build your own tilt-over antenna mast

Here's the answer to a structurally sound, low-cost mast using ordinary hand tools and readily available hardware

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This tilt-over antenna mast fulfills the need for a lightweight, low-cost amateur rotary beam support that can be raised or lowered in a few minutes by one man without assistance. As shown in the accompanying sketches and photographs, the design requires materials and tools commonly available to most amateurs, takes up only modest backyard space, and unlike lattice-type metal or wood towers, is quite unobtrusive, especially when painted to blend with the background.

The project originated when I was pondering ways and means for supporting a lightweight Mosley TA33 Jr. three-element beam. The obvious solution to the problem would be to purchase and erect one of a large number of available steel towers, but this was ruled out for esthetic and financial reasons. Using the rooftop or chimney was likewise unacceptable. One alternative remained; a new design had to be conceived that was structurally sound, low in cost, and easy to build and manipulate.

Over the weeks many ideas were tried and rejected, and during the construction period many revisions were made. The tilt-over mast and antenna have been in operation for several months, during which they've been lowered and raised many times without incident. I've included a detailed stress analysis, complete with quantitative data in this article (see Appendix). The analysis considers loads encountered in raising and lowering the structure, as well as those resulting from wind velocities up to 80 miles per hour.

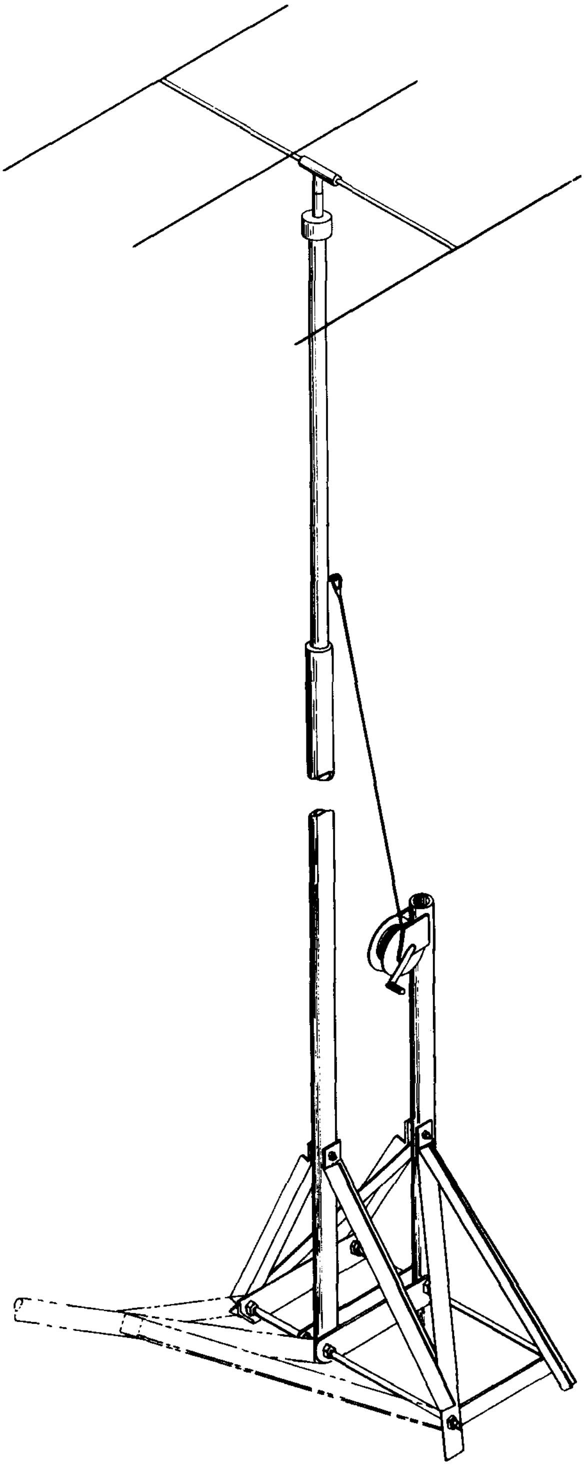


fig. 1. Complete tilt-over mast structure showing mast-hinge assembly.

