IMPEDANCE MATCHING DEVICES
For Simple Wire Antennas

John Bryant and Bill Bowers

In recent years, it has become standard practice to use 52 ohm coaxial cable lead-ins for almost all wire receiving antennas used by DXers. This trend is no doubt driven by the rapid increase in RF interference-producing devices in almost everyone's home and neighborhood. With simple end fed antennas, standard practice has been to connect the center conductor of the coaxial cable to the antenna wire and leave the braid/shielding unconnected at the top. The braid of the coax then shields the center cable; RF interference is drawn off the braid at the receiver and goes to ground. This strategy is very successful in reducing near-field noise.

As this practice developed, many DXers have been concerned about the potential signal loss at the junction between the main antenna and the coaxial cable. Simple wire antennas are inherently high impedance devices and the coaxial cable is , of course, quite low impedance. Many DXers wondered if this obvious mis-match (and thus, signal loss) really made any difference at all. The conventional wisdom has been that it does not. The reasoning is that if the antenna system is well matched to the receiver AT THE RECEIVER, all is okay. The reasoning continues that if an antenna has enough gain so that you can clearly hear 'band' or atmospheric hoise, then any additional gain is really unnecessary; you will hear any signal which shows above the general band noise.

Several factors led us to question this wisdom:

A) In DXing, we are often trying to hear very weak signals right at the noise floor of our receivers. It seems wrong to willingly accept a loss of gain through a severe antenna/lead-in mis-match when it can easily be corrected.

B) There are many times that even the Tropical Bands are extraordinarily quiet. Under those conditions, reception may very well be limited by circuit noise in the receiver. Under these conditions, a higher gain antenna would be very useful.

C) At least two devices intended for use between coax lead-in and simple wire antennas have been marketed in the past two years. It seemed reasonable to test their effectiveness.

ANTENNA IMPEDANCE

A single straight run of antenna wire, end fed, is generally considered to be a high impedance device, usually measuring 400 to 700 ohms. However, it is very important to note that impedance naturally varies with frequency and antenna length. The end impedance of an end-fed antenna is related to its electrical wave length. There is always high impedance at the far end of the antenna wire. Antennas which are one-quarter wave length (or odd multiples of 1/4 wave length) present LOW impedance to the receiver. An antenna of less than 1/4 wave length, or 1/2 wave length (or its multiples) presents HIGH impedance the receiver. So, if an impedance matching device is used to significantly lower the impedance of the antenna (say a 10 to 1 device to reduce 600 ohms to 60 ohms) there will be frequencies where the impedance will be transformed to too low a value.

Radio amateurs solve this problem by operating over a restricted frequency range or its multiples and designing appropriate length antennas. SW and MW DXers are in a much more difficult position since the frequency ranges of their interests are so much broader. They are faced with either not using impedance matching at the antenna/lead-in interface and having a severe impedance mis-match at most frequencies, or, using an impedance matching transformer and dropping the impedance too much near those frequencies where the wire represents 1/4, 3/4, 5/4... wave length. The only complete solution to this problem would be the have a remotely controlled variable antenna tuner at the junction between the antenna and the coax lead-in. Our concern in this project was to determine whether an impedance matching device was actually beneficial.

TEST SET-UP

Over the past two years, we have done a good bit of comparison testing of antennas. The results were published in Proceedings 1992-93 ("Active Antennas") and in this edition ("Very Large Ferrite Loops"). The testing apparatus employs mechanically and electrically identical coaxial cable lead-ins, low-loss coax switches and an ICOM R-9000 receiver. This receiver is particularly useful because its spectrum display of received signals is marked off with 10 dB signal level increments. Most of our measurements were made using a combination of the spectrum display and the R-9000's large mechanical/electrical S-meter.

We did several different runs of the tests presented below. The first runs were made using two identical 150' antennas about 20' apart. Although the data generally appeared to be quite acceptable, there were a few anomalies which might been due to interaction between the two antennas. The final tests presented below were made using a single wire antenna. Two identical coax lead-ins were run to the antenna. At the antenna, two 12v relays were used; they were wired so that one lead-in was active while the other was grounded. Thus, we could instantaneously compare signal levels between a 'bare' lead-in and one with an impedance matcher in-line between the antenna and the lead-in.

