Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Simulation results for Option V]
Date Submitted: [September 19, 2005]
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Re: [Response to Call for Proposals]

Abstract: [This document describes a modulation proposal for the TG4a.]

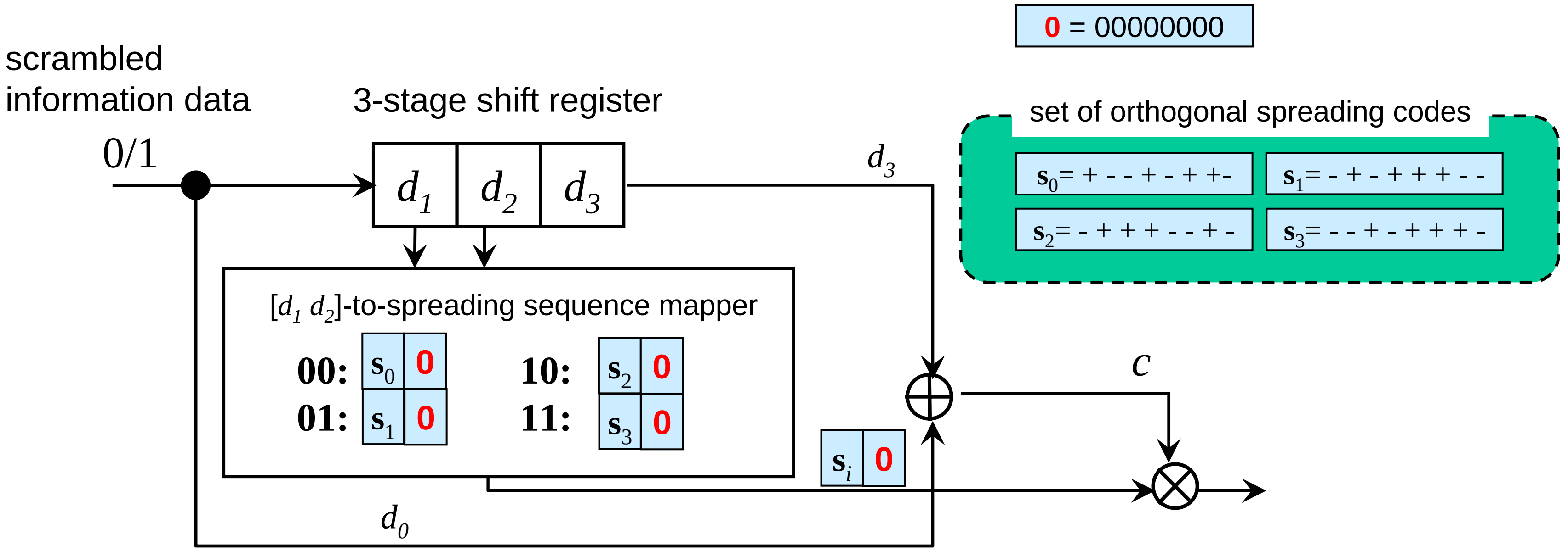
Purpose: [Proposal Presentation for the IEEE802.15.4a standard.]

Simulation Results For Option V

[Super-orthogonal convolutional (SOC) coded DS-UWB systems]

Kenichi Takizawa, Tomoko Matsumoto, Huan-Bang Li, and Ryuji Kohno

Super-Orthogonal Convolutional (SOC) Coded DS-UWB systems (05-0496-01)

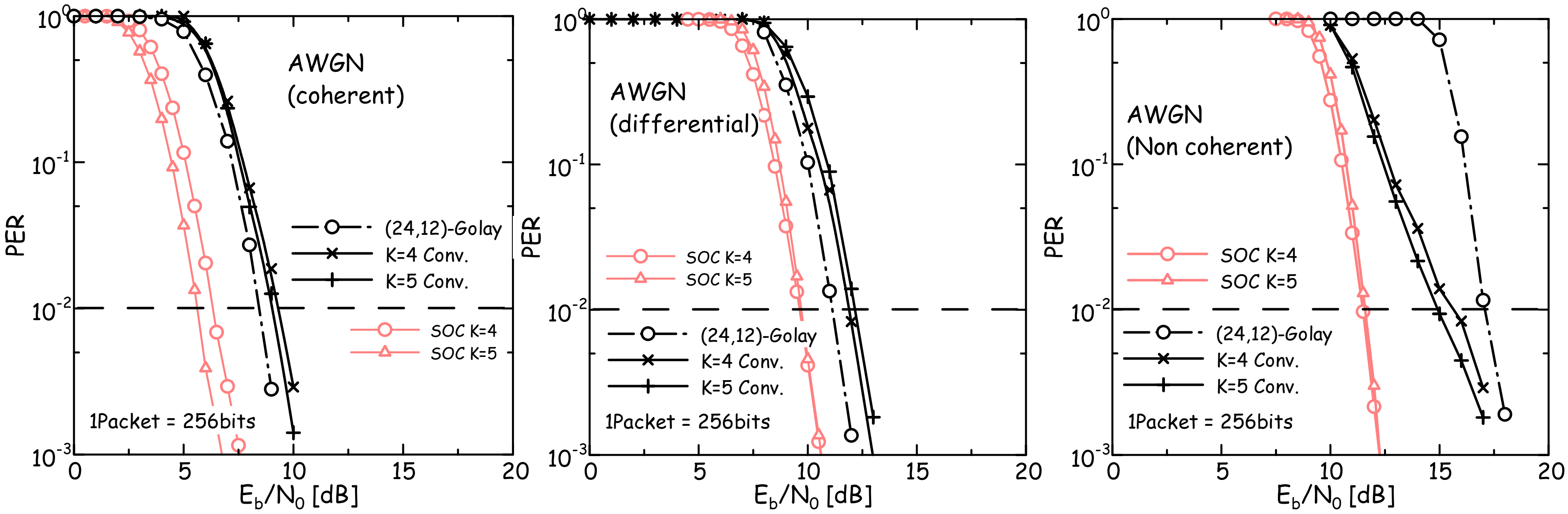


SOC coding combines FEC coding and DS spreading

Why SOC coded DS-UWB systems ?

Simulation results (AWGN)

