Efficient Transmitter Design Techniques in Digital Communication

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CONTENTS

***Abstract*—A brief description of Efficient Transmitter Design (ETD) techniques is provided. These include Interleaver/Deinterleaver for combating bursty errors, Physical Layer Framing for the efficient detection of Frame starting, and Pulse Shaping to combat InterSymbol Interference.**

1. Interleaver/Deinterleaver

For 8PSK, 16APSK, and 32APSK mapping schemes, a block interleaver [1] is used to mitigate the effects of bursty channel. For Concatenated Channel coding schemes bit interleaving is necessary. The mapped data is serially put as column wise and searially read out row wise. Fig. 1 shows bit interleaving scheme for 8PSK.

Fig. 2 shows the BER comparison of 8PSK mapping scheme with and without interleaver.

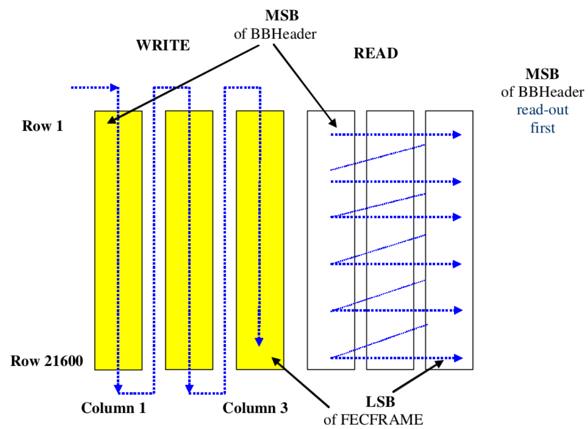

Fig. 1: Bit Interleaver Structure for 8PSK mapping scheme

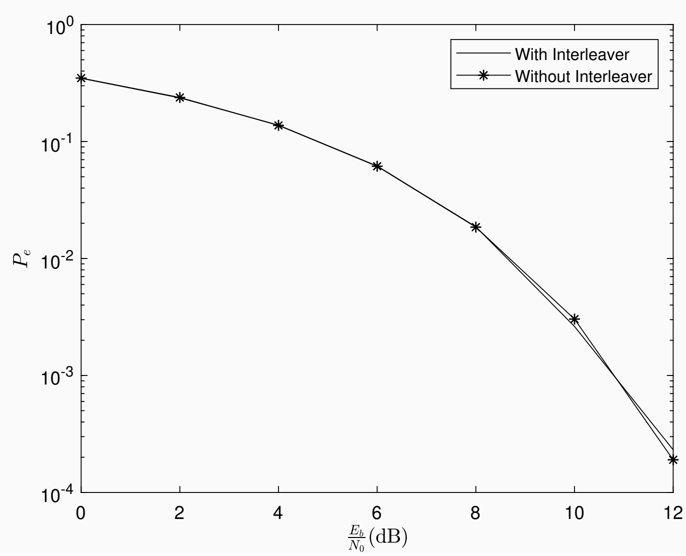

Fig. 2: Bit interleaver for 8PSK

2. Physical Layer Framing(PLFRAMING)

PLFRAMING is useful for specifying the modulation scheme, code rate and frame characteristics, useful for Frame synchronization at the receiver. Fig. 3 shows the Typical Structure of PLFRAME according to [1]. SOF=Starting Of Frame and $PLSC$=Physical Layer Signalling Code.

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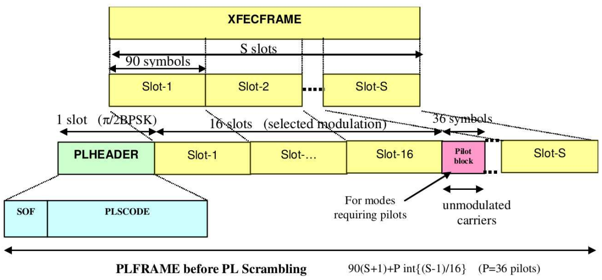

Fig. 3: Structure of PLFRAME.

