

5G NSA Planning: NR Operating Band & SSB Planning(NSA Series#5)

Optimization



Technology



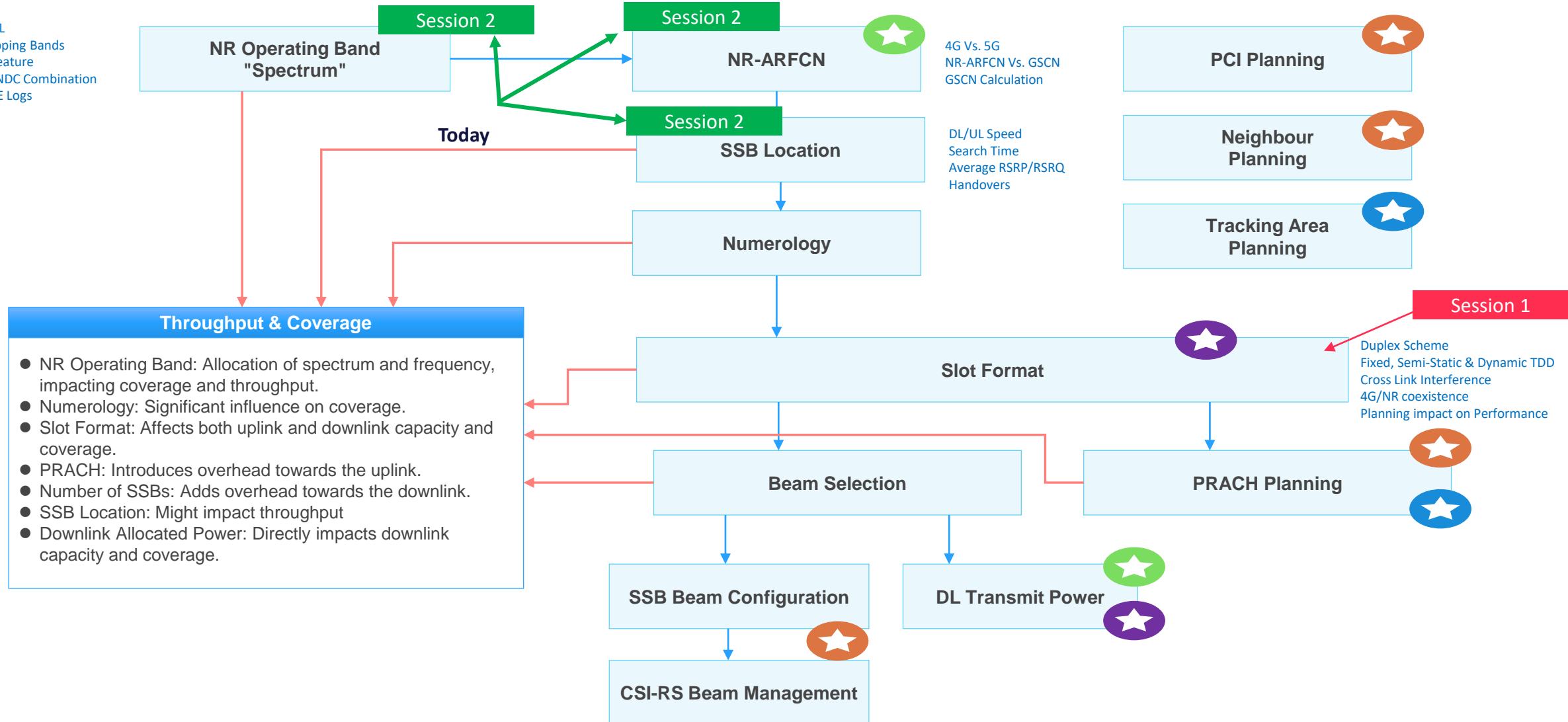
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 ★ Follow 4G
 ★ Regulatory Requirements

SUL/SDL
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 MFBI Feature
 CA & ENDC Combination
 from UE Logs

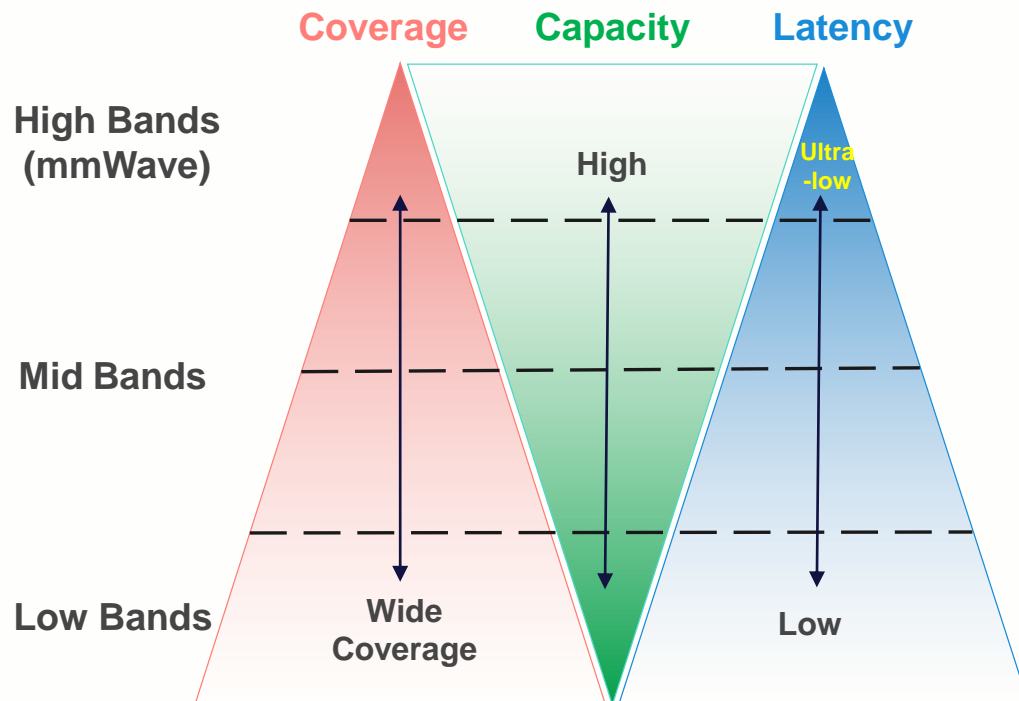


NR Operating Band

- Up to 20x Higher Bandwidth and New Spectrum Definition. (ex. mmwave)
- NR Offers Less Guard-band and Higher spectrum utilization compared to 4G.

