1. Introduction

A. History of Radio

HO: A Brief History of the Radio

B. Radio Transmission Systems

There are more "radios" being built than every before!

1. Telephony

* Cellular
* PCS
* Global Satellite Systems
* Microwave Links

2. Broadcasting

* AM radio, FM radio, VHF/UHF TV
* Satellite Links
* Direct Broadcasting

3. Networking

* Wireless LANs
* Picocells

4. Radar and Navigation

* Global Positioning System (GPS)
* Radar detection, tracking and imaging
* Radio Frequency Identification (RFID)

Q: *Just what* ***is*** *a radio ?*

A: A device that transfers **information** to a distant site, by means of **unbounded** electromagnetic propagation.

A radio system has **three** sections, with **antennas** serving as **couplers** between each section:

1. HO: The Radio Transmitter
2. HO: The Propagation Channel
3. HO: The Radio Receiver

D. The Electromagnetic Spectrum

We can propagate energy anywhere within the electromagnetic spectrum, but we typically use frequencies **less** than, say, **40 GHz**.

HO: The Electromagnetic Spectrum

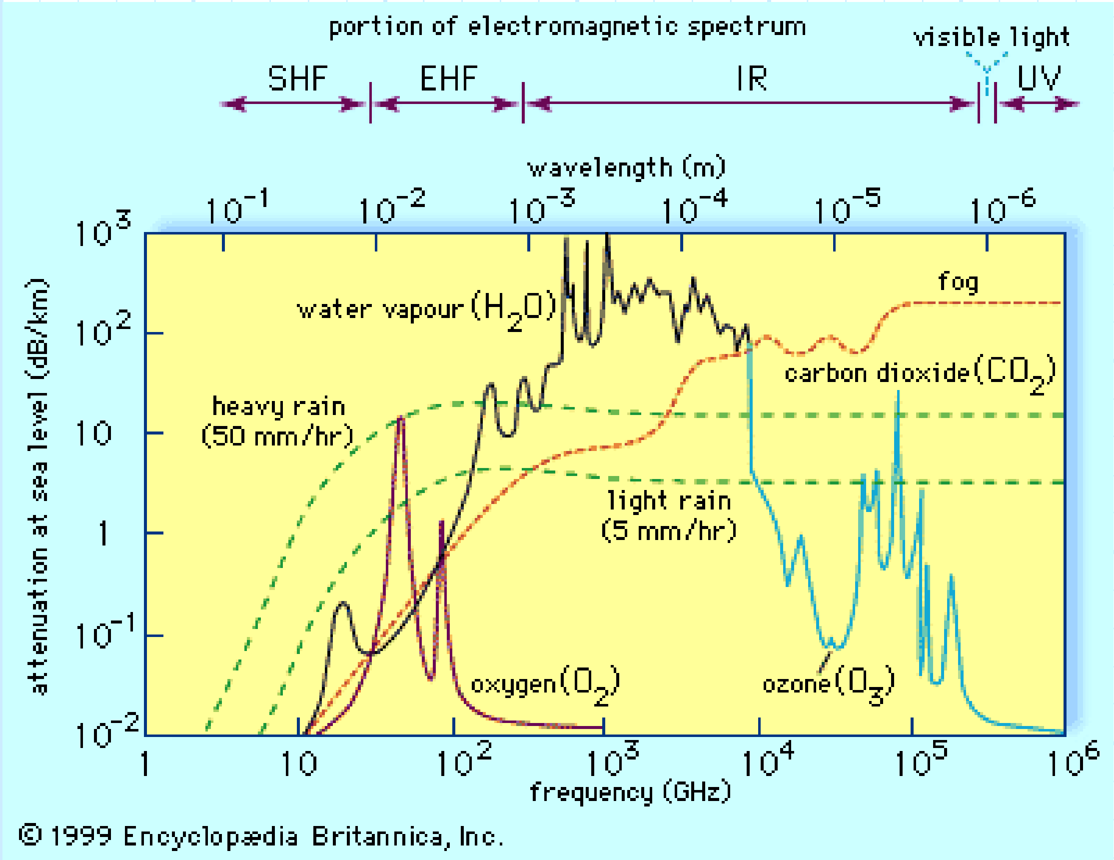
HO: FCC Spectrum Chart

Q: *Why don't we use frequencies greater then 40 GHz ?*

A: Two reasons:

1) The **difficulty** in making electronic components.

