

Lesson 11

OSCILLATORS, PLL and SIGNAL MODULATION

ACMA Syllabus February 2024 Chapters 3.6 and 3.7

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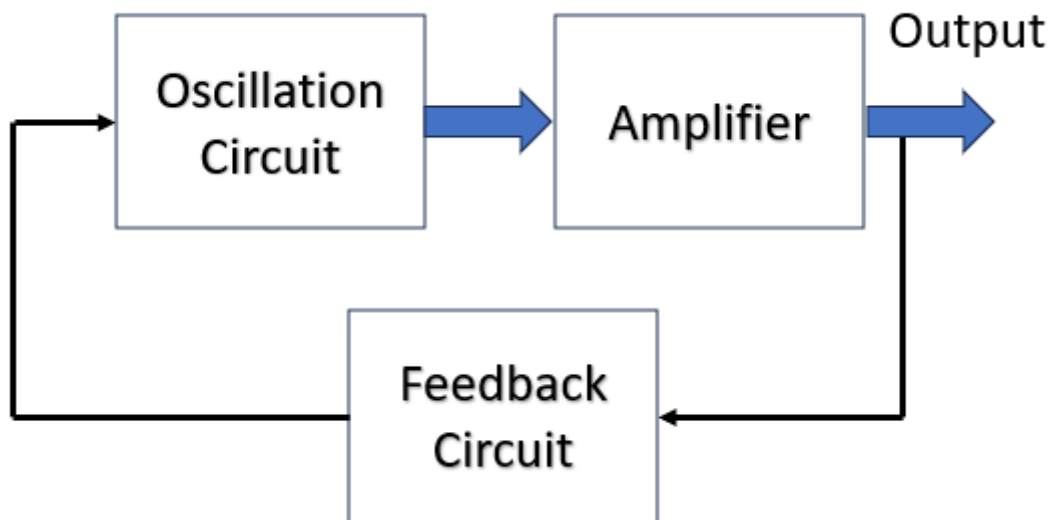
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Oscillators

An oscillator is a circuit that produces a continuous, repeated, alternating waveform without any input. The oscillator relies on feedback to keep the oscillator in frequency and phase. See below.

Feedback

Signal feedback from output in phase with the input signal is termed *positive feedback*. Signal feedback that is out of phase by 180° with respect to the input signal is termed *negative feedback*.



Oscillators are grouped in two categories.

- The linear or harmonic oscillator produces a sinusoidal output.
- The nonlinear or relaxation oscillator which produces square or other wave shape outputs.

Oscillators can be fixed frequency or variable.

Oscillators are often characterised by the frequency of their output signal:

- A low-frequency oscillator generates a frequency below 20 Hz.
- An audio oscillator produces frequencies in the audio range from 20 Hz to 20 kHz.
- A radio frequency oscillator produces signals in the range of 100 kHz to 100 GHz.

Oscillator Stability Essentials

Oscillator frequency output can be unstable if the following issues are not controlled.

Temperature Change

Temperature changes can alter the parameters of crystals, resistors, capacitors and inductors.

A Temperature Compensated Crystal Oscillator (TCXO) provides a more precise and stable output. An Oven-Controlled crystal oscillator (OCXO) keeps crystals at a consistent elevated temperature.

Mechanical Vibrations

External vibrations can cause short-term phase fluctuations in the output signal, known as phase noise. The ideal oscillator should have a combination of mechanical isolation and electrical compensation to reduce phase noise.

Power Supply

A regulated and well filtered power supply is essential for a stable oscillator.

Control Parasitic Oscillations

Parasitic oscillation is undesirable feedback in the oscillator and can be caused by feedback in the oscillator amplifier. An example of parasitic oscillations is if a mic is held too close to the speaker and the amplifier goes into uncontrolled oscillation.

Oscillator Types

Beat Frequency Oscillators

A beat frequency oscillator (BFO) is a dedicated oscillator used to create an audio frequency signal from Morse code radiotelegraphy (CW) transmissions. The signal from the BFO is mixed with the received signal to create a heterodyne or beat frequency which is heard as a tone in the speaker. BFOs are also used to demodulate single-sideband (SSB) signals by restoring the carrier that was suppressed at the transmitter.

