

# FEC FOR UPSTREAM INITIAL AND FINE RANGING



**Presenters:** BZ Shen, Avi Kliger and Rich Prodan

- **Number of Information bits in the initial ranging burst: 56 bits**
  - 6 Bytes for MAC address plus 1 Byte downstream channel ID
- **Performance requirements**
  - Reception at a very low level
    - Very low SNR
    - Allow low transmission power and small guard band with no interference to adjacent signals in the OFDMA frame
  - Very good protection against false detection at low SNR
    - Requires CRC
  - Low probability of misdetection ( $<1e-2$ ) with low SNR
- **Low constellation size**
  - Suggest BPSK
- **Number of sub-carriers (not including guard-band):**
  - 32 with 50 kHz spacing and 64 with 25 KHz spacing
- **Proposing FEC plus CRC**
  - FEC: LDPC code with maximum 5 iterations message passing decoding
    - Compared with BCH code
  - CRC: 24-bit CRC
  - Four admission Slots (8 OFDM symbols)

- **Number of information bits for FEC**

- Number of information bits of initial ranging + 24-bits of CRC:  $56+24=80$

- **FEC: (128,80) code**

- Using BPSK  $\rightarrow$  8 OFDM symbols
- Compare two codes

- BCH:  $t=6$

- Punctured LDPC code

- Mother LDPC (160,80)

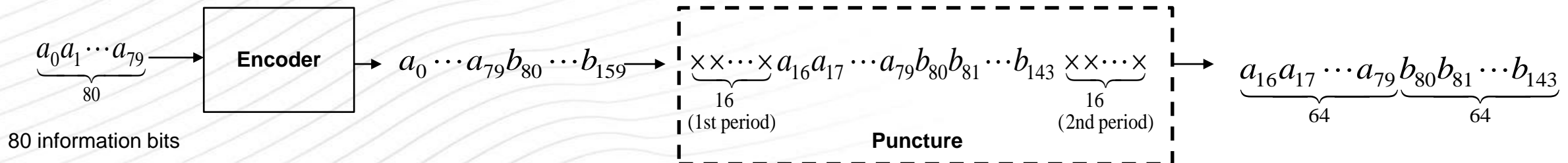
- 5x10 base parity check matrix
- Sub-matrix size (lifting value) equal 16.

- Puncturing two periods  $\rightarrow$  (128,80) code

- Period 1: size 16 start at 0 (puncturing information bits)
- Period 2: size 16 start at 144 (puncturing parity bits)

