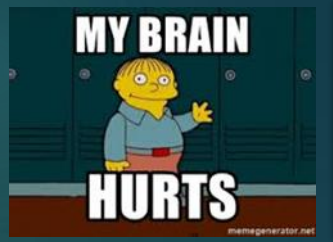
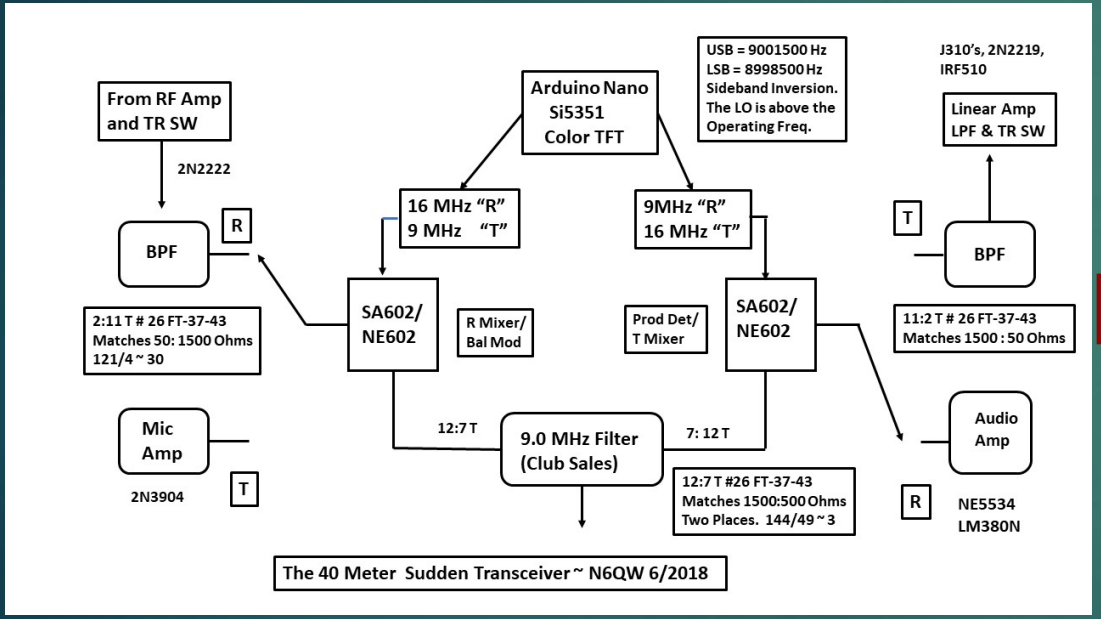


Sideband Inversion, Carrier Suppression and all that…

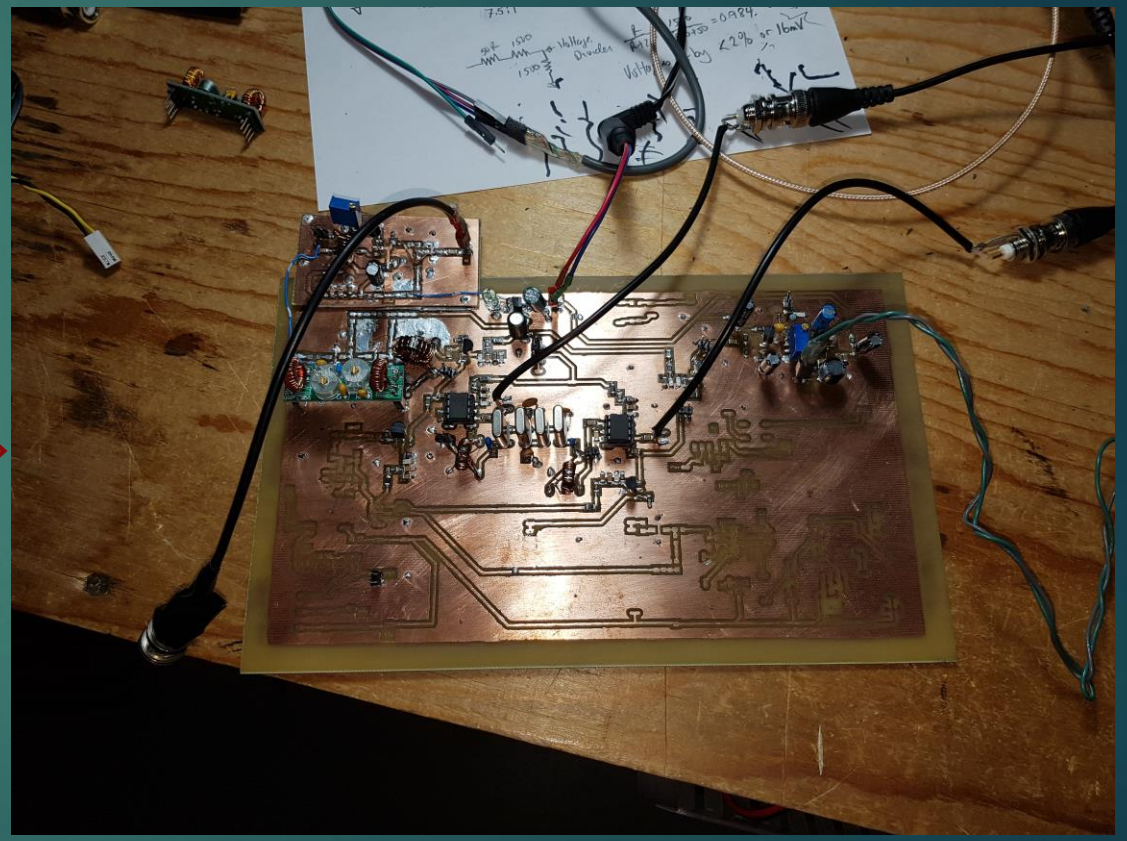
Note: This is only applicable if you are designing your own Superhet Radio.
Kits and commercial radios account for sideband inversion

Dave VE3OOI

How it Started?



Modified for Multiband and 12 MHz IF



Dueling 612's Transceiver

SIDEBAND INVERSION

- Sometimes referred to as spectrum inversion
- Swapping of LSB (Lower Side band) and USB (Upper Side Band) depending on how mixing is done
- High Side Injection: Happens when LO (Local Oscillator) frequency is higher than incoming RF (Radio Frequency) input signal. Alternatively, IF (Intermediated Frequency) is lower that LO
  - i.e., LO > RF, or IF < LO

You could start out with an UPPER sideband signal coming out of your sideband generator, then, after you mix it with your VFO (or Si5351!) you end up with a LOWER sideband signal.

Bill Meara, N2CQR

Sideband reversal occurs in mixing only if the signal with the modulation is subtracted from the signal that isn't modulated.

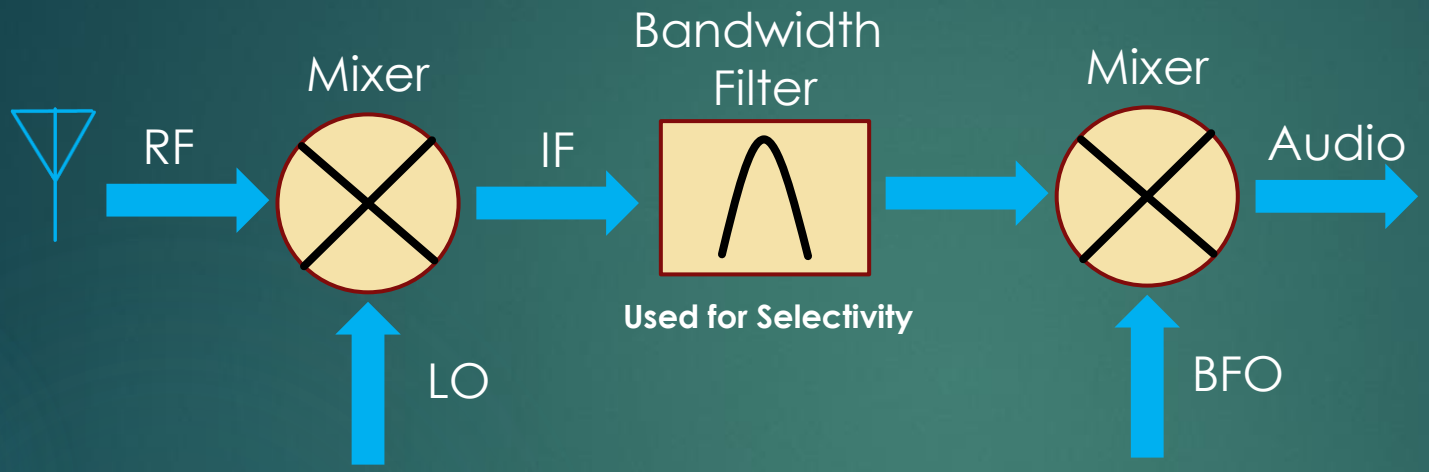
Joel Hallas, W1ZR

Wikipedia Says….

