Table 5.2.2.2.1-10: Codebook for 6-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

	$i_{1,1}$	$i_{1,2}$	i_2	
codebookMode = 1-2				
$N_2 > 1$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
where $W^{(6)}_{l,l',l'',m,m'.m'',n} = \dfrac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$.				

Table 5.2.2.2.1-11: Codebook for 7-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

	$i_{1,1}$	$i_{1,2}$	i_2	
codebookMode = 1-2				
$N_1 = 4, N_2 = 1$	$0,\ldots,\dfrac{N_1O_1}{2}-1$	0	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 > 4, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 = 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,\dfrac{N_2O_2}{2}-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 > 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
where $W^{(7)}_{l,l',l'',m,m'.m'',m'',n} = \dfrac{1}{\sqrt{7P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$.				

Table 5.2.2.2.1-12: Codebook for 8-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

	$i_{1,1}$	$i_{1,2}$	i_2	
codebookMode = 1-2				
$N_1 = 4, N_2 = 1$	$0,\ldots,\dfrac{N_1O_1}{2}-1$	0	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 > 4, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 = 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,\dfrac{N_2O_2}{2}-1$	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 > 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
where $W^{(8)}_{l,l',l'',l''',m,m'.m'',m''',n} = \dfrac{1}{\sqrt{8P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$.				

5.2.2.2.2 Type I Multi-Panel Codebook

For 8 antenna ports {3000, 3001, …, 3007}, 16 antenna ports {3000, 3001, …, 3015}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to 'typeI-MultiPanel',

- The values of N_g, N_1 and N_2 are configured with the higher layer parameters *ng-n1-n2*. The supported configurations of $\left(N_g, N_1, N_2\right)$ for a given number of CSI-RS ports and the corresponding values of (O_1, O_2) are given in Table 5.2.2.2.2-1. The number of CSI-RS ports, $P_{\text{CSI-RS}}$, is $2N_g N_1 N_2$.

- When $N_g = 2$, *codebookMode* shall be set to either '1' or '2'. When $N_g = 4$, *codebookMode* shall be set to '1'.

The bitmap parameter *ng-n1-n2* forms the bit sequence $a_{A_c-1}, ..., a_1, a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that PMI reporting is not allowed to correspond to any precoder associated with the bit. The number of bits is given by $A_c = N_1 O_1 N_2 O_2$. Bit $a_{N_2 O_2 l + m}$ is associated with all precoders based on the quantity $v_{l,m}$, $l = 0, ..., N_1 O_1 - 1$, $m = 0, ..., N_2 O_2 - 1$, as defined below. The bitmap parameter *ri-Restriction* forms the bit sequence $r_3, ..., r_1, r_0$ where r_0 is the LSB and r_3 is the MSB. When r_i is zero, $i \in \{0, 1, ..., 3\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $v = i + 1$ layers.

Table 5.2.2.2.2-1: Supported configurations of $\left(N_g, N_1, N_2\right)$ and (O_1, O_2)

Number of CSI-RS antenna ports, $P_{\text{CSI-RS}}$	$\left(N_g, N_1, N_2\right)$	(O_1, O_2)
8	(2,2,1)	(4,1)
16	(2,4,1)	(4,1)
	(4,2,1)	(4,1)
	(2,2,2)	(4,4)
32	(2,8,1)	(4,1)
	(4,4,1)	(4,1)
	(2,4,2)	(4,4)
	(4,2,2)	(4,4)

Each PMI value corresponds to the codebook indices i_1 and i_2, where i_1 is the vector

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,4} \end{bmatrix} & v = 1 \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,3} & i_{1,4} \end{bmatrix} & v \in \{2,3,4\} \end{cases}$$

and v is the associated RI value. When *codebookMode* is set to '1', $i_{1,4}$ is

$$i_{1,4} = \begin{cases} i_{1,4,1} & N_g = 2 \\ \begin{bmatrix} i_{1,4,1} & i_{1,4,2} & i_{1,4,3} \end{bmatrix} & N_g = 4 \end{cases}.$$

When *codebookMode* is set to '2', $i_{1,4}$ and i_2 are

$$i_{1,4} = \begin{bmatrix} i_{1,4,1} & i_{1,4,2} \end{bmatrix}$$
$$i_2 = \begin{bmatrix} i_{2,0} & i_{2,1} & i_{2,2} \end{bmatrix}.$$

The mapping from $i_{1,3}$ to k_1 and k_2 for 2-layer reporting is given in Table 5.2.2.2.1-3. The mapping from $i_{1,3}$ to k_1 and k_2 for 3-layer and 4-layer reporting is given in Table 5.2.2.2.2-2.

- UE shall only use $i_{1,2} = 0$ and shall not report $i_{1,2}$ if the value of N_2 is 1.

