ELE101 SDR&DSP&Decibel

Murat Sever
ytregitim@gmail.com

Outline

- Quick review
- SDR & Digital Communications
- Decibel Calculation
- Python 101

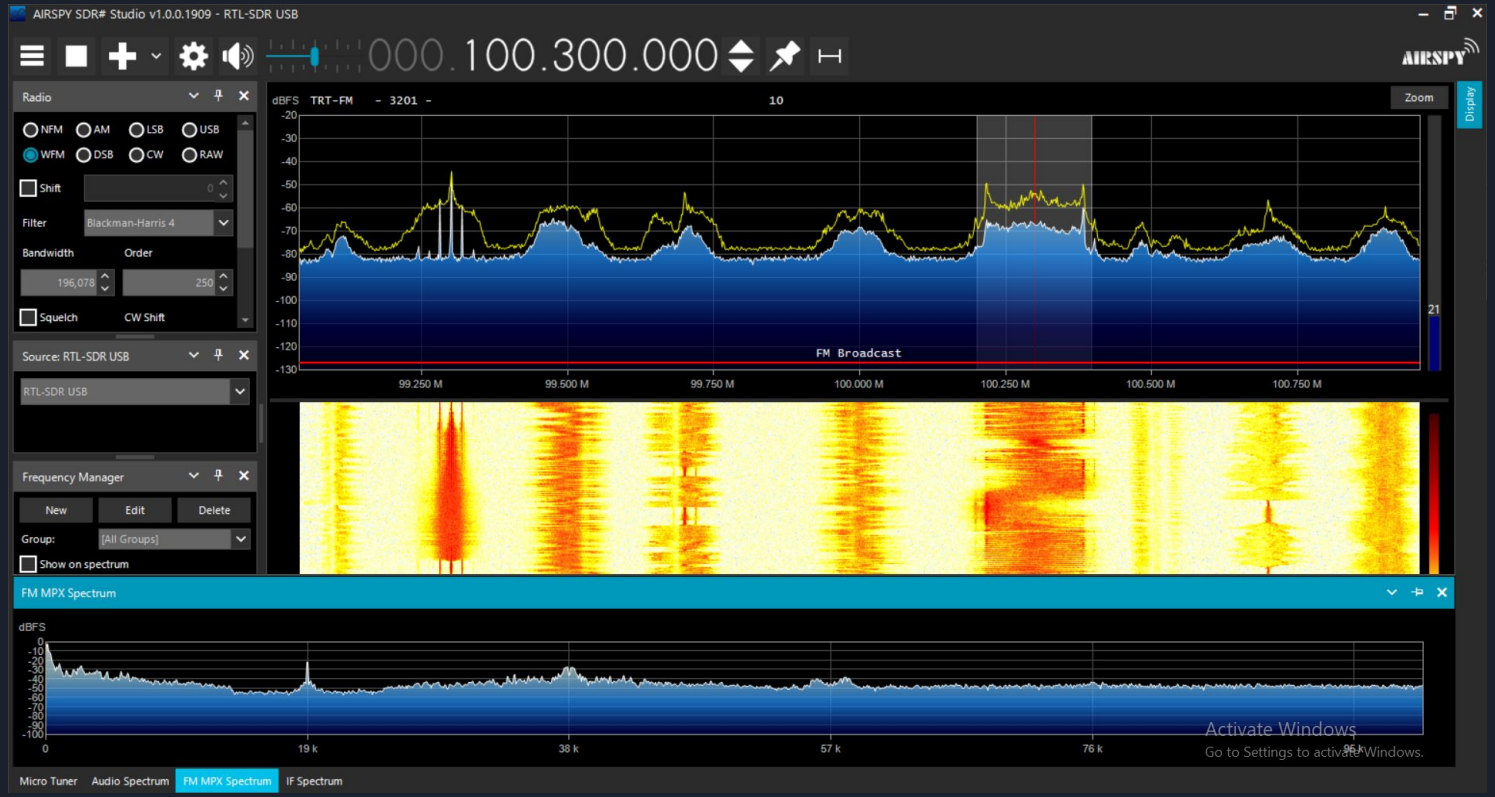
Review

- Git-GitHub
- Linux
- miniconda
- Jupyter Lab
- Python
- Communication Systems

Assignment Submission

- Accept the assignment
- A new repo will be created for you, automatically
- Clone assignment repo into your PC
- change to your local directory (using cd command)
- Follow instructions in the README file
- Submit your assignment using git commands
    - *git add .*
    - *git commit - m “something message here”*
    - *git push*

Merhaba Dünya: WBFM



Communication Systems

- Described as Band, Frequency, or Wavelength
- Bands: VHF
- Frequency: 100 MHz
- Wavelength: 3 m
- lambda * frequency = speed of light
  - $\lambda * f = c$
- Wavelength (in m) = 300 / (frequency in MHz)

