CMP-4204
Wireless Technologies

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Diarmuid O'Briain

- **Defence Forces**
  - Communications and Information Services Corps
- **US Robotics**
  - Technical Trainer
- **3Com**
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- **UTStarcom**
  - Technical Services Manager
- **Ripple Communications Limited**
  - Chief Technical Officer
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  - Associate Lecturer

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- **Chartered Engineer (CEng)**
- **Fellow of Engineers Ireland (FIEI)**
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- **Member Uganda Institute of Professional Engineers (MUIPE)**
- **Institute of Electrical and Electronics Engineers (MIEEE)**

IET The Institution of Engineering and Technology

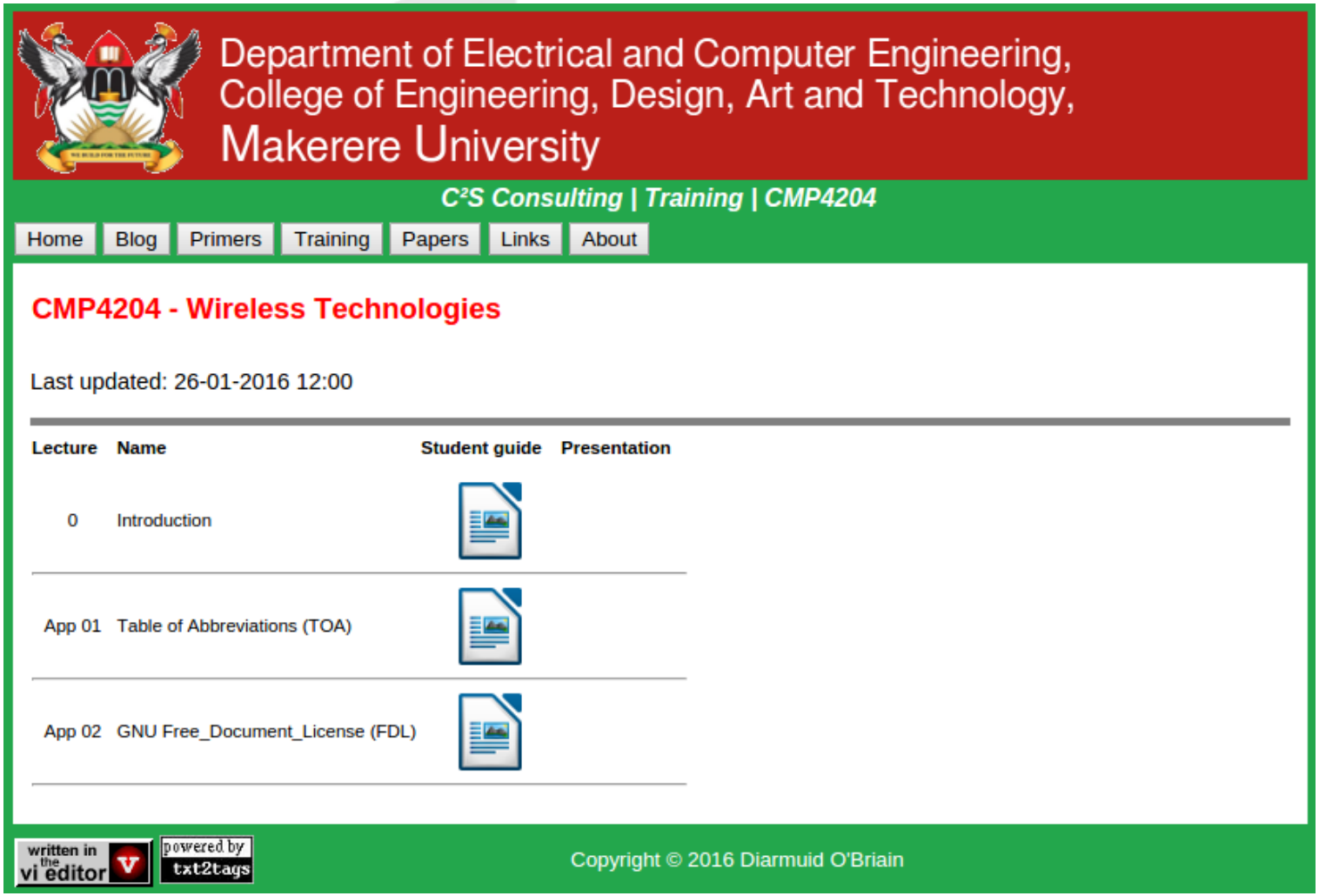
ENGINEERS IRELAND

IEEE

UGANDA INSTITUTION OF PROFESSIONAL ENGINEERS

Course webpage

http://www.obriain.com/training/CMP4204/



Course sections

- Lecture set 00 - Module Introduction
- Lecture set 01 - Radio Principles
- Lecture set 02 - Antenna Principles
- Lecture set 03 - Digital Modulation
- Lecture set 04 - Internetworking Models
- Lecture set 05 - Microwave Radio
- Lecture set 06 - Wireless Local Area Networks
- Lecture set 07 - Personal Access Networks
- Lecture set 08 - 2G, GSM, CDMA and GPRS Cellular Mobile
- Lecture set 09 - WiMAX HiperLAN HiperWAN
- Lecture set 10 - 3G and UMTS Cellular mobile
- Lecture set 11 – 4G LTE Cellular mobile
- Lecture set 12 – 5G NR Cellular mobile

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Lecture 1

Radio Principles

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Radio Spectrum

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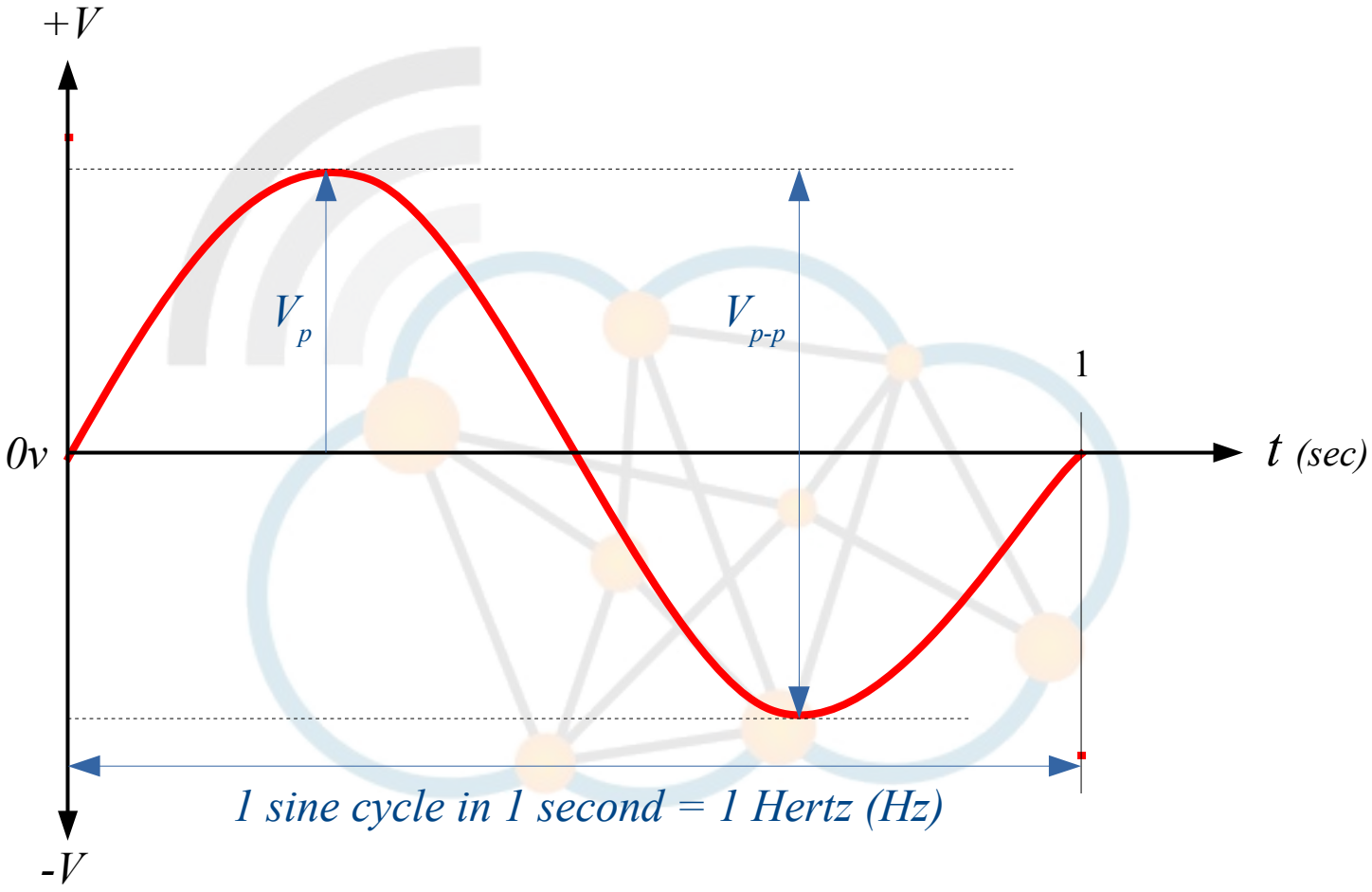
Sine wave and Hertz

