TSG-RAN Working Group 1 meeting #9
Dresden, Germany

*TSGR1#9(99)*j30

November 30 - December 3, 1999

Agenda Item: **Ad Hoc 4**

Source: **Siemens**

Title: **TFCI mapping in Compressed Mode for Uplink and Downlink**

Document for: **Information and Discussion**

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1. Abstract

This paper delivers a TFCI bit mapping algorithm, which occupies optimally the TFCI fields per slot and frame of the downlink channel in compressed mode. Additionally changes to the actual TFCI mapping scheme of the uplink channel by using an improved algorithm are presented.
These proposed methods for both up- and downlink do not cause any complexity increase and yield some important advantages.

2. Introduction

The current solution for achieving compressed mode without reducing the TFCI bits per frame is to change the slot format. For the uplink table 13 of Specification 25.212 already provides the different slot formats in compressed mode depending on the transmitted slots per frame. Thus the frame format is changed so that no TFCI bits get lost. Since an unique slot format per frame is required, the TFCI fields per frame can not mach the exact TFCI bit number (30 bits). For the downlink there does not exist any specified downlink slot format for the compressed mode, but an adequate proposal was created by Ericsson [1]. Despite of some changes and discussion of this proposal the main issue of mapping the 30 TFCI bits to the available TFCI bit fields will remain in the same manner. Corresponding to the uplink, in the downlink there will be in most cases more than 30 TFCI bit fields available, too. So this contribution proposes a mapping algorithm especially for the downlink and improves the existing algorithm for the uplink.

3. TFCI mapping algorithm

The question is how to pad the redundant TFCI bit fields in the compressed mode case. In order to get an optimised solution, a basic problem must be considered. After each transmission gap the transmit power control is more or less disturbed. That means the probability of a disturbed transmission because of a disturbed power control decreases with the distance (in slot units) to the transmission gap. As a result the slot succeeding to the transmission gap is supposed to have a weak power control performance. Among other things the following algorithms are based on this knowledge.

3.1 TFCI mapping algorithm for the Uplink Channel

In comparison to the downlink there are no DTX bits allowed in the uplink. Currently Specification 25.212, section 4.2.5.4.2.1 instructs to repeat the bits, which are transmitted subsequently after the transmission gap, in the redundant TFCI bit fields at the end of the frame. If the TG (transmission gap) is located at the end of the frame, the repetition order will be arbitrary.
We propose basically two changes of the current mapping instruction. First of all before repetition is conducted the previously punctured bits of the (32,10) sub-code of second order Reed-Muller code are used to fill up the redundant TFCI fields. This is done because repetition of a basic code is more performance promising than repetition after puncturing. These two previously punctured bits should be placed at the end of the frame if possible, because this would not cause too much changes in the actual specification. Moreover if unoccupied TFCI fields still remain, repetition of the TFCI bits transmitted directly after the gap will take place. But we propose to reverse the actual repetition order. This means that the bits, which are transmitted originally immediately after the gap i. e. at the weakest

position, are repeated as late as possible i. e at the strongest position. This will give an even distribution of the quality over the TFCI bits.
Thus, the section 4.2.5.4.2.1 would be modified to:

-- TS 25.212 Version 3.0.0, section 4.2.5.4.2.1 ------------------------------------

4.2.5.4.2.1 Uplink

For uplink compressed mode, ~~by method B~~ the slot~~frame~~ format is changed so that no TFCI bits are lost. The different slot~~frame~~ formats in compressed mode do~~can~~ not match the exact number of TFCI bits for all possible TGLs. The previously punctured bits b_{30} and b_{31} and r~~R~~epetition of the TFCI bits is therefore used.
Denote the number of bits available in the TFCI fields of one compressed radio frame by D, the ~~repeated~~ redundant bit~~s~~ fields by d_k, and the number of bits in the TFCI field in a slot by N_{TFCI}. Let E=29~~30-1~~-($N_{first}N_{TFCI}$)mod 30. If $N_{last}\neq14$, then E corresponds to the number of the first TFCI bit in the slot directly after the TG. The following relations then define the TFCI mapping~~repetition~~.
If D>32, then

$$d_{D-31} = c_{(E-(D-33)) \bmod 30}, d_{D-32} = c_{(E-(D-34)) \bmod 30}, \ldots, d_2 = c_{(E-(D-D)) \bmod 30}, d_1 = b_{31}, d_0 = b_{30}$$

else

$$d_1 = b_{31}, d_0 = b_{30}$$

~~$d_{D-31} = c_{E \bmod 30}, d_{D-32} = c_{(E-1) \bmod 30}, d_{D-33} = c_{(E-2) \bmod 30}, \ldots, d_0 = c_{(E-(D-31)) \bmod 30}$~~

The bits are mapped to the slots in descending order starting with the original bits (c_{29} ...c_0) and followed by the repeated ones (d_{D-31} ...d_2) and finally by d_1 and d_0, i.e. c_{29} is sent as first bit in the TFCI field of the first transmitted slot and d_0 as last bit in the TFCI field of the last transmitted slot. If there are only 30 TFCI fields, non of the d bits will be sent.

-- End of TS 25.212 Version 3.0.0, section 4.2.5.4.2.1 -----------------------------------

In order to present this mapping algorithm and to illustrate the changes, an expressive example is given:

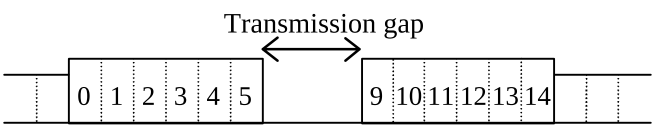


Figure 1: *Compressed mode example*

TGL = 3; N_{first} = 6; N_{TFCI} = 3 (corresponding to table 13 of TS 25.212); D = 36;

Current TFCI mapping to the available TFCI fields per frame:

TFCI:	$c_{29}\ c_{28}\ c_{27}$	$c_{26}\ c_{25}\ c_{24}$	$c_{23}\ c_{22}\ c_{21}$	$c_{20}\ c_{19}\ c_{18}$	$c_{17}\ c_{16}\ c_{15}$	$c_{14}\ c_{13}\ c_{12}$	GAP	GAP	GAP
Slot:	0	1	2	3	4	5	6	7	8

TFCI:	$c_{11}\ c_{10}\ c_{09}$	$c_{08}\ c_{07}\ c_{06}$	$c_{05}\ c_{04}\ c_{03}$	$c_{02}\ c_{01}\ c_{00}$	$c_{11}\ c_{10}\ c_{09}$	$c_{08}\ b_{07}\ b_{06}$
Slot:	9	10	11	12	13	14

Proposed TFCI mapping to the available TFCI fields per frame:

TFCI:	$c_{29}\ c_{28}\ c_{27}$	$c_{26}\ c_{25}\ c_{24}$	$c_{23}\ c_{22}\ c_{21}$	$c_{20}\ c_{19}\ c_{18}$	$c_{17}\ c_{16}\ c_{15}$	$c_{14}\ c_{13}\ c_{12}$	GAP	GAP	GAP
Slot:	0	1	2	3	4	5	6	7	8

TFCI:	$c_{11}\ c_{10}\ c_{09}$	$c_{08}\ c_{07}\ c_{06}$	$c_{05}\ c_{04}\ c_{03}$	$c_{02}\ c_{01}\ c_{00}$	$c_{08}\ c_{09}\ c_{10}$	$c_{11}\ b_{31}\ b_{30}$
Slot:	9	10	11	12	13	14

Gained Advantages:
The hamming distance of the TFCI codewords in compressed mode will be increased in most of the compressed mode cases by using the two previously punctured TFCI bits additionally. Some examples of the minimum hamming distance are shown in table 1.

