Antennas

The Windom off-centre fed dipole

PHOTO 1: M0CVO HW-40HP off-centre-fed dipole antenna.

THE DIPOLE. The centre-fed dipole is the most fundamental of all antennas. It is the most popular antenna used by amateurs worldwide, largely because it is very simple to construct and is an effective performer. A centre-fed dipole can be any electrical length as long as it is configured in a symmetrical fashion with two equal length sides. However, in its simplest form, it is made half a wavelength long at the operating frequency because such an arrangement is easiest to feed. The current and voltage distribution on a half wave antenna is shown in **Figure 1**, with high current and low voltage in the centre. Impedance is a ratio of current and voltage, which indicates a low impedance at the centre; a suitable point to feed the antenna using low impedance 50Ω feeder.

At the ends of the antenna, the voltages are high and the current low so the impedances at these points are high. Note that the current and voltage ratios either side of the centre feed point are mirror images of each other and such an antenna is said to be balanced. Ideally, the dipole antenna should be fed with twin wire feeder where the RF power in each conductor of the transmission line is equal, thereby cancelling radiation or interference pickup on the line.

In previous Antennas, I have discussed the pros and cons of a balanced feed and balanced antennas **[1]**, noting that it is probable that the strictly balanced feeder arrangements were derived from commercial practice. These commercial installations used multiple transmitters and antennas. Furthermore, the antennas were located some distance from the transmitters and any unbalance on the feeders resulted in radiation loss and cross-talk to nearby feeders.

OFF-CENTRE-FED ANTENNAS. The half wave dipole is just fine for a single band but if used on higher frequencies the feed impedances can vary dramatically. However, if the feed point is moved part of the way from the centre of the dipole the feed impedance can be increased to any impedance; a 300Ω point is shown in Figure 1. It also has some implications for multibanding the dipole. The current distribution diagram shown in **Figure 2** is based on one by DJ2KY. It shows the current on a half-wave length of wire on 80m superimposed on the current distribution on other higher bands. It can be seen that the current amplitudes on some of the bands coincide at sixth of a wavelength from the end, described by DJ2KY as a 'Windom point' **[2]**.

The current distributions shown in Figure 2 are idealistic, showing the current distributions in free space. In practice, these currents can have slightly different amplitudes and phases due to the proximity of the ground. Furthermore, amplitudes of the current variations along the antenna element may not be constant on the higher frequencies when the antenna is fed off centre. Nevertheless, the impedances found at the sixth of a wavelength point are fairly close together on some bands.

Most off-centre-fed dipole (OCFD) antennas appear to be fed with coaxial cable (**Figure 3**). The currents on the centre core of coax cable (I_1) and the inside of the shield (I_2) are equal and opposite. The two conductors are closely coupled along their entire length, so the equal and antiphase current relationship is strongly enforced. This I_1/I_2 relationship is completely independent of the coax environment. The cable can be taped to a tower or buried, yet the equal and opposite nature of I_1 and I_2 inside the cable remain the same.

Enter the 'skin effect' **[3]**, which causes HF currents to flow only (very) close to the surfaces of conductors. This causes the inner and outer surfaces of the coaxial shield behave as two entirely independent conductors. When a coaxial feed is used, the unbalanced nature of an OCFD antenna causes a difference between the currents flowing either side of the feed point. This difference current is shown in Figure 3 as I_3, and is equal to (I_1-I_2). Current I_3 has to flow somewhere. It cannot flow down the inside of the cable because I_1 and I_2 must be equal, so instead it flows down the outside of the outer sheath. As a result, the feed line becomes part of the radiating antenna **[4]**.

A COMMERCIAL OCFD. There are many commercial OCFD antennas on the market and the M0CVO HW-40HP antenna, shown in **Photo 1**, is one of them **[5]**. The centre consists of a plastic balun box with a SO239 input socket and screws with wing nuts for connection to the dipole elements. Strain relief and a support point are provided by three metal key rings attached through holes in the flange at the top of the box. The insulators at the other ends of the elements are of a very decent, heavy duty type. The antenna is supplied fully assembled as shown in Photo 1. Overall, it is 21.28m (66ft) long and described as an off centre fed dipole designed to operate on the 40m (7MHz), 20m (14MHz), 15m (21MHz) and 10m (28MHz) bands. The documentation with this antenna goes on to say, "Having a feed point 1/3 of the way along instead of halfway gives an impedance of between 300 and 400Ω… a 4:1 current balun is added at the feed point to alter the impedance to something closer to the required 50Ω. This then allows the antenna to be fed using standard 50Ω coaxial cable such as RG8 or RG213".

