# The Long-Boom Quagi

## What, you're not on 432 yet? If it's the need for an antenna that's stopping you, you've got the green light now — this 15-element quagi.

By Wayne Overbeck,* K6YNB/N6NB

No, a quagi is not the sound made by a certain species of duck found only in northern California and southern Alaska. A quagi is merely one of the most interesting amateur antenna designs to come down the pike in recent years. The author first described this combination of cubical quad and Yagi-Uda design techniques about a year ago[1] and the response from amateurs seemed to demand further work on the design. The result is a quagi for 432 MHz, a band of ever-increasing interest among vhf operators working direct, moonbounce and through the OSCAR 7 satellite.

What does the quagi have going for it that makes it an attractive alternative to both the quad and Yagi-Uda arrays? Easy, noncritical construction, for one thing, as well as simple matching of the feed line to the driven element. Also, quagi fires have been fed by recent discussions of the advantages of quad loops over rod-type driven elements (such as used in straight Yagi-Uda designs).[2] Not that there has been any doubt about that, as attested in past work by acknowledged experts Orr and Lindsay.[3,4]

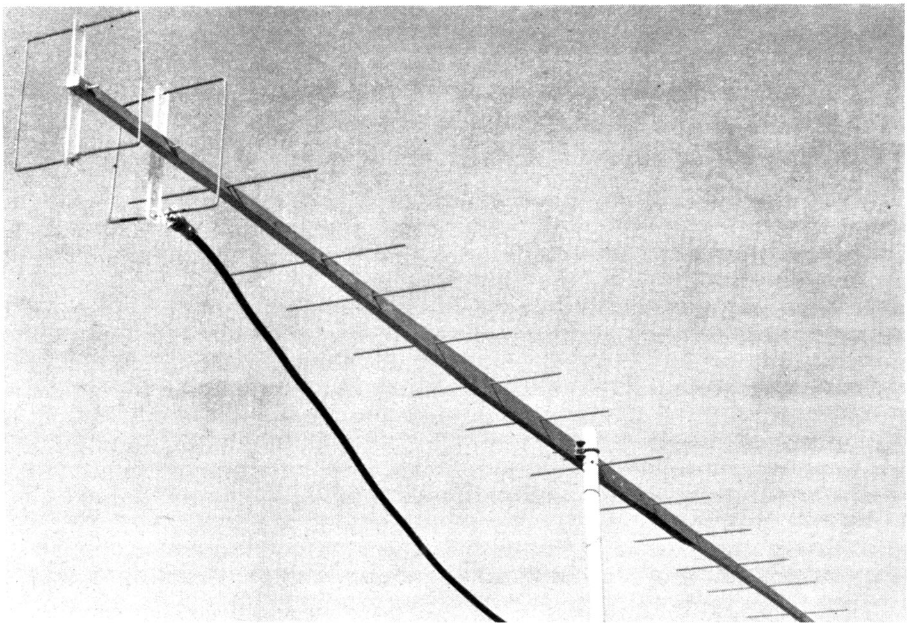
Finally, Danish scientist Appel-Hansen has produced results[5] indicating that while quad loops make excellent driven elements and reflectors, rods seem to be superior directors. Thus, the quagi, for your 432-MHz pleasure.

The vhf quagis were designed by amateurs, using amateur methods. Although developed independently of Appel-Hansen's work, they are a practical application of the principles he demonstrated. The effectiveness of the original quagi design is well known, and numerous amateurs have asked if the quagi principle could be applied to a super-long antenna for 432-MHz work.

The answer is the 15-element array to be described. It is just as easy to reproduce as the smaller eight-element quagi, but it offers nearly 15 dB gain over a dipole (dBd). Boom length of the antenna is 5λ (11.5 feet or 3.51 meters for 432 MHz). Obviously, this boom length makes such an antenna impractical for use on the lower amateur frequencies, but at 432 MHz it fits nicely on a 12-foot (3.66 meter) length of 1 × 2-inch (25 × 50-mm) lumber.

### Long-Boom Performance

The 15-element quagi has been tested repeatedly against other long-boom antennas, including the 16-element, log-periodic Yagi described by Holladay[6] (made commercially by KLM Electronics), and the 21-element, F9FT Yagi. When the 15-element quagi was designed,



The long-boom quagi is elegant in its simplicity. Tapering the boom lends greater rigidity to the structure. The most difficult part of this project may be obtaining lumber straight enough for accurate alignment of the elements.

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[1] References appear on page 21.

the KLM long Yagi was used as a reference standard against which to test the new array. In several test-range experiments the quagi's gain was found to be comparable to that of the 16-element, log-periodic Yagi.

