Title:

Channel coding and new interleaving scheme for the US1 Codec uplink slot format, using 8-PSK.

Source:

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Abstract:

This contribution provides performance results of simulations of a particular channel coding scheme and interleaving for the US1 codec which can be used over the uplink timeslot format.

Recommendation:

Review and adopt.

Notices:

Introduction

This contribution presents a new channel coding and interleaving scheme for the US1 codec for IS-136+ with the uplink timeslot format. The uplink time slot format preserves the CDVCC and SACCH fields, and accommodates 9 pilots symbols for channel tracking purposes. It also includes 7 symbols for guard, ramp and FPC signaling for fast power control. This time slot format results in 372 payload bits. We give results for the partition of speech bits in classes as proposed in [2]. This partition has 89 class 1A bits (including 8 CRC bits), 74 class 1B bits, and 89 class 2 bits. Class 1A bits and class 1B bits are convolutional encoded respectively with a rate ½ followed by 6 bits puncturing, and a rate 2/3 code, both with tail biting. We present results for 1 slot interleaving and for 2 slots chain interleaving. We also show results for constraint lengths K=6 and K=7. For clarity we will refer to this channel encoding and interleaving scheme as US1-UP. Error rate performance curves are presented at Doppler frequencies of 10 and 184 Hz. These curves are compared to the curves obtained with the channel coding and interleaving schemes presented in [1] (UWC). For the purposes of this contribution, the demodulation scheme used was coherent detection with perfect knowledge of channel state information. It should be noted that we also have verified the equivalency of performance between US1-UP and a similar encoding and interleaving scheme using the original partition of 88 class 1A bits, 76 class 1B and 89 class 2 bits.
It is shown that the performance of 2 slots chain interleaving is 3-5 dB superior than 1 slot interleaving in class 1A FER and class 1B FER, and 2-4 dB in class 1A and class 1B BER. Increasing the constraint length from K=6 to K=7 is advantageous for both class 1A and class 1B. Furthermore, US1-UP, with 2 slot interleaving and K=7, performs as well as UWC at 10 Hz Doppler, and is 0.5 dB better than UWC at 184 Hz Doppler. It should be noted that the UWC slot format has 378 payload bits (6 more than US1-UP), and that the code rate used in class 1A is exactly ½, while the code rate for class 1B is 2/3.
For class 1B, it is shown that at 10 Hz Doppler with US1-UP and 2 slot interleaving there is 2 dB improvement over UWC in FER. However, at 10 Hz Doppler US1-UP gives the same performance as UWC in class 1B BER with K=6, and about 0.5 dB improvement with K=7. At 184 Hz the new interleaving scheme, proposed here, is responsible for gains in both class 1B FER (1.5 dB with K=7, at FER=10^{-2}) and class 1B BER (1.2 dB with K=7, at BER=10^{-3}).
Based on the above conclusions we recommend to adopt for the US1 codec uplink, the channel coding schemes with K=7 for both 1 and 2 slot interleaving proposed here.

Simulation Details

1) US1-UP simulation details

Channel Encoding
The US1 speech frame considered here consists of 81 class 1A, 74 class 1B and 89 class 2 bits as first proposed in [2]. The class 1A bits are protected by a 8-bit CRC. The 81 class 1A and 8 CRC bits are encoded using a rate 1/2 convolutional code with tail biting. 6 output bits are punctured with the puncturing matrix in figure 1. This produces 172 coded bits. The class 1B bits are encoded using a rate 2/3 convolutional code (punctured rate ½ code) with tail biting. Figure 1 also shows the puncturing matrix for the class 1B bits. This produces another 111 coded bits. Thus, the encoding process produces 283 coded bits. Combining these with the 89 class 2 bits yields 372 total data bits used for speech. Thus bits $b_0,\ldots,b_{171}$ are coded class 1A plus CRC bits, bits $b_{172},\ldots,b_{282}$ are coded class 1B bits, and $b_{283},\ldots,b_{371}$ are class 2 bits. Constraint lengths of K=6 and K=7 were simulated for both codes. The polynomials used for K=6 and K=7 are shown in figure 2. We will refer to this speech bits partition and channel coding as US1-UP.
Although the results are not presented here, we have also verified the equivalency of performance between US1-UP and a similar encoding scheme starting, however, from the original partition of 88 class 1A bits, 76 class 1B bits, and 88 class 2 bits.

$$\text{Class 1A: } \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \end{bmatrix}$$

$$\text{Class 1B: } \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

Figure 1. Puncturing matrices for class 1A and class 1B bits.

$$G_{k=6}=[\ 075 \quad 053\ ]$$

$$G_{k=7}=[\ 0133 \quad 0171\ ]$$

Figure 2. Polynomials for K=6 and K=7, in octal representation.

