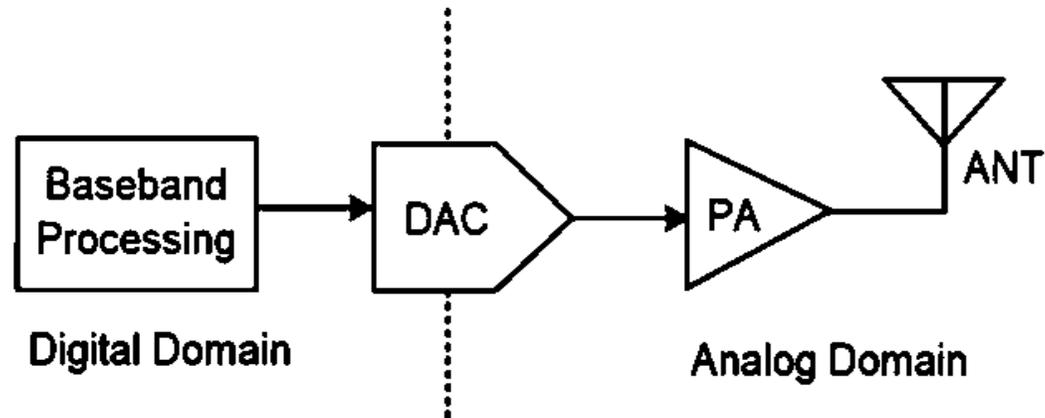
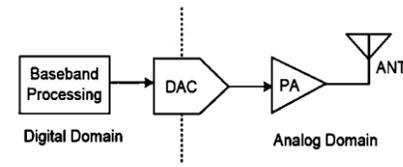


# Fundamentals of SDR

## RAHSDR480



# Introduction to Course



Essentials of SDR

SDR Hardware  
Architecture

Communication  
Layers

Software for SDR

SDR Selection  
Criteria

Application of  
SDRs



# 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



# Fundamentals of SDR:RAHSDR480

## Module-1:Essentials of SDR

RAHSDR480\_L01\_P01\_R01:Communication Block and Terminology



# COMMUNICATION BLOCK AND TERMINOLOGY

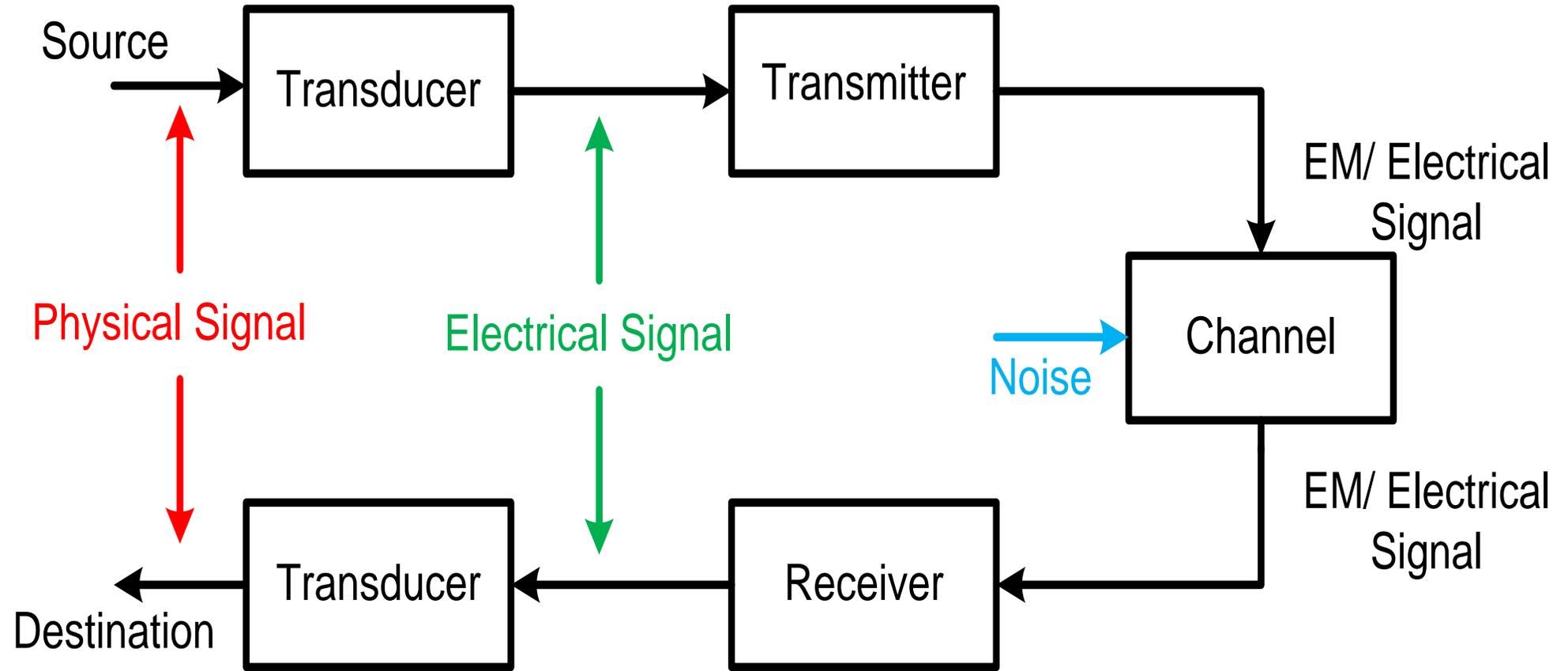
The objective of Communication System is that what we send we can exactly receive it without any loss (ideal case) or with minimum loss (practical case).



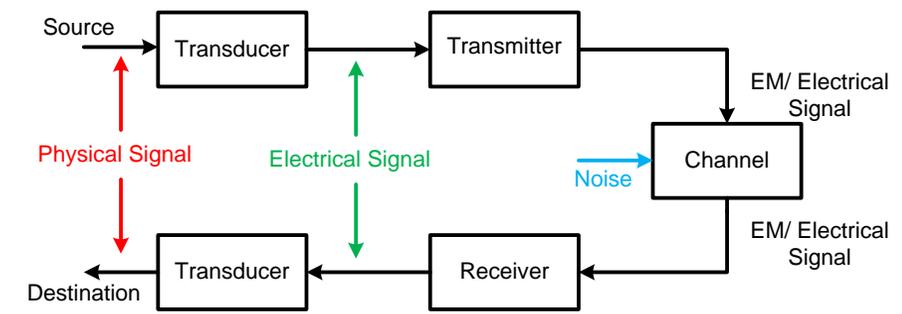
This loss can be minimized using several communication system and methods along with security.



CONT....



# CONT....



➤ 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.



