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

Submission Title: [**A modified SHR for 802.15.4ad Low Rate (LR)**]
Date Submitted: 14 May 2025
Source: Hiroshi Harada and Jaeseok Lim (Kyoto University)
Address Yoshidahonmachi. Sakyo, Kyoto, 606-8501, Japan
Voice: +81-75-753-5317 , E-Mail: hiroshi.harada@i.kyoto-u.ac.jp

Re: [Wireless Next Generation, Long Range extension enhancements to 802.15.4-2020]

Abstract: Discuss the SHR for 802.15.4ad Low Rate (LR) at the receiver and propose a modified SHR. A part of this contribution supported from the commissioned research (No. JPJ012368C05101) by National Institute of Information and Communications Technology (NICT) , Japan is included.

Purpose: Discuss SHR for 802.15.4ad Low Rate (LR) at receiver and propose a modified SHR.

A modified SHR for 802.15.4ad Low Rate (LR)

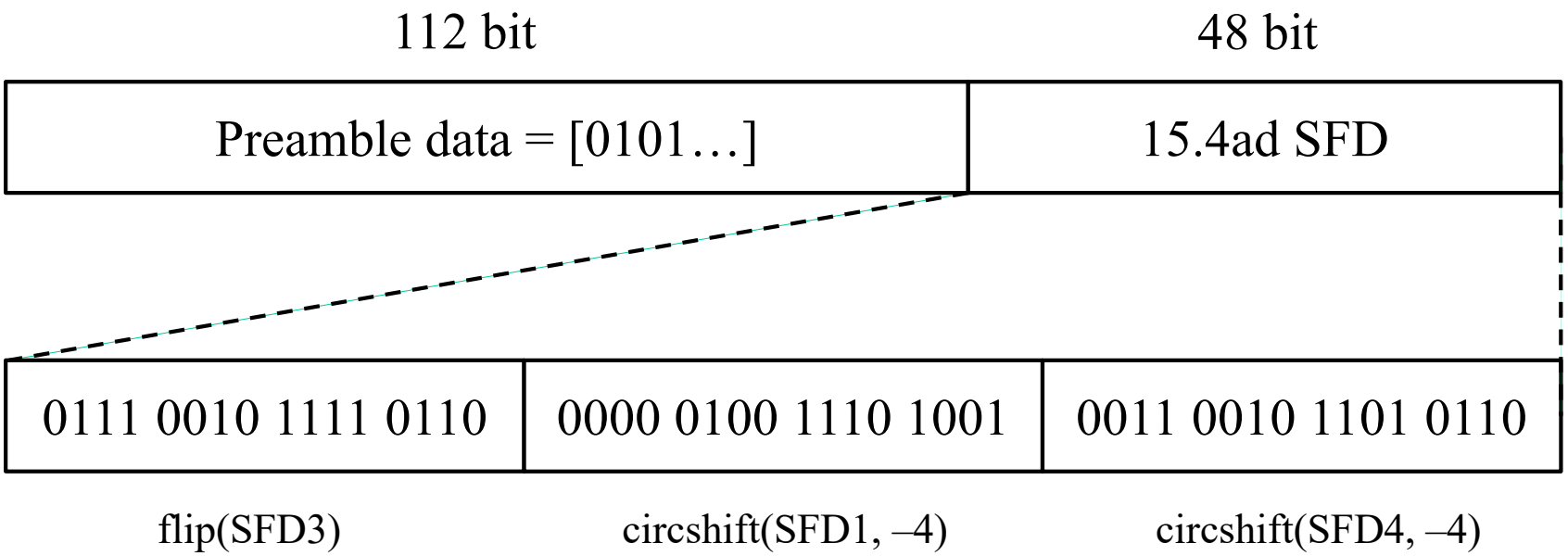
May 14, 2025

Hiroshi Harada, Ph.D., IEEE fellow, and Jaeseok Lim
Kyoto University

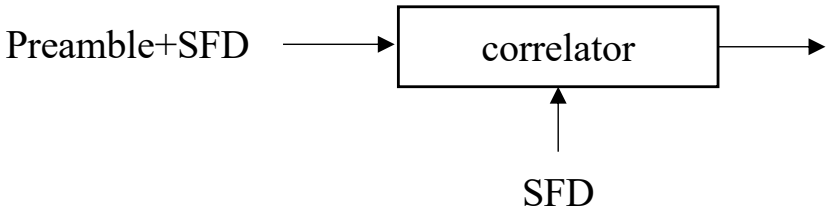
Background

- We have already proposed IEEE 802.15.4 SUN FSK Low Rate (LR) and SUN OFDM LR in 15-25/0035r0
- In these proposals, SHR(Synchronization Header) uses the SFD used in the existing 802.15.4 SUN FSK
- The synchronization characteristics of this SHR at the receiver side were evaluated in 15-25/0150r1
- However, after further consideration, a better SHR was discovered based on Golay sequence. This contribution document demonstrates the synchronization characteristics of this new method
- Additionally, as reference data, we present the cross-correlation characteristics between the proposed SHR and the SFD used in the existing 802.15.4 SUN FSK

