

# Partial Proposal for 802.11n: ITRI Preamble Specification

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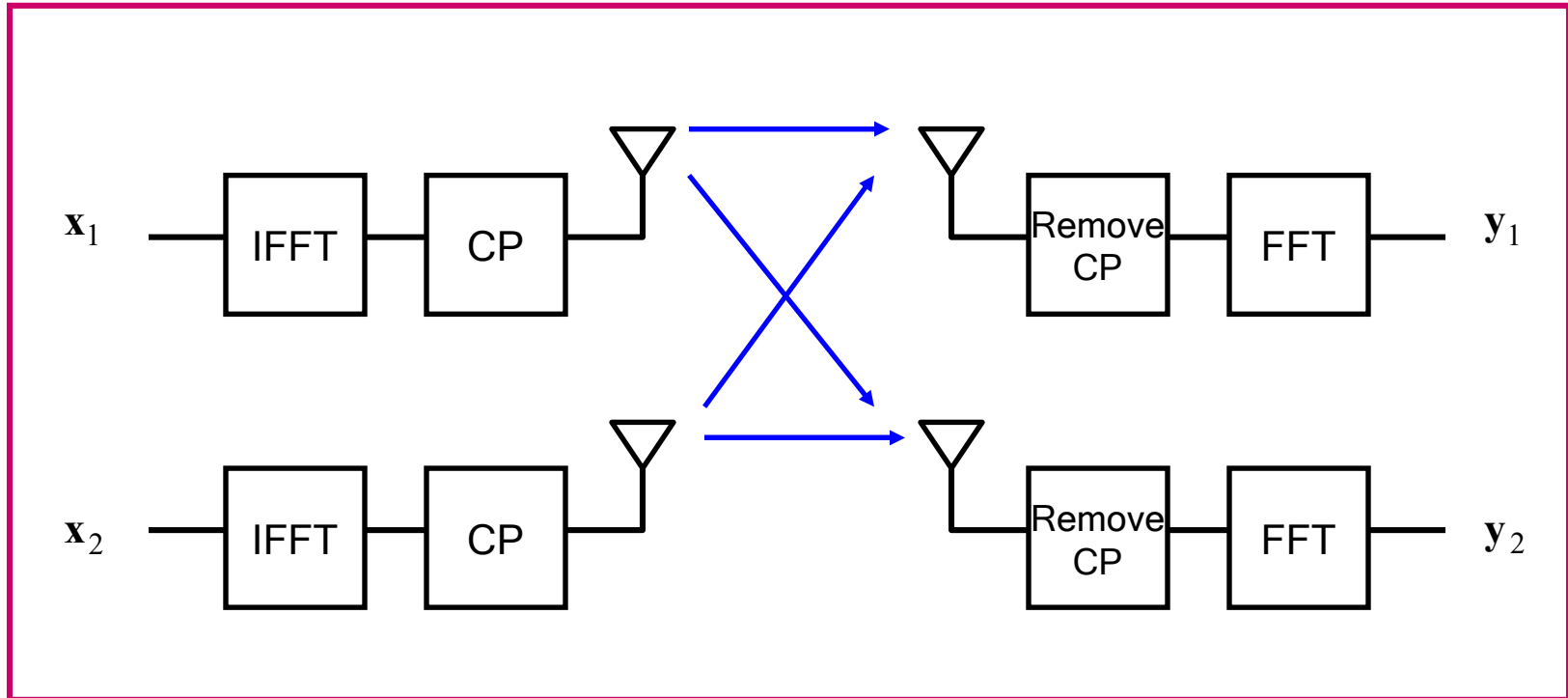
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# Outline

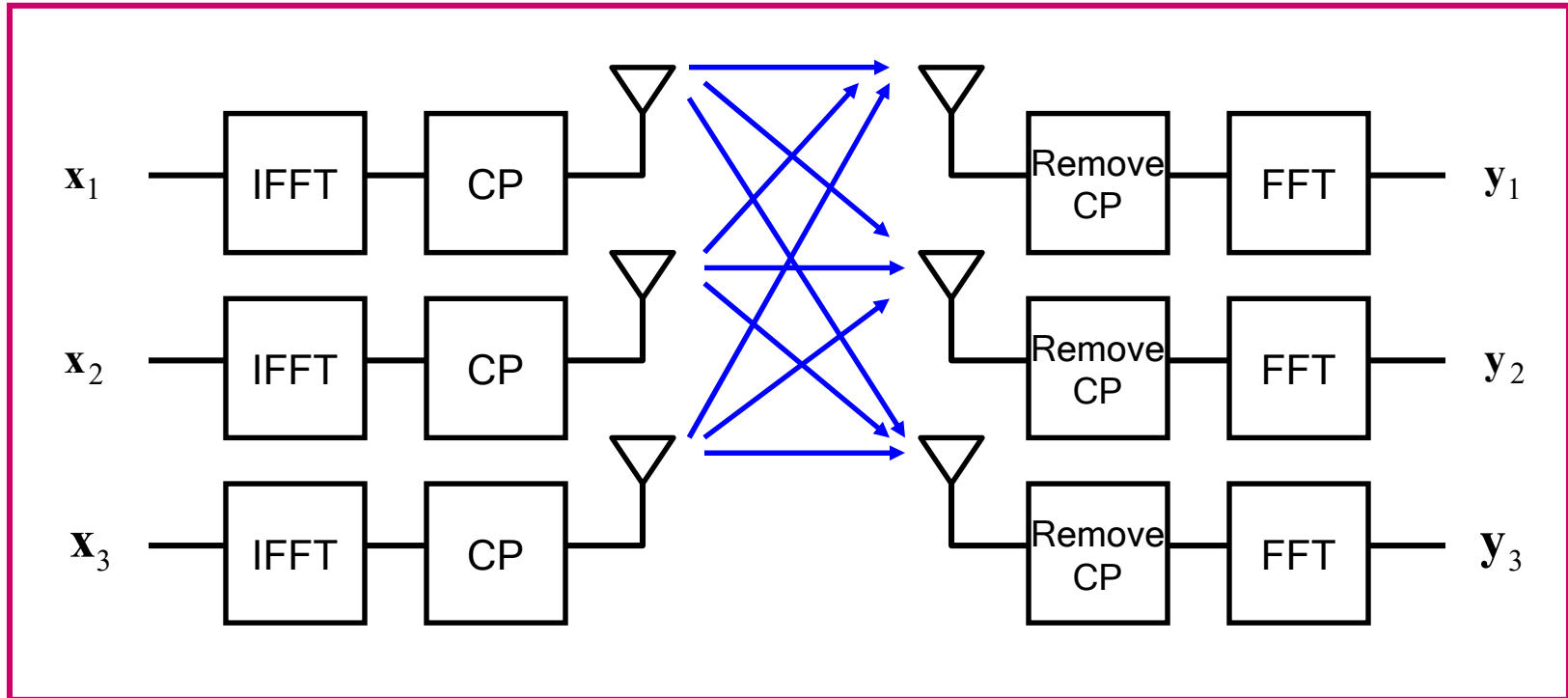
- System block diagram
- Proposed preamble structure
- Short training symbol
  - Purpose of short training symbol
  - Construction of short training symbol
  - Numerical Results
- Long training symbol
  - Purpose of long training symbol
  - Construction of long training symbol
  - Numerical Results
- Conclusion

