RF Systems Course: Introduction

Introduction

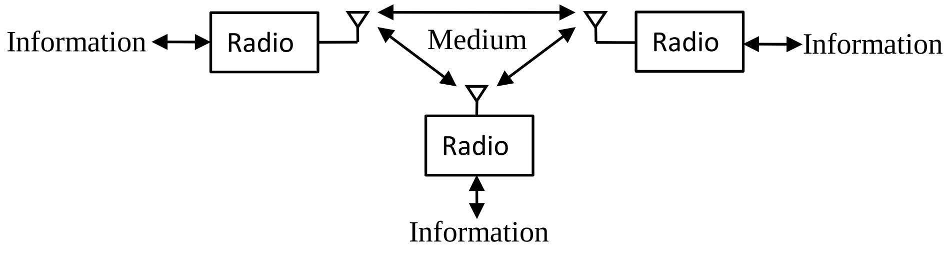
- Wireless technology is now ubiquitous
- Over decades so many communications devices become part of our daily lives
- people connect computers wirelessly to internet using WiFi in office/home/public places
- cell phones that provide not only voice, but text and internet access as well.
- cars have GPS for navigation and blue tooth transceivers for wireless headsets to allow us to talk while driving.
- In the past communication device could be designed by only a handful of people
- now hundreds or maybe even thousands are involved
- Many specialists required at many different levels to make a product
- perhaps now no one single person could ever have all the required skills to know or design a whole system.
- As devices become more complicated becomes harder for us as engineers to understand how the bits and pieces that we work on fit into grander scheme.
- It is the goal of this course to help the students to expand their vision beyond the scope of their own detailed research and help them to see how all the separate parts fit together to make a whole device.

What is a Radio and why do we need one?

- simple definition of a radio: A radio is a communication device that allows information to travel wirelessly from one place to another over some medium.

- medium often air, but electromagnetic signals also propagate through walls, trees, water, etc.

- more technically precise: A radio is a communication device that takes some information, converts that information into the form of an electrical signal, takes the electrical signal and transmits it across the medium using only a pre-determined band of frequencies. It also reverses this process for signals that it receives over the medium from other radios.



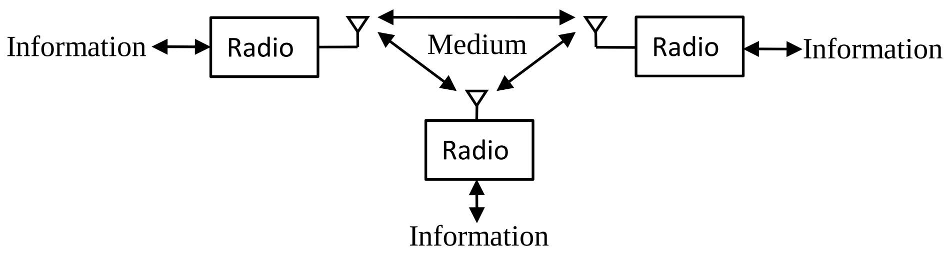
What is a Radio and why do we need one?

- why do we need one?

- Speaking/listening form of wireless communication.
- We all speak/listen using signals (voice) at same frequencies.
- voices carry short distance -> don’t interfere with conversations in other rooms/buildings/ cities.
- when a group of people all in one room, we hear everything, but able to focus on one voice and filter out rest
- Biology/brains are truly amazing -> radios not able duplicate this performance.
- If radios all “talked” at the same frequencies no one would be able to “hear” anything!

- ability of radio to translate each conversation into a different part of the spectrum is an important reason why we need a radio.

- important consideration for radios when transmitting over the air is that the size of an antenna
- It is inversely proportional to the frequency at which it must operate.
- higher frequencies -> smaller antennas
- if aim is small wireless devices, then frequency must be high.



The Radio Spectrum

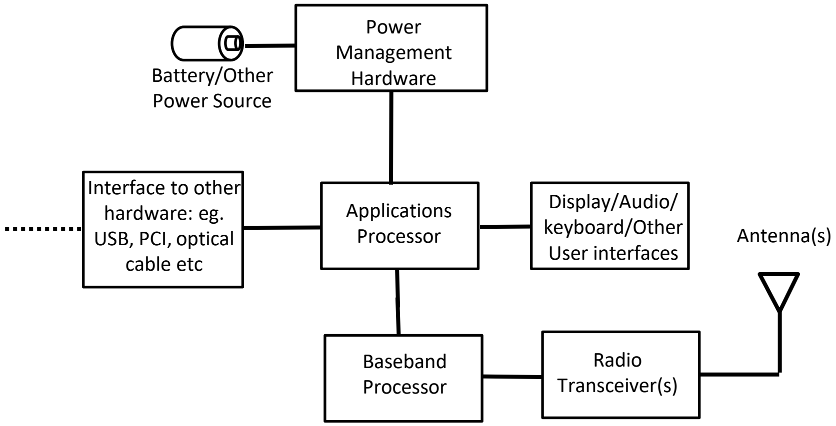
- anyone transmitting affects everyone -> government gets involved
- laws regulate who can use what part of the radio spectrum and for what purpose.
- E.g. military has dedicated parts of the spectrum reserved -> radar systems
- companies with cellular networks pay large $$ use bands exclusively.
- Other bands are “unlicensed” -> free for anyone to use provided follow rules transmitted power.
- industrial, scientific and medical (ISM) bands are examples of these unlicensed bands.
- UWB listed in table operates at low power over wide range of frequencies (even across frequencies allocated to other applications).
- allowed to do this as long as the transmit power is very low.

