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Re:	IEEE 802.16m-08/042, “Call for Contributions on Project 802.16m Draft Amendment Content”. Topic: “Downlink Physical Structure”.
Abstract	The contribution proposes the text for the DL PHY Structure.
Purpose	To be discussed and adopted by TGm for the 802.16m amendment.
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Proposed Text of DL PHY Structure for the IEEE 802.16m Amendment

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1. Introduction

This contribution addresses the “Downlink Physical Structure” as requested in IEEE 802.16m-08/042, “Call for Contributions on Project 802.16m Draft Amendment Content”. The contribution attempts to address the competing requirements set forth in System Description Document regarding downlink physical structure and interference mitigation fractional frequency re-use technique as well as those requirements set forth in the System Requirements Document regarding cell coverage.

The authors have made attempts to harmonize the SDD text with other 16m members. We would like to acknowledge the work of Tayeoung Kim and his colleagues of whom we share some common text.

2. Considerations for DL Physical Structure

The text proposed in this document is in accordance with the agreements in SDD subclause 11.5. The subclause defines a complex structure that is governed by many objectives whose parameterization must be considered as part of the permutation structure. The parameters are as follows:

- **Bandwidth –** The bandwidth determines the total number of physical resource units. The SDD requires the new 16m P-SCH be confined to a fixed bandwidth of 5 MHz. It is quite likely that the PBCH Stage 3 description may restrict its structure to 5 MHz as well. Therefore, the permutation must account for how a 5 MHz bandwidth differs from bandwidths that are greater than 5 MHz.
- **Frequency Selectivity/Diversity –** The SDD supports both frequency selective allocations by using localized or contiguous resource units and frequency diversity allocations through distributed resource units. To this purpose, the SDD defines both a N1=4 and N2=1 outer permutation scheme[1]. The ratio of PRUs allocated to N1 and N2 blocks must be known prior to the permutation of those blocks and is intrinsically linked to the partitioning of FFR zones. Ideally, a mobile station should not need to know this partitioning before it attempts to decode the PBCH. Moreover, the amount of broadcast information required to communicate this information must be accounted for in the proposal and hopefully minimized.
- **Fraction Frequency Reuse –** The FFR partitions provide a means for multiplexing different re-use schemes similar to the PUSC permutation in 16e. The outer permutation maps frequency diverse blocks into the FFR partitions. In order to be effective, the FFR partitions must be coordinated across all sectors within a cell and potentially across multiple cells. Effectively, this suggests that the outer permutation is identical across a region if not the whole network. Therefore, it is assumed that the outer permutation is common to all 16m cells and is only governed by the partition between N1 and N2.

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[1] It is acknowledged that N1=4 and N2=1 are TBD in the SDD. The authors choose to support these values as part of the Stage 3 text proposal. It is impossible to capture all potential configurations in one cohesive structure. Other Stage 3 proposals may elect different values for N1 and N2.

However, it is clear that the number of blocks allocated to N2 is related to the number of FFR partitions and cell configuration. Depending on the desired effective re-use pattern (e.g. 1x1x1, 1x3x1, 1x3x3, 1x4x2, 1x4x4 or 1x4x1) anywhere from 1 to 7 FFR partitions are envisioned. At a minimum, each FFR partition should contain at least two PRUs in order to support frequency diverse allocations. Therefore, if 7 FFR partitions are desired (e.g. SDD Figure 45), at least 14 PRUs need to be set aside for N2 outer permutation.

- **Broadcast Channel –** Initial access dictates that mobile determine essential parameters as part of a bootstrapping process. The mobile must be able to locate the P-SCH and PBCH within the DL permutation without any specific knowledge of a system configuration.

Text proposal for inclusion in the 802.16m amendment

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3. Definitions

Insert the following at the end of section 3:

xx. PRU : 18x6 (consecutive subcarriers) which include the resource unit before the outer permutation.

xx. DRU: This has still 18x6 PRU structure, which is going to be permuted by DL/UL inner permutation

xx. CRU: This has still 18x6 RU structure, which will pass-through inner permutation (i.e. is not going to be inner permuted).

xx. LRU : Basic logical unit for distributed and localized resource allocations.

xx. Distributed-LRU: the LRU which is obtained from distributed allocation after inner permutation

xx. Contiguous-LRU: the LRU obtained from contiguous allocation via. pass-through inner permutation

Insert a new section 15:

15. Advanced Air Interface

15.3. Physical layer

15.3.5. Downlink physical structure

Each downlink subframe is divided into a number of frequency partitions, where each partition consists of a set of physical resource units across the total number of OFDMA symbols available in the subframe. Each frequency partition can include contiguous (localized) and/or non-contiguous (distributed) physical resource units. Figure 1 illustrates the downlink physical structure in the example of two frequency partitions with frequency partition 2 including both localized and distributed resource allocations