Average PRF = 15.4375MHz

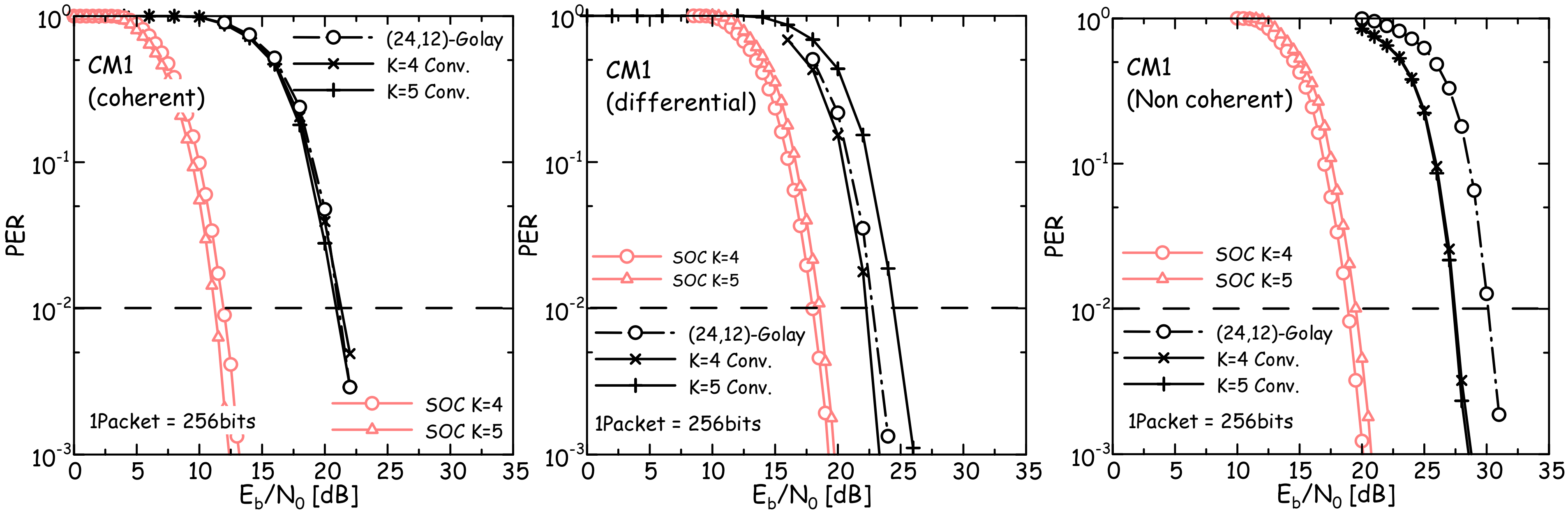


K=4: [15,17] K=5: [23, 35]

SOC gives better PER performance.

Simulation results (CM1)

Average PRF = 15.4375MHz

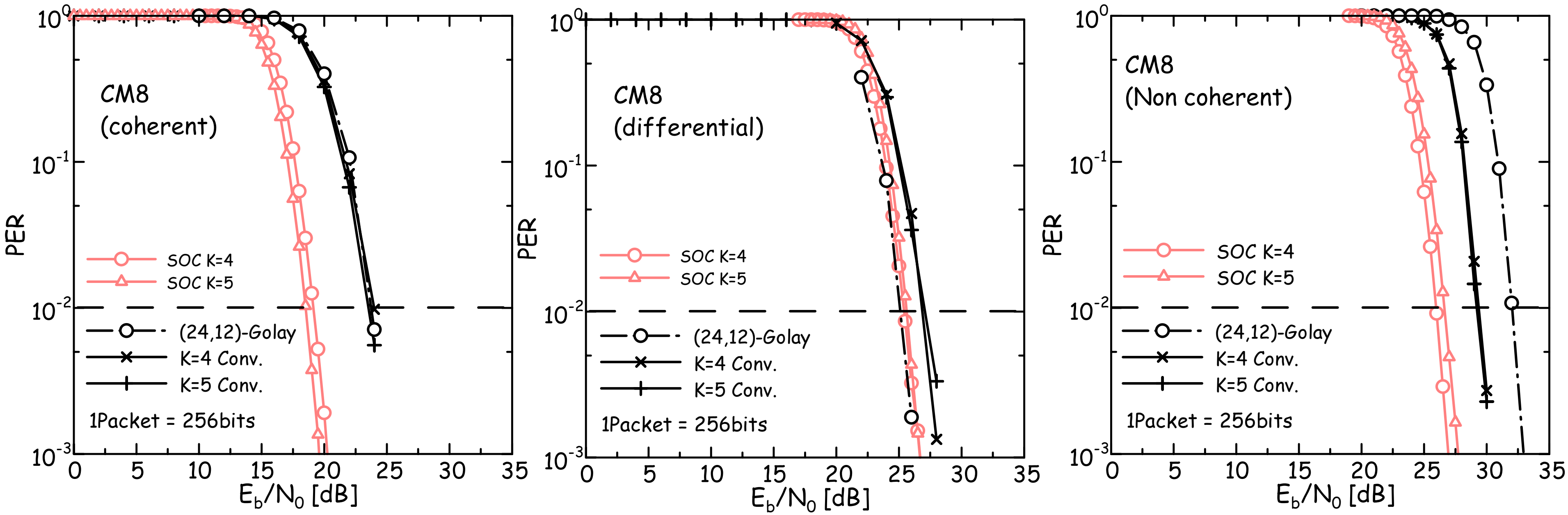


K=4: [15,17] K=5: [23, 35]

SOC gives better PER performance.

Simulation results (CM8)

Average PRF = 15.4375MHz

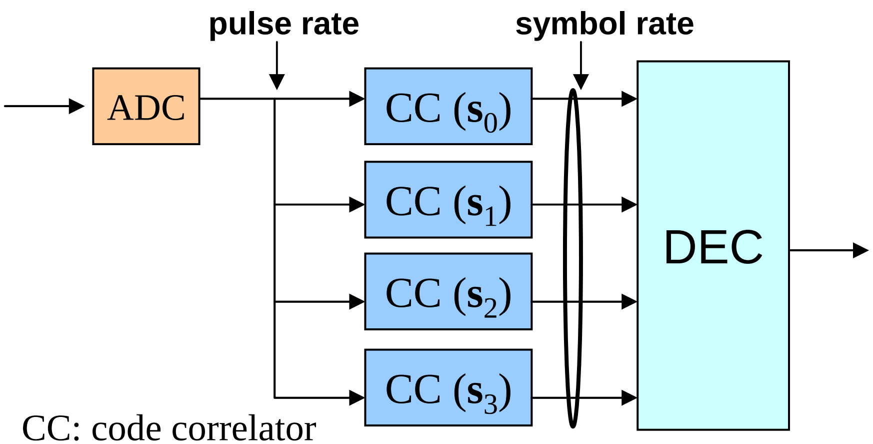


K=4: [15,17] K=5: [23, 35]

SOC gives better PER performance.

Complexity (Required Processing Speed)

K=4 SOC decoder

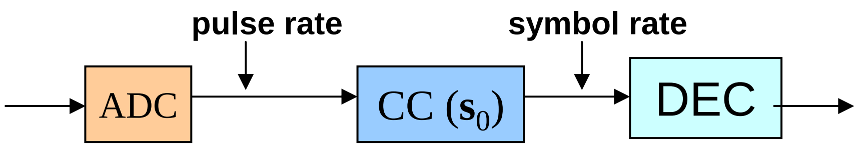


CC: code correlator

00:	s_0	0
01:	s_1	0
10:	s_2	0
11:	s_3	0

code correlators	4
# of encoder's states	$2^{K-1}=2^3=8$
Required processing speed	Symbol rate

Convolutional decoder



0:	s_0	0
1:	$-s_0$	0

code correlators	1
# of encoder's states	$2^{K-1}=2^3=8$
Required processing speed	Symbol rate

Complexity (Gate count)

