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Performance Analysis of Multi-pulse PPM for Optical Wireless Hierarchical Transmission System

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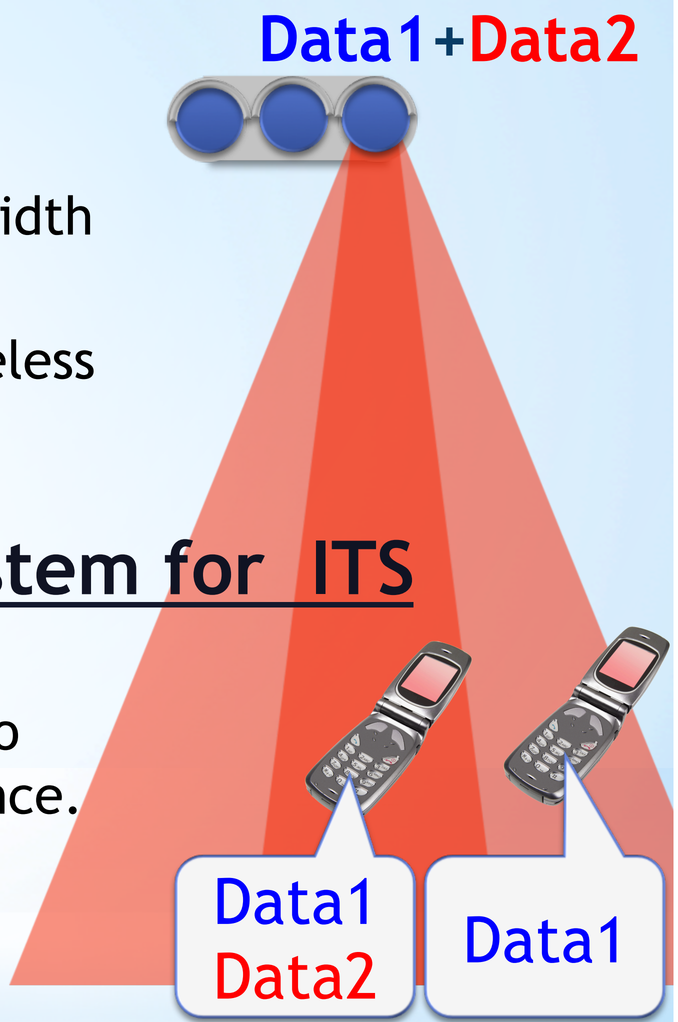
*Optical wireless (OW) broadcasting

- **Advantages**
  - ✓ High information capacity
  - ✓ Worldwide available and unlicensed bandwidth
  - ✓ Does not interfere with radio bands

  Promising supplement to already existing wireless RF technologies.



- **OW hierarchical Transmission system for ITS**
  [Yamazato,2007][Oka, 2008]

  - the broadcasted messages can be divided into two or more classes according to its importance.

  ✓ **The important information(Data1)** must be recovered by all receivers.

  ✓ **The less important information(Data2)** can only be recovered by the "fortunate" receivers.

*Hierarchical transmission system

Ways to realize the Optical wireless Hierarchical transmission

Fusion modulation using Intensity Modulation(IM)	Hierarchical Constellations using subcarrier IM	Hierarchical coding using Image enhancement
✓ Compatible with on-off signaling ✓ Low immunity against ambient noise ✓ Photo-Diode(PD)	✓ Robust system for ambient noise ✓ Requires higher optical clock rate ✓ PD and Image sensor	✓ Robust system for ambient noise ✓ Parallel processing ✓ Image sensor

We focus on the Fusion modulation (most simple way).

* We propose new hierarchical MPPM modulation.
* Moreover, we evaluate the proposed system taking into account optical wireless noises.