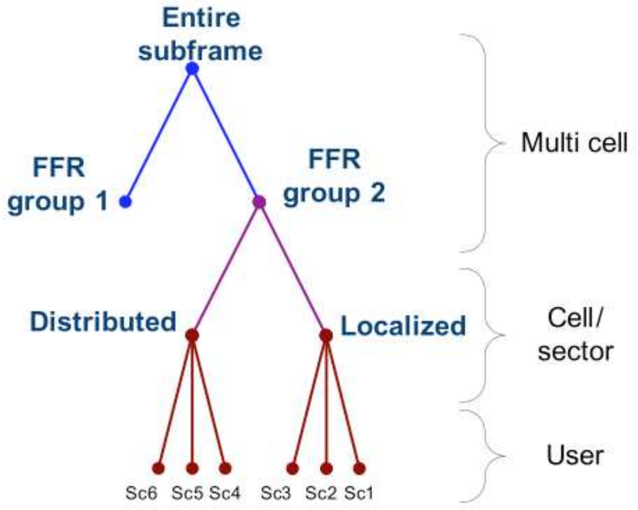

Figure 1 – Example of downlink physical structure

15.3.5.1. DL symbol structure

15.3.5.1.1. Physical and logical resource unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 subcarriers and N_{sym} is 6 OFDMA symbols for type-1 sub-frames, and N_{sym} is 7 OFDM symbols for type-2 sub-frames. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocation. A LRU is $P_{sc}\times N_{sym}$ subcarriers for type-1 sub-frames and type-2 sub-frames. Note that the LRU includes in its numerology the number of pilots that are used in a PRU. The effective number of data tones in an LRU depends on the number of allocated pilots.

15.3.5.1.2. Distributed logical resource unit

The logical distributed resource unit (Distributed LRU) can be used to achieve frequency diversity gain. The distributed LRU contains a group of subcarriers which are spread across the distributed resource allocations within a frequency partition. The size of the DRU equals the size of PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols. The minimum unit for forming the DRU is equal to a pair-tone defined as a pair of adjacent subcarriers in frequency.

15.3.5.1.3. Localized logical resource unit

The localized logical resource unit (Localized LRU) can be used to achieve frequency-selective scheduling gain. The Localized LRU contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the CRU equals the size of the PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols.

15.3.5.2. Multiplexing resource unit

DRU and CRU can both be used in the same sub-frame so that frequency diversity and frequency-selective transmissions are simultaneously supported. The DRU and CRU are only used on different PRUs in the frequency division multiplexing manner.

15.3.5.3. Subchannelization and resource mapping

15.3.5.3.1. Basic symbol structure

The subcarriers of an OFDMA symbol are partitioned into $N_{g,left}$ left guard subcarriers, $N_{g,right}$ right guard subcarriers, and N_{used} used subcarriers. The DC subcarrier is not loaded. The N_{used} subcarriers are divided into N_{PRU} PRUs. Each PRU contains pilot and data subcarriers. The number of used pilot and data subcarriers depends on MIMO mode, rank and number of multiplexed MS as well as the type of the subframe, i.e., type-1 or type-2..

Table 1 – Subcarrier partitioning

FFT size, N_{FFT}	512	1024	2048
Number of DC Subcarriers (N_{dc})	1 (Index 256, counting from 0)	1 (Index 512, counting from 0)	1 (Index 1024, counting from 0)
Number of Guard Subcarriers, Left ($N_{g,left}$)	40	80	160
Number of Guard Subcarriers, Right ($N_{g,right}$)	39	79	159
Number of Used Subcarriers (N_{used}) (including all possible allocated pilots and the DC subcarrier)	433	865	1729
Number of Physical Resource Units (N_{PRU})	24	48	96

15.3.5.3.2. Downlink subcarrier to resource unit overview

The DL subcarrier to resource unit mapping process is defined as follows and illustrated in Figure 2:

1. First-level or outer permutation is applied to the PRUs in the units of N_1 and N_2 PRUs, where N_1=4 and N_2 =1 or 2 depending on system bandwidth.

2. Distributing the reordered PRUs into frequency partitions.

3. The frequency partition is divided into CRU and/or DRU for each resource group. Sector specific permutation can be supported and direct mapping of the resources can be supported for localized resources. The sizes of the distributed/localized resources are flexibly configured per sector. Adjacent sectors do not need to have same configuration of localized and distributed resources

4. The localized and distributed groups are further mapped into LRUs by direct mapping of CRU and by inner permutation on DRUs, as shown in Figure 2.