As an example, consider an IF SSB signal centered at frequency F_{if} = 45000 Hz. The baseband frequency it needs to be shifted to is F_b = 2000 Hz. The BFO output waveform is $\cos(2\pi \cdot F_{\text{bfo}} \cdot t)$. When the signal is multiplied by (aka *heterodyned with*) the BFO waveform, it shifts the signal to $(F_{\text{if}} + F_{\text{bfo}})$, *and* to $|F_{\text{if}} - F_{\text{bfo}}|$, which is known as the *beat frequency* or *image frequency*. The objective is to choose an F_{BFO} that results in $|F_{\text{if}} - F_{\text{bfo}}| = F_b$ = 2000 Hz. (The unwanted components at $(F_{\text{if}} + F_{\text{bfo}})$ can be removed by a lowpass filter; for which an output transducer or the human ear may serve).

There are two choices for F_{bfo}: 43000 Hz and 47000 Hz, called *low-side* and *high-side* injection. With high-side injection, the spectral components that were distributed around 45000 Hz will be distributed around 2000 Hz in the reverse order, also known as an inverted spectrum. That is in fact desirable when the IF spectrum is also inverted, because the BFO inversion restores the proper relationships. One reason for that is when the IF spectrum is the output of an inverting stage in the receiver. Another reason is when the SSB signal is actually a lower sideband, instead of an upper sideband. But if both reasons are true, then the IF spectrum is not inverted, and the non-inverting BFO (43000 Hz) should be used.

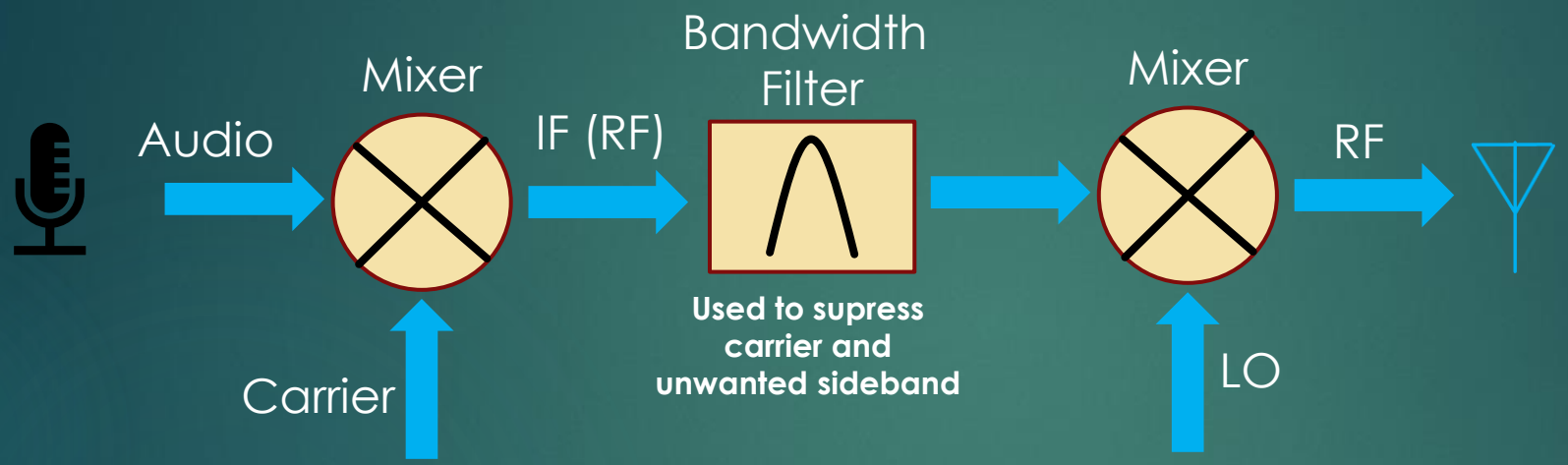
BACK TO BASICS: SUPERHETERODYNE RECEIVER



- Mix incoming radio frequency (RF) signal (from Antenna) to an intermediate frequency (IF)
- Use filter to limit bandwidth and improve selectivity
- E.g., bandwidth of 700 Hz for CW, 3KHz for SSB

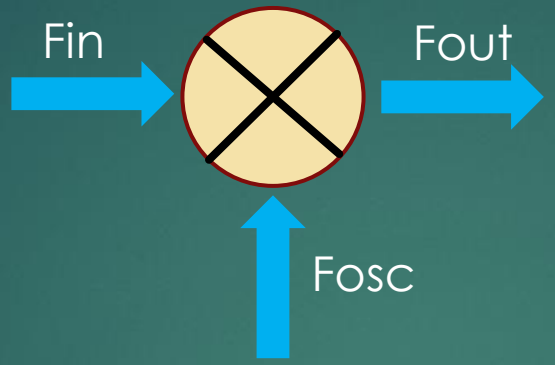
A **superheterodyne receiver**, often shortened to **superhet**, is a type of radio receiver that uses frequency mixing to convert a received signal to a fixed intermediate frequency (IF) which can be more conveniently processed than the original carrier frequency. It was long believed to have been invented by US engineer Edwin Armstrong, but after some controversy the earliest patent for the invention is now credited to French radio engineer and radio manufacturer Lucien Lévy.[1][*unreliable source?*] Virtually all modern radio receivers use the superheterodyne principle; except those software-defined radios using *direct sampling*.

BACK TO BASICS: SUPERHETERODYNE TRANSMITTER



- Mix/Modulate incoming audio signal (microphone) with a carrier (Oscillator) to an intermediate frequency (IF) which is RF
- Filter IF to only pass desired sideband (i.e., supress carrier and other sideband)
- Limit bandwidth to be transmitted
- Mix IF with another Oscillator to generate desired RF to antenna

BACK TO BASICS: MIXING

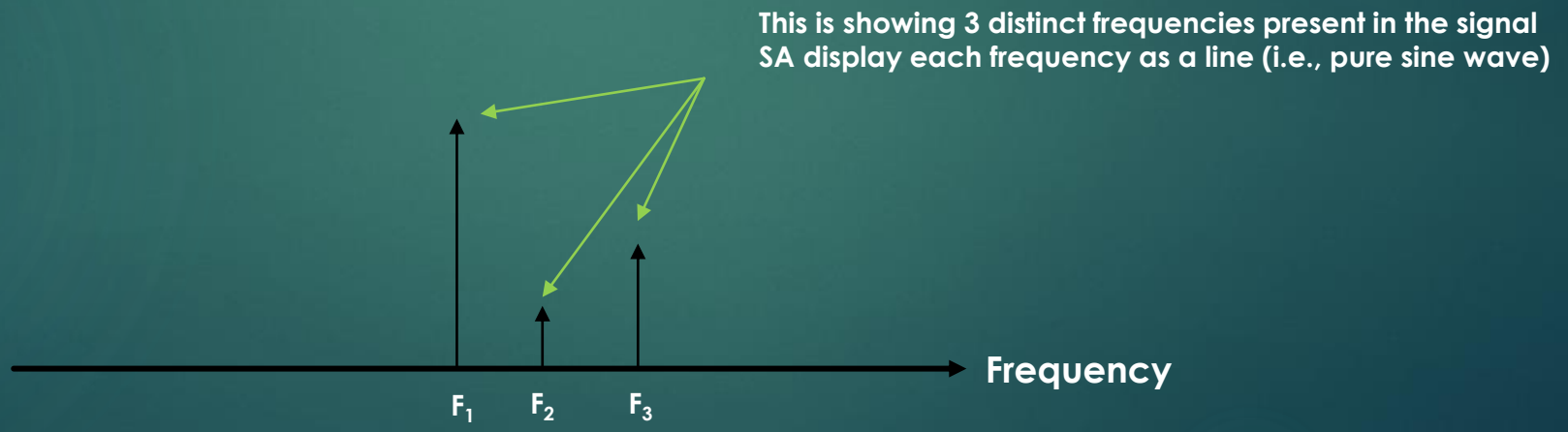


- Fout = m x Fosc +/- n x Fin (for all m & n)
- That is,
  - Fout = m x Fosc – n x Fin
  - Fout = m x Fosc + n x Fin
- m and n represents harmonic number (1st harmonic, 2nd harmonic, etc.)
- Let's only consider the fundamental frequency
- Let's assume m=1 and n=1
  - $Fout_1$ = Fosc – Fin
  - $Fout_2$ = Fosc + Fin

