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RF

By Zack Lau, W1VT

Feeding Open-Wire Line at VHF and UHF

It can be quite challenging to make a high-power balun that works well at VHF and UHF by scaling ferrite-core designs used at HF. The upper fre quency response limit can be increased by making the wires shorter, but smaller cores must be used to get a sufficient number of turns for effective coupling between the turns. Obviously, smaller cores won't handle much power. Thus, while ferrite cores may work for lossy TV baluns, I wouldn't recommend them for transmit applications at VHF and UHF. A loss of 0.5 dB may not be significant in casual receiving applications like cable TV, but it is quite substantial at the 1000-W level—it is a loss of 10.9% or 109 W![1]

Fortunately, it is seldom necessary to cover a wide frequency range—most VHF antennas cover only one amateur band. Thus, one can use a narrow-bandwidth design, and avoid lossy ferrite materials.

A balun that works well at VHF is shown in Fig 1, using a λ/2 of coax. It is often used to feed Yagi antennas. It is important to use an electrical λ/2 and shorten the physical coax length by its velocity factor. (Sometimes, people use a section of copper-jacketed semi-rigid coax such as UT-141A to reduce the difficulty of weather-proofing.) This has a 4:1 ratio, typically transforming a balanced 200-Ω load to an unbalanced 50-Ω load. However, it could also be used to transform a 300-Ω twin lead to 75-Ω coax. The velocity factor is 0.70, so a 71.4-cm length has an electrical length of 102 cm. Solid-dielectric cables are often preferred; as foam or partial air dielectrics may show more variation in measured velocity factors.

A λ/2 of coax does two things—it reflects the input impedance to the output and introduces a 180° phase shift. Thus, if the coax is terminated in 100 Ω, it reflects the 100-Ω load as

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[1]Notes appear on page 61.

100 Ω, no matter what the impedance of the coax. The two 100 Ω loads in parallel provide the desired 50-Ω input impedance. For a single frequency, the impedance of the coax doesn't matter very much. However, the impedance does affect the bandwidth of the balun. For resistive terminations, raising the coax impedance improved the bandwidth of the input match, as shown in Fig 2. Thus, 75- or 100-Ω coax might be used to improve balun bandwidth. RG-62 and RG-133A are two types of 93-Ω coax that are commercially available, the latter being more suitable for high-power work.

Since RG-133A may be difficult to find, I've made 100-Ω coax in the past out of 0.5-inch brass tubing and #12 copper wire.

The equation for the characteristic impedance (Z_0) of air-dielectric coax is

$$Z_0 = 138 \log\left(\frac{D}{d}\right) \quad \text{(Eq 1)}$$

Where D is the inside diameter of the outer conductor and d is the outside diameter of the center conductor. Thus, with a wall thickness of 14 mils,

$$Z_0 = 138 \log\left(\frac{0.5-(2\times 0.014)}{0.0808}\right) = 106\,\Omega \quad \text{(Eq 2)}$$

I used thin Teflon spacers to hold the center conductor in place. Thus, instead of searching for rarely manufactured RG-125/U or 150-Ω coax, you might make your own from tubing and wire.

Typical line impedances for commercial twin-lead or open wire are 300 and 450 Ω, not 200 Ω. Thus, a matching transformer is needed to go from 200 Ω to the desired line impedance. Charles Emil Ruckstuhl, W1ZJD, showed that a λ/4 of 300-Ω twin-lead could be used to match a 200-Ω balun to 450-Ω homebrew ladder-line.[2] He used a λ/2 balun of RG-213 to feed a 500-foot run of ladder line on 2 meters. This is shown schematically in Fig 3.

Transmission-line impedances other than 450 Ω can also be matched with a λ/4 line section. The impedance of the section is:

$$Z_0 = \sqrt{Z_{out} \times Z_{in}} \quad \text{(Eq 3)}$$

For 300 Ω, the impedance is:

$$\sqrt{300 \times 200} = 245\,\Omega \quad \text{(Eq 4)}$$

This impedance is non-standard, but this can be generated at home or modified from commercially available transmission lines. Andrew Griffith, W4ULD, describes a technique for modifying ladder line with a propane torch and a wooden jig.[3] Andrew lowers the impedance by reducing the spacing and reforming the polyethylene insulation.

