The DBJ-2: A Portable VHF-UHF Roll-up J-pole Antenna

By: Edison Fong WB6IQN
email: edison_fong@hotmail.com

Abstract

The theory for a single band J-pole is first described. Based on these fundamentals, a technique is introduced to extend these principles to achieve dual band operation. In particular, a VHF and UHF antenna for the amateur bands. A description is then given on how this dual band principal is applied to a fully portable "roll-up" J-pole antenna. Measured results are then presented.

Introduction

It has now been two years since the original article on the dual band J-pole appeared in the February 2003 issue of QST [1]. Since then, I have had over 500 inquires regarding the antenna. Everyone has reported good results and a few curious individuals even built the antenna and confirmed my measurements. Several cities are using this antenna for their schools, churches and emergency operations center. Why choose such an antenna? When budgets are tight and one strides for good performance to price ratio, the DBJ-1 (**D**ual **B**and **J**-pole**–1**) is an excellent choice. The materials in quantity cost about $5 per antenna and what one gets is a VHF/UHF base station antenna with ½ wave vertical performance on both VHF and UHF bands. If a small city wishes to build a dozen of these antenna for schools, public buildings, etc. it would cost about $60. Not for one, but the entire dozen. Being built of PVC pipe, it is UV protected and waterproof. To date, I have personally constructed over 400 of these antennas for various groups and individuals and have had excellent results. In fact, one has lasted in the mountains of McCall, Idaho for four winters and is still fully functional. The most common request is for a portable roll up version of this antenna for backpacking or ARES. This paper describes 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, it will be referred to as the DBJ-2.

Principles of the DBJ-1

The DBJ-1 is based on the popular J-pole. The advantage of the J-pole, as shown in Figure 1, is that it has no ground radials which makes it easy to construct using inexpensive materials from the local hardware store. For its simplicity and small size, it offers excellent performance and consistently outperforms a ground plane. Its radiation pattern is extremely close to the "ideal" dipole due to the fact that it is end fed which gives virtually no disruption to the radiation pattern due to the feedline. The traditional center fed dipole will always have distortion in its pattern due to the feedline being at the center. The other choice for a good radiator is the traditional ground plane antenna with 3 to 5 radials. The main disadvantage of this configuration is that it is not very convenient to construct. Finding a simple technique to attach the radials reliably with easily obtainable materials is difficult. The ground plane also has much higher wind load due to its ground radials. This makes it undesirable in areas that experience rough weather conditions. A J-pole inside a PVC pipe has very low wind load due to the fact the PVC pipe has no sharp edges or corners.

The basic J-pole antenna works in the following way. The radiator is a half-wave vertical configuration, much like a dipole. What separates this design from a center fed vertical dipole is the method of feeding the half-wave element. Because the feedline in a conventional dipole is center fed, the radiation pattern is disrupted due to the coax feeding the dipole element at right angles at the center of the dipole. The result is a radiation pattern which is off centered since there is usually a tower or some kind of structure which physically supports the vertical dipole. The J-pole is end fed so it does not disrupt the dipole pattern.

The J-pole works by matching a low impedance (50 ohms) to a hi impedance point to feed the ends of a ½ wavelength vertical dipole. This condition is satisfied with a 1/4 wave matching stub shorted at one end and open at the other. The impedance then repeats every one-half wavelength, or every 360^{o} around the Smith Chart. Between the shorted end and the high impedance end; there is a point which is close to 50 ohms. This is the point where the coax is tapped off. By experimenting, this point is found to be about 1 ¼ inches from the shorted end. This makes intuitive sense since 50 ohms is closer to a short than an open circuit. Although the Smith Chart shows that this point is slightly inductive, it is still an excellent match for 50 ohms. At resonance, the SWR is below 1.2:1. Figure 1 shows such a piece of 300 ohm twinlead. The 15 ¼ " quarter wave section serves as a transformer with its input at 50 ohms and its output at some hi impedance point at the quarter wave mark. One might ask, "Why 15 ¼ "? Isn't 1/4 wave at 2 meters about 18 ½"? Yes, but the shorten length is due to the fact that twinlead has a reduced velocity factor over air (about 0.8) and must be shorten by about 20%.

The J-pole configuration described here works well for several reasons. First, there is virtually total decoupling of the input feedline with the half-wave radiator element and second; it minimizes the higher angle of radiation exhibited by a non ideal groundplane.

But this only describes a single band VHF J-pole. How does this become a dual band J-pole?

Adding Dual Band to the J pole

To add UHF to the VHF J-pole requires some explanation. The modification is performed in several steps.

