March 13, 2023

The tuning problem in the TJ DC RX

**Here is the problem:**

For the capacitive element in the LC circuit, we have essentially two 660 pF caps in series. This results in a total capacitance of 330 pf. I measured 362 pF.

To get a resonant frequency of 7.0 MHz with 362 pF we need 1.428 uH.

To get 1.428 uH on the PTO coil form we need about 21 turns of wire.

21 turns on our coil form yields 1.440 uH and resonates with 362 pf at 6.9708 MHz

That’s pretty close to what we need, but the problem arises when we screw in the brass tuning screw. This reduces the inductance and raises the frequency. Putting the screw all the way in reduces the inductance to 1.138 uH resulting in a resonant frequency of 7.8414 MHz. So with a coil this large (that we must use if we want to tune down to 7.0 MHz) we end up with a tuning range that is far too large. We only need 7.0 to 7.3. In effect, this means that we end up using only a small portion of the tuning range: We can turn the screw approximately 34 times, but only 6 turns keep us withing the range of 7 to 7.3 MHz (the 40 meter band). There is about 50 kHz per turn of the dial. This makes tuning difficult. It becomes more difficult to separate stations and tune them in. It would be better if we could tune across the band using more turns of the dial. At least 15 turns of the dial would be nice: That would mean about 20 kHz per turn. But how can we do this?

**Possible solution #1: Steel screw with tighter pitch on the turns.**

Just using a steel screw slows the tuning rate down. In a normal PTO we increase the inductance (and reduce the frequency) by gradually introducing a ferrous material that increases the inductance of the coil, pushing the frequency of oscillation down. But our brass screw is non-ferrous. This means that putting it into the core does not change the permeability of the coil. The permeability of brass is the same as that of air.

What does happen, however, is that introducing the brass screw into the coil causes currents to flow in the screw. These are called eddy currents. In effect they become shorted secondary coils. And they have the effect of lowering the inductance of the coil – this is why the frequency of the oscillator increases as we screw in the brass screw.

When you use a steel screw you get both effects: As you screw it in, eddy currents flow in the screw, reducing the inductance and increasing the frequency of oscillation. But you are also introducing ferrous material – this pushes in the opposite direction, increasing induction and lowering the frequency of oscillation. I think the eddy current effect dominates, but the increase in permeability pushes in the opposite direction. This means that with a steel screw you have to use more turns to cover the same frequency range.

For example, using the same coil, with screw of the same thread pitch (the same nuts), with both screws ten turns in, one turn of the brass screw moved the inductance .014 uH. The same single turn of the steel screw only moved the inductance .005 uH. So just because of metallurgy, the steel screw will lead to a lower (better) tuning rate. I used a Hillman 4579 screw that is steel with a Zinc (anti-corrosive) coating.

But there is more: steel screws are also available with tighter (#28) thread pitches. This too means that more turns are needed to move through the same tuning range.

I found that using a steel screw with #28 thread pitch allowed for the coverage of the 40 meter band in approximately 11 turns of the dial. That is much better than what we got with the brass screw: About 27 kHz per turn instead of the 50 kHz per turn that we got with brass. But it is not quite good enough. It would be better if we could use the entire range of that PTO coil form.

**Solution Two: Add a fixed inductor in series with the PTO coil.**

After some noodling, I decided to split up the inductor: A portion of it would remain fixed, the other portion would continue to be tunable.

I estimated that I was starting out with a coil of about 1.428 uH. So I just put a 1 uH choke in series with the variable inductor and reduced the variable coil to about .428 uH (about 9 coil turns). This worked, but it worked a bit too well! It would not tune the entire 40 meter band. So I figured I needed less fixed inductance and more variable inductance. I found an air-cored coil in my junk box and cut it so that it measured about .650 uH. I added turns to the variable coil, going to a total of 15 turns. This REALLY worked well and yielded the 26 or 27 turns to tune across 40 meters that you can see in the video.

**YMMV – Keep it simple!**

Like they used to say in the commercials: Your Mileage May Vary. There are many ways of doing this. The objective is smooth tuning across the 40 meter band. I think that by varying the pitch of the variable coil turns you could get a more linear tuning response. You might also be able to get similar results by changing the amount of capacitance in the feedback network (which is also the frequency determining element in this simple Colpitts oscillator). But remember that simplicity and a low parts count was one of our objectives in this. This mod adds only 1 part (the fixed inductor), requires the removal of some turns from the main tuning cap, and perhaps the replacement of the brass screw with a steel #28 screw and nuts.