# understacking high-frequency Yagi antennas

A novel system for stacking beams on a tower to minimize mast damage in heavy weather

**Installation of a single Yagi** antenna on a tower, whether the tower is guyed or not, provides a clean looking system that will no doubt perform as predicted. If a commercially manufactured antenna is used, and there is no desire to make adjustments for optimum performance, mounting it in the clear away from all surrounding objects is the only way to do it. That, however, is not very cost effective. A second beam means a second tower, a third beam requires a third tower, and so on. I quit with three towers — but I want beams for 40 through 10 meters.

Stacking distances of 10 feet (3 meters) or more aren't generally suited to high-frequency beam installations because it's difficult to prevent the mast from bending in severe weather. Ultra-strong steel masts are expensive, heavy, and do not provide easy access to the top antenna. By understacking antennas, rather than overstacking them, a number of features develop which overcome these problems.

Understacking takes advantage of a unique relationship between the system weight and the effect of gravity. With conventional stacking arrangements, the weight of the top antenna *adds* to the bending moment at the base of the mast. Understacking *subtracts* the antenna weight from the bending moment because gravity aids in keeping the mast in a vertical position.

A number of other feature benefits come into play. First, installing, tuning, or repairing the stacked antenna is relatively easy because it is mounted within reach of the person climbing the tower. Properly designed tilting hardware makes it easy to reach any point on the boom of either antenna. Element repair or matching-network adjustments are relatively simple. Building the system shown in the photographs was a one-man project — no help was needed.

A primary objective for any antenna system is to have it remain intact during foul weather. One disasterous event which can destroy an antenna, especially one that is stacked above another, is a hurricane — or hurricane-force winds. Even with two days of notice (hurricanes are somewhat predictable!), an antenna stacked high on a mast offers little opportunity to take damage avoidance steps to weather the storm. With understacking, however, you can climb the tower and tie in the stacked antenna with heavy rope. When the boom of the stacked antenna is fastened securely to the tower face, the chance of mast damage is eliminated. Furthermore, the mast and boom of the stacked antenna are fastened at a point where the top set of guy wires have the greatest strength — right at the guy point. The tie-in procedure reduces the load above the top set of guy wires to one antenna surface instead of two.

Further security is built into the system by installing a torsion bar assembly at the very top of the tower; see the photographs. The benefit is obvious: during hurricane season (June through November), a ready-made set of guy wires is kept on hand. If they are needed, it is a simple task to install them (it can be done in less than an hour). With the extra guy wires in place, there is little chance of tower damage from high winds. Whether or not the antenna survives extremely high winds is a different matter. Keep in mind, though, it is far easier to repair a bent

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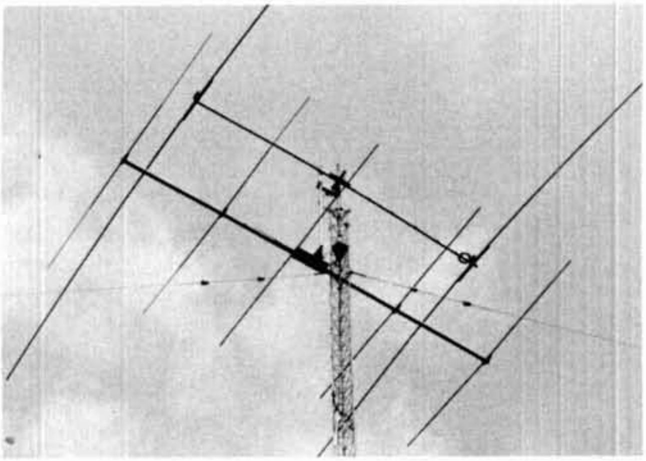


**The antenna installation at W1XT. Shown are a two-element, 40-meter Yagi and an understacked five-element, 10-meter Yagi.**

antenna than it is to fix a bent tower!

There are a few minor benefits to understacking as well. The auxiliary mast is a torsion tube which reduces stress on both the tower legs and the rotor. The empty span between Yagis is ideally suited to the installation of a small vhf antenna.

