



Every now and again during research for background material for RSARS e-Library articles, a new source of really well written articles is discovered. The Mississauga Amateur Radio Club Ontario Canada produces a well written newsletter with interesting material from its club members, Ed Spingola's (VA3TPV) three articles describing Multi-band HF Antennas appear in the February, March, April 2010 editions of "The Communicator".

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*"It is the exchange of ideas and information that makes Ham Radio what it is"*  
Ed Spingola



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## The Communicator

Newsletter of the Mississauga Amateur Radio Club

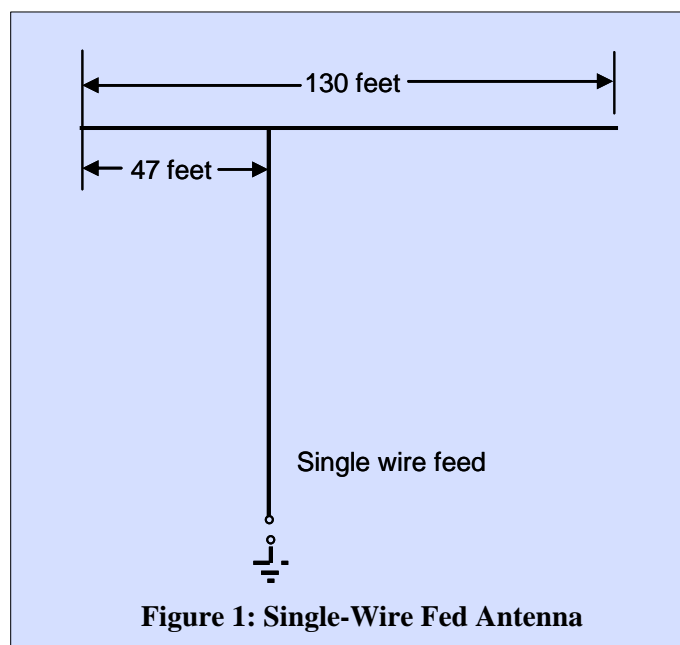
### Multiband HF Antennas, Part 3, Windom and OCF Dipole By Ed Spingola, VA3TPV

In the first two parts of this series on Multiband HF Antennas, we had a look at the G5RV and its cousins the W5ANB and the ZS6BKW, the Fan Dipole, and the Trap Dipole multiband HF antennas. These antennas are balanced antennas since their construction is symmetrical

about the feed point. In our quest for a single wire HF all band antenna, the attention in Part 3 of this series will look at a class of asymmetric antennas where the feed point is not at the centre of the antenna. These antennas are commonly called Off-Center-Fed (OCF) dipoles. However, before we get in what we commonly think of as an Off-Center Fed Dipole, I will give some historical background on the development of this class of antennas.

#### Background

In the 1920's radio amateurs were experimenting with single-wire-feed systems to couple the transmitter energy to the antenna system. The single-wire feed-line has been credited to Frank Conrad, 8XK, of Westinghouse, who used it in the broadcast band to feed a quarter-wavelength grounded (Marconi) antenna. The Marconi antenna is commonly what we refer today as a grounded vertical antenna with ground radials. The next step was made by Landon, 8VN, who connected the single feed-wire to the junction of the antenna and an above ground counterpoise<sup>1</sup>. Later Williams, 9BXQ, modified the system by stretching the counterpoise as part of the antenna<sup>2</sup>. Williams had arrived at the T-configuration of Figure 1: Single-Wire Fed Antenna.



#### Windom

Loren Windom, 8GZ/8ZG, was an amateur radio operator living in the Columbus, Ohio, area. Windom was an active experimenter working on antennas. In July, 1926, Robert S. Kruse, QST Technical Editor, published an article giving the know knowledge, at that time, of how to feed antennas<sup>4</sup>. The article included a discussion by Windom on how to adjust an off-center fed antenna. The method included hanging an RF current indicator, a light bulb, at the center of the antenna and adjusting the feed point, the point at which the single wire feed is connected to the antenna, for maximum lamp brilliance. This method could only be done on a dark night. Daytime tuning was out of the question. Incidentally, Windom was a Law student at Ohio State University and became associated with John Byrne, 8DKZ, a student in electrical engineering.



