A116-3-1

THE QUANTUM LOOP

A COMPACT, HIGH-GAIN FERRITE ROD ANTENNA

Gerry Thomas

With the price of ferrite rods going through the roof, I decided to see if I could design a loop antenna using a minimum of ferrite and a maximum of amplifier. The result of this experimentation is a loop I call the *Quantum Loop* ("quantum" -- a small packet of energy; "loop" -- well, you know loop).

Whereas most loop amplifiers for antennas using 10"-16" rods put out between 15 dB and 25 dB of gain, my more modest 8" rod antenna would require an additional 6-12 dB of gain. So, I was shooting for amplification in the 30-35 dB range. As it turned out, I was able to design an amp that delivers between 42-48 dB of gain across its tuning range. Of course, this degree of amplification would be of little benefit if you had 20 dB of amplifier hiss to go along with it. So, low-noise components were chosen and the result is quite satisfying. Also, because this level of gain is not always desirable (overloading problems can occur in receivers with lesser front-ends/mixers), a gain control was included in the design.

In addition to the preceding requirements, I also have a few preferences of my own regarding loop operation: (1) I prefer the tuning knob to be on the stationary loop base and not on the revolving loop head; (2) I like a loop head which rotates continuously (without stops) and, of course, tilts; (3) I also wanted a loop head that was removable so that the antenna could easily be placed in a suitcase; and (4) for the sake of domestic tranquillity, I desired a finished loop which looked sufficiently attractive to spare me from the critical comments which loops usually evoke from my wife.

BRIEF DESCRIPTION

The *Quantum Loop* measures approximately 10"(H) x 7"(D) x 8-1/2"(W) at its maximum points (see Figure 1). The loop head housing is constructed of black plexiglas and is connected to the black, sloped-front amplifier base by a chromed tube pedestal. The amplifier is a two-stage, balanced input/unbalanced output design with low-noise JFETs in the first stage and a low-noise MOSFET in the second; both stages are arranged in a common-source configuration.

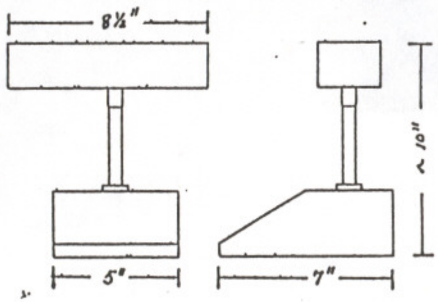


Figure 1. *Quantum Loop* dimensions.

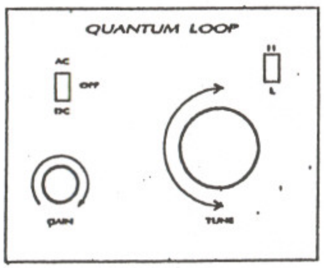


Figure 2. Front panel controls.

The loop tunes from 530 kHz to 2000 kHz in two ranges and has a variable gain control and on/off switch. Power is supplied by either a 9VDC battery or an AC wall adapter (switch selectable). Figure 2 shows the front panel lay-out.

CONSTRUCTION DETAILS

Be aware that the construction of the *Quantum Loop* is LABOR INTENSIVE! If this project is beyond your available time or abilities, see the last paragraph of this article.

A. Loop Head Housing --

The overall dimensions of the housing are 8-1/2"(L) x 1-3/4"(H) x 2-1/2"(D). The *Quantum Loop's* ferrite housing is constructed of black plexiglas; all panels are 1/8" thick with the exception of the base panel which is a sturdier 3/16" in thickness. The pieces are cut to the dimensions illustrated in Figure 3.

