Initial Access
Synchronization Signal Block (SSB) in 5GNR

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What is the use of a SSBlock?

- Cell Search
  - To initially search for a cell and "lock on" to the network
  - Cell search (new cells) for mobility when the UE is in idle/inactive state

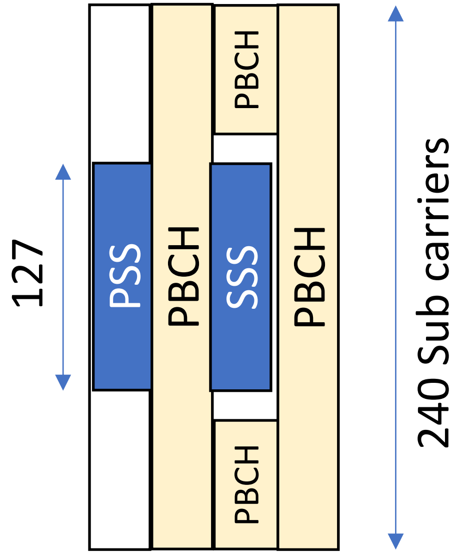
- Initial Search
  - Must obtain a reference point (time and frequency) in the grid
  - Must obtain some basic parameters of the cell
    - Cell ID, Coreset0 location, SCS??
  - Must have the ability by decoding some control information
    - to perform the next step (PRACH).

Bits or Physical waveforms

- When a UE does an initial search
  - It does not know anything about the network
    - Doesn’t even know the SCS
- So, sending information using bits will be difficult
- Information/synchronization has to be broadcasted using waveforms
- Information is obtained by “correlating” waveforms.

SS Block (Synchronization signal block)

- Consists of
  - PSS (Primary Synchronization signal)
  - SSS (Secondary Synchronization signal)
  - PBCH (Physical Broadcast signal)
- An SS block spans
  - 4 OFDM symbols (numbered from 0 … 3)
  - 240 sub carriers (numbered from 0 … 239) (20 RB)
- PSS: 127 SC
- SSS: 127 SC , (8 +9) empty SC, 48 SC each for PBCH
- PBCH: 2nd OFDM symbol, 4th OFDM symbol, 48 SC on both sides of SSS



These must be set to zero

$$v = N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 4$$

Channel or signal	OFDM symbol number l relative to the start of an SS/PBCH block	Subcarrier number k relative to the start of an SS/PBCH block
PSS	0	56, 57, …, 182
SSS	2	56, 57, …, 182
Set to 0	0	0, 1, …, 55, 183, 184, …, 239
	2	48, 49, …, 55, 183, 184, …, 191
PBCH	1, 3	0, 1, …, 239
	2	0, 1, …, 47, 192, 193, …, 239
DM-RS for PBCH	1, 3	$0+v, 4+v, 8+v, \ldots, 236+v$
	2	$0+v, 4+v, 8+v, \ldots, 44+v$ $192+v, 196+v, \ldots, 236+v$

No of RE for PBCH: 576 (240+240+48+48)
No of DMRS RE: 144
No of information RE for PBCH = 576-144 =432

Physical-layer cell ID

- There are **1008** unique-physical layer cell ID's in 5G NR
  - 504 in LTE
- Encoded in PSS and SSS sequences

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

where $N_{\text{ID}}^{(1)} \in \{0,1,\ldots,335\}$ and $N_{\text{ID}}^{(2)} \in \{0,1,2\}$.

- Required to decode physical layer information
  - Pilot generation uses this as a "random seed"

*Not to be confused by cell ID

Primary Synchronization Signal (PSS)

- M Sequence (Maximal length sequence)
- Modulation: BPSK

$$d_{PSS}(n) = 1 - 2x(m)$$

$$m = \left(n + 43N_{ID}^{(2)}\right) \bmod 127$$

$$0 \leq n < 127$$

$$x(i+7) = \left(x(i+4) + x(i)\right) \bmod 2$$

$$\left[x(6) \quad x(5) \quad x(4) \quad x(3) \quad x(2) \quad x(1) \quad x(0)\right] = \left[1 \quad 1 \quad 1 \quad 0 \quad 1 \quad 1 \quad 0\right]$$

Used to obtain N_{ID}^2

Secondary Synchronization Signal (SSS)

- Gold Sequence
- Modulation: BPSK

$$d_{SSS}(n) = [1 - 2x_0((n + m_0)\bmod 127)][1 - 2x_1((n + m_1)\bmod 127)]$$

$$m_0 = 15\left\lfloor \frac{N_{ID}^{(1)}}{112} \right\rfloor + 5N_{ID}^{(2)}$$

$$m_1 = N_{ID}^{(1)} \bmod 112$$

$$0 \le n < 127$$

$$x_0(i + 7) = (x_0(i + 4) + x_0(i))\bmod 2$$

$$x_1(i + 7) = (x_1(i + 1) + x_1(i))\bmod 2$$

$$[x_0(6) \quad x_0(5) \quad x_0(4) \quad x_0(3) \quad x_0(2) \quad x_0(1) \quad x_0(0)] = [0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1]$$

$$[x_1(6) \quad x_1(5) \quad x_1(4) \quad x_1(3) \quad x_1(2) \quad x_1(1) \quad x_1(0)] = [0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1]$$