Yazılım Tabanlı Radyo

YTR Özellikleri

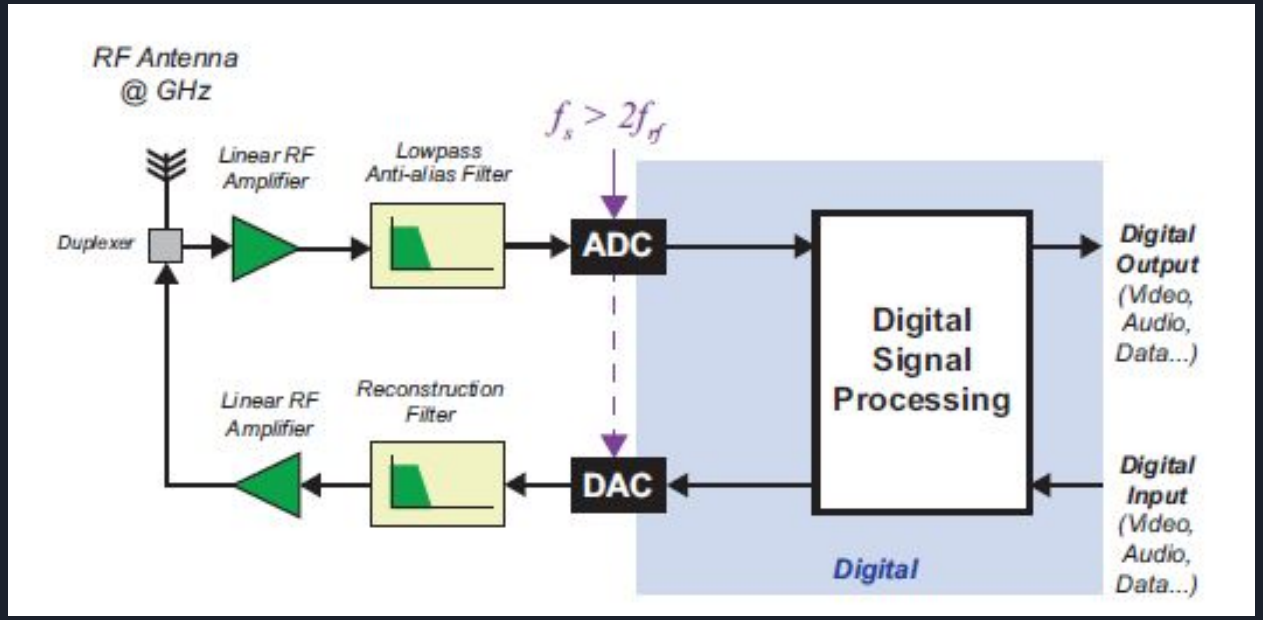
- Frekans Kapsaması
- Dar/Geniş anlık bant genişliği

  Ara yüz (USB, Ethernet, PCIe)
- Rx/Tx, half-duplex, full-duplex, MIMO
- Preselektörler
- Bütçe: 50$-...k$

RTL-SDR

- 8-bit ADC
- 24MHz-1.7GHz (değişkenlik gösterebilir)
- 2.4Msps BW (kararlı) 3.2MHz'e kadar
- "*HamItUp*" upconverter
  - HF kapsam

