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A Tri Band Antenna for 2 meters, 220 MHz, and 70cm Antenna Without Radials

By: Edison Fong (WB6IQN)

US patent – 9,608,336
QST March 2017

Previous Antennas

- DBJ-1 (QST 2003)
- DBJ-2 (QST 2007)
- DBJ-UHF (CQ 2012) patent 8,947,313

Over 18,000 have been constructed with the help of my students at UC Santa Cruz – Silicon Valley

50% ham use 50% commercial

All of our ideas come from users.

By Edison Fong, WB6IQN

The DBJ-1: A VHF-UHF Dual-Band J-Pole

Searching for an inexpensive, high-performance dual-band base antenna for VHF and UHF? Build a simple antenna that uses a single feed line for less than \$10.

Two-meter antennas are small compared to those for the lower frequency bands, and the availability of repeaters on this band greatly extends the range of lightweight low power handhelds and mobile stations. One of the most popular VHF and UHF base station antennas is the J-Pole.

The J-Pole has no ground radials and it is easy to construct using inexpensive materials. For its simplicity and small size, it offers excellent performance. Its radiation pattern is close to that of an "ideal"

dipole because it is end fed; this results in virtually no disruption to the radiation pattern by the feed line.

The Conventional J-Pole

I was introduced to the twinlead version of the J-Pole in 1990 by my long-time friend, Dennis Monticelli, AE6C, and I was intrigued by its simplicity and high performance. One can scale this design to one-third size and also use it on UHF. With UHF repeaters becoming more popular in metropolitan areas, I accepted the challenge to incorporate both bands into one antenna with no degradation in performance. A common feed line would also eliminate the need for a duplexer. This article describes how to convert the traditional single band ribbon J-Pole design to dual-band operation. The antenna is enclosed in UV-resistant PVC pipe and can thus withstand the elements with only the antenna connector exposed. I have had this

antenna on my roof since 1992 and it has been problem-free in the San Francisco fog.

The basic configuration of the ribbon J-Pole is shown in Figure 1. The dimensions are shown for 2 meters. This design was also discussed by KD6GLF in *QST*.¹ That antenna presented dual-band resonance, operating well at 2 meters but with a 6-7 dB deficit in the horizontal plane at UHF when compared to a dipole. This is attributable to the antenna operating at its third harmonic, with multiple out-of-phase currents.

I have tested single-band J-Pole configurations constructed from copper pipe, 450 Ω ladder line, and aluminum rod. While all the designs performed well, each had shortcomings. The copper pipe J-Pole matching section would be exposed to the

¹J. Reynante, KD6GLF, "An Easy Dual-Band VHF/UHF Antenna," *QST*, Sep 1994, pp 61-62.

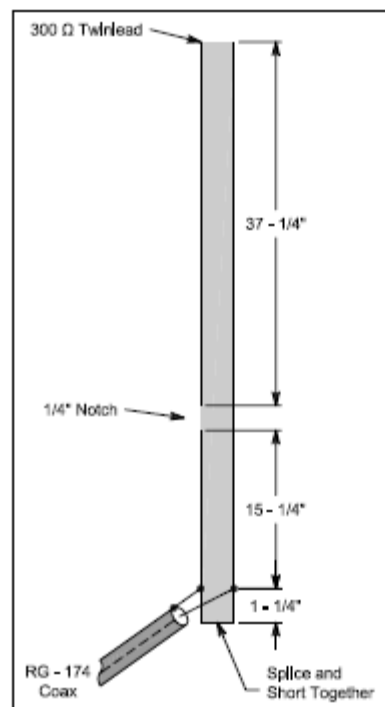


Figure 1—Basic diagram and dimensions for the original 2-meter ribbon J-Pole.

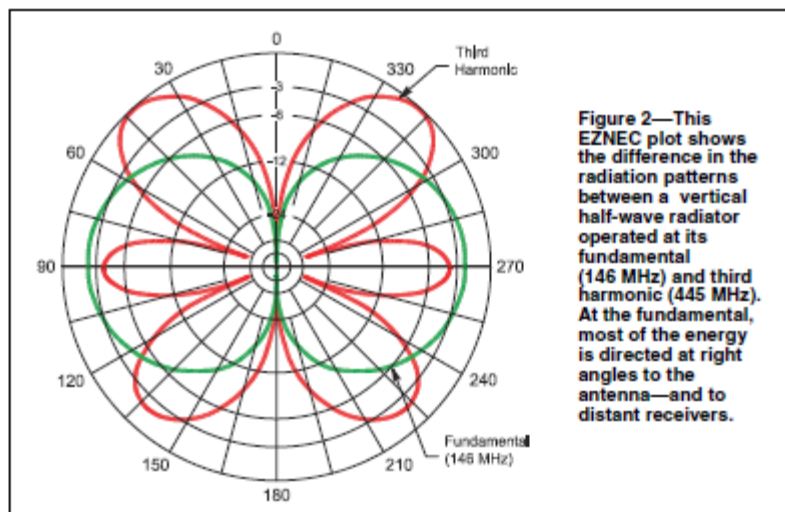


Figure 2—This EZNEC plot shows the difference in the radiation patterns between a vertical half-wave radiator operated at its fundamental (146 MHz) and third harmonic (445 MHz). At the fundamental, most of the energy is directed at right angles to the antenna—and to distant receivers.

The DBJ-2: A Portable VHF-UHF Roll-Up J-pole Antenna for ARES

WB6IQN reviews the theory of the dual band 2 meter / 70 cm J-pole antenna and then makes detailed measurements of a practical, easy to replicate, "roll-up" portable antenna.

Edison Fong, WB6IQN

It has now been more than three years since my article on the dual band J-pole (DBJ-1) appeared in the February 2003 issue of *QST*.¹ I have had over 500 inquiries regarding that antenna. Users have reported good results, and a few individuals even built the antenna and confirmed the reported measurements. Several major cities are using this antenna for their schools, churches and emergency operations center. When asked why they choose the DBJ-1, the most common answer was value. When budgets are tight and you want a good performance-to-price ratio, the DBJ-1 (Dual Band J-pole-I) is an excellent choice.

In quantity, the materials cost about \$5 per antenna and what you get is a VHF/UHF base station antenna with $\lambda/2$ vertical performance on both VHF and UHF bands. If a small city builds a dozen of these antennas for schools, public buildings, etc it would cost about \$60. Not for one, but the entire dozen!

Since it is constructed using PVC pipe, it is UV protected and it is waterproof. To date I have personally constructed over 400 of these antennas for various groups and individuals and have had excellent results. One has withstood harsh winter conditions in the mountains of McCall, Idaho for four years.

The most common request from users is for a portable "roll-up" version of this antenna for backpacking or emergency use. To address this request, I will describe how the principles of the DBJ-1 can be extended to a portable roll-up antenna. Since it is the second version of this antenna, I call it the DBJ-2.

Principles of the DBJ-1

The earlier DBJ-1 is based on the J-pole,² shown in Figure 1. Unlike the popular ground plane antenna, it doesn't need ground

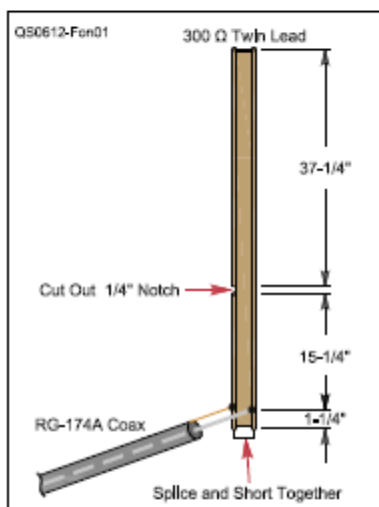


Figure 1 — The original 2 meter ribbon J-pole antenna.

radials. The DBJ-1 is easy to construct using inexpensive materials from your local hardware store. For its simplicity and small size, the DBJ-1 offers excellent performance and consistently outperforms a ground plane antenna.

Its radiation pattern is close to that of an ideal vertical dipole because it is end-fed, with virtually no distortion of the radiation pattern due to the feed line. A vertically polarized, center-fed dipole will always have some distortion of its pattern because the feed line comes out at its center, even when a balun is used. A vertically polarized, center-fed antenna is also physically more difficult to construct because of that feed line coming out horizontally from the center.

The basic J-pole antenna is a half-wave vertical configuration. Unlike a vertical dipole, which because of its center feed is usually mounted alongside a tower or some kind of metal supporting structure, the radiation

pattern of an end-fed J-pole mounted at the top of a tower is not distorted.

The J-pole works by matching a low impedance (50 Ω) feed line to the high impedance at the end of a $\lambda/2$ vertical dipole. This is accomplished with a $\lambda/4$ matching stub shorted at one end and open at the other. The impedance repeats every $\lambda/2$, or every 360° around the Smith Chart. Between the shorted end and the high impedance end of the $\lambda/4$ shorted stub, there is a point that is close to 50 Ω and this is where the 50 Ω coax is connected.

By experimenting, this point is found to be about $1\frac{1}{4}$ inches from the shorted end on 2 meters. This makes intuitive sense since 50 Ω is closer to a short than to an open circuit. Although the Smith Chart shows that this point is slightly inductive, it is still an excellent match to 50 Ω coax. At resonance the SWR is below 1.2:1. Figure 1 shows the dimensions for a 2-meter J-pole. The $15\frac{1}{4}$ inch $\lambda/4$ section serves as the quarter wave matching transformer.

A commonly asked question is, "Why $15\frac{1}{4}$ inches?" Isn't a $\lambda/4$ at 2 meters about 18 $\frac{1}{2}$ inches? Yes, but twinlead has a reduced velocity factor (about 0.8) compared to air and must thus be shortened by about 20%.

