In Part 1, I described a simple 160 and 80 meter base matching assembly for a 43 foot antenna. While that unit is very effective and inexpensive to build, it is also a little inconvenient in that you must connect it when it is needed, and you must also manually enable 160 or 80 meter operation using straps. This month, we’ll look at a more versatile matching assembly that is completely remote-controllable for operation on all bands. Again, this base matching network will significantly eliminate SWR-related coax losses and unun mismatch losses, and assist inside tuners in providing a match on 160 and 80 meters.

The All Band Matching Solution

As discussed in Part 1, a 43 foot vertical antenna requires approximately 50 µH of inductance to resonate the antenna. On 80 meters, approximately 9 µH is needed for resonance. For the matching solution shown in Figure 1, I used an MFJ 404-0669 air wound coil and two Array Solutions RF-30 relays for up to full legal limit matching on all bands from 160 to 10 meters. A 2.1 × 5.5 mm dc power jack located below the SO-239 connector provides for relay control voltage inputs of 0 V, +12 or –12 V dc. The control input MOVs and bypass capacitors are mounted on a 6 terminal strip inside the matching assembly.

The matching unit operates as follows: With no control voltage applied, the inductor is disconnected and the unun is connected across the antenna feed point thereby preserving the original compromise SWR on 60-10 meters.

When +12 V is applied, the inductor is connected across the antenna feed point and inductor turns are shorted to resonate the antenna on 80 meters. In addition, part of the large coil is shorted out to resonate the antenna on 80 meters.

When the voltage is reversed, the short across the coil is removed and the matching section resonates the antenna on 160 meters. In both the 160 and 80 meter cases, the unun secondary taps into the inductor at the 200 Ω point, providing a proper match to the unun on these bands. This keeps the unun secondary voltage reasonable, and the feed line and unun losses very low as well.

I built the matching unit into an 8 × 8 × 4 inch NEMA weatherproof box available from home supply stores. This box is too small to fit the entire inductor length needed, so I split the inductor into two pieces as can be seen in Figure 1. The long inductor section consists of 61 turns, and the short

Figure 1 — The split inductor mounted in the NEMA enclosure. Alternatives are to use a larger box and keep the inductor intact or use the toroid wound inductor specified in Part 1.

Figure 2 — All parts mounted in the NEMA enclosure.

Figure 3 — Voltage unun connections (MFJ 10 10989D shown).
inductor section consists of 12 turns. While I preferred the more compact size of this box, you may wish to use the larger 12 × 12 × 4 inch NEMA box that can contain the full uncut inductor length needed.

All internal wiring uses insulated #14 AWG stranded wire. I attached the wires to the coil tap points using the MFJ coil clips called out in the parts list. You can solder the wires directly to the coil, but this is difficult due to the #12 AWG size of the coil wire and the spacing of the turns. The coil is mounted with #8 stainless steel screws, washers, lock washers and nuts also used for the ground and antenna feed terminals. Table 1 lists the parts and part sources, and Figure 2 shows the final matching unit with all components mounted. Note the terminal strip with the MOVs and bypass capacitors.

Since the antenna is unbalanced, a current balun or voltage unun is typically used. A voltage unun should be wired as shown in Figure 3.

