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# Experiments with 5G-Air Interface JRC Radio Spectrum Lab

**J.Bishop, J-M Chareau, F.Bonavitacola**

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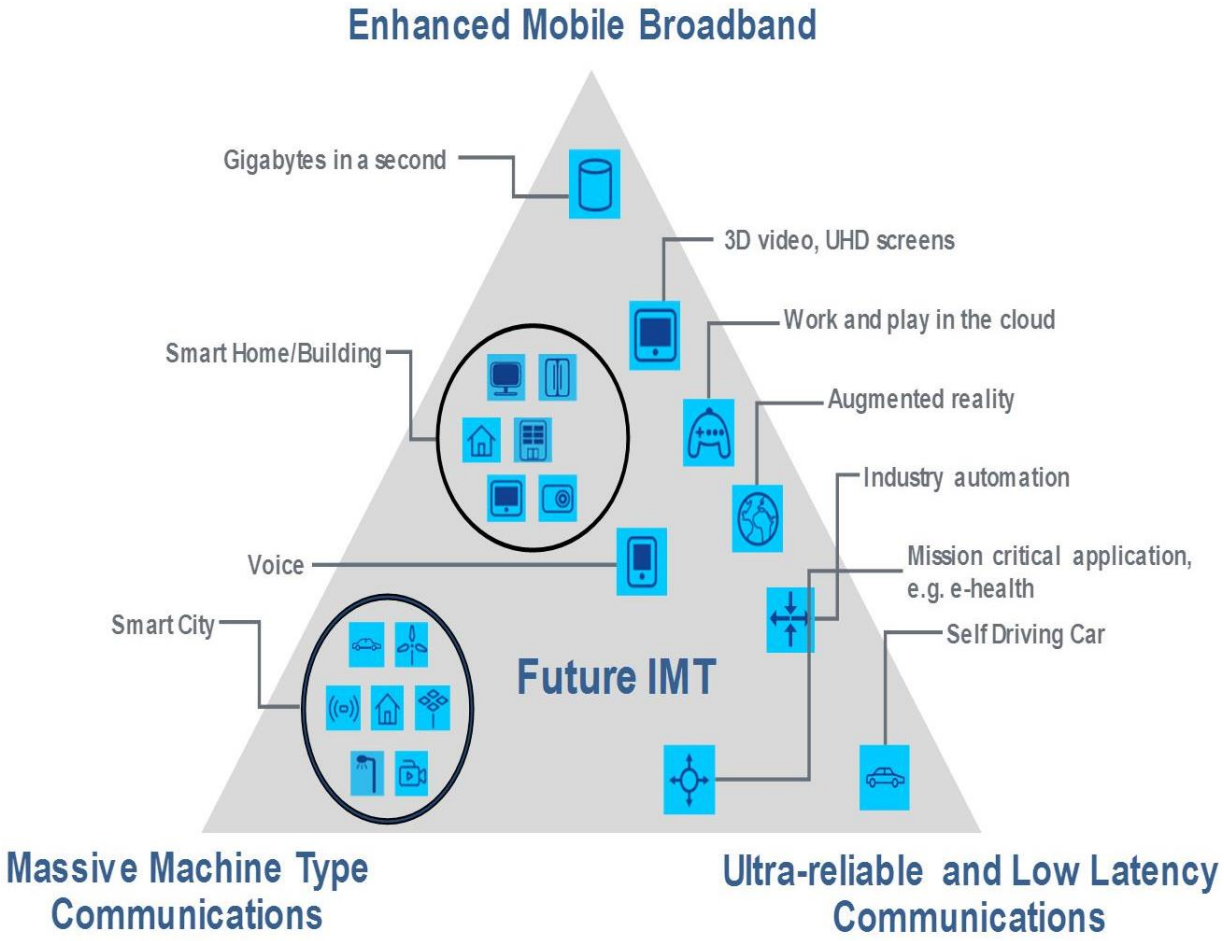
# ITU IMT-2020 Vision

- Mobile broadband:
  20Gb/s peak
  100Mb/s user experienced
- Internet of things (IoT):
  $10^6$ devices/$km^2$
- Low Latency:
  1ms
- 4G shall evolve into 5G




https://ec.europa.eu/digital-single-market/en/policies/5G

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# 4G Evolution to 5G

- Goal: common air interface for all IMT-2020 use-cases
- 18 month 3GPP Release cycle
- Gradual introduction of new features (r.15 first mention of "New Radio" - NR)

3GPP TS 38.211 V1.0.0 (2017-09)

*Technical Specification*

**3rd Generation Partnership Project;**
**Technical Specification Group Radio Access Network;**
**NR;**
**Physical channels and modulation**
**(Release 15)**

5G

3GPP
A GLOBAL INITIATIVE

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# NI Products

- NI LabView for Communications (Win64)
- NI LTE Framework
- NI-USRP 2943R & 2944R
- NI MXI Interface cards (require PCs with PCIe x16 Gen.3 slot)

# Capabilities of NI LTE Framework

- Subset of 3GPP LTE Release 10 PHY & MAC functions
- 20MHz Bandwidth (100 PRBs = 1200 sub-carriers)
- Primary synchronisation signal (PSS) only
- Cell- & UE- reference signals (channel estimation)

