Radio Receivers

Presented by:

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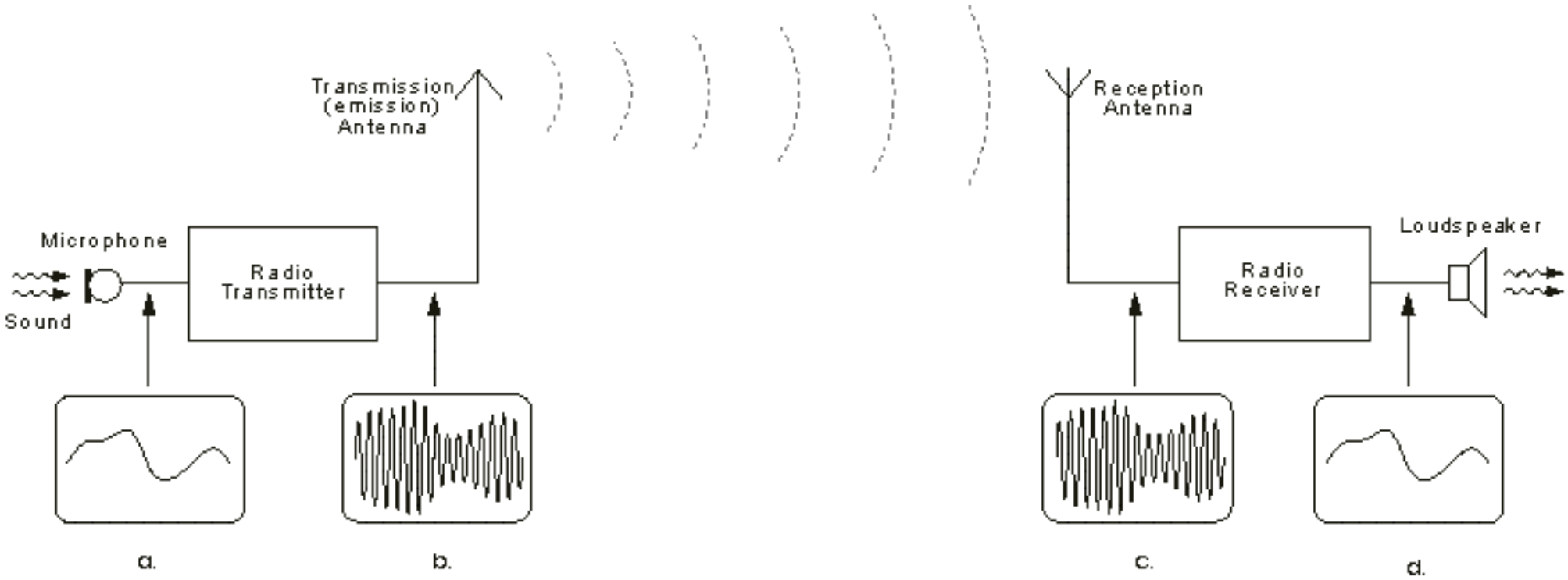
Radio Emissions and receivers

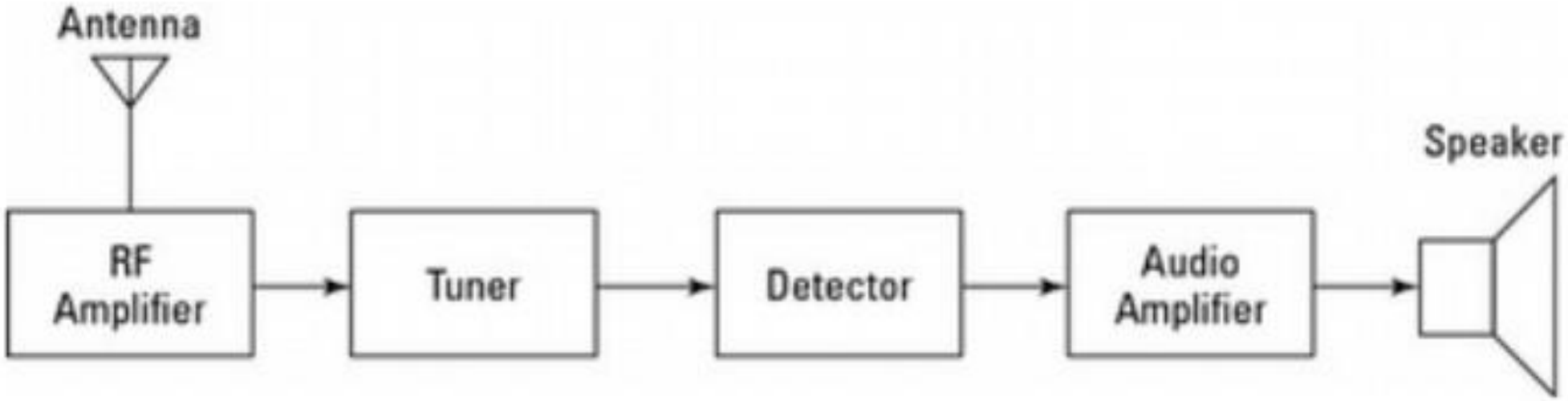
- There are many natural sources of radio wave emissions - Lightning, Celestial bodies such as Jupiter, Sun and other stars
- There are also man-made sources such as Mobile towers, WiFi modems, Commercial broadcasts, electrical sparks, etc.
- We use electronic circuits known as radio receivers to capture these radio emissions and convert them into something usable
- In a typical receiver (Rx), uses an antenna to capture radio waves, processes those waves to extract only those waves that are vibrating at the desired frequency, extracts the audio signals that were added to those waves, amplifies the audio signals, and finally plays them on a speaker

SIARS

Typical Transmission and Reception path



Building blocks of a receiver

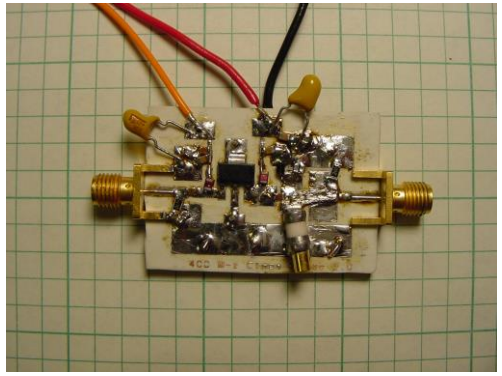


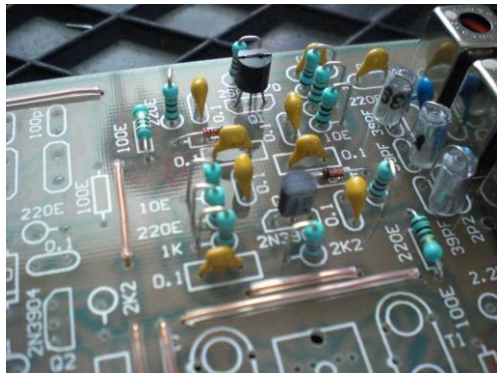
Rx in detail : Antennas

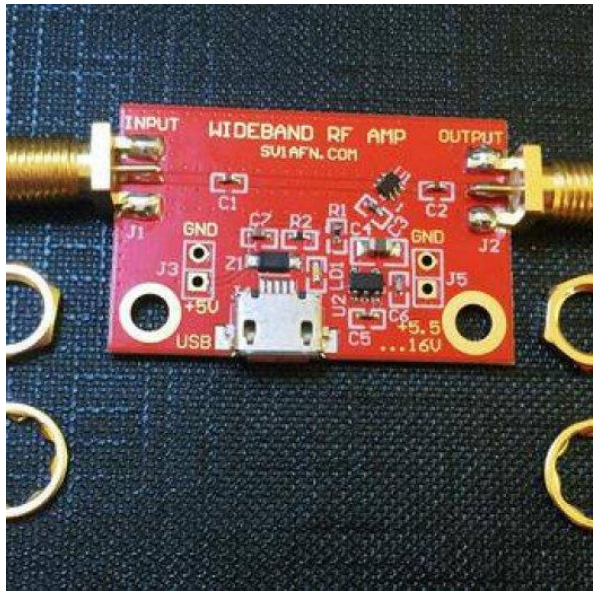
- The antenna captures radio waves from the ionosphere
- When a wire is exposed to radio waves, a small AC signal is induced in the antenna; in microvolts
- In case of a transmitter, the antenna is responsible for getting the radio waves into the ionosphere

Rx in detail : RF Amplifiers

- The RF amplifier is used to boost the very weak AC signal that the antenna picks up into something usable
- They are very sensitive in nature, since they need to work in with very little input
- It is usually wideband – it picks up all frequencies and amplifies them equally

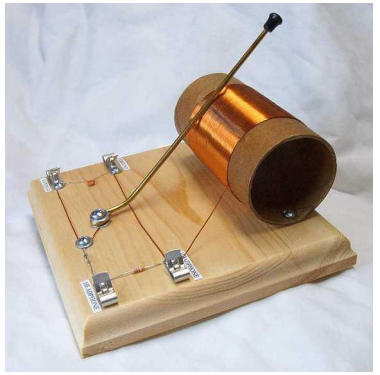


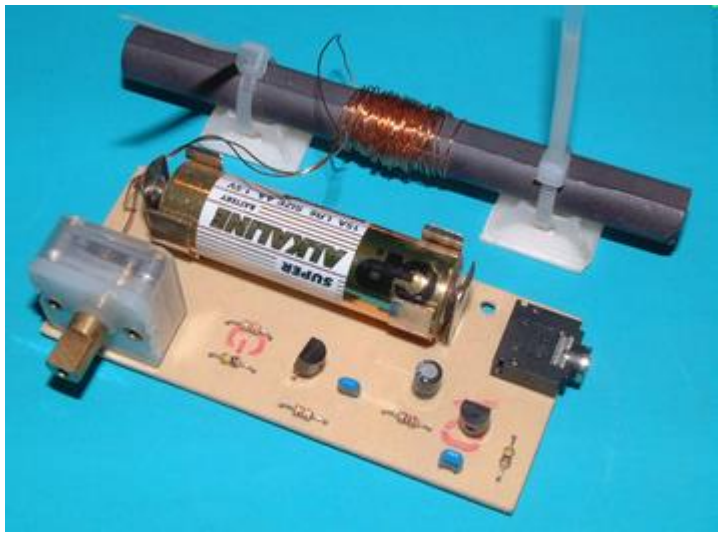




Rx in detail : Tuner

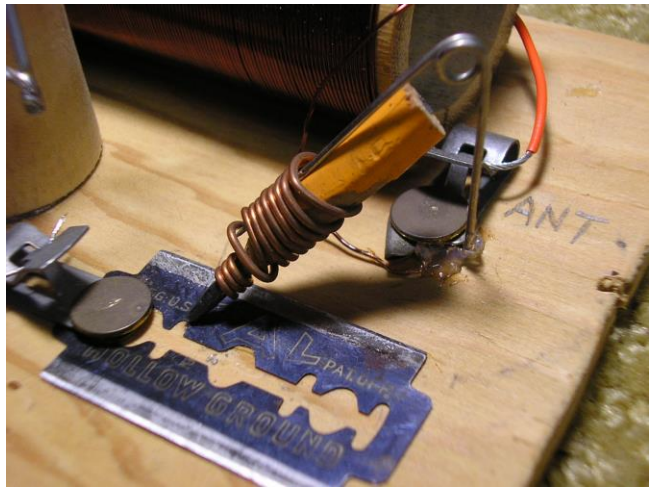
- A tuner is a circuit used to extract the desired frequency radio waves from a mix of all frequency radio waves
- It is usually a "*resonant*" circuit – it allows signals which match its resonant frequency and rejects the rest
- A tuner is usually made up of a coil and capacitor – at least one which can be varied to 'tune' into a signal





