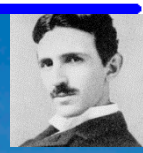
WCRG Wireless Communications Research Group



UNIVERSITY OF
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5G Test Facilities

Djuradj Budimir[#1,+2]

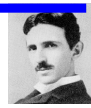
[#]Wireless Communications Research Group,
School of Computer Science and Engineering,
London, UK

[+]Schoolo of Electrical Engineering,
University of Belgrade, Serbia.

5 October 2018, Belgrade, Serbia

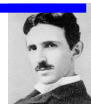
2nd E-Mobility Forum

DIGITAL MOBILITY



Outline of Presentation

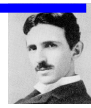
- Introduction
- 5G Frequency Spectrum
- Measurement Facilities (Test Equipment)
- Fabrication Facilities
- Computing Facilities
- WCRG Examples



Introduction

5G

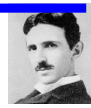
Today one of the *most dynamic sector of our global economy* is mobile wireless communications. The Telecommunications and **internet technology** are now an essential part of everyday life. The rapid growth of internet has increased the demand for high speed data connections. This growth is taking place all over the world in both developed and developing countries.



Users expect

high speed communication,
high quality,
and
reliability to easily access this resource.

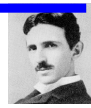
Wireless technologies are playing an increasingly important role in the implementation of broadband services and networks.



European leadership

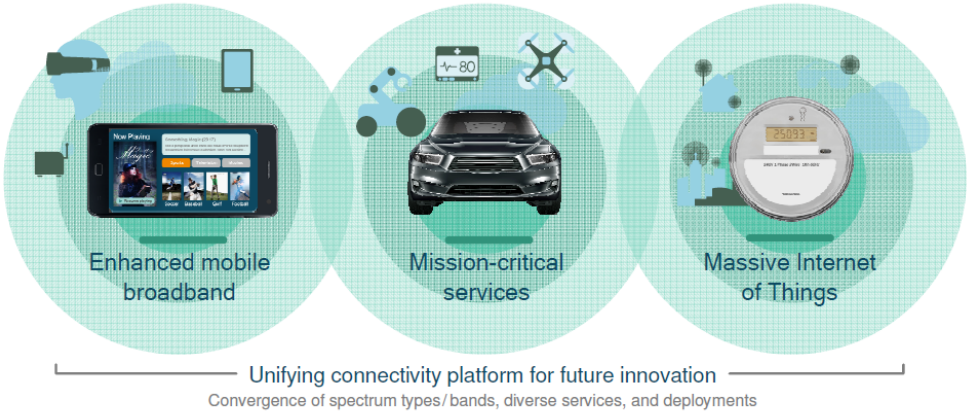
The European telecommunications industry plays a crucial role in successfully developing 5G technologies, and making Europe the leader in the field, which would ensure EU economic growth and jobs. ***Currently, the industry ensures 1.3 million EU jobs, representing a mobile telecommunication economy of €160bn***.

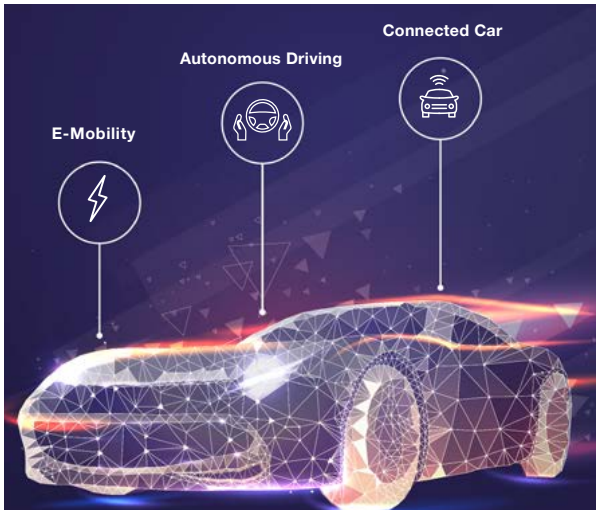
The average 10-year time cycle between two generations of communications infrastructures is quickly shrinking. Therefore, now it's time to kick-start 5G investment and position European industrial players in order to seize the first-mover advantage.