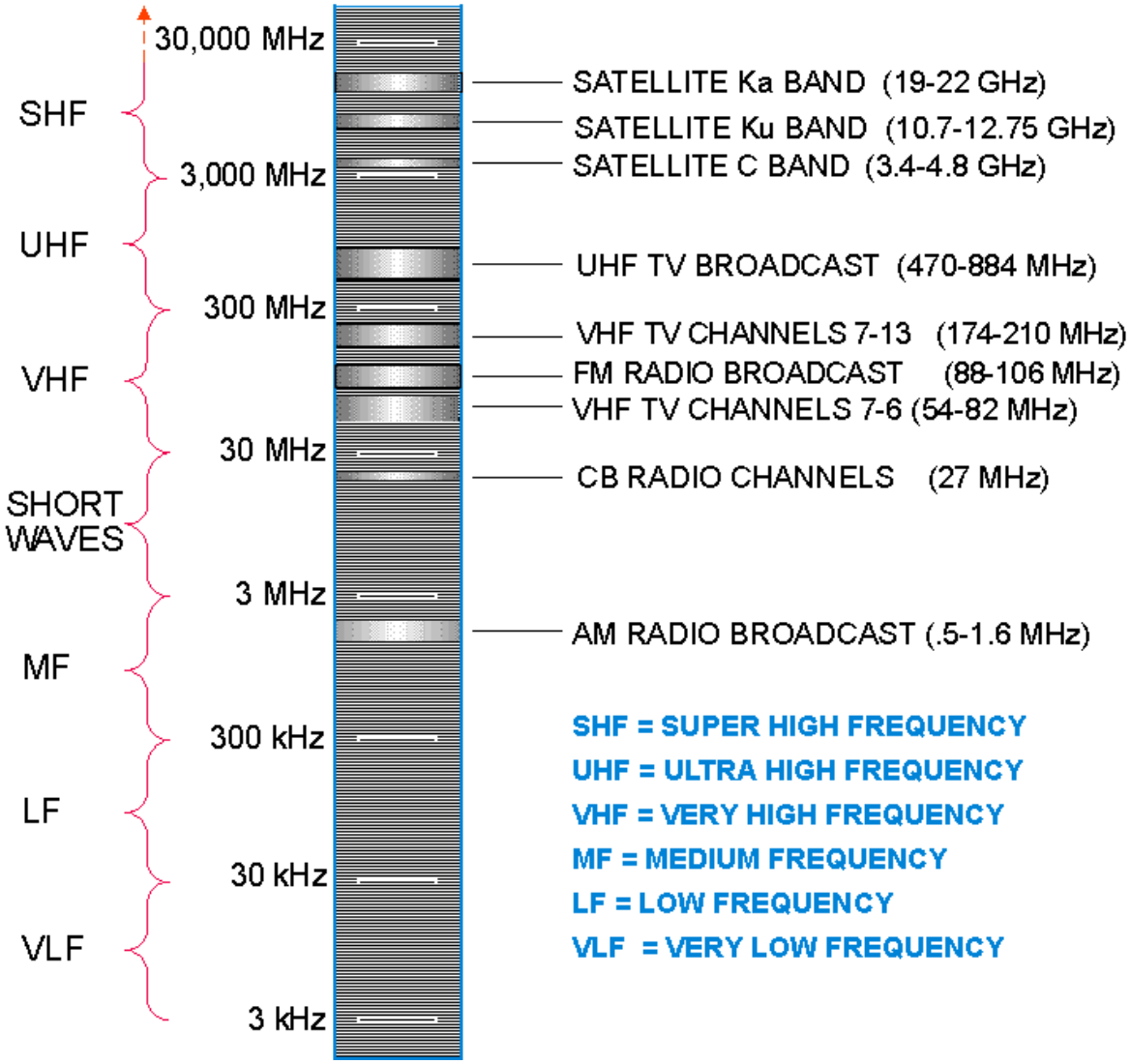


Frequency terms

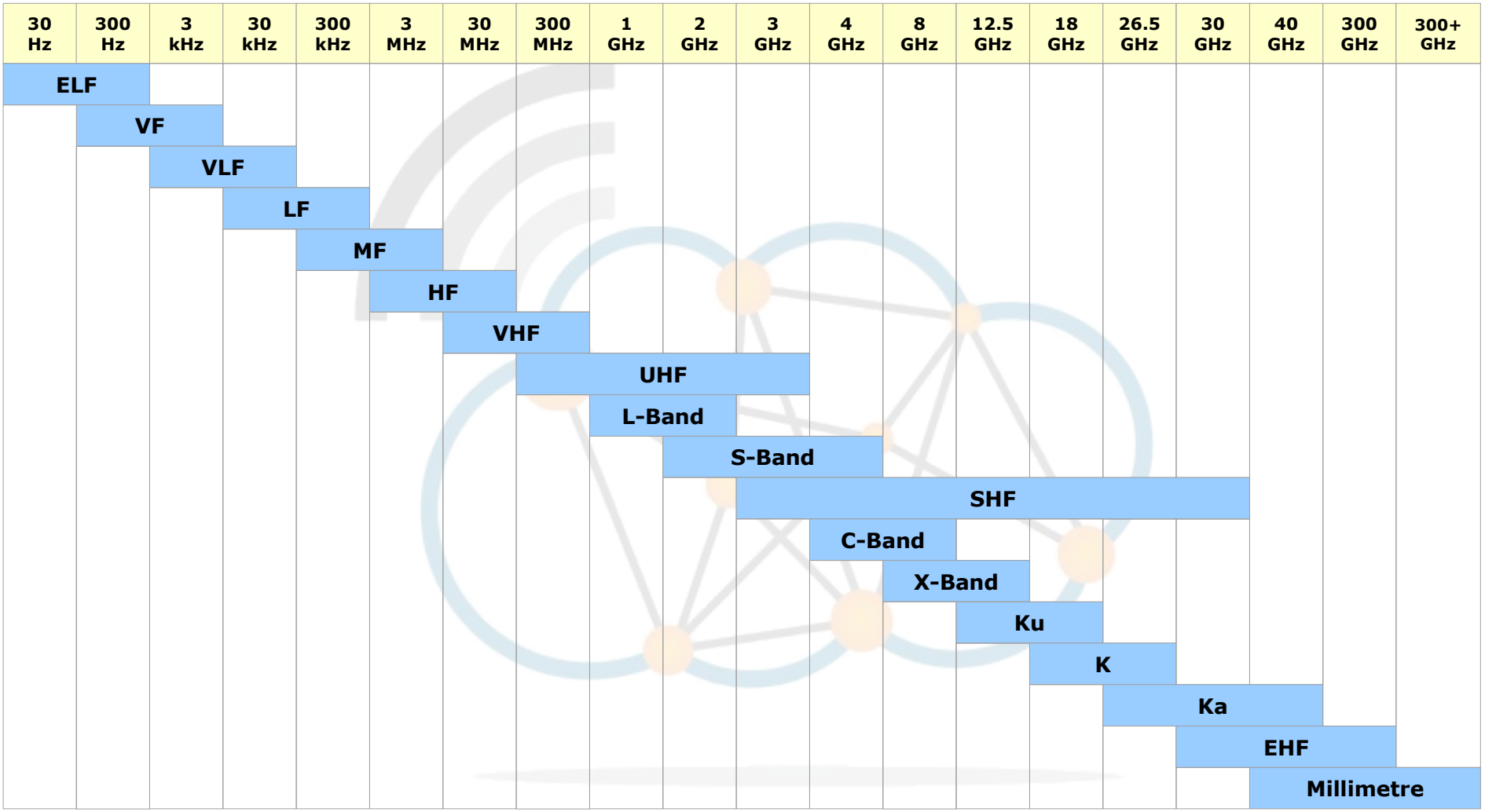
- Common Day-to-Day Frequencies:
  - AC Power out of the wall: 60Hz
  - “Over the phone” Voice: 300Hz to 3400Hz
  - Typical home stereo: 20Hz to 20kHz
  - FM Radio: 88Mhz to 106Mhz

- Hertz (Hz) is a measure of frequency
- Megahertz (MHz), 1 Million Hertz
- Gigahertz (GHz), 1 Billion Hertz
- 1000 MHz = 1 GHz

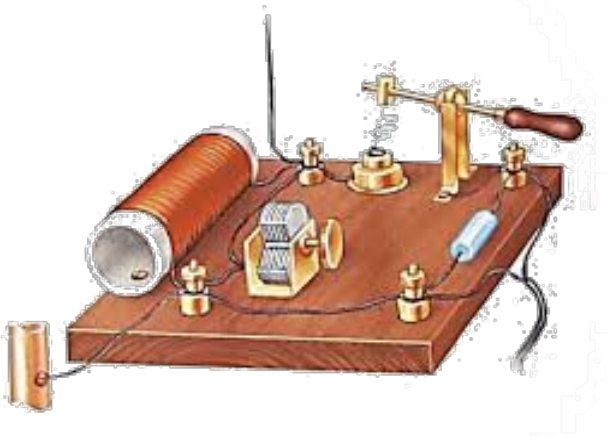
The electro magnetic spectrum



Frequency Bands



The Marconi experiments



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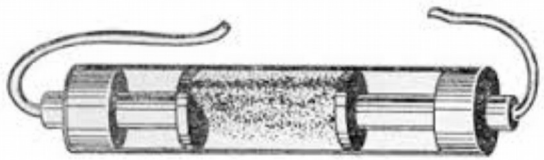