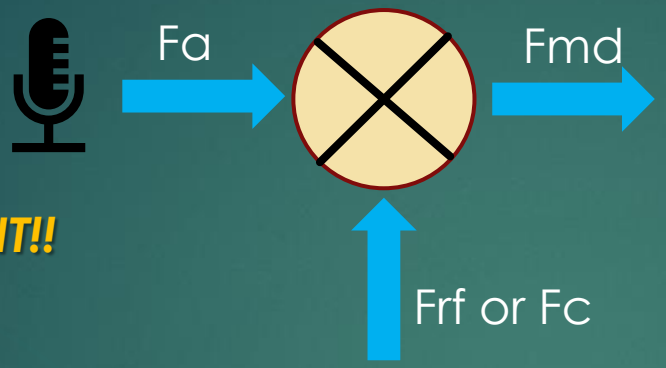
CONVENTION

1. From here on I will be discussing frequency domain. It's the output in a spectrum analyzer

2. In the time domain, we use an Oscilloscope which does not distinguish multiple frequencies



BACK TO BASICS: GENERATING SIDE BANDS

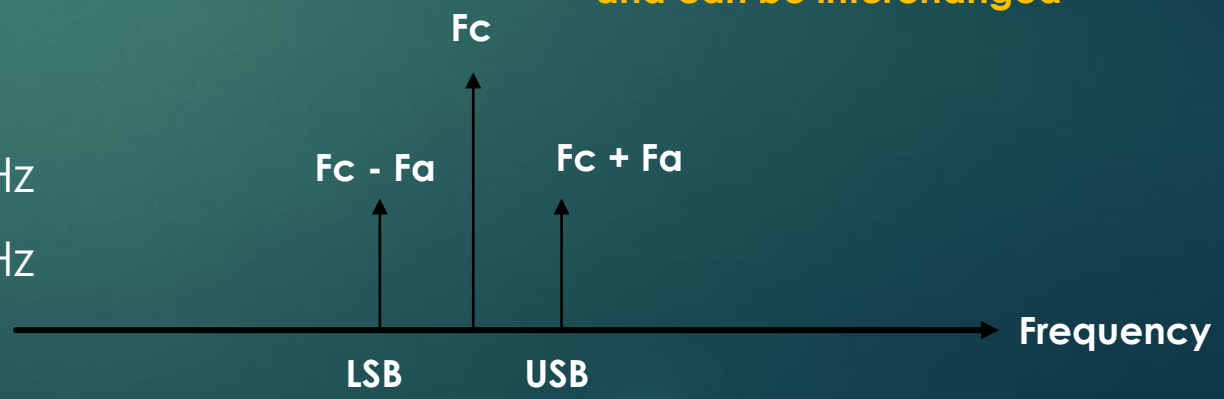


Fa = Audio Frequency (e.g., 1500 Hz)
Frf or Fc = Radio Frequency Carrier (e.g., 7.1 MHz)
Fmd= Modulated Radio Frequency output

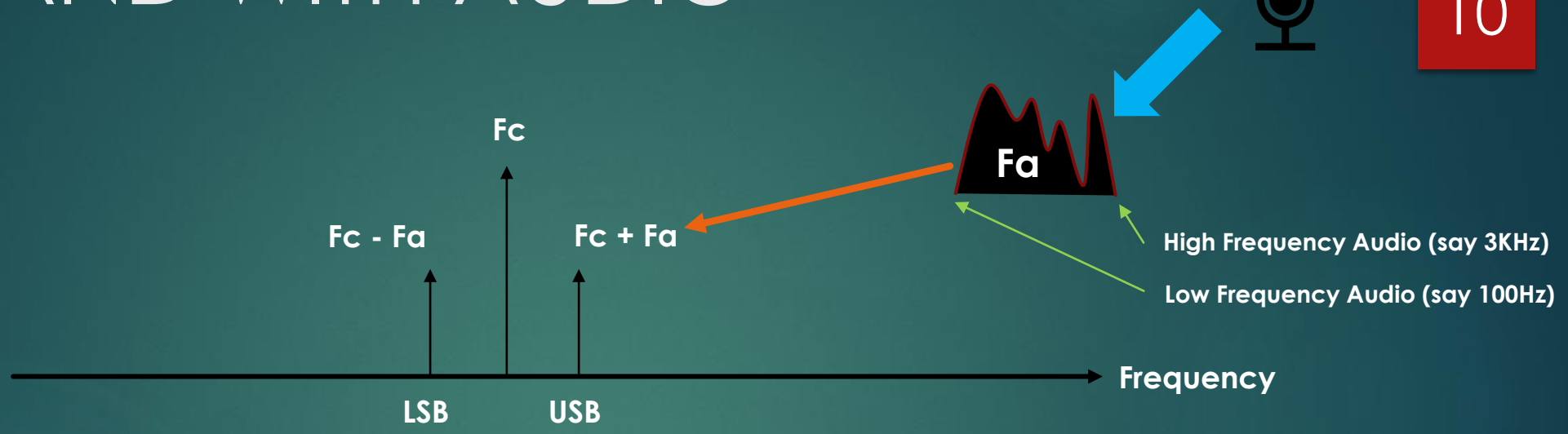
THIS IS VERY IMPORTANT!!

- Let's mix (modulate) a carrier radio frequency (e.g., 7.1 MHz) with an audio frequency (e.g., 1500 Hz). *Remember m=n=1 i.e., Fundamental only*
  - Fmd = Frf + Fa = Fc + Fa (USB)
  - Fmd = Frf – Fa = Fc – Fa (LSB)
- E.g.
  - Fc + Fa (USB) = 7100000 + 1500 = 7101500 Hz
  - Fc – Fa (LSB) = 7100000 - 1500 = 7098500 Hz

Note: USB and LSB are identical and can be interchanged



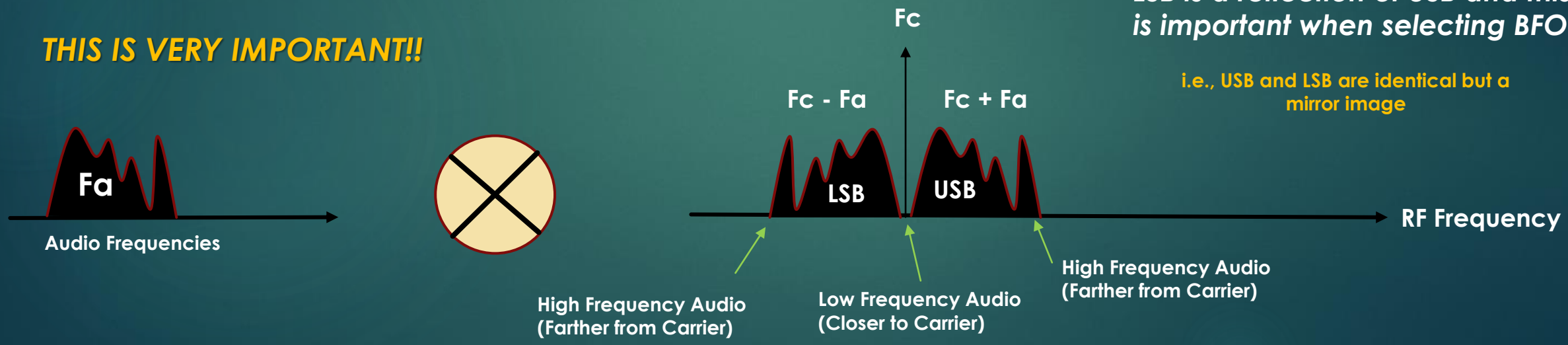
SIDEBAND WITH AUDIO



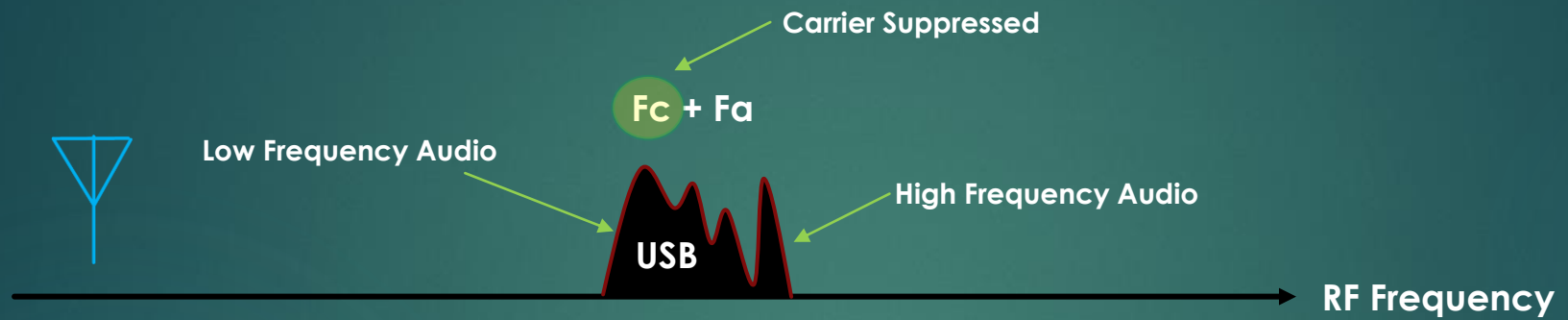
THIS IS VERY IMPORTANT!!

