Amateur Radio Service General Class

Exam Preparation Class
October 24, 2019
Session 2

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These slides are uploaded to my website

https://k7ojl.com/class-course-materials/general-class-course-materials/

just before class each week. Depending on how the class goes, they may get updated after the class.

The General Class Question Pool (all questions and answers) is posted to my website

https://k7ojl.com/wp-content/uploads/2019/10/2019-2023GeneralClassPoolFinalRelease.pdf


Questions from Last Week?
Any Issues with hamstudy.org?

Class Overview

- Digital Modes Demo
- Propagation
- Your HF Transmitter
- Your HF Receiver
- Oscillators and Components

"A ham - pod?"

Propagation

LUF … MUF

- **MUF**: Maximum useable frequency between two points on the earth
  - A predicted number based on history and x-ray absorption of the D-layer
  - Frequencies above the MUF pass through the ionosphere
- **LUF**: Lowest useable frequency between two points on the earth
  - A calculated number based on the amount of RF absorption by the ionosphere's D-layer
  - Frequencies below the LUF are absorbed
- When the LUF is higher than the MUF shortwave contacts are not possible
- If the LUF is lower than the MUF, choose a frequency just below the MUF

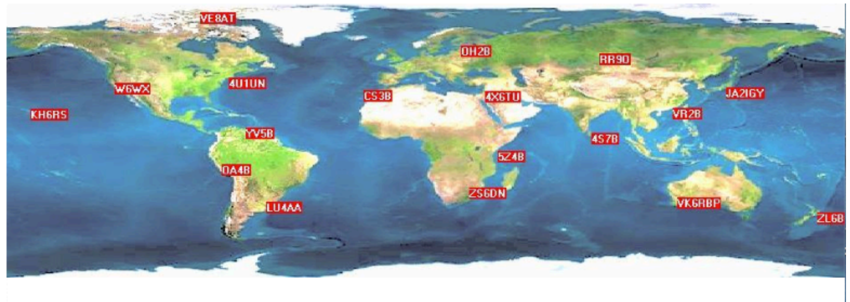
http://www.hamqsl.com/solar3.html

How to know if communication is possible? Check the beacons!

Factors affecting the MUF: Time of day and season, path distance and location, and solar radiation and ionospheric disturbances

When selecting a frequency with the lowest attenuation when transmitting, select a frequency just below the MUF

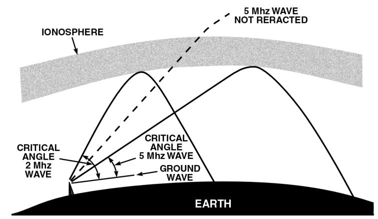
G3B02, G3B03, G3B04, G3B05, G3B06, G3B07, G3B08, G3B11



http://www.ncdxf.org/beacon/beaconlocations.html

Critical Angle

- The **highest takeoff angle** that will return a radio wave to the earth under specific ionosphere conditions
- Frequency, time of day, condition of the ionosphere all affect the Critical Angle



G3C04

Sky Wave vs Ground Wave

Radio waves travel straight out from the antenna in a pattern determined by the antenna configuration. Some of the energy will “hug” the ground for a ways. This is known as “**ground wave**”.

In certain circumstances some of the energy is reflected by the ionosphere back towards the ground. This is known as “**sky wave**”.

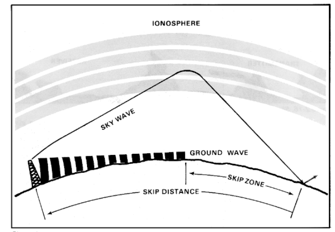
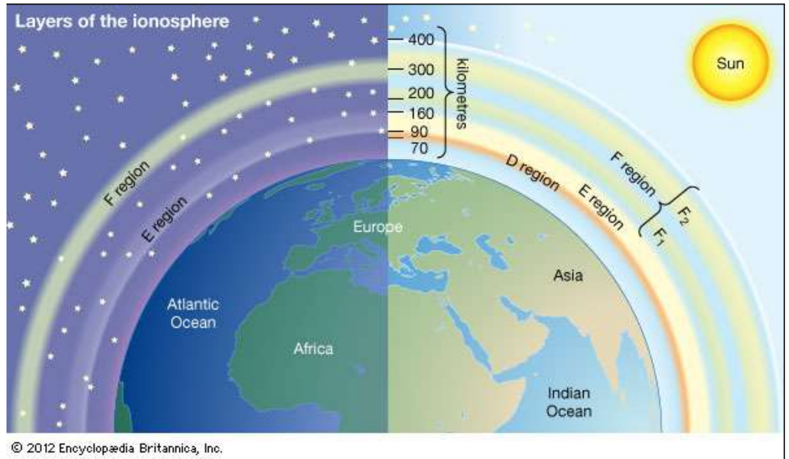


