TSG-RAN Working Group 1 meeting #5
Helsinki, Filand
July 13-16, 1999

TSGR(99)913

Agenda item:

Source: **Samsung**

Title: **Harmonization impact on TFCI and New Optimal Coding for extended TFCI with almost no Complexity increase**

Document for: **Proposal**

Abstract

TFCI code is very important because decoder depends on the rate information which was carried by TFCI bits. So, TFCI decoding fails, whole decoding also fails. Therefore using a good code for TFCI is very important. However, during studies on Harmonzation impact on TFCI, we found some problems. The current coding scheme for extended TFCI is not optimal at all, so there is considerable performance degradation. Based on this observation, we propose new optimal coding scheme for extended TFCI with almost no complexity increase because we reuse inverse hadamard transform (IHT). Moreover, this code can be generated by natural and simple extension of the current (32,6) TFCI coding.

Current Coding Scheme for TFCI

In this section, the current coding scheme is described.

For 6bit TFCI case, the current coding scheme is as following .

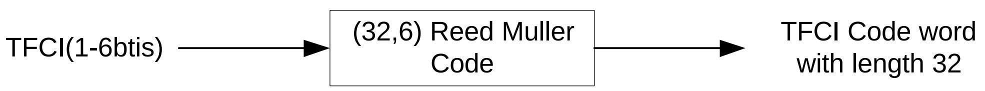

Fig1. The current coding scheme for 6 bit TFCI case

Mapping of the TFCI bits to the code words is described in the following table.

Table 1. mapping of 6bit TFCI bits into codewords

Information bits	Code word
000000	$C_{32,1}$
000001	$\overline{C}_{32,1}$
000010	$C_{32,2}$

.....	.....
111101	$\overline{C}_{32,31}$
111110	$C_{32,32}$
111111	$\overline{C}_{32,32}$

For 7-10bit TFCI case, the current coding scheme is as following .

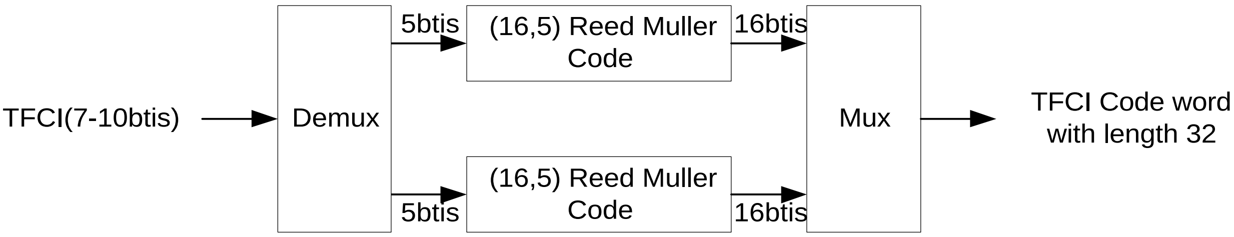

Fig2. The current coding scheme for 7-10bit TFCI case

Mapping of the TFCI bits to the code words is described in the following table.

Table 2. mapping of 7-10TFCI bits into Code words

Information bits	Code word
00000	$C_{16,1}$
00001	$\overline{C}_{16,1}$
00010	$C_{16,2}$
.....	.....
11101	$\overline{C}_{16,15}$
11110	$C_{16,16}$
11111	$\overline{C}_{16,16}$

Harmonization impact on TFCI coding and Problems of the current coding scheme for extended TFCI

As we see in the figure in this section, there is no significant performance degradation by puncturing the current TFCI. The performance difference is about 0.1dB in AWGN, so we can say that there is no significant impact on TFCI by puncturing the current code. However, we see big performance difference between current (32,6) and (16,5) Reed Muller code. There is more than 0.8.dB performance difference in the operating point in AWGN. 0.8dB diffrence in AWGN is not a small difference, and this difference must be bigger in fading environment.We should start to think if we can avoid this situation.