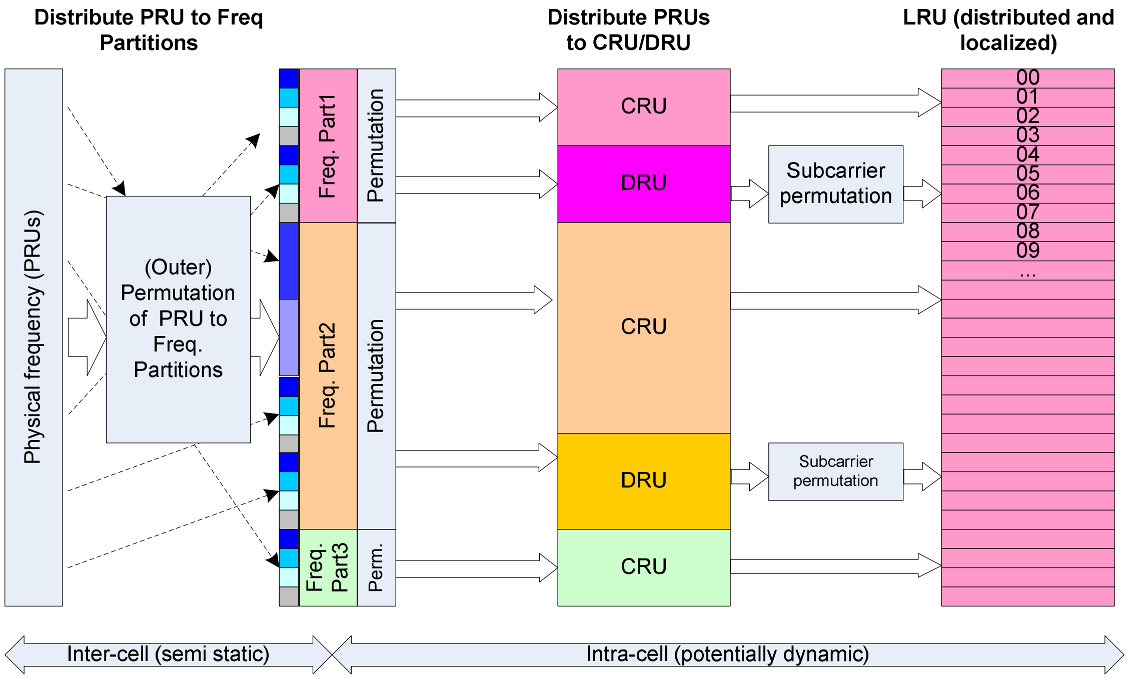

Figure 2 – Illustration of the downlink subcarrier to resource block mapping.

15.3.5.3.3. Downlink subcarrier to partition mapping

This subclause describes how the PRUs are re-ordered and mapped into physical PRUs.

15.3.5.3.3.1. Segment Partitioning

The physical PRUs are subdivided into N1=4 & N2=1 segments based on a system-wide N2 ratio signaled in PBCH. N1 segments, called Contiguous Segments, are suitable for frequency selective allocations as they provide a contiguous allocation of PRUs in frequency. N2 segments, called Distributed Segments, are suitable for frequency diverse allocation and are subject to an outer permutation. Contiguous Segments are not subject to an outer permutation and may not be used for DRUs

A 5-bit field Contiguous Segment Count (CSC) field determines how many segments are allocated to Contiguous Segments. The number of PRUs allocated to Contiguous Segments is $N_{CS.,}$ where $N_{CS.} = 4\text{*CSC}$. The remainder of the PRUs are allocated to Distributed Segments. The number of PRUs allocated to Distributed Segments is $N_{DS.,}$ where $N_{DS.} = N_{PRU.} - N_{CS.}$. The mapping of the PBCH is FFS and may be incorporated in the segmentation process.

PRUs are segmented and reordered into two groups distributed segment PRUs and contiguous segment PRUs, called DS-PRUs and CS-PRUs, respectively. The set of PRUs is number 0 to (N_{PRU}-1). The set of DS-PRUs are numbered 0 to ($N_{DS} - 1$). The set of CS-PRUs are numbered 0 to ($N_{CS} - 1$).

DS-PRUs are drawn from the set of PRUs to provide 4th order frequency diversity while maximizing the number of frequency contiguous CS-PRUs. The mapping of PRUs to DS-PRUs and CS-PRUs is shown in Figure 3(a) and (b), respectively. The mapping of PRUs to DS-PRUs and CS-PRUs are defined by the following formula.

$$DS\text{-}PRU_j = PRU_i \qquad \text{(Eq 1)}$$

where
$$i = \begin{cases} j & for \quad j < \left\lceil \frac{N_{DS}}{4} \right\rceil \\ j + 4\left\lfloor \frac{CSC}{3} \right\rfloor & for \quad \left\lceil \frac{N_{DS}}{4} \right\rceil \leq j < \frac{N_{DS}}{2} \\ j + 4\left(CSC - \left\lfloor \frac{CSC}{3} \right\rfloor \right) & for \quad \frac{N_{DS}}{2} \leq j < N_{DS} - \left\lceil \frac{N_{DS}}{4} \right\rceil \\ j + 4CSC & for \quad j \geq N_{DS} - \left\lceil \frac{N_{DS}}{4} \right\rceil \end{cases}$$

$$CS\text{-}PRU_k = PRU_i \qquad \text{(Eq 2)}$$

where
$$i = \begin{cases} k + \left\lceil \frac{N_{DS}}{4} \right\rceil & for \quad k < 4\left\lfloor \frac{CSC}{3} \right\rfloor \\ k + \frac{N_{DS}}{2} & for \quad 4\left\lfloor \frac{CSC}{3} \right\rfloor \leq k < 4\left(CSC - \left\lfloor \frac{CSC}{3} \right\rfloor \right) \\ k + \left(N_{DS} - \left\lceil \frac{N_{DS}}{4} \right\rceil \right) & for \quad k \geq 4\left(CSC - \left\lfloor \frac{CSC}{3} \right\rfloor \right) \end{cases}$$

