All what you need to know about 5G SSB

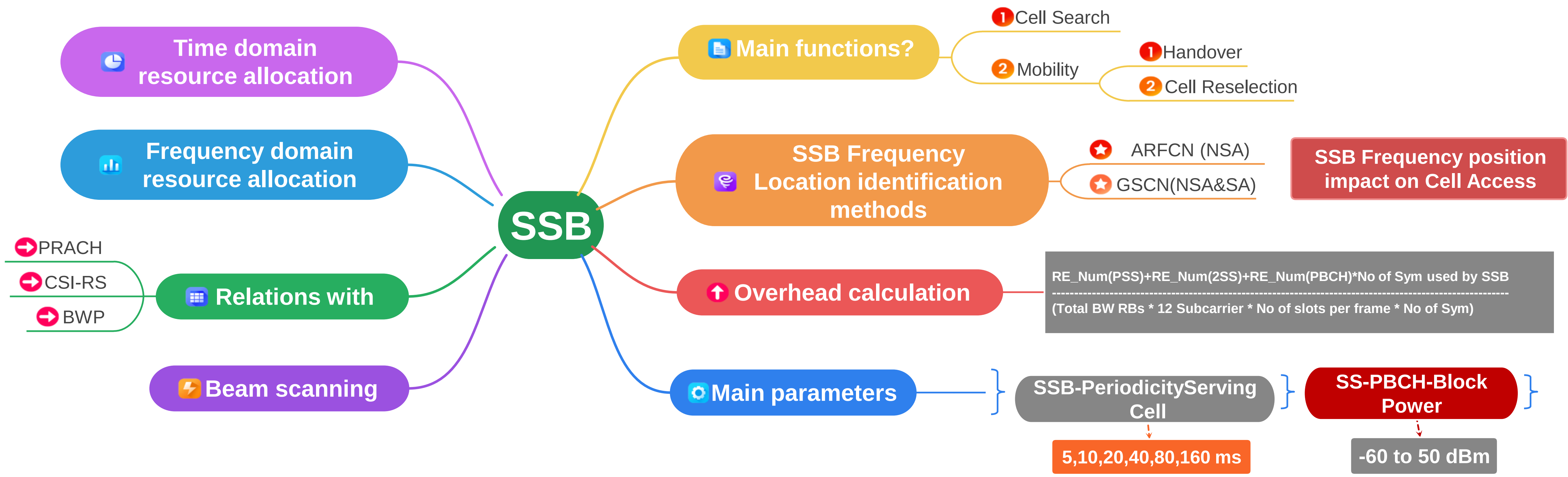
Optimization

Technology

Mohamed Eladawi

All information about: What we need to know about 5G SSB

In this video, we are going to cover most of what we need to know about 5G SSB ”Synchronization signal block”, let's have a look into the following mind-mapping figure which covers most of the related information about SSB.



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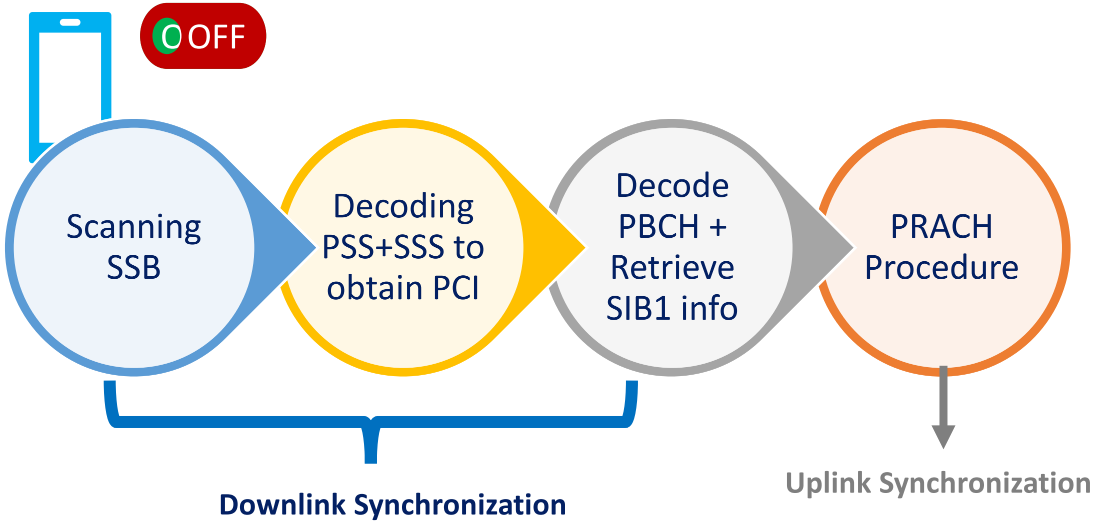
What are the meaning and main functionality of SSB?

