Build a Simple 12-Meter Beam

Will *you* be ready for the exciting DX doings in store at 24 MHz during Solar Cycle 22? If there's a rotatable gain antenna on your 12-meter-band wish list, this three-element array may provide the sock you seek!

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With the new sunspot cycle well underway, thoughts of worldwide F_2 openings on ten meters come to mind like long-forgotten memories. This cycle, however, we'll be able to tap the DX possibilities of a new band between 10 and 15: the *12-meter* band (24.89-24.99 MHz).

Cycle 22's DX promise gave me a strong incentive for considering ways of improving upon my rarely used 12-meter half-wave dipole. A few manufacturers make antennas that cover the 10- and 24-MHz bands, but I could not locate a source for a 12-meter monoband Yagi.[1] Okay, then, how about ham ingenuity? For a given design, a 12-meter beam should be just a bit larger than its 10-meter counterpart—and a *three-element* 12-meter beam should be quite compact and easy to construct. It is! Here's how to build a 12-meter monobander capable of putting you on 24 MHz in *style.*

Element and Boom Dimensions

I arrived at boom and element lengths through the process described in the sidebar, "Design Details." Fig 1 shows the results of my calculations. With a firm antenna design in hand, the next step was to figure out how to build the antenna solidly!

Simplifying Yagi Construction

As I considered various approaches to assembling the 12-meter beam, I realized that two unsolved problems had prevented me from home-brewing a beam antenna for any of the other ham bands: the difficulty of achieving *secure* element-to-boom mountings using commonly available hardware, and procurement of the aluminum tubing necessary to construct the elements and boom.

