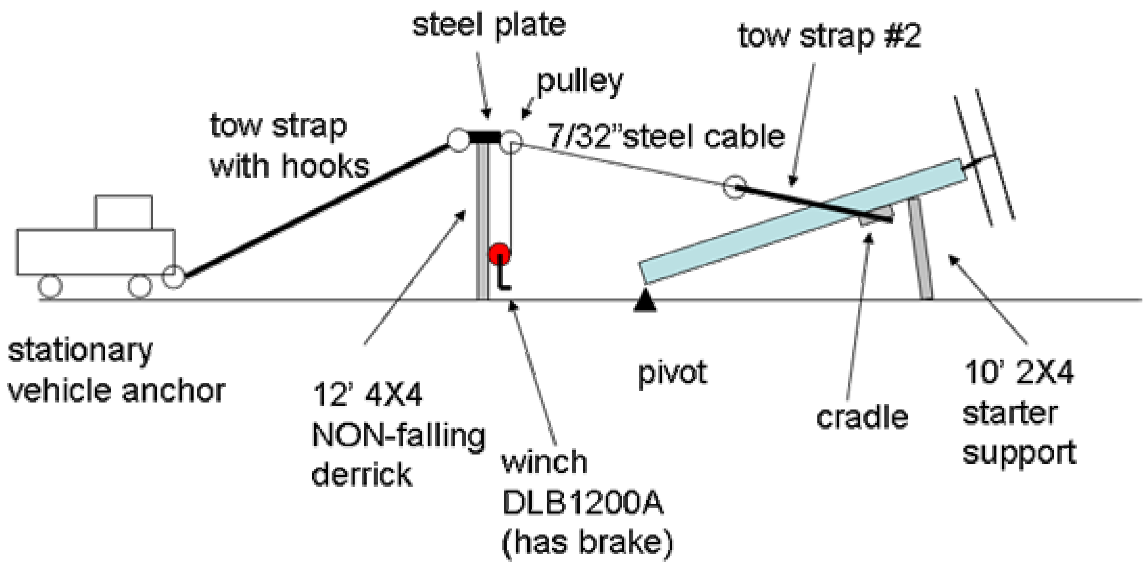
Tower Raising with a Non-Falling Derrick - N6MW 27 Aug 2010

Inspired by N6RK's approach to tower raising, an alternate approach has been developed that may be useful under some conditions. As notionally indicated here, this method basically replaces the moving vehicle with a winch for raising, but now the "derrick" element stays upright. This scheme avoids the use of any ground anchors, aside from a stationary vehicle that serves as a temporary anchor point, and it allows precise control of the cable motion.



For the application at N6MW, the tower is a 30' aluminum Universal Towers model 9-30 weighing just 55 pounds. Without the rotor and antenna this can easily be walked up by one person. With the rotor and antenna, it requires two hefty people or three not so hefty people for walking up. So if you always have hefty help available, the following information is not needed. Still the same method can be used for a more challenging tower. However, my goal here was one-man operation, and engineering entertainment.

Here are a few points about the components:

The starting point for the tower is resting on a 10' 2X4 support since the most stressful part of the journey is lift off – elevating the tower substantially reduces the initial stresses. This elevation is also needed to mount the antenna on the tower when tilted over. (At N6MW, this 2X4 is set up to be self supporting so it won't fall on anything vital as the tower is raised and it can be pre-positioned for lowering.)

The tower hinges at the base on two legs, each with a single (loosened) bolt. (The final assembly has two bolts in each of the three legs.)

The winch cable plus tow strap is attached to the tower using a "cradle" made from 2X10 lumber. The cradle has 2X4 attachments (tower side) that closely fit into the tower Z cross bars so the stress along the tower from lifting is primarily distributed over two or three welds of the Z lattice. (For a heavier tower, additional precautions may be in order, perhaps more along the lines of the N6RK cradle.) Two U bolts across the legs hold the cradle in place but do not carry any lifting stress . A tow strap is wrapped a few times around the cradle through the cut outs on the sides of the 2X10. This assures that the legs of the tower do not get squeezed together by tension in the strap. The ends of the tow strap are then attached to the winch cable with a heavy ring (this requires careful empirical selection of the starting point for the strap wrapping to make the lengths equal).