## System block diagram ( 2 x 2 case )



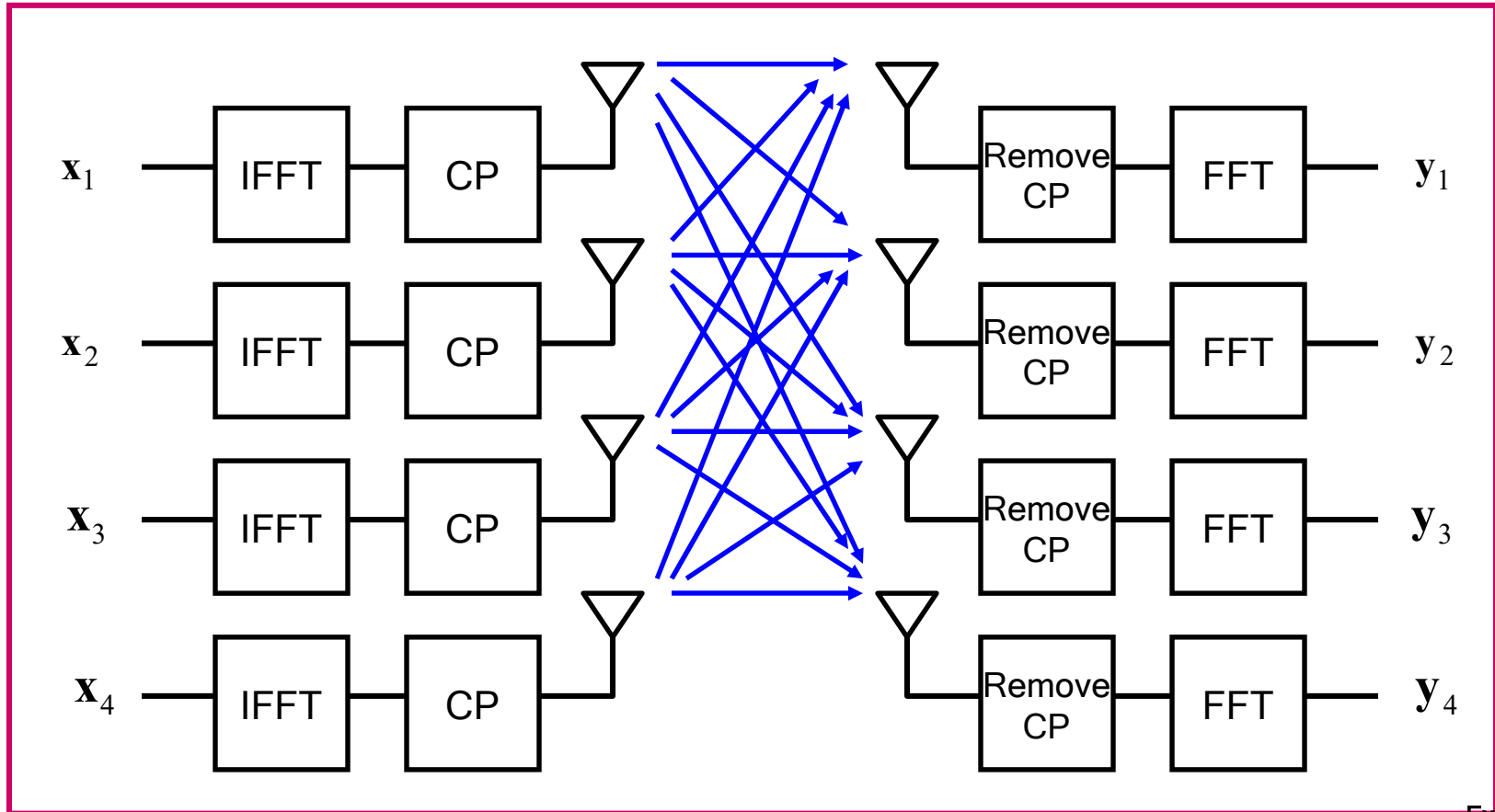
$$\mathbf{y}_j = \sum_{i=1}^2 \mathbf{H}_{j,i} \mathbf{x}_i + \mathbf{n}_j, j = 1, 2$$

## System block diagram ( 3 x 3 case )



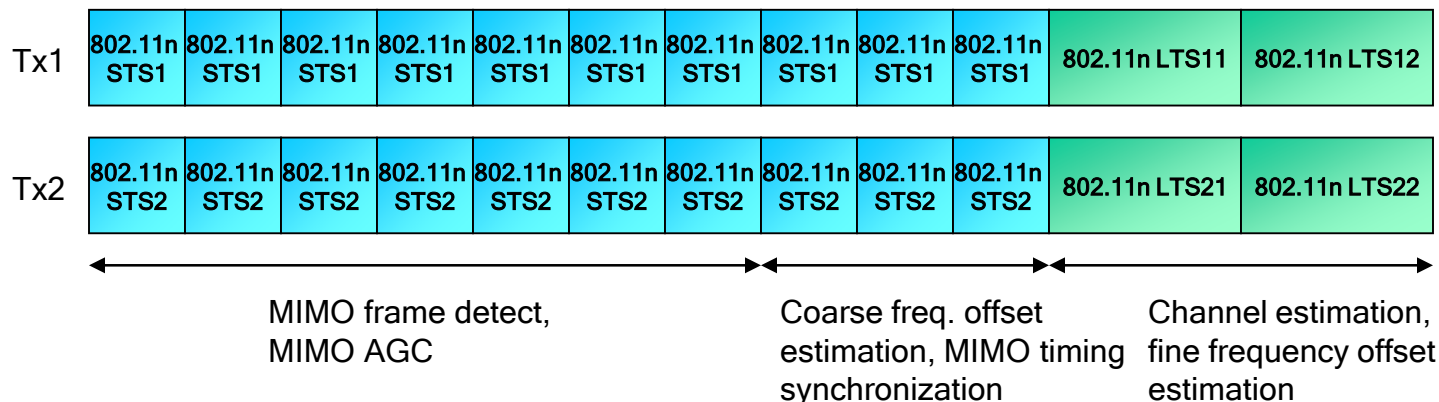
$$\mathbf{y}_j = \sum_{i=1}^3 \mathbf{H}_{j,i} \mathbf{x}_i + \mathbf{n}_j, j = 1, 2, 3$$

## System block diagram ( 4 x 4 case )



$$\mathbf{y}_j = \sum_{i=1}^4 \mathbf{H}_{j,i} \mathbf{x}_i + \mathbf{n}_j, j = 1, 2, 3, 4$$