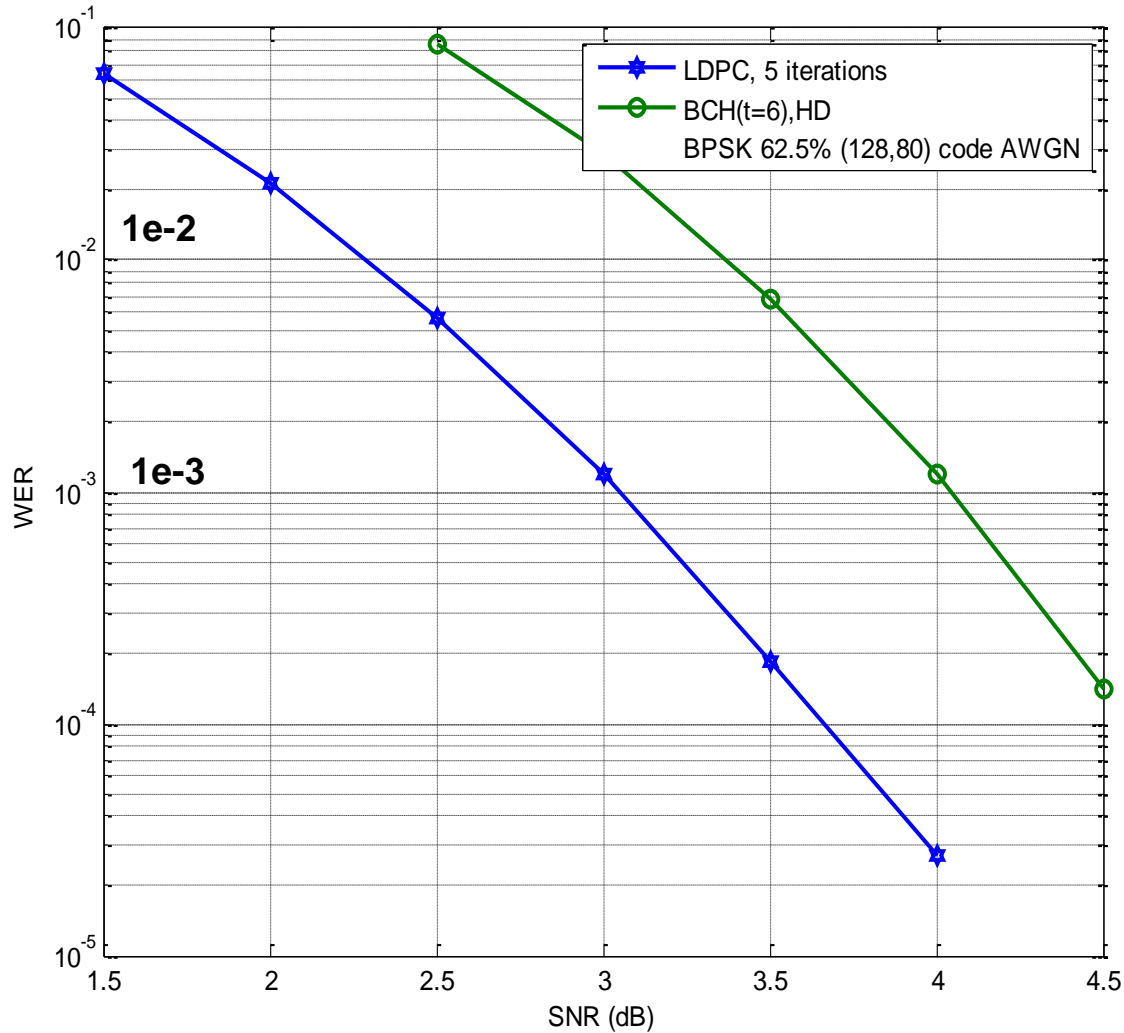
Parity check matrix

1	11	10	12	7	9	-1	-1	-1	-1
2	1	14	15	14	14	12	-1	-1	-1
0	9	3	2	-1	-1	11	7	-1	-1
6	8	-1	10	3	-1	-1	10	4	-1
12	13	11	-1	0	-1	-1	-1	5	2



# BPSK PERFORMANCES (INITIAL RANGING)

WER(word error rate)



SNR (dB)	BCH(128,80)		LDPC (128,80)	
	FEC WER	Ideal 24bit CRC $P_{ue}$	FEC WER	Ideal 24bit CRC $P_{ue}$
1				
1.5			6.4e-2	7.7e-12
2			2.1e-2	4.2e-14
2.5	8.5e-2	6.9e-10	5.6e-3	8.6e-17
3	2.9e-2	9.0e-12	1.2e-3	7.8e-20
3.5	6.7e-3	2.0e-14	1.8e-4	1.2e-23
4	1.2e-3	1.2e-17		
4.5	1.4e-4	1.4e-21		
5				

$P_{ue}$  : undetectable error rate with an ideal CRC

# CYCLIC REDUNDANCY CHECK (CRC) CODE FOR INITIAL RANGING

- **CRC code:**

- Number of information bits: 56
- Parity bits: 24

- **Ideal 24-bit CRC with estimated performance**

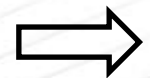
- **Optimized 24-bit CRC**

- Proposed by G. Castagnoli, S. Bräuer, and M. Herrmann \* in 1993
- Generator polynomial

$$g_{CRC24}(x) = x^{24} + x^{22} + x^{20} + x^{19} + x^{18} + x^{16} + x^{14} + x^{13} + x^{11} + x^{10} + x^8 + x^7 + x^6 + x^3 + x + 1$$