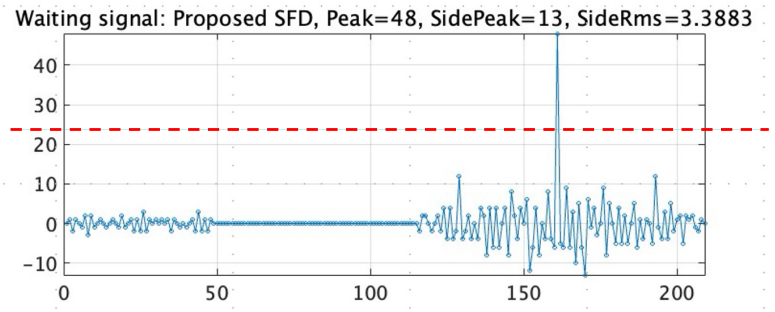
SHR proposed in 15-25/0150r1



A synchronization method for SHR in 15-25/0035r0 at the receiver

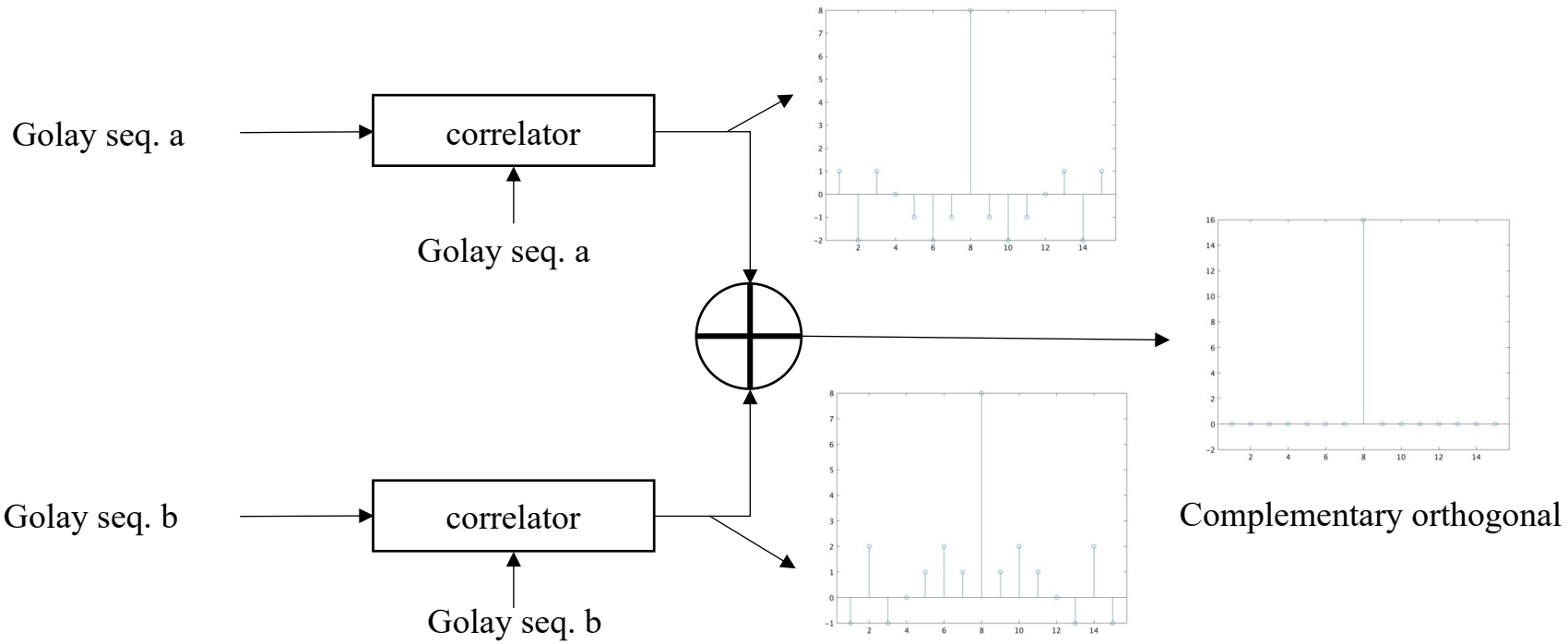


Threshold

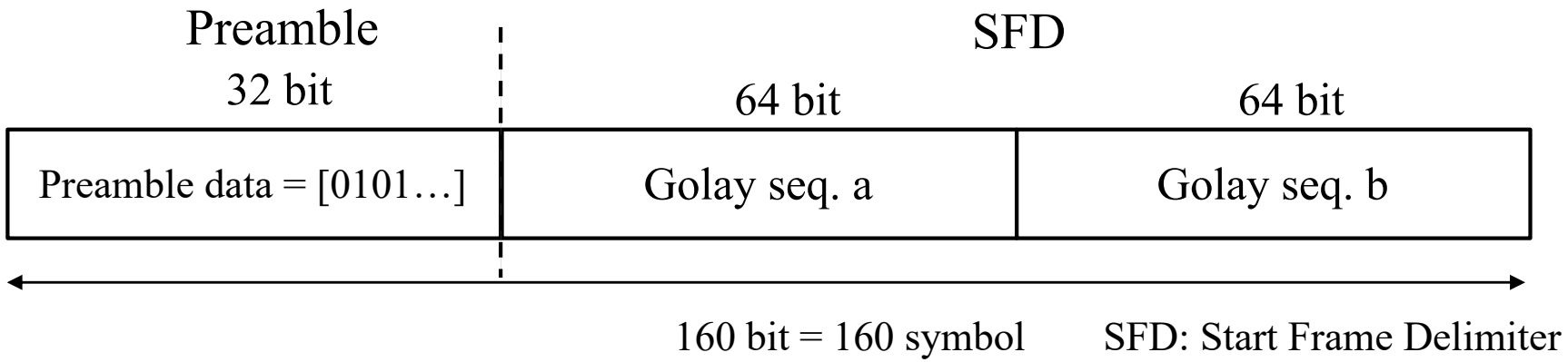


Golay sequence

- Constructed using a pair of complementary symbols a and b [2]
- The sum of the autocorrelations of symbols a and b is completely orthogonal