2) The Earth's atmosphere rapidly **attenuates** the propagating wave!



The History of Radio

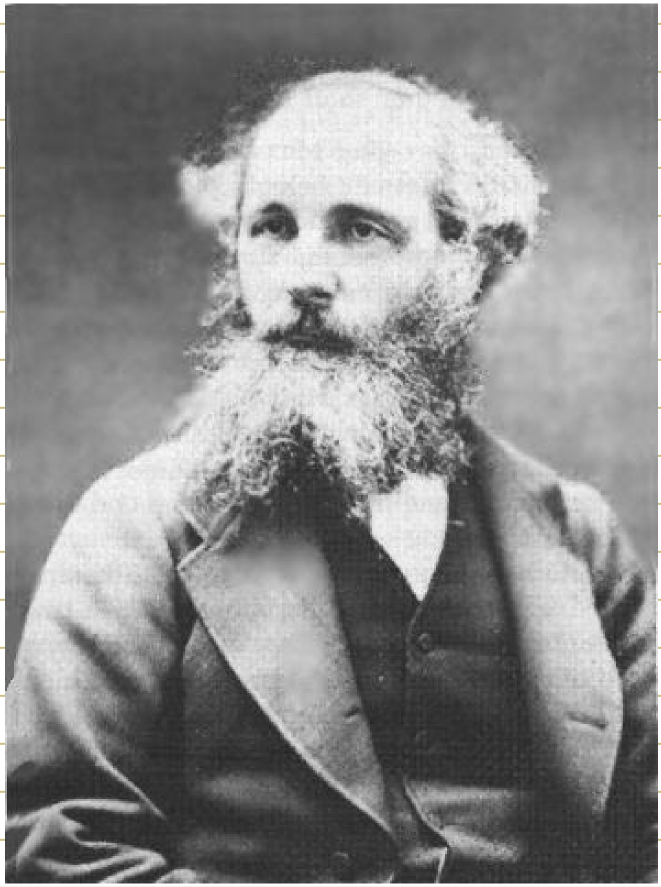
- The **history** of radio can be traced through the lives of these people:
  - Maxwell
  - Hertz
  - Heavyside
  - Marconi
  - DeForest
  - Armstrong
  - Farnsworth
  - Sarnoff

European

Married on December 1, 1923, Howard and Marion Armstrong went to Palm Beach for their honeymoon. Here on the beach Howard tunes in the world's first "portable" radio, a wedding gift to his bride.

James Clerk Maxwell

- **Unified** Electric and Magnetic Theory.
- Predicted Electromagnetic **Wave Propagation**
- Theorized that **light** was an electromagnetic wave.
- Could "**low-frequency**" waves be generated ?



James Clerk Maxwell (1831-1879)

Heinrich Hertz

Heinrich Hertz (1857-1894)

- Experimentally **verified** Maxwell's Theories.
- Generated and propagated "**radio waves**"
- Built **first** transmitter, antenna, and receiver apparatus.

Guglielmo Marconi

- The "**inventor** of radio".
- Improved and **commercialized** Hertz' apparatus.
- Used for radio **telegraphy**.
- Among the first **radio engineers**.

Guglielmo Marconi
(1874-1937)

Oliver Heavyside

- Mr. Heavyside was perhaps the first true **electrical engineer**.
- He was an **odd** recluse, who was entirely **self taught**!
- Although unappreciated in his time, he provided **mathematical** solutions to important problems.
- Among his accomplishments are **transmission line theory** and Heavyside (**Laplace**) Transforms.

Oliver Heavyside

1850-1925

Lee DeForest

- Invented the "audion" **vacuum tube**.
- Allowed for **ampflication** and **detection**.
- Led to first transmission of **voice and music**.