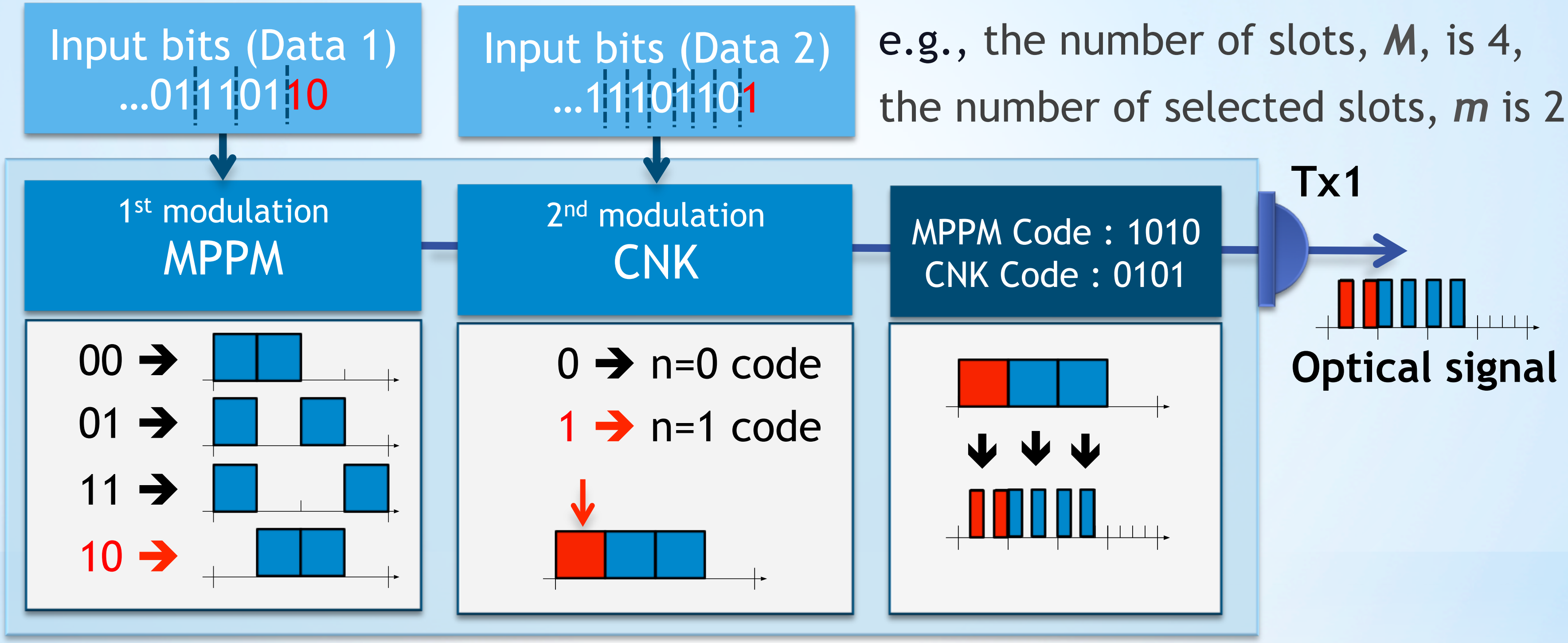
*MPPM : Multi-pulse Pulse Position Modulation

Contents

*Transmitter and symbol structure

- **Combine multi-pulse PPM (MPPM) with code number keying (CNK)**

e.g., the number of slots, *M*, is 4, the number of selected slots, *m* is 2.



Step 1) According to data1, ***m* slots are selected** from *M* slots.

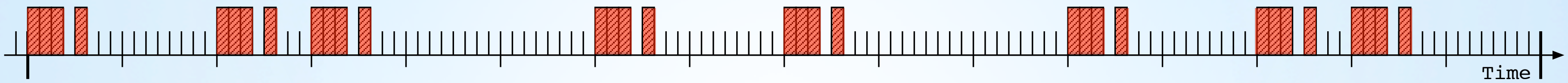
Step 2) According to data2, ***n* slots are selected from *M-m* slots**(no overlap).

Step 3) ***m* MPPM codes are generated in the *m* slots**,

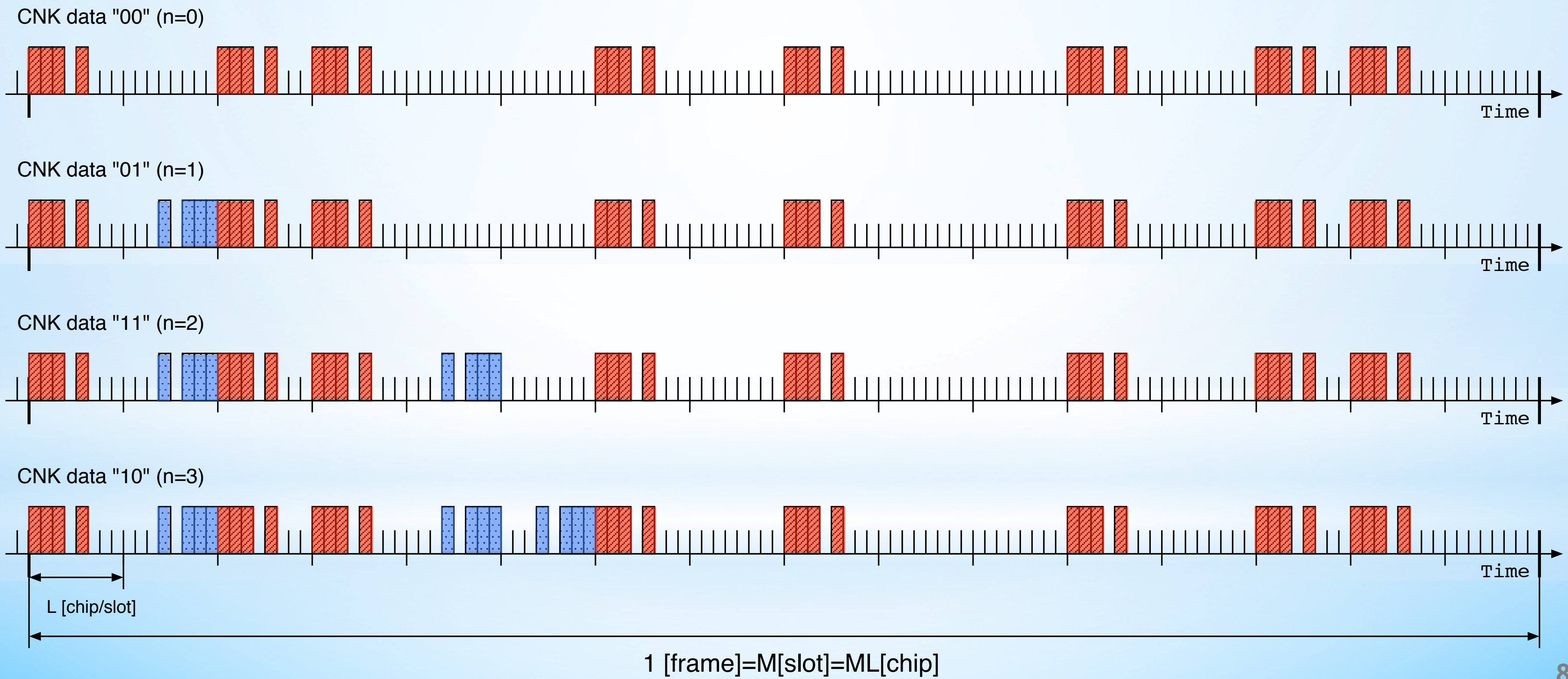
while ***n* CNK codes are generated in the *n* slots**.