A conventional J-pole configuration works well because there is decoupling of the feed line from the $\lambda/2$ radiator element, since the feed line is in line with the radiating $\lambda/2$ element. Thus, pattern distortion is minimized. But this only describes a single band VHF J-pole. How do we make this into a dual band J-pole?

Adding a Second Band to the J pole

To incorporate UHF coverage into a VHF J-pole requires some explanation. (A more detailed explanation is given in my February 2003 *QST* article.) First, a 2 meter antenna does resonate at UHF. The key word here is

¹Notes appear on page 00.

An Omnidirectional Gain Antenna for UHF without Radials

Challenged by a client to design a unique antenna for UHF, WB6IQN came up with a product that surprised him by the increase in gain over the typical collinear antenna. Here is his design adapted for the Amateur Radio Service.

By Ed Fong,* WB6IQN

It has been five years since I published my last article on antennas in QST. Since then, with the help of my graduate students, we have delivered over 5000 of both the base station (DBJ-1) and portable (DBJ-2) dual-band J-pole antennas^{1,2}. These antennas have seen use in both amateur and commercial deployment. I usually get my new ideas from fellow hams since they are the ones who use these antennas on a daily basis.

The antenna presented in this article came about through a request from a commercial telemetry company, AC Daughtry Inc. in New Jersey. It had a very interesting request which I am sure is also shared by the ham community. AC Daughtry Inc. makes telemetry equipment that transmits on the commercial UHF band (465 MHz) in a meshed network. Its application transmitted low power (less than +30 dBm). In the extreme, they would link 10–15 miles

per hop. They needed more than just a rubber duck antenna or ground plane antenna. Here is a condensed summary of the specifications:

1. The antenna needed to be low cost (under \$30).
2. It needed a gain of at least +5 dB over a $1/4\lambda$ whip that was placed on top of the transceiver metal cabinet.
3. The antenna had to withstand extreme outdoor weather conditions with winds over 100 mph and harsh winter conditions in New Jersey.
4. Absolutely no radials (or other protruding elements) due to increased wind load and birds perching on them. With hundreds deployed in a meshed network, they had to be maintenance free. I was told that just one field service call cost the company over \$200.

AC Daughtry basically wanted what every ham desires—low cost, high performance, and good reliability. The high

wind load requirement, cost, and reliability eliminated a multi-element beam as a solution. It is unlikely that one could build a multi-element beam without complex machined parts for the target price. Also, each one would then need to be individually adjusted for best performance and periodically checked for detuning. In the northeastern United States, an exposed gamma match (as used in a beam antenna) would only last, at

*e-mail: <edfong@ieee.org>

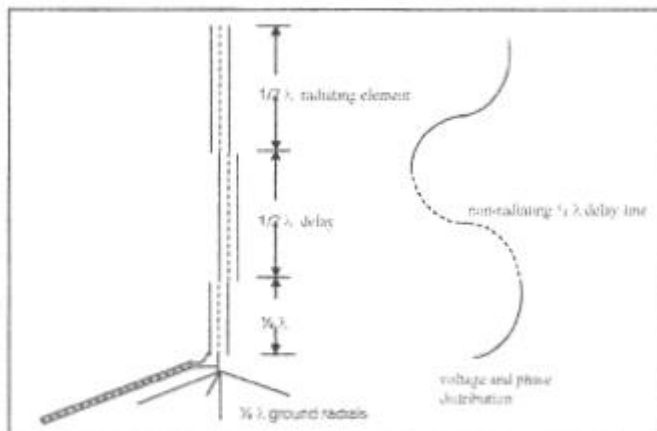


Figure 1. A 2-element collinear, using a ground plane as the root antenna. The voltage and phase are shown on the right.

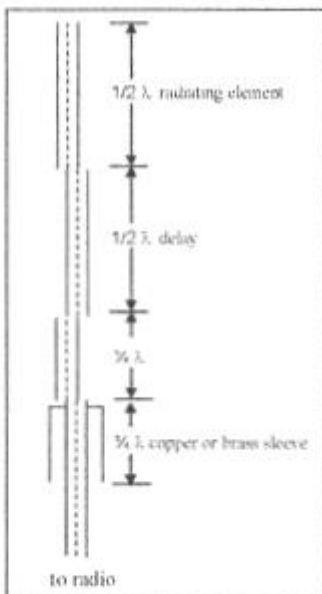


Figure 2. Many commercial antenna manufacturers use the $1/4\lambda$ sleeve in place of the radials for both durability and a slightly lower angle of radiation. Due to the high impedance at the end of the $1/4\lambda$ sleeve interacting with the coax shield, SWR of this configuration is usually high.

A Tri-Band Antenna without Radials for 2 Meters, 1.25 Meters, and 70 Centimeters

An innovative revision of a design the author originally published in QST in 2003.

Edison Fong, WB6IQN, and
Tessa Fong, KJ6QXM

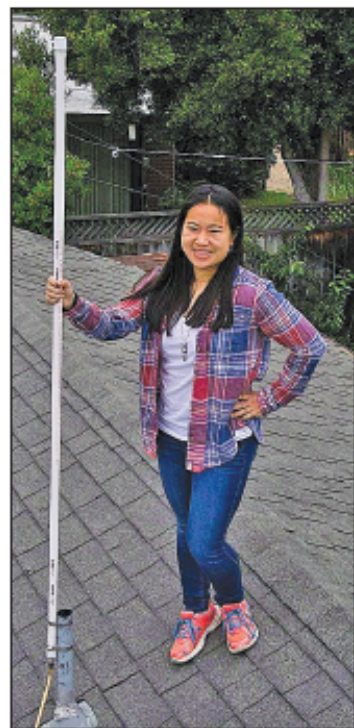
Twenty years ago, a single-band handheld transceiver would have been adequate for most emergency activities, because they were conducted on VHF. Today, both VHF and UHF are used for emergency communications by organizations such as ARES and RACES. In some areas, even the UHF amateur band is full. This was the primary motivation for introducing

the DBJ-1 dual-band J-pole and the DBJ-2 roll-up portable version.^{1,2} Edison, WB6IQN, and his students have built thousands of these over the last 10 years for various ARES/RACES clubs and government agencies.

An often-repeated request was whether the 1.25-meter band could be added to the DBJ-1. In the San Francisco Bay Area, 1.25 meters has some FM voice channels, but its most important use is for packet radio.

Since the development of Outpost Packet Message Manager by Jim Oberhofer, KN6PE, 1.25-meter packet is not only popular in the Bay Area, but has spread nationwide.³ Thus, one antenna that covers 2 meters, 1.25 meters, and 70 centimeters would be very desirable. This would simplify the need for multiple antennas during an emergency deployment. The 1.25-meter band is not harmonically related to any other ham band, and thus, its antenna dimensions for that band are not related to those in the 2-meter or 70-centimeter band. This makes impedance matching difficult, and the construction of such an antenna is not obvious.

If you already own a dual-band DBJ-1, this article will explain how to include the 1.25-meter band by adding some wire, a longer piece of RG-174 lead-in coax, and replacing the 5-foot section of PVC pipe with a 6-foot piece. After maybe an hour's worth of work, you will have a TBJ-1 — a tri-band J-pole — as shown next to Tessa Fong, KJ6QXM, in the lead photo.



[Edison Fong, WB6IQN, photo]

Requirements for an ARES/RACES Antenna

Interviews with multiple emergency coordinators, including American Red Cross and FEMA personnel

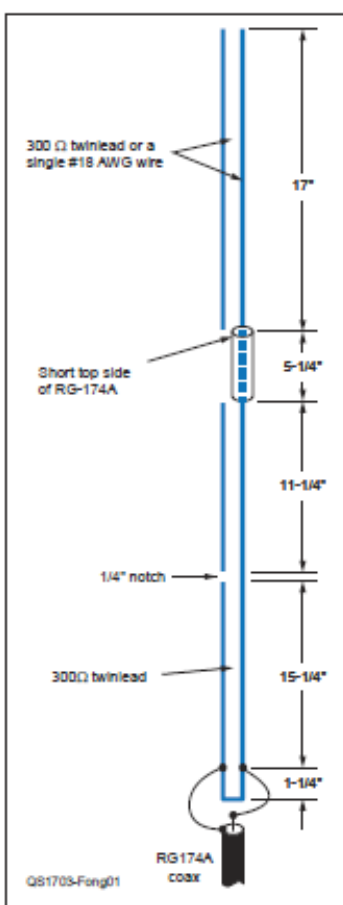


Figure 1 — The original DBJ-1 dual-band J-pole shows the approximate dimensions used when the antenna is inserted into a 3/4-inch OD Class 200 PVC pipe.



US009608336B1

(12) **United States Patent**
Fong

(10) **Patent No.:** **US 9,608,336 B1**
(45) **Date of Patent:** **Mar. 28, 2017**

(54) **RADIAL-FREE COLLINEAR
OMNI-DIRECTIONAL TRIBAND HALF
WAVELENGTH ANTENNA WITH VIRTUAL
GROUND, SINGLE COAXIAL CABLE
FEEDPOINT, AND WITH MINIMAL
INTERACTION OF ADJUSTMENT
BETWEEN BANDS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 47 days.

(21) Appl. No.: **14/834,435**

(22) Filed: **Aug. 25, 2015**

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H01Q 9/04 (2006.01)
H01Q 21/30 (2006.01)
H01Q 9/18 (2006.01)
H01Q 1/36 (2006.01)

(52) **U.S. Cl.**
CPC **H01Q 21/30** (2013.01); **H01Q 1/362**
(2013.01); **H01Q 9/18** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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* cited by examiner

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Esq.

