Notes on <u>Harmonic</u> Windom, Off Center Fed Dipoles (OCFD) and End Fed Multiband Antennas   N6MW 12/24/23

These antennas are generally a half wave at the lowest frequency and so then they are harmonic at several higher ham bands that may provide resonant (or near) antennas on several bands.
I will address in the Appendix those multiband "random length" dipole antennas, or non-resonant End Fed, that generally purposely are non-resonant in the ham bands but with lengths said to be chosen to avoid excessively high SWRs in most ham bands.

Windom versions - beware that the names for different versions are used inconsistently. Many are fed as a dipole but at ~ 33% distance along a horizontal wire. Generally they are fed as an OCFD with a 4:1 transformer at that off center location.

True Original Windom - <u>single</u> wire feed OC to an elevated horizontal wire. **This is not a dipole**. It is not commonly referenced.

Windom ladder line feed dipole OCF. This is sometimes seen and is presented with ladder line feed as a vertical part and then may have a "balun" transformer and perhaps a choke followed by coax to the TX. Note that the ladder line serves to transform the antenna impedance in a manner depending on the length, frequency and transmission line impedance.

Windom coax feed - coax OCF (Fritzel FD4 OCF Dipole 4:1 "balun"), now a common version.

https://www.qsl.net/sv1bsx/windom/windom.html 4:1 transformer at 33% point. Coax feed. It appears to have no choke.

http://rfanat.ru/s13/windom.html 4:1 transformer at 36% point. Coax feed. It appears to have no choke.

These versions may suffer from unchoked common mode currents (CMC) making tuning problematic since that can depend on the length of the coax feedline which may produce significant loses if the SWR is high and if near the ground and/or RF feedback.

New Carolina Windom - coax feed at 38% point with a 4:1 UNUN (not a current Balun), followed with a choke well the feed point (20' below for 80m). The coax length between the UNUN and the choke is intended to have radiating currents on that part of the coax outer braid as CMC to provide benefits to the pattern with vertical polarization and perhaps resonant frequency. This version is common. For example, see https://hamuniverse.com/k4iwlnewwindom.html taped at 38% with a 4:1 UNUN.

Most Windoms have a length that is a half wave at the lowest design frequency and intended to have useful SWRs in the bands that are harmonics of that frequency.

OCFD
The OCFD antennas are generally similar to the Windom except that they use a coax fed "current Balun" at the feed point, usually 4:1, or balun/choke combination unit that chokes off CMC to the feedline below the feed point. The length of the coax following the choke to the TX should have limited impact on the SWR. In some cases, such an OCFD is even called a Windom, which serves to confuse

the issue.
W8IJ addresses this for his OCFD at https://www.w8ji.com/windom_off_center_fed.htm with 20% tap and 4:1 current balun (which blocks CMC) using a 1/2 wave 80m (137 ft long) which has resonances with decent SWR in the bands that are harmonics of 80 m. Here is an EZNEC version of that case.

