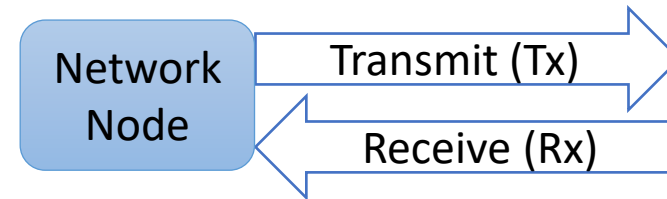
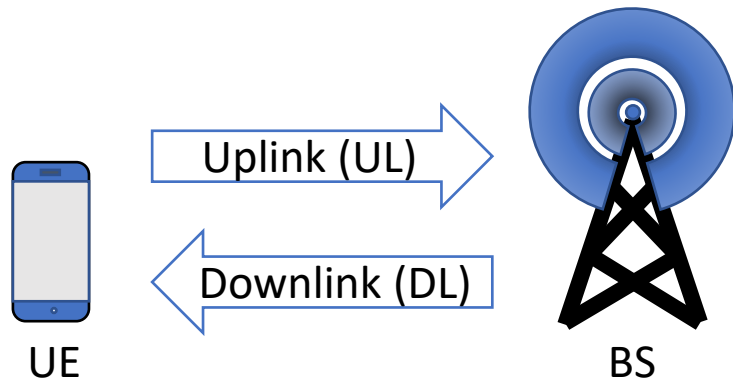


# Lab 2

5G NR DL control signals, synchronization signals

# UE and RAN

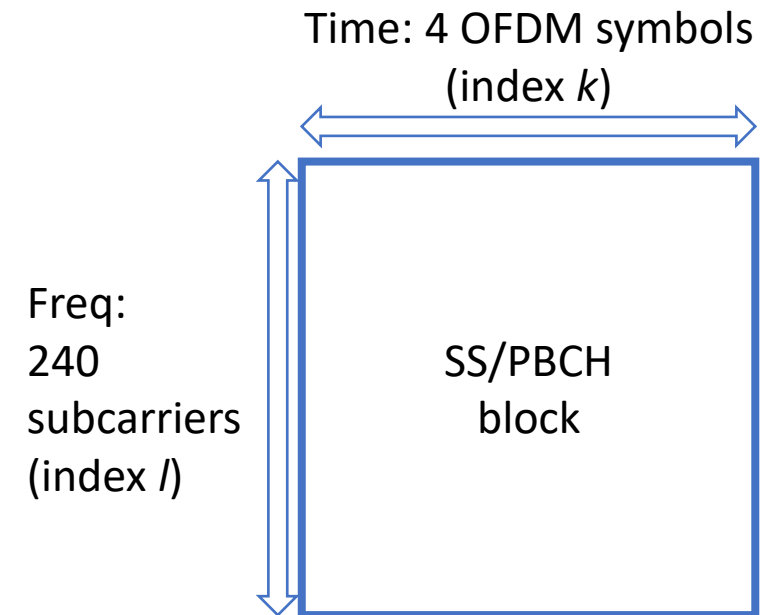


# Synchronization

- Uplink synchronization
  - Needed for UE to know when to transmit
  - Random access channel (RACH)
- Downlink synchronization
  - Needed for UE to know when the frame and OFDM symbol starts
  - Synchronization signal block, physical broadcast channel (SS/PBCH)

# Synchronization signals in DL

- Primary and secondary synchronization signals 3GPP TS 38.211 [1]
  - Primary synchronization signal (PSS), used in DL
  - Secondary synchronization signal (SSS), used in DL
  - SS/PBCH block, used in DL, contains
    - PSS
    - SSS
    - PBCH
    - DM-RS for PBCH
- Synchronization procedures 3GPP TS 38.213 [2]
- SS/PBCH block needs grid of 240 subcarriers and 4 OFDM symbols [1]