Overtone Oscillator

This is an oscillator running at a harmonic of the original frequency. An overtone oscillator frequency allows a crystal oscillator to run at an odd multiple of the main crystal frequency and is a simple way to frequency multiplication in crystal oscillators.

Voltage Controlled Oscillator (VCO)

A VCO is an oscillator whose output frequency is controlled by an input voltage.

Variable Frequency Oscillator (VFO)

A Variable Frequency Oscillator (VFO) is an integral part of transmitters and receivers.

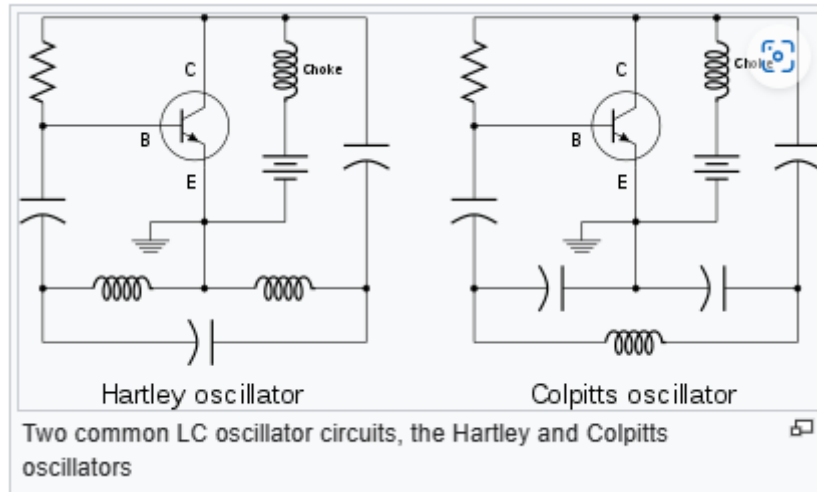
Discrete component Oscillators

Non digitised or packaged oscillators using discrete components such as inductors and capacitors.

Common Oscillators

Colpitts' Oscillator

A Colpitts oscillator is an LC oscillator for a certain frequency. The distinguishing feature of the Colpitts oscillator is that the feedback taken from a voltage divider of two capacitors in series across the inductor.



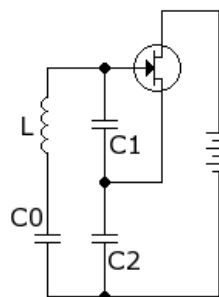
Wikipedia

Hartley Oscillator

The Hartley oscillator is an oscillator in which the oscillation frequency is determined by a tuned circuit. The distinguishing feature of the Hartley oscillator is that the tuned circuit consists of a single capacitor in parallel with two inductors in series (or a single tapped inductor), and the feedback signal is taken from the center connection of the two inductors.

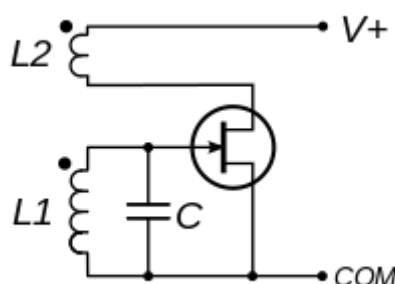
Clapp Oscillator

The Clapp oscillator is an LC oscillator using a particular combination of an inductor and three capacitors and a positive feedback network. The oscillator has good frequency stability.