Simplified implementation of control channels, so cannot interoperate with COTS equipment (i.e. phones, base stations)

# Organisation of the NI LTE Framework

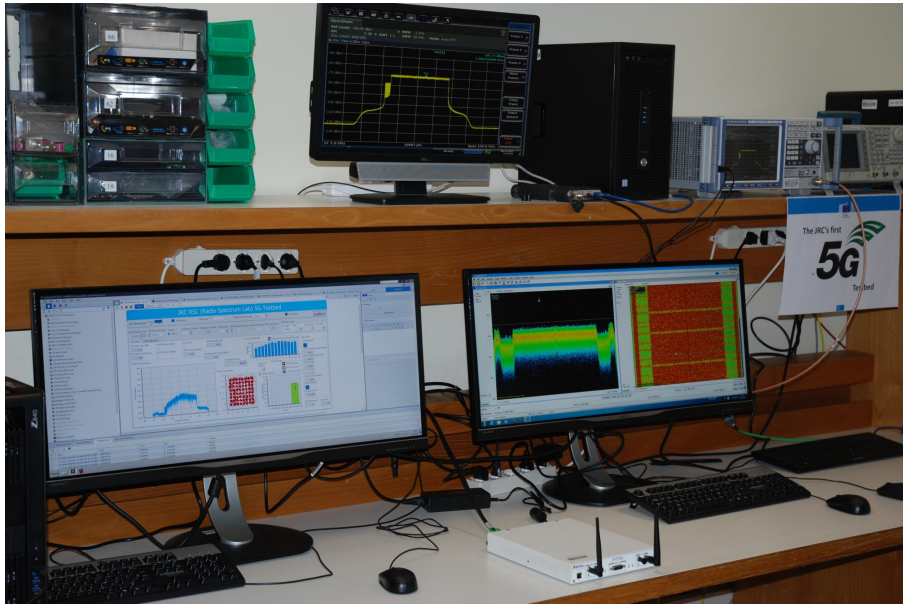
- Simplified MAC layer runs on host PC
- PHY layer runs on NI-USRP FPGA (Xilinx Kintex-7)

Labview for Communications toolchain converts from GVI to VHDL, and then produces an FPGA "bitfile"

Used eNodeB & UE sample code as starting point for experimentation

# Test Setup

- Single input – single output (SISO)
- 2943R (Rx)  120MHz BW
- 2944R (Tx)  160MHz BW
- 4K Video streaming
- R&S FSV-7 Signal analyser
- Tektronix RSA 306





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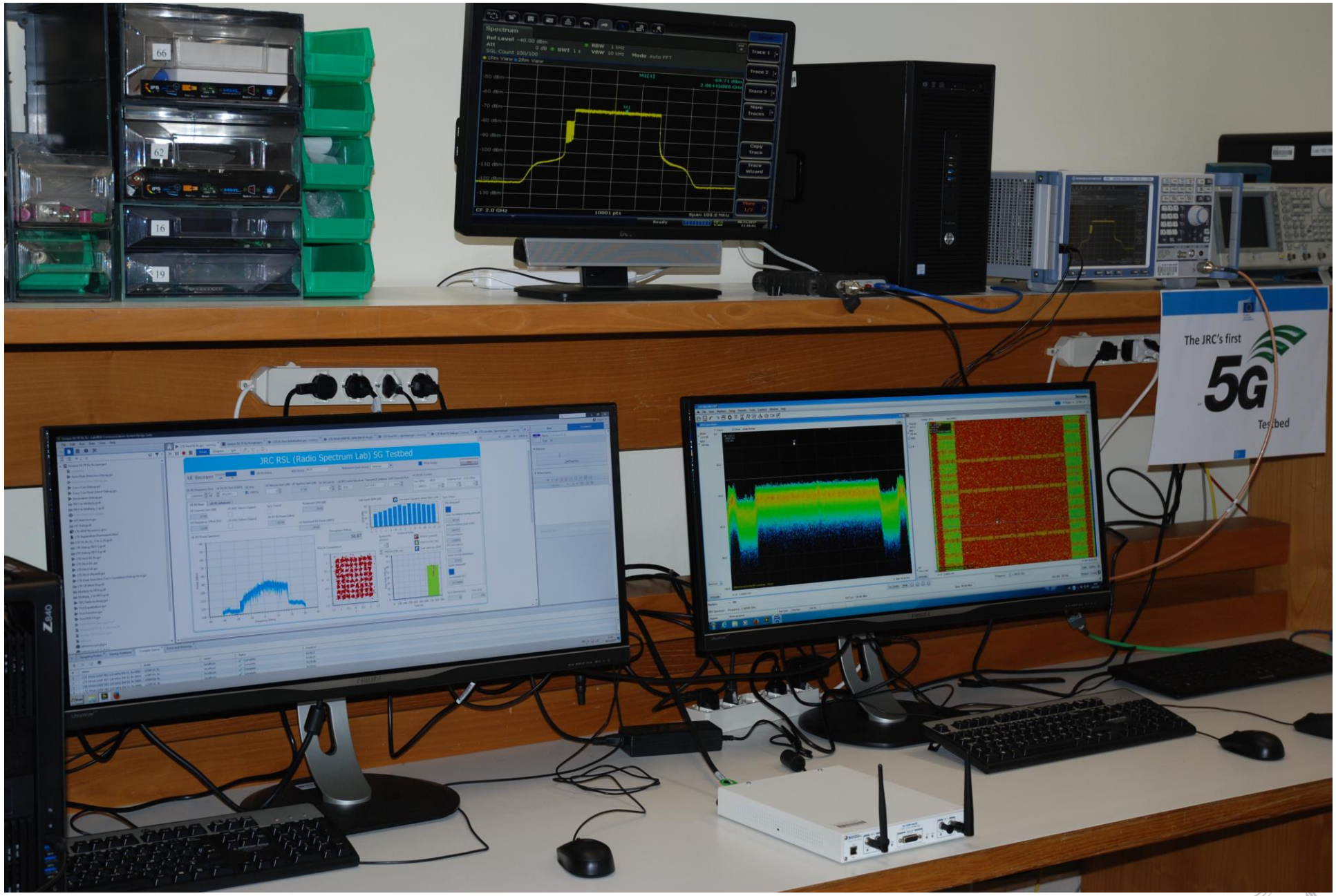