Alternatively, the equation for open wire line is:

$$Z_0 = 276 \log\left(\frac{2s}{d}\right) \quad \text{(Eq 5)}$$

Where Z_0 is the line impedance
s is the spacing between the centers of the lines d is the diameter of the wires

Or,

$$s = \left(\frac{d}{2}\right) 10^{\left(\frac{Z_0}{276}\right)} \quad \text{(Eq 6)}$$

Thus, if the impedance is 245 Ω and #12 wire (with a diameter of 80.8 mils)

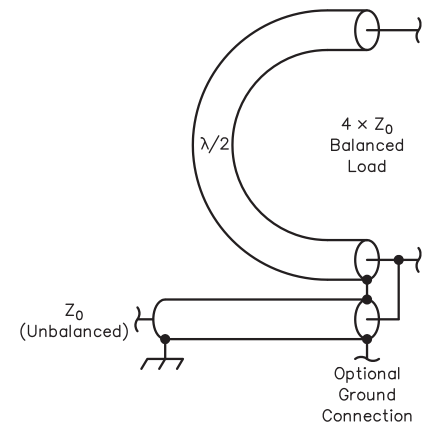

Fig 1—A 4:1 balun using λ/2 of coax.

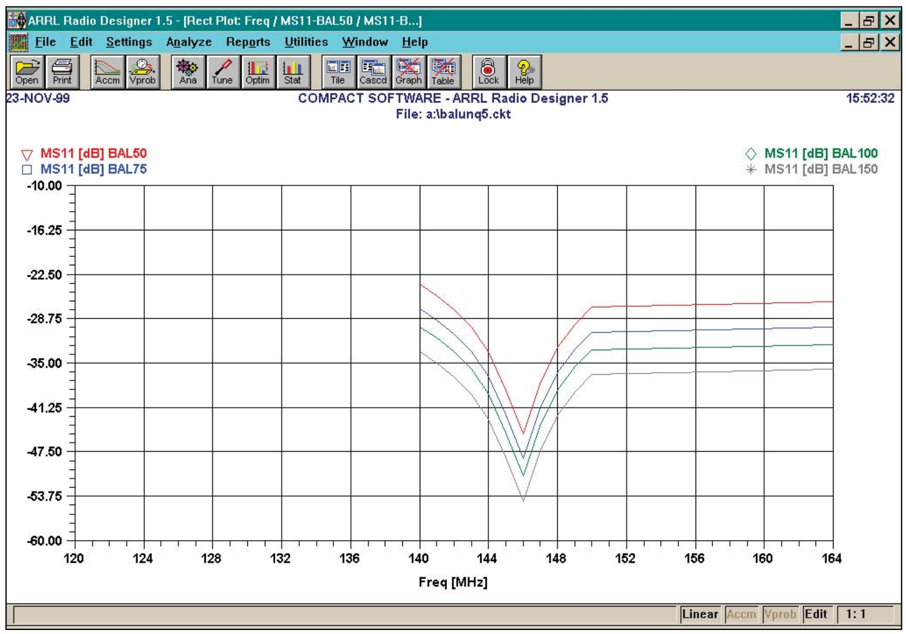

Figure 2—Raising the coax impedance to from 50 to 150 Ω improves the bandwidth of a 50:200 Ω λ/2 coaxial balun.

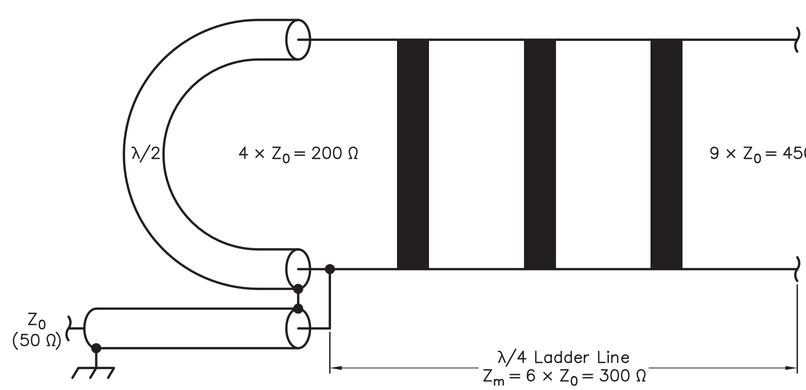

Fig 3—A 9:1 balun using λ/2 of coax and a 300-Ω λ/4 matching section.

is available; the required spacing is 312 mils.