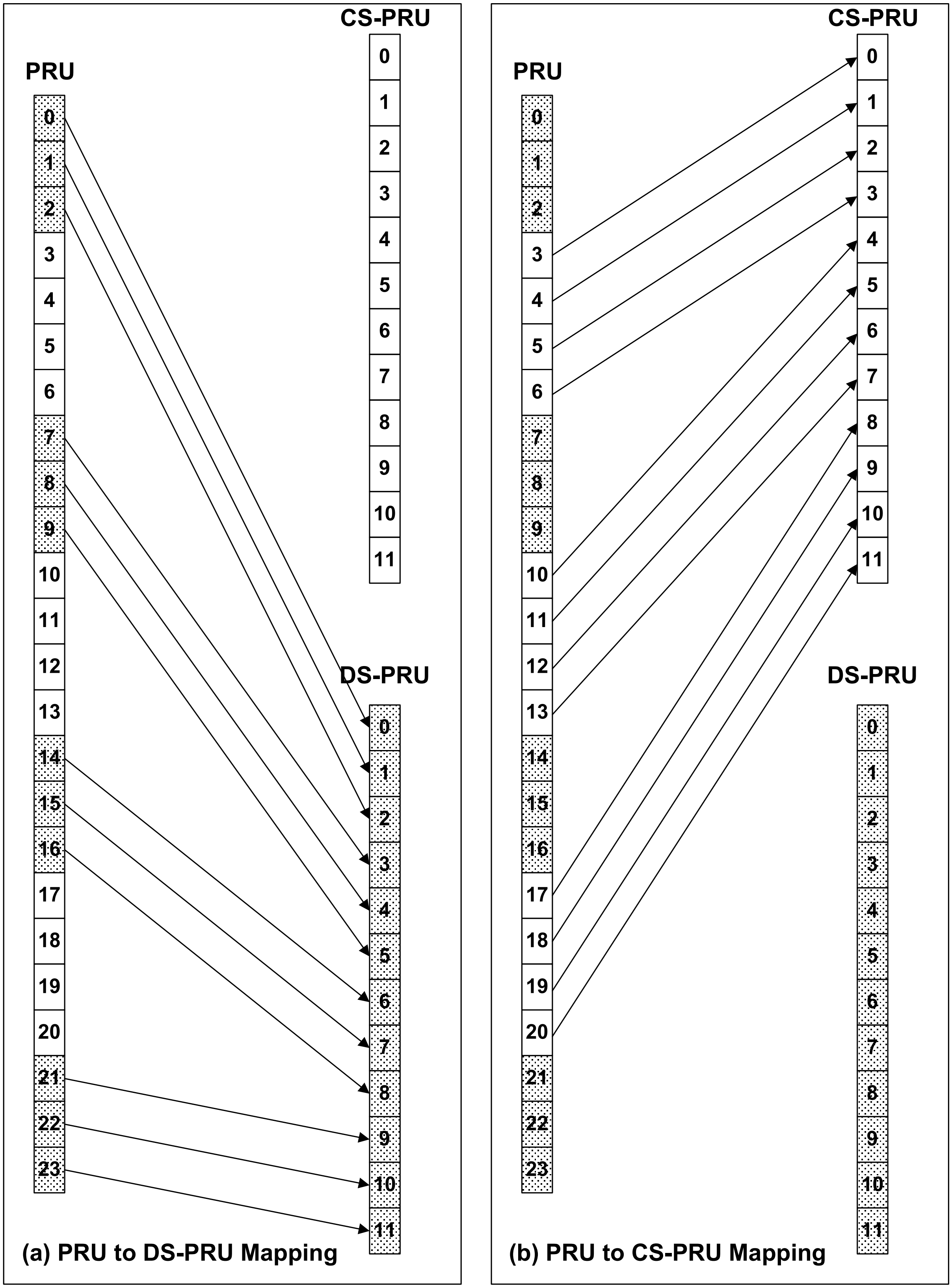

Figure 3 PRU to DS-PRU and CS-PRU mapping for BW=5 MHz, CSC=3

15.3.5.3.3.2. Outer permutation

The outer permutation maps the DS-PRU to Permuted DS-PRUs (P-DS-PRUs) to insure frequency diverse PRUs are allocated to each FFR partition. Equation (3) provides a mapping from PRUs to DS-PRUs which guarantees every 4 consecutive PRUs provide 4th order frequency diversity.

$$P\text{-}DS\text{-}PRU_j = DS\text{-}PRU_i \qquad \text{(Eq 3)}$$

$$\text{where} \quad i = (j \bmod 4)\frac{N_{DS}}{4} + \left\lfloor \frac{j}{4} \right\rfloor \quad \mathit{for} \quad j < N_{DS}$$

Other functions for the outer permutation are for further study.

Following the outer permutation of the DS-PRUs, P-DS-PRUs are concatenated with the CS-PRUs to form the Re-ordered PRUs (R-PRUs). The concatenation is captured in the following equation.

$$R \cdot PRU = \begin{cases} CS \cdot PRU_j & \mathit{for} \quad j < N_{CS} \\ P \cdot DS \cdot PRU_{j-N_{CS}} & \mathit{for} \quad j \geq N_{CS} \end{cases} \qquad \text{(Eq 4)}$$

Figure 4 depicts the concatenation of CS-PRUs with P-DS-PRUs to form R-PRUs.