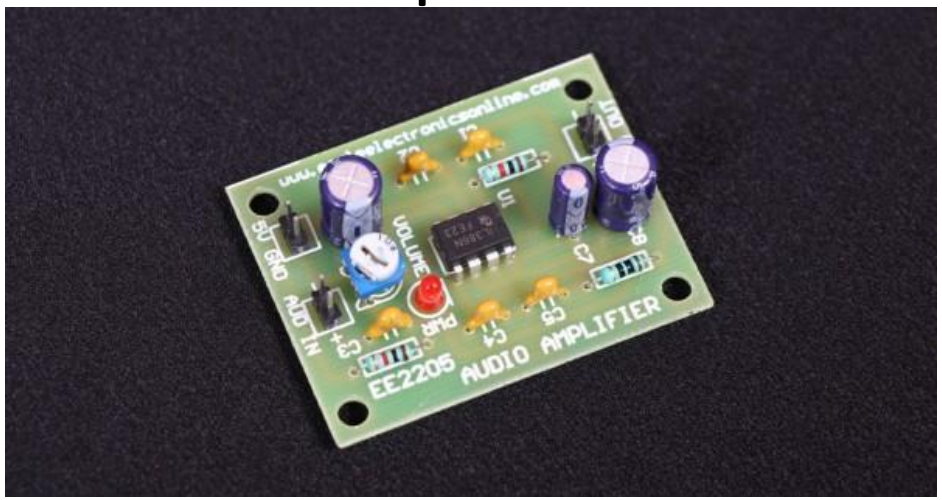
Rx in detail : Detector

- A detector “detects” the audio in a radio wave and converts it into audio
- A very simple detector is a diode detector in a crystal radio – it converts the incoming AM RF signal into Pulsating DC Audio
- For FM circuits, the detector is slightly more complex!



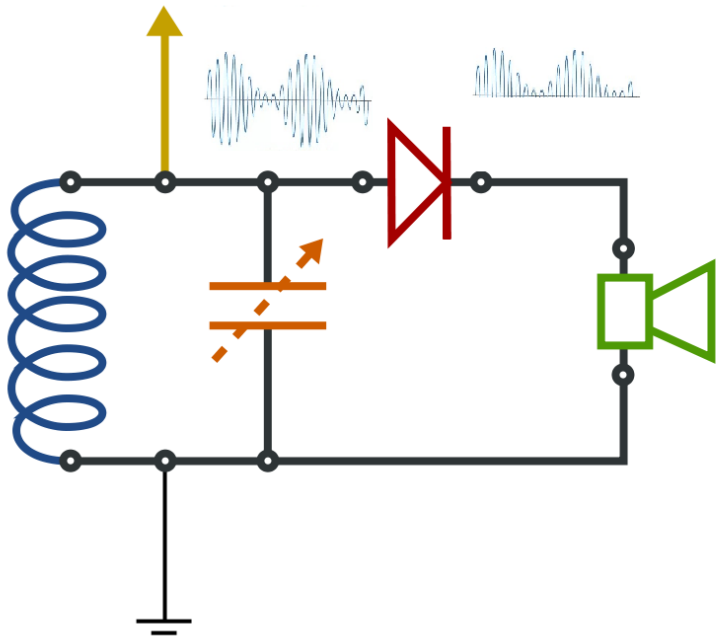
Rx in detail : Audio amplifier

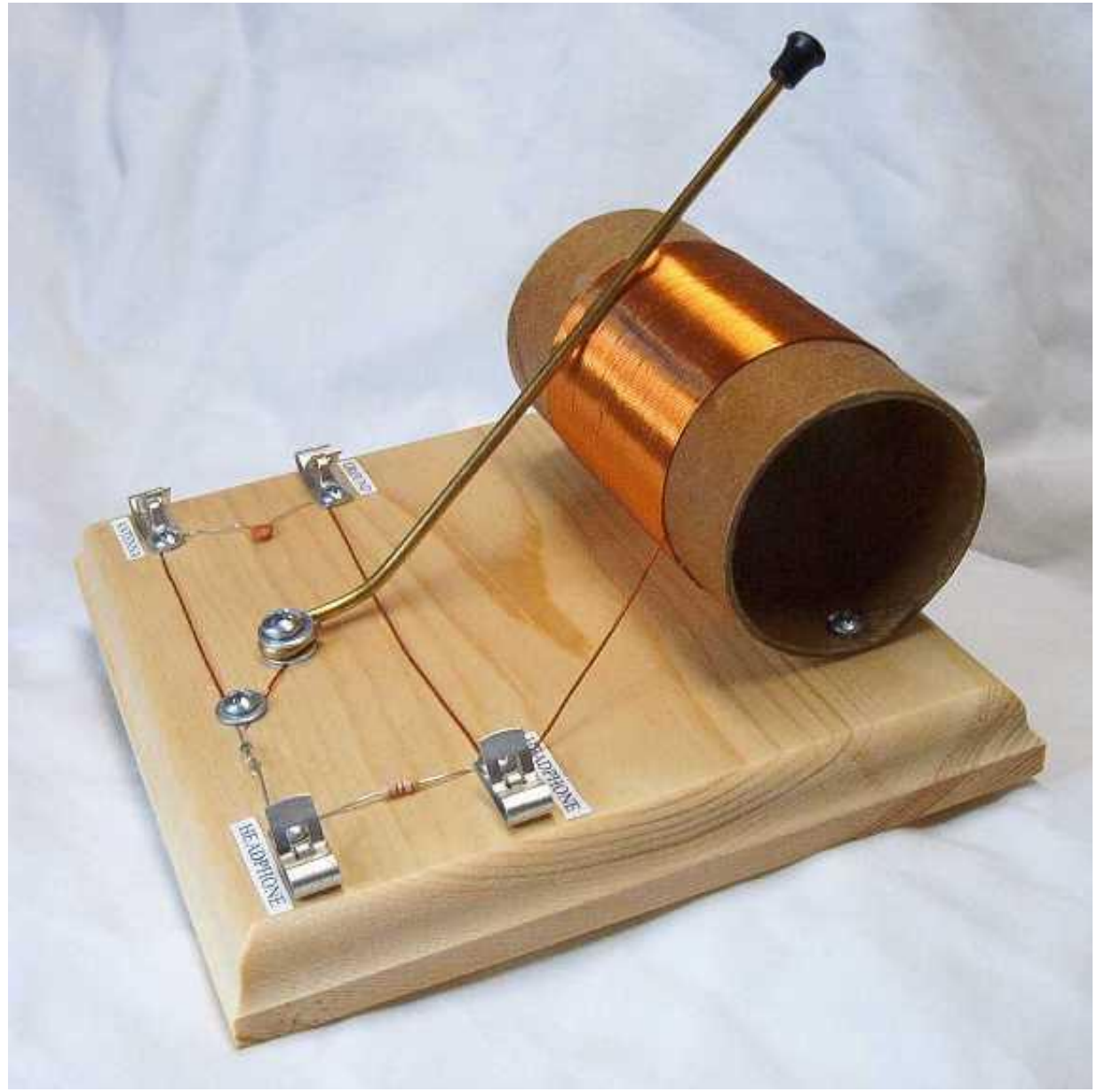
- The audio amplifier is used to boost the weak audio signal from the detector to make it audible
- It can vary from simple one transistor circuit to complex IC based designs



Types of Radios : Crystal Radio

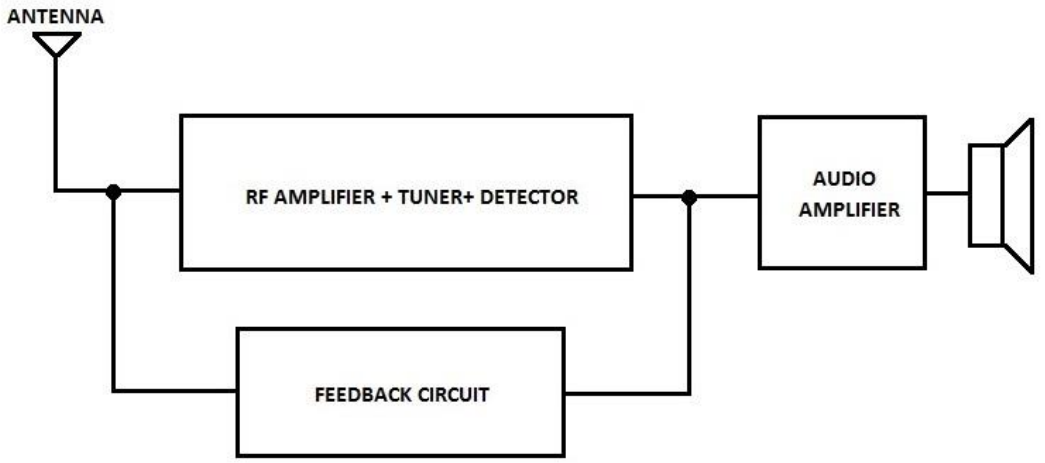
- Crystal radio is the simplest radio receiver circuit, consisting of the bare minimum parts needed for a radio
- It has a tuned circuit and a diode detector that directly power high impedance earphones
- It uses no external power but needs a long antenna and good ground connection to work
- It has low selectivity and would receive all stations at once!



