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

Submission Title: [SFD and FEC proposal]

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Re: [ ]

Abstract: [Propose SFD values and FEC schemes for 802.15.4g standard]

Summary

- This document presents two 16-bit SFDs, and convolution code (R=1/2,K=4).
- SFD: 3 plans are available for FEC and Non-FEC identification

Plan	SFD Value for FEC	SFD value for Non-FEC
A	0xF68D	0x7BC9
B	0x6F4E	0x904E
C	0x21F6	0xC9C2

- FEC:

Mode	R	m	n	k	L	g0	g1
Systematic	1/2	3	2	1	4	{1 1 1 1}	{1 1 0 1}
Non Systematic	1/2	3	2	1	4	{1 1 1 1}	{1 1 0 1}

Proposal on SFD

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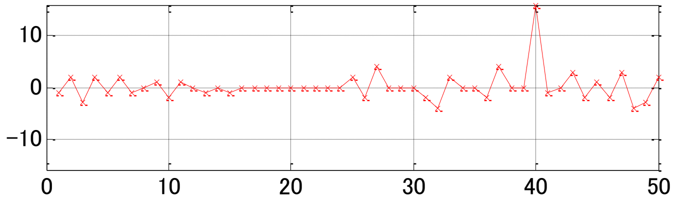
Plan	SFD Value for FEC mode	SFD value for Non-FEC mode
A	0xF68D	0x7BC9
B	0x6F4E	0x904E
C	0x21F6	0xC9C2

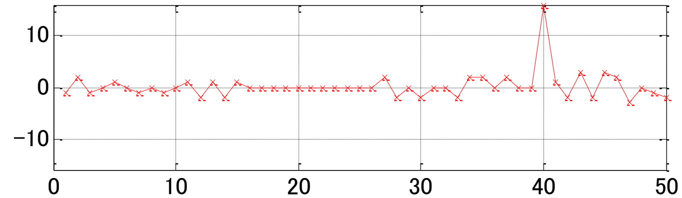
- Reasons to select the SFD values
  - Plan A: Good auto- and cross- correlation values with moderate peak in 15.4d SHR
  - Plan B: Good FA (false alarm) and MD (Miss detection) probabilities with moderate peak in 15.4d SHR
  - Plan C: Better FA and MD probabilities than option B with higher peak in 15.4d SHR
  - Note: Shall attain lower FA and MD probabilities when FEC is used for payload
- Topic to be clarified: Robustness of the selected SFD when FEC is used
  - Should attain robustness so that the performance is negligible against payload performance

Correlation performance of Plan A (a=0xF68D, b=0x7BC9)

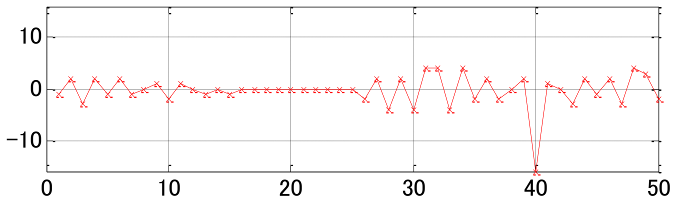
- Left figs: Correlation values between a and 15.4g preamble (24 bit) + a, -a, b, or -b
- Right figs: Correlation values between b and 15.4g preamble (24 bit) + a, -a, b, or-b
- Note: maximal correlation values between 15.4d-preamble+15.4d-SFD and a, -a, b, or –b are 6



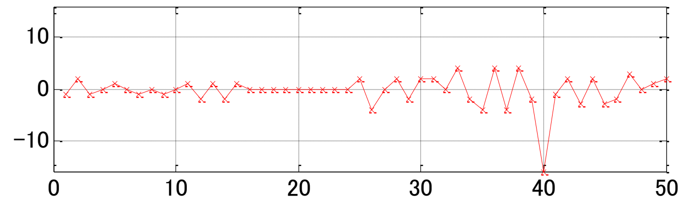
Auto correlation a, SidePeak=4,SideRms=1.6013



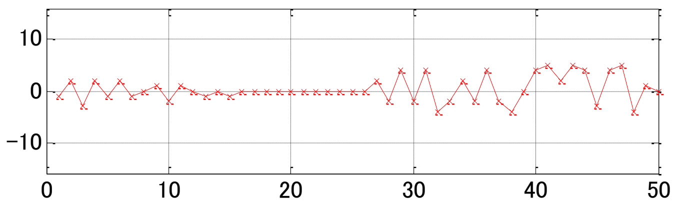
Auto correlation b, SidePeak=2,SideRms=1.1094