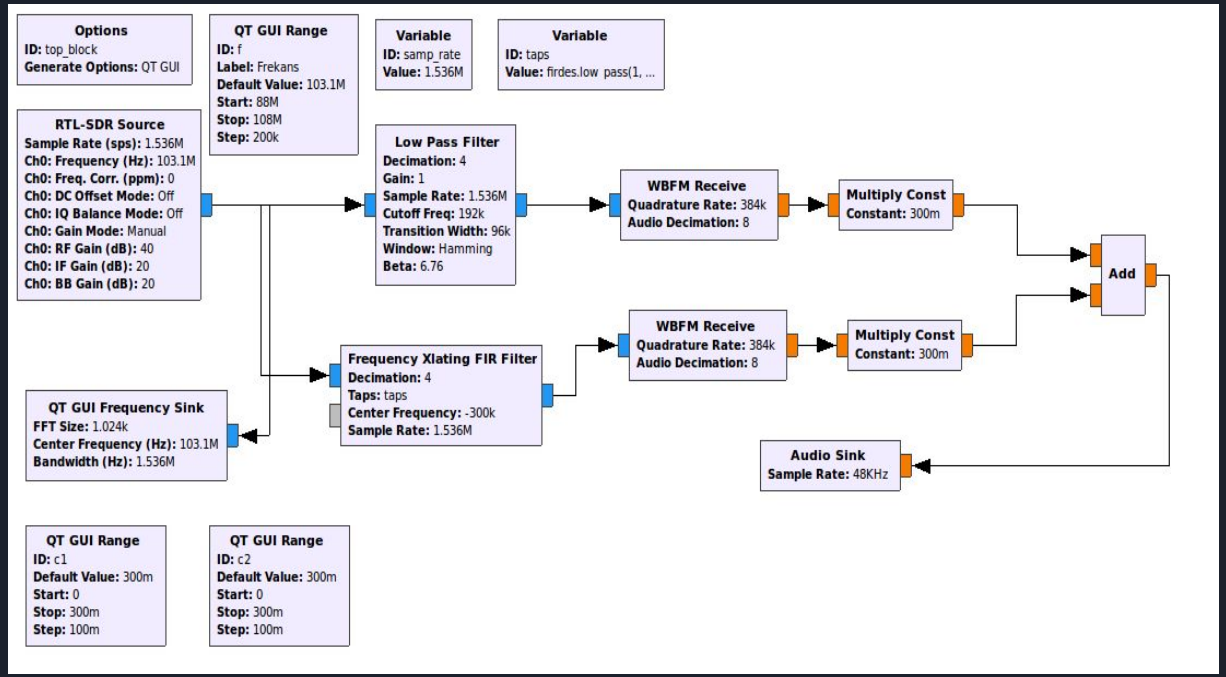
YTR Mimarisi



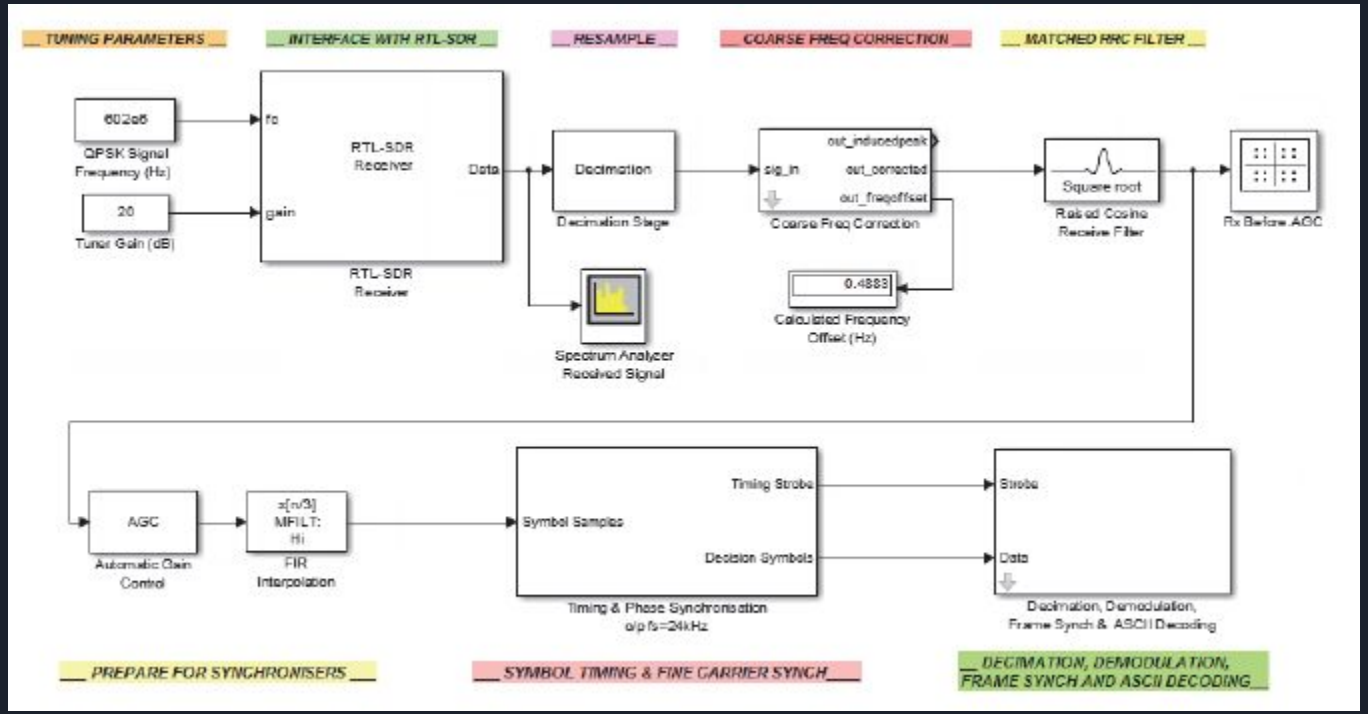
SDR Ortamları

- Hazır uygulamalar
  - SDR# (Windows)
  - gqrx (Linux, Mac)
  - SDR++, SDRAngel
- Kod tabanlı
  - C++, MATLAB, Python
- Blok tabanlı
  - GNU Radio, Simulink, LabView