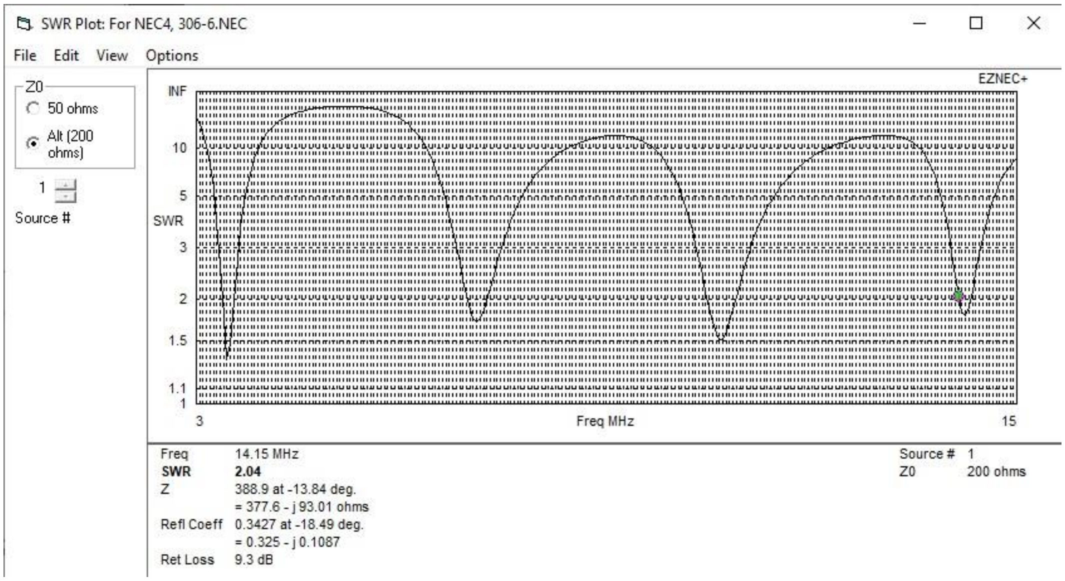

Figure 1. W8JI OCFD with a 4:1 transformer.

Other similar examples are
https://www.dj0ip.de/off-center-fed-dipole/80m-ocf/ 4:1 Voltage Balun+added attached choke 20% tap point and
https://palomar-engineers.com/tech-support/tech-topics/antenna-notes/off-center-fed-dipole-notes 4:1 Balun+added choke 20% tap point.

END FED

This is often called an EFHW (end fed half wave) that is, like the Windom and OCFD, approximately a half wave at the lowest operating frequency and which is intended to operate on the harmonics as well. So at some level it is just a different choice for the ratio between the short and long ends of the OCF dipole. In extreme cases, the short ends are so small that they are physically absent and there is only a virtual short end from incidental electrical interactions with the required balun (or “ground”). The balun ratios for EFHWs range from 9:1 to as large as 64:1. For the latter, for example, a match to 50 ohms would occur for a raw EF impedance of ~3200 ohms. The issue of CMC likely becomes a substantial issue for the larger ratios.

There are also commercial verticals (e.g. Cushcraft and HyGain) that are really EFHW, though not usually mentioned, and usually have some minimal counterpoise (“no radials”). These units appear to have more complex multi-band matching methods plus frequency dependent physical structures as in traps and stubs. The short end of these antennas is often referred to a counterpoise and may comprise multiple short wires. {Note that this is a horse of a very different color from the infamous 43' all band vertical which is explicitly non-resonant but with radials and intended to provide compromise of not too large SWRs on the ham bands that may be tunable with a ATU. See Appendix}

Matching at Multiple Frequencies with OCF

When the different frequencies of interest are harmonically related, this improves the chances that the current/voltage patterns of the dipole are all multiples of half waves so the OCF% offset will not alter the comforting sinusoidal appearance of the current patterns. However, even though there may be a resonance near a desired frequency (X near zero, close to a SWR minimum), the resistive component of antenna impedance at that point will not be at 50 ohms but a value that depends both on the OCF% AND the frequency. Therefore, it is a more complex question as to what transform ratio is best for a transformer ("balun") to best match at multiple frequencies. Here is an example from EZNEC of an 80 m Half Wave length dipole showing the variation of the approximate antenna resistance (Rant) with 30 %OCF at 3.5 and 7.1 MHz.