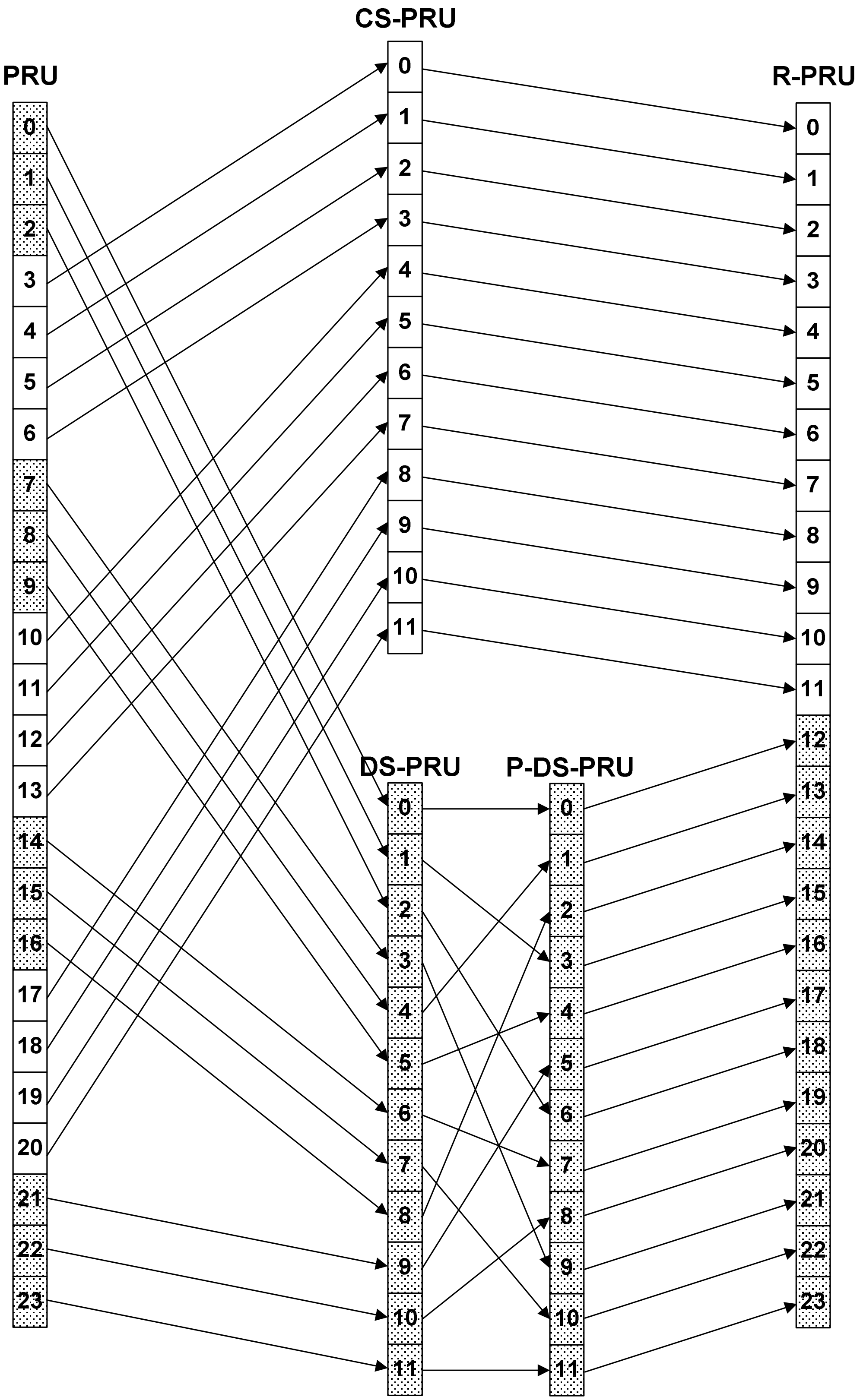

Figure 4 Mapping from PRUs to R-PRUs for BW=5 MHz, CSC=3

15.3.5.3.3.3. FFR partitioning

The P-PRUs are allocated to one or more FFR partitions. By default, only one partition is present. This is called the primary partition or FFR_0. Optionally, the S-BCH may define one or more secondary FFR partitions. Up to 6 secondary partitions may be defined. All secondary partitions are of equal size. When present, the secondary partitions are defined by a 9-bit field transmitted in the S-BCH called the FFR Configuration. The first three bits carry a field called FFR Count (FFRC) that defines the number of secondary FFR partitions. The remaining 6 bits carry a field called FFR Size (FFRS) that defines the size of all secondary FFR partitions.

The mapping of *R-PRUs* to the primary FFR permutation is governed by the following equation*:*

$$FFR_i\text{-}PRU_j = R\text{-}PRU_k \text{ for } i \leq FFRC$$

where

$$k = \begin{cases} j & \text{for} \quad i = 0 \quad \text{and} \quad j < \left(N_{PRU} - FFRC \cdot FFRS\right) \\ j + (i-1) \cdot FFRS + \left(N_{PRU} - FFRC \cdot FFRS\right) & \text{for} \quad 0 < i \leq FFRC \quad \text{and} \quad j < FFRS \end{cases}$$

Figure 5 depicts the FFR partitioning for FFRC=3, FFRS=3, BW=5 MHz and CSC=3.

