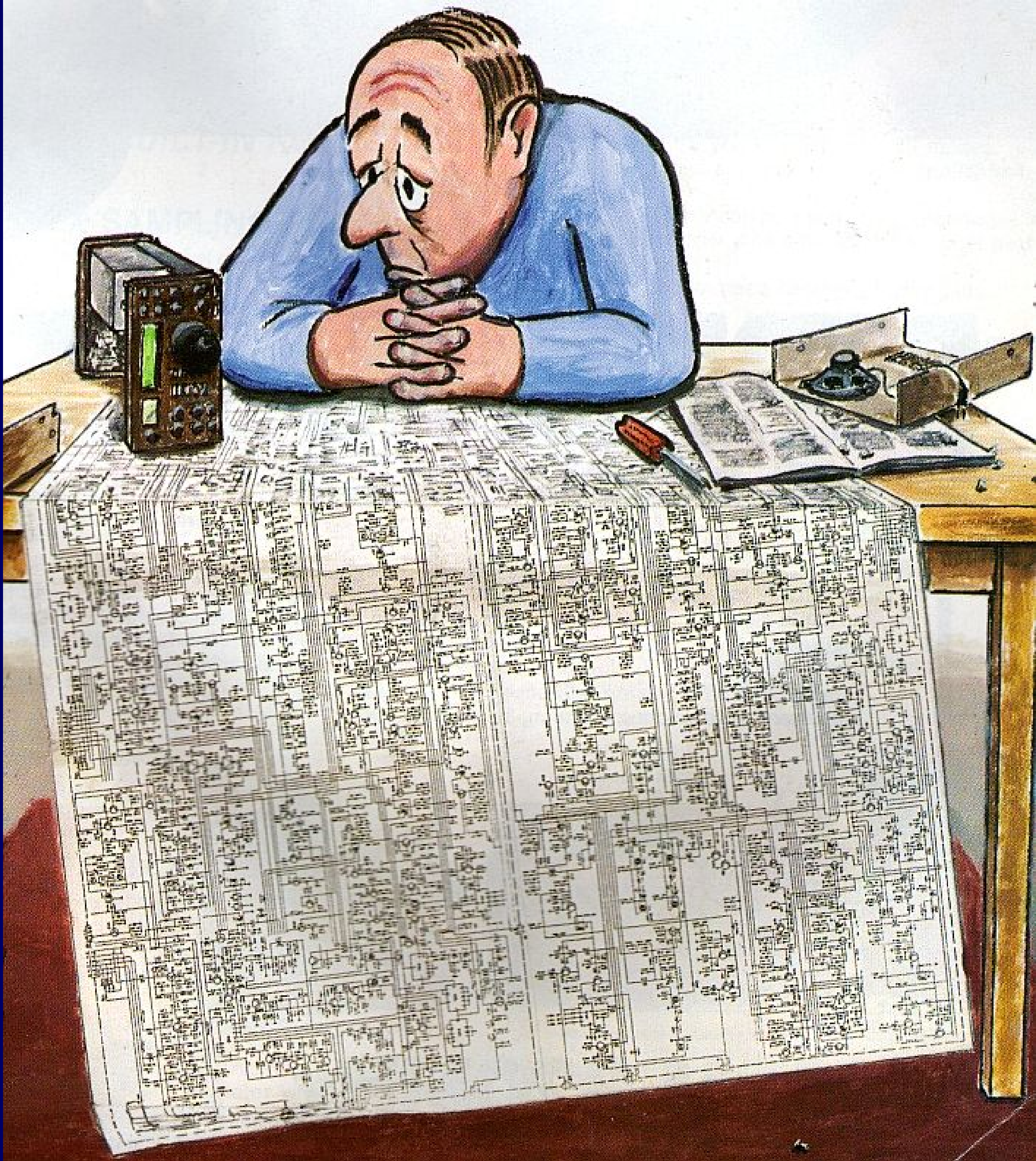
Transmitters

Electron Pumps that convert DC Power into AC Power




over
SRM 6

An Early Amateur Spark Gap Transmitter
Combine High Voltage and Exposed Wiring,
What Could Possibly Go Wrong?

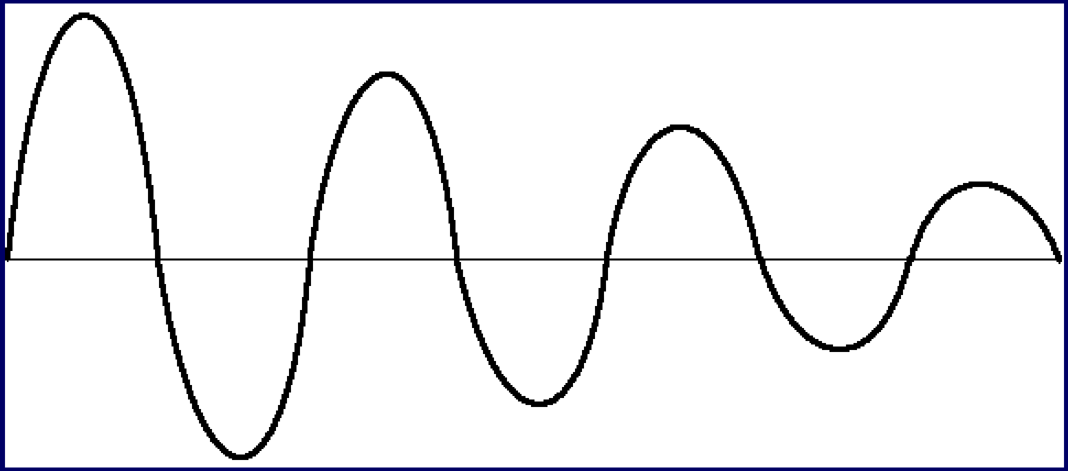

AMATEUR
RADIO
K5LN
K5LN
3:29

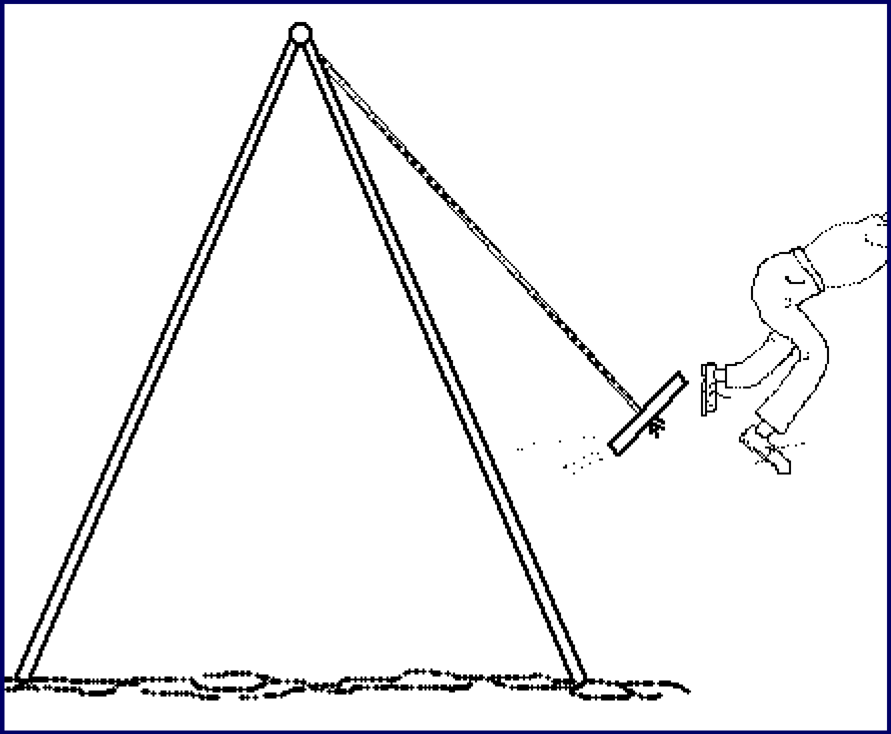

AMERITRON
AL-811 AMPLIFIER
BAND
LOAD
PLATE
METER
XMT
POWER
K3EYK
K3EYK
KENWOOD
SP-230
REALISTIC
IC-27A
RS-20A
QST
A Peaceful Holiday Season to All!

Collins Gear mid shelf, Modern Elecraft on the bottom shelf,
And Station Accessories on the top shelf.

Resonant Systems

A child's swing is a resonant system. When energy is put into the mass by a push the mass will swing back and forth at a constant rate, a frequency of swings per unit of time. The amplitude will decrease over time because of friction .

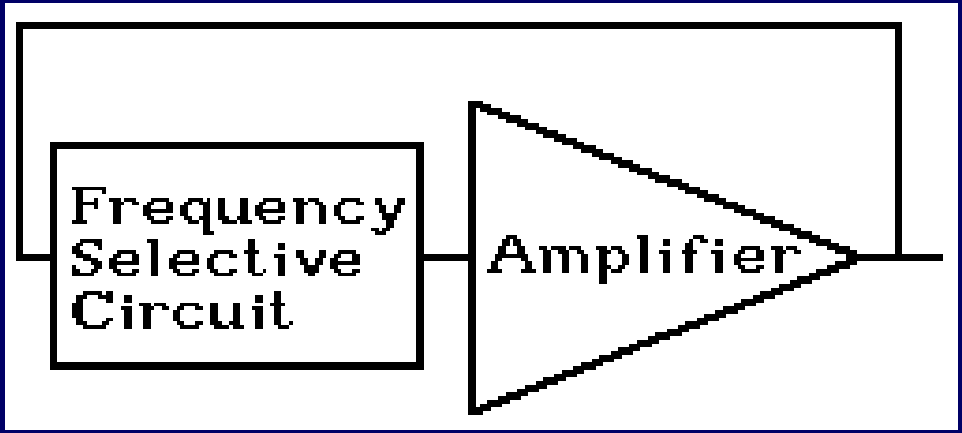




A constant amplitude of swing requires a well timed push

An Oscillator combines a Resonant Circuit to set the Frequency with an Amplifier to provide the energy to continue the oscillation.

Oscillator

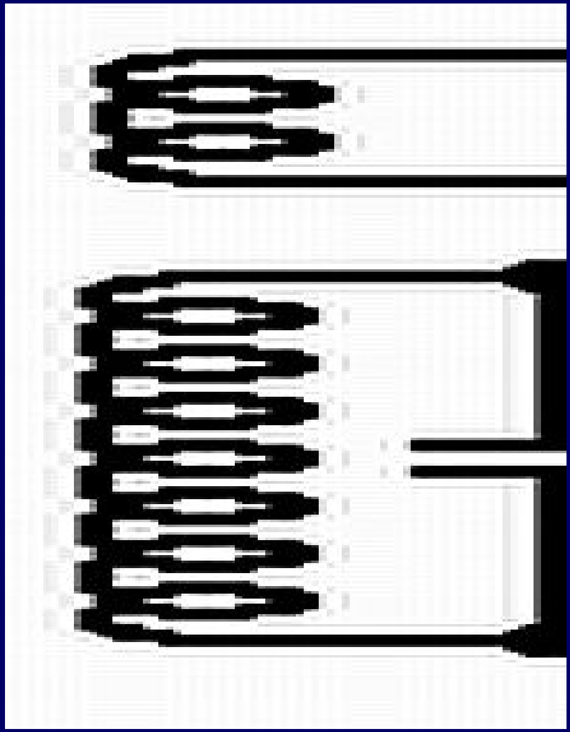


Heinrich Barkhausen (1881-1956) said in 1921:
“For a positive feedback system, oscillation will occur when the loop gain (the product of forward gain and feedback gain) has a phase shift of zero and a magnitude of unity.”

“Amplifiers oscillate and oscillators amplify”

Whenever the positive feedback gain of the entire system is equal to or greater than one, the circuit will oscillate.

Armstrong Oscillator 1912



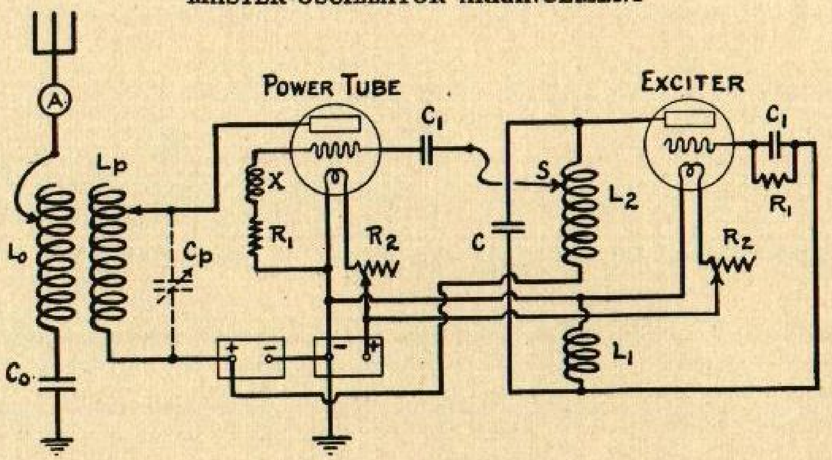
Edwin Armstrong was the first to apply positive feedback to a resonant tank circuit with an Audion vacuum tube, in 1912.

The “Tickler Coil” from the active device returns a small amount of energy in phase with the energy in the tank circuit, ensuring continuous oscillations.

Armstrong later understood that adding an antenna to the tank circuit and moving the tickler coil away so that oscillations did not occur caused the circuit to greatly amplify the received signals and also greatly improved the selectivity of the tank circuit. The “Regenerative Receiver” was a mainstay of the amateur community for many years.

TRANSMITTING CIRCUIT NO. 7

MASTER-OSCILLATOR ARRANGEMENT



DETAILED DESCRIPTION

Circuit Symbol.	Unit.	General Description.	Power. 5 w.	Power. 50 w.	Power. 250 w.
L_0	Antenna inductor.....	see Art. 44 (*a*)			
C_0	Antenna series condenser...........	.0003 to .003 mfd.	8000 v.	8000 v.	8000 v.
L_p	Plate coupling coil....	4″ dia.	30 t.	30 t.	30 t.
C_p	Plate tuning condenser	variable, .0005 mfd.	500 v.	1500 v.	3000 v.
C_1	Grid condenser.......	.002 mfd.	1500 v.	1500 v.	1500 v.
R_1	Grid resistance.......	5000 to 10,000 ohms			
X	R.F. choke-coil.......	see Art. 44 (*d*)			
C	Oscillating circuit condenser...........	.001 mfd.	2000 v.	4000 v.	8000 v.
L_2	Oscillating circuit plate coil..............	6″ dia.	7	9	10
L_1	Oscillating circuit grid coil..............	6″ dia.	7	5	4
R_2	Filament rheostat....	....	2 a.	8 a.	16 a.
A	Antenna ammeter....	....	2 a.	4 a.	8 a.

Note.—The construction of coils L_1 and L_2 is the same as that of the antenna inductor L_0. (See Art. 44 (*a*).)

This schematic of an Armstrong Transmitter dates from the early 1920s.

The Exciter Tube creates the oscillation with C and L1+L2.

The Power Tube creates a time varying current in the coil Lp, which magnetically couples to the antenna coil, creating an alternating current in the antenna wire.

An alternating current in a wire creates electromagnetic waves which radiate away from the antenna. RADIO !

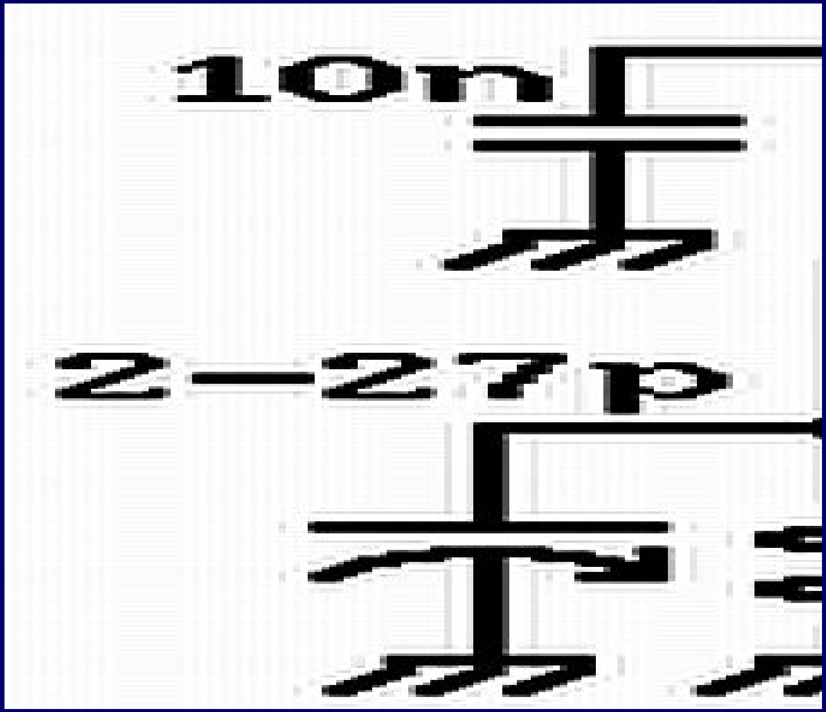
Desirable Oscillator Characteristics

Frequency Stability:

Frequency should stay constant for long periods of time. Frequency Drift is measured in Hz of drift per hour.

Changes in temperature or supply voltage will change the frequency.

Pierce Quartz Crystal Oscillator 1923



In 1923 W.G. Cody demonstrated to G.W. Pierce the frequency stability of a quartz disk oscillator. Pierce then designed a vacuum tube circuit that maintained oscillation.

“Rock Stable”

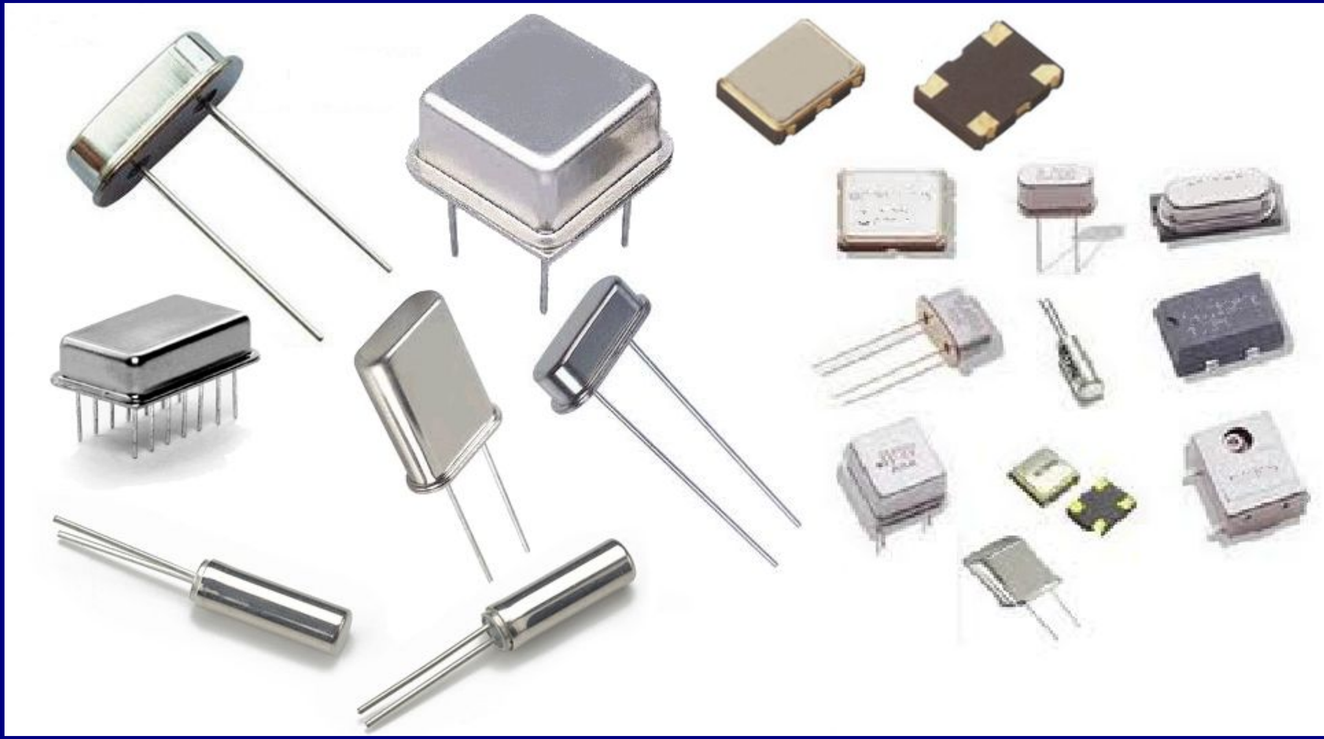
The Crystal operates in Series resonant mode, creating a 180^{o} phase shift between the Drain and the Gate.

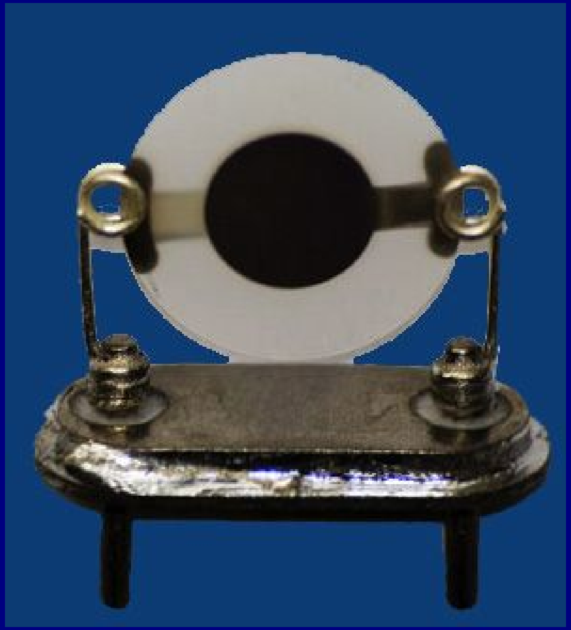
The 2-27pF trimmer cap provides some adjustment for the crystal frequency. The Pierce oscillator is probably the most reliable of the simple oscillators for simple transmitter use.