Used to obtain N_{ID}^{1}

PSS and SSS

- PSS and SSS sequences are used to
  - Locate the position of the SSB in time and frequency (by the RX)
  - Compute frequency offsets
- They have very good correlation (auto and cross) properties
  - Can be used to identify the N_ID1 and N_ID2.
  - Also, the location of SSB.
- Once the PSS and SSS (SS block) are located in time and frequency
  - We should identify the slot number and SFN

Time Location

- In either half of the Frame (half-frame)
  - Symbols (OFDM) index with respect to the beginning of the half frame
- 5 Cases

Case	SCS	Freq range	Paired/unpaired	Symbols	Indices
Case A	15 KHz	< 3GHz		{2,8}+14.n	n =0,1
		> 3GHz < 6 GHz			n =0,1,2,3
Case B	30 KHz	< 3GHz		{4,8,16,20}+28.n	n=0;
		> 3GHz < 6 GHz			n=0,1
Case C	30 KHz	< 3GHz	Paired (FDD)	{2,8}+14.n	N=0,1
		> 3GHz < 6 GHz			N=0,1,2,3
		< 2.4GHz	Unpaired (TDD)		N=0,1
		>2.4 < 6 GHz			N=0,1,2,3
Case D	120 KHz			{4,8,16,20}+28.n	N=0,1,2,3,5,6,7,8,10,11,12,13,15,16,17,18
Case E	240 KHz			{8,12,1,6,20,32,36,40,44}+56.n	N=0,1,2,3,5,6,7,8

Time location (Contd…)

- The SSB in half frame are indexed from 0 to L_{max} -1
  - L_{max} range
    - 4 for < 3GHz
    - 8 for 3<f<6 GHz
    - 64 for f> 6Ghz
  - Based on the SSB that the UE locked, the UE should infer the index of the SS block so that it can identify the OFDM symbol
  - It should also find out the half frame .

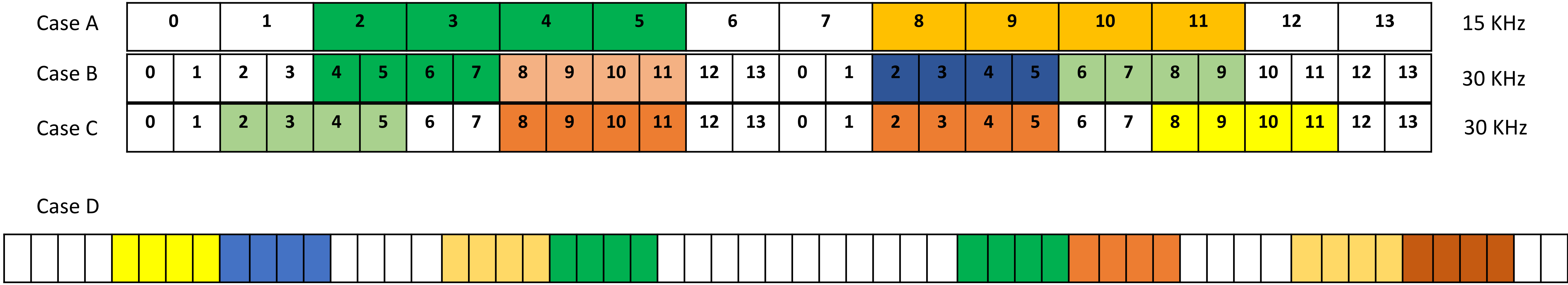
- The case is chosen according to Table 5.4.3.3-1 and Table 5.4.3.3-2 in [38.104] (See next slide).

Table 5.4.3.3-1: Applicable SS raster entries per *operating band* (FR1)

NR *Operating band*	SS Block SCS	SS Block pattern[1]	Range of GSCN (First – <Step size> – Last)
n1	15 kHz	Case A	5279 – <1> – 5419
n2	15 kHz	Case A	4829 – <1> – 4969
n3	15 kHz	Case A	4517 – <1> – 4693
n5	15 kHz	Case A	2177 – <1> – 2230
	30 kHz	Case B	2183 – <1> – 2224
n7	15 kHz	Case A	6554 – <1> – 6718
n8	15 kHz	Case A	2318 – <1> – 2395
n12	15 kHz	Case A	1828 – <1> – 1858
n20	15 kHz	Case A	1982 – <1> – 2047
n25	15 kHz	Case A	4829 – <1> – 4981
n28	15 kHz	Case A	1901 – <1> – 2002
n34	15 kHz	Case A	5030 – <1> – 5056
n38	15 kHz	Case A	6431 – <1> – 6544
n39	15 kHz	Case A	4706 – <1> – 4795
n40	15 kHz	Case A	5756 – <1> – 5995
n41	15 kHz	Case A	6246 – <3> – 6717
	30 kHz	Case C	6252 – <3> – 6714
n50	15 kHz	Case A	3584 – <1> – 3787
n51	15 kHz	Case A	3572 – <1> – 3574
n65	15 kHz	Case A	5279 – <1> – 5494
n66	15 kHz	Case A	5279 – <1> – 5494
	30 kHz	Case B	5285 – <1> – 5488
n70	15 kHz	Case A	4993 – <1> – 5044
n71	15 kHz	Case A	1547 – <1> – 1624
n74	15 kHz	Case A	3692 – <1> – 3790
n75	15 kHz	Case A	3584 – <1> – 3787
n76	15 kHz	Case A	3572 – <1> – 3574
n77	30 kHz	Case C	7711 – <1> – 8329
n78	30 kHz	Case C	7711 – <1> – 8051
n79	30 kHz	Case C	8480 – <16> – 8880
NOTE 1: SS Block pattern is defined in section 4.1 in TS 38.213 [10].			

