A lightweight 20 foot stressed dish for 1296 MHz EME

Marc Franco, N2UO

Introduction

Building a large dish for 1296 MHz EME can be a complex and expensive project. Every time the diameter is doubled, 6 dB of additional gain can be obtained, but the dish area and weight are actually quadrupled.

After using a 10’ stressed dish for about 9 years, I decided that it was time to build a larger antenna, settling for a 20’ dish with similar characteristics and construction style as the my 10 footer.

Design criteria

Stressed dishes were made popular by Al Katz K2UYH and Dick Knadle K2RIW [1] [2] [3]. Many EME operators have built them and used them for long periods of time, usually until the antennas were destroyed by a powerful storm. The basic principle of stressed dishes relies on the approximation of the parabolic shape by pulling the ends of the spokes with ropes, wires or strings. For small and shallow dishes (10’ and f/d 0.5), the method works quite well. However, for larger diameters and deeper reflectors, the surface error increases significantly, leading to a loss of gain [4]. One way to overcome this problem is to pre-bend the spokes so that their shape will not be totally determined by the pulling force of the strings. This method worked out very well on the 10 foot antenna, so I decided to apply it again.

Most EME operators keep their dishes pointing up when not in use to minimize wind load. A 20’ stressed dish is a large structure and would have to be mounted at least 10’ high. This doesn’t look like something that will survive strong winds, so I realized that I needed to do something different if I wanted to use the dish for several years. I had to devise a way to bring the dish as close as possible to the ground, and tie it down with several ropes. This is much easier said than done when a large structure is involved.

Mount construction

I started the project by designing the mount. I used a Rohn 25 flat top cap 8’ tower section (25AG4) with a 3 inch weatherproof thrust bearing at the top, and a hinged base (R-BPH25G), so the tower could be raised to the vertical position during operation, but kept almost horizontal and close to the ground when the dish is not in use (Fig. 1). I bought all the tower hardware at a heavily discounted price from hams and at various hamfests. I found a 1945 prop-pitch motor at the right price for the azimuth control, and my neighbor donated a 24” linear actuator for the elevation from his old TVRO dish.

I built two OE5JFL-style 10-bit optical encoders [5] for positioning control. It took quite an effort to get them to work properly, but the cost of the parts was only a fraction of a commercial unit. The elevation encoder relies on a weight attached to it for reading the elevation, and the azimuth encoder is coupled to the dish support pipe with 2 sprockets obtained by splitting in half the main sprocket of a lightweight winch that I purchased at a hamfest. The azimuth mechanism is shown in detail in Fig. 2 and Fig. 3.

The antenna movements are controlled by an auto-tracker designed by OE5JFL [6]. The relays, power supplies and remote tracking unit are all housed in a weatherproof metal box mounted on the tower section, as shown in Fig. 4. The prop-pitch motor runs off 5 V dc for very low speed (nominal 28 V), and the elevation operates with 18 V dc instead of its typical 24 V.

The dish is mounted on a surplus TVRO polar mount converted to azimuth-elevation. I added a frame made with 2”x4” wood to increase the distance between the mount and the reflector in order to clear the tower section at low elevation (Fig. 5).

Reflector structure design and construction

The stressed dish structure consists of 20 spokes attached to a 2’ center disk. The spokes are 10’ long aluminum conduit used for electrical installations [7]. Their cost is higher than regular aluminum tubing for antenna construction. However, shipping by truck 10’ long pieces can easily double the total cost of the material, so I opted for the electrical conduit that I could pick up myself. The conduit comes with an end coupler to attach two pieces together, which comes really handy since it provides extra strength at the ends.

The spokes must be pre-bent in order to accurately follow the parabolic curve once they are installed and pulled by the ropes. This process can take considerable time if it is done by hand, like I did. First, it is recommended to cut a template of the dish’s profile to use throughout the reflector construction. I used a large piece of Styrofoam home insulation for the template, which I had to join since they come in 8’ long pieces. The Styrofoam is about 1” thick and very light, so it can be handled quite easily.

In order to find out the exact shape at which the spokes had to be pre-bent, I attached one of them to a vise like if the spoke were attached to the dish hub, and then pulled the end to match the template’s shape in the best possible way. I then bent the spoke in small amounts to minimize the error throughout its length. Once I was satisfied with the first spoke’s shape, I used it as a template to bend the rest of them.