Quartz: Silicon Dioxide

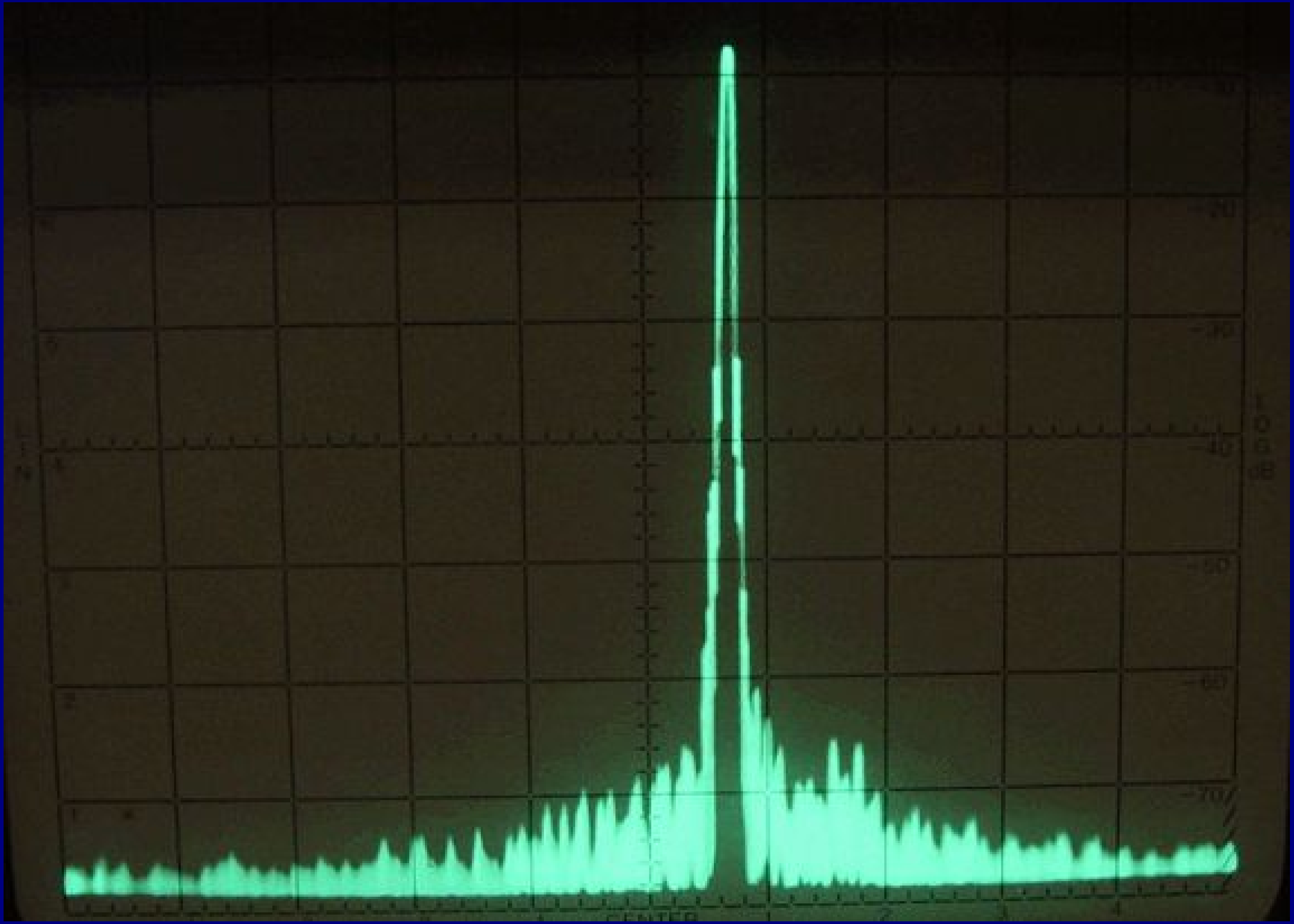
Piezoelectric: Electrical field bends the crystal structure.

Dimensionally exceptionally stable with temperature, so a crystal does not change size. Resonant frequency depends upon size, both disk diameter and thickness.





Many Standard Frequency Crystals and whole Oscillators are “on the shelf” available, and custom Frequencies can be ordered with a two week delivery for reasonable cost.



Spectrum Scan of a Continuous Wave Signal. The Carrier is of Constant Amplitude and Single Frequency. The only information conveyed is "I Am Here."

Modulation

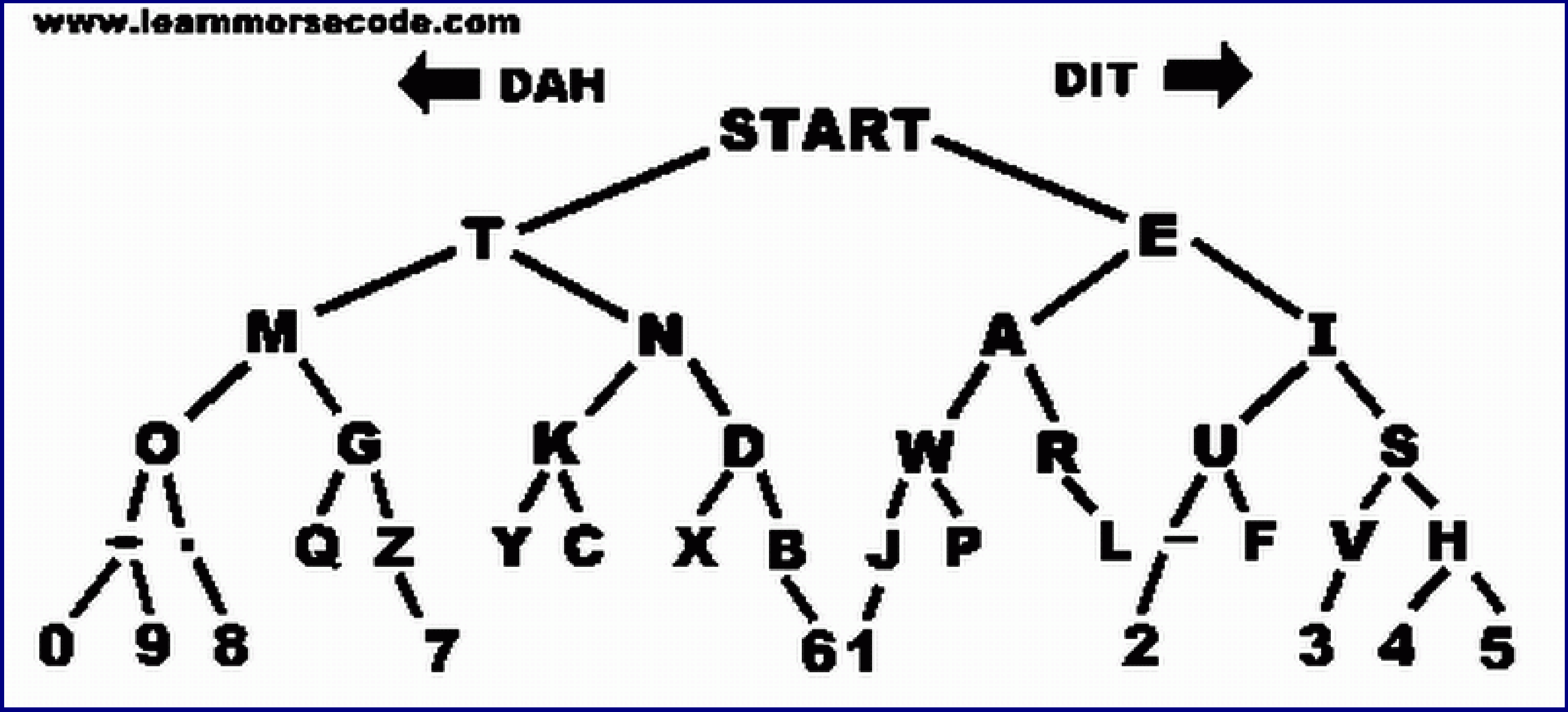
Changing the Radio Signal to convey Information

A Radio Signal, or “Carrier”, may be changed in three ways, by Amplitude, by Frequency, and by Phase. Some modulation schemes use all three methods at the same time.

The most basic modulation method is to turn the carrier on and off, letting the pattern of on periods carry meaning, such as with Morse Code, or “CW”.

CW is short form for Continuous Wave, and refers to the unmodulated carrier emitted by the keyed transmitter.

The first fully digital mode, invented by Alfred Vail, was coded with dots, spaces and dashes. A radio frequency carrier is switched on with each press on a key, also by Vail.




Alfred Vail


ALFRED VAIL

A CW Transmitter - Simplified

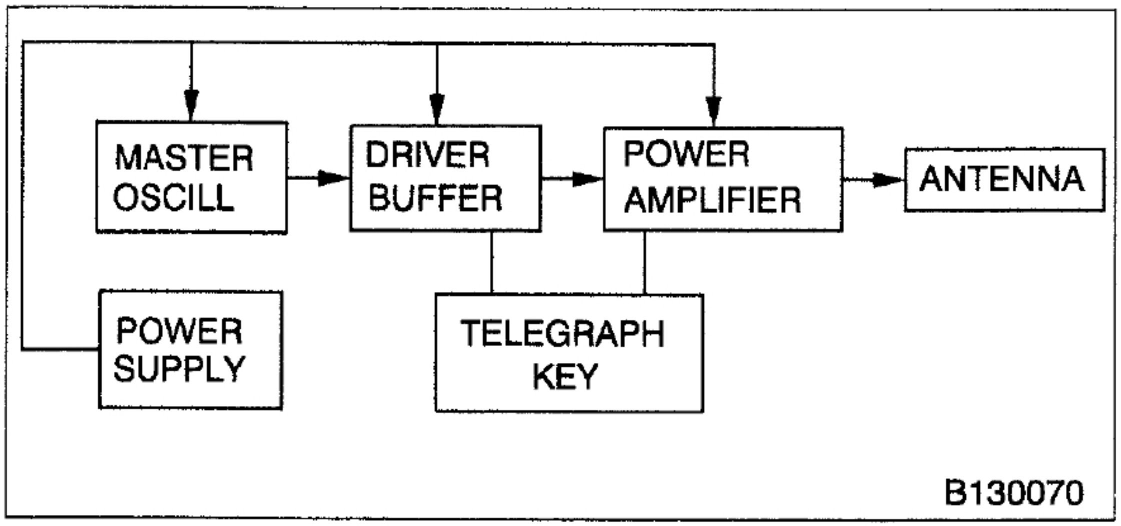


Fig 13-4

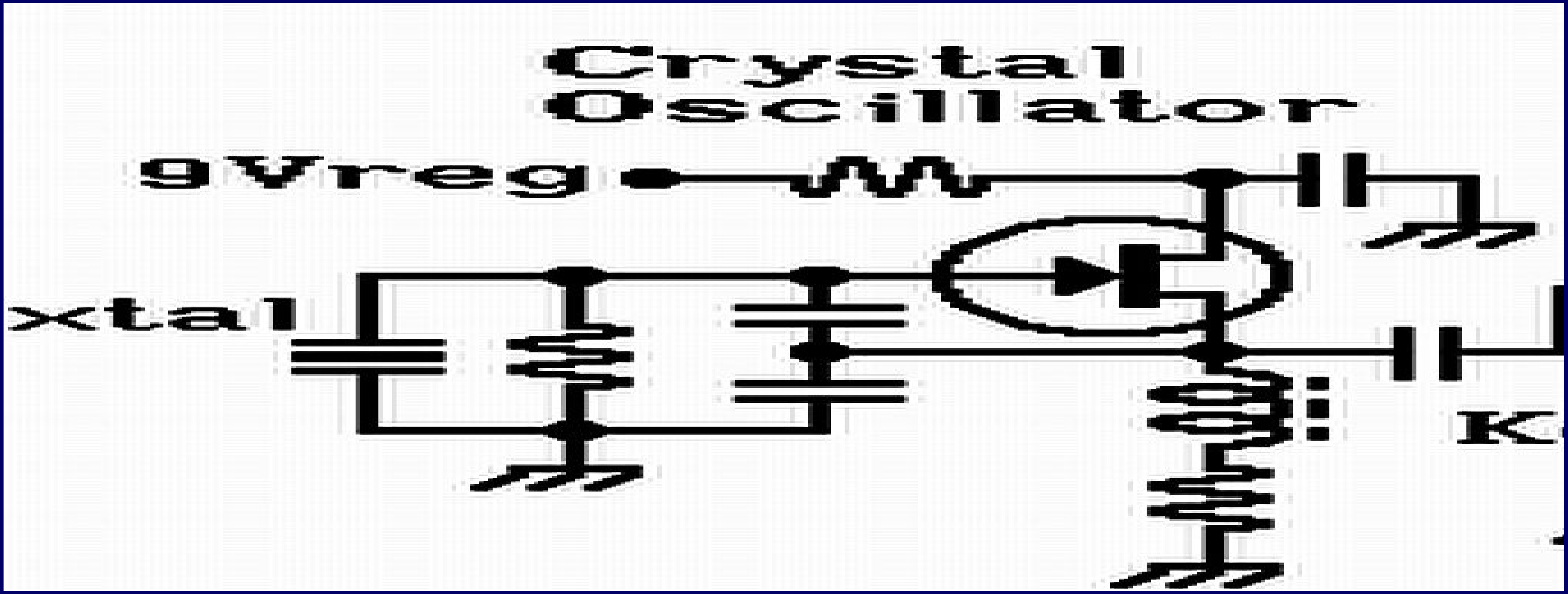
Block diagram of a CW transmitter.

The Carrier Oscillator creates the radio frequency alternating current signal at the desired frequency.

The keyed driver/buffer amplifies the RF signal when the key is closed. This amplifier also shields the oscillator from changes in the Power Amplifier which may shift the RF frequency.

The Power Amplifier develops the RF energy which is then coupled to the antenna for radiation. This stage may be keyed, or a class C amplifier which draws DC current only when driven.

Simple QRP CW Transmitter

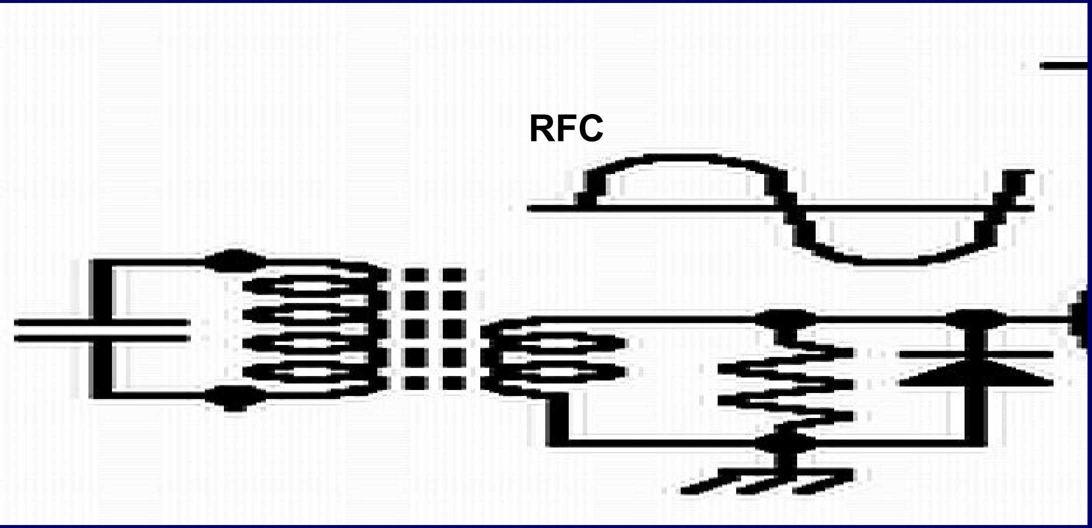


A Colpitts Crystal Oscillator generates a continuous carrier signal.

The Keyed RF Amplifier only amplifies when the key is closed and DC current flows, sending dots or dashes in Morse Code.

The Final RF amplifier is turned on by the keyed RF and drives a parallel resonant tank circuit which is link coupled to an antenna.

Class C RF Output Stage



Many CW and FM Transmitters use a Class C output for Power

An RF Choke applies B+ to the Transistor Collector

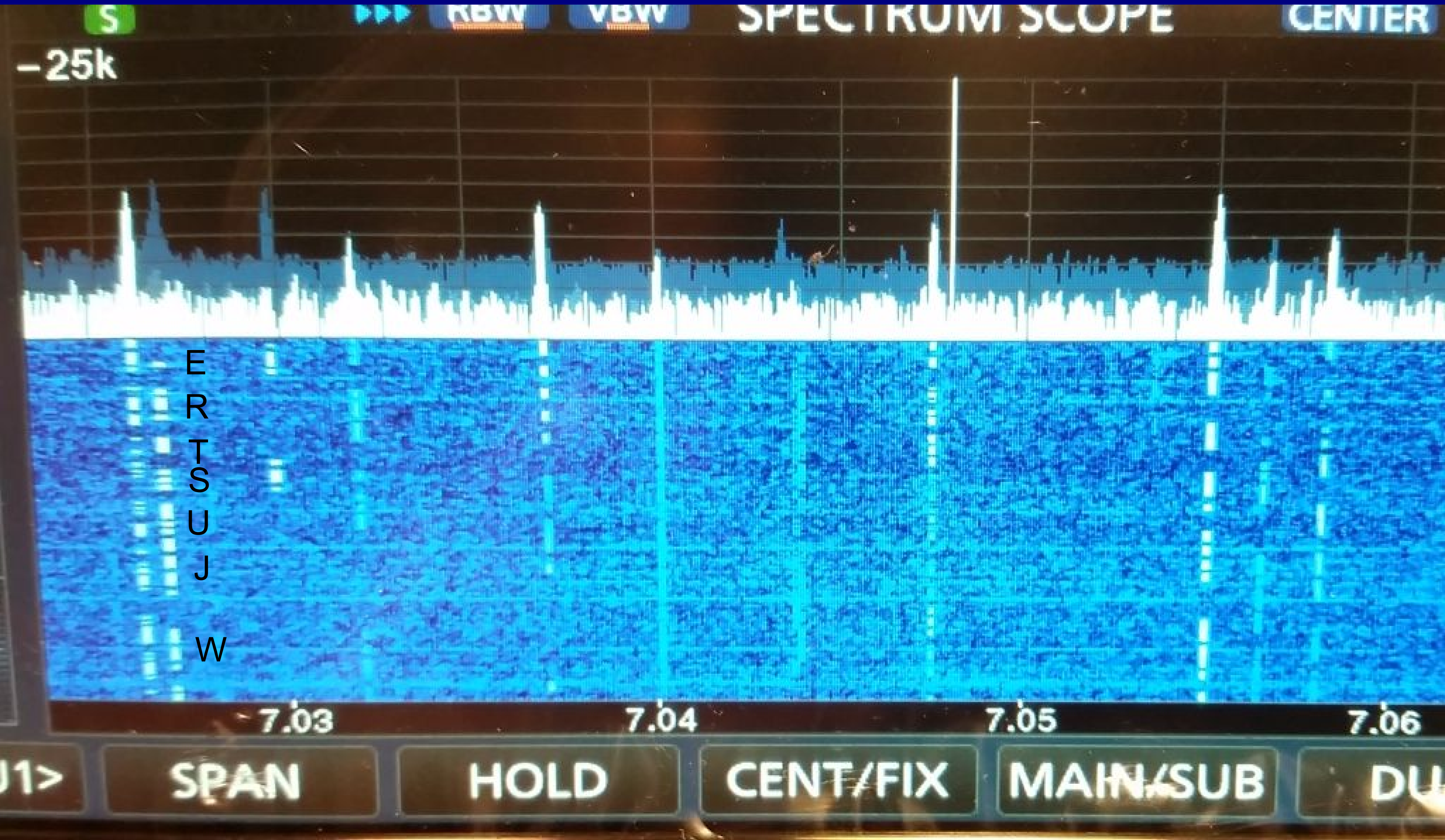
The Transistor is driven completely on by the input signal

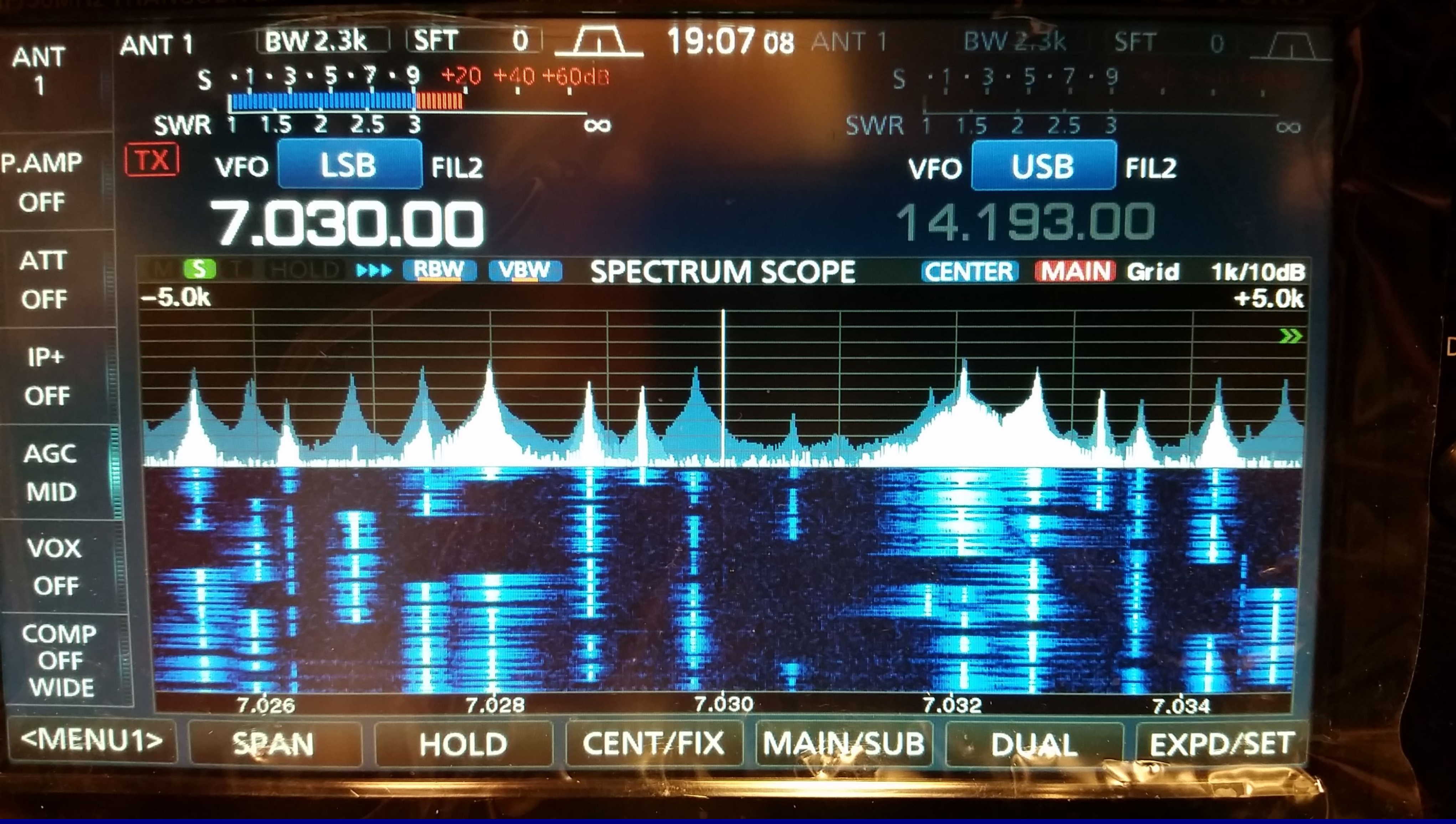
An Impedance Matching Low Pass Filter converts the Collector pulses to a fair approximation of a pure sine wave

The Collector Impedance is very low, just an ohm or two, so lots of current flows.   A typical Antenna Load is 50Ω.