	Min. hamming distance Current scheme	**Min. hamming distance Proposed method**
Case 1: N_{first} = 6; TGL = 3	11	12
Case 2: N_{first} = 0; TGL = 3	10	12
Case 3: N_{first} = 6; TGL = 1	12	12
Case 4: N_{first} = 0; TGL = 1	11	12

Table 1: *Current TFCI mapping compared with the proposed method by using some compressed mode examples*

You can recognise that the hamming distance is improved by the distance of 1 or 2 in most of the cases.

Additionally we propose to reverse the conventional repetition order. This is done because of the expected poor power control performance subsequently to the transmission gap. So the probably most disturbed TFCI bits after the TG would be repeated in a most apart position (as possible) to the TG.

3.2 Simulations for the proposed TFCI mapping algorithm in the Uplink Channel

Some exhausting and sophisticated simulations would be necessary to prove the whole performance gain of the proposed TFCI mapping algorithm. Nevertheless, the proposal of reversing the repetition scheme does not actually require any simulations for proving the achieved advantage.
The affects of using the previously punctured TFCI bits before repetition are shown in table1 by presenting the minimum hamming distance. Figure 2 provides some simulation results, which we carried out using a AWGN channel model. This simulations should suffice to provide some additional insights of the performance of the modified TFCI mapping scheme. Figure 2 presents the gained performance by using the proposed and conventional method applied to the compressed mode case, which is described in section 3.1 (case 1: TGL = 3; N_{first} = 6; N_{TFCI} = 3; D = 36). Another compressed mode pattern, i. e. TGL = 3; N_{first} = 6; N_{TFCI} = 0; D = 36 (case 2), is also evaluated.
You can recognise that the utilisation of the previously punctured TFCI bits before repetition yields a gain of about 0,15dB.

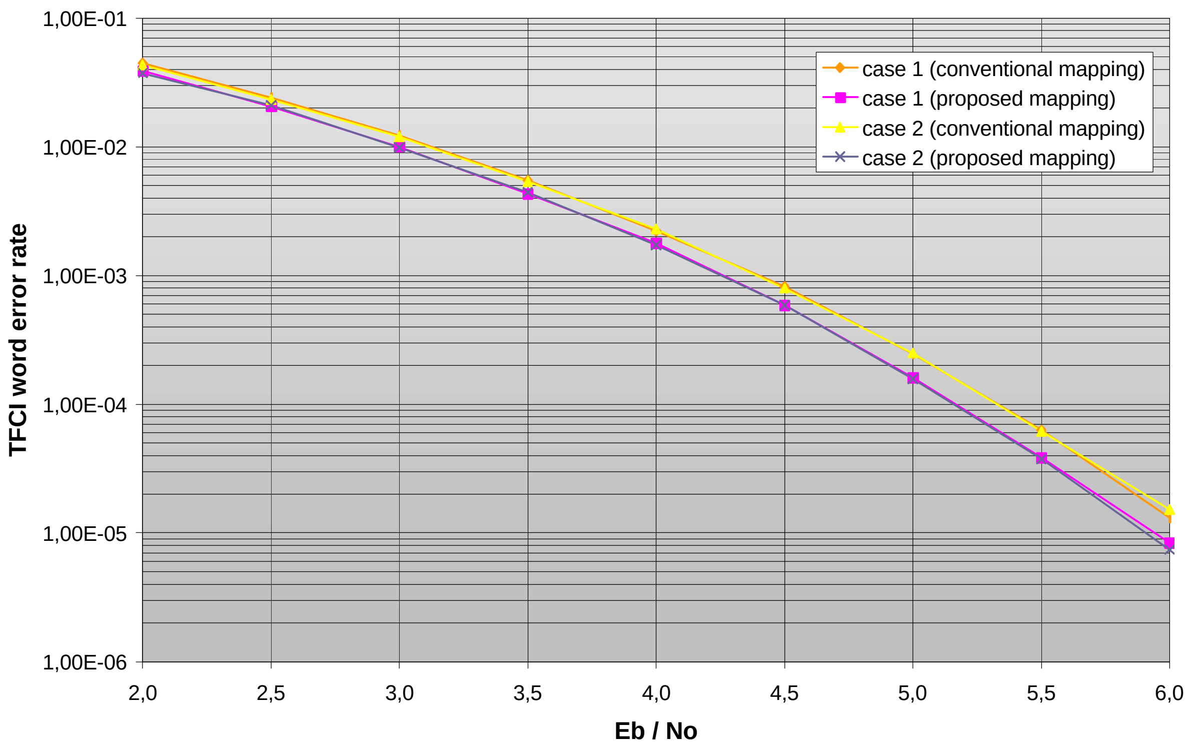


Figure 2: *Comparison of the conventional and the proposed TFCI mapping in an AWGN channel*

3.3 TFCI mapping algorithm for the Downlink Channel

At the moment it is proposed to restock the remaining TFCI fields with DTX bits at the end of the frame subsequently after the original TFCI bits. We basically agree to use DTX bits, but we propose to move the DTX bits directly after the transmission gap, if possible. Thus, the DTX bits are allocated to the most unreliable TFCI fields, and the TFCI bits are mapped to the most reliable TFCI fields. If there are more redundant TFCI fields than TFCI fields after the transmission gap, then the remaining DTX bits will be distributed uniformly to the TFCI fields, that precede the gap.

Chapter 4.2.5.4.2.2 would then contain the following text:

-- TS 25.212 Version 3.0.0, section 4.2.5.4.2.2 ------------------------------------

4.2.5.4.2.2 Downlink

For downlink compressed mode, the slot format is changed so that no TFCI bits are lost. The different slot formats in compressed mode can not match the exact number of TFCI bits for all possible TGLs. The previously punctured bits and DTX is therefore used in the remaining TFCI fields.

D-C-1 DTX bits are mapped to the slots subsequently to the TG. If there are less TFCI bits after the TG than *D-C-1* bits, then DTX is also used at TFCI bit position $k \cdot i$,

where $i = \left\lfloor \dfrac{N_{TFCI} \cdot N_{first}}{D - C - 1 - N_{after} \cdot N_{TFCI}} \right\rfloor$,

k= 1,..., $D - C - 1 - N_{after} \cdot N_{TFCI}$ and

N_{after}=*Number of slots after the gap*. (If N_{last} will be in the second frame, then N_{after}=0.)

The TFCI bits (corresponding to section 4.3.5.3) are mapped to the remaining TFCI bit positions in descending order.