Baluns can also be modeled on a computer—I've modeled the both the 50 to 200 and 50 to 450 Ω baluns using *Amateur Radio Designer* (ARD).[4] This software has a three-port model. The open-wire line is modeled as two separate ports each having one half of the line impedance. Thus, a 450-Ω open-wire is modeled as two 225-Ω coaxial lines (see Fig 4). When creating the ARD report form, don't forget to click on **Terms**... to set the proper terminations of 50, 225 and 225 Ω.

The performance of the balun can be determined by looking at the phase and power relationships between the ports. Ideally, there would be exactly 3 dB of loss from the input of the balun to each of the balanced outputs and a 180° phase difference between the transmission coefficients. Thus, if port 1 is the input and ports 2 and 3 are the outputs, you want to see 180° phase differences between PS21 and PS31. It is erroneous to expect a 180° phase shift for PS32, the phase of the transmission

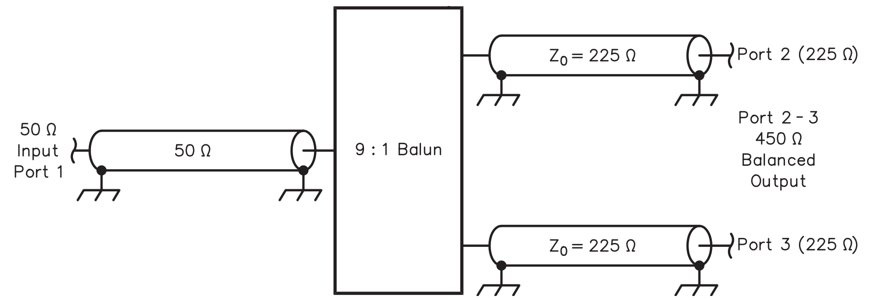

Fig 4—Modeling a 450-Ω balanced line as two 225-Ω coaxial lines with ARD's three-port model.

Table 1—Improved performance of a 9:1 balun using 75-Ω coaxial λ/2 balun (50TO450B) versus one using 50-Ω coax (50TO450L). Both use a 300-Ω λ/4 matching stub to go from 200 to 450 Ω.

Compact Software - ARRL Radio Designer 1.5 14-JUL-99 11:54:58
File: C:\ARD\BALUNQ5.CKT