Modern Receivers incorporate a Band Scan and Waterfall display which shows all the signals in a set bandwidth.

This is a small portion of the 40m CW Band.





Captured during a CW Contest last weekend. Each division is 1kHz and you can see some CW signals are very wide, as much as 600 Hz. This is due to high keying speed, and over driving the transmitter with a computer generated audio signal.

Amplitude Modulation

Canadian Reginald Fessenden, in 1906, was the first radio experimenter to apply amplitude modulation to a continuous wave signal generated by a very high frequency rotary generator. His broadcast included voice and music.

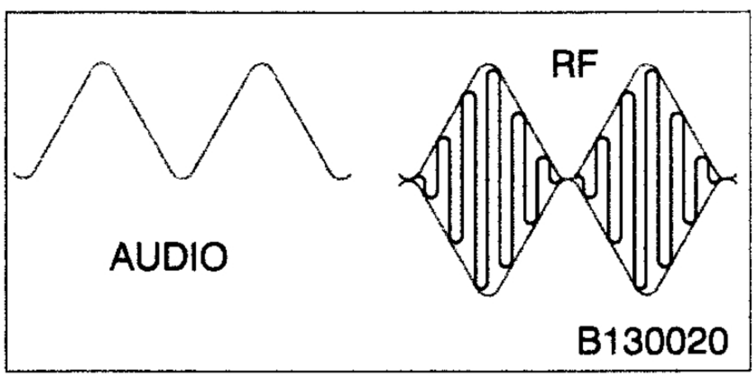
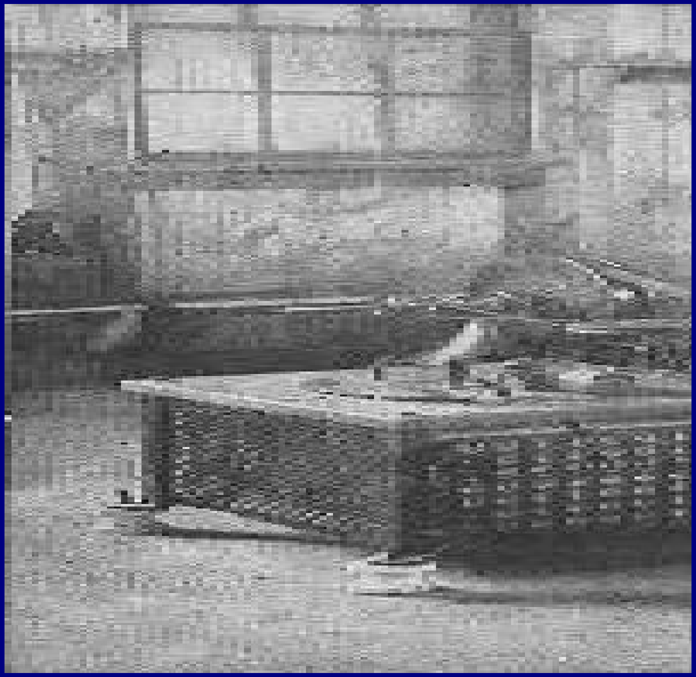


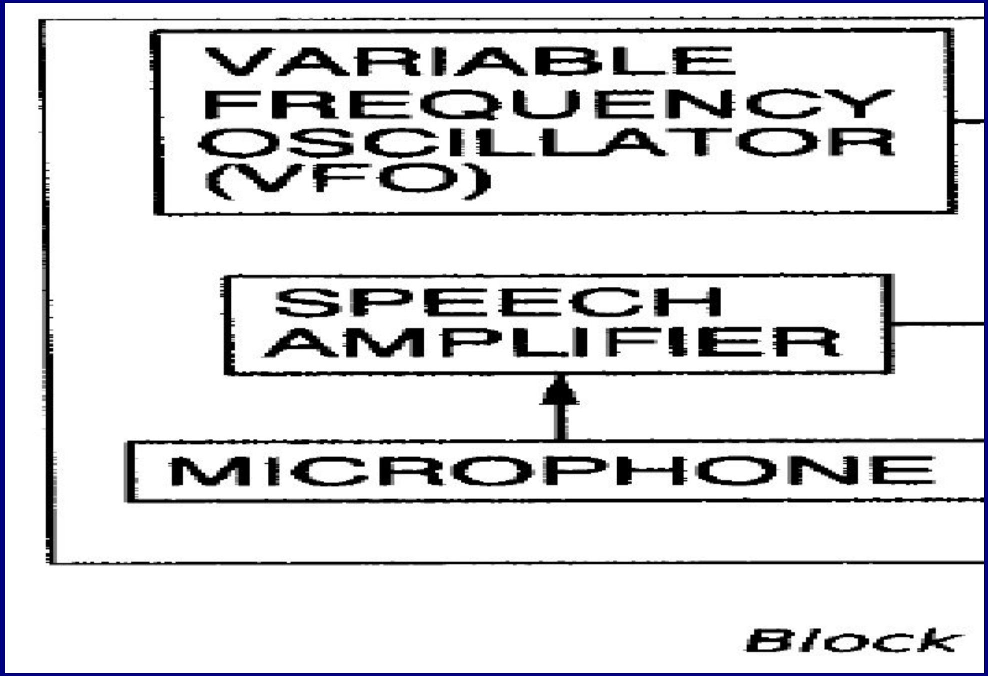
Fig 13-1

In AM modulation, the amplitude of the continuous radio wave is varied i proportion to the modulating signal.



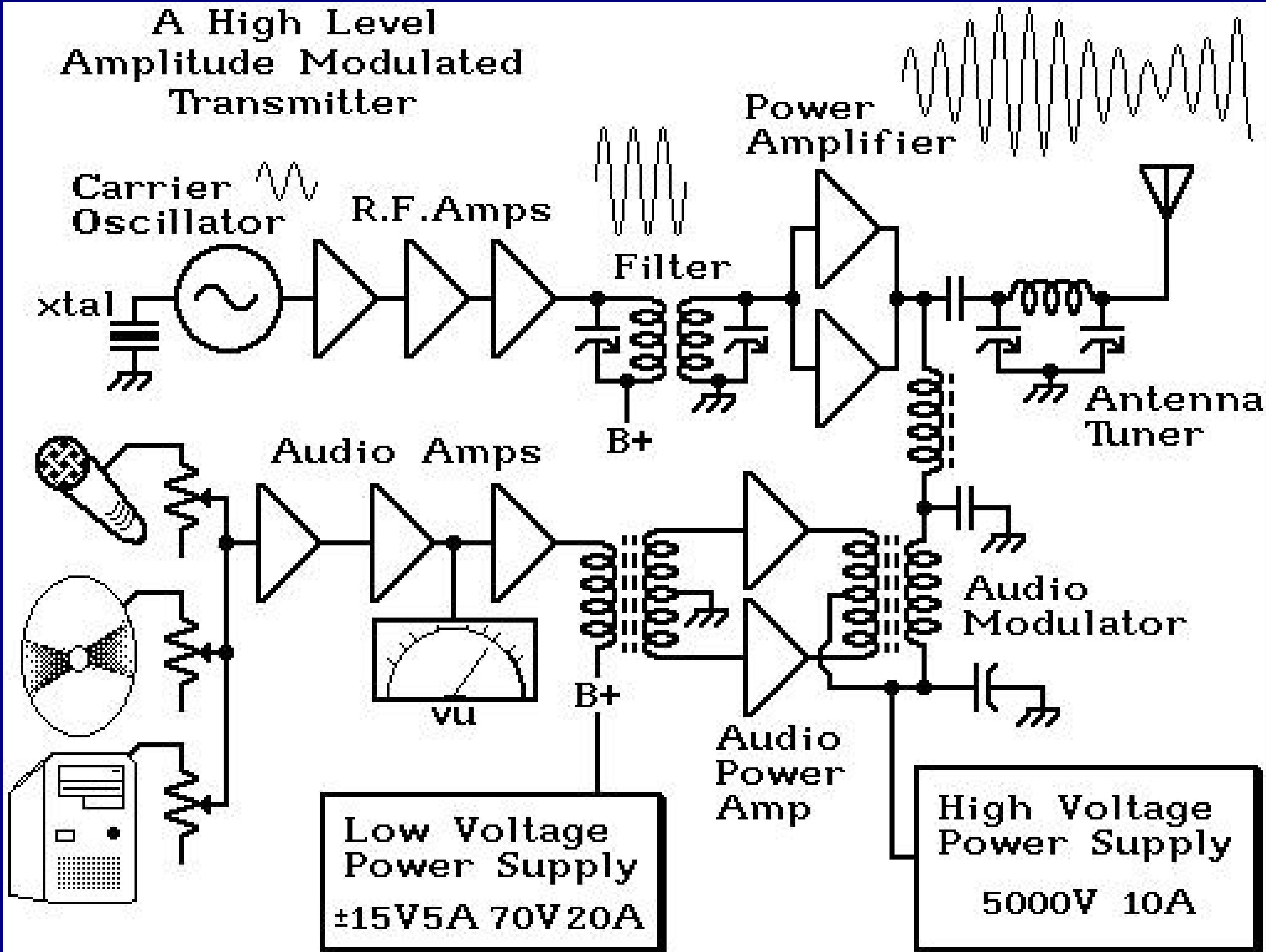
A Simplified Amplitude Modulated Transmitter

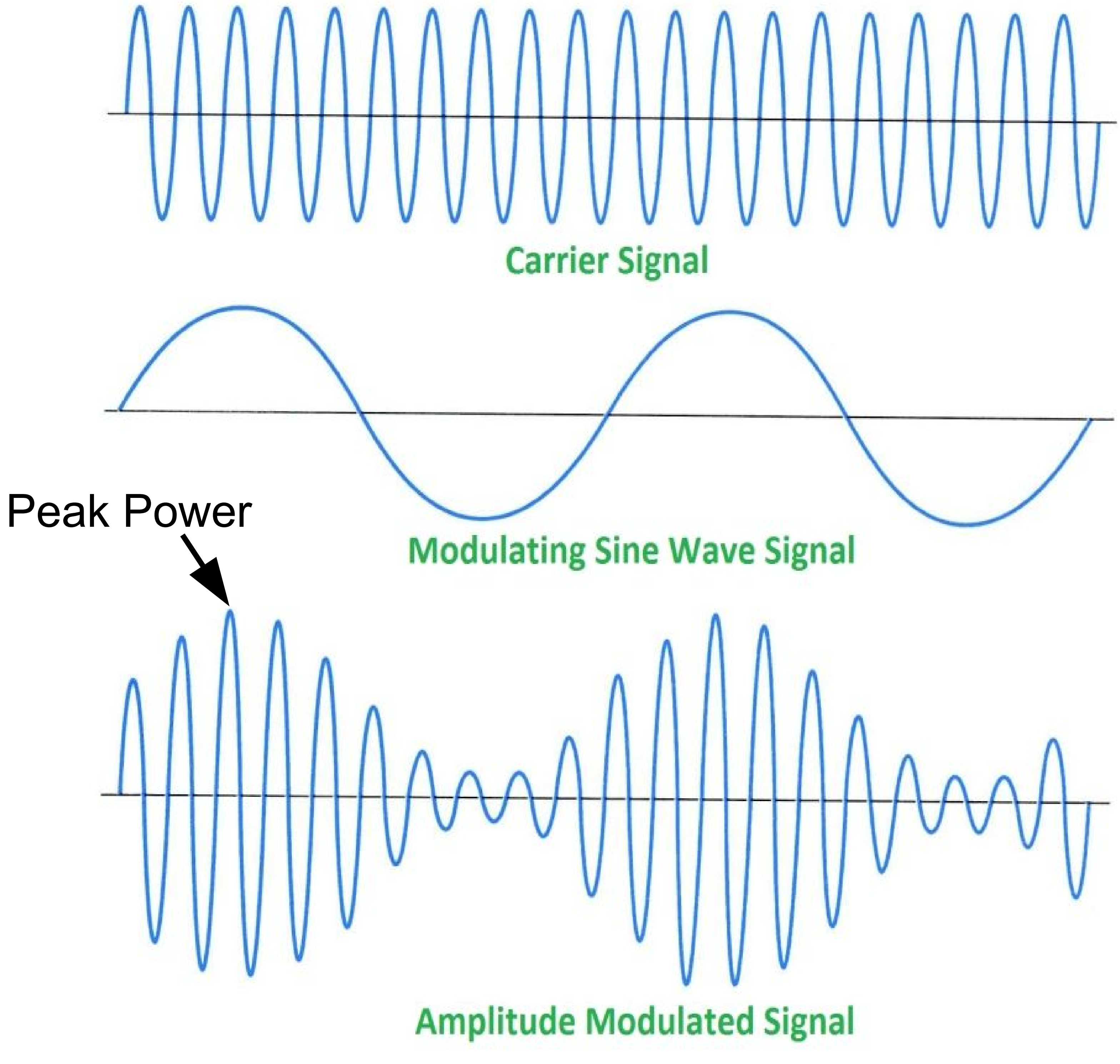
A VFO allows a change in transmit frequency, but getting stability is very hard.

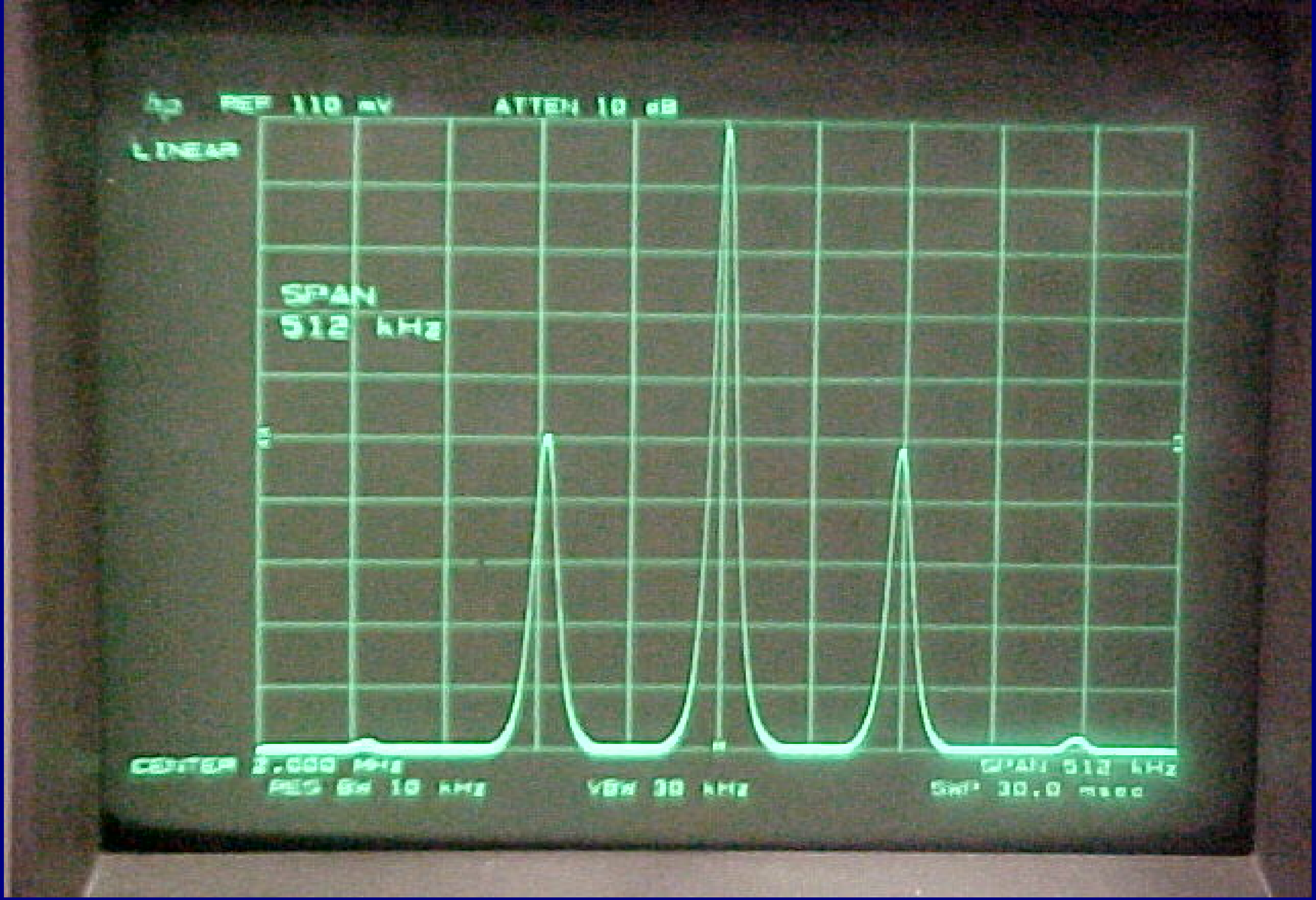


A Frequency Multiplier generates harmonics of the VFO frequency and then amplifies one of them. Almost never used with a VFO because it would worsen VFO drift.

The Microphone-Speech Amplifier-Modulator is basically a very powerful PA system, generating as much audio power as the RF Power Amplifier makes in RF.
Unlike your home HiFi, the audio frequency response is limited to 200Hz to 3000Hz, as this is where the speech intelligence is most effective for communications grade audio.


A High Level
Amplitude Modulated
Transmitter
Carrier
Oscillator
xtal
R.F.Amps
Filter
B+
Power
Amplifier
Antenna
Tuner
Audio Amps
VU
B+
Audio
Power
Amp
Audio
Modulator
Low Voltage
Power Supply
±15V5A 70V20A
High Voltage
Power Supply
5000V 10A


Carrier Signal
Peak Power
Modulating Sine Wave Signal
Amplitude Modulated Signal



Spectrum Scan of a carrier (central peak) amplitude modulated by a single tone. Two Sidebands are created, lower than the carrier by the frequency of the audio tone, and higher than the carrier by the frequency of the modulating tone.

The Radio Carrier does not change in amplitude with AM.

