



**KEYSIGHT
WORLD 2020**

5G NR Dynamic Spectrum Sharing Drivers & Test Implications

Project Manager / Keysight Technologies

Alex Liang



Why DSS?



NR Band

BIG BANDWIDTH FOR EMBB

- **FR1 (410 MHz – 7.125 GHz)**
 - Bands numbered from 1 to 255
 - *No longer can be commonly referred to as sub-6 GHz!*
- **FR2 (24.250 - 52.600 GHz)** → *Soon to be extended to 114.25 GHz*
 - Bands numbered from 257 to 511
 - Commonly referred to as mmWave

- Large BW for throughput
- Bad coverage due to high frequency

NR operating band	Uplink (UL) operating band BS receive / UE transmit $F_{UL_low} - F_{UL_high}$	Downlink (DL) operating band BS transmit / UE receive $F_{DL_low} - F_{DL_high}$	Duplex Mode
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD

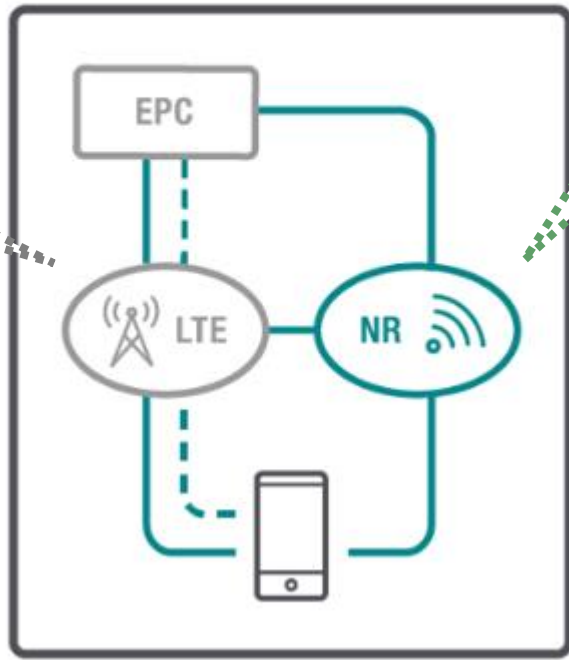
NSA – ENDC , option 3x

TEMPORARY PHASE FOR 5G

PDCP split

OPTION 3X: Non-Standalone NR,
LTE assisted, EPC connected

• Low band/
mid band for
coverage



• High band for
throughput
performance

B3N78

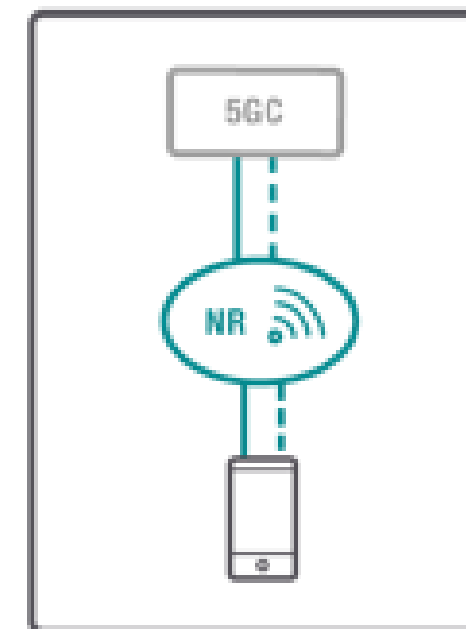
Re-farming band

HOW TO COVER BOTH 4G ONLY USES AND 5G USERS?

Table 5.2-1: NR operating bands in FR1

NR operating band	Uplink (UL) operating band BS receive / UE transmit $F_{UL_low} - F_{UL_high}$	Downlink (DL) operating band BS transmit / UE receive $F_{DL_low} - F_{DL_high}$	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD ¹

OPTION 2: Standalone NR



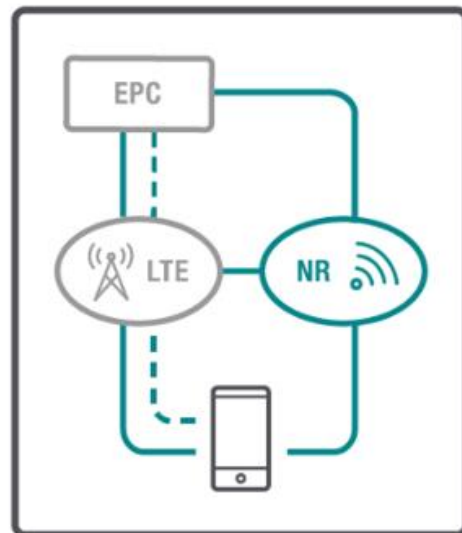
N3-N78

NSA – ENDC , option 3x

TEMPORARY PHASE FOR 5G

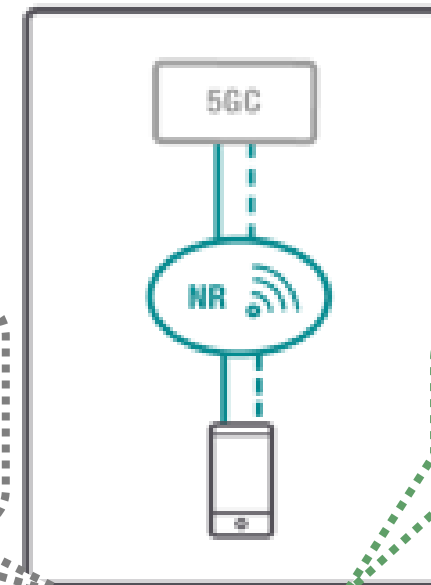
PDCP split

OPTION 3X: Non-Standalone NR,
LTE assisted, EPC connected



B3N78

OPTION 2: Standalone NR

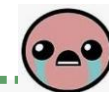


N3N78

- Low band/
mid band for
coverage

- High band for
throughput
performance

- How about LTE legacy
users?