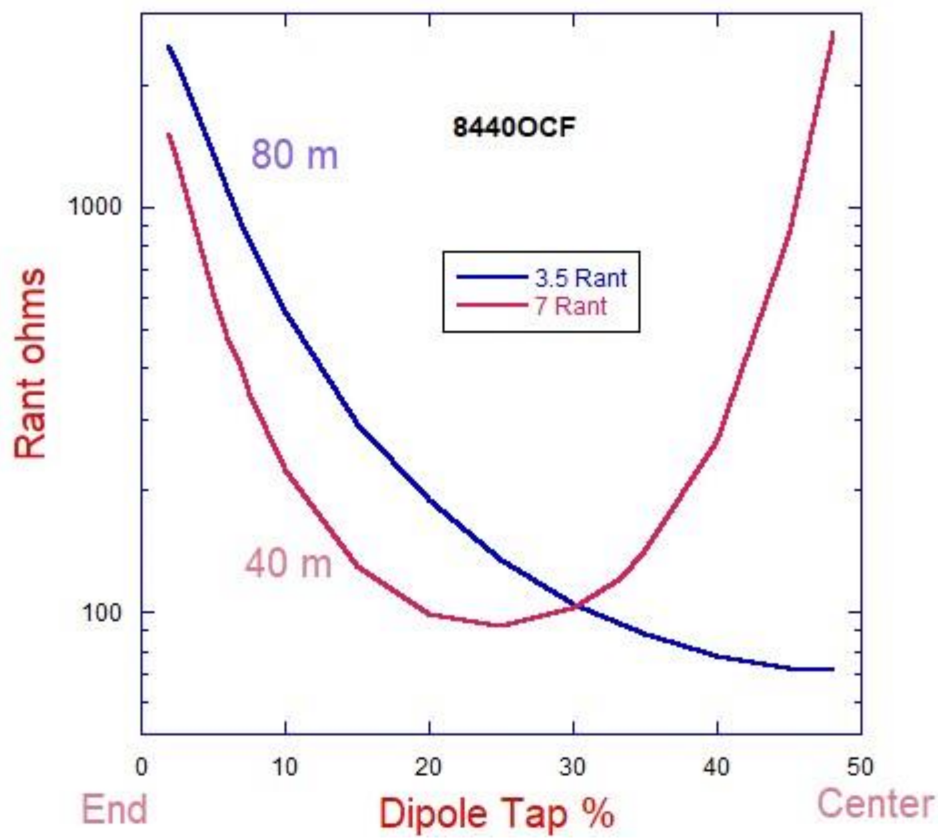

Figure 2. Real parts of Antenna impedance for an 80m OCF at 3.5 and 7 MHz verses the tap point.

Near OCF 50%, the 80m case is 73 ohms (a standard center fed HW dipole) but the 40m value has a very high impedance since it is a full wave dipole in this case. Near 30% (commonly used for Windom) the two impedances are nearly the same and could be pretty well both matched to 50 ohms with a 2:1 transformer. It is certainly not assured that this will remain true for higher harmonics.

However, Windom antennas are pretty much universally fed with 4:1 transformers. This may be because the transformers (i.e., UNUNs, more later) used for Windoms are not the sort that provide CMC choking so the antenna is effectively lengthened by the feed line.

Near 20% offset a 4:1 transformer is pretty good and at bit below 10% (now getting to be more an End Fed) a 9:1 transformer may be okay. But again, this matching is not assured to continue to higher frequencies.

A better analysis would require adding other frequencies for the matching tests but it is easier to just make a series of EZNEC runs over a wider range of frequencies and visually compare the SWR vs Frequencies for different transformer ratios. Still this is not fully satisfying due both the issues of EZNEC variation with the parameters used and the fact that there is uncertainty in the effects of ground and surroundings so experimentation with lengths will probably be needed for adjustments in real life. Here are some examples from EZNEC for different dipole split ratios giving the Transformer ratio needed for a 50 ohm match in Fig. 3. For example, both 80 and 40 would be matched fairly well with a 2:1 transformer when the offset is 30% as in Fig. 2.