Reordering and Interleaving

After encoding, the bits are arranged in priority order format (class 1 followed by class 2). The resulting vector of 372 bits is indexed from 0 to 371 and reordered using the matrix given in figure 3. For 1 slot interleaving these 372 reordered bits are directly transmitted row by row. For 2 slot interleaving, after reordering the bits as shown above, the odd-indexed rows (1,3,…,25) are exchanged with the corresponding rows from the next speech frame. Thus, the even indexed rows (0,2,…,24) are kept within the same slot, e.g. slot 1, but the odd-indexed rows are placed in the next slot, e.g. slot 4.

Row 0	0, 17,283, 34, 51,300, 68, 85,317,102,119,334,136,152,351,
Row 1	1, 18,284, 35, 52,301, 69, 86,318,103,120,335,137,153,352,
Row 2	172,180,188,196,204,212,220,228,236,244,252,260,268,276,353,
Row 3	2, 19,285, 36, 53,302, 70, 87,319,104,121,336,138,154,354,
Row 4	3, 20,286, 37, 54,303, 71, 88,320,105,122,337,139,155,355,
Row 5	173,181,189,197,205,213,221,229,237,245,253,261,269,277,356,
Row 6	4, 21,287, 38, 55,304, 72, 89,321,106,123,338,140,156,357,
Row 7	5, 22,288, 39, 56,305, 73, 90,322,107,124,339,141,157,358,
Row 8	174,182,190,198,206,214,222,230,238,246,254,262,270,278,359,
Row 9	6, 23,289, 40, 57,306, 74, 91,323,108,125,340,142,158,360,
Row 10	7, 24,290, 41, 58,307, 75, 92,324,109,126,341,143,159,361,
Row 11	175,183,191,199,207,215,223,231,239,247,255,263,271,279,362,
Row 12	8, 25,291, 42, 59,308, 76, 93,325,110,127,342,144,160,363,
Row 13	9, 26,292, 43, 60,309, 77, 94,326,111,128,343,145,161,364,
Row 14	176,184,192,200,208,216,224,232,240,248,256,264,272,162,280,
Row 15	10, 27,293, 44, 61,310, 78, 95,327,112,129,344,146,163,365,
Row 16	11, 28,294, 45, 62,311, 79, 96,328,113,130,345,147,164,366,
Row 17	177,185,193,201,209,217,225,233,241,249,257,265,273,165,281,
Row 18	12, 29,295, 46, 63,312, 80, 97,329,114,131,346,148,166,367,
Row 19	13, 30,296, 47, 64,313, 81, 98,330,115,132,347,149,167,368,
Row 20	178,186,194,202,210,218,226,234,242,250,258,266,274,168,282,
Row 21	14, 31,297, 48, 65,314, 82, 99,331,116,133,348,150,169,369,
Row 22	15, 32,298, 49, 66,315, 83,100,332,117,134,349,151,170,370,
Row 23	179,187,195,203,211,219,227,235,243,251,259,267,275,171,371,
Row 24	16, 33,299, 50, 67,316,
Row 25	84,101,333,118,135,350

Figure 3. Reordering Matrix for Interleaving in US1-UP.

Modulation
The data bits are mapped to 8–PSK symbols using the Gray mapping shown in figure 4 (the least significant bit is the right most bit).

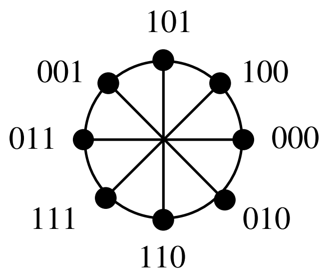


Figure 4. Gray mapping.

