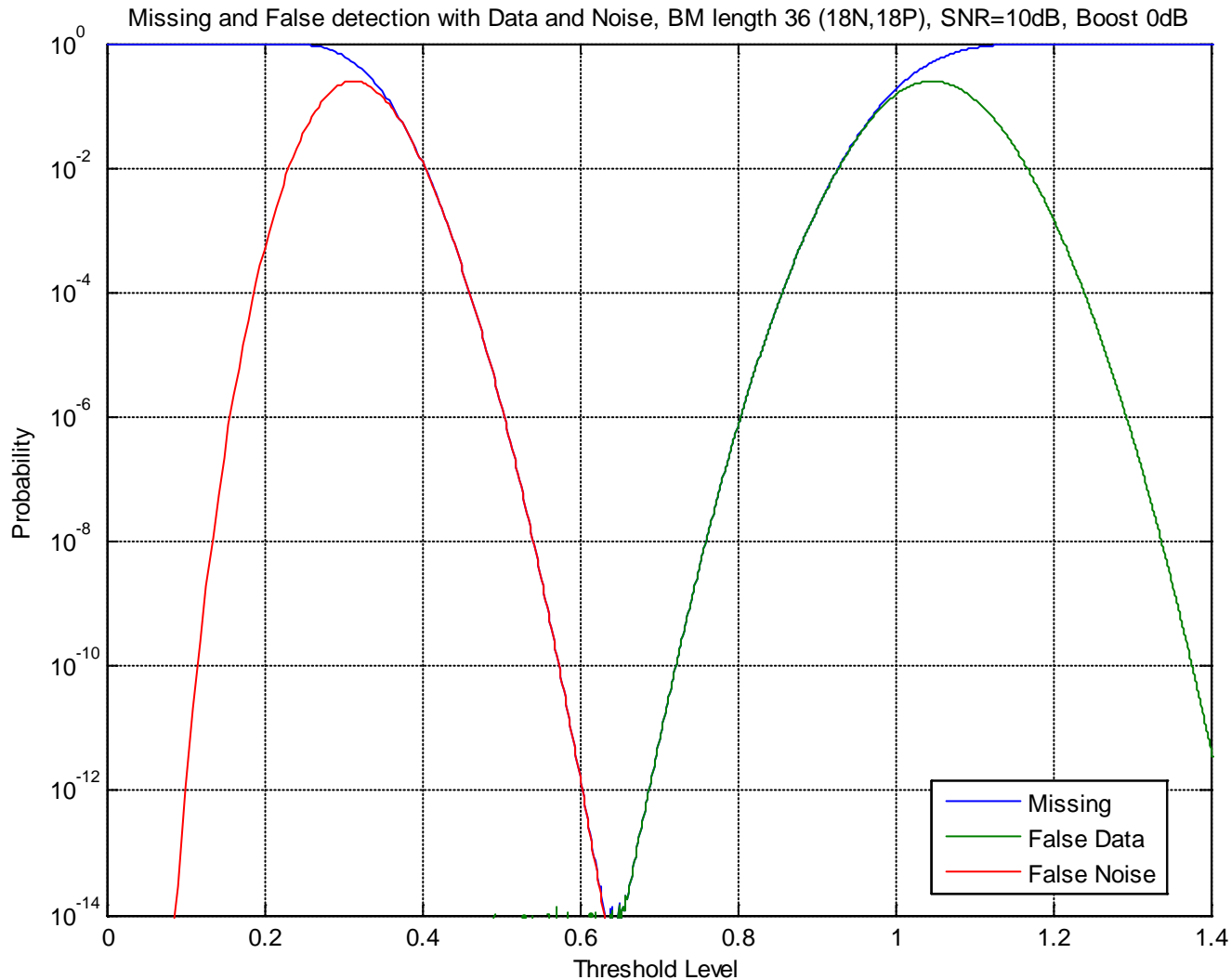


BM 4x3

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

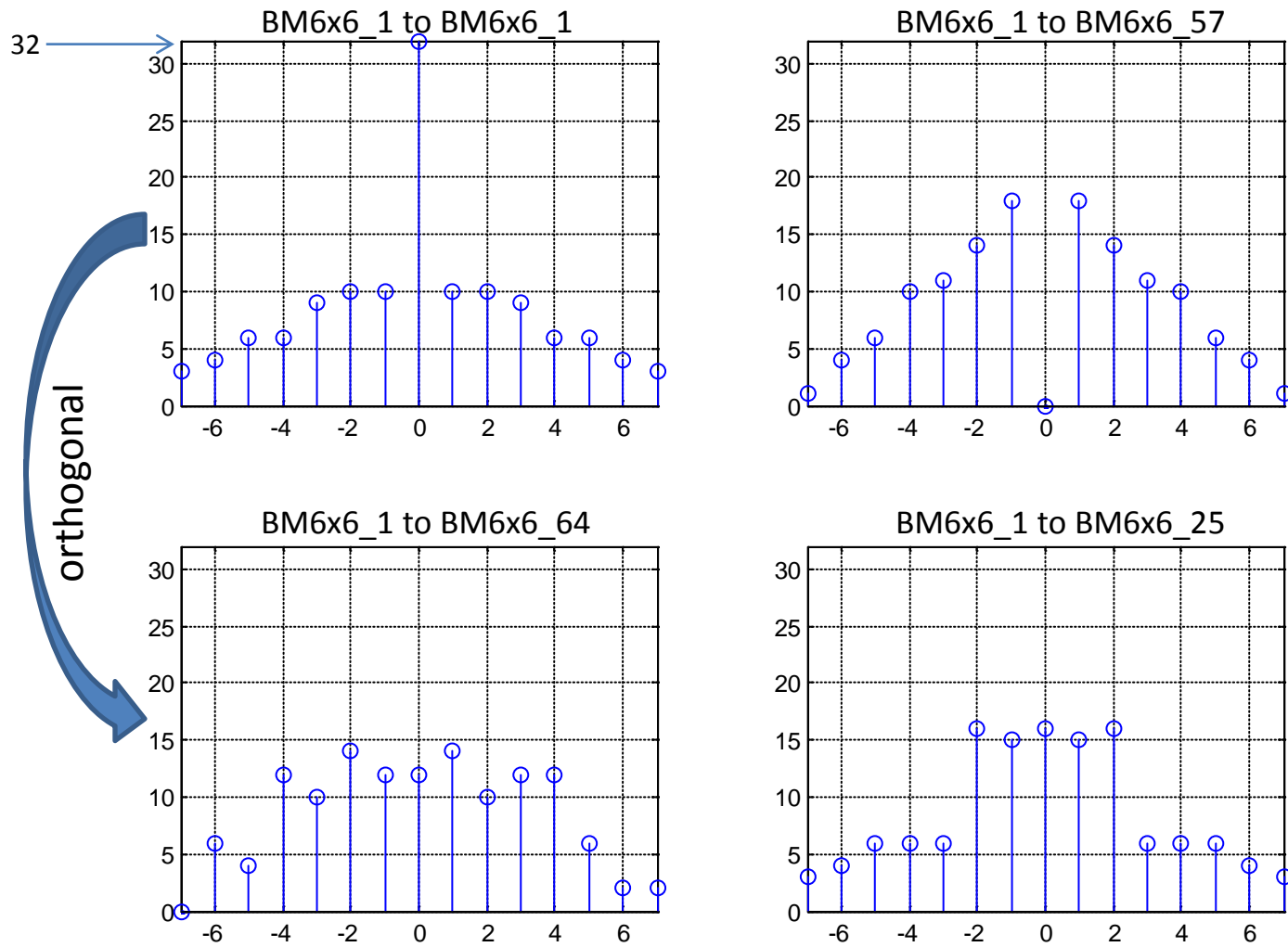
0	1	1	0	0	1	0	1
1	0	0	1	1	0	0	1
1	0	0	1	0	1	1	0
0	1	1	0	1	0	1	0
0	1	0	1	1	0	1	0
1	0	1	0	0	0	1	1
0	0	1	1	1	1	0	0
1	1	0	0	0	1	0	1

