

Recap and corrections of Lab 3

SIB1:

/.../

ssb_PositionsInBurst : **inOneGroup**

'10000000'B

ssb_PeriodicityServingCell (2) ms20

tdd_UL_DL_ConfigurationCommon (3)

_TDD_UL_DL_ConfigCommon

referenceSubcarrierSpacing (1) kHz30

pattern1 (6) _TDD_UL_DL_Pattern

dl_UL_TransmissionPeriodicity (5) ms2p5

nrofDownlinkSlots 3

nrofDownlinkSymbols 10

nrofUplinkSlots 1

nrofUplinkSymbols 2

pattern2 (6) _TDD_UL_DL_Pattern

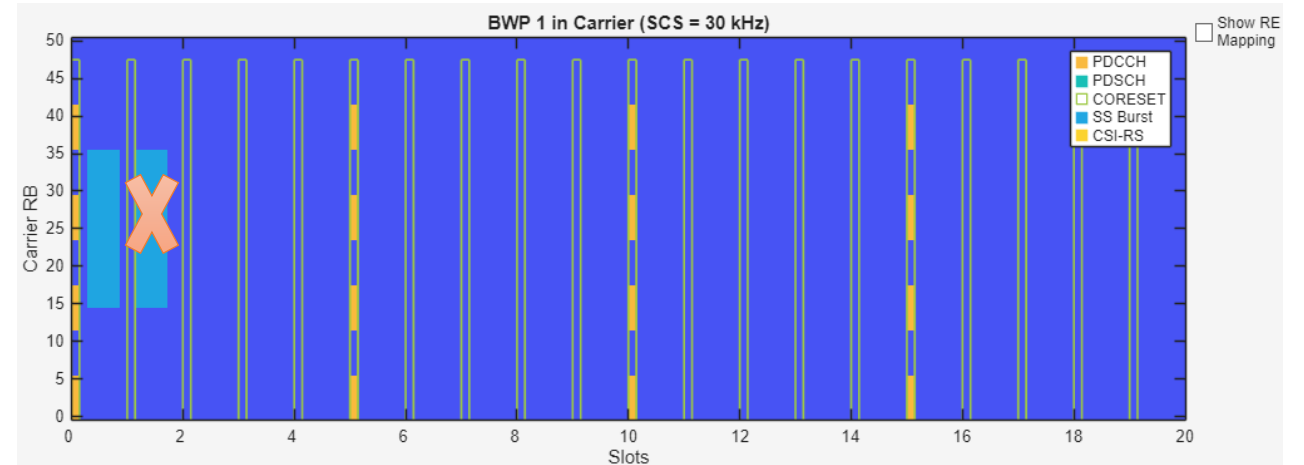
dl_UL_TransmissionPeriodicity (5) ms2p5

nrofDownlinkSlots 2

nrofDownlinkSymbols 10

nrofUplinkSlots 2

nrofUplinkSymbols 2



Payload

MIB:
/.../
cellBarred (1) notBarred
intraFreqReselection (0) allowed

Yes/No
checkbox

▼ Payload

Data source: MIB ▼

DM-RS type A position: 2 ▼

Cell barred

Intra-frequency reselection

PDCCH Config SIB1: 165

SIB1 Indices: 10,5

Enable SIB1

cellBarred **ENUMERATED** {barred, notBarred},
intraFreqReselection **ENUMERATED** {allowed, notAllowed},

Search space, correction

monitoringSlotPeriodicityAndOffset : Slots for PDCCH Monitoring configured as periodicity and offset. *For example, if the value is sl1, it mean that UE should monitor the SearchSpace at every slot. if the value is sl4, it mean that UE should monitor the SearchSpace in every fourth slot.*

monitoringSymbolsWithinSlot : Symbols for PDCCH monitoring in the slots configured for PDCCH monitoring. The most significant (left) bit represents the first OFDM in a slot. The least significant (right) bit represents the last symbol. *This indicates the starting OFDM symbols that UE should search for a SearchSpace. For example, if the value is '1000000000000', it mean that UE should start searching from the first OFDM symbol. if the value is '0100000000000', it mean that UE should start searching from the second OFDM symbol.*

```

commonSearchSpaceList 3
_SearchSpace
searchSpaceId 1
controlResourceSetId 0
monitoringSlotPeriodicityAndOffset sl5 0
duration 2
monitoringSymbolsWithinSlot (0x2000) '1000000000000'B
nrofCandidates 5
aggregationLevel1 (0) n0
aggregationLevel2 (0) n0
aggregationLevel4 (2) n2
aggregationLevel8 (0) n0
aggregationLevel16 (0) n0
searchSpaceType common: 5
dci_Format0_0_AndFormat1_0 : No Information Element
_SearchSpace
searchSpaceId 2
controlResourceSetId 0
monitoringSlotPeriodicityAndOffset sl1 0
monitoringSymbolsWithinSlot (0x3000) '1100000000000'B
nrofCandidates 5
aggregationLevel1 (0) n0
aggregationLevel2 (0) n0
aggregationLevel4 (2) n2
aggregationLevel8 (0) n0
aggregationLevel16 (0) n0
searchSpaceType common: 5
dci_Format0_0_AndFormat1_0 : No Information Element
_SearchSpace
searchSpaceId 3
controlResourceSetId 0
monitoringSlotPeriodicityAndOffset sl5 0
duration 2
monitoringSymbolsWithinSlot (0x2000) '1000000000000'B
nrofCandidates 5
aggregationLevel1 (0) n0
aggregationLevel2 (0) n0
aggregationLevel4 (2) n2
aggregationLevel8 (0) n0
aggregationLevel16 (0) n0
searchSpaceType common: 5
dci_Format0_0_AndFormat1_0 : No Information Element
    
```

↓
↓
↓

ID	CORESET ID	Type	Start Symbol	Slot Period	Slot Offset	Duration	Candida... Aggreg...	Label
1	0	common	0	5	0	2	[0 0 2 0 0]	SearchSp
2	0	common	0	1	0	1	[0 0 2 0 0]	SearchSp
3	0	common	0	5	0	2	[0 0 2 0 0]	SearchSp

2 PDCCH candidates on aggregation level 4

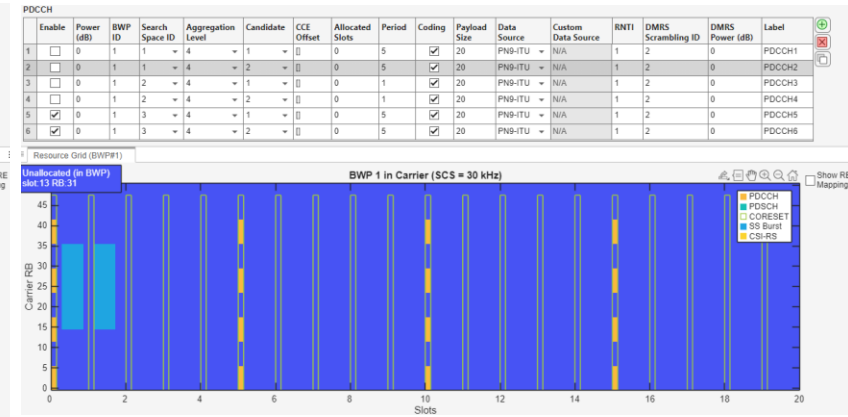
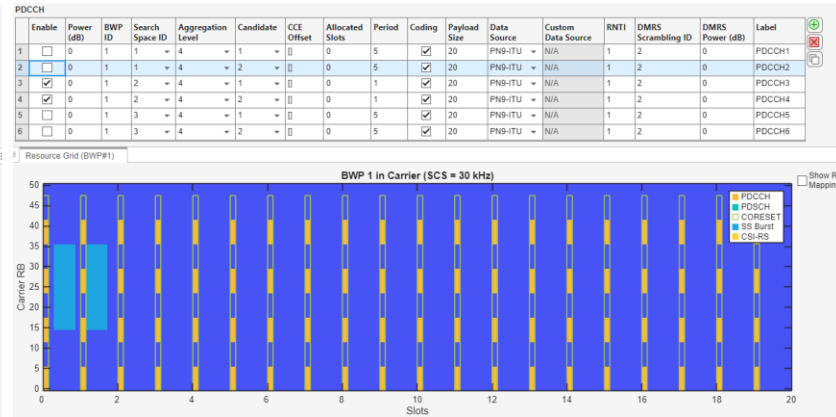
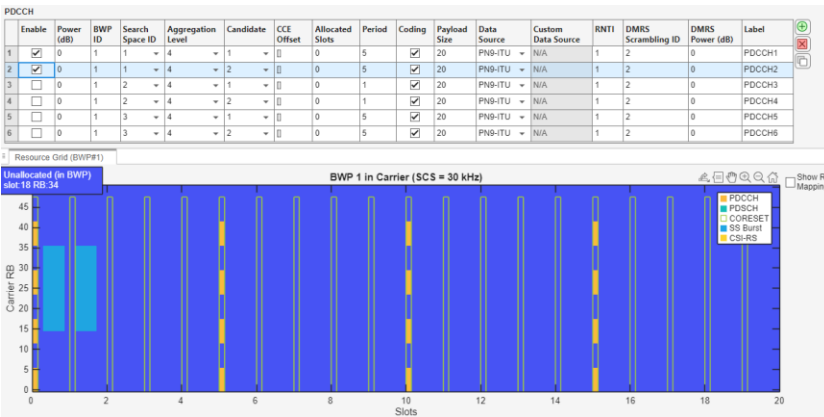
Data from Lab3_example_MSI.txt