Figure 2-15. Low angle sky-wave transmission path.

RF energy below 2MHZ is rarely reflected by the ionosphere during daylight.

Sky wave propagation is also called “skip”

The Ionosphere

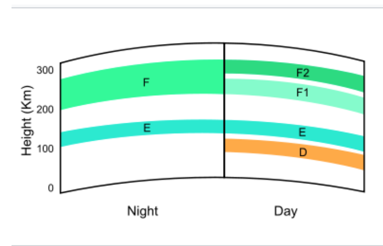


The ionospheric layers reach their maximum height and density when the sun is overhead.

G3C02

The ‘D’ Layer

- Appears during daytime
- Closest to the earth (35 to 55 miles above the earth surface)
- Many more neutral molecules than ionized molecules, more free electrons
- Significantly attenuates medium frequency and high frequency (below 5 MHz) radio waves

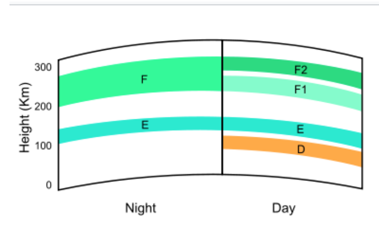


Ionized by strong emissions of solar hydrogen. Constant radiation is required otherwise the ions quickly neutralize. Consequently, the D layer abruptly disappears shortly after sunset. RF up to 5 MHz is consistently absorbed. Above that RF at high angles gets through and can be reflected by the E, F2, or (possibly but not likely) F1 layers. Lower angles have further to travel through the D layer and are attenuated relative to the angle (lower angles, more attenuation). The higher the frequency, the lower the angle can be before significant attenuation occurs.

G3C01, G3C11

The 'E' Layer

- Appears during daytime and thins significantly at night
- Middle ionospheric layer (55 to 95 miles
- Can produce "skip" of up to 1,200 miles
- Significant amounts of ionized oxygen molecules
- Reflects radio frequencies below 10 MHz and may attenuate higher frequencies
- Occasionally sporadic E events occur where frequencies up to 50 MHz are reflected



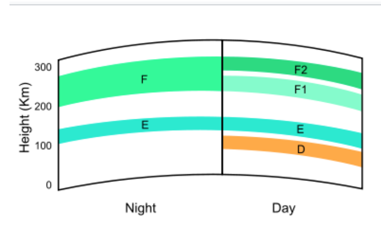
Ionized by short-wavelength ultraviolet light and long-wavelength X-ray radiation. Thins out dramatically when the sun sets. Potential for E layer skip is diminished by D layer absorption. As frequency increases such that the RF penetrates the D layer, it also usually is high enough to penetrate the E layer.

However, sometimes "clouds" of E layer free electrons form which will reflect higher HF and lower VHF signals. Sporadic E is often a springtime phenomena and can result in 1,200 mile skip at these frequencies.

G3B10

The ‘F’ Layers

- Splits into the F1 / F2 layers during daytime
- Combines into one F layer during the night
- Highest ionospheric layer (90 to 130 miles
- Responsible for almost all of the high frequency (above 10 MHz) skywave propagation



Ionized by ultraviolet radiation from the sun. During the daylight two distinct regions form, F1 and F2. Because of the lower density of free electrons, recombination is fairly slow when the sun sets. The F1 recombines more rapidly than the F2 and at night the two regions essentially collapse into one region as the night progresses.