The center hub consists of a 2’ diameter disk and a 2x2 feet plate made of ¼” thick aluminum. The spokes are sandwiched between the disk and the plate. The whole structure is held together with #8 stainless screws and nuts (Fig. 6).

The spokes are pulled from their ends by $^{3}/_{32}$" UV-resistant Dacron double weave rope. Phillystran could be used for more reliable performance, but at a much higher cost. One end of the rope is attached to the spokes with small size turnbuckles for minor surface adjustments, while the opposite end is attached to a 3’ long aluminum tubing 2 ¼” in diameter mounted at the center of the hub, which also serves as part of the feed support. Fig. 6 and Fig. 7 show details of the construction.

After the spokes and the ropes are installed and adjusted, a wire ring must be installed to form the rim of the dish. The easiest way to do this is to drill through the couplings that come with the electrical conduit and run a galvanized fencing wire ring around the dish. I actually ended up running two rings for additional strength, as it can be seen in Fig. 8.

Reflector surface construction

The material for the reflector surface must be lightweight, inexpensive, and able to maintain its shape between the spokes. Unfortunately, it is very difficult to meet all those requirements at once.

Galvanized hardware cloth is too heavy to be used on a large stressed dish. Aluminum expanded metal can be made to order and the opening size and sheet gauge can be selected for optimum RF leakage and weight. Unfortunately, its cost is beyond most budgets.

The last choice I considered was regular aluminum window screening. It is by far the lowest cost and lighter weight, but it is hard to maintain its shape between the spokes due to its lack of rigidity. The opening is so small that leakage would not be a problem.

Aluminum window screening requires additional support between the spokes in order to maintain the shape. For that purpose, I installed 7 additional fencing wire rings. The first two are at 9” intervals, the following 4 rings at 18” distance from each other, and the last ring again at 9” from the previous one. The rings can be seen in Fig. 9.

One problem I found after installing the rings was that I would actually need to attach the mesh at intervals closer than the distance between the rings. Unfortunately, those attachment points would not be leveled with the rings. I realized that by cutting short pieces of ¾” plastic electrical conduit and then cutting those pieces in half into a “U” shape, they would snap onto the aluminum spokes very nicely, and they would provide almost the additional height needed to level the mesh. See Fig. 10 for details.

I purchased a 100’ long by 4’ wide roll of charcoal aluminum screening. I cut ten 10’ long pieces, and then I cut them in half in an angle, starting 5” from one end, and finishing 5” from the opposite end, as shown in Fig. 11. I mounted the 20 screen pieces on the dish using hundreds of small pieces of aluminum MIG wire, and trimmed the edges as necessary. The pieces of screen overlap a few inches to minimize RF leakage. I normally start by attaching the mesh to the center of the dish, then I attach the opposite end to the outer ring, making sure the mesh is stressed, and finally I install the rest of the wires. Fig. 12 shows details of the mesh installation.

Feed support

The feed support details are shown in Fig. 13. I used a combination of aluminum tubing and 2” copper elbows used for water installations. All tubes had slits cut at their ends and the various pieces are held together by several stainless steel hose clamps.

The feed is held in place by two supports made with 1 ½” diameter aluminum tubing and two pieces of wood covered with weather seal ribbon material to smooth out the surface and prevent damage to the feed. There is an additional support that holds the larger diameter part of the feedhorn and prevents misalignment.

The feedhorn and the outdoor electronics are mounted at more than 10’ away from the hub. In order to help support this significant weight and prevent feed misalignment at different elevation angles, two steel cables are run between the feedhorn and the counterweight structure. In addition, four ropes stretch from the feedhorn to the rim of the dish to provide additional support when the antenna is at 90 degree elevation.

Counterweight and raising mechanism

Such a lightweight but large dish is not likely to survive strong winds if it is up in the air, even if it is facing up to minimize wind load. In addition, a 20’ dish is a significantly large structure and for various reasons one might want to keep it out of sight when not in use, which happens to be approximately 96 % of the time for regular EME operation (one weekend a month for a few hours). This could be accomplished by lowering the dish as close as possible to the ground and holding it down with several ropes.

Since the support tower in this design is fitted with a hinged base, it should be possible to tilt the tower down using a winch. However, there are two problems with this approach. First, the force required when the tower is close to the ground would be very strong if the winch is also mounted on the ground, and second, the counterweights would hit the ground, limiting how much the tower could be lowered.