Freq (MHz)	*MS11 (dB) 50TO 450B*	*MS21 (dB) 50TO 450B*	*MS31 (dB) 50TO 450B*	*PS21 (deg) 50TO 450B*	*PS31 (deg) 50TO 450B*	*MS11 (dB) 50TO 450L*	*MS21 (dB) 50TO 450L*	*MS31 (dB) 50TO 450L*	*PS21 (deg) 50TO 450L*	*PS31 (deg) 50TO 450L*
120.000	–27.60	–3.08	–3.10	–66.6	134.9	–18.19	–3.45	–2.89	–59.7	135.6
121.000	–28.06	–3.06	–3.11	–67.6	133.2	–18.68	–3.42	–2.91	–60.9	133.8
122.000	–28.54	–3.06	–3.11	–68.5	131.5	–19.19	–3.38	–2.93	–62.1	132.0
123.000	–29.03	–3.05	–3.12	–69.5	129.8	–19.72	–3.35	–2.94	–63.4	130.2
124.000	–29.52	–3.04	–3.13	–70.5	128.1	–20.26	–3.32	–2.96	–64.6	128.5
125.000	–30.03	–3.04	–3.13	–71.4	126.5	–20.81	–3.29	–2.97	–65.8	126.7
126.000	–30.56	–3.03	–3.13	–72.4	124.8	–21.39	–3.27	–2.99	–67.0	124.9
127.000	–31.10	–3.03	–3.13	–73.3	123.1	–21.99	–3.24	–3.00	–68.2	123.2
128.000	–31.65	–3.03	–3.14	–74.3	121.3	–22.61	–3.22	–3.01	–69.4	121.4
129.000	–32.23	–3.03	–3.14	–75.2	119.6	–23.25	–3.20	–3.03	–70.6	119.6
130.000	–32.83	–3.03	–3.14	–76.1	117.9	–23.92	–3.19	–3.04	–71.8	117.9
131.000	–33.46	–3.03	–3.14	–77.0	116.2	–24.63	–3.17	–3.05	–73.0	116.1
132.000	–34.11	–3.03	–3.13	–77.9	114.5	–25.37	–3.15	–3.06	–74.1	114.4
133.000	–34.80	–3.03	–3.13	–78.8	112.7	–26.14	–3.14	–3.06	–75.3	112.6
134.000	–35.53	–3.03	–3.13	–79.7	111.0	–26.97	–3.13	–3.07	–76.5	110.9
135.000	–36.30	–3.03	–3.13	–80.6	109.3	–27.86	–3.12	–3.08	–77.6	109.1
136.000	–37.13	–3.03	–3.13	–81.5	107.5	–28.81	–3.11	–3.09	–78.8	107.4
137.000	–38.03	–3.03	–3.13	–82.4	105.8	–29.84	–3.10	–3.09	–79.9	105.6
138.000	–39.02	–3.04	–3.12	–83.2	104.0	–30.98	–3.09	–3.10	–81.0	103.9
139.000	–40.10	–3.04	–3.12	–84.1	102.2	–32.26	–3.09	–3.10	–82.2	102.1
140.000	–41.33	–3.04	–3.12	–85.0	100.5	–33.70	–3.08	–3.10	–83.3	100.4
141.000	–42.74	–3.04	–3.12	–85.8	98.7	–35.40	–3.08	–3.11	–84.5	98.6
142.000	–44.41	–3.04	–3.12	–86.7	96.9	–37.44	–3.07	–3.11	–85.6	96.9
143.000	–46.45	–3.04	–3.12	–87.5	95.2	–40.00	–3.07	–3.11	–86.7	95.1
144.000	–49.08	–3.04	–3.12	–88.4	93.4	–43.40	–3.07	–3.11	–87.8	93.4
145.000	–52.79	–3.04	–3.12	–89.2	91.6	–47.76	–3.07	–3.12	–89.0	91.6
146.000	–58.68	–3.04	–3.12	–90.1	89.9	–48.96	–3.07	–3.12	–90.1	89.9
147.000	–61.69	–3.04	–3.12	–90.9	88.1	–44.78	–3.07	–3.12	–91.2	88.1
148.000	–54.84	–3.04	–3.12	–91.8	86.3	–41.03	–3.07	–3.12	–92.4	86.4
149.000	–50.34	–3.04	–3.12	–92.6	84.5	–38.24	–3.07	–3.11	–93.5	84.6
150.000	–47.29	–3.04	–3.12	–93.5	82.8	–36.07	–3.07	–3.11	–94.6	82.9
151.000	–44.98	–3.04	–3.12	–94.3	81.0	–34.28	–3.08	–3.11	–95.7	81.1
152.000	–43.13	–3.04	–3.13	–95.2	79.2	–32.77	–3.08	–3.11	–96.9	79.4
153.000	–41.57	–3.04	–3.13	–96.1	77.5	–31.46	–3.09	–3.10	–98.0	77.6
154.000	–40.23	–3.03	–3.13	–96.9	75.7	–30.28	–3.09	–3.10	–99.2	75.9
155.000	–39.04	–3.03	–3.13	–97.8	74.0	–29.23	–3.10	–3.10	–100.3	74.1
156.000	–37.97	–3.03	–3.14	–98.7	72.2	–28.26	–3.11	–3.09	–101.4	72.4
157.000	–37.00	–3.03	–3.14	–99.6	70.5	–27.36	–3.12	–3.08	–102.6	70.6
158.000	–36.11	–3.03	–3.14	–100.4	68.7	–26.52	–3.13	–3.08	–103.8	68.8
159.000	–35.27	–3.03	–3.14	–101.3	67.0	–25.73	–3.14	–3.07	–104.9	67.1
160.000	–34.49	–3.03	–3.15	–102.2	65.3	–24.98	–3.16	–3.06	–106.1	65.3
161.000	–33.76	–3.02	–3.15	–103.1	63.5	–24.27	–3.17	–3.05	–107.2	63.6
162.000	–33.06	–3.02	–3.15	–104.1	61.8	–23.60	–3.19	–3.04	–108.4	61.8
163.000	–32.40	–3.03	–3.15	–105.0	60.1	–22.95	–3.20	–3.03	–109.6	60.1
164.000	–31.77	–3.03	–3.15	–105.9	58.4	–22.32	–3.22	–3.02	–110.8	58.3

```
*Model 2-meter 50-ohm to 450-ohm balun
*Half wave balun and quarter wave matching section
*Model of 100 ft of UT-141A semi-rigid coax
BLK
CAB 1 2 Z=50 P=1200000MIL V=0.70 C1=.348913 C2=.024644
141LINE:2POR 1 2
END

*Model of 100 ft of 300 ohm transmitting
*tubular parallel line.
*Data from page 19.2 1999 ARRL Handbook
BLK
CAB 1 2 Z=300 P=1200IN V=0.80 C1=.105641 C2=.022346