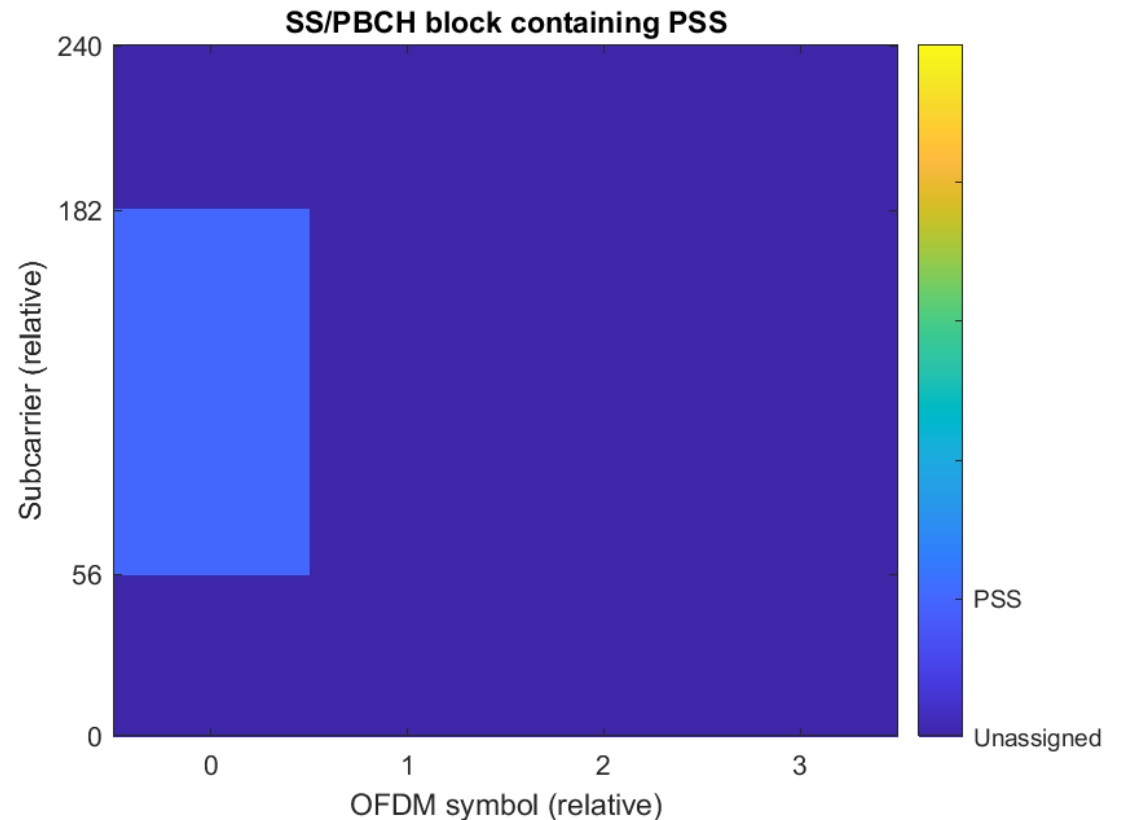


[1] 3GPP, "TS 38.211 - NR; Physical channels and modulation," 2020, [Online]. Available: <https://www.3gpp.org/DynaReport/38211.htm>

[2] 3GPP, "TS 38.213 - NR; Physical layer procedures for control," 2021. [Online]. Available: <https://www.3gpp.org/DynaReport/38213.htm>

