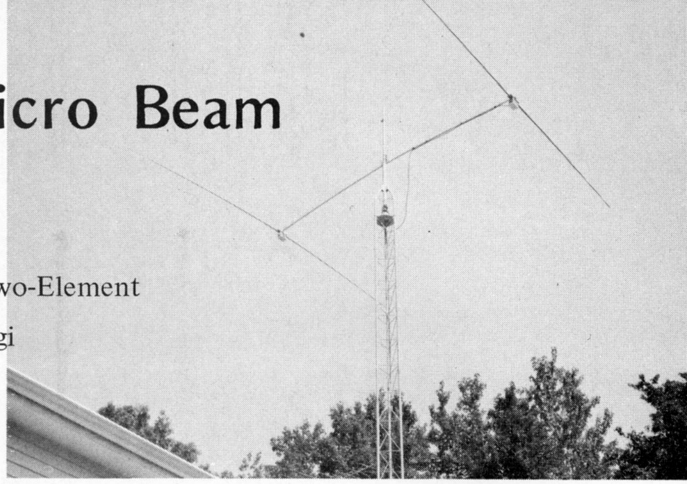
The HW-40 Micro Beam



A Helically Wound Two-Element 40-Meter Yagi

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IT SHOULD BE an accepted fact that in order for something to be good it need not be expensive or big. Certainly this concept has been proven many times in amateur radio, and antennas should be included in the lineup of good things that can be made smaller than normal size. Disconsolate pleas from apartment dwellers and other amateurs who live on property that is too small in area to permit the use of large 40-meter antennas prompted the authors to develop the antenna described here. The particular dimensions represented in this design were dictated primarily by the kind of fiberglass tubing that was immediately available. Kirk quad spreaders were obtained for use as forms on which to wind the helical elements. Longer (or shorter) elements can be used with good results, and this article is intended as a guide in the design of similar antennas.

The HW-40 is scaled down to 28 percent of full size. Two elements are used, each being 18 feet in length, tip-to-tip. Thus, the elements are just two feet longer than those of a full-size 10-meter Yagi. A 16-foot-long Reynolds aluminum-tubing boom (two 8-foot lengths joined) provides 0.12-wavelength spacing between the driven element and reflector. The weight of the array is approximately 25 pounds, making it practical to use a TV-type antenna rotator with the system.

Design Considerations

Some may argue that helically wound antennas will tend to radiate off the ends of the elements (axial mode), and that the condition will prevent the Yagi from exhibiting normal front-to-side and front-to-back characteristics. It was established by Kraus[1], that axial-mode radiation occurs only when a helix is one wavelength or greater in circumference. Generally, when the circumference is less than two-thirds wavelength, a nearly sinusoidal type of current distribution exists. This is effected by alternate reinforcement and cancellation of the two traveling waves which are directed oppositely. Each is of nearly identical current amplitude (I_O), hence the T_O transmission mode results for both traveling waves on the helix. Because of the foregoing condition the helices of this antenna radiate in the *normal mode* and will exhibit linear polarization characteristics. The diameter of these helices is merely .0009469 wavelength, eliminating any opportunity for axial-mode radiation. Front-to-side and front-to-back checks of the beam indicate, indeed, that normal-mode radiation is occurring. A number of relative tests were performed locally at distances up to 20 miles, and the front-to-back characteristics indicate a 10-dB figure. Front-to-side checks confirm a figure of approximately 28 dB. The effect is not so pronounced when receiving high-angle incoming signals. Depending upon the time of day, distance involved, and other propagation factors, various directivity traits will be observed.

Helically wound elements were chosen in preference to lumped-inductance elements in order to obtain linear voltage and current distribution across the elements, and to make the matching technique less difficult. Even if end-loaded elements with capacitance hats were used, the 18-foot dimension would make it impossible to use a gamma match of conventional design. Because of the very low value of radiation resistance of short loaded antennas, other conventional matching schemes would not lend ease to matching a 50-ohm coaxial feeder to the system.