(57) **ABSTRACT**

An omni-directional triband antenna operates without ground radials with gain commensurate with a half wavelength vertical on each band. The triband antenna includes a dual-band twinlead J-pole providing half wavelength radiators for UHF and VHF, and an impedance transformer defining feedpoints to which a length Lc of coaxial cable is attached. The Lc lower end is the triband antenna connector port. Intermediate band radiators are first and second wire elements that collectively are a half-wavelength at the intermediate band. The first element is wound helically about the impedance transformer, with upper end floating and lower end connected to a first feedpoint. The second element is wound helically about the Lc upper portion of coaxial cable, with upper end connected to the remaining feedpoint, and lower end of the element floating. The helical windings radiate vertically and there is no cross-interference between antenna radiation in any of the three bands.

20 Claims, 12 Drawing Sheets



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DBJ-1 - was developed because folks ask whether there was a simple way to convert a 2 meter J-pole into a dual band J-pole

DBJ-2 was developed from the successful performance of the DBJ-1 but folks requested a portable version.

DBJ-UHF was developed from a grant from AC Daughty to develop a low cost medium gain MESH antenna for UHF.

220 MHz not only has repeaters but has become a default band for packet. This is because its modulation is very dense and thus can cause interference to voice channels on the same band.

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Many request for a Tri band base antenna

Not harmonically related to 2 mt or 70cm.

Very difficult.

ARES/RACES /FEMA - requirements

- Must be easy to erect during an emergency. One piece construction desirable.
- Low cost. Certainly far less than commercially available tri band antennas which retail in the \$150 range.
- Good performance
- 5- 6 ft or so in length and radial free for durability.
- Single feed line for VHF/UHF/220MHz operation.
So one antenna works for all bands.

Can the popular DBJ-1 dual band base antenna be adapted to also work at 220 MHz with minimal changes and no degradation of performance at 2 meters and 70cm?

Review of the Literature

J. L. Harris - Stack tri band J-pole QST 1980

Suffers the same problem of 2 mt section radiating at UHF.

Comet CX-333 \$162 uses 3 radials (uses traps)

Diamond – X3200A \$164 uses 3 radials (uses traps)

D. Mariotti – Heavy Duty Multi Band Vertical Antenna – CQ
October 2015 (very expensive)

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Product Features

... 5. Kit Includes: KT-8900R, Speaker Microphone, 6 ft DC Cable with ...



BTECH MINI UV-25X4 25 Watt Tri-band Base, Mobile Radio: 136-174mhz (VHF), 220-230mhz (1.25M), 400-520mhz (UHF) Amateur (Ham)

by BTECH

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Product Features

... Mobile Radio Kit Includes: BTECH UV-25X4, Speaker Mic, 6 foot DC ...



BTECH UV-5X3 5 Watt Tri-Band Radio: 130-179.99mhz (VHF), 220-225.99mhz (1.25M), 400-520.99mhz (UHF) Amateur (Ham)

by BTECH

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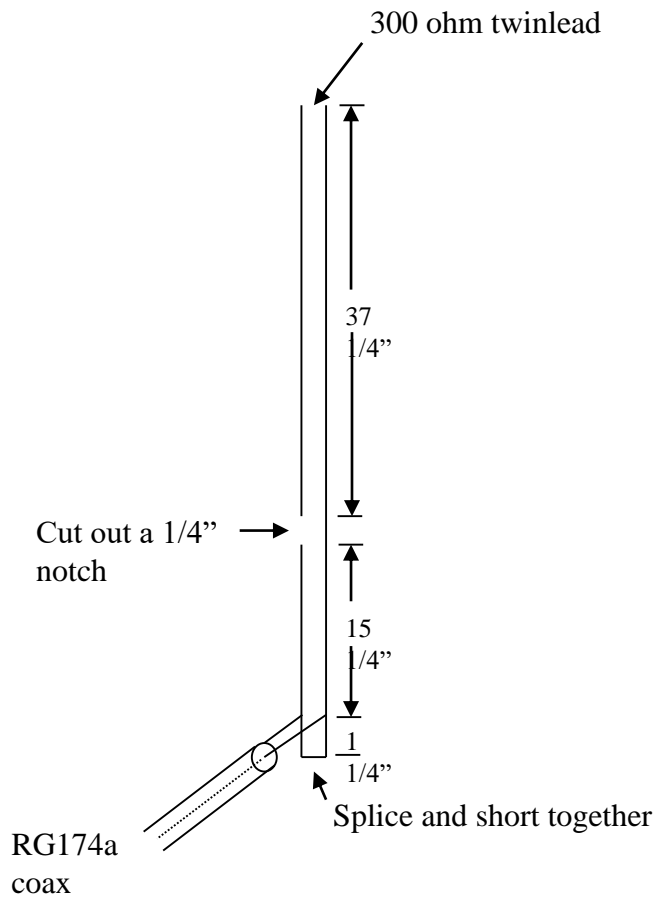
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Review of a Dual Band VHF/UHF Antenna

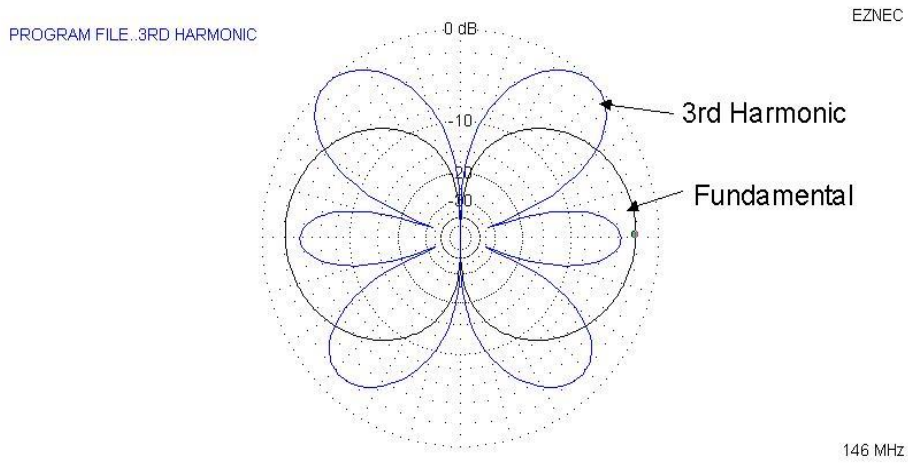
- No inductors, no capacitors, because they are not easily reproduced.
- I tried all types of configurations, but this one seems to work the best.
- Basically matching is the same at VHF and UHF.
- A 1/4 wave decoupling stub (RG174) is used at UHF

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The original 2 meter ribbon J-Pole.

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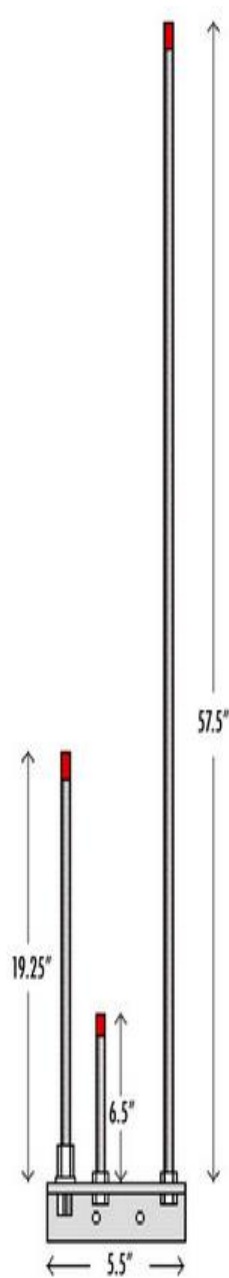
Horizontal pattern of fundamental and 3rd harmonic. At the third harmonic most of the energy is launched at 45°.

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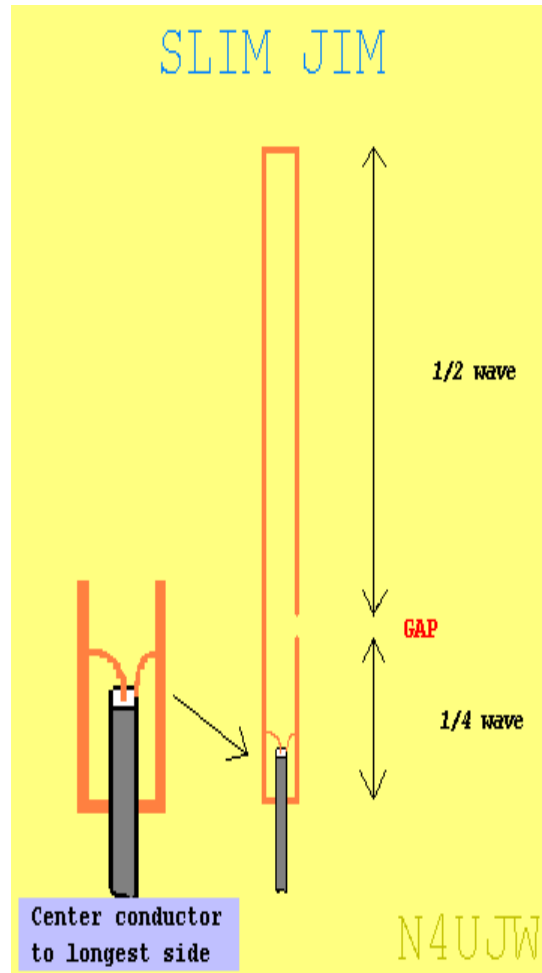
Copper J limited to VHF due to minimum spacing of the parallel pipes. Does not work well for 70cm.

