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Hairpin Tuners for Matching Balanced Antenna Systems

Balanced Transmatch designs for 28 to 450 MHz.

John Stanley, K4ERO

Once more, the advantages of ladder line for HF antennas were well presented in July 2008 *QST*.[1] Before WWII surplus brought us cheap coax, balanced feeders were almost always used for VHF as well. In the January 1942 *QST* reproduction that was included with The 2007 ARRL Handbook, we find that both home-brew and commercial VHF gear all used balanced lines.[2] For a given cost, open wire ladder line, window line or even TV twin lead can give you a lower loss installation than trying to buy large diameter coax in an effort to keep the losses to an acceptable level. This is dramatically demonstrated by comparing losses in various line types.[3] So, we wonder, why do so few present-day operators use ladder line or twin lead on the VHF frequencies? Might one reason be the lack of suitable *antenna tuners* (transmatches) for those bands? If balanced tuners were available, would ladder line be as popular at VHF as it has become at HF?

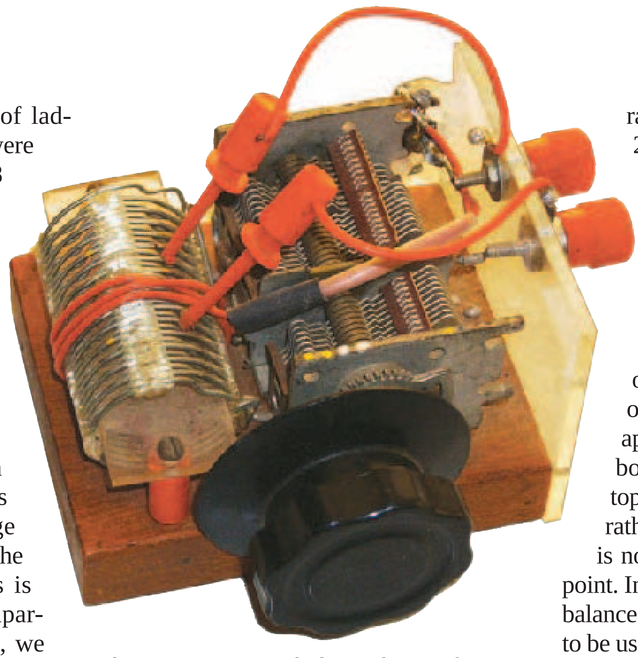

Figure 1 — K4ERO balanced tuner for 60 through 15 meters.

Balanced Tuners for HF Use

The ARRL Handbook, *The ARRL Antenna Book* and other ham publications have always included designs for balanced tuners.[4,5] Adam Nathanson, N4EKV, has one of many good Web sites showing this type of tuner at **www.n4ekv.com/tuners.asp**. I have used tuners like this for years with good results. Figure 1 shows the one I use at up to 100 W on the HF bands.

As noted in Volume 6 of *The ARRL Antenna Compendium*, I lean toward tuners with a fixed link and tapped coil.[6] The match is found by tuning the capacitor and adjusting the output side to connect to a variable number of turns, keeping the taps equidistant from the coil ends. Other versions use the taps for coarse tune and a variable capacitor in series with the link for finer tuning.

Balanced Tuners for the Higher Frequencies

One of the problems with this type of tuner is that as the frequency goes higher, the number of turns on the coil goes down rather quickly. By the time you get to 28 MHz, there may be only four turns on the coil. This means that the adjustment *steps* available are very limited. You can tap to either two or four turns, or if you are willing to unbalance the tap positions, or can access the opposite side of the coil, you could use one or three turns. In either case, the operation is compromised. Another approach is to connect one tap to the bottom of the coil, instead of to the top, effectively using fractions of a turn rather than whole turns, but this often is not feasible from a mechanical standpoint. In addition the symmetry and thus the balance are affected. If this type of tuner is to be used on 10 meters and higher, we need to rethink the design.