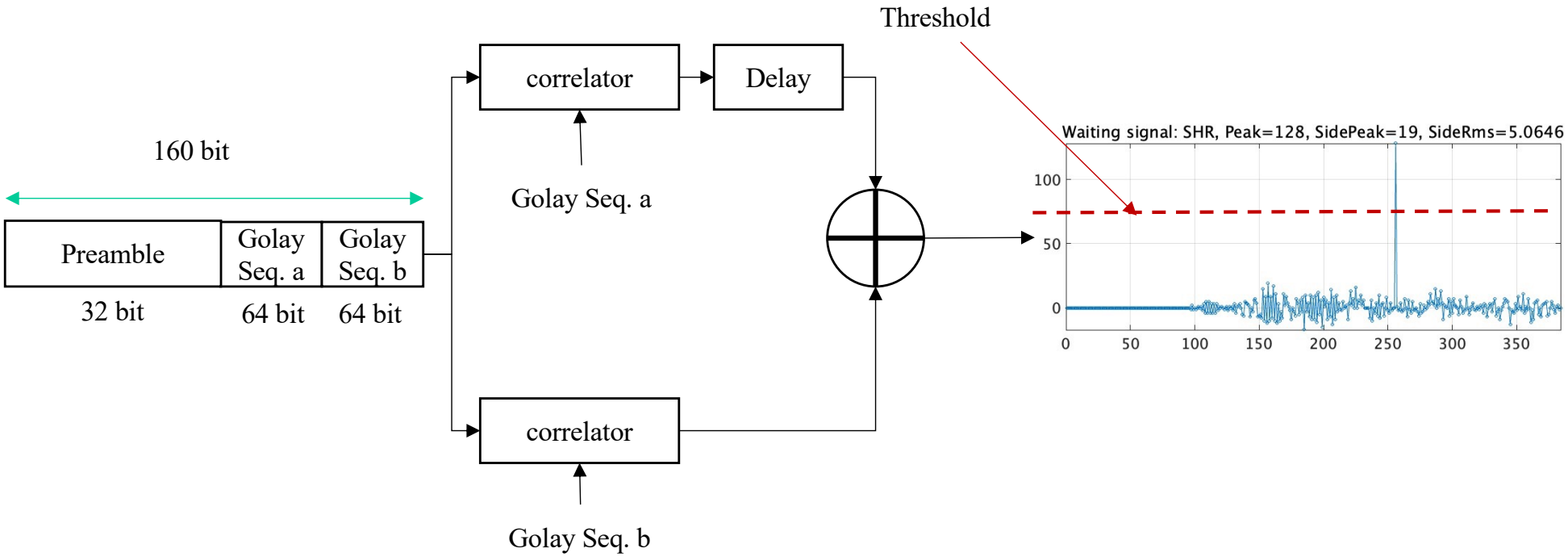
New SHR proposal



	Golay seq. a	Golay seq. b
Value	0x63AF05C963500536	0x6CA00AC66C5F0A39

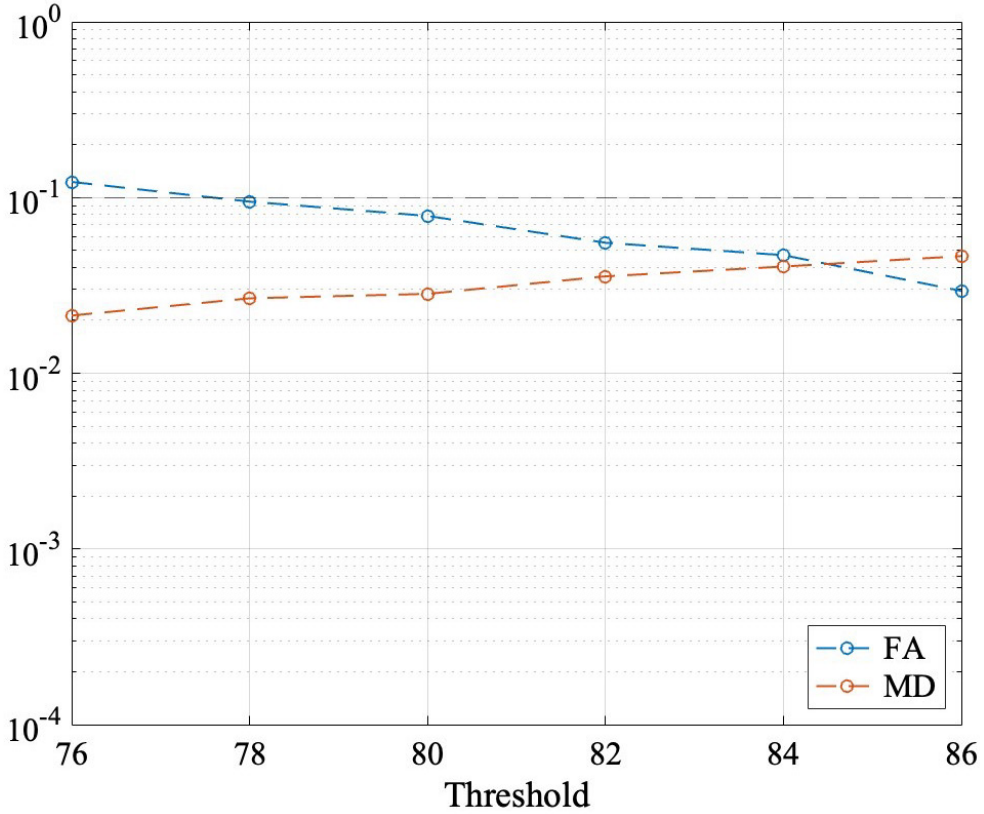
The sequence is based on [1]

A synchronization method for new SHR at the receiver



FA (False Alarm), MD (Miss Detection), and Threshold for proposed SHR

- FA and MD characteristics below 10^{-1} achieve with threshold = 80
- 2GFSK, SNR = 0 dB, AWGN