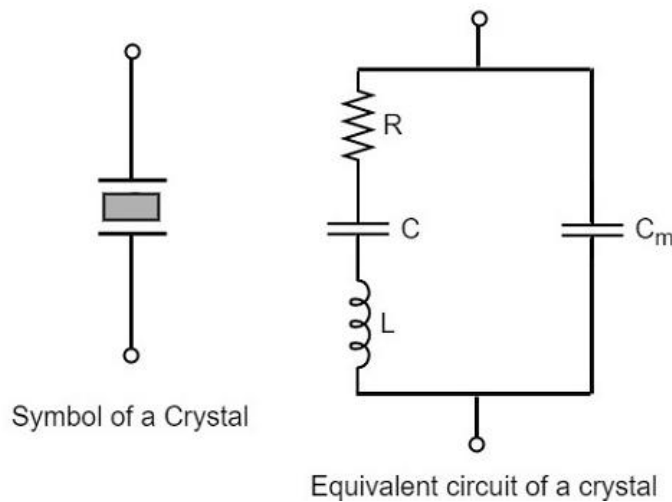
Armstrong Oscillator

The Armstrong oscillator is an oscillator circuit which uses an inductor and capacitor to generate oscillation and is the earliest oscillator circuit. This oscillator was used in the first vacuum tube radio transmitters. It is also called a "tickler oscillator" because its distinguishing feature is that the feedback signal is magnetically coupled into the tank inductor "tickler coil" in the output circuit.



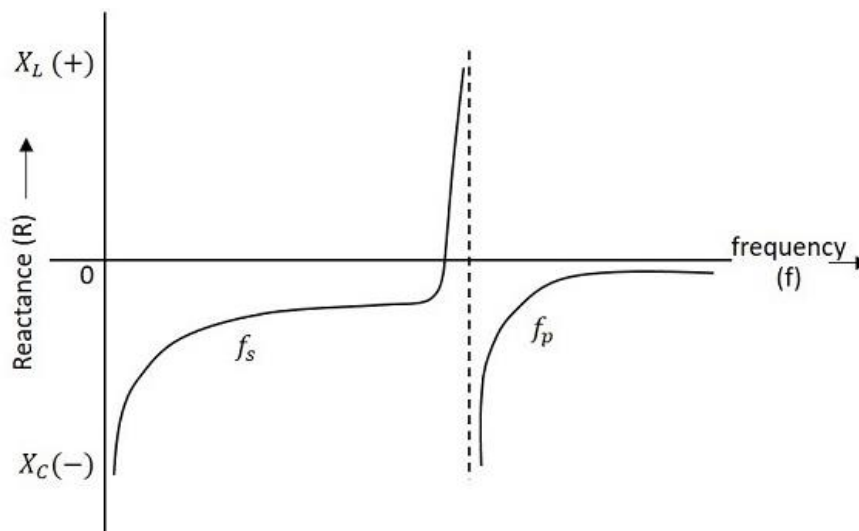
Crystals

A quartz crystal equivalent circuit is shown below.



When the crystal is not vibrating, the device looks like a capacitor C_m . When vibrating, the circuit is a LCR configuration.

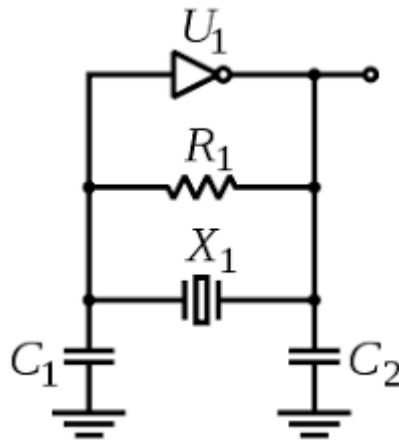
A quartz crystal provides both series and parallel resonance as shown in the graph below.



f_s is the series frequency and f_p is the parallel frequency response.

Pierce Oscillator

The Pierce oscillator is an oscillator well-suited for use in piezoelectric crystal circuits. Virtually all digital IC clock oscillators are of Pierce type, as the circuit can be implemented using a minimum of components. The low manufacturing cost of this circuit and the outstanding frequency stability of the quartz crystal give it an advantage over other designs in many consumer electronics applications. The most-common linear oscillator in use is the crystal oscillator where the output frequency is regulated by a piezo-electric quartz crystal.



U1 is an inverter.

X1 is the crystal.