## Proposed Preamble Structure ( 2 x 2 case )



## Proposed Preamble Structure ( 3 x 3 case )

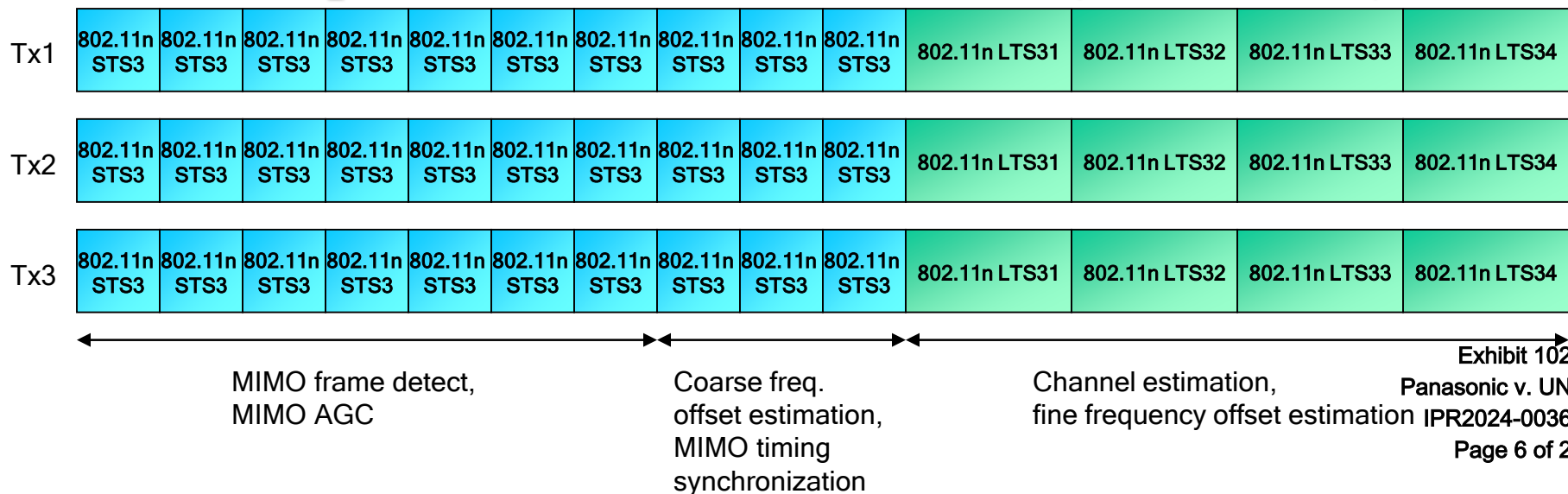


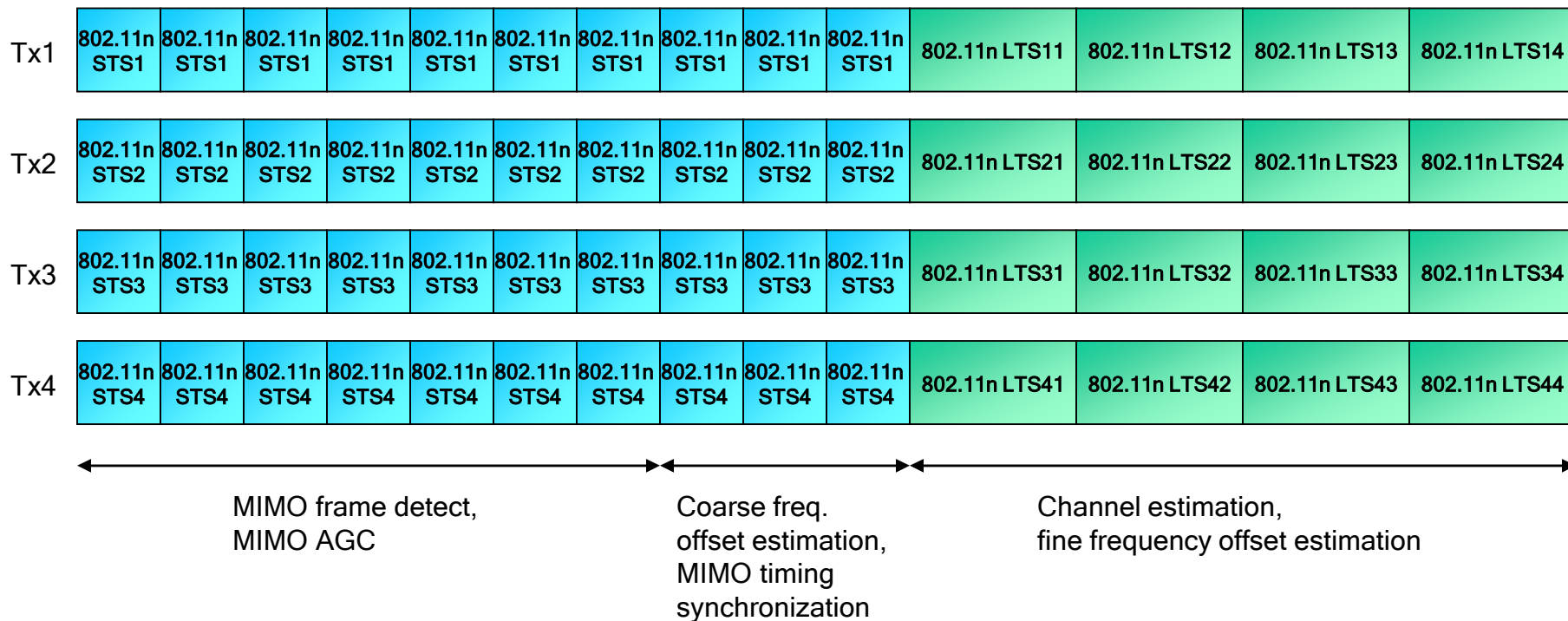
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## Proposed Preamble Structure ( 4 x 4 case )



● Overlapped preambles structure is proposed



Lower overhead caused by preamble

## Preamble Parameters

|                         |                 |
|-------------------------|-----------------|
| Carrier Frequency       | 5 GHz           |
| Bandwidth               | 20 MHz          |
| Sample period           | 50 ns           |
| FFT size                | 64 (3.2 us)     |
| Cyclic prefix           | 16 (0.8 us)     |
| STS Modulation / length | QPSK / 32       |
| LTS Modulation / length | BPSK / 64       |
| Number of TX antenna    | 2,3,4           |
| Antenna spacing         | Half wavelength |
| Channel model           | B,D,E           |

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## Short Training Symbol (STS)

- Purposes of STS
  - Frame detection, AGC and Coarse frequency offset estimation
  - The new STSs from different Tx antenna have zero cross-correlation.
  - The preamble consists of several concatenated copies.
- Backward compatibility
  - Assume there exists a protection mechanism similar to the case of 11g and 11b.
  - We propose that the new STSs should not be detected by legacy systems.
  - The new STS should have the period longer than the legacy systems.



## Construction of Short Training Symbols

- The properties of the proposed STSs
  - Period of 32 samples
  - Zero cross-correlation of the STSs
  - Low detection probability for 11a systems
- The short training symbols are designed in frequency domain.
- Time domain waveform of the *i*th STS is obtained by

$$s_i(n) = \frac{1}{64} \sum_{k=0}^{63} S_i(k) e^{j \frac{2\pi}{64} nk}$$

## Proposed Short Training Symbol ( 3x3 case )

$$\mathbf{S}_{1,\{-26,26\}} = \sqrt{(13/12)} \times \{0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 0\}$$

$$\mathbf{S}_{2,\{-26,26\}} = \sqrt{(13/12)} \times \{0, 0, 1+j, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0\}$$

$$\mathbf{S}_{3,\{-26,26\}} = \sqrt{(13/12)} \times \{0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 1-j, 0, 0\}$$

|      | PAPR(dB) |
|------|----------|
| STS1 | 6.57     |
| STS2 | 5.33     |
| STS3 | 5.33     |

## Proposed Short Training Symbol ( 4x4 case )

$$\mathbf{S}_{1,\{-26,26\}} = \sqrt{(13/9)} \times \{ 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 0, 0, 0 \}$$

$$\mathbf{S}_{2,\{-26,26\}} = \sqrt{(13/9)} \times \{ 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0, 0, 0, 0 \}$$

$$\mathbf{S}_{3,\{-26,26\}} = \sqrt{(13/9)} \times \{ 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 0, 0, -1+j, 0, 0, 0, 0 \}$$

$$\mathbf{S}_{4,\{-26,26\}} = \sqrt{(13/9)} \times \{ 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0, 0, 0, 0, 0, 0, 1-j, 0, 0 \}$$

|      | PAPR(dB) |
|------|----------|
| STS1 | 4.2597   |
| STS2 | 5.2069   |
| STS3 | 4.2597   |
| STS4 | 4.7712   |

## Proposed Time-Domain STS (1/2)

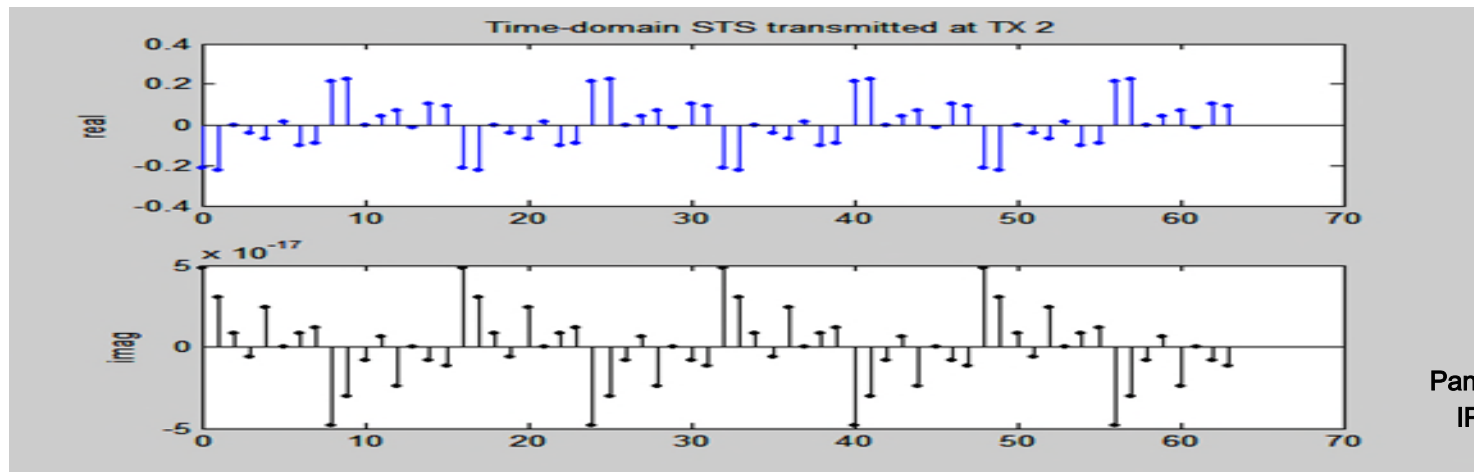
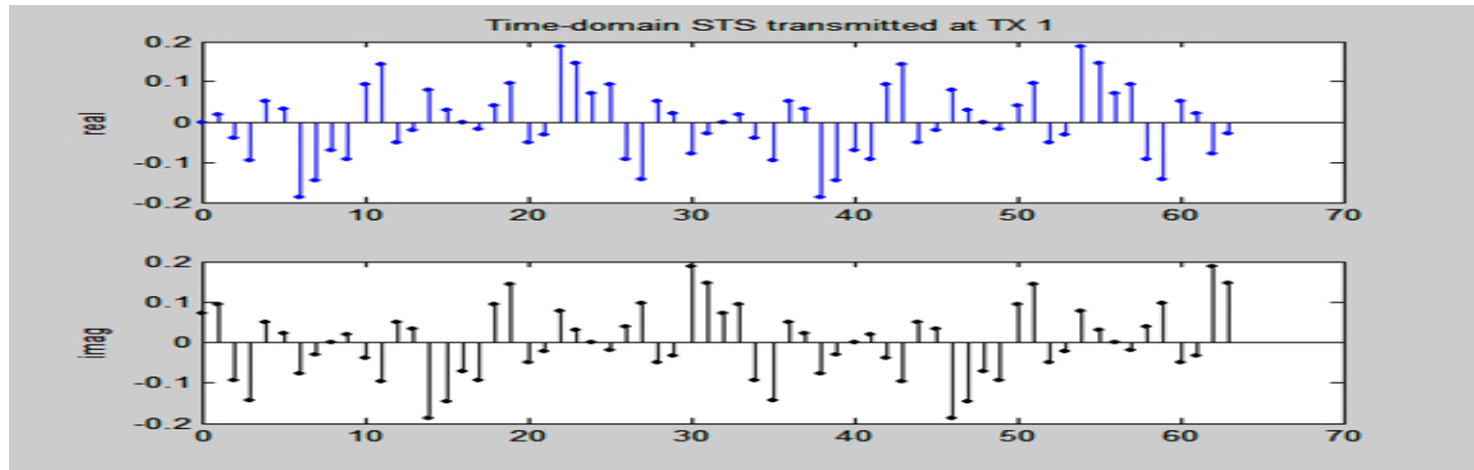