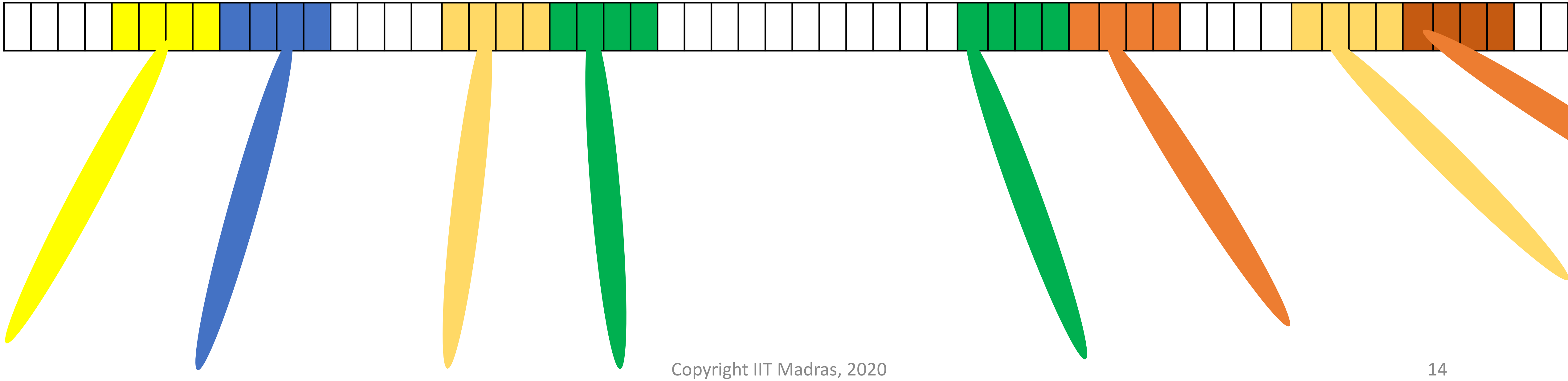
Table 5.4.3.3-2: Applicable SS raster entries per *operating band* (FR2)

NR *Operating band*	SS Block SCS	SS Block pattern[1]	Range of GSCN (First – <Step size> – Last)
n257	120 kHz	Case D	22388 – <1> – 22558
	240 kHz	Case E	22390 – <2> – 22556
n258	120 kHz	Case D	22257 – <1> – 22443
	240 kHz	Case E	22258 – <2> – 22442
n260	120 kHz	Case D	22995 – <1> – 23166
	240 kHz	Case E	22996 – <2> – 23164
n261	120 kHz	Case D	22446 – <1> – 22492
	240 kHz	Case E	22446 – <2> – 22490
NOTE 1: SS Block pattern is defined in section 4.1 in TS 38.213 [10].			


Case A
0 1 2 3 4 5 6 7 8 9 10 11 12 13
15 KHz
Case B
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
30 KHz
Case C
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
30 KHz
Case D

Beam Sweeping

- SSB can be used for beam sweeping in MMwave systems (can also be used in sub 6 GHz)
  - Beams are extremely narrow, and this makes initial lock on difficult.
  - Each SSB in the half frame can point to a different direction in space.
  - Based on the SSB index that the UE can decode
    - It uses a PRACH associated with the index to inform the BS (later about it)



SS Burst

- A collection of SS Blocks in a half frame (5ms)
- Particularly useful for synchronization in mmwave systems
- Periodicity:
    - 5/10/20/40/80/160 ms
    - Default periodicity: 20 ms (for initial cell search)
- Allowed SCS 15, 30 KHz
    - 120,240 KHz
- Max no of SS bocks for a burst
    - 4 for < 3GHz (2 bits)
    - 8 for 3<f<6 GHz (3 bits)
    - 64 for f> 6Ghz (6 bits)

[Why is there no 60 KHz?: TO reduce the number of searches when SCS is unknown]

Periodicity of SSB

- ssb-periodicityServingCell
  - ENUMERATED { ms5, ms10, ms20, ms40, ms80, ms160, spare2, spare1 }
  - If not configured, UE assumes 5 ms (half frame)
- For initial cell selection, a UE may assume that half frames with SS/PBCH blocks occur with a periodicity of 2 frames (20 ms). [38.213]
- *MIB* is always transmitted on the BCH with a periodicity of 80 ms and repetitions made within 80 ms [38.331, 5.2.1]

RRCReconfiguration →CellGroupConfig →ServingCellConfigCommon →ssb-periodicityServingCell

For an SS/PBCH block, the UE shall assume

- antenna port $p = 4000$ is used for transmission of PSS, SSS, PBCH and DM-RS for PBCH,
- the same cyclic prefix length and subcarrier spacing for the PSS, SSS, PBCH and DM-RS for PBCH,
- for SS/PBCH block type A, $\mu \in \{0, 1\}$ and $k_{\mathrm{SSB}} \in \{0, 1, 2, ..., 23\}$ with the quantities k_{SSB} , and $N_{\mathrm{CRB}}^{\mathrm{SSB}}$ expressed in terms of 15 kHz subcarrier spacing, and
- for SS/PBCH block type B, $\mu \in \{3,4\}$ and $k_{\mathrm{SSB}} \in \{0, 1, 2, ..., 11\}$ with the quantity k_{SSB} expressed in terms of the subcarrier spacing provided by the higher-layer parameter *subCarrierSpacingCommon* and $N_{\mathrm{CRB}}^{\mathrm{SSB}}$ expressed in terms of 60 kHz subcarrier spacing;
- the centre of subcarrier 0 of resource block $N_{\mathrm{CRB}}^{\mathrm{SSB}}$ coincides with the centre of subcarrier 0 of a common resource block with the subcarrier spacing provided by the higher-layer parameter *subCarrierSpacingCommon*. This common resource block overlaps with subcarrier 0 of the first resource block of the SS/PBCH block.

