The Mast Project

Objective: Mount a mast to hold weather sensors, a flag, or an antenna (in this case, weather sensors) to allow access to mounted devices without requiring either a ladder or supporting structure. Access for painting the mast or performing maintenance on fixed items such as pulleys or top ornament is required. The entire mast and payload must be accessible from ground level.

Options considered: One method is to use a telescoping set of poles, but that hides the upper sections inside the lower ones when lowered and intermediate-height loads are a problem.. Another is to mount a fixed length mast that can be rotated down, parallel or near parallel depending on load dimensions, to the ground, making the entire length, including the attached payload, available for maintenance. This was the method chosen.

The mast

1. If you have a true friend, such as I have in Bernie J, you have someone who will be of more help that you deserve. He will also be a skilled welder and will own his own welding equipment. He will also know what type of pipe to buy, wisely counseling against buying galvanized, threaded pipe for the project. Instead he will select lighter weight yet strong pipe with no threads to weaken the joints, and he will construct a sturdy mast.

2. The mast consists of three lengths of pipe in decreasing outer diameters, minimizing both weight and wind load, while allowing excellent support for the mounted load. In our case we are to mount a 6-pound multiple weather sensor package part-way up and an anemometer at the top. Overall length was not critical but a target range of 15 to 20 feet was established.

   a. The bottom section, the part that will accept the mounting pins and therefore will have two weakening holes drilled into it, is 2 ¼" OD, 7' long. *Photo 1* shows the joint between the lower and middle sections.

   b. The middle section is 1 5/8" OD, 4' 10" long.

   c. The top section is 1 1/4" OD, 6' 2" long.

   d. Finished length is 18'. It will sit slightly off the ground, so actual finished height will be higher.

Photo 1

3. Each of the lengths is welded together with strengthening as required to make a good fit. The joints are very strong and exceed any load requirements they are expected to encounter. We are located in Florida, so the mast is expected to remain up during our typical

hurricane winds. The anemometer is rated to read up to 175 mph, so the mast is expected to withstand those wind forces.

4. *See Photo 2.* Holes were drilled in two locations. These will accept the pivot pins and were strengthened by the addition of outer bearing surfaces and inside pass-through tubes. The pass-through tubes also make it easier to drill perfectly accurate through-holes. This accuracy really shows when the pins are inserted -- it's a long way through the outside post, through the two walls of the mast, and through the next post.

5. The two pins were constructed of zinc-plated cold rolled steel and are 5/8" diameter. A T-handle was welded at one end for use when removing the pins. Length of the pins is such that when fully inserted they are flush with the opposite end of the post. There would be no problem if they were longer, but I would not want them shorter. Because they hold the weight of the mast and payload, anything less than full penetration of both posts wastes support capability, and shorter pins would allow rainwater to rest in the holes.

Photo 2

The base

1. See *Photo 3.* Two pressure-treated 8-foot long 4x6 posts were placed with the long sides (nominal 6" dimension) facing each other – the long sides would be the "interior" of the base and would directly contact the mast. They were cut at an angle on the top end to encourage rain runoff. 6-foot lumber could have been used, but overbuilding is typical around here and I felt the extra leverage of support was worth the small extra cost of the wood.

2. Spacer blocks were toenailed between the posts to establish proper spacing for the mast. The spacer block for the above-ground portion was removed after the posts were set in place, so it is not visible in the photo.

3. The posts being secured as a base unit, holes for pivot pins were drilled through both posts. Hole size was for slip but firm fit of the pins. If both posts are securely aligned edge-to-edge, accurate lateral placement of the holes is simply by measuring on center from the edge. Note that if the top and bottom sets of holes are not in a true plane the mast will not be vertical when raised. Longitudinal (vertical) placement is best achieved by having the mast between the posts and drilling to match predrilled mast holes.

4. The base was placed in a hole 42 inches deep and approximately 3 inches wider than the wood.

5. Fast-setting concrete was poured into the hole and the posts were set for true vertical in both directions. It is critical that the posts be vertical in both directions if the mounted load requires leveling. Certain weather sensors are such a load.

6. Though not required, small pieces of lightweight aluminum sheet scrap were fixed to the top of the posts to further reduce rain intrusion

7. A small piece of wood was placed between the posts, near the bottom of the mast. This lighter colored piece can be seen in the photo just above ground level, under the horizontal mast. In normal use, to lower the mast the bottom pin would be pulled and the mast rotated on the top pin downward to the left. This piece of wood prevents the mast from tipping in the wrong direction when the lower pin is pulled– the bottom of the mast will contact the wood stop, limiting its movement. In the photo the top pin is removed and the mast has been rotated on the bottom pin, not usual for use, to allow for the next process.

8. If all you require is a sturdy mast that is readily accessible in its full length for maintenance, the project is complete. However, our project requires orientation of the anemometer to True North, so there is more to be done.

Photo 3

Finding True North

1. There are several ways to find True North, as opposed to Magnetic North, each with its own quirks, procedures, and achievable accuracies.
    a. One is to use a common handheld GPS unit. Good luck with that.
    b. Another is to use a magnetic compass and to correct the magnetic variation for the installation location. If your location is free of magnetic interference from electrical or heavy ferrous metal objects, you have a good sighting compass, and have an airport reasonably close you can get the magnetic variation figure from there.
    c. Another is to use a process that begins with identifying Solar Noon. This is the method chosen -- it is a simple process and each step provides the information needed for the next one.