Static spectrum sharing VS Dynamic spectrum sharing

LTE 10MHz

NR 10M Hz

- Static spectrum sharing

- Dynamic spectrum sharing

LTE x MHz

NR (20-x)M Hz

LTE x MHz

NR (20-x)M Hz

NR (20-x)M Hz

DSS Target

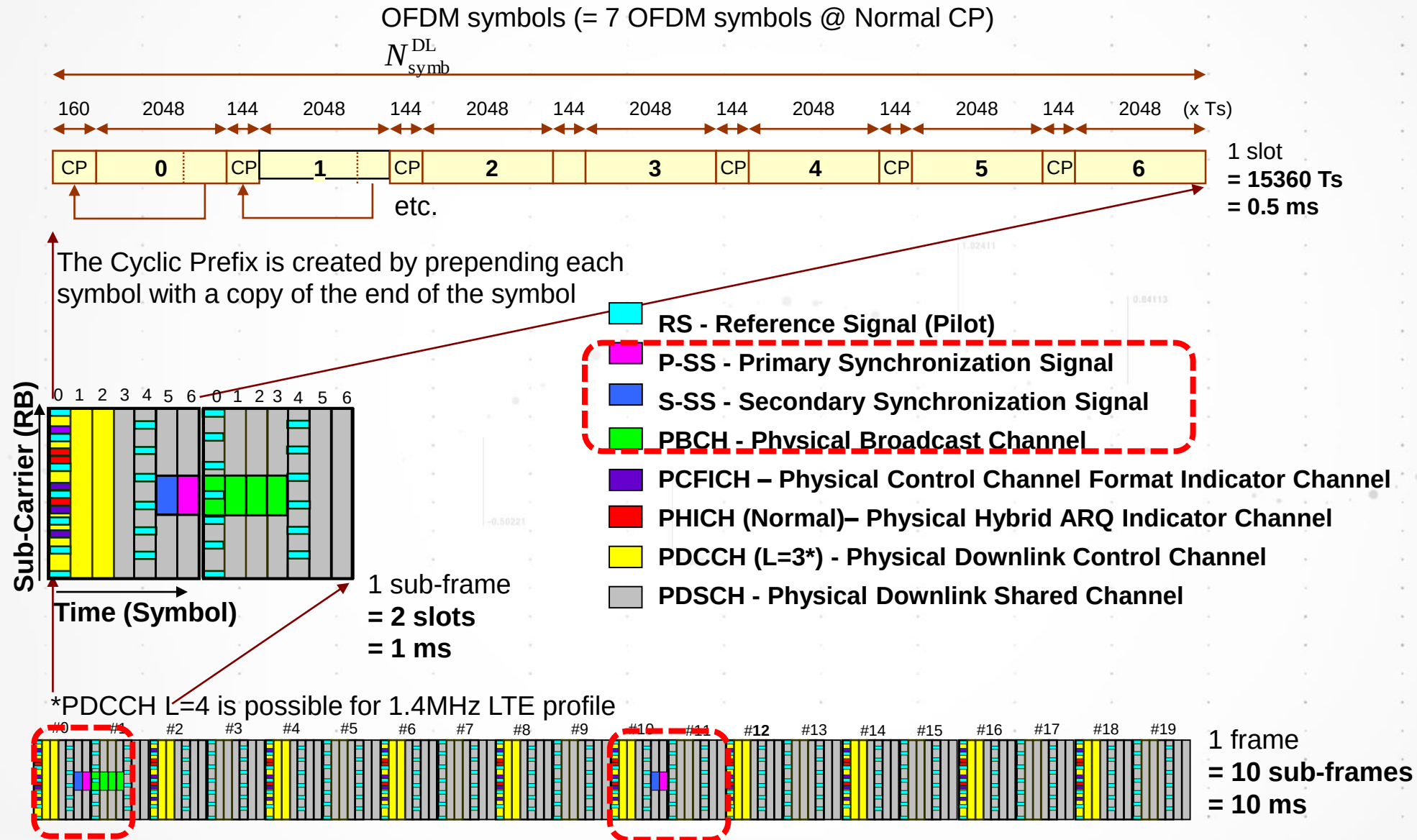
REQUIREMENTS FOR DSS

- LTE / NR use the same carrier , resource is scheduling dynamically

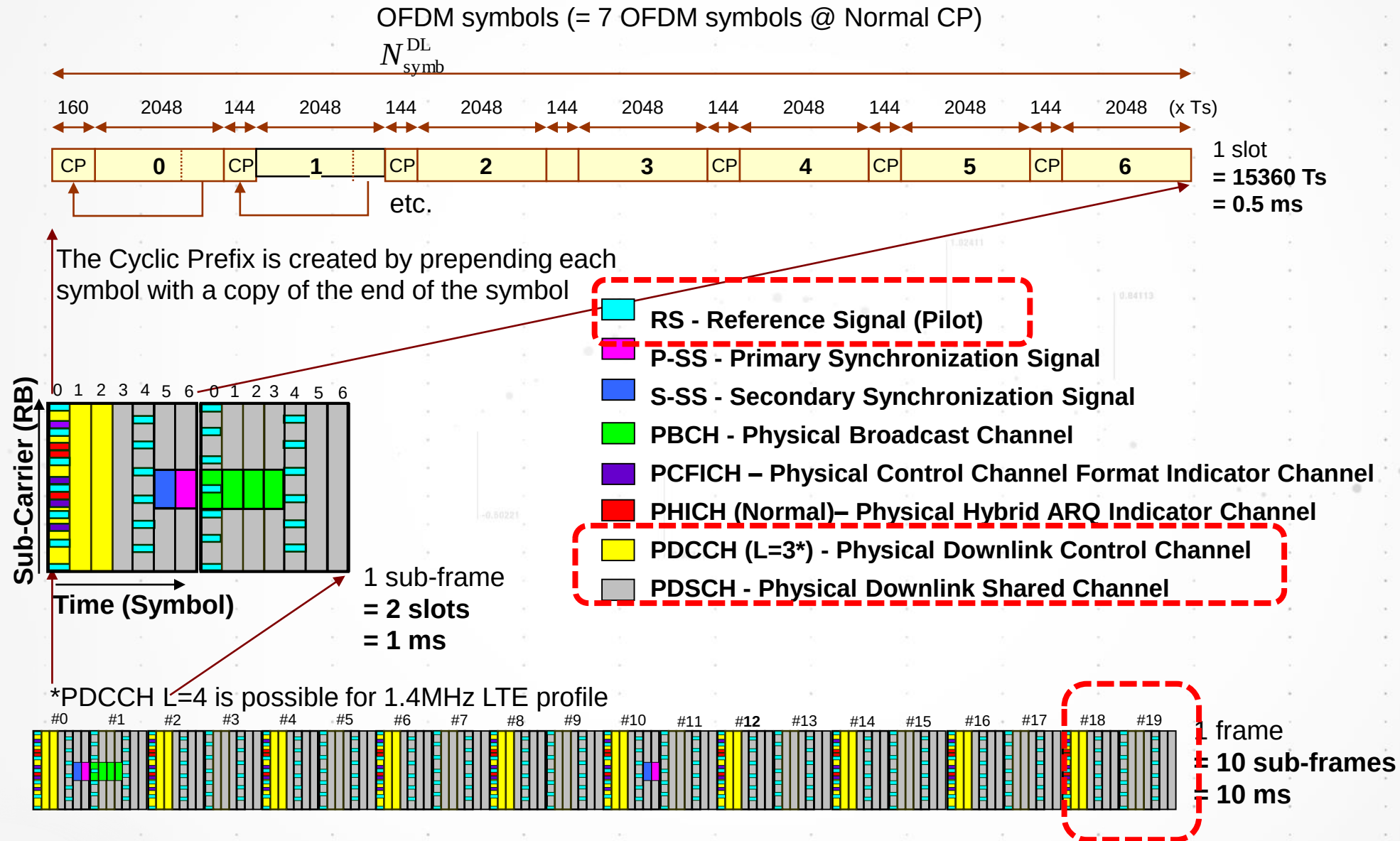
How DSS? – Connected Mode



Recapture LTE Downlink FDD Frame Structure

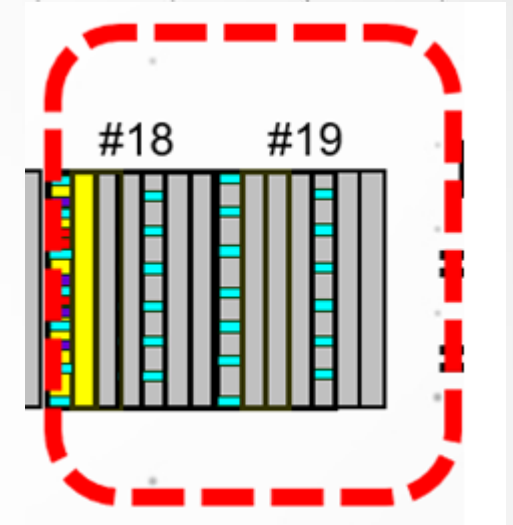


Recapture LTE Downlink FDD Frame Structure

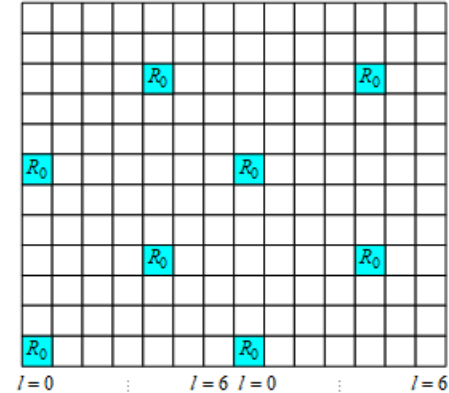


NR connected - PDSCH Rate-Matching for LTE CRS

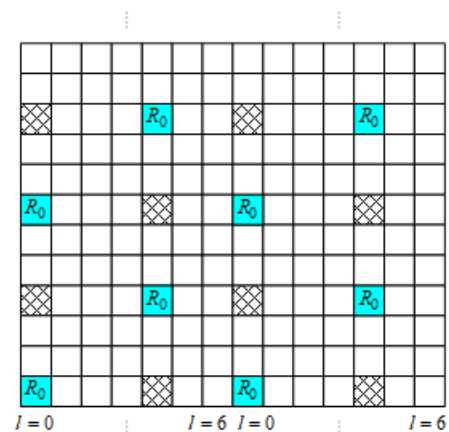
- LTE **CRS** is periodically transferred in time domain and discretely transferred in frequency domain.
- Carefully configure time-frequency radio resource in DSS subframe
 - **bypass** the resource allocated to LTE CRS
 - schedule unused radio resource for NR operation



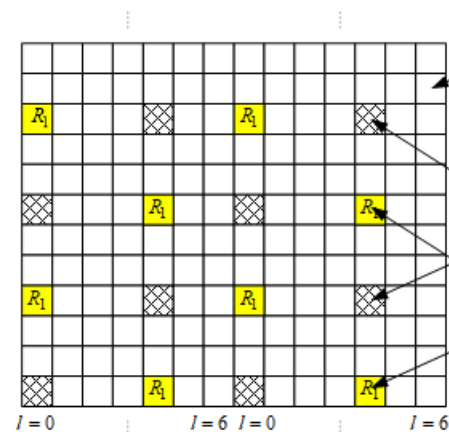
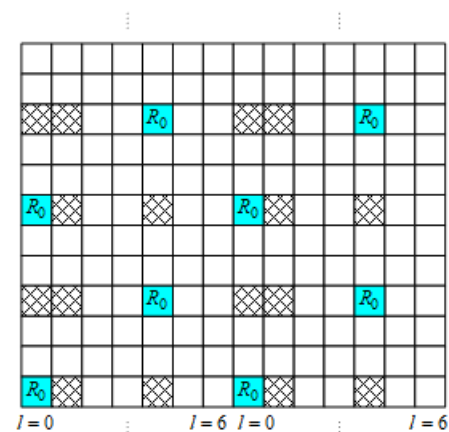
One antenna port



Two antenna ports

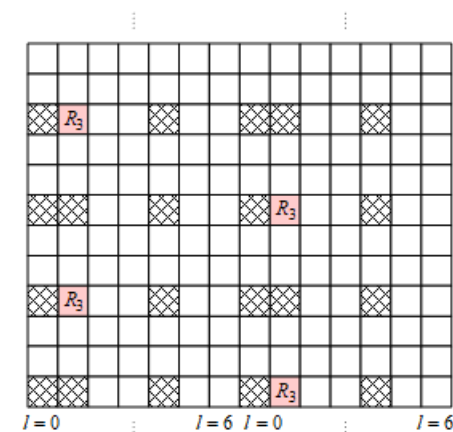
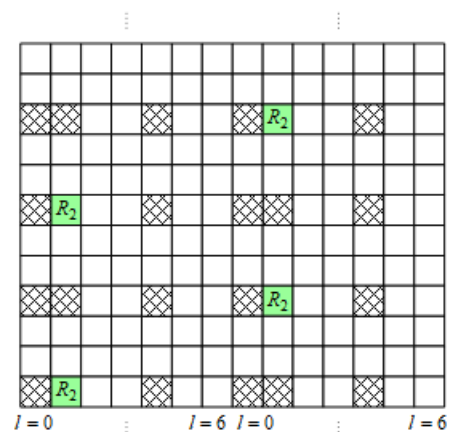
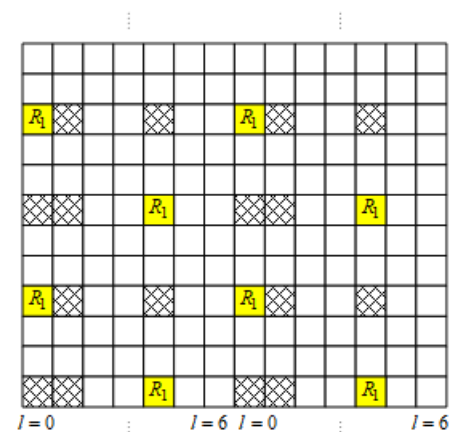


Four antenna ports

Resource element (k,l)

