WIRELESS COMMUNICATION

BLM5134 – Week 3

WHY WIRELESS COMMUNICATION?

- Freedom from wires.
- No bunch of wires running from here and there.
- “Auto Magical” instantaneous communication without physical connection setup e.g.- Bluetooth, Wi-Fi.
- Global coverage
- Communication can reach where wiring is infeasible or costly
- E.g.- rural areas,buildings,battlefield,outerspace.
- Stay connected,flexiblity to connect multiple devices.

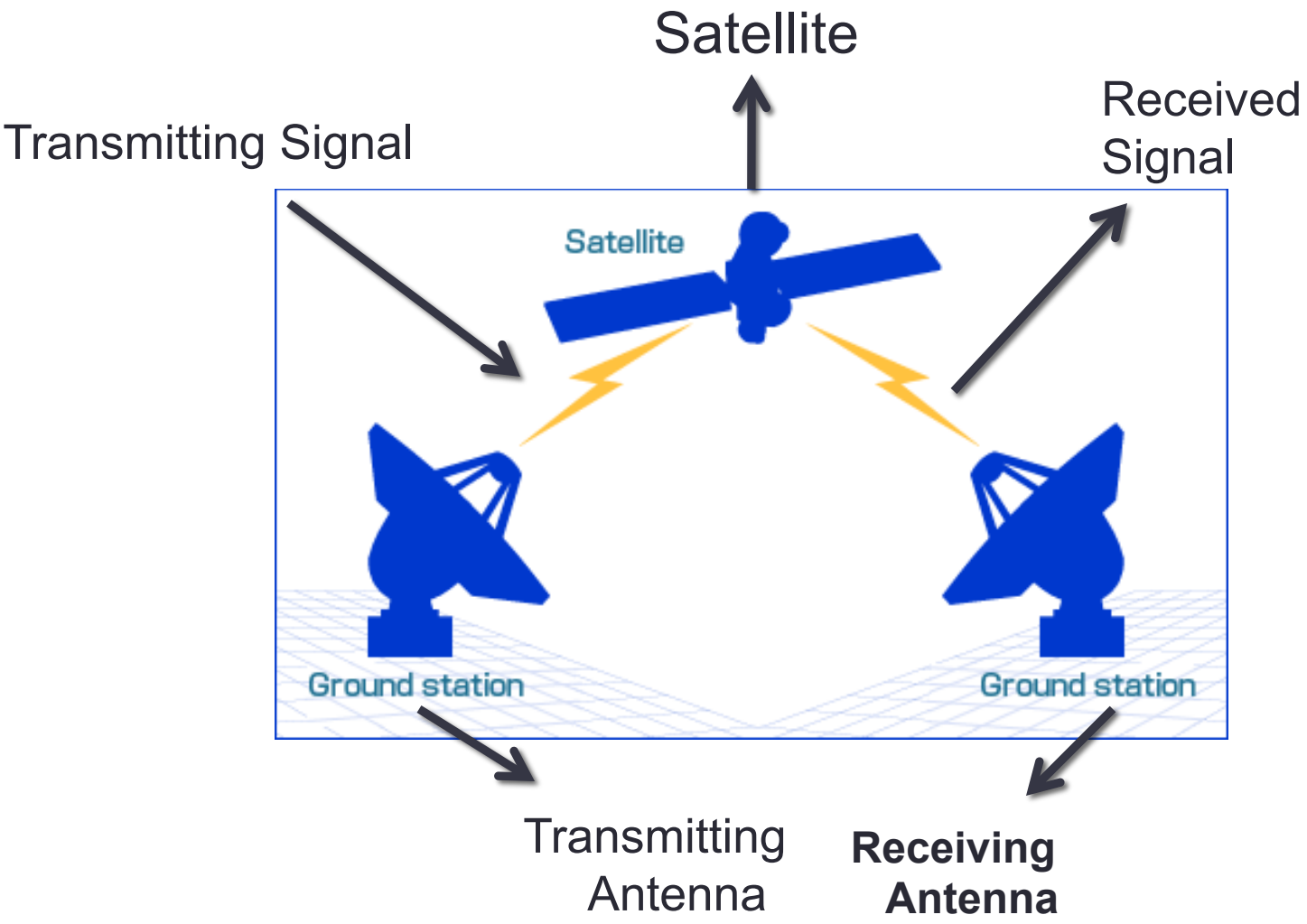
WHAT IS WIRELESS COMMUNICATION?

- Transmitting/receiving voice and data using electromagnetic waves in open space.
- The information from sender to receiver is carried over a well defined channel.
- Each channel has a fixed frequency bandwidth & capacity(bit rate).
- Different channels can be used to transmit information in parallel and independently.

TYPICAL FREQUENCIES

• FM RADIO	88 MHZ
• TV BROADCAST	200 MHZ
• GSM PHONES	900 MHZ
• GPS	1.2 GHZ
• PCS PHONES	1.8 GHZ
• BLUETOOTH	2.4 GHZ
• Wi-Fi	2.4 GHZ

How communication takes place?



TYPES OF WIRELESS COMMUNICATION

RADIO TRANSMISSION:-

easily generated, Omni-directional , travel long distance , easily penetrates buildings.

- PROBLEMS:- frequency dependent , relatively low bandwidth for data communication , tightly licensed by government.

MICROWAVE TRANSMISSION:- widely used for long distance communication , relatively inexpensive.

- PROBLEMS:- don’t pass through buildings , weather and frequency dependent.

TYPES OF WIRELESS COMMUNICATION

INFRARED AND MILIMETER WAVES:-

Widely used for short range communication , unable to pass through solid objects , used for indoor wireless LANs , not for outdoors.

LIGHT WAVE TRANSMISSION:- unguided optical signal such as laser , unidirectional , easy to install , no license required.

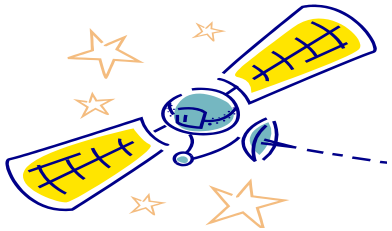
PROBLEMS:- unable to penetrate rain or thick fog , laser beam can be easily diverted by air.

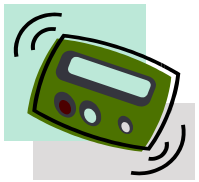
Wireless Communication Pros. and Cons.

- Advantages:
  - Working professionals can work and access Internet anywhere and anytime without carrying cables or wires wherever they go. This also helps to complete the work anywhere on time and improves the productivity.
  - A wireless communication network is a solution in areas where cables are impossible to install (e.g. hazardous areas, long distances etc.)
  - Wireless networks are cheaper to install and maintain
- Disadvantages:
  - Has security vulnerabilities
  - High costs for setting the infrastructure
  - Unlike wired communication, wireless communication is influenced by physical obstructions, climatic conditions, interference from other wireless devices

CURRENT WIRELESS SYSTEMS

- CELLULAR SYSTEM
- WIRELESS LANs
- SATELLITE SYSTEM
- PAGING SYSTEM
- PANs(BLUETOOTH)