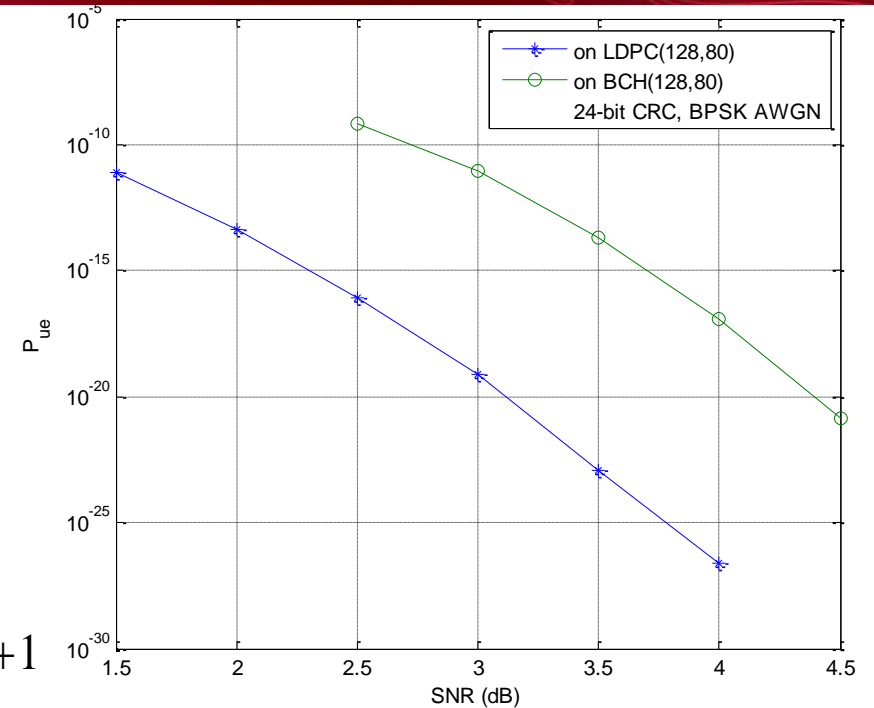
$b_0, b_1, \dots, b_{55}$  : 56 input bits

$p_0, p_1, \dots, p_{23}$  : 24 parity bits



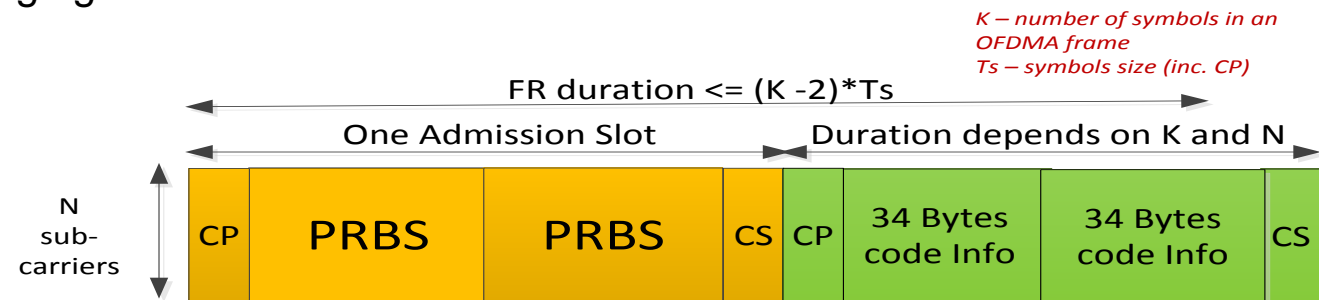
$$b_0x^{79} + b_1x^{78} + \dots + b_{55}x^{24} + p_0x^{23} + p_1x^{22} + \dots + p_{22}x^1 + p_{23} = 0 \text{ mod } g_{CRC24}(x)$$

- The code can 100% correctly detect 7 bit errors in the information bits
- This 24-bit CRC polynomial was used by FlexRay, an automotive network communications protocol.