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## Proposed Time-Domain STS (2/2)

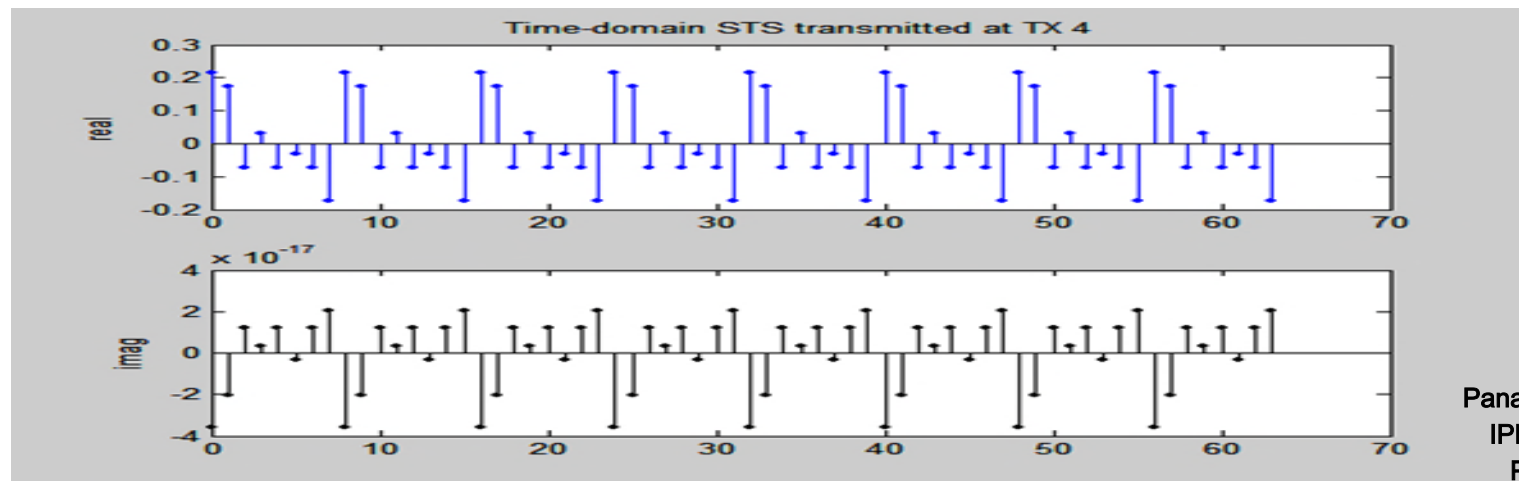
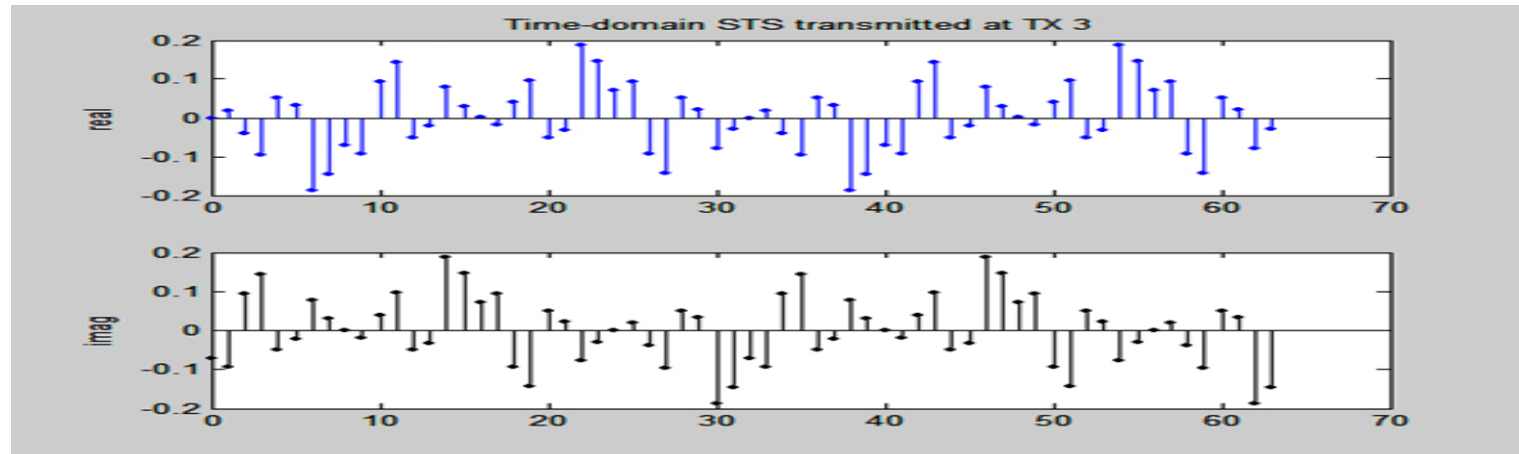
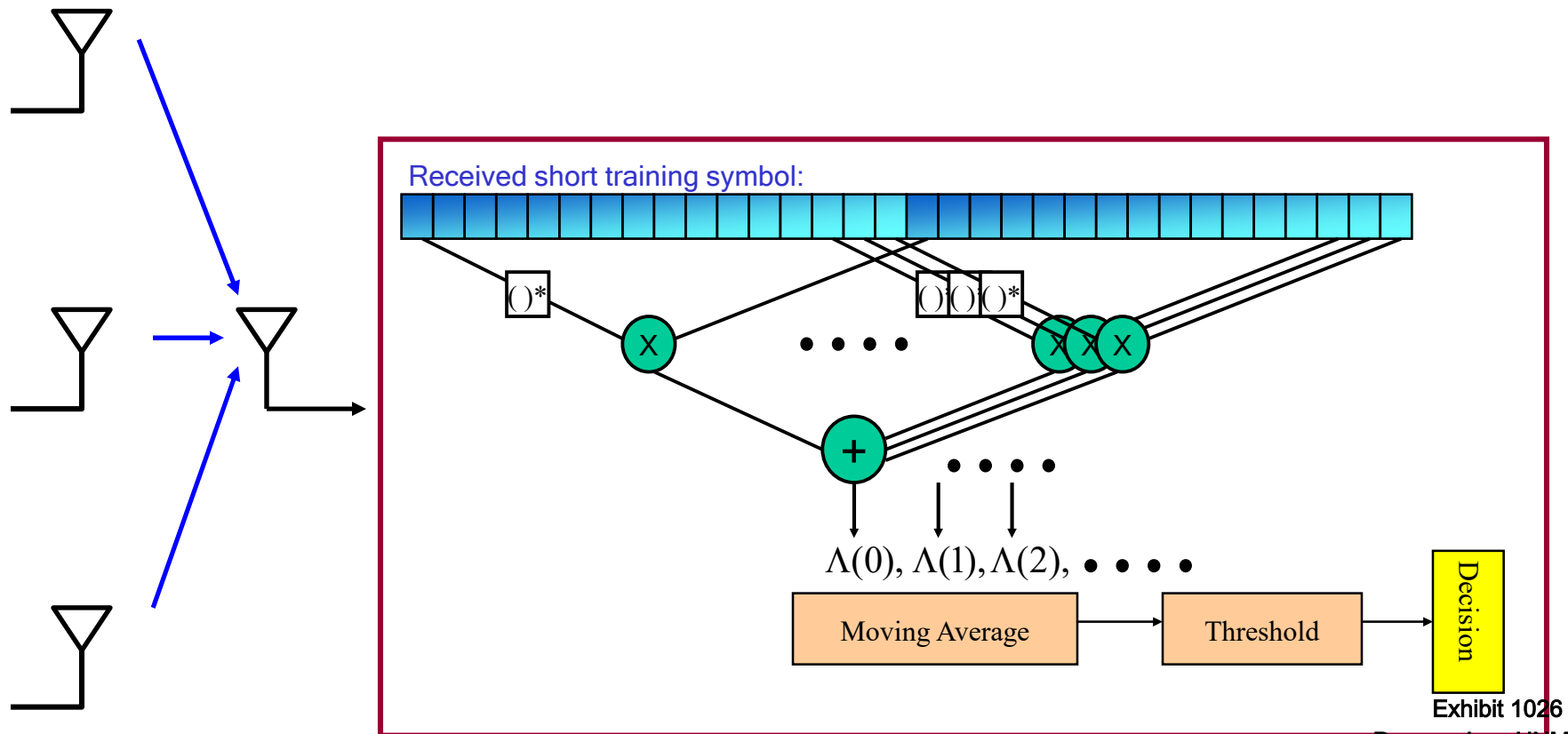


