low-cost UHF antenna tower

Chimney-mounted perforated tubing provides accessible 57-foot skyhook

This article describes a design for a UHF antenna tower that can be constructed very simply and at a price most hams should be able to afford — less than $200.00. This type of tower is ideal for Amateur Fast Scan Television applications, among others.

Before the design was begun, several ground rules were established:

- The tower should be attached to the chimney of the house. (The advantage is obvious; the chimney would serve as the base for the tower and also provide extra height.)

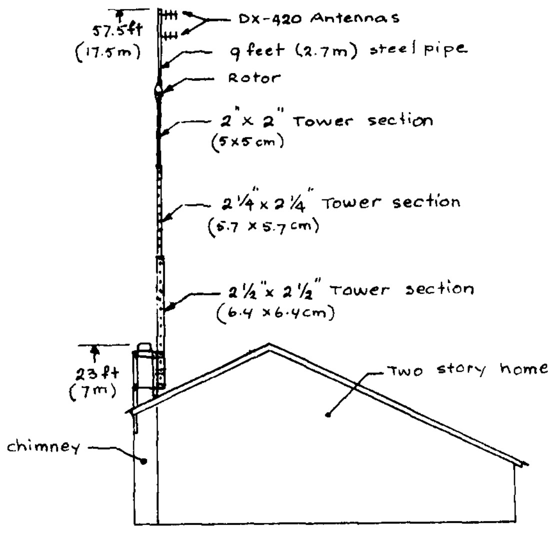

fig. 1. Tower and antenna assembly measures 57.5 feet (17.5 meters) from ground.

- For aesthetic reasons, no guy wires were to be included. This meant that the tower had to be strong enough to withstand 80-mile per hour (128 km per hour) winds with an antenna area of 2 ft^2 (0.19 m^2), which is sufficient for two or more UHF-type antennas.
- For ease of maintenance, the tower must be a tiltover.
- The tower sections had to be light enough to allow construction and assembly to be carried out without the need for a crane.

the chimney must take the load

The first order of business was the necessity of establishing the strength factor of the chimney for a given side load. This is very important; not all chimneys are strong enough to support a mast. At this site, the chimney is constructed from an inner column of tube segments surrounded with a brick-cemented outer shell. The space between the brick shell and the tube segments is filled with concrete reinforced with four 1/2-inch (1.27-cm) steel rods. This is common practice in Southern California. A check with the county masonry society revealed that this type of chimney should be capable of sustaining a side load of 1000 pounds (454 kg).

The next step requires calculating the strength specifications for the tower itself. Because no guy wires were planned to support the tower above the chimney, the combined strength of the tower, the rotator mounted on top, and the antennas above the rotator must be sufficient to sustain violent winds up to 80 miles per hour, or 128 km per hour. (A detailed analysis is included at the end of this article.)

The tower and antenna assembly consists of a set of chimney mounting brackets; three lengths of square tubing sections, each successively smaller in diameter and fitting inside the previous tube; a rotator; and a

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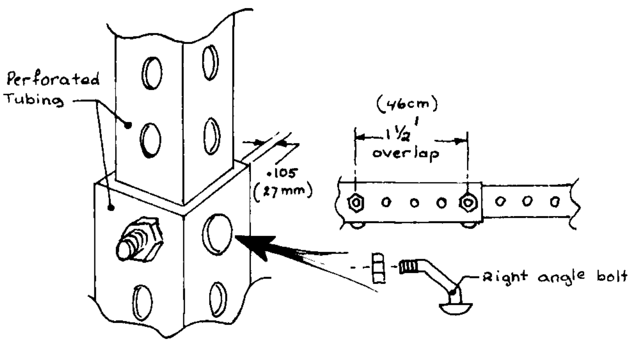

fig. 2. Right angle bolts connect tubing sections.

9-foot (2.74 meters) long, 16-gauge (2 mm) galvanized steel 1-5/8 inch (4.1-cm) I.D. tube with two DX-420 Cushcraft antennas mounted to it. The total height, measured to the tip of the antenna mounting tube is 57.5 feet (17.5 meters) above the ground. This includes the 23-foot (7-meter) high chimney. (See **fig. 1**).

construction details of tower and chimney mounts

The tower was assembled from three lengths of Telespar perforated tubing. This type of tubing was designed for sign posts, storage racks, and benches. Of the many unique properties of the tubing, its modularity makes it most useful for antenna mounting. Each segment of tubing was designed to fit into the next larger tube diameter. Right angle bolts provided by the supplier fasten the sections of tubes together. (See **fig. 2**). An overlap of 1-1/2 feet (46 cm) should be maintained to allow for sufficient strength. Since cost and simplicity were of primary concern, no elaborate motor driven or other type of mechanism to lower or raise the tower was included. Access to the antennas was achieved by making it a tiltover assembly with a hinge.