Four novel features are included in the design and construction of the mast:

A boat winch mounted on a short, fixed support pipe for raising and lowering the mast.

A rigid hinge or pivot assembly at the base, which prevents lateral deflection of the mast and antenna assembly during erection.

Two sets of symmetrically placed guying cables to maintain the mast in the vertical position without buckling.

Auger or screw anchors in the soil as high-strength fastenings for the guying cables and winch pipe support.

In all cases, safety factors of at least 2 to 1 were used to compensate for any small design approximations and to insure adequate resistance to high winds.

construction

The first step in the project is to accumulate the parts listed in **table 1.** The only precaution here is to be sure to purchase 1/8-inch diameter, 1800-pound-breaking-strength stranded-steel aircraft cable and **not** galvanized *iron sashcord* (which resembles the proper material) with a breaking strength of only 540 pounds. Stainless steel cable is even better, but it's quite expensive.

The screw anchors may be obtained from Spaulding Products, Frankfort, Indiana. Other materials are obtainable from plumbing and hardware supply sources. The winch is obtainable from Sears-Roebuck at about $6.00 for the smallest unit, with a capacity of 1000 pounds. Good construction practice for any device that must withstand weather calls for at least two coats of paint. Don't overlook this essential item.

ground work

Selection of a site comes next. Be sure that an unobstructed radius equal to the mast, plus antenna and rotor height, is available in the vertical plane for raising and lowering. In the example shown here,

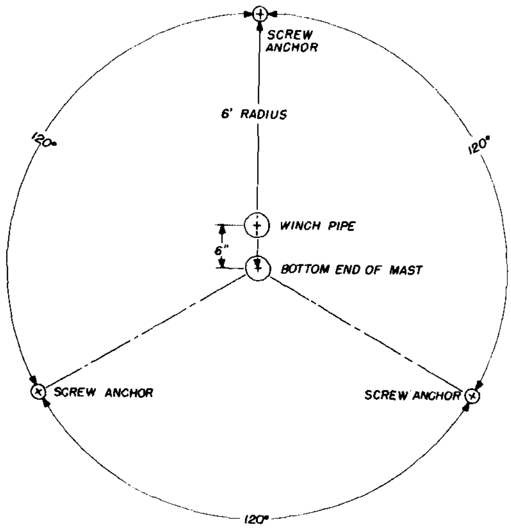


fig. 2. Plan view of the tilt-over mast base site.

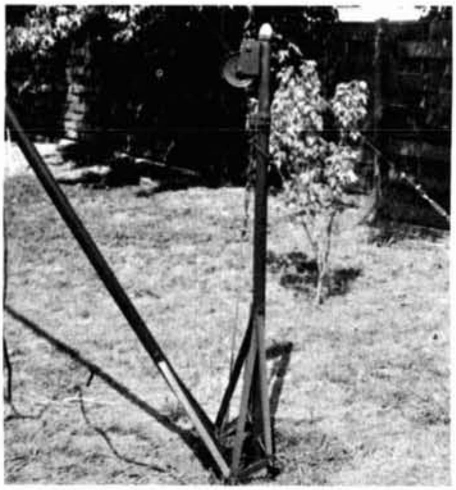
this amounts to a distance of about 35 feet plus adequate clearance for the antenna boom and elements.