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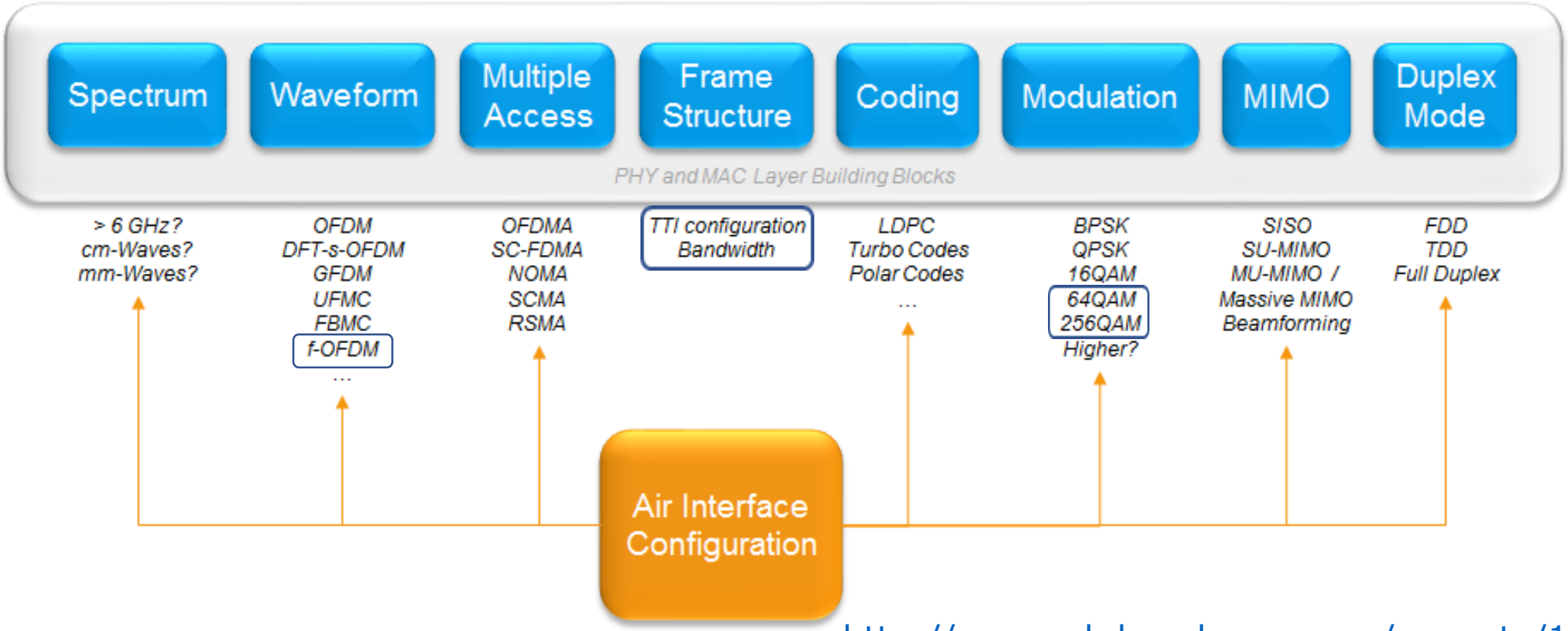
# Scope of Presentation