Guglielmo Marconi

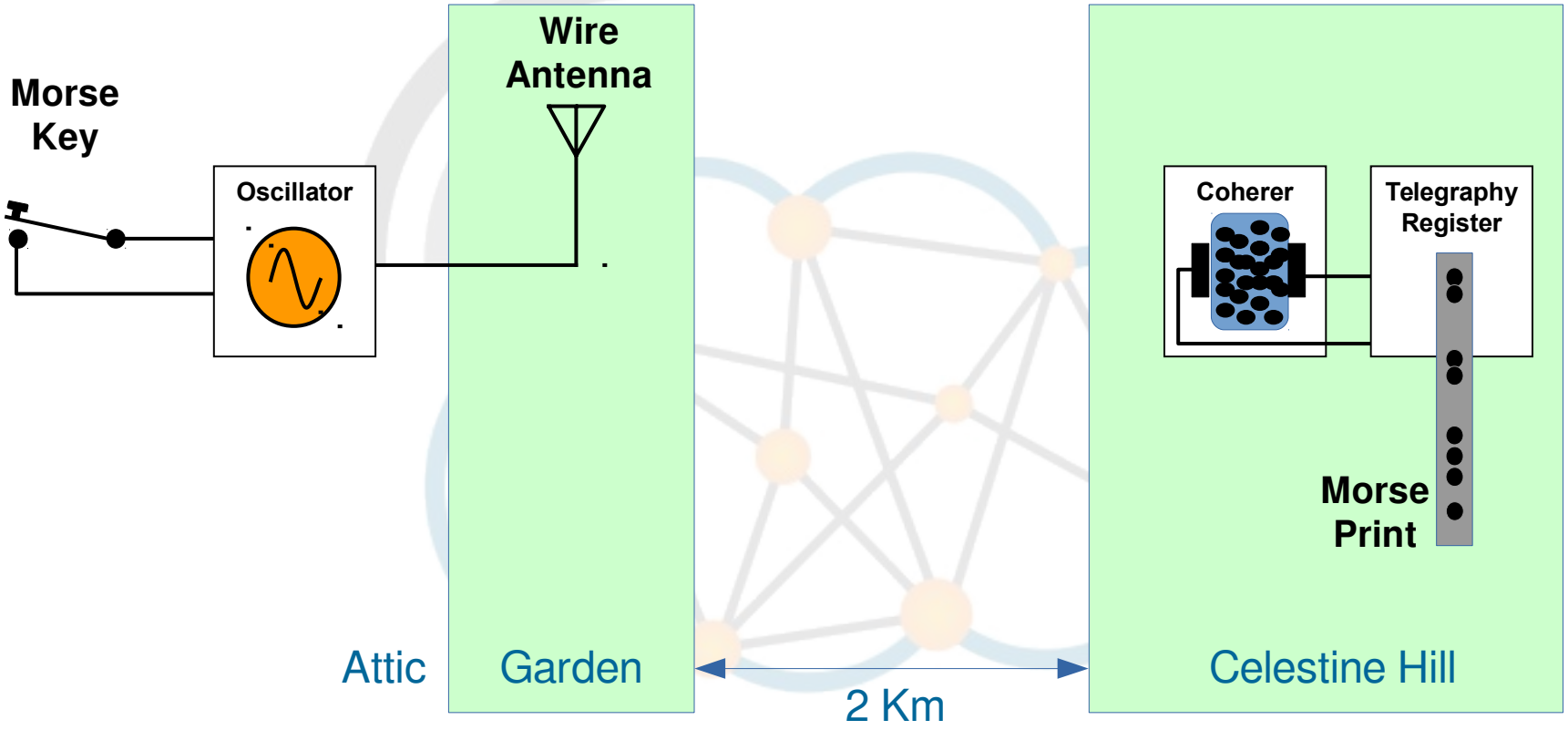
- At Villa Griffone in Italy, Guglielmo Marconi carried out experiments in 1894/5.
- He connected a spark-producing radio oscillator with a morse key from the attic “Silkworm Room” to a long wire antenna suspended in the garden.
- He transmitted a signal to and beyond Celestine Hill, 2 Km away.
- On the hill he had a coherer receiver, basically a tube filled with iron filings, connected to a telegraphy register, a device that prints morse on paper to receive the transmitted signal.