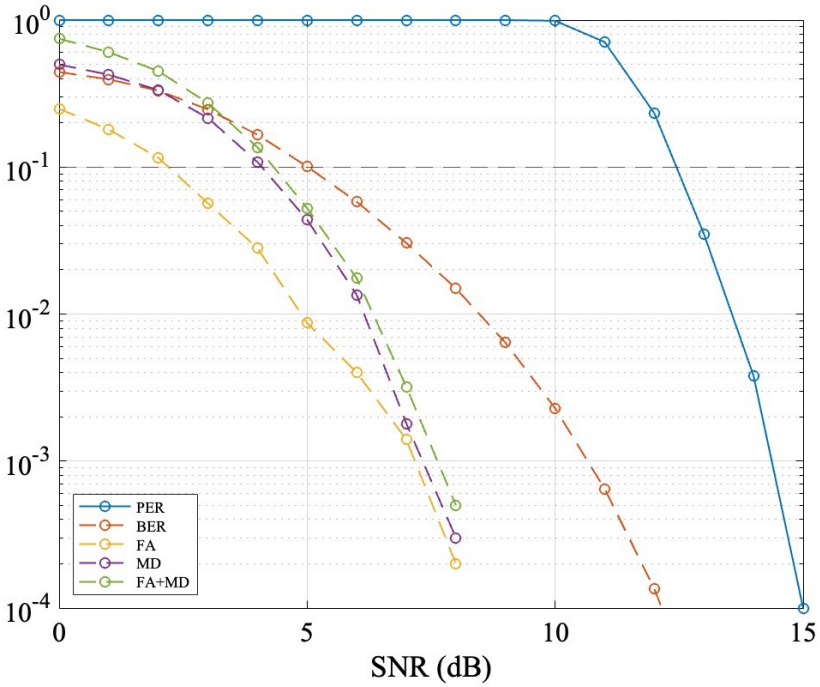


SNR and received signal power conversion

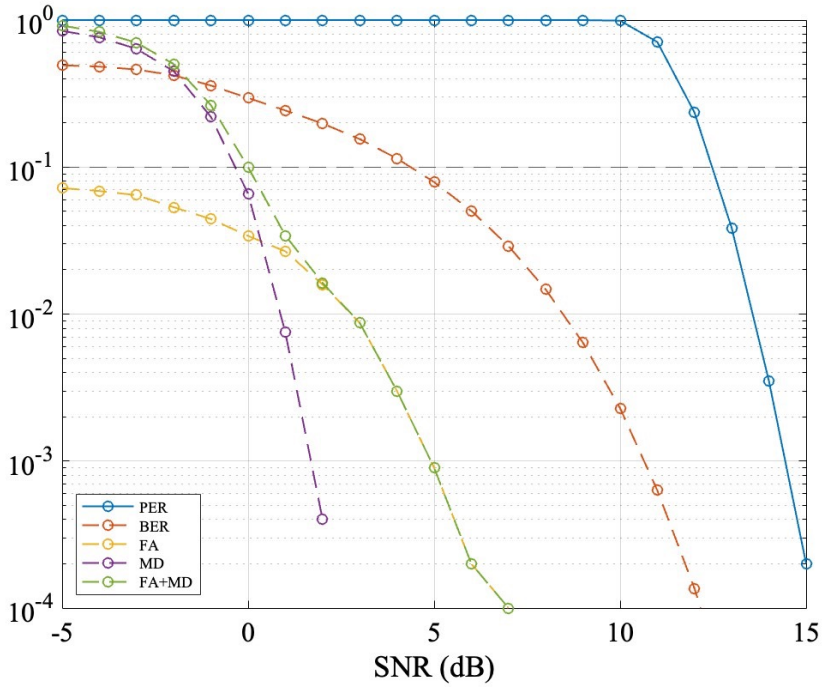
- In the case of Noise Figure (NF) =0dB and bandwidth =31.25/3 kHz, noise power should be -133.8 dB
- The conversion between SNR and received signal power is shown as follows

SNR(dB)	Received power (dBm)
-10	-143.8 dBm
-5	-138.8 dBm
0	-133.8 dBm
5	-128.8 dBm
10	-123.3 dBm

FA, MD Characteristics (2GFSK, w/o FEC, AWGN)



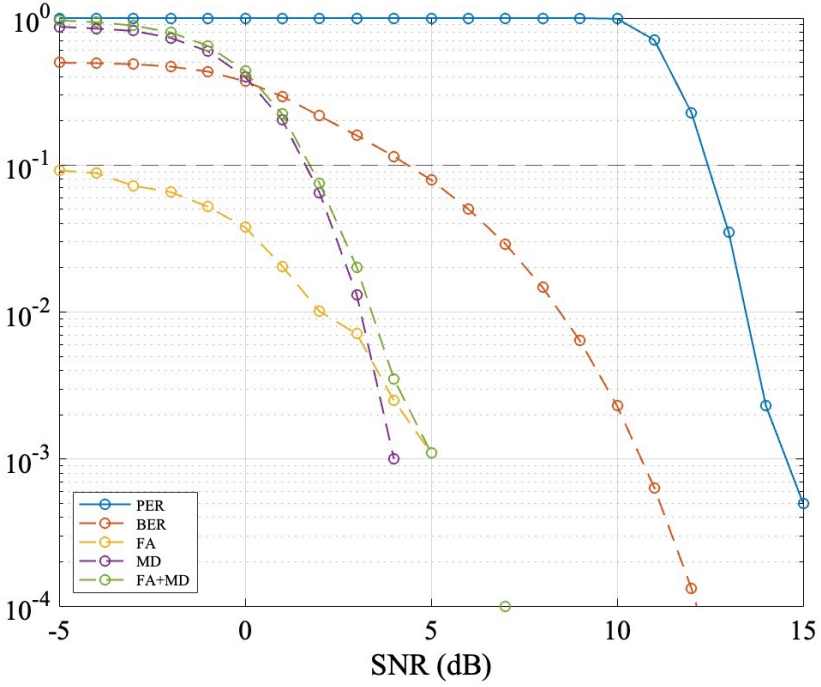
15.4g SFD



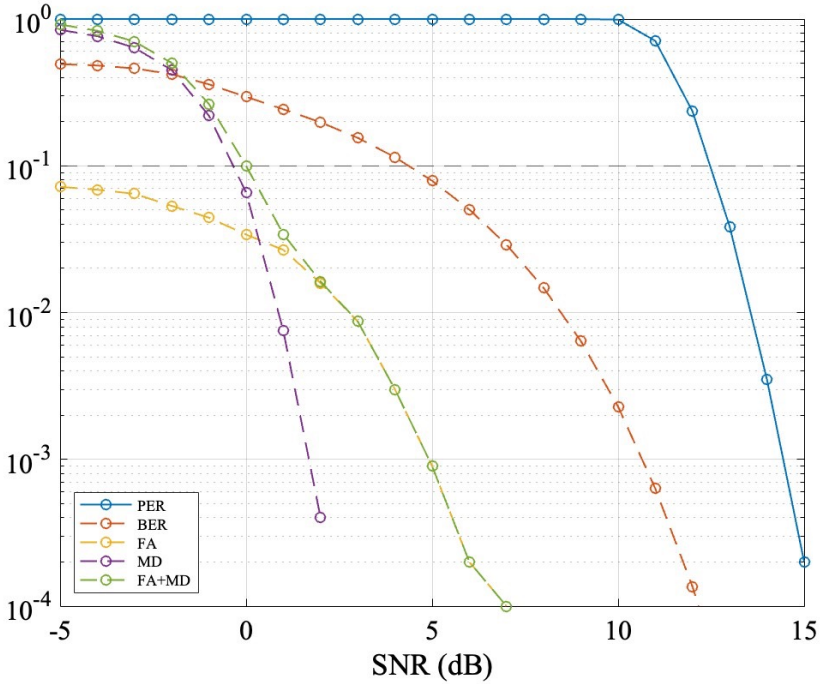
Proposed Golay-based SFD

- The required SNR is 0 dB (received power -133.8 dBm) to achieve error rate of 10^{-1} by using proposed SFD.
- When using Golay-based SFD, approximately 4.5 dB margin can be gained in frame synchronization compared to 15.4 g SFD

