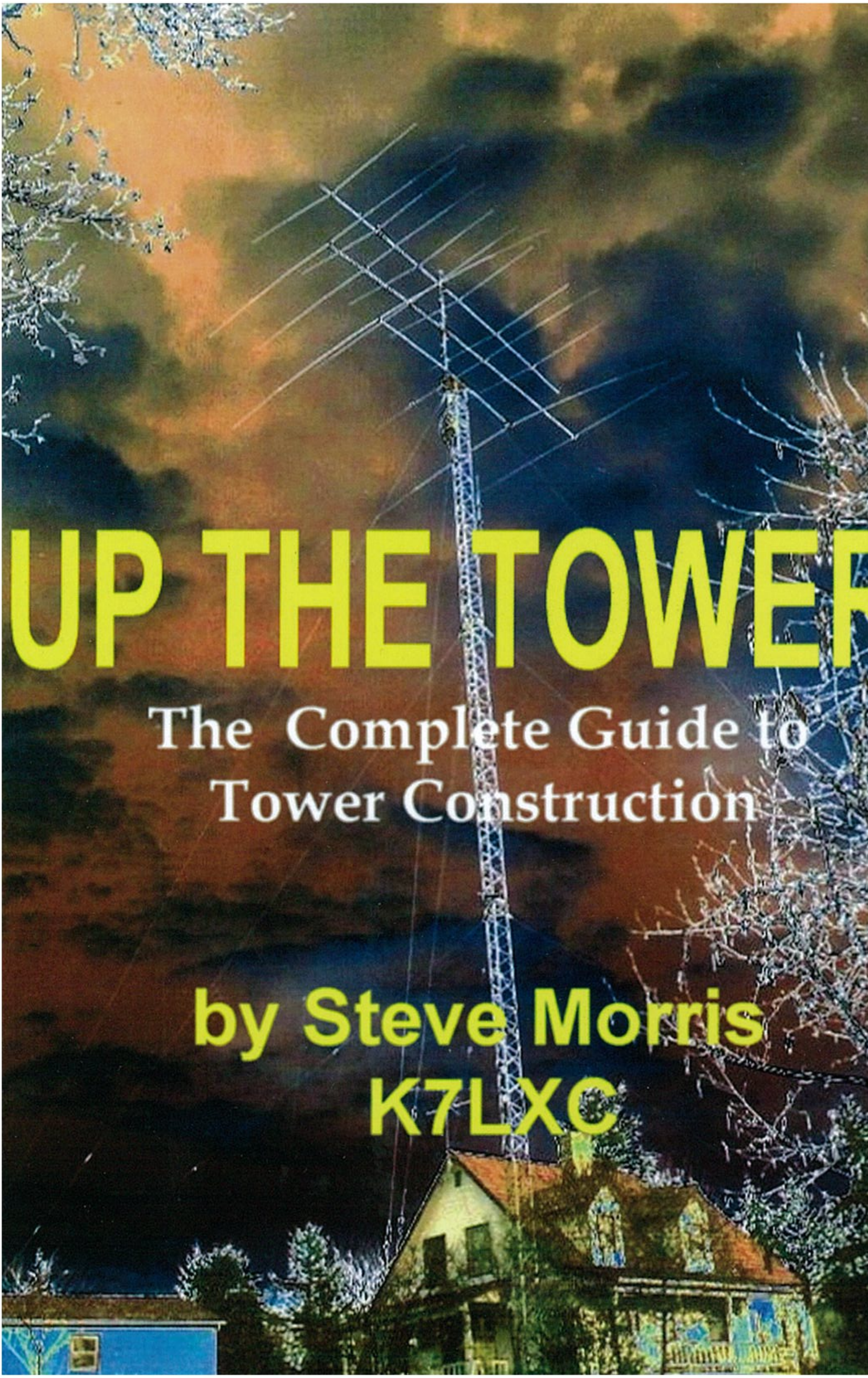
UP THE TOWER
The Complete Guide to
Tower Construction
by Steve Morris
K7LXC

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Up The Tower

The Complete Guide To Tower Construction

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Introduction
by Bob Locher, W9KNI

Steve Morris is a master of tower work. Not only has he done it all "Up the Tower" but he truly brings a broad-based understanding of towers to this work. Steve has had an accomplished career as a ham, both as a hobby and in the business of amateur radio, and years of experience in erecting, climbing and installing towers, rotators and antennas. This book presents the knowledge he has gained.

Steve's years of acting as moderator of the "Tower Talk" internet reflector have further helped him prepare this book, helping him to understand what subjects confuse newcomers.

Steve would be the first to tell you that a successful tower project is well over half finished before the concrete is ever poured – planning and design lead to successful execution. Steve's book tells you how to do the planning, the design – and the execution! All with safety and engineering as paramount objectives.

If you are planning any tower installation, this book will certainly be your guide and companion and the best investment you can make. There has never been a comprehensive book for amateur radio towers, but it was worth the wait – now we have Steve's masterpiece.

de Bob Locher, W9KNI

Foreword

Although I was first licensed in 1960, being in the service, college and having a new family put me off the air for almost ten years. Not until 1978, with the assistance of childhood buddy Jim Hadlock, K7WA, did I get back on the air with some simple wire antennas. "Wire antennas work!" was the entry in my logbook after making my first few contacts. My enthusiasm was increasing by leaps and bounds and before I knew it, I had purchased a used tower and a used cubical quad antenna. Since I had never before attempted anything like this, I tried to find out what to do. I had more questions than answers but armed with only the help of the ROHN catalog, Jim and a couple of others, we got it up. Boy, now I was cruising the HF bands and having **fun!**

A year or two later, a big windstorm came through and bent over the installation. After repairing everything and adding a set of guys, I was back in business. Looking back, I see that my lessons were learned the hard way and fortunately without any damage to life or property; I was lucky. I did more and more tower and antenna work and I still had to learn everything the hard way. I even progressed to the point where I started up my own tower services contracting company. Starting out with hams, I soon got more and more involved in cellular, communications and broadcast work and I learned even more from each of those projects.

In 1991 I started writing a column on tower construction for the *National Contest Journal* because I wanted to share my experiences and lessons with other hams, and hopefully help them avoid learning the hard lessons themselves. That is why I wrote this book; I don't want you to learn everything the hard way by doing things you shouldn't be doing and having failures that could be endangering your life and property and could have been prevented. I want you to have all of the answers at your fingertips in this book; I want you to be able to install a tower and antenna system safely and reliably.

This wasn't an adventure that I took on by myself; I would like to thank these folks for their contributions over the years: Brett Graham, KB7G/VS6BG/VR2BG, who was my first tower partner on several tower adventures; Rush Drake, W7RM (SK, Silent Key), whose vision and ingenuity (not to mention heavy duty ginpole and winch!) helped me more than once; Tom Taormina, K5RC, my first editor at the *National Contest Journal,* who encouraged my column and helped me improve my writing; Pat Meeks, KS7L, who created much of the art and enhanced most of the remainder; to my original editor and publisher, John Pollock, K7MCX, for his encouragement and the long hours spent in whipping this book into initial shape; and of course Bob Locher, W9KNI, who has encouraged, cajoled and mentored me on this project. In addition, thanks to the people who read and provided input into the form and content of the book, including Rob Brownstein, K6RB, Jim Duffy, W6EU, Bob Epstein, K8IA and Frank Donovan, W3LPL. Thank you!.

This book has been written for those who wish to safely build their own tower and antenna system. It is not intended to be used for commercial purposes. To have both a safe and reliable project, the author recommends that you adhere to the various safety guidelines outlined in this book. Your safety is important and should not be jeopardized.

The reader is ultimately responsible for his own safety, and for all decisions he makes concerning his safety. The reader must, himself, verify the accuracy of information provided, and the text constituting general information intended to make the tower climber aware of the dangers. The book provides no particular advice, for any particular, localized, situation that I have not fully analyzed.

In the United States, worker safety is regulated by the Occupational Safety and Health Agency (OSHA). As a private individual, you (as well as your friends who assist you in your tower building project) are exempt from OSHA coverage. Although you are not required to follow the OSHA rules and regulations, for safety purposes my advice is that you apply them in your project. Because safety is so very important, OSHA rules and regulations are discussed from time to time throughout this book. However, it must be clearly understood that this book is a "do it yourself" guide to the private construction of amateur radio or personal radio towers and/or antenna systems, and is **not** intended to be an OSHA compliant textbook. Some of the equipment and techniques described in this book are not OSHA compliant but are presented because the author has found them to be safe and valuable for private radio tower construction purposes.

Although the author and publisher of this book have used their best efforts in preparing the book and the material contained in it, they make no warranty of any kind, expressed or implied, with regard to the material contained in this book or its application in the construction of any tower and antenna systems. The author and publisher shall not be liable in the event of incidental or consequential damages in connection with, or arising out of, the application of any of the material or contents of this book. Users of this book should consult the provisions governing limitation of liability and disclaimer of warranties in connection with equipment, tools and supplies purchased and utilized in the construction of any tower and/or antenna system. Regardless of who does the work, your careful attention to the safety guidelines outlined in this book should provide you with a completed project that is safe, successful and reliable.

1

Do you really need a tower?

Any type of radio communications requires an antenna. Whether it's a microwave dish, a shortwave dipole or beam, or a half-mile wire strung across a canyon for submarine traffic, nothing happens without it. In order to radiate effectively, these antennas need to be mounted up in the air, on a tower or structure of some sort. Those of you who have tried, with varying levels of success, to operate out of an apartment or condo know how frustrating and limiting that situation can be. On the other hand, those of you who have had the good fortune to own or operate from a good station with tall towers and effective antennas know how thrilling that experience is. This book is written for anyone who has ever contemplated installing an outdoor antenna system, may be planning one or who already has some experience but wants to know more about proper tower system construction and techniques.

The negatives

One of the biggest challenges for many people is the cost. Even a used tower and antenna system can mean an investment of a thousand dollars or more. Hire someone to install it for you and the cost goes up. Another problem is that it may be difficult to get the necessary permits and permissions to build your dream antenna system. Hearings with building department boards and civil law suits are no longer uncommon. Neighbors can be a big negative if they are opposed to your installation. Just one complaining neighbor can be a real irritant, not only to you but also to the local building department. This can be a case where the "squeaky wheel" gets greased, usually to your disadvantage.

While some proposed towers wind up being challenged due to perceived radiation emission problems, many of the confrontations are because of aesthetic reasons. Even if a tower doesn't block their view, a neighbor may feel that it is an unnecessary eyesore. Of course for the owner it's a case of beauty being "in the eye of the beholder." Some people use the argument that a tower will lower the resale values in a neighborhood. In my opinion, this is a pretty weak argument and more of a smokescreen. Not only have I never seen any professional surveys that reflect that negative view but also my experience in selling my own home was that my first two offers included the tower!


Photo 1: A lovely station to aspire to. Your dream station?

The positives

The biggest positive for installing any type of outdoor antenna system is that you'll be able to transmit and receive much more effectively. High antennas almost always work better than low antennas, and very rarely will you get an antenna "too high." When it comes to antenna and tower projects, the "sky **is** the limit."

A properly installed tower and antenna system will also reward you with years of reliable performance. In case of a public emergency, your antenna system may well be the key to saving lives and property. The ultimate reward, though, is that a decent tower and antenna system will result in your having much more enjoyment from your radio station and your hobby.

2
ANTENNA SUPPORTS

Once you've decided that you want to put up an antenna, you still have many choices to make. The first is probably which kind of an antenna you want to install. The second choice is what kind of support to use.

Trees

The first amateur radio antennas were simple wires and their owners typically strung them in whatever trees that were handy. We'll look more closely at trees in Chapters 26 and 27.

Wooden utility poles

Wooden poles are not nearly as popular as they were in the past. There was a time when reasonably priced steel towers with amateur compatible hardware were not readily available. With utility poles springing up as electricity and telephones became almost universal in America, amateurs devised innovative ways in which to use these antenna supports. You may still be tempted to put up one of these wooden poles for any number of reasons.

Usable poles can be obtained new in just about any part of the country and used ones can sometimes be found in the pole yard of your local utility or telephone company. As long as it is sound and the base is treated with a preservative, all you need to do is find someone to put it up for you. A pole-setting rig can be hired that will drill the hole and set the pole in one visit. If you have a neighbor or buddy who's a lineman, then you might have someone who can install it and work on it for you. The big problem is that there is no hardware available for amateur antenna use, so you'll have to fabricate your own rotator mounting and antenna hardware. You can lag screw a pipe to the side of the pole and use a mast-mounted rotator, or you can get more exotic with a rotator mounting cage of some sort. You'll have to improvise much of this as you go along. The lack of hardware is a disadvantage to pole use. They're also harder to climb and work on than a steel tower; you may need lineman's climbing spurs at some point. In addition, they're dirty and can give you nasty splinters.

Other wooden supports

During the 1950's and 60's, ham magazines frequently contained articles with a construction project for a wooden tower or mast of some sort. These fell (no pun intended) into disfavor because they really couldn't provide a long term, safe, reliable antenna support. These days, with a variety of modestly priced steel and aluminum towers available, you shouldn't even consider building one of these.

Push-up masts

With lengths from 20 to 50-feet, push-up masts used to be very popular for TV antennas and could also be used for small ham antennas. With the advent of satellite TV, the push-up mast has fallen out of favor. They used to be available from Radio Shack but they don't stock them anymore. Rohn makes them but nowadays they have to be shipped from somewhere and many times the shipping cost exceeds the cost of the mast so they're not really feasible anymore. The material used for these push-ups is relatively heavy but not very strong. Since each ten-foot section needs to be guyed, a forty-foot push-up will have four sets of guy wires. It's a tricky proposition to put one of these up since all of the guy wires must be pre-installed, and you have to push it up from the bottom while trying to keep it from tipping over. If you only have a small VHF/UHF installation to put up, if you've got someone who knows how to safely install one of these and if you don't mind not being able to service your installation, this can be an inexpensive way to go.

Roof mounted supports

A very simple way to get started is to use a roof-mounted tower for your antenna support. These come in different configurations, from light-duty tripods designed for TV antenna mounting to a real live 4-legged mini-tower that will take a rotator and mast. The key is securing the tower without damaging the roof; and not falling off while doing it!

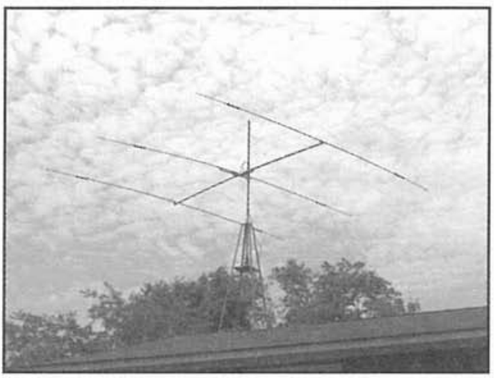

Photo 1: A good way to mount an antenna. AA2OW's roof-mounted tower. AA2OW photo.

For safety's sake, always use a fall-arrest system of some sort while working on a roof. A simple method is to tie a large loop or rope around a chimney; then tie yourself into that with a long lanyard or piece of rope attached to your fall-arrest harness.

Securing the tower to the roof isn't difficult; for smaller towers just be certain the lag screws are attached directly into roof trusses, then use a roof patching tar to seal the holes against water damage. For larger towers, use all-thread or long lag bolts through the roof and into a backing plate such as a long 2x4 or 2x6 that runs between 3 to 4 trusses; then attach the nuts and lockwashers from inside the attic.

Two important things to keep in mind. First, anytime you penetrate a roof membrane it can leak. Use roofing tar or patching compound liberally, and check out the installation from inside the attic occasionally to insure that no water is leaking into the house. Second, while roof-mounted towers are fairly benign to most roofs, a moderate sized tower using roof guy anchors can actually loosen a roof over time. Back and forth wind forces on twenty or thirty feet of Rohn *25G* can cause permanent roof dislocation problems. A thoughtful and carefully over-engineered job will minimize this type of problem.

If you have a small city lot, you may consider using a chimney or other building feature. This is not encouraged since chimneys (along with other house appurtenances) are not good from a structural standpoint and many are in poor condition to begin with. Chimneys are heavy but have no structural strength so they are not good places for mounting HF yagis. They can be used for VHF/UHF verticals or yagis though.

You can drape wire antennas around the house and yard; they'll probably work just fine. This may be a challenge, and exploiting your limitations may well make you a better and more resourceful operator.

If you can use any existing appurtenances such as a vent pipe, mast or roof structure to attach an end of a wire antenna, it may make things fairly simple. The major problem with any roof-mounted installation is avoiding penetrating the roof membrane at all costs. Your biggest obstacle may well be convincing your landlord or building manager or spouse that your installation will have no impact on the integrity of their roof.

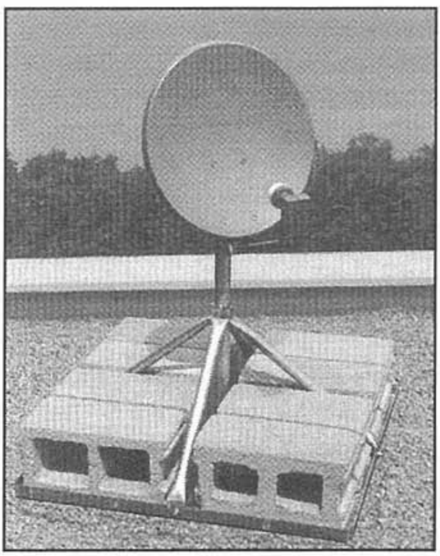

Photo 2: Non-roof penetrating gravity mount. Easily adaptable to ham antenna applications.

If you can't attach to anything already on the roof, you still have one good option; using some sort of gravity mount. A gravity mount is held down by gravity, usually by placing concrete blocks on the mount itself. Rooftop satellite dishes are commonly installed with this type of device. Commercial mounts are available that will hold a satellite dish, are fully galvanized and have a typical price of around $250. These might be overkill for amateur use because a ten-foot dish has over forty square feet of wind loading where an all-band HF vertical typically has less than four, but they would be very reliable. The parts consist of a tray to hold the cement blocks, the mast for antenna mounting and bracing between the tray and the mast. If you make one of these from aluminum angle, it should be quick and simple to fabricate. Be sure to use stainless steel hardware. Obviously you need some flat roof area to set this on.

Tower basics

Tower sections consist of legs and diagonal and horizontal braces. They can either be round members such as ROHN *25G* or angled members that use 90 or 60 degree angles for legs, diagonals or horizontals. Round membered towers such as ROHN 25G, etc. are the most common for amateur towers. The tower face is that outward facing area between the legs that has the braces.

TV antenna towers

There are many towers that were specifically designed and installed for TV antennas. These tend to be at the low end of suitability for amateur use. They were not designed for the larger loads of ham antennas, but are used by thousands of amateurs nonetheless.

These TV antenna towers are generally forty-feet or so in height and are installed without guy wires. The most common are the ROHN-SPAULDING (NOW ROHN) *AX* OR *BX* series-types and a tubular-legged-type, similar to ROHN 25G.

The *BX*-type is made from stamped steel, and has X bracing. The X's are not connected to each other and the common failure point is between the braces. Also, the rotator and top plates are made from sheet metal and can crack from wind-induced metal fatigue For small tribanders and VHF arrays they are just fine, but be careful of overloading the ones using the smaller sections. Rohn cautions that these towers should be limited to antennas with boom lengths of less than 10 feet since they have minimal torsion resistance.

There are several TV-type tower varieties including the Rohn

6G and 20G. Other types typically have tubular legs but only have horizontal bracing and lack diagonal braces. These are okay for small antennas but engineering caution should be used in all installations. The Rohn 6G is in this category. Rohn 20G on the other hand does have the Z-bracing and is the same size as 25G and in fact the accessories are compatible, but there are only 7 horizontals instead of the 8 horizontals of 25G and thus does not have the torsion resistance of 25G. Rohn cautions that 20G is not suitable for commercial, ham, CB or guyed installations.

Self-supporting towers

Rohn used to produce the popular *BX* series of towers consisting of models *BX* (standard), *HBX* (heavy-duty) and *HDBX* (extra-heavy-duty). This tower series was originally designed for TV antenna use and has its limitations for amateur applications. There are eight tapered *BX* sections that are used in all configurations. The *BX8* is the largest section, and is used as the bottom section of the *HDBX* series. The *BX1* section is the smallest section and is the top section of the *BX* series. Although the *HBX* series is rated at ten-square feet of antenna load and the *HDBX* is rated at eighteen-square feet, the wind pressure is only 20 PSF, or 70 MPH, and the maximum boom length "should be limited to ten-feet." The maximum height of an *HBX* is 56 feet and the maximum height for an *HDBX* is 48 feet. If you want to go higher than 60 feet with a self-supporting tower, a crank-up tower, Trylon, AN Wireless or Rohn *SSV* may be your choices. A self-supporting commercial tower such as the Trylon or *SSV* will not only be price competitive against a similar sized crank-up but also will be rated and certified at higher wind speeds.

Here are a couple of more points about the *BX* series. They are riveted together, not welded, and they are not hot-dipped galvanized after assembly as are Rohn *25G* or *45G*. The integrity of the galvanizing does not last as long as the hot-dipped variety. Because the braces are installed at the X angle and are not flat, your feet take a real beating when you have to work on one of these towers. And when you get up around the rotator, sometimes you can't get your feet to fit in anywhere.

Don't let me discourage you from putting one of these up. In their favor, they are relatively inexpensive, are common almost everywhere and can be picked up used for as little as $100. Just be aware of their limitations.

ROHN *BX* used to be called *"SPAULDING"* and the same design is currently manufactured in Canada as *"DELHI"* towers.

UNIVERSAL MANUFACTURING (www.UniversalTowers.com) produces a line of self-supporting aluminum towers that are touted as being lightweight, rust free and easy to assemble. They are, indeed, all of those things. They weigh approximately half as much as their ROHN *BX* counterparts, their aluminum parts won't rust and, being lighter, they go together easily. The price you pay is for the higher cost of the aluminum materials; that price can be two to four times that of a comparable steel tower. There are only two slight drawbacks to using an aluminum self-supporting tower. One is that the tower will move around quite a bit when you are up working on it. The other is a potential for leg hole elongation over time as the tower rocks in the wind. The aluminum leg will be working against the steel nut and bolt, and in severe cases can elongate the bolt hole, potentially to failure. Another aluminum tower manufacturer is Heights Tower Systems (www.heightstowers.com) who also makes crank-ups in addition to their line of freestanding towers. The crank-up version is also available in a trailer-mounted configuration.

Their base size requirements are slightly larger than for ROHN *BX,* using a five-foot square hole six-feet deep and six yards of concrete. Some additional accessory items are available. One big caution is that aluminum tower sections should never be placed directly in concrete. The corrosive effects of concrete (it contains lye) will destroy the aluminum tower sections where galvanized steel sections do not suffer the same fate.

Rohn SSV

Rohn SSV is a professional, relatively heavy-duty tower line that has been traditionally used by commercial communications and broadcast users. Freestanding up to 320 feet, this is a more challenging erection job, since the sections can weigh hundreds of pounds and are twenty-feet long instead of ham-standard ten-foot sections. The easiest way to erect this tower is to assemble all of the sections while they are laying on the ground, then to use a crane to pick up each section and lower it into place. Figure about a half-day to assemble each section, and four hours of crane time to stack one hundred feet of it in the air.

Trylon Titan towers

Fairly new to ham applications, Trylon makes a nice self-supporter that'll go up to 96-feet. At that height it's a relatively light-duty tower (rated for 15 square feet at 70 MPH) but the capacity increases as you decrease the height more or less. What happens is that there are 12 sections with the biggest being 46" across the bottom face and the smallest being 9" across the top. As you add or remove top or bottom sections, the height and capacity varies. It's possible to get a moderate height tower with lots of capacity as the top section gets larger. For example the T500-72 is the most popular ham configuration and will handle 45 square feet at 70 MPH for a moderate amount of money. There are top and rotator plates available as well.

Photo 3: A Trylon Titan self-supporting tower in Bandon, OR. The proud owners are W7WVF and N7YYG.

Trylon also makes a Super Titan that is more similar to Rohn SSV in its specs and price.

AN Wireless

AN Wireless makes a line of very robust self-supporting towers. Since a tower cost is a function of how much steel is in it, they also have robust price tags. Check www.anwireless.com for more info.

House-bracketed towers

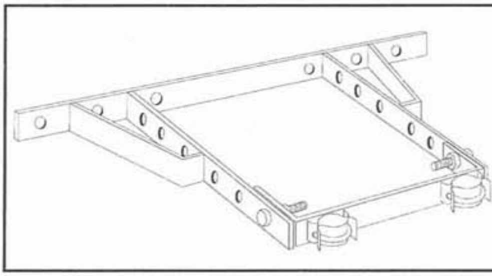

Figure 1: Rohn housebracket

Rohn 25G, 45G and 55G can all be installed using a house-bracket attached to the building as part of the structure. Current Rohn specs allow the top of the tower to be above the house-bracket 14 feet or more depending on windspeed conditions and antenna load. Consult a Rohn catalog or the Rohn website (www.rohnnet.com) for more details.