After you select the location of the mast base and lay out the site as shown in **fig. 1,** drive the 2-inch pipe until it projects about 2 inches above the ground. This forms the socket that receives the 1½-inch winch pipe. (The location of this socket is about 6 inches to the rear of the bottom end of the antenna mast.) Then insert the 1½-inch winch pipe into the 2-inch pipe until the winch pipe bottoms. Fasten the assembly together with a 3/8-inch steel bolt, lock washer and nut. (See **fig. 2.**)

Next, drive the three screw anchors into the ground 120 degrees apart at a radius of 6 feet from the bottom end of the antenna mast as a center (see **fig. 1**). The technique for installing these anchors is as follows: After the location is spotted, make a shallow depression 6 inches in diameter by 6 inches deep. Then using a length of 3/4-inch pipe as a handle through the eye of the screw anchor, twist the auger end of the anchor into the ground, using downward pressure while

table 1. Parts list for the tilt-over mast.

part	description	quantity
galvanized iron pipe	2-ft x 2-inch diameter (nom)	1
galvanized iron pipe	7-ft x 1½-inch diameter	1
galvanized iron pipe	10-ft x 1½-inch diameter	1
galvanized iron pipe	21-ft x 1¼-inch diameter	1
extruded aluminum alloy pipe	3-ft x 1¼-inch diameter	1
boat winch	1000-lb capacity	1 (Sears)
aircraft cable	galvanized steel 1/8-inch diameter 1800 lb rating	210 ft
turnbuckle	5/16-inch x 6-inch	7
screw anchor	4-ft x 6-inch diameter helix	3 (Spaulding Products)
wire rope clip	1/8-inch	58
wire rope thimble	1/8-inch	39
galvanized or stainless steel bolts	3/8-inch diameter x 4-inch long	5
eye bolt, galvanized iron	3/8-inch diameter x 4-inch long	1
guy ring	To fit 1¼-inch pipe	1
threaded galvanized steel rod	½-inch diameter x 2 ft	2
galvanized angle iron	1¼-inch flange x 1/8-inch thick	15 ft
miscellaneous locknuts, lock washers and flat washers		30-40
paint		½ gallon

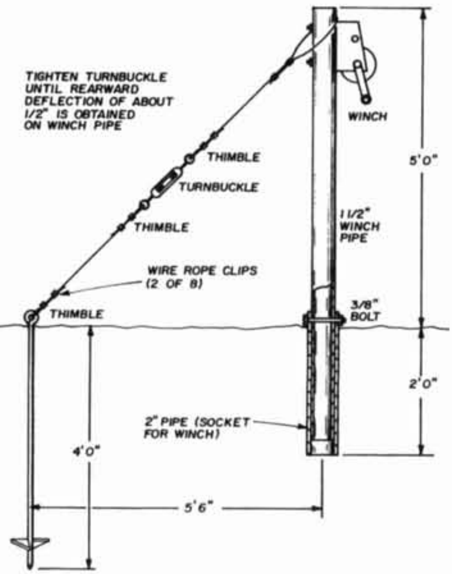


turning. Initial moistening of the hole may be necessary to start the anchor.

Twist the anchors into the ground until only the circular eyes protrude. When installed in average backyard soil, these anchors can withstand a pull of over 2000 pounds.

Mount the winch near the top of the $1\frac{1}{2}$-inch pipe at a height of about 5 feet above the ground, using two 3/8-inch diameter steel bolts, lock washers and nuts.

fig. 3. Winch pipe support.



The top of this pipe is then anchored to the rearmost screw anchor eye by a tension assembly consisting of steel cable, turnbuckle, thimbles and wire rope clips as shown in **fig. 2.**

pivot assembly

The next step is the construction of the pivot, or hinge assembly about which the mast tilts. The basic materials here are