FA, MD Characteristics (2GFSK, w/o FEC, AWGN)



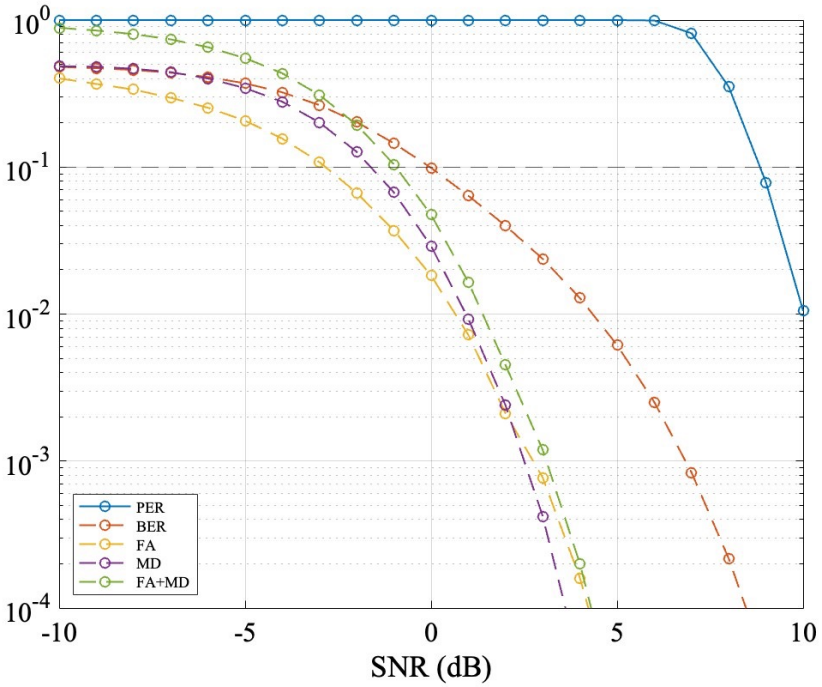
15-25/0150r1



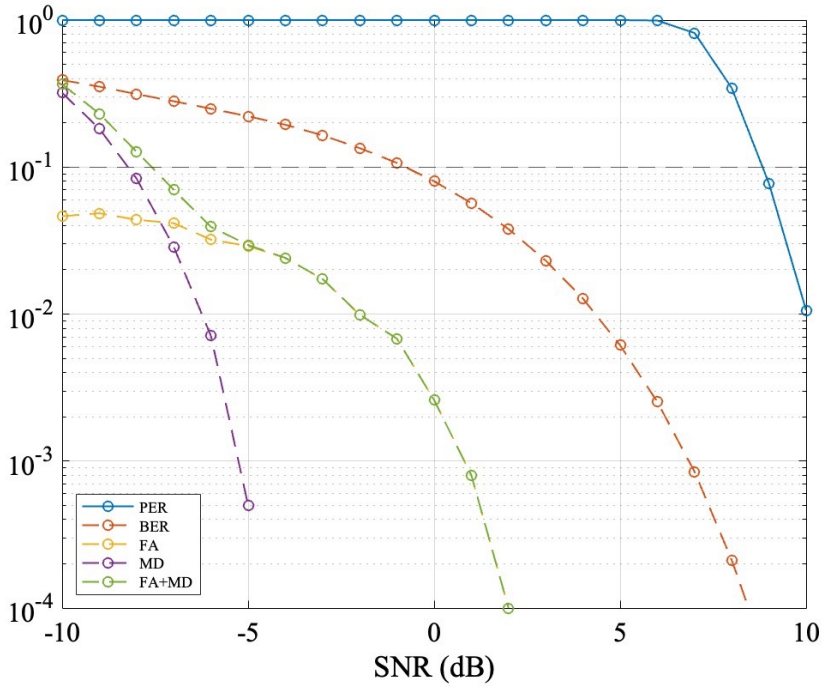
Proposed Golay-based SFD

- The required SNR is 0 dB (received power -133.8 dBm) to achieve error rate of 10^{-1} by using proposed SFD.
- When using Golay-based SFD, approximately 2 dB margin can be gained in frame synchronization compared to 15-25/0150r1SFD

FA, MD Characteristics (BPSK, w/o FEC, AWGN)



