KEYSIGHT WORLD2018

Understanding the 5G NR Physical Layer

Senior Application Engineer/ Keysight Technologies

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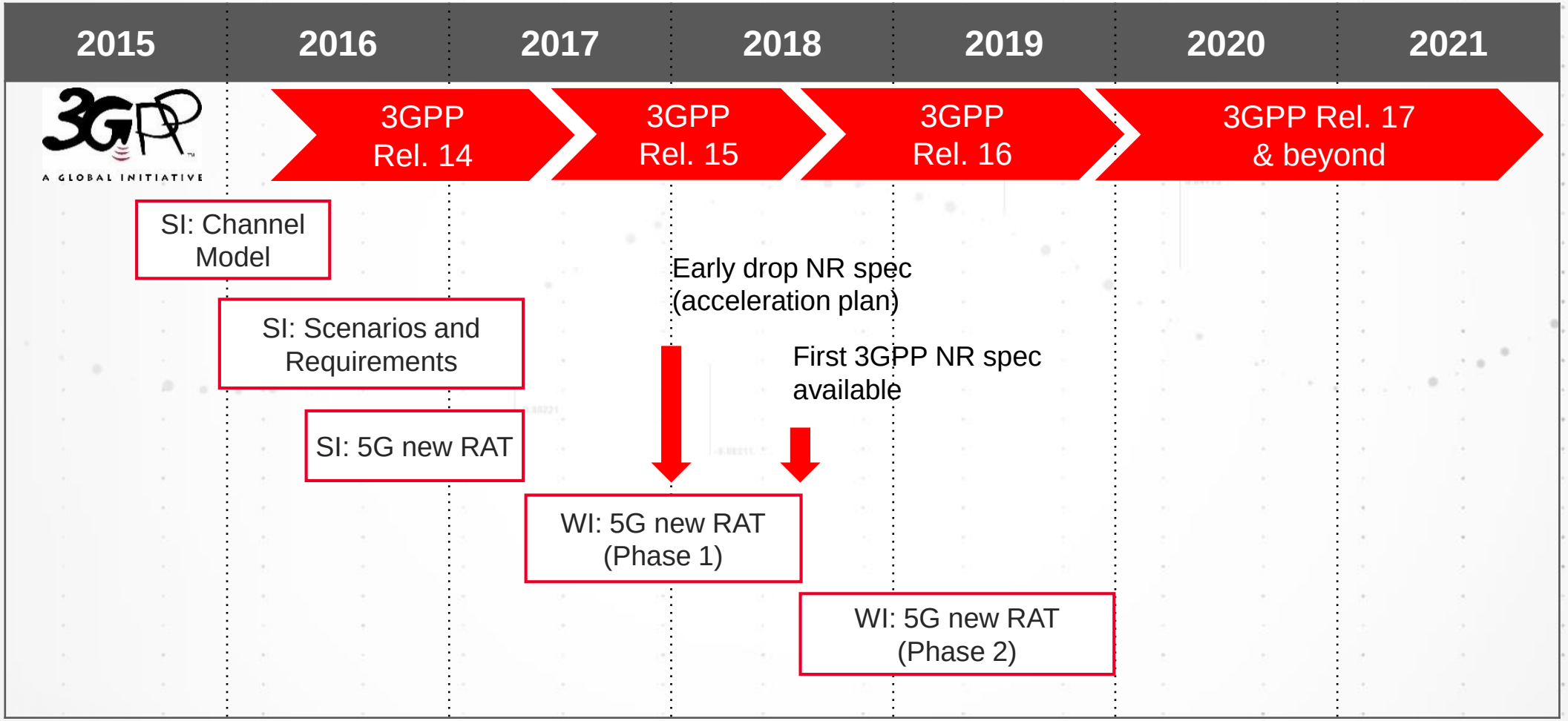
3GPP NR RAN1 Roadmap

UPDATE ON 3GPP RAN1 NR ROADMAP



3GPP NR Use Cases

3GPP Rel. 15 covers eMBB and URLLC

eMBB

Enhanced Mobile Broadband (eMBB)

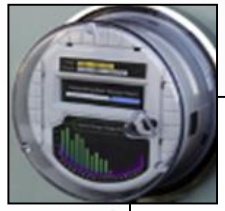
- 10-20 Gbps peak
- 100 Mbps whenever needed
- 10000x more traffic
- Macro and small cells
- Support for high mobility (500 km/h)
- Network energy saving by 100 times

URLLC

Ultra Reliable Low Latency Communication (URLLC)

- Ultra responsive
  - <1 ms air interface latency
  - 5 ms E2E latency
- Ultra reliable and available (99.9999%)
- Low to medium data rates (50 kbps - 10 Mbps)
- High speed mobility

mMTC



Massive Machine Type Communication (mMTC)

- High density of devices ($2x10^5$ - $10^6/km^2$)
- Long range
- Low data rate (1 - 100 kbps)
- M2M ultra low cost
- 10 years battery
- Asynchronous access

3GPP NR Rel-15 Scope

3GPP NR ROADMAP & INTRODUCTION

- Acceleration of eMBB Non-Standalone mode by **December'17**
  - Standalone standardization dates as expected (June'18)
- Use cases:
  - Enhanced Mobile Broadband (eMBB)
  - Ultra Reliable Low Latency Communications (URLLC)
- Carrier aggregation operation
- Inter-RAT mobility between NR and E-UTRA

✓ **IN SCOPE**

- Frequencies beyond 52.6 GHz
  - Other types of waveforms
- mMTC – Machine type communications
- Internetworking with non-3GPP systems (e.g. WiFi)
- Vehicular communications
- Multicast services and multimedia broadcast
- Unlicensed spectrum access

⊘ **OUT OF SCOPE**

Waveform, Numerology and Frame Structure

Waveform

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- **Waveform** (for eMBB/URLLC and < 52.6 GHz)
  - DL Waveform: OFDM
  - UL Waveform: OFDM or SC-FDMA
    - OFDM targeted at high throughput scenarios
    - SC-FDMA targeted at power limited scenarios
- **Multiple Access**
  - Orthogonal Multiple Access
  - Non-Orthogonal Multiple Access (NOMA) not supported in Rel-15
- **Bandwidth**
  - Maximum CC bandwidth is 400 MHz
  - Maximum number of subcarriers is 3300
    - 4096-FFT is needed
  - Maximum number of CCs is 16

Numerology Definition

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- Scalable subcarrier spacing

$$\Delta f = 2^{\mu} \cdot 15\ kHz$$

- Parameters defining a numerology:
  - Subcarrier spacing (i.e. μ parameter)
  - Cyclic prefix (i.e. Normal/Extended)

μ	Δf = 2μ·15 kHz	Cyclic Prefix
0	15 kHz	Normal
1	30 kHz	Normal
2	60 kHz	Normal, Extended
3	120 kHz	Normal
4	240 kHz	Normal

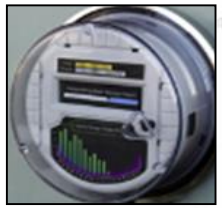
Why different OFDM Numerology

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- 5G NR use an unified air interface to cover different use cases using **Sub-6G & mmWave**

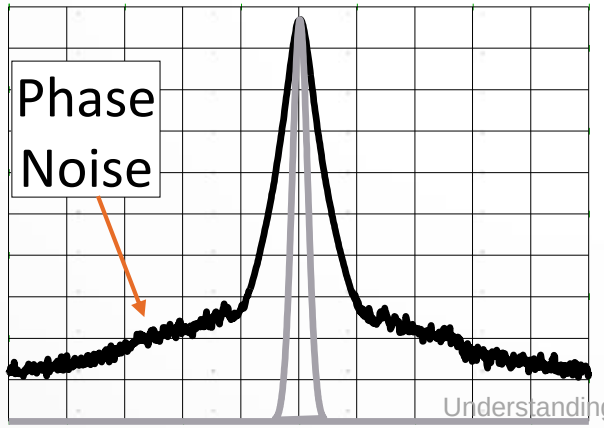
eMBB

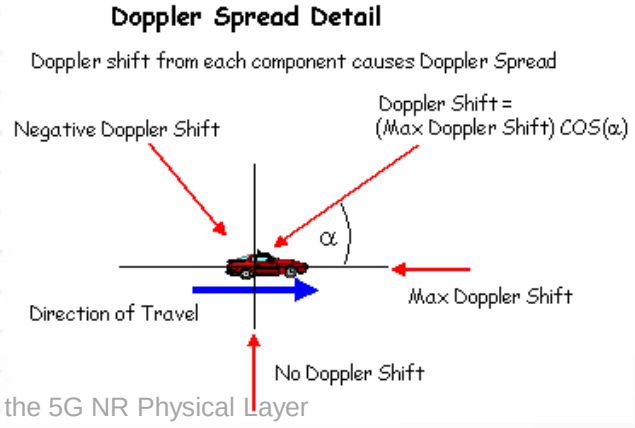
URLLC



mMTC

- The selection of numerology would be based on:
  - Phase noise
  - Doppler shift





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- Parameters defining a numerology:
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  - Cyclic prefix (i.e. Normal/Extended)

	μ	Δf = 2μ·15 kHz	Cyclic Prefix	
Sync < 6 GHz	0	15 kHz	Normal	Data < 6 GHz
	1	30 kHz	Normal	
	2	60 kHz	Normal, Extended	Data > 6 GHz
Sync > 6 GHz	3	120 kHz	Normal	
	4	240 kHz	Normal	

URLLC

Why different OFDM Numerology

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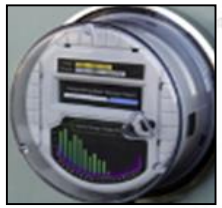
- 5G NR use an unified air interface to cover different use cases using **Sub-6G & mmWave**