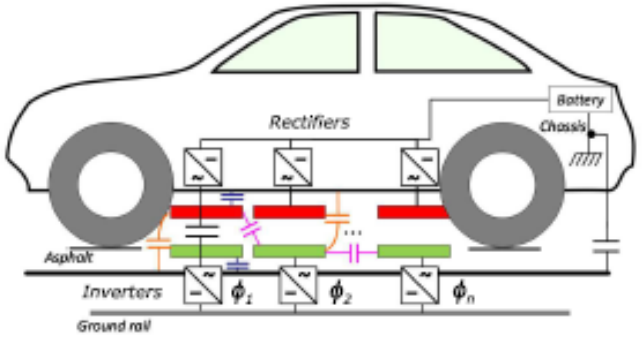
5G Technology

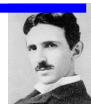
Over $12 Trillion 5G-related goods and services in 2035



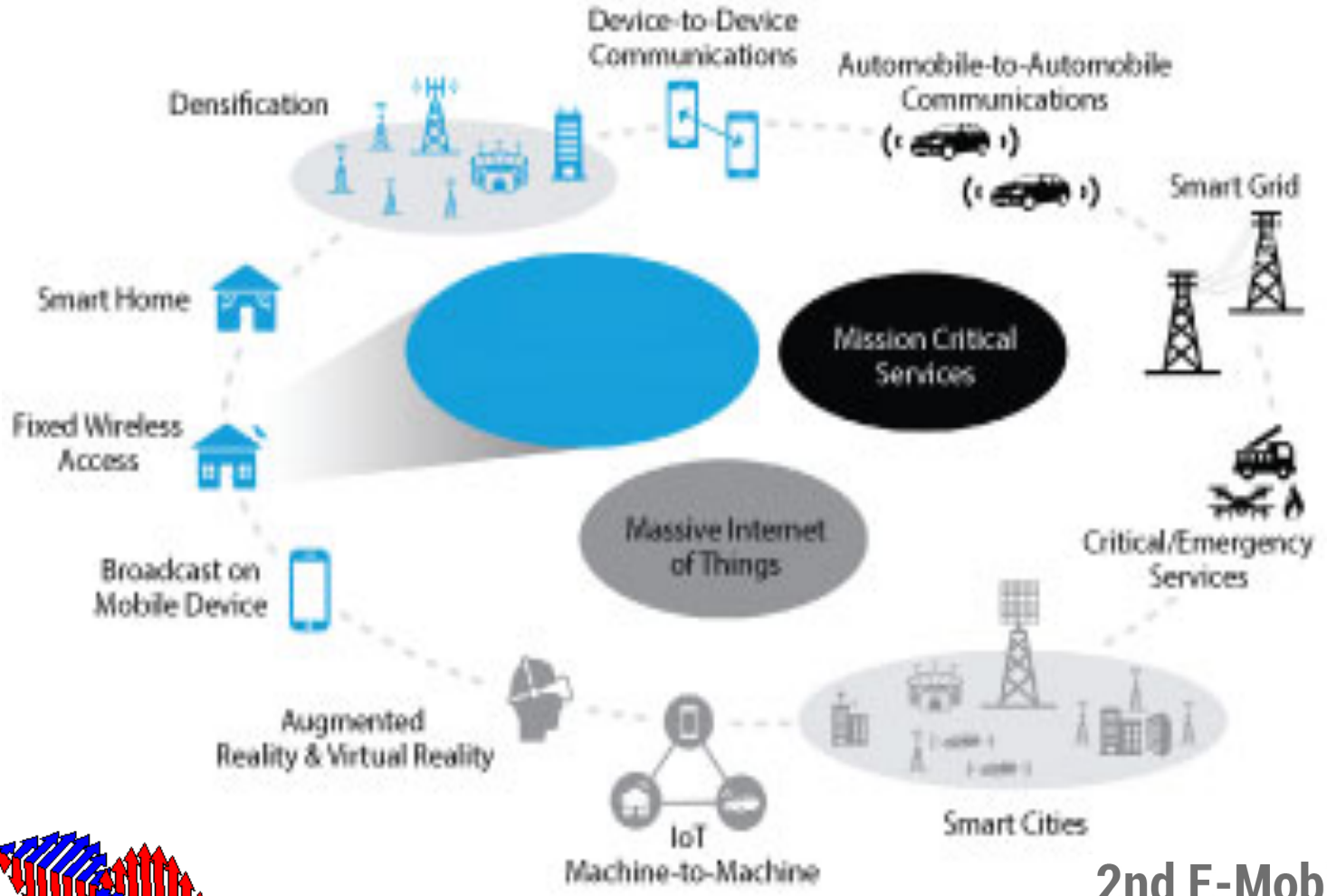


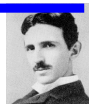
5G will enable $12 trillion of global economic activity in 2035