Boom-to-Element Mounting

For years, various configurations of flat

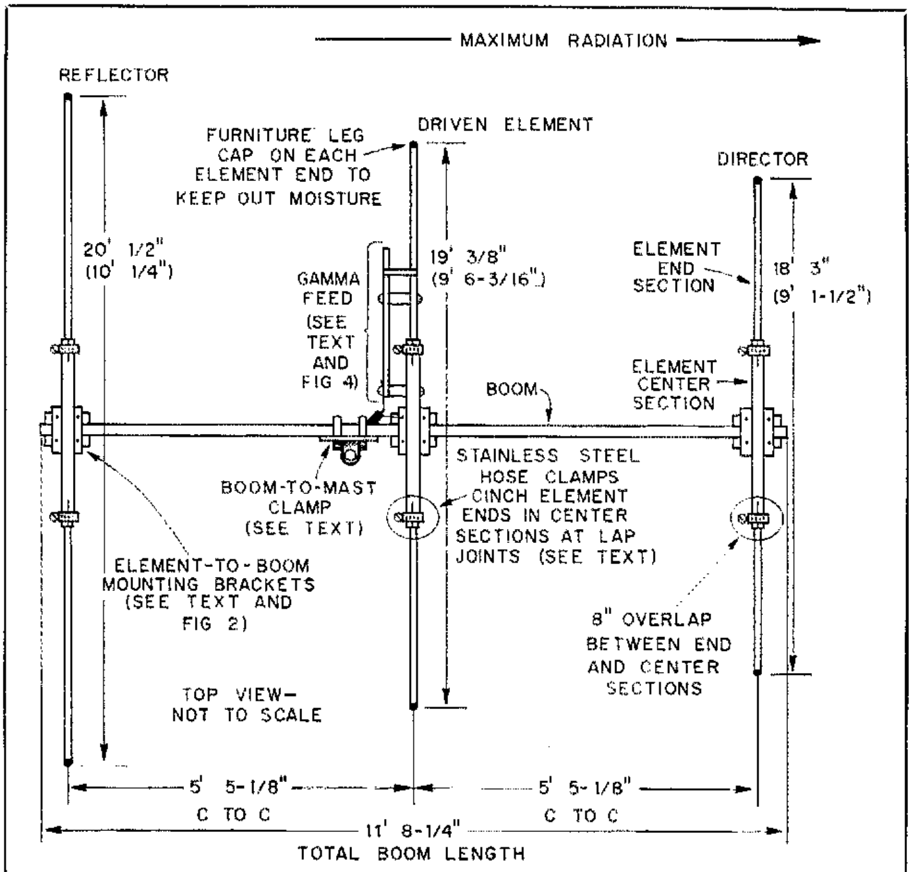

Fig 1—Design of the three-element Yagi for 12 meters. The dimensions shown correspond to a design frequency of 24.95 MHz and were arrived at through the process described in the sidebar, "Design Details." In the author's antenna, the elements and boom consist of Schedule 40 aluminum (6061-T6 material) pipe (inner diameters: boom, 2 inches; center section, 1 inch; element end, ¾ inch). Aluminum tubing (6061-T6 material) is recommended as a substitute for the pipe used by the author as follows: Boom—1/8-inch wall, 2-inch OD; element center sections, 1-inch OD; element end sections—7/8-inch OD. The gamma rod is ½-inch OD 6061-T6 tubing. See note 4 and the sidebar, "Tubing Versus Pipe: What's the Difference?" for more information.

The boom bisects each element; dimensions in parentheses give element lengths either side of the boom as an aid to construction. All element center sections are 3 feet long. Because of the 8-inch overlap between the center sections and element ends, each element end must be 8 inches longer than might seem apparent from this drawing. (For example, the director length is 18 feet, 3 inches. The director center section accounts for 3 feet of this. Each director end section must make up half of the remainder [15 feet, 3 inches] *plus the 8 inches necessary for the overlap between the element end and center sections.*) No need to get out your calculator; here are element end section dimensions that include 8 inches of overlap: director—8 feet, 3½ inches; driven element—8 feet, 8-3/16 inches; reflector—9 feet, 2¼ inches. See text for information on construction, adjustment and parts procurement.

[1]Notes appear on page 25.

metal plates and U bolts have been used to secure elements to booms in Yagi antennas. Unless made-for-application cradle blocks or saddles are used between the tubing and plates in such an installation, plate/U bolt mountings may allow the antenna elements to rotate on the boom during periods of high wind or heavy ice. Such element mounting schemes may have another drawback: Galvanized or stainless steel U bolts are often hard to locate in sizes appropriate for use with relatively slender element tubing. Further, the small parts count necessary for constructing a single antenna may hinder the builder in finding the right parts at the right price.

A second class of element-to-boom mounting methods entails the use of bolts that pass vertically through the boom and/or element. Depending on the relationship between tubing diameter and bolt-hole size, though, such bolt-through-tubing schemes can seriously degrade the mechanical strength of the tubing.

The element-to-boom mounting method I used to build the 12-meter Yagi is not necessarily new or unique; nonetheless, it has not been widely publicized. This method does not use U bolts and does not require vertical holes in any tubing member. Rather, four short pieces of aluminum angle stock are fastened to the element and boom using commonly available hardware, as shown in Fig 2. This method uses basic materials, is simple to employ and clamps the element to the boom firmly, with no danger of element movement or breakage by the mounting hardware.

Getting Aluminum Pipe or Tubing

Finding pipe or tubing for the antenna's boom and elements can require detective work. I was able to purchase Schedule 40 6061-T6 aluminum pipe of various diameters through my company. The limited range of sizes available resulted in less-than-ideal choices for boom and element material, but I was able to choose pipe sizes that produce an extremely rugged beam. (Actually, I was fortunate that the pipe sizes I chose for the Yagi elements fit together as smoothly as they did. To learn why you should proceed cautiously if you

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Design Details

Standard, well-known equations were used to calculate element length and spacing. The element lengths are calculated using equations shown in *The ARRL Antenna Book.** For the driven element,

$$\ell = \frac{475}{f} \qquad \text{(Eq 1)}$$

For the director,

$$\ell = \frac{455}{f} \qquad \text{(Eq 2)}$$

For the reflector,

$$\ell = \frac{500}{f} \qquad \text{(Eq 3)}$$

where

ℓ = length in feet
f = frequency in megahertz

As an aid to selecting element spacing and boom length, the wavelength at 24.950 MHz was calculated in inches with the equation

$$\lambda = \frac{11{,}811}{f} \qquad \text{(Eq 4)}$$

where

λ = wavelength in inches
f = frequency in megahertz

The element spacing was set at 0.14 λ for nearly optimum gain. This was also the spacing chosen by Lawson† in many of his Yagi design examples. Fig 1 of the main text shows values for element lengths and spacings at the design frequency, 24.950 MHz.