*Symbol structure

Conventional MPPM system (M=16,m=8) PN for MPPM (11101000)



Proposed system (M=16,m=8,N=4) PN for MPPM (11101000), PN for CNK (00010111)



*Codes for MPPM and CNK

- Modified pseudo orthogonal M-sequence sets (kozawa 2007)
  - For example when code length, L, is 4,

$$PN = \begin{bmatrix} PN_1 \\ PN_2 \\ PN_3 \end{bmatrix} = \begin{bmatrix} 1,0,1,0 \\ 1,1,0,0 \\ 1,0,0,1 \end{bmatrix}, \quad \overline{PN} = \begin{bmatrix} \overline{PN_1} \\ \overline{PN_2} \\ \overline{PN_3} \end{bmatrix} = \begin{bmatrix} 0,1,0,1 \\ 0,0,1,1 \\ 0,1,1,0 \end{bmatrix}, \quad RC = PN - \overline{PN} = \begin{bmatrix} +1,-1,+1,-1 \\ +1,+1,-1,-1 \\ +1,-1,-1,+1 \end{bmatrix}$$

  - Code characteristics

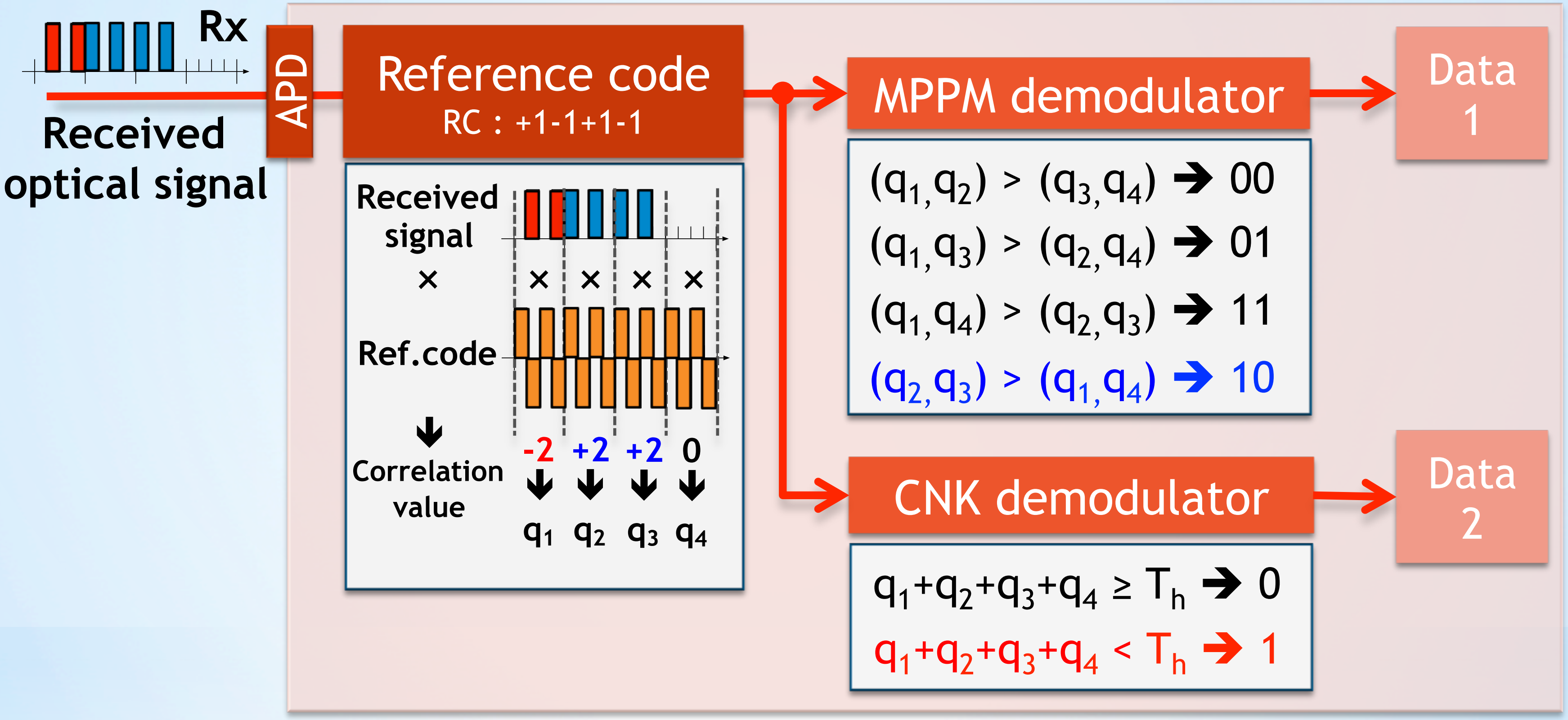
$$PN \, RC^{-1} = \frac{L}{2} E \, , \qquad \overline{PN} \, RC^{-1} = -\frac{L}{2} E$$