Table 5.1-1: Definition of frequency range

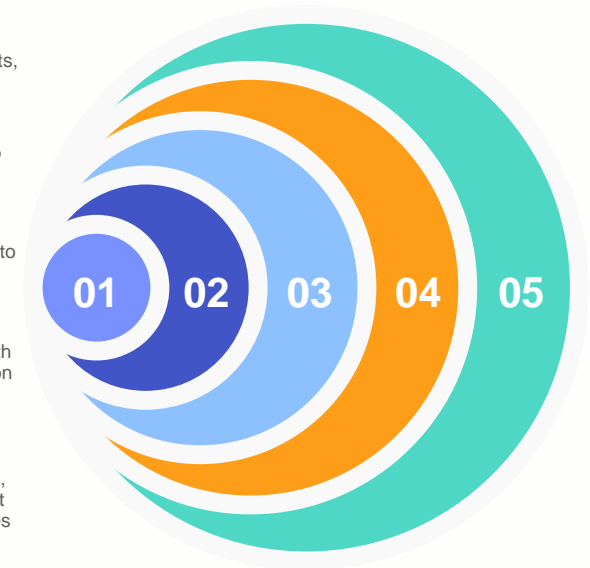
Frequency range designation	Corresponding frequency range
FR1	410 MHz ~ 7125 MHz
FR2	24250 MHz ~ 52600 MHz



*Source: 3GPP TS 38.101-1

NR Operating Bands Considerations

- 01 Coverage and Capacity needs**
Assess how the acquired spectrum will address the operator's coverage and capacity requirements, especially in densely populated areas.
- 02 Bandwidth**
Allocated bandwidth is a key factor contributing to capacity and throughput improvement.
- 03 ENDC Band Combination**
The supported ENDC BW combination is taken into account during any new spectrum auction.
- 04 CA Band Combination**
Operators consider CA band combinations for both contiguous and non-contiguous carrier aggregation.
- 05 Ecosystem and Device Support**
Evaluate the availability of devices and network equipment that support the new spectrum bands, as well as the development of an ecosystem that can leverage the spectrum for innovative services and applications.



NR Operating Band- How to check current bandwidth information from UE Logs?

3GPP TS 38.101- Table 5.2-1: NR operating bands in FR1

NR operating band	FUL_low – FUL_high	FDL_low – FDL_high	Duplex Mode	Band
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD	Low Band
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD	Mid-Band 1
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD	Mid-Band 1
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD	Mid-Band 2
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD	Mid-Band 2
n80	1710 MHz – 1785 MHz	N/A	SUL	Mid-Band 1
n29	N/A	717 MHz – 728 MHz	SDL	Low Band

Table 5.3.2-1: Maximum transmission bandwidth configuration N_{RB}

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	189	217	245	273
60	N/A	11	18	24	31	38	51	65	79	93	107	121	135

Concepts

Supplementary Downlink (SDL)
Supplementary Uplink (SUL)

EN-DC Bandcombination
NR CA Bandcombination

Operating Bands Overlap and
MFBI Feature

RRC Reconfiguration(During SgNB Addition)

```
spCellConfig {
  servCellIndex 7,
  reconfigurationWithSync {
    spCellConfigCommon {
      physCellId 309,
      downlinkConfigCommon {
        frequencyInfoDL {
```

```
  absoluteFrequencySSB [redacted]
  frequencyBandList {
    FreqBandIndicatorNR 78
  },
  absoluteFrequencyPointA ([redacted])
  scs-SpecificCarrierList {
    SCS-SpecificCarrier {
      offsetToCarrier 0,
      subcarrierSpacing kHz30,
      carrierBandwidth 273
```

NR Operating Band – ENDC Band and NR CA Bandcombination



3GPP TS 38.101-3 (5G) Inter-band EN-DC within FR1 (Three bands)

EN-DC configuration	Uplink EN-DC configuration (NOTE 1)
DC_1A-3A_n3A	DC_1A_n3A DC_3A_n3A ²
DC_1A-3A_n5A DC_1A-3C_n5A	DC_1A_n5A DC_3A_n5A DC_3C_n5A

3GPP TS 38.101-3 (5G) Inter-band EN-DC within FR1 (Four bands)

EN-DC configuration	Uplink EN-DC configuration (NOTE 1)
DC_1A-3A_n3A-n41A	DC_1A_n3A DC_1A_n41A DC_3A_n3A ⁴ DC_3A_n41A
DC_1A-3A_n3A-n77A ²	DC_1A_n3A DC_1A_n77A DC_3A_n3A ¹ DC_3A_n77A

3GPP TS 38.101-1 (5G) – Carrier Aggregation

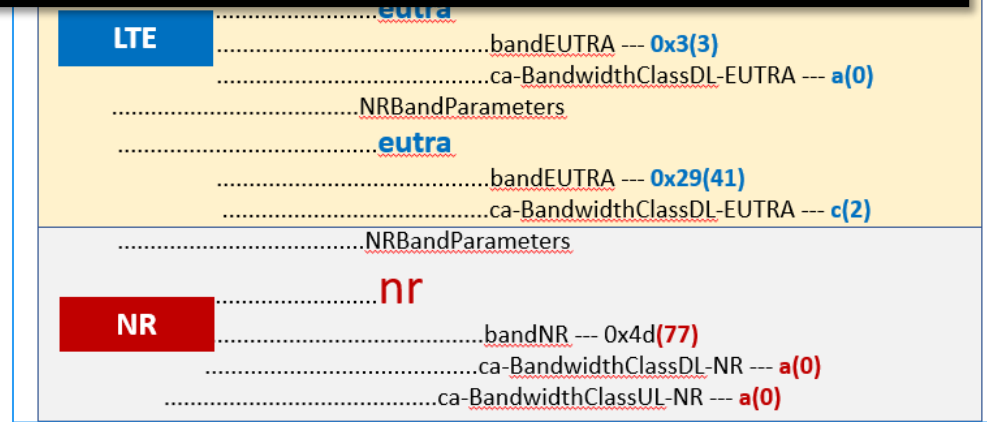
Table 5.2A.1-2: Intra-band non-contiguous CA operating bands in FR1