Not used for transmission on this antenna port

Reference symbols on this antenna port

REF [36.211](#) Figure 6.10.1.2-1

even-numbered slots odd-numbered slots

even-numbered slots odd-numbered slots

even-numbered slots odd-numbered slots

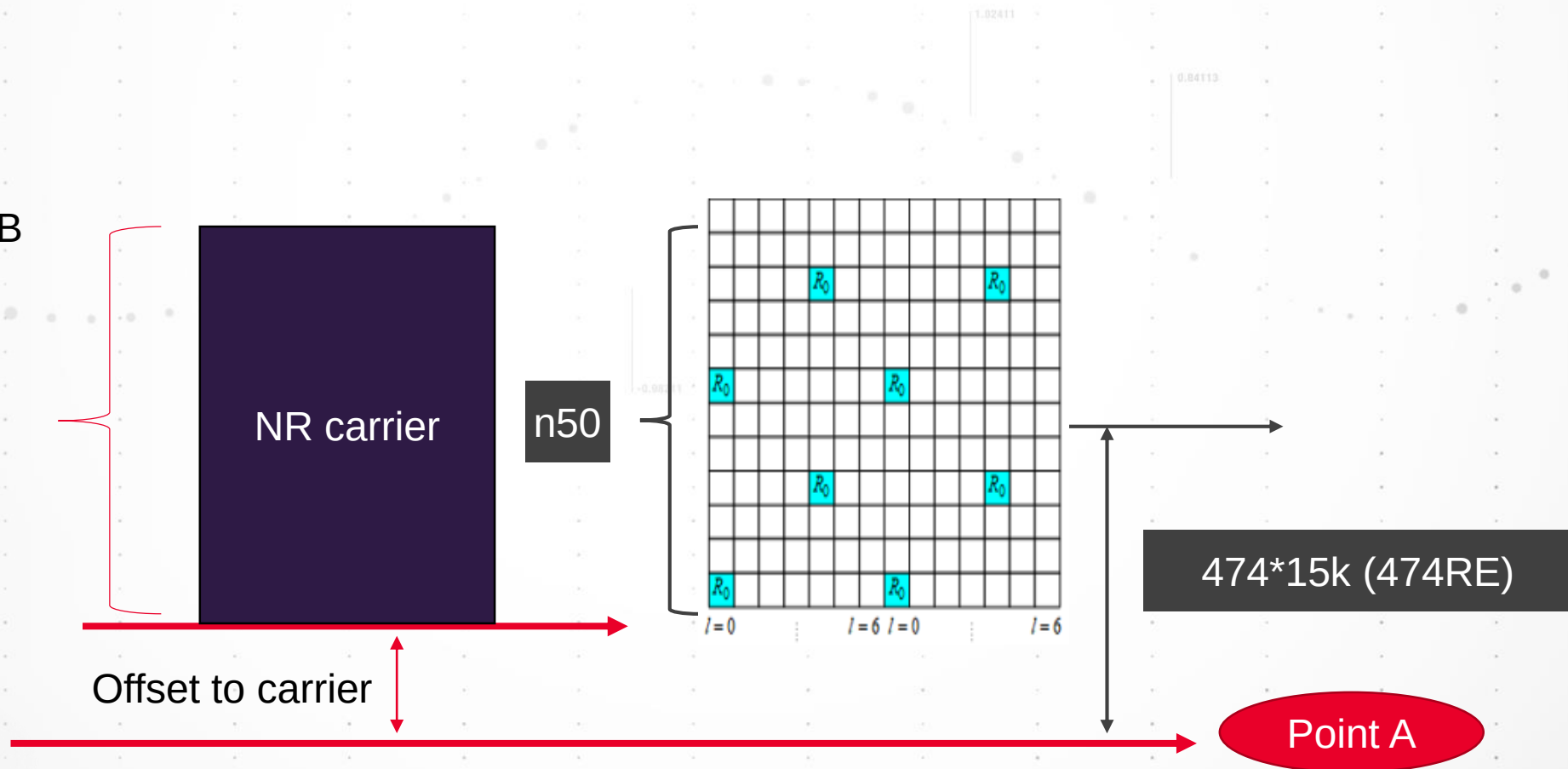
even-numbered slots odd-numbered slots

```

[Sequence]:setup
[Int32]:carrierFreqDL : 474
[Enum]:carrierBandwidthDL : eRateMatchPatternLTE_CRS_carrierBandwidthDL_n50

```

Channel RB



Quick Config

TDD UL-DL Config

Scheduling Map

Slot Config

PDSCH TDRA

PUSCH TDRA

Link Adaptation

Rate Matching

Common

Dedicated Only

LTE Rate Matching applied to Serving Cell Config Common Information Element

Enabled

✓

Manual Config

DL Carrier Frequency (offset in REs)

474

Carrier Bandwidth

10 MHz

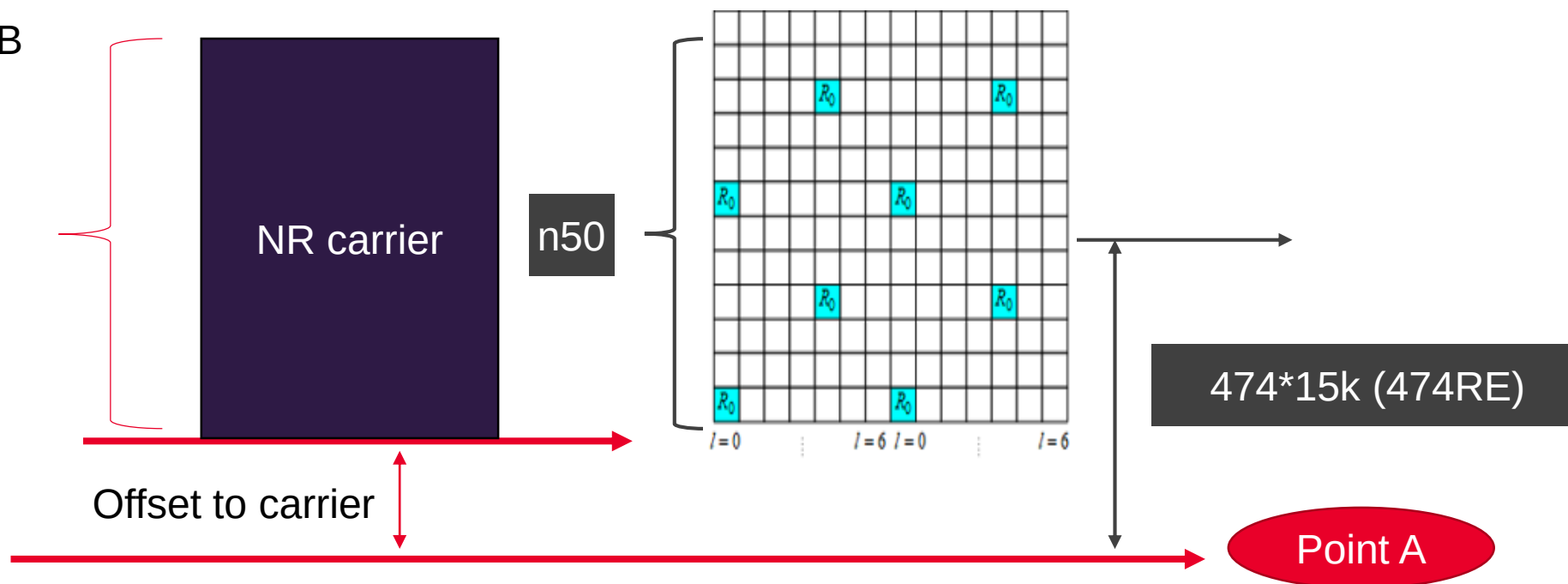
Number of CRS Ports

N2

V Shift

N1

Channel RB



To Avoid Collision between NR PDSCH and LTE PDCCH

Quick Config TDD UL-DL Config Scheduling Map Slot Config **PDSCH TDRA** PUSCH TDRA Link Adaptation Rate Matching

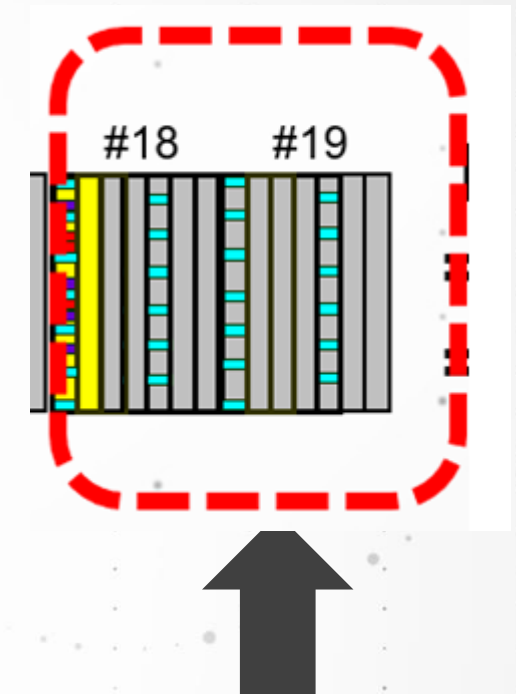
☐ Default A Table ☐ Common Table ☒ Dedicated Table Initial BWP ▼

Number of Entries: 1

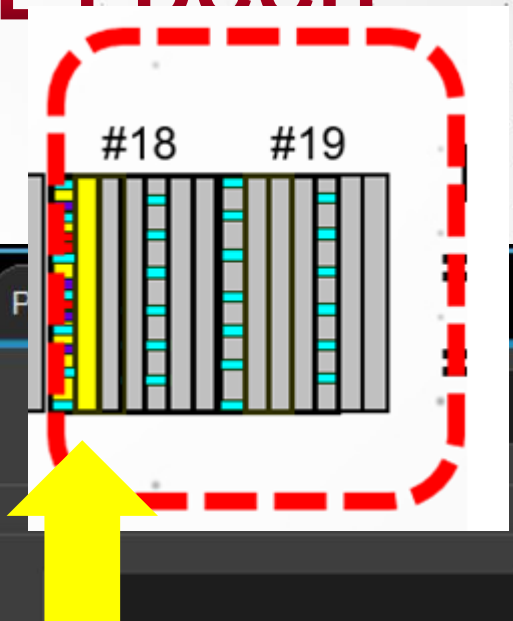
Index	K0	Symbol Start	Symbol Length	Type	Index Used
0	0	3	11	Type A ▼	Yes
1	0	1	10	Type A ▼	No
2	0	1	10	Type A ▼	No
3	0	1	10	Type A ▼	No
4	0	1	10	Type A ▼	No
5	0	1	10	Type A ▼	No
6	0	1	10	Type A ▼	No
7	0	1	10	Type A ▼	No

Preset: Sweep Symbol Start ▼ Apply

System Scheduling Cell PHY Beam Mgmt MAC/RLC/PDCP RRC/NAS IMS BLER/Tput CSI Assisted Tx Meas