http://www.rohde-schwarz.com/appnote/1MA271

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# Bandwidth Increase

$\Delta f = 30kHz$ / $T_{Symbol} = 33.3\mu s$ / $40MHz\ BW$

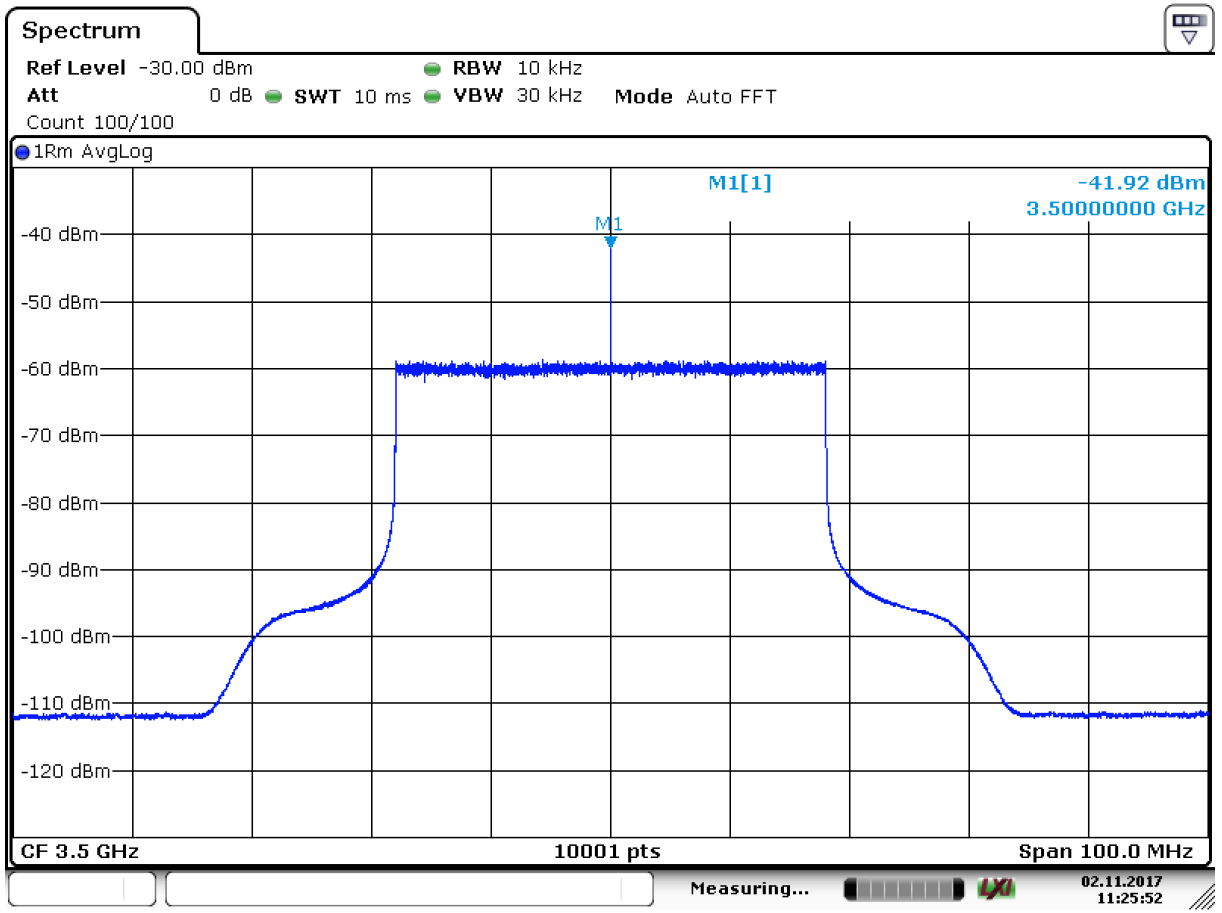
- OFDM "numerology":

$$\Delta f = {}^{1}/_{T_{Symbol}}$$

- Currently used in LTE 4G:

$\Delta f = 15kHz$ $\quad$ $T_{Symbol} = 66.7\mu s$

1200 subcarriers maximum
18MSymbols/sec
Up to 64QAM: 6 bits/symbol

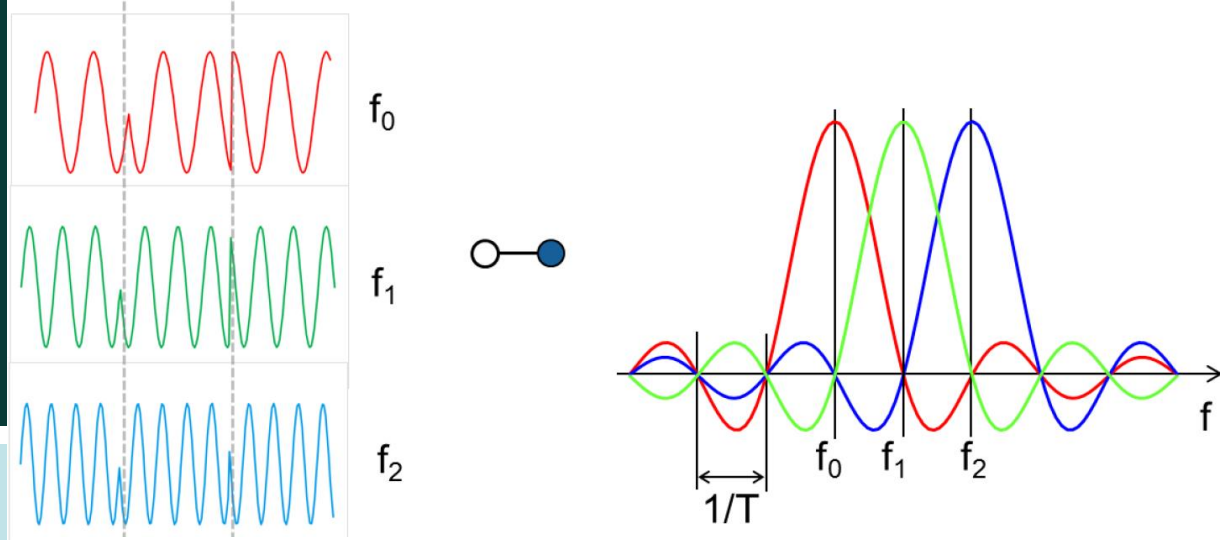


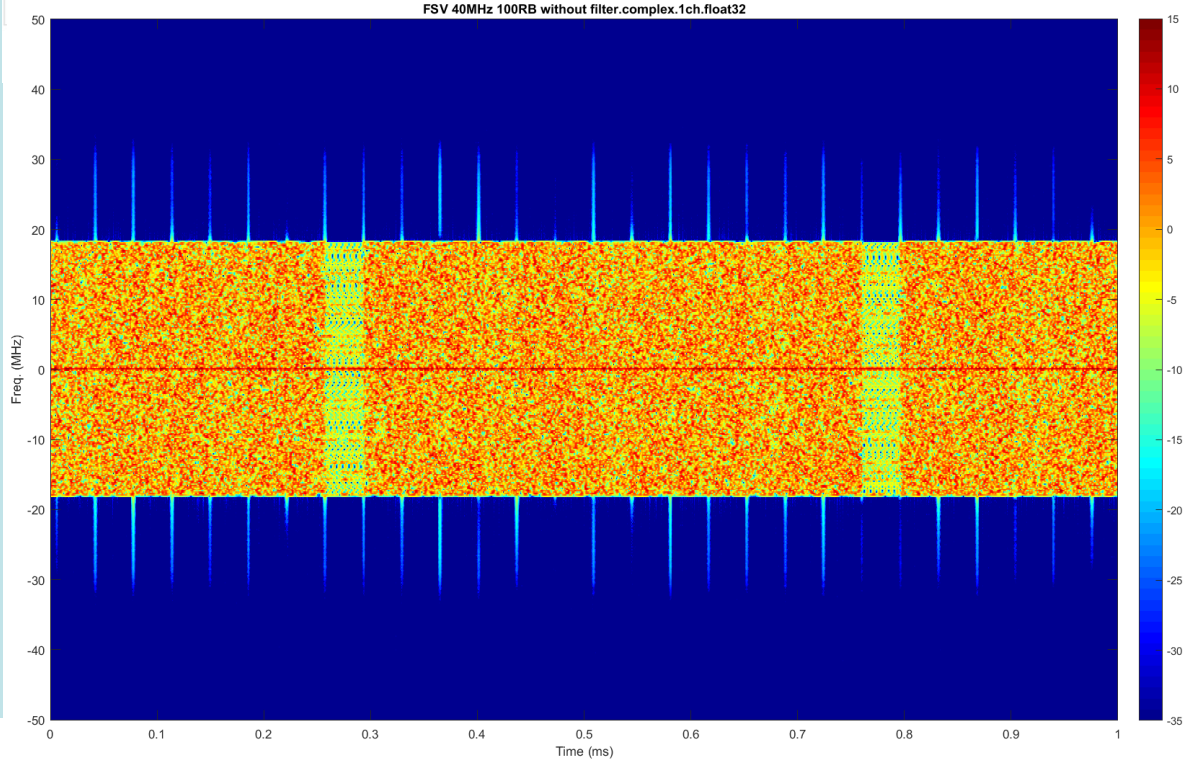
# Waveform Improvement

- Out of band (OOB) emissions
- $\Delta f, T_{Symbol}$ -> carrier orthogonality
- Minimise inter carrier interference

BUT

- Phase shifts at symbol boundaries introduce unwanted frequencies
- LTE 4G 20MHz channel include 10% guard bands