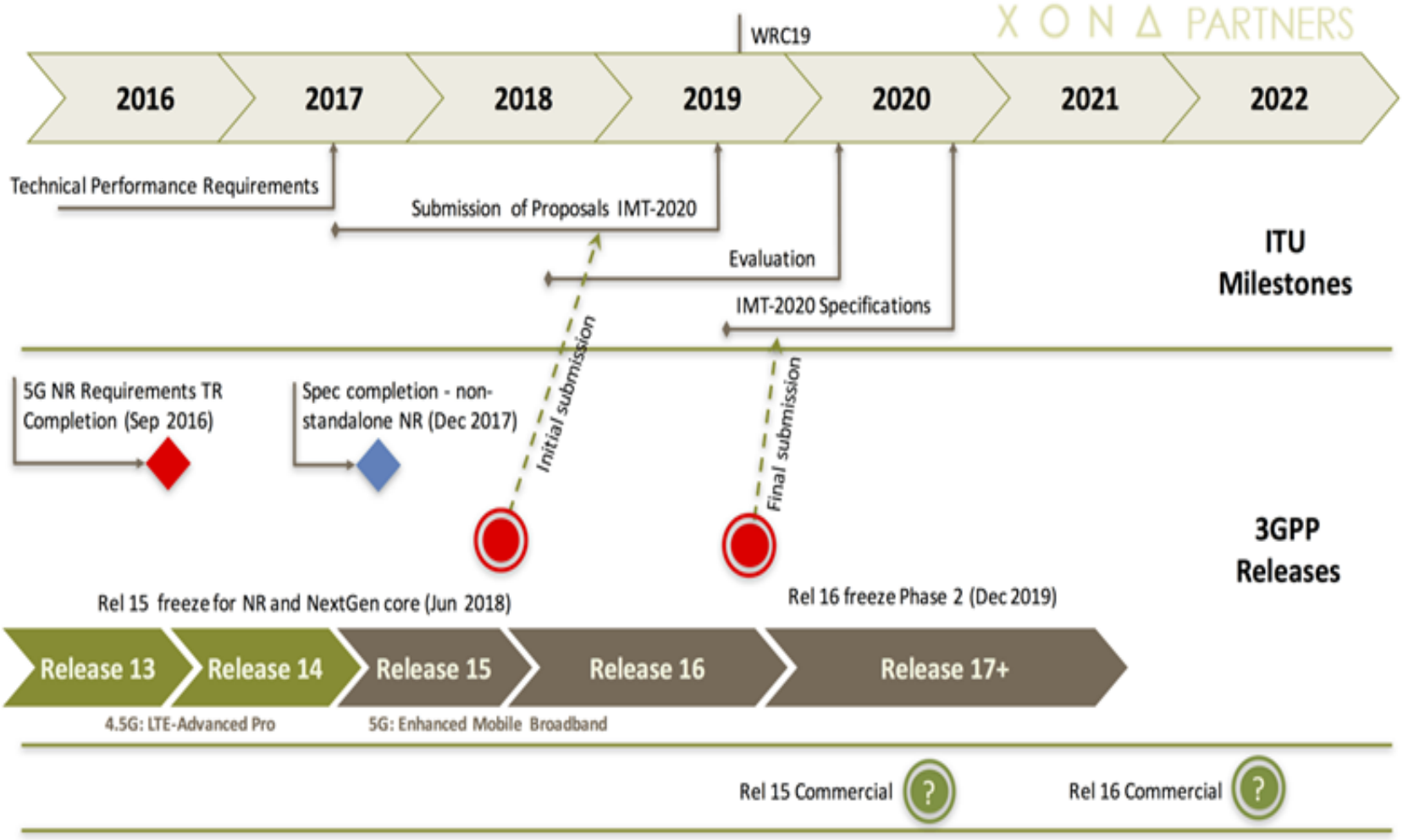


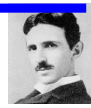
5G use cases


Device-to-Device Communications
Automobile-to-Automobile Communications
Densification
Smart Grid
Smart Home
Mission Critical Services
Fixed Wireless Access
Massive Internet of Things
Critical/Emergency Services
Broadcast on Mobile Device
Augmented Reality & Virtual Reality
Smart Cities
IoT Machine-to-Machine



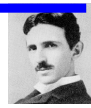
5G standardisation timeline
Standards development & deployment





The main parameters of the NR 5G are

frequency range
3GPP Release 15:
FR1: 0.45 GHz to 6.0 GHz (sub-6 GHz)
FR2: 24.25 GHz to 52.6 GHz (mmWave)
Modulation type: up to 256 QAM (DL, UL)
Transmission method/multiple access:
CP-OFDM (DL); CP-OFDM, DFT-s-OFDM (UL)
Duplex: Dynamic TDD; FDD
Channel bandwidth:
Network operators: 100 MHz/CC (Component Carrier),
Max. 800 MHz (8CC)
3GPP:
max. 100 MHz/CC (Sub-6 GHz)
max. 400 MHz/CC (mmWave)
Peak data rate: >20 Gb/s (DL)



Standardization forums: 3GPP

Frequency range: 3GPP Rel-15