Lee DeForest (1873-1961)

Edwin Howard Armstrong

Edwin H. Armstrong
(1890-1954)

- Perhaps the **greatest** EE in history.
- Inventor of the:
  - feedback **amplifier**
  - electronic **oscillator**
  - super-hetrodyne **receiver**
  - **FM** radio.
- These inventions allowed for the transmission of **voice and music**.
- His ideas are still **widely used** today!

Philo T. Farnsworth

- Inventor of electronic **television**.
- Largely **self-taught**.
- Developed initial design while in **high school**!
- A victim of **bad timing** and small capital.

Philo T. Farnsworth (1907-1971)

David Sarnoff

RCA mastermind
David Sarnoff

- Began as telegraph operator for Marconi.
- Originated idea of "broadcasting."
- Became president of the Radio Corporation of America
- Was not an engineer — and the only guy who became **really** wealthy!

The Radio Transmitter

There are **5** main components of a transmitter:

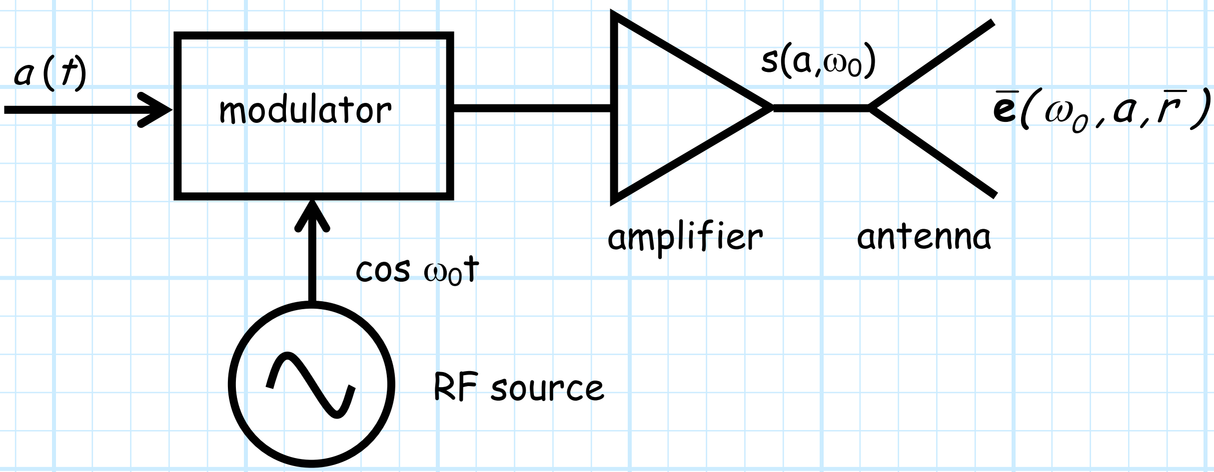
1) The **signal** *a(t)*

2) The radio frequency (RF) **source**

3) The **modulator**

4) The **amplifier**

5) The **antenna**



The Radio Transmitter System

Let's examine each component:

1) The signal *a(t)* – This is the **information** we are trying to transmit. It may be in either **digital** or **analog** form. It also may have been encoded to remove redundancy, in a process known as **source coding**.

2) RF source – Generates **electromagnetic** energy at RF/microwave frequencies that are suitable for electromagnetic propagation (subject to FCC restrictions !).

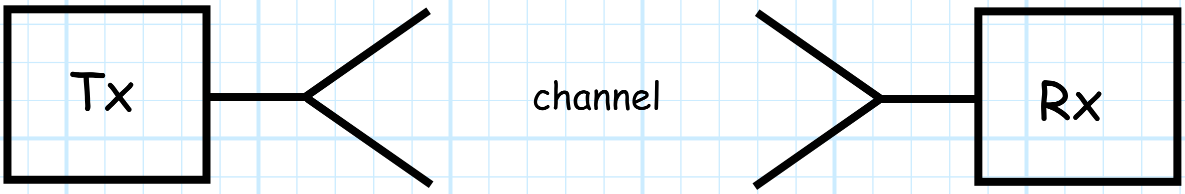
3) Modulator – Places signal *a(t)* (i.e., the information) onto the RF signal, known as the carrier. Accomplished by modulating some parameter of the carrier signal – e.g., magnitude, phase, frequency, or some combination thereof. In general, this process is called **channel coding**. Its goal is to maximize the **rate** at which information is sent, while minimizing the effect of unknown **channel** parameters.