During the daytime, the F2 layer plays almost no role reflecting RF below 10 MHz since these signals don’t get to the F2 layer. Signals above 20 MHz pass right through the F1 layer, but rarely arrive during the daytime as they would be reflected by the E and F2 layers.

The F2 layer is the most important layer as it has the highest density of free electrons and ionized particles. During daylight the F2 layer reflects almost all RF below 30 MHz that reaches the F2 and not absorbed by the D layer or reflected by the E layer.

Skip of up to 2,500 miles is common in one hop using the F2 region.

G3B09, G3C03

Ionosphere Effect on Radio Waves

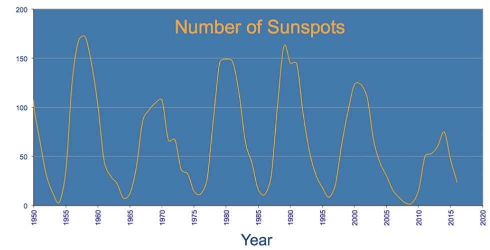
Band	Day	Night
160 80	D layer absorbs	D layer disappears E skip
40	Mostly D layer absorbs Some E and F1 Skip	Some F skip Mostly E skip
20 17 15 12	Passes through D Some E skip Mostly F1 skip	D, E, F2 disappear Slight F Skip
10	High solar flux good F2 and F1 skip	Slight F skip
6	High solar flux some F1 scatter Tropo ducting Sporadic E	Tropo ducting Sporadic E

There is almost always daytime skywave propagation on 20 meters. Depending on the condition of the ionosphere the skip can be up to 4,000 miles! Multi-skip is also possible with a highly-charged F1/F2 layers. A serious geomagnetic storm will affect 20 meter skywave propagation.

15, 12, and 10 meters are the least reliable for long-distance communications during periods of low solar activity

G3A04, G3A07, G3C05

Sunspots



- Sunspots vary in an eleven-year cycle. We are currently at a solar minimum
- The sun rotates on a 28-day cycle. The number of visible sunspots changes as the sun rotates
- The number of sunspots affects the Solar Flux Index. The higher the index, the better opportunity for long-distance skip

During low sunspot periods, 15, 12, and 10 meter skywave propagation is highly unlikely barring some other phenomenon such as tropospheric ducting, sporadic-E, meteor scatter, or auroral propagation

G3A01, G3A10

Important Definitions

- **Solar Flux Index**: Measured daily in Ottawa, Canada. It is a measure of solar radiation at 10.7cm
- **K-Index**: An indication of the stability of the earth's magnetic field as measured in Boulder, CO. Low K-Index means stable high-frequency propagation
- **A-Index**: An average over time of the K-Index and indicates the long-term stability of the earth's magnetic field. Open-ended, can vary from 0-30 during quiet activity and up to 100 or more during geomagnetic storms

G3A05, G3A12, G3A13

Geomagnetic Field

K Index	A Index	HF Skip
1-4	0-7	Bands normal
4	8-15	Bands unsettled
4	16-30	Bands unpredictable
5	30-60	lower bands unstable
6	50-99	Few skywaves below 15 MHz
7-9	100-400	Radio blackout likely

High geomagnetic activity may produce auroras. VHF radio waves can be reflected off auroras. Aurora reflected waves have a “fluttery” sound.
A **geomagnetic storm** is a temporary disturbance in Earth’s magnetosphere and has the potential (depending on the strength of the storm) to degrade high-latitude HF propagation.

G3A06, G3A08, G3A09

Sudden Ionospheric Disturbances

A sudden ionospheric disturbance (SID) is any one of several ionospheric perturbations, resulting from abnormally high ionization/plasma density in the D region of the ionosphere and caused by a solar flare and/or solar particle event.