FR1: 0.45 GHz to 6.0 GHz (sub-6 GHz)

Subcarrier spacing: 15/30/60 kHz

Maximum bandwidth:

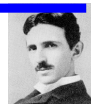
5/10/15/20/25/40/50/60/80/100 MHz

Frequency range: 3GPP Rel-15

FR2: 24.25 GHz to 52.6 GHz (mmWave)

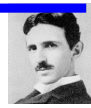
Subcarrier spacing: 60/120/240 kHz

Maximum bandwidth: 50/100/200/400 MHz 200/400 MHz



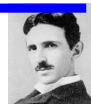
	LTE	NR Phase 1
Frequency of Operation	Up to 6 GHz	Up to 52 GHz
Carrier Bandwidth	Max: 20 MHz	Max: 100 MHz (@ <6 GHz) Max: 1 GHz (@ >6 GHz)
Carrier Aggregation	Up to 32	Up to 16
Analog Beamforming (dynamic)	Not supported	Supported
Digital Beamforming	Up to 8 Layers	Up to 12 Layers
Channel Coding	Data: Turbo Coding Control: Convolutional Coding	Data: LDPC Coding Control: Polar Coding
Subcarrier Spacing	15 kHz	15, 30, 60, 120, 240* kHz
Self Contained Subframe	Not Supported	Can be implemented
Spectrum Occupancy	90% of Channel BW	Up to 98% of Channel BW

Table 1 – Proposed mm-wave frequency bands for 5G. *For future study, not part of LTE Release 15