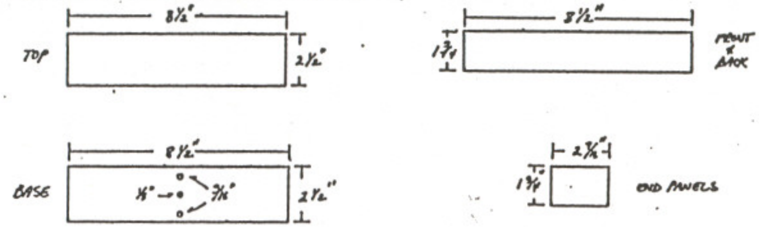


Figure 3. Loop housing panel dimensions.

One hole (1/8" diameter) is drilled in the base panel to allow the passage of the loop coil's wires down to the amplifier base and two 3/16" holes are drilled to permit the fastening of the tilting assembly. The panels are glued together to form the box-like housing with the front panel left off until the rod/coil assembly is installed.

B. Tilt Assembly --

The tilt assembly is constructed of the stationary part of a Radio Shack microphone holder (#33-371). Remove the screws holding the two parts of the holder together and discard the upper part and the screws. Drill out the center of the holder to allow the passage of the coil wires to the 1/4" phone plug (to be installed later). Tap the holes which held the pivoting portion of the holder with a 5/16" tap to accept two 5/16" x 3/8" cap screws. Use two 1/2" angle brackets to form the platform upon which the base of housing will be attached and fasten to the tapped mike holder with the tap screws (nylon washers can be added to make tilting smoother, if you wish). The holes in the angle brackets will have to be enlarged and the right angles of one end rounded to permit unobstructed tilting. Figure 4 illustrates the tilt assembly, the chromed tube pedestal, and phone plug bearing.

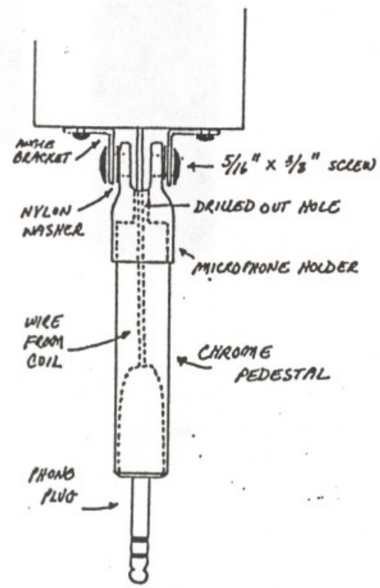


Figure 4. Tilt, pedestal, and plug assembly.

C. Chrome Pedestal and Base --

The chrome tube pedestal is a threaded microphone tube and screws into the

A116-3-2

microphone holder (preceding section). I bought the 6" model (Atlas Sound AD-8B) and cut it in half to provide a 3" pedestal. I also used a chrome base collar (Atlas Sound AD-11B) to add lateral stability. Unfortunately, these collars have an interior thread which must be removed by filing or reaming before the pedestal tube can rotate freely. Because the chrome tube is grounded and because it shares ground with loop coil and electronic circuitry, it is noticeably "RF hot" in some situations (e.g., deep nulls). To remedy this, I slid a 1-1/2" length of 5/8" (ID) clear vinyl tubing onto the tube to insulate it and provide a comfortable grip for loop head rotation.

D. Phone Plug Bearing --

The loop head rotates on a standard 1/4" phone jack which has been epoxied into the interior of the chrome tube (see Figure 4). Wires from the loop coil are routed down through the microphone holder and chrome tube and are soldered to the plug's terminals. Don't waste your time with the Taiwanese/Korean/Japanese phone plugs and jacks; they are generally constructed of inferior materials and will break or wear out in relatively short order. Use only American-made Switchcraft components (#12B and #297); they are heavy, nickel-plated brass and are still going strong after six years in my loops.