PDCCH

PDCCH candidates in search space 1

PDCCH candidates in search space 2

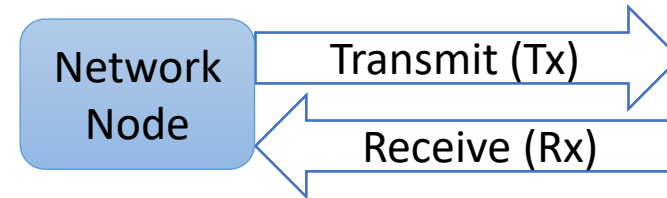
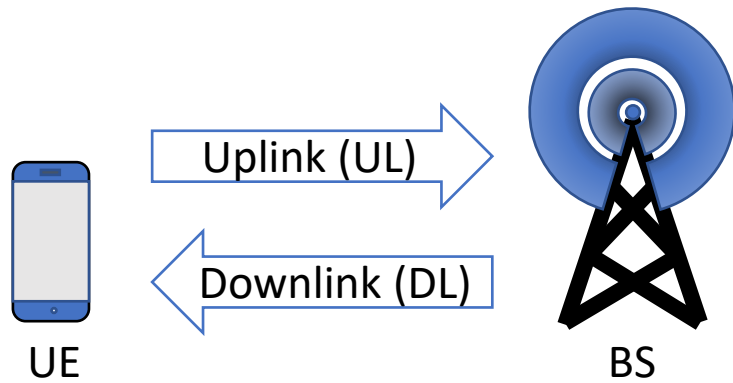
PDCCH candidates in search space 3



Lab 4

5G NR channels and signals in UL

UE and RAN



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

- On physical layer:
 - Physical Random Access Channel (PRACH)
 - Physical Uplink Control Channel (PUCCH)
 - Physical Uplink Shared Channel (PUSCH)

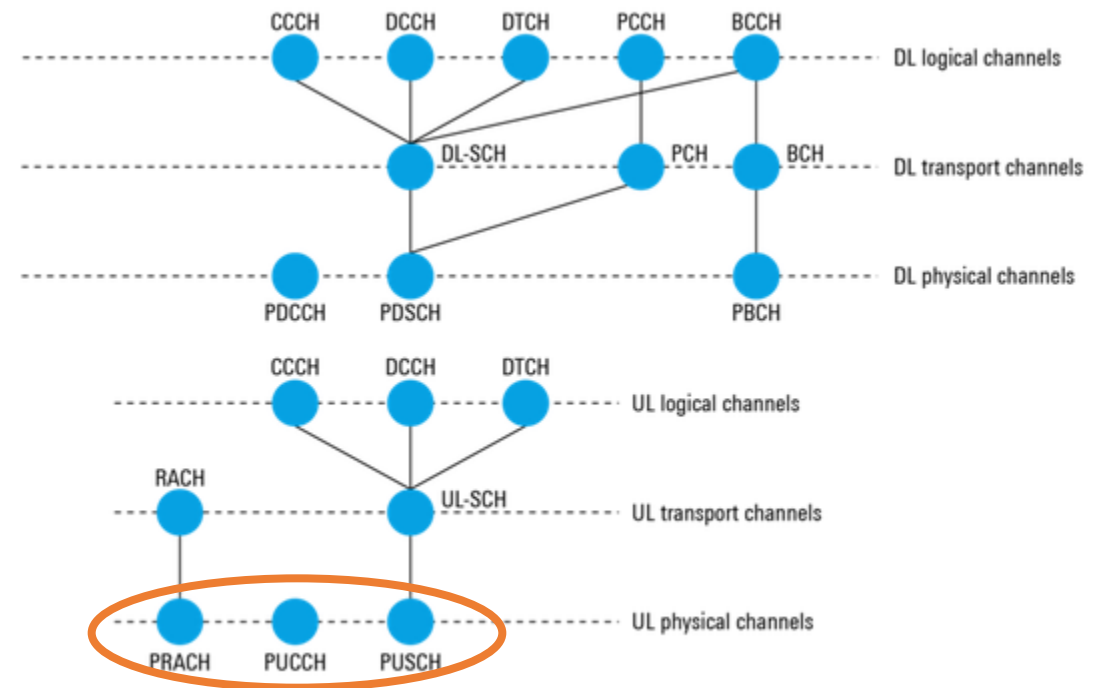
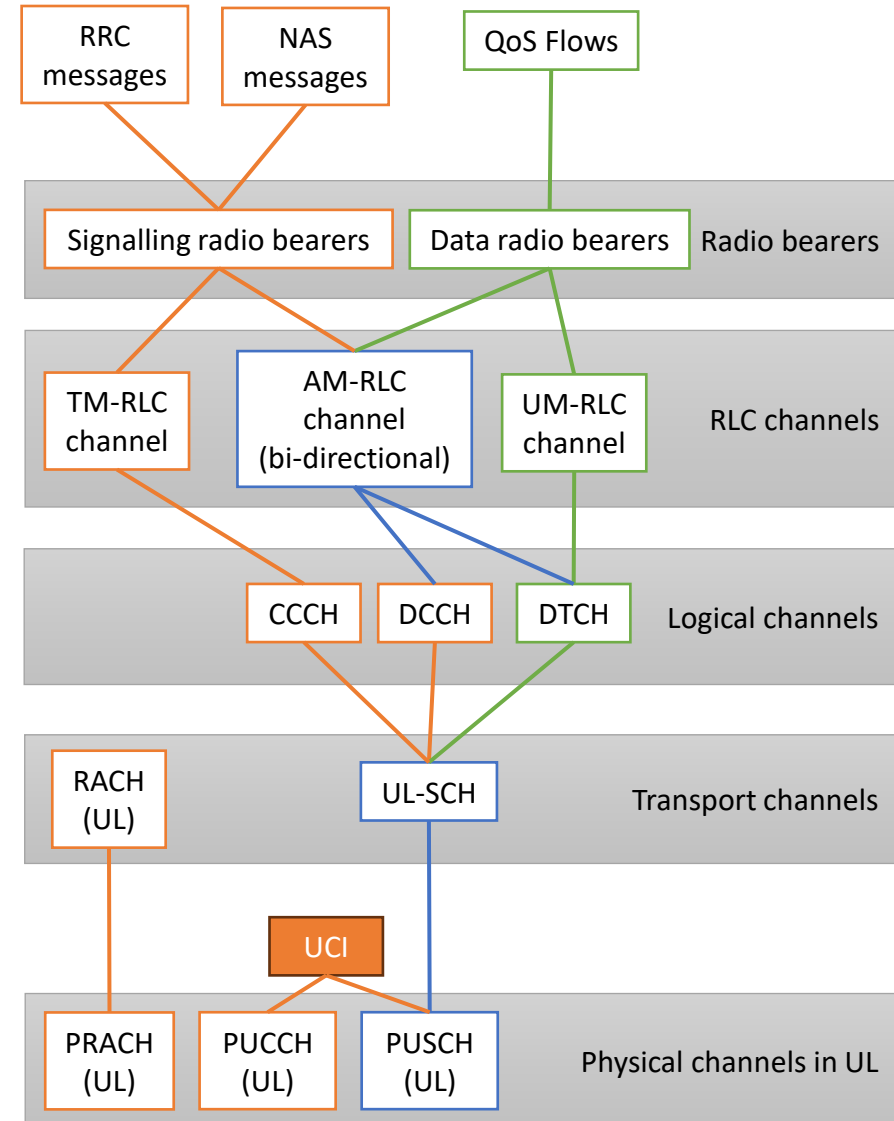


Fig. 1-10 NR logical, transport and physical channel mapping for the uplink and downlink.