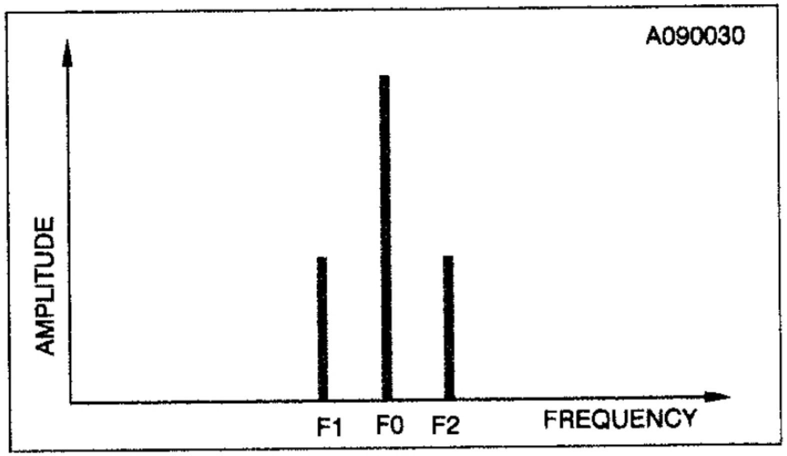


Fig 13-2

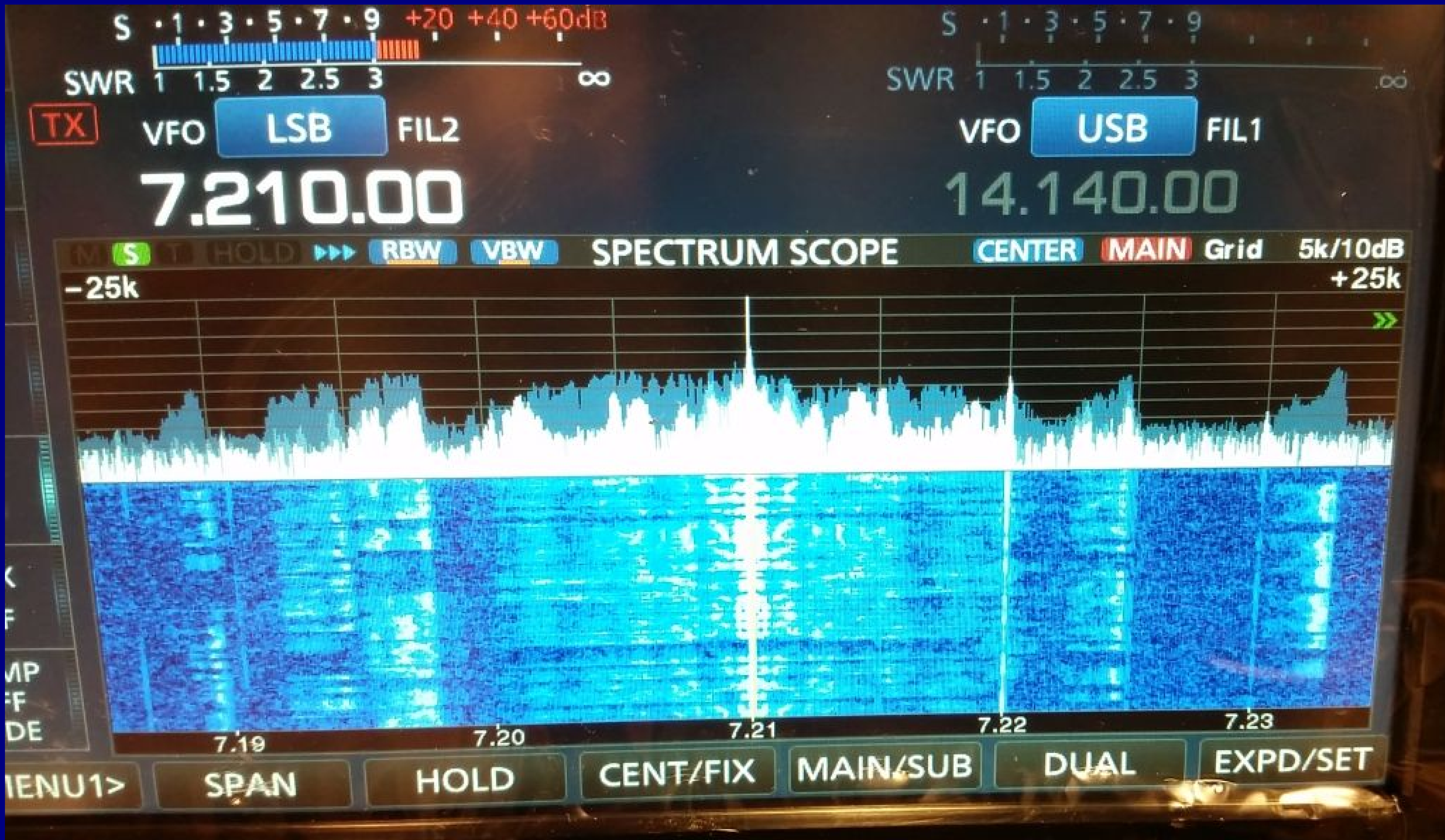
Additional power in the transmitted AM signal is contained in sidebands found on either side of the carrier at a spacing equal to the frequency of the modulating signal. The power in the carrier is constant.

The Upper and Lower Sidebands carry all the information, tones or vocal audio. Each sideband contains 25% of the carrier power at 100% modulation. Thus a 1kW AM transmitter will put out a maximum of 1.5kW on modulation peaks.

The Carrier serves as a frequency reference and allows for accurate demodulation of the sidebands with simple diode detectors.

AM Broadcasters are allowed to positively modulate to 135%, but must not negitively modulate beyond 100%, or they go off the air!

Some foreign Shortwave Broadcasters transmit within the 40m Ham Band. This AM transmission on 7210kHz shows the central carrier and identical sidebands +&- 12kHz.



This fine example of an Amateur Homebrew Amplitude Modulated 1kW Transmitter is designed as Modules which are rack mounted.

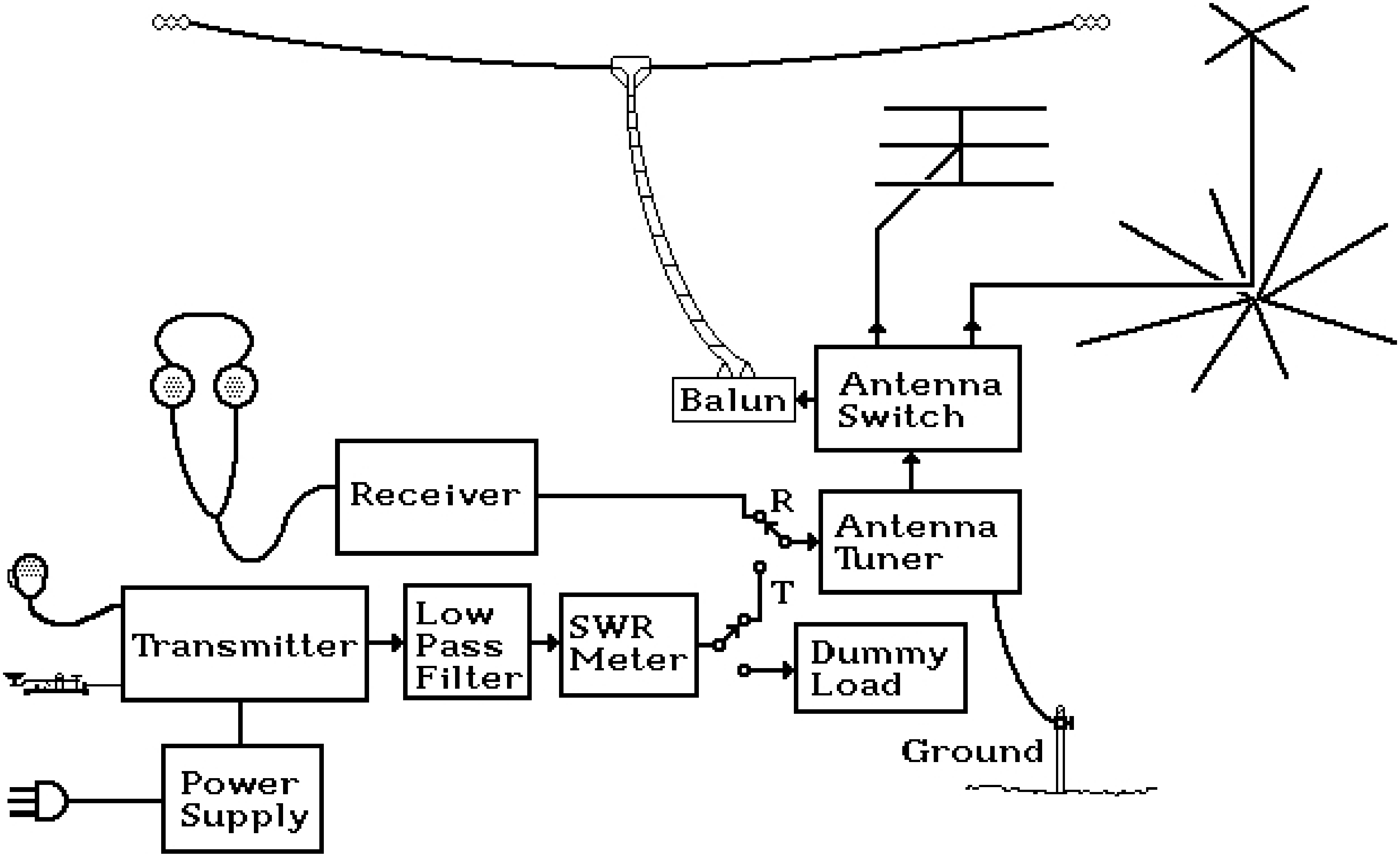
The exciter is crystal controlled, so operation is on a single favourite frequency.

Change the crystal to QSY.

Windows allow the operator to access power tube performance.

The Audio Modulation tubes are seen in the bottom window, while the Radio Frequency Power tubes are seen in the top windows.

All power tubes are Eimac 3-500Z.



An Amateur Station pre 1970

The Problem With Harmonics

Most transmitter power output stages create Harmonics of the fundamental signal. A Harmonic is a multiple of the fundamental frequency. Most problematic are the 3^{rd} and 5^{th}.

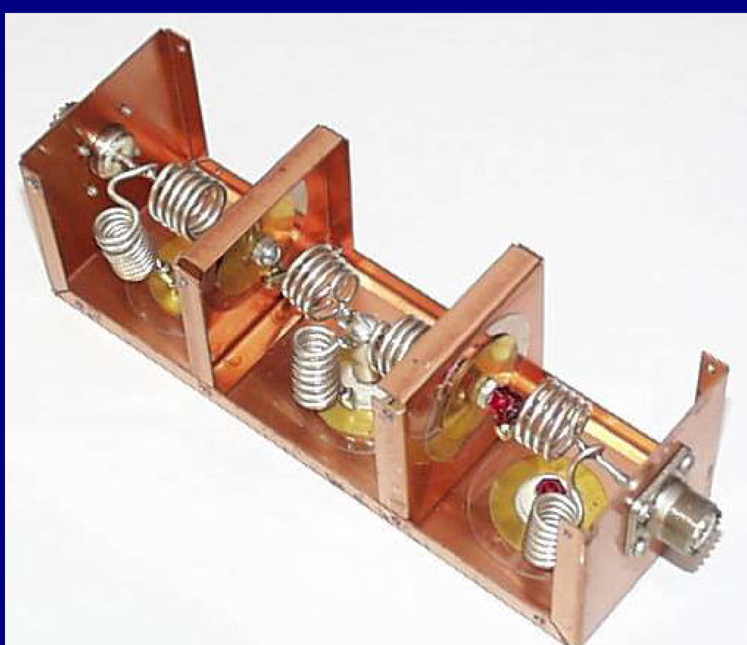
Harmonic outputs can interfere with other spectrum users.
For Example: On the 15m band the third harmonic of 21MHz is 63MHz, right in the TV Channel 3 allocation.

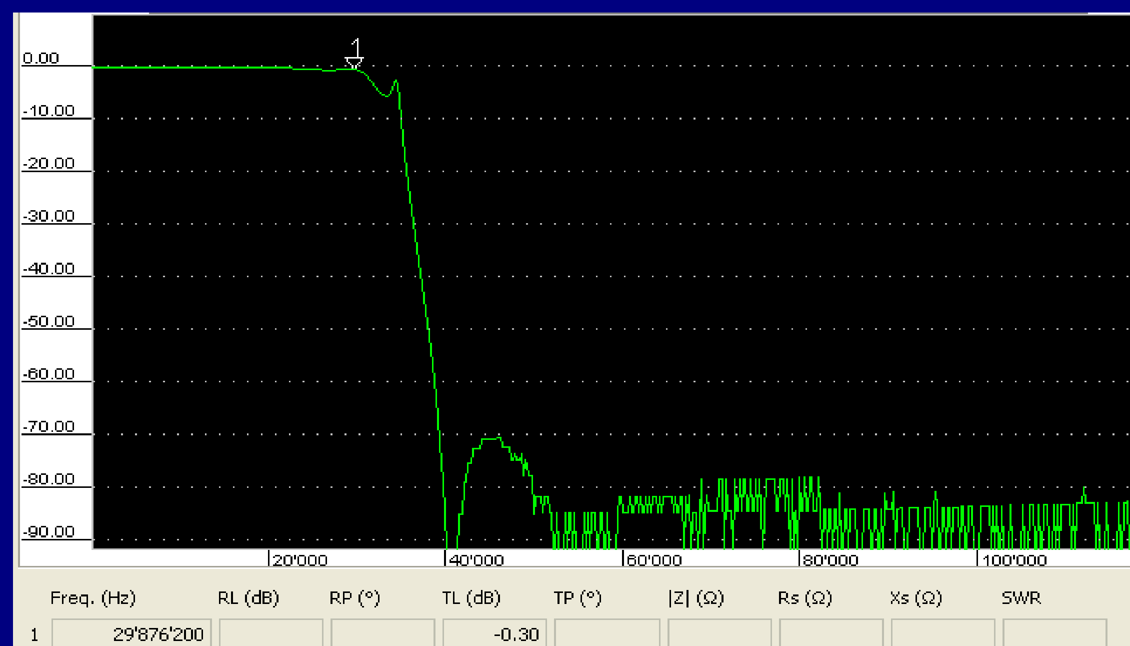
Modern power output stages include special low pass filters that pass the desired band and suppress higher frequencies to remove the harmonic energy.

Homebrew and older transmitters relied upon external filters.

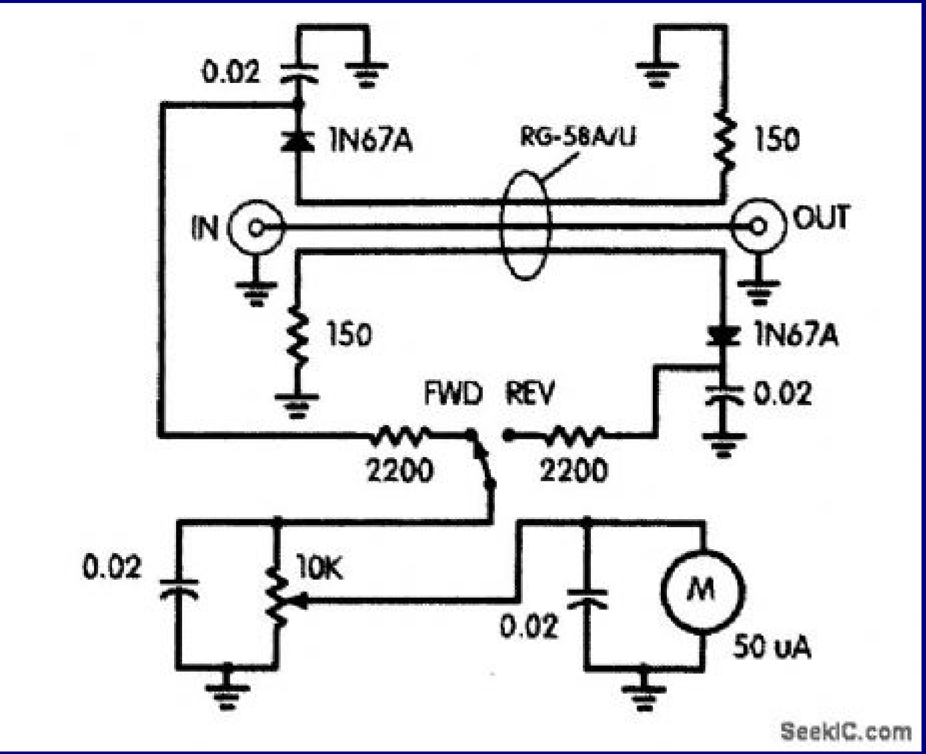
Low Pass Filter

Passes all frequencies below 30MHz, Cuts off everything in the TV and FM band. Prevents Amateur Transmissions from interfering with TV Broadcast reception.

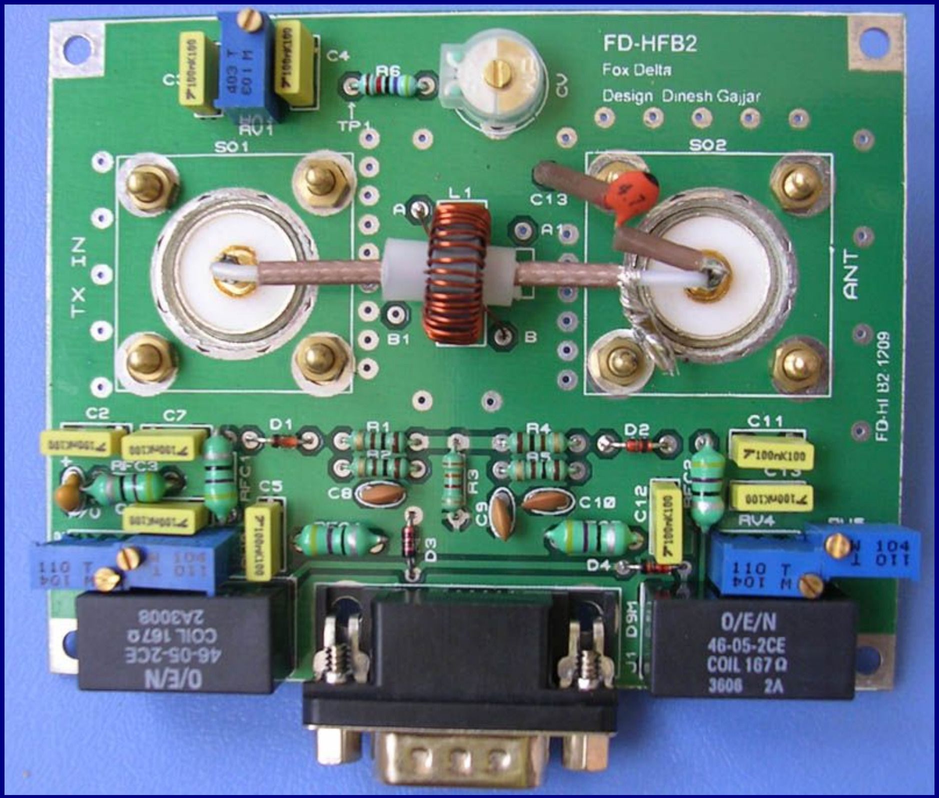




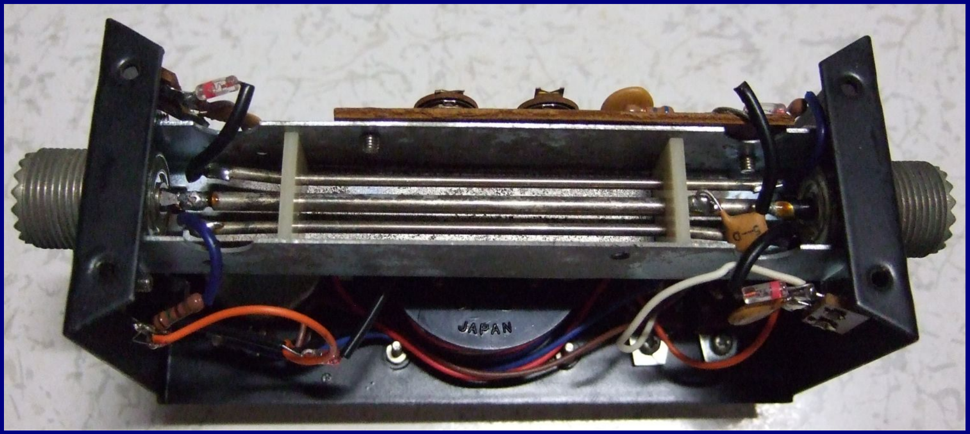
Standing Wave Ratio Meter



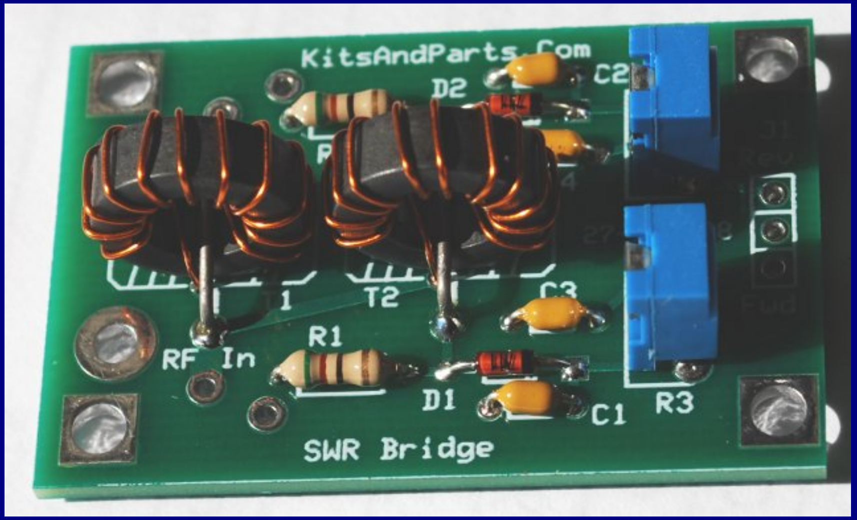
SWR Pickups



Brune Bridge has good frequency range, and linear power response, but must be trimmed for directionality and high frequency compensation. Easy to build and adjust for high accuracy.



Line Sampler Not very sensitive at low frequency.