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## Numerical Results

- Since the nonzero tones of the STSs are disjoint, the cross-correlation of each pair of STSs is 0.
- Each STS has a period of 32 samples ( 1.6 us ) in time domain.

# Frame Detection Scenarios (1/2)



Conventional frame detection algorithm of 11a systems

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## Frame Detection Scenarios (2/2)

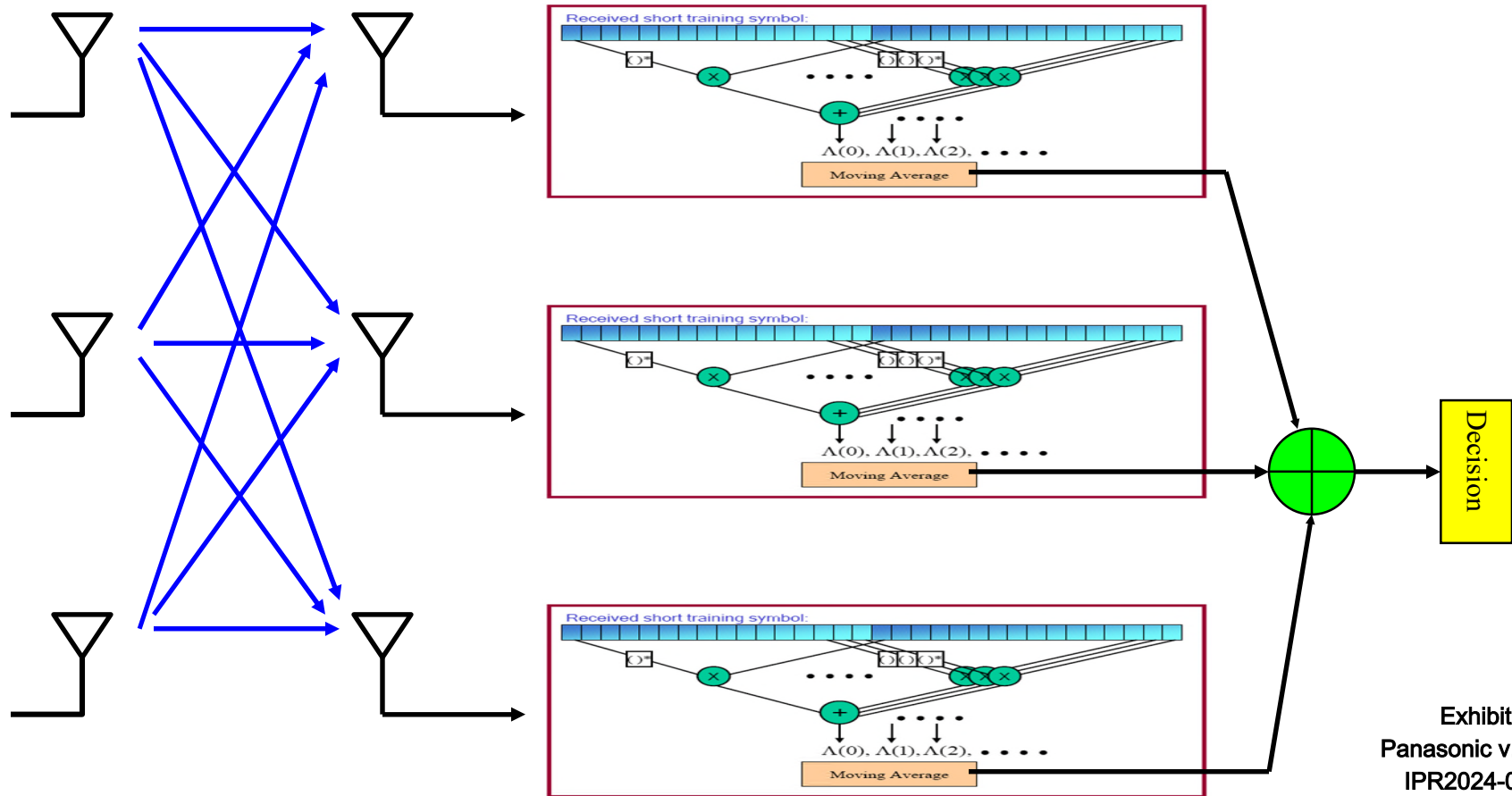
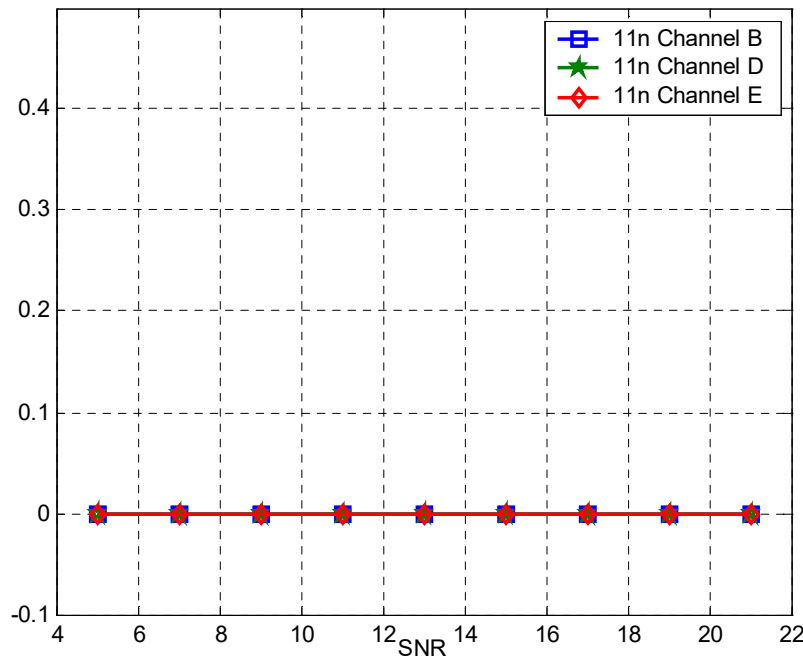


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# Numerical Results

The detection probability of the proposed STSs ( 3 x 3 mode ) in a 11a receiver over channel B,D and E which is tested over 1000 channel realizations.

Detected prob. over 1000 preambles and 3x1 IEEE 802.11n channels



The detection probability of the proposed STSs ( 4 x 4 mode ) in a 11a receiver over channel B,D and E which is tested over 1000 channel realizations.