GNU Radio


Options
ID: top_block
Generate Options: QT GUI
QT GUI Range
ID: f
Label: Frekans
Default Value: 103.1M
Start: 88M
Stop: 108M
Step: 200k
Variable
ID: samp_rate
Value: 1.536M
Variable
ID: taps
Value: firdes.low_pass(1, ...
RTL-SDR Source
Sample Rate (sps): 1.536M
Ch0: Frequency (Hz): 103.1M
Ch0: Freq. Corr. (ppm): 0
Ch0: DC Offset Mode: Off
Ch0: IQ Balance Mode: Off
Ch0: Gain Mode: Manual
Ch0: RF Gain (dB): 40
Ch0: IF Gain (dB): 20
Ch0: BB Gain (dB): 20
Low Pass Filter
Decimation: 4
Gain: 1
Sample Rate: 1.536M
Cutoff Freq: 192k
Transition Width: 96k
Window: Hamming
Beta: 6.76
WBFM Receive
Quadrature Rate: 384k
Audio Decimation: 8
Multiply Const
Constant: 300m
Add
WBFM Receive
Quadrature Rate: 384k
Audio Decimation: 8
Multiply Const
Constant: 300m
Frequency Xlating FIR Filter
Decimation: 4
Taps: taps
Center Frequency: -300k
Sample Rate: 1.536M
QT GUI Frequency Sink
FFT Size: 1.024k
Center Frequency (Hz): 103.1M
Bandwidth (Hz): 1.536M
Audio Sink
Sample Rate: 48KHz
QT GUI Range
ID: c1
Default Value: 300m
Start: 0
Stop: 300m
Step: 100m
QT GUI Range
ID: c2
Default Value: 300m
Start: 0
Stop: 300m
Step: 100m

Simulink


TUNING PARAMETERS
INTERFACE WITH RTL-SDR
RESAMPLE
COARSE FREQ CORRECTION
MATCHED RRC FILTER
602e6
QPSK Signal Frequency (Hz)
20
Tuner Gain (dB)
fc
gain
RTL-SDR Receiver
Data
RTL-SDR Receiver
Decimation
Decimation Stage
Spectrum Analyzer Received Signal
out_inducedpeak
sig_in
out_corrected
out_freqoffset
Coarse Freq Correction
0.4883
Calculated Frequency Offset (Hz)
Square root
Raised Cosine Receive Filter
Rx Before AGC
AGC
Automatic Gain Control
x[n/3] MFILT: Hi
FIR Interpolation
Symbol Samples
Timing Strobe
Decision Symbols
Timing & Phase Synchronisation o/p fs=24kHz
Strobe
Data
Decimation, Demodulation, Frame Synch & ASCII Decoding
PREPARE FOR SYNCHRONISERS
SYMBOL TIMING & FINE CARRIER SYNCH
DECIMATION, DEMODULATION, FRAME SYNCH AND ASCII DECODING

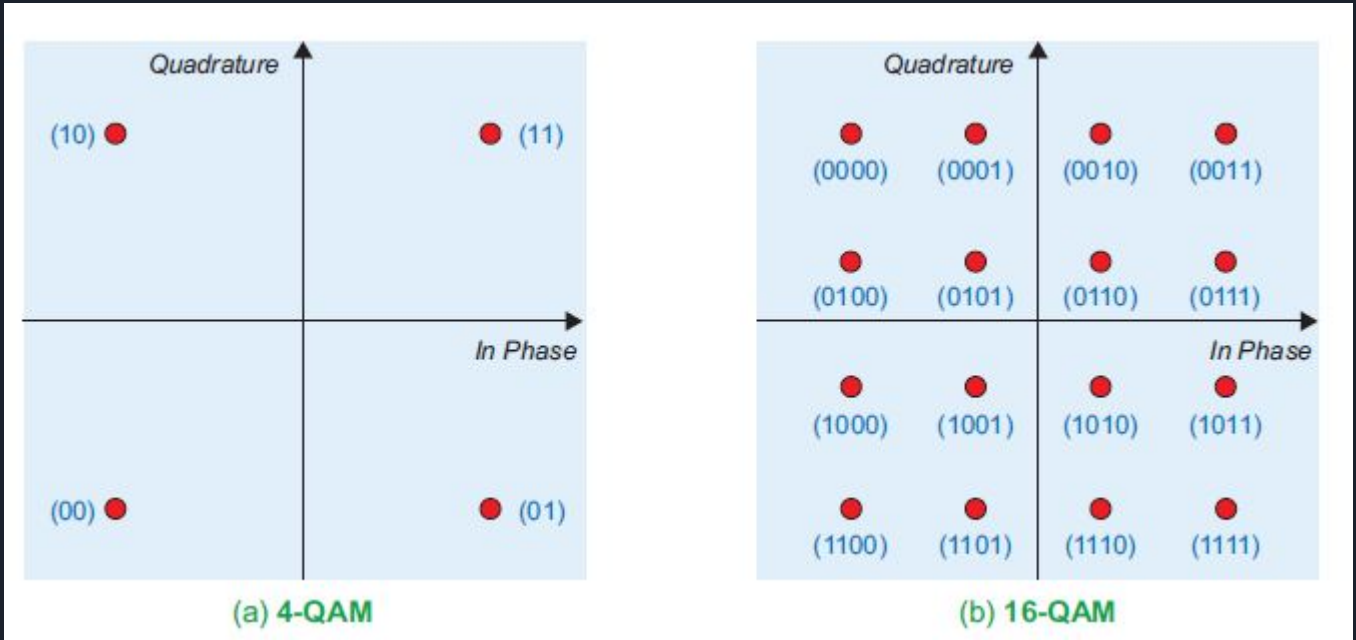
Projeler, projeler ...

