Adapting a Three Element Tape Measure Beam for Power Line Noise Hunting

Find that noise source to point your power utility in the right direction.

James T. Hanson, W1TRC

I have been using an MFJ-852 power line noise meter in conjunction with my homemade ultrasonic power line arc detector to track down power line noise.[1] The MFJ-852 meter uses a simple, built-in dipole antenna for reception. In the process of hunting down power line noise, I came across a situation in which I just could not pinpoint the noisy pole with my MFJ-852 power line noise meter. I decided that there must be more than one noise source in the vicinity. ARRL Lab RFI Engineer Mike Gruber, W1MG, pointed out the difficulty of using the MFJ-852 power line noise meter in a complex noise environment in his November 2006 *QST* review of the meter.[2] Because of the problem I was having at this location, I decided to replace the simple dipole used in the MFJ-852 with a directional three element Yagi.

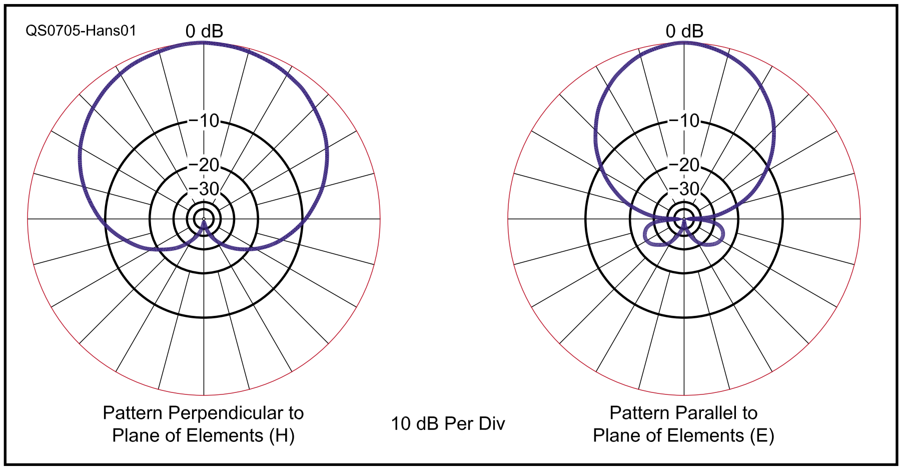

Figure 1 — YAGI-CAD predicted tape measure beam patterns.

An Easy to Make Yagi for the '852

While doing some searches on the Internet, I came across the Web site of Joe Leggio, WB2HOL, titled "Tape Measure Beam Optimized For Radio Direction Finding."[3] Joe developed a three element tape measure beam that he optimized for 2 meter fox hunting. The characteristics that have made his design such a success for fox hunting include all of the desirable features of an antenna optimized for power line noise hunting. These features include a very high front-to-back ratio, low cost, easy construction with simple hand tools and lightweight portability.

The antenna evolved during a search for a beam with a really great front-to-back ratio to use in hidden 2 meter transmitter hunts. The design exhibits a very clean pattern and is perfect for radio direction-finder (RDF) use. It trades a bit of forward gain in exchange for a very deep notch in the pattern toward the rear. These features, along with ease of construction and low cost, convinced me that this would be an ideal antenna to use for power line noise hunting.

One characteristic that is common to both RDF and noise hunting beam antennas is ease of getting it in and out of a car. This feature is accomplished by the use of steel tape measure elements. The elements can easily be folded when fitting the antenna into a car and yet, because of the short lengths at VHF/UHF frequencies, they are self-supporting.

Another desirable design goal was to use materials that were easy to obtain. The beam uses schedule 40 PVC pipe and fittings available at any hardware store for the boom and element supports. This keeps the cost for the antenna very low. The element supports consist of PVC crosses and Ts. The elements are cut from a steel tape measure.