Freestanding 25G, 45G and 55G towers are a sub-set of house-bracketed towers since you're again using a guyed tower in a non-guyed scenario. Again, check the Rohn specs to see what the limitations are.

Crank-up towers

Crank-up towers have their advocates and they can be an elegant solution to many tower installation challenges. Basically, a crank-up tower is made up of two or more tower sections that nest inside each other and are pulled up progressively with a system of cables, pulleys and a winch. These winch crank-up systems are either electrically powered or are manually operated. They are generally self-supporting and require a large base foundation similar to those discussed above. The purpose, by the way, for a large foundation for a self-supporting tower is so that the center of gravity of the tower is below the ground level. Otherwise a big wind and big wind pressure could cause it to tip over.

Many amateurs feel a crank-up increases the safety of their installation by being able to crank it down in case of a windstorm. Well, yes and no. If you keep it cranked down except when you're actually using it, you can minimize any windstorm effects. Unfortunately if your tower is cranked up and a wind storm comes along, you probably won't be able to crank it down because of the wind pressure on the sections; that is of course, if you're home in the first place. Some crank-ups have positive pull-down which would allow you to lower the tower in spite of having wind force on it. Also, going outside at night in the middle of a storm to crank it down may be a deterrent in itself. A motorized system with the up-down switch in the shack is an elegant, although expensive, alternative. When raising or lowering a crank-up tower, you ALWAYS need to be looking at the tower as it's moving. It is not uncommon for something to snag if you're not looking at it and able to respond immediately, you can have a serious breakage – usually in the cables. If you're using a hamshack remote control and not paying attention, you're asking for trouble.

Along with being able to lower the antenna system, many crank-ups have the ability for the whole tower and antenna system to be lowered horizontally or tilted-over to facilitate antenna work. Again you're adding another layer of mechanical complexity and cost that may or may not be worth it. The forces that are generated by tilting a tower over and lifting it back up again are tremendous and are not to be taken lightly. Unless you have good engineering and fabrication experience, don't try to fabricate the tilt-over hardware yourself. The manufacturer spent a lot of money to design and fabricate a safe tilt-over fixture and that is the one you should use. Don't try to reinvent the wheel!

Photo 4: An impressively loaded and effective US Tower crank-up system owned by K6KR.

The smaller and less expensive crank-ups can either be tubular in design or use more conventional latticed sections. The medium and large configurations are for the most part diagonally braced towers.

Do not guy a crank-up tower if the manufacturer does not specify it. The added tension of the guy wires could increase the force on the tower hoisting cable enough to cause it to fail.

The LXC Prime Directive

Throughout this book I'm going to refer to the LXC Prime Directive repeatedly. Simply put, it states that you should always "DO what the manufacturer says." Don't reinvent the wheel or conjure up something yourself. Professional engineers and designers have come up with the designs and specs and there is very little chance that an amateur could do the same credible job. In all cases, the automatic default for any tower system question is the manufacturer's specifications.

There is a corollary to the Prime Directive and it is "DON'T do what the manufacturer doesn't tell you." In other words, if the manufacturer doesn't say to do something specifically, don't do it. I was personally involved with an antenna installation where when the antenna was finished, the owner sprayed the whole thing with acrylic spray paint. Did the manufacturer say to do that? No, they didn't. What happened was that the paint reacted with the lexan element brackets and in a couple of days they all cracked and had to be replaced.

Guyed towers

The accepted standard for amateur tower installations is guyed towers in general, and ROHN *25G*, *45G* and *55G* in particular. ROHN products are strong, reliable, relatively easy to erect and have a wide array of amateur compatible accessories.

With a face width of twelve inches and a ten-foot section weight of forty pounds, a ROHN ginpole and a ground crew is the recommended way to install ROHN *25G*. A practical height limit of 190 feet at 90 MPH wind speed gives you 7.8 square feet of antenna load capacity. A 100-foot installation yields 9.1 square feet of antenna capacity, enough for a small stack of monoband yagis or a high performance tribander. An experienced crew can erect up to a hundred feet a day of this popular tower.

ROHN *45G* is 18 inches across the face and a ten-foot section weighs 70 pounds. This robust tower is rated up to 240 feet in 90 MPH winds, with a windload rating of 16.3 square feet. At a height of 100 feet the wind loading is 21.5 square feet, after you've added back in the 8.0 square feet deducted for symmetrical antenna mounts per the catalog general notes.

Rohn 55G weighs 90 pounds per section and can be installed up to 300 feet in 90 MPH winds. It has a gross capacity of 17.4 square feet in that maximum configuration. The Rohn ginpole erection fixture is not rated for 55G because of its weight so a more suitable one must be used.

Photo 5: A populated guyed tower at the former XE2DV on the eastern shore of the Sea of Cortez. W7ZR was the owner.

Rotating towers

A rotating tower is probably the best tower platform for installing the ultimate high performance antenna system. As your experience and goals increase over time, you'll come to realize that the most competitive stations are utilizing stacks of antennas, that is, multiple monoband yagis mounted on the same tower that are phased together to provide maximum gain and performance. The increases in gain, performance and effectiveness are dramatic.

Since these antennas need to be mounted a distance apart, typically one wavelength, a rotating tower system allows you to turn the whole array to aim it at a particular target. As you can imagine, besides being the best as well as the strongest, the rotating tower systems are the most expensive. You need a special bearing setup at the bottom on which the system turns and then you need one or more rotating guy rings that allow the tower to turn inside of them.

Rotating towers were first exploited in Finland. One of their local amateurs came up with the design and started to manufacture them. Not only did he make the rotating guy rings but he also produced the tower sections. Since he was a school teacher, he built them over the winter, then went around and installed them in the summer. There are dozens of these systems in Finland and the price was very reasonable; a 120 foot rotating tower approximately fifteen years ago was around $1200—installed!

Originally designed by Dick Weber, K5IU, his Rotating Tower Structures rotating tower hardware is now available from Paul Nyland, K7PN, thru Custom Metalworks (www.custommetalworks.com). There is another version from Rich Bennett, K0XG that is also well designed and beefy (www.K0XG.com). Both are relatively expensive. And if you embark on this path, you'll probably want to use Phillystran non-conductive guy wires that minimize potential destructive interaction but also adds to the cost. This is not a project for the faint hearted.

Big Berthas

The Big Bertha is a self-supporting tubular rotating monopole and it is typically regarded as the ultimate tower. Their origins are from the 50's, and they are currently available up to 300 feet (yikes!) from Scott Johns, W3TX at www.superberthaguy.com. It sits on a very large block of concrete with a large cylindrical socket tube set into it. The socket is partially filled with oil and then the sealed bottom end of the tower is dropped into the socket where the tower partially floats in the oil, resulting in very low effort needed to rotate it. Seeing one of these works of art in the flesh is an impressive sight.

3
Planning

When an amateur first gets a gleam in his or her eye about putting up antennas, it may seem that the "sky's the limit." Unfortunately, it's not too long before reality, in the form of land limitations, legal, aesthetic, financial and spousal considerations, along with neighbor and legal complications, sets in. Although each one of these obstacles can be dealt with effectively, a fair amount of planning is required for any successful installation.

Goals

Building an amateur antenna system is an exciting proposition; starting with a blank sheet of paper only adds to the possibilities. The first question you've got to ask yourself is what do you want your station to do? Is your main goal to chase DX, handle transcontinental radio traffic, work VHF/UHF like never before or talk to your buddies in Arizona every morning on 20-meters? Each purpose has its own set of possibilities and solutions. You have to decide what you want your station to do. The information in this book will then help you assemble that station once you've decided. Regardless of which way you want to go, you'll need antennas and antenna supports to reach your goal.

Lots, property and acreage

No matter how little property you have available, you can get on the air and have fun. Many articles have been written for apartment and condo dwellers about hidden and indoor apartment antennas. If this is your situation, do your homework and do the best you can.

Roof mounted antennas

If you have only a small city lot, you may want to consider using a chimney or other building features, or putting a roof-mount tower on the roof. Likewise, you can drape wire antennas around the yard and house and they'll probably work just fine. It will be challenging and exploiting your limitations might just make you a better operator. After years of operating from world-class multioperator stations, Homer Spence, K7RA (SK), decided that the challenge for him was to operate his own station from his apartment in downtown Seattle, barefoot, with a vertical on top of his building. He was still able to work DX stations around the world while enjoying the thrill and challenge of operating his modest station.

A small tower

If you've got enough property available (zoning aside), you'll probably start thinking about a tower and similar possibilities. Forty to fifty feet of ROHN *25G* attached to the side of your house with house brackets will enable you to put up a beam and give you a place to hang wire antennas with a minimum of cost and fuss. Go up any higher and you'll need to guy the tower.

To put up a guyed 60-foot tower, you'll need ¼ acre or a piece of land 130' square in order to accommodate the guy wires and anchors. For a 100' tower, you'll need 0.6 acre and a piece of land 190' square. (An acre is approximately 44,000 square feet.)

In any case, my advice is to go with what you've got and get on the air. It's much better to have some sort of working antenna than not and if you can't get it very high, it'll still radiate and you'll still be on the air. If you've got a funky trap vertical, mount it on a fence post and start transmitting. Look for possibilities and not limitations. You'll always be able to improve or upgrade later.

Your tower height is up to you, but don't forget that more height means more gain and more efficiency, up to a point. Many articles and books have been written with antenna height as the subject and I'm not going to reinvent the wheel here. Again, do your homework and your planning around your specific conditions and goals. I will mention that you should try to shoot for 50-feet as a minimum for HF. An effective antenna system on a 100-foot tower will enable you to work anything you want and you may even win a contest or two.

Taller installations

For taller installations there are two things to keep in mind. First, once you exceed 200-feet above ground level (AGL) you'll have to comply with FAA regulations for lighting and painting. *FAA Advisory Circular 70/7460-1H* spells out these regulations. From a practical standpoint, most hams stay below this height for obvious reasons. The second point is that if you are anywhere near an airport,

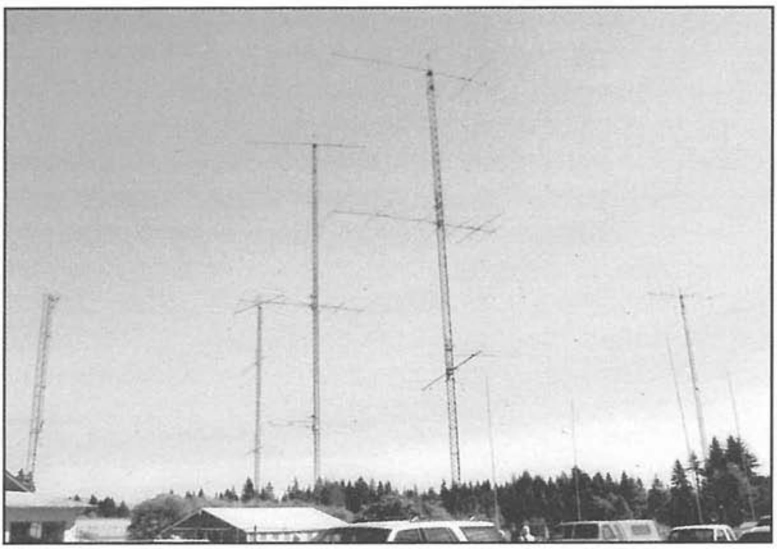

Photo 1: With the proper planning, this could be your new heavy metal station. Station built by W7RM (SK).

you have to comply with the FAA proximity height limitations. Contact your nearest FAA office for more information on this one.

Plan ahead

At some time in the future you may decide to expand your antenna farm, or to put up larger artillery. It's usually too late, and/or too expensive, at that point to upgrade your installation. For a relatively small additional cost and effort of a larger hole and more concrete, you can install a pad larger than that called for by your initial tower. If and when you ever decide to upgrade, you'll have a base for a larger tower. Do it while it is easy; you'll later likely be congratulating yourself for being clever and planning ahead!

4

LAND USE REGULATION OF AMATEUR RADIO TOWERS

[I have never attended law school, let alone passed a bar exam. I rely on knowledgable attorneys for legal advice. And I am pleased to have permission from CQ *to reprint portions of an article by Wyland Dale Clift, NA1L, who is a recognized expert both in legal and amateur radio matters, which has invaluable advice on this important subject.—S.M.]*

Local, state and Federal laws affecting amateur radio antennas and towers are a result of continuous legal developments as new cases are decided by the courts. The modern era of amateur radio antenna law was ushered in by a dramatic development in 1985. After years of sustained lobbying by the AMERICAN RADIO RELAY LEAGUE and others, the Federal Communications Commission (FCC) ordered limited Federal preemption of state and local antenna ordinances in a ruling it called *PRB-1*.[1] That order finally curbed the runaway trend by local government officials to place ever greater restrictions on antenna height and placement through zoning ordinances.

Had this trend continued, it would have meant the virtual prohibition of functional, high frequency amateur radio antennas in most cities, towns and villages with zoning regulations. Fortunately, the FCC passed *PRB-1*. But since 1985, the strengths and weaknesses of *PRB-1* have been tested and examined in several reported court cases. *PRB-1* got a boost when the recent rewriting of *Amateur Radio Rules* incorporated the original 1985 *PRB-1* order into the text of *Part 97.15* of the *Amateur Rules.* But other cases, such as the 1990 decision in the U.S. Court of Appeals for the Fourth Circuit, denied a ham operator relief from a zoning board of adjustment's decision in spite of *PRB-1*.[2] To the surprise and consternation of ham-attorneys, the court interpreted *PRB-1* in such a way as to allow the ZBA's decision to stand. The ham operator in that case was not permitted to exceed a 17-foot antenna height limit! While this decision is by no means a setback to pre-*PRB-1* days, it requires some readjustments in preparing an application for a tower permit, especially if it involves a hearing for a special permit.

Knowing and understanding the legal foundation of your right to erect an antenna and tower are just as important as knowing the correct construction techniques. This chapter will teach you about zoning and building permits. It will also help you prepare for a hearing if one is required in order to put up the antenna to the height you need. If you are well prepared you lessen your risk of denial. Hearings are also an opportunity to enhance the public relations image of amateur radio.

Every amateur operator seeking to put up a tower should first check out the requirements for obtaining a building permit. Failure to obtain the necessary permits could subject you to fines, forfeitures and the threat of arrest. This is not meant to scare anyone, but zoning ordinances and building codes are laws. And anyone who thinks he is above the law could find himself on the losing end of a very expensive legal battle. Furthermore, if you do your homework, virtually any ham radio operator who has enough real estate necessary for the safe installation of a ham radio tower should be able to legally erect a functional antenna system without interference from state or local governments.

Get copies of the regulations first

Regulations pertaining to antennas and the way in which building and zoning departments process permit requests vary from town to town and county to county. Therefore, the first, and most important step is to get a copy of the regulations. Phone the building or zoning department, or go in person to obtain a copy of the zoning ordinances. Get the whole booklet! Do not cut corners by getting a copy of only those pages you think might be applicable. Even if the clerk offers to photocopy for you only those pages that pertain to antennas, make note of those sections that are mentioned, but do not accept anything less than the entire booklet. Be wary of statements such as: "This section is all you have to worry about." Such statements are not binding on the building or zoning department. And the "helpful" clerk can always claim that you mislead him or her in how you explained what you want to do. It is well worth paying for the entire booklet: it usually costs between $10 and $25. Besides, you need to know a lot more than just the sections under which the town regulates antenna heights.

You will need to know what procedures are followed in applying for a permit. You will also need to know how to appeal an adverse decision if you do not get a favorable ruling from the building inspector or zoning enforcement officer on the first try. If you ever need to seek the advice of a lawyer, the first thing he or she will need to see is the entire booklet anyway. Obtain the entire booklet of zoning regulations now, and study it. This is the building and zoning department's "bible," and it must be followed to the letter.

"Use" and "dimensional" zoning

Be certain you understand what zoning regulations are. Zoning regulations are laws that establish the uses permitted and the minimum and maximum dimensional requirements of structures in established areas or "zones." Ninety-nine percent of the time the ham operator will want to put the antenna/tower at his home, which is located in a residential zone. Since the overwhelming majority of jurisdictions hold amateur radio to be a normal, accessory (as opposed to primary) use of residential property, there is usually no argument that an amateur antenna and tower is a proper, accessory structure for use in a residential zone. Swimming pools, tennis courts, garages, tool sheds and similar structures are examples of other accessory structures for normal accessory uses of residential property.

A commercial garage, however, is an example of an accessory structure use that would not be proper in a residential zone.

Very rarely do we see cases where the issues are whether amateur radio antennas and towers are proper accessory structures and whether amateur radio is a proper use in a residential zone. But in addition to use rules, zoning regulations also establish rules as to how high structures are permitted to be. These are dimensional rules. You may find that zoning ordinances require that your proposed antenna/tower must be held to height, minimum setback rules and other dimensional limits. Similarly, other "buildings" or "structures" must comply with certain maximum height and setback rules in a residential zone. Dimensional limits, particularly height, usually are at the heart of the legal issue in most court cases involving amateur radio antennas and towers.

After you get your copy of the zoning ordinances and have leafed through it looking for "antenna height," if it is not apparent how antennas are regulated, do not celebrate yet. Read the "definitions" section, which generally is near the beginning of the zoning ordinances booklet. Sometimes the zoning ordinances' definition of "building" is broad enough to include an antenna/tower so that the rules limiting building height also apply to towers and antennas. Of course, antennas and towers may be defined specifically and thereby be limited. If the regulations do not define antennas and towers specifically, and if the definition of "building" does not seem to cover towers and antennas, see if there is a definition of "accessory structures." It may be broad enough to include antennas and towers.

Building codes

Zoning regulations, you will recall, involve whether a use is permitted in a zone, and they establish the dimensional limits, such as height and placement from the borders of your property. There is yet another aspect to the regulation of your antenna and tower: building codes. Building codes are laws based on standards related to safety that have been agreed upon by engineers from the architectural, structural, civil and other engineering disciplines. There has always been some confusion because in many municipalities, especially in smaller towns, building and zoning functions are consolidated in one department, or even one person. The building official might also be the zoning official or zoning enforcement officer. Even if they are separate departments or if there are both a zoning enforcement officer and a building official, they usually work in tandem. For example, if you apply for a building permit without even checking what the zoning ordinances allow, the building official will usually run it by the zoning enforcement officer first to make sure that what you are proposing is allowed per the zoning ordinances. If zoning ordinances would be violated, the building official or the building department will not give you a building permit, even if you meet all the requirements of the building codes. You must first meet zoning, and then building requirements. Once the building official checks with zoning and finds that your antenna/tower is a proper use in the zone and will not violate the zoning regulations pertaining to dimensions, your construction must be done in accordance with building codes. Fortunately, this is rarely a problem. Tower manufacturers provide detailed specifications and plans for proper installation in accordance with all building codes.

Zoning and building officials

After you have had a chance to study the zoning regulations, make an outline of your understanding of how the regulations apply to your proposed installation. If the clerk or secretary pointed out certain sections to be concerned with when you first picked up the zoning ordinances booklet, you may have discovered that he or she was right! But now you understand and can see for yourself how the regulations apply to you; that is what is important. However, if the regulations are making no sense, get help now. Consult a lawyer or talk with someone who has already gone through the process. You should feel confident if you have familiarized yourself with the zoning ordinances well enough to be able to discuss how and which of the regulations apply to antenna towers. Your next step is to call and make an appointment to see the zoning official and/or the building official. Which one do you see first? If you live in a smaller town, the building official and the zoning official may be one and the same person. In larger cities, they usually are at least located in the same department. The clerk will be able to direct you to the proper person(s). If your town has not had many amateur radio operators apply for permits for towers, you may even find yourself referred to the "town planner," who helped write and adopt the zoning ordinances and who is usually consulted to help figure out how the regulations apply to a request that is somewhat out of the ordinary. If your municipality's ordinances require a hearing, however, you will speak with someone who can address zoning issues. Remember, the emphasis for zoning will be dimensions and use, so be prepared to discuss the proposed location, height, and purpose of the antenna structure. Be prepared to discuss building-code concerns, too. For this area of the law you should take along basic engineering data that is provided by the tower manufacturer to satisfy any building-code concerns, and be prepared to discuss how it will be anchored and, if required, guyed. It will be helpful to take along a drawing of your property that shows the locations of your boundary lines, the house and other buildings, and the proposed location for the tower. If you got a survey of your property when you bought your house, make a photocopy of it that can be marked up to show the proposed antenna structure.

Incidentally, in reading the zoning regulations you may find that you must submit a certified site plan. This can cost several hundred dollars. However, you may be able to save the cost of a certified site plan if you have read the zoning regulations carefully. Some zoning regulations contain a provision that allows you to substitute a hand-drawn sketch, provided you ask for a waiver of the more stringent rules calling for surveys and engineering data. The zoning official or board may need to agree first that a certified site plan is not necessary to accurately depict the proposed antenna structure before you put in your formal application. Look for this provision and, if your town's zoning regulations have it, discuss it with the zoning official because it could save you an unnecessary expense.

Meeting strategy

The zoning official is going to interpret how zoning laws are applied to the facts of your situation. What he or she says will be the first indication of the steps the municipality will want you to take to get a permit for your installation. Be sure to listen carefully to what the zoning official says, and take written notes. Zoning officials are supposed to help you understand the requirements for applying for a zoning permit. Again, if you have previously obtained and read the zoning ordinance booklet and understand the regulations, you are going to get a lot more out of your meeting than if you go into it "cold." The zoning official will be more willing to discuss the matter with you, too, because you have taken the time to study the regulations. If the zoning official starts to say something you interpret to be negative, make sure that you understand his or her reasoning. Even though this reasoning may be wrong, listen to it and thoroughly understand the basis for this opinion. Effective opposition to an adverse position taken by the zoning official will be possible only if you follow this vitally important step. This is **not** the time to discuss *PRB-1* with the zoning official. First of all, he or she is not likely to know what you're talking about. Second, he or she is not going to agree with you that their regulations are flawed. Remember, the zoning regulations are the "bible," and the municipality has endorsed them with the force of law. Further, if you are going to talk about legal issues, he or she is going to want to talk to their lawyer; who is, of course, the town attorney.

Special permits or special uses

In many situations, the zoning official will have the authority to grant a zoning permit without involving any other official or board. Then, if he or she is also the building official, you can get your building permit right there on the spot after filling out the application and paying the fee. However, depending on how your local town's ordinances are written, it may be necessary for you to seek the permission of a zoning commission, zoning board of appeals, or other land-use board. Most often this means that the zoning regulations are set up so that in order to exceed the "usual" height restrictions, you need to apply for a special permit (also called "special exceptions" or "conditional use permits"). It simply means that drafters of the ordinances decided that certain uses or structures can be permitted only after a public hearing and demonstration of special need. If you obtained the entire booklet of zoning regulations and familiarized yourself with it, a special-permit requirement will not come as a shock to you during your visit with the zoning official. Although a special permit undoubtedly means more red tape and delay for the ham operator, such a requirement in and of itself is not illegal in the eyes of the law, including the FCC's *PRB-1 Preemption Order* (discussed later). It does provide a forum for potential opposition from neighbors, however, so preparation for the hearing is all-important. Also keep in mind that the higher you want to go with the tower, the more evidence and preparation will be required to establish your need for the structure.

In case of difficulty

If there is a problem, it will be one of two varieties. It may be a matter of interpretation of the ordinance by the zoning official. Or the ordinance may be written in such a way that no one could reasonably come up with any other interpretation. If the ordinance is prohibitive under any reasonable interpretation, you should immediately seek the advice of a lawyer. If the problem is that you disagree with the zoning official's interpretation of the zoning regulations, that is not as serious. Though you may need a lawyer to resolve an issue regarding interpretation, you first can carry the issue yourself a little further if you wish. Tell the zoning official that you have a different interpretation, and ask him or her for specific comments. See if you can narrow it down as to where the problem lies.

If it is a problem with the way in which the ordinance is written—that is, under no possible interpretation can you get your permit—it is the more serious problem. This may mean that the ordinance is illegal and, therefore, invalid. The town or city officials won't like that, and they are more apt to fight vigorously against having their ordinance invalidated. They would much rather have to change an interpretation for a particular situation than scrap their ordinance. If you run into an unresolvable problem with the zoning official, inspector, or other supernumerary, you should then, as a last resort, tell him or her about *PRB-1*. As already mentioned, however, more often than not you will find that it does not help at this level. At most, all you can get across is that the Federal government, through the FCC, has acted in this area under a Preemption Order called *PRB-1*. You can say that local governments cannot prohibit antenna towers, nor can they unreasonably restrict them in terms of size and height. However, it is best not to get into a lengthy discussion of the nuances of the legal doctrine of Federal Preemption with the zoning official.