If we look at the paper [1], we can see the minimum dsitance of the code of length 32. Those values are summarized in the following table1.

	6 TFCI bits	7 TFCI bits	8 TFCI bits	9 TFCI bits	10 TFCI bits
Optimal minimum distance	16	14	13	12	12

Table 3. Optimal bound of the minimum distance for the code of length 32

Considering the table above, we can see that the current (32,6) Reed Muller code achieves the optimality because the minimum distance of the current (32,6) Reed Muller code is 16. However, the current coding scheme for (32,7-10) code is not optimal at all because the minimum distance of the current (16,5) Reed Muller code is 8. Therefore, we can expect a considerable performance degradation comparing with the optimal code. Furthermore, concatenating short code is a bad idea in terms of the performance.

Therefore, we should try to find a new code which can improve the performance for Extended TFCI, and does not require much complexity increase at the same time.

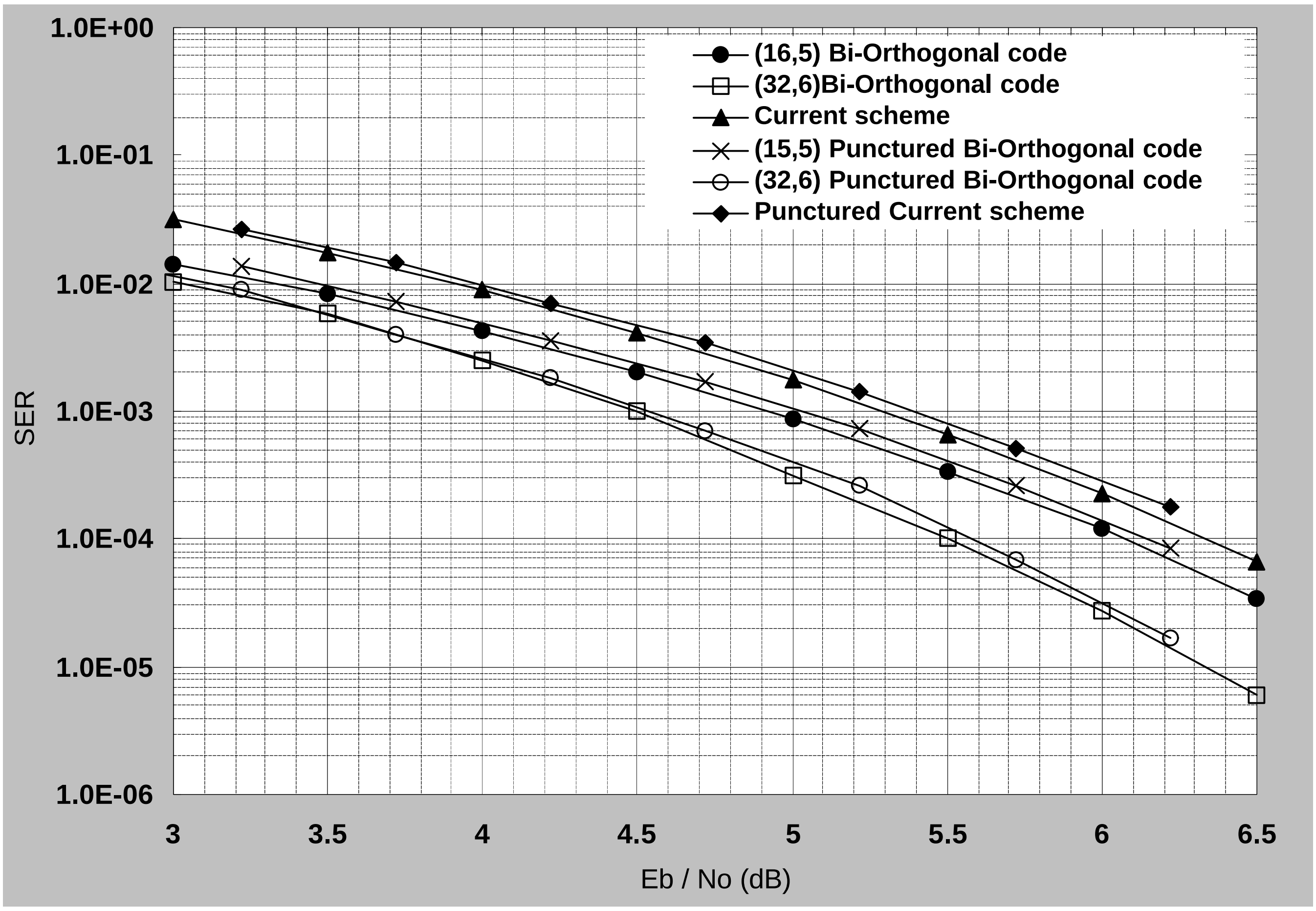

Fig 3 .SER performance of TFCI in AWGN

Proposed New TFCI Coding scheme

Based on Problems described in the previous section, we hope to have a better code than the current coding. Surprisingly, we can find a optimal code in the sense of a natural extension of the current (32,6) First Order Reed Muller code. Using sub-code of Second order Reed Muller code, we can achieve that goal. Second order reed Muller code consists of codewords that added some masks to the current First Order Reed Muller code.