Time Slot Format
The timeslot format used for the US1-UP simulations is shown below.

G	R	Plt	Fpc	Data	Sync	Sacch	Data	Plt	Data	Cdvcc	Data	Plt
9	9	9	3	96	14 s	12	90	9	90	12	96	9

Figure 5. Slot format for US1 uplink.

Demodulation
Coherent detection with known channel state information was used to demodulate the received signals. Only one branch (no diversity) was assumed.

Channel Decoding
Viterbi decoding using soft decision metrics as inputs was used to perform the error correction. The decoded class 1A bits were then used to regenerate the CRC bits which were then compared to the decoded CRC bits. The FER curves presented in the next section show the rate at which frames result in a CRC mismatch. The decoded class 1B bits were compared to the known class 1B bits prior to encoding at the transmit end to determine the decoded class 1B BER and class 1B FER curves shown in the next section.

2) <u>UWC simulation details</u>

The channel coding scheme, the interleaving scheme and the slot format used to generate the UWC curves are described in [1]. In particular, the partitioning is 88 class 1A bits (including 8 CRC bits), 76 class 1B bits, 88 class 2 bits. The class 1A bits are encoded with a rate ½ convolutional encoder with tail biting and K=6. The class 1B bits are encoded with a rate 2/3 convolutional encoder with tail biting and K=6. The payload for UWC slot format is 378 bits.

Performance Results

Simulations on 10,000 frames of data were performed to collect class 1A FER-BER, class 1B FER-BER and class 2, modem BER statistics for the coding schemes discussed above at Doppler frequencies of 10 Hz and 184 Hz. Figs. 1 and 4 show FER for class 1A and class 1B at 10 and 184 HZ Doppler respectively. Figures 2 and 5 show BER performance curves for class 1A and class 1B at 10 and 184 Hz

Doppler respectively. Figs. 3 and 6 show class 2 BER and modem BER at 10 Hz and 184 Hz respectively. Each plot contains several curves that are explained below:

US1-UP-2 – Ideal coherent detection using known CSI, with partitioning equal to 89 class 1A, 74 class 1B and 89 class 2 bits, new channel coding, 2 slot interleaving , and timeslot format in figure 5.

US1-UP-1 – Ideal coherent detection using known CSI, with partitioning equal to 89 class 1A, 74 class 1B and 89 class 2 bits, new channel coding, 1 slot interleaving , and timeslot format in figure 5.

UWC – Ideal coherent detection using known CSI, with partitioning equal to 88 class 1A, 76 class 1B and 88 class 2 bits, channel coding, interleaving, and timeslot format as in [1].

At 10 Hz Doppler and for FER=10^{-2}, figure 1 shows that US1-UP-2 with K=6 is about 0.4 dB worse in class 1A FER than UWC. This is due to the puncturing introduced in class 1A. However if we increase the constraint length to K=7, US1-UP-2 performs as well as UWC in class 1A FER. Looking at class 1B FER, figure 1 shows that US1-UP-2 with K=6 is about 1.5 dB better than UWC, and about 2 dB better with K=7. US1-UP-2 performs better in class 1B FER due to a better interleaving scheme than the one used for UWC. Figure 1 also shows that with 1 slot interleaving (US1-UP-1 curves) we loose about 5 dB in class 1A FER and about 3.5 dB in class 1B FER (at FER=10^{-2}).
Although figure 1 shows that US1-UP-2 performs better than UWC in class 1B FER for both constraint lengths K=6 and 7, figure 2 shows that US1-UP-2 with K=6, performs the same as UWC in class 1B BER. We gain about 0.5 dB in class 1B BER if we increase K to 7.
Again (figure 2), 1 slot interleaving introduces about 4 dB loss in class 1A BER, and about 3 dB loss in class 1B BER , at BER=10^{-2}. This loss increases to 5 dB for class 1A BER, and to 4 dB for class 1B BER at BER=$2*10^{-3}$.
In terms of uncoded BER, figure 3 shows that US1-UP-1 and US1-UP-2 have the same performance as UWC in class 2 BER.