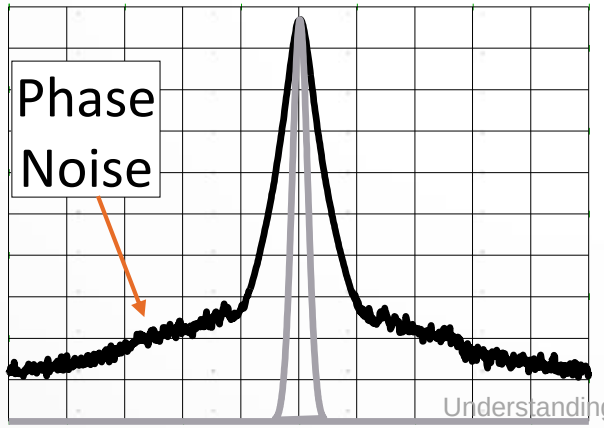
eMBB

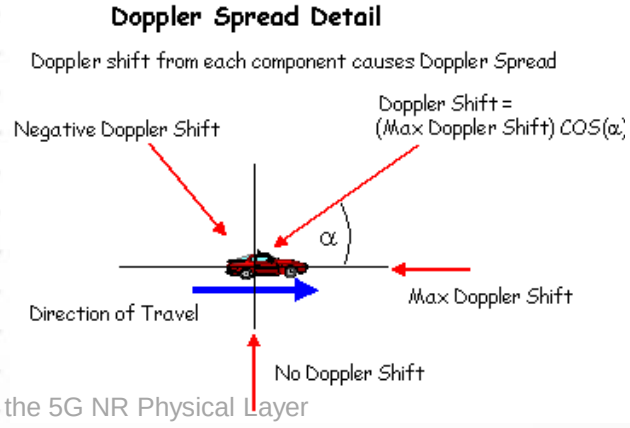
URLLC



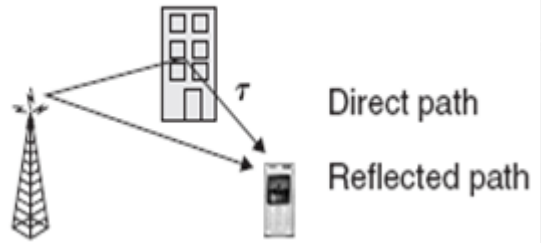
mMTC

- The selection of numerology would be based on :
  - Phase noise
  - Doppler shift
  - Delay spread



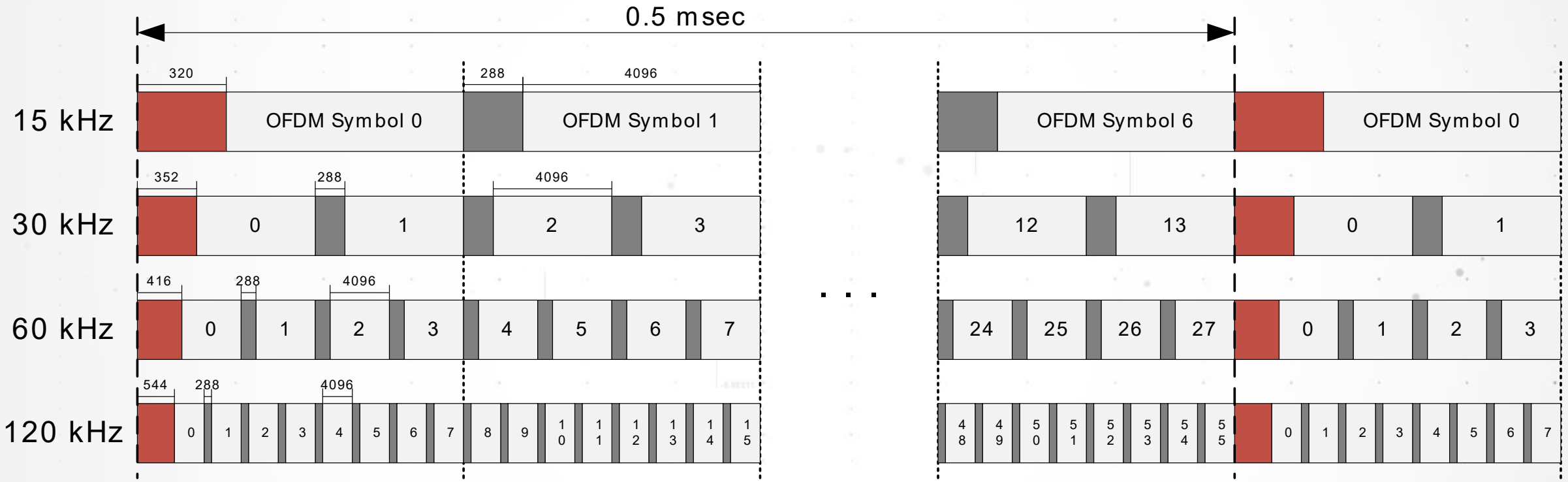


Delay spread



Numerology Example (Normal CP)

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE



- Each symbol length (including CP) of 15 kHz equals the sum of the corresponding 2^{μ} symbols at F_s
- Other than the first OFMD symbol in every 0.5 ms, all symbols within 0.5 ms have the same length

Numerology Definition

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

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$$\Delta f = 2^{\mu} \cdot 15\ kHz$$

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Sync < 6 GHz	0	15 kHz	Normal	Data < 6 GHz
	1	30 kHz	Normal	
	2	60 kHz	Normal, Extended	Data > 6 GHz
Sync > 6 GHz	3	120 kHz	Normal	
	4	240 kHz	Normal	

URLLC

Physical Resources

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- Resource elements are grouped into Physical Resource Blocks (**PRB**)
- Each PRB consists of **12 subcarriers**

μ	Δf	$N_{RB}^{min,\mu}$	$N_{RB}^{max,\mu}$
0	15 kHz	20 (240 subcarriers)	275 (3300 subcarriers, 49.5 MHz)
1	30 kHz	20	275 (3300 subcarriers, 99 MHz)
2	60 kHz	20	275 (3300 subcarriers, 198 MHz)
3	120 kHz	20	275 (3300 subcarriers, 396 MHz)
4	240 kHz	20	138

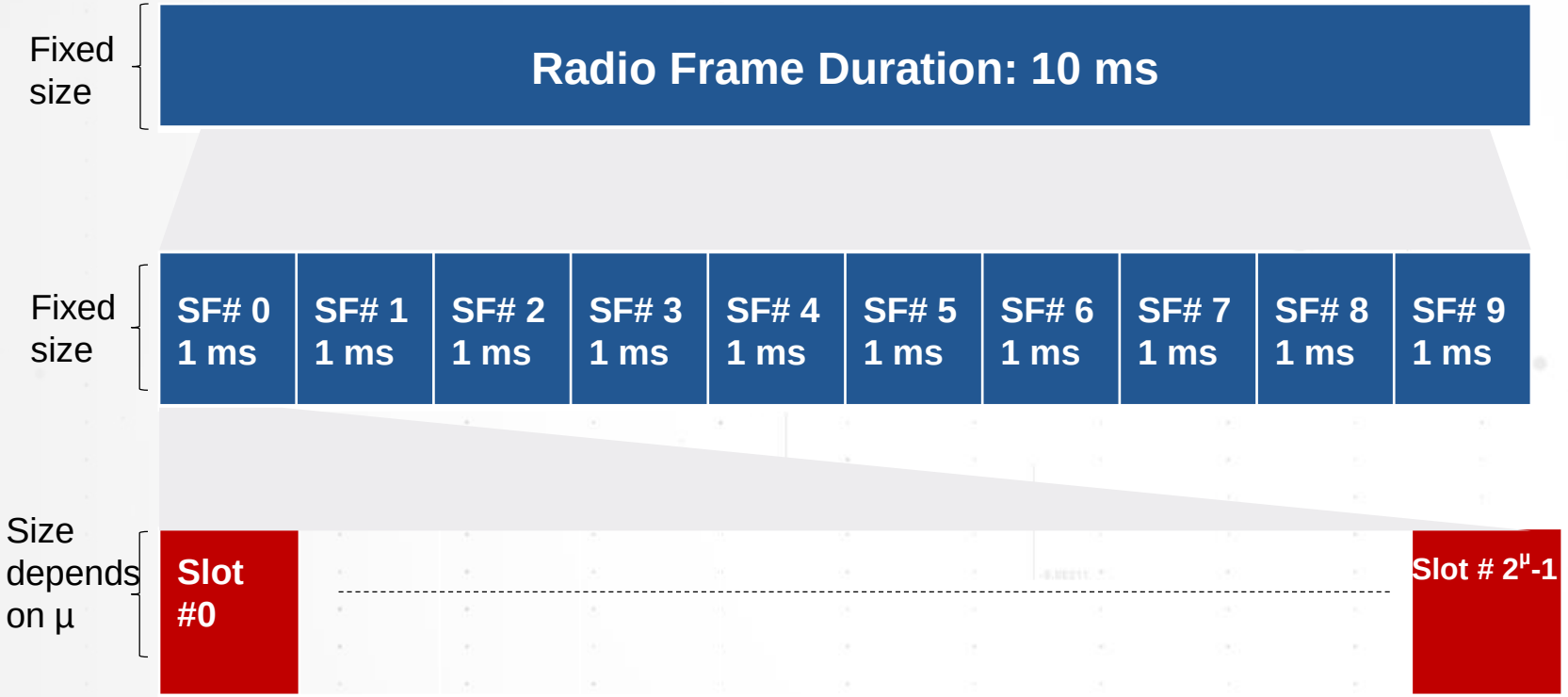
Mixed Numerology

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- Multiplexing different numerologies (**BWP is configured with a single numerology**)
  - TDM and/or FDM for downlink and uplink
  - Rel-15 NR UEs are not mandated to support simultaneous DL reception or UL transmission of multiple FDM physical channels (e.g. PDSCH, PDCCH, PUSCH, PUCCH) with different numerologies at the same time
- Two FDM use cases
  - **Use Case #1:** Data/Data
    - Not supported in DL (for Rel-15)
    - Not supported in UL (for Rel-15)
    - Supported between DL and UL (i.e. different numerologies in DL and UL)
  - **Use Case #2:** Data/Synchronization
    - Optional from UE point of view