UL channels

- Physical Random Access Channel (PRACH)
 - For random access
- Physical Uplink Control Channel (PUCCH)
 - Contains uplink control information (**UCI**), which contains **ACK/NAK**, Channel Quality Indicator (**CQI**), scheduling request (**SR**)
 - UCI can be sent on PUCCH or PUSCH
- Physical Uplink Shared Channel (PUSCH)
 - Contains UE data, and associated reference signals

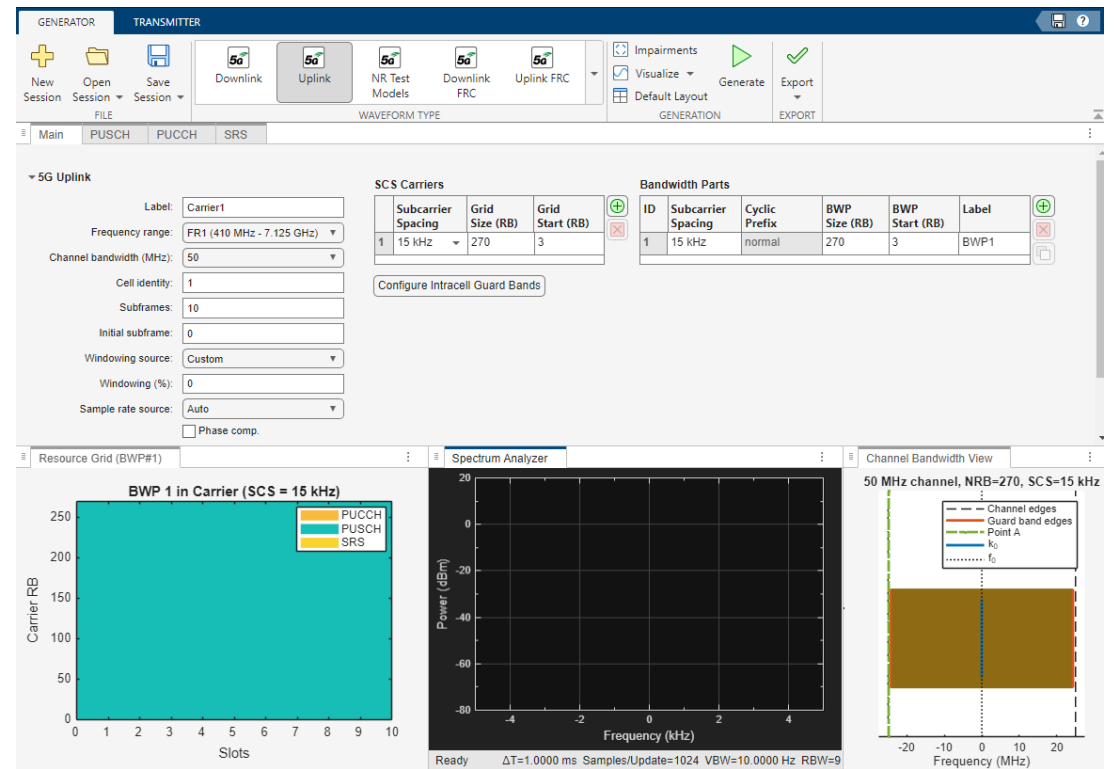


<https://se.mathworks.com/videos/5g-explained-uplink-control-information-in-5g-nr-1566972297188.html>

<https://se.mathworks.com/videos/5g-explained-uplink-data-in-5g-nr-1558601656873.html>

Wireless Waveform Generator Uplink

- Main
 - Carrier, SCS carrier, BWP
- PUSCH
 - PUSCH, DM-RS, PT-RS
- PUCCH
 - PUCCH, UCI
- SRS



Data from Lab4_example_MSI.txt

MCC: 248, MNC: 27 [1/1]
5G NR Channel 1#10 @ 3948.960 MHz (663264) [1/1]
gNodeB - ID:47/177 PCI:1
Position
State: not available
Database: Base Station not in Database
Provider: MCC: 248, MNC: 27
GCI: 248 27 1000 47/177
Subcarrier Spacing: -
Bands as list: 77
Carrier Bandwidth: 18.360 MHz
BWP Bandwidth: 18.360 MHz
BWP Center Frequency: 3949.98 MHz
TDD Configuration: DDDFU (2.5 ms) | DDFUU (2.5 ms)
TDD Configuration(full): D3-d10-f2u2-U1 D2-d10-f2u2-U2
(N)SA Support: SA Supported
RAN slicing: no
RedCap Support: n.a.

BCCH BCH Message
_BCCH_BCH_Message message: **mib**
systemFrameNumber (0x37) '110111'B
systemFrameNumber[] (55) 55
subCarrierSpacingCommon (1) scs30or120
ssb_SubcarrierOffset 0
dmrs_TypeA_Position (0) pos2
pdccch_ConfigSIB1 2
controlResourceSetZero 10
searchSpaceZero 5
cellBarred (1) notBarred
intraFreqReselection (0) allowed
spare (0x00) '0'B

System Information Block 1
_SIB1
cellSelectionInfo 5
q_RxLevMin -65
q_RxLevMin[dBm] (-130) -130
cellAccessRelatedInfo : plmn_IdentityInfoList
(7) _PLMN_IdentityInfo
plmn_IdentityList : _PLMN_Identity
mcc 3
MCC_MNC_Digit 2
MCC_MNC_Digit 4
MCC_MNC_Digit 8
mnc 2
MCC_MNC_Digit 2
MCC_MNC_Digit 7
trackingAreaCode (0x0003e8)
'0000000000000111101000'B
trackingAreaCode[] (1000) 1000
cellIdentity (0x00002fb10)
'00000000000000000000010111101100001'B
cellIdentity[36Bit 28/8] (12209) 47/177
cellReservedForOperatorUse (1) notReserved
si_SchedulingInfo 5
schedulingInfoList : _SchedulingInfo
si_BroadcastStatus (0) broadcasting

si_Periodicity (3) rf64
sib_MappingInfo 2
_SIB_TypeInfo
type (1) sibType3
valueTag 0
_SIB_TypeInfo
type (0) sibType2
valueTag 0
si_WindowLength (3) s40
servingCellConfigCommon 10
downlinkConfigCommon 5
frequencyInfoDL 3
frequencyBandList : _NR_MultiBandInfo
freqBandIndicatorNR 77
offsetToPointA 24
scs_SpecificCarrierList : _SCS_SpecificCarrier
offsetToCarrier 0
subcarrierSpacing (1) kHz30
carrierBandwidth 51
initialDownlinkBWP (3) _BWP_DownlinkCommon
genericParameters (3) _BWP
locationAndBandwidth 13750
subcarrierSpacing (1) kHz30
pdccch_ConfigCommon setup:
_PDCCH_ConfigCommon
controlResourceSetZero 10
searchSpaceZero 5
commonSearchSpaceList 3
_SearchSpace
searchSpaceId 1
controlResourceSetId 0
monitoringSlotPeriodicityAndOffset sI5: 0
duration 2
monitoringSymbolsWithinSlot (0x2000)
'10000000000000'B
nrofCandidates 5
aggregationLevel1 (0) n0
aggregationLevel2 (0) n0
aggregationLevel4 (2) n2
aggregationLevel8 (0) n0
aggregationLevel16 (0) n0
searchSpaceType common: 5
dci_Format0_0_AndFormat1_0 : No
Information Element
_SearchSpace
searchSpaceId 2
controlResourceSetId 0
monitoringSlotPeriodicityAndOffset sI1: 0
monitoringSymbolsWithinSlot (0x3000)
'11000000000000'B
nrofCandidates 5
aggregationLevel1 (0) n0
aggregationLevel2 (0) n0
aggregationLevel4 (2) n2
aggregationLevel8 (0) n0
aggregationLevel16 (0) n0
searchSpaceType common: 5
dci_Format0_0_AndFormat1_0 : No

Information Element
_SearchSpace
searchSpaceId 3
controlResourceSetId 0
monitoringSlotPeriodicityAndOffset sI5: 0
duration 2
monitoringSymbolsWithinSlot (0x2000)
'10000000000000'B
nrofCandidates 5
aggregationLevel1 (0) n0
aggregationLevel2 (0) n0
aggregationLevel4 (2) n2
aggregationLevel8 (0) n0
aggregationLevel16 (0) n0
searchSpaceType common: 5
dci_Format0_0_AndFormat1_0 : No
Information Element
searchSpaceSIB1 0
searchSpaceOtherSystemInformation 1
pagingSearchSpace 3
ra_SearchSpace 2
pdscch_ConfigCommon setup: _PDSCCH_ConfigCommon
pdscch_TimeDomainAllocationList 4
_PDSCCH_TimeDomainResourceAllocation
k2 0
mappingType (0) typeA
startSymbolAndLength 40
_PDSCCH_TimeDomainResourceAllocation
k0 0
mappingType (0) typeA
startSymbolAndLength 54
_PDSCCH_TimeDomainResourceAllocation
k0 0
mappingType (0) typeA
startSymbolAndLength 53
_PDSCCH_TimeDomainResourceAllocation
k0 0
mappingType (0) typeA
startSymbolAndLength 67
bch_Config : modificationPeriodCoeff
n2
pcch_Config 6
defaultPagingCycle (2) rf128
nAndPagingFrameOffset quarterT: 1
ns (2) one
firstPDCCH_MonitoringOccasionOfPO
sCS120KHzZoneT_SCS60KHzHalfT_SCS30KHzQuarterT_SCS15KHz
oneEighthT: 1
_of27_3
uplinkConfigCommon 3
frequencyInfoUL 5
scs_SpecificCarrierList : _SCS_SpecificCarrier
offsetToCarrier 0
subcarrierSpacing (1) kHz30
carrierBandwidth 51
p_Max 20
initialUplinkBWP (6) _BWP_UplinkCommon
genericParameters (3) _BWP

locationAndBandwidth 13750
subcarrierSpacing (1) kHz30
rach_ConfigCommon setup: _RACH_ConfigCommon
rach_ConfigGeneric 10
prach_ConfigurationIndex 98
msg1_FDM (0) one
msg1_FrequencyStart 13
zeroCorrelationZoneConfig 15
preambleReceivedTargetPower -104
preambleTransMax (6) n10
powerRampingStep (1) dB2
ra_ResponseWindow (7) sl80
ssb_perRACH_OccasionAndCB_PreamblesPerSSB
one: n56
ra_ContentionResolutionTimer (7) sf64
rsrp_ThresholdSSB 37
prach_RootSequenceIndex l139: 0
msg1_SubcarrierSpacing (1) kHz30
restrictedSetConfig (0) unrestrictedSet
pusch_ConfigCommon setup:
_PUSCH_ConfigCommon
pusch_TimeDomainAllocationList 10
_PUSCH_TimeDomainResourceAllocation
k2 2
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 2
mappingType (1) typeB
startSymbolAndLength 41
_PUSCH_TimeDomainResourceAllocation
k2 3
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 3
mappingType (1) typeB
startSymbolAndLength 41
_PUSCH_TimeDomainResourceAllocation
k2 4
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 5
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 6
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 9
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 10
mappingType (1) typeB
startSymbolAndLength 27

