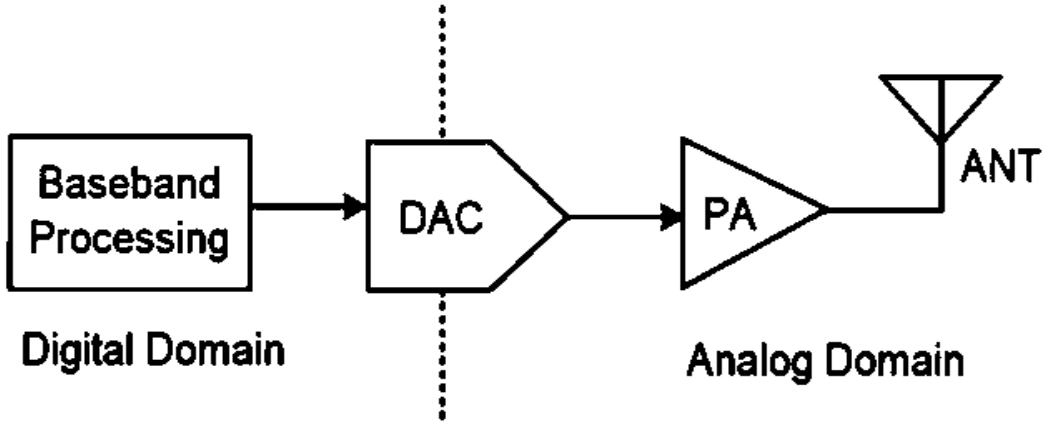
Fundamentals of SDR

RAHSDR480



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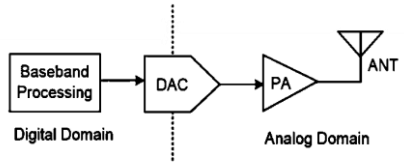
Introduction to Course



Essentials of SDR

SDR Hardware Architecture

Communication Layers

Software for SDR

SDR Selection Criteria

Application of SDRs

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Module-1: Essentials of SDR

- Communication Block and Terminology
- SDR definition
- Advantage of SDR
- History and Evolution of Radios
- Software Communications Architecture (SCA)
- Software-Defined Networking (SDN)
- Communication Standards and Signals
- Time and Frequency domain
- Decibel units

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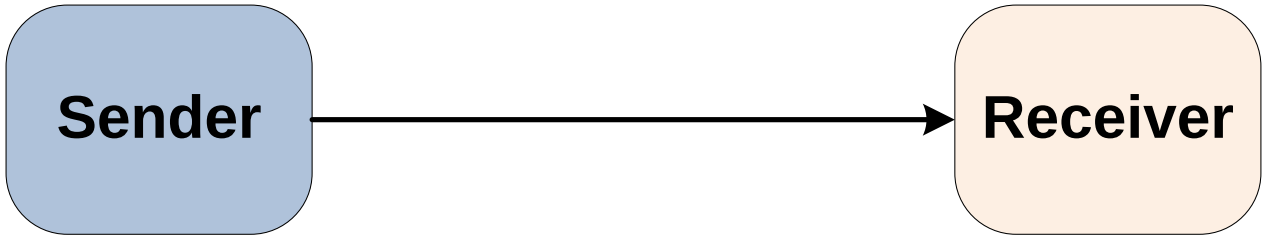
Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P01_R01:Communication Block and Terminology

COMMUNICATION BLOCK AND TERMINOLOGY

The objective of Communication System is that what we send we can exactly receive it without any loss (ideal case) or with minimum loss (practical case).



A,B, C ***A,B, C***

This loss can be minimized using several communication system and methods along with security.

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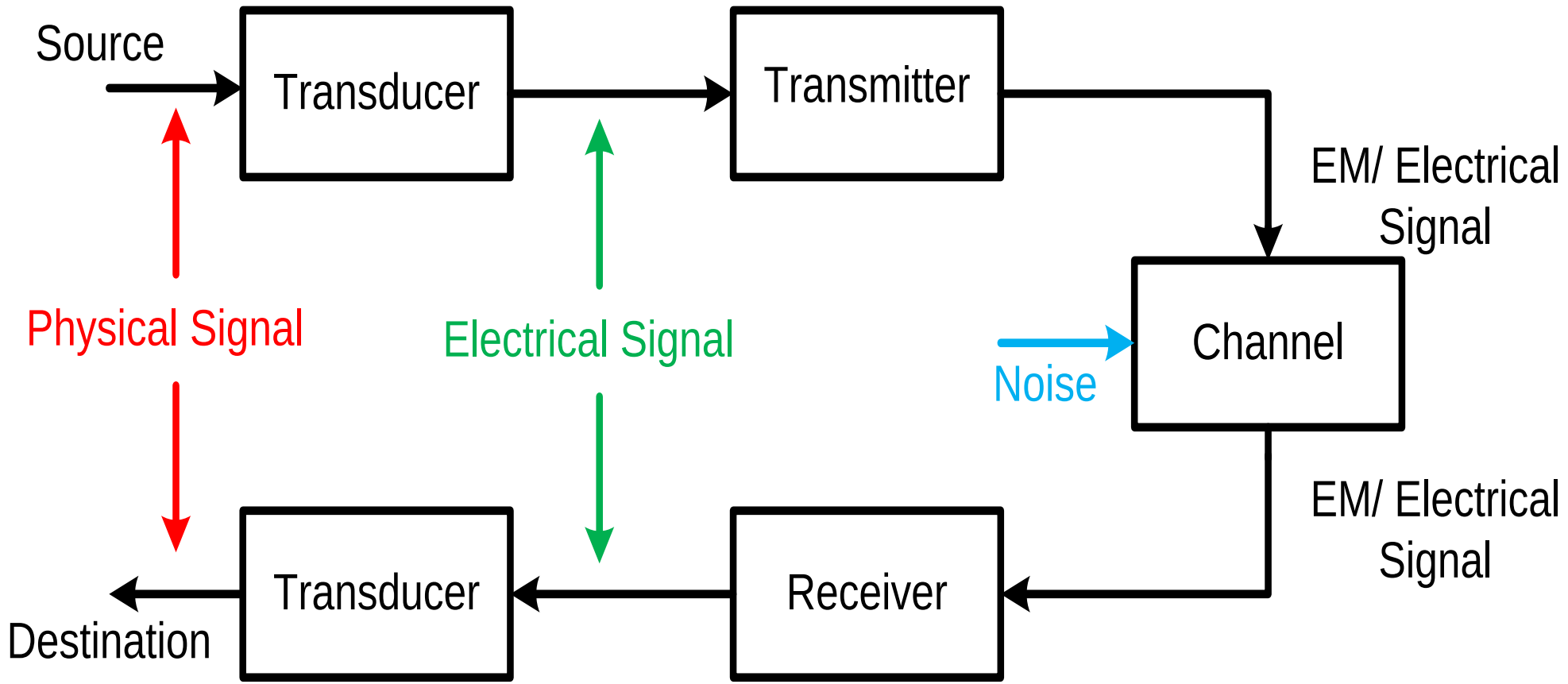

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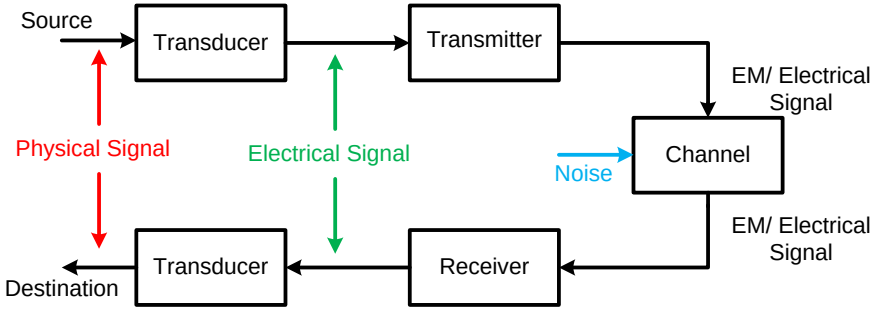

- Source: Information media (Audio, Video, Voice, Words, Picture etc.)

- Transducer: Energy conversion from one form to another (Ex: Physical to Electrical or vice-versa or any other.

  Example: Microphone –Audio into electrical signals.

  Photo detector – Converts light signals into electrical signals.

- Transmitter: It is a set of equipment used to generate and transmit electromagnetic waves carrying message or signals.

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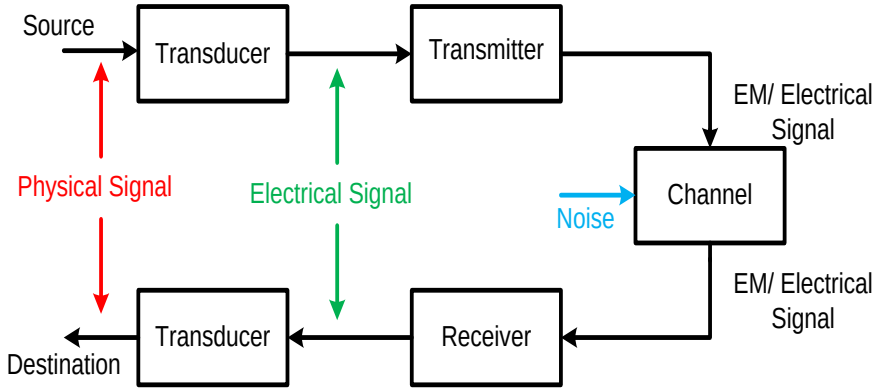
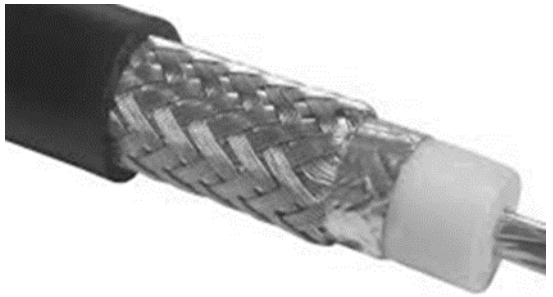
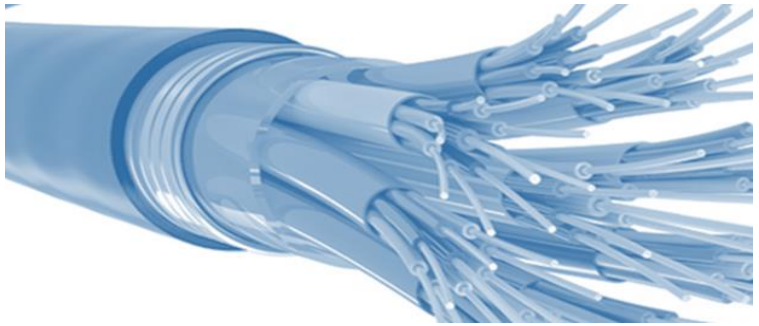


- Channel: Signal propagation medium can be wired (Twisted pair, Parallel wire communication, Coaxial Cable or Optical Fiber cable) or wireless (Free space or Air interface).





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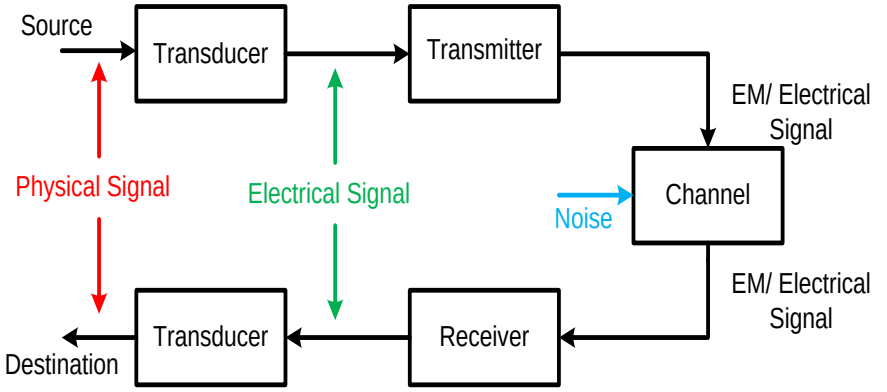
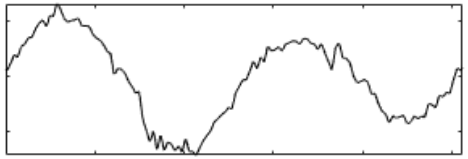
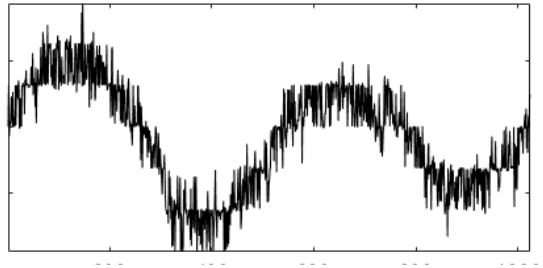


- Noise: Noise is an unwanted signal that interferes with the transmitted signal. The noise signal degrades the transmitted signal quality.





- Receiver: A device that accepts a radio signal and deliver information extracted from it.
- Destination:

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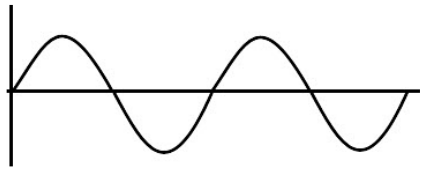
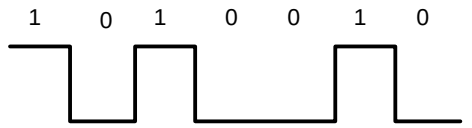
Communication System

Analog



- No privacy
- Cannot merge data from different sources
- No error correction capability

Digital



- Privacy preserved (data encryption).
- Can merge different data (voice, video and data) and transmit over a common digital.
- Error correction capability

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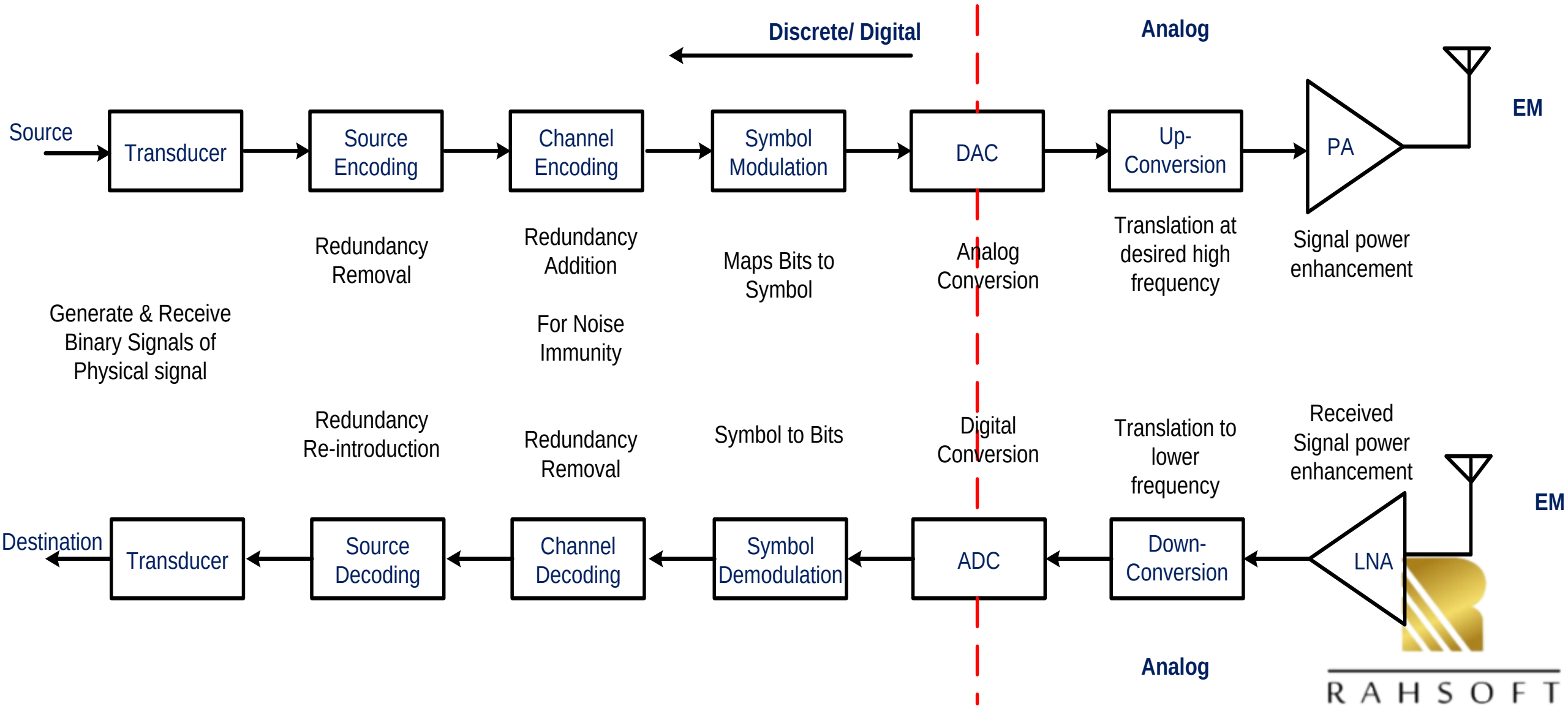
CONT….

Digital Communication System Block Diagram



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In this topic we have learnt about the

- ✓ Basic building blocks of Communication
- ✓ The common terminology used
- ✓ Analog Communication
- ✓ Digital communication and it building blocks.

➢ Next we are going to learn SDR

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P02_R01: SOFTWARE DEFINED RADIO

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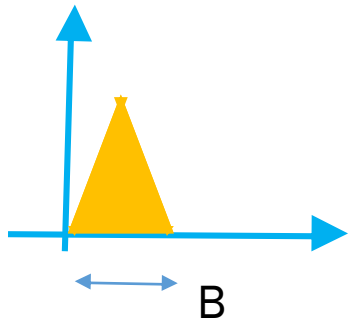
SOFTWARE DEFINED RADIO

- Radio: A System or device incorporating for wirelessly transmitting or receiving electromagnetic waves to enable the transfer of information.
- Software Defined: Use of software in Radio to implement operating functions.
- Software Defined Radio (SDR): Radio in which all or some of the functions of radio are software defined.
- Baseband: It designates a frequency range starting at zero Hertz.



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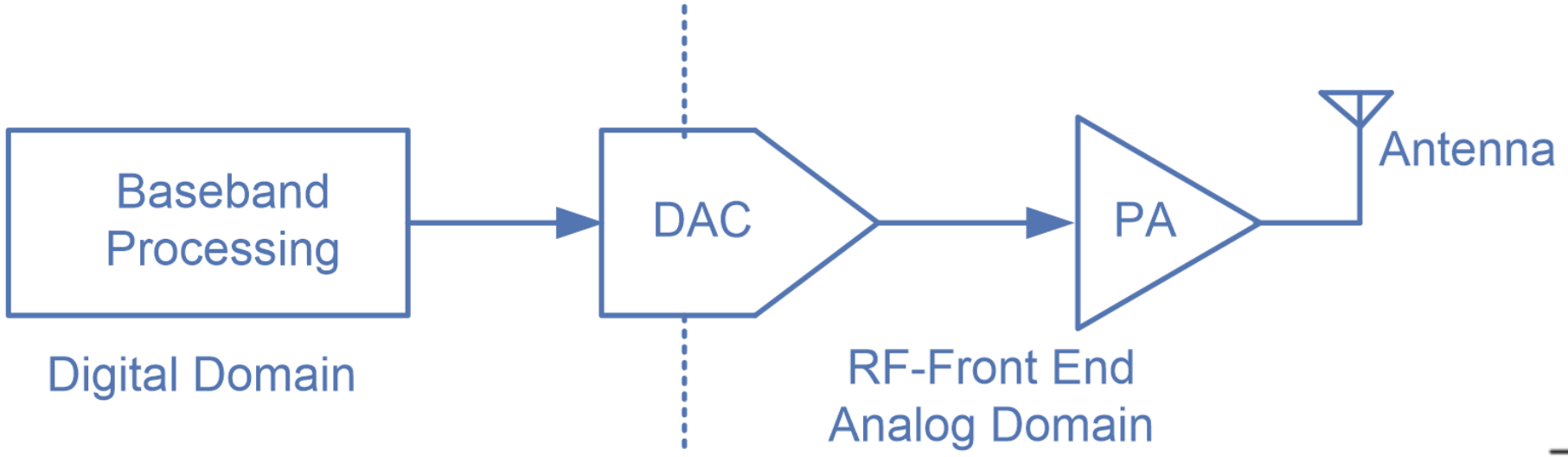
CONT….

- SDR refers to a generic hardware consisting of DSPs/GPP/GPU/FPGA along with RF front end where most of the functional radio modules of a radio system such as signal generation, modulation/demodulation, coding and managing the link layer protocols at the software end are implemented in baseband.
- Unlike the traditional hardware radio, which used Application Specific Integrated Circuit (ASIC) to implement each radio element.



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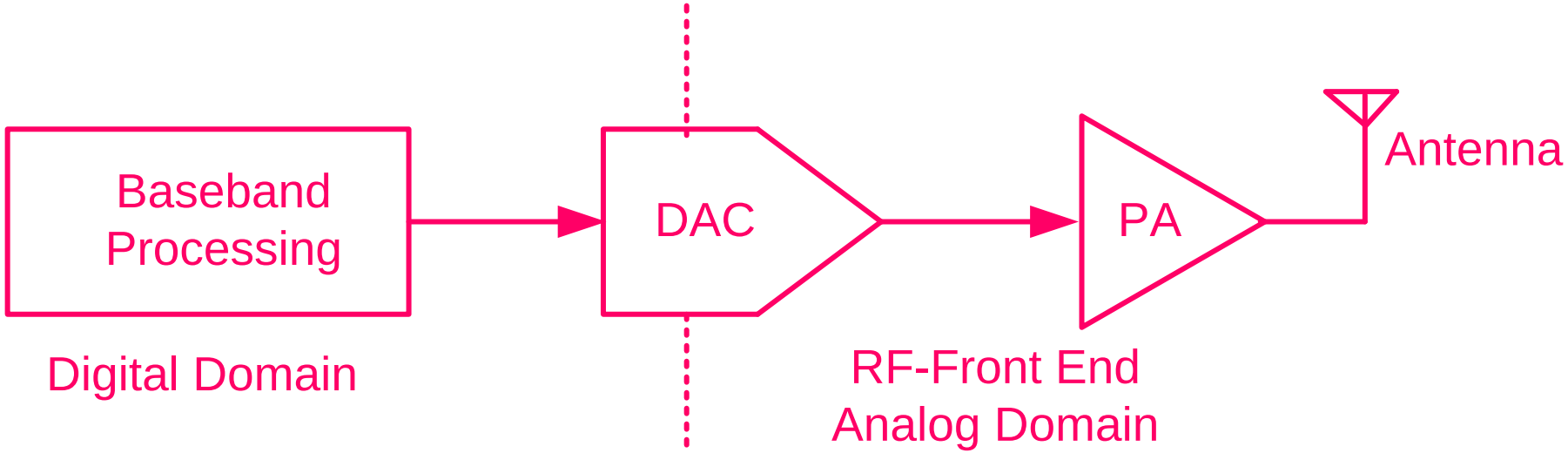
- The ideal SDR architecture exploits a DAC almost at the antenna and moves most of the RF typical functions to the digital domain.



