In summary, then,

(1) V_B is -1.625 volts with respect to ground and V_E is -1.5 volts with respect to ground. Thus, V_E is less negative than V_B making V_E positive with respect to V_B.

(2) The emitter is positive with respect to the base and this is proper forward bias in the emitter-base junction of a PNP transistor. The magnitude of the bias is simply the potential difference between V_B and V_E, i.e., V_{EB} = 0.125 volts.

Fifth: The discussion now turns to determining the collector-base junction bias, V_{CB}. To do this V_B (previously determined) and V_C must be used. V_C is the collector voltage measured with respect to ground. V_B = -1.625 volts. To determine V_C subtract V_{RL} (the voltage drop across R_L) from V_{CC}. V_C, then, is -3.375 volts with respect to ground.

In summary, V_B is -1.625 volts with respect to ground whereas V_C is negative with respect to V_B, that is, the collector is negative with respect to the base and this is proper bias in the collector-base junction of a PNP transistor. The magnitude of the bias is simply the potential difference between V_C and V_B or -1.75 volts. This is the collector-base reverse bias in the circuit.

Sixth: Since the voltages needed were determined in previous steps, solving for V_{CE}, the collector-to-emitter voltage, is short work. V_C and V_E are used to find V_{CE}. From the previous step, V_E was found to be -1.5 volts. The potential difference of V_C with respect to V_E is -1.875 volts. This indicates that V_C is 1.875 volts more negative than V_E. Therefore, V_{CE} = -1.875 volts.

Recapitulation

Transistor currents:
I_B = 0.088 mA
I_C = 6.73 mA
I_E = 6.818 mA

Transistor element voltages with respect to chassis ground:
V_B = -1.625 volts
V_E = -1.5 volts
V_C = -3.375 volts

Transistor Junction Bias Voltages With Respect To The Base:
V_{EB} = 0.125 volts (emitter-base junction forward bias)
V_{CB} = -1.75 volts (collector-base junction reverse bias)

And, finally, it was determined that the voltage at the collector, with respect to the emitter, V_{CE}, is -1.875 volts.

Of the recapped items, the three that establish the d.c. operating point (Q-point) of a transistor amplifier are I_B, I_C and V_{CE}. Refer to fig. 2 for a graphic illustration.

An incidental offshoot of the analysis is that the **beta** β of a transistor can also be determined. The beta of a transistor is the ratio which indicates how effective a device is in developing a large collector current as a result of a small base current. The formula is $\beta = I_C/I_B$. Thus, in the example in fig. 1, β = 6.73/0.88 = 76.47. There is 76.47 times more collector current than there is base current.

This article has offered a detailed mathematical d.c. analysis of a common-emitter, R-C coupled Class A voltage amplifier. The principle necessary tools for such an analysis are a proper application of basic Ohm's Law and an appreciation of voltage drops and potential differences between two points.

A d.c. load line, with the d.c. Q-point, was drawn on an abbreviated average collector characteristic curve (fig. 2). The expectation here is that the reader could see the three factors that set the operating point on the load line.

All computed values were confirmed with a 33,000 ohms per volt v.o.m. ■

Does bigger mean better? Sometimes, thinks K5DUT, especially when it comes to quads. Read about his six-element giant in this article.

The Monster Quad

BY DON WINDFIELD*, K5DUT

The cubical quad antenna has gained popularity in recent years due to its excellent performance. The larger ones are growing in number. It has been said that quads will not stay up in adverse weather, especially the large ones. With proper material and construction they will stay up. Large quads have been in use at this QTH for over four years with no problems but make no mistake about it, to build a large quad that stays up, takes proper planning, materials and workmanship.

In the Fort Worth area, large quads are popular and a backlog of information has been gained from constructing and tuning them. Many things have been tried and tested with some definite conclusions about what will work well and what will not.

One of the hardest parts of a "Monster Quad" construction project is to figure out what material will last in the wind and ice.

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This is most important if the antenna is expected to stay up a number of years without problems. Many readily available quad spreaders are not suitable for use in heavy icing conditions and 70+ mph winds. It is too easy to compromise, for suitable spreader sources are few in number. There are three weak points that give the most trouble in a quads survivability: the spreaders, the wire, and the method of attaching the wire to the spreaders.

Pole vaulting poles or strong material is recommended. Do not use aluminum tubing or other conducting material for spreaders. The element wire can be small gauge aircraft trim cable (stainless steel or copper plated). Regular six strand galvanized guy wire makes a rugged element wire and is cheap. It will stay up many years without failure. Although its conductivity is less than copper, there is no noticeable loss of performance with it. In areas of light icing, solid strand #12 copper motor rewinding wire works well. Be sure to pre-stretch it. I have used it here for several years without a single broken wire.