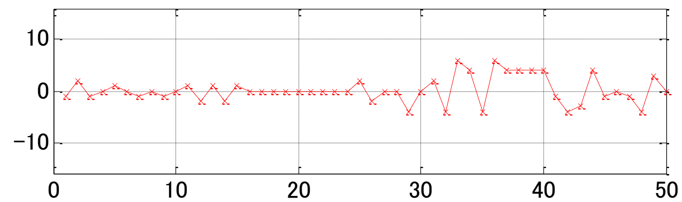
Auto correlation image a, SidePeak=4,SideRms=2



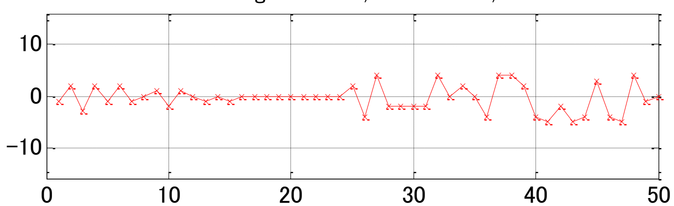
Auto correlationstd image b, SidePeak=4,SideRms=1.9215



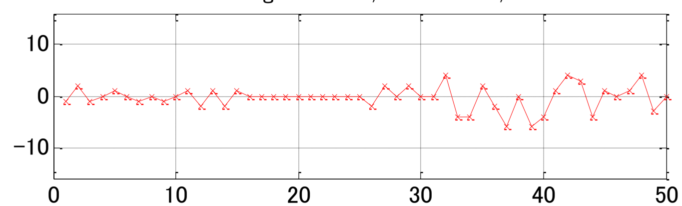
Cross correlation b with a, SidePeak=4,SideRms=1.9748



Cross correlation a with b, SidePeak=6,SideRms=2.4083



Cross correlation image b with a, SidePeak=4,SideRms=2.0736

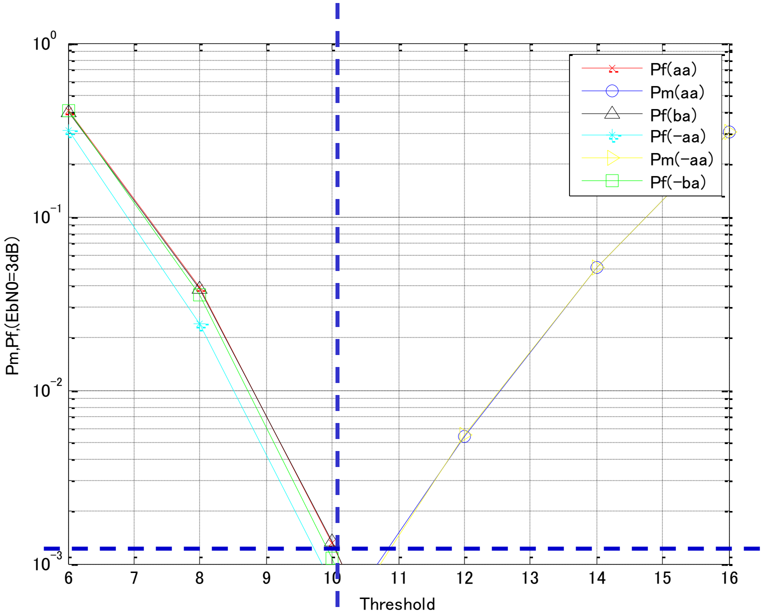


Cross correlation image a with b, SidePeak=6,SideRms=2.0976

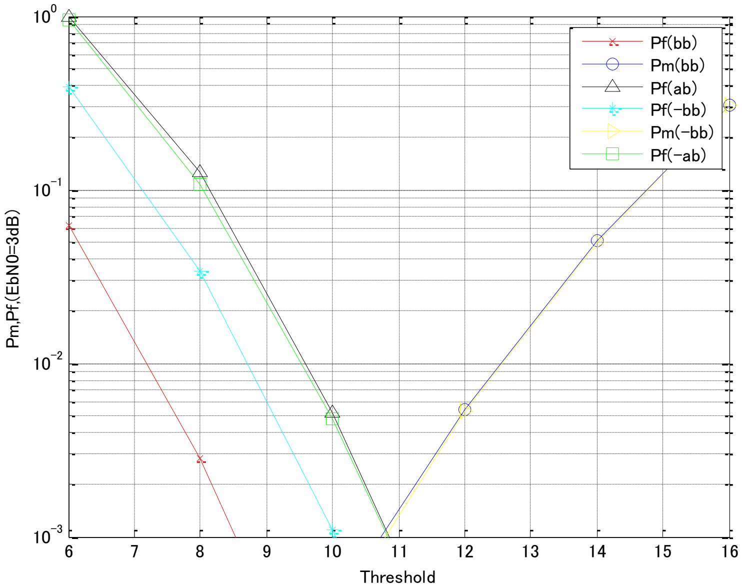
MD and FA probabilities (Pm and Pf) Plan A (a=0xF68D, b=0x7BC9) at Eb/N0=3dB

From left figure, the optimum threshold is equal to 10. Then, we can achieve error rate of 1.3 x 10^{-3}. If PER performance of payload is higher than 1.3 x 10^{-3} at Eb/No =3dB the selected SFD is robust enough not to affect payload performance.

