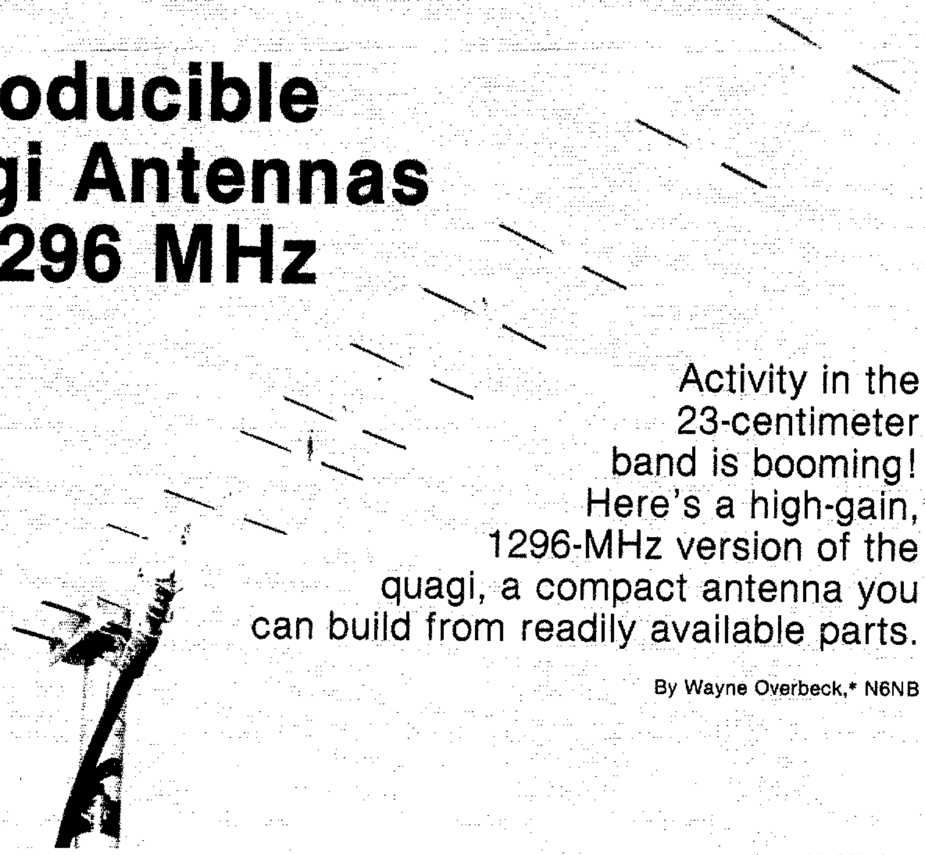
Reproducible Quagi Antennas for 1296 MHz



Activity in the 23-centimeter band is booming! Here's a high-gain, 1296-MHz version of the quagi, a compact antenna you can build from readily available parts.

By Wayne Overbeck,* N6NB

The 1296-MHz band — 23 centimeters if you prefer — is bustling with activity. In many areas, there are more stations on 1296 MHz today than there were on 432 MHz only a few years ago. Two brands of ssb/cw transverters for 1296 MHz are now available off the shelf, and hundreds of these units have been sold. Meanwhile, commercial varactor triplers and receiving converters are also selling briskly. Many uhf enthusiasts, of course, wouldn't think of buying a "turn-key" system; they build their own, thank you.

Antennas for 1296 MHz can, however, present a dilemma. Helical and parabolic dish antennas work well there, as do various horn and collinear designs. But they can be bulky, offering relatively little gain for their size. Furthermore, even though most of these antennas are broadband types, they present enough construction, feed and impedance-matching difficulties to discourage some builders.

