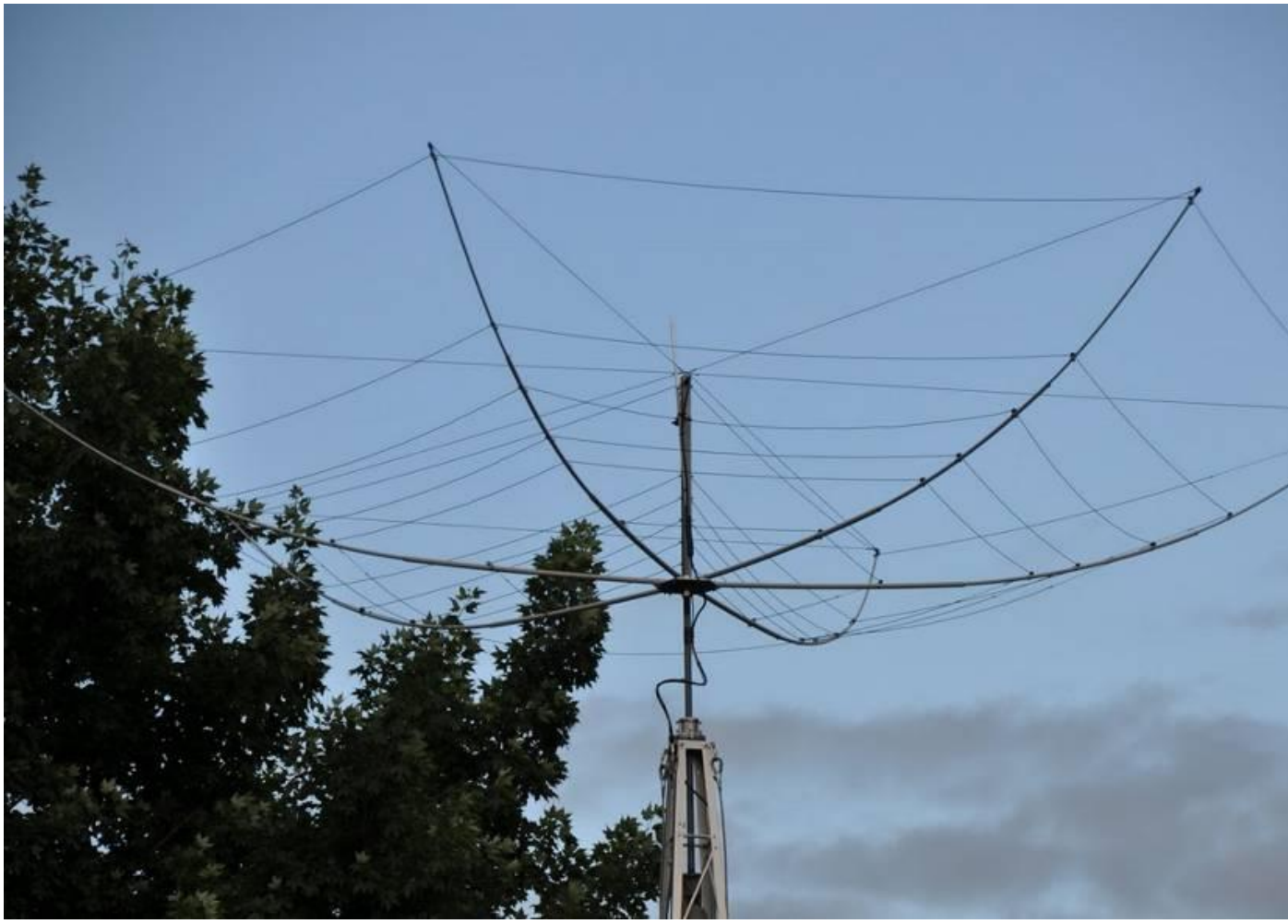
ROOF TOWER AND HEXAGONAL BEAM (June 2010, Revised: November 4, 2015)

I have been a ham for several sun spot cycles. The last several years have seen the sunspots go to zero bringing the low bands to life. I have been building simple low band antennas mostly for domestic contesting. In early 2010, the sunspot numbers are starting to climb and the higher bands are now coming to life. Therefore I need a good high band antenna to support domestic contesting and some DXing. My location does not lend itself to a ground mounted tower and after much consideration I settled on a small tower on my garage roof to support a 6 band hexagonal beam. The antenna height is approximately 35 feet. It will not be a great antenna (a great antenna is three elements at 60 feet for more gain and lower radiation angle), but it is the best I can do at this location. I am sharing the details of this antenna project for whatever you might find inspiring or informative for your own station.