NR CA Band	NR Band (Table 5.2-1)
CA_n3(*)	n3
CA_n7(*)	n7
CA_n25(*)	n25
CA_n41(*)	n41
CA_n48(*)	n48
CA_n66(*)	n66
CA_n77(*)	n77
CA_n78(*)	n78

Source: 3GPP TS 38.101-3 5G

Source: NR in Bullets

	EN-DC Band Combination	E-UTRA Band 1	E-UTRA Band 2	E-UTRA Band 3	E-UTRA Band 4	NR Band 1	NR Band 2
2 Bands	DC_1_n28	1	-	-	-	n28	-
	DC_1_n40	1	-	-	-	n40	-
3 Bands	DC_1-3_n28	1	3	-	-	n28	-
	DC_1-3_n77	1	3	-	-	n77	-
4 Bands	DC_7_n28_n78	7	-	-	-	n28	n78
	DC_1-3-5_n78	1	3	5	-	n78	-
5 Bands	DC_1-3-7_n28	1	3	7	-	n28	-
	DC_1-3-7-7_n78	1	3	7	-	n78	-
6 Bands	DC_1-3-5-7_n78	1	3	5	7	n78	-
	DC_1-3-5-7-7_n78	1	3	5	7	n78	-
6 Bands	DC_1-3-7-20_n28-n78	1	3	7	20	n28	n78

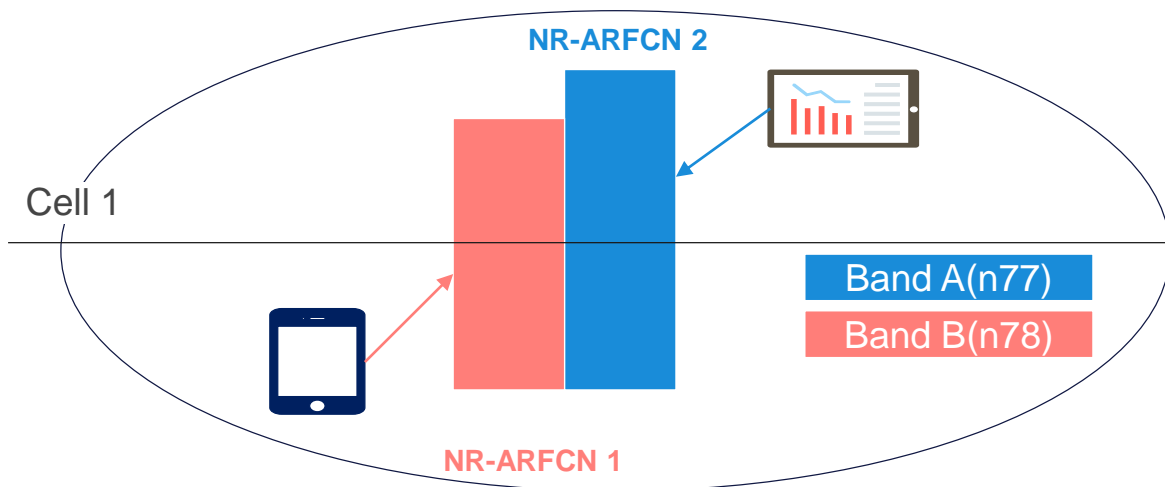


NR Operating Band – Band Overlapping & MFBI Feature



Band	Frequency(MHz)									
n77	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200
n78	3300	3400	3500	3600	3700	3800				

Band	Frequency(MHz)								
n2	1850	1860	1870	1880	1890	1900	1910		
n25	1850	1860	1870	1880	1890	1900	1910	1915	



ENDCX2SETUPRESPONSE for 5G NSA

```

> nrCellID
configured-TAC: [redacted]
> broadcastPLMNs: 1 item
> nrModelInfo: fdd (0)
  > fdd
    > ul-NRFreqInfo
      nRARFCN: [redacted]
      > freqBandListNr: 2 items
        > Item 0
          > FreqBandNItem
            freqBandIndicatorNr: 25
            supportedSULBandList: 0 items
          > Item 1
            > FreqBandNItem
              freqBandIndicatorNr: 2
              supportedSULBandList: 0 items
        > dl-NRFreqInfo
          nRARFCN: [redacted]
          > freqBandListNr: 2 items
            > Item 0
              > FreqBandNItem
                freqBandIndicatorNr: 25
                supportedSULBandList: 0 items
            > Item 1
              > FreqBandNItem
                freqBandIndicatorNr: 2
                supportedSULBandList: 0 items
  