- Hava Trafik Kontrolü
- Uçaklar, ADS-B
- Gemiler, AIS
- Hava Durumu Balonları/Uyduları
- Lastik basıncı
- Tersine Mühendislik: Medikal cihazlar
- Pasif Radar
- Yön/Konum Bulma

Sayısal Haberleşme

- Gürültüye Dayanıklılık
- Sıkıştırma ve Verimlilik
- Güvenlik
- Tekrar Oluşturma ve Kaydetme

Sayısal Modülasyon



Mobilite

- 1990’lar mesajlaşma, 2G, kbps
- 2000s 3G, 100kbps, WiFi
- Bugün: LTE, WiFi, MIMO
- Yarın: 5G, IoT
- Akıllı Telefonlar (velcro yaklaşımı, ~8 radios)
  - GSM (900M)
  - GPS (1.5G)
  - WiFi, Bluetooth (2.4G)
  - LTE (800M)
  - UMTS (2.1G)

The HISTORY and FUTURE of Wi-Fi

Learn more about IEEE 802.11 testing:
www.rohde-schwarz.com/wlan

HOME AND OFFICE NETWORKS | M2M AND IoT NETWORKS | ROOM AND DESK AREA NETWORKS | VEHICLE NETWORKS

WavesLAN, the starting point for Wi-Fi development, was used for wirelessly connecting cashing machines.

802.11 b
Higher speed physical layer extension in the 2.4 GHz band
Spatial streams: 1x1 SISO | Modulation type: CCK
Channel bandwidth: 22 MHz | Bands: 2.4 GHz
Transmission/access method: CSMA/DSSS

802.11 a
High speed physical layer in the 5 GHz band
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 20 MHz | Bands: 5 GHz
Transmission/access method: CSMA/OFDM

Need for faster speed and better distance coverage.

802.11 g
Further higher data rate extension
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 20 MHz | Bands: 2.4 GHz
Transmission/access method: CSMA/OFDM

The ability to connect to the internet via mobile devices and the rising number of smartphones on the market required the introduction of features like MIMO.

802.11 n
Enhancements for higher throughput (HT)
Spatial streams: 4x4 SU-MIMO | Modulation type: 64QAM
Channel bandwidth: 40 MHz | Bands: 2.4/5 GHz
Transmission/access method: CSMA/OFDM

More and more people wanted Wi-Fi at home and at work. High speed Wi-Fi was therefore required in the 5 GHz spectrum to relieve the over-crowded 2.4 GHz spectrum.

802.11 ac
Enhancements for very high throughput (VHT)
Spatial streams: 8x8 DL-MU-MIMO | Modulation type: 256QAM
Channel bandwidth: 160 MHz | Bands: 5 GHz
Transmission/access method: CSMA/OFDM

Designed for in-room/desk network applications requiring very high data rates such as for HD video streaming.

802.11 ad
Directional multi-gigabit (DMG) in the 60 GHz band
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 2.16 GHz | Bands: 60 GHz
Transmission/access method: CSMA/SC

Achieves up to 20 Gbit/s throughput and enables extended distances for enlarged application space.

802.11 ay
Enhanced DMG (EDMG) in bands above 45 GHz
Spatial streams: 8x8 MU-MIMO | Modulation type: 64QAM
Channel bandwidth: 8.64 GHz | Bands: > 45 GHz
Transmission/access method: CSMA/OFDM

Enables use of the sub GHz spectrum for IoT and remote internet applications.