BM8x9_28

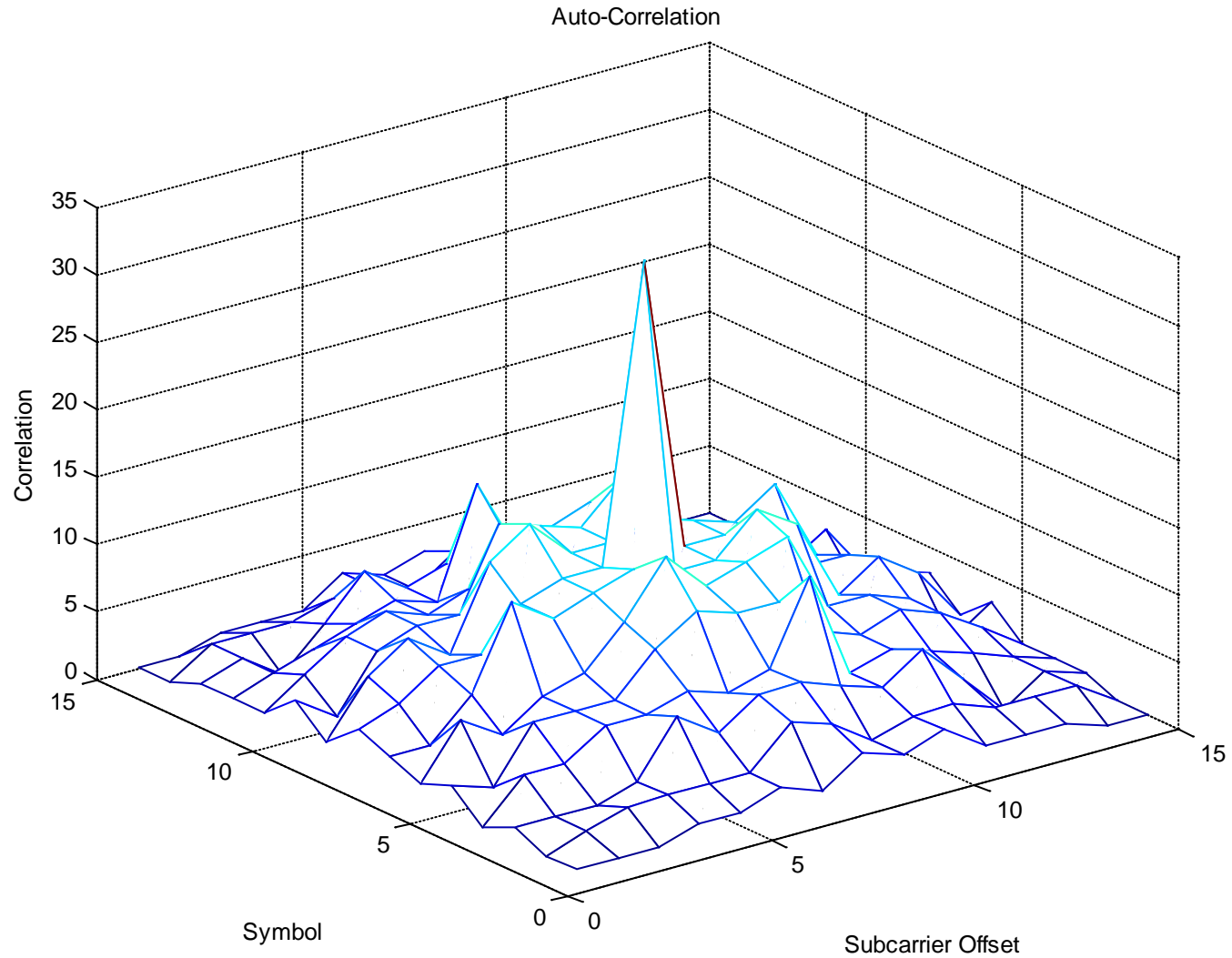
1	0	0	1	0	1	0	1
0	1	1	0	0	1	1	0
0	1	1	0	1	0	0	1
1	0	0	1	1	0	1	0
0	0	1	1	1	0	1	0
1	1	0	0	0	0	1	1
0	1	0	1	1	1	0	0
1	0	1	0	0	1	0	1