E. Loop Amplifier Base --

I chose a sloped-front aluminum cabinet (which allows more comfortable tuning) to house the loop's amplifier. The LMB752 (from Mouser) fits the bill nicely but comes in a beige/tan color scheme which I changed to satin black. First, mount the Switchcraft 1/4" phone jack in the center of the top of the cabinet, then mount the chrome collar (which reinforces the chrome pedestal) so that it too is centered (sheet metal screws are fine). Drill holes in the rear of the cabinet to accommodate the battery holder, patch cord connection, and AC adapter jack and install these components. The other holes in the cabinet depend on your lay-out of the electronic circuitry, so I won't give specific dimensions for those. I have found the sloped front of the cabinet to be ergonomically effective in permitting fine tuning knob adjustments and reducing arm/wrist fatigue so a sloped front cabinet is definitely recommended.

F. Amplifier Details --

Figure 5 provides the schematic of the loop amplifier. Parts lay-out is not particularly critical as long as straight-line design and minimal lead length principles are followed.

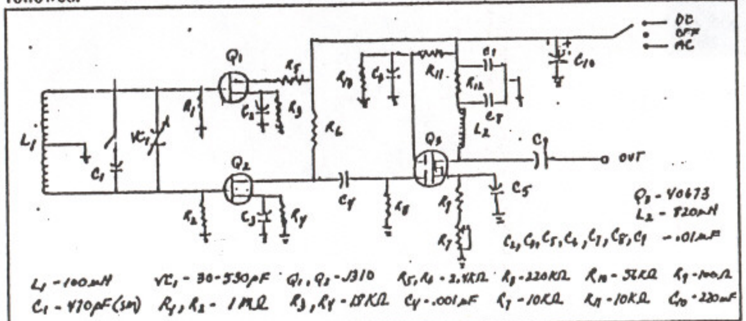


Figure 5. Loop amplifier schematic.

VC1 is a dual-ganged, 15-266 pF polyvaricon variable capacitor (Mouser # 24WC001) with the two gangs connected to provide a capacitance range of about 30-530 pF. (This capacitor requires a shaft extension -- a .625" x .25" nylon spacer glued and held in place by a 2.5mm x .75" machine screw; VC1 must be mounted on a plastic base). C1 is a 470 pF silver mica capacitor which is switched across VC1 to allow low-end tuning. The signals from the rotor and stator tabs of the VC1 are routed to the gates of Q1 and Q2. Transistors Q1 and Q2 are J310 JFETS. These are extremely low noise devices and provide approximately 20 dB of gain across the tuning range. They are arranged in a common source configuration with source by-pass capacitance (C2 and C3). The signal is taken off the drain of one transistor and capacitively coupled (C4) to Gate 1 of Q3. Transistor Q3 is a dual-gate, diode protected, low-noise MOSFET (40673); it, too, is in the common source configuration with gain being controlled at the source by R7. [NOTE: After designing and testing this circuit, I learned that Motorola and RCA were ceasing production of the 40673 MOSFET; the recommended substitute is the 3N201, but I have not yet tried it]. L2 is an inductor measuring 820 uH which resonates with the stray capacitance of the components and circuit to provide an amplification peak at the low end of the tuning range. Actually any choke in the 800 - 1200 uH range should be suitable because the stray capacitances can vary a bit depending on a number of factors. The output of Q3 is taken off the drain and is capacitively coupled to the output jack for connection to the receiver. You may notice that there is no impedance matching network or low impedance emitter-follower circuitry in this amplifier design. The gain of the amplifier is such that I decided to design for a medium impedance output to adequately match either high (500-1000 Ohm) or low (50 Ohm) receiver inputs. The gain of the *Quantum Loop* is sufficiently high that I didn't feel it was worth it to perfectly match impedances to gain a couple of dB.