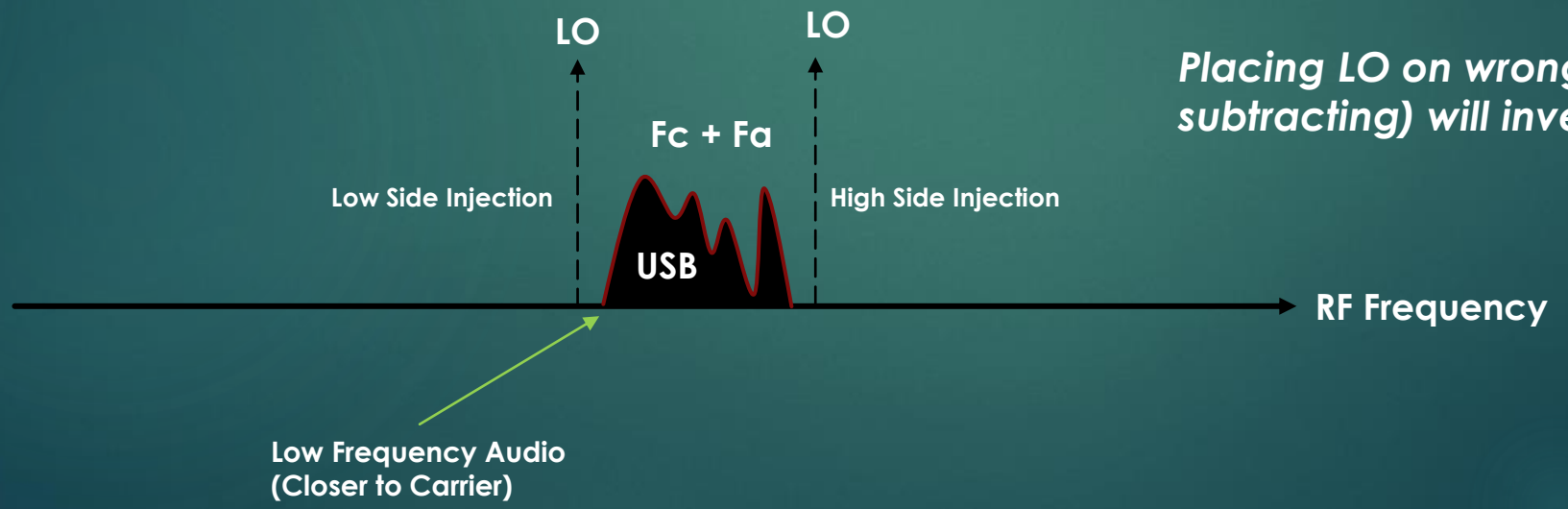
LSB is a reflection of USB and this is important when selecting BFO !!

i.e., USB and LSB are identical but a mirror image



SINGLE SIDEBAND SUPRESSED CARRIER TRANSMISSION

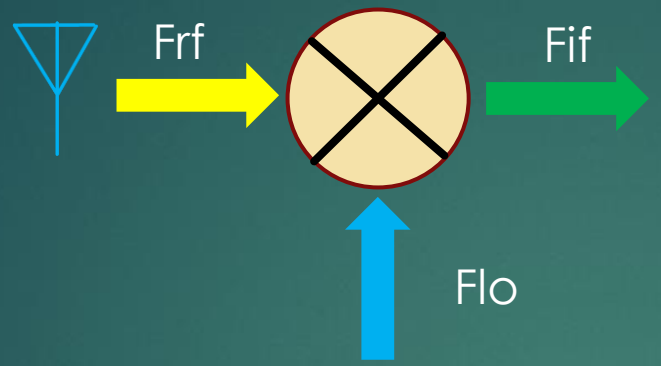




Placing LO on wrong side (and subtracting) will invert the audio.

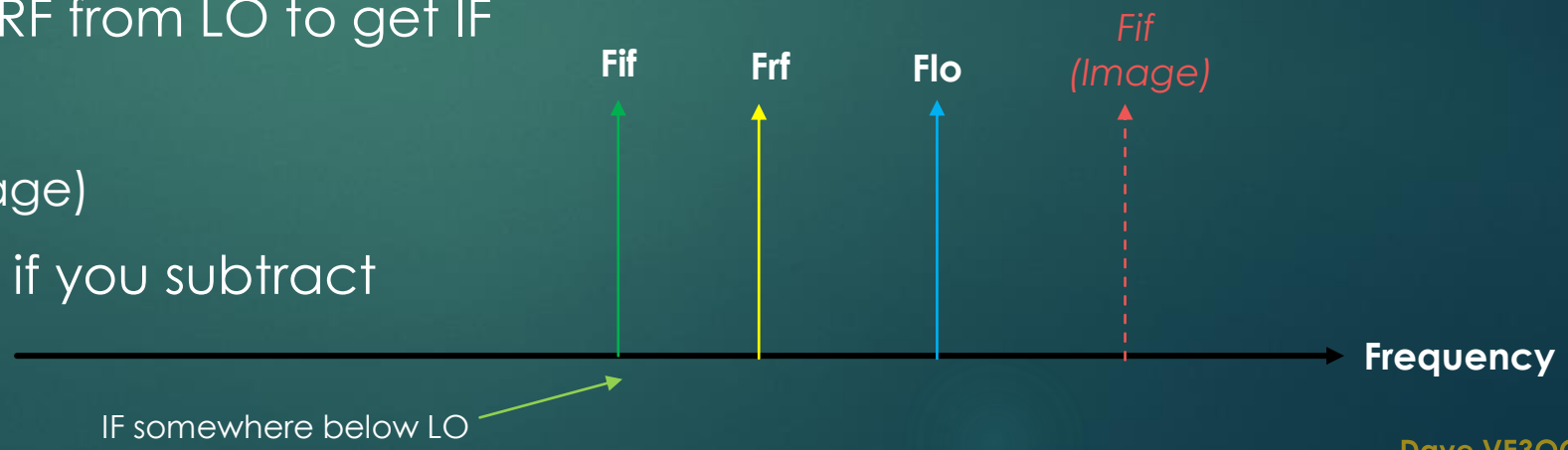
LET'S BREAK IT DOWN

FIRST MIXER: GENERATE IF



Frf = Radio Frequency input (modulated carrier suppressed)
Flo = Local Oscillator Frequency
Fif = Intermediate Frequency

- Recall for m=n=1, a mixer generates two frequencies:
  - Fif = Flo + Frf
  - Fif = Flo - Frf
- Sideband inversion is only when LO is higher than RF or IF (i.e., LO > RF, or LO > IF)
- If LO > RF, Need to subtract RF from LO to get IF
  - Fif = Flo - Frf
  - Fif = Flo + Frf (unwanted image)
- If LO < RF, No inversion even if you subtract