BM8x8_33

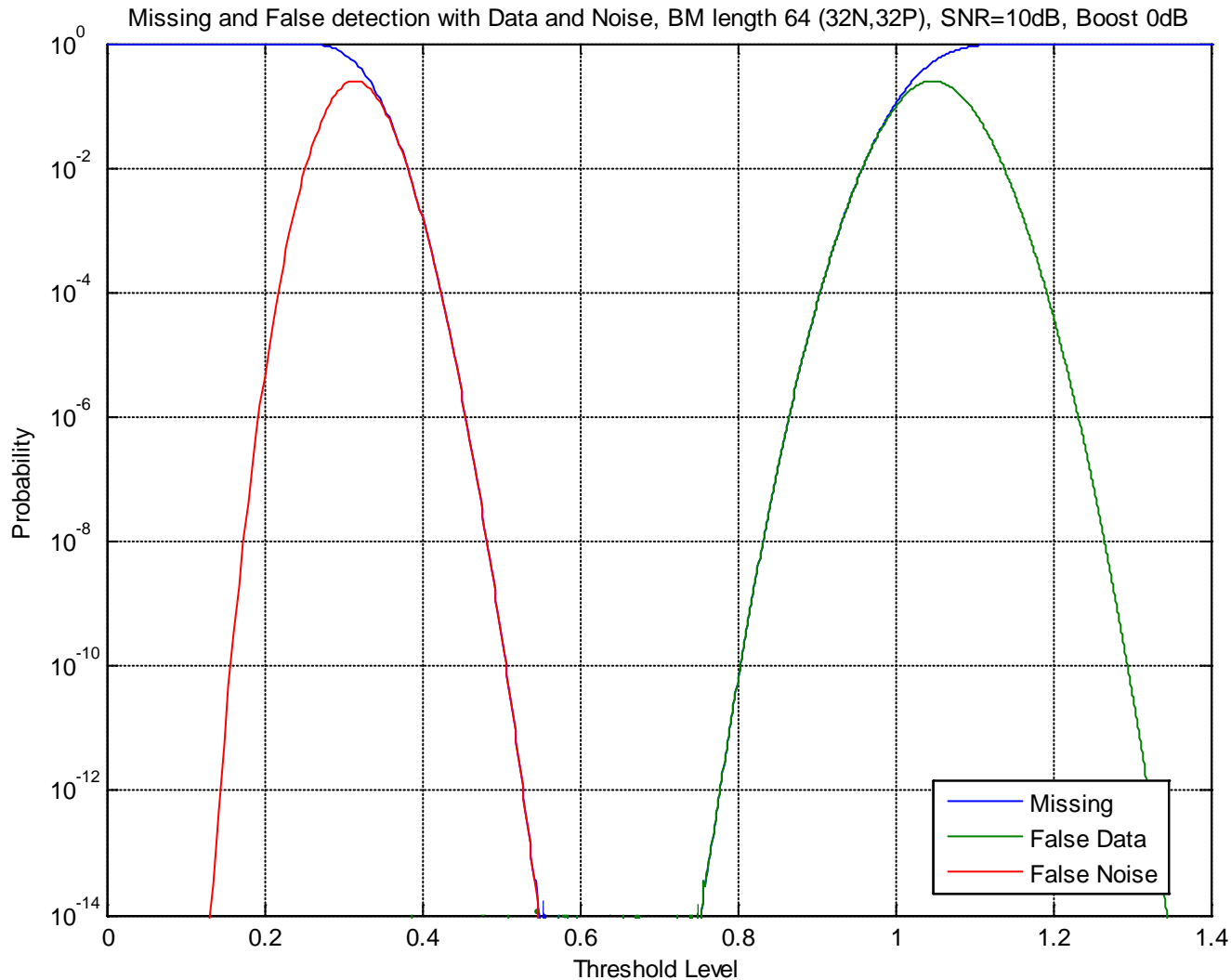
2-D 6x6 Sequence Correlation



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

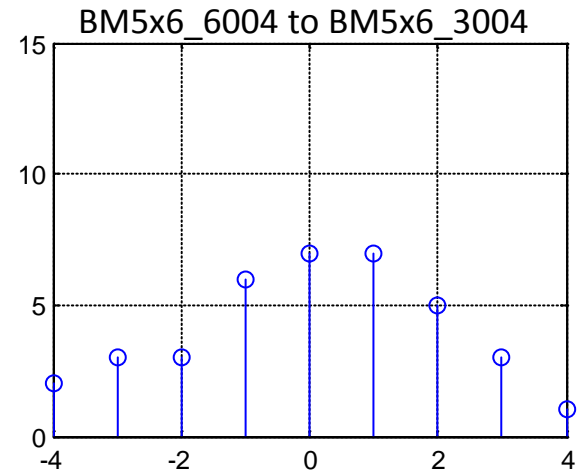
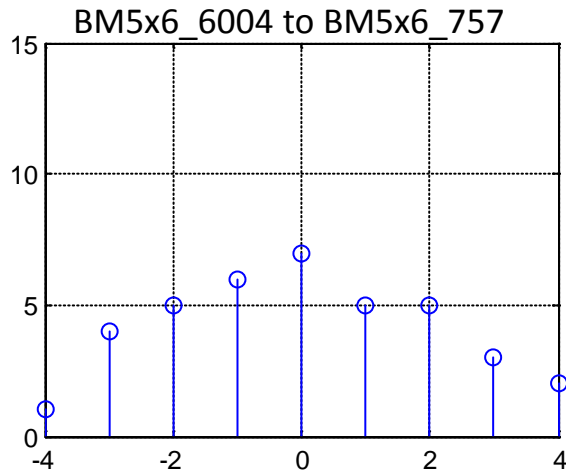
