SC-FDMA – the new LTE uplink explained

Moray Rumney

20th March 2008

Agenda

- Brief overview of LTE
- Standards documents
- LTE downlink and uplink transmission schemes
- Uplink physical layer definition
- SC-FDMA signal analysis
- Agilent LTE measurement solutions overview

Previous Agilent LTE webcasts

Concepts of 3GPP LTE

TechOnline , September 20, 2007

This webcast will cover what LTE is, where it came from and provide context against the other 3.9G technologies such as HSPA+ and WiMAX™. There will be a brief introduction to the new OFDM air interface as well as the complimentary changes being planned for the network system architecture evolution or SAE.

Addressing the Design & Verification Challenges of 3GPP LTE

TechOnline , October 02, 2007

This webcast will investigate system design and verification challenges of 3GPP LTE and show how Agilent's new design simulation capabilities can help.

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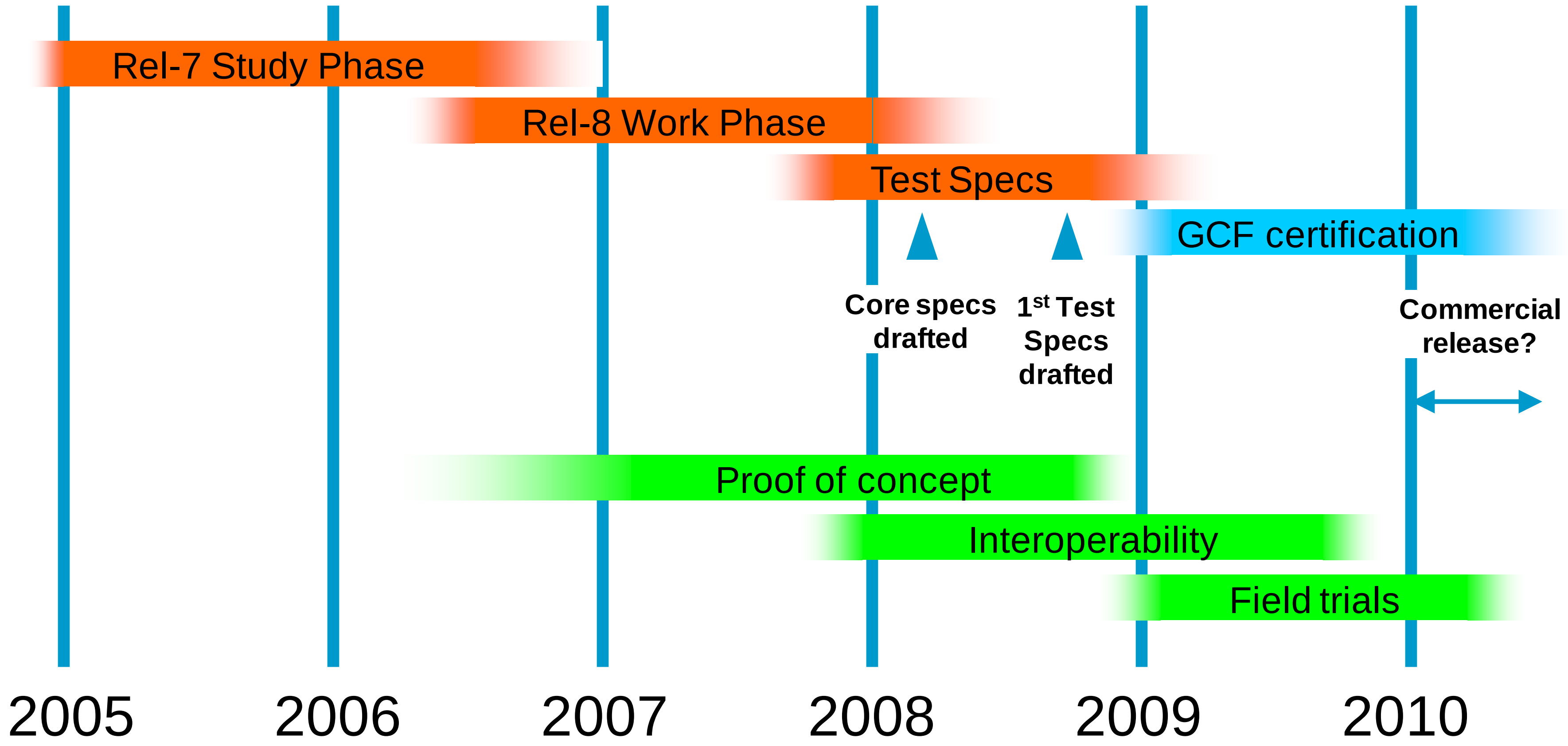
3GPP standards evolution (RAN & GERAN)

1999

2009

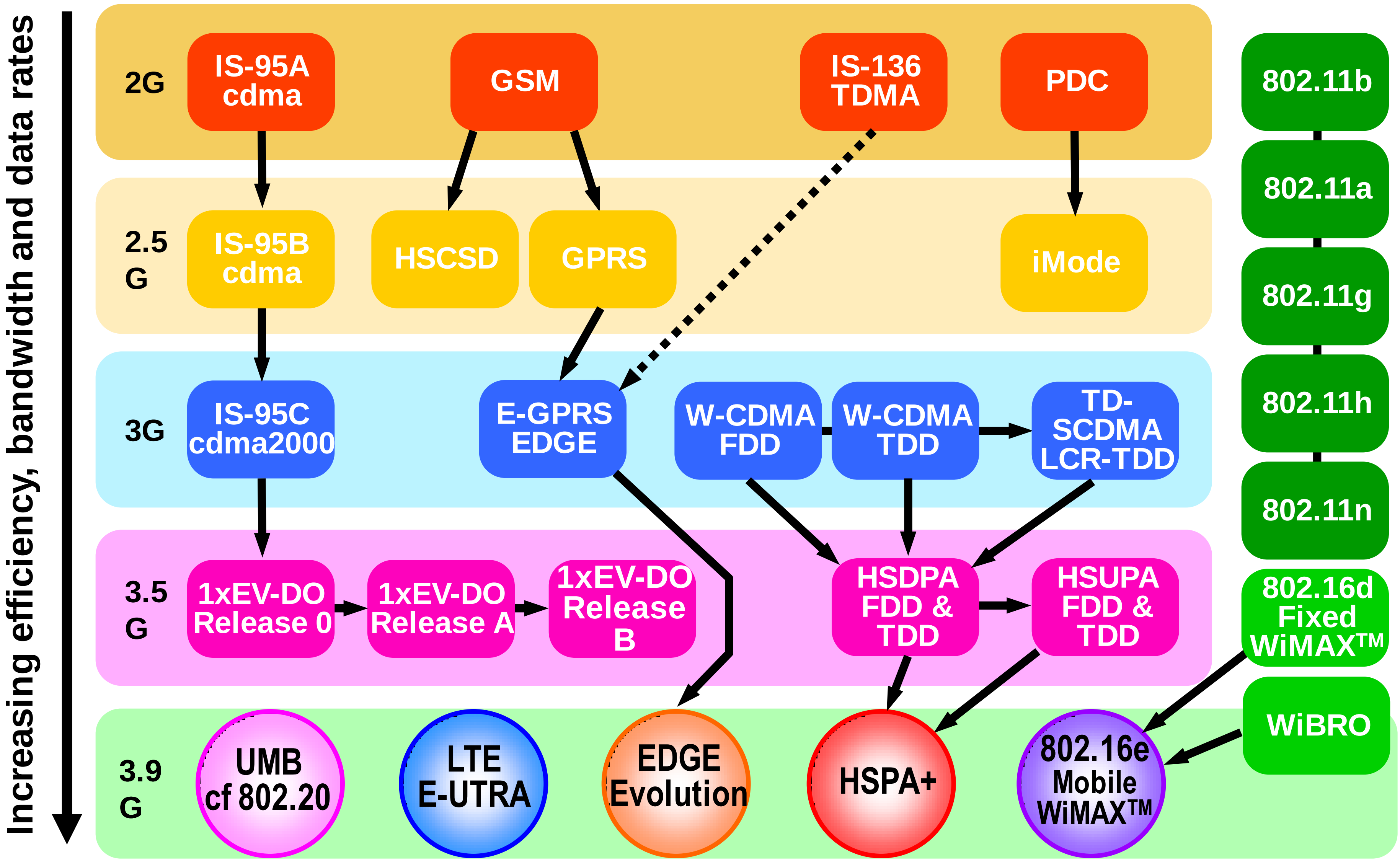
Release	Commercial introduction	Main feature of Release
Rel-99	2003	Basic 3.84 Mcps W-CDMA (FDD & TDD)
Rel-4	Trials	1.28 Mcps TDD (aka TD-SCDMA)
Rel-5	2006	HSDPA
Rel-6	2007	HSUPA (E-DCH)
Rel-7	2008+	HSPA+ (64QAM DL, MIMO, 16QAM UL). Many smaller features plus LTE & SAE Study items
Rel-8	HSPA+ 2009 LTE 2010+	LTE Work item – OFDMA air interface SAE Work item New IP core network Edge Evolution, more HSPA+
Rel-9	2011 – 2014	LTE Evolved MBMS, IMT-Advanced (4G)

LTE timeline for 3GPP, GCF & LSTI



- LSTI = LTE/SAE Trial initiative - an industry consortium which aims to accelerate the commercial introduction of LTE
- Agilent are active members of 3GPP, GCF and LSTI

Wireless evolution: Five competing 3.9G systems



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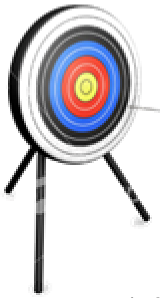
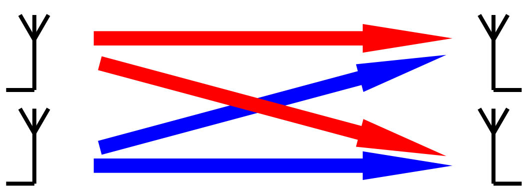
LTE at a glance!

Nov 04 LTE High level requirements



- Reduced cost per bit
- More lower cost services with better user experience
- Flexible use of new and existing frequency bands
- Simplified lower cost network with open interfaces
- Reduced terminal complexity and reasonable power consumption

MIMO



Multiple Input Multiple Output

Spectral Efficiency

3-4x HSDPA (downlink)

2-3x HSUPA (uplink)

Latency

Idle ➔ active < 100 ms

Small packets < 5 ms

SPEED!

Downlink peak data rates (64QAM)			
Antenna config	SISO	2x2 MIMO	4x4 MIMO
Peak data rate Mbps	100	172.8	326.4
Uplink peak data rates (Single antenna)			
Modulation	QPSK	16 QAM	64 QAM
Peak data rate Mbps	50	57.6	86.4

Flexible Channel Bandwidths

MHz
1.4
3
5
10
15
20

Mobility

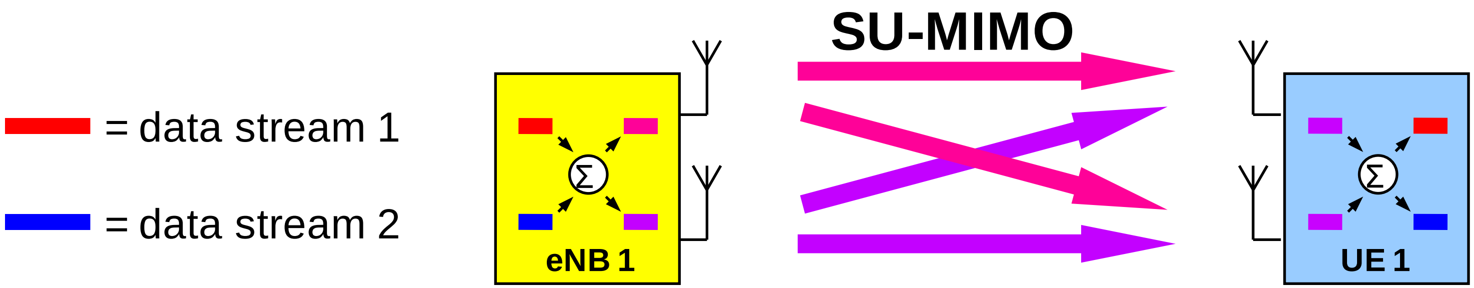
Optimized: 0–15 km/h

High performance: 15-120 km/h

Functional: 120–350 km/h

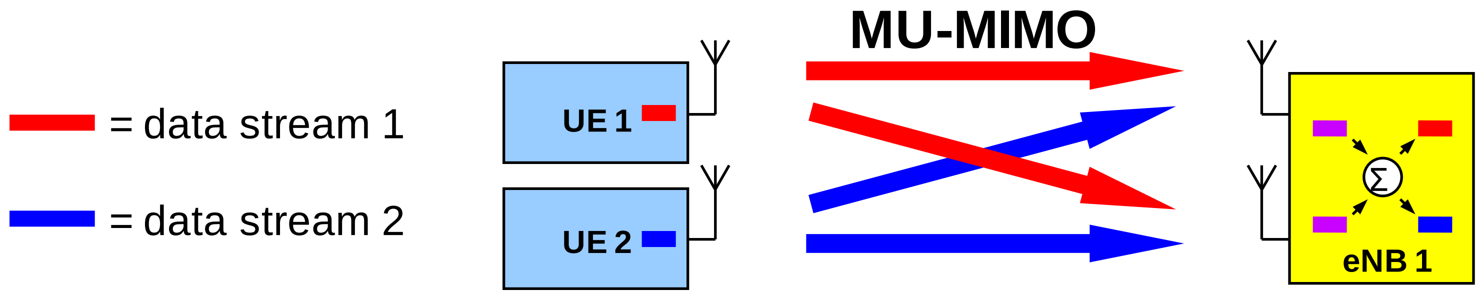
Under consideration: 350–500 km/h

Single user MIMO



- This is an example of downlink 2x2 single user MIMO with precoding.
- Two data streams are mixed (precoded) to best match the channel conditions.
- The receiver reconstructs the original streams resulting in increased single-user data rates and corresponding increase in cell capacity.
- 2x2 SU-MIMO is mandatory for the downlink and optional for the uplink

Multiple user MIMO



- Example of uplink 2x2 MU-MIMO.
- In multiple user MIMO the data streams come from different UE.
- There is no possibility to do precoding since the UE are not connected but the wider TX antenna spacing gives better de-correlation in the channel.
- Cell capacity increases but not the single user data rate.
- The key advantage of MU-MIMO over SU-MIMO is that the cell capacity increase can be had without the increased cost and battery drain of two UE transmitters.
- MU-MIMO is more complicated to schedule than SU-MIMO

UE categories

- In order to scale the development of equipment, UE categories have been defined to limit certain parameters
- The most significant parameter is the supported data rates:

UE Category	Max downlink data rate	Number of DL transmit data streams	Max uplink data rate	Support for uplink 64QAM
1	10 Mbps	1	5 Mbps	No
2	50 Mbps	2	25 Mbps	Not yet decided
3	100 Mbps	2	50 Mbps	Not yet decided
4	150 Mbps	Not yet decided	50 Mbps	Not yet decided
5	300 Mbps	4	75 Mbps	Yes

All figures provisional from TS 36.306 V8.0.0.
The UE category must be the same for downlink and uplink

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LTE documents from the study phase (Rel-7)

The latest study phase technical documents can be found at:

- www.3gpp.org/ftp/Specs/html-info/25-series.htm

- 23.882 System Architecture Evolution
- 25.912 Feasibility study for Evolved UTRA and UTRAN
- 25.913 Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN)
- 25.813 Radio interface protocol aspects
- 25.814 Physical Layer Aspects for Evolved UTRA

Most of these are no longer being kept up to date now the work has transferred to the 36-series (Rel-8) specifications

However these document still provide a useful overview that may be difficult to find in the formal specifications

LTE 3GPP Specifications (Rel-8)

- After the LTE study phase in Rel-7, the LTE specifications are defined in the 36-series documents of Rel-8
- There are six major groups of documents
  - 36.8XX & 36.9XX Technical reports (background information)
  - 36.1XX Radio specifications (and eNB conformance testing)
  - 36.2XX Layer 1 baseband
  - 36.3XX Layer 2/3 air interface signalling
  - 36.4XX Network signalling
  - 36.5XX UE Conformance Testing*
- The latest versions of most of the documents can be found at
  www.3gpp.org/ftp/Specs/html-info/36-series.htm
- The 36.5XX documents are not yet under change control and are at
  ftp://ftp.3gpp.org/tsg_ran/WG5_Test_ex-T1/Working_documents/

* Agilent leads the 3GPP work item for LTE UE RF conformance testing and is editor of TS 36.521-1 (similar in scope to 34.121-1 for UMTS).

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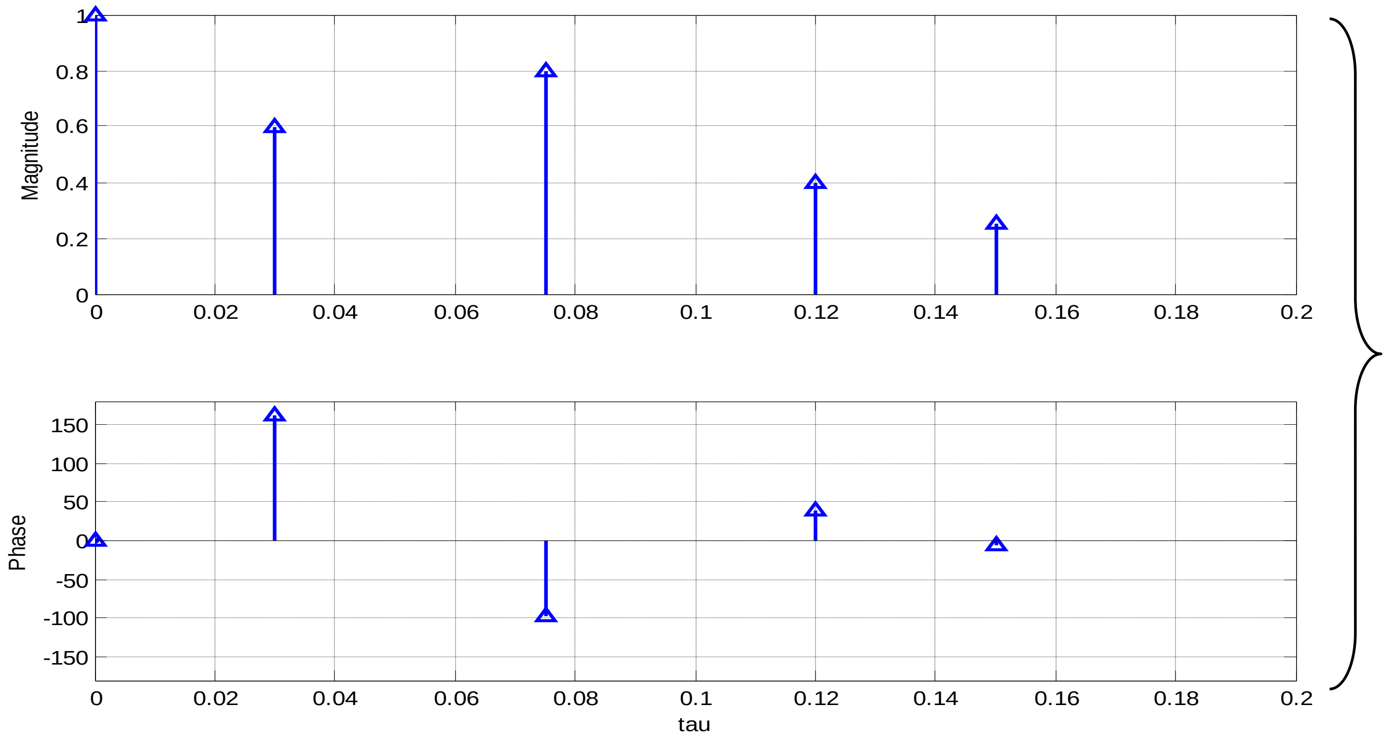
Orthogonal Frequency Division Multiplexing The basis for LTE's downlink transmission