Coherer receiver

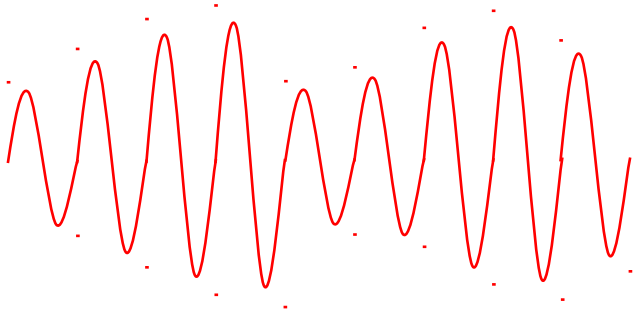
- A tube containing a pair of electrodes spaced a small distance apart with metal filings between them.
- When a radio signal is received the metal particles cling together (cohere). This reduces the resistance between the electrodes thereby permitting a signal to pass.
- This signal triggers the telegraphy register to make a 'dit'.



Guglielmo Marconi



Analogue Modulation



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Modulation

- All the early work was telegraphy based.
- In 1900, 5 years after Marconi made the first radio transmission a Reginald Fessenden passed the first voice transmission over 1.5 Km using Amplitude Modulation (AM).
- His first transmitted words were, "*Hello. One, two, three, four. Is it snowing where you are, Mr. Thiessen?*".

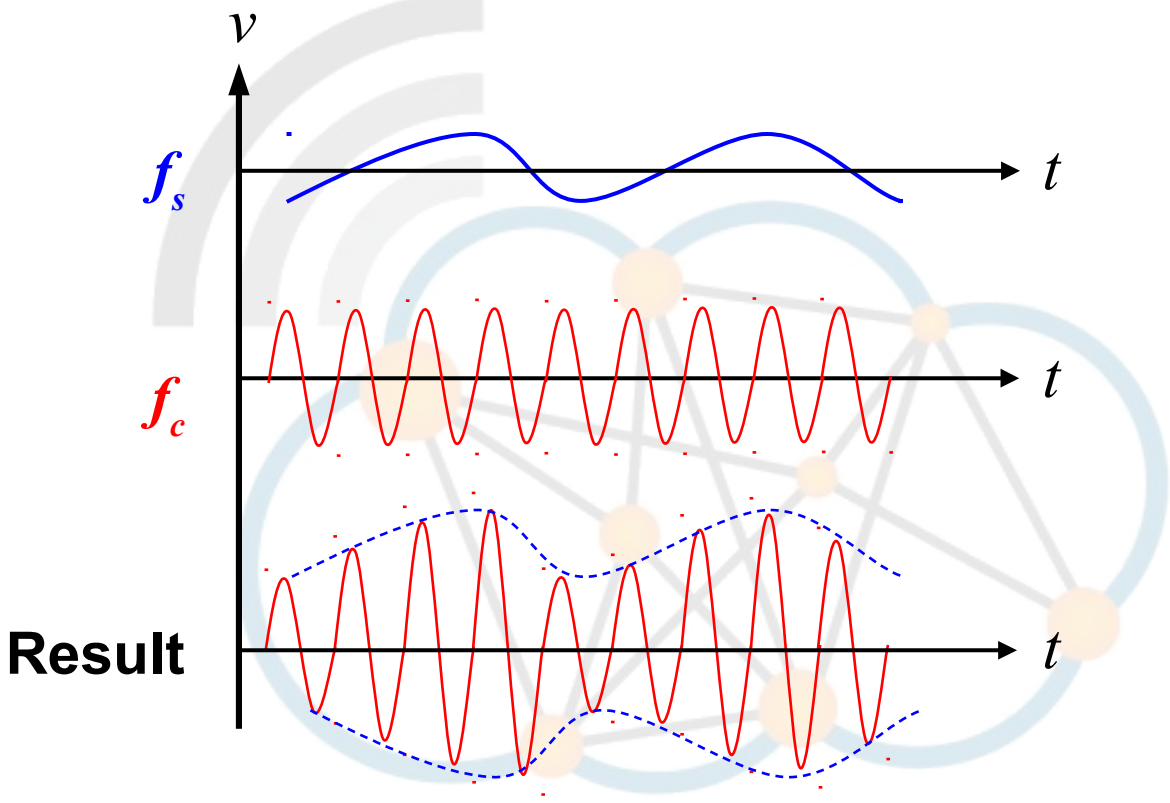
Modulation

- Modulation describes a range of techniques for encoding information on a carrier signal (f_c), typically a sine-wave signal. A device that performs modulation is known as a modulator.
- Basic modulation techniques:
  - **Amplitude modulation (AM)**
  - **Frequency modulation (FM)**
  - **Single sideband modulation (SSB)**

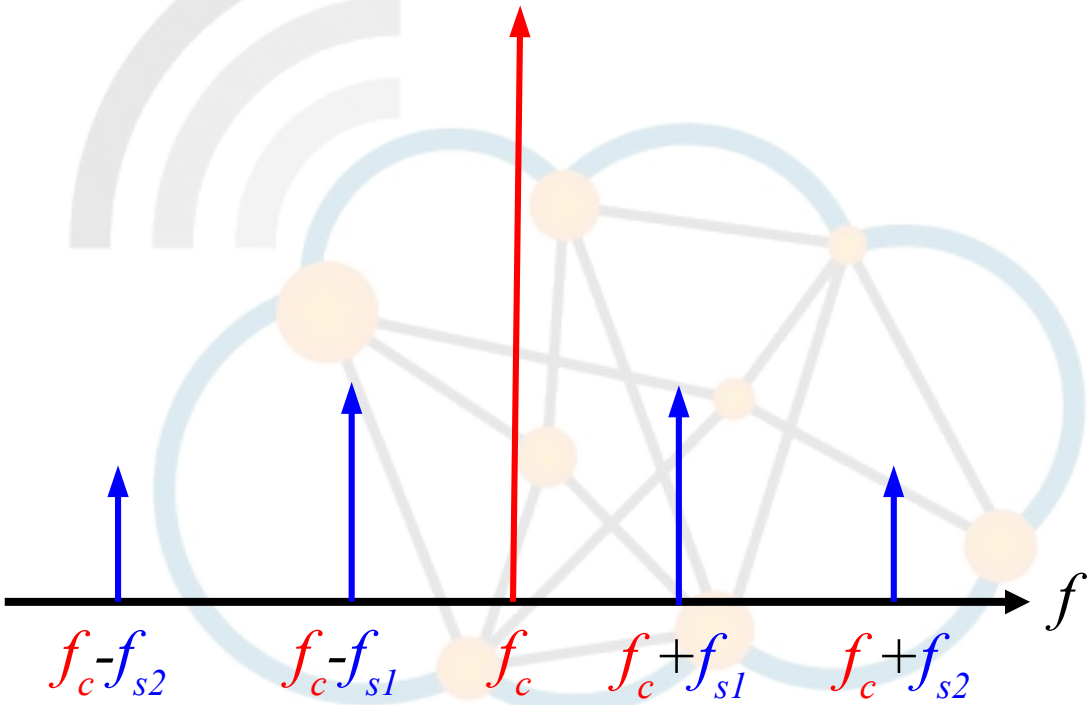
Amplitude Modulation (AM)

- AM – modulation method used to send a signal (f_s), typically using radio.
- AM modulates the amplitude of a carrier signal.
- AM produces a modulated output that has twice the bandwidth of the modulating signal
  - significant power component at the original carrier frequency.