# Primary synchronization signal (PSS)

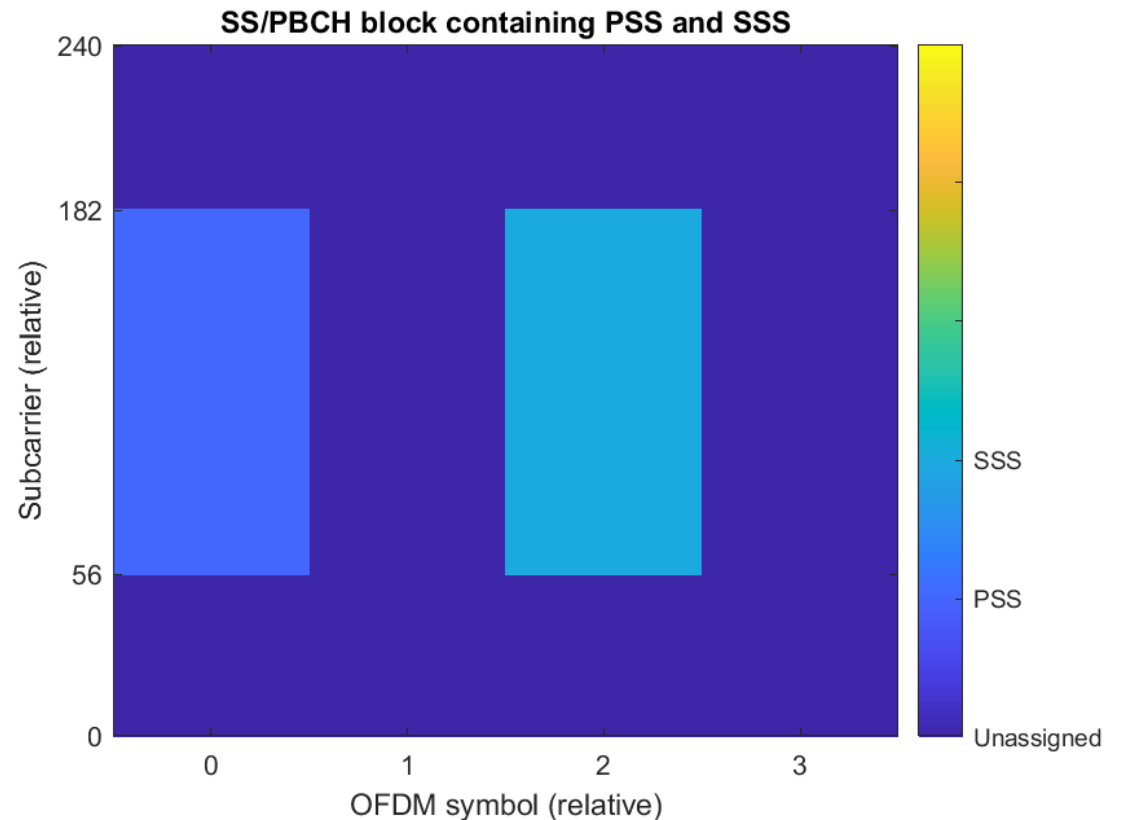
- Contains physical cell identifier (PCI)
- PSS location in resource grid [1]
  - Time: OFDM symbol number 0 relative to the start of SS/PBCH block
  - Frequency: subcarriers number 56-182 relative to the start of SS/PBCH block



[1] 3GPP, "TS 38.211 - NR; Physical channels and modulation," 2020, [Online]. Available: <https://www.3gpp.org/DynaReport/38211.htm>