## mechanical components

Fabrication of the hardware is simple and can be done easily in the home workshop. There are three different pieces to the system: an 11-foot (3.3-meter) long galvanized steel mast, two boom-tilt assemblies, and two angle brackets to support the auxiliary mast at the top of the main mast. Standard discount store automotive muffler clamps are used to hold everything in place. Plated clamps are usually found in the hardware department rather than in the automotive section.

The mast sections are made from 1½-inch galvanized waterpipe. Because waterpipe is specified by inside diameter (ID), not outside dimension (OD), the outer dimension for the 1½-inch pipe is slightly under 2 inches (50 mm). This size is ideally suited to 1-7/8 inch (48 mm) clamps although 2-inch (50 mm) clamps are satisfactory. Galvanized waterpipe is available from most plumbing supply dealers but be prepared for a stiff price. The material used here cost nearly $20!

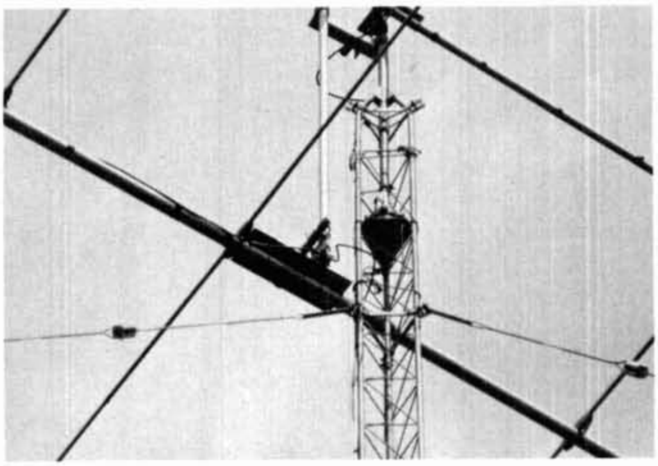
The two top mounted angle brackets are 12 inches (30 cm) long and provide adequate tower clearance for the auxiliary mast. The aluminum stock is 3 inches (8 cm) on a side and ¼-inch (6 mm) thick. The upper angle piece is equipped with six muffler clamps, three on each end; the lower one has two at each mast connection point.

Both boom-tilting assemblies are shown in the photographs. The ½-inch (25 mm) thick plate (aluminum) has a horizontal pipe section held in place by a group of muffler clamps. Each Yagi has its boom-to-mast plate turned horizontal so that it may sit on the tilt assembly plate. Loose clamp hardware allows relatively free tilting of the boom to any position for the installation of the elements. The top boom-tilt assembly is fastened to the main mast and not the auxiliary one. This helps offset the leaning action caused by the lower antenna.

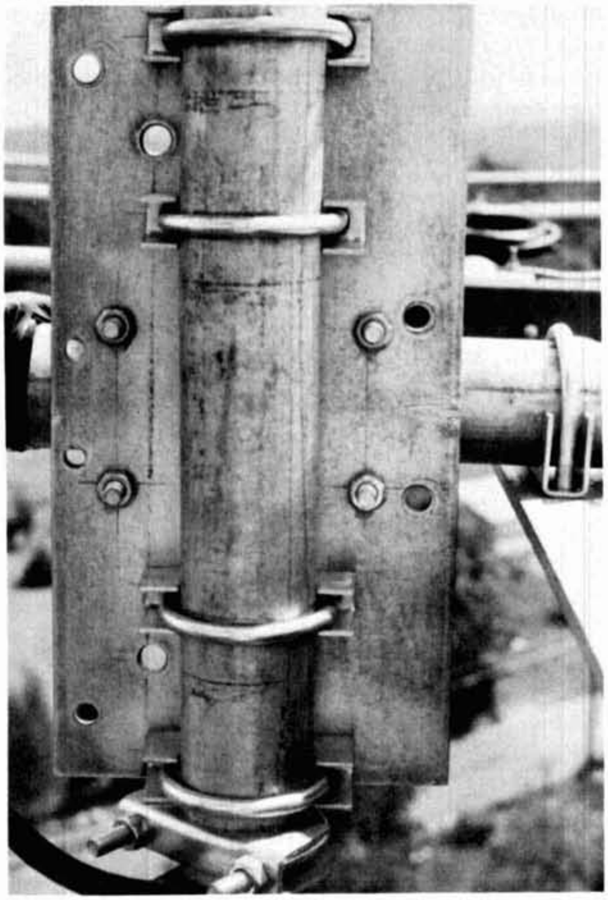
## system description

A five-element, 24-foot (7.2 meter) boom 10-meter Yagi is stacked under a two-element electrically shortened 40-meter beam (Mosley S-402) which has 46-foot (13.8-meter) long elements. The Mosley antenna was selected because of its low wind surface profile as compared to a full sized array. The high $Q$ of a loaded antenna makes it necessary to assure no detuning occurs as a result of other hardware being in close proximity to it.