RF could get tangled in all the wires!

Glen Martin Roof Tower:

The antenna is supported by a 17.5 foot tall Glen Marin roof tower model RT-1832.

Roof reinforcement: I made a spread sheet to estimate the tower wind load area and estimate the 90 mile per hour wind load on a fully loaded tower. The forces applied to the roof by wind acting on the tower (a lever) and antenna can be considerable. For the roof tower to remain erect and the roof to be spared damage, it is necessary to reinforce the roof as Glen Martin recommends. Braces between the rafters distribute the forces over seven rafters. The tower is attached to the roof using bolts that go through the tower leg brackets, the roof and the brace. Glen Martin recommends using lag bolts but that just doesn't seem strong enough. Climbing up to the sun baked rafters and installing the braces was the most difficult task in this project.

Added roof reinforcement for tower

Guy cables: According to Glen Martin, this tower does not need guys. After making the wind loading spread sheet, I decided that I should add guy cables to the tower to distribute some of the load to other parts of the roof. I estimated the tension in the guy cables to be 1100 pounds at 90 miles per hour if the base completely failed. I chose HPTG21001 Phillystran rated at 2100 pounds breaking strength for the guy cables. Of course the guys will never see that kind of tension because the roof/base will take most of the load. It is not easy to estimate the actual tension in the guys because the tower and roof have to actually flex before the guys take any load. I lightly tensioned the guys so as to not put additional static downward load on the tower. I chose non-conductive

Phillystran to not avoid resonances and antenna pattern distortion. The guy grips attached to the ends of Phillystran were easy to install. Not inexpensive!

Roof reinforcement for the guy cable attachment points

Assembly: The tower comes in one 9 foot long box in pieces. There are 192 ¼ inch stainless steel bolts and matching nylock nuts used to fasten the braces and legs together. The instructions are sparse, printed double sided on two legal size pages. It took a bit of guessing to layout the pieces so that assembly could proceed in an orderly manner with all those bolts one by one. A problem arose when some of the bolts seized before they were fully tightened. I would try to loosen a seized bolt and I wouldn't loosen. The only solution was to apply enough force to a bolt until it broke. I spent an hour or more investigating the problem. It seems that aluminum filings from the tower were getting into the threads. Then the nylon insert in the nut would grind the filings into the thread and then the bolt would seize. The most troublesome holes were the ones that didn't line-up exactly (in the legs where the lower and upper sections bolt together). I tried lubrication. I tried cleaning the holes. I tried being very gentle inserting the bolts. Nothing helped. About 20 percent of the bolts had the problem. Eventually I ran out of bolts and discovered I could buy replacements at the local hardware store for about $50. I called Glenn Martin. They had not heard of the problem before but sent me 45 additional bolts and nuts. Jim, KE0L, helped me fasten the lower section to the upper section while the whole thing was on the roof. He too learned how to break bolts when they seized.

Overall the tower seems sturdy although I would not climb it even though it has steps on one side. It would be easy to misstep and bend a diagonal brace. It is only rated for a 110 pound load. Fifty years ago I did weight 120 pounds.

Collection of seized and subsequently broken bolts and nuts. A few bolts were recovered but unusable.