To attach the wire to a spreader, use about eight inches of Teflon® tubing, four pieces per element. Slip these over the element wire. They attach to the spreaders with small aluminum clamps (called Adel clamps), one around the Teflon® tubing and the other around the spreader. These clamps are used in the aircraft industry and are available as surplus.

Another method that works well and is used by many of the local quad builders, is to use Tye Wraps to attach the Teflon® to the spreader. Tye Wraps are used in the electrical industry and are very strong. Use only the black ones. Two or three are used at each attach point. They are much quicker and easier to use than the clamp method but not as strong.

As far as the spiders, the standard homebrew T-6 aluminum angle and muffler clamp construction works well and needs no further improvement. Use thick angle and plate the clamps for long life.

The boom needs to be designed for the wind load of the antenna and builders of some of the larger quads have gotten into trouble here. Attempts to use the popular and cheap three inch irrigation tubing on long Monster Quad booms have met with disaster. It will not hold up in high winds without reinforcement. Two inch thick wall tubing guyed at four points along a fifty foot boom also failed to stay up in the Texas winds and ice. Yes, we get ice here; some winters it's quite heavy and with winds in excess of 70 mph. A successful 50 foot boom design with only one cable to take out the vertical sag has been in use here for four years. It is pictured in this article. It is as follows: Center piece, three inch o.d., .250" wall tubing, twelve foot long. Two and one quarter inch tubing press fit into each end of the three inch piece, 12 feet each side. The end pieces are .125" wall two inch O.D. tubing eight foot long, press fit into the two and one quarter pieces. All are T-6 aluminum round tubing. The material was purchased locally at the scrap yards. The same material is quite expensive when purchased new.

This covers the most troublesome areas of reliability when building a Monster Quad. The rest is more or less good quad building practice. Be sure to use good strong terminal ends at the driven element wire attach points. Silver solder them if you use steel wire. Use good strong Teflon® terminal blocks and brass screws and hardware. Number 10 hardware is used here. Be careful to provide mechanical strength to the feedline attach points to remove strain from the feedline.

As far as the electrical design of the Monster Quad, good information is available. Some of the things that work well here are: use one feedline for each driven element on multi band Quads; one feedline up the tower to a relay bank is good. For superior front to back ratio, use dual reflectors. Clarence Moore, the inventor of the quad antenna, speaks highly of this design. Forty dB+ front-to-back and sixty dB front-to-side ratio is possible with dual reflectors. Do not use aluminum tubing for spreaders. The popular 1:1 baluns do little for quad performance and after trying them it is felt that they are not necessary for quad antennas.

Some tri-band quads came up with peculiar tuning problems that at first were baffling. The problems were traced to such things as the 20 meter driven element being detuned by the 10 meter feedline, which was coupled to the 20 meter element by the 10 meter element.