Frame Structure

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE



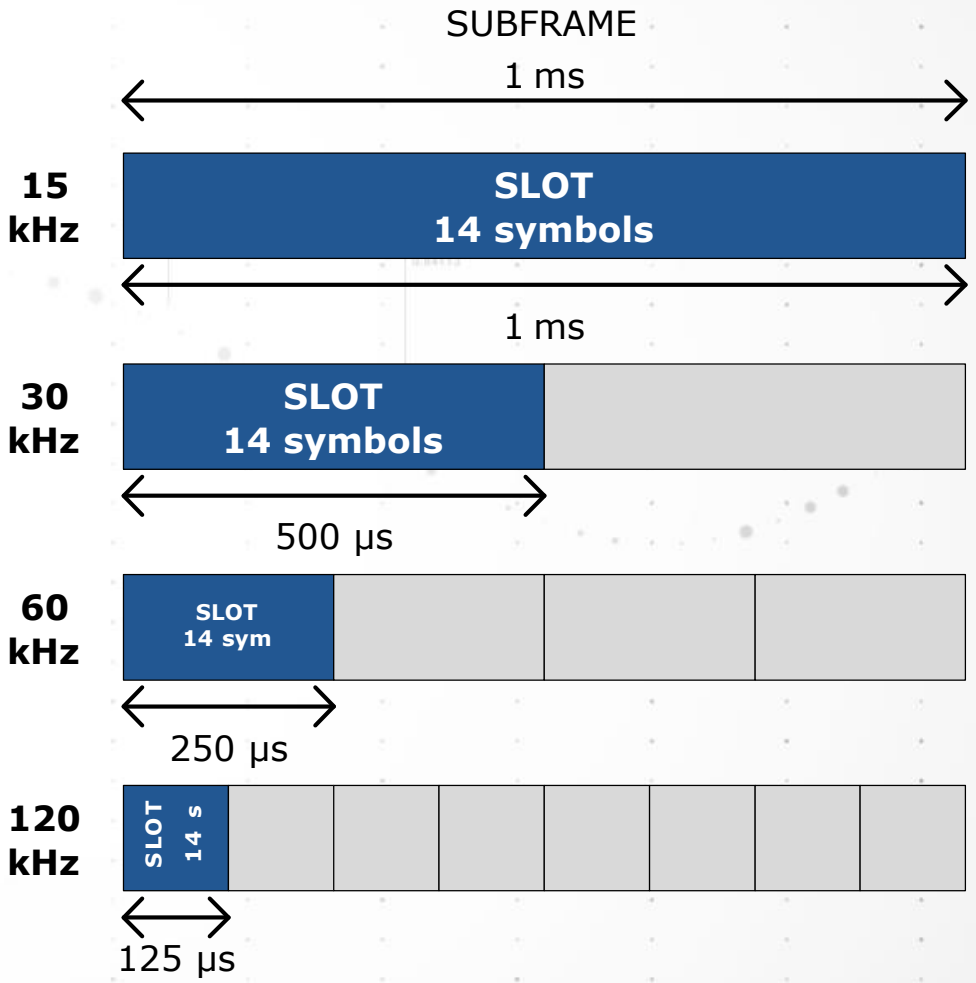
A slot is one possible scheduling unit.
Mini-Slot is a minimum scheduling unit with 7, 4 or 2 OFDM symbols

μ	N^{slot}_{symb}	$N^{subframe,\mu}_{slot}$	$N^{frame,\mu}_{slot}$	Slot duration
0 *15 kHz*	14	1	10	1 ms
1 *30 kHz*	14	2	20	500 µs
2 *60 kHz (normal CP)*	14	4	40	250 µs
2 *60 kHz (extended CP)*	12	4	40	250 µs
3 *120 kHz*	14	8	80	125 µs
4 *240 kHz*	14	16	160	62.5 µs

Frame Structure

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

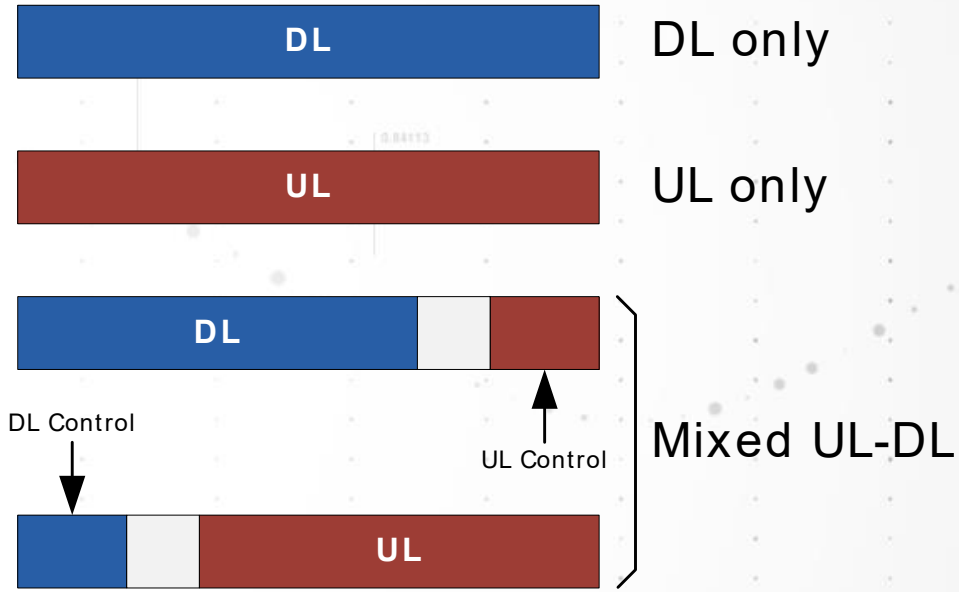
- Frame: 10 ms
- Subframe: Reference period of 1 ms
- Slot (slot based scheduling)
  - **14 OFDM symbols**
  - One possible scheduling unit
    - Slot aggregation allowed
  - Slot length scales with the subcarrier spacing
    - $Slot\ length = {}^{1\ ms}/_{2^{\mu}}$
- Mini-Slot (non-slot based scheduling)
  - **7, 4 or 2 OFDM symbols**
  - Minimum scheduling unit



Slot Structure

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

- A slot can be:
  - All downlink
  - All uplink
  - Mixed downlink and uplink
    - Static, semi-static or dynamic
- Slot aggregation is supported
  - Data transmission can be scheduled to span one or multiple slots



5G NR Slots Formats

D: Downlink symbol
U: Uplink symbol
X: Flexible symbol

TS 38.211 TABLE 4.3.2-3: SLOT FORMATS

Format	Symbol number in a slot													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	D	D	D	D	D	D	D	D	D	D	D	D	D	X
4	D	D	D	D	D	D	D	D	D	D	D	D	X	X
5	D	D	D	D	D	D	D	D	D	D	D	X	X	X
6	D	D	D	D	D	D	D	D	D	D	X	X	X	X
7	D	D	D	D	D	D	D	D	D	X	X	X	X	X
8	X	X	X	X	X	X	X	X	X	X	X	X	X	U
9	X	X	X	X	X	X	X	X	X	X	X	X	U	U
10	X	U	U	U	U	U	U	U	U	U	U	U	U	U
11	X	X	U	U	U	U	U	U	U	U	U	U	U	U
12	X	X	X	U	U	U	U	U	U	U	U	U	U	U
13	X	X	X	X	U	U	U	U	U	U	U	U	U	U
14	X	X	X	X	X	U	U	U	U	U	U	U	U	U
15	X	X	X	X	X	X	U	U	U	U	U	U	U	U
16	D	X	X	X	X	X	X	X	X	X	X	X	X	X
17	D	D	X	X	X	X	X	X	X	X	X	X	X	X
18	D	D	D	X	X	X	X	X	X	X	X	X	X	X
19	D	X	X	X	X	X	X	X	X	X	X	X	X	U
20	D	D	X	X	X	X	X	X	X	X	X	X	X	U
21	D	D	D	X	X	X	X	X	X	X	X	X	X	U
22	D	X	X	X	X	X	X	X	X	X	X	X	U	U
23	D	D	X	X	X	X	X	X	X	X	X	X	U	U
24	D	D	D	X	X	X	X	X	X	X	X	X	U	U
25	D	X	X	X	X	X	X	X	X	X	X	U	U	U
26	D	D	X	X	X	X	X	X	X	X	X	U	U	U
27	D	D	D	X	X	X	X	X	X	X	X	U	U	U
28	D	D	D	D	D	D	D	D	D	D	D	D	X	U
29	D	D	D	D	D	D	D	D	D	D	D	X	X	U
30	D	D	D	D	D	D	D	D	D	D	X	X	X	U
31	D	D	D	D	D	D	D	D	D	D	D	X	U	U
32	D	D	D	D	D	D	D	D	D	D	X	X	U	U
33	D	D	D	D	D	D	D	D	D	X	X	X	U	U
34	D	X	U	U	U	U	U	U	U	U	U	U	U	U
35	D	D	X	U	U	U	U	U	U	U	U	U	U	U
36	D	D	D	X	U	U	U	U	U	U	U	U	U	U
37	D	X	X	U	U	U	U	U	U	U	U	U	U	U
38	D	D	X	X	U	U	U	U	U	U	U	U	U	U
39	D	D	D	X	X	U	U	U	U	U	U	U	U	U
40	D	X	X	X	U	U	U	U	U	U	U	U	U	U
41	D	D	X	X	X	U	U	U	U	U	U	U	U	U
42	D	D	D	X	X	X	U	U	U	U	U	U	U	U
43	D	D	D	D	D	D	D	D	D	X	X	X	X	U
44	D	D	D	D	D	D	X	X	X	X	X	X	U	U
45	D	D	D	D	D	D	X	X	U	U	U	U	U	U
46	D	D	D	D	D	D	X	D	D	D	D	D	D	X
47	D	D	D	D	D	X	X	D	D	D	D	D	X	X
48	D	D	X	X	X	X	X	D	D	X	X	X	X	X
49	D	X	X	X	X	X	X	D	X	X	X	X	X	X
50	X	U	U	U	U	U	U	X	U	U	U	U	U	U
51	X	X	U	U	U	U	U	X	X	U	U	U	U	U
52	X	X	X	U	U	U	U	X	X	X	U	U	U	U
53	X	X	X	X	U	U	U	X	X	X	X	U	U	U
54	D	D	D	D	D	X	U	D	D	D	D	D	X	U
55	D	D	X	U	U	U	U	D	D	X	U	U	U	U
56	D	X	U	U	U	U	U	D	X	U	U	U	U	U
57	D	D	D	D	X	X	U	D	D	D	D	X	X	U
58	D	D	X	X	U	U	U	D	D	X	X	U	U	U
59	D	X	X	U	U	U	U	D	X	X	U	U	U	U
60	D	X	X	X	X	X	U	D	X	X	X	X	X	U
61	D	D	X	X	X	X	U	D	D	X	X	X	X	U
62 – 255	Reserved													