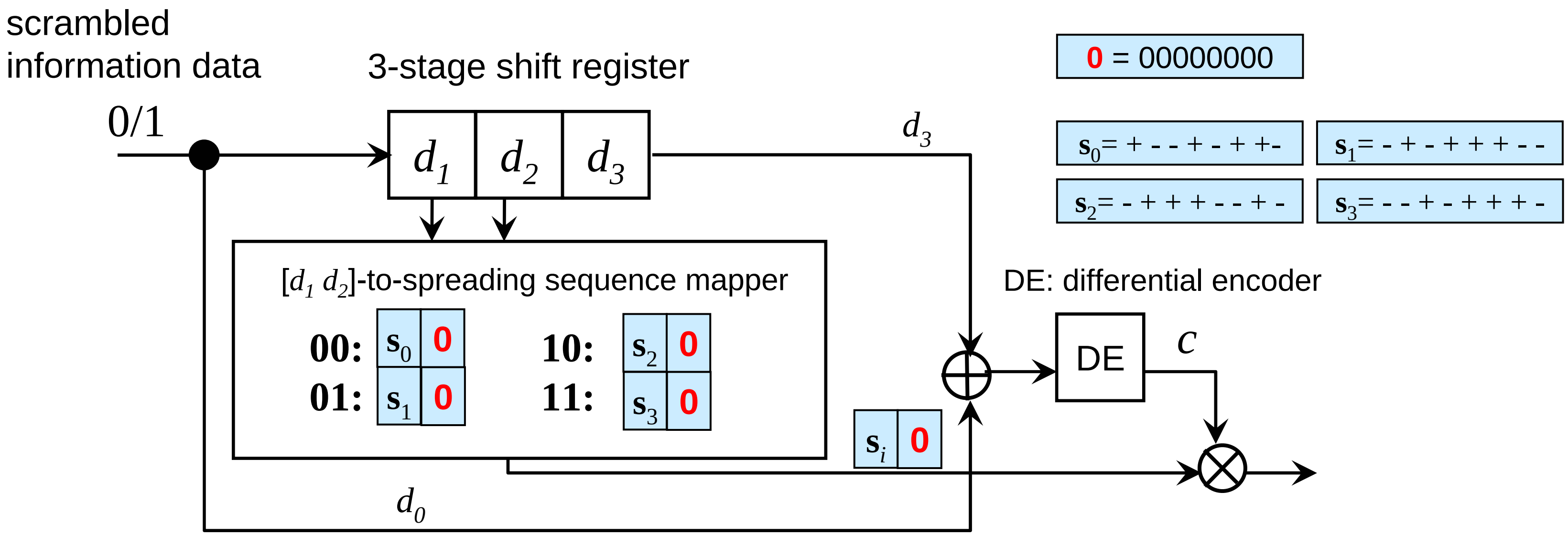
	K=4 SOC	K=5 SOC	K=4 Conv.	K=5 Conv.	(24,12)-Golay
Coding rate	1/8	1/8	1/2	1/2	1/2
Spreading rate	1/2	1/2	1/8	1/8	1/8
Req. clock rate (@DSP)	Symbol rate*	Symbol rate*	Symbol rate	Symbol rate	Symbol rate
Gate count (decoder)	~8K	~32K	~4K	~8K	~1K

*: A set of multiple code correlator is required. In this case, we need 4 for K=4 or 8 for K=5 code correlators.

SOC decoder is reasonable low complexity and low power consumption.

Simulation results on different modulations

K=4 SOC encoder for Coherent mode



Peak PRF = 30.875MHz

if c = 0,	s_i	0	0	0
if c = 1,	$-s_i$	0	0	0

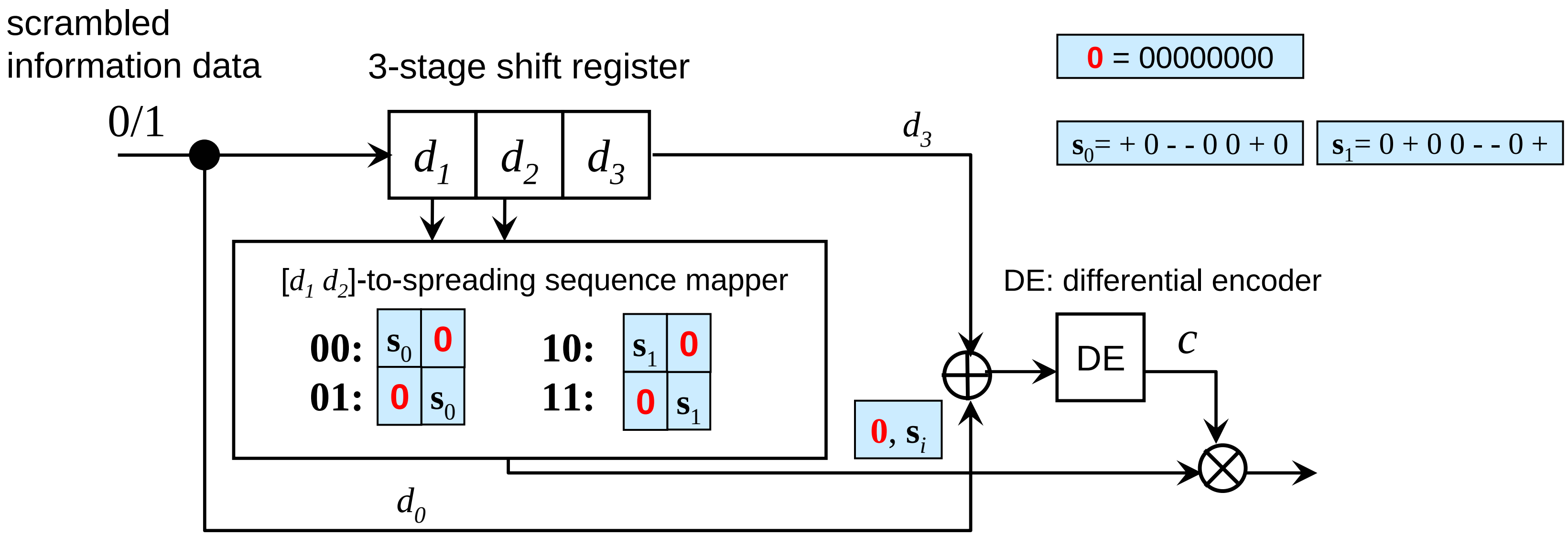
Peak PRF = 61.75MHz

if c = 0,	s_i	0	0	0	0	0	0	0
if c = 1,	$-s_i$	0	0	0	0	0	0	0

Peak PRF = 247MHz

if c = 0,	s_i	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
if c = 1,	$-s_i$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

K=4 SOC encoder for Non-coherent mode



Peak PRF = 30.875MHz

if c = 0,	0, s_i		0	0
if c = 1,	0	0	0, $-s_i$	

Peak PRF = 61.75MHz

if c = 0,	0, s_i		0	0	0	0	0	0
if c = 1,	0	0	0	0	0, $-s_i$		0	0

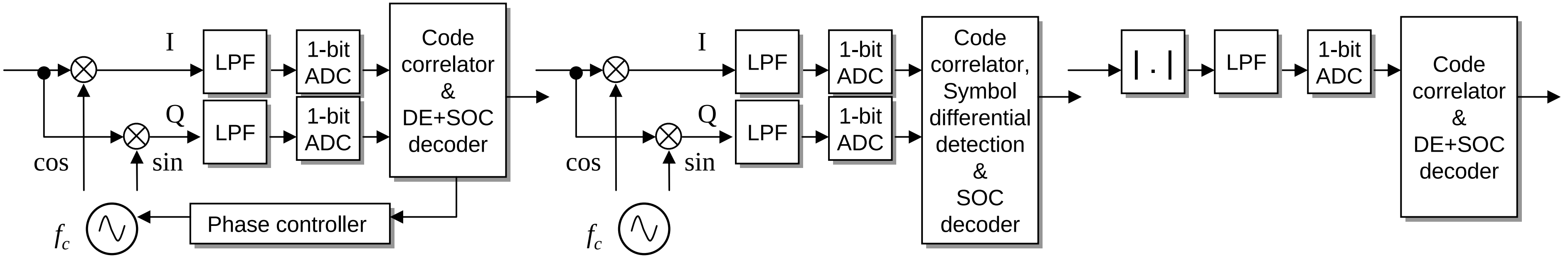
Peak PRF = 247MHz

if c = 0,	0, s_i		0	0	0	0	0	0	0	0	0	0	0	0	0	0
if c = 1,	0	0	0	0	0	0	0	0	0, $-s_i$		0	0	0	0	0	0