# Secondary synchronization signal (SSS)

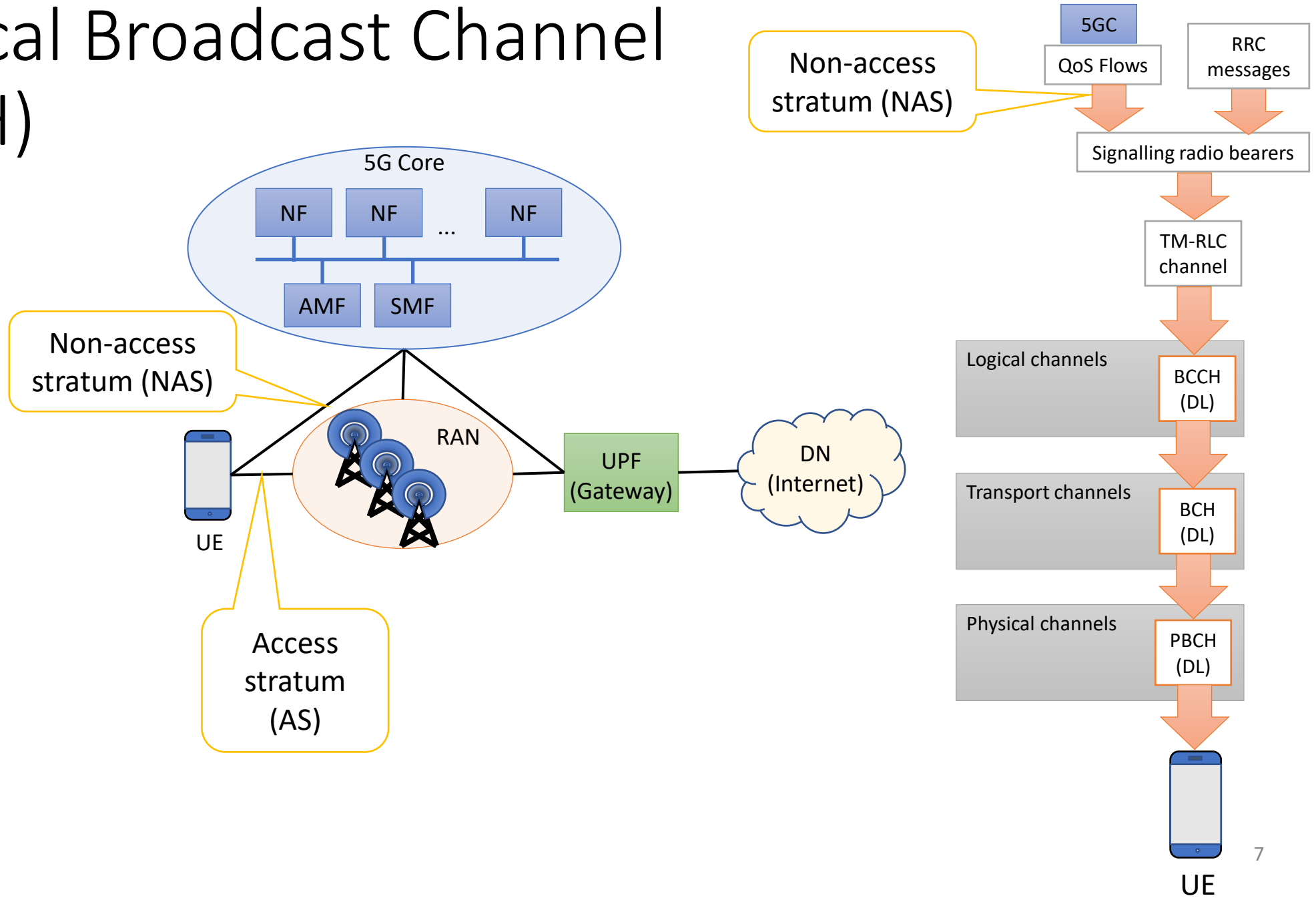
- Contains physical cell identifier (PCI)
- SSS location in resource grid [1]
  - Time: OFDM symbol number 2 relative to the start of SS/PBCH block
  - Frequency: subcarriers number 56-182 relative to the start of SS/PBCH block



[1] 3GPP, "TS 38.211 - NR; Physical channels and modulation," 2020, [Online]. Available: <https://www.3gpp.org/DynaReport/38211.htm>

# Physical Broadcast Channel (PBCH)

- PBCH



# NR access stratum protocol channels [1]

- QoS Flow [1, section 5.7]
  - QoS Flow ID (QFI)
  - Supports both GBR and non-GBR QoS Flows
  - Characterized by QoS profile