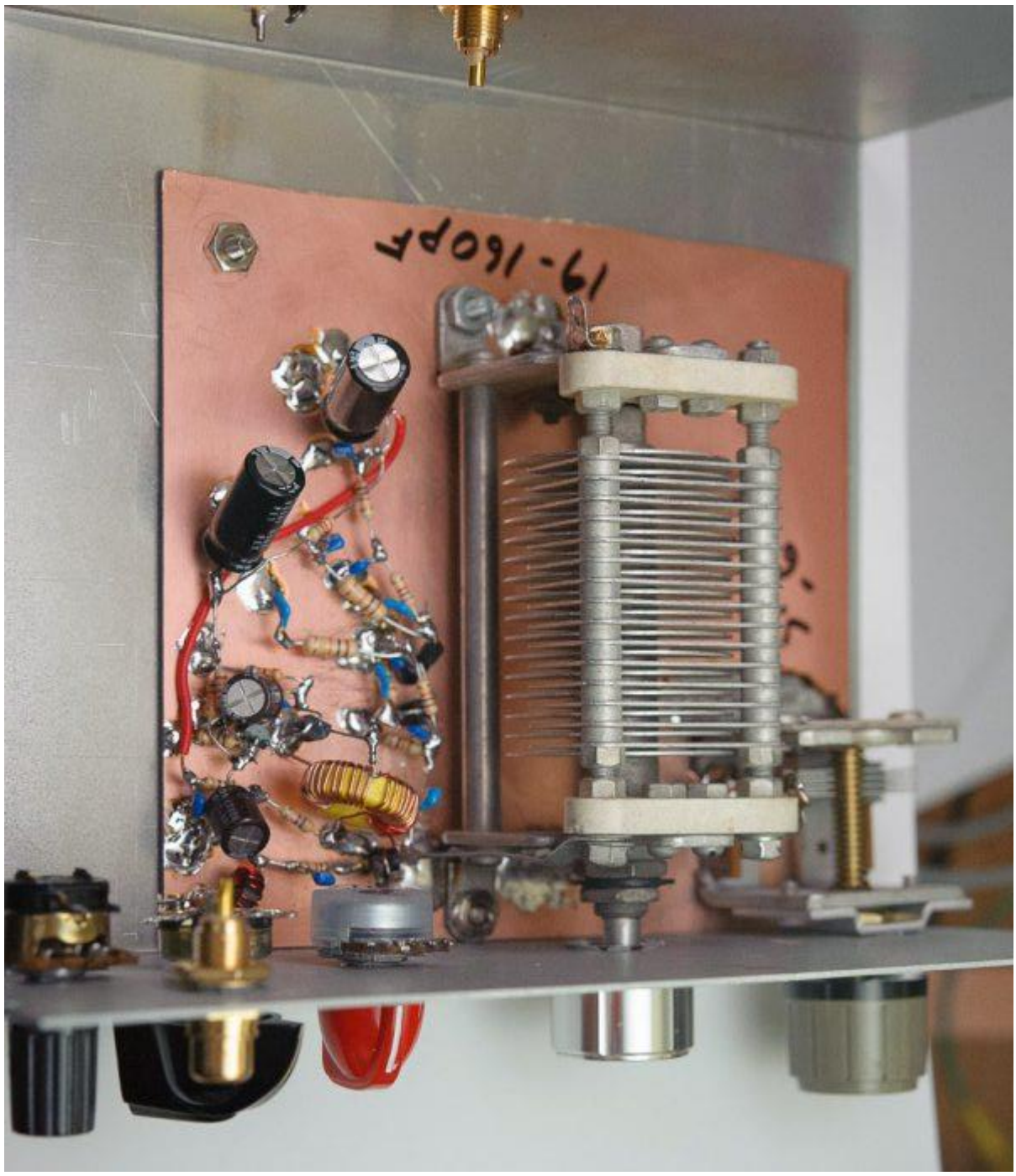

EARPHONE
EARPHONE

Types of Radios : Regenerative Receivers

- A regenerative receiver uses a single active device to amplify the received signal several times before it is detected; “regenerate” the received signal
- Used in early radios; positive feedback design causes it to transmit if not careful
- Tuning was very touchy; one wrong knob twist kills the signal reception

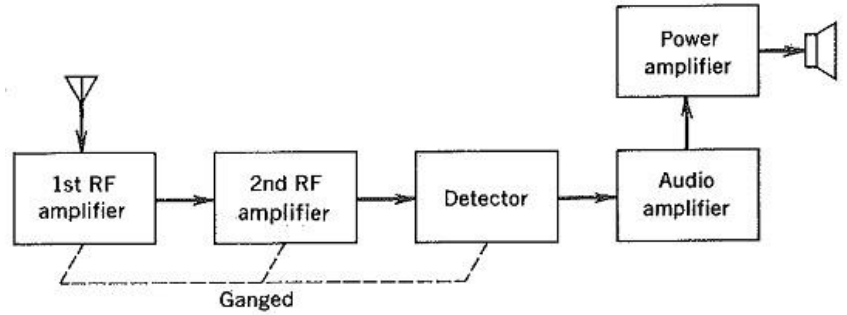


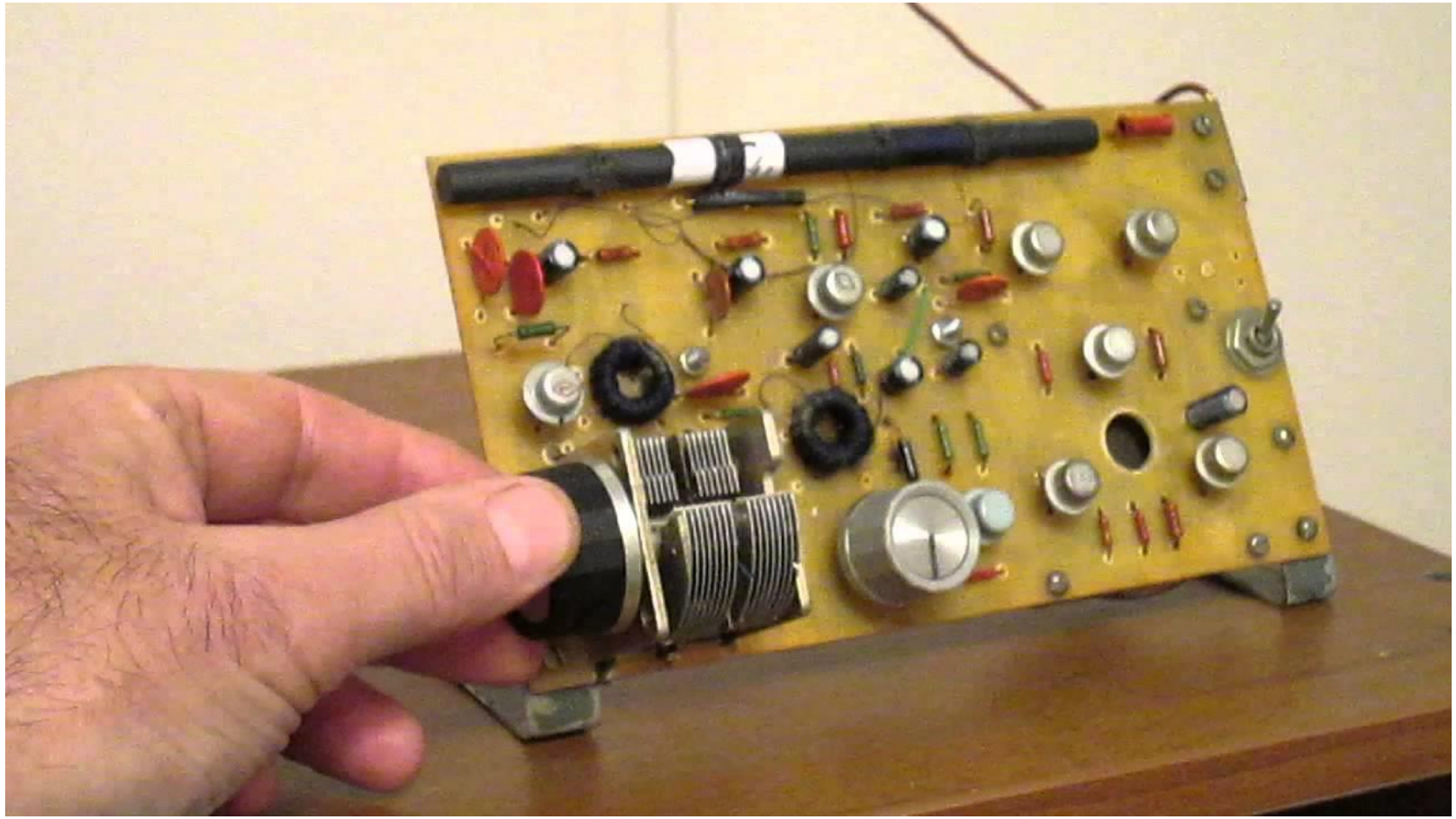

QRPGuys K8TND
Regenerative Receiver
www.qrpguys.com
Volume
Regen
Fine
Tuning
Tuning


19-160PF

Types of Radios : TRF receiver

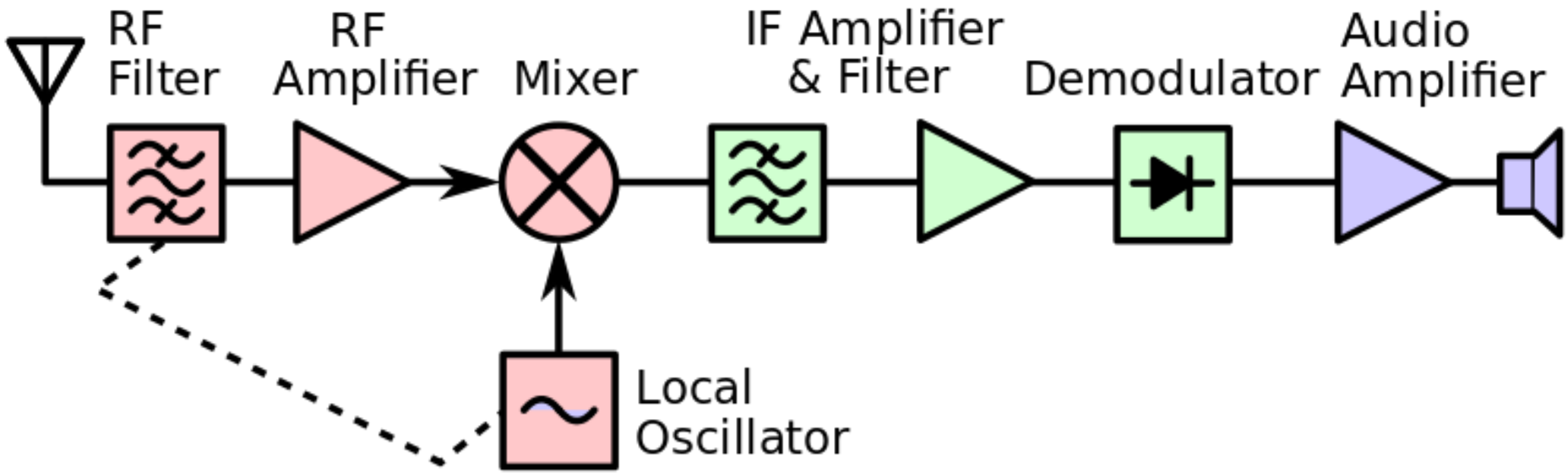
- TRF or Tuned Radio Frequency receivers are radio circuits in which all stages before the detector are tuned to a frequency
- There are usually 2 or 3 RF amplifiers in series, which amplifies only the signal that is desired and rejects other signals acting like a tuner
- They were simple to produce for lower frequencies but get complex on higher frequencies