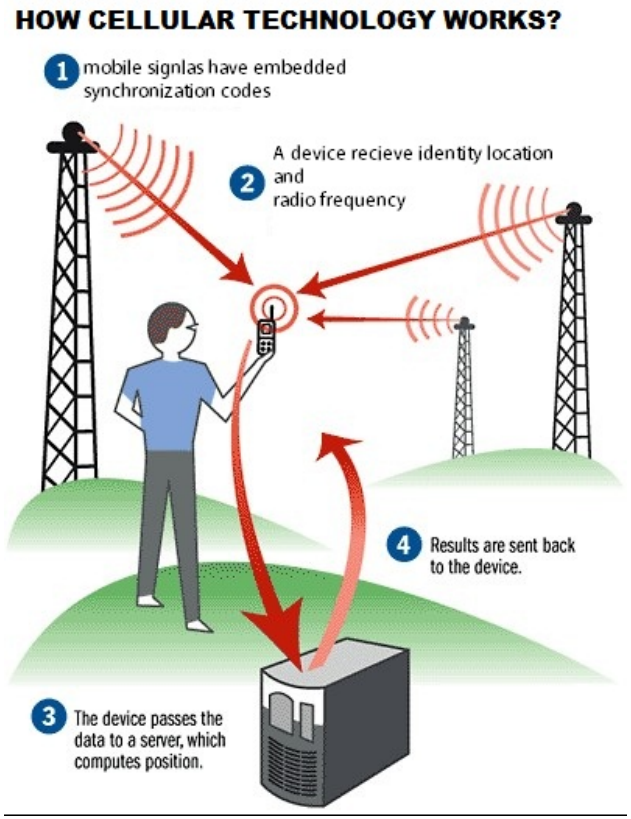


What is cellular system?

Definition

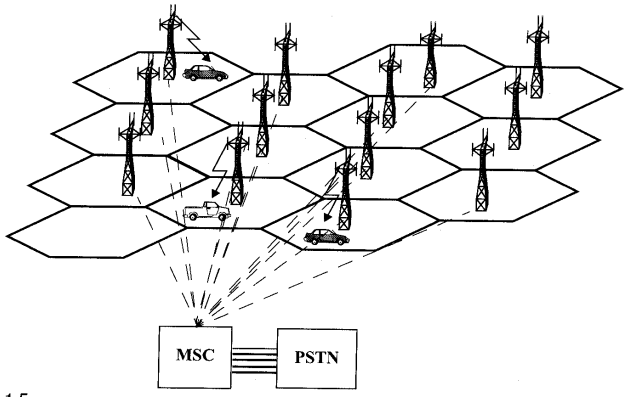
Wireless communication technology in which several small exchanges (called cells) equipped with low-power radio antennas (strategically located over a wide geographical area) are interconnected through a central exchange. As a receiver (cell phone) moves from one place to the next, its identity, location, and radio frequency is handed-over by one cell to another without interrupting a call.

Practical



Cellular Telephone Systems

- Provide connection to the PSTN for any user location within the radio range of the system.
- Characteristic
  - Large number of users
  - Large Geographic area
  - Limited frequency spectrum
  - Reuse of the radio frequency by the concept of “cell”.
- Basic cellular system: mobile stations, base stations, and mobile switching center.

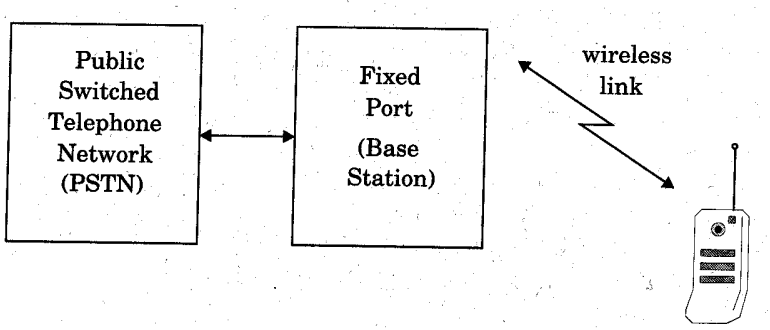


Base Station and Mobiles

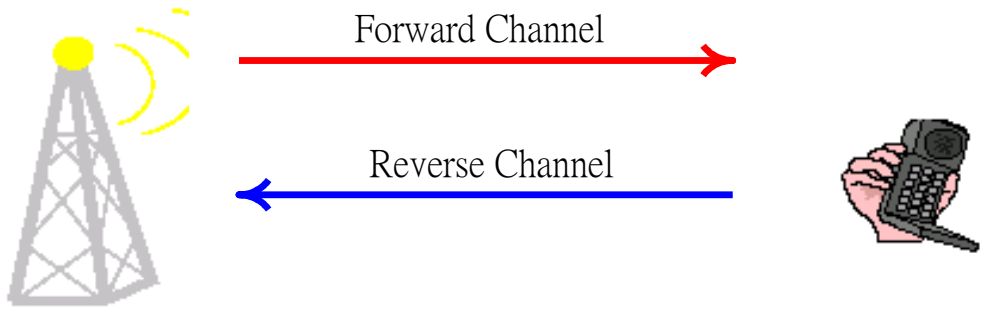
- Communication between the base station and mobiles is defined by the standard common air interface (CAI)
  - Forward voice channel (FVC): voice transmission from base station to mobile
  - Reverse voice channel (RVC): voice transmission from mobile to base station
  - Forward control channels (FCC): initiating mobile call from base station to mobile
  - Reverse control channel (RCC): initiating mobile call from mobile to base station

Cordless Telephone System

- Cordless telephone systems are full duplex communication systems.
- First generation cordless phone
  - in-home use
  - communication to dedicated base unit
  - few tens of meters
- Second generation cordless phone
  - outdoor
  - combine with paging system
  - few hundred meters per station



- Classification of mobile radio transmission system
  - Simplex: communication in only one direction
  - Half-duplex: same radio channel for both transmission and reception (push-to-talk)
  - Full-duplex: simultaneous radio transmission and reception (FDD, TDD)
- Frequency division duplexing uses two radio channel
  - Forward channel: base station to mobile user
  - Reverse channel: mobile user to base station
- Time division duplexing shares a single radio channel in time.

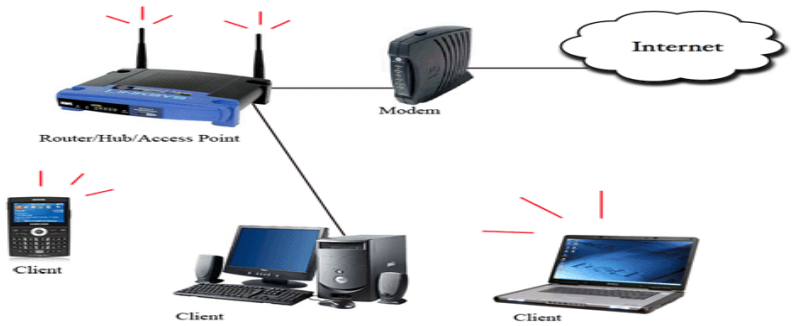


Example of Mobile Radio Systems

- Examples
  - Cordless phone
  - Remote controller
  - Hand-held walkie-talkies
  - Pagers
  - Cellular telephone
  - Wireless LAN
- Mobile - any radio terminal that could be moves during operation
- Portable - hand-held and used at walking speed
- Subscriber - mobile or portable user

Wireless local area network(WLAN)

- WLAN connect local computers
- Range (100 m) confined region
- Break data into packets
- Channel access is shared
- Backbone internet provides best service
- Poor performance in some application like videos
- Low mobility



Wi-Fi Advantages

- **Ease of Integration and Convenience** – The wireless nature of such networks allows users to access network resources from nearly any convenient location.
- **Mobility** – With the emergence of public wireless networks, users can access the internet even outside their normal working environment.
- **Expandability** – Wireless networks are capable of serving a suddenly-increased number of clients with the existing equipment. In a wired network, additional clients require additional wiring.