1. SSB stands for synchronization signal block and is used during Cell Search and Mobility.
2. It consists of PSS, SSS, and PBCH.
3. It Occupy 20RBs and 4Symbols.



PCI Calculation

$$N_{ID}^{cell} = 3N_{ID}^{(1)} + N_{ID}^{(2)}$$

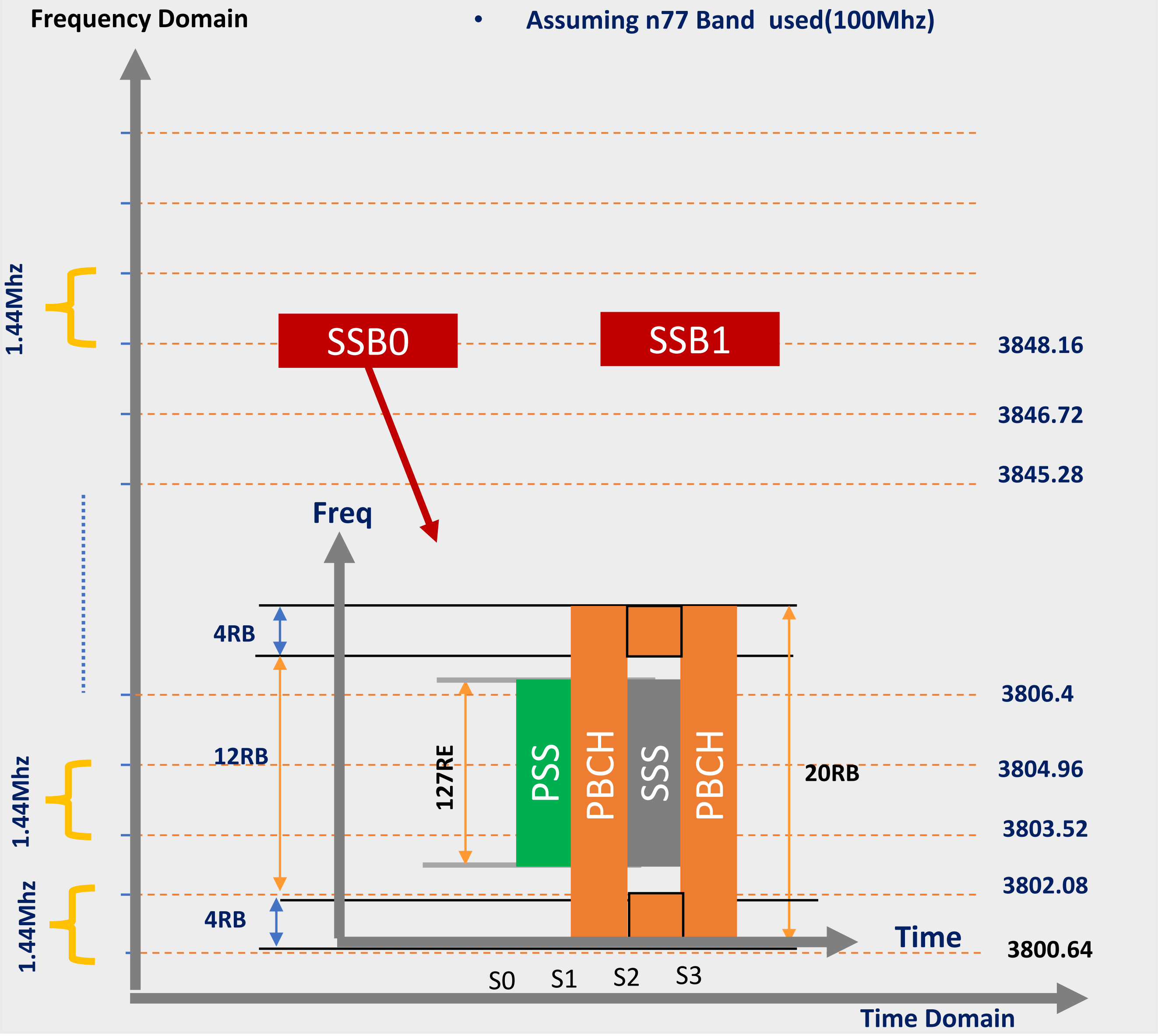
Where
$N^{(1)}_{ID}$ = (SSS) and its range is from {0 to 335}
$N^{(2)}_{ID}$ = (PSS) and its range is from {0, 1, 2}

SIB1 Content

- RxLevMin , RxLevMinOffset. Etc…
- Related scheduling parameters for SIB 2 →9.
- (T300, T301 , T310 , N310 , T319,**etc**
- RACH parameters.

SSB Frequency position detection simulation

- **Assuming SSB configured at mid of the band**
- **Assuming n77 Band used(100Mhz)**



What are the methods used to configure SSB Frequency Location?