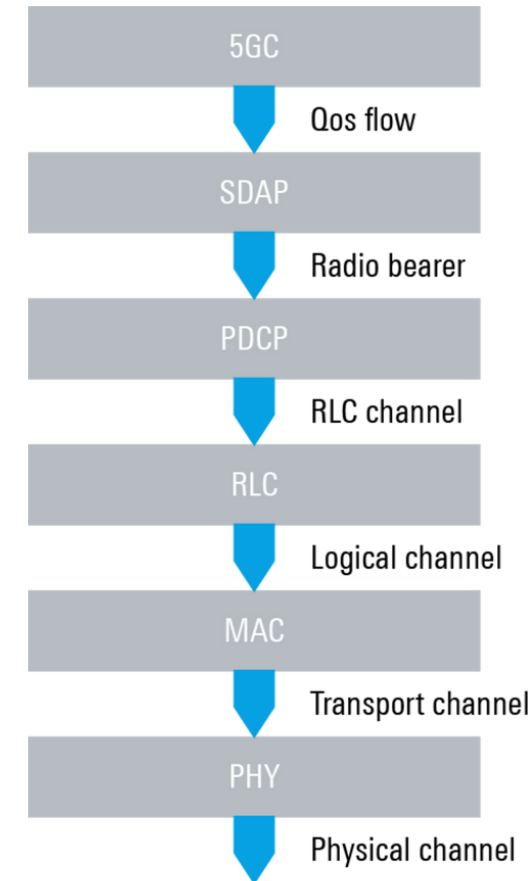


Fig. 1-8 NR Access Stratum Protocol channels.

[1] *5G New Radio. Fundamentals, procedures, testing aspects.* 2020. Rohde&Schwarz [Online]. Available: <https://gloris.rohde-schwarz.com/ebooks/5G>

