The Unraveling of Drake's TR-4 Series SSB Filter Scheme

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Questions:

Some of the most frequently asked questions ask on the Drake Technical Net (7238 kHz 2000Z on Sunday) are:

1) Why did R.L. Drake have those two red lights for upper and lower side-band on the front of their TR-4 series H.F. transceivers?
2) Why does Drake use crystals on some bands and not others?
3) Why does the dial read backwards on 20-meters compared to the rest of the bands in the TR-4?

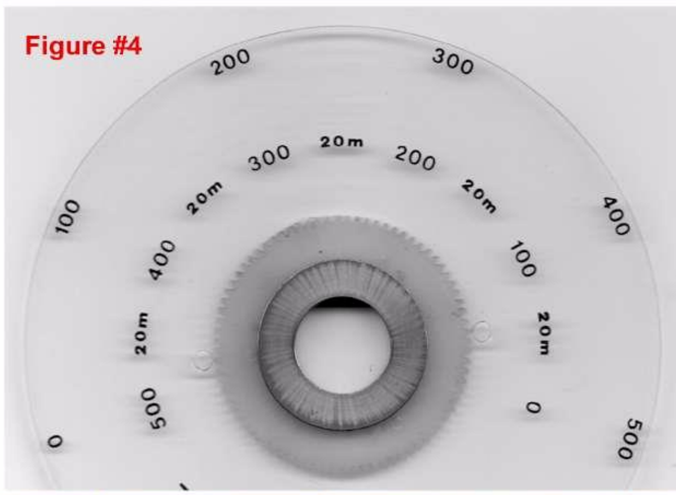
Unraveling:

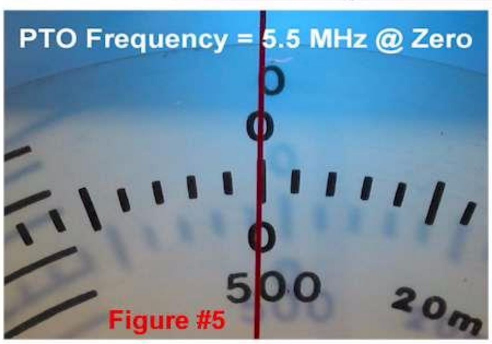
Drake had developed a new VFO in 1962 being able to cover a 600 kHz range with 1 kHz accuracy using a variable inductor. Using this newly acquired VFO, Drake called it a Permeability Tuning Oscillator (PTO), same as Variable Frequency Oscillator (VFO). Note: Drake uses a variable inductor, which has permeability (hence the name PTO) and not a capacitor to tune the 4.9 kHz to 5.5 kHz range for all their gear from the TR-3, TR-4 to the TR-7 series. As single side-band (SSB) gained ground in the late 50's and early 60's, trying to find a way of generating a solid stable frequency and use it in a simple way was the key to success.

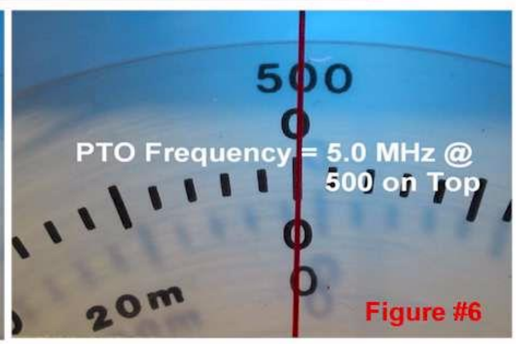
Drake was one of the first to use a 9 MHz I.F. frequency, which many manufacturers copied after they came out with the TR-3 in 1963 (their first transmitter after the 2-B), and later the TR-4 series. Having a stable PTO at 4.9 to 5.5 MHz makes it easy to start with two of the ham bands ready to be used without extra crystal mixing by using some simple mathematics as can be seen in Figure-1. I'll use 5.0 to 5.5 MHz to make it simpler, the extra 100 kHz extended to 4.9 MHz is not important, just a greater spread and confuses the issue for this article.

Mathematics:

Refer to Figure-4, 5 & 6 to follow the dial calibration as I go along here and explain what is happening with the relationship of the PTO frequency and where the dial is for each band. I have shown in Figures 7 to 11 each band and how the lights are shown for the correct side-band for that band in normal operation.