Antenna Design Details

A shareware computer aided Yagi design program called *YAGI-CAD* written by Paul McMahon, VK3DIP, was used to design and evaluate the antenna.[4] A summary of the theoretical beam characteristics achieved is contained in Table 1. A plot of the E (electric field) and H (magnetic field) plane beam patterns predicted by *YAGI-CAD* is included in Figure 1. Notice that the beam has a theoretical front-to-back ratio of 50 dB. I have found the front-to-back ratio to be very impressive in actual use.

Table 1
Three Element Tape Measure Beam Performance Predicted by YAGI-CAD

Gain	7.3 dBd
Front-to-back ratio	>50 dB
Beamwidth, 3 dB E-plane	67.5°
Beamwidth, 3 dB H-plane	111°

The Yagi Elements

The beam consists of a boom constructed out of ½ inch PVC schedule 40 pipe and fittings and elements cut from 1 inch wide steel tape measure. I found a 25 foot, 1 inch wide tape measure at the bargain table of a local hardware store for under $5. This provided more than enough tape to build a three element beam at 135 MHz, the operating frequency of the MFJ-852 power line noise meter. I have since discovered that Home Depot also stocks a 25 foot, 1 inch wide tape measure for under $5. Inductive hairpin matching is used to match the antenna to 50 Ω coax.

Coax Termination

In the original RDF application, RG-58,

[1]Notes appear on page 31.

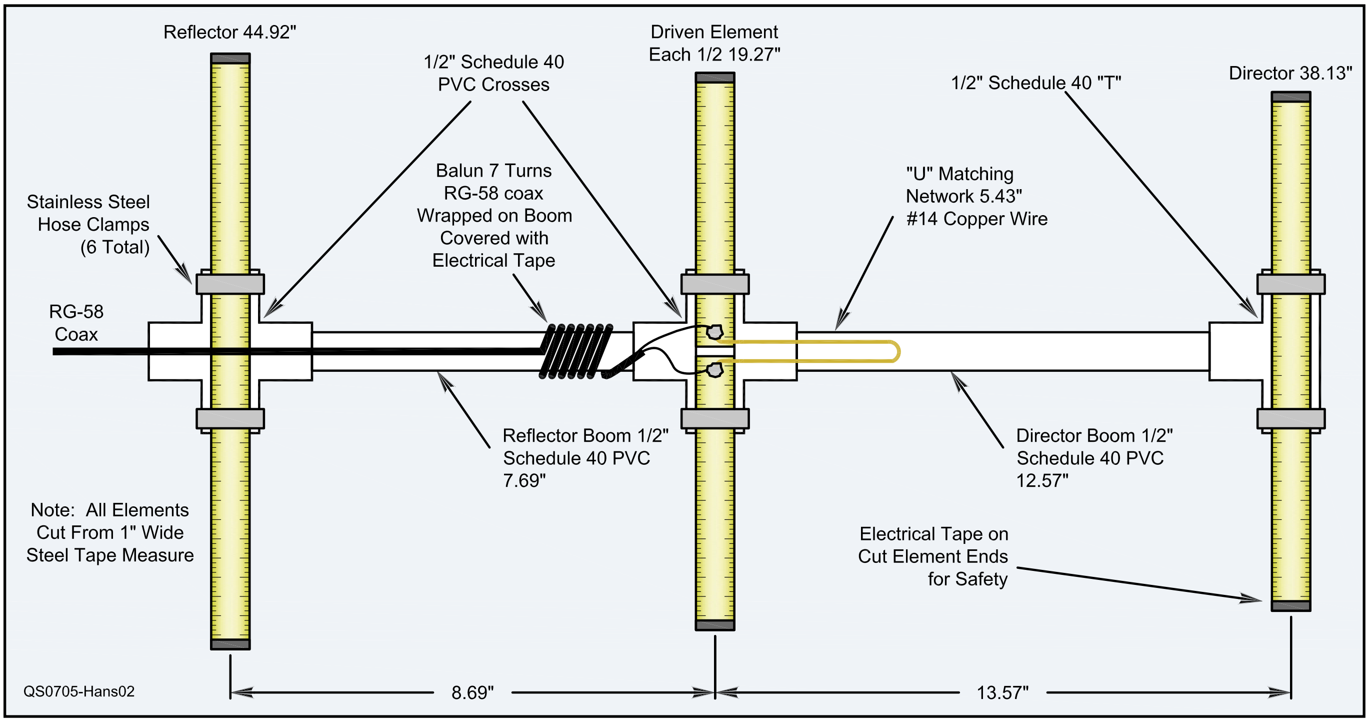

Figure 2 — 135 MHz tape measure beam assembly.