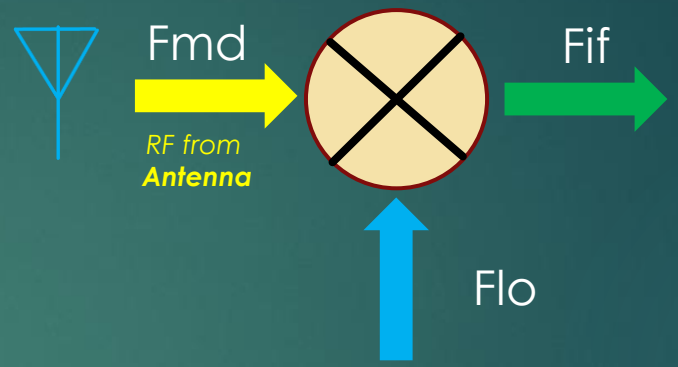


FIRST MIXER: GENERATE MODULATED IF

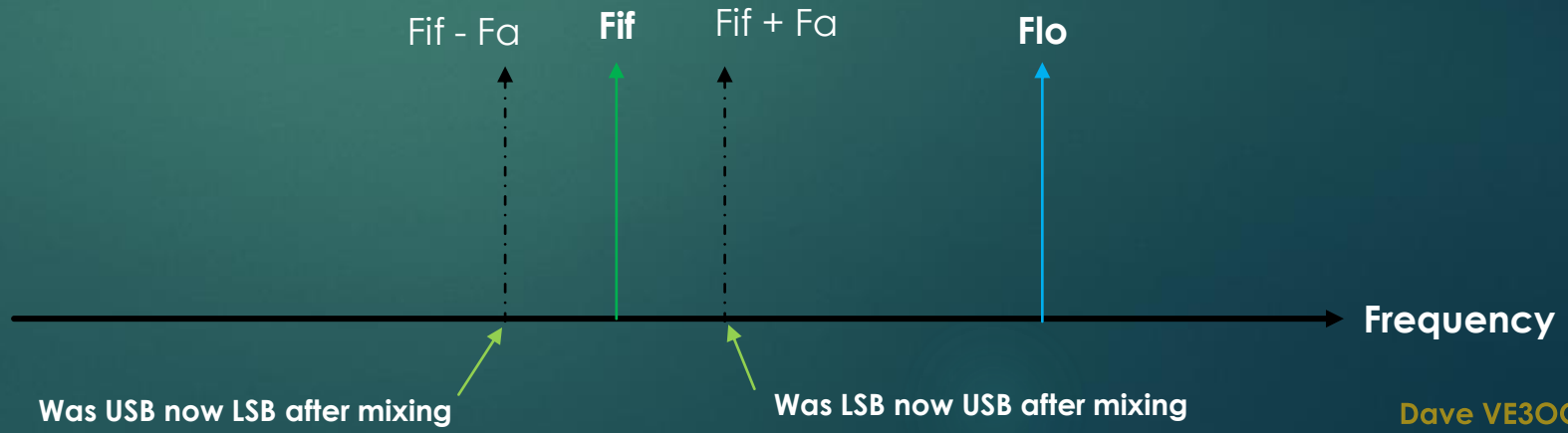
- Recall, for modulated carrier
  - Fmd = Fc + Fa (USB)
  - Fmd = Fc - Fa (LSB)

See Slide 9

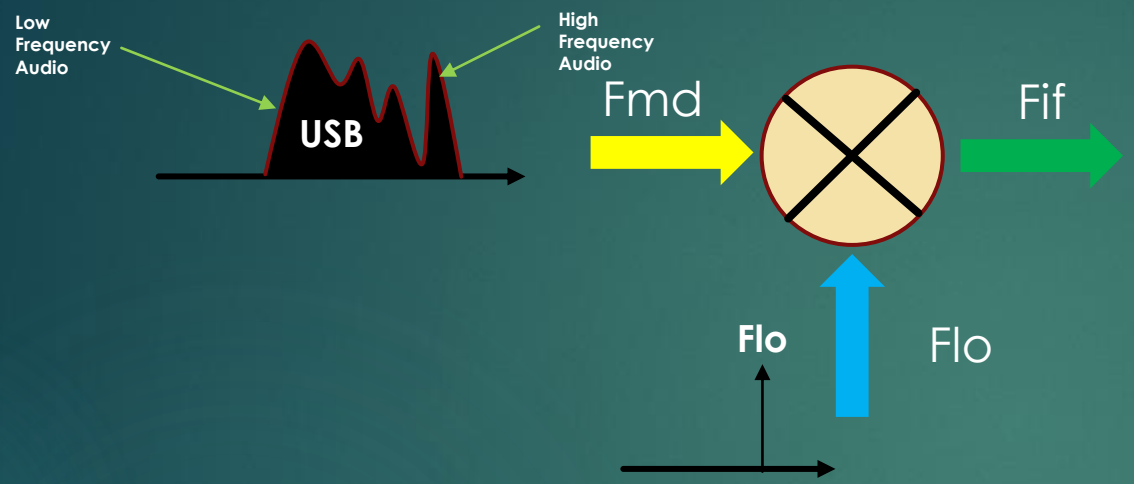
- If we inject Fmd into mixer, what is the IF.
  - Fif = Flo + Fmd
  - Fif = Flo - Fmd
  - Only focus on subtraction part of mixed artifact
  - Fif = Flo – (Fc + Fa) (USB)
  - Fif = Flo – (Fc - Fa) (LSB)
- Expand and you get
  - Fif = Flo – Fc - Fa (was USB)
  - Fif = Flo – Fc + Fa (was LSB)
- Buf Fif = Flo – Fc and so
  - F_1 = Fif - Fa (now LSB, was USB)
  - F_2 = Fif + Fa (now USB, was LSB)



Fmd = Modulated Radio Frequency input (carrier supressed LSB/USB)
Flo = Local Oscillator Frequency
Fif = Intermediate Frequency
Fa = Audio Frequency that modulates carrier



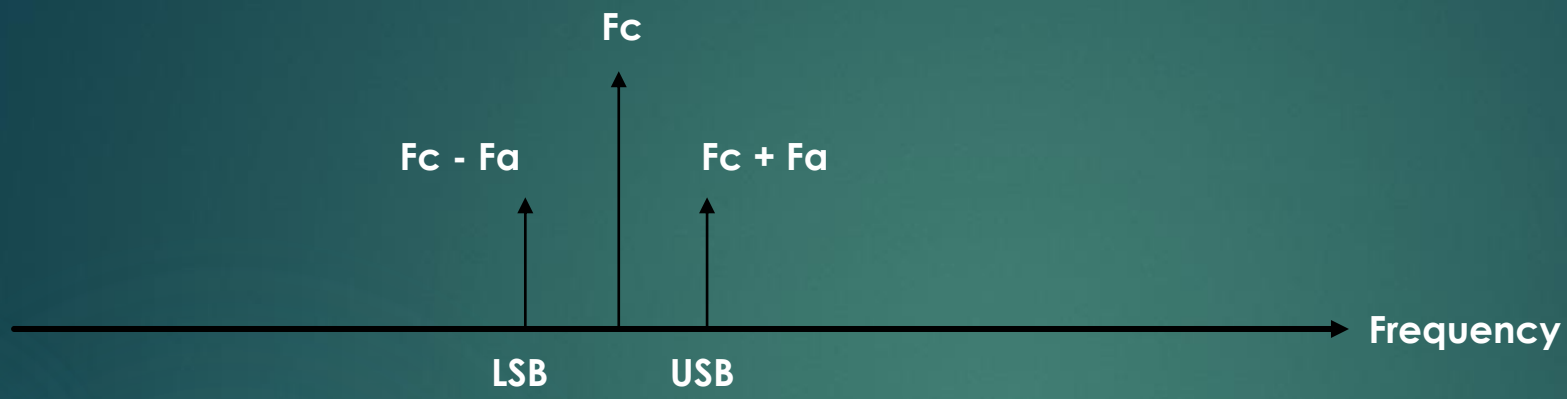
ALTERNATE VIEW



Fmd = Modulated Radio Frequency input (modulated)
Flo = Local Oscillator Frequency
Fif = Intermediate Frequency

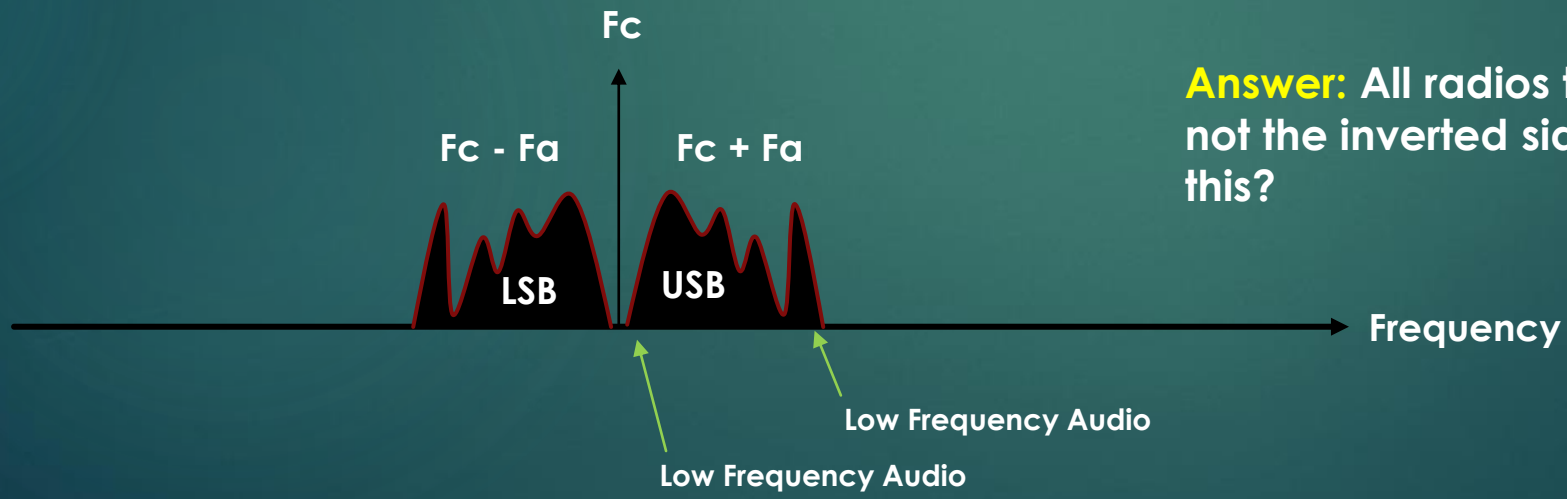
ADDRESS IN TRANSMIT CHAIN

CARRIER SUPRESSION:
Why is Sideband Inversion Important?

