Project

A 100W Balanced Z-Match Tuner for 1.8-30MHz

Operating position at St Anthony's Point, Cornwall in May 2006, when a 61m doublet was tuned by the balanced EZ-match tuner (right), in its K2/100-matching box.

I have spent some excellent holidays on the Devon/Cornwall coast, including lighthouse cottages where, close to the sea, h.f. propagation is enhanced and radio operation can be very satisfying. The popular Elecraft K2 rig is an excellent compact transceiver for such ventures but there's always the question of what antenna to put up.

Perhaps, the simplest effective multi-band antenna for temporary operation is a simple doublet, fed with balanced feeder. For this, I have used 300Ω ribbed feeder but 450Ω flat ribbon or open wire feeders should work equally well. I often put up temporary doublet antennas with end-to-end lengths of up to 82.5m, allowing efficient operation from 1.8 MHz upwards.

I'm about to describe the construction of a compact 100W all-band (h.f.) Z-match tuner, to match 'balanced' antennas and sit alongside the K2/100 transceiver. One major issue is how to match the varying impedances at the end of the balanced feeder to the standard 50Ω unbalanced impedance at the output of the transceiver. A common solution is to use an unbalanced 'antenna tuning unit' (a.t.u.) and feed the balanced transmission line via a 4:1 balun. Typically, these units are often an integral part of modern rigs.

While the a.t.u. setup may yield reasonable results if the impedance at the feeder side of the balun is close to 200Ω, it is much more likely that, on some bands, impedances of several thousand ohms may exist at the rig end of the feeder. This sort of impedance usually leads to significant r.f. losses at this point and unacceptable heating of the balun. For this reason, I decided to build a balanced Z-match to enable me to match a doublet antenna (including a G5RV) directly to my K2.

The tuner described here will also cope with horizontal multi-band loop antennas. My design goals included: a minimum capability of 100W, coverage of all h.f. bands as well as visual indication to help in finding a match.

The starting point of the design is the traditional and classic Z-match circuit, as described in many editions of the RSGB's *Radio Communications Handbook*. **Neill Taylor G4HLX** kindly lent me his vintage KW EZ-match for inspection. This unit covers the 3.5-28MHz bands, and, although this tuner is fairly bulky, most of the interior is empty. If you have an old one of these units (or can pick one up cheaply at a rally, for example) then the coils and capacitors can be used in the present design.

I have checked the size of these components and they will fit in the Elecraft EC2 enclosure, possibly with a slightly different layout to the one I finally adopted. So, if you are prepared to cannibalise an old bit of kit (as this will perhaps cause screams of agony from some – it's perhaps not for the purists) that route could be simple. The loss of a vintage tuner will be outweighed by a more compact and feature-rich version.

Design & Construction

The whole tuner fits neatly inside the EC2 enclosure (it's the same size as the K2), **Fig. 1**. As with all other projects, it's advisable to collect all the main parts of the tuner together and see how they will all fit in the enclosure before cutting any holes. Once this is done, the various holes in the EC2 enclosure can be marked and cut. Before final assembly, each of the enclosure panels was brought into electrical contact with the others.

I used 'sandpaper' to remove the grey paint from small areas of the interior aluminium panel surfaces where they are bolted to each other using the supplied Elecraft joining blocks. I also included a ground terminal on the rear panel using a 3mm bolt and a 'wing' nut as can be seen in **Fig. 2**.

I also decided to extended the original design, adding 1.8MHz to the standard coverage by adding an extra inductor (L1) shown in **Fig. 3**. I have also incorporated a three-position ceramic wafer switch to change between the three tuning

Geoff Cottrell G3XGC decided he needed a matcher unit for his K2 transceiver, here's the one he created to put St. Anthony's Point, Cornwall on the air when he worked Hawaii on 7MHz c.w!

Fig. 1: The tuner with top panel removed.

