Technician License Course
Chapter 2
Radio and Electronics Fundamentals

PHYS 401
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P. Reiff, Rice University
Basic Station Organization

• Station Equipment
  – Receiver
  – Transmitter
  – Antenna
  – Power Supply

• Accessory Station Equipment

• Repeaters
What Happens During Radio Communication?

• Transmitting (sending a signal):
  – Information (voice, data, video, commands, etc.) is converted to electronic form.
  – The information in electronic form is attached or embedded on a radio wave (a carrier).
  – The radio wave is sent out from the station antenna into space.
What Happens During Radio Communication?

• Receiving end:
  – The radio wave (carrier) with the information is intercepted by the receiving station antenna.
  – The receiver extracts the information from the carrier wave.
  – The information is then presented to the user in a format that can be understood (sound, picture, words on a computer screen, response to a command).
What Happens During Radio Communication?

• This sounds pretty simple, but it in reality is pretty complex.
• This complexity is one thing that makes ham radio fun...learning all about how radios work.
• Don’t be intimidated. You will be required to only know the basics, but you can learn as much about the “art and science” of radio as you want.
The Basic Radio Station

Schematic (block) diagram shows major components
The Receiver and Controls

- Main tuning dial for received frequency (or channel) selection.
- Frequency display.
- Volume control.
- Other accessory controls for mode (kind of information to process), filters (to mitigate interference), etc.
The Transmitter and Controls

• Main tuning dial for transmitted frequency (or channel) selection.
• Frequency display.
• Power control (transmitted signal strength).
• Other accessory controls for mode (kind of information to process), etc.
The Transceiver

• You will notice that many of the controls of the transmitter and receiver are the same.
• Most modern transmitters and receivers are combined in one unit – called a transceiver.
  – Saves space
  – Cost less
• Many common electronic circuits are shared in the transceiver.
Transceiver Controls

- Some are physical knobs that you manually adjust.
- Some are controlled by computer and you control the settings with keypad entries that program a computer in the transceiver.
- Many keys have two or more functions... hit the “function” key first for second function.
Antenna

• The antenna exposes your station to the world.
  – Facilitates the radiation of your signal into space (electromagnetic radiation).
  – Intercepts someone else’s signal.

• Most times the transmitting and receiving antenna are the same antenna.

• Connected to your station by a connecting wire called a feed line.
Transmit/Receive (TR) Switch

• If the station antenna is shared between the transmitter and receiver, the TR switch allows the antenna to be switched to the transmitter when sending and to the receiver when receiving.
  – In a transceiver, this TR switch is inside the unit and requires no attention by the operator.
  – (for most rigs, it’s a “PTT” on the mike – Push To Talk)
  – Default is receive mode
  – VOX operation: transmits if it hears a signal above specified level (hands-free)
Power Supply

• Your radio station needs some sort of power to operate.
  – Battery
  – Household current converted to proper voltage
  – Alternative sources
Power Supply

• Most modern radios operate on 12 volts direct current (dc).
  – A power supply converts household current to the type of current and the correct voltage to operate your station.
  – Could be internal, might be external.
• You are probably familiar with common AC to DC power supplies.
Basic Station Accessories

- Human interface accessories:
  - Microphones
  - Speakers
  - Earphones
  - Computer
  - Morse code key
  - TV camera
  - Etc.

- Station performance accessories:
  - Antenna tuner
  - SWR meter (antenna match checker)
  - Amplifier
  - Antenna rotator (turning antenna)
  - Filters
  - Etc.
Accessory Equipment

[Diagram showing a transceiver connected to a microphone, speaker, headphones, amplifier, and straight key.]
Special Stations You Will Use (Repeaters)

- Repeaters are automated stations located at high places that receive and then retransmit your signal – simultaneously.
  - Dramatically improves range.
  - Most cities have several 2m and 70cm repeaters
  - Some are linked by air or by computer
- The basic components of a repeater are the same as your station: receiver, transmitter, antenna and power supply.
Repeaters

• But, repeaters are transmitting and receiving at the same time using the same antenna.
• This requires a very high quality and specialized filter to prevent the transmitted signal from overpowering the receiver.
• This specialized filter is called a duplexer.
Repeater

Antenna (shared)