To confirm the new design's performance and reproducibility, a second 15-element quagi was built directly from the dimensions that appear in Table 1, with the original antenna out of sight. This "cookbook" quagi was taken to the three major vhf antenna gain competitions in the United States in the spring and summer of 1977. In all three measurements, the quagi's performance was very similar to that of the larger, more expensive, commercial antennas. At the Central States VHF Conference, the 15-element quagi and 16-element KLM antenna were rated at identical gains, with the 21-element F9FT array about 1 dB greater than both. On the other hand, the quagi outperformed both the F9FT antenna and the KLM in the sun noise measurements at the East Coast VHF Society's session. When the same antennas were measured with a nearby signal source, however, the best F9FT and KLM antennas topped the quagi by 0.8 to 1.0 dB. That result was closely duplicated at the West Coast VHF Conference.

**About Building Quagis**

Since the original "VHF Quagi" article appeared in *QST* for April, 1977, hundreds of hams have successfully reproduced these antennas. However, several builders have written the author that they were having difficulty getting their quagis to work. These difficulties stem from three causes:

1) *Failure to observe correct polarization* — The photos in *QST* show *horizontally polarized* arrays, but vertical polarization is standard in fm and repeater work. Several builders have written complaining that they built quagis and put them up "just like you showed it in *QST*" only to find that their groundplanes would get into the local repeater better! For fm service, the quagi must be vertically polarized. That means the directors must be vertical and the feed point must be on the side of the driven element. Despite its square shape, a quad-type loop is not universally polarized — it is vertical or horizontal, depending on where it is fed.

2) *Failure to allow for overlaps at joints* — The dimensions given for the driven element and reflector are *net* dimensions. The builder must allow excess length for any overlap when the loop ends are soldered.

3) *Failure to use the specified wire type* — While any conductor of the proper diameter (1/8 inch or 3.2 mm) is fine for the directors, the driven element and reflector loops must be made of no. 12 TW wire *with its insulation in place*. Use of bare wire — or any other size wire — will require a correction in loop length. One builder used brazing rod for his driven element and had to increase the length 1.7 percent to get the VSWR down to a normal 1.2 at resonance. But once he made that correction, his eight-element quagi was measured at 13.8 dBd gain at the West Coast VHF Conference last May!

**Table 1**
**432-MHz, 15-Element, Long-Boom Quagi Construction Data**

*Element Lengths — Inches (mm)*

R — 28" loop (711)
DE — 26-5/8" loop (676)
D1 — 11-3/4 (298)
D2 — 11-11/16 (297)
D3 — 11-5/8 (295)
D4 — 11-9/16 (294)
D5 — 11-1/2 (292)
D6 — 11-7/16 (291)
D7 — 11-3/8 (289)
D8 — 11-5/16 (287)
D9 — 11-5/16 (287)
D10 — 11-1/4 (286)
D11 — 11-3/16 (284)
D12 — 11-1/8 (283)
D13 — 11-1/16 (281)

*Interelement Spacing — Inches (mm)*

R-DE — 7 (178)
DE-D1 — 5-1/4 (133)
D1-D2 — 11 (279)
D2-D3 — 5-7/8 (149)
D3-D4 — 8-3/4 (222)
D4-D5 — 8-3/4 (222)
D5-D6 — 8-3/4 (222)
D6-D7 — 12 (305)
D7-D8 — 12 (305)
D8-D9 — 11-1/4 (286)
D9-D10 — 11-1/2 (291)
D10-D11 — 9-3/16 (233)
D11-D12 — 12-3/8 (314)
D12-D13 — 13-3/4 (349)

Boom — 1 × 2-inch × 12-ft (25 × 51-mm × 3.66-m) Douglas fir, tapered to 5/8 inch (16 mm) at both ends.
Driven element — No. 12 TW copper-wire loop in square configuration, fed at center bottom with type N connector and 52-ohm coax.
Reflector — No. 12 TW copper-wire loop, closed at bottom.
Directors — 1/8-inch (3.2 mm) rod passing through boom.

The consensus of all these measurements seems to be that all of these long-boom antennas are very good performers, with none holding a decisive advantage over any other in gain. Whether an amateur buys a long 432-MHz Yagi or "rolls his own" will depend on his budget, schedule and personal preferences. With this quad-driven array, gone are the days when first-rate, 432-MHz Yagis could be built only by those having special skills and elaborate test equipment. No longer must a builder match impedances and struggle with critical baluns to get a 432-MHz Yagi to take power efficiently. To duplicate this antenna, all the builder need do is cut the rods and wire loops to within about 1/32 inch (0.8 mm) of the dimensions given in Table 1.

As with any uhf project, the quagi builder should use the materials specified or expect to do some extra "tweaking." Any sort of 1/8-inch (3-mm) rod stock will do for the directors, but the quad loop must be no. 12 AWG (2-mm) TW *covered* copper wire (available from electrical suppliers). If you use bare wire (or any other diameter wire) for the loop elements, be prepared to adjust the lengths. A wood (or other nonconductive) boom is used. The quad loops are supported by Plexiglas strips while the director rods pass through the boom.