802.11 af
Television very high throughput (TVHT)
Spatial streams: 4x4 DL-MU-MIMO | Modulation type: 256QAM
Channel bandwidth: 6/7/8 MHz | Bands: sub GHz
Transmission/access method: CSMA/OFDM

802.11 ah
Sub 1 GHz License exempt
Spatial streams: 4x4 DL-MU-MIMO | Modulation type: 256QAM
Channel bandwidth: 1/2/4/8/16 MHz | Bands: sub GHz
Transmission/access method: CSMA/OFDM

The heavy use of Wi-Fi meant that a new approach was required. OFDMA allows multiple devices to communicate simultaneously.

802.11 ax
Enhancement for high efficiency (HE) Wi-Fi
Spatial streams: 8x8 MU-MIMO | Modulation type: 1024QAM
Channel bandwidth: 160 MHz | Bands: 2.4/5/6 GHz
Transmission/access method: CSMA/OFDM/OFDMA

802.11 be
Enhancements for extreme high throughput (EHT)
Spatial streams: 16x16 MU-MIMO | Modulation type: 4096QAM
Channel bandwidth: 320 MHz | Bands: 2.4/5/6 GHz
Transmission/access method: CSMA/OFDM/OFDMA

The advent of home office and schooling as well as industrial applications require improved data throughput, reduced latency and efficiency.

802.11 p
Wireless access in vehicular environments
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 10 MHz | Bands: 5.9 GHz
Transmission/access method: CSMA/OFDM

Provide Wi-Fi based car-to-car communications to enable emerging intelligent traffic services.

802.11 bd
Enhancements for next generation vehicular (NGV)
Spatial streams: 2x2 SU-MIMO | Modulation type: 256QAM
Channel bandwidth: 10, 20 MHz | Bands: 5.9/60 GHz
Transmission/access method: CSMA/OFDM

Meet today's and tomorrow's rising demands on V2X communications on the way to fully autonomous vehicles.

Multi-antenna transceiver methods

The evolution from SISO to single-user and multi-user MIMO was essential to meet data throughput demands.

Single input single output (SISO)
Use of a single antenna on access points and devices for sequential communications of the access point with connected devices, applying a carrier sense multiple access (CSMA) scheme to control spectrum access.

Single-user multiple input multiple output (SU-MIMO)
Use of multiple antennas to improve data throughput, applying a carrier sense multiple access /CSMA) scheme to control spectrum access.

Multi-user MIMO
Based on OFDMA, MU-MIMO allows simultaneous communications of stations in parallel. Beamforming enables multiple users to apply individual MIMO schemes at the same time to ensure efficient communications.

Test and measurement solutions from Rohde & Schwarz

R&S®CMW270
wireless connectivity tester
The non-cellular expert designed for testing Wi-Fi access points (AP) and stations (STA) in signaling and non-signaling mode.

R&S®CMW100
communications manufacturing test set
Ultra-compact non-signaling tester optimized for production line testing including 4G, 5G and Wi-Fi 6 wireless technologies.

R&S®SMW200A
vector signal generator
The flagship of signal generation – supports Wi-Fi modulation at full bandwidth and enables MIMO testing with real-time fading.

R&S®SMBV100B
vector signal generator
The new benchmark in its class with up to 500 MHz modulation bandwidth and perfect accuracy even at high output power levels.

R&S®FSW
signal and spectrum analyzer
Setting standards in innovation and usability for testing Wi-Fi devices with 800 MHz real-time analysis bandwidth.

R&S®FSVA3000
signal and spectrum analyzer
The right choice for Wi-Fi RF spectrum and signal analysis in R&D. Supports 1GB MHz analysis bandwidth.

R&S®TS8997
regulatory test system for wireless devices
Testing of wireless devices operating in the ISM bands in line with ETSI and FCC standards.

R&S®OST200
RF Bugnotic chamber
Ideal environment for RF analysis during development. Supports a wide range of radiated test applications for Wi-Fi devices.

ROHDE&SCHWARZ
Make ideas real

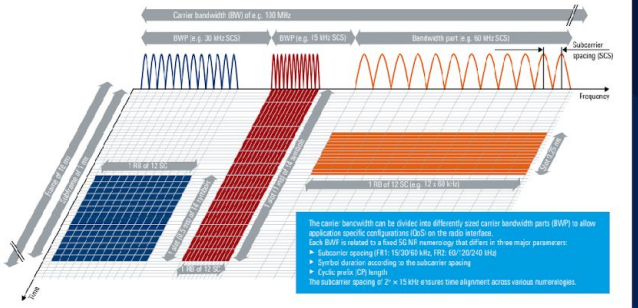
Hücresel Teknoloji

- 1G - 1979
  - Analog, voice only
- 2G - 1991
  - SMS, MMS, WAP
  - TDMA
  - 200k
- 3G UMTS - 1998
  - WCDMA
  - 5M
- 4G LTE - 2008
  - OFDMA
  - 1.4M-20M
- 5G - 2019