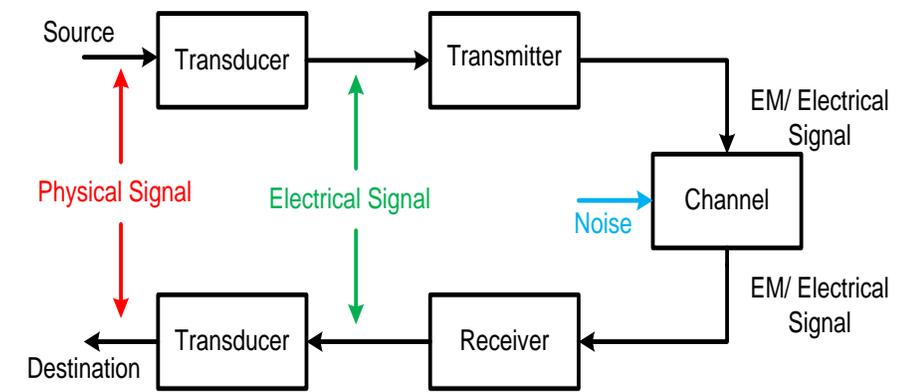
Photo detector – Converts light signals into electrical signals.



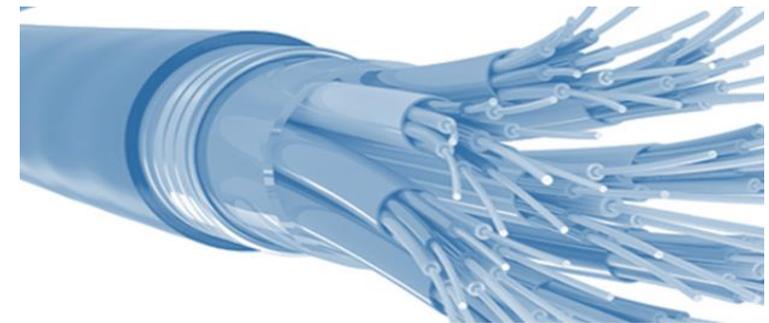
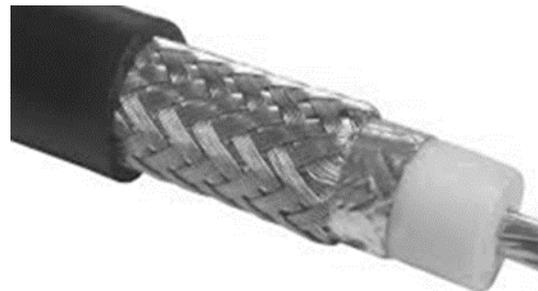
➤ Transmitter: It is a set of equipment used to generate and transmit electromagnetic waves carrying message or signals.



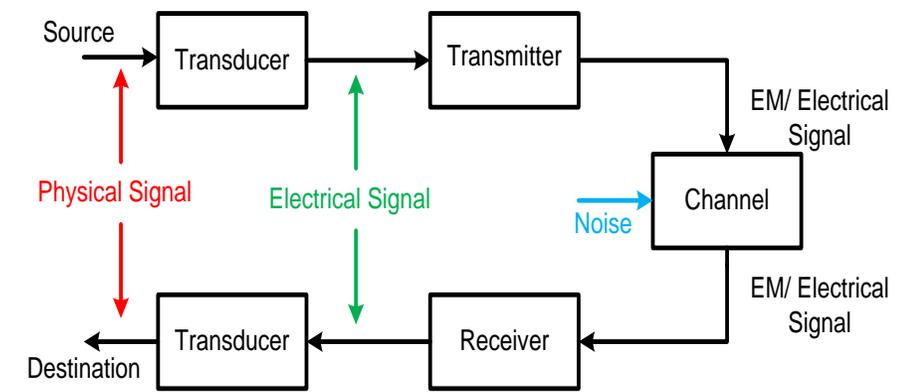
CONT....



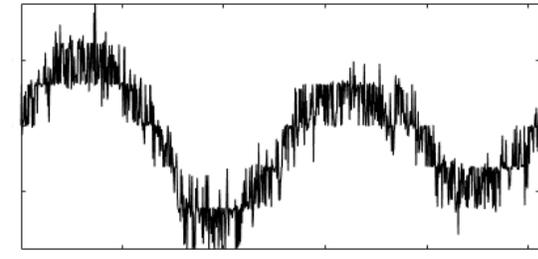
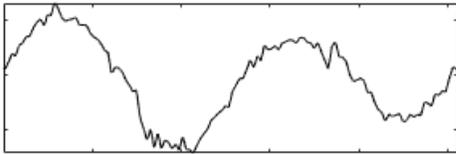
- Channel: Signal propagation medium can be wired (Twisted pair, Parallel wire communication, Coaxial Cable or Optical Fiber cable) or wireless (Free space or Air interface).



CONT....



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

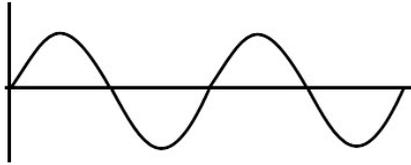


- **Receiver:** A device that accepts a radio signal and deliver information extracted from it.
- **Destination:**