The winch (a DLB1200A, which of course has an automatic brake) is bolted to the 12' Non-Falling 4X4 derrick post and the 7/32" stranded steel cable runs through a pulley at the top (note the skillful use of duct tape to assure the pulley does not slip off its mounting).

A steel plate, with attachment points (holes) for the pulley and the second tow strap going to the anchor, is attached to the top of the derrick. The attachment of the plate to the derrick post does not need to be very heavy duty since it is not a shear stress point.

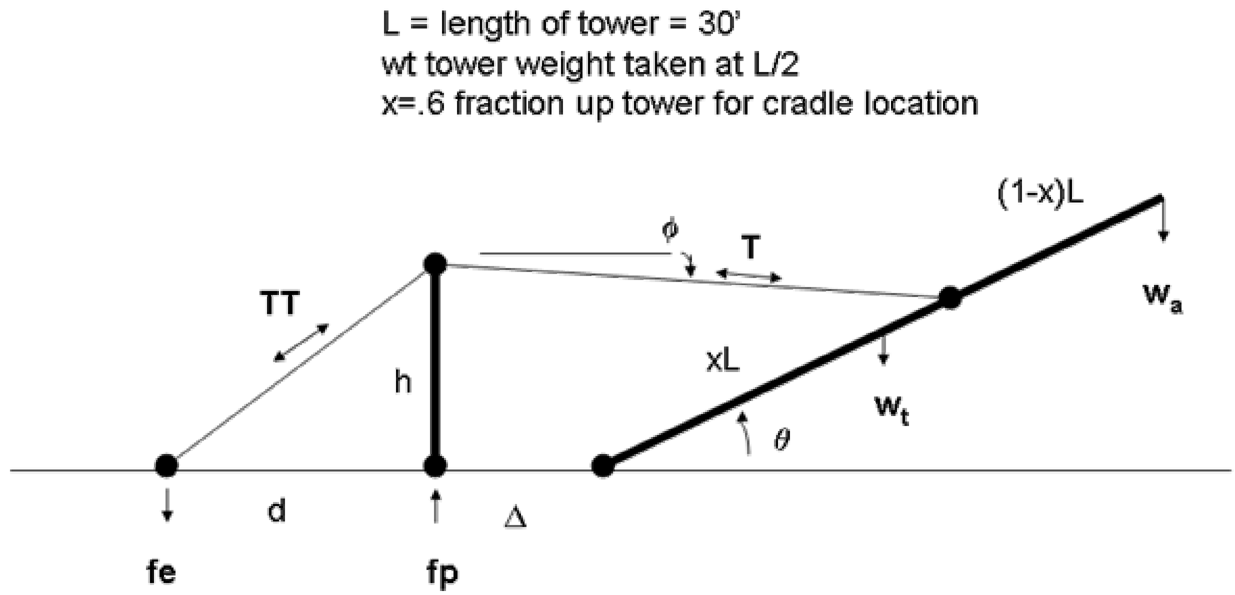
Near the bottom of the 4X4 derrick post there is a 3' 2X10 cross member that is primarily to assist in setting it up. Once the lines are attached to the tower and vehicle anchor, this 2X10 does nothing since the derrick is then stable in the vertical position (it can not fall sideways) and there are no shear forces along the bottom to cause it to slip horizontally. The bottom of the derrick is not attached to anything but just rests on the ground (in a shallow hole).

The length of tow strap (20' here) going to the vehicle anchor dictates the anchor location (but along the line from the tower through the derrick of course). The anchor tow strap will stretch (more than the doubled tower tow strap) so the initial configuration before lift off may require the derrick to be tilted back toward the anchor a bit so it is not too far off upright during the lift.

One caution in selection of the derrick length, derrick placement away from the tower, anchor placement and cradle attachment height is to be sure that when the tower is fully elevated, the derrick is not lifted off the ground. This can be handled by making sure that an imaginary line from the anchor point to the fully raised position of the cradle goes below the top of the derrick. Even if the derrick post is lifted off the ground near the end of the lift, it will not impact the tower raising but it will be a safety hazard.