Wi-Fi Disadvantages

- **Radio Frequency** transmission and wireless networking signals are subjected to a wide variety of interference including the complex propagation effects that are beyond the control of the network administrator.
- **Security Problems** – Wireless networks may choose to utilize some of the various encryption technologies.
- **Range** will be insufficient for a larger structure – and, in order to increase its range, repeaters or additional access points have to be purchased.
- The speed on most wireless networks will be slower than the slowest common wired networks.
- Installation of an infrastructure-based wireless network is a complex to set up.

Bluetooth Technology

- Bluetooth technology uses radio waves to communicate between devices. Most of these radio waves have a range of 15-50 feet.
- According to the official Bluetooth website, Bluetooth uses a low-power signal with a maximum range of 50 feet with sufficient speed to enable transmission of data.
- The pairing process identifies and connects any two devices to each other. It also prevents interference from other non-paired Bluetooth devices in the area.
- It uses maximum power only when it is required, thus preserving battery life.

Zigbee

- ZigBee devices are designed for low-power consumption.
- ZigBee is used in Commercial Applications like sensing and monitoring applications.
- ZigBee uses very low power and extremely long device battery life.
- ZigBee gives flexibility to do more with the reliable wireless performance and battery operation.

Satellite system

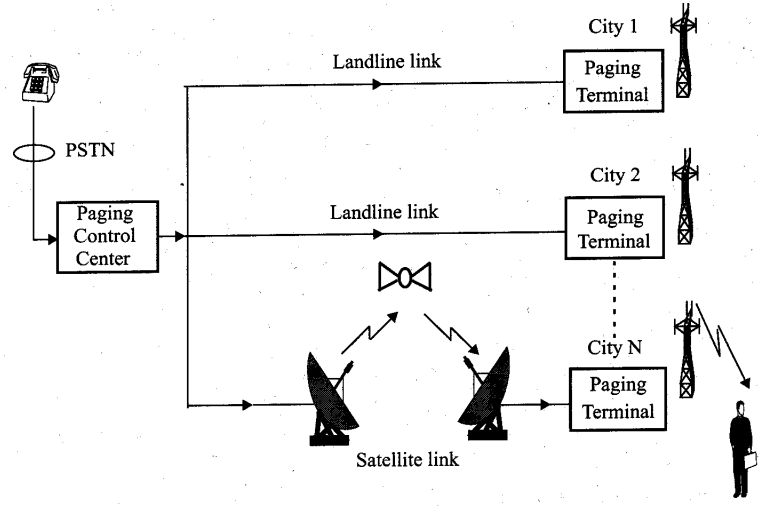
- Global coverage
- Optimized for good transmission
- Expensive base stations.
- Voice and data transmission
- Telecommunication application
- GPS , global telephone connection
- TV broadcasting , military , weather broadcasting

Paging system

- Broad coverage for short messages
- Message broadcast from all base stations
- Simple terminals
- Optimized for one way transmission
- Answer back hard
- Overtaken by cellular

Paging Systems

- Conventional paging system send brief messages to a subscriber
- Modern paging system: news headline, stock quotations, faxes, etc.
- Simultaneously broadcast paging message from each base station.
- Large transmission power to cover wide area.

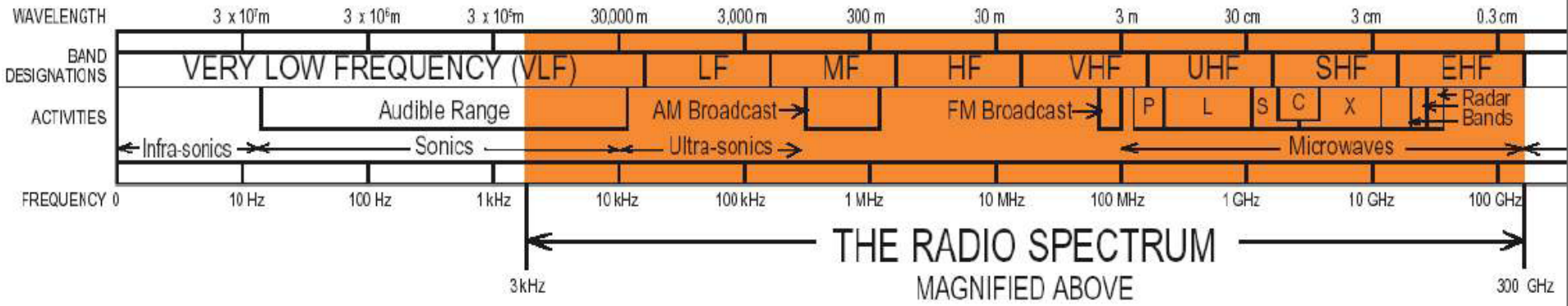


Microvawe

- Microwave is an effective type of wireless data transmission that transfers information using two separate methods.
  - transmit data through the wireless media of a microwave is the satellite method that transmits information via a satellite that orbits 22,300 miles above the Earth.
    - 11-14 Ghz , 1-10 Mbps
  - a terrestrial method, in which two microwave towers with a clear line of sight between them are used ensuring no obstacles to disrupt that line of sight.
    - 4 GHz to 6 GHz or 21 GHz to 23 GHz , 1 – 10 Mbps

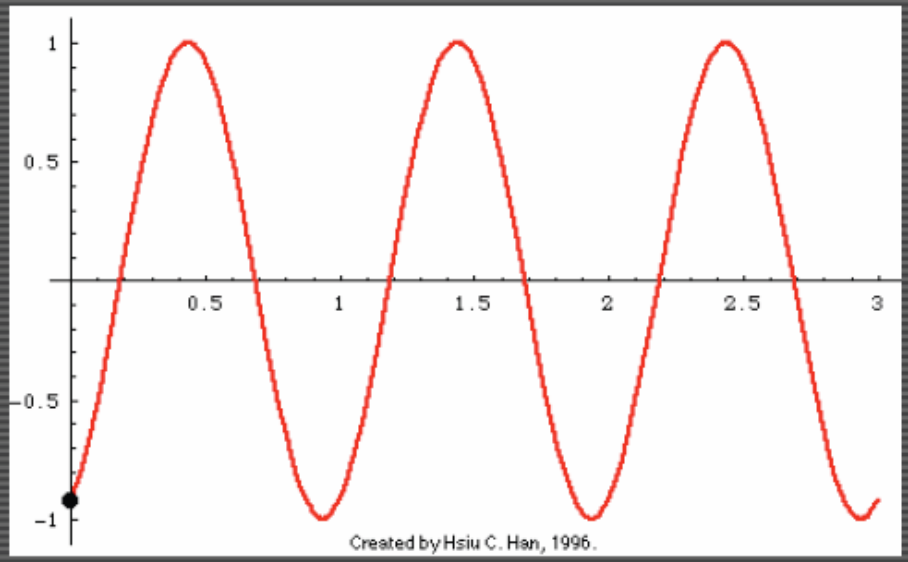
What is RF?

Radio Frequency is an electromagnetic signal with a frequency between 3 kHz and 300 Ghz



RF signals carry analog or digital information

- Analog: Information content varies continuously over time
  - *Example: radio and TV stations*
- Digital: Information content consists of discrete units (e.g., 0s and 1s)
  - *Example: Cell phones and wireless networks*



- Frequency: the number of times a signal goes through a complete "up and down" cycle in one second of time. **1 Hz**

- Amplitude: the maximum voltage reached in one cycle. 1V

- Wavelength: the distance a radio wave will travel during one cycle.
  - $$\lambda = c/f$$
  - λ is the wavelength, in meters
  - c is the speed of light, 299793 m/s
  - f is the frequency, in Hz

Frequency	Wavelength
900 MHz	0.33 m
2.4 GHz	*0.125 m*
5.0 GHZ	0.06 m

Carrier Wave

How do we send *information* in a radio signal?