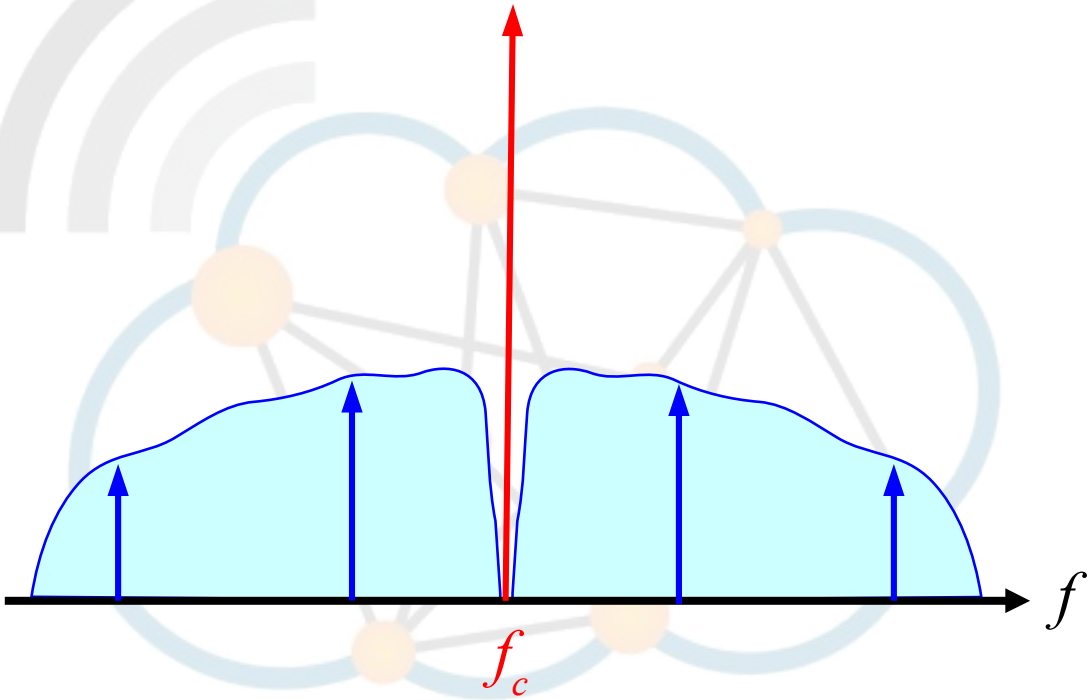
Amplitude Modulation (AM)



Amplitude Modulation (AM)



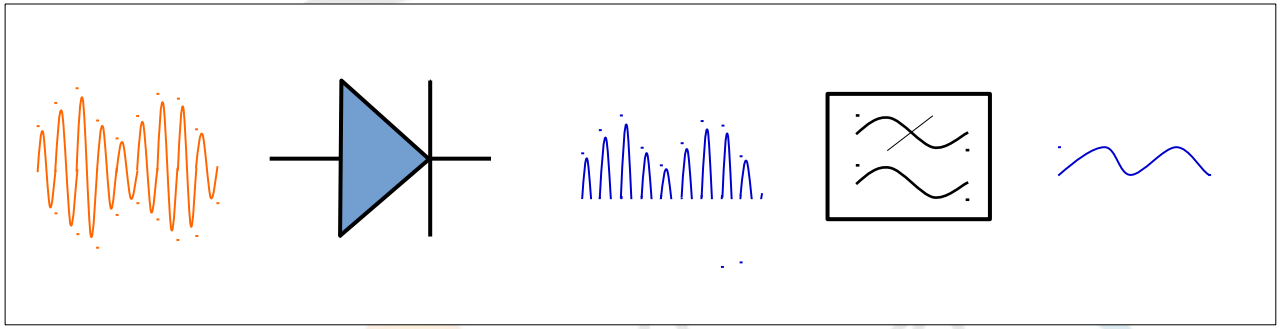
Amplitude Modulation (AM)



Amplitude Modulation (AM)

- The working principles of AM radio are:
  - A carrier wave (f_c) introduces an alternating electrical voltage in the receiving antenna.
  - Modulating the wave causes the amplitude of these electrical voltages to be greater or smaller but in equal and opposite amounts.

Amplitude Modulation (AM)



- The receiver uses a diode to remove either the positive or negative part of the electrical signal
- A Low Pass Filter (LPF) filters to recover the audible sound.

Amplitude Modulation (AM)

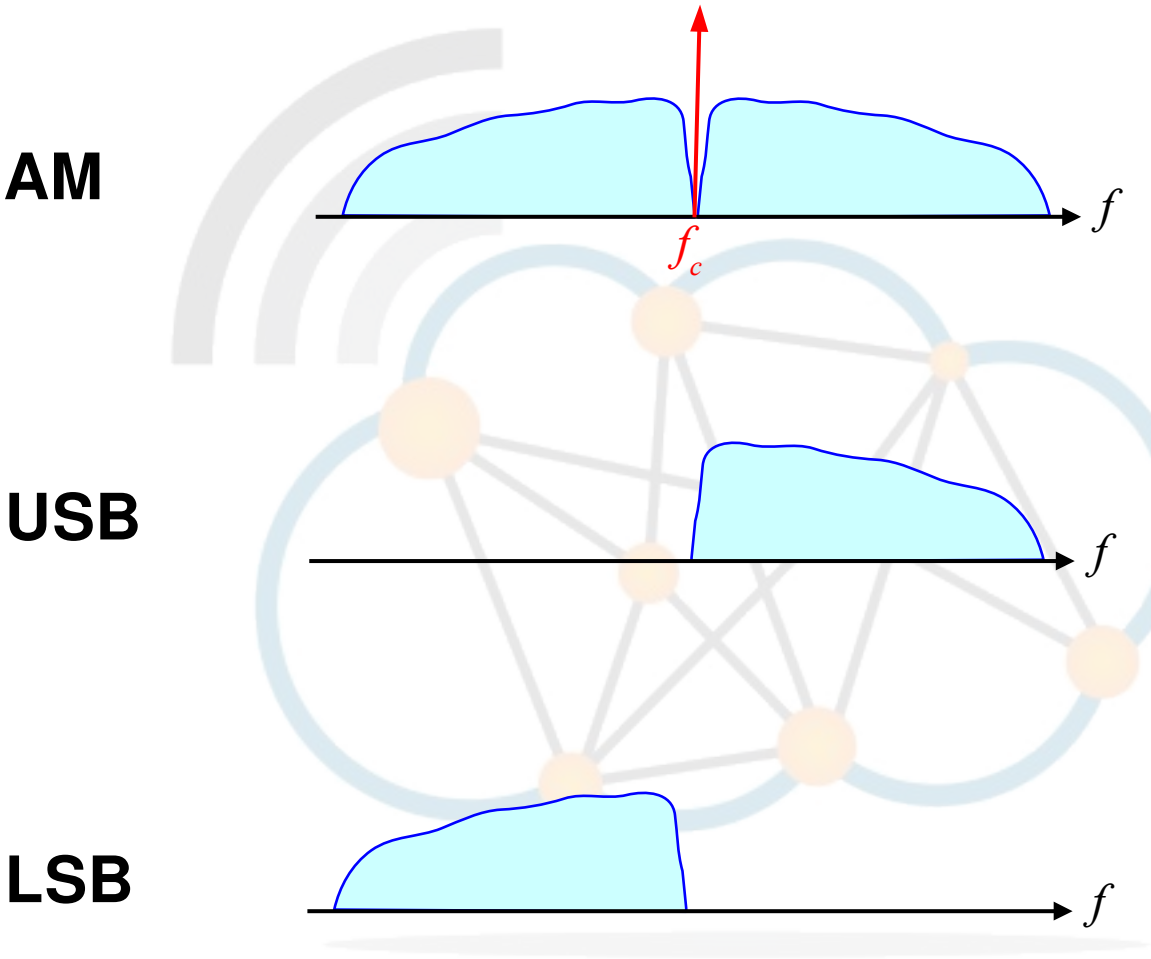
- One of the attractions of AM is that decoding the signal at the receiver is very simple.
- This was significant for the early days of commercial radio when electronic components were still quite expensive.
- It was one of the most popular methods for sending voice and music over radio during the 20th century.