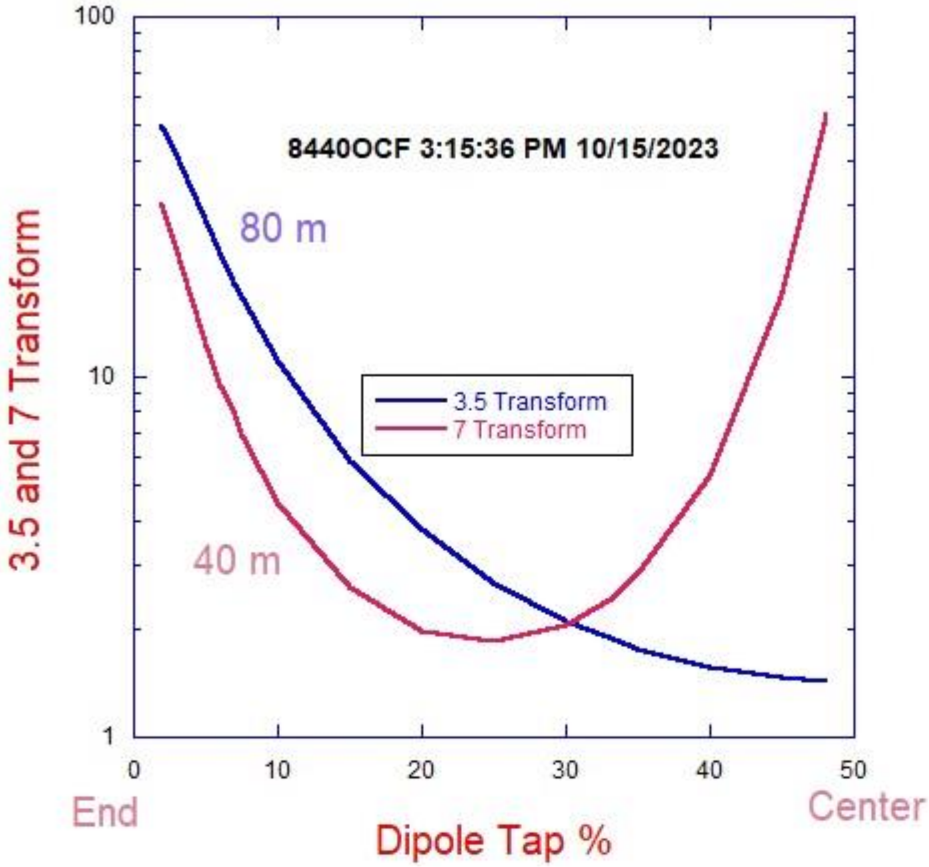

Figure 3. Value of N for a N:1 transformer for an 80m OCF to match 3.5 and 7 MHz verses the tap point selection.

A downside to OCFD harmonic antennas is the frequency locations of the SWR minima are not individually controllable. This can be a problem for SSB bands when starting at 75 meters since the higher frequency minima often fall above those ham bands.

"Baluns", UNUNs, Chokes and Transformers, Oh My

There are many sources of "balun" information on the www. Not all are well informed or well defined. Some sources are generally better regarded than others but there is no one magic guide. The discussion by K9YC that includes baluns (e.g., www.audiosystemsgroup.com › RFI-Ham.pdf) and one by W8JI for DX Engineering (e.g., https://static.dxengineering.com › pdf › choosing the correct balun.pdf) appear to have well studied information from respected authors who have numerous other postings. You may note that these authors can be a bit caustic.

The following is a very short, and not at all complete, indication of the rough meaning of some terms.

"Balun" - This is a broad name for which there are a substantial number of subtypes, which are very often not spelled out in individual cases.

Transformers - All such devices of the N:1 or 1:N type "baluns" are transformers of some sort although they seldom seem to be the kind that have separate primary and secondary windings as seen in power supply transformers. Rather they are properly called "autotransformers" with some shared aspects of the windings. The N:1 designation generally means the antenna impedance to be matched is N times the feedline impedance, say 50 ohms. Some authors call this 1:N so care may be needed.

Choke - This is sometimes called a 1:1 current balun but its essential use is to limit the CMC on the outside of the braid on feed line coax. It is generally not a 1:1 "transformer." A very common variety is formed by a length of coax coiled around a toroid which is a part of the feed line. Sometimes the coax feed line itself is simply coiled to provide some inductance or multiple ferrite beads are placed on the coax feedline. A test of the benefit of a 1:1 balun choke can be to see if the SWR differs with and without the balun.

We now come to some sub-categories:

UNUN - Conventional wisdom says that an UNUN is a unit that matches an unbalanced line, typically coax, to an unbalanced antenna. The challenge can be determining what electrically qualifies as an unbalanced antenna. UNUNs are never 1:1. UNUNs that are N:1, when the builder/seller chooses to share the wiring information, appear to always have the feature that the input feed line (usually with an SO-239 connector) has a wire directly from the ground (braid) side of this connector to one of the output terminals where the antenna connects. That side is generally shown with polarity **-** and is said to be for the "ground side" of the antenna, which corresponds, apparently, to the short end of an OCF dipole or the counterpoise or even no connection at all. Such a unit is usually said to provide NO CMC choking, which is not surprising.

"True" Balun - Conventional wisdom says that a N:1 balun is a unit that matches an unbalanced line, typically coax, to a balanced antenna. There are very few antennas that are truly balanced but a horizontal center fed dipole in the clear is close. OCF antennas are said to be unbalanced, for example. All commercial units found described as Balun, not UNUNs, **do not** have a wire on either side of the SO-239 that connects directly to either antenna side connector and there is no polarity.