The SID results in a sudden increase in radio-wave absorption that is most severe in the upper medium frequency and lower high frequency ranges, and as a result often interrupts or interferes with telecommunications systems

G3A02

Some More Facts

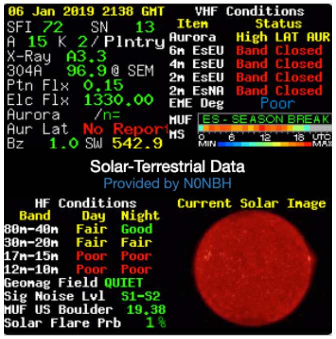
- X-ray and ultraviolet radiation takes about 8 minutes to travel from the earth to the sun
- Charged particles from **Coronal Mass Ejections** (CME) take 20-40 hours to reach the earth
- High levels of radiation (usually caused by a solar flare, a coronal hole, or CME) can cause a geomagnetic storm. A serious storm can wipe out radio communications
- A geomagnetic storm affects the magnetosphere, a region beyond the ionosphere
- High geomagnetic activity often generates auroras which can reflect VHF signals
- Solar wind from a **Solar Coronal Hole** will seriously degrade skywave propagation
- During the summer there is a high level of atmospheric noise (static)

Most summer static can be attributed to lightning

G2D11, G3A03, G3A11, G3A14

Propagation Forecasts

- Forecasts are available on a number of websites. Most popular is at https://www.qrz.com/
- Detailed information can be seen at http://www.hamqsl.com/solar.html



Space Weather Woman

- Dr. Tamitha Skov
- Produces a weekly propagation forecast published on YouTube
- https://www.youtube.com/channel/UCkXjdDQ-db0xz8f4PKgKsag

Dr. Skov's propagation forecasts are an excellent way to learn about upcoming solar events such as coronal holes (generates geomagnetic storms), sunspot forecasts, and aurora events.

G5A06

Scatter

- **Skip zone** is between farthest extent of ground wave propagation and nearest single-hop propagation.
- But signals can scatter off irregularities in the ionosphere and reach points in the skip zone. Signals will be weak.
- Signals can also scatter off the ground and reflect back through the ionosphere into the skip zone.
- Scatter signals usually sound fluttery (multiple paths).

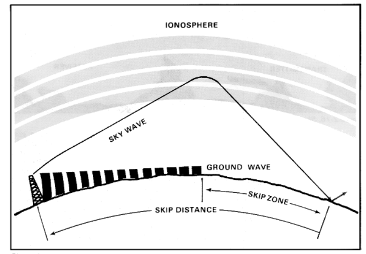


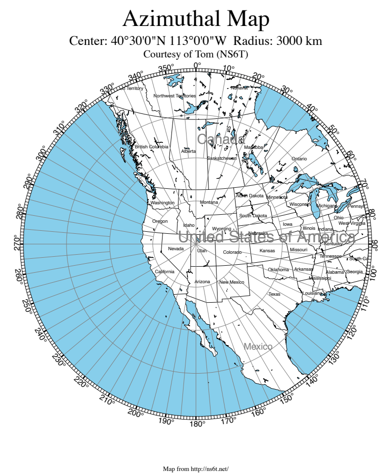
Figure 2-15. Low angle sky-wave transmission path.

G3C07, G3C08, G3C09

Azimuthal Map

Azimuthal Map shows the bearing (and sometimes distance) from a specific location.

https://ns6t.net/azimuth/azimuth.html



G2D04

Long Path / Short Path

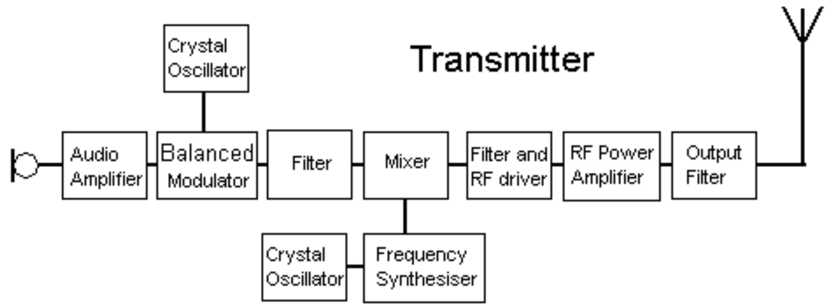
A skywave signal sometimes arrives at your receiver both by short path and the long way around. The long path will sound like a well-defined echo.

Sometimes, because of how “skip” is working, long path may work better using directional antennas. Point the antenna 180 degrees away from the short path.