```

SIB1 for 5G SA & 4G

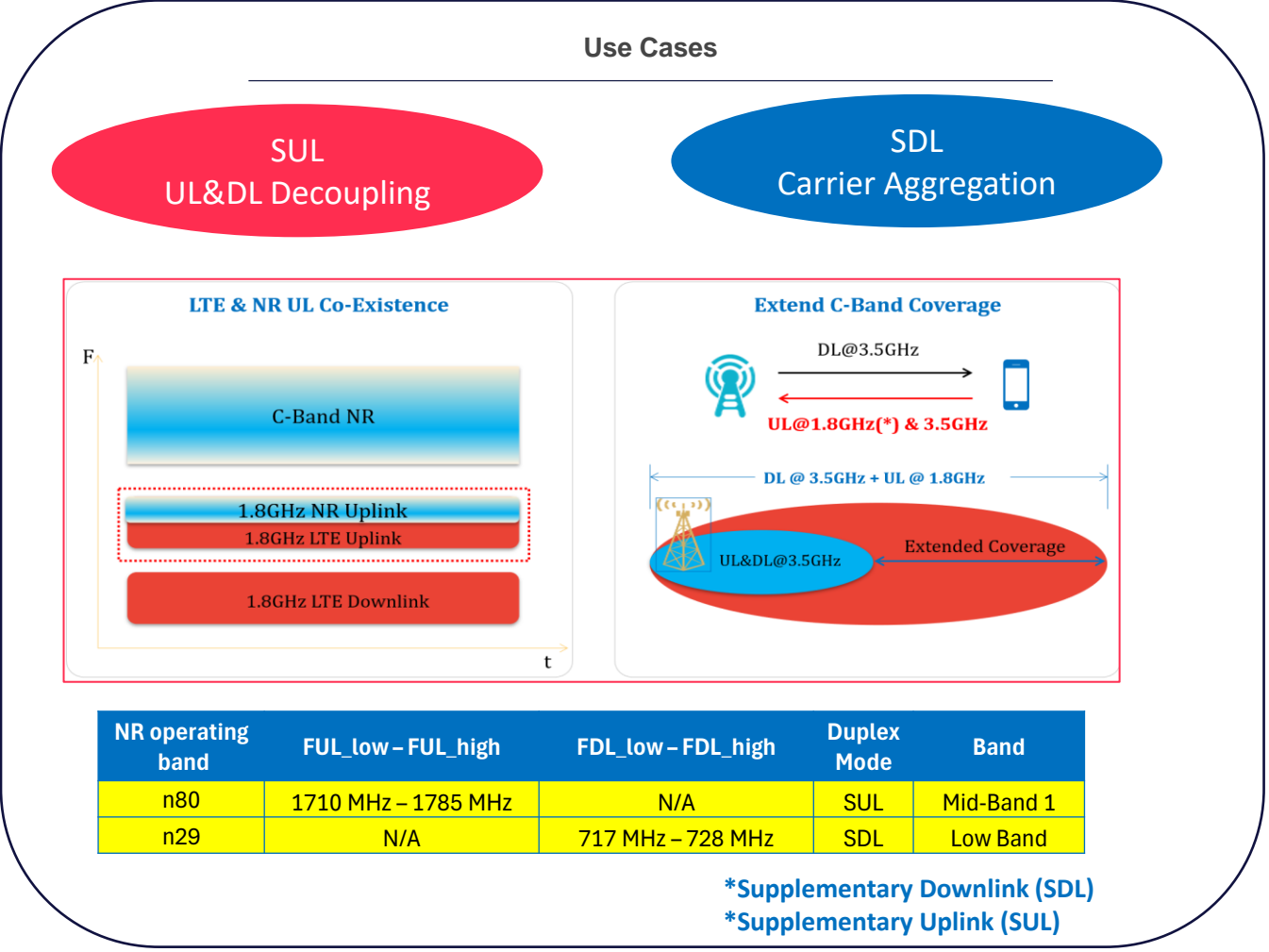
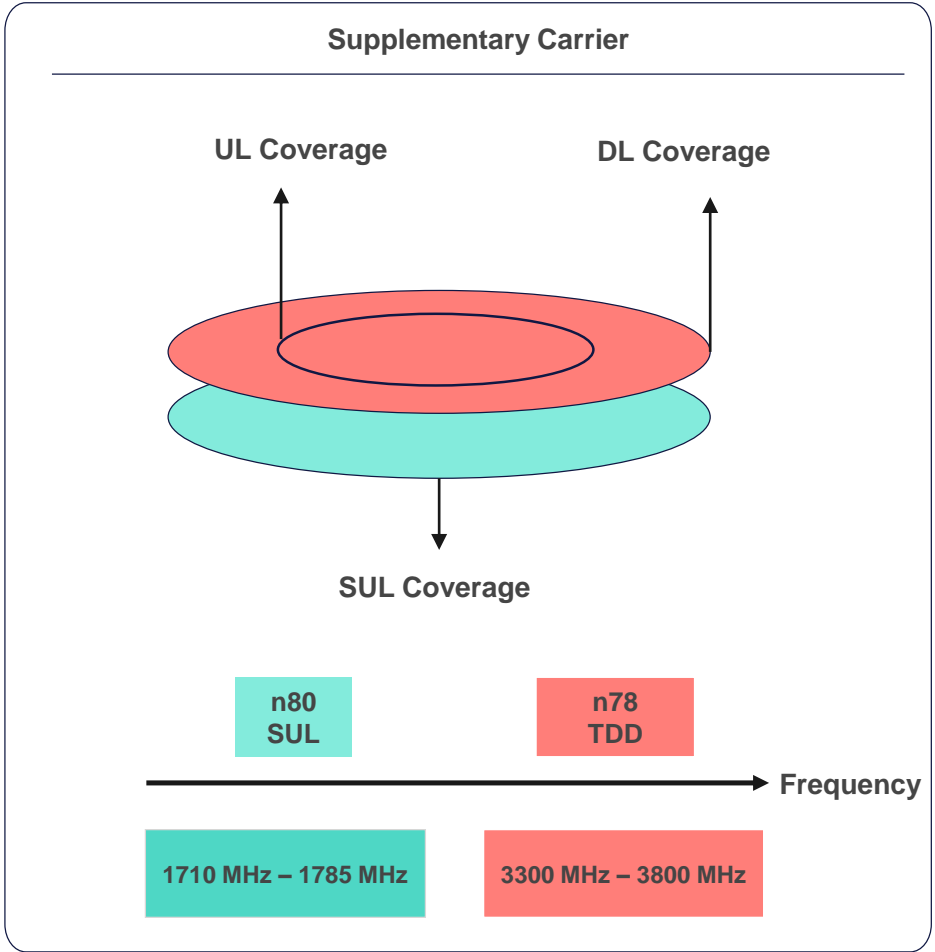
```

downlinkConfigCommon
{
  frequencyInfoDL
  {
    frequencyBandList
    {
      {
        freqBandIndicatorNR 25
      },
      {
        freqBandIndicatorNR 2
      }
    }
  }
}
  
```

Inter-band EN-DC	n77	n78
Inter-band (two bands)	Nb = 96	Nb = 88
Inter-band (three bands)	Nb = 282	Nb = 317
Inter-band (four bands)	Nb = 229	Nb = 323
Inter-band (five bands)	Nb = 57	Nb = 118
Inter-band (six bands)		Nb = 7

- Common UE that supports band A Camps on band A.
- MFBI-capable UE that supports band B but does not support band A Camps on band B.
- MFBI-capable UE that supports band A but does not support band B Camps on band A.

