

Table 6.12-1: OFDM parameters.

Configuration	Cyclic prefix length N_{CP}
Normal cyclic prefix	$\Delta f = 15 \text{ kHz}$ 160 for $I = 0$ 144 for $I = 1, 2, \dots, 6$
	$\Delta f = 7.5 \text{ kHz}$ 512 for $I = 0, 1, \dots, 5$ $\Delta f = 7.5 \text{ kHz}$ 1024 for $I = 0, 1, 2$
Extended cyclic prefix	$\Delta f = 15 \text{ kHz}$ 512 for $I = 0, 1, \dots, 5$
	$\Delta f = 7.5 \text{ kHz}$ 1024 for $I = 0, 1, 2$

 $\Delta f = 15 \text{ kHz} : \text{IFFT Length} = 2048$ $\Delta f = 7.5 \text{ kHz} : \text{IFFT Length} = 4096$

Sampling Rate (Complex) = 30.72 MHz

Table 6.2.3-1: Physical resource blocks parameters. DL

Configuration	N_{sc}^{RB}	N_{symb}^{DL}
Normal cyclic prefix	$\Delta f = 15 \text{ kHz}$ 12	7
Extended cyclic prefix	$\Delta f = 15 \text{ kHz}$ $\Delta f = 7.5 \text{ kHz}$ 24	6 3

The PHICH duration is configurable by higher layers according to Table 6.9.3-1. The duration configured puts a lower limit on the size of the control region signalled by the PCFICH.

In TDD, the PSS shall be mapped to the third OFDM symbol in subframes 1 and 6.

Table 6.9.3-1: PHICH duration in MBSFN and non-MBSFN subframes.

PHICH duration	Non-MBSFN subframes		MBSFN subframes On a carrier supporting both PDSCH and PMCH
	Subframes 1 and 6 in case of frame structure type 2 TDD	All other cases	
Normal	1	1	1
Extended	2	3	2

For frame structure type 1, the number of PHICH groups $N_{\text{PHICH}}^{\text{group}}$ is constant in all subframes and given by

FDD

$$N_{\text{PHICH}}^{\text{group}} = \begin{cases} N_g \left(\sqrt{N_{\text{RB}}^{\text{DL}} / 8} \right) & \text{for normal cyclic prefix} \\ \frac{1}{2} \cdot N_g \left(\sqrt{N_{\text{RB}}^{\text{DL}} / 8} \right) & \text{for extended cyclic prefix} \end{cases}$$

where $N_g \in \{1/6, 1/2, 1, 2\}$ is provided by higher layers. The index $n_{\text{PHICH}}^{\text{group}}$ ranges from 0 to $N_{\text{PHICH}}^{\text{group}} - 1$.

TDD

For frame structure type 2, the number of PHICH groups may vary between downlink subframes and is given by $m_i \cdot N_{\text{PHICH}}^{\text{group}}$ where m_i is given by Table 6.9.1-1 and $N_{\text{PHICH}}^{\text{group}}$ by the expression above. The index $n_{\text{PHICH}}^{\text{group}}$ in a downlink subframe with non-zero PHICH resources ranges from 0 to $m_i \cdot N_{\text{PHICH}}^{\text{group}} - 1$.

Table 6.9-1: The factor m_i for frame structure type 2. TDDConfig

Uplink-downlink configuration	Subframe number i								
	0	1	2	3	4	5	6	7	8
0	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-

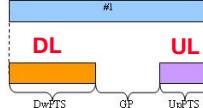
This is the perfect picture for base-station. But for UE, we need to shift every UL subframe to the left. This is why we have a special subframe when switching from DL to UL. But we don't have a special subframe when switching from UL to DL.

Table 6.7-1: Number of OFDM symbols used for PDCCH. CFI

Subframe	Number of OFDM symbols for PDCCH when $N_{\text{RB}}^{\text{DL}} > 10$	Number of OFDM symbols for PDCCH when $N_{\text{RB}}^{\text{DL}} \leq 10$
Subframe 1 and 6 for frame structure type 2 TDD	1, 2 1, 2	2 2
MBSFN subframes on a carrier supporting both PMCH and PDSCH for 1 or 2 cell specific antenna ports		
MBSFN subframes on a carrier supporting both PMCH and PDSCH for 4 cell specific antenna ports		2 2
MBSFN subframes on a carrier not supporting PDSCH	0	0
All other cases	1, 2, 3	2, 3, 4