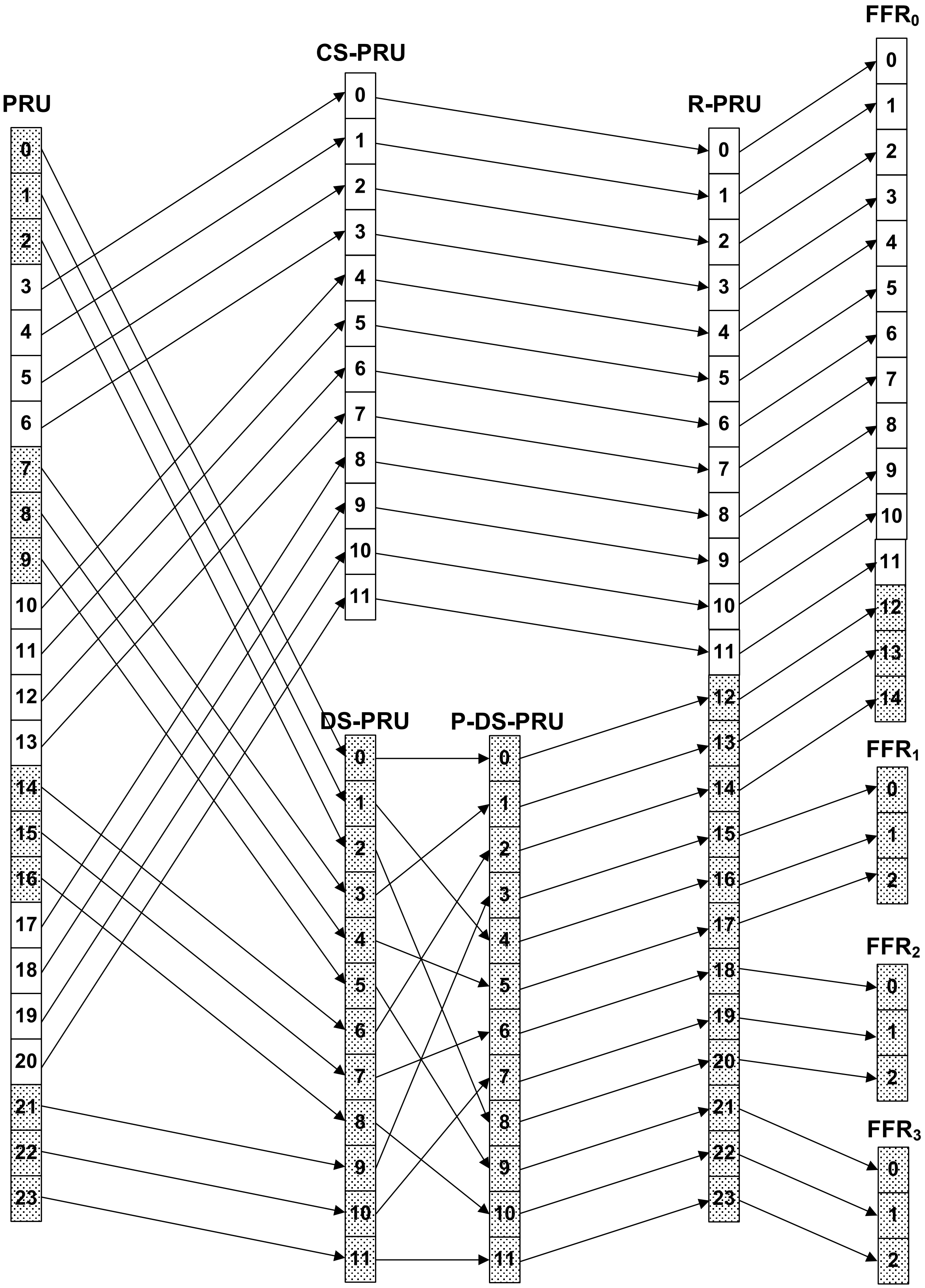

Figure 5 FFR partitioning

15.3.5.3.4. Partition subchannelization

FFR_i-PRUs will be mapped to logical LPRUs. All further PRU and subcarrier permutation will be constrained to the PRUs within the FFR partition.

15.3.5.3.4.1. Secondary permutation

The FFR_i-PRUs may be permuted on a sector specific basis. The primary FFR partition, FFR_0, is never permuted by a secondary permutation. Permutation of the secondary permutation will be signaled by a 1-bit secondary permutation field in the S-BCH.

The secondary permutation of FFR_i-PRUs will be governed by the following equation:

$$P\text{-}FFR_i\text{-}PRU_j = FFR_i\text{-}PRU_k \text{ for } 0<i \leq FFRC$$

where k =f(Cell ID)

The PRU permutation function, *f(x)*, is FFS.

15.3.5.3.4.2. CRU/DRU allocation

The partition between CRUs and DRUs is done on a sector specific basis. By default, all P-FFR-PRUs are allocated to CRUs. DRU allocation is signaled in two step process. A 1-bit field Tone-Base Permutation Enabled bit in the P-BCH signals that DRU tone-based permutations are enabled. A 12-bit DRU allocation field in the S-BCH signals the allocation of PRUs in the primary and all secondary permutations. The DRU allocation field is sub-divided into a Primary DRU allocation field and a secondary DRU allocation field. The primary DRU allocation field, $DRU_{primary}$, is 6 bits long and signals how many DRUs are allocated in the primary FFR partition. The secondary DRU allocation field, $DRU_{secondary}$, is also 6 bits long and signal how many DRUs are in the secondary FFR partition.

The following equations map the P-FFR-PRUs to FFR-DRUs and FFR-CRUs when DRU tone-based PRUs are enabled.*:*

$$FFR_i \bullet CRU_j = \begin{cases} P \cdot FFR_0 \cdot PRU_j & for \quad i=0 \quad and \quad j < N_{PRU} - FFRC \cdot FFRS - DRU_{primary} \\ P \cdot FFR_i \cdot PRU_j & for \quad 0<i<FFRC \quad and \quad j < FFRS - DRU_{secondary} \end{cases}$$

$$FFR_i \cdot DRU_j = P \cdot FFR_i \cdot PRU_k$$

where

$$k = \begin{cases} j + \left(N_{PRU} - FFRC \cdot FFRS - DRU_{primary}\right) & for \quad i=0 \quad and \quad 0 \leq j < DRU_{primary} \\ j + \left(FFRS - DRU_{secondary}\right) & for \quad 0<i<FFRC \quad and \quad 0 \leq j < DRU_{secondary} \end{cases}$$

15.3.5.3.4.3. DRU inner permutation

The inner permutation defined for the DL distributed resource allocations within a frequency partition spreads the subcarrriers of the LDRU across the whole distributed resource allocations. The granularity of the inner permutation is equal to a pair of tones.