CORRECTION: VC1 should read Mouser # 24TR218. Ref # C1=470pf(SM), C2, C3, C5, C6, C7, C8, C9=.01uF. C4=.001, L1=100uF, L2=820uF, Q1 & Q2=J310, Q3=40673, R1 & R2=1 meg, R3 & R4=1.8K, R5 & R6=2.4K, R7=10K, R8=220K, R9=100, R10=56K, R11=10K, R12=270, VC1=10-532pf & C10=220uF.

the drain of one transistor and capacitively coupled (C4) to Gate 1 of Q3. Transistor Q3 is a dual-gate, diode protected, low-noise MOSFET (40673); it, too, is in the common source configuration with gain being controlled at the source by R7. [NOTE: After designing and testing this circuit, I learned that Motorola and RCA were ceasing production of the 40673 MOSFET; the recommended substitute is the 3N201, but I have not yet tried it]. L2 is an inductor measuring 820 uH which resonates with the stray capacitance of the components and circuit to provide an amplification peak at the low end of the tuning range. Actually any choke in the 800 - 1200 uH range should be suitable because the stray capacitances can vary a bit depending on a number of factors. The output of Q3 is taken off the drain and is capacitively coupled to the output jack for connection to the receiver. You may notice that there is no impedance matching network or low impedance emitter-follower circuitry in this amplifier design. The gain of the amplifier is such that I decided to design for a medium impedance output to adequately match either high (500-1000 Ohm) or low (50 Ohm) receiver inputs. The gain of the *Quantum Loop* is sufficiently high that I didn't feel it was worth it to perfectly match impedances to gain a couple of dB.

G. Coil Winding/Ferrite Rod --

The ferrite rod I used has a permeability of 125 mu and is 8" in length and 3/8" in diameter. The coil is of litz wire (64") resulting in 31 turns (with a center tap at turn 16) on a 1/2" polystyrene coil form (this tubing is available from aquarium supply houses). If you are using the more popular Amidon 7-1/2" rod, you will need 66-68" of litz and 33 turns to cover the tuning range. The overall inductance of the coil is 100 uH when centered on the ferrite rod. It is extremely important that both legs (to ground) be exactly equal in inductance in order to attain perfect loop balance. (An inductance meter is invaluable here and is well worth the $125-$150 outlay to the inveterate experimenter.) The coil's center tap and ends are soldered to a three-lug terminal strip mounted in the loop housing and RG-174U coax continues the signal path out of the housing, down the chrome tube to terminate on the lugs of the 1/4" phone jack. RG-174U coax then routes the signal from the jack to the circuit board and the rotor and stator of VC1. Equal lengths of coax from each side of the coil must be used throughout this routing to preserve the balance of the coil.

The ferrite rod/coil assembly is shock-mounted in a length of pipe insulating foam (available from hardware stores) which fits snugly in the loop housing. At this point, you can wrap a width of conductive tape (aluminum or copper) 3/4ths of the way around the foam which, when connected to the terminal strip's ground lug, will provide shielding for the loop. Quite frankly, I've found that shielded loops work only in certain situations and generally reduce the coil's Q (and therefore, loop gain) so, there's a trade-off.

H. Power Supply -- The *Quantum Loop* requires 9VDC which can be supplied by either a 9-volt battery or a 9-volt AC adapter and can be selected by a front panel-mounted switch. The *Quantum Loop* draws between 10 and 15 mA which is about 2X-3X the current requirements of some of my earlier amplifiers but, nonetheless, a 9-volt battery should last a fair length of time.

I. Signal Output -- The output of the JFET/MOSFET amplifier is routed to a cabinet-mounted jack and ultimately fed via cable to the receiver. Over the years I must have tried about two dozen different kinds of patch cables. It's been my experience that in loop applications the impedance of these cables is irrelevant. I've used everything from 50 Ohm coax to high impedance microphone cable and have never been able to discern any difference at all. What *is* important, however, is the amount of shielding the cable possesses. Coax cable shielding runs from about 70% to 100%; choose 100% shielded cable and your site/night/vertical effects will be minimized. The best cable I've found is computer Local Area Network trunk cable such as "Ethernet." Unfortunately, this stuff is really expensive and hard to find in short lengths. There exists 100% shield RG-8/M, RG-58, and various microphone cables; use one of these.