There are certain penalties one must accept when using physically shortened antennas of this kind, and an in depth treatment of the subject was given by Sevick in *QST*.[2] It was a fortunate circumstance in this case that the feed-point impedance of the beam turned out to be approximately 12 ohms. Therefore, a 4:1 toroidal balun was installed at the feed point to provide a near-perfect match to the 50-ohm transmission line. In addition to encountering low values of feed

[1] Kraus, *Antennas*, First Edition, Chap. 7.

* Assistant Technical Editor, *QST*.
** Technical Editor, *QST*.

[2] Sevick, "The Ground-Mounted Short Vertical," *QST* for March, 1973, p. 13.

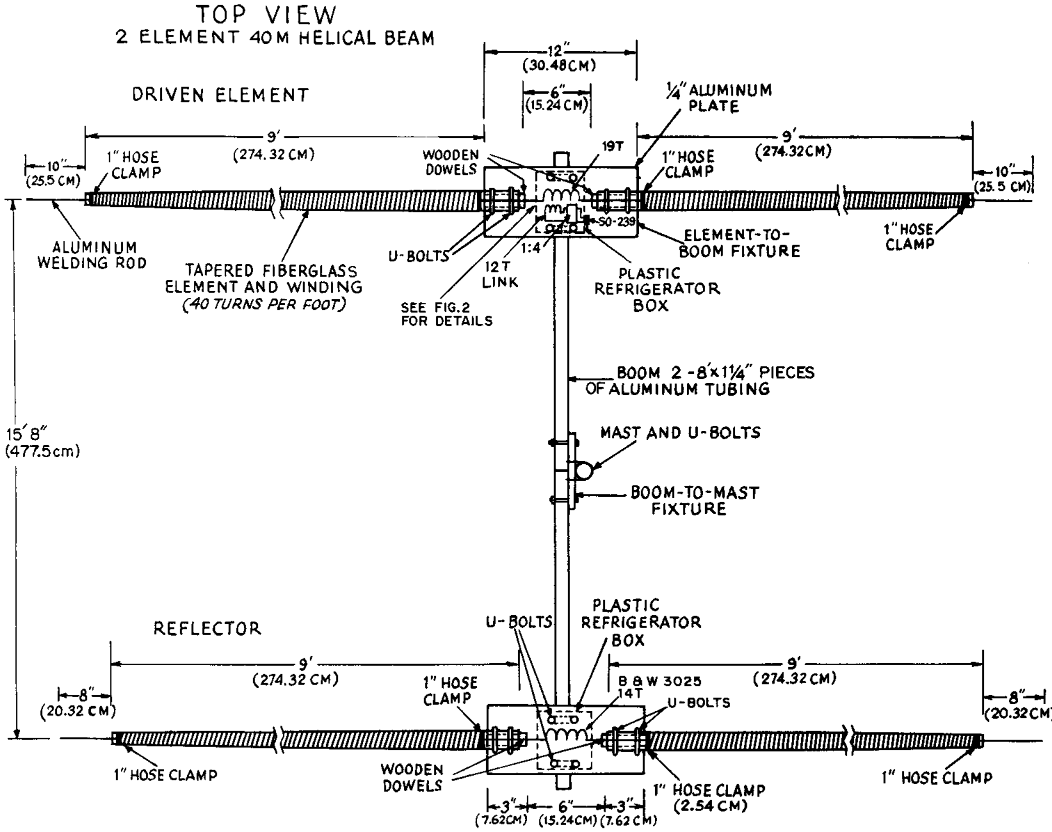

Fig. 1 — Overall dimensions for the 40-meter short beam. The boom consists of two pieces of standard 1-1/4-inch dia. Do-It-Yourself aluminum tubing.