LINE:2POR 1 2
END

*Verify that the attenuation constants
*are the same when modeled as two 150 ohm
*transmission lines
blk
cab 1 3 z=150 p=1200in v=0.80 c1=0.105641 c2=0.022346
cab 2 4 z=150 p=1200in v=0.80 c1=0.105641 c2=0.022346
trf 100 1 0 2 r1=50 r2=300
trf 200 3 0 4 r1=50 r2=300
300line:2por 100 200
end

*Model 2-meter balun—50 ohms unbalanced to 200 ohms balanced
*Note: ports 2 and 3 are 100 ohms with respect to ground
BLK
CAB 1 2 Z=50 P=.719M V=0.7 C1=.348913 C2=0.024644
BALUN:3POR 1 1 2
END

******************************************************
*Look at the effect of coax impedance on a 4:1 balun

*Balun with 50 ohm coax
BLK
CAB 1 2 Z=50 P=0.719M V=0.7 C1=.348913 C2=0.024644
TRF 1 1 2 R1=200 R2=50
BAL50:2POR 1 2
END

*Balun with 75 ohm coax
BLK
CAB 1 2 Z=75 P=0.719M V=0.7 C1=.348913 C2=0.024644
TRF 1 1 2 R1=200 R2=50
BAL75:2POR 1 2
END

*Balun with 100 ohm coax
BLK
CAB 1 2 Z=100 P=0.719M V=0.7 C1=.348913 C2=0.024644
TRF 1 1 2 R1=200 R2=50
BAL100:2POR 1 2
END

*Balun with 150 ohm coax
BLK
CAB 1 2 Z=150 P=0.719M V=0.7 C1=.348913 C2=0.024644
TRF 1 1 2 R1=200 R2=50
BAL150:2POR 1 2
END
******************************************************

*Balun with 200 to 450 ohm transmission line transformer
*Quarter wave of 300 ohm line as matching section
*Zero loss case
blk
cab 1 2 z=50 p=0.719m v=0.7 c1=0 c2=0
trl 1 3 z=150 p=0.488m v=0.95
trl 2 4 z=150 p=0.488m v=0.95
50to450:3por 1 3 4
end
*
*Balun with 200 to 450 ohm transmission line transformer
*Quarter wave of 300 ohm line as matching section
*lossy line case with UT-141A 50 ohm semi-rigid balun
blk
cab 1 2 z=50 p=0.719m v=0.7 c1=0.34913 c2=0.02464
CAB 1 3 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
CAB 2 4 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
50to450l:3por 1 3 4
end

*Balun with 200 to 450 ohm transmission line transformer
*Quarter wave of 300 ohm line as matching section
*lossy line case with 75 ohm coax for the balun
*loss set equal to that for UT-141A
blk
cab 1 2 z=75 p=0.719m v=0.7 c1=0.34913 c2=0.02464
CAB 1 3 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
CAB 2 4 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
50to450b:3por 1 3 4
end

*Balun with 200 to 450 ohm transmission line transformer
*Quarter wave of 300 ohm line as matching section
*lossy line case with 100 ohm coax for the balun
*loss set equal to that for UT-141A
blk
cab 1 2 z=100 p=0.719m v=0.7 c1=0.34913 c2=0.02464
CAB 1 3 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
CAB 2 4 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
50to450c:3por 1 3 4
end

*Balun with 200 to 450 ohm transmission line transformer
*Quarter wave of 300 ohm line as matching section
*lossy line case with 150 ohm coax for the balun
*loss set equal to that for UT-141A
blk
cab 1 2 z=150 p=0.719m v=0.7 c1=0.34913 c2=0.02464
CAB 1 3 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
CAB 2 4 Z=150 P=16.18IN V=0.80 C1=.105641 C2=.022346
50to450d:3por 1 3 4
end

*Lengthen line lengths to optimize for
*both 144 and 432 MHz.
*Balun with 200 to 450 ohm transmission line transformer
*Quarter wave of 300 ohm line as matching section
*lossy line case with 75 ohm coax for the balun
*loss set equal to that for UT-141A
blk
cab 1 2 z=75 p=0.729m v=0.7 c1=0.34913 c2=0.02464
CAB 1 3 Z=150 P=0.416m V=0.80 C1=.105641 C2=.022346
CAB 2 4 Z=150 P=0.416m V=0.80 C1=.105641 C2=.022346
50to450x:3por 1 3 4
end
freq
*step 120mhz 164mhz 1mhz
*1mhz 10mhz 100mhz 1000mhz
step 140mhz 150mhz 1mhz
step 420mhz 450mhz 1mhz
end

opt
*Optimizer used to determine attenuation constants for 300 ohm twin
  lead
line f=1mhz ms21=-0.09dB
line f=10mhz ms21=-0.3dB
line f=100mhz ms21=-1.1dB
line f=1000mhz ms21=-3.9dB
end
```