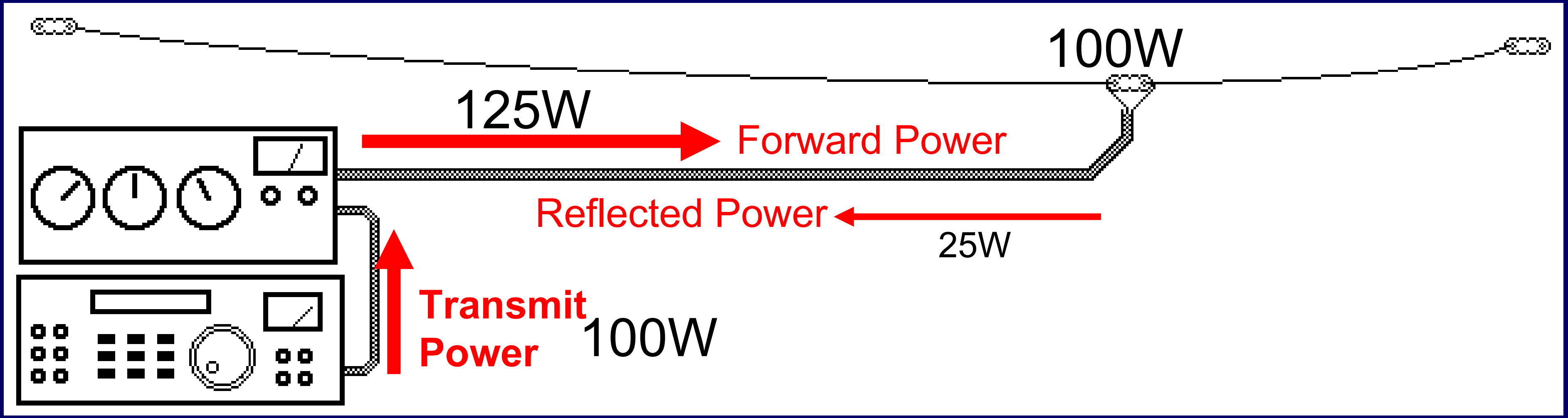
Tandem Bridge Good frequency range and linear power response.

Commercial Antenna Tuners

VE3GSO SWR/Power Meter, C-L-C Antenna Tuner, Antenna Switch


3
2
1
Load
+12
Input

Antenna Reactance, either Inductive or Capacitive, does not Dissipate Power, but Returns Power to the Source.



The Antenna Tuner creates a Conjugate Match for the Reflected Power so it is returned to the Antenna along with the Forward Power.

The Transmitter sees a perfect load match and no Reflected Power. Maximum Power is achieved!

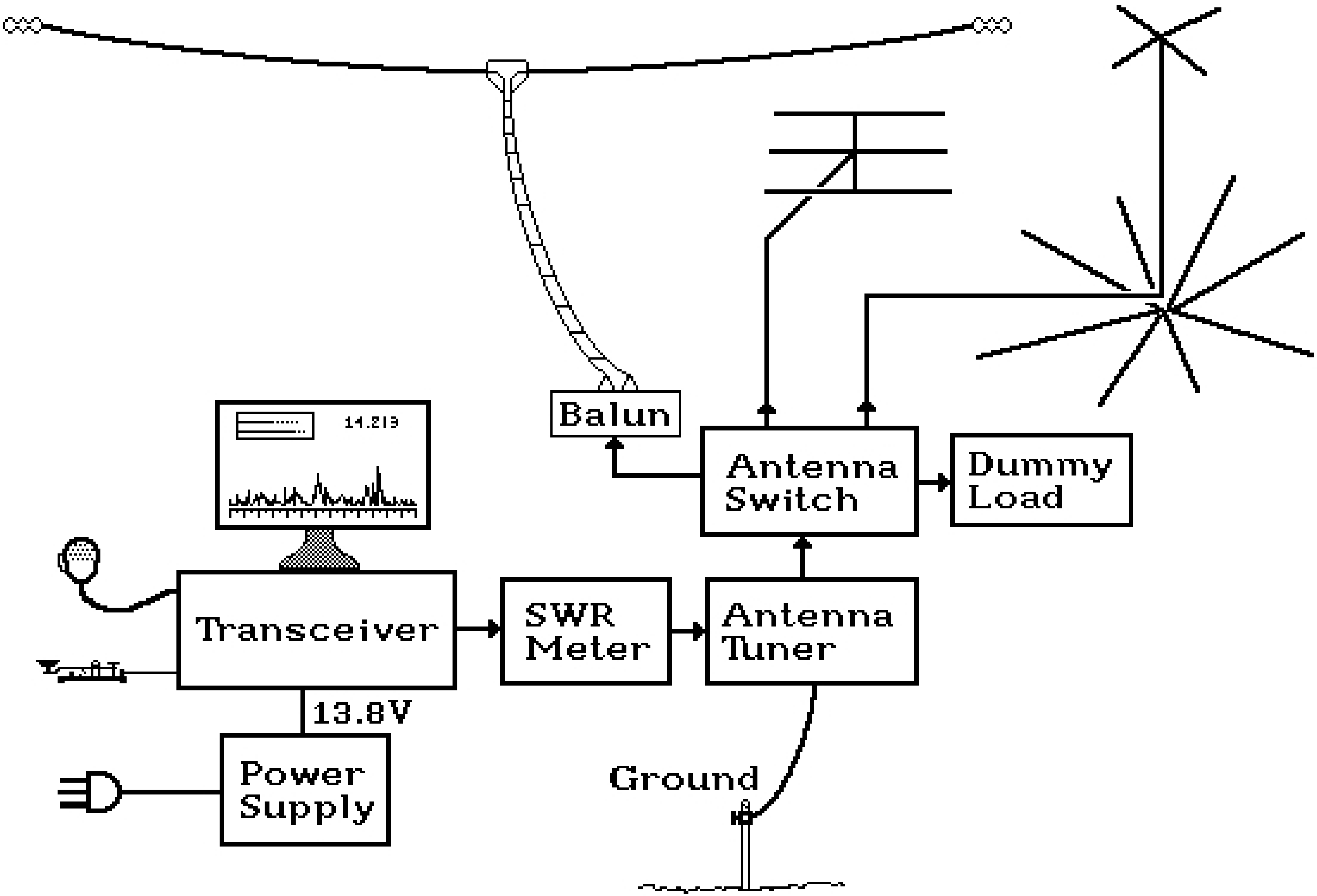
Dummy Load

A 50Ω non-inductive resistor housed in a well shielded container to prevent radiation.

Used for transmitter tune up and testing. The resistor may be bathed in oil to increase heat dissipation.

A simple 50Ω load can be made with 20 of 1000Ω 2W carbon resistors in parallel.

A large oil bath will triple the Power dissipation.



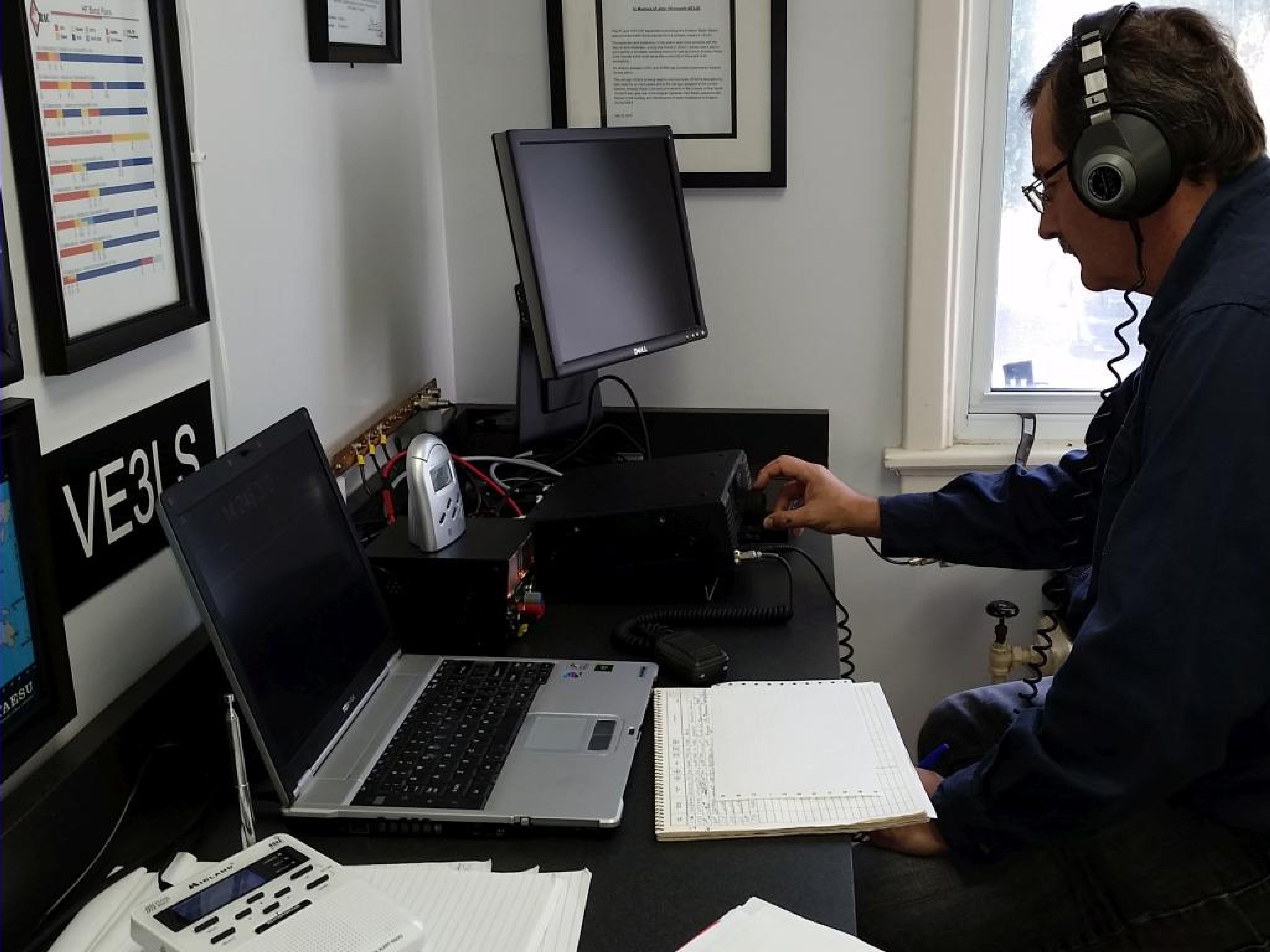
A Modern Amateur Station Layout

A Pre-WARC 100W Solid State Transceiver

In the late 70's this rig was a marvel of miniaturization. It was reasonably stable after an hour of warmup, delivered 100W output, and was within a modest budget.

Notice that the digital readout does not agree with the mechanical dial, a common fault that drove some owners quite mad.

LARC Club Station VE3LON
Icom IC-718 & LDG IT-100 Auto Tuner


VE3LS

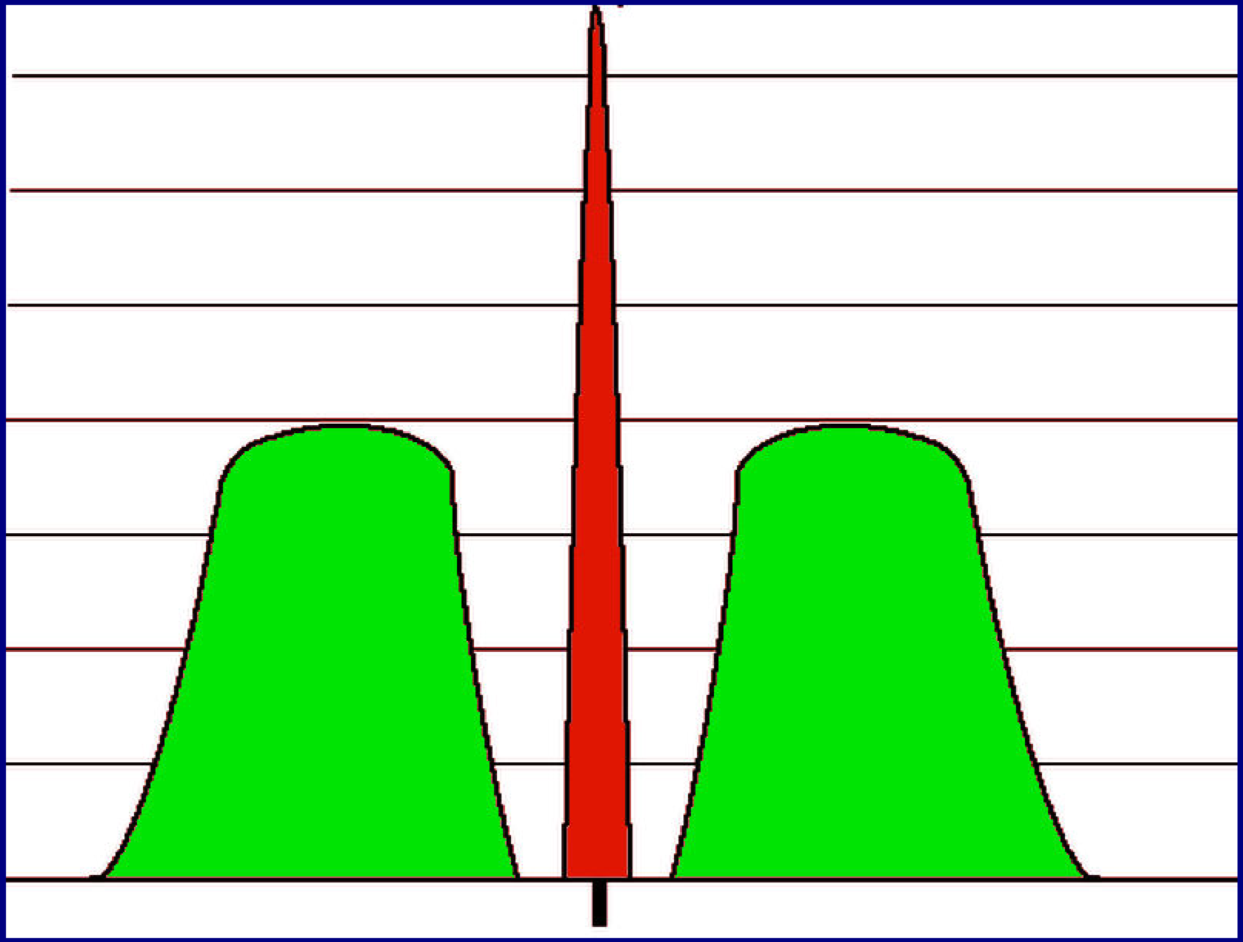

BEACON MONITOR
IBM
SAMSUNG

Amplitude Modulation Creates two Identical Sidebands

Each Sideband contains the same information.

The Carrier is at Full Power, serving only to demodulate the sidebands in simple AM diode detectors.

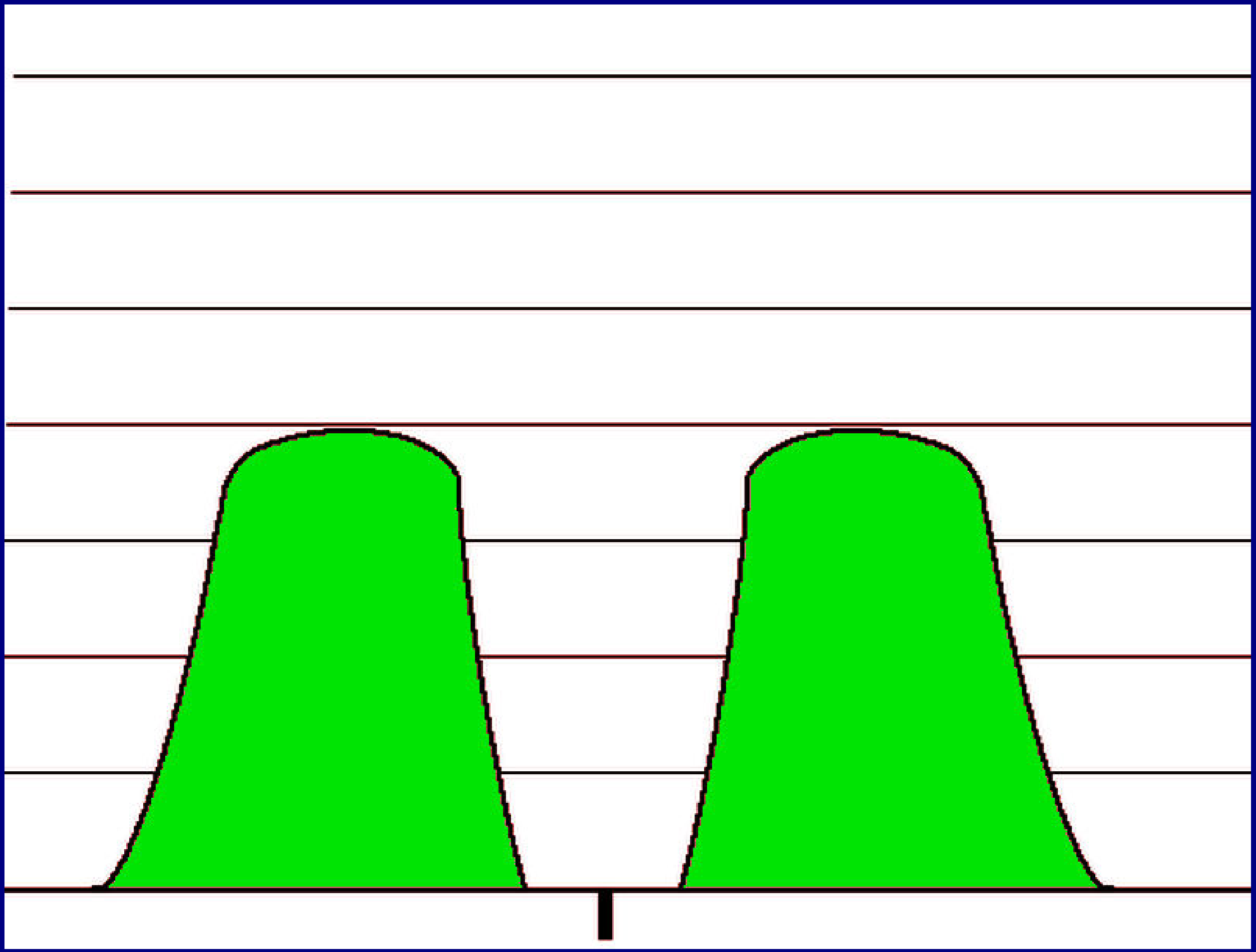
For Hams this is a waste of Precious Transmitter Power



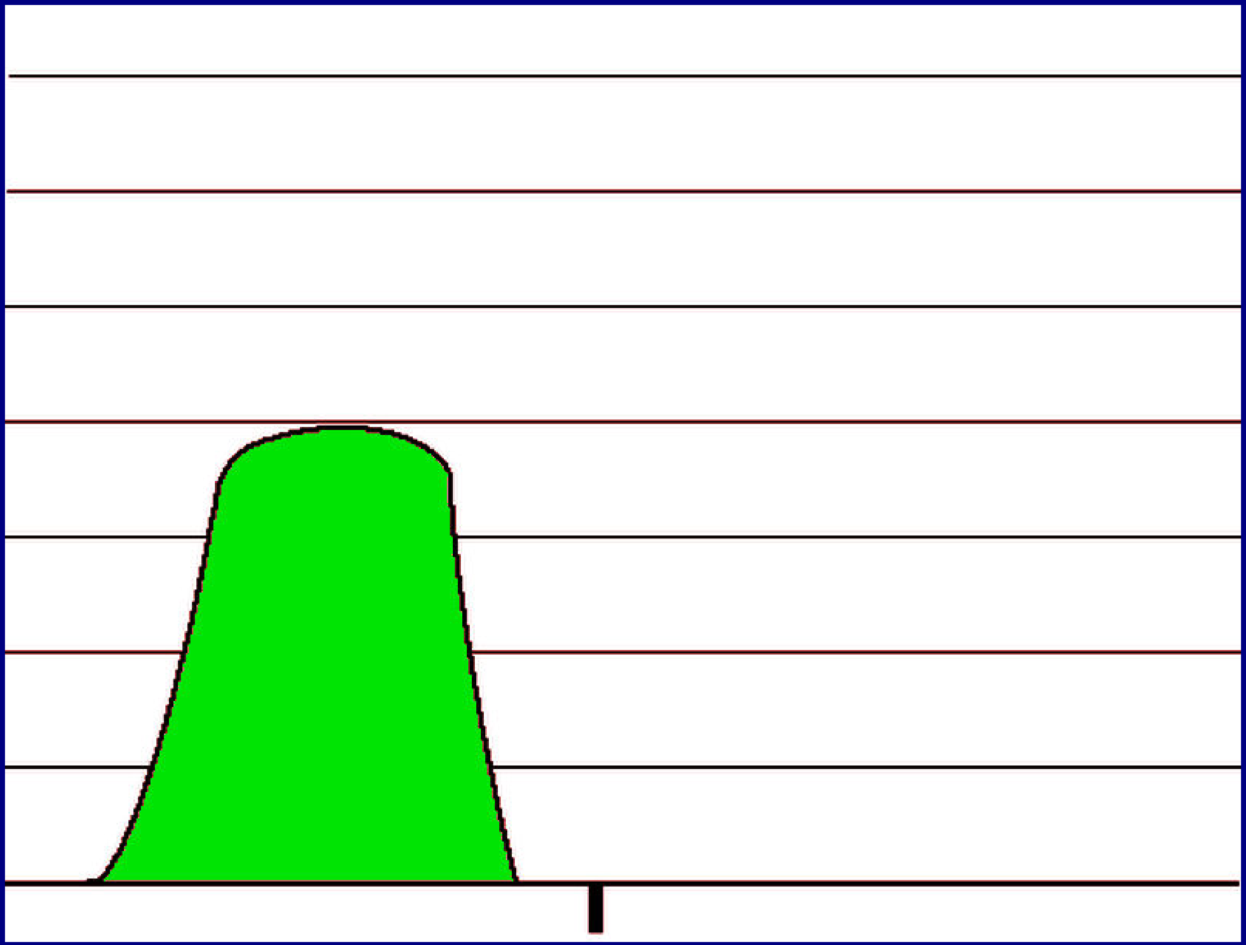
A Balanced Mixer creates both Sidebands, Upper and Lower.