As with the smaller eight-element quagis, the long-boom 15 should be fed directly with 52-ohm coaxial cable. A type N connector is soldered into the midpoint of the bottom side of the driven loop. The feed-line coax is brought perpendicularly to the antenna feed point, running along the boom or (preferably) directly to the supporting mast.

Like the smaller quagis and other antennas, long-boom 15s can be stacked in pairs, fours, eights or 16s for additional gain. With this much gain over a dipole for each bay, a stacking distance of six to seven feet is recommended at 432 MHz. Since these antennas can be built of much lighter materials than the 16-element, log-periodic Yagi, they represent a practical as well as economical approach for moonbounce work. Allowing for normal feed-line losses, 16 long-boom quagis should deliver nearly 26 dB gain over a dipole, while about 23 dB would be attainable with only eight bays. Even the larger 16-bay array would be only about 20 × 20 feet (6 × 6 meters) in size, not that big by EME standards!

However, any EME system consisting of long-boom antennas poses special mechanical problems because all bays must track accurately enough so that they all point at the moon at once. As the author learned during an Alaskan moonbounce DXpedition, this can be difficult under adverse environmental conditions.[7]

## Conclusion

There you have it, a long-boom version of the quagi antenna that offers very high gain without high cost or undue construction complexity. Anyone who takes reasonable precautions to follow the listed dimensions should be able to achieve the same results! The author again wishes to thank WB6RIV for his antenna-range assistance!

**References**

[1] Overbeck, "The VHF Quagi," *QST*, April, 1977.

[2] Belcher and Casper, "Loops vs. Dipoles — Analysis and Discussion," *QST*, August, 1976.

[3] Orr, *Quad Antennas*, 2nd ed., Radio Publications, Inc., Wilton, CT 1970.

[4] Lindsay, "Quads and Yagis," *QST*, May, 1968.

[5] Appel-Hansen, "The Loop Antenna with Director Arrays of Loops and Rods," *IEEE Transactions on Antennas and Propagation*, July, 1972, p. 516.

[6] Holladay, "High Gain Yagi for 432 MHz," *Ham Radio*, Jan., 1976.

[7] Overbeck, "Moonbounce Boondoggle," *QST*, Feb., 1977.

# Technical Correspondence

## ADDITIONAL BANDS FOR THE QUAGI

☐ A number of amateurs have written the author inquiring about the use of the vhf quagi (*QST* for April, 1977) on frequencies other than the three amateur bands for which dimensions were given (144, 220 and 432 MHz). Within the vhf spectrum, mathematically scaling the quagi to other frequencies is a relatively simple matter. To do so, take each dimension given for the amateur band nearest the desired frequency and apply this formula:

$$\text{New dimension} = \frac{\text{original dimension} \times \text{original frequency}}{\text{new frequency}}$$

Thus, the driven element for the ATS-1 and ATS-3 weather satellites at 135.6 MHz would be computed as follows:

$$DE_{135.6} = \frac{82 \times 144.5}{135.6} = 87.38 \text{ in. } (2.22 \text{ m})$$

Each element length and interelement spacing dimension should be scaled to the new frequency, using the same formula. Between about 100 and 500 MHz, this mathematical scaling procedure will produce an antenna delivering substantially the same performance as the original design. However, the builder should bear in mind that a given element diameter "looks" three times as large at 432 MHz as at 144 MHz, for instance. Unless the diameter is reduced as the frequency increases, the element lengths must be adjusted accordingly. Example: When 1/8-inch rod is used for the directors, the 432-MHz quagi requires directors fully 1/4-inch shorter than the mathematical scaling from 2 meters would suggest, and the dimensions given in *QST* included this correction.

In scaling a quagi to a frequency reasonably close to an amateur band, the calculation may be made from the nearby ham band and this variation in element diameter-to-length ratio may be ignored. But for a frequency far removed from 144, 220 or 432 MHz, it would be best to calculate from amateur bands above and below the desired frequency and then interpolate between the two sets of dimensions.

For frequencies significantly higher than 500 MHz or lower than 100 MHz, construction techniques would typically vary so much from the original design that the correct element lengths may be expected to deviate substantially from those mathematically derived. The best approach in such a case would be to experimentally determine the correct element lengths. — *Wayne Overbeck, N6NB, Pepperdine University, Malibu, CA 90265*

## NARROW-BAND MODULATION

☐ The purpose of this letter is to raise some questions regarding narrow-band modulation schemes and related matters. Bandwidth as a measure of quality in a communication scheme is straightforward in the clear-channel case. Cutting the bandwidth in half doubles the number of clear channels, obviously a gain. However, the following will show that this simple test is not sufficient in situations where there are *no* channels, but instead random positions of signals. The test is also not sufficient if channels are shared, i.e., where there is mutual interference between stations. Since amateur operations involve the last two items, it seems that we need a way of evaluating the gain or loss involved in narrow-bandwidth plans.