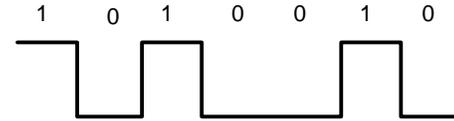
## Communication System

### Analog



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

### Digital

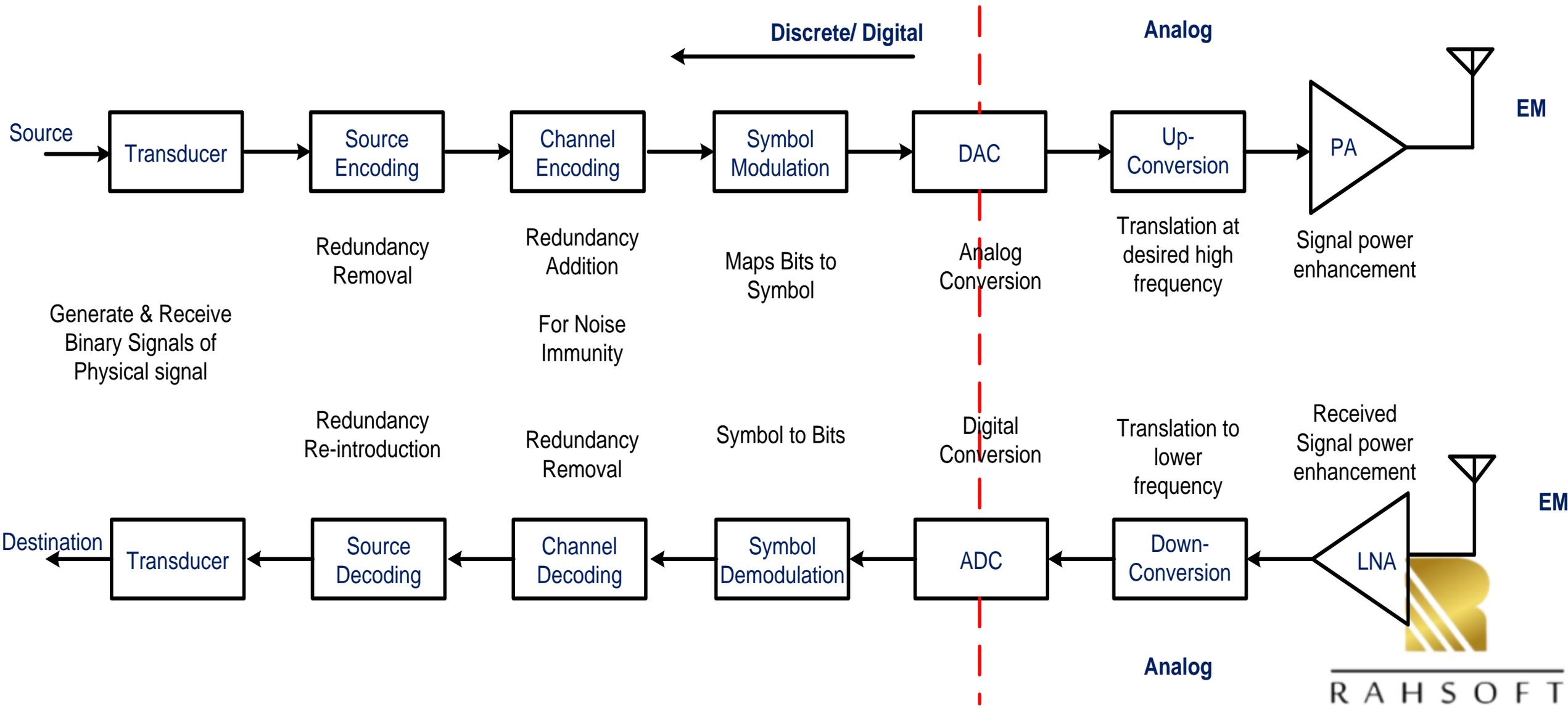


- Privacy preserved (data encryption).
- Can merge different data (voice, video and data) and transmit over a common digital.
- Error correction capability



CONT....

# Digital Communication System Block Diagram



**In this topic we have learnt about the**

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

➤ **Next we are going to learn SDR**



# Fundamentals of SDR:RAHSDR480

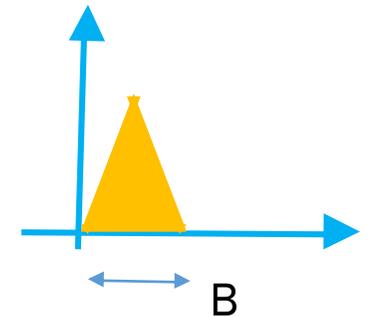
## Module-1:Essentials of SDR

RAHSDR480\_L01\_P02\_R01: SOFTWARE DEFINED RADIO



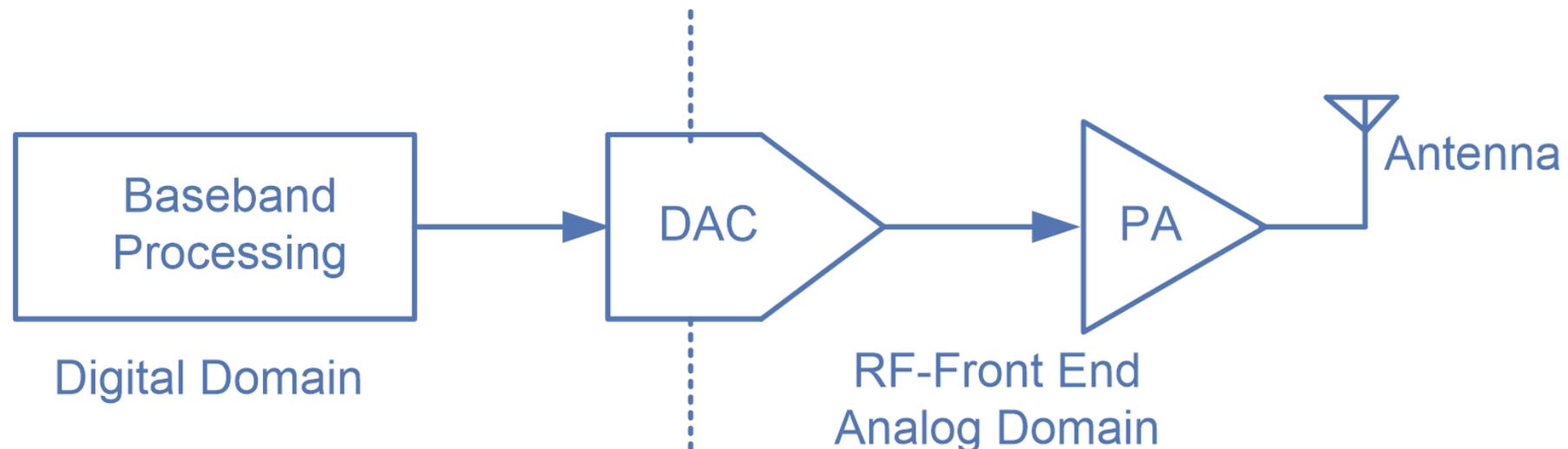
# SOFTWARE DEFINED RADIO

- 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.



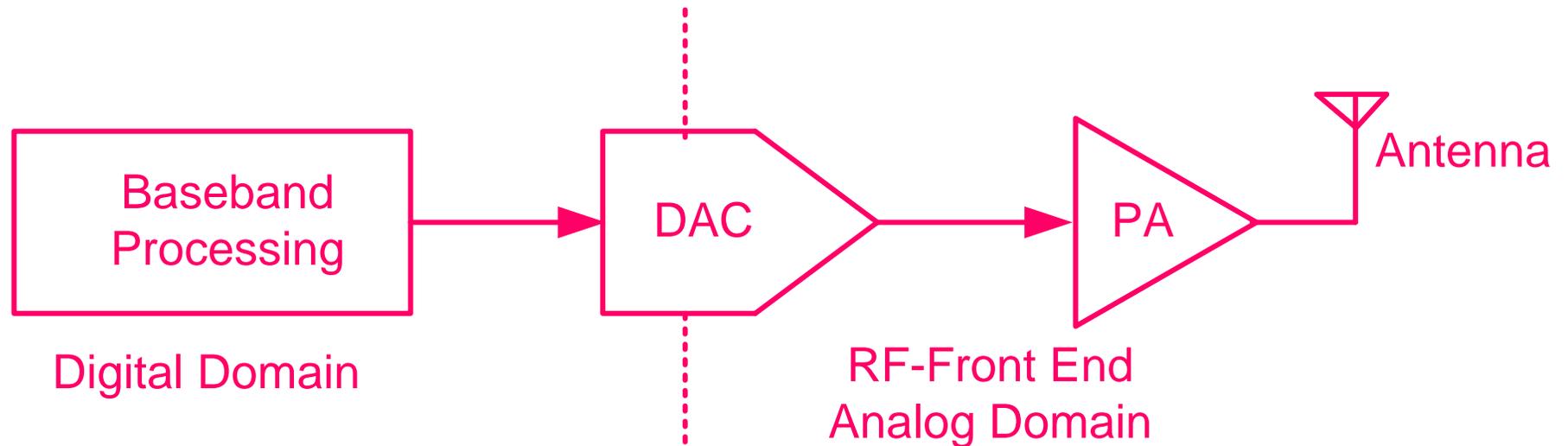
## CONT....