To Avoid Collision between NR PDCCH and LTE PDCCH



Bandwidth Parts HARQ PDSCH PDSCH DMRS **PDCCH** PRACH PUSCH PUSCH DMRS

☒ Enable PDCCH ☐ Coresets ☐ Common Search Space ☒ UE Specific Search Space

UE Specific Search Spaces

- UESS 1**
- UESS 2
- UESS 3
- UESS 4
- UESS 5
- UESS 6
- UESS 7

Search Space Configuration

Search Space Enabled: ☒

Coreset ID: 1

Monitoring Symbol Bitmap (hex): 0004

DCI Formats Monitored: 0_1 And 1_1

Aggregation Candidates

Level 1: 0

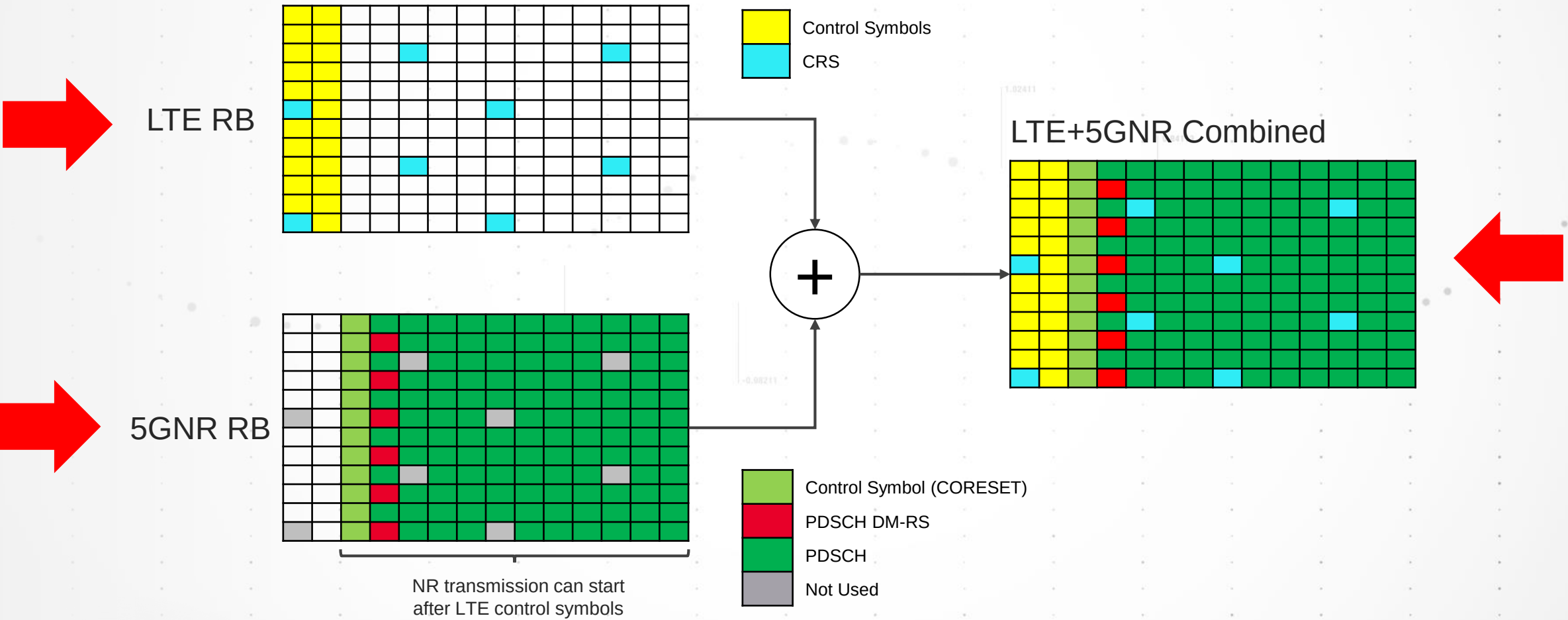
Search Space ID:

Monitoring Period / Offset: 1 0

000000000001000 (binary) >> 0004 (HEX)

LTE-CRS RE Rate Matching

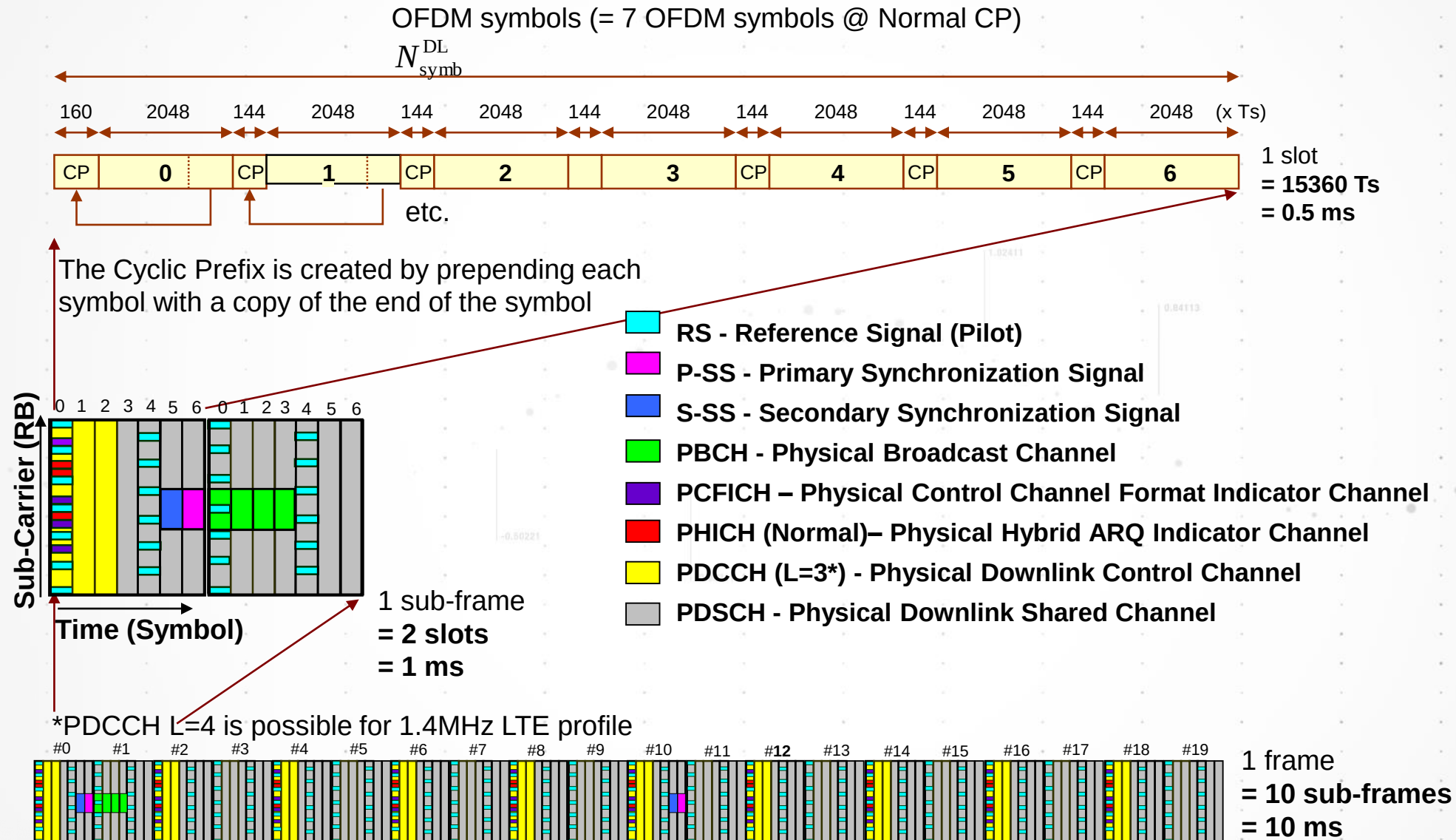
5G NR avoids LTE-CRS Resource Elements (RE)