**Table 1**

<table>
<thead>
<tr>
<th>Description</th>
<th>Source/Part Number*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-C3 — 0.10 µF capacitor</td>
<td>Mouser 581-SR215C104KAR.</td>
</tr>
<tr>
<td>J1 — SO-239 UHF coax jack</td>
<td>MFJ-7721.</td>
</tr>
<tr>
<td>J2 — Jack, dc power, 2.1 × 5.5 mm</td>
<td>Mouser 163-1060 EX.</td>
</tr>
<tr>
<td>K1, K2 — Power Relay, 3PDT</td>
<td>Array Solutions RF-3PDT-15.</td>
</tr>
<tr>
<td>L1 — Inductor, 12 79 µH</td>
<td>MFJ 404-0669.</td>
</tr>
<tr>
<td>MOV1-MOV3 — MOV, 18 V dc</td>
<td>Mouser 576-V22ZA2P.</td>
</tr>
<tr>
<td>S1 — DPDT center-off switch</td>
<td>All Electronics MTS-12.</td>
</tr>
<tr>
<td>T1 — Unun, 1:4 ratio, 1.5 kW</td>
<td>MFJ 10 10989D.</td>
</tr>
<tr>
<td>T2 — 12 V, 1 A wall transformer</td>
<td>All Electronics DCTX-1218.</td>
</tr>
<tr>
<td>0 V: 60-10 m +12 V: 80 m</td>
<td>MFJ 755-4001.</td>
</tr>
<tr>
<td>0 V: -10 m -12 V: 160 m</td>
<td>Mouser 548-34.</td>
</tr>
<tr>
<td>Terminal strip, 6-lug</td>
<td>All Electronics 1551-GBK.</td>
</tr>
<tr>
<td>Test clips, (5 required)</td>
<td>Mouser 13AC130.</td>
</tr>
</tbody>
</table>

*All Electronics parts are available from [www.allelectronics.com](http://www.allelectronics.com); Array Solutions parts are available from [www.arraysolutions.com](http://www.arraysolutions.com); MFJ parts are available from [www.mfjenterprises.com](http://www.mfjenterprises.com) and Mouser parts from [www.mouser.com](http://www.mouser.com).
band edge. Therefore, you can simply short one or more of the upper (short coil) inductor turns in order to tune the network higher to your desired 160 meter frequency.

To do this, first leave off the wire leads that attach between the relay contacts and the tap points on the coil. Build up short jumpers using the test-clips and micro-clips (perfect for the coil turn taps) called out in the parts list, and attach these between the relay contacts and the coil, using the suggested tap points shown on the schematic.

Connect the matching assembly to the base of your 43 foot vertical. Then enable 160 meter operation by applying –12 V dc, and jumper turns on the 12 turn inductor with a short lead attached until you find your desired 160 meter resonance point. Next, move the 160 meter relay tap point until you get minimum SWR. Now permanently short the turns on the short coil by soldering a piece of #16 AWG buss wire across these turns.

As you can see from my photos, I needed to short six turns on this coil. Next enable 80 meter operation (apply +12 V to the relays assembly) and select the coil shorting point for your desired resonant frequency and the tap point for best SWR. Finally remove the test clips leads, attach the coil clips, and solder wires between the coil clips and relay.

My final results for 160 and 80 meters are shown in Figures 8 and 9 as measured with my RigExperts AA-200 connected directly at the antenna. This means that all power will be absorbed by the 3 \( \Omega \) radiation resistance. From Ohm’s law:

\[
I = \sqrt{\frac{1500}{3}} = 22.4 \text{ A}_{\text{RMS}},
\]

\[
V_{\text{RMS}} = I_{\text{RMS}} \times Z = 22.4 \times 600 = 13,440 \text{ V},
\]

\[
V_{\text{PEAK}} = \sqrt{2} \times V_{\text{RMS}} = 19,004 \text{ V}.
\]

Very few hams have a ground system that is lossless. Even 10 \( \Omega \) of ground loss is better than most hams achieve, especially on 160 meters. For this next exercise we will assume a ground loss of 10 \( \Omega \), which means we will be matching our power into a total ground plus radiation resistance of 13 \( \Omega \). Therefore:

\[
I = \sqrt{\frac{1500}{13}} = 10.74 \text{ A}_{\text{RMS}},
\]

So, \( V_{\text{RMS}} = 10.74 \times 600 = 6446 \text{ V} \), and,

\[
V_{\text{PEAK}} = 9114 \text{ V}.
\]