Table 6.8.1-1: Supported PDCCH formats

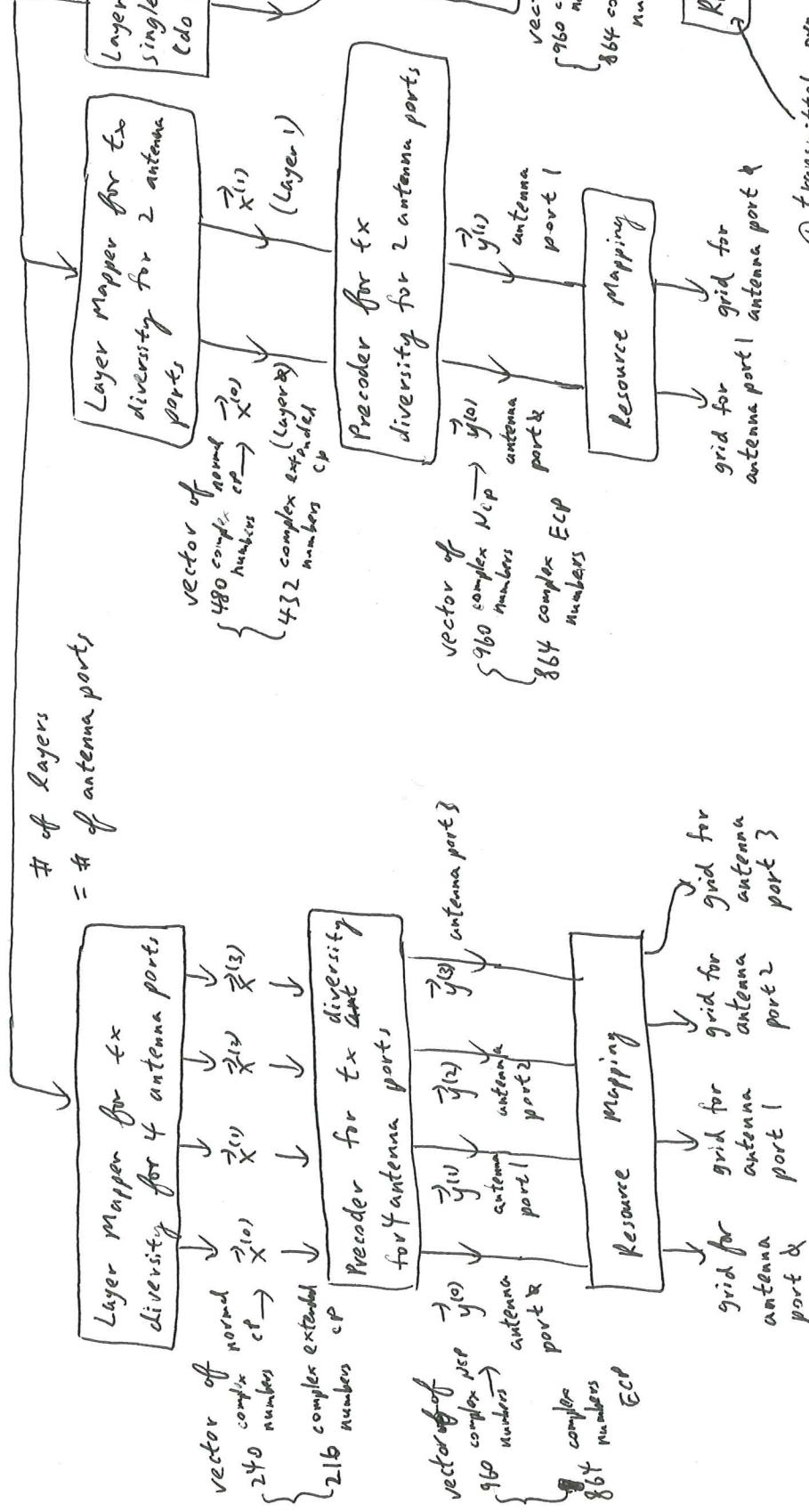
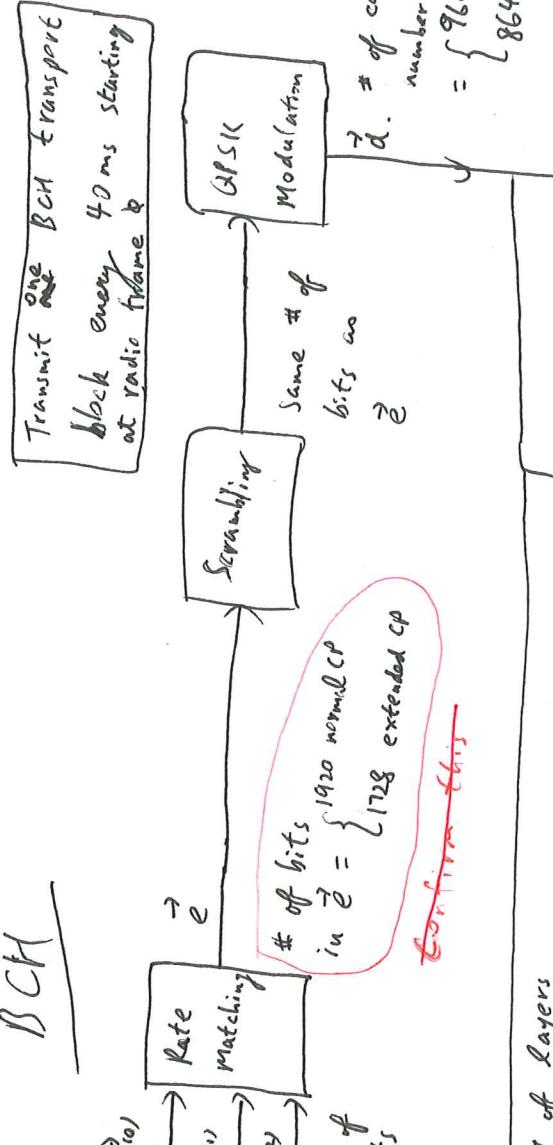
PDCCH format	Number of CCES	Number of resource-element groups	Number of PDCCH bits
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576



Special subframe configuration SSC	Normal cyclic prefix in downlink		Extended cyclic prefix in downlink	
	DwPTS	Normal cyclic prefix in uplink	UpPTS	Normal cyclic prefix in uplink
0	3		3	
1	9		8	
2	10	1	9	1
3	11		10	
4	12		3	
5	3		8	2
6	9	2	9	2
7	10		-	-
8	11		-	-

 $\Delta f = 15 \text{ kHz}$

BCH



- ① transmitted over 4 radio frames starting at radio frame 0
- ② Always in slot 1, subframe 0.
- ③ Around DC. $\ell = 0, 1, 2, 3$

CFI

$$CFI = \{1, 2, 3\}$$

$$N_{RB}^{DL} > 10 :$$

Time span of DCI
in that the same = CFI = {1, 2, 3}

subframe in units
of OFDM symbols (i.e. PDCCHs) in current
subframe

$$N_{RB}^{DL} \leq 10 :$$

Time span of DCI in the same = CFI + 1 = {2, 3, 4}
subframe in units
of OFDM symbols

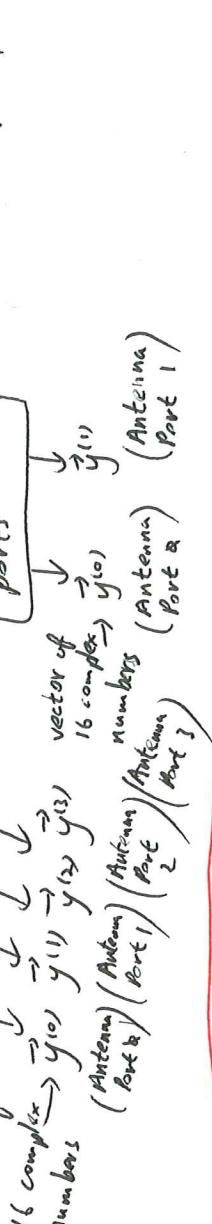
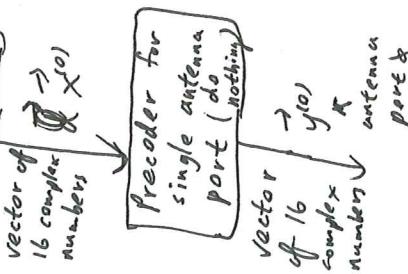
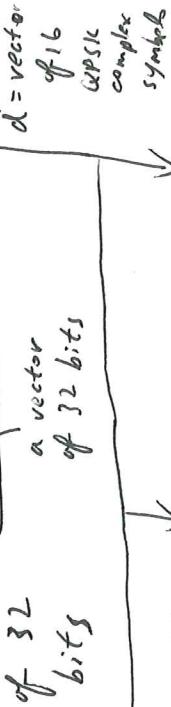
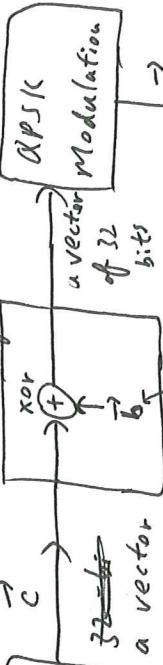
CFI is always transmitted in the
first OFDM symbol in a subframe