How DSS? – Idle Mode

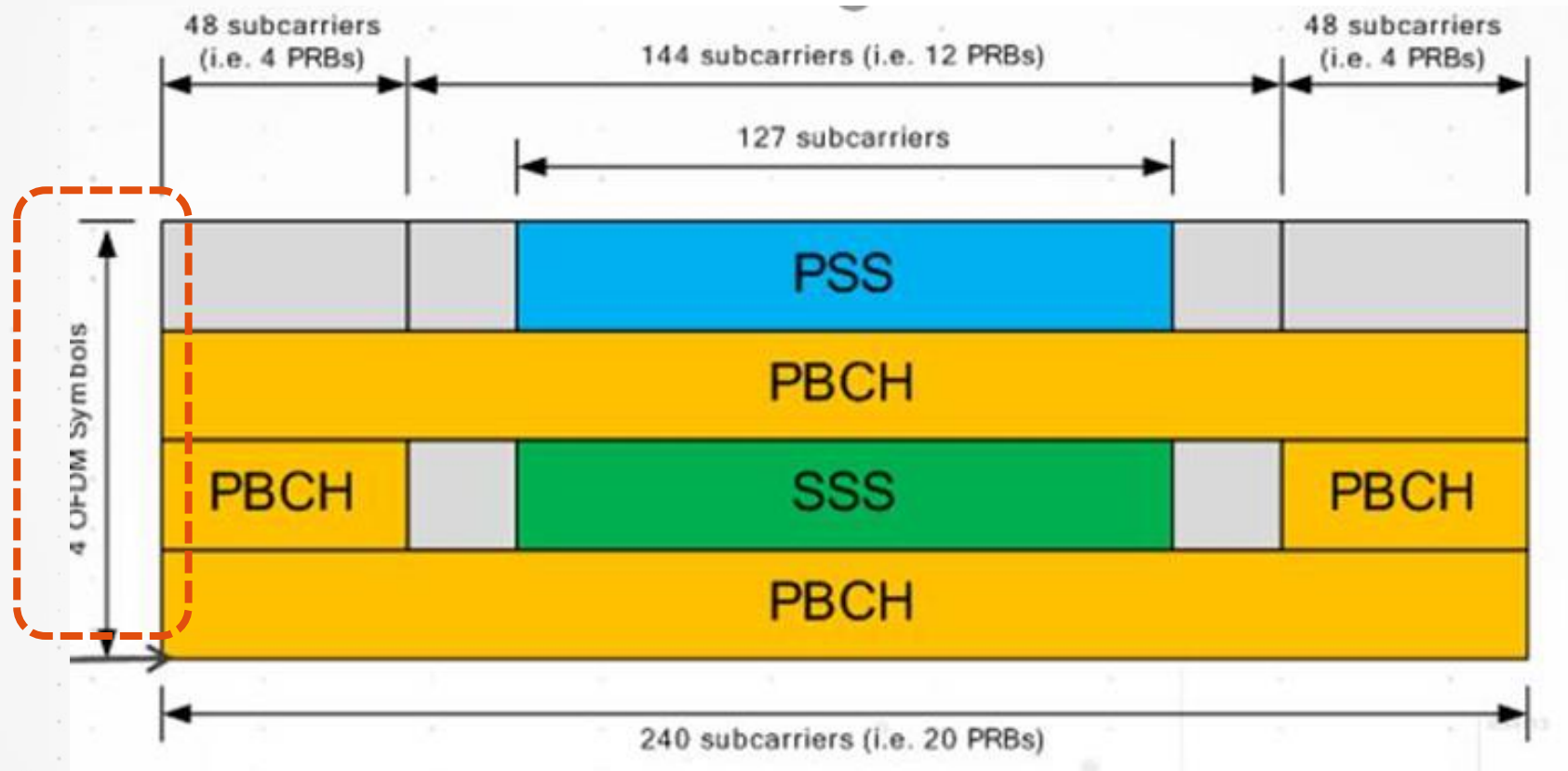


Recapture LTE Downlink FDD Frame Structure



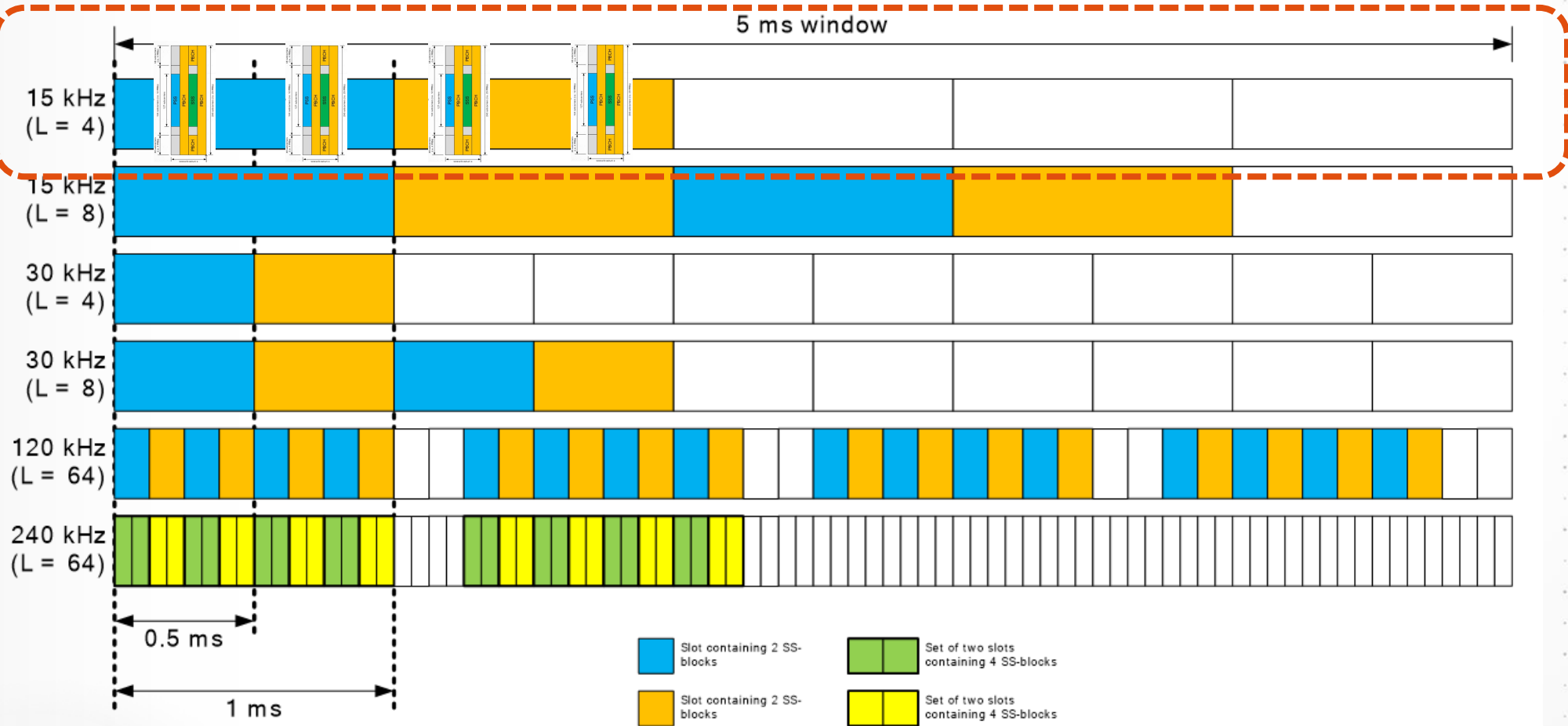
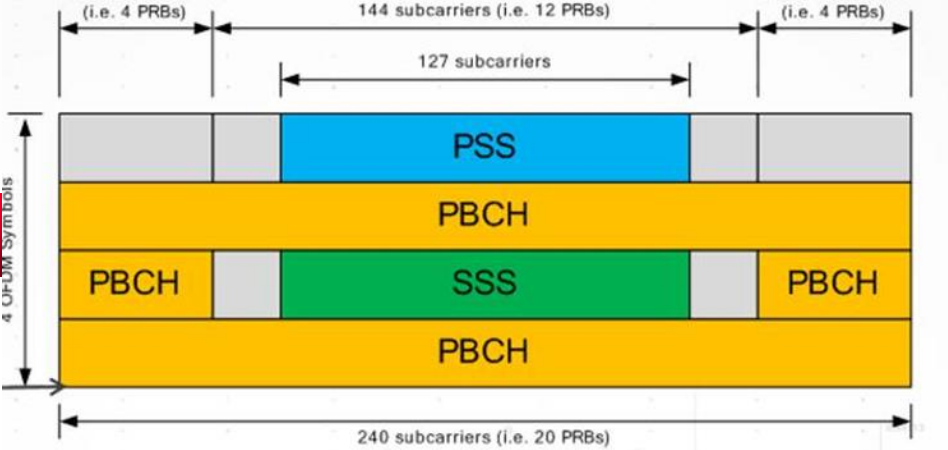
NR SSB

SSB RECAPTURE



NR SSB

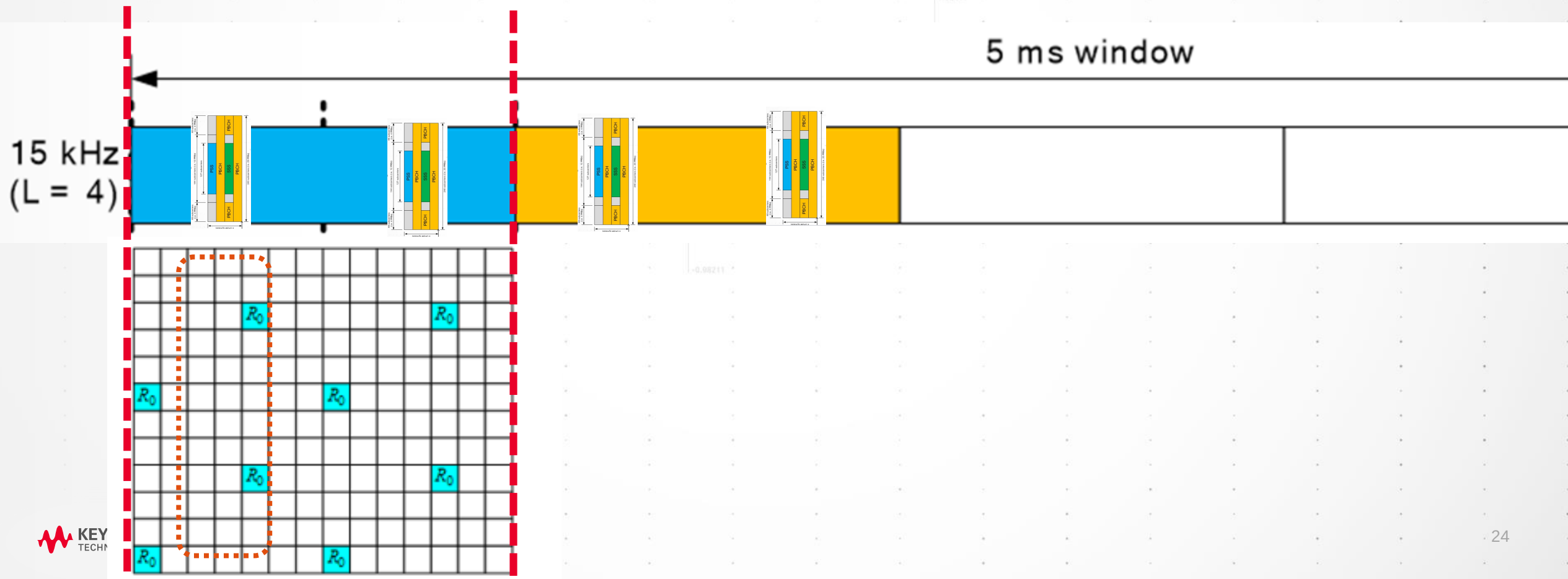
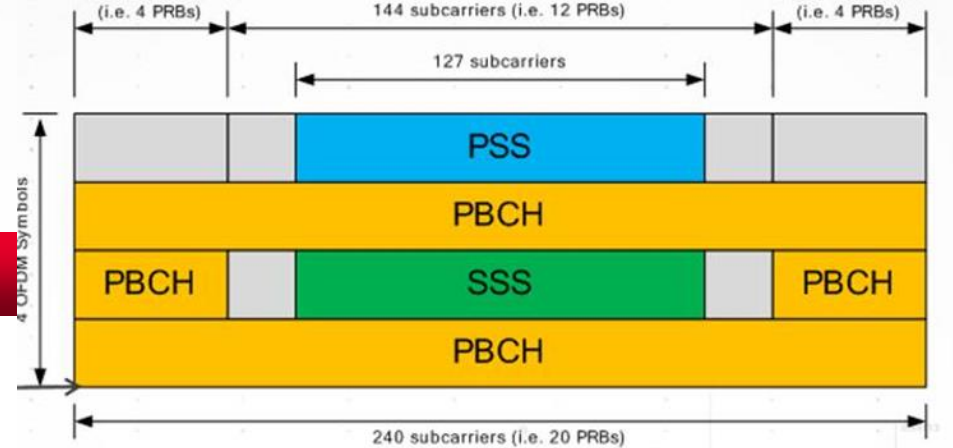
SSB RECAPTURE



CASE A
Frequency <3G
SCS 15k

NR SSB

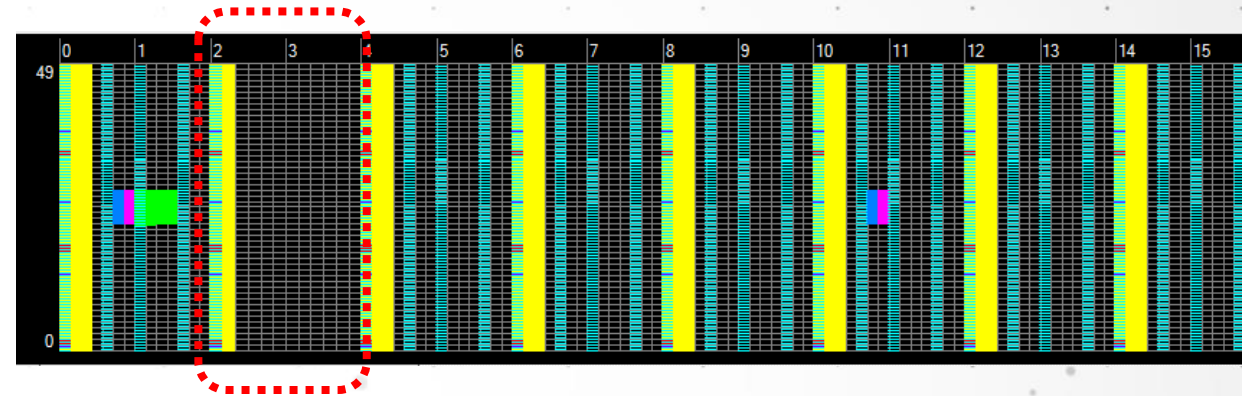
SSB RECAPTURE



MBSFN Configuration in LTE

CONFIGURE MBSFN SUBFRAME

- The 1st and 2nd symbols in LTE MBSFN subframe should be used for LTE CRS and control channel, but the other resource may be free when no multicast/broadcast data transmission
- NR SSB, SIBs, CSI-RS, TRS and PDSCH data can be transmitted on the free resource in LTE MBSFN subframe to bypass LTE CRS
- The number and locations of MBSFN subframes within a specific radio frame is determined by Network and is broadcasted to UE via SIB.
- Support 15kHz SCS