Frequency range/LTE band	Operators whose request is included in the frequency range
3.3-4.2 GHz	DOCOMO, KDDI, SBM, CMCC, China Unicom, China Telecom, KT, SK Telecom, LG Uplus, Etisalat, Orange, Telecom Italia, British Telecom, Deutsche Telekom
4.4-4.99 GHz	DOCOMO, KDDI, SBM, CMCC, China Unicom, China Telecom,
24.25-29.5 GHz	DOCOMO, KDDI, SBM, CMCC, KT, SK Telecom, LG Uplus, Etisalat, Orange, Verizon, T-mobile, Telecom Italia, British Telecom, Deutsche Telekom
31.8-33.4GHz	Orange, Telecom Italia, British Telecom
37-40 GHz	AT&T, Verizon, T-mobile
1.427-1.518G	Etisalat
1710-1785MHz/1805-1880MHz (Band 3)	CMCC, China Telecom
2500-2570MHz/2620-2690MHz (Band 7)	CHTTL, British Telecom
880-915MHz/925-960MHz (Band 8)	CMCC
832–862MHz/791–821MHz (Band 20)	Orange
703-748MHz/758–803MHz (Band 28)	Orange
2496-2690MHz (Band 41)	Sprint, China Telecom, C-Spire, China Unicom
1710-1780MHz/2110-2200MHz (band 66)	T-mobile
1920-1980MHz/2110-2170MHz (Band 1)	China Unicom, China Telecom

Table 2. Proposed New Radio (NR) Spectrum



Facilities available:

Measurement Facilities (Test Equipment)

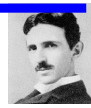
Keysight E8361A 67GHz Vector Network Analyzer for testing components for wireless and mobile communications.

Keysight N8684A 1.0 GHz Signal Generator, E4406A VSA Series Transmitter Tester, E4433B ESG-D Series RF Signal Generator, 8970B™ 26.5 GHz Noise Figure Meter, 8971C™ 26.5 GHz Noise Figure Test Set.

Keysight N5182A 6 GHz MXG Vector Signal Generator, E4433B ESG-D Series RF Signal Generator and E4406A VSA Series Transmitter Tester.

Cascade SUMMIT 9000 Wafer Probe, with four positions.

Fabrication Facilities
LPKF ProtoMat Circuit Board Plotters
LPKF CAD/CAM Systems



Computing Facilities

Keysight/Agilent *ADS2017* software.

Keysight/Agilent *Momentum* software for modeling 2.0D/2.5D complex passive structures.

CST *Microwave Studio* software for modeling 3D complex passive structures.

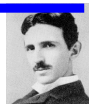
***em* Sonnet software for modeling 2D/2.5D planar passive structures.**