Transmitted signal out

Received signal in

Transmitter

Duplexer

Receiver

Speech from received signal
Fundamentals of Electricity

• When dealing with electricity, what we are referring to is the flow of electrons through a conductor.
  – Electrons are negatively charged atomic particles.
    • The opposite charge is the positive charge - protons
  – A conductor is a material that allows electrons to move with relative freedom within the material.
Fundamentals of Electricity

• In electronics and radio, we control the flow of electrons to make things happen.
• You need to have a basic understanding of how and why we control the flow of electrons so that you can better operate your radio.
Basic Characteristics of Electricity

• There are three characteristics to electricity:
  – Voltage
  – Current
  – Resistance

• All three must be present for electrons to flow.
Basic Characteristics of Electricity

- The flow of water through a hose is a good analogy to understand the three characteristics of electricity and how they are related.
Characteristics of Electricity are Inter-related

• Voltage, current and resistance must be present to have current flow.
• Just like water flowing through a hose, changes in voltage, current and resistance affect each other.
• That effect is mathematically expressed in Ohm’s Law.
Ohm's Law

• E is voltage
  – Units - volts
• I is current
  – Units - amperes
• R is resistance
  – Units - ohms

• R = E/I
• I = E/R
• E = I x R
Moving Electrons Doing Something Useful

• Any time energy is expended to do something, work is performed.
• When moving electrons do some work, power is consumed.
• Power is measured in the units of Watts.
Power Formula

• Power is defined as the amount of current that is being pushed through a conductor or device to do work.
  – \( P = E \times I \)
  – \( E = \frac{P}{I} \)
  – \( I = \frac{P}{E} \)
Two Basic Kinds of Current

• When current flows in only one direction, it is called direct current (dc).
  – Batteries are a common source of dc.
  – Most electronic devices are powered by dc.

• When current flows alternatively in one direction then in the opposite direction, it is called alternating current (ac).
  – Your household current is ac.
The Electric Circuit: An Electronic Roadmap

- For current to flow, there must be a path from one side of the source of the current to the other side of the source – this path is called a circuit.
  - There must be a hose (conductive path) through which the water (current) can flow.

- The following are some vocabulary words that help describe an electronic circuit.
Series Circuits

- Series circuits provide one and only one path for current flow.
Parallel Circuits

- Parallel circuits provide alternative paths for current flow. (net resistance is *less than the smallest resistor!*
Short and Open Circuits

• When there is an unintentional current path that bypasses areas of the circuit – this is a short circuit condition.

• When the current path is broken so that there is a gap that the electrons cannot jump – this is an open circuit condition.
Electronics – Controlling the Flow of Current

• To make an electronic device (like a radio) do something useful (like a receiver), we need to control and manipulate the flow of current.

• There are a number of different electronic components that we use to do this.
The Resistor

- The function of the resistor is to restrict (limit) the flow of current through it.
- Circuit Symbol
The Capacitor

• The function of the capacitor is to temporarily store electric charge.
  – Like a very temporary storage battery.
  – Stores energy in an electrostatic field.

• Circuit Symbol
The Inductor

- The function of the inductor is to temporarily store electric current.
  - Is basically a coil of wire.
  - Stores energy in a magnetic field.

- Circuit Symbol
The Transistor

- The function of the transistor is to variably control the flow of current.
  - Much like an electronically controlled valve.
  - An analogy, the faucet in your sink.

- Circuit Symbol

NPN (Not Pointing iN)
PNP (Pointing iN Proudly)
The Integrated Circuit

- The integrated circuit is a collection of components contained in one device that accomplishes a specific task.
  - Acts like a “black-box”
  - Usually includes transistors

- Circuit Symbol
Protective Components – Intentional Open Circuits

- Fuses and circuit breakers are designed to interrupt the flow of current if the current becomes uncontrolled.
  - Fuses blow – one time protection.
  - Circuit breakers trip – can be reset and reused.