Fig. 2: And seen from the back.

ranges easily. The ranges are: 1.8, 3.5–10 and 10–30MHz. Tuning and loading adjustments are performed using two reduction vernier drives (6:1) attached to variable capacitors C1 and C2. Note that both ends of C1 are 'hot' and so an insulated shaft coupler is required.

I happened to have an old Yaesu FC-902 a.t.u. in the 'junk box', which provided the variable capacitors C1 (430pF) and C2, a split stator (2x290pF) unit, as well as the wafer switch. The FC-902 unit is rated at 500W and it's therefore possible (although untested) that my Z-match could also handle this power.

Transformers T1 and T2 were wound using 1.65mm (16s.w.g.) tinned copper wire on a piece of 32mm pvc plumbing pipe covered with cling-film and attached to the inside (primary) and outside (secondary) of 4x4mm hollow square section pvc tubes using hot melt glue.

Covered Pipe

The primary is wound on the covered pipe first, then the support tubes are glued in place. This is then followed by winding and gluing the secondary turns in place. The central pipe former was later removed (made easier by the cling-film), leaving an air-cored assembly supported by the pvc tubes.

The coil details are: T1 primary, 5-turns 32mm diameter, with 6mm spacing. This is overwound with the secondary, consisting of 5-turns of 40mm diameter, also with 6mm spacing. For T2 its primary of 8-turns of 32 mm diameter with 6mm spacing, is overwound with 6 turns 40 mm diameter with 6mm spacing for the secondary winding.

The 1.8MHz inductor, L1, is formed from 16-turns wound to 36mm diameter, with 3mm spacing. I used a ceramic former for L1, but an air-cored version would work just as well. The wafer switch is operated using a 6mm diameter fibreglass rod shaft extender, running through the centre of T1 to the front panel. This layout enabled all the components to fit inside the enclosure with the minimum of internal wiring lengths.

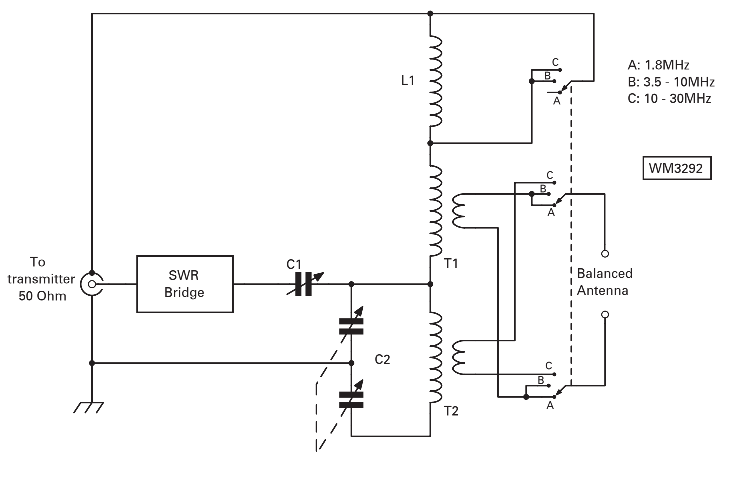
Match Making

An indication of the state of the antenna match made is given by the front-panel reflectometer analogue display derived from a conventional bridge circuit (**Fig. 4**). The circuit is a modified version of the one used in the Elecraft KPA100. Meter M1 simply displays a 'reflected power' signal to assist in finding the optimum match.

If your transceiver has adequate s.w.r. monitoring facilities, then the reflected power circuit could be omitted. But the analogue meter display is easy to use and very helpful.

Inside the rear panel, a length of RG58 coaxial cable is connected to the SO239 'TX' socket, where its screen is grounded. This passes through the centre of the bridge transformer toroid T3, forming a single turn r.f. coupling link s.w.r. sensor, **Fig. 5**. At the 'Z-match end', only the central conductor of the cable is soldered

Fig. 3: Circuit diagram of Z-match.



