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Introduction

Code signalling has been introduced in 3.84 Mcps TDD [1], whereby the number of the active codes is signalled to the UE (common midamble case) by modulating the midamble shifts, and thus a notable reduction of the implementation complexity of the blind code detection is realised. However, a further reduction could be achieved if additional information, such as a subset of the total codes which encloses all the active codes, could be also signalled to the UE.

This advanced code signalling scheme was proposed for the wideband TDD in [2], but some doubts were raised regarding the observed small performance degradation in some radio environments when the burst type 2 with three midamble shifts was used. This performance degradation was caused by the non-ideal cross-correlation properties of the different midamble shifts in conjunction with the relatively small length (256 chips) of the burst type 2. It should be noted here that the burst type 1 does not deteriorate the link performance when three midambles are present, primarily because of its large length (512 chips).

In narrowband TDD, only one burst type is specified which has a length of 144 chips. Given the fact that the narrowband TDD employs one third of the chip rate of the wideband TDD, it is anticipated that such performance degradation would not occur or at least it would be reasonably small, and therefore the advanced code signalling scheme is readily applicable.

Being a large capacity system, the narrowband TDD will require the utilisation of advanced receivers not only at the Node-B but also at the UE, necessitating the reduction of its implementation complexity. Having adopted such a scheme, it can be found that significant savings could be realised.

Description

[1] proposes the signalling of the number of active codes, fact that improves the effectiveness of the blind channelisation code detection. Nevertheless, the UE still has to search over the whole range of the 16 possible codes in order to determine which are the active ones. By restricting the search over a smaller subset L (Figure 1), which encloses all the active codes N, then gains both in complexity and error performance could be achieved. Apparently, the complexity reduces because the matched-filtering operation is performed for a number of possible codes which is always smaller than 16. Furthermore, the error performance improves because the blind detection algorithm has to decide for the active codes from a smaller number of decision variables.

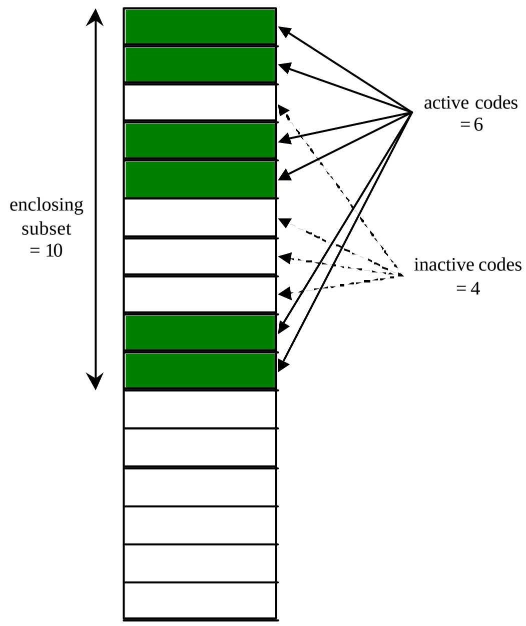

Figure 1. Active codes and their enclosing subset

The enclosing subset L could get values from 1 to 16 and given a value of L, N ranges from 1 to L, resulting in a total of 136 possible combinations. In order to signal this amount of information a minimum of 10 midamble shifts is required when up to three midambles could be simultaneously used:

$$10 + \binom{10}{2} + \binom{10}{3} = 175 \geq 136$$

where $\binom{a}{b} = \frac{a!}{b!\,(a-b)!}$ are the possible combinations.

Consequently, when the system is configured such as the number of midambles K $\geq$ 10 then all the necessary information could be signalled to the UE but unfortunately at certain radio environments where K < 10, the signalling capacity is somewhat reduced. One way of tackling this problem, is by decreasing the granularity of the enclosing subset. Thus, instead of having a step M = 1, this could be increased to 2 (and hence L could range from 2 to 16), 4 and so forth, decreasing in this way the number of signalled combinations. It can be easily seen that for K = 8, the signalling capacity could accommodate the number of combinations required for the signalling of L = 2 to 16 and N = 1 to L, and similarly for K = 6 of L = 4 to 16 and N = 1 to L.

Hereinafter, given that the signalling capacity for K = 4 or 2 is very small (actually it can not properly signal even the number of active codes), this contribution does not deal with these particularly low values. Thus, for K = 4 the already existent solution from wideband TDD is assumed in use, whereas for K = 2 it is assumed that no signaling will take place at all.