First of all, a 2 meter antenna resonates at UHF. Notice I said “resonates”, I did not say “works” at UHF. Resonating is one thing, working well as an antenna is another. A tuned LC circuit will resonate but that does not imply that it is a good antenna. One must understand that the ¼ wave matching stub works as a ¾ wave matching stub at UHF with virtually no loss except the transmission line losses of the extra ½ wave at UHF. The UHF signal is simply taking one more revolution around the Smith Chart.

The uniqueness of the DBJ-1 concept is that it not only resonates on both bands but actually performs as a ½ wave radiator on both bands. An interesting fact to note is that almost all antennas will “resonate” at their third harmonic. For that matter, any odd harmonic(3, 5, 7, etc.) This can be easily seen via a Smith Chart since the impedance repeats every ½ wave length. This is why a 40 meter dipole can be used on 15 meters. Similarly, a 150 MHz antenna can be used at 450 MHz with a respectable SWR. The difference is that the performance at the third harmonic is poor when the antenna is used in a vertical configuration as in the J pole shown in Figure 1. This can be best explained by a 19 inch 2 meter vertical over an ideal ground plane. At 2 meters, it is a ¼ wave length vertical (approximately 18 inches). At UHF (450MHz) it is a ¾ wavelength vertical. Unfortunately, the additional ½ wavelength at UHF is out of phase with the bottom ¼ wavelength, thus cancellation occurs on the radiation pattern and the majority of the energy is launched at 45^o. This results in about a 4-6 dB loss on the horizontal plane over a conventional ¼ wavelength vertical over a groundplane. A horizontal radiation pattern is shown in Figure 2. Notice that the ¾ wave radiator has most of its energy at 45 degrees.

Thus, although an antenna can be made to work at its 3rd harmonic, its performance is poor. What is needed is a simple reliable method to decouple the remaining ½ wavelength at UHF of the 2 meter radiator but have it remain electrically at VHF. This will result in independent ½ wavelength radiators at both VHF and UHF frequencies. The DBJ-1 executes this arrangement by using a combination of coaxial stubs and 300 ohm twin lead cable as shown in Figure 3. Discrete capacitors and inductors were intentionally avoided in the matching because they are lossey and have extreme variation in production.

Referring to Figure 3 and starting from the connector at the bottom and proceeding vertically is the RG174a lead in cable. Eighteen inches was chosen so that the bottom portion of the antenna can be used to mount the antenna almost on any surface without disturbing the electrical characteristics of the antenna. Next is the ¼ wave VHF impedance transformer made from 300 ohm twin lead. It’s approximate length is 15 inches made from 300 ohm twinlead. It is shorted at the bottom and thus is an open circuit (aka. hi impedance) at the end of the ¼ wave section. This matches well to the ½ wave radiator which is approximately 1 meter long. The 50 ohm tap is about 1 ¼ inches from the short.

For UHF operation, the ¼ wave matching stub is now a ¾ wave matching stub. This is electrically a ¼ wave stub with an additional ½ wavelength. This ideally does not change the impedance since it is simply seen as an extra 360^o trip around the Smith Chart. Since the purpose of the matching stub is for impedance matching and not radiation, it does not directly affect the radiation efficiency of the antenna. It does however suffer some transmission loss from the additional ½ wavelength which would not be needed if it were not for the dual band operation. The best approximation of this loss is about 0.1 dB. Next comes the ½ wave radiating element for UHF which is about 12 inches. To make it electrically terminate at 12 inches, a ¼ wave short at UHF using RG174a is used. Since a ¼ wave short is an open at the other end, the open end is a hi impedance. This open end is then connected to the end of the 12 inches. The "open circuit" from this ¼ wavelength coax is only valid at UHF. Also, notice that it is 4 ½ inches and not 6 inches due to the velocity factor of RG174a which is about 0.6.

At the shorted end of the RG174a is the final 18 inches of 300 ohm twinlead. The 12 inches for the UHF 1/2 wavelength, the 4 ¼ inches of RG174a for the decoupling stub at UHF, and the 18 inches of twinlead provide for the 1/2 wavelength at 2 meters. Note that the total does not add up to a full 36 inches as one may think. This is because the ¼ wave UHF RG174a shorted stub is inductive at 2 meters thus slightly shortening the antenna.

Making it Portable

The single most common question that people ask regarding the DBJ-1 is how it can be made portable. The original published article had the antenna (Fig. 3) inserted into Class 200 PVC pipe [1]. To make it portable was quite a challenge for me. After much thought, I came up with the following.