Detected prob. over 1000 preambles and 4x1 IEEE 802.11n channels

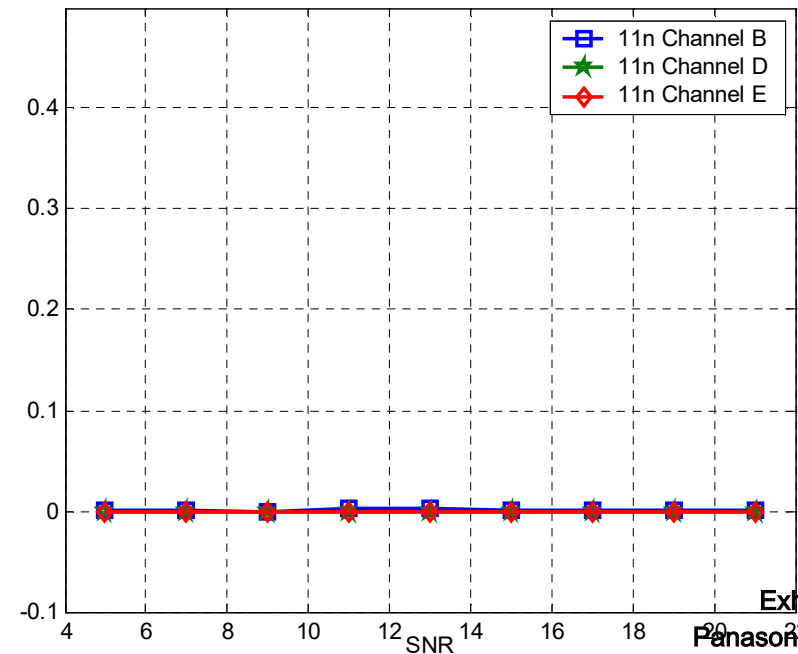


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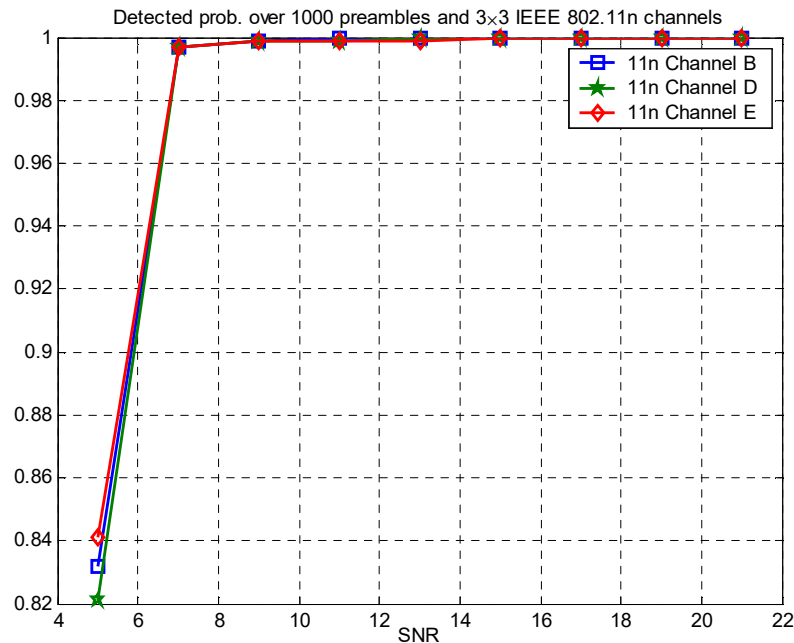
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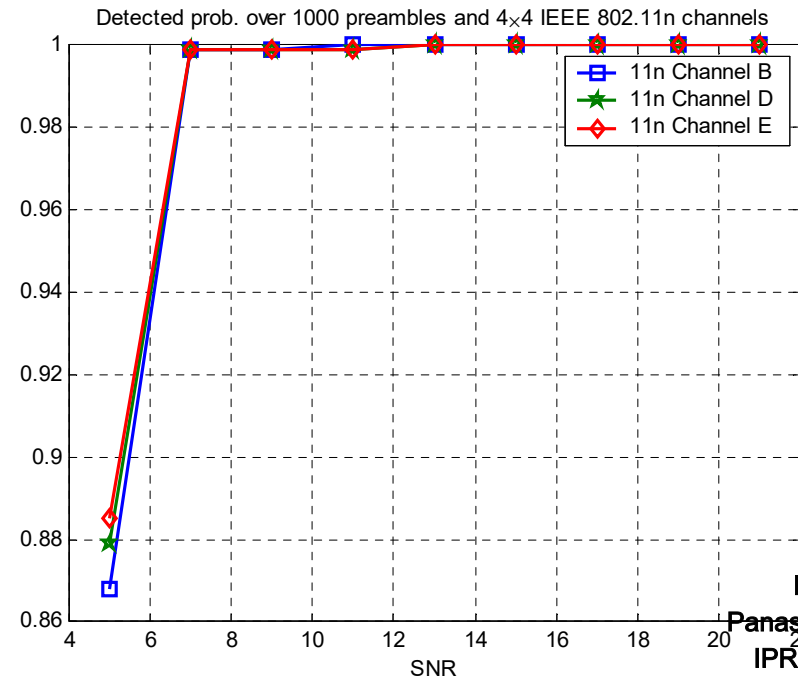
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# Numerical Results

The detection probability of the proposed STSs ( 3 x 3 mode ) in a 11n receiver over channel B,D and E which is tested over 1000 channel realizations.



The detection probability of the proposed STSs ( 4 x 4 mode ) in a 11n receiver over channel B,D and E which is tested over 1000 channel realizations.



## Long Training Symbol (LTS)

- Purposes of LTS
  - fine frequency offset estimation, Channel estimation
- The proposed LTS
  - 2 x 2 system: the LTS occupies 2 OFDM symbol periods
  - 3 x 3 system: the LTS occupies 4 OFDM symbol periods
  - 4 x 4 system: the LTS occupies 4 OFDM symbol periods

# The Structure of Proposed LTS

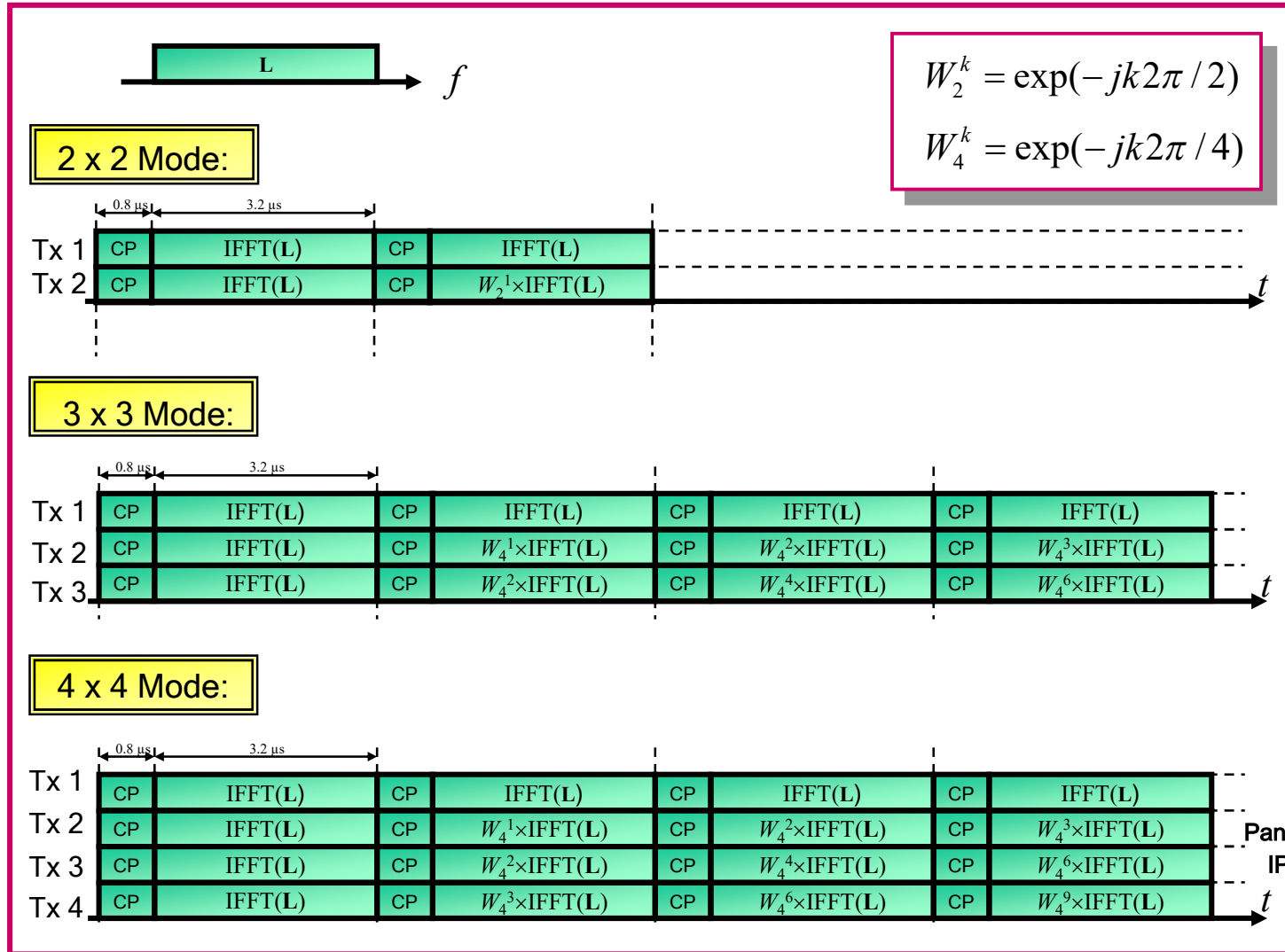


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## Long Training Symbol (LTS)

- The proposed LTSs are constructed with a basis sequence  $\mathbf{L}$ .
- We choose  $\mathbf{L}$  the same as the long training sequence described in 11a

$$\mathbf{L}_{\{-26,26\}} = \{ 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1 \}.$$

- The properties of the proposed LTSs are determined by  $\mathbf{L}$ .
- With the proposed LTSs, the receiver can effectively and efficiently estimate the frequency domain responses of MIMO channel.