MBSFN

**Multimedia Broadcast multicast service
Single Frequency Network**

Subframes Config

DL RB Allocation

Quick Config

MBSFN

LTE sib2
NR RRC reconfigUse MBSFN configuration for DSS ☐

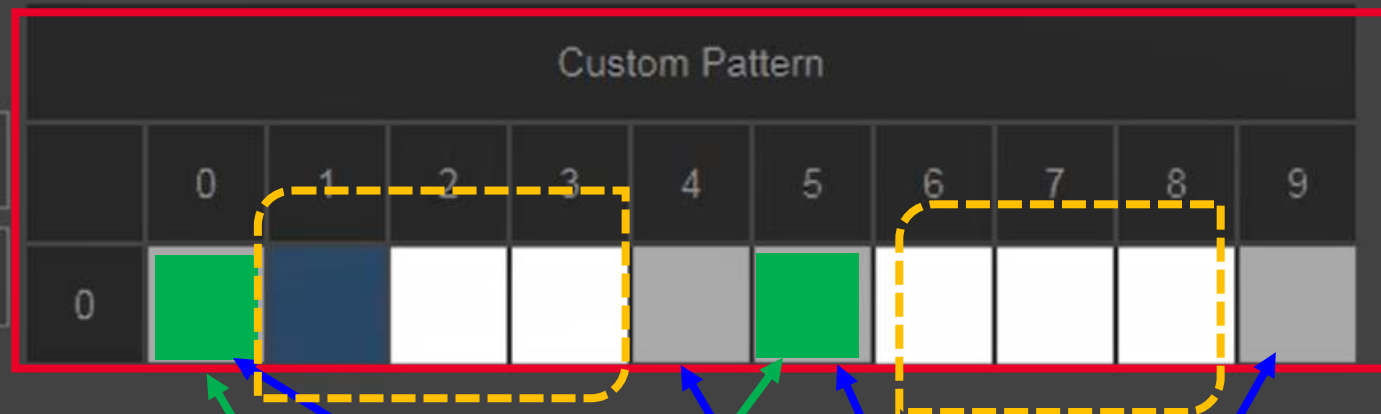
Selected Subframe Configuration 1 ▼

Mbsfn Subframe Configuration

Is Allocated ☒

Radio Frame Allocation Period: 2 ▼

Radio Frame Allocation Offset: 0

Use Four Frames: ☐

Usage

☒ [Array]: mbsfn_SubframeConfigList [1..8] +☒ [Sequence]: EUTRA_MBSFN_SubframeConfig☒ [Enum]: radioframeAllocationPeriod : eEUTRA_MBSFN_SubframeConfig_radioframeAllocationPeriod_n1☒ [Int32]: radioframeAllocationOffset : 0☒ [Choice]: subframeAllocation1☒ [BitString]: oneFrame : 100000☐ [Sequence]: fourFrames☐ [Sequence]: subframeAllocation2 : NULLSYNC
(PSS/SSS/PBCH)

paging

Use MBSFN configuration for DSS ☐

Selected Subframe Configuration

1 ▼

SFN mod
radioframeAllocationPeriod =
radioframeAllocationOffset

Mbsfn Subframe Configuration

Is Allocated ☒

Custom Pattern

Radio Frame Allocation Period:

2 ▼

Radio Frame Allocation Offset:

0

	0	1	2	3	4	5	6	7	8	9
0										

Use Four Frames:

☒ [Array]:mbsfn_SubframeConfigList [1..8] +☒ [Sequence]:EUTRA_MBSFN_SubframeConfig☒ [Enum]:radioframeAllocationPeriod : eEUTRA_MBSFN_SubframeConfig_radioframeAllocationPeriod_n2☒ [Int32]:radioframeAllocationOffset : 0☒ [Choice]:subframeAllocation1☒ [BitString]:oneFrame : 100000☐ [Sequence]:fourFrames☐ [Sequence]:subframeAllocation2 : NULL☒ [Enum]:nrofCRS_Ports : eRateMatchPatternLTE_CRS_nrofCRS_Ports_n2☒ [Enum]:v_Shift : eRateMatchPatternLTE_CRS_v_Shift_n1

Use MBSFN configuration for DSS ☐

Selected Subframe Configuration 1 ▼

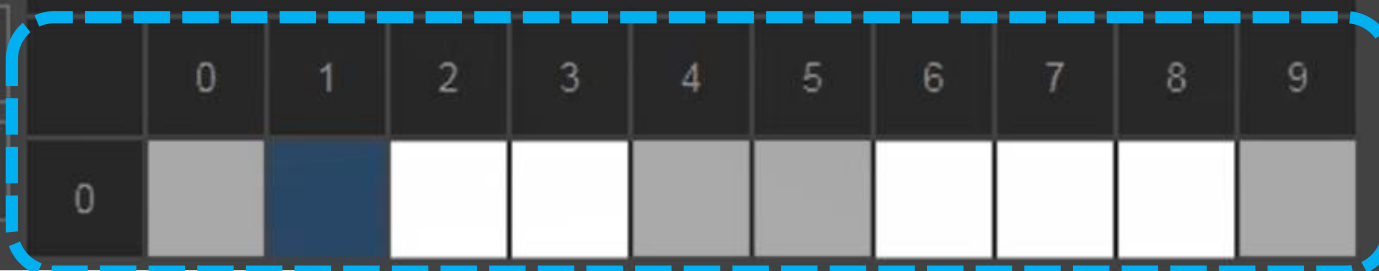
Mbsfn Subframe Configuration

Is Allocated ☒

Radio Frame Allocation Period: 2 ▼

Radio Frame Allocation Offset: 0

Custom Pattern



Frame Number (SFN)

MBSFN

0

YES

1

2

YES

3

4

YES

5

6

YES

7

igible

TDD UL subframe
(bit forced to 0)

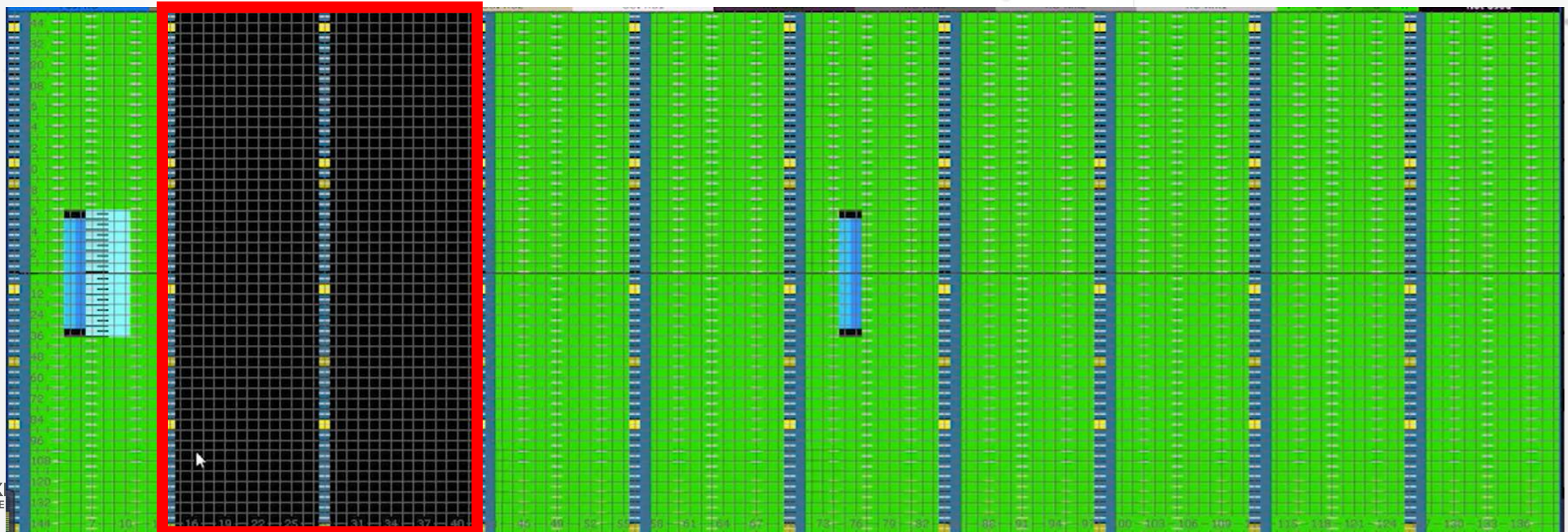
resents this bit not used (0)

resents this bit is used (1)

DSS - Dynamic Spectrum Sharing

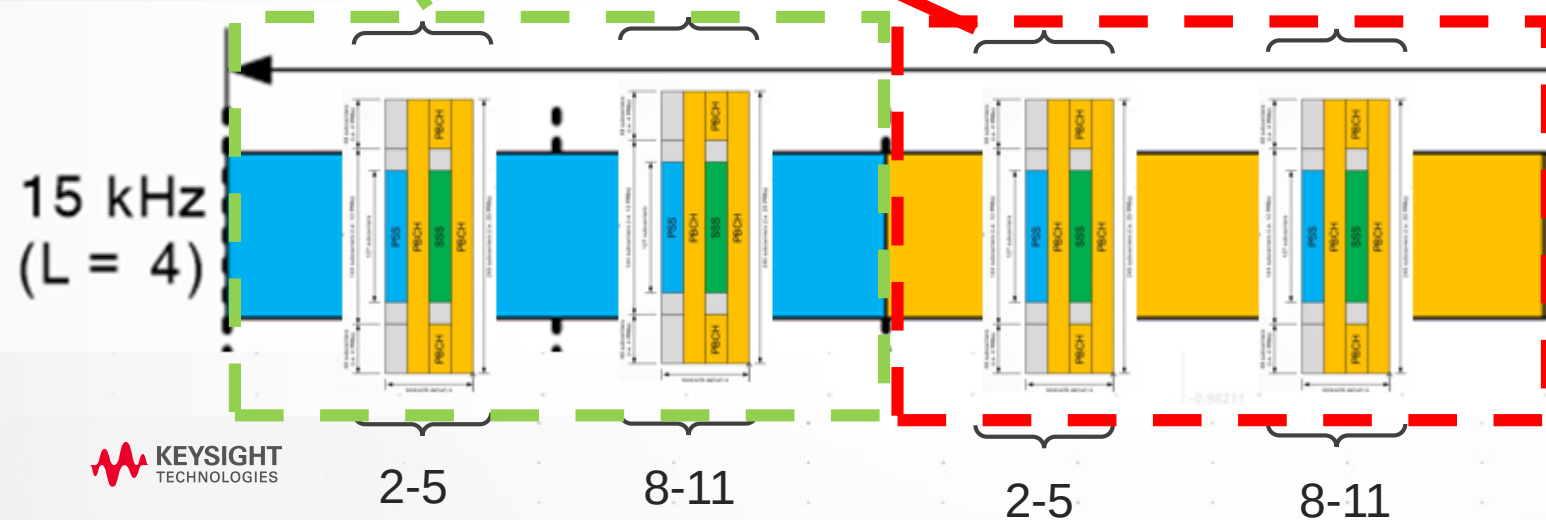
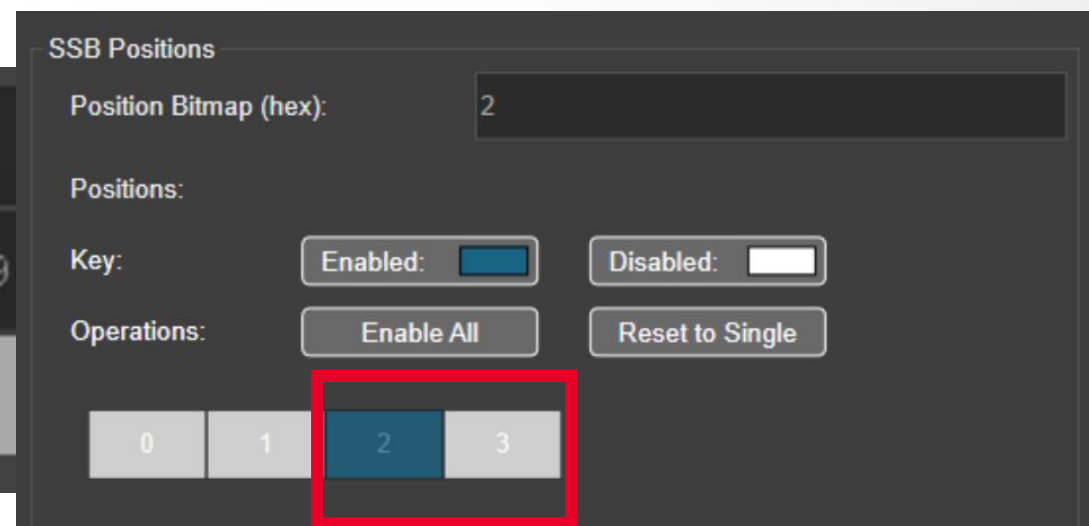
CONFIGURE MBSFN SUBFRAME