The key is making it all one piece. Any splices and the durability is compromised. I choose to make it from one piece of 300 ohm twin lead and then cut out the unused conductive portions leaving the backbone structure intact. Figure 4 shows a version suitable for portable use. It is made from one piece of 300 ohm twinlead. The cut outs parallel to the ¼ wave stub are necessary to minimize coupling of the electrically unused portion of the 300 ohm twinlead. Because this antenna does not sit inside a PVC tube, it radiates directly into the air. This makes the dimension of this antenna slightly longer than the original DBJ-1 due to the increase in velocity factor. The dimensions are about 5% longer. Cover both the bottom tap point and UHF matching stub with heat shrinkable tubing

Some notes on using the antenna. To this date, I have made about a dozen of these antennas for prototyping. It makes a great antenna to put into your emergency communications kit. It fits easily into a ziploc bag. Here are some hints for best performance. The top end of the antenna is a high impedance point, so keep objects (even if they are nonmetallic) away from this point as far as possible. As with any antenna, it works best as high as possible and in the clear. Drill a small hole at the top tip of the antenna and loop a tie wrap around it so it can be used as loop for connecting to a string for hoisting. Make sure the string is non-conductive.

Measured Results

As the chart shows, this antenna should give a good 6dB improvement over a rubber duck antenna. In actual practice, since the antenna can be mounted higher than the rubber duck at the end of one's HT, results of +10dB are not uncommon. This is the electrical equivalent giving 4 watt handie talkie a boost of up to 40 watts.

Table I Measured relative performance of the dual band antenna at 146MHz.

VHF ¼ wave mobile	VHF rubber duck	Standard VHF J-Pole	Dual Band J-Pole
-24.7db	-30.5 dB	-24.34 dB	-23.47 dB

Table II Measured relative performance of the dual band antenna at 445 MHz.

UHF ¼ wave mobile	UHF rubber duck	Standard VHF J-Pole	Dual Band J-Pole
-38.8 dB	-45.3 dB	-45 dB	-38.8 dB

As can be seen, the dual band J-pole configuration outperforms the 2 meter J-pole operating at UHF by about 6 dB's. This is SIGNIFICANT. Figure 5a shows a spectrum analyzer plot of the standard 2 meter J-pole at UHF and Figure 5b shows the modified J-pole at UHF. Basically, the 2 meter J-pole performs equivalently to a rubber duck when used at UHF. Also note that there is NO measureable difference in performance at 2 meters with the modified J-pole versus a conventional J-pole. One also has confidence in these measurements since the rubber duck is about -6dB's from that of the ¼ wave mobile antenna at both VHF and UHF. This agrees well with the previous literature.

Reference

1. Edison Fong, "The DBJ-1: A VHF-UHF Dual Band J-pole," QST, Feb. 2003 pp. 38-40

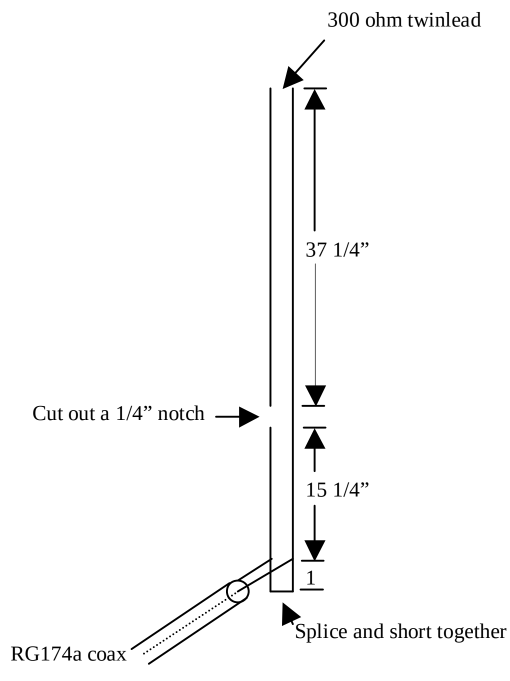

Figure 1 The original 2 meter ribbon J-Pole.

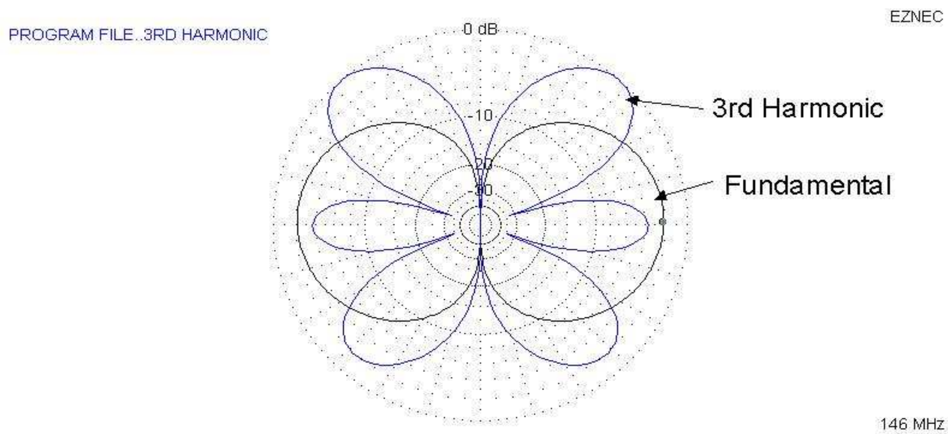

Figure 2 Horizontal pattern of fundamental and 3rd harmonic. At the third harmonic most of the energy is launched at 45°.

