

# 信号发生器



# Agenda

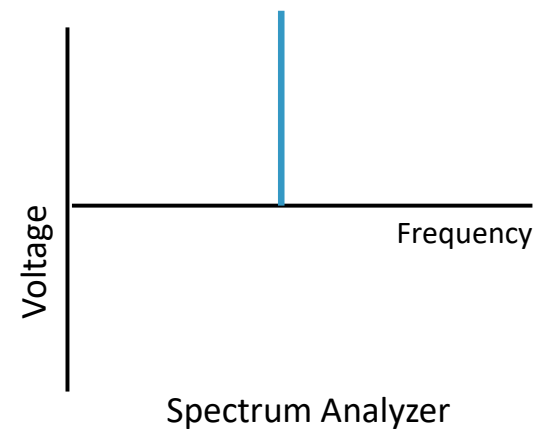
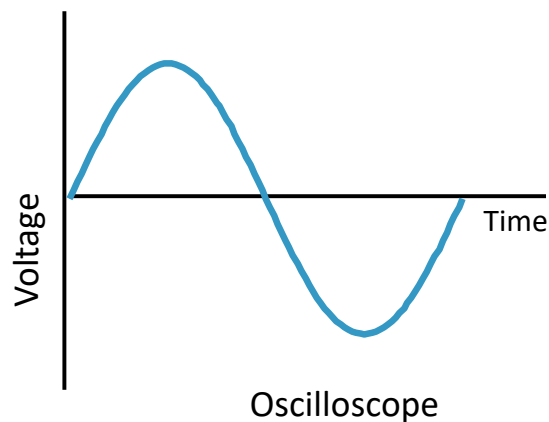
- **Generating Signals**

- Continuous Wave (CW)
- Sweep Signal
- Analog Modulation
- Digital Modulation

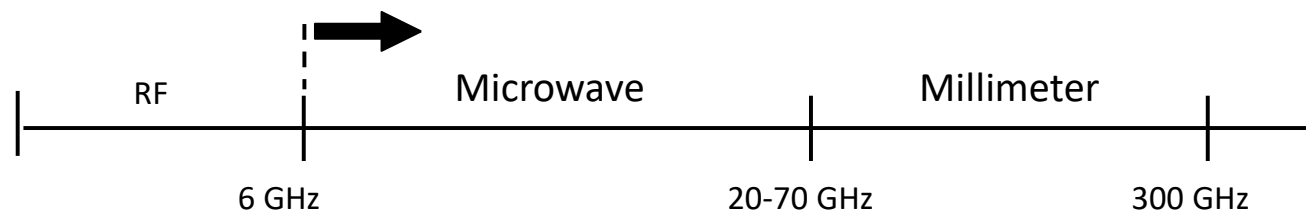
- Signal Generator Architecture
- Basic Applications
- Applications in Modern Wireless Communications

# Generating Signals – No Modulation

## Continuous Wave (CW)



The sine wave is the **basic, non-modulated** signal: It is useful for stimulus/response testing of **linear components** and for Local Oscillator substitution. Available frequencies range from low RF to Millimeter.



# CW Source Specifications

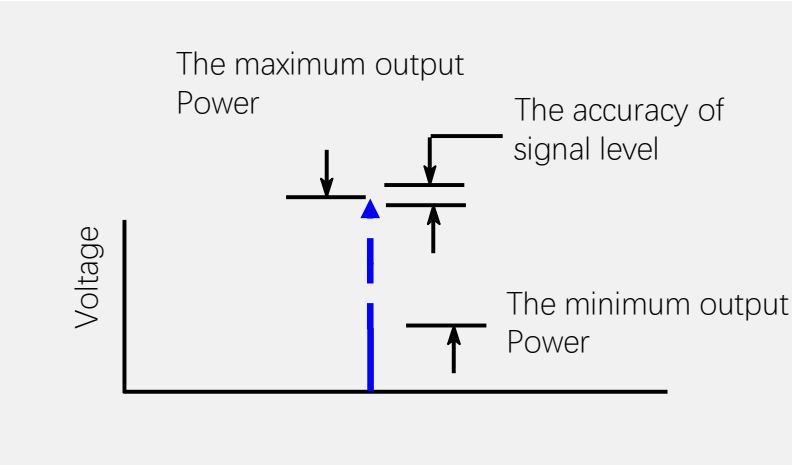
## Amplitude Parameters

- Range (-136dBm to +13dBm)
- Accuracy (+/- 0.5dB)
- Resolution (0.02dB)
- Switching Speed (15ms)
- Reverse Power Protection



| Power              | Options 501-504 | With Option UNB | Option 506      |
|--------------------|-----------------|-----------------|-----------------|
| 250 kHz to 250 MHz | +11 to -136 dBm | +15 to -136 dBm | +12 to -136 dBm |
| > 250 MHz to 1 GHz | +13 to -136 dBm | +17 to -136 dBm | +14 to -136 dBm |
| > 1 to 3 GHz       | +10 to -136 dBm | +16 to -136 dBm | +13 to -136 dBm |
| > 3 to 4 GHz       | +7 to -136 dBm  | +13 to -136 dBm | +10 to -136 dBm |
| > 4 to 6 GHz       | N/A             | N/A             | +10 to -136 dBm |

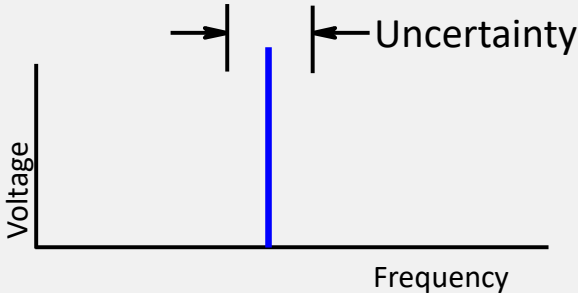
| Level accuracy [dB]            |               |                   |                    |            |
|--------------------------------|---------------|-------------------|--------------------|------------|
| Options 501-504 <sup>1,2</sup> |               |                   |                    |            |
|                                | Power level   |                   |                    |            |
|                                | +7 to -50 dBm | < -50 to -110 dBm | < -110 to -127 dBm | < -127 dBm |
| 250 kHz to 2.0 GHz             | ±0.5          | ±0.5              | ±0.7               | (±1.5)     |
| 2.0 to 3 GHz                   | ±0.6          | ±0.6              | ±0.8               | (±2.5)     |
| 3 to 4 GHz                     | ±0.7          | ±0.7              | ±0.9               | (±2.5)     |



# CW Source Specifications

## Frequency

- Range: Range of frequencies covered by the source
- Resolution: Smallest frequency increment.
- Accuracy: How accurately can the source frequency be set.
- Frequency change speed: How fast the frequency change



### Frequency range

Option <sup>1</sup>

|     |                                        |
|-----|----------------------------------------|
| 501 | 250 kHz to 1 GHz                       |
| 502 | 250 kHz to 2 GHz                       |
| 503 | 250 kHz to 3 GHz                       |
| 504 | 250 kHz to 4 GHz                       |
| 506 | 250 kHz to 6 GHz [requires Option UNJ] |

Frequency minimum 100 kHz <sup>2</sup>

|                         | Standard                    | High Stability (1E5)          |
|-------------------------|-----------------------------|-------------------------------|
| Aging Rate              | <±1ppm/yr.                  | <±0.1ppm/yr.                  |
| Temperature (0-55deg C) | <±1ppm, typical             | <±0.005ppm, typical           |
| Line Voltage            | <±0.1ppm(+5%,-10%), typical | <±0.002ppm(+5%,-10%), typical |

### Example

Accuracy =  $\pm f_{CW} * \tau_{aging} * \tau_{cal}$

$f_{CW}$  = CW frequency = 1 GHz

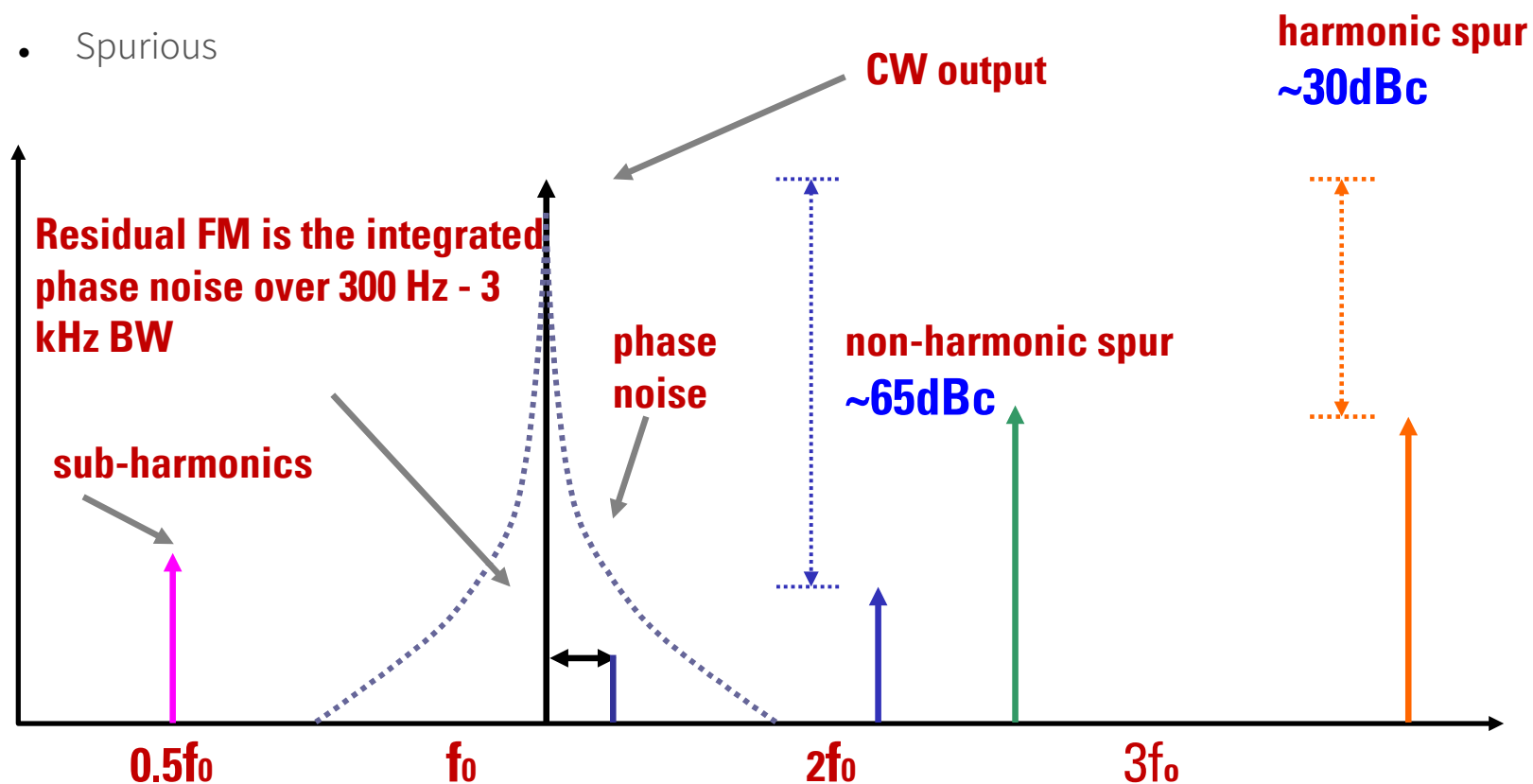
$\tau_{aging}$  = aging rate = 0.1ppm/year

$\tau_{cal}$  = time since last calibrated = 1 year

# CW Source Specifications

## Spectral Purity

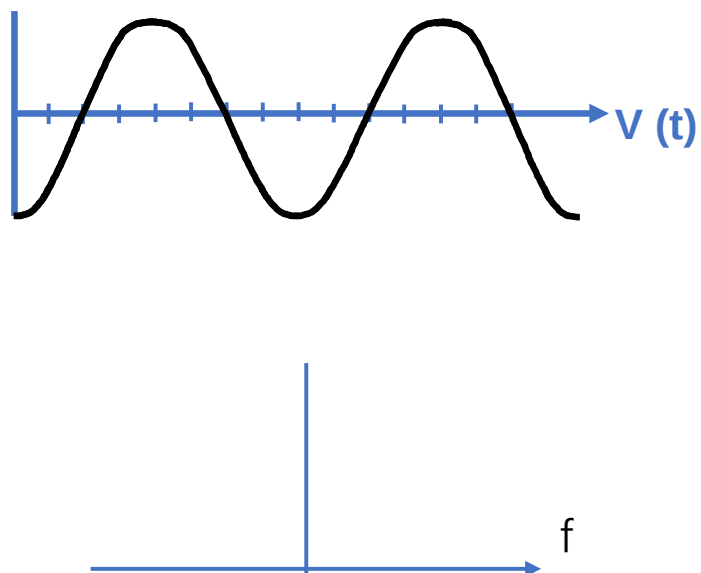
- Phase Noise
- Residual FM
- Spurious



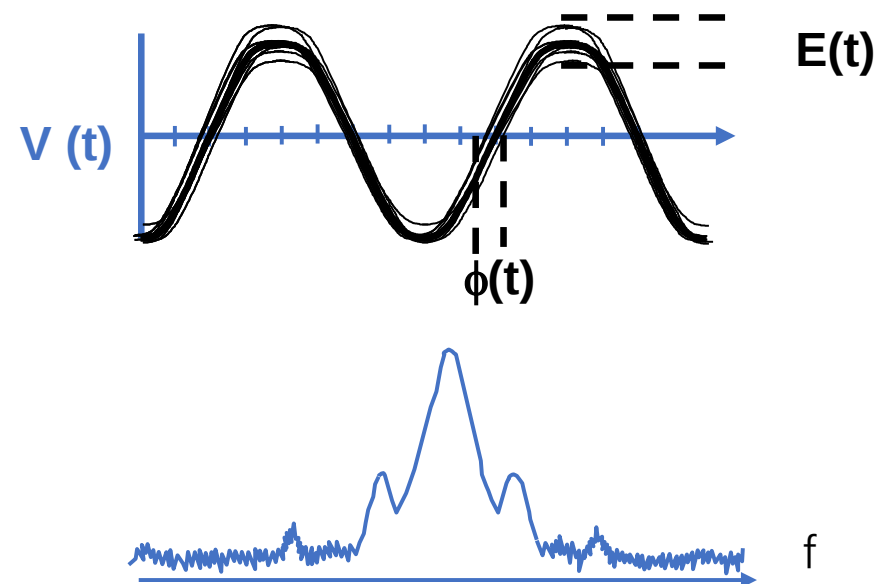
# CW Source Specifications

## Spectral Purity: Phase Noise—Basic Concepts

Idea signal

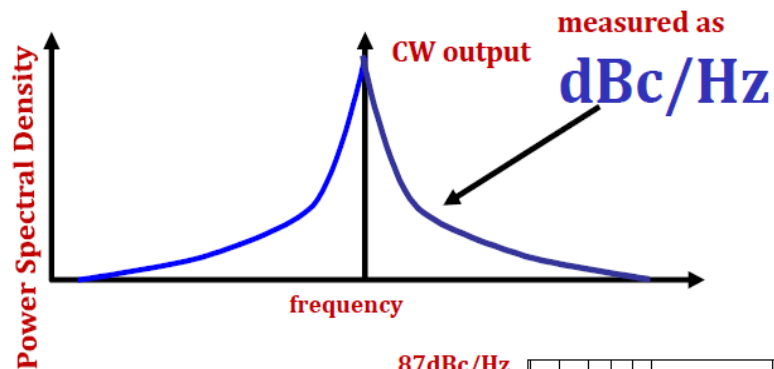


Real world signal



# CW Source Specifications

Spectral Purity: Phase Noise—Performance

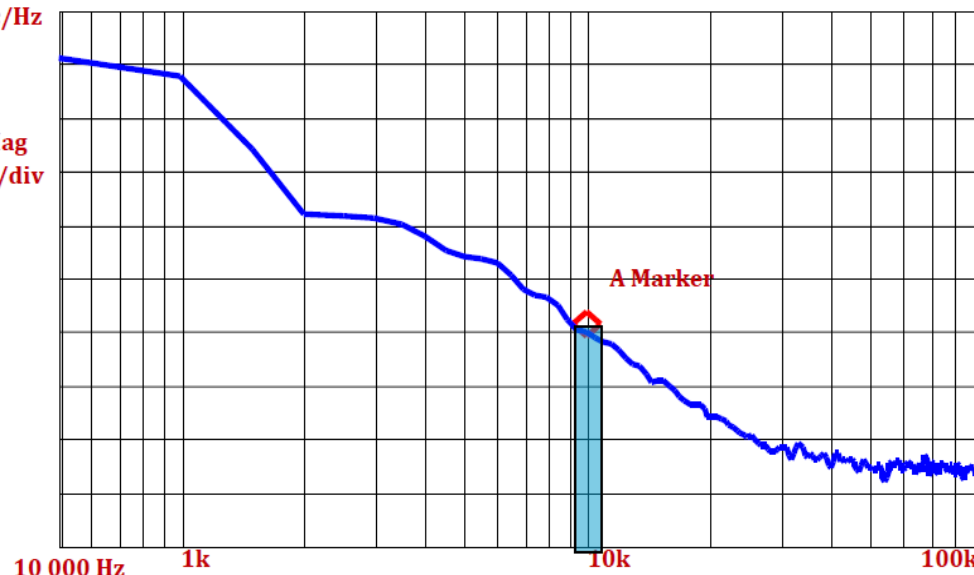


**N5182B**

-87dBc/Hz @10Hz offset  
-93dBc/Hz @ 100Hz offset  
-123dBc/Hz @1KHz offset  
-141dBc/Hz @10kHz offset  
.....