Yagis? Building an efficient Yagi for 1296 MHz is even more difficult. As recently as 1979, the leading 432/1296-MHz moonbounce newsletter dismissed Yagis as generally impractical at 1296 MHz. Yet, parasitic beam antennas do work at 1296 MHz, and they offer excellent gain in small packages. A wide-spaced, 10-element beam is only about *2 ft* (0.6 m) long on this band. One commercial manufacturer's 28-element loop-Yagi has become something of a standard of performance on 23 cm. Also, a 1296-MHz version of the respected F9FT Yagi is now available. These are excellent designs, but they do not lend themselves to amateur construction. Those lacking special uhf expertise and sophisticated test equipment have had trouble duplicating antennas of this sort. Some amateurs have wondered if the quagi antenna, which has become known for its simplicity, is suitable for 1296 MHz.

The Quagi Antenna

Since the original article on the quagi was published in *QST*,[1] thousands have been built worldwide. The quagi is described in *The Radio Amateur's Handbook* and the *Antenna Handbook*[2] by Orr and Cowan. This design has been republished in amateur journals in such diverse countries as the Soviet Union, India and South Africa. A Japanese firm is now making quagis commercially.

The quagi (pronounced with a hard "g" so that it rhymes with Yagi) is a hybrid antenna combining some of the advantages of the cubical quad and the conventional Yagi. Perhaps its best attribute is ease of construction. The driven loop can be fed directly with 50-Ω coaxial cable without any impedance-matching device. Numerous vhf newcomers have built the quagi as their first homemade antenna for any frequency above 30 MHz.

The quagi has been used in vhf work from fm to moonbounce. German EME enthusiast Johann Bruinier, DL9KR, who has become known for his outstanding signal off the moon, has published the design of his quagi-based 432-MHz EME array.[3]

Because of its simplicity and good performance, the antenna would seem to be an ideal home-constructed one for 1296 MHz. However, the original article only presented dimensions for 144, 220 and 432 MHz. Some amateurs who tried to scale mathematically the original quagi design to 1296 MHz have experienced disappointing results.

*Department of Communications, California State University/Fullerton, Fullerton, CA 92634

[1]Notes appear on page 15.

Table 1

Dimensions, 1296-MHz Cubical-Quad and Quagi Antennas

Note: All lengths are gross lengths. See text and photos for construction technique and recommended overlap at loop junctions. All loops are made of no. 18 AWG solid-covered copper bell wire. The Yagi-type directors are 1/16-in. brass brazing rod. See text for a discussion of director taper.

Feed: Direct with 52-ohm coaxial cable to UG-290 connector at driven element; run coax symmetrically to mast at rear of antenna.

Boom: 1/4-in.-thick Plexiglas, 30 in. long for 10-element quad or quagi and 48 in. long for 15-element quagi. 84 in. for 25-element quagi. Inches × 25.4 = mm

10-Element Quagi for 1296 MHz

Element	*Length (in.)*	*Construction*	*Element*	*Interelement Spacing (in.)*
Reflector	9.5625	(loop)	R-DE	2.375
Driven El.	9.25	(loop)	DE-D1	2.0
Director 1	3.91	(brass rod)	D1-D2	3.67
Director 2	3.88	(brass rod)	D2-D3	1.96
Director 3	3.86	(brass rod)	D3-D4	2.92
Director 4	3.83	(brass rod)	D4-D5	2.92
Director 5	3.80	(brass rod)	D5-D6	2.92
Director 6	3.78	(brass rod)	D6-D7	4.75
Director 7	3.75	(brass rod)	D7-D8	3.94
Director 8	3.72	(brass rod)		

15-Element Quagi for 1296 MHz

The first 10 elements are the same lengths (inches) as above, but the spacing from D6 to D7 is 4.0 in. here; D7 to D8 is also 4.0 in.

Director 9	3.70		D8-D9	3.75
Director 10	3.67		D9-D10	3.83
Director 11	3.64		D10-D11	3.06
Director 12	3.62		D11-D12	4.125
Director 13	3.59		D12-D13	4.58

25-Element Quagi for 1296 MHz

The first 15 elements use the same element lengths and spacings as the 15-element model. The additional directors are evenly spaced at 3.0-in. intervals and taper successively by 0.02 in. per element. Thus, D23 is 3.39 in.