After mapping all pilots, the remainders of the used subcarriers are used to define the data subchannel. To allocate the data subchannels, the remaining subcarriers are paired into contiguous tone-pairs. Each subchannel consists of a group of tone-pairs. The exact partitioning of tone-pairs into subchannels is FFS.

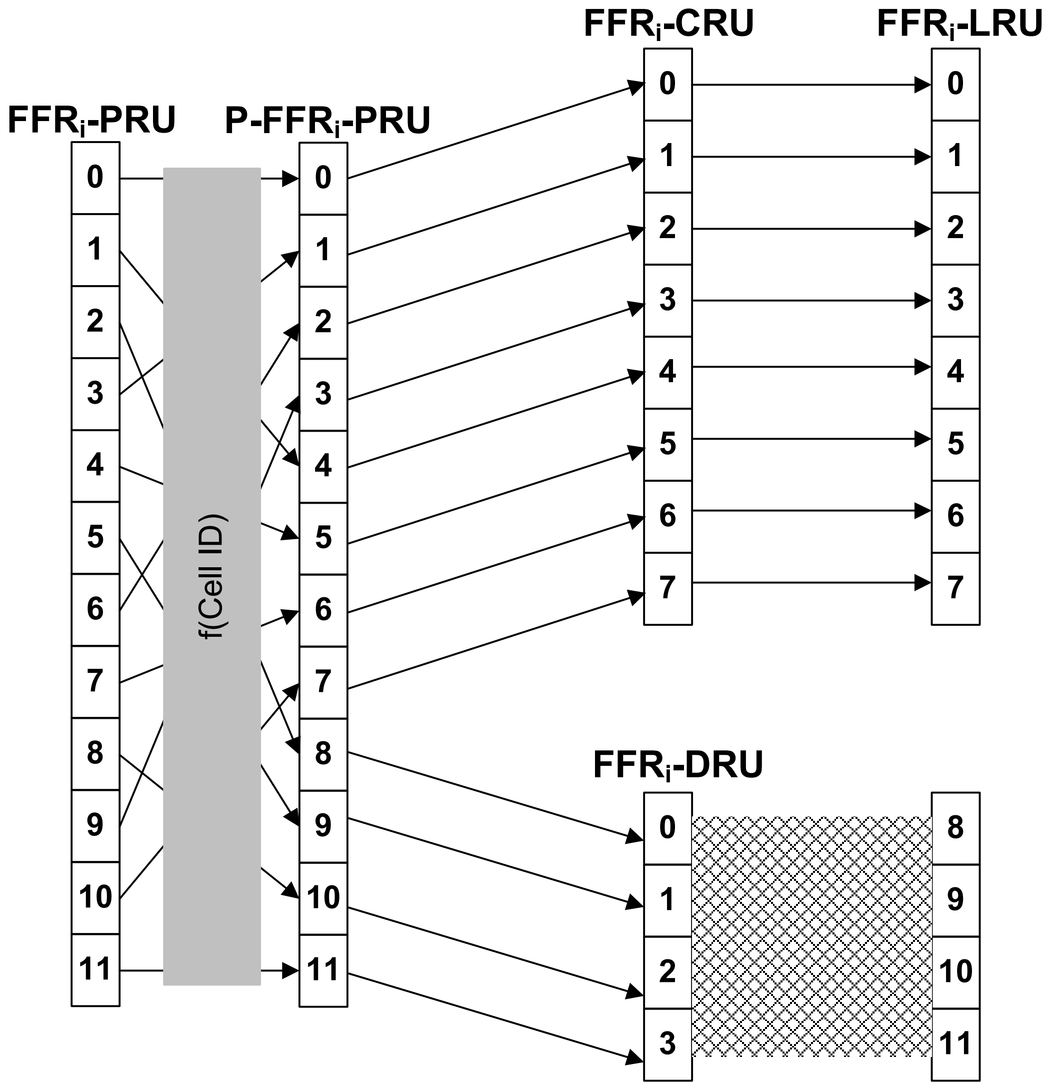

Figure 6 Partition subchannelization

15.3.5.4. Pilot structure

The transmission of pilot subcarriers in the downlink is necessary for enabling channel estimation, measurements of channel quality indicators such as the SINR, frequency offset estimation, etc. To optimize the system performance in different propagation environments and application, both common and dedicated pilot structures are supported.

The categorization in common and dedicated pilots is done with respect to their usage. The common pilots can be used by all MSs. Dedicated pilots can be used with both localized and diversity allocations. Pilot subcarriers that can be used only by a group of MSs are a special case of common pilots and are termed shared pilots. The dedicated pilots are associated with a specific resource allocation, can be only used by the MSs allocated to said specific resource allocation, and therefore can be pre-coded or beamformed in the same way as the data subcarriers of the resource allocation.

The pilot structure is defined for up to four transmission (Tx) streams and there is a unitified pilot pattern design for common and dedicated pilots. There is equal pilot density per Tx stream, while there is not necessarily equal pilot density per OFDMA symbol of the downlink subframe. Further, there is equal number of pilots for each PRU. The pilots can be used for channel estimation, measurements (CQI and interference mitigation/cancellation), frequency offset estimation and time offset estimation.