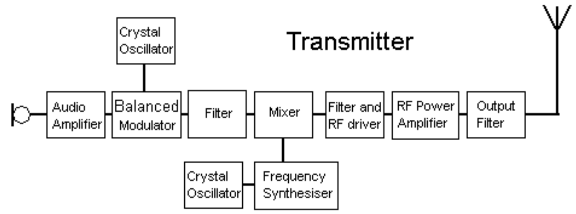
G2D06, G3B01

Your HF Transmitter

HF SSB Transmitter



Balanced Modulator



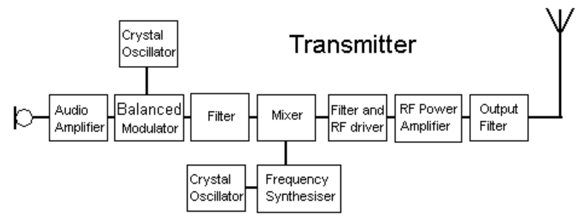
A **balanced modulator** combines the signal from the carrier oscillator and speech amplifier and sends the result to the filter where one of the sidebands is suppressed and the remaining signal sent to the **Mixer**

SSB signals are about 2.8 kHz wide, narrower than double sideband, frequency modulation, or phase modulation. Some digital modes have narrower bandwidths.

Due to the narrow bandwidth, SSB is a more efficient user of available transmitter power.

G7C01, G7C02

Mixer



A mixer is a non-linear device that takes two radio signals and creates the sum and difference frequencies of the two input frequencies. These are called **intermediate frequencies** (IF)

A nearby signal can sometimes also generate the same intermediate frequency and cause interference. This is called "**Image Response Interference**"

G7C03, G8B11

Speech Processor

- A speech processor may increase the intelligibility of phone signals during poor conditions
- It essentially increases the **average power** of the signal
- Used when not needed it may distort the signal
- Some modern transceivers have a built-in speech processor that can be enabled when desired. There are also add-on devices.
- Overmodulation will result in excessive bandwidth

Bottom Line: Use only when absolutely needed.

An incorrectly adjusted speech processor will cause distorted speech, splatter on adjacent frequencies, and excessive background pickup.

G4D01, G4D02, G4D03, G8A08

Automatic Level Control

The **ALC** acts as an “electronic governor” to throttle back the transmit power in case you overdrive the input with too much mic gain or too much computer drive (for data).

Most modern transceivers have an ALC indicator on the monitor. Look for small deviations. Anything more than that indicates an overdrive situation.

ALC is usually required when driving an amplifier to prevent distortion due to excessive drive. Excessive drive can damage the amplifier.

Properly adjusting the ALC is setting the correct transmit audio or microphone gain.

G2A12

A Couple of Things

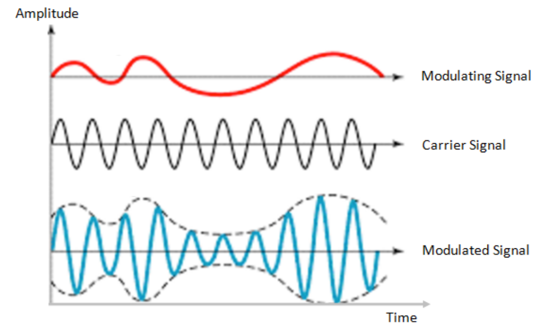
Flat Topping: signal distortion caused by over driving the signal. The signal as viewed on an oscilloscope will have the tops and bottoms of the signal clipped off.

Two-tone Test: The linearity of a transmitter (or an amplifier) is tested by injecting two tones that are not a harmonic of each other. Again, the test is viewed on an oscilloscope.

PTT vs VOX: Voice actuated transmit (VOX) allows for hands-free operation, however be aware of background noise when using VOX.

G2A10, G4B07, G4B15, G8A10

AM Signal Modulation Envelope



The modulation envelope of an amplitude modulated signal is created by connecting the peak values of the modulated signal as shown in the bottom diagram

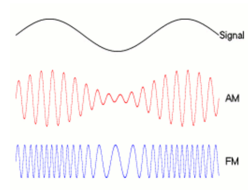
G8A11

Frequency Modulation

While AM varies the amplitude of a signal to convey speech, FM varies the frequency of the signal to convey speech.