Types of Radios : Superhet receiver

- Super-heterodyne or “superhet” receiver is the most common type of receiver circuits used in our everyday lives; TV’s, AM/FM radios, Radars, etc.
- Heterodyne means to mix to frequencies together to produce a beat frequency, namely the difference between the two; the term super-heterodyne refers to creating a beat frequency that is lower than the original signal
- In a superhet, the desired frequency is mixed with another frequency (*Intermediate Frequency*); this allows tuned amplifier circuits optimized to a fixed frequency (IF) on which they can work


RF
Filter
RF
Amplifier
Mixer
IF Amplifier
& Filter
Demodulator
Audio
Amplifier
Local
Oscillator

Superhet's explained ..

- The idea behind a super-heterodyne radio is simple; the desired signal (f_1) of a frequency (Ex: 6 MHz) is mixed with a locally generated signal (f_2) (Ex: 5 MHz) in a circuit known as a mixer
- The mixer outputs two sets of frequencies, f_1+ f_2 and f_1- f_2 , i.e. 6+5 MHz = 11 MHz and 6 – 5 MHz = 1 MHz ; both contain the audio from the original signal
- These frequencies are passed on to a fixed frequency (IF) filter (Ex: 1 MHz); Any signals that are converted down and then fall within the limits of the filter will be amplified and passed on to the next stage; Those that fall outside the pass-band of the IF are rejected.

Superhet's explained …

- The filter is designed to reject high frequency signals such as the amplified RF input from the antenna and the locally generated signal fed to our mixer, thus, giving us only the required signal at a much lower frequency than the original frequency
- The filter's output is then fed to the demodulator, which recovers the audio signal and feeds it to the audio amplifier

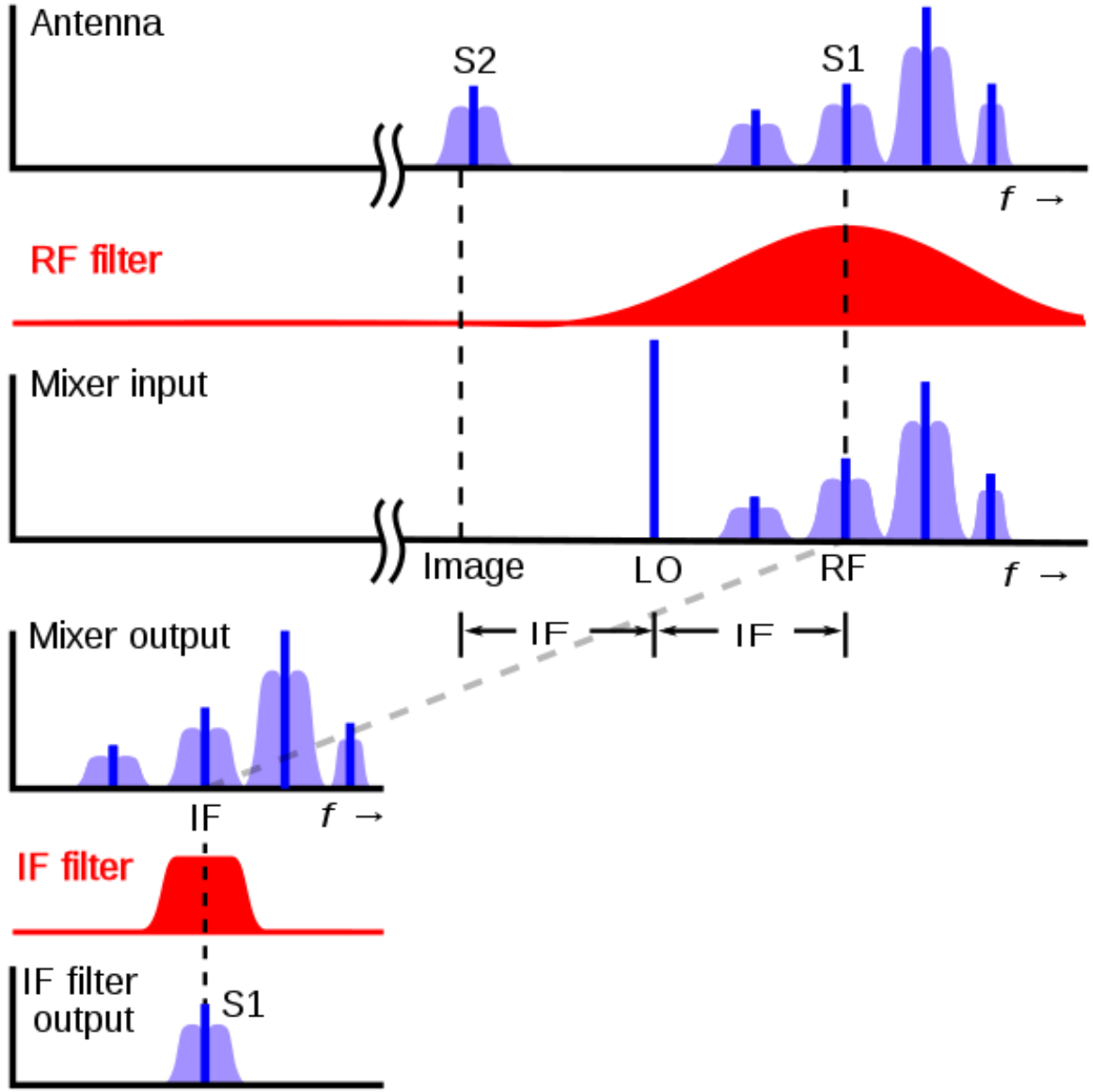

Antenna
S2
S1
f →
RF filter
Mixer input
Image
LO
RF
f →
IF
IF
Mixer output
IF
f →
IF filter
IF filter output
S1

Image frequency – bane of superhets

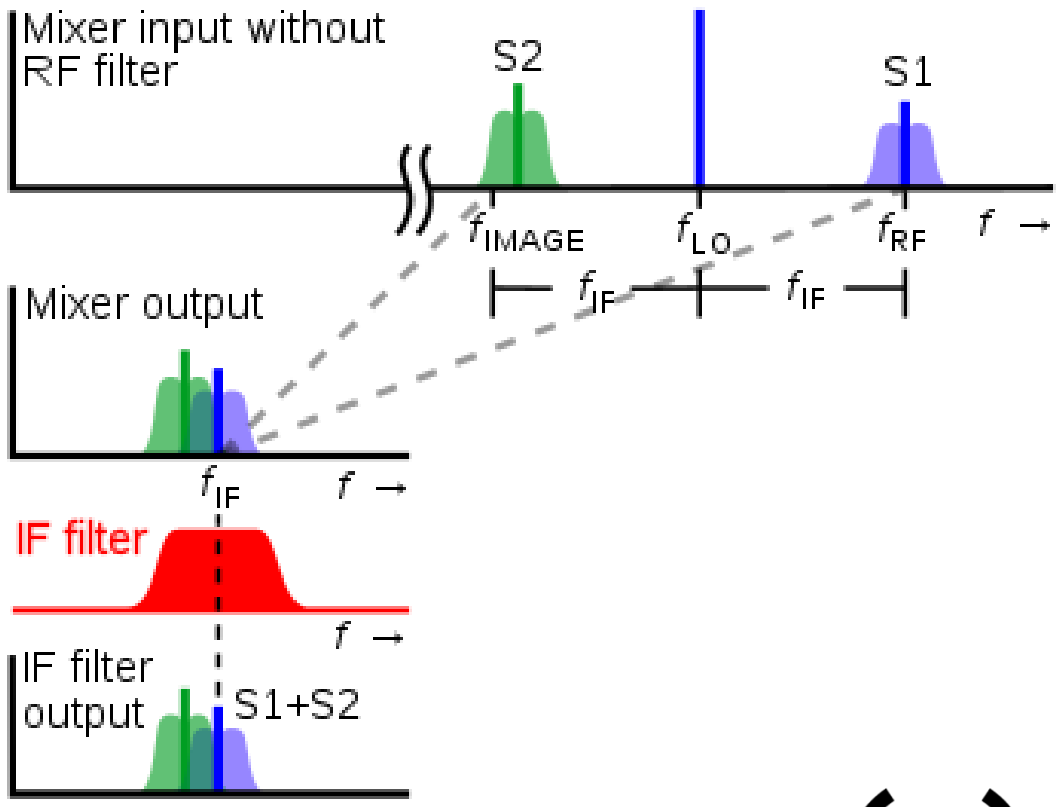
- An image frequency is an undesired input frequency equal to the station frequency plus (or minus) twice the intermediate frequency
- Image frequency results in two stations being received at the same time, thus producing interference
- Image frequencies can be eliminated by using a proper filter on the incoming signal in a super-heterodyne receiver

Understanding Image frequency

For example: an AM broadcast station at 580 kHz is tuned on a receiver with a 455 kHz IF.

The local oscillator is tuned to 580 + 455 = 1035 kHz; But a signal at 580 + 455 + 455 = 1490 kHz is also 455 kHz away from the local oscillator; so both the desired signal and the image, when mixed with the local oscillator, will appear at the intermediate frequency.

This image frequency is within the AM broadcast band. By using a tuned circuit before the mixer, we can prevent the signal entering the mixer, or more correctly reduce its level to an acceptable value



Advantages of superhets

- By reducing to a lower frequency, lower frequency components can be used; No need for expensive high frequency components!
- Superior Selectivity can be achieved by using sharp IF filter which also gives it good sensitivity as it filters unwanted signals at the IF level
- Super-heterodyne receiver designs are scalable, and the same design can be used for other frequencies too due to the fixed frequency IF

Factors of receiver performance

- It is important to have comparison characteristics when describing a receiver's performance or while comparing two receivers
- We use sensitivity, selectivity, noise and fidelity as the factors that affect a receiver's performance characteristics
- Sensitivity is the ability of a receiver to identify, amplify and detect the weakest of signals at its input; how "sensitive" is the receiver to the weakest of signals? It is measured in dBm or microVolts
- Selectivity is a measure of performance of a receiver to respond only to the radio signal it is tuned to (such as a radio station) and reject other signals nearby in frequency; it is measured in dB

Factors of receiver performance ..

