

Some Thoughts on Antennas and Feedlines

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In keeping with the antenna focus recently, here is a discussion of some antenna and feedline topics. First of all, let me make it clear that I am not an RF engineer, just an amateur radio operator. Because of that, I relied on research as well as my own experiences to write this article. I have always had a bit of a problem with calling an antenna resonant. An antenna is only resonant at one frequency. But we usually need to use antennas over a range of frequencies, so it is also important for the antenna to be "broad-banded" that is to remain close to resonance over a wide frequency range.

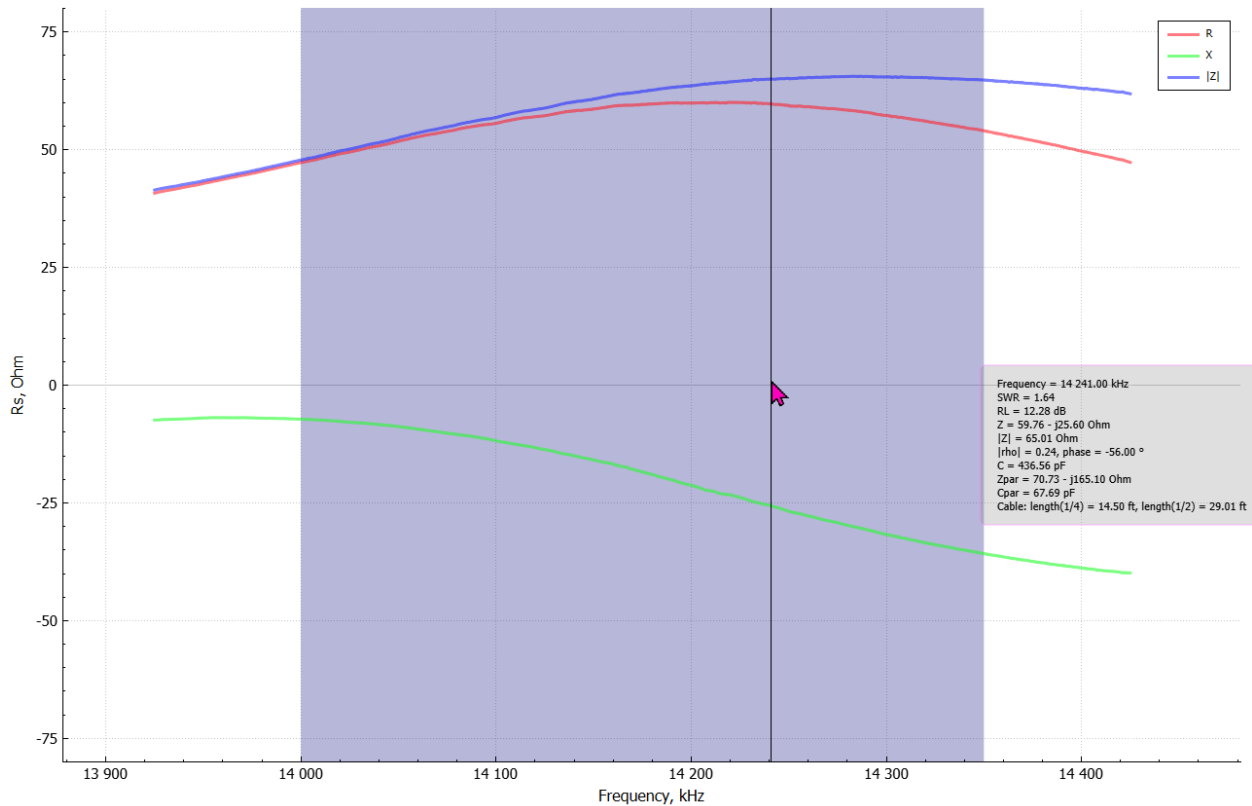
Many hams firmly believe that you must use resonant antennas and it is often stated that resonant antennas are best. The real situation is more complicated because as Dave Cassler (KE0OG) says about antennas – everything affects everything. Resonance is just one factor in antenna design / selection. Other factors may be more important depending on your use case. For example, DX'ers want a low take off angle and directionality, radiation pattern is important, some may choose to use an amplifier to compensate for losses in the antenna system, the local ham network participant may prioritize NVIS, space restrictions or HOA limits or cost may be deciding factors, etc.

What do we mean by resonance? Resonance is when the impedance of an antenna at a given frequency is purely resistive. For amateur radio, this means a 50Ω resistance without any reactance ($50 \pm j \Omega$). But what does resonance mean in a physical sense? Using a dipole as an example, for resonance, each leg is $\frac{1}{4} \lambda$ (wavelength) in electrical length. When the radio wave leaves and then returns to the feedpoint, it is exactly in phase with the next wave arriving from the feedline. Therefore, the energy is most efficiently transferred from the feedline to the antenna and radiated. A good analogy / explanation using a common real-world example is at [this link](#).