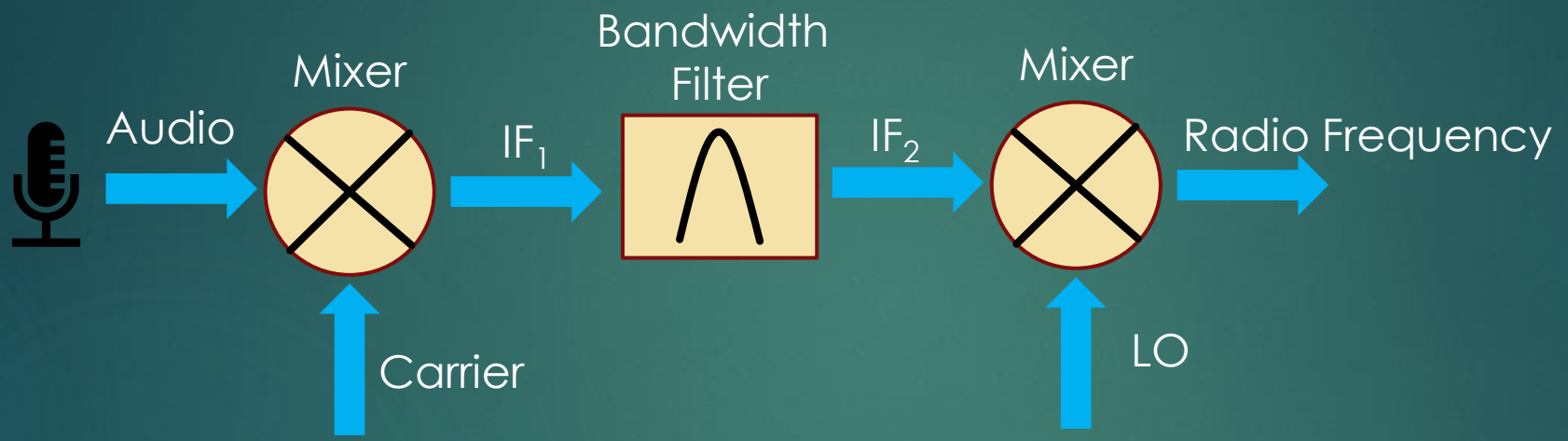


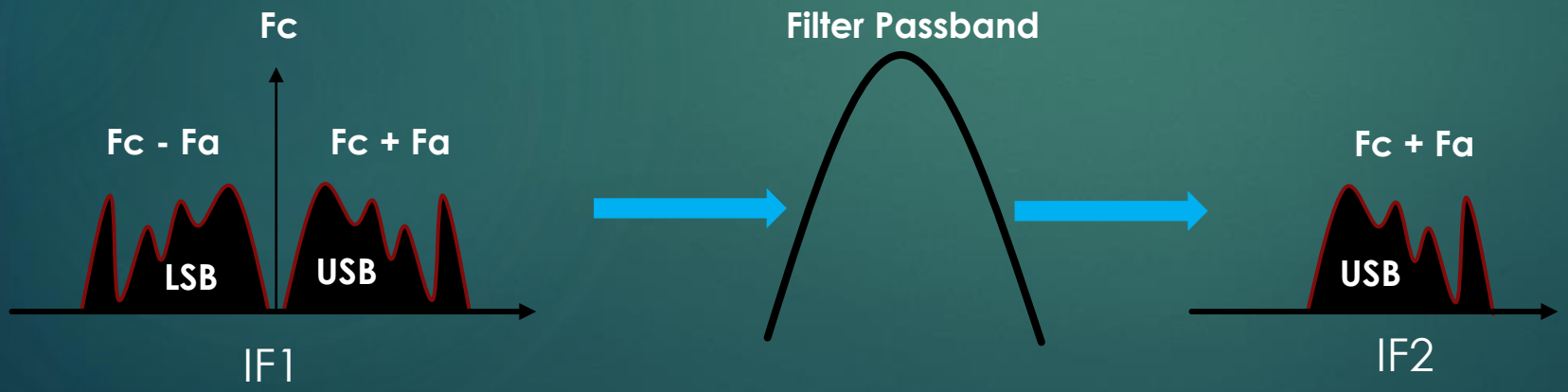
Need to remove the carrier and only select USB or LSB when receiving or transmitting

Answer: All radios transmit USB and LSB and not the inverted sideband….How do you to this?