The Carrier is Suppressed by Phase Cancellation.

This Double Sideband, Suppressed Carrier Signal could be transmitted as is, with each sideband serving as a back up if Selective Fading is a problem in the communications link.

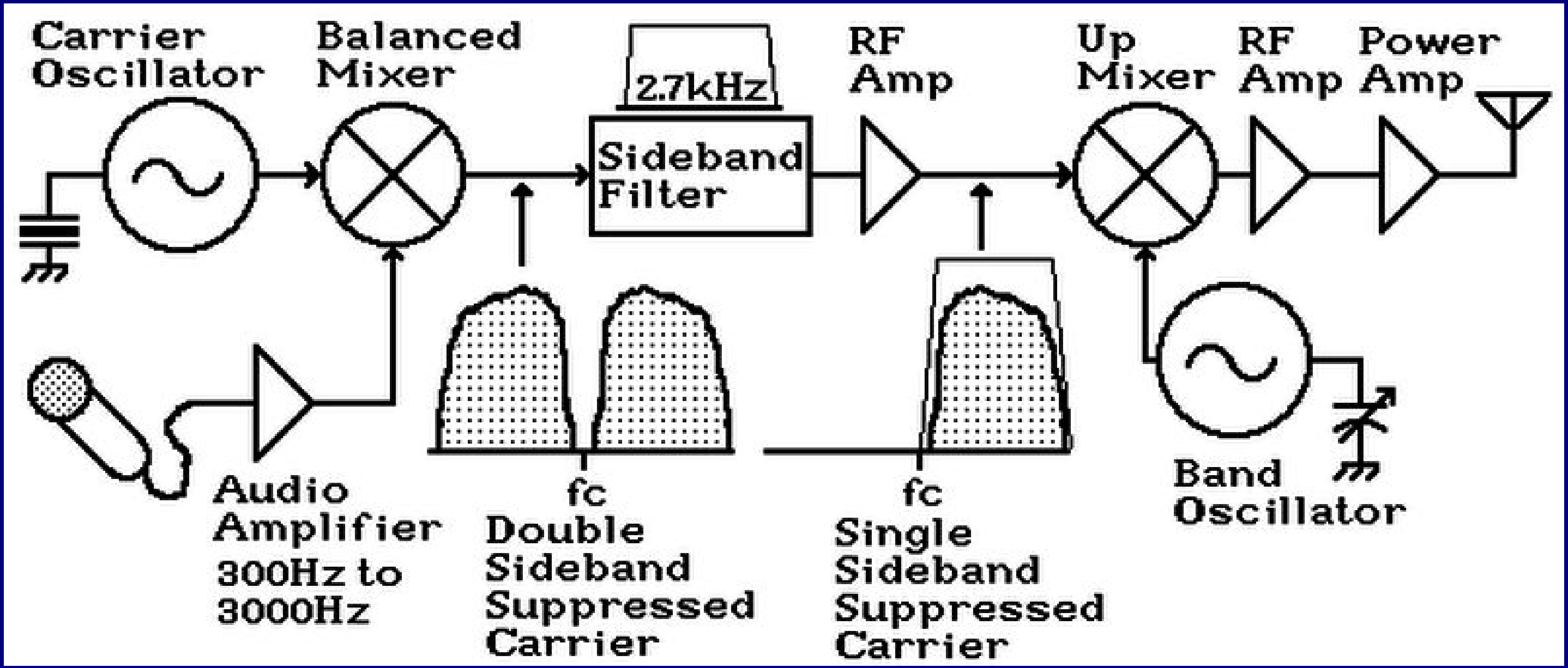


A Selective Filter of 2.7kHz Bandwidth removes one of the Sidebands, resulting in a Single Sideband Suppressed Carrier Signal, (SSBSC or SSB) which makes maximum use of the Transmitter Amplifier Power Available.



Single Sideband Suppressed Carrier Generation

Sideband Filter Method



A Carrier signal is modulated in a balanced mixer to create a double sideband suppressed carrier signal.

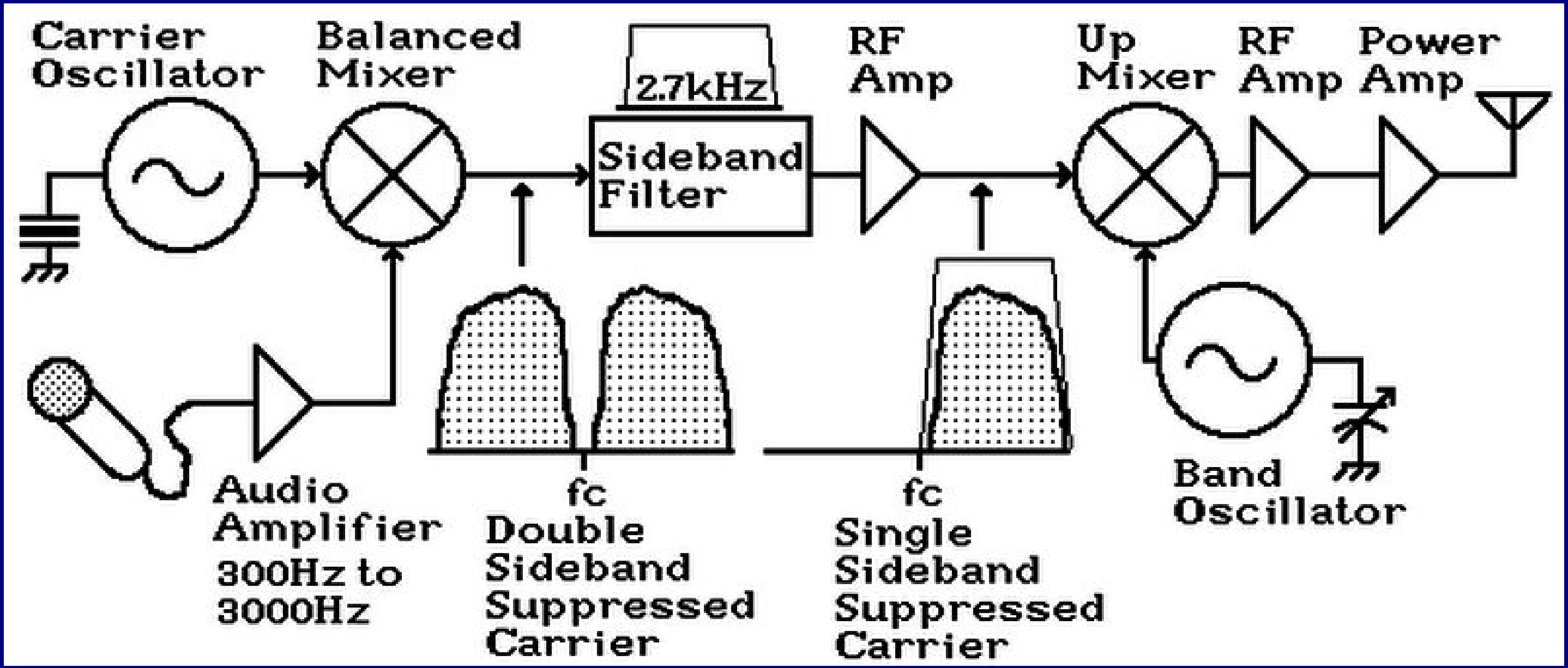
A narrow band filter, 2.7kHz, passes one sideband and blocks the opposite sideband.

This Single Sideband Signal is then mixed with a second oscillator to the desired RF band.

A 9MHz Carrier creates USB and when mixed with a 5MHz B.O. sums to create USB on 14MHz <u>OR</u> if subtracted creates LSB on 4MHz.

Single Sideband Suppressed Carrier Generation

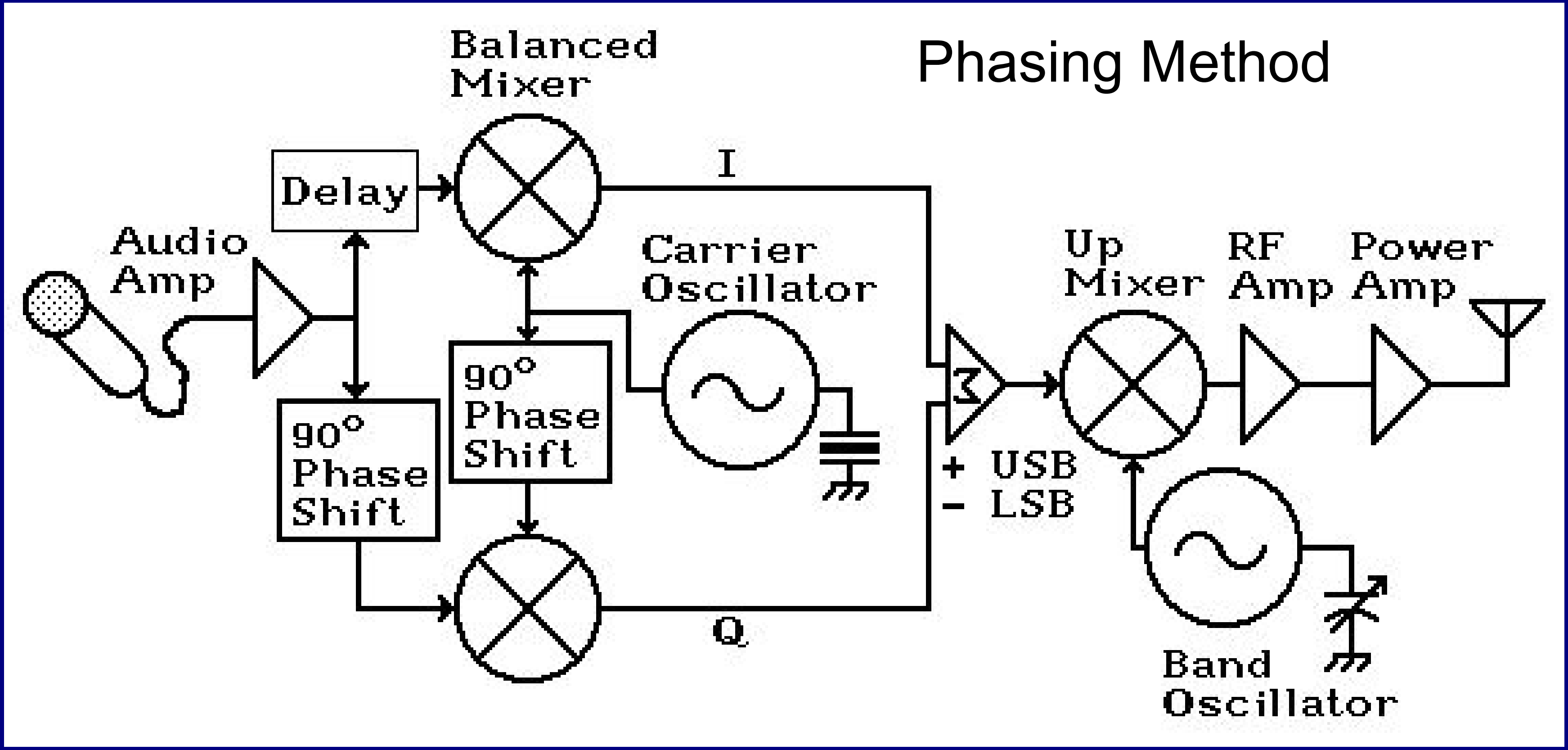
Sideband Filter Method



The RF amplifiers used to increase SSB power levels must be highly Linear, which means signals are not distorted in any way.

Class A or AB_2 amplifiers are used, which are less efficient than Class C, but do not distort the SSB signal.

Single Sideband Suppressed Carrier Generation



Carrier and Audio are mixed in a balanced mixer to create In Phase DSBSC.

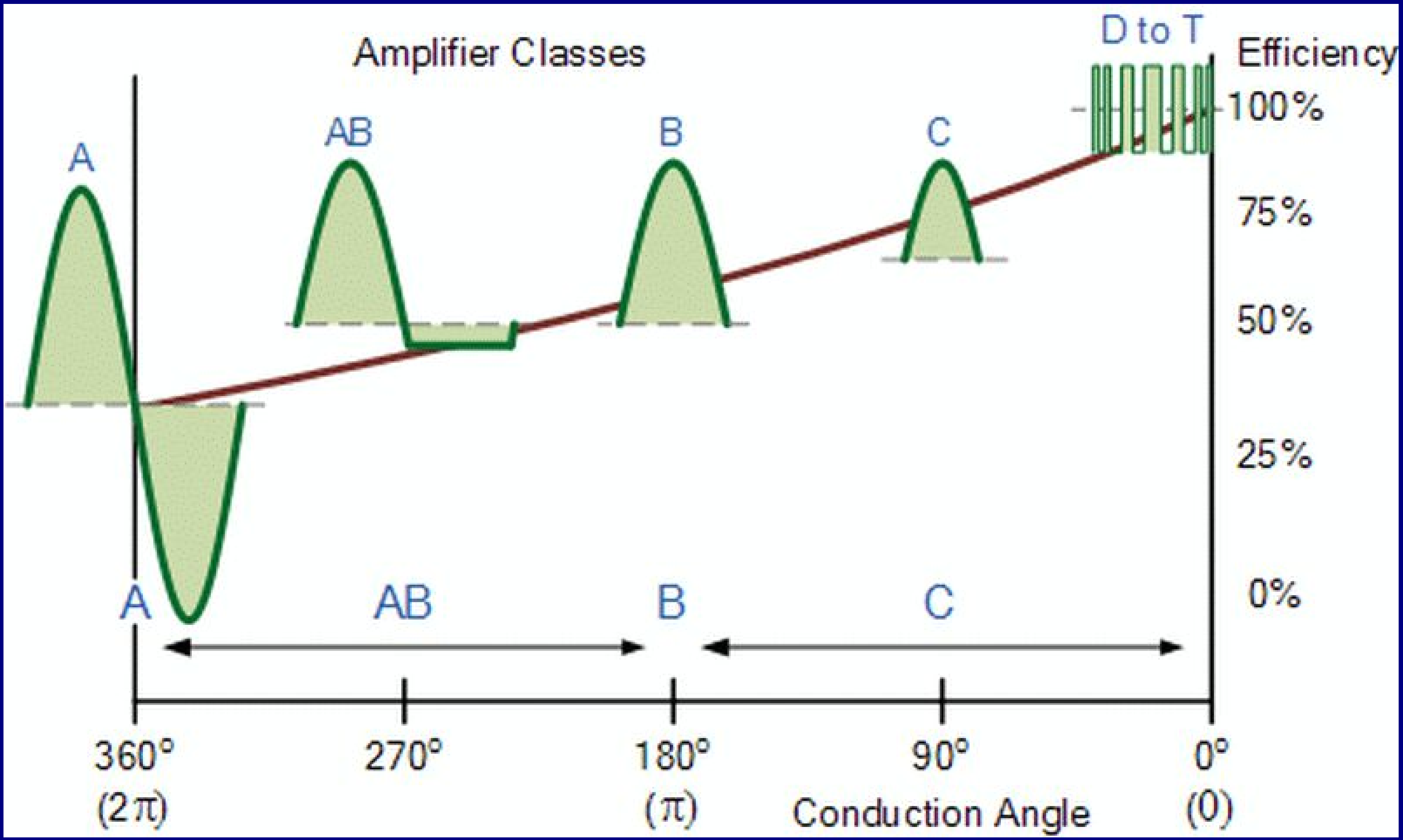
90° Phase Shifted Carrier and Audio are mixed in a balanced mixer to create Quadrature Double Sideband Suppressed Carrier.

When I and Q are summed a Upper Sideband Signal is generated.

When I and Q are subtracted a Lower Sideband Signal is generated.

The SSB signal is then mixed to the final transmit frequency.

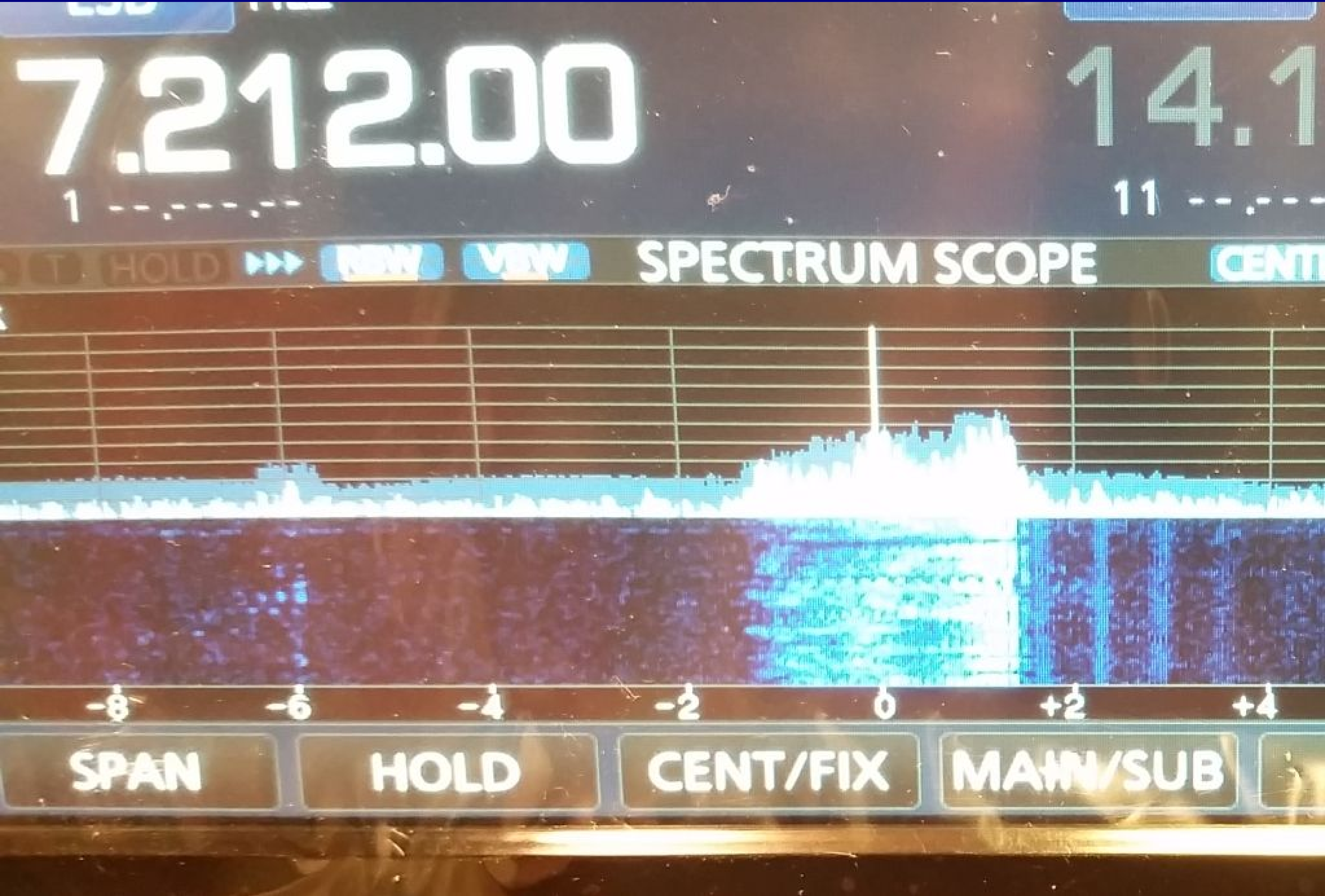
Amplifier Operating Classes



Only Class A amplifiers reproduce the entire waveform cycle with little distortion. The price they pay is poor Power Efficiency, which means lots of waste heat in the amplifier.

SSB amplifiers must be Linear, amplifying without distortion. Usually Class AB is used.

A Strong and a Weak SSB signal



Time for a 5 minute break

Frequency Modulation

There are three ways to modulate a radio carrier:

1. Amplitude Modulation
2. Frequency Modulation
3. Phase Modulation

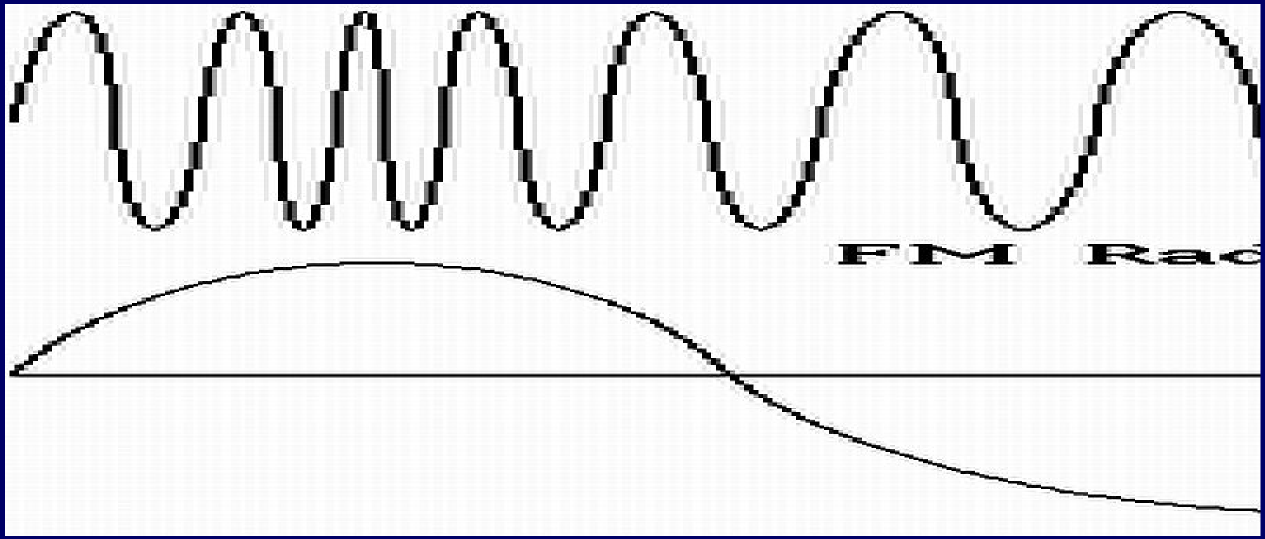
Edwin Howard Armstrong was the first to develop circuits to create and receive FM, in 1933.