As a check of my calculations, I scaled Lawson's example of a three-element, 10-meter Yagi‡ by the ratio of the desired band-center frequencies (f1 [10 meters] and f2 [12 meters]):

$$\frac{f1}{f2} = \frac{28.400\text{ MHz}}{24.950\text{ MHz}} = 1.138 \qquad \text{(Eq 5)}$$

Scaling Lawson's 10-meter design to 12 meters results in element length and spacing values that agree with the values shown in Fig 1 to within 1%. The element taper schedule and boom diameter used in my 12-meter antenna also closely match those of the scaled version of Lawson's computer optimized design.—*Donald D. Button, AJ1T*

*Gerald L. Hall, ed., *The ARRL Antenna Book* (Newington: ARRL, 1988), p 11-11.
†Lawson, James L., *Yagi Antenna Design* (Newington: ARRL, 1987), Chapter 8.
‡*Yagi Antenna Design*, p 8-28.

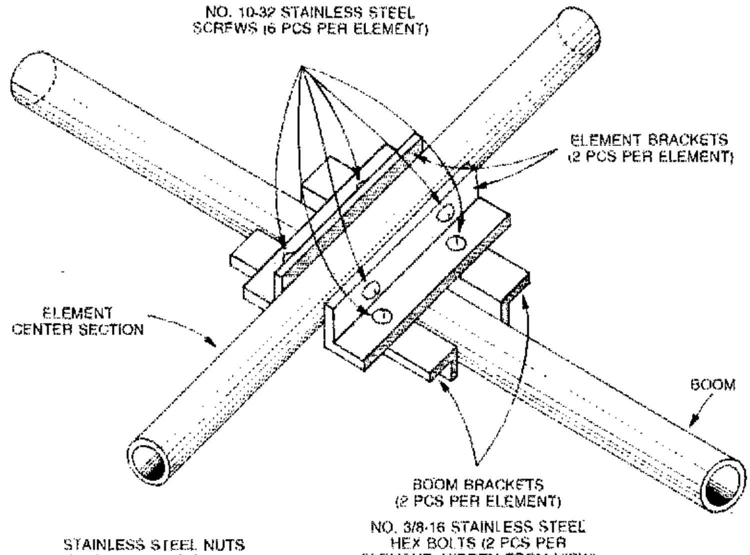

Fig 2—The elements of the 12-meter beam are mounted to the boom with 1¾ × 1¾ × 1/8-inch-thick aluminum angle brackets, and nos. 3/8-16 (boom) and 10-32 (element) stainless steel hardware. (In all cases, the mounting bolts and screws pass through the tubing diametrically.) No. 10-32 hardware fastens the element brackets to the boom brackets. This sturdy construction method does away with the U bolts, saddles and backing plates commonly used in element-to-boom mountings. See text.

Tubing Versus Pipe: What's the Difference?

Although *pipe* and *tubing* may at first seem to be used as synonyms throughout this article, they aren't: Metal pipe and metal tubing aren't the same. Most metal pipe is manufactured by extrusion and is generally intended to convey gases or liquids. Metal tubing, most of which is drawn—not extruded—is generally intended to be used for structural purposes.

Pipe sizes are generally specified—*scheduled*—in terms of *inner* diameter (ID) and wall thickness. These characteristics are important in piping systems because pipe must be able to withstand the pressure of the liquid or gas carried within it. Because pipe is generally intended to be threaded—on the outside—and connected with threaded couplings, scheduled pipe sizes don't lend themselves to the snug telescoping (lap) joints necessary in the construction of the tapered antenna elements.

Tubing, on the other hand, is specified by *outer* diameter (OD) and wall thickness in sizes *intended* to facilitate snug lap jointing. Because of this, and because tubing is generally manufactured to closer tolerances than pipe, tubing is the material of choice for constructing antennas.