L : code length
E : unit matrix

- Code for MPPM and CNK ;
  - *PN* is used for MPPM
  - $\overline{PN}$ is used for CNK
  - *RC* is used for the reference code at the receiver

Receiver and symbol detection

- Demodulate MPPM data and CNK data individually



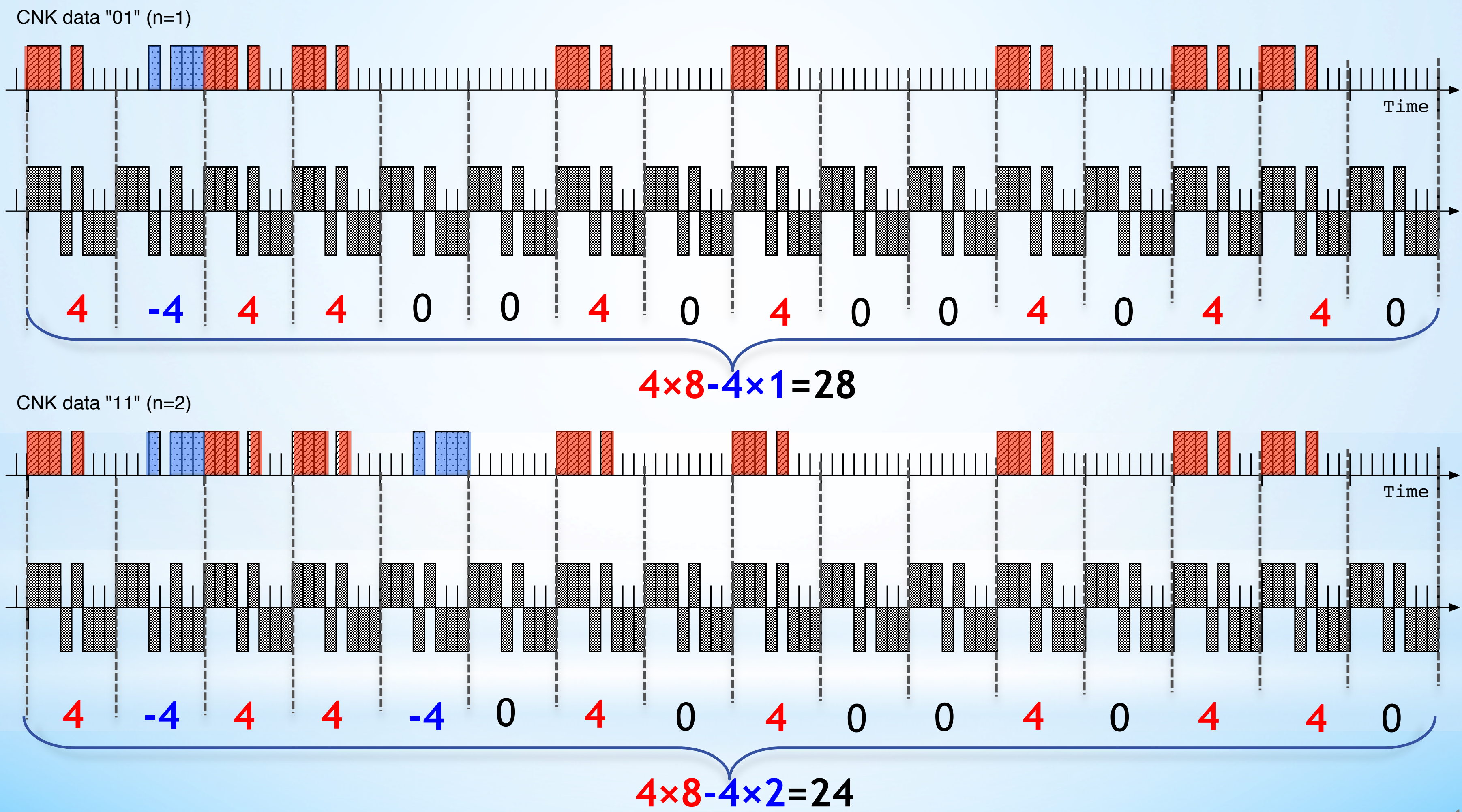
Step 1) Received signal is correlated by the reference code in each slot.