Now consider the performance at 184 Hz Doppler. In figure 4 we can see that US1-UP-2 with K=6 has about the same performance as UWC in class 1A FER, but has about 0.5 dB improvement with K=7. The improvements are higher in class 1B FER: about 0.8 dB with K=6, and about 1.5 dB with K=7 (at FER=10^{-2}). These are improvements that can be gained with the interleaving scheme used in US1-UP-2. Figure 4 also shows that with 1 slot interleaving (US1-UP-1 curves) there is about 2.5 dB loss over 2 slot interleaving (US1-UP-2) in both class 1A FER and class 1B FER.
While at 10 Hz Doppler the new 2 slot interleaving scheme gives a slight advantage in class 1B BER, figure 5 shows that, at 184 Hz Doppler, US1-UP-2 performs 0.5-2 dB better than UWC in class 1B BER.
Finally figure 6 shows that class 2 BER is identical for US1-UP-2, US1-UP-1 and for UWC, while US1-UP-1 and US1-UP-2 have a better modem BER than UWC.

In conclusion, this contribution shows that with the proposed channel coding and 2 slot interleaving schemes, it is possible to better the performance achievable with UWC proposal [1], while allowing a slot format that has 6 less payload bits. Based on the above discussion, it is recommended that the proposed channel coding with K=7 for both 1 and 2 slot interleaving schemes, and the uplink slot format discussed in this contribution be adopted for use with the US1 vocoder for IS136+.

References

[1]. Ericsson, "Details of coding used in UWC US1 evaluation", TIA45.3.5/98.03.17
[2]. Ericsson, "Performance results for 8-PSK", TR45.3.5/98.04.06.09