# Proposed Frequency-Domain LTS

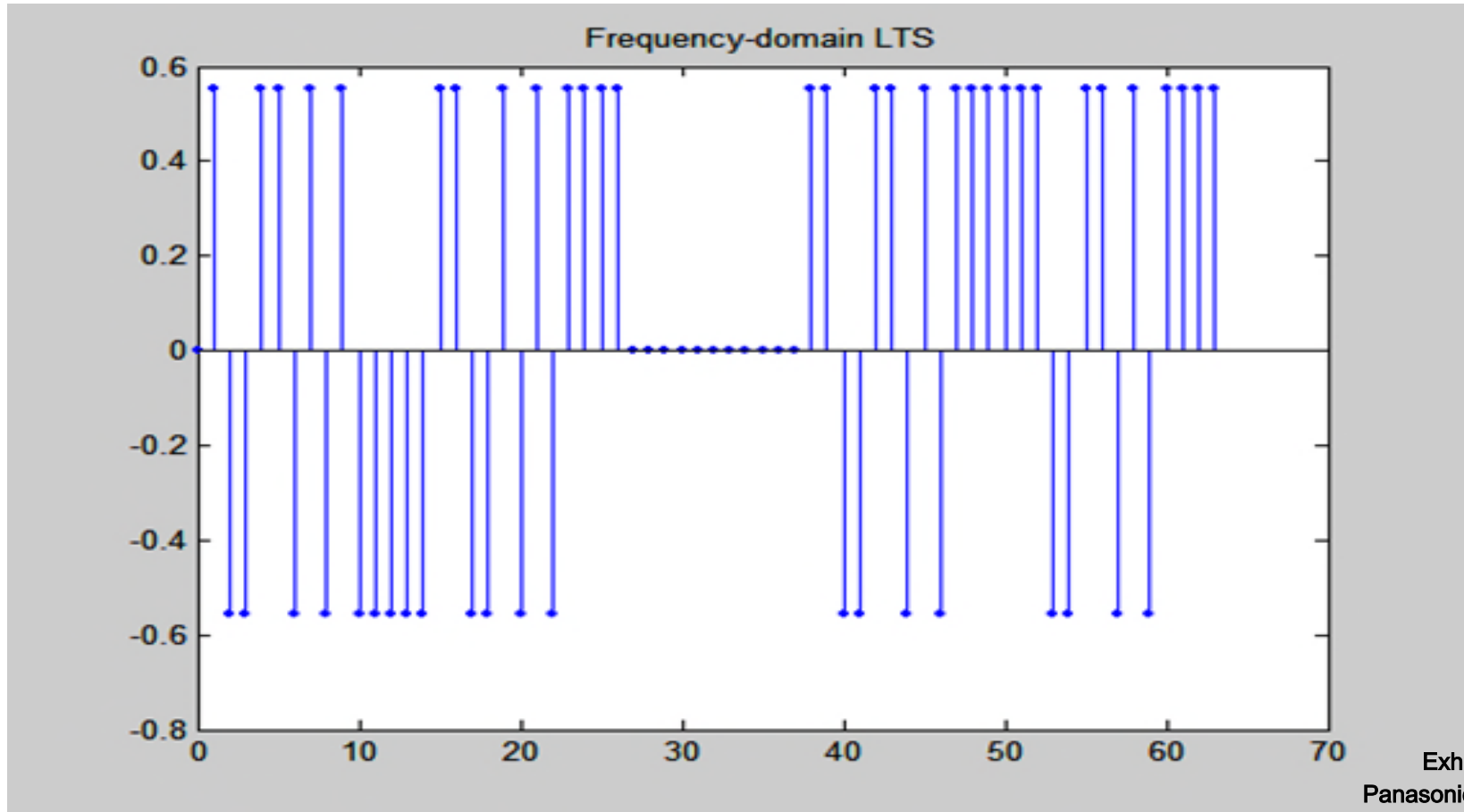


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## Proposed Time-Domain LTS (w/o CP)

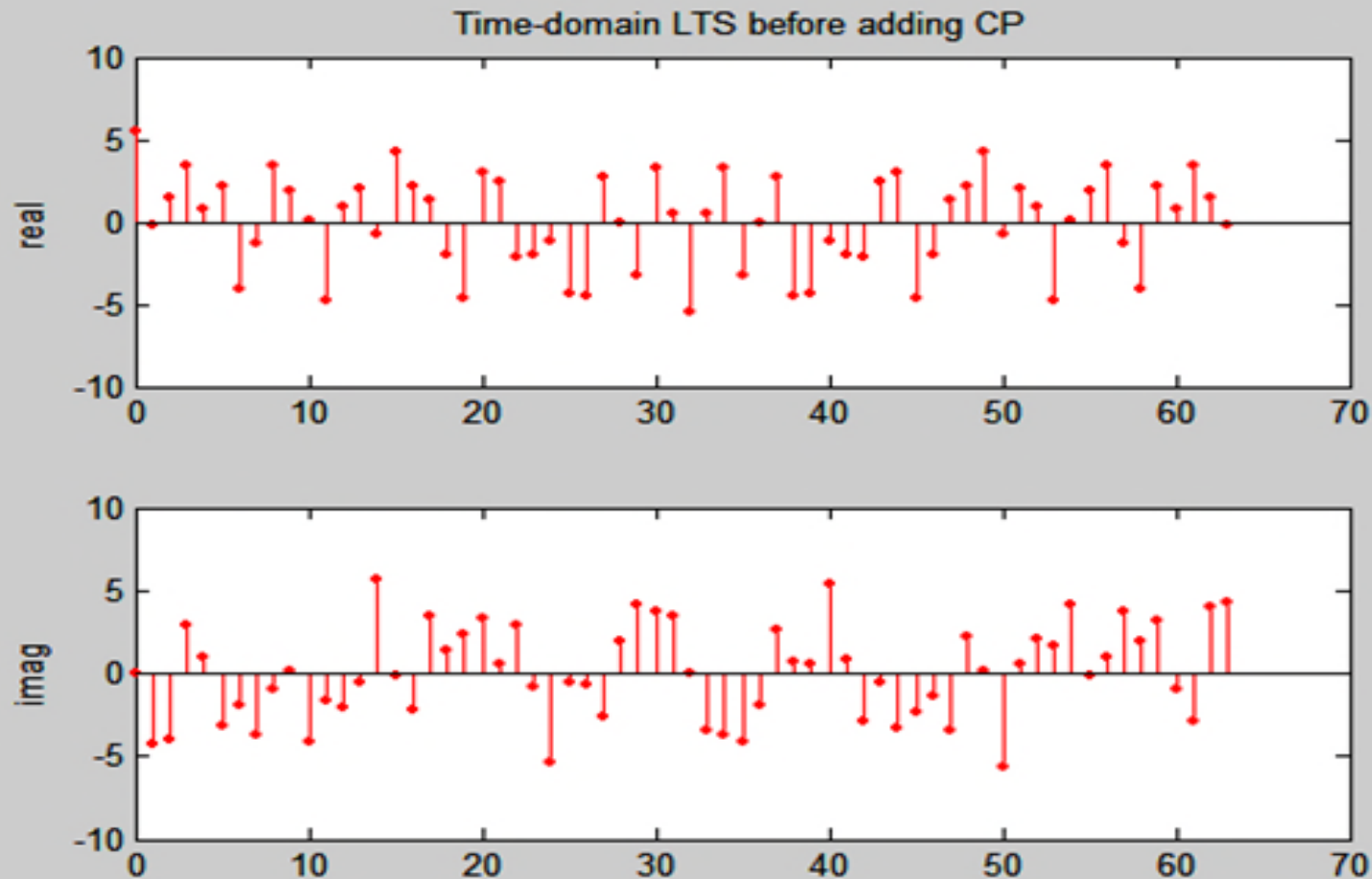


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## Proposed Time-Domain LTS (w/ CP)