scalar
single
vector

$$CFI = 1, 2 \text{ or } 3$$

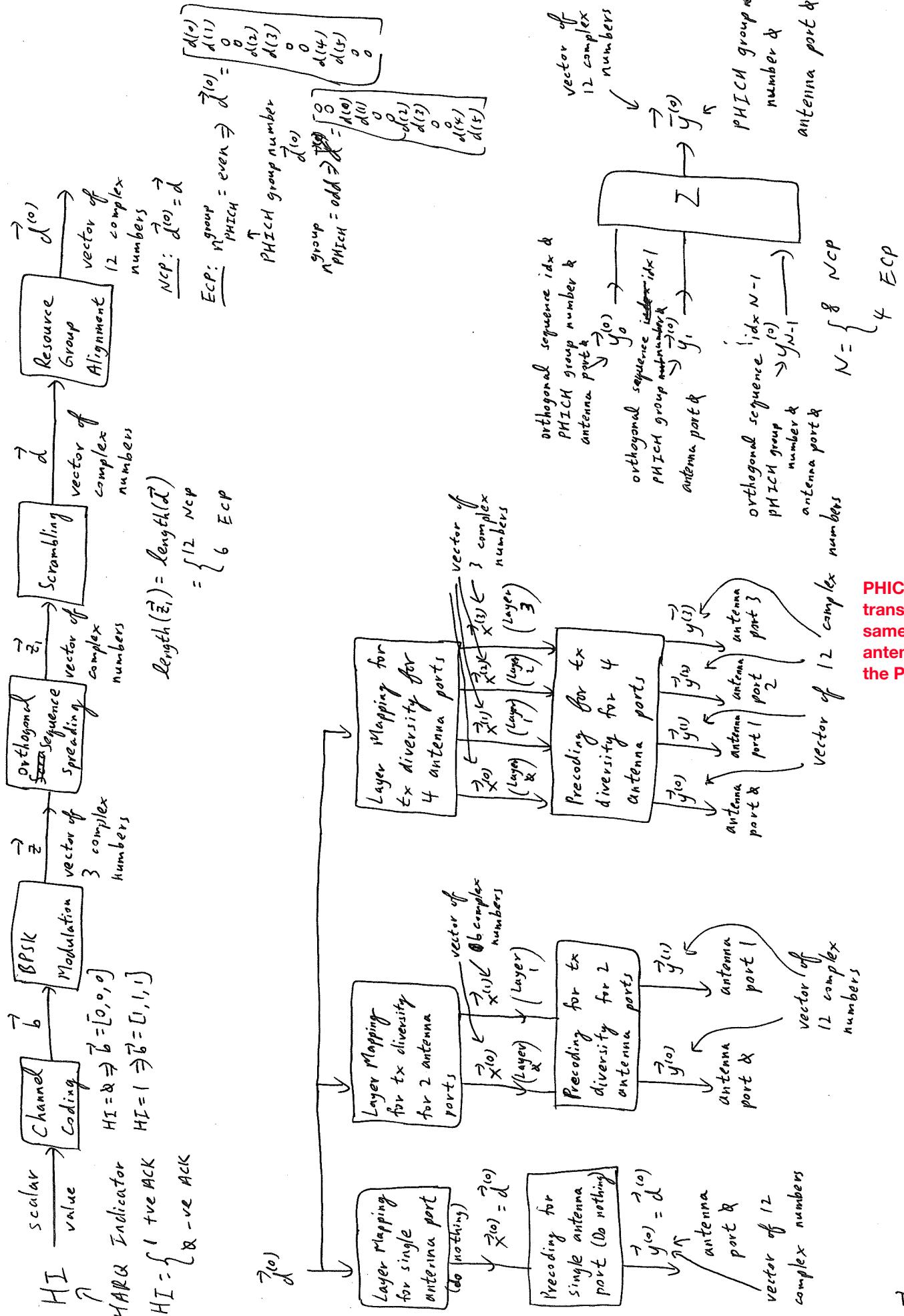
$$N_{RB}^{DL} > 10 :$$

Scrambling



PCFICH shall be transmitted on the
same set of antenna ports as the PDCP

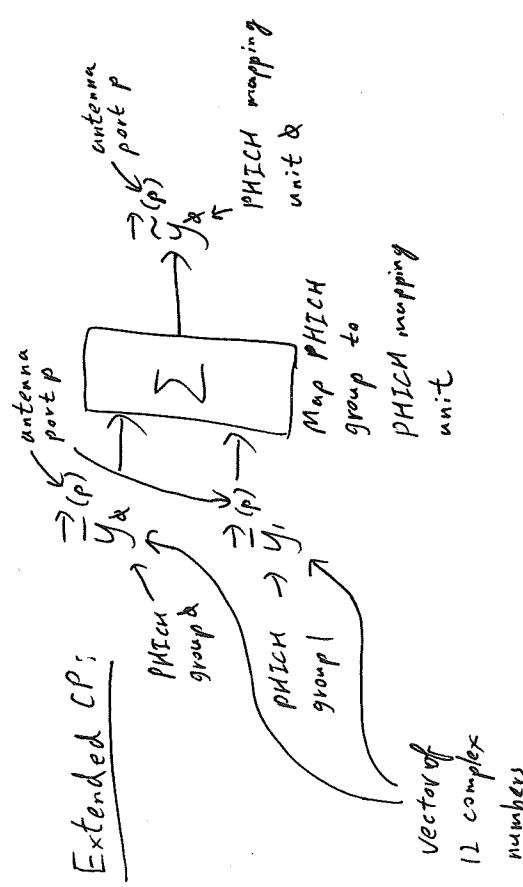
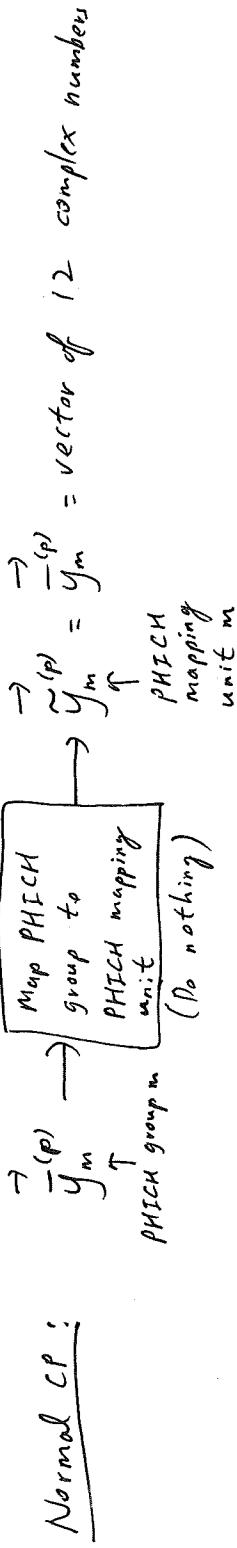
HI (1/2)