Figure 2(A) is a schematic of the conventional tapped link coupled tuner. Figure 2(B) is a representation of what I call a *hairpin* tuner. The electrical properties are essentially identical, but the physical layout of the hairpin type is optimum for the higher frequencies. By making the main inductor in the shape of a hairpin, or shorted transmission line, instead of a single layer solenoid coil, as is used in the conventional design, the tuner becomes much easier to build and adjust. The use of a short short-circuited transmission line section as an inductor is nothing new. It has been used for VHF/UHF circuits for many years.

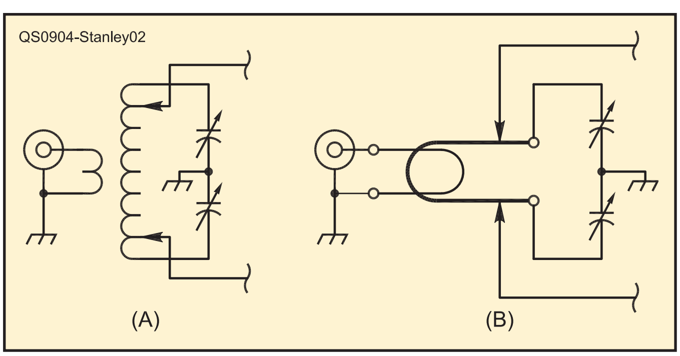

Figure 2 — Balanced tuner configurations. At (A) conventional tapped coil based tuner, at (B) the hairpin equivalent.

Building Hairpin Tuners

For some time I have been using a hairpin inductor in a balanced tuner for 6 and 10 meters, and recently I built one for each of the 144, 220 and 432 MHz bands. The approach is the same on each frequency. A section of transmission line was used instead of the coil typically used on lower frequencies.

[1]Notes appear on page 36.

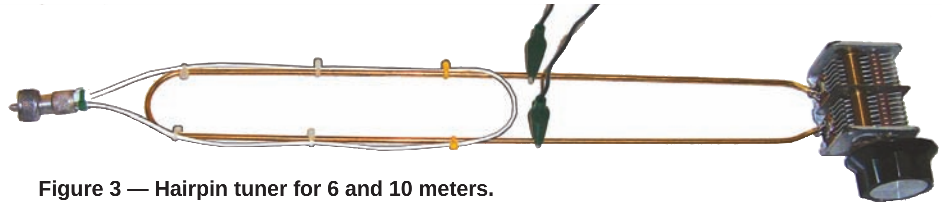

Figure 3 — Hairpin tuner for 6 and 10 meters.

Figure 4 — 144 MHz version of a hairpin tuner.

The capacitor was a split stator or butterfly design. The input link is a single turn inductor that overlaps a portion of the main transmission line inductor and the output taps were taken at whatever point of the hairpin that gives the best match.

The advantage of this layout is that moving the taps to any point on the hairpin is the same as tapping on different numbers of turns on a coil, except that with the hairpin, it is very convenient to make the adjustment in as fine a step as may be desired. In all of my designs, the coupling loop is held to the main hairpin by cable ties. This allows some adjustment of the coupling loop, but holds the loop sufficiently snug so that it is not likely to move around accidentally. Use less loop coupling for higher Q with more selectivity and more loop coupling for lowest loss.

Making them Play

The frequency tuning range percentage will depend on the capacitor used. For widest range, select one with a high minimum to maximum capacitance ratio. All of the capacitors I have tried have provided adequate range to cover the desired amateur band. The range can be extended to cover a second band by putting fixed capacitors in parallel with the variable tuning capacitor. For example, the 6 meter version, shown in Figure 3, works for 10 meters with the addition of a parallel 40 pF fixed ceramic capacitor, while the 220 MHz version, shown in Figure 5, works fine on 2 meters with the addition of a 12 pF ceramic. As it is, the 2 meter version just makes it to 222 MHz, so two bands are possible without switching caps. A single tuner could also work on 10 and 6 meters without switching by careful component selection.