A number of other factors were involved in selecting these antenna designs. The 10-meter beam has a boom length slightly longer than double the spacing between antennas which means that the top antenna interferes with rotating the lower boom vertical. Since the longest 10-meter element is shorter than the boom length for the 40-meter antenna (20 feet or 6 meters), it is a simple matter to turn one boom 90 degrees (horizontally) and tilt the 10-meter boom end and element up between the two 40-meter elements. The 24-foot (7.2 meter) boom length on the 10-meter beam was selected to provide element positions which would not be directly under the elements



**The guy-wire torsion bracket is mounted just above the bottom rung of the tower top section. The 10-meter antenna rotates just above the top set of guys. An empty torsion assembly at the top of the tower is available for an additional set of guy cables if they should be necessary.**



**The 10-meter tilt assembly attaches to the auxiliary mast with four muffler clamps. Note the clamp at the very bottom of the mast. It is needed to keep the tilt assembly from slipping off the auxiliary mast and is an absolute requirement.**

above. For one thing, this gives slightly more separation between elements than the vertical dimension indicates. More importantly, however, during a bad ice storm, the top elements won't droop and make contact with the lower antenna. Also, melting ice from the top elements will drop between the lower 10-meter ones. Falling ice can play havoc with the antennas beneath!

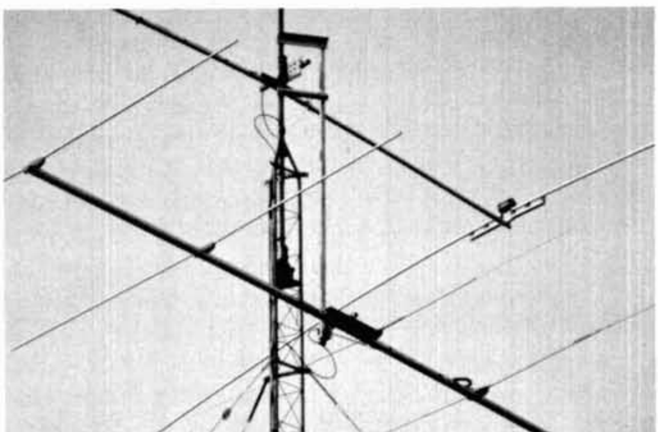
Interaction tests were required to assure no interaction between antennas. The Mosley antenna was installed first. An SWR curve was plotted, front-to-back measurements were taken, and the relative signal strength of a local broadcasting station were made (W1AW is 25 miles away and visible on a clear day). Next, the 10-meter Yagi was installed and similar measurements were performed. Rechecking the 40-meter tests showed no difference in the figures. Rotating the top antenna 90 degrees with respect to the lower one had no influence on the test results of either antenna. The conclusion is that stacking these two antennas 10 feet (3 meters) apart is sufficient to avoid detuning either one.

Mechanically, the system is stable and strong. The slightly off-center mounting of the auxiliary mast causes the main mast to lean to one side. This is counteracted to some extent by the top tilt assembly being mounted to the main mast with the horizontal pipe extending in the other direction. There is no binding in the tower top sleeve. The relatively long main mast to the rotor makes the misalignment insignificant. You should not attempt this type of understacking, however, if the rotor is mounted directly beneath the tower sleeve — or worse yet, if the rotor is mounted above the sleeve. Under these conditions, the lateral forces would destroy the rotor in short order.

