some notes on cubical quad measurements

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Much has been written, and probably much remains to be written, about cubical quad antennas. A review of measurement methods for these popular antennas seems in order for those desiring to improve the performance of their quads and for those who wish to build one from scratch.

The basic beam consists of a driven element and reflector. Measurement data are given here for arrays with n-elements, however, for those interested in a larger antenna.

Test equipment includes:

1. Accurately calibrated receiver
2. Grid-dip oscillator
3. Antennascope (rf bridge)
4. Swr bridge
5. Signal source capable of providing a few watts at the frequencies of interest.

The accurately calibrated receiver is used to check the grid-dip oscillator to obtain a frequency reading within one-half percent. The signal source may be your transmitter or transceiver if power can be reduced to a few watts.

driven element resonant frequency

First, disable all elements except the driven element. Open these elements and fold the wire back over itself. If you don't do this, you'll get several readings on the GDO when it's coupled to the driven element. Now loosely couple the GDO by using a small "gimmick" made from a male coax connector and a short loop of wire. Solder one end of the wire to the connector shell, and connect the other end to the center pin, making a loop about a half-inch in diameter.

The gimmick replaces the coax on the driven element for the measurement. Next, raise the antenna as high as you can conveniently reach to make the measurement. The plane of the antenna should be perpendicular to the ground. Find the resonant point, using the GDO with very loose coupling, then check the GDO with your calibrated receiver. This should give an accurate measurement of the driven element resonant frequency. If there are other elements to be measured, proceed in the same manner. Keep a record of the data.

Cubical quad driven elements are cut according to the relationship

$$L = 1000/f$$

where

L is the length of wire (feet)
f is the resonant frequency (MHz)

Some manufacturers use a constant of 1005, but the difference, in terms of total percent length, is insignificant for amateur work.

On 20 meters, the wire length should be changed 5.7 inches for each frequency change of 100 kHz. In other words, if your driven element resonates at 14.2 MHz, and you want it to resonate at 14.3 MHz, subtract 5.7 inches from the total length, or about 1.5 inches from each side (4 × 1.5 = 6, which is close enough).

reflector resonant frequency

If coils are used in the reflector to lower its frequency, simply couple the GDO loosely to the coil, and measure f; it should be 3 to 5 percent lower than the driven element at the point chosen for it's operating frequency. If a stub is used to lower the frequency, couple the GDO to the stub. If you can't get a satisfactory reading by this method, then coil up the wire in the stub to make a small loop, and couple the GDO to the loop. The loop should be a single turn, or even a half turn, to get the correct resonant frequency. If f is obtained by increasing the wire length 3 to 5 percent, follow the procedure given above.

director resonant frequency

An identical procedure is used for checking director resonant frequency. These elements should resonate from 3 to 5 percent higher in frequency than that of the driven element. (I use 5 percent.) It's possible, if more than one director is used, to resonate the first director at 5 percent, the second at 4 percent, etc. No data have been obtained concerning shortening each director from the previous one by a fixed amount, but yagis are often constructed in this manner, so the same reasoning might apply to a quad.

input impedance

Couple the antennascope or rf bridge to the GDO, and couple the output of the rf bridge to the driven element. Set the GDO at the desired frequency, and tune for a minimum dip on the rf bridge. Next, read the input impedance on the rf bridge. A curve may be plotted, if desired, of frequency versus input impedance. It will give you a good idea on how flat the line really is. Remember, loose coupling is used in all measurements in order not to affect accuracy due to oscillator pull.

The coupling line between the rf bridge and the driven element should be as short as possible, not more than six inches to a foot, and should be coax cable of the same impedance used to feed the quad. Also the reflector and director must be in place, and connected, for these readings. The quad should be in exactly the same condition as it will be when used, except for height above the ground.

front-to-back ratio

Raise the quad in a vertical position above ground and as high as possible. You must still be able to reach the reflector coils, or the stub, whichever is used. Next, energize the quad at the resonant frequency. Point the quad **away** from where the measurements will be taken. This may be either a cooperating amateur a few blocks away, or your own receiver a few blocks away, or a field strength meter a few wavelengths away.