-- End of TS 25.212 Version 3.0.0, section 4.2.5.4.2.1 ------------------------------------

The conventional method and the proposed mapping scheme is applied to the following compressed mode examples of figure 3:

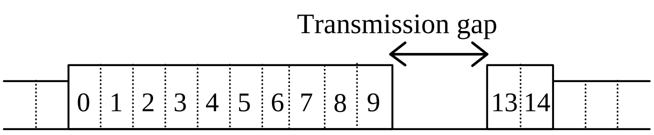


Figure 3: *Compressed mode example*

SF = 256; TGL = 3; N_{first} = 10; N_{TFCI} = 4; D = 48;

Current TFCI mapping to the available TFCI fields per frame:

TFCI: | c_{29} c_{28} c_{27} c_{26} | c_{25} c_{24} c_{23} c_{22} | c_{21} c_{20} c_{19} c_{18} | c_{17} c_{16} c_{15} c_{14} | c_{13} c_{12} c_{11} c_{10} | c_{09} c_{08} c_{07} c_{06} |
Slot: 0 1 2 3 4 5

TFCI: | c_{05} c_{04} c_{03} c_{02} | c_{01} c_{00} c_{DTX} c_{DTX} | c_{DTX} c_{DTX} c_{DTX} c_{DTX} | c_{DTX} c_{DTX} c_{DTX} c_{DTX} | *GAP* | *GAP* |
Slot: 6 7 8 9 10 11

TFCI: | *GAP* | c_{DTX} c_{DTX} c_{DTX} c_{DTX} | c_{DTX} c_{DTX} c_{DTX} c_{DTX} |
Slot: 12 13 14

Proposed TFCI mapping to the available TFCI fields per frame:

TFCI:	$c_{31}\ c_{30}\ c_{29}\ c_{28}$	$c_{DTX}\ c_{27}\ c_{26}\ c_{25}$	$c_{24}\ c_{DTX}\ c_{23}\ c_{22}$	$c_{21}\ c_{20}\ c_{DTX}\ c_{19}$	$c_{18}\ c_{17}\ c_{16}\ c_{DTX}$	$c_{15}\ c_{14}\ c_{13}\ c_{12}$
Slot:	0	1	2	3	4	5

TFCI:	$c_{DTX}\ c_{11}\ c_{10}\ c_{09}$	$c_{08}\ c_{DTX}\ c_{07}\ c_{06}$	$c_{05}\ c_{04}\ c_{DTX}\ c_{03}$	$c_{02}\ c_{01}\ c_{00}\ c_{DTX}$	*GAP*	*GAP*
Slot:	6	7	8	9	10	11

TFCI:	*GAP*	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$
Slot:	12	13	14

Furthermore an additional example is given:

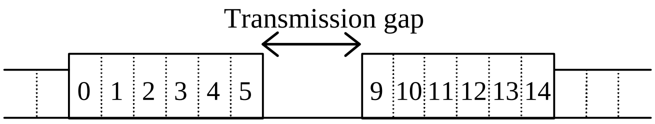


Figure 4: *Further compressed mode example*

SF = 256; TGL = 3; N_{first} = 6; N_{TFCI} = 4; D = 48;

Current TFCI mapping to the available TFCI fields per frame:

TFCI:	$c_{29}\ c_{28}\ c_{27}\ c_{26}$	$c_{25}\ c_{24}\ c_{23}\ c_{22}$	$c_{21}\ c_{20}\ c_{19}\ c_{18}$	$c_{17}\ c_{16}\ c_{15}\ c_{14}$	$c_{13}\ c_{12}\ c_{11}\ c_{10}$	$c_{09}\ c_{08}\ c_{07}\ c_{06}$
Slot:	0	1	2	3	4	5

TFCI:	*GAP*	*GAP*	*GAP*	$c_{05}\ c_{04}\ c_{03}\ c_{02}$	$c_{01}\ c_{00}\ c_{DTX}\ c_{DTX}$	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$
Slot:	6	7	8	9	10	11

TFCI:	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$
Slot:	12	13	14

Proposed TFCI mapping to the available TFCI fields per frame:

TFCI:	$c_{31}\ c_{30}\ c_{29}\ c_{28}$	$c_{27}\ c_{26}\ c_{25}\ c_{24}$	$c_{23}\ c_{22}\ c_{21}\ c_{20}$	$c_{19}\ c_{18}\ c_{17}\ c_{16}$	$c_{15}\ c_{14}\ c_{13}\ c_{12}$	$c_{11}\ c_{10}\ c_{09}\ c_{08}$
Slot:	0	1	2	3	4	5

TFCI:	*GAP*	*GAP*	*GAP*	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$
Slot:	6	7	8	9	10	11

TFCI:	$c_{DTX}\ c_{DTX}\ c_{DTX}\ c_{DTX}$	$c_{07}\ c_{06}\ c_{05}\ c_{04}$	$c_{03}\ c_{02}\ c_{01}\ c_{00}$
Slot:	12	13	14

4. References

[1] TSGR1#9(99)i50; Dresden, Germany;11-1999; Ericsson; CR 25.212-005: Compressed mode by higher layer scheduling

3GPP/SMG Meeting #9
Dresden, Germany, Nov 30 – Dec 03, 1999

***Document* R1-99j30**
e.g. for 3GPP use the format TP-99xxx
or for SMG, use the format P-99-xxx

CHANGE REQUEST

Please see embedded help file at the bottom of this page for instructions on how to fill in this form correctly.

25.212	**CR**	**020**	Current Version:	3.0.0

GSM (AA.BB) or 3G (AA.BBB) specification number ↑ *↑ CR number as allocated by MCC support team*

For submission to:	TSG-RAN #6	for approval	X	strategic		(for SMG use only)
list expected approval meeting # here ↑		for information		non-strategic		

Form: CR cover sheet, version 2 for 3GPP and SMG *The latest version of this form is available from: ftp://ftp.3gpp.org/Information/CR-Form-v2.doc*

Proposed change affects: *(at least one should be marked with an X)*	(U)SIM		ME	X	UTRAN / Radio	X	Core Network

Source: Siemens **Date:** 1999-11-24

Subject: TFCI mapping in Compressed Mode for Uplink and Downlink

Work item:

Category:				**Release:**	
	F	Correction		Phase 2	
	A	Corresponds to a correction in an earlier release		Release 96	
(only one category	B	Addition of feature	X	Release 97	
shall be marked	C	Functional modification of feature		Release 98	
with an X)	D	Editorial modification		Release 99	X
				Release 00	

Reason for change: The TFCI bit Mapping to the available TFCI fields in compressed mode can be improved in order to achieve an enhanced TFCI decoding performance.

Clauses affected: 4.3.3, 4.3.5.4.1, 4.2.5.4.1.1, 4.2.5.4.1.2, 4.3.5.4.2, 4.2.5.4.2.1, 4.2.5.4.2.2

Other specs affected:			
	Other 3G core specifications		→ List of CRs:
	Other GSM core specifications		→ List of CRs:
	MS test specifications		→ List of CRs:
	BSS test specifications		→ List of CRs:
	O&M specifications		→ List of CRs:

Other comments: This CR also incorporates the changes of the CR 003 which affect the relevant sections.

If the TFCI consist of less than 10 bits, it is padded with zeros to 10 bits, by setting the most significant bits to zero. The receiver can use the information that not all 10 bits are used for the TFCI, thereby reducing the error rate in the TFCI decoder. The length of the TFCI code word is 30 bits. Thus there are 2 bits of (encoded) TFCI in every slot of the radio frame.

Firstly, TFCI is encoded by the (32,10) sub-code of second order Reed-Muller code. The code words of the (32,10) sub-code of second order Reed-Muller code are linear combination of 10 basis sequences: all 1's, 5 OVSF codes ($C_{32,1}$, $C_{32,2}$, $C_{32,4}$, $C_{32,8}$, $C_{32,16}$), and 4 masks (Mask1, Mask2, Mask3, Mask4). The 4 mask sequences are as following table 7.

Table 7: Mask sequences

Mask 1	00101000011000111111000001110111
Mask 2	00000001110011010110110111000111
Mask 3	00001010111110010001101100101011
Mask 4	00011100001101110010111101010001

For information bits a_0 , a_1 , a_2 , a_3 , a_4 , a_5 , a_6 , a_7 , a_8 , a_9 (a_0 is LSB and a_9 is MSB), the encoder structure is as following figure 11.