# Logical, transport, physical channels (R&S 5G book)

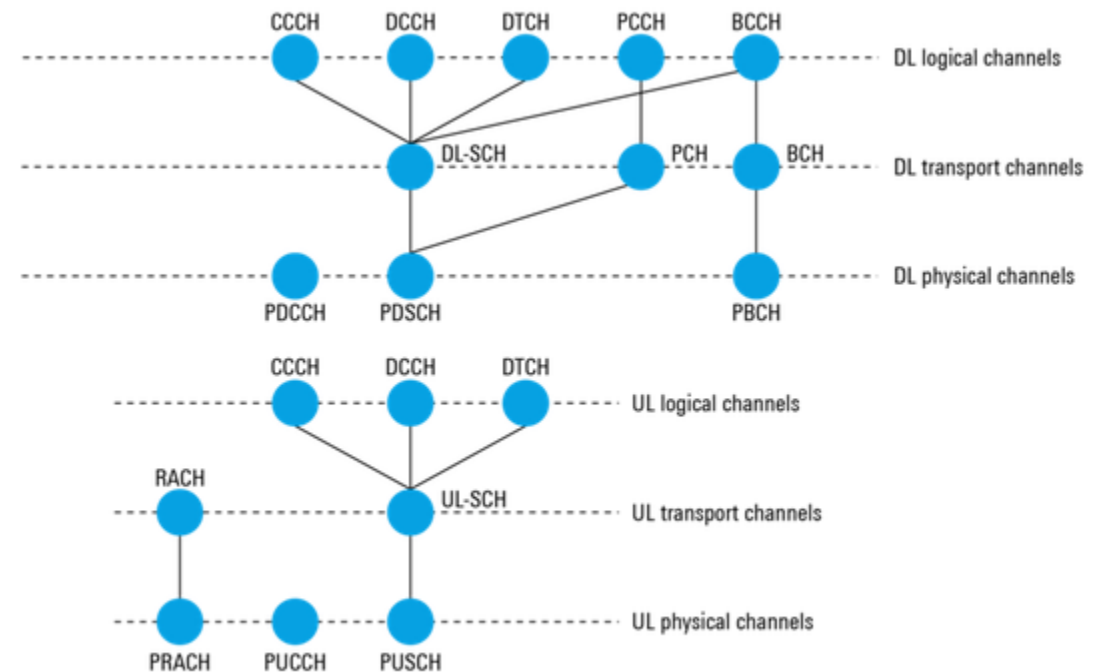
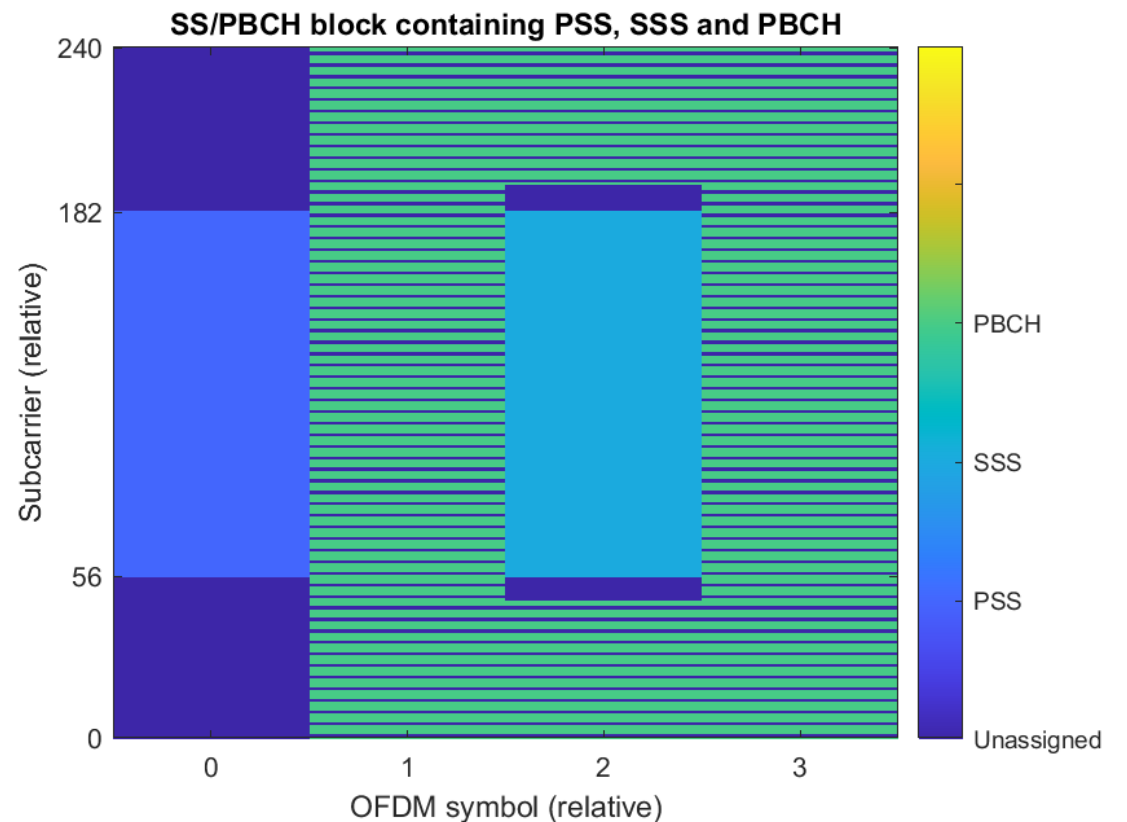


Fig. 1-10 NR logical, transport and physical channel mapping for the uplink and downlink.