Then, the number of mask is decided by the number of TFCI bits exceeding 6bit. In n bit TFCI case, 2^{n-6} - 1 masks is used for coding. For example, if we have 8bits for TFCI, then 3 masks are needed. To cover 10bit TFCI, 15 masks are needed. We can think the current (32,6) Reed Muller has a mask which consists of all zeros.

For 6-10bit TFCI case, the proposed coding scheme is as following .

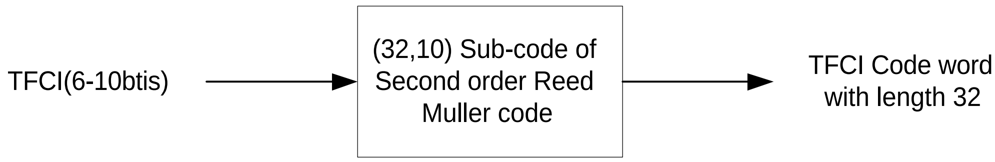

Fig 4. The Proposed coding scheme

Mapping of the TFCI bits to the code words is described in the following table.

Table 4. Mapping of 6-10bit TFCI bits into codeword corresponding to the proposed scheme

Information bits	Code word	Information bits	Code word	Information bits	Code word
0000000000	$C_{32,1}$	0001000000	$M_1 + C_{32,1}$	......	......
0000000001	$\overline{C}_{32,1}$	0001000001	$M_1 + \overline{C}_{32,1}$	0001000000	$M_{15} + C_{32,1}$
0000000010	$C_{32,2}$	0001000010	$M_1 + C_{32,2}$	0001000001	$M_{15} + \overline{C}_{32,1}$
.....	.....	......	......	......	......
0000111101	$\overline{C}_{32,31}$	0001111101	$M_1 + \overline{C}_{32,31}$	0001111101	$M_{15} + \overline{C}_{32,31}$
0000111110	$C_{32,32}$	0001111110	$M_1 + C_{32,32}$	0001111110	$M_{15} + C_{32,32}$
0000111111	$\overline{C}_{32,32}$	0001111111	$M_1 + \overline{C}_{32,32}$	0001111111	$M_{15} + \overline{C}_{32,32}$

We see that the new coding scheme for extended TFCI is made by just adding 15 masking functions to the current (32,6) Reed Muller code. The minimum distance of the new scheme is 12 as the optimal bound, and can be made as an extension of the current (32,6) Reed Muller code.