Single SideBand Modulation (SSB)

SSB is a refinement of the technique of AM designed to be more efficient in its use of power and bandwidth.

- The AM signal has two frequency-shifted copies of the modulated signal on either side of the remaining carrier signal.
- To produce an SSB signal, apply a filter to remove one of the sidebands, and the carrier signal.
- The remaining sideband still contains the entire information content of the AM signal but using substantially less bandwidth and power, but cannot now be demodulated by a simple envelope detector.

Single SideBand (SSB)



Single SideBand Modulation (SSB)

To recover the original signal from an SSB signal, the carrier must be replaced with an extra 'false carrier' signal, prior to sending the signal to a standard envelope detector.

- For this to work, the false carrier must be accurately adjusted to match the frequency of the original carrier.

AM Radio
Block Diagrams

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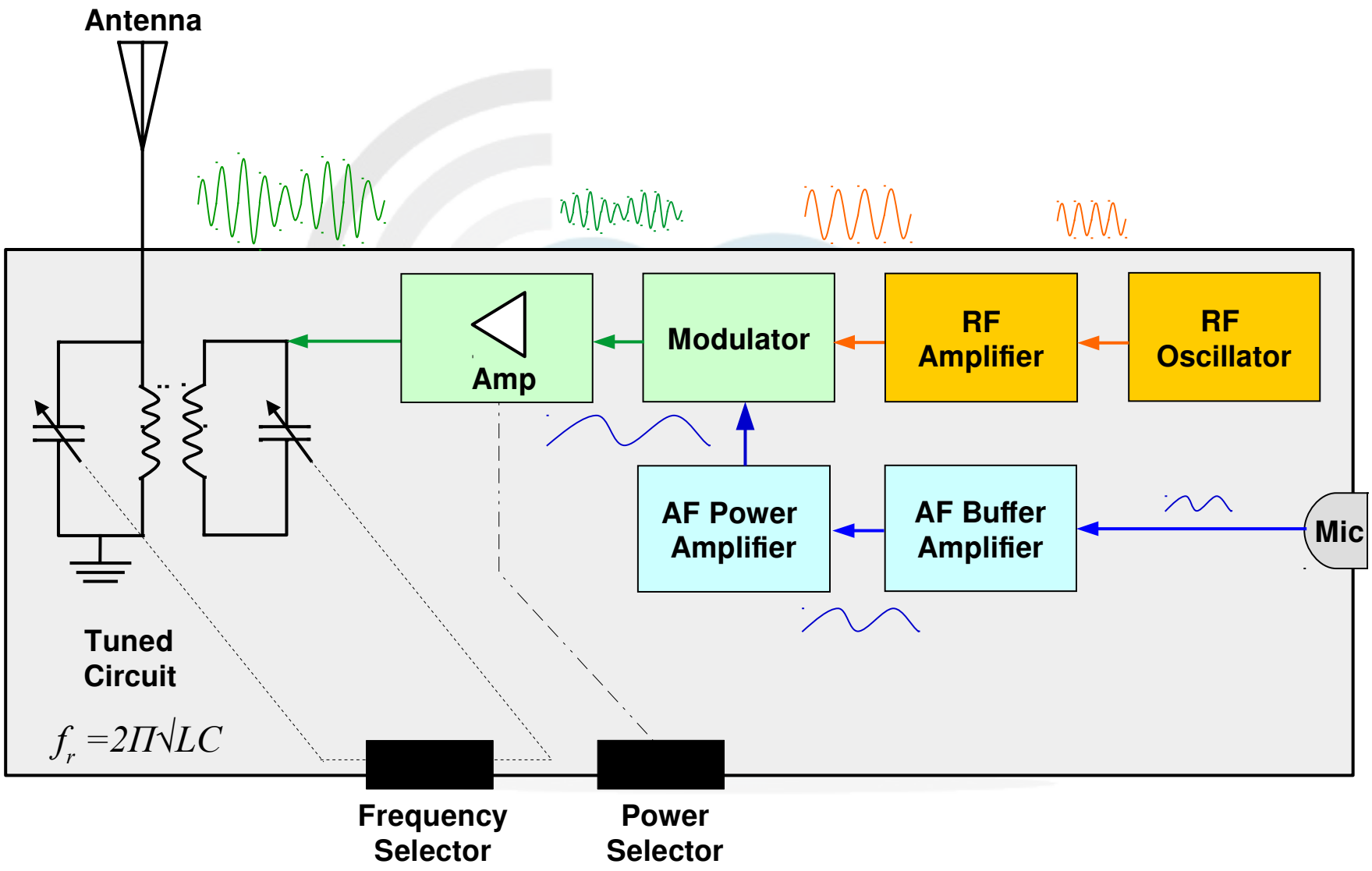
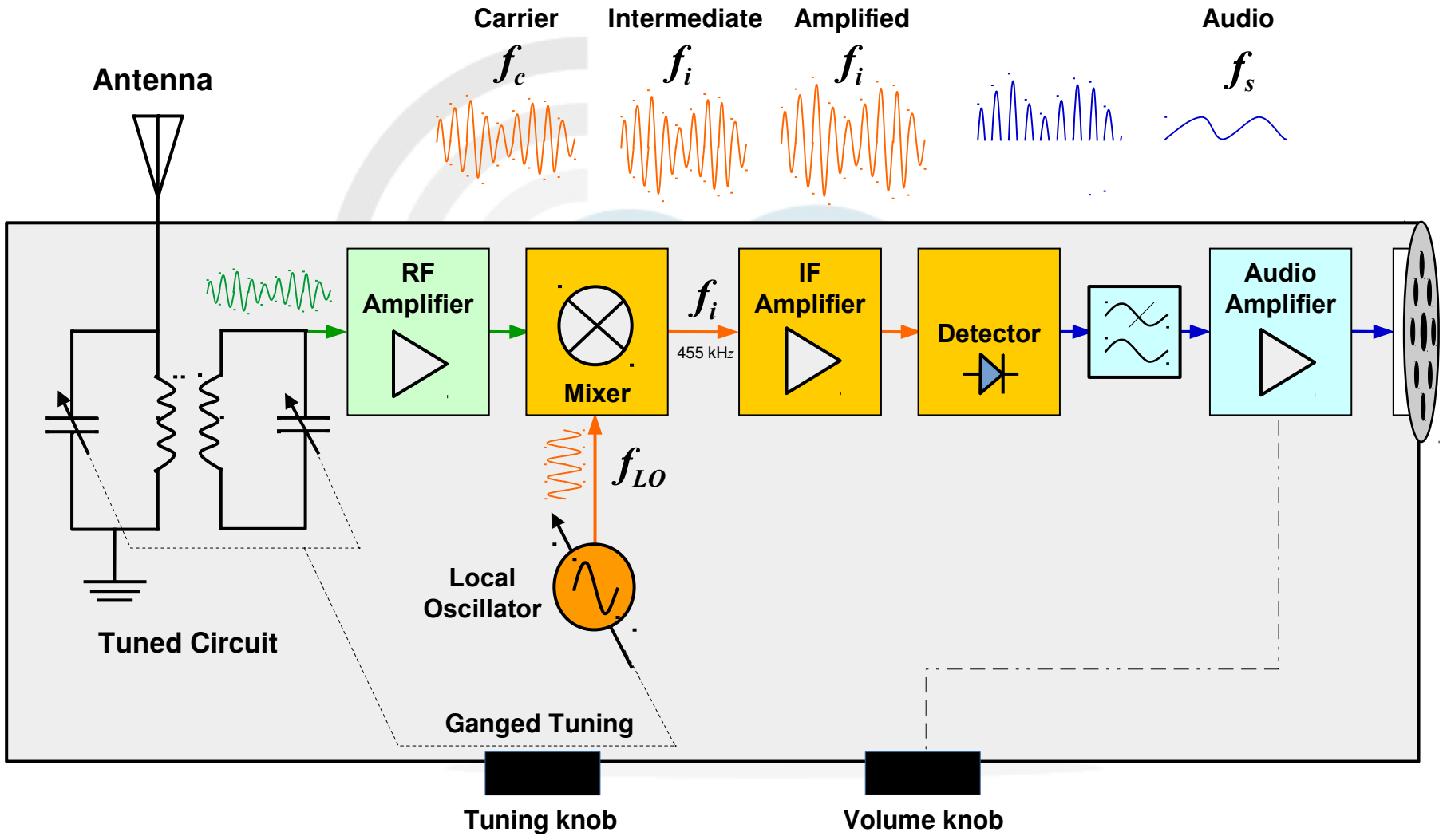
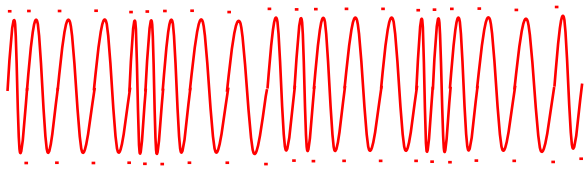
AM Transmitter