- The main question that might come to your mind is, How do we configure the SSB Frequency position?
- Generally, two main ways are used to configure the SSB Frequency position.

ARFCN

"Absolute Radio-frequency channel number"

1- It is delivered in the RRC Reconfiguration message to inform the UE about the center frequency of SSB Block directly.

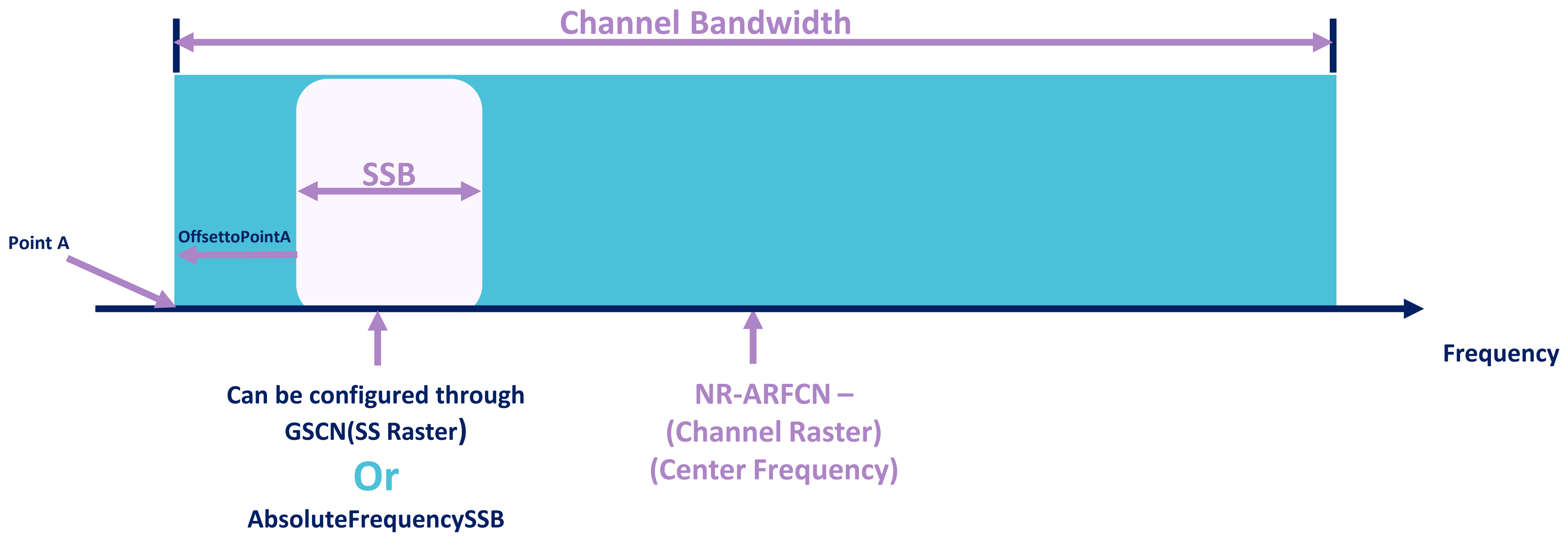
2- Mainly used in 5G NSA and Handovers.

GSCN

"Global Synchronization Channel Number"

1- It is used to Define a set of allowed center frequencies for the SSB block.

2- It can be used in 5G NSA & SA.



SSB Frequency Location identification and calculation methods

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Method 1 - Channel Raster -ARFCN