Hints (Know the oscillators)

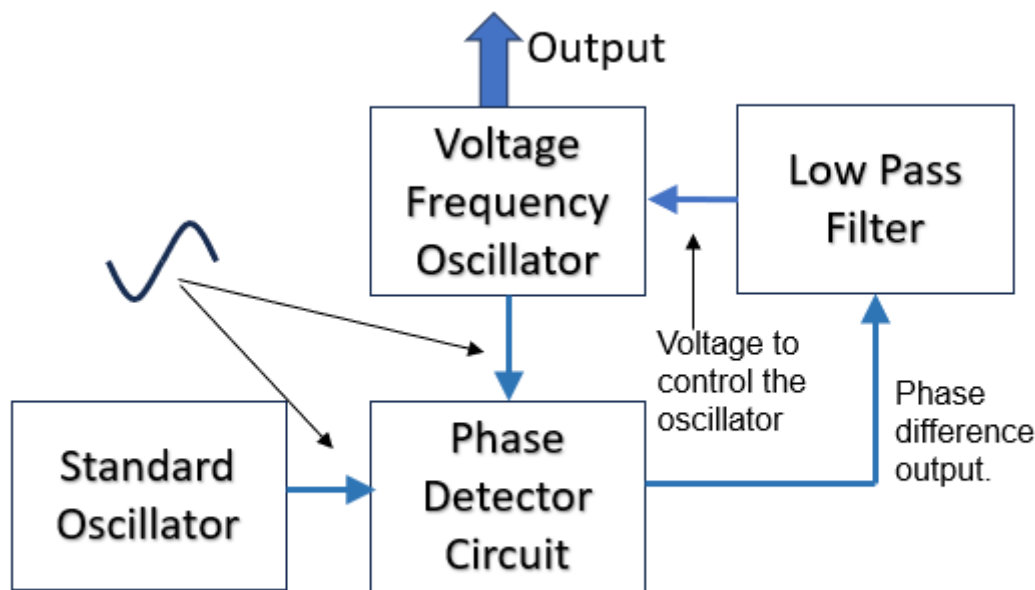
- Hartley oscillator has feedback from tapped inductors. (*H*)artley = *Henries* = *inductors*
- Colpitts oscillator has feedback from tapped capacitors. (*C*)olpitts = *capacitance*
- Clapp oscillator has feedback from tapped capacitors but in parallel with series tuned circuit.
- The Armstrong oscillator has feedback from a tapped transformer. *Strong arm to lift the transformer.*
- Pierce oscillator has a crystal.

Frequency Multiplier

A frequency multiplier transforms the input frequency to an output frequency which is a multiple (harmonic) of the input frequency. Frequency multipliers consist of a nonlinear circuit that distorts the input signal and consequently generates harmonics of the input signal. A subsequent bandpass filter selects the desired harmonic frequency and removes the unwanted fundamental and other harmonics from the output

Phase Locked Loop [PLL] Oscillator

A phase-locked loop compares the phase of a reference oscillator to the phase of an adjustable oscillator. When the comparison is in steady state, the phase of the output frequency and the phase of the incoming frequency are in sync. This is called locked. See diagram below+



Phase Locked Loop (PLL) Oscillator

A PLL consists of three key components:

1. **Phase detector**, AKA phase comparator or mixer, compares the phases of two signals and generates a voltage according to the phase difference.
2. **Low-pass filter** that attenuates the high-frequency component of the input signal to smoothen and flatten the signal to make it DC.
3. **Voltage-controlled oscillator (VCO)** is regulated by the voltage from the low pass filter. The VCO generates a sinusoidal signal.

The PLLs are used in many applications from frequency synthesizers to FM demodulators and signal reconstitution.