_PUSCH_TimeDomainResourceAllocation
k2 11
mappingType (1) typeB
startSymbolAndLength 27
msg3_DeltaPreamble 1
p0_NominalWithGrant -96
pucch_ConfigCommon setup:
_PUCCH_ConfigCommon
pucch_ResourceCommon 15
pucch_GroupHopping (0) neither
hoppingId 1
p0_nominal -108
timeAlignmentTimerCommon (7) infinity
ssb_PositionsInBurst : inOneGroup
'10000000'B
ssb_PeriodicityServingCell (2) ms20
tdd_UL_DL_ConfigurationCommon (3)
_TDD_UL_DL_ConfigCommon
referenceSubcarrierSpacing (1) kHz30
pattern1 (6) _TDD_UL_DL_Pattern
dl_UL_TransmissionPeriodicity (5) ms2p5
nrofDownlinkSlots 3
nrofUplinkSlots 1
nrofUplinkSymbols 2
pattern2 (6) _TDD_UL_DL_Pattern
dl_UL_TransmissionPeriodicity (5) ms2p5
nrofDownlinkSlots 2
nrofUplinkSlots 2
nrofUplinkSymbols 2
ss_PBCH_BlockPower -6
ims_EmergencySupport (0) True
ue_TimersAndConstants 7
t300 (3) ms400
t301 (3) ms400
t310 (6) ms2000
n310 (6) n10
t311 (1) ms3000
n311 (0) n1
t319 (3) ms400
nonCriticalExtension _SIB1_v1610_IEs: nonCriticalExtension
_SIB1_v1630_IEs nonCriticalExtension: _SIB1_v1700_IEs
redCap_ConfigCommon_r17
_RedCap_ConfigCommonSIB_r17: cellBarredRedCap_r17
cellBarredRedCap1Rx_r17 (1) notBarred
cellBarredRedCap2Rx_r17 (1) notBarred
intraFreqReselectionRedCap_r17 (0) allowed

Main: carrier

MCC: 248, MNC: 27 [1/1]

5G NR Channel 1#10 @ 3948.960 MHz (663264) [1/1]

gNodeB - ID:47/177 PCI:1

Position

State: not available

Database: Base Station not in Database

Provider: MCC: 248, MNC: 27

GCI: 248 27 1000 47/177

Subcarrier Spacing: -

Bands as list: 77

Carrier Bandwidth: 18.360 MHz

BWP Bandwidth: 18.360 MHz

BWP Center Frequency: 3949.98 MHz

TDD Configuration: DDDFU (2.5 ms) | DDFUU (2.5 ms)

TDD Configuration(full): D3-d10-f2u2-U1 D2-d10-f2u2-U2

(N)SA Support: SA Supported

RAN slicing: no

RedCap Support: n.a.

} Slot
format

The screenshot shows a configuration window for a 5G Uplink carrier. At the top, there are tabs for 'Main', 'PUSCH', 'PUCCH', and 'SRS', with 'Main' selected. Below the tabs, the '5G Uplink' section is expanded, showing various parameters in a form-like layout:

- Label: Carrier1
- Frequency range: FR1 (410 MHz - 7.125 GHz)
- Channel bandwidth (MHz): 20
- Cell identity: 1
- Subframes: 10
- Initial subframe: 0
- Windowing source: Custom
- Windowing (%): 0
- Sample rate source: Auto
- Phase comp.

Below the 5G Uplink section, the 'Filtering Configuration' section is also expanded, showing:

- Filtering: None

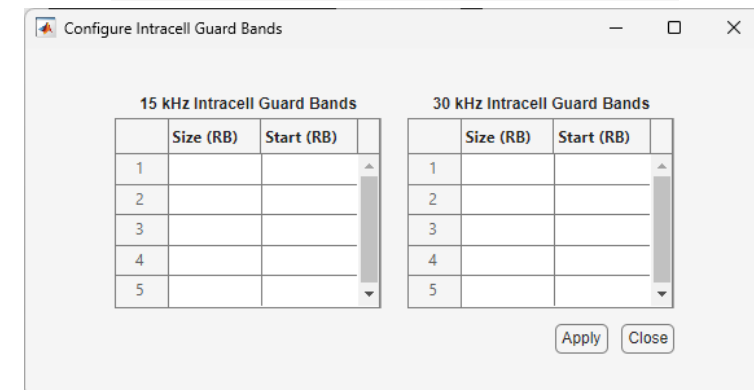
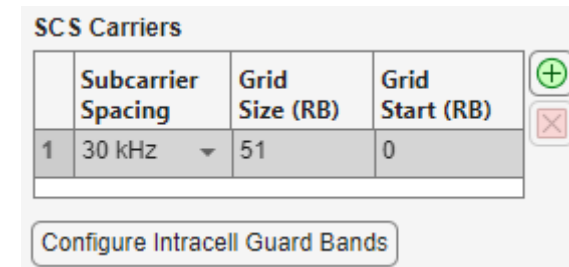
Data from Lab4_example_MSI.txt

Main: SCS carrier

BCCH BCH Message

```
_BCCH_BCH_Message message: mib
  systemFrameNumber (0x37) '110111'B
  systemFrameNumber[] (55) 55
  subCarrierSpacingCommon (1) scs30or120
  ssb_SubcarrierOffset 0
  dmrs_TypeA_Position (0) pos2
  pdcch_ConfigSIB1 2
    controlResourceSetZero 10
    searchSpaceZero 5
  cellBarred (1) notBarred
  intraFreqReselection (0) allowed
  spare (0x00) '0'B
```

Data from **Lab4_example_MSI.txt**



Main: BWP

MCC: 248, MNC: 27 [1/1]

5G NR Channel 1#10 @ 3948.960 MHz (663264) [1/1]

gNodeB - ID:47/177 PCI:1

Position

State: not available

Database: Base Station not in Database

Provider: MCC: 248, MNC: 27

GCI: 248 27 1000 47/177

Subcarrier Spacing: -

Bands as list: 77

Carrier Bandwidth: 18.360 MHz

BWP Bandwidth: 18.360 MHz

BWP Center Frequency: 3949.98 MHz

TDD Configuration: DDDFU (2.5 ms) | DDFUU (2.5 ms)

TDD Configuration(full): D3-d10-f2u2-U1 D2-d10-f2u2-U2

(N)SA Support: SA Supported

RAN slicing: no

RedCap Support: n.a.

Data from **Lab4_example_MSI.txt**

Bandwidth Parts

ID	Subcarrier Spacing	Cyclic Prefix	BWP Size (RB)	BWP Start (RB)	Label
1	30 kHz	normal	51	0	BWP1

System Information Block 1

_SIB1

/.../

uplinkConfigCommon 3

frequencyInfoUL 5

scs_SpecificCarrierList :

_SCS_SpecificCarrier

offsetToCarrier 0

subcarrierSpacing (1) kHz30

carrierBandwidth 51

p_Max 20

initialUplinkBWP (6) _BWP_UplinkCommon

genericParameters (3) _BWP

locationAndBandwidth 13750

subcarrierSpacing (1) kHz30

locationAndBandwidth

RIV - resource indicator value

For UL on same BWP

if $(L_{RBs} - 1) \leq \lfloor N_{BWP}^{size} / 2 \rfloor$ then

$$RIV = N_{BWP}^{size} (L_{RBs} - 1) + RB_{start}$$

else

$$RIV = N_{BWP}^{size} (N_{BWP}^{size} - L_{RBs} + 1) + (N_{BWP}^{size} - 1 - RB_{start})$$

where $L_{RBs} \geq 1$ and shall not exceed $N_{BWP}^{size} - RB_{start}$.

For UL on different BWP

The resource indication value is defined by

if $(L'_{RBs} - 1) \leq \lfloor N_{BWP}^{initial} / 2 \rfloor$ then

$$RIV = N_{BWP}^{initial} (L'_{RBs} - 1) + RB'_{start}$$

else

$$RIV = N_{BWP}^{initial} (N_{BWP}^{initial} - L'_{RBs} + 1) + (N_{BWP}^{initial} - 1 - RB'_{start})$$

where $L'_{RBs} = L_{RBs} / K$, $RB'_{start} = RB_{start} / K$ and where L'_{RBs} shall not exceed $N_{BWP}^{initial} - RB'_{start}$.

If $N_{BWP}^{active} > N_{BWP}^{initial}$, K is the maximum value from set $\{1, 2, 4, 8\}$ which satisfies $K \leq \lfloor N_{BWP}^{active} / N_{BWP}^{initial} \rfloor$; otherwise $K = 1$.

