

MODULATION

How? How Much? Too Little? Too Much?

Alachua County ARES® /
North Florida Amateur Radio Club
TECH NITE
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Why modulation?

- CARRIER (definition): A steady radio frequency wave.
- Created by some form of oscillator (may be analog, may be digital with digital/analog converter)
- Amplified as necessary
- Matched impedance between Final Amplifier (“Power Amplifier”) and transmission line / antenna

Information Transferred by Carrier

- Your Frequency
-
-
-
- That's it...

How can we transfer information (i.e. TALK)??

- Must VARY something about the CARRIER in order to talk or send any information
- **VERY EASIEST MODULATION** is to DISCONNECT the power supply and RECONNECT the power supply at intervals.... MORSE CODE.
- Because this has only TWO STATES (on, off) information is transferred by a serial data protocol of pre-arranged ON's and OFF's.
- Multiple different serial data protocols have been invented. American Morse is different from International Morse
- These are the only known serial data protocols that can be understood directly by the human brain. Typical speeds are 1-2 characters/second

More Advanced Modulation

- The next modulation invented early in the 20th century was to vary the power supply voltage not by ON/OFF, but by ANALOG.
- Microphone signals were amplified greatly and used to control the **POWER SUPPLY VOLTAGE** to the last stage of a powerful carrier amplifier transmitter.
- Tube Transmitters: Known as “Plate Modulation”

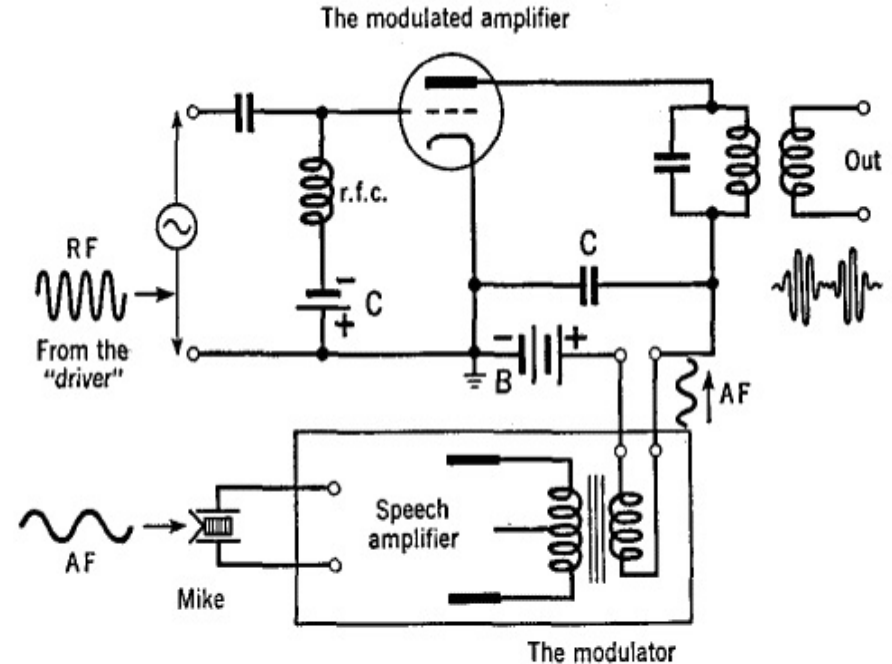


Fig. 16 G. Further details of plate modulation. More elaborate and practical circuits will be given later