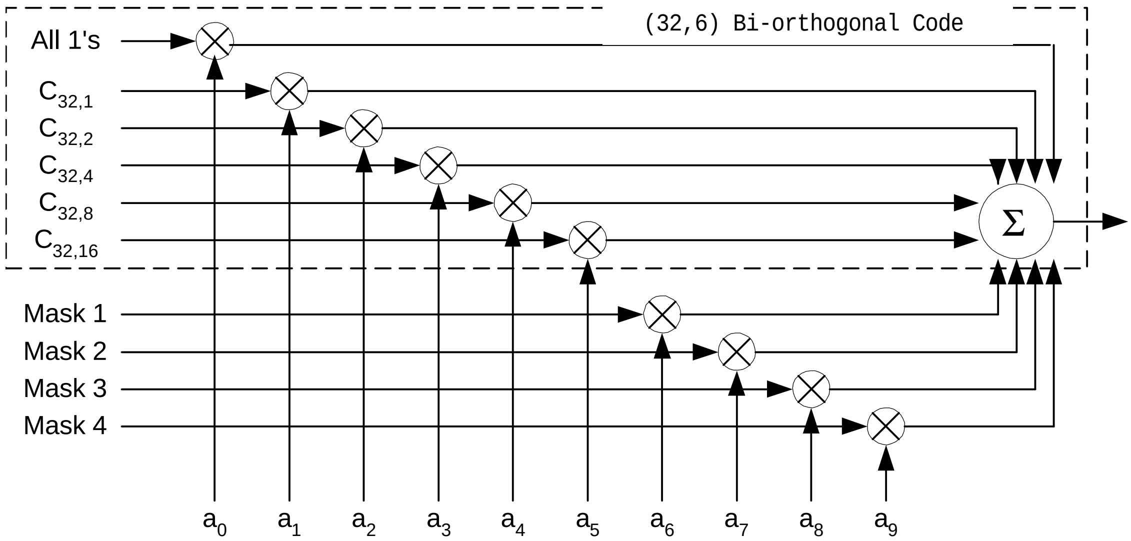


Figure 11: Encoder structure for (32,10) sub-code of second order Reed-Muller code

Then, the output~~code~~ words of the (32,10) sub-code of second order Reed-Muller code are punctured into length 30 by puncturing output bits c_0 and c_{16} ~~1st and 17th bits~~. The remaining punctured bits are denoted by b_k, k = 0, 1, 2, …, 29 (k = 29 corresponds to the MSB bit). For compressed mode, the bits c_0 and c_{16} are denoted by b_{30} and b_{31}.

In downlink, when the SF is lower tha~~e~~n 128 the encoded and punctured TFCI code words are repeated four times yielding 8 encoded TFCI bits per slot. Mapping of repeated bits to slots is explained in section 4.3.5.

4.3.4 Operation of Transport-format-combination indicator (TFCI) in Split Mode

In the case of DCH in Split Mode, the UTRAN shall operate with as follows:

- If one of the links is associated with a DSCH, the TFCI code word may be split in such a way that the code word relevant for TFCI activity indication is not transmitted from every cell. The use of such a functionality shall be indicated by higher layer signalling.

TFCI information is encoded by biorthogonal (16, 5) block code. The code words of the biorthogonal (16, 5) code are from two mutually biorthogonal sets, $S_{C_{16}} = \{C_{16,0}, C_{16,1}, ..., C_{16,15}\}$ and its binary complement,

$\overline{S}_{C_{16}} = \{\overline{C}_{16,0}, \overline{C}_{16,1}, ..., \overline{C}_{16,15}\}$. Code words of set $S_{C_{16}}$ are from the level 16 of the code three of OVSF codes defined in document TS 25.213. The mapping of information bits to code words is shown in the table 8.

Table 8: Mapping of information bits to code words for biorthogonal (16, 5) code

Information bits	Code word
00000	$C_{16,0}$
00001	$\overline{C}_{16,0}$
00010	$C_{16,1}$
...	...
11101	$\overline{C}_{16,14}$
11110	$C_{16,15}$
11111	$\overline{C}_{16,15}$

Biorthogonal code words, $C_{16,i}$ and $\overline{C}_{16,i}$, are then punctured into length 15 by puncturing the 1st bit. The bits in the code words are denoted by $b_{j,k}$, where subscript *j* indicates the code word and subscript *k* indicates bit position in the code word (*k* =14 corresponds to the MSB bit). The punctured bit in each code word is denoted by $b_{j,15}$; it will only be used in compressed mode.

4.3.5 Mapping of TFCI words

4.3.5.1 Mapping of TFCI word

As only one code word for TFCI is needed no channel interleaving for the encoded bits are done. Instead, the bits of the code word are directly mapped to the slots of the radio frame as depicted in the figure 12. Within a slot the more significant bit is transmitted before the less significant bit.

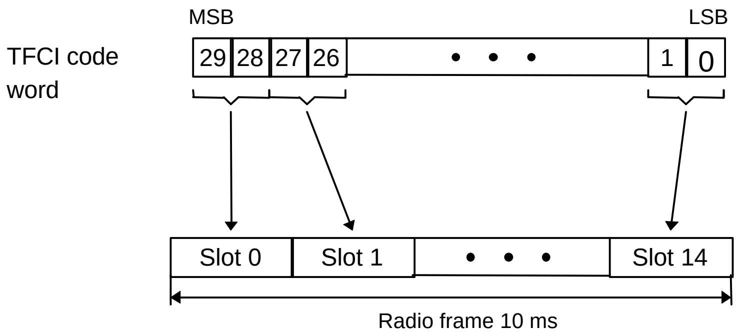


Figure 12: Mapping of TFCI code words to the slots of the radio frame

For downlink physical channels whose SF is lower than 128, bits of the TFCI code words are repeated and mapped to slots as shown in the table 9. Code word bits are denoted as b_k^l, where subscript *k*, indicates bit position in the code word (*k* =29 is the MSB bit) and superscript *l* indicates bit repetition. In each slot transmission order of the bits is from left to right in the table 9.

Table 9: Mapping order of repetition encoded TFCI code word bits into slots.