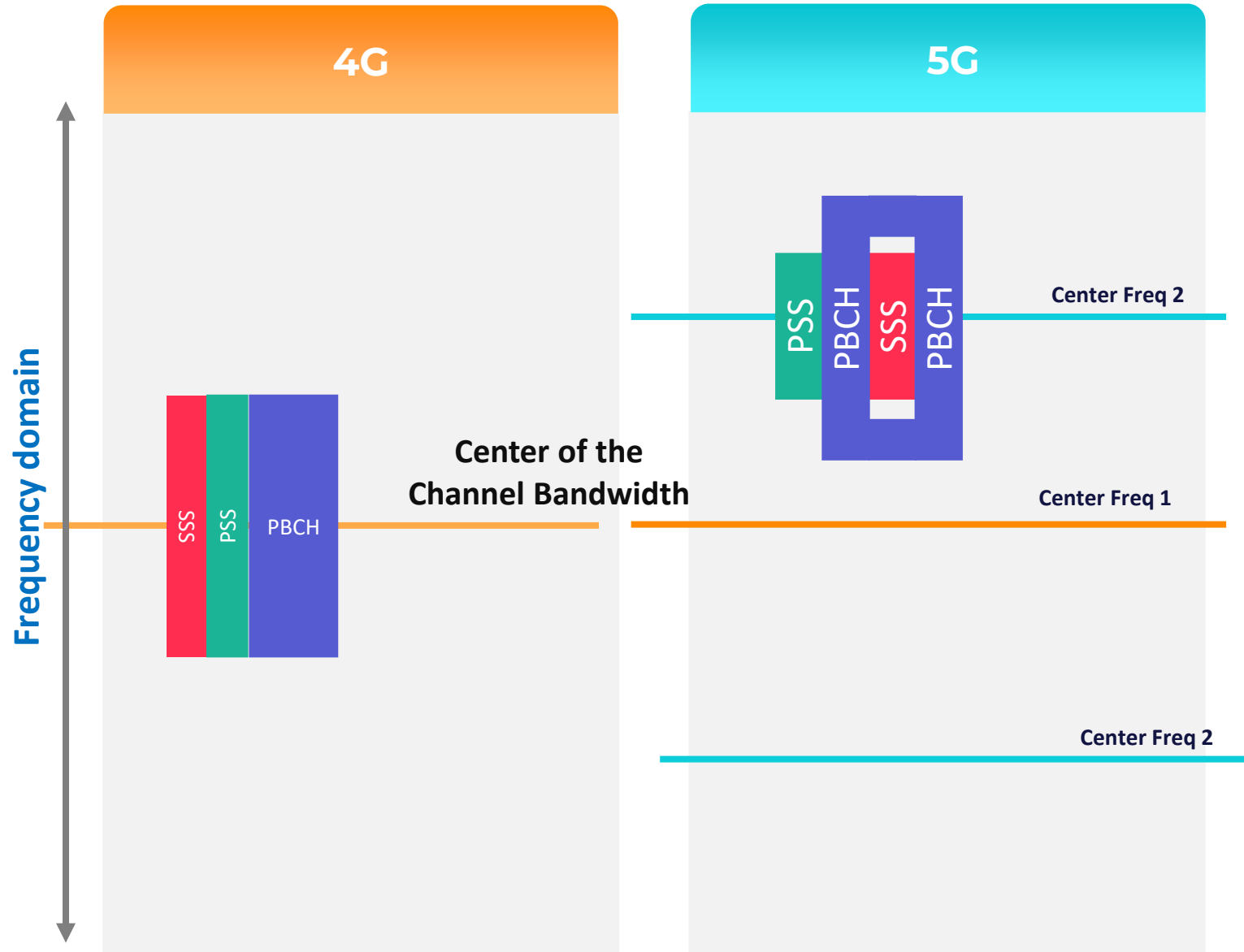
NR Operating Band – Supplementary Carrier



PBCH & Synchronization Signals: 4G Vs. 5G

Differences with LTE

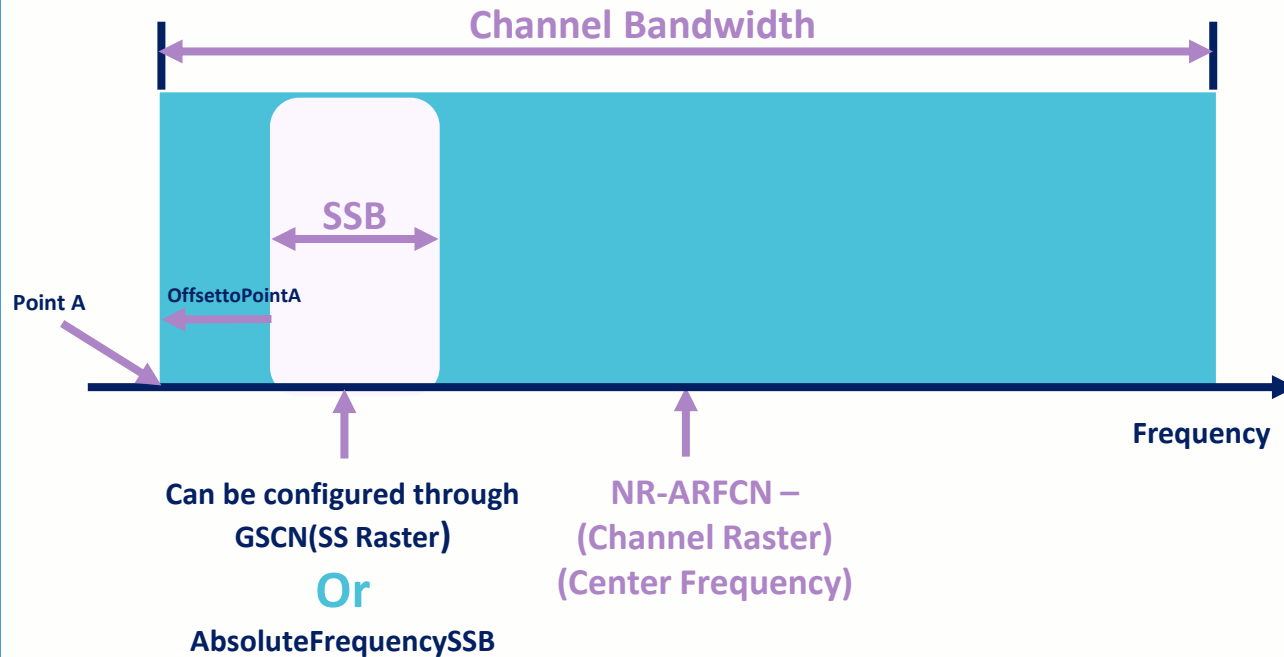
- SS in NR can be flexibly configured in any position on the carrier and do not need to be positioned at the center frequency.
- Each 5G Cell requires to configure 2 center frequencies.
 1. New Radio Absolute Radio Frequency Channel Number (NR-ARFCN) for channel bandwidth
 2. Global Synchronization Channel Number (GSCN) for SS/PBCH Blocks
- SSB Center Frequency Configuration can be configured using two methods
 1. NR-ARFCN (NSA Only)
 2. GSCN (NSA & SA)
- SSB Center Frequency Subcarrier spacings for the PSS/SSS vary with operating frequency bands and are specified by 3GPP.