http://www.vias.org/basicradio/basic_radio_17_04.html

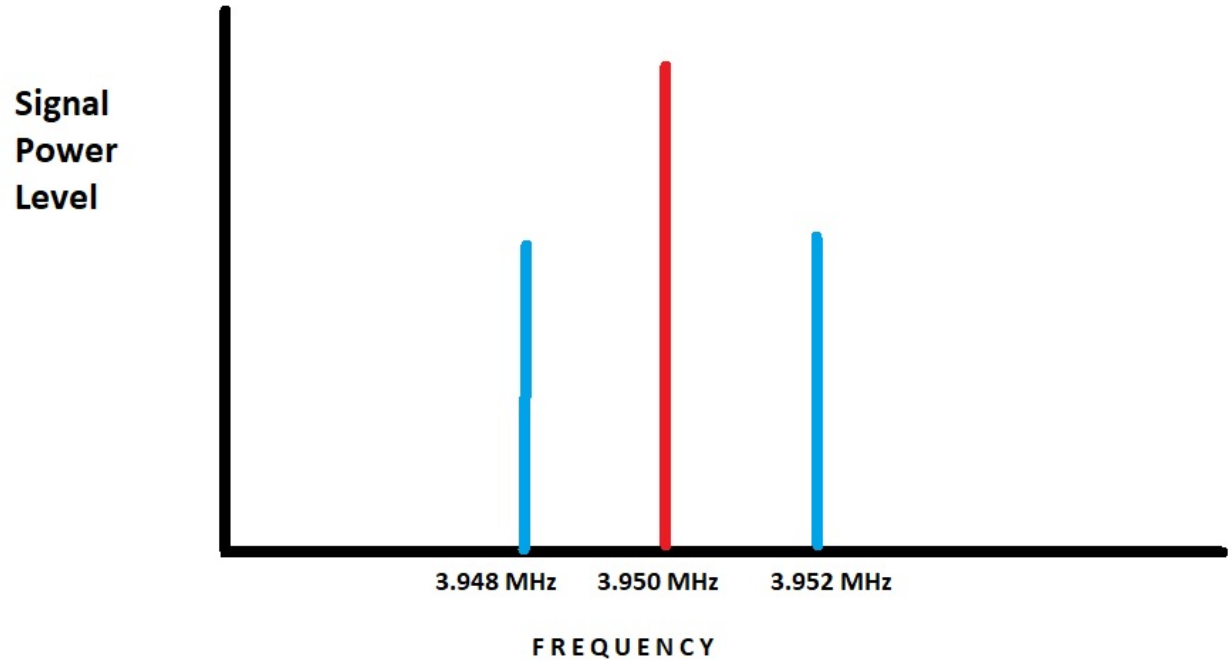
Double SIDE BAND

- AM Modulation brought SIDEBANDS to radio.
- Modulating by varying the power level is MULTIPLYING the power of the carrier amplifier by the power level of the MICROPHONE.
- Multiplying in TIME, has the impact of ADDING/SUBTRACTING in the frequency domain.
 - Has to do with a Trigonometry Equation
- Radio now had SIDEBANDS

$$\cos \theta \cos \varphi = \frac{\cos(\theta - \varphi) + \cos(\theta + \varphi)}{2}$$
$$\sin \theta \sin \varphi = \frac{\cos(\theta - \varphi) - \cos(\theta + \varphi)}{2}$$

Looking in the “Waterfall” or Frequency Domain

- Carrier frequency is in the middle



Improved Modulations

- Huge wasted power in the CARRIER
- (real problem for the \$\$\$\$ of traditional AM radio stations!)
- The carrier is basically unnecessary to be transmitted – can be added back in BY THE RECEIVER
- “Beat Frequency Oscillator” (BFO)
- Have to get the BFO right into the correct place to avoid “Donald Duck” – but huge improvements in efficiency and DISTANCE you could go with power.

Ways to create AM Modulation without Carrier

- **FILTERS** – typically CRYSTAL FILTERS to get the very sharp edges of response required, to cut out the undesired sideband and carrier. From there, LINEAR amplification is required.
- **Balanced MODULATORS** were developed that were able to null out the CARRIER (but not the other sideband). This allowed for simpler crystal filters (saving \$\$\$)
- There are **mathematical methods** to create double-sideband or single-sideband signals mathematically (in microprocessors) – linear amplification is then required

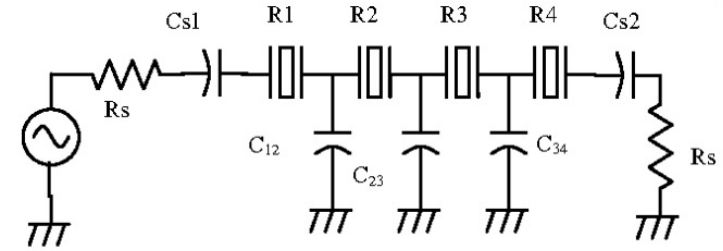
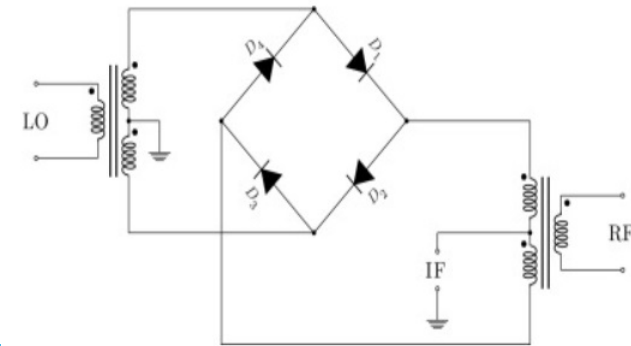


Fig 5 4th order Crystal filter

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Published in 2013 International Conference on Communication and Signal Processing 2013
Design and realization of crystal band pass filter using discrete crystal resonators