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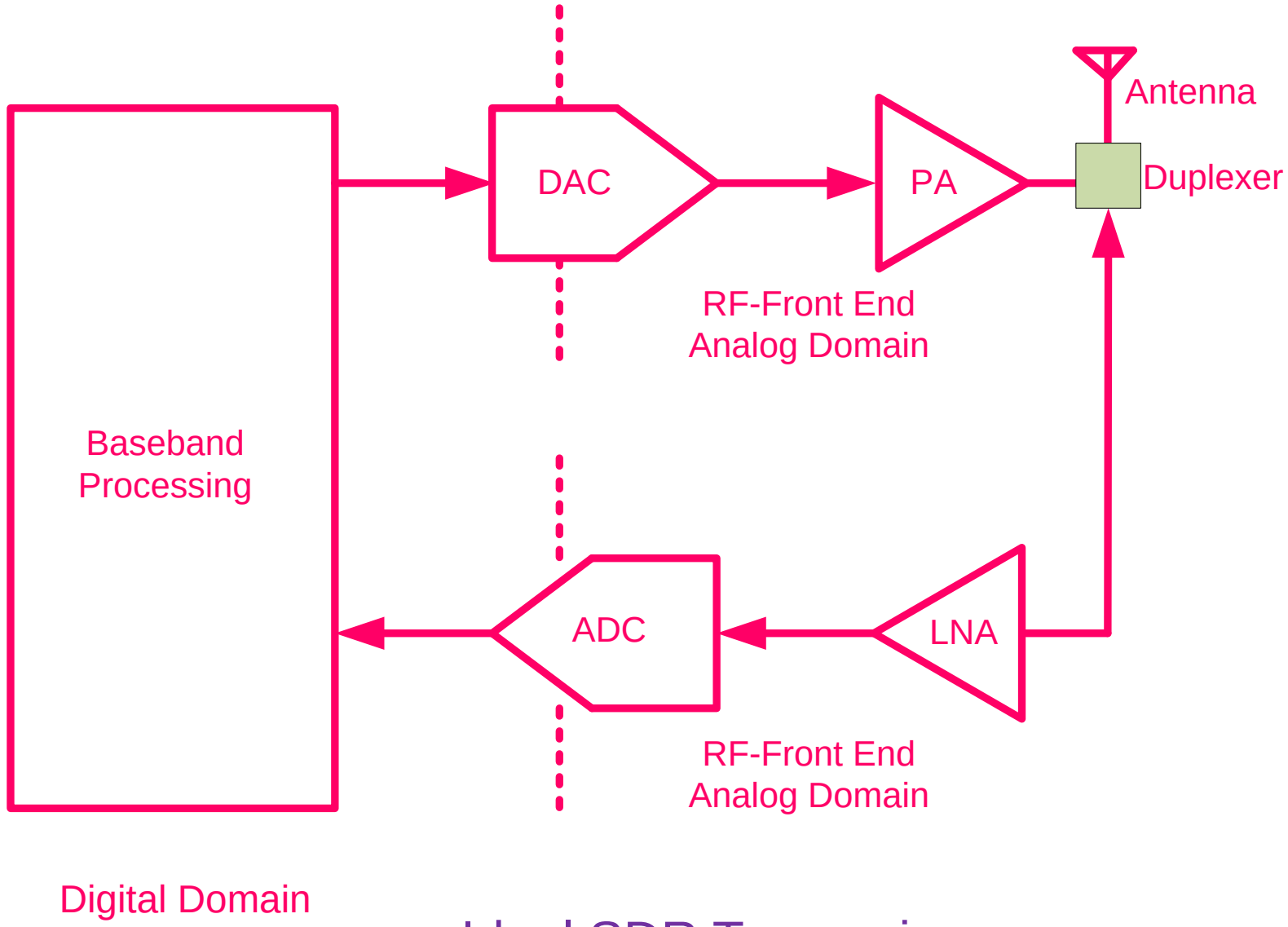

Ideal SDR Transceiver

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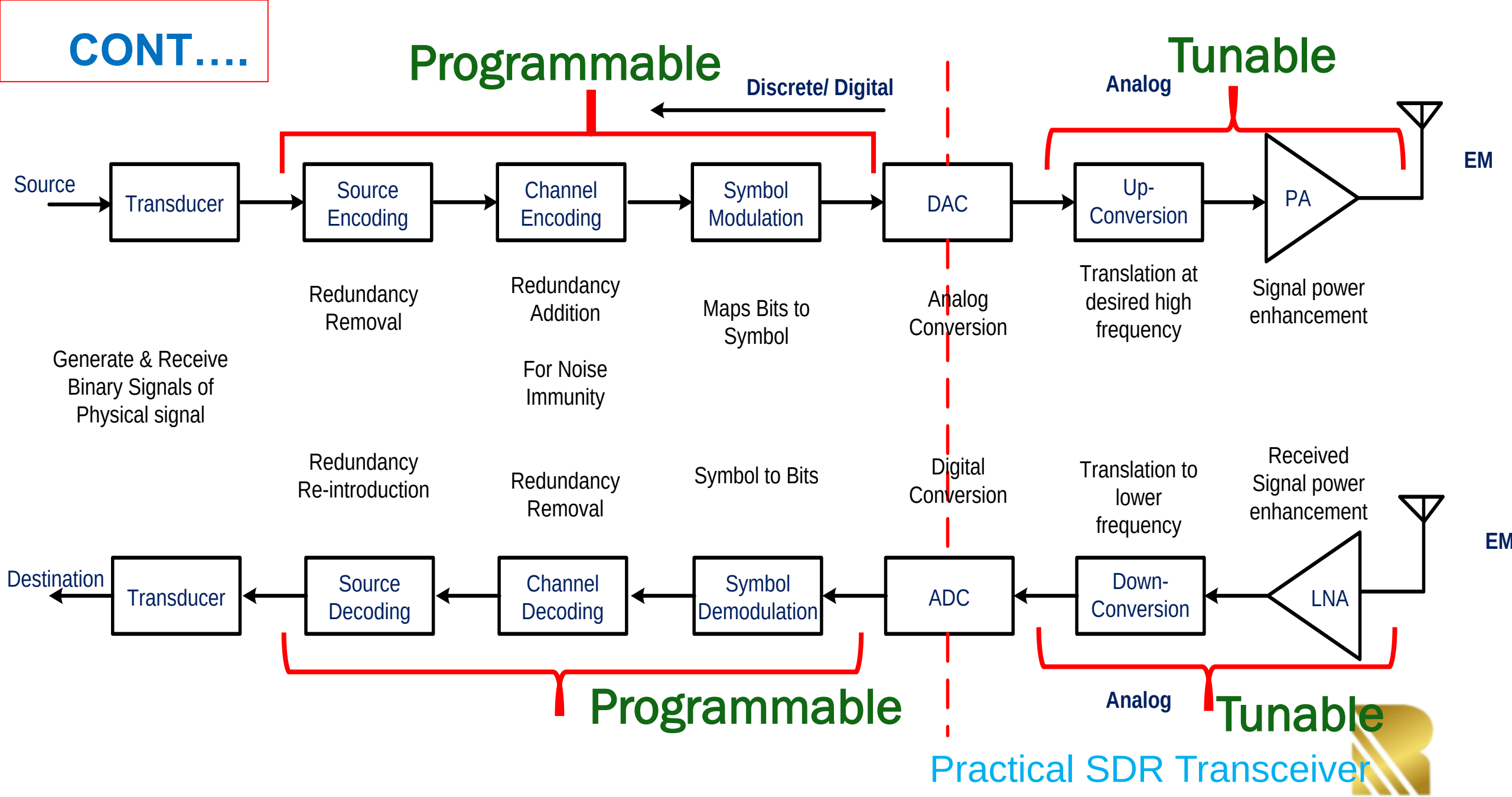

Practical SDR Transceiver

In the SDR, the programmable part can be realized in the Software.

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In this topic we have learnt about the

- ✓ SDR and its building blocks along with transition from Digital communication to SDR.

- ➢ Next we are going to learn advantage of SDR

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P03_R01: ADVANTAGE OF SDR/ What SDR can Do?

ADVANTAGE OF SDR/ What SDR can Do?

- **Flexibility:**

✓ By merely editing some code, the designer can change the functionality of a radio system without having to physically change a hardware configuration.

✓ New updates are provided to user without any interference.

✓ Support different band of operation example: Phone- 2G,3G and 4G all can run on a single handset.

✓ This modification functionality could decrease the physical complexity, size, and cost of radio networks by having one device perform multiple functions.

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CONT….

- Automatic Gain Control:

✓ The gain can be tuned with software to met best performance in the presence of noise.

- Digital Filtering:

✓ Filters can be implanted by writing codes for desired application, ex. Noise cancellation, echo cancellation etc.

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CONT….

- Diverse community support:

✓ Open source software and hardware's are available using which you can create your own SDR and hence you will be benefit by the work of others.

- Ease of Testing & Implementation:

✓ Ease of Testing & Implementation of communication standards has advantage of SDRs over hardware-defined counterparts.

✓ The testing and implementation would be simpler, cheaper, and quicker.

✓ Allow researchers and developers to design a test-bed for wireless communication systems.

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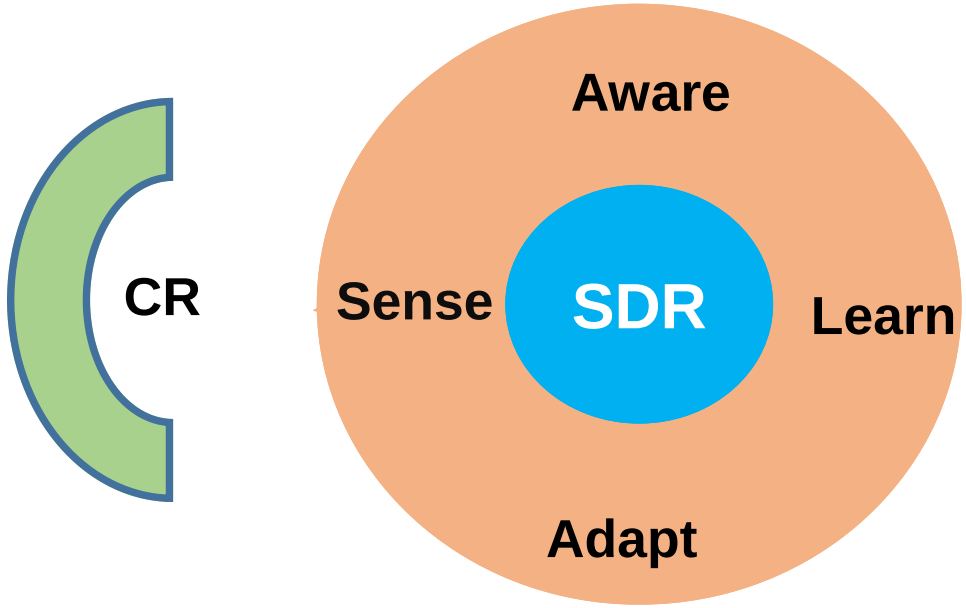
- Cognitive Radio:

✓ Additional hardware in the form of sensors and actuators to enable more cognitive radio applications.



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In this topic we have learnt about the

- ✓ ADVANTAGE OF SDR/ What SDR can Do?

- ➢ Next we are going to learn History and Evolution of Radios

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P04_R01: HISTORY AND EVOLUTION OF RADIOS

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HISTORY AND EVOLUTION OF RADIOS

1984	E-Systems coins “software radio” term
1991	SPEAKeasy
1992	Joseph Mitola publishes paper about software radio at IEEE
1996	Creation of the SDR Forum
1997	Creation of the JTRS (Joint Tactical Radio System)
1998	Automated code generation for embedded SDR
2001	GNU Radio
2004	FCC first approval of a commercial SDR
2004	2004 PHY processors
2006	TI and Xilinx come together to facilitate embedded SDR development
2009	First commercial single-chip RF front-end
2009	Onward Several Chips/Evaluation Platform from Analog Devices, Texas Instruments and Xilinx are available

https://www.nutaq.com/blog/short-history-software-defined-radio-sdr-technology

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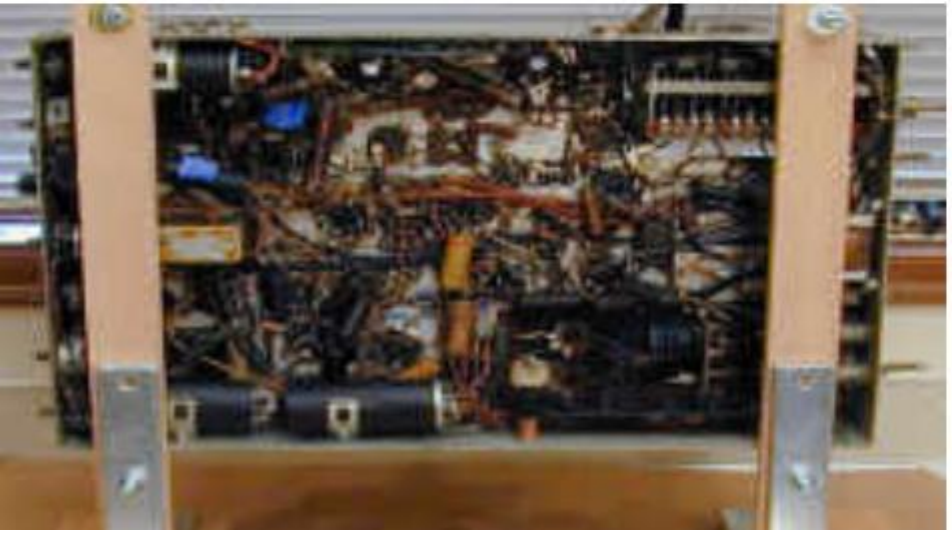
CONT….

Conventional Radios



Li'l 7 built by Volker in Italy

Images retrieved from http://antiqueradio.org

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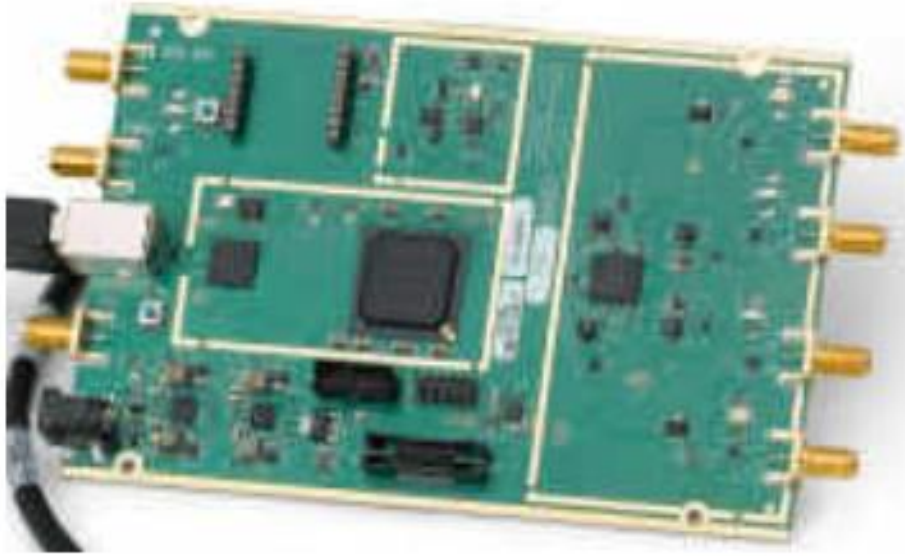
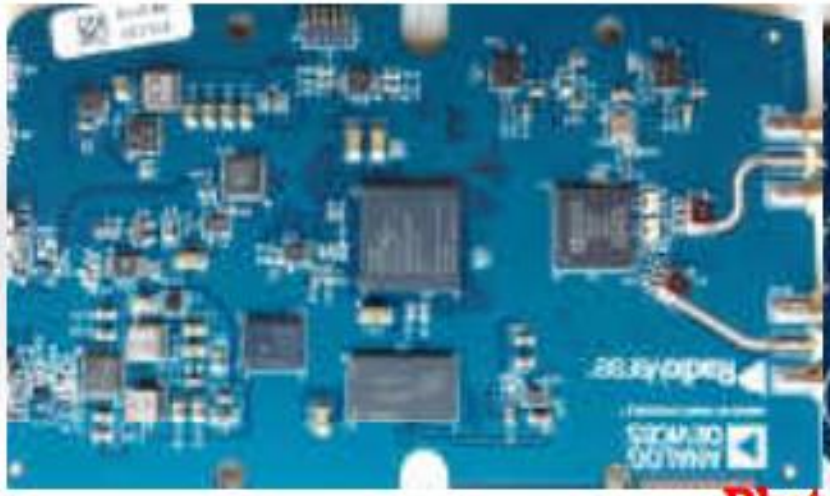
CONT….

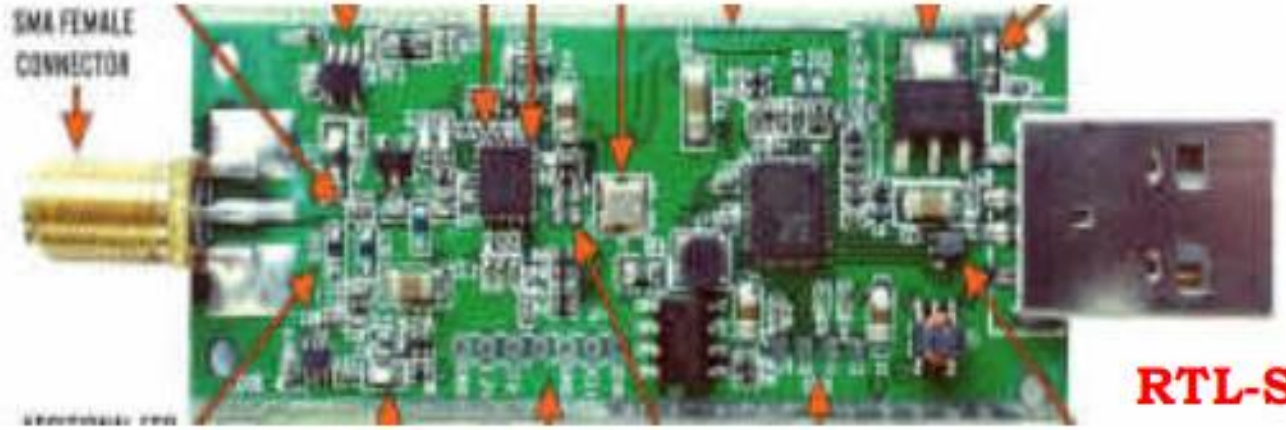
SDRs



USRP B210



Plutosdr



RTL-SDR

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ttps://digitalxradio.com/2017/11/12/hello-world/
ttps://in.mathworks.com/hardware-support/usrp.html
.ttps://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/adalm-pluto.html#eb-documer

In this topic we have learnt about the

✓ How the Radios has been evolved

➢ Next we are going to learn SCA

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P05_R01:SOFTWARE COMMUNICATIONS ARCHITECTURE (SCA)

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SOFTWARE COMMUNICATIONS ARCHITECTURE (SCA)

- Architectural framework created to assist in the development of SDR communication.
- Allows application software to be more easily ported across radio platforms.
- It is an open architecture framework.
- Interoperability of communication systems and reduce development and deployment costs.
- Latest version is SCA 4.1.

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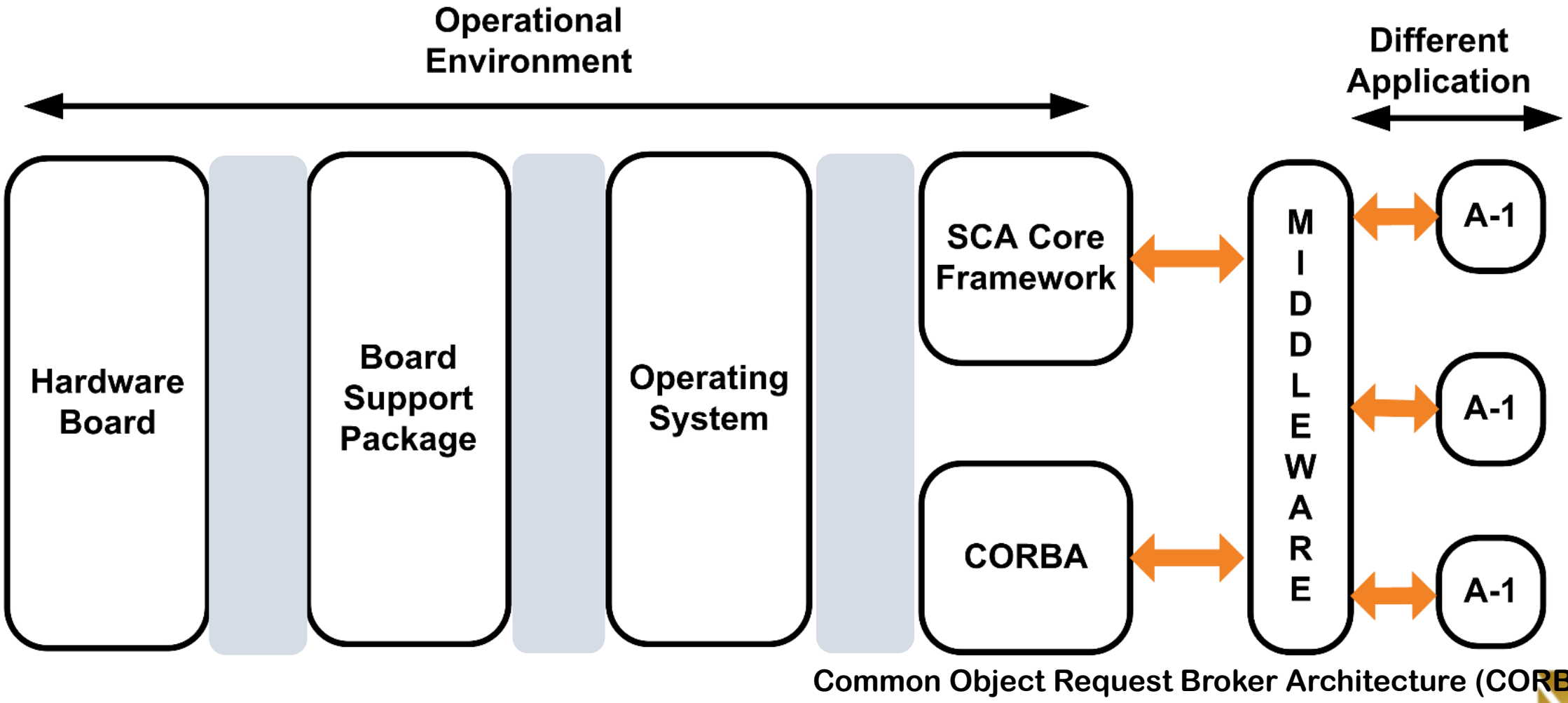

Common Object Request Broker Architecture (CORBA)

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CONT….

SCA is published by the Joint Tactical Networking Center (JTNC) to achieve following goals.

- Cost-effective utilization of commercial off the-shelf (COTS) technology.
- Waveform portability
- Software reuse

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CONT….

- Interoperability
- Technology insertion
- Hardware abstraction

SCA is complete and robust open SDR architecture, but it is not a requirement to implement SDR technology.

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CONT….

- Benefits of using SCA
  - ✓ Interface specifications
  - ✓ Application program interfaces (APIs)
  - ✓ Behavioral specifications
  - ✓ Rules
- Operating system for radios which executes applications and controls hardware
- Implementation-independent framework which ensures interoperability of SCA products

- Next we are going to learn SDN

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P06_R01:SOFTWARE-DEFINED NETWORKING (SDN)

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SOFTWARE-DEFINED NETWORKING (SDN)

- SDN technology is an approach to network management that enables dynamic, programmatically efficient network configuration in order to improve network performance and monitoring, making it more like cloud computing than traditional network management.

- SDN permit routers and switches to run simple programs, which can alter forwarding rules, modify a packet or drop it which created todays programmable switches and routers.