NR-ARFCN & GSCN (Center Channel BW & SSB Position)

1. NR-ARFCN stands for New Radio Absolute Radio Frequency Channel Number.
2. GSCN stands for Global synchronization channel number, can be used in both 5G-NSA & 5G SA, and is known as a **Synchronization** raster.

2 Center Frequencies required for NR Cell

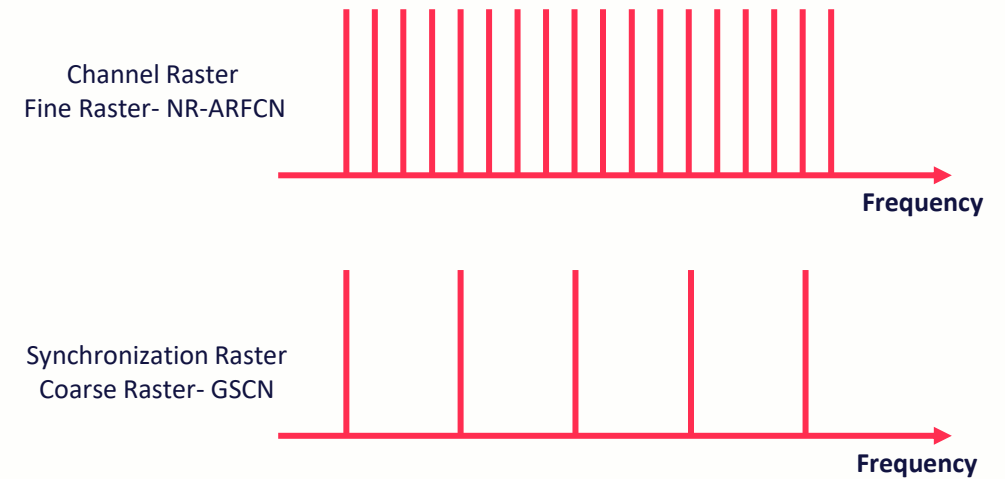


$$\text{NR-ARFCN} = \text{NREF-Offs} + (\text{FREF} - \text{FREF-Offs}) / \Delta\text{FGlobal}$$

GSCN = Formula vary with different band range

2 Center Frequencies required for NR Cell

- The Synchronization Raster defined a set of allowed center frequencies for the Synchronization Signal / Physical Broadcast Channel block.
- The Synchronization raster has a relatively low resolution (1.2, 1.44 & 17.27 MHz) to reduce the number of positions a UE must check when completing a band scan, i.e., the band scan procedure becomes faster and more efficient.



SSB Frequency Location identification and calculation methods

1. ARFCN is used to calculate center channel bandwidth and Absolute-SSB-Frequency and is called channel raster.
2. It is used **only in 5G-NSA**.
3. The Channel Raster has a relatively **high resolution** using Low-Frequency scan granularity (**15,30,60 & 100Khz**).
4. The Absolute Radio frequency Number is **delivered in the** RRC Reconfiguration message, which means that the UE will receive the SSB Frequency domain position directly from the 4G Leg.

ARFCN-Calculation

$$NR-ARFCN = NREF-Offs + (FREF - FREF-Offs) / \Delta F_{Global}$$

Frequency range (GHz) "Input"	ΔF Global (KHz) "Input"	FREF-Offs (MHz) "Input"	NREF-Offs "Input"	Range of NR-ARFCN 'Out-put'
0 - 3000	5	0	0	0 - 599999
3000 - 24250	15	3000	600000	600000 - 2016666
24250 - 100000	60	24250.08	2016667	2016667 - 3279165

The center frequency proposed " FREF" is **2530Mhz**, which falls in the first category, which means that **ΔF Global & FREF-Offs = zero**.