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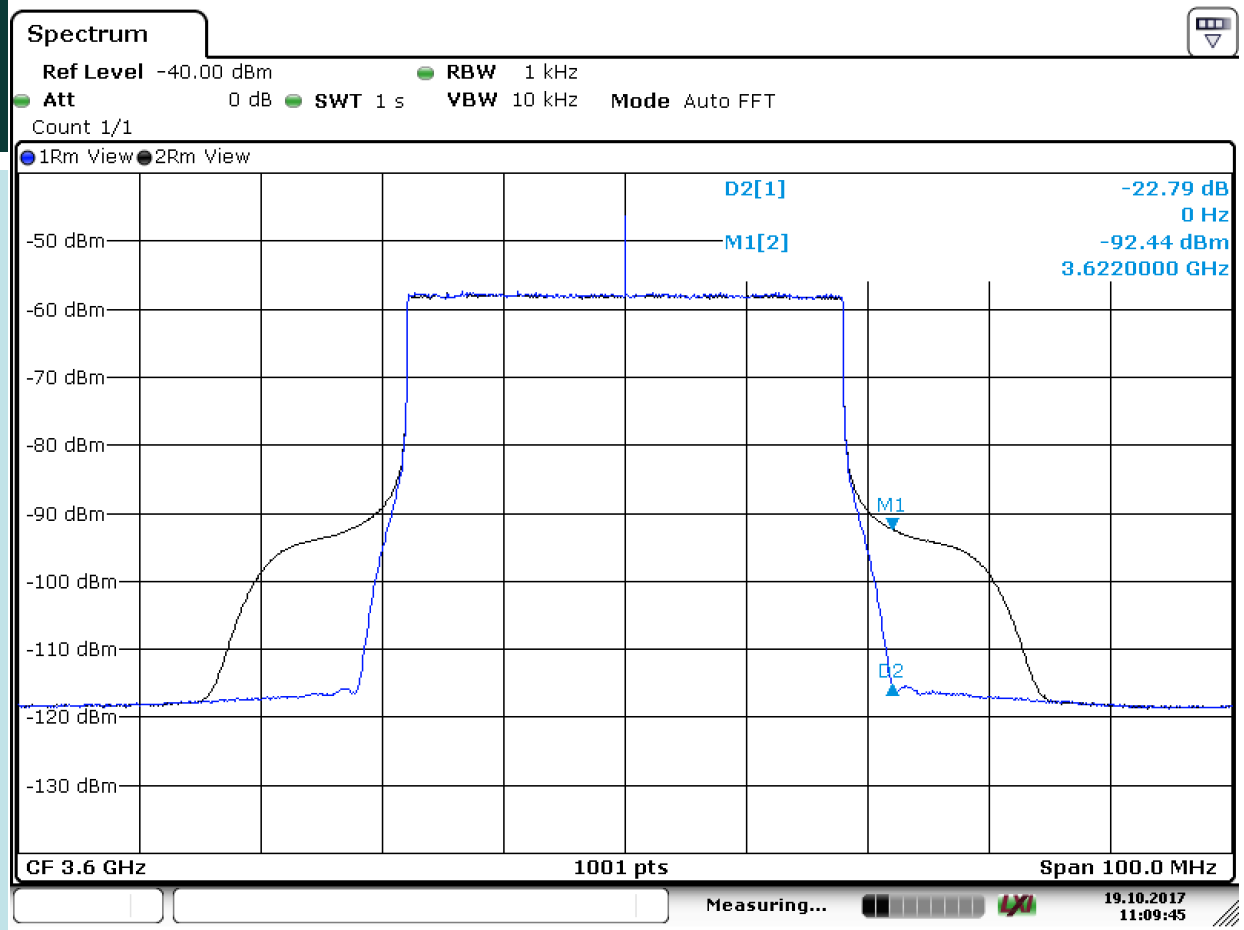
# Spectrum Shaping

$$\Delta f = 30kHz \;/\; T_{Symbol} = 33.3\mu s \;/\; 40MHz\ BW$$

- 25 tap FIR filter (Xilinx IP) inserted before DAC block
- Added to LTE Framework Downlink sample code
- Running in FPGA
- Measurement shows 22dB reduction in OOB emissions