A116-3-3

LOOP OPERATION

A. Set-up -- Plug the loop head fully into the amplifier base and connect the patch cable to both the loop base and receiver. Install a 9-volt battery or plug in the AC adapter and turn the loop and receiver on. Position the loop away from the radio's digital display (if it has one) and as far away from electrical wiring and other antennas as is practical. Positioning the *Quantum Loop* too near radios with poorly shielded cabinets (e.g., portables) could result in antenna/circuitry interactions and a resulting oscillation.

B. Tuning -- The *Quantum Loop* tunes in two ranges: 530-700 kHz in the "L" position; and 700-2000 kHz in the "H" position. In lieu of a vernier tuning dial, I opted for a dual diameter tuning knob. This is nothing more than a skirted knob measuring 1-1/2" at the skirt and about 7/8" at the grip. The smaller diameter grip allows for fast tuning while tuning by using the wider skirt permits easier fine tuning. Tuning of the *Quantum Loop* is very sharp and should be done carefully.

C. Gain Setting -- The *Quantum Loop* possesses more than adequate gain for most of my DXing situations. I've found that most radios (at least those I own) tend to perform best if the station of interest is producing no higher than an S-9 on the S-meter. Running the *Quantum Loop* so that most signals are in this ball park will take a load off your radio's front-end and mixer. As you are adjusting the gain, you will notice that the range of adjustment does not allow you to completely eliminate moderately strong and strong stations. This was a design decision on my part because I've never had the need to completely eliminate the signal (via gain setting) of a desired station. A brouhaha by users, however, would cause me to change the design. On a related topic, the dynamic range of the front-end J310 JFETs is in excess of 100 dB (according to the manufacturer and my own tests). I've not measured the present JFET/MOSFET amplifier for dynamic range because I've only used it in loop applications where signal levels are pitifully low.

D. Nulling -- I usually position the loop so that my elbow rests on the desktop and my fingers grip and rotate either the insulated vinyl tube or the microphone holder; I don't use the loop housing to rotate the antenna because the height is a little less comfortable and because the added leverage could strain the plug/jack.

To null weak to moderately strong stations, simply rotate the antenna for a minimum signal. As the null approaches, slow down, the null is very sharp and the deepest null is at a single point in the semi-circular rotation. On strong stations, especially locals in the daytime, it will probably be necessary to both rotate and tilt the loop. For this, I usually grip the loop housing to simultaneously tilt and rotate the loop. Here too, the deepest null will occur at a precise combination of tilt and rotation. I have no problem completely eliminating all of my locals but the strongest is only 10 kW; it is possible that a station producing unusual signal polarization will resist all attempts at nulling. Luckily, these stations are fairly rare.

On a related note: If the *Quantum Loop* is constructed as described, i.e., ensuring identical inductances in each leg of the coil path, you will end up with a nearly perfectly balanced loop (except for the fact that I've found a very slight measureable difference in the rotor's and stator's capacitances to ground). If you were to operate this loop far from antennas, housing wiring, metal cabinets, etc., the two opposite nulls would be virtually identical in depth and exactly 180 degrees apart. However, this ideal DXing location is not the typical one. Consequently, depending upon your location, you may find one null to be slightly deeper than the other and one null to be slightly skewed by a few degrees. In practical DXing terms, there's little you can do about this.

E. Routine Maintenance -- I've been using this basic design since about 1986 with no major failures. About the only thing I do to maintain the loop is occasionally remove the loop head from the amplifier base and clean and lubricate the phone plug with WD-40. I similarly clean and lubricate the stabilizing collar on the top of the base periodically.