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) / ΔFGlobal

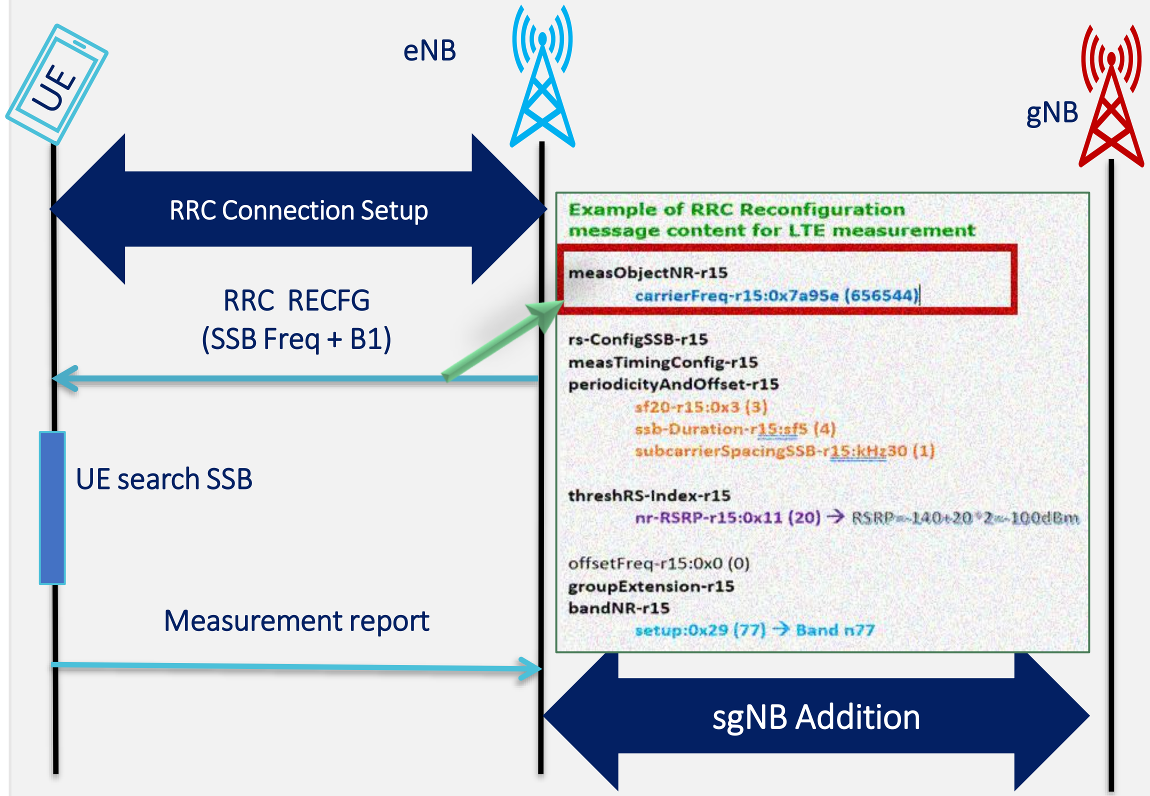
Frequency range (GHz) "Input"	ΔF Global (KHz) "Input"	FREF-Offs (MHz) *"Input"*	NREF-Offs *"Input"*	Range of NR-ARFCN 'Out-put"
0 - 3000	5	0	0	0 - 599999
3000 - 24250	15	3000	600000	600000 - 2016666
24250 - 100000	60	24250.08	2016667	2016667 - 3279165

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**

Signaling Overview



SSB Frequency Location identification and calculation methods

Method 2 – Synchronization raster Raster -GSCN

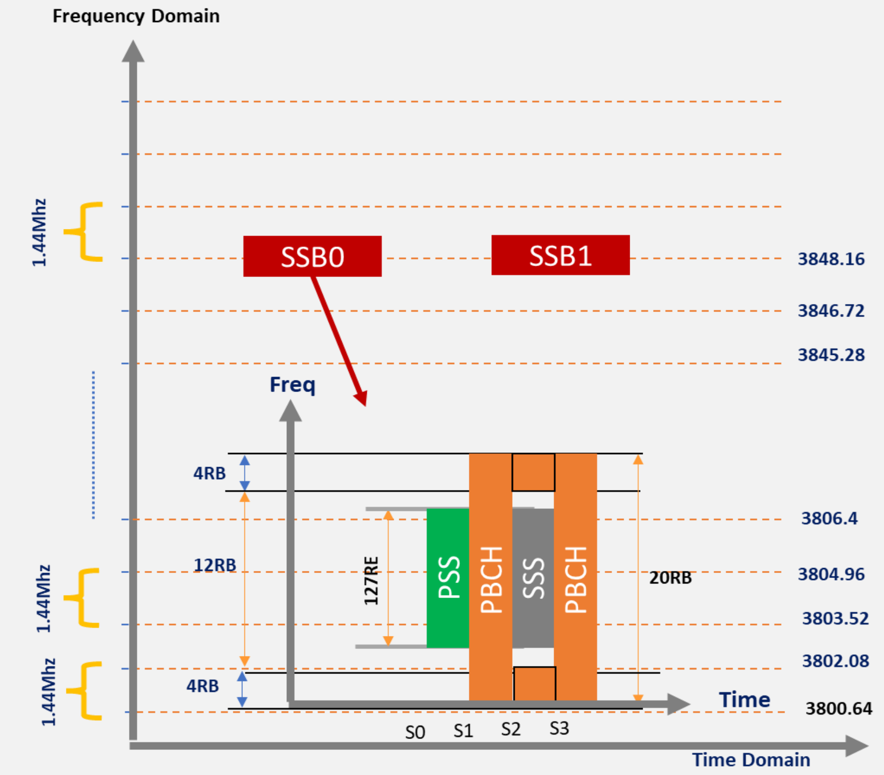
1. GSCN stands for Global synchronization channel number, can be used **in both 5G-NSA & 5G SA,** and is known as a **Synchronization** raster.
2. The Synchronization Raster defined **a set of allowed center frequencies** for the Synchronization Signal / Physical Broadcast Channel block.
3. The Synchronization 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.