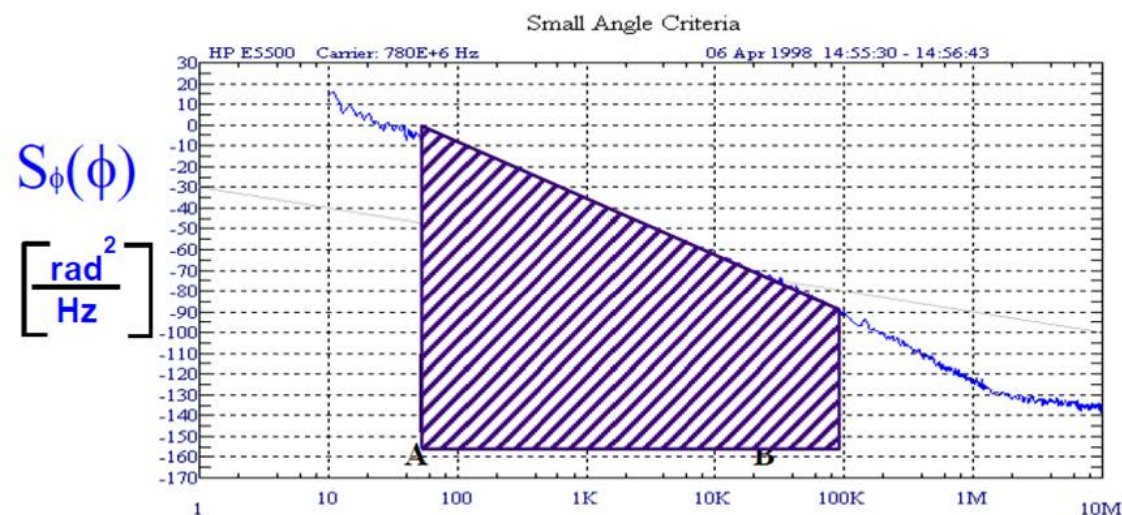
87dBc/Hz

LogMag  
5 dBc/div



# CW Source Specifications

## Spectral Purity: Residual FM



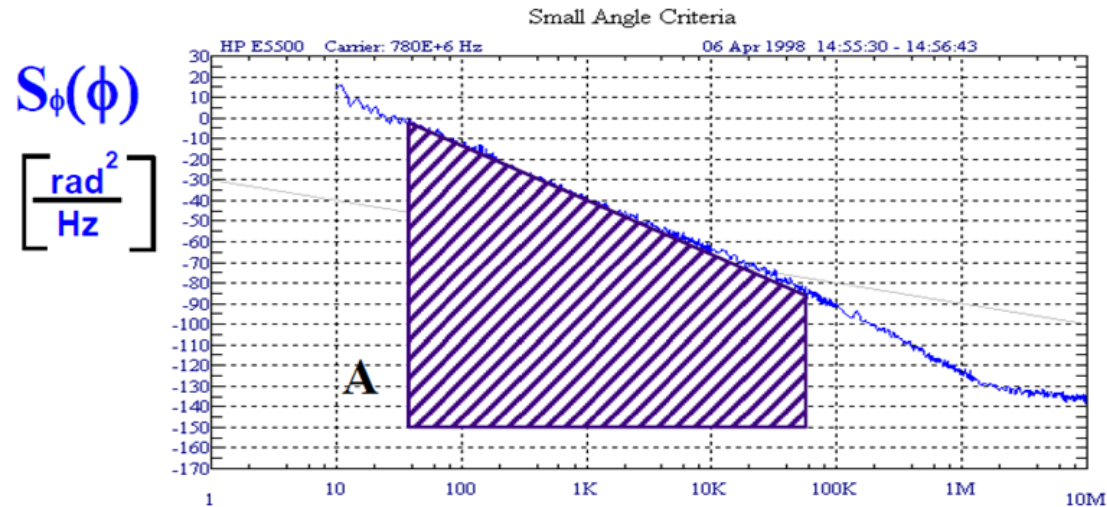
**Residual FM =**

*Total rms frequency deviation within a specified bandwidth*

$$\text{Residual FM} = \sqrt{\int_A^B f^2 S_{\phi}(f) df} = \sqrt{\int_A^B S_v(f) df} \quad [\text{Hz}]$$

# CW Source Specifications

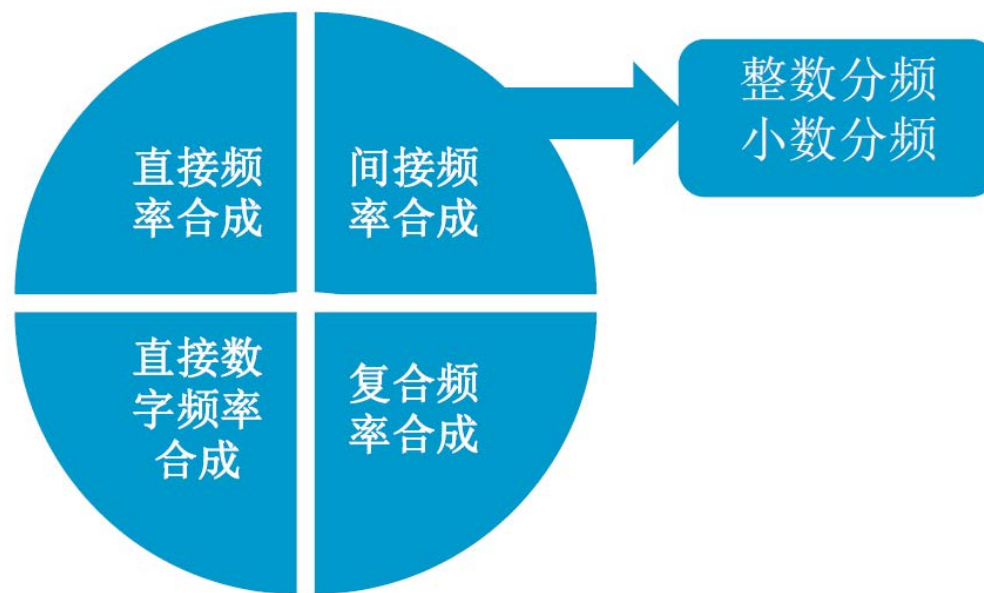
## Spectral Purity: Phase Jitter



$$\text{Phase Jitter} = \sqrt{\int_A^B S_{\phi}(f) df} \quad [\text{rad}] \quad \text{Relative to } 1 \text{ rad}_{\text{rms}} = [\text{dB}]$$
$$\text{Phase Jitter} = \frac{360}{2\pi} \sqrt{\int_A^B S_{\phi}(f) df} \quad [\text{degrees}]$$

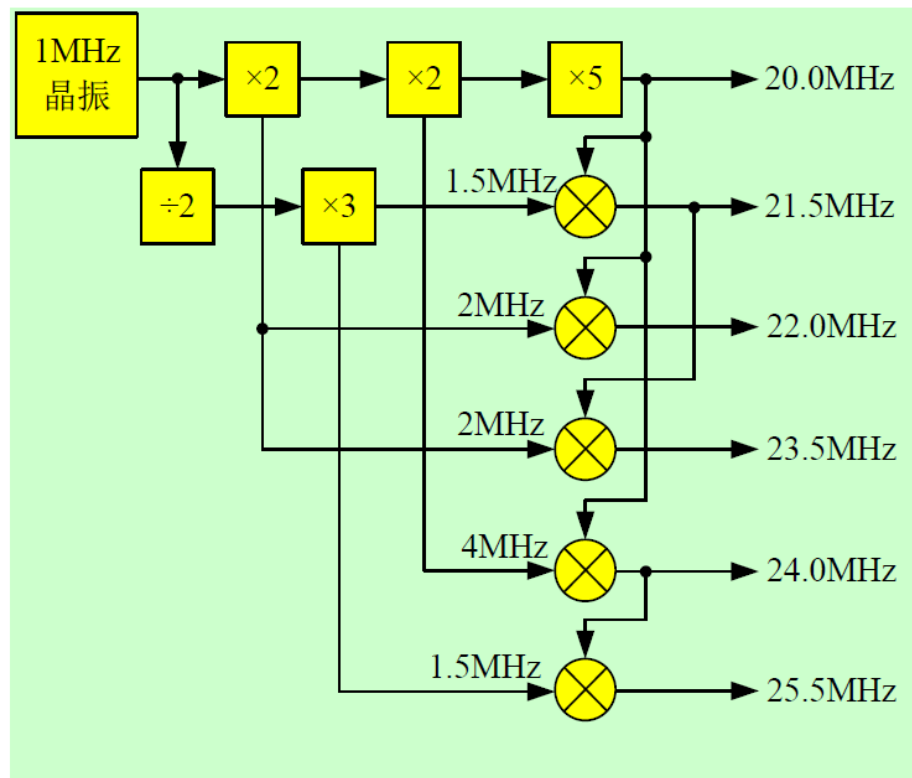
# CW Source Specifications

## Frequency Synthetic Technology



# CW Source Specifications

## Direct Frequency Synthesis

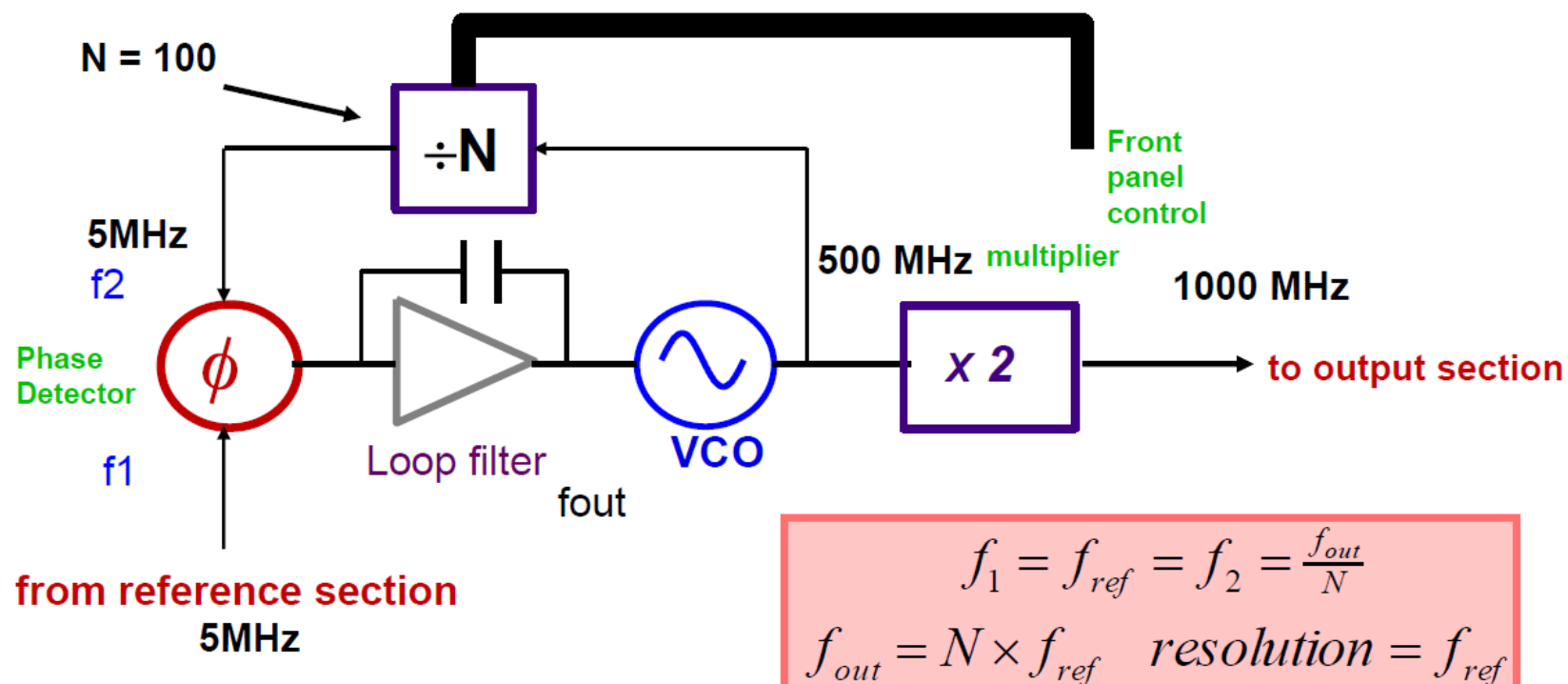


### 分频-混频-倍频式合成器

- 一个参考频率经过倍频、分频、混频
- 6个输出频率可以同时输出，最小频率间隔0.5MHz
- 输出信号的频率稳定度较高
- 输出信号的频率无法调整

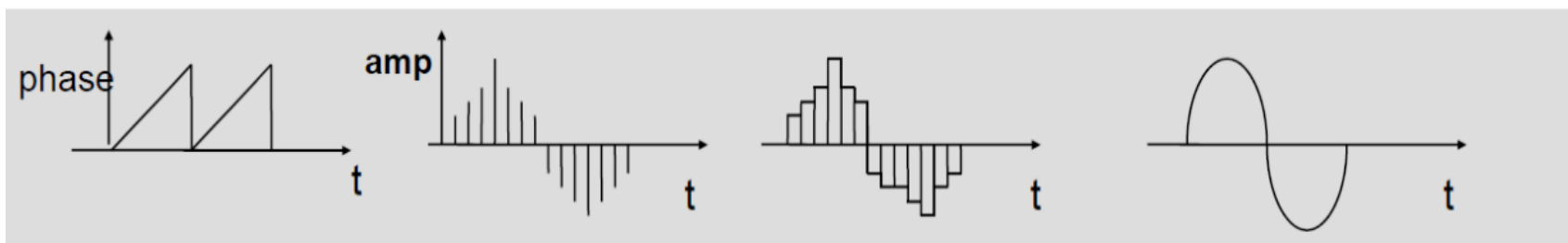
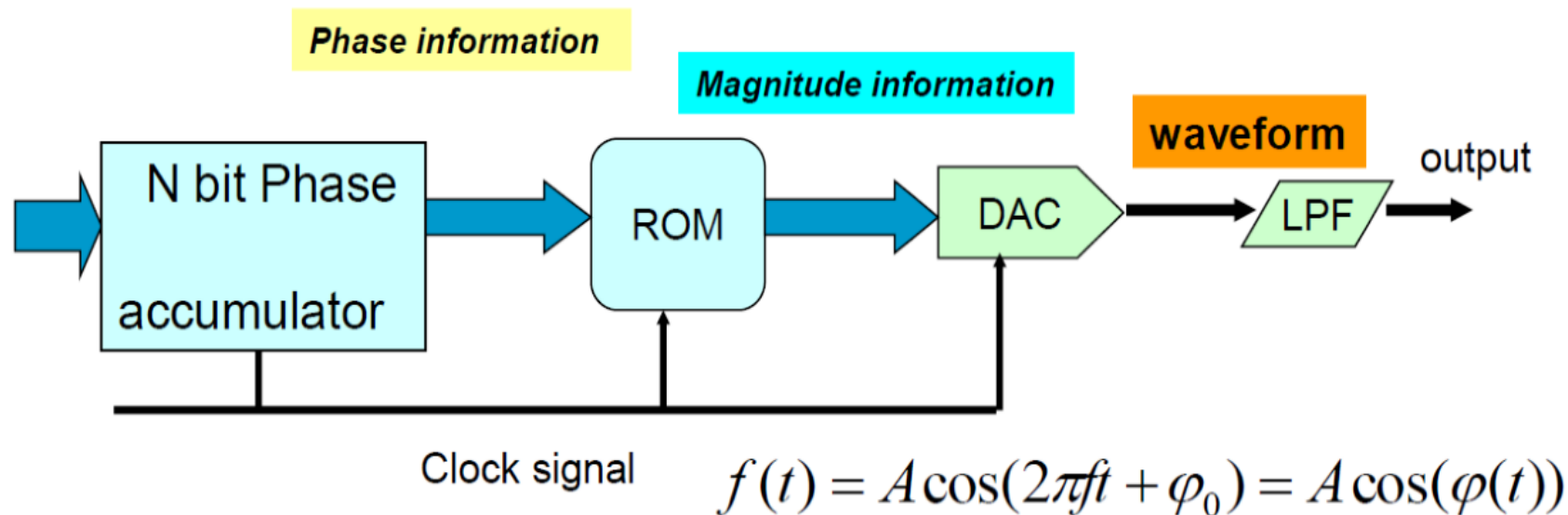
# CW Source Specifications

## Indirect Frequency Synthesis



# CW Source Specifications

## Direct Digital Synthesizer (DDS)



# CW Source Specifications

## Summary of Synthesis

| 频率合成方法   | 关键技术              | 优点                                                                                                       | 缺点                                                                                  | 主要应用                                                                                  |
|----------|-------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 直接频率合成   | 振荡器（晶体振荡器；介质振荡器等） | 频率稳定度高                                                                                                   | 输出频率固定                                                                              | <ul style="list-style-type: none"><li>▪ 参考源</li><li>▪ 单频系统</li><li>▪ 频率捷变系统</li></ul> |
| 间接频率合成   | 锁相环               | <ul style="list-style-type: none"><li>✓ 输出频率范围宽</li><li>✓ 高频率分辨率</li><li>✓ 频率稳定度好</li><li>✓ 灵活</li></ul> | <ul style="list-style-type: none"><li>▪ 分辨率指标和相位噪声指标折衷</li><li>▪ 频率切换速度有限</li></ul> | 电子系统本振                                                                                |
| 直接数字频率合成 | 数字电路技术；DAC        | <ul style="list-style-type: none"><li>✓ 很高的频率分辨率</li><li>✓ 频率捷变</li><li>✓ 复杂波形合成</li></ul>               | <ul style="list-style-type: none"><li>▪ 输出频率范围有限</li><li>▪ 频谱杂散指标</li></ul>         | 频率捷变系统                                                                                |

# Agenda——Signal Generator

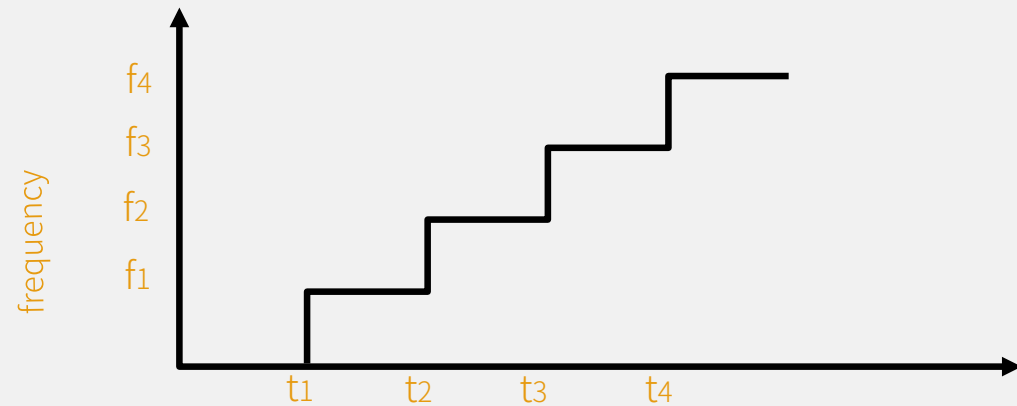
- **Generating Signals**
  - Continuous Wave (CW)
  - **Sweep Signal**
  - Analog Modulation
  - Digital Modulation
- Signal Generator Architecture
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# Sweep Source Specifications