10-Element Cubical Quad for 1296 MHz

Reflector	9.563	(loop)	R-DE	2.375
Driven El.	9.25	(loop)	DE-D1	2.0
Director 1	8.5	(loop)	D1-D2	3.94
Director 2	8.375	(loop)	D2-D3	2.94
Director 3	8.34	(loop)	D3-D4	3.625
Director 4	8.31	(loop)	D4-D5	2.875
Director 5	8.125	(loop)	D5-D6	2.625
Director 6	8.0	(loop)	D6-D7	2.5
Director 7	8.125	(loop)	D7-D8	3.25
Director 8	8.0	(loop)		

Thus, the author set out empirically to optimize the antenna for 1296.[4] The result was a family of quagi antennas offering excellent forward gain for their small size. As is true of their lower-frequency counterparts, these 1296-MHz quagis require neither exotic construction materials nor elaborate test equipment. A number of amateurs, including some new to the band, have already duplicated the antennas described here.

The photos (Figs. 1 to 4) show these quagis, which range from a 27-in. (686-mm) long, 10-element design to a 25-element array on a 7-ft (2.1-m) boom. Table 1 gives the dimensions for each design. As with parasitic antennas designed for other frequencies, a point of diminishing returns is evident here. The gain increases rapidly for the first several wavelengths of boom, but then additional gain becomes increasingly difficult to attain. The 10- and 15-element quagis are probably the best compromises between high gain and compactness. The gain of the little 10-element version is amazing for its size.

A Cubical Quad for 1296 MHz

This may not be the time to reopen the old quad-vs.-Yagi controversy, *but* the author also devoted considerable effort to designing a reproducible, homemade cubical quad (or loop-Yagi, if you wish) for 1296 MHz. The result was a 10-element quad design, an antenna virtually identical to the 10-element quagi in both boom length and measured gain. If you want to be able to say you're using a cubical quad on 1296 MHz, Table 1 includes the dimensions for one that works well.

Some years ago, a Danish scientist reported that the gain of an antenna varies only a little when loop-type directors are substituted for Yagi-type rods if the driven element is a quad *loop*.[5] He found that the rods made slightly better directors, but that the difference was less than 1 dB. My conclusion is much the same, although I eventually came up with a cubical-quad design that equalled the forward gain of a similar-size quagi at 1296 MHz.

To get the quad to perform that well, I had to depart somewhat from the typical quad design. In Table 1, you'll note that the 10-element quad uses director loops that are *tapered* in length. Many quad designers specify that all directors are to be uniform in length, but it seemed apparent during the antenna-range work for this article that more gain could be achieved by varying the director lengths. Note also that the directors do not taper uniformly from long to short. Rather, there were instances where variations in that pattern produce better gain. In particular, the seventh director is a little longer than the sixth one. Repeated experiments with a seventh director shorter than the sixth one failed to produce as much gain as was obtained when the seventh director was slightly longer.

What about a pure Yagi at 1296 MHz? There's no question that a dipole type of driven element can be made to work at that frequency. But getting high efficiency and a good impedance match presents a difficult challenge. Since the goal was to come up with easy-to-duplicate 1296-MHz antennas, I stuck to quads and quagis.

Construction Details

Just about everyone who has ever written a construction article for an Amateur Radio magazine has received at least one letter that begins, "I built your antenna (amplifier, keyer or whatever) just like you said in *QST* except . . ." The letter writer then says it doesn't work and asks for help in fixing it.

At 1296 MHz even slight variations in design or building materials may cause substantial changes in performance. The 1296-MHz antennas described here will work every time — but only if you use the same materials and build them exactly as described here. This is not to discourage experimentation. Innovation and experimentation are part of Amateur Radio. But if you want to modify these 1296-MHz antenna designs, you might consider building one antenna *exactly* as described here, so that you have a reference against which to compare your variations.