- Correlator values: a



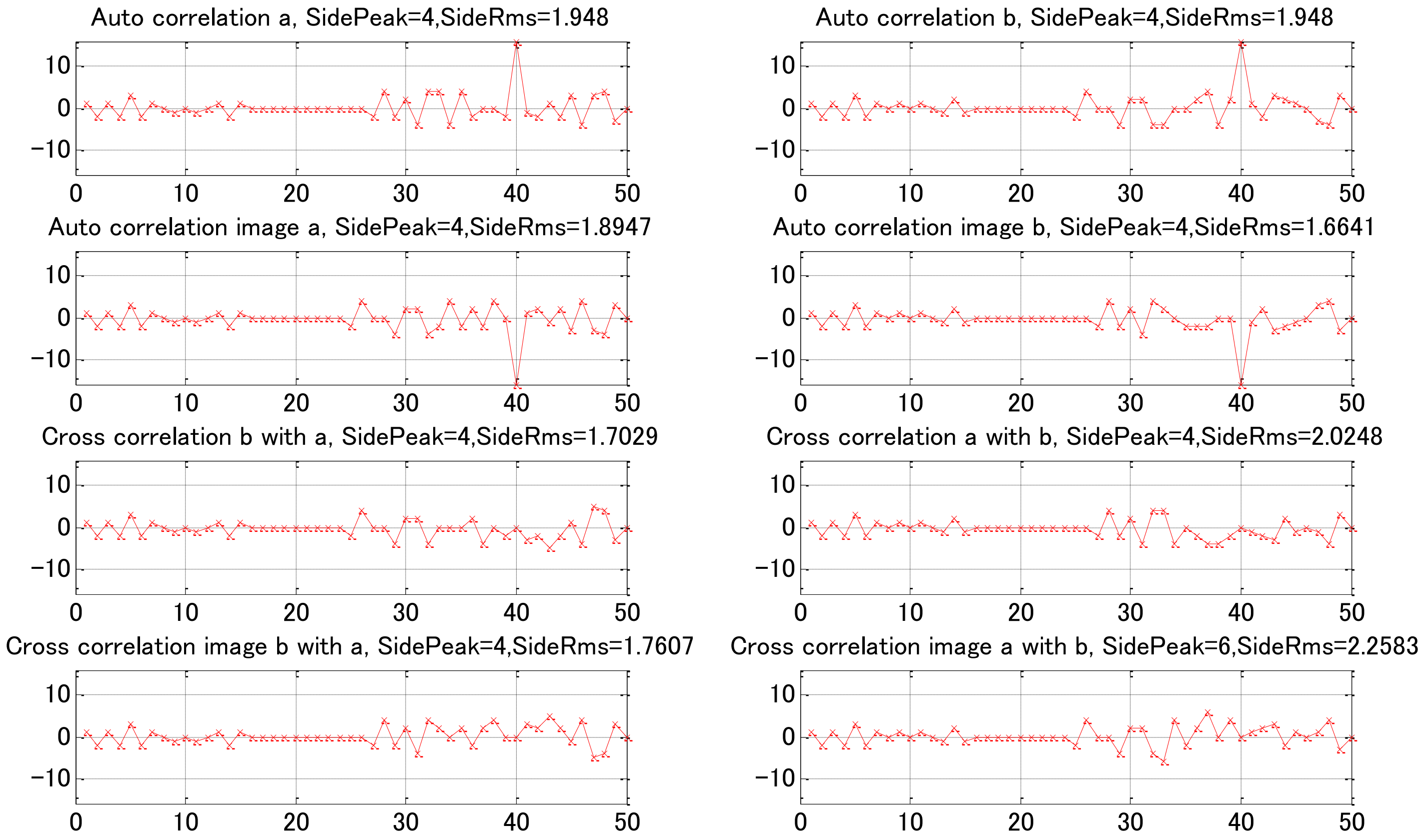
- Correlator values: b



Pf(xy) denotes that Input signal in correlators is Preamble + x and correlator values are y

Correlation performance of Plan B (a=0x6F4E, b=0x904E)