- OFDM is already widely used in non-cellular technologies and was considered by ETSI for UMTS in 1998
- CDMA was favoured since OFDM requires large amounts of baseband processing which was not commercially viable ten years ago
- OFDM advantages
  - Wide channels are more resistant to fading and OFDM equalizers are much simpler to implement than CDMA
  - Almost completely resistant to multi-path due to very long symbols
  - Ideally suited to MIMO due to easy matching of transmit signals to the uncorrelated RF channels
- OFDM disadvantages
  - Sensitive to frequency errors and phase noise due to close subcarrier spacing
  - Sensitive to Doppler shift which creates interference between subcarriers
  - Pure OFDM creates high PAR which is why SC-FDMA is used on UL
  - More complex than CDMA for handling inter-cell interference at cell edge

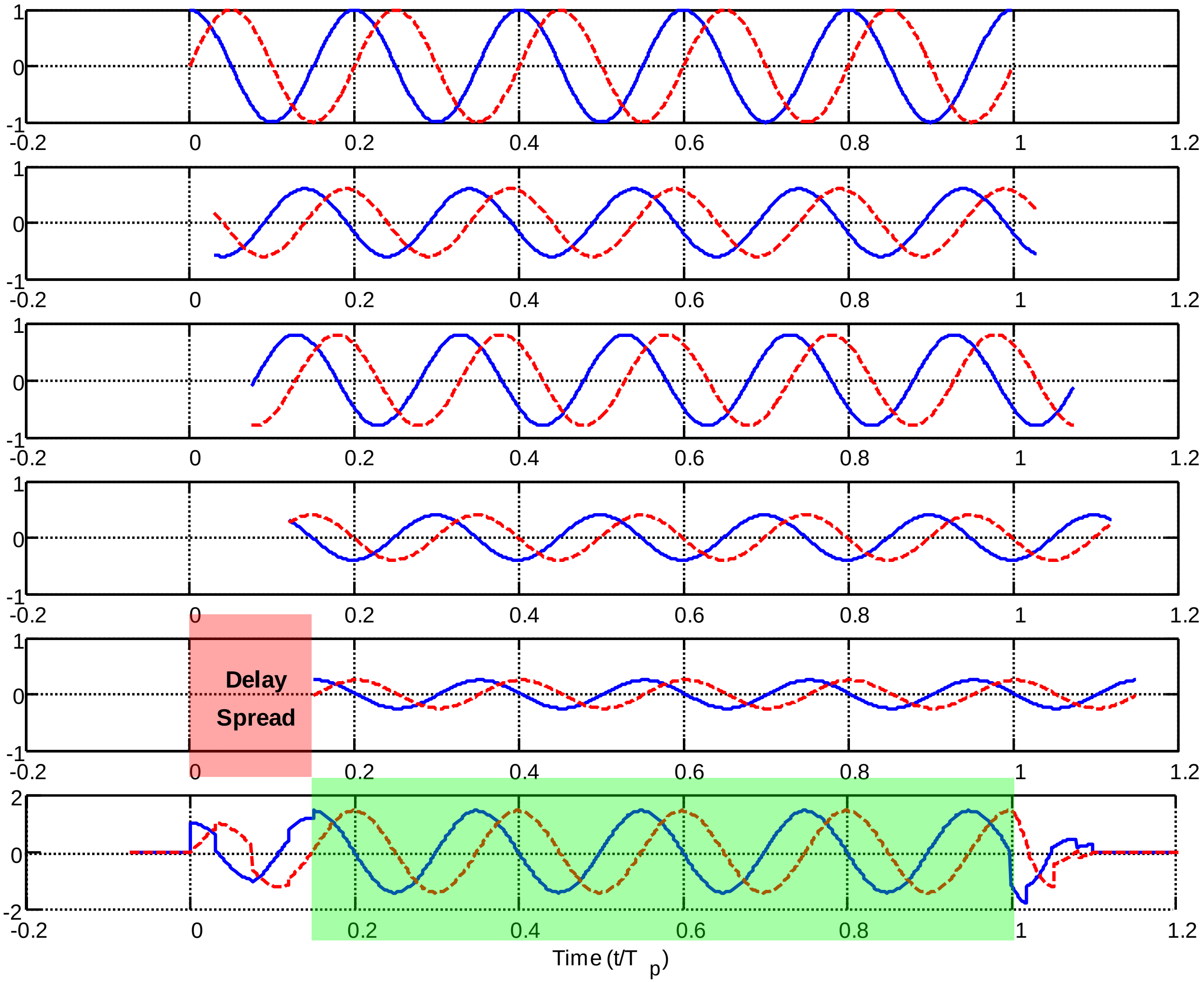
OFDM and multipath resistance

- Multipath causes multiple copies of the transmitted signal to be received. Each copy is at a fixed time offset but at random amplitude and phase.
- If multipath copies from adjacent symbols arrive at the receiver at the same time this creates inter-symbol interference and loss of performance



Example of five-ray multipath

OFDM and multipath resistance



The received signal is only pure after the last ray arrives and before the first ray disappears

This reduces the useful symbol length by 15% being the difference in path delay – also known as the delay spread

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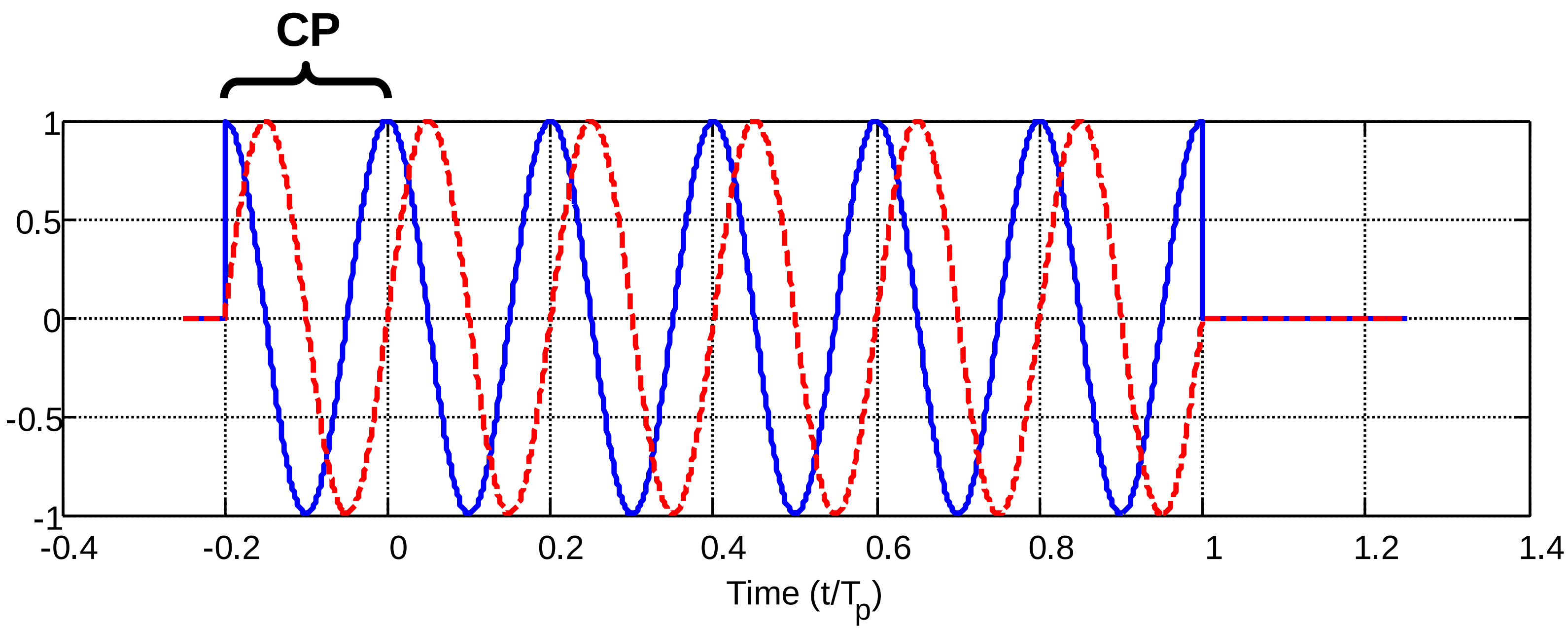
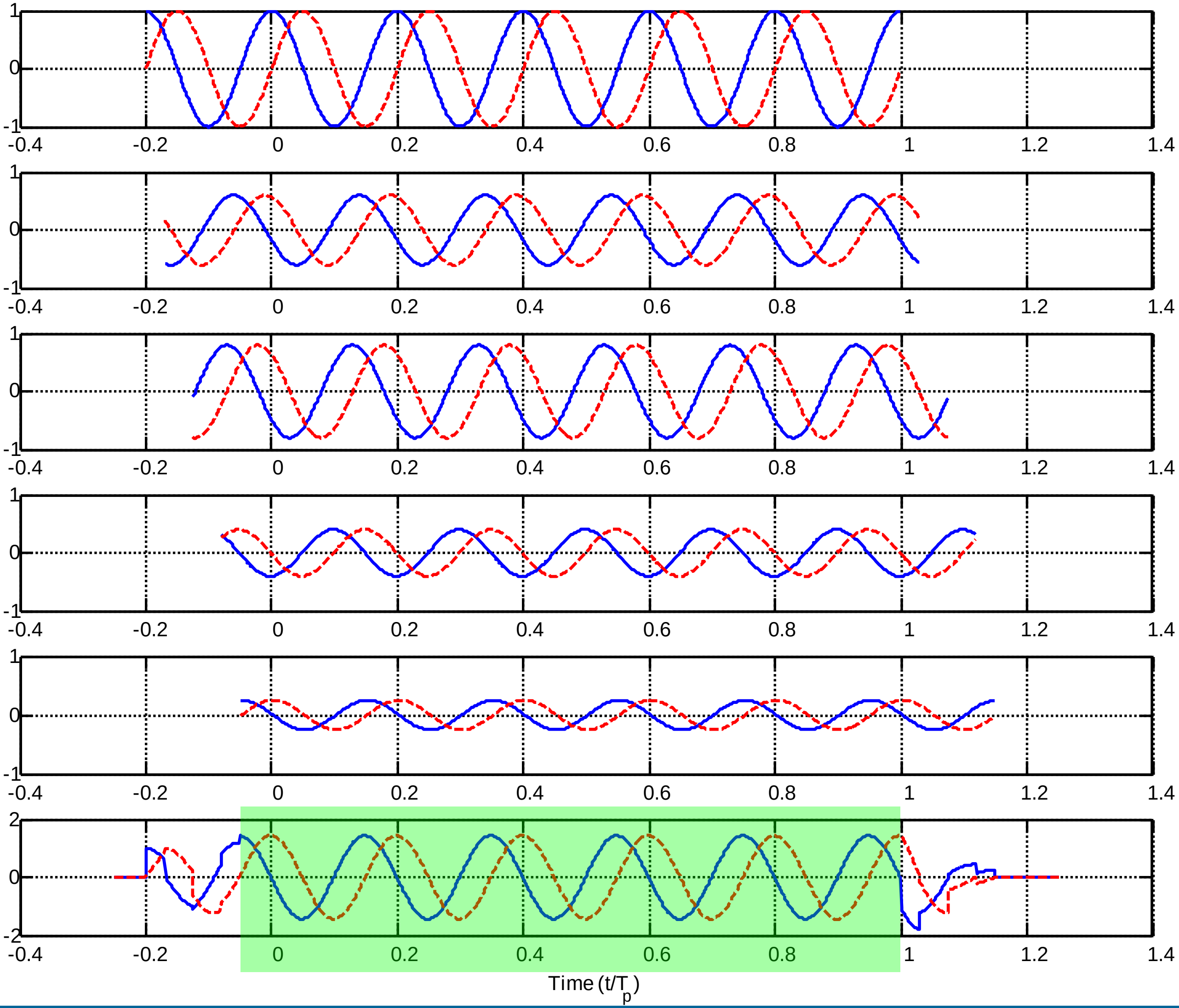
OFDM and multipath resistance
Adding the cyclic prefix (CP)

- The useful symbol length can be restored by extending the length of each symbol by copying the end of the symbol to the start (cyclic prefix)
- Provided the length of this cyclic prefix is at least as long as the significant multipath then the receiver can sample the signal from the start of the cyclic prefix and completely avoid interference from the adjacent symbols at the expense of a proportional decrease in system capacity



Cyclic Prefix provides multipath protection



In this example the CP is 20% of the symbol and since the delay spread was only15% the symbol is received cleanly from -0.05 to 1.

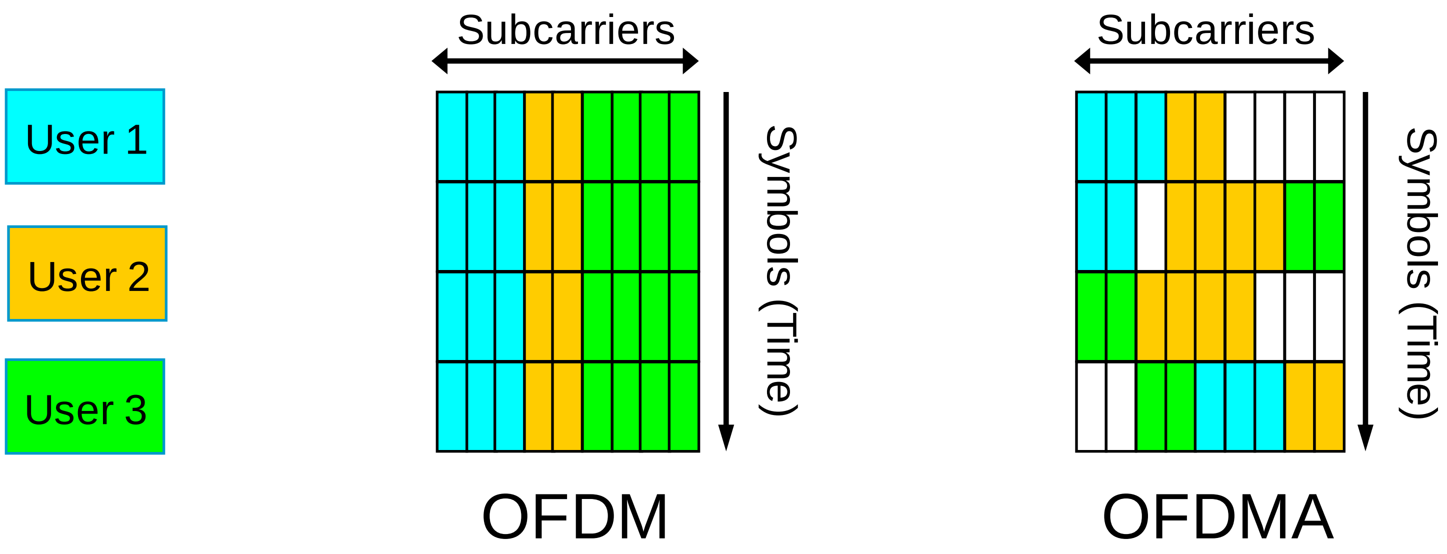
In LTE the normal CP is 4.69 µs for a 66.7 µs symbol length

This is a 7% sacrifice of capacity to provide multipath protection up to a 1.4 km delay spread.

An extended CP up to 33.3 µs (10 km) exists with lower capacity

OFDM vs. OFDMA

- LTE uses OFDMA which is a more advanced form of OFDM where subcarriers can be allocated to different users over time
- This provides much-needed frequency diversity in cases where the data rate is low meaning a narrow frequency allocation which is susceptible to narrow-band fading

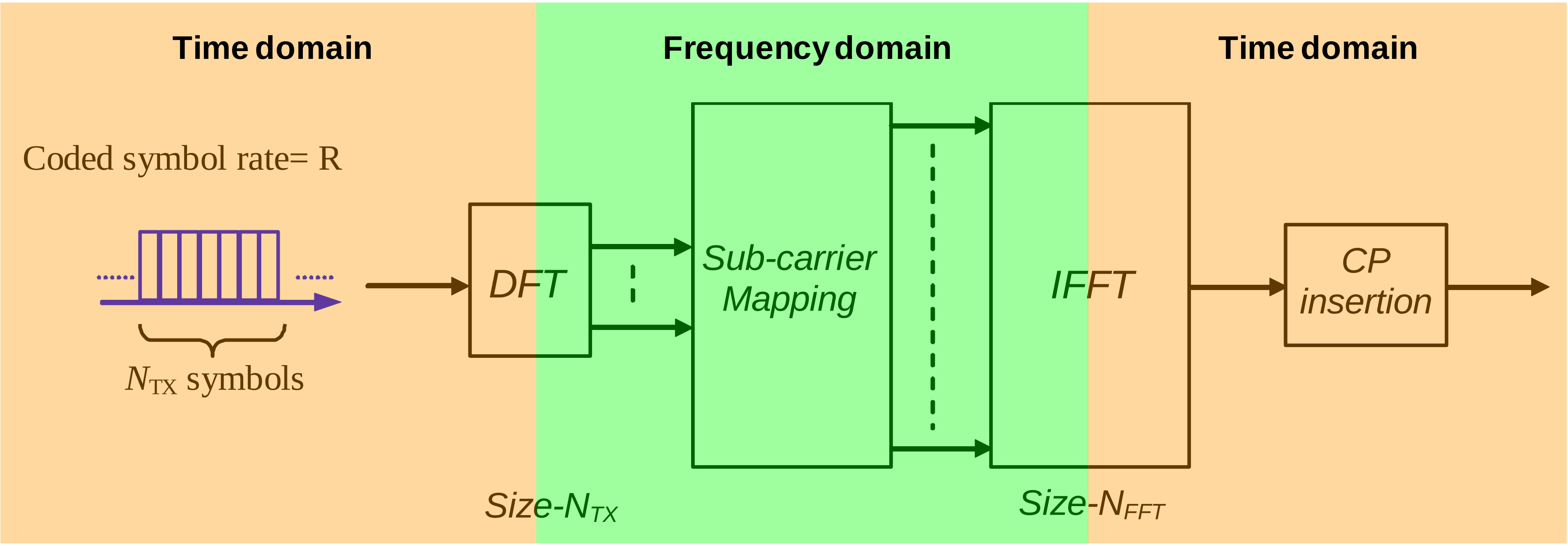


Single Carrier FDMA: The LTE uplink transmission scheme

- SC-FDMA is a new concept in transmission and it is important to understand how it works
- When a new concept comes along no single explanation will work for everyone
- To help put SC-FDMA in context we will use six different ways of explaining what SCFDMA is all about
- In summary: SC-FDMA is a <u>hybrid</u> transmission scheme combining the low peak to average (PAR) of single carrier schemes with the frequency allocation flexibility and multipath protection provided by OFDMA

1. Explaining SC-FDMA

- The first explanation of SC-FDMA comes from the LTE physical layer "study phase" report (3GPP TR 25.814) which had the following diagram:



TR 25.814 Figure 9.1.1-1 Transmitter structure for SC-FDMA.