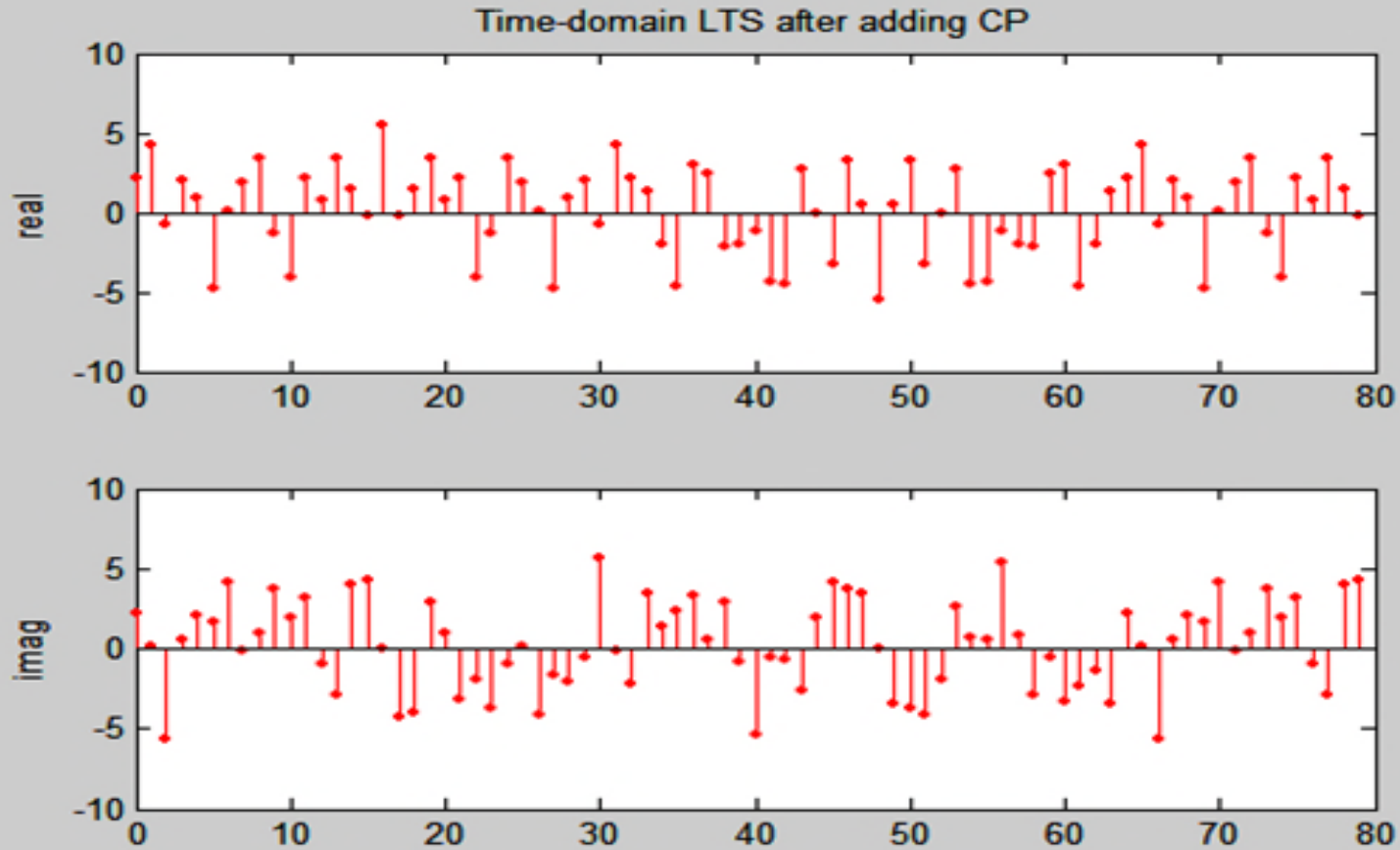
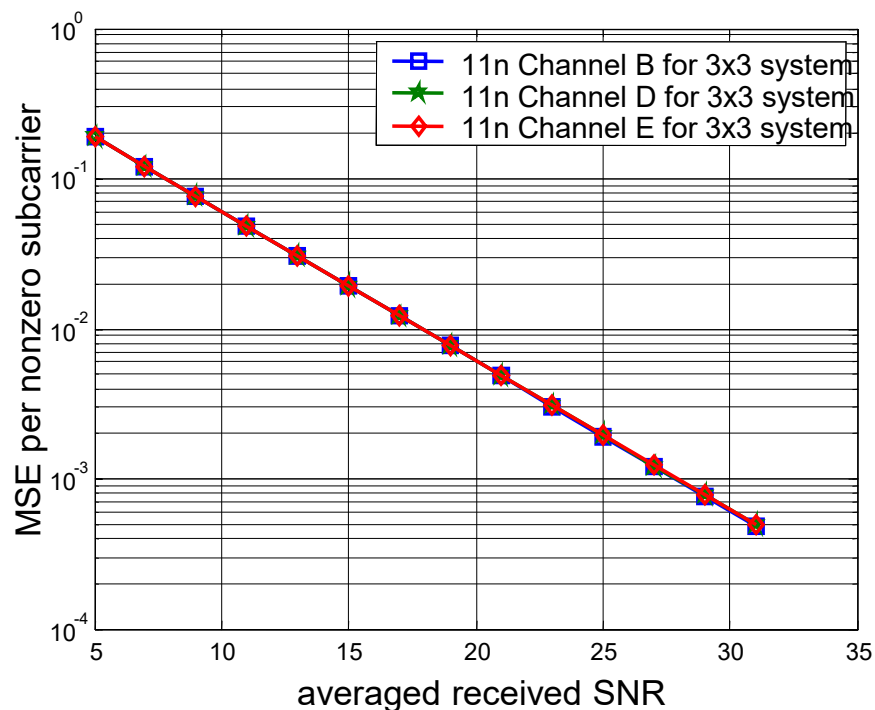


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# Numerical Results

The MSE of the channel estimates with proposed LTSs for 3x3 mode over channel B, D and E.



The MSE of the channel estimates with proposed LTSs for 4x4 mode over channel B, D and E.

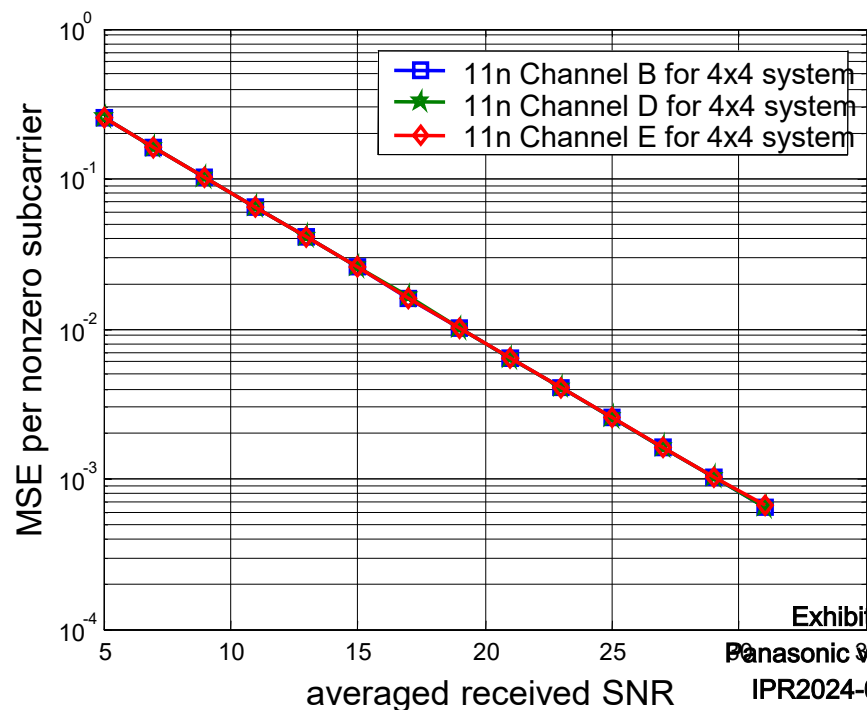


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## Conclusion

- We propose STSs with the properties of
  - Period of 32 samples
  - Zero cross-correlation of the STSs
  - Low detection probability for 11a systems
- With the proposed LTSs, the receiver can effectively and efficiently estimate the frequency domain responses of MIMO channel.