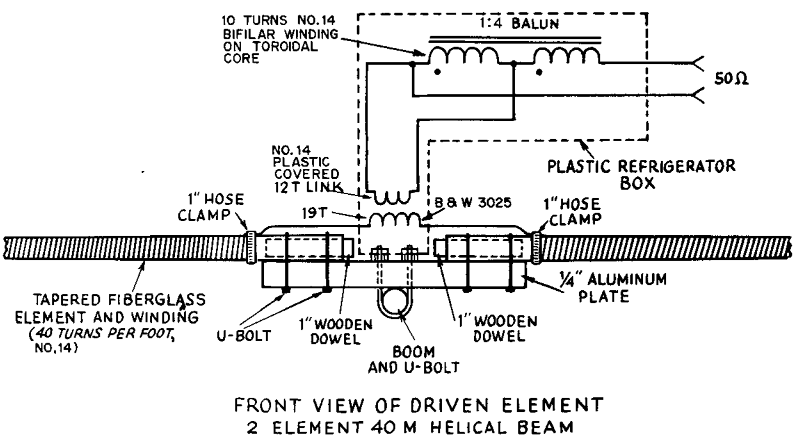

Fig. 2 — Schematic diagram of the balun assembly mounted inside the plastic utility box. The core is a single T-200-2 Amidon. The 12-turn link is wound directly over the 19-turn Mini-ductor.

impedance, the bandwidth of loaded elements is greatly less than with full-size antennas. This beam was tuned for operation at a center frequency of 7050 kHz. It works well from 7025 to 7075 kHz, with an SWR no greater than 2:1. It is flat at 7050 kHz. Those wishing to ,duplicate this Yagi should be willing to accept this design trade-off in the interest of having an effective directional antenna. It is recommended, therefore, that it be tuned for one's favorite part of the 40-meter band. The use of a Transmatch will, however, permit excursions into portions of the band where the SWR becomes greater than 1:1.

Construction Details

The construction of the 40-meter beam is very simple and requires no special tools or hardware. Two fiberglass 15-meter quad arm spreaders are mounted on an aluminum plate with U volts, as shown in the photograph. A wooden dowel is inserted approximately six inches in the end of each fiberglass arm to prevent the U bolts from crushing the poles. The aluminum mounting plate is equipped with U-bolt hardware for attachment to the 1-1/4-inch diameter boom.

A plastic refrigerator box is mounted on each element support plate and is used to house a Miniductor coil. No. 14 copper wire is used for the elements. The wire is wound directly on the fiberglass poles at a density of *40 turns per foot* (not turns per inch!) for a total of 360 evenly spaced turns. The wire is attached at each end with an automotive hose clamp of the proper size to fit the fiberglass rods. Since the fiberglass is tapered, care must be taken to keep the turns from sliding in the direction of the tips. Several pieces of plastic electrical tape were wrapped around the pole and wire at intervals of one foot. All of the element half sections are identical in terms of wire and pitch. Coil dimensions and type are given in Fig. 1.

The driven-element matching system consists of a 4:1 balun transformer and a link tightly coupled to the Miniductor. Complete details are given in Fig. 2.

Mounted at the end of each element (held in place by the hose clamp) is a short section of stiff copper wire used to allow for final tuning of the system as well as to broaden the frequency response of the antenna. Since the overall antenna is very small in relation to a full-sized array, the SWR points of 2:1 are rather close to each other, as mentioned earlier. The antenna shown in the photograph provides an SWR of less than 2:1 within about 25 kHz either side of resonance. Tuning the antenna for phone-band operation should not be difficult and the procedure outlined below should be suitable.

Tuning

The parasitic element is adjusted to be about four percent lower in frequency than the driven element. A grid-dip oscillator was coupled to the center loading coil and the element tips were trimmed (a quarter of an inch at a time!) until the GDO indicated resonance to be at 6.678 MHz. For phone band use, the ends could be snipped for 6.840 MHz. Adjusting the driven element is simple. Place an SWR meter or power meter at the input connector and cut the end wires (or add some if necessary) to obtain a proper match between line and antenna.