- Colour coding has been added here to show the change from time to frequency and back again. This diagram is not in the final specifications.
- The processing steps explain why SC-FDMA is sometimes described in the specs as Discrete Fourier Transform Spread OFDM (DFT-SOFDM)

2. Explaining SC-FDMA

- The three key processing steps shown in 25.814 are formally defined in the physical layer specification 36.211 v8.1.0 as:

DFT →

$$z(l \cdot M_{\mathrm{sc}}^{\mathrm{PUSCH}} + k) = \frac{1}{\sqrt{M_{\mathrm{sc}}^{\mathrm{PUSCH}}}} \sum_{i=0}^{M_{\mathrm{sc}}^{\mathrm{PUSCH}}-1} d(l \cdot M_{\mathrm{sc}}^{\mathrm{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\mathrm{sc}}^{\mathrm{PUSCH}}}}$$

$$k = 0, \ldots, M_{\mathrm{sc}}^{\mathrm{PUSCH}} - 1$$

$$l = 0, \ldots, M_{\mathrm{symb}} / M_{\mathrm{sc}}^{\mathrm{PUSCH}} - 1$$

Subcarrier mapping →

$$\tilde{n}_{\mathrm{PRB}}(n_s) = \begin{cases} \left(\tilde{n}_{\mathrm{VRB}} + f_{\mathrm{hop}}(i) \cdot N_{\mathrm{RB}}^{\mathrm{sb}}\right) \bmod N_{\mathrm{RB}}^{\mathrm{sb}} \cdot N_{\mathrm{sb}} & \text{mirroring disabled} \\ \left(\tilde{n}_{\mathrm{VRB}} + f_{\mathrm{hop}}(i) \cdot N_{\mathrm{RB}}^{\mathrm{sb}} + \left[\left(N_{\mathrm{RB}}^{\mathrm{sb}} - 1\right) - 2\left(\tilde{n}_{\mathrm{VRB}} \bmod N_{\mathrm{RB}}^{\mathrm{sb}}\right)\right]\right) \bmod N_{\mathrm{RB}}^{\mathrm{sb}} \cdot N_{\mathrm{sb}} & \text{mirroring enabled} \end{cases}$$

$$i = \begin{cases} n_s / 2 & \text{inter-subframe hopping} \\ n_s & \text{intra-subframe hopping} \end{cases}$$

$$n_{\mathrm{PRB}}(n_s) = \tilde{n}_{\mathrm{PRB}}(n_s) + N_{\mathrm{RB}}^{\mathrm{PUCCH}}$$

$$\tilde{n}_{\mathrm{VRB}} = n_{\mathrm{VRB}} - N_{\mathrm{RB}}^{\mathrm{PUCCH}}$$

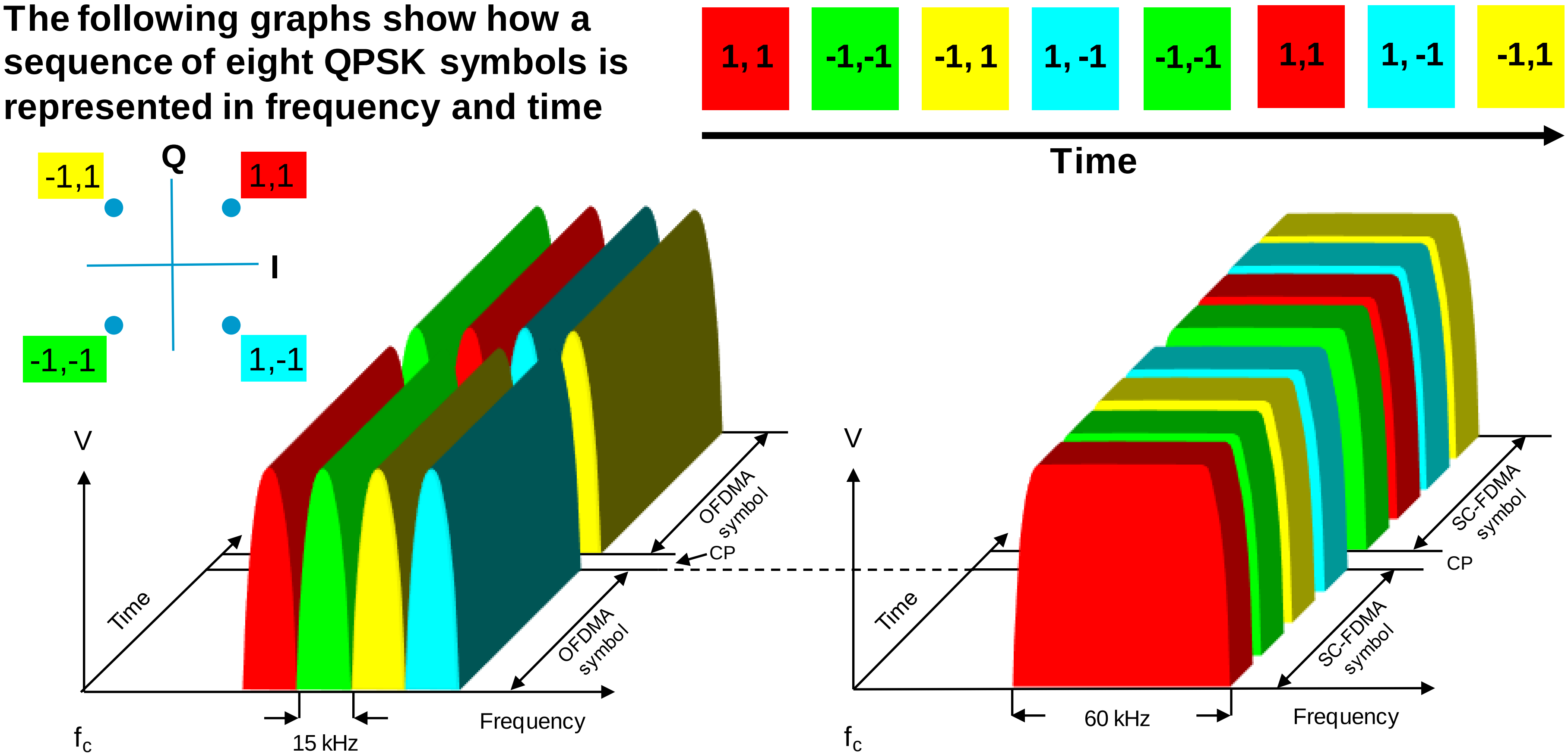
IFFT →

$$s_l(t) = \sum_{k=-\left\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}} / 2 \right\rfloor}^{\left\lceil N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}} / 2 \right\rceil - 1} a_{k^{(-)},l} \cdot e^{j2\pi(k+1/2)\Delta f\left(t - N_{\mathrm{CP},l} T_s\right)}$$

- Although essential for detailed design, formal definitions like these do not provide insight to most people of the underlying concepts

3. Comparing OFDMA and SC-FDMA QPSK example using M=4 subcarriers

The following graphs show how a sequence of eight QPSK symbols is represented in frequency and time



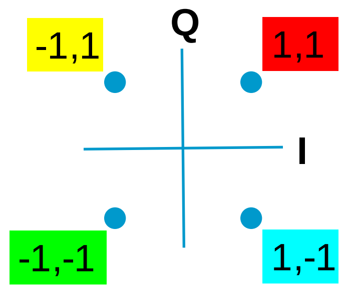
OFDMA
Data symbols occupy 15 kHz for one OFDMA symbol period

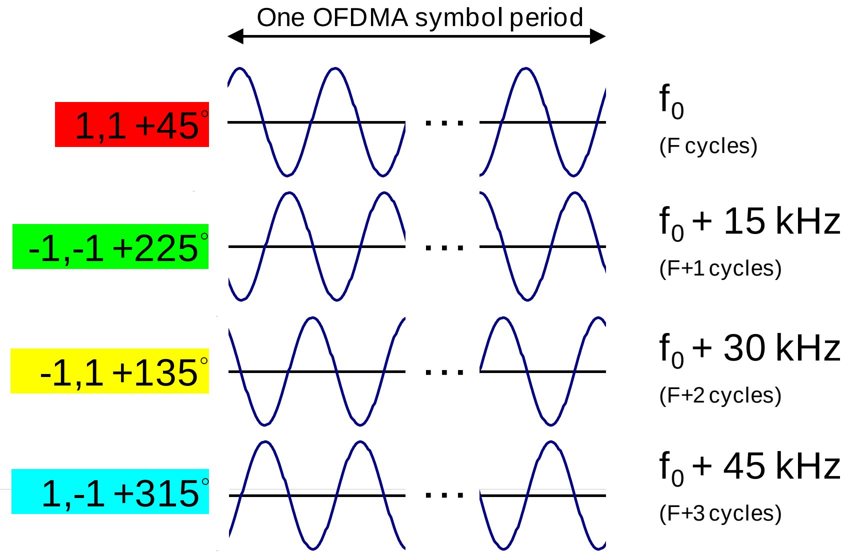
SC-FDMA
Data symbols occupy M*15 kHz for 1/M SC-FDMA symbol periods

OFDMA signal generation
QPSK example using M=4 subcarriers

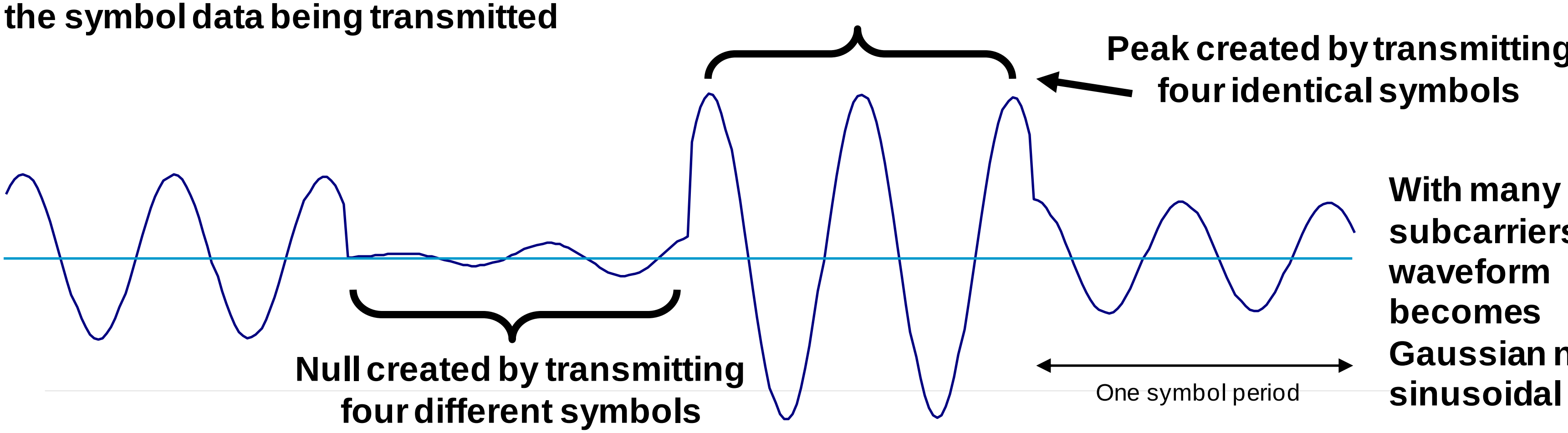
Each of M subcarriers is encoded with one QPSK symbol

M subcarriers can transmit M QPSK symbols in parallel





The amplitude of the combined four subcarrier signal varies widely depending on the symbol data being transmitted



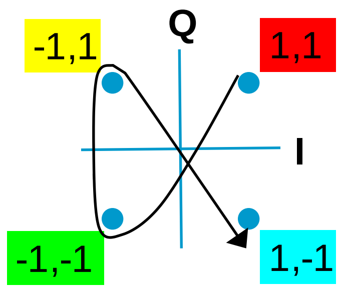
With many subcarriers the waveform becomes Gaussian not sinusoidal

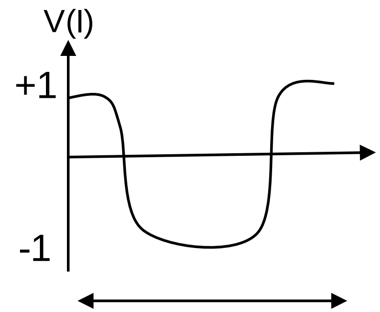
SC-FDMA signal generation
QPSK example using M=4 subcarriers

To transmit the sequence:

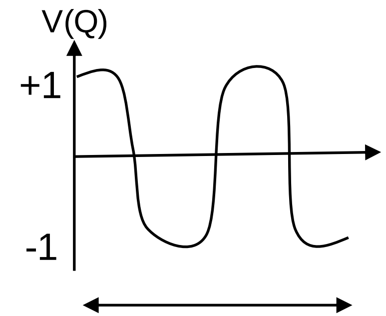
1, 1 -1,-1 -1, 1 1,-1

using SC-FDMA first create a time domain representation of the IQ baseband sequence



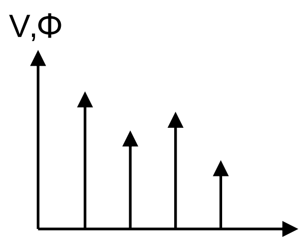


One SC-FDMA symbol period



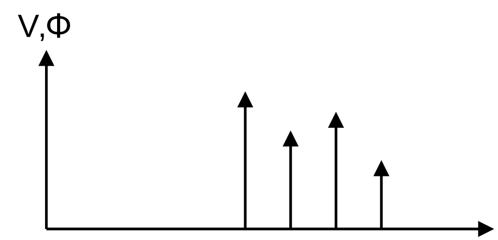
One SC-FDMA symbol period

Perform a DFT of length M and sample rate M/(symbol period) to create M FFT bins spaced by 15 kHz



Frequency

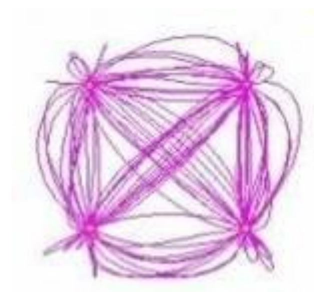
Shift the M subcarriers to the desired allocation within the system bandwidth



Frequency

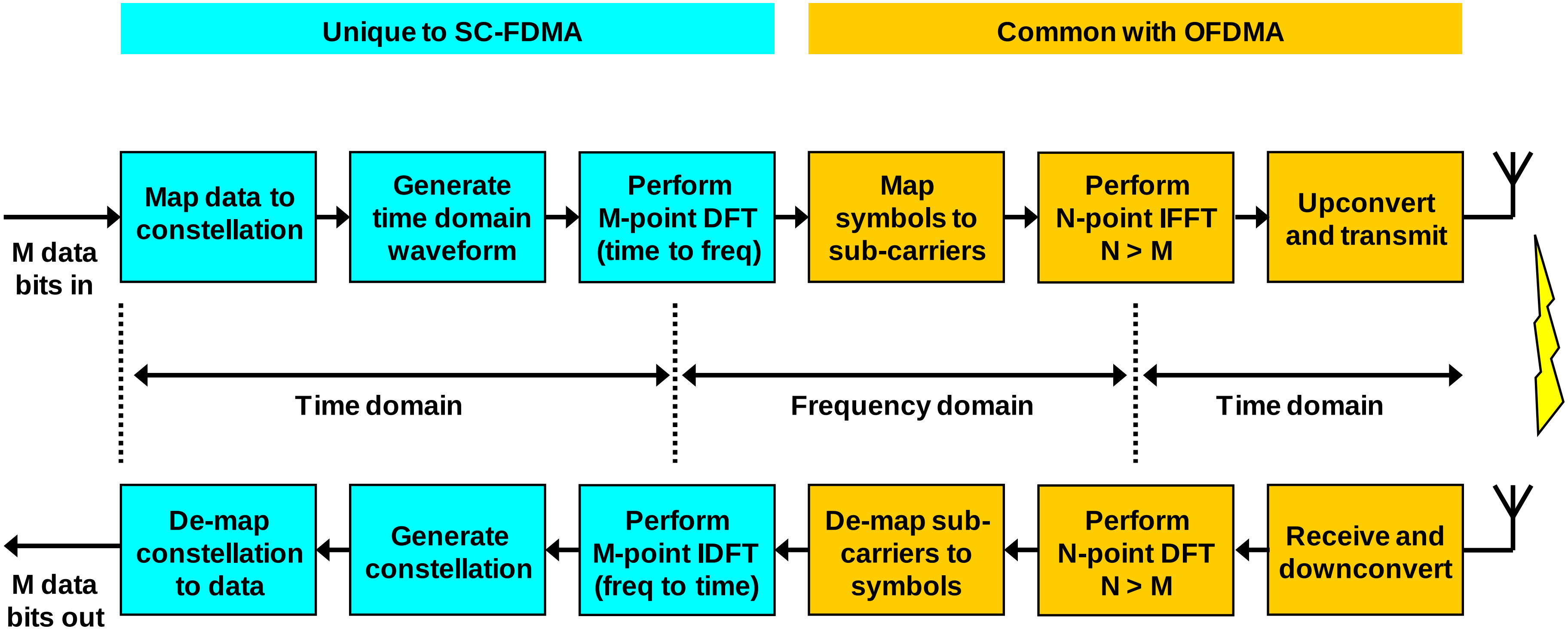
Perform an IFFT to create a time domain signal of the frequency shifted original

Insert the cyclic prefix between SC-FDMA symbols and transmit



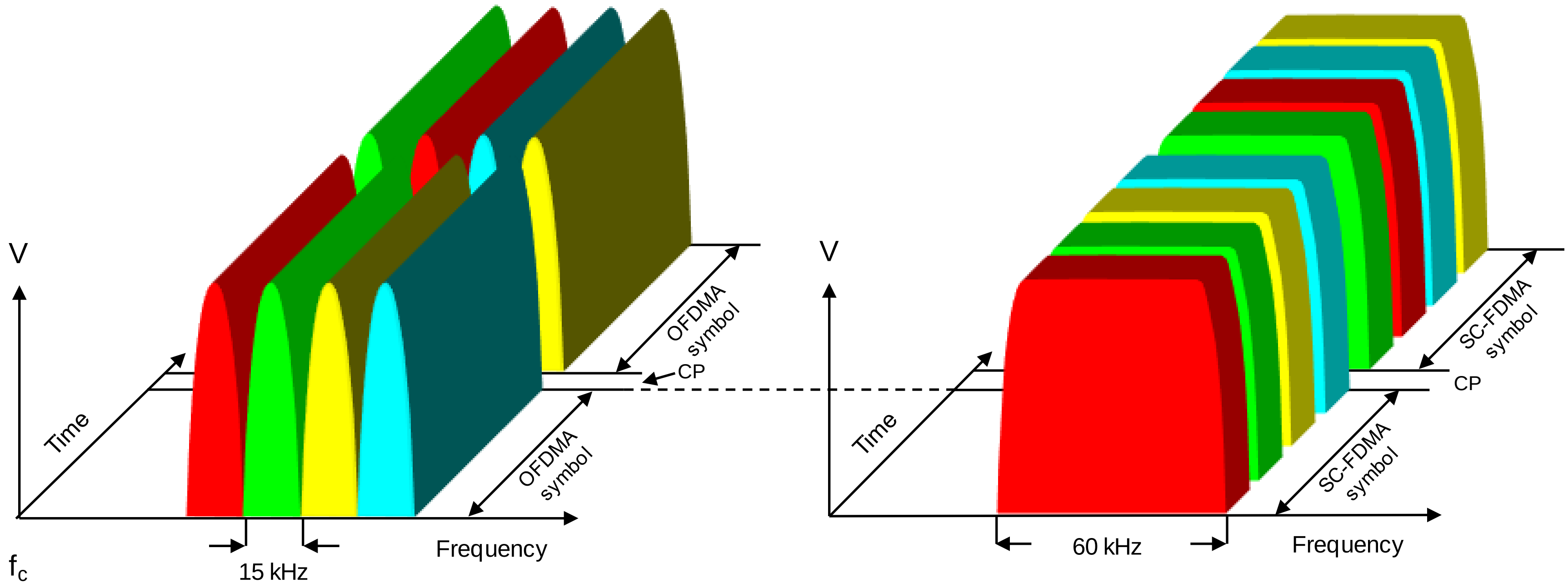
Important Note: The PAR is the same as the original QPSK data symbols