I used Schedule 40 pipe to construct my 12-meter beam because it was readily available—and because I was able to find 1- and ¾-inch-ID Schedule 40 pipe that overlapped snugly without additional work. Actually, I was lucky: The design-center OD of ¾-inch Schedule 40 pipe is 1.051 inches and the design-center *ID* of *1-inch* Schedule 40 pipe is 1.049 inches! If the pipe I purchased had been smack on design center, the OD of the element end sections would have been several thousandths of an inch larger than the ID of the element centers—and I would have had to turn the element ends on a lathe to get them to fit inside the element center sections.

If you can find a good deal in pipe *that fits together snugly with minimum play,* use it by all means. If in doubt, though, go with the tubing sizes mentioned at Fig 1 and in note 4 of the main text. Stick with 6061-T6 aluminum if at all possible; it's the best for antenna construction. In any case, be sure to discuss your requirements with your aluminum supplier—he or she should be able to set you up with the right material for the job.—*Donald D. Button, AJ1T*

decide to build your beam elements out of pipe instead of tubing, see the sidebar, "Tubing Versus Pipe: What's the Difference?") The finished Yagi is certainly more rugged than most commercial beams that use thin-wall, drawn tubing. This is one antenna that will stay up for a long, long time!

You don't have to work a deal through your employer to build *your* 12-meter beam, though. Check your telephone directory's Yellow Pages for aluminum suppliers. If you can't find a local tubing source, at least one firm exists that will sell small quantities of tubing to hams.[2]

Feeding the 12-Meter Yagi

A simple gamma-rod arrangement matches the driven element to the 50-ohm coax feed line. I calculated the dimensions of the gamma matching section using the Smith chart analysis technique described in *The ARRL Antenna Book.*[3] Of course, you can use other means of matching the 12-meter Yagi to your feed line if you prefer. We'll discuss the adjustment of the matching section after we build the antenna.

Building the Beam

Each element consists of a 3-foot center section of 1-inch Schedule 40 aluminum pipe between two pieces (the element ends) of ¾-inch pipe.[4] Slit the ends of each center section with a hacksaw (four 1½-inch-deep cuts spaced at 90° around the circumference of the pipe) to allow insertion of the element end sections.[5] (Be sure to make the end sections long enough to provide at least 8 inches of overlap where the center and end sections of each element join.) Use all-stainless-steel hose clamps to secure the element end pieces in the slit center-section ends as shown in the reference cited at note 5. Before assembling the element ends to their corresponding center sections, apply conductive anti-oxidation grease (Penetrox®, No-Alox®, Oxiban® or a similar compound) to the overlapping portions of each element. Place plastic furniture-leg caps on the element and boom ends to keep out moisture and keep your antenna from singing in the wind.

Mounting the Elements to the Boom

The boom consists of an 11-foot, 8¼-inch length of 2-inch-ID Schedule 40 aluminum pipe. The outer diameter of this material is 2-3/8 inches. That's certainly very strong boom material for such a small antenna!

As shown in Fig 1, the driven element is located at the center of the boom, and the director and reflector are equally spaced from the driven element. After you have cut the boom to size, clearly mark the location of each element on the boom.

The element-to-boom mounting brackets (Fig 2) consist of 6-inch lengths of 1¾ × 1¾ × 1/8-inch aluminum angle stock. Four pieces of angle stock are used per element: two element brackets and two boom brackets. Cut the angle stock to size. Next, drill bracket-to-tubing mounting holes in each bracket that satisfy the two conditions specified at Fig 3. Don't drill the inter-bracket mounting holes yet.

Two conditions must be met in mounting the elements to the boom: (1) The elements must all lie in the same plane and (2) the elements must be exactly perpendicular to the boom. Condition 1 is the trickier of the two to satisfy; the secret to keeping all three elements in the same plane lies in proper installation of the element and boom brackets. Here's how to do this: Use a long, flat board as a reference plane. Clamp the boom to the board for stability. Use the drilled boom brackets as templates to mark the boom for drilling by placing all six brackets flush with the board *and* with the boom, the bracket-to-boom mounting holes toward the boom. Center each boom-bracket pair (director, driven element and reflector) on the location of each element. Using the brackets as templates, mark the boom for drilling. Next, drill a small pilot hole at each mark and confirm that these holes are properly aligned with the boom-bracket holes. Finally, enlarge each hole to pass the no. 3/8-16 boom-bracket