The **deviation** of the resulting signal is directly related to the amplitude of the input.

Once the desired waveform is created, then a **multiplier** generates the desired transmit frequency.



If the initial modulation of an FM signal is 12.21 MHz and the transmitted signal is 146.52 MHz, then the multiplier is generating the 12th harmonic of the signal…

G8A03, G8B04

Calculating the Bandwidth and Deviation of an FM Signal

- To calculate the bandwidth of an FM signal we must know the modulation frequency and the deviation
  - The bandwidth is (deviation + modulation frequency) * 2
  - If the deviation is 5 kHz and the modulation frequency is 3 kHz, then (5+3) * 2 = 16 kHz
- To calculate the deviation of an FM signal we must know the initial deviation and the multiplier (this may require two separate calculations)
  - The deviation of an FM signal is the initial deviation in Hz divided by the multiplier

What is the frequency deviation for a 12.21 MHz reactance modulated oscillator in a 5 kHz deviation, 146.52 MHz phone transmitter?

The deviation at the transmit frequency is 5 kHz. The initial deviation (to be calculated) and the initial oscillator (12.21 MHz) were run through a multiplier which used the 12th harmonic to generate the 146.52 MHz transmit frequency (146.52 / 12.21 = 12). That means that the initial deviation multiplied by 12 is the resulting 5 kHz deviation. Divide 5000 by 12 to get the signal deviation: 416.66 Hz, which would round to 416.7 Hz (the correct answer).

G8B06, G8B07

Phase Modulation vs Frequency Modulation

- The differences are very subtle and result in the same output from a receiver
- In FM, the frequency of the carrier wave varies as per the voltage of the modulating signal input
- In PM the phase of the carrier wave varies as per the voltage of the modulating signal input
- A reactance modulator produces FM when applied to an oscillator. However, when that output is fed into a subsequent amplifier, PM emerges

Frequency Modulation is the process that changes the instantaneous frequency of an RF wave to convey information

Phase Modulation is the process that changes the phase angle of an RF wave to convey information

G8A02, G8A04

Amplifiers

- **Class A**: The most linear type of an amplifier, but not very efficient. Used for AM, SSB, Video, etc., since there is very low distortion
- **Class C**: Not very linear but very efficient in a narrow frequency range. Used for CW, FM, PM. Not suitable for amplitude modulated signals as they will be distorted
- **Class A-B**: Compromise between Class A and B. Reasonable linearity and more efficient

Linearity describes how faithful the resulting wave form is when compared to the input wave form.

Efficiency describes how much DC power is needed to derive the desired Peak Envelope Power. For instance, if 100 watts of CW output power takes 250 watts of DC input power, the efficiency is 100 / 250 or 40%

G7B02, G7B08, G7B10, G7B11

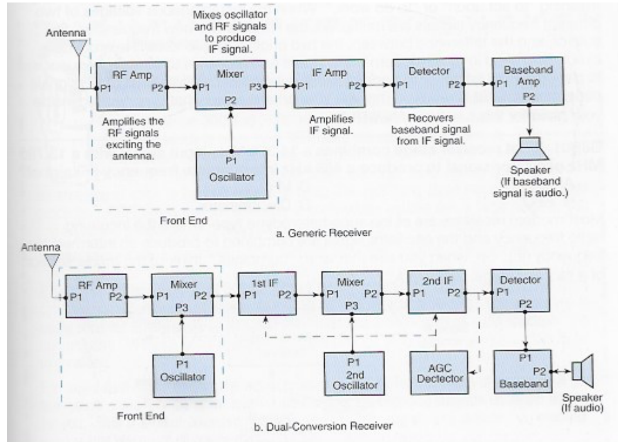
Amplifier Errata

- When new tubes are put into the final amplifier stage (either in a transmitter or an amplifier), they must be “neutralized” to prevent **self-oscillation**. The manual will describe the process. Transistor final stages don’t require neutralization
- In a vacuum tube amplifier, adjusting the plate current means adjusting the current for the maximum dip while adjusting for maximum power output (without exceeding the maximum allowed)
- Excessive drive power will lead to permanent damage to an amplifier
- Modern transmitters have an **Automatic Level Control** which limits the power to the amplifier to reduce distortion

G4A04, G4A05, G4A07, G4A08, G4A14, G7B01

Your HF Receiver

Your Receiver



Most basic components: An oscillator, a mixer, and a product detector. Note that in an FM receiver, the product detector is replaced with a “discriminator” whose function is to convert deviation into voltage.