~~Slot~~	~~TFCI code word bits~~							
~~0~~	~~b_{29}^{1}~~	~~b_{29}^{2}~~	~~b_{29}^{3}~~	~~b_{29}^{4}~~	~~b_{28}^{1}~~	~~b_{28}^{2}~~	~~b_{28}^{3}~~	~~b_{28}^{4}~~
~~1~~	~~b_{27}^{1}~~	~~b_{27}^{2}~~	~~b_{27}^{3}~~	~~b_{27}^{4}~~	~~b_{26}^{1}~~	~~b_{26}^{2}~~	~~b_{26}^{3}~~	~~b_{26}^{4}~~
~~2~~	~~b_{25}^{1}~~	~~b_{25}^{2}~~	~~b_{25}^{3}~~	~~b_{25}^{4}~~	~~b_{24}^{1}~~	~~b_{24}^{2}~~	~~b_{24}^{3}~~	~~b_{24}^{4}~~
~~3~~	~~b_{23}^{1}~~	~~b_{23}^{2}~~	~~b_{23}^{3}~~	~~b_{23}^{4}~~	~~b_{22}^{1}~~	~~b_{22}^{2}~~	~~b_{22}^{3}~~	~~b_{22}^{4}~~
~~4~~	~~b_{21}^{1}~~	~~b_{21}^{2}~~	~~b_{21}^{3}~~	~~b_{21}^{4}~~	~~b_{20}^{1}~~	~~b_{20}^{2}~~	~~b_{20}^{3}~~	~~b_{20}^{4}~~
~~5~~	~~b_{19}^{1}~~	~~b_{19}^{2}~~	~~b_{19}^{3}~~	~~b_{19}^{4}~~	~~b_{18}^{1}~~	~~b_{18}^{2}~~	~~b_{18}^{3}~~	~~b_{18}^{4}~~
~~6~~	~~b_{17}^{1}~~	~~b_{17}^{2}~~	~~b_{17}^{3}~~	~~b_{17}^{4}~~	~~b_{16}^{1}~~	~~b_{16}^{2}~~	~~b_{16}^{3}~~	~~b_{16}^{4}~~
~~7~~	~~b_{15}^{1}~~	~~b_{15}^{2}~~	~~b_{15}^{3}~~	~~b_{15}^{4}~~	~~b_{14}^{1}~~	~~b_{14}^{2}~~	~~b_{14}^{3}~~	~~b_{14}^{4}~~
~~8~~	~~b_{13}^{1}~~	~~b_{13}^{2}~~	~~b_{13}^{3}~~	~~b_{13}^{4}~~	~~b_{12}^{1}~~	~~b_{12}^{2}~~	~~b_{12}^{3}~~	~~b_{12}^{4}~~
~~9~~	~~b_{11}^{1}~~	~~b_{11}^{2}~~	~~b_{11}^{3}~~	~~b_{11}^{4}~~	~~b_{10}^{1}~~	~~b_{10}^{2}~~	~~b_{10}^{3}~~	~~b_{10}^{4}~~
~~10~~	~~b_{9}^{1}~~	~~b_{9}^{2}~~	~~b_{9}^{3}~~	~~b_{9}^{4}~~	~~b_{8}^{1}~~	~~b_{8}^{2}~~	~~b_{8}^{3}~~	~~b_{8}^{4}~~
~~11~~	~~b_{7}^{1}~~	~~b_{7}^{2}~~	~~b_{7}^{3}~~	~~b_{7}^{4}~~	~~b_{6}^{1}~~	~~b_{6}^{2}~~	~~b_{6}^{3}~~	~~b_{6}^{4}~~
~~12~~	~~b_{5}^{1}~~	~~b_{5}^{2}~~	~~b_{5}^{3}~~	~~b_{5}^{4}~~	~~b_{4}^{1}~~	~~b_{4}^{2}~~	~~b_{4}^{3}~~	~~b_{4}^{4}~~
~~13~~	~~b_{3}^{1}~~	~~b_{3}^{2}~~	~~b_{3}^{3}~~	~~b_{3}^{4}~~	~~b_{2}^{1}~~	~~b_{2}^{2}~~	~~b_{2}^{3}~~	~~b_{2}^{4}~~
~~14~~	~~b_{1}^{1}~~	~~b_{1}^{2}~~	~~b_{1}^{3}~~	~~b_{1}^{4}~~	~~b_{0}^{1}~~	~~b_{0}^{2}~~	~~b_{0}^{3}~~	~~b_{0}^{4}~~

Slot	TFCI code word bits							
0	b^{1}_{29}	b^{1}_{28}	b^{1}_{27}	b^{1}_{26}	b^{1}_{25}	b^{1}_{24}	b^{1}_{23}	b^{1}_{22}
1	b^{1}_{21}	b^{1}_{20}	b^{1}_{19}	b^{1}_{18}	b^{1}_{17}	b^{1}_{16}	b^{1}_{15}	b^{1}_{14}
2	b^{1}_{13}	b^{1}_{12}	b^{1}_{11}	b^{1}_{10}	b^{1}_{9}	b^{1}_{8}	b^{1}_{7}	b^{1}_{6}
3	b^{1}_{5}	b^{1}_{4}	b^{1}_{3}	b^{1}_{2}	b^{1}_{1}	b^{1}_{0}	b^{2}_{29}	b^{2}_{28}
4	b^{2}_{27}	b^{2}_{26}	b^{2}_{25}	b^{2}_{24}	b^{2}_{23}	b^{2}_{22}	b^{2}_{21}	b^{2}_{20}
5	b^{2}_{19}	b^{2}_{18}	b^{2}_{17}	b^{2}_{16}	b^{2}_{15}	b^{2}_{14}	b^{2}_{13}	b^{2}_{12}
6	b^{2}_{11}	b^{2}_{10}	b^{2}_{9}	b^{2}_{8}	b^{2}_{7}	b^{2}_{6}	b^{2}_{5}	b^{2}_{4}
7	b^{2}_{3}	b^{2}_{2}	b^{2}_{1}	b^{2}_{0}	b^{3}_{29}	b^{3}_{28}	b^{3}_{27}	b^{3}_{26}
8	b^{3}_{25}	b^{3}_{24}	b^{3}_{23}	b^{3}_{22}	b^{3}_{21}	b^{3}_{20}	b^{3}_{19}	b^{3}_{18}
9	b^{3}_{17}	b^{3}_{16}	b^{3}_{15}	b^{3}_{14}	b^{3}_{13}	b^{3}_{12}	b^{3}_{11}	b^{3}_{10}
10	b^{3}_{9}	b^{3}_{8}	b^{3}_{7}	b^{3}_{6}	b^{3}_{5}	b^{3}_{4}	b^{3}_{3}	b^{3}_{2}
11	b^{3}_{1}	b^{3}_{0}	b^{4}_{29}	b^{4}_{28}	b^{4}_{27}	b^{4}_{26}	b^{4}_{25}	b^{4}_{24}
12	b^{4}_{23}	b^{4}_{22}	b^{4}_{21}	b^{4}_{20}	b^{4}_{19}	b^{4}_{18}	b^{4}_{17}	b^{4}_{16}
13	b^{4}_{15}	b^{4}_{14}	b^{4}_{13}	b^{4}_{12}	b^{4}_{11}	b^{4}_{10}	b^{4}_{9}	b^{4}_{8}
14	b^{4}_{7}	b^{4}_{6}	b^{4}_{5}	b^{4}_{4}	b^{4}_{3}	b^{4}_{2}	b^{4}_{1}	b^{4}_{0}

4.3.5.2 Mapping of TFCI word in Split Mode

After channel encoding of the two 5 bit TFCI words there are two code words of length 15 bits. They are mapped to DPCCH as shown in the figure 13. Note that $b_{1,k}$ and $b_{2,k}$ denote the bit *k* of code word 1 and code word 2, respectively.

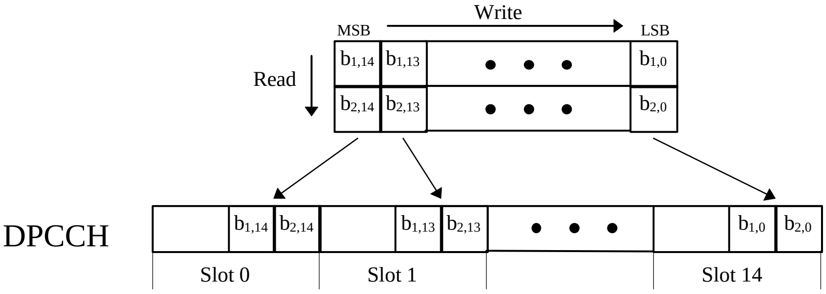


Figure 13: Mapping of TFCI code words to the slots of the radio frame in Split Mode

For downlink physical channels whose SF is lower than 128, bits of the extended TFCI code words are repeated and mapped to slots as shown in the table 10. Code word bits are denoted as $b^l_{j,k}$, where subscript *j* indicates the code word, subscript *k* indicates bit position in the code word (*k*=14 is the MSB bit) and superscript *l* indicates bit repetition. In each slot transmission order of the bits is from left to right in the table 10.