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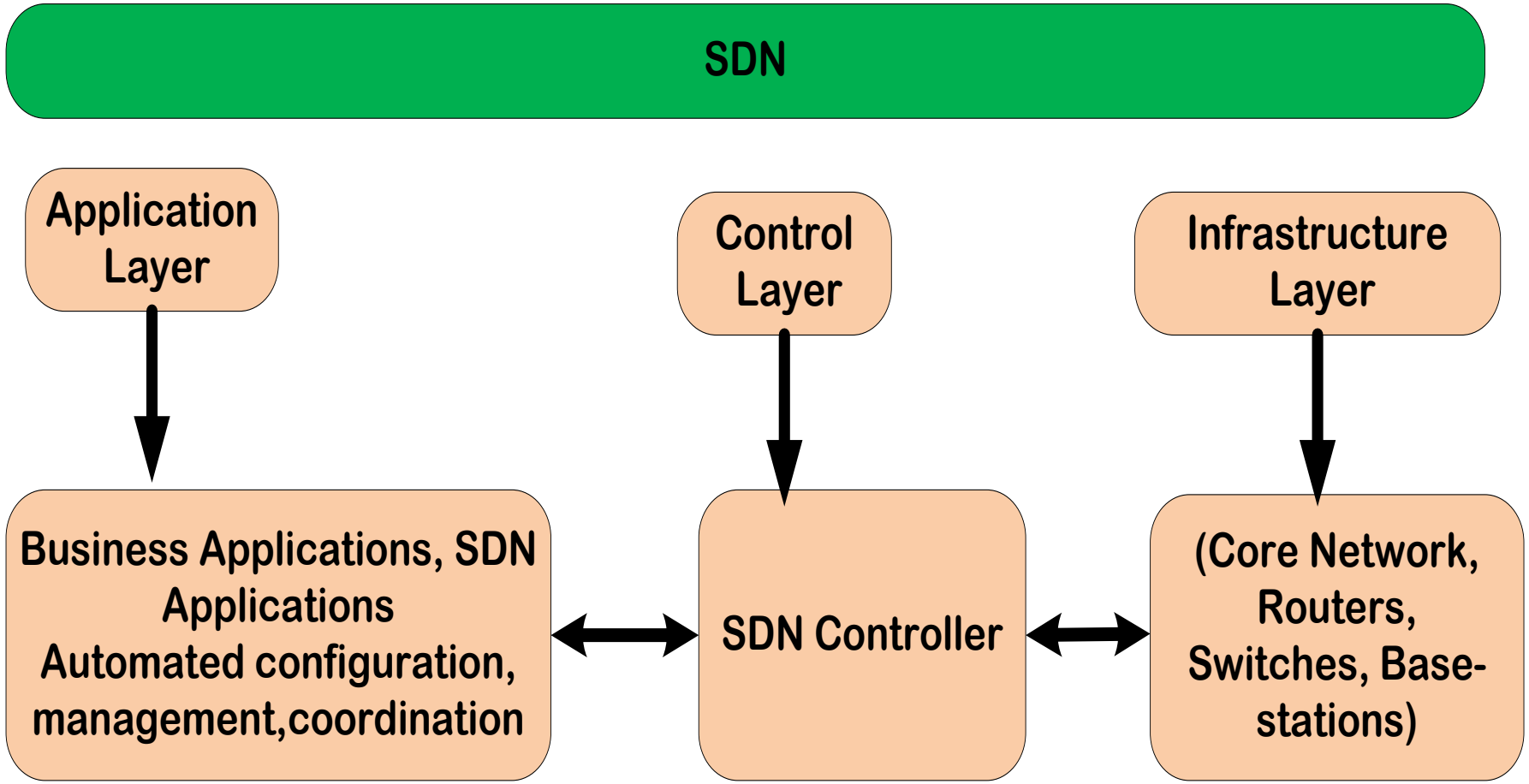

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In this topic we have learnt about the

- ✓ Benefits of using SDN
- ➢ Next we are going to learn Communication Standards and Signals

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P07_R01: COMMUNICATION STANDARDS and SIGNALS

COMMUNICATION STANDARDS and SIGNALS

A unified Future proof platform

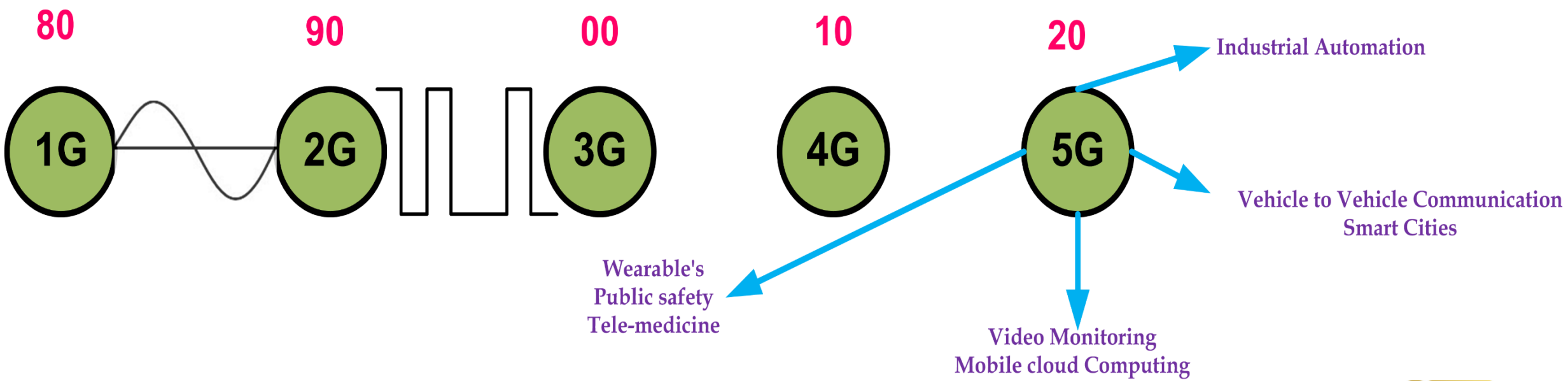
Analog
AMPS, NMT

Digital
GSM, IS-95

Wireless
WCDMA,
HSPA+, EV-DO

Mobile Broadband
LTE, LTE-A

High speed wireless
5G New Radio



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CONT….

- Single-tone
- Two-tone
- Multi-carrier
- GSM

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CONT….

- WCDMA
- LTE
- LTE Carrier aggregation

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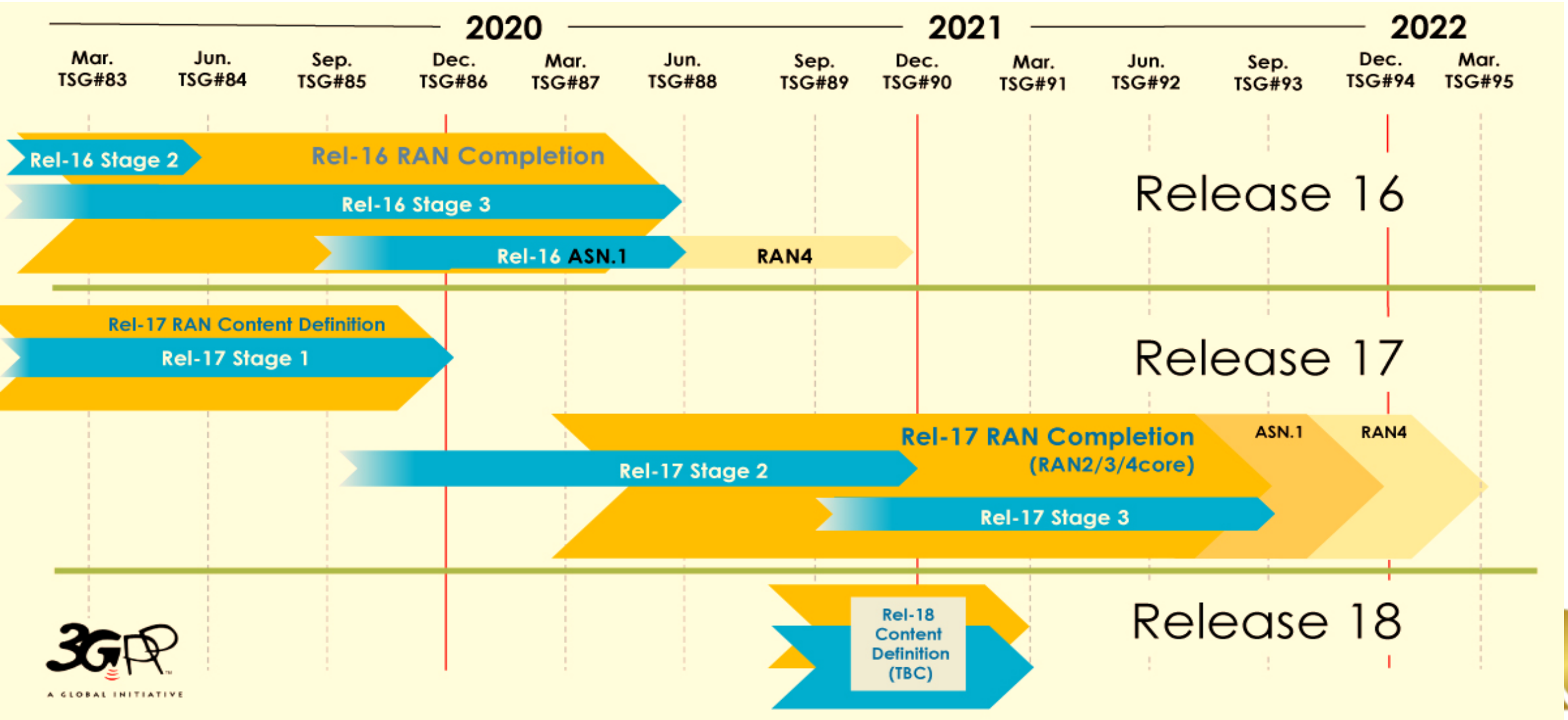
CONT....



https://www.3gpp.org/images/articleimages/Releases/graphic_version3_SP-200222.jpg

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In this topic we have learnt about the

- ✓ Communication Standards and different signals

- ➢ Next we are going to learn Time and Frequency domain

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P08_R01:TIME AND FREQUENCY DOMAIN

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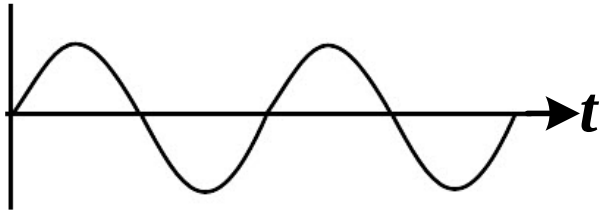
TIME AND FREQUENCY DOMAIN

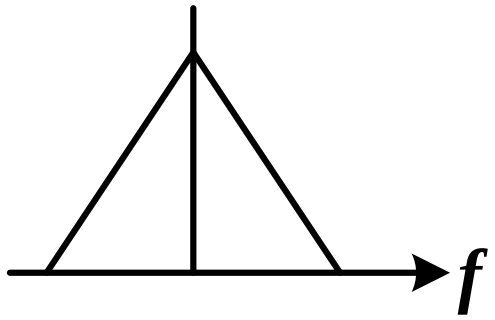
Time Domain



- Real world is in time domain.
- Independent variable is *t*

y(t)

Frequency domain



- Independent variable is *f*

- Transformation is used to convert a time domain function to a frequency domain function and vice versa.

Y(f)

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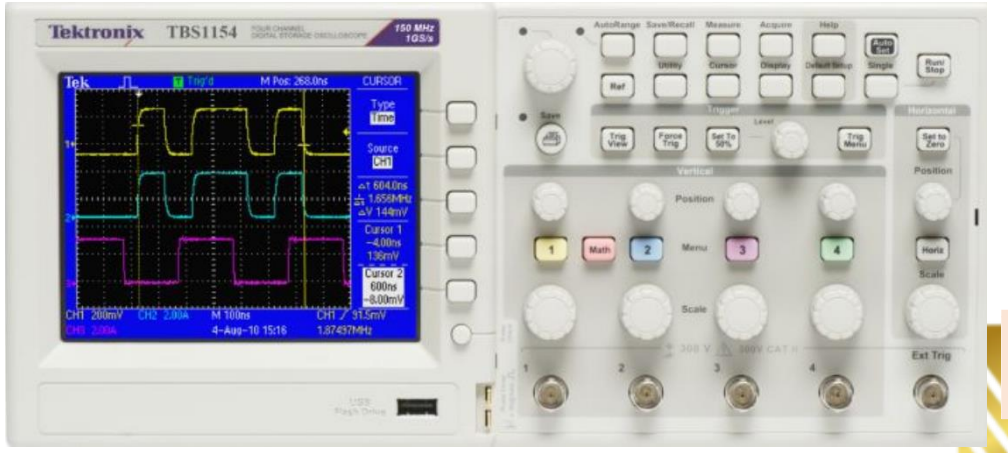
CONT….

Time Domain How to Measure

- For an electronic signal, the time domain analysis is mainly based on the voltage – time plot or the current – time plot. In a time domain analysis, the variable is always measured against time.
- The CRO and DSO is the most common device when analyzing electrical signals on a time domain.
- Other computer instrumentation, graphs and raw numerical data can be used to analyze data on a time domain.

CRO



DSO

http://www.lodestarelec.com/15-analogue_oscilloscope-s.jpg

https://download.tek.com/datasheet/TBS1000-Digital-Storage-Oscilloscope-Datasheet-3GW285576.pdf

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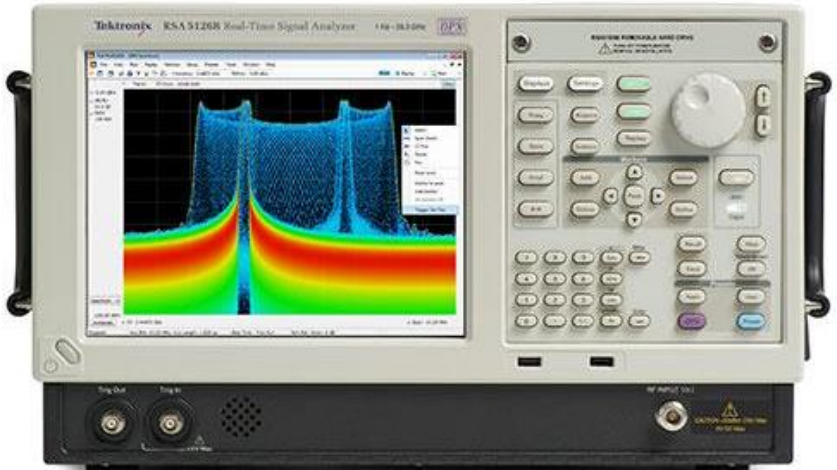
CONT….

Frequency Domain How to Measure

- The most important concept in the frequency domain analysis is the transformation.
- The most common transformation used in the frequency domain is the Fourier transformations.
- Fourier transformation is used to convert a signal of any shape into a sum of infinite number of sinusoidal waves.

Spectrum Analyzer



https://www.tek.com/spectrum-analyzer/rsa5000#

In this topic we have learnt about the

✓ Time and frequency domain measurements

➢ Next we are going to learn about Decibel units

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Fundamentals of SDR:RAHSDR480

Module-1:Essentials of SDR

RAHSDR480_L01_P09_R01:DECIBEL UNITS

DECIBEL UNITS

- ✓ Need of decibel?
- ✓ It is easier to measure voltage and current easily at lower frequencies but it is difficult to measure at higher frequencies. Ex: Power of 1000 Watt
- ✓ Use of a logarithmic scale to make calculation simpler and comparison is more useful.
- ✓ Decibel is used to express the ratio of one value of a power or field quantity to another, on a logarithmic scale

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CONT….

Power ratio

The power ratio in decibels (dB) is 10 times base 10 logarithm of the ratio of P_1 and P_0:

$$Ratio_{dB} = 10 \cdot \log_{10}(P_1 / P_0)$$

Amplitude ratio

The ratio of quantities like voltage, current and sound pressure level are calculated as ratio of squares.

$$Ratio_{dB} = 10 \cdot \log_{10}(V_1^2 / V_0^2) = 20 \cdot \log_{10}(V_1 / V_0)$$

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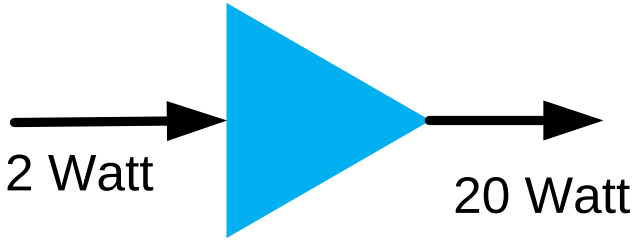
CONT….

The power in decibel-watts ($P_{(dBW)}$) is equal to 10 times base 10 logarithm of the power in watts ($P_{(W)}$):

$$P_{(dB)} = 10 \cdot \log_{10}(P_{(W)} / 1W)$$



What is input power and output power in dB?

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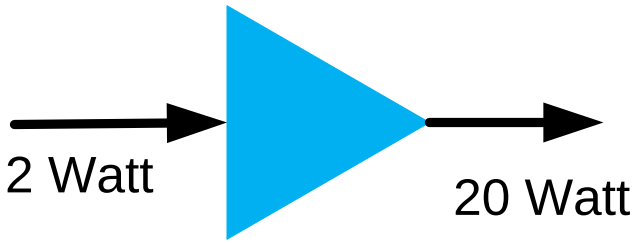
CONT….

The power in decibel-milliwatts ($P_{(dBm)}$) is equal to 10 times base 10 logarithm of the power in milliwatts ($P_{(mW)}$):

$$P_{(dBm)} = 10 \cdot \log_{10}(P_{(mW)} / 1mW)$$



What is input power and output power in dBm?

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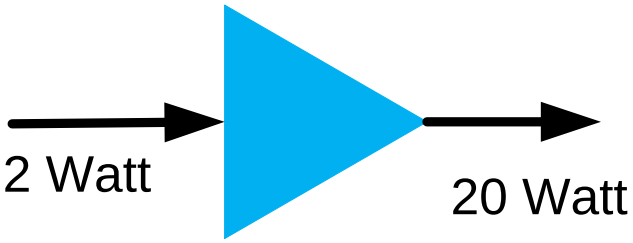
CONT….



- What is the Gain of this device?

Power (dBm)	Power (watt)
0	0.001
10	0.01
20	0.1
30	1
40	10
50	100
60	1000
70	10000

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CONT….

- Convert 15 watt to dB and dBm also verify $P_{dBm} = P_{dB} + 30$

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P01_R01:SDR Hardware

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SDR Hardware

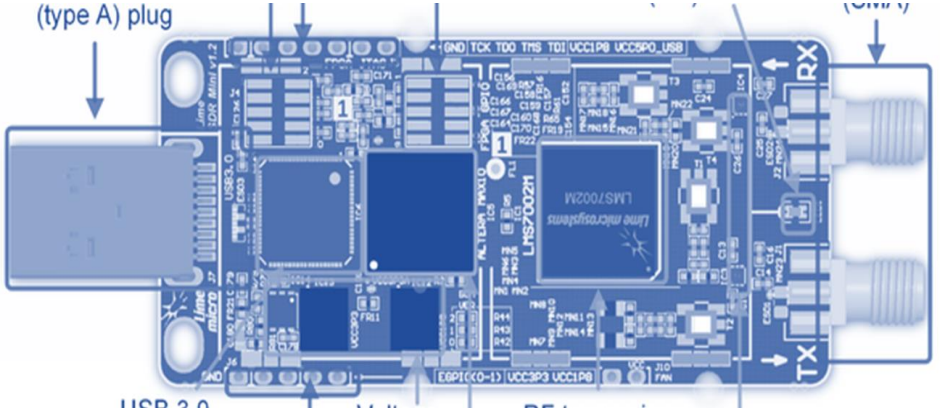
SDR

Discrete/
Digital/
Baseband Section

Analog\
RF-Front end\
Bandpass Section

DSP/FPGA

RF-Front end



Heterodyne

Homodyne

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CONT….

Receiver Selectivity

- Ability of a receiver to select a desired signal in the presence of other unwanted signals.

Receiver Sensitivity

- Lowest signal power level at the input of a receiver which guarantees proper working of a wireless receiver.

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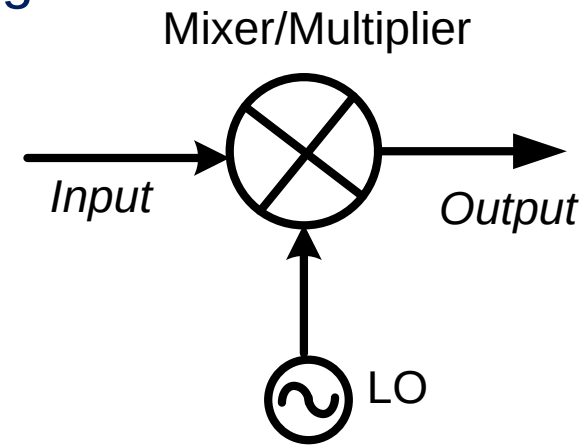
CONT….

Frequency mixer

- Using Input and LO (two signals)are applied to a mixer, yields new signals at the sum and difference of the original frequencies in ideal mixer.



- Other frequency components may be present in a practical mixer.
- **Used to shift signals from one frequency range to another, also known as heterodyning.**
- Ex: In Superheterodyne receiver is a mixer used to translate the received signals to a IF.
- Used to modulate a carrier signal in radio transmitters.

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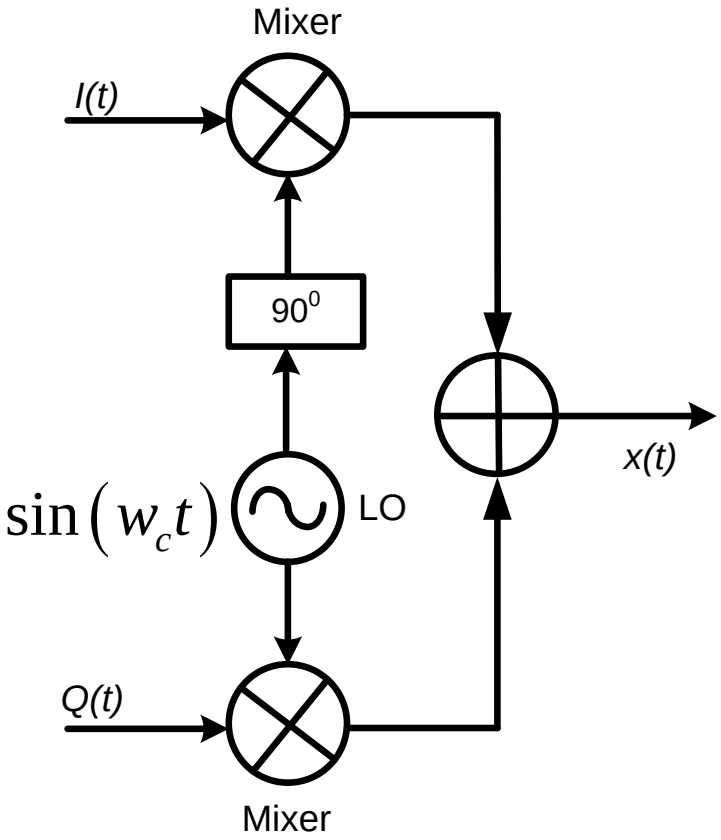
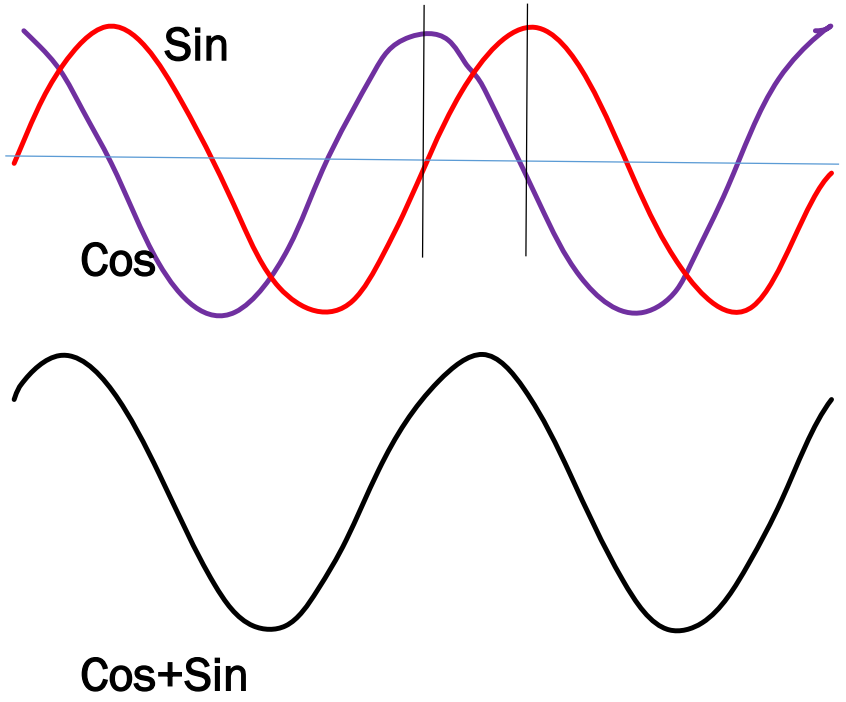
CONT….