Encoder Sturcture

In this section , encoder structure of the new proposed scheme is described. In fact, all walsh code with length 32 is a vector space of dimension 5. So, there are 5 basis for vector space, for example, $W_{32,2}$, $W_{32,3}$, $W_{32,5}$, $W_{32,9}$, $W_{32,17}$. The current encoding structure is shown in the box of the figure below. The other is the addition because of the extension form (32,6) Reed Muller code. As you see, additional complexity for this extension in the encoder is very minor, and we can also expect a simple decoding procedure because of this natural extension.

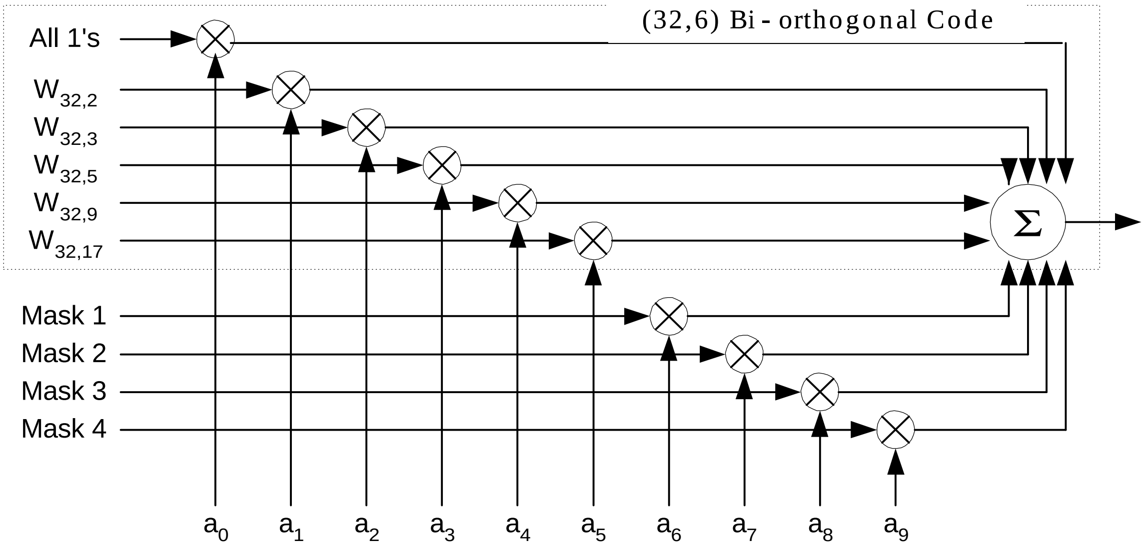

Fig 5 . Encoder structure

Actually, this basis is very meaningful, because, for (32,6) code case, if code index n is transferred into binary form $(a_0a_1a_2a_3 \ldots a_5)_2$, a_i=0,1, code becomes a a_5*$W_{32,17}$ + a_4* $W_{32,17}$ + a_3* $W_{32,17}$ + a_3* $W_{32,17}$ + a_2* $W_{32,17}$. Moreover, we select a mask set {0,M_1,M_2,M_3, ... ,M_{15}} as a vector space with demension 4, and we can choose a basis, M_1,M_2,M_3,M_4. Then, codeword set is a vector space of dimension 10 with $W_{32,2}$, $W_{32,3}$, $W_{32,5}$, $W_{32,9}$, $W_{32,17}$, M_1, M_2, M_3, M_4 , and all1's vector as basis. So, using the basis, the very simple encoder can be implemented, and the structure is as follows.

M1 = 00101000011000111111000001110111

M2 = 00000001110011010110110111000111

M3 = 00001010111110010001101100101011

M4 = 00011100001101110010111101010001

For example, when input TFCI bits $(0010010001)_2$, output coded symbol is

a_9*Mask4 + a_8* Mask3 + a_7*Mask2 + a_6 * Mask1 + a_5*$W_{32,17}$ + a_4*$W_{32,9}$+ a_3*$W_{32,5}$ + a_2*$W_{32,3}$ + a_1*$W_{32,2}$ + a_0*all 1's

= (00000001110011010110110111000111) + (00000000111111110000000011111111) +

(11111111111111111111111111111111)

= 11111110110011011001001011000111

Selecting masks is very important for good codeword. Actually, masks can be derived from Gold Code

Weight Distribution

Weight distribution and the minimum distance are the most important factor to determine the performance of the Linear Block code. In this section, we compare the weight distribution and minimum distance of the current coding scheme with that of proposed coding scheme in detail.