Carrier wave

- An RF signal – usually a sinusoid – that carries information
- Carrier is usually a much higher frequency than the information itself!
  - *Ex: 2.4 GHz 802.11b networks carry a lot less than 2.4 GBit/sec of data....*
  - *Rather, carry up to 11 MBit/sec of information*
- Why use a carrier??
  - *Easier to generate a sinusoid signal, and it will travel further.*

Carrier wave frequency

- The frequency of a radio transmission is the center frequency of the carrier
  - *Actual frequency of the carrier changes over time, e.g., with FM transmission*

Signal Modulation

How do we encode information in a carrier wave?

An information signal must be *modulated* onto the carrier wave

- That is, we must modify the carrier wave in some way...
- Receiver must *demodulate* the carrier to get back the original signal

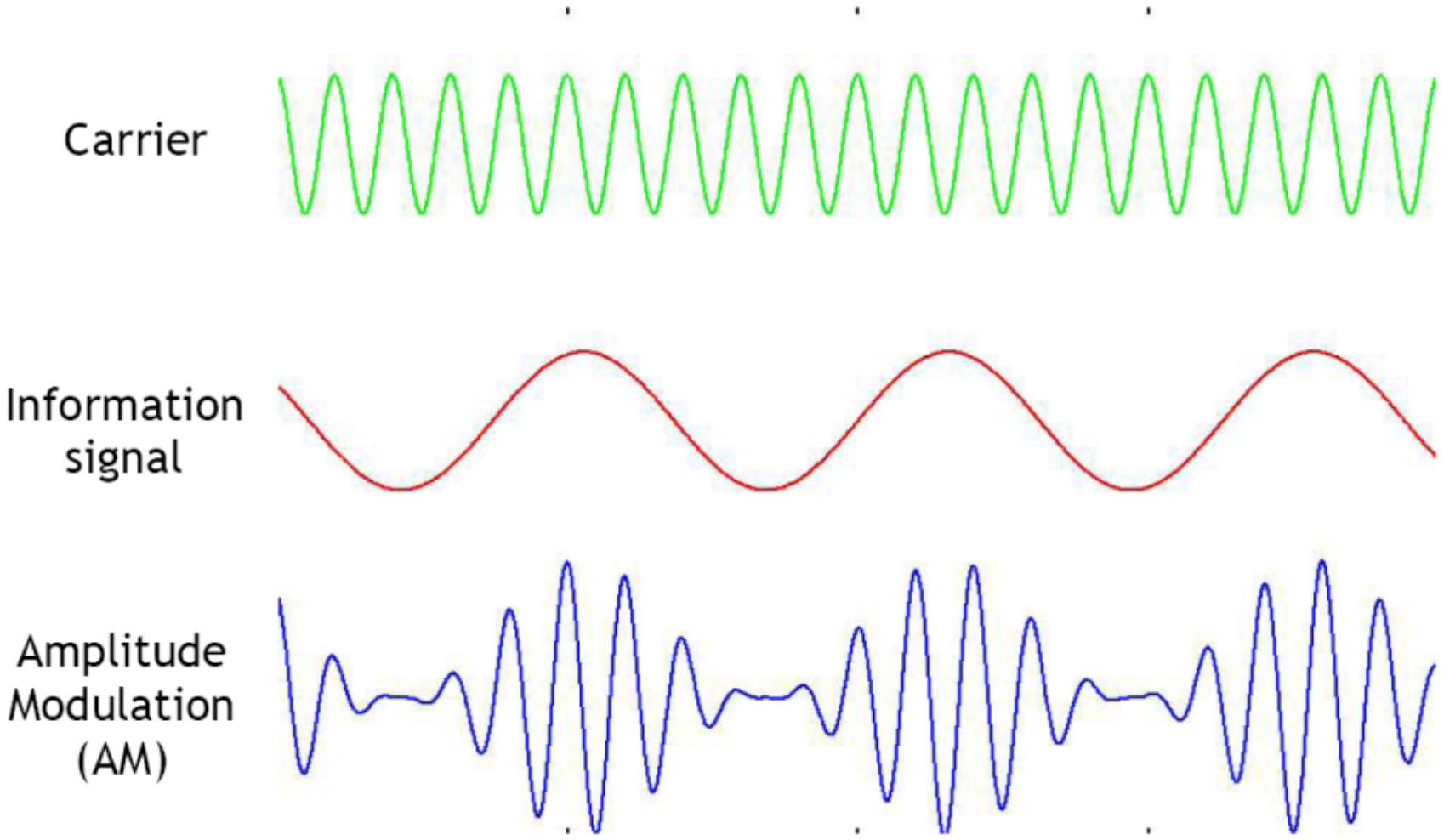
Amplitude Modulation (AM)

- Modify the *amplitude* of the carrier with respect to the amplitude of the signal

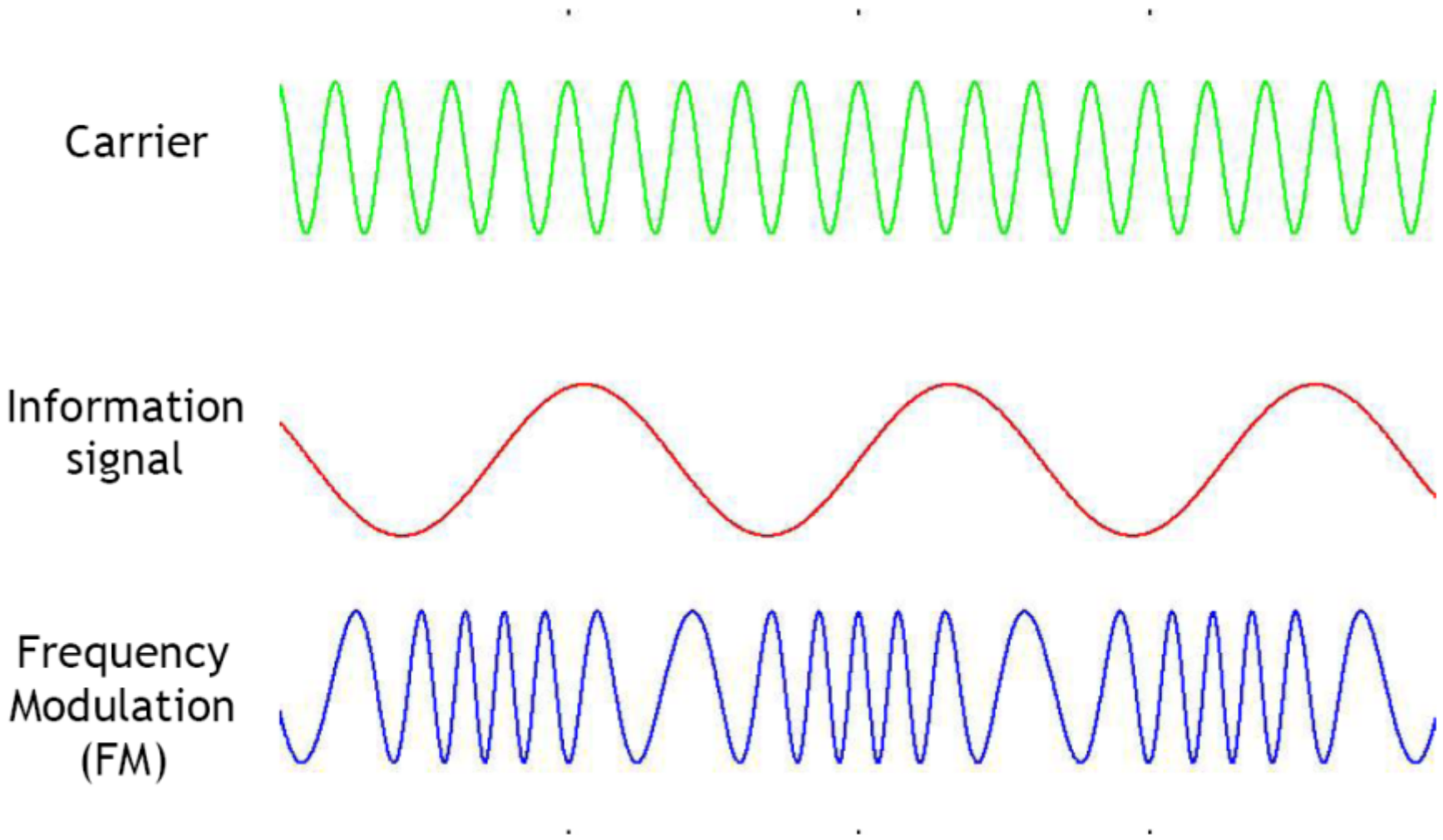
Frequency Modulation (FM)