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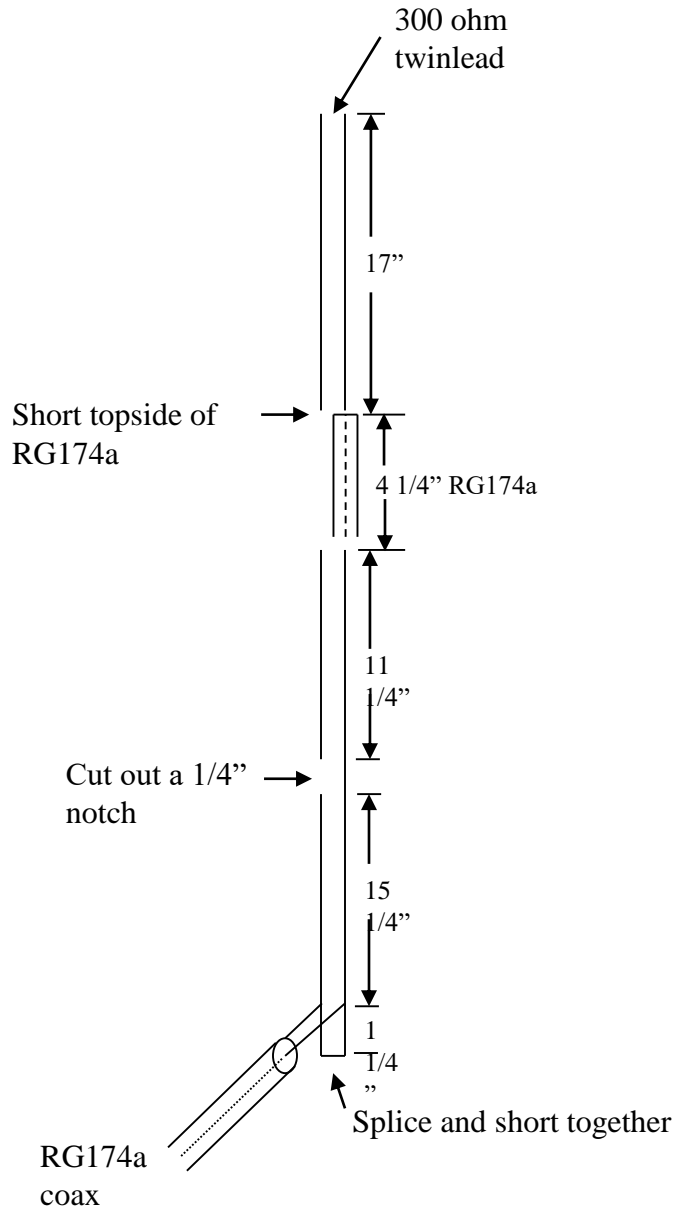
Arrow – VHF/UHF J-pole – does not have decoupling at UHF.

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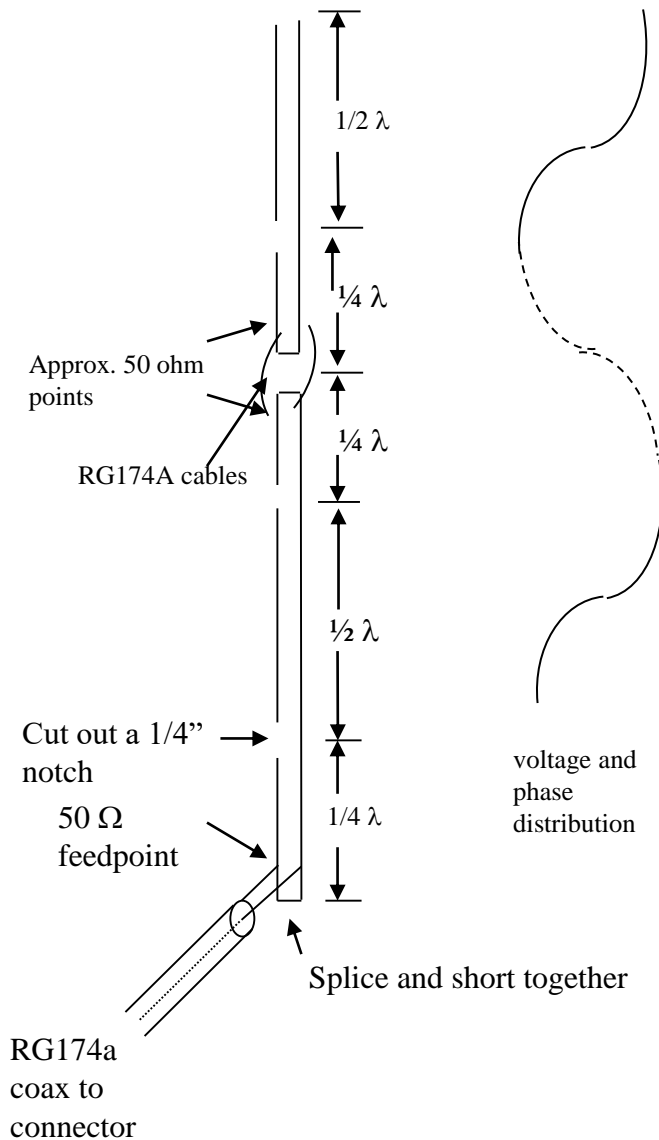
According to Dr. Larry Cebik and myself, there is NO validity to the Slim Jim. Every simulation we have done and physical models both Dr. Cebik and myself have built give the same results as a J-pole.

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The 2 meter J-pole modified for both VHF and UHF operation.

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The two element UHF phase conlinear with the voltage and phase given on the right. Dimensions are given for insertion into $3/4$ inch 200 PSI pvc pipe. US patent 8,947,313

but during transmit, the SWR needle was jumping all over the place. One of these installations was almost in the desert and the other was close to the ocean, on different sides of mountain ranges. One week, the station tested flawlessly; two days later, after a rare rain event, another test was conducted and the result was that the equipment was receiving, but not transmitting. Upon examination, the most inexpensive component of the entire installation was intermittently failing — the amateur

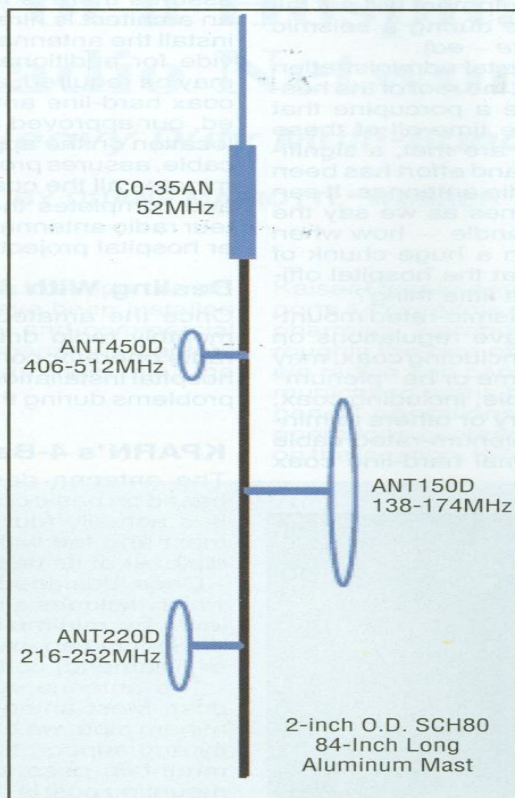
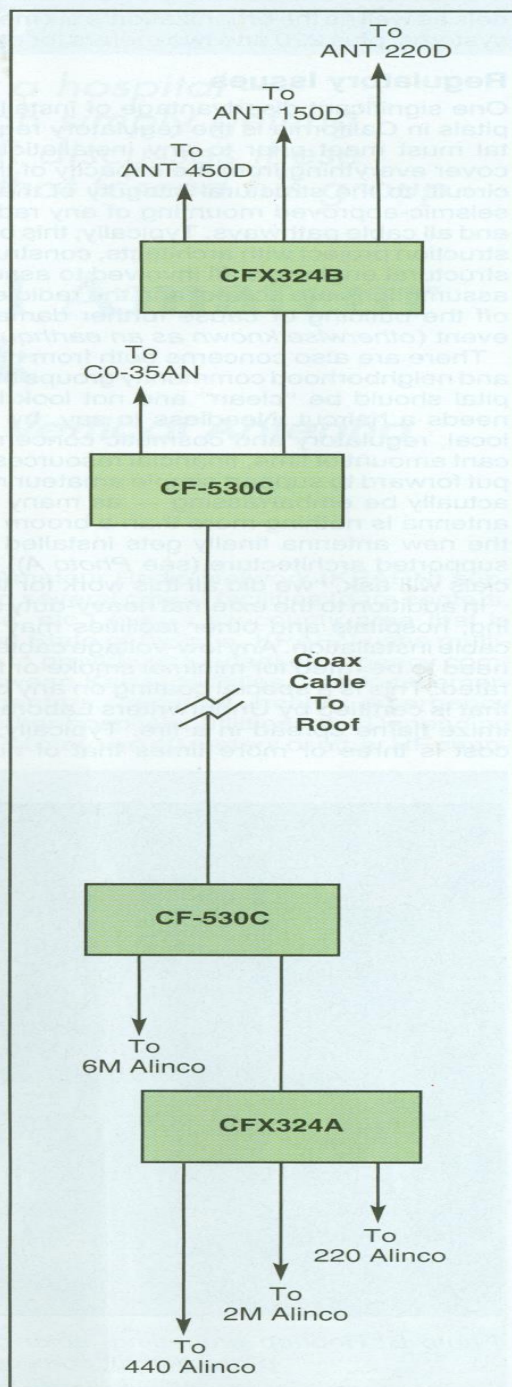


Figure 1. Basic configuration of the four-band commercial amateur radio antenna.