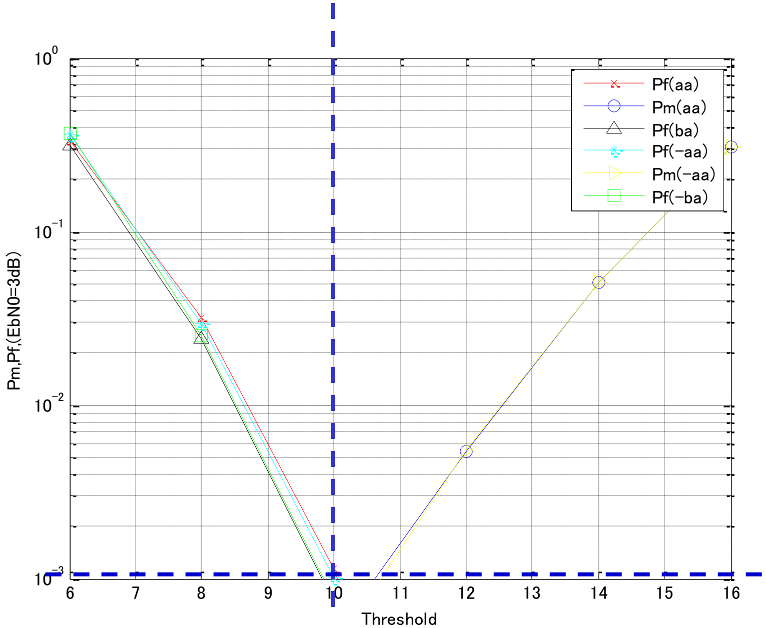
- Left figs: Correlation values between a and 15.4g preamble (24 bit) + a, -a, b, or -b
- Right figs: Correlation values between b and 15.4g preamble (24 bit) + a, -a, b, or-b
- Note: maximal correlation values between 15.4d-preamble+15.4d-SFD and a, -a, b, or –b are 4



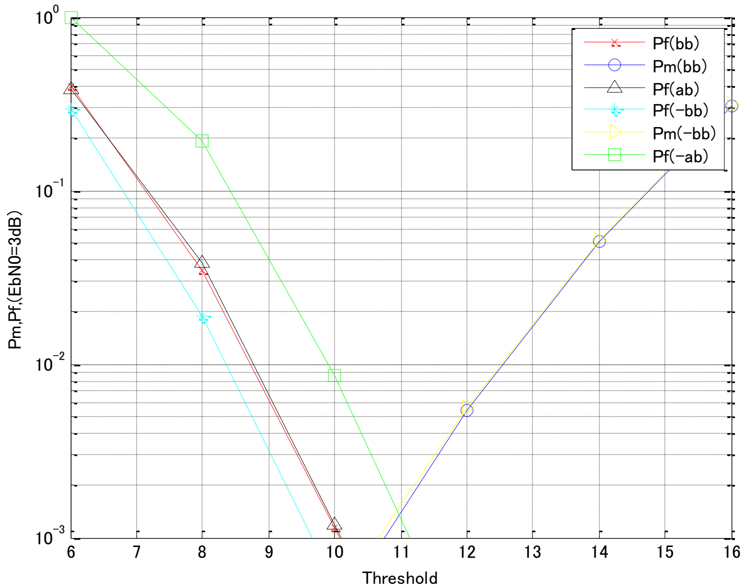
MD and FA probabilities (Pm and Pf) -Plan B (a=0x6F4E, b=0x904E) at Eb/N0=3dB-

From the left figure, the optimum detection threshold is equal to 10. Then, we can achieve error rate of 1.1 x 10^{-3}. If PER performance of payload is higher than 1.1 x 10^{-3} at Eb/No =3dB, the selected SFD is robust enough not to affect payload performance.