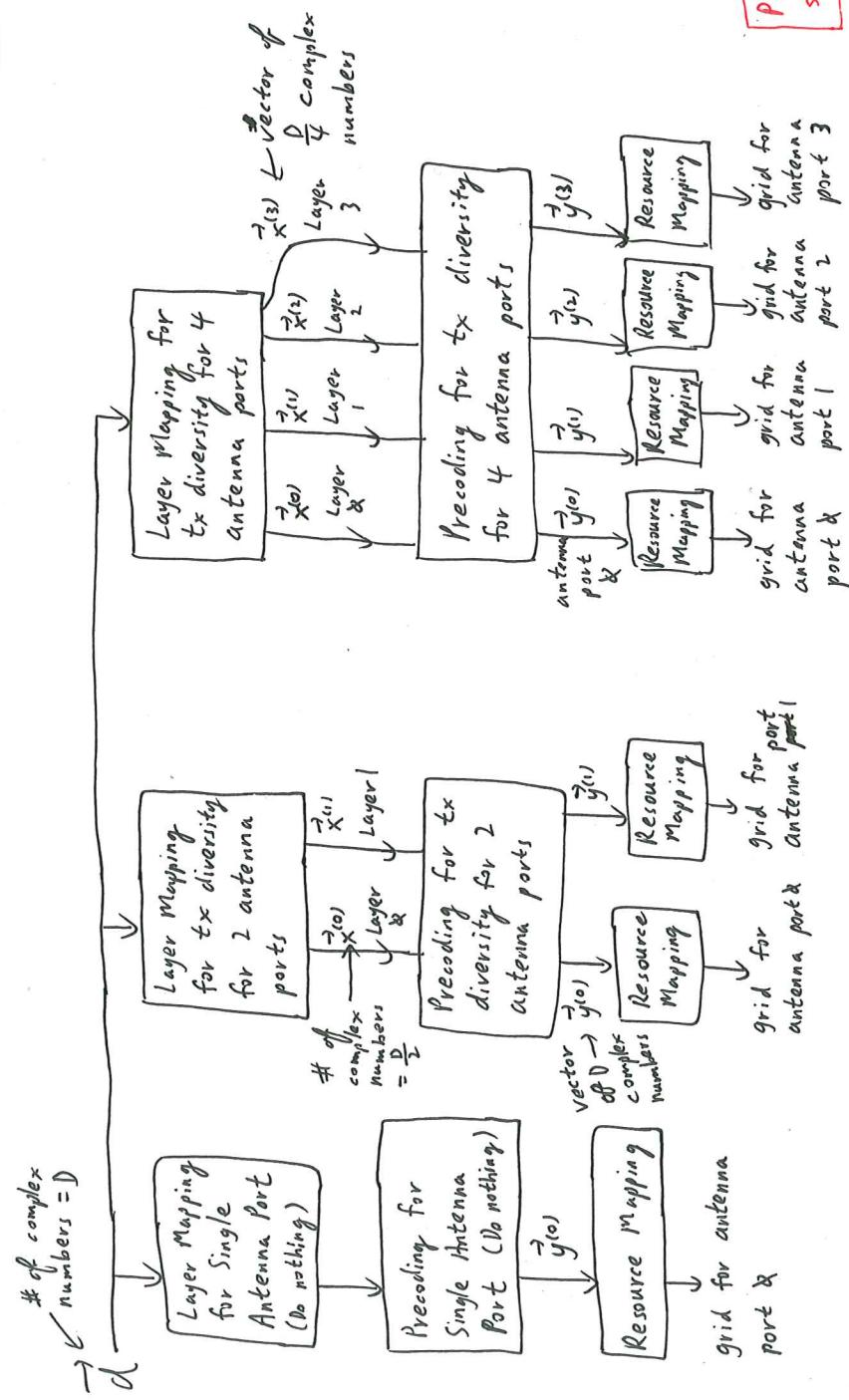
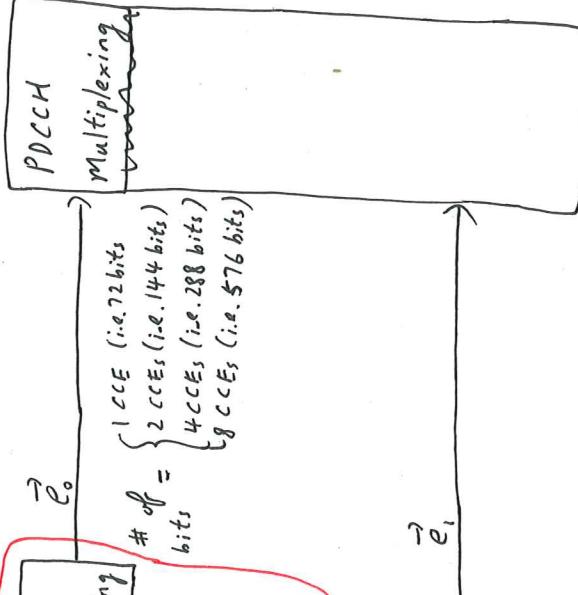
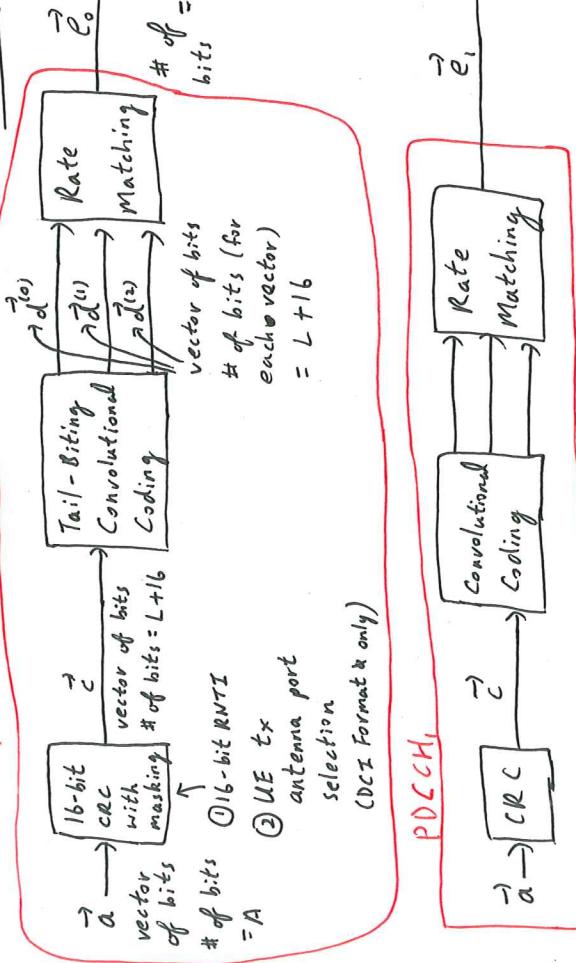
PHICH shall be transmitted on the same set of antenna ports as the PBCH.