GSCN-Calculation

Frequency range (GHz)	Range of N	Range of M	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.

Initial Access in 5G SA done through blind detection and scanning



Frequency domain resource allocation

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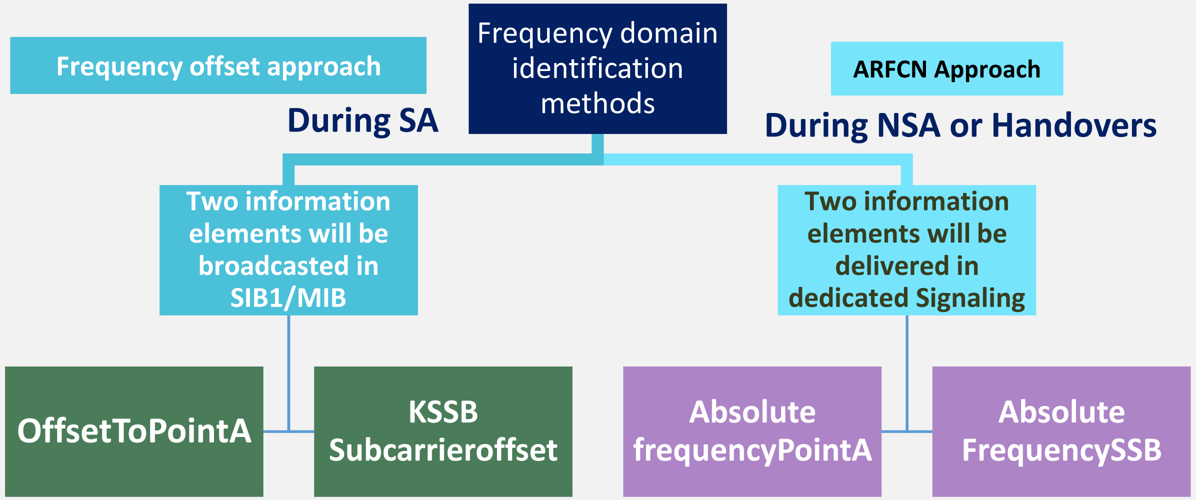
What exactly does it mean by frequency resource allocation in SSB?

- Well, after the UE blindly detect SSB during the initial access, still frequency resource location is not known to the UE,
- accordingly, additional information will be delivered to the UE to be able to find and specify SS/PBCH block frequency domain position within the channel bandwidth.

- In general, there are two methods to identify the frequency domain position of the UE during 5G Standalone and Non-Standalone



AbsolutefrequencyPointA : Absolute frequency position of the reference resource block (Common Resource Block 0). Its lowest subcarrier is also known as Point A and it represents the frequency-location of point A expressed as in ARFCN

OffsettoPointA: Defines a resource Block offset between **Common Resource Block 0** and **Common Resource Block** which overlaps with the start of the SSB

AbsoluteFrequencySSB: identifies the position of resource element subcarrier 0 of resource block 10 of the SS block (expressed as in ARFCN)

kSSB: Defines a subcarrier offset from **subcarrier 0** of the Common resource Block identified by offsettoPointA to the **subcarrier 0** of SSB

Frequency domain resource allocation

Frequency offset Approach/Method 1 - Illustration

After UE completes the band scan and identifies SSB frequency domain, the UE **Still does not know the position of channel bandwidth relative to SSB,**

The UE will decode MIB/SIB1 to retrieve a combination of Kssb and OffsetoPointA information to locate the Channel Bandwidth position.

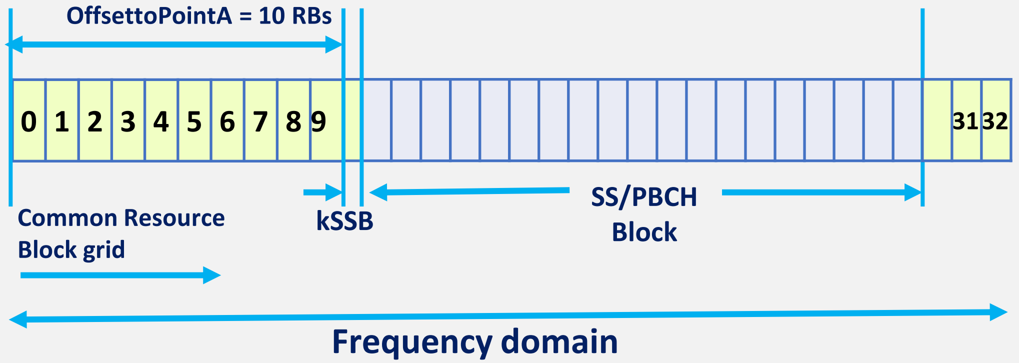
MIB

System frame number:--
subCarrierSpacingCommon:scs30or120
ssb-SubcarrierOffset:0x2(KssB)