Simulation results for different modulations

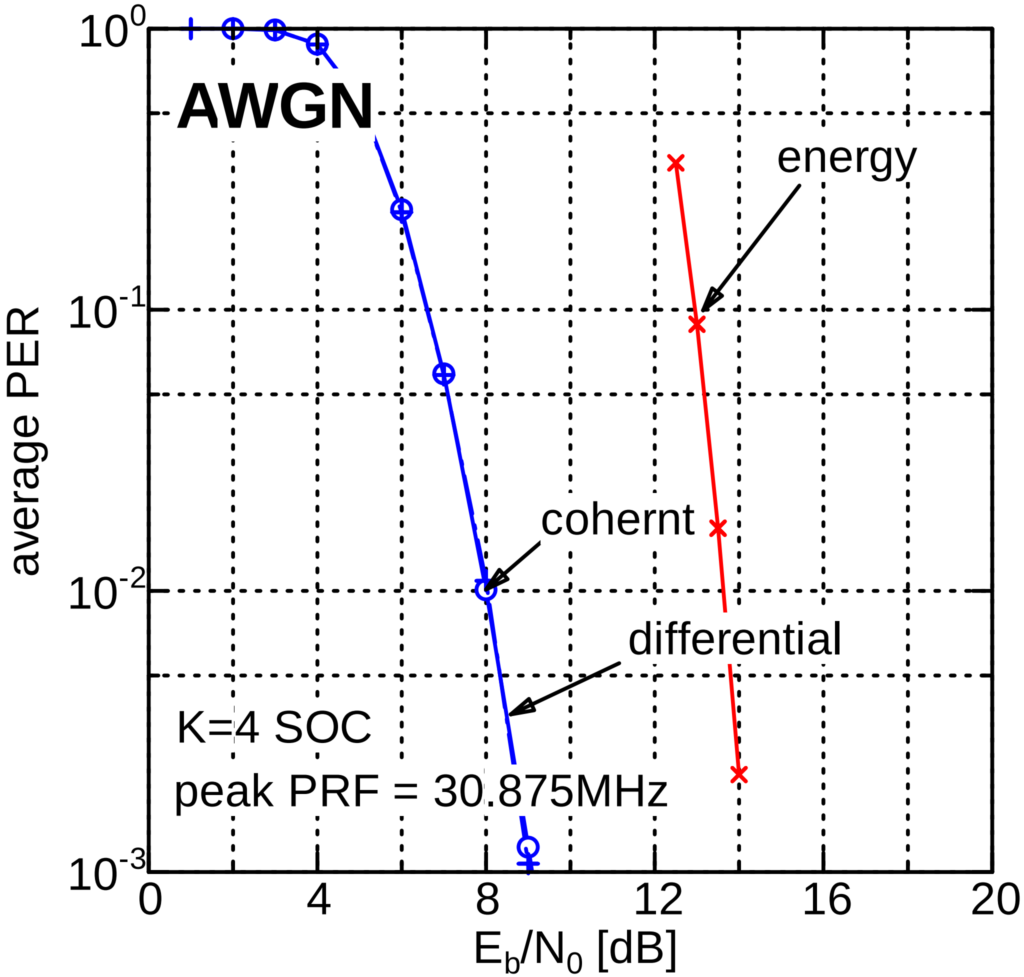
Parameters Used In Simulation

- Data rate: 0.965Mbps (Mandatory)
- Band: mandatory
- Pulse shape: 500-MHz Gaussian pulse
- Receiver: Coherent detection and Energy detection
- ADC: 1bit pulse-rate ADC
- No rake reception and no equalization
- SOC decoder: 8-state Viterbi hard decision decoder