Slot Format Indication

WAVEFORM, NUMEROLOGY AND FRAME STRUCTURE

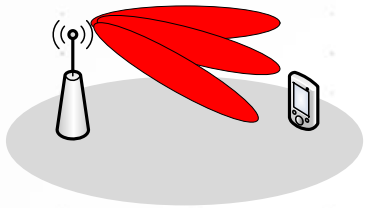
- Slot Format Indication informs the UE whether an OFDM symbol is ***Downlink***, ***Uplink*** or ***Flexible***
- SFI can indicate link direction over one or many slots (configured through RRC)
- The SFI carries an index to a pre-configured UE-specific table (configured through RRC)
- SFI can be either:
  - **Dynamic** (i.e. through a DCI)
    - UE assumes there is no conflict between dynamic SFI and DCI DL/UL assignments
  - **Static** or **semi-static** (i.e. through RRC)

Initial Access and Beam Management

Initial Access Procedure

INITIAL ACCESS AND BEAM MANAGEMENT

TRxP-Wide Coverage



Beam-sweeping transmission

Beam-sweeping transmission

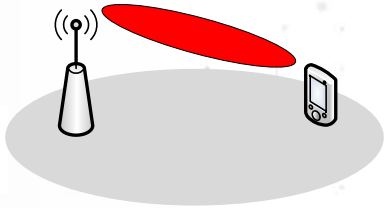
Synchronization Signals

System Information

Basic information for all UEs

Beam-sweeping reception

Random Access Channel



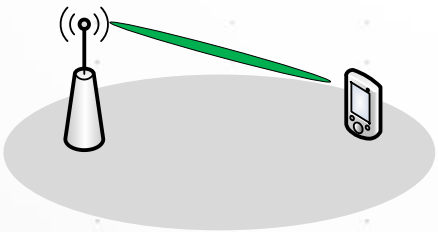
UE-specific selected beam

Random Access Response & System Information

Required only for UEs after random access

Single-beam or Beam-sweeping

UE-Specific Coverage

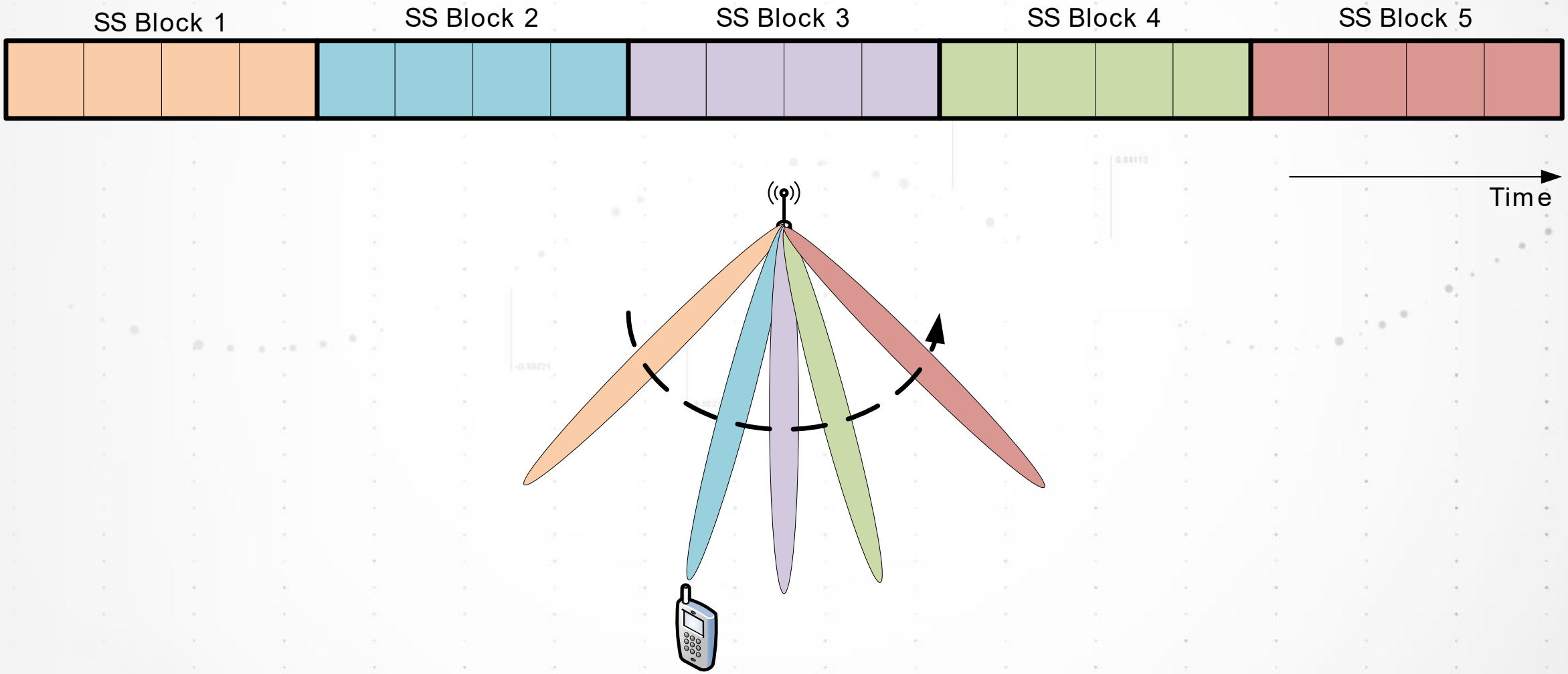


UE-specific beamforming

Data and control channels

Beam-Sweeping and Initial Access

INITIAL ACCESS AND BEAM MANAGEMENT

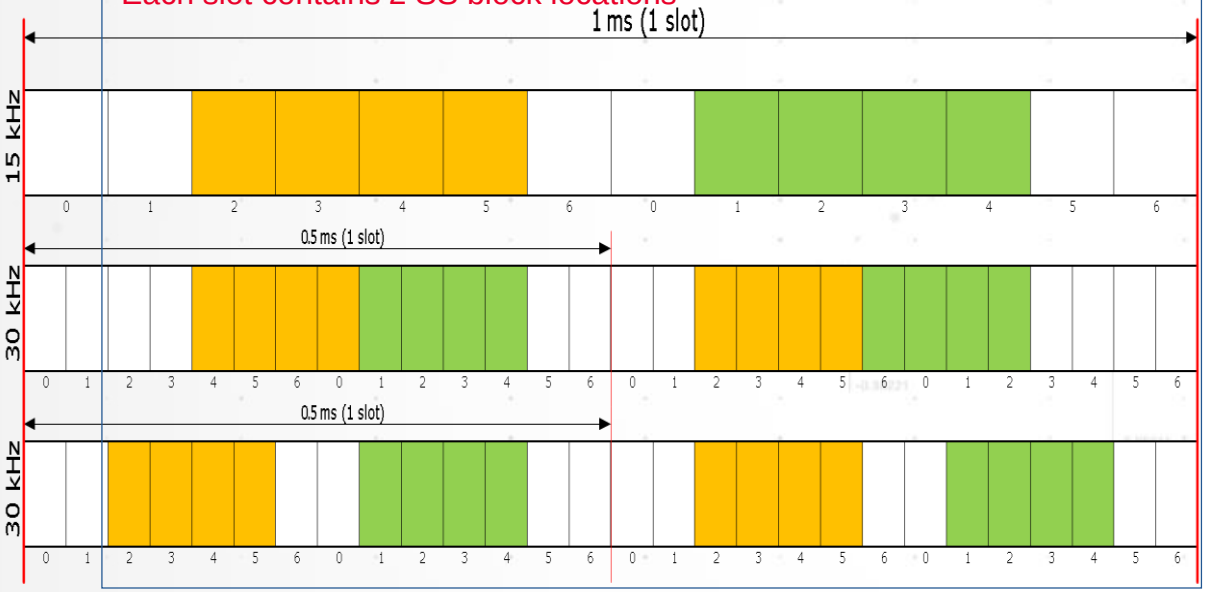


SS Block Mapping Location

INITIAL ACCESS AND BEAM MANAGEMENT

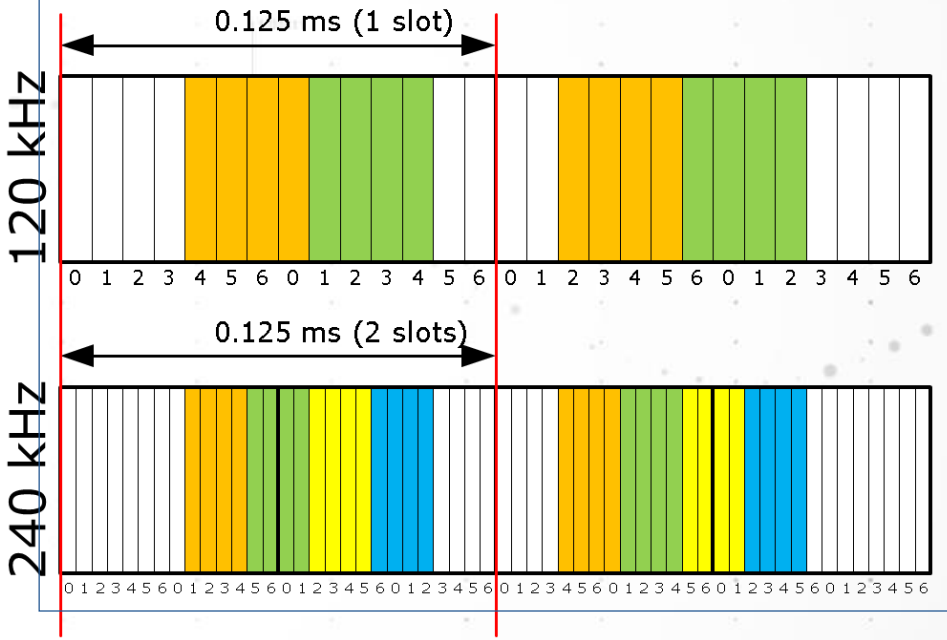
SSB mapping locations for **< 6 GHz**:

Each slot contains 2 SS block locations



Note: 30 kHz has two different mappings. 2nd one has empty symbols between each SS Block allowing UL/DL transmission for low latency applications. User need to specify the correct mapping in Signal Studio and VSA

SSB mapping locations for **> 6 GHz**:

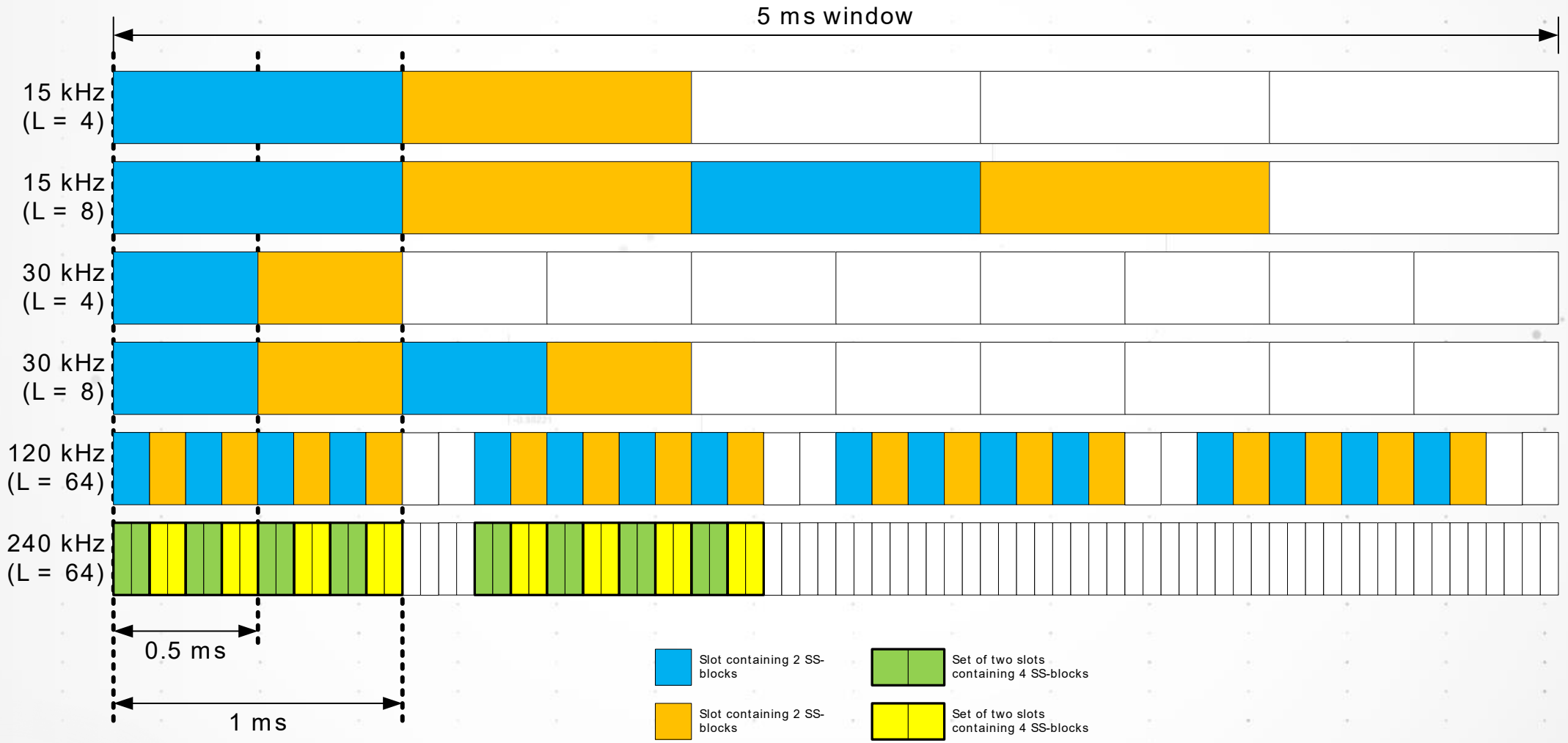


2 SS block locations in each slot

4 SS block locations in each two slots

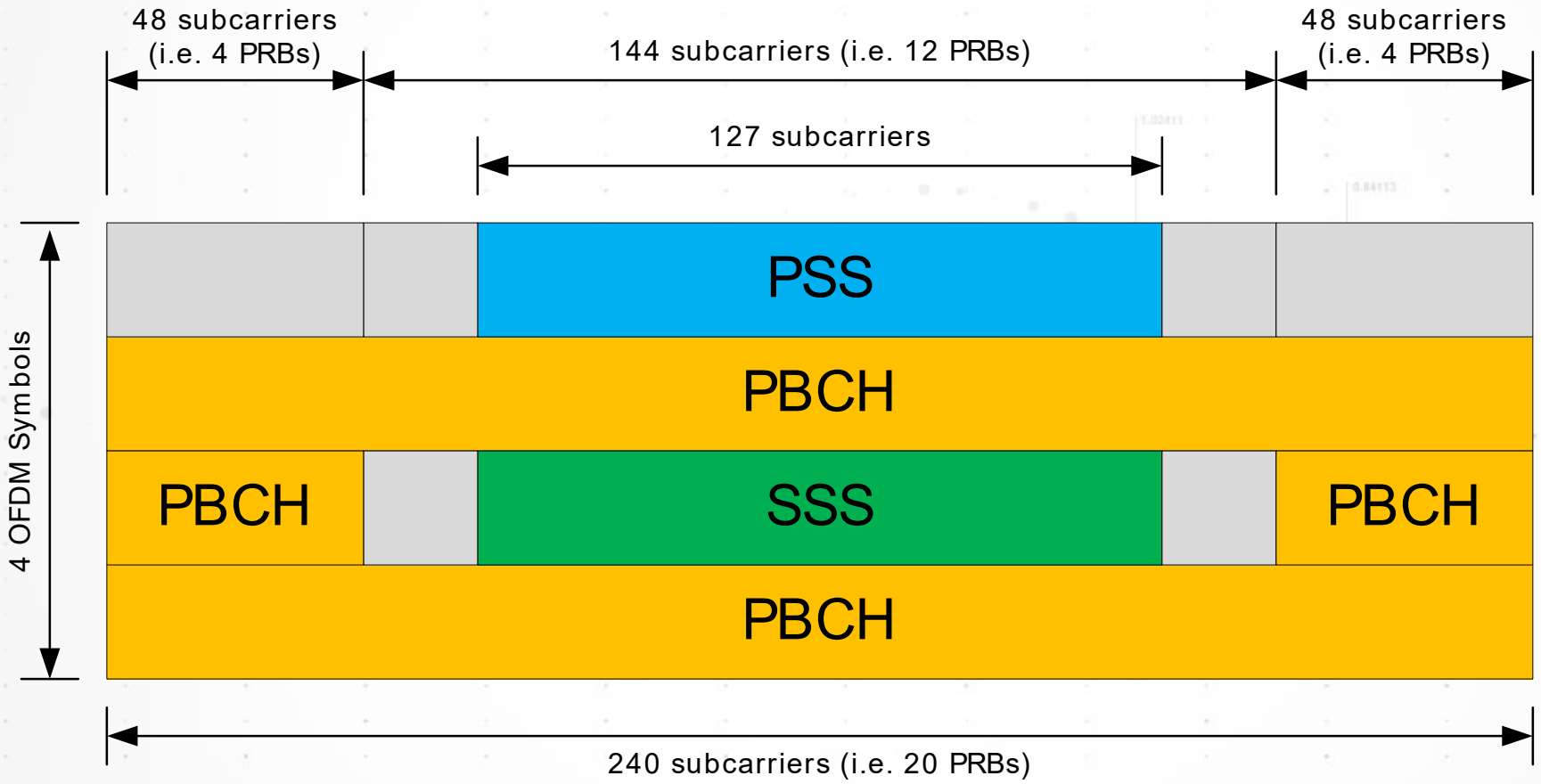
SS Burst Set Composition

INITIAL ACCESS AND BEAM MANAGEMENT



SS Block Composition

INITIAL ACCESS AND BEAM MANAGEMENT



Minimum System Bandwidth

INITIAL ACCESS AND BEAM MANAGEMENT

- The PSS, SSS and PBCH transmission define the minimum component carrier bandwidth:
  - **< 6GHz**
    - **15 kHz** subcarrier spacing: 5 MHz
    - **30 kHz** subcarrier spacing: 10 MHz (Minimum bandwidth for LTE-NR coexistence)
  - **> 6 GHz**
    - **120 kHz** subcarrier spacing: 50 MHz
    - **240 kHz** subcarrier spacing: 100 MHz

Random Access Preamble (PRACH)