The brackets are of an all-welded construction. A detailed drawing (**fig. 3**) outlines the construction features of the front bracket which supports the tower.

The rear bracket is almost the same as the front bracket, with the exception that no tower brackets are included. The author chose to make the bracket longer, reaching further down the chimney for added strength and to provide a better stress distribution in the chimney. Each chimney width will be different; thus the inside bracket dimension will be unique for each installation. The 4.5-foot (137-cm) bracket height should be maintained in order to provide adequate base support. Remember, the tower, rotator, boom, and antennas weigh approximately 150 pounds (68 kg). The front bracket weighs approximately 80 to 100 pounds (36 to 46 kg) and the rear bracket approximately 70 to 90 pounds (32 to 41 kg).

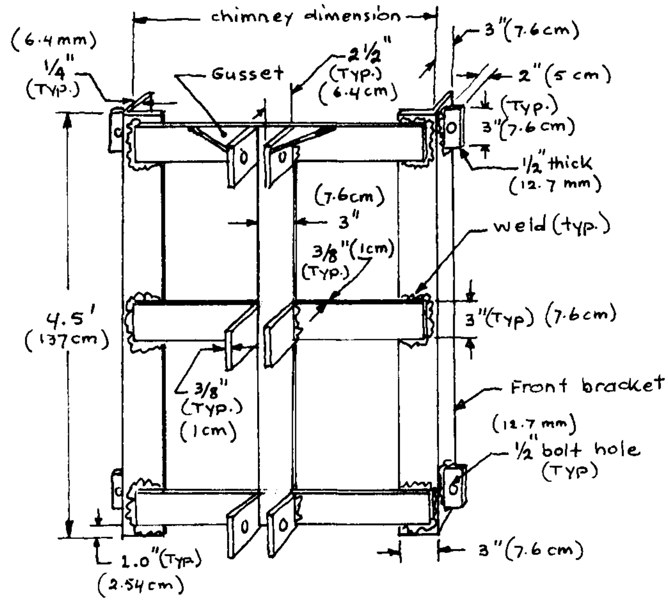

fig. 3. Construction details of front bracket assembly.

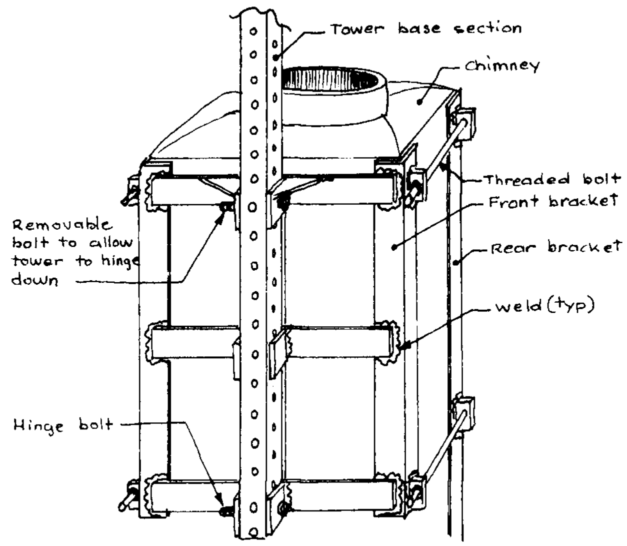

fig. 4. Hinge assembly, consisting of a front and rear bracket, is fastened with two 2-foot long threaded bolts.

After the brackets are completed, apply rust preventing paint and measure the width of the chimney accurately; the welded bracket assembly cannot be readjusted to fit the chimney. (A bolted construction may work loose or cause twisting in heavy winds.)

The sandwich mounting of the front and rear brackets, using 1/2-inch (12.7-mm) bolts, serves two purposes: first, it eliminates the need for drilling into masonry and mounting of lag bolts, which are unreliable in this application; second, it helps prevent the failure of masonry between the bricks. If the chimney is not straight you may have to insert shims between the brackets and the chimney for stability.