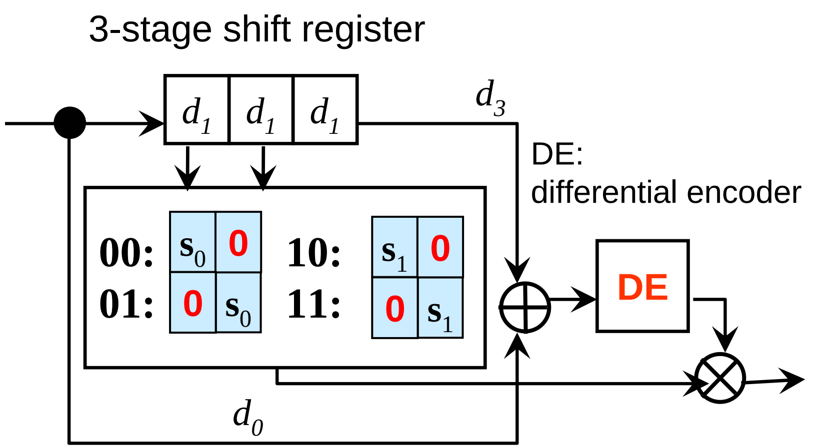


Coherent detection　　Differential detection　　Energy detection

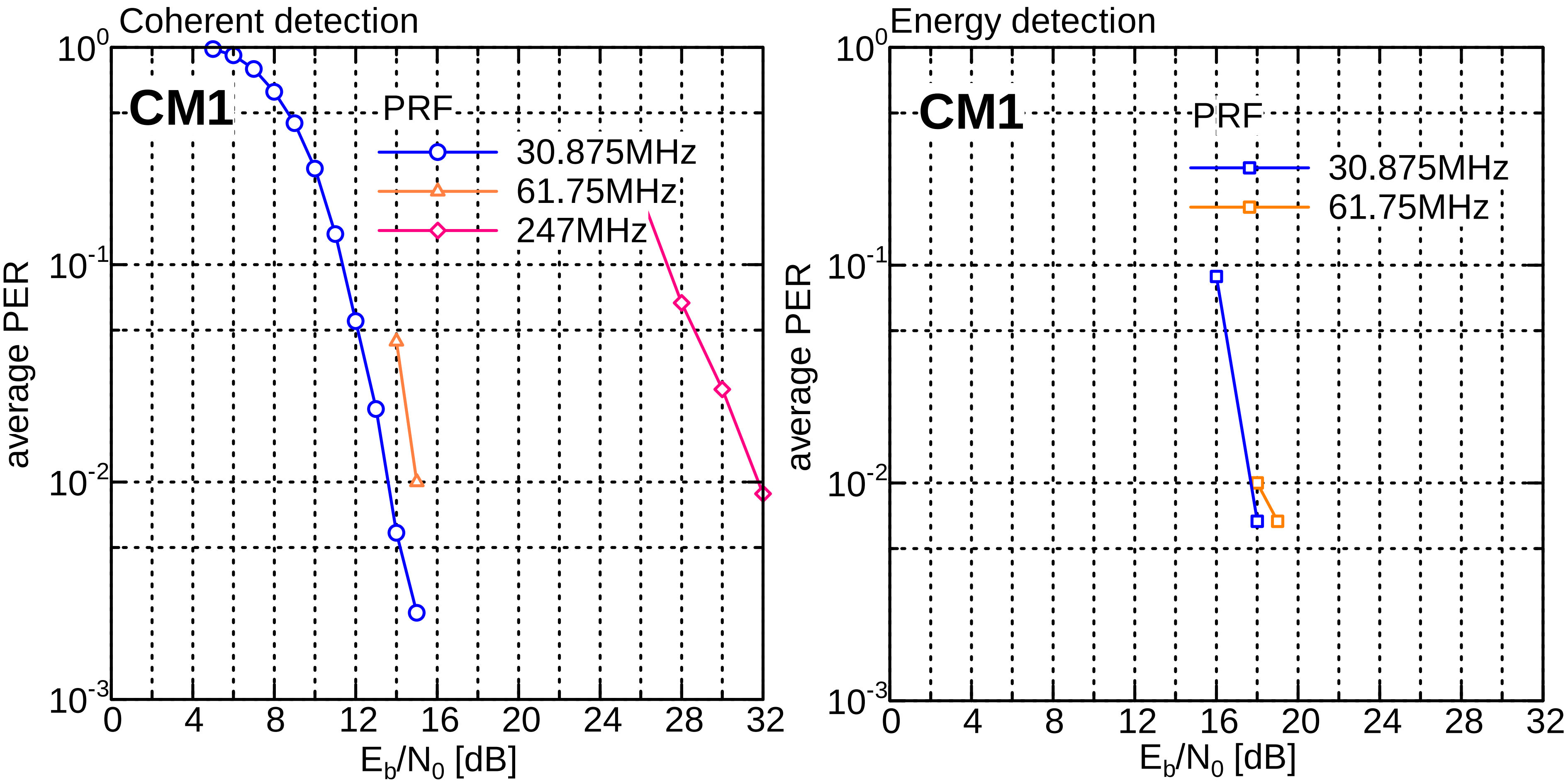
PER With AWGN Channel



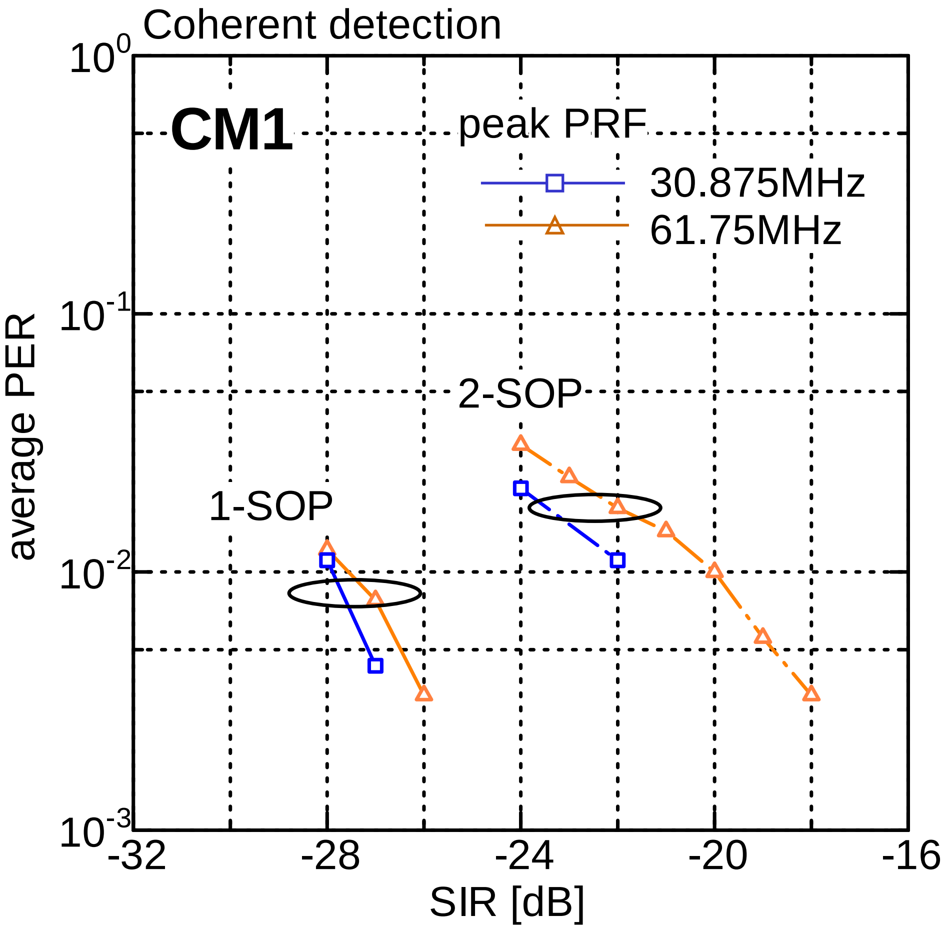
Differential detection provides the equivalent performance with coherent detection because differential coding is done at the transmitter side.