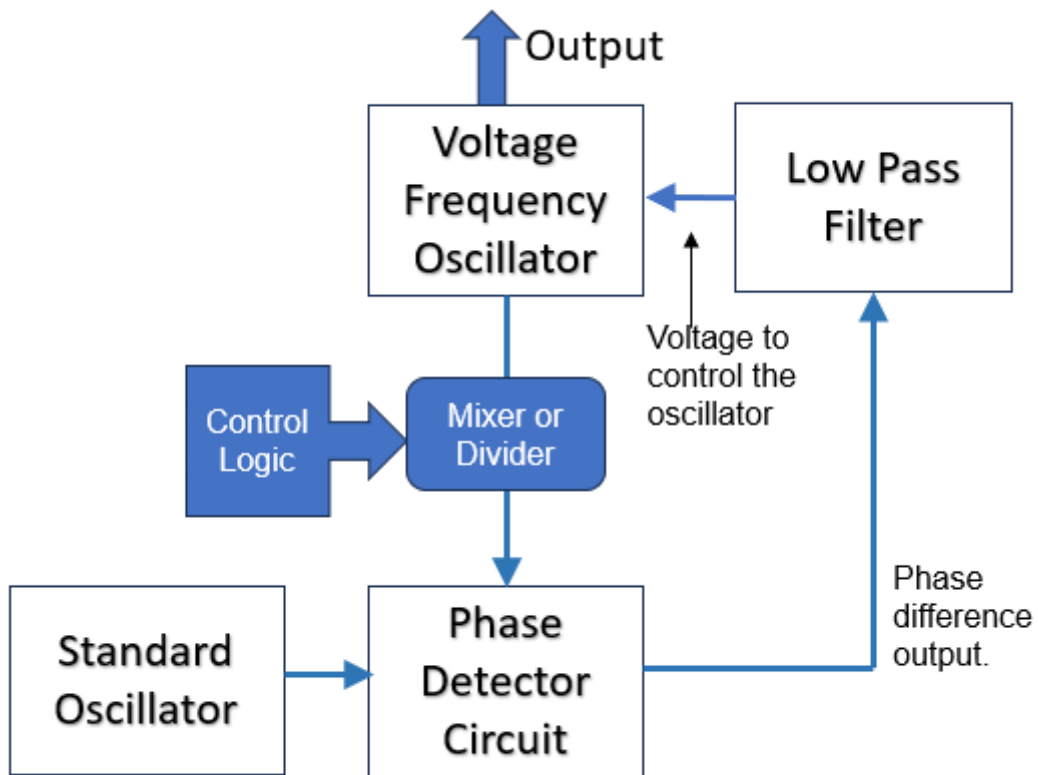
PLL Frequency Synthesis

A frequency synthesizer allows the designer to generate a variety of output frequencies as multiples of a single reference frequency.

If we controlled the feedback from the VCO to the phase comparator, the output frequency would be changed.

The **Analogue PLL synthesiser** has a mixer between the VCO and the phase detector.

The **Digital PLL synthesiser** inserts a digital divider in the loop between the VCO and the phase detector. The VCO frequency will be divided and run at the divided times the standard oscillator frequency. Programming the division ratio of the divider changes the output frequency. This makes the frequency synthesizer programmable.

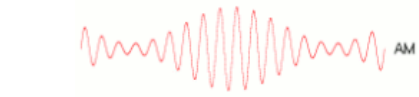


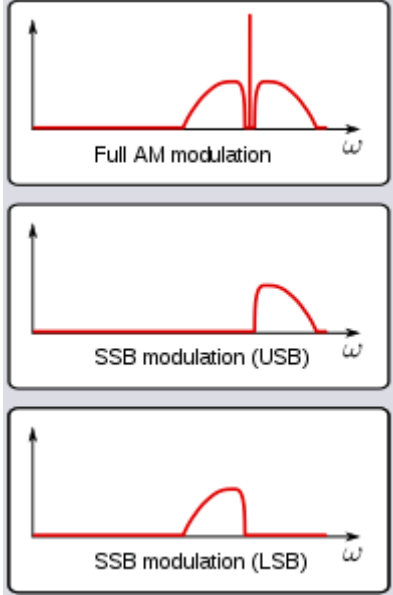


Phase Locked Loop (PLL) Synthesiser

Signal Modulation

Analogue Modulation

In the amateur radio arena, there are four primary methods of modulating an analogue signal with an intelligent signal. The primary modulation methods used by radio amateurs are AM, FM, CW and SSB.