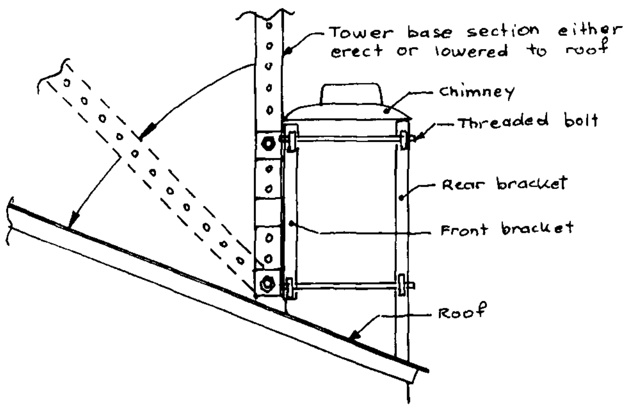

fig. 5. Remove upper mast bolt to lower tower to roof.

parts list

tower parts

quantity	*part number*	*description*
1	24F12*	perforated tubing 2-1/2 × 2-1/2 inches (6.4 × 6.4 cm), wall thickness 0.105 inch (2.7 mm), 12-feet (3.7 m) long, pre-galvanized steel
1	22F12*	perforated tubing 2-1/4 × 2-1/4 inches (5.7 × 5.7 cm), wall thickness 0.105 inch (2.7 mm), 10-feet (3 m) long, pre-galvanized steel
1	20F12*	perforated tubing 2 × 2 inches (5 × 5 cm), wall thickness 0.105 inch (2.7 mm), 10-feet (3m) long, pre-galvanized steel
2	TL070*	right angle bolt, electro-galvanized finish
2	TL050*	right angle bolt, electro-galvanized finish
1		tubing 1-5/8 inch (4.1 cm) ID, wall thickness 1/16 inch (1.6 mm), 9-feet (2.7 m) long

*Telespar parts can be obtained from the Unistruct Corporation, 14600 South Marquardt Avenue, Santa Fe Springs, California 90670.

bracket parts

quantity	*description*
2	angle iron 3 × 3 × 1/4 inch (7.6 cm × 7.6 cm × 6.4 mm), 52 inches (1.37 m) long
2	angle iron 3 × 3 × 1/4 inch (7.6 cm × 7.6 cm × 6.4 mm), 6 to 8 feet (1.8 to 2.4 m) long
6	flat cold rolled steel plate 3 inches (7.6 cm) wide, 3/8 inch (1 cm) thick, length dependent on chimney width
6	flat cold rolled steel plate 3 × 2-1/2 × 3/8 inches (7.6 × 6.4 × 1 cm)
8	flat cold rolled steel plate 3 × 2 × 1/2 inch (7.6 cm × 5 cm × 1.27 cm)
2	galvanized steel bolt 5 inches (12.7 cm) long × 1/2 inch (1.27 cm) thick
8	galvanized steel nut for 1/2 inch (1.27 cm) bolt
4	galvanized threaded bolt 3 feet (91 cm) long — dependent on chimney dimensions
1	flat cold rolled steel plate 3 inches (7.6 cm) wide, 3/8 inch (1 cm) thick, 52 inches (1.3 m) long

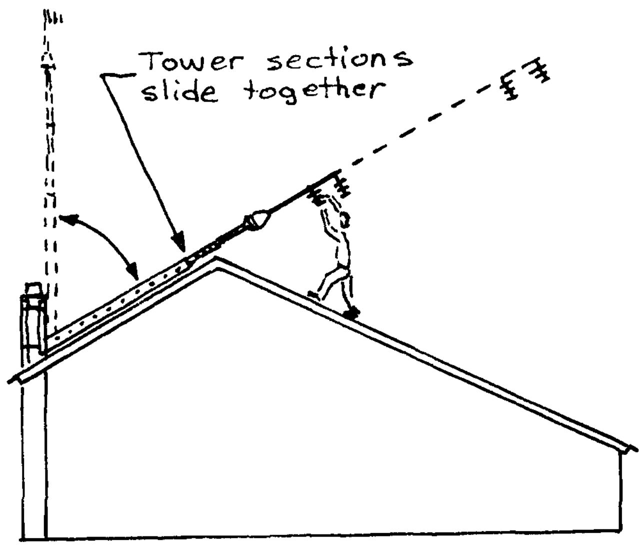

fig. 6. To reach antennas, simply remove bolts joining sections, sliding one section inside the other.

