Antenna Masts: Safety and Selection

Whether you are using a mast in a permanent installation or a temporary public service application, this valuable advice from a tower professional can help you avoid disaster.

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Nearly every amateur who contemplates a tower will need to include a mast to support his or her antenna — or antennas. While some hams simply mount their beams on the side rails (the vertical legs) and rotate the whole tower, most of us rely on masts installed within the tower. Masts also come into play for temporary installations, such as those at public service events.

Either way, choosing the proper mast isn’t a decision to take lightly. Your personal safety, not to mention the safety of your antenna, depends in large part on the type of mast you select.

Mast Material
Consider the mast material itself. I’ve encountered almost every mast material during my years as a ham tower professional, from wood to fiberglass, conduit to fence rail, water pipe to aluminum, and various steel alloys. However, the fact remains there’s neither a single nor simple solution for every situation. In all cases, though, a basic understanding of some physics, along with the inherent strength of the materials, will help you choose wisely and stay within your budget.

Years ago, hams thought nothing of using water pipe as mast material. The common pipe available locally and cheaply is known as ASTM 120. It is heavy, which led users to think it must be strong enough for the task. This was often true, but at other times these masts failed spectacularly, as shown in Figure 1.

A few minutes with the ASM International Handbook demonstrates that for common water pipe, no minimum yield strength is specified at all! Water pipe is intended to convey fluids from point A to point B and is not rated for structural uses, although it is often pressed into service for light loads. Water pipe is also measured by its inside diameter (ID), so a smaller size (1.5-inch ID) is required in order to mate with our common 2-inch diameter U-bolts, clamps, and rotators. The actual outer diameter (OD) will still be under-sized — about 1.9 inches, in fact. If you were considering water pipe for your project, proceed with great caution. For all but the lightest jobs, you should use mast material that is designed for structural applications and rated accordingly.

Calculating Stresses and Strengths
When selecting a mast, you must ensure it will be strong enough. That means the mast’s strength must be greater than the stress of the loads you will place upon it, with an additional margin for safety.

The bending stress on your antenna mast depends upon:

- The wind load area presented by the antennas specified in square feet
- The antenna position on the mast above the top bearing
- The mast’s cross-sectional area
- The peak wind velocity

The strength of your mast is determined by:

- The yield strength of the mast material in psi (pounds per square inch)
- The cross-sectional dimensions of the mast (wall thickness and diameter)

Obtaining the data for calculating the bending stress is easy enough. You can obtain the information you need from manufacturer’s data, your own measurements, and your local county wind speed ratings (along with additional information that your nearest National Weather Service office can provide).2 The data for yield strength is obtained from the mast vendor.

Consult Chapter 26 of the ARRL Antenna Book for the fundamental formulas to calculate stress on masts.3 You can also use commercial mast selection software. DX Engineering (www.dxengineering.com) and Champion Radio (www.championradio.com) both sell software that allows you to simply “plug in” your values to de-
terminate the strength of materials required in your installation. Once you’ve done that, choose a mast that meets the requirements.

You may find that a simple antenna system can be supported easily. For example, if a single small tribander is going to be mounted only a couple of inches above a tower-top thrust bearing, water pipe may work because the bending stress will be very low. But if a “Christmas tree” array of 10 through 20 meter monobanders is going on that mast, you must use very high-strength mast material such as 4130 steel, which is strengthened with chromium and molybdenum.

**Mast Installation**

Once you have obtained a mast, the next challenge is to install it safely. The most common problem encountered during mast installation is maneuvering that long, heavy mast up the tower and into position. Here are some helpful suggestions.

If you are building a new tower, install the mast as soon as it is practical. For instance, if you are using a 24-foot length of tubing, install the mast inside the tower as soon as you have the first 30 feet of tower erected. It is much easier to install the mast inside the tower sections and pull it up, rather than attempting to lower it into the relatively small diameter sleeve or thrust bearing, from above the tower.