## Frequency

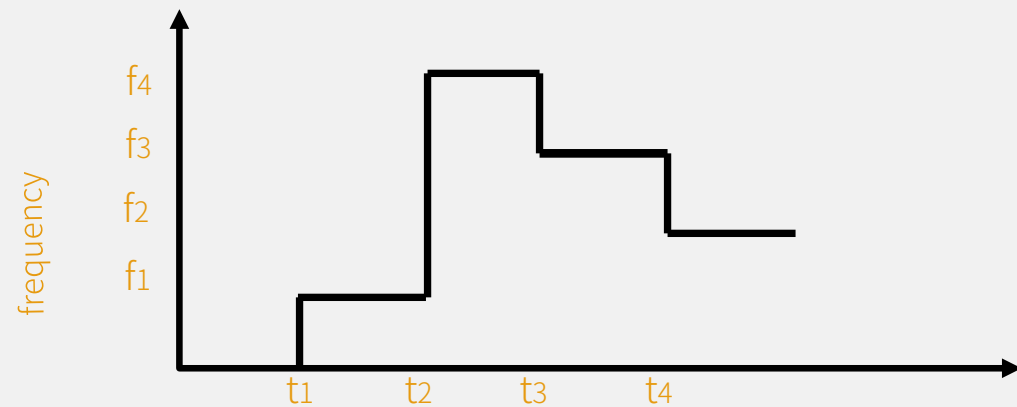
### – Step Sweep

- Accuracy
- number of points
- switching time



### – List Sweep

- Accuracy
- switching time
- dwel time

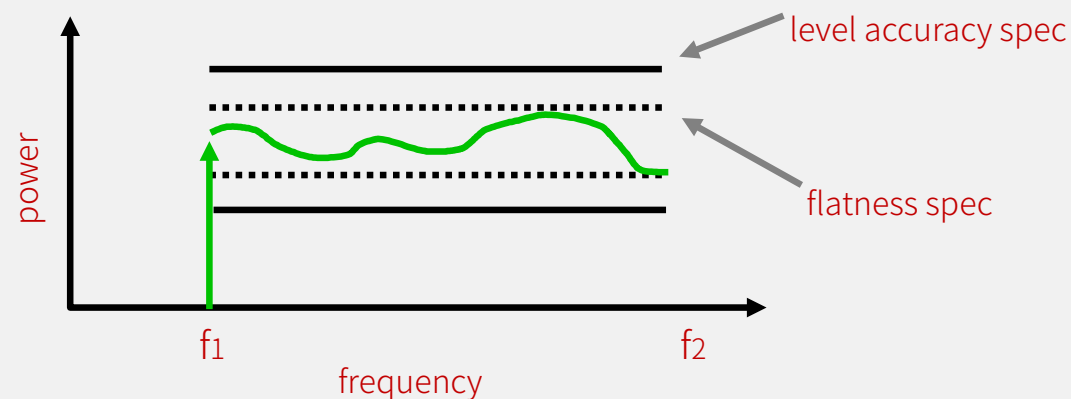


# Sweep Source Specifications

## Amplitude

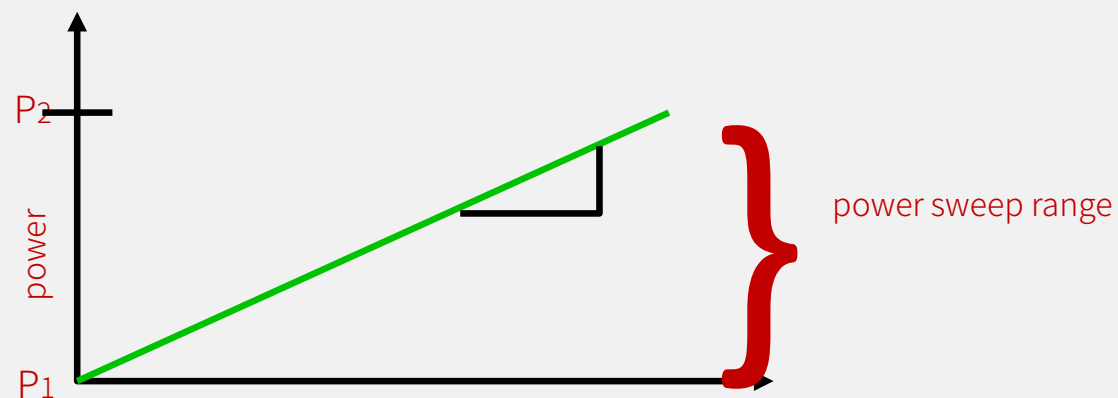
### – Frequency Sweep

- Level Accuracy
- Flatness
- Source Match (SWR)



### – Power Sweep

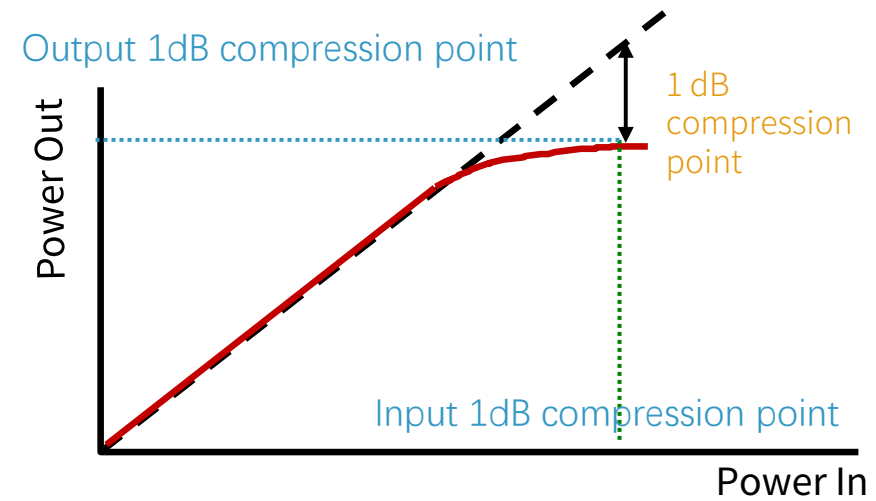
- Power Sweep Range
- Power Slope Range
- Source Match (SWR)



# Sweep Source Specifications

## Applications & Critical Specifications

- Frequency Response
  - Level Accuracy
  - Output Power (Level)
  - Flatness
  - Speed
  - residual FM
- Amplifier Compression
  - Power Range



# Agenda——Signal Generator

- **Generating Signals**
  - Continuous Wave (CW)
  - Sweep Signal
  - **Analog Modulation**
  - Digital Modulation
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# Generating Signals - Modulation

Where The Info is?

$$V(t) = A(t) \cos[2\pi f(t) + \Phi(t)]$$

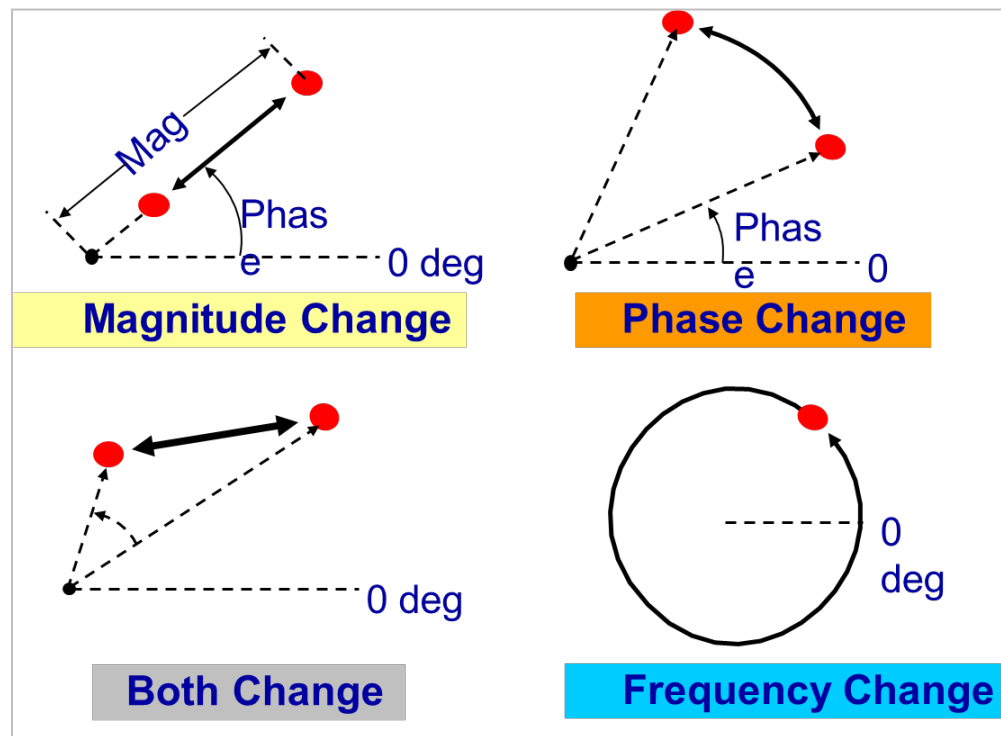
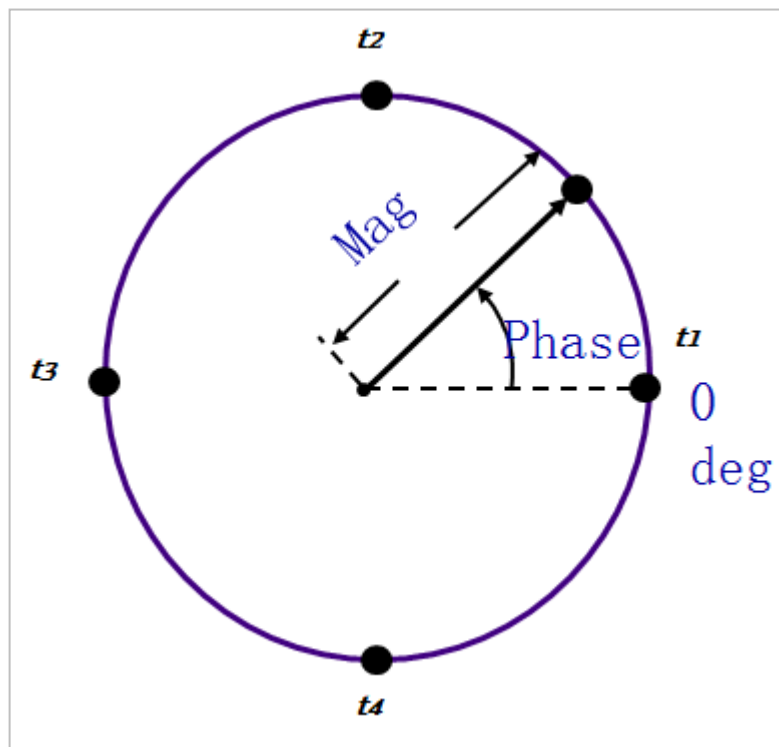
AM, Pulse

FM

PM

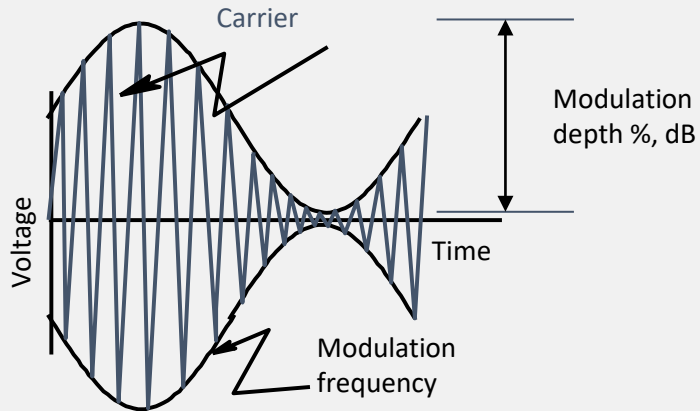
# Generating Signals - Modulation

What Can Be Changed?



# Generating Signals - Analog Modulation

## Amplitude Modulation

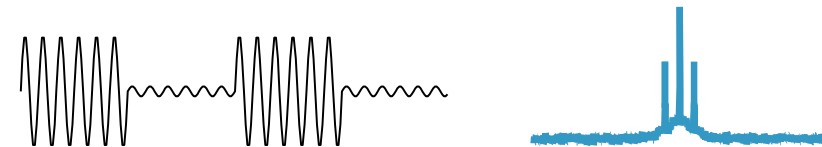


Where are AM signals used?

- AM Radio
- Antenna scan
- ASK (early digital 100101)

### Important Characteristics for Amplitude Modulation

- **Modulation frequency (rate)**-rate the modulating signal varies the amplitude of the Carrier
- **Depth of modulation (Mod Index)** – ratio of the peak of Modulating signal to the carrier signal amplitude  $V_{\text{peak mod}} / V_{\text{carrier}}$
- Distortion %

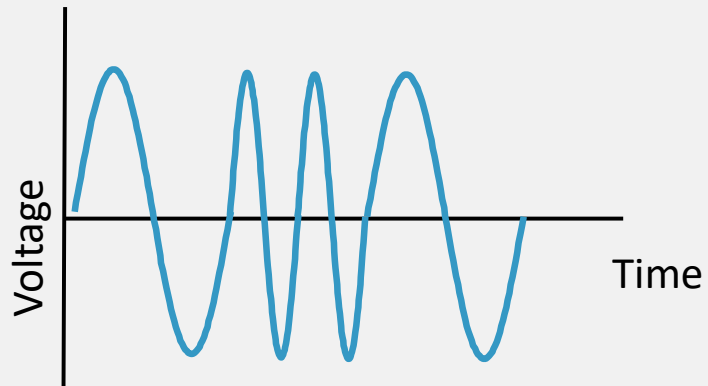


# Generating Signals – Analog Modulation

## Frequency Modulation

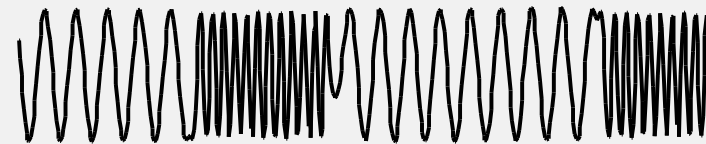
$$V(t) = A \cos[2\pi f_c t + \beta \sin 2\pi F_m t]$$

$\beta$  is the modulation index, where  $\beta$   
 $= \Delta F_{dev} / F_m$



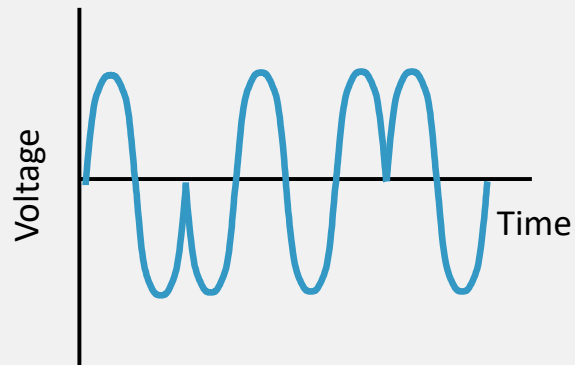
Important Characteristics  
for Frequency Modulation

- **Frequency Deviation ( $\Delta F_{dev}$ )**-Amplitude of Modulating signal determines how far in Frequency the carrier signal will shift
- **Modulation Frequency ( $F_m$ )**-Determines how quickly carrier will shift from one frequency to another
- Accuracy
- Resolution
- Distortion (%)
- Sensitivity (dev/volt)



# Generating Signals – Analog Modulation

## Phase Modulation



$$V(t) = A \cos[2\pi f_c t + \beta 2\pi F_m t]$$

Where  $\beta = \Delta\theta$ , the peak phase deviation

## Important Characteristics

### for Phase Modulation

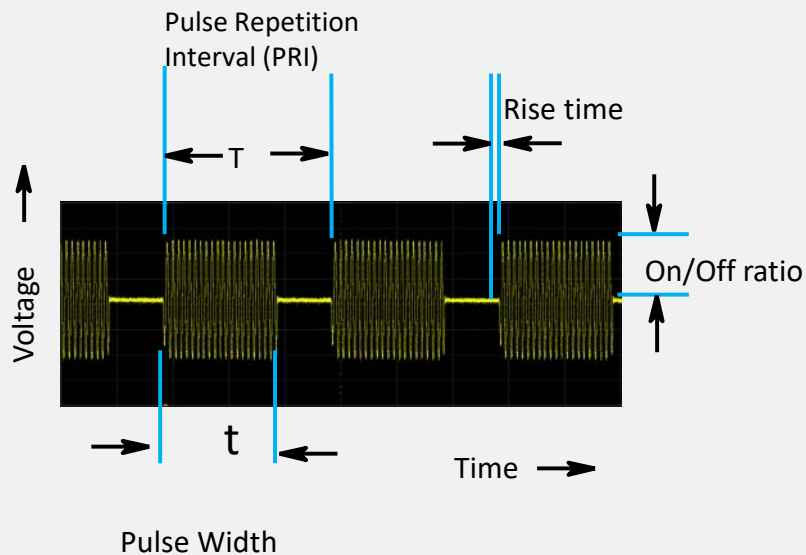
- **Phase deviation ( $\Delta\theta$ )**-amplitude of modulating signal determines the amount of phase deviation.
- **Modulation Rate ( $F_m$ )**- determines how quickly carrier will shift from one phase to another.
- **Accuracy**

### Where are Phase Modulated signals used?

- PSK (early digital 1010)
- Radar (pulse coding)

# Generating Signals – Analog Modulation

## Pulse Modulation

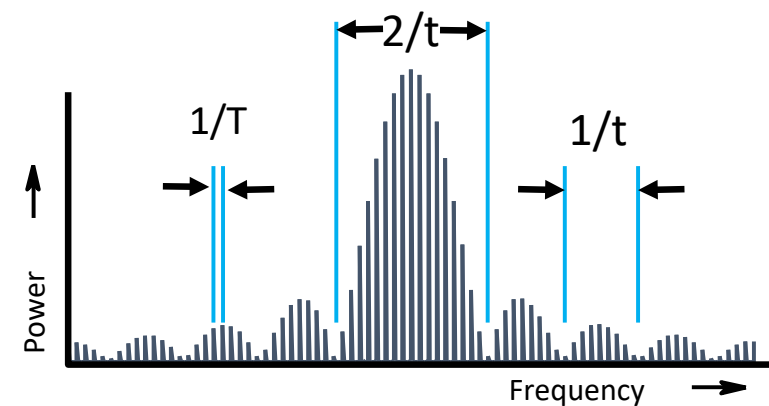


Where are Pulse Modulated signals used?

- Radar
- High Power Stimulus/Response
- Communications

Important Characteristics  
for Pulse Modulation

- Pulse width ( $t$ )
- PRF ( $1/T$ )
- Duty cycle ( $t/T$ )
- On/Off ratio (dB)
- Rise time (ns)



# Agenda └ Signal Generator

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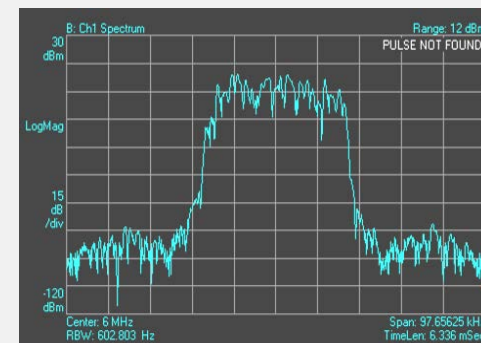
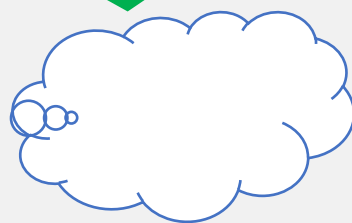
# Generating Signals - Digital Modulation

## From Bits to Modulated Signal

Now we are going to show how information is transmitted by digital modulation.

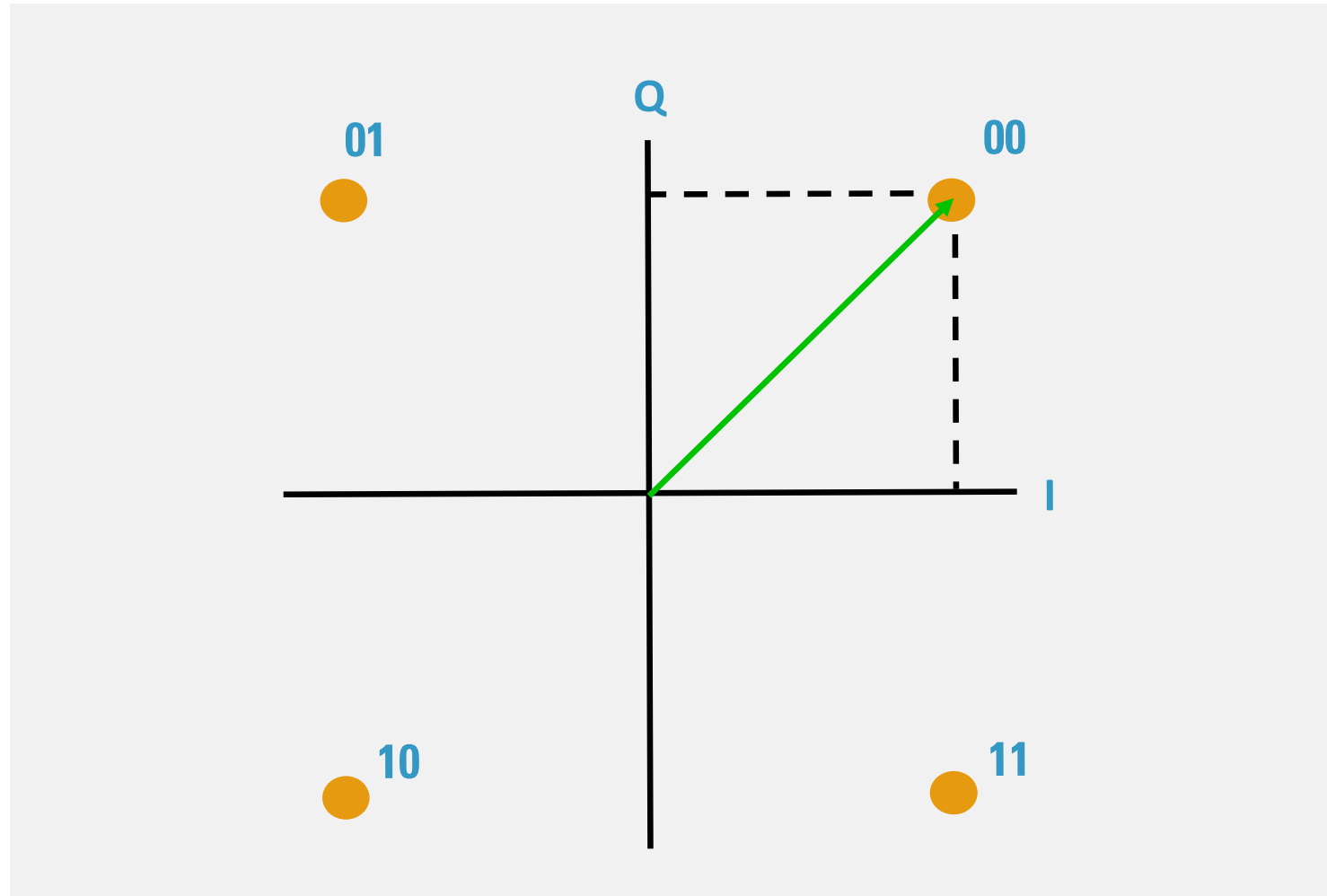
Our example is a QPSK transmitter.