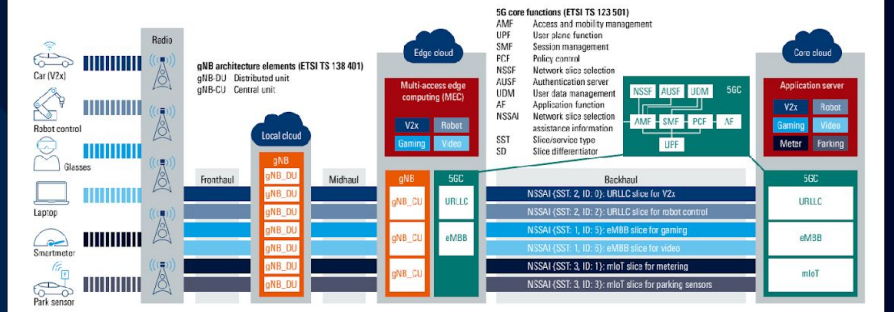
DEMYSTIFYING 5G NR

For more information:

Flexible 5G NR numerology

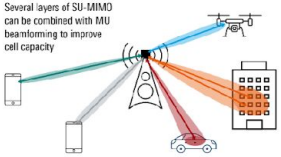


Flexible 5G network architecture with different virtualization layers



Increasing cell capacity with massive MIMO

Several layers of SU-MIMO can be combined with MU beamforming to improve cell capacity



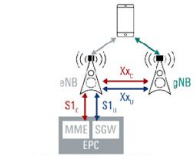
Key parameters in line with 3GPP Rel. 16

Key parameters	FR1	FR2
Carrier aggregation	Up to 16 carriers	
Bandwidth per carrier	5/10/15/20/25/30/40/50/50/70/80/90/100 MHz	50/100/200/400 MHz
Subcarrier spacing	15/30/60 kHz	60/120/240 kHz
Maximum modulation scheme	DL and UL: 256QAM	
MIMO scheme	DL: up to 8 layers UL: up to 4 layers	DL: up to 2 layers UL: up to 2 layers
Duplex mode	TDD (focus), FDD	TDD
Access scheme	DL: CP-OFDM, UL: CP-OFDM, DFT-s-OFDM	

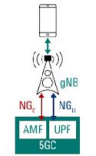
5G NR flexible numerologies

Subcarrier spacing (in kHz)	15	30	60	120	240
Symbol duration (µs)	66.7	33.3	16.7	8.33	4.17
CP duration (µs)	4.7	2.3	1.2 (normal CP) 4.13 (extended CP)	0.59	0.29
Maximum nominal system bandwidth (in MHz)	50	100	100 (FR1) 200 (FR2)	400	400
Maximum FFT size	4096	4096	4096	4096	4096
Symbols per slot	14	14	14 (normal CP) 12 (extended CP)	14	14
Slots per subframe	1	2	4	8	16
Slots per frame	10	20	40	80	160