Table 2
Three Element Tape Measure Beam Dimensions (Inches)*

Frequency (MHz)	146.565	135	224	432
Reflector length	41.38	44.92	27.07	14.04
Driven element length	35.50	38.54	23.23	12.04
½ driven element length	17.75	19.27	11.61	6.02
Director length	35.13	38.13	22.98	11.92
Reflector to driven element center to center spacing	8.00	8.69	5.23	2.71
Reflector PVC length (see Note 1)	7.00	7.69	4.23	1.71
Director to driven element center to center spacing	12.50	13.57	8.18	4.24
Director PVC length (see Note 1)	11.50	12.57	7.18	3.24
U matching total length	5.00	5.43	3.27	1.70

*The length of PVC can vary somewhat depending on the PVC fitting exact dimensions. The critical antenna dimensions are the center to center element spacings.

50 Ω coax is connected directly to the driven element and matching network. I decided to create a balun by wrapping several turns of the coax around the boom right after the connection. This has also been done on a number of antennas that have been built for RDF use. The balun makes the transition from the balanced antenna feed point to the unbalanced coax. It should help generate a symmetrical antenna pattern. There is a measured antenna pattern plot on the Web site referenced in Note 4 that shows that the pattern is somewhat distorted. The pattern was taken without a balun, and it has not been redone with a balun.

Adapting to Other Frequencies

The original tape measure beam was designed for a 2 meter fox hunt frequency of 146.565 MHz. Since the MFJ-852 power line noise meter operates at a frequency of 135 MHz, the dimensions must be changed for this frequency. This is readily accomplished using Equations 1 and 2 that scale the dimensions of the 146.565 MHz design by the inverse of the new frequency. Equation 1 is used to scale the element lengths, element spacing and hairpin match length. Equation 2 is used to scale the reflector to the driven element and the director to the driven element boom lengths, which are shortened to take into account the length added by the PVC cross and T. Equation 2 is based on a distance of 1.25 inches from the edge of the PVC cross or T to the center of the corresponding beam element, and a penetration of the boom sections of 0.75 inch into the corresponding cross and T. This difference is 0.5 inch, which is multiplied by 2 to account for each end. This is where the 1 comes from in Equation 2. If you find the dimensions of your PVC parts differ from this, an adjustment to the factor "1" in Equation 2 should be made, so that the resultant element spacing is correct.

$$L_N = L_{146.565} * (146.565/F_N) \qquad \text{[Eq 1]}$$
$$L_B = L_E - 1 \qquad \text{[Eq 2]}$$

where:

L_N is the element length, element spacing or hairpin match length in inches at the new frequency.

$L_{146.565}$ is the corresponding 146.565 MHz antenna element length, element spacing or hairpin match length in inches.

F_N is the new frequency in MHz.

L_B is the boom length in inches at the new frequency.

L_E is the element to element spacing in inches at the new frequency.

The final dimensions for several different frequencies are included in Table 2. I found that the design scaled from 146.565 MHz to 135 MHz very well, and Joe Leggio, WB2HOL, has informed me that it scales up to 440 MHz just as well. It is recommended that if a 440 MHz version is built, that a ½ inch wide tape measure be used in place of 1 inch tape measure used in this model. Remember that as frequency increases, the tolerance of the dimensions gets tighter so at the higher frequencies, accuracy becomes more important. The antenna does not scale well if small diameter element material such as welding rod is substituted for the tape measure elements.