- **LTE SIB2**: configure MBSFN subframe location in a radio frame
 - **mbsfn-SubframeConfigList** - **mbsfn-SubframeConfig**
 - $\text{SFN mod radioFrameAllocationPeriod} = \text{radioFrameAllocationOffset}$
 - *subframeAllocation* to configure MBSFN subframe location, for example, configure subframes 1 and 2 as MBSFN subframe
- **LTE SIB13**: configure non-MBSFN
 - **MBSFN-AreaInfoList**
 - *non-MBSFNregionLength*: configure the number of symbols for non-MBSFN region, for example, configure 1st symbol



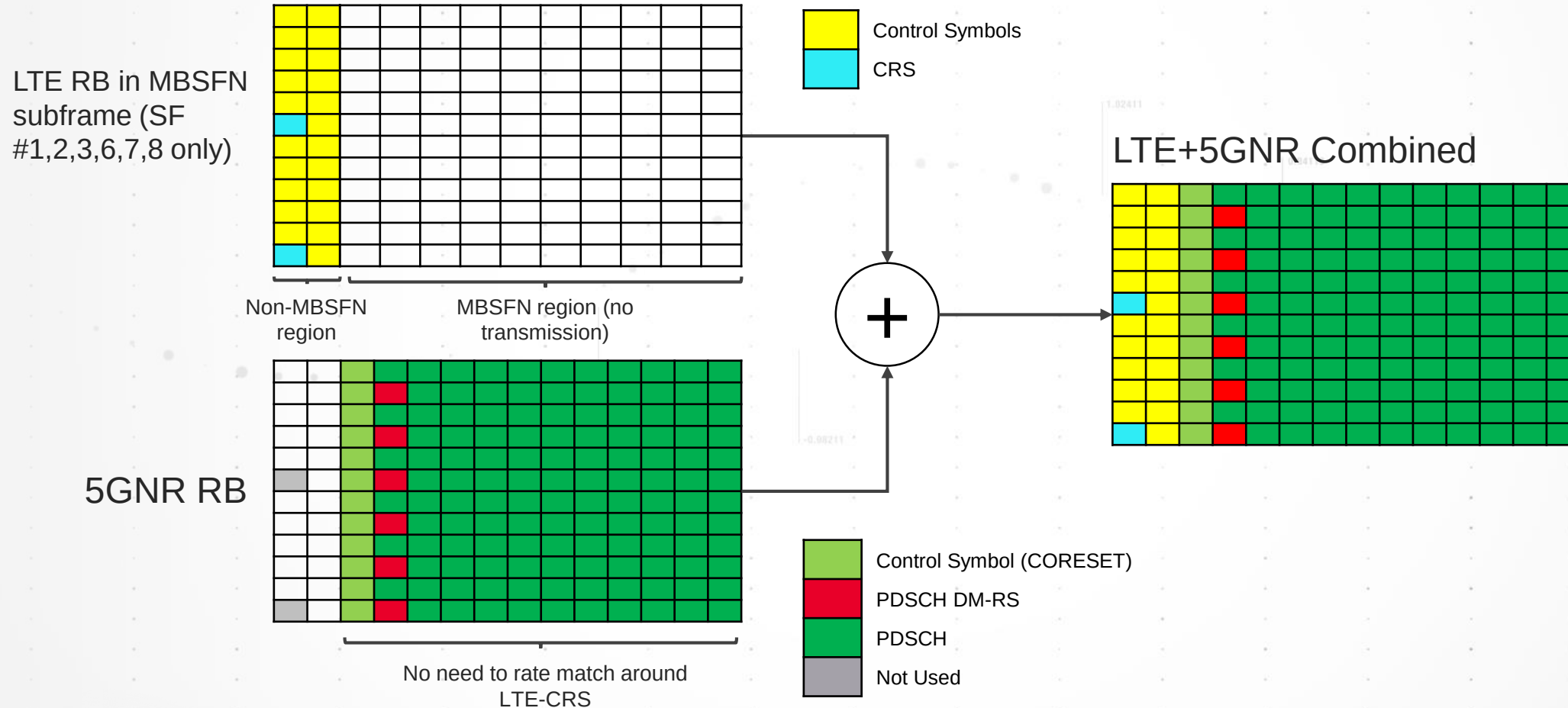
DSS - Dynamic Spectrum Sharing

CONFIGURE NR SSB RESOURCE IN MBSFN SUBFRAME

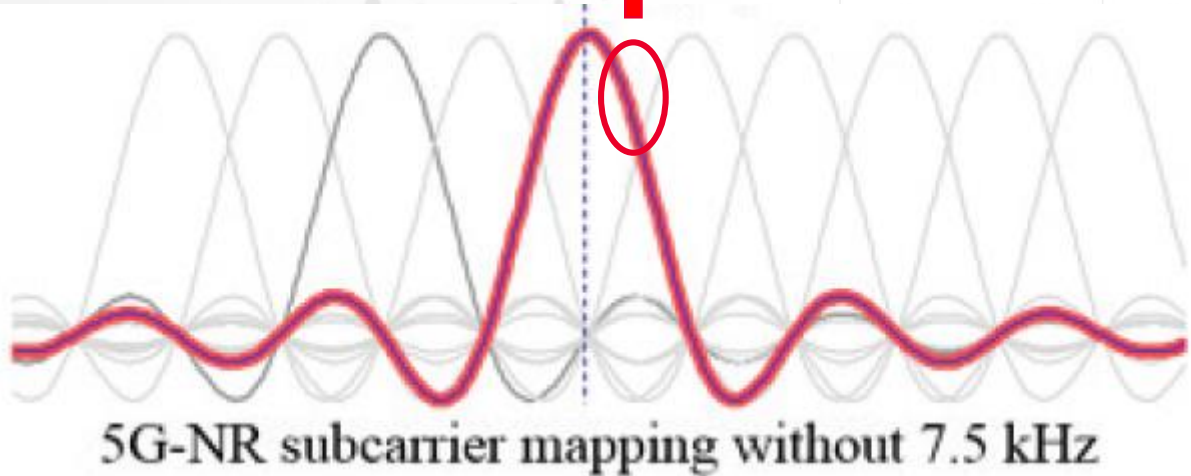
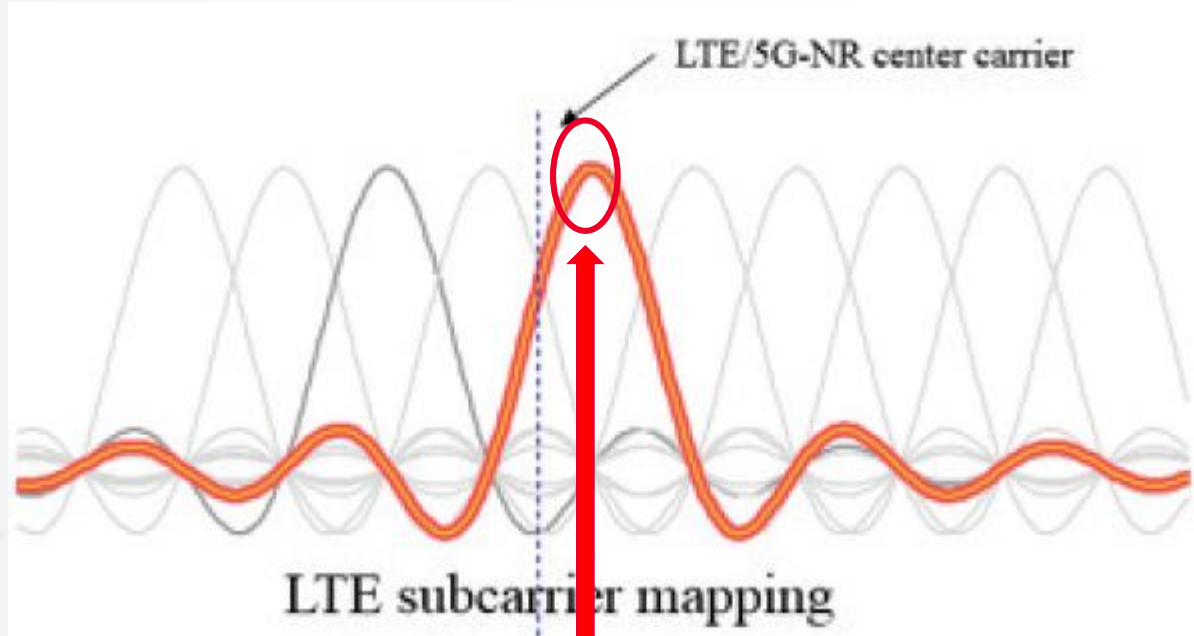