[1] 5G New Radio. Fundamentals, procedures, testing aspects. 2020. Rohde&Schwarz [Online]. Available: <https://gloris.rohde-schwarz.com/ebooks/5G>

# Physical Broadcast Channel (PBCH)

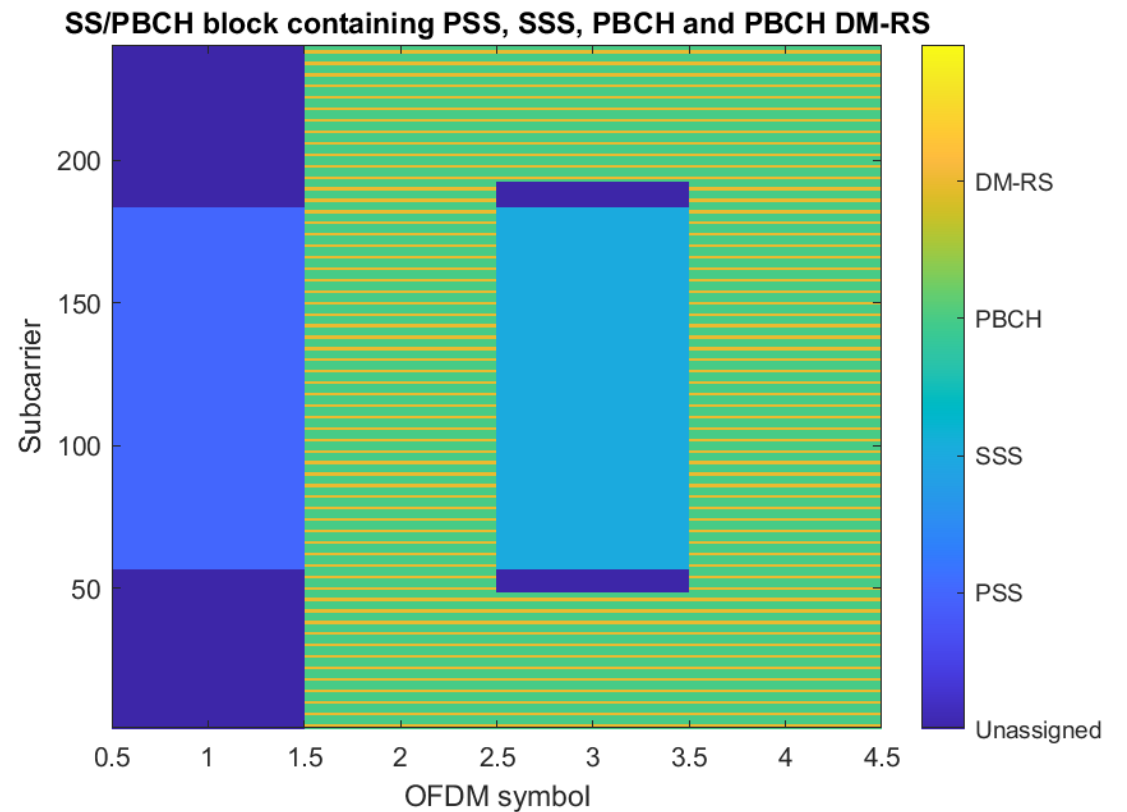
- UE acquires time and frequency synchronization with the serving cell based on receptions of SS/PBCH blocks
- PBCH contains system frame number (SFN)
- PBCH location in resource grid relative to SS/PBCH
  - OFDM symbols number 1 and 3, and subcarriers number 0-239
  - OFDM symbol number 2 and subcarriers number 0-47 and 192-239
- PBCH carries system information
  - master information block (MIB) periodically



[1] 3GPP, "TS 38.213 NR; Physical layer procedures for control," 2021.  
[Online]. Available: <https://www.3gpp.org/DynaReport/38213.htm>