- Circuit Symbol
Other Circuit Symbols

Schematic Symbols Used in Circuit Diagrams

Labelling conventions: B is a sequential number. (X) is the component designation. Examples - Q3, L11, R8, Q5

- **LED (E19)**
- **Diode/Rectifier**
- **Voltage Variable Capacitor**
- **Bridge Rectifiers**
- **Circuit Interrupters**
- **120 V Receptacles**
  - Female
  - Male
- **Batteries (BT#)**
  - Single Cell
  - Multicell
- **Grounds**
  - Chassis
  - Earth
  - A - Analog
  - D - Digital
- **Resistors (R#)**
- **Variable Tapped**
- **Thermistor**
- **Capacitors (C#)**
- **Variable Electrolytic**
- **Fixed**
- **Split-Stacker**
- **Feed-Through**
- **Inductors (L#)**
- **Air Core**
- **Adjustable Iron Core**
- **Ferrite Bead**
- **Transistors (Q#)**
- **P-Channel**
- **N-Channel**
- **Junction FET**
- **Single Gate**
- **Dual Gate**
- **Depletion Mode**
- **Enhancement Mode**

[Image of circuit symbols]
Putting It All Together in a Circuit Diagram
Dealing with Very Big and Very Small Numeric Values

• In electronics we deal with incredibly large and incredibly small numbers.
• The international metric system allows for short hand for dealing with the range of values.
Metric Units (always use scientific notation in your homework!!)

**Table 2-1**  
International System of Units (SI)—Metric Units

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Multiplication Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tera</td>
<td>T</td>
<td>$10^{12} = 1,000,000,000,000$</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>$10^9 = 1,000,000,000$</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>$10^6 = 1,000,000$</td>
</tr>
<tr>
<td>Kilo</td>
<td>k</td>
<td>$10^3 = 1000$</td>
</tr>
<tr>
<td>Hecto</td>
<td>h</td>
<td>$10^2 = 100$</td>
</tr>
<tr>
<td>Deca</td>
<td>da</td>
<td>$10^1 = 10$</td>
</tr>
<tr>
<td>Deci</td>
<td>d</td>
<td>$10^{-1} = 0.1$</td>
</tr>
<tr>
<td>Centi</td>
<td>c</td>
<td>$10^{-2} = 0.01$</td>
</tr>
<tr>
<td>Milli</td>
<td>m</td>
<td>$10^{-3} = 0.001$</td>
</tr>
<tr>
<td>Micro</td>
<td>μ</td>
<td>$10^{-6} = 0.000001$</td>
</tr>
<tr>
<td>Nano</td>
<td>n</td>
<td>$10^{-9} = 0.000000001$</td>
</tr>
<tr>
<td>Pico</td>
<td>p</td>
<td>$10^{-12} = 0.000000000001$</td>
</tr>
</tbody>
</table>
Radio Waves are AC

- You have already learned that in an alternating current (ac) the electrons flow in one direction one moment and then the opposite direction the next moment.
- Radio waves (electromagnetic radiation) are ac waves.
- Radio waves are used to carry the information you want to convey to someone else.
Wave Vocabulary

- Before we study radio waves, we need to learn some wave vocabulary.
  - Amplitude
  - Frequency
  - Period
  - Wavelength
  - Harmonics
Now for a Powerful Demonstration

• What happens when you drop a magnet through a non-ferrous conductive pipe?
How Radio Waves Travel

• You have just witnessed in a way how radio waves travel.
  1. Moving electrons in the antenna create a magnetic field.
  2. This changing magnetic field creates an electric field.
  3. Then back and forth between magnetic and electric fields from point A to point B.
Wavelength

- The distance a radio wave travels during one cycle.
  - One complete change between magnetic and electric fields.

\[ \lambda = \frac{c}{f} = \frac{300}{f} \text{ in MHz} \]
Finding Where You are on the Radio Dial

• There are two ways to tell someone where to meet you on the radio dial (spectrum).
  – Band
  – Frequency
Radio Frequency (RF) Spectrum

- The RF spectrum is the range of wave frequencies which will leave an antenna and travel through space.
- The RF spectrum is divided into segments of frequencies that basically have unique behavior.
Radio Frequency (RF) Spectrum
So, Where Am I?

• Back to how to tell where you are in the spectrum.
• Bands identify the segment of the spectrum where you will operate.
  – Wavelength is used to identify the band.
• Frequencies identify specifically where you are within the band.
Another Use for Frequency and Wavelength

• For the station antenna to efficiently send the radio wave out into space, the antenna must be designed for the specific operating frequency.
  – The antenna length needs to closely match the wavelength of the frequency to be used.
  – Any mismatch between antenna length and frequency wavelength will result in radio frequency energy being reflected back to the transmitter, not going (being emitted) into space.
Antennas are Part Capacitor – Part Inductor – Part Resistor

• Antennas actually have characteristics of capacitor, inductor and resistor electronic components.