- 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.

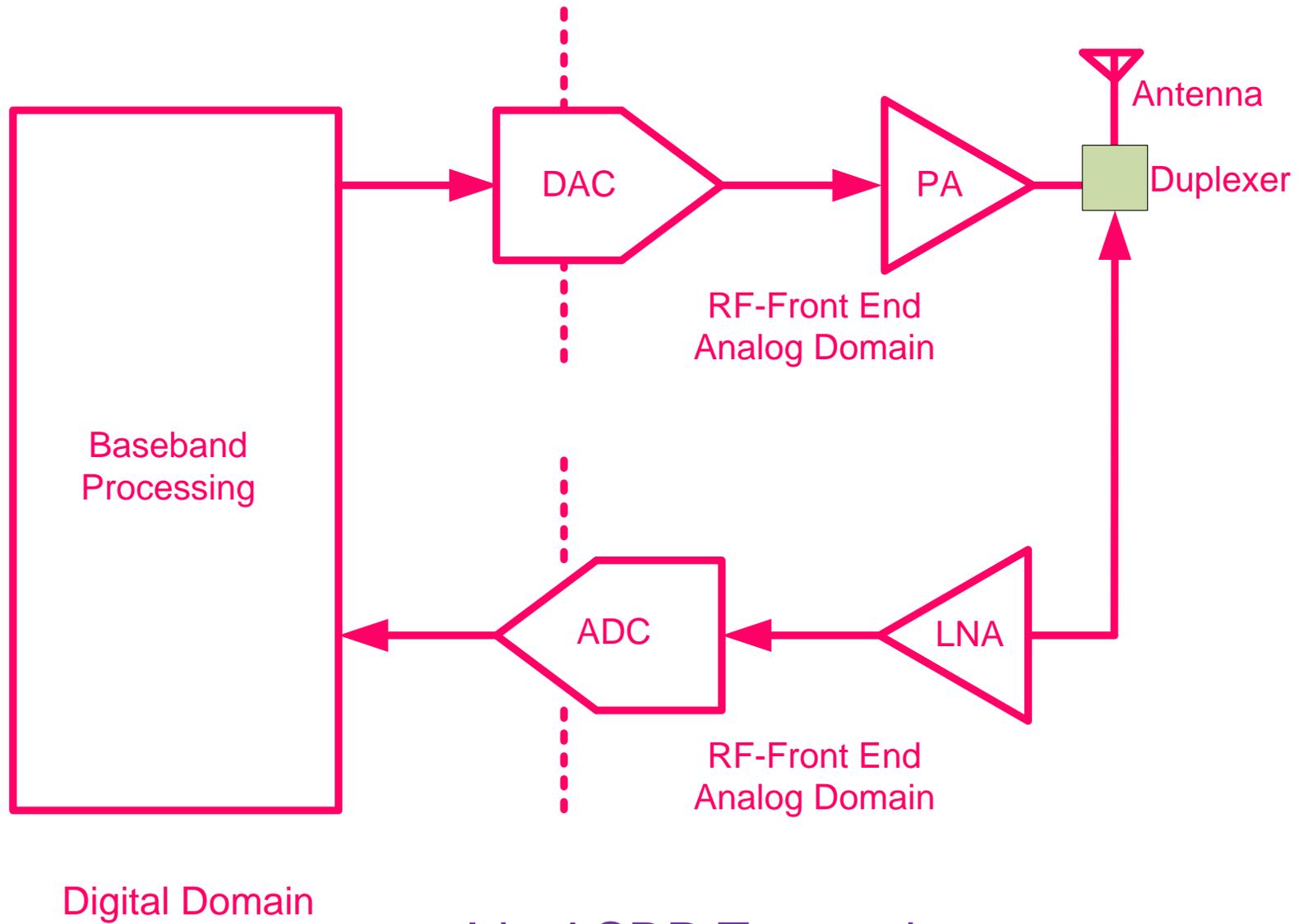


## CONT....

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



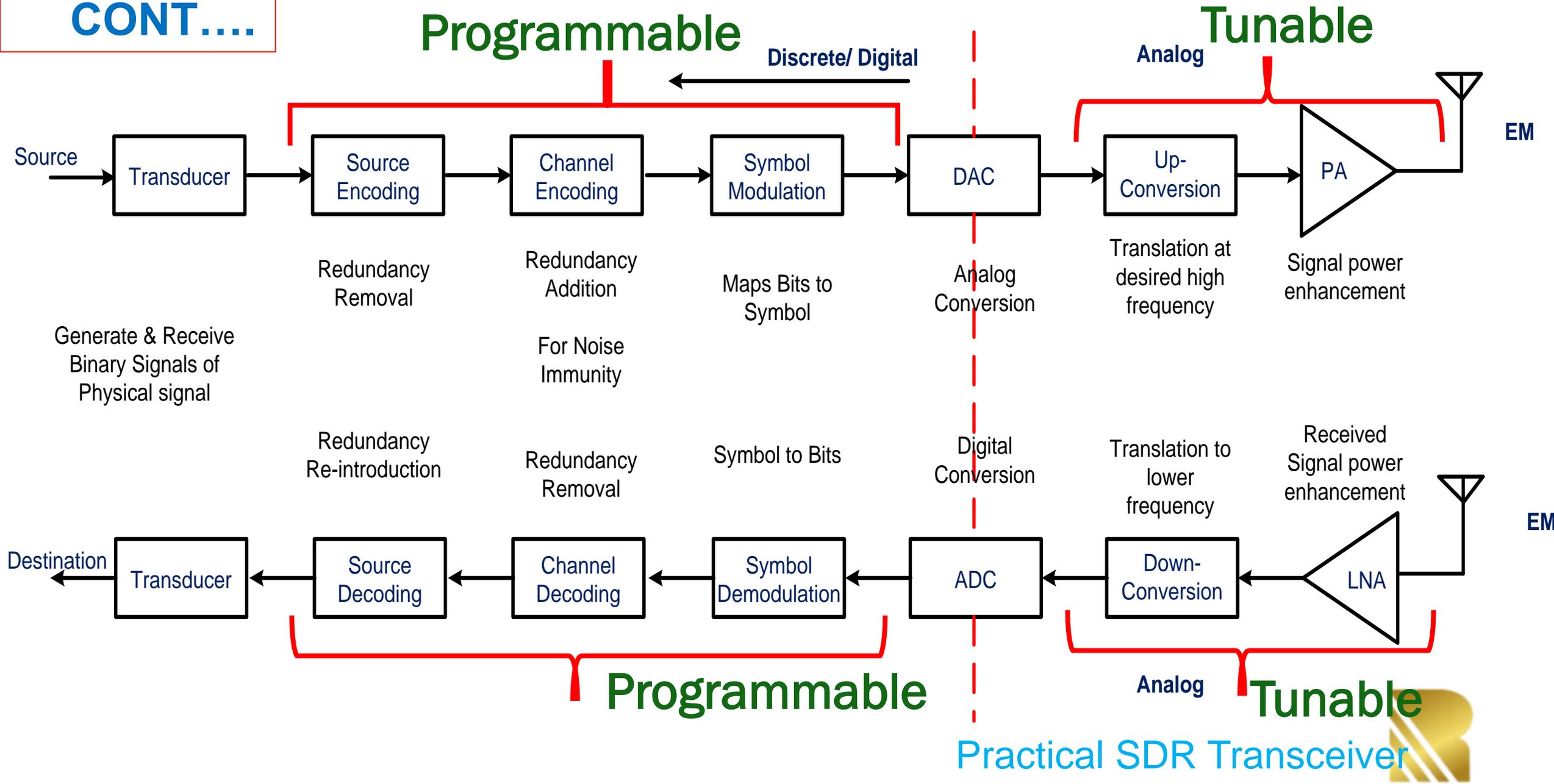
CONT....



