5G Downlink Reference Signals

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Downlink Reference Signals

- Demodulation Reference Signal (DMRS) for PDSCH
- DMRS for PDCCH
- DMRS for PBCH
- Phase-tracking reference signals for PDSCH
- CSI reference signals.

DMRS for PDSCH

- DMRS is always transmitted with PDSCH
  - Present exactly in the UE allocation
- Same ports as PDSCH
  - Range: 1000-1011
- Helps in fine channel estimate.

PDSCH DMRS

- Sequence Generation

$$r(n) = \frac{1}{\sqrt{2}}\left(1 - 2 \cdot c(2n)\right) + j\frac{1}{\sqrt{2}}\left(1 - 2 \cdot c(2n+1)\right).$$

$$c_{\text{init}} = \left(2^{17}\left(N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1\right)\left(2N_{\text{ID}}^{n_{\text{SCID}}} + 1\right) + 2N_{\text{ID}}^{n_{\text{SCID}}} + n_{\text{SCID}}\right) \bmod 2^{31}$$

$$c_{\text{init}} = \left(2^{17}\left(N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1\right)\left(2N_{\text{ID}}^{n_{\text{SCID}}} + 1\right) + 2N_{\text{ID}}^{n_{\text{SCID}}} + n_{\text{SCID}}\right) \bmod 2^{31}$$

- The sequence generation depends on
  - l : The OFDM symbol number
  - $n_{s,f}$: The slot number
  - N_{scid}
    - Can be 0 or 1 if DCI format 1_1 is used (DMRS sequence initialization – 1 bit)
    - Otherwise, it is set to 0.

$N_{\text{ID}}^{n_{\text{SCID}}}$

$N_{\text{ID}}^{0}, N_{\text{ID}}^{1} \in \{0,1,\ldots,65535\}$

  - If DCI 1_1 is used
    - Given by the higher layer parameter scramblingID0 and scramblingID1.
      - Present in the IE *DMRS-DownlinkConfig*
  - If DCI 1_0 is used
    - Given by the higher layer parameter scramblingID0
  - Otherwise

```
-- ASN1START
-- TAG-DMRS-DOWNLINKCONFIG-START

DMRS-DownlinkConfig ::=             SEQUENCE {
    dmrs-Type                           ENUMERATED {type2}                                  OPTIONAL,   -- Need S
    dmrs-AdditionalPosition             ENUMERATED {pos0, pos1, pos3}                       OPTIONAL,   -- Need S
    maxLength                           ENUMERATED {len2}                                   OPTIONAL,   -- Need S
    scramblingID0                       INTEGER (0..65535)                                  OPTIONAL,   -- Need S
    scramblingID1                       INTEGER (0..65535)                                  OPTIONAL,   -- Need S
    phaseTrackingRS                     SetupRelease { PTRS-DownlinkConfig  }               OPTIONAL,   -- Need M
    ...
}

-- TAG-DMRS-DOWNLINKCONFIG-STOP
-- ASN1STOP
```

DMRS-DownlinkConfig field descriptions
dmrs-AdditionalPosition Position for additional DM-RS in DL, see Tables 7.4.1.1.2-3 and 7.4.1.1.2-4 in TS 38.211 [16]. If the field is absent, the UE applies the value pos2. See also clause 7.4.1.1.2 for additional constraints on how the network may set this field depending on the setting of other fields.
dmrs-Type Selection of the DMRS type to be used for DL (see TS 38.211 [16], clause 7.4.1.1.1). If the field is absent, the UE uses DMRS type 1.
maxLength The maximum number of OFDM symbols for DL front loaded DMRS. 'len1' corresponds to value 1. 'len2 corresponds to value 2. If the field is absent, the UE applies value len1. If set to len2, the UE determines the actual number of DM-RS symbols by the associated DCI. (see TS 38.214 [19], clause 7.4.1.1.2)
phaseTrackingRS Configures downlink PTRS. If absent or released, the UE assumes that downlink PTRS are not present. See TS 38.214 [19] clause 5.1.6.3
scramblingID0 DL DMRS scrambling initialization (see TS 38.211 [16], clause 7.4.1.1.1). When the field is absent the UE applies the value Physical cell ID (physCellId) configured for this serving cell."
scramblingID1 DL DMRS scrambling initialization (see TS 38.211 [16], clause 7.4.1.1.1). When the field is absent the UE applies the value (physCellId) configured for this serving cell.

Mapping to Physical resources

$$a_{k,l}^{(p,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_t(k') w_t(l') r(2n+k')$$

$$k = \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases}$$

$$k' = 0, 1$$

$$l = \bar{l} + l'$$

$$n = 0, 1, \ldots$$

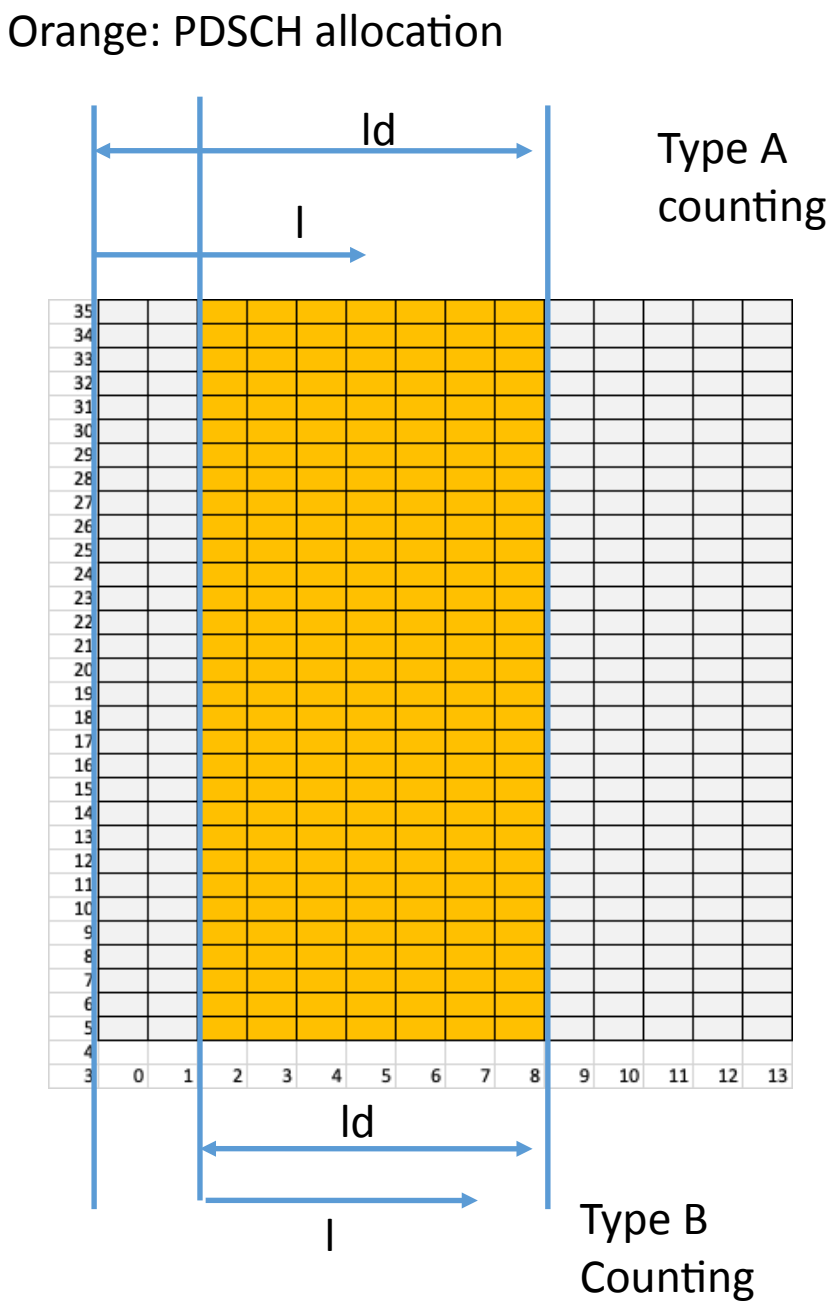
Type 1: Density ½ (Better channel estimate and hence provides better reliability)

Type 2: Density 1/3

Type1/Type2: Chosen by IE *DMRS-Downlinkconfig*

Time domain locations

- Type A PDSCH mapping
  - l is defined relative to the start of the slot
  - Defn: ld is the duration between the first OFDM symbol of the slot and the last scheduled OFDM symbol in the PDSCH
- Type B PDSCH mapping
  - l is defined relative to the start of the PDSCH resources
  - Defn: ld is the number of OFDM symbols scheduled in PDSCH



Single and double symbol DMRS

- Two types of DMRS
  - Single symbol: l’ = 0
  - Double symbol: l’={0,1}
- If DMRS-DownlinkConfig ▭ maxLength
  - is not configured
    - Single symbol DMRS is used
  - if configured to “len2”
    - Determined by the associated DCI [SEE LAST 2 SLIDES]

Single symbol DMRS supports only maximum of 6 ports while Double Symbol DMRS support 12 ports

Table 7.4.1.1.2-5: PDSCH DM-RS time index l' and antenna ports p.

Single or double symbol DM-RS	l'	*Supported antenna ports* p	
		Configuration type 1	*Configuration type 2*
single	0	1000 – 1003	1000 – 1005
double	0, 1	1000 – 1007	1000 – 1011

Table 7.4.1.1.2-3: PDSCH DM-RS positions $\bar{l}$ for single-symbol DM-RS.

l_d in symbols	DM-RS positions $\bar{l}$							
	PDSCH mapping type A				PDSCH mapping type B			
	dmrs-AdditionalPosition				*dmrs-AdditionalPosition*			
	0	*1*	*2*	*3*	*0*	*1*	*2*	*3*
2	-	-	-	-	l_0	l_0		
3	l_0	l_0	l_0	l_0	-	-		
4	l_0	l_0	l_0	l_0	l_0	l_0		
5	l_0	l_0	l_0	l_0	-	-		
6	l_0	l_0	l_0	l_0	l_0	l_0,4		
7	l_0	l_0	l_0	l_0	l_0	l_0,4		
8	l_0	l_0, 7	l_0, 7	l_0, 7	-	-		
9	l_0	l_0, 7	l_0, 7	l_0, 7	-	-		
10	l_0	l_0, 9	l_0, 6, 9	l_0, 6, 9	-	-		
11	l_0	l_0, 9	l_0, 6, 9	l_0, 6, 9	-	-		
12	l_0	l_0, 9	l_0, 6, 9	l_0, 5, 8, 11	-	-		
13	l_0	l_0, l_1	l_0, 7, 11	l_0, 5, 8, 11	-	-		
14	l_0	l_0, l_1	l_0, 7, 11	l_0, 5, 8, 11	-	-		

Table 7.4.1.1.2-4: PDSCH DM-RS positions $\bar{l}$ for double-symbol DM-RS.

l_d in symbols	DM-RS positions $\bar{l}$					
	PDSCH mapping type A			PDSCH mapping type B		
	dmrs-AdditionalPosition			dmrs-AdditionalPosition		
	0	1	2	0	1	2
<4				-	-	
4	l_0	l_0		-	-	
5	l_0	l_0		-	-	
6	l_0	l_0		l_0	l_0	
7	l_0	l_0		l_0	l_0	
8	l_0	l_0		-	-	
9	l_0	l_0		-	-	
10	l_0	l_0, 8		-	-	
11	l_0	l_0, 8		-	-	
12	l_0	l_0, 8		-	-	
13	l_0	l_0, 10		-	-	
14	l_0	l_0, 10		-	-	

- For PDSCH Type A
  - l0 = 3 if dmrs-TypeA-Position = Pos3 (**MIB message**)
  - Otherwise l0 =2
- For PDSCH type B
  - l0 = 0
- Dmrs-additionalPosition(IE: DMRS-DownlinkConfig)
  - **Default: pos2.**
  - Others: have to be explicitly specified in the IE

Exceptions (Check the spec)

- Dmrs-additionalPosition = pos3 is supported only when dmrs-TypeA-Position = pos2.
- …..
- …..
- …..

- The UE may assume that no DM-RS collides with the SS/PBCH block.

Frequency allocation

$$a_{k,l}^{(p,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_t(l') r(2n+k')$$

$$k = \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases}$$

$$k' = 0, 1$$

$$l = \bar{l} + l'$$

$$n = 0, 1, \ldots$$

Table 7.4.1.1.2-1: Parameters for PDSCH DM-RS configuration type 1.