***EPFIL* software for electromagnetic modeling, design and optimization waveguide filters.**

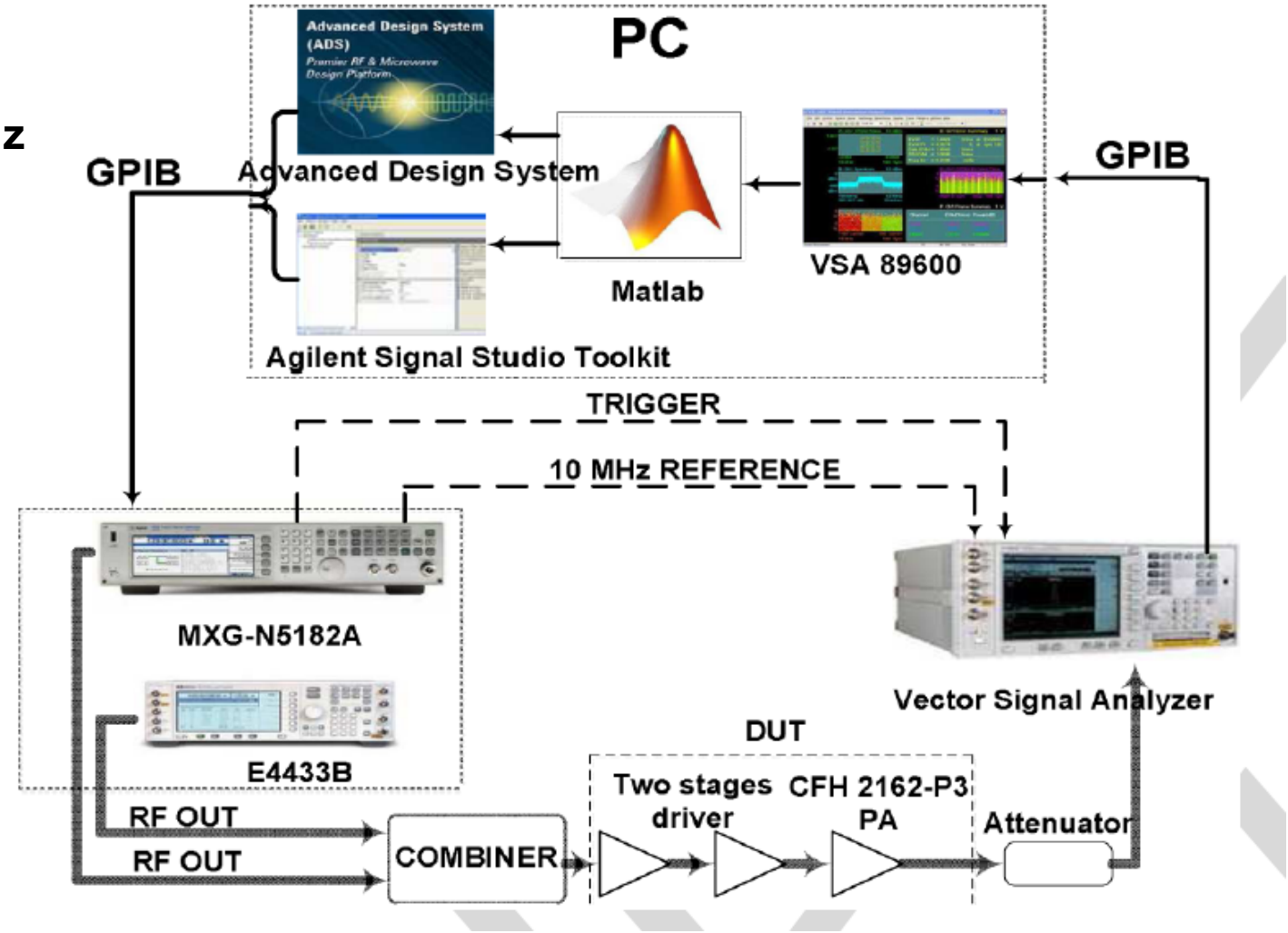
Comarco Wireless Technologies-EDX, SignalPro™:

MATLAB

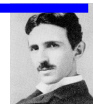
WCRG Results



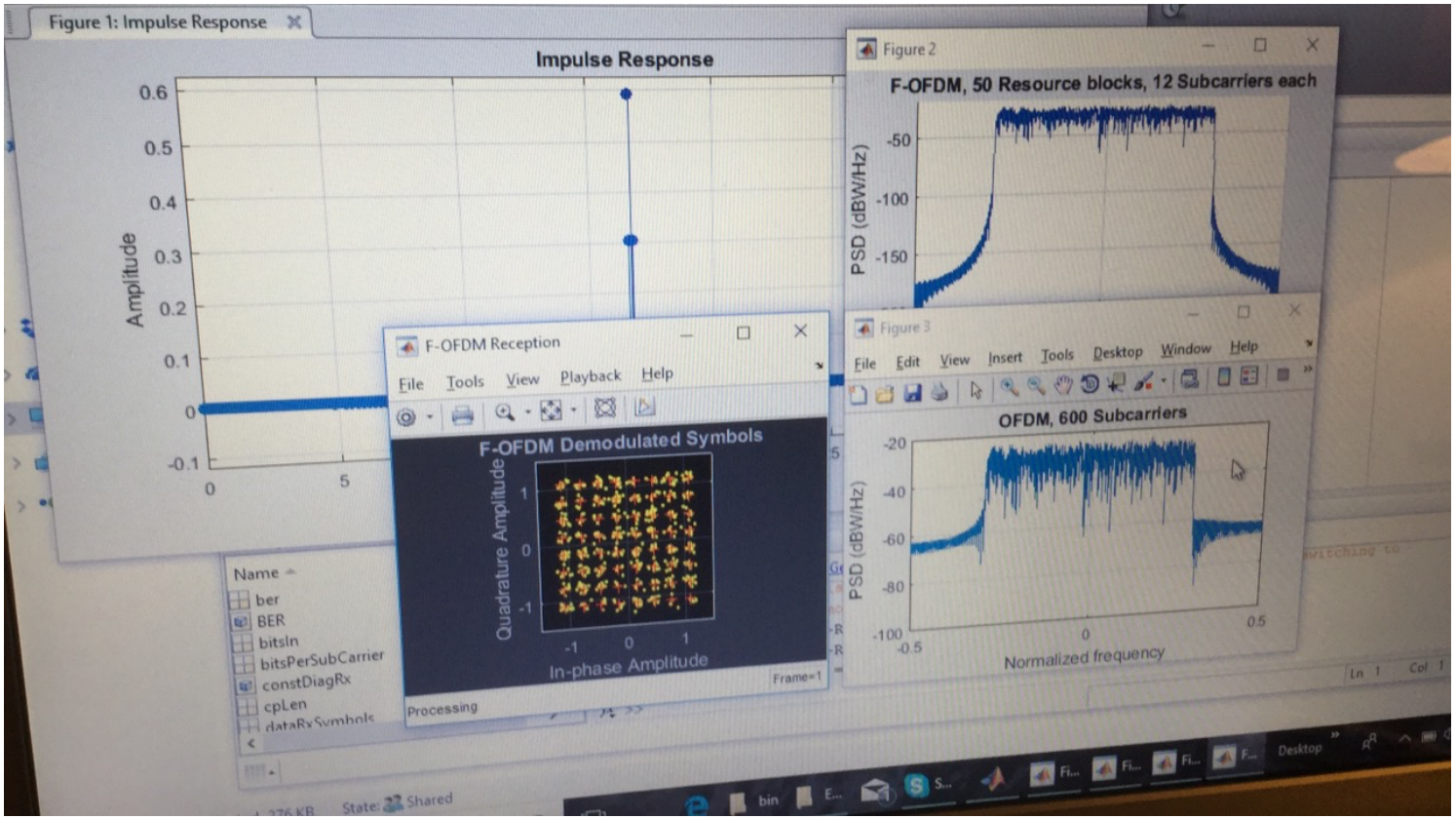
f=1.52/0.7 GHz



Experimental setup of single band transmitter for 5G mobile system

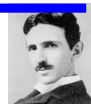


WCRG Results

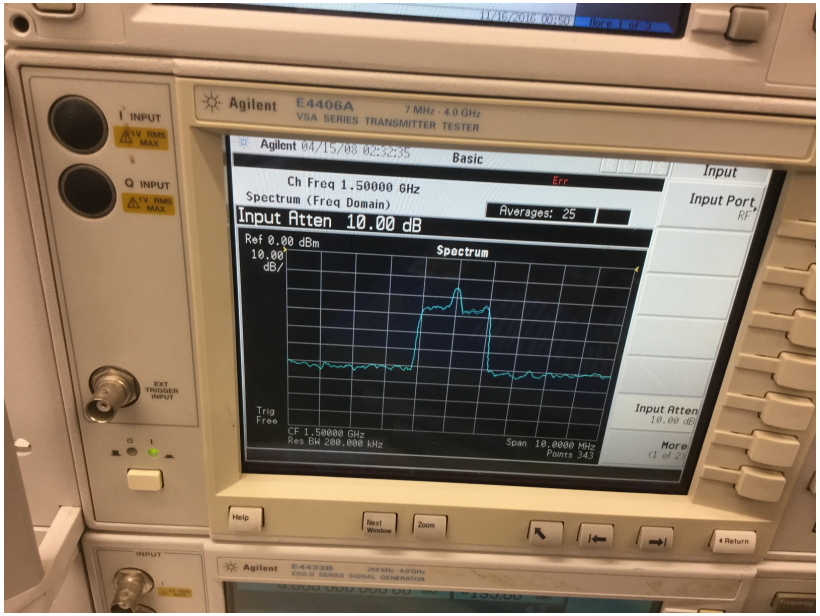


5G waveform: Matlab

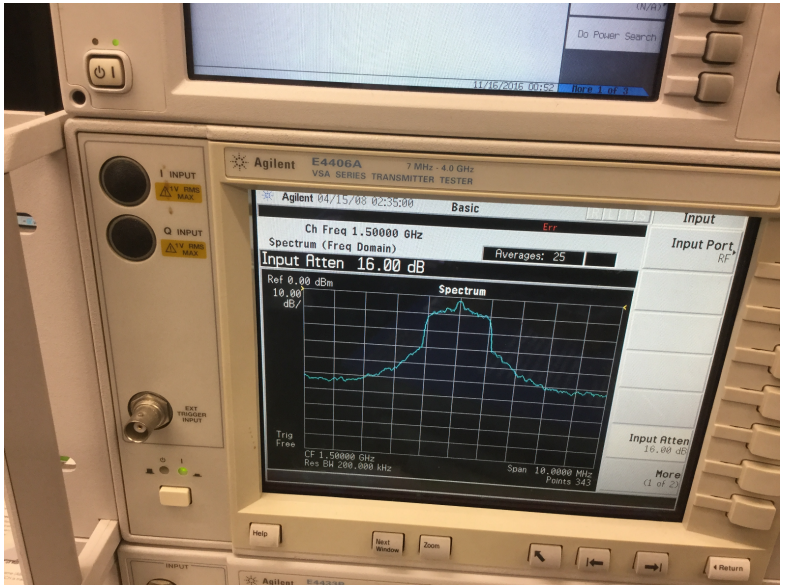
WCRG Results



Example: 5G Waveform (FBMC signal at input of a power amplifier as DUT



5G Waveform (FBMC signal at output of a power amplifier as DUT



1520 MHz 5G band