INITIAL ACCESS AND BEAM MANAGEMENT

- PRACH sequence is Zadoff-Chu based
- Two different preamble lengths
  - **Long sequence** (L = 839)
    - Only for < 6 GHz
    - Subcarrier spacing and bandwidth:**1.25 kHz (1.25 MHz)** and **5 kHz (5 MHz)**
  - **Short sequence** (L = 139)
    - Intended for > 6 GHz (i.e. for beam-sweeping)
    - Can be used bot below and above 6 GHz
    - Subcarrier spacing and bandwidth: < 6 GHz: **15 kHz (2.5 MHz)** and **30 kHz (5 MHz)**
      > 6 GHz : **60 kHz (10 MHz)** and **120 kHz (20 MHz)**

Downlink and Uplink Channels

Downlink and Uplink Physical Channels/Signals

DOWNLINK AND UPLINK CHANNELS

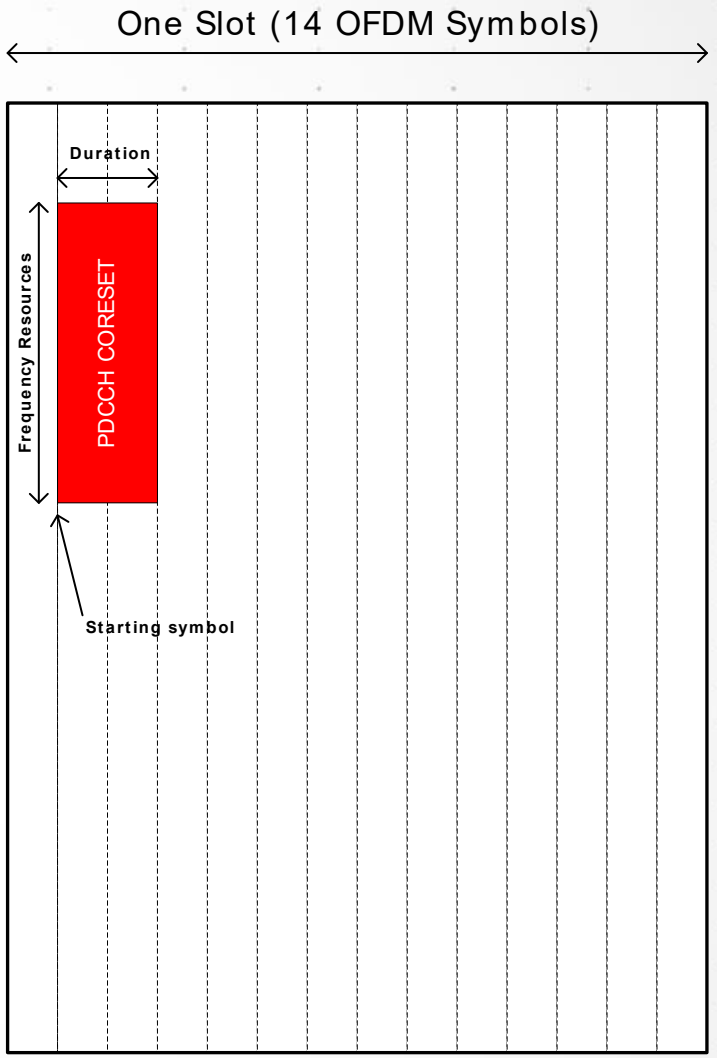
	NR Channels/Signals	Description	LTE Equivalent
Uplink	PUSCH PUSCH-DMRS, PUSCH-PTRS	Physical Uplink Shared Channel	PUSCH PUSCH-DMRS
	PUCCH PUCCH-DMRS	Physical Uplink Control Channel	PUCCH PUCCH-DMRS
	PRACH	Physical Random Access Channel	PRACH
	SRS	Sounding Reference Signal	SRS
Downlink	PDSCH PDSCH-DMRS, PDSCH-PTRS	Physical Downlink Shared Channel	PDSCH PDSCH-DMRS
	PBCH PBCH-DMRS	Physical Broadcast Channel	PBCH
	PDCCH PDCCH-DMRS	Physical Downlink Control Channel	PDCCH, EPDCCH EPDCCH-DMRS
	CSI-RS	Channel-State Information Reference Signal	CSI-RS
	TRS	Tracking Reference Signal	
	PSS	Primary Synchronization Signal	PSS
	SSS	Secondary Synchronization Signal	SSS

Purple = New NR channels/signals vs. LTE
Note: LTE ONLY channels such as PCFICH, PHICH, C-RS, etc…are not shown

PDCCH CORESET(ControlResourceSet)

DOWNLINK AND UPLINK CHANNELS

- A **control resource set** (CORESET) is defined as a set of REGs under a given numerology
- Configured by UE-specific **higher-layer signaling**:
  - Frequency-domain resources
  - Starting OFDM symbol (OFDM symbol #0, #1 or #2)
  - Time duration (maximum duration of 3 OFDM symbols)



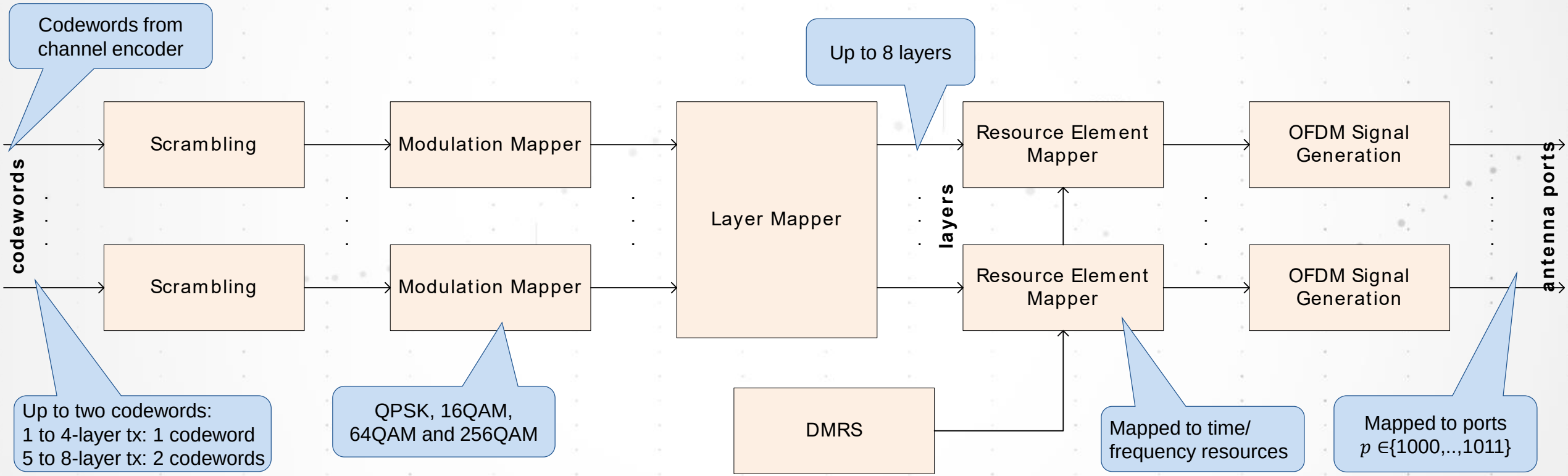
PDCCH

DOWNLINK AND UPLINK CHANNELS

- Carries **DCI**
- Modulation: **QPSK**
- RNTI is mask onto DCI CRC bits
- 1 PDCCH CCE = **6 REGs**
  - A REG is one PRB during one OFDM symbol
- **One-port transmit diversity** scheme with REG bundling per CCE (i.e. the same precoder is used for the REGs in a REG bundle)