The OCF antenna, to become known as a Windom3 antenna, was described by Loren Windom, W8GZ/W8ZG, in QST, Sept. 1929. The Windom is an antenna fed off-center at the 1/3 point with a single vertical feed-wire, not the familiar two wire ladder line that we may use today. Because of the off-center feed, the Windom is not a balanced antenna. The Windom dimensions are shown in Figure 1: Single-Wire Fed Antenna.

In Windom's QST, Sept. 1929, article, Windom clearly states that he is not the inventor of this antenna configuration but merely the documenter of work done by John Byrne, of Bell Telephone Laboratories, Ed Brooke, also of Bell Telephone Laboratories, and John Ryder, under the direction of Prof. W. L. Everitt of the Department of Electrical Engineering, Ohio State University. Windom gives sole credit to the above mentioned and notes that he is only the reporter. In fact it is a little more complicated than this. Windom had occasionally assisted Byrne with his antenna measurements and was completely familiar with the procedures. Also, Byrne was publishing his work, part of his final year thesis, and did not want to publish in the amateur radio journal. As it turned out due to a delay in the publication of Byrne's article in the Proceedings of the IRE, Oct, 1929, Windom's article was the first in print to describe this work. An Australian amateur radio journal was the first to associate the name Windom with a 1/3 single wire-fed antenna.

Let's summarize where we are at this point in history. We have an off-center-fed multiband HF antenna fed at approximately the ratio of 1/3. The total antenna length is  $\ll$  wavelength at the lowest frequency of operation. The feed point of approximately 1/3 is chosen such that there are no standing waves i.e. SWR 1:1 at the operating frequency in the feed-wire. It was well known at that time that the approximate 1/3 feed point was influenced by such factors as antenna wire height and diameter. Thus the antenna needed to be tuned in situ.

## Antenna Theory

One of the most important aspects of an antenna is its impedance which is composed of both resistance and reactance. The resistance and reactance depend upon a large number of factors including height above ground, wire diameter, nearby obstructions,

and the length of the antenna compared to a half-wavelength. The feed point impedance can be calculated with antenna modelling programs such as EZNEC, Nec2Go, 4NEC2, NEC4WIN, etc. It is well known that the impedance of a resonant antenna only has a resistance component and has no reactance. Since the antenna is resonant, the reactance looking into any other point along the antenna, also has no reactance. The inductive and the capacitive reactance cancel as in a parallel tuned circuit. What about the resistive component of the impedance?

For a half-wavelength dipole, the resistive component at the center of the antenna is considered to be 72 ohms when the antenna is in free space. The input impedance at any point along its length can be calculated knowing the input impedance at its center i.e. 72 ohms. When an antenna is very thin, the current distribution along its length is essentially cosinusoidal, as shown in Figure 2.

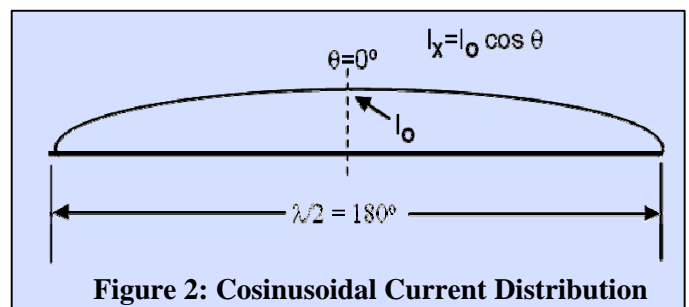


Figure 2: Cosinusoidal Current Distribution

The resistance component of the impedance as a function of length along the antenna becomes

$$R_x = R_o / (\cos \theta)^2$$

Where  $R_o = 72$  ohms, and  $\theta =$  distance in degrees from the center of the antenna. The theoretical input resistance of a half-wavelength dipole varies from 72 ohms at the center of the antenna to several thousand ohms near the ends of the antenna.