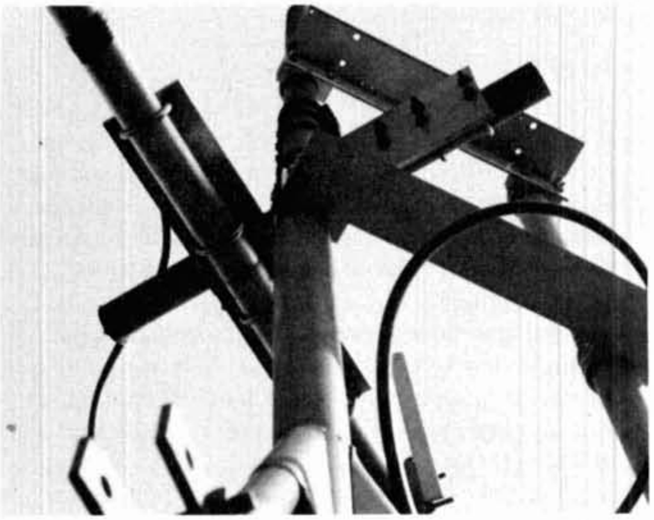
There have been two tests of the mechanical strength and reliability of the stacking procedure. In August, 1979, a severe storm whipped through central Connecticut, tearing roofs off buildings and uprooting trees. The local weather service measured wind velocities of 70 mph (110 km/h) for more than an hour. After the storm, the system inspection showed only a 40-meter element to be rotated around the boom; everything else was intact. During early September, Tropical Storm David generated wind gusts up to 70 mph (110 km/h); this time there was no damage. In neither case was the top set of guy wires installed (the extra set) or the lower boom tied into the tower face. A good deal of confidence was developed by these two events. After the first storm, it was a simple matter to tilt down the 40-meter boom and straighten the twisted reflector.

## hardware installation

There are numerous ways an Amateur can approach this kind of a project. The testing requirements, however, dictated the order in which compo-



**The top angle brackets have been offset to give a greater spacing between the tower legs and the 10-meter boom.**



**Two angle brackets are used to hold the auxiliary mast in place. One is attached above the 40-meter tilt assembly; the other is connected below.**

nents were installed. It would be wise for anyone duplicating this system to perform tests similar to those mentioned earlier. If two antennas are put up and one doesn't operate correctly, it could be very difficult to determine the source of the problem.

First, install the tilt hardware to the main mast. Next, position the 40-meter boom on the horizontal tilt assembly pipe. With the appropriate boom end tilted down along side the tower, attach one element. It is necessary to tie a rope to the opposite boom end from where the first element is connected. It should be done before the boom leaves the ground. The rope is needed to pull the non-element end down after the first one is attached. With both elements connected, the antenna weight is balanced and vertical rotation around the tilt assembly is easy. Exercise extreme care when turning the boom up or down. Be sure the clamps can't slide off the horizontal pipe. The pulling rope must be strong and tied securely in place. If the rope breaks or slips half way through the tilting process, the heavy end will swing down with a vengeance.

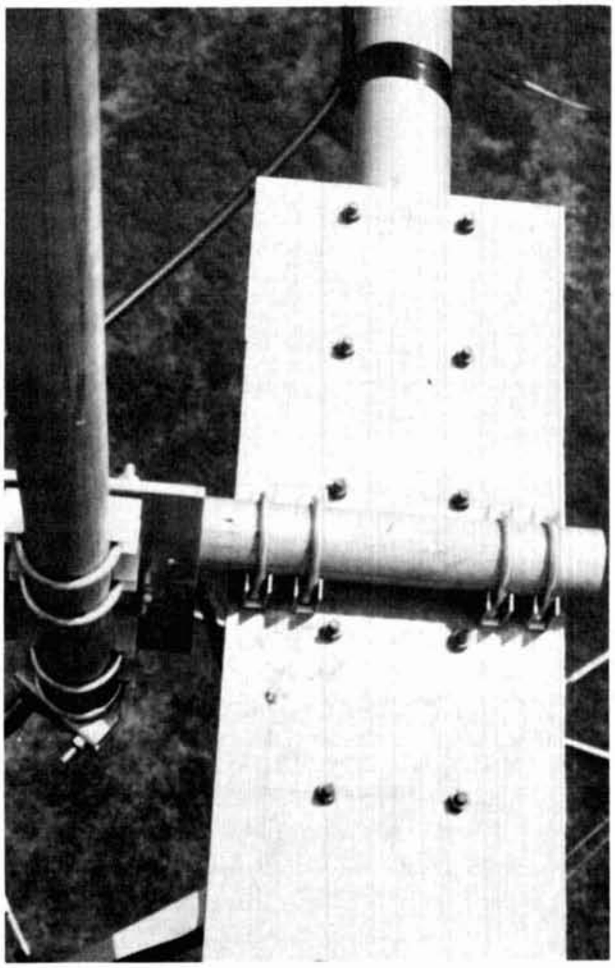
Once the 40-meter beam is installed and tested, the two auxiliary mast supports are clamped in place; one gooes above the 40-meter tilt assembly and the other mounts beneath it. Muffler clamps should be attached to the far end of the angle stock, ready to accept the auxiliary mast. Slip the mast pipe up through the clamps and secure all of the hardware. The 10-meter boom-tilt assembly can be attached to the auxiliary mast before it leaves the ground or after the mast is in place.