- Noise is the limiting factor of sensitivity; since noise sources can be internal or external, we specifically discuss the internal noise, generated by the electronic components in a receiver; it is expressed in Signal to Noise Ratio or in dB
- Signal to Noise Ratio is the ratio of the incoming signal to the mean noise present in a receiver; all receivers will require the signal to exceed the noise by some amount

Receiver add-on’s

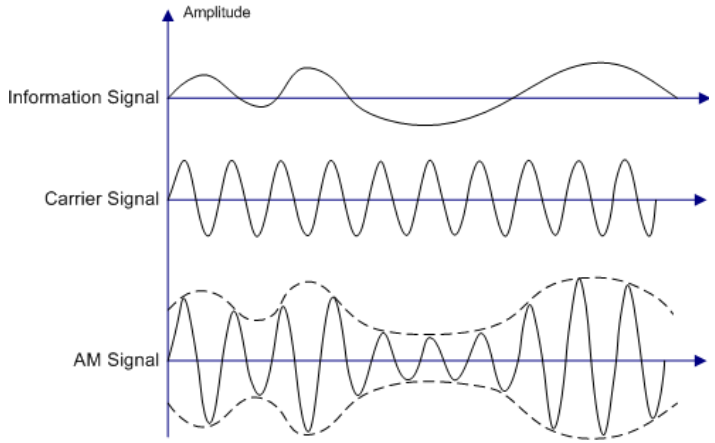
- Automatic Volume or Gain Control (AVC/AGC) is a circuit that keeps the output volume on a receiver constant despite of variations in the input signal; it makes it unnecessary to constantly keep adjusting the volume on a radio when a signal grows weaker or stronger
- Squelch circuits provide an option to mute the audio on a receiver when there is no signal on a frequency; it unmutes the audio circuit only when the received signal crosses a certain minimum level

Types of modulation

- Modulation is the process of adding information or intelligence to a waveform; in simple terms, it's the process of adding voice to a RF wave
- There are 3 main types of modulation; Amplitude Modulation, Frequency Modulation, Phase Modulation, and Continuous Wave
- In India, AM and FM transmissions are commercially used in radio broadcasting; for analog TV transmissions Voice channel is FM and Video channel is AM

Amplitude Modulation

- Amplitude Modulation, or AM, is the oldest forms of voice transmission (1901); it is still in use today in commercial broadcasting and aviation industry
- In an AM Signal, a wave of constant frequency (Carrier wave) has its amplitude vary according to the audio signal

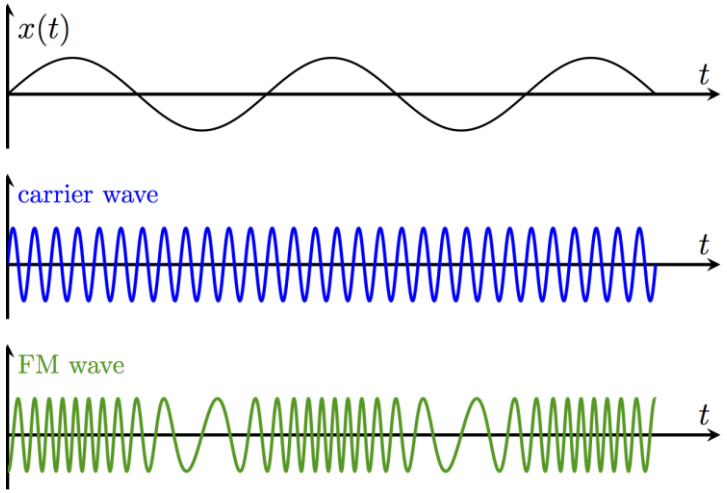


AM – advantages and disadvantages

Advantages	Disadvantages
• Simple to implement a transmitter	• Not an efficient form of transmission; power hungry
• Can be demodulated with a few components/minimal circuitry	• Not efficient in terms of signal size (bandwidth), bandwidth is twice the size of max. audio freq.
• Receivers can be made cheaply – better consumer reach	• Most noise is amplitude based, hence it is noisy and sensitive to electrically noisy environments

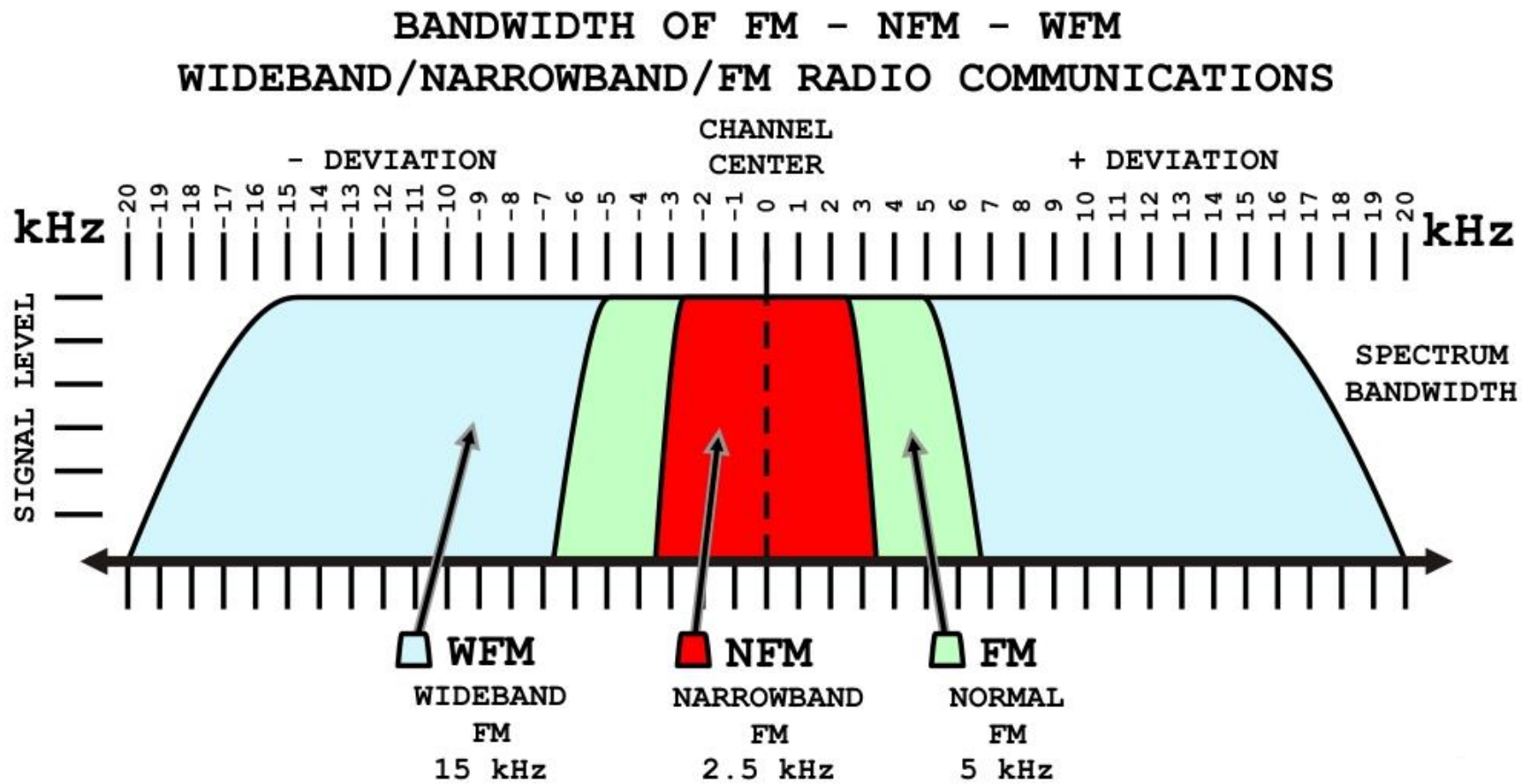
Frequency Modulation

- Frequency Modulation, or FM, is another popular choice of voice transmission; It is almost as old as AM but gained acceptance only by the 60's
- In FM, a wave of constant amplitude has its frequency vary according to the audio signal