THE IMPEDANCE MATCHERS

The ICE Model 180 Antenna Receive-Only Matching Assembly

Industrial Communications Ltd. PO Box 18495, Indianapolis, IN 46218-0495. 1-800-423-2666. Cost $32.00 + S/H

The ICE Matcher is an extraordinarily well made device enclosed in an RF-tight cast aluminum box using stainless steel hardware. It is based on a ferrite-cored transformer tapped so that impedance transformation is set for 300,450 or 600 ohm input from the antenna. Output ia a standard 50-239 'coax' connection. The device is intended to be pole or mast mounted at the receiver end of the wire antenna. Unlike any other device tested, the ICE model 180 includes a resistor and neon bulb arrangement to bleed off harmful static electricity from the antenna. Further, this matcher contains a capacitor in series with the signal so that low voltage DC may be run up the coax to control switches, etc. There is also an external grounding lug, if grounding the transformer at the antenna is desired. Like other products from Industrial Communications Engineers, this device is very well made using excellent components and is fairly priced.

The Magnetic Longwire Balun

RF Systems/Doevon Electronics, The Netherlands. Obtained from Universal Radio, Reynoldsburg, OH 1-800-431-3939 Cost: $59.95 + $3.00 S/H

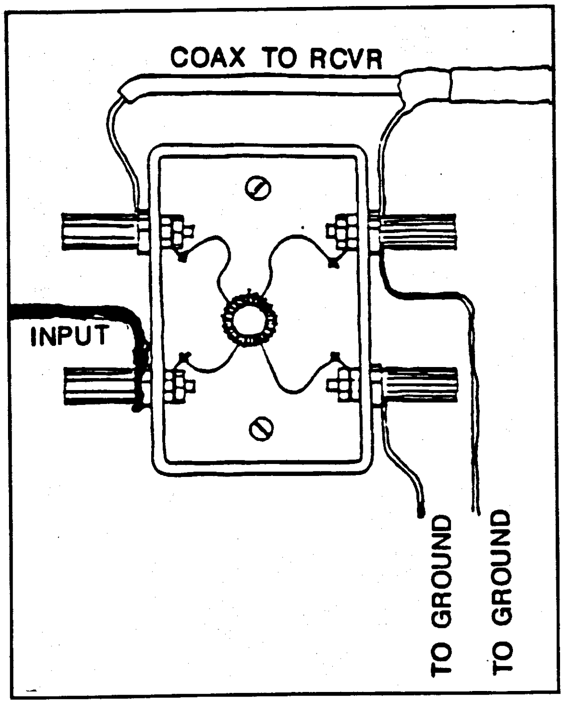
The Magnetic Longwire Balun is completely encapsulated in a cylindrical plastic housing with a binding post on one end and a S0-239 coax connector on the other. There is no external grounding stud and the impedance transformation ratio (about 9 or 10 to 1) is not user selectable. The unit is intended to hang from the antenna wire, with the lead-in hanging below the balun itself.

To quote from the manufacturer's 4-page pamphlet....

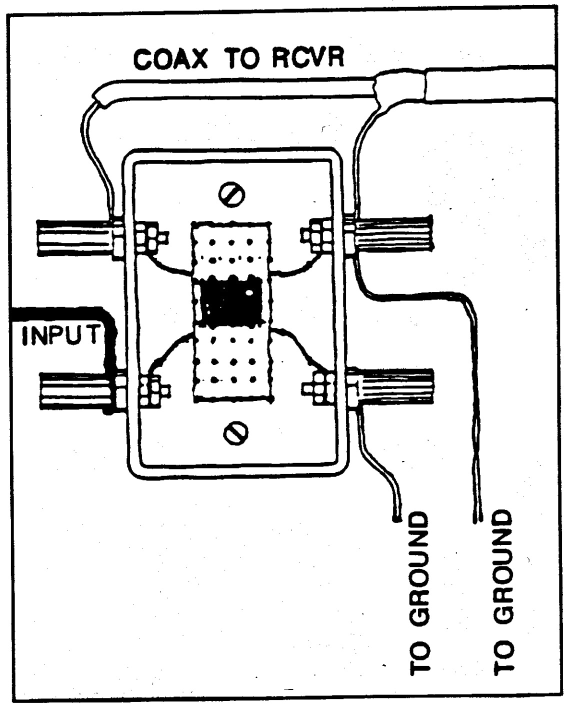
> *"The Magnetic Longwire Balun is a compact, weather-proof matching unit. It consists of a special patented transformer with magnetic field coupling. The impedance transformation ratio changes with frequency. The end result is a simple device which you connect to the end of a longwire antenna (or in the middle of the "T" antenna). The other end of the unit has an SO-239 socket designed to match 50 ohm coaxial feeder cable. The advantages are immediate. The lead-in cable is immune from local man-made interference, and doesn't have to be isolated from its supports."*