Using this information, Windom, Byrne, et al, found that the 1/3 feed point was a good match i.e. low SWR for a single wire feeder.

## Harmonic Operation

Off-centre-fed antennas have an advantage over balanced center-fed dipoles because an off-center fed antenna will also resonate on approximately even-order harmonics. However, because of antenna end effects, the harmonic resonant frequencies are not exact multiples of the half-wavelength resonant frequency.



A half-wavelength antenna resonant at 3.725 MHz will also resonate at 7.235, 14.656, 22.077, and 29.498 MHz. Some of these frequencies are outside of the amateur bands. An antenna tuner may help in some situations, but may not be possible in others because of excessive SWR.

Another aspect of harmonic operation is that the antenna impedance increases with increasing harmonic frequency. The resonant frequencies of an antenna are given by

$$FO = 481/LT \text{ for } n=1 \text{ and}$$

$$FO = 492(n-0.05)/LT \text{ for } n>1$$

Where  
 n is the number of half-wavelengths at resonance  
 FO = resonant frequency in MHz  
 LT = overall length of the antenna in feet

The following table<sup>13</sup> gives the impedance of a dipole at the fundamental and various harmonics.

- Fundamental: 73 ohms
- 2nd Harmonic: 94 ohms
- 3rd Harmonic: 106 ohms
- 4th Harmonic: 115 ohms
- 5th Harmonic: 121 ohms
- 6th harmonic: 127 ohms
- 7th Harmonic: 131 ohms
- 8th Harmonic: 135 ohms
- 9th Harmonic: 138 ohms
- 10th Harmonic: 141 ohms
- 11th Harmonic: 144 ohms
- 12th harmonic: 147 ohms

## Carolina Windom

The Carolina Windom, as the name implies, is a variation of the single wire-fed Windom antenna. The Carolina Windom was devised by Edgar Lambert, WA4LVB, Jim Wilkie, WY4R, and Joe Wright, W4UEB, who modified Windom's single wire-fed antenna to form a dipole fed with a parallel feed-line. The Carolina Windom is the first off-center fed dipole antenna.

The original Carolina Windom was 131 feet 10 inches in length and resonates at 3550 Mhz at a height of 35 feet.

The antenna works on the 10 to 80 m bands with a tuner.

There are many variations of the Carolina Windom. However, all have a ratio of 37.8 to 62.2% to the feed point. The version shown in Figure 3 covers the 10 through 80 meter bands with the use of a tuner.

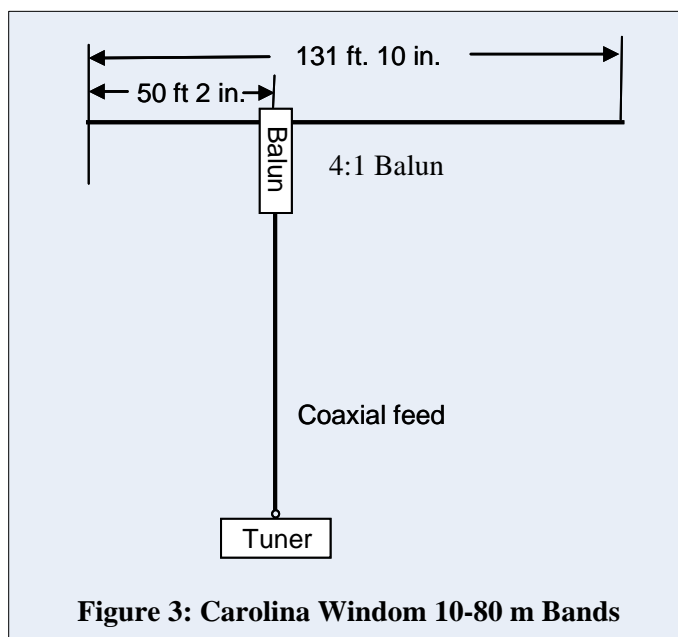


Figure 3: Carolina Windom 10-80 m Bands

Figure 4 shows a short 66 foot version of the Carolina Windom by K4IWL which covers the 10 through 40 meter bands<sup>21</sup>. This version has a 4:1 balun at the antenna, 10 feet of RG-58 coax, and a line isolator (choke) at the end where it meets the coax to the transceiver.