MIB→ subCarrierSpacingCommon

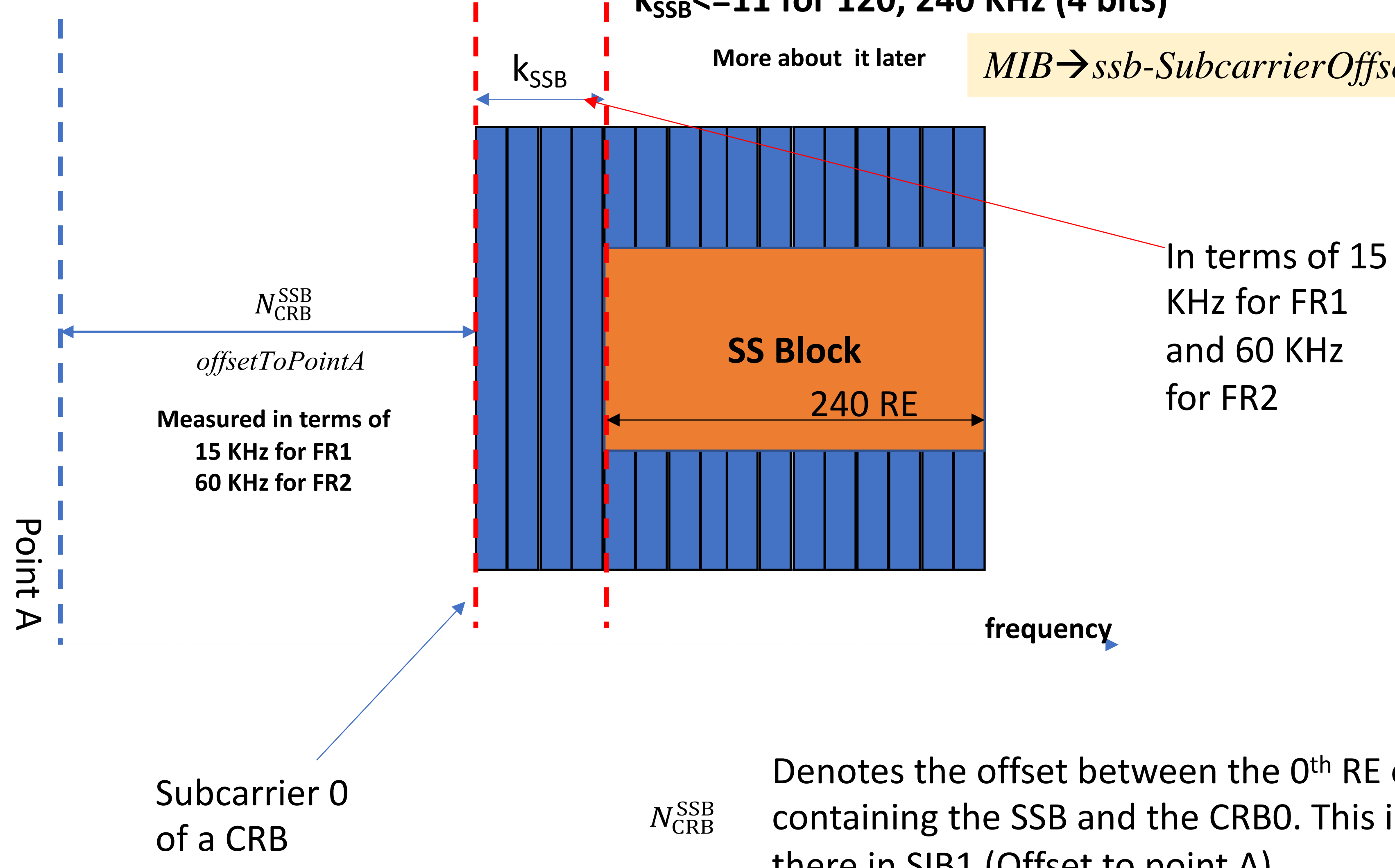
Freq Location (grid)

k_{SSB}<=23 for 15, 30 KHz (5 bits)

k_{SSB}<=11 for 120, 240 KHz (4 bits)

More about it later

MIB→ssb-SubcarrierOffset (k_{SSB} MSB bits)



N_{CRB}^{SSB} Denotes the offset between the 0th RE of the CRB containing the SSB and the CRB0. This information is there in SIB1 (Offset to point A)

Frequency location (on Raster)

38.211, 38.104

- SSB is Located on the synchronization raster
  - Need not be aligned with the resource grid

Frequency range	SS block frequency position SS_{REF}	GSCN	Range of GSCN
0 – 3000 MHz	N * 1200kHz + M * 50 kHz, N=1:2499, M ϵ {1,3,5} (Note)	3N + (M-3)/2	2 – 7498
3000 – 24250 MHz	3000 MHz + N * 1.44 MHz N= 0:14756	7499 + N	7499 – 22255
24250 – 100000 MHz	24250.08 MHz + N * 17.28 MHz N= 0:4383	22256 + N	22256 – 26639
NOTE: The default value for operating bands with SCS spaced channel raster is M=3.			