S. Nandanwar, A. Patel, Surinder Singh



<https://www.sciencedirect.com/topics/engineering/balanced-mixer>

LINEAR Amplifier

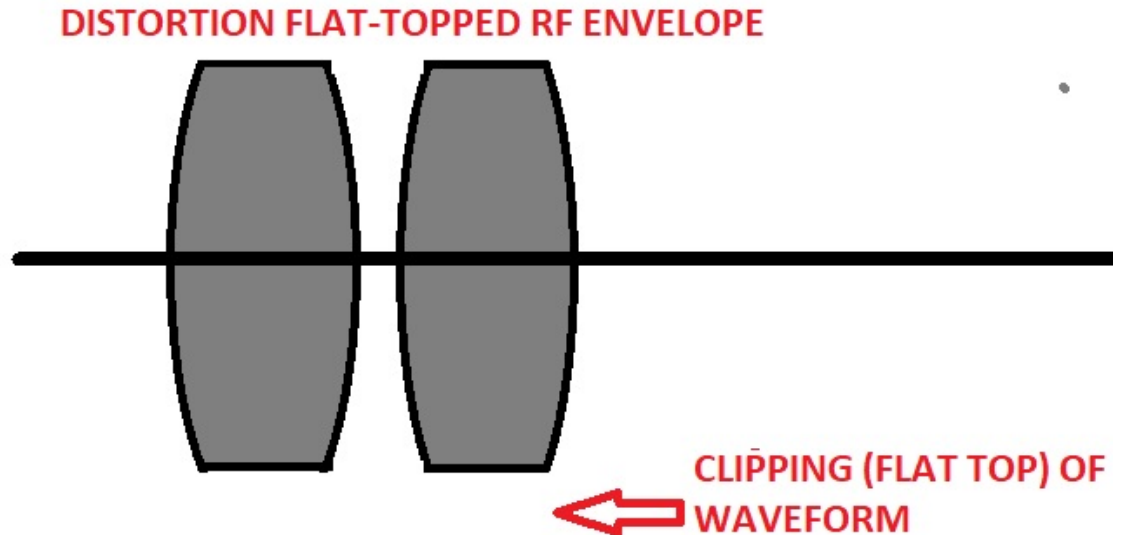
- Notice that all the methods listed above require LINEAR amplification afterwards.
- LINEAR = output is a faithful multiplication of the input.
- In Other Words: even whispers are transmitted perfectly, sounding like whispers!
- Class C Amplifiers ARE NOT LINEAR. They will not transmit “whispers”
- Class A, AB, B amplifiers CAN BE LINEAR when properly adjusted.

Changing Gears

- Now moving to ways to “foul this up”
- 1. Foul up the modulation.
- 2. Foul up the amplification.

Non-Linear Amplification

- Attempting to push 75 watts out of an amplifier that can only produce 50 watts will result in **FLAT TOPPING**.



Distortion from Over Driving Modulator

- Just like the Power Amplifier, the MODULATOR STAGE has a “limit” as well.
- If you overdrive the MODULATOR, distortion starts immediately.
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- You can have the most linear amplifier in the world, and will faithfully reproduce THE DISTORTION!!
- CRUCIAL LEARNING POINT:
 - Dropping the “power level” lower will STILL have a distorted signal if your distortion occurred as a result of overdriving the modulator....

Over Driving & Distortion

- When an amplifier or modulator is driven into distortion, additional “modulation” now occurs BETWEEN the signals it was handling or producing.
- Normally if you have two people whistling into a mic at different tones, you will get TWO TONES transmitted.
- When you drive into NON LINEARITY....the two tones begin to MODULATE EACH OTHER.

- Harmonics of their tones are created.
- 1kHz tone upper sideband from 3.950 (hence, 3.951) now creates a 2nd harmonic at $2 \times 3.951 = 7.902$ MHz
- This now “beats” with the 500 Hz tone the other person was whistling $(3.950 + 500 \text{ Hz}) = 3.9505$.
- Difference frequency is now: $7.902 - 3.9505 = 3.9515$
- THAT comes across as a 1500 Hz completely NEW TONE that came out of nowhere.
- 2Xone tone - 1Xother tone is known as a “3rd Order Intermod Product”

- ODD numbered “products” will generally be WITHIN THE TRANSMITTABLE RANGE – and will be transmitted as a new, distortion “intermodulation product”
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- We have literally SEEN this in our License courses by driving a simple transmitter overly hard – and NEW SIGNALS popup on the spectrum analyzer.....
- Intermodulation distortion. From non linear transmitter.

- Intermodulation Distortion can arise from other things also.
- Rectifying rusty fence wireconnection in the near field of multiple repeaters = IMD products.
- Non linear Repeater transmitter output(FM repeater amplifiers are Class C) seeing OTHER repeaters coming back from its amplifier = INTERMODULATION and distortion frequencies arising.
 - For this reason, devices that only allow RF to go ONE DIRECTION known as “circulators” are used on the output of high quality repeater installations in busy areas.