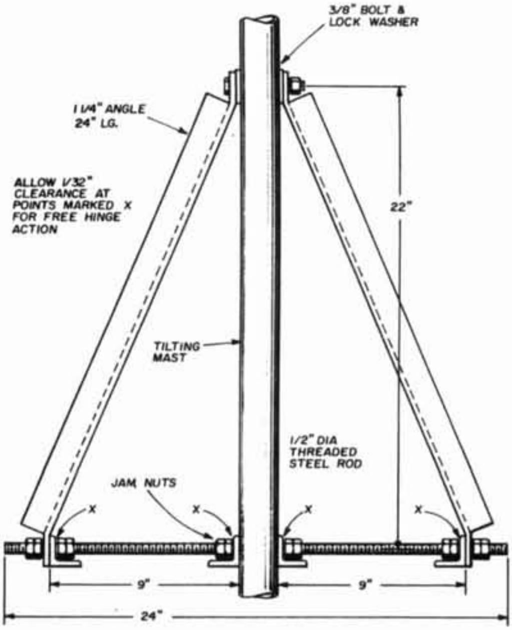


fig. 4. Mast hinge assembly detail. Leave nuts slightly loose to permit antenna mast to pivot; use jam nuts (two on each side) to secure.

various lengths of angle iron to form the rigid triangular gussets and the threaded $\frac{1}{2}$-inch diameter steel rods that form the transverse axle and compression members as shown in **figs. 3** and **4.**

The flanges on angle-iron members are trimmed and bent at the ends to permit them to be joined as shown. When properly assembled, the hinge structure permits the mast to tilt about the pivot axis, while the axis is rigidly held in space by the balance of the triangular hinge structure. The latter is stationary with respect to the winch pipe. Tighten all nuts securely with

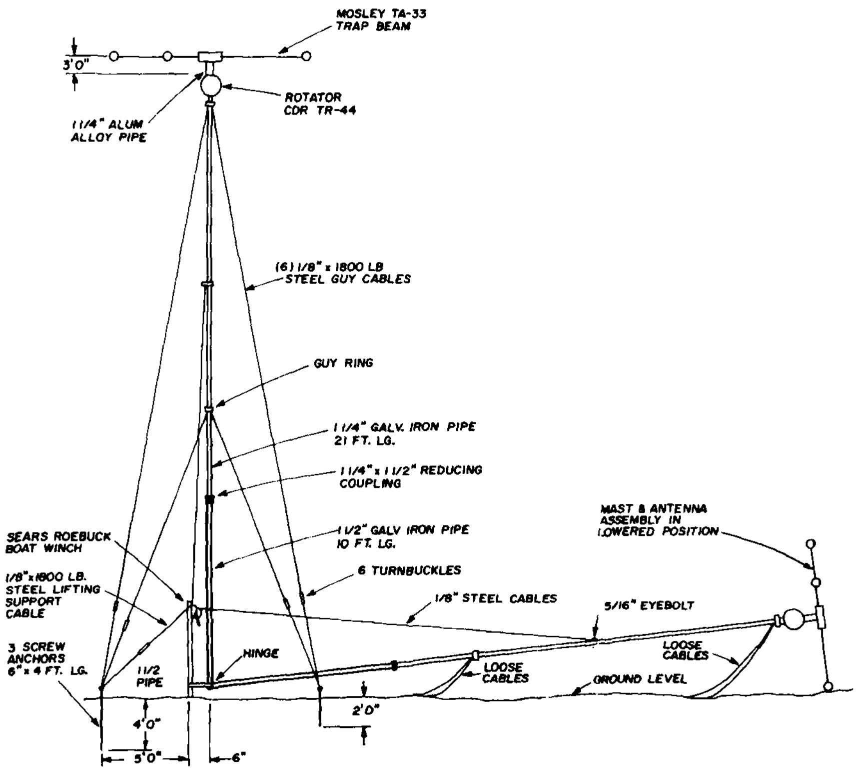


fig. 5. Completed tilt-over mast.

the exception of those on the pivot axis (**fig. 3**). These are left slightly loose to permit the triangular assembly on the antenna mast to rotate about the axis of the threaded rod. Be sure to use flat washers and lock washers, or locknuts.