G3TXQ Broadband Hexagonal Beam by K4KIO:

The antenna is a hexagonal beam for 20, 17, 15, 12, 10 and 6 meters. For more information: http://www.k4kio.com/ . I chose the hexagonal beam because of its small size and light weight. There are trees all around and not enough space for a full size multi-band antenna. I chose the K4KIO version because all the wires are cut to length and the hardware is completely installed on the spreaders and center plate. The center post is made of square aluminum tubing and is the shield for the feed line between driven elements. An internal structure is the center conductor of the feed line (very innovative). Every wire is packaged separately. The instruction sheet is well written and assembly went smoothly. It was a nice day and I did not hurry so assembly took several hours. I assembled the antenna in the front yard and had many gawkers drive-by staring at the contraption I was building. One suggested it was a clothes rack.

After all the trouble with assembling the tower, I was glad I didn't have to cut wires and spacing ropes to length, and didn't have to position hose clamps along the spreaders properly.

Lightning protection:

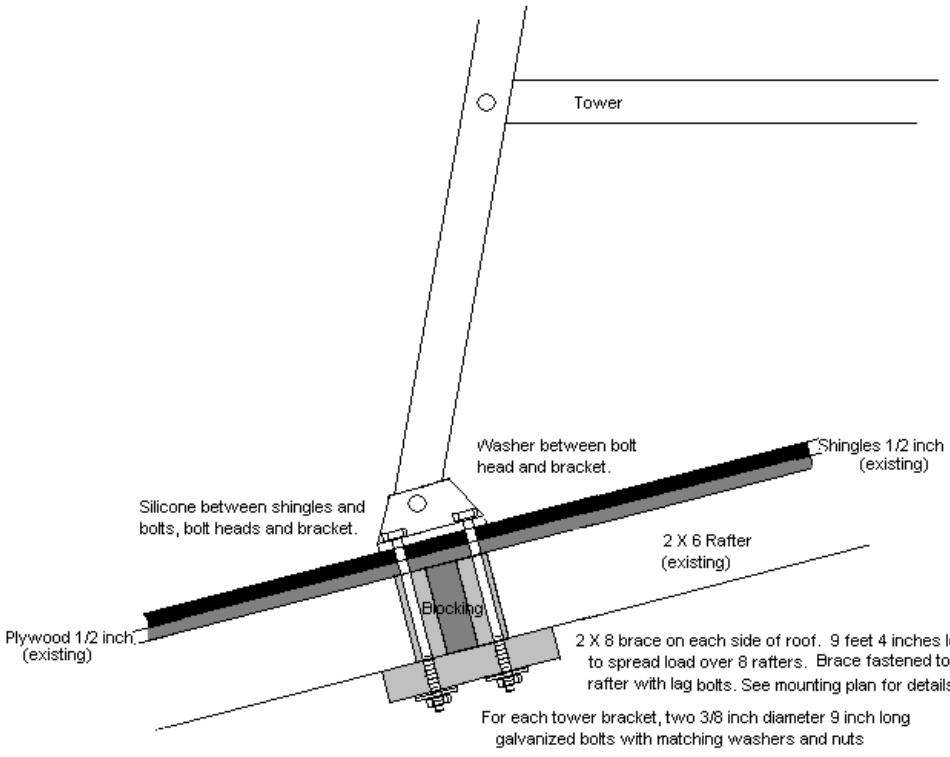
Several prominent hams in the Minnesota Wireless Association have been struck by lightning in recent years. Coax, antenna switches, radios, amplifiers, computers, and household items were destroyed. I am hoping I will not be struck by lightning. Especially I would like to avoid a lightning strike causing a fire. I added a lightning rod (available from Glen Martin) to my beam. One number 4 wire from the lightning rod goes to a ground rod. The wire is connected to both the top and bottom of the tower. Another number 4 wire goes from the bottom of the tower to a second ground rod.

Hexagonal beam without spreaders and wires. Notice the lightning rod, feed line connection and balun chokes on the feed line. The lightning rod is insulated from the aluminum center post because the center post is part of the feed system.

Rotator:
The rotator is a 1976 vintage Ham 2. It was in service for eleven years rotating a cubical quad at 72 feet and has been sitting in the “save box” ever since.