SIB1

frequencyBandList
freqBandIndicatorNR: XXX
offsetToPointA:0x10(Number of RBs)

Frequency offset to SSB from point A = Offset to Point A + kSSB

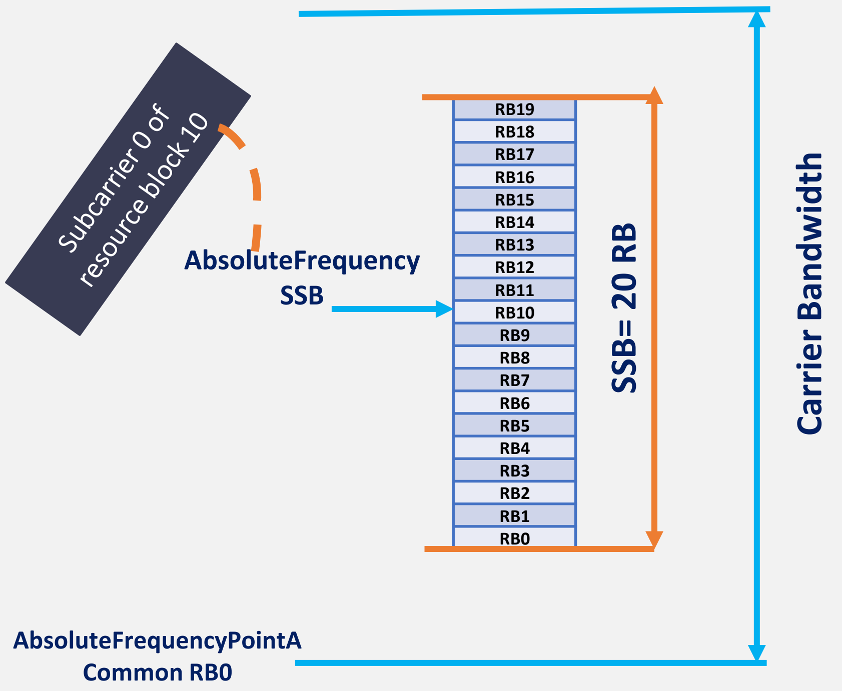


ARFCN Approach/Method 2 - Illustration

The Frequency domain of an SS/PBCH Block within the channel bandwidth can be specified using a pair of absolute frequencies delivered in the dedicated signaling “RRC Reconfiguration message.”

RRC Reconfiguration “spCellConfig”

1- absoluteFrequencySSB 656544(ARFCN)
2- absoluteFrequencyPointA 653378(ARFCN)
OffsettoCarrier 0
SubCarrierSpacing kHz 30
CarrierBandwidth 51



Time domain resource allocation

According to 3GPP 38213-h30, the first symbol indexes for candidate SS/PBCH blocks are determined according to → (1) SCS of SSB blocks, (2) Frequency Band, and (3) Duplex mode.

The number of SSB beams supported in a cell will be indicated through a parameter called SSB-PositionInBurst.

Example from Layer3

ServingCellConfigCommonSIB

Ssb-PositionsInBurst

inOneGroup1111000

1 indicates active SSB
0 indicates inactive SB

The Below figure will illustrate how the SSB resources will be allocated in the time domain for Case A to C

<table>
<tr><th rowspan="2">SCS</th><th rowspan="2">Case</th><th rowspan="2">Band</th><th colspan="14">1st Slot</th><th colspan="14">2nd Slot</th><th colspan="14">3rd Slot</th><th colspan="14">4th Slot</th></tr>
<tr><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th></tr>
<tr><td>15Khz</td><td>A</td><td><3GHz</td><td></td><td></td><td colspan="4">SSB1</td><td></td><td></td><td colspan="4">SSB2</td><td></td><td></td><td></td><td></td><td colspan="4">SSB3</td><td></td><td></td><td colspan="4">SSB4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

***Five-time domain positions (Case A to case E) are specified according to the protocol**
***TDD 2.4 Band is currently using Case C**
*** All SSBs will be transmitted in total 5ms, usually in the first half of the frame**