As with any antenna installation, safety is an absolute requirement. I have found the best procedure is to plan every step of the process in advance. Abbreviated notes are used to avoid mistakes.

## boom-to-tower spacing adjustment

The auxiliary mast aligns on center with the tower when the support angle brackets are parallel to the 40-meter boom. The lower tilt assembly offsets the 10-meter beam sufficiently to clear the tower during rotation. Sway in the auxiliary mast caused by wind may allow the 10-meter boom to occasionally bump into the tower leg at some headings. Twenty turns of polypropylene rope are wrapped around the 10-meter boom where it comes close to the tower. The rope acts as a bumper pad during very high winds.

To increase the spacing between the boom and the tower legs, change the position of the angle supports toward perpendicular with the 40-meter boom. The lower beam will need to be repositioned slightly for a corrected heading; an 8-inch (20 cm) clearance



**The homemade 10-meter beam mounts to the tilt assembly with four muffler clamps. The coaxial cable loop must be positioned so that rotation of the system doesn't crimp or cut it.**

is adequate. Note the offset of the angle brackets in some photographs.

## pitfalls

It is possible to forget some of the basics of good engineering practice. For instance, the auxiliary mast is indeed a 10-foot (3-meter) long lever arm and will flex the main mast pipe. An antenna of much larger dimensions than described here would likely cause one of the masts to bend if extremely severe weather were encountered. For use with bigger systems, hard steel tubing is recommended in place of waterpipe.

Another important consideration is tower loading. The tower shown here is 100 feet (30 meters) of Rohn 25 guyed at 33, 66, and 91 feet (10, 20, and 27 meters). The unsupported top section has a torsion guy assembly mounted just below the bottom rung which keeps lateral forces off the tower leg bolts. The load rating for Rohn 25 tower is 6 square feet (0.55 $meter^2$) of antenna; many Amateurs exceed that with large six-element Tribander. The surface area rating for the Mosley S-402 is about 3.8 square feet (0.35 $meter^2$). The lower five-element Yagi adds another 2.5 square feet (0.23 $meter^2$) of surface area. This tower is sufficiently loaded for maximum safe operation (note that tower load ratings assume a rotor, mast, and cables and should not be included in the calculations).

## other combinations

Interaction between antennas is always a possibility when more than one antenna is placed on a tower. Many Amateurs have experienced difficulty in operation when 15- and 40-meter antennas are mounted together on the same tower. The end result is usually poor front-to-back ratio with the 15-meter system. The high $Q$ of a Tribander accentuates the problem. For this reason, you should be cautious about installing a Tribander and a loaded 40-meter beam on the same support. If interaction does result, the simple solution is to turn one of the antennas 90 degrees with respect to the other. Double dial calibration would then be required.

A combination of antennas ideally suited to understacking is a small "Christmas Tree" of monobanders for 20, 15, and 10 meters. The largest antenna should go at the top and the smallest in the middle of the auxiliary mast. In this manner, the heaviest Yagi is mounted just above the top tower sleeve, and the next largest antenna will have its weight at the bottom of the auxiliary mast to counteract the bending moment.

No matter what combination of antennas is selected, be sure not to overload the tower. Hardware falling from the sky is hazardous to your neighbors!

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More Details? CHECK—OFF Page 94