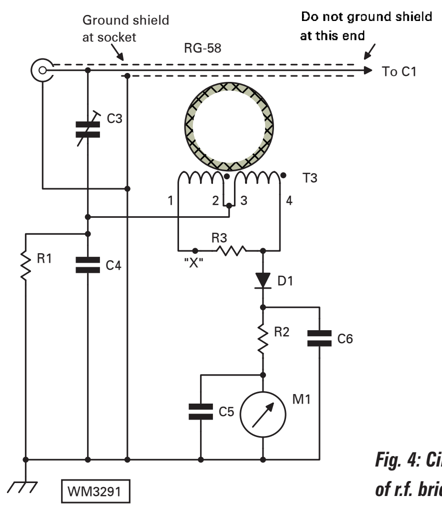


Fig. 4: Circuit diagram of r.f. bridge.

to C1. It is important **not** to ground the cable screen on this side of T3. A short piece of heat-shrink sleeve insulates the screen connection near the cable connection with C1.

The bridge was built on a small (70x50mm) rectangle of copper-clad printed circuit board (p.c.b.) material. The board is bolted and grounded to the input socket rear face. The bifilliar wound toroidal transformer T3 is easily constructed using two 280mm lengths of 0.45mm (26 s.w.g.) enamelled wire, one red and one green (**Fig. 6**). Loosely twist the red and green wires together over their whole length.

The wires should cross over each other about every 10mm. Wind 12 turns on the ferrite core, covering about 80% of the core exactly as shown in Fig. 6. Clip the wires to a length of about 30mm and strip and tin the last 10mm of the wires, making sure there are no shorts. T3 was secured vertically on the board at one point on its perimeter with a blob of hot melt glue.

The other components are then added allowing space to pass the RG58 link through the centre of the core (it will just fit). The coaxial cable screen is grounded to the board. One end of trimmer capacitor C3 is connected directly to the centre terminal of the TX socket, (**Fig. 7**).

To calibrate the s.w.r bridge, apply a c.w. carrier through the sensor into a matched dummy load and adjust C3 to give zero reading on M1 when the s.w.r. is 1:1. Either use the transceiver or an external s.w.r. meter to verify this. Once set, I found the null to be consistent over the whole frequency range covered. If no null is obtained check the connections of T3!

The value of R2 can be changed to suit the particular meter and power level used. You could add a front panel 'high-low' power toggle switch, to vary the meter sensitivity. Such a switch would simply change the value of the 'resistor' R2.

It's also possible to use this bridge to obtain a 'forward power' signal. To do this, just duplicate the detector and metering circuit on the right hand side of R3, at the point marked 'X'. In practice, however, the reflected power reading gives all the information necessary to achieve a repeatable match of 1:1 s.w.r. (as validated with an external commercial s.w.r. meter).

In practice...

The unit operates extremely well. At home, with an 18m span doublet antenna at a height of 9.2m and fed with 300Ω ladder line, I could obtain matches on all bands 1.81-29MHz with s.w.r values of 1:1. Using the vernier controls on the tuning capacitors, C1 and C2, is highly recommended, as on some bands the resonances can be extremely sharp.

Component List

C1	430pF variable capacitor
C2	2x290pF split-stator variable capacitor
C3	30pF miniature preset variable capacitor
C4, C5	10nF (often marked '103') r.f. decoupling
S1	Ceramic wafer switch (3-pole, 3-way)
T1, T2	(see text)
T3	12t bifilliar wound on FT 50-43 ferrite core
L1	(see text).
R1	3.3kΩ 0.25W
R2	22kΩ 0.25W
R3	200Ω 1W
D1	Diode IN4148 or equivalent

M1 miniature 50μA panel meter (thanks **Derek M0BNZ** for the meter!)
Vernier (2 off): 60mm diameter Jackson Brothers 6:1 reduction vernier dials. These were obtained from **www.mainlinegroup.co.uk/jacksonbrothers/4080.htm**.
Enclosure: EC2 (with 1in stand) from Elecraft direct **www.Elecraft.com/**
1.65mm dia. tinned copper wire for winding T1, T2 and L1.
SO239 panel mount socket, two screw terminals, 3mm bolt and wing nut assembly, heat shrink.