Figure 2. Single-line drawing of antenna and transceiver connectivity. ➔



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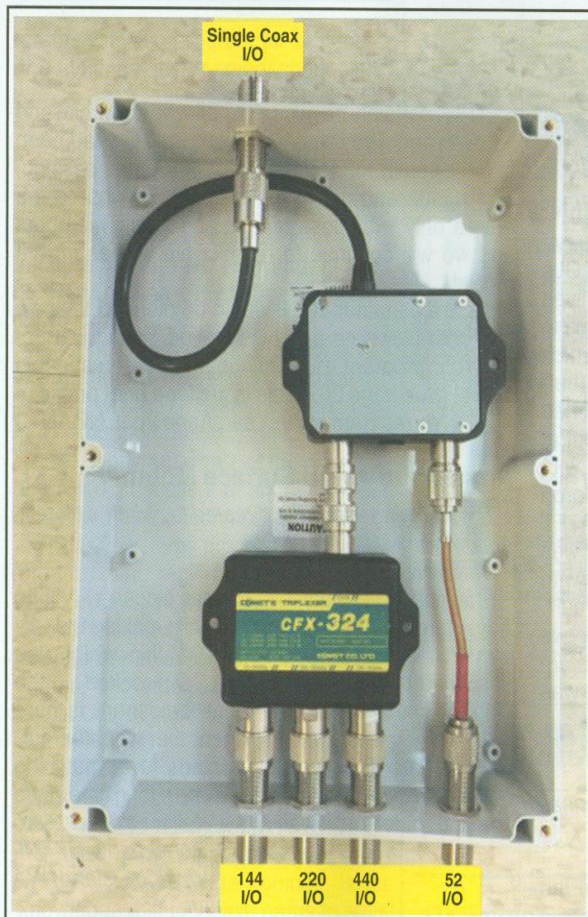


Photo C. Weatherproof housing at base of four-antenna mast. Note this is an early picture. The top connector has since been moved to the bottom to prevent moisture potential — though that has not been an issue recently in light of California's severe drought.

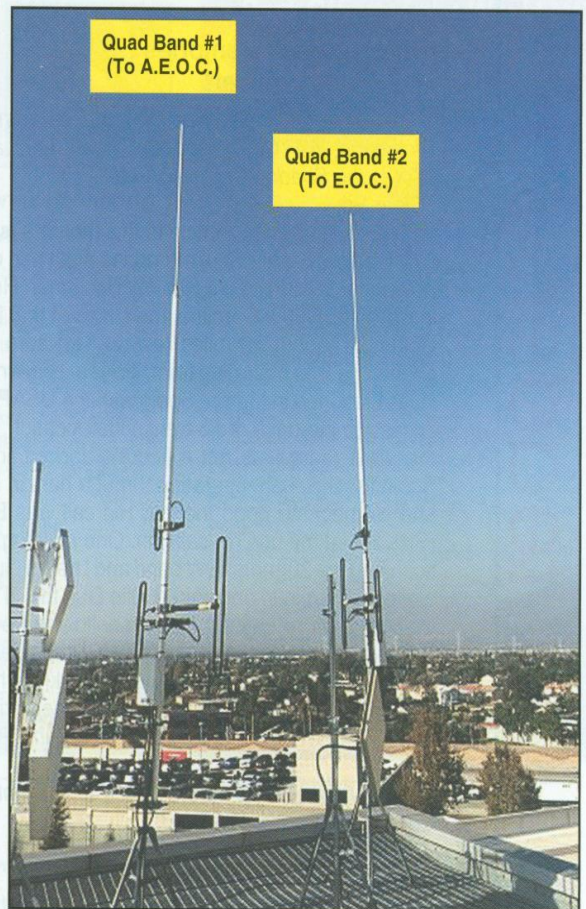
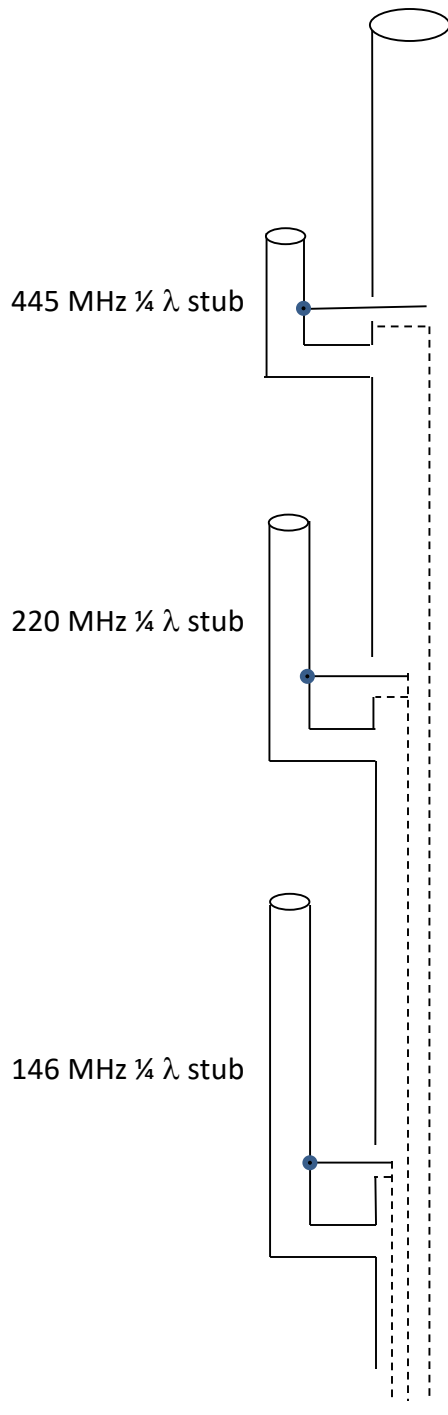


Photo D. Quad-band amateur radio antennas installed on hospital roof.

antenna for the railroad industry and amateur radio. After some work and experimentation, KPARN developed a very



The shield side of the RG174 is soldered onto the main pole and the center conductor is soldered onto the $\frac{1}{4} \lambda$ stub.

UHF performance is quite poor- transmission line matching is poor due to the wide spacing of the copper pipe. It is about 2 inches. 300 ohm twinlead which has a spacing of about $\frac{1}{4}$ inch is much more ideal.

Attach all three RG174 lines to a single feed.

Figure 4 - Tri-band J-pole. (J. Harris) The three RG174a cables are combined at the bottom. The shield side of the coax at each of feedpoints is soldered to the main copper pole.

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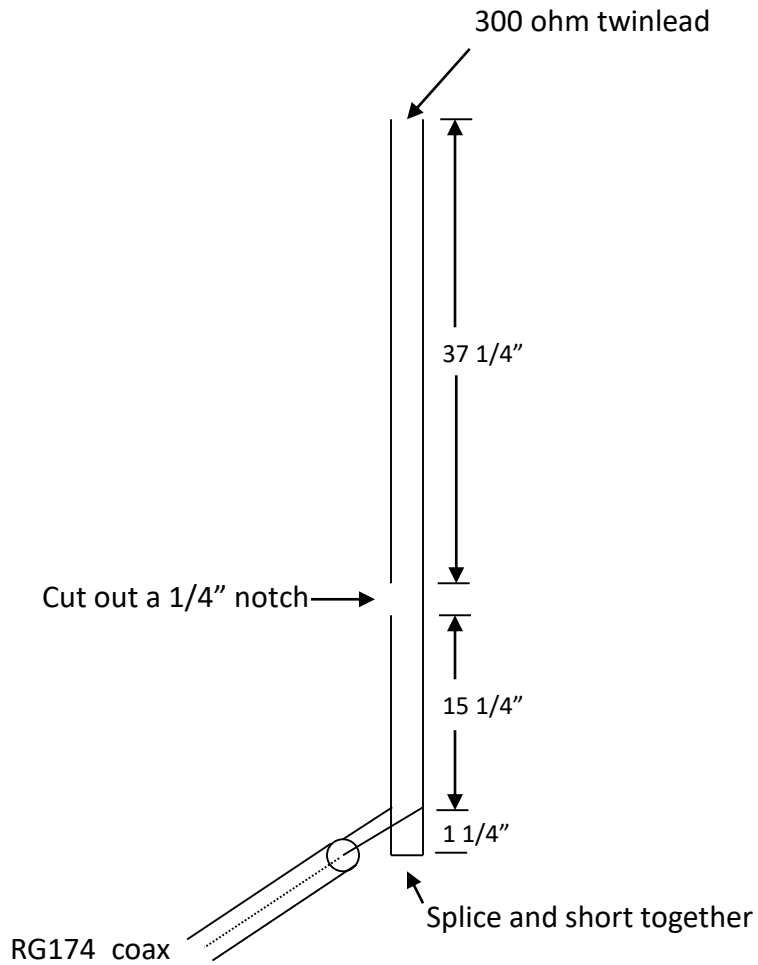


Figure 1 The dimensions of the original 2 meter 300 ohm ribbon J-Pole for insertion into $\frac{3}{4}$ inch 200 psi pvc pipe.