4) Power Amplifier – Increases the power (i.e., energy flow) of the modulated carrier signal, without (hopefully) distorting it.

5) Antenna – Acts as the **coupling** mechanism between the bounded e.m. wave of a transmission line and the unbounded propagating wave in space. Often, an antenna is required to launch the unbounded wave in a specific **direction**.

The Propagation Channel

The propagation channel – The **space** between the antennas!

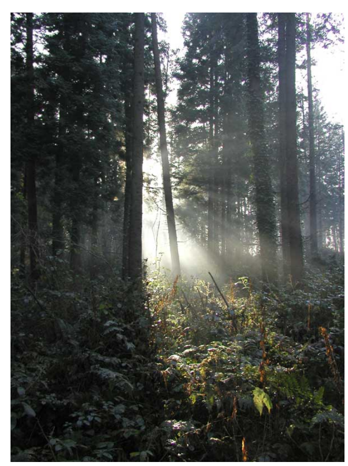


* **Ideally**, the channel is **free-space** (i.e., nothing).

* In reality, the channel is full of **stuff** !
  E.G., buildings, trees, rain, plasma, gasses, and the **Earth**.

Problem : This "stuff" modifies the **propagating** wave. Therefore, we must consider the e.m. phenomena of:

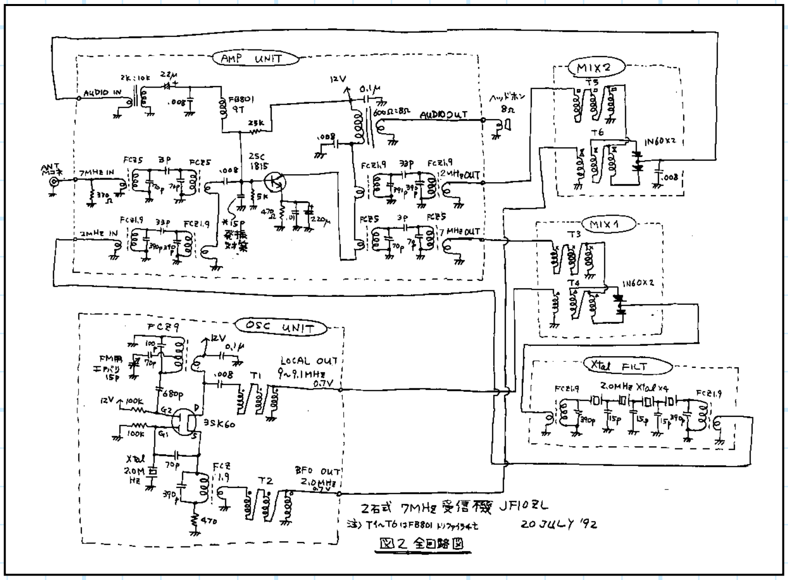
* scattering
* refraction
* reflection
* diffraction
* extinction



The Radio Receiver

There are 8 basic components in a **radio receiver**:

1) Antenna
2) Low-noise Amplifier (LNA)
3) Preselection Filter
4) Local Oscillator/Mixer
5) Intermediate Frequency (IF) Amplifier
6) IF Filter
7) Detector/Demodulator
8) The recovered signal $\hat{a}(t)$



← A **receiver** design schematic I found on the web.

Note the amplifier (amp), oscillator (osc), mixer (mix), and filter (filt) sections.

Let's examine each component:

1) **Antenna** – **Couples** the incoming e.m. propagating wave into the receiver.

