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Considerations for Wire Size in Wire Antennas

Wire Antenna Considerations

While most discussions of antenna sag (Joel Hallas, W1ZR, "How High Should You Hang That Wire Antenna?" *QST*, Feb 2013, and the March 2014 and March 2015 "Technical Correspondence" columns) concentrate mainly on the calculations of sag, the effect of wire size on antenna strength is not adequately covered. Using the antenna sag equations, I ran into a counterintuitive conclusion that antenna strength may not be affected by wire size. The following discussion shows how I came to that conclusion and how you can improve the strength of a wire antenna.

When the time comes to string your wire antenna, the question of wire size often comes up. The initial feeling usually is that the strength of the antenna is a function of wire gauge. That is not necessarily the case, however, as I will show.

Using the data and equations for a sagging transmission line from Howard W. Sams & Company *Reference Data for Engineers*, we can calculate the tension in the wire and show some interesting relationships.[1] The equations of interest are:

$$H = WL^2 / 8S \quad \text{[Eq 1]}$$

$$L_C = L + 8S^2 / 3L \quad \text{[Eq 2]}$$

$$S = WL^2 / 8H = [(L_C - L)\, 3L / 8]^{1/2} \quad \text{[Eq 3]}$$

where:

L = length of the span, in feet
L_C = length of wire, in feet
S = sag in the middle, in feet
H = tension in the wire, in pounds
W = weight of wire, in pounds per foot.

The same equations are also given in Pender's *Handbook for Electrical Engineers*.[2] They apply to the case where the antenna end points are at the same level. When there is a difference in elevation, the formulas become a little more complicated, but the results are similar. A typical wire antenna configuration is shown in Figure 1.

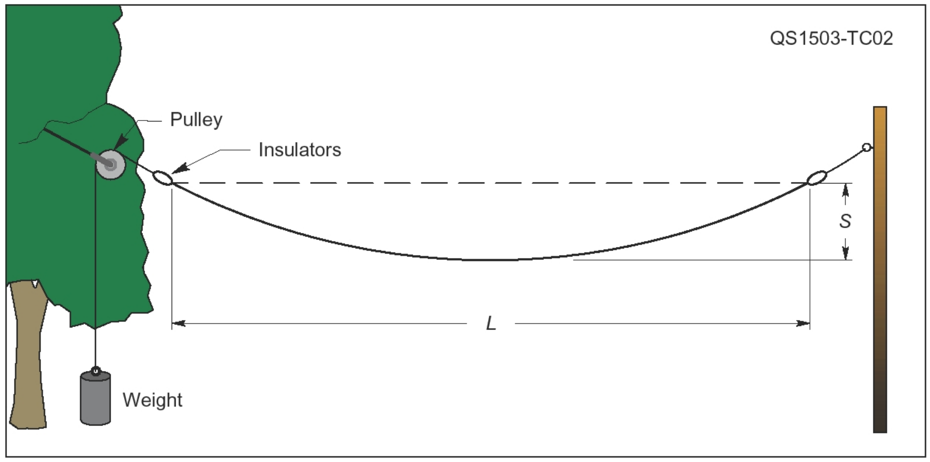

Figure 1 — This drawing illustrates a typical wire antenna installation. One or both ends can use a pulley and weight arrangement to maintain tension in the wire, while allowing the end supports to move in the wind. Note that the length of wire, L_C, will be slightly longer than the distance between the end supports, *L*.

Knowing the required antenna length, L_C, the distance between the supports (insulators), *L*, can be calculated using Equation 2. Then, knowing the weight of wire per foot, *W*, the wire tension for different values of wire sag can also be calculated using Equation 1. These results are shown in Table 1. From that table we can draw several conclusions:

1) For a given antenna length and sag, the wire gauge has no effect on the strength of the antenna if we define strength as the ratio of breaking load to wire tension. This will be confirmed later.

2) Stronger antennas result from either or both shorter spans, *L*, and greater sag, *S*.

3) Tension, *H*, is also an indication of how much weight you will have to use on the end of the wire as shown in Figure 1 to obtain the desired sag.

4) The "Safety Factor" column gives you an idea of the safety margin (allowance for ice, wind, and so on). It also shows that wire gauge has no effect for any given antenna configuration.

5) For longer antennas, more sag should be allowed, to reduce the stress on the wire.