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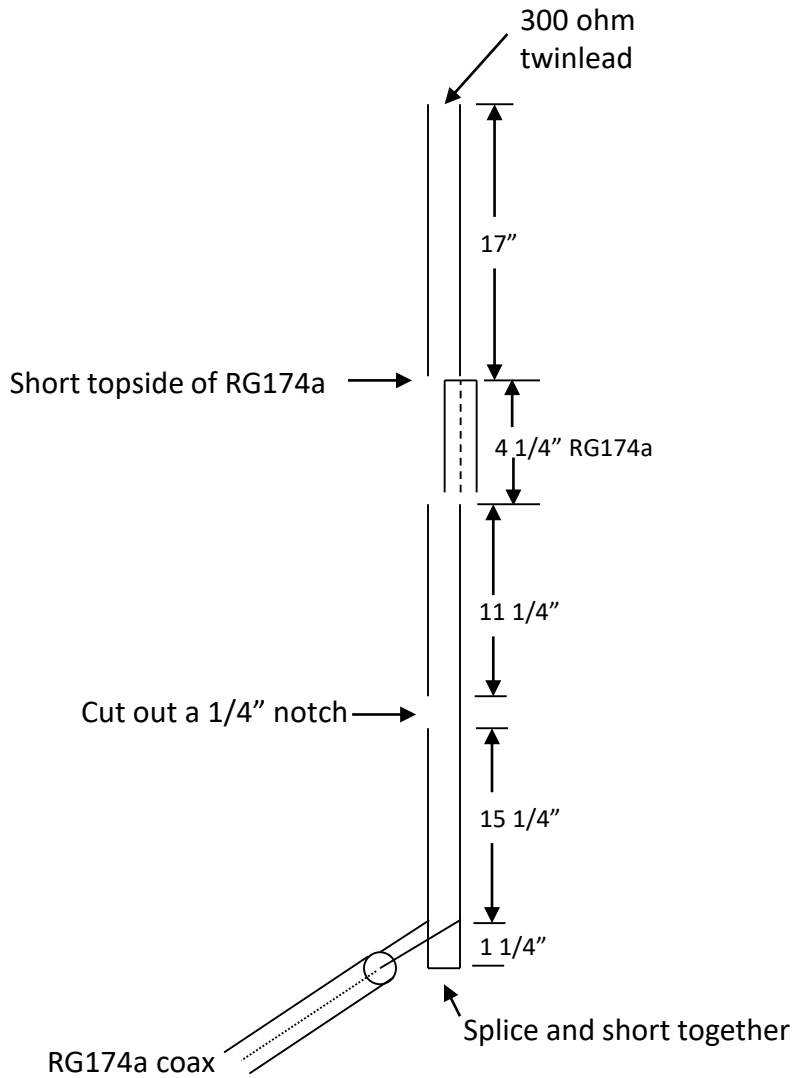


Figure 2 The original DBJ-1 dual band J-pole. with detailed dimensions for insertion into a 3/4 inch Class 200 PVC pipe.

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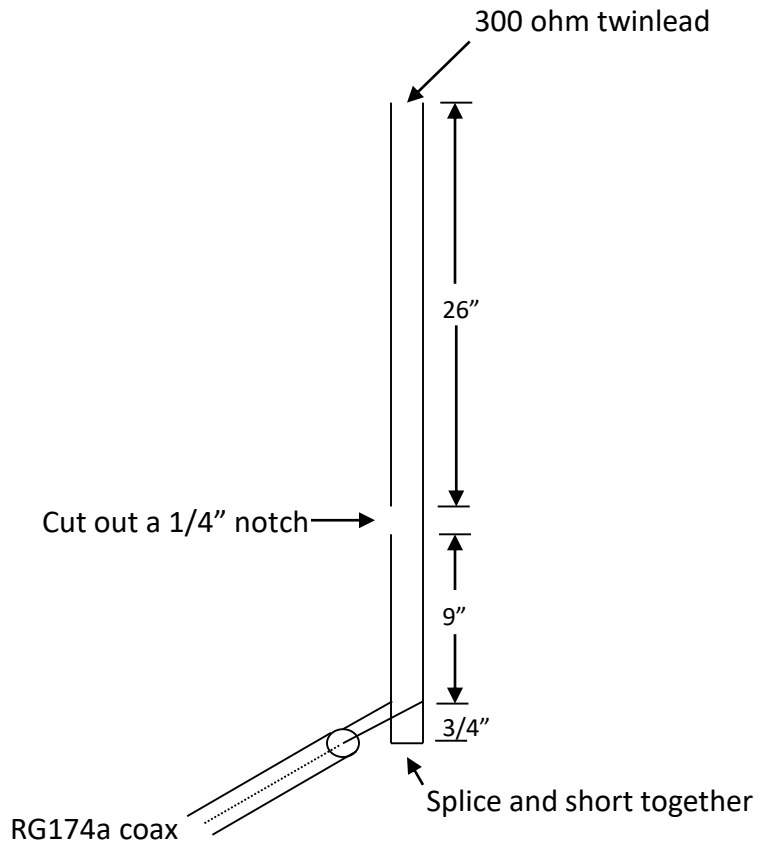
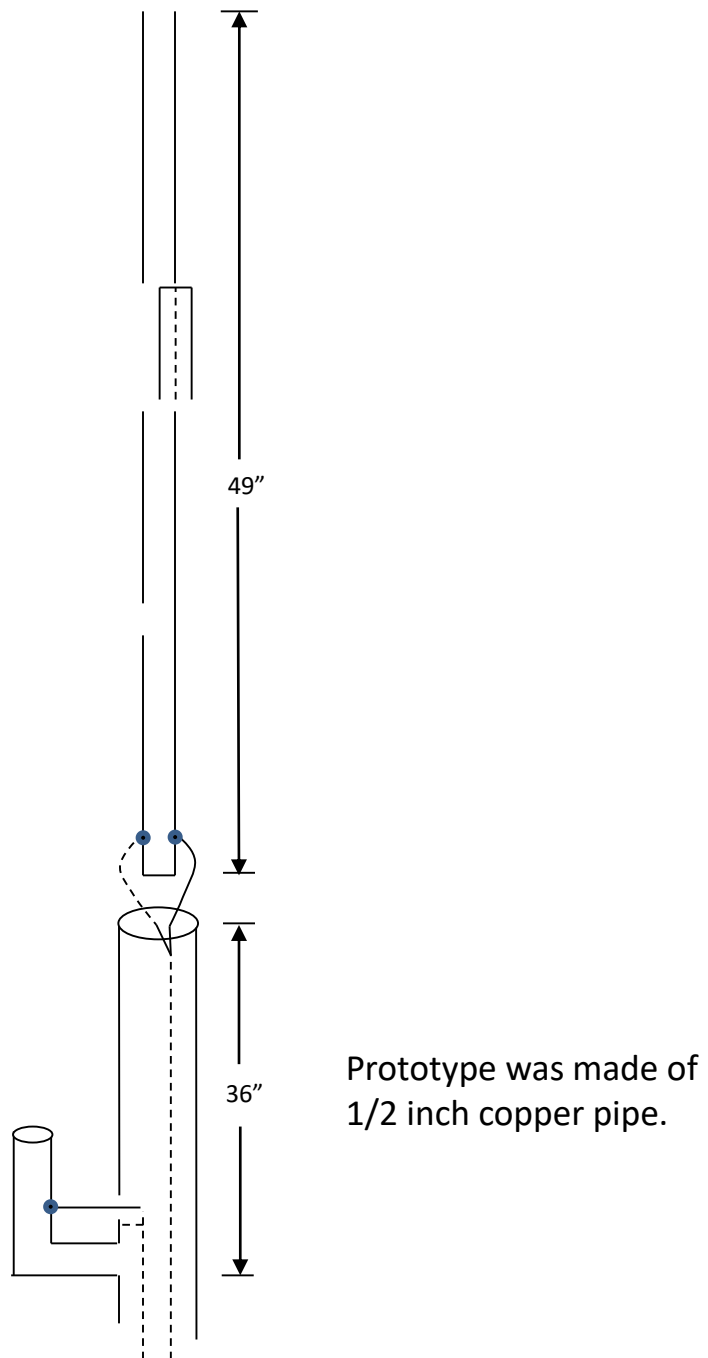


Figure 3 - 220 MHz 300 ohm ribbon J-pole with dimensions for insertion into $\frac{3}{4}$ inch 200 psi pvc pipe.

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Attach both RG174 cables for single feed.

Figure 5 - Dual band J-pole with a 220 MHz copper pipe J-pole attached at the bottom. With the lead-in coax, total length approaches 8ft. Not practical for implementation although triband operation is achieved.

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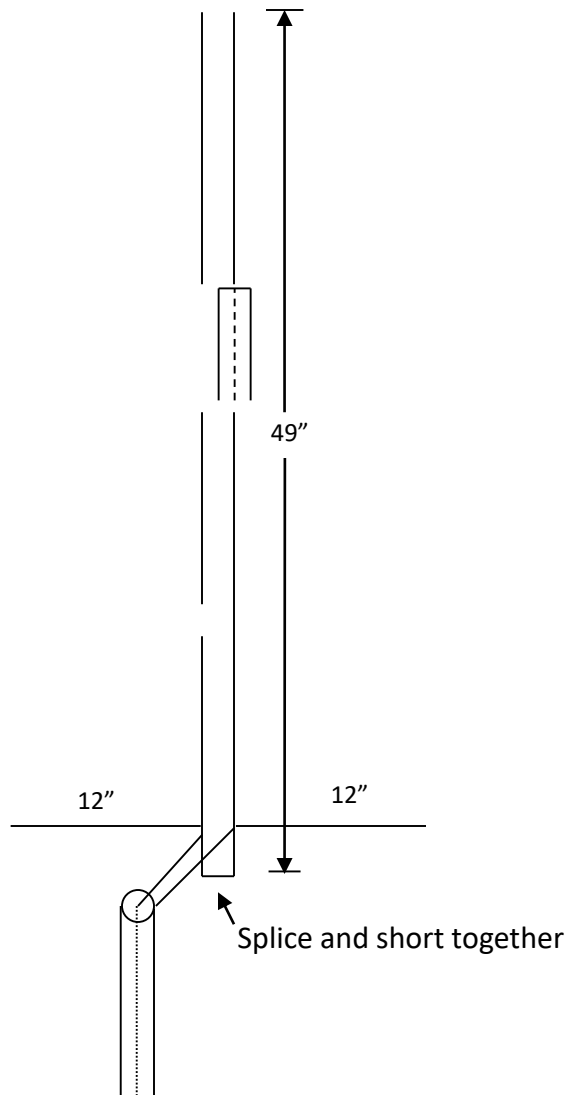


Figure 6 - Dual band J-pole with a 220 MHz horizontal dipole.