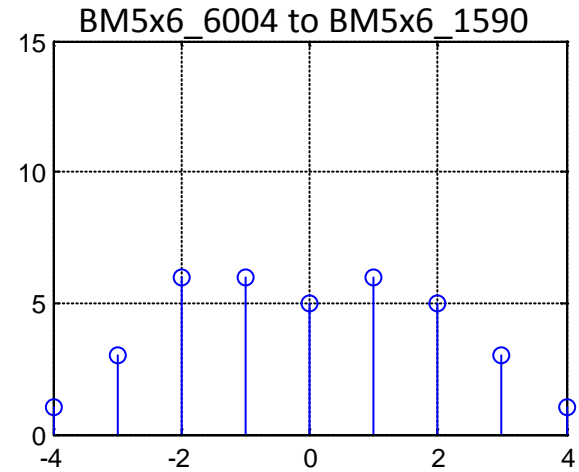
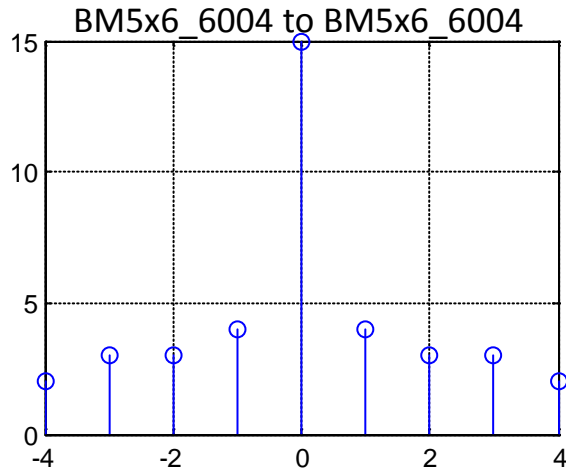
0	0	1	0	1	1
1	1	0	0	0	1
1	0	0	1	1	0
1	0	1	1	0	0
0	1	0	0	1	1

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