This is but the first of several places where the manufacturer makes the claim that the 'transformation ratio changes with frequency.' At the end of the tests, the authors cut the Magnetic Balun apart. The housing is rather cleverly assembled from a short section of plastic plumbing pipe and two end caps. Inside the case we found what appears to be a normal ferrite-based transformer further encapsulated in plastic 'potting' material. Rather than cutting further, Bill put the device on his sophisticated test bench. Sure enough, DX Systems' claim that 'transformation ratios change with frequency' is simply NOT TRUE and is, at best, very misleading advertising and a clear misrepresentation. The manufacturer also states that this "balun" provides "static protection" This is also not true in the accepted technical sense of the term since there is no external grounding stud on the unit. The only path for static charges to take to ground is down the coaxial shield to the receiver chassis. You should also note that the parts and material costs of this device, if purchased RETAIL on the open market, cannot exceed $6.00, less than 1/10th of the purchase price. Finally, this device is NOT a balun. The normally accepted definition of "balun" is a transformer which converts from <u>bal</u>anced to <u>un</u>balanced configuration. This unit is an impedance matching device designed to attach an <u>un</u>balanced feed line to an <u>un</u>balanced antenna. Although the foregoing description is harsh, the "Magnetic Longwire Balun" is misrepresented by the manufacturer and is VERY unfairly priced.

Hall-Patch Impedance Matcher



"Mini-Circuit" Impedance Matcher



The Hall-Patch Impedance Matcher

(Home-brew device. Details were first published in Proceedings 1988. See sketch above.)

This matcher uses a torroidal (doughnut-shaped) ferrite core which is available from Amidon Associates, Dominguez Hills, CA. Phone: 310-763-5770. Note that ferrite torroids are produced with differing frequency characteristics; the one used was a FT-50-43 and the design was selected to optimize performance MW and the Tropical Bands. Binding posts are shown in the drawing above for the connection. However, most DXers prefer to install an SO-239 connector.

The 'Mini-Circuit' Impedance Matcher

(Home-brew device. Details were first published in Proceedings 1992-93. See sketch above.)

The 'Mini-Circuit' balun is quite similar to the other home-brew impedance device above. However, in this latter case, the impedance transforming device is a RF transformer chip (similar in appearance to an integrated circuit chip) manufactured by RF Mini-Circuits, P.O. Box 350166, Brooklyn, NY 11235-0003. Phone: 718-934-4500. Inside the chip is a very small transformer wound on a ferrite bead the size of a large match head. Like the cores from Amidon, the RF Mini-Circuit transformers must be selected for the frequency range of interest. The tested unit is based on a 9 to 1 ratio transformer (T9-1) whose RF range is .15-200 MHz.

CONCLUSIONS AND RECOMMENDATIONS–SHORTWAVE

The accompanying chart records our comparison of signal strengths (in decibels) between the 150' test antenna with and without the impedance matcher in place. As you can see, both of the commercially produced impedance matchers worked well on shortwave. They were particularly effective on the Tropical Bands and on the higher frequency International Bands. The dip in performance of all the matchers at the 5 to 8 MHz frequencies is probably due to the 150' antenna being at lower impedance over those frequencies. The Mini-Circuit based 'home-brew matcher also performed relatively well on shortwave, showing no losses at any frequency and good gain on the Tropical Bands. The other home-brew matcher based on the hand-wound torroid also performed very well on 90 and 120 meters. However, significant losses were noted at and above 5 MHz These losses were almost certainly due to the core material selected.