Ideal SDR Transceiver



CONT....



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

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



# 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.



## CONT....

### ➤ Automatic Gain Control:

- ✓ The gain can be tuned with software to meet 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.



## CONT....

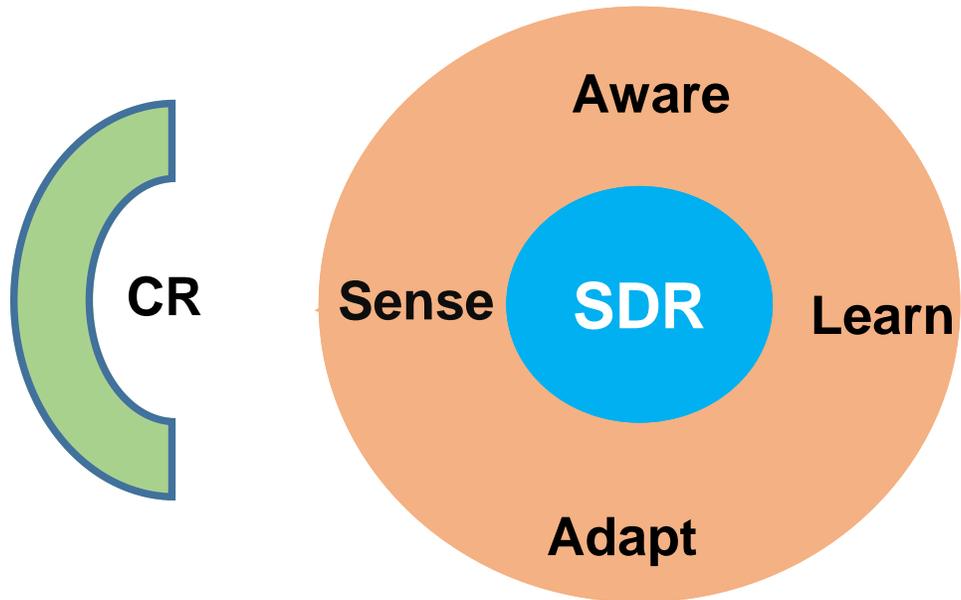
- Diverse community support:
  - ✓ Open source software and hardware's are available using which you can create your own SDR and hence you will be benefit by the work of others.
- Ease of Testing & Implementation:
  - ✓ Ease of Testing & Implementation of communication standards has advantage of SDRs 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.



## CONT....

### ➤ Cognitive Radio:

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



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



# Fundamentals of SDR:RAHSDR480

## Module-1:Essentials of SDR

RAHSDR480\_L01\_P04\_R01: HISTORY AND EVOLUTION OF RADIOS



# 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 |



**CONT....**

## Conventional Radios



**Li'l 7 built by  
Volker  
in Italy**

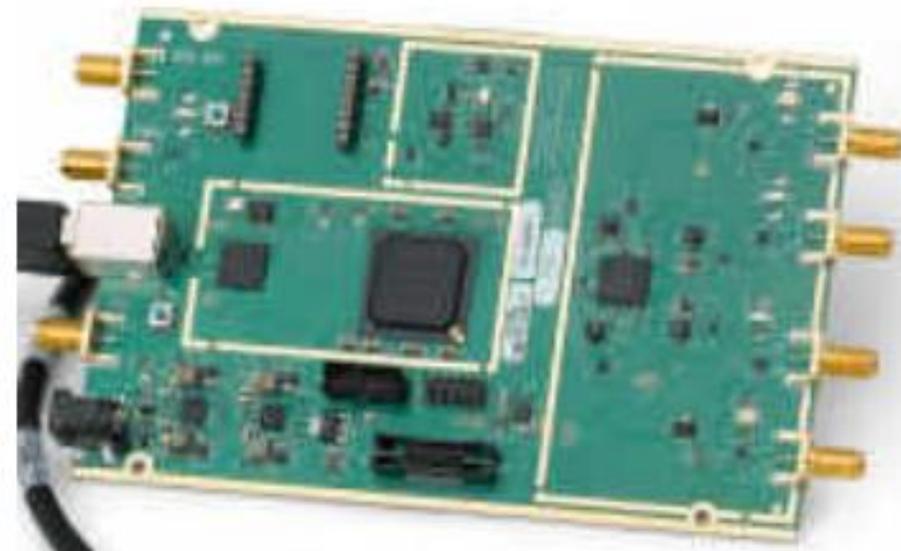
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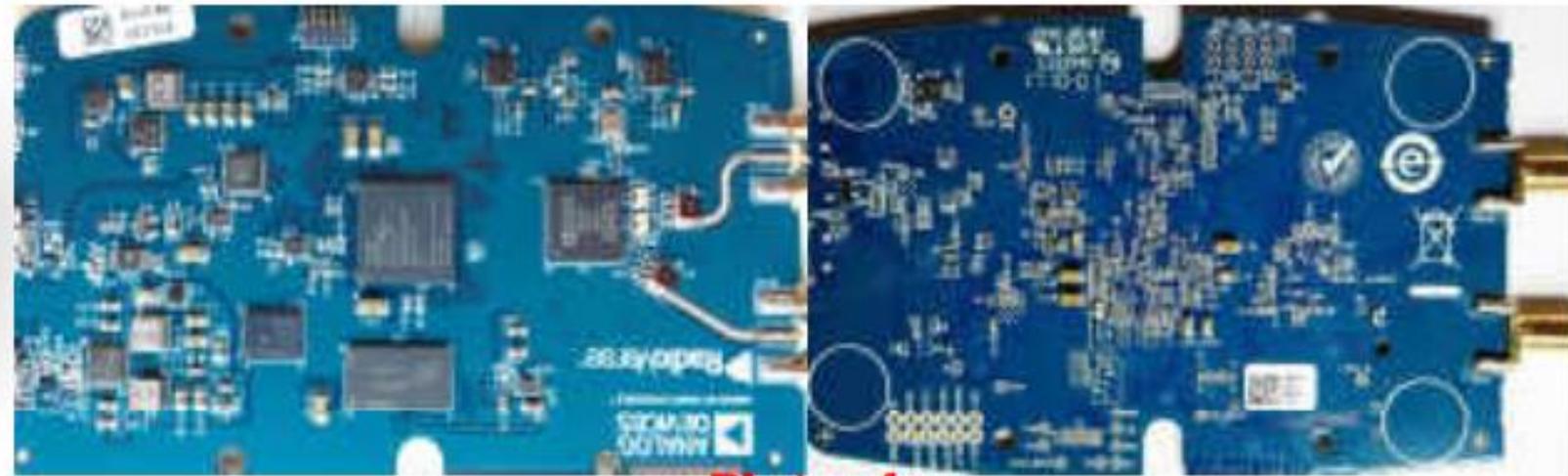
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CONT....