2. Finding Solar Noon begins with finding your exact longitude and latitude; if you are setting up a weather station you will need this information anyway. This can be done with a handheld GPS, with software such as Microsoft Streets and Trips, or by using services such as http://GoogleEarth.com, http://AcmeMapper.com, or several others. My preferred one is http://stevemorse.org/jcal/latlon.php because it is quick and it will give you the results of eight different online address-lat/long converters all at once if you enter a street address. It is by far the easiest of the software and online versions I know and seeing the multiple results gives you an idea of the small inaccuracies that creep into such computations.

3. Knowing your exact latitude and longitude, preferably in decimal degrees format, you now need to determine when Solar Noon occurs at your location. Note that Solar Noon does not occur at noon on your wrist watch. Of many available online, one Solar Noon calculator I know of will allow you to print a Solar Noon calendar for every day of the year on one sheet of paper. This is handy because you may not know which day is going to have unobstructed sunlight at the proper time. Go to http://www.solar-noon.com, enter the required information, and then print the calendar.

4. Now make sure your watch is set correctly by going to one of the online time standards. I use http://www.nrlmry.navy.mil/TC.html because I also use it as a weather information source during hurricane season. Unless your watch is an hour off, you are concerned only with the minutes and seconds portion of the display.

5. Now let's find True North. You need direct, cloudless sunlight, but you need it for only a few seconds at the time indicated on your newly printed calendar. The basic process is simple. Hang a taut string, and at the time shown on your Solar Noon calendar, note the shadow of the string. The line of shadow from the string points to True North.

6. Because the device I will be mounting and aiming later will be mounted on the mast, I wanted to take my reading of True North from directly over where the center of the mast will be when it is vertical. That's why I pulled the top pin and pivoted the mast down on the bottom one. It gave me the best exposure of centering in both directions, as far down the mast as I could possibly get. See *Photos 4 and 5*, for the easy setup.

7. The longer the string is, the longer the shadow will be, so I wanted as much height as I could get without making a lot of work for myself. What you see are two pieces of wood clamped to a ladder and a string suspended from the end of the horizontal one. A plumb bob hangs from the other end of the string and it is centered on the mast and the lower pin.

8. When the magic moment arrived my wife held a scrap of plywood near the top of the post and in the thin shadow. I put a piece of rebar in the ground where the shadow ran off the end of the plywood to mark the spot. In the distance of about 30 inches, the length of the plywood scrap, the shadow had spread to just about the diameter/width of the rebar, so it worked out well. I went out the following day and at Solar Noon, a few seconds earlier than the day before (use the calendar); the shadow was right across the top of the rebar. If I look from the center of the mast to the rebar I am looking directly toward True North. That information allows me to align the anemometer so it will properly indicate wind direction. I'm now ready to mount the sensor package and anemometer.

Photo 4

Photo 5

Alternatives and substitutes.

1. I could have used galvanized pipe and reducers to "taper" down as I went up. But knowing the weight of what I have, I wouldn't want to be handling that mast as it rotates down if it were galvanized pipe.

2. The pins could have been cheaper bar stock, rebar, or long bolts. Bolts would probably have been the worst choice because with all that weight on them, those threads cutting into the wood on the way out would probably make pin removal a nightmare, not to mention eating the hole out with each removal. I first thought the pins should have something to keep them from backing out on their own, but after removing them a few times during the setup I realize what should have been obvious – all that weight makes it impossible

for them to come out. Removal requires a sizeable ball peen hammer and punch bar; the T-handle is good for the last few of inches.

3. For mounting the lumber in the ground a good sand/dirt pack may well have sufficed. In this area most fence posts are secured that way. But, I had leftover concrete to get rid of.

4. For True North measurement I could have just nailed a broomstick to the top of the fence and hung the string from there. The plumb bob could have been a bolt, and it didn't have to be centered on the mast – it just depends on how you want to transfer that information to mounting something on the mast.

There is no alternative or substitute, however, for a good friend with a giving heart. In addition to the welding that I couldn't possibly do, Bernie made possible in a couple of days what would have taken me a week to do, <u>if</u> I could have actually done it at all, and I had my doubts but was going to give it a shot. Until Solar Noon and True North, I did <u>maybe</u> one percent of the work on the project.

The finished product

See *Photos 6 and 7*.

The top of the mast is 18' 3" above ground.

The anemometer is 7 inches above the mast at 18' 10".

The rain gauge base (the black part of the sensor package) is 9' above ground The manufacturer, Davis, calls the package the Integrated Sensor Suite (ISS).

Without the payload mounted, the top end weighs 18 pounds when the mast is rotated horizontal.

Oh, and yes, the mast is <u>perfectly</u> vertical, according to both my 30" bubble level, and the rain gauge circular bubble level, not to <u>my</u> credit and camera angle notwithstanding.

Project complete, August 22, 2009.

Photo 6

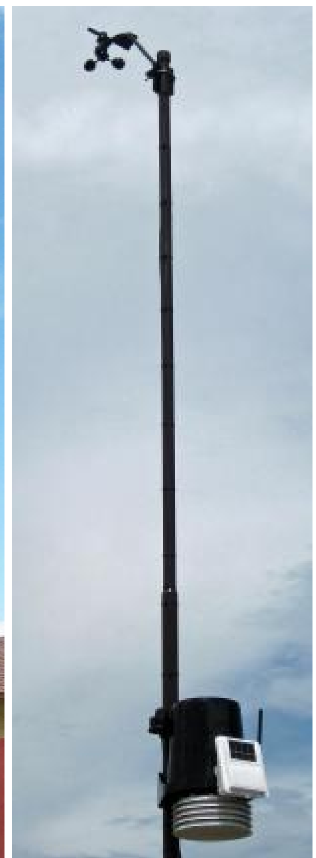

Photo 7