• Capacitors and inductors, because they store energy in fields, react differently to ac than dc.
  – Special kind of resistance to the flow of ac – called reactance.
Resonance

• Because capacitors and inductors store energy in different ways, the stored energy can actually cancel each other under the right conditions.
  – Capacitors – electric field
  – Inductors – magnetic field

• Cancelled current = no reactance, just leaving resistance.
Resonant Antenna

- If an antenna is designed correctly, the capacitive reactance cancels the inductive reactance.
- Theoretically, the resulting reactance is zero.
  - Leaving only resistance – meaning minimum impediment to the flow of the radio frequency currents flowing in the antenna and sending the radio wave into space.
  - Each additional wave you send to the antenna is in phase with the last one (don’t cancel each other out)
Adding Information - Modulation

• Now that we know where we are in the RF spectrum and are sending a radio wave into space.
• When we imprint some information on the radio wave, we modulate the wave.
  – Turn the wave on and off
  – Voice AM and FM
  – Data
• Different modulation techniques are called modes.
Morse Code – On and Off

Unmodulated RF Signal

Turning On & Off with a Key

Modulated By an Audio Signal

Dot
Dash

Morse Code Signal
Amplitude Modulation (AM)

- In AM, the amplitude of the carrier wave is modified in step with the waveform of the information (voice).
Characteristics of Voice AM

AM signals consist of three components:
- Carrier
- Lower sideband
- Upper sideband

• Voice bandwidth is from 300 Hz to 3 kHz.
• AM bandwidth is twice the voice bandwidth.
Characteristics of Voice

- Sound waves that make up your voice are a complex mixture of multiple frequencies.
- When this complex mixture is embedded on a carrier, two sidebands are created that are mirror images.
Single Sideband Modulation (SSB)

- Since voice is made up of identical mirror image sidebands:
- We can improve efficiency of transmission by transmitting only one sideband and then reconstruct the missing sideband at the receiver.
Frequency Modulation (FM)

- Instead of varying amplitude, if we vary the frequency in step with the information waveform – FM is produced.
- FM signals are much more resistant to the effects of noise but require more bandwidth.
- FM bandwidth (for voice) is between 5 and 15 kHz.
Transmitting Data

• Data is made up of binary bits 1 and 0.
  – On and off states
• Modems translate the data into a format capable modulating a carrier wave.
• A terminal node controller (TNC) is a specialized modem used in ham radio.
  – There are many more kinds of modems developed as data transmission technology advances.
Basic Data Transmission Setup
The Antenna System

• **Antenna**: Facilitates the sending of your signal to some distant station.
  – Back to the falling magnet

• **Feed line**: Connects your station to the antenna.

• **Test and matching equipment**: Allows you to monitor antenna performance.
The Antenna (Some Vocabulary)

• Driven element: Where the transmitted energy enters the antenna.

• Polarization: The direction of the electric field relative to the surface of the earth.
  – Same as the physical direction
    • Vertical
    • Horizontal
    • Circular
The Antenna (Some Vocabulary)

• Omni-directional – radiates in all directions.
• Directional beam – focuses radiation in specific directions.
• Gain – apparent increase in power in a particular direction because energy is focused in that direction.
  – Measured in decibels (dB) (logarithmic)
  – 10 dB is a power of 10
  – 3 dB is a factor of 2
Antenna Radiation Patterns

- Radiation patterns are a way of visualizing antenna performance.
- The further the line is away from the center of the graph, the stronger the signal at that point.
- The antenna shown beams to the right

Strong null behind… -40 dB = 10,000x less
Elevation shows preferred direction slightly up from horizontal.
Impedance – AC Resistance

• A quick review of a previous concept: impedance.
  – Antennas include characteristics of capacitors, inductors and resistors
• The combined response of these component parts to alternating currents (radio waves) is called Impedance.
Antenna Impedance

- Antennas have a characteristic impedance.
- Expressed in ohms – common value 50 ohms.
- Depends on:
  - Antenna design
  - Height above the ground
  - Distance from surrounding obstacles
  - Frequency of operation
  - A million other factors
Antenna versus Feed Line

• For efficient transfer of energy from the transmitter to the feed line and from the feed line to the antenna, the various impedances need to match.
• When there is mismatch of impedances, things may still work, but not as effectively as they could.
Feed Line types

• The purpose of the feed line is to get energy from your station to the antenna.