\*G. Castagnoli, S. Bräuer, and M. Herrmann, "Optimization of Cyclic Redundancy-Check Codes with 24 and 32 Parity Bits", IEEE Transactions on Communications, vol. 41, No. 6, pp. 883-892, June 1993.

- Configurable narrow band signal integrated into a data OFDMA frame
- Unicast (no contention)
- Comprised of one Admission Slot (similar to Initial Ranging) and 34 Bytes of data
- **Configurable**
  - Must fit into a single OFDMA frame
  - Time shift
  - TX Power
  - Number of sub-carriers
  - Preamble sequence – same as Initial Ranging
- **Data**
  - 34 Bytes (272 bits)
  - Use Admission Slot structure
  - QPSK with FEC

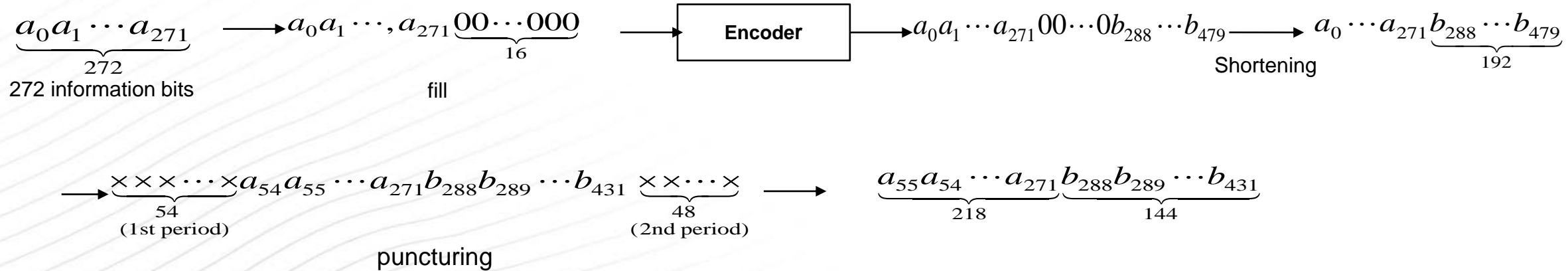


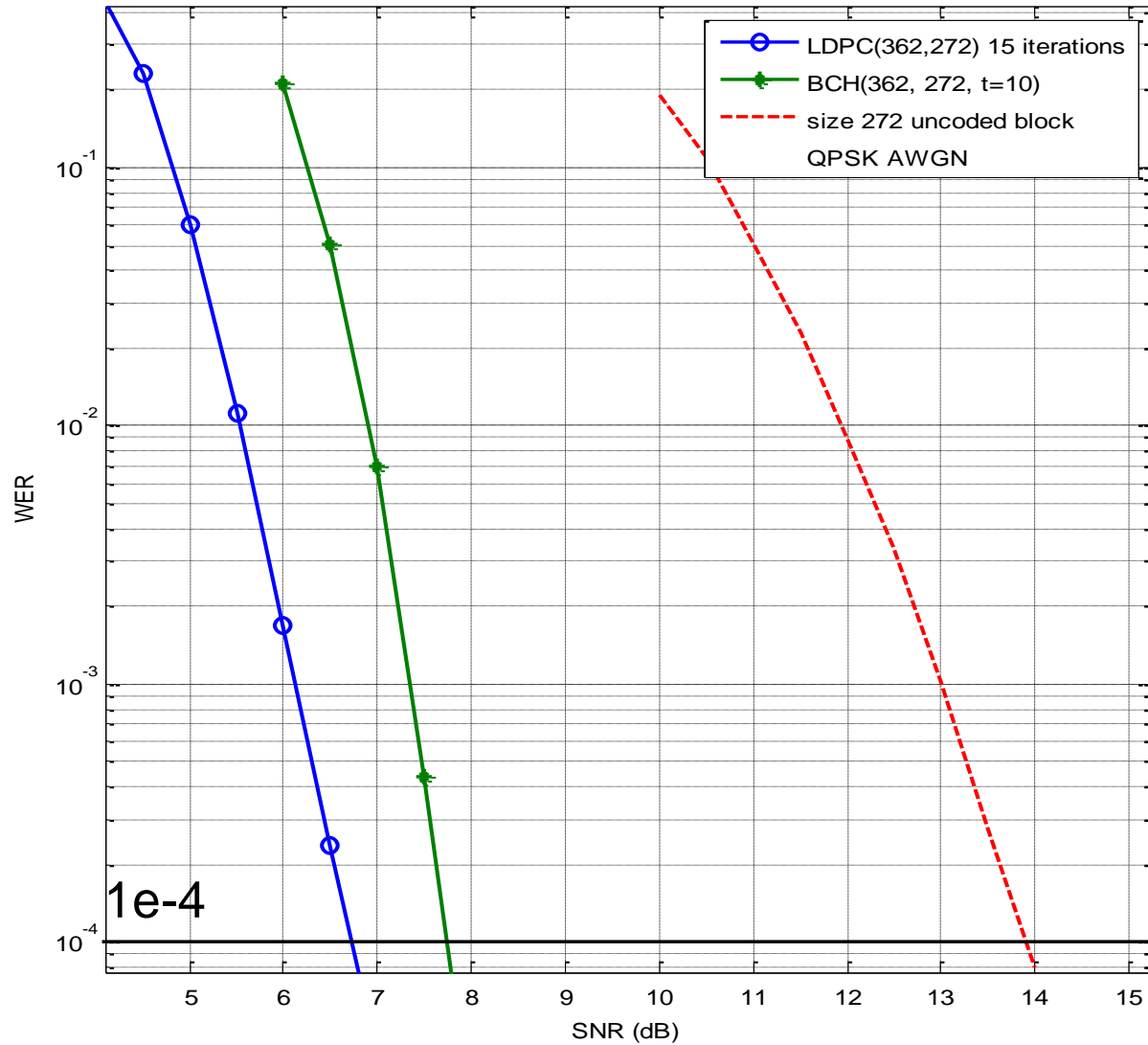
## Compare two rate 0.75 FEC codes

- BCH code, t=10
- Shortened and punctured LDPC code
  - Mother LDPC (480,288) code used for PLC FEC code
  - Shortening and puncturing
    - Shortening: size 16; starting at position 272
    - Puncturing
      - Period 1: size 54 start at 0 (puncturing information bits)
      - Period 2: size 48 start at 432 (puncturing parity bits)

Parity check matrix

16	1	28	9	40	38	16	-1	-1	-1
28	42	36	11	39	9	8	38	-1	-1
5	2	18	16	25	47	-1	2	19	-1
18	18	40	18	0	34	-1	-1	7	32







- **FEC codes for initial and fine ranging were defined and performance evaluated**
  - (128,80) punctured LDPC code with 24-bit CRC for initial ranging on BPSK
    - The performance is about 1dB better than BCH code
  - (362,272) shortened and punctured LDPC code for fine ranging on QPSK
    - The performance
      - About 7 dB better than uncoded
      - About 1 dB better than same rate BCH code
- **Proposal to adopt these two FEC systems**

**Move to:**

**Adopt the LDPC FEC codes in shen\_3bn\_01\_1113.pdf:**

- The (128,80) punctured LDPC code with 24-bit CRC for initial ranging on BPSK
- The (362,272) shortened and punctured LDPC code for fine ranging on QPSK

**Moved: BZ Shen**

**Second: Avi Kliger**

Thank you