- Correlator values: a



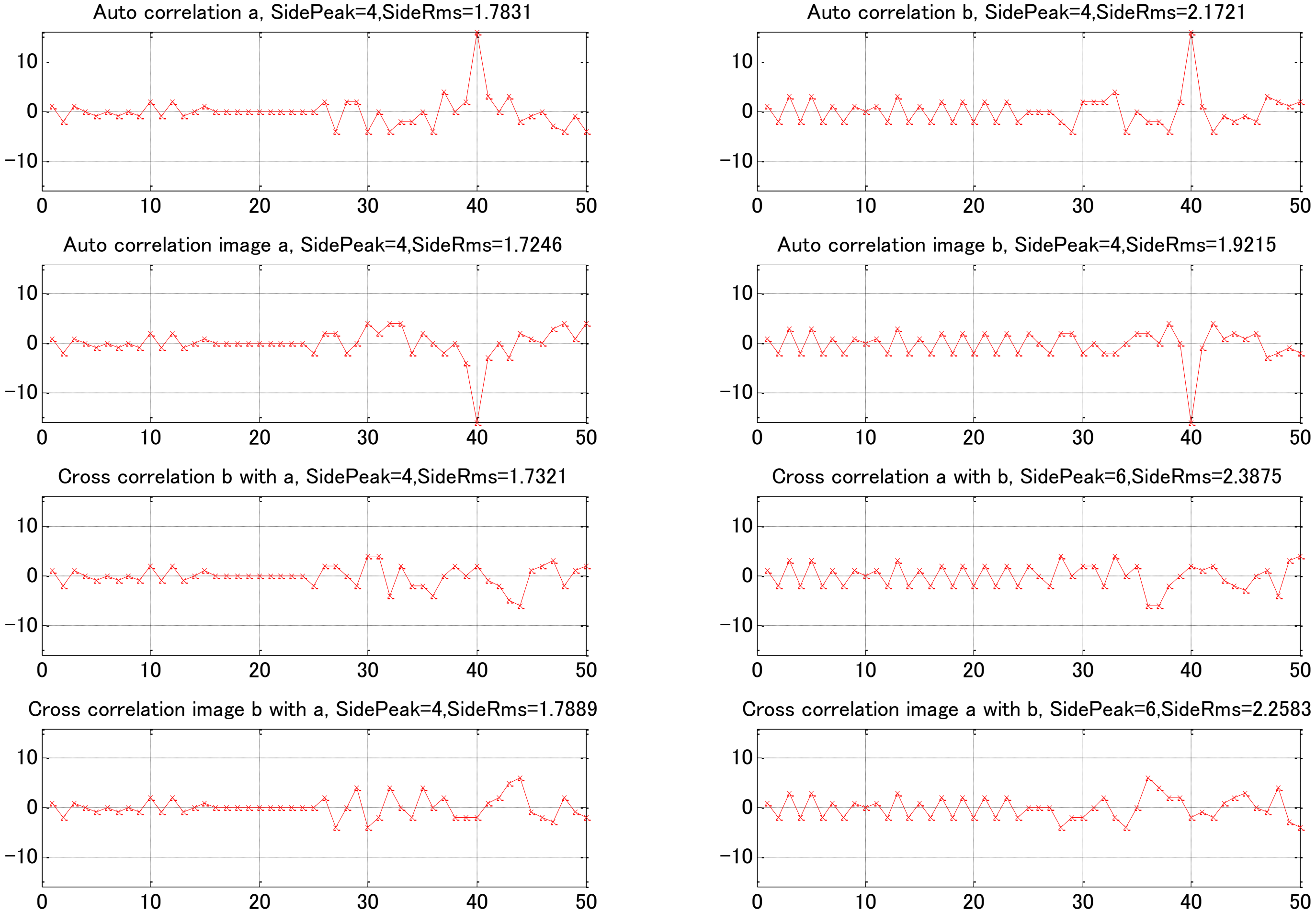
- Correlator values: b



Pf(xy) denotes that Input signal in correlators is Preamble + x and correlator values are y

Correlation performance of Plan C(a=0x21F6, b=0xC9C2)

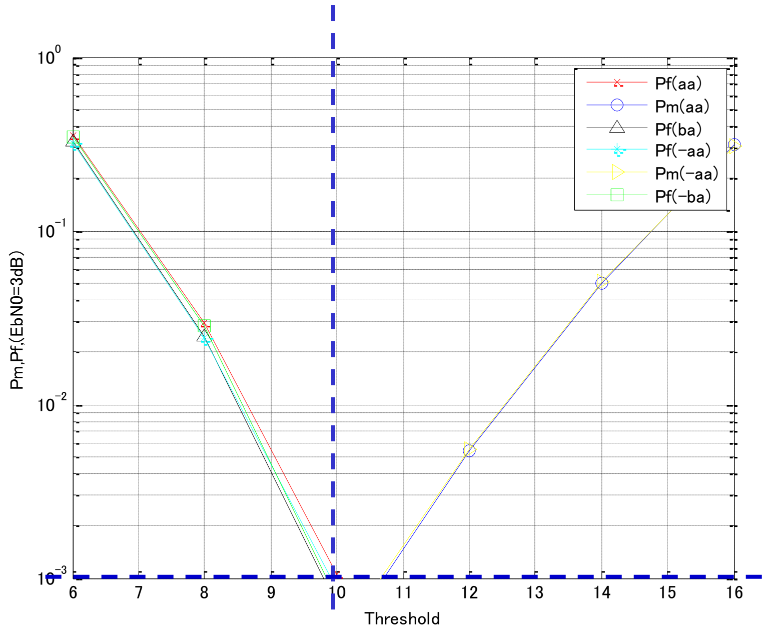
- Left figs: Correlation values between a and 15.4g preamble (24 bit) + a, -a, b, or -b
- Right figs: Correlation values between b and 15.4g preamble (24 bit) + a, -a, b, or-b
- Note: maximal correlation values between 15.4d-preamble+15.4d-SFD and a, -a, b, or –b are 6