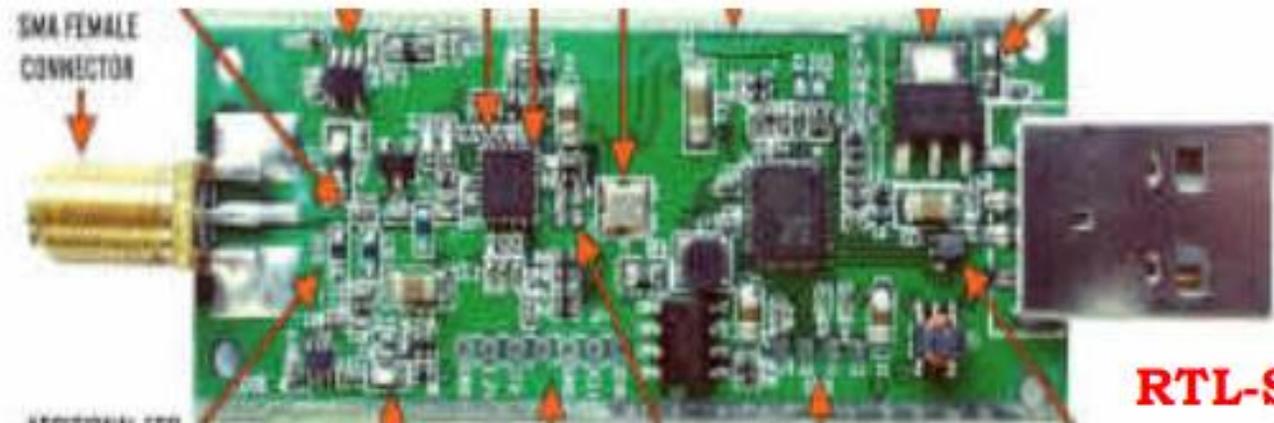
## SDRs



**USRP B210**



**Plutosdr**



**RTL-SDR**

<https://www.rtl-sdr.com/buy-rtl-sdr-dvb-t-dongles/>

<http://www.ettus.com/all-products/UB210-KIT/>

<https://www.flickr.com/photos/csete/33235669001/in/photostream/>

<https://digitalxradio.com/2017/11/12/hello-world/>

<https://in.mathworks.com/hardware-support/usrp.html>

<https://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/adalm-pluto.html#eb-documentation>

In this topic we have learnt about the

✓ How the Radios has been evolved

➤ Next we are going to learn SCA



# Fundamentals of SDR:RAHSDR480

## Module-1:Essentials of SDR

RAHSDR480\_L01\_P05\_R01:SOFTWARE COMMUNICATIONS ARCHITECTURE (SCA)



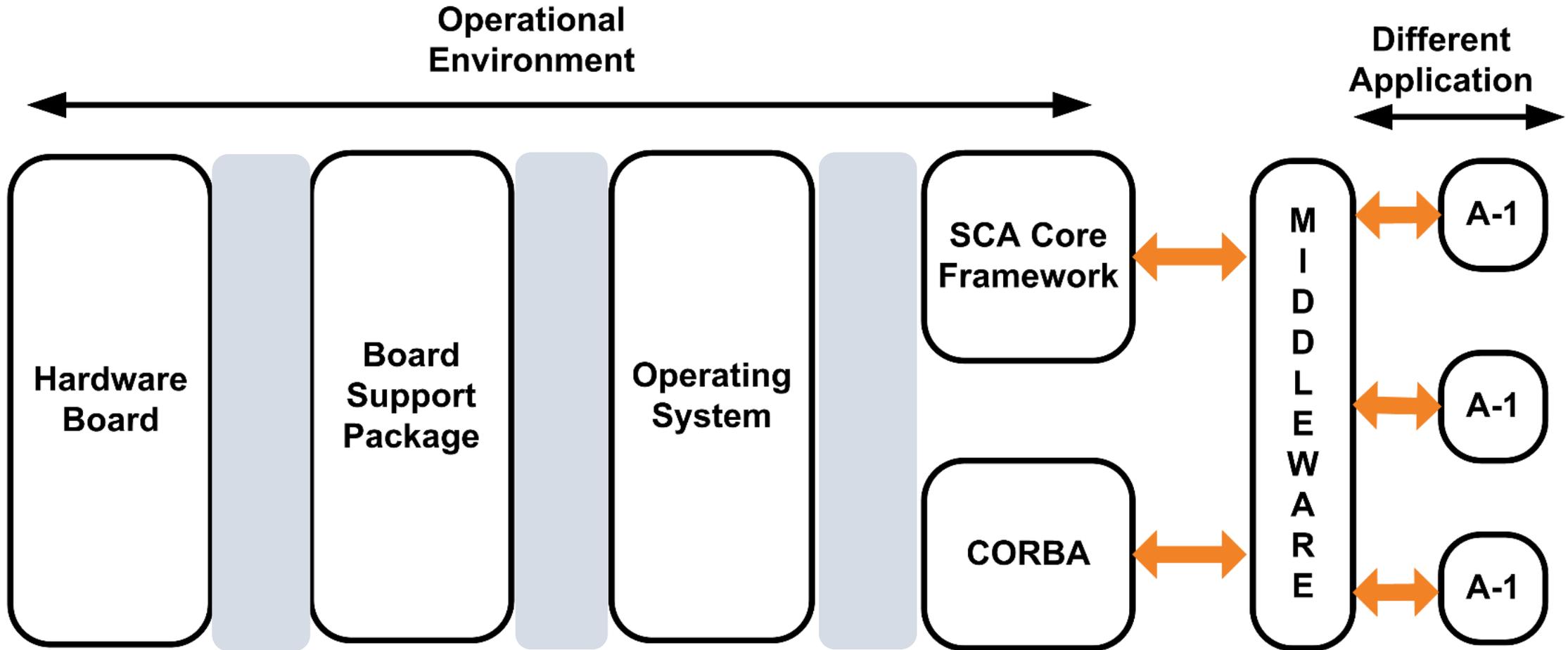
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# SOFTWARE COMMUNICATIONS ARCHITECTURE (SCA)

- 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.