4. SC-FDMA and OFDMA signal generation and reception



Simplified model of SC-FDMA and OFDMA signal generation and reception

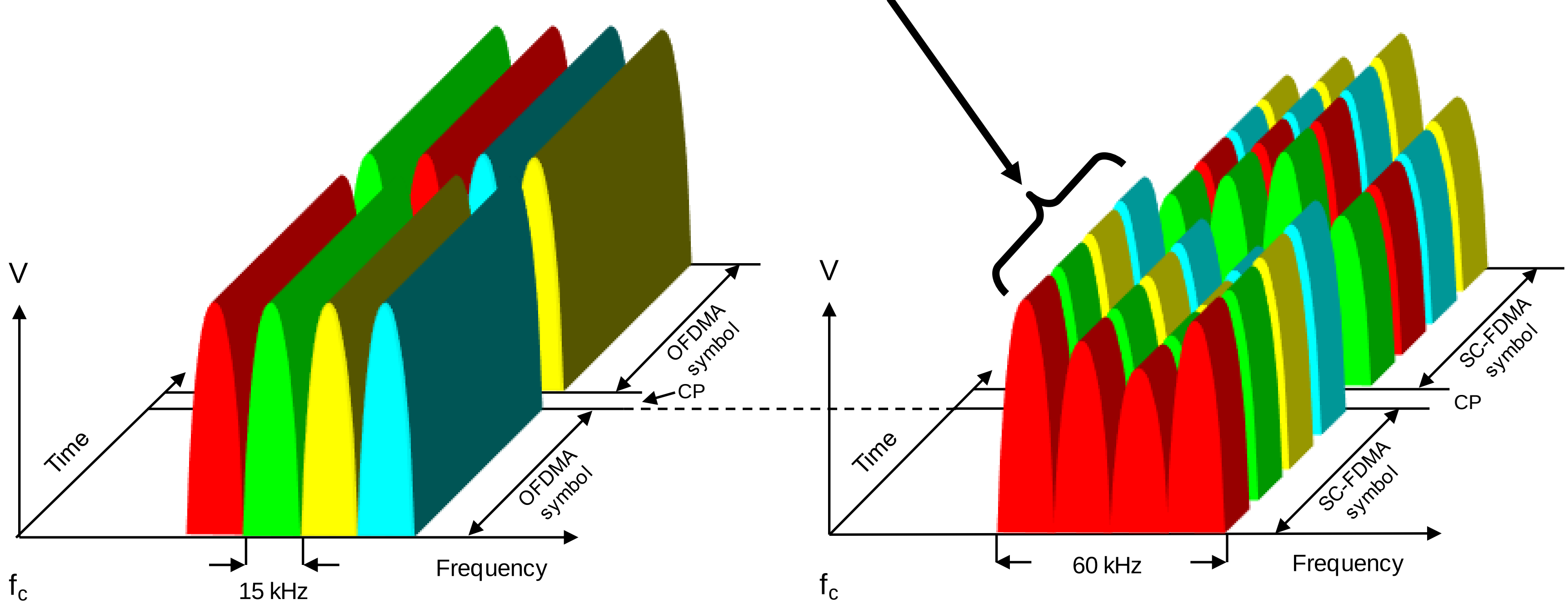
5. Comparing OFDMA and SC-FDMA
PAR and constellation analysis at different BW



Transmission scheme	OFDMA		SC-FDMA	
Analysis bandwidth	15 kHz	Signal BW (M x 15 kHz)	15 kHz	Signal BW (M x 15 kHz)
Peak to average power ratio (PAR)	Same as data symbol	High PAR (Gaussian)	< data symbol (not meaningful)	Same as data symbol
Observable IQ constellation	Same as data symbol at 66.7 µs rate	Not meaningful (Gaussian)	< data symbol (not meaningful)	. Same as data symbol at M X 66.7 µs rate

6. Comparing OFDMA and SC-FDMA Multipath protection with short data symbols

The subcarriers of each SC-FDMA symbol are not the same across frequency as shown in earlier graphs but have their own fixed amplitude & phase for the SC-FDMA symbol duration. The sum of M time-invariant subcarriers represents the M time-varying data symbols.



OFDMA

Data symbols … one OFDMA…

SC-FDMA

…y M*15 kHz for … bol periods

It is the constant nature of the subcarriers throughout the SC-FDMA symbol that means when the CP is inserted, multipath protection is achieved despite the modulating data symbols being much shorter.

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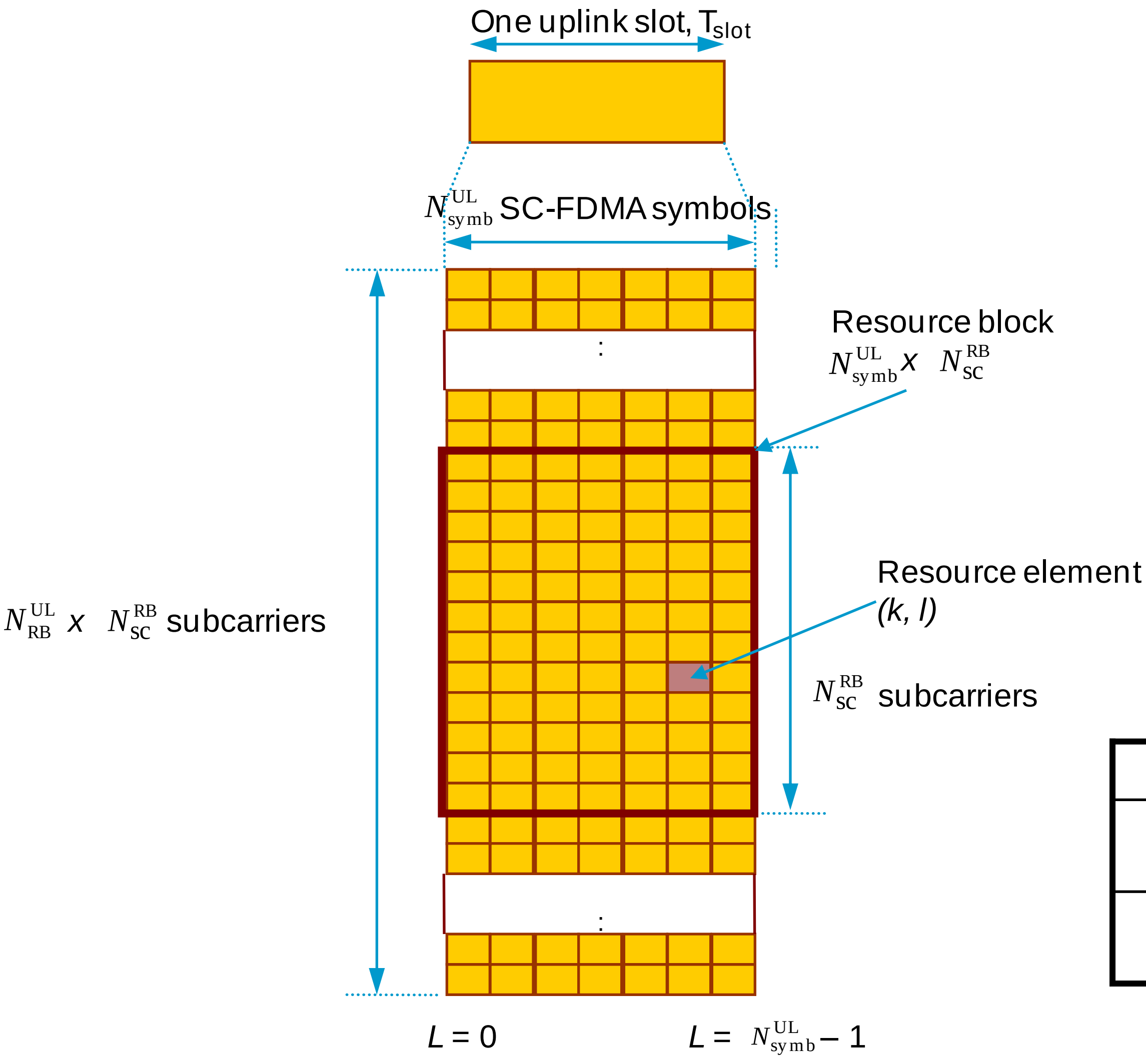
Uplink slot structure, resource block and resource element



The minimum allocation for transmission is known as a Resource Block (RB)

An RB lasts 0.5 ms and occupies180 kHz

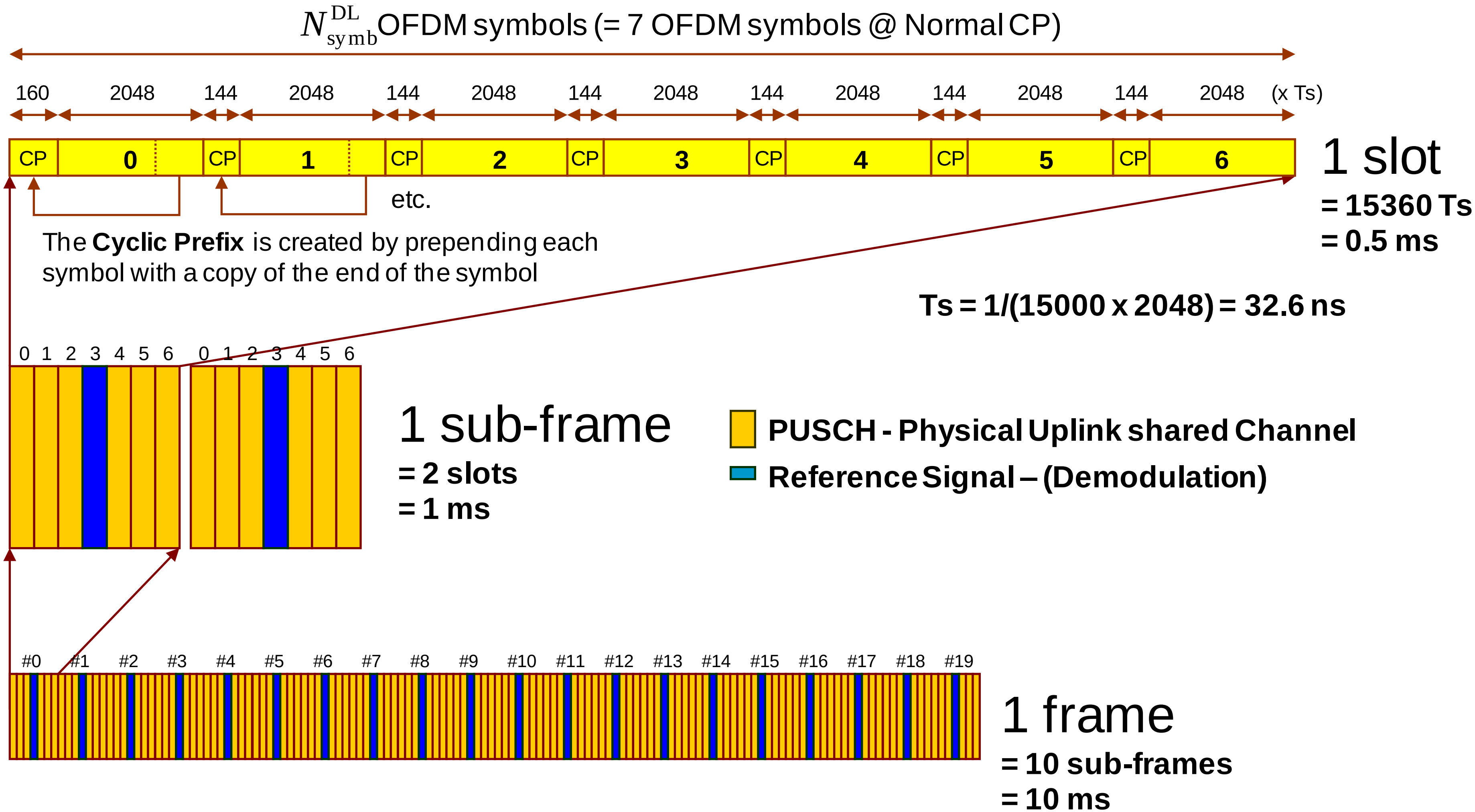
This is 12 subcarriers at the standard 15 kHz spacing

Condition	N^{UL}_{symb}	N^{RB}_{SC}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

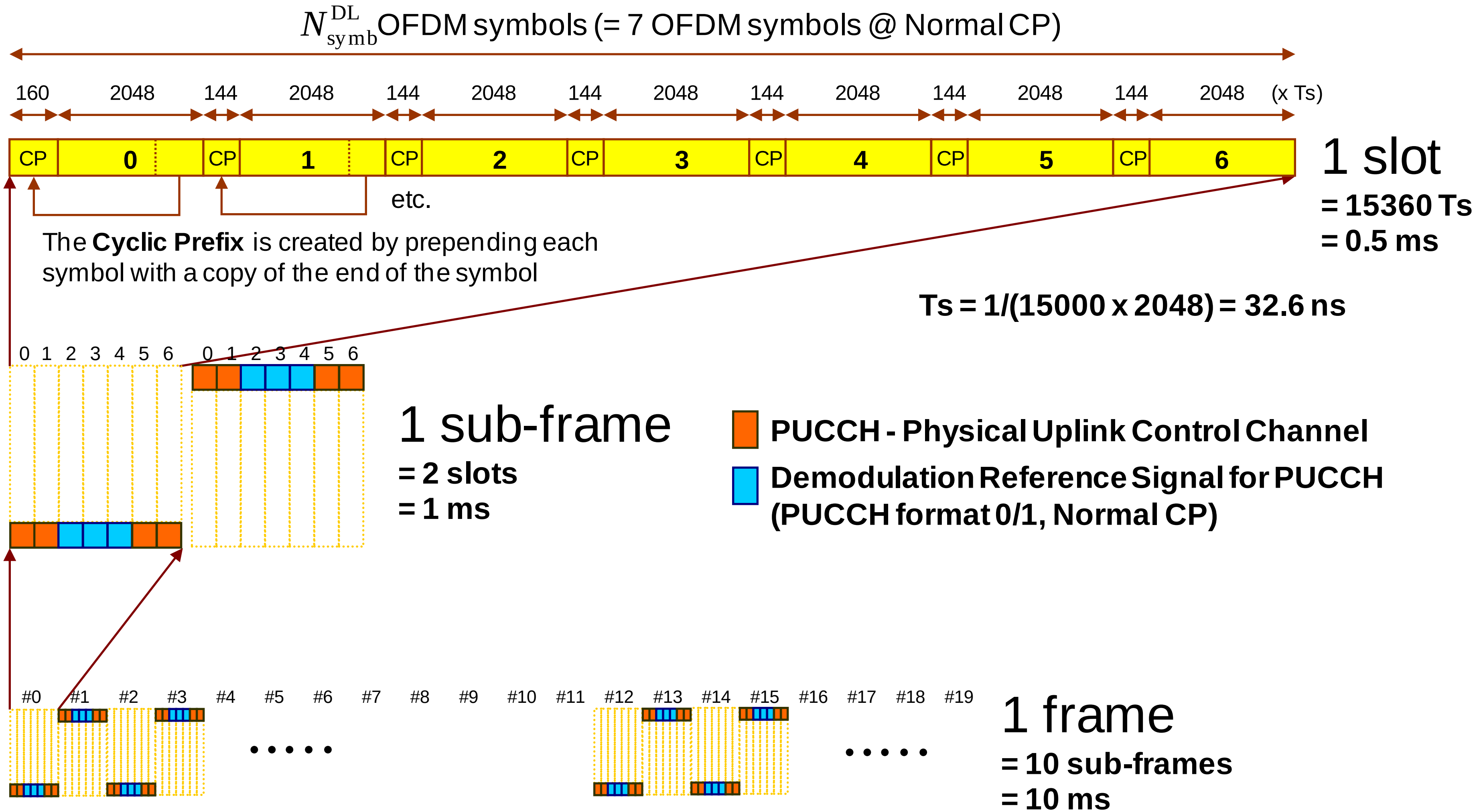
Uplink physical signals and channels

UL Signals	Purpose	Modulation Sequence	Physical Mapping
DM-RS (Demodulation Reference Signal)	Used for synchronization to the UE and UL channel estimation Associated with a transport channel	u^{th} root Zadoff-Chu	SC-FDMA symbol #3 of every slot
UL Channels	**Purpose**	**Modulation Scheme**	**Physical Mapping**
PRACH (Physical Random Access Channel)	Call setup	QPSK	Not yet defined
PUCCH (Physical Uplink Control Channel)	Scheduling, ACK/NACK	BPSK & QPSK	Any assigned RB but not simultaneous with PUSCH
PUSCH (Physical Uplink Shared Channel)	Payload	QPSK, 16QAM, 64QAM	Any assigned RB but not simultaneous with PUCCH

Uplink frame structure type 1 (FDD) PUSCH mapping



Uplink frame structure type 1 (FDD) PUCCH mapping



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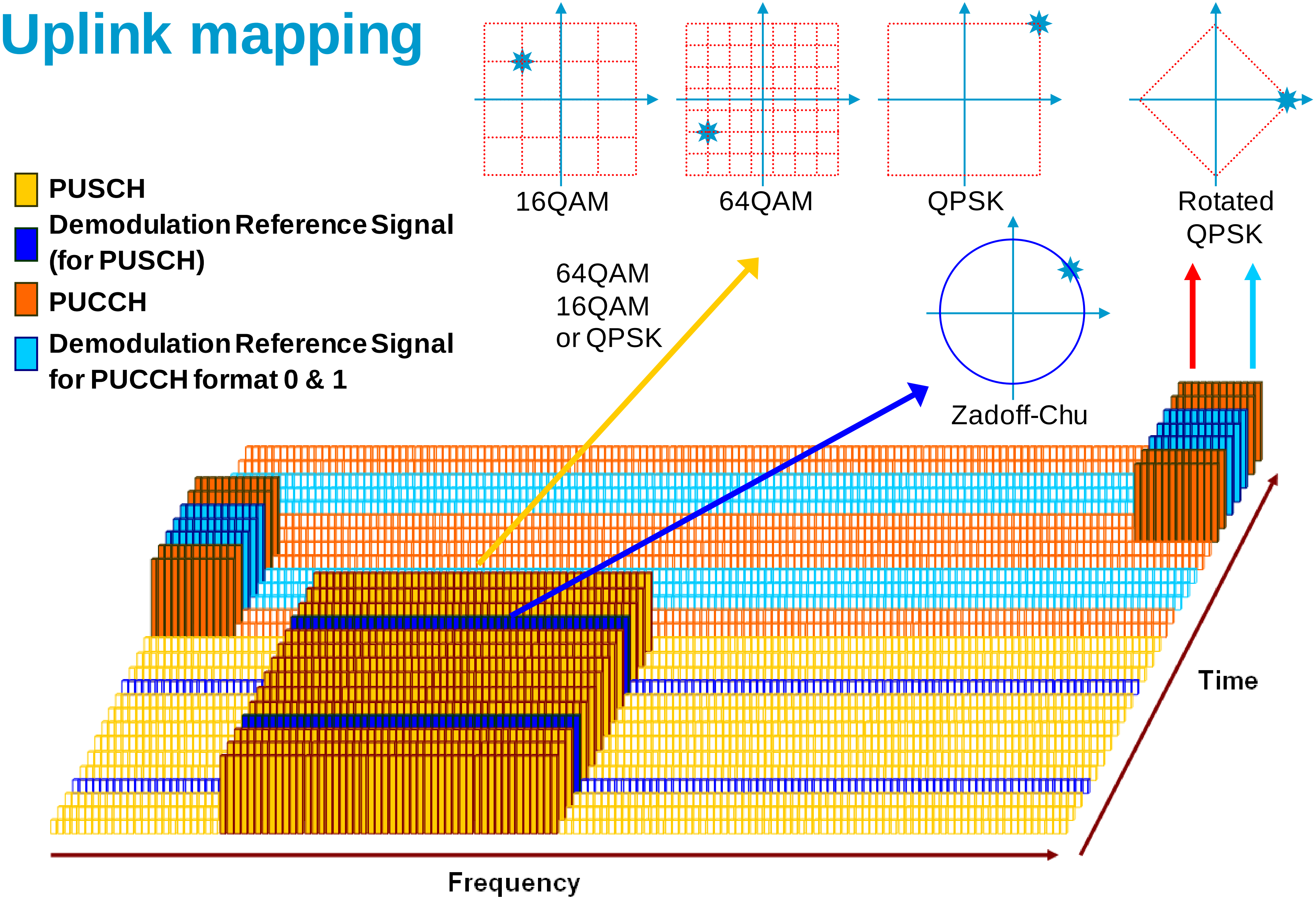
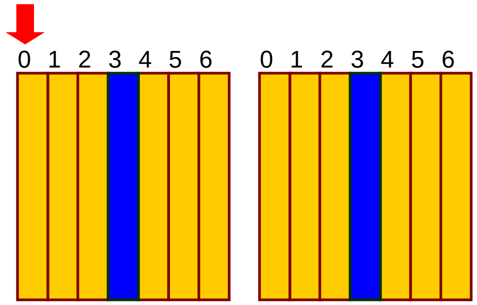
Uplink mapping