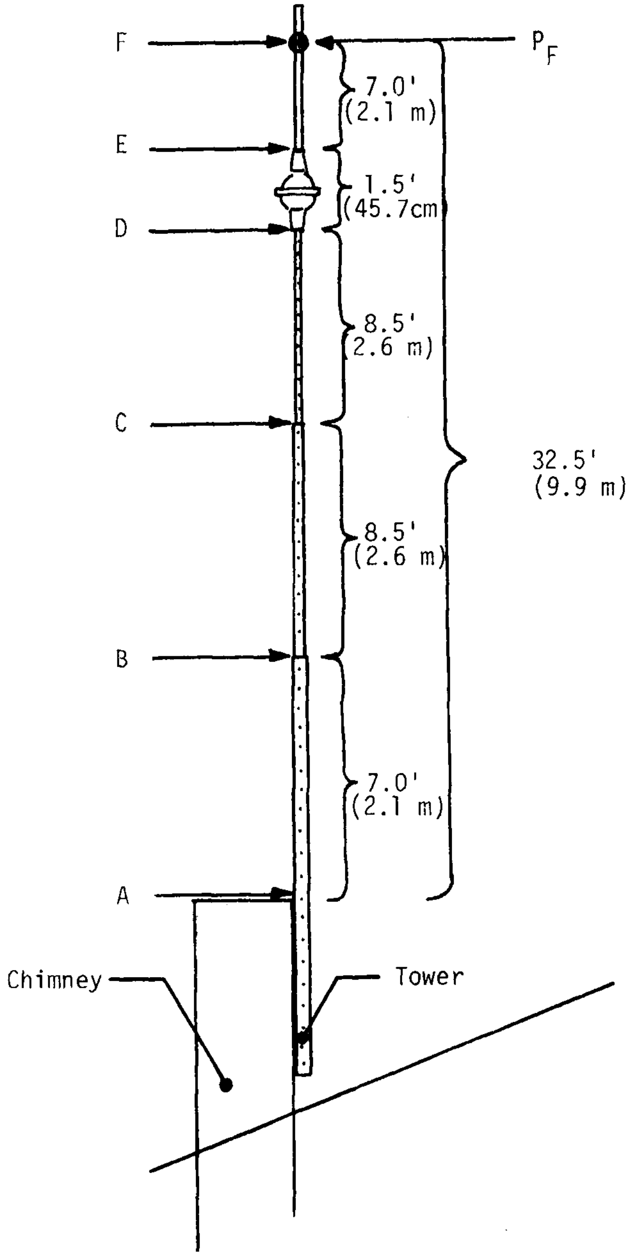

fig. A1. Tower/antenna configuration.

Designed to be part of a welded bracket straddled around the chimney, the hinge is fastened together with 1/2-inch (12.7-mm) two-foot long threaded bolts available at most hardware stores. (See **fig. 4.**) **Fig. 5** illustrates how the tower can be lowered to the roof by removing the upper mast bolt.

If you have a pitched roof, how do you reach the antennas after the mast is hinged down? The mast is 39.5-feet (12-meters) long, measured from the hinge point. It overhangs the rooftop by 27 feet (8.2 meters). Therefore, the design includes the sectional feature shown in **fig. 6**. Since three square tubes slide together, merely removing the two sets of bolts that hold the sections together allow shortening the mast to the point where the antennas can be easily reached.

In terms of the rotator, antennas, and tubes supporting these antennas, each individual must consider the options available and choose the most appropriate configuration. The tower constructed by the author was tested involuntarily when *seven* major storms swept through the Los Angeles area with wind velocities up to 100 miles per hour (160 km) during the winter of 1982-1983. The tower, brackets, and antenna sustained no damage; the tower is still perfectly vertical, and no stress cracks or other minor damage has been observed on the brackets or tower.

acknowledgement

My sincere thanks to Bob Provost for providing the mechanical analysis for the tower design.

appendix

antenna tower stress analysis

The following is a stress analysis of an antenna tower attached to a chimney. This analysis may be used as a guideline for any tower configuration. The simplified approach assumes a cantilever beam with a projected antenna surface area of 2 feet^2 (0.19 meter^2). The object of the analysis is to determine the wind velocity a given tower/antenna configuration can endure without damage.