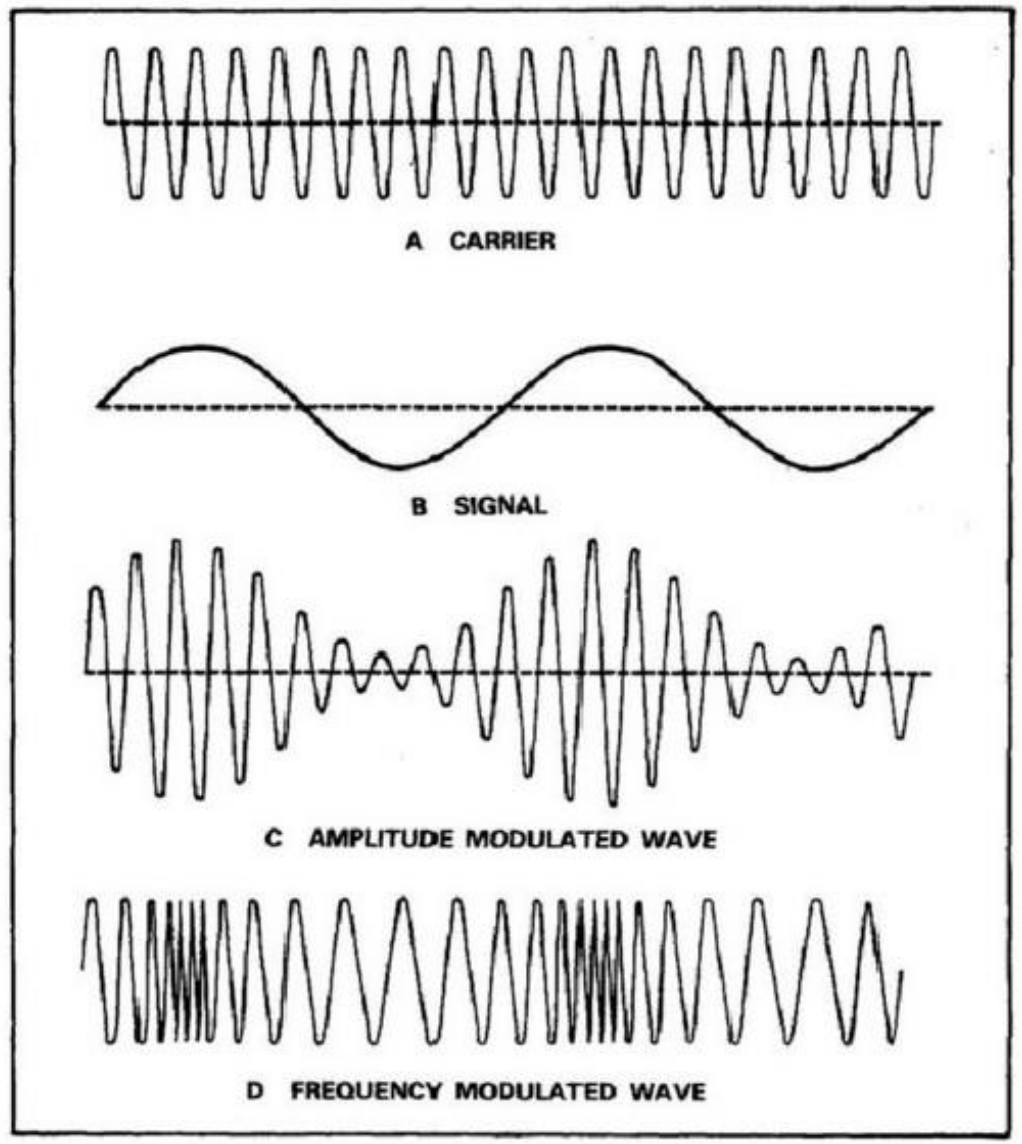
Wide and Narrow Band FM

- The amount by which an FM signal varies is known as its deviation; For example if an FM signal at 100 MHz has a deviation of 4 KHz, its carrier can move anywhere from 99.8 MHz to 100.2 MHz (± 4 KHz)
- Deviation is important as it determines the size (bandwidth) of the signal
- Commercial FM broadcast stations (88-105 MHz) have a deviation of about 75 KHz, to support high quality audio transmission; this is known as Wide-Band FM (WBFM) – occupies lot of spectrum!
- 2-way communication users such as amateur radio users do not care about voice quality as much as conserving spectrum and, hence, use a lower bandwidth of about 2.5-3.5 KHz – this is known as Narrow- Band FM (NBFM) – more users in given spectrum!


BANDWIDTH OF FM - NFM - WFM
WIDEBAND/NARROWBAND/FM RADIO COMMUNICATIONS
CHANNEL
CENTER
- DEVIATION
+ DEVIATION
kHz
kHz
-20 -19 -18 -17 -16 -15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
SIGNAL LEVEL
SPECTRUM
BANDWIDTH
WFM
WIDEBAND
FM
15 kHz
NFM
NARROWBAND
FM
2.5 kHz
FM
NORMAL
FM
5 kHz

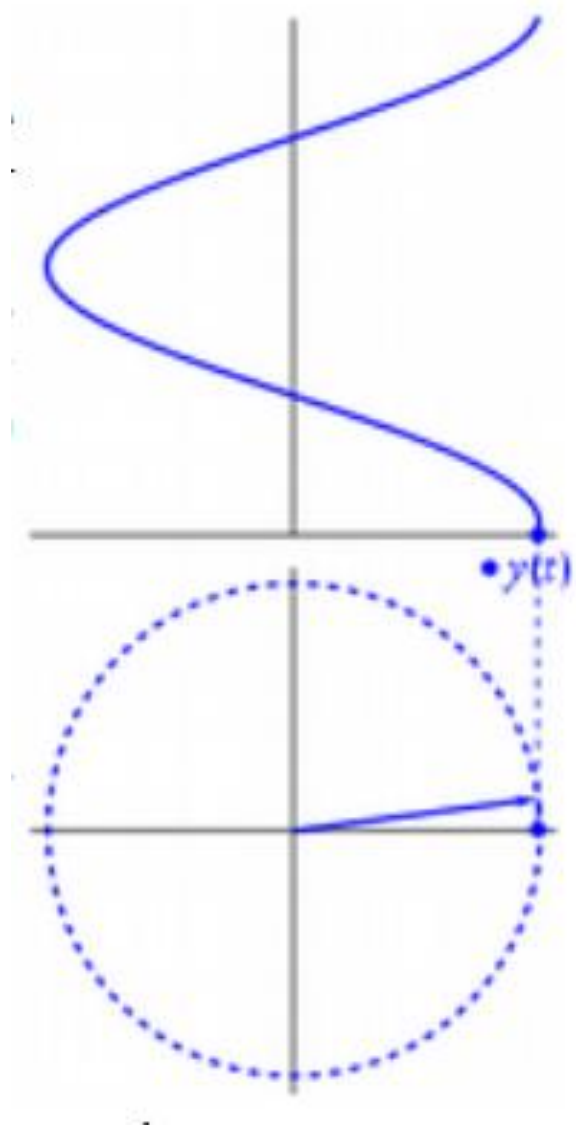
FM – advantages and disadvantages

Advantages	Disadvantages
• Resilient to Noise	• Requires complex circuitry to demodulate
• Transmission equipment is efficient	• Not efficient in terms of signal size (bandwidth) compared to other modes
• Resilient to signal strength fluctuations	• Fm filters used to limit bandwidth introduce slight distortion


A CARRIER
B SIGNAL
C AMPLITUDE MODULATED WAVE
D FREQUENCY MODULATED WAVE

Recap : Phase

- A radio frequency signal consists of an oscillating carrier in the form of a sine wave is the basis of the signal
- The instantaneous amplitude follows this curve moving positive and then negative, returning to the start point after one complete cycle - it follows the curve of the sine wave.
- This can also be represented by the movement of a point around a circle, the phase at any given point being the angle between the start point and the point on the waveform.

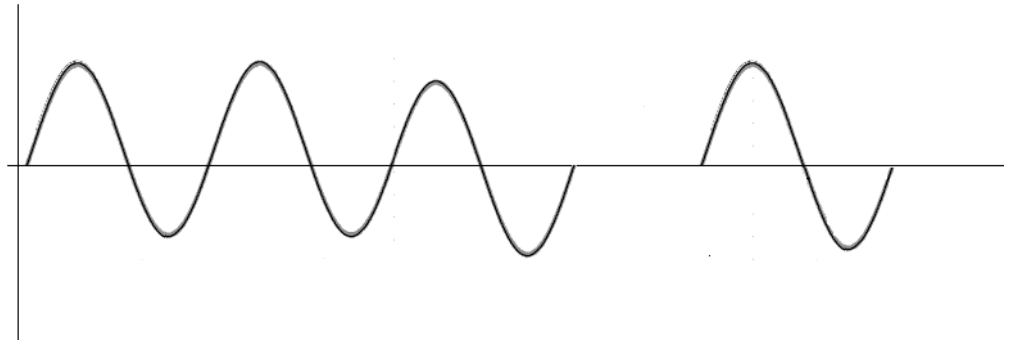

y(t)

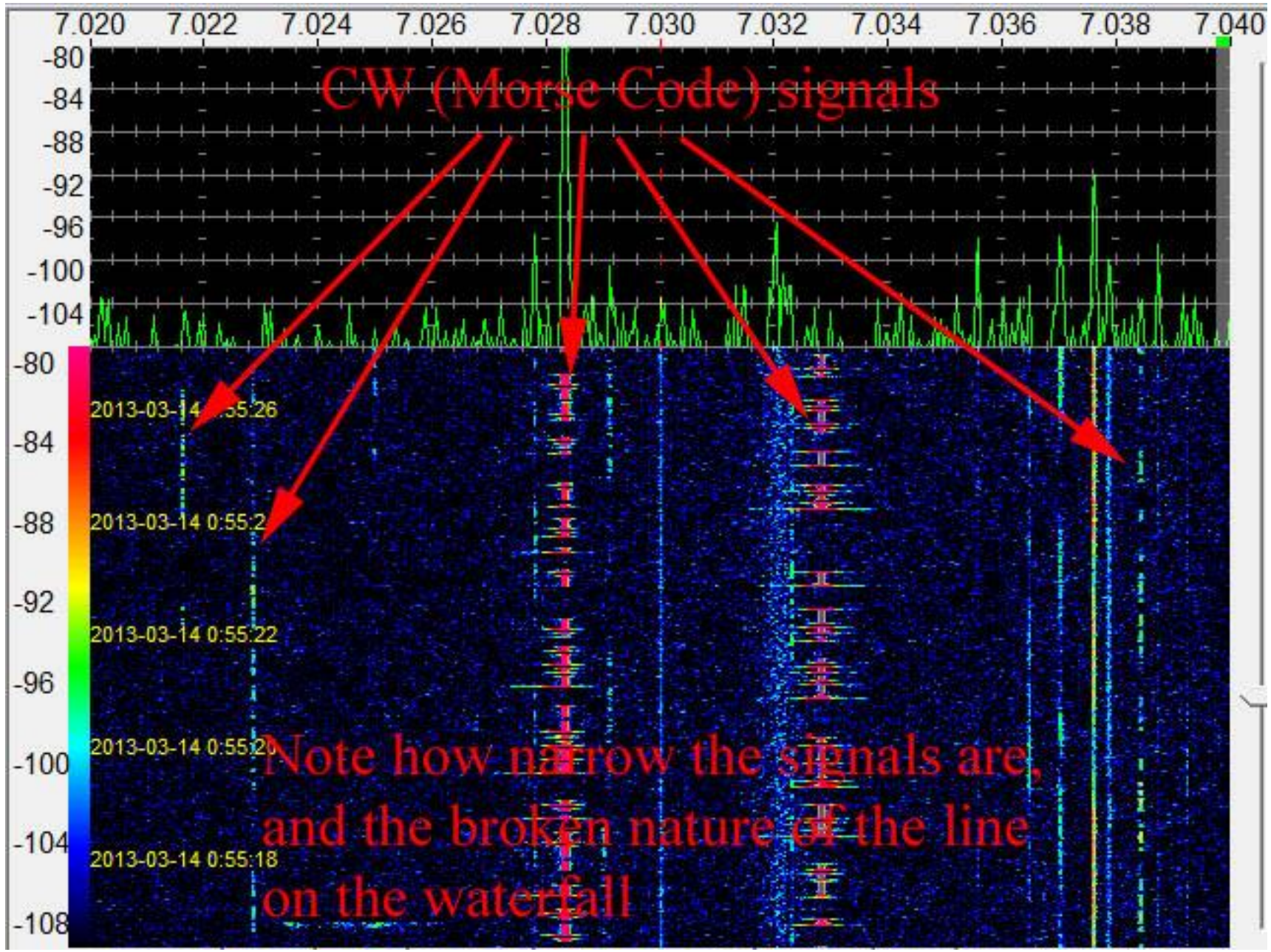
Phase Modulation

- Phase Modulation, or PM, is a modulation pattern that encodes information as variations in the instantaneous phase of a carrier wave
- It is not widely used for broadcasting due to complexity in the hardware but is widely used for transmitting digital information
- Phase modulation works by modulating the phase of the signal, i.e. changing the rate of change of phase according to the input
- There is some slight changes in the frequency in a PM signal due to the interlinked nature of phase and frequency