AM Superhetrodyne Receiver



Frequency Modulation



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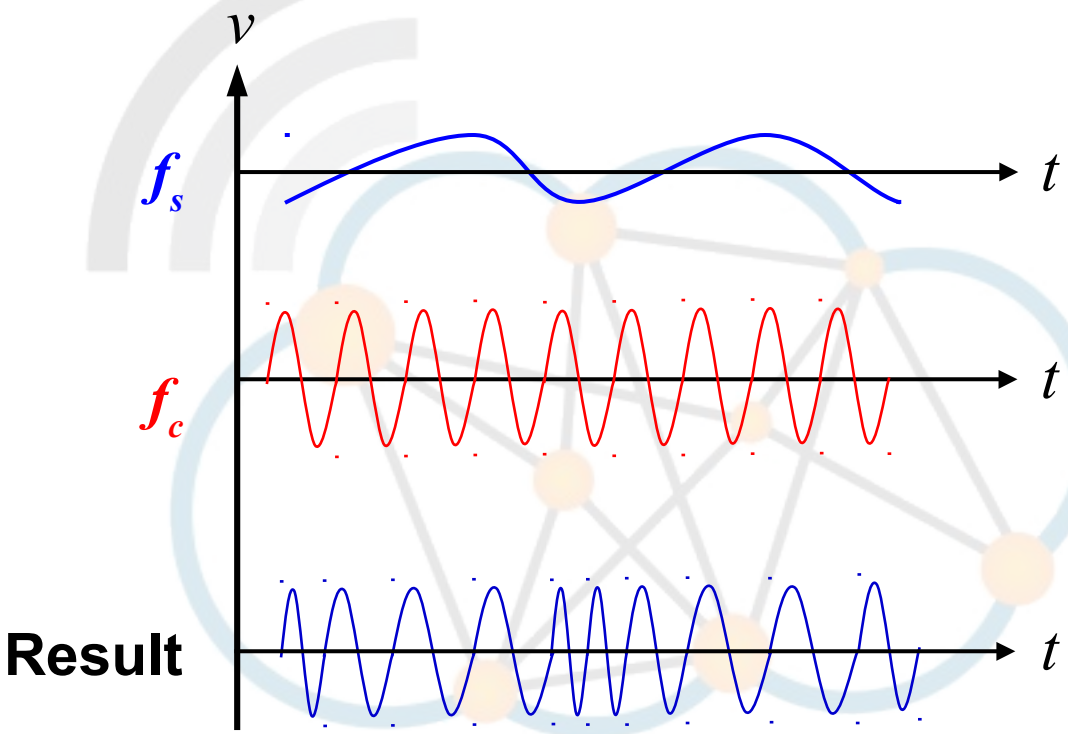
Frequency Modulation (FM)

- Frequency Modulation (FM) is the encoding of information into a carrier wave by variation of its instantaneous frequency in accordance with an input signal.

Frequency Modulation (FM)



Frequency Modulation (FM)

- FM requires a wider bandwidth than amplitude modulation by an equivalent modulating signal, but this also makes the signal more robust against interference.
- FM is also more robust against simple signal amplitude fading phenomena.
- Because of this, FM was chosen as the modulation standard for high frequency, high fidelity radio transmission: hence the term "***FM radio***".