Table 5.4.3.1-1: GSCN parameters for the global frequency raster

The synchronization raster is mapped to the 120^{th} RE (SC) of the SSB (5.4.3.2, 38.104).

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NOTE 1: SS Block pattern is defined in section 4.1 in TS 38.213 [10].			

Table 5.4.3.3-2: Applicable SS raster entries per *operating band* (FR2)

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	240 kHz	Case E	22996 – <2> – 23164
n261	120 kHz	Case D	22446 – <1> – 22492
	240 kHz	Case E	22446 – <2> – 22490
NOTE 1: SS Block pattern is defined in section 4.1 in TS 38.213 [10].			

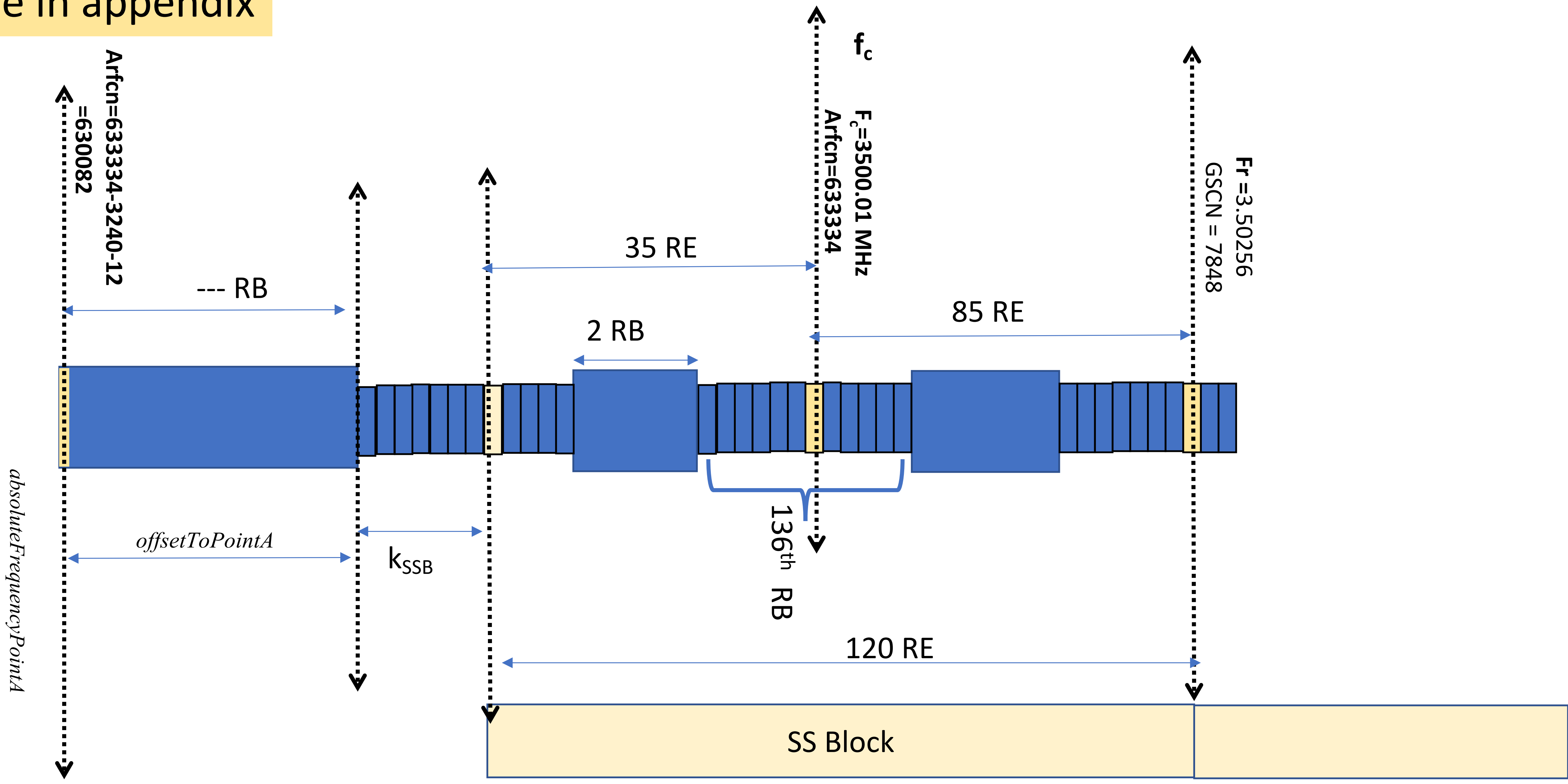
Example (n78 band 3.3-3.8GHz), 100 MHz BW, 30 KHz SCS. Center Freq around 3.5

- [38.104, Table 5.3.2-1] N_{RB} = 273
- From 5.4.2.3.1, 38.104
  - The raster is 30KHz or N_{ref} step size is 2
  - the closest raster point is 633334 (NR-ARFCN)
  - Corresponds to 3500.01 MHz.
- Band n78 correspond to Case C [38.104, 5.4.3.3-1]
  - GSCN range for this band is 7711-8051
- Suppose we choose GSCN = 7848 for SS Block
  - Corresponds to fssb = 3.50256 GHz.
- Difference between fc and fssb
  - (3.50256- 3.50001) = 2550 KHz = 170 ARFCNs = 85 RE’s (30 KHz)

Frequency	GSCN
3.498240000000000	7845
3.499680000000000	7846
3.501120000000000	7847
3.502560000000000	7848
3.504000000000000	7849
3.505440000000000	7850
3.506880000000000	7851
3.508320000000000	7852
3.509760000000000	7853
3.511200000000000	7854
3.512640000000000	7855

Example (n78 band 3.3-3.8GHz), 100 MHz BW, 30 KHz SCS. Center Freq around 3.5

See slide in appendix



After locking on to SSS and PSS

- SSBlock subcarrier spacing (from the frequency band)
- Frequency location of the start of SSBlock
- Timing location
  - You know that you would have locked onto one of the SSBlock
    - One of the possible OFDM symbols (for example {2,8}+14.n}
    - Slot no (with ambiguity)
- Cell id.