By changing frequency according to the modulating signal the radio signal can be amplitude limited and not lose the signal.

Noise is AM, so is eliminated by amplitude limiting.

Edwin and Marion Armstrong on their honeymoon at Palm Beach, Dec, 1923 with the Superheterodyne radio he built for her as a wedding gift.

The FM Waveform



The FM Radio Signal changes Frequency in accordance to the modulation signal amplitude.

A high signal voltage creates a high frequency deviation, while a low voltage creates a small frequency deviation.

A high audio frequency modulating signal creates a high rate of change of frequency, while a low audio frequency modulating signal changes the frequency slowly.

The amplitude or power of the FM signal does not change.

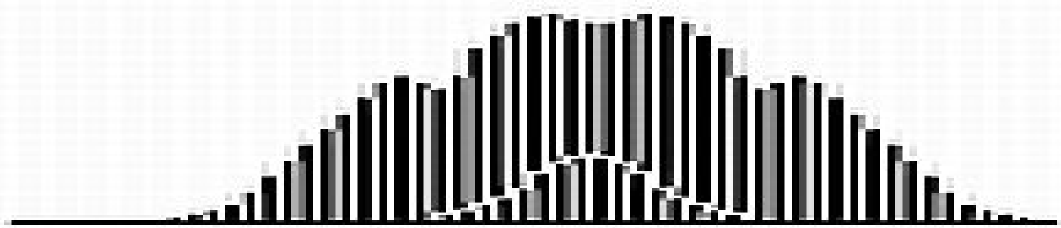
T

Natural Noise is AM
eliminate AM Noise,

150Hz–4KHz ~ ±4KHz
20Hz–10KHz ~ ±25KHz
20Hz–15KHz ~ ±75KHz
60Hz–4.2MHz ~ 12.5MHz

FM Transmitters

Modulated FM is a



FM Rece
Carrier,

FM signals may be

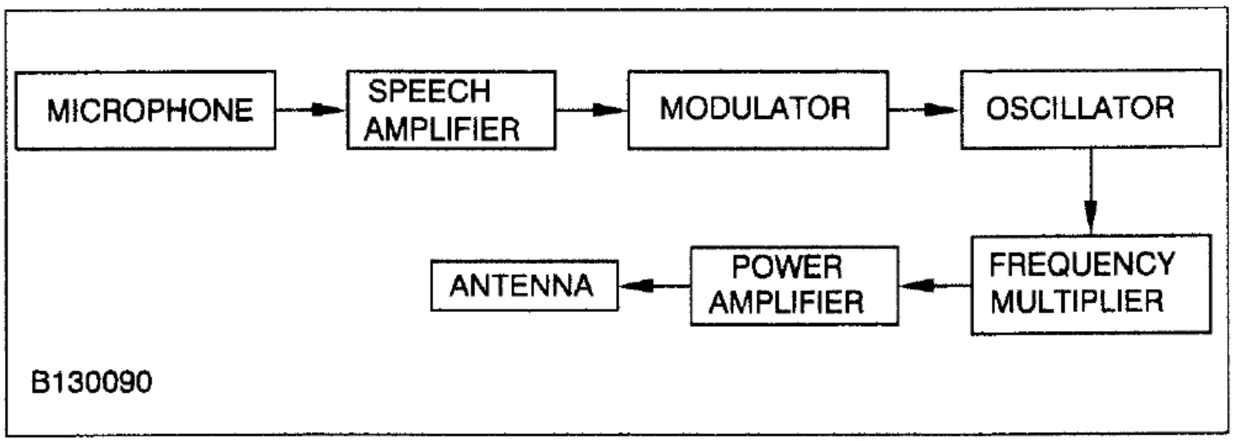


Fig 13-6
Block diagram of an FM transmitter.

The Microphone converts Acoustic Signals into Electrical Signals.

The Speech Amplifier increases the audio signal while limiting the frequencies to 300Hz to 3000Hz. Pre-emphasis is also applied to increase higher frequencies and decrease low frequencies.

The Modulator changes the frequency of the RF Oscillator in accordance with the strength of the audio signal.

The Oscillator Frequency may be Frequency Multiplied to bring the FM signal up to the Transmit Frequency. 2X, 3X, 4X, 6X are used.

The Power Amplifier increases the FM signal to the power required for the communication application.

The FM Transmitter

Audio for FM is frequency limited and amplitude limited to limit the bandwidth of the FM sidebands to the specified radio channel.

Audio for FM is pre-emphasised to increase the strength of the high frequencies so that in the receiver the audio can be de-emphasised to reduce high frequency noise.

Amplification of the Frequency Modulated Carrier may be done in high efficiency Class C amplifiers and frequency multipliers.

Power Amplifiers are also Class C for high efficiency.

Terms Definition

Centre Frequency: The carrier frequency of the transmitter without any modulating audio. eg: 147.06 MHz

Deviation: The amount of frequency shift of the radio carrier to either side of the Centre Frequency. eg: +&- 5kHz

Modulation Index: The ratio of the Carrier Deviation to the Frequency of the Modulating Signal.

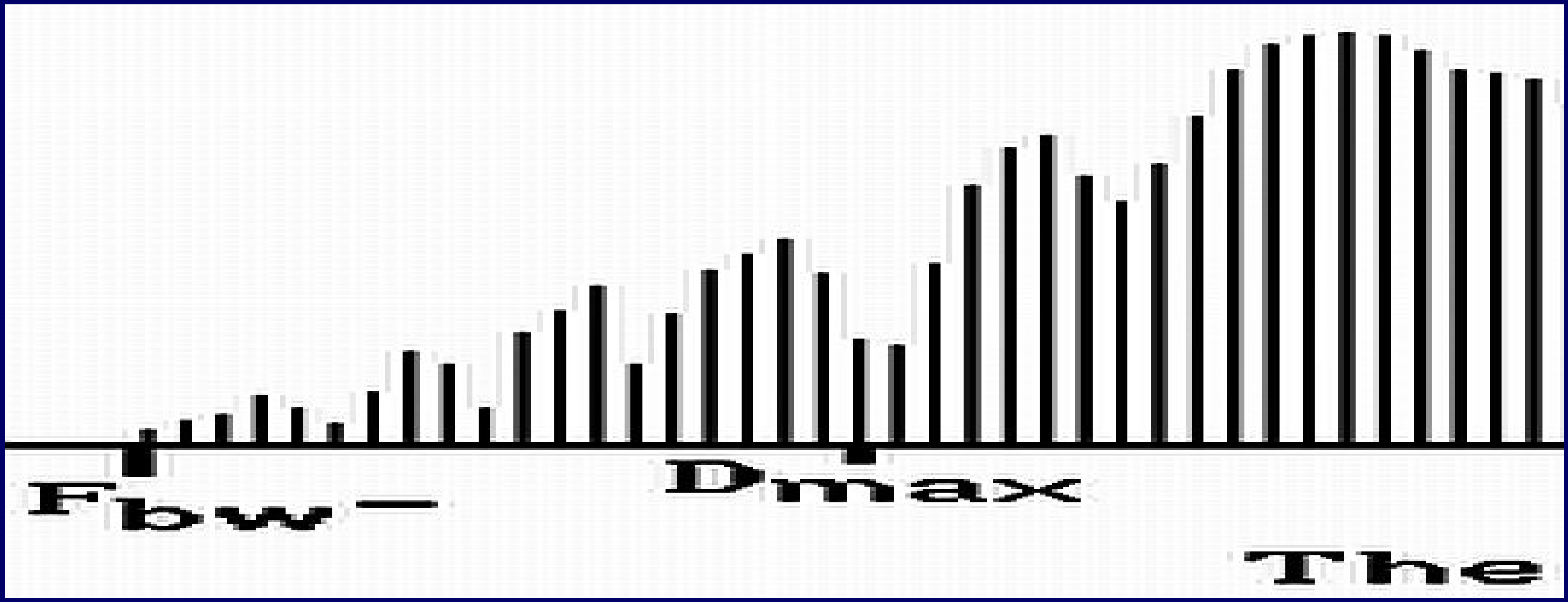
M.I. = Deviation / Modulating Frequency

Deviation Ratio: Peak Deviation / Highest Modulating Frequency

eg: 5kHz / 3kHz = 1.666

FM noise suppression improves with higher Deviation Ratio.

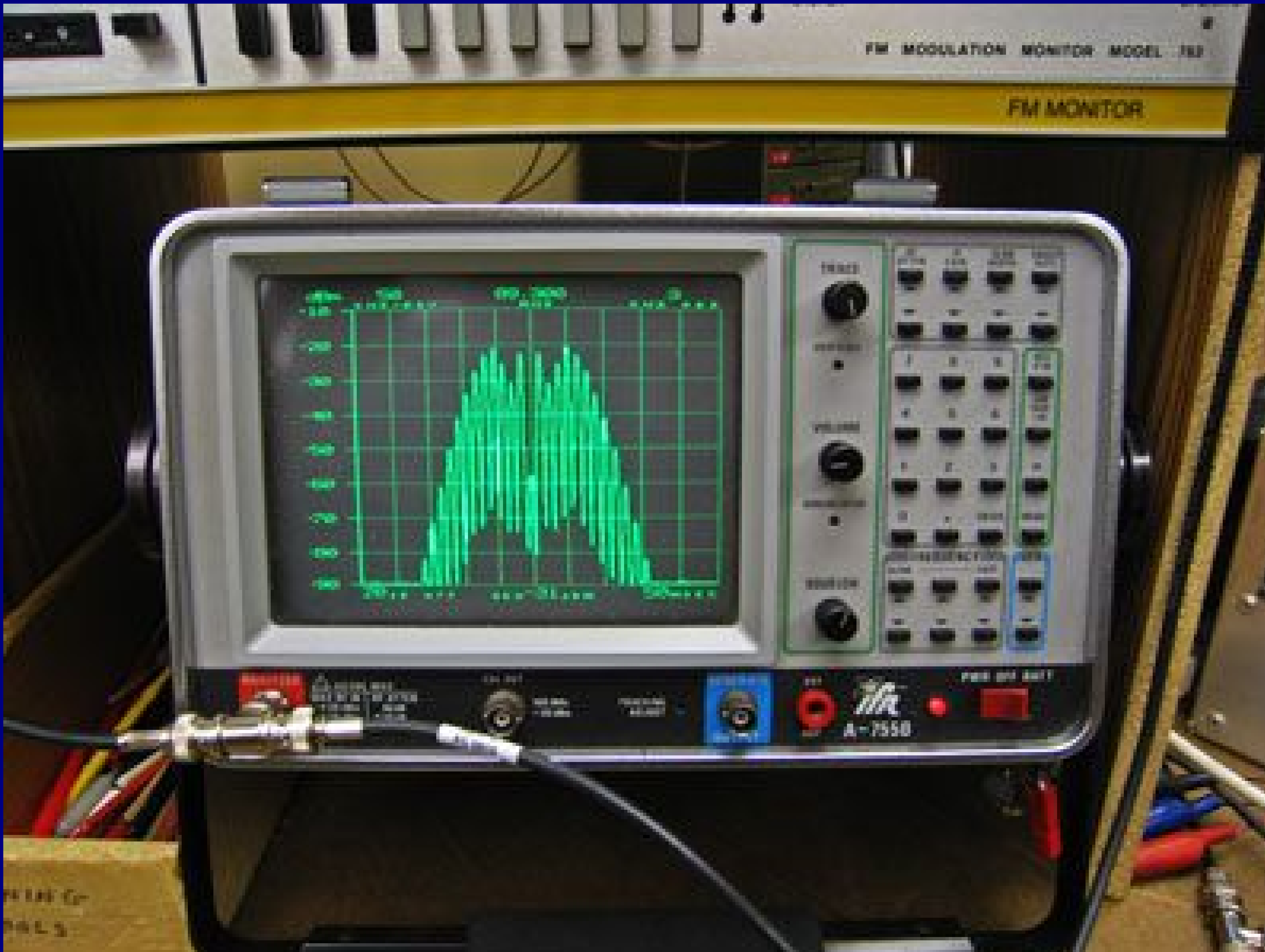
Frequency Modulated Sidebands



As the full strength radio carrier deviates in frequency it deposits power across a wide band of frequencies, in direct accordance with the modulating signal amplitude and frequency.

A FM Radio Carrier is much wider than a similar AM signal, but noise immunity and higher fidelity is worth it. FM radio is best suited to higher frequency bands where bandwidth is available.

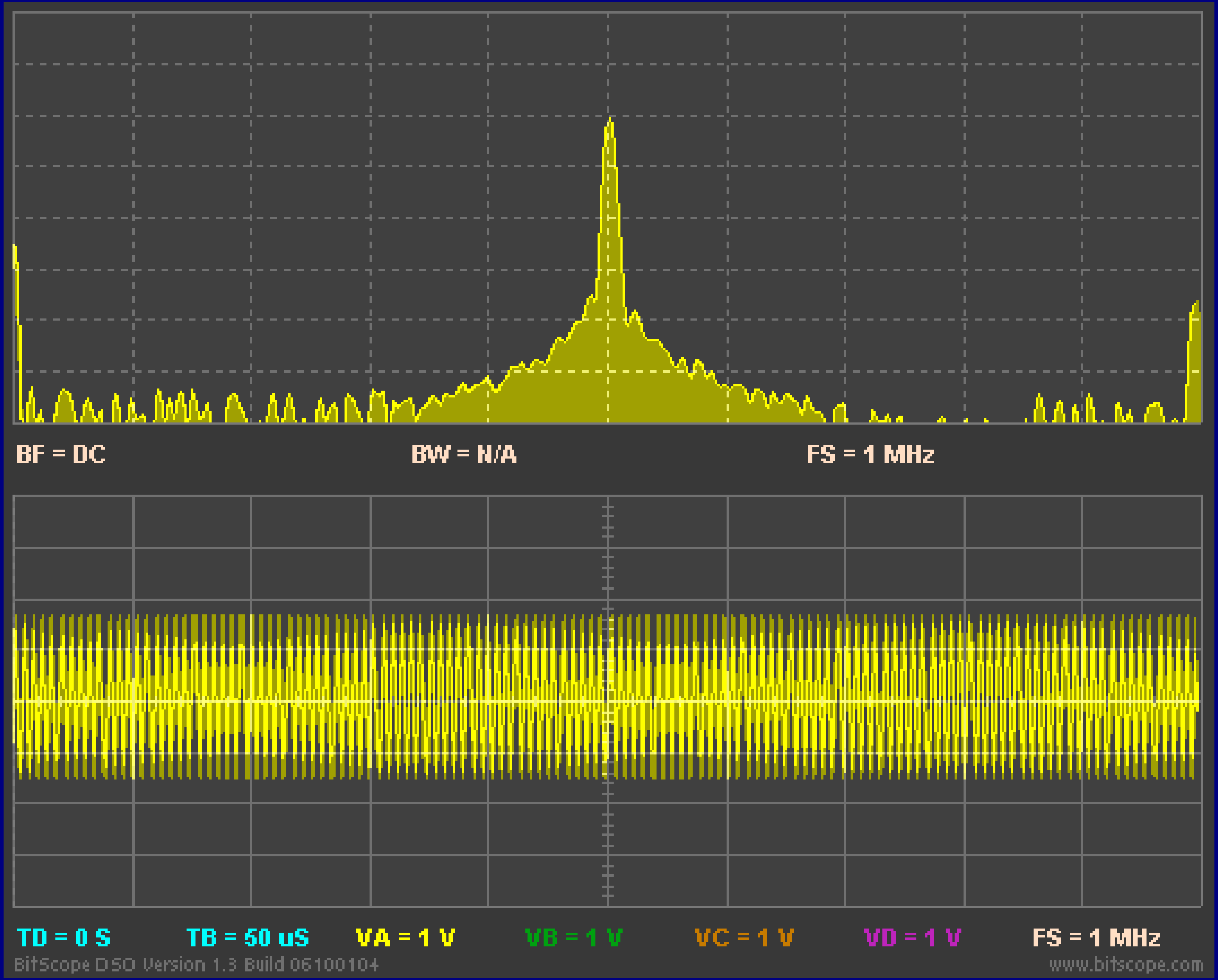
At a Modulation Index of 2.4 the carrier disappears with all transmitter power contained in the sidebands. A Bissell Null.



At some Modulating frequency and deviation, all the carrier power is in the sidebands and the carrier frequency is empty.

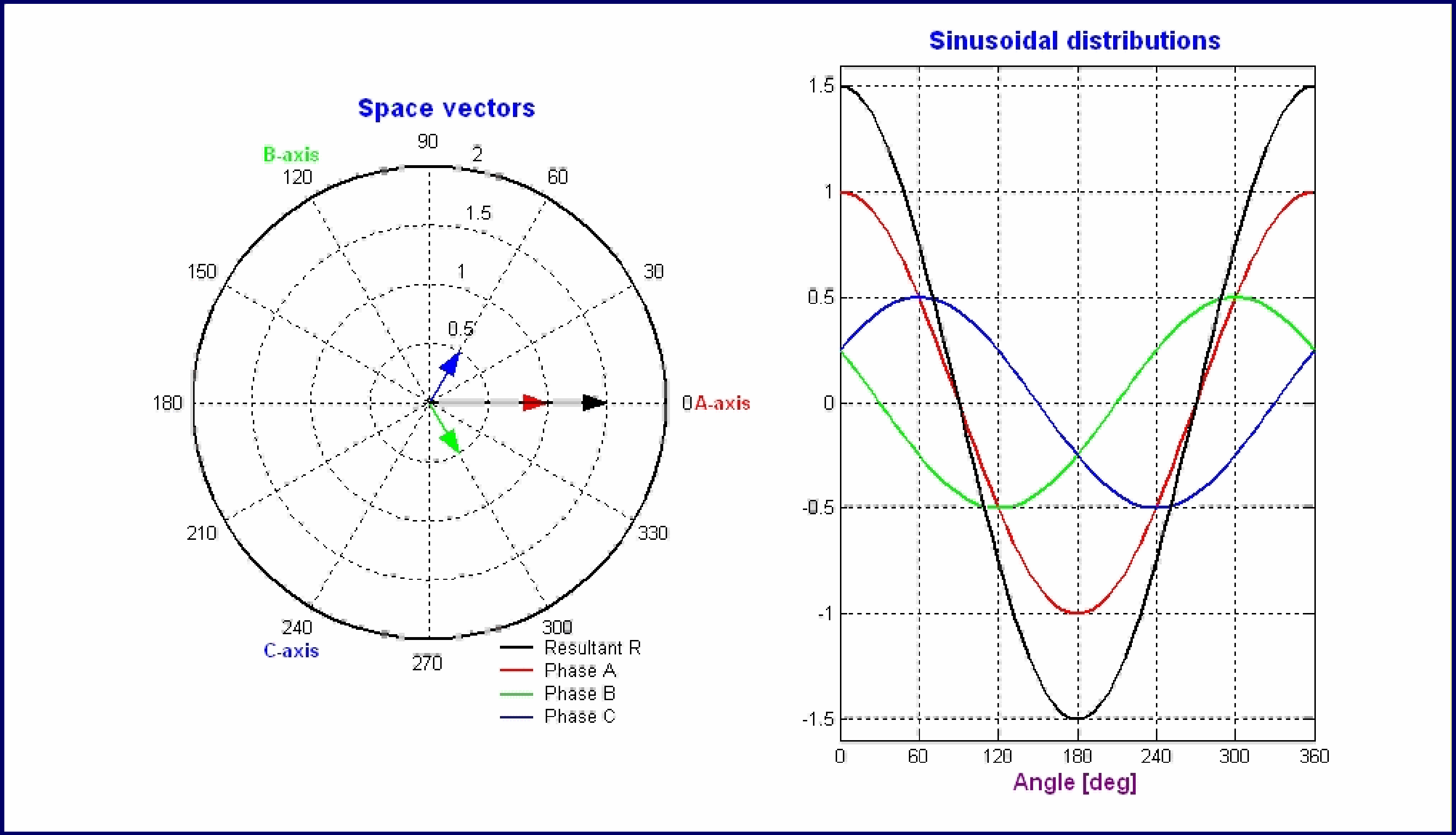
Freq

Time



A Carrier Frequency Modulated by a swept frequency signal

Phase Modulation



A Sine Wave can be thought of as a Vector Rotating Counter-Clockwise, with one full rotation in one Cycle.

The Length of the Vector represents the amplitude of the signal.

The Number of full rotations in one second is the Frequency.

The position in Degrees away from the 0 position at any moment is the phase of the signal at that moment.