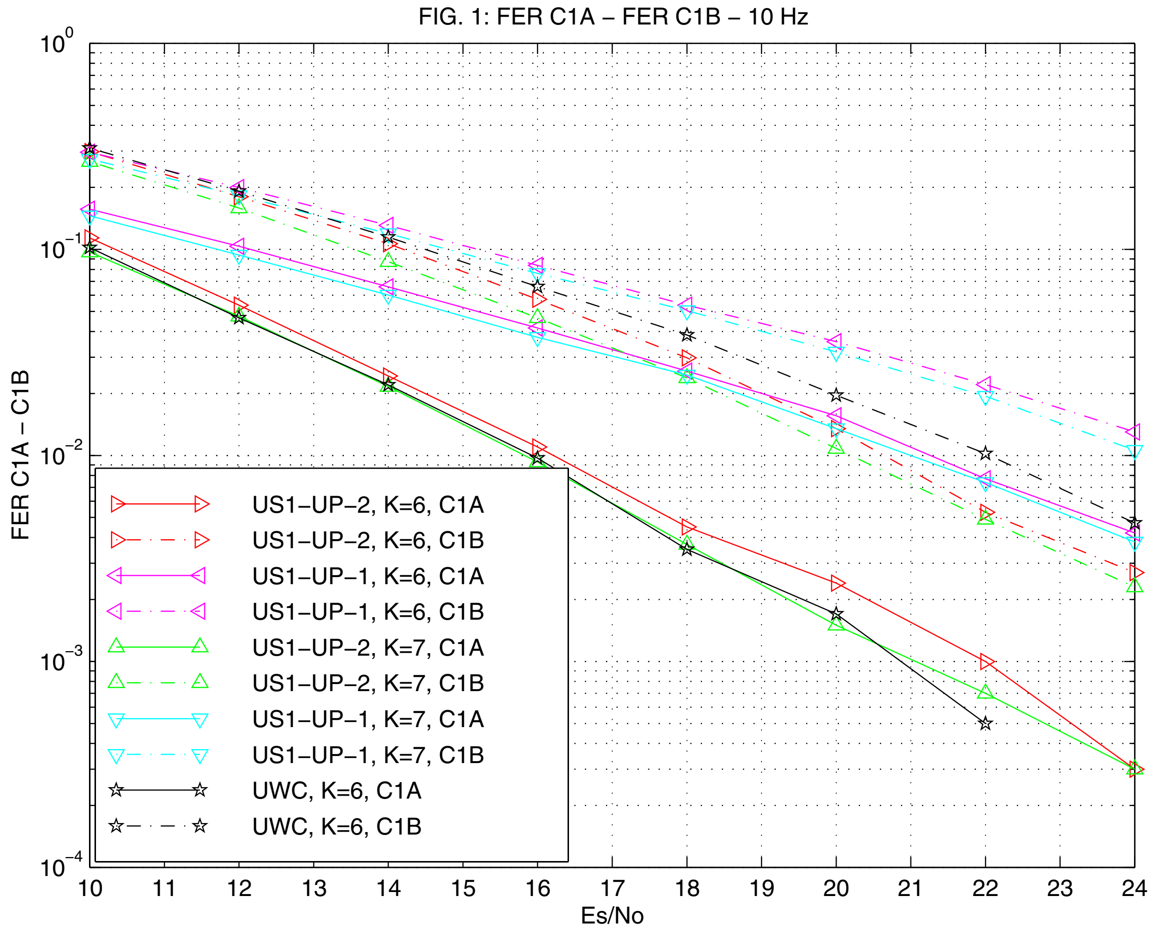


FIG. 1: FER C1A – FER C1B – 10 Hz
FER C1A – C1B
Es/No
US1–UP–2, K=6, C1A
US1–UP–2, K=6, C1B
US1–UP–1, K=6, C1A
US1–UP–1, K=6, C1B
US1–UP–2, K=7, C1A
US1–UP–2, K=7, C1B
US1–UP–1, K=7, C1A
US1–UP–1, K=7, C1B
UWC, K=6, C1A
UWC, K=6, C1B