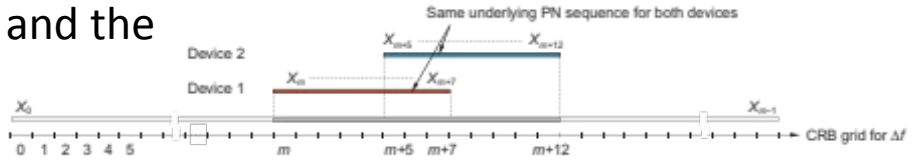
p	CDM group λ	Δ	$w_f(k')$		$w_t(l')$	
			$k'=0$	$k'=1$	$l'=0$	$l'=1$
1000	0	0	+1	+1	+1	+1
1001	0	0	+1	-1	+1	+1
1002	1	1	+1	+1	+1	+1
1003	1	1	+1	-1	+1	+1
1004	0	0	+1	+1	+1	-1
1005	0	0	+1	-1	+1	-1
1006	1	1	+1	+1	+1	-1
1007	1	1	+1	-1	+1	-1

Table 7.4.1.1.2-2: Parameters for PDSCH DM-RS configuration type 2.

p	CDM group λ	Δ	$w_f(k')$		$w_t(l')$	
			$k'=0$	$k'=1$	$l'=0$	$l'=1$
1000	0	0	+1	+1	+1	+1
1001	0	0	+1	-1	+1	+1
1002	1	2	+1	+1	+1	+1
1003	1	2	+1	-1	+1	+1
1004	2	4	+1	+1	+1	+1
1005	2	4	+1	-1	+1	+1
1006	0	0	+1	+1	+1	-1
1007	0	0	+1	-1	+1	-1
1008	1	2	+1	+1	+1	-1
1009	1	2	+1	-1	+1	-1
1010	2	4	+1	+1	+1	-1
1011	2	4	+1	-1	+1	-1

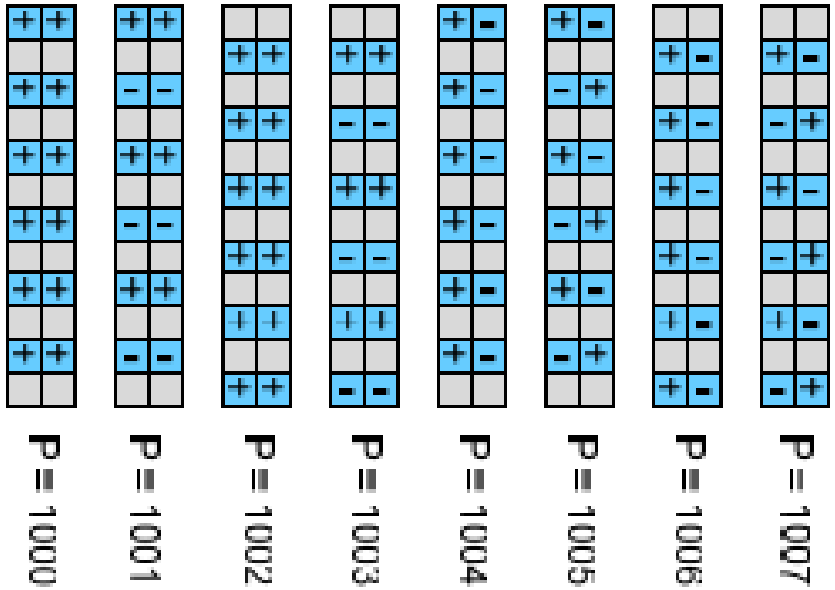
Reference point for k

- Lowest block in Coreset 0 if the PDCCH is associated with Coreset 0 and the search space is scrambled with SI-RNTI
- Otherwise, subcarrier 0 in common resource block 0
  - This implies that you generate for the entire frequency grid and choose the DMRS in your frequency allocation



Configuration Type 1

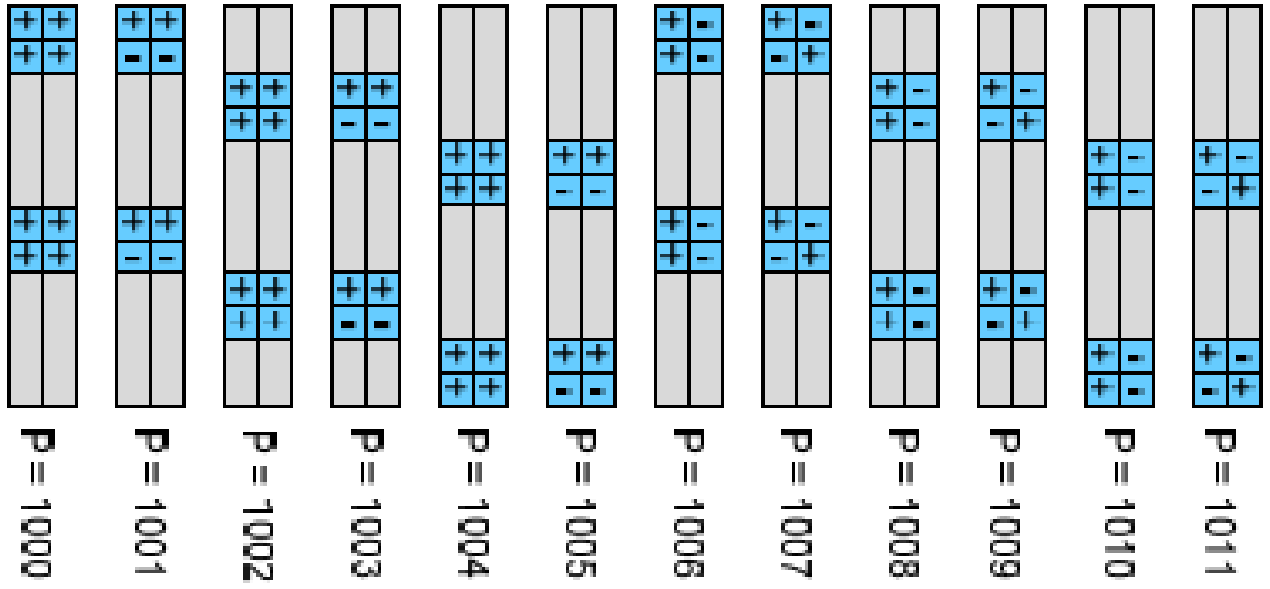
8 ports with double-symbol DMRS
2 FD-OCC x 2 Combs x 2 TD-OCC



Antenna Ports

Configuratuion Type 2

12 ports with double-symbol DMRS
2 FD-OCC x 3 Frequency Offsets x 2 TD-OCC

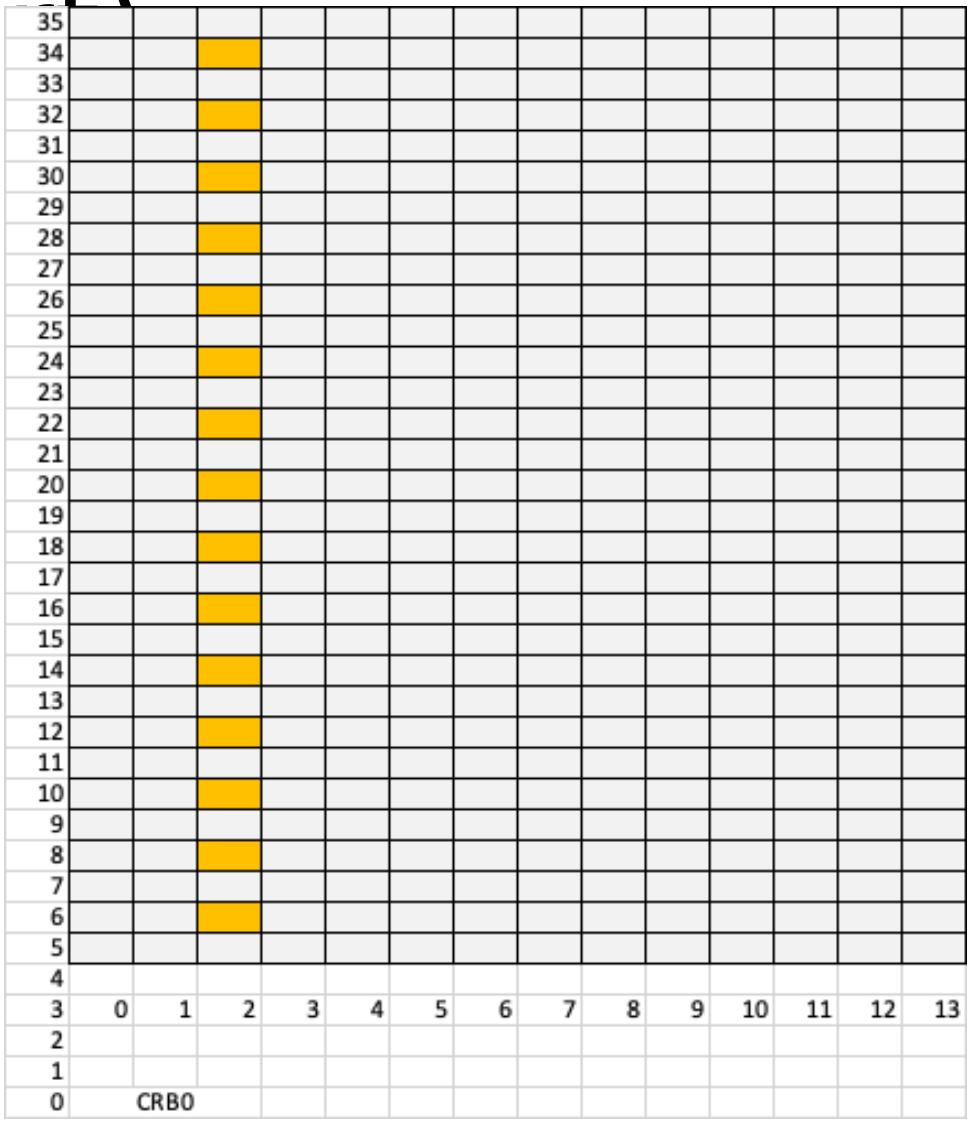


Taken from: https://www.sharetechnote.com/html/5G/5G_PDSCH_DMRS.html

Examples (Single po…)

- Type A PDSCH mapping
- DMRS
  - Single Symbol
  - Type 1
  - AdditionalPosition = pos2
- Ld = 7

- P = 1000
- Delta =0
- l0 = 2
- Bar l = l0
- l' =0



$$a_{k,l}^{(p,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_t(l') r(2n+k')$$

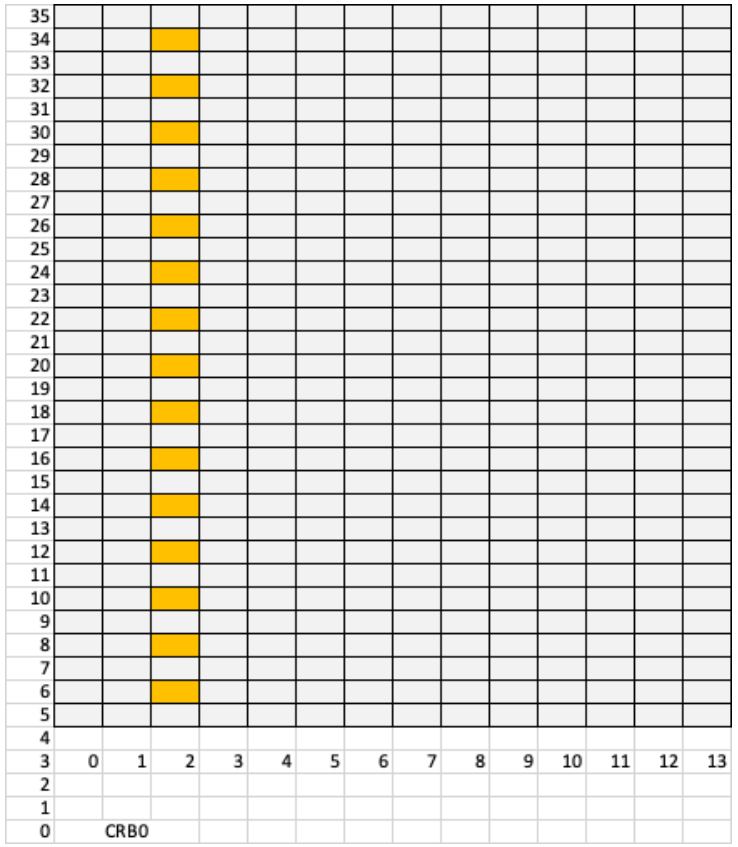
$$k = \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases}$$