<u>80-meters:</u> The 80-meter band will start the dial at 3.5 MHz on the left side, counter clockwise and tune up to 4.0 MHz clockwise, refer to Figure-1. The microphone amplifier drives the balanced-modulator mixing with the 9.0 MHz carrier-oscillator, now there are two side-bands upper and lower developed after the mixing is done. The following two 9 MHz crystal filters will remove one of the side-bands in the 9 MHz I.F., which in this case will be the upper side-band (USB). Selecting the wanted lower side-band (LSB), the red lights on the front panel will then tell which one is desired. Using Figure-1, follow as I explain.

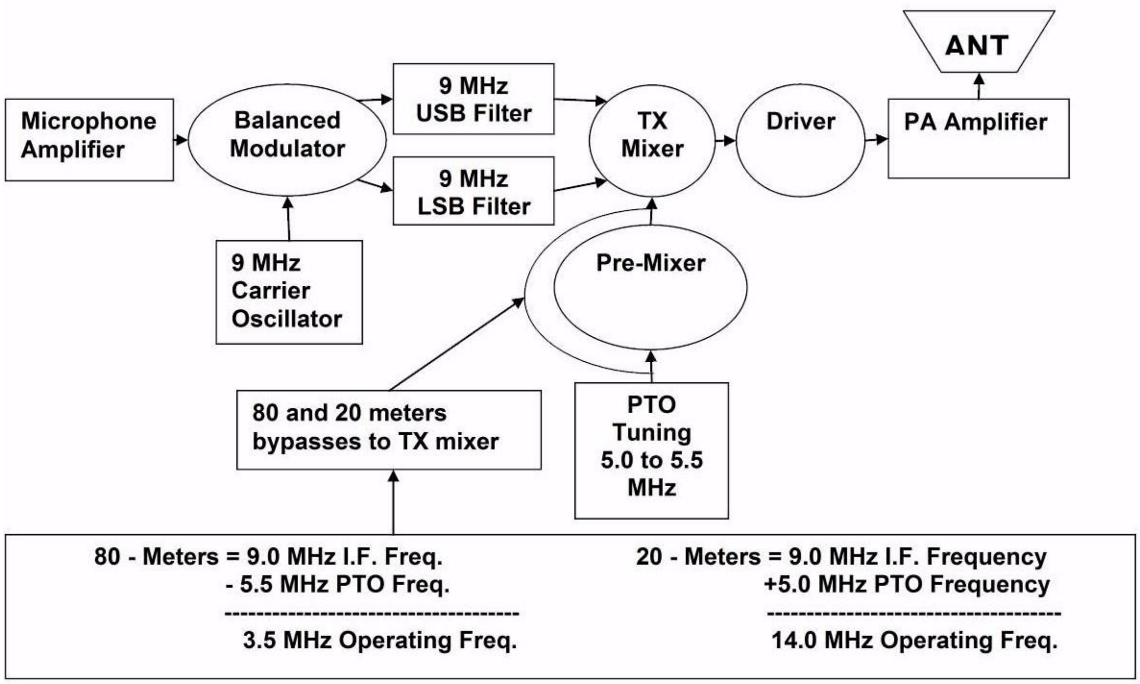


Figure #1

The PTO frequency of 5.5 MHz is at the lower end of the dial will now bypass the pre-mixer, and go directly to the transmit (TX) mixer where it is mixed with the 9 MHz I.F. subtracting the 5.5 MHz PTO frequency and comes up with the 3.5 MHz lower side-band (LSB), then to the driver and PA stage.

20-Meters: The 20-meter band will start at the right side of the dial clockwise at 14.0 MHz and then tune towards the left counter clockwise to go up to 14.5 MHz. Having covered the early balanced modulator stage, let's go right to the 9 MHz I.F. stage. Refer to Figure-1 again, the PTO frequency of 5.0 MHz is at the high end of the dial will now bypass the pre-mixer and go directly to the transmit (TX) mixer where it is added to the 9 MHz I.F. signal and comes up with the 14.0 MHz upper side-band (USB), then to the driver and PA stage. The dial has to be read backwards, but we have another ham band and so far no extra crystals are used, great engineering. Wow, I hope you got that ok, it is a bit confusing at first, but keep going and we will get the rest of the bands next!

Adding More Bands:

In Figure 2, there is a crystal oscillator added for 40, 15, and 10-meters, which is selected with the band-switch. When 80 and 20-meters were used, the upper and lower side-bands fed directly to the transmit (TX) mixer and nothing changed, and now we have to add 3 more bands. In Figure 2, see the math used to come up with the correct frequencies at the bottom of the drawing. Figure 3 also will help in the math and which side-band is used.