FIG. 2: BER C1A – BER C1B – 10 Hz

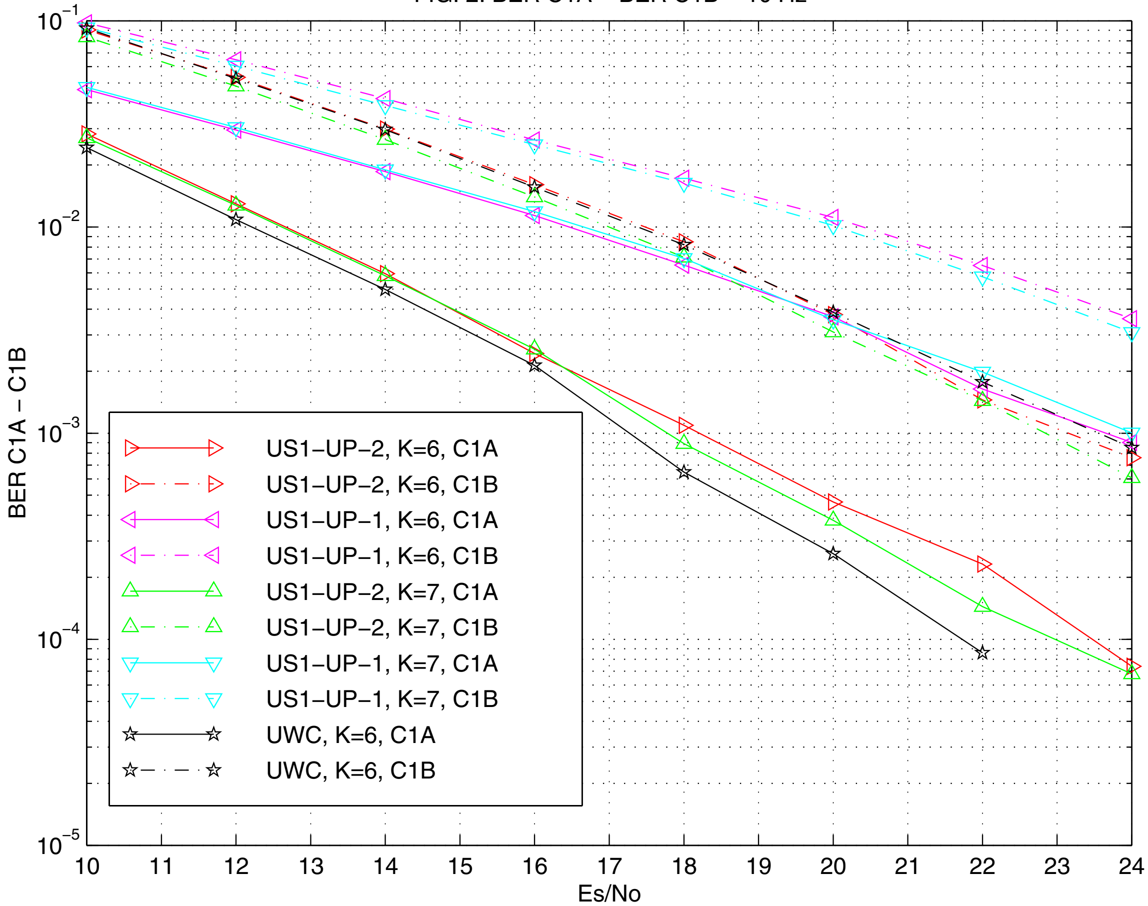
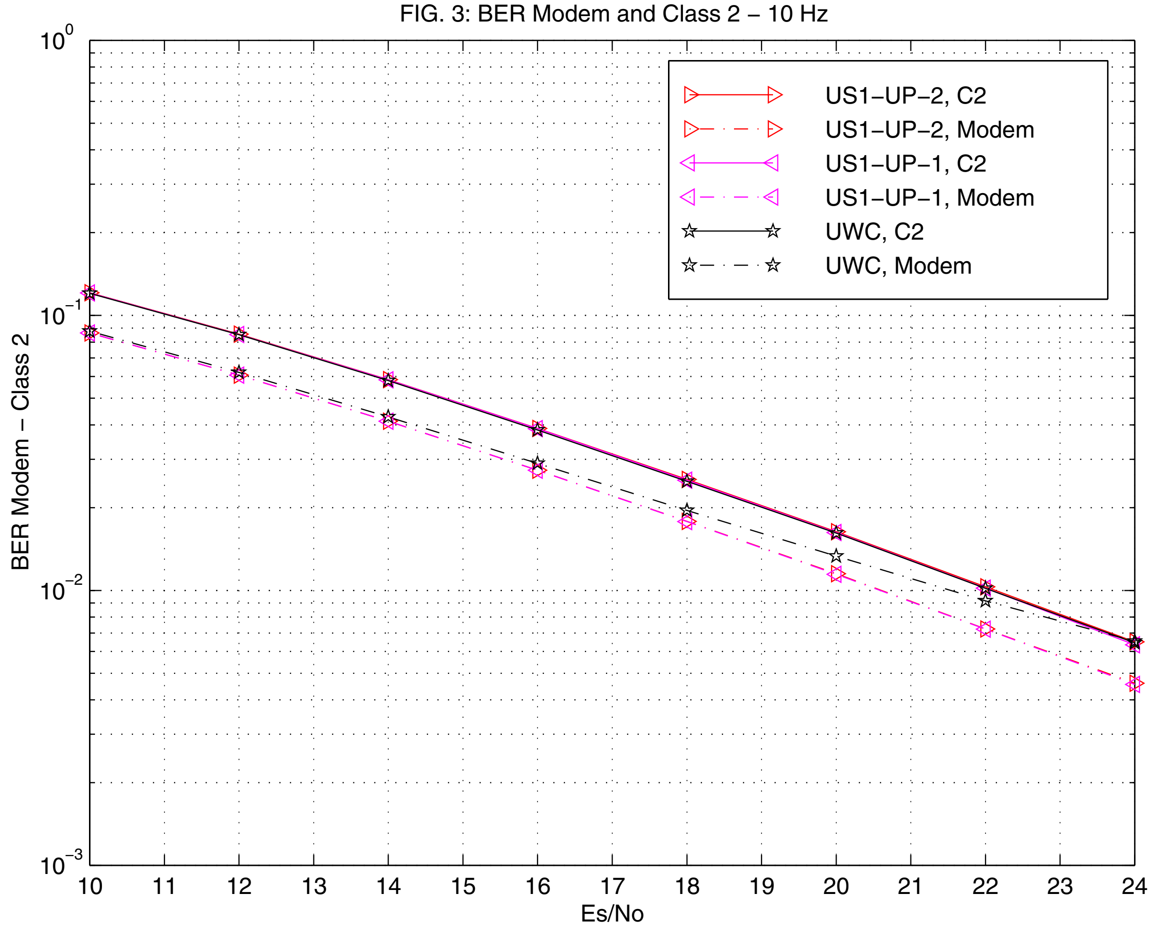