The quagis (and the cubical quad) are built on 1/4-in. (6-mm)-thick Plexiglas booms. The driven element and reflector (and also the directors in the case of the cubical quad) are made of insulated no. 18 AWG solid-copper bell wire, available at hardware and electrical supply stores. Other types and sizes of wire will work equally well, but the dimensions will vary with the wire diameter. Even removing the insulation usually necessitates changing the loop lengths.

Quad loops are approximately square (Figs. 2 and 5) although the shape is relatively noncritical. However, the element lengths *are* critical. At 1296 MHz, variations of 1/16 in. (1.6 mm) may alter the performance measurably, and a 1/8-in. (3.2-mm) departure can cost several decibels of gain. The loop lengths given are *gross* lengths. Cut the wire to these lengths and then solder the two ends together. There is a 1/8-in. (32-mm) overlap where the two ends of the reflector (and director) loops are joined, as shown in the photographs.

The driven element is the most important of all. The no. 18 wire loop is soldered to a standard UG-290 chassis-mount BNC connector as shown in the photographs. This exact type of connector must be used to ensure uniformity in construction. Any substitution may alter the driven-element electrical length. One end of the 9.25-in. (235-mm) driven loop is pushed as far as it will go into the center pin and soldered. Then the loop is shaped and threaded through small holes drilled in the Plexiglas support. Finally, the other end is fed into one of the four mounting holes on the BNC connector and soldered. In most cases, the best VSWR is obtained if the end of the wire just passes through the hole so that it is flush with the opposite side of the connector.

If you have a Bird wattmeter, even one without an element calibrated for 1296 MHz, you can adjust the driven-element

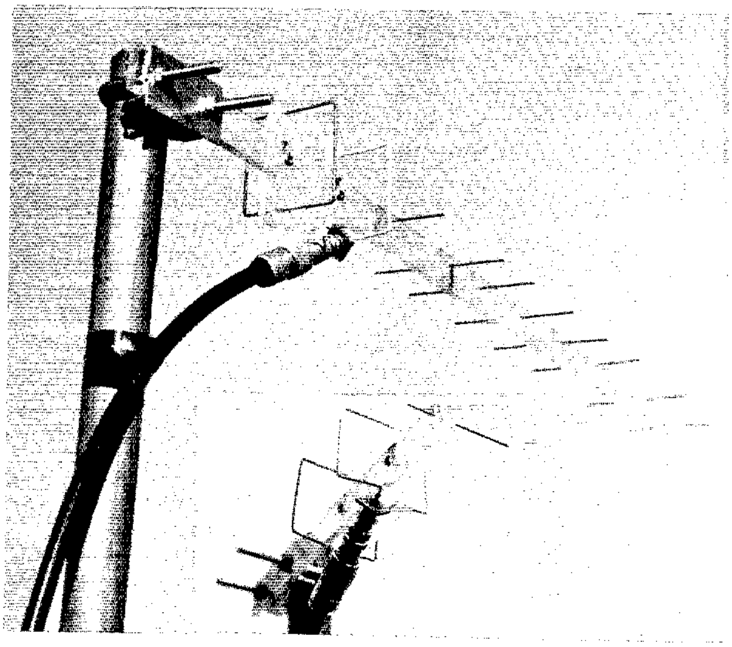


Fig. 1 — A closer view of the 10-element version of the 1296-MHz quagi shown in the lead photograph. It is mounted on a 30-in. (760-mm) Plexiglas boom with a 3- × 3-in. (76- × 76-mm) square of Plexiglas to support the driven element and reflector. Note how the driven element is attached to a standard UG-290 BNC connector. The elements are held in place with silicone sealing compound.