111001011010...



# Generating Signals - Digital Modulation

## QPSK Constellation Diagram



# Generating Signals - Digital Modulation

## Serial Bit Stream

Suppose these are the bits we want to send:

0110110001...

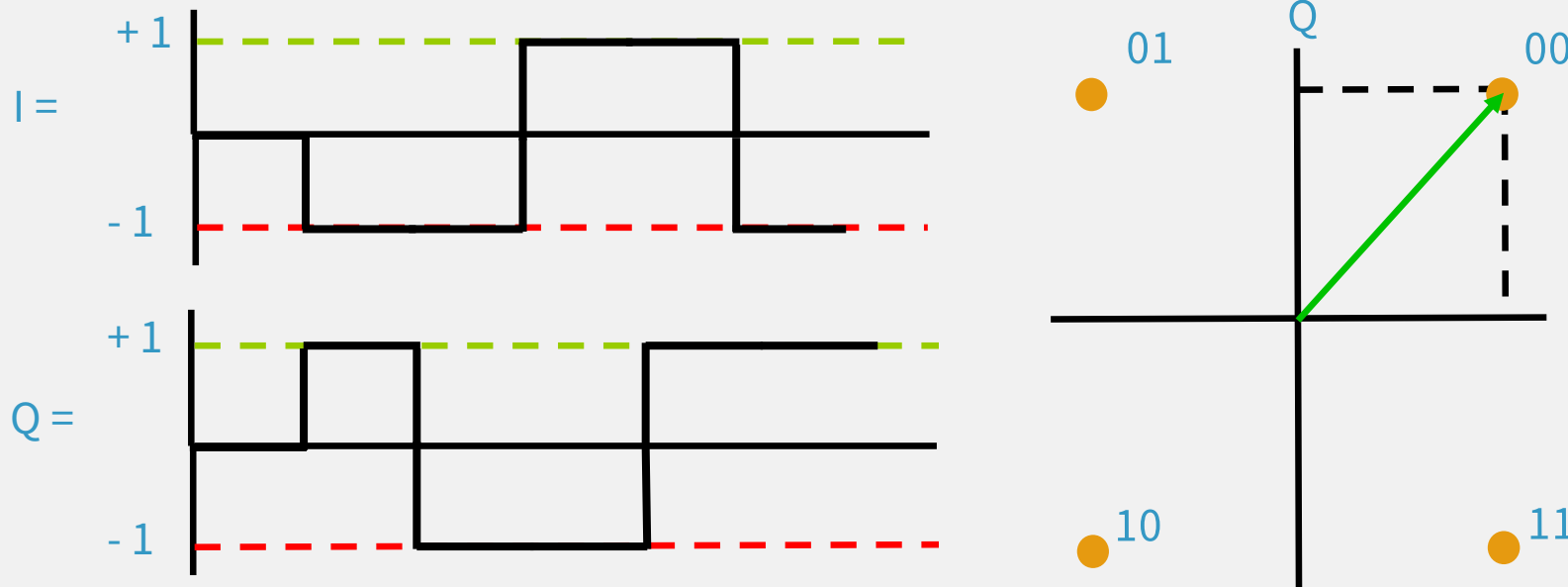
So we group them into 2-bit symbols:

01      10      11      00      01      ...

# Generating Signals - Digital Modulation

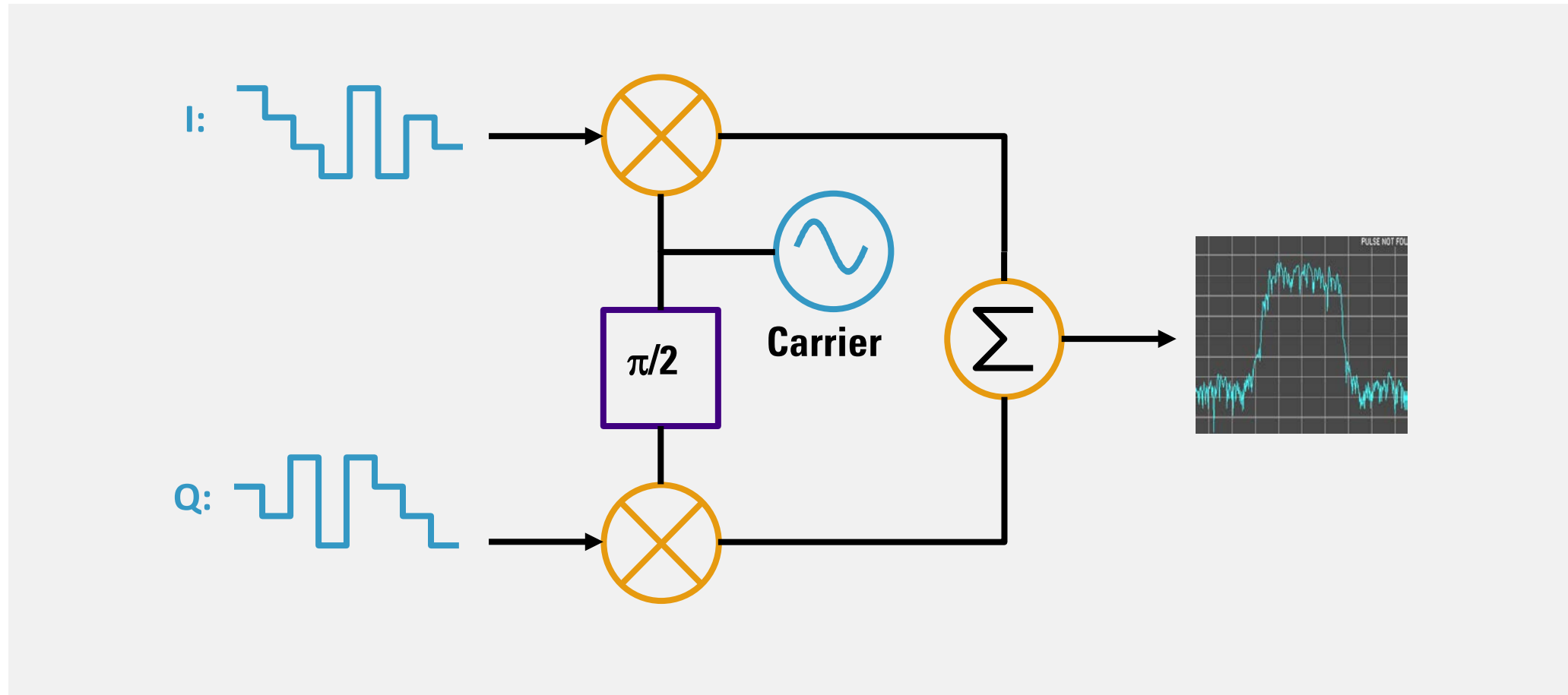
## Two Waveforms

I and Q voltages represent 01 10 11 00 01 ...



# Generating Signals - Digital Modulation

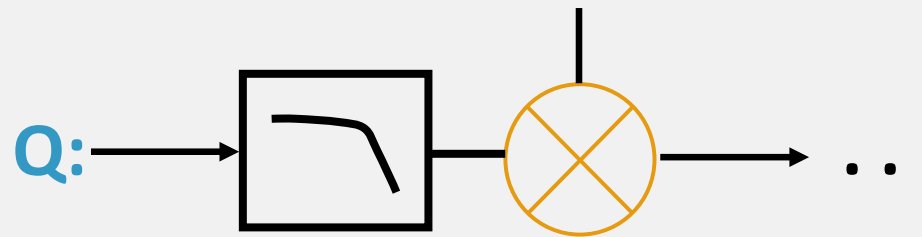
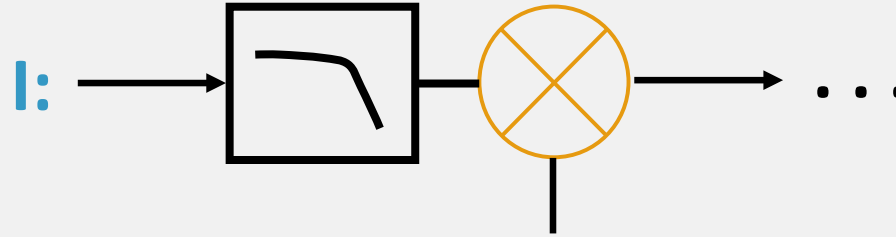
## I-Q Modulator



# Generating Signals - Digital Modulation

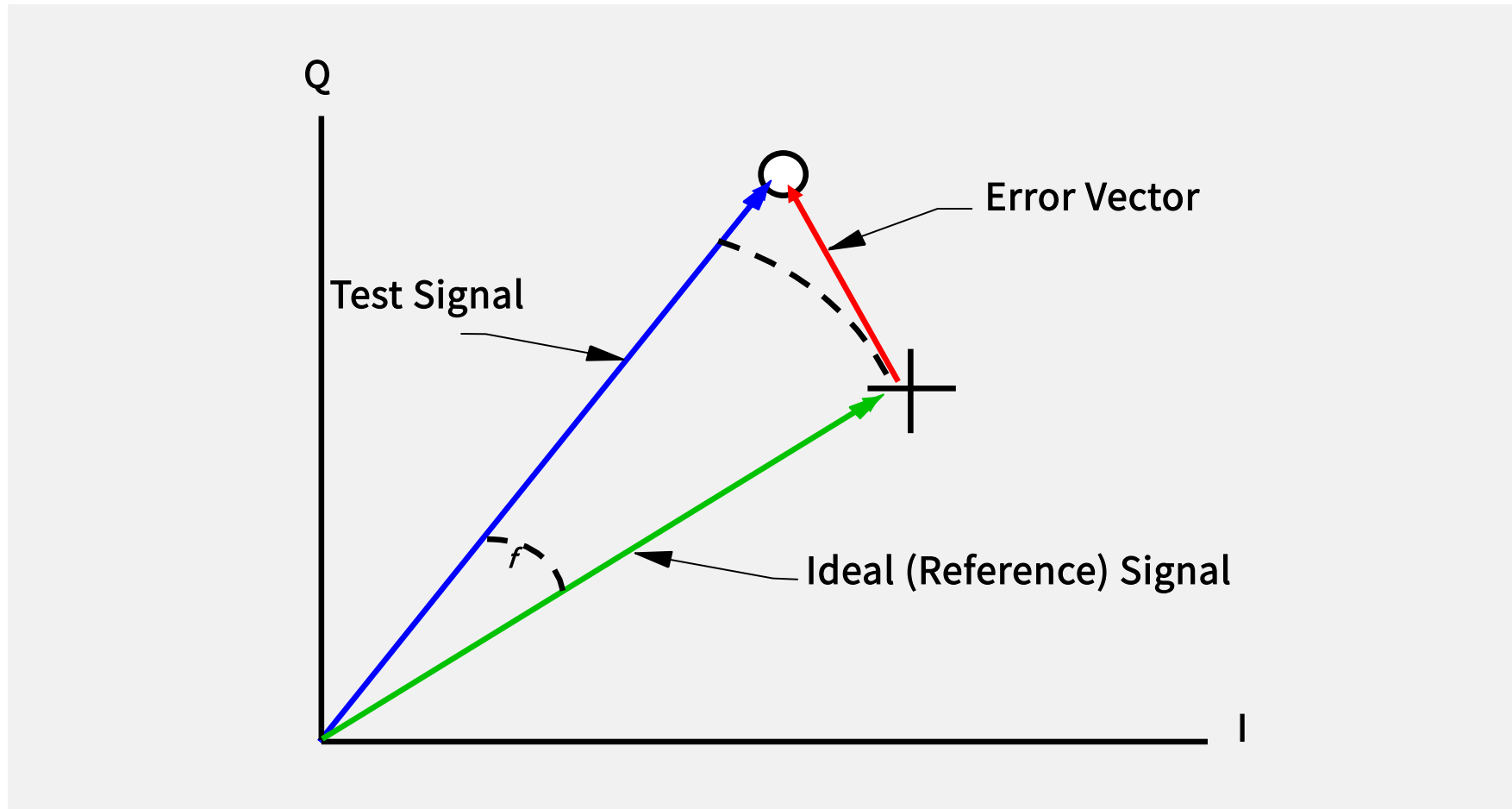
## Limiting Bandwidth

Low pass filters are added at inputs



# Generating Signals - Digital Modulation

## Modulation Accuracy - EVM

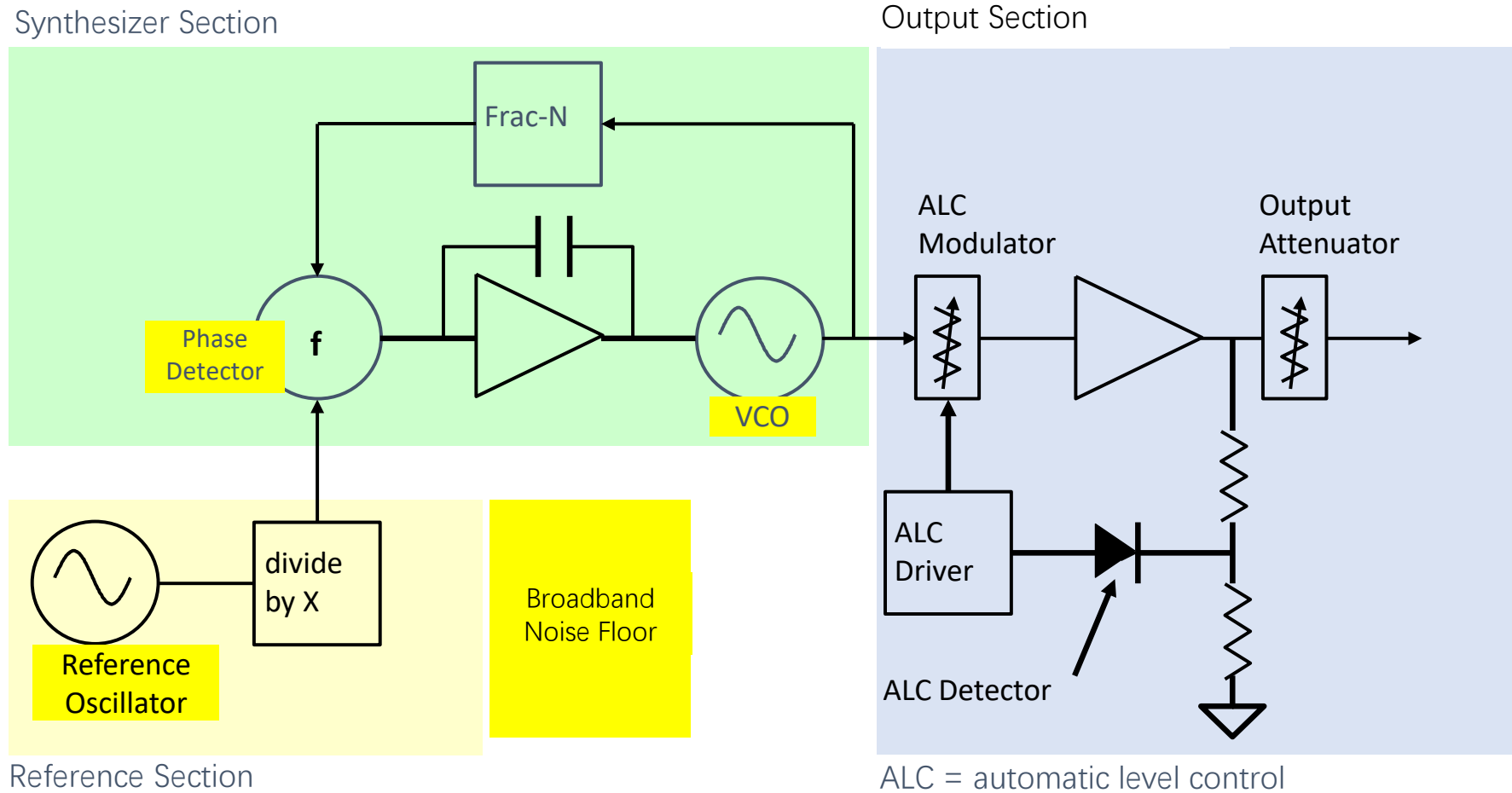


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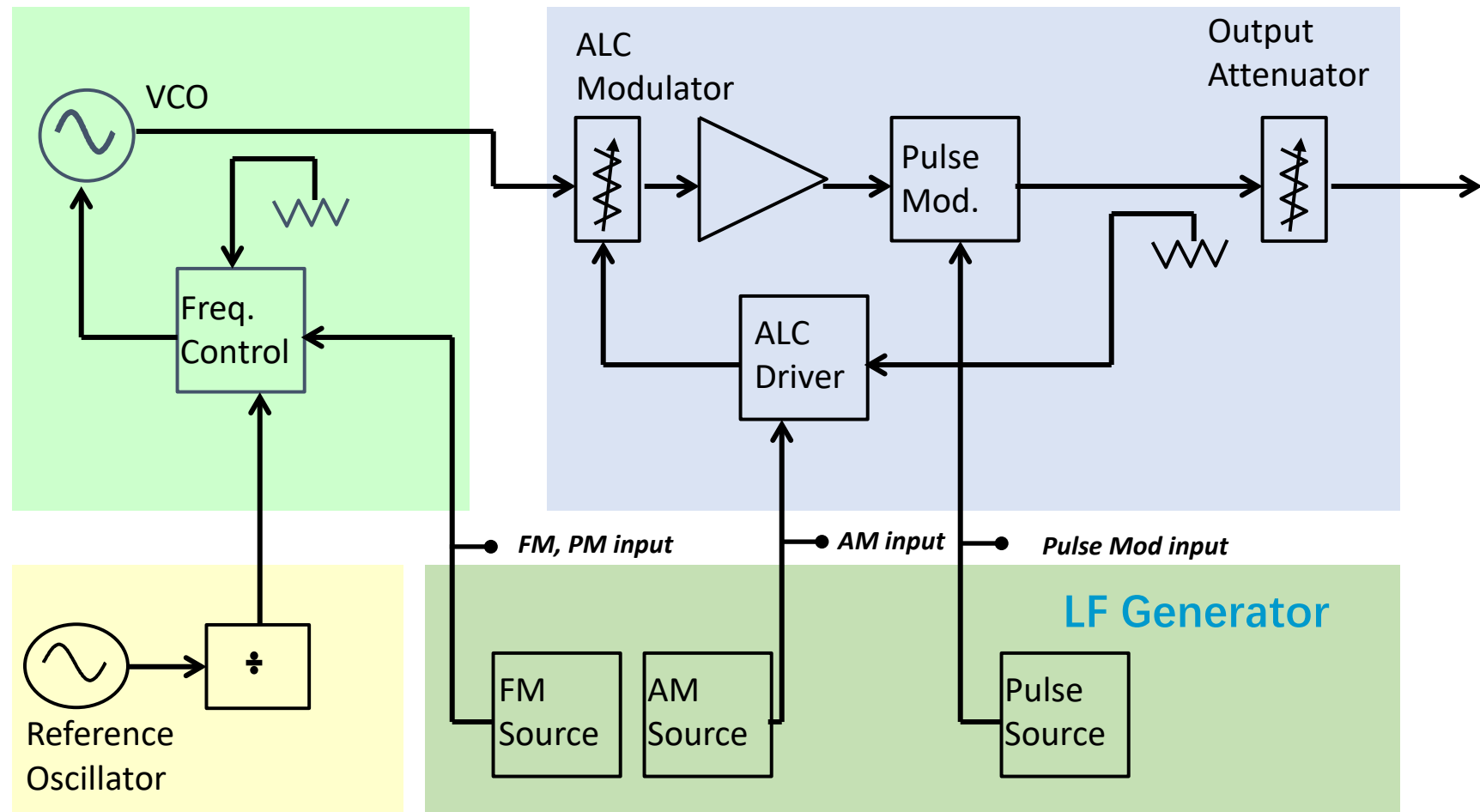
# CW Signals – Block Diagram