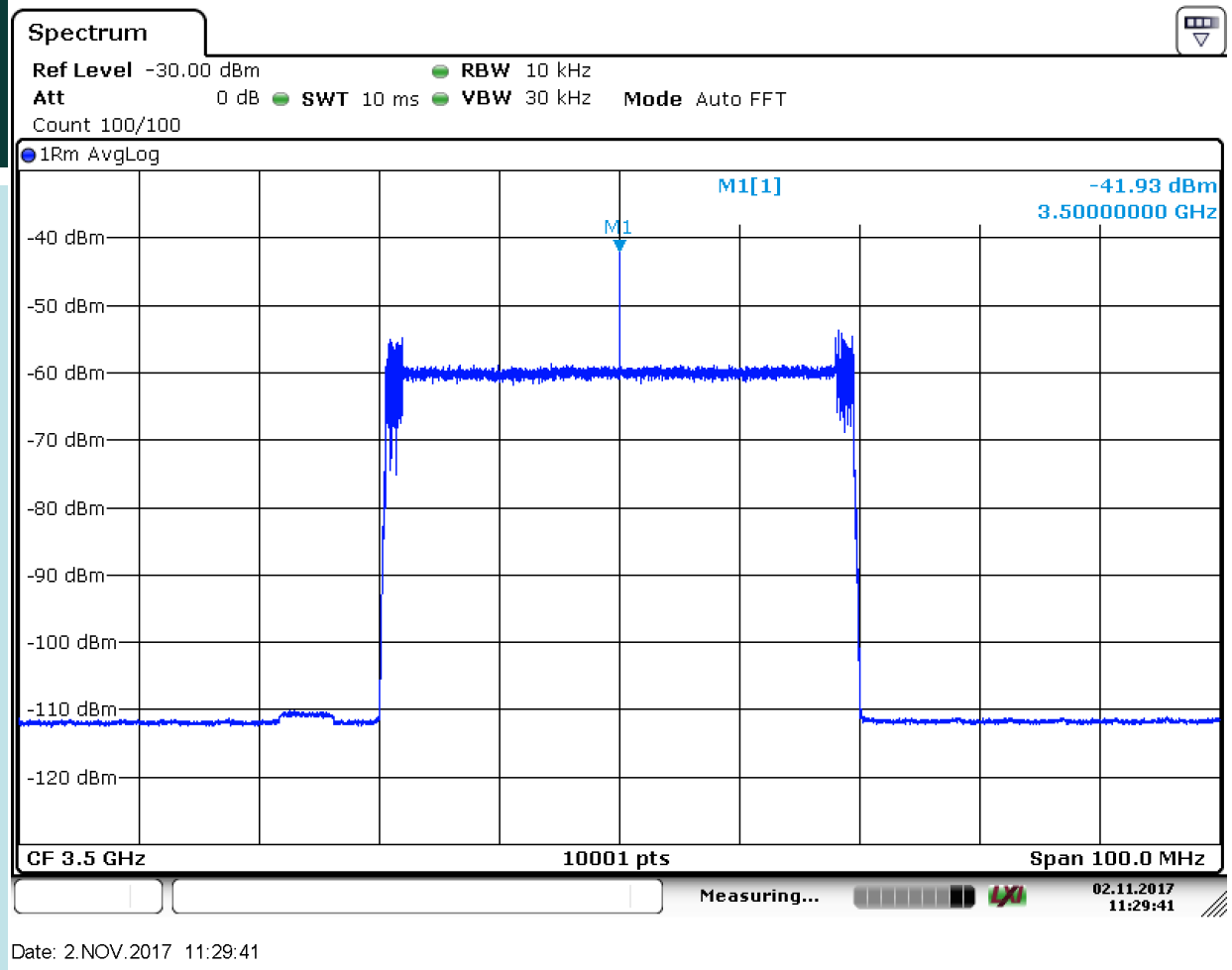


# Mixed Numerologies

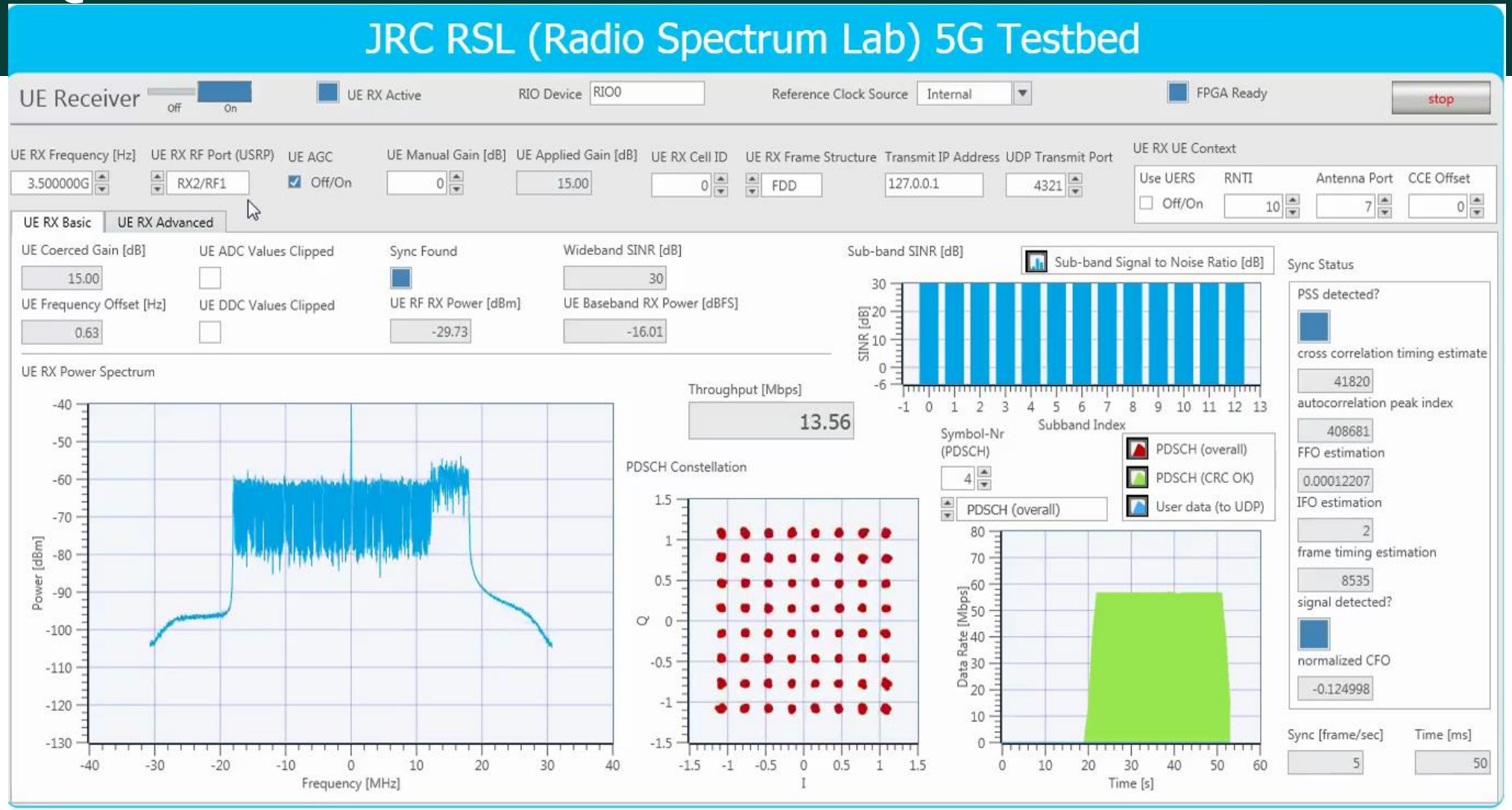
- Sharper (here 233 tap) FIR filter
- Results in occupied bandwidth increase from 90% to 97.5%
- Allows sub-bands with different numerologies:

  i.e. narrowband IoT link (here in guardband) coexisting with high-throughput link

$$\Delta f = 30kHz \;/\; T_{Symbol} = 33.3\mu s \;/\; 40MHz\ BW$$



# 64QAM Modulation

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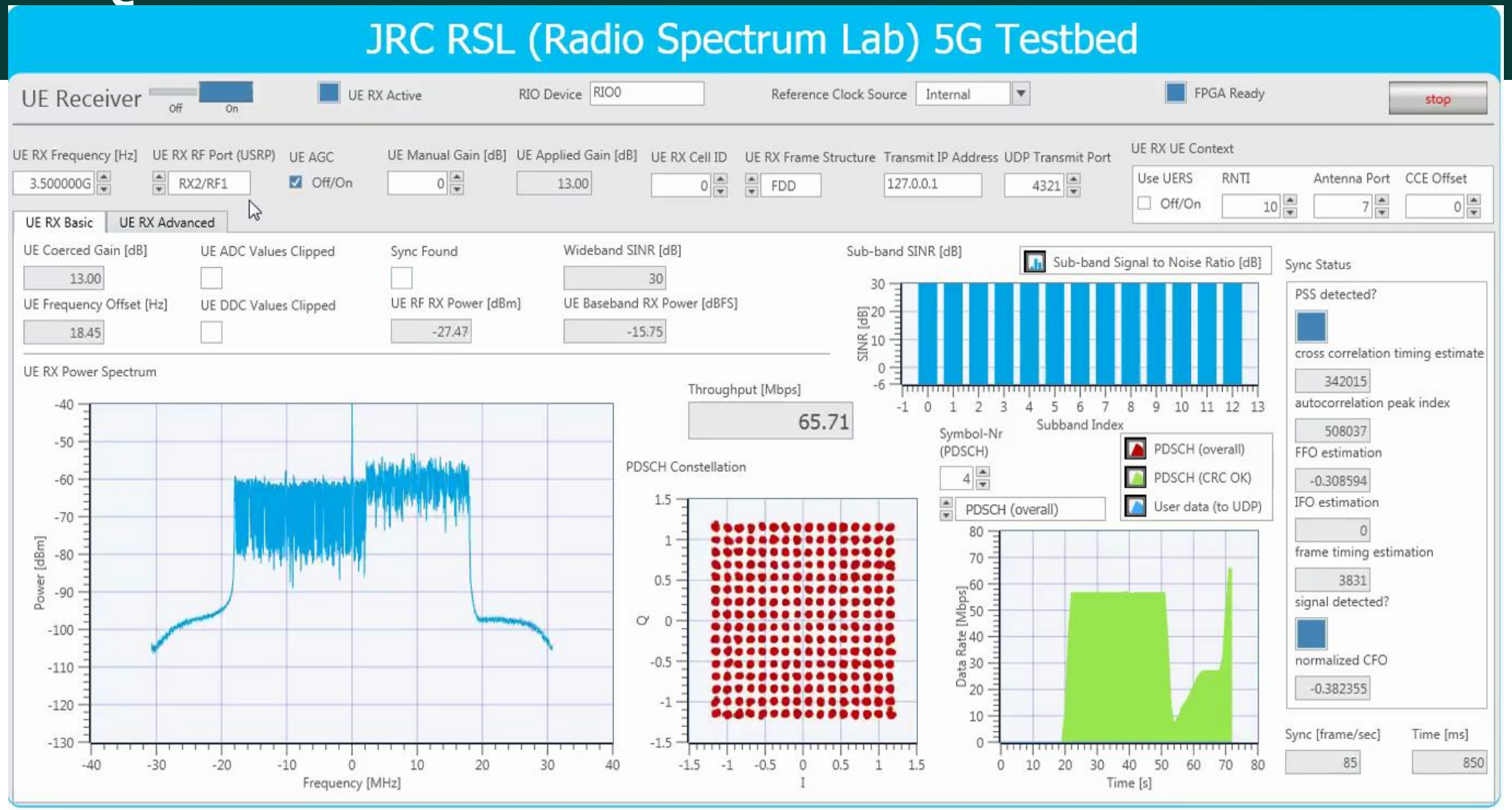
# 256QAM Modulation

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# Any questions?

You can find me james.bishop@ec.europa.eu

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