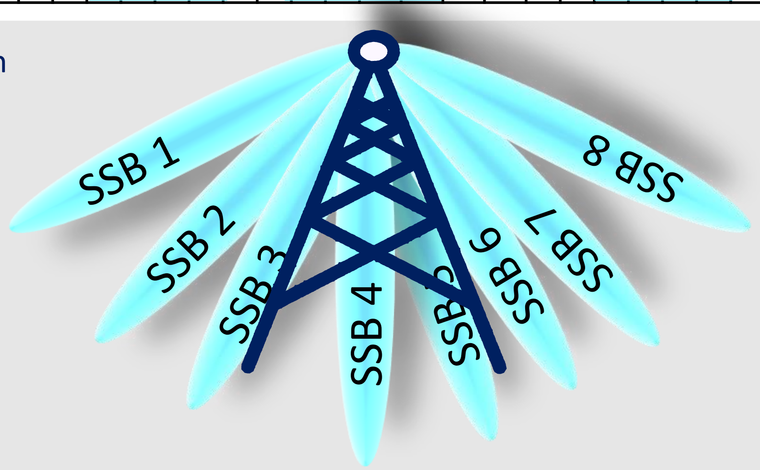
SSB Beam Sweeping/Scanning

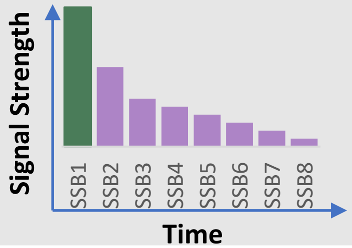
- Beam sweeping is a new concept newly introduced in 5G where g-NodeB can transmit a sequence of SSB beams in a different direction.
- Simply, gNB can transmit a sequence of SSB beams; beam sweeping is implemented by changing the direction of each SSB Transmission.

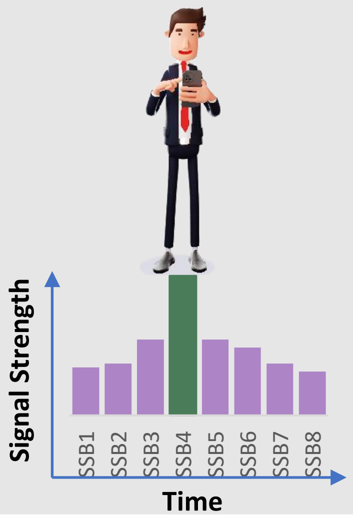
SCS	Case	Band	1st Slot														2nd Slot														3rd Slot														4th Slot													
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	0	1	2	3	4	5	6	7	8	9	10	11	12	13	0	1	2	3	4	5	6	7	8	9	10	11	12	13	0	1	2	3	4	5	6	7	8	9	10	11	12	13
30Khz	C	<3GHz			SSB1						SSB2								SSB3						SSB4								SSB5						SSB6								SSB7						SSB8					

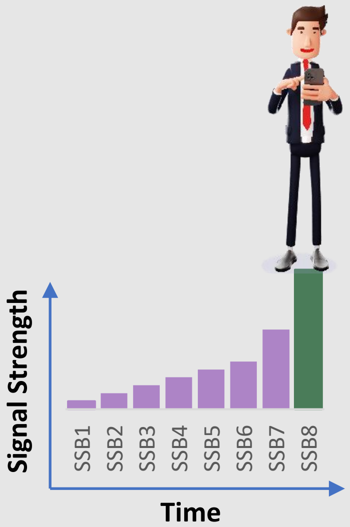
All beams are simultaneously active, but each beam is allocated a separate SS/PBCH block within the SS/PBCH Burst, so each beam transmits its SS/PBCH Block with different timing.

This allows the UE to see the transmissions from each beam and beam indices, which clearly can be identified based on the timing of the SS/PBCH block.









Main Parameters

3GPP TS 38.213 specified 3 main parameters that can be tuned for SSBs and are being transmitted through SIB1 or Dedicated Signaling(RRC Reconfiguration message)

Parameter Name	Description	Value
SSB Periodicity	1-SSB Periodicity specifies the periodicity of SSB Burst 2-In other words, it controls the number of times the SSB will be transmitted in the time domain	(5, 10, 20, 40, 80, 160ms)
Ss-PBCH-BlockPower	Indicates the power of a single resource element used by SSS/PBCH/DMRS	(-60 to 50 dBm)
SSB-PositionInBurst	The inOneGroup bit string indicates which SS/PBCH within a group are active	Ex1: 1111000(means 4 SSBs are transmitted) Ex2 : 1111111(means 8 SSBs are transmitted)

Example from Layer3

ServingCellConfigCommonSIB

Ssb-PositionsInBurst

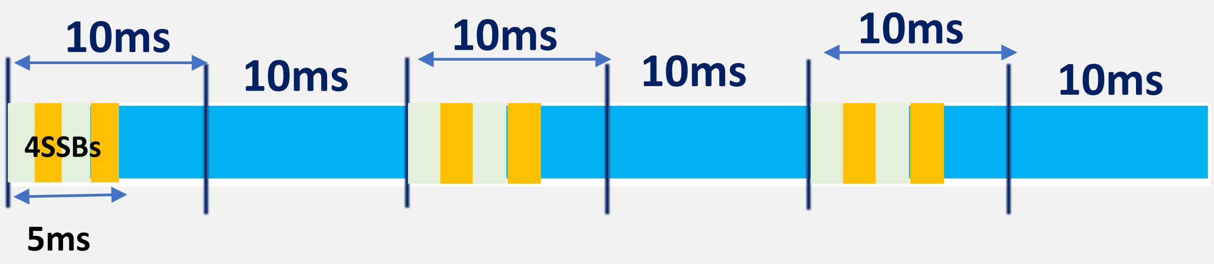
inOneGroup1111000

ssb-PeriodicityServingCell:m20

ss-PBCH-BlockPower: 0x13(19)