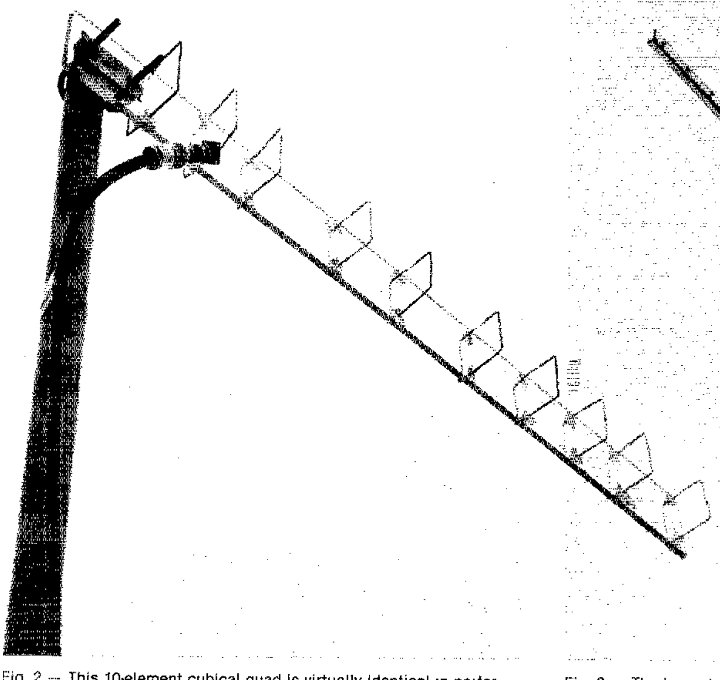


Fig. 2 — This 10-element cubical quad is virtually identical in performance to the 10-element quagi. A 3- × 30-in. (76- × 760-mm) sheet of Plexiglas supports the elements, which are offset slightly to allow room for the feed point on the driven element. All elements are made of insulated no. 18 AWG solid-copper wire.

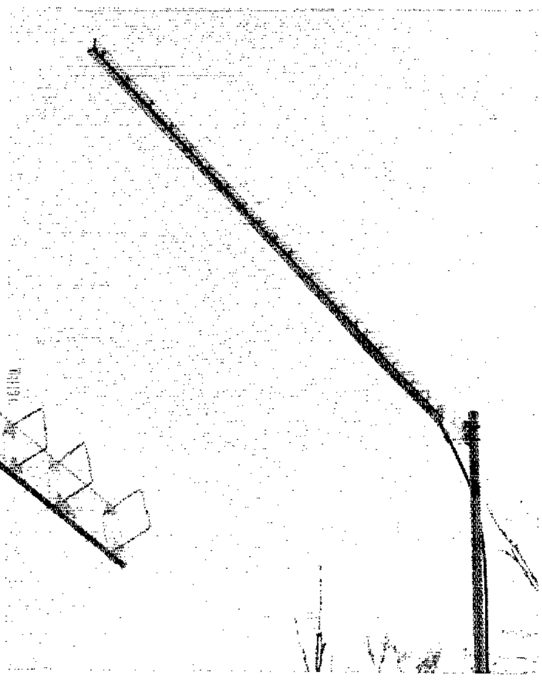


Fig. 3 — The largest quagi tested on 1296 MHz. This 25-element model is built on two tapered 7-ft (2.1-m) lengths of Plexiglas that form a right angle for additional mechanical stability. In case you're thinking of building one like it for the 20-meter band instead of 23 centimeters, the boom length will be a mere 650 ft (198 meters)!

loop to resonance. First, build the complete antenna and mount it a few feet above the ground, pointing away from all obstructions. Attach a 2-ft (0.6-m) length of RG-8/U cable from the driven element to the wattmeter and provide some strain relief for the cable, perhaps by taping it securely to the supporting mast. Before soldering the driven loop into a mounting hole on the BNC connector, apply some power and adjust the end of the loop in and out of the mounting hole for minimum reflected power. After each adjustment, step away from the antenna to get an accurate reading. It should be possible to approach unity VSWR with 50-Ω coaxial cable. Even without making this adjustment, however, the VSWR will be close to unity if the wire is cut to the proper length and soldered to the connector as shown in the photographs.