Coding & decoding procedure

Although narrowband TDD specifies a wide range for K (K = 16, 14, … 6) having the necessary signalling capacity, the proposed scheme effectively does not distinguish among those allowing for a simple procedure to be used for all of them (minimisation of memory requirements at the UE by using a single look-up table).

Let assume that the narrowband TDD system is configured with a value of K whose correspondent step value of the enclosing subset is M. Let also L be the size of this subset which encloses N active codes. For this triplet (L, N, M) the combination number X is calculated by:

$$X = \frac{L\left(\frac{L}{M} + 1\right)}{2} + N$$

For every possible value of the triplet (L, N, M), this formula gives a combination number within the range 1 to 136 (for M = 1), 1 to 72 (for M = 2) and 1 to 40 (for M = 4). Knowing the X combination number, the coding table cited in Annex A is used in order to find the corresponding midamble combination.

At the UE, the midamble positions are determined and given the known system configuration number K, the midamble combination number is calculated. The special construction of the coding table aids to the fast determination of the corresponding X combination value (both in ascending order) and finally the values of L and N could be easily found.

Performance degradation

The concurrent presence of more than one midambles causes some degradation of the performance of the channel estimation, fact that directly impacts the link performance. In this section, this performance degradation is estimated for a number of different radio scenarios.

The following figures depict the error curves for 1 and 6 active codes (channel cases 2 & 3) when only one midamble is transmitted and when three midambles are transmitted concurrently (proposed scheme). For the comparison of these curves it is concluded that a small degradation is observed of about 0.3 dB (1 code – Case 3) at 1% BER, which reduces as the number of the active codes increases. Thus, when 6 codes are active this drops to 0.1 dB. Similarly, for Case 2 the found degradation is 0.25 dB and 0.08 dB respectively.

Table 1 quotes the performance degradation found in all the considered test scenarios. In general, only when 1 code is active the degradation could be as high as 0.3 dB, but when there are more than 2 active codes, the degradation ranges between 0.1 dB to 0.2 dB. Lastly, under normal load conditions of 8 to 10 active codes, the degradation is up to 0.1 dB, and the same degradation is expected at higher load conditions as well.