I managed to solve both problems at once by using a very simple approach. The counterweights consist of two blocks of concrete each, mounted at one end of a 2x4 inch piece of wood, while the opposite end of the wooden support is attached to the dish hub with a ½” galvanized bolt, loose enough to allow the wooden support to rotate (Fig. 5). This allows the counterweight to move up and down, but not sideways. A steel cable is used to support the counterweight when the dish is in operation, allowing it to always be at ninety degrees with respect to the hub. The far end of the counterweight is fitted with casters, so when the dish is lowered to its resting position, the casters hit the ground and the counterweights fold over, permitting the dish to be lowered very closely to the ground. At the same time, since the counterweights are resting on the ground when the tower is lowered, the winch no longer supports their weight. Fig. 14 shows the dish being raised to its operating position at the point when the counterweights are about the lift off the ground.

Conclusion

The finished antenna is shown in Fig. 15. It has already been used for several months with great success. It survived several storms without damage, and the raising mechanism has worked flawlessly. The antenna is fed by a dual-mode feedhorn with a 5-step septum polarizer [8].

Snow seems to be its worst enemy so far. We had several inches of snow this winter, and after an inch or two I quickly noticed that the weight was in excess to what the structure could support. Since the dish is normally stored looking up and would become a snow collector, I resorted to spread some rock salt on it before it started to snow, which did not allow snow to accumulate. Since rock salt can affect metallic parts, the dish must be thoroughly cleaned afterwards.

A stressed dish is probably the least expensive construction method to build a high gain antenna for 1296 MHz EME. Most of the materials used where purchased locally at hardware stores. Moreover, the antenna is light enough to be mounted on a tilt tower to keep it close to the ground when not in use.

References

[1] Allen Katz, K2UYH, “Simple Parabolic Antenna Design”, CQ Magazine, August 1966.
[2] Dick Knadle, K2RIW, “A Twelve-Foot Stressed Parabolic Dish”, QST, August 1972.
[3] Allen Katz, K2UYH, “Stress Dishes Revisited”, 10th International EME Conference Proceedings, Prague, Czech Republic, August 2002.
http://www.astrorun.com/~fr5dn/radio/Stress%20DISH%20revisited.PDF
[4] The ARRL UHF/Microwave Experimenter’s Manual, page 9-38.
[5] Hannes Fasching OE5JFL, http://www.qsl.net/oe5jfl/encoder.htm
[6] Hannes Fasching, OE5JFL, http://www.qsl.net/oe5jfl/ant_cont.htm
[7] Allied Tube & Conduit Product Catalog, http://www.alliedtube.com/electrical-raceways/conduit/emt.asp
[8] Marc Franco, N2UO, “Computer Optimized Dual Mode Circularly Polarized Feedhorn”, 13th International EME Conference Proceedings, Florence, Italy, August 2008. http://www.ok1dfc.com/eme/technic/septum/N2UO%20opt.pdf

Fig. 1 – The antenna is kept close to the ground at 90 degree elevation when not in use. Note the support structure to relief the winch.