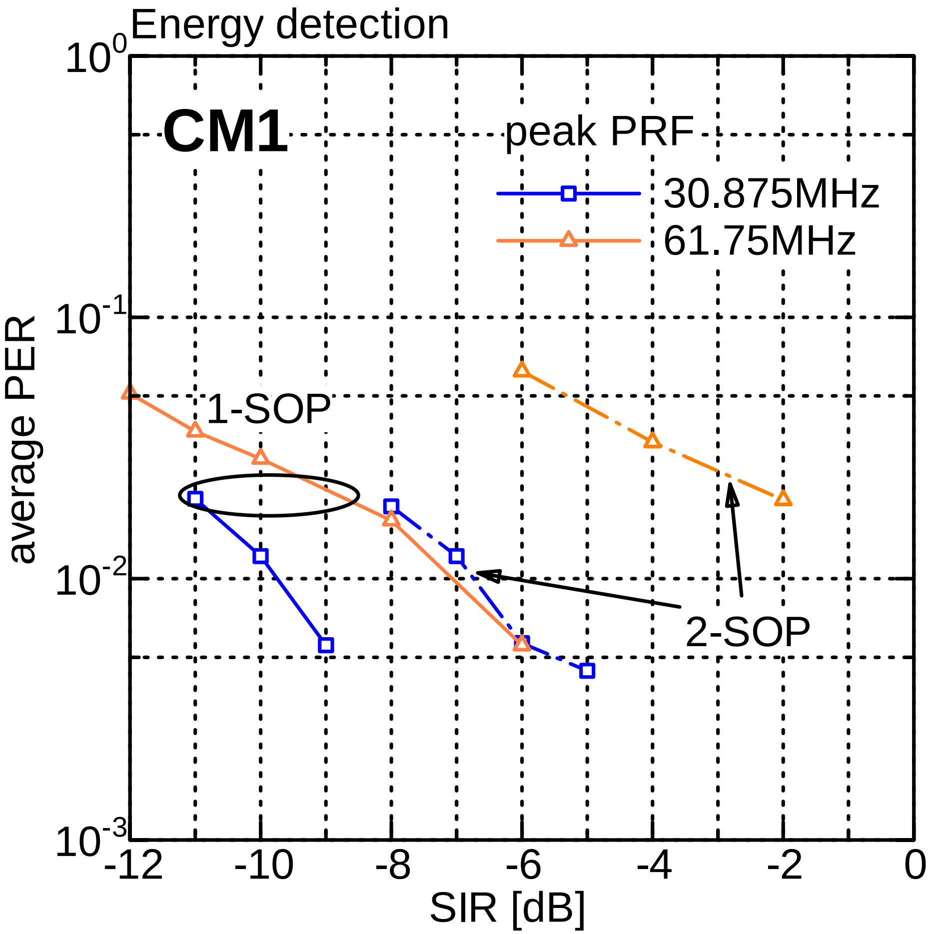


PER With CM 1

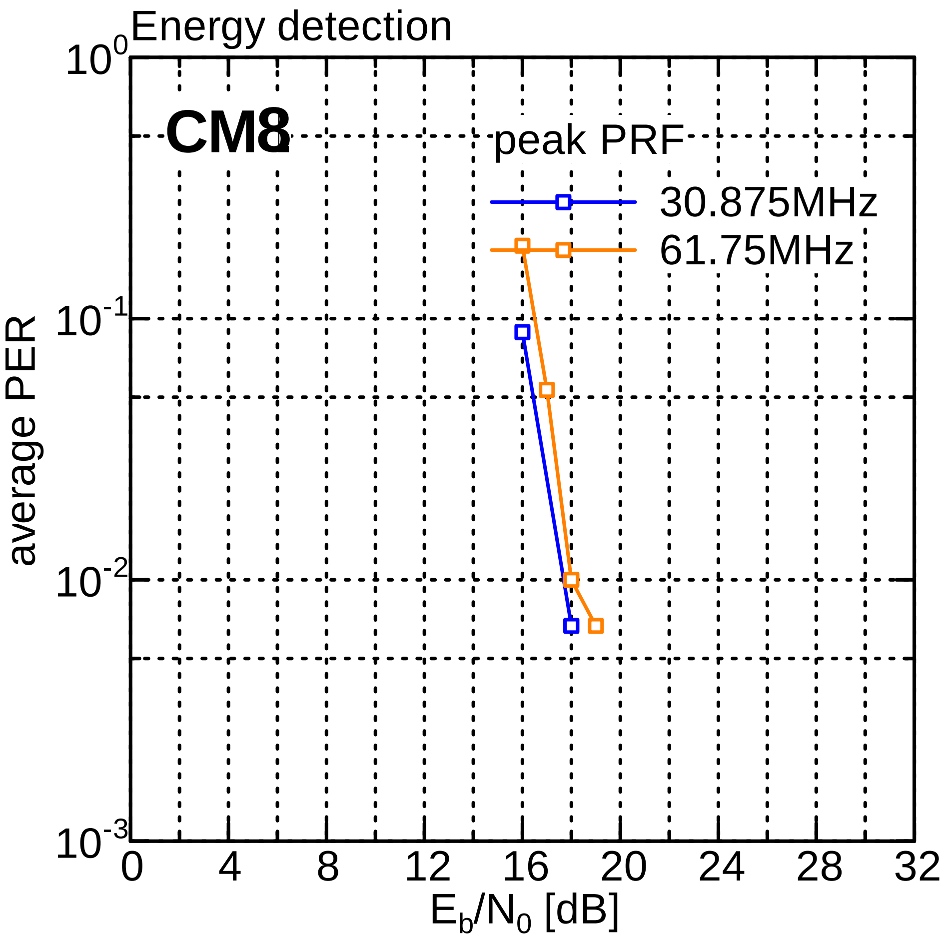

Coherent detection
CM1
PRF
30.875MHz
61.75MHz
247MHz
average PER
10^0
10^{-1}
10^{-2}
10^{-3}
0 4 8 12 16 20 24 28 32
E_b/N_0 [dB]
Energy detection
CM1
PRF
30.875MHz
61.75MHz
average PER
10^0
10^{-1}
10^{-2}
10^{-3}
0 4 8 12 16 20 24 28 32
E_b/N_0 [dB]