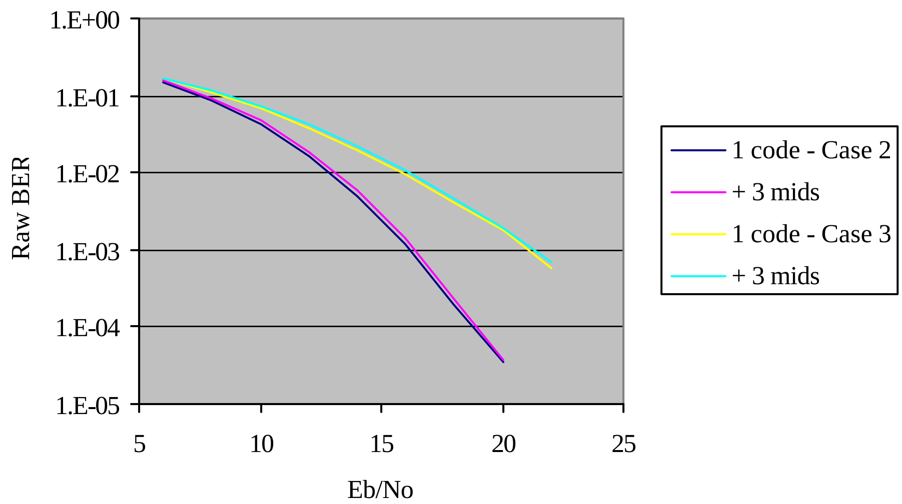

Figure 2. Error curves for 1 active code

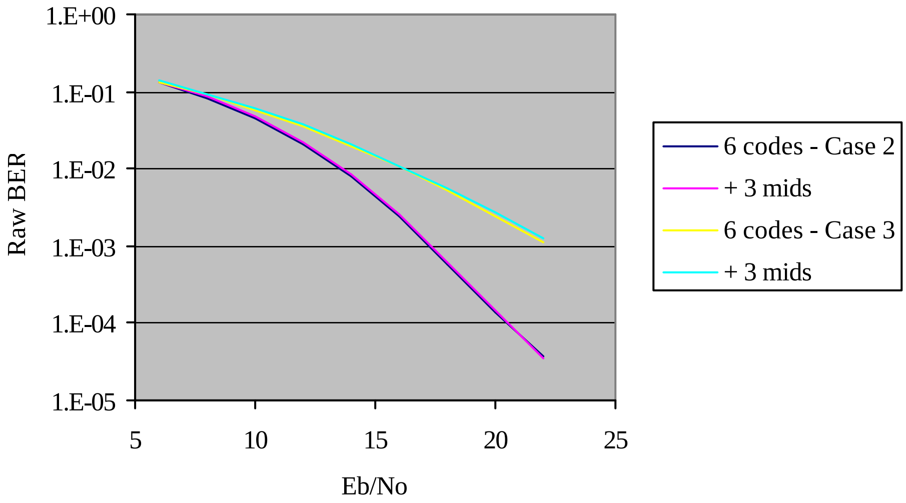

Figure 3. Error curves for 6 active codes

Active codes	Case 1	Case 2	Case 3	Pedestrian B
1	.24	.25	.30	.26
2	.23	.19	.15	.15
4	.14	.12	.14	.12
6	.12	.08	.10	.11
8	.09	.05	.10	.08
10	.10	.06	.10	.10

Table 1. Performance degradation with respect to the single midamble transmission (measured at 1% BER)

In conclusion, the performance degradation due to the utilisation of three midambles is generally characterised quite reasonable. Only when there is one active code, the performance degradation is somewhat increased but in practice this could be avoided by carefully designing the coding table. Indeed, the coding table in Annex A has been designed in order that the most common cases which have only one active code are coded by using up to two midambles.

Complexity savings

For the detection of the active codes, a matched-filter operation is running over a number of received symbols n. Obviously, the larger the value of n, the more accurate the detection but at the same time the larger the required computational complexity, which is given by:

$$C_{MF} = n\ R\ (Q + W - 1) \text{ complex accumulations}$$

where R is the number of the possibly active codes (this is equal to 16 if the UE does not have any a priori information of where the active codes are located within the entire set), Q is the spreading factor (= 16) and W is the channel length in chips.

The knowledge of the number of the active codes allows the UE to reduce the matched-filter operation over a smaller portion of the received signal. It has been estimated that in order to achieve acceptable performance, the matched-filter operation should run over 30 symbols if there is no such a priori information about their number. Alternatively, it should run over about 10 symbols if this information is available to the UE.

Additionally, the knowledge of the enclosing subset of the active codes could result in extra complexity savings because R is reduced and becomes equal to L. These savings for various cases are quoted in the following table:

Examined case		Complexity savings		
L	K	Active codes	Subset	Overall
1	10	66.7%	93.8%	97.9%
8	10	66.7%	50.0%	83.3%
10	10	66.7%	37.5%	79.2%
16	10	66.7%	0.0%	66.7%
1	8	66.7%	87.5%	95.8%
8	8	66.7%	50.0%	83.3%
10	8	66.7%	37.5%	79.2%
1	6	66.7%	75.0%	91.7%
8	6	66.7%	50.0%	83.3%
10	6	66.7%	25.0%	75.0%

Table 2. Complexity savings due to the signalling of the number of the active codes, additional savings due to the signalling of their enclosing subset and overall savings for various cases

The decrease of the correlation length from 30 symbols to 10 symbols due to the signalling of the number of the active codes produces a flat reduction of the complexity by 66.7% irrespective of the actual number of active codes or their enclosing subset. In addition to that and depending upon the size of the of the enclosing subset (slot load) and number of possible midamble shifts K (system configuration), further savings could be realised between 0% - 93.8%, with average savings for typical slot loads between 25% - 50%, irrespective of the system configuration. This brings the average overall savings between 75% - 83.3%. Having in mind that this operation will be running in every slot whilst the UE is active, it is concluded that the presented complexity savings are very important.

In reality, the previous figures could be even more improved because of the fact that the a priori knowledge of the enclosing subset, which is generally smaller than 16, allows the UE to improve the performance of the code detection procedure due to the reduction of the decision variables. This performance improvement could be exploited by decreasing the correlation length to less than 10 symbols reducing as a result further the complexity.

Conclusion

This paper presented an advanced code signalling scheme suitable for the narrowband TDD. The proposed scheme is readily applicable, does not degrade notably the link error performance and achieves essential complexity savings at the UE.