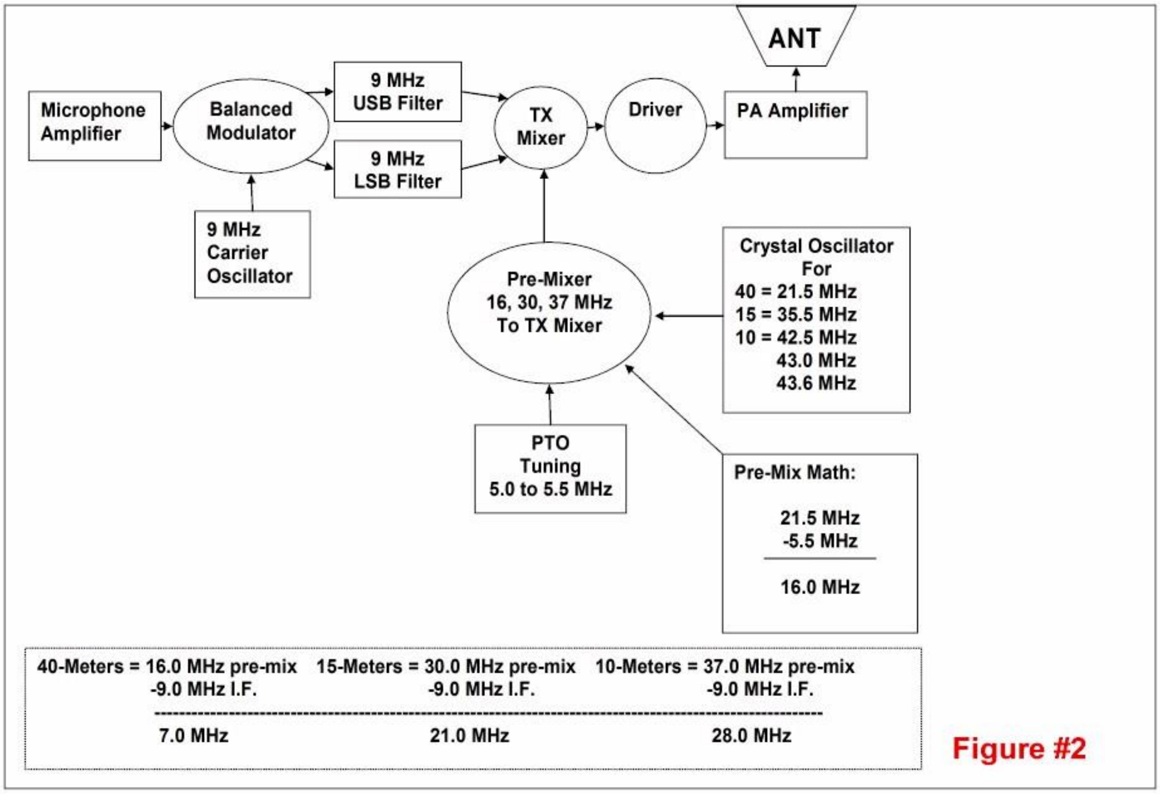


Figure #2

Band Selected	Actual 9 MHz Side-Band	Heterodyne Crystal	PTO Frequency	Injection Frequency	Dial Setting	Actual Frequency & Side-Band
80	9 MHz LSB	Not Used	-5.5 MHz	Pass Through	0	3.5 MHz LSB
40	-9MHz USB	21.5 MHz	-5.5 MHz	16.0 MHz	0	7.0 MHz LSB
20	9 MHz USB	Not Used	+5.0 MHz	Pass Through	500	14.0 MHz USB
15	-9 MHz LSB	35.5 MHz	-5.5 MHz	30.0 MHz	0	21.0 MHz USB
10	-9 MHz LSB	42.5 MHz	-5.5 MHz	37.0 MHz	0	28.0 MHz USB

Figure #3

40-meters: The crystal used for 40-meters is 21.5 MHz and when subtracting the PTO frequency of 5.5 MHz in the pre-mixer, will come out to be 16.0 MHz. The 16.0 MHz frequency will now mix with the 9 MHz I.F. subtracting the 9 MHz I.F. and since we want 40-meters to be on the lower side-band (LSB), then the 9.0 MHz I.F. frequency must be on the upper side-band (USB). There is an inversion of side-bands during this mixing of signals, so now we end up with the correct 7.0 MHz lower side-band (LSB).

