Proposal for PMA training frame, scrambler, and 4B6B coding

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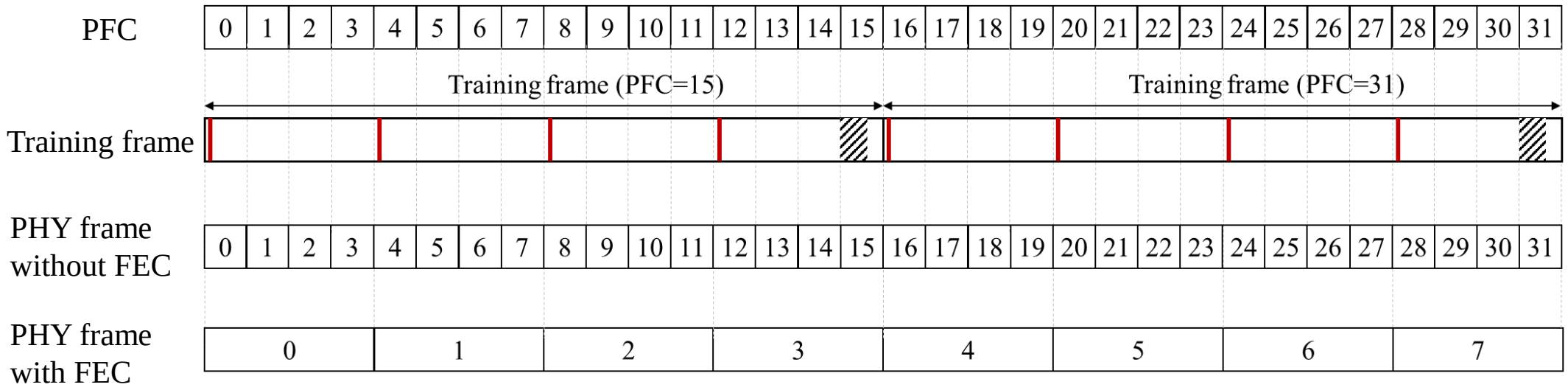
Introduction

- Most of the PMA training based on 4B6B PAM2 have achieved consensus.
- Simulation results (Tingting_3dg_01_29_10_2024, Murray_3dg_04a_11132024 , Tingting_3dg_15_01_2025) have confirmed that 4B6B coding using NND 6-tuples and the random bit Sg_n is well-behaved without significant concern over data correlation.
- This presentation gives a proposal of the training frame, the scrambler, and line coding used during PMA training for 100BASE-T1L.

PMA Training Frame

- The PMA training frame follows a similar approach as in Clauses 97. During PMA training, the training frame with indicators is used to establish the PHY frame and block boundaries.
- Each training frame is composed of 16 partial PHY frames. Each partial PHY frame has 128 bits, aligned with the PHY frame without FEC.
- All the bits in each training frame are zero except:
  - The 2nd bit (in red) in every four partial PHY frames is set to 1 to align the PHY frames and facilitate scrambler synchronization.
  - The 12-octet InfoField (in black shadow) in the 16th partial PHY frame.



PMA Training Scrambling

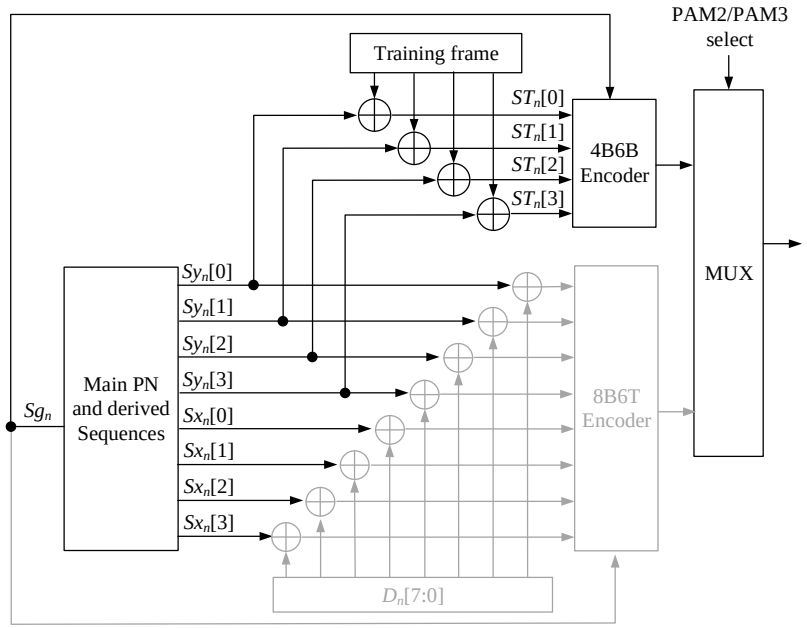
- The training frame with embedded InfoField is XORed with the scrambler bits $Sy_n[3:0]$ (also used in data mode) in nibble width. The 1st bit of each partial PHY frame is scrambled with $Sy_n[0]$ (i.e. $Scr_n[0]$).
  - Definition of the scrambler bits $Sy_n[3:0]$ refers to Murray_3dg_02_09172024.
  - Setting the 1st bit of the first 15 partial PHY frames to zero, makes $Scr_n[0]$ available on the 1st bit of each nibble except the InfoField, facilitating scrambler synchronization.
- The scrambled nibble $ST_n[3:0]$ during training can be expressed as:

$$ST_n[3] = \begin{cases} Sy_n[3] \oplus \text{InfoField}_{(4n+3 \bmod 128)} & 480 \le (n \bmod 512) \le 503 \\ Sy_n[3] & \text{otherwise} \end{cases}$$

$$ST_n[2] = \begin{cases} Sy_n[2] \oplus \text{InfoField}_{(4n+2 \bmod 128)} & 480 \le (n \bmod 512) \le 503 \\ Sy_n[2] & \text{otherwise} \end{cases}$$

$$ST_n[1] = \begin{cases} Sy_n[1] \oplus \text{InfoField}_{(4n+1 \bmod 128)} & 480 \le (n \bmod 512) \le 503 \\ Sy_n[1] \oplus 1 & \text{else if } (n \bmod 128) = 0 \\ Sy_n[1] & \text{otherwise} \end{cases}$$

$$ST_n[0] = \begin{cases} Sy_n[0] \oplus \text{InfoField}_{(4n \bmod 128)} & 480 \le (n \bmod 512) \le 503 \\ Sy_n[0] & \text{otherwise} \end{cases}$$



4B6B PAM2 Coding

- The scrambled nibble $ST_n[3:0]$ is mapped to PAM2 6-tuple with bounded running disparity during PMA training.
- Each of the 16 4-bit values is associated with one of the non-negative disparity (NND) 6-tuples, shown in the right table.
  - Each NND 6-tuple has a unique complementary code group (not in the table), generated by negating each element of the NND 6-tuple. Both 6-tuples correspond to the same 4-bit value.
- The running disparity (RD) at the transmitter is controlled as follows:
  - If both RD and the disparity of the 6-tuple associated with the 4-bit value are positive, then the 6-tuple is negated before transmission.
  - If RD is zero or the disparity of the 6-tuple corresponding to the 4-bit value is zero, then the random bit Sg_n determines whether to negate the 6-tuple before transmission.
  - RD is recomputed after transmission of each 6-tuple.
- The mathematical expression for the running disparity control process can refer to Curran_3dg_01_01202025.

4 bits input	NND PAM2 6-tuples					
0000	-1	1	-1	1	-1	1
0001	-1	-1	1	1	-1	1
0010	-1	1	1	1	1	1
0011	1	-1	1	-1	1	1
0100	-1	1	-1	1	1	-1
0101	1	1	1	-1	1	-1
0110	-1	1	1	-1	-1	1
0111	-1	1	-1	-1	1	1
1000	1	1	1	1	-1	-1
1001	-1	-1	-1	1	1	1
1010	-1	-1	1	-1	1	1
1011	-1	-1	1	1	1	-1
1100	1	1	-1	1	1	-1
1101	-1	1	1	-1	1	-1
1110	-1	1	1	1	-1	-1
1111	1	1	-1	-1	1	1

Conclusion

- The proposed PMA Training frame is similar to Clauses 97, 149, and 165 with small modifications:
  - Composed of 16 partial PHY frames with 128 bits per partial frame
    - The 2nd bit in every four partial PHY frames are set to 1, to establish PHY frame alignment and facilitate scrambler synchronization.
  - InfoField in the 16th partial PHY frame of each training frame
- The training frame is XORed with the scrambler bits $Sy_n[3:0]$ in a nibble width.
  - $Sy_n[3:0]$ is also used in data mode and is defined in Murray_3dg_02_09172024.
- Every 4 scrambled bits are encoded to a PAM2 6-tuple with bounded disparity during training.

Q & A