Co-Existence with LTE-MBSFN Subframe

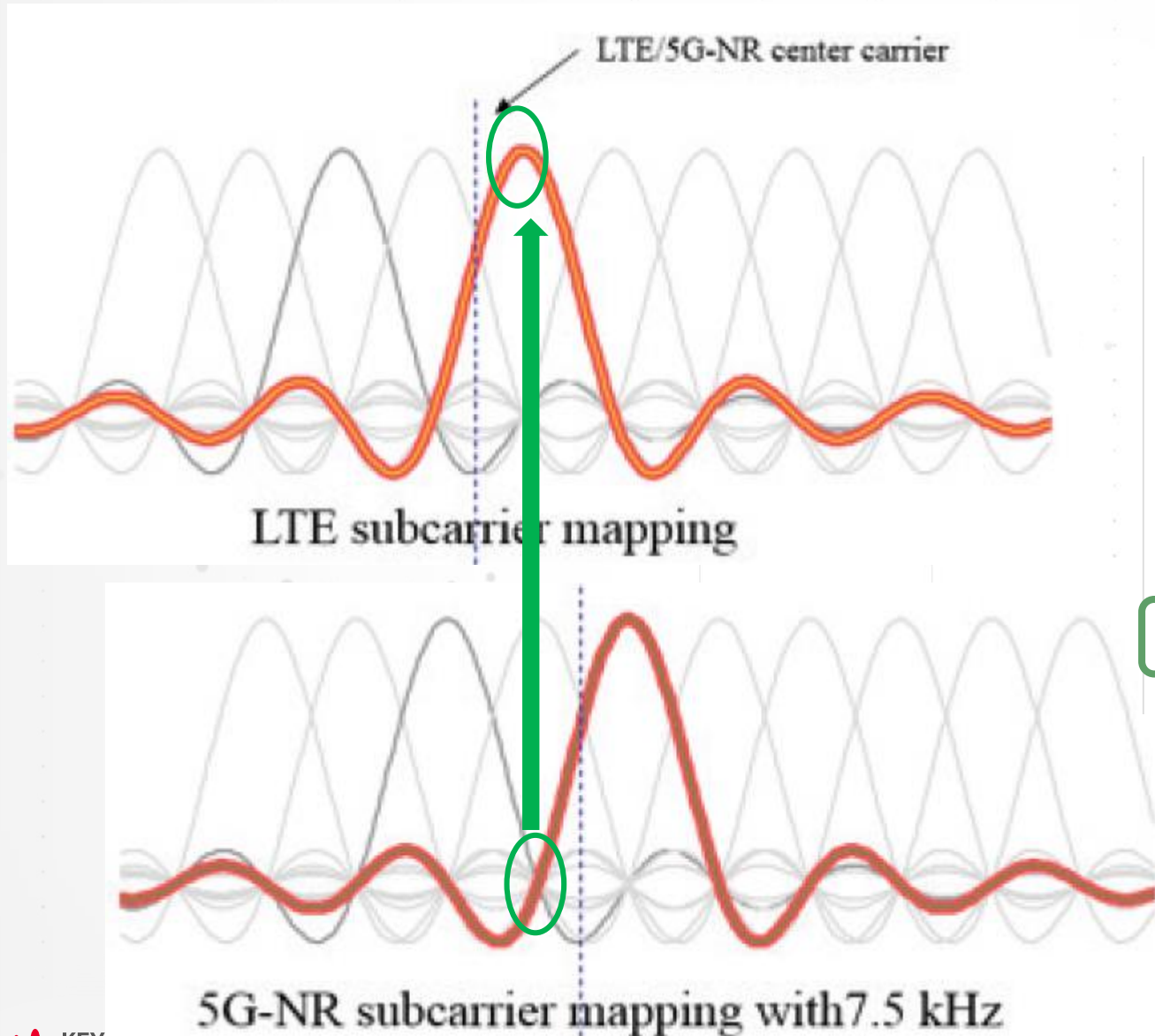
LTE MBSFN subframe does not transmit CRS except control symbols



NR Uplink in DSS



NR Uplink in DSS – 7.5k shift



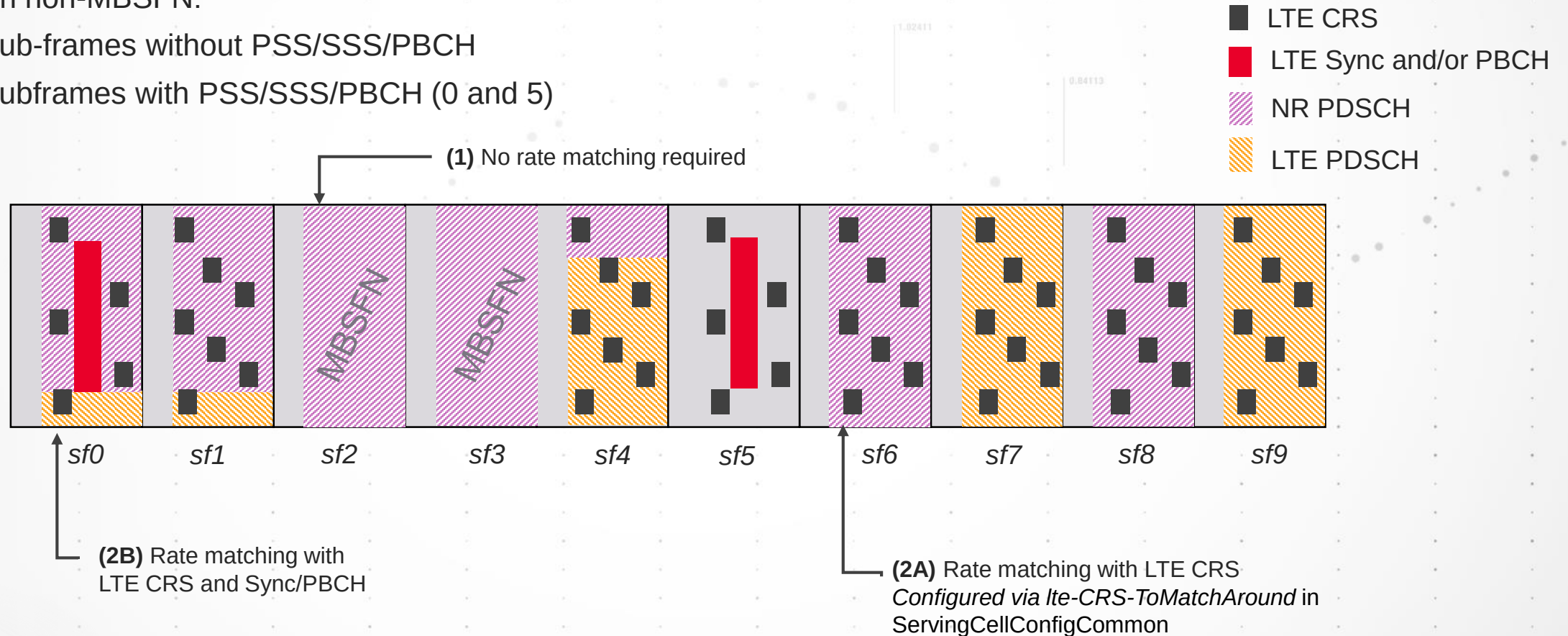
```
[Choice]:lte_CRS_ToMatchAround
  [Sequence]:release
  [Sequence]:setup
    [Int32]:carrierFreqDL : 474
    [Enum]:carrierBandwidthDL : eRateMatchPatternLTE_CRS_carrierBandwidthDL_n50
    [Array]:mbsfn_SubframeConfigList [1..8]
      [Sequence]:EUTRA_MBSFN_SubframeConfig
        [Enum]:radioframeAllocationPeriod : eEUTRA_MBSFN_SubframeConfig_radioframeAllocationPer
        [Int32]:radioframeAllocationOffset : 0
        [Choice]:subframeAllocation1
          [BitString]:oneFrame : 100000
          [Sequence]:fourFrames
          [Sequence]:subframeAllocation2 : NULL
        [Enum]:nrofCRS_Ports : eRateMatchPatternLTE_CRS_nrofCRS_Ports_n2
        [Enum]:v_Shift : eRateMatchPatternLTE_CRS_v_Shift_n1
      [Array]:rateMatchPatternToAddModList : NULL
      [Array]:rateMatchPatternToReleaseList : NULL
      [Enum]:ssbSubcarrierSpacing : eSubcarrierSpacing_kHz15
      [Sequence]:tdt_UL_DL_ConfigurationCommon : NULL
    [Int32]:ss_PBCH_BlockPower : 15
```

DSS Case

DIFFERENT USE CASES

Three use cases:

1. NR is in MBSFN
2. NR is in non-MBSFN:
 - A. Sub-frames without PSS/SSS/PBCH
 - B. Subframes with PSS/SSS/PBCH (0 and 5)



DSS solution Overview



5G NES Hardware Components

3 KEY BUILDING BLOCKS



UXM 5G Wireless Test Platform (E7515B)

- <6GHz Frequency range
- 4G and 5G supported in one UXM 5G
- Scalable bandwidth 8Tx/4Rx @800MHz, 4Tx/2Rx @1600MHz
- Integrated RFIO + Internal fading
- Support for RF, IF, Host and BBIQ interfaces (slow and full rate)
- Support for 10GbE connectivity



Common Interfacing Unit (E7770A)

- Same unit for both PROPSIM CE and UXM 5G
- Supports up to 8x heads, with scalability for more
- Flexibility to add new heads to support new bands
- Supports high IF connection (6-12 GHz)



mmWave Transceiver for 5G (RRH)

- Supports 24.25 to 43.5GHz frequency coverage with 1x RRH
- Compact, bi-directional
- Supports both OTA and cabled testing

5G Device End-To-End Solutions

PORTFOLIO

5G Device Development Solutions



Protocol
R&D Toolset



RF Automation
Toolset



Functional
KPI Toolset



5G Device Acceptance Solutions



Protocol
Conformance
Toolset



RF/RRM DVT +
Conformance
Toolset



Protocol Carrier
Acceptance
Toolset



RF/RRM Carrier
Acceptance
Toolset



5G MFG Solutions



Manufacturing



Network Emulator



Channel Emulator



mmWave OTA Solutions

Interactive 5G stack
with common tools

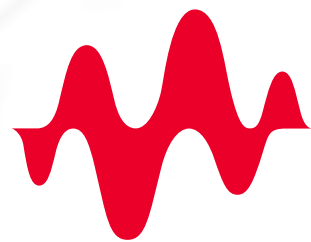


Common measurement science,
logging
and automation

Keysight Test App Support

DSS REQUIREMENTS

Feature description	Test App	Comments
UL 7.5 kHz shift	Supported	
5G PDSCH rate matching around LTE CRS	Supported	
5G PDSCH rate matching around LTE sync/PBCH channels	Supported	Via Static Patterns with ASN
Alternative DMRS position for co-existence with LTE CRS	Supported	Only required for 1x specific config
Support for LTE MBSFN subframes	Supported	Used to transmit SSB without colliding with LTE CRS
Mixed numerology (SSB = 30 kHz, PDSCH = 15kHz)	Internal Testing	Not required for initial roll out as only MBSFN subframes will be used



KEYSIGHT
TECHNOLOGIES