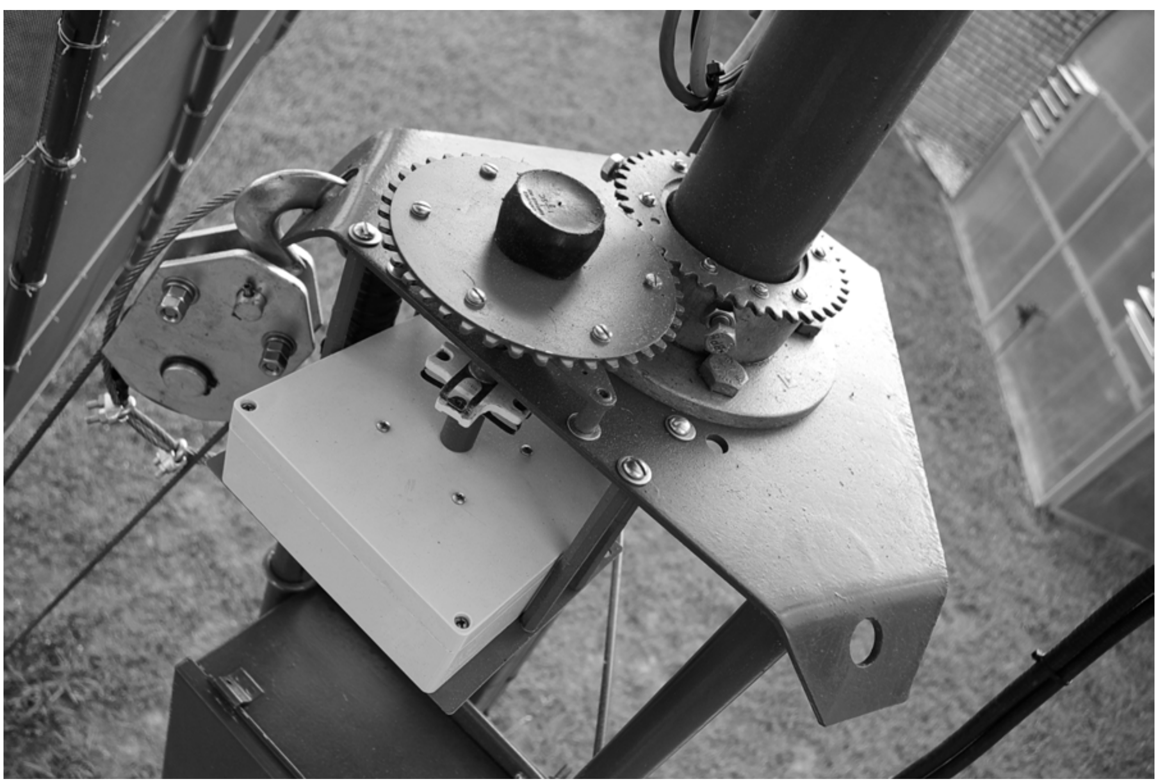

Fig.2 – Azimuth optical sensor (large white box) coupled to the main support pipe by means of two sprockets. Note the heavy duty pulley for the elevation of the tower.

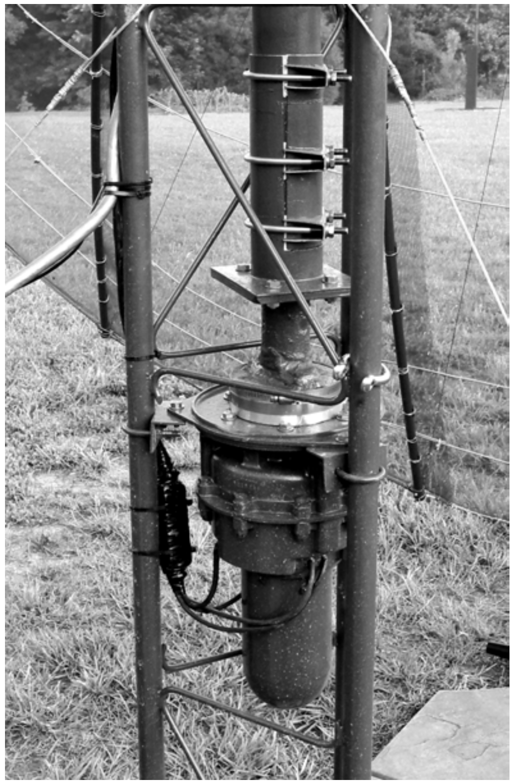

Fig. 3 – Prop pitch motor used for the azimuth movement.