[1] 3GPP, „TS 38.214 – NR; Physical layer procedures for data“, 2022,
[Online]. Available: <https://www.3gpp.org/DynaReport/38214.htm>

locationAndBandwidth

```

System Information Block 1
  _SIB1
  /.../
  uplinkConfigCommon 3
    frequencyInfoUL 5
      scs_SpecificCarrierList :
      _SCS_SpecificCarrier
        offsetToCarrier 0
        subcarrierSpacing (1) kHz30
        carrierBandwidth 51
        p_Max 20
        initialUplinkBWP (6) _BWP_UplinkCommon
        genericParameters (3) _BWP
          locationAndBandwidth 13750
          subcarrierSpacing (1) kHz30
    
```

CBW	max RB	Equation	RIV Calculation	locationAnd Bandwidth
5	11	(1)	$275*(11-1)+0$	2750
10	24	(1)	$275*(24-1)+0$	6325
15	38	(1)	$275*(38-1)+0$	10175
20	51	(1)	$275*(51-1)+0$	13750
25	65	(1)	$275*(65-1)+0$	17600
30	78	(1)	$275*(78-1)+0$	21175
40	106	(1)	$275*(106-1)+0$	28875
50	133	(1)	$275*(133-1)+0$	36300
60	162	(2)	$275*(275-162+1)+(275-1-0)$	31624
70	189	(2)	$275*(275-189+1)+(275-1-0)$	24199
80	217	(2)	$275*(275-217+1)+(275-1-0)$	16499
90	245	(2)	$275*(275-245+1)+(275-1-0)$	8799
100	273	(2)	$275*(275-273+1)+(275-1-0)$	1099

Main: BWP

```
System Information Block 1
  _SIB1
  /.../
  uplinkConfigCommon 3
    frequencyInfoUL 5
      scs_SpecificCarrierList :
      _SCS_SpecificCarrier
        offsetToCarrier 0
        subcarrierSpacing (1) kHz30
        carrierBandwidth 51
        p_Max 20
        initialUplinkBWP (6) _BWP_UplinkCommon
        genericParameters (3) _BWP
          locationAndBandwidth 13750
          subcarrierSpacing (1) kHz30
```

Data from **Lab4_example_MSI.txt**

Bandwidth Parts					
ID	Subcarrier Spacing	Cyclic Prefix	BWP Size (RB)	BWP Start (RB)	Label
1	30 kHz	normal	51	0	BWP1

UL and DL slots

Data from **Lab4_example_MSI.txt**

SIB1:

```
./.../  
tdd_UL_DL_ConfigurationCommon (3) _TDD_UL_DL_ConfigCommon  
  referenceSubcarrierSpacing (1) kHz30  
  pattern1 (6) _TDD_UL_DL_Pattern  
    dl_UL_TransmissionPeriodicity (5) ms2p5  
    nrofDownlinkSlots 3  
    nrofDownlinkSymbols 10  
    nrofUplinkSlots 1  
    nrofUplinkSymbols 2  
  pattern2 (6) _TDD_UL_DL_Pattern  
    dl_UL_TransmissionPeriodicity (5) ms2p5  
    nrofDownlinkSlots 2  
    nrofDownlinkSymbols 10  
    nrofUplinkSlots 2  
    nrofUplinkSymbols 2
```

2.5 ms

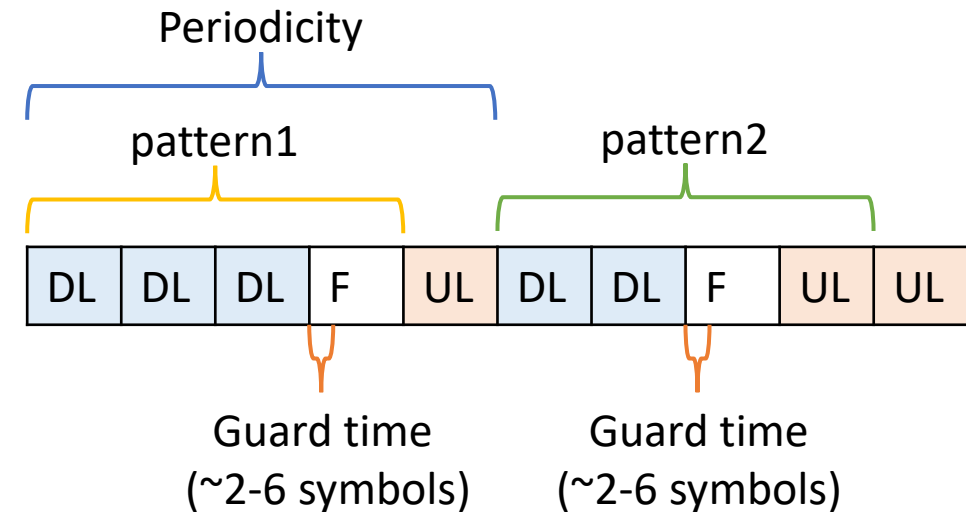
SCS=30 → $\mu=1$

1 frame duration 10 ms

Frame contains 10 subframes

Subframe contains slots $2^\mu \rightarrow 2$ slots

In 1 ms there is 2 slots → 2.5 ms is 5 slots



3GPP TS 38.213 section 11.1,

https://www.sharetechnote.com/html/5G/5G_tdd_UL_DL_configurationCommon.html

Signals (in UL transmitted by UE)

- Demodulation reference signal (DM-RS) – for channel estimation and equalization, for power control
 - For PUSCH
 - Different sequences depending on transform precoding enabled or disabled
 - For PUCCH
 - Different sequences depending on PUCCH format 1, 2, 3 or 4
- Phase-tracking reference signal (PT-RS) – to suppress phase noise
 - Can be used for PUSCH
 - Different sequences depending on transform precoding enabled or disabled
- Sounding Reference signal (SRS) – sent by UE to enable channel estimation
 - Aperiodic, periodic or semi-persistent (triggered)

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

PUCCH

- Format
- Modulation
- Start symbol and length
- Slot allocation
- Period

The screenshot displays the 'Wireless Waveform Generator' software interface. The main window is titled 'TRANSMITTER' and features a toolbar with options like 'New Session', 'Open Session', 'Save Session', 'Downlink', 'Uplink', 'NR Test Models', 'Downlink FRC', and 'Uplink FRC'. Below the toolbar, there are tabs for 'Main', 'PUSCH', 'PUCCH', and 'SRS'. The 'PUCCH' tab is active, showing a table with the following data:

Label	Enable	Format	Power (dB)	BWP ID	Mod...	Start Symbol	Symbol Length	Slot Alloc...	Period	PRB Set	nID	RNTI	Coding
1 PUCCH1	<input type="checkbox"/>	For...	0	1	Z-Chu	13	1	[0:9]	10	0	N/A	N/A	<input type="checkbox"/>

Below the table, there is a 'Resource Grid (BWP#1)' view showing 'BWP 1 in Carrier (SCS = 30 kHz)'. The grid plots 'Carrier RB' (0 to 40) against 'Slots' (0 to 20). A legend indicates that PUCCH is represented by orange, PUSCH by green, and SRS by yellow. A blue box highlights 'Unallocated (in BWP) slot:6 RB:43'. On the right side, the 'PUCCH 1 - Advanced Configuration' panel is visible, showing settings for 'PUCCH format: 0', 'Label: PUCCH1', 'Modulation: Z-Chu', and other parameters.

PUCCH

- Carries UCI from UE to gNB
- PUCCH formats 0-4
- Long PUCCH formats contain DMRS time-division multiplexed with UCI
- PUCCH format 2 contains DMRS frequency multiplexed
- PUCCH formats 0, 1 and 4 enable multi-UE multiplexing

Format	Long/short	Number of symbols	UCI payload	UCI payload in bits	UE multiplexing capacity in same PRB	Frequency hopping
0	short	1 or 2	small	Up to 2	6 UEs	No
1	long	4 to 14	small	Up to 2 bit	Up to 84 UEs	No
					Up to 36 UEs	yes
2	short	1 or 2	large	More than 2 bit	No	No
3	long	4 to 14	large	More than 2 bit	no	No
4	long	4 to 14	moderate	More than 2 bit	Up to 4 UEs	No

3GPP. (2024). TS 38.300 NR; NR and NG-RAN Overall Description; Stage 2.