Step 2) MPPM symbol is declared by **selecting *m* correlation values**, which are larger than the other ***M-m*** correlation values.

Step 3) CNK symbol is declared by threshold detection with the magnitude of sum of ***M*** correlation values.

* Symbol detection

Proposed system (M=16,m=8,N=4) PN for MPPM (11101000), PN for CNK (00010111)



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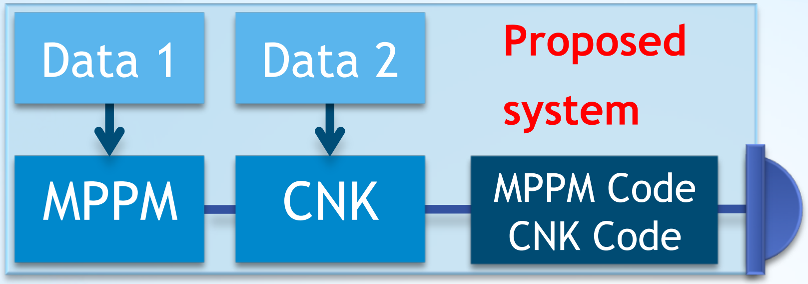
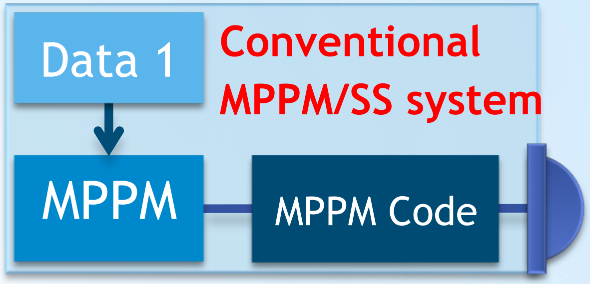
*Evaluation : DTR and SER

- Comparing the proposed system with the conventional MPPM system





- Numerical conditions

Transmitter		Laser wavelength	830 [nm]	OW channel	Scintillation model	Log-normal Turbulence
Transmitter		Optical clock rate	120 [MHz]	OW channel	Scintillation logarithm variance	σ_s^2=0.01
Transmitter		Code length : L	L=16	OW channel	Background noise	P_b=-45 [dBm]
Transmitter		Modulation extinction ratio	100	Receiver	APD Gain	100
Transmitter	MPPM	The num.of MPPM slots : ***M***	16,32	Receiver	Quantum efficiency	0.6
Transmitter	MPPM	The num.of selected slots : ***m***	1,…,*M*-1	Receiver	Receiver load resistor	1030 [Ω]
Transmitter	CNK	The maximum num.of selected slots : ***N***	*M*-*m*+1	Receiver	Receiver noise temperature	1100 [°K]