Table 10: Mapping order of repetition encoded TFCI code word bits to slots in Split Mode

~~Slot~~	~~TFCI code word bits in split mode~~							
~~0~~	~~$b^1_{1,14}$~~	~~$b^2_{1,14}$~~	~~$b^3_{1,14}$~~	~~$b^4_{1,14}$~~	~~$b^1_{2,14}$~~	~~$b^2_{2,14}$~~	~~$b^3_{2,14}$~~	~~$b^4_{2,14}$~~
~~1~~	~~$b^1_{1,13}$~~	~~$b^2_{1,13}$~~	~~$b^3_{1,13}$~~	~~$b^4_{1,13}$~~	~~$b^1_{2,13}$~~	~~$b^2_{2,13}$~~	~~$b^3_{2,13}$~~	~~$b^4_{2,13}$~~
~~2~~	~~$b^1_{1,12}$~~	~~$b^2_{1,12}$~~	~~$b^3_{1,12}$~~	~~$b^4_{1,12}$~~	~~$b^1_{2,12}$~~	~~$b^2_{2,12}$~~	~~$b^3_{2,12}$~~	~~$b^4_{2,12}$~~
~~3~~	~~$b^1_{1,11}$~~	~~$b^2_{1,11}$~~	~~$b^3_{1,11}$~~	~~$b^4_{1,11}$~~	~~$b^1_{2,11}$~~	~~$b^2_{2,11}$~~	~~$b^3_{2,11}$~~	~~$b^4_{2,11}$~~
~~4~~	~~$b^1_{1,10}$~~	~~$b^2_{1,10}$~~	~~$b^3_{1,10}$~~	~~$b^4_{1,10}$~~	~~$b^1_{2,10}$~~	~~$b^2_{2,10}$~~	~~$b^3_{2,10}$~~	~~$b^4_{2,10}$~~
~~5~~	~~$b^1_{1,9}$~~	~~$b^2_{1,9}$~~	~~$b^3_{1,9}$~~	~~$b^4_{1,9}$~~	~~$b^1_{2,9}$~~	~~$b^2_{2,9}$~~	~~$b^3_{2,9}$~~	~~$b^4_{2,9}$~~
~~6~~	~~$b^1_{1,8}$~~	~~$b^2_{1,8}$~~	~~$b^3_{1,8}$~~	~~$b^4_{1,8}$~~	~~$b^1_{2,8}$~~	~~$b^2_{2,8}$~~	~~$b^3_{2,8}$~~	~~$b^4_{2,8}$~~
~~7~~	~~$b^1_{1,7}$~~	~~$b^2_{1,7}$~~	~~$b^3_{1,7}$~~	~~$b^4_{1,7}$~~	~~$b^1_{2,7}$~~	~~$b^2_{2,7}$~~	~~$b^3_{2,7}$~~	~~$b^4_{2,7}$~~
~~8~~	~~$b^1_{1,6}$~~	~~$b^2_{1,6}$~~	~~$b^3_{1,6}$~~	~~$b^4_{1,6}$~~	~~$b^1_{2,6}$~~	~~$b^2_{2,6}$~~	~~$b^3_{2,6}$~~	~~$b^4_{2,6}$~~
~~9~~	~~$b^1_{1,5}$~~	~~$b^2_{1,5}$~~	~~$b^3_{1,5}$~~	~~$b^4_{1,5}$~~	~~$b^1_{2,5}$~~	~~$b^2_{2,5}$~~	~~$b^3_{2,5}$~~	~~$b^4_{2,5}$~~
~~10~~	~~$b^1_{1,4}$~~	~~$b^2_{1,4}$~~	~~$b^3_{1,4}$~~	~~$b^4_{1,4}$~~	~~$b^1_{2,4}$~~	~~$b^2_{2,4}$~~	~~$b^3_{2,4}$~~	~~$b^4_{2,4}$~~
~~11~~	~~$b^1_{1,3}$~~	~~$b^2_{1,3}$~~	~~$b^3_{1,3}$~~	~~$b^4_{1,3}$~~	~~$b^1_{2,3}$~~	~~$b^2_{2,3}$~~	~~$b^3_{2,3}$~~	~~$b^4_{2,3}$~~
~~12~~	~~$b^1_{1,2}$~~	~~$b^2_{1,2}$~~	~~$b^3_{1,2}$~~	~~$b^4_{1,2}$~~	~~$b^1_{2,2}$~~	~~$b^2_{2,2}$~~	~~$b^3_{2,2}$~~	~~$b^4_{2,2}$~~
~~13~~	~~$b^1_{1,1}$~~	~~$b^2_{1,1}$~~	~~$b^3_{1,1}$~~	~~$b^4_{1,1}$~~	~~$b^1_{2,1}$~~	~~$b^2_{2,1}$~~	~~$b^3_{2,1}$~~	~~$b^4_{2,1}$~~
~~14~~	~~$b^1_{1,0}$~~	~~$b^2_{1,0}$~~	~~$b^3_{1,0}$~~	~~$b^4_{1,0}$~~	~~$b^1_{2,0}$~~	~~$b^2_{2,0}$~~	~~$b^3_{2,0}$~~	~~$b^4_{2,0}$~~

Slot	TFCI code word bits							
0	$b^1_{1,14}$	$b^1_{1,13}$	$b^1_{1,12}$	$b^1_{1,11}$	$b^1_{2,14}$	$b^1_{2,13}$	$b^1_{2,12}$	$b^1_{2,11}$
1	$b^1_{1,10}$	$b^1_{1,9}$	$b^1_{1,8}$	$b^1_{1,7}$	$b^1_{2,10}$	$b^1_{2,9}$	$b^1_{2,8}$	$b^1_{2,7}$
2	$b^1_{1,6}$	$b^1_{1,5}$	$b^1_{1,4}$	$b^1_{1,3}$	$b^1_{2,6}$	$b^1_{2,5}$	$b^1_{2,4}$	$b^1_{2,3}$
3	$b^1_{1,2}$	$b^1_{1,1}$	$b^1_{1,0}$	$b^2_{1,14}$	$b^1_{2,2}$	$b^1_{2,1}$	$b^1_{2,0}$	$b^2_{2,14}$
4	$b^2_{1,13}$	$b^2_{1,12}$	$b^2_{1,11}$	$b^2_{1,10}$	$b^2_{2,13}$	$b^2_{2,12}$	$b^2_{2,11}$	$b^2_{2,10}$
5	$b^2_{1,9}$	$b^2_{1,8}$	$b^2_{1,7}$	$b^2_{1,6}$	$b^2_{2,9}$	$b^2_{2,8}$	$b^2_{2,7}$	$b^2_{2,6}$
6	$b^2_{1,5}$	$b^2_{1,4}$	$b^2_{1,3}$	$b^2_{1,2}$	$b^2_{2,5}$	$b^2_{2,5}$	$b^2_{2,3}$	$b^2_{2,2}$
7	$b^2_{1,1}$	$b^2_{1,0}$	$b^3_{1,14}$	$b^3_{1,13}$	$b^2_{2,1}$	$b^2_{2,0}$	$b^3_{2,14}$	$b^3_{2,13}$
8	$b^3_{1,12}$	$b^3_{1,11}$	$b^3_{1,10}$	$b^3_{1,9}$	$b^3_{2,12}$	$b^3_{2,11}$	$b^3_{2,10}$	$b^3_{2,9}$
9	$b^3_{1,8}$	$b^3_{1,7}$	$b^3_{1,6}$	$b^3_{1,5}$	$b^3_{2,8}$	$b^3_{2,7}$	$b^3_{2,6}$	$b^3_{2,5}$
10	$b^3_{1,4}$	$b^3_{1,3}$	$b^3_{1,2}$	$b^3_{1,1}$	$b^3_{2,4}$	$b^3_{2,3}$	$b^3_{2,2}$	$b^3_{2,1}$