Figure 5—The *Amateur Radio Designer* file used to model baluns.

Table 2—Performance of a Dual-Band 432/144 MHz Balun

Compact Software—*ARRL Radio Designer* 1.5 15-JUL-99 09:37:30
File: balunq5.ckt

Freq (MHz)	*MS11 (dB) 50TO 450B*	*MS21 (dB) 50TO 450B*	*MS31 (dB) 50TO 450B*	*PS21 (deg) 50TO 450B*	*PS31 (deg) 50TO 450B*	*MS11 (dB) 50TO 450L*	*MS21 (dB) 50TO 450L*
140.000	–41.33	–3.04	–3.12	–85.0	100.5	–33.70	–3.08
141.000	–42.74	–3.04	–3.12	–85.8	98.7	–35.40	–3.08
142.000	–44.41	–3.04	–3.12	–86.7	96.9	–37.44	–3.07
143.000	–46.45	–3.04	–3.12	–87.5	95.2	–40.00	–3.07
144.000	–49.08	–3.04	–3.12	–88.4	93.4	–43.40	–3.07
145.000	–52.79	–3.04	–3.12	–89.2	91.6	–47.76	–3.07
146.000	–58.68	–3.04	–3.12	–90.1	89.9	–48.96	–3.07
147.000	–61.69	–3.04	–3.12	–90.9	88.1	–44.78	–3.07
148.000	–54.84	–3.04	–3.12	–91.8	86.3	–41.03	–3.07
149.000	–50.34	–3.04	–3.12	–92.6	84.5	–38.24	–3.07
150.000	–47.29	–3.04	–3.12	–93.5	82.8	–36.07	–3.07
420.000	–32.28	–3.06	–3.22	105.5	–58.9	–22.70	–3.27
421.000	–32.89	–3.06	–3.22	104.6	–60.6	–23.34	–3.25
422.000	–33.53	–3.06	–3.22	103.7	–62.3	–24.00	–3.23
423.000	–34.19	–3.06	–3.22	102.8	–64.1	–24.69	–3.21
424.000	–34.89	–3.06	–3.22	101.9	–65.8	–25.42	–3.20
425.000	–35.63	–3.06	–3.22	101.0	–67.5	–26.18	–3.19
426.000	–36.41	–3.06	–3.22	100.1	–69.3	–26.99	–3.17
427.000	–37.24	–3.06	–3.21	99.2	–71.0	–27.85	–3.16
428.000	–38.14	–3.06	–3.21	98.3	–72.8	–28.78	–3.15
429.000	–39.12	–3.06	–3.21	97.5	–74.5	–29.78	–3.14
430.000	–40.19	–3.06	–3.21	96.6	–76.3	–30.87	–3.14
431.000	–41.39	–3.07	–3.21	95.7	–78.0	–32.08	–3.13
432.000	–42.76	–3.07	–3.21	94.9	–79.8	–33.43	–3.12
433.000	–44.34	–3.07	–3.20	94.0	–81.6	–34.98	–3.12
434.000	–46.23	–3.07	–3.20	93.2	–83.3	–36.78	–3.12
435.000	–48.57	–3.07	–3.20	92.3	–85.1	–38.90	–3.11
436.000	–51.57	–3.07	–3.20	91.4	–86.9	–41.37	–3.11
437.000	–55.33	–3.07	–3.20	90.6	–88.7	–43.79	–3.11
438.000	–57.45	–3.07	–3.20	89.8	–90.4	–44.59	–3.11
439.000	–54.50	–3.07	–3.20	88.9	–92.2	–42.86	–3.11
440.000	–50.84	–3.07	–3.20	88.1	–94.0	–40.31	–3.11
441.000	–47.97	–3.07	–3.20	87.2	–95.7	–37.98	–3.11
442.000	–45.72	–3.07	–3.21	86.4	–97.5	–35.99	–3.12
443.000	–43.88	–3.07	–3.21	85.5	–99.3	–34.30	–3.12
444.000	–42.33	–3.07	–3.21	84.6	–101.0	–32.84	–3.13
445.000	–40.99	–3.06	–3.21	83.8	–102.8	–31.54	–3.13
446.000	–39.80	–3.06	–3.21	82.9	–104.6	–30.38	–3.14
447.000	–38.73	–3.06	–3.22	82.0	–106.3	–29.33	–3.15
448.000	–37.75	–3.06	–3.22	81.2	–108.1	–28.36	–3.15
449.000	–36.85	–3.06	–3.22	80.3	–109.8	–27.46	–3.16
450.000	–36.01	–3.06	–3.22	79.4	–111.6	–26.62	–3.18