- Modify the *frequency* of the carrier with respect to the amplitude of the signal

Signal Modulation



Signal Modulation



Digital Modulation

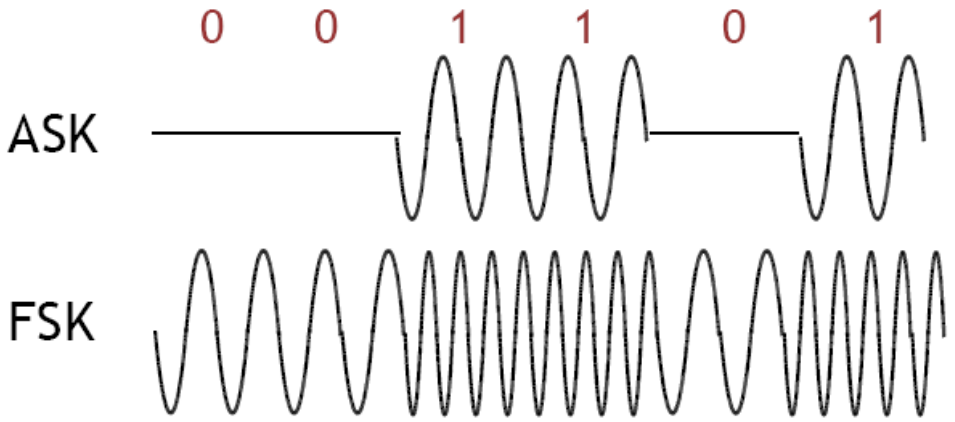
How do we modulate *digital* signals?

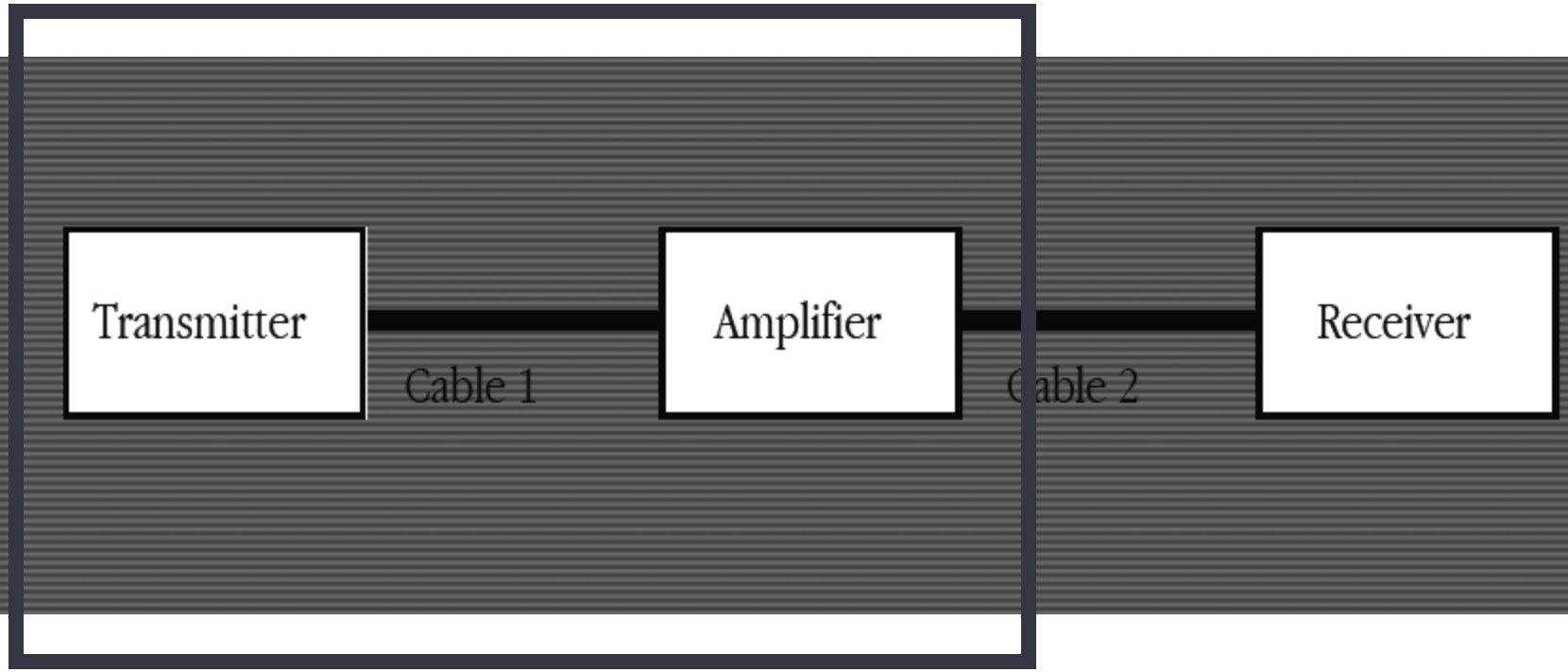
Amplitude shift keying (ASK)

- "0" bit is the absence of the carrier (flat signal)
- "1" bit is the presence of the carrier with some fixed amplitude

Frequency shift keying (FSK)

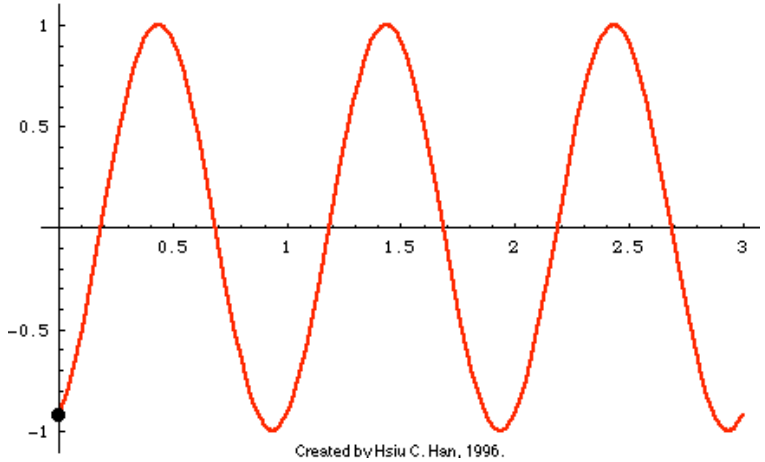
- "0" bit is carrier at frequency f_0 ; "1" bit is carrier at frequency f_1