• Basic feed line types.
  – Coaxial cable (coax).
  – Open-wire or ladder line.

• Each has a characteristic impedance, each has its unique application.
Coax

- Most common feed line.
- Easy to use.
- Matches impedance of modern radio equipment (50 ohms).
- Some loss of signal depending on coax quality (cost).
Open-Wire/Ladder Line

- Not common today except in special applications.
- Difficult to use.
- Need an antenna tuner to make impedance match – but this allows a lot of flexibility.
- Theoretically has very low loss.
Test and Matching Equipment

• Proper impedance matching is important enough to deserve some simple test equipment as you develop your station repertoire.

• Basic test equipment: SWR meter.

• Matching equipment: Antenna tuner.
Standing Wave Ratio (SWR)

- If the antenna and feed line impedances are not perfectly matched, some RF energy is not radiated into space and is returned (reflected) back to the source.
  - Something has to happen to this reflected energy – generally converted into heat or unwanted radio energy (bad).
The SWR meter is inserted in the feed line and indicates the mismatch that exists at that point. You make adjustments to the antenna to minimize the reflected energy (minimum SWR).
Nothing is Perfect

• Although the goal is to get 100% of your radio energy radiated into space, that is virtually impossible.

• What is an acceptable level of loss (reflected power or SWR?)
  – 1:1 is perfect.
  – 2:1 should be the max you should accept (as a general rule).
    • Modern radios will start lowering transmitter output power automatically when SWR is above 2:1.
  – 3:1 is when you need to do something to reduce SWR.
Antenna Tuner

• One way to make antenna matching adjustments is to use an antenna tuner.
• Antenna tuners are impedance transformers (they actually do not tune the antenna).
  – When used appropriately they are effective.
  – When used inappropriately all they do is make a bad antenna look good to the transmitter...the antenna is still bad.
How to use an Antenna Tuner

• Monitor the SWR meter.
• Make adjustments on the tuner until the minimum SWR is achieved.
  – The impedance of the antenna is transformed to more closely match the impedance of the transmitter.
Radio Wave Propagation: Getting from Point A to Point B

• Radio waves propagate by many mechanisms.
  – The science of wave propagation has many facets.

• We will discuss three basic ways:
  – Line of sight
  – Ground wave
  – Sky-wave
Line-of-Sight

• If a source of radio energy can been seen by the receiver, then the radio energy will travel in a straight line from transmitter to receiver.
  – There is some attenuation of the signal as the radio wave travels

• This is the primary propagation mode for VHF and UHF signals.
VHF and UHF Propagation

- VHF & UHF propagation is principally line of sight.
- Range is slightly better than visual line of sight.
- UHF signals may work better inside buildings because of the shorter wavelength.
- Buildings may block line of sight, but reflections may help get past obstructions.
- Reflections from a transmitter that is moving cause multi-path which results in rapid fading of signal – known as picket fencing.
Ground Wave

- Some radio frequency ranges (lower HF frequencies) will hug the earth’s surface as they travel
- These waves will travel beyond the range of line-of-sight
- A few hundred miles
Ionosphere

- Radiation from the Sun (UV/ Xray) momentarily will strip electrons away from the parent atom in the upper reaches of the atmosphere.
  - Creates ions and free electrons
- The region where ionization occurs is called the ionosphere.
Levels of the Ionosphere

- Density of the atmosphere affects:
  - The intensity of the radiation that can penetrate to that level.
  - The amount of ionization that occurs.
  - How quickly the electrons recombine with the nucleus.
The Ionosphere – An RF Mirror

- The ionized layers of the atmosphere actually act as an RF mirror that reflect certain frequencies back to earth. (actually just large-angle refraction, like a mirage)
- Sky-wave propagation is responsible for most long-range, over the horizon communication.
- Reflection depends on frequency and angle of incidence.
Sunspot Cycle

• The level of ionization depends on the radiation intensity of the Sun.
• Radiation from the Sun is connected to the number of sunspots on the Sun’s surface.
  – High number of sunspots, high ionizing radiation emitted from the Sun.
• Sunspot activity follows an 11-year cycle.
• Higher density ionosphere reflects higher frequency radio waves (and all lower freq)
  (MUF = max usable frequency)