15-meters: The crystal used for 15-meters is 35.5 MHz and when subtracting the PTO frequency of 5.5 MHz in the pre-mixer, will come out to be 30 MHz. The 30 MHz frequency will now mix with the 9.0 MHz I.F. subtracting the 9 MHz I.F. and since we want 15-meters to be on the upper side-band (USB), then the 9.0 MHz I.F. frequency must be on the lower side-band (LSB) in order to be on 21.0 MHz upper side-band (USB).

10-meters: The crystal for 10-meters is 42.5 MHz and when subtracting the PTO frequency of 5.5 MHz in the pre-mixer, will come out to be 37.0 MHz. The 37.0 MHz frequency will now mix with the 9.0 MHz I.F. subtracting the 9 MHz I.F. and since we want 10-meters to be on the upper side-band (USB), then the 9.0 MHz I.F. frequency must be on the lower side-band (LSB) in order to come out on 28.0 upper side-band (USB).

This gets a little intense, but there is more. On the receive side the same holds true, but there is a separate RX mixer and then on to the product-detector and finally to the audio amplifier and speaker. Everything is just in reverse, but nothing changes as far as switching the side-band selector, it follows the transmitter.

In Figure 3, I have shown how the frequencies are used and you can see that for 80 and 20-meters, there is just a pass through of the signals starting from the 9 MHz I.F. to the PA amplifier without any changes. Another bit of info, Drake would design circuits that functioned with few parts, as this was their mode of operation and it worked very well for them.

There is something else that is important to cover, when you select the side-band switch in the "X" position, this is for the C.W. offset and in CW/A.M. the 9 MHz carrier-oscillator gets moved up about 1 kHz and is used in conjunction with un-balancing the carrier in the balanced-modulator. Drake used an extra relay near the 9 MHz oscillator to pull in components to shift the 9 MHz oscillator. Why you ask? Well if you have two transceivers and are using C.W. they can operate and have a "beat-tone" or else there would be no tone to listen to in the receiver. The upper side-band (USB) filter is always used in the "X" position and this is why the lights change on the front panel when switching the band-switch, so the offset frequency of 9.001 MHz can pass through the 9 MHz upper side-band filter no matter what band your on. Remember as the band-switch is selected, the 9 MHz I.F. has to be in the correct position for all that mixing or pass through for each operating band and side-band. Refer to Figure-3, the only bands that keep the actual correct side-band in line, are 80 and 20-meters.

Summary:

The TR-4 series H.F. transceivers had about ten different models having minor changes in SSB filters from the early "soup-can" 4-pole version to the single hermetically sealed 6-pole version and finally the 8-pole dual-filter version, some were gray at first, then blue, then silver depending on the manufacturer. Many of the tubes were changed in the line up, but performance was basically the same except when Drake came out in 1977 with the TR-4CW and TR-4CW/RIT. The CW versions also had a 6-pole 500 Hz C.W. filter you could switch in for great receive C.W. performance without having to monkey around with pass-band adjustments, it just worked great!

As a side note, Drake was one of the few manufactures to use dual crystal filters vs. using a single crystal filter. The dual filter made it possible to switch between upper and lower side-band without having to re-tune the PTO/VFO, since it was always at zero no matter which side-band you selected.

In 1963 the side-band filters did not cost that much. I'm sure Drake would have done something different, but what they created was a SSB transceiver having a great sounding radio for the price, plenty of power 150 watts output, that today can still rival some of these new fangled rigs costing 10 times the price for the standard five ham bands 80 to 10-meters. I personally love the TR-4 series radios, as they have some of the best recovered audio and automatic gain control (AGC) of any radio out there, and of course the good transmit audio as most of you folks can hear when they are on the air. If you ever get your hands on a good used TR-4 series, you'll be amazed at the great performance for such a simple radio.

80-Meters and LSB selected.

40-Meters and LSB selected


SSB
X-CW
X-AM
0 1 2 3 4 5 6 7 8 9 10
UPPER
LOWER
RF TUNE
BAND
21.0
14.0
28.0
7.0
28.5
3.5
29.1
SIDEBAND
X
20-Meters and
USB selected


SB
X-CW
X-AM
0 1 2 3 4 5 6 7 8 9 10
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