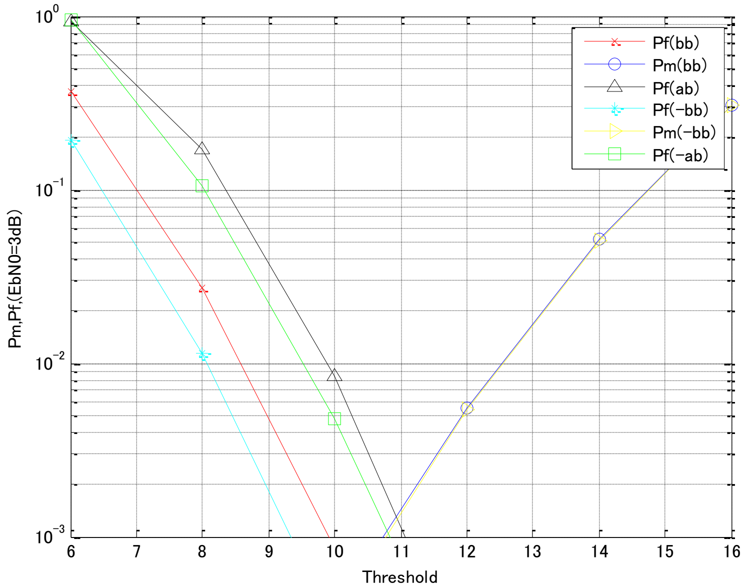
MD and FA probabilities (Pm and Pf) -Plan C(a=0x21F6, b=0xC9C2) at Eb/N0=3dB-

From the left figure, the optimum detection threshold is equal to 10. Then, we can achieve error rate of 1.0×10^{-3}. If PER performance of payload is higher than 1.0×10^{-3} at Eb/No =3dB, the selected SFD is robust enough not to affect payload performance.

- Correlator values: a



- Correlator values: b

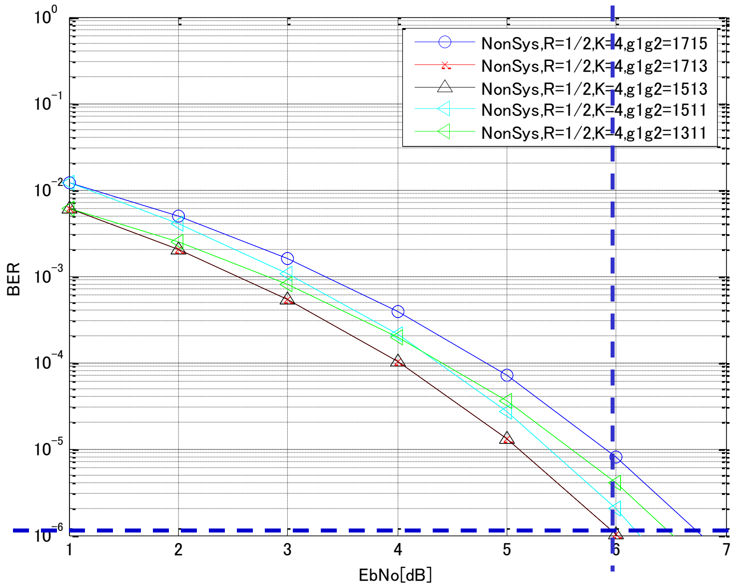


Pf(xy) denotes that Input signal in correlators is Preamble + x and correlator values are y

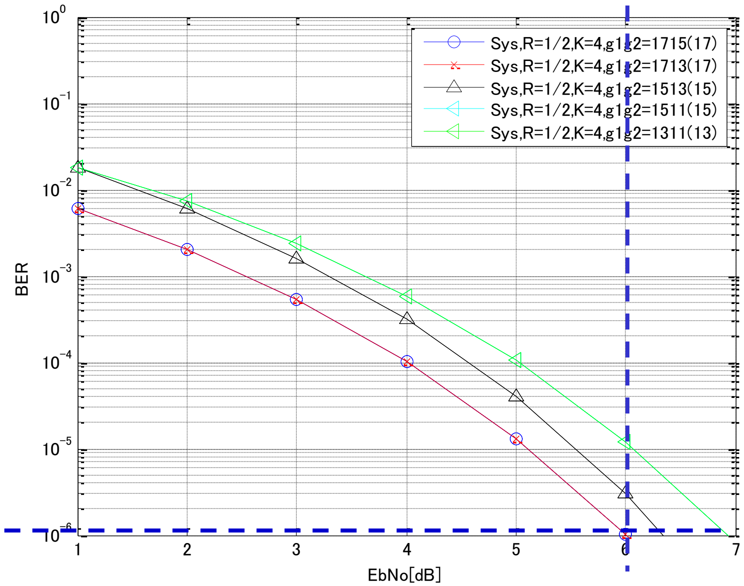
PER performance of payload when used FEC

We can achieve bit error rate (BER) of 1.0 x 10^{-6} at Eb/No=6dB (CNR=3dB) when using the convolutional code (R=1/2, K=4). When the payload length is 1500 byte, payload packet error rate (PER) amounts to 1.2 x 10^{-2} . Since error rate of start frame delimiting by the SFD (1.3 x 10^{-3} 1.1 x 10^{-3} or 1.0 x 10^{-3}) at Eb/No=3 dB (CNR=3dB) is better than the PER at the same CNR, the SFD offers sufficient robustness even when FEC is used in payload.