$$NR-ARFCN = 0 + (2530000Khz - 0) / 5Khz = 506000$$

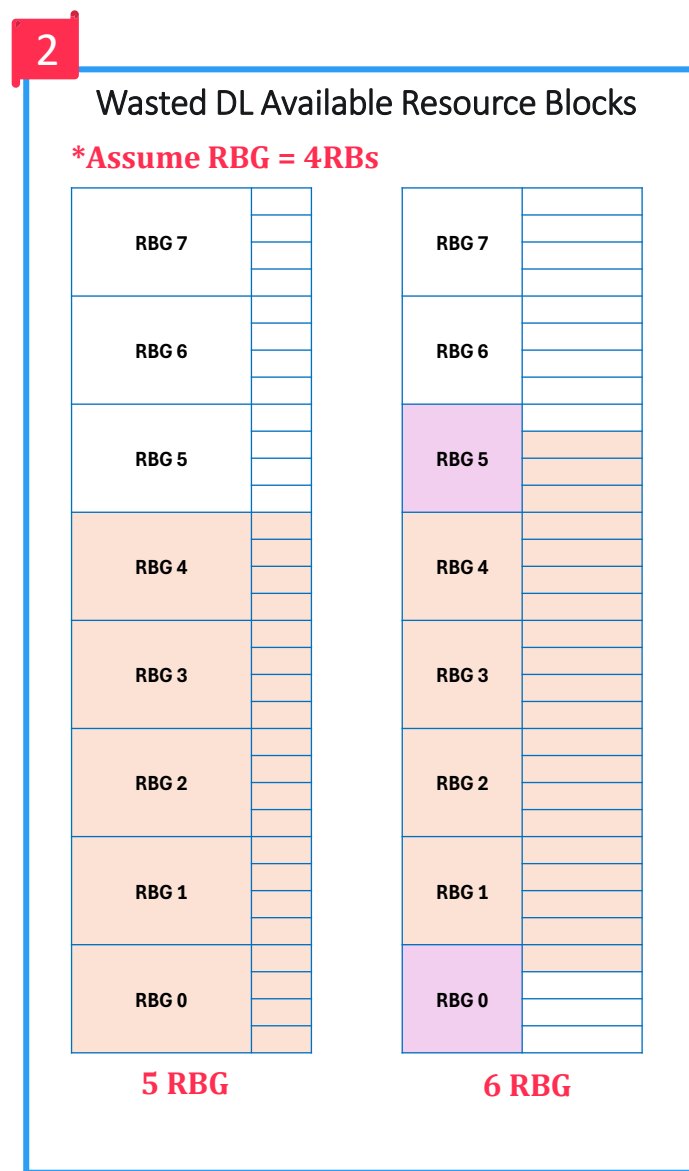
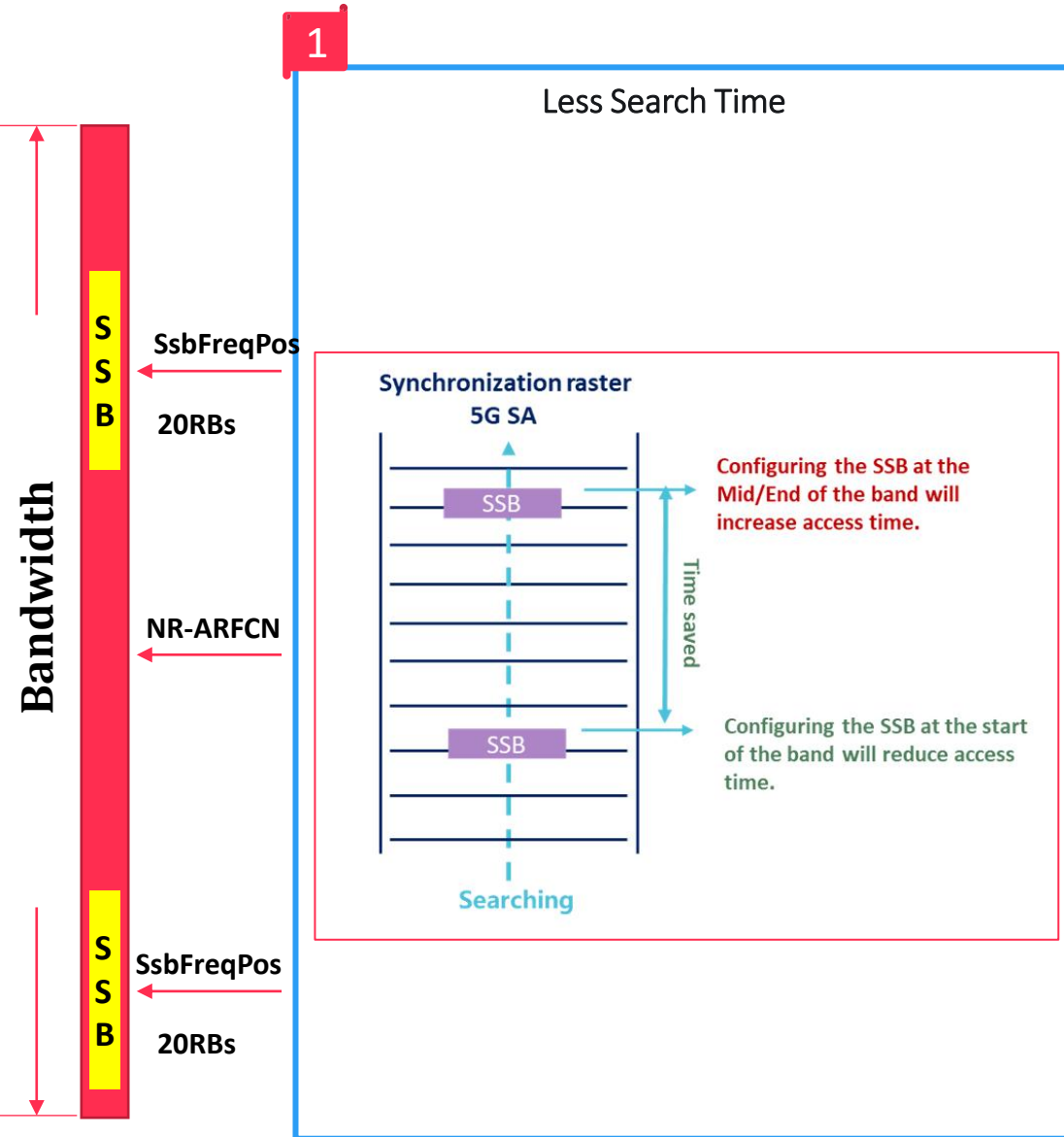
*FREF: Center Frequency

GSCN

Frequency range (GHz)	Range of N	Range of M	SSB Frequency Position SSREF	GSCN
0 - 3000	1 - 2499	1,3,5	$N * 1.2MHz + M * 50kHz$	$3N + (M-3)/2$
3000 - 24250	0 - 14756	-	$3000MHz + N * 1.44MHz$	$7499 + N$
24250 - 100000	0 - 4383	-	$24250.08MHz + N * 17.28MHz$	$22256 + N$