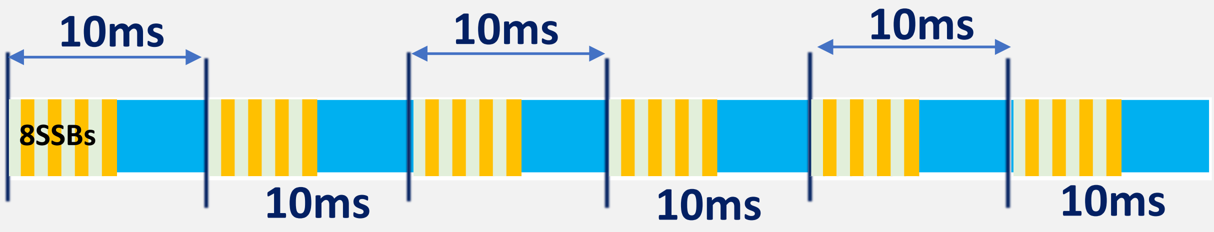
Example1 will simulate

1. SSB Periodicity → 20ms
2. SSB-PositionInBurt→ 1111000 (4SSBs are active)



Example2 will simulate

1. SSB Periodicity → 10ms
2. SSB-PositionInBurt→ 11111111 (8SSBs are active)



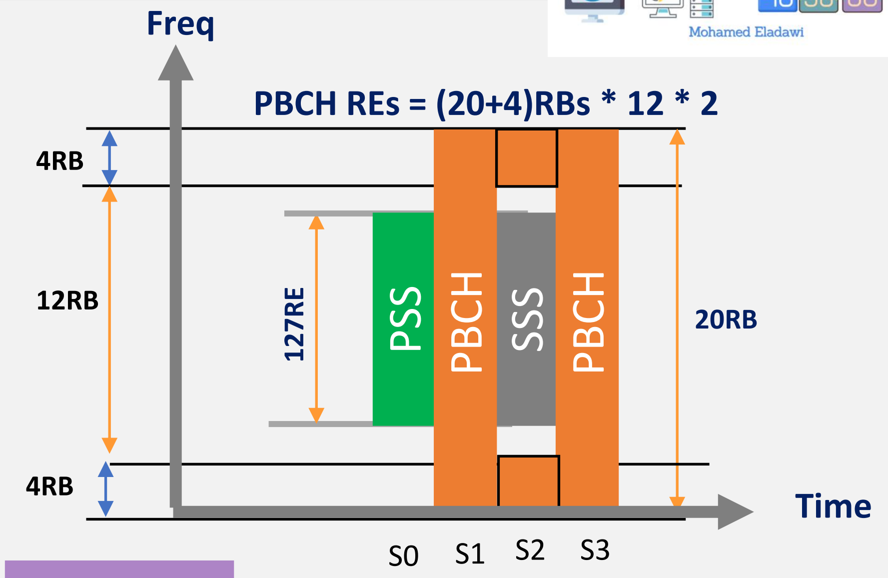
Frame

Overhead calculation

The Overhead consumed by SSB will vary with different Bandwidths and SCS configurations. The following are the main factors involved in SSB overhead calculation.

1. The sum of the Number of PSS, SSS, and PBCH Resource elements (Fixed Values)
2. Number of SSBs in a frame(Changes based on configuration)
3. Total Resource blocks (Variables), Total number of slots per frame(Variables)
4. Total Number of symbols(Fixed Values)

In more simple words, you need to calculate the total number of resource elements being used by SSBs in a frame and then divide it by the complete available resources in the frame; let's have a look at the formula suggested for calculating SSB overhead%



SSB Overhead % = (PSS REs + SSS REs + PBCH REs × No of SSBs in frame) / (Total RBs × 12 subcarrier × No of slots per frame × No of symbols)

Now assume

Bandwidth = 40Mhz
SCS = 30Khz
No of SSB beams =8

SSB Overhead % = (127 PSS REs + 127 SSS REs + 576 PBCH REs × 8SSBs) / (106RB (40Mhz) × 12 subcarrier × 20Slots (SCS 30Khz) × 14 Symbols) = 1.94%