Basic Building blocks of RF Source: Four Phase Noise Contributors



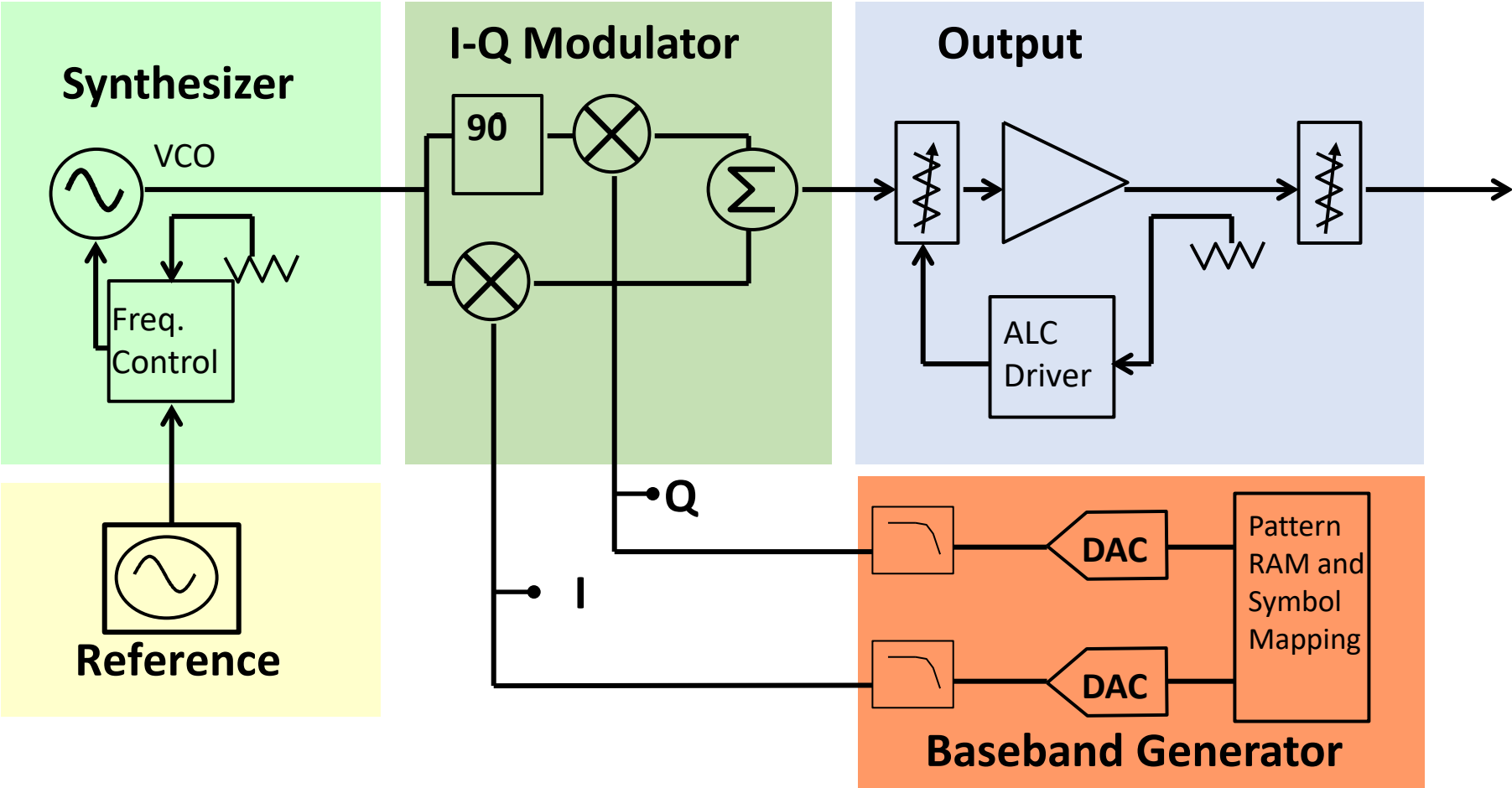
# Signal Generator– Modulation

Generation of AM, FM, PM & Pulse Signal



# Vector Signals – Block Diagram

Adding an internal Baseband Generator



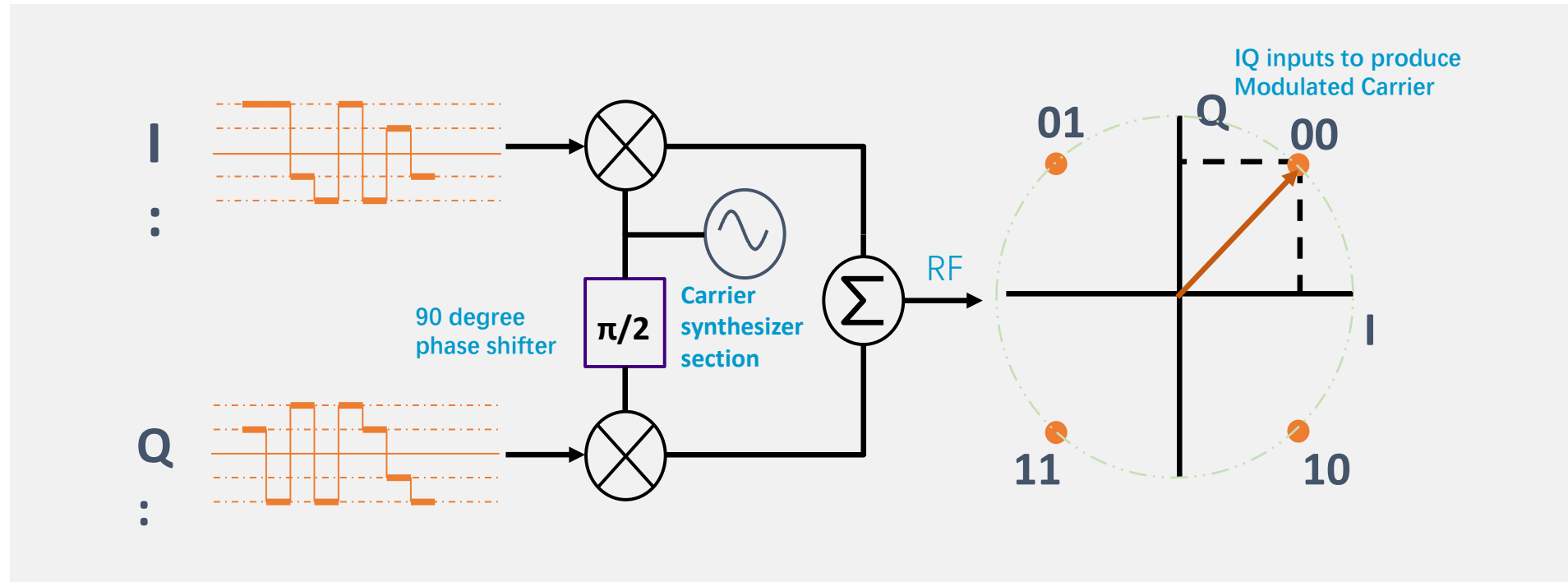
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# Vector Signals – Block Diagram

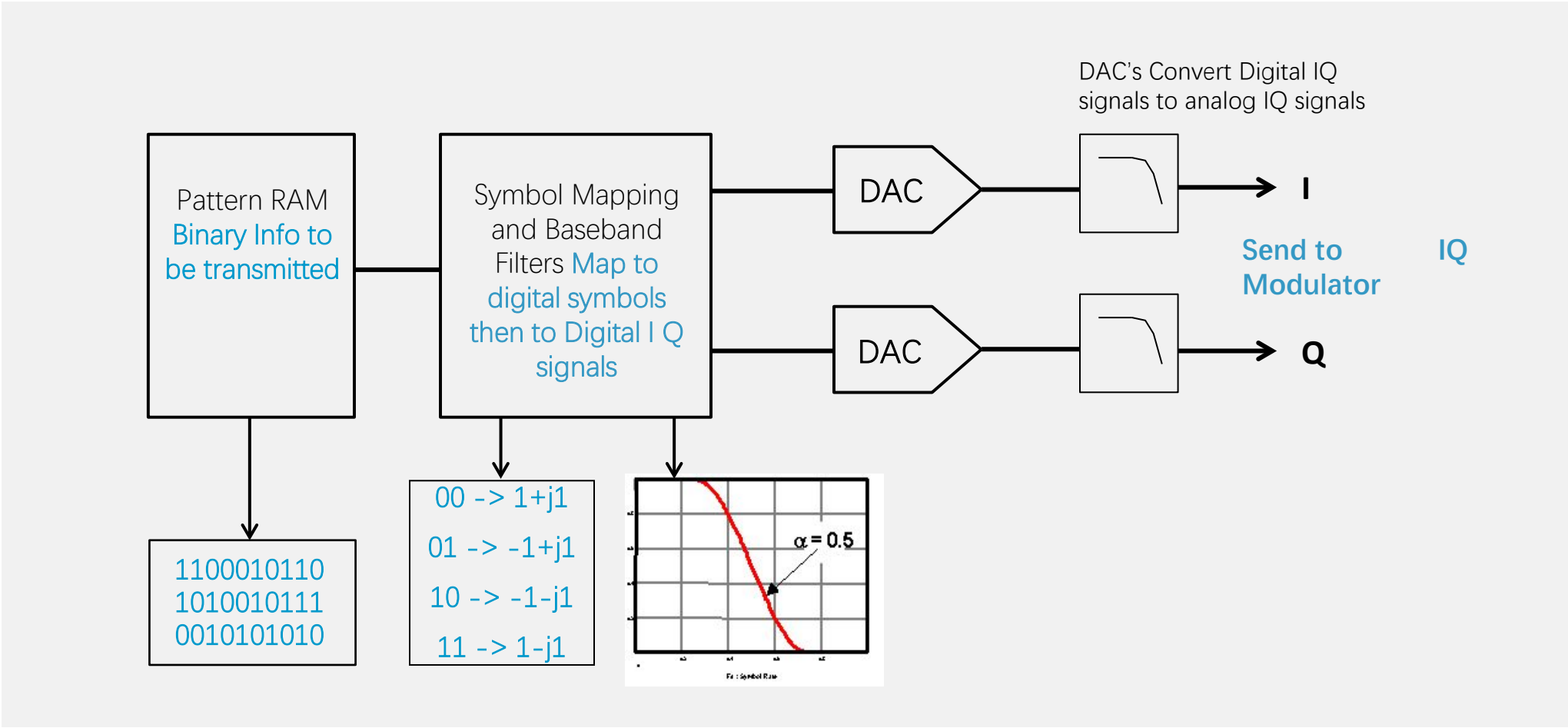
## IQ Modulator



- Good Interface with Digital Signals and Circuits
- Can be Implemented with Simple Circuits
- Fast, accurate state change

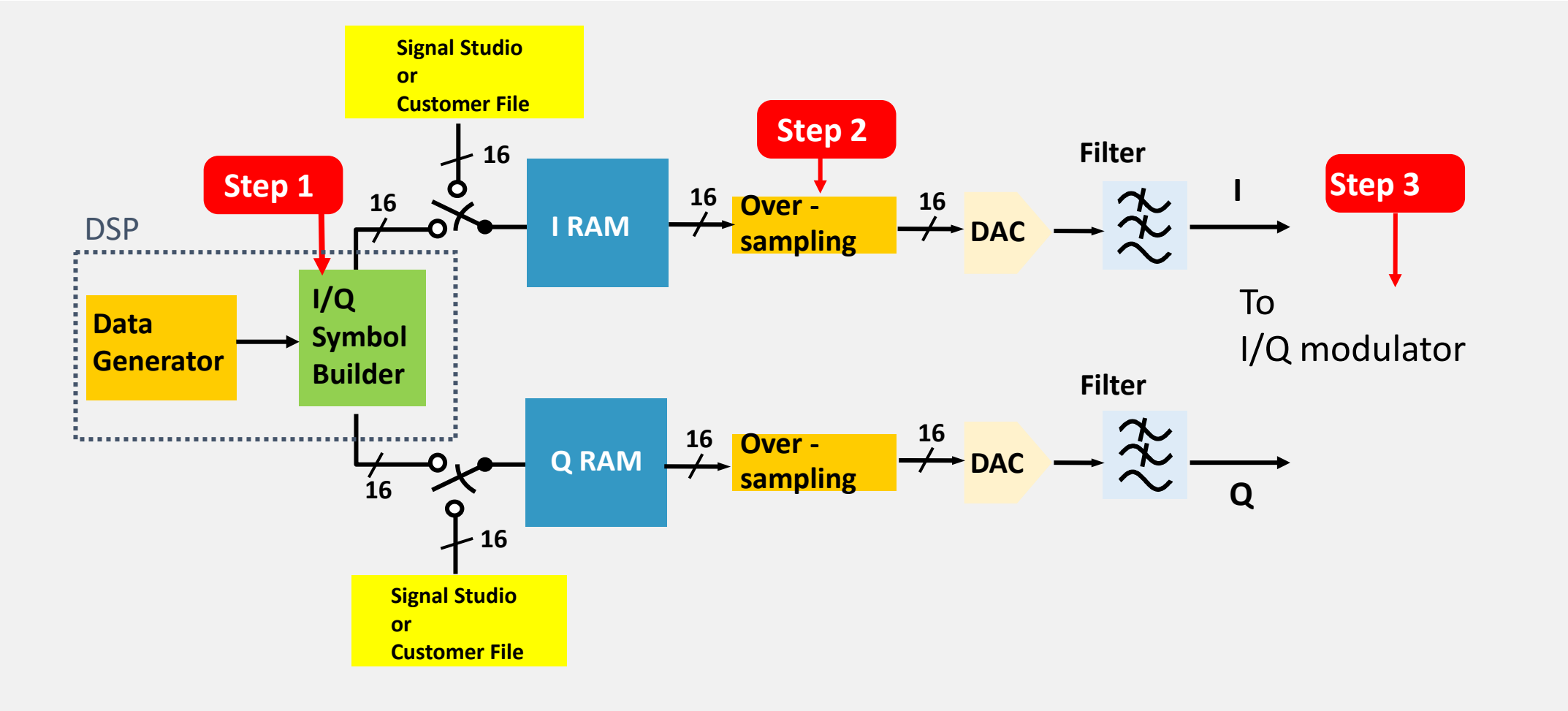
# Vector Modulation Signals – BBG Block Diagram

Baseband IQ signal generation- Contains information to be transmitted



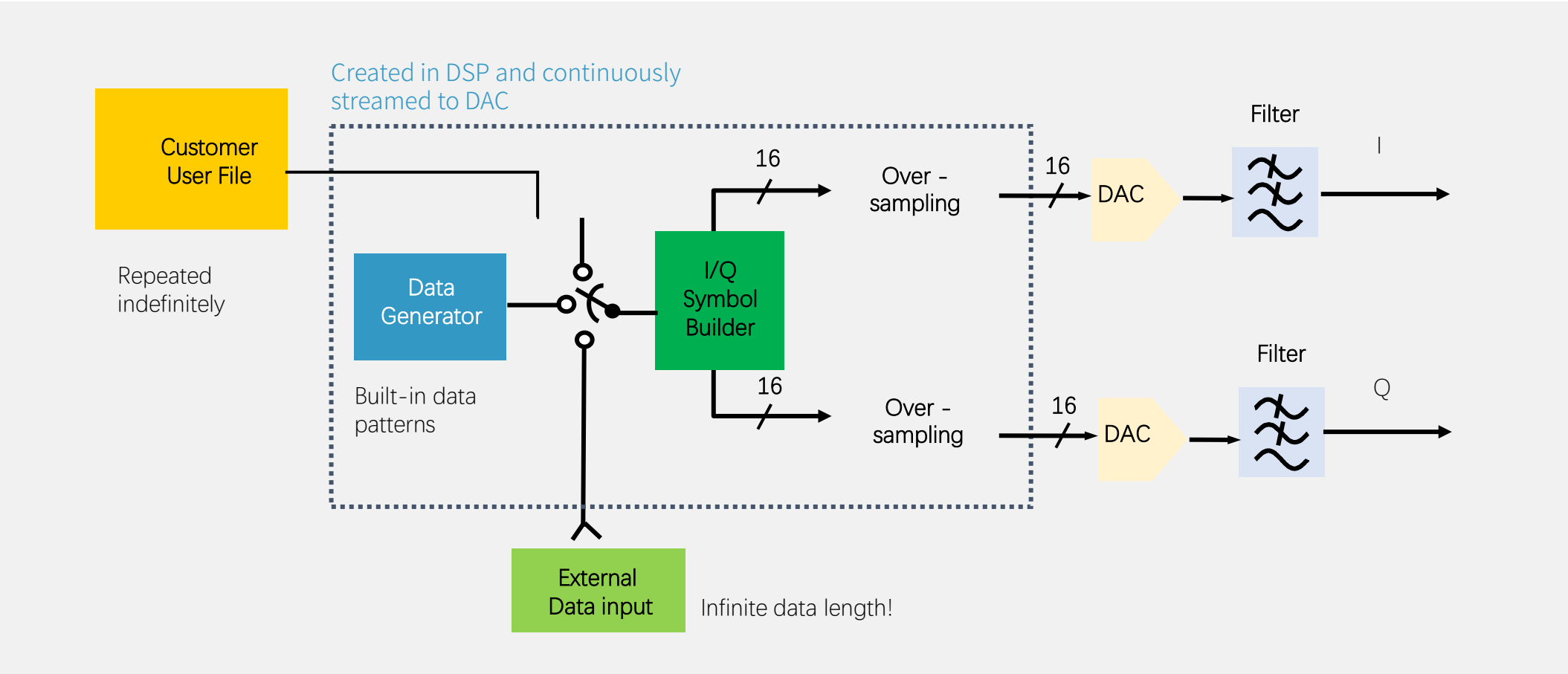
# Vector Modulation Signals – BBG Block Diagram