G7C07

Receiver Components

- The **mixer** processes signals from the RF amplifier and the oscillator and sends the result to the intermediate frequency (IF) filter.
- The process of mixing two RF signals (done by a mixer) is called "**Heterodyning**".
  - The term **Intermodulation** means when two signals in a non-linear circuit or connection produce unwanted spurious outputs
- The **product detector** combines signals from the IF amplifier and a **beat frequency oscillator** (BFO) and sends the output to the Audio Amplifier.
- Strong adjacent signals may cause "**image response**" interference if the adjacent signal is +- the IF frequency. For example, if the IF frequency is 455 kHz and the radio is tuned to 14.255 MHz, a signal 455 kHz above (14.710) or 455 kHz below (13.800) may cause image response interference.

Intermod suppression is one of the key specifications of a receiver

Some receivers will have an "attenuator function" that will attenuate incoming signals. It is used to reduce signal overload due to strong incoming signals so that weak signals may be heard

Match the receiver bandwidth to the bandwidth of the operating mode as it results in the best signal-to-noise ratio

The oscillator (also called the **local oscillator**) is varied or tuned to convert signals of different frequencies to the **intermediate frequency** (IF)

G4A13, G7C03, G8B01, G8B02, G8B03, G8B09, G8B12

Product Detector vs Discriminator

- In a SSB receiver the **product detector** is used to combine signals from the IF amplifier and BFO and send the result to the AF amplifier
- In an FM receiver the product detector is replaced with a **discriminator** which converts the frequency shift into voltage

G7C04, G7C08

Digital Signal Processing

- **DSP** refers to processes that eliminate background static to improve the intelligibility of the desired signal, i.e., noise reduction and therefore improved signal to noise ratio
  - Digital processing makes may different filter types possible over what analog filters can provide
  - Many modern receivers have DSP capabilities that can be switched in or out
  - Audio DSP add-on boxes can be purchased which go between the radio's output and an external speaker and provide many of the same capabilities
- DSP allows these to create multiple filter bandwidth settings as well as bandwidth shape settings
- Too much noise reduction can result in distorted signals
- Some receivers have the ability to shift the IF frequency to avoid interference

Some of the DSP filter types include noise reduction, notch filtering, audio equalization. For instance, a notch filter is used to remove adjacent signals in the receiver passband. Very useful for strong adjacent signals overpowering a weaker, desired signal. Some modern receivers will do automatic notch filtering. Don't forget the RF Gain control! Sometimes reducing the gain will improve the reception of weaker signals.

Digital Signal Processing requires a means of converting the incoming signal to a digital representation, a digital processing chip to do the requested filtering, and then a means of converting the resulting digital signal back to an analog signal.

G4A11, G4A17, G4C12

The S-Meter

The signal strength meter (**S-Meter**) is part of the receiving circuit and is tied into the “**automatic gain control**” circuit.

The AGC circuit adjusts the audio gain of a signal to “level” the signals heard on a frequency.

If the AGC is turned off, the S-Meter doesn’t work. Set the AGC to “fast” for CW, “slow" or “automatic” for SSB.

When enabled, the S-Meter will measure the received signal strength.

To change the S meter reading on a distant receiver from S8 to S9 requires raising the output of a transmitter approximately 4 times.

G4D04, G4D06, G4D07

Let's Look at Some Components

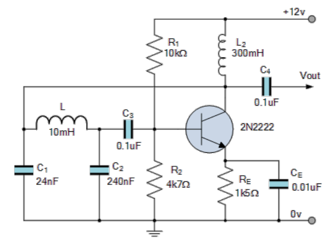
Oscillator

An **oscillator** is an amplifier with positive **feedback.**

It usually has a tuned circuit to set its oscillation frequency (in the old days it was crystal driven).

It requires a small amount of feedback to stay in operation.

The frequency is determined by the values of the capacitor(s) and inductors(s) in the tank circuit.