Quadrature Modulation





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In this topic we have learnt about the

- ✓ SDR Hardware, Sensitivity, Selectivity, Frequency Mixer, Quadrature Modulation

- ➢ Next we are going to Super-Heterodyne Architecture

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P02_R01:Super-Heterodyne Architecture

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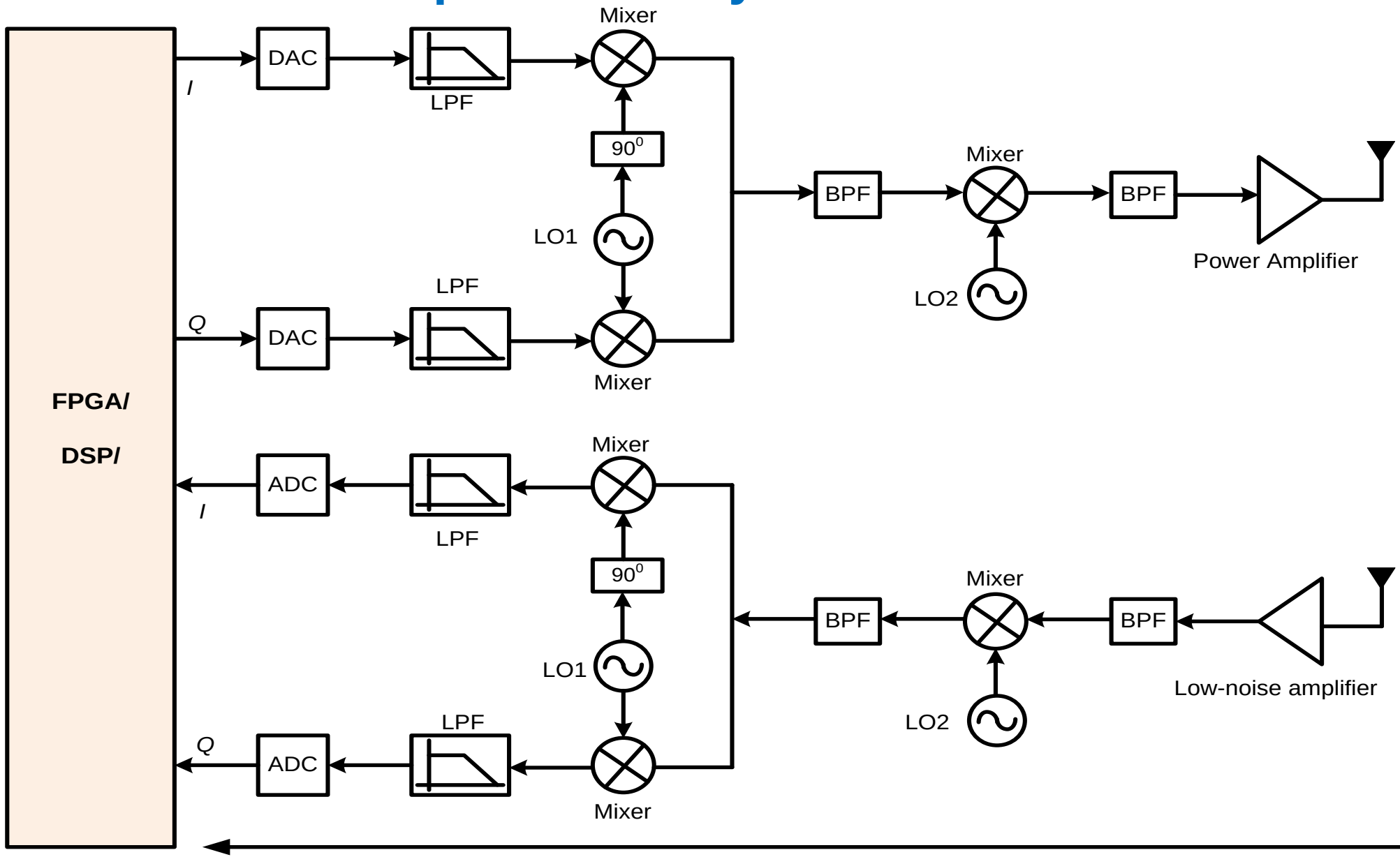
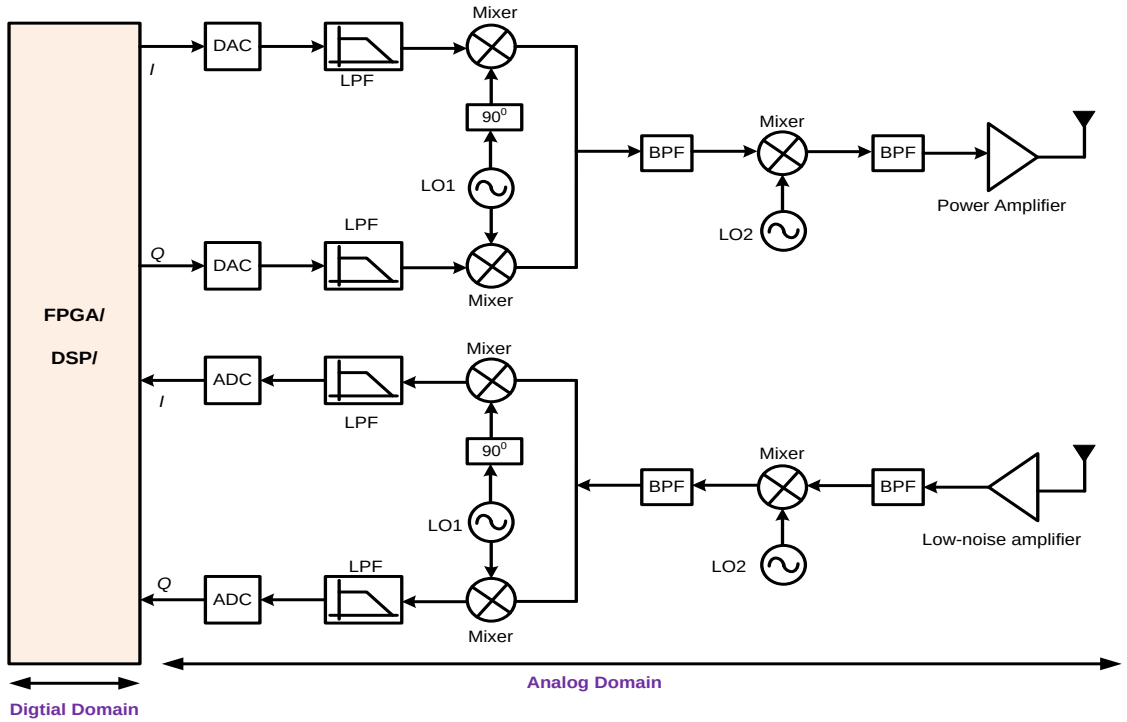
Super-Heterodyne Architecture



RAHSOFT

CONT….



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In this topic we have learnt about the

- ✓ Super-Heterodyne Architecture

- ➢ Next we are going to learn Homodyne Architecture

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P03_R01:Homodyne Architecture

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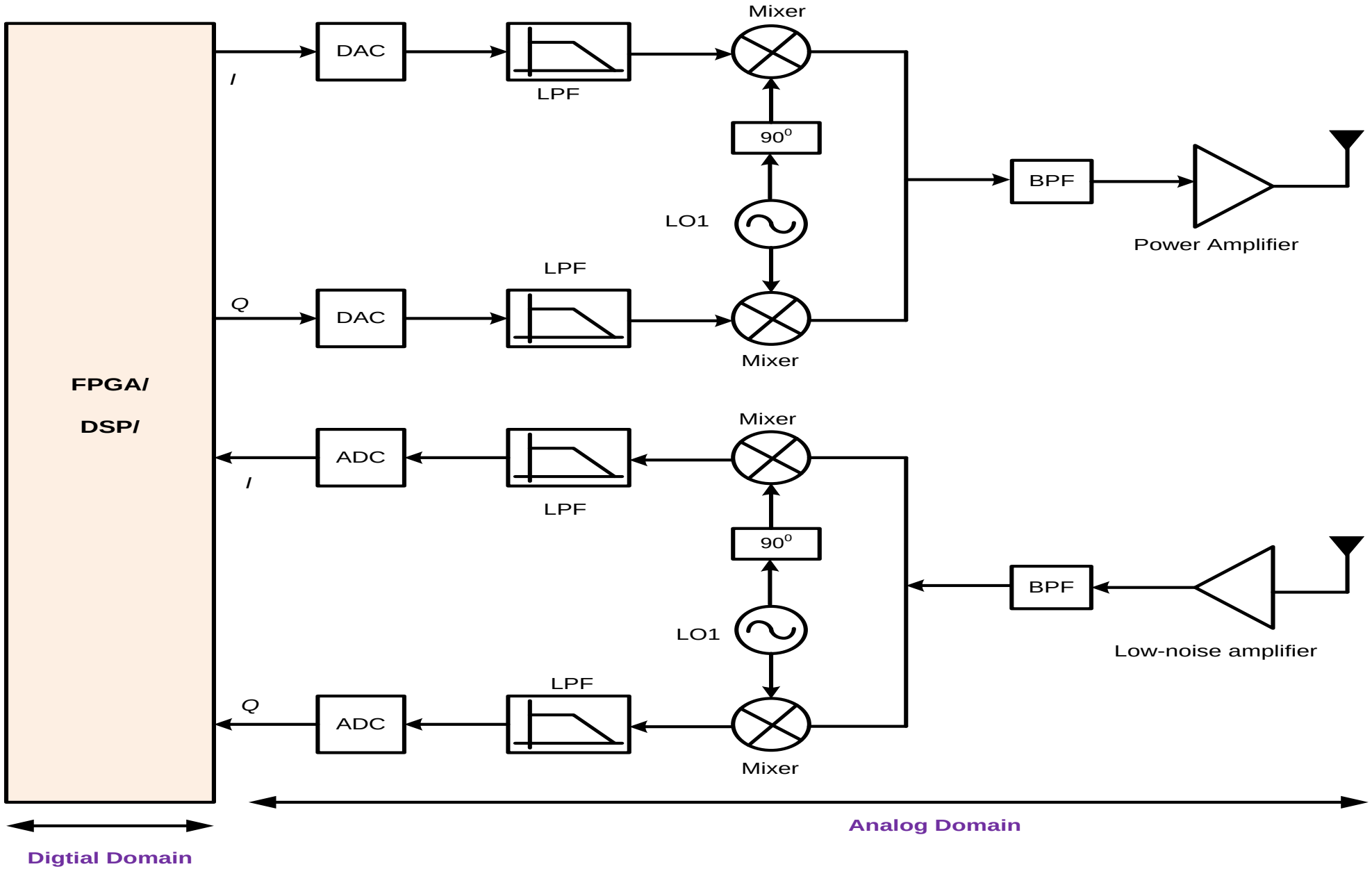
Homodyne Architecture



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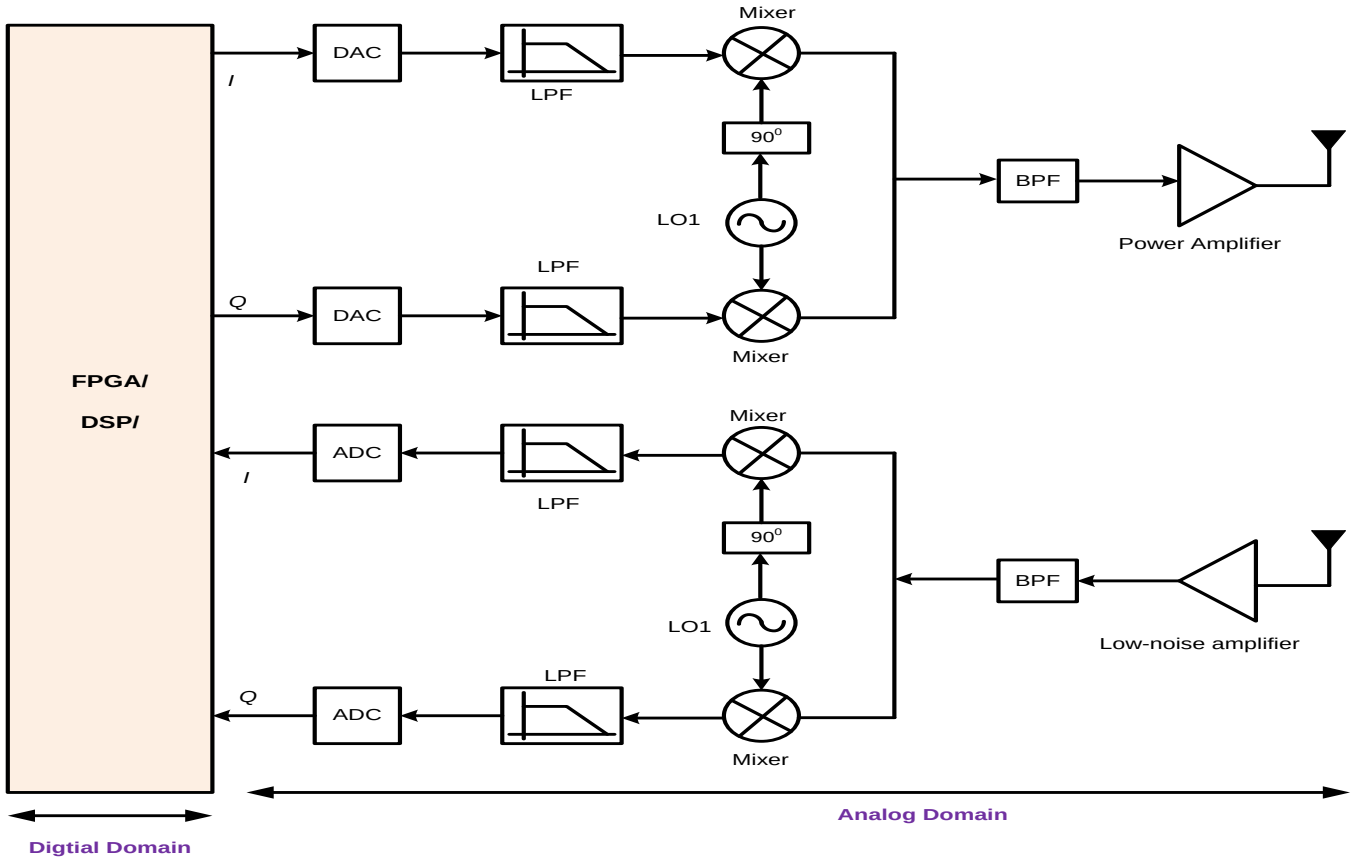
CONT....



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In this topic we have learnt about the

- Homodyne Architecture

- Next we are going to learn Lo Leakage and DC Offset

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P04_R01:LO LEAKAGE AND DC OFFSET

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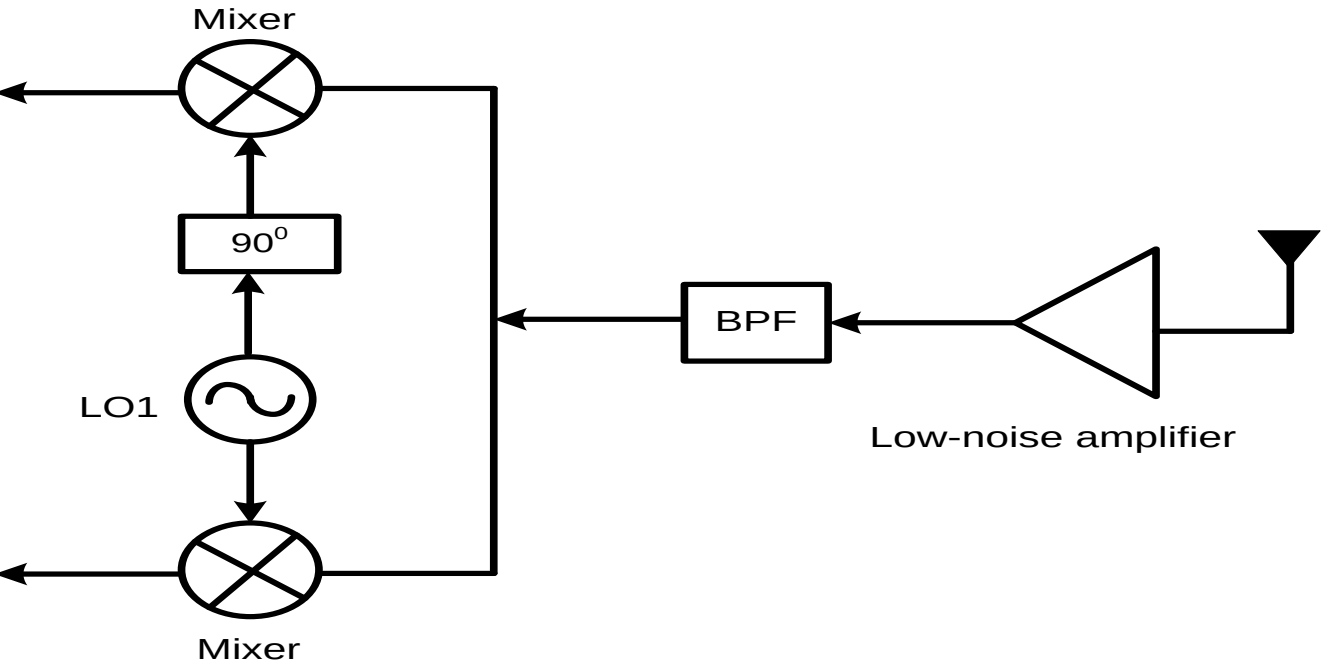
LO LEAKAGE AND DC OFFSET

- Since LO is not perfect, there is LO leakage which causes self-mixing at mixer to produce a DC component.

- This contribute to a large DC offset due to high gain of receiving chain.



$$sin^2x = \frac{1 - cos2x}{2} \quad cos^2x = \frac{1 + cos2x}{2}$$

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CONT….

Heterodyne

- RF=LO1+LO2

Homodyne

- RF=LO1

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In this topic we have learnt about the

- ✓ LO LEAKAGE AND DC OFFSET

- ➢ Next we are going to learn I/Q MISMATCH OR I/Q IMBALANCE

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P05_R01:I/Q MISMATCH OR I/Q IMBALANCE

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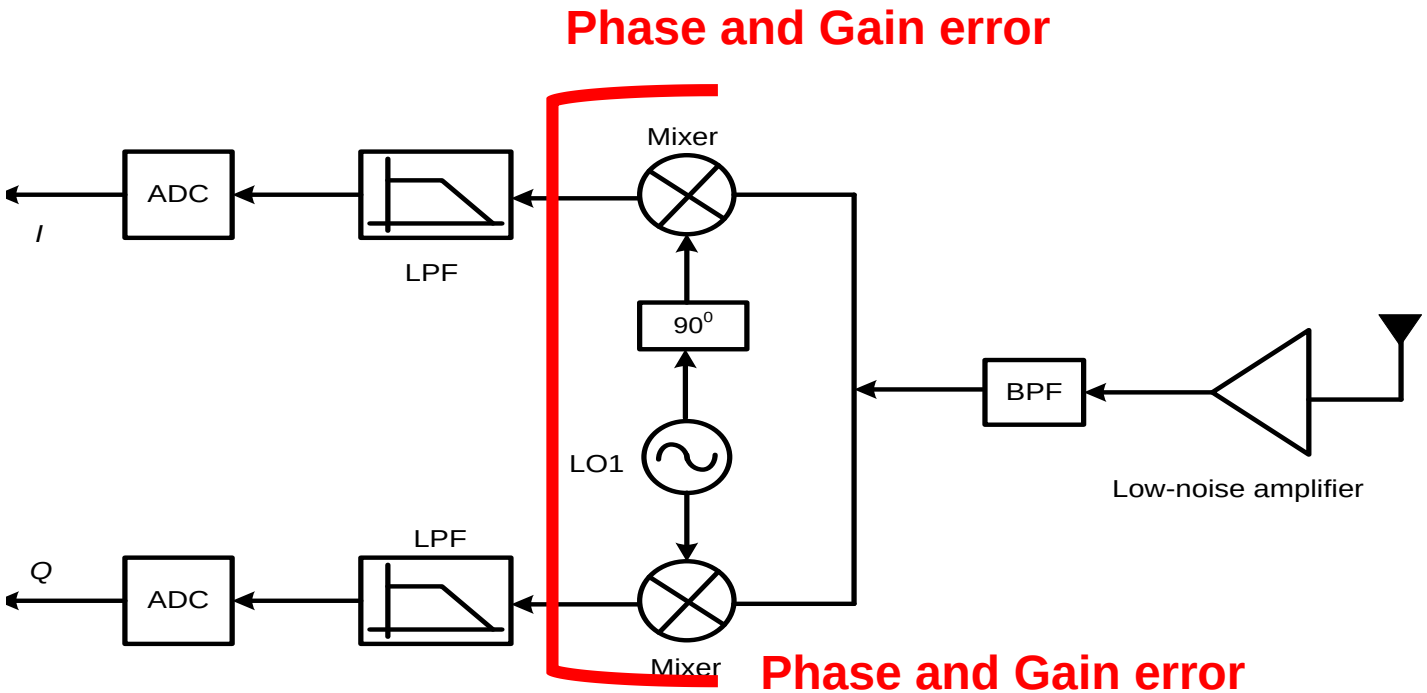
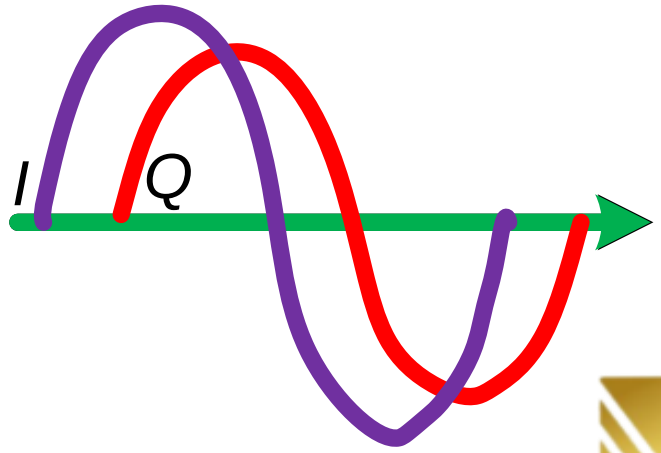
I/Q MISMATCH OR I/Q IMBALANCE

- Since the 90 degree phase shift is not ideal since it is an analog component.
- The matched pair of mixers is converting the same input signal with the dual version of the LO.
- Mismatches between the two LO signals and/or between two paths of down-conversion mixers, cause signals to be corrupted, either due to amplitude or phase differences.