CONT....



Common Object Request Broker Architecture (CORBA)



**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**



**CONT....**

- **Interoperability**
- **Technology insertion**
- **Hardware abstraction**

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

# 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**



# Fundamentals of SDR:RAHSDR480

## Module-1:Essentials of SDR

RAHSDR480\_L01\_P06\_R01:SOFTWARE-DEFINED NETWORKING (SDN)

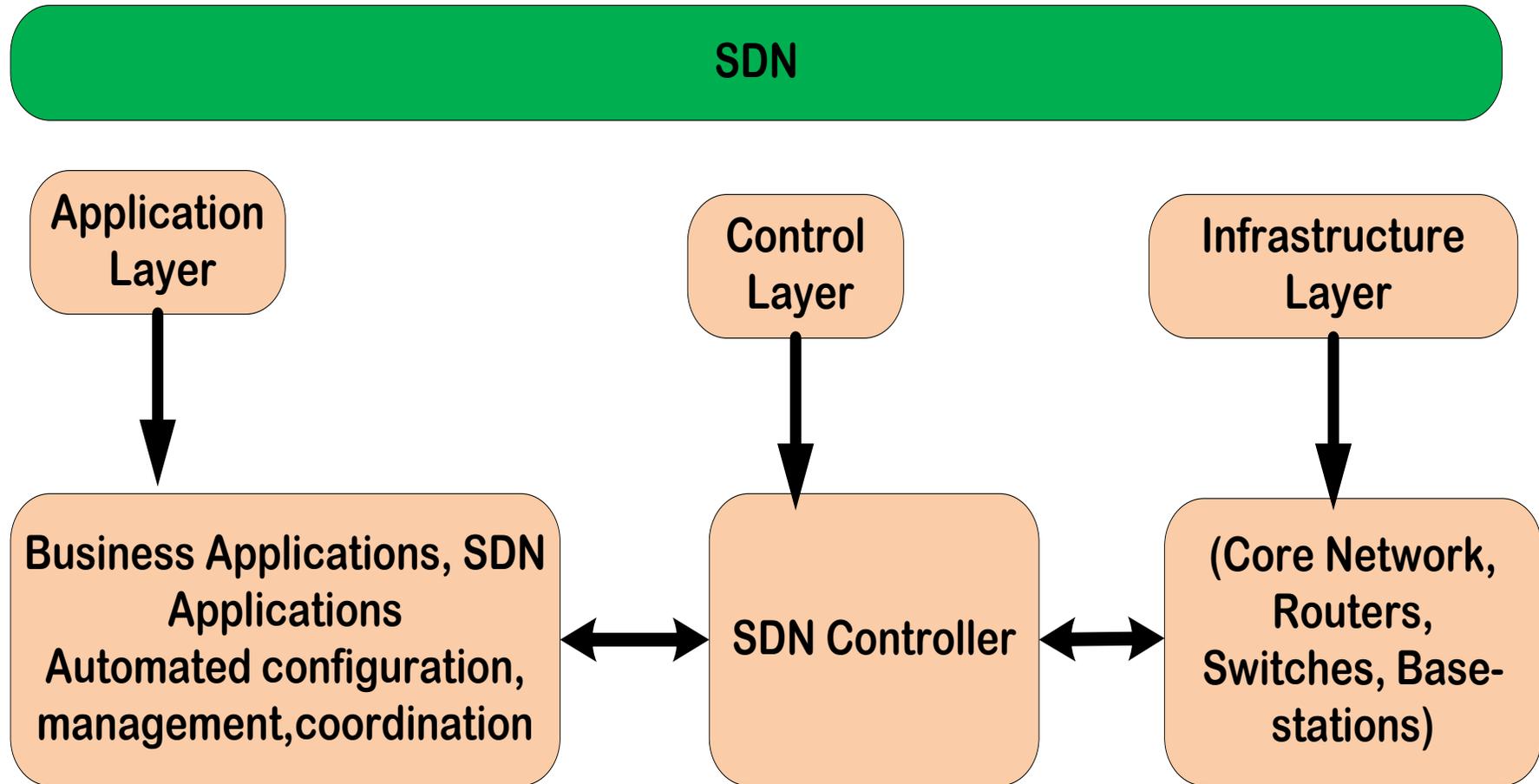


# SOFTWARE-DEFINED NETWORKING (SDN)

- 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 today's programmable switches and routers.



CONT....



**In this topic we have learnt about the**

**✓ Benefits of using SDN**

**➤ Next we are going to learn Communication Standards and Signals**



# 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

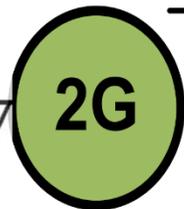
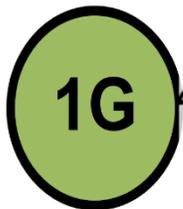
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90