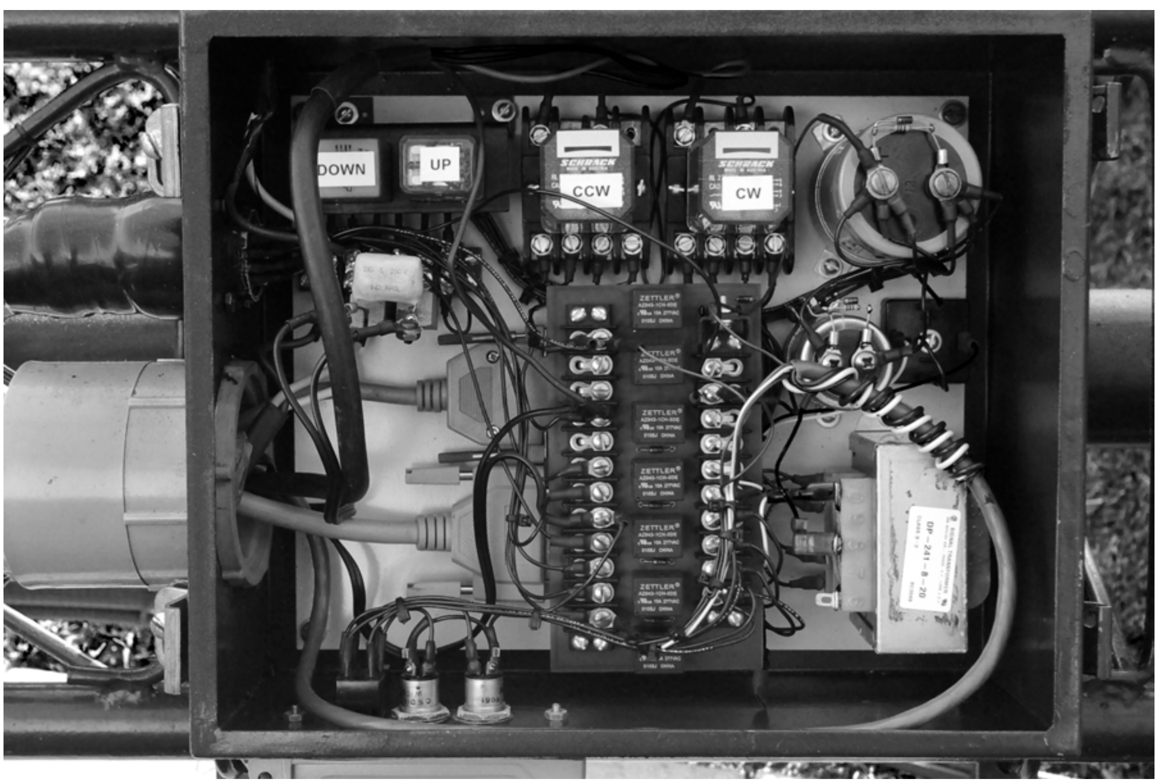

Fig. 4 – Outdoor control box and associated electronics.

Fig. 5 – Hub and elevation actuator. The white box is the optical elevation sensor.

Fig. 6 – Details of the hub, showing the two aluminum plates and part of the feed support structure.

Fig. 7 – 20 Dacron ropes are attached to the feed support to pull the end of the spokes.

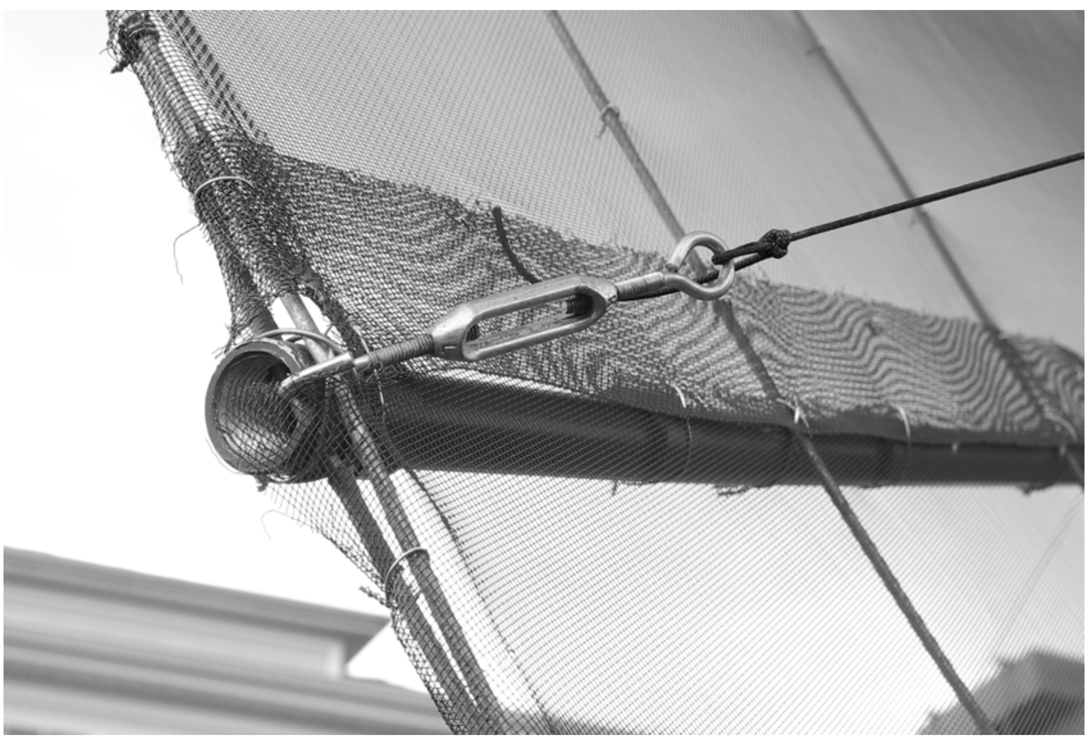

Fig. 8 – Detail of the attachment of the rope to the spokes and outer ring.