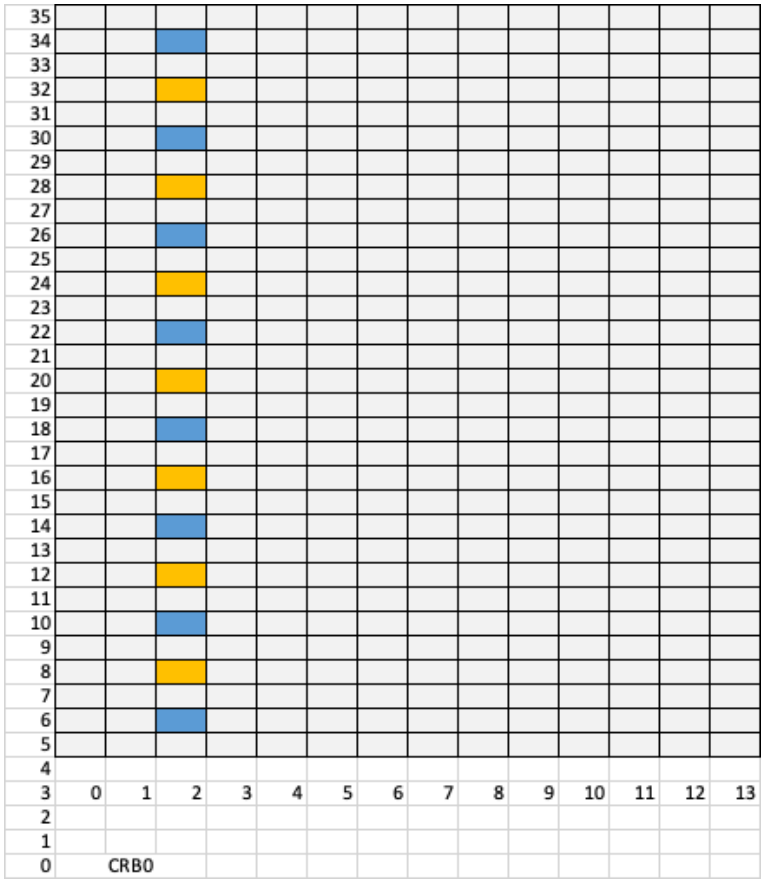
$$k' = 0,1$$

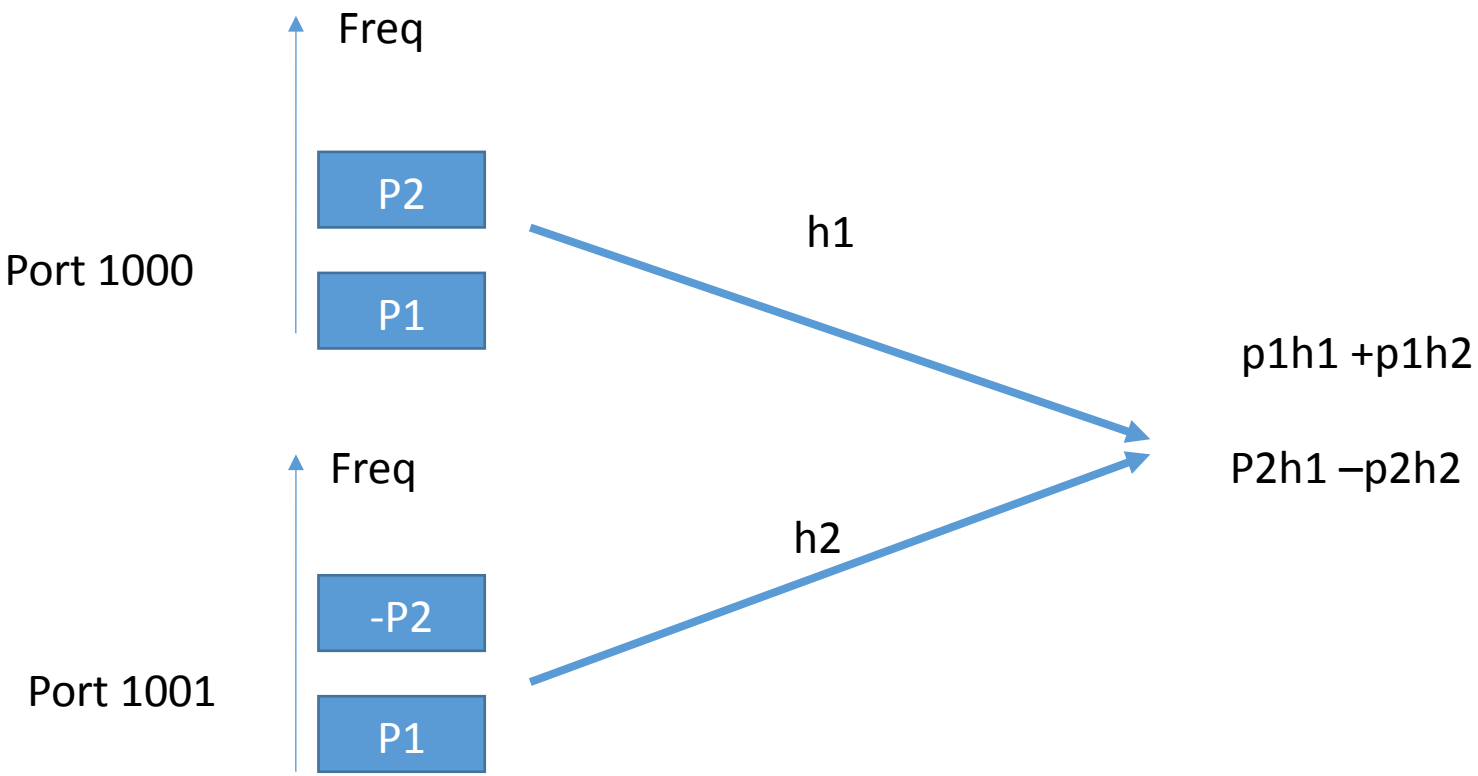
$$l = \bar{l} + l'$$

$$n = 0,1,\ldots$$

Example two ports P = 1000, 1001



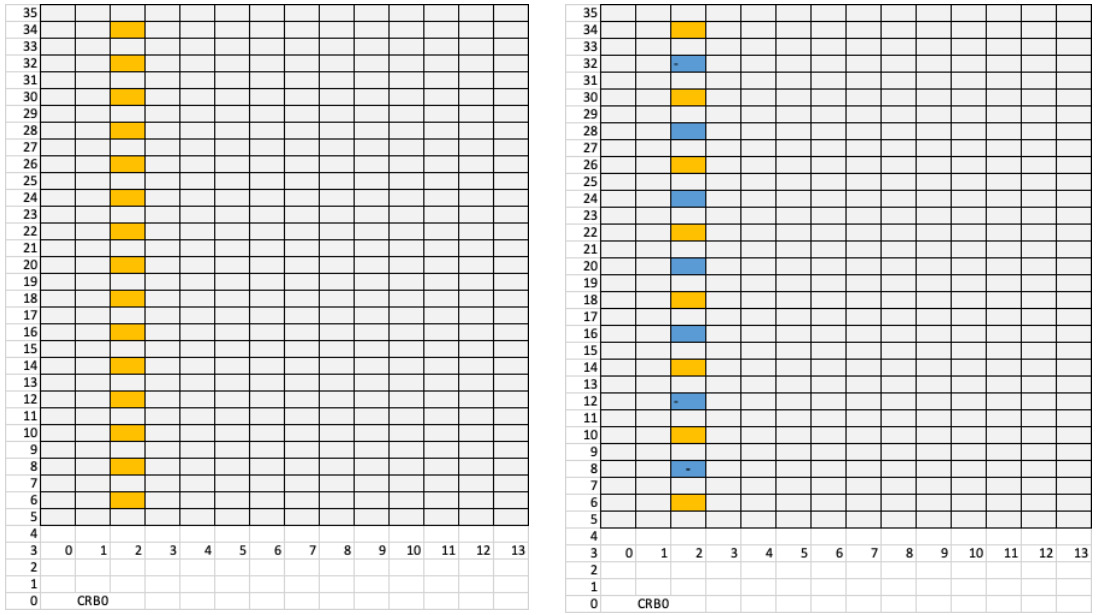




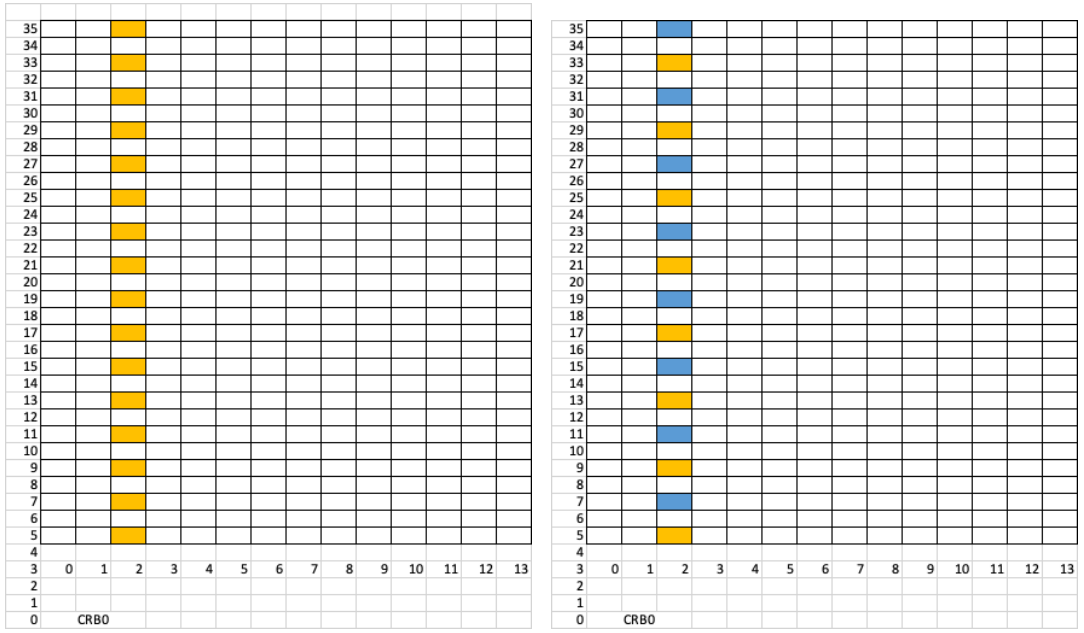
Assumptions

1. The channel is almost the same between the adjacent sub-carriers.

Example 4 ports P = 1000, 1001, 1002, 1003



CDM group 0

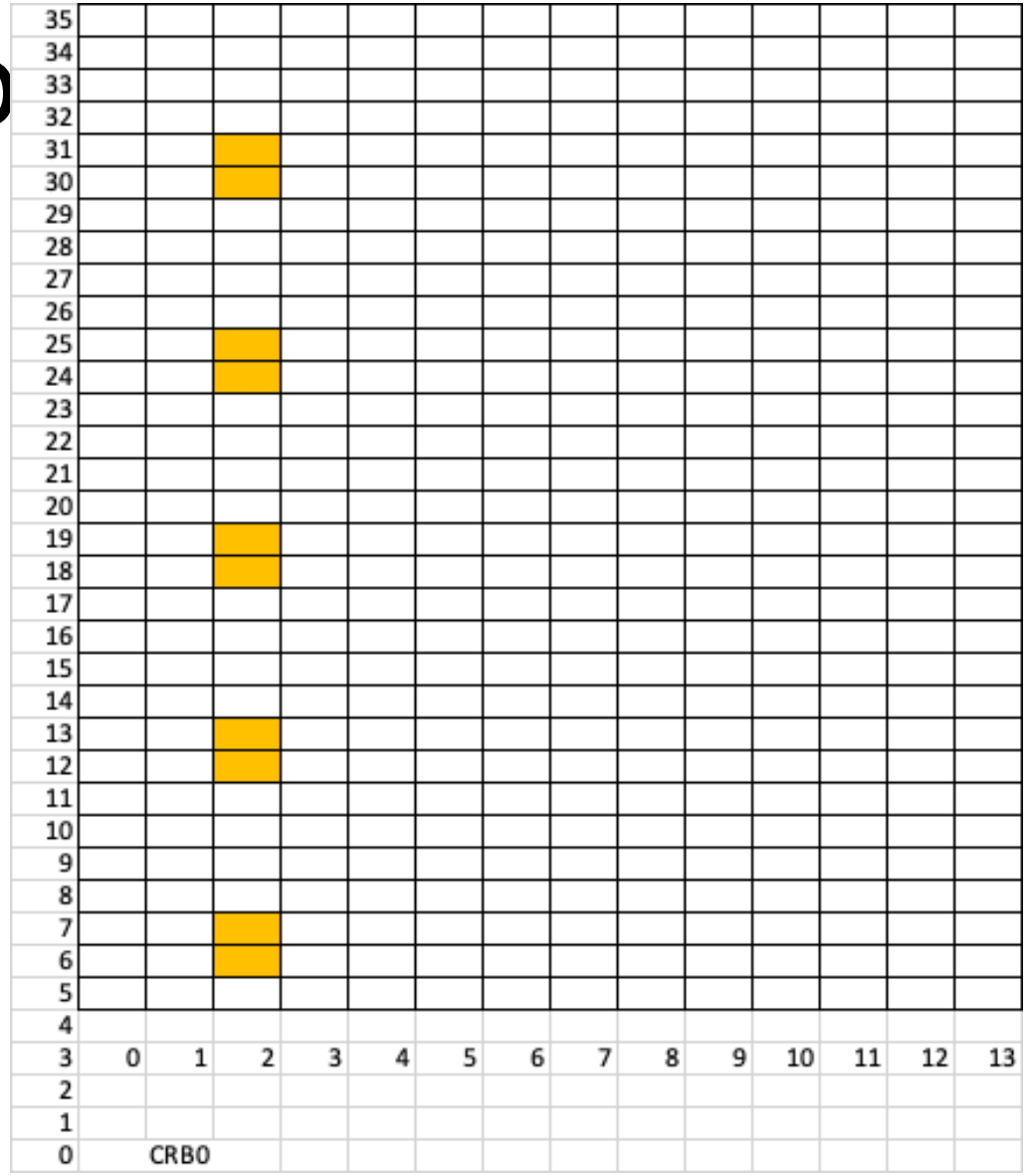


CDM group 1

Examples (Single po

- Type A PDSCH mapping
- DMRS
  - Single Symbol
  - Type 2
  - AdditionalPosition = pos2
- Ld = 7

- P = 1000
- Delta =0
- l0 = 2
- Bar l = 2
- l' =0



$$a_{k,l}^{(p,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_t(l') r(2n+k')$$

$$k = \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases}$$

$$k' = 0,1$$

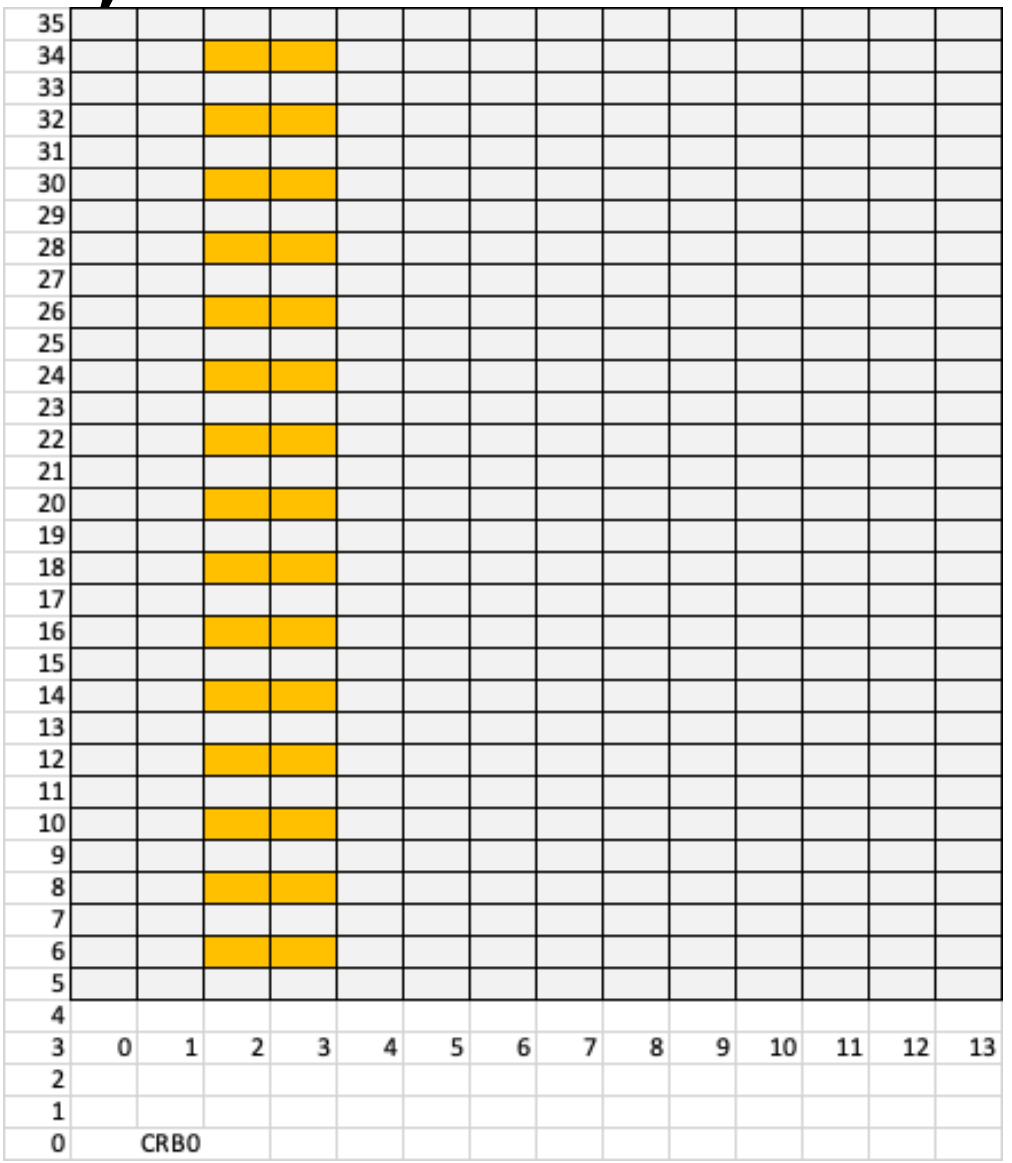
$$l = \bar{l} + l'$$

$$n = 0,1,\ldots$$

Examples (Single port, Dual symbol DMRS)