If the antenna is not resonant, then some of the arriving energy is reflected back towards the transmitter. Upon reaching the transmitter, it is reflected back to the antenna over and over. So, in effect, all of the energy should be radiated by the antenna eventually. However, this is not the case due to losses in the transmission line which convert some of the reflected energy to heat. This means that low quality of the coax and poor SWR can compound one another and lead to lower efficiency. As I will show later, high quality coax can go a long way to reduce total losses even with a poorly matched antenna system. An excellent article that discusses these factors in greater details can be found [here](#).

Most hams build or buy an antenna and then tune it for minimum SWR at the end of a run of coax in the band(s) of interest. This is not the same as tuning for resonance at the antenna. As an example of a non-resonant antenna with good SWR, consider my 80M Horizontal Skyloop (see QST articles in November 1985, April 2002 and August 2002). This is a multi-band wire

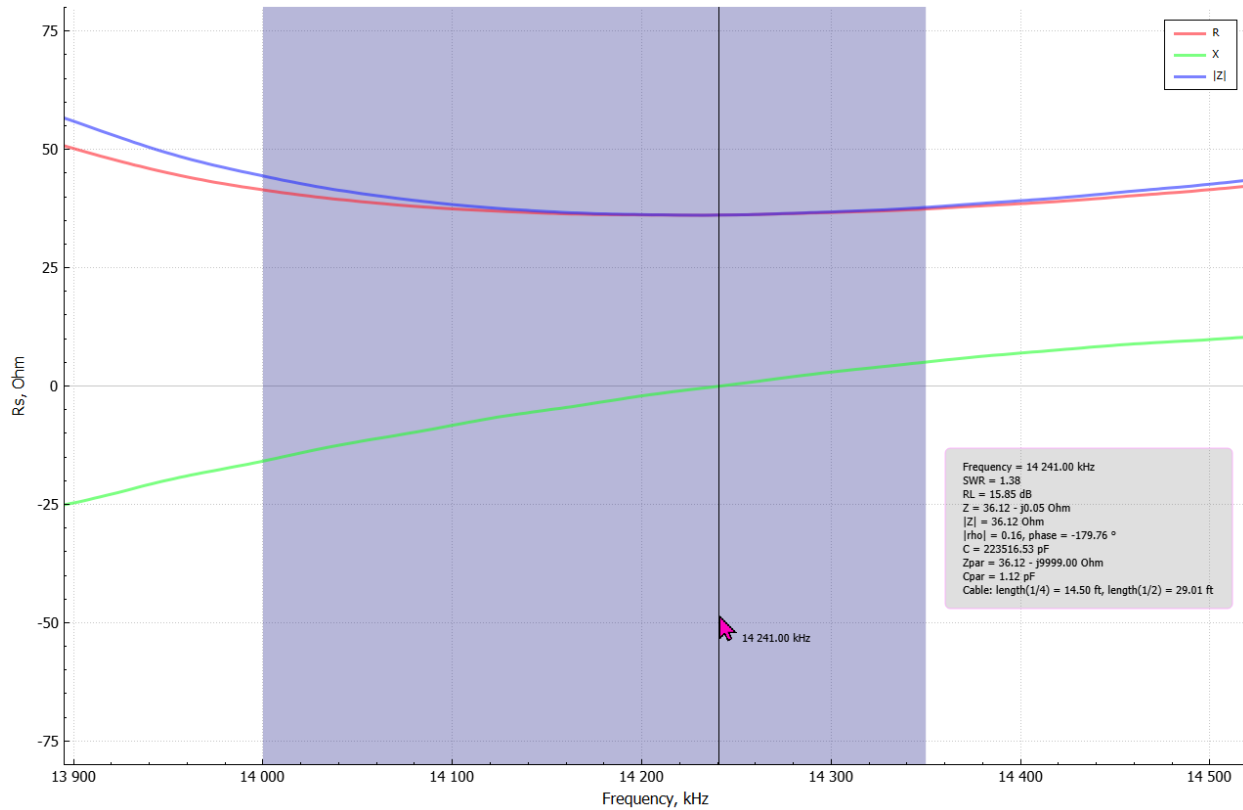
antenna. It is made using wire that is a full-wavelength long for the lowest band. An 80M Skyloop is about 272' long and fed with 450 or 600 Ω ladder line. A 4:1 balun is needed since the feedpoint impedance is about 200 Ω . The minimum SWR for this antenna in the 20M band is 1.17:1 (measured at the transmitter end of the feed line). The impedance, resistance and reactance for the 20M band are shown in the figure below. The reactance is negative (capacitive) across the entire band, so resonance does not occur. There are resonance points in the 80M and 40M bands, but not most other bands.



My example “resonant” antenna is a LPDA (Log Periodic Dipole Array). This is a series of tubular aluminum dipoles mounted on an 18’ boom. The elements increase in length and spacing moving away from the feedpoint to create the characteristic trapezoidal shape. The feedpoint is a 4:1 balun and element phasing alternates. This arrangement allows low-SWR (<2:1) operation from 13 MHz to 32 MHz. The LPDA is, in effect, a “variable 3-element Yagi”. The minimum SWR for this antenna in the 20M is 1.37:1 (at the transmitter end of the feedline). The impedance, resistance and reactance for the 20M are shown in the figure below. The reactance is initially negative, but turns inductive (crosses X-axis) at about 14.241 MHz – the resonance point. Note that the impedance (Z) equals the resistance (R) at that point.