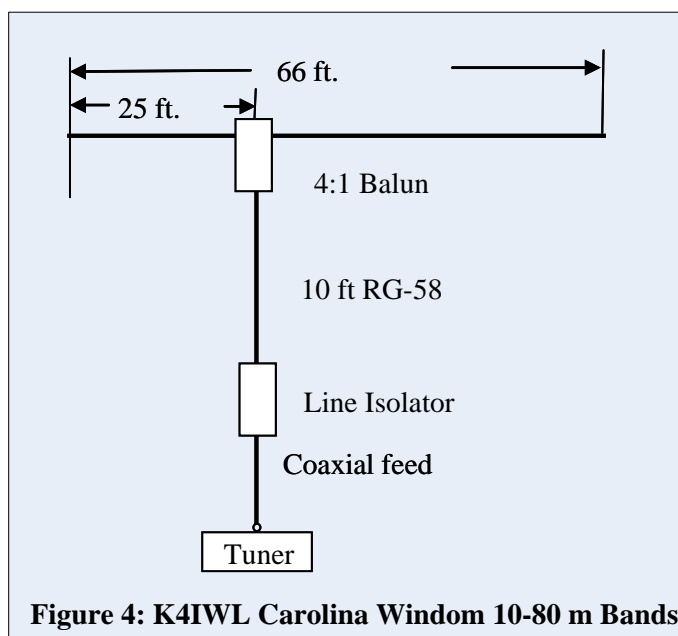


Figure 4: K4IWL Carolina Windom 10-80 m Bands



One final OCF dipole, Figure 5, this time for the 6, 10, 20, and 40 meter bands, is by Rick Littlefield, K1BQT, and was presented in QST, June 2008. What is different about this version is the inclusion of the 6 meter band and a return to the 1/3 feed point ratio. The feed point impedance is 120 to 140 ohms and required a 2.8:1 balun. See the K1BQT article<sup>22</sup> for a description of this 2.8:1 balun.

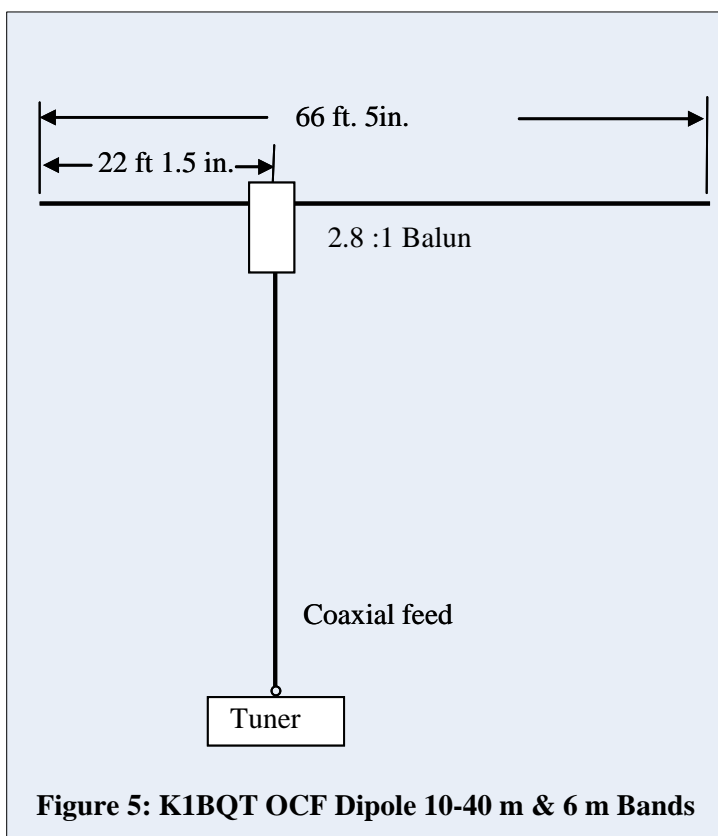


Figure 5: K1BQT OCF Dipole 10-40 m & 6 m Bands

## Making Off-Center-Fed Dipoles Work

Off-center-fed dipoles are by nature an unbalanced antenna. Care must be taken to ensure that there is no feedline radiation to upset the operation of the antenna. Otherwise high SWRs on the higher bands will result. But how can one accomplish this?