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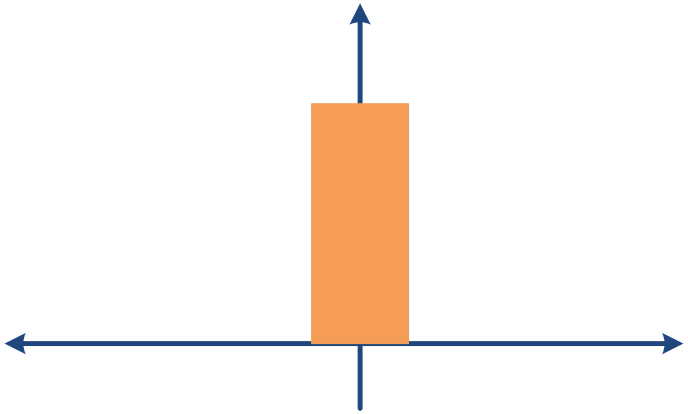
CONT….



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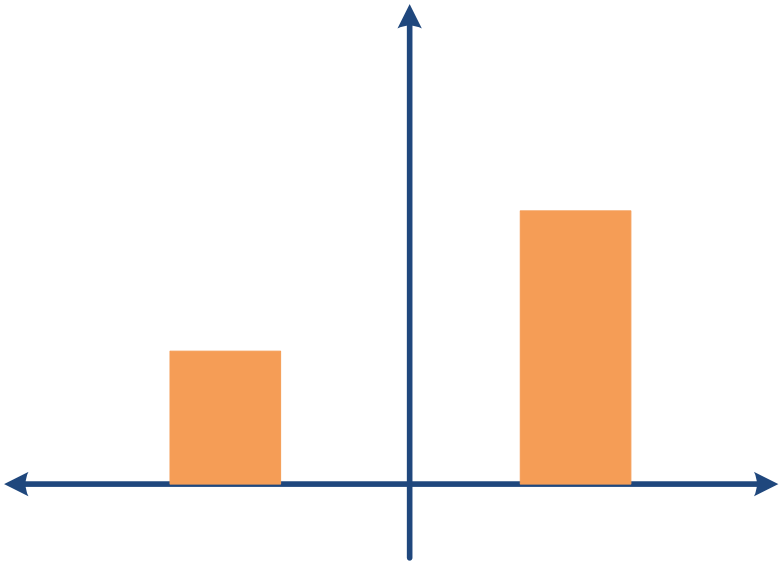
CONT….



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In this topic we have learnt about the

- ✓ I/Q MISMATCH OR I/Q IMBALANCE
- ➢ Next we are going to learn HETERODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P06_R01:HETERODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES

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HETERODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES

- **Advantages**

- Can easily adapt itself to many different standards requirements achieving a very good sensitivity and selectivity.

- DC offset of the first few stages is removed by BPF, and that of the last stage is suppressed by the total gain in the proceeding stages.

- The LO frequency is out of the band and suppressed by BPF.

- **Disadvantages**

- Need of many external components, i.e. the image rejection filter, complexity of the structure causes problems if a high level of integration is necessary.

- It is a major drawback from the costs point of view.

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In this topic we have learnt about the

- ✓ HETERODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES
- ➢ Next we are going to learn HOMODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P07_R01:HOMODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES

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HOMODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES

- **Advantages**

- Less complex and easy integration on chip.
- Easy availability of baseband signal.

- **Disadvantages**

- DC offset
- IQ imbalance

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In this topic we have learnt about the

- ✓ HOMODYNE ARCHITECTURE ADVANTAGES & DISADVANTAGES
- ➢ Next we are going to learn Comparison of both Architecture

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P08_R01:Comparison of both Architecture

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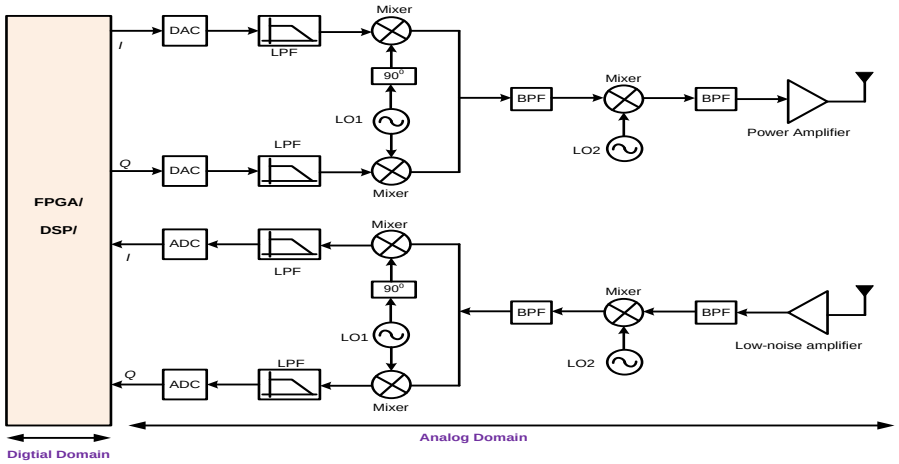
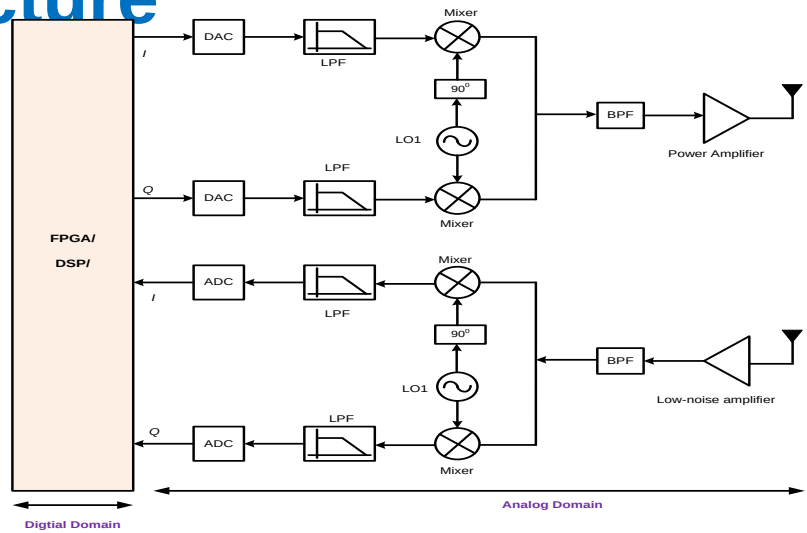
Comparison of both Architecture





- High complex, & difficult for chip based implementation.
- DC offset and LO leakage and IQ imbalance is not much significant.
- Costly due to more extra analog component.

- Easier for chip-based implementation.
- DC offset and LO leakage and IQ imbalances are very much significant.
- Less costly.

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In this topic we have learnt about the

- ✓ Comparison of both Architecture
- ➢ Next we are going to learn SDR Companies

RAHSOFT

Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P09_R01:SDR Companies-I

SDR Companies

Analog Devices (Front-End)

ICs	Bandwidth (MHz)	Function	Frequency (GHz)
AD9361	56	2Rx, 2Tx	0.07-6
AD9364	56	1Rx, 1Tx	0.07-6
AD9363	20	2Rx, 2Tx	0.325-3.8
AD9371	100 Rx, 250 Tx, ORx	2Rx, 2Tx, ORx, SnRx	0.3-6
AD9375	100 Rx, 250 Tx, ORx	2Rx, 2Tx, ORx, SnRx	0.3-6
ADRV9009	200 Rx, 450 Tx, ORx	2Rx, (1 ORx), 2Tx	0.075-6
ADRV9008-1	200 Rx	2Rx	0.075-6
ADRV9008-2	450 Tx, ORx	2Tx,1 ORx	0.075-6
ADRV9026	200 Rx, 450 Tx, ORx	4Rx, 4Tx, 2 ORx	0.075-6
ADRV9002	.12 to> 40	2Rx, 2Tx	0.03-6

https://www.analog.com/media/en/news-marketing-collateral/solutions-bulletins-brochures/radioverse-tech-and-radio-design-ecosystem.pdf

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CONT….

Front-End		Baseband	Applications
	Evaluation Boards	**Carrier Platforms**	
AD936x	AD-FMCOMMS2 (AD9361), AD-FMCOMMS3 (AD9361), AD-FMCOMMS4 (AD9364), AD-FMCOMMS5 (AD9361)	Xilinx® ZC706, ZC702, VC707, KC705, AC701, ZedBoard™, MITX045	3G/4G Pico cell, SDR, 3G/4G macro BTS, massive MIMO, Radar, Test equipment, Phased Array, UHF, VHF, Satellite Communication, Point-to-pint communication
AD9371	ADRV9371-N/PCBZ, ADRV9371-W/PCBZ	EVAL-TPG-ZYNQ3, Xilinx ZC706	
AD9375	ADRV9375-W/PCBZ, ADRV9375-N/PCBZ	EVAL-TPG-ZYNQ3, Xilinx ZC706	
ADRV9008 ADRV9009	ADRV9009-W/PCBZ, ADRV9008-1W/PCBZ, ADRV9008-2W/PCBZ	EVAL-TPG-ZYNQ3, Xilinx ZCU102, Intel® Arria® 10 SoC	
ADRV9026	ADRV9026-HB/PCBZ, ADRV9026-MB/PCBZ, ADRV9026-LB/PCBZ	ADS8-V2EBZ, ADS9-V2EBZ, Intel Arria 10 SoC	
ADRV9002	ADRV9002NP/W1/PCBZ, ADRV0992/NP/W2/PCBZ	Xilinx ZC706 (others TBA)	

https://www.analog.com/media/en/news-marketing-collateral/solutions-bulletins-brochures/radioverse-tech-and-radio-design-ecosystem.pdf

In this topic we have learnt about the

- ✓ Analog Device based SDR
- ➢ Next we are going to learn other SDRs

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P010_R01:SDR Companies-II

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CONT….

National Instruments

USRP-2900
USRP-2901
USRP-2920
USRP-2921
USRP-2922
USRP-2930
USRP-2932
USRP-2940

- Many others with frequency range from 50 MHz to 6GHz

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CONT….

LimeSDR

ICs	Frequency (GHz)	Bandwidth (MHz)	Function	Duplex	Sampling Rate (MSPS)
LMS6002D	03-3.8	28	SISO	Full	40
LMS7002M	0.0001-3.8	>60	MIMO	Half and Full	ADC-160 DAC-640

Open source

https://limemicro.com/technology/

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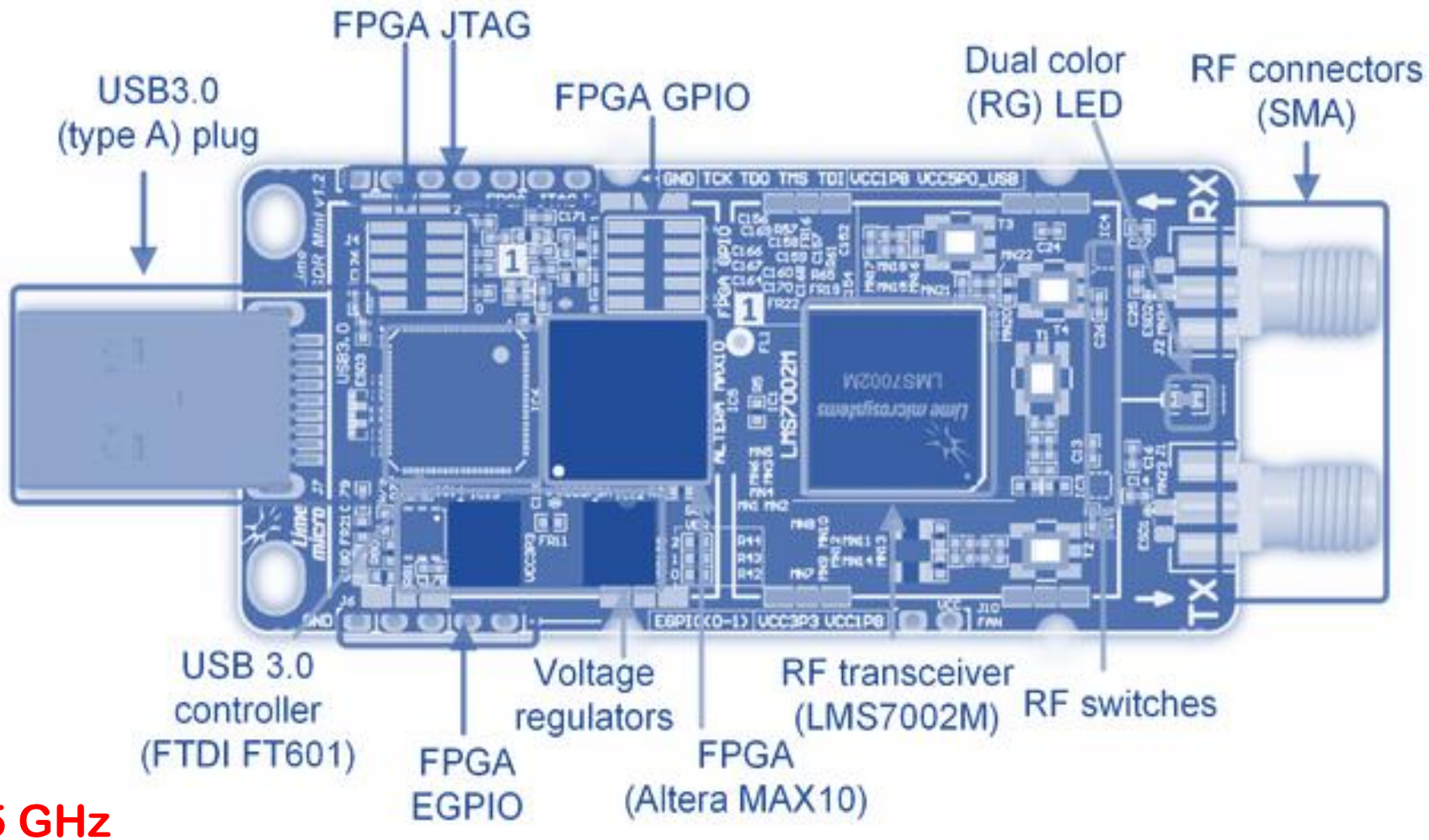
CONT….

LimeSDR



Frequency Range: 10 MHz - 3.5 GHz
RF Bandwidth 30.72 MHz
Sample Rate: 30.72 MSPS
Tx & Rx Channel: 1

https://wiki.myriadrf.org/images/thumb/2/24/LimeSDR-Mini_v1.2_top_componens.png/640px-LimeSDR-Mini_v1.2_top_componens.png

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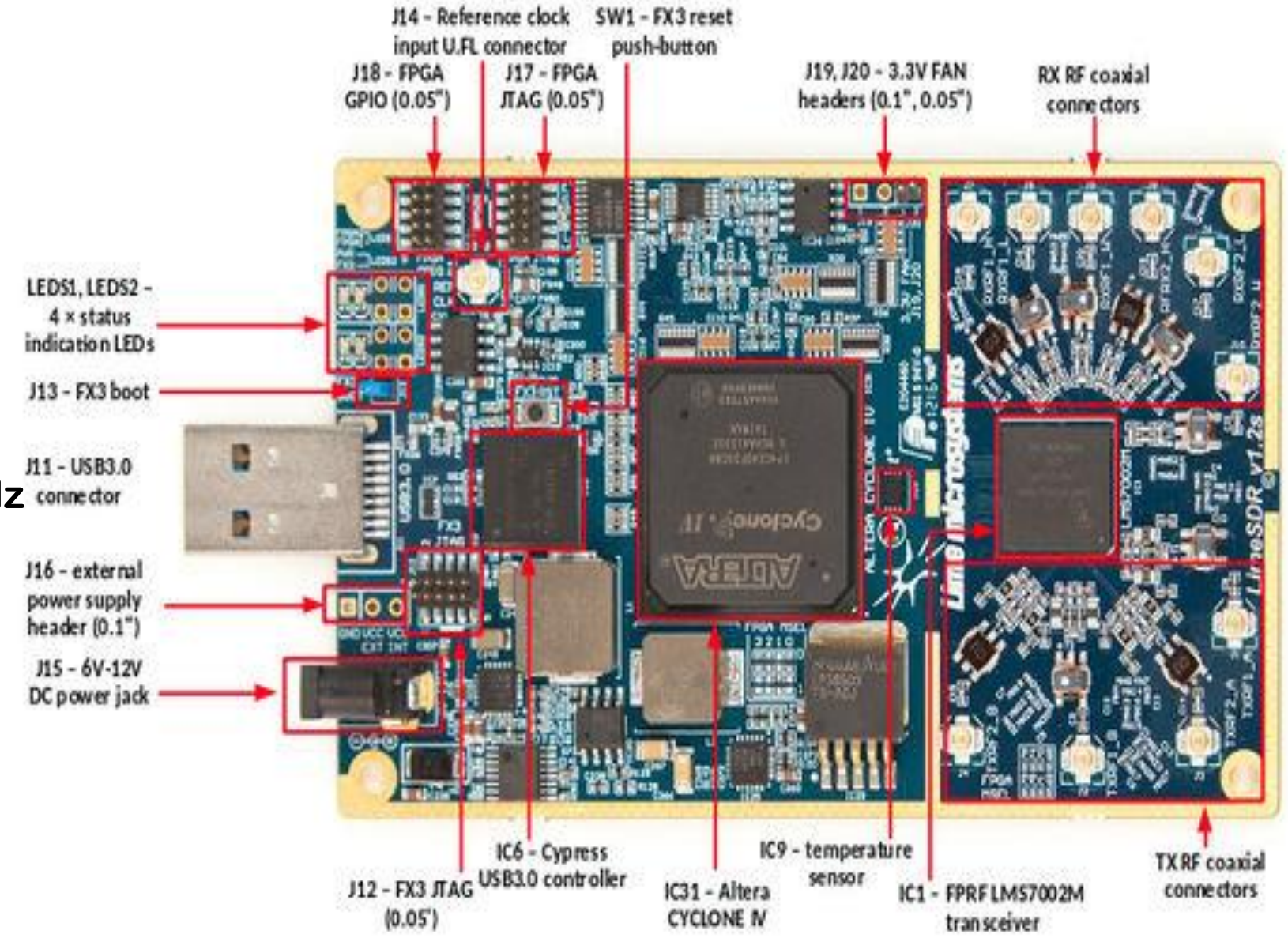
CONT….

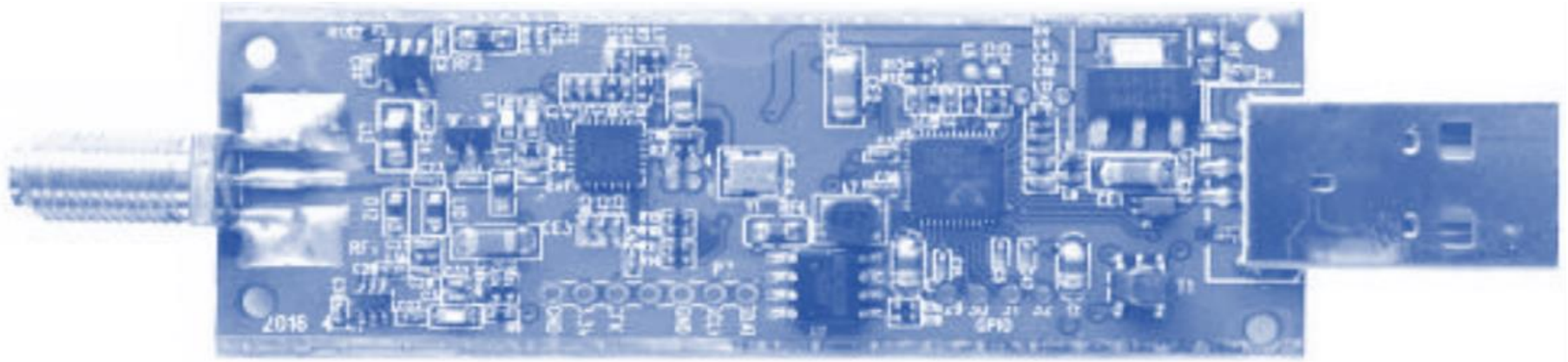
RF Transceiver: LMS7002M MIMO
FPGA: Altera Cyclone IV
Frequency range: 100 kHz – 3.8 GHz
Bandwidth: 61.44 MHz
2×2 MIMO



https://wiki.myriadrf.org/images/thumb/3/3b/LimeSDR-USB-Overview.jpg/550px-LimeSDR-USB-Overview.jpg

CONT….

RTL-SDR



Bandwidth: Up to 2.4 MHz stable
ADC: RTL2832U 8-bits
Frequency Range: 500 kHz – 1766 MHz

https://www.rtl-sdr.com/wp-content/uploads/2018/02/RTL-SDR-Blog-V3-Datasheet.pdf

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CONT….