*Result : DTR

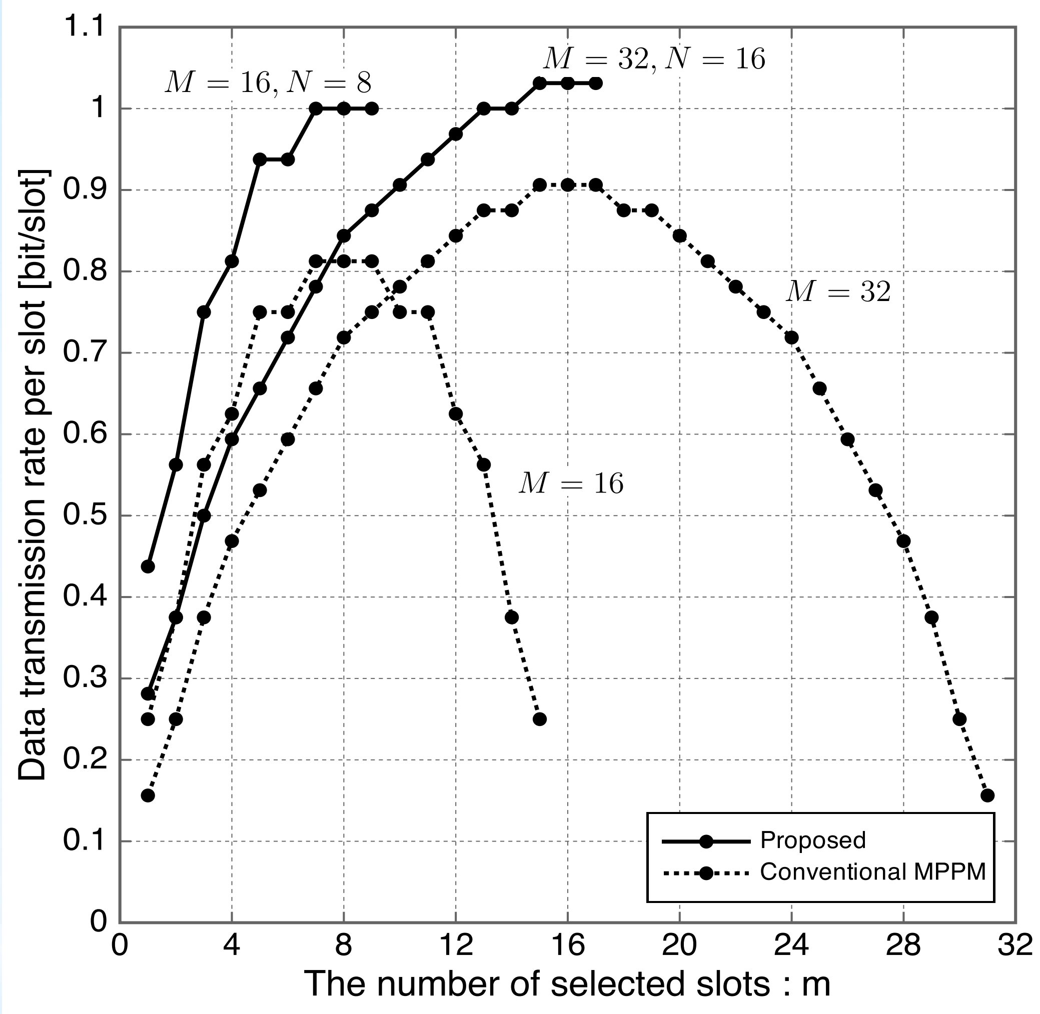


Fig.1, DTR vs. m

- ✓ DTR of the proposed system is better than that of the conventional MPPM system.
- ✓ DTR can achieve upper bound when the *m* is half of *M*.
- ✓ DTR of the conventional MPPM system is decreases when m is larger than half of *M*.

*Result : SER vs. P_{bit} (M=16,m=8)