Non-systematic convolutional code (R=1/2,K=4)



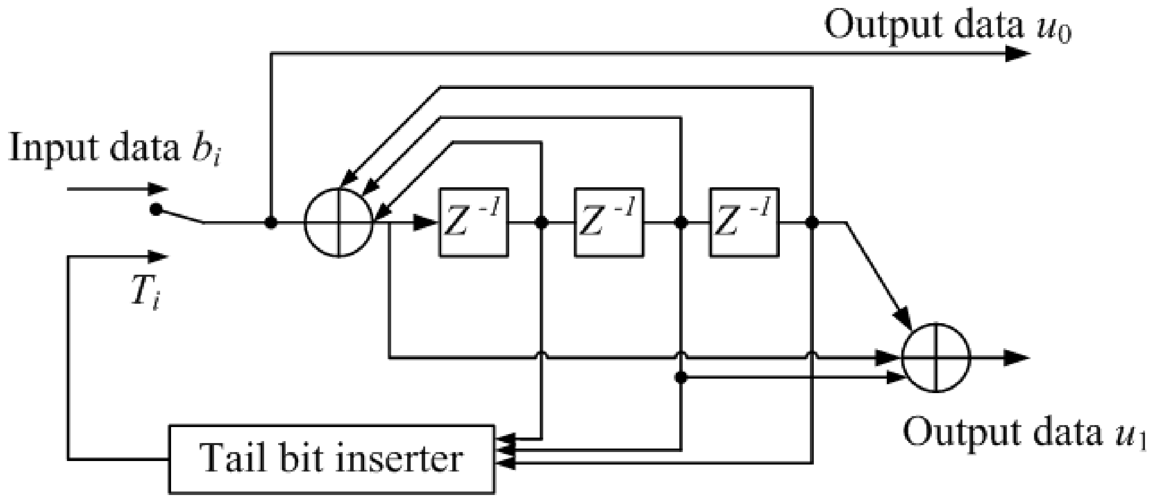
Systematic convolutional code (R=1/2,K=4)



Proposal on FEC

Proposed FEC

- Configuration: r = 1/2 , m =3, n = 2, k = 1, L = 4, g0={1 1 1 1}, g1={1 1 0 1}; and feedback connection is set to g1 as shown in the following figure.
  - Free distance is the same as non-systematic convolutional code, which can be calculated from built-in matlab function ‘distspec’.
- Tail-bits are inserted according to the shift register values in order to set final state to be 0.