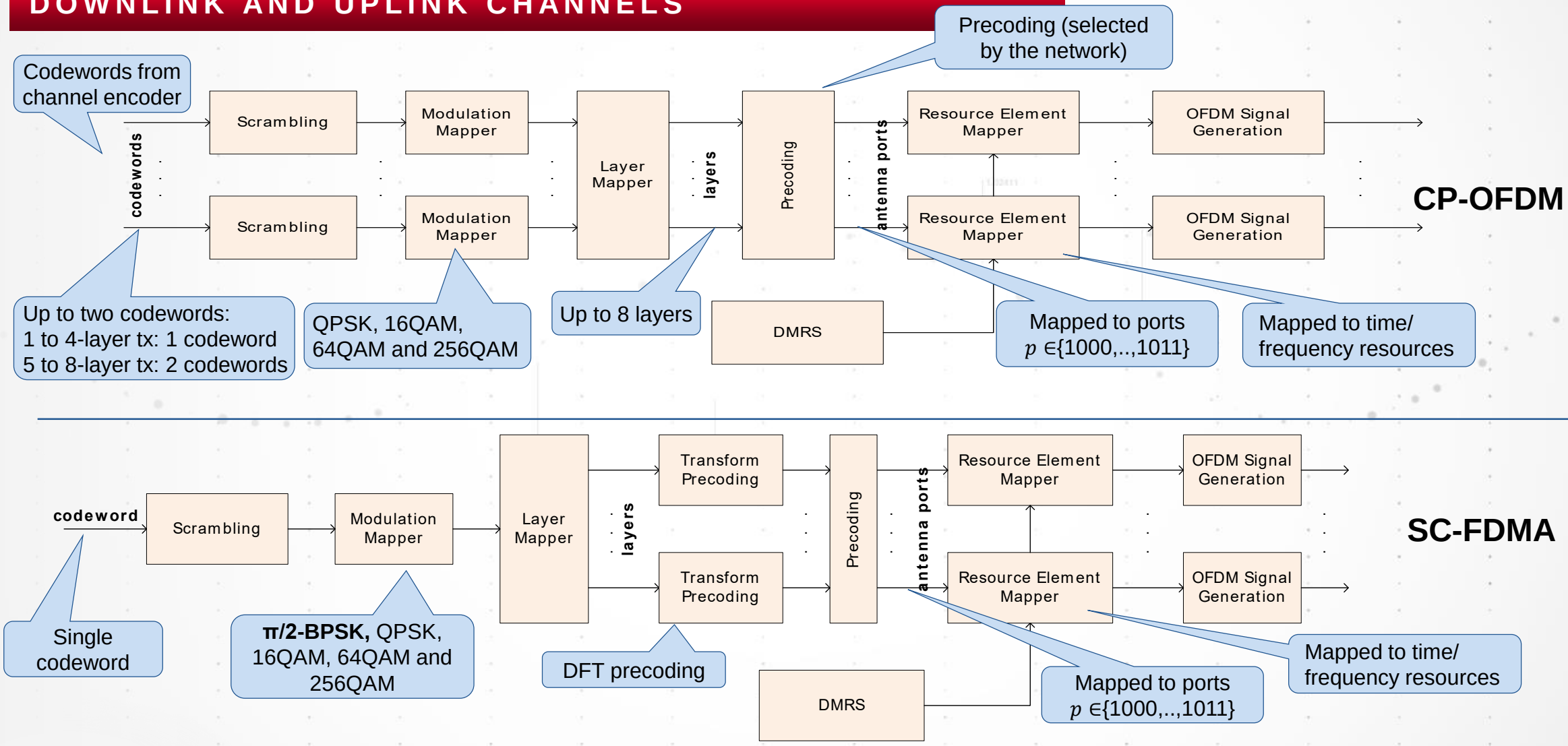
PDSCH Processing Chain

DOWNLINK AND UPLINK CHANNELS



PUSCH Processing Chain

DOWNLINK AND UPLINK CHANNELS



Reference Signals

DOWNLINK AND UPLINK CHANNELS

- ***Demodulation Reference signals (DM-RS)*** for acquisition of ***PBCH*** and ***PDSCH***
  - **DM-RS for PBCH is spread over the same bandwidth as the PBCH (on the same symbols)**
- ***Channel State Information Reference Signal (CSI-RS)*** for connected state beam management
  - **Refinement of the beam when a UE is in the connected state (and moving)**
- ***Phase Tracking Reference Signal (PT-RS)*** is for beam acquisition and identification by each specific UE
  - **Implemented using CSI-RS for the specific UE**
  - **Fine time and frequency tracking**
  - **Path delay spread and Doppler spread**

Summary

LTE vs. NR Comparison

	LTE	New Radio (Based on 3GPP Rel. 15)
Frequency band	Sub-6 GHz	Sub-6 GHz, mmWave (up to 52.6 GHz)
Maximum Bandwidth (per CC)	20 MHz	50 MHz (@ 15 kHz), 100 MHz (@ 30 kHz), 200 MHz (@ 60 kHz), 400 MHz (@120 kHz)
Maximum CCs	5 (Rel.10) / 32 (Rel.12). Current implementation is 5.	16 (allowed BW and CCs combinations TBD)
Subcarrier Spacing	15 kHz	$2^n \cdot 15$ kHz TDM and FDM multiplexing
Waveform	CP-OFDM for DL; SC-FDMA for UL	CP-OFDM for DL; CP-OFDM and DFT-s-OFDM for UL
Modulation	Up to 256 QAM DL (moving to 1024 QAM); Up to 64 QAM UL	Up to 256 QAM UL & DL
Maximum Number of Subcarriers	1200	3300
Subframe Length	1 ms (moving to 0.5 ms)	1 ms
Latency (Air Interface)	10 ms (moving to 5 ms)	1 ms
Slot Length	7 symbols in 500 µs	14 symbols (duration depends on subcarrier spacing) 2, 4 and 7 symbols for mini-slots
Channel Coding	Turbo Code (data); TBCC (control)	LDPC (data); Polar Codes (control)
Initial Access	No beamforming	Beamforming
MIMO	Up to 8x8	Up to 8x8 for sub 6G, up to 2x2 for mmWave
Reference signals	UE Specific DMRS and Cell Specific RS	Front-loaded DMRS (UE-specific)
Duplexing	FDD, Static TDD	FDD, Static TDD, Dynamic TDD

5G NR Test Solution for Signal Generation and Analysis

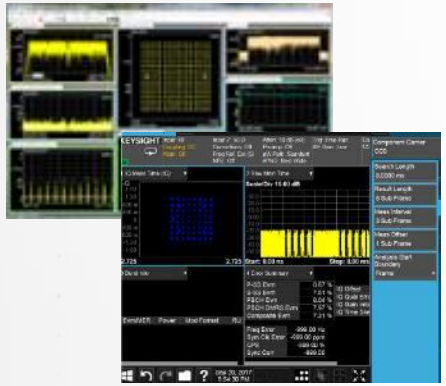
Keysight Solution for Transmitter and Receiver Test

FROM SUB-6GHZ TO MILLIMETER WAVE

SW

N7631C Signal Studio for 5G NR

89600 VSA Software (89601B-BHN)



X-app for 5G NR(N9085EM0E)

HW – SUB-6GHZ

N5182B MXG Signal Generator

M9421A PXI VXT Vector Transceiver

E6640A EXM Wireless Test Set

MXA Signal Analyzer

PXA Signal Analyzer

UXA Signal Analyzer

M9393A mmW Signal Analyzer

HW – MILLIMETER WAVE

M8190A AWG + E8257D PSG

M9383A mmW Signal Generator

MXA Signal Analyzer

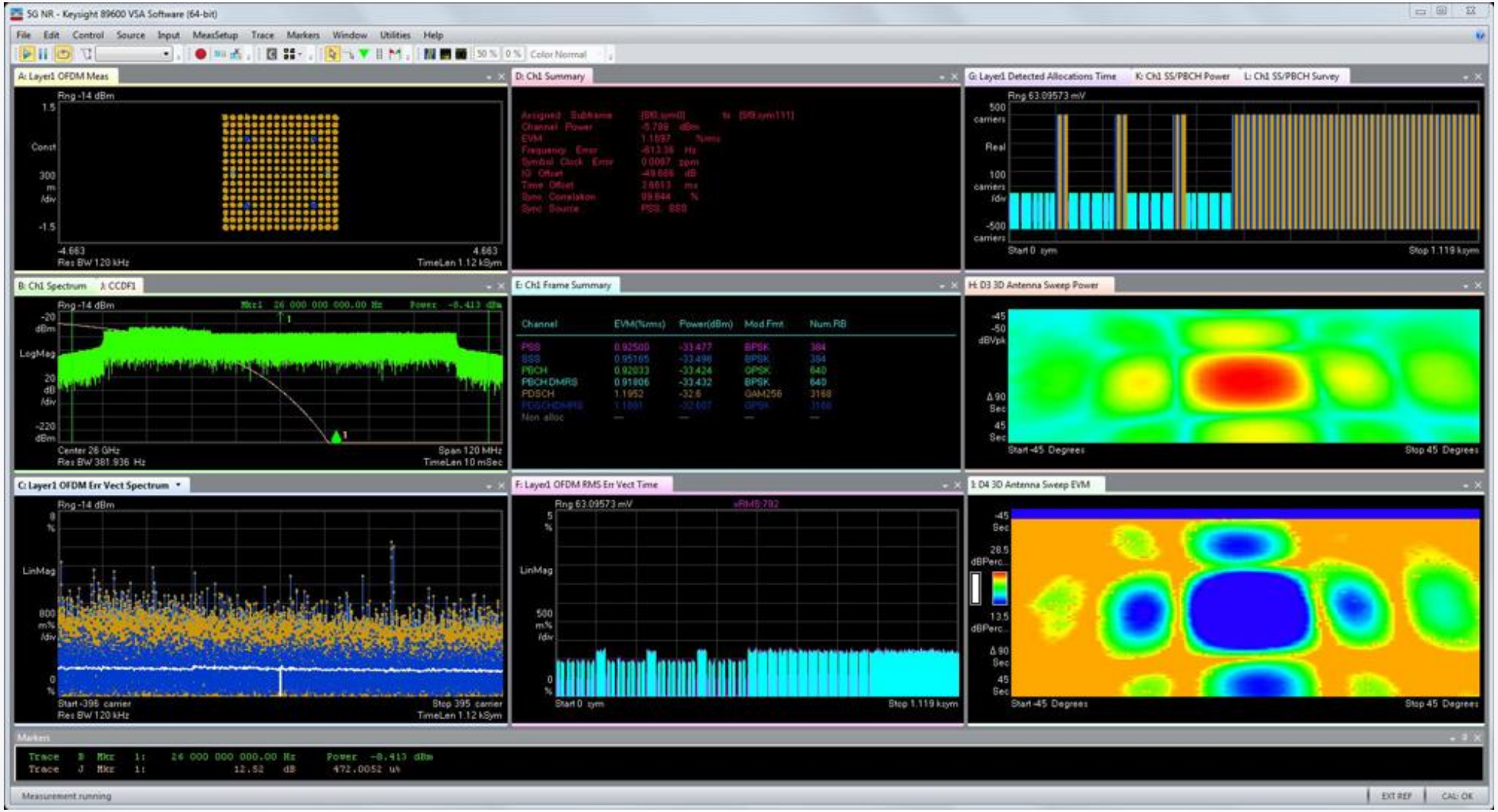
PXA Signal Analyzer

UXA Signal Analyzer

M9393A mmW Signal Analyzer

89601B-BHN Vector Signal Analysis SW for 5G NR

1ST SHIPMENT WITH IN-DEPTH 5G NR ANALYSIS



89600 VSA

X-Series 5G NR Measurement Application

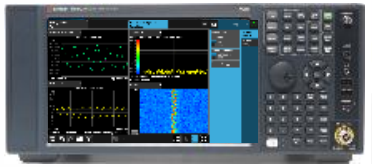
X-Series Apps

HARDWARE PLATFORM SUPPORTS - BENCHTOP XSA

"B model" X-series Signal Analyzers (Multi-Touch)

N9000B CXA
Leading low-cost tool

- 9 kHz to 26.5 GHz,
- 25 MHz BW



N9010B EXA
Maximum value up to mmWAve

- 10 Hz to 44 GHz
- 40 MHz BW

N9020B MXA
Optimum choice for wireless

- 10 Hz to 50 GHz
- 160 MHz BW
- Real Time SA

N9030B PXA
Benchmark for demanding applications

- 3 Hz to 50 GHz,
- 510 MHz BW
- Real Time SA

1st

N9040B/41B UXA
Wide-open performance

- 3 Hz to 50 GHz (N9040B)
- 3 Hz to 110 GHz (N9041B)
- 5 GHz BW with external oscilloscope
- 1 GHz internal BW
- Real Time SA – 255 MHz