-A way to generate a carrier wave
-A way to "add" a signal wave to the carrier wave
-An antenna to radiate the combined waveform
-A "ground" connection to reference the antenna
-A voltage source to drive the transmission

Generate a carrier wave



Requirements for an oscillator:

- **Amplification**
- **A frequency determining device**
- **Positive feedback**

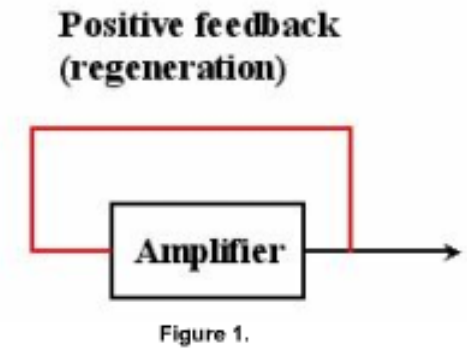
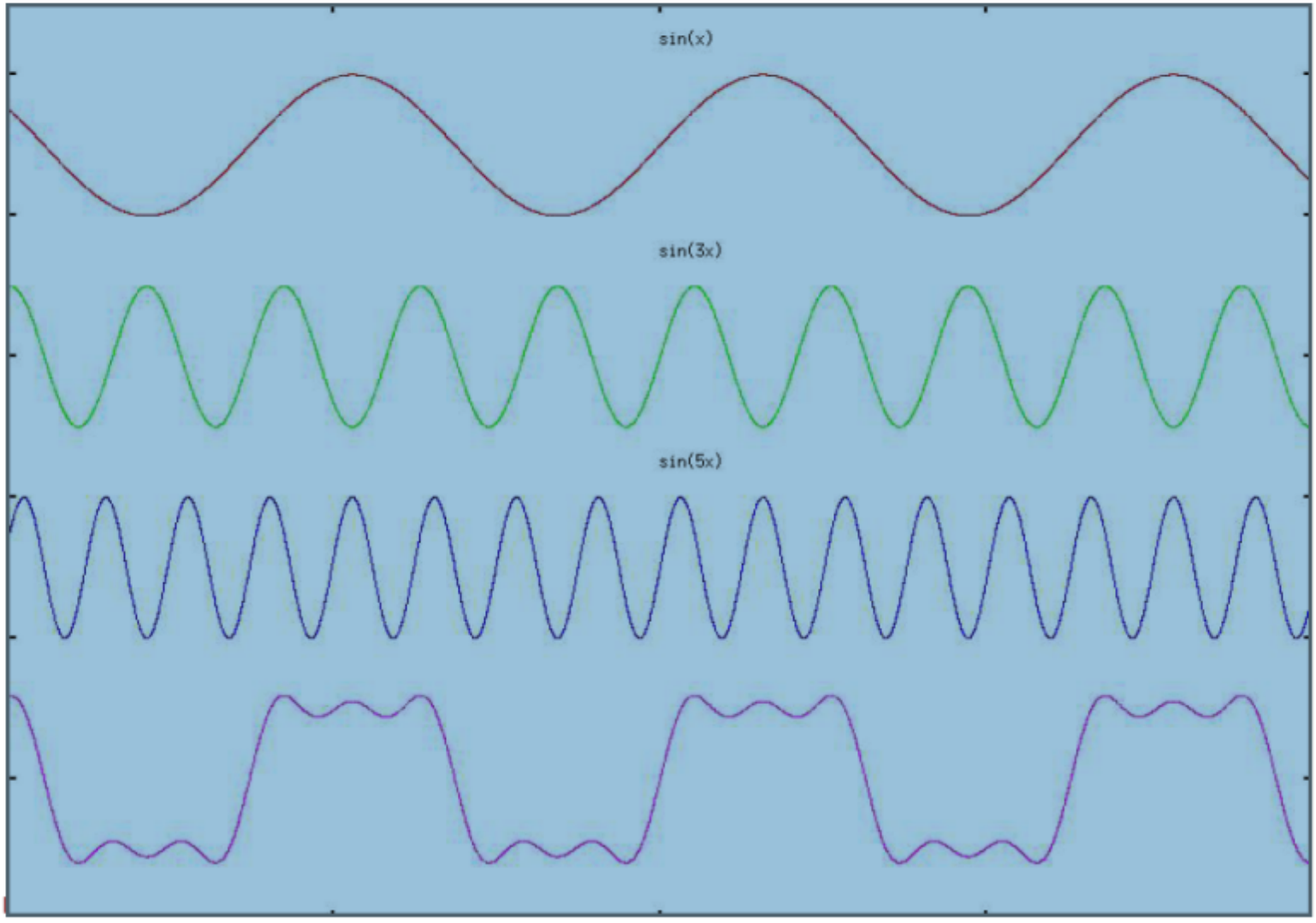


Figure 1.

Bandwidth

A typical signal will include many frequencies

- Fourier theorem: Any periodic signal is a combination of sinusoids



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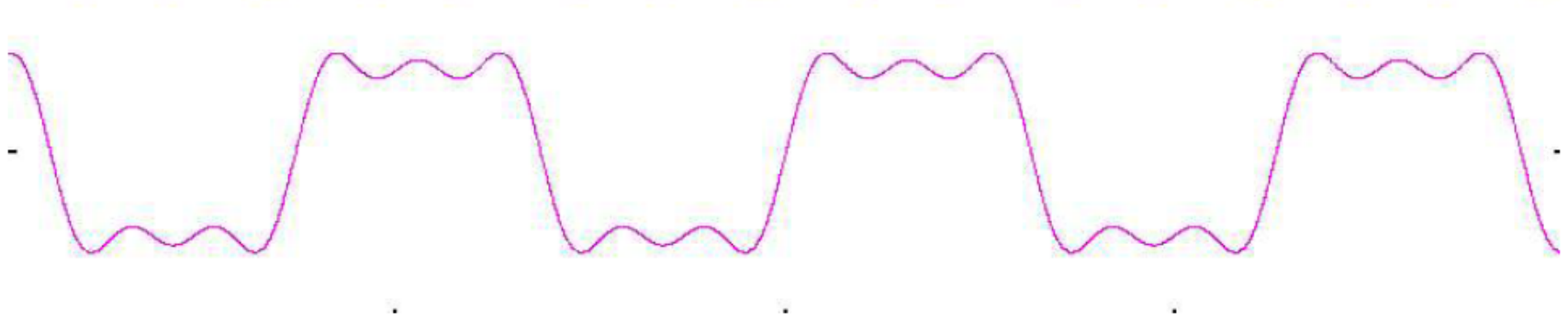


Spectrum: The range of frequencies in a signal

- In this case, [f ... $5f$]