The configuration of the tower/antenna model is shown in **fig. A1**.

First, one needs to determine the moment of inertia (I_{SQ}) of sections "*A*" through "*F*," using equation:

$$I_{SQ} = 1/12\ (O.D.^4 - I.D.^4) \qquad \textbf{(A1)}$$

$$I_A = 1/12\ [(2.50)^4 - (2.29)^4] = 0.9635\ in.^4$$

Next, the *bending stress* (σ) as a function of wind force (P) needs to be determined.

$$\sigma = \frac{MC}{I} \qquad \textbf{(A2)}$$

where M = moment (arm)
C = distance to neutral axis of cross section
I = moment of inertia

For section "*A*" the bending stress is:

$$\sigma_A = \frac{(32.5\ ft)\ (P\ lb)\ [(1/2 \cdot 2.50\ in)]\ (12\ in/ft)}{0.9635\ in^4}$$

$$\sigma_A = 506.0\ (P)\ lb/in^2$$

The following table summarizes the results:

section	CG distance	tower cross section (inches)	wall thick (inches)	I	σ PSI
F	—	—	—	—	—
E	7.0	1-5/8 × 1-5/8	1/16	0.1592	428.7 P
D	8.5	*	—	—	—
C	17.0	2 × 2	0.105	0.4778	426.9 P
B	25.5	2-1/4 × 2-1/4	0.105	0.6925	497.1 P
A	32.5	2-1/2 × 2-1/2	0.105	0.9635	506.0 P

*Extra strong section used, calculation not necessary.

As can be seen from the table, Section *A* experiences the largest stress for a given wind force (Section *C*, the least). (In other words, Section *A* would be the first section to break.) The maximum wind force a section can withstand is based on the strength of the material.

The yield strength of the tower material is $\sigma\ yield = 33\ ksi$ (33,000 lb/in^2). Any bending stress less than 33 ksi applied to the cross section will *not* permanently deform the tower section.

The ultimate strength of the tower material is $\sigma\ ultimate = 52\ klb/in^2$. Any bending stresses from 33 to 52 klb/in^2 applied to the cross section may result in permanent deformation. Stresses above 52 klb/in^2 will cause the tower section to break.

Solving for the unknown wind force yields:

$$506.0\ P = 33\ klb/in^2$$

$$P = 65.22\ lbs$$

Wind force is related to wind velocity as follows:

$$P = \frac{A \varrho V^2}{g} \qquad \textbf{(A3)}$$

where A = antenna area
ϱ = density of air (0.076 lbm/ft^3 at 66°F)
V = wind velocity
g = gravitational acceleration

$$P = \frac{(2 ft^2)\ (0.076\ lbm/ft^3)\ [(V\ miles/hr)\ \frac{1}{3600}\ \frac{hr}{sec}\ (5280\ ft/mile)]^2}{32.186\ [ft/sec^2\ (lbm/lbf)]}$$

$$P = 0.01016\ V^2\ lbs \text{ or } V = \sqrt{\frac{P}{0.01016}}$$

Therefore, the maximum wind velocity cross section "*A*" can withstand is:

$$V_{yield} = \sqrt{\frac{65.22}{0.01016}} = 80\ mph$$

and

$$V_{ultimate} = \sqrt{\frac{103.64}{0.01016}} = 101\ mph$$

Although the simplified calculations show a V_{yield} of 80 mph, winds up to and over 100 mph have not resulted in tower material yield at this location. It appears that using the equations outlined above should provide a conservative means of calculating the strength of a tower.

(The same analysis in metric units is available. Send an SASE . . . **Editor.**)

ham radio

John Marshall Haerle, WB5IIR

The Amateur Radio community was recently saddened to learn of the untimely death of John Haerle, WB5IIR, in an automobile accident August 1.

A popular author and lecturer active on 160 meters, John had been affiliated with Gates Radio as chief engineer for sales, and later with Collins Radio, where he served as director of advertising and public relations and also headed that organization's broadcast division.

Surviving are his wife, Rose; a son, Dan; and a granddaughter.

A scholarship fund has been established in John's name at North Texas State University; checks may be made payable to the North Texas State University Scholarship Fund and sent to the Dallas Amateur Radio Club, P.O. Box 173, Dallas, Texas 75220.

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