A matter of interpretation

If there is a reasonable interpretation of the regulations under which you should be allowed to put up the antennal tower, but the zoning official does not agree, you can usually apply, get denied by the zoning official, and then appeal the zoning official's decision to a zoning board of appeals. The procedure for appealing a ruling by a zoning official will be outlined in the regulations which, again, you have because you bought the entire zoning ordinances booklet, right? Basically, if you appeal the zoning official's decision, it means you are given a second chance to explain what amateur radio is, what kind of antenna structure you want to erect, and what your alternative interpretation is that would permit you to erect your antenna installation.

PRB-1 should be used to persuade the zoning board of appeal that it should adopt your more reasonable interpretation. Now you should point out that Federal law requires towns to adopt as reasonable an interpretation as possible. If there is no possible interpretation of the zoning regulations that would allow a functioning amateur radio antenna, then the zoning board of appeal should be told that *PRB-1* is a binding Federal regulation that supersedes their own law if there is a conflict. This puts tremendous pressure on the zoning board of appeal to try to accommodate your needs. The zoning board of appeal's interpretation of their own zoning ordinances will be affected by the binding order that was made by the FCC in *PRB-1*.

The heart of *PRB-1* is comprised of only a few sentences, and their importance justifies quoting here: "Upon weighing these interests [state vs. Federal interests] we [the FCC] believe a limited preemption policy is warranted. State and local regulations that operate to preclude amateur communications in their communities are in direct conflict with Federal objectives and must be preempted." *Amateur Radio Preemption, 101 FCC2d 952, 960 (1985)* ... "We [the FCC] will not, however, specify any particular height limitation below which a local government may not regulate, nor will we suggest the precise language that must be contained in local ordinances, such as mechanisms for special exceptions, variances, or conditional use permits. Nevertheless, local regulations which involve placement, screening, or height of antennas based on health, safety, or aesthetic considerations must be crafted to accommodate reasonably amateur communications, and to represent the minimum practicable regulation to accomplish the local authority's legitimate purpose." *Id., 101 FCC2d 952, 960 (1985)*. You can also give the zoning board of appeals a copy of *Part 97.15* from your copy of the *Amateur Radio Rules*, since this, too, states the basis of *PRB-1*.

PRB-1 and Federal preemption

Credit is due the ARRL for a long-fought battle to get the FCC to take a stand against overly-restrictive regulation of amateur radio antennas and towers by adopting *PRB-1*. However, as you can see from the above-quoted passage from *PRB-1* ,which is the "heart" of the preemption order, *PRB-1* has its limitations. It holds that no municipality may prohibit amateur radio communications. It also says that state or local regulations restricting amateur radio antennas must do so in the least restrictive way while still accomplishing its legitimate goals. In other words, the local regulations cannot constitute "overkill." But make no mistake about it, state and local governments can, under the specific language of *PRB-I*, regulate antennas for reasons of health, safety and welfare. But, they must balance the local interests against the Federal interests. Earlier, the case of *Williams v. City of Columbia, South Carolina*[2] was mentioned. In that case the radio amateur proposed an antenna system that would be 28 feet high when retracted and 55 to 65 feet high when fully extended. The city's zoning ordinances required anyone wanting to erect an antenna higher than 17 feet to apply to the zoning board of adjustment for a "special exception."

(Remember, a "special exception" is just another name for a "special permit" or "conditional use permit.") The radio amateur, Williams, had trouble primarily because of a rule that a local board's finding of the facts is given great deference when reviewed on appeal. In other words, the court will not "retry" the case on the facts unless there is clear evidence of unfairness or bias. And proving unfairness and/or bias is very difficult.

What this case means for radio amateurs is that when you apply for a special permit, special exception, or conditional use permit, it is extremely important to be prepared to explain the Federal interests in amateur radio. For example, if you look at the basis and purpose of the Amateur Radio Service you will find that there is a Federal purpose in promoting emergency communications, technical advancement, development of communications techniques, and promoting international goodwill. You must show a relationship between the need for your particular antenna installation and the promotion of one or more, and preferably all, of these Federal interests. It may be obvious to us that there is a relationship between antenna height as it affects long-distance communications and your ability to enhance international goodwill. However, that will not be obvious to a zoning board or a reviewing court. You must establish this "on the record" at your hearing. Want to put an antenna on your tower to access the amateur satellites? There is a direct relationship between advancing the technical and communications arts and your antenna. And, of course, your antenna can also be used for emergency communications and drills. You must show this relationship to Federal goals to counteract the interests the local government has in regulating an antenna system. In many cases, local government interest has been expressed as avoiding the adverse impact of the proposed use on the aesthetic character of the surrounding neighborhood, and promoting health and safety.

Safety, aesthetics, and property values

Now let's get back to the local zoning official or zoning board. The first thing to do is to make sure that you can establish that the proposed antenna and tower will be safe. On matters of safety, there can and should be no compromise by the municipality. If the installation does not meet building-code requirements, no zoning board or building official or court will allow it because safety is at stake. The manufacturer's specifications must be followed.

Aesthetics and welfare, particularly the effect on surrounding property values, are more likely to be areas where the municipality has to make compromises because of the strong, countervailing Federal interests being promoted by amateur radio. Your task is basically threefold. You must demonstrate your need for the proposed antenna and the safety of the structure, and you have to show that you have taken reasonable steps to lessen the impact on surrounding property. The ARRL has several helpful papers and pamphlets. These materials include a summary and collection of legal cases from around the country. Also, if you need help establishing the need for the height of your antenna, the LEAGUE has a paper written by Gerald Hall, K1TD, on the relationship between antenna height and the effectiveness of communications. Finally, there is a list of "volunteer counsel," attorneys listed at www.ARRL.org and who are willing to provide an initial consultation to the ham-radio operator free of charge. There may be a volunteer counsel near you. At the very least, you should obtain these materials to help you prepare for a hearing. *[Contact the Regulatory Information Department, ARRL Headquarters, 225 Main Street, Newington, CT 06111. phone: 860-594-0200, fax: 860-594-0259]*

If you haven't already done so, try to gauge the opposition of the neighborhood prior to a hearing. Be prepared to answer all reasonable questions. While radio frequency interference (RFI) matters do not fall under the jurisdiction of the local zoning board, your reaction to questions about RFI might be used by the zoning board members to judge your character, which could form the unwritten and unstated basis for a denial. A zoning board member is more likely to give the benefit of the doubt to someone who sounds like a responsible, good neighbor.

If a neighbor is concerned about RFI, one of the most effective ways of dealing with this concern is to explain that while years ago, the homebrew nature of ham stations may have resulted in some hams being responsible for some radio frequency interference problems, that is hardly the case today. Today, the level of amateur radio sophistication is such that RFI is rarely a problem, and when it is, the fault almost always lies with the device that is experiencing the interference. This has been borne out so often that in 1982 the U.S. Congress passed a law, *Public Law 97-259,* that gave the FCC the exclusive jurisdiction over matters of RFI to home electronic devices. The FCC has the expertise to deal with such matters, and you then explain to the zoning board members that you would work with the neighbor and the FCC so that they (the zoning board members) would not be shouldered with that problem in the rare event RFI occurs.

When a tower is impossible

There are some circumstances under which it is impossible erect a tower. Condominiums are an example. A condominium owner "owns" only that which exists within the confines of the four walls that form his or her unit. The rest of the building and the land are either owned by someone else, or they are owned in common by all the unit holders. Unless you can persuade the condominium association to allow you to put up an antenna in a common area, you had better become familiar with so-called invisible antennas or limited space antennas in attics or crawl spaces above the ceiling. You cannot expect to erect a tower on land or a building that you do not own outright. You need the permission of the owner(s).

Private restrictions, commonly called "CC&Rs," which stands for covenants, conditions and restrictions, are another aspect of antenna/tower regulation that has nothing to do with the government officials. These are the "fine print" that may be referenced in the deed to your property, especially if you are in a planned subdivision that has underground utilities. Your best bet before proceeding with your plans is to take a copy of your deed to an attorney to have a limited title search done for the specific purpose of determining whether private restrictions will affect you. This area of the law is the next major battleground since it is difficult to find newly constructed homes without these prohibitive private rules.

Local governments must be reasonable

With respect to governmental, as opposed to private restrictions, it comes down to one simple fact. Any ham radio operator, provided he or she has a Federal license and the private property rights to a sufficiently sized parcel of land, has the right under Federal law to erect a tower and antenna subject to the "reasonable" regulation of the local or state government. The big question, of course, is what is "reasonable." The majority of the court cases interpreting *PRB-I* have told local governments that they were not reasonable in their regulation of amateur radio antennas. A US District Court in New York struck down a 25-foot height limitation as being unreasonable and found that the local government there had failed to make a reasonable accommodation for amateur antennas.[3] Another US District Court in Washington State sided with a radio amateur who asserted that the local government was being unreasonable when the ham was unable to get a special permit for a 75-foot retractable radio antenna.[4] And in California, a U.S. District Court invalidated a zoning ordinance governing radio antennas where the city failed to explore alternatives to a blanket denial of the ham operator's application for a special permit.[5]

Since the Williams case, there has been more encouraging *PRB-1*-related news. An Ohio ham operator was awarded his attorney's fees by a Federal judge.[6] And in Colorado another Federal judge invalidated an ordinance.[7] The Boulder County, Colorado ordinance was invalidated because it put the amateur into a "catch-22" situation. It required the filing of a special-use permit in order to obtain a permit for an antenna taller than 35 feet, but the standards under which special permits were decided virtually assured that you would be denied. The County has filed a petition for rehearing, however, so this decision was not final as of press time. Sometimes a clash cannot be avoided. Lawyers and judges have just begun to explore the legal limits of *PRB-1*. But if you are like most ham operators, you want to know how best to go about putting up the highest tower you can without getting into a big legal hassle.

The key to winning approval is persuading the board or zoning official that you actually need the tower you are proposing and have taken all reasonable steps to lessen its impact on the neighborhood. In the event there is an appeal to a court, the legal arguments nearly always come down to whether you have presented enough evidence at the local-board level to show that without the tower you will not be able to communicate effectively. The burden of proving that need gets progressively more difficult as you plan to go higher with your tower. In difficult cases a qualified expert on radio propagation may be necessary.

Other factors, such as the neighborhood being "exclusive," can result in your application being put to the test. In these cases the crucial factor is whether the ham operator has taken all reasonable steps to lessen the visual impact of the tower on the neighborhood. In difficult cases, a qualified real estate appraiser may be needed to testify that in his or her expert opinion the proposed tower would not adversely affect neighboring real estate values. These cases are difficult and extraordinary, but I mention them to make the point that ham operators sometimes have to be realistic about their plans. When your plans are "ambitious" because of the lot size or visual impact to neighbors, it requires more preparation to prove need and to illustrate that steps have been taken to lessen the structure's impact on surrounding property.

Special problems

If you live near an airport, check the requirements of *Part 97.15(b)* of the *Amateur Rules*. Depending on your distance from the airport and the length of the longest runway, you may need to keep your tower below a certain height or follow special rules for lighting and marking it. If you fit certain criteria, you must file both *Federal Aviation Administration (FAA) Form 7460-1* with the FAA, and *FCC Form 854* with the FCC and await their approvals.

An easy way to avoid having to file these forms is to keep your antenna height below a formula given in *Part 97.15(b)*. If you live near an airport runway more than one kilometer long (3250 feet), you should keep your antenna height below a slope of 100 to 1. In other words, if your antenna elevation is more than one meter (3.25-feet) higher than the airport runway elevation for each 100 meters (325 feet) you are located from the nearest runway longer than one kilometer (3250 feet), you must get special permission. If the airport runway is less than one kilometer (3250 feet) in length, you should keep your antenna height below a slope of 50 to 1. In other words, if the elevation of your antenna is more than two meters (6.5 feet) higher than the airport runway elevation for each 100 meters (325 feet) you are located from the nearest runway that is shorter than one kilometer (3250 feet), you must get special permission. Finally, if you live hear a heliport, you must keep your antenna height below a slope of 25 to 1. In other words, if the elevation of your antenna is more than four meters (13 feet) higher than the helicopter landing pad's elevation for each 100 meters (325 feet) you are located from the landing pad, you must get special permission.

If you keep these slopes in mind, 100 to 1 (long runways), 50 to 1 (shorter runways), and 25 to 1 (heliports), you can avoid special notifications. Simply take the distance from the nearest runway or landing pad, and divide it by the appropriate slope. For example, if you are one mile away, or 5280 feet, and the runway is shorter than 3250 feet, thereby requiring a 50 to 1 slope, simply divide 5280 by 50, and you get 105.6 feet. But if the runway is 3250 feet or longer, and the slope requirement is 100 to 1, you may go only to a height of 52.8 feet (5280 divided by 100).

There are also some exemptions from the slope rule. You can always erect an antenna up to twenty feet above the ground or above any other natural object or existing man-made structure (except, of course, a tower). Be sensible in taking advantage of this exemption. If in doubt, check with a lawyer. If you live in certain parts of Maryland, West Virginia and Virginia near the National Radio Astronomy Observatory at Green Bank or the Naval Research Laboratory at Sugar Grove, you will not be permitted to increase the height of your antenna unless you give written notice of your plan to the Interference Office, National Radio Astronomy Observatory, Box 2, Green Bank, WV 24944. The reason for this restriction is a concern over possible interference to these sensitive government facilities.

Remember that if you plan to erect an antenna that is higher than 61 meters (200 feet) above ground level, you will **always** need prior FCC approval. *See Part97.15(a) of the Amateur Rules.*

Summing it all up

Emphasis from the start should be on the more practical aspects of planning a successful campaign for getting the necessary approvals for a tower. Be realistic about the physical limitations of your parcel of land. Go on an information gathering mission at the local building department to see which officials and which regulations are applicable to your proposed antenna installation. Discuss your plans with the local zoning or building official. Determine whether the zoning official's interpretation of how the rules will apply to your plans is fair or should be challenged. Also, determine whether a hearing for a special permit will be necessary. If you are dissatisfied with the local zoning official's interpretation, obtain information from the ARRL and seek legal advice from an attorney as to whether there is any reasonable interpretation of the regulations that would permit you to put up the antenna/tower. If there is no reasonable interpretation of the ordinances as they stand, then you need to seek either a variance from the regulations themselves or make a frontal assault on the ordinance as being in violation of *PRB-1*. Once you get into this area of the law, professional legal advice is necessary.

1 *Amateur Radio Preemption, 101 FCC2d 952, 50 Fed. Reg. 38813(1985).*
2 *Williams v. City of Columbia , South Carolina, 906 F.2d 994 (4th Cir. 1990) (1990 U.S. App. LEXIS10884).*
3 *Bodony v. Incorporated Village of Sands Point, 681 F.Supp. 1009(E.D.N.Y. 1987).*
4 *Bulchis v. City of Edmonds, 671 F.Supp. 1 270 (W.D.Wash.1987).*
5 *Howard v. City of Burlingame, No. C-87-5329 (N.D. Cal. July 29, 1988) (1988 WESTLAW 169074).*
6 *Macmillan v. City of Rock River, 748 F.Supp. 1241, 1990 U.S. Dist. LEXIS 13591 (N.D. Ohio, Sept.21, 1990).*
7 *D.R. Evans v. Board of county Commissioners of the county of Boulder, Colorado, 1990 U.S. Diet. LEXIS 16123 (D. Cole. November 13, 1990).*

Glossary of terms

Accessory Use, Building or Structure: A subordinate use, building or structure customarily incidental to and located on the same lot occupied by the main use, building or structure. In a residential zone the house would be the main building, and its use as a residence would be the main use. Garages, swimming pools, tennis courts, and amateur radio antennas are examples of accessory structures.

BOCA Code: A set of engineering standards for structures established by the Building Officials & Code Administrators International, Inc., a nonprofit standard-setting group based in Illinois. Many states and towns base their own state or town building code on the BOCA code, with some variations.

Building: The word "building," as used in local zoning and building regulations, can mean more than what common-sense tells you. The "definitions" sections of some regulations will define building in such a way as to include antennas and other structures. If you find that the height limitations apply only to "buildings," check the definitions section before you conclude that it doesn't apply to antennas.

Building Code: The regulations that deal with the engineering, safety and integrity of structures. Wind-loading standards are part of the building code.

Building Inspector: The part-time or full-time employee of the municipality who interprets whether your proposed construction conforms with the zoning regulations and building code. His or her interpretation can be appealed (usually to the Zoning Board of Appeals). If the decision challenged is only with respect to the building code, however, appeal may be to a different board, usually called the Building Board of Appeals. Larger towns may have a Zoning Enforcement Officer (ZEO, see below), leaving the Building Inspector to deal only with building code enforcement. Also, don't be surprised if there are multiple building inspectors for the electrical and structural aspects of your proposed antenna.

Building Permit: Once your plans have been reviewed, you are given the "go-ahead" in the form of a building permit. The permit is usually displayed on the construction site. Inspections can occur at any stage of construction.

Covenants: Private restrictions that were placed on the land records by a previous owner (usually the subdivision developer) that can control everything from how many cars you may park in the driveway to whether or not outdoor antennas are permitted. The covenants are held to be a private matter between the lot owner and the other owners in the neighborhood for whose benefit the restrictions purportedly were adopted. Covenants are also known as "CC&Rs", which stands for covenants, conditions and restrictions. A title search by an attorney **before** purchase of the lot is the best way to avoid these problems.

Exception: *See Special Exception or Special Use Permit.*

Height restrictions: Usually, height restrictions are imposed by a chart of minimum dimensional requirements. Other sections of the regulations may provide for exceptions to the chart. Look for a distinction to be made between primary buildings and accessory structures because permitted heights for accessory structures may be different. Also, the regulations may provide that cupolas, flagpoles, antennas, and similar structures are exempt from the height requirements.

Planning Commission (sometimes a combined Planning and Zoning Commission): A land-use board that is charged with recommending changes in the districting of zones. It may be charged with approving subdivision proposals. These functions may be combined into one board with the Zoning Commission functions. Consult your zoning regulations to determine the exact function of each of the following boards: Planning Commission, Zoning Commission, (a combined Planning and Zoning Commission), and Zoning Board of Appeals (ZBA).

Plot Plan: A drawing showing the property or lot, the structures presently erected on it, and the location of the proposed antenna structure. Dimensions from structures and boundaries are usually required to be indicated. Some regulations require that the drawing be accurate and drawn by a certified surveyor. Before spending money on a surveyor, consult the regulations or building inspector to determine how precise the plot plan has to be.

***PRB-1*:** A declaratory ruling by the Federal Communications Commission that imposes a duty on state and local governments to (1) not prohibit amateur radio communications within their municipalities and (2) be reasonable in their regulations to the extent that the restrictions imposed on amateur radio antennas constitute the minimum practicable regulation necessary to achieve the municipality's legitimate goals of providing for the health, safety and welfare of the community. *Amateur Radio Preemption, 101 FCC2d 952* (1985). Recently *PRB-1* was codified in the Amateur Rules. *See Section 97.15(e).*

Preemption: A legal term that indicates that one law takes priority over another law. By the Supremacy Clause of the U.S. Constitution, Federal law takes priority over state or local government when there is a conflict.

Special Exception, Special Use Permit, or Conditional Use Permit: A permitted use in a zone, but one which is not automatically permitted. In other words, the zoning regulations require that the applicant demonstrate special need or meet other requirements to the satisfaction of the Zoning Commission. However, the land-use board that passes judgment on these may be a board other than the Zoning Commission, e.g., the Planning Commission or the Zoning Board of Appeals. Consult your zoning regulations to find out what the particular scheme is in your town. It is not unusual for zoning regulations to require a special exception, special use permit or conditional use permit for an antenna. Such a requirement is not illegal per se. However, *PRB-1* requires that any restrictions imposed be reasonable.

Structure: The definition of "structure" may exclude such things as cupolas, belfries, antennas or other things that normally extend above the roof line. Look for the height limitations imposed on structures or buildings; then determine whether there are any exceptions to these height limitations. *Also, see "Building" above.*

Variance: A mechanism whereby one may obtain special relief from the zoning regulations. Usually granted by the Zoning Board of Appeals (ZBA), the applicant must show practical difficulties or unnecessary hardship. The difficulty or hardship usually may not be self-imposed, which automatically renders the amateur radio operator ineligible for the variance. (But for the fact that the ham operator wants to construct the antenna, there would be no hardship, or so the reasoning goes.) There are two kinds of variances: Use Variances and Dimensional Variances. The kind sought by amateur radio operators are almost always dimensional, which means that you want a variance from the height or setback requirements imposed by the zoning regulations. Some states distinguish between the two kinds by making it easier to qualify for dimensional variances. Other states make no distinction.

Volunteer Counsel: A list of ham radio operators who are attorneys and who have registered with the ARRL as willing to provide an initial consultation free of charge to hams with antenna problems. *Contact: ARRL Hq., Regulatory Information Department, 225 Main Street, Newington, CT 06111.*

Zone: A district indicated on the zoning map that provides for a uniformity of regulation for that particular area. It is important to determine into which zone your property lies. For example, one type of residential zone may be more lenient by permitting higher structures than another type of residential zone.

Zoning Board of Appeals (ZBA): The land-use board usually charged with hearing applications for variances and appeals from the interpretation of the building inspector or zoning enforcement officer (ZEO). In other words, when a building inspector or ZEO is believed to have incorrectly applied the regulations to a proposed antenna structure, the appeal is made to the ZBA.

Zoning Commission (sometimes a combined Planning and Zoning Commission): The land use board that established the various zoning districts and zoning regulations and hears applications for changes in the toning maps and regulations. It sometimes hears applications for special exceptions, depending on the regulations' particular organization. The Town Council or Board of Selectmen may not have delegated this law making power to the Zoning Commission, in which case the Town Council or Zoning Commission makes the decisions as to what the regulations are or ought to be.

Zoning Enforcement Officer (ZEO): A full-time or part-time employee of the municipality who is responsible for interpreting the zoning regulations and deciding whether the particular structure or building proposed is allowed in the particular zone. Often the duties of the ZEO are rolled into one person, the Building Inspector, who then handles the questions of both the appropriateness for the zone and compliance of the plans to the building code. The decisions regarding zoning are appealable to the ZBA. Decisions regarding the building code, however, are usually appealable to a special board, usually called the Building Board of Appeals.

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Other regulatory concerns

Standards, compliances and regulations for tower construction keep increasing, making it evermore difficult and expensive for amateurs to put up towers. The court and legal battles that you read about in *QST, CQ,* and even your local newspapers are primarily about zoning and related issues such as covenants and other restrictions. Even if your property is zoned to permit tower construction, getting your building permit has become more difficult as more and more cities and counties are adopting more stringent building regulations, including the Uniform Building Code (UBC). You may have to comply with structural building codes related to wind speeds, structural wind loading and, in some cases, soil integrity if your building department invokes the UBC. Unfortunately, *PRB-1* doesn't apply in this process.

The vast majority of tower-building amateurs historically have not bothered to actually obtain building permits. But any project these days is likely to come under the close scrutiny of not only the local building department but also unfriendly, or at least unsympathetic, neighbors. Generally if you put up an unpermitted tower, the only way you could run into a problem is if a neighbor complains to the building department. Even if you are not causing any kind of interference, they could call and file a complaint. The targeted department will generally follow-up with, at the least, a phone call. Or worse.

During one of my many tree-installed yagi projects, my customer got a call from the FAA while I was still up in the tree. A neighbor had spotted the new antenna installation and felt that we had surely broken some law. My customer, an airline pilot, deflected the FAA call by explaining the situation to their satisfaction. Next came a call from the county building department inquiring into whether he had a permit for the installation. To make a long story short, the neighbor (the squeaky wheel) got the county to insist that the ham needed a permit for the tree installation. Even though the building department never cited any building regulation for a tree installation, the squeaky wheel kept complaining and, after a nine-month running battle with the county, the ham finally threw in the towel and bought a building permit. Two months later he got a letter from someone higher up in the building department who determined that he indeed did not need a permit and refunded his money. In order to placate the squeaky wheel neighbor, the building department underlings had "made up" the requirement. This was the second instance of a big brouhaha surrounding a tree mounted yagi in the Seattle area and they both resulted in the building departments backing down after realizing that trees weren't covered by either their building regulations or the UBC. But it just goes to show you that the squeaky wheel gets greased. If you've got antagonistic neighbors, you'll probably have problems relating to your tower installation. Obtaining a building permit for a tower may go a long way toward keeping the neighbors at bay. As far as trees are concerned, for the most part you can probably just go ahead and do what you want.

Legal help

Besides the ARRL Volunteer Counsels previously mentioned, there is an internet reflector called Ham-Law. It's where the legal eagles hang out to discuss tower legal issues. It's open to anyone to join so you can ask a question there and you'll probably get an answer. They do NOT give legal advice but may be helpful nonetheless. You can join by sending an email to listserver@mail.altlaw.com. There aren't any archives – everything happens in real time.