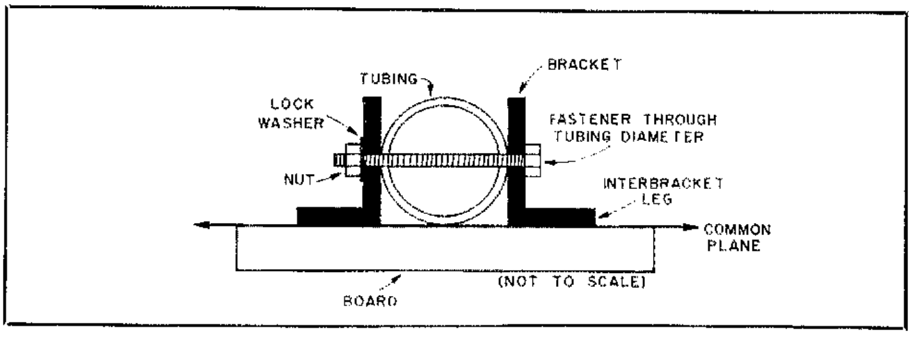

Fig 3—Each mounted bracket must satisfy two conditions: (1) Its mounting bolt or screw must pass through the tubing diametrically and (2) the plane of its interbracket leg must be tangential to the tubing along the entire length of the bracket. See the text for how to accomplish this easily with the help of a board as a reference plane.

mounting bolts. Unclamp the boom from the board and set it aside. Now, use the same technique to locate and drill the bracket-to-element mounting holes (for no. 10-32 screws) in the element center sections.

Attach the six boom brackets to the boom with no. 3/8-16 galvanized or stainless steel bolts, nuts and lock washers. Attach the six angle brackets to the element center sections with no. 10-32 stainless steel screws, nuts and lock washers.

Assembly of the elements to the boom must be done outdoors. All three elements will lie on the same plane if you've been careful installing the mounting brackets to the elements and boom; the critical part of element-to-boom assembly is ensuring that the elements are mounted *perpendicular to the boom*. Drill holes large enough for no. 10-32 interbracket screws in the element brackets. Set each element on the boom one by one—element brackets to boom brackets—and adjust their positions for proper perpendicularity and centering. Once you've determined the proper position for a given element, use its drilled element brackets as templates to mark the corresponding boom brackets for drilling. Drill the boom brackets to pass no. 10-32 holes and mount the elements to the boom.

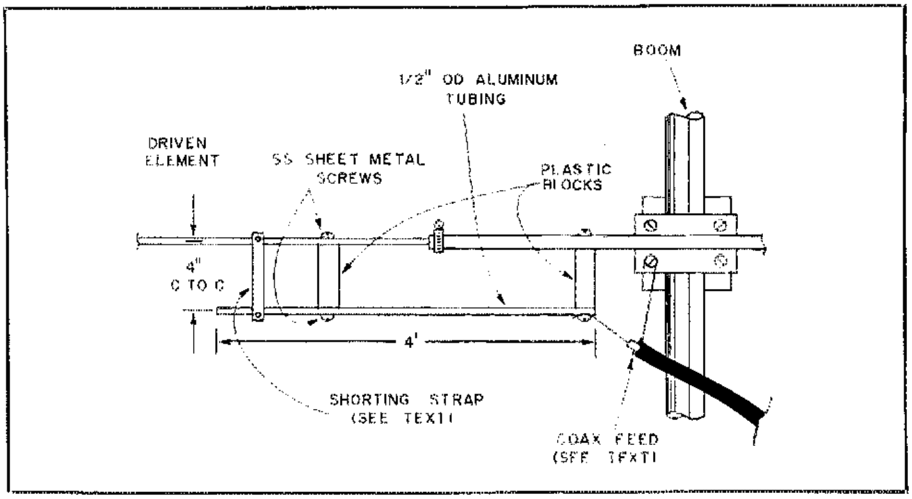

Fig 4—Detail of the gamma matching section for the 12-meter beam. The gamma rod and driven element are spaced 4 inches center to center; the separator blocks have notches cut in each end to seat the element and gamma rod tubing. See the text for details on connecting the feed line to the driven element and how to determine the position of the gamma shorting strap.