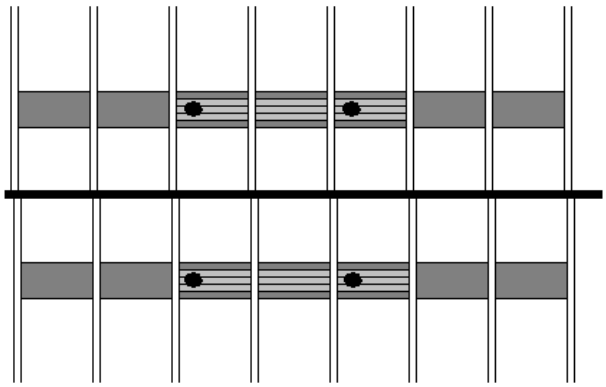
Building Permit:
The city of Maple Grove requires a building permit for amateur radio towers. I downloaded the applicable city ordnance from the Maple Grove web site. The city ordnance refers to the Minnesota building code. I downloaded the applicable portion of the Minnesota building code. I also reviewed the requirements for a building permit. They didn’t say what they needed for a tower building permit, but they did say what they wanted for a deck building permit. An e-mail to the inspections department told them I would like a building permit for an amateur radio tower, and ask if the only requirement was the city ordinances. They responded saying that since I live on a lake, the Department of Natural Recourses (DNR) limits the height of structures along the lake to 40 feet.

After carefully reading all the material, I wrote a construction permit application. I sought to show how my installation would be within the limits of the city and DNR ordnances and the tower would be capable of supporting the selected antenna. I included a plot plan/front and side elevations, a copy of the tower manual (showing how the roof should be reinforced), a specification for the hexagonal beam, and drawings of the roof reinforcements.



Tower Mount Details
Section at tower mounting

Revised 2010 04 03 RRR



View from above showing added blocking and bracing and location of tower mounting.

Shingles and plywood removed from roof to show structure.

One 1/4 inch lag bolt fastens the brace to every rafter. Lag bolt length is 5 inches and is in the center of the brace. Washer are under the head of the bolt.

Key of roof and bracing components

Rafter - 16 inch centers but not perfectly aligned across the ridge rafter

Ridge Rafter at peak of roof

Added Blocking between rafters under tower

Added brace to spread load between rafters
2 X 8 by 9 feet 4 inches long

Mounting points for tower (32 inches between legs)

Tower mounting details
Mounting plan

Revised 2010 04 03 RRR

One bright sunny day I went over to city hall and walked up to the construction permit “window”. I said I wanted a construction permit for an antenna tower. The clerk didn’t know what to do with me (there aren’t many amateur radio towers in Maple Grove) but called someone else to help me. I reviewed the permit application with him. He seemed OK with my application. I filled out a form with my name, address, and phone number and was told it would be ready in a day or two.

Next day I received a phone call telling me the permit was ready. I returned to city hall, paid, and went home with a permit in hand. It said I needed to build the tower and antenna as planned and then call for a final inspection. ….Whew one big step successfully taken!

Next I ordered the tower, antenna, guy cables, and cables and gathered wood bracing and other hardware material locally. This stuff is really expensive, hope it works! When assembly and installation was completed, I called the inspection department and ask for final inspection. The most probing questions were related to the zoning ordinances rather than the workmanship. A bit

disconcerting since zoning questions should have been resolved before issuing the building permit. Anyway it is now official.

Construction pictures:
Thanks to Jim, KE0L and Neill, NR0L for helping me (Roger), K0MPH install the beast.


Bottom section mounted on the roof.

Roger and Jim connecting the top section to the bottom section.

Assembled antenna, with the lightning rod attached.

Neill and Roger mounting the antenna to the mast.

Jim and Roger rest after raising the beast. Neill did all the hard work!

A beauty (before the guy cables are attached.)


Next day. Guy cables attached under stormy skies.

Preliminary Results:
The SWR at the transmitter end of the coax (and WX0B Six Pack) running 100 watts is very good on all bands except 12 (2.5:1) meters and marginal on 6 meters (2:0 on the low 500 Khz). I am not sure why the higher SWR on two bands. Maybe the lightning rod addition to the antenna is affecting tuning. The radio's auto tuner handles the SWR very well on 12 and 6 meters so I am not concerned about the SWR.