Non-standalone and standalone deployment

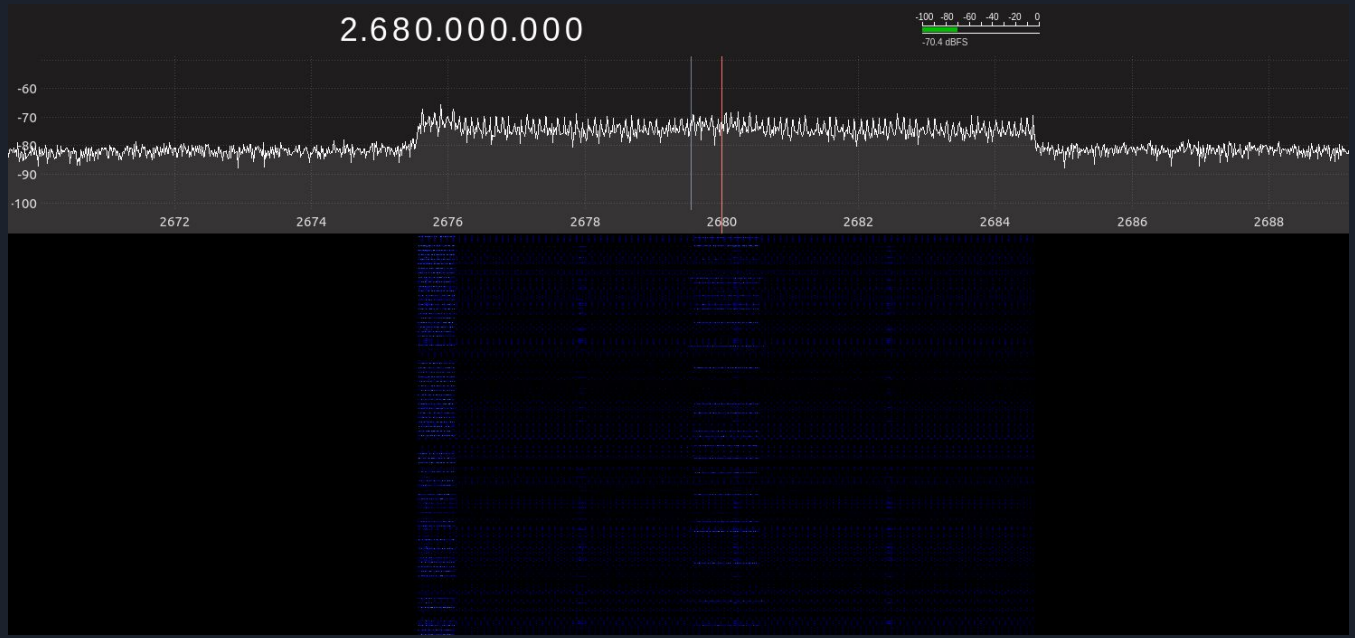


Option 3: DC EN:E-UTRA-NR

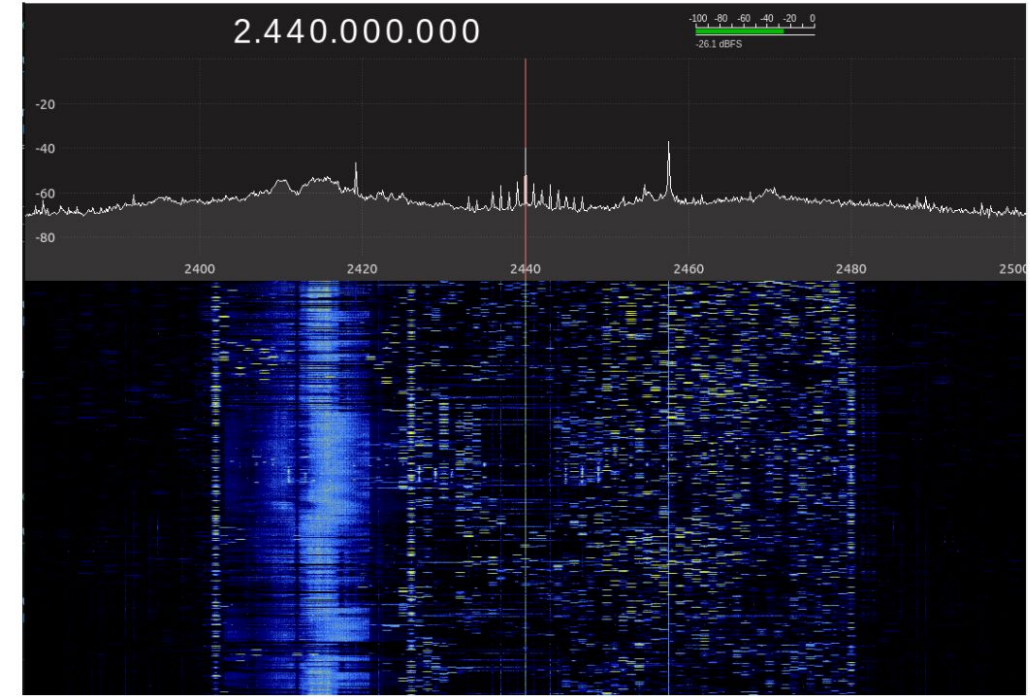


Option 2: Standalone

Hücresel Teknoloji - 4G



Bluetooth



- 2.4 GHz ISM Band
  - 2.402-2.480 MHz
- Adaptive Freq. Hopping:
  - Classic: 79 x 1MHz
  - LE: 40 x 2 MHz

Daha fazlası

- Atölye çalışması
- Programlama (Python)
- Amatör radyo faaliyetleri
  - Field Day
  - Fox Hunt
- Uydu
  - NOAA
  - ISS
  - QO-100

Decibel Calculation

- Logarithmic unit of ratio
- Mathematical definition
  - 10*log(A/B)
- Add / Subtract
- 3dB around 2x
- We can calculate all others
  - Ratio(0.5) = -3dB
  - Ratio(1) = 0
  - Ratio(20) = Ratio (2*10) = 3dB + 10dB = 13dB

Important Points

- What relative to?
  - I am 3 dB taller than my brother
- Amplitude vs. Power
- Negative values
  - 5dB loss
  - -5dB gain

Absolute values

- dBm is relative to 1mW
- dBV is relative to 1V
- dBuV is relative to 1uV

Why dB is Helpful?

- Consider a transmit example
  - Output 5dBm
  - Filter has insertion loss of 3dB
  - Amplifier 12dB
  - Cable of 2dB loss
- What is the power at the antenna?
  - 5dBm - 3dB + 12dB - 2dB = 12dBm

Thanks!

ytregitim@gmail.com
LinkedIn: murat-sever