The Boom-to-Mast Clamp

Unlike the element-to-boom mountings, the boom-to-mast clamp *does* rely on U bolts and a metal plate (a 6- × 8-inch piece of ¼-inch-thick aluminum).[6] The end of the plate is located two inches from the driven element mounting brackets on the reflector end of the boom, as indicated in Fig 1. This helps to balance the antenna at its mounting point. (The antenna's center of gravity lies between the driven element and reflector because the elements increase in length from director to reflector.) I used galvanized U bolts (between boom and clamp, and clamp and mast) to mount the antenna in place.

The Gamma Matching Section

The gamma-matching rod consists of a 4-foot length of ½-inch-OD aluminum tubing. I mounted mine to the driven element by means of two plastic blocks that have notches cut in each end (Fig 4). This assembly is held together, and to the driven element, by stainless steel sheet metal screws that pass through the element and the tuning rod into the blocks. (The next section, Adjustments, describes the construction of the gamma shorting strap.) The inner conductor of the coaxial feed line is connected to the boom end of the gamma rod; the coax shield is connected to a solder lug under one of the driven element bracket mounting screws.

Adjustments

Make a temporary gamma shorting strap from a scrap of stranded antenna wire to permit experimentation in finding the best match. Next, mount the beam in an accessible test position as far off the ground as feasible. (I mounted the beam to my tower about 20 feet above the ground for this step.)

Adjust the length of the driven element for the lowest SWR at 24.95 MHz. (In my case, this length was within a few inches of the calculated length shown in Fig 1.) Next, adjust the gamma match shorting wire for an acceptable SWR across the band. I obtained an SWR of about 1.8 across the band when I slid the gamma shorting wire to a point about 40 inches down the rod from the boom.

Once you've determined the optimum position for the matching short, make a permanent shorting strap out of 1/16-inch-thick aluminum sheet stock. (I used a piece 5 inches long and ¼ inch wide.) Fasten this to the element and the gamma rod with no. 10-32 stainless steel machine screws, lock washers and nuts. (As I mentioned earlier, you may prefer to use a balun-fed hairpin or T matching arrangement instead of the gamma; such may allow an even better match across the band than I achieved. The match I obtained, however, is good enough to allow my solid-state transceiver to deliver full power anywhere in the band.)

I adjusted the length of neither the director nor reflector after I constructed them to the lengths called out in Fig 1. If you wish, you can optimize the antenna's gain and front-to-back ratio with the help of another 12-meter operator. Simply adjust

Some Comments on Parts Procurement

As mentioned in the main text and note 2, aluminum tubing is available from a number of sources. The angle stock I used for mounting the elements to the boom may be available through the same aluminum distributors that stock the tubing necessary for the boom and elements. (I've also seen *steel* angle stock for sale at lumberyards that would work fine if carefully rust proofed with rust-preventive paint or a similar product.)

One source for the boom-to-mast plate material is your local salvage yard. Steel plate is rather common and is excellent for this purpose if thoroughly rust proofed.

The U bolts used for the antenna-to-mast mounting can be made at home using zinc-plated, threaded rod stock (available at hardware stores). Using the boom and mast as forms, carefully bend the rod stock around the pipe and cut off the excess length with a hacksaw. For added leverage, slip a length of scrap water pipe over the free end of the threaded rod. If you use homemade U bolts, coat them with rust-preventive paint after they are installed.

Hardware stores often sell stainless steel hardware in popular sizes. Such sources should be able to supply you with the element-to-boom hardware, and the hose clamps necessary for cinching the element ends to the element centers. Also, check your Yellow Pages under "Fasteners" or "Screws" for a distributor who can sell at the retail level. Such firms are likely to carry the 3/8-inch bolts you need in galvanized or stainless-steel form.

Anti-oxidation grease is available from larger hardware stores and electrical supply houses.—*Donald D. Button, AJ1T* the reflector length for minimum signal off the back of the beam, and the director for maximum forward signal strength.

On the Air

I mounted the 12-meter beam eight feet above my tribander (at the 80-foot level)—but not before I thoroughly weatherproofed the antenna end of the coaxial feed line with electrician's tape to prevent moisture from entering and damaging the cable.