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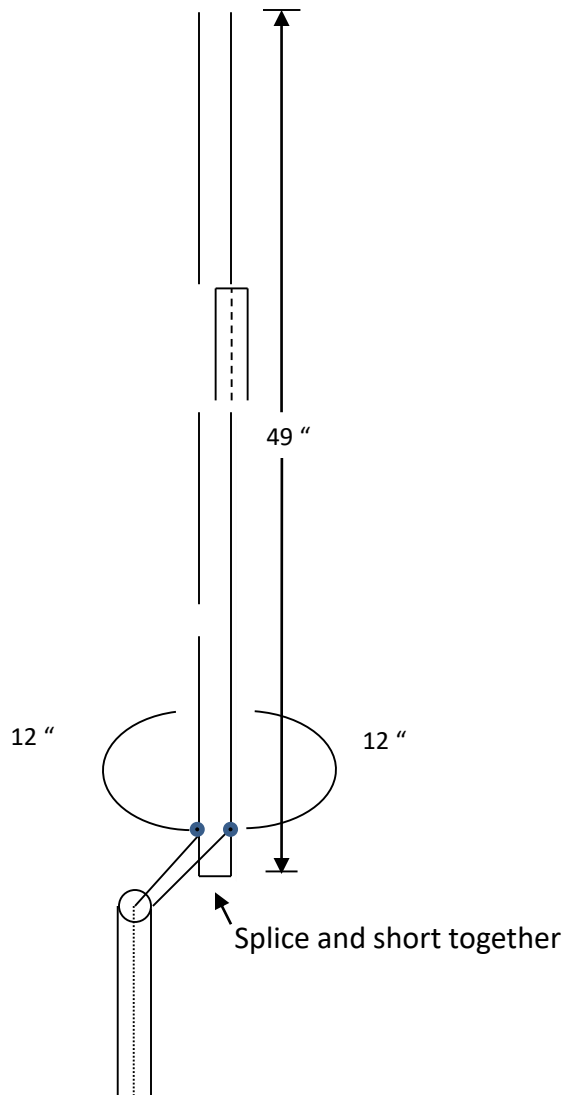


Figure 7 - Tri band antenna with semi vertical polarization. Not practical for implementation.

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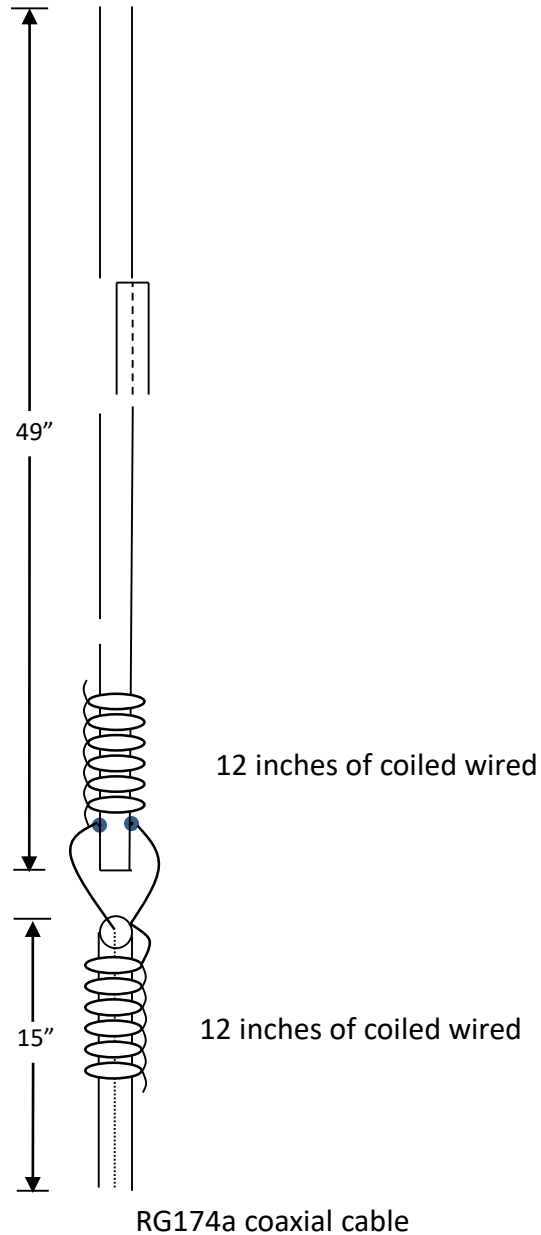


Figure 8 - Tri band antenna with helical loop which allows for insertion into a $\frac{3}{4}$ inch pvc pipe. Total length is 5 $\frac{1}{2}$ feet which is a practical length for $\frac{3}{4}$ inch 200 psi pvc pipe.

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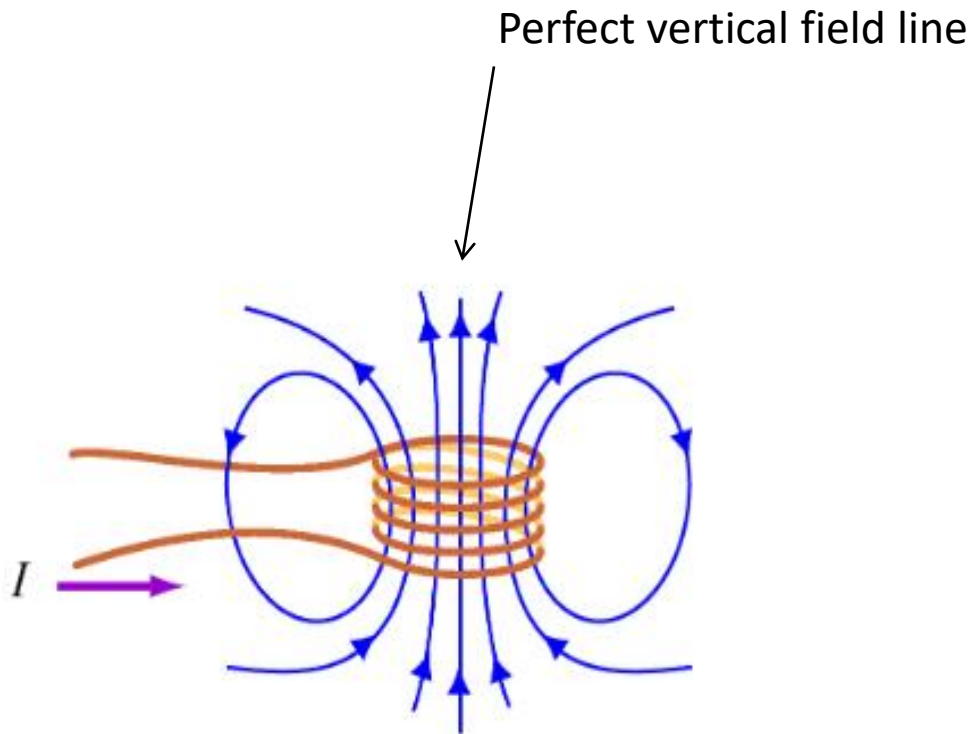


Figure 10 Showing the directions of the magnetic field being driven by a current. The fields are not disturbed if the coil is perfectly symmetric and an ideal thin wire is inserted at the exact center.

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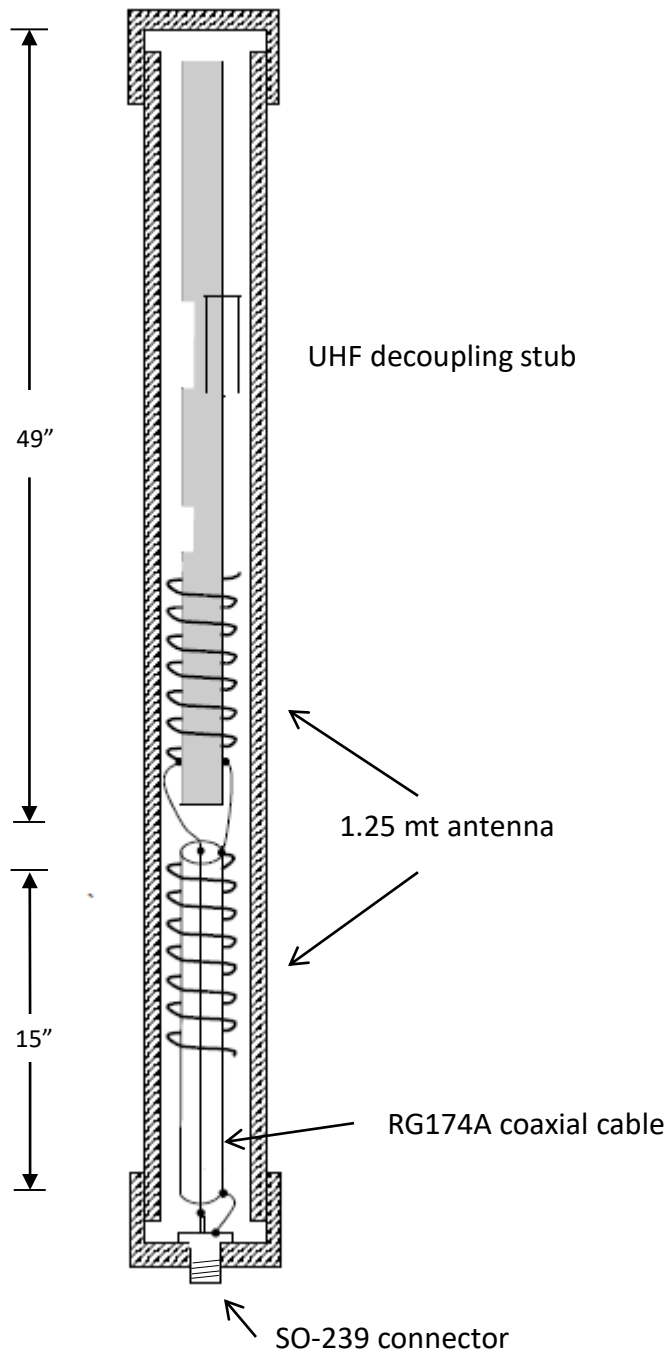


Figure 11 - Tri band antenna with helical loop (not drawn to scale) which allows for insertion into a $\frac{3}{4}$ -inch PVC pipe. Total length is 5 $\frac{1}{2}$ feet which is a practical length for a $\frac{3}{4}$ inch 200 psi PVC pipe.