Pilot patterns are proposed for efficiency and performance. Pilot pattern A is used for 1 and 2 Tx streams DL dedicated and common pilot pattern, as shown in Figure 7. For the subframe consisting of 5 or 7 OFDMA symbols, one of OFDMA symbols is deleted or added. In the figures, the pilot *k* denotes a common and dedicated pilot for the *k*-th Tx stream.

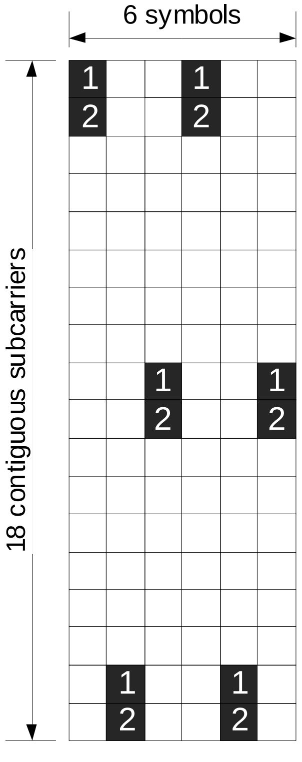

Figure 7 – Pilot pattern A for 1/2 Tx streams.

The interlaced pilot patterns can be generated by cyclic shifting the pilot pattern A. The interlaced pilot patterns are shown in Figure 8 and can be optionally used by different BSs. The use of interlaced pilot pattern is FFS.

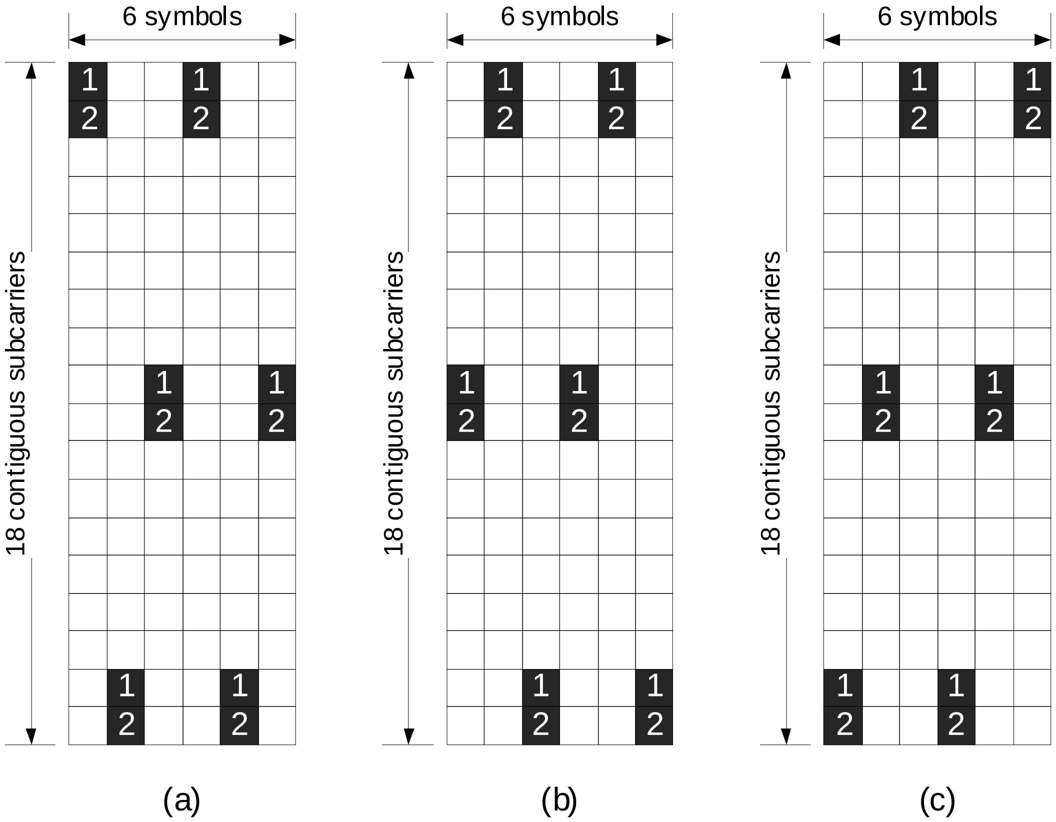

Figure 8 – Interlaced pilot pattern A for 1/2 Tx streams.

The pilot pattern B is used for 4 Tx streams DL dedicated and common pilot pattern, as shown in Figure 9. For the subframe consisting of 5 OFDMA symbols, the third or fourth OFDMA symbol is deleted. For the subframe consisting of 7 OFDMA symbols, the third or fourth OFDMA symbol is added in the end of the subframe

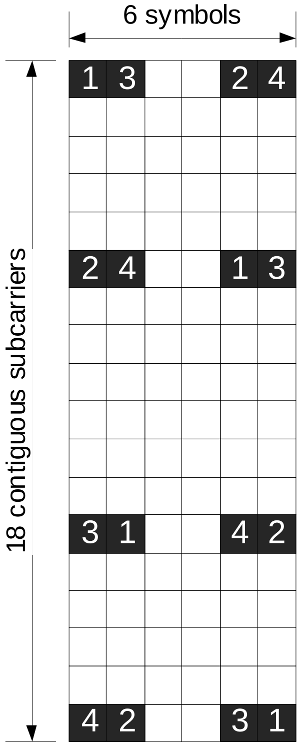

Figure 9 – Pilot pattern B for 4 Tx streams.

15.3.5.4.1. DL reference pilot structure

[TBD]

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