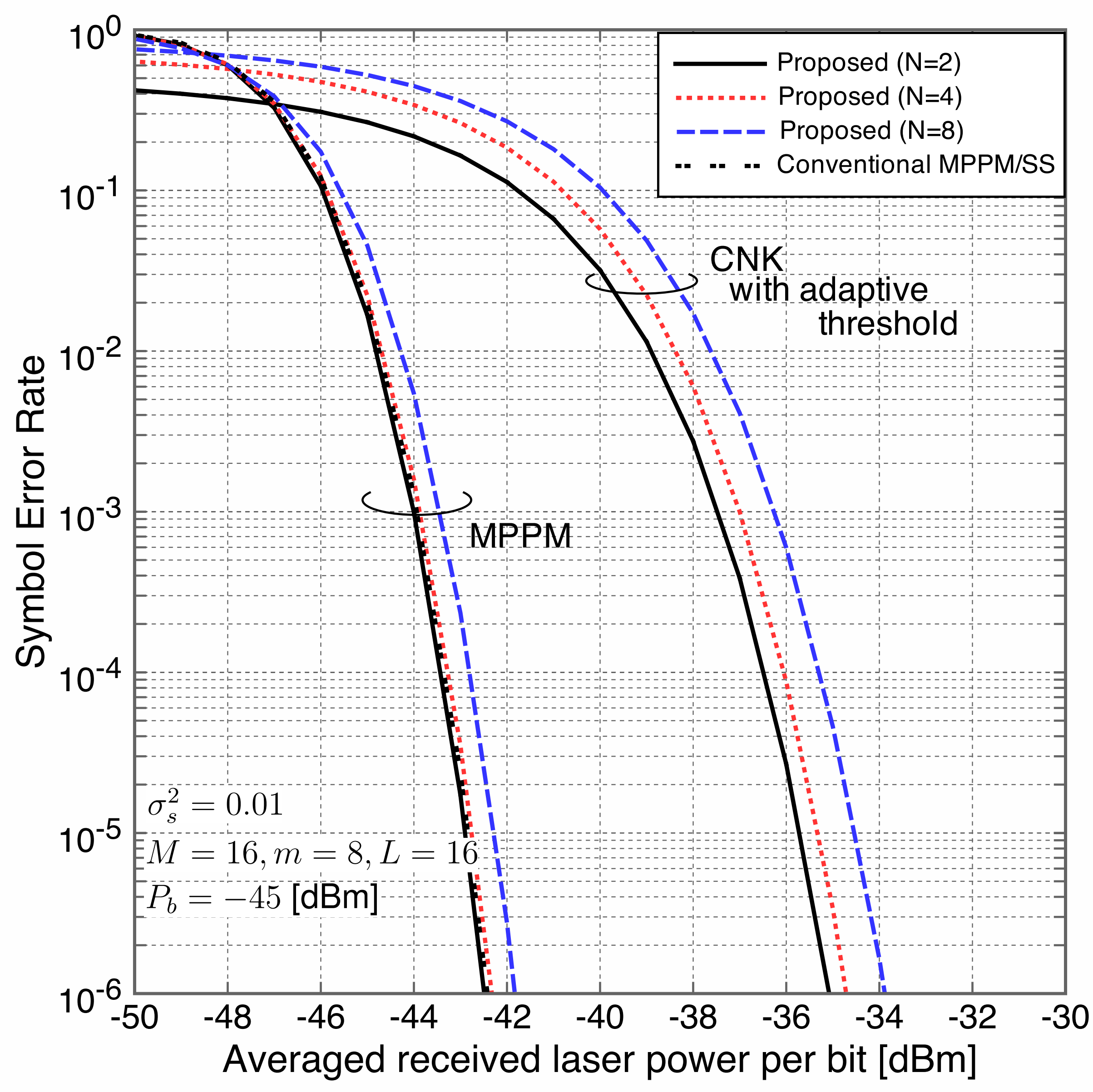
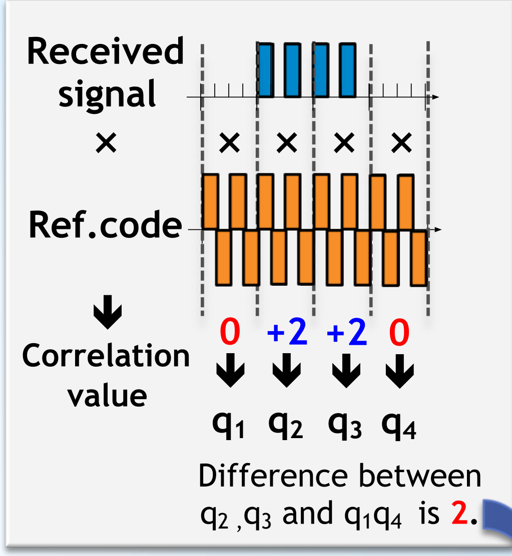
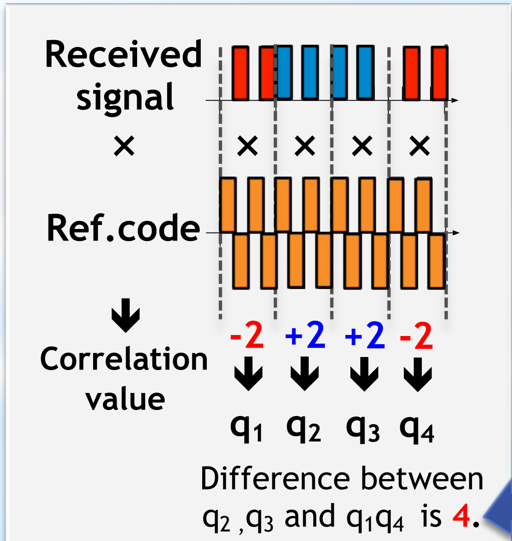


Fig.2, SER vs. P_{bit}

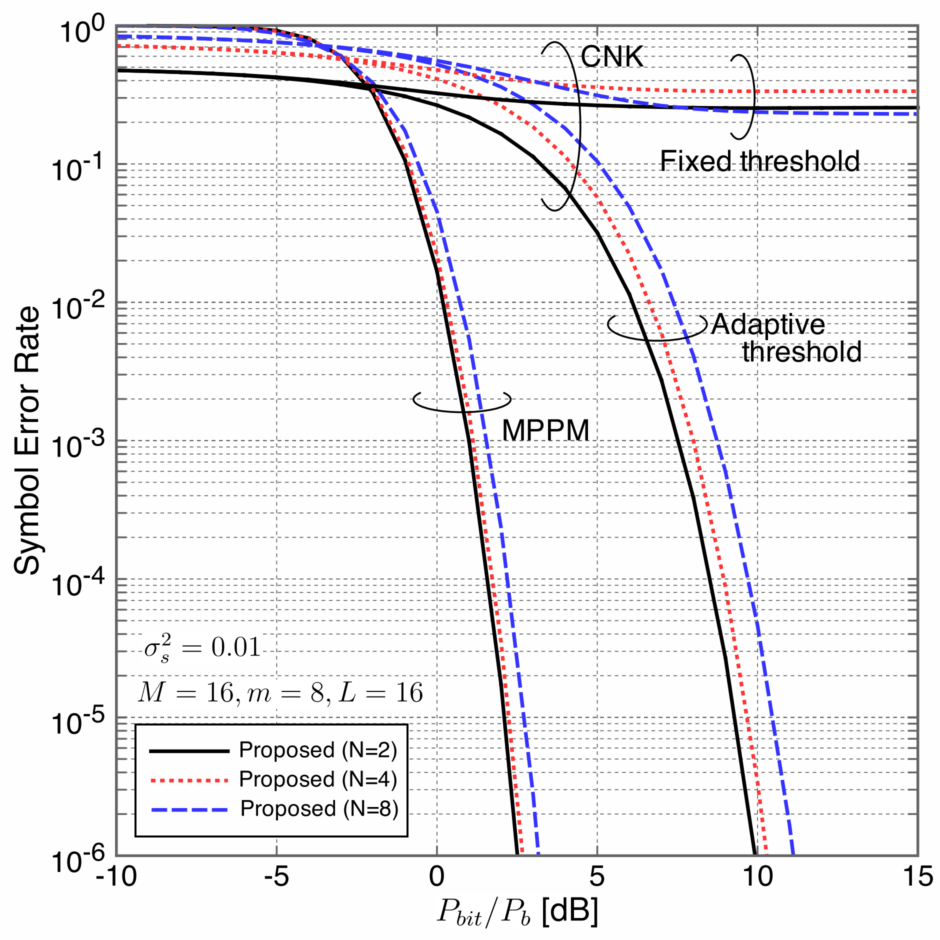
◆ Conventional system(M=4)