A line isolator or current choke at the transceiver end will help reduce radiation on coaxial feed lines. The impedance of the isolator should be at least 4-times the antenna impedance being transformed.

Secondly, a good balun should be used at the antenna. An example of how to construct a 4:1 balun suitable for OCF dipoles is given by Zak<sup>13</sup>, QEX Mar/Apr 2001.

RFC1 is 11 turns of RG-58C on FT140-43 ferrite core. T1 and T2 are 8 turns #20 AWG enamelled wire bifilar wound on FT82-61 ferrite core. K1QBT's 2.8:1 balun has a similar architecture to Figure 6,

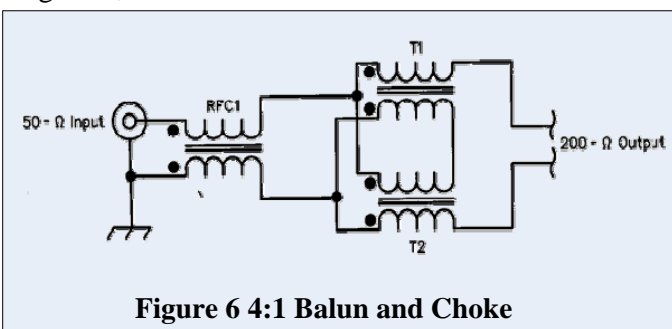


Figure 6 4:1 Balun and Choke

however, the implementation is slightly different. To obtain the 3:5 turns ratio, K1QBT used a binocular core consisting of two 1 1/8 x 1/3 inch ID 43-mix sleeves (Fair Rite 2643540002 or equivalent, permeability of 850) cores. The 3 turn primary was made of 16 AWG stranded wire covered with Teflon tubing. The secondary was made of 5 turns of 18 AWG double coated enamelled wire. The 1:1 current balun was made with two 1 1/4 inch OD 43-mix toroids (Fair Rite 59430016012 or FT120-3) stacked together. The transmission line consisted of 12 turns of twisted pair made from 18 AWG high temperature wire wound together with 4 to 6 turns per inch.

## Ultimate Off-Center Fed Dipole

Serge Stroobandt, ON4AA, has produced, in my opinion, the ultimate OCF dipole, a "6-Band HF Center-Loaded Off-Center"<sup>19</sup> version using a combination of centre loading and off-centre-feed for multiple bands. See the Figure 7.

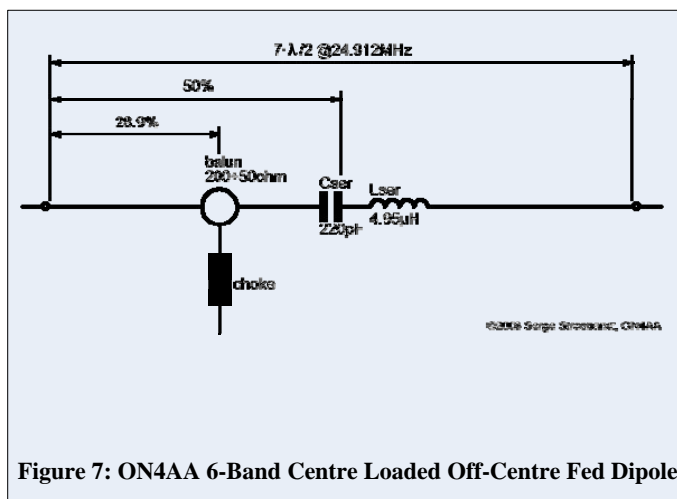


Figure 7: ON4AA 6-Band Centre Loaded Off-Centre Fed Dipole





ON4AA's web site gives a comprehensive history of the off-center fed dipole's development and the technical rationale for the various designs which ultimately lead to the final design. The 6-Band Center-Loaded Off-Center Fed Dipole is more complicated to build than the standard OCF dipole.