In developing these quagi designs, I tried several other connector types, including the SMA. Measuring the difference in gain or VSWR between a driven element using an SMA and one with a less expensive BNC connector was impossible. A number of dealers who advertise in *QST* sell the UG-290 BNC connector, usually for about $2 each.

The quagi directors are made of 1/16-in. (1.6 mm) brass brazing rod, available at welding shops. Lengths of the directors are critical, but a ruler with 1/16-in. or 1-mm scale divisions is adequate for the job.

A good way to obtain the correct director lengths is to cut one piece of welding rod slightly less than 4 in. (102 mm) long, and then file it down to the specified length for the first director. This length should be 3.91 in. (99.3 mm), about halfway between the 3-7/8- and 3-15/16-in. marks on a ruler. Make as many additional directors as needed for the particular size quagi you are building, filing each director down until it is just perceptibly shorter than the previous one. You need not measure each director exactly, provided the first and last ones are the correct lengths, and the ones in between are tapered evenly from the longest to the shortest. If you have access to a bench grinder, the director-making process goes much faster, but the work can be done accurately with only a hand file.

The entire antenna is mounted in front of the supporting mast, since the mast may be nearly a quarter wavelength in diameter at 1296 MHz. The feed line runs directly away from the driven element, passing below the reflector on its way from the BNC connector to the mast.

A 3- × 30-in. (76- × 762-mm) sheet of Plexiglas is sufficient for either the 10-element quad or quagi. It may be cut to 1 in. (25.4 mm) or less where it supports the quagi directors. A 48-in. (1219-mm) length of Plexiglas will be required for the 15-element quagi, while the 25-element array is made by gluing two 7-foot (2.1-m) pieces of Plexiglas together at right angles (forming a T) for additional mechanical stability.

Other Observations

The idea of feeding the driven element of a cubical quad directly with coaxial cable troubles some amateurs: They feel a balun is absolutely essential. While a *well-designed* balun will reduce feed-line radiation and increase the antenna efficiency somewhat, the losses introduced by adding a balun may offset any increase in efficiency, even at frequencies much lower than 1296 MHz. Many builders are better off feeding a quad or quagi directly with coaxial cable, especially at uhf. If the feed line is routed to the antenna in a symmetrical fashion, there should be no problem of pattern skewing, nor should there be any measurable performance degradation because a balun isn't used.

Another question that is asked about the quagi is whether or not other materials can be used for a boom. At lower frequencies, bamboo and fiberglass have become popular as alternatives to the wooden booms specified in the original article. But at 1296 MHz, Plexiglas seems to be one of the few readily available and inexpensive materials that work well. Some other insulators are not very effective at 1296 MHz. For instance, I mounted one 1296-MHz quagi on a fiberglass boom (a commercial spreader for a 20-meter quad) and measured an immediate 2.5-dB performance degradation. A metallic boom will work, but only if the director lengths are adjusted appropriately.

Some readers may want to phase multiple bays of 1296-MHz quagis for additional gain. For the 15-element quagi, the proper stacking distance is 20 to 24 in. (508 to 610 mm). However, making a phasing harness that will perform well at 1296 MHz may be difficult. The velocity factors of coaxial cables can vary slightly from the nominal values, but even small variations can cause serious problems on a frequency where 2 in. (51 mm) amount to more than a quarter wavelength for most cables. The best advice for those who lack an accurate means for determining electrical lengths of cables at 1296 MHz is to use identical lengths of 50-Ω cable (cut from the same roll) to feed each bay. Then bring each of the four feed lines together at a power divider similar to the ones made by KLM Electronics. At this writing, KLM is not marketing a 1296-MHz power divider, but the RSGB *VHF/UHF Manual* describes how to build one.[6]