Mode	MOD COD	Mode	MOD COD	Mode	MOD COD	Mode	MOD COD
QPSK 1/4	1_D	QPSK 5/6	9_D	8PSK 9/10	17_D	32APSK 4/5	25_D
QPSK 1/3	2_D	QPSK 8/9	10_D	16APSK 2/3	18_D	32APSK 5/6	26_D
QPSK 2/5	3_D	QPSK 9/10	11_D	16APSK 3/4	19_D	32APSK 8/9	27_D
QPSK 1/2	4_D	8PSK 3/5	12_D	16APSK 4/5	20_D	32APSK 9/10	28_D
QPSK 3/5	5_D	8PSK 2/3	13_D	16APSK 5/6	21_D	Reserved	29_D
QPSK 2/3	6_D	8PSK 3/4	14_D	16APSK 8/9	22_D	Reserved	30_D
QPSK 3/4	7_D	8PSK 5/6	15_D	16APSK 9/10	23_D	Reserved	31_D
QPSK 4/5	8_D	8PSK 8/9	16_D	32APSK 3/4	24_D	DUMMY PLFRAME	0_D

Fig. 4: MODCOD coding for various mapping schemes. Subscript D denotes decimal e.g. 1_D = 00001 in binary

A. Generation of SOF

SOF consistutes a fixed sequence $18D2E82_{HEX}$ (length=26 bits) in binary format which is from right to left.

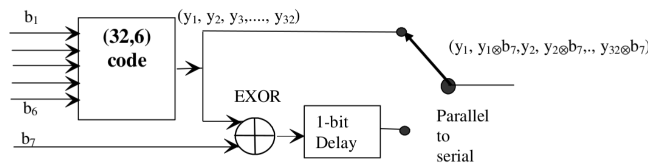

Fig. 5: Physical Layer Signalling generation

B. Generation of PLSC

- Generation of PLSC involes definining 7 symbols and multiplying first 6 symbols with the defined G matrix in [1]. First 5 symbols called as MODCOD filed and next 2 symbols as TYPE field.
- First 5 symbols represents MODCOD which specifies Frame's mapping scheme and code rate. Fig. 4 shows the MODCOD coding for various mapping schemes.
- Next 2 symbols represents TYPE filed which specifies Frame length and presence and absesnce of pilot fileds. This is shown in Table I.
- Similarly, Fig. 5 shows the generation of 64 bit using the MODCOD and TYPE bits.
- After the generation of PLS code, we will again scramble the PLS Code with the fixed SCR sequence which is defined in [1].

$$PLSC = PLSC \oplus SCR \tag{2.1}$$

Bit-6	Bit-7	Frame Type	Pilots
0	0	Normal	No
0	1	Normal	Yes
1	0	Short	No
1	1	Short	Yes

TABLE I: Frame Type

C. PLHEADER

The PLHEADER has SOF (26 symbols) and PLSC (64 symbols) sequences, that are modulated by rotating QPSK by $\frac{\pi}{4}$. This is also known as $\frac{\pi}{2}$-BPSK.

$$I_{2i-1} = Q_{2i-1} = \frac{1}{\sqrt{2}}(1 - 2y_{2i-1}) \quad i = 1, 2, \ldots, 45 \tag{2.2}$$

$$I_{2i} = -Q_{2i} = -\frac{1}{\sqrt{2}}(1 - 2y_{2i-1}) \quad 1, 2 \ldots, 45 \tag{2.3}$$

where $y_i \in \{0, 1\}, i = 1, \ldots, 90$.

D. Generation of Pilots

Pilot block consists of $P = 36$ symbols. Each pilot is composed of un-modulated complex symbol.Where, $I = Q = \frac{1}{\sqrt{2}}$

E. PLFRAME Calculations

PLFRAME calculations are available in Tables II and III. The PLFRAME length is calculated as

$$L = SOF + PLSC + (90 * S_{SLOTS}) + (36) * P_{SLOTS} \tag{2.4}$$

where,

$$S_{SLOTS} = \frac{N}{90 \times \log_2 M}, P_{SLOTS} = \left\lfloor \frac{(S_{SLOTS} - 1)}{16} \right\rfloor$$

N = Frame Type(64800/16200 bits),M = Mapping order(4/8/16/32), depending upon the modulation scheme.