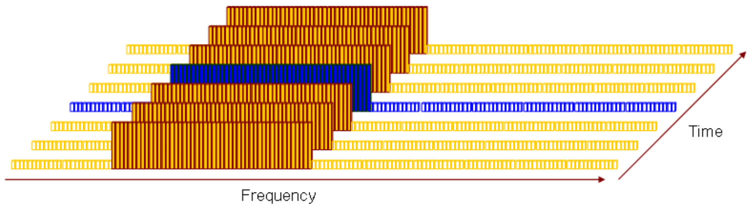


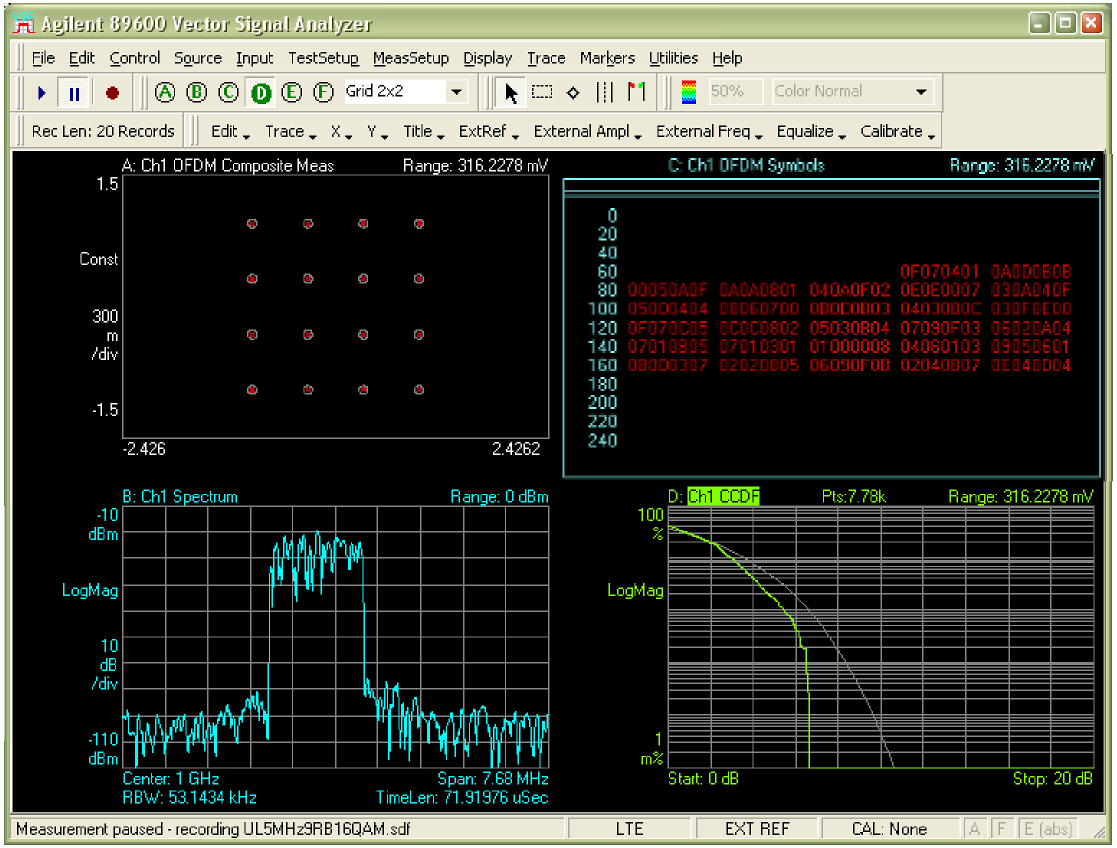
Uplink frame structure analysis- 16QAM PUSCH

- **PUSCH - Primary Uplink shared Channel**
- **Reference Signal – (Demodulation)**

Slot #0 Symbol #0
PUSCH







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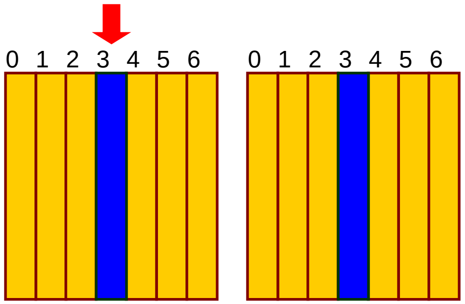
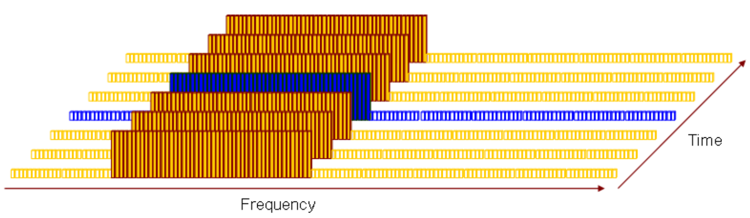
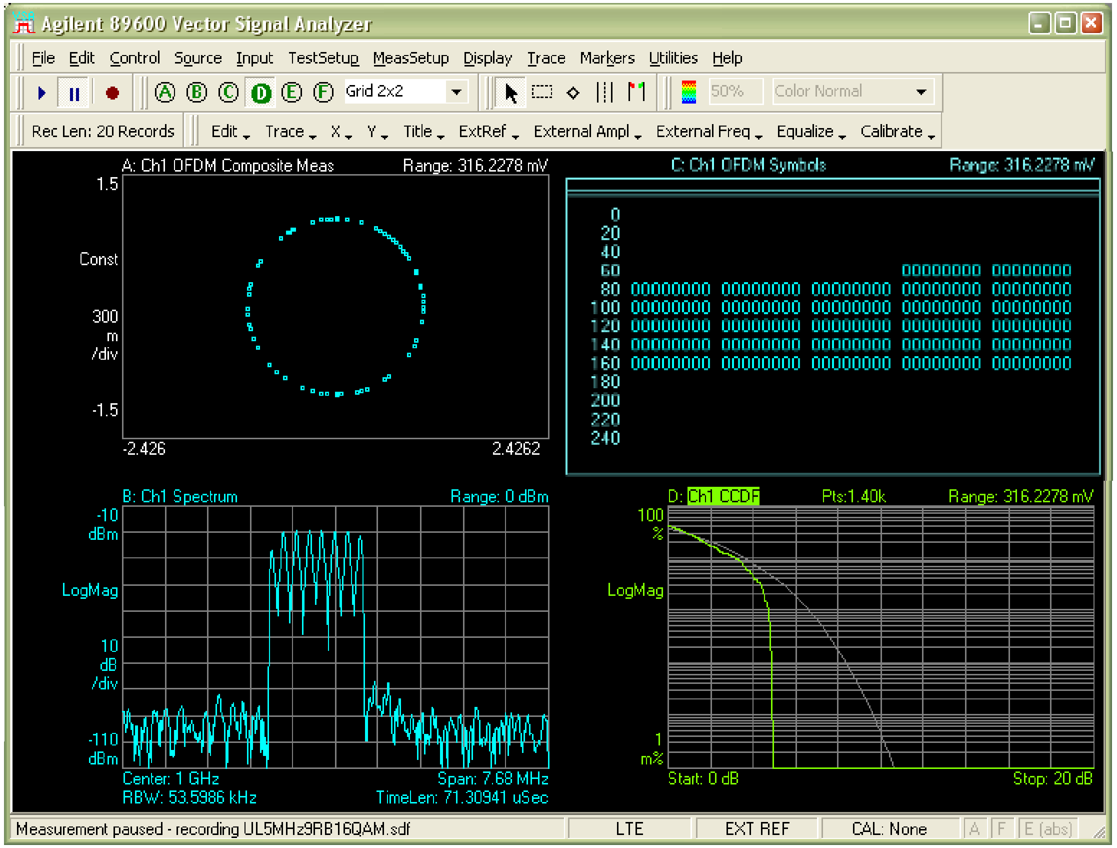
Uplink frame structure analysis - DMRS

- **PUSCH - Primary Uplink shared Channel**
- **Reference Signal – (Demodulation)**

Slot #0 Symbol #3
DMRS



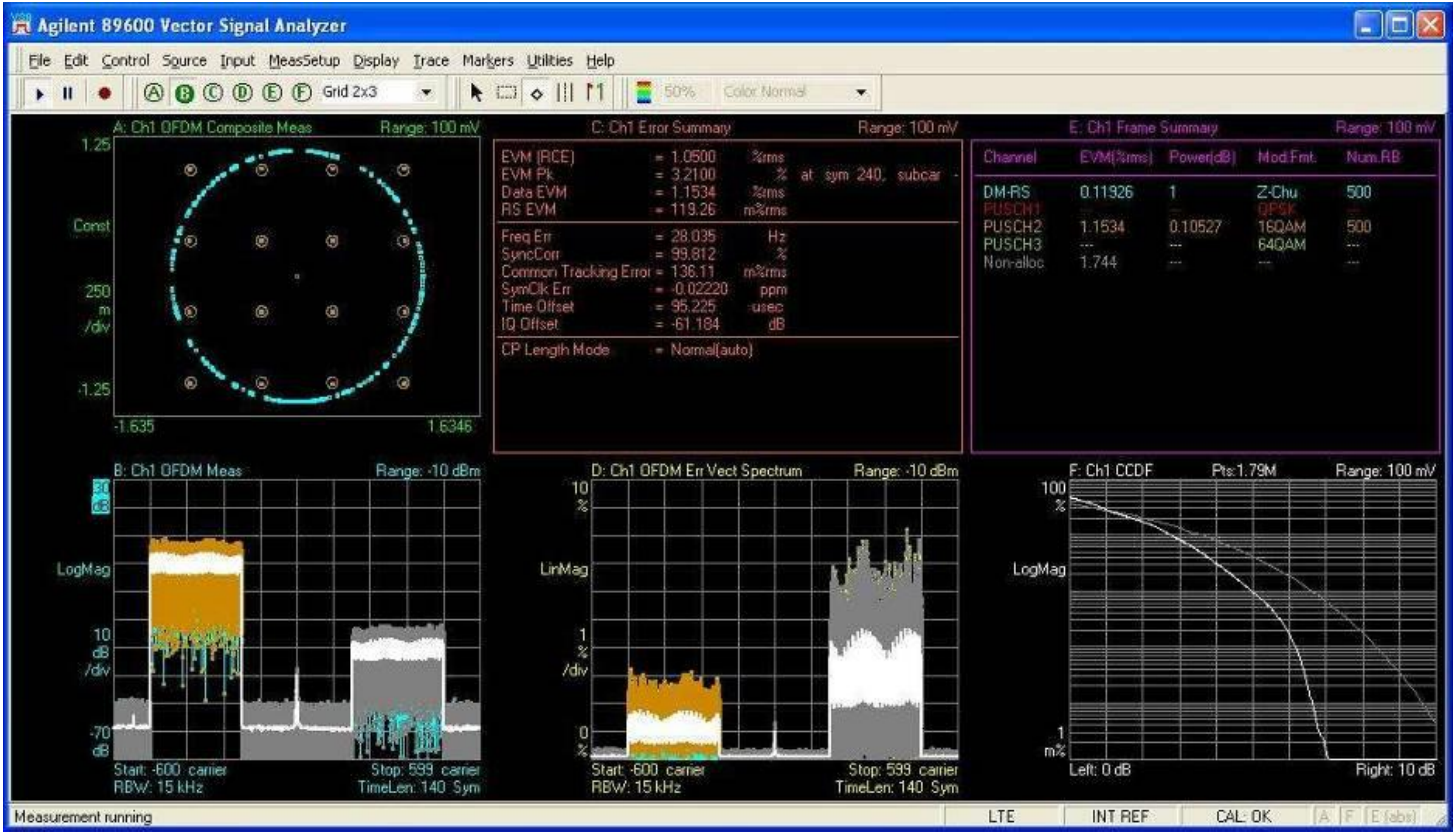




Agenda

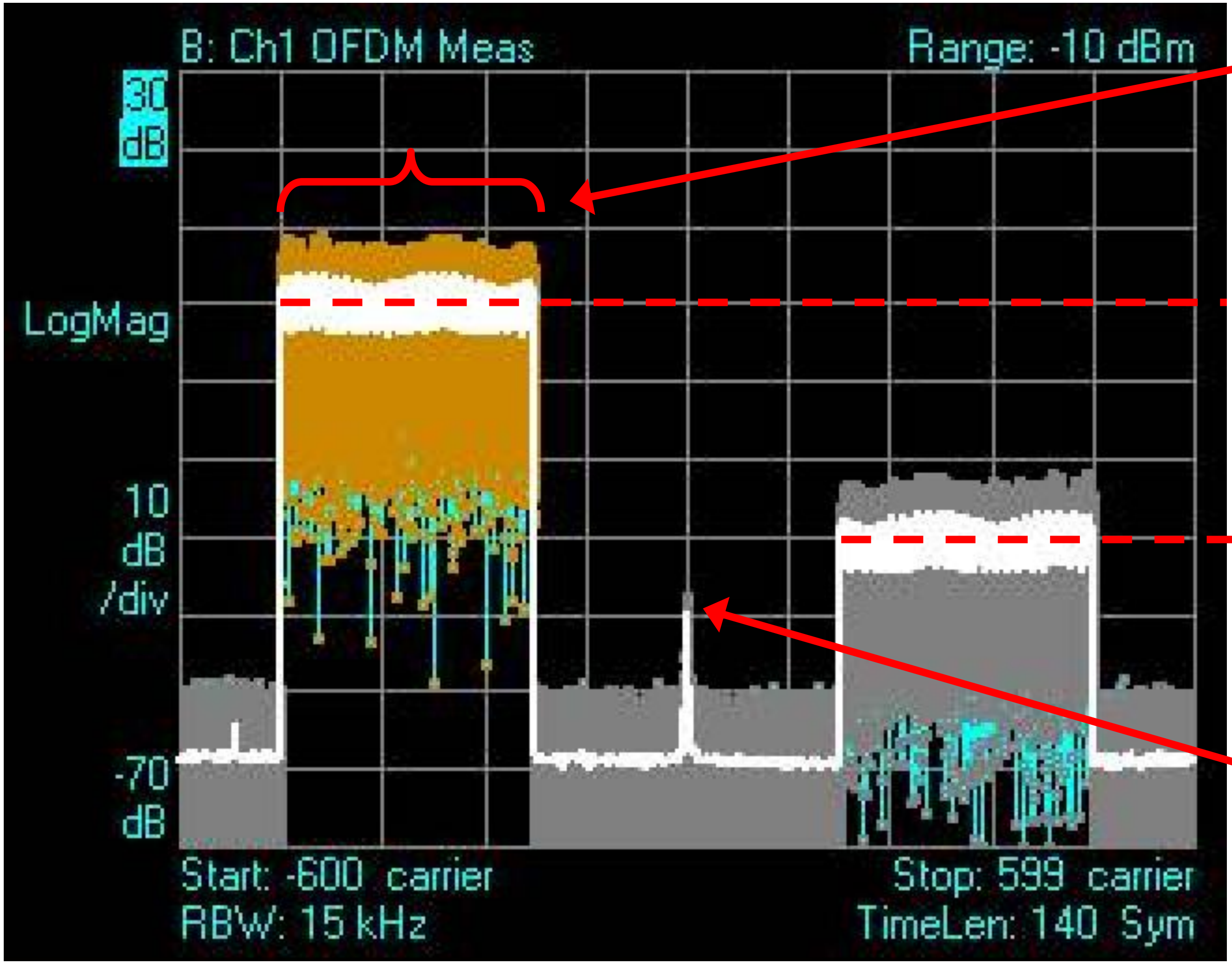
- Brief overview of LTE
- Standards documents
- LTE downlink and uplink transmission schemes
- Uplink physical layer definition
- SC-FDMA signal analysis
- Agilent LTE measurement solutions overview

SC-FDMA signal analysis using Agilent 89601A



Agilent Technologies

Frequency allocation and in-band emissions

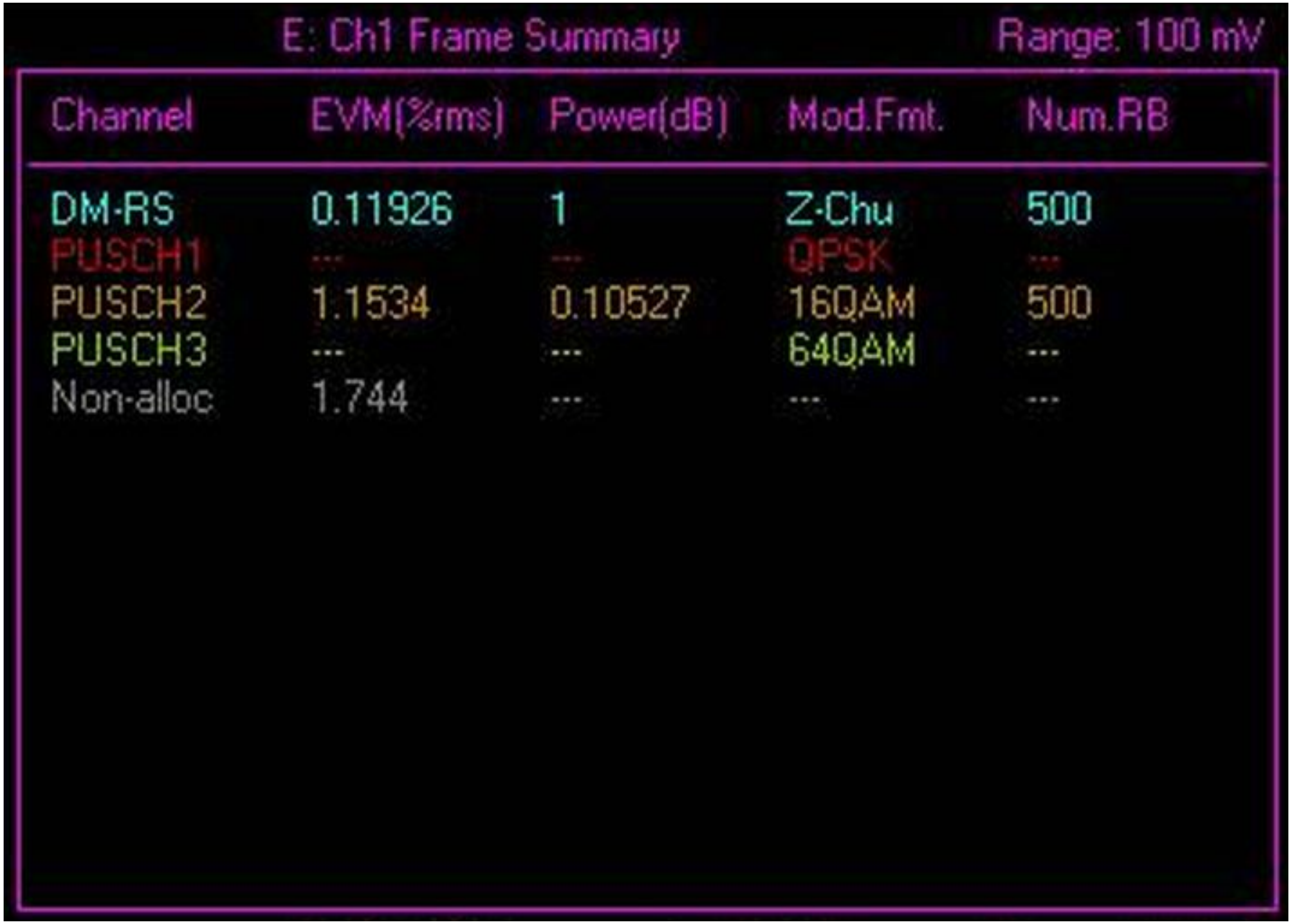


300 allocated subcarriers
= 25 RB
= 4.8 MHz

Approx -30 dBc in-band spurious emissions at the image subcarrier frequencies created using a 0.5 dB IQ gain imbalance