I also keep a tabled record of the TX frequency and C1 and C2 vernier settings (on a scale of 0-100) as this make returning to a match quick and easy. these day-to-day settings are surprisingly reproducible.

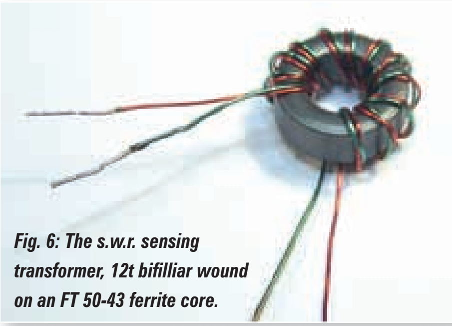


Fig. 6: The s.w.r. sensing transformer, 12t bifilliar wound on an FT 50-43 ferrite core.

In May 2006, the Z-match was put through its paces at a portable location in Cornwall with a 61m doublet (at a height of a little over 10m) fed by 19.6 of 300Ω ribbed feeder and facing west out over the sea. I obtained excellent results, including some USA west-coast stations worked. The best DX being a QSO with Hawaii on 7MHz c.w. In fact, the unit is so handy that I am considering using it full-time at my home location! ●

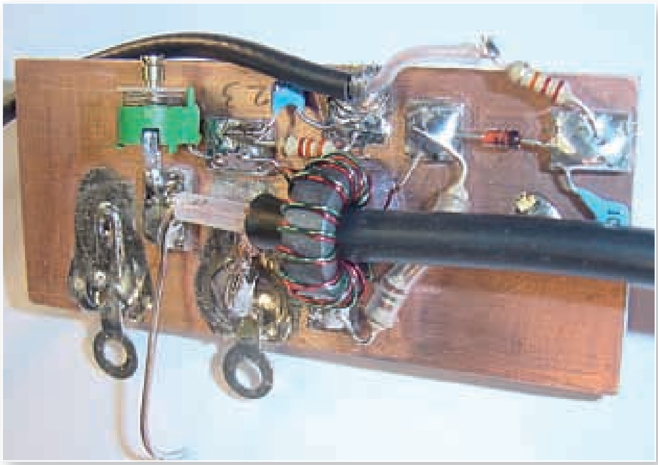


Fig. 5: Bridge board ready for installation. The protruding solder lugs will be bolted and grounded to the inside of the SO239 socket on the rear panel. The thin coaxial cable (to the left) leads to the front panel meter M1, the cable to the right goes to C1.

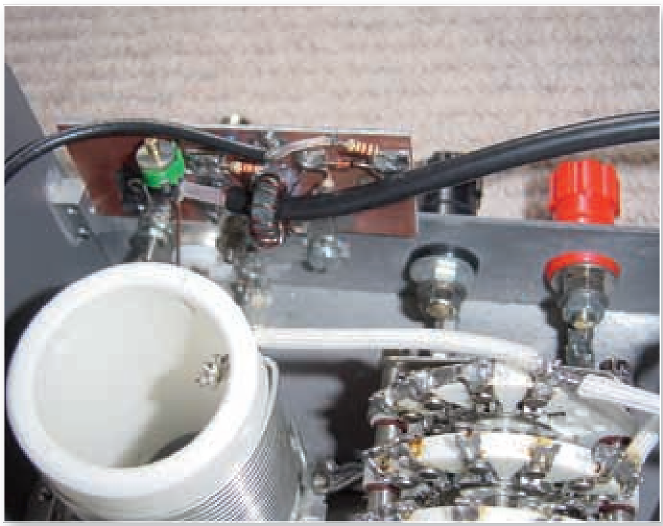


Fig. 7: The s.w.r. sensing p.c.b. is mounted on the back of the input socket.