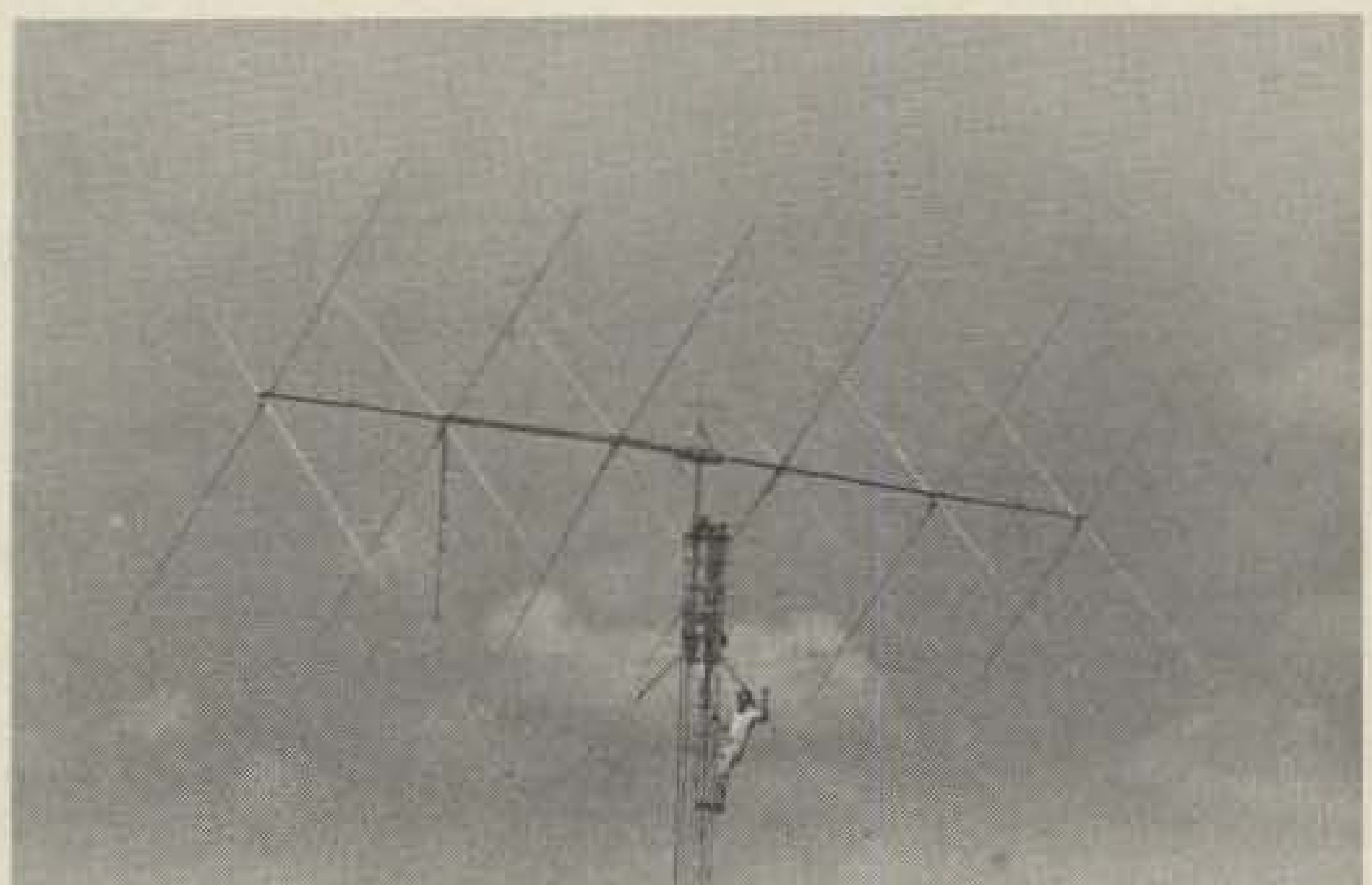
A feed system that eliminates this type of problem is discussed in Bill Orr's "Quad Antenna Handbook" (page 50, paragraph 1). That system is in use here and works well. With a tri-band quad on a fifty foot boom and six frames at equal ten foot spacing, the 15 meter and particularly 10 meter element spacing is a bit wide by accepted formula. The performance on the air is excellent however and one wonders if the performance is down at all.

Collectively many hours have been spent by the local Quad "tuners" with the usual antenna experimenters tools and instrumentation. It is generally agreed among us that once the antenna is in the "ballpark," additional hours of fine tuning are not worth the effort. Usually, the results amount to "peanuts" as far as forward gain increases are concerned. Front-to-back tuning is fairly critical and takes some fine "tweaking" for maximum performance. Monster Quads are forgiving as far as loss in forward gain with mildly mistuned elements.

There are no so called "secret dimensions" that perform magic with quads and good quad information is readily available. An excellent article is in *QST*, May 1968, called "Quads & Yagis" by Jim Lindsey, now W7ZQ. Also an excellent article on tuning is published in *73* magazine called "Easy Tuning of Multielement Quads," by W4AZK.

It is felt from measurements here that the maximum gain of a Monster Quad occurs with the elements tuned within 1.5 to 2% different in frequency from the driven element. The reflector is longer and the directors are shorter, of course. Several quad suppliers recommend 5% detuning and while more bandwidth and easier tuning is achieved, somewhat less gain is the result.

A method of tuning that works well here is as follows: with a reasonable match to the driven element, (2:1 or less), tune the reflector and the driven element for desired resonant frequency. Check the front-to-back ratio. Use a grid-dip meter and a calibrated receiver to check the frequency of the grid dipper



Note how the Monster Quad dwarfs the author.

and tune all the directors 1.5 to 2% higher in frequency than the driven element. On 20 meters with the driven element at 14.200 MHz, careful field strength measurements have shown maximum forward gain occurs with all directors tuned to about 14.375 MHz.

Check each element several times to get the average frequency with the grid dipper. With each adjustment there is interaction and everything must be checked and rechecked. No tuning stubs are used. Direct element length variation is used. The tuning of directors is quite broad and only small changes occur on a field strength reading when everything is getting close. In fact, it is quite difficult to tune the directors with a field strength meter and once the proper point is found, the grid-dip method is faster and provides a repeatable set of figures that can be duplicated quickly on another antenna of like design at another site.

During one of the tuning sessions an interesting thing was tried, with the antenna tuned for maximum forward gain, the reflector was peaked for best front-to-back-ratio. The measured forward gain dropped little with this change.