Table 5.2.2.2.2-2: Mapping of $i_{1,3}$ to k_1 and k_2 for 3-layer and 4-layer CSI reporting

$i_{1,3}$	$N_1=2, N_2=1$		$N_1=4, N_2=1$		$N_1=8, N_2=1$		$N_1=2, N_2=2$		$N_1=4, N_2=2$	
	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2
0	O_1	0	O_1	0	O_1	0	O_1	0	O_1	0
1			$2O_1$	0	$2O_1$	0	0	O_2	0	O_2
2			$3O_1$	0	$3O_1$	0	O_1	O_2	O_1	O_2
3					$4O_1$	0			$2O_1$	0

Several quantities are used to define the codebook elements. The quantities φ_n, a_p, b_n, u_m, and $v_{l,m}$ are given by

$$\varphi_n = e^{j\pi n/2}$$

$$a_p = e^{j\pi/4} e^{j\pi p/2}$$

$$b_n = e^{-j\pi/4} e^{j\pi n/2}$$

$$u_m = \begin{cases} \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \cdots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix} & N_2 > 1 \\ 1 & N_2 = 1 \end{cases}$$

$$v_{l,m} = \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \cdots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$

Furthermore, the quantities $W_{l,m,p,n}^{1,N_g,1}$ and $W_{l,m,p,n}^{2,N_g,1}$ ($N_g \in \{2,4\}$) are given by

$$W_{l,m,p,n}^{1,2,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ \varphi_n \varphi_{p_1} v_{l,m} \end{bmatrix} \quad W_{l,m,p,n}^{2,2,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ -\varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ -\varphi_n \varphi_{p_1} v_{l,m} \end{bmatrix}$$

$$W_{l,m,p,n}^{1,4,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ \varphi_n \varphi_{p_1} v_{l,m} \\ \varphi_{p_2} v_{l,m} \\ \varphi_n \varphi_{p_2} v_{l,m} \\ \varphi_{p_3} v_{l,m} \\ \varphi_n \varphi_{p_3} v_{l,m} \end{bmatrix} \quad W_{l,m,p,n}^{2,4,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ -\varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ -\varphi_n \varphi_{p_1} v_{l,m} \\ \varphi_{p_2} v_{l,m} \\ -\varphi_n \varphi_{p_2} v_{l,m} \\ \varphi_{p_3} v_{l,m} \\ -\varphi_n \varphi_{p_3} v_{l,m} \end{bmatrix}$$

where

$$p = \begin{cases} p_1 & N_g = 2 \\ \begin{bmatrix} p_1 & p_2 & p_3 \end{bmatrix} & N_g = 4 \end{cases},$$

and the quantities $W_{l,m,p,n}^{1,N_g,2}$ and $W_{l,m,p,n}^{2,N_g,2}$ ($N_g = 2$) are given by

$$W_{l,m,p,n}^{1,2,2} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ \varphi_{n_0} v_{l,m} \\ a_{p_1} b_{n_1} v_{l,m} \\ a_{p_2} b_{n_2} v_{l,m} \end{bmatrix} \quad W_{l,m,p,n}^{2,2,2} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ -\varphi_{n_0} v_{l,m} \\ a_{p_1} b_{n_1} v_{l,m} \\ -a_{p_2} b_{n_2} v_{l,m} \end{bmatrix}$$

where

$$p = \begin{bmatrix} p_1 & p_2 \end{bmatrix}$$
$$n = \begin{bmatrix} n_0 & n_1 & n_2 \end{bmatrix}.$$

The codebooks for 1-4 layers are given respectively in Tables 5.2.2.2.2-3, 5.2.2.2.2-4, 5.2.2.2.2-5, and 5.2.2.2.2-6.

Table 5.2.2.2.2-3: Codebook for 1-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

codebookMode = 1, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,\ldots,N_g - 1$	i_2	
$0,\ldots,N_1 O_1 - 1$	$0,\ldots,N_2 O_2 - 1$	$0,1,2,3$	$0,1,2,3$	$W_{i_{1,1},i_{1,2},i_{1,4},i_2}^{(1)}$
where $W_{l,m,p,n}^{(1)} = W_{l,m,p,n}^{1,N_g,1}$.				

codebookMode = 2, $N_g = 2$					
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,2$	$i_{2,0}$	$i_{2,q}$, $q = 1,2$	
$0,\ldots,N_1 O_1 - 1$	$0,\ldots,N_2 O_2 - 1$	$0,1,2,3$	$0,1,2,3$	$0,1$	$W_{i_{1,1},i_{1,2},i_{1,4},i_2}^{(1)}$
where $W_{l,m,p,n}^{(1)} = W_{l,m,p,n}^{1,N_g,2}$.					