PBCH

DMRS for PBCH

38.211
38.213
38.104

$$r(m) = \frac{1}{\sqrt{2}}\left(1 - 2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1 - 2\cdot c(2m+1)\right)$$

$$c_{\text{init}} = 2^{11}\left(\bar{i}_{\text{SSB}}+1\right)\left(\left\lfloor N_{\text{ID}}^{\text{cell}}/4\right\rfloor+1\right)+2^{6}\left(\bar{i}_{\text{SSB}}+1\right)+\left(N_{\text{ID}}^{\text{cell}} \bmod 4\right)$$

L_{max} [maximum SSB as in 38.104]	$\bar{i}_{ssb}$	i_{ssb}	
4	$\bar{i}_{ssb}=i_{ssb}+4n_{hf}$	Is the two least significant bits of the SSB index L	N_{hf}=0 (first half frame) N_{hf}=1(Second half frame)
8	$\bar{i}_{ssb}=i_{ssb}$	Is the three least significant bits of the SSB index L	
64	$\bar{i}_{ssb}=i_{ssb}$	Is the three least significant bits of the SSB index L	

DMRS locations

$$v = N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 4$$

	PBCH OFDM symbol	RE
DM-RS for PBCH	1, 3	$0+v, 4+v, 8+v, \ldots, 236+v$
	2	$0+v, 4+v, 8+v, \ldots, 44+v$ $192+v, 196+v, \ldots, 236+v$

Bits for PBCH

- No of RE for PBCH: 576 (240+240+48+48)
- No of DMRS RE: 144
- No of information RE for PBCH = 576-144 =432
- QPSK modulation: 2 bits/RE (symbols)
- Total available bits = 432*2 = 864
- This PBCH message is of 32 bits, is CRC attached by 24 bits, polar encoded and rate matched
  - Effective code rate of approximately 1/15 (Huge redundancy)

MIB Message

```
BCCH-BCH-Message ::=                SEQUENCE {
    message                             BCCH-BCH-MessageType
}

BCCH-BCH-MessageType ::=            CHOICE {
    mib                                 MIB,
    messageClassExtension               SEQUENCE {}
}

-- TAG-BCCH-BCH-MESSAGE-STOP
-- ASN1STOP
```

1 bit for choice

```
-- ASN1START
-- TAG-MIB-START

MIB ::=                             SEQUENCE {
    systemFrameNumber                   BIT STRING (SIZE (6)), (6 bits)
    subCarrierSpacingCommon             ENUMERATED {scs15or60, scs30or120}, (1 bit)
    ssb-SubcarrierOffset                INTEGER (0..15), (4 bits)
    dmrs-TypeA-Position                 ENUMERATED {pos2, pos3}, (1 bit)
    pdcch-ConfigSIB1                    PDCCH-ConfigSIB1, (8 bits)
    cellBarred                          ENUMERATED {barred, notBarred}, (1 bit)
    intraFreqReselection                ENUMERATED {allowed, notAllowed}, (1 bit)
    spare                               BIT STRING (SIZE (1)) (1 bit)
}

-- TAG-MIB-STOP
-- ASN1STOP
```

MIB: 24 bits

```
-- ASN1START
-- TAG-PDCCH-CONFIGSIB1-START

PDCCH-ConfigSIB1 ::=                SEQUENCE {
    controlResourceSetZero              ControlResourceSetZero,
    searchSpaceZero                     SearchSpaceZero
}

-- TAG-PDCCH-CONFIGSIB1-STOP
-- ASN1STOP
```

```
-- ASN1START
-- TAG-CONTROLRESOURCESETZERO-START

ControlResourceSetZero ::=          INTEGER (0..15)

-- TAG-CONTROLRESOURCESETZERO-STOP
-- ASN1STOP
```

```
-- ASN1START
-- TAG-SEARCHSPACEZERO-START

SearchSpaceZero ::=                 INTEGER (0..15)

-- TAG-SEARCHSPACEZERO-STOP
-- ASN1STOP
```