2) **Low-Noise Amplifier** – **Boosts** the power of the initial signal above the receiver noise.

3) **Preselector Filter** – Allows **only** the frequency band of interest to pass into the receiver (e.g., for FM radio 88-108 MHz).

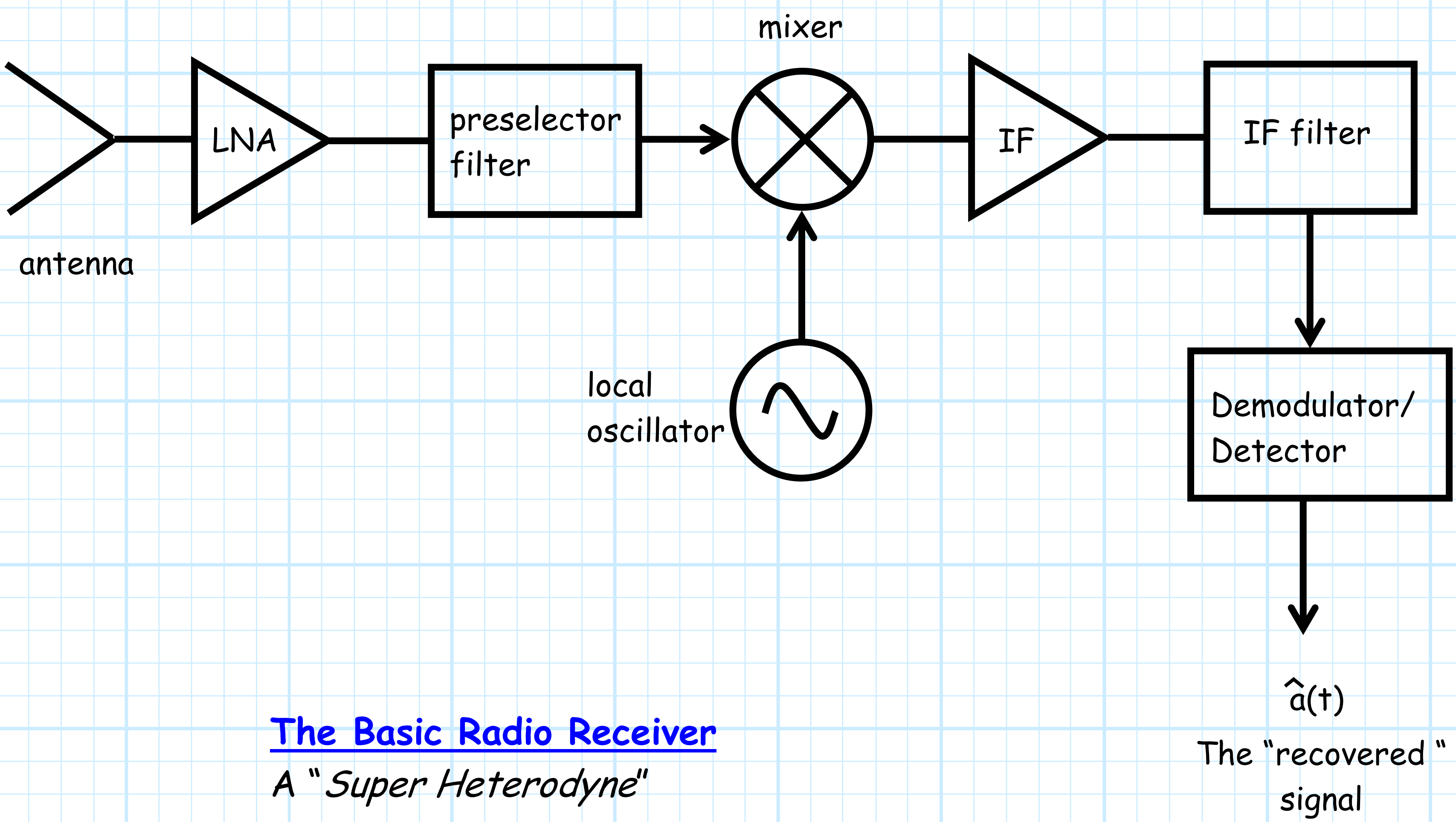
4) **Local Oscillator/Mixer** – **Translates** the signal from its propagation frequency to a lower, fixed intermediate frequency (IF).