Now, adjust the stub or the coils (number of turns) until a minimum reading is obtained on the receiver or field strength meter. Measure the reflector frequency again, and if it isn't within 3 to 5 percent range there is something wrong with your measurements or your method of measuring.

standing wave ratio

In all cases, when using an swr bridge, first set the bridge "wide open," or at its most sensitive point. Then feed in just enough rf to get a full scale reading in the forward direction. Next, reverse the bridge, and read the swr. It's not necessary to hoist the quad in place to make these measurements. Quads have no open ends and thus are quite insensitive to nearby objects.

If the swr bridges were perfect, it wouldn't matter whether the bridge operated at the full-power output of the transmitter or at very much reduced power. Measuring instruments are not perfect of course, hence their limitations must be taken into account. Remember, too, that when the swr bridge is set to read reflected power, it also reads a small fraction of the incident power, and any stray coupling will affect the accuracy of the reading. Also note that the true swr will always be lower, but never higher, than the instrument indicates.

A theoretically perfect swr bridge would read the same regardless of the amount of power fed to it. In a way, therefore, the difference between the full-power reading and the reduced-power reading is somewhat of a test for the quality of the bridge assuming that no power is leaking to the reverse diode.

Now, let's assume that the actual mismatch is 2:1 between the feed line and the antenna. This is the **maximum** you can read on the bridge regardless of where you insert the bridge into the line. If there is in fact a mismatch, you'll obtain a different reading everywhere along the line. If the true input impedance is 50 ohms, then if you measure one-half wavelength from the input point, taking the coax propagation factor into consideration, the measured impedance will be 50 ohms.

At one-quarter wavelength from the input point the measurement would be either 25 or 100 ohms, depending upon whether or not the quad input impedance was higher or lower than that of the cable. However, at exactly one-half wavelength from the feed point, it would be immaterial what cable impedance were used as long as the propagation factor is accounted for in measuring the one-half wavelength.

The reason for this is that the reflected voltage, traveling back along the line from load to source, meets the incident voltage. If these voltages meet at multiples of one-half electrical wavelength on the line, the voltages will add, because at that instant they will be exactly in phase. It is possible, with certain line lengths, to get a reading of 1:1 when the actual swr is considerably greater than this. The only way to be sure is to use several different line lengths of the same cable, and if the swr comes out approximately the same, then you're reasonably sure that the swr is being read correctly. With a perfect match the swr will be 1:1 regardless of where the meter is placed.

optimum element spacing

According to reference 1, the optimum gain occurs in a quad with 0.125-wavelength spacing between driven element and reflector. If the spacing is increased to 0.25 wavelength the gain falls off about one dB. There is an infinite number of spacings that may be used on any beam, but I found that 0.125 wavelength between reflector and driven element is indeed optimum. (The input impedance is about 50 ohms as well.) I also found that a 0.1-wavelength spacing between driven element and director, or directors, leaves little to be desired.

It's true that many successful quad users space the elements at considerably greater distances with possibly some advantages. But from a practical standpoint, spacings as indicated above have many advantages also, such as a reasonable size structure that can be rotated with a rotator of moderate strength, and one that can be put on a tower of the ordinary ham variety.

To obtain the excellent performance of a multielement quad (unless you want to use a boom of 25 to 50 feet), spacings of the order of 0.125 wavelength between driven element and reflector, and 0.1 wavelength between driven element and directors, are quite in order.[2,3]

references

1. William I. Orr, W6SAI, "Quad Antennas," Radio Publications, Inc., Wilton, Connecticut, 1959.

2. J. E. Lindsay, Jr., W0HTH, "Quads and Yagis," *QST*, May, 1968, p. 11.

3. L. W. VanSlyck, W4YM, "How Come?" *73*, February, 1968, p. 14.

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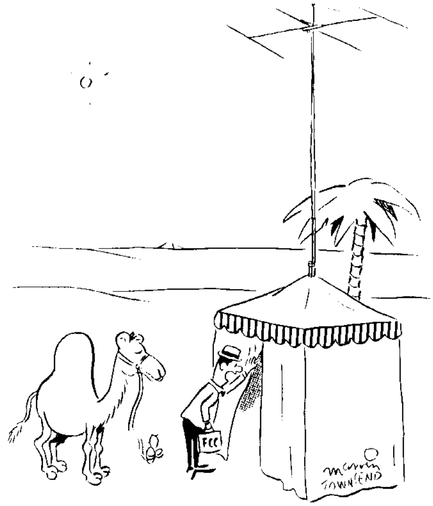

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