On the first evening, I made three QSOs with Russian stations on 20 CW. One was portable and working other Russians in a contest, so I had to break through the closer and louder stations. Then I spent a little time in the June VHF contest and made over 100 QSOs on 6 meters. Last weekend the All Asian contest I netted a few JAs and Russians on 20 meters before church.

It appears to work! I am looking forward to a fun contest season next fall.

Update: Snow storm damage and repair (July 27, 2011)

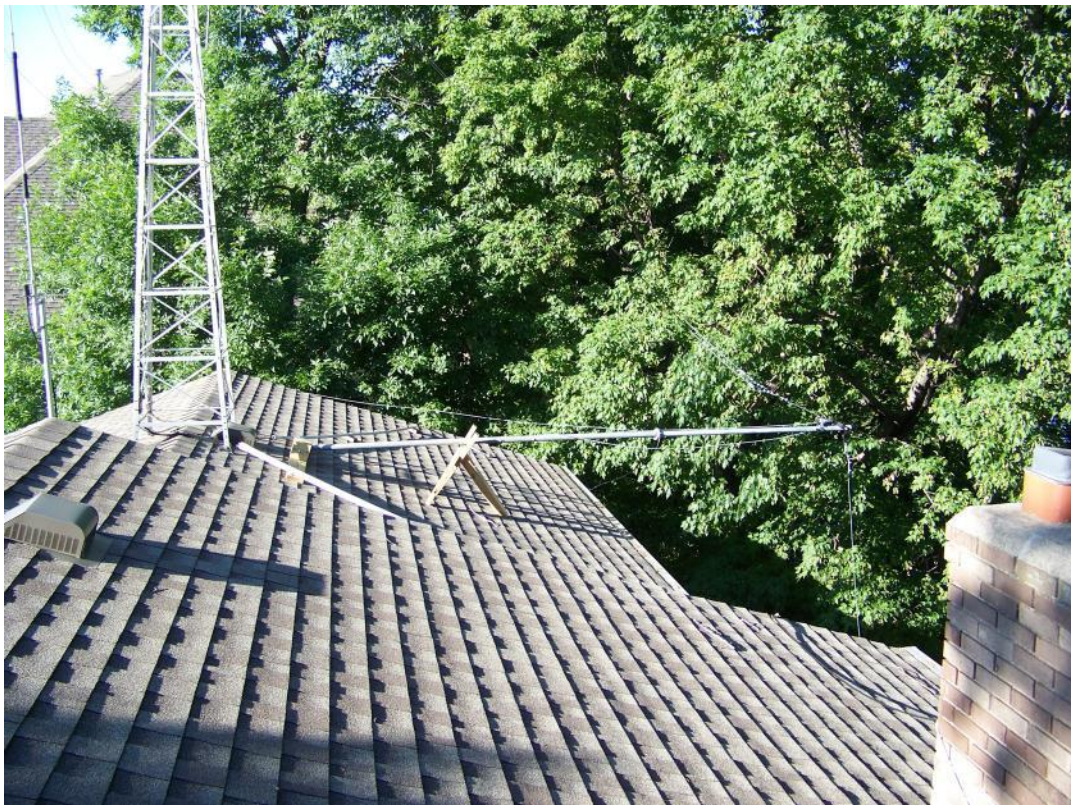
On Saturday November 13, 2010, the first major snow storm arrived in Minnesota. Several inches of heavy wet snow arrived in four hours. The snow accumulated on the antenna wires, ropes and spreaders causing four spreaders to break. The beam became unbalanced when the spreaders broke causing the mast and center pole to bend. – I did not expect a snow storm to damage the

antenna. I calculated that ½ inch radial ice (the local design criteria) would weigh 213 pounds and doubted that the antenna would survive such an ice accumulation. In retrospect, if I would have been home that Saturday morning, I may have saved the antenna by shaking the structure and causing some of the snow to fall off. There was no wind during this storm.