Multiple PSK Modulation Schemes

PSK - Phase Shift Keying

BPSK - Binary Phase Shift Keying

QPSK - Quadrature Phase Shift Keying

O-QPSK - Offset Quadrature Phase Shift Keying

8 PSK - 8 Point Phase Shift Keying

16 PSK - 16 Point Phase Shift Keying

QAM - Quadrature Amplitude Modulation

16 QAM - 16 Point Quadrature Amplitude Modulation

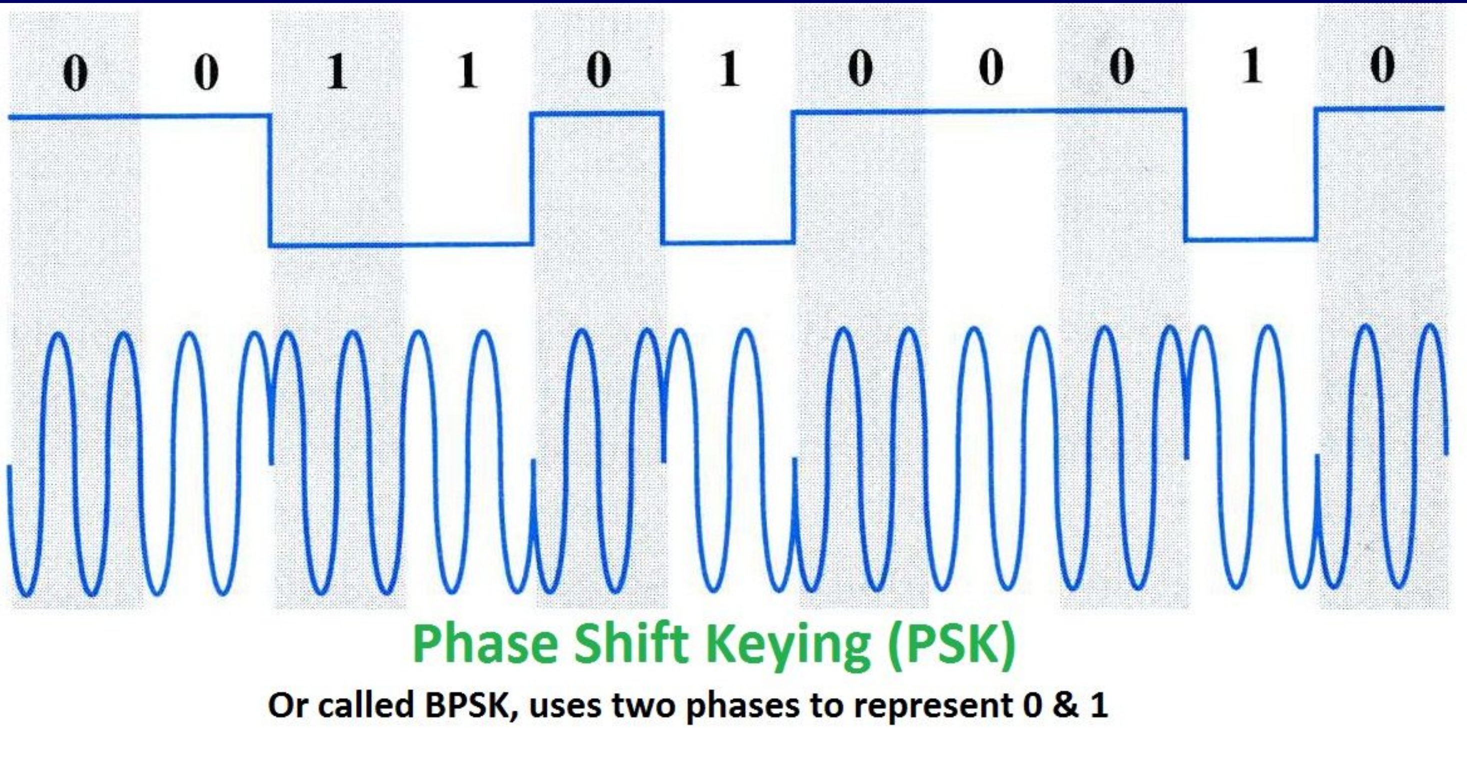
64 QAM - 64 Point Quadrature Amplitude Modulation

256 QAM - 256 Point Quadrature Amplitude Modulation

MSK - Minimum Shift Keying

GMSK - Gaussian filtered Minimum Shift Keying

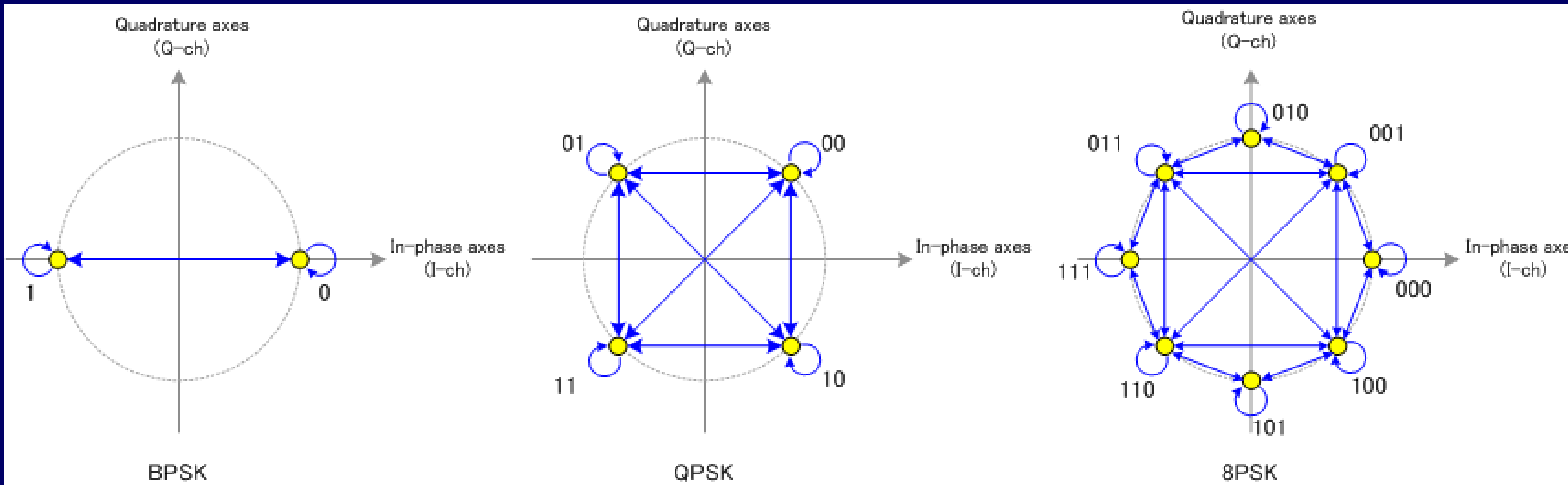
Binary Phase Shift Keying



This 180° Phase Shift encodes a change of state from a 0 to 1 or a 1 to 0. The phase shift occurs at the zero crossover.

PSK-31 uses a phase shift at 31 symbols per second to provide reliable communications at low power.

Phase Modulation

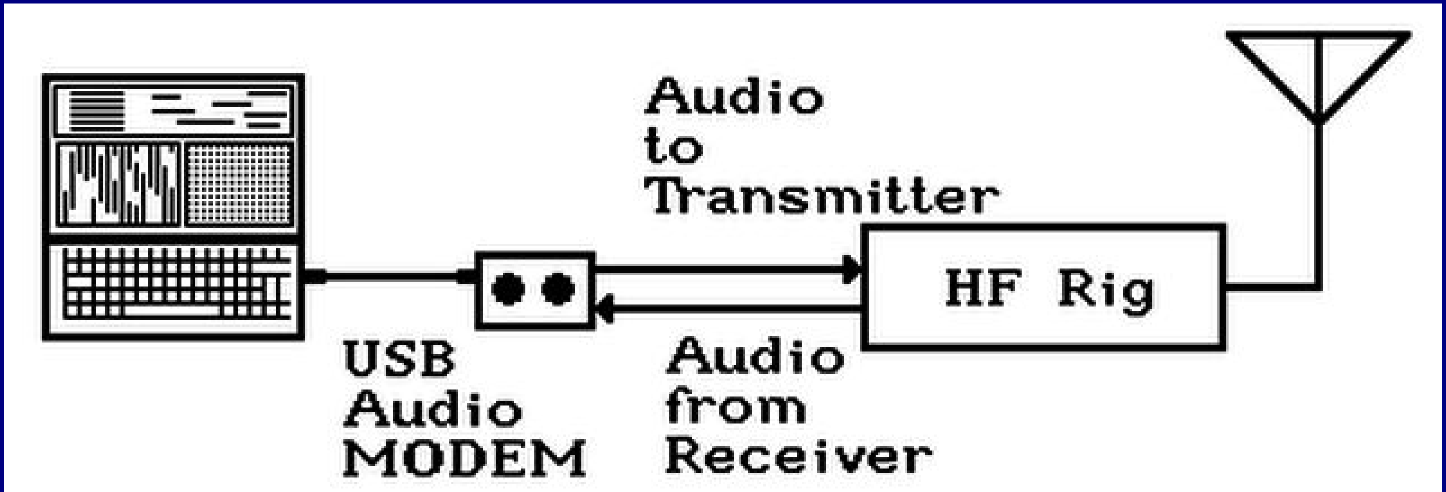


An instantaneous change of position of the Vector, in Binary PSK a 180 degrees phase shift, modulates two data bits: 0 and 1.

Multiple Phase Positions and Amplitudes are possible. In Quadrature PSK two bits are sent at a time using four phases.

Each Separate Position means a different symbol, so that a simple phase change can communicate multiple Bits, such as in 8PSK, where three bits are sent at a time.

Modern Digital Communication Modes



Amateur Radio is fortunate to have many knowledgeable and generous members who utilize their skills to create Software that is freely available to everyone for the Digital Mode of choice.

A USB connected MODEM (Modulator-Demodulator) creates the Audio Tones that encode the computer data for transmission by any SSB transceiver.

Olivia, PSK31, PSK63, Pactor, FT-8, RTTY, WSPR, SSTV, MFSK, Throb, Hellschreiber, Field Hell, DV, Packet, Contesta, JT65M, Thor, Domino, MT63, HamDRM, Digital SSTV, etc.

www.hfradio.org.uk/html/digital_modes.html

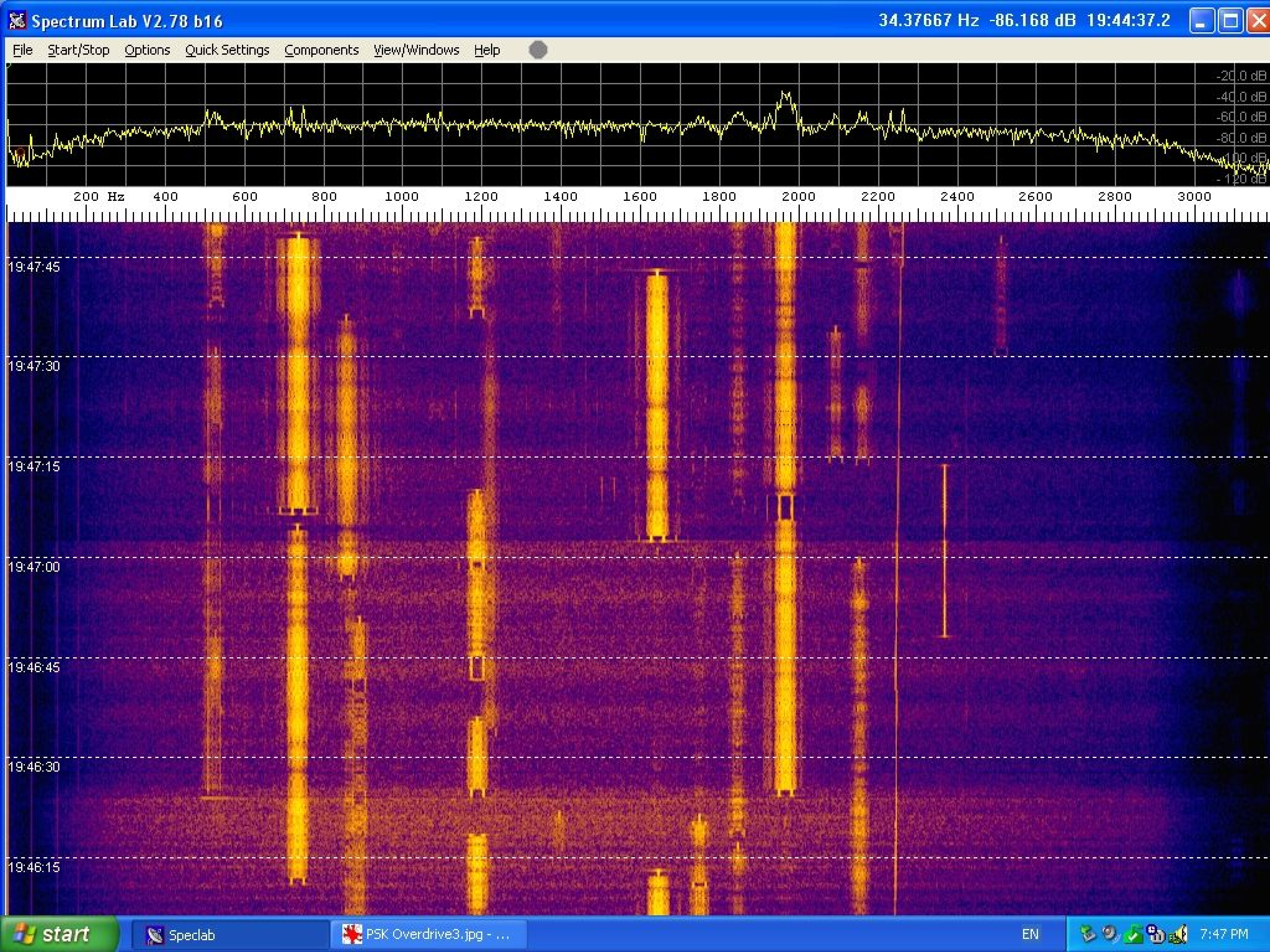
PSK31

PSK31 is a digital communications mode ideal for live keyboard-to-keyboard conversations, similar to radioteletype.

Concept proposed by Pawel, SP9VRC and developed completely by Peter Martinez, G3PLX

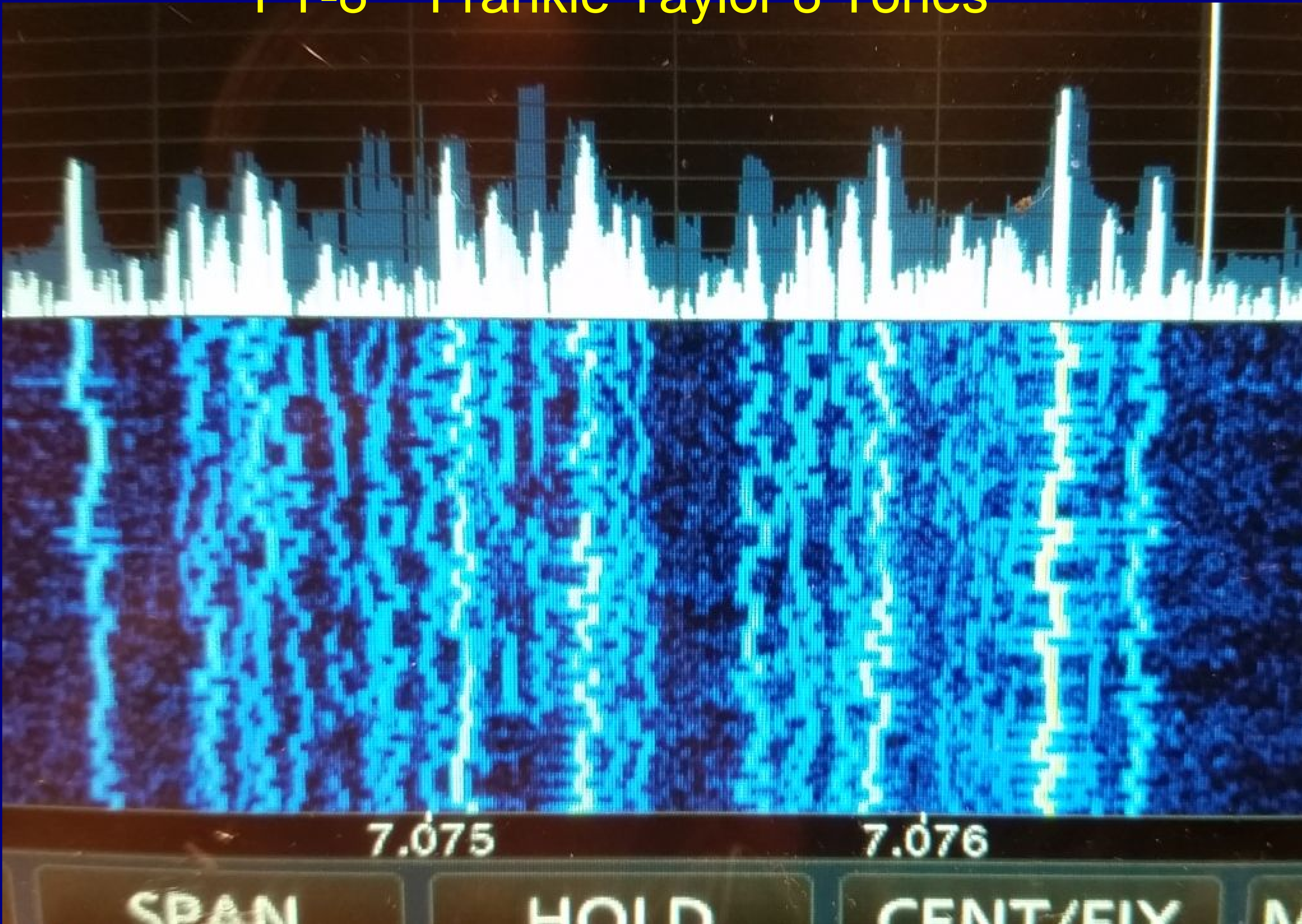
Data rate is 31.25 bauds (about 50 word-per-minute), with narrow bandwidth (approximately 60 Hz at -26 dB) reduces its susceptibility to noise, and ideal for QRP.

It uses BPSK modulation without error correction or QPSK modulation with error correction:

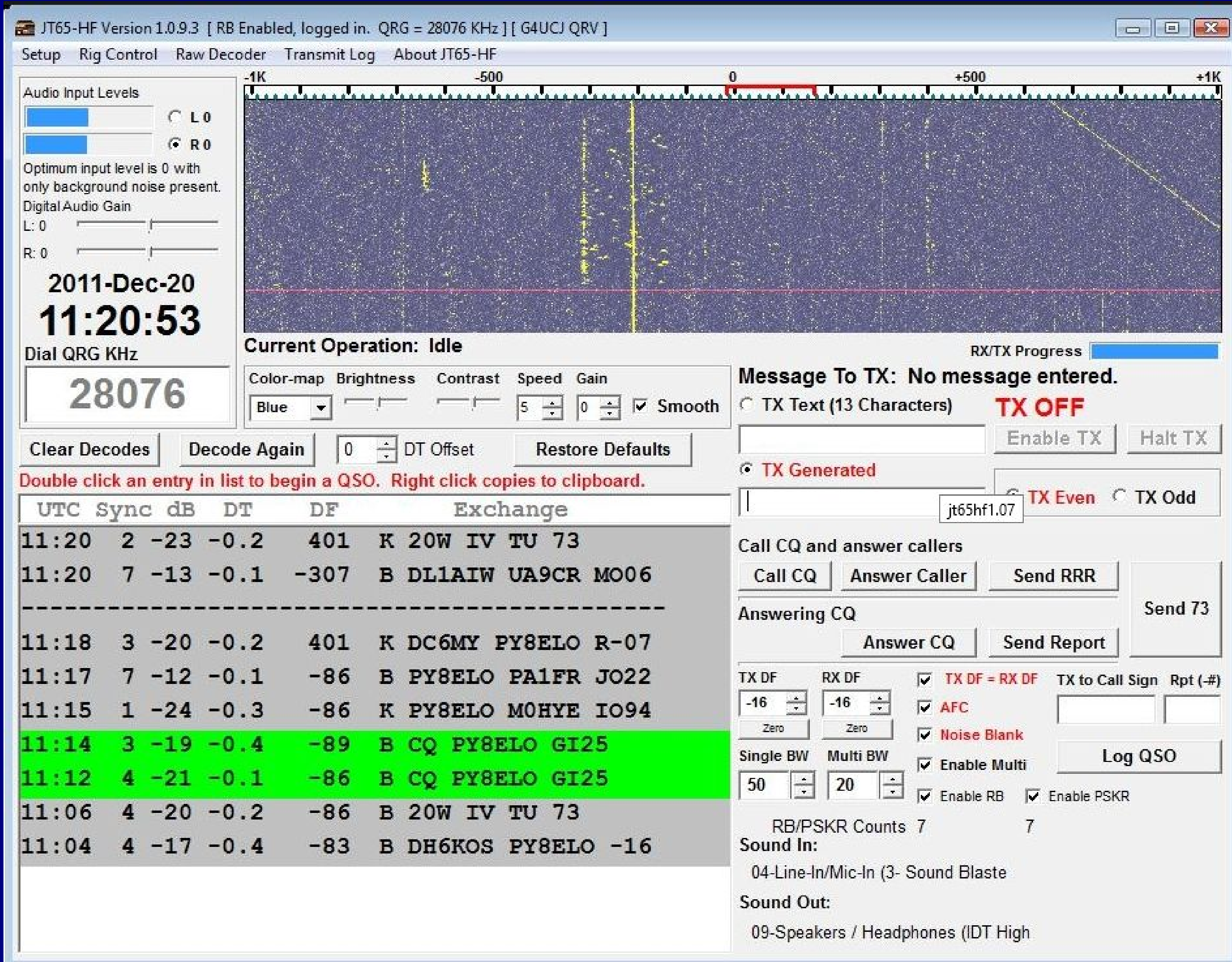


Spectrum Lab V2.78 b16
34.37667 Hz -86.168 dB 19:44:37.2
File Start/Stop Options Quick Settings Components View/Windows Help
-20.0 dB
-40.0 dB
-60.0 dB
-80.0 dB
-100 dB
-120 dB
200 Hz 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
19:47:45
19:47:30
19:47:15
19:47:00
19:46:45
19:46:30
19:46:15
start
Speclab
PSK Overdrive3.jpg - ...
EN
7:47 PM

FT-8 Frankie Taylor 8 Tones



JT65-HF Dr. Joe Taylor

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