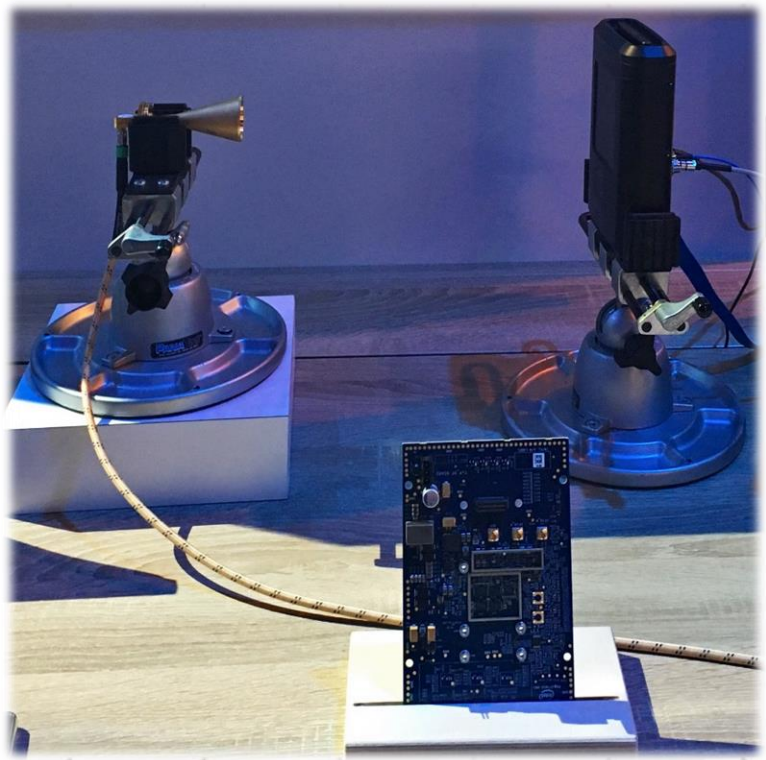
Acquisition wider than 100MHz BW

Note: for the installed-base "A" model X-series Signal Analyzers

- 5G NR X-app is NOT available on the native softkey GUI environment.
- Need to install Multi-Touch front-panel migration kit:
  - ✓N90x0AK-MTU:
  - ✓N90x0AK-MTP:

Keysight Technologies enabled 5G NR R&D

MWC2018 INTEL SHOWCASE 39GHZ 5G RFIC



Keysight UXA Signal Analyzer

MWC2018 - Keysight enabled ASTRI 5G NR BTS Test

HTTPS://ABOUT.KEYSIGHT.COM/EN/NEWSROOM/PR/2018/26FEB-NR18021.SHTML

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Keysight Technologies, ASTRI Demonstrate Test & Measurement Solution for Verifying 3GPP Release 15 NR compliant 5G base station Reference Designs at Mobile World Congress 2018

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SANTA ROSA, Calif., February 26, 2018

Keysight Technologies, Inc. (NYSE: KEYS), a leading technology company that helps enterprises, service providers, and governments accelerate innovation to connect and secure the world, announced a joint demonstration of a 3GPP release 15 5G base station reference design with Hong Kong Applied Science and Technology Research Institute (ASTRI) at Mobile World Congress 2018. The demonstration will be on display at the Fujian Sunnada Network Technology Co., Ltd., exhibit, Hall 5 Stand 5G70, and will use Keysight's PXA X-Series signal analyzer and the 5G New Radio (NR) ready 89601B VSA software (VSA) for modulation analysis.

Keysight recently launched the industry's first commercially available 5G NR software solutions, which include full product design cycle simulation, signal creation and analysis with uplink and downlink directions, enabling transmitter and receiver simulation and test. Keysight's VSA software offers in-depth analysis and troubleshooting tools that enable developers to identify complexity in their 5G NR designs.

"ASTRI has worked with Keysight on 5G research and development for the past three years," said Dr. Victor Kwan, Senior Manager, Wireless Systems Communications Technologies at ASTRI. "Keysight's strong local and worldwide support combined with its industry-leading capabilities in demodulation and vector signal analysis helps us address 5G NR design and test challenges, quickly and effectively."

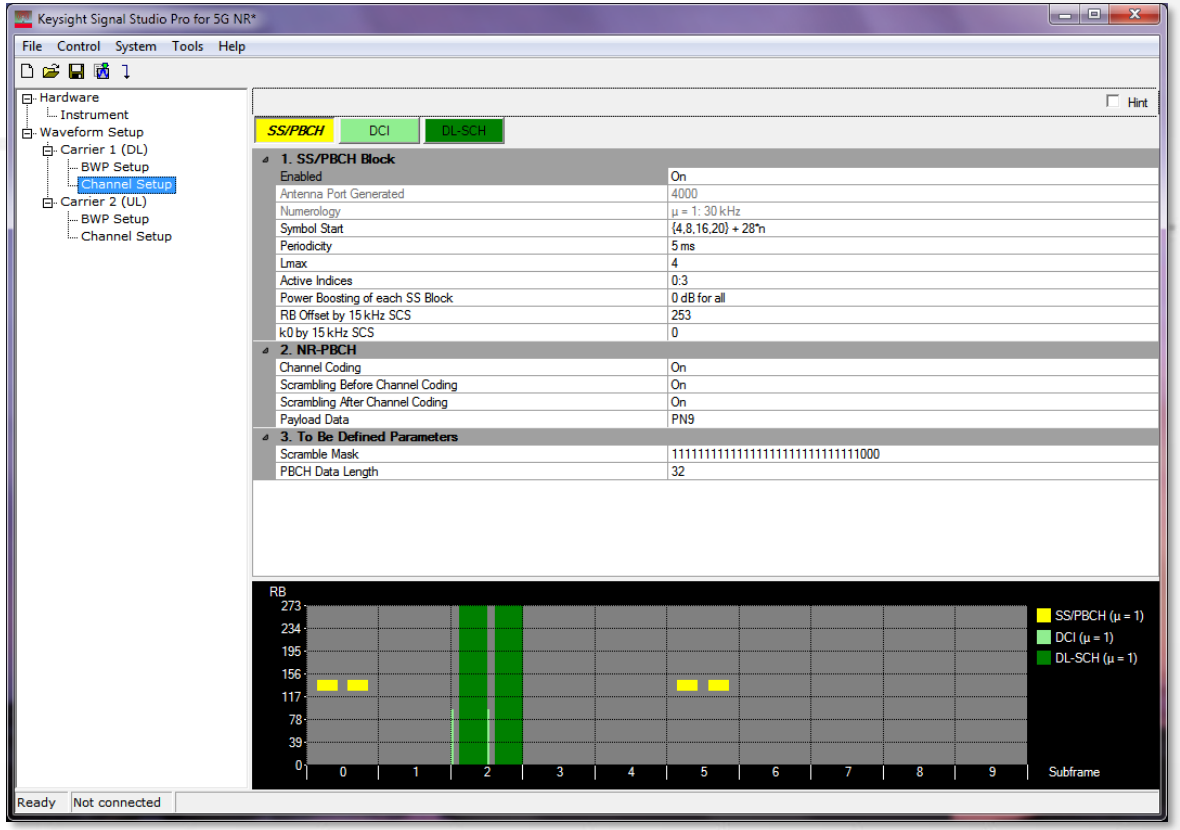
Keysight's VSA software uses color coding based on physical channel type and marker coupling across different measurements to highlight aspects of complex NR signal structure. This reveals specific signal and channel effects and impairments that allow engineers to quickly gain needed insight and get their product to market. Used in conjunction with Keysight high performance X-Series and modular signal analyzers with wide bandwidth and wide frequency coverage, designers can generate 5G NR measurements in sub-6GHz and mmWave frequencies with optimal performance.

N7631C Signal Studio Pro for 5G NR

VERSION 1.0.2 IS OFFICIALLY RELEASED

Signal Studio

- **Support PHY layer for L1 and component test based on latest 3GPP TS38 standards**
  - Variable numerology
    - Subcarrier Spacing: 15kHz, 30kHz, 60kHz, 120kHz, 240kHz
  - Downlink/Uplink channels
  - Carrier aggregation
  - Channel coding
    - LDPC for data channels, Polar for control channels
  - Multi-antenna transmission for UL and DL
    - Up to 4x4
- Significant generation speed improvement
  - All-new signal generation engine
- Support flexible signal configuration
  - Graphical display for frame resource allocation
  - Crest factor reduction (CFR)
  - Arbitrary resampling
- Programming API



Signal Generation Hardware Platform Supports

BENCH TOP AND MODULAR

- Sub-6GHz
  - MXG-B/EXG-B X-Series RF Vector Signal Generator
- mmWave
  - M9383A PXIe Vector Signal Generator
  - M8190A AWG+ PSG
  - M8190A AWG Stand-Alone (w/ external Up Converter)

Keysight Technologies enabled 5G NR Chipset R&D

MWC2018 MEDIATEK SHOWCASE

- Keysight Technologies N5182B MXG Signal Generator enable Mediatek 5G Sub-6GHz Prototype Testing

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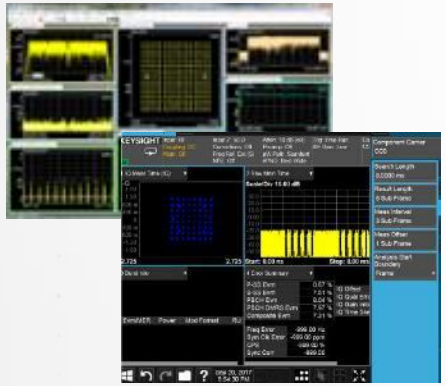

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M8190A AWG + E8257D PSG

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MXA Signal Analyzer

PXA Signal Analyzer

UXA Signal Analyzer

M9393A mmW Signal Analyzer


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