Continuous Wave

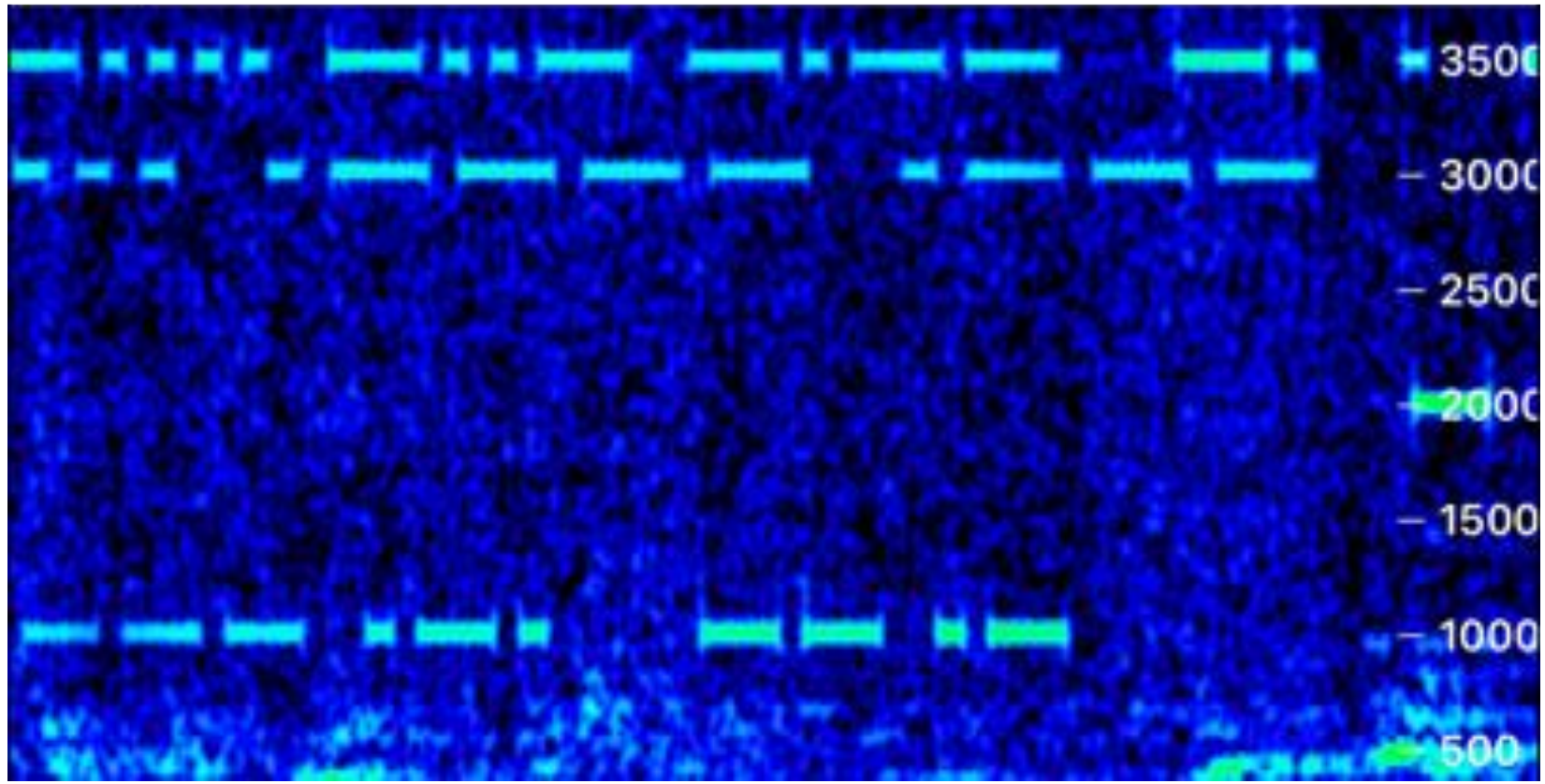
- Continuous wave (CW) is also the name given to an early method of radio transmission, in which a carrier wave is switched on and off ; A continuous wave or continuous waveform (CW) is an electromagnetic wave of constant amplitude and frequency of infinite duration
- Information is carried in the varying duration of the on and off periods of the signal, for example by Morse code, in early radio.




7.020
7.022
7.024
7.026
7.028
7.030
7.032
7.034
7.036
7.038
7.040
-80
-84
-88
-92
-96
-100
-104
CW (Morse Code) signals
2013-03-14 0:55:26
2013-03-14 0:55:2
2013-03-14 0:55:22
2013-03-14 0:55:20
2013-03-14 0:55:18
Note how narrow the signals are,
and the broken nature of the line
on the waterfall

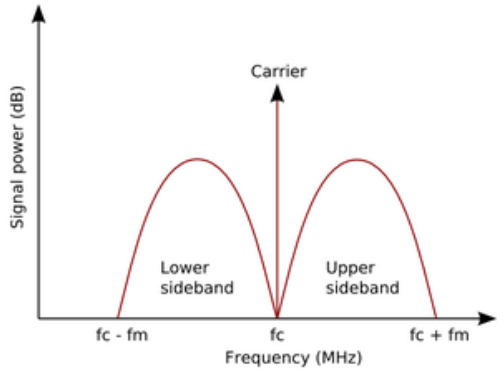
Hearing CW - BFO

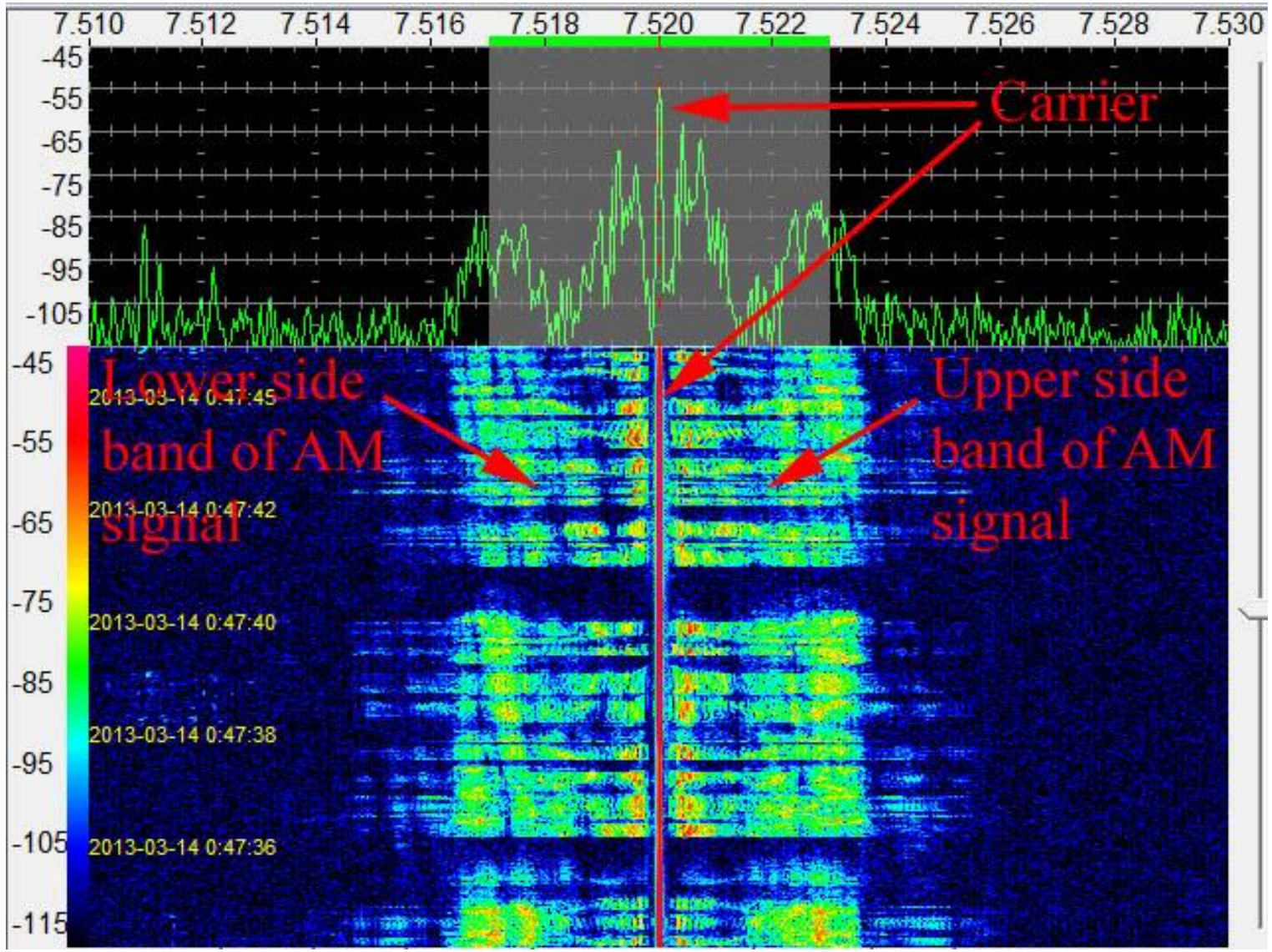
- CW is transmitted as an unmodulated carrier; to make it audible, a BFO (Beat Frequency Oscillator) is used as the carrier signal is removed in a superhet by its IF filter
- The frequency of the BFO is a few hundred Hz lower or higher than the frequency of the CW signal; an audio tone with a tone height equal to the difference of the frequencies of the CW signal and the BFO oscillator is produced by injecting the BFO signal into the demodulator
- Without a BFO, CW signals sound like the receiver audio muting during the dits and dahs; the BFO re introduces the tone


3500
3000
2500
2000
1500
1000
500

Single Sideband (SSB)