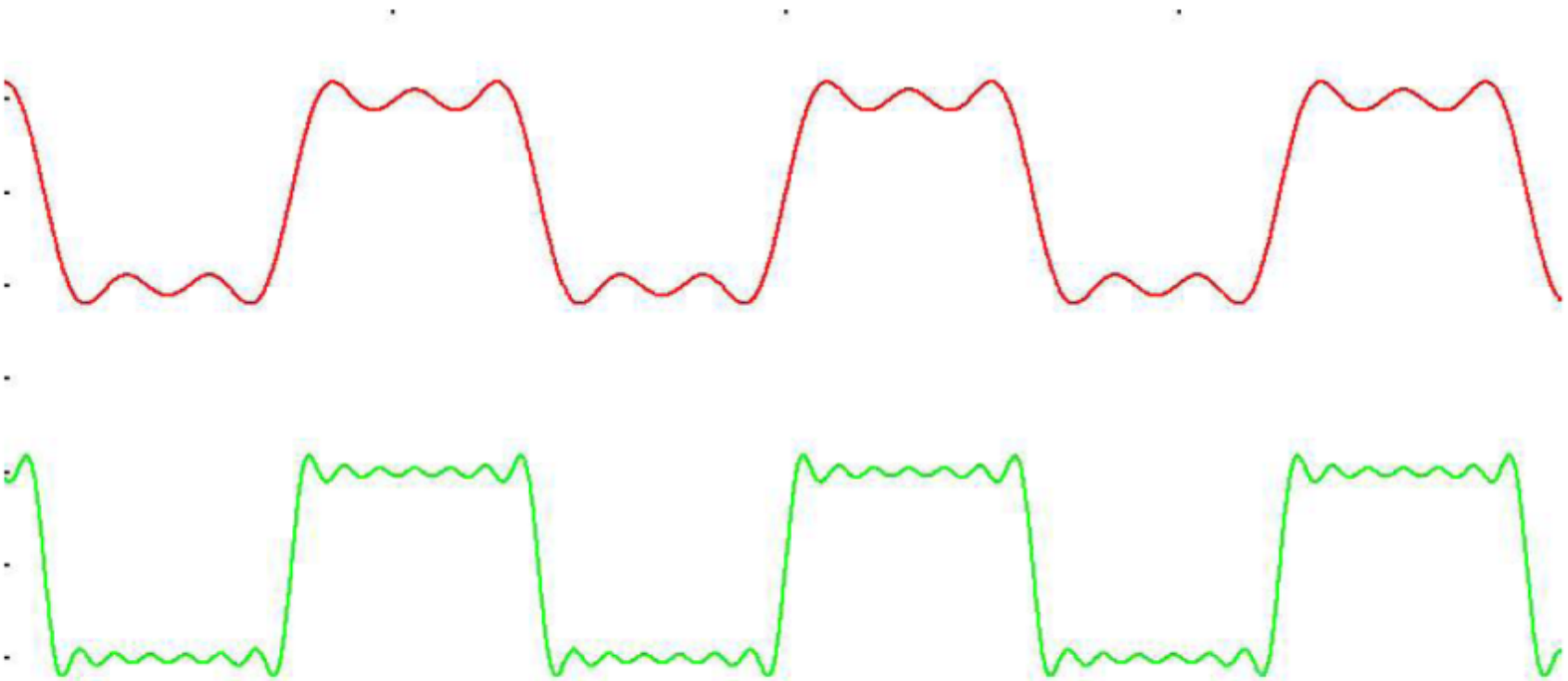
Bandwidth: The width of the spectrum

- In this case, ($5f - f$) = $4f$

Bandwidth

What happens if we increase the bandwidth?

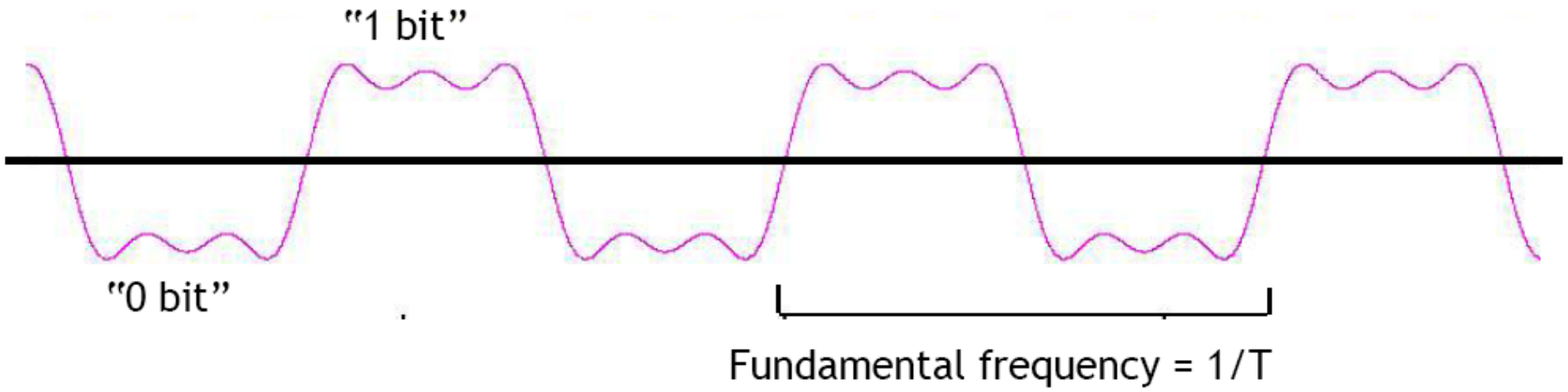
- Consider two waves, one with bandwidth 4*f*, the other with bandwidth 12*f*:



- As the bandwidth increases, the wave approximates a square wave.
- A perfect square wave (or any true digital signal) has *infinite bandwidth*

Data Rate and Bandwidth

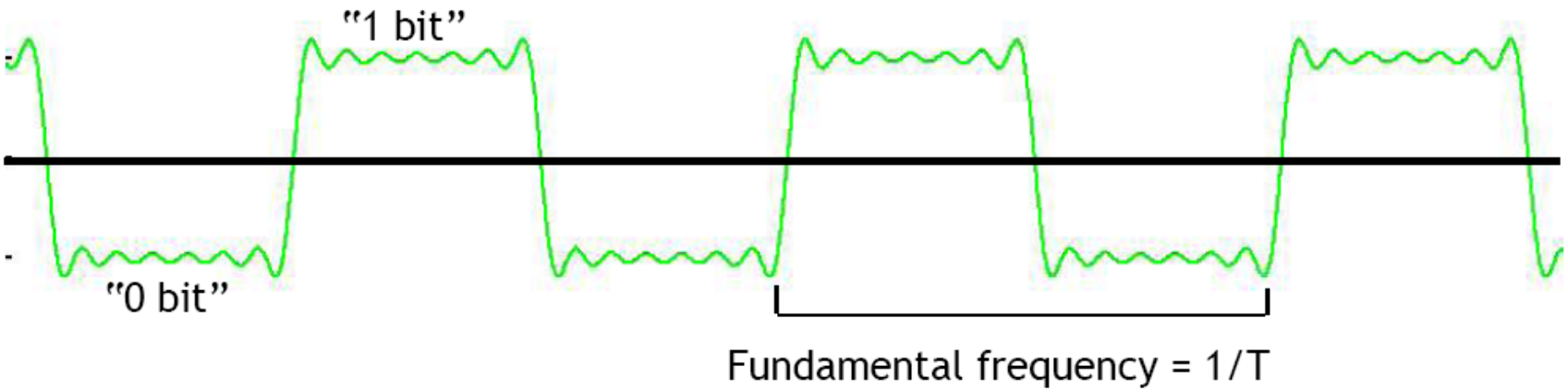
What is the relationship between bandwidth of a signal and its information-carrying capacity?