coefficient going from port 2 to port 3.

Table 1 shows the results of modeling the balun with 50- and 75-Ω coax. Surprisingly, simulations showed that the 75-Ω coax worked better than the 50, 100 and 150-Ω varieties, assuming the coax loss are constant.

The balun will also operate on odd harmonics. Remember that the λ/2 line for the balun must supply a 180° phase shift. At odd harmonics, the coax adds $(2\times w) + 1$ 180° shifts, where w is a whole number. Alternatively, the coax adds $w\times360°$ plus an additional 180° phase shift. Of course, the $w\times360°$ phase shifts equal a 0° phase shift, so the net effect of the longer line is still a 180° phase shift. In practice, the longer line will narrow the bandwidth of the balun, but the balun may still be useful for narrow-band work. Similarly, the coax is still a multiple of λ/2, which is required to reflect the proper impedance between the ends of the coax. Table 2 shows the 144- and 432-MHz performance of a 450:50 Ω balun using λ/2 and λ/4 transmission lines cut for 144 MHz. I used 75-Ω coax, as it offers a better bandwidth than 50-Ω coax.

Notes

[1]Percentage loss= $100\left(1-10^{\left(\frac{-\text{loss}}{10}\right)}\right)$

[2]C. Ruckstuhl, W1JZD,"A Simple Dirt-Cheap No-Loss Transmission Line, Almost," *Proceedings of the 19th Eastern VHF/UHF Conference of the Eastern VHF/UHF Society* (Newington: ARRL, 1993), pp 65-75.

[3]A. Griffith, W4ULD, "The 1/3-Wavelength Multiband Dipole," *QST*, September 1993, pp 33-35.

[4]ARRL products are available from your local ARRL dealer or directly from the ARRL. Mail orders to Pub Sales Dept, ARRL, 225 Main St, Newington, CT 06111-1494. You can call us toll-free at tel 888-277-5289; fax your order to 860-594-0303; or send e-mail to **pubsales@arrl.org**. Check out the full ARRL publications line on the World Wide Web at **http://www.arrl.org/catalog**. □□

Next Issue in QEX

Mark Mandelkern, K5AM, brings us the fifth and final segment on his homebrew transceiver. As we wrap up the series, the focus is on the control system, PTOs, frequency counter and construction details. Mark is also working on a piece for us about the "front-end" designs—the parts that change from band to band.

We begin a look at another high-performance homebrew rig with the first part of John Stephensen, KD6OZH's series on his *ATR-2000*. It's a synthesized, 20-meter mono-bander designed with due regard for actual conditions found on 14 MHz at John's QTH. He sets forth his goals and neatly explains the rationale behind his architectural choices. He gives circuit examples that address the needs for low phase noise and high receiver dynamic range. Check it out.

Jim Kocsis, WA9PYH, has been experimenting with 1691-MHz weather-satellite imaging and contributes his down-converter design. This synthesized unit may also cover several Amateur Radio bands with slight modifications. Jim uses convenient 50-Ω blocks, where possible. The result is an efficient and compact design: There is only one alignment point!

Johan Van de Velde, ON4ANT, presents his homebrew, multi-band Yagi design. He examines tradeoffs in element spacing and boom length and weighs his computer-modeling results before beginning construction. If you want to cover several HF bands with very good performance, look at his interlaced designs. □□