Parameters	HackRF One	Ettus B200	Ettus B210	PlutoSDR	RTL-SDR	LimeSDR
Freq. Range	1MHz-6GHz	70MHz-6GHz	70MHz-6GHz	300MHz-3.8GHz	22MHz-2.2GHz	100kHz-3.8GHz
Bandwidth	20MHz	61.44MHz	61.44MHz	20MHz	3.2MHz	61.44MHz
DAC/ADC	8 bits	12 bits	12 bits	12 bits	8 bits	12 bits
Sample Rate	20MSPS	61.44MSPS	61.44MSPS	40MSPS	3.2MSPS	61.44MSPS
Tx Channels	1	1	2	1	0	2
Receivers	1	1	2	1	1	2
Duplex	Half	Full	Full	Full	N/A	Full

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In this topic we have learnt about the

- ✓ SDR Companies and their SDR systems
- ➢ Next we are going to do a Tear down of a SDR

RAHSOFT

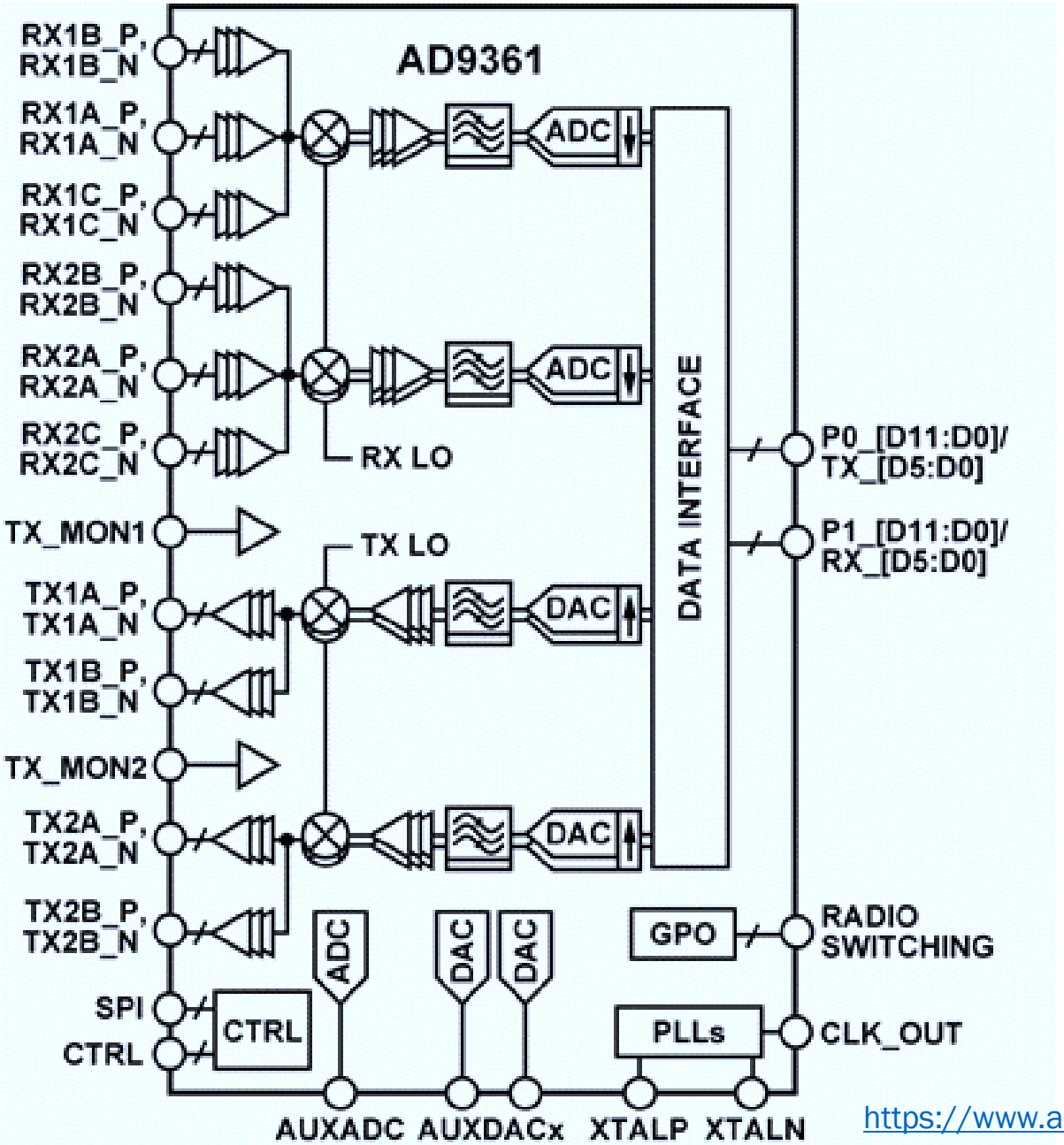
Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P11_R01:Tear down of a SDR-I

RAHSOFT

Tear down of a SDR



- 2 × 2 transceiver
- Integrated 12-bit DACs and ADCs
- TX range: 47 MHz to 6.0 GHz
- RX range: 70 MHz to 6.0 GHz
- Tunable channel bandwidth: <200KHz to 56 MHz
- Automatic and manual gain control
- APPLICATIONS

Point to point communication systems

Femtocell/picocell/microcell base stations

General-purpose radio systems

https://www.analog.com/en/products/ad9361.html

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Fundamentals of SDR:RAHSDR480

Module-2:SDR Hardware Architecture

RAHSDR480_L02_P12_R01:Tear down of a SDR-II

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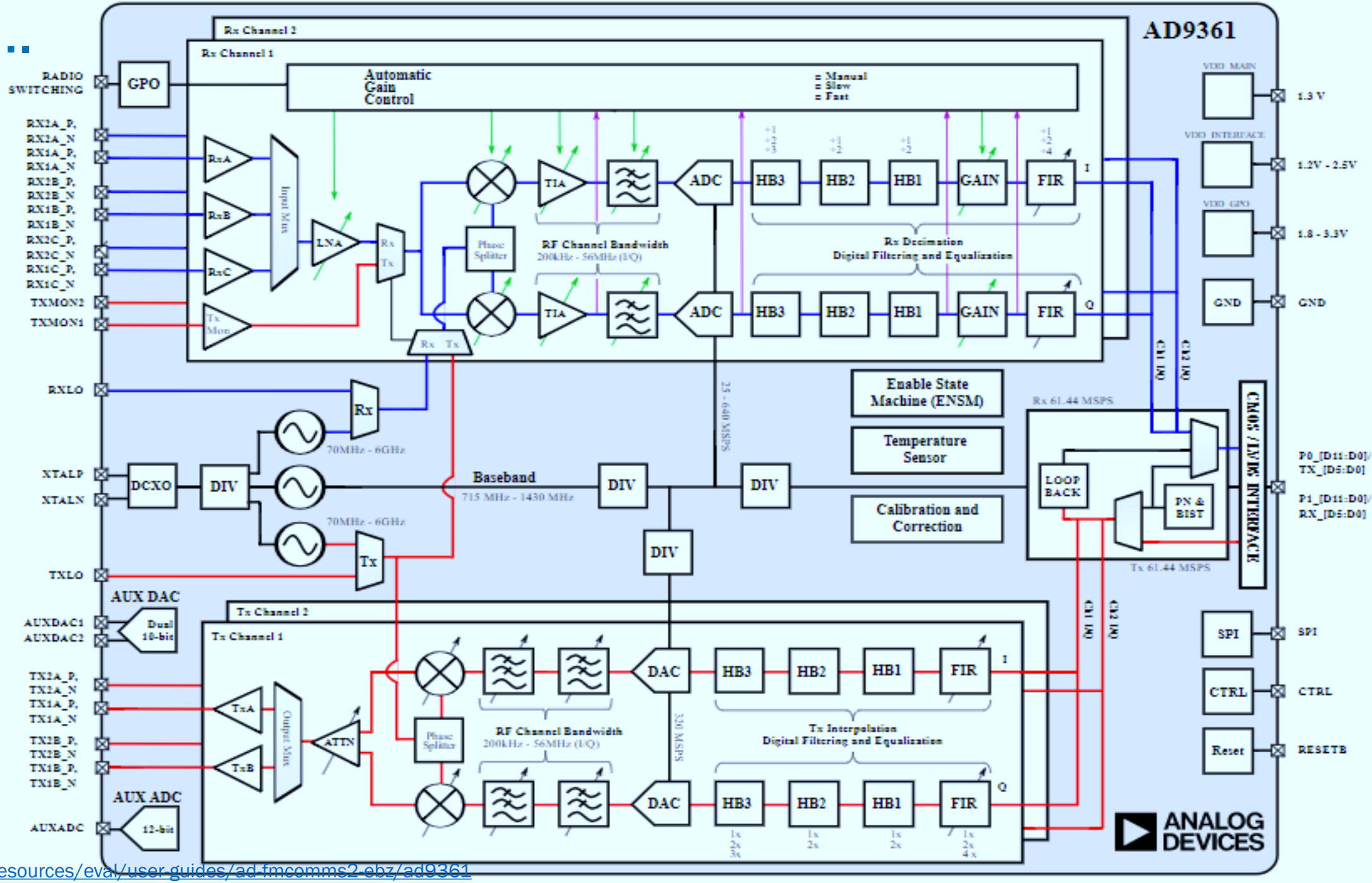
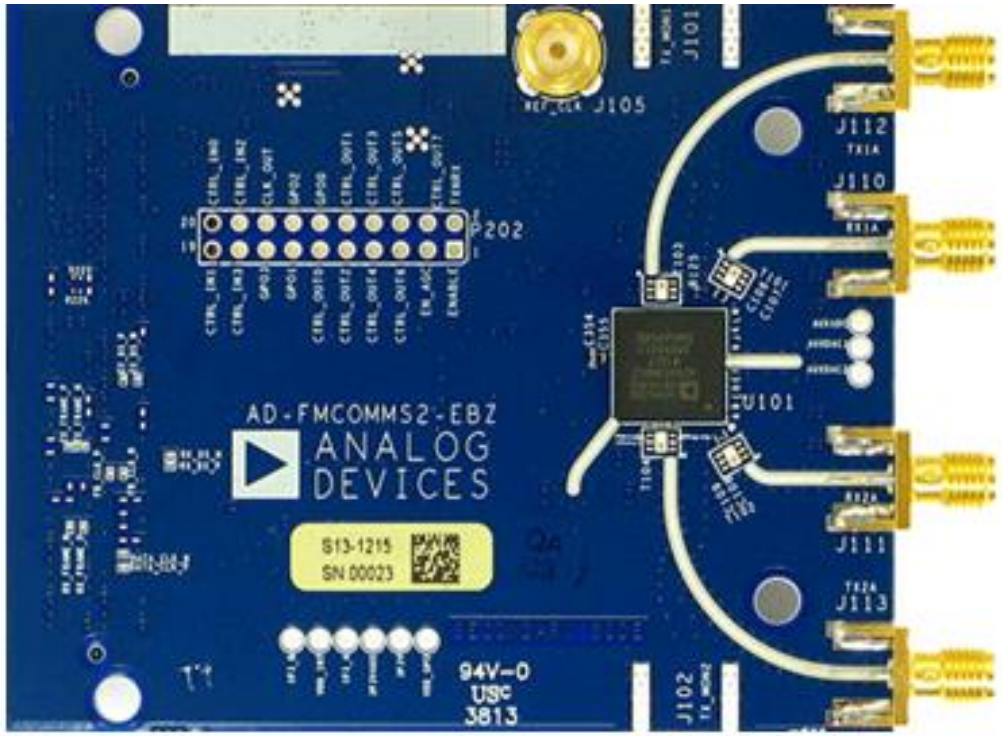
CONT....

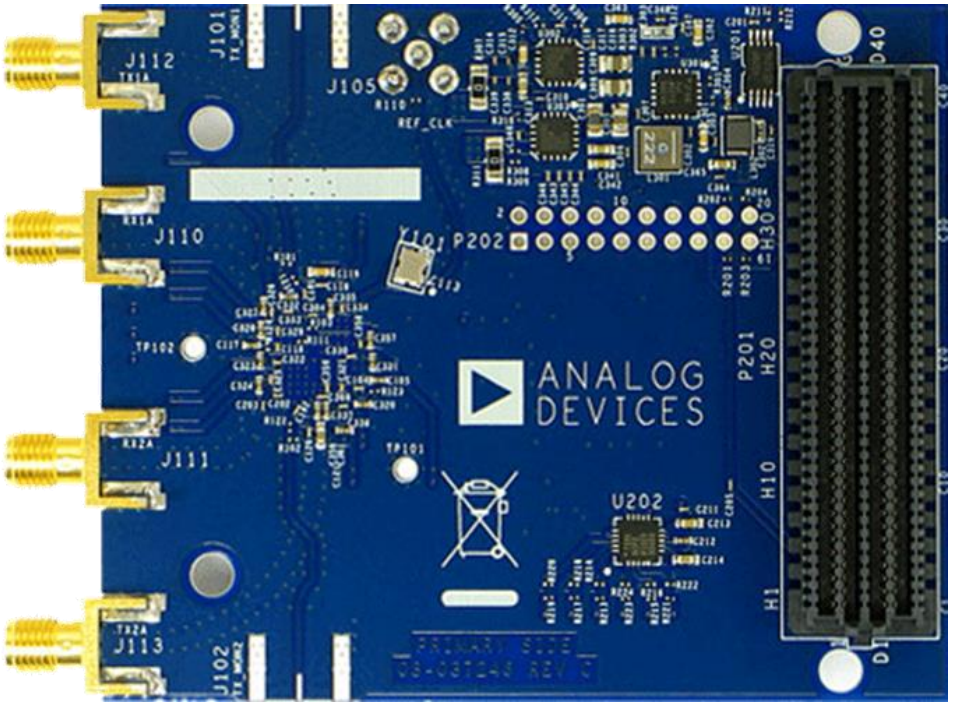


https://wiki.analog.com/resources/eval/user-guides/ad-fmcomms2-ebz/ad9361

CONT….

AD-FMCOMMS2-EBZ





https://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/EVAL-AD-FMCOMMS2.html

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In this topic we have learnt about the

- ✓ Tear down of a SDR
- ➢ Next we are going to learn Module-3: Communication Layer

RAHSOFT

Fundamentals of SDR:RAHSDR480

Module-3:Communication Layer

RAHSDR480_L03_P01_R01:Motivation

Motivation

Fundamentals of SDR:RAHSDR480

Module-3:Communication Layer

RAHSDR480_L03_P02_R01:Communication Layer

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Communication Layer

OSI-7 layers

Application	Data	Network access to application, ex. Web Browser
Presentation	Data	Encryption (HTTPS)
Session	Data	Start and End session
Transport	Segments	End to End Connection and Reliability
Network	Packets	Determine best path for sink, Logical addressing (IP)
Data Link	Frames	Switches, Physical addressing
Physical	Bits	Media, Signal, Binary Transmission, Network Interface Cards

In this topic we have learnt about the

- ✓ Communication Layer
- ✓ Next we are going to learn Module-4: Software for SDR

RAHSOFT

Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P01_R01: Processing Architecture for SDR

RAHSOFT

Processing Architecture for SDR

- General Purpose Processor
- Digital Signal Processor
- Field Programmable Gate Arrays
- Graphics Processing Unit
- Advanced RISC Machine

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In this topic we have learnt about the

- ✓ Processing Architecture for SDR
- ✓ Next we are going to learn SDR Software

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P02_R01: SDR Software

SDR Software

- The development environment is a pre-built packages.
- Signal Processing Blocks.
- Open Source.
- Hardware Support.
- Available Platform

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CONT….

S.N.		Platform	Type
1.	SDR#	Windows	Free
2.	HDSDR	Windows	Free
3.	SDR-RADIO.COM V2/V3	Windows	Free
4.	Linrad	Windows/Linux/macOS	Free
5.	GQRX	OSX/Linux	Free
6.	CubicSDR	Linux/Windows/macOS	Free
7	SDRUno	Windows	Free
8.	SigDigger	Linux	Free
9.	ShinySDR	GNU Radio	Free
10.	WebRadio	Linux	Free
11.	OpenWebRX	Python Based	Free
12.	Sodira	Windows	Trial/Paid
13.	SDR Touch	Android	Trial/Paid
14.	RTLSDR Scanner	Windows	Free
15.	Pothos SDR	Windows	Free
16.	Advance Design System (ADS)	Windows	Trial/Paid
17.	NI Labview	Linux/Windows	Trial/Paid
18.	SDR angel	Linux/Windows	Free
19.	IIO Oscilloscope	Linux/Windows/macOS	Free
20.	GNU Radio	Linux/Windows/macOS	Free
21.	MATLAB	Linux/Windows/macOS	Trial/Paid
22.	Scilab	Linux/Windows/macOS	Free
23.	SystemVue	Windows	Trial/Paid
24.	Python	Linux/Windows/macOS	Free

In this topic we have learnt about the

- ✓ SDR Software
- ✓ Next we are going to learn IIO Oscilloscope

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P03_R01: IIO Oscilloscope

IIO Oscilloscope

- The ADI IIO Oscilloscope is a cross platform GUI application, which demonstrates the interface of different transceiver boards.
- It supports data transmission and capture and data can be plotted in time domain, frequency domain, constellation and cross-correlation.
- This application shows several settings of SDRs to modify and view using GUI.
- Transmit only designed signals.

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CONT....

ADI IIO Oscilloscope

File Settings Help

Debug | DMM | AD936X | AD936X Advanced

Controls | Block Diagram

AD9361 / AD9364 Global Settings

Active ENSM: fdd | Calibration Mode: auto | TRX Rate Governor: nominal | Filter FIR configuration:

ENSM Modes: fdd | Calibration Modes: auto | TRX Rate Governor Available: nominal | (None)

RX Path Rates: BBPLL: 983.040 ADC: 245.760 R2: 122.880 R1: 61.440 RF: 30.720 RXSAMP: 30.720

TX Path Rates: BBPLL: 983.040 DAC: 122.880 T2: 122.880 T1: 61.440 TF: 30.720 TXSAMP: 30.720

Auto Filter

XO Correction 40000037

AD9361 / AD9364 Receive Chain

RF Bandwidth(MHz): 18.000 | Sampling Rate (MSPS): 30.719999 / 30.719999 | RX LO Frequency(MHz): 2400.000000 | External RX LO | RF Port Select: A_BALANCED | Fastlock Profile: 0 | Store | Recall

Tracking: Quadrature, RF DC, BB DC

RX 1

Hardware Gain(dB): 71.00

RSSI(dB): 107.25 dB

Gain Control: slow_attack

Gain Control Modes: slow_attack

AD9361 / AD9364 Transmit Chain

RF Bandwidth(MHz): 18.000 | Sampling Rate (MSPS): 30.719999 / 30.719999 | TX LO Frequency(MHz): 2450.000000 | External TX LO | RF Port Select: A | Fastlock Profile: 0 | Store | Recall

TX 1

Attenuation(dB): 10.00

Reload Settings

CONT....

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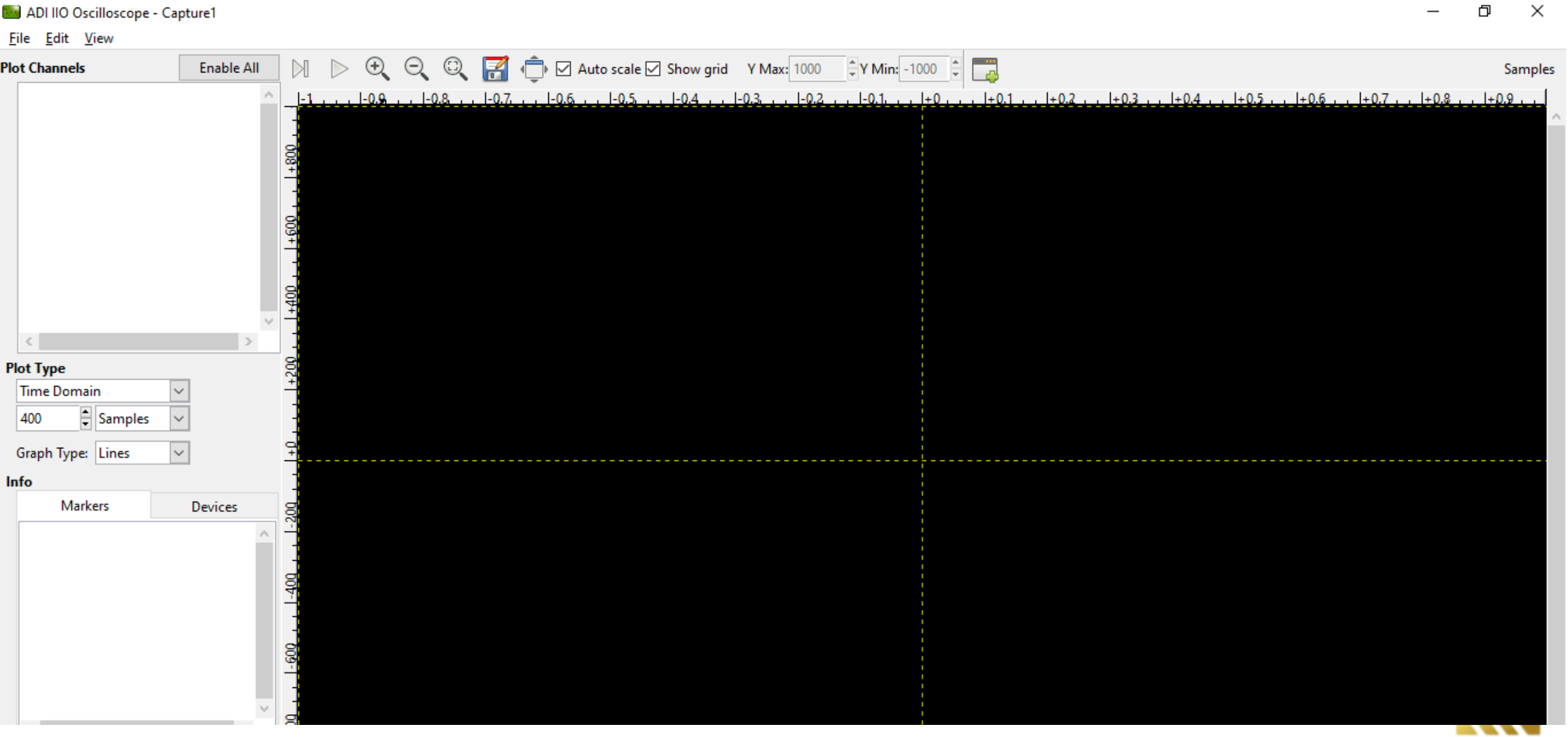
CONT....



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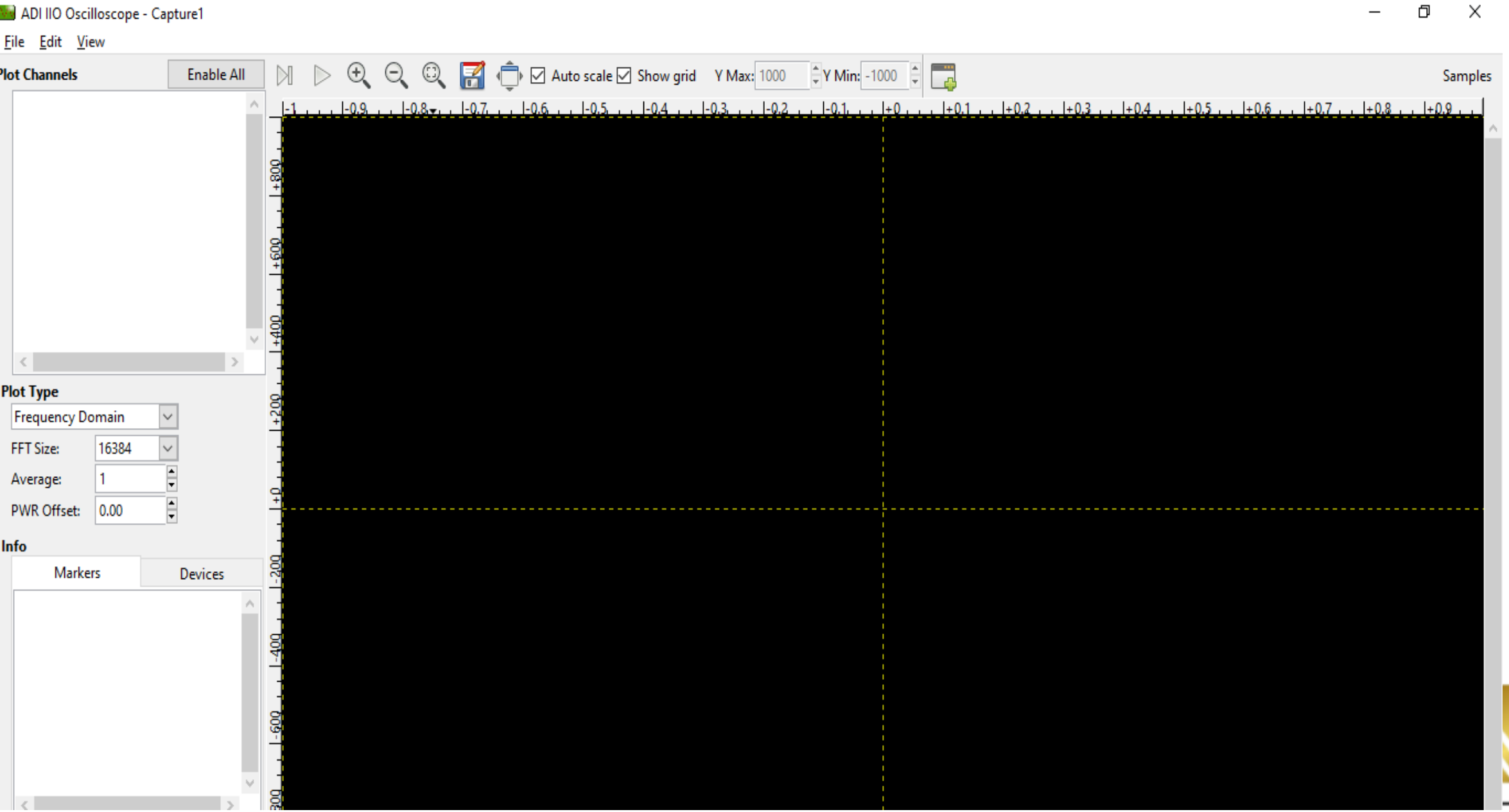
CONT....