Performance Characteristics

Once the initial near-ground tuning of the elements was completed, the HW-40 was carried aloft and mounted on the 40-foot tower at W1CER. Final touching up of the matching and element resonances was effected after the beam was in place on the tower. It is important to realize that shortened antennas are sensitive to changes in environment because of their narrow-band characteristics. Thus, height above ground, and distance from nearby objects will cause some change in resonance of the elements. The resonant frequency of the HW-40 changed some 150 kHz between tuning at several feet above ground to final tweaking atop the tower.

It should be noted that the 40-meter beam has yet to be tested at an ideal height above ground. A distance of 40 feet above the earth is not much more than one-quarter wavelength at 7 MHz, though performance thus far has been better than one might expect when using a beam or dipole less than one-half wavelength above ground.

Comparisons were made between the beam and three types of wire antennas . . . an inverted-V, a 3/4-wavelength end-fed wire, and a full-wave 40-meter loop (with its theoretical 2-dB gain).[3] The results have been interesting, though at times rather confusing. The confusion results from the time-of-day/propagation syndrome mentioned earlier. At no time, however, did the inverted-V or 3/4-wavelength antennas surpass the performance of the HW-40. The beam was always as good as or better than the other two radiators, regardless of band conditions or time. During contacts with European or South American DX stations, the beam was always the best antenna, usually by two S units or more. During daytime contacts out to, say, 1000 miles, the wire antennas equalled the beam at times.

When comparing the beam to the full-wave loop, results became less easy to evaluate. That is, the antennas took turns being best. Frequently, the loop outperformed the beam (in the favored direction of the loop) both on short-haul and DX contacts. At other times the beam had the edge by a couple of S units. At this time it is impossible to say which antenna would provide the best all-year, all-around service. But, it has been observed that the beam is far less subject to pickup of man-made and atmospheric noise because of its narrow-band characteristics (the loop exhibits the opposite bandwidth trait – broad). Reduction in noise during reception can be a blessing, especially when working with the weaker signals! Another beneficial effect of the narrow-band feature is that strong, near-frequency signals do not so severely affect the receiver with respect ot overloading and cross modulation, as is the situation with other types of antennas. The proof of this came when trying to operate while W1AW (two blocks away from W1CER) was transmitting code practice. Until the beam was erected it was impossible to use the 40-meter band, but with the beam connected to the receiver, and with the antenna pointed away from W1AW, it became possible to operate within 10 kHz of W1AW without knowing that station was on the air! So, if some kW operator lives down the street from you, this little beam could put you back in business.

While running approximately 80 watts output, the short beam has been extremely effective in working DX. DX stations now answer our CQs, whereas with the wire antennas (loop excepted) this seldom happened. Signal reports from DX

[3] DeMaw, "The Novi-Loop," *QST* for Oct., 1973.

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stations average 579, with many 589 and 599 reports. During QRP operation with the beam (2 watts output), a number of DX stations have been raised and worked. The signal reports are lower of course, but RST 559 and 569 indicates that something good must be happening! One unrelated event occurred while testing the beam and loop with the QRP setup: a station in the 4th call area called CQ and was answered. He came back and said, "No QRP lids, CQ kWs only." It's unlikely that the HW-40 beam can be blamed for that, especially since we went on to work five European stations later that day with the 2-watt equipment!

Acknowledgements

The authors wish to express gratitude to those who helped construct, test and erect the 40-meter beam. Special thanks to WA1JLD, who "clomped" up and down the ARRL test tower, and the W1CER station tower, numerous times with test gear (and the beam) until the final design goals were met. Thanks also to W1NPG who labored silently while winding the helices, and subsequently endured the unbearable Connecticut heat-wave temperatures of August, while putting two coats of exterior spar varnish on the completed elements. The element dimensions and turns information were developed by K1PLP to test a newly developed calculator program.