<https://www.3gpp.org/DynaReport/38300.htm>

Uplink Control information (UCI)

- UCI contains (combinations of):
 - Channel state information (CSI)
 - HARQ feedback, ACK/NAK (1 or 2 bits)
 - Scheduling request (SR)

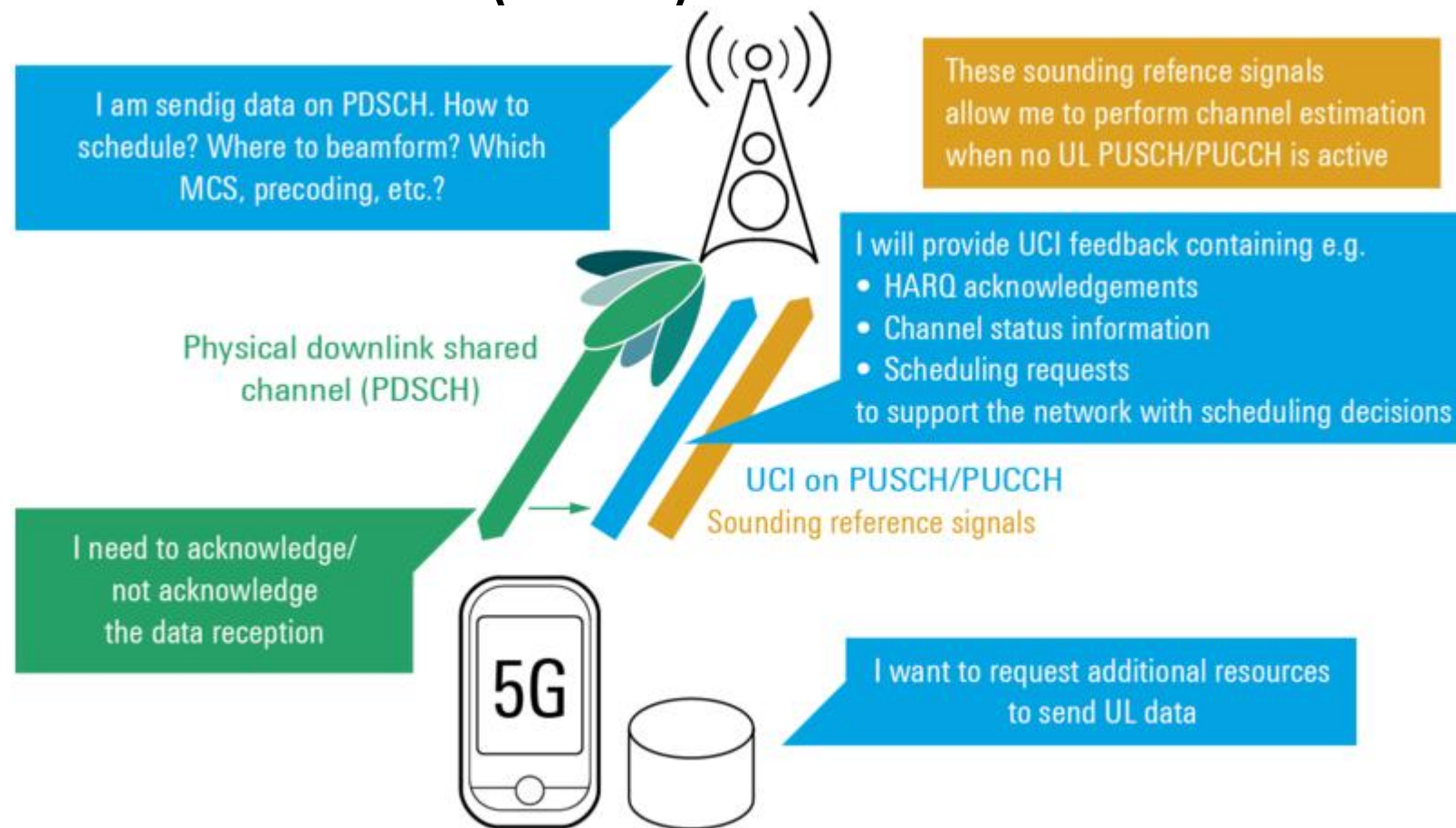


Fig. 2-74 Uplink control information (UCI) – general model overview.

R&S. (2020). 5G New Radio. Fundamentals, procedures, testing aspects.

<https://gloris.rohde-schwarz.com/ebooks/5G>

Scheduling request (SR)

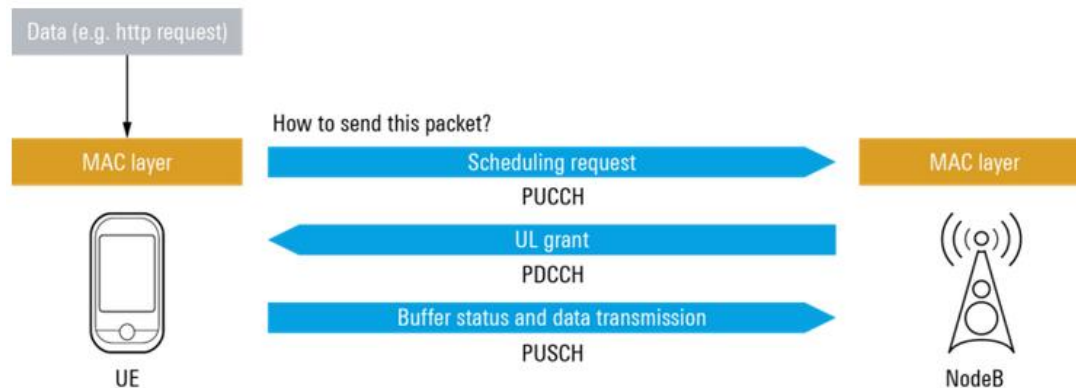


Fig. 2-67 Scheduling request procedure.

- Each logical channel associated with specific SR id per cell and BWP.
- UE may transmit SR as soon as it has data in the applicable buffer of logical channel
- If no PUCCH resources then UE starts random access procedure
- Buffer Status Report (BSR)

R&S. (2020). 5G New Radio. Fundamentals, procedures, testing aspects.

<https://gloris.rohde-schwarz.com/ebooks/5G>

PUCCH

Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration

Index	PUCCH format	First symbol	Number of symbols	PRB offset RB_{BWP}^{offset}	Set of initial CS indexes
0	0	12	2	0	{0, 3}
1	0	12	2	0	{0, 4, 8}
2	0	12	2	3	{0, 4, 8}
3	1	10	4	0	{0, 6}
4	1	10	4	0	{0, 3, 6, 9}
5	1	10	4	2	{0, 3, 6, 9}
6	1	10	4	4	{0, 3, 6, 9}
7	1	4	10	0	{0, 6}
8	1	4	10	0	{0, 3, 6, 9}
9	1	4	10	2	{0, 3, 6, 9}
10	1	4	10	4	{0, 3, 6, 9}
11	1	0	14	0	{0, 6}
12	1	0	14	0	{0, 3, 6, 9}
13	1	0	14	2	{0, 3, 6, 9}
14	1	0	14	4	{0, 3, 6, 9}
15	1	0	14	$\lfloor N_{BWP}^{size}/4 \rfloor$	{0, 3, 6, 9}

pucch_ConfigCommon setup: _PUCCH_ConfigCommon
 pucch_ResourceCommon **15**
 pucch_GroupHopping (0) neither
 hoppingId 1
 p0_nominal -108

Data from Lab4_example_MSI.txt

51/4=12,75

PUCCH														
	Label	Enable	Format	Power (dB)	BWP ID	Modulat...	Start Symbol	Symbol Length	Slot Allocation	Period	PRB Set	nID	RNTI	Coding
1	PUCCH1	<input checked="" type="checkbox"/>	Format 1	0	1	BPSK	0	14	[0:9]	10	0	N/A	N/A	<input type="checkbox"/>

[1] 3GPP, "TS 38.213 - NR; Physical layer procedures for control," 2022, [Online]. Available: <https://www.3gpp.org/DynaReport/38213.htm>

PUSCH

- Carry UE data in UL
- LDPC coding scheme
- DMRS reference signals (type A or type B)
- UCI can be multiplexed