The following example will further illustrate the unimportance of wire gauge when the sag is fixed. Let us assume we have an antenna 100 feet long and because of nearby objects below the wire, the sag is limited to 0.0719 feet (not a very realistic situation, but physically possible). We start with a #18 AWG copper wire. The tension in the wire is 85 pounds. See the "Copper" rows in Table 2. The breaking load of this size copper wire is also 85 pounds, so the antenna will break. The intuitive solution is to go to a larger and stronger wire. As the table shows, this will not help. As the breaking load increases with larger wires, the tension resulting from the given sag also increases proportionally. Thus, the ratio of breaking load to wire tension — in this case 1:1 — remains constant.

There are three possible solutions to prevent the antenna from breaking:

1) Increase the sag; this may not be possible since the sag, in some cases, may be limited by the need to clear trees (in my case),

Table 1
Antenna Wire Sag Data

L_c	Sag, *S*	Supports	Wire Gauge	Wire Weight, *W*	Tension, *H*	Breaking Load	Safety Factor
25	1	24.89	10	0.03143	2.4345	529.2	217
		24.89	14	0.01243	0.9628	213.5	222
		24.89	18	0.004917	0.3809	85.47	224
	4	23.16	10	0.03143	0.5267	529.2	1005
		23.16	14	0.01243	0.2083	213.5	1025
		23.16	18	0.004917	0.0824	85.47	1037
100	1	99.97	10	0.03143	39.2665	529.2	13
		99.97	14	0.01243	15.53	213.5	14
		99.97	18	0.004917	6.15	85.47	14
	4	99.57	10	0.03143	9.7379	529.2	54
		99.57	14	0.01243	3.851	213.5	55
		99.57	18	0.004917	1.523	85.47	56

Table 2
Examples for Wire Materials With 100 Foot Wire (L_c) and 0.719 Foot Sag (*S*)

Material	Wire Gauge	Wire Weight, *W*	Tension, *H*	Breaking Load
Copper	10	0.03143	546	529
	14	0.01243	216	214
	18	0.004917	85	85
Aluminum	10	0.00955	166	234
	14	0.00378	66	103
	18	0.00149	26	32
Cu/Steel	10	0.028	487	1136
	14	0.0114	198	400
	18	0.0045	78	160

sheds, and other objects.

2) Use a lighter wire with approximately the same breaking strength.

3) Use a stronger wire with approximately the same weight.

Since we cannot increase the sag in our example, two solutions present some possibilities. In case of the lighter wire, the switch to aluminum offers some improvement. This is shown in Table 2 in the "Aluminum" rows. The ratio of breaking load to wire tension is now approximately 1.4:1. This is somewhat better, but still not a comfortable situation.

The last solution involves the use of copper clad steel wire. This is a considerable improvement, as shown in the "Cu/Steel" rows. The breaking load is now about twice that of copper and the wire weight actually decreased. The ratio now is more than 2:1. This is much better. This discussion does not include the effects of insulation, ice, snow, and wind on the strength of the antenna.

The above discussion deals with the wire gauge selection from the strength point of view. It does not take into account RF power levels or other factors. What I find interesting is that the conclusion is counter-intuitive. The main points to remember are:

1) If the antenna breaks because the wire tension is equal to or exceeds the breaking load, going to a larger diameter wire will not help. A possible remedy may be to use aluminum or copper-clad wire or increase allowed sag.

2) For a given antenna length, the amount of allowable sag determines antenna strength.

3) In most applications, the distance between antenna supports is very close to the antenna length.

4) When the sag is limited because of space limitations, use either aluminum or copper-clad steel wire.

5) Wire insulation has a small negative effect on antenna strength.

6) In certain locations it may be desirable to heat the antenna (by passing a direct current through it to de-ice it) since the snow/ice increases the wind loading.

This analysis indicates that, for most Amateur Radio wire antennas, the wire strength is not a problem. I use insulated stranded wire for my antennas. — *73, Andrzej (Andy) Przedpelski, K0ABP, 7260 Terrace Pl, Boulder, CO 80303*; **k0abp@arrl.net**

[1] *Reference Data For Engineers*, Howard W. Sams & Co., Inc., 8th edition, "Miscellaneous Data" chapter, on page 48-19.]

[2] Harold Pender, Ed. In Chief, *Handbook for Electrical Engineers*, J. Wiley & Sons, 1922.