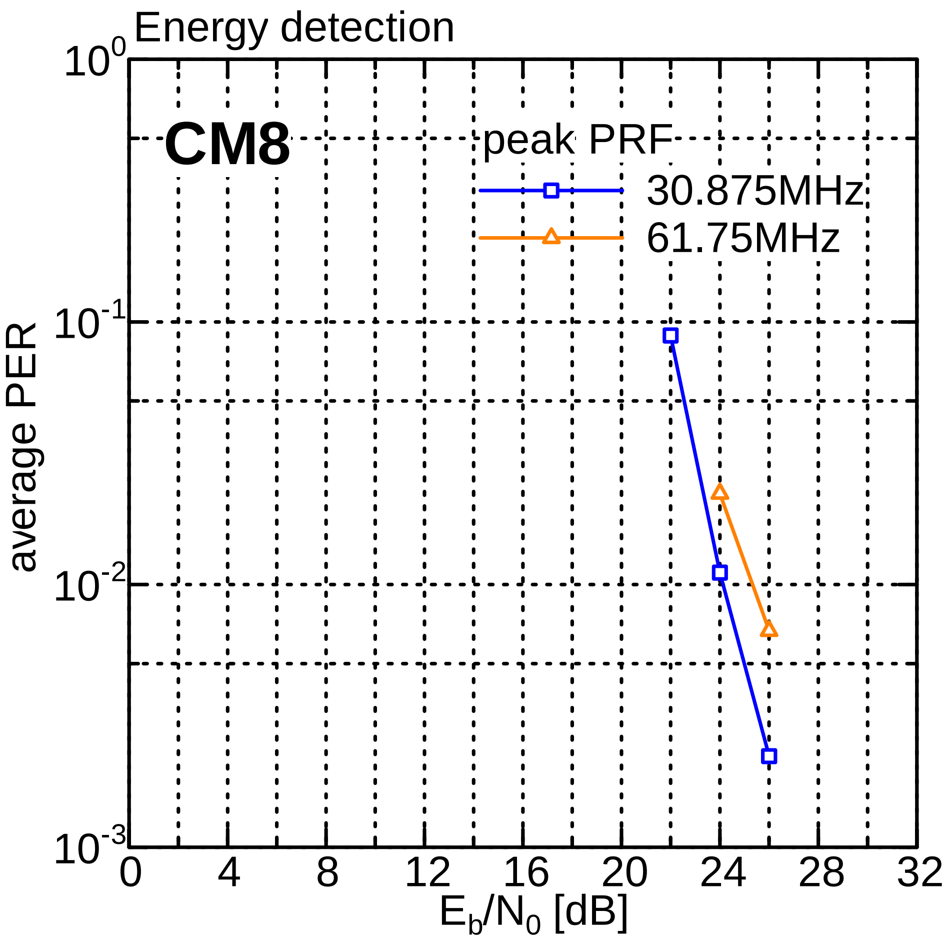
SOP Performance With CM1



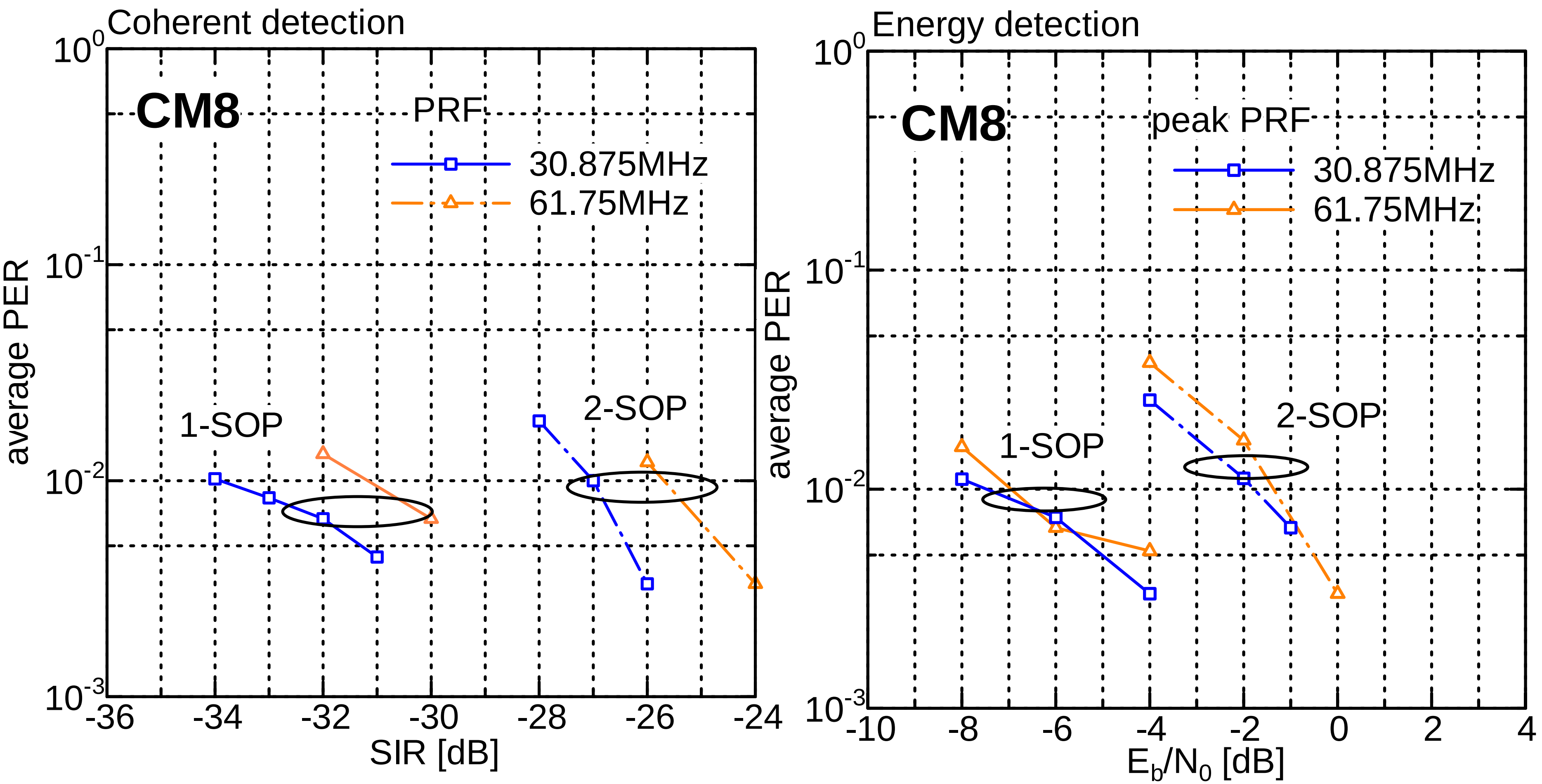


PER With CM8


Energy detection
CM8
peak PRF
30.875MHz
61.75MHz
average PER
10^0
10^{-1}
10^{-2}
10^{-3}
0
4
8
12
16
20
24
28
32
E_b/N_0 [dB]

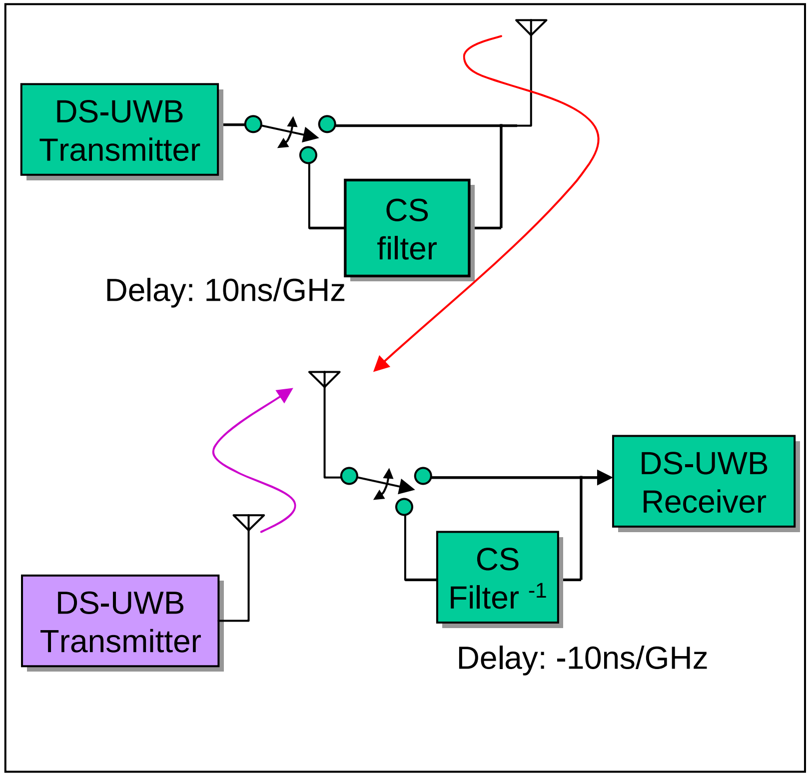

Energy detection
CM8
peak PRF
30.875MHz
61.75MHz
average PER
10^0
10^{-1}
10^{-2}
10^{-3}
0
4
8
12
16
20
24
28
32
E_b/N_0 [dB]