The balun was tested and found to have a transformer action of 4:1 as claimed. It was not possible to determine if the balun was a current (as claimed) or voltage transformer because the unit was sealed. The antenna

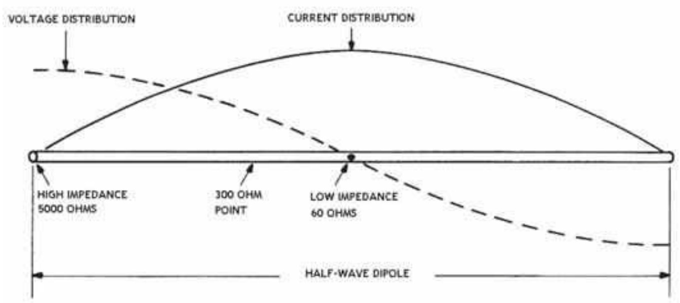

FIGURE 1: Voltage, current and impedance distribution on a half wave dipole.

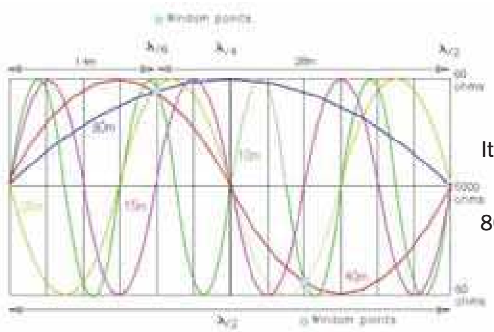

FIGURE 2: The current distribution diagram based on one by DJ2KY. It shows the current on a half-wave length of wire on 80m superimposed on the current distribution on other higher bands.

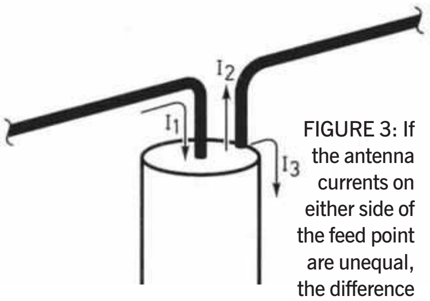

FIGURE 3: If the antenna currents on either side of the feed point are unequal, the difference $I_3 = I_1 - I_2$ will flow down the outside of the cable.

was fixed 10m high at one end and 7m high at the other, with the long element at the high end. (I had previously used this location for a 7MHz dipole during 501kHz/7MHz cross-band tests with VO1NA).

The results of impedance and SWR measurements, measured using the AIM 4170 via a 9m calibrated length of RG58, are shown in **Figure 4**. SWR is indicated with the thick red graph. Impedances Zmag and Theta are represented by the thin red and purple lines respectively. I noticed that the SWR on 7MHz varied when I touched the coax PL259 connector, indicating the presence of I_3 currents on the outer braid of the coax. Lowest SWR readings were obtained when the coax was laid on the ground. The antenna was then connected via a 25m length of coax to the shack and an MFJ-854 RF current meter was used to measure I_3 currents. With 100W of 7.02MHz RF fed to the antenna, the RF current I_3 at the bottom of the vertical section of coax to the antenna was 500mA. I measured 300mA at the shack end of the coax. These currents were less on the higher frequency bands. In spite of these currents on the outside of the coax no adverse affects such as RF in the shack, TV or audio equipment interference were experienced.

In general, the antenna performed reasonably well. Eastern USA and EU contacts were made on 7MHz without any difficulty. The antenna could be fed without an ATU on the 7, 14 and 28MHz bands (as you might expect from looking at Figure 4), in spite of the resonances being rather low in frequency. The antenna certainly would not load directly on 21MHz as claimed but this band and all the others could be loaded easily using an ATU.