<p>Amplitude modulation (AM)</p>	<p>AM is a modulation technique where the amplitude of the carrier is varied in proportion to that of the message signal.</p>	
<p>Frequency modulation (FM)</p>	<p>FM is a modulation technique where the frequency of the carrier wave is varied by the message signal.</p>	
<p>Continuous Wave (CW)</p>	<p>The term continuous wave refers to a method of radio transmission in which a sinusoidal carrier wave is switched on and off as in Morse code.</p>	
<p>Single-Sideband modulation (SSB)</p>	<p>SSB is a refinement of amplitude modulation, SSB uses transmitter Single-sideband modulation avoids this bandwidth increase, and the power wasted on a carrier, at the cost of increased device complexity and more difficult tuning at the receiver.</p>	 <p style="text-align: right; font-size: small;">Wikipedia Single-sideband modulation - Wikipedia</p>

Digital Modulation

Digital modulation of the carrier wave is where a digital is superimposed on an analog carrier.

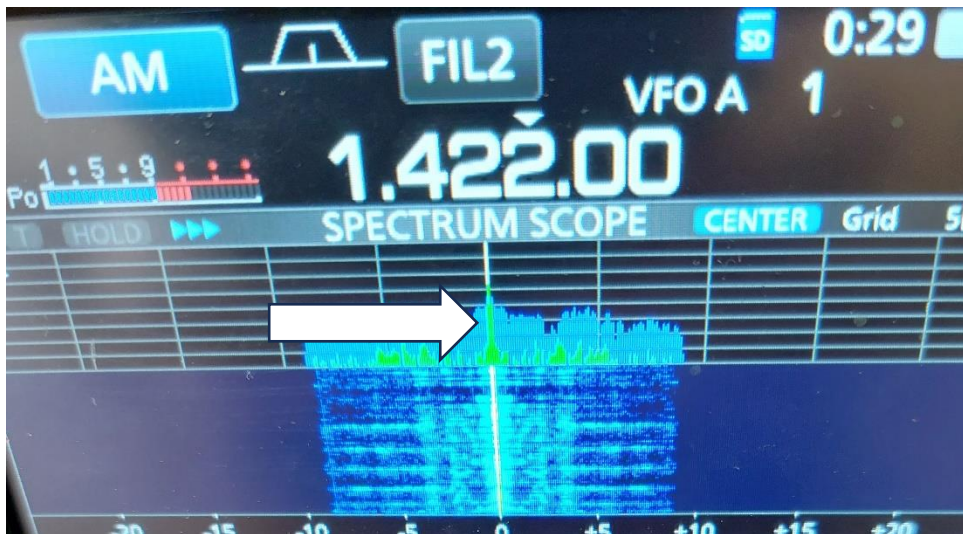
In **Amplitude Shift Keying (ASK)**, different amplitude levels are assigned to different binary values. The carrier wave's instantaneous amplitude is modified based on the digital signal's value.

In **Frequency Shift Keying (FSK)**, the carrier frequency is switched between two predetermined frequencies, one representing a binary 0 and the other representing a binary 1.

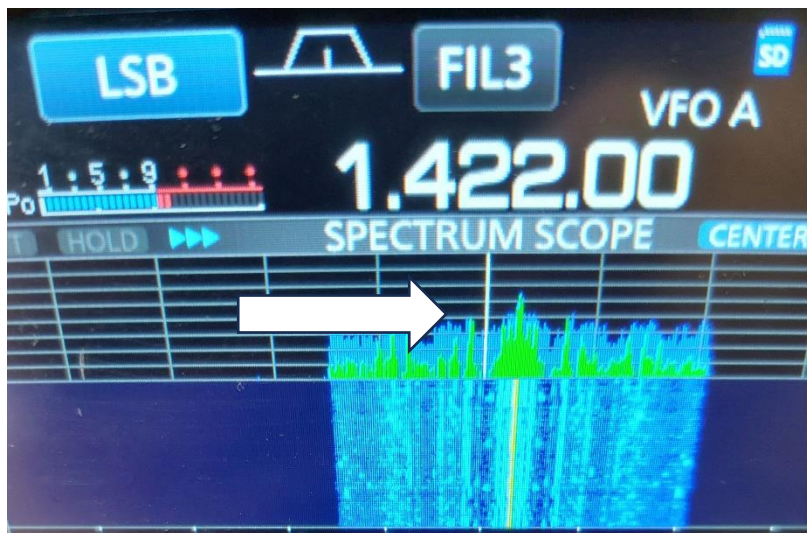
In **Phase Shift Keying (PSK)**, the phase of the carrier wave is adjusted at specific intervals based on the digital signal being transmitted