Current and Voltage Versions -

Here are some examples:
https://k4lrg.org/building-an-off-center-fed-ocf-dipole/ "balun" is an UNUN,
https://www.qsl.net/sv1bsx/windom/windom.html "balun" appears to be an UNUN,
https://www.balundesigns.com All units here called UNUNs have a direct connection of the coax braid side input to one antenna terminal of the output. Note that some antenna recommendations on this site are sometimes not conventional.

https://www.dxengineering.com/parts/dxe-mc20-1-1t#documentation. The
DXE-MC20-V4-1 Maxi-Core® 20 - 4:1 Voltage Balun has minimum CMC effects on purpose
All claimed "current baluns" viewed, whether 1:1 or N:1 are said to have some CMC choke benefits. None have a wire connection of the coax braid side to one antenna terminal.

A few "baluns" are described as "Voltage Baluns" for which the standard story is that the output terminals are said to attempt have equal voltages. Recommendations of the use of this version are generally limited and vague. Current Baluns are said to attempt to provide equal currents on the output terminals and provide some CMC protection. This type seems to be the normal recommendation but the stories are not fully clear.

Appendix: Purposely non-resonant (before transformations) multiband antennas

G5RV – Here is an example with center (NOT OFF) fed 93' dipole with 39.5 ' ladder line followed by short coax length (only for modeling) to the TX. The ladder line acts as a frequency dependent impedance transformer.
https://www.dxzone.com/the-truth-about-the-g5rv-antenna/

Various versions of this antenna exist depending on the bands of interest to the user with variations in dipole and ladder line lengths. Higher bands may be an issue.