How to fix modulator distortion

- DECREASE THE AUDIO SIGNAL going to the modulator!
- Turn DOWN the mic gain!
- Turn DOWN the Winlink “drive power”
- Turn DOWN the WSJT-X power slider
- Turn DOWN the FLDGI output power attenuator
- Turn DOWN the JS8 power slider
- As a licensed radio operator you are responsible to know how to operate your equipment, including avoiding overdriving.

Automatic Level Control

- SPECIFICALLY to avoid over-driving the modulator, or amplifier, modern Single Sideband Radios include AUTOMATIC LEVEL CONTROL (ALC)
- This will kick in and drop the drive if you are at the clipping level.
- Problem: this work OK for voice....but it is its OWN FORM OF DISTORTION for most digital signals. Works OK for FSK (frequency shift keying) favored by VARA....and POOR for Phase Shift Keying using by ARDOP, PACTOR, PSK31.....

Easy peasy way to avoid all distortion

- 1. Set your “power level” for 100 watts.
- 2. Adjust a steady TUNE type signal or similar from your application until the MEASURED output power is FIFTY WATTS.
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- There isn't much more that you can do. At this point, unless you have a HORRIBLE SWR, and a “foldback” radio, your ALC (Automatic Level Control) will read ZERO.

Other Ways To Distort

- Lousy Amplifier. Class C amplifier are NOT LINEAR and nothing will make them linear. They START in “cutoff” so “whispers” will never be heard.
- Class C amplifiers are sometimes sold for 2meter FM – and you CANNOT use them for 2 meter SSB.
- The CLASS of an amplifier is set by the “bias” If you set the “Bias” incorrectly, you can turn your fancy amplifier into a CLASS C AMPLIFIER and distort all over the place.
- As a licensed radio amateur, you are responsible.....

Repetition

- Linear operation generally means ZERO ALC indication
- Linear operation generally means LESS POWER even at peak, than what you “dialed in” on the “power setting”
- On Single Side Band, “linear” means that changes in drive ALWAYS make a change in output. If you are “flat topped”you aren’t linear. Adjust the TX GAIN on your signalink until the output power STARTS TO DROP and you are now linear

UNDER MODULATION

- The opposite of Over Modulation.
- On HF SSB – your output power is much less than expected
- On VHF/UHF FM – your signal is “full quieting” but “light” – no one can hear you. You are “whispering” by having your mic gain or TX GAIN set TOO LOW.
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FM POWER OUTPUT IS CONSTANT

- FM does not work like SSB.
- Output power is ALWAYS CONSTANT.
- Only the FREQUENCY varies as you provide audio modulation.
- Therefore you cannot prove linear operation by watching an output power meter
- You must LISTEN with another receiver. If you are way “softer” or “louder” than the others.... Your modulation is too low or too high.

FM RADIOS

- Tend to have level limits to avoid huge splatter (I think)
- Biggest problem is people either
 - Too FAR from the Mic (can't hear them,...and they ALWAYS drift back away even when you tell them over and over you can't hear them)
 - Too HIGH GAIN – and they sound like they are SHOUTING at you

FM MODULATORS

- Completely different from SSB or AM modulators
- FREQUENCY is changed, not Power.
- Generally tweaks an OSCILLATOR STAGE.
- Changing an L or a C by microphone voltage, changes the resonance of the oscillator....and thus creates FM Modulation.
- Alternative is a Phase Locked Loop where you drive the loop error signal from the microphone and thus it FM modulates.
- Phase Modulation and FM modulation are RELATED.
- One of them EMPHASIZES HIGH AUDIO.... The other doesn't
- Otherwise, they are indistinguishable

FM Modulators / Demodulators

- Terms like “reactance modulator”
- “Frequency discriminator” (FM demodulator)
- Ideally, they provide NO response or creation of AMPLITUDE changes....
- Perfect systems don't exist.

DX Advantage

- Single Sideband signals on 2 meters can be heard adequately at much lower signal levels than FM signals.
- Therefore “DX” on 2 meters is often done with SSB or CW
- FM gets a break from “ducting” occasionally and has strong signals

Digital HF Operations

- More complicated because you MUST maintain transmitter linearity.
- Separates the solid operators from those not quite so.....
- In RECEIVING you wish to have the widest possible bandpass at the IF frequency, and NO NOISE BLANKERS or other alterations (distortion) – Let the SOFTWARE do its work on a “clean” original signal.

How can you measure HF output power?

- \$10 SWR meter from a hamfest.
- \$25 SWR meter from Amazon
- Relative Power setting on meter
- You can even watch the current drawn from the power supply.
- Typical HF efficiency is 60-70%.