Capacitor Options

The most difficult component to find will likely be the split stator capacitor. There are ways of designing your own capacitor and it is made easier because of the relatively small capacitance required at these frequencies. For all of the designs shown here, I took capacitors from my well stocked junk box. You less well equipped folks will have to search at a hamfest or check out the basement of one of the local old timers. Commercial capacitors are available, but the price may shock you. You could also choose to use a single section capacitor instead of the split stator. In that case, the capacitor shaft and frame will be "hot" and must be floated above ground. You will have to tune it via a long insulated shaft. And, of course, the balance will be somewhat compromised. The method does work and a suitable single section capacitor may be easier to find, however . Alternatively you could use a pair of identical capacitors to ground if you adjusted them each to the same setting or worked out a common shaft arrangement. Fussy, but it could work. Target dimensions and component values for the bands in this range are shown in Table 1.

Inductor Choices

The length of the hairpin will depend on the value of your capacitor. The values below represent tuners I have built and should give you a good starting point. Match the hairpin width to the spacing of the capacitor terminals, or bend the ends of the hairpin in or out at the capacitor end in order to make the connections. Spacing does affect the inductance value so keep it close to what you see in the photos.

My inductors are ⅛ inch diameter brass rod, but they could be soft copper tubing or wire in sizes from 12 gauge up to ¼ inch. Brass welding rods from the hardware store could also be used. A smaller diameter means the hairpin should be shortened a bit as the inductance per inch will be higher. The links should be insulated wire, either enameled or PVC coated or, best of all, Teflon insulated. The 6 meter tuner in Figure 3 uses the shield of Teflon coax as the link. My links do not make electrical contact anywhere with the main hairpin. The coax shield and center of the hairpin could both

Table 1
Hairpin Tuner Component Values, Dimensions and Frequency Range

Band	*Capacitor Value (pF/Section)**	*Inductor Length (Inches)***	*Tuning Range (MHz)****
10 Meters	95-170	15	26-34
6 Meters	15-90	15	36-90
2 Meters	3-20	6	110-225
222 MHz	3-10	4	220-330
432 MHz	3-4	1.5	390-440

*Effective capacity is ½ of the value/section.
**All inductors made of ⅛ inch brass rod.
***Range may by reduced or shifted by reactive loads.

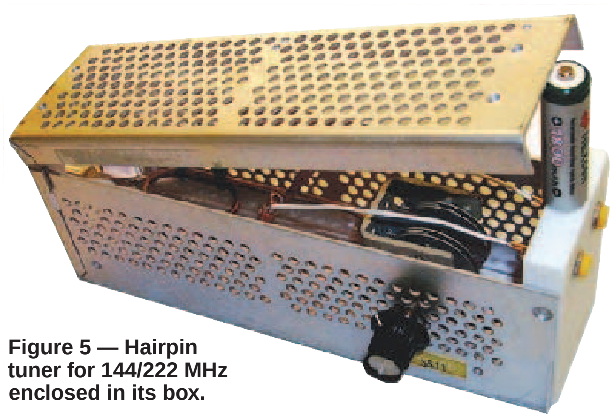

Figure 5 — Hairpin tuner for 144/222 MHz enclosed in its box.