LO leakage around -39 dBc caused by IQ impairments

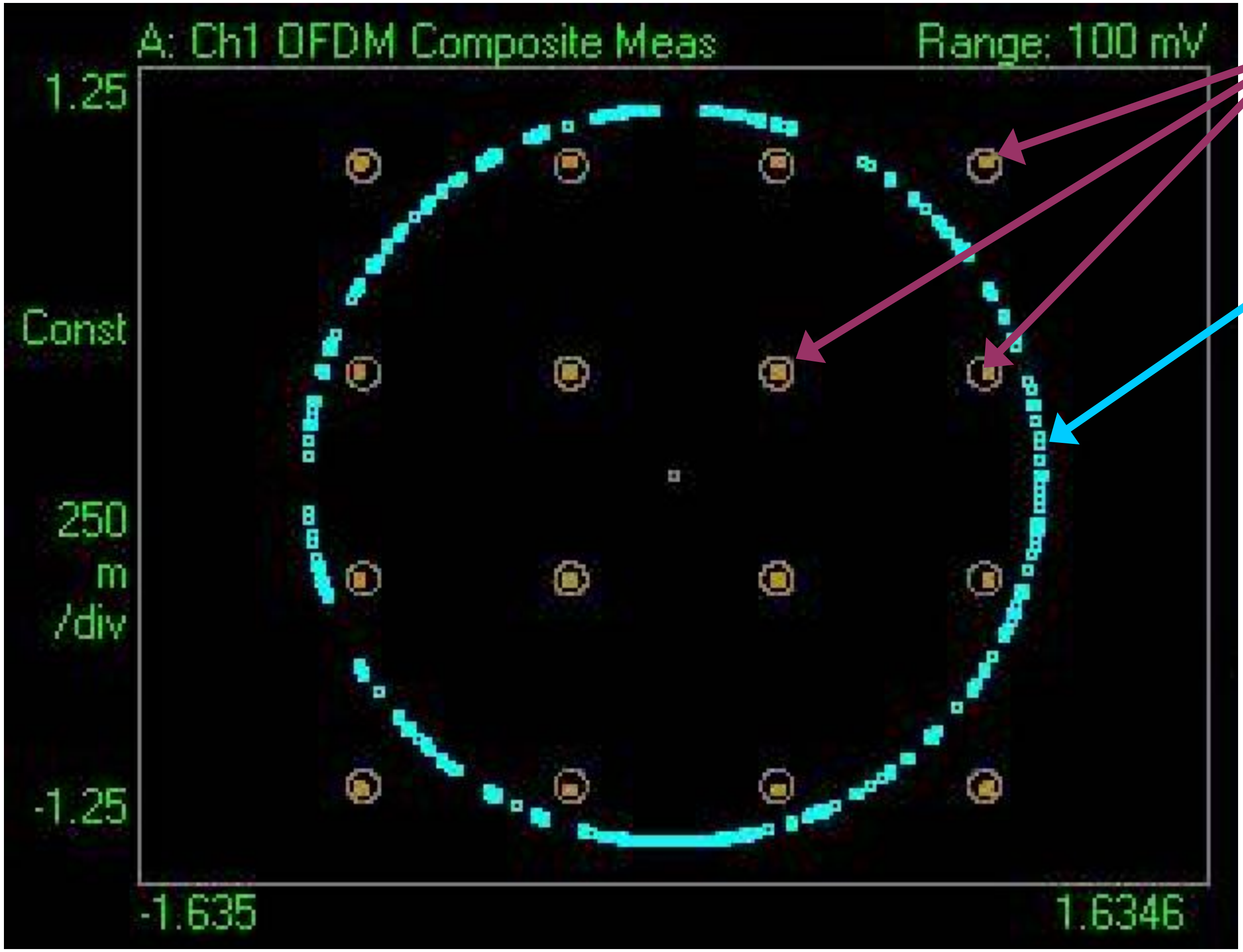
Blind detection of signal composition



The analyzer has auto-detected two signals: a demodulation reference signal with Zadoff-chu sequence and a 16QAM data channel

EVM summaries of both are provided

Modulation analysis
16QAM data plus CAZAC Reference Signal



The 16QAM data channel

The reference signal (pilot)

In this example there is a 1 dB RS power boost to distinguish the RS from the 16QAM data constellation

DM-RS modulation

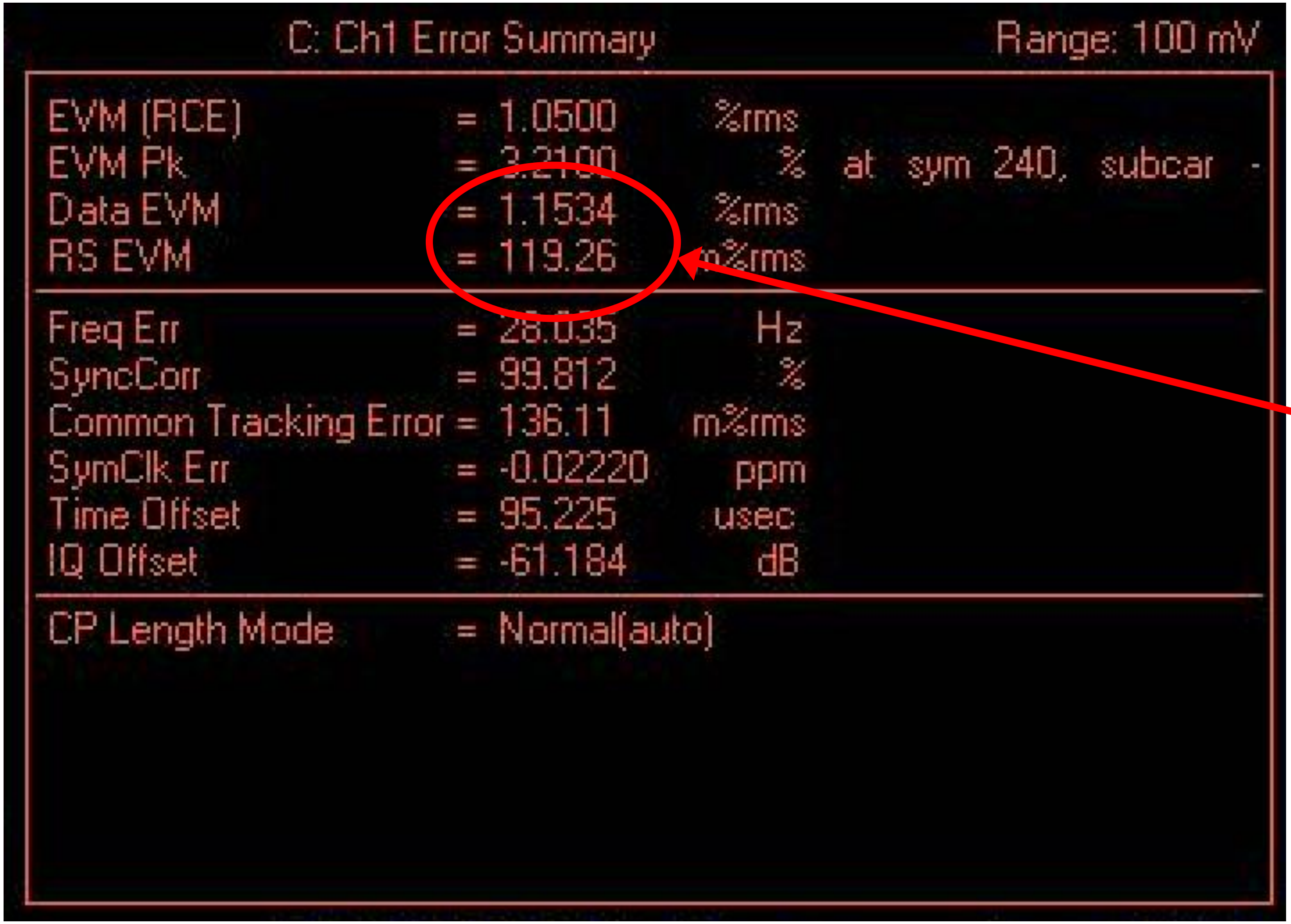
- The unity circle produced by the DM-RS may look random but is the result of phase modulating each successive subcarrier to create a constant amplitude zero auto-correlation (CAZAC) sequence
- There are 30 different sequences defined providing orthogonality between users
- The sequence follows a Zadoff-chu progression

$$x_q(m) = e^{-j\frac{\pi q m(m+1)}{N_{\mathrm{ZC}}^{\mathrm{RS}}}}, \quad 0 \le m \le N_{\mathrm{ZC}}^{\mathrm{RS}} - 1$$

where $N_{\mathrm{ZC}}^{\mathrm{RS}}$ is the first prime number less than the required number of subcarriers, and m is the subcarrier number of the q^{th} sequence

- For allocations less than 3 resource blocks (36 subcarriers) it is not possible to use a zadoff-chu sequence so the RS are modulated with a simpler computer-generated QPSK sequence of length 12 or 24

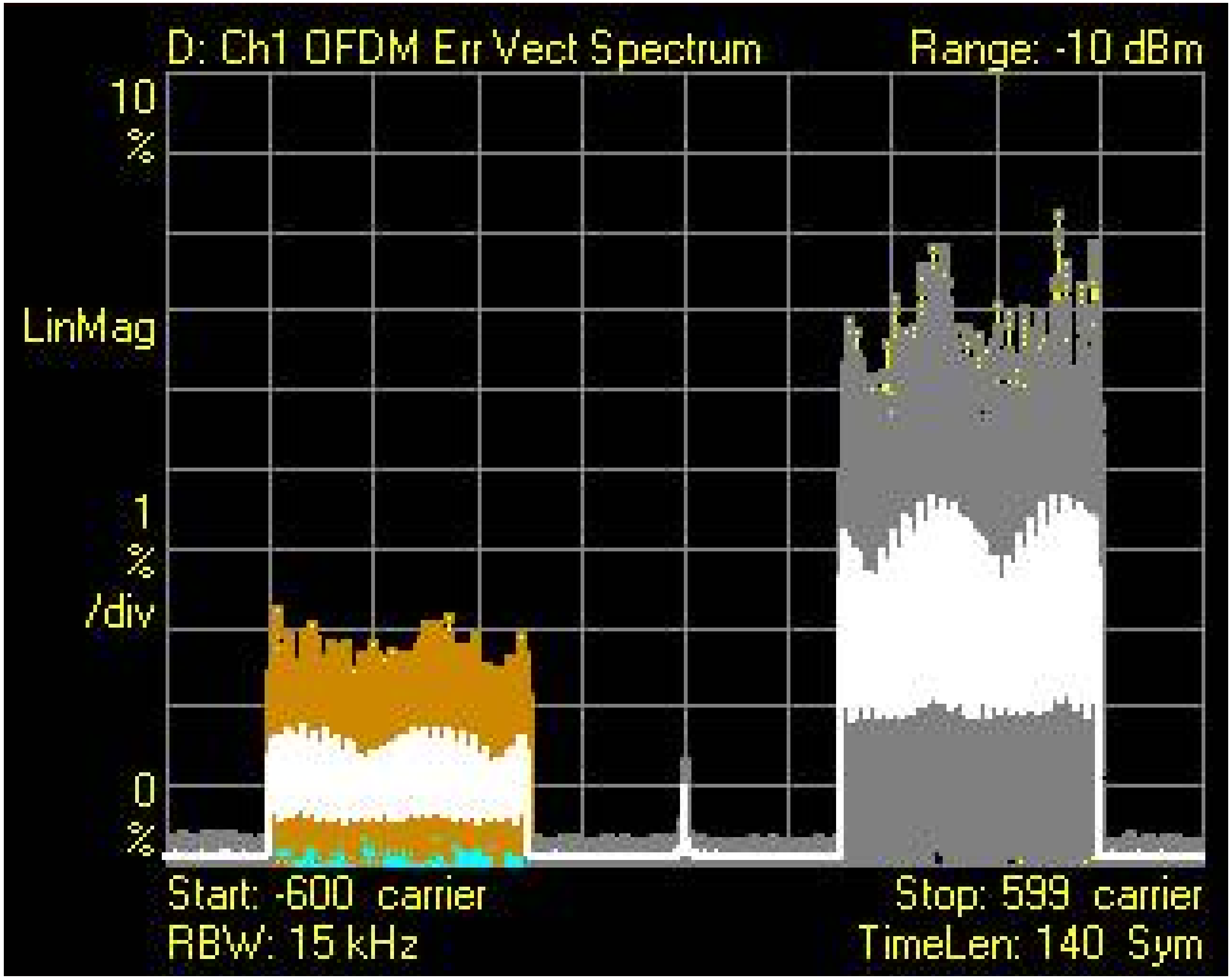
Modulation accuracy summary



A detailed modulation accuracy analysis by RS and data

The data EVM is much higher than the RS EVM due to a deliberate 0.1 dB gain boost which was then ignored to create data-specific EVM

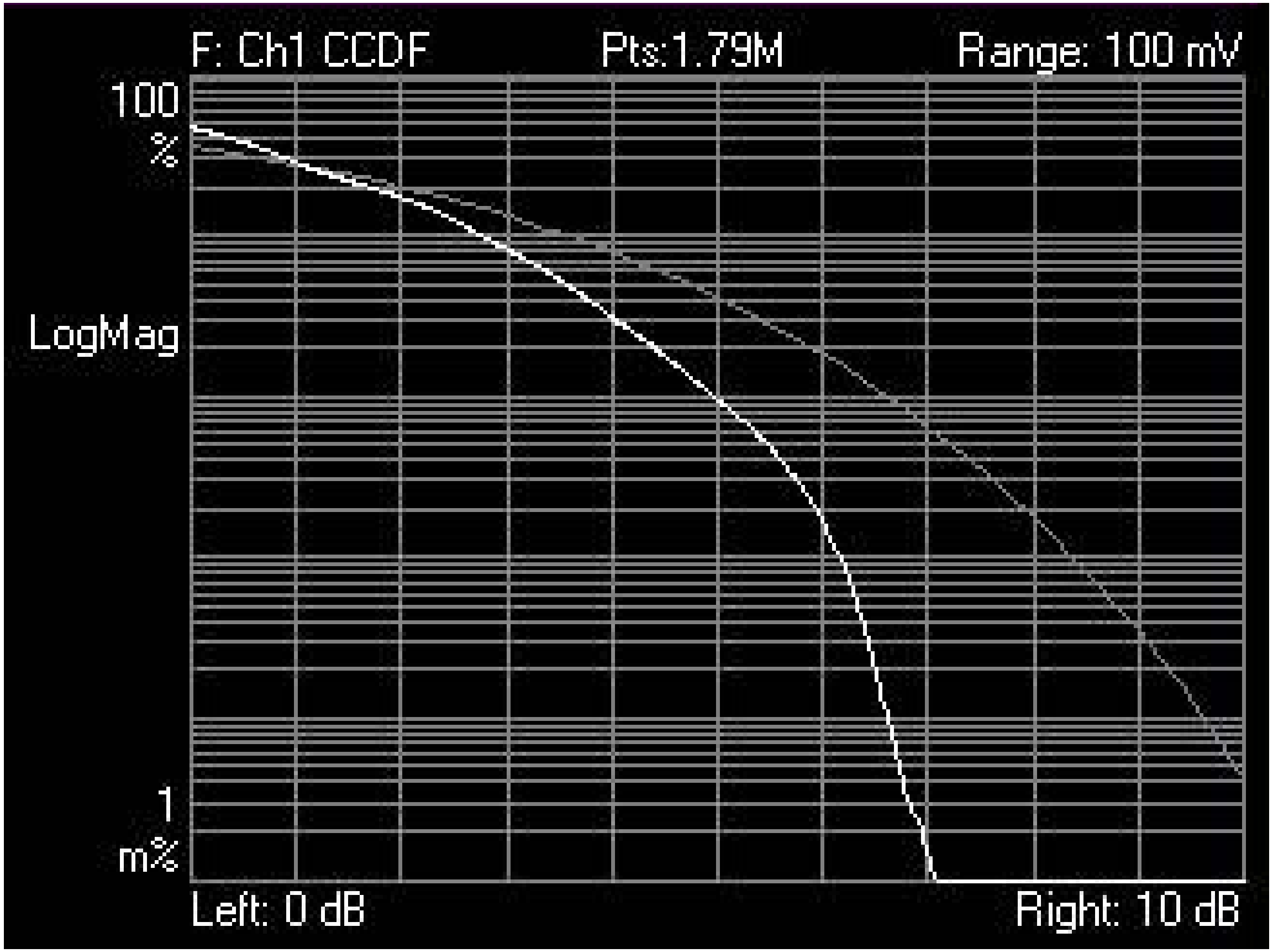
EVM by subcarrier



The instantaneous EVM of the allocated subcarriers is shown in brown and the average over the measurement interval is in white.

EVM for the LO feed through and non-allocated subcarriers is measureable but these impairments are specified separately from EVM

Complimentary cumulative distribution function



This result defines why SC-FDMA was developed. It clearly shows that for this 16QAM example the CCDF is several dB below the Gaussian reference line which is what OFDMA would have given. This extra headroom lowers costs in the power amplifier and reduces battery drain.