Another resource that is invaluable is the zoning book by Fred Hopengarten, K1VR, called Antenna Zoning for the Radio Amateur. It's published by the ARRL and available at most ham radio stores. He has recently come out with a commercial version, the Antenna Zoning Book - Professional Edition: Cellular, TV, Radio and Wireless Internet.

These books aren't cheap. The rationale is that it's worth about the same as 30 minutes spent with a real attorney but is much more comprehensive and available.

Building departments

Regardless of whether your local building department invokes the UBC or another set of building codes, it really comes down to the engineer or permit specialist that you talk with who makes their interpretation of what is needed to comply with their regulations to issue a permit. It is likely that they probably haven't run into anyone building a tower before and you'll probably have to start out by helping them interpret their regulations vis-a-vis your tower project. And I'll guarantee you that if you talk to three different people in the department, you'll likely get three different interpretations or answers to your questions. Call the office a couple of times until you find someone that seems reasonable that you can work with, then stick with them. Otherwise you'll have to educate someone else and they probably have a different interpretation anyway.

The Uniform Building Code

What about the UBC itself? The UBC is one of many building codes used by building departments nationwide as a way of standardizing building codes and compliances. Your building department may also have additional regulations and compliances above the UBC. The UBC sets the standards for structures, which are primarily buildings. It doesn't specifically take towers into consideration so you might want to try to convince your building department that your tower isn't a habitable structure and isn't governed by the UBC. Since that's not very likely, what you're stuck with is to make your tower comply with the UBC. This means your tower will need to meet a wind pressure and ice loading condition for your county as well as concrete foundation, rebar and grounding codes. A typical specification for western Washington State is a wind pressure equal to a 90 MPH wind with ½-inch of radial ice. One complication that you may run into is that the manufacturer may use the latest *TIA-222* standard for calculating wind pressure while the UBC uses a different calculation method. Since it's not UBC, the building department may not want to accept the manufacturer's calculations. A letter from the manufacturer is one way to get around this problem.

EIA/TIA-222-G

The standard that is used by tower manufacturers and engineers designing towers and tower installations is the *ANSI/EIA/TIA-222-G, Structural Standard Antenna Supporting Structures and Antennas.* This is the official standard from the American National Standards Institute, the Electronic Industries Association and the Telecommunications Industry Association and is the industry bible. The current standard, *Revision G,* contains the TIA Minimum Basic Wind Speeds for each county in the United States as well as many additional tower specifications. The lowest windspeed is 70 MPH (the entire states of Kentucky and Arkansas) and the highest is 140 MPH for Dade County in Florida.

Building permits and drawings

Let's say you don't have any restrictions on tower erection, your tower will meet the UBC wind pressure spec and you want to do the right and legal thing by getting a building permit. In most cases, to obtain a building permit you'll need stamped engineering drawings from a licensed local Professional Engineer (P.E.) for your state. If you buy a crank-up manufactured in California that has their stamped tower drawings from their P.E. in California, those drawings are generally only acceptable in California. The drawings that you might need could include the information from the manufacturer regarding wind speed calculations, anchor/base detailed construction data and a plat layout of the installation. Getting a P.E. to run the calculations on your installation and prepare the necessary paperwork to obtain a permit can run anywhere from a case of beer if your licensed P.E. buddy does them to several thousand dollars if you have it done by an engineering firm. I'd probably budget $250 to $1000 for these stamped drawings. Ask around in your local area to see if there is any P.E. that would be willing to do it for a minimal fee. We have a couple of engineers in my area who charge $60 per hour and who budget four hours for the job; this is a real bargain.

Soil tests

Although not specifically called for by the UBC, many building departments are now requiring soil tests. This is to insure that the soil will support the installation and this requires another engineering stamp, this time by a geotechnical engineer. These are not cheap studies. A geotechnical firm will typically charge several thousand bucks for this study. If the building department requires it, you'll need it anywhere you build in the city or county. Even if you're forty-miles from the nearest town on a mountain-top somewhere, you may be required to submit this in order to get your permit. You can see that although providing this documentation is not difficult, it is measured in hundreds of dollars and is another disincentive for getting a building permit. I work with a local P.E. who also does soil tests. His fee of $1500 for all of the necessary paperwork is a bargain; there aren't too many other similarly talented engineers around. Also, if these are the standards now, you can rest assured that the *TIA-222* and the UBC will both be continually revised upward incorporating ever higher requirements and compliances.

Options?

What are the options? Ignoring the law may work for you, but any complaint might result in your being ordered to take your tower down. If you've documented the base and anchors by taking photographs before the concrete was poured and can provide the necessary engineering data after the fact, you may only be fined for not obtaining a permit and you can retro a permit. You may want to find a more tower-friendly place to live although these are getting more scarce all the time. Or you might want to bite the bullet and get the permit.

Environmental considerations

Here's a wrinkle that's beginning to appear in some places in the U.S. If you are planning on building your tower on a "wetlands" area, you may have to go through a State Environmental Protection Agency (SEPA) review. The agency has to determine whether the environmental impact is "significant" or "nonsignificant." As part of the process, you may have to put an ad in the paper announcing your plans; interested parties then have thirty days to respond. A local contester who was building a new station in western Washington had to write letters to his neighbors informing them of his intention to put up a tower. Just before the deadline expired, he was "invited" to appear before a meeting of all of the concerned neighbors so that they could quiz him about his installation. Fortunately, after telling them about himself, his hobby and the specific installation, their concerns were addressed and they were satisfied that his installation was not going to pose any threat; their concerns had more to do with cellular and microwave perceived problems. Citizen groups everywhere are increasingly fighting cellular and microwave towers on not only aesthetic but also on potential RF radiation grounds. In fact, a couple of companies that manufacture cellular monopoles have introduced monopoles that look just like trees with sides that look like bark and branches up above just like a real tree just to respond to this citizen sensitivity.

So what should you do if you're contemplating putting up a tower? Even if the project is just a gleam in your eye, I'd call the local building department for specific permit requirements. Then, I'd get the permit. A building permit is usually good for a year or more and may be renewed, so you might be 'grandfathered' in should codes and requirements change in the future. Since permits will probably only be harder to obtain in the future, this may be a good insurance policy for you. If nothing else, just be aware that the cost of putting up a tower from now on won't just be the cost of the steel and concrete.

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NEIGHBORS

Your dream antenna system may just be your neighbor's nightmare. To the average suburbanite, the sudden appearance of a 100-foot radio tower above the neighborhood skyline will probably raise all kinds of fears and concerns. Do we have a spy living on the block? Will there be interference to my stereo, TV or telephone? What will happen to my property values? What if it falls down? What if my kids climb up there and get electrocuted? What about cancer-causing radio emissions? We've all heard about, known personally or read about someone who put up a tower (or tried to) and wound up in court with their neighbors. We even had a local ham castigated on TV as the "Neighbor From Hell." In the absence of a regulation requiring you to notify your neighbors, you have two choices.

The public relations approach

Your first option is to be "Mister Nice Guy." I've heard about amateurs who managed to get their neighbors involved early on by telling them what they were planning to do. These must have been reasonable people who had their fears and concerns addressed and resolved by the tower owner. You can help them by explaining that you want to talk to people around the world; bring them into your shack and show them some of your QSL cards or awards. You could tell them about the public service aspect and their possible need for reliable communications in times of emergency. Telling them about the phone patches that you handled during Desert Storm would be impressive.

The PR approach is a combination of tact, common sense and patience. Concurrently you could put up a small antenna and put up a bigger one in a few months. Or add another tower section a couple of times a year. I've been told that all tower work in the Faroe Islands was done during stormy weather so the neighbors never actually saw anyone putting up towers or antennas.

No more Mister Nice Guy

The second path is to proceed with your project with no involvement of your neighbors. If you've done everything by the book, especially obtaining a building permit, there really isn't much that the neighbors can say about the installation. The problems arise when you've skipped the legal and permit process, then a neighbor complains to the local building department or other authority. At that point you are busted and don't really have any legal grounds on which to stand.

I personally have found the "Mister Nice Guy" approach to be of little help. When my neighbors didn't like where my tower was going to go on my property, I relocated it and I've regretted it ever since. Now I'm more inclined to refer them to the building department or FCC if they have a complaint. You decide which way you want to go.

Spouses

Spousal approval can sometimes be more difficult to obtain than neighbors' or building department's. Perhaps you could convince her or him that this is a dream you've had since you were a kid (it's probably true anyway.) It is almost certainly far cheaper than that boat you've been looking at; besides, now you won't have to spend all that time hunting, fishing, golfing, etc. Or maybe this new tower is a good place to put that new yard light, TV antenna, birdhouse, whatever. (Holding my breath until I turn blue usually works for me!)

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HIRE SOMEONE OR DO IT YOURSELF?

The first option is to do it yourself. If you observe **all** of the safety practices and equipment in this book, use common sense in all instances, and back away from anything with which you don't feel completely comfortable, you will likely keep yourself out of trouble. In spite of minimal and sometimes inadequate equipment, poor technique and poor planning, amateur related tower accidents are amazingly infrequent, with accidental deaths quite rare. Most of these accidents and deaths could have been prevented by using the proper equipment and techniques. Building your own station can be as rewarding as using it. If you're like me, building a reliable tower and antenna system is fun as well as challenging.

Tower service contractor

Your second option is to hire a licensed tower rigging company, and utilize their experience and equipment. They're insured, and they have almost certainly done numerous far larger and more complicated projects than a typical amateur installation. They will get it done much more quickly and safely than you will, and it may well be a most worthwhile investment for you.

Although hiring professionals may run several hundred to several thousand dollars, your installation will be done correctly the first time, as well as more quickly than you can do it. A local ham had a weekend place where he wanted to build a nice station. As he had never done anything like this before, not only did he have a learning curve to go through but also he never did figure out some of the hardware. He also wasted time doing some things twice. He spent six straight weekends, travelling two-hundred miles each way to the site, and getting people to help him before he more or less finished the project. His wife was ready to leave him. A professional rigging crew could have accomplished the same project in approximately four days at a cost of around $2500. Only you can decide if it's worth it or not. Don't forget, when you pay someone to do tower or antenna work, they immediately fall under OSHA regulations.

If you hire someone, make sure that their safety equipment is okay before you let them near your tower. States now require that workers have a fall arrest system when climbing towers. This includes an OSHA approved Class II full body harness and fall arrest lanyard. In addition, anyone you hire must have liability insurance. In many states, they must also be a licensed contractor. If they're not licensed, you assume all the risk if anything should happen. In fact, if someone you've hired has an accident or causes an accident, you could be held financially responsible for any damages and the person you hired could sue you for any number of things, including not providing a safe workplace. Don't take the chance, if they don't have the license(s) and insurance, don't hire them.

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Documentation

As soon as you start planning any type of outdoor antenna and tower project, get yourself a file folder, a three-ring binder or something else in which to keep everything. You'll have to refer back to your notes and calculations as you go along, so it's easier to have everything in one place. Sketches, notes and manufacturer's specifications are invaluable additions to your file. Also, keep notes from all telephone conversations, including date and subjects covered, especially those with building department personnel and others who may be able to influence your installation. A hardware listing of guy wire sizes and type, lengths, mast ID and OD, etc. is also worthwhile.

A picture may be worth a thousand words

Once you get outside and start construction, take pictures of everything, particularly the civil work. If there is ever any question regarding hole size or materials, photographs can become extremely valuable. If a building inspector ever wants additional information about any aspect of your installation, good pictures can likely provide it.

A few dollars invested now can save hundreds or even thousands if questions about your installation ever arise. And don't just throw those finished prints in a drawer with your other snapshots; file them in the same folder or binder with all your other installation documents.

Good documentation can help you solve station problems. During a CQWW SSB contest some years ago, pioneering multi-operator station N2AA developed a serious problem with one of their antennas. Since it was the end of October in New York and it was dark, effecting a quick repair was going to be challenging. Fortunately they had kept excellent records and in fact found the potential source before they even went outside. Their analysis was correct and it only took a couple of minutes to fix the problem and they were back on the air. Granted a large multi-tower station is pretty complex but keeping good records can help any station.

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Collecting the hardware

Once you've decided what kind of tower you're going to put up, and where you're going to put it, you'll need to start collecting the hardware. By the time you track down all the materials and get them delivered to the site, you could (and probably will) spend a couple of months in this phase.

The tower

This part is easy. Once you've decide what you want to put up, all you have to do is call up the retailer or manufacturer and order it. ROHN puts out packages of *25G* and *45G* that include additional hardware such as guy wires and torque arms that will save you some work.

More hardware

If you're going to track down everything yourself, plan on spending lots of time on the phone or on the internet. One place that can prove to be invaluable is a local source of scrap metal. There are likely one or more good salvage yards in your area; a few phone calls and visits can give you an idea of what they can provide. Many times they'll have galvanized angle iron, tubing and pipe as well as stainless steel and aluminum. It doesn't hurt to stockpile some of this stuff because it'll be real handy at some point in the future, and chances are pretty good that if you go back to get some, it'll be gone. Another tremendous help is a good fastener or nut-and-bolt store. Their main market is industrial companies, so they'll likely be in the industrial part of town. Again, the *Yellow Pages* with a few phone calls and visits will give you an idea of what's available.

Two excellent online resources are Grainger Industrial Supply (www.grainger.com) who seems to have just about everything, and McMaster-Carr (www.mcmaster.com) who also has an extensive line of products.

The hardware maxim

Not only must you use the correct hardware for the application, but also it must be made from the correct material. The **only** acceptable materials for tower constructions are:

Galvanized: Steel parts are hot-dipped when galvanized and can be recognized by their dull, rough grey finish. A stock of galvanized nuts, bolts and U-bolts is very desirable. Galvanized and non-galvanized nuts and bolts are **not** compatible. The galvanizing process leaves a thin coating of zinc on the threads that will not take a normal or stainless steel part. You must use galvanized nuts with galvanized bolts. There is also galvanized hardware available that has been plated rather than hot-dipped. The finish is shinier and not as thick as the galvanized one. Antenna hardware U-bolts are commonly this variety. They're not as long lasting as the hot-dipped ones but are acceptable in most cases.

Stainless steel: Stainless steel (SS) nuts and bolts are more common than the galvanized variety but are generally more expensive. You can also sometimes find SS tubing, angle and plate at your local salvage yard. It is a relatively hard material, making it difficult to cut or drill but it can be real handy in many instances. Again, a stash of various SS materials can come in handy. SS nuts and bolts can gall easily, which results from one metal losing metal to another because of heat or molecular attraction resulting from friction. The nut and the bolt fuse together and they're impossible to remove. You either have to grind them apart or break them off to separate them. If you use a little bit of grease or lubricant on the threads, you'll minimize this problem.

Aluminum: Aluminum angle, plate, tubing and pipe can be handy as well for creating mounts and other appurtenances. It is easy to fabricate and can be used for lots of mounting and installation solutions. The biggest problem in my opinion is that aluminum is soft and can be damaged by rubbing against a harder material, such as steel. This is what can happen to an aluminum mast that is drilled and pinned with a SS bolt to lock it to the rotator. The constant wind pressure can cause the hole to gall, or enlarge, and fail over time.

In general, be wary of any unidentified material, particularly if it's going to be used in a critical application. If in doubt, don't use it. Also, if you're not sure about the suitability of any hardware, leave it outside for a few weeks and see what happens. If it starts to rust, recycle it over the back fence or take it to the dump; just don't use it.

Additional hardware

Here is some additional hardware that you'll probably need (when I need to buy something, I always try to buy at least a few extras to add to my spare hardware collection; I encourage you to do the same):

Clevises: A clevis is a device used to couple things together. It is generally U-shaped and has a pin to connect the holes at the two ends of the U. It functions just like a carabiner but has a removable pin that screws into the clevis body. Clevises are sometimes also referred to as shackles. While you can get clevises in many different sizes and capacities, their main drawback compared to a carabiner is that it consists of two pieces and one of the pieces can be accidentally dropped. They should be used in places where you need a permanent coupling, such as between the turnbuckle and guy anchor or between the tower guy attachment and the guy wire thimble.

Clamps: Cable clamps are used to clamp two pieces of wire together. Their most common use is to secure a guy wire tieback. This is where the guy wire is bent 180° and clamped to itself, producing a loop for attachment to another part of the guy wire system. You should always use a minimum of three clamps on any guy wire tieback.

Thimble: A thimble is the device that goes into the loop of the guy wire tieback. Its purpose is to evenly distribute the strain on the guy wire loop.

All-thread: All-thread is threaded rod stock. It is available in stainless steel, galvanized and plated finishes. Most hardware stores carry it in four or five-foot lengths. It can be very handy for tower anchor bolts or other applications.

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Corrosion

Corrosion is one of the biggest problems in tower and antenna installations. Knowing more about it will help you to use appropriate materials and stay away from problematic ones.

In its raw form, metal is usually found in ore. Energy is added to the metal in the extraction process. In the long term, metal returns to its natural, corroded state when it gives off the added energy.

Any metal by itself will eventually oxidize due to exposure to the oxygen in the atmosphere. The aluminum in our antennas creates the powdery aluminum oxide you find when you take an antenna apart, while steel oxidation produces the rust that you want to avoid.

Bi-metallic corrosion

When two metals with the right properties are in contact in the presence of an electrolyte, bimetallic corrosion takes place. It's the same chemical process that takes place in batteries. Specifically, electrons from one metal (called the anodic metal) flow across the joint or junction to the other metal (called the cathodic metal). In bimetallic joints, the more anodic metal is always the one that corrodes.

The electrolyte is typically some kind of salt or other compound (such as zinc) dissolved in water making the solution conductive. Rain (particularly acid rain), mist or condensation are sufficient for bimetallic corrosion to begin.

Galvanic incompatibility

Galvanically incompatible metals are ones that readily corrode when in contact with other metals because of their ranking on the galvanic chart. When you must use different materials, it is best to use metals that are close together on the chart. You can see that on a zinc galvanized tower, aluminum and mild steel are the most compatible.

If you use materials such as copper and brass when installing your tower ground system, you can see that you will have problems with corrosion almost immediately.

Antioxidants

Various compounds are available for combating corrosion. These are antioxidants and most commonly used metals have several products designed specifically for each of them.

For aluminum antennas, most manufacturers provide a packet of antioxidant with their products. Retarding oxidation is not only a good electrical idea but also it functions as an anti-seize when you go to take the antenna apart in the future.

These antioxidants are sometimes incorrectly called "conductive pastes or greases." In general, these antioxidant compounds are comprised of a vehicle material with metallic chips in suspension. It is these conductive chips, not the vehicle material, that give it its conductive properties. What happens is that the particles will pierce the layer of oxidation while preventing corrosion by isolating the joint from the air. BUTTERNUT's "*BUTTER-IT'S-NOT*" uses copper dust in a molybdenum suspension while M^2 paste uses copper and graphite flakes in a petroleum base.

There are other commercial products available for copper joints which should be used on ground systems. Just be certain to use the right one for the job.

While you can see the obvious positive effects of these compounds on antennas and ground systems, you should also use some type of grease or antioxidant inside the legs of your tower sections. Not only will it make assembling the sections easier as the legs slide together, when you take it down, the antioxidants will have made your job easier since the legs won't be seized up due to oxidation.

Relative Galvanic Series In Sea Water
ANODIC END
Magnesium
Zinc
Galvanized steel
Aluminum
Mild Steel
Iron
50-50 lead/tin solder
Stainless Steel
Tin
Nickel (active)
Brass
Aluminum-bronze
Copper
Nickel (passive)
Silver
Gold
CATHODIC END

Rust

Steel towers and hardware will rust unless steps are taken to prevent it. In the case of towers, they should be galvanized steel or aluminum. Hardware, including U-bolts, nuts, bolts and other fasteners should either be made out of stainless steel (SS) or be galvanized. Because the galvanizing process deposits a thin coating of zinc on the hardware, you can't interchange SS and galvanized nuts and bolts.

Surface rust is rust that is either deposited when you have water from a rusted piece of hardware run down a surface such as a tower leg or active rust that hasn't yet penetrated the layer of galvanizing. Neither condition is serious but you should repair those spots during your annual inspection. Just take your wire brush to scrub off the rust and then spray the spot with a cold-galvanizing paint. Cold-galv, as it is called, is available at almost any spray paint rack. Look at the contents to make sure that it's got zinc in it. The LPS COMPANY makes a very good cold-galv spray that is relatively expensive (another case of getting what you pay for) but adheres very well. Besides using antioxidants on towers and antennas, they should be used in ground system joints as well as in marine environments.

Connectors

Since just about every coax joint you use will be a *PL-259*, *N*-connector or *F* fitting, my recommendation for outdoor use is to use the silver connectors instead of the nickel plated variety. When nickel oxidizes it produces nickel oxide, which is a nonconductor: whereas silver oxide is a conductor.

Antioxidant products

Because most antioxidant products are usually available only from various specialized distributors and suppliers, it is not possible to walk into your local hardware store and expect to see much of a selection. The following list of manufacturers and suppliers should be of some help:

Manufacturer: BENCHER, INC.
241 Depot St
Antioch, IL 60002
Ph: 847-838-3195
Fax: 847-838-3479
www.bencher.com
Product: *Butter-It's-Not*
Source: Direct, if not stocked by local authorized dealer
Note: Contains copper dust in a molybdenum suspension

Manufacturer: GB ELECTRICAL
Gardner Bender
PO Box 3241
Milwaukee, WI 53201-3241

800-624-4320, press 1
www.gardnerbender.com/
Product: *OX-GARD*
Source: Available from many electrical supply houses and retail outlets such as Home Depot and other hardware stores

Manufacturer: IDEAL INDUSTRIES, INC.
Becker Place
Sycamore, IL 60178 USA
800-435-0705
www.idealindustries.com
Product: *NOALOX*
Source: Available from some hardware stores and supply houses
Note: Contains zinc particles suspended in a carrier

Manufacturer: SANCHEM, INC.
1600 S. Canal Street
Chicago, IL 60616
312-733-6111
www.sanchem.com
Product: *NO-OX-ID "A-SPECIAL"*
Source: Direct from manufacturer

Manufacturer: THOMAS & BETTS CORPORATION
8155 T&B Boulevard
Memphis, TN 38125
Phone: 901-252-8000
www.thomasandbetts.com
Product: *Aluma-Shield*
Source: Available from many electrical supply houses
Note: Contains zinc particles suspended in a petroleum base

Manufacturer: FCI
Versailles, France
http://portal.fciconnect.com/
Product: *Burndy Penetrox*
Source: Available from many supply houses and some retailers
Note: Zinc particles suspended in a natural based compound

Manufacturer: ILSCO CORPORATION
4730 Madison Road
Cincinnati, Ohio 45227
513-533-6200
Product: *DE-OX*
Source: Available from electrical supply houses
Note: Green colored grease with no noticeable particles in suspension

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Foundations and guy anchors

Foundations and anchors that are installed in the earth provide the most basic and important structural parts of the tower so having the correct foundation and anchors is vitally important. The purpose of the base in a self-supporting tower is to move the center of gravity of the tower below the ground and be big enough to exceed the overturning moment of the wind pressure against the tower. The purpose of the base in a guyed tower is to basically keep the base from sinking in the ground. There's virtually no overturning moment with a guyed tower since the guys take the horizontal wind forces.

According to their "Encyclopedia of Anchors" (available free from the A.B. Chance Co. - 573-682-8414), there are nine soil classifications of soil makeup and structural capacity. While a discussion of the exact values and measuring techniques are out of the scope of this book, the soil classification data gives you some idea of the problems that can be encountered when designing appropriate earth anchors. The only way you can get an accurate profile of your soil is to pay for a geotechnical survey. It's relatively expensive and involves digging several holes with a backhoe to expose the earth.

For very basic purposes of this book, soil and its loadbearing capacity is divided into three main categories: normal, rock and sand.

Normal soil — Normal soil can be made up of loam, clay or just about anything that isn't rock or sand.

Rock — Special design considerations need to be taken into account when dealing with either rock or sand. Rocky ground is usually either solid rock, like granite, or shattered, where you have soil around the rock but not enough to be able to excavate easily. Either way the rock itself can provide a very secure anchor.

Rock can be drilled, which gives you two options for your anchor. The first is to use rock expansion bolts. These use mechanical pressure to hold them in place. They are very strong and will provide a bombproof rock anchor. The other option is to use suitable sized all-thread or suitable anchor bolt (available at any hardware store), then epoxy it into the hole. There are special industrial epoxies that you should use. Contact a local rock anchor supplier for more information on these two methods. (These techniques work very well for concrete as well.)

You could use the rock itself for the tower base and anchors as well. Why would you jackhammer away a bunch of rock for the base and then pour concrete back in the hole when you've already got some nifty rock just sitting there ready to use?

After ensuring that the rock is indeed big enough and intact enough to be useful, you can either drill right into the rock for base anchor rods or pour concrete over the rock to make a nice square form. The concrete and the rock need to be joined so you'd need to drill a sufficient number of holes for an adequate number of pieces of rebar to bond the rock and concrete together. An engineer should calculate hole and rod sizes and design.