Quadrature Amplitude Modulation (QAM) is a method that involves two message signals. The amplitudes of two carrier waves are modulated (often using ASK). These two carrier waves are out of phase with each other by 90 degrees. The waves are then added together to create a single signal. Once broadcast and received, these two signals are demodulated and then separated. QAM's higher data rate capabilities and robustness to noise and interference make it a preferred choice for various digital communication systems.

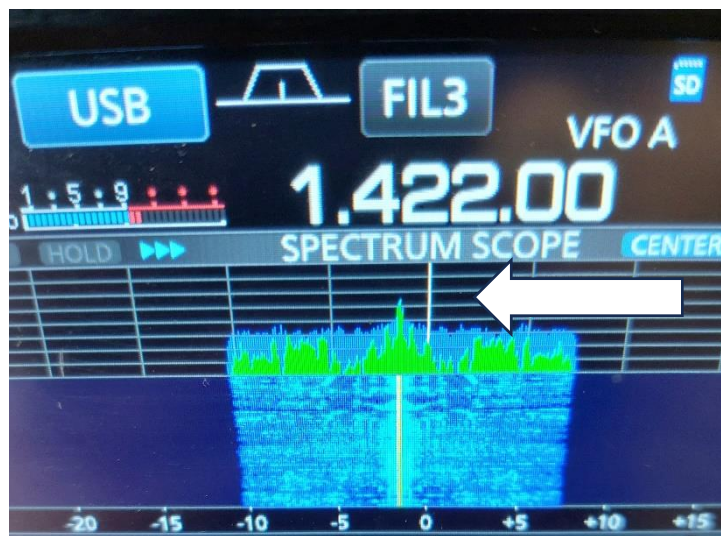
Signal Spectrum Images



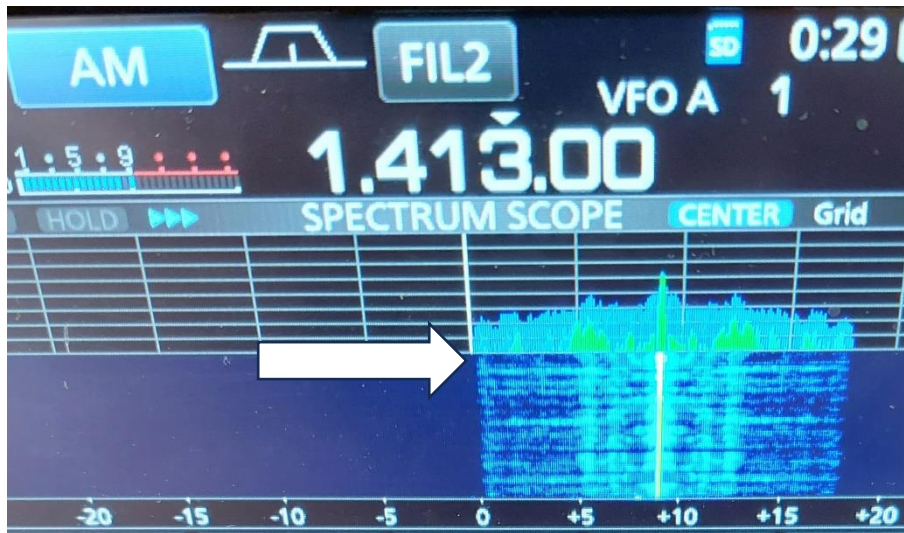
A double-sided AM signal with the carrier at 1.422 MHz.



The arrow indicates the Lower Side Band (LSB) of the signal.



The arrow indicates the Upper Side Band (USB) of the signal.



The arrow indicates the lower end of the signal band at 1.413 MHz.



The arrow indicates the lower end of the signal band at 1.431 MHz.

The total bandwidth for the station's signal occupies 18 kHz.

Go to Lesson 11 questions.