Table 1.1: Some well-known frequency allocations for different applications.

Frequency Band	Use
535 kHz – 1605 kHz	AM Radio Band
54 MHz – 72 MHz	TV Channels 2-4
76 MHz – 88 MHz	TV Channels 5-6
88 MHz – 108 MHz	FM Radio
174 MHz – 216 MHz	TV Channels 7-13
512 MHz – 608 MHz	TV Channels 21-36
614 MHz – 698 MHz	TV
824 MHz – 849 MHz Transmit 869 MHz – 894 MHz Receive	GSM 850 / IS-95 (CDMA)
902 MHz – 928 MHz	ISM and cordless phones
890 MHz – 915 MHz Transmit 935 MHz – 960 MHz Receive	GSM 900
1.57542 GHz	GPS
1710 MHz – 1785 MHz Transmit 1805 MHz – 1880 MHz Receive	GSM 1800
1850 MHz – 1910 MHz Transmit 1930 MHz – 1990 MHz Receive	GSM 1900 and IS-95
2.4 GHz – 2.5 GHz	ISM, cordless phones and WLAN
5.47 GHz – 5.725 GHz	WLAN
3.168 GHz – 10.552 GHz	Ultra Wide Band (UWB)

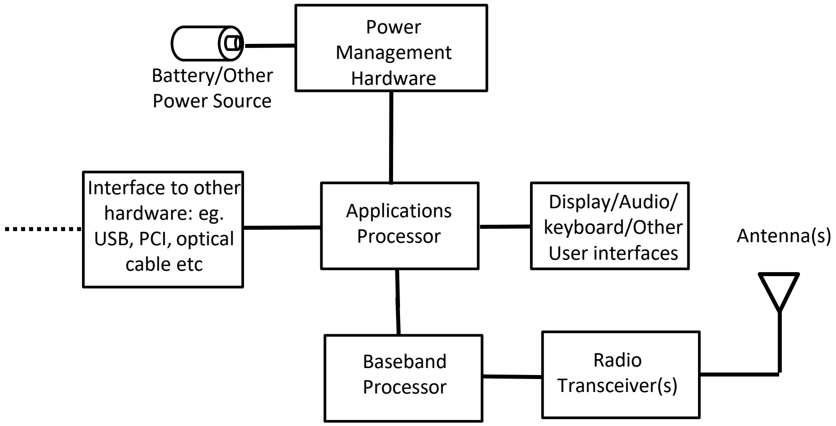
A Communication Device

- Engineers often focused on the one part of a communication device related to their area of expertise, may have vague understanding of how the overall system works.
- In a modern communication device the actual hardware and software that is involved in communicating is usually only a small part of the overall device.
- At the heart is the applications processor, which runs the device's operating system. In addition to running user applications such as playing music or games, the operating systems controls all the hardware components of the device.
- device likely contain variety of user interface elements speaker/microphone/keyboard/touch-sensitive screen/display/camera
- hardware and software are involved in managing the power source of the device.
- circuitry may clean up the power supply noise, create other voltage references, monitor if voltage gets too low or too high.
- The device may interface with other hardware via a host of interfaces such as USB, PCI or other, particularly if the device is embedded into a computer (such as a WLAN card).
- There will also likely be several different wireless communications interfaces, such as IEEE 802.11 WLAN, Bluetooth, and different cellular network interfaces.