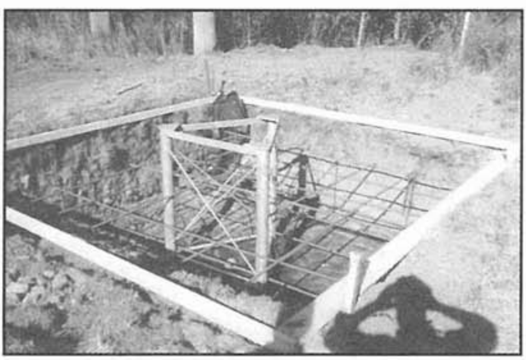

Photo 1: Typical self-supporting base with rebar, base section and ground level form.

There are a

number of tools available for drilling in rock including a jackhammer, an impact hammer with a coring bit or hand-held rock drill. Check with your local rental store and see what they recommend.

Sand

Sand presents another problem because it has very little holding power. Larger than normal concrete anchors cast with the concrete block sitting partially out of the ground is one option. This type is usually poured into a form and then backfilled around it. If you use a large enough block of concrete, it won't go anywhere. A big deadman can also be installed. This is a buried anchor with a big plate or dish buried at the ground end. Again, consult with an engineer to insure the holding power of these anchors.

Forms

The only concrete form you really need is for the part that is above ground level. You can just use some 2x4's to make a nice rectangular form that is slightly tilted to allow water to run off. The point is that if you make the form perfectly level, the water will pool instead of running off. For larger bases, the concrete may sag in the middle of the base so take extra care to provide a water pathway off the top of the base. Do not use a form in the hole unless there is a structural problem with the soil; e.g. river bottom rip rap that is prone to sloughing. The tower specs call for the concrete to placed against undisturbed soil so no form is needed in the hole.

Siting the tower and guy anchors

If you're going to put up a self-supporting tower, all you have to worry about is the best spot to locate the base. Practical siting considerations include excavator and concrete truck accessibility and proximity to overhead power lines. You'll also want to avoid buried power, telephone, gas, water and sewer lines along with septic tanks and drainage fields. If you don't know the location of any of these, its a always a good idea to phone your local utility companies, or better yet, *"Call before you dig"* or *"Underground utilities"* services as listed in your local phone directory. These services, using an 800 number, cover most areas of the U.S., and provide centralized databases for all utilities in their region. You give them the exact physical address of the location where you plan to dig; if it is in their database they will send computerized notices to every utility which could possibly be affected. This can range from two or three in a rural area to as many as fifteen in a dense urban neighborhood. The utilities then have 48 hours (this may vary in different regions) to send out their locating crews to identify any buried lines. There is normally no charge for this service, unless you call to tell them you plan to dig the next day, in which case there you could be charged for "emergency service."

To test this service, I phoned in an address in the small town in which I live. Their computer came up with eight utilities that needed notification: the city, the water district, three telephone companies, the power company, the gas company and the state department of transportation. (It would never have occurred to me that so many folks could be interested!) If you have trouble finding a 1-800 number, phone any local utility; they'll be able to give you the number for your area.

For a guyed tower, you must make the same evaluation for the base and then determine where your guy wire anchors should go. The easiest way to select the optimum site it is to take one of the tower sections and stand it up in one of your chosen spots. Then look through the tower face to the opposite leg and you can see the plane of the guy wires. By looking at all three legs, you can see if your anchors are going to be in the clear. If they're not, simply lift up your tower section and rotate it until you've got the guy anchors located where you want them. Be sure to check for any trees in the guy wire lanes. Next, take your tape measure and go out the desired distance (80% of the height of the tower is a minimum) and mark the spot. Do that for each guy anchor and you're all set.

Excavation

Now you've got some soil to move. You could do it the old fashioned way with a shovel and wheelbarrow if the hole(s) aren't too big but it's much easier to make a phone call and either hire a contractor or have an excavator delivered by your local rental yard. Doing it yourself is fun and easy. You need an excavator with enough reach to dig down far enough. There are plenty of Kubotas, Bobcats, etc. available and within 10 minutes you'll be doing a decent job.

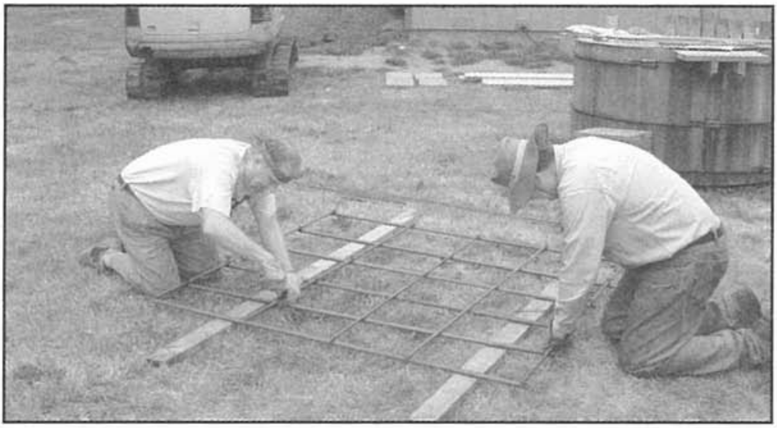

Photo 2: Building a rebar cage.

You need to decide what to do with the excavated soil. It fluffs up when it's dug up; a 5-cubic yard hole is going to produce about 10-cubic yards of soil.

I always have the excavator do several more jobs besides digging the hole(s). You'll need it to move the heavy rebar cage (50-200 pounds in some cases) to the hole and lower it in. You may need it to hold the bottom tower section or base fixture in the hole so you can attach it to the rebar cage and level it. You might need the excavator to unload the tower and/or move it to the hole. I always prefer to use a piece of equipment rather than manhandling something heavy and awkward and I recommend you do the same.

Photo 3: The finished cage after a couple of hours. Note the X bracing on each face. The extra lengths will be cut off with a hand grinder.

Reinforcing bar

After you've got everything sited, dig the holes specified by the manufacturer and install the required reinforcing bar, or rebar. Rebar is specified by a size; #2, #4, etc. The sizes refer to eighths of an inch. For instance, #4 rebar is $^4/_8$" or $\frac{1}{2}$", #6 rebar is $^6/_8$" or $\frac{3}{4}$", etc. The most common is

#4 (½"). Get the size the manufacturer calls for and install your rebar in the hole in the prescribed manner.

For rebar cages, you'll probably need to do a little bit of bending and cutting but it's pretty straightforward. You'll need to wire the rebar together and you can get rolls of tie wire or baling wire for that at any hardware store. If you're going to have your base and anchors inspected before the concrete is poured, the inspector will want to ensure that the rebar does not touch the soil on the bottom or sides. Otherwise the rebar will rust away and degrade the integrity of the anchor. If this is a large hole for a good sized self-supporter or crank-up, you may want to have your rebar cage fabricated and installed by professionals. Rebar is fairly hard and can be difficult to cut. Use your circular saw and aggregate cutting blade or hand grinder (don't forget your safety glasses) to cut it efficiently.

Photo 4: Lowering the rebar cage with a backhoe. Note nylon sling use.

A rebar cage made up of horizontal and vertical pieces has little to no stability so you'll need to add additional pieces of rebar on each face in an X configuration. This will stiffen the rebar cage up significantly.

Guy anchors

The ROHN specifications for anchors calls for only ½ yard of concrete with the hole refilled with dirt, or backfilled. Dirt, or normal soil, offers almost as much integrity or strength as the concrete does so backfilling minimizes your concrete requirement. Some people dig the prescribed hole and then go ahead and fill it with concrete. This is okay too, just a little more expensive. The total concrete called for by ROHN for a base and three anchors for a 25G tower is only 2.5 cubic yards. As many concrete companies have three or four yard minimums, you may want to have a use for the excess or mix it yourself, which is a lot of work!

Tower base

If you're installing a round-legged tower, such as ROHN *25G* or *45G,* put at least four inches of sand in the bottom of the hole for water drainage. Rain water and condensation will run down the inside of the legs and it needs some place to drain. If it can't drain out, the water will start to corrode the inside of the legs and can eventually eat through the metal and you'll never see it because it's on the inside. Also, if you have standing water in the legs, a good winter storm can freeze the trapped water and the ice can split the legs.

Some tower manufacturers offer a cement base section or base bolts that are designed specifically to be installed in the concrete base. For crank-up towers, be sure to use the manufacturer's specs or manufactured base section. If you are putting up a used tower, such as *BX, 25G* or *45G*, and don't have a genuine base section, simply bury a section of the tower itself in the concrete. When you move, just hacksaw it off at the top of the base and use it for the next base section. Although your tower will shrink a few feet each time you reinstall the tower, this is still a practical thing to do. If you are putting up a used crank-up and don't have a factory concrete base fixture to install, you must use exactly the same size and grade of hardware that they specify. Again, do what the manufacturer says. Call them for more information. If you have any questions about your installation, get a licensed Professional Engineer involved.

Concrete considerations

Now that you've got the hole dug and the rebar cage installed, it's time to call the building inspector. If an inspection isn't required, then you're ready to order the concrete.

A typical tower concrete spec calls for 2500-3000 psi strength. You just call your local concrete supplier and order it. You won't need any accelerants or exotic mixes, the standard mix is fine. Engineering specs call for 28 days for a full cure. Keep the concrete damp for maximum strength.

Here's an easy way to get your tower installed faster by decreasing the cure time. Instead of the typical 2500 psi concrete, order

5000 psi. It's only slightly more expensive and it'll cure to 50% of its specified strength (2500 psi) in 4 days at 70 degrees F, thus saving yourself weeks of cure time.

The easiest scenario is if the concrete truck can back right up to the hole and chute it in. In 15 minutes it'll be poured and all you have to do is finish the top of it. If the truck can't back up to the hole, you can either get your buddies over to hump it with some wheelbarrows or you can call a concrete pumping company.

The most economical concrete pumper is a trailer or truck-mounted line pump. It can pump up to 400 feet and can be used in most situations. A snorkel pumper is useful if you have to go over something but is generally more expensive. It takes a smaller gravel size in order to be pumped thru the hose so be sure to let your concrete supplier know if it's being pumped. The pumping company works with the concrete batching plant all the time so they might be able to coordinate it for you.

Leveling the base section using base bolts

Leveling the tower is a very important initial step. There are two types of base attachments methods: 1) a base using threaded anchor bolts or 2) a base using another method: e.g. with hollow round or angle legs.

Anchor bolts have the advantage of being able to adjust the tower plumb using the leveling nuts on the anchor bolts. This way the anchor bolts don't have to be perfectly plumb – you have a good amount of adjustment even after the concrete has hardened.

Many times an anchor bolt template can be made insuring proper fit when you install the tower. A plywood wooden template or a welded anchor bolt fixture can be buried in the concrete as it's a one-time use device. One way to make an anchor bolt fixture is to attach and tighten the anchor bolts to the bottom section or base fixture (as in the case of a crank-up) and then with the anchor bolts sticking out horizontally, they can now be welded together. Rebar or any scrap metal lying around will suffice for the anchor rod braces. Weld the metal brace pieces between each leg in two rows. Weld one row near the bottom of the bolts and the other row near the top, but not so far up that they'll stick out of the concrete. Once they're welded, the anchor bolt fixture can be removed and secured into the hole in preparation for the concrete pour. Dealing with this anchor bolt fixture is much easier than wrestling around the anchor bolts attached to the base fixture.

Next, secure the anchor bolt fixture to the rebar cage with tie wire. Lie on the ground and look across the top of the wooden horizontal forms to insure the anchor bolts will stick out of the finished concrete adequately. You can lay a 2x4 across the top of the bolts and put your bubble level on it to check for level. Leave six to eight inches of bolt sticking out, or more if you need it for the base and leveling nuts. Take the nuts off of the anchor bolts and tape the threads with electrical tape. That way, you won't get concrete in the threads during the pour.

When you're ready to install the bottom section, put a leveling nut on first followed by a large washer, if necessary, and run it down the thread until it is an inch or so above the top of the concrete foundation. Now lower the section or base into place and put on the top washer and nut. By tightening or loosening the bottom leveling nuts, you can plumb the tower at anytime. You can do the first section right away and then make any adjustments to plumb as you finish the installation. For large self-supporting towers, a transit sighted on two legs will give you an accurate result. Tighten up the top nuts and you're all done.

Leveling the base section of other towers

There are two ways to level the bottom section of a tower that doesn't have base bolts. Any tower base requires some sort of rebar cage. You can tie the tower section that is going to be encased in the concrete to the rebar cage to stabilize it and the rebar. Next, run a temporary piece of rope from each leg to a stake 6-8 feet away from the leg. You can adjust the temporary lines with a comealong to hold the section plumb while the concrete is being poured and until the concrete sets.

You can use either a bubble level on each leg in the case of a guyed tower or suspend a plumb line from the middle of the tower for a tapered self-supporting tower. I just use a piece of string with a big nut on the end of it for my plumb line. Since all it is is a vertical reference point, it doesn't make any difference where it is installed in the tower. Once the plumb line is still and not moving, simply sight through the opposite face along a leg edge and adjust your temporary ropes until all of the legs are in-line with the plumb line. If the wind is blowing your plumb line around, put the bottom of it in a bucket of water and it'll stay put. While a bubble, or spirit, level can be fairly accurate, an electronic level will give you plumb within $^{1}/_{10}$ of a degree for really accurate results. The only thing that's plumb on a tapered tower is the right and left edge of the leg as you're facing the leg so that's where you put your level. Another method is to shoot it with a transit. In any case industry standards let you be out of plumb 3 inches per 100 feet for a guyed tower so you can be off slightly without causing a fatal problem.

Guy anchor options

You may want to put in an elevated guy anchor. This is useful if you don't have enough distance to your guy anchors (this basically reduces the length a foot for every foot of vertical of your elevated anchor) or if you want to have your guy wires up out of the way so that you can walk under or mow around them. A big (six-inch or more) steel I-beam is one way to go. I've seen railroad ties used as elevated ground anchors and these are definitely industrial strength. A good rule-of-thumb is to have 60% of the anchor above ground and 40% below.

Photo 5: The business end of an elevated guy anchor made from a husky I-beam. Note the back guy on the right for added strength.

Don't forget that with a six foot elevated anchor you've got a six foot moment arm also. The bending moment force is a result of force times length, so the force can quickly become very large. If you are contemplating doing this, have an engineer take a look at it or have them design it. That should keep you out of trouble.

I've seen big pipes used as elevated guy anchors but they are much weaker than I-beam types – they just don't have the rigidity in the planes necessary for maximum strength. If you're going to use a pipe, or tall I-beam, you may want to back-guy it.

Filling a pipe guy anchor with concrete increases the strength of the pipe only slightly. If you feel better by filling the pipe with concrete, go ahead but remember that in this case the added strength is primarily psychological. The best material for an elevated guy anchor is an I-beam because it provides stiffness in a couple of planes where a round pipe does not.

An anchoring technique commonly used by utility companies is the screw earth anchor. ROHN offers a 5/8" x 4' screw anchor but it is only intended for temporary installations as it has only 2500 pounds of holding power. Larger ones are available but you have to be able to auger them into the ground. Again, do what the manufacturer says and put in the specified anchors.

Torque arms

Attaching the guy wires to the tower can be done in several ways. The simplest, but not recommended, is to simply put the Preformed grip around the leg. A better method, but still not recommended, is to use a big shackle with the Preformed grip and thimble hooked shackled around the leg. The best parts to use are what the manufacturer provides. ROHN, for instance, has a guy bracket assembly that uses medium sized oval rings between the bracket and the end of the guy wire. These brackets also add torsional rigidity to the tower structure.

The ROHN guy bracket historically had steel bars approximately twelve-inches long; these were referred to as "torque arms" because they supposedly provided additional torsional rigidity to the tower. When ROHN incorporated a later EIA/TIA-222 revision into their tower designs, they redesigned the guy brackets to what is available now and phased out the old torque arms. Hams had been using these torque arms for years and couldn't believe that ROHN was no longer going to sell them. It seems that the old torque arms didn't meet the new *EIA/TIA-222* spec and in fact didn't really provide much in the way of additional torsion resistance. What they did do was to decrease the twisting of the tower while it was being climbed. After much protesting from the field, ROHN started offering them again. If you've got some of the old torque arms, go ahead and use them; the new ones are just an improved design.

Star brackets

For really big antenna arrays that generate large amounts of torque to a tower when the wind is blowing, you may want to use a guy fixture called a star bracket or torque arm stabilizer. These devices are somewhat larger than the torque arms mentioned previously but they also have two guy wires attached to each point instead of one. Each of the two guy wires goes to a different guy anchor and this arrangement practically eliminates any applied torque to the tower. This approach is commonly used on guyed towers that have microwave dishes on them that can't move in the wind. Your 75-meter beam tower should have these as well.

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Safety and safety equipment

Climbing and working on towers is potentially dangerous. Safety and safety equipment are the keys to the safe and reliable installation, maintenance and enjoyment of your tower and antenna system.

OSHA

OSHA is the Occupation Safety and Health Agency of the Federal Government that sets minimum safety standards for workers. Each state has an agency that is responsible for enforcing the OSHA regulations in that state. In addition, your state agency may have stricter regulations than OSHA; OSHA regulations are just the minimum requirements. Washington State laws exceed OSHA regulations in many cases; as a result they have an excellent safety record.

The key word here is **occupation**. If you are getting paid or paying someone to do tower work, you or they must comply with the federal and state regulations. If you are simply working on your own system, or someone else's without pay, then you don't fall under the OSHA/state laws. But you should still observe them! You should use only OSHA/state approved safety equipment and follow the regulations applicable to your activity. By doing this, you'll be giving yourself a large and acceptable safety margin while working.

Safety belts and fall arrest equipment

The most important pieces of safety equipment are the Fall Arrest Harness (FAH) and the accompanying lanyards. The FAH is the part that you wear and that the lanyards attach to. The FAH has leg loops and suspenders to help spread the fall forces over more of your body and has the ability to catch you in a natural position with your arms and legs hanging below you where you're able to breath normally.

Photo 1: The well-dressed climber. Note the positioning lanyard on the left waist D-ring and the end of the fall arrest lanyard on the right D-ring.

There are 2 or more lanyards. One is the positioning lanyard. That is, it holds you in working position and attaches to the D-rings at your waist. They can be adjustable or fixed and are made from different materials such as nylon rope, steel chain or special synthetic materials. An adjustable positioning lanyard will adjust to almost any situation whereas a fixed-length one is typically either too long or too short. The rope type is the least expensive version.

Photo 2: Rear view of climber. The fall arrest lanyard is connected to the D-ring between the shoulder blades.

By the way leather safety equipment was outlawed some years ago by OSHA so please don't use any of it. This includes the old fashioned safety belt that was used for years but offers no fall arrest capability. If you drop down off while wearing a safety belt, your body weight can cause it to rise up your waist to your ribcage where it will immobilize your diaphragm and you'll suffocate. On the other hand you can use your safety belt for positioning when it's used over and in conjunction with your FAH. Just don't depend on it to catch you in case of a fall.

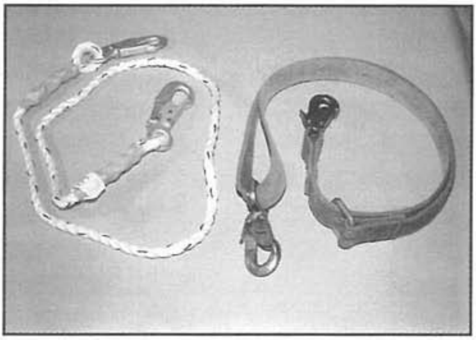


Photo 3: A rope positioning lanyard on the left and an adjustable version on the right. They both use double locking snap-hooks on the ends.

The other lanyard is the fall arrest lanyard and attaches to a D-ring between your shoulder blades. The other end attaches to the tower above your work position and catches you in case of a fall. The simplest is a 6' rope lanyard which is inexpensive but doesn't offer any shock absorption. There are also shock absorbing varieties which typically have bar-tacked stitches that pull apart under force and decelerate you.

Don't cut corners on buying or using safety equipment; you bet your life on it every time you use it!

Climbing the tower

OSHA rules and good common sense say you should be attached to the tower 100% of the time. You can do this several ways. One is to attach the fall arrest lanyard above you and climb up to it. Use your positioning lanyard to hold you while you detach it and move it up again. Repeat as necessary. An alternative is to use 2 fall arrest lanyards. This way you can leapfrog them up the tower.

What you use and how you use it is up to you. As long as you've got the right safety equipment and follow the basic rules you won't have any problems.

Safety climb systems

Most commercial towers have a safety climb system that is typically a 3/8" steel cable that runs from the top to the bottom of the tower and the climber uses a special trolley that attaches to the cable from the FAH. The trolley will slide up freely but will clamp the safety cable if weight is put on it, thus preventing you from sliding down the cable and tower. They are rare on amateur towers but are worth considering.

Mountain climbing harnesses

Some amateurs feel that mountain climbing harnesses offer a less-expensive option for a safety belt.

The first problem with using a mountain climbing harness is that most of them require you to tie the harness directly to a rope or to a carabiner. I wouldn't trust most hams to tie a figure 8 to attach themselves to anything. You could use a locking carabiner as an attachment point but it is another piece of hardware that could fail or open up at an inconvenient time.

Second, there are no D-rings to attach any sort of positioning lanyard to; the only thing you have is that one carabiner that connects the loops in the front. The nylon loop that is on the front of the climbing harness is only designed to position the leg loops and is intended to be used only with a climbing rope or carabiner, not the metal snaps of your lanyard that you frequently snap on and off.

Climbing belts are designed to be used only with climbing ropes and hardware, not with tower tools or equipment. They also don't have any provisions for convenient attachment of tool or bolt bags.

The final problems are that a mountain climbing harness may be designed for a force of only 1,000 pounds while OSHA fall arrest gear must be designed for 5,000 pounds of strength, and the mountain climbing harness has no fall arrest capability. Although the main advantage of a mountain climbing harness is low cost, it does have its limitations for tower work and I cannot recommend it. Use only the tools designed specifically for the job and you can't go wrong.

Safety equipment suppliers

Chances are you've got a safety store in your area. They have some safety equipment and accessories that you can use but your best bet is to search the internet for what you need since tower climbing equipment is not very common. One vendor is Champion Radio Products (www.championradio.com) that is owned by the author and specializes in tower related products.

Vendors such as Klein, Petzl, DBI-Sala and others all provide OSHA approved safety equipment. They tend to sell the more expensive products but they're preferred by professionals who wear and work in them all day.

These companies will have many other goodies including canvas buckets, tool pouches and other hardware. Plan on spending $150 and up for a new FAH and lanyard. Just look at it as inexpensive life insurance.

Boots

Boots should be leather with a steel or fiberglass shank. Diagonal bracing on ROHN *25G* is only $^5/_{16}$" rod—spending all day standing on that small step will take a toll on your feet. The stiff shank will support your weight and protect your feet; tennis shoes will not.

Leather boots are mandatory on towers like Rohn BX that have sharp X-cross braces. Your feet are always on a slant and the tower is a real meat grinder on your feet.

Photo 4: Our climber on the tower. His positioning lanyard is attached to the tower and the fall arrest lanyard is hooked to the tower above him.

Hard hats

The hard hat is highly recommended. Just make sure they are OSHA approved and that you and your crew wear them. As you'll be looking up and down a lot while wearing your hard hat, a chin strap is essential to keep it from falling off. Look for the ANSI or OSHA label on the hard hat; that should be the minimum safety compliance for your helmet.

Safety goggles

Approved safety goggles should be worn to prevent eye injury. Look for ANSI or OSHA approval.

Gloves

If you do a lot of tower work, your hands will take a beating. Gloves are essential and I like to keep several spare pairs for ground crew members who show up without them. Cotton gloves are fine for gardening but not for tower work; they don't provide enough friction for climbing or working with a haul rope. Leather gloves are the only kind to use; either full leather or leather-palmed are fine.

The softer the gloves the more useful they'll be. Stiff leather construction gloves are fine for the ground crew but I prefer the pigskin and other soft leathers because you can thread a nut or do just about any other delicate job with these gloves on.

The mental game

One of the most important aspects of safety is having the knowledge and awareness that will enable you to do a job safely and efficiently. You must have the mental ability to climb and work at altitude while constantly rethinking all connections, techniques and safety factors. Climbing and working on towers is 90% mental. Mental preparedness is something that must be learned. This is an occasion where there is no substitute for experience.

When it comes to tower climbing, my experience has been that only a small percentage of people will climb and work at altitude. The biggest obstacle for anyone is making the mental adjustment. Properly installed towers are inherently safe and accidents are relatively rare. The only thing stopping most people is their own mind and attitude.

Would you have any trouble standing on a 24" by 24" piece of one-inch plywood on the ground? Of course not. Could you stand on that same four square foot platform 100 feet in the air? The only difference is in your mind. I know that it's easier said than done but you must make the mental adjustment if you are going to do any tower work.