Arbitrary waveform generator



# Vector Modulation Signals – BBG Block Diagram

Real-time waveform generator

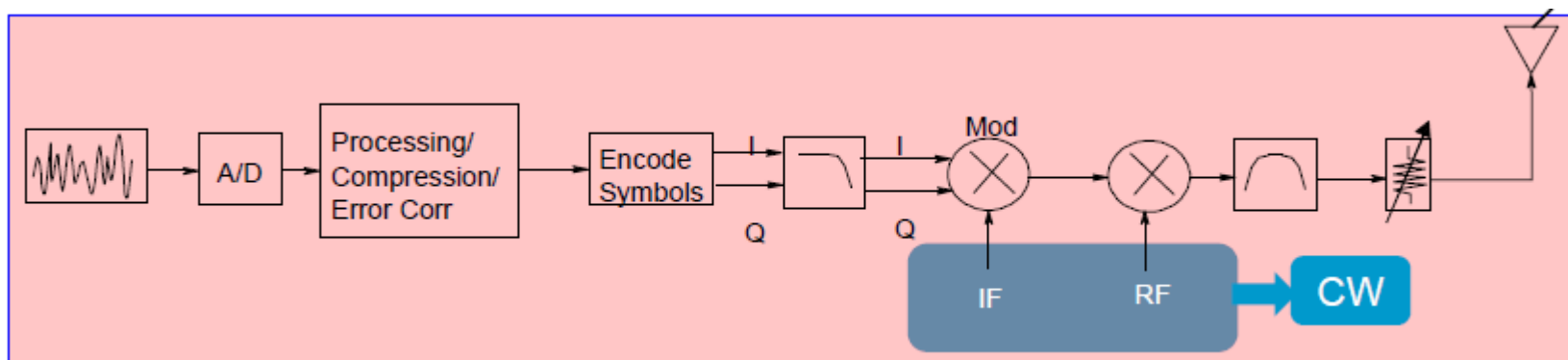


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# Basic Applications

## Serve as an Oscillator

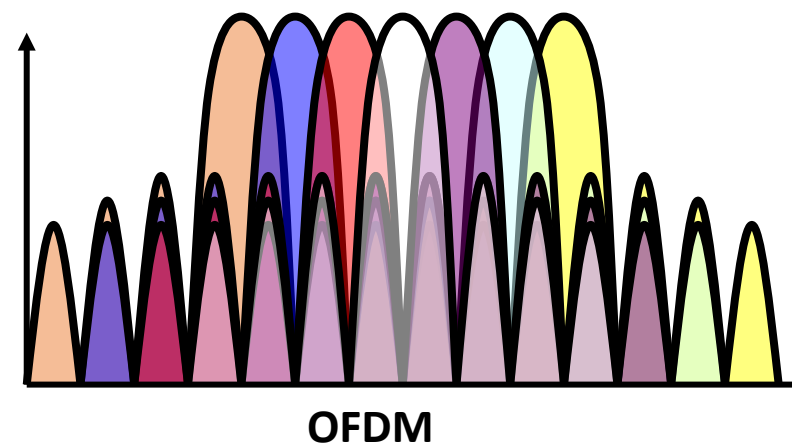
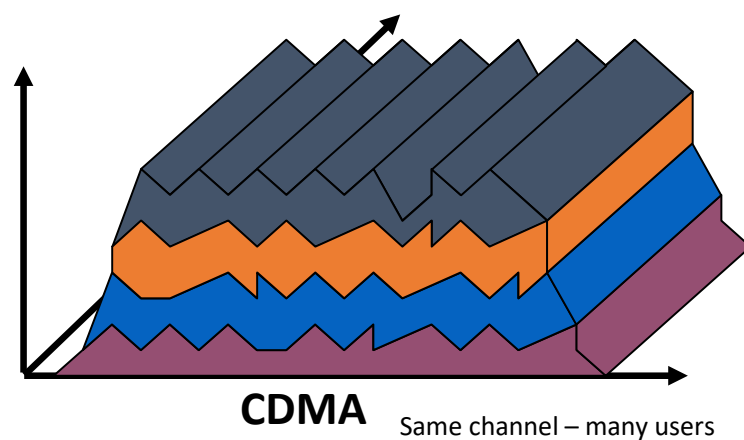
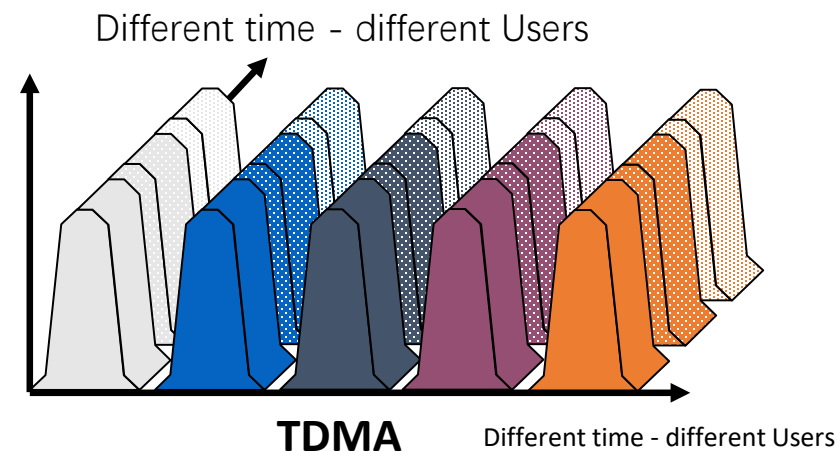
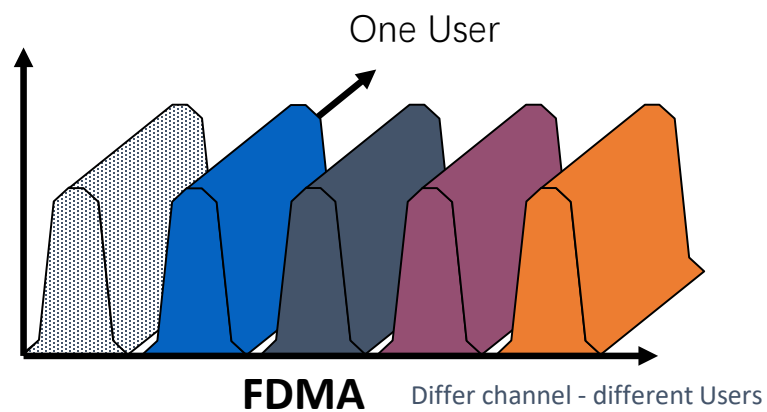


- Enhanced phase noise performance
- High stability time base
- Lower aging rate



# Basic Applications

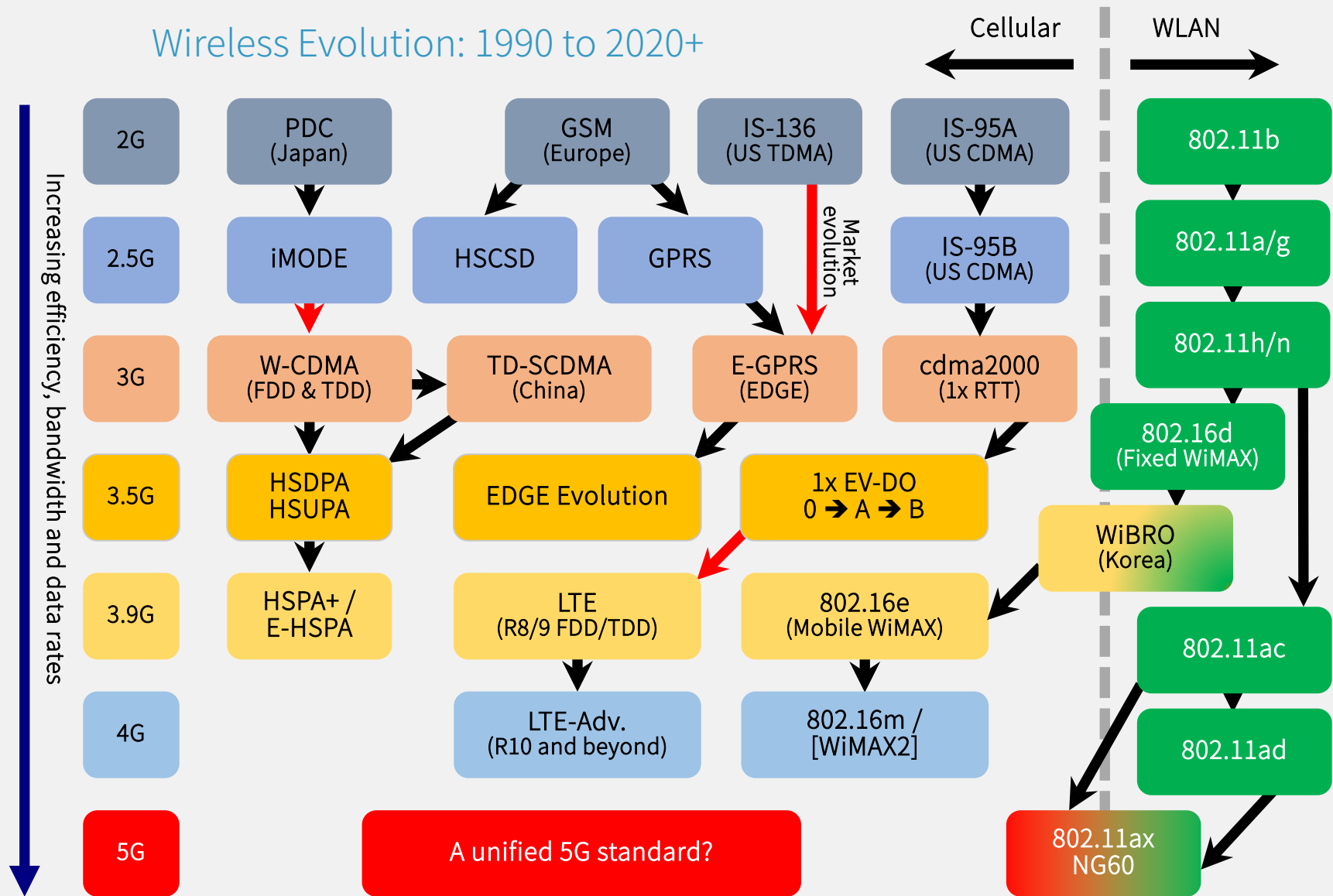
## Digital Format Access Schemes



# Agenda——Signal Generator

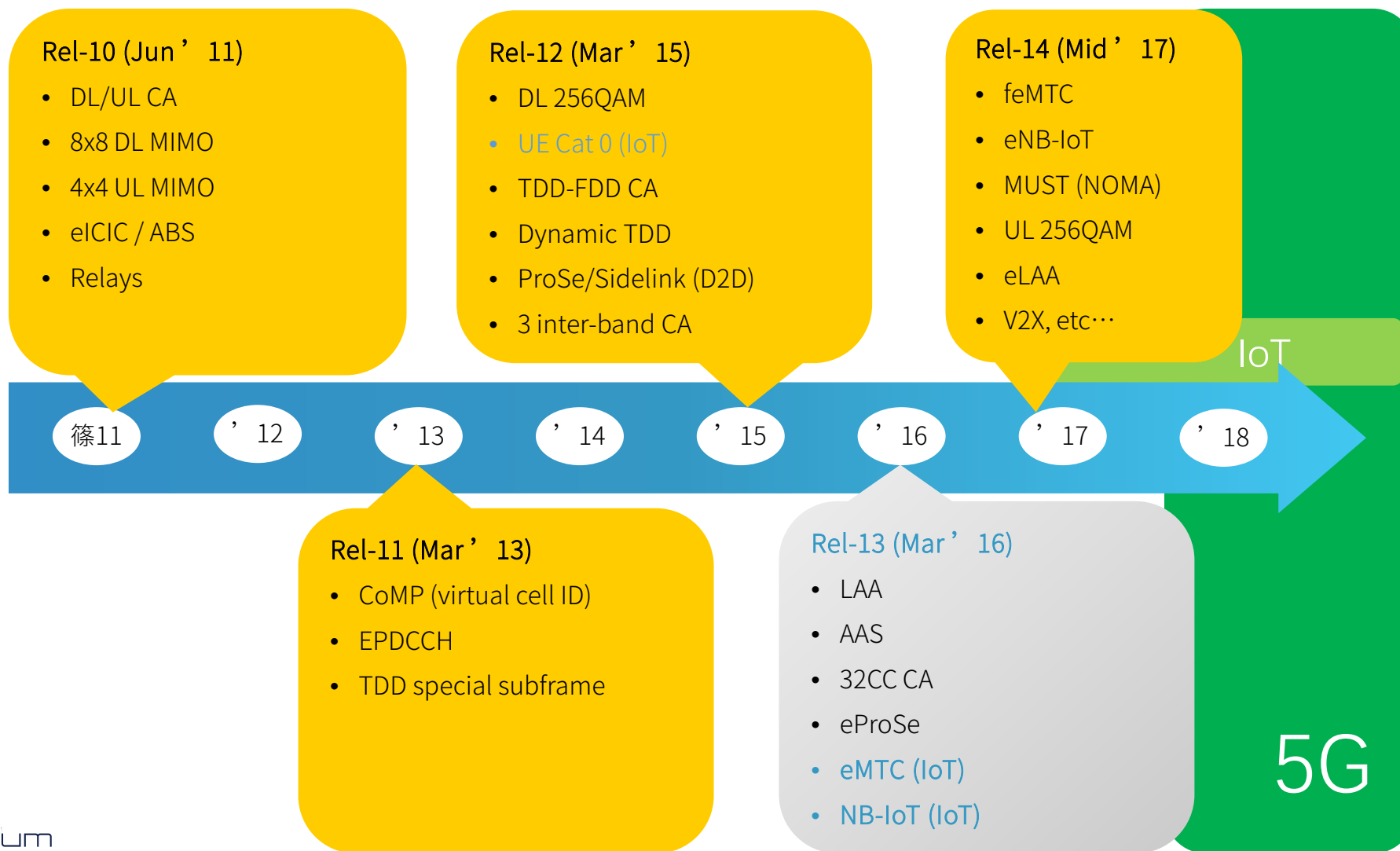
- Generating Signals
  - Continuous Wave (CW)
  - Sweep Signal
  - Analog Modulation
  - Digital Modulation
- Signal Generator Architecture
- Basic Applications
- **Applications in Modern Wireless Communications**

# Wireless Evolution: 1990 to 2020+



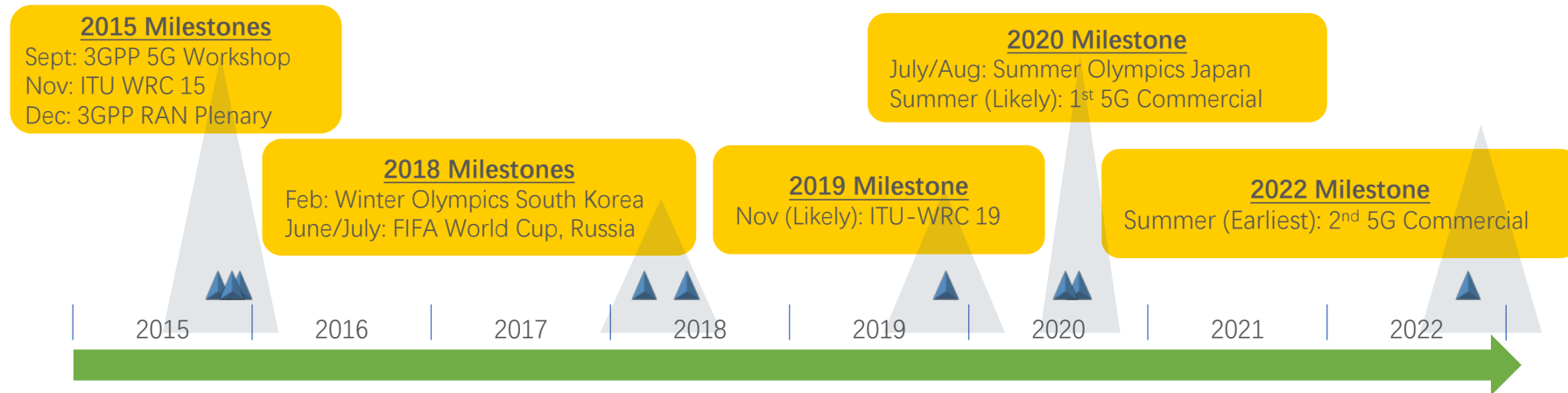
# 3GPP LTE/LTE-Advanced Evolution...

## Introduction



# 5G Standardization Timeline

Industry rallying around these cardinal dates



- Mid/Late 2020: commercialization focused below 6GHz (standard must be complete before end 2018). 2022 or later for mmWave commercialization (technology, spectrum)
- 2018 and 2020 Olympics will showcase 5G.
- 3GPP Workshops & Plenary in Sept and Dec 2015 is official start to 5G standards work

# Application in LTE- N7624B/N7625B

## **N7624(5)B Signal Studio Basic Waveform for LTE and LTE-Advanced FDD (TDD) Component Testing**

- Create spectrally-correct LTE and LTE-Advanced FDD signals for ACLR and spectral mask type testing
- Predefined setups for E-UTRA test models (E-TM) and reference measurement channels (RMC)
- Set parameters such as channel power and modulation type for modulation quality testing

## **N7624B Signal Studio Advanced Capability, Real-time Signal Generation, LTE FDD eNB Receiver Testing**

- Choose a pre-defined fixed reference channel (FRC) configurations
- Create PUSCH sounding reference signals (SRS), including frequency hopping and UCI multiplexing
- Use the PUCCH wizard to create multi-user configurations
- Customize RV index sequence for HARQ retransmission
- Create real-time uplink LTE signals for closed-loop HARQ and timing adjustment testing

## **N7624B Signal Studio Advanced Waveform for LTE and LTE-Advanced FDD UE Receiver Testing**

# Application in LTE

# Basic TDD Carrier

- Basic : use waveform playback mode to create and customize waveform files needed to test components and transmitters – E-TM (Test Model Wizard)
- Advanced: address applications in LTE receiver test, including the verification of baseband designs and the integration of the baseband and RF modules. – FRC

Quick Setups

Hardware

Instrument

Licenses

Waveform Setup

Carrier 1

Downlink

Transport Channel

Physical Channel

Resource Block

Uplink

Transport Channel

Physical Channel

Resource Block

Configuration : LTE TDD 1 Carrier (Modified)

Predefined CarrierAdd CarrierDelete CarrierCopy Carrier

| Carrier     | State | Radio Format  | Configuration                       | Frequency Offset | Power    |
|-------------|-------|---------------|-------------------------------------|------------------|----------|
| Carrier ... | On    | Basic LTE TDD | Full filled QPSK 5MHz (25 RB) (M... | 0.000000 Hz      | 0.000 dB |

Carrier 1 -- Basic LTE TDD

Frequency Offset

Power

Timing Offset

Initial Phase

Symbol Rolloff Length

Baseband Filter

Pre-Filter Clipping

Post-Filter Clipping

2.LTE TDD Frame Configuration

Uplink Downlink Configuration

Switch-point Periodicity

Allocation Configuration

Special Subframe Configuration

DwPTS Length

GP Length

UpPTS Length

3.LTE TDD Common Parameters

Physical Layer Cell ID Group

Physical Layer Cell ID Sector

Cell ID

System Bandwidth

Total number of Resource Blocks

Total number of Occupied Sub-carriers

Subcarrier Spacing

Cyclic Prefix

Number of Subcarriers for Resource Block

Number of Symbols for Resource Block

0.000000 Hz

0.000 dB

0.000 (us)