All in all, I'm quite satisfied with the overall design and performance of the *Quantum Loop* but am open to suggestions for improvement. As I mentioned earlier, this is a very labor intensive construction project which requires tools and test equipment that may not be available to everyone. For this reason, I've assembled the components to make about 20 *Quantum Loops*. The price for one of these initial 20 is $125 (plus $4 UPS). This includes the AC adapter, patch cord, and connector of your choice (specify standard UHF, BNC, RCA, or alligator clips). You can contact me at 3635 Chastain Way, Pensacola, FL 32504. 73's....GT

QUANTUM LOOP UPDATE

Gerry Thomas

Since the publication of the original *Quantum Loop* article, several things have transpired including notification of errors in the article, suggested improvements in the circuit, availability of the *Quantum Loop*, and pricing.

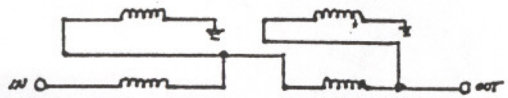
ERRATA

1. The stock number of VC1 from Mouser Electronics is 24TR218 (the number cited in the article was an old stock number).
2. R12 in the circuit diagram was unlabeled; it should be 270 Ohms.

SUGGESTED IMPROVEMENTS

1. MOSFET 40673 is nearly impossible to find these days. I've switched to the 3N201 (or ECG 454/NTE454) and these direct substitutes work fine.
2. The Mini-Circuits T16-1 or T16-6T work well as RF transformers to lower the output impedance of the loop (and thereby more closely match the standard 50 Ohm input impedance of most non-portable receivers). These run between $4.45 and $5.65 direct from Mini-Circuits (P.O Box 166, Brooklyn, NY 11235).

If you don't want to purchase one of these commercial models, you can wind your own 16:1 unbalanced-to-unbalanced transformer. You'll need two FT50-43 ferrite toroids (Amidon Associates, 2216 East Gladwick St., Dominquez Hills, CA 90220) and four, nine-inch lengths of 28 gauge (about) wire. Create two bifilar windings (i.e., twist two wires together) and wind nine turns, evenly spaced, around one toroid and repeat the process for the second toroid. Connect the wires as described in the schematic below.



3. Mark's other suggested improvements also are effective and are incorporated in all future *Quantum Loops*.

QUANTUM LOOP AVAILABILITY

By the time this update appears, all 20 of the initial run of *Quantum Loops* will be gone. I have ordered the necessary parts for more *Quantum Loops* but I don't expect to be ready to ship more until mid-July at the earliest.

QUANTUM LOOP PRICING

As I was ordering parts for more loops, I was dismayed to discover that many of the components had increased significantly in price (e.g., cabinets--up $5.00). Combined with the Mark Connelly improvements and the necessity to have new printed circuit boards made (with their accompanying set-up fees), I must raise the price of the *Quantum Loop* to $135 (plus $5.00 UPS). Fortunately, I've ordered enough parts so that this should remain the price for the foreseeable future (i.e., the next DX season).

Thanks for your understanding (and response to the *Quantum Loop*)...

Gerry Thomas, 3635 Chastain Way, Pensacola, FL 32504

REPLY TO MARK CONNELLY'S QUANTUM LOOP TEST EVALUATION AND IMPROVEMENTS

Gerry Thomas

(A 120) reprint

First of all, I want to thank Mark for taking the time to thoroughly evaluate the *Quantum Loop*. I especially want to thank him for expending the time and energy to come up with the fixes he suggested.

Living in Pensacola, Florida has many advantages but among the disadvantages is a total lack of high-powered radio stations to test experimental antennas under adverse, high-signal level conditions. I had never noticed most of the problems Mark found in his urban location other than a signal clipping under high-level signal generator output levels. In routine DX use, these were not a problem at this location.

I, however, thoroughly welcome the opportunity to correct these shortcomings because I designed and built the *Quantum Loop* to be the best ferrite loop available. If you have already purchased a *Quantum Loop*, please return it to me (I'll reimburse your shipping costs (up to $5.00)) so that I can incorporate Mark's improvements. If you are thinking of purchasing one of the remaining initial 20 loops, be advised that Mark's improvements will be incorporated at no cost.

Again, thanks Mark for making what I think is a good loop, better.