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20



Wearable's  
Public safety  
Tele-medicine

Video Monitoring  
Mobile cloud Computing

Industrial Automation

Vehicle to Vehicle Communication  
Smart Cities



# CONT....

➤ **Single-tone**

➤ **Two-tone**

➤ **Multi-carrier**

➤ **GSM**



**CONT....**

➤ **WCDMA**

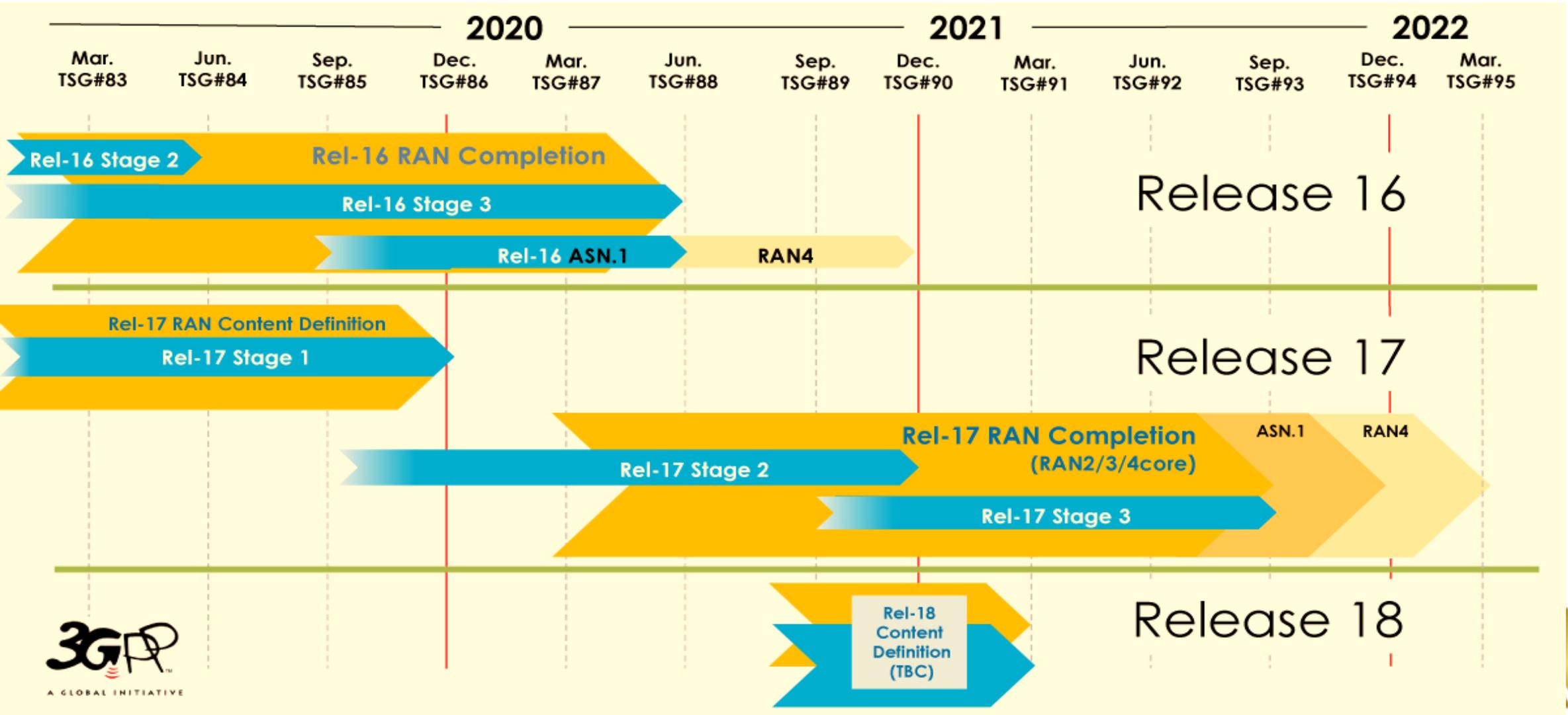
➤ **LTE**

➤ **LTE Carrier aggregation**



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# CONT....



In this topic we have learnt about the

✓ **Communication Standards and different signals**

➤ **Next we are going to learn Time and Frequency domain**



# Fundamentals of SDR:RAHSDR480

## Module-1:Essentials of SDR

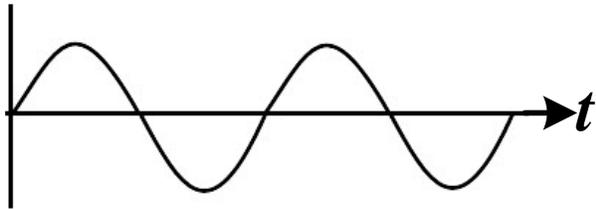
RAHSDR480\_L01\_P08\_R01:TIME AND FREQUENCY DOMAIN



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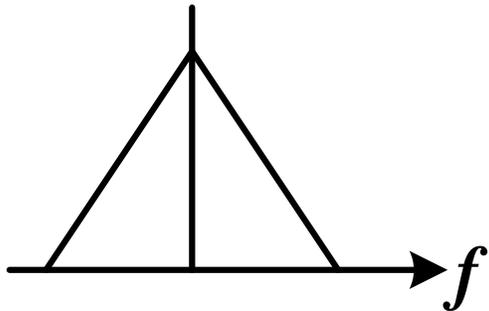
# TIME AND FREQUENCY DOMAIN

## Time Domain



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

## Frequency domain



- Independent variable is  $f$

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

$y(t)$



$Y(f)$



# 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](http://www.lodestarelec.com/15-analogue_oscilloscope-s.jpg)

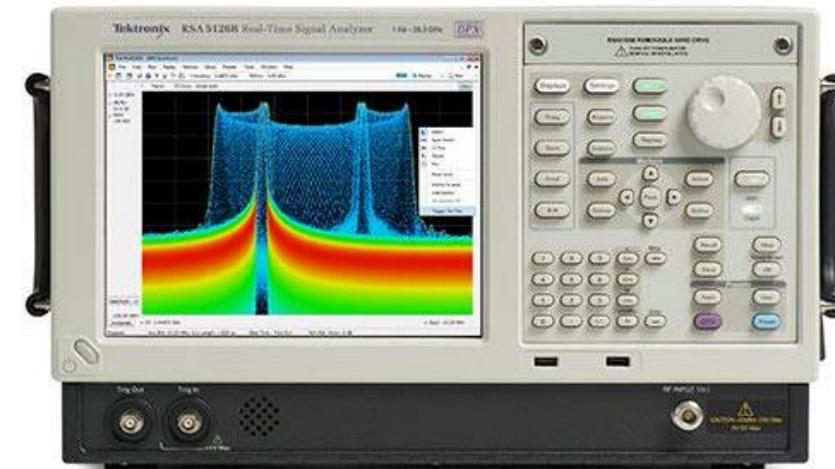
<https://download.tek.com/datasheet/TBS1000-Digital-Storage-Oscilloscope-Datasheet-3GW285576.pdf>

# 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



In this topic we have learnt about the

- ✓ Time and frequency domain measurements

- Next we are going to learn about Decibel units



# 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



## 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.

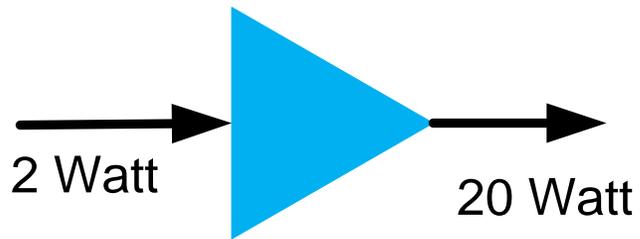
$$Ratio_{dB} = 10 \cdot \log_{10}(V_1^2 / V_0^2) = 20 \cdot \log_{10}(V_1 / V_0)$$



## CONT....

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

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



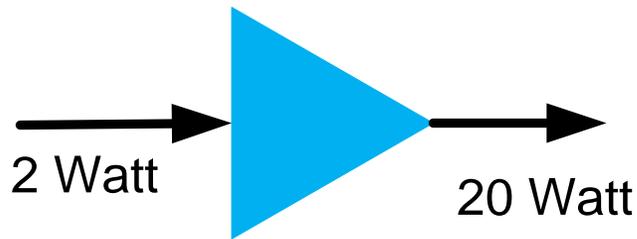
What is input power and output power in dB?



## CONT....

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

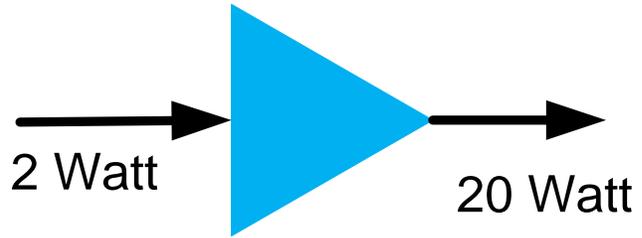
$$P_{\text{dBm}} = 10 \cdot \log_{10}( P_{\text{mW}} / 1\text{mW} )$$



What is input power and output power in dBm?



**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        |



**CONT....**

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

