Multiband Operation with Open-Wire Line

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Despite the mechanical difficulties associated with open-wire line, there are some compelling reasons for its use, especially in simple multiband antenna systems. Every antenna system, no matter what its physical form, exhibits a definite value of impedance at the point where the transmission line is connected. Although the input impedance of an antenna system is seldom known exactly, it is often possible to make a close estimate of its value with computer modeling software.

As an example, the table lists the computed characteristics versus frequency for a multiband, 100-ft long center-fed dipole or "flat top" antenna, placed 50 ft above average ground. A non-resonant 100-ft length was chosen as an illustration of a practical size that many radio amateurs could fit into their backyards, although nothing in particular recommends this antenna over other forms. It is merely used as an example.

Modeled Data for a 100-ft Flat-Top Antenna

Freq (MHz)	*Antenna Impedance (Ω)*	*Input VSWR RG-213 Coax*	*Loss of 100 ft RG-213 Coax (dB)*	*Loss of 100 ft 450- Ω Line (dB)*	*Max Voltage RG-213 Coax at 1500 W*	*Max Voltage 450- Ω Line at 1500 W*
1.8	4.18 –*j* 1590	33.7	26.0	8.8	1507	10950
3.8	37.5 –*j* 354	16.7	5.7	0.5	1177	3231
7.1	447 +*j* 956	12.3	5.9	0.2	985	2001
10.1	2010 –*j* 2970	12.1	10.1	0.6	967	2911
14.1	87.6 –*j* 156	4.6	2.4	0.3	587	1747
18.1	1800 +*j* 1470	7.7	6.8	0.3	753	1600
21.1	461 –*j* 1250	4.6	3.2	0.1	585	828
24.9	155 +*j* 150	3.6	2.6	0.2	516	1328
28.4	2590 +*j* 772	6.7	9.4	0.5	703	1950

These values were computed using version 3 of the antenna modeling program, EZNEC (**www.eznec.com**). Antenna impedance computed using 499 segments and with the Real Ground model.

Examine the table carefully in the following discussion. Columns three and four show the SWR on a 50-Ω RG-213 coaxial transmission line directly connected to the antenna, followed by the total loss in 100 ft of this cable. The impedance for this non-resonant, 100-ft long antenna varies over a very wide range for the nine operating frequencies. The SWR on 50-Ω coax connected directly to this antenna would be extremely high on some frequencies, particularly at 1.8 MHz, where the antenna is highly capacitive because it is very much shorter than a resonant length. The loss in 100 ft of RG-213 at 1.8 MHz is a staggering 26 dB with an SWR of 33.7:1.

Contrast this to the loss in 100 ft of 450-Ω open-wire line. Here, the loss at 1.8 MHz is 8.8 dB. While 8.8 dB of loss is not particularly desirable, it is about 17 dB better than the coax! Note that the RG-213 coax exhibits a good deal of loss on almost all the bands due to mismatch. Only on 14 MHz does the loss drop down to 0.9 dB, where the antenna is just longer than 3/2-λ resonance. From 3.8 to 28.4 MHz the open-wire line has a maximum loss of only 0.6 dB.

Columns six and seven in the table list the maximum RMS voltage for 1500 W of RF power on the 50-Ω coax and on the 450-Ω open-wire line. The maximum RMS voltage for 1500 W on the open-wire line is extremely high, at 10,950 V at 1.8 MHz. The voltage for a 100-W transmitter would be reduced by a ratio of

$$\sqrt{\frac{1500}{100}} = 3.87:1$$

This is 2829 V, still high enough to cause arcing in many antenna tuners, although it only occurs at specific points that are multiples of 1/2 λ from the load. In practice, the lower voltages present along the transmission line are within the operating range of most tuners although you should remain aware that high voltages may be present along the line at some points.

The performance of our 100 foot flat top might be very poor on 160 meters for an additional reason. Not only will the radiated power will be much smaller than 1500 watts due to the high loss in the transmission line, the radiation will be maximum at 90 degrees of elevation (i.e. straight up), so this is a very poor DXing antenna.

Both of these drawbacks can be overcome very easily by changing the configuration of the system. If the two wires of the transmission line are tied together and fed against ground at the point where the line reaches ground, the antenna becomes a T which is a top-loaded vertical or monopole. This antenna has a radiation maximum at about 18 degrees and a null at 90 degrees. This is a very good DXing antenna on 160 meters. The impedance is low and easily matched with an L network or other type of antenna tuner.

Performance on 3.5 MHz as a top loaded vertical will also be good for DXing because the radiation peak is at about 19 degrees and there is a null directly overhead. Switched back to operation as a horizontal “flat top” close to resonance on 3.5 MHz, it has reasonable efficiency and makes a good high angle radiator for close in communications.

Thus, an effective arrangement can be made by switching the antenna from a flat top to a top-loaded vertical configuration. For best efficiency, a good ground system is needed. Multiple radials on the ground are effective as are a few raised radials.

On 14.1 MHz this antenna comes very close to being a fair match to RG-213 and a very effective antenna. If it is made a bit longer to 107 feet, it will be resonant on 14.1 MHz where it is 3/2 λ long and has a feed point impedance of 103 Ω, according to *EZNEC 5*. Here, the SWR will be about 1.8:1 and the loss in RG-213 will be about 0.9 dB. This is quite acceptable considering that the resulting cloverleaf radiation pattern has a bit over 8 dBi of peak gain.

In general, such a non-resonant antenna is a proven, practical multiband radiator when fed with 450-Ω open-wire ladder line connected to an antenna tuner. A longer antenna would be preferable for more efficient 160 meter operation, even with open-wire line. The tuner and the line itself must be capable of handling the high RF voltages and currents involved for high-power operation. On the other hand, if such a multiband antenna is fed directly with coaxial cable, the losses on most frequencies are prohibitive. Coax is most suitable for antennas whose resonant feed-point impedances are close to the characteristic impedance of the feed line.