- This wave can carry 2 bits every period, or 1 bit per T/2 sec
- If T = 1 μsec, the *fundamental frequency* f = 1 MHz
- *Data rate* is $2 * 10^6$ = 2 Mbps

Data Rate and Bandwidth

What is the relationship between bandwidth of a signal and its information-carrying capacity?



- What if we double the bandwidth?
- If the fundamental frequency is the same, data rate is identical!
  - *But ... this is a "cleaner" signal.*
  - *A receiver will be much more likely to discern 0 and 1 bits from this waveform.*
- In general: the greater the bandwidth, the less distortion in the signal.

- Power: in the RF world, the power is commonly used to quantify a signal, instead of the amplitude.
- Power is expressed in *Watts*.
- For low-frequency signals, the power is given by
- $$P=EI$$
- For high-frequency signals with no reactance, by the root-mean-square values.
- For high-frequency signals with reactance, RF power is a vector, 2-D, quantity.

Gain, loss, and decibels

Ratio between two signal power levels is often measured in *decibels (dB)*:

- gain(dB) = $10 \log_{10} (P_{out} / P_{in})$
- loss(dB) = $-10 \log_{10} (P_{out} / P_{in}) = 10 \log_{10} (P_{in} / P_{out})$
- Where P_{out} is the output power level, and P_{in} is the input power level

Example

- Signal with power level 10mW transmitted over a wireless channel.
- Receiver gets a signal of 2mW.

$$\text{Loss} = 10 \log (10/2) = 10(0.698) = 6.98 \text{ dB}$$

mW and dBm

Decibels refers to relative *changes* in magnitude, not absolute values

So ... we define the *dBW (decibel-Watt)* as a reference

- 1 Watt of transmission power == 0 dBW
- Example: WGBH, 89.7FM in Boston transmits at 100,000 Watts
- Power in dBW = 10 * log(100,000W / 1W) = 10 * 5 = 50 dBW

For wireless networks, the *dBm (decibel-milliwatt)* is more useful

- 1 mW transmission power == 0 dBm
- 10 mW == 10 dBm
- 0.1 mW == -10 dBm
- 802.11b networks have a max transmit power of 100 mW == 20 dBm

Bandwidth Allocation

In the U.S., the FCC is responsible for allocating radio frequencies.

Why allocate the radio spectrum?

- Prevent interference between different devices
- It would be unfortunate if the local TV station interfered with police radio...

Generally, any transmitter is limited to a certain bandwidth

- e.g., a single 802.11 channel is 30 MHz “wide”

FCC also regulates the *power* and *placement* of transmitters

- Consumer devices generally limited to transmitting < 1 W of power
- Can't have two TV stations on channel 5 next to each other


NOT ALLOCATED
RADIONAVIGATION
FIXED
MARITIME MOBILE
MARITIME MOBILE
FIXED
MARITIME MOBILE
MARITIME MOBILE
Radiolocation
RADIONAVIGATION
Radiolocation
MARITIME MOBILE
MARITIME MOBILE
AERONAUTICAL RADIONAVIGATION
3 kHz
300 kHz
300 kHz
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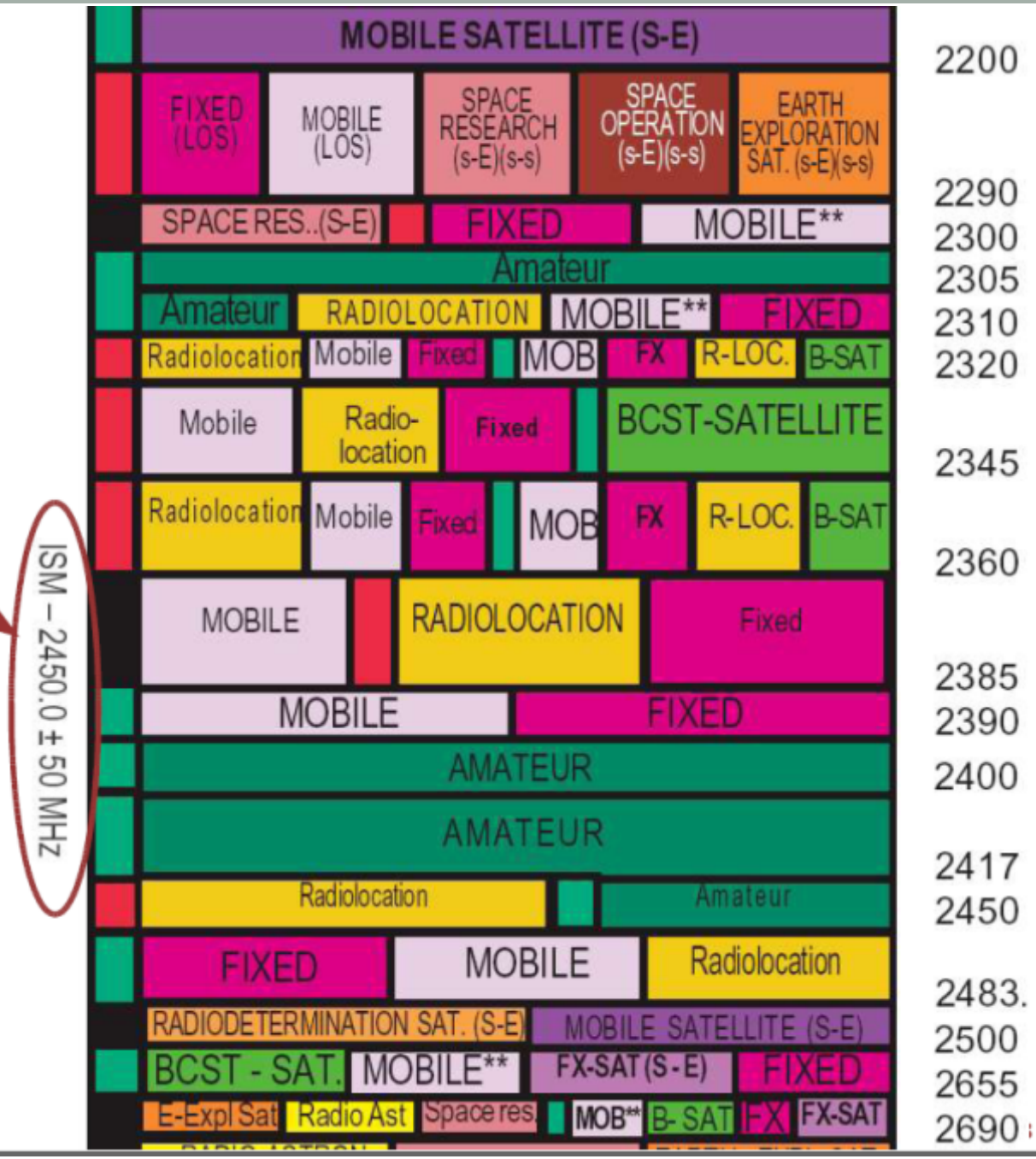
ISM:
Industrial,
Scientific,
and Medical



ISM and UNII bands

FCC Part 15 Rules regulate transmissions in U.S.

- ITU is worldwide governing body; individual countries regulate based on their recommendations
- Most consumer products operate in “unlicensed” bands set aside by FCC
- Rules allow devices to transmit up to some power limit

Industrial, Scientific, and Medical (ISM) bands

- 433 MHz and 868 MHz in Europe
- 902-928 MHz in US
- 2.4000 – 2.4835 Ghz worldwide
- Peak output: 1 W (30 dBm)
  - *However, most devices operate at much lower transmission powers, e.g., 100 mW or less*

Unlicensed National Information Infrastructure (UNII) bands

- 5.725 – 5.875 GHz