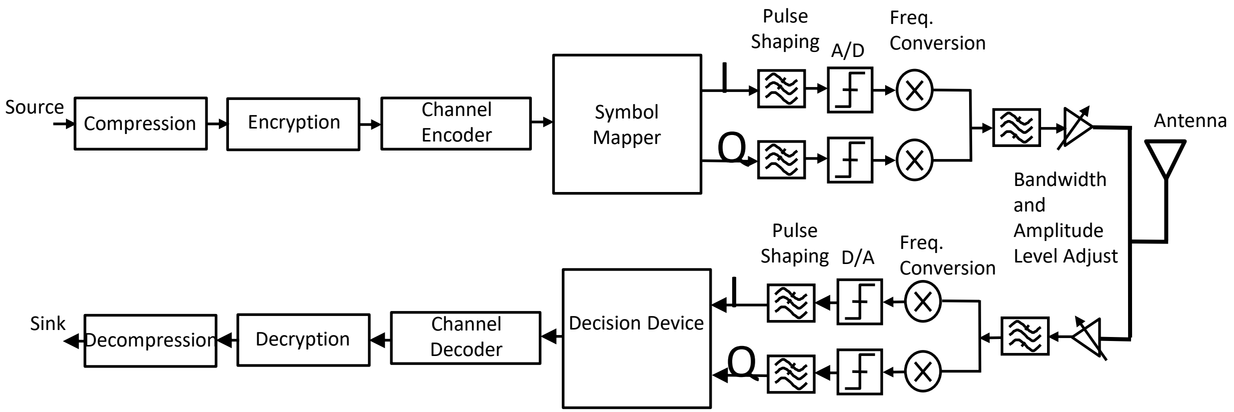
A Communication Device

- When applications processor needs to transmit some data over a wireless interface, forwards packet of bits to BBP
- BBP is dedicated hardware unit that is responsible for controlling interface
- BBP encodes data for transmitting interprets data received
- BBP controls radio by adjusting gain/operating frequency/changing operating modes/turning on(off) different functions.
- BBP decides modulation (higher data rate mod. if the signal is strong or a lower rate if the signal is weak).
- BBP determines when to transmit, when to receive data, how to handle handoff between cells, other high-level issues in environment with many users
- BBP performs various baseband digital signal processing operations on transmitted data before passing it to radio transceiver, which generates a radio-frequency analog signal suitable for transmission over the air via the attached antenna.



A Communication Device

- starts by receiving information from the applications processor
- Channel encoding (error control coding) bits added to facilitate error detection and correction at the receiver.
- may be as simple as adding parity bits from a cyclic redundancy check (CRC) code for error detection or from some more complicated error correcting code such as a convolutional code or a low density parity check (LDPC) code.
- Symbol mapper -> change the bits into baseband waveforms
- After conversion waveforms filtered by pulse shaping filter to optimize bandwidth
- radio front end then up-converts the signal by modulating a carrier wave, filters it to make sure there is no energy outside the desired frequency band, and amplifies the carrier to a specific power level to drive the transmitting antenna.



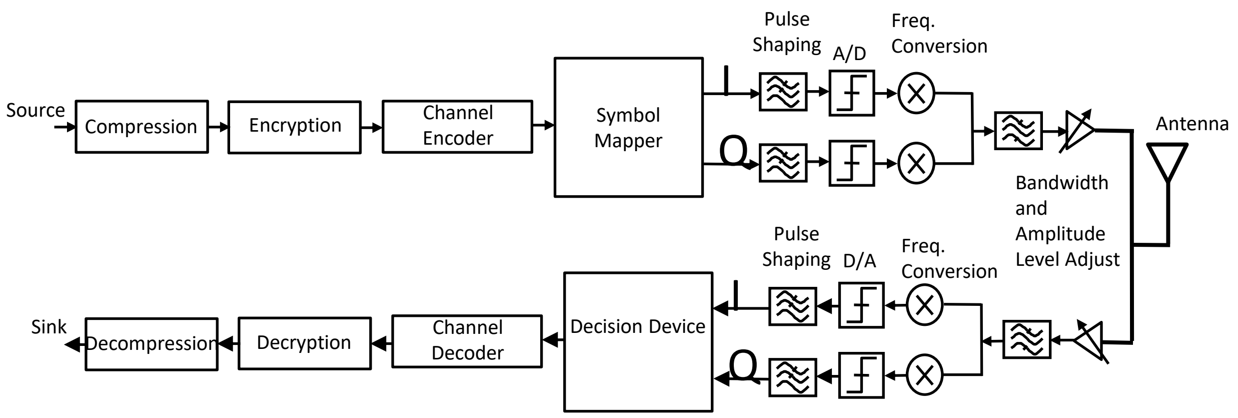
A Communication Device

- Once the energy has traveled across the channel the radio front end must detect the received signal, amplify it and return it to baseband, providing an output signal with fixed average power.

- Filtering at the receiver prevents the radio from having to process unwanted signals that may be present at other frequencies.

- In the digital domain some further filtering (with a filter matched to the transmitted pulse shape) may be performed to maximize the signal-to-noise ratio (SNR), after which it is converted back into bits by the decision device.

- Once in this form, error correction is performed and the information is decrypted and decompressed.



Baseband Signal Processing vs RFIC Design

Table 1.2 Relationships between BBP and RF Design

	BBSP	RF
Signals	Implemeneted as bits or quantized discrete-time samples.	Must be represented at voltages, currents, or power signals.
Implementing a Signal Processing Function	Function is implemented using code. Implementation can be almost ideal (finite number of quantization levels)	Function is implemented at the transistor level using non ideal components.
Typical Design Tools	Capable of simulating complex baseband waveforms without a carrier.	Capable of simulating carriers without modulation data.
Complexity of Operations	Can be very complex at the expense of hardware and power.	Implements simple functions at very high speeds with relatively low power consumption compared to a digital implementation.