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In this topic we have learnt about the

- ✓ IIO Oscilloscope
- ✓ Next we are going to learn GNU RADIO

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P04_R01: GNU RADIO

GNU RADIO

- GNU Radio is a open source Software toolkit for SDR that offers signal processing blocks for the implementation of SDRs.

- Provides hardware support along with simulation like environment.

- Broadly used in research, industry, academia, and hobbyist environments to support both wireless communications research and real-world radio systems.

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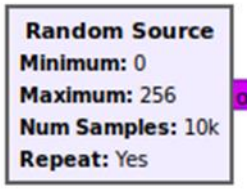
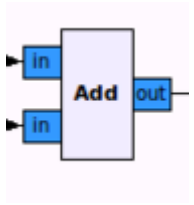
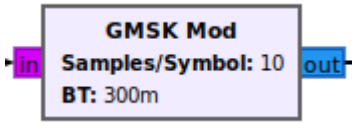
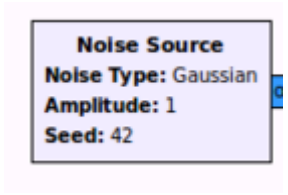
CONT....

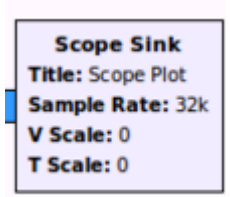
- The individual processing stages can be thought of blocks which can be configured.

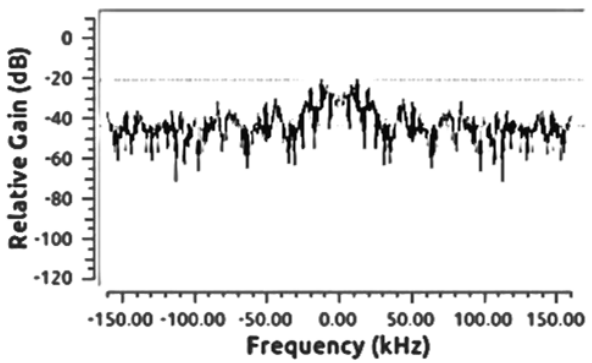


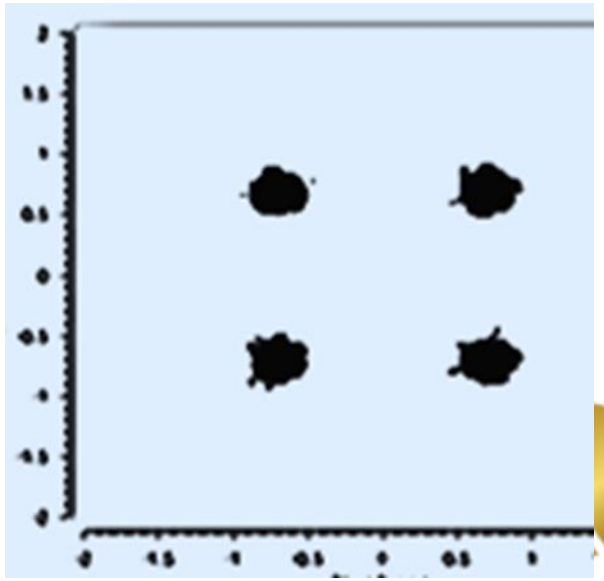












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CONT….

Different Blocks

Waveform Generation

- Constant Source
- Noise Source
- Signal Source (Square, Sine etc.)

Modulators

- AM Demod
- Continuous Phase Modulation
- PSK Mod / Demod
- GFSK Mod / Demod
- GMSK Mod / Demod
- QAM Mod / Demod
- WBFM Receive
- NBFM Receive

Math Operators

- Abs
- Add
- Complex Conjugate
- Divide
- Integrate
- Log10
- Multiply
- RMS
- Subtract

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CONT....

Filters

- Band Pass / Reject Filter
- Low / High Pass Filter
- IIR Filter
- Generic Filter bank
- Hilbert
- Decimating FIR Filter
- Root Raised Cosine Filter
- FFT Filter

Channel Models

- Fading Model
- Dynamic Channel Model
- Frequency Selective Fading Model

Instrumentation

- Constellation Sink
- Frequency Sink
- Histogram Sink
- Number Sink
- Time Raster Sink
- Time Sink
- Waterfall Sink

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CONT….

Fourier Analysis

- FFT
- Log Power FFT
- Goertzel (Resamplers)
- Fractional Resampler
- Polyphase Arbitrary Resampler
- Rational Resampler (Synchronizers)
- Clock Recovery MM
- Correlate and Sync
- Costas Loop
- FLL Band-Edge
- PLL Freq Det
- PN Correlator
- Polyphase Clock Sync

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In this topic we have learnt about the

- ✓ GNU RADIO
- ✓ Next we are going to learn NI LabVIEW

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P05_R01: NI LabVIEW

NI LabVIEW

- A graphical programming interface where the created user interfaces is integrated into the development cycle.

- This graphical approach allows non-programmers to build programs by drag & drop of the virtual representations of lab equipment with which they are already familiar.

- LabVIEW programs-subroutines are termed virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector pane.

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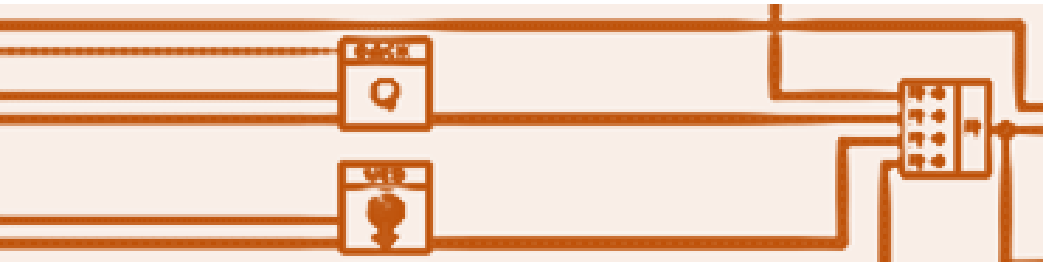
CONT….

- Also useful in Industrial application & data acquisition.
- Can program FPGA.



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In this topic we have learnt about the

- ✓ NI LabVIEW
- ✓ Next we are going to learn Python

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P06_R01: Python

Python

- Python is a open source Software toolkit for SDR that offers signal processing blocks for the implementation of SDRs.
- Lot of pre-built signal Processing Libraries are available.

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In this topic we have learnt about the

- ✓ Python
- ✓ Next we are going to learn MATLAB

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P07_R01: MATLAB

MATLAB

- MATLAB or matrix laboratory is a programming language & numerical computing environment developed by MathWorks.
- Operations like matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.
- Also consist of Simulink where option of block wise programming is available.
- Useful in engineering, science, and economics.

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In this topic we have learnt about the

- ✓ MATLAB
- ✓ Next we are going to learn Scilab

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P08_R01: Scilab

Scilab

- Scilab is a free and open-source, cross-platform numerical computational package and a high-level, numerically oriented programming language.
- It can be used for signal processing, statistical analysis, image enhancement, fluid dynamics simulations, numerical optimization, and modeling, simulation of explicit and implicit dynamical systems and symbolic manipulations.
- Xcos is a graphical editor to design hybrid dynamical systems models. Models can be designed, loaded, saved, compiled and simulated.
- Xcos is freely available and distributed with Scilab.

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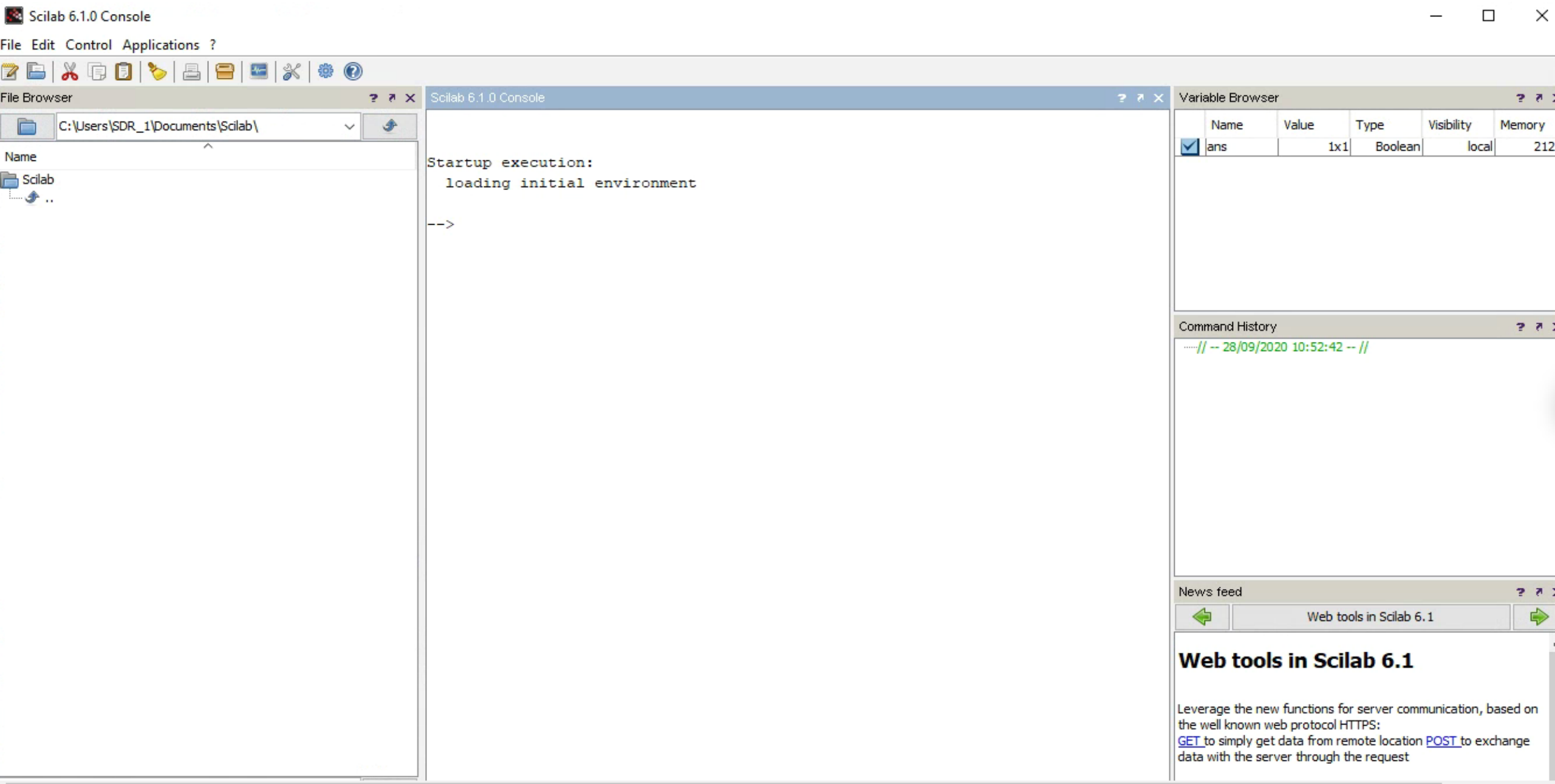
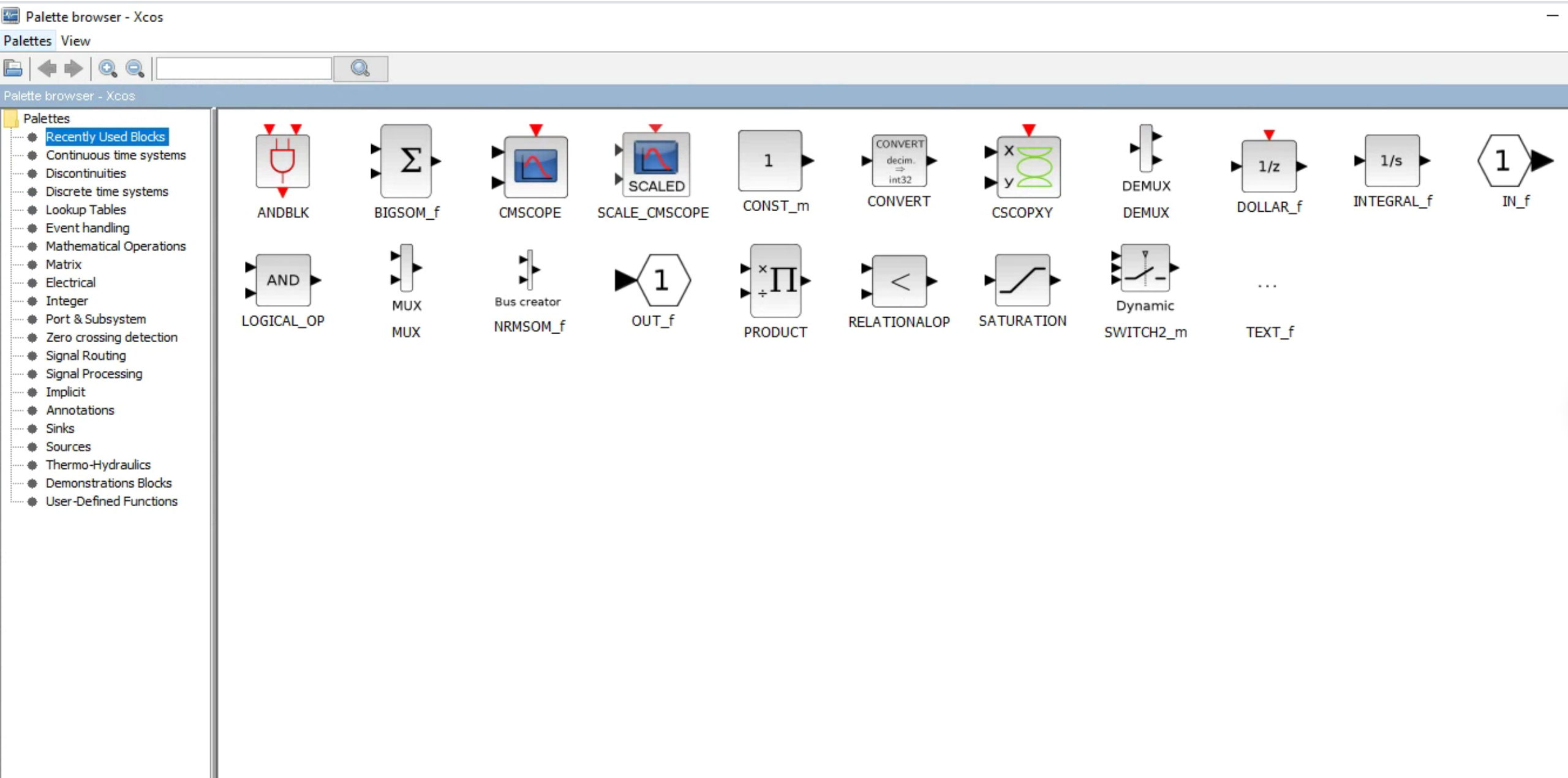
CONT....


Scilab 6.1.0 Console
File Edit Control Applications ?
File Browser
C:\Users\SDR_1\Documents\Scilab\
Name
Scilab
..
Scilab 6.1.0 Console
Startup execution:
loading initial environment
-->
Variable Browser
Name
Value
Type
Visibility
Memory
ans
1x1
Boolean
local
212
Command History
// -- 28/09/2020 10:52:42 -- //
News feed
Web tools in Scilab 6.1
Web tools in Scilab 6.1
Leverage the new functions for server communication, based on the well known web protocol HTTPS:
GET to simply get data from remote location POST to exchange data with the server through the request

CONT....


Palette browser - Xcos
Palettes View
Palette browser - Xcos
Palettes
Recently Used Blocks
Continuous time systems
Discontinuities
Discrete time systems
Lookup Tables
Event handling
Mathematical Operations
Matrix
Electrical
Integer
Port & Subsystem
Zero crossing detection
Signal Routing
Signal Processing
Implicit
Annotations
Sinks
Sources
Thermo-Hydraulics
Demonstrations Blocks
User-Defined Functions
ANDBLK
BIGSOM_f
CMSCOPE
SCALE_CMSCOPE
CONST_m
CONVERT
CSCOPXY
DEMUX
DEMUX
DOLLAR_f
INTEGRAL_f
IN_f
LOGICAL_OP
MUX
MUX
Bus creator
NRMSOM_f
OUT_f
PRODUCT
RELATIONALOP
SATURATION
Dynamic
SWITCH2_m
TEXT_f

In this topic we have learnt about the

- ✓ Scilab
- ✓ Next we are going to learn SDR Angel

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P09_R01: SDR Angel

SDR Angel

- SDR angel is an signal analyzer frontend to various hardware.
- Blade RF
- Hack RF
- LimeSDR
- PlutoSDR
- SoapySDRa
- USRP
- XTRX

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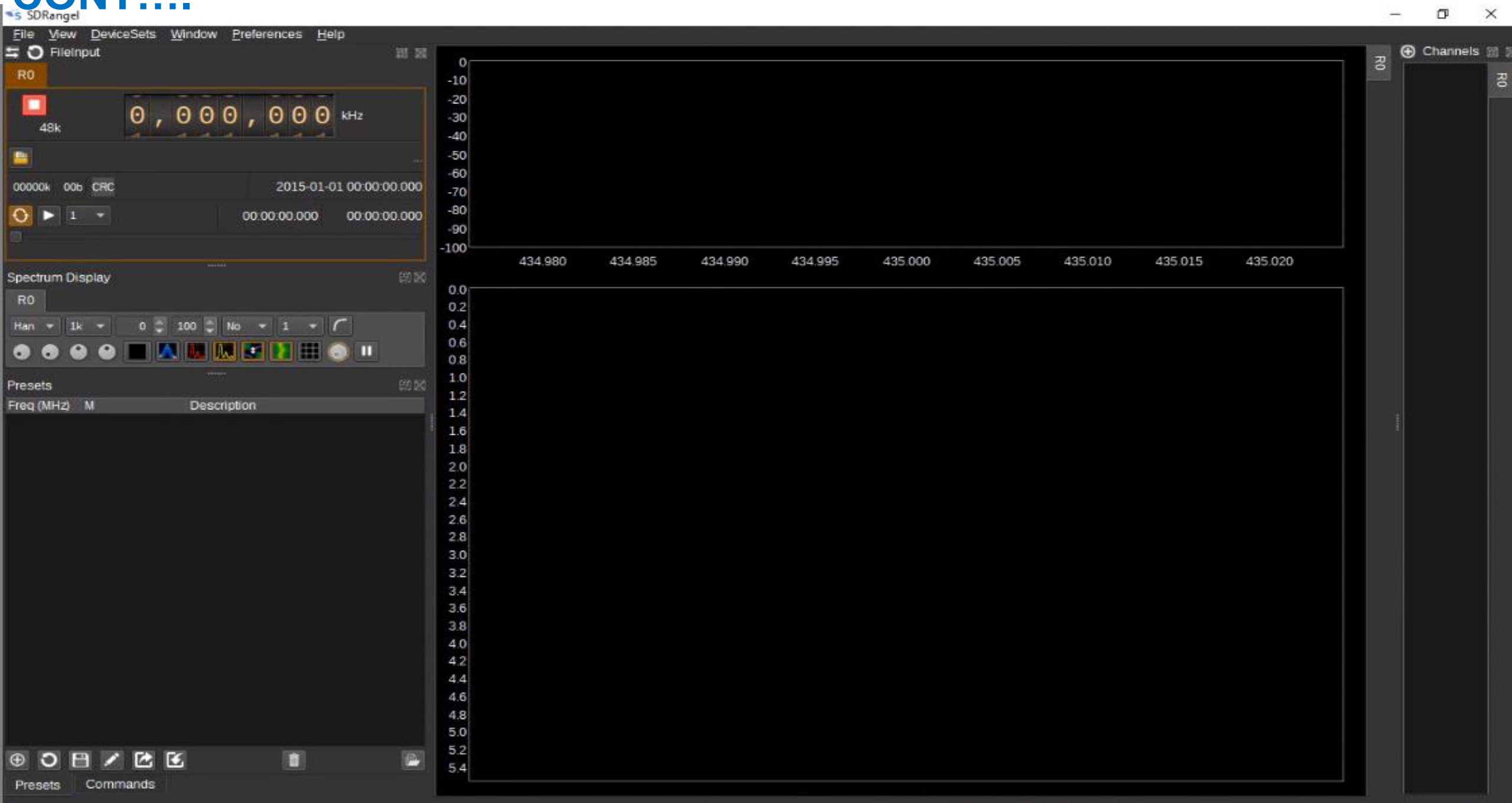
CONT....


SDRangel
File View DeviceSets Window Preferences Help
FileInput
R0
48k
0,000,000 kHz
00000k 00b CRC
2015-01-01 00:00:00.000
1
00:00:00.000
00:00:00.000
Spectrum Display
R0
Han 1k 0 100 No 1
Presets
Freq (MHz) M Description
Presets Commands
0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100
434.980 434.985 434.990 434.995 435.000 435.005 435.010 435.015 435.020
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0 5.2 5.4
R0
Channels
R0

In this topic we have learnt about the

- ✓ SDR Angel
- ✓ Next we are going to learn SDR Sharp

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P10_R01: SDR Sharp

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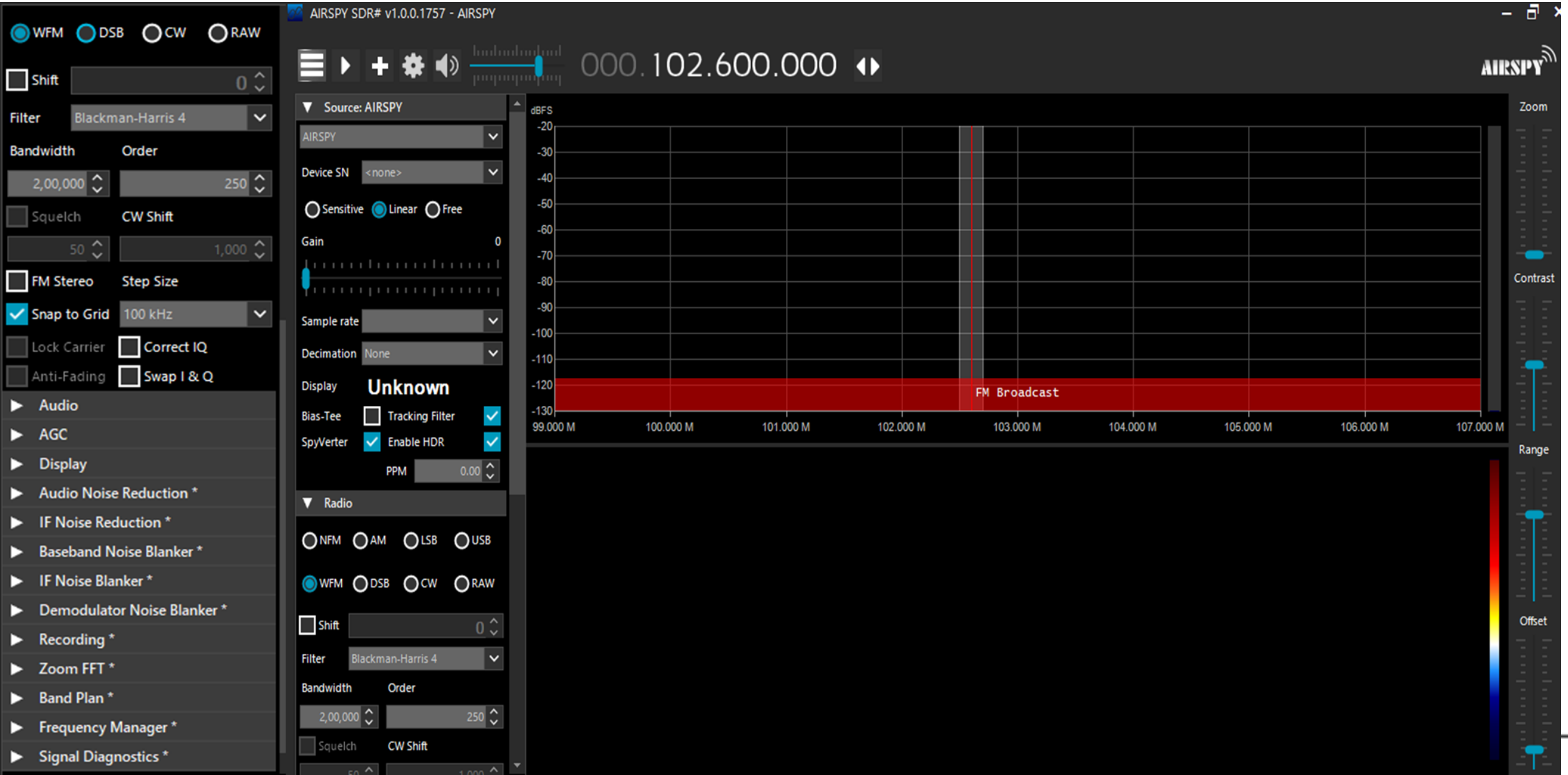
SDR Sharp

- The best free SDR software for Airspy and RTL-SDR dongles!