Fig. 9 – View from the back of the dish, highlighting the mesh support wire rings and counterweights.

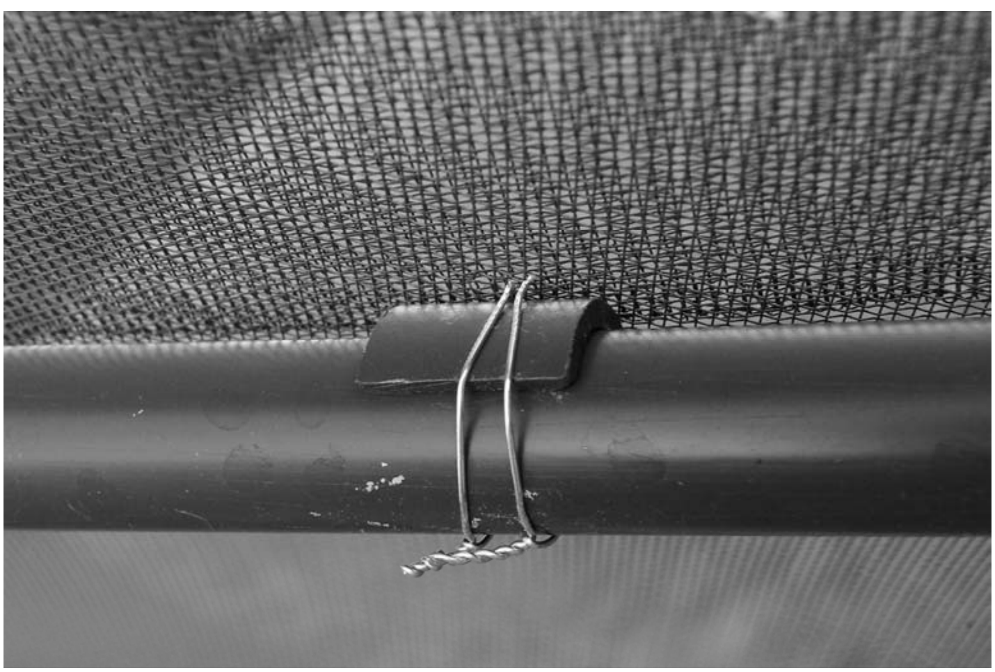

Fig. 10 – Plastic snap-on piece to provide additional attachment points for the mesh.