5) **IF Amplifier** – A high-gain amplifier that greatly **increases** signal power (i.e., to a detectable level).

6) **IF Filter** - Allows **only** the signal of interest to pass. Bandwidth is typically that of the desired signal. (e.g., 200 kHz for FM radio, 20 kHz for AM radio).

7) **Detector/Demodulator** – **Extracts** the signal information (or, at least tries to !) from the IF signal.

8) **The Recovered Signal** $\hat{a}(t)$ - The receiver's "**guess**" at what the original signal was. Ideally, $\hat{a}(t) = a(t)$, but channel propagation "uncertainties" and noise make **perfect** reproduction impossible !



<u>The Basic Radio Receiver</u>

A "*Super Heterodyne*"

The Electromagnetic Spectrum

Below is a description of standard Radio Frequency "Bands", as well as the applications that use them.

Band	Frequency				
Extremely Low Frequency (ELF)	0		to	3	KHz
Very Low Frequency (VLF)	3	KHz	to	30	KHz
Radio Navigation & maritime/aeronautical mobile	9	KHz	to	540	KHz
Low Frequency (LF)	30	KHz	to	300	KHz
Medium Frequency (MF)	300	KHz	to	3000	KHz
AM Radio Broadcast	540	KHz	to	1630	KHz
Travelers Information Service	1610	KHz			
High Frequency (HF)	3	MHz	to	30	MHz
Shortwave Broadcast Radio	5.95	MHz	to	26.1	MHz
Very High Frequency (VHF)	30	MHz	to	300	MHz
Low Band: TV Band 1 - Channels 2-6	54	MHz	to	88	MHz
Mid Band: FM Radio Broadcast	88	MHz	to	174	MHz
High Band: TV Band 2 - Channels 7-13	174	MHz	to	216	MHz
Super Band (mobile/fixed radio & TV)	216	MHz	to	600	MHz
Ultra-High Frequency (UHF)	300	MHz	to	3000	MHz
Channels 14-70	470	MHz	to	806	MHz
L-band:	500	MHz	to	1500	MHz
Canada DARS	1452	MHz	to	1492	MHz
Personal Communications Services (PCS)	1850	MHz	to	1990	MHz
Unlicensed PCS Devices	1910	MHz	to	1930	MHz

S-band for DARS	2310	MHz	to	2360	MHz
microwave TV	2500	MHz	to	2700	MHz
Superhigh Frequencies (SHF)	3	GHz	to	30.0	GHz
***C**-band & big-dish 6-10'*	3600	MHz	to	7025	MHz
***X**-band:*	7.25	GHz	to	8.4	GHz
***Ku**-band & small-dish 1-4'*	10.7	GHz	to	14.5	GHz
***Ka**-band*	17.3	GHz	to	31.0	GHz
Extremely High Frequencies (EHF) (Millimeter Wave Signals)	30.0	GHz	to	300	GHz
Additional Fixed Satellite	38.6	GHz	to	275	GHz
Infrared Radiation	300	GHz	to	810	THz
Visible Light	810	THz	to	1620	THz
Ultraviolet Radiation	1.62	PHz	to	30	PHz
X-Rays	30	PHz	to	30	EHz
Gamma Rays	30	EHz	to	3000	EHz

This chart derived from ADEC and FCC charts

The point here is basically, **all** of the "usable" electromagnetic spectrum has been **allocated** to some application—and **new** applications are being developed all the time!

Thus, as radio engineers, we must **assume** that there is—or at least could be—a significant signal at **any** and **all** possible frequencies. This is the **challenge** of a radio engineer. Effectively, there are thousands of people all **whispering** very softly—all at the **same time**. The radio engineers job is to amplify **one** of these voices, while **suppressing** all the others, so that single voice can be clearly **understood**!