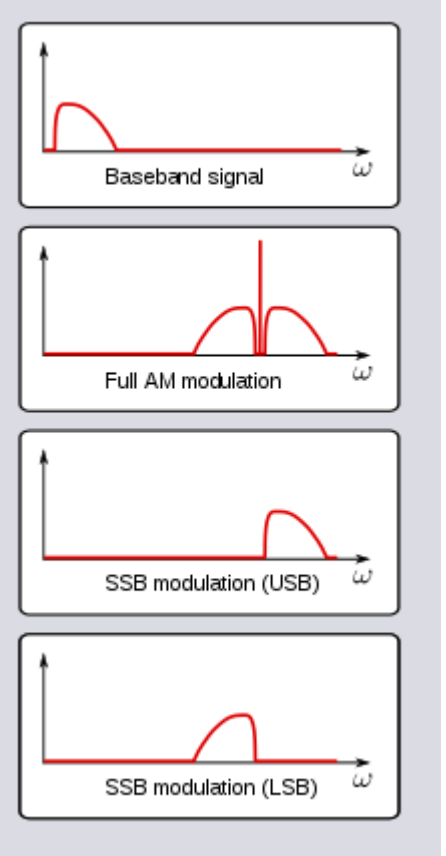
- AM is the simplest and easiest form of voice modulation, but they are not efficient in terms of power and spectral usage
- An AM signal consists of a carrier signal in the middle and two sets of frequencies, known as sidebands
- There are two sidebands; upper (USB) and lower (LSB) sidebands , which contain the modulated audio

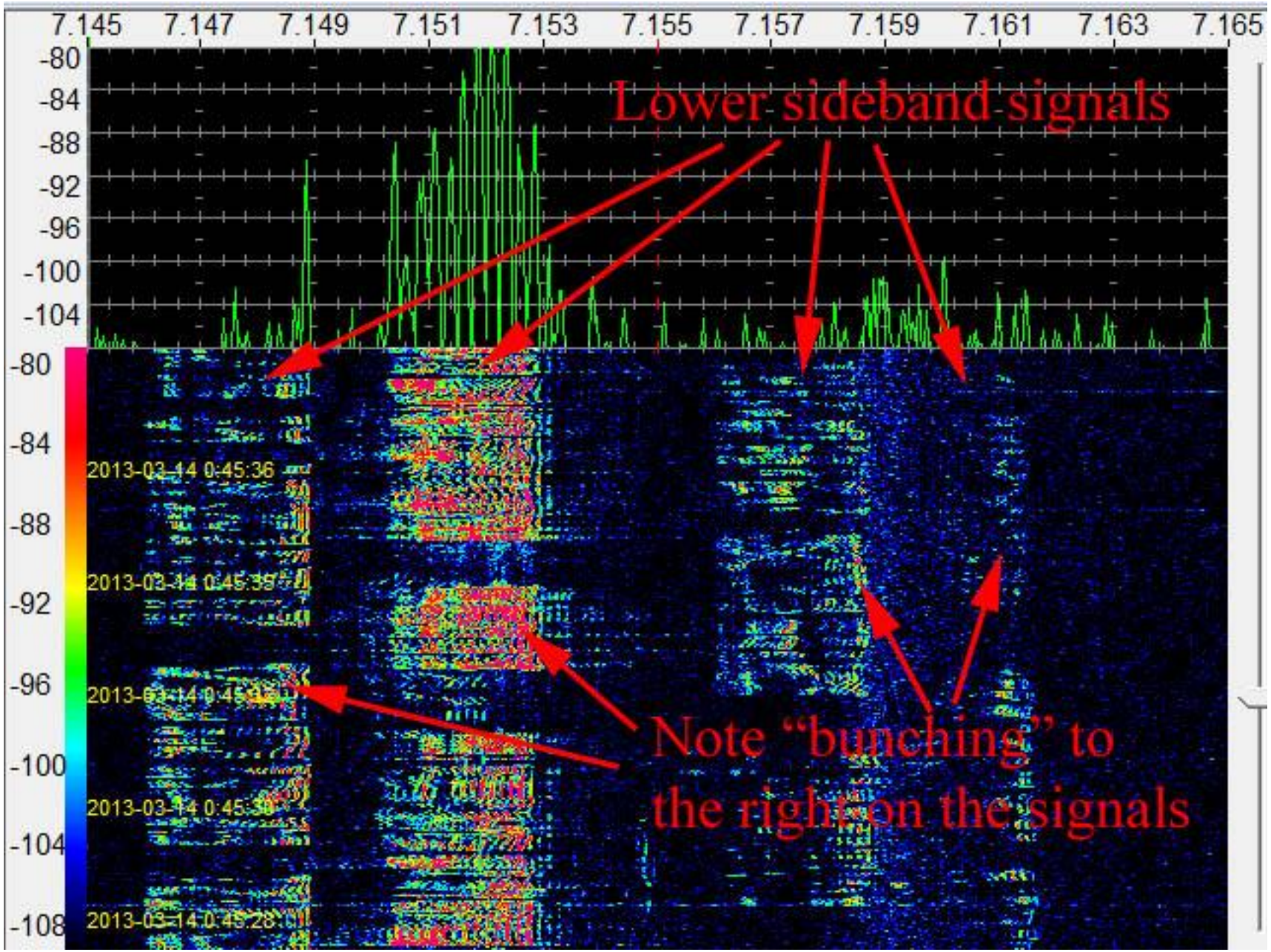


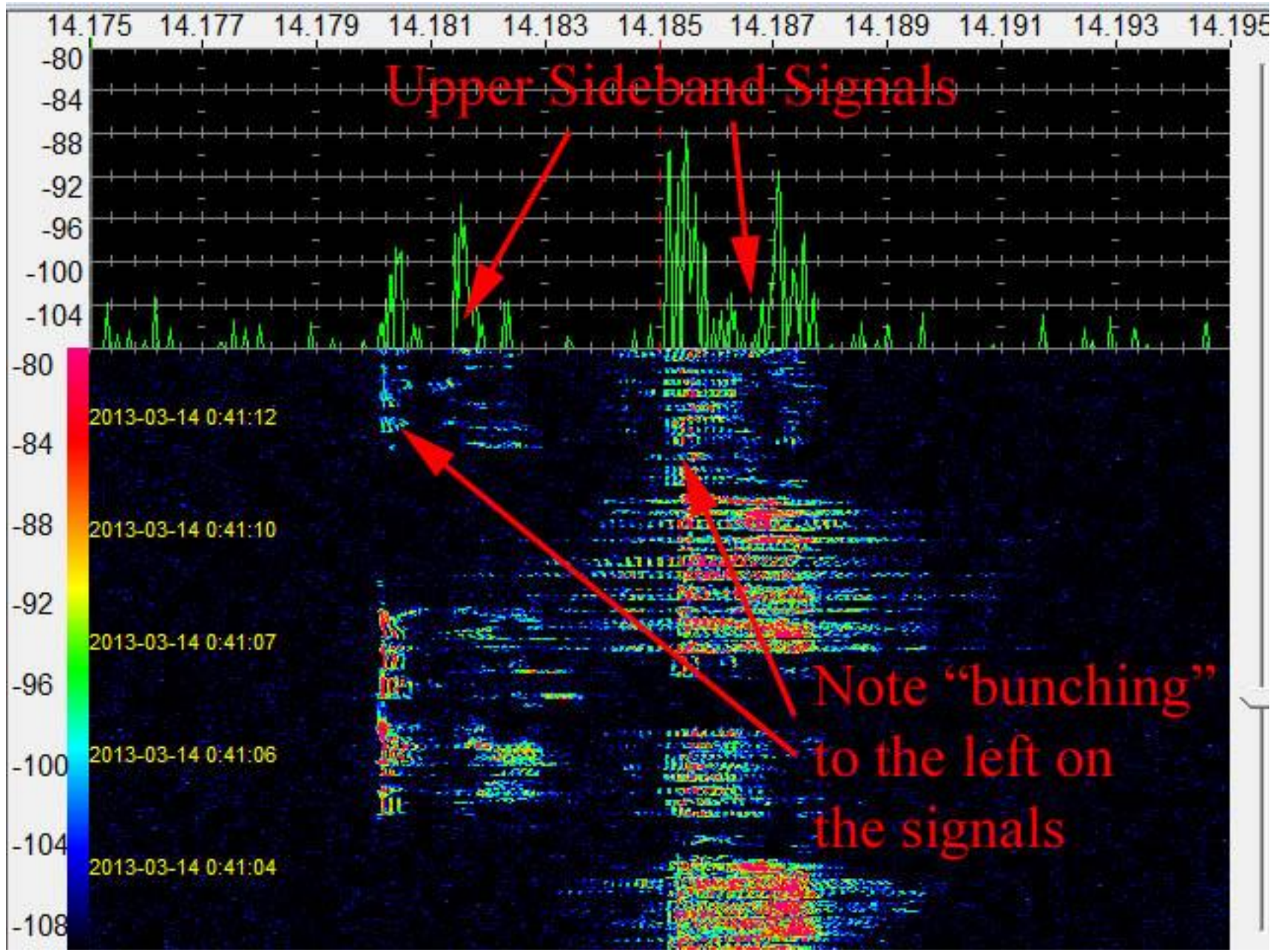

7.510
7.512
7.514
7.516
7.518
7.520
7.522
7.524
7.526
7.528
7.530
-45
-55
-65
-75
-85
-95
-105
Carrier
Lower side band of AM signal
Upper side band of AM signal
2013-03-14 0:47:45
2013-03-14 0:47:42
2013-03-14 0:47:40
2013-03-14 0:47:38
2013-03-14 0:47:36
-115

Single Sideband

- Single sideband is a method of modulation in which the carrier and one of the sidebands are eliminated
- This results in an efficient signal in which the transmitted power is not wasted on the carrier and one of the sidebands
- In a superhet, a BFO is needed to reintroduce the audio component, otherwise the audio sounds like ‘Donald Duck’
- LSB below 10MHz and USB above 10 MHz is the norm, although it can vary based on the use




7.145
7.147
7.149
7.151
7.153
7.155
7.157
7.159
7.161
7.163
7.165
-80
-84
-88
-92
-96
-100
-104
Lower sideband signals
2013-03-14 0:45:36
2013-03-14 0:45:33
2013-03-14 0:45:30
2013-03-14 0:45:28
-108
Note "bunching" to
the right on the signals


14.175
14.177
14.179
14.181
14.183
14.185
14.187
14.189
14.191
14.193
14.195
-80
-84
-88
-92
-96
-100
-104
Upper Sideband Signals
2013-03-14 0:41:12
2013-03-14 0:41:10
2013-03-14 0:41:07
2013-03-14 0:41:06
2013-03-14 0:41:04
-108
Note "bunching"
to the left on
the signals

Thank you!

Questions and doubts in the chat box!

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