- Type A PDSCH mapping
- DMRS
  - Dual Symbol DMRS maxLength= len2
  - Type 1
  - AdditionalPosition = pos2
- Ld = 7

- P = 1000
- Delta =0
- l0 = 2
- Bar l = 2
- l' ={0,1}



$$a_{k,l}^{(p,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_t(l') r(2n+k')$$

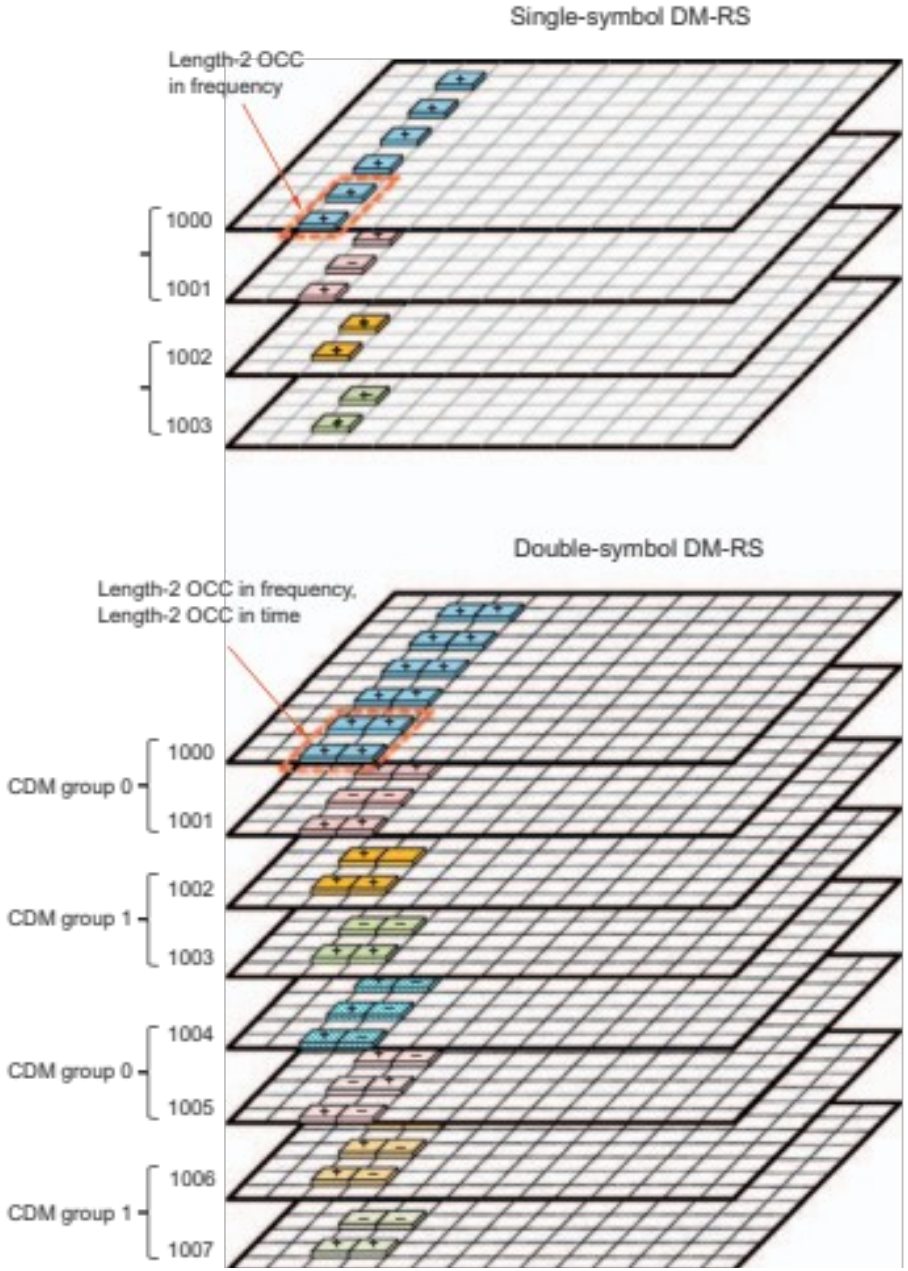
$$k = \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases}$$

$$k' = 0,1$$

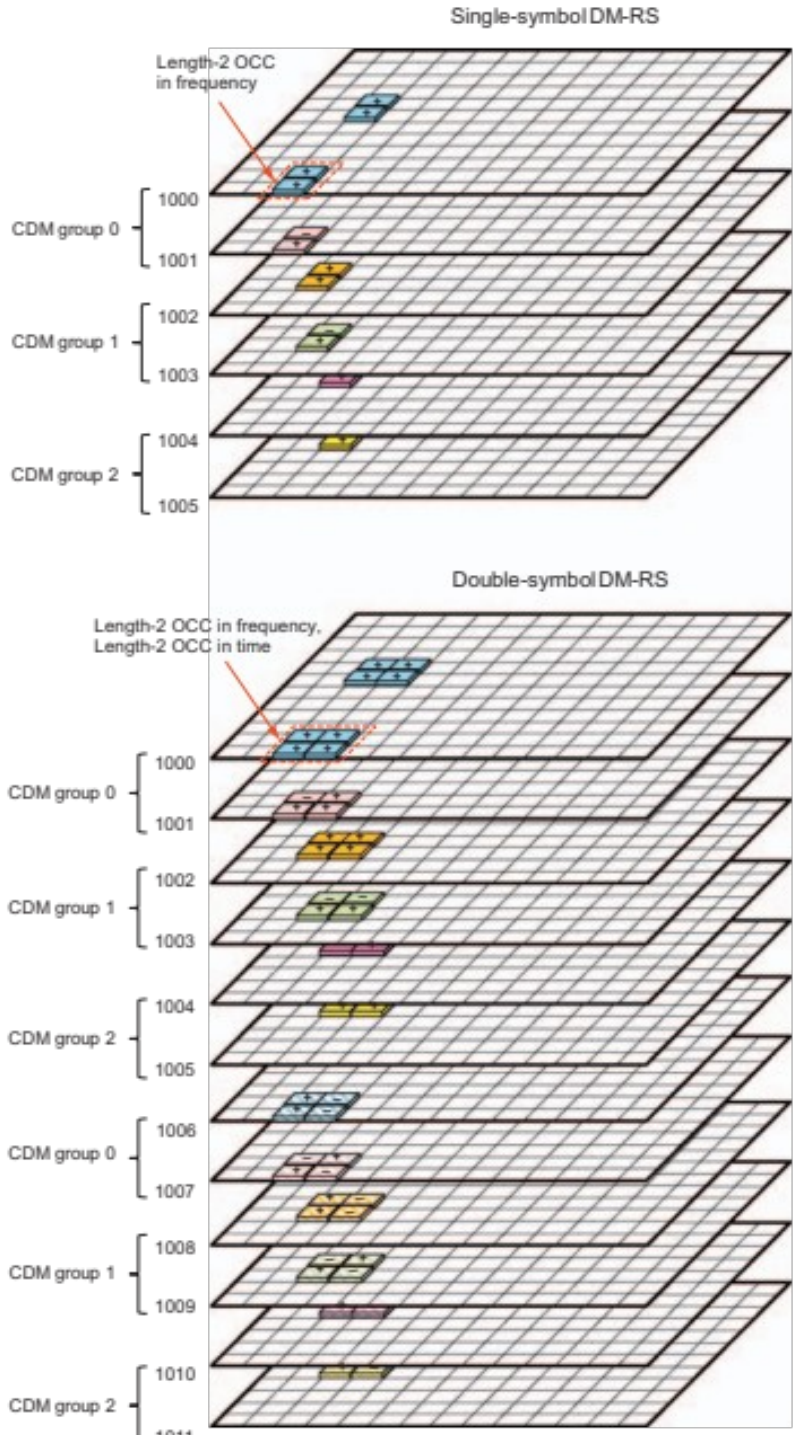
$$l = \bar{l} + l'$$

$$n = 0,1,\ldots$$

Type 1 DMRS


Single-symbol DM-RS
Length-2 OCC in frequency
1000
1001
1002
1003
Double-symbol DM-RS
Length-2 OCC in frequency, Length-2 OCC in time
CDM group 0
1000
1001
CDM group 1
1002
1003
CDM group 0
1004
1005
CDM group 1
1006
1007

Type 2 DMRS


Single-symbol DM-RS
Length-2 OCC in frequency
CDM group 0
1000
1001
CDM group 1
1002
1003
CDM group 2
1004
1005
Double-symbol DM-RS
Length-2 OCC in frequency, Length-2 OCC in time
CDM group 0
1000
1001
CDM group 1
1002
1003
CDM group 2
1004
1005
CDM group 0
1006
1007
CDM group 1
1008
1009
CDM group 2
1010

Default DMRS

- Configuration type 1 + Single symbol DMRS is applicable to transmissions scheduled by DCI 1_0 [Basic and default control configuration]
  - Paging and SI
  - Before BS provides UE with PDSCH-config.

DCI format for single-symbol or double-symbol DMRS

- Only there in DCI format 1_1.
  - DCI format 1_0 only uses single-symbol DMRS
    - MIMO is not supported
- Tied in very much with MIMO.
- DCI format 1-1 (38.212)

Antenna port(s) – 4, 5, or 6 bits as defined by Tables 7.3.1.2.2-1/2/3/4, where the number of CDM groups without data of values 1, 2, and 3 refers to CDM groups {0}, {0,1}, and {0, 1,2} respectively. The antenna ports $\{p_{0,\ldots,}p_{\upsilon-1}\}$ shall be determined according to the ordering of DMRS port(s) given by Tables 7.3.1.2.2-1/2/3/4.

How does the UE know how any Antenna ports have been used?

- Index to the tables.

Table	Dmrs-type	MaxLength (if 2 Indicates choice between single symbol/double symbol DMRS)	# of bits in DCI
7.3.1.2.2-1	1	1	4
7.3.1.2.2-2	1	2	5
7.3.1.2.2-3	2	1	5
7.3.1.2.2-4	2	2	6

Table 7.3.1.2.2-2: Antenna port(s) (1000 + DMRS port), *dmrs-Type*=1, *maxLength*=2

One Codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols	Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1	0	2	0-4	2
1	1	1	1	1	2	0,1,2,3,4,6	2
2	1	0,1	1	2	2	0,1,2,3,4,5,6	2
3	2	0	1	3	2	0,1,2,3,4,5,6,7	2
4	2	1	1	4-31	reserved	reserved	reserved
5	2	2	1				
6	2	3	1				
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	2	0,2	1				
12	2	0	2				
13	2	1	2				
14	2	2	2				
15	2	3	2				
16	2	4	2				
17	2	5	2				
18	2	6	2				
19	2	7	2				
20	2	0,1	2				

Index indicated by DCI bits

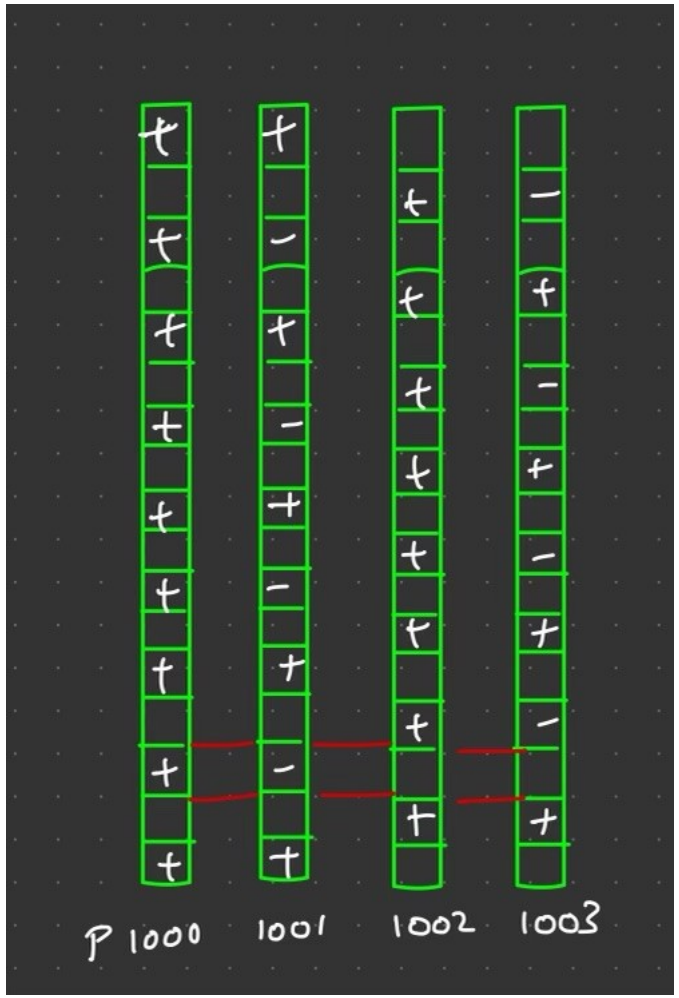
CDM groups

DMRS ports 1000+ #

Single – symbol/Double symbol DMRS

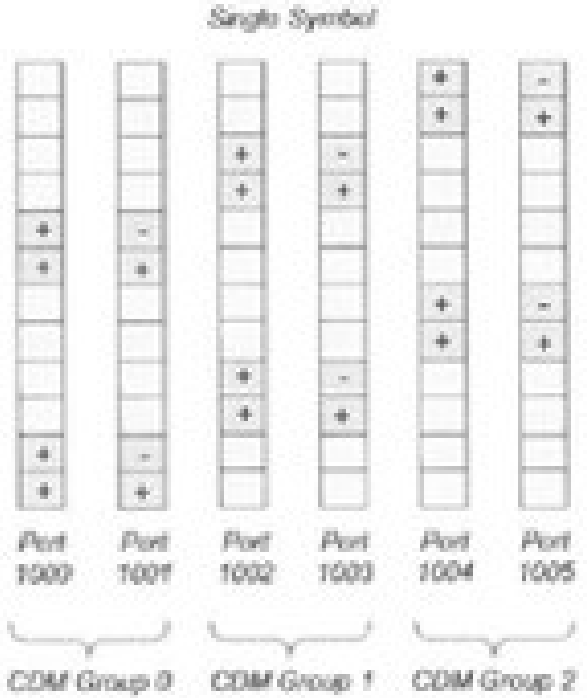
CDM group and the ports uniquely identify the DMRS