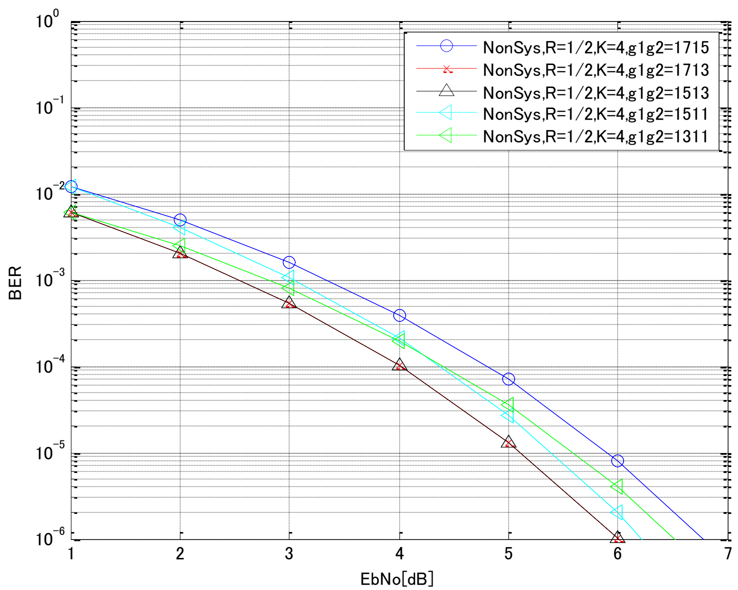


BER performance

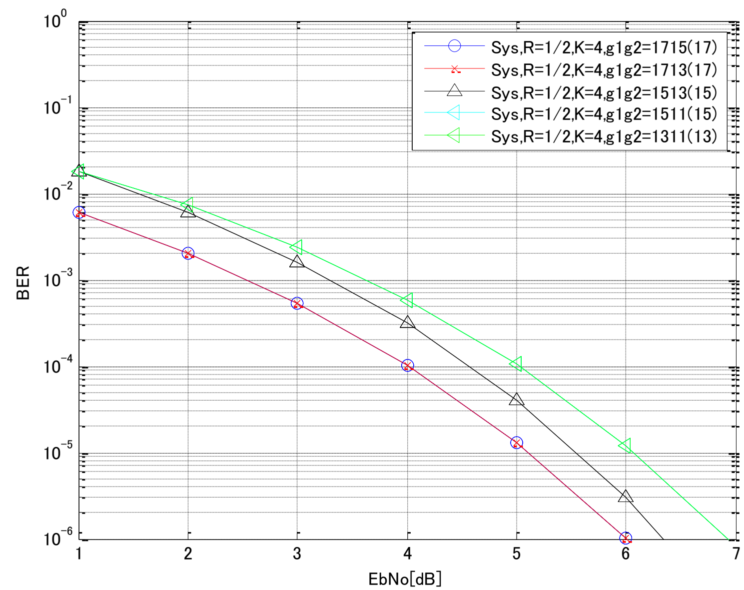
•Same bit-error performance between sys. conv. [g0,g1]= [17 13,17] and non-sys. conv. [g0,g1]= [17 13]

•Both offers the best performance (Eb/N0=6dB at BER=10^-6) in all

Non-systematic convolutional code (R=1/2,K=4)



Systematic convolutional code (Feedback is g0) (R=1/2,K=4)



Reasons to use systematic code

- Merits when envisaged an environment where there are mixed users that have non-FEC mode only and both non-FEC and FEC modes, respectively and some of users are near transmitter and others are far from transmitter
  - If used systematic codes, the transmitters have only to send the data encoded by the systematic codes and **the receivers can select decoding methods of the received data by using redundancy bit or not. Systematic code based system also permits users to have only non-FEC mode**
  - If used non-systematic codes, the transmitter needs to decide whether the transmitter uses coding or not in advance and all of users need to have FEC decoding function. **Non-Systematic code based system can not permit users who have only non-FEC mode**

– **Both Systematic and non-systematic convolutional coding have merits and demerits, so the proposal for IEEE802.15.4g may need to combine both of them**

FEC Proposal for IEEE 802.15.4g (1/2)

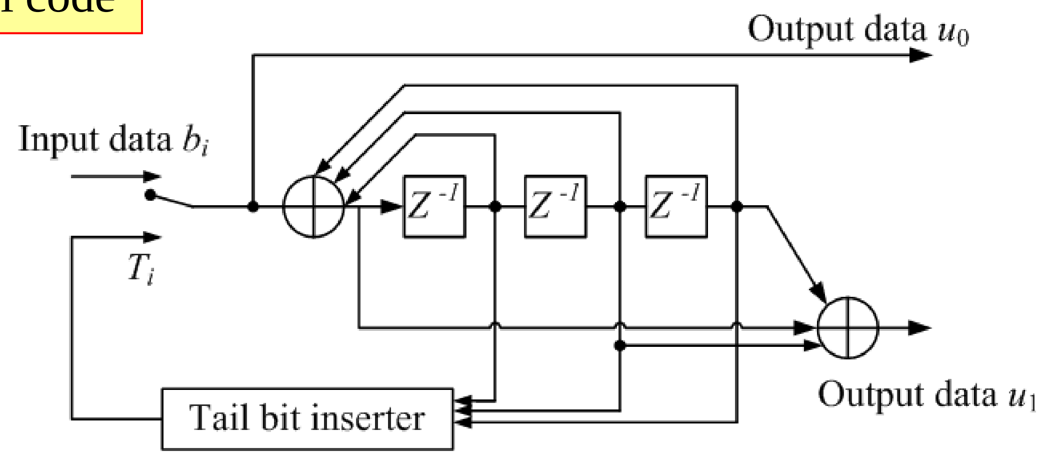
- Two convolutional codes will be optional FEC

Mode	R	m	n	k	L	g0	g1
Systematic	1/2	3	2	1	4	{1 1 1 1}	{1 0 1 1}
Non Systematic	1/2	3	2	1	4	{1 1 1 1}	{1 0 1 1}

R: Coding rate
m: number of memory registers
n: number of output bits
k: input bits
L: Constraint length (n+1)
g0: Connection vector 0
g1: Connection vector 1

FEC Proposal for IEEE 802.15.4g (2/2)

Systematic convolutional code



Convolutional code