0 Deg

0 Ts

On

100.0 %

100.0 %

0

5 ms

D,S,U,U,U,D,S,U,U,U

0

3 Symbols

10 Symbols

1 Symbols

0

0

0

5 MHz (25RB)

25

300

15 kHz

Normal

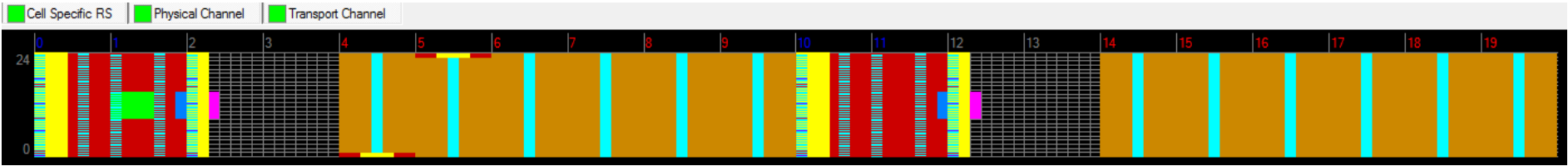
12

7

TDD configuration

# Application in LTE –Basic TDD Downlink

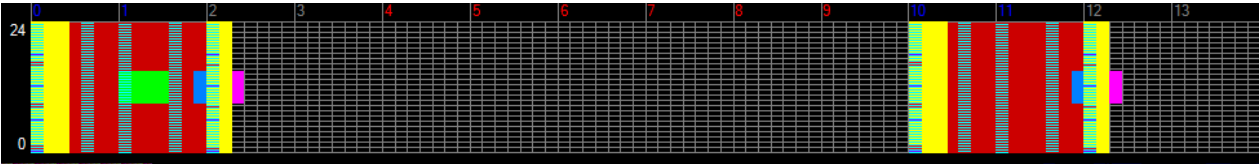
|                                                |               |
|------------------------------------------------|---------------|
| <b>1. Cell Parameters</b>                      |               |
| State                                          | On            |
| Antenna Port                                   | 0             |
| Total Number of Antennas                       | 1 Antenna     |
| Power Definition Type                          | Total Power   |
| Reference Signal Transmit Power (RSTP)         | -34.77 dBm    |
| OFDM Symbol Transmit Power (OSTP)              | -10.00 dBm    |
| <b>2. Cell Specific Reference Signal</b>       |               |
| Cell Specific Reference Signal Power           | 0.000 dB      |
| Cell Specific Reference Signal Frequency Shift | Cell ID mod 6 |
| PDSCH Cell Specific Ratio                      | pB/pA=1       |
| <b>3. Synchronization Signals</b>              |               |
| Primary Synch Signal State                     | On            |
| Primary Synch Signal Power                     | 0.000 dB      |
| Secondary Synch Signal State                   | On            |
| Secondary Synch Signal Power                   | 0.000 dB      |
| P-SS/S-SS Transmit Antenna Port                | Port 0        |



# Application in LTE –Advanced TDD Downlink

| # | Channel | State | Power | Data         | Higher Layer | Resource Block Collection |
|---|---------|-------|-------|--------------|--------------|---------------------------|
| 1 | PBCH    | On    | 0.000 | Higher Layer | CH2:BCH      | -                         |
| 2 | PDCCH   | On    | 0.000 | -            | -            | -                         |
| 3 | PDSCH   | On    | 0.000 | Higher Layer | CH1:DL-SCH   | 1,2                       |
| 4 | PDSCH   | On    | 0.000 | Higher Layer | CH1:DL-SCH   | 3,4                       |
| 5 | PCFICH  | On    | 0.000 | -            | -            | -                         |
| 6 | PHICH   | On    | 0.000 | -            | -            | -                         |

|                                                |                 |
|------------------------------------------------|-----------------|
| 1. Cell Parameters                             |                 |
| State                                          | On              |
| Antenna Port                                   | 0               |
| Total Number of Antennas                       | 1 Antenna       |
| Power Definition Type                          | Total Power     |
| Reference Signal Transmit Power (RSTP)         | -34.77 dBm      |
| OFDM Symbol Transmit Power (OSTP)              | -10.00 dBm      |
| 2. Cell Specific Reference Signal              |                 |
| Cell Specific Reference Signal Power           | 0.000 dB        |
| Cell Specific Reference Signal Frequency Shift | Cell ID mod 6   |
| PDSCH Cell Specific Ratio                      | pB/pA=1         |
| 3. Positioning Reference Signals (PRS)         |                 |
| State                                          | Off             |
| Power                                          | 0.000 dB        |
| Antenna Mapping for Port 0                     | 1               |
| Number of PDCCH Symbols                        | 2               |
| PRS Bandwidth                                  | 5 MHz (25RB)    |
| Number of Consecutive DL Subframes (N_PRS)     | 1 subframe      |
| PRS Configuration Index (I_PRS)                | 0               |
| PRS Periodicity (T_PRS)                        | 160 (subframes) |
| PRS Subframe Offset (Delta_PRS)                | 0               |
| PRS Muting Sequence Length                     | 2               |
| PRS Muting Sequence                            | 1,1             |
| 4. Synchronization Signals                     |                 |
| Primary Synch Signal State                     | On              |
| Primary Synch Signal Power                     | 0.000 dB        |
| Secondary Synch Signal State                   | On              |
| Secondary Synch Signal Power                   | 0.000 dB        |
| P-SS/S-SS Transmit Antenna Port                | Port 0          |



# Application in LTE –Configure TDD Uplink and Downlink

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The image displays two screenshots of the NeuHelium software interface, illustrating the configuration of TDD Uplink and Downlink parameters.

**Top Screenshot: Downlink Setup**

- Carrier 1** is selected in the left sidebar.
- Downlink** is selected in the left sidebar.
- 1. Cell Parameters** table:

| Parameter                            | Value     |
|--------------------------------------|-----------|
| State                                | On        |
| First M-Sequence for Scrambling Code | 1         |
| Pre-clocking number for PRBS         | 1600      |
| Antenna Port                         | 0         |
| Total number of Antennas             | 1 Antenna |
- 2. Cell specific Reference Signal** table:

| Parameter                                | Value         |
|------------------------------------------|---------------|
| Cell specific Reference Signal Power     | 2.50 dB       |
| Cell specific Reference Signal Frequency | Cell ID mod 6 |
- 3. Synchronization Signals** table:

| Parameter                    | Value   |
|------------------------------|---------|
| Primary Synch Signal State   | On      |
| Primary Synch Signal Power   | 0.65 dB |
| Secondary Synch Signal State | On      |
| Secondary Synch Signal Power | 0.65 dB |
- State** dropdown menu is set to **On**. A hint box states: "Double-click or use the drop-down menu to turn the carrier off or on."
- Grid View:** Shows a time-frequency grid with subcarriers 0-24 and symbols 0-19. The grid is populated with red and green bars, indicating signal transmission.

**Bottom Screenshot: Uplink Setup**

- Carrier 1** is selected in the left sidebar.
- Uplink** is selected in the left sidebar.
- 1. Cell Parameters** table:

| Parameter                            | Value |
|--------------------------------------|-------|
| State                                | On    |
| First M-Sequence for Scrambling Code | 1     |
| Pre-clocking number for PRBS         | 1600  |
| PUSCH DFT Swap                       | On    |
- 2. Sounding Reference** table:

| Parameter                      | Value        |
|--------------------------------|--------------|
| State                          | Off          |
| Subframe Assignment            | 2            |
| Power                          | 0.00 dB      |
| Occupied Resource Block Size   | 25           |
| Occupied Resource Block Offset | 0            |
| Symbol Position                | First Symbol |
| Group Index                    | 0            |
| Sequence Index                 | 0            |
- State** dropdown menu is set to **On**. A hint box states: "Double-click or use the drop-down menu to turn the carrier off or on."
- Grid View:** Shows a time-frequency grid with subcarriers 0-24 and symbols 0-19. The grid is populated with orange bars, indicating signal transmission.

**Annotations:**

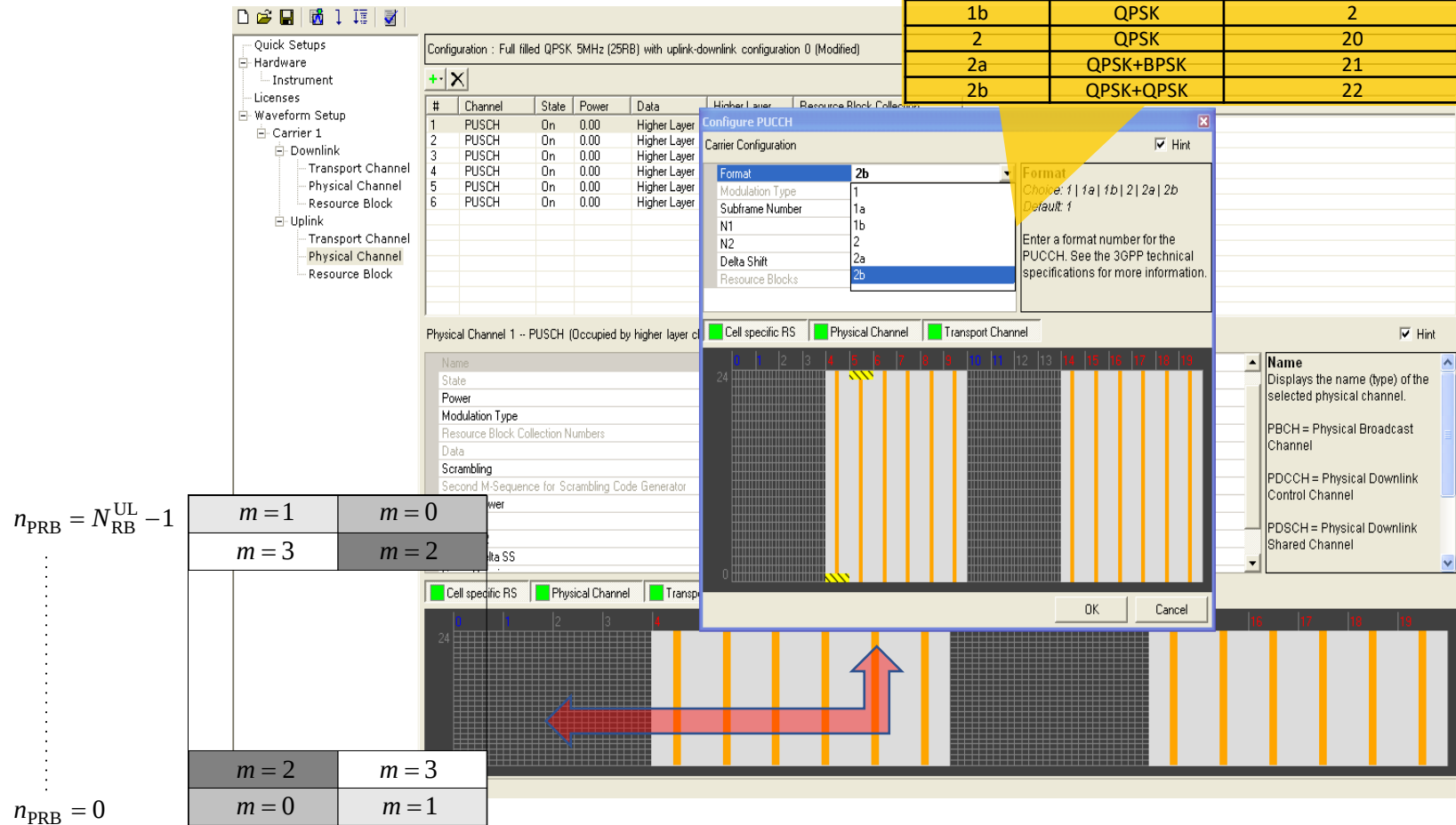
- A yellow box highlights the **State** dropdown menu in both screenshots, with a note: "Clicking the ON/OFF button to enable DL/UL signal".

# Application in LTE –Basic LTE TDD- Uplink PUCCH

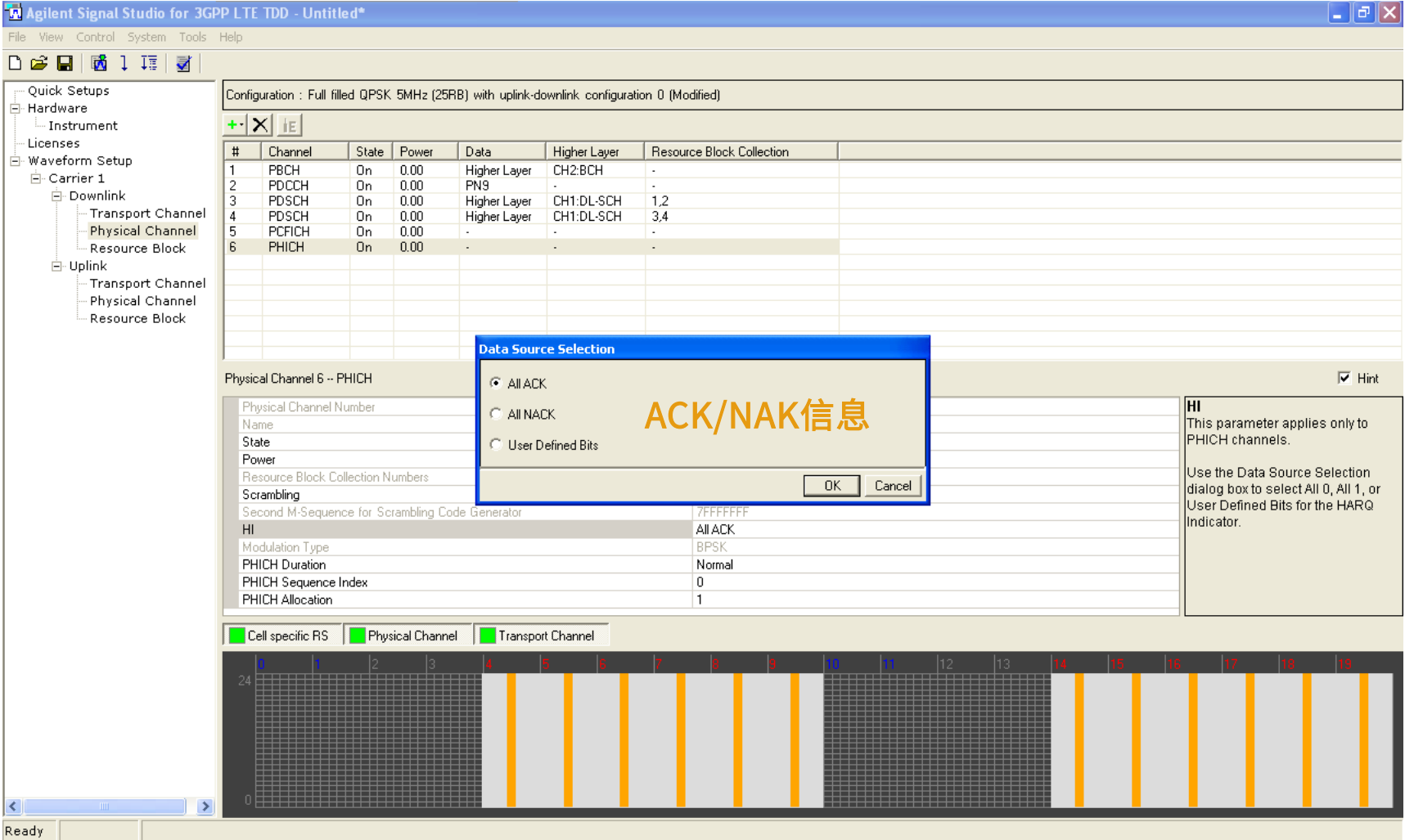
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| PUCCH format | Modulation scheme | Number of bits per subframe, $M_{bit}$ |
|--------------|-------------------|----------------------------------------|
| 1            | N/A               | N/A                                    |
| 1a           | BPSK              | 1                                      |
| 1b           | QPSK              | 2                                      |
| 2            | QPSK              | 20                                     |
| 2a           | QPSK+BPSK         | 21                                     |
| 2b           | QPSK+QPSK         | 22                                     |



# Application in LTE –Basic LTE TDD- PHICH



# Application in LTE    Advanced LTE TDD- Uplink FRC

Configuration : Full filled QPSK 5MHz (25 RB)

Predefined Config.UL FRC WizardUL RMC WizardPUCCH Wizard

Uplink Setup

1. Cell Parameters

StateOff

Antenna Port0

Total Number of Antennas

PUSCH DFT Swap

2. Sounding Reference Signal

State

Power

Group/Sequence Hop

Subframe Configuration

Maximum UpPTS

Number of Format 4

Cyclic Shift (nSRS\_C)

Bandwidth Configuration

Bandwidth (B\_SRS)

Transmission Comb

Hopping Bandwidth (B\_H)

Frequency Domain FRC

Configuration Index (C)

Periodicity (Tsrs)

Subframe Offset Configuration

Frequency Hopping

FRC Wizard

FRC Configuration

System Bandwidth5 MHz (25RB)

FRC TypeFRC for reference sensitivity and in-channel selectivity (QPSK, R=1/3)

Reference Channel A1A1-1

RB Offset0

SRS State (Optional)Off

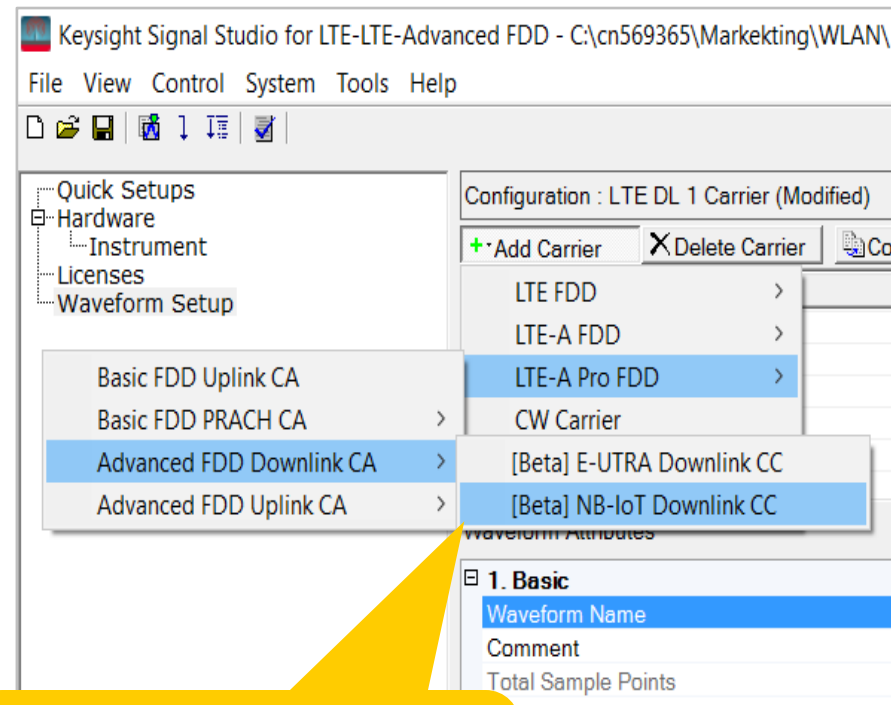
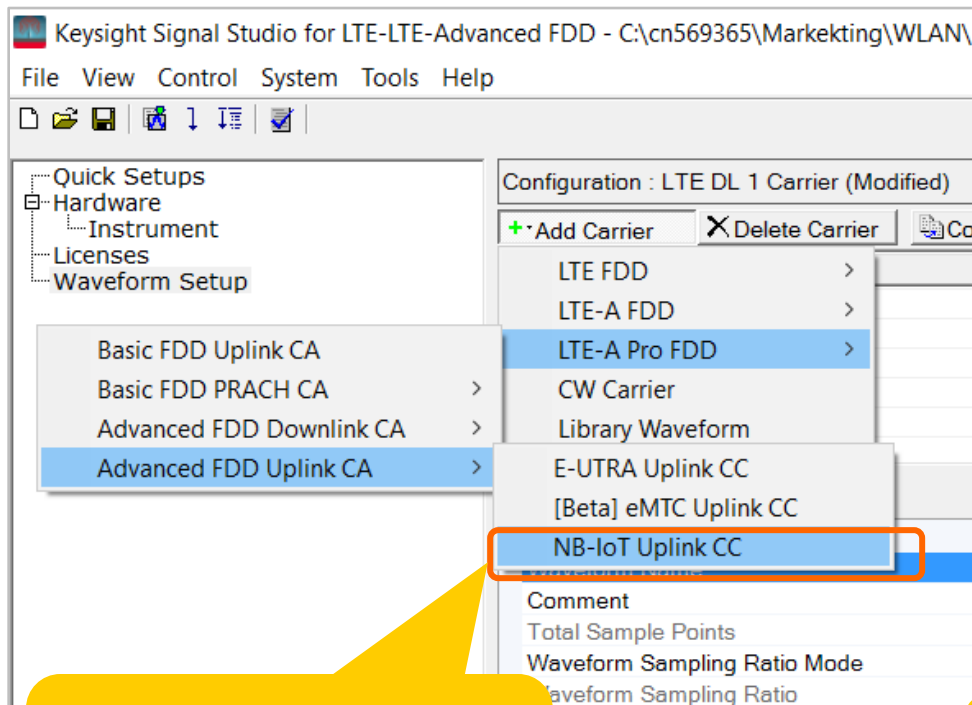
FRC for reference sensitivity and in-channel selectivity (QPSK, R=1/3)

|                                                              |      |
|--------------------------------------------------------------|------|
| Allocated Resource Blocks                                    | 6    |
| DFT-OFDM Symbols per Subframe                                | 12   |
| Modulation                                                   | QPSK |
| Code Rate                                                    | 1/3  |
| Payload Size (bits)                                          | 600  |
| Transport Block CRC (bits)                                   | 24   |
| Code Block CRC Size (bits)                                   | 0    |
| Number of Code Blocks                                        | 1    |
| Coded Block Size including 12bits trellis termination (bits) | 1884 |
| Total Number of Bits per Subframe                            | 1728 |
| Total Symbols per Subframe                                   | 864  |

OK

Cancel

# Application in NB\_IoT – NB-IoT Component Carrier



Note: “Beta” features are included but hidden by default. Select “Show Beta Features” under View menu.