FIG. 3: BER Modem and Class 2 – 10 Hz



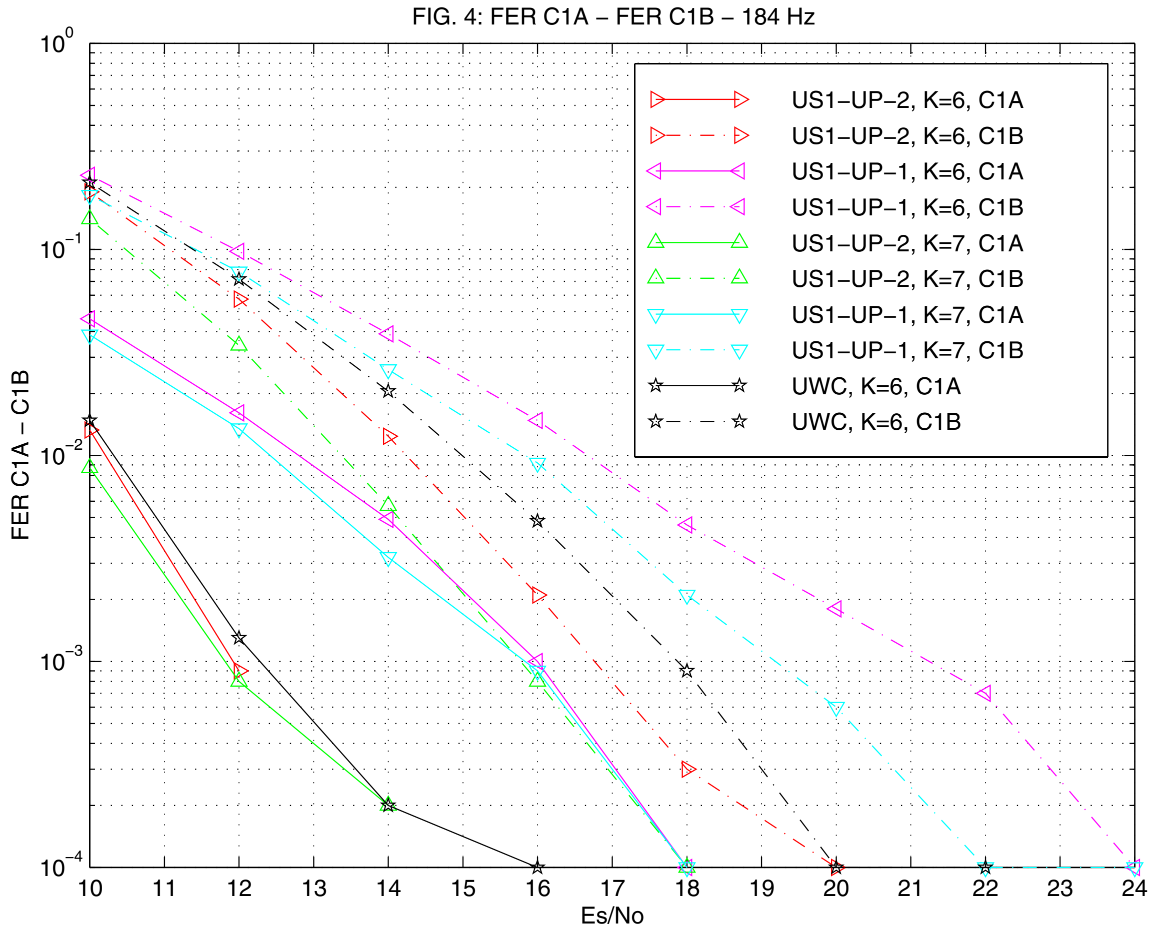


FIG. 4: FER C1A – FER C1B – 184 Hz
FER C1A – C1B
Es/No
10^0
10^-1
10^-2
10^-3
10^-4
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
US1–UP–2, K=6, C1A
US1–UP–2, K=6, C1B
US1–UP–1, K=6, C1A
US1–UP–1, K=6, C1B
US1–UP–2, K=7, C1A
US1–UP–2, K=7, C1B
US1–UP–1, K=7, C1A
US1–UP–1, K=7, C1B
UWC, K=6, C1A
UWC, K=6, C1B