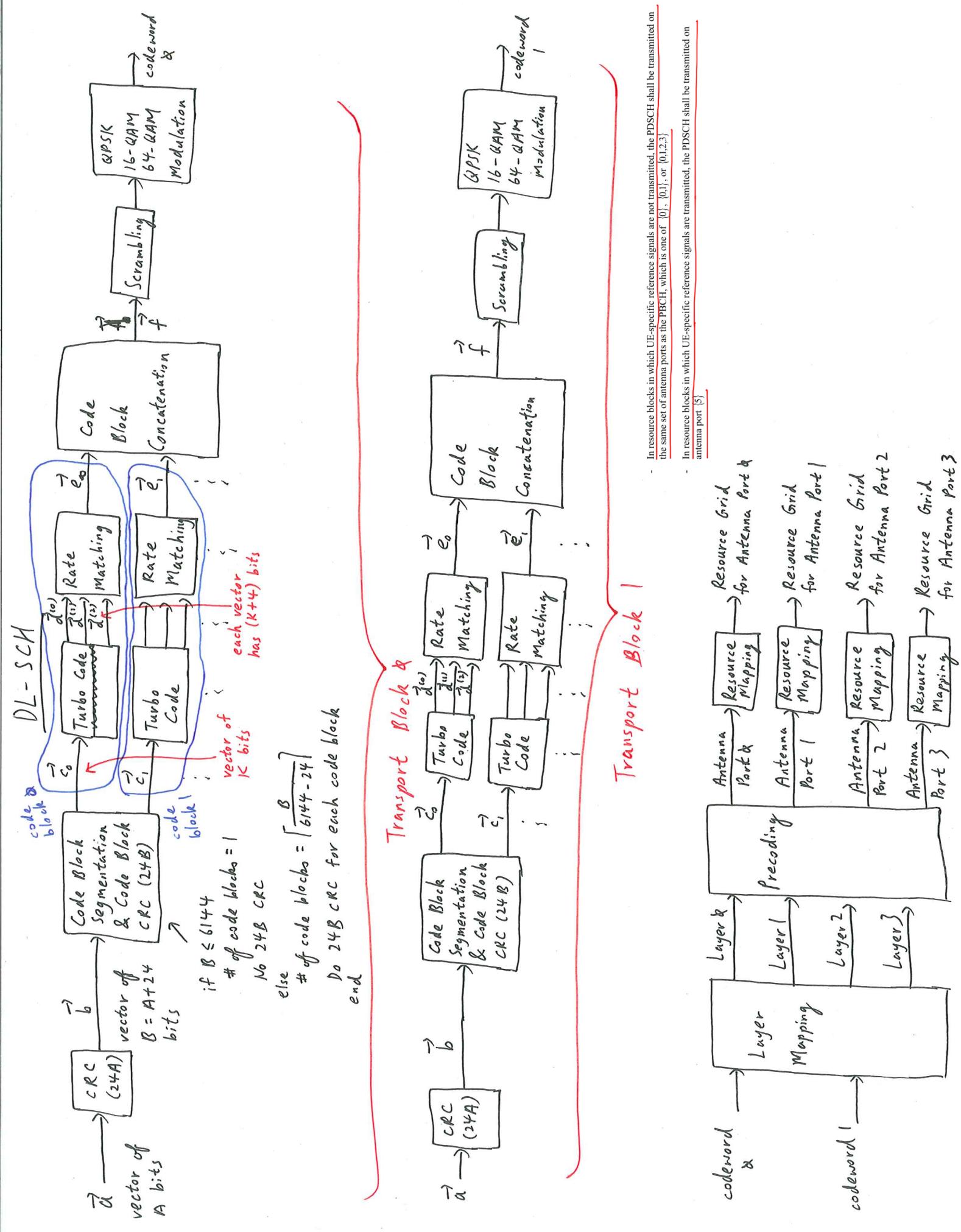
$y^{(10)}$ corresponds to PHICH sequence index i within PHICH group number j for antenna port k

HT (2/2)



PDCCH





SC-FDMA Table 5.2.3-1: Resource block parameters.

Configuration	$N_{\text{sc}}^{\text{RB}}$	$N_{\text{symb}}^{\text{UL}}$
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

Table 5.6-1: SC-FDMA parameters.

Configuration	Cyclic prefix length $N_{\text{CP},l}$
Normal cyclic prefix	160 for $l = 0$
	144 for $l = 1, 2, \dots, 6$
Extended cyclic prefix	512 for $l = 0, 1, \dots, 5$

 $\Delta f = 15 \text{ kHz} : \text{IFFT Length} = 2048$

Sampling Rate (Complex) = 30.72 MHz

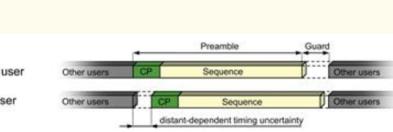
**In case of base-station perspective, downlink radio frame is perfectly aligned with uplink radio frame.**

Figure 8.1-1: Uplink-downlink timing relation

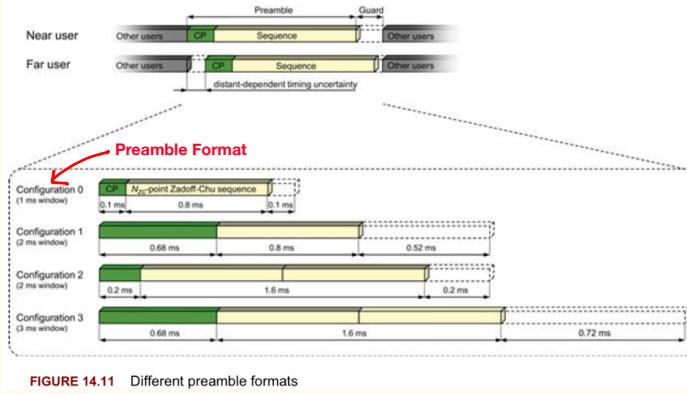
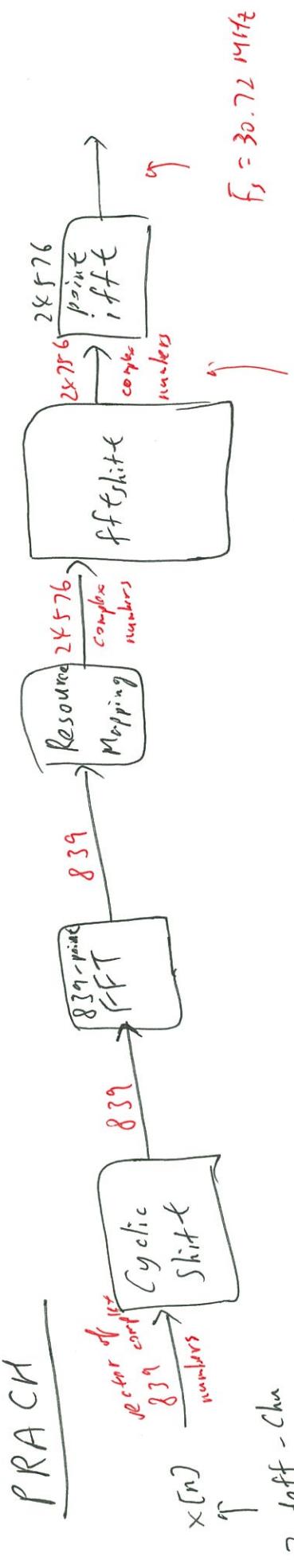


FIGURE 14.11 Different preamble formats

8.1 Uplink-downlink frame timing

Transmission of the uplink radio frame number i from the UE shall start $(N_{\text{TA}} + N_{\text{TA offset}}) \times T_s$ seconds before the start of the corresponding downlink radio frame at the UE, where $0 \leq N_{\text{TA}} \leq 20512$, $N_{\text{TA offset}} = 0$ for frame structure type 1 and $N_{\text{TA offset}} = 624$ for frame structure type 2. Note that not all slots in a radio frame may be transmitted. One example hereof is TDD, where only a subset of the slots in a radio frame is transmitted.

1 subframe = 1 ms = 30720 Ts



Sequence
with physical
root sequence
number n .

Zadoff-Chu

Sequence

with physical

root sequence

number n .