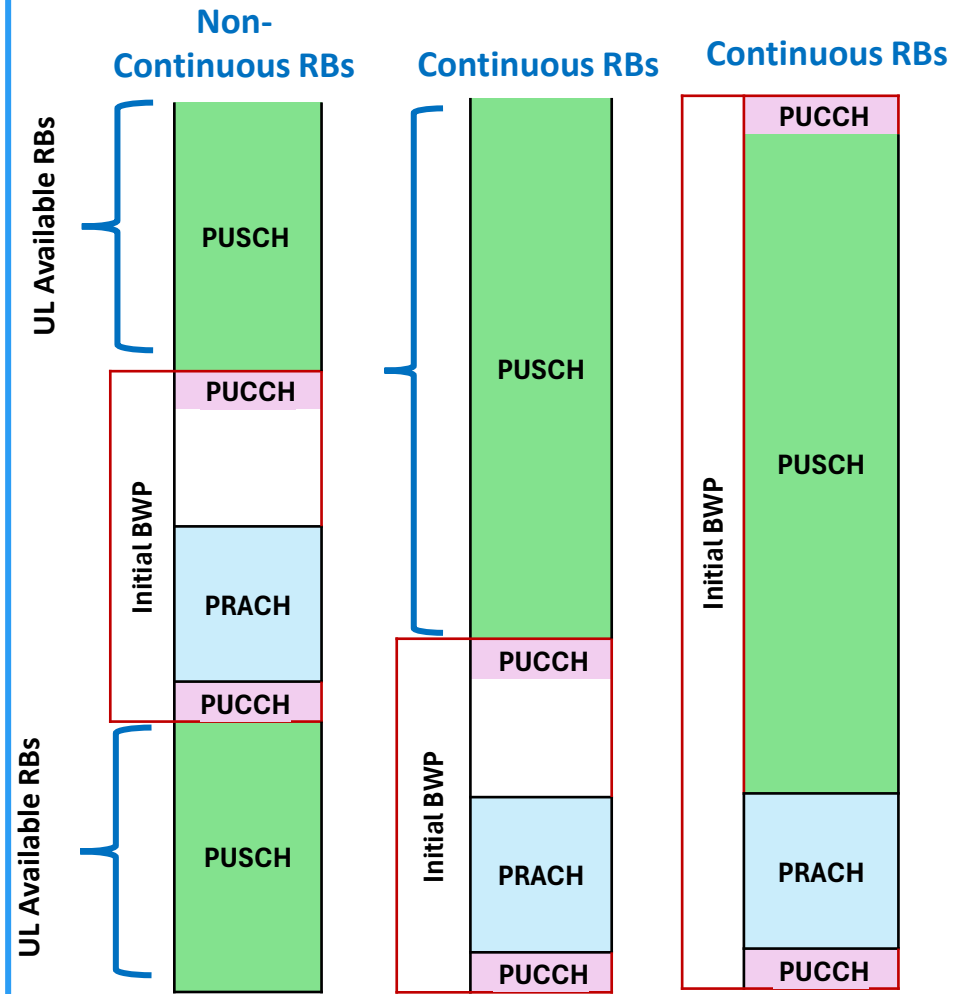
- The GSCN is equivalent to NR-ARFCN used by channel raster and is defined in 3 sections to increase spacing between raster entries to shorten the initial access time for higher operating bands.
- The N and M Variables maintain subcarrier alignment between the main channel and SS-PBCH when using the 100 kHz Channel Raster.
- Operating bands above 3 GHz do not use the 100 kHz channel raster.

SS/PBCH different positions impact(1)



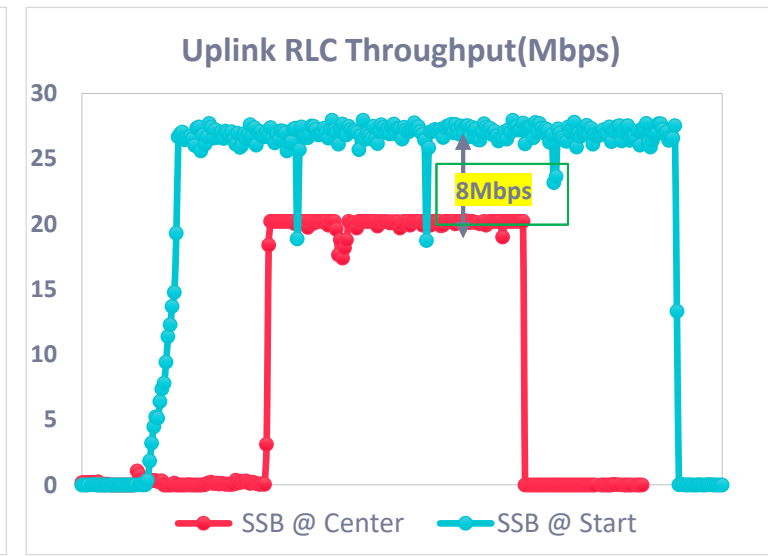
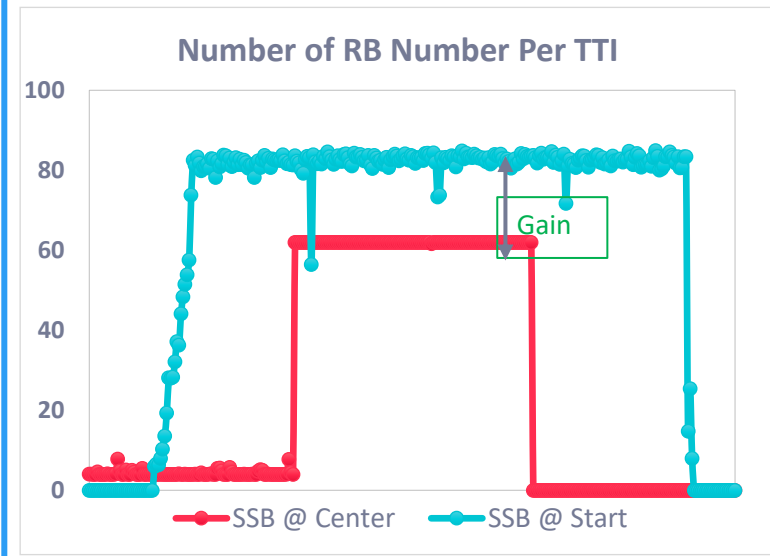
SS/PBCH different positions impact(2)

Different SSBs Position Simulation



Field Results

- 23 RBs more are allocated when SSB frequency position is configured @ start.
- UL Throughput increased by 8 Mbps



*Traces for Device only Support UL RA Type 1

*NR BW = 40 Mhz

UE Capability Check

```

...ra-Type0-PUSCH --- supported(0)
...dynamicSwitchRA-Type0-1-PDSCH --- supported(0)
...dynamicSwitchRA-Type0-1-PUSCH --- supported(0)
...pdsch-MappingTypeA --- supported(0)
...pdsch-MappingTypeB --- supported(0)

```