◆ Proposed system(M=4)



*Result : SER vs. Pbit/Pb (*M*=16, m=8)



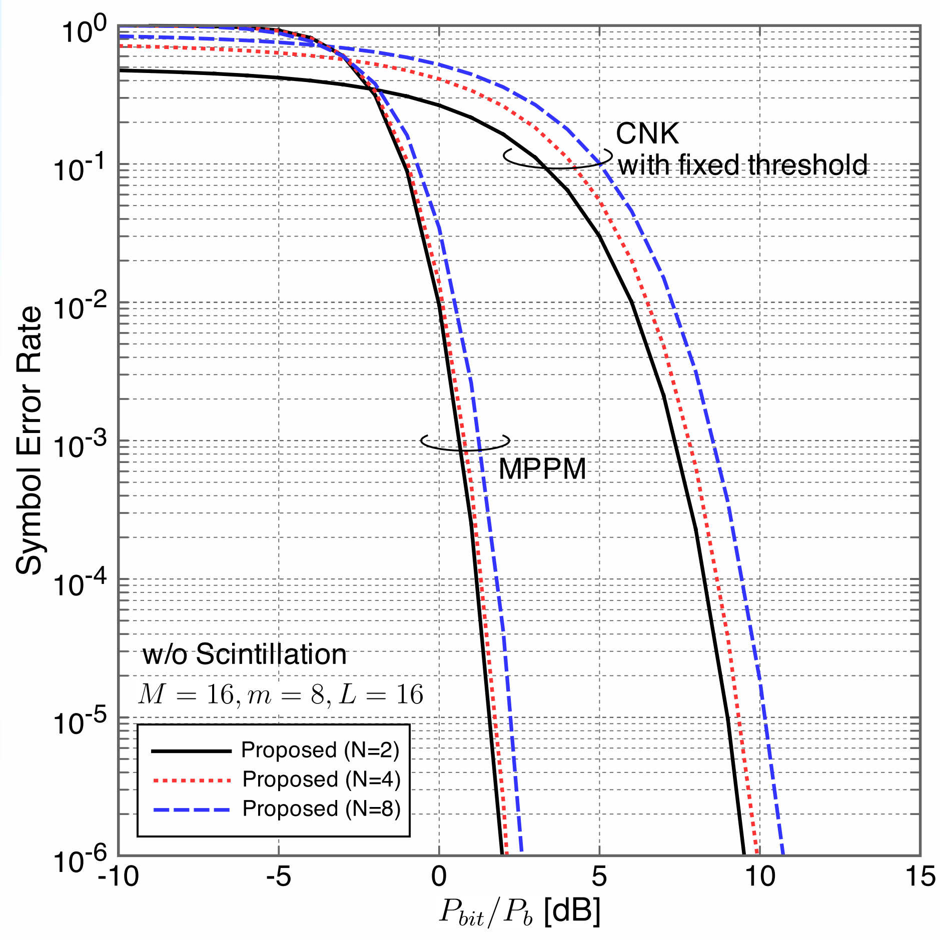


Fig.3, SER vs. Pbit/Pb w/ scintillation

Fig.4, SER vs. Pbit/Pb w/o scintillation

Conclusion

- We proposed the hierarchical MPPM system using PN codes.
- We analyzed and evaluated the proposed system from theoretical analysis.
  - **The proposed system can;**
    - ✓ **Improve the data transmission** rate compared with the conventional MPPM system.
    - ✓ Achieve to SER of conventional MPPM.
    - ✓ Transmit MPPM data and CNK data hierarchical because there is the difference between SER of MPPM and SER of CNK.
  - **Future works;**
    - ✓ Evaluation of the system in the parallel transmitter case.
    - ✓ Comparing with conventional hierarchical systems.

Thank you.