These measurements are easily made by various antenna analyzers at the transceiver end of the feedline. These measurements do not tell us about properties at the antenna or losses in the antenna system. For that there are various online or standalone calculators. I have found an application called HRC31 that is very powerful for this use (see the July/August 2025 issue of QEX). There is also an [online calculator](#) which is somewhat easier to use, but has less features.

The online calculator requires you to know the SWR at the antenna feedpoint, so get ready to climb! The two calculators agreed quite well for the few points that I checked.



Using HRC31 for the Skyloop with 600 Ω ladder line and transmitted power of 100W shows that the power delivered to the antenna will be 94.8W (0.23 dB loss). Since this is fed with ladder line, the SWR at the antenna is very high (12.7:1) compared to at the transmitter (1.17:1), but the 50' of ladder line is virtually lossless, so the high SWR does not matter. For the LPDA with ½" heliax, the power delivered to the antenna is 91.6W (0.38 dB loss). Most of the loss is due to losses in the 150' of heliax. The SWR at the antenna is 1.43:1 and essentially the same as at the transmitter (1.37:1). With these very different antenna systems, virtually identical power is delivered to the antennas. However, most of the loss occurs at the feedpoint in the case of the loop (SWR Loss) and in the heliax in the case of the LPDA (Matched Loss).

Another very useful feature of these calculators is comparing the performance of the antenna system with various types of feed line. Using the LPDA example at resonance (14.241 MHz, R = 36.1 Ω, I compared several types of coax as shown in the table below. A few points can be made from the results: 1.) in all cases the bulk of the power loss is due to losses in the coax (Matched Loss) and not SWR Loss; 2.) using LMR-400 or heliax improves power transfer greatly over RG-8X even in the 20M band.

Coax Type (150')	SWR @ Ant., x.xx:1	Matched Loss, dB	SWR Loss, dB	Total Loss, dB	Power@Ant., W	Power Increase, % (dB)
RG-8X	1.62	1.61	0.13	1.74	66.96	N/A
LMR-400	1.47	0.71	0.05	0.76	83.97	25.4 (1.0)
1/2" Heliac	1.43	0.36	0.02	0.38	91.62	37.3 (1.4)
7/8" Heliac	1.41	0.20	0.01	0.21	95.36	42.4 (1.5)

While these results for the various feed lines are not that surprising, it is helpful to see the magnitudes of the differences. It is also interesting to note that used heliac from communication tower demolition or refurbishment is readily available at hamfests. I was able to procure 1/2" heliac for my tower project and 7/8" heliac for the DETARC Alto tower project for less than the cost of new LMR-400 equivalent coax.

What about non-resonant conditions? In the table below, I used a 100W transmitter, 150' of LMR-400 and 14.241MHz and varied the resistance and impedance measured at the transmitter to see how the SWR at the antenna and the power losses changed. Going from a transmitter SWR of 1.00:1 to 2.62:1 only reduced the power delivered to the antenna by 11.6% or 0.54 dB. These power losses are quite small compared to the losses when varying the type of feed line as discussed above (~25 – 42%).

Doing calculations like this has resulted in me stressing much less about my SWR and led me to increase the quality of my feed lines whenever I can. I recently added an Telepost LP-100A, a vector wattmeter to the shack. This is essentially highly accurate NanoVNA with NIST traceable calibration that can take full legal limit. It measures and displays forward and reflected power, SWR, resistance and reactance at the output of the transmitter (or amplifier). I mainly use it to monitor forward and reflected power.

While I am not that concerned with SWR for my antennas when used on the correct band, I have been known to accidentally transmit into the wrong antenna and create an excessive SWR situation. The LP-100A provides visual and sonic alarms at your chosen SWR value. If you route your amplifier keying line through it, it also prevents keying the amplifier upon alarm, possibly averting a damage to the amplifier due to high reflected power levels. This is great for amplifiers that do not have built-in protection circuits and adds another layer of protection for those that do.

At Transmitter, Ω (SWR)	SWR at Ant., x.xx:1	Matched Loss, dB	SWR Loss, dB	Total Loss, dB	Power at Ant., W
50-j0.01 (1.00:1)	1.00	0.72	0.00	0.72	84.78
50-j05 (1.11:1)	1.13	0.72	0.00	0.72	84.70
50-j15 (1.35:1)	1.43	0.72	0.04	0.76	84.03
50-j25 (1.64:1)	1.82	0.72	0.11	0.83	82.64
75-j25 (1.77:1)	2.01	0.72	0.15	0.87	81.89
100-j0 (2.00:1)	2.37	0.72	0.24	0.96	80.31
25-j25 (2.62:1)	3.59	0.72	0.54	1.26	74.94