Table 5.2.2.2.2-4: Codebook for 2-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

codebookMode = 1, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,\ldots,N_g - 1$	i_2	
$0,\ldots,N_1 O_1 - 1$	$0,\ldots,N_2 O_2 - 1$	$0,1,2,3$	$0,1$	$W_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}^{(2)}$
where $W_{l,l',m,m',p,n}^{(2)} = \frac{1}{\sqrt{2}} \begin{bmatrix} W_{l,m,p,n}^{1,N_g,1} & W_{l',m',p,n}^{2,N_g,1} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-3.				

codebookMode = 2, $N_g = 2$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,2$	$i_{2,q}$, $q = 0,1,2$	
$0,\ldots,N_1 O_1 - 1$	$0,\ldots,N_2 O_2 - 1$	$0,1,2,3$	$0,1$	$W_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}^{(2)}$
where $W_{l,l',m,m',p,n}^{(2)} = \frac{1}{\sqrt{2}} \begin{bmatrix} W_{l,m,p,n}^{1,N_g,2} & W_{l',m',p,n}^{2,N_g,2} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-3.				

Table 5.2.2.2.2-5: Codebook for 3-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

codebookMode = 1, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1, \ldots, N_g - 1$	i_2	
$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0,1,2,3$	$0,1$	$W^{(3)}_{i_{1,1}, i_{1,1}+k_1, i_{1,2}, i_{1,2}+k_2, i_{1,4}, i_2}$
where $W^{(3)}_{l,l',m,m',p,n} = \dfrac{1}{\sqrt{3}} \begin{bmatrix} W^{1,N_g,1}_{l,m,p,n} & W^{1,N_g,1}_{l',m',p,n} & W^{2,N_g,1}_{l,m,p,n} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

codebookMode = 2, $N_g = 2$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,2$	$i_{2,q}$, $q = 0,1,2$	
$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0,1,2,3$	$0,1$	$W^{(3)}_{i_{1,1}, i_{1,1}+k_1, i_{1,2}, i_{1,2}+k_2, i_{1,4}, i_2}$
where $W^{(3)}_{l,l',m,m',p,n} = \dfrac{1}{\sqrt{3}} \begin{bmatrix} W^{1,N_g,2}_{l,m,p,n} & W^{1,N_g,2}_{l',m',p,n} & W^{2,N_g,2}_{l,m,p,n} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

Table 5.2.2.2.2-6: Codebook for 4-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

codebookMode = 1, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1, \ldots, N_g - 1$	i_2	
$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0,1,2,3$	$0,1$	$W^{(4)}_{i_{1,1}, i_{1,1}+k_1, i_{1,2}, i_{1,2}+k_2, i_{1,4}, i_2}$
where $W^{(4)}_{l,l',m,m',p,n} = \dfrac{1}{\sqrt{4}} \begin{bmatrix} W^{1,N_g,1}_{l,m,p,n} & W^{1,N_g,1}_{l',m',p,n} & W^{2,N_g,1}_{l,m,p,n} & W^{2,N_g,1}_{l',m',p,n} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

codebookMode = 2, $N_g = 2$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,2$	$i_{2,q}$, $q = 0,1,2$	
$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0,1,2,3$	$0,1$	$W^{(4)}_{i_{1,1}, i_{1,1}+k_1, i_{1,2}, i_{1,2}+k_2, i_{1,4}, i_2}$
where $W^{(4)}_{l,l',m,m',p,n} = \dfrac{1}{\sqrt{4}} \begin{bmatrix} W^{1,N_g,2}_{l,m,p,n} & W^{1,N_g,2}_{l',m',p,n} & W^{2,N_g,2}_{l,m,p,n} & W^{2,N_g,2}_{l',m',p,n} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

5.2.2.2.3 Type II Codebook

For 4 antenna ports {3000, 3001, …, 3003}, 8 antenna ports {3000, 3001, …, 3007}, 12 antenna ports {3000, 3001, …, 3011}, 16 antenna ports {3000, 3001, …, 3015}, 24 antenna ports {3000, 3001, …, 3023}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to 'typeII'

- The values of N_1 and N_2 are configured with the higher layer parameter *n1-n2-codebookSubsetRestriction*. The supported configurations of (N_1, N_2) for a given number of CSI-RS ports and the corresponding values of (O_1, O_2) are given in Table 5.2.2.2.1-2. The number of CSI-RS ports, $P_{\text{CSI-RS}}$, is $2N_1 N_2$.

- The value of L is configured with the higher layer parameter *numberOfBeams*, where $L=2$ when $P_{\text{CSI-RS}} = 4$ and $L \in \{2,3,4\}$ when $P_{\text{CSI-RS}} > 4$.