Since random location and shared channels both involve interference, it seems reasonable to use interference produced as a measure. The most common measure is the spectral power density, the output power divided by the bandwidth. As usually used by the CCIR (International Consultative Radio Committee), this is a transmitter quantity, the bandwidth being of the emitted signal. It can also be used as a system quantity, with the bandwidth being that of the receiver. Where systems of radically different types are sharing, the CCIR has also used the audio bandwidth and the resulting spectral power density multiplied by transmitted bandwidth, which is just the total power radiated.

Change in system design can yield a gain or loss in communication capability. At present there is no standard for this. One I have used is based on the fact that the measure should increase as transmitted information power increases, and also increase as the receiver input needed to give a fixed output signal-to-noise ratio decreases. This leads to the ratio of transmitted information power divided by required receiver input (for standard output S/N) as the measure for communication potential.

Suppose we apply these concepts to a simple "narrow-band phone" system, in which the modulation is folded to give a signal of just half the usual bandwidth. With no power change, the spectral power density will double, so the interference potential has increased by 3 dB. At the receiver, the information power is the same, but the receiver noise will be less by a factor of two because of the decreased bandwidth, so the communication potential also increases by 3 dB. Using the ratio of the two measures as the net effect, there is no overall gain or loss.

With respect to standard receivers, the total power radiated is the same, so there is no change in relative interference. Assuming the signal can be read, there is no change in communication potential. However, if two stations should be introduced to take advantage of the apparent gain due to decreased bandwidth, the interference would increase by 3 dB. The increase, however, is because of the increase in number of stations, and not because of the modulation scheme.

This analysis is obviously simplified, both in assumptions as to the system employed and in neglect of such factors as changes in subjective interference with pitch changes, etc. However, I believe the analysis does show the dangers of using emitted bandwidth as the only measure of improvement.

It is instructive to apply these principles to other situations. For the old argument of ssb versus a-m, we find a reduction of interference potential of about 16 dB for ssb, but a loss in communication potential of 3 dB (due to the fact that there is no second sideband to add coherently). Overall, there is a net gain of about 20:1, but this is caused by the elimination of the carrier, and not by the reduction in bandwidth.

Many stations are using speech processors. These increase the average radiated power, typically by 6 to 10 dB. Under weak-signal conditions this increases the communication effectiveness; subjectively, the gain may be very great. However, the processor also increases the interference potential by the same 6 to 10 dB, and, under strong signal conditions, the processor may actually reduce the subjective communications potential. Overall, the processor is worthwhile only if kept switched out unless needed.

Because it occupies the same bandwidth, slow-scan TV has been placed in the phone segments of the amateur bands. However, since its carrier is on 100 percent of the time, SSTV has about 16-dB greater interference potential than ssb. If slow scan were sharing with cw, assuming 200 Hz as a practical receiver bandwidth, slow scan would have about 10-dB less interference potential than a cw signal of equal strength.

These examples seem to say that we need to reexamine the principles of sharing in the Amateur Service. In particular, they do seem to indicate clearly that bandwidth alone is not the proper criteria for making decisions. — *R. P. Haviland, W4MB, 2100 S. Nova Rd., Box 45, Daytona Beach, FL 32019*

## FURTHER NOTES ON THE MORSE KEYBOARD

☐ For the benefit of the many amateurs who are building the "Inexpensive Morse Keyboard" described in *QST* for January, 1978, these corrections have been furnished by the author. In transposing the article for publication, the data inputs to U9 and U10 were reversed. These exchanges should be made.

| *IC* | *Pin* | | | | *IC* | *Pin* |
|---|---|---|---|---|---|---|
| U9 | 12 | Change | lead | to | U10 | 11 |
| U9 | 11 | " | ' ' | ' ' | U10 | 10 |
| U9 | 10 | " | ' ' | ' ' | U10 | 9 |
| U10 | 11 | " | ' ' | ' ' | U9 | 12 |
| U10 | 10 | " | ' ' | ' ' | U9 | 11 |
| U10 | 9 | " | ' ' | ' ' | U9 | 10 |
| U1B | 15 | Connect to pin 13 of U2B (not pin 3). | | | | |
| U6 | 6 & 7 | Connect to ground. | | | | |

Other changes:

A8 is connected to pin 14 of U12 (not pin 13).

E goes from A7 to B5.

F goes from A5 to B3.

Comma goes from A8 to B4.

Period goes from A9 to B5.

Connect a 100-kΩ resistor from pins 5 and 6 of U11 to ground.

U14 is a type 4001 (not 4011 as shown).

The pinout for the type 4051 IC should indicate pin 1 as I/O-4.