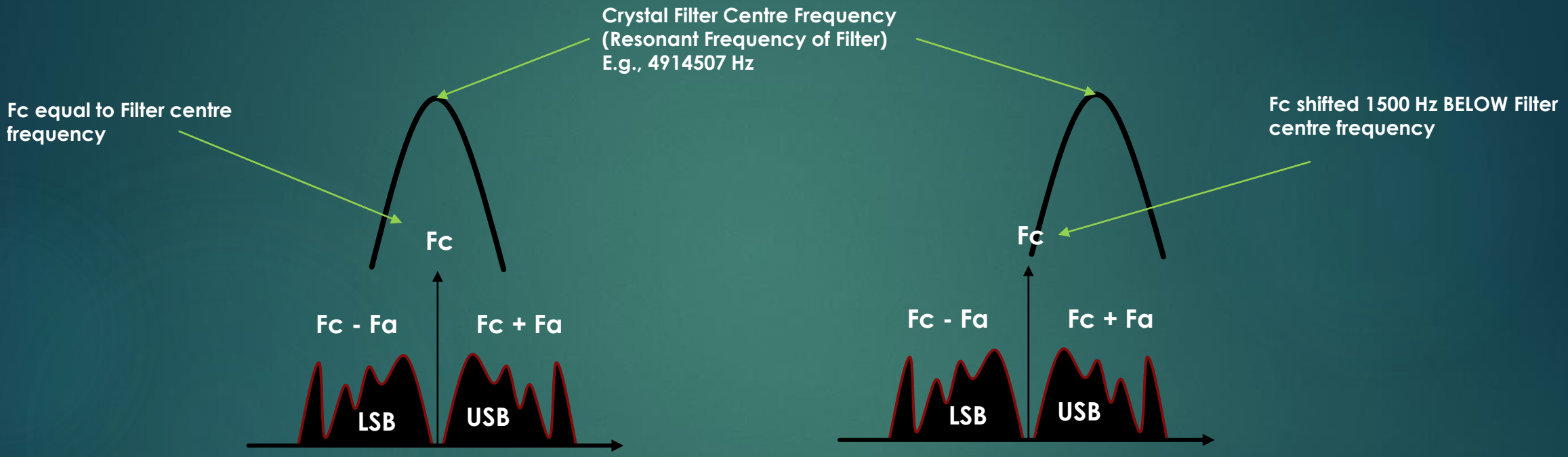


THE BANDWIDTH FILTER (Crystal Filter) Transmitter

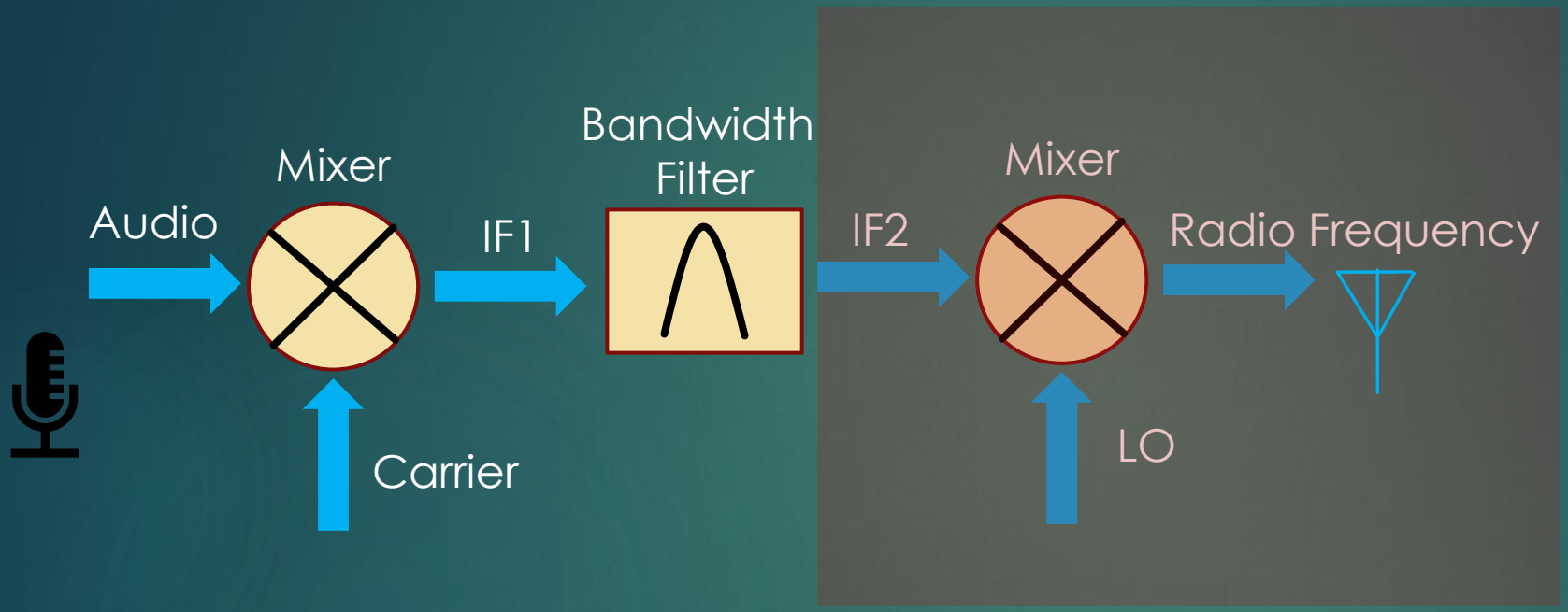




THE BANDWIDTH FILTER (Crystal Filter) Transmitter



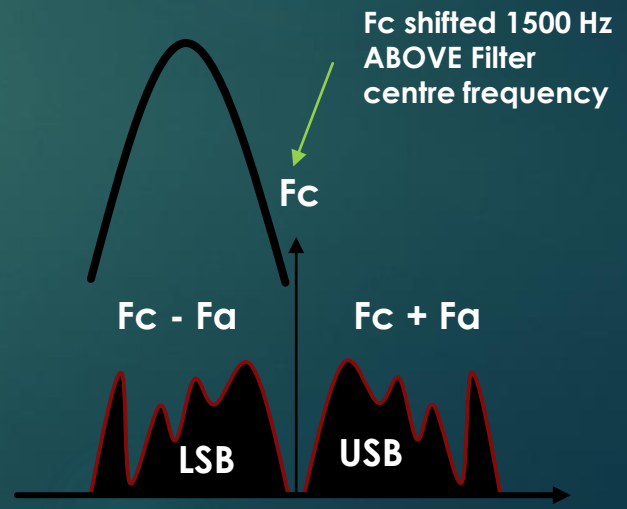
THE BANDWIDTH FILTER (Crystal Filter) Transmitter



If LO is higher than IF_2, Sideband will be inverted.

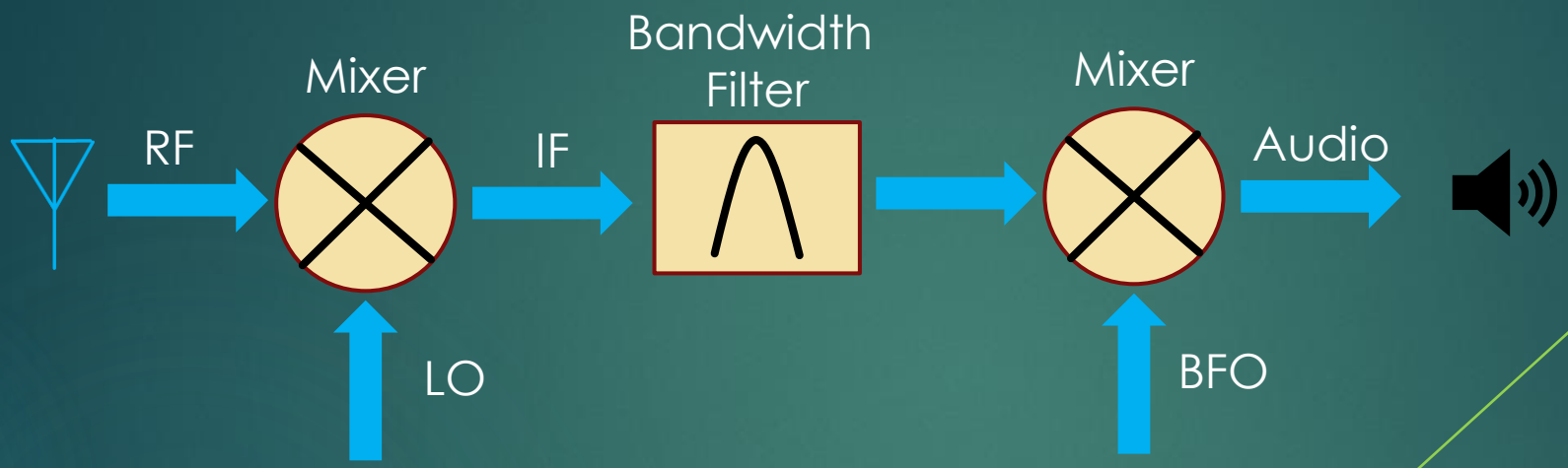
i.e., $RF=LO-IF_2$

- To get proper orientation, need to "invert" Carrier.
  - Filter USB to transmit LSB.
  - Filter LSB to transmit USB



ADDRESS IN RECEIVE CHAIN

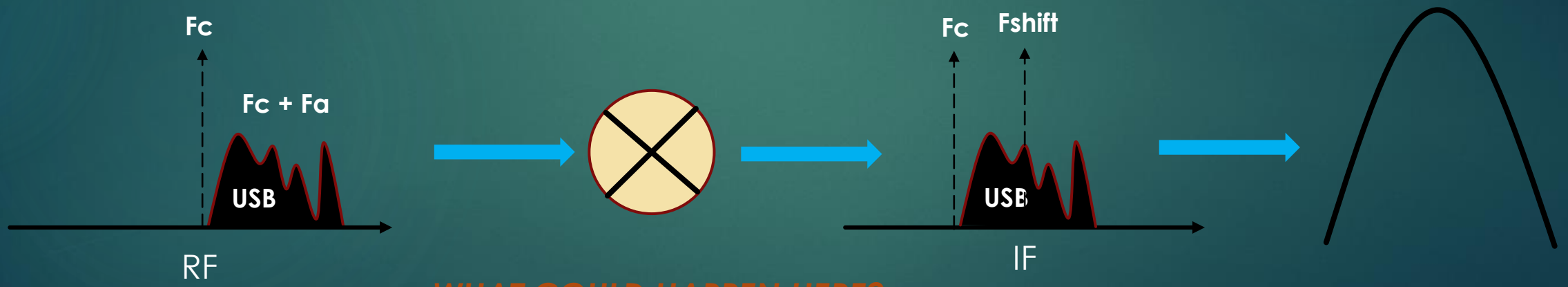
The Bandwidth Filter (Crystal Filter) RECEIVER



Filter Centre Frequency to only pass USB

Mixer shifts incoming RF to be within the filter passband

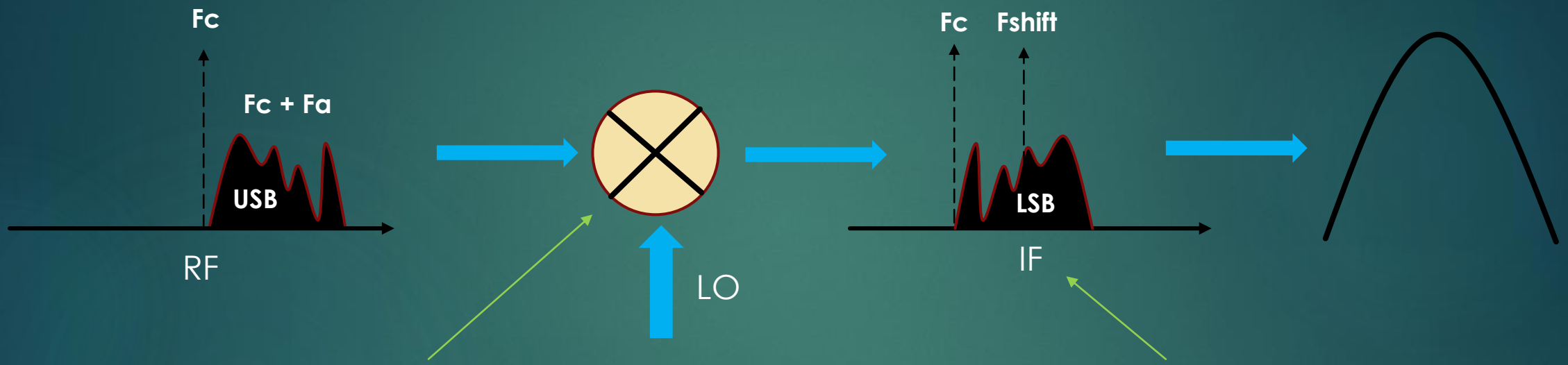
Need to shift Fc + centre of USB



WHAT COULD HAPPEN HERE?