SOP Performance With CM8

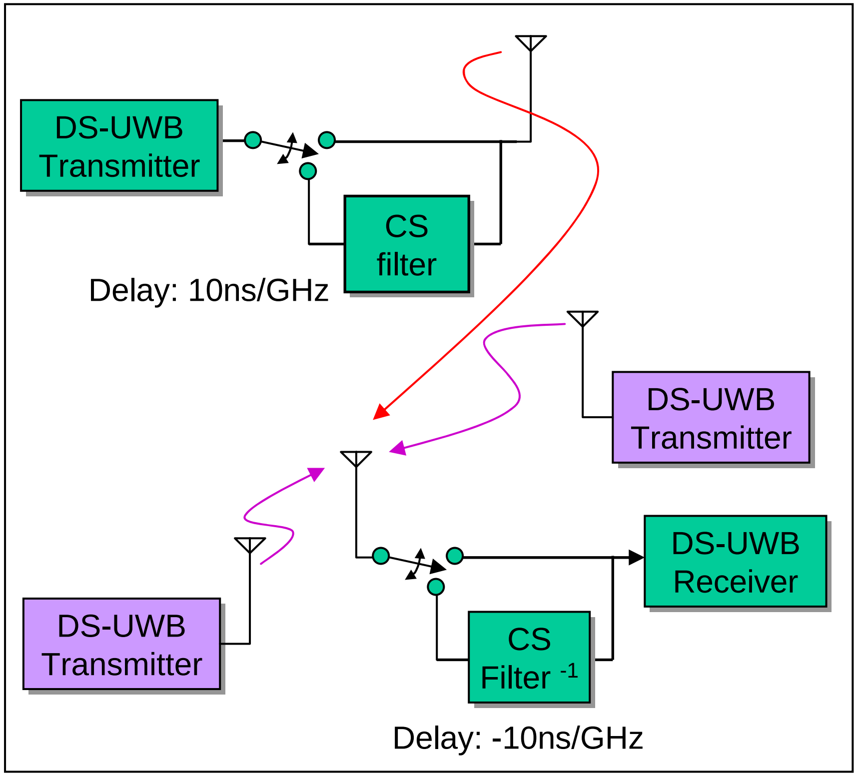


Option V with optional CS-filtering

Block Diagram For SOP Simulation

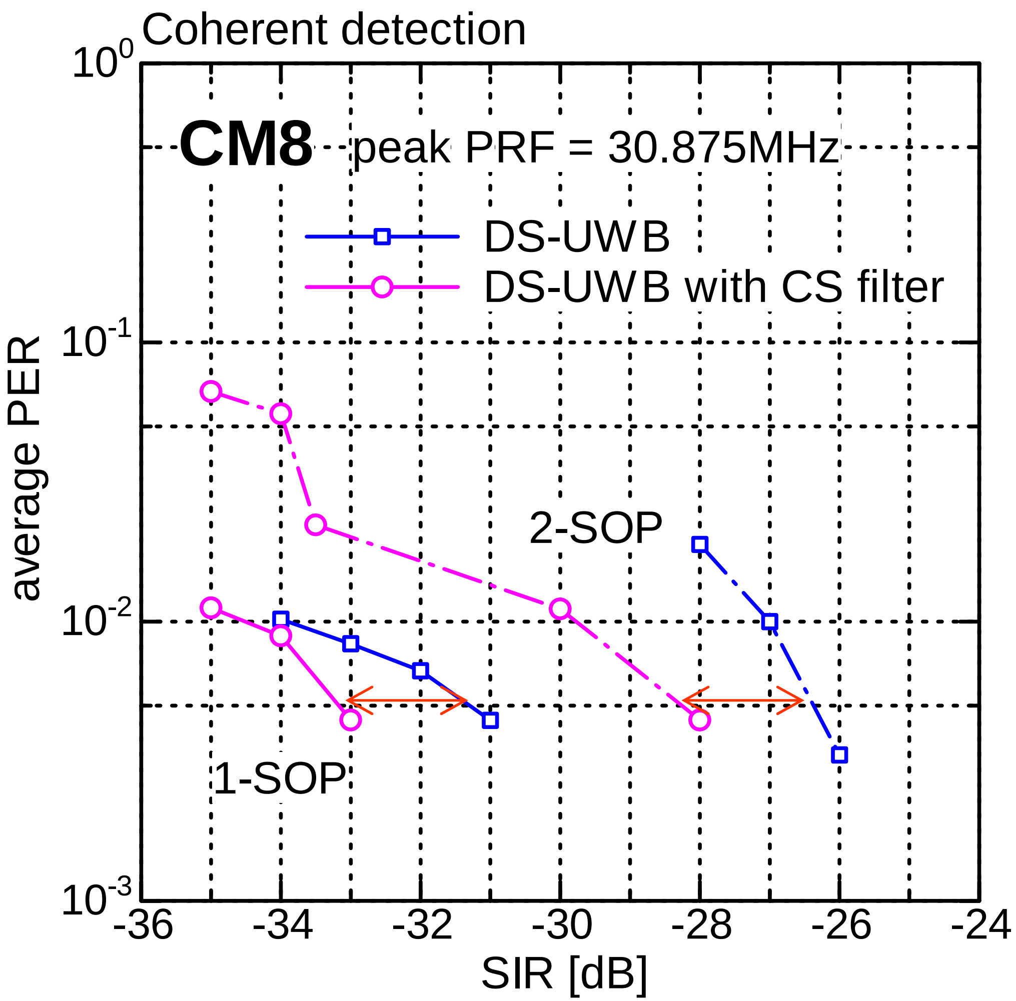


1-SOP



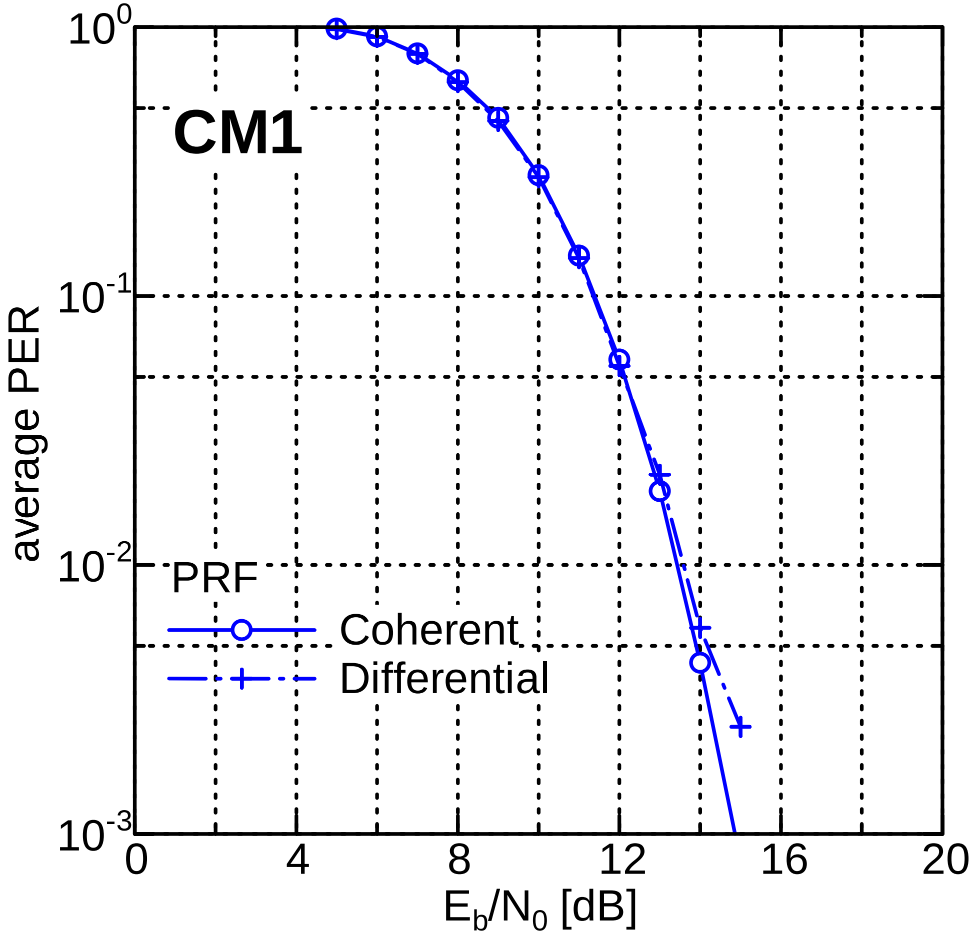
2-SOP

Enhanced SOP With CS Filtering



Option V with differential detection

PER With CM1



Differential detection gives the comparable performance with coherent detection by a simple Rx structure.

Conclusion Remarks

- Super-orthogonal convolutional coding
  - Combination of FEC coding and DS-spreading: **Joint optimization of coding and spreading**
  - Gives better performance than convolutional coding with similar complexity.
- Simulation results
  - PER performance in AWGN, CM1 and CM8
  - 1-SOP and 2-SOP performance in CM1 and CM8
  - CS filtering gives superior SOP performance
  - Symbol-differential detection, which can be implemented with a simple RX structure, provides comparable performance to coherent detection