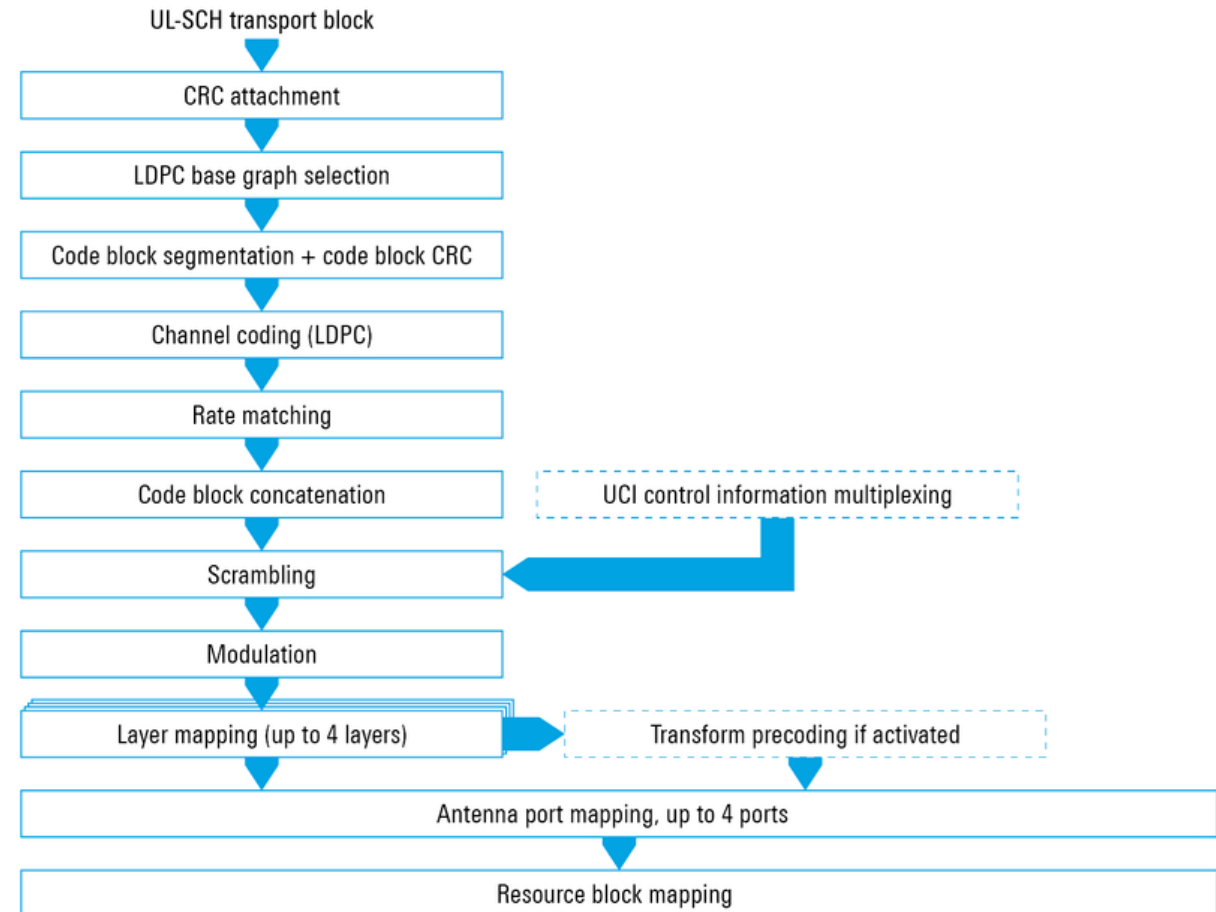


Fig. 1-70 PUSCH physical layer processing.

R&S. (2020). 5G New Radio. Fundamentals, procedures, testing aspects.

<https://gloris.rohde-schwarz.com/ebooks/5G>

PUSCH

```

pusch_ConfigCommon setup: _PUSCH_ConfigCommon
pusch_TimeDomainAllocationList 10
_PUSCH_TimeDomainResourceAllocation
k2 2
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 2
mappingType (1) typeB
startSymbolAndLength 41
_PUSCH_TimeDomainResourceAllocation
k2 3
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 3
mappingType (1) typeB
startSymbolAndLength 41
_PUSCH_TimeDomainResourceAllocation
k2 4
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 5
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 6
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 9
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 10
mappingType (1) typeB
startSymbolAndLength 27
_PUSCH_TimeDomainResourceAllocation
k2 11
mappingType (1) typeB
startSymbolAndLength 27
msg3_DeltaPreamble 1
p0_NominalWithGrant -96
  
```

- The slot where the UE shall transmit the PUSCH is determined by K_2 as $\left\lceil n \cdot \frac{2^{\mu_{\text{PUSCH}}}}{2^{\mu_{\text{PDCCH}}}} \right\rceil + K_2$ where n is the slot with the scheduling DCI, K_2 is based on the numerology of PUSCH, and μ_{PUSCH} and μ_{PDCCH} are the subcarrier spacing configurations for PUSCH and PDCCH, respectively, and
- The starting symbol S relative to the start of the slot, and the number of consecutive symbols L counting from the symbol S allocated for the PUSCH are determined from the start and length indicator $SLIV$ of the indexed row:
 - if $(L-1) \leq 7$ then

$$SLIV = 14(L-1) + S$$
 - else

$$SLIV = 14(14-L+1) + (14-1-S)$$
 - where $0 < L \leq 14 - S$, and
- The PUSCH mapping type is set to Type A or Type B as defined in clause 6.4.1.1.3 of [4, TS 38.211] as given by the indexed row.

Table 6.1.2.1-1: Valid S and L combinations

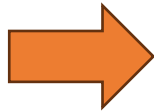
PUSCH mapping type	Normal cyclic prefix			Extended cyclic prefix		
	S	L	$S+L$	S	L	$S+L$
Type A	0	{4,...,14}	{4,...,14}	0	{4,...,12}	{4,...,12}
Type B	{0,...,13}	{1,...,14}	{1,...,14}	{0,...,11}	{1,...,12}	{1,...,12}

Data from
Lab4_example_MSI.txt

[1] 3GPP, „TS 38.214 – NR; Physical layer procedures for data“, 2022, [Online]. Available: <https://www.3gpp.org/DynaReport/38214.htm>

PUSCH SLIV

27 41



S	L	L-1	Last Symbol	SLIV	Valid Mapping Type (Normal CP) PUSCH
0	1	0	0	0	Type B
	2	1	1	14	Type B
	3	2	2	28	Type B
	4	3	3	42	Type A,Type B
	5	4	4	56	Type A,Type B
	6	5	5	70	Type A,Type B
	7	6	6	84	Type A,Type B
	8	7	7	98	Type A,Type B
	9	8	8	97	Type A,Type B
	10	9	9	83	Type A,Type B
	11	10	10	69	Type A,Type B
	12	11	11	55	Type A,Type B
	13	12	12	41	Type A,Type B
	14	13	13	27	Type A,Type B
1	1	0	1	1	Type B
	2	1	2	15	Type B
	3	2	3	29	Type B
	4	3	4	43	Type B
	5	4	5	57	Type B
	6	5	6	71	Type B
	7	6	7	85	Type B
	8	7	8	99	Type B
	9	8	9	96	Type B
	10	9	10	82	Type B
	11	10	11	68	Type B
	12	11	12	54	Type B
	13	12	13	40	Type B

S	L	L-1	Last Symbol	SLIV	Valid Mapping Type (Normal CP) PUSCH
2	1	0	2	2	Type B
	2	1	3	16	Type B
	3	2	4	30	Type B
	4	3	5	44	Type B
	5	4	6	58	Type B
	6	5	7	72	Type B
	7	6	8	86	Type B
	8	7	9	100	Type B
	9	8	10	95	Type B
	10	9	11	81	Type B
	11	10	12	67	Type B
	12	11	13	53	Type B
3	1	0	3	3	Type B
	2	1	4	17	Type B
	3	2	5	31	Type B
	4	3	6	45	Type B
	5	4	7	59	Type B
	6	5	8	73	Type B
	7	6	9	87	Type B
	8	7	10	101	Type B
	9	8	11	94	Type B
	10	9	12	80	Type B
	11	10	13	66	Type B

S	L	L-1	Last Symbol	SLIV	Valid Mapping Type (Normal CP) PUSCH
4	1	0	4	4	Type B
	2	1	5	18	Type B
	3	2	6	32	Type B
	4	3	7	46	Type B
	5	4	8	60	Type B
	6	5	9	74	Type B
	7	6	10	88	Type B
	8	7	11	102	Type B
	9	8	12	93	Type B
	10	9	13	79	Type B
5	1	0	5	5	Type B
	2	1	6	19	Type B
	3	2	7	33	Type B
	4	3	8	47	Type B
	5	4	9	61	Type B
	6	5	10	75	Type B
	7	6	11	89	Type B
	8	7	12	103	Type B
6	1	0	6	6	Type B
	2	1	7	20	Type B
	3	2	8	34	Type B
	4	3	9	48	Type B
	5	4	10	62	Type B
	6	5	11	76	Type B
	7	6	12	90	Type B
	8	7	13	104	Type B

S	L	L-1	Last Symbol	SLIV	Valid Mapping Type (Normal CP) PUSCH
7	1	0	7	7	Type B
	2	1	8	21	Type B
	3	2	9	35	Type B
	4	3	10	49	Type B
	5	4	11	63	Type B
	6	5	12	77	Type B
	7	6	13	91	Type B
8	1	0	8	8	Type B
	2	1	9	22	Type B
	3	2	10	36	Type B
	4	3	11	50	Type B
	5	4	12	64	Type B
9	1	0	9	9	Type B
	2	1	10	23	Type B
	3	2	11	37	Type B
	4	3	12	51	Type B
	5	4	13	65	Type B
10	1	0	10	10	Type B
	2	1	11	24	Type B
	3	2	12	38	Type B
11	1	0	11	11	Type B
	2	1	12	25	Type B
	3	2	13	39	Type B
12	1	0	12	12	Type B
	2	1	13	26	Type B
13	1	0	13	13	Type B

```

pusch_ConfigCommon setup: _PUSCH_ConfigCommon
  pusch_TimeDomainAllocationList 10
    _PUSCH_TimeDomainResourceAllocation
      k2 2
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 2
        mappingType (1) typeB
        startSymbolAndLength 41
    _PUSCH_TimeDomainResourceAllocation
      k2 3
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 3
        mappingType (1) typeB
        startSymbolAndLength 41
    _PUSCH_TimeDomainResourceAllocation
      k2 4
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 5
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 6
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 9
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 10
        mappingType (1) typeB
        startSymbolAndLength 27
    _PUSCH_TimeDomainResourceAllocation
      k2 11
        mappingType (1) typeB
        startSymbolAndLength 27
  msg3_DeltaPreamble 1
  p0_NominalWithGrant -96