Pick a calm day to tune the antenna. On windy days the meters dance all over the place. Lots of on-the-air tests to DX stations have been made with Monster Quads tuned various ways. They were compared to a standard antenna that did not change. Single tests are unreliable and only a lengthy series of tests, with the results averaged, gives good indication of performance differences. Tests were made with a two element quad as the standard and a four element quad was tested against it. Then a four element quad was used as a standard and a six element Monster Quad was tested against it. The test periods ran for about one year each. Results were averaged and were interesting. Because every S-meter is different, I will not quote exact dB figures, but in general the difference was about one and one half to two S units in favor of the four element quad over the two element quad. With the four and six element quads, the difference was closer and ran about one-half to one S unit in favor of the six element quad. These figures were taken from the DX stations S-meters and were made up of reported signal strength transmitted from the quads under test.

Some of the things learned while using the same antennas and making receive comparisons were interesting. After many tests it seems that the smaller quad antennas receive much better than they transmit when they are compared with a larger quad. For instance, a two element quad at times would receive almost as well as a four element quad. Never did it transmit as loud a signal as the Monster Quad. It appears that the differences show more readily in transmitted signal strength than in receiving ability when comparing large and small quad antennas. These tests were done with the antenna height from 60 to 80 feet.

Later, tests were made with a two element quad on 20 meters mounted on a 120 foot tower. On a separate tower 300 feet away, a four element 20 meter quad was mounted at 120 feet. The test period was brief but much of the same results were noticed at 120 feet as those at the lower levels.

When comparing the Monster Quads to large monoband Yagis, the quads seem to be better receiving antennas. They are quieter under normal conditions and during periods of precipitation static, the quads will usually copy Q5 while with the Yagis static was many dB over S9, covering up stations on frequency. A problem that occurs with quads can be quite serious for those of you that have icing conditions. When the quad is covered with ice, it is severely detuned and almost useless as a transmit antenna. The yagis are detuned a bit but work fine.

Another problem for city dwellers is that a Monster Quad is ugly. Most neighbors hate the sight of them. One local ham here however has a neighbor lady that thinks his six element Quad is the most beautiful thing in the neighborhood! It's a diamond shaped one. (Maybe she likes diamonds).

To properly tune a large quad, easy access to the antenna results in a better job and a crank-up or lay-over tower is almost a necessity. Monster Quads on fixed towers usually turn out to be monstrous tuning problems. On a fixed tower, the proper way to do it is to assemble the quad and tune it at a lower height where it can be easily reached. Strangely, few hams do this. Maybe it's because building the thing is so much more work than anticipated, they just want to get it up and over with. Most times it is then discovered that the results are not what was expected and the antenna is used as-is.

I have talked with several hams that were displeased with their quad antennas but most of them did little or no tuning, yet top performance was expected.

Large quads take heavy duty towers and heavy duty rotaters. "Prop Pitch" rotators are used by all the local Monster Quad owners here. The popular Ham-M rotator has been tried and is not up to the job.

As far as which is better, square-shaped loops or diamond, the square loops allow a shorter distance from the Quad boom to the bottom wire. This permits the top set of guy wires on the tower to be closer to the boom. This distance can become critical with a large quad on a mast. A diamond shape offers somewhat better ice resistance and the feedlines can be tied to the bottom spreader. The electrical difference appears to be very little. An article by W7KAR, March 1977 *QST*, ("Evolution of a Quad Array"), shows that the two different shaped loops can be intermixed with no deterioration of performance.

A well built Monster Quad is expensive to build and usually takes much more time and effort than the builder imagined. Any corner cutting can result in a broken mess on the roof in mid-winter. One DXer here found that out the hard way. Needless to say, that kind of quad works very poorly.

After all the hard work, is a Monster Quad worth the effort? Many DXers here think so. At this writing, six Monster Quads are up in Fort Worth and more are going up. For the amateur that is limited to one tower and boom at a modest height, a multi-band Monster Quad along with the usual DXers tools, a k.w. amplifier, good location, etc., gives DX performance that rivals the long boom monoband yagis perched on cloud scraping towers. The quads will do it at a lower height, (about two-thirds as high). As high performance DX antennas, the tri-band Monster Quads in this area are installed at sixty five to eighty feet and put their owners in the top few that dominate in DX pileup performance. The multiband Monster Quads are the only antennas here that seriously challenge the dominance of the large mono-band yagis on tall separate towers.

After several years of using quad antennas, it has become obvious that with all other things equal, the multi-band quad will equal and most times exceed the performance of a mono band yagi of a like number of elements and offer this performance from a lower height than the yagi. In the area are some forty through ten meter quads. To equal their performance with yagis, much more hardware and expense would be necessary and this is where the real advantage of a large multi-band quad becomes apparent. It is possible to have an all band antenna farm with one tower and boom with a multi-band quad. A full size eighty through ten meter quad is on paper here and will be going up some time in the future in the area. As a closing note, some of the local DXers with monoband yagis have replaced them with multi-band Monster Quads and are well pleased with an increase in DX performance.