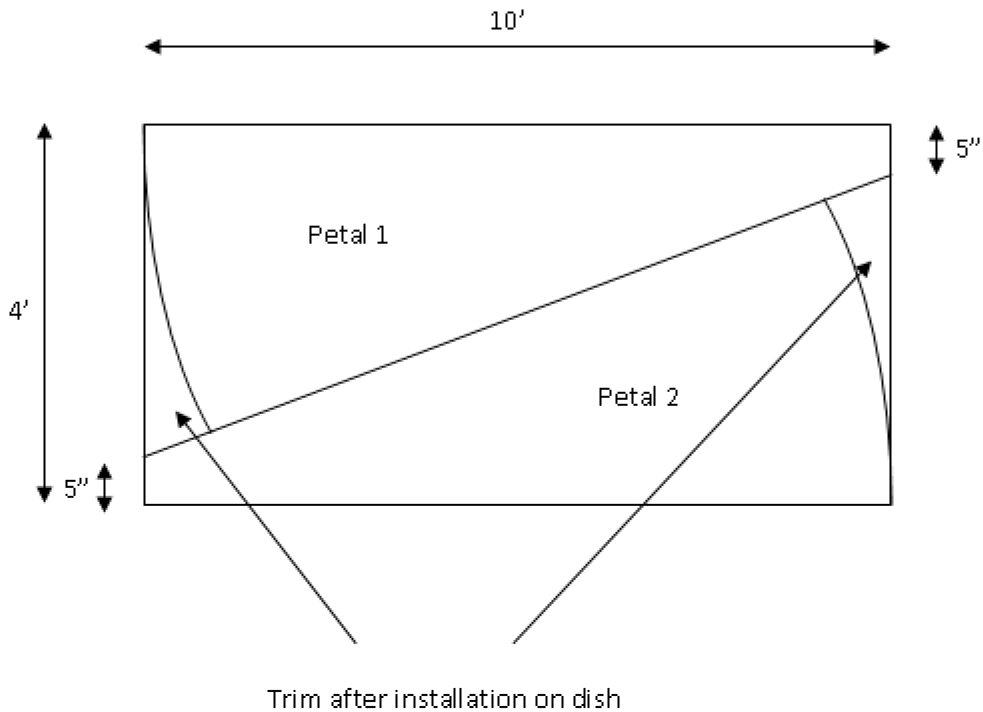

Fig. 11 – A 10’ long piece of aluminum window screening can provide 2 petals if cut as shown.

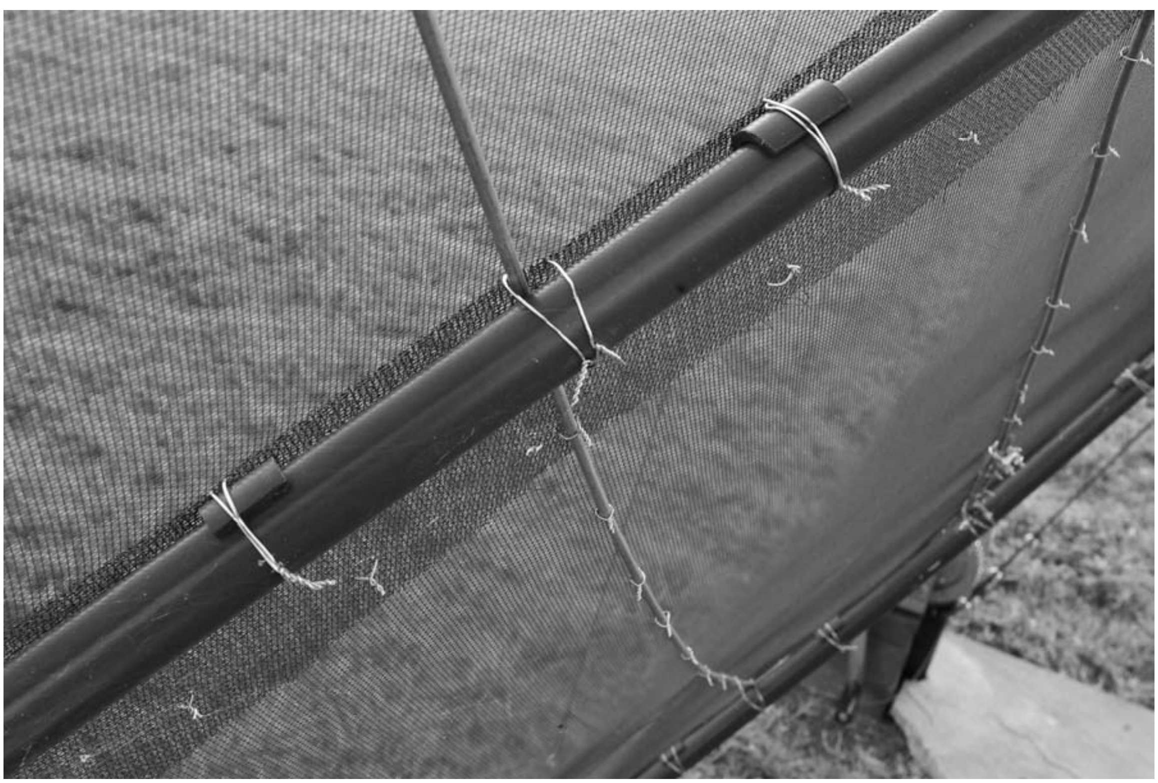

Fig. 12 – View of the mesh attachment method using aluminum MIG wire.

Fig. 13 – View of the feedhorn and support structure.

Fig. 14 – Antenna being raised to the operating position. The counterweights are about to lift off the ground.

Fig. 15 – View of the antenna in the operating position.