Stresses on Components (or Maybe you'll need a bigger cable?):

Various engineering type calculations were carried out before purchase of components. This included evaluation of the meaning of vendors words on the strength of their products. The basic geometry for the stress calculations is this drawing:



A spreadsheet using the relevant values shows how (in feet, pounds and degrees) the parameters change as the tower is elevated. Here theta is the angle of the tower relative to the ground and the rows in yellow are for the angles that are initially supported by the 10' 2X4 before the elevation begins. At his point the tension in the anchor tow strap (TT) is a bit over 300 pounds, the tension in the cable (T) is a bit less than 300 pounds and the force of the cradle parallel to the tower supported by the Z lattice is a bit over 200 pounds (also the total force on the two hinge bolts). As the winch is cranked up, giving larger theta, these values decrease and quickly become quite modest. Of course, when the tower is lowered the situation is a bit more exciting since the stresses get larger and larger just as it reaches the support. So far, this has worked fine through several cycles.

L	wa	wt	th(deg)	h	d	x	Δ	phi(deg)	T #	TT	fe	fp	F_cradle para
30	60	55	0	12	16	0.6	10	23	370	425	255	401	340
30	60	55	5	12	16	0.6	10	20	338	395	237	355	305
30	60	55	10	12	16	0.6	10	18	308	367	220	314	273
30	60	55	15	12	16	0.6	10	15	282	340	204	277	244
30	60	55	20	12	16	0.6	10	12	257	314	188	243	217
30	60	55	25	12	16	0.6	10	9	233	288	173	211	192
30	60	55	30	12	16	0.6	10	7	211	262	157	182	170
30	60	55	35	12	16	0.6	10	4	190	237	142	155	148
30	60	55	40	12	16	0.6	10	1	170	213	128	131	128
30	60	55	45	12	16	0.6	10	-2	151	188	113	108	110
30	60	55	50	12	16	0.6	10	-5	132	164	99	88	93
30	60	55	55	12	16	0.6	10	-8	114	141	85	69	77
30	60	55	60	12	16	0.6	10	-11	96	118	71	53	63
30	60	55	65	12	16	0.6	10	-14	79	96	58	39	49
30	60	55	70	12	16	0.6	10	-17	62	75	45	27	37
30	60	55	75	12	16	0.6	10	-20	46	54	33	17	27
30	60	55	80	12	16	0.6	10	-24	30	35	21	9	17
30	60	55	85	12	16	0.6	10	-27	15	17	10	3	8
30	60	55	89	12	16	0.6	10	-30	3	3	2	0	2

The 4X4 post shows no sign of flexing, but a 2X4 would probably not be adequate. The 2" single ply tow straps are rated at a "breaking strength" of 10,000 pounds. However the "working strength" is claimed to be 1/3 of that. Furthermore, many such straps claim not to be appropriate for "lifting." It is hard to know just what all the means but yet other straps (still 10,000 # breaking) like this do claim for "vertical" use, the limit is ~1500 pounds. I'm guessing the vertical rating is the relevant one here but industry standards seem to be less than clear. The anchor strap stretched a few % under 300 pounds constant tension. The heavy duty pulley used was rated at 2.4 tons which should be more than fine. The steel plate is ¼" thick and calculations indicate that is overkill. The winch is rated at 1200 pounds but that assumes that reel is not too full. Still this is well less than the 300 pound tension in the cable. Turning the winch is never difficult. The 7/32" stranded steel cable is rated at about 5000 pounds breaking strength and, it appears from various bits of information, the working strengths are generally claimed to be about ¼ of that. So it should be fine at 1000 pounds. (Again getting useful information from the vendors is a struggle.)

This tower claims to handle a 9 sq ft wind load at 80 mph. Conventional wisdom then suggests a force of 16 pounds/sqft at 80 mph so that would be about 150 pounds perpendicular to the tower. For my case the weight of the antenna plus rotor is about 60 pounds which suggests that the tower should easily handle being lifted from the horizontal from the cradle location since the torque will be much less that the rated torque from wind loading. This is not quite guaranteed since the distribution of the forces is not really the same. In any case, the tower never seemed to flex in any disturbing way when it was raised. This is all a bit short of proof that this scheme is a brilliant idea.

All told, if someone is thinking of using this method for a heavier/larger tower, it would pay to consider boosting up the ratings on some of the components and the cradle attachment is probably the weakest link. Some pictures follow.

The set up after raising. The 10’ 2X4 support is at the right.

The cradle with tow strap.

The steel plate on top of the derrick post.

The winch attached with 3 bolts through the 4X4.