About thirty years ago I got involved in mountain climbing in Washington state. One of the most important lessons I learned, and that is directly applicable to tower climbing is that when you climb, you have four points of attachment and security—two hands and two feet. When climbing, move only one point at a time. That leaves you with three points of contact and a wide margin of safety if you ever need it. This is in addition to having your fall-arrest lanyard connected at all times.

Another recommended technique is to always do everything the same way every time. That is, always wear your positioning lanyard on the same D-ring and always connect it in the same way. Always look at your belt D-ring while clipping in with your safety strap. This way you'll always confirm that you're belted in. There is a story of a fellow who went to work for a local cable company and went out on his first line job. After he got up the pole, he threw his belt around and clipped in. Hearing the reassuring click of his safety belt, he leaned back, only to find that he'd clipped into his screwdriver! He didn't fall but was so shaken that it turned out to be his first and last day on the job. Don't let that happen to you. Always look!

Check your safety equipment before each use

You should also check your safety equipment everytime before you use it. Inspect it for any nicks or cuts to your belt and safety strap. Professional tower workers are required to check their safety equipment every day.

Inclement weather

Tower work is the easiest when the weather is nice and the sun is shining. Unfortunately, that doesn't always coincide with your construction schedule or repair priority.

For raising tower sections or antennas, a relatively windless day is preferred. Professional climbers usually do their trickiest lifts first thing in the morning when the chance of wind is the least. This'll work for ham work too. Don't push on in marginal conditions; you may wind up doing more harm than good. Obviously you don't ever want to climb during a lightning storm.

As far as rain goes, unless it's coming in horizontally it's more of a nuisance. For ham towers, you'll always be belted in and you won't be walking across any rain slicked surfaces, so working in the rain is possible. Just dress with good rain gear and you'll be able to still get some work done.

Don't hesitate to call off your project, though. If you're not sure if the weather is good enough, it probably isn't.

More tips

1. Don't climb with anything in your hands; attach it to your safety belt if you must climb with it or have your ground crew send it up to you in a bucket.
2. Don't put any hardware in your mouth; not only does it taste funny but also you could swallow something.
3. Remove any rings and/or neck chains; they can get hooked on things.
4. Be on the lookout for bees, wasps and their nests; there aren't too many bigger surprises when you're climbing a tower (imagine a nest big enough to engulf a portion of *25G*!). If you do run into a hornet, wasp or other stinging insect, use Adolph's Meat Tenderizer on the sting. There is an enzyme in it that'll cut the pain within a minute or two. I always have a bottle with me just in case.
5. Don't climb when tired; that's when most accidents occur.
6. Don't try to lift anything by yourself; one person on a tower has very little leverage or strength. Let the ground crew use their strength; save yours for when you really need it or you'll quickly run out of arm strength.
7. If something doesn't work one way, re-rig, then try again.

13

Tower Climber and Ground crew

There are three important factors for the success of any tower work; attitude, knowledge and communication.

An attitude emphasizing safety will keep you from taking unnecessary risks. It means doing everything in a manner that is safe for all involved. It also means knowing when to back away from something in which you're not fully confident.

Knowledge is gained not only from experience but also from research such as reading this book and talking with folks who have done it before. Don't reinvent the wheel; use all available resources to plan and successfully execute your project.

The best resource around for tower related topics is TowerTalk, the tower and HF antenna construction internet reflector. There are almost 2000 members and it is a source of answers to just about any related question. To subscribe, send an email to towertalk-request@contesting.com with <subscribe> in the subject and you'll be all set. There are also Tower Talk archives at www.contesting.com.

Communication is more than just agreeing on a simplex frequency for your handhelds. Everyone on the tower and on the ground must be kept fully informed at all times. A tower crew that has previously worked together likely has their communications protocols and signals worked out, whereas an inexperienced group of buddies and/or volunteers must be directed in their assignments at each step along the way if they are going to work together safely and efficiently.

Remember that any tower project will take longer than expected; usually by a factor of two or three. Don't try to rush anything to get the project finished; this will only decrease your margins of safety and greatly increase the chance that you'll end up doing things more than once. Even experienced crews run into delays such as missing tools, incorrect size hardware, etc.

Pre-work meeting

On project day, the first thing you should do is have a session with the entire crew and go over what is going to be accomplished, and the order and manner in which it is going to be done. You should also cover all safety issues, commands and equipment related to the job. Point out any hazards in the work area such as power lines, etc. Explain any specialized equipment or tools, including carabiners and slings, come-alongs, hoisting grips, etc. If you're going to be using a come-along, be sure that someone knows how to work it. For some reason, successful come-along operation eludes the first-time user, so spend some time explaining and learning how to use it. Point out where a phone is and any phone numbers that may be needed in an emergency. You should also discuss and understand what to do in an emergency situation. For minor emergencies, knowing where the closest medical facility is will be valuable. Since just about everyone will have a cellphone, calling 911 won't present any problems for bigger emergencies. The problem is that many emergency services professionals have not been trained for high angle rescue such as lowering someone off of a tower so you're probably going to be on your own at least initially. Search and rescue crews are used to working with ropes and other hardware for extrications so hopefully your 911 operator will be able to put you in touch with them. Physical trauma can set in quickly even with a Fall Arrest Harness so quick action is vital.

Let your crew know that they must not be standing around the bottom of the tower unless they must specifically be there. This is the danger zone for dropped tools and hardware.

RULE #1. The guy up on the tower is in charge.

Do what he tells you. Don't do what he doesn't tell you. Being on the ground crew is usually pretty boring, but don't take it upon yourself to do anything that would have any impact up on the tower. With very few exceptions, don't do anything unless directed to. If you're not sure about something, ask the guy on the tower.

RULE #2. When talking to the tower crew, look up at them and talk in a loud, concise voice.

Although it may be still and quiet where you are on the ground, the ambient noise level on the tower is always significantly higher. The three main sources of noise at altitude are dogs, traffic and wind. Combine those with being 50 to 150 feet up in the air and you have major communication obstacles. I've found VHF/UHF handhelds to be useful. Stan Griffiths, W7NI, suggests using the inexpensive VOX-operated headsets that run less than a watt on the 47MHz band. Make sure you have good communications between the ground and the tower. And make sure that all batteries are fully charged!

Commands

Here are the commands that I use. I make certain that everyone understands each of the commands and that they all use the same ones. All of the commands refer to the 'load' (antenna, tower section, etc.) and are applied to the 'haul rope' (the line to which the load is attached).

"Tension" tells your crew to put tension on the line, to take up any slack.

Once you have some **Tension**, you can move the load with **"Up"** or **"Down"** commands.

"Slack" means giving the load some slack.

"All slack" means the ground crew may gradually and gently release their grip on the load.

"Stop" is obvious and **"Stand by"** indicates that they should maintain their assignment while awaiting the next command. Again, the guy on the tower is in charge; don't do anything without his instruction.

If you drop something, alert the ground crew immediately. Yell **"Look out below!** or **"Headache!"** so that they can get out of the way of the wayward bolt, nut or tool. Their hardhats only provide minimal protection against this occurrence. Concentrate on not dropping anything. Dropped items are not only dangerous but it also means that you're doing sloppy work. A good rigger might only drop something once or twice a year—or even less.

There are also several common hand signals that you may want to use. Simple ones for up, down and stop can be useful, particularly in high-noise situations. Just make certain everyone knows what they are.

RULE #3. Really communicate.

I insist that my ground crew keeps me really informed. If I lower something to the ground, I want the ground crew to tell me that it's **"On the ground".** If I'm waiting for them to do something, I want them to tell me when it's **"Ready"** or **"Just a minute".** More than once I've been waiting and waiting for something that was ready, but the ground crew didn't tell me so we both stood there for some time until I asked for a status report. It's much easier to communicate and also much more efficient.

Take care of your crew

If you've managed to talk a bunch of your buddies or radio club members into helping you, by all means roll out the red carpet for them. They're giving up their time to help you and they deserve it. Make an effort to provide lots of water or iced tea and by all means feed everybody a nice lunch. (A six-pack or keg may be welcome, but only **after** all tower work is finished.) They may even come back sometime in the future to help you again!

Crew size

For small antenna jobs, two people (one on the tower and one on the ground) are usually enough. Even erecting *25G* (40 pounds per section) can be accomplished with two people, but this is a case where a third person to handle the tag line is real handy. For *45G,* you'll want to have two people on the haul rope as these sections weigh 70 pounds each, and a section with guy brackets is close to 100 pounds. Commercial riggers commonly use some type of winch or windlass to haul up heavy loads. For working with large antennas, such as 40-meter beams, two people on the tower along with one or two tag line folks plus two to four on the haul rope means that you'll need a large crew.

The guy on the tower

If you're the guy on the tower, I'm assuming that the reason that you're up there is because you know what you're doing. Before you climb the tower, do what airplane pilots traditionally do; walk around it and make a thorough visual inspection. Look at the base for cracked or rusted legs or missing hardware. Go out to the anchors to check the turnbuckles, clamps and other hardware. Look for bee or wasp nests. Never assume that any tower is safe to climb, always inspect it thoroughly before you take that first step.

Whenever I'm working with someone on a tower, before we do any maneuver, I always explain how we're going to do it and the sequence that we're going to use. This way, they will understand the process and will do the right thing at the right time, hopefully. This is particularly important if you're up there with someone that you've never worked with before. Sometimes you both assume that the other guy is going to do something obvious that needs doing and then neither of you does it. This can be dangerous. Go over everything. If the person has little experience, he'll get an education while he's at it. It'll also make it easier the next time you work together.

Put your tools either in your bucket or tool bags on your belt. Try to avoid putting anything on a flat surface such as the rotator plate or thrust bearing plate; they can roll off.

Avoid using ac-powered tools on the tower. Battery powered tools are safer; you can buy, borrow or rent them. If you must use ac-powered tools, make certain they are insulated and that the extension cords are suitable. Zip cord extensions are tacky and dangerous. Make certain your ground crew knows where to disconnect the extension cords, and/or where the breaker box is located.

14
Toolbox

Any job anywhere is easier and safer if you've got the right tools and tower work is no exception. If you are a weekend mechanic or handyman, you've probably already got most of what you need; all you need to do is add a few specialized items and you're good to go.

If, on the other hand, all you have is a hammer, pair of pliers and a screwdriver, you'll need to make a trip or two to the tool store before you can really do anything. When my son reached the age where he was using (and losing) my tools, I went to Sears and bought him a basic set of *Craftsman* tools and a toolbox for less than $100 That's probably about right for a minimum set of wrenches, sockets, etc.

Once you have them, you'll be all set whenever any of your buddies want help on their tower. There's nothing worse than rolling up to spend a day working and your buddy can't supply any really useful tools. Be prepared; you'll never go wrong.

Basic toolbox

Most amateur tower and antenna work can be done with a minimum of handtools. Nut sizes of 7/16", 1/2" and 9/16" are all you'll usually need.

Essential tools

1 set of combination wrenches: 7/16", ½" and 9/16"
1 set of sockets 3/8" drive
1 each deep sockets: 7/16", ½", 9/16"
1 each screwdrivers (blade and Phillips)
2 adjustable pliers or *Channellocks*
1 diagonal cutters (dikes)
1 razor blade utility knife
2 pulleys
1 driftpin or centering punch (for lining up tower sections)
1 hammer (I have a couple of feet of line on mine so it'll hook onto my belt or a tower member)
3 each adjustable *(Crescent)* wrenches—small, medium, and large
1 bubble level
6 carabiners
6 one-inch nylon webbing slings — 2' long
250' rope (or more - this is enough for working on a 100' tower)
1 canvas bucket (for parts hauling and storage)
1 Loos PT-2 guy wire tensioner
1 set nutdrivers
1 (or more) come-along or hand cable winch
1 (or more) cable grips
1 circular saw with aggregate blade or hand grinder (for cutting metal, including guywires)
1 tag line (¼" is fine—you chose the size and length)
1 cordless drill, with assorted bits and socket driver
1 set drill bits including step-drill, e.g. Uni-Bit
1 antenna analyzer, e.g. MFJ-269
1 ginpole
1 soldering gun and solder

Come-alongs

A come-along, or hand cable winch, is very useful for pulling tower sections together, tightening tramlines and tensioning guy wires. You'll probably find more uses for it. Cheap ones are fifteen to twenty dollars and are fine for occasional use. The best ones for tower work are the ones that have spring-loaded safety latches over the end of the hooks. Learn how to work it because you'll have to explain it to other people since come-along use eludes the first time user.

Photo 1: Canvas tower bucket.

Cable grips

Two tools that go together are the come-along and the cable grip. A cable grip is a spring-loaded device that slides up the guy wire but clamps down when you put tension on it. Klein is the primary supplier of them and they come in lots of sizes and designs for use with various materials. For amateur use, the Klein 1613-40 is for 3/16" and ¼" EHS guy material which happens to be what 90% of amateur towers use. When erecting a tower I carry 3 of them along with 3 come-alongs so that I can put initial tension on all 3 guy wires at the same time.

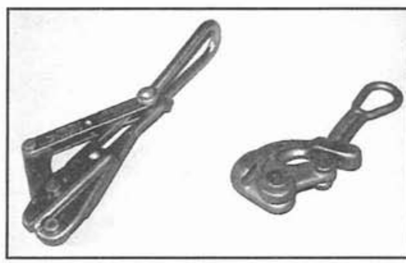


Photo 2: Klein Chicago cable grip on left and Klein Haven's grip on right.

Steel cutter

Eventually you'll need to cut some steel. Guy wires, rebar, pipe, tubing, tower sections, etc. are all

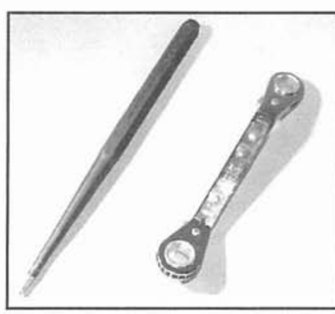


Photo 3: Drift-pin or taper punch and ratchet box-end ratchet wrench.

materials that can be cut easily with the right tool. I started out using a circular saw with a steel cutting aggregate blade. It was cumbersome and heavy but it worked. And since the steel cutting blades are cheap, it was an easy way to go. But the best cutting tool is a 4-1/2" hand, or angle grinder. Get one-eighth inch steel cutting blades for all your cutting jobs. You can also get grinding wheels, wire brushes and other accessories for it.

Cordless drill

You'll use this all the time, and it's just not for drilling. Other tasks you can use it for are tightening nuts, hose clamps and other hardware and wire brushing. While a typical household drill is okay for occasional small jobs, it's worth the investment to get one with higher voltage. The minimum voltage for the drill should be 12 volts. Higher voltages like 18 and even 36 volts are currently available. And be sure to have a spare battery. My Milwaukee cordless drill even has a half-inch chuck – a very desirable feature!

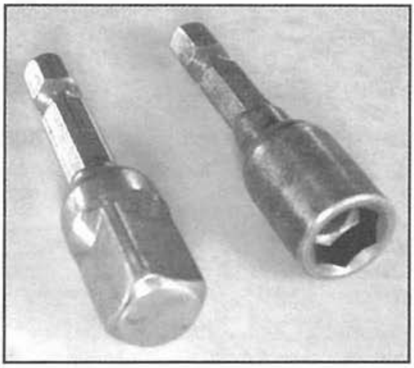


Photo 4: Drill socket driver for 3/8" sockets and 5/16" nut setter for hose clamps.

Drill bits

You'll obviously need a set of drill bits. Other very handy items are step-drill bits (also known as Unibits), socket drivers and single-sized nut drivers.

Ever tried to expand an existing hole? You take a bigger size drill bit and start drilling. Unfortunately many times the hole will ovalize as you try to make the hole bigger. The

Photo 5: Step drill bits. The one on the left goes from 1/8" to ½". The one on the right goes from 3/16" to 7/8".

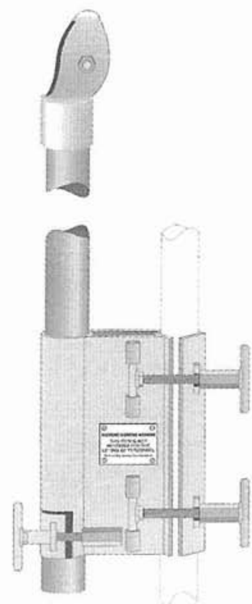
solution is a step-drill, or Unibit. Most have a chisel tip to get you started and then you just keep drilling until you get the desired sized hole. Easy. And it's perfectly round every time.You'll wonder how you ever lived without them!

Antenna analyzer

These fabulous devices have made working on antennas easier than ever before. I have used an MFJ-259 for years and prefer it since you can sweep the frequency spectrum while you look for a dip.

Ginpole

The purpose of a ginpole is to provide a pick-point up high enough so that you can lift an object above the top of the tower, then drop it into place. Typical ginpole loads would be tower sections (10 feet long) and masts (6 to 22 feet long). You want to pick up these loads just above their mid or balance point, so that they will come up in the correct upright position for installation. The ROHN ginpole is twelve feet long, just right for lifting a ten-foot tower section. For twenty foot masts, a twelve-foot ginpole is very marginal because there is barely ten feet of working length available from the ginpole and a big mast will probably exceed the rating for the Rohn ginpole which is rated for a 45G section that weighs 70 pounds. Large, heavy-duty masts require special handling; there are several options for their installation. *(See chapter 18, 'Tower Erection')*



Drawing 1: Ginpole, drawing based on Rohn EF2545.

For ROHN *25G* and *45G*, a ROHN ginpole will be quite sufficient. Often these can be borrowed or rented from a local radio store or club so you don't necessarily have to own one. For ROHN *BX*, Trylon Titan or towers from other manufacturers that have angle legs, a different ginpole is needed. A universal ginpole can be fabricated utilizing a 12-foot to 15-foot piece of 6061-T6 aluminum pipe, or equivalent (2.0" OD, 1/8" wall is probably sufficient). If the ginpole doesn't have the correct leg mounting fixture, you can simply lash the ginpole to a leg with some short-lines- this will suffice for most ham towers. Take care to insure that the ginpole won't slip down the leg. I use a sling with two carabiners on it - one carabiner hooks the bottom of the ginpole and the sling attaches to a convenient tower member with the other carabiner.

Pulleys

Pulleys are used constantly in tower and antenna projects. There's always one at the top of the tower for the haul rope that will be used to bring up parts, equipment or hardware. Steel pulleys are relatively inexpensive and plentiful. Their biggest drawback for amateur projects is weight; a small one weighs two or more pounds. Climbing with a few of them on your belt turns into work. They cost $25 to $35, and can be found in many hardware stores or rigging shops.

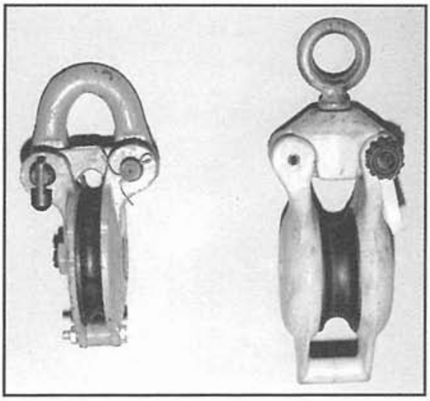


Photo 6: Closed snatch block pulleys.

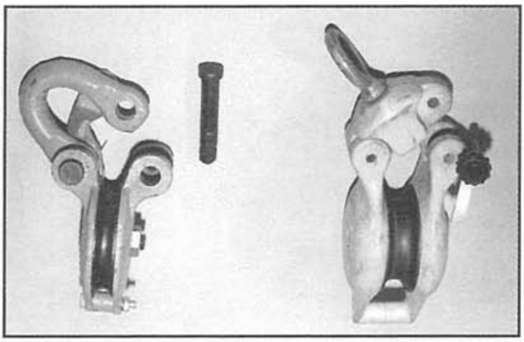


Photo 7: Open snatch block pulleys.

The best pulleys I've found are made from nylon and are used by utility company line crews. Their nonconducting advantage for high voltage work is obvious, but they are just wonderful for amateur projects and available from Champion Radio Products. Two important things to consider when shopping for pulleys are sheave size and sheave clearance. A sheave is a wheel with a groove in it, the wheel in the pulley. A two-inch diameter sheave is the minimum size you should consider. Anything smaller adds more friction to the effort of your haul rope, etc. A three-inch or four-inch pulley is even better.

The kind of pulley you want is called a snatch-block. With a snatch-block, the top of the pulley opens up so that you can put the pulley anywhere on the rope.

You want a jam-proof pulley that has zero clearance between the sheave and the pulley body. If there is any way for your haul rope or cable to jump the pulley and get jammed, it almost certainly will.

15

Carabiners and slings

One of the more valuable lessons I learned from my mountain climbing days was the value and incredible usefulness of two pieces of climbing hardware; carabiners and nylon webbing slings.

Carabiners and snap-links

Carabiners are steel or aluminum snap-links with spring loaded gates; they are invaluable for dozens of tower work tasks. For example, put one at the end of your haul rope, then attach it to rotators, parts bucket or virtually anything else which needs to be raised or lowered. A carabiner can be a third hand on the tower; you

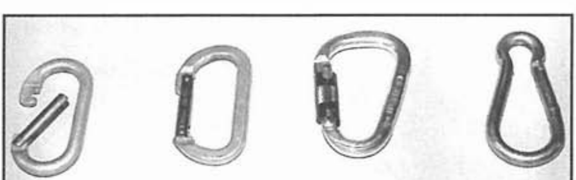


Photo 1: Typical carabiners and snaplink. Carabiner on left is open for illustration purposes only. Second carabiner is in normal closed position. Third carabiner has automatic spring gate lock. Snaplink on right is steel variety.

can clip a carabiner to almost anything with a rung or diagonal brace. You can instantly hang a pulley from a tower rung. Any place where you would use a shackle, you can use a carabiner. A shackle has two pieces, either of which will be dropped at an inopportune time whereas a carabiner is one piece and attaches in a flash. I carry twelve to fifteen carabiners on my belt at all times and I'm amazed at the number of times I've used all of them.

Carabiner ratings

Mountain climbing carabiners used to be rated for breaking strength; a typical rating was 2000 kilograms (4400 pounds) or more. The problem was that this was a static load condition and didn't really reflect their use in dynamic climbing or falling situations. Carabiners are now rated in kiloNewtons (kN); this reflects a more realistic dynamic load stress. (One kN equals 225 pounds of force.) Current ratings for mountain climbing carabiners are typically in the 6 to 10 kN (1350-2250 pounds of force) range with the gate open and 18-25 kN (4050-5625 pounds of force) with the gate closed.

A word of caution: mountain climbing carabiners are **not** OSHA approved. As they are for private use, they don't have to be compliant. And in the case of tower construction they're just going to be used for loads anyway. OSHA approved carabiners are also available, these are called safety hooks and can be purchased from your safety equipment supplier. OSHA approved devices are usually made out of steel, instead of the aluminum used in mountain climbing carabiners, and generally are the locking type. A typical rating for a commercial carabiner is 40kN (9,000 pounds of force), a much higher rating than mountain climbing types. On the other hand, mountain climbers have been trusting their lives to carabiners for almost fifty years and the current versions are made out of sophisticated materials and thoroughly tested. You may feel that they are safe for you to use also. They typically cost $6 to $10 and will last for years with little or no maintenance. But if and when the gate no longer opens and closes smoothly, they should be discarded.

Slings

The other indispensable tool is the loop sling made from one-inch nylon tubular webbing. The sewn webbing loops can be wrapped around large or irregularly shaped objects. They have around the same breaking strength as carabiners (approximately 4000 pounds, or 18.1 kN force) and are very handy for amateur applications and loads. Wrapping one around a tower rung or leg provides a convenient place to hang tools, parts or a pulley.

Like carabiners they are not OSHA approved but they're used for mountain climbing protection everyday so if you don't feel that one-inch webbing slings are appropriate for you, you can purchase OSHA approved slings from your safety equipment supplier. Like carabiners, these are not typically used in tower work for fall protection - they're used for load hauling. The OSHA approved ones are typically made from yellow nylon and are certified for a given strength factor. They are available in different sizes, and configurations from having loops at each end to being a continuous loop like one-inch mountain climbing slings. Although they are more expensive than the one-inch webbing slings, they will last for years and are an excellent rigging and safety investment. I personally use the lighter mountain climbing types for everything except big loads like a tower.

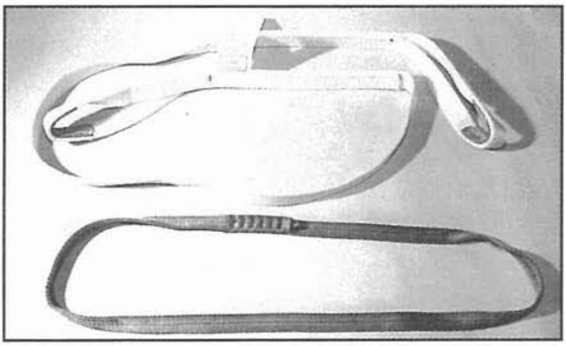


Photo 2: Nylon sling on top has an eye in each end. Bottom sling is endless loop.