5G waveform : 3 MHz FBMC signal

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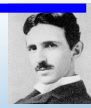
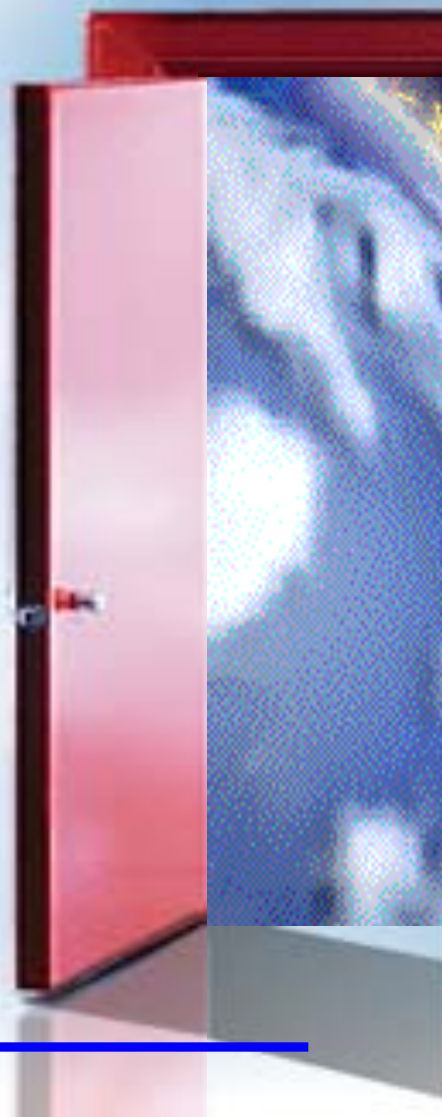


THANK YOU

Questions?



Email: d.budimir@wmin.ac.uk
Email: d.budimir@etf.rs
Web: http://www2.wmin.ac.uk/~budimid/
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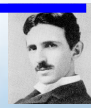

XBAJA

Email: d.budimir@wmin.ac.uk
Email: d.budimir@etf.rs
Web: http://www2.wmin.ac.uk/~budimid/

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