The antenna's performance is outstanding. With it, I've had many contacts with Europe, South America and Africa. The Yagi also enabled me to take advantage of the strong band openings to Europe that were fairly common last spring. Most stations were worked on the first call.

Although I did not adjust the element lengths to optimize any aspect of the Yagi's performance other than SWR bandwidth, the antenna seems to possess a front-to-back ratio of about five S units (as roughly measured on my transceiver's S meter). Front-to-side ratio is even better: about seven S units. The antenna's forward gain appears to be near the textbook value of about 8 dBi, based on the clearly defined pattern I perceive as I rotate the antenna while receiving.

Twelve meters stands to *really* strut its stuff during Solar Cycle 22. The simple 12-meter beam I've described here can help you take advantage of the band at its DX best. So, go to it! If you build one of these antennas, please let me know your results.

Notes

[1]A 12-meter monobander has since been announced by Cushcraft.—*Ed.*

[2]Metal and Cable Corporation, Inc, 2170 E Aurora Rd, PO Box 117, Twinsburg, OH 44067, tel 216-425-8455.

[3]Gerald L. Hall, ed., *The ARRL Antenna Book* (Newington: ARRL, 1988), pp 26-17, 26-18, 28-14 and 28-15.

[4]I encourage builders to use somewhat thinner-walled tubing for the elements, such as ¾-inch OD, 0.058-inch-wall tubing for the element ends and 7/8-inch OD, 0.058-inch-wall tubing for the element center sections. (This particular combination is attractive because the 0.009-inch difference between the element center ID [0.759 inch] and element end OD [0.75 inch] would provide a snug fit at the element lap joints.) Tubing of this size should be entirely adequate for this antenna design and is available from the supplier listed in note 2, as well as other sources. I used Schedule 40 pipe because it was readily available. If you use tubing of size and wall thickness adequate for good mechanical strength, the electrical performance of your antenna should closely duplicate that of my antenna. For more on the difference between pipe and tubing, see the sidebar, "Tubing Versus Pipe: What's the Difference?"

[5]For more on this and other aspects of constructing antennas with aluminum tubing, see Mark Wilson, ed., *The 1988 ARRL Handbook* (Newington: ARRL, 1987), pp 33-4 to 33-6.

[6]See note 5.

Don Button, born in 1957, was first licensed as WN2IMD in 1969. In 1971, he upgraded to General class and the call sign WA2IMD. From 1972 to 1973, he participated in his high school radio club in Chatham Township, New Jersey, and taught code to other students. In 1980, he upgraded to Amateur Extra Class, received the call sign AJ1T and shortly thereafter received his Bachelor of Science degree in Electrical Engineering from the University of Delaware. After his graduation, he was employed by the Raytheon Company, Wayland, Massachusetts, and Sanders Associates, Nashua, New Hampshire, as a microwave antenna design engineer. He is presently employed by Gabriel Electronics, Inc, Scarborough, Maine, where he leads several antenna design projects in the land-based communications industry.

Don is Assistant Technical Coordinator for ARRL's Maine section, as well as secretary for the Portland Amateur Wireless Association. He enjoys HF DXing and ragchewing on SSB and CW, as well as HF and VHF packet radio. His other interests include downhill skiing, digital audio, photography and church activities. He lives with his wife, Gail, who is not a ham, but who has been spotted now and again on the tower helping Don raise his latest collection of aluminum and wire!

New Products

MAGNETIC-PICKUP AUDIO SIGNAL TRACER

☐ Electron Processing has introduced the SCHMAGUE, an audio-signal tracer that uses a magnetic pickup mounted on a wand with a 6-foot cord, for troubleshooting equipment. The SCHMAGUE allows audio-signal tracing without electrical or physical connection to the equipment under test; it detects the magnetic field around wires, amplifies it, and feeds it to an internal speaker. The SCHMAGUE runs on a 9-V battery, and is housed in a 5.3 × 4 × 1.5-inch enclosure. A phono jack provides signal output for a monitor scope or frequency counter. Price class: $59.95 (quantity discounts available). To order, or for more information, contact Electron Processing, Inc, PO Box 708, Medford, NY 11763, tel 516-764-9798.—*Rus Healy, NJ2L*