In TFCI 6bit case, the current scheme and the proposed scheme have the same codeword, so the minimum distance and weight distribution is also equal. Then, the minimum distance is 16 and the weight distribution is as following table.

Table 5. The weight distribution of the current (32,6) bi-orthogonal code

Codeword Weight	Occurence
0	1
16	62
32	1

While, the current scheme and the proposed scheme have the different minimum distance and weight distribution Then, the minimum distance is 16 and the weight distribution is as following table. As we can see, the difference of the minimum distance between the current scheme and the proposed scheme is 4. In Coding Theory, the difference 4 of the minimum distance is very high. As we mentioned about, the performance is about 1dB. The weight distribution of two scheme is as follows.

Table 6. Comparison of weight distribution of the current & proposed scheme for 7-10bit TFCI case

Current scheme		Proposed scheme	
Codeword Weight	Occurence	Codeword Weight	Occurence
0	1	0	1
8	60	12	240
16	902	16	542
24	60	20	240
32	1	32	1

Performance

In this section, we show the comparison of the performance for 3 coding schemes by the simulation in AWGN channel and fading channels. The compared 3 coding schemes are as follows.

1. New proposed sub-code of Second order Reed Muller code
2. Current coding scheme ((16,5) x 2) for the extended TFCI bit
3. Single (16,5) Bi-orthogonal Code

In AWGN, new proposed Sub-code of Second order Reed Muller code has about more than 0.6dB as a coding gain compared with the current scheme. And, in fading channel with vehicular speed 30km, new proposed Sub-code of Second order Reed Muller code has about 3.5dB coding gain compared with the current scheme. This is the tremendous gain to consider the change of the current Extended TFCI coding scheme. This new code gives us a great coding gain, and does not require much complexity increase at the same time because of natural extension of the current code.