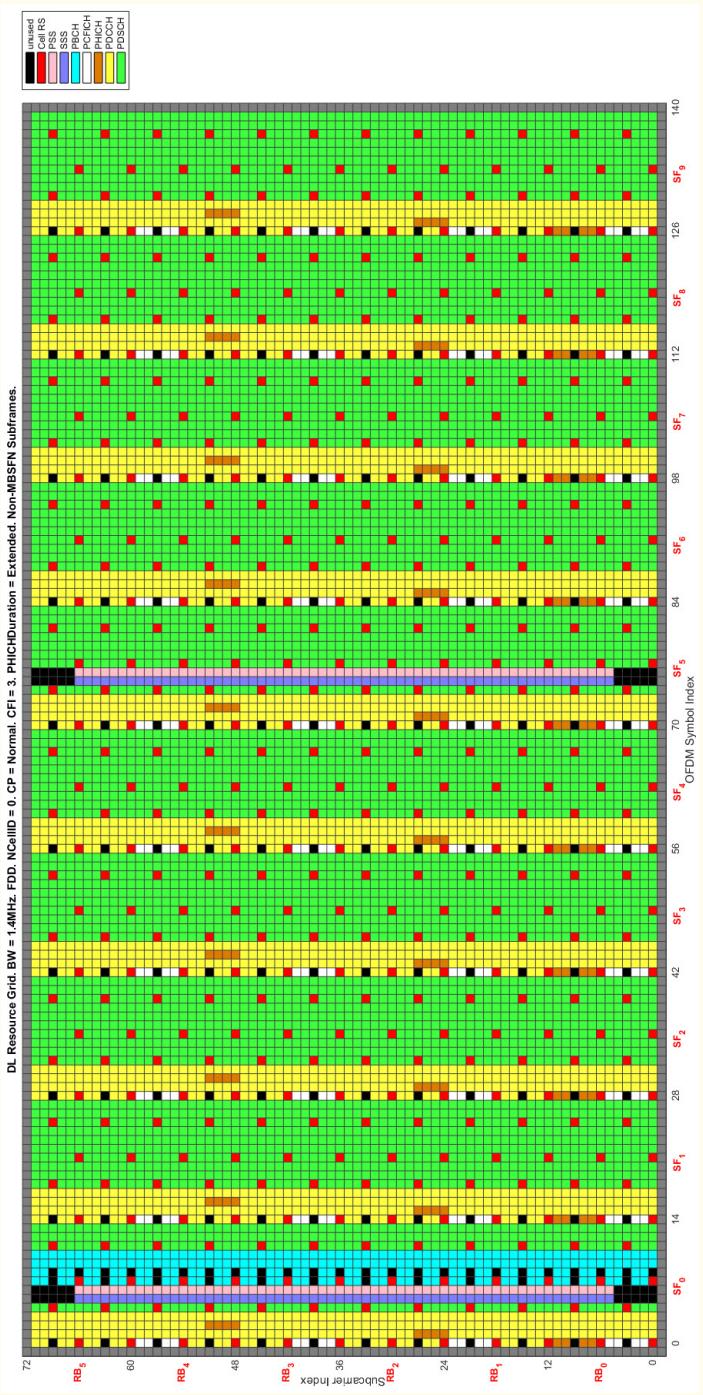
$$\Delta f = 1250 \text{ Hz}$$

$$f_s = 30.72 \text{ MHz}$$

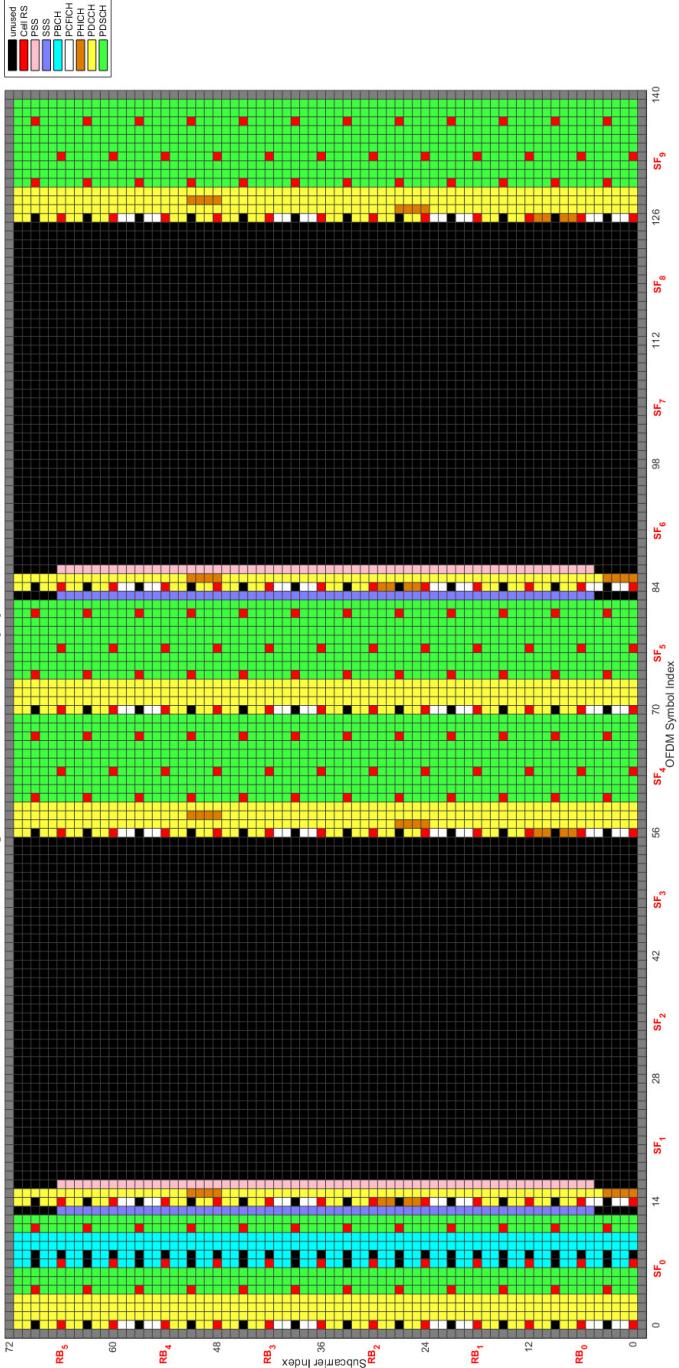
$$f_s = 30.72 \text{ MHz}$$

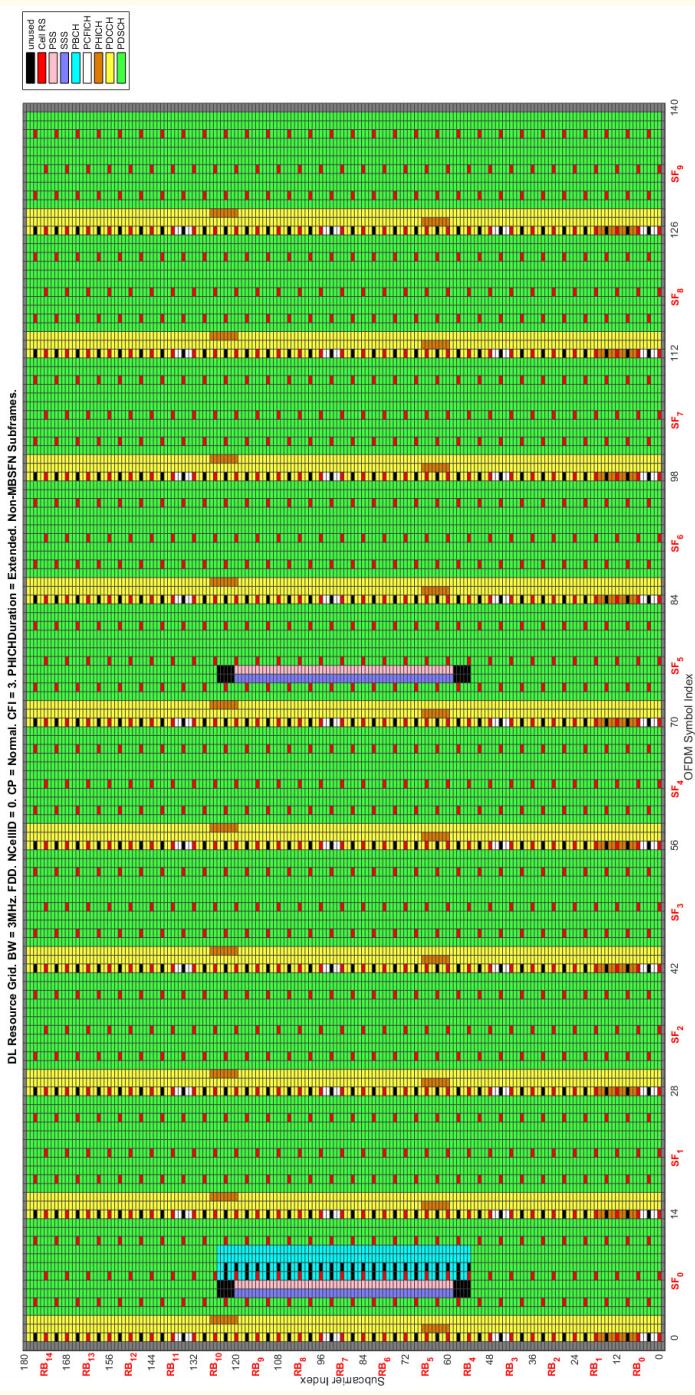
$$\Delta f = \frac{f_s}{N}$$

LTE | Gain | test PRACH.m

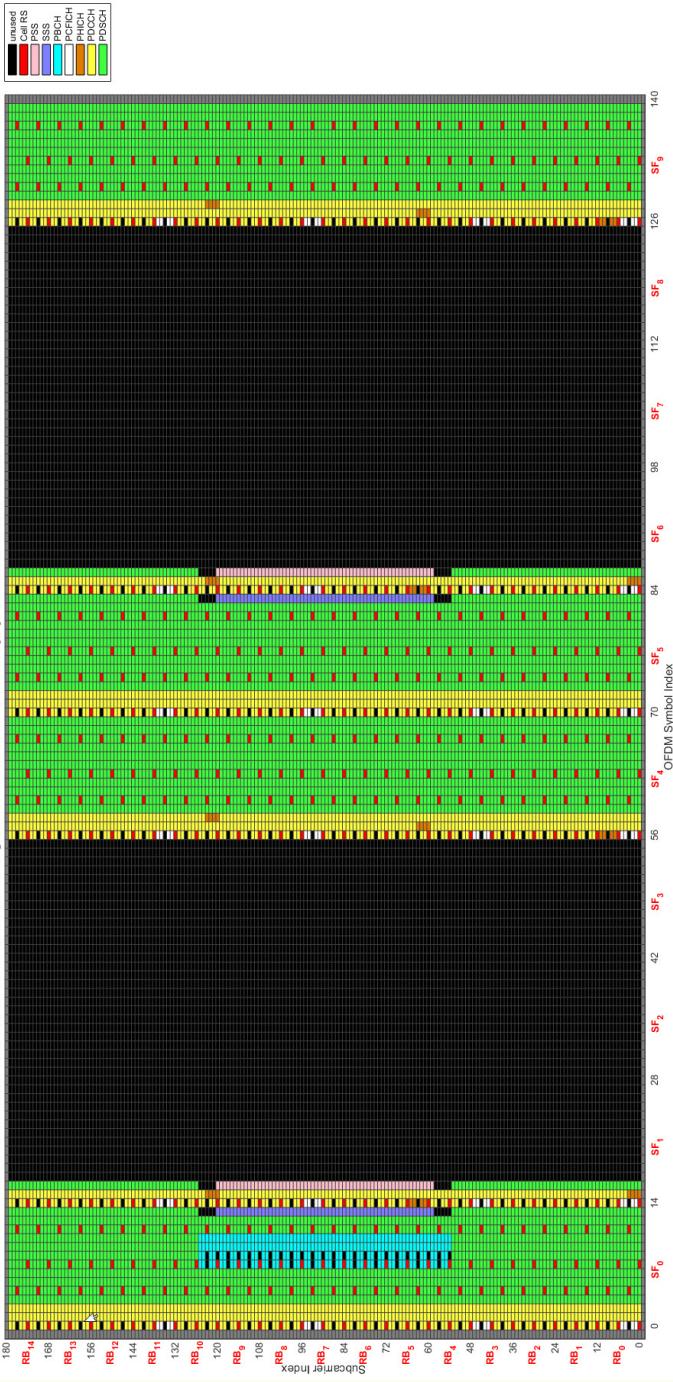


DL Resource Grid. BW = 1.4MHz. TDD. TDDConfig = 1. PCHDuration = Extended. Non-MBSFN Subframes.





DL Resource Grid BW = 1MHz, TDD, TDDConfig = 1, NCellID = 0, CP = Normal, CFI = [2,3], PHICHDuration = Extended, NonMBSFN Subframes.



Many sequences can be represented by a Fourier integral of the form

$$x[n] = \frac{1}{2\pi} \int_{-\pi}^{\pi} X(e^{j\omega}) e^{j\omega n} d\omega, \quad \text{DTFT} \quad (2.130)$$

where

$$X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n] e^{-jn\omega}. \quad (2.131) \quad W_N = e^{-j(2\pi/N)}$$

Generally, the DFT analysis and synthesis equations are written as follows:

$$\text{Analysis equation: } X[k] = \sum_{n=0}^{N-1} x[n] W_N^{kn}, \quad 0 \leq k \leq N-1, \quad (8.67)$$

$$\text{Synthesis equation: } x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] W_N^{-kn}, \quad 0 \leq n \leq N-1. \quad (8.68)$$