Putting it All Together

A drawing that shows all of the 135 MHz antenna construction details is included in Figure 2. The PVC components are not glued together. There is enough friction in the PVC pipe to hold the beam together and this allows it to be taken apart easily for transportation.

The tape measure can be cut with a pair of tin snips or a heavy pair of scissors. No matter how you cut the elements, be very careful. The edges are very sharp and will inflict a nasty cut if you are careless. Use some emery cloth to remove the really sharp edges and burrs resulting from cutting the elements to size. It is also a good idea to chamfer the edges by cutting about ⅛ inch off each corner. Put some vinyl electrical tape on the ends of the elements to protect from getting cut. Wear safety glasses while cutting the elements. Those bits of tape measure can be hazardous.

When I cut the tape, I used the tape measure itself to measure the length of the elements. I started out by cutting the end of the tape off at the 2 inch point and added 2 inches to the length of the first cut element to determine where the second cut should be made. I then trimmed the remaining tape to the next whole inch mark on the tape, and with simple arithmetic determined where the next cut should be made. I continued this process until all of the elements were cut to size.

Keeping Track of What's What

Notice that the driven element and reflector both use PVC crosses while the director element uses a PVC T. This was done purposely to make it easy to recognize the director and reflector elements when assembling the beam.

The wire size and type of wire used for the hairpin match is not critical. Hams have used anything from 22 to 14 gauge stranded or solid wire. I used 14 gauge solid copper house wire. It appears to be a good choice from a mechanical survivability point of view.

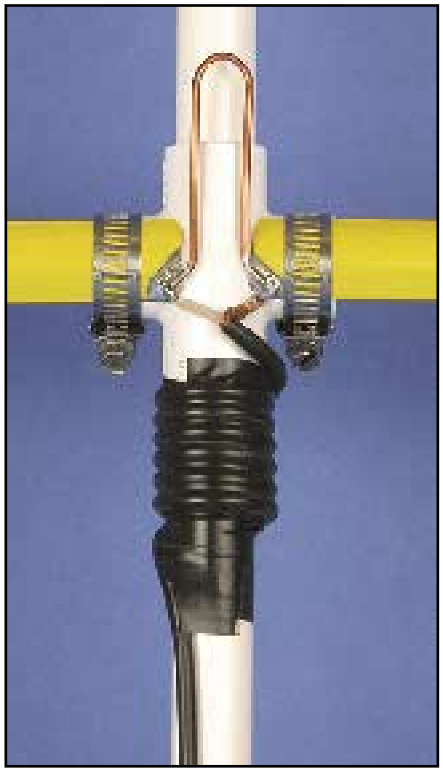

Figure 3 — Hairpin match and balun details.

Holding it Together

The elements are attached to the PVC fittings with stainless steel hose clamps. The only tricky part of assembling the beam is soldering the coax and hairpin match to the driven element, since the PVC will melt if you apply too much heat. One solution to this potential problem is to do the soldering before assembling the driven element to the PVC fittings.

Hooking it Up

Remove the paint from the corner of the driven element tape with some emery cloth and tin the steel tape. Temporarily tape the driven elements to a piece of scrap wooden board using electrical tape so the element ends are ¾ inch apart. Pre-form the hairpin match into a U shape so the spacing is ½ inch. Flare the last ¼ inch of the hairpin match out about 45°. Now solder the hairpin match and the coax to the elements. Carefully remove the electrical tape and position the assembly over the PVC cross. Slip the stainless steel clamps over the ends of the elements and tighten the clamps. The final assembly should look like the detail in Figure 3. After winding and wrapping the balun with electrical tape, the RG-58 coax was cut about 2 feet beyond the end of the reflector PVC cross and a BNC male connector installed on the coax. Figure 4 is a photograph of the assembled beam. Fine-tuning of the final match can be accomplished by increasing or decreasing the gap between the driven element halves. I checked the match with an MFJ-259B SWR analyzer and found that it was very close to 1.1:1.