11	$b^3_{1,0}$	$b^4_{1,14}$	$b^4_{1,13}$	$b^4_{1,12}$	$b^3_{2,0}$	$b^4_{2,14}$	$b^4_{2,13}$	$b^4_{2,12}$
12	$b^4_{1,11}$	$b^4_{1,10}$	$b^4_{1,9}$	$b^4_{1,8}$	$b^4_{2,11}$	$b^4_{2,10}$	$b^4_{2,9}$	$b^4_{2,8}$
13	$b^4_{1,7}$	$b^4_{1,6}$	$b^4_{1,5}$	$b^4_{1,4}$	$b^4_{2,7}$	$b^4_{2,6}$	$b^4_{2,5}$	$b^4_{2,4}$
14	$b^4_{1,3}$	$b^4_{1,2}$	$b^4_{1,1}$	$b^4_{1,0}$	$b^4_{2,3}$	$b^4_{2,2}$	$b^4_{2,1}$	$b^4_{2,0}$

4.3.5.3 Mapping of TFCI in compressed mode

The mapping of the TFCI bits in compressed mode is dependent on the transmission time reduction method. Denote the TFCI bits by c_0, c_1, c_2, c_3, c_4, …, c_C, where:

- $c_k = b_k$, C = 3129, for the channels whose spreading factor is equal to or more than 128when there are 2 TFCI bit in each slot.

- $c_0 = b^4_0, c_1 = b^3_0, c_2 = b^2_0, c_3 = b^1_0, c_4 = b^4_1, c_5 = b^3_1, \ldots, c_{119} = b^1_{14}$,

  $_0 = b^4, c_1 = \ ^4, c_2 = b^4, \ _3 = b^4, c_4 = \ ^4, \cdots, c_{119} = b^1, \ _{120} = b^4, c_{121} = \ ^4, \ldots, c_{126} = b^1, \ _{127} = b^1$

  , =127, for the channels whose spreading factor is less than 128.when there are 8 TFCI bits in each slot.

  $c_0 = b_{2,0}, c_1 = b_{1,0}, c_3 = b_{2,1}, c_4 = b_{1,1}, \ldots, c_{29} = b_{1,14}$,

  $c_0 = b_{2,0}, c_1 = b_{1,0}, c_2 = b_{2,1}, c_3 = b_{1,1}, \cdots, c_{29} = b_{1,14}, c_{30} = b_{2,15}, c_{31} = b_{1,15}$, C=31, in split mode for the channels whose spreading factor is equal to or more than 128.in split mode when there are 2 TFCI bits in each slot.

-

  $c_0 = b^4_{2,0}, c_1 = b^3_{2,0}, c_2 = b^2_{2,0}, c_3 = b^1_{2,0}, c_4 = b^4_{1,0}, c_5 = b^3_{1,0}, \ldots, c_{119} = b^1_{1,14}$

  $c_0 = b^4_{2,0}, c_1 = b^4_{2,1}, \ldots, c_3 = b^4_{2,3}, c_4 = b^4_{1,0}, c_5 = b^4_{1,1}, \ldots, c_7 = b^4_{1,3}, c_8 = b^4_{2,4}, \ldots, c_{119} = b^1_{1,14}$,

  $c_{120} = b^4_{2,15}, c_{121} = b^4_{1,15}, \ldots, c_{126} = b^1_{2,15}, c_{127} = b^1_{1,15}$, C=127, in split mode for the channels whose spreading factor is less than 128.in split mode when there are 8 TFCI bits in each slot.

The TFCI mapping for each transmission method is given in the sections below.

4.3.5.4.1 Compressed mode method A

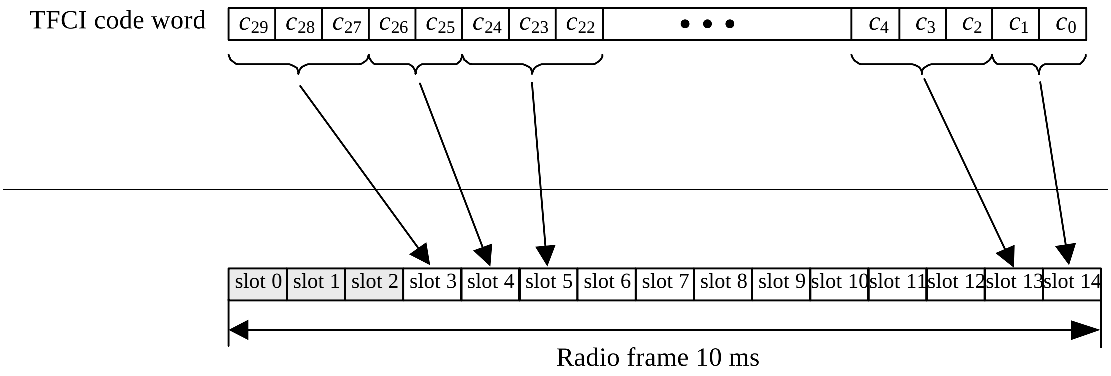
For compressed mode by method A, all the TFCI bits are mapped to the remaining slots. The number of bits per slot in uncompressed mode is denoted by Z and $Z = (C + 1)/15$. The mapping to slots for different TGLs are defined below.

4.2.5.4.1.1 TGL of 3 slots

Slot number 3 + 2x contain bits $c_{C-(\frac{5}{2}Z)x}, c_{C-(\frac{5}{2}Z)x-1}, \ldots, c_{C-(\frac{5}{2}Z)x-(\frac{3}{2}Z-1)}$, where x = 0, 1, 2, 3, 4, 5

Slot number 4 + 2x contain bits $c_{C-\frac{3}{2}Z-(\frac{5}{2}Z)x}, c_{C-\frac{3}{2}Z-(\frac{5}{2}Z)x-1}, \ldots, c_{C-\frac{3}{2}Z-(\frac{5}{2}Z)x-(Z-1)}$, where x = 0, 1, 2, 3, 4, 5

The case when C = 29 is illustrated in figure 14.



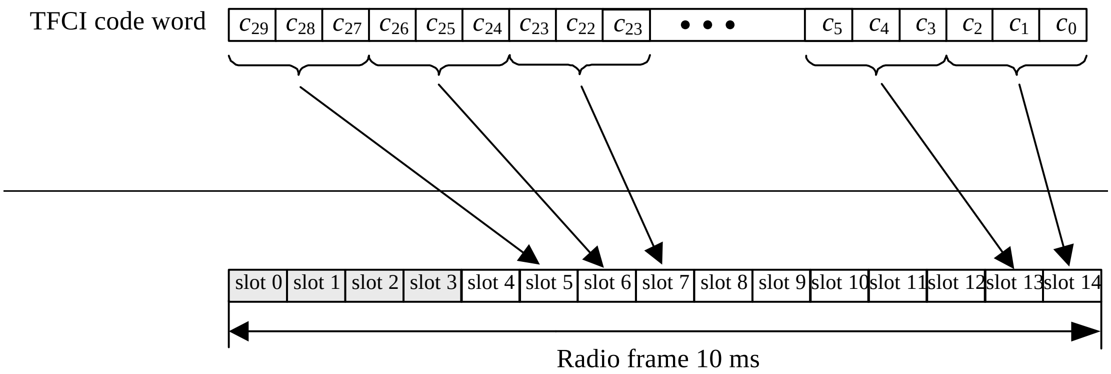
~~**Figure 14: Mapping of TFCI code with TGL of 3 slots.**~~