However, the performance is greatly enhanced by providing a usable antenna on 6 bands instead of the usual 4 bands. The ON4AA antenna works without a tuner over the entire bandwidth of the 80, 40, 30, 20, 15 and 10m-band, simply by adjusting the output-tank of your tube power amplifier. (If you have a transistor amplifier as a final stage, you definitely will need an antenna-tuner though.)

You can download the NEC modeling file for this antenna from the ON4AA web site<sup>19</sup>. Try this NEC modeling file to see the antenna's performance. The ON4AA antenna is 40.658 meters in length, which is 7 half-wavelengths at 24.912 MHz. The antenna is constructed and tuned as follows:

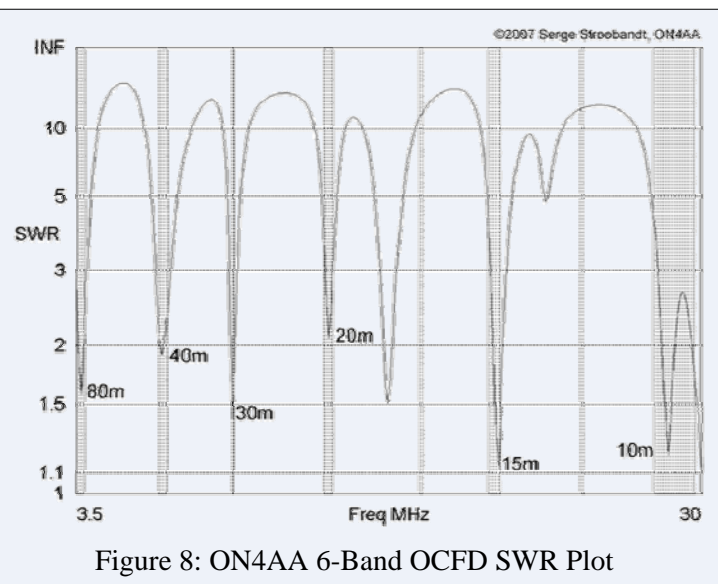


Figure 8: ON4AA 6-Band OCFD SWR Plot

## Tuning the ON4AA Antenna

- 1) First determine the actual length which will resonate at 24.912 MHz. This length will be approximately 40.658 meters, more or less, depending upon height, ground factors, near by obstructions, etc. Start with a 42 meter wire.
- 2) Prepare a 24.912 MHz half-wave resonant length of coaxial cable with the choke attached.
- 3) Cut the antenna wire in the middle by folding it and holding both ends.
- 4) Connect the coaxial cable prepared in step 2 to the center of the antenna.

- 5) Hang the antenna at its intended height, and measure the frequency where the antenna resonates. Write this value down.
- 6) Lower the antenna and trim of a few centimetres.
- 7) Re-measure the resonant frequency. Repeat steps 5 to 7 until the resonant frequency is exactly 24.912 MHz.
- 8) Remove the choke and connect the L and C loading network at the centre of the antenna.
- 9) Measure 28.9% of the total length and cut the antenna at this point to connect the 4:1 balun.
- 10) Hoist the antenna to its final height and begin having fun.

## Summary

In the above antennas, the design strategy has been to choose a feed point i.e. offset ratio, which gave a common or close to common impedance on as many bands as possible. In some cases the feed point ratio was such that the feed point impedance was approximately 130 or 200 ohms necessitating the use of a 2.8:1 or 4:1 balun respectively. The shorter 66 foot versions are also worth consideration for those that do not have the space for a full size 80m antenna. All the antennas presented must be tuned in situ for best performance. The ON4AA antenna promises the best performance in a single wire, no trap, multiband HF antenna. The ON4AA antenna resonates on the 80, 40, 30, 20, 15 and 10m-band and is definitely the one to try for those that have the space



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