The exact dimensions of the hinge assembly are not critical, and the sketches and photographs illustrate construction techniques. In general, the distance between mast and winch pipe should be kept short (about 6 to 8 inches). The triangular assembly of **fig. 5** shows dimensions that will give adequate lateral support for the 35-foot mast.

mast assembly

The next step is to lay the 1½-inch pipe on the ground and assemble it to the movable triangular hinged member via the two drilled holes, which receive the threaded rod and upper 3/8-inch bolt respectively. The assembly at this point should resemble **fig. 6.** Now screw the reducing coupling to the free end of the 1½-inch mast pipe, and then follow this with the 1¼-inch pipe.

You should now have about 31 feet of iron pipe on the ground. Drill a 3/8-inch hole 23 feet from the bottom end of the 1½-inch pipe. This receives the 3/8-inch eyebolt, which will be the main lifting member when the mast is raised. (See

table 2. Parameters used in raising-and-lowering stress analysis.

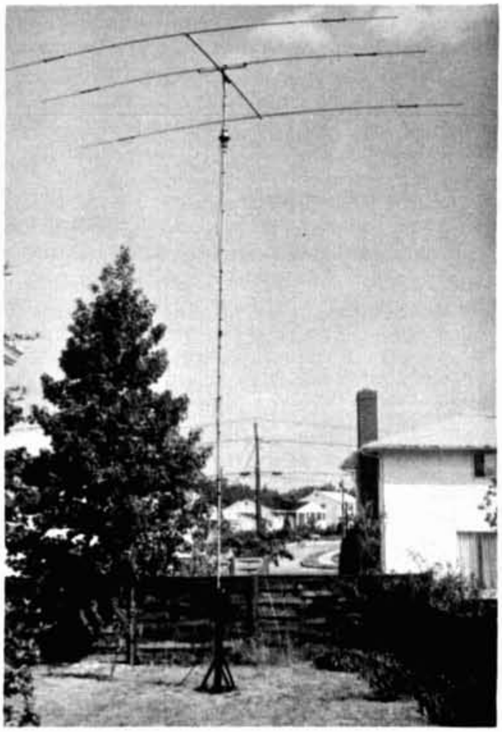
part	lifting stress (lbs)	breaking strength (lbs)
main lift cable	539	1800
eyebolt	117	2000
winch pipe	117	—
winch	539	1000 (rated load)
winch support cable	737	1800

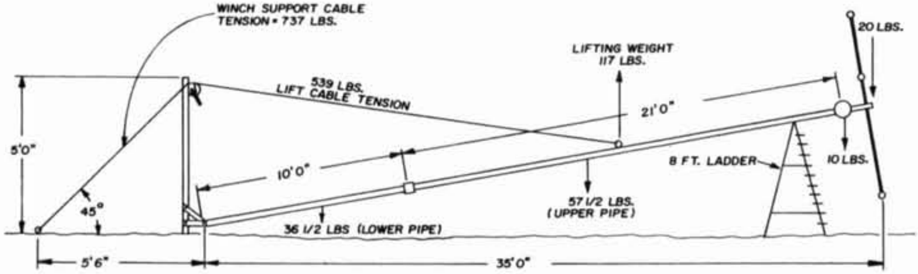
photograph.) Following this, attach the guy ring at the midpoint ($16\frac{1}{2}$-foot) level, and fasten three guy cables to the ring using thimbles and wire-rope clips. Mount the antenna rotator at the end of the mast pipe assembly, and fasten three guy cables to the base of the rotator as shown in the photograph.

up she goes

At this time you're ready to raise the mast and rotator to about 8 feet, so that the beam can be assembled to the rotator. To do this, attach one end of a length of 1/8-inch aircraft cable to the 3/8-inch eyebolt, and attach the other end to the drum of the winch, allowing one or two layers of cable to accumulate on the drum before taking up tension.

If the winch is now cranked until the rotator clears the ground by 9 or 10 feet, an 8-foot ladder may be placed under the mast near the rotator, and the winch can be cranked backward until the mast is supported in part by the ladder.