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Full Size Dipole vs. Coiled Dipole with 12 ft of wire through the center

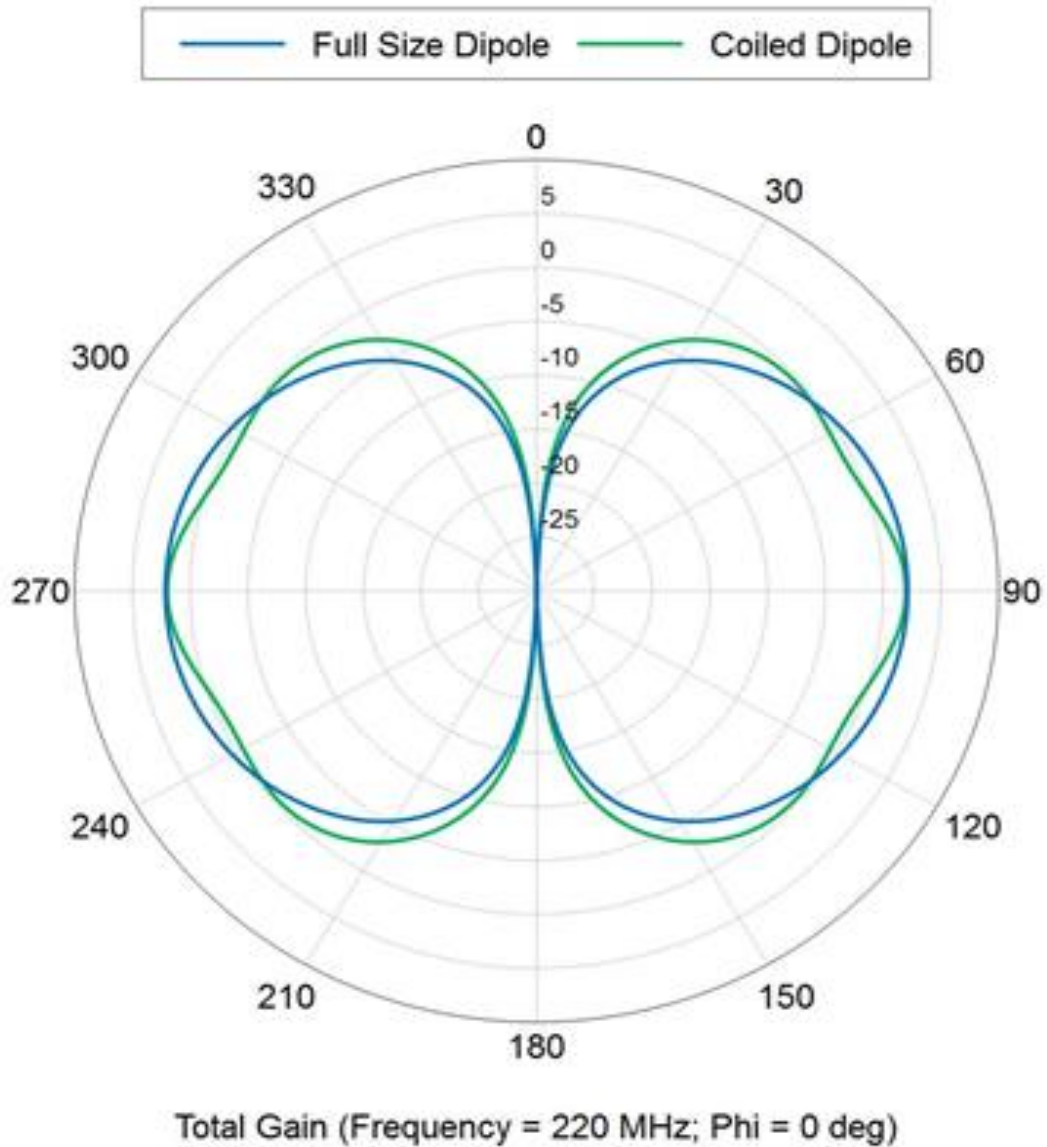


Figure 14 Feko [5] simulation of an ideal dipole at 220 MHz superimposed on the coil dipole with 12 ft of #14 coated wire (mimics RG174A coax) through the ideal center of the coiled dipole.

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Figure 12 Tessa Fong, KJ6QXM, standing next to the completed triband antenna mounted on a roof vent pipe.

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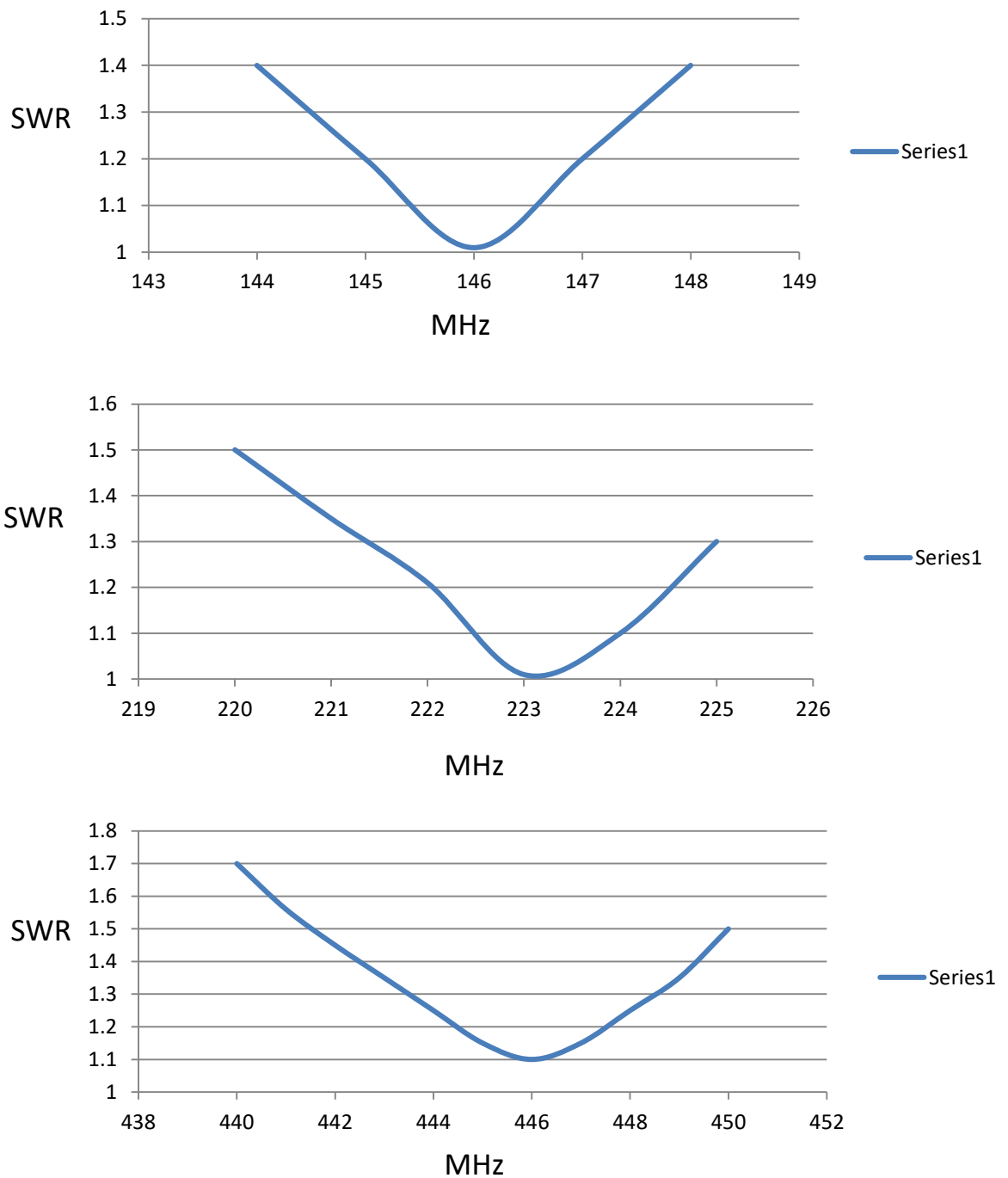


Figure 11 - SWR measurements on 2 meters, 220 MHz and 70cm. All within acceptable limits.

Conclusions - Presented here is a novel base station antenna which covers the VHF (2 meter), 220 MHz, and 70cm amateur band. Matching is excellent on all three bands and can be tuned independently. This antenna meets the demands set by ARES/RACES group for ruggedness, easy deployment, and performance. It requires no radials, is totally weather protected, and only 5 ½ feet tall.

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50 ft RG8x coax cable with molded PL259 connectors \$25

6ft extensions cables (BNC male to BNC female) \$5

BNC – female to PL259 (adapter for roll up DBJ-2 to mobile or base) \$2