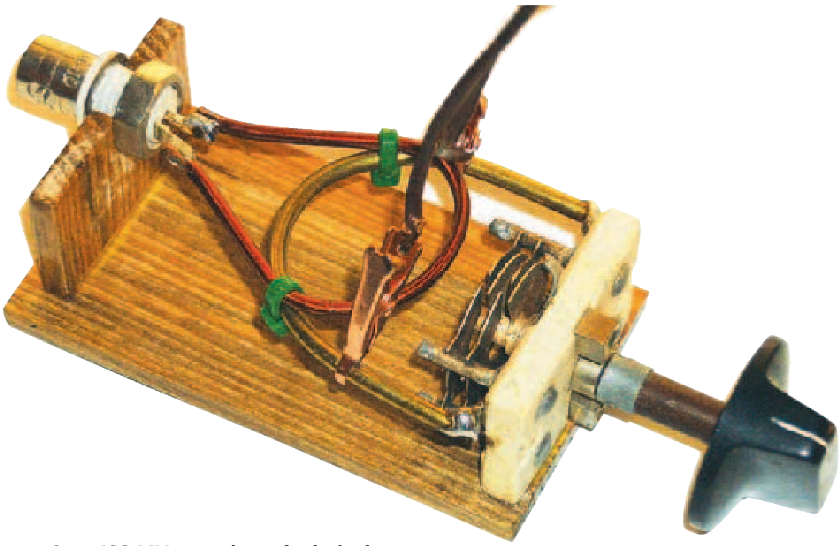

Figure 6 — 432 MHz version of a hairpin tuner.

be grounded to a chassis, if desired.

Tuning Up

Tuning consists of setting the taps to an intermediate position and adjusting the capacitor for minimum SWR. If SWR is not as low as desired, move the taps a bit either towards or away from the capacitor and readjust the capacitor. You should be able to find tap settings that allow the SWR to be reduced to 1:1.

Safety Considerations

Note that neither of the tuners described above are shown installed within a chassis of any kind. This is to show the construction more clearly. Also, I must admit that during tests, I got away with this because I used low power and am very careful not to touch the *hot* parts of the circuit. I also have a non-metallic operating desk. The open construction is useful during experiments.

I definitely do not recommend this approach for general use. You will want to put your tuner in a shielded box of some kind, probably with a hinged lid to allow you to move the taps as shown in Figure 5. You should *never* adjust the tap clips with power applied. The tuning shaft should be brought out through the enclosure where an insulated knob should be installed for tuning even though with a split stator capacitor the shaft should be at ground potential. For high power, the use of a suitable enclosure is essential, especially if the tuner is to be installed close to the operating position. This is to prevent RF burns from contact as well as exposure to excess RF levels.

Remember that your body is more susceptible to pick up from VHF fields than is the case at HF. If you put the tuner well away from the operating position in a place that is protected from access by family members or pets, you may be able to use a somewhat more open construction as is sometimes done with conventional home brew tuners. Radiation from an unenclosed tuner of any type can be enough to cause interference with nearby electronics devices and could cause fires if anything flammable comes in contact with the hot parts of the circuit.

These tuners have been tested with 100 W on 10 and 6 meters, 50 W on 2 meters and 20 W on 70 cm, the maximum output of my rig. For higher power, the designs can be scaled, remembering that the bigger it gets, the lower the frequency for the same geometry. Thus, a design similar to that used here for 432 MHz, but three times larger, would probably work fine with a full kW, but on 144 MHz. Since my 20 W, 432 MHz design uses an inductor that is about as short as is practical (see Figure 6), getting up to 1 kW at 432 MHz, might prove difficult with this design. At the least, a different type of capacitor would be required.

I hope that these simple to build and adjust tuners will start a trend towards greater use of balanced feeders on the higher frequencies just as ladder line has become the favorite for many on the lower bands.

Notes

[1]J. Hallas, W1ZR, "Getting on the Air—Your Second HF Antenna," *QST*, Jul 2008, pp 69-70.

[2]B. Goodman, W1JPE, "Receivers for 112-Mc. Emergency Work," *QST*, Jan 1942, pp 18-25, 74-75.

[3]*The ARRL Handbook for Radio Communications,* 2009 Edition, Figure 21.4. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 0261 (Hardcover 0292). Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[4]See Note 3, p 21.13.

[5]R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition, p 25-3. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[6]J. Stanley, K4ERO, "The Filtuner," *ARRL Antenna Compendium, Volume 6.* Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 7431. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

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