AWGN Channel

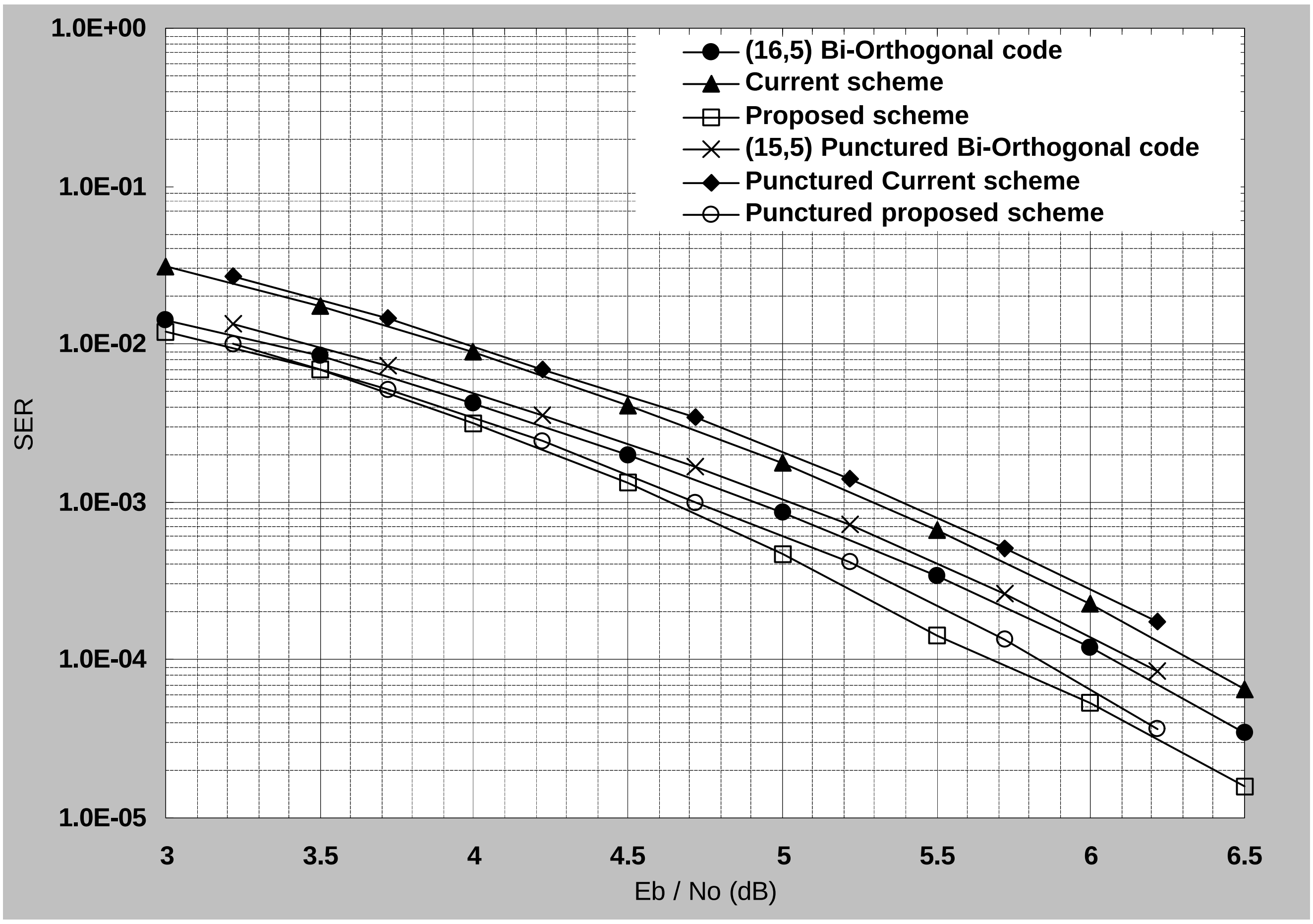

Fig 6. Performance curve in AWGN channel

Fading Channel

- JTC Model
- Vehicular Speed : 30Km
- No power control
- ideal estimation
- 1-path