Taking it Apart

When it is not in use, and when transporting the beam, disassemble the elements and director portion of the boom. The boom section that goes to the reflector is kept attached to the driven element since it has the coax balun attached. Each of the elements can be folded back on itself and slipped into the corresponding PVC cross or T to minimize its size. The disassembled components are shown in Figure 5. I carry the beam pieces in a plastic shopping bag.

Interfacing the Beam to the MFJ-852 Power Line Noise Meter

The final part of the project is to interface the beam with the MFJ-852 power line noise meter. The MFJ-852 has a metal front

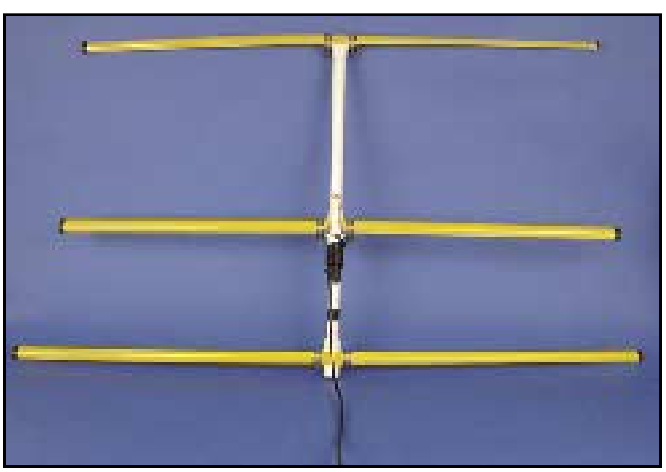

Figure 4 — Assembled 135 MHz tape measure beam.

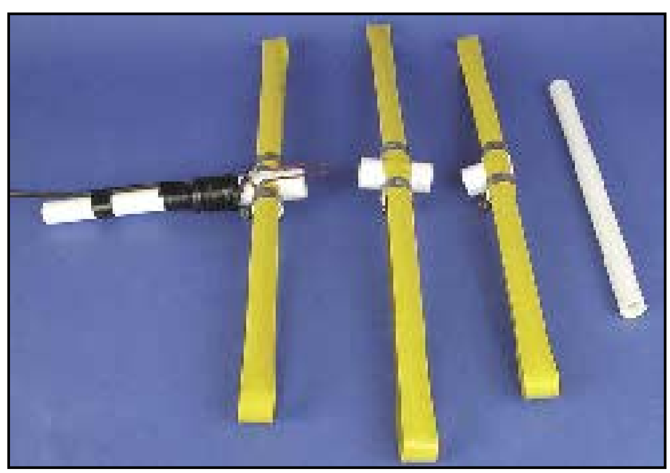

Figure 5 — Disassembled beam ready for transport.

panel but it is in a plastic box. I wanted to shield the electronics from any stray pickup to preserve the deep notch off the back of the beam, so I removed the plastic box and unsoldered the antenna coax connection from the PC card. The plastic box, telescoping antenna sections and coax balun are not used. I then mounted the MFJ-852 power line noise meter front panel and electronics to a cutout in a 3 × 5 × 4 inch aluminum BUD box (BUD part number AU-1028). I mounted a BNC female connector to the box and used a short length of small diameter 50 Ω coax (RG-174 or equivalent) to connect the coax connector to the MFJ-852 printed circuit card. The holes in the MFJ-852 printed circuit card have a very small diameter, so I found it necessary to use a piece of 22 gauge bus wire to make the connection to the coax shield.

Figure 6 — Shielded MFJ-852 mounted in metal Bud box.

Noise Hunting With the Three Element Beam

The beam makes a big difference when tracking down noise if there are two or more noise sources in relatively close proximity. I have found that the null off of the back of the beam is a very good indicator of the direction of the noise. I have found that it works best if I can get some distance (100 yards or more) away from multiple noise sources. In the complex environment I was investigating, I found that I could get more than one null off of the back of the beam, and each null pointed me to a noisy pole. Once I found the area where poles were generating noise, I was able to hear the arcing on the offending poles using my ultrasonic detector, and I was able to pinpoint the exact noise sources.[5]

The MFJ-852 signal strength meter has a dynamic range of about 50 dB. To extend the range, I carry a small, homemade, 20 dB, 50 Ω π-section attenuator in a shielded enclosure with BNC connectors. The attenuator can be connected between the antenna and the MFJ-852 to extend the dynamic range. I have found the attenuator to be helpful if the signal strength gets too strong.