A Colpitts Oscillator

In previous eras, the student had to be able to draw this circuit from memory. In those days, a vacuum tube replaced the transistor.

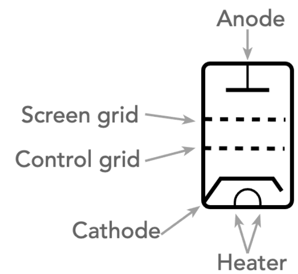
In most modern transceivers, a **Direct Digital Synthesizer** (DDS) is used as a high-stability variable frequency oscillator (VFO) with the stability of a crystal oscillator. The DDS is a digital circuit

The keyword about an oscillator is **feedback.**

G7B07, G7B09, G7C05, G7C16

Vacuum Tubes

- Current flows from the cathode to the anode
- The electrical charge on the **control grid** determines how much current flows
  - A small varying current on the control grid can modulate a large current flowing to the Anode
- The **screen grid** is used to reduce the grid-to-plate capacitance



G6A10, G6A12

Transistor Types

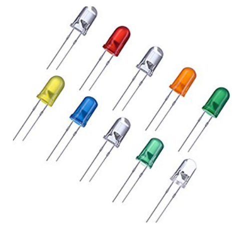
- **MOSFET**: a metal-oxide field effect transistor characterized by separating the gate from the channel with a thin insulating layer
- **Bipolar**: transistors used as a switch (off or on). A small amount change in collector-base voltage will cause a large change in collector current allowing the transistor to switch between cut-off and saturation quickly. The stable operating points for a bipolar transistor are its saturation and cutoff regions
- **Power**: transistors used in power supplies deal with large voltages and currents. Power transistors are insulated to prevent them from accidentally connecting to ground and causing a short circuit

Bipolar transistors or commonly used as switches. The active region is ambiguous whereas the saturation region and the cutoff region are clearly on or off

G6A07, G6A09

Diodes

- Diodes allow current to flow in one direction only once the **threshold voltage** is reached
- Different types of diodes have different “junction threshold voltages”, the voltage at which the diode conducts current
  - Germanium diodes conduct at about 0.3v whereas conventional diodes conduct at about 0.7v
- Schottky diodes conduct at about 0.15 to 0.46v. They are very fast and have lower capacitance than conventional diodes



LED’s conduct similarly to a conventional diode (0.7v). They have the advantage over incandescent bulbs of much lower power consumption, much faster response time, and a much long lifespan

A diode begins conducting current when the device is “**forward biased**”, that is, a voltage above the junction threshold voltage must be applied which saturates the diode material allowing current to flow

An LED is forward biased when emitting light

G6A03, G6A05, G6B08

Miscellaneous Components

- **LCD**: Liquid crystal display, made up of substances that change optical properties when exposed to an electrical field. LCD's produce no light so ambient lighting or backlighting is required
- **MMIC**: Monolithic Microwave Integrated Circuit, used by microwave operators on up 10 GHZ
- **Microprocessor**: A computer on a single integrated circuit

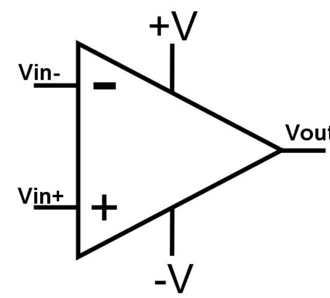
Microprocessors generally use **CMOS** (complementary metal oxide semiconductor) integrated circuits rather than **TTL** (transistor-transistor logic) integrated circuits because CMOS has much lower power consumption.

Microprocessors and computer have two types of memory, **non-volatile** and **volatile**. Volatile memory is erased when power is removed. Read Only Memory (**ROM**) is a type of non-volatile memory.

G6B02, G6B03, G6B04, G6B05, G6B09

Analog Devices

- Not all semiconductor devices operate in the digital realm!
- **Operational Amplifiers** (op-amps) are the most ubiquitous devices and can produce an output hundreds or thousands of times larger than the input
- **Linear Voltage Regulators** are also used in almost every device to smooth out the voltage and keep it within specifications



An Op Amp

G6B06


Questions? Comments?