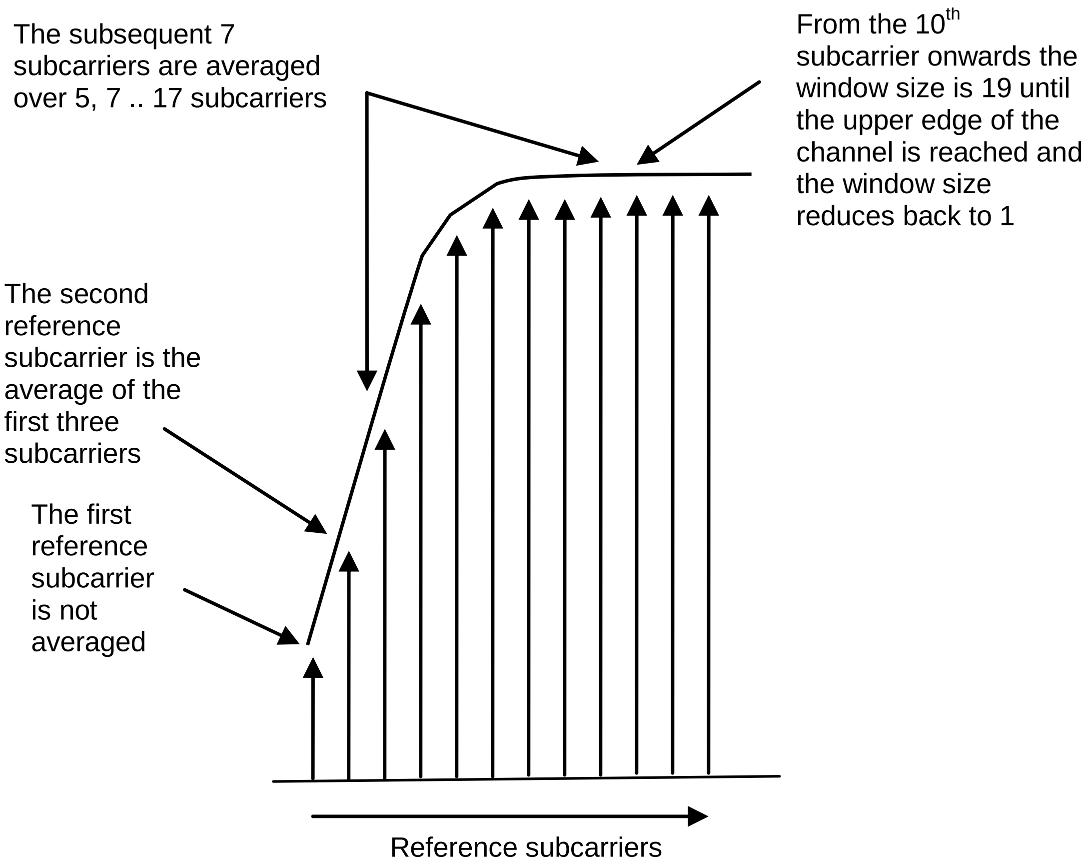
Important notes on EVM
No transmit/receive filter will be defined

- In UMTS a transmit/receive filter was defined
  - Root raised cosine $\alpha = 0.22$
- This filter was also used to make EVM measurements
  - Deviations from the ideal filter increased the measured EVM
- In LTE with OFDMA/SC-FDMA no filter is defined
- The lack of a filter creates opportunities and problems:
  - Signal generation can be optimized to meet in-channel and out of channel requirements
  - Signal reception and measurement have no standard reference
- It is expected that real receivers will use the downlink reference signals (pilots) to correct for frequency and phase
  - But no standard for how to do this will be specified
- So what corrections should be applied to measurements?

Important notes on EVM
The role of EVM measurements

- The role of EVM measurements should be to provide a reference for signal quality which can be usefully used in the transmit/receive link budget to assess system performance
- The measurement definition should ideally match what is used in real receivers
  - Receiver equalizer algorithms are considered proprietary so it has been necessary to define an independent equalizer for measurements
- The EVM equalizer should apply a reasonable level of correction consistent with what is possible with a real-time receiver
  - It is counter-productive to use metrology-grade processing to minimize EVM e.g. by using knowledge of the transmitted data or iterative non real-time optimizations
  - Minimizing EVM might look good for the transmitter but does nothing to improve the link budget or the performance of the receiver

Important notes on EVM
Downlink EVM equalizer definition



TR 36.804 v1.0.0 Figure 6.8.1.1-1: Reference subcarrier smoothing in the frequency domain

For the downlink, the EVM equalizer has been constrained

Rather than use all the RS data to correct the received signal a moving average is performed in the frequency domain across the channel which limits the rate of change of correction

There is no limit on the dB amount of correction

[802.16e WiMAX™ has +2/-4 dB limits at the channel edge, ± 2 dB in the central 50% and 0.1 dB between subcarriers]

Important notes on EVM
Uplink EVM equalizer definition

- This has not yet been fully defined
- The current proposal is to use a similar approach to WiMAX
  - Unconstrained equalizer
  - Define amplitude flatness across the channel
- In addition it may be necessary to constrain the phase variation as well since this is equally important as a source of demodulation errors

Important notes on EVM
EVM requirements

- EVM requirements are still to be finalized
- There will not just be one uplink EVM requirement
- EVM will likely be defined by
  - Modulation depth
  - Position within the channel bandwidth
  - Power level
- The current requirements for signals above -40 dBm are:

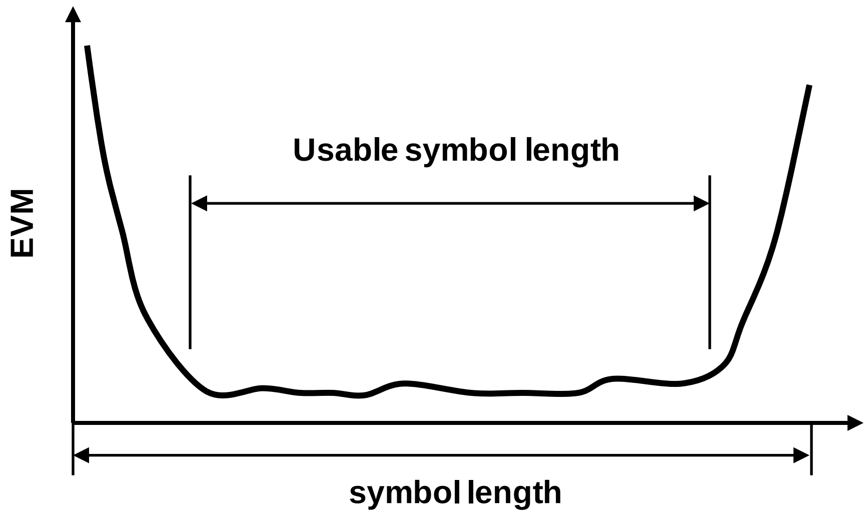
Parameter	Unit	Level
QPSK	%	17.5
16QAM	%	12.5
64QAM	%	[tbd]

TS 36.101 v8.1.0 Table 6.5.2.1.1-1: Minimum requirements for Error Vector Magnitude

- It is not expected that 64QAM will be allocated at the edge of the signal

Important notes on EVM
EVM vs. time – impact on CP reduction

- The lack of a defined transmit filter means that trade-offs can be made between in-channel performance and out of channel performance (ACLR, Spectrum emission mask)
- But applying too aggressive filtering can introduce delays to the signal which appear like multipath and reduce the effective length of the CP



Impact of time domain distortion induced by shaping of the transmit signal in the frequency domain

- For this reason EVM is defined across a window at two points in time either side of the nominal symbol centre

Important notes on EVM
EVM vs. time – impact on CP reduction

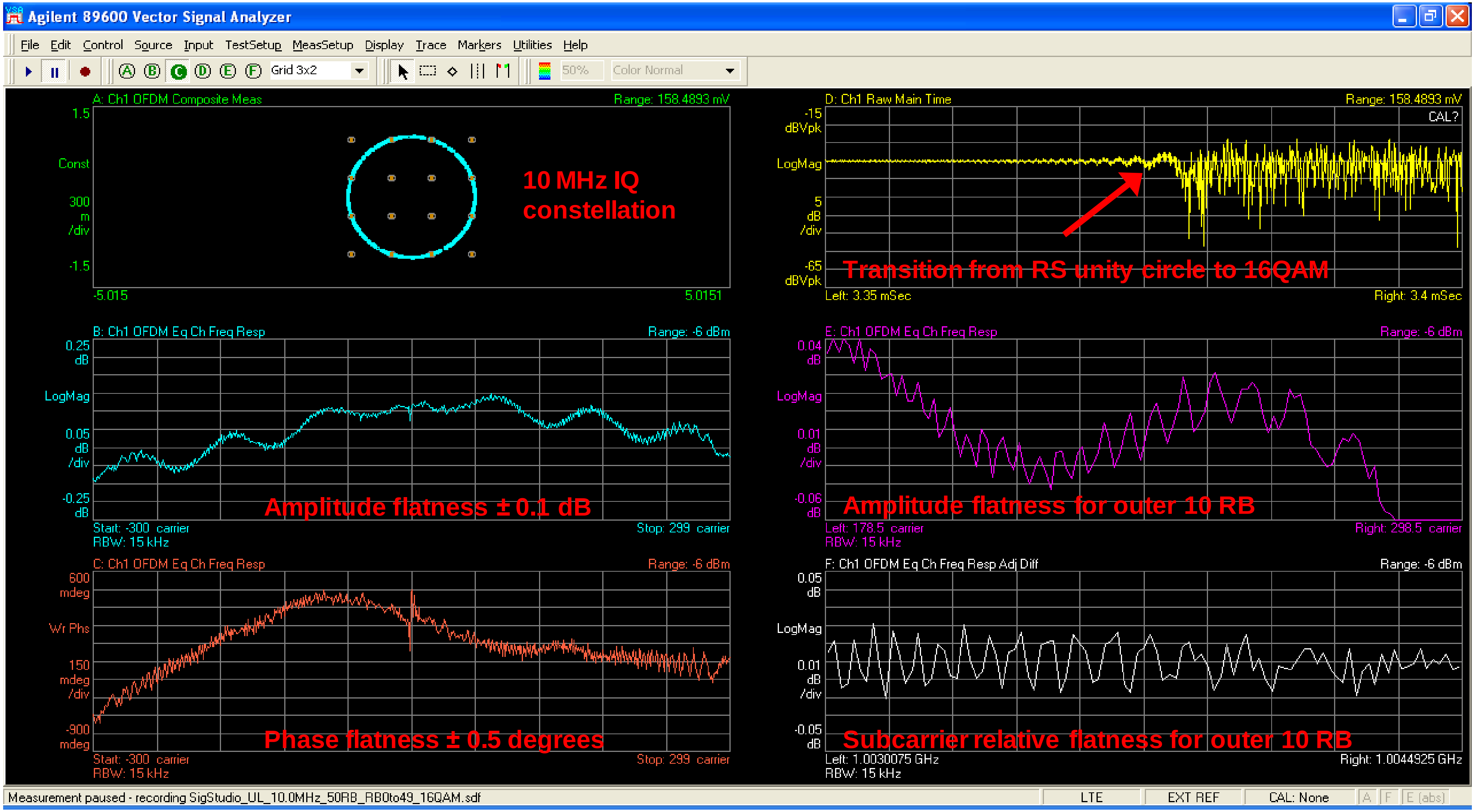
- The window lengths for the uplink are not yet defined but here are the downlink values from 36.804:

Bandwidth MHz	FFT size	Number of useful RBs	Cyclic prefix length N_{cp}	EVM window length *W*	Ratio of *W* to total CP (%)
1.4	128	6	9	[7]	[77.8]
3	256	15	18	[15]	[83.3]
5	512	25	36	[32]	[88.8]
10	1024	50	72	[66]	[91.7]
15	1536	75	108	[102]	[94.4]
20	2048	100	144	[136]	[94.4]

TS 36.804 v1.0.0 Table 6.8.1.1-2 EVM window length

- The EVM is measured at two points in time – W/2 and + W/2
- The narrowest bandwidths allow the most relaxation with nearly one quarter of the CP being used up by transmit filter distortion

Analyzing the equalizer results from an ideal SC-FDMA signal



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Agilent Measurement Solutions and plans for LTE - Commitment

Agilent is providing the broadest range of design and test tools across the R&D lifecycle for LTE

- Support for early R&D in components, base station equipment and mobile devices, with design automation tools and flexible instrumentation based on existing measurement platforms
- Test solutions for product integration, conformance and interoperability testing are being developed
- Manufacturing test capability will follow for early deployment

Agilent 3GPP LTE Portfolio

Software Solutions

- E8895 ADS LTE Library
- N7624B LTE Signal Studio
- 89601A LTE VSA Software

NEW!

E6620A Wireless Communications Platform

Agilent/Anite SAT LTE – Protocol Development Toolset

NEW!

Coming Soon!

Drive Test

Analyzers, Sources, Scopes, Logic Analyzers

Digital VSA

MXA/MXG R&D

Network Analyzers, Power supplies, and More!

Coming Soon!

Agilent/Anite Signalling and RF conformance test systems

NEW!

Distributed Network Analyzers

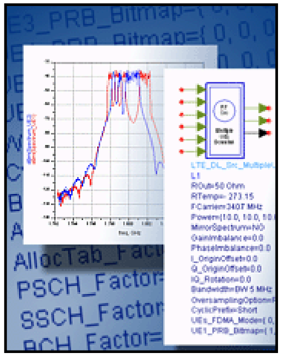
Product development | **Conformance & IOT** | **Deployment**

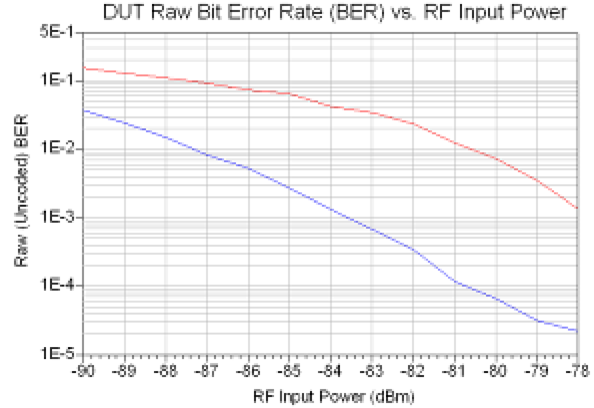
Advanced Design System 3GPP LTE Wireless Library

For system and circuit design & verification

- Downlink OFDMA and uplink SC-FDMA sources and receivers
- Pre-configured examples with EVM and BER measurements
- Connectivity with Agilent test equipment

Combine simulation with sources and analyzers for powerful R&D prototype hardware testing..





Agilent Technologies LTE Connected Solutions:
LTE Uplink EVM & Raw BER Measurement

Work Bench
LTE_UL_MXG
Download_ADS_LTE_to_MXG

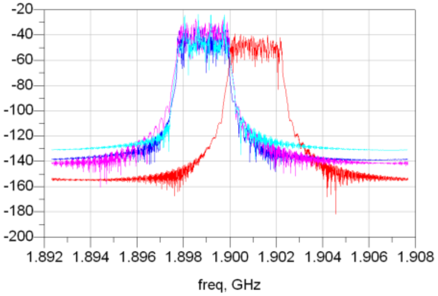
Work Bench
LTE_UL_MXA_CS
Capture_&_Analyze_LTE_with_MXA

SEQUENCER
Sequencer
Sequencer1
TestBench[1]="Download_ADS_LTE_to_MXG"
TestBench[2]="Capture_&_Analyze_LTE_with_MXA"

Var Eqn
VAR
VAR1
DUT_Input_Power_dBm=-10
DUT_Frequency_MHz=1950

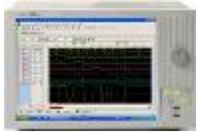
Download

Signal generator

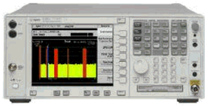


RF or Mixed-Signal DUT

Analyze



Logic Analyser



Spectrum Analyser

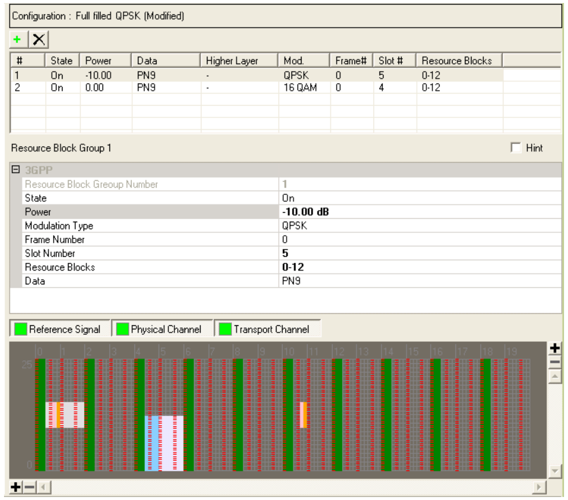
http://eesof.tm.agilent.com/products/ads_main.html

Signal creation software
N7624B Signal Studio for LTE

User-friendly, parameterized and reconfigurable 3GPP LTE signal generation software for Agilent ESG-C or MXG RF Signal Generators.

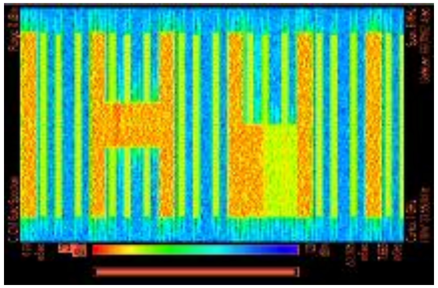
- **PHY Layer partially coded signals for component test**
- **Transport Layer fully coded signals for Rx Test**
- **Downlink MIMO pre-coding up to 4x4 (Spatial Multiplexing/Tx Diversity)**
- **Multiple UE setup for UL**
- **Fixed-tap Fading**