Using Receivers Other Than the MFJ-852 Power Line Noise Meter

Any VHF or UHF receiver capable of receiving AM can be used with a tape measure beam to hunt for power line noise. There are several homemade and modified commercial receivers documented on the ARRL Technical Information Service (TIS) Web page.[6]

One example of a simple receiver is a tuned radio frequency (TRF) design by Rick Littlefield, K1BQT, published in the March 2001 issue of *QST*.[7] Rick let me try out one of his receivers that he had mounted in a shielded box for me with an SMA connector for the antenna. I purposely went hunting for some power line noise (it is never very far away) and was able to successfully hear and locate a noise source with this receiver using the tape measure beam.

There are also a growing number of small handheld receivers and transceivers that include general coverage receivers operating up to 1 GHz. Any that include an AM detector are suitable. Some of these receivers include a signal strength indicator or a switchable attenuator between the antenna and receiver can also be used to determine relative signal strength when pinpointing the noise source. A suitable switchable attenuator with 42 dB total range is described in the *QST* article titled “A Line Noise Sniffer That Works.”[8] This article can be found on the ARRL TIS Web page. The article also describes how to use an attenuator when tracking down a noise source.

As Mike Gruber pointed out in his review of the MFJ-852, one of the unique requirements of a noise locating receiver is wide bandwidth, since noise is a wide band signal and the receiver sensitivity improves with bandwidth. The MFJ-852 has an IF bandwidth of 100 kHz. While most general coverage receivers will have bandwidths much narrower than this, the reduced sensitivity will be partially compensated for by the gain of the tape measure beam.

Notes

[1] J. Hanson, W1TRC, “A Home-made Ultrasonic Power Line Arc Detector,” QST, Apr 2006, pp 41-45.
[2] M. Gruber, W1MG, “Product Review — MFJ-852 Power Line Noise Meter,” QST, Nov 2006, pp 75-76.
[3] **home.att.net/~jleggio/projects/rdf/rdf.htm**.
[4] **www.teara.org**.
[5] See Note 1.
[6] **www.arrl.org/tis/tismenu.html**.
[7] R. Littlefield, K1BQT, “A Simple TRF Receiver for Tracking RFI,” QST, Mar 2001, pp 32-36.
[8] W. Leavitt, W3AZ, “A Line Noise ‘Sniffer’ That Works,” QST, Sep 1992, pp 52-55.

Jim Hanson, W1TRC, has been an ARRL member for over 50 years. He received his General class license in 1951, his Advanced class license in 1952 and his Amateur Extra class license in 1984. His primary ham radio interest has been working DX and he is at the top of the phone and mixed DXCC Honor Roll. Jim has a BS degree in electrical engineering and retired in 2004 from Raytheon Company Inc, where he worked on radar receiver and low noise exciter designs. He holds several patents relating to radar design. You can reach the author at 8 Ethelyn Cir, Maynard, MA 01754 or **w1trc@arrl.net**.

New Products

MFJ 144/440 MHz YAGI ANTENNA

◊ The MFJ-1760 Yagi antenna uses 3 elements on 144 MHz and 5 elements on 440 MHz and requires only one feed line. Power rating is 500 W, the longest element is 40.5 inches, the boom length is 45 inches and the antenna weighs 2 pounds. The MFJ-1760 works with masts up to 1.5 inches diameter. A similar product, the DB-2345, is available from MFJ’s Hy-Gain product line. Price: MFJ-1760, $79.95; Hy-Gain DB-2345, $89.95. To order or for your nearest dealer, call 800-647-1800 or see **www.mfjenterprises.com**.