DMRS and PDSCH multiplexing



- For multiport transmission, data cannot be sent on certain RE so that there is no interference between the DMRS and PDSCH.
- This is indicated by DCI 1_1 (MIMO) format and is in 38.212 [7.3.1.2.2-1 and subsequent tables]. See next slide

From Bullets



2-1: Antenna port(s) (1000 + DMRS port), *dmrs-Type*=1, *maxLength*=1

One Codeword: Codeword 0 enabled, Codeword 1 disabled		
Value	**Number of DMRS CDM group(s) without data**	**DMRS port(s)**
0	1	0
1	1	1
2	1	0,1
3	2	0
4	2	1
5	2	2
6	2	3
7	2	0,1
8	2	2,3
9	2	0-2
10	2	0-3
11	2	0,2
12-15	Reserved	Reserved

Examples:

- UE can transmit 0 or 1 value to indicate one port.
  - No of CDM groups without Data =1
- UE wants to transmit 2 ports
  - Can choose Value 2
  - No of CDM groups without Data =1
- UE want to transmit 4 ports
  - Value =10
  - No of CDM groups without data =2.
- Multi-user MIMO 4 users
  - Single port for each user
  - Values: 3,4,5,6 for each user
  - No of CDM groups without data =2

CSI-RS

Channel state information reference signals (CSI-RS)

- CSI reporting
  - Used to obtain the “channel quality” from the BS to the UE
  - CQI, RI and PMI
- Time and frequency synchronization (in addition to SSB)
- Beam management
- Measurements
  - Interference
  - Channel

Two types of CSI-RS

- Zero-power CSI-RS
  - Reserved RE (zeros are inserted)
    - Helps to rate match.
    - Are neglected
- Non-Zero-power CSI-RS
  - Normal CSI-RS

- Always need not be present
  - As per need/requirement

CSI-RS generation

$$r(m) = \frac{1}{\sqrt{2}}\left(1 - 2 \cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1 - 2 \cdot c(2m+1)\right)$$

$$c_{\text{init}} = \left(2^{10}\left(N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1\right)\left(2n_{\text{ID}} + 1\right) + n_{\text{ID}}\right) \bmod 2^{31}$$

- QPSK signals
- Cinit depends on
  - Slot number
  - OFDM symbol number
  - nID (higher layer parameter)
    - *scramblingID* or *sequenceGenerationConfig*

```
NZP-CSI-RS-Resource ::=             SEQUENCE {
    nzp-CSI-RS-ResourceId               NZP-CSI-RS-ResourceId,
    resourceMapping                     CSI-RS-ResourceMapping,
    powerControlOffset                  INTEGER (-8..15),
    powerControlOffsetSS                ENUMERATED{db-3, db0, db3, db6}                 OPTIONAL,   -- Need R
    scramblingID                        ScramblingId,
    periodicityAndOffset                CSI-ResourcePeriodicityAndOffset                OPTIONAL,   -- Cond PeriodicOrSemiPersistent
    qcl-InfoPeriodicCSI-RS              TCI-StateId                                     OPTIONAL,   -- Cond Periodic
    ...
}
```

```
CSI-RS-ResourceMapping ::=          SEQUENCE {
    frequencyDomainAllocation           CHOICE {
        row1                                BIT STRING (SIZE (4)),
        row2                                BIT STRING (SIZE (12)),
        row4                                BIT STRING (SIZE (3)),
        other                               BIT STRING (SIZE (6))
    },
    nrofPorts                           ENUMERATED {p1,p2,p4,p8,p12,p16,p24,p32},
    firstOFDMSymbolInTimeDomain         INTEGER (0..13),
    firstOFDMSymbolInTimeDomain2        INTEGER (2..12)
    cdm-Type                            ENUMERATED {noCDM, fd-CDM2, cdm4-FD2-TD2, cdm8-FD2-TD4},
    density                             CHOICE {
        dot5                                ENUMERATED {evenPRBs, oddPRBs},
        one                                 NULL,
        three                               NULL,
        spare                               NULL
    },
    freqBand                            CSI-FrequencyOccupation,
    ...
}
```

```
-- ASN1START
-- TAG-CSI-FREQUENCYOCCUPATION-START

CSI-FrequencyOccupation ::=         SEQUENCE {
    startingRB                          INTEGER (0..maxNrofPhysicalResourceBlocks-1),
    nrofRBs                             INTEGER (24..maxNrofPhysicalResourceBlocksPlus1),
    ...
}
```

The IE for CSI-RS

CSI-RS-ResourceMapping field descriptions
cdm-Type CDM type (see TS 38.214 [19], clause 5.2.2.3.1).
density Density of CSI-RS resource measured in RE/port/PRB (see TS 38.211 [16], clause 7.4.1.5.3). Values 0.5 (*dot5*), 1 (one) and 3 (three) are allowed for X=1, values 0.5 (*dot5*) and 1 (one) are allowed for X=2, 16, 24 and 32, value 1 (one) is allowed for X=4, 8, 12. For density = 1/2, includes 1-bit indication for RB level comb offset indicating whether odd or even RBs are occupied by CSI-RS.
firstOFDMSymbolInTimeDomain2 Time domain allocation within a physical resource block. See TS 38.211 [16], clause 7.4.1.5.3.
firstOFDMSymbolInTimeDomain Time domain allocation within a physical resource block. The field indicates the first OFDM symbol in the PRB used for CSI-RS. See TS 38.211 [16], clause 7.4.1.5.3. Value 2 is supported only when DL-DMRS-typeA-pos equals 3.
freqBand Wideband or partial band CSI-RS, (see TS 38.214 [19], clause 5.2.2.3.1)
frequencyDomainAllocation Frequency domain allocation within a physical resource block in accordance with TS 38.211 [16], clause 7.4.1.5.3. The applicable row number in table 7.4.1.5.3-1 is determined by the frequencyDomainAllocation for rows 1, 2 and 4, and for other rows by matching the values in the column Ports, Density and CDMtype in table 7.4.1.5.3-1 with the values of nrofPorts, cdm-Type and density below and, when more than one row has the 3 values matching, by selecting the row where the column (k bar, l bar) in table 7.4.1.5.3-1 has indexes for k ranging from 0 to 2*n-1 where n is the number of bits set to 1 in frequencyDomainAllocation.
nrofPorts Number of ports (see TS 38.214 [19], clause 5.2.2.3.1)

CSI-FrequencyOccupation field descriptions
nrofRBs Number of PRBs across which this CSI resource spans. Only multiples of 4 are allowed. The smallest configurable number is the minimum of 24 and the width of the associated BWP. If the configured value is larger than the width of the corresponding BWP, the UE shall assume that the actual CSI-RS bandwidth is equal to the width of the BWP.
startingRB PRB where this CSI resource starts in relation to common resource block #0 (CRB#0) on the common resource block grid. Only multiples of 4 are allowed (0, 4, ...)

Mapping to Physical Resources

$$a_{k,l}^{(p,\mu)} = \beta_{\text{CSIRS}} w_f(k') \cdot w_t(l') \cdot r_{l,n_{s,f}}(m')$$

$$m' = \lfloor n\alpha \rfloor + k' + \left\lfloor \frac{\bar{k}\rho}{N_{sc}^{RB}} \right\rfloor$$

$$k = nN_{sc}^{RB} + \bar{k} + k'$$

$$l = \bar{l} + l'$$

$$\alpha = \begin{cases} \rho & \text{for } X = 1 \\ 2\rho & \text{for } X > 1 \end{cases}$$

$$n = 0,1,\ldots$$

Occupies only the RB for which the UE is configured.

X: is the number of ports (1,2,4,8,12,16,24,32)
Rho: density (0.5, 1, 3)

Table 7.4.1.5.3-1: CSI-RS locations within a slot.

Row	Ports X	Density ρ	*cdm-Type*	$(\bar{k},\bar{l})$	CDM group index j	k'	l'
1	1	3	No CDM	(k_0,l_0), (k_0+4,l_0), (k_0+8,l_0)	0,0,0	0	0
2	1	1, 0.5	No CDM	(k_0,l_0),	0	0	0
3	2	1, 0.5	FD-CDM2	(k_0,l_0),	0	0, 1	0
4	4	1	FD-CDM2	(k_0,l_0), (k_0+2,l_0)	0,1	0, 1	0
5	4	1	FD-CDM2	(k_0,l_0), (k_0,l_0+1)	0,1	0, 1	0
6	8	1	FD-CDM2	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0)	0,1,2,3	0, 1	0
7	8	1	FD-CDM2	(k_0,l_0), (k_1,l_0), (k_0,l_0+1), (k_1,l_0+1)	0,1,2,3	0, 1	0
8	8	1	CDM4 (FD2,TD2)	(k_0,l_0), (k_1,l_0)	0,1	0, 1	0, 1
9	12	1	FD-CDM2	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0), (k_4,l_0), (k_5,l_0)	0,1,2,3,4,5	0, 1	0
10	12	1	CDM4 (FD2,TD2)	(k_0,l_0), (k_1,l_0), (k_2,l_0)	0,1,2	0, 1	0, 1
11	16	1, 0.5	FD-CDM2	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0), (k_0,l_0+1), (k_1,l_0+1), (k_2,l_0+1), (k_3,l_0+1)	0,1,2,3, 4,5,6,7	0, 1	0
12	16	1, 0.5	CDM4 (FD2,TD2)	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0)	0,1,2,3	0, 1	0, 1
13	24	1, 0.5	FD-CDM2	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_0,l_0+1), (k_1,l_0+1), (k_2,l_0+1),(k_0,l_1), (k_1,l_1), (k_2,l_1), (k_0,l_1+1), (k_1,l_1+1), (k_2,l_1+1)	0,1,2,3,4,5, 6,7,8,9,10,11	0, 1	0
14	24	1, 0.5	CDM4 (FD2,TD2)	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_0,l_1), (k_1,l_1), (k_2,l_1)	0,1,2,3,4,5	0, 1	0, 1
15	24	1, 0.5	CDM8 (FD2,TD4)	(k_0,l_0), (k_1,l_0), (k_2,l_0)	0,1,2	0, 1	0, 1, 2, 3
16	32	1, 0.5	FD-CDM2	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0),(k_0,l_0+1), (k_1,l_0+1), (k_2,l_0+1), (k_3,l_0+1), (k_0,l_1), (k_1,l_1), (k_2,l_1), (k_3,l_1), (k_0,l_1+1), (k_1,l_1+1), (k_2,l_1+1), (k_3,l_1+1)	0,1,2,3, 4,5,6,7, 8,9,10,11, 12,13,14,15	0, 1	0
17	32	1, 0.5	CDM4 (FD2,TD2)	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0), (k_0,l_1), (k_1,l_1), (k_2,l_1), (k_3,l_1)	0,1,2,3,4,5,6,7	0, 1	0, 1
18	32	1, 0.5	CDM8 (FD2,TD4)	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_3,l_0)	0,1,2,3	0,1	0,1, 2, 3

```
CSI-RS-ResourceMapping ::=          SEQUENCE {
    frequencyDomainAllocation           CHOICE {
        row1                                BIT STRING (S
        row2                                BIT STRING (S
        row4                                BIT STRING (S
        other                               BIT STRING (S
    },
    nrofPorts                           ENUMERATED {p1,p2
    firstOFDMSymbolInTimeDomain         INTEGER (0..13),
    firstOFDMSymbolInTimeDomain2        INTEGER (2..12)
    cdm-Type                            ENUMERATED {noCDM
    density                             CHOICE {
        dot5                                ENUMERATED {e
        one                                 NULL,
        three                               NULL,
        spare                               NULL
    },
    freqBand                            CSI-FrequencyOccu
    ...
}
```

Time domain allocation

- Time domain locations are provided by higher layer parameters
  - *firstOFDMSymbolInTimeDomain (Provides l0)*
  - *firstOFDMSymbolInTimeDomain2 (provides l1)*
- Defined relative to the start of the slot

$l_0 \in \{0,1,\ldots,13\}$ and $l_1 \in \{2,3,\ldots,12\}$

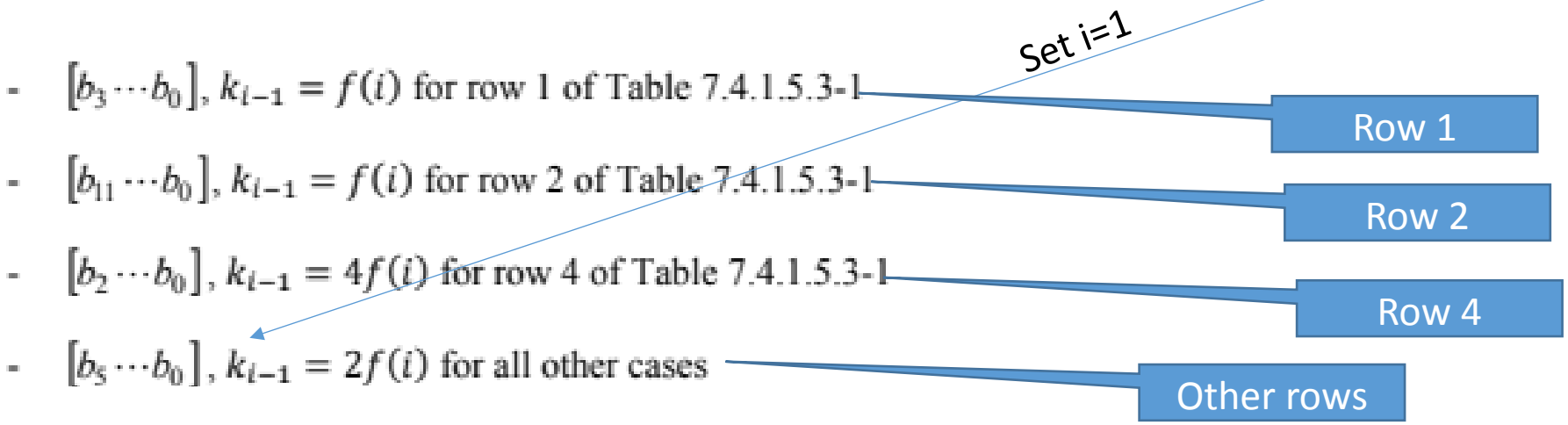
Frequency domain allocation

- Depends on if Row 1, Row2 , Row4 or Others is chosen in NZP-CSI-RS
  - Row 1,2, 4 (from the table are signaled explicitly)
  - Other rows have to be inferred from the number of ports, CDM type.
- Starting RB is given by higher layer parameter
  - CSI-RS-ResourceMapping ␣ CSI-FrequencyOccupation ␣ startingRB
    - PRB where this CSI resource starts in relation to common resource block #0 (CRB#0) on the common resource block grid. Only multiples of 4 are allowed (0, 4, ...)
- No of PRB's is given by higher layer parameter
  - CSI-RS-ResourceMapping ␣ CSI-FrequencyOccupation ␣ *nrofRBs*
  - Number of PRBs across which this CSI resource spans.
  - Only multiples of 4 are allowed

Freq domain allocation (contd..)