Another very simple matching network

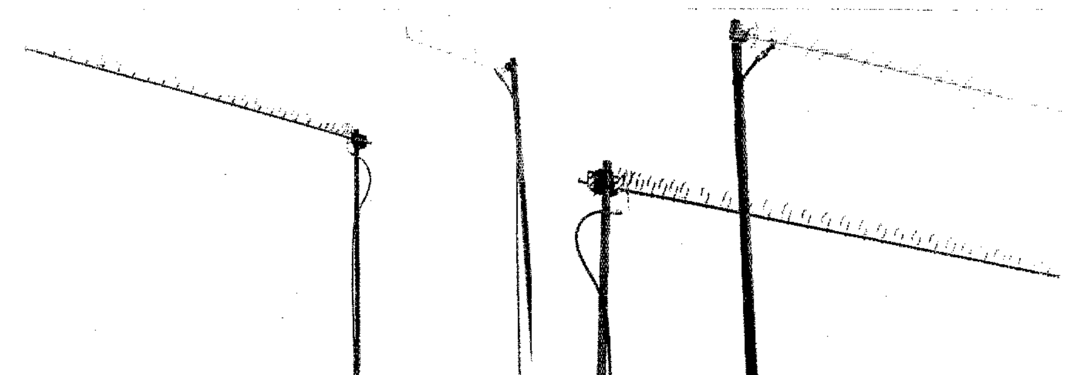


Fig. 4 — Returning to the seaside antenna range where the 432-MHz quagi designs were tested several years ago, the author used this location to measure the performance of a 15-element quagi and a 10-element cubical quad against a commercially made 28-element loop-Yagi. Although much smaller, both approached the gain of the 8-ft (2.4-m) long loop-Yagi. With a 4-ft (1.2-m) boom, the 15-element quagi is an excellent compromise between gain and physical size.

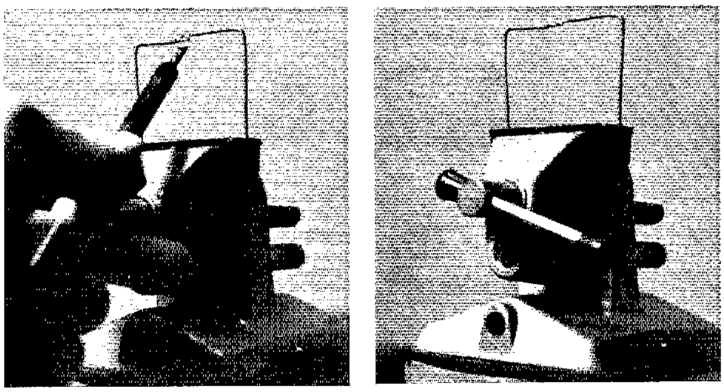


Fig. 5 — These photos show the construction method used for the 1296-MHz quad type parasitic elements. The two ends of the no. 18 AWG copper wire are brought together with an overlap of 1/8 in. (3 mm) and soldered.

for 1296 MHz, this one made from nothing more complicated than three UG-107A/U coaxial T connectors, was described some years ago by Reed Fisher.[7] Feeding his antenna with identical lengths of 50-Ω cable, Fisher simply brought each pair of feed lines to a UG-107 and then joined the two UG-107s with a third one. This works, because paralleling each pair of cables drops the impedance to 25 Ω, but each half of a UG-107 is about one-quarter wavelength at 1296 MHz. Thus, the center UG-107 acts as two quarter-wave transformers, raising the impedance on each side to 100 Ω. That value is again divided by two at the center point, getting the system back to 50 Ω. This is probably the best way to phase four bays if you have access to UG-107A/U connectors.

Performance and Conclusions

In both forward gain and directivity, typical 1296-MHz quagis, built and described here, come very close to the performance level of the 144-, 220- and 432-MHz quagi designs.

The author used a commercially made 28-element loop-Yagi as a reference in developing these 1296-MHz antennas. Gain for the 25-element quagi is similar to that of the commercially made loop-Yagi, while the smaller 15-element quagi is only about 1.5 dB down from the loop-Yagi. The 10-element quagi is another dB down, as is the 10-element cubical quad. In terms of gain per ounce, the 10-element, 1296-MHz quagi is in a class by itself. The TV type of U bolt that attaches the antenna to a mast weighs almost as much as the entire antenna.