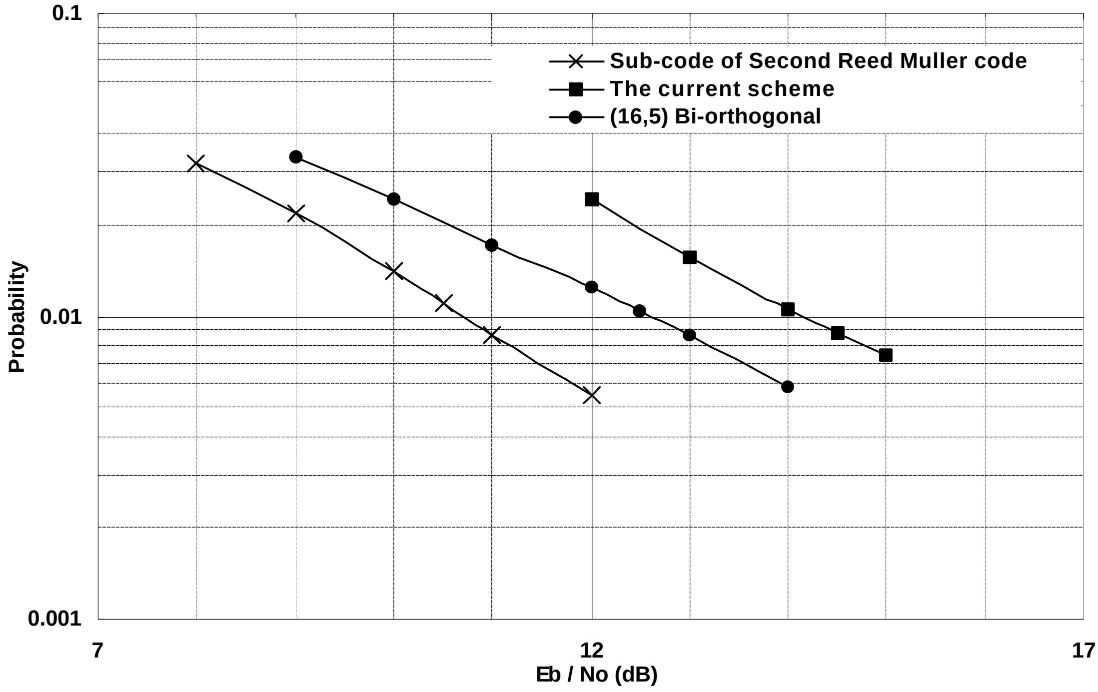

Fig 7. Performance curve in Fading channel with vehicular speed 30km

Decoder Structure

In this section, we will describe the decoding structure correspoding to the encoding structure in the previous section. For decoding, we can reuse the fast hadamard transform for current (32,6) First order Reed Muller code. The decoding structure is as follows.

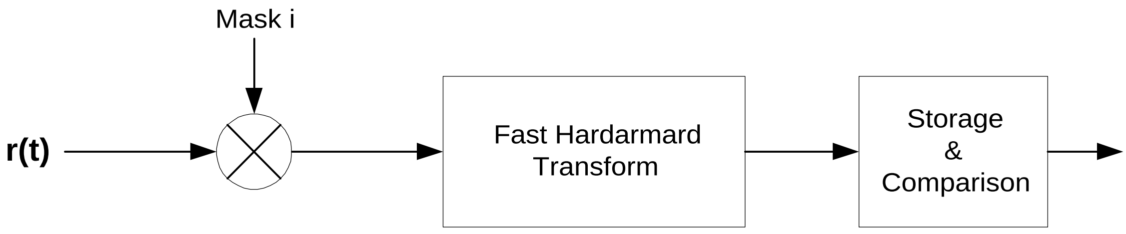

Fig 8. Decoder Structure

In the figure, when we recieve the signal **r(t)**, we multiply all possible mask with the recieved signal, and perform the fast hadamard transform 15times or less iteratively. Then, the decoding complexity is not increased much because we reuse the current Hadamarad Transform, but the decoding delay is increased about 16times. But this increase of decoding time is not matter comparing with other process for demodulation. If we assume a reuse of the current Hadamard Transform, then it needs about 64 cycles to finish to decode 32 length Hadamard, So for the decoding of new proposed scheme, it needs about 64*16 cycles. If we have a hardware operating with 70 MHz clock, then decoding delay for the current scheme is about 0.9µs and it for new coding is about 14.6µs. This decoding time delay is no problem at all for the real-time implmentation.

Conclusion

During studies on Harmonization impact on TFCI, we found some performance problem in the extended TFCI coding. The current coding scheme is not optimal at all, and too far from optimal. Considering the importance of TFCI because of big influence on link performance, we need to have a good code. In this proposal, we proposed new optimal TFCI coding which achieves a big performance improvement (0.6 dB in AWGN and 3.5 dB in Fading). It also turns out that this new code can be generated by natural and simple extension of the current (32,6) First order reed Muller code, so there is no significant complexity increase to decode. So we strongly recommend to change the current Extended TFCI coding scheme to new proposed one. There is no reason not to use optimal code which does not require much complexity increase.

Reference

[1] : "An Updated Table of Minimum-Distance Bounds for Binary Linear Codes" – A.E. Brouwer and Tom Verhoeff, IEEE Transactions on Information Theory, VOL. 39, N). 2, March 1993