In my case, I have a 600 W PEP output amplifier. Assuming 10 \( \Omega \) ground loss:

\[
I = \frac{\sqrt{600}}{13} = 6.8 \text{ A}_{\text{RMS}},
\]

So, \( V_{\text{RMS}} = 6.8 \times 600 = 4080 \text{ V} \), and,

\[
V_{\text{PEAK}} = 5769 \text{ V}.
\]

For the case of a 100 W transceiver, we end up with \( V_{\text{PEAK}} = 2353 \text{ V} \). I’ve experimented with two different relays. One is the Array Solutions RF-10 DPDT relay which has 1.7 kV peak contact-to-contact and 3.1 kV peak contact-to-coil voltage breakdown ratings. I did some testing and found that this relay is a good solution for up to about 500 W of power on 160 meters when the two sets of contacts are put in series. The second relay is the RF-3PDT-15, which has 3.1 kV peak contact-to-contact and 5.3 kV peak contact-to-coil voltage breakdown ratings.

Besides having twice the contact breakdown rating as the RF-10, the 3PDT-15 is also a 3PDT relay, so an additional set of contacts can be put in series to increase the breakdown voltage. This relay can be used in a full legal limit application if applied properly in the circuit. Depending on your power level and ground losses, the less expensive and smaller RF-10 may be all you need. Make the calculations to determine which relay is more appropriate for you.

**Conclusion**

The matching network discussed in this article will permit very effective operation of SWR related cable and unun loss, and is easily matched with my MFJ-998, an in-shack tuner.

**Operation**

Operation of this matching unit couldn’t be simpler. When no control voltage is applied, the antenna functions as it always has on 60 through 10 meters. For 80 meter operation, apply +12 V dc, and for 160 meter operation apply –12 V dc. The matching unit connected to the base of my 43 foot vertical is shown in Figure 10.

**A Word About RF Voltages**

Since this unit uses relays for selecting the different bands, and relays have voltage ratings, a discussion of RF voltages is appropriate. RF voltages at the base of an untuned vertical can be quite high. As the antenna becomes shorter, the capacitive reactance becomes higher and so the resultant voltage drop across this reactance plus the radiation resistance increases. With the 43 foot vertical, the worst situation will occur on 160 meters with a capacitive reactance of about 600 \( \Omega \). The radiation resistance is approximately 3 \( \Omega \). Let’s look at a few examples:

Assume a perfect, no loss ground and 1500 W of power properly matched to the antenna. This means that all power will be absorbed by the 3 \( \Omega \) radiation resistance. From Ohm’s law:

\[
I = \sqrt{\frac{1500}{3}} = 22.4 \text{ A}_{\text{RMS}},
\]

\[
V_{\text{RMS}} = I_{\text{RMS}} \times Z = 22.4 \times 600 = 13,440 \text{ V},
\]

\[
V_{\text{PEAK}} = \sqrt{2} \times V_{\text{RMS}} = 19,004 \text{ V}.
\]

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**Conclusion**

The matching network discussed in this article will permit very effective operation of
your 43 foot vertical on all bands from 160 through 10 meters. Although on 10, 12 and 15 meters the elevation angle of the peak is higher than optimum for DX, it will still allow contacts. Feel free to experiment a little. You might prefer to use the toroid from Part 1 in this design instead of the air-core inductor. If you are not running more than about 500 W, the less expensive RF-10 relays are all you will need. Have fun, and I’ll see you on the low bands.

Amateur Extra class operator and ARRL Life Member Phil Salas, AD5X, was first licensed as WN3BCQ in 1964. Ham radio became the reason he subsequently pursued a career in electrical engineering. Phil earned BSEE and MSEE degrees from Virginia Tech and SMU, respectively, and worked in new product development for the next 33 years. Phil is now retired and spends his days split between ham radio related projects and enjoying time with his wife Debbie, NSUPT. You can reach Phil at 1517 Creekside Dr, Richardson, TX 75081 or at ad5x@arrl.net.