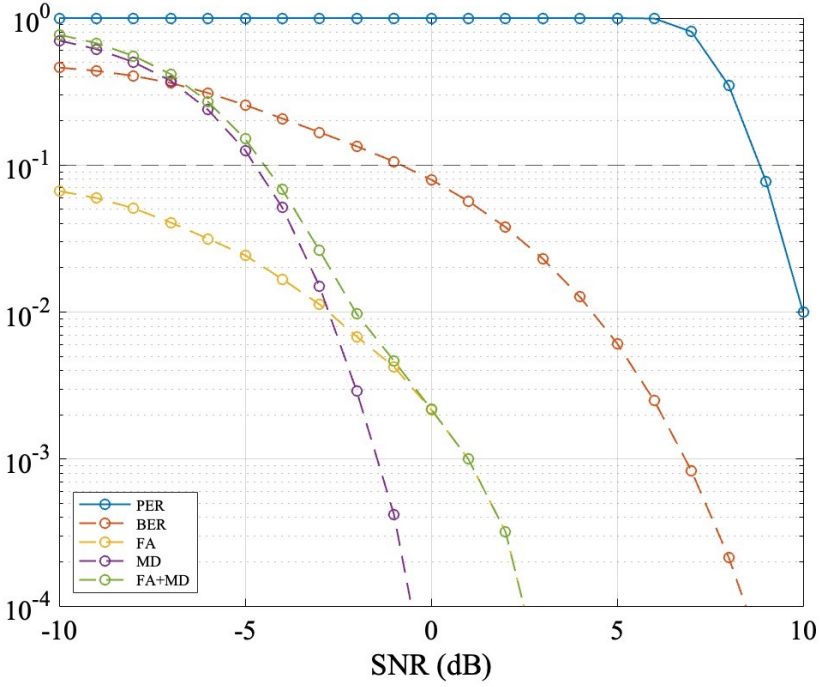
15.4g SFD



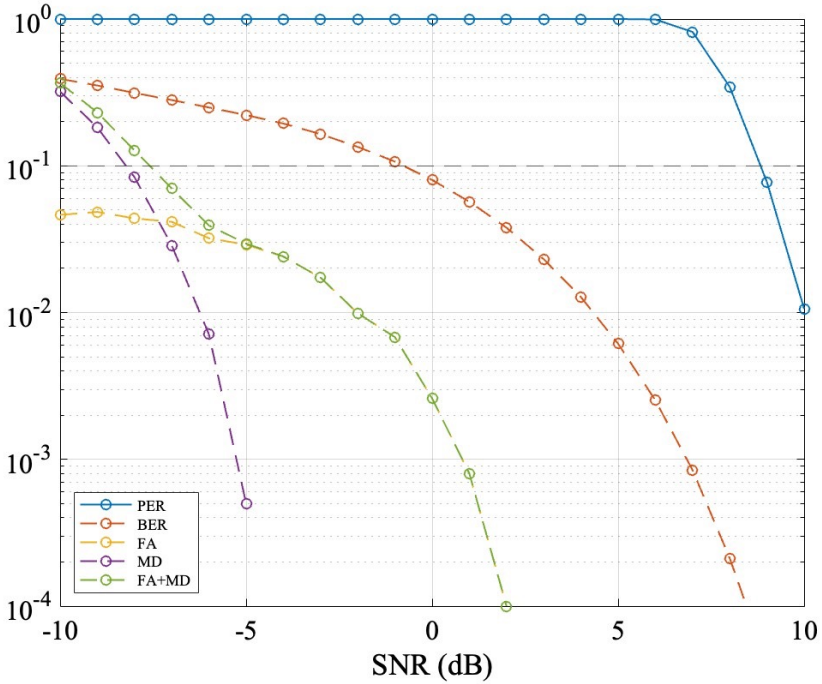
Proposed Golay-based SFD

- The required SNR is -7 dB (received power -140.8 dBm) to achieve error rate of 10^{-1} by using proposed SFD.
- When using Golay-based SFD, approximately 7 dB margin can be gained in frame synchronization compared to 15.4 g SFD

FA, MD Characteristics (BPSK, w/o FEC, AWGN)



15-25/0150r1



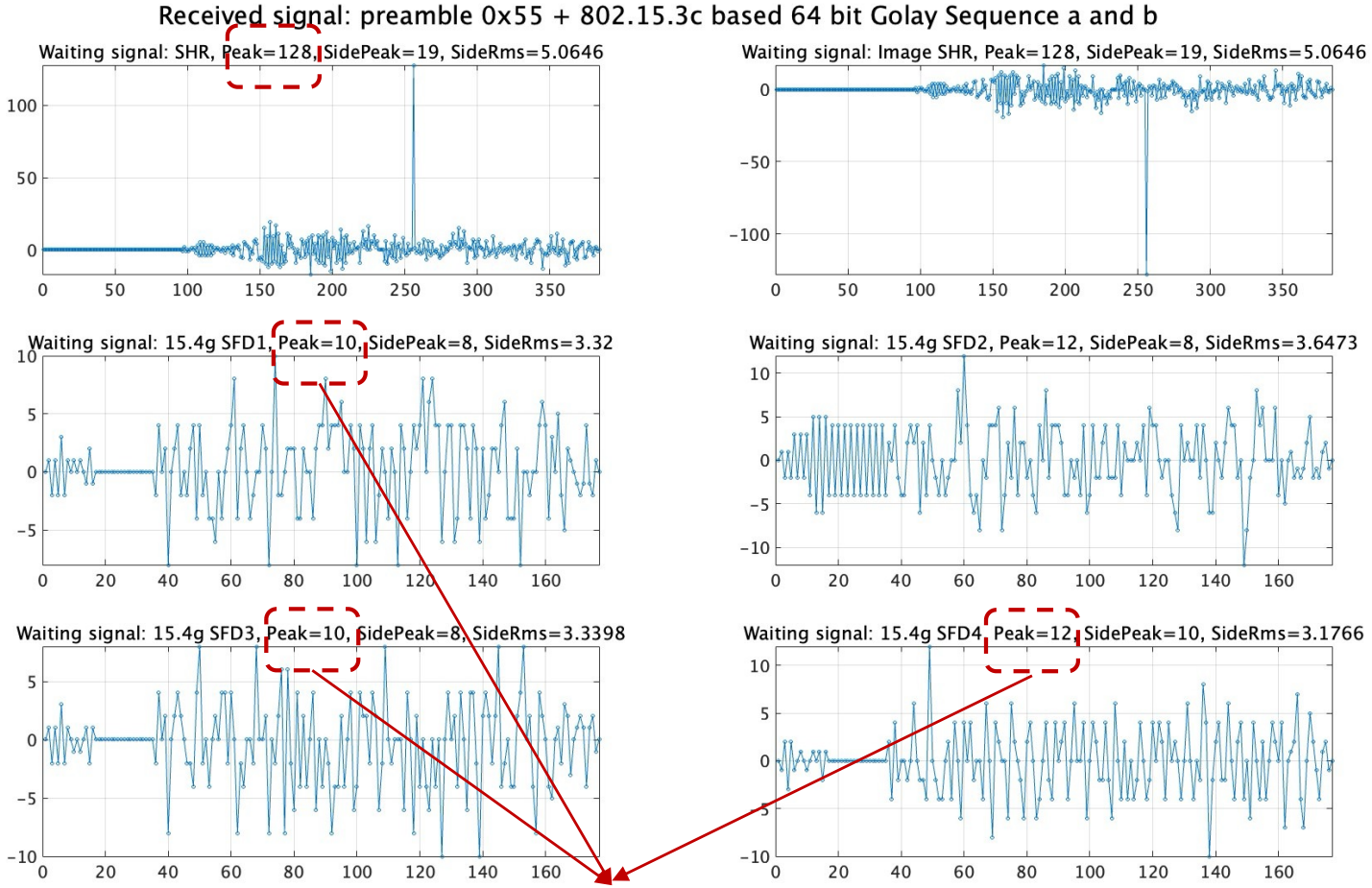
Proposed Golay-based SFD

- The required SNR is -7 dB (received power -140.8 dBm) to achieve error rate of 10^{-1} by using proposed SFD.
- When using Golay-based SFD, approximately 4 dB margin can be gained in frame synchronization compared to 15-25/0150r1SFD