References

[1] Mitsubishi Electric, Siemens AG, “Number of codes signalling for the DL common midamble case”, Tdoc R1-00-1089 CR 031r1, Berlin, August 2000

[2] Motorola, “Proposal for enhanced code signalling”, offline discussion paper, August 2000

Annex A: Coding table

X value	midamble combination decimal	octal			
1	1	0	0	0	1
2	2	0	0	0	2
3	3	0	0	0	3
4	4	0	0	0	4
5	5	0	0	0	5
6	7	0	0	0	7
7	6	0	0	0	6
8	8	0	0	1	0
9	9	0	0	1	1
10	10	0	0	1	2
11	12	0	0	1	4
12	13	0	0	1	5
13	14	0	0	1	6
14	16	0	0	2	0
15	17	0	0	2	1
16	18	0	0	2	2
17	19	0	0	2	3
18	20	0	0	2	4
19	21	0	0	2	5
20	22	0	0	2	6
21	24	0	0	3	0
22	25	0	0	3	1
23	26	0	0	3	2
24	28	0	0	3	4
25	32	0	0	4	0
26	33	0	0	4	1
27	34	0	0	4	2
28	35	0	0	4	3
29	36	0	0	4	4
30	37	0	0	4	5
31	38	0	0	4	6
32	40	0	0	5	0
33	41	0	0	5	1
34	42	0	0	5	2
35	44	0	0	5	4
36	48	0	0	6	0
37	49	0	0	6	1
38	50	0	0	6	2
39	52	0	0	6	4
40	56	0	0	7	0
41	64	0	1	0	0
42	65	0	1	0	1
43	66	0	1	0	2
44	67	0	1	0	3
45	68	0	1	0	4
46	69	0	1	0	5
47	70	0	1	0	6
48	72	0	1	1	0

49	73	0	1	1	1
50	74	0	1	1	2
51	76	0	1	1	4
52	80	0	1	2	0
53	81	0	1	2	1
54	82	0	1	2	2
55	84	0	1	2	4
56	88	0	1	3	0
57	96	0	1	4	0
58	97	0	1	4	1
59	98	0	1	4	2
60	100	0	1	4	4
61	104	0	1	5	0
62	112	0	1	6	0
63	128	0	2	0	0
64	129	0	2	0	1
65	130	0	2	0	2
66	131	0	2	0	3
67	132	0	2	0	4
68	133	0	2	0	5
69	134	0	2	0	6
70	136	0	2	1	0
71	137	0	2	1	1
72	138	0	2	1	2
73	140	0	2	1	4
74	144	0	2	2	0
75	145	0	2	2	1
76	146	0	2	2	2
77	148	0	2	2	4
78	152	0	2	3	0
79	160	0	2	4	0
80	161	0	2	4	1
81	162	0	2	4	2
82	164	0	2	4	4
83	168	0	2	5	0
84	176	0	2	6	0
85	192	0	3	0	0
86	193	0	3	0	1
87	194	0	3	0	2
88	196	0	3	0	4
89	200	0	3	1	0
90	208	0	3	2	0
91	224	0	3	4	0
92	256	0	4	0	0
93	257	0	4	0	1
94	258	0	4	0	2
95	259	0	4	0	3
96	260	0	4	0	4
97	261	0	4	0	5
98	262	0	4	0	6
99	264	0	4	1	0
100	265	0	4	1	1
101	266	0	4	1	2
102	268	0	4	1	4

103	274	0	4	2	2
104	273	0	4	2	1
105	272	0	4	2	0
106	276	0	4	2	4
107	280	0	4	3	0
108	288	0	4	4	0
109	289	0	4	4	1
110	290	0	4	4	2
111	292	0	4	4	4
112	296	0	4	5	0
113	304	0	4	6	0
114	320	0	5	0	0
115	321	0	5	0	1
116	322	0	5	0	2
117	324	0	5	0	4
118	328	0	5	1	0
119	336	0	5	2	0
120	384	0	6	0	0
121	352	0	5	4	0
122	385	0	6	0	1
123	386	0	6	0	2
124	388	0	6	0	4
125	392	0	6	1	0
126	400	0	6	2	0
127	416	0	6	4	0
128	448	0	7	0	0
129	512	1	0	0	0
130	513	1	0	0	1
131	514	1	0	0	2
132	516	1	0	0	4
133	520	1	0	1	0
134	528	1	0	2	0
135	544	1	0	4	0
136	576	1	1	0	0