Signal Strength Comparison in Decibels

FREQ.	I.C.E 600 ohm	I.C.E 300 ohm	Magnetic BALUN	Torroid BALUN	Mini-Circuits
2.5 MHz WWV	10	7	12	6	10
3.33 MHz CHU	10	5	10	10	7
5.0 MHz WWV	5	5	3	-6	0
7.335 MHz CHU	0	2	0	-10	0
10.0 MHz WWV	3	5	0	-2	2
15.0 MHz WWV	4	6	5	0	4

If you are interested in purchasing a ready-made matcher, there is no choice: buy the ICE unit. At the 600 ohm setting, it performed about identically with the "Magnetic Balun". It offers full static protection, a choice of grounding configuration and also allows a choice of impedance ratios to meet individual preferences. Note, however, the comment

150 Ft. Wire Antenna

FREQ.	I.C.E. 600 ohm	I.C.E. 300 ohm	Magnetic BALUN	Torroid BALUN	Mini-Circuits
580 kHz WIBW	7	3	8	9	8
780 kHz KSPI	11	6	9	9	8
890 kHz KBYE	10	8	5	7	5
1000 kHz KTOK	5	8	3	2	2
1140 kHz KPRW	0	3	0	-4	-3
1220 kHz KTLV	-3	0	-2	-8	-7
1340 kHz KXXY	-5	-5	-5	-8	-7
1490 kHz KOKC	-8	-5	-2	-2	0
1600 kHz KUSH	2	3	2	0	3

Signal loss or gain in decibels

50 Ft. Wire Antenna

FREQ.	I.C.E. 600 ohm	I.C.E. 300 ohm	Magnetic BALUN	Torroid BALUN	Mini-Circuits
580 kHz WIBW	18	3	33	33	29
780 kHz KSPI	8	4	11	11	10
890 kHz KBYE	8	6	11	13	9
1000 kHz KTOK	11	5	13	12	8
1140 kHz KPRW	15	10	12	13	10
1220 kHz KTLV	15	12	12	12	9
1340 kHz KXXY	14	10	9	11	7
1490 kHz KOKC	16	12	18	21	18
1600 kHz KUSH	12	8	12	20	13

Signal loss or gain in decibels

related to the blocking capacitor which is found in the Medium Wave recommendations to follow. If "home-brewing" is your choice, it is hard to go wrong with the Mini-Circuit based design. If you would like to construct a matcher based on ferrite torroids, we suggest that you select the core material with particular attention to the intended frequency range. With either home-brew design, we suggest adding full static discharge protection similar to that used in the ICE unit. This can be achieved by connecting a small neon bulb (Radio Shack #272-100) from the signal path to ground.

CONCLUSIONS AND RECOMMENDATIONS–MEDIUM WAVE

As with the shortwave tests, the accompanying charts record the differences in signal strength (in decibels) between the antenna with and without the impedance matcher being tested. Please note carefully the differences between our first test using a 150' antenna and the second one using 50' of wire! Discussing performance with the 150' wire first: The almost uniform loss pattern in the upper half of the band is due to the fact that the 150' wire was performing as a 1/4 wave antenna as discussed at the beginning of this article. Antenna impedance had dropped low enough at these frequencies that we were OVER transforming and incurring losses because the antenna plus matcher was presenting far too low impedances to the 52 ohm coax. This theoretical supposition was proved in the second medium wave tests using only 50' of wire. Antenna lengths of 100' or less always present high impedance to the lead-in at medium wave frequencies since those lengths are less than 1/4 wave length, even at the top of the medium wave band. As you can see, all matchers performed very well using the shorter antenna. SPECIAL NOTE: The blocking capacitor in the ICE unit begins to think that signals below about 600 kHz. are DC current and to block them. Unless you plan to run DC up your coax, we recommend opening the ICE box and placing a jumper across the capacitor.

Again, if you wish to purchase a ready-made matcher, the ICE unit connected at 600 ohms is the only choice. If you wish to home-brew your matchers, either a ferrite torroid of appropriate material or the Mini-Circuit chip seem to perform equally well on medium wave.

FINAL REMARKS

It seems clear that appropriately selected impedance matching devices will improve the gain of simple wire antennas. Your S-meter will go up using one of these gizmos. However, our test numbers DO NOT address the issue of effective useful gain. Were the experts right when stating "everyone in the boat goes up with the rising tide"? Our findings in this area are more subjective. However, during our tests, we DID notice a number of instances where the signal-to-noise ratio of weak signals was improved significantly. We also noticed that the 'valleys' of most rapidly fading signals were filled in by the stronger signals available using an impedance matcher.

If you are using a simple wire antenna, we strongly recommend using the appropriate impedance matcher if you wish to use coaxial cable lead-ins.