```

PUSCH

S=0, L=14

S=0, L=13

PUSCH																			
	Enable	Power (dB)	BWP ID	Modulation (CW 1)	Modulation (CW 2)	Num Layers	Mapping Type	Start Symbol	Symbol Length	Slot Alloc...	Period	PRB Set	nID	RNTI	Coding	Code... (CW 1)	Code... (CW 2)	Transform Precoding	Enable PT-RS
1	<input checked="" type="checkbox"/>	0	1	QPSK	N/A	1	B	0	14	[3:3]	10	[0:50]	[]	1	<input checked="" type="checkbox"/>	0.5137	N/A	<input type="checkbox"/>	<input type="checkbox"/>
2	<input checked="" type="checkbox"/>	0	1	QPSK	N/A	1	B	0	13	[7:8]	10	[0:50]	[]	1	<input checked="" type="checkbox"/>	0.5137	N/A	<input type="checkbox"/>	<input type="checkbox"/>

```

tdd_UL_DL_ConfigurationCommon (3) _TDD_UL_DL_ConfigCommon
  referenceSubcarrierSpacing (1) kHz30
  pattern1 (6) _TDD_UL_DL_Pattern
    dl_UL_TransmissionPeriodicity (5) ms2p5
    nrofDownlinkSlots 3
    nrofDownlinkSymbols 10
    nrofUplinkSlots 1
    nrofUplinkSymbols 2
  pattern2 (6) _TDD_UL_DL_Pattern
    dl_UL_TransmissionPeriodicity (5) ms2p5
    nrofDownlinkSlots 2
    nrofDownlinkSymbols 10
    nrofUplinkSlots 2
    nrofUplinkSymbols 2

```

Data from
Lab4_example_MSI.txt

Physical Random Access Channel (PRACH)

- Channel open for every UE except if cell barred (indicated in MIB)
- PRACH access rules and PRACH resource allocation are broadcasted via SIB
- 2 types of PRACH access procedures
 - Contention-based random access (CBRA)
 - Contention-free random access (CFRA)

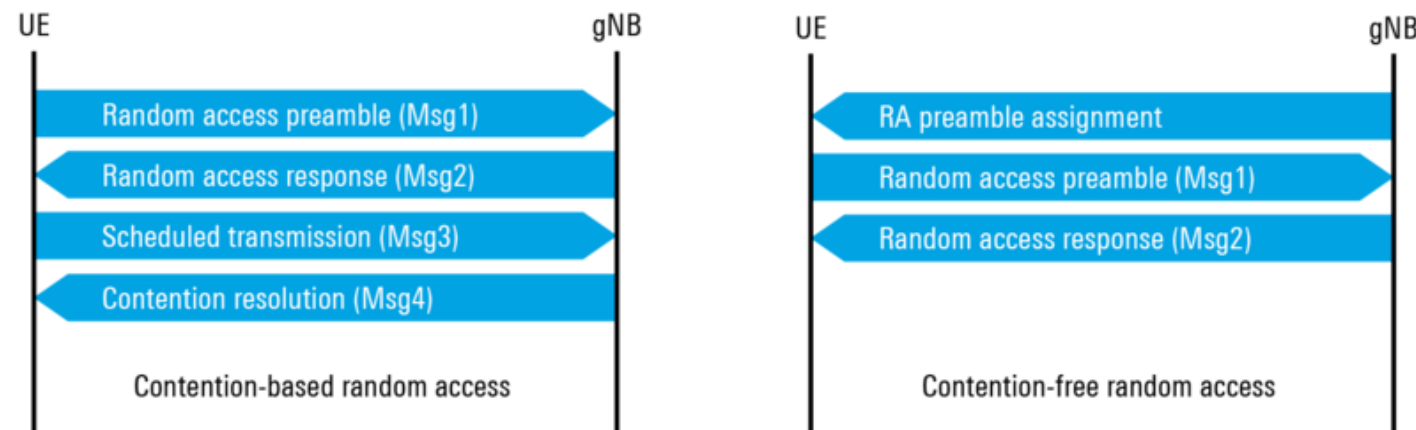


Fig. 2-20 Contention-based and contention-free random access procedure in 5G NR.

R&S. (2020). 5G New Radio. Fundamentals, procedures, testing aspects.

<https://gloris.rohde-schwarz.com/ebooks/5G>

PRACH




SIB1:

```
rach_ConfigCommon setup: _RACH_ConfigCommon
  rach_ConfigGeneric 10
    prach_ConfigurationIndex 98
    msg1_FDM (0) one
    msg1_FrequencyStart 13
    zeroCorrelationZoneConfig 15
    preambleReceivedTargetPower -104
    preambleTransMax (6) n10
    powerRampingStep (1) dB2
    ra_ResponseWindow (7) sl80
  ssb_perRACH_OccasionAndCB_PreamblesPerSSB one: n56
  ra_ContentionResolutionTimer (7) sf64
  rsrp_ThresholdSSB 37
  prach_RootSequenceIndex l139: 0
  msg1_SubcarrierSpacing (1) kHz30
  restrictedSetConfig (0) unrestrictedSet
```

Data from

Lab4_example_MSI.txt

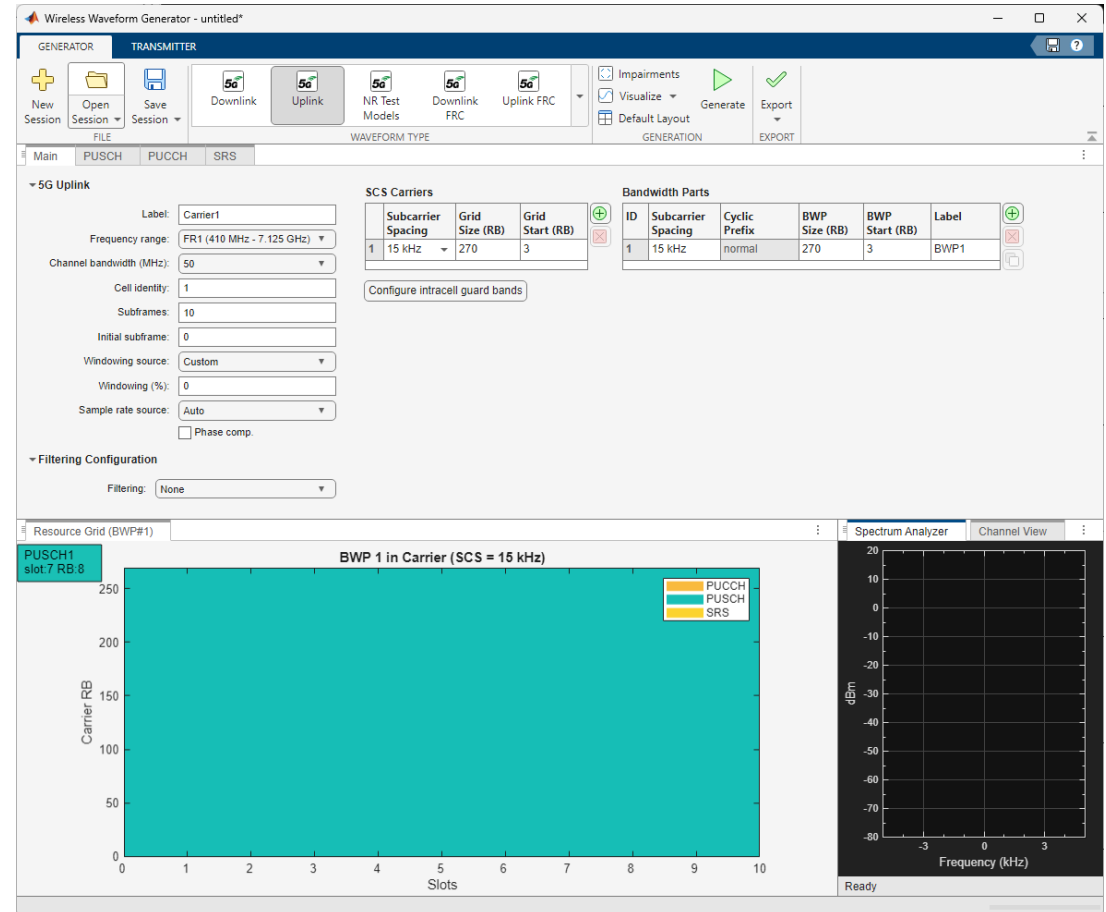
SRS

SRS																	
	Enable	Power (dB)	BWP ID	SRS Ports	Symbol Start	SRS Symb...	Slot Alloc...	Period	Frequ... Start	nRRC	CSRS	BSRS	bHop	Repet...	KTC	kBarTC	
1	<input type="checkbox"/>	0	1	1 ▾	13 ▾	1 ▾	[0:9]	10	0	0	0	0 ▾	0 ▾	1 ▾	2 ▾	0 ▾	  

- Sounding Reference signal (SRS) – sent by UE to enable channel estimation
 - Aperiodic, periodic or semi-persistent (triggered)
- SRS resources are not reported in MIB and SIB1
- Select one example on site
https://www.sharetechnote.com/html/lte_toolbox/Matlab_LteToolbox_5G_SRS_SCS120_2p.html
and show it on the resource grid

Tasks

- Use 5G Waveform Generator for UL
- Explain and illustrate the contents of decoded MSI (Lab4_example_MSI.txt)
 - Carrier, SCSCarrier
 - BWP
 - PUCCH
 - PUSCH
 - SRS



Lab report (1 page PDF)

- Lab number, title, author, date
- Explain and illustrate the contents of scanner decoded MSI (Lab4_example_MSI.txt)
 - Carrier, SCSCarrier
 - BWP
 - PUCCH
 - PUSCH
 - SRS
- Summary and conclusions