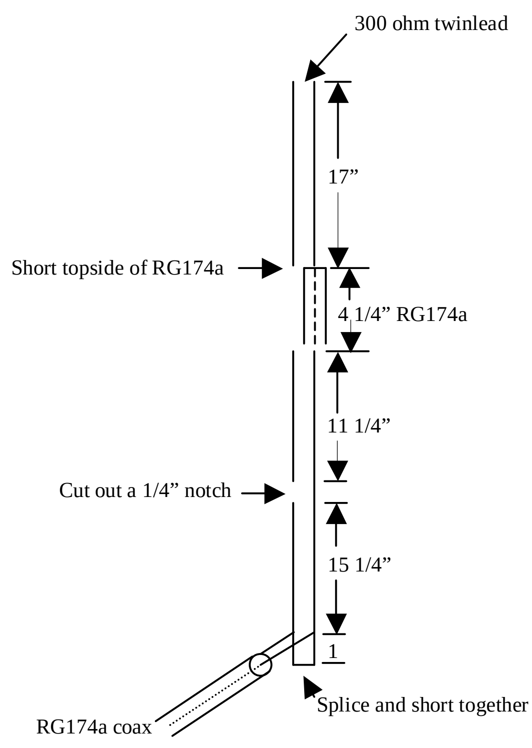

Figure 3 The 2 meter J-pole modified for both VHF and UHF operation.

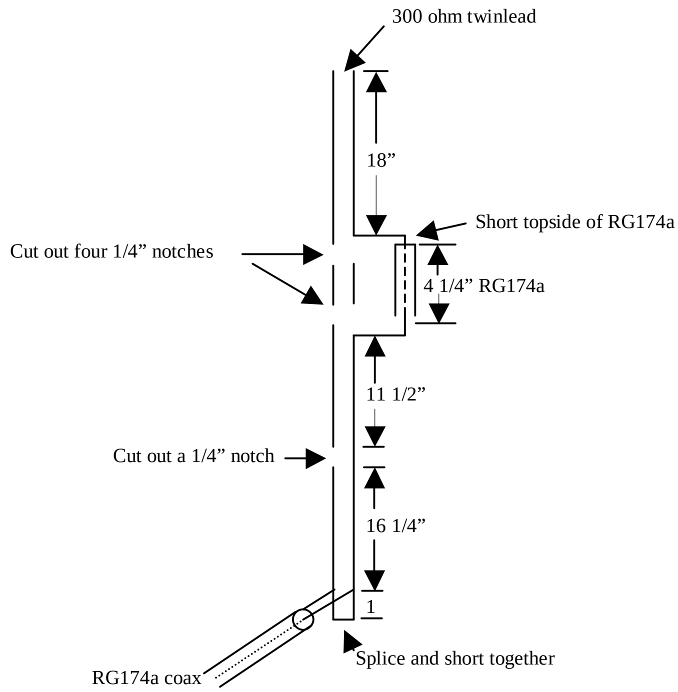

Figure 3 The dual band J-pole modified for portable operation. Note that dimensions are slightly longer due to the velocity factor of air.

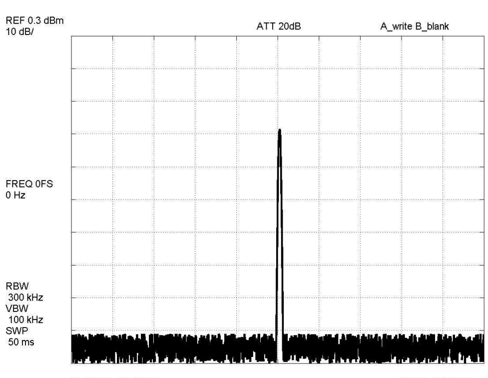

Figure 4a 2 meter J-pole at UHF.

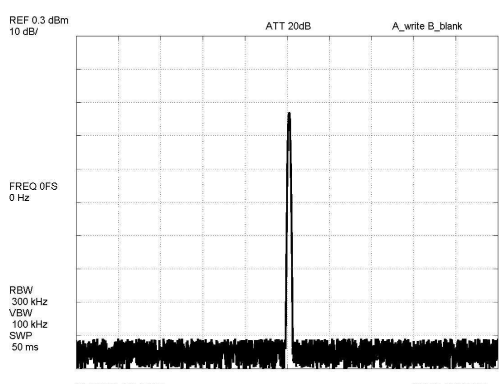

Figure 4b DBJ-1 at at UHF.