Required SNR and power

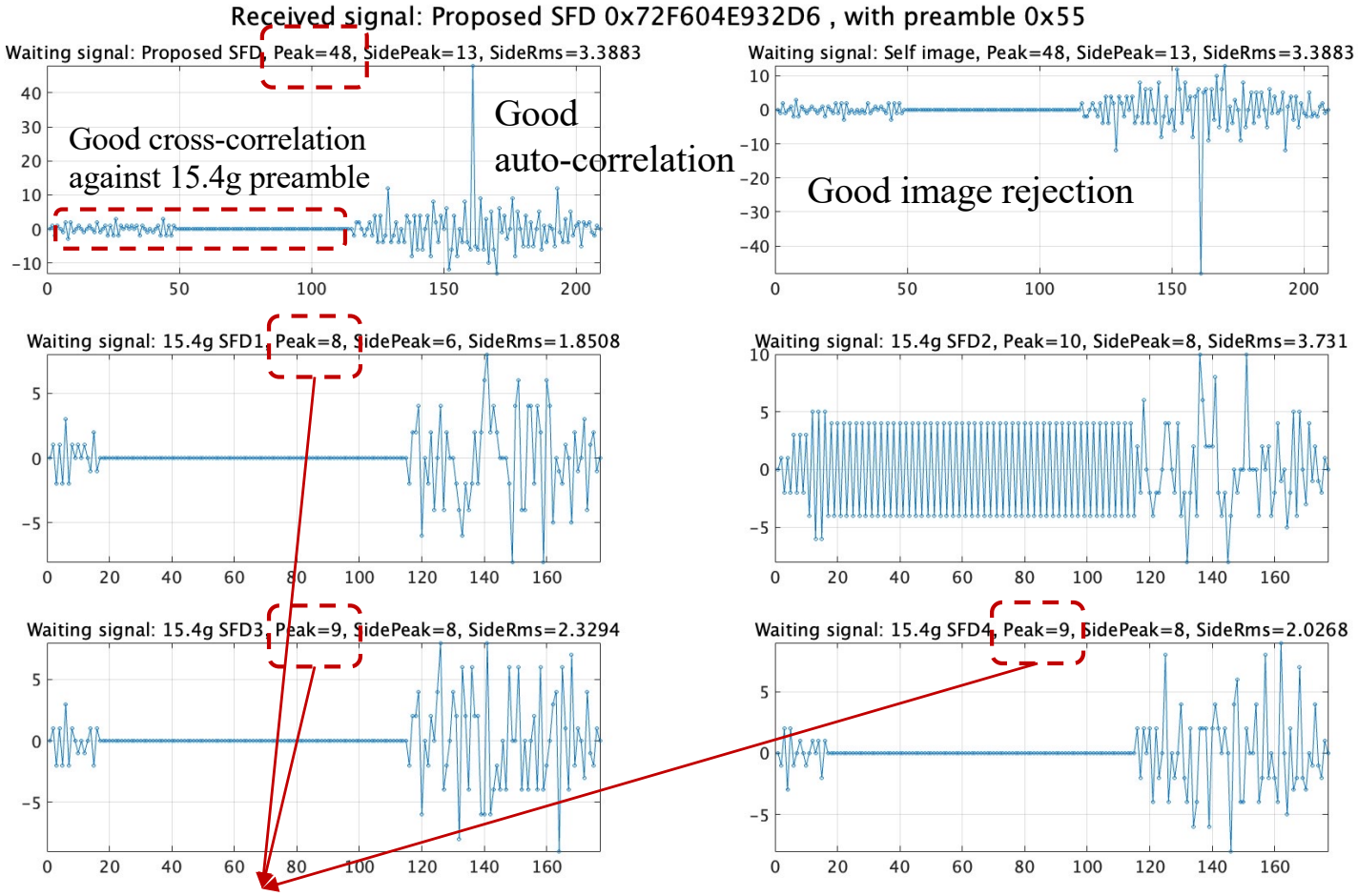
	Required error rate	AWGN	
		Required SNR(dB)	Required power(dBm)
FSK	10^{-1}	0	-133.8
BPSK	10^{-1}	-7	-140.8

Correlation characteristics when using proposed SHR (Kyoto Univ.)



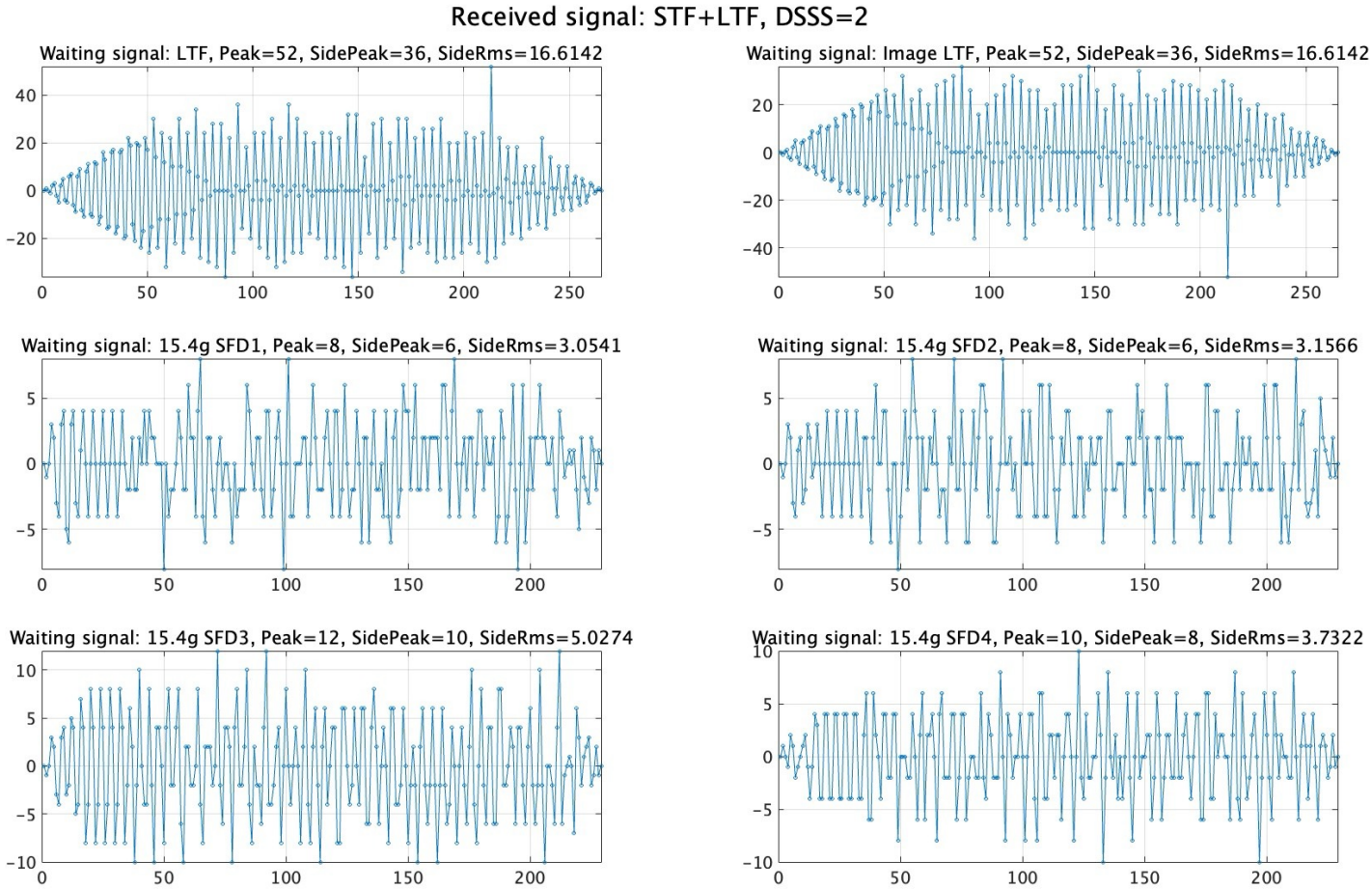
moderate cross-correlation peak with mandatory 15.4g SFD