Simply lower the mast into the tower sections and let it rest on the tower foundation as you build the rest of the tower. (The longer the mast, the less likely it will fit into the tower between the rungs of regular lattice tower, so take advantage of the opportunity!) It is then an easy task to raise it once the tower is complete, pulling it up and through the bearing. Use muffler clamps as safety stops above the bearing, and slings to lift it into place.

If you are replacing a mast and must lower the new mast through the bearing from above, you will likely find the following technique helpful. Any long mast, no matter its material or how light, will exert some serious bending forces (torque or moment) on the person climbing the tower. It’s very hard to hold such a thing in position, guiding it down and through a hole only slightly larger than the mast’s own diameter. Add some wind and some wobble, and any climber will begin to worry. Such work is dangerous and not trivial.

**Mast Alignment and Realignment**

Despite torquing things down as tightly as you can, you may one day look up and notice your antenna(s) have turned from their normal position. At the top of the tower, you find one of two things: either the antenna has slipped on the mast, or the mast has slipped in the rotator. Such slipping is quite common on chrome-moly masts, for example, because of the steel’s hardness.

I do not recommend pinning masts to antennas or rotators with a bolt through the mast. In worst-case scenarios, rotators and antennas are then more likely to break, which is always more troublesome and costly compared to a simple readjustment. Slipping arises from the typical U-bolts used to hold the mast in place. They simply do not have sufficient surface contact area. Some extra “clamping power” is called for to prevent such slippage. A commercial product, the aptly named “Slipp-Nott,” available from Tennadyne (www.tennadyne.com/slipp_nott.htm) and shown in Figure 3, works great if you use the common 2-inch mast material. The Slipp-Nott provides nearly 90% surface contact area, producing greater holding force.

Another option is using U-bolts with “flattened” clamping areas, such as those developed by Cycle 24 (now sold by DX Engineering). Shown in Figure 4A, those bolts have more contact area between the mast and the bolt, increasing the clamping force. Photo 4B is of my homebrew version that adds a second U-bolt with short straps to clamp the mast above the rotator clamp. Although the Cycle 24 clamp is shown, a standard U-bolt can also be added and will add to the overall holding ability.

**Conditions Beyond Your Control**

If you do a simple search for wind tables, charts or wind zone diagrams, you’ll encounter confusing and sometimes conflicting data. While measuring wind velocity is easy enough, the charts usually provide averages of wind speed over long periods of time. Unfortunately, it is the gusts or peak wind speeds that wreak havoc with antenna systems.

Because we can’t predict when gusts will occur, it becomes necessary to gather all the relevant data, make some educated calculations, and proceed accordingly. But modeling, figuring, and software-driven conclusions will only take us so far. At some point we have to let experience guide our choices. If you don’t have that experience, or are unwilling to take the risk, consult a professional engineer familiar with conditions in your area.

Besides wind, which we can design for, there is ice to consider in some regions. Again, we can design for ice loads, but here is a significant point to remember: we cannot design for what will happen to structures when the ice comes off. Ice never sheds in a predictable fashion. Ice tumbles off in bits and pieces. The load changes dramatically as the ice departs. Add some
wind and you’ve potentially set the stage for disaster.

One of my clients recently suffered a broken boom on his C-19XR Yagi antenna during a fairly uncommon North Carolina ice storm. Compiling some simple figures, I reasoned that once the beam was loaded with ice, it likely weighed more than 200 pounds. When the wind began whipping up, the strength of the boom was quickly exceeded and it failed.

Despite your best efforts, it isn’t always possible to build in a sufficient safety margin for every scenario and still remain within a reasonable budget. If that is the case, consider purchasing insurance to protect you. Insurance should cover the cost of removing damaged antennas, masts, and tower hardware — a job best left to professionals with the proper equipment and years of experience.

Be Safe and Wise; Prepare and Plan

Here is a truth that should be universally acknowledged: an antenna system is first in a ham’s hierarchy of hardware and if there is a tower in your plans, the mast should be near the top (pun intended) of the items on which to concentrate your attention. Start by choosing mast material that is strong enough for the loads you expect it to support. Prepare yourself for the job of installation before you start up the tower. And be sure to leave yourself plenty of margin both in material selection and safety (always use a body harness) when working aloft.

Notes


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