~~4.2.5.4.1.2 TGL of 4 slots~~

~~Slot number 4 does not contain any TFCI bits.~~

~~Slot number 5 + x contain bits $c_{C-(\frac{3}{2}Z)x}, c_{C-(\frac{3}{2}Z)x-1}, \ldots, c_{C-(\frac{3}{2}Z)x-(\frac{3}{2}Z-1)}$, where x = 0, 1, 2, 3, …, 9~~

~~The case when C = 29 is illustrated in figure 15.~~



~~**Figure 15: Mapping of TFCI code with TGL of 4 slots**~~

4.3.5.34.1~~2~~ Uplink c~~C~~ompressed mode ~~method B~~

~~4.2.5.4.2.1 Uplink~~

For uplink compressed mode~~, by method B~~ the slot~~frame~~ format is changed so that no TFCI bits are lost. The different slot~~frame~~ formats in compressed mode do~~can~~ not match the exact number of TFCI bits for all possible TGLs. The previously punctured bits b_{31} and b_{30} and r~~R~~epetition of the TFCI bits is therefore used.

Denote the number of bits available in the TFCI fields of one compressed radio frame by D, the ~~repeated~~redundant bit~~s~~ fields by d_k, and the number of bits in the TFCI field in a slot by N_{TFCI}. Let E=29~~30-1~~-($N_{first}N_{TFCI}$)mod 30. If $N_{last}\neq 14$, then E corresponds to the number of the first TFCI bit in the slot directly after the TG. The following relations then define the TFCI mapping~~repetition~~.

If D>32, then

$$d_{D-31} = c_{(E-(D-33)) \bmod 30}, d_{D-32} = c_{(E-(D-34)) \bmod 30}, \ldots, d_2 = c_{(E-(D-D)) \bmod 30}, d_1 = c_{31}, d_0 = c_{30}$$

else

$d_1 = c_{31}, d_0 = c_{30}$

$d_{D-31} = c_{E \bmod 30}, d_{D-32} = c_{(E-1) \bmod 30}, d_{D-33} = c_{(E-2) \bmod 30}, \ldots, d_0 = c_{(E-(D-31)) \bmod 30}$

The bits are mapped to the slots in descending order starting with the original bits (c_{29} ...c_0) and followed by the repeated ones (d_{D-31} ...d_2) and finally by d_1 and d_0, i.e. c_{29} is sent as first bit in the TFCI field of the first transmitted slot and d_0 as last bit in the TFCI field of the last transmitted slot. If there are only 30 TFCI bits in the frame, non of the *d* bits will be sent.

4.32.5.34.2.2 Downlink compressed mode

<Editor's note: Detailed description for downlink is FFS>

For downlink compressed mode, the slot format is changed so that no TFCI bits are lost. The different slot formats in compressed mode can not match the exact number of TFCI bits for all possible TGLs. The previously punctured bits and DTX is therefore used in the remaining TFCI fields.

D-C-1 DTX bits are mapped to the slots subsequently to the TG. If there are less TFCI bits after the TG than *D-C-1* bits, then DTX is also used at TFCI bit position $k \cdot i$,

where $i = \left\lfloor \frac{N_{TFCI} \cdot N_{first}}{D - C - 1 - N_{after} \cdot N_{TFCI}} \right\rfloor$,

$k = 1, \ldots, D - C - 1 - N_{after} \cdot N_{TFCI}$ and

N_{after}=*Number of slots after the gap*. (If N_{last} will be in the second frame, then N_{after}=0.)

The TFCI bits (corresponding to section 4.3.5.3) are mapped to the remaining TFCI bit positions in descending order.

4.4 Compressed mode

In compressed mode, slots N_{first} to N_{last} are not used for transmission of data. As illustrated in figure 16, which shows the example of fixed transmission gap position with single frame method, the instantaneous transmit power is increased in the compressed frame in order to keep the quality (BER, FER, etc.) unaffected by the reduced processing gain. The amount of power increase depends on the transmission time reduction method (see section 4.4.3). What frames are compressed, are decided by the network. When in compressed mode, compressed frames can occur periodically, as illustrated in figure 16, or requested on demand. The rate and type of compressed frames is variable and depends on the environment and the measurement requirements.

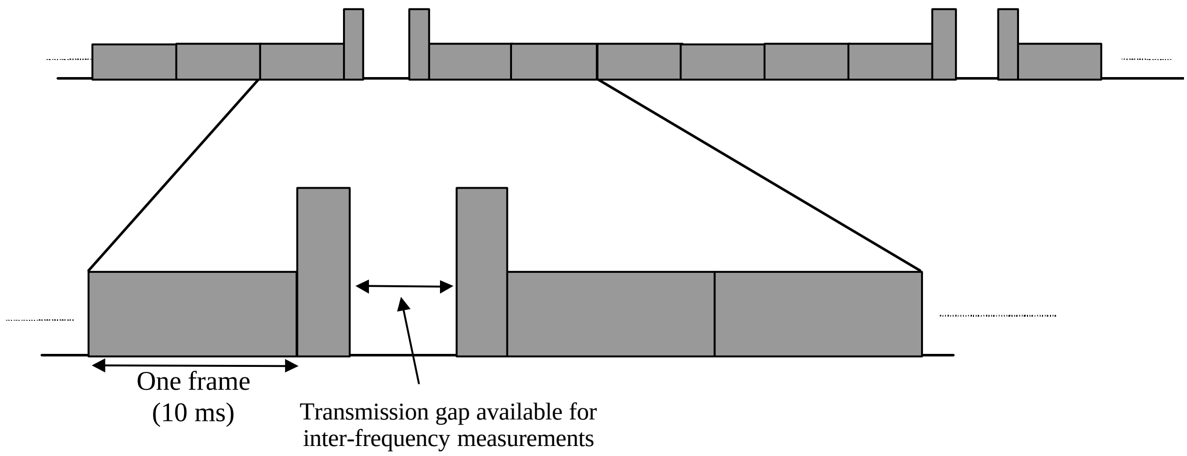


Figure 16: Compressed mode transmission

4.4.1 Frame structure in the uplink

The frame structure for uplink compressed mode is illustrated in figure 17.

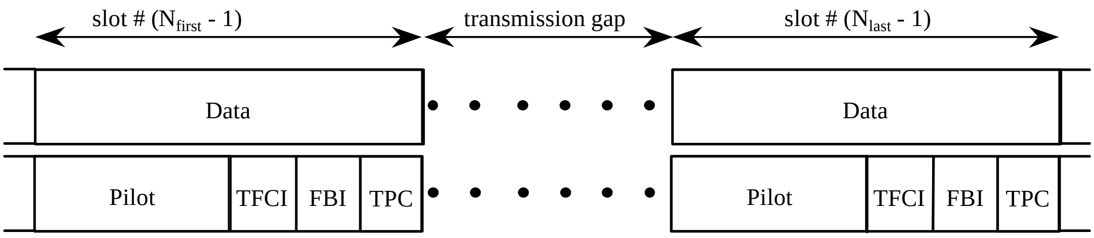


Figure 17: Frame structure in uplink compressed transmission

4.4.2 Frame structure types in the downlink

There are two different types of frame structures defined for downlink compressed transmission. Type A is the basic case, which maximises the transmission gap length. Type B, which is more optimised for power control, can be used if the requirement of the transmission gap length allows that.

- With frame structure of type A, BTS transmission is off from the beginning of TFCI field in slot N_{first}, until the end of Data2 field in slot N_{last} (figure 18(a)).