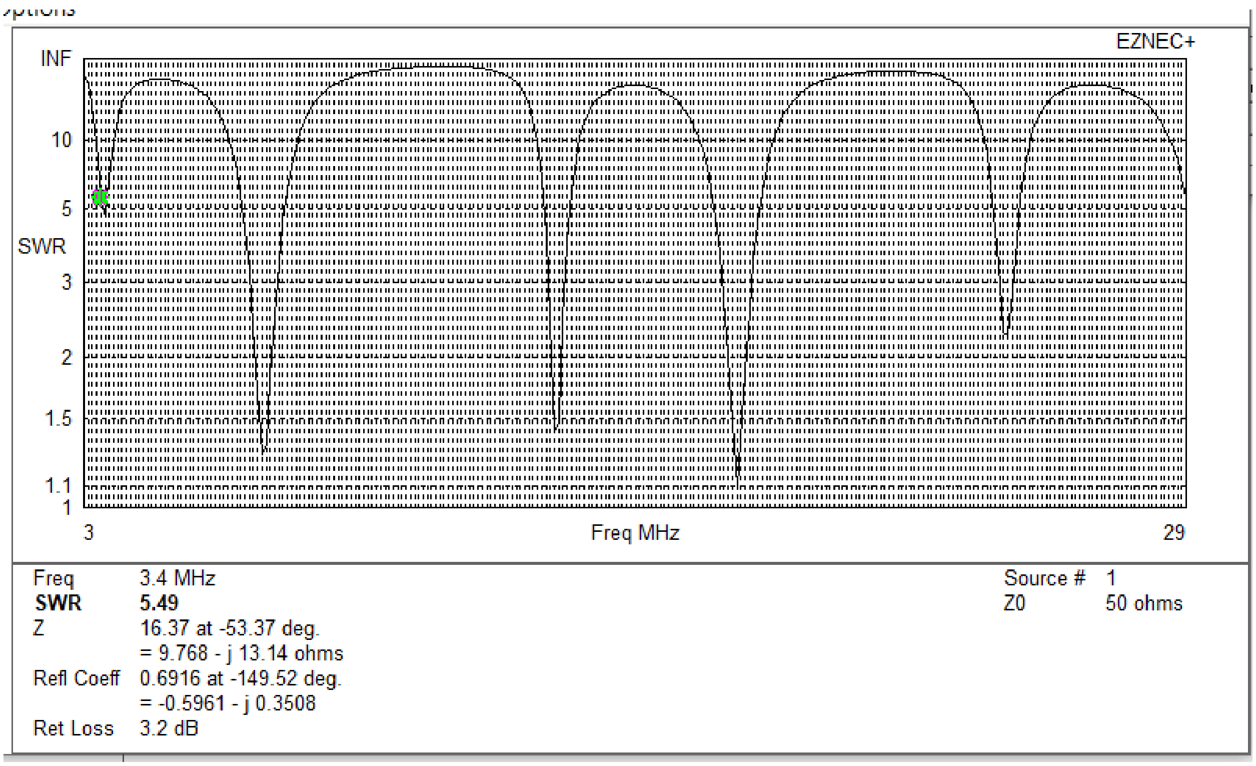

Figure 4. SWR curve for a typical G5RV antenna with lowest useful frequency 3.5 MHz.

The 43' Vertical

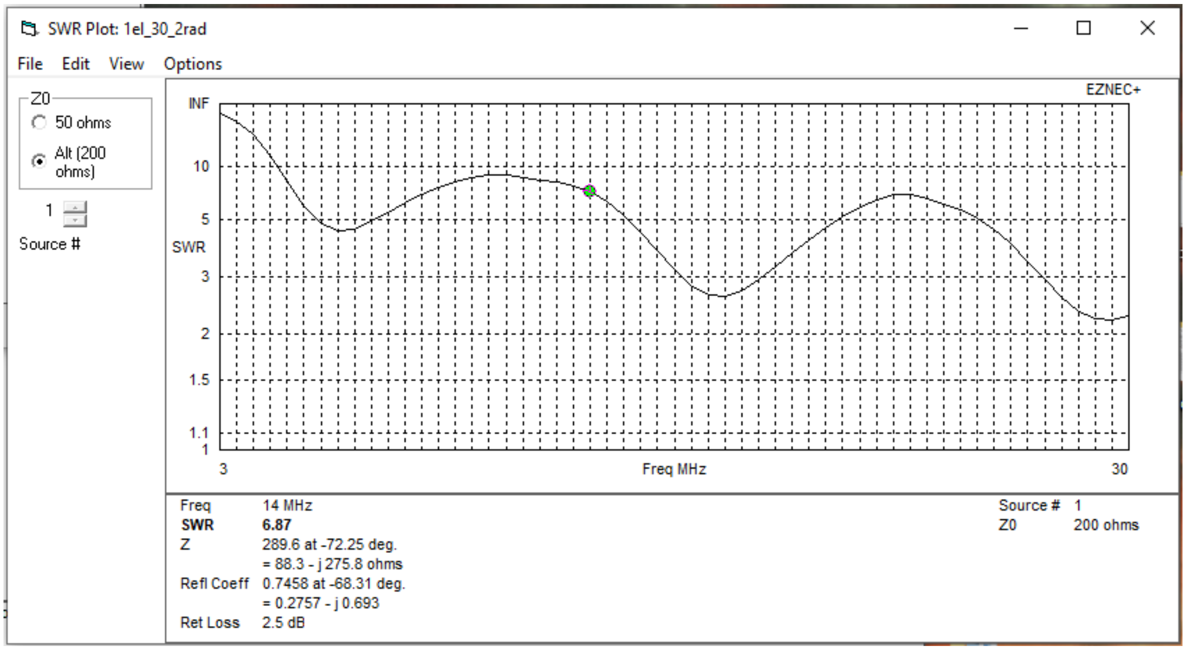

Figure 5. SWR curve for a 43' vertical with eight 43' radials and a 4:1 UNUN transformer, effectively with a choke..

Without a choke at the base, the coax feedline may substantially alter the curve depending on its length. The manufacturers of such antennas sometimes recommend specific lengths of coax feedline without explanation of the motivation.

Mystery Antenna
https://www.iw5edi.com/technical-articles/w5gi-mystery-antenna. This is center fed dipole with unusual 14 MHz stubs and a specific length ladder line feed before the final coax. It has a focus on 20 meters, purposely giving a lobed azimuthal pattern. It is true that modeling with conventional software is not adequate to describe this antenna due to model limitations for transmission lines that do not allow signal emissions. However, it stretches belief that the SWR can be so good on all bands except 10 MHz. Without a choke, the length of the coax may be a significant factor. But there may also be significant losses that can serve to lower SWR at the unannounced cost of signal reduction.