Correlation characteristics when using 15-25/0150r1 SHR (Kyoto Univ.)



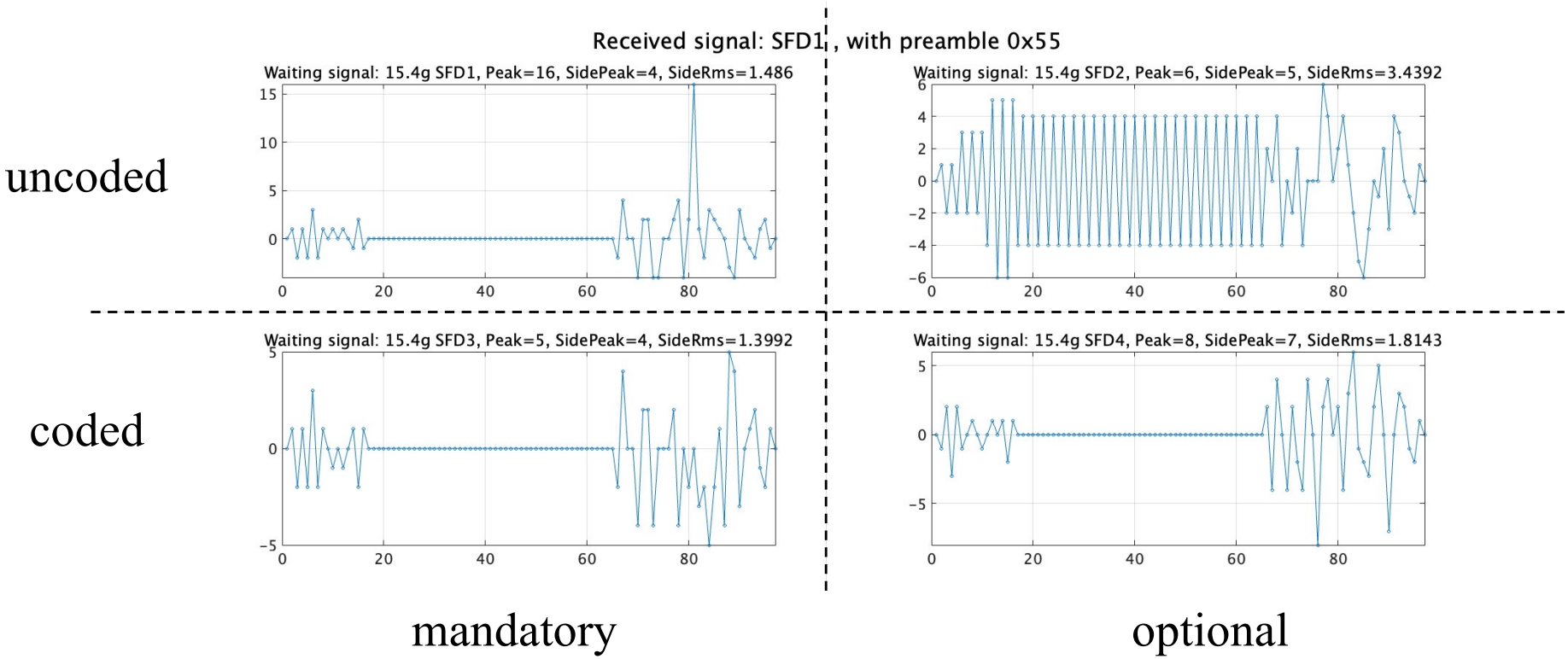
moderate cross-correlation peak with 15.4g SFD

Correlation characteristics when using 15-24/0651r0 (TI)



Correlation characteristics when using 15.4g SFD

- Received signal: 15.4g preamble + 15.4g SFD1 [2]
- Waiting signal: SFD 1,2,3,and 4



Reference

[1] IEEE Computer Society, "IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.3: Amendment 2: Millimeter-wave-based Alternative Physical Layer Extension," in IEEE Std 802.15.3c-2009 (Amendment to IEEE Std 802.15.3-2003) , vol., no., pp. 66, 12 Oct. 2009.

[2] Liru LU, Hiroshi HARADA, Ryuhei FUNADA, Chin-Sean SUM, Design of the Start-Frame-Delimiter Pair for 802.15 Smart Utility Network System, IEICE Transactions on Communications, 2013, Volume E96.B, Issue 3, Pages 730-736, March, 2013.