MIB field descriptions
cellBarred Barred means the cell is barred, as defined in TS 38.304 [20].
dmrs-TypeA-Position Position of (first) DM-RS for downlink (see TS 38.211 [16], clause 7.4.1.1.2) and uplink (see TS 38.211 [16], clause 6.4.1.1.3).
intraFreqReselection Controls cell selection/reselection to intra-frequency cells when the highest ranked cell is barred, or treated as barred by the UE, as specified in TS 38.304 [20}.
pdcch-ConfigSIB1 See TS 38.213 [13]. Determines a common ControlResourceSet (CORESET) a common search space and necessary PDCCH parameters. If the field ssb-SubcarrierOffset indicates that SIB1 is not present, the field pdcch-ConfigSIB1 indicate the frequency positions where the UE may find SS/PBCH block with SIB1 or the frequency range where the network does not provide SS/PBCH block with SIB1 (see TS 38.213 [13], clause 13).
ssb-SubcarrierOffset Corresponds to k_{SSB} (see TS 38.213 [13]), which is the frequency domain offset between SSB and the overall resource block grid in number of subcarriers. (See TS 38.211 [16], clause 7.4.3.1). The value range of this field may be extended by an additional most significant bit encoded within PBCH as specified in TS 38.213 [13]. This field may indicate that this cell does not provide SIB1 and that there is hence no CORESET#0 configured in MIB (see TS 38.213 [13], clause 13). In this case, the field pdcch-ConfigSIB1 may indicate the frequency positions where the UE may (not) find a SS/PBCH with a control resource set and search space for SIB1 (see TS 38.213 [13], clause 13).
subCarrierSpacingCommon Subcarrier spacing for SIB1, Msg.2/4 for initial access, paging and broadcast SI-messages. If the UE acquires this MIB on a carrier frequency <6GHz, the value scs15or60 corresponds to 15 Khz and the value scs30or120 corresponds to 30 kHz. If the UE acquires this MIB on a carrier frequency >6GHz, the value scs15or60 corresponds to 60 Khz and the value scs30or120 corresponds to 120 kHz.
systemFrameNumber The 6 most significant bit (MSB) of the 10-bit System Frame Number. The 4 LSB of the SFN are conveyed in the PBCH transport block as part of channel coding (i.e. outside the MIB encoding), as defined in clause 7.1 in TS 38.212 [17].

PBCH Message (contents)

MIB message

$A_0, A_1, A_2, \ldots, A_{22}, A_{23}$	$A_{24}, A_{25}, A_{26}, A_{27}$	A_{28}	A_{29}, A_{30}, A_{31}

- $A_{24}, A_{25}, A_{26}, A_{27}$: **4, 3, 2 and 1 LSB of SFN** **(Other 6 bits in MIB)**
- A_{28}: **Half frame bit**
- A_{29}, A_{30}, A_{31}:

  $L_{MAX} = 64$
  6,5,4 bits of the SSB index *(This is for 120/240 KHz)*

  Otherwise,
  A_{29} = MSB of K_{ssb}
  Other bits are reserved.
  (Recall Kssb is 5 bits for 15/30 KHz and 4 bits for 120/240 KHz)

- This message of 32 bits, is CRC attached by 24 bits, polar encoded and rate matched.
- QPSK modulated to fit into PBCH RE

Finally (after decoding SSBlock)

- The band you are operating in (for example n78)
- K_{SSB}
  - From decoding MIB (4 bits) (Sufficient for 120/240 SCS): [ssb-SubcarrierOffset]
  - MSB from decoding PBCH A_{29}(required for 15/30 SCS)
- System Frame Number
  - 6 bits from MIB: [systemFrameNumber]
  - 4 bits from PBCH (A_{24},A_{25}, A_{26}, A_{27} of PBCH other than MIB)
- SSB index
  - L_{max}=4 (2 bits),8 (3 bits) : Use DRMS generation (blind decoding with all combinations of cinit)
  - L_{max}= 64
    - Use DMRS generation for 3 bits
    - MSB 3 bits from PBCH (A_{29},A_{30}, A_{31})
- Half frame
  - From DMRS (and also PBCH (A_{28})).
- SCS
  - From MIB: [subCarrierSpacingCommon]
- SIB1 information
  - From MIB: [PDCCH-ConfigSIB1]
    - Coreset0
    - SearchSpace0

Power allocation of SSS/PSS and EPRE

- The UE assumes that SSS, PBCH DM-RS, and PBCH data have same EPRE
- The UE may assume that the ratio of PSS EPRE to SSS EPRE in a SS/PBCH block is either 0 dB or 3 dB.
- The EPRE of SSB will be used subsequently (after SIB decoding) to
  - find out the path loss
  - Fix the initial power of PRACH.

Questions

- For Decoding PBCH, how do you know the SCS?
  - Depends on the frequency band you use and is specified in 38.101-1 or 38.103
- Should we always transmit Lmax SSBs in a burst?
  - No need. Lmax is the maximum supported.

- SSB periodicity issues.

  - SSB periodicity is assumed to be ms5, ms10, ms20, ms40, ms80, ms160

    - However, it says, a UE may assume that half frames with SS/PBCH blocks occur with a periodicity of 2 frames

    - How are the above two points compatible with each other.

  - It says MIB is always transmitted on the BCH with a periodicity of 80 ms (and repetitions made within 80 ms).

    - What does it mean? So the SFN value is not changed for every frame (how is this compatible with 1 and 2)?
      - MIB has only the MSB 's of the SFN (6 bits). The 4 LSB's are present in PBHC payload. This would correspond to 160 ms and hence the MIB does not change for 160 ms . The PBCH payload (bits 24 to 27) changes though every frame.

Questions..

- What is the relation between dc carrier, point A and the global raster?
  - See next few slides
- Why is both kssb and offsettoPointA required?
  - When you just synchronize (after SSB decoding), only kssb is decoded. Kssb is required so that the reference (For Coreset 0 start) is on the CRB boundary.
  - offsettoPointA is there in SIB1 and can only be decoded once the position of Coreset 0 is known through Kssb.

Trivia

- SSBlock can have different SCS compared to the other Physical channels.