Sideband Inversion

The Bandwidth Filter (Crystal Filter) RECEIVER



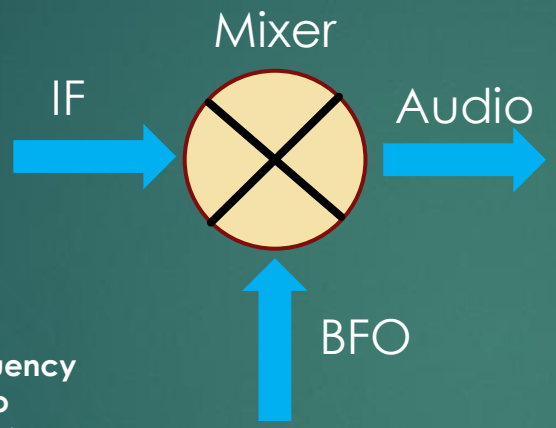
If LO above RF, the 1st Mixer inverts sideband

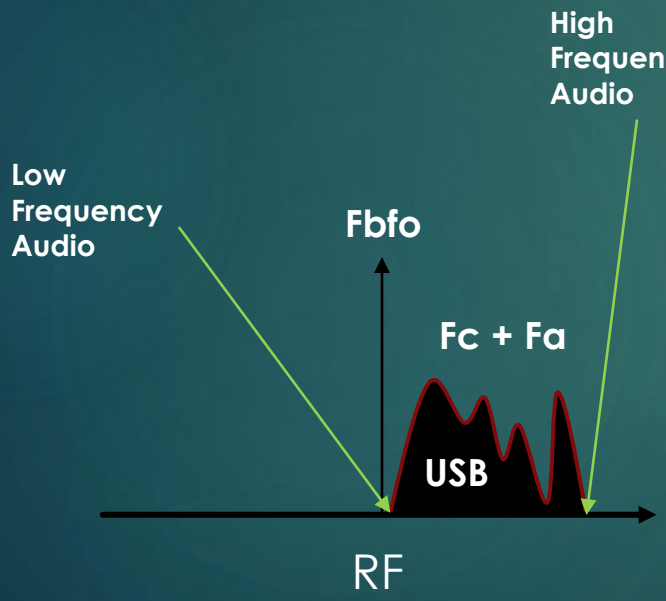
i.e., IF = LO - RF

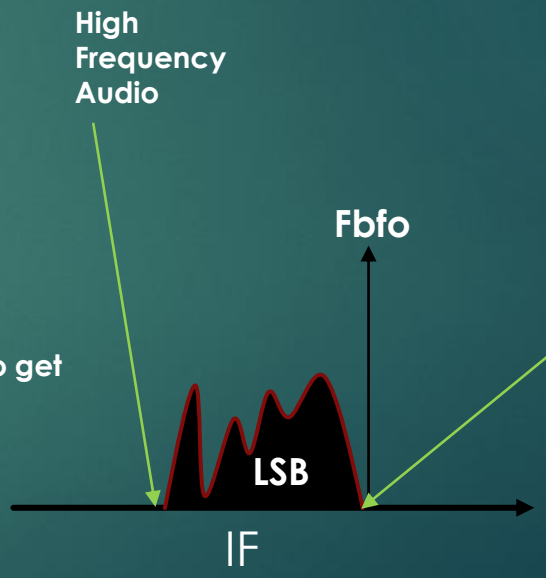
USB input to mixer
LSB output from the mixer

Note: USB and LSB are identical and can be interchanged

The Bandwidth Filter (Crystal Filter) RECEIVER



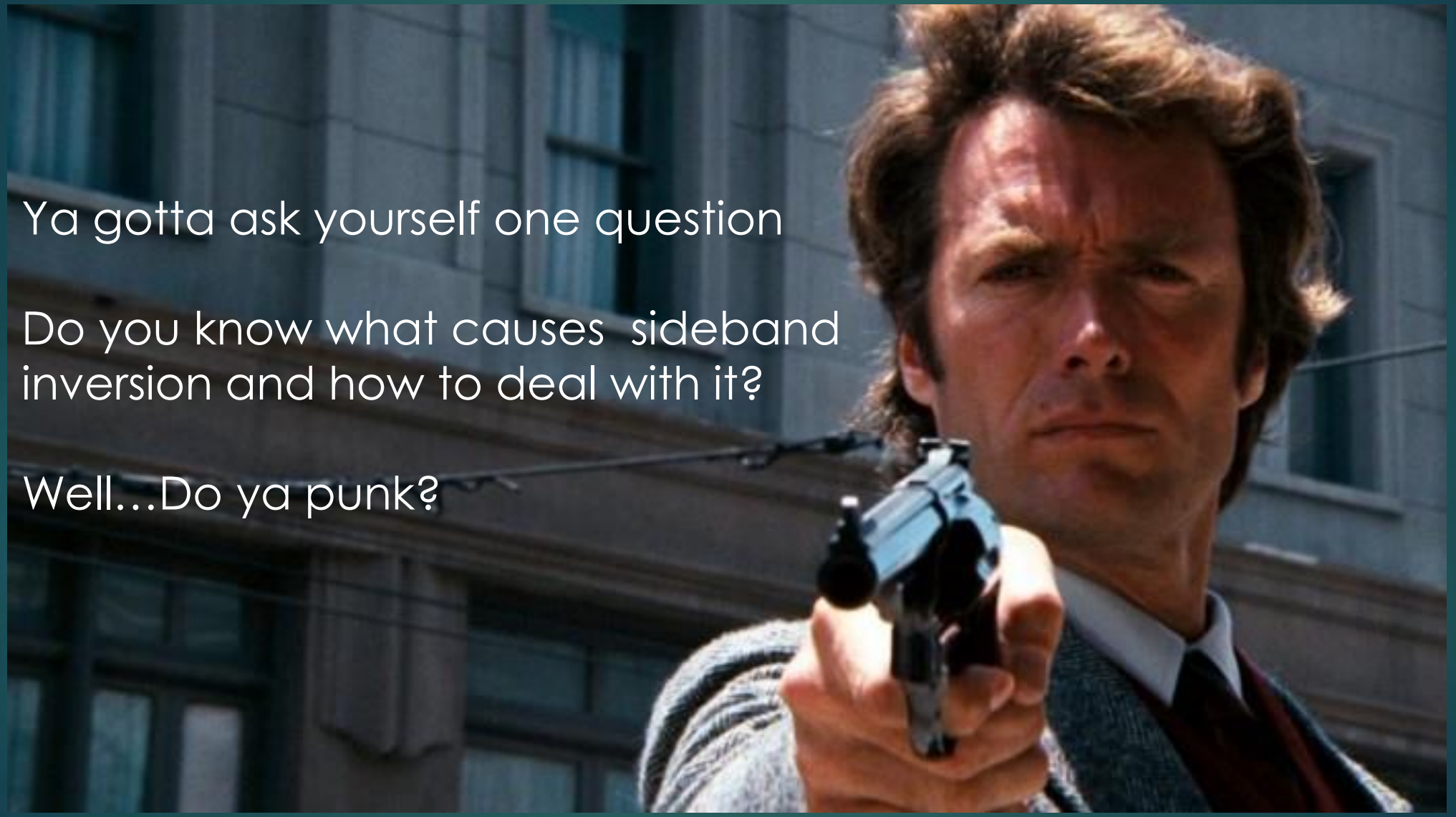




Fbfo needs to be below or above signal in order to get low/high frequency orientation

Need to account for sideband inversion when determining BFO frequency

e.g., LSB, Fbfo = Filter Centre frequency + 1500 Hz
e.g., USB, Fbfo = Filter Centre frequency - 1500 Hz


Ya gotta ask yourself one question
Do you know what causes sideband inversion and how to deal with it?
Well…Do ya punk?