During the storm

After the storm

During the winter the roof was covered with snow and it wasn't safe to repair. In spring time we had many rainy and cold days and repair efforts took a long time. I designed and built a falling derrick system to lower and raise the tower safely. A winch fastened to a lower rear deck made it easy to lower and raise the tower. Calculations predicted that the maximum tension in the cable between the derrick and the tower would be 250 pounds. The maximum tension in the winch cable would be 150 pounds. The compression force on the derrick would be 300 pounds maximum.



Falling derrick made from two sections of a telescoping TV mast that I have been saving for 35 years.

Winch fastened to the deck.

Antenna lowering party. Left to right: Roger K0MPH, Jim KE0L, and Neill NR0L.

Once the antenna was taken down and the damage accessed, I ordered replacement parts from Leo, K4KIO. At the time of the antenna purchase, K4KIO, warranted the antenna against any storm damage and he replaced four center fiberglass sections and the center post. Only the bottom insulator of the center post was damaged, but Leo sent me a complete new center post. - I also ordered the 1.9 inch flange to go along with a heavier 1.9 inch diameter mast. In all there really wasn't much damage to the antenna. (Leo told me that four antennas had been damaged by storm this year out of 350). – Engineering challenge: It might be possible to make the antenna more robust for those of us in the frozen northland. I plan to study an idea floated by Leo using a principles "learned" from mechanical engineering class long ago.

The new mast was installed and the antenna assembled in the front yard. It again received attention from those passing by including the city foreman of the street repaving project whose uncle was a ham.

Jim, KE0L helps me attach the antenna to the mast.


Attaching the antenna to the mast.

Jim provided the muscle to tilt the antenna into position. He cranked with one hand
and held his i-phone in the other hand making a video of his efforts. See http://www.youtube.com/watch?v=4Sy4Jy8u4gA . Jim is a bit “cranky” in the video.

Beauty restored.

The SWR at the transmitter end of the coax (and WX0B Six Pack) is very good on all bands except 12 meters (2:1) (improved from before and as advertised). On six meters, the tuning was perfect on the lower 500 khz (improved from before). I did not install the lightning rod this time and moved the balun closer to the top of the center post.

I used the antenna in the July NAQP RTTY contest with good results on 20 meters. I am glad to have it back and hope that the weather next fall isn't so severe (and that I am home to try and shake some of the water / snow off the antenna). In the 1970s and 1980s, I had a cubical quad that was damaged once by an ice storm but it weathered several others, so hopefully the hexagonal beam will survive the next one.

Update: Performance Report (April 18, 2013)

After two years the antenna has not experienced any more damage. Every November and March (and this year April) there is concern that another freezing rain storm or wet heavy snow storm will destroy the antenna but so far the storms have been "mild"..... I see that KIO technology has an Ice Cord Set available for the antenna. The Ice Cord Set is meant to increase survivability in an ice storm. I would purchase a set immediately if I didn't have to lower the antenna to install the cord set.

How does it work? The 2011 - 2013 contest seasons were barn burners with 20,000 contact and wins in the following contests:

- 2011 – CQ WW CW low power assisted – first place for the 10th call area
- 2011 – ARRL Sweepstakes CW low power unlimited – first place Minnesota – division winner
- 2012 – ARRL DX CW low power unlimited – first place Minnesota and division winner
- 2012 – ARRL DX Phone low power unlimited – first place Minnesota and division winner
- 2012 – ARRL Sweepstakes CW low power unlimited – first place Minnesota (results not yet published)
- First place Minnesota in state QSO parties: New England, Indiana, Mississippi, 7th call area, Florida, Tennessee, and maybe a few more

While many of the QSOs are on 160, 80, or 40 meters, these wins would not have been possible without the hex beam. It is truly amazing that a small footprint 2 element beam at 35 feet could actually help win a few certificates or plaques in the highly competitive contest world.

In addition, I have worked many new countries with the antenna. I have made as many as 15 band mode contacts with some dx-expeditions. So am I happy? Yes I am happy!.... well... well but it would be even better if the antenna were at 60 feet instead of 35 feet!

Update: Performance Report (November 4, 2015)

Five years after the antenna was installed, it is still going strong with nothing more done to it since the ice storm. It has been a fun ride going through the sunspot maximum with this antenna. Many thousand QSOs have been made on this antenna.