In this topic we have learnt about the

- ✓ SDR Sharp
- ✓ Next we are going to learn SystemVue

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Fundamentals of SDR:RAHSDR480

Module-4:Software for SDR

RAHSDR480_L04_P11_R01: SystemVue

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SystemVue

- Connect system-level design to RF circuit simulation. Verify physical layer system designs. Interoperate with test equipment while wireless standards evolve.

- Validate baseband and RF integration early
- Streamline verification with pre-built test benches
- Easily connect to test equipment
- Perform 5G architecture development and validation
- Create and verify algorithms with baseband libraries
- Simulate real-world scenarios.
- Standards libraries.

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In this topic we have learnt about the

- ✓ SystemVue
- ✓ Next we are going to learn Module-5:SDR SELECTION CRITERIA

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P01_R01: MOTIVATION

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MOTIVATION

- This module covers the different aspects of SDR so that we can choose our SDR based on parameters such as:

- Bandwidth
- Transmitter Power
- Frequency Coverage
- Dynamic Range
- Cost - Efficiency Trade-off
- RF Input to Receiver
- Error-vector magnitude (EVM)

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In this topic we have learnt about the

- ✓ MOTIVATION for SDR selection
- ✓ Next we are going to learn Bandwidth & Sampling rate

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P02_R01: Bandwidth & Sampling rate

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Bandwidth & Sampling rate

- Requirement of signal transmission e.g. GSM, WCDMA, LTE or LTE-CA
- Tone transmission
- FM transmission
- How much bandwidth need to be monitored if uses as a spectrum analyzer?

EX:

Nyquist Criteria:

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In this topic we have learnt about the

- ✓ Bandwidth & Sampling rate
- ✓ Next we are going to learn TRANSMITTER POWER

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P03_R01: TRANSMITTER POWER

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TRANSMITTER POWER

- Total power required for transmission.
- Data sheet generally talk about power of transmitter for single tone.

- Channel power decreases with increase in bandwidth.

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In this topic we have learnt about the

- ✓ TRANSMITTER POWER
- ✓ Next we are going to learn FREQUENCY COVERAGE

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P04_R01: FREQUENCY COVERAGE

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FREQUENCY COVERAGE

- Need of transmission e.g
- VHF, UHF, 5G sub 6 GHz

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In this topic we have learnt about the

- ✓ FREQUENCY COVERAGE
- ✓ Next we are going to learn DYNAMIC RANGE

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P05_R01: DYNAMIC RANGE

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DYNAMIC RANGE

- Signal-to-noise-ratio (SNR) = 6.02 N + 1.76 dB
- Quality of transmission

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In this topic we have learnt about the

- ✓ DYNAMIC RANGE
- ✓ Next we are going to learn Cost-Efficiency Trade-off

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P06_R01: Cost-Efficiency Trade-off

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Cost-Efficiency Trade-off

In this topic we have learnt about the

- ✓ Cost-Efficiency Trade-off
- ✓ Next we are going to learn Error-Vector Magnitude

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P07_R01: Error-Vector Magnitude

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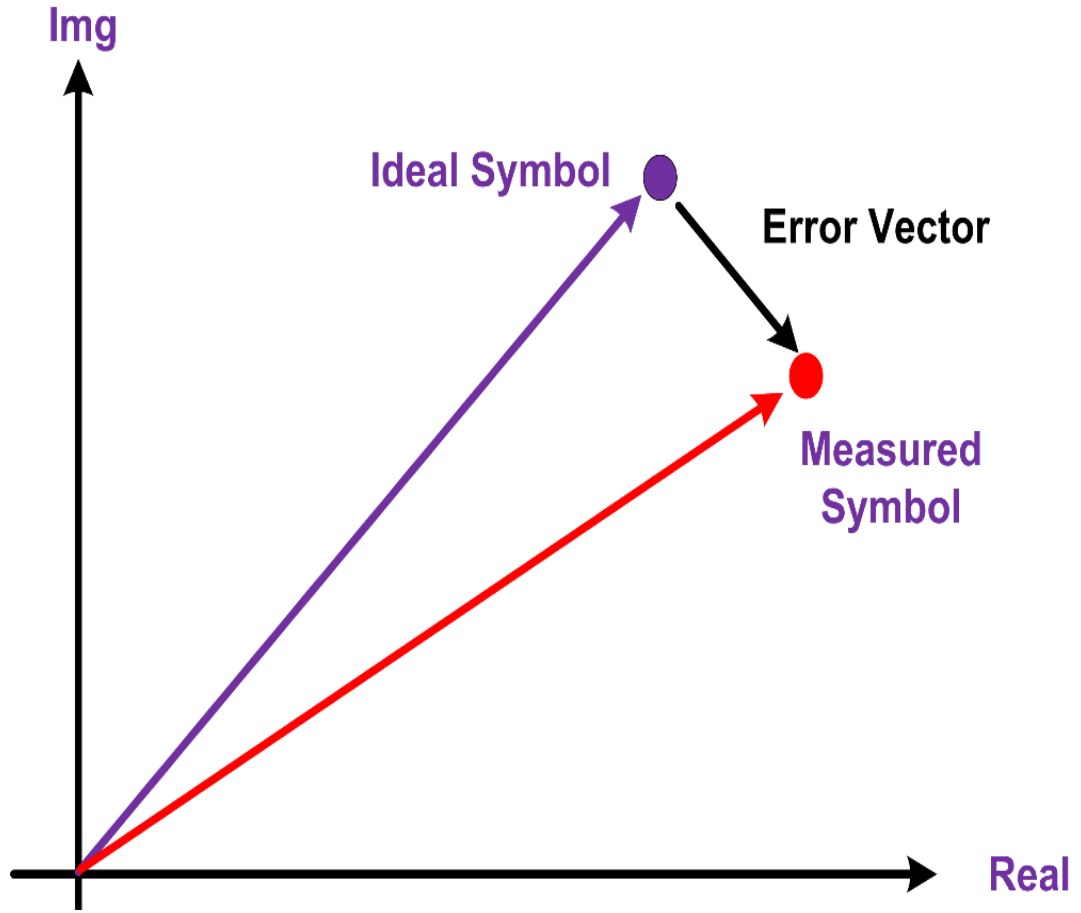
Error-Vector Magnitude

- The modulation quality of the transmission is determined using the EVM metric.
- To compute EVM, the received constellation is compared with the ideal constellation.
- The error vector for each point in the constellation is measured to provide accurate modulation performance.



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In this topic we have learnt about the

- ✓ Error-Vector Magnitude
- ✓ Next we are going to learn MAXIMUM RF INPUT TO RECEIVER

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Fundamentals of SDR:RAHSDR480

Module-5:SDR SELECTION CRITERIA

RAHSDR480_L05_P08_R01: MAXIMUM RF INPUT TO RECEIVER

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MAXIMUM RF INPUT TO RECEIVER

- Maximum input power to avoid the damage to receiver

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In this topic we have learnt about the

- ✓ MAXIMUM RF INPUT TO RECEIVER
- ✓ Next we are going to learn Module-6:Application of SDRs

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Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P01_R01: Radio Access Network- (RAN)

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Radio Access Network- (RAN)

- The RAN is the link between the network and the phone and it provide radio access and coordinate the management of resources across the radio sites.

- Part of mobile communication system.

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Radio Access Network- (RAN)

- GRAN: GSM Radio access network
- GERAN: GSM-Enhanced Data rates for GSM Evolution (EDGE) RAN
- UTRAN: Universal Mobile Telecommunications Service (UMTS) RAN
- E-UTRAN: Evolved UMTS Terrestrial RAN
- C-RAN: Cloud RAN or Centralized RAN
- V-RAN: Virtual RAN
- O-RAN: Open RAN

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In this topic we have learnt about the

- ✓ Radio Access Network- (RAN)
- ✓ Next we are going to learn Open Radio Access Network- (O-RAN)

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Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P02_R01: Open-Radio Access Network- (O-RAN)

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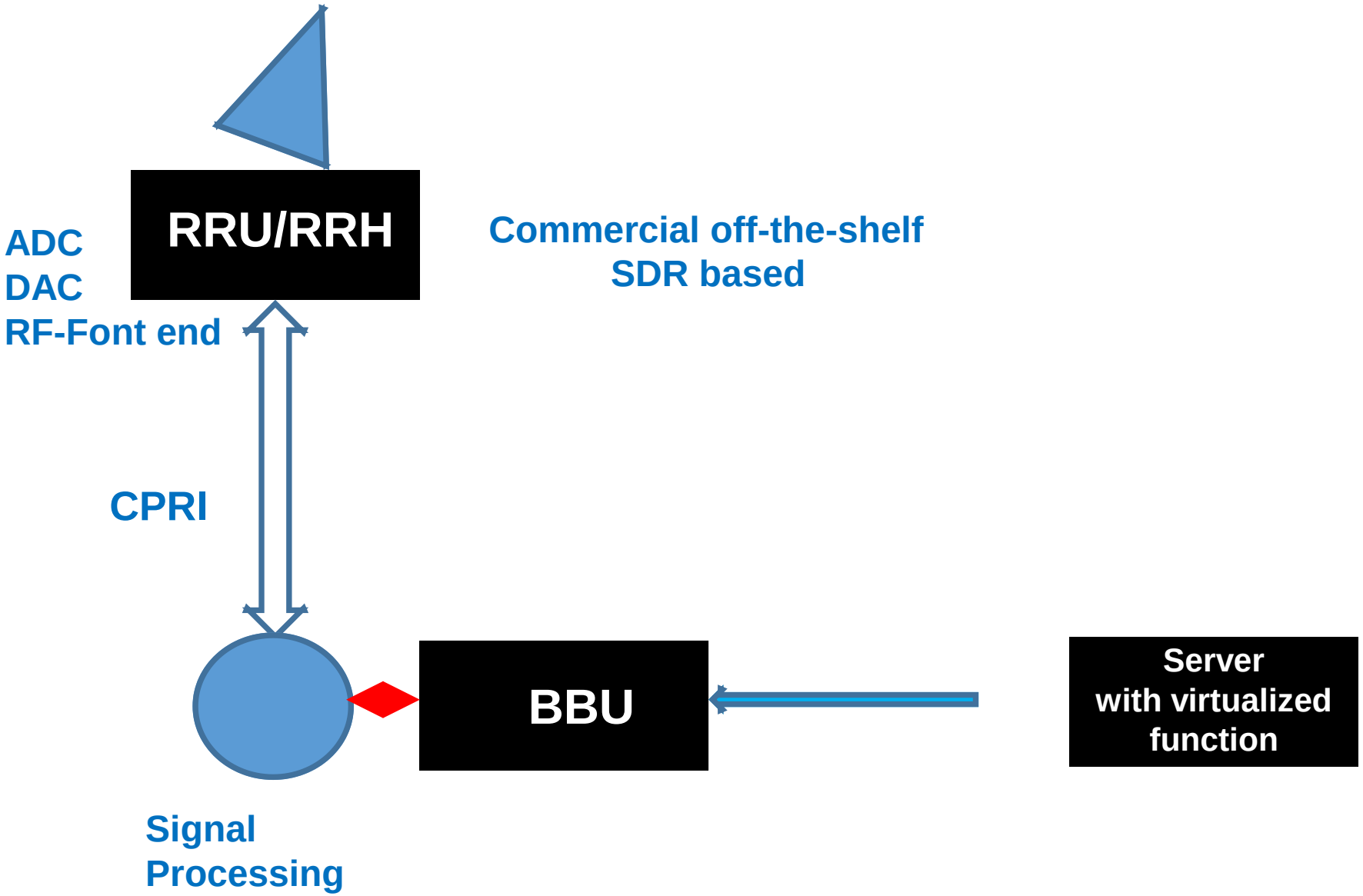
Open-Radio Access Network- (O-RAN)



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In this topic we have learnt about the

- ✓ Open Radio Access Network- (O-RAN)
- ✓ Next we are going to learn Global Navigation Satellite System (GNSS)

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Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P03_R01: Global Navigation Satellite System (GNSS)

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Global Navigation Satellite System (GNSS)

- European GNSS Agency the GNSS refers to a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location. By definition, GNSS provides global coverage.

- Using SDR software program the focus on signal processing also it control multiple processes inside the receiver.

- Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) and China's BeiDou Navigation Satellite System. Indian Regional Navigation Satellite System NavIC (Navigation with Indian Constellation)

In this topic we have learnt about the

- ✓ Global Navigation Satellite System (GNSS)
- ✓ Next we are going to learn Radar applications

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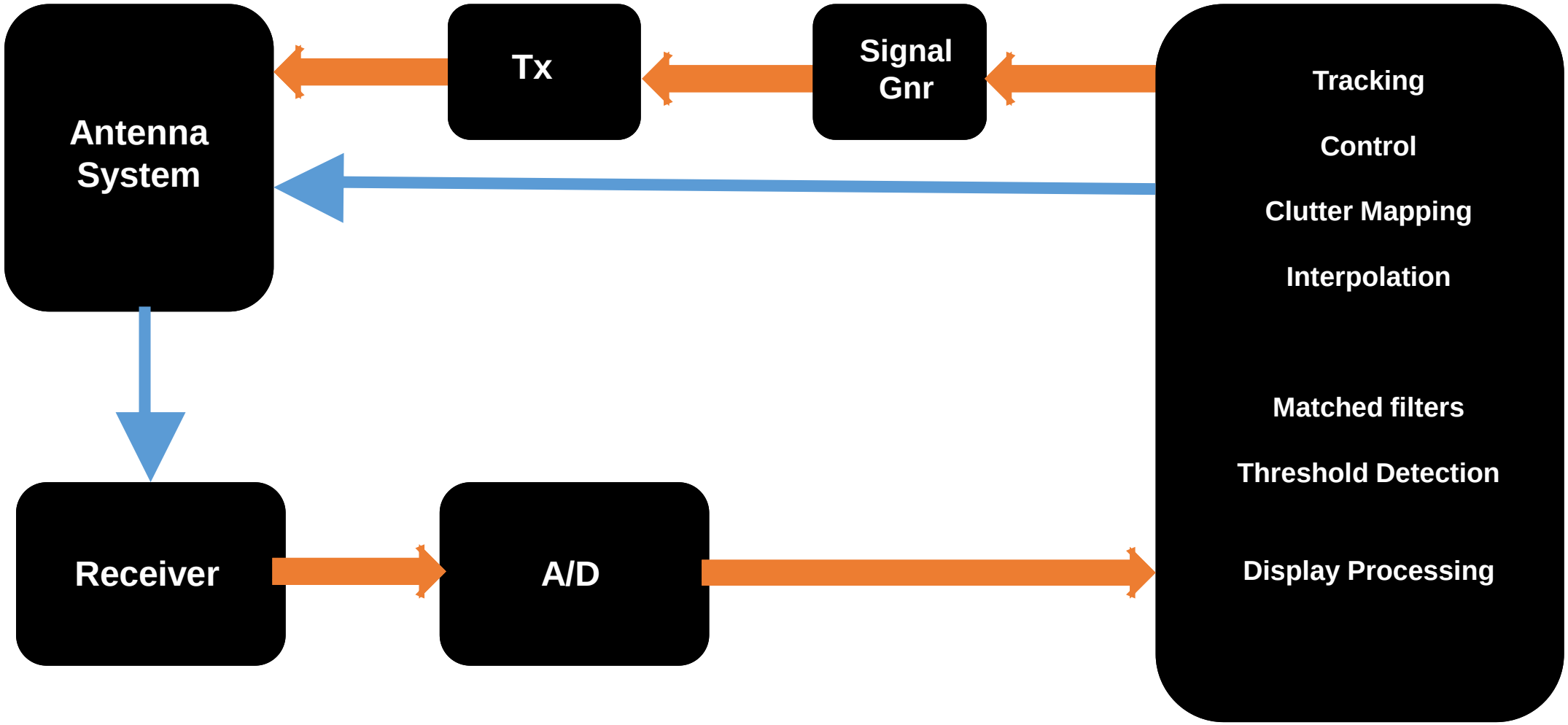
Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P04_R01:Radar applications

Radar applications



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In this topic we have learnt about the

- ✓ Radar applications
- ✓ Next we are going to learn Ham Radio

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Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P05_R01:Ham Radio

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Ham Radio

- Amateur radio, also known as ham radio, is the use of radio frequency spectrum for purposes of non-commercial exchange of messages, wireless experimentation, self-training, private recreation, radio sport, contesting, and emergency communication.

- The term "amateur" is used to specify "a duly authorized person interested in radio electric practice with a purely personal aim and without commercial interest“.

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In this topic we have learnt about the

- ✓ Ham Radio
- ✓ Next we are going to learn Signal Generator

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Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P06_R01: Signal Generator

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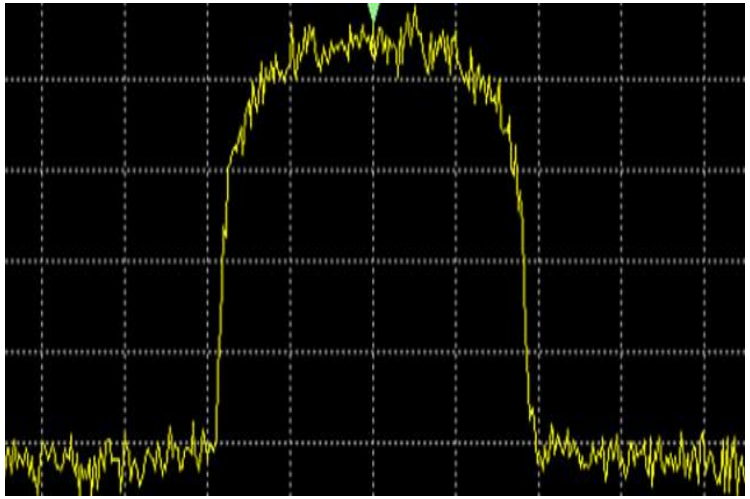
Signal Generator



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In this topic we have learnt about the

- ✓ Signal Generator
- ✓ Next we are going to learn Signal Analyzer

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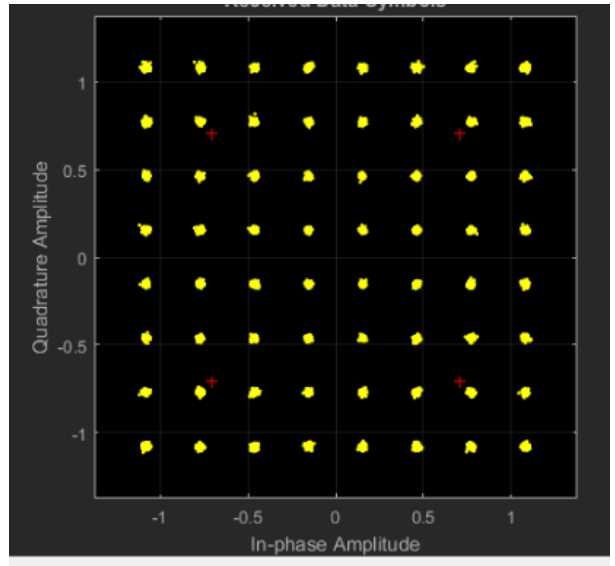
Fundamentals of SDR:RAHSDR480

Module-6:Application of SDRs

RAHSDR480_L06_P07_R01:Signal Analyzer

Signal Analyzer



RAHSOFT

In this topic we have learnt about the

- ✓ Signal Analyzer
- ✓ Next we are going to learn _____

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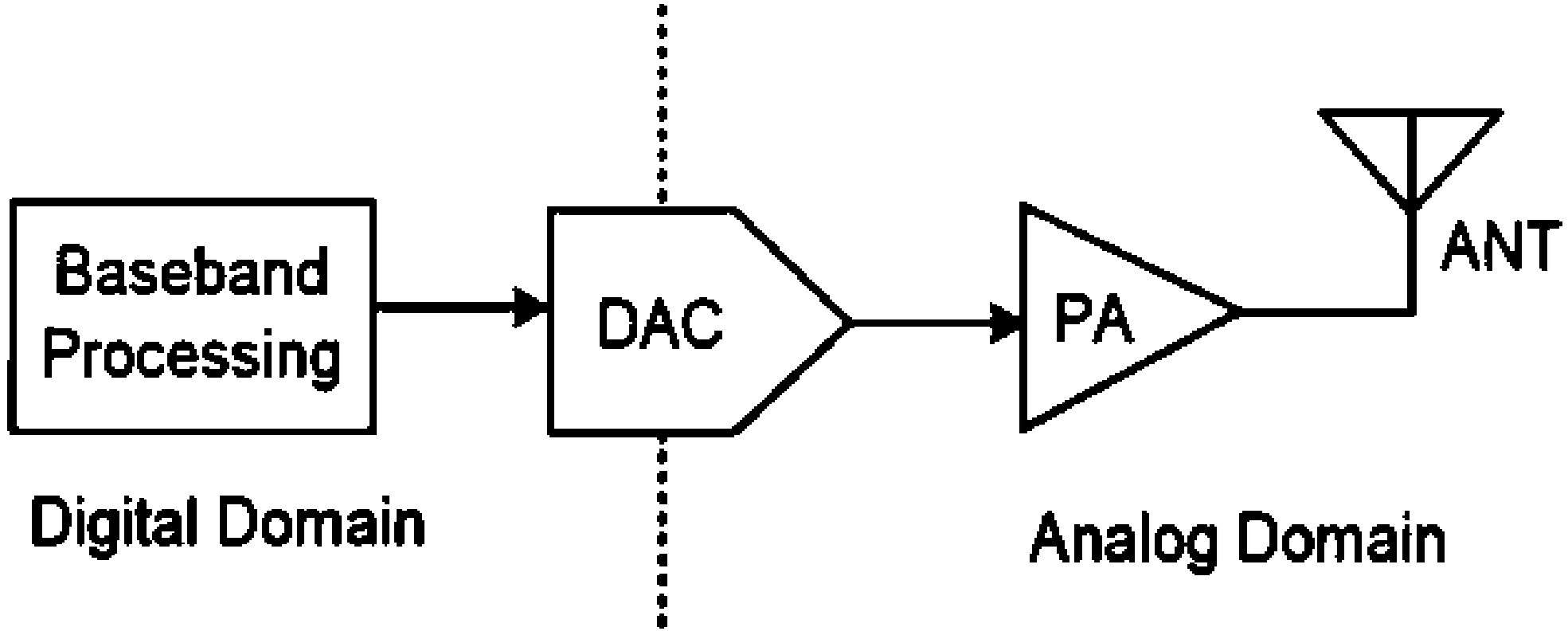

Please comply with local laws when performing radio experiments

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