Extra Material

Channel Raster

$$F_{REF} = F_{REF\text{-}Offs} + \Delta F_{Global} (N_{REF} - N_{REF\text{-}Offs})$$

Table 5.4.2.1-1: NR-ARFCN parameters for the global frequency raster

Frequency range (MHz)	ΔF_{Global} (kHz)	$F_{REF\text{-}Offs}$ (MHz)	$N_{REF\text{-}Offs}$	Range of N_{REF}
0 – 3000	5	0	0	0 – 599999
3000 – 24250	15	3000	600000	600000 – 2016666
24250 – 100000	60	24250.08	2016667	2016667 – 3279165

For each frequency band, the (N_{REF}) step sizes are provided in <> in the tables on the RHS

In frequency bands with two ΔF_{Raster}, the higher ΔF_{Raster} applies to channels using only the SCS that equals the higher ΔF_{Raster}.

Table 5.4.2.2-1: Channel Raster to Resource Element Mapping

	$N_{RB} \bmod 2 = 0$	$N_{RB} \bmod 2 = 1$
Resource element index k	0	6
Physical resource block number n_{PRB}	$n_{PRB} = \left\lfloor \frac{N_{RB}}{2} \right\rfloor$	$n_{PRB} = \left\lfloor \frac{N_{RB}}{2} \right\rfloor$

Table 5.4.2.3-1: Applicable NR-ARFCN per *operating band* in FR1

NR *Operating band*	ΔF_{Raster} (kHz)	Uplink Range of N_{REF} (First – <Step size> – Last)	Downlink Range of N_{REF} (First – <Step size> – Last)
n1	100	384000 – <20> – 396000	422000 – <20> – 434000
n2	100	370000 – <20> – 382000	386000 – <20> – 398000
n3	100	342000 – <20> – 357000	361000 – <20> – 376000
n5	100	164800 – <20> – 169800	173800 – <20> – 178800
n7	100	500000 – <20> – 514000	524000 – <20> – 538000
n8	100	176000 – <20> – 183000	185000 – <20> – 192000
n12	100	139800 – <20> – 143200	145800 – <20> – 149200
n20	100	166400 – <20> – 172400	158200 – <20> – 164200
n25	100	370000 – <20> – 383000	386000 – <20> – 399000
n28	100	140600 – <20> – 149600	151600 – <20> – 160600
n34	100	402000 – <20> – 405000	402000 – <20> – 405000
n38	100	514000 – <20> – 524000	514000 – <20> – 524000
n39	100	376000 – <20> – 384000	376000 – <20> – 384000
n40	100	460000 – <20> – 480000	460000 – <20> – 480000
n41	15	499200 – <3> – 537999	499200 – <3> – 537999
	30	499200 – <6> – 537996	499200 – <6> – 537996
n50	100	286400 – <20> – 303400	286400 – <20> – 303400
n51	100	285400 – <20> – 286400	285400 – <20> – 286400
n65	100	384000 – <20> – 402000	422000 – <20> – 440000
n66	100	342000 – <20> – 356000	422000 – <20> – 440000
n70	100	339000 – <20> – 342000	399000 – <20> – 404000
n71	100	132600 – <20> – 139600	123400 – <20> – 130400
n74	100	285400 – <20> – 294000	295000 – <20> – 303600
n75	100	N/A	286400 – <20> – 303400
n76	100	N/A	285400 – <20> – 286400
n77	15	620000 – <1> – 680000	620000 – <1> – 680000
	30	620000 – <2> – 680000	620000 – <2> – 680000
n78	15	620000 – <1> – 653333	620000 – <1> – 653333
	30	620000 – <2> – 653332	620000 – <2> – 653332
n79	15	693334 – <1> – 733333	693334 – <1> – 733333
	30	693334 – <2> – 733332	693334 – <2> – 733332
n80	100	342000 – <20> – 357000	N/A
n81	100	176000 – <20> – 183000	N/A
n82	100	166400 – <20> – 172400	N/A
n83	100	140600 – <20> –149600	N/A
n84	100	384000 – <20> – 396000	N/A
n86	100	342000 – <20> – 356000	N/A

Table 5.4.2.3-2: Applicable NR-ARFCN per *operating band* in FR2

NR *Operating band*	ΔF_{Raster} (kHz)	Uplink and Downlink Range of N_{REF} (First – <Step size> – Last)
n257	60	2054166 – <1> – 2104165
	120	2054167 – <2> – 2104165
n258	60	2016667 – <1> – 2070832
	120	2016667 – <2> – 2070831
n260	60	2229166 – <1> – 2279165
	120	2229167 – <2> – 2279165
n261	60	2070833 – <1> – 2084999
	120	2070833 – <2> – 2084999

Example (n78 band 3.3-3.8GHz), 100 MHz BW, 30 KHz SCS. Center Freq around 3.5

- [38.104, Table 5.3.2-1] N_{RB} = 273
- From 5.4.2.3.1, 38.104
  - The raster is 30KHz or N_{ref} step size is 2
  - the closest raster point is 633334 (NR-ARFCN)
  - Corresponds to 3500.01 MHz.
- Global Raster granularity = 15 KHZ
- 273RB = 273*12 RE * 30 KHz
- PRB mapping = floor(273/2)= 136 RB
  - 6^{th} Sub carrier.
- 135 RB correspond to
  - 135*12*2 = 3240 ARFCN
- 6 RE correspond to 12 ARFCN

Since ARFCN corresponds to 15 KHz
Our SCS = 30 KHz