5	4	1	FD-CDM2	$(k_0, l_0), (k_0, l_0 + 1)$	0,1	
6	8	1	FD-CDM2	$(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0)$	0,1,2,3	
7	8	1	FD-CDM2	$(k_0, l_0), (k_1, l_0), (k_0, l_0 + 1), (k_1, l_0 + 1)$	0,1,2,3	
8	8	1	CDM4 (FD2,TD2)	$(k_0, l_0), (k_1, l_0)$	0,1	

- What subcarriers in each RB?



- f(i) is the bit number of the i^{th} bit in the bitmap set to 1 [row 1 and row 2]
  - Example: [0 0 1 0 0 1] ==> f(1) = 0, f(2) = 3
  - Example: [0 1 0 1 0 0] ==> f(1) = 2, f(2) = 4
  - Example: [0 0 1 0 1 1 0]==> f(1)=1, f(2) =2, f(3) =4 [row 1 and 2]
  - Example: [0 0 1 0 1 1 0]==> f(1)=2*1, f(2) =2*2, f(3) =2*4 [row 8]

- Repeated across ceil(1/rho) of the resource blocks

CDM type and ports

- CDM is used to distinguish multiple ports
  - 32 ports are allowed
- CDM + FDM + TDM is used.
- Types: NoCDM, FD-CDM2, CDM4-FD2-TD2, CDM8-FD2-TD4
- Example: FD-CDM2: use the same frequency and use 2-orthogonal code in Freq

No-CDM

Index	$w_f(0)$	$w_t(0)$
0	1	1

Fd-CDM2

Index	$[w_f(0) \quad w_f(1)]$	$w_t(0)$
0	$[+1 \quad +1]$	1
1	$[+1 \quad -1]$	1

CDM4-FD2-TD2

Index	$[w_f(0) \quad w_f(1)]$	$[w_t(0) \quad w_t(1)]$
0	$[+1 \quad +1]$	$[+1 \quad +1]$
1	$[+1 \quad -1]$	$[+1 \quad +1]$
2	$[+1 \quad +1]$	$[+1 \quad -1]$
3	$[+1 \quad -1]$	$[+1 \quad -1]$

CDM4-FD2-TD2

Index	$[w_f(0) \quad w_f(1)]$	$[w_t(0) \quad w_t(1) \quad w_t(2) \quad w_t(3)]$
0	$[+1 \quad +1]$	$[+1 \quad +1 \quad +1 \quad +1]$
1	$[+1 \quad -1]$	$[+1 \quad +1 \quad +1 \quad +1]$
2	$[+1 \quad +1]$	$[+1 \quad -1 \quad +1 \quad -1]$
3	$[+1 \quad -1]$	$[+1 \quad -1 \quad +1 \quad -1]$
4	$[+1 \quad +1]$	$[+1 \quad +1 \quad -1 \quad -1]$
5	$[+1 \quad -1]$	$[+1 \quad +1 \quad -1 \quad -1]$
6	$[+1 \quad +1]$	$[+1 \quad -1 \quad -1 \quad +1]$
7	$[+1 \quad -1]$	$[+1 \quad -1 \quad -1 \quad +1]$

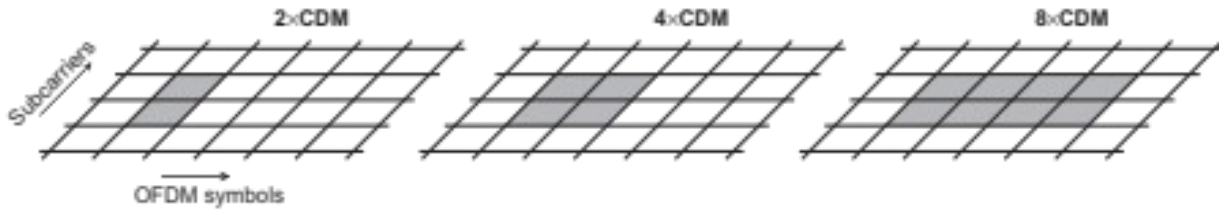
Port Mapping and CDM

$$p = 3000 + s + jL;$$
$$j = 0,1,\ldots,N/L-1$$
$$s = 0,1,\ldots,L-1;$$

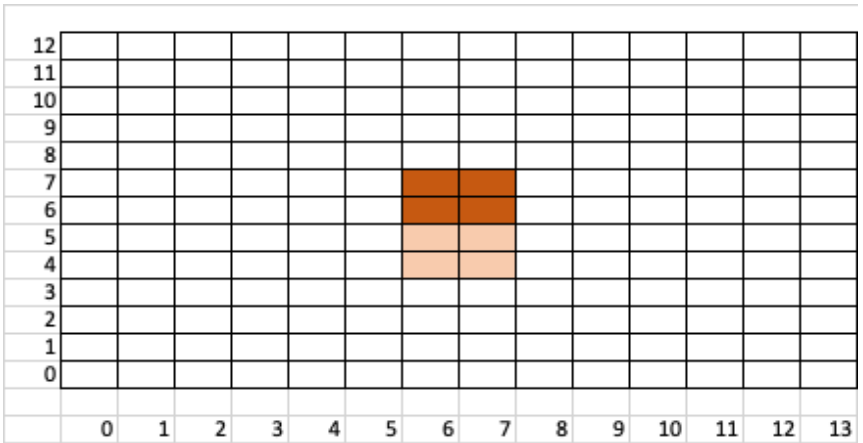
10	12	1	CDM4 (FD2,TD2)	(k_0, l_0), (k_1, l_0), (k_2, l_0)	0,1,2	0, 1	0, 1
11	16	1, 0.5	FD-CDM2	(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0), $(k_0, l_0 + 1)$, $(k_1, l_0 + 1)$, $(k_2, l_0 + 1)$, $(k_3, l_0 + 1)$	0,1,2,3, 4,5,6,7	0, 1	0

So, if you have 16 ports and use FD-CDM2, s = 0,1, and j = 0…7

CDM groups are numbered in increasing frequency and then in increasing time



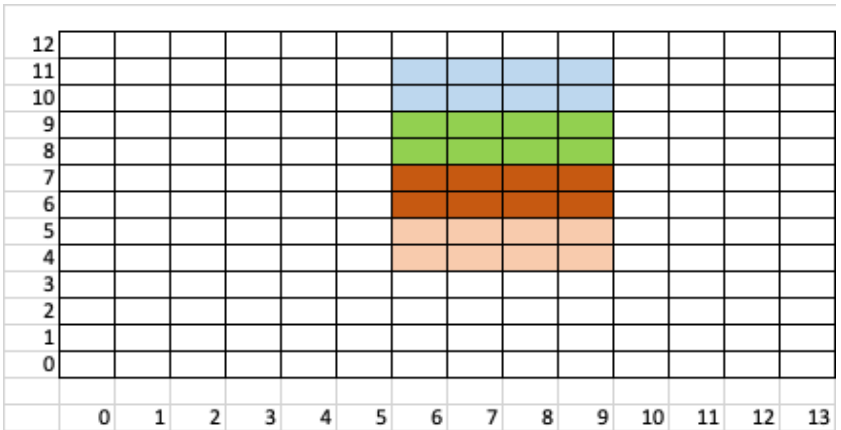
8	8	1	CDM4 (FD2,TD2)	$(k_0, l_0), (k_1, l_0)$	0,1	0, 1	0, 1



Assume k0 = **4, k1 =6,**
l0 =6

18	32	1, 0.5	CDM8 (FD2,TD4)	$(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0)$	0,1,2,3	0,1	0,1, 2, 3

Assume k0 = **4, k1 =6, k2=8, k3=10, l0 =6**

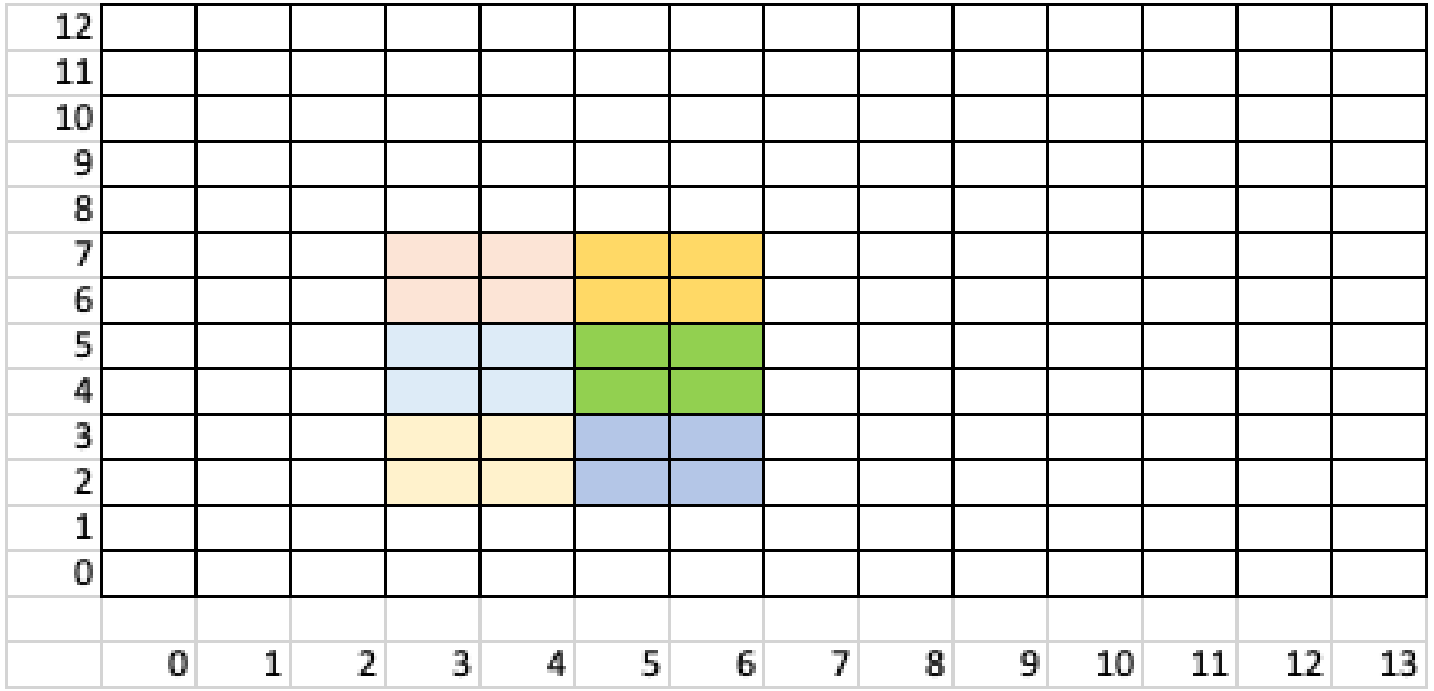


Examples of CSIRS.

$$k = nN_{sc}^{RB} + \bar{k} + k'$$
$$l = \bar{l} + l'$$

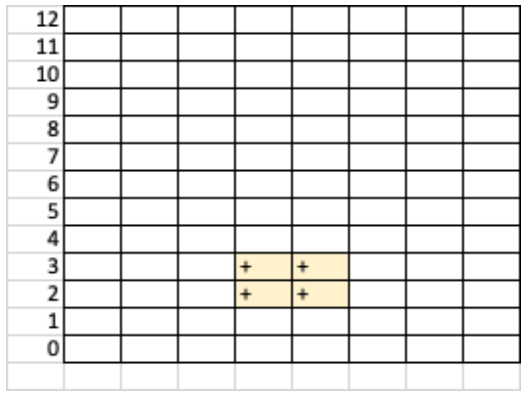
Row	Ports X	Density ρ	*cdm-Type*	$(\bar{k},\bar{l})$	CDM group index j	k'	l'
14	24	1, 0.5	CDM4 (FD2,TD2)	(k_0,l_0), (k_1,l_0), (k_2,l_0), (k_0,l_1), (k_1,l_1), (k_2,l_1)	0,1,2,3,4,5	0, 1	0, 1

density = one
nrofPorts = p24
cdm-Type = CDM4(FD2,TD2)
frequencyDomainAllocation.other = 001110.
firstOFDMSymbolinTimeDomain = 3
fitstOFDMSymbolinTimeDomain2 = 5