# Demodulation reference signals (DM-RS)

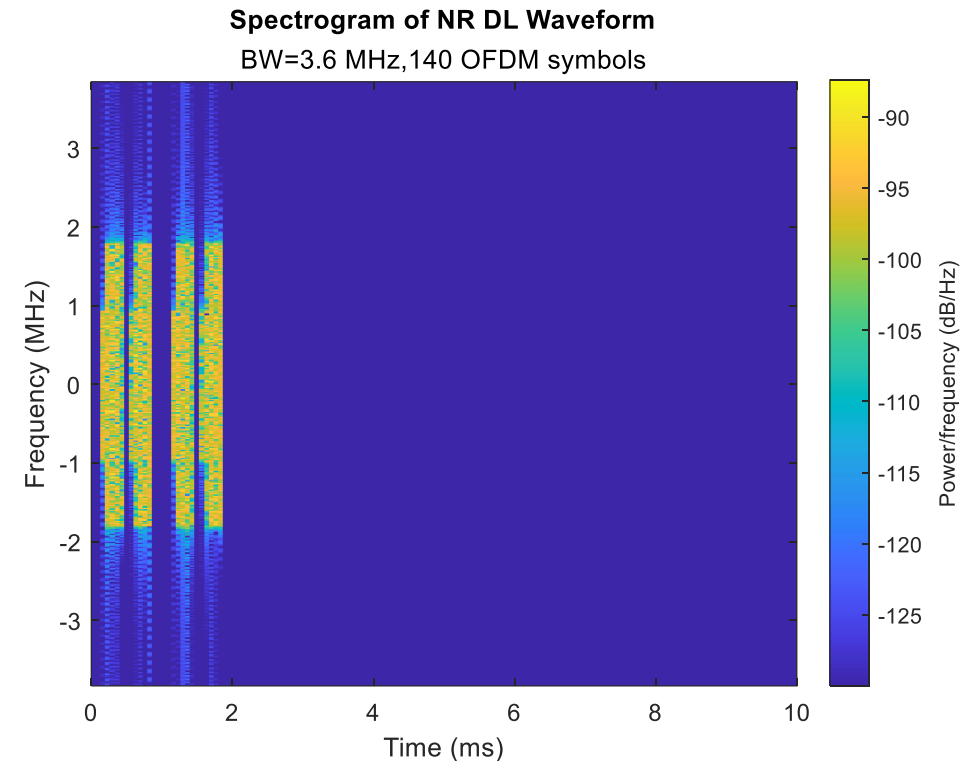
- DM-RS are for reference of demodulation of MIB
- DM-RS use each 4th subcarrier of PBCH
  - Subcarriers calculated by:  
cell id mod 4



# SS/PBCH on waveform image

## For Waveform

- [ssb = nrWavegenSSBurstConfig](#)
  - Creates complete SS/PBCH block



[1] Synchronization Signal Blocks and Bursts [MATLAB]

<https://se.mathworks.com/help/5g/gs/synchronization-signal-blocks-and-bursts.html>

[2] <https://se.mathworks.com/videos/5g-explained-synchronization-signal-blocks-in-5g-nr-1577445332091.html>

# Tasks for lab 2

- $\mu=0$ , and  $\mu=1, 3$  or  $4$
- Compare resource grid for frame and waveform.
- 4 figures:
  1. Fig.1 grid for  $\mu=0$
  2. Fig.1 grid for other  $\mu$
  3. Fig.2 DL waveform for  $\mu=0$
  4. Fig.2 DL waveform for other  $\mu$
- Create SS/PBCH block which contains
  1. PSS
  2. SSS
  3. PBCH
  4. DM-RS
- In the slot, the symbol 1 is occupied by PSS, symbols 2 and 4 are occupied with PBCH and symbol 3 is occupied by SSS and PBCH. Calculate for each symbols 1-4 how many resource elements are not used for SSB block.

# Hints for calculation

- Calculate how many REs can be used for UE data transmission in RB (12 subcarriers and 1 slot) which contains any or all of the synchronization signals
  - The SS/PBCH block duration is less than 1 slot, so it is present in the slot during the slot time
  - The SS/PBCH block width in frequency scale is more than 12 subcarriers, so there are options when the set of 12 subcarriers contains the SS/PBCH block or some of the 12 subcarriers contain SS/PBCH block.

# Lab report

- 1 page PDF, minimum text size 10 pt
- Contents:
  - Lab number, title, author, date
  - Introduction
  - Tasks, results
  - Summary and conclusions