Bearing in mind the asymmetrical nature of the feed, currents on the outside of the coax are inevitable. Some method of controlling them is necessary. Some OCFD builders go to a lot of trouble to eliminate common mode currents from the feed line. The arrangement shown in **Figure 5 [6]** is a multiband OCFD, which uses a 4:1 transformer plus two additional current chokes on the coax. Additionally the coax braid is connected to earth. All these precautions minimise radiation from the feeder on transmit, particularly important if one is using high power. It also reduces interference pick up on receive. I managed to reduce the current on the M0CVO antenna to 120mA in the shack by using a single W2DU current choke.

Overall, I was reasonably impressed with this antenna, although I wonder whether the metal rings would eventually wear through the flange of the plastic balun box.

FIGURE 4: Impedance and SWR measurements of the M0CVO HW-40HP antenna, measured using the AIM 4170.

THE CAROLINA WINDOM. Other antenna designs use the feeder radiation to advantage, a method described by G2HCG as 'Controlled Feeder Radiation' **[7]**. With this method, a current choke is placed some distance from the feed point so that the length of the radiating section of the feeder is preset. A commercial application of this is used with an OCFD known as the Carolina Windom. This antenna is also fed approximately 1/3 from the end using 50Ω coax and the feeder is encouraged to radiate due to the asymmetrical feed point. The physical length over which the feeder radiates is limited to 3m (10ft) by a 'line isolator', presumably a coax outer braid current choke. Radio Works who manufacture this antenna **[8]** have coined a title for the radiating section of feeder and called it VERT (Vertically Enhanced Radiation Technique). Several versions of the Carolina Windom are marketed by Radio Works.

It occurred to me that the M0CVO HW-40HP antenna could be converted to a Carolina Windom simply by adding a current choke 3m (10ft) down from the balun at the antenna feed point. While this reduced the common mode currents considerably, it had an adverse effect on the SWR – to such a degree that the ATU was necessary for all the bands. I don't know why this should be; suffice it to say there is more to the OCFD than meets the eye.

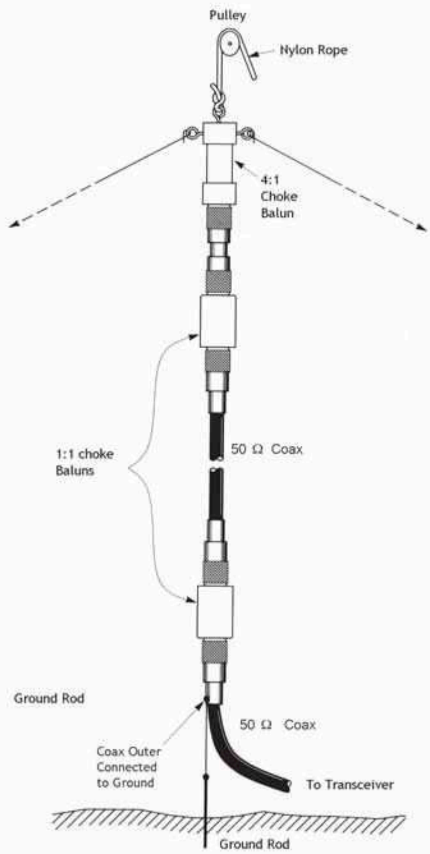

FIGURE 5: The feed system of a multiband OCFD, showing a method for eliminating antenna (I_3) currents.

REFERENCES AND NOTES

[1] 'Antennas', *RadCom* January 2006 & March 2006.
[2] The original Windom antenna, popular in the 1940s, comprised a wire element fed by a single wire 'feeder' approximately 1/3 from the end. Such a configuration had to be fed against ground similar to an inverted L antenna.
[3] http://en.wikipedia.org/wiki/Skin_effect
[4] The equal and opposite currents I_1 and I_2 are often referred to as differential mode currents. I_3 currents are often referred to as common mode currents; in some literature they are also referred to as antenna currents presumably because they cause radiation.
[5] m0cvoantennas.co.uk
[6] From How to Design Off-Center-Fed Multiband Antennas Using That Invisible Transformer In The Sky, Frank Witt, AI1H, *The ARRL Antenna Compendium, Volume 3*.
[7] Controlled Feeder Radiation, B Sykes, G2HCG, *Radio Communication* May 1990.
[8] www.radioworks.com