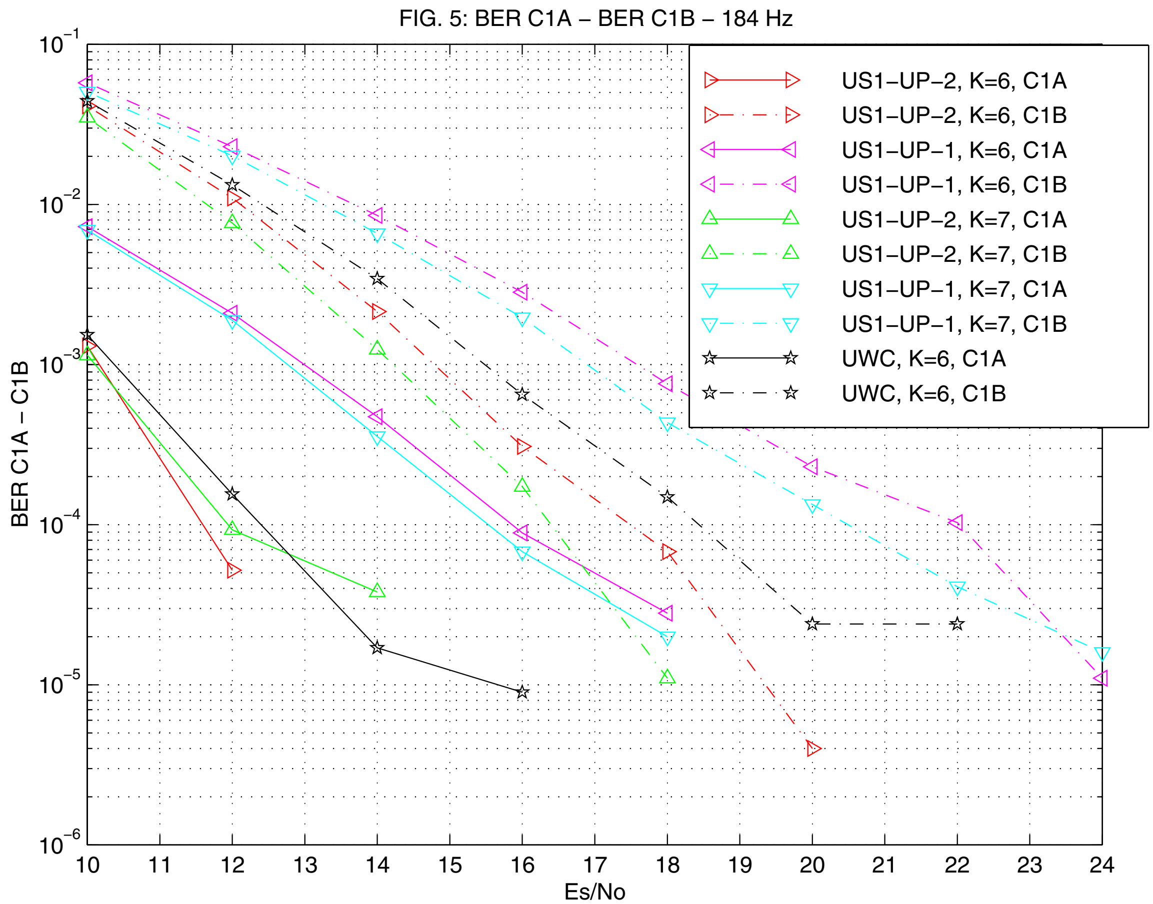


FIG. 5: BER C1A – BER C1B – 184 Hz
BER C1A – C1B
Es/No
US1–UP–2, K=6, C1A
US1–UP–2, K=6, C1B
US1–UP–1, K=6, C1A
US1–UP–1, K=6, C1B
US1–UP–2, K=7, C1A
US1–UP–2, K=7, C1B
US1–UP–1, K=7, C1A
US1–UP–1, K=7, C1B
UWC, K=6, C1A
UWC, K=6, C1B

FIG. 6: BER Modem and Class 2 – 184 Hz