How much gain over a dipole do these antennas develop? The manufacturer of the 28-element loop-Yagi rates the gain at 20 dB over an isotropic source, or 17.8 dB over a dipole. At the various conference sessions on vhf antenna measuring held in recent years, these loop-Yagis and most other 1296-MHz antennas have usually exhibited something less than their theoretical gain figures. Loop-Yagis typically are measured at 14- or 15-dB gain over a dipole. Using that number as a reference, the long quagi also delivers 14- or 15-dB gain over a dipole, while the smaller 15-element version offers about 13 dBd of gain. The 10-element quagi or quad will deliver about 12 dBd of gain.[8] When you compare these little quads and quagis with helical, horn and dish antennas big enough to provide that kind of gain at 1296 MHz, the difference in size is remarkable.

It hasn't been long since the adage among vhf people was, "Yagis don't work at 432 MHz." Maybe conventional Yagis are a little tricky at uhf, but Yagis that use quad loops, log-periodic cells and folded dipoles as driven elements have revolutionized our thinking about 432-MHz antennas in the last few years. Now the same sort of rethinking is going on at 1296 MHz. The day when you had to find a way to support (and aim) a 6-ft (1.8-m) dish to get decent gain at 1296 MHz is history. QST

Notes

[1] W. E. Overbeck, "The VHF Quagi," *QST*, April 1977, pp. 11-14.
[2] W. Orr and S. Cowan, *The Radio Amateur Antenna Handbook* (Wilton, CT: Radio Publications, 1978).
[3] *432 and Above EME News*, Jan. 1980.
[4] For a description of the antenna-range techniques used to design these antennas, see Overbeck, "Measuring Antenna Gain with Amateur Methods," *QST*, October 1977, p. 11.
[5] J. Appel-Hansen, "The Loop Antenna with Director Arrays of Loops and Rods," *IEEE Transactions on Antennas and Propagation*, July 1972, p. 516.
[6] D. S. Evans and G. R. Jessop, *VHF/UHF Manual*, (London: Radio Society of Great Britain, 1976), p. 8.49.
[7] R. E. Fisher, "A Successful 1296-MHz Yagi," Ham Radio, May 1972.
[8] After this was written, some of these antennas were tested at the 1981 West Coast UHF Conference in Sunnyvale, California. The 15-element 1296-MHz quagi was measured at 14.0 dB gain over a dipole. The 10-element model was measured at 13.5 dBd gain.

Strays

PICTURES FROM SATURN

☐ Voyager II, an interplanetary spacecraft, will make its closest approach to Saturn on August 25, 1981. To celebrate this event, the Jet Propulsion Laboratory ARC station (W6VIO), in Pasadena, California, will re-form and transmit, from August 15 through 30, SSTV images of Saturn and its rings and satellites as the pictures are received from Voyager II. The SSTV operation will be on or about 14,235, 21,340 or 28,680 kHz as conditions allow. Ssb and cw on 40-10 meters, ssb and fm on 2 meters, and fm on 220 MHz will also be used. Most of the activity will be conducted each day between 1830 and 2030 UTC. A color photo QSL will be available for an s.a.s.e. to W6VIO, 4800 Oak Grove Dr., Pasadena, CA 91103. DX stations QSL via ARRL bureau. — *Dr. Norman L. Chalfin, K6PGX*

MISSING SLIDE SHOW

☐ The ARRL slide show, *Arecibo* (stock number SC-16), was lost at the Dayton Hamvention. Anyone with information of its whereabouts please contact Joyce Martin, ARRL Film Librarian, tel. 203-666-1541, ext. 219.

Richard Ward, W6DZH, of Van Nuys, California, contemplates the view from about 3000 feet above the Mojave Desert. Ward had just completed what is thought to be the first successful transcontinental, direct-dial telephone call from a hot air balloon. Using his 2-meter HT, the call was made from Southern California to East Windsor, Connecticut, on March 28, 1981. *(photo by Howard Stapleton)*