Lifting loads with slings

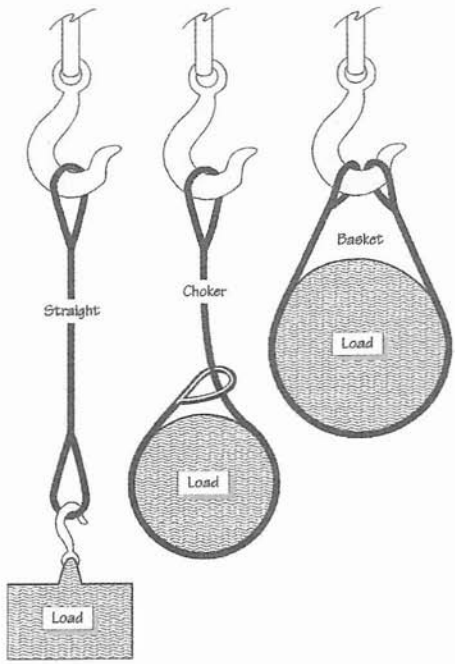
Slings are typically used in one of three rigging configurations:

1. Straight pull — A simple direct vertical attachment.

2. Choker — Wrap the sling around the load one or more times, insuring that you pull the loop through itself on each wrap, cinch it tight, clip it into a carabiner and pull it up! This is called a choker; the secret to this operation is that the more tension you put on the sling, the tighter it gets. Remember the Chinese finger puzzle

when you were a kid? The more you pulled it, the tighter it got. You could only get it off when you relaxed the tension and pushed your fingers together. The same principle is at work here and it will simplify your mast raising projects immensely.

What system do you use if you have a heavy mast to install? How do you attach it to the haul line? Do you jury rig something? Nylon slings are invaluable for pulling up masts, from small ones to the 3" × ½" wall monsters. Just rig your sling as a choker, then haul away. I've never had one slip but you can add a U-clamp above the sling for redundant protection.



Drawing 1: Three basic hitches.

A choker will work in many other cases where you have an irregular load to haul, not just masts. Using a sling as a choker will reduce the lifting capacity of the sling by as much as 30% though.

3. Basket — Basket hitches distribute a load equally between the two legs of a sling. The greater the angle between the two legs, the smaller the capacity of the sling.

Big carabiners and gorilla hooks

Larger carabiners are available that have locking gates; these will give you an added degree of safety, particularly if you are using them for your own protection or if you just want to be doubly safe. They're only a couple of dollars more than the standard, non-locking types. Also, there are **big** carabiners available; these are used for rescue work and other applications where you need a wider gate open-ing. These are sometimes called gorilla hooks or rebar hooks and are perfect for larger tower rungs (ROHN BX, etc.) and larger loads. OSHA compli-

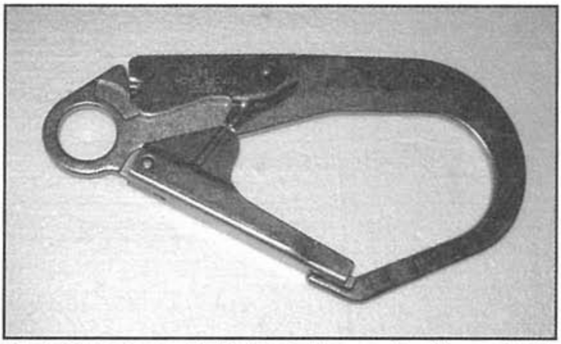


Photo 3: A rebar or gorilla hook. The mouth will open 2.5".

ant devices are offered by your safety equipment supplier, and in some cases are the same ones that are available from climbing hardware stores.

Using carabiners and slings

These devices are revolutionary for tower and antenna work and they are safer than most of the alternatives. If you are doing tower and antenna work, you should be using carabiners and loop slings. And the beauty is that you can use them for just about anything. Need a spare hand? It's right there. Need to hook your rope onto something? No problem. Try the carabiners and slings—they'll make your job faster, easier and safer.

One carabiner/sling trick I frequently use is to take a two-foot sling and loop it through the fixture of the ROHN gin pole assembly, then clip both ends with the carabiner. You now have the ability to clip it onto a haul rope, clip it onto your safety belt to bring it up to the next section or you simply have something to grab onto when you're moving it around or attaching it to a tower leg. This is invaluable as there is nothing on the gin pole fixture itself to hook anything on to.

Here are some other ways that you can use carabiners and slings for your tower project:

1. Attach a sling to an anchor rod as an attachment point for one end of the come-along for pulling guywires.
2. Clip a carabiner onto a rung at the bottom of the tower, then attach your haul rope snatch block

pulley to it.

3. Use a sling to hoist each tower section and to keep it vertical.
4. Put a loop through your level, then clip it to your belt with a carabiner.
5. Always have a carabiner clipped into the bowline at the end of your haul rope and tag line for quick load attachment.
6. Clip a carabiner into the U-bolt on your rotator to haul it up.

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Ropes, knots and rope management

If you are going to do tower and antenna work, you'll be using ropes. The most common uses are for haul rope, tag lines and temporary guys.

Manila

Manila is still the best known natural fiber rope. At one time it was the best rope available but it is steadily losing ground to the synthetic fiber ropes. Manila must be handled and stored with care as any dampness will cause it to rot and, of course, materially damage its effectiveness and safety.

Polypropylene

Polypropylene is used to make lightweight, strong ropes that have extensive uses. They float on water, are rot-proof and are unaffected by water, oil, gasoline and most chemicals. Polypropylene rope is relatively stiff and doesn't take a knot well.

Nylon

Nylon is the strongest fiber rope commercially available. Due to its elasticity, nylon ropes can absorb sudden shock loads that would break ropes of other fibers. They have very good resistance to abrasion and will last four to five times longer than natural fiber ropes. Nylon ropes are rot-proof and are not damaged by oils, gasoline, grease, marine growth or most chemicals.

Dacron

A dacron rope is advertised in the ham radio magazines. It comes in three sizes (3/32", 3/16" and 5/16") and its claim to fame is that it is UV resistant. This would be an excellent candidate for any rope left outside such as permanent haul ropes or wire antenna halyards.

Table 1 - Rope Sizes and Safe Working Load Ratings (in pounds) - 3 strand twisted line

Diameter	Manila	Nylon	Dacron	Polypropylene
1/4	120	180	180	210
3/8	215	405	405	455
1/2	420	700	700	710
5/8	700	1140	1100	1050

Table 2 - Rope Sizes and Safe Working Load Ratings (in pounds) - Double braided line

Diameter	Nylon	Dacron
1/4	420	350
3/8	960	750
1/2	1630	1400
5/8	2800	2400

Rope lay

All rope is twisted, or laid; and just about all laid rope is three-strand construction. This laid rope is what you'll find at your local hardware store. Another type of rope is known as braid-on-braid, or kernmantle. This has a laid core that is covered with a braided jacket to produce a strong, handsome, easy handling rope. In most instances, braid-on-braid rope is stronger than twisted rope of the same material and diameter. It is available in various synthetic fibers. Marine supply stores and mountain climbing stores carry a large variety of braid-on-braid types as well as a variety of types and sizes.

Which rope to use

There are several factors to help you make an informed choice about which rope to buy. First, decide which size will suit your needs, based on working load sizes. Most amateur loads are less than 100 pounds, very rarely do they get above 250 pounds. So a haul rope having a working load range between 100 and 250 pounds will handle just about anything. Second, choose the type and material of your rope. Polypropylene rope is stiffer and more difficult to knot than nylon. Nylon and braid-on-braid ropes are softer and will take a knot very easily. The softer ropes also coil more easily and are more resistant to kinking. Finally choose the length that will be the most useful for you. If you double the size of your typical tower and add 25%, you'll have plenty. A 100-foot tower times two gives you 200 feet plus 50 feet (25% of 200) for a total desired haul rope length of 250 feet.

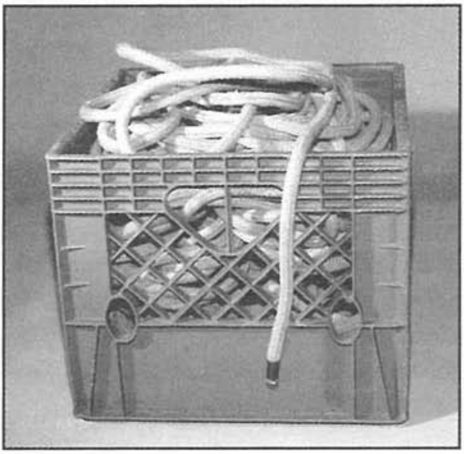


Photo 1: One convenient way to store your rope.

I haven't mentioned price because you generally get what you pay for and you know what your budget will allow. Prices vary from $18 for 600 feet of ¼" polypropylene to $125 or more for 165 feet of high quality kernmantle climbing rope.

I carry two lengths of $^{9}/_{16}$" braid-on-braid for haul ropes. One is approximately 175-feet long and can be used on towers up to 80 feet. The other haul rope is around 350-feet long and can be used for tower work up to 165-feet. The shorter rope is coiled when not in use and the longer one is simply fed into a plastic crate for storage. If you feed the rope into the crate properly, the rope will feed out of the crate without kinking or knotting.

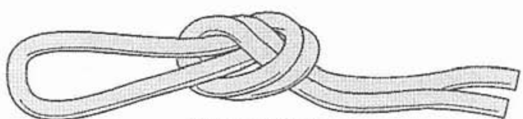
Make certain that the rope ends will not unravel. Most supply stores will cut the length with a hot knife; that will do the best job of sealing the ends. You can do it at home by simply melting the ends with a lighter. An alternative is to tightly wrap a few layers of electrical tape around the ends. Be sure to tape the ends of all your ropes.

Knots

Once you've got your rope, you'll be tying and untying it dozens, even hundreds, of times. You can do about 98% of your tower and antenna work with only three knots—and you already know one of them. It's all but impossible to use a rope without tying any knots in it, remember that any knot will decrease the breaking strength of the rope—usually 40% or more. Choose and use the correct rope and knots for the job, and you should have no problems.

Overhand knot

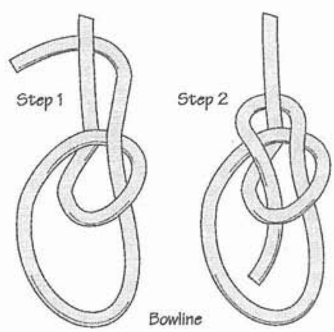
When you tie your shoes, you're using overhand knots. These are tied by making an overhand loop, then passing the end under and up through the loop and then tightening. A very handy use for the overhand knot is when you need a loop in the middle of your rope. Just double the rope over for about two feet, tie an overhand knot and you have an instant loop.



Overhand Knot
In The Middle of a Rope

The bowline

This is perhaps the most useful knot you can know; if you're going to be stuck on a desert island and you can only take one knot with you, this is it. The bowline forms a loop that will not slip or jam, yet unties easily. It is used for hoisting, joining two ropes and fastening a rope to a ring or carabiner. This is the "rabbit comes up



Bowline

through the hole, around the tree and back down the hole" knot that you likely learned as a Boy Scout. To tie it, form a small loop in the rope. Run the end up through the loop, behind the standing part, then back down through the loop. Pull tight. Practice this one until you can make it almost automatically.

Figure-eight knot

Although the bowline is a handy knot, it isn't foolproof; it requires a bit of practice to get it right every time. A simpler knot that may be used in most situations in place of a bowline is the figure-eight knot. It is tied just like a doubled overhand, except that the rope is twisted an additional half-turn before the knot is pulled through the loop. It is one of the few knots that can be easily untied after holding a severe impact load, such as a falling mountain climber. It's only disadvantage for tower work is that it is a physically larger knot, and it takes a bit more rope than a bowline. Figure-eight or bowline; either knot will serve you well.

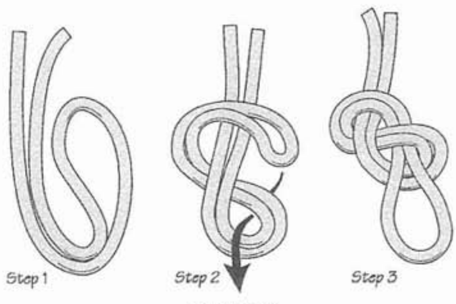
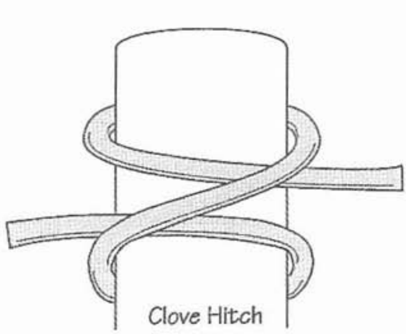


Figure 8 Knot

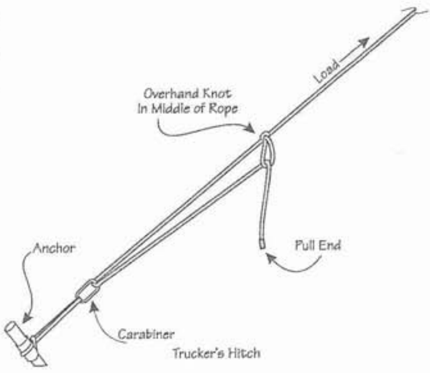
The clove hitch

Once you've mastered the bowline and/or the Figure-eight knot(s), the other very useful knot you may want to learn is the clove hitch. It can be invaluable when you're working with round objects, and it can be put on or around almost any object very quickly.


Clove Hitch

Truckers' hitch

Many times you're working with a rope and you want to tighten the rope as much as you can but using a rope grip and come-along just isn't practical or possible. The answer to this problem is to use a truckers' hitch. You simply tie an overhand knot up the rope to give you a loop towards the load end, run the end of the rope through a carabiner or shackle at a convenient anchor point, put the end through the loop and then pull back to tighten the rope. This technique gives you twice the mechanical advantage of pulling on the single rope and acts as a mini-come-along to really tighten the rope.



Rope care

Inspect your rope periodically and replace it if there is any visible serious abrasion or damage. Mountain climbers routinely replace their ropes after they sustain a single hard fall, which can cause invisible internal damage; also after their ropes are exposed to a season or two of deteriorating ultraviolet sunlight. Here are some additional tips for using ropes:

1. Be certain your rope size is adequate for the job; don't use a rope that is too small.
2. Dry your rope before storing it. Natural fibre (Manila) ropes will mildew and rot if stored wet. I occasionally put my nylon ropes in the clothes dryer for a bit (low heat) when they've become really soaked.
3. Don't store ropes in direct sunlight; UV deterioration will significantly weaken them.
4. Cut out and discard any badly worn or abraded portions of a rope; better to have two shorter ropes you can trust than one long one that is suspect. Heat and/or tape the new ends to prevent unraveling.
5. Keep your rope clean. Don't drag it through the mud, nor over a rough or gritty surface. Don't ever step on it, either!
6. Watch for kinks; they can cause permanent damage and

weakening.

7. Protect ropes from all chemicals such as acids, oils, gasoline, paints, solvents, etc.
8. Avoid sudden strains; shock loading or jerking may cause failure.
9. Avoid overloading. A safe working load for a rope is ten- to twenty-percent of its breaking strength.
10. Avoid abrasion. If the rope must run over a tower leg or any surface with a sharp edge, protect it with a layer or two of canvas or other such material.
11. Avoid sharp angle bends; these can greatly affect the strength of a rope.

17

Guy wires

One of the most innocuous elements of a tower installation is the guy wires. Not as aesthetic as tower sections, nor as elegant as antennas, guy wires are the heart of a reliable guyed tower system. Almost any tall amateur tower is going to be guyed. Rohn *25G, 45G* and *55G* are the most common towers used by amateurs and they all need to be guyed.

Guy wire failure is not common, but does happen. Overloading is the typical culprit, but sometimes a tree will fall across guys; that's also guaranteed to require a call to the insurance company. One obscure failure was an amateur who taped the ground anchor ends of his guys at the turnbuckles. Over the years, the water ran down the guywires and was trapped by the tape. That led to rusting; since the rusting was hidden by the tape, it couldn't be seen. Eventually all it took was a large windstorm to snap the rusted windward guy and the top half of the tower buckled. It's another instance of doing something that the manufacturer didn't tell you to do. A more common failure is for some critical piece of hardware to break or pull out.

Guy wire grades

Steel guy wire comes in several different grades. ROHN specifications call for EHS (Extra High Strength) cable exclusively. As you can see by the chart, this is the strongest steel cable available.

Typical 3/16" steel guy wire specifications	
Common Grade:	**1,540 pounds**
Utility Grade:	**2,400 pounds**
***Siemens-Martin* Grade:**	**2,550 pounds**
High Strength Grade:	**2,850 pounds**
Stainless Steel Aircraft:	**3,700 pounds**
Extra High Strength Grade:	**3,990 pounds**
***Phillystran:* HPTG4000**	**4,000 pounds**

This chart shows the importance of following the tower manufacturer's recommendations for the proper guy material and strength. Just because you bought a reel of 3/16" steel guy wire real cheaply at last year's flea market doesn't mean that it is suitable for use in your installation. Like masts of unidentified material, be very cautious about using unidentified guy material. High strength grade is rated almost 30% lower than EHS.

Some other EHS sizes and strengths are:	
1/4"	**6,650 pounds breaking strength**
5/16"	**11,200 pounds breaking strength**
3/8"	**15,400 pounds breaking strength**

Cable fittings

The three most common methods of terminating guy wires are to use cable clamps, swaged or crimped pressed fittings or Preformed guy grips.

Cable clamps

The most common, and the cheapest cable fittings are cable clamps. Always use three per joint and make certain that the saddle is on the live side of the guy wire.

When you put your guy wire through a thimble or insulator and double it back to put your cable clamps on it (this is called a turnback), you have two different wires. The continuous one that bears the weight of the guy wire forces is called the "live" end and the short piece that is turned back is called the "dead" end. It's "dead" because it is not weight bearing. The cable clamp consists of two parts; the U-bolt and the saddle. The saddle portion provides the majority of the holding capacity of the clamp. The saddle goes on the "live" side of the cable. The saying goes "don't saddle a dead horse." In other words, don't put the saddle on the dead side of the turnback. A clamp mounted backwards loses 40% of the holding capacity of a properly installed clamp.

SEQUENCE FOR INSTALLING CABLE CLAMPS:

1. Turn back the specified amount of wire from the thimble or loop ($3^3/_4$" for $^3/_{16}$" cable). Apply the first clip one base width from the dead end of the wire. Install the U-bolt over the dead end of the wire, with the live end resting in the saddle. Tighten the nuts evenly, alternating from one nut to another, until reaching the recommended torque.
2. Apply the second clamp as near the loop or thimble as possible. Tighten the nuts finger-tight only.
3. Place the third clamp between the two, then tighten each U-bolt evenly, alternating from one nut to the other until reaching the recommended torque.

When tightening cable clamps, torque them so that they are tight; a typical specification for $^1/_4$" CROSBY clips is 15 foot-pounds of torque.

When assembling a tower, guy wires or antenna, let everything sit overnight; then go back over every nut and bolt the next day. You'll be surprised at how loose many of the connections have become. What the hardware is doing is going through one temperature cycle of expansion and contraction. By letting it cycle one or more times; then going over the hardware again, you'll eliminate the possibility of loose or potentially loose hardware.

Swaged fittings

Swaged fittings produce a strong, clean connection; if you don't like the cobbled look of lots of cable clamps, swaging may be for you. The most common swages are *Nicopress* fittings.

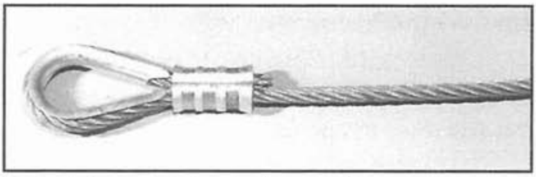


Photo 1: A swaged guy wire termination.

While the fittings themselves are relatively inexpensive, you have to buy or rent a *Nicopress* tool to crimp them onto the guy wire. And you can't remove them once they're crimped on.

Preforms

Preformed guy grips (or *Big-Grip Dead-Ends*) are the easiest to use, and naturally the most expensive. You simply curl them onto the end of the guy wire to produce a permanent termination. Preformed cable grips have virtually replaced cable clamps for power, telephone, and communications companies. Factory specs say that you can remove

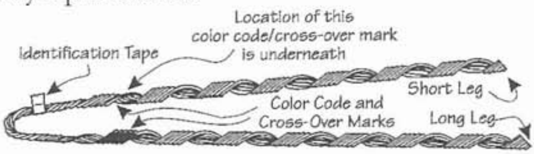


Figure 1: Phillystran grip.

and reapply the grips twice. If removal is necessary after a guy grip has been installed for a period greater than three months, it must be replaced. If you can't find them locally, ham magazine advertisers will be happy to ship you as many as you need.

Preforms are color-coded for wire sizes, as follows:

1/8"	blue	9/32"	blue
3/16"	red	5/16"	black
1/4"	yellow	3/8"	orange

Use only the correct size Preforms for the cable you are using. Cables and related hardware, including cable clamps and Preforms, are designed for a certain number of strands in the wire rope, and for a specific lay for each cable size. Do not mix different hardware. NOTE: Preformed grips have 2 sets of cross-over marks. The set closest to the loop is for normal guy wire attachment. The set farthest from the loop are for when the guy wire goes thru an insulator.

Installing Preforms

Preformed guy grips are precision devices, designed to be installed by hand; do not use any tools to install them. They should be installed only in conjunction with heavy-duty wire rope thimbles.

1. Insert a heavy-duty thimble into the eye of the Preform, then through the attaching hardware (shackle, etc.).
2. Wrap the first leg (either one) around the guy wire with two complete wraps. Simply wrap them around the guy wire. Line up the crossover marks, then wrap the second leg with two complete wraps, ending opposite the first leg.
3. Complete the installation by either simultaneously wrapping both legs (keeping the legs opposite each other) or alternate the legs a couple of wraps at a time. Bending the EHS guy wire as you wrap the Preform leg around it will make it easier to attach.
4. Finish the short leg first, then the long leg.
5. Seat the ends of the legs by hand. If that won't do it then use a flathead screwdriver under the end of the strands. For *Phillystran* you may need to separate the strands to finish the ends of the Preform.
6. Attach a black tie-wrap or end sleeve around the grip at the end to secure it.

Cutting guy cable

Many different methods have been used over the years to cut guy cable. These days, EHS (extra high strength) guy wire is the standard and special cutters are needed to cut this hard wire. Always wear your safety goggles when working with guy wires. There can be lots of metal chips floating around when you cut them or the guy wire can easily whip around and hit you in the face or other body parts.

An older method of cutting guy wire is to use a big chisel and a hammer to split the cable. These days you can rent or borrow a boltcutter. Just make certain it will cut EHS, not just soft metal. Another method is to use a circular power saw with a metal cutting aggregate blade. These blades are less than $4 at your neighborhood hardware store and will cut pipe mast material as well. A hand grinder works very well also. With guy wire, use electrical tape not only to mark where you want to cut but also to prevent the guy wire from unraveling after it's cut.

Phillystran®

Introduced in 1973, *Phillystran* gives the strength of EHS steel wire with the added advantage that it is nonconducting, thus it's electrically transparent to RF. It consists of a polyurethane resin impregnated aramid rope with a thick extruded jacket of specially formulated polyurethane. Its nonconductive property makes it ideal for tower systems where some antennas will be under or close to guy wires. Guy wire interaction with stacks and wire antennas will be eliminated by using *Phillystran.*

When the original *Phillystran* was introduced, only special (and expensive) cable end sockets could be used. Besides costing $18 each thirty years ago, you had to pot each socket end with a special, messy potting compound.

A new, improved *Phillystran* was introduced several years ago that not only consists of a new core formula but also a different jacket material.

The new *Phillystran* cable grips

The manufacturer recently introduced *Phillystran* compatible Preformed guy grips, or, as they call them, *Big Grip Dead-Ends.* What makes these different than the ones that you use for normal ¼" or ⅜" EHS is that these are longer than normal and have a different lay (twist) to match the characteristics of *Phillystran.*

They are installed generally the same way, except that you must keep some tension on the *Phillystran* while installing the Preform, and you may have to split the strands on the end of the Preform in order to finish wrapping them on. This is because the *Phillystran* is very flexible, particularly when compared to good old EHS. Other than that, they're just like the Preforms that you're used to using.

Guy wire interaction and segment lengths

It is commonly accepted that metal guy wires interact and influence RF radiation. AM radio towers are loaded verticals and their owners go to great lengths to isolate them from their guy wires. Some amateurs have used their calculators to determine non-resonant lengths for use on their towers, and felt satisfied with their conclusions. I've seen guy wire segment lengths of 22 or 26 feet used as commonly accepted benign lengths. Of course, you could neutralize the whole problem by using *Phillystran* but amateurs being a parsimonious bunch typically blanch at the thought of spending that kind of money. Suggested non-resonate guy lengths can be found in the ARRL Antenna Book.