Download your free demo copy at:
www.agilent.com/find/signalstudio



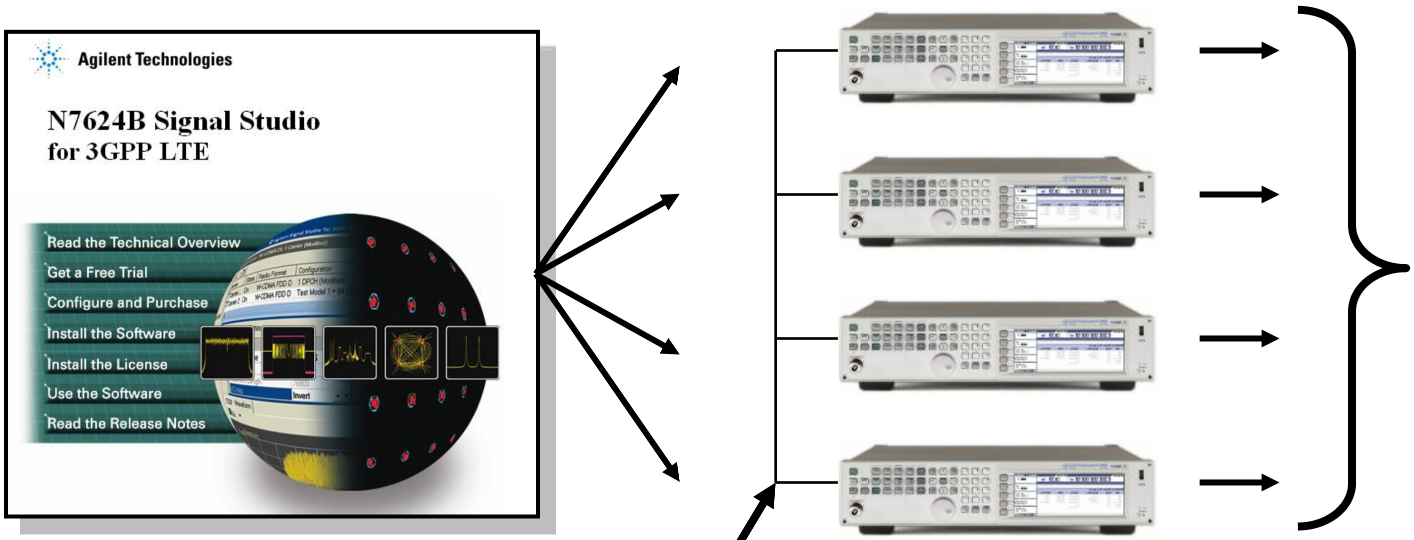
MXG

ESG-C



Rx Testing LTE – UL or DL, RF or Digital

Common GUI for MIMO Signal Generation and Channel Properties



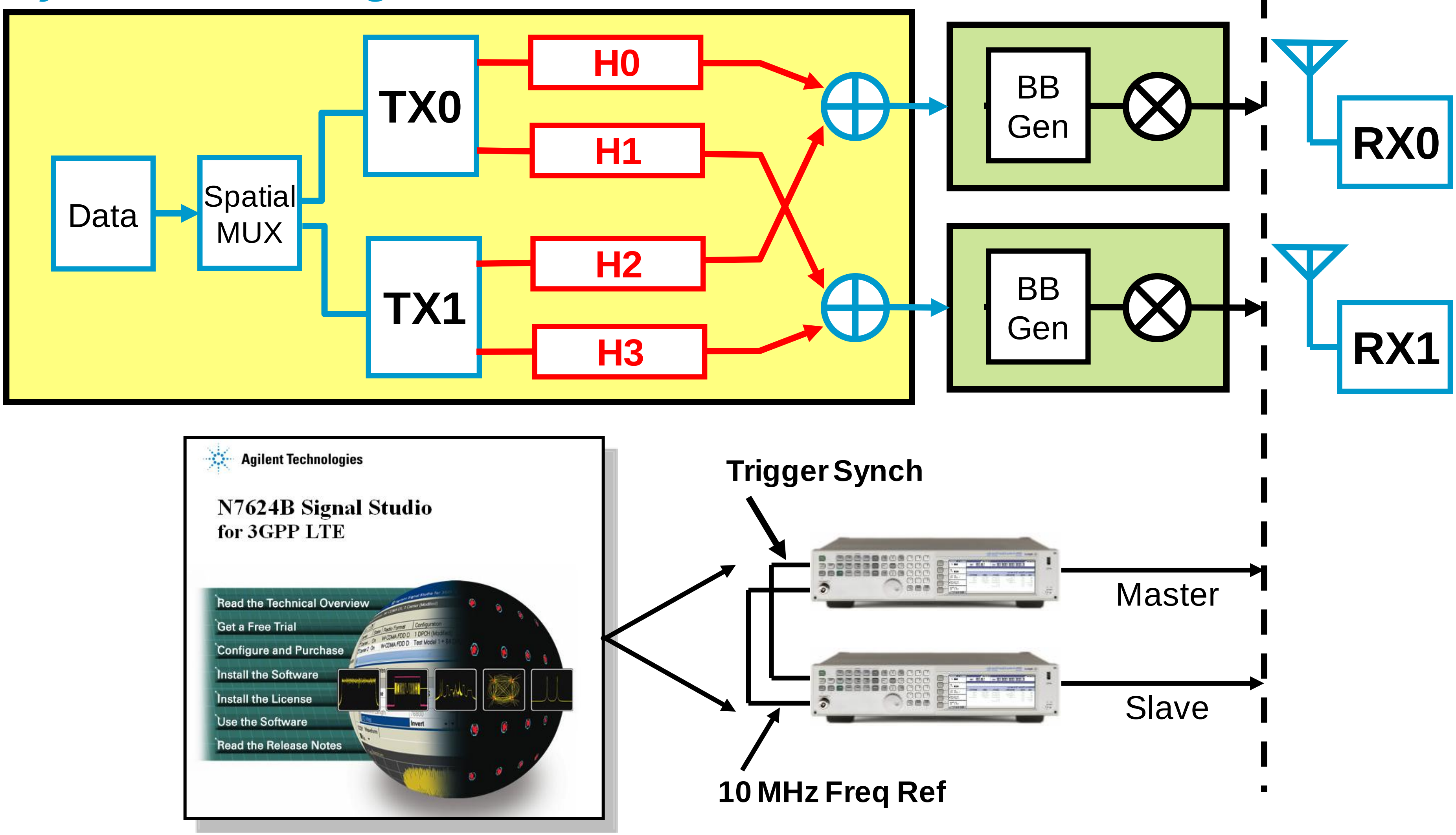
10 MHz Freq Ref

Separate HW for flexible configurations up to 4x4

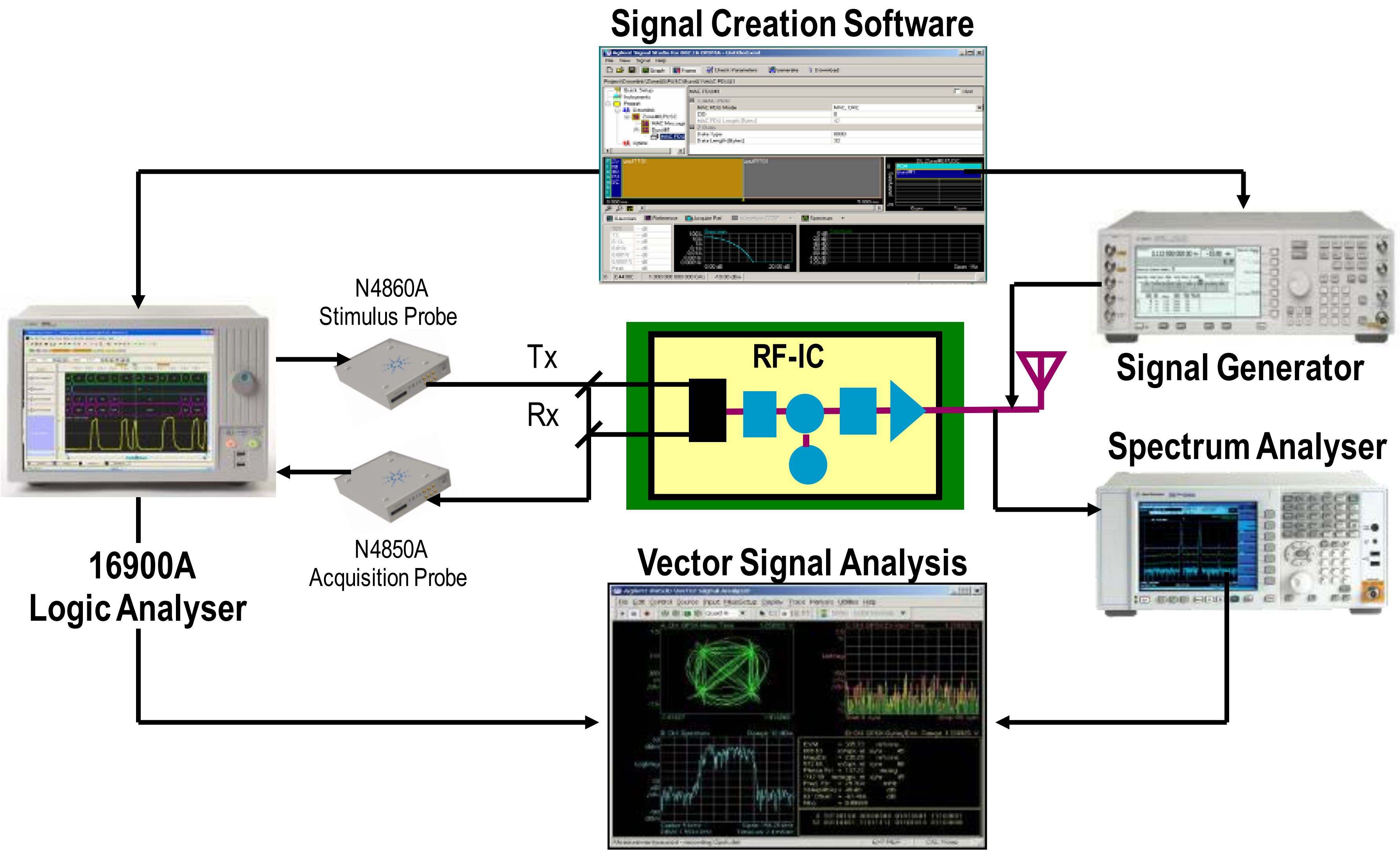
Lower cost per channel with fixed-tap fading
Allows for flexible deployment of hardware

LTE MIMO: Measurement Reference Plane

System Building Blocks



Crossing the RF digital divide



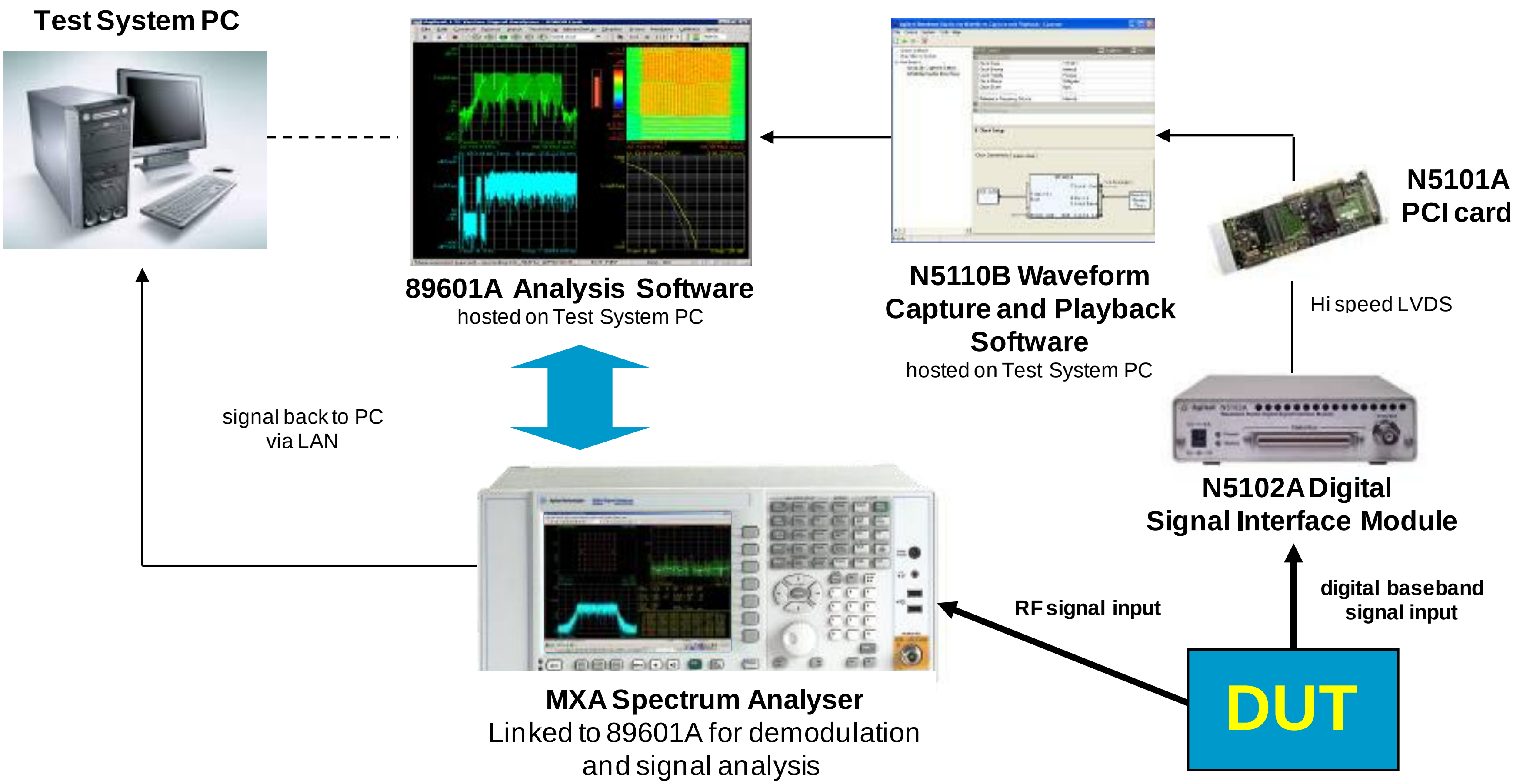
BB-IC / RF-IC Validation & Integration

Tools for detailed evaluation of RF-IC, BB-IC and other phone sub-system (e.g. camera, display) interfaces.

Use ADS, Signal Studio and 89601 VSA software for I/Q data generation and signal analysis.

- DigRF v3.0 available now.
- MIPI D-PHY available now.
- DigRF v4.0 in development.

LTE Signal Analysis with RF and digital input

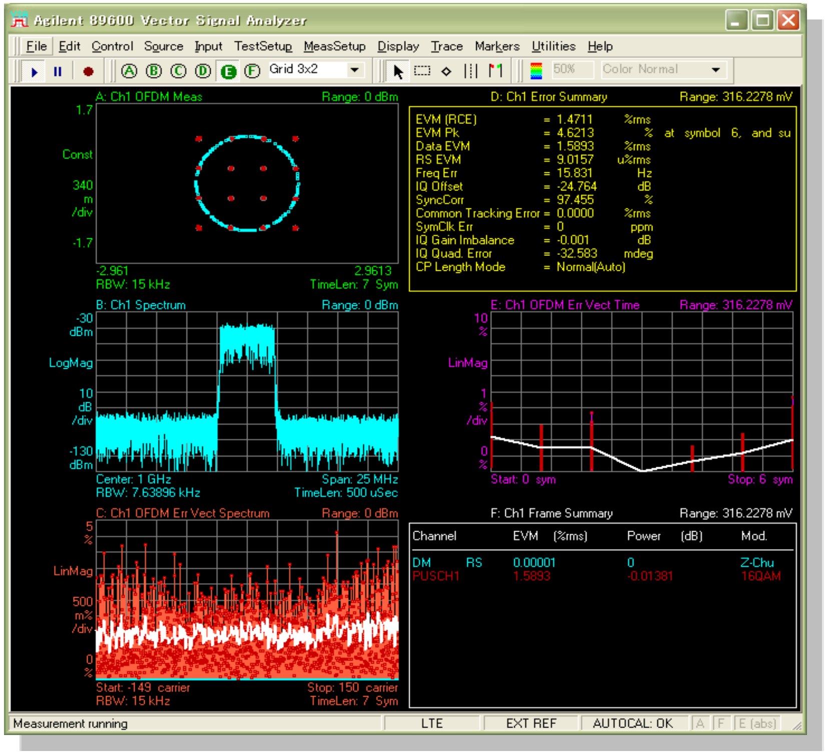


LTE signal analysis using Agilent 89601A vector signal analyzer software

LTE measurement metrics:

- Sync Correlation, Frequency Error, IQ Offset,
- Composite EVM (Peak & RMS),
- Channel EVM & Power metrics

  DL: P-SCH, S-SCH, RS, P-BCH, PDCCH, up to 6 PDSCH's, UL: DM-RS, PUSCH
- Common Pilot Error, Symbol Clock Error
- CP length & CP mode



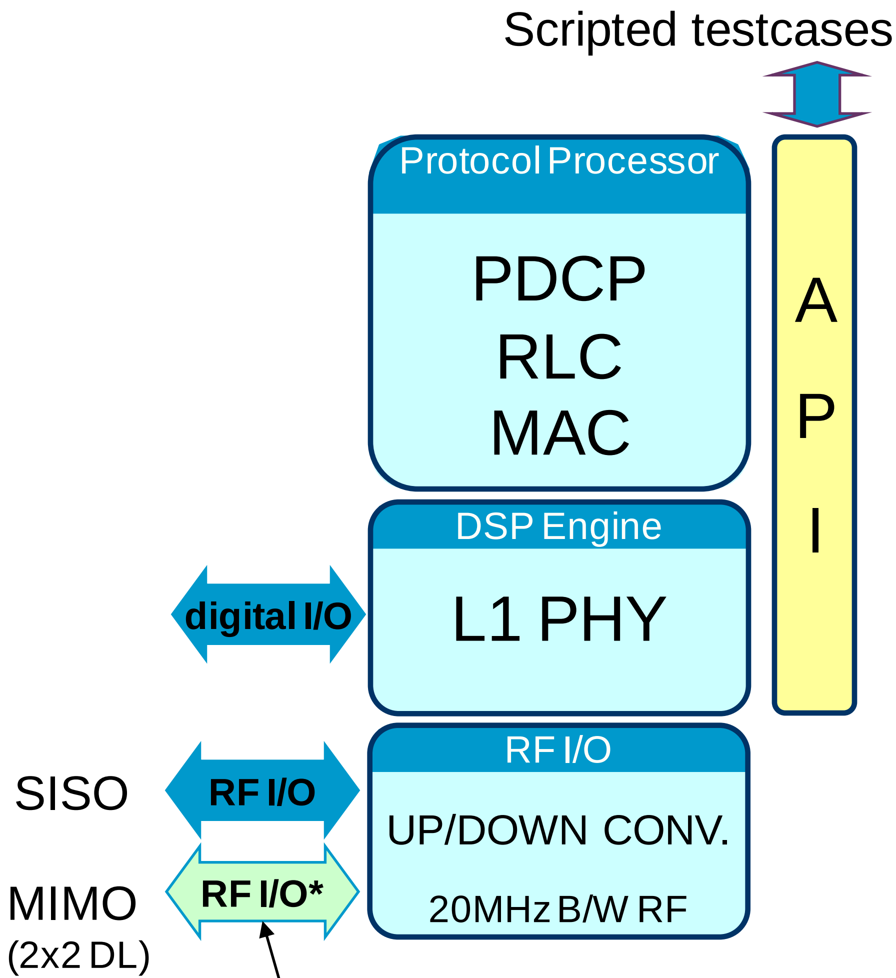
LTE measurement traces:

- Power vs. Spectrum or Time,
- RB Error Mag Spectrum or Time,
- RB Power Spectrum or Time,
- RMS Error Vector Spectrum or Time
- Common Tracking Error,
- EQ Chan Freq Response, EQ Impulse Response,
- Error Summary, Frame Summary
- Symbol demod bits table
- I/Q measurement/constellation
- CCDF, CDF, PDF

Download your free 89601A demo copy at: www.agilent.com/find/89600

Agilent Technologies

E6620A Integrated Mobile Test Platform



*Optional 2nd Source/Receiver for 2x2 MIMO

Scalable single box base station emulator
- 2G/3G/3.9G (LTE) capable
- LTE L1-L2 signaling stack + scripting API
- 20MHz BW
- Data rates up to 100 Mbps DL / 50 Mbps UL
- 2x2 MIMO
- Support for two independent cells
- Built-in Fading
- RF Parametric Measurements

Introduction: Aug 2008

Agilent and Anite in partnership

- *accelerating LTE test solutions*

Combining strengths to bring a full-range of LTE solutions to market faster

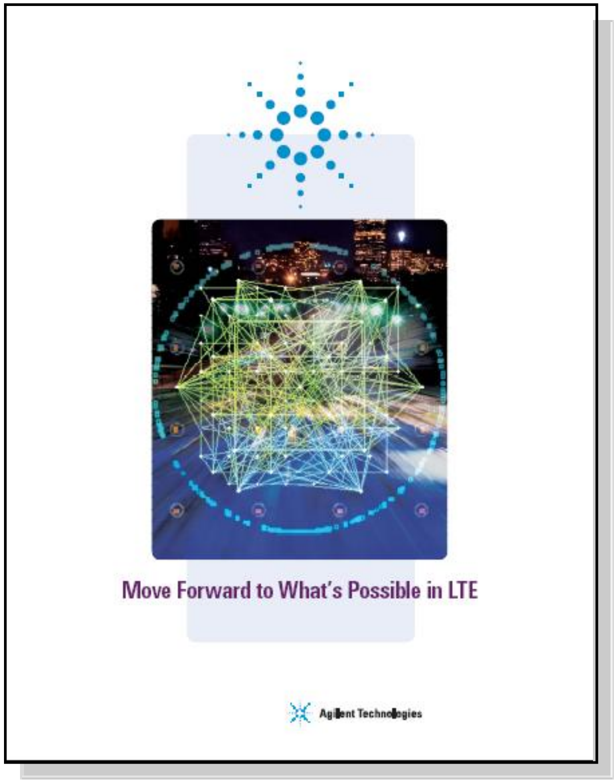
- Anite protocol development system built on Agilent's new E6620A hardware platform
- Agilent E6620A wireless communications test set provides a 3GPP Release 8 LTE protocol stack

Anite SAT LTE Protocol Tester with Development Toolset built on the Agilent E6620A

First to market toolset for UE protocol development

NEW LTE Literature

www.agilent.com/find/lte



Brochure (5989-7817EN)

LTE Poster (5989-7646EN)