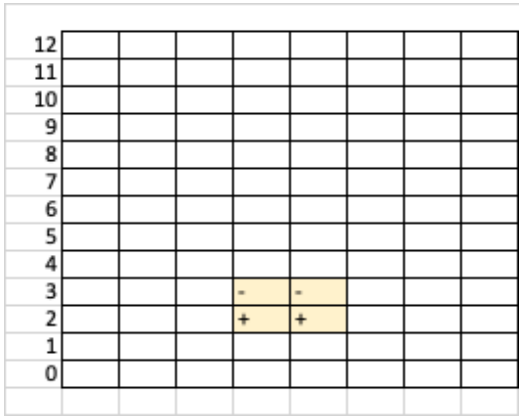


K0 = 2
K1 = 4
K2 = 6

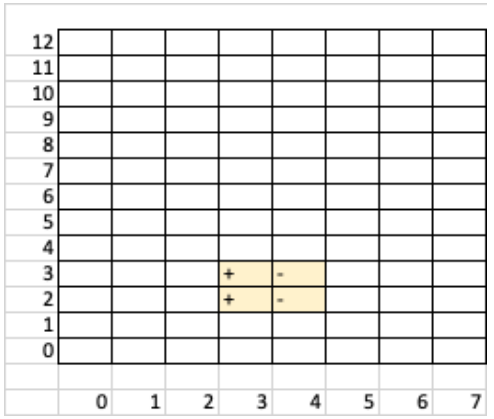
l0= 3
l1 = 5



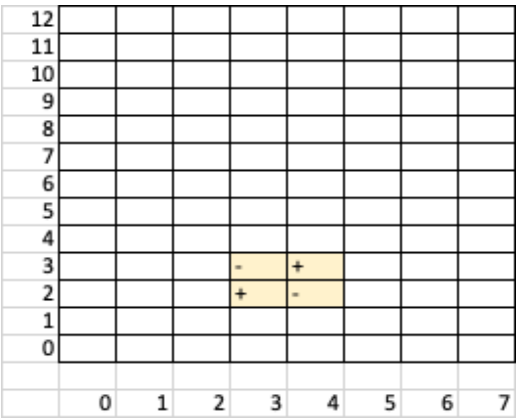
P= 3000



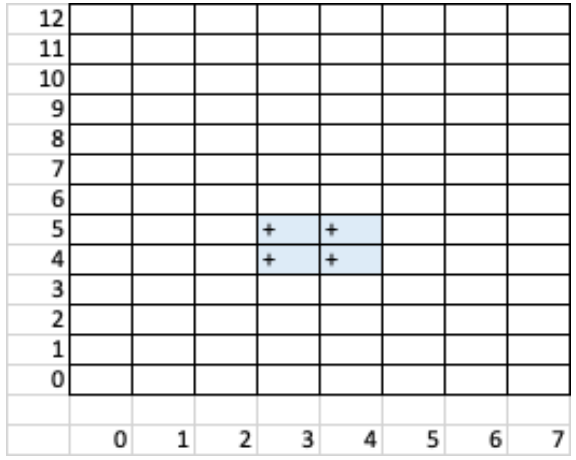
P= 3001



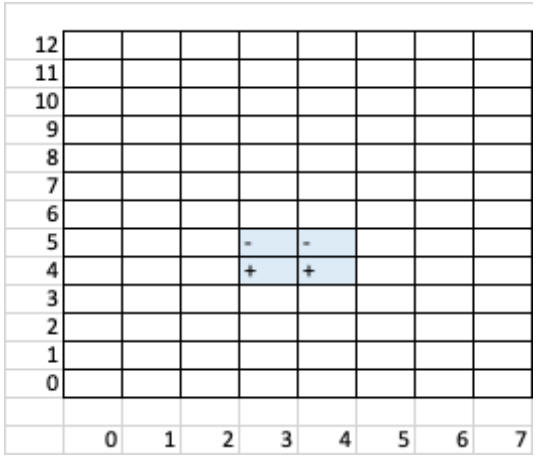
P= 3002



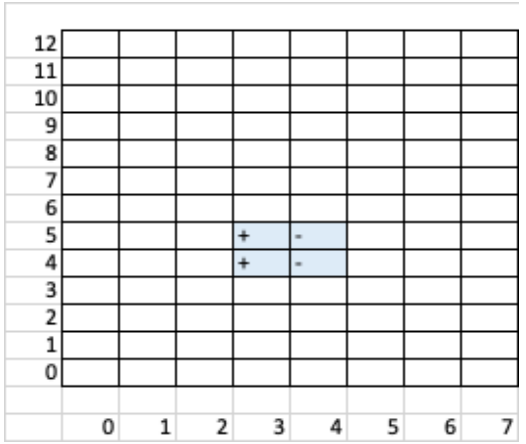
P= 3003



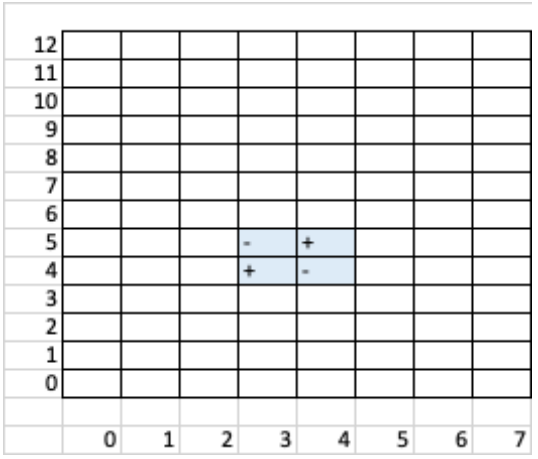
P= 3004



P= 3005



P= 3006



P= 3007

- Periodic transmission: Transmit periodically
- Semi-Persistent transmission:
  - Activated or deactivated via MAC control elements
  - When activated, it is periodic till deactivated
- Aperiodic transmission: Signaled via DCI

Persistent/Semi-persistent scheduling

- CSI-RS is transmitted in slots satisfying

$$\left(N_{\text{slot}}^{\text{frame},\mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}\right) \bmod T_{\text{CSI-RS}} = 0$$

Periodicity choices are

- 4, 5,8,10,16,20,32,40,64,80,160,320 and 640 slots.

```
CSI-ResourcePeriodicityAndOffset ::=    CHOICE {
    slots4                              INTEGER (0..3),
    slots5                              INTEGER (0..4),
    slots8                              INTEGER (0..7),
    slots10                             INTEGER (0..9),
    slots16                             INTEGER (0..15),
    slots20                             INTEGER (0..19),
    slots32                             INTEGER (0..31),
    slots40                             INTEGER (0..39),
    slots64                             INTEGER (0..63),
    slots80                             INTEGER (0..79),
    slots160                            INTEGER (0..159),
    slots320                            INTEGER (0..319),
    slots640                            INTEGER (0..639)
}
```

CSI-RS for Tracking (TRS)

TRS

```
-- TAG-NZP-CSI-RS-RESOURCESET-START
NZP-CSI-RS-ResourceSet ::=          SEQUENCE {
    nzp-CSI-ResourceSetId               NZP-CSI-RS-ResourceSetId,
    nzp-CSI-RS-Resources                SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourcesPerSet)) OF NZP-CSI-RS-ResourceId,
    repetition                          ENUMERATED { on, off }
    aperiodicTriggeringOffset           INTEGER(0..6)
    trs-Info                            ENUMERATED {true}
    ...
}

-- TAG-NZP-CSI-RS-RESOURCESET-STOP
-- ASN1STOP
```

- TRS is a special case of the CSI-RS resources
- Configured through the notion of CSI-RS resource sets
- Mainly used by UE for frequency and time tracking
  - Periodic pilots in time and frequency
- Mainly indicated by *NZP-CSI-RS- ResourceSet* $\sqsubset$ *trs-Info*
  - *If yes, then the UE can assume*
    - *All the antenna-ports to the port index for CSI-RS (3000+x) is the same for all the CSI-RS resources*
    - Periodic, with the CSI-RS resources in the *NZP-CSI-RS-ResourceSet* configured with same periodicity, bandwidth and subcarrier location

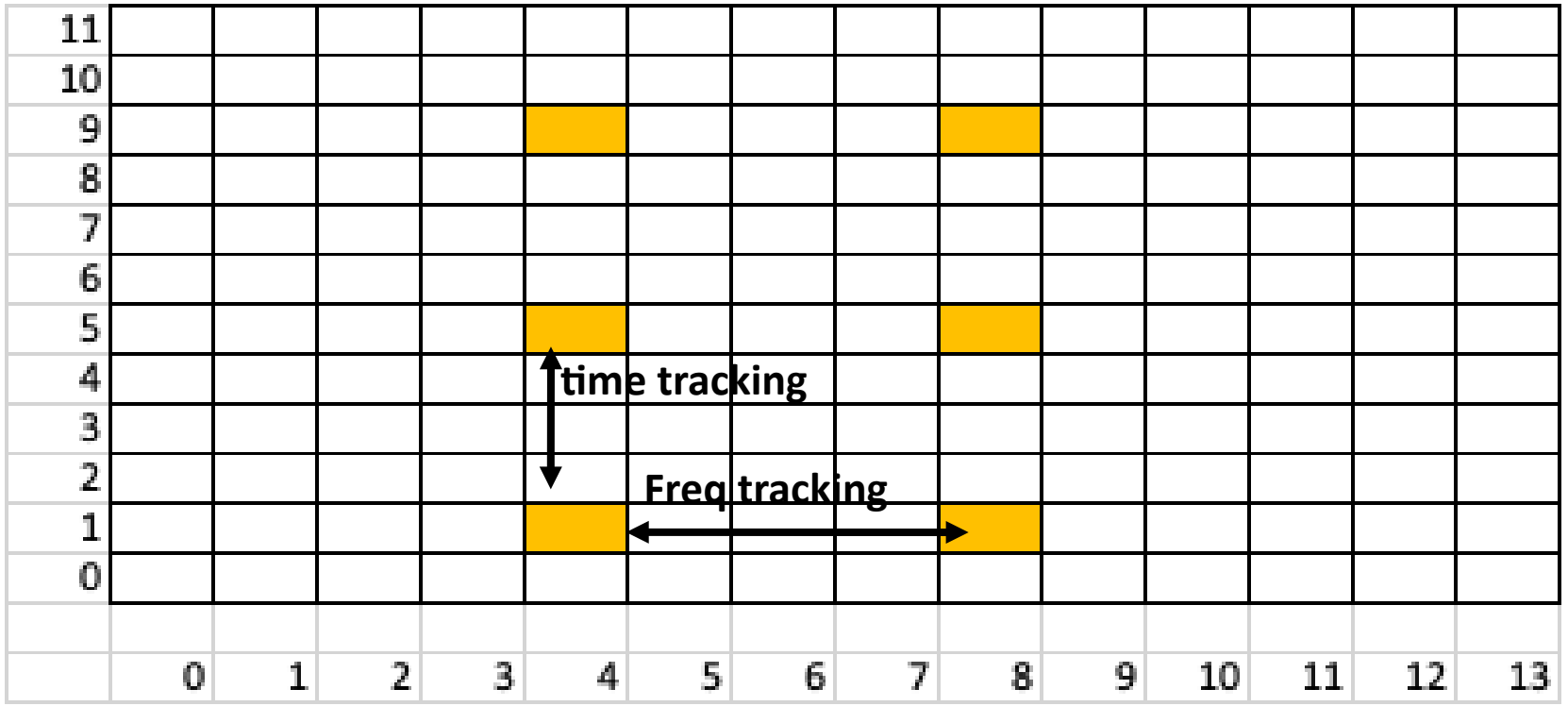
TRS properties

- *NZP-CSI-RS-Resource* with the following restrictions
  - The time domain locations are given as
    - *firstOFDMSymbolInTimeDomain*
    - *firstOFDMSymbolInTimeDomain2*

- $l \in \{4,8\}$, $l \in \{5,9\}$, or $l \in \{6,10\}$ for frequency range 1 and frequency range 2,
- $l \in \{0,4\}$, $l \in \{1,5\}$, $l \in \{2,6\}$, $l \in \{3,7\}$, $l \in \{7,11\}$, $l \in \{8,12\}$ or $l \in \{9,13\}$ for frequency range 2.

  - *Single–port CSI RS with density =3*
  - *Bandwidth* of the CSI-RS resource (CSI-RS-ResourceMapping ▭ CSI-FrequencyOccupation ▭ *nrofRBs) is capped at a maximum of 52 RB*
  - if periodic: Periodicity is 2^u*Xp where Xp = 10,20,40 or 80

- FR1:
  - *NZP-CSI-RS-ResourceSet* consists of four periodic NZP CSI-RS resources in two consecutive slots with two periodic NZP CSI-RS resources in each slot.
- FR2:
  - The UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS- ResourceSet* consists of two periodic CSI-RS resources in one slot
  - **or** with a *NZP-CSI-RS-ResourceSet* of four periodic NZP CSI-RS resources in two consecutive slots with two periodic NZP CSI-RS resources in each slot.
- So essentially for FR1, there are at least two CSI-RS resources in the set with different slot offsets and other parameters being the same.