FM Radio
Block Diagrams

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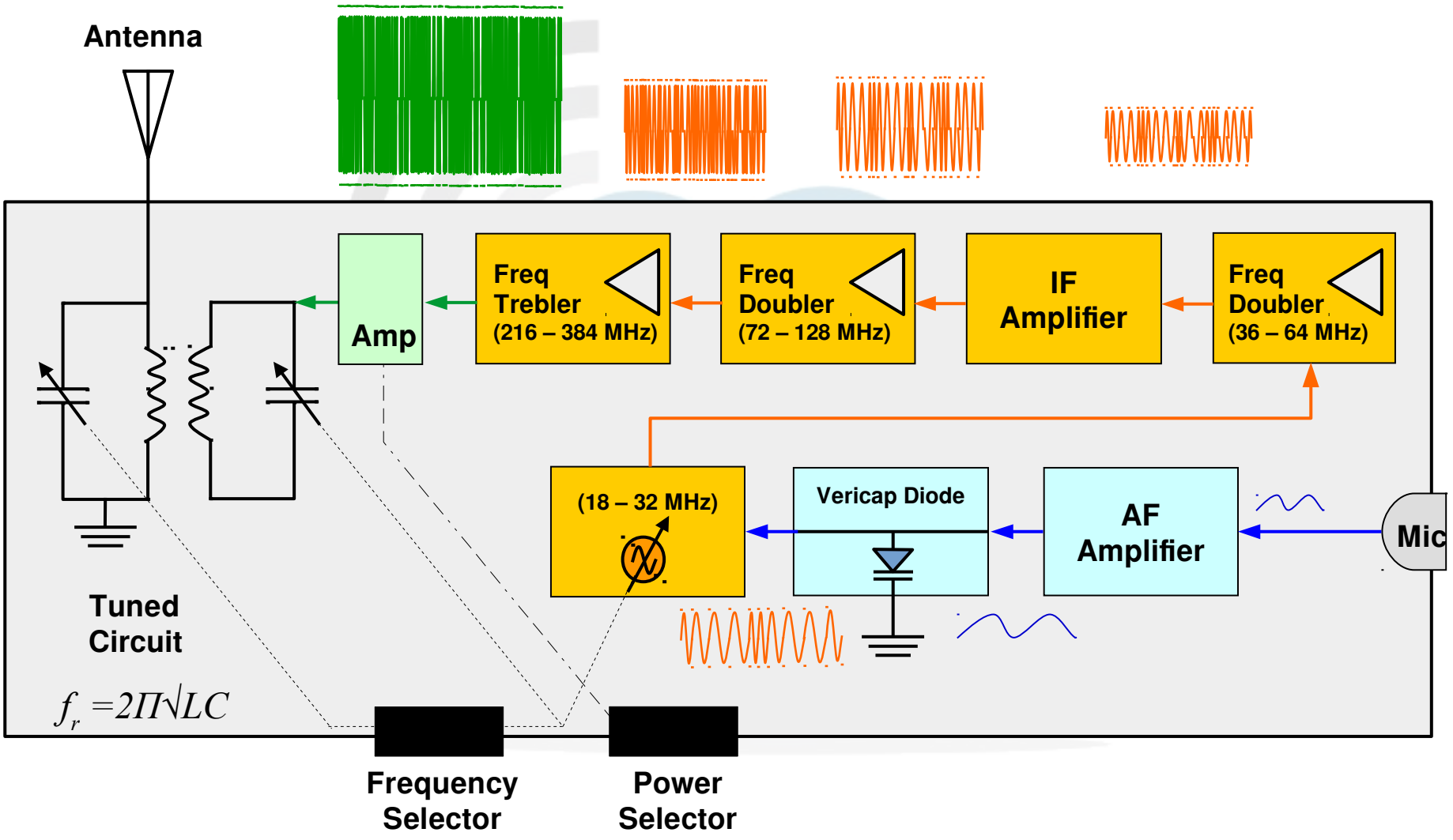
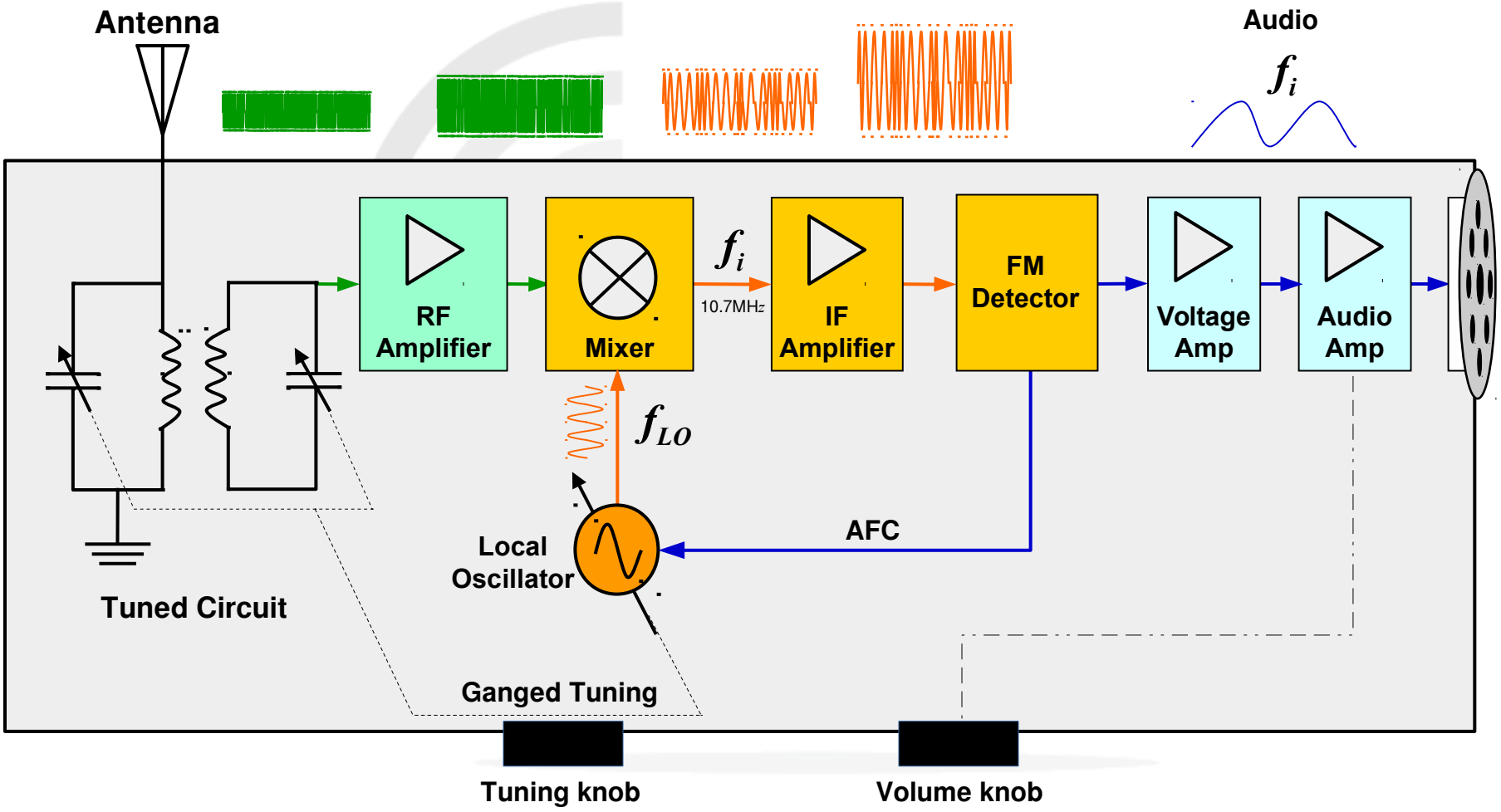
FM Transmitter



FM Receiver


Antenna
Audio
f_i
RF Amplifier
Mixer
f_i
10.7MHz
IF Amplifier
FM Detector
Voltage Amp
Audio Amp
f_{LO}
Local Oscillator
AFC
Tuned Circuit
Ganged Tuning
Tuning knob
Volume knob

FM Superhetrodyne receiver

- Basic FM detector:
  - FM signal carries no amplitude variations a demodulator block that senses frequency variations is required.
  - Insensitive to amplitude variations as these could add extra noise.
- Foster–Seeley discriminator:
  - A transformer, tuned to the carrier frequency, is connected to two rectifier diodes.
  - If the input equals the carrier frequency, the two halves of the tuned transformer circuit produce the same rectified voltage and the output is zero.
  - As the frequency of the carrier changes, the balance between the two halves of the transformer secondary changes, and the result is a voltage proportional to the frequency deviation of the carrier.

FM Superhetrodyne receiver

- PLL FM detector:
  - A Phase Locked Loop (PLL) can be used to make an FM demodulator.
  - Incoming FM signal can be fed into the reference input, and the Voltage Controlled Oscillator (VCO) drive voltage used to provide the detected audio output.
- Quadrature FM detector:
  - This form of FM detector block is widely used within ICs. IT is simple to implement and provides a good linear output.
- Automatic Frequency Control (AFC)
  - Assuming that a receiver is nearly tuned to the desired frequency, the AFC circuit in the receiver develops an error voltage proportional to the degree to which the receiver is mistuned.
  - This error voltage is then fed back to the tuning circuit in such a way that the tuning error is reduced.

Thank You

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