Clockwise moments $= (\text{beam wt} \times 35) + (\text{rotor wt} \times 31) + (\text{wt of lower pipe} \times \frac{10}{2}) + (\text{wt of upper pipe} \times 20\frac{1}{2})$

$= (20 \times 35) + (20 \times 31) + (36.5 \times 5) + (57.5 \times 20.5)$

$= 2683$ ft lb

(lifting wt at eyebolt, W_L) $\times$ 23 ft $= 2683$ ft lb

$W_L = 2683/23 = 117$ lb

Angle A $= \arctan 5/23 = 12.3°$

$$\text{Cable tension} = \frac{117}{\tan 12.3°} = 539 \text{ lb}$$

Stress on winch pipe in compression is equal to $W_L = 117$ lb

$$\text{Tension on winch support cable} = \frac{(539 \times \cos 12°)}{\sin 45°} = 737 \text{ lb}$$

Stress on screw anchor $= 737$ lb

fig. 6. Stress analysis for lifting operation.

The antenna assembly is now secured to the 3-foot length of 1¼-inch extruded thick-wall aluminum alloy pipe, and the pipe is inserted into the rotator and firmly clamped into place. Since the TA33 Jr. beam weighs only 20 pounds, this operation is not too difficult.

The rest of the operation consists of raising the entire assembly gradually with the winch until almost vertical, attaching the two sets of guy cables to the screw anchors and bringing the mast into true vertical position using the turnbuckles for adjustment.

The tension in the lifting cable may now be reduced, since its function has been fulfilled, and it will not be used again until you want to lower the antenna mast.

The middle set of guys prevents the slender pipe structure from buckling while the main guy cables (attached to the rotator) maintain the mast in a vertical position. True vertical is established near the base, using a carpenter's level, while the upper part of the mast is visually aligned using neighboring structures as references. You can now stand back and proudly view your mast and antenna, which will appear as in **fig. 7.** Give them a coat of paint, and you're ready for many months of trouble-free operation.

table 3. Wind load stress analysis parameters.

part	wind load stress	load carrying ability
guy cable	870 lbs	1800 (breaking strength)
screw anchor (in dense clay soil)	870 lbs	2000 (holding strength)
rotator casting anchorage	7000 psi	14000-23000 psi (yield strength)

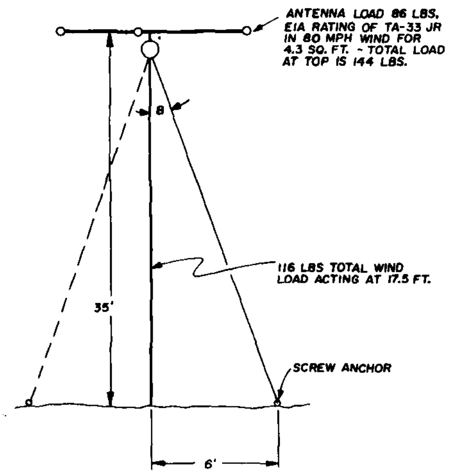


fig. 7. Wind load stress analysis.

Angle B = arctan 6/35 = 9.7°

Stress in projected area of mast pipe = approximately

$$\frac{(2 \text{ in} \times 420 \text{ in})}{144} = 5.83 \text{ sq ft}$$

Mast wind load $= \frac{5.83}{4.3} \times 86 = 116$ **lb acting at half-way point**

This is equivalent to an additional wind load of 116/2 = 58 lb acting at the top

Thus, total wind load at top = 86 + 58 = 144 lb

Assuming cable prestress of 25 lb, cable tension =

$$25 + \frac{144}{\tan 9.7°} = 870 \text{ lb}$$

appendix

stress consideration

Two separate structural stress situations were taken into account in the design of the tilt-over mast. The first occurs only during raising and lowering, while the second is concerned with resistance of the structure to high winds.

In the first situation the critical design parameters are:

1. Lifting cable tension
2. Lifting eyebolt strength
3. Deflection of the mast pipe assembly
4. Stress on the winch, winch support pipe and winch support cable
5. Tension on the screw anchor holding the winch support cable