CSI-RS Framework

- Four types of CSI reference signals
  - NZP-CSI reference signals
    - Channel measurements
    - Interference measurements
  - CSI Interference measurement resources (Used to measure intercell interference)
  - Zero power CSI reference signals
    - [Used to rate-match for CSI-RS signals not transmitted on a particular UE (made to be zero). Might be transmitted for other UE]

FIRST LEVEL: ServingCellConfig␣csi-MeasConfig

```
-- ASN1START
-- TAG-CSI-MEASCONFIG-START

CSI-MeasConfig ::=                  SEQUENCE {
    nzp-CSI-RS-ResourceToAddModList     SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-Resources)) OF NZP-CSI-RS-Resource   OPTIONAL, -- Need N
    nzp-CSI-RS-ResourceToReleaseList    SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-Resources)) OF NZP-CSI-RS-ResourceId OPTIONAL, -- Need N
    nzp-CSI-RS-ResourceSetToAddModList  SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourceSets)) OF NZP-CSI-RS-ResourceSet
                                                                                                                  OPTIONAL, -- Need N
    nzp-CSI-RS-ResourceSetToReleaseList SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourceSets)) OF NZP-CSI-RS-ResourceSetId
                                                                                                                  OPTIONAL, -- Need N
    csi-IM-ResourceToAddModList         SEQUENCE (SIZE (1..maxNrofCSI-IM-Resources)) OF CSI-IM-Resource           OPTIONAL, -- Need N
    csi-IM-ResourceToReleaseList        SEQUENCE (SIZE (1..maxNrofCSI-IM-Resources)) OF CSI-IM-ResourceId         OPTIONAL, -- Need N
    csi-IM-ResourceSetToAddModList      SEQUENCE (SIZE (1..maxNrofCSI-IM-ResourceSets)) OF CSI-IM-ResourceSet     OPTIONAL, -- Need N
    csi-IM-ResourceSetToReleaseList     SEQUENCE (SIZE (1..maxNrofCSI-IM-ResourceSets)) OF CSI-IM-ResourceSetId   OPTIONAL, -- Need N
    csi-SSB-ResourceSetToAddModList     SEQUENCE (SIZE (1..maxNrofCSI-SSB-ResourceSets)) OF CSI-SSB-ResourceSet   OPTIONAL, -- Need N
    csi-SSB-ResourceSetToReleaseList    SEQUENCE (SIZE (1..maxNrofCSI-SSB-ResourceSets)) OF CSI-SSB-ResourceSetId OPTIONAL, -- Need N
    csi-ResourceConfigToAddModList      SEQUENCE (SIZE (1..maxNrofCSI-ResourceConfigurations)) OF CSI-ResourceConfig
                                                                                                                  OPTIONAL, -- Need N
    csi-ResourceConfigToReleaseList     SEQUENCE (SIZE (1..maxNrofCSI-ResourceConfigurations)) OF CSI-ResourceConfigId
                                                                                                                  OPTIONAL, -- Need N
    csi-ReportConfigToAddModList        SEQUENCE (SIZE (1..maxNrofCSI-ReportConfigurations)) OF CSI-ReportConfig  OPTIONAL, -- Need N
    csi-ReportConfigToReleaseList       SEQUENCE (SIZE (1..maxNrofCSI-ReportConfigurations)) OF CSI-ReportConfigId
                                                                                                                  OPTIONAL, -- Need N
    reportTriggerSize                   INTEGER (0..6)                                                            OPTIONAL, -- Need M
    aperiodicTriggerStateList           SetupRelease { CSI-AperiodicTriggerStateList }                            OPTIONAL, -- Need M
    semiPersistentOnPUSCH-TriggerStateList    SetupRelease { CSI-SemiPersistentOnPUSCH-TriggerStateList }         OPTIONAL, -- Need M
    ...
}

-- TAG-CSI-MEASCONFIG-STOP
-- ASN1STOP
```

Report config

```
-- ASN1START
-- TAG-CSI-REPORTCONFIG-START

CSI-ReportConfig ::=                SEQUENCE {
    reportConfigId                          CSI-ReportConfigId,
    carrier                                 ServCellIndex                   OPTIONAL,   -- Need S
    resourcesForChannelMeasurement          CSI-ResourceConfigId,
    csi-IM-ResourcesForInterference         CSI-ResourceConfigId            OPTIONAL,   -- Need R
    nzp-CSI-RS-ResourcesForInterference     CSI-ResourceConfigId            OPTIONAL,   -- Need R
```

```
reportConfigType                        CHOICE {
    periodic                                SEQUENCE {
        reportSlotConfig                        CSI-ReportPeriodicityAndOffset,
        pucch-CSI-ResourceList                  SEQUENCE (SIZE (1..maxNrofBWPs)) OF PUCCH-CSI-Resource
    },
    semiPersistentOnPUCCH                   SEQUENCE {
        reportSlotConfig                        CSI-ReportPeriodicityAndOffset,
        pucch-CSI-ResourceList                  SEQUENCE (SIZE (1..maxNrofBWPs)) OF PUCCH-CSI-Resource
    },
    semiPersistentOnPUSCH                   SEQUENCE {
        reportSlotConfig                        ENUMERATED {sl5, sl10, sl20, sl40, sl80,
        reportSlotOffsetList                    SEQUENCE (SIZE (1.. maxNrofUL-Allocations))
        p0alpha                                 P0-PUSCH-AlphaSetId
    },
    aperiodic                               SEQUENCE {
        reportSlotOffsetList                    SEQUENCE (SIZE (1..maxNrofUL-Allocations)) O
    }
},
reportQuantity                          CHOICE {
    none                                    NULL,
    cri-RI-PMI-CQI                          NULL,
    cri-RI-i1                               NULL,
    cri-RI-i1-CQI                           SEQUENCE {
        pdsch-BundleSizeForCSI                  ENUMERATED {n2, n4}
    },
    cri-RI-CQI                              NULL,
    cri-RSRP                                NULL,
    ssb-Index-RSRP                          NULL,
    cri-RI-LI-PMI-CQI                       NULL
},
reportFreqConfiguration                 SEQUENCE {
    cqi-FormatIndicator                     ENUMERATED { widebandCQI, subbandCQI }
    pmi-FormatIndicator                     ENUMERATED { widebandPMI, subbandPMI }
    csi-ReportingBand                       CHOICE {
        subbands3                               BIT STRING(SIZE(3)),
        subbands4                               BIT STRING(SIZE(4)),
        subbands5                               BIT STRING(SIZE(5)),
        subbands6                               BIT STRING(SIZE(6)),
        subbands7                               BIT STRING(SIZE(7)),
        subbands8                               BIT STRING(SIZE(8)),
        subbands9                               BIT STRING(SIZE(9)),
        subbands10                              BIT STRING(SIZE(10)),
```

```
        enabled                                 NULL,
        disabled                                SEQUENCE {
            nrofReportedRS                          ENUMERATED {n1, n2, n3, n
        }
    },
    cqi-Table                       ENUMERATED {table1, table2, table3, spare1}
    subbandSize                     ENUMERATED {value1, value2},
    non-PMI-PortIndication          SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-Resource
    ...,
    [[
    semiPersistentOnPUSCH-v1530             SEQUENCE {
        reportSlotConfig-v1530                  ENUMERATED {sl4, sl8, sl16}
    }
    ]]
}

CSI-ReportPeriodicityAndOffset ::=  CHOICE {
    slots4                                  INTEGER(0..3),
    slots5                                  INTEGER(0..4),
    slots8                                  INTEGER(0..7),
    slots10                                 INTEGER(0..9),
    slots16                                 INTEGER(0..15),
    slots20                                 INTEGER(0..19),
    slots40                                 INTEGER(0..39),
    slots80                                 INTEGER(0..79),
    slots160                                INTEGER(0..159),
    slots320                                INTEGER(0..319)
}

PUCCH-CSI-Resource ::=              SEQUENCE {
    uplinkBandwidthPartId               BWP-Id,
    pucch-Resource                      PUCCH-ResourceId
}
```

```
        rank1-2
        rank2-2
    },
    portIndex1
}

PortIndex8::=
```

```
        PortIndex2
        SEQUENCE(SIZE(2)) OF PortIndex2

    NULL

INTEGER (0..7)
```

```
ndex8
NCE(SIZE(2)) OF PortIndex8
NCE(SIZE(3)) OF PortIndex8
NCE(SIZE(4)) OF PortIndex8
NCE(SIZE(5)) OF PortIndex8
```

```
CSI-ResourceConfig ::=      SEQUENCE {
    csi-ResourceConfigId        CSI-ResourceConfigId,
    csi-RS-ResourceSetList      CHOICE {
        nzp-CSI-RS-SSB              SEQUENCE {
            nzp-CSI-RS-ResourceSetList  SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourceSetsPerConfig)) OF NZP-CSI-RS-ResourceSetId
                                                                                                        OPTIONAL, -- Need R

            csi-SSB-ResourceSetList     SEQUENCE (SIZE (1..maxNrofCSI-SSB-ResourceSetsPerConfig)) OF CSI-SSB-ResourceSetId
                                                                                                        OPTIONAL  -- Need R
        },
        csi-IM-ResourceSetList      SEQUENCE (SIZE (1..maxNrofCSI-IM-ResourceSetsPerConfig)) OF CSI-IM-ResourceSetId
    },

    bwp-Id                      BWP-Id,
    resourceType                ENUMERATED { aperiodic, semiPersistent, periodic },
    ...
}
```

```
-- ASN1START
-- TAG-NZP-CSI-RS-RESOURCESET-START
NZP-CSI-RS-ResourceSet ::=          SEQUENCE {
    nzp-CSI-ResourceSetId               NZP-CSI-RS-ResourceSetId,
    nzp-CSI-RS-Resources                SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourcesPerSet)) OF NZP-CSI-RS-ResourceId,
    repetition                          ENUMERATED { on, off }                                          OPTIONAL,   -- Need S
    aperiodicTriggeringOffset           INTEGER(0..6)                                                   OPTIONAL,   -- Need S
    trs-Info                            ENUMERATED {true}                                               OPTIONAL,   -- Need R
    ...
}

-- TAG-NZP-CSI-RS-RESOURCESET-STOP
-- ASN1STOP
```

```
-- ASN1START
-- TAG-CSI-SSB-RESOURCESET-START

CSI-SSB-ResourceSet ::=             SEQUENCE {
    csi-SSB-ResourceSetId               CSI-SSB-ResourceSetId,
    csi-SSB-ResourceList                SEQUENCE (SIZE(1..maxNrofCSI-SSB-ResourcePerSet)) OF SSB-Index,
    ...
}

-- TAG-CSI-SSB-RESOURCESET-STOP
-- ASN1STOP
```

```
-- ASN1START
-- TAG-CSI-IM-RESOURCESET-START

CSI-IM-ResourceSet ::=              SEQUENCE {
    csi-IM-ResourceSetId                CSI-IM-ResourceSetId,
    csi-IM-Resources                    SEQUENCE (SIZE(1..maxNrofCSI-IM-ResourcesPerSet)) OF CSI-IM-ResourceId,
    ...
}
-- TAG-CSI-IM-RESOURCESET-STOP
-- ASN1STOP
```

```
NZP-CSI-RS-Resource ::=             SEQUENCE {
    nzp-CSI-RS-ResourceId               NZP-CSI-RS-ResourceId,
    resourceMapping                     CSI-RS-ResourceMapping,
    powerControlOffset                  INTEGER (-8..15),
    powerControlOffsetSS                ENUMERATED{db-3, db0, db3, db6}                 OPTIONAL,   -- Need R
    scramblingID                        ScramblingId,
    periodicityAndOffset                CSI-ResourcePeriodicityAndOffset                OPTIONAL,   -- Cond PeriodicOrSemiPersistent
    qcl-InfoPeriodicCSI-RS              TCI-StateId                                     OPTIONAL,   -- Cond Periodic
    ...
}
```

```
CSI-RS-ResourceMapping ::=          SEQUENCE {
    frequencyDomainAllocation           CHOICE {
        row1                                BIT STRING (SIZE (4)),
        row2                                BIT STRING (SIZE (12)),
        row4                                BIT STRING (SIZE (3)),
        other                               BIT STRING (SIZE (6))
    },
    nrofPorts                           ENUMERATED {p1,p2,p4,p8,p12,p16,p24,p32},
    firstOFDMSymbolInTimeDomain         INTEGER (0..13),
    firstOFDMSymbolInTimeDomain2        INTEGER (2..12)
    cdm-Type                            ENUMERATED {noCDM, fd-CDM2, cdm4-FD2-TD2, cdm8-FD2-TD4},
    density                             CHOICE {
        dot5                                ENUMERATED {evenPRBs, oddPRBs},
        one                                 NULL,
        three                               NULL,
        spare                               NULL
    },
    freqBand                            CSI-FrequencyOccupation,
    ...
}
```

```
-- ASN1START
-- TAG-CSI-FREQUENCYOCCUPATION-START

CSI-FrequencyOccupation ::=         SEQUENCE {
    startingRB                          INTEGER (0..maxNrofPhysicalResourceBlocks-1),
    nrofRBs                             INTEGER (24..maxNrofPhysicalResourceBlocksPlus1),
    ...
}
```

The IE for CSI-RS

```
-- ASN1START
-- TAG-CSI-IM-RESOURCE-START

CSI-IM-Resource ::=                 SEQUENCE {
    csi-IM-ResourceId                   CSI-IM-ResourceId,
    csi-IM-ResourceElementPattern           CHOICE {
        pattern0                                SEQUENCE {
            subcarrierLocation-p0                   ENUMERATED { s0, s2, s4, s6, s8, s10 },
            symbolLocation-p0                       INTEGER (0..12)
        },
        pattern1                                SEQUENCE {
            subcarrierLocation-p1                   ENUMERATED { s0, s4, s8 },
            symbolLocation-p1                       INTEGER (0..13)
        }
    }                                                                               OPTIONAL,   -- Need M
    freqBand                        CSI-FrequencyOccupation                         OPTIONAL,   -- Need M
    periodicityAndOffset            CSI-ResourcePeriodicityAndOffset                OPTIONAL,   -- Cond PeriodicOrSemiPersistent
    ...
}

-- TAG-CSI-IM-RESOURCE-STOP
-- ASN1STOP
```

Measurement Config

CSI Report Config 1

1) Resources (multiple) for
   1) Channel Measurement
   2) NZP IM
   3) CSI-IM

2) What reports to generate
3) Time domain behavior
   1) Periodic/Aperiodic/

CSI-Resource Configs (Define what signals to use to compute CSI, Periodic/aperiodic/Persistent)

NZP-CSI Resource Sets

NZP-CSI-Resource (s) : 1

NZP-CSI-Resource (s): ..M

CSI-SSB Resource Sets

SSB - Indices

CSI-IM Resource Sets

CSI-IM Resource (s): 1

CSI-IM Resource (s): N

CSI Report Config 2

CSI Report Config N

- Mapping of the Resource sets and (Resources) are done through their ID's.
- So, the same Resource (and resource sets) can be re-used for different CSI-Report configs.

Reports are configured.

Reports utilize CSI-resource

Table 5.2.1.4-1: Triggering/Activation of CSI Reporting for the possible CSI-RS Configurations.

CSI-RS Configuration	Periodic CSI Reporting	Semi-Persistent CSI Reporting	Aperiodic CSI Reporting
Periodic CSI-RS	No dynamic triggering/activation	For reporting on PUCCH, the UE receives an activation command, as described in subclause 6.1.3.16 of [10, TS 38.321]; for reporting on PUSCH, the UE receives triggering on DCI	Triggered by DCI; additionally, subselection indication as described in subclause 6.1.3.13 of [10, TS 38.321] possible as defined in Subclause 5.2.1.5.1.
Semi-Persistent CSI-RS	Not Supported	For reporting on PUCCH, the UE receives an activation command, as described in subclause 6.1.3.16 of [10, TS 38.321]; for reporting on PUSCH, the UE receives triggering on DCI	Triggered by DCI; additionally, subselection indication as described in subclause 6.1.3.13 of [10, TS 38.321] possible as defined in Subclause 5.2.1.5.1.
Aperiodic CSI-RS	Not Supported	Not Supported	Triggered by DCI; additionally, subselection indication as described in subclause 6.1.3.13 of [10, TS 38.321] possible as defined in Subclause 5.2.1.5.1.

CSI-RS Framework