	SHORT FRAME (16200 bits)								
PLFRAME	SOF	PLSC	Slot-i	S_{SLOTS}	Pilot Symbols	P_{SLOTS}	#Pilots	Without Pilots	With Pilots
QPSK	26	64	90	90	36	5	180	8190	8370
8PSK	26	64	90	60	36	3	108	5490	5598
16APSK	26	64	90	45	36	2	72	4140	4212
32APSK	26	64	90	36	36	2	72	3330	3402

TABLE II: Short frame details.

	NORMAL FRAME (64800 bits)								
PLFRAME	SOF	PLSC	Slot-i	S_{SLOTS}	Pilot Symbols	P_{SLOTS}	#Pilots	Without Pilots	With Pilots
QPSK	26	64	90	360	36	22	792	32490	33282
8PSK	26	64	90	240	36	14	504	21690	22194
16APSK	26	64	90	180	36	11	396	16290	16686
32APSK	26	64	90	144	36	8	288	13050	13338

TABLE III: Long frame details.

3. Pulse Shaping

Let X_k be the modulated symbol in the kth time slot. Then the mth sample of the transmitted symbol in the kth time slot is

$$S_k(m) = h_k(m) * X_k \tag{3.1}$$

where $h_k(m), m = 1, \ldots, M; k = 1, \ldots, N$ are samples of the pulse shaping filter [1] obtained from

$$H(f) = \begin{cases} 1 & |f| < f_N(1-\alpha) \\ \left\{\frac{1}{2} + \frac{1}{2}\sin\frac{\pi}{2}\left[\frac{f_N - |f|}{\alpha}\right]\right\}^{\frac{1}{2}} & |f| = f_N(1-\alpha) \\ 0 & |f| > f_N(1+\alpha) \end{cases} \tag{3.2}$$

where f_N is the Nyquist frequency and $\alpha = 0.35, 0.25$ or 0.2. Let the mth received sample in the kth time slot be $Y_k(m)$. At the Receiver, the symbol to be demodulated is then obtained as

$$Y_k(m) * h_k(M-m) \tag{3.3}$$

The following code plots Fig. 6 using pulse shaping.

```
wget https://github.com/gadepall/EE5837/raw/
    master/ETD/codes/pulse_shaping_qpsk_final.
    py
```

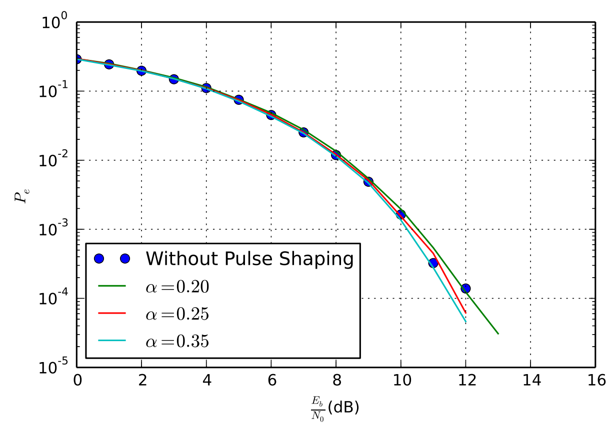

Fig. 6: SER comparison for QPSK with and without the pulse in (3.2).

References

[1] A. Morello and V. Mignone, "DVB-S2X: The New Extensions to the Second Generation DVB Satellite Standard DVB-S2," *Int. J. Satell. Commun. Netw.*, vol. 34, no. 3, pp. 323–325, May 2016. [Online]. Available: https://doi.org/10.1002/sat.1167