# Application in NB\_IoT – UL FRC Wizard

## UL FRC Wizard

A14 FRC for NB-IoT reference sensitivity  
A15 FRC for NB-IoT dynamic range  
A16 FRC for NB-IoT NPUSCH format 1

UL FRC Wizard

Uplink FRC Configuration (Base Station Rx Test based on 36.141)

System Bandwidth

FRC Type

Fixed Reference Channel

200 kHz (1RB)

A14 FRC for NB-IOT reference sensitivity (PI/2 BPSK, R=1/3)

A14-1

FRC for NB-IOT reference sensitivity (PI/2 BPSK, R=1/3) A14-1

Sub-carrier spacing (kHz)

Number of tone

Diversity

Modulation

Frequency offset

Channel estimation length (ms)

Number of NPUSCH repetition

IMCS / TBS

Payload size (bits)

Allocated resource unit

Code rate (target)

Code rate (effective)

Transport block CRC (bits)

Code block CRC size (bits)

Number of code blocks - C

Total number of bits per resource unit

Total symbols per resource unit

Tx time (ms)

15 kHz

1

No

PI/2 BPSK

0

4

1

0 / 0

32

2

1/3

0.29

24

0

1

96

96

16

Choose the specified FRC

OK

Cancel

 NeuHelium

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# Application in NB\_IoT – UL-SCH Node

## UL-SCH Node

Component Carrier 1

- Uplink
  - Channel Setup

Component Carrier 2

- Uplink
  - Channel Setup

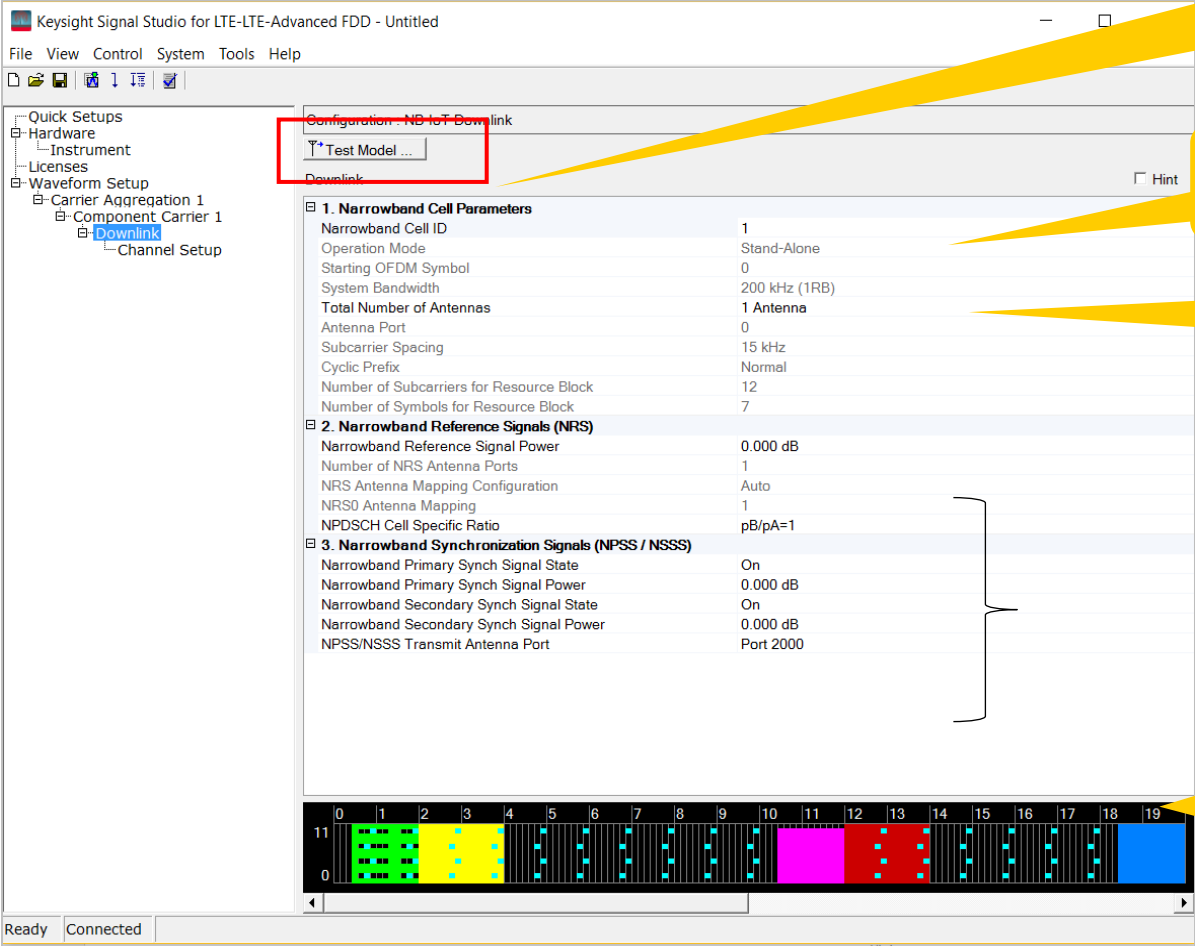
1 -- UL-SCH1

|                                                                           |                            |                                                               |
|---------------------------------------------------------------------------|----------------------------|---------------------------------------------------------------|
| RNTI                                                                      | 1 (0001)                   |                                                               |
| <b>2. NPUSCH Settings</b>                                                 |                            |                                                               |
| NPUSCH Format                                                             | 1                          | NPUSCH format 1 (UL-SCH) or 2 (UCI)                           |
| Subcarrier Spacing                                                        | 15 kHz                     | 3.75kHz or 15kHz                                              |
| Number of Subcarriers in Resource Block                                   | 12                         |                                                               |
| Number of Subcarriers in Resource Unit (N <sub>RU_sc</sub> )              | 3                          | # of subcarriers in RU                                        |
| Subcarrier Offset in RB (n <sub>sc</sub> )                                | 1                          |                                                               |
| Number of Repetitions (N <sub>Rep</sub> )                                 | 1                          | # of Repetition                                               |
| Number of Resource Units (N <sub>RU</sub> )                               | 1                          | # of Resource Unit                                            |
| Number of Slots in Resource Unit (N <sub>UL_slots</sub> )                 | 8                          |                                                               |
| Number of Consecutive Slots for RV Index (B)                              | 8                          |                                                               |
| Number of Consecutive Transmission Slots (N)                              | 8                          |                                                               |
| Number of Mapping Slots for NPUSCH (N <sub>slots</sub> )                  | 2                          |                                                               |
| Number of Repetitions of Identical Slots (M <sub>NPUSCH_identical</sub> ) | 1                          |                                                               |
| <b>3. DM-RS NPUSCH Settings</b>                                           |                            |                                                               |
| Multi-Tone Base Sequence Auto Calculation                                 | On                         |                                                               |
| Multi-Tone Base Sequence Index (u)                                        | 2                          |                                                               |
| Cyclic Shift (alpha)                                                      | 0                          |                                                               |
| Group Hopping                                                             | Off                        |                                                               |
| Group Assignment NPUSCH (Delta <sub>SS</sub> )                            | 0                          |                                                               |
| <b>4. Transmission Settings</b>                                           |                            |                                                               |
| Data                                                                      | PN9                        |                                                               |
| MCS Index                                                                 | 0                          | For $N_{SC}^{RU} = 1$ and MCS = {0,1} is BPSK, otherwise QPSK |
| RV Index Configuration                                                    | Auto                       |                                                               |
| RV Index Sequence                                                         | 0,2                        |                                                               |
| Transmission Configuration Length                                         | 1 (4 ms)                   |                                                               |
| Transmission Configuration                                                | 1 Transmission is defined. |                                                               |
| Start Frame (nf)                                                          | 0                          |                                                               |
| Start Subframe (ns)                                                       | 0                          |                                                               |

MCS Index  
Range: 0 to 12  
(Subcarrier Spacing = 3.75 kHz)  
Default: 0

# Application in NB\_IoT – Downlink Configuration

## NB-IoT Downlink Configuration



Configure N-TM in Test Model Wizard (Beta in Mar Release)

Stand-alone(/guard-band) or in-band

# of antenna (1 or 2)

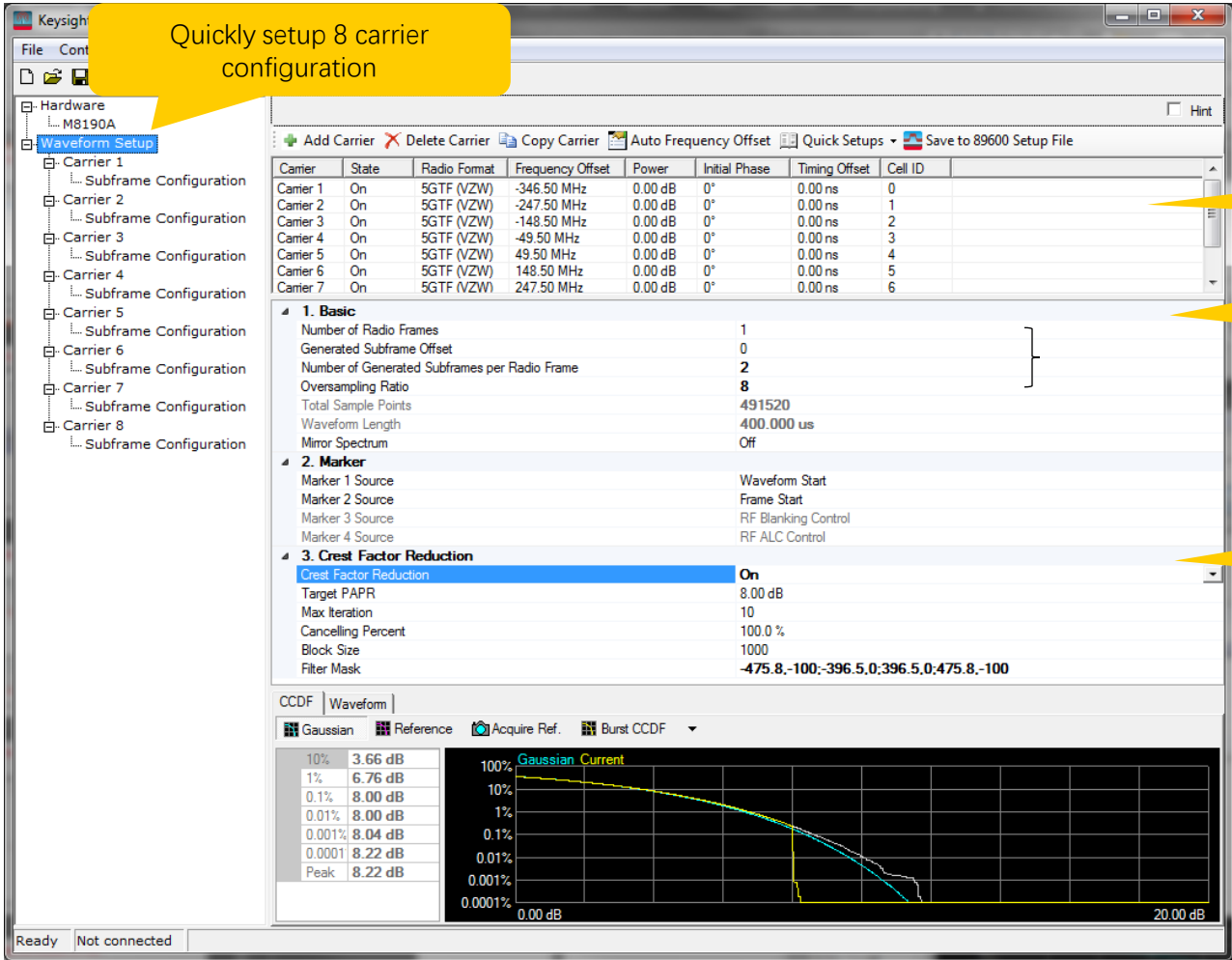
Resource map shows color coded channel allocation

# Application in Verizon 5G- Features

## Signal Generation Based on VZW Pre-5G Spec

- Main PHY layer structure are implemented for signal generation
  - Support multi-user channels generation
  - Support transport channel coding for DL-SCH, UL-SCH, BCH, DCI, and UCI
    - LDPC and tail biting CC
  - DCI Auto Generation with xPDSCH and xPUSCH scheduling information
  - Multi-Antenna Transmission
    - Tx Diversity and Spatial Multiplexing
  - High Speed case for KT5G spec
- Support flexible signal configuration
  - Both single carrier and multi-carrier are supported
    - 8 Carrier Configuration Preset
- Support flexible signal configuration (Cont' d)
  - Graphical display for frame resource allocation
  - User can assign resource blocks to both downlink and uplink channels.
  - Support generating DL and UL signal at the same time.
  - Support partial generation of one radio frame
- Signal verification methods
  - User can export the demod setup of VSA software from Signal Studio for VSA demodulation.
    - Requires VSA Custom OFDM (89601B-BHF)

# Application in Verizon 5G- User Interface



Quickly setup 8 carrier configuration

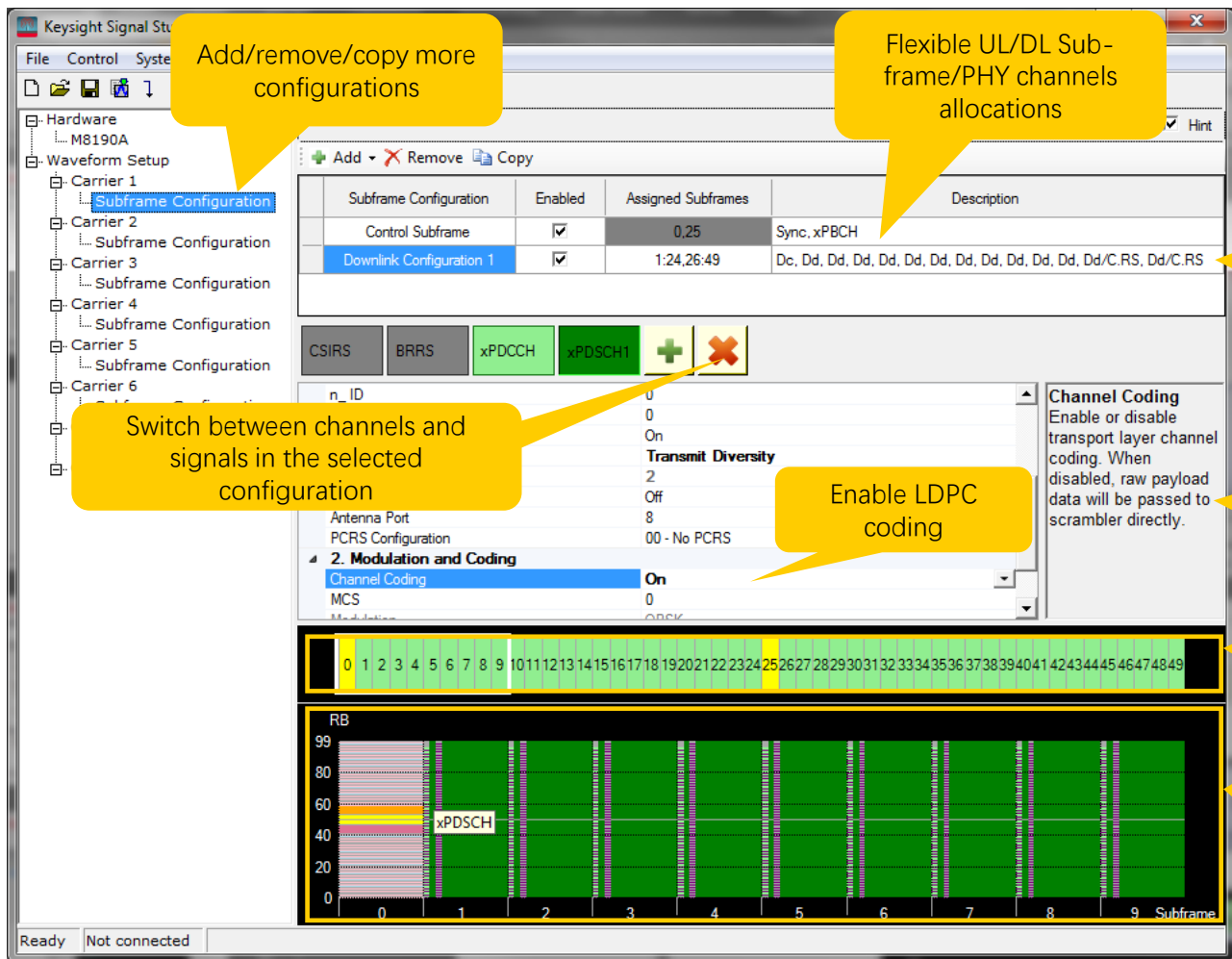
Export multi-measurement VSA configuration

# of frames and subcarriers to generate waveforms

Crest Factor Reduction(CFR) reduces peak-to-average ratio

# Application in Verizon 5G- Subframe Configuration

## Subframe Configuration



Check symbol types  
in the configuration

Select MIMO Transmission Mode:  
Diversity or Spatial Multiplexing

## Quick navigation between 50 subframes

Resource Allocation Map shows channel configuration (Hovering mouse gives channel and signal name in a tooltip)

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