That is, the fact that $X[k] = 0$ for k outside the interval $0 \leq k \leq N-1$ and that $x[n] = 0$ for n outside the interval $0 \leq n \leq N-1$ is implied, but not always stated explicitly. The relationship between $x[n]$ and $X[k]$ implied by Eqs. (8.67) and (8.68) will sometimes be denoted as

$$x[n] \xleftrightarrow{\mathcal{DFT}} X[k]. \quad (8.69)$$

In recasting Eqs. (8.11) and (8.12) in the form of Eqs. (8.67) and (8.68) for finite-duration sequences, we have not eliminated the inherent periodicity. As with the DFS, the DFT $X[k]$ is equal to samples of the periodic Fourier transform $X(e^{j\omega})$, and if Eq. (8.68) is evaluated for values of n outside the interval $0 \leq n \leq N-1$, the result will not be zero, but rather a periodic extension of $x[n]$. The inherent periodicity is always present. Sometimes, it causes us difficulty, and sometimes we can exploit it, but to totally ignore it is to invite trouble. In defining the DFT representation, we are simply recognizing that we are interested in values of $x[n]$ only in the interval $0 \leq n \leq N-1$, because $x[n]$ is really zero outside that interval, and we are interested in values of $X[k]$ only in the interval $0 \leq k \leq N-1$ because these are the only values needed in Eq. (8.68) to reconstruct $X[n]$.

TABLE 8.2 SUMMARY OF PROPERTIES OF THE DFT

Finite-Length Sequence (Length N)	N -point DFT (Length N)
1. $x[n]$	$X[k]$
2. $x_1[n], x_2[n]$	$X_1[k], X_2[k]$
3. $a x_1[n] + b x_2[n]$	$a X_1[k] + b X_2[k]$
4. $X[n]$	$N x[(-(k))_N]$
5. $x[(n-m))_N]$	$W_N^{km} X[k]$
6. $W_N^{-\ell n} x[n]$	$X[((k-\ell))_N]$
7. $\sum_{m=0}^{N-1} x_1[m] x_2[((n-m))_N]$	$X_1[k] X_2[k]$
8. $x_1[n] x_2[n]$	$\frac{1}{N} \sum_{\ell=0}^{N-1} X_1[\ell] X_2[((k-\ell))_N]$
9. $x^*[n]$	$X^*[(-(k))_N]$
10. $x^*[(-(n))_N]$	$X^*[k]$
11. $\mathcal{R}e\{x[n]\}$	$X_{\mathcal{R}e}[k] = \frac{1}{2} [X[((k))_N] + X^*[(-(k))_N]]$
12. $j\mathcal{I}m\{x[n]\}$	$X_{\mathcal{I}m}[k] = \frac{1}{2} [X[((k))_N] - X^*[(-(k))_N]]$
13. $x_{\mathcal{R}e}[n] = \frac{1}{2} \{x[n] + x^*[(-(n))_N]\}$	$\mathcal{R}e\{X[k]\}$
14. $x_{\mathcal{I}m}[n] = \frac{1}{2} \{x[n] - x^*[(-(n))_N]\}$	$j\mathcal{I}m\{X[k]\}$
Properties 15–17 apply only when $x[n]$ is real.	
15. Symmetry properties	$\begin{cases} X[k] = X^*[(-(k))_N] \\ \mathcal{R}e\{X[k]\} = \mathcal{R}e\{X[(-(k))_N]\} \\ \mathcal{I}m\{X[k]\} = -\mathcal{I}m\{X[(-(k))_N]\} \\ X[k] = X[(-(k))_N] \\ \angle\{X[k]\} = -\angle\{X[(-(k))_N]\} \end{cases}$
16. $x_{\mathcal{R}e}[n] = \frac{1}{2} \{x[n] + x[(-(n))_N]\}$	$\mathcal{R}e\{X[k]\}$
17. $x_{\mathcal{I}m}[n] = \frac{1}{2} \{x[n] - x[(-(n))_N]\}$	$j\mathcal{I}m\{X[k]\}$

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{j2\pi k \alpha t}$$

Example 2.16 Frequency Response of the Moving-Average System

The impulse response of the moving-average system of Example 2.3 is

$$h[n] = \begin{cases} \frac{1}{M_1 + M_2 + 1}, & -M_1 \leq n \leq M_2, \\ 0, & \text{otherwise.} \end{cases}$$

Therefore, the frequency response is

$$H(e^{j\omega}) = \frac{1}{M_1 + M_2 + 1} \sum_{n=-M_1}^{M_2} e^{-j\omega n}. \quad (2.121)$$

For the causal moving average system, $M_1 = 0$ and Eq. (2.121) can be expressed as

$$H(e^{j\omega}) = \frac{1}{M_2 + 1} \sum_{n=0}^{M_2} e^{-j\omega n}. \quad (2.122)$$

Using Eq. (2.55), Eq. (2.122) becomes

$$\begin{aligned} H(e^{j\omega}) &= \frac{1}{M_2 + 1} \left(\frac{1 - e^{-j\omega(M_2+1)}}{1 - e^{-j\omega}} \right) \\ &= \frac{1}{M_2 + 1} \frac{(e^{j\omega(M_2+1)/2} - e^{-j\omega(M_2+1)/2})e^{-j\omega(M_2+1)/2}}{(e^{j\omega/2} - e^{-j\omega/2})e^{-j\omega/2}} \\ &= \frac{1}{M_2 + 1} \frac{\sin[\omega(M_2 + 1)/2]}{\sin \omega/2} e^{-j\omega M_2/2}. \end{aligned} \quad (2.123)$$

The magnitude and phase of $H(e^{j\omega})$ for this case, with $M_2 = 4$, are shown in Figure 2.19.

If the moving-average filter is symmetric, i.e., if $M_1 = M_2$, then Eq. (2.123) is replaced by

$$H(e^{j\omega}) = \frac{1}{2M_2 + 1} \frac{\sin[\omega(2M_2 + 1)/2]}{\sin(\omega/2)}. \quad (2.124)$$

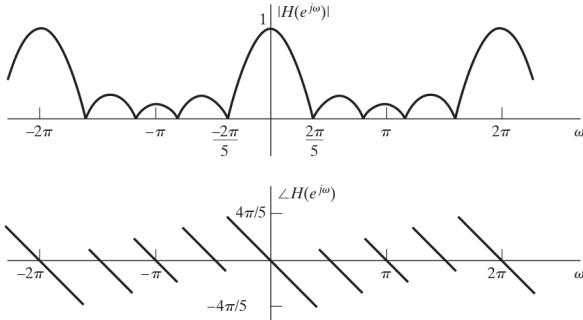
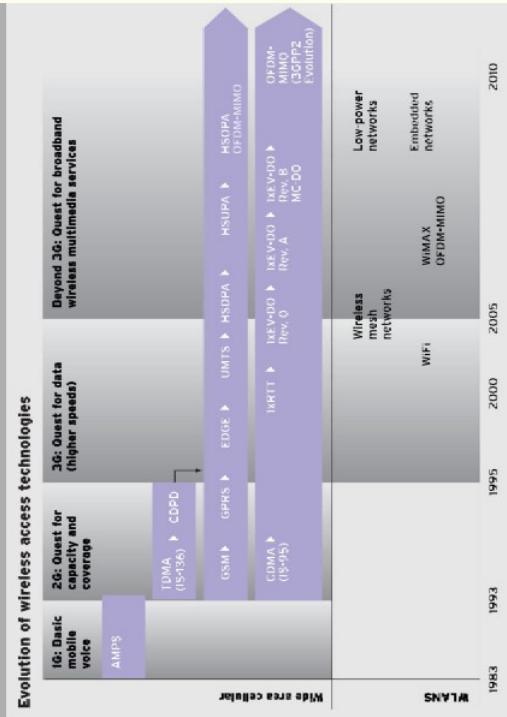
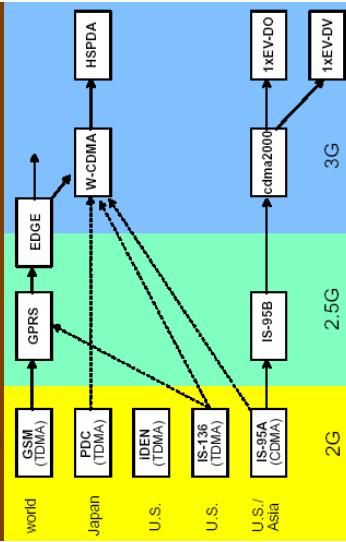


Figure 2.19 (a) Magnitude and (b) phase of the frequency response of the moving-average system for the case $M_1 = 0$ and $M_2 = 4$.

Evolution of 3G Standards



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