A well known contester and respected station builder, Lew Gordon, K4VX, wrote an article that appeared in *QST* (August, 1993, page 22). It argued that his computer modeling revealed that although conductive guy wires do disturb the patterns of antennas mounted on towers, "these effects are of no practical importance." You can decide what works for you.

Pulling the guy wires

Once you've got the guys cut to their appropriate lengths and have them attached to the tower, you need to pull them so you can attach them to the turnbuckle at the guy anchor. One method is to pull them by hand with a moderate amount of force and then secure them to the anchor. This will deflect the tower slightly but will put some initial tension on them. Another method is to use a come-along and cable grip. Use one of your nylon slings around the guy anchor for attachment of the other end of the come-along.

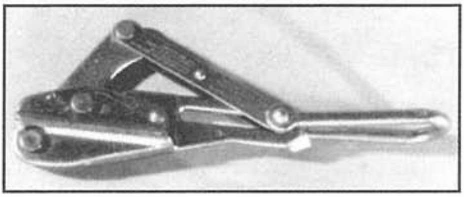


Photo 2: Klein Chicago grip.

With just one of each you'll spend a lot of time rigging and derigging it and taking from anchor to anchor. If possible, use of 3 come-alongs and 3 grips will let you do it much faster and easier. In the absence of a Klein grip or similar puller, you can use an extra Preformed grip as a temporary attachment point for your come-along. Since you'll be using it a bunch of times, you can't use it as a permanent grip but it's fine for a temporary.

Guy tension

One thing I can guarantee you is that 90% of hams don't know what their guy wire tension is and also that it's either too much or too little - usually the latter.

As far as guy wire tension, the rule of thumb is to tension the guy to 10% of its breaking strength. With $^{3}/_{16}$" EHS that would be approximately 400 pounds. How do you know when you've got the right amount of tension? One way is to put an instrument called a dynamometer in-line and measure the tension directly. They're expensive to buy ($900!), but can be rented. I found one in Seattle for $40 a day, but it took several phone calls to find it.

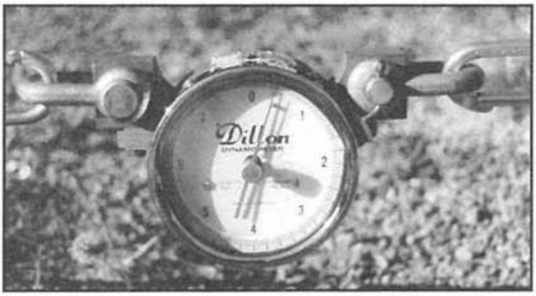


Photo 3: A Dillon Dynamometer.

An accurate, inexpensive device for measuring guy tension is now available. It's the Loos Tensionometer and was designed to be used for tensioning sailboat rigging but works very well with ham tower guys. It's also easy to use. I ran a test with the Loos against an expensive calibrated Dillon dynamometer and the Loos was surprisingly accurate. They're available from Champion Radio Products (www.championradio.com).

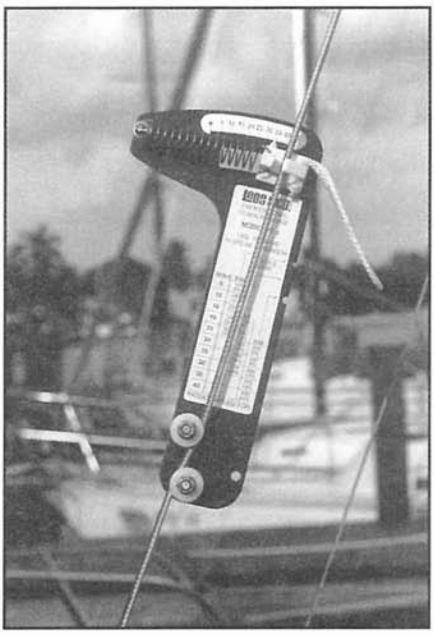


Photo 4: Loos PT-2 tension meter.

While the Loos was developed for tensioning sailboat rigging (typically

7x19 stainless steel cable), it can be used for other materials. As the tension on a cable is increased, it becomes more rod-like. I put some 3/16" EHS in series with some 3/16" 7x19 galvanized cable and a length of HPTG4000 Phillystran and put 400 pounds of tension on it. I used a recently calibrated Dillon to set the tension. Then I measured each segment of cable and they all measured within a couple of percent of the Dillon, proving the accuracy and usability of the Loos for different materials. The only caveat is that since Phillystran is typically thicker than its wire cousins, only the HPTG4000 will fit into the keeper at the top of the Loos to be measured directly. Since recommended Phillystran installation calls for steel cable from the end of the Phillystran (about 10-15' up) to the anchor, you can measure the tension on the steel with no problem. The reason for the steel down to the anchor is not only can the Phillystran be cut easily with a razor knife, but also the PVC jacket can also catch fire either from vandalism or a ground fire causing a tower failure.

Even if you have to estimate guy tension, the important point is to tighten all the guys so they're all approximately the same. Having them all equalized is mechanically important.

Safety wiring turnbuckles

The last thing you do to your guy wires is to safety wire them. The idea is to keep the turnbuckles from unwinding accidentally. Just take some pieces of leftover guy cable (you'll have lots of it) and loop it through the anchor shackle and the turnbuckles, securing the ends with a cable clamp. If you extend the safety loop thru the anchor as well, you get additional safety in case of turnbuckle failure.

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Tower erection

Okay, you've completed the permit process, you've spent the money for the tower and the holes have been installed. Now you're ready to finally start heading up—upwards toward RF nirvana. Let the erection begin!

The LXC Maxim of Manageability

As you start to construct your tower, my advice is to break everything down into bite-sized pieces and just do one step at a time. Trying to combine two or more steps in the same task is asking for trouble. What I mean is don't try to bring up the guy wires already attached to the tower section; bring them up after the section and guy brackets are installed. Don't bring the feedline up with the antenna; instead put a jumper from the feedpoint to the mast or antenna switch and bring up the feedline separately. Anytime you violate this maxim, you'll usually wind up doing things twice, along with undoing what you've already done. You'll be more efficient by doing things one step at a time.

Prepping the tower sections

For a Rohn round-legged tower such as 25G and 45G, there are several things you can do to make your job easier. Do these while the tower sections are still on the ground. First, there will be galvanizing in many of the leg bolt holes on new tower sections. They've been hot-dipped galvanized and there'll be lots of galvanizing around some of the holes. You won't be able to get your bolt through some of them without a lot of effort and gouging up the leg bolts. Rohn cautions **not** to drill them out. Use your driftpin or taper punch and a hammer to enlarge the hole. Only drill it as a last resort, and then only enough to clear out the hole.

Next, check the inside of each lower leg for that same galvanizing problem. A round file will take care of any excess inside. Believe me, it's much easier to do on the ground than up in the air.

Third, fit the sections together to insure a relatively easy fit. You may find that one leg won't line up; this isn't uncommon. With a piece of pipe or another tower section, gently bend the out-of-line leg until it slips on. This also is easier to do on the ground. Used tower sections will generally slip together more easily because they've already been installed, but pre-fitting them on the ground is always recommended. Mark both legs with tape or a felt marker to insure they go together the same way they did on the ground.

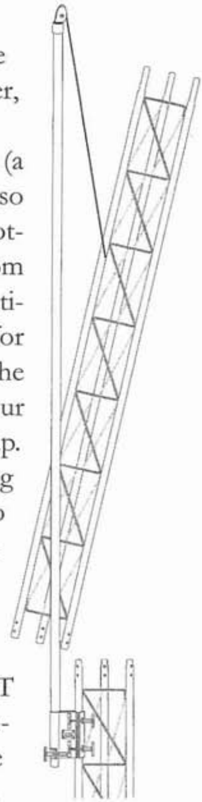
The last thing to do to your round legged-tower before you start sending the sections up is to put some grease around the inside of each lower leg. Not only will they slide on more easily during installation but also the grease will help to minimize corrosion and oxidation between the sections and make removal easier. If you skip this step, it may take a hydraulic jack or scissor jack to pry the sections apart when you want to take it down.

If you want to have the tower conductive, e.g., you're going to shunt-feed it, then use an antioxidant as the leg grease to promote good electrical contact.

Section stacking

After rigging the ginpole (the haul rope goes up the middle of the pipe, across the pulley, then down to the load), attach the leg bracket to the top of the top section, below the top brace. Make certain that it's secure before you push the ginpole mast up to the extended position where it'll be ready for the lift. Your ground crew will attach the haul rope to the section and, on the command of the tower climber, will start to pull on the haul rope.

Route the haul line through a snatch block (a snatch block is a pulley that opens up at the top so you can put it in the middle of a rope) at the bottom of the tower to transfer the hauling effort from pulling down to pulling horizontally. Pulling vertically is all arm strength plus you're a likely target for falling objects being close to the tower. Using the snatch block will let you put the rope around your hips and just walk backwards to pull the load up. You'll be using larger muscle groups, and hoisting will be much easier in addition to being able to watch the load as it's travelling and you'll be out of the danger zone.



Drawing 1: Rohn ginpole, drawing based on EF2545.

Anytime you need to hold onto a haul rope, put it around your hips, then bring the tail end or dead end in front of you. DO NOT tie the rope around your waist - this is potentially dangerous. Aiming the tail end in the same direction as the load rope, grasp both ropes with one or both hands while wearing leather gloves. This is the best way to hold onto or brake a rope load. Don't depend on just using your hands; it's not as reliable a technique and your hands will quickly tire. With the rope secured around you, you can comfortably hold it for quite some time.

The tower section should be rigged so that it goes up more or less vertically; the heavier the section, the more important this becomes. Put a sling around a leg at about 3/4 of the way up the section and that'll be your pick point. As soon as it clears the top of the tower, yell **"stop,"** then **"down slow"** when you're ready to have the section delivered where you want it.

If two legs are out of alignment, use your come-along to pull them together, or put the come-along around the bottom of the whole section and tighten it up to pull the legs together.

This is a common practice when putting up BX and Trylon towers. If you don't have a come-along, ratchet operated truck straps work great. One person on a tower doesn't have a whole lot of leverage, and if you find that the sections line up but you can't get them to slide down, get out the come-along or Tower*Jack and pull it down into place.

The Tower*Jack is a hinged device that allows additional leverage when prying sections apart or pulling them together. The latest version also has a leg aligner so you get two handy tools for the price of one. They're available from Champion Radio Products (www.championradio.com).

Stack an appropriate number of sections (typically up to the next guy point), then bring up the first set of guys and attach them. Your ground crew can use their cable grips and come-alongs to put the initial tension on them, then attach them to the anchors. You'll be able to tell them which ones to tighten and which ones to loosen as you use your level on the leg to plumb the tower. Once that's done, all you have to do it repeat the same steps until all the sections are in place and guyed.

The most important part of the tower erection to plumb is the first segment including the first set of guys. Once that segment is plumb, all you have to do is look up the face of the tower and you'll be able to see if everything above it lines up - it'll be pretty obvious. If it doesn't, just adjust the come-along or turnbuckle to get it straight.

Installing the mast

There are two methods for installing your mast. For small and medium sized masts, just use your ginpole to bring it up and drop into the tower from the top. Use a long sling as a choker by wrapping it around the mast two or three times, then put it through its own loop. The choker should be above the balance point so that the mast goes up vertically. This is relatively easy.

If you've got aspirations for big antennas or stacks of antennas, you're probably going to have a big mast. These can weigh over 100 pounds and are typically 20-plus feet long. A twenty-foot mast is about the limit for a ROHN ginpole as the net working height is only about ten-feet, plenty for a ten-foot section but marginal for a hefty twenty-foot mast. It's a lot of work to get an industrial strength mast up high enough to clear the top of the tower, then lowered down into the thrust bearing. There is a sizable pucker factor if you're the guy on the tower with this big piece of metal hanging over your head swinging around.

An easier alternative is to put the mast inside the tower at an early point, after you've got perhaps two sections, or twenty feet, of tower installed. Lift up the mast with the ginpole and, muscling it into place if necessary, lower it down so that it rests on the concrete base pad. Continue building your tower.

You'll need to bring it all the way up through the tower, through the rotator shelf and then up through the top plate and thrust bearing. This can be easily done by using the ginpole, feeding the haul line through a face of the tower near the top and lowering the haul line down the middle of the tower. Tie a choker around the mast about $^{1}/_{3}$ of the way down the mast and clip your carabiner to the haul line. Then you and a couple of friends can pull the beast up. All you have to do is to steer it through the thrust bearing and secure it. Once it is held by the thrust bearing, re-rig it to pull it up the rest of the way. The only thing you must do is slide your choker further down the mast.

Once the mast is poking up above the top of the tower slightly and is captured by the thrust bearing, this is an opportunity to install the first, or top, antenna on the mast. If you're really planning ahead, you've measured and marked where each antenna will be mounted and where the thrust bearing will be. Once the first antenna is installed, pull the mast up with the come-along to the point where you can attach the second antenna. Hoist again and you've got three antennas installed. Repeat the sequence until all the antennas are installed. Be certain to mark the spacing measurement with a felt pen while the mast is on the ground to avoid any stacking confusion.

Be very careful about your rigging and where your haul rope travels over the tower parts. Having the haul rope pass over a round brace is okay, but you don't want it to pull over something sharp, such as the edge of the rotator plate or something similar.

Each antenna on the mast should be installed with a jumper from the feedpoint (since it'll probably be out of reach) long enough to reach the mast, where it'll eventually be connected to its main feedline or relay box. Don't try to install any antenna with the entire feedline already attached. It'll give you lots of headaches during installation and you'll invariably wind up rerouting it anyway.

Antenna stacking suggestion

In most installations, I recommend placing the 40-meter beam on the bottom of the stack, just above the top of the tower. Over the years you'll typically have to do more maintenance on bigger beams than any tribanders or monobanders, and its much easier to take down and work on if it's on the bottom of the stack. The incremental increase in height as a percentage of wavelength that you gain by putting the 40-meter beam on top is not very significant overall (an additional ten feet on 40-meters is only 7% of a wavelength). I think the greatly improved ability to work on it more than makes up for any compromise in height above ground.

Installing the rotator

While the rotator is still on the ground, hook it up to the control box and test its operation. Don't wait until it's up on the tower to find out that it doesn't work. After you're assured that the operation is satisfactory, turn the rotator until it indicates north or another known direction, then get it ready for hoisting. It doesn't really matter which way the rotator is physically installed in the tower as you'll be able to orient the antennas when you mount them on the mast. If you skip this North-orientation step, you won't know what the rotator direction is once it is installed and you'll have to stop everything while you hook up the cable and control box and determine the direction. This is a waste of time; plan ahead and do this beforehand.

To haul up the rotator, clip a carabiner onto a U-bolt or thru-bolt on the neck of the rotator or put it in a bucket. Bring up the rotator, install it under the mast, let the mast down and most of the heavy work is done. While other rotators and newer Hy-Gain models have cable plugs that make it easier to do it in steps, trying to attach the rotator cable to the terminal strip on the bottom of a *T2X* or *Ham IV* is painful but manageable up on the tower. To haul up the control cable separately, simply tie a lazy overhand knot in the cable and snap that into your hauling carabiner.

I used to recommend that the weight of the mast and antenna system be taken up by the thrust bearing and not the rotator. This may be done by putting a screwdriver under the bottom of the mast, between the mast and top of the rotator, and prying up enough to lift the mast off the rotator. Tighten the thrust bearing bolts first, then the rotator U-bolts or clamp bolts. This will insure that the thrust bearing is holding the mast and antenna weight and not the rotator.

A case can be made for putting weight on the rotator. The rotators typically run on some sort of bearings and the bearings should be seated in order to operate as designed. In the case of the Orion 2800, the factory recommends that the entire weight of the system should be ON the rotator. While I'm not aware of any long-term rotator failure trends due to them not supporting any weight, it's probably best to have some weight on the rotator. This isn't a simple task (e.g. How much weight? How do you measure it?) so the choice is ultimately up to the user and I don't think you'll have a problem either way.

To minimize the possibility of bind in the rotator/mast/thrust bearing system, work your way down when doing the final tightening. Do the thrust bearing first, the rotator mast clamps next, the rotor shelf bolts, and then the rotator base bolts last.

Rotation loops

There are 2 ways to make a rotation loop for your cables. One way is to tape all the cables coming down the mast together and then allow an extra 3-4 feet before securing it to a tower leg. The bundle will have some rigidity and that will help keep it out of harm's way. Make sure that it doesn't snag on anything and you'll be good to go. The second method only works if you have a flat-topped tower. You wind the cable around the mast 2-3 times in a diameter that is smaller than the top plate so that it lays on the flat surface. This is the same method used by those pneumatic masts mounted on electronic newsgathering trucks.

Securing cables down the tower

While electrical tape doesn't have much strength, it's sufficient for a small number of cables taped to the tower leg. Additional strength can be obtained by using tie wraps. Black ones can be good in UV but white ones will deteriorate rapidly. In either case, wrapping them with a layer or two of electrical tape will prevent any UV damage.

For bigger bundles of cables or bigger, heavier cables, use of a hoisting grip is a good method. A Kellum grip is a closed woven sleeve that holds the cable like a Chinese finger puzzle – the more you pull it, the tighter it gets. They are sized very specifically. It's easy to pass a naked cable thru it but it's not easy to put a piece of RG-8 with a PL-259 on the end thru it. Andrew also makes woven hoisting grips but theirs are open and you sew them together with a supplied piece of small wire. The advantage here is that they can be installed anywhere on the cable and the grip can be pushed together to allow a connector to pass thru it.

A simpler, cheaper way to go is to use a hose clamp at the top of the tower to take the weight. Be careful not to deform the cables and this will work fine.

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Masts

The mechanical design of any antenna system is even more important than the electrical design, as a critical mechanical failure can wipe out even the best electrically designed antenna. One extremely important part of any rotating beam antenna system is the mast; the pipe which supports the antennas themselves and couples them to the rotator. A typical antenna system consists of a tower with a rotator mounted inside and several feet below the top of the tower. A mast is clamped to the rotator and extends several feet above the top of the tower. One or more beam antennas will be mounted on that mast. The "design" of the mast, in this case, consists mostly of determining the alloy and dimensions since all masts will take the same basic shape of a cylindrical tube or pipe. The design of the system will also include making sure that the antenna loads are properly distributed and not too great for the mast chosen. The overall objective is to make certain that the mast will not permanently bend when subjected to high wind forces.

The Math

The math and physics involved with mast specifications is outside the scope of this book. For the best discussion of this topic, read the excellent treatise Physical Design of Yagi Antennas by Dr. David B. Leeson, ex-W6QHS, now W6NL.[1] This is a great addition to your tower library.

Pipe vs. tubing

The industrial use and characteristics of pipe and tubing are very different. Tubing is rated for yield strength whereas pipe is typically not. Pipe is most commonly used for transporting liquids where yield strength is not a factor. Heavy duty pipe can be rated as Schedule 40, Schedule 80 or another such rating. While pipe can be very heavy, that doesn't directly translate into strength, specifically yield strength. For small sized installations where you are either installing small antennas or have them mounted right at the top of the tower, you can probably get away with pipe but it has its limitations and should be avoided if at all possible.

Table 1 - Yield Strength of Pipe and Tubing

Material	Specification	Yield Strength, lb/in^2
Pipe	A120	Not rated
	A53, A106	30,000
Drawn aluminum tube	6063-T5	15,000
	6063-T832	35,000
	6061-T6	35,000
	6063-T835	40,000
	2024-T3	42,000
Extruded aluminum tube	7075-T6	70,000
Structural steel	A36	33,000
Carbon steel, cold drawn	1016	50,000
	1022	58,000
	1026	72,000
	1026 heat treated	85,000
	1027	70,000
	1041	87,000
	1144	90,000
Alloy steel	2330	119,000
	4130 cold worked	75,000
	4340 1550 degree F quench	162,000
Stainless steel	AISI 405 cold worked	70,000
	AISI 440C heat-treated	275,000

Mast strength

When specifying a mast, it is important to choose a strong alloy.

1. David R. Lesson, "Physical Design of Yagi Antennas," (American Radio Relay League, 1992).

All metals have a property called "yield strength" which is a measure of the point at which a metal will permanently deform (bend) under stress. It is the yield strength which determines the suitability of a mast for an application; exceed the yield strength and you'll have a failure. The higher the yield strength, the better that alloy will be for a mast; also the more expensive.

Another factor beside the alloy that has a significant effect on the relative strength of a mast material is the mast fabrication process. Fabrication categories of carbon steel tubing are electric resistance welded (ERW), cold-drawn butt welded (CDBW), cold drawn (CD) and drawn over mandrel (DOM). In addition, heat treatment is a major variable in steel. It makes a big difference in strength and can be worth the additional cost.

Mast size

Just about everything having to do with HF beam installations is geared to a two-inch O.D. (outer diameter) mast. Mast mounting brackets, U-bolts, rotators, tower rotator shelves and thrust bearings are all designed around a two-inch mast. If you wind up using water pipe, it has a 1.9" O.D. and will cause your rotator to turn slightly eccentrically if you use a thrust bearing. Most VHF/UHF antenna hardware, on the other hand, is designed for masts of 1.50" to 1.75" O.D.; the standard for most TV antennas.

If you have a large array, you may chose to use a three-inch mast. ROHN makes a three-inch thrust bearing so that is no problem. The YAESU and the ORION rotators use a self-aligning mast clamp that will accommodate just about any size mast. If you standardize on two-inch hardware you won't go wrong.

Wind load

This is the term engineers use when designing towers and other structures. These are the minimums, and you should increase the wind speed figure if you live in a spot that has potentially higher wind speeds, such as on top of a ridge or near water.

Calculating wind loading is an engineering exercise explained extensively in the Leeson book. What's important here is that wind speed, along with antenna load in square feet, are the two determining factors for tower construction and mast selection.

The wind speeds for all US counties can be found in the latest TIA-222 publication and also on the Champion Radio Product website under Tech Notes (www.championradio.com/windspeed.php). It's a good idea to confirm this with your local building department since sometimes their wind speed is different (higher) than the TIA-222 rating.

There are several mast calculators available. There's at least one on the internet and you can also get an inexpensive one from Champion Radio Products; the Mast, Antenna and Rotator Calculator (MARC) Program.

You should also increase the engineering factors if you anticipate ice loading. If in doubt, you'll never go wrong by over-engineering your installation. Figures and specifications in the ROHN catalogs for amateur towers typically use 70, 90 and 110 MPH. Ninety miles per hour corresponds to a pressure of 32.4 pounds per square foot. An increase of wind speed from 90 to 100 MPH (approximately 11%) increases the pressure from 32.4 to 40.0 PSF (approximately 23%). This is not a linear relationship; a small increase in wind speed puts a lot of extra stress on an antenna system.

Table 2 - Wind Speed and Pressure

Mean Velocity	Wind Pressure
50.0 MPH	10.0 PSF
60.0 MPH	14.4 PSF
70.7 MPH	20.0 PSF
86.6 MPH	30.0 PSF
100.0 MPH	40.0 PSF
111.8 MPH	50.0 PSF
122.5 MPH	60.0 PSF

Table 3 - Sample Bending Moments & Yield Strength

Sample antenna is SteppIR element yagi with 9.7 square feet of windloading calculated with Mast, Antenna and Rotator Calculator (MARC) Program, available from www.championradio.com.

Windspeed	Antenna height above tower	Bending Moment	Recommended yield strength
70 MPH	1 foot	2344 in-lbs	15,000 psi
	5 feet	11,987 in-lbs	39,000 psi
	10 feet	24,645 in-lbs	46,000 psi
90 MPH	1 foot	3903 in-lbs	87,000 psi
	5 feet	19,962 in-lbs	46,000 psi
	10 feet	41,042 in-lbs	87,000 psi
110 MPH	1 foot	5471 in-lbs	25,000 psi
	5 feet	27,981 in-lbs	55,000 psi
	10 feet	57,527 in-lbs	115,000 psi

Aluminum masts

From the table, you can see that the yield strengths of some types of aluminum tubing will handle decent antenna loads. There are two major problems, however, even at higher yield strengths. Aluminum can provide reduced fatigue life. And aluminum will gall over time if it is subjected to rubbing against a harder material such as a steel U-bolt or SS bolt intended to pin the mast to the rotator. Be cautious about using aluminum masts in critical applications since they only have a moderate amount of yield strength, and don't use one at all if it has no alloy markings on it.

Steel mast coatings

Steel masts must be coated to prevent rusting. The most common treatment is to have the mast hot dipped galvanized. If your mast doesn't come treated this way, you may be able to get it done locally if you live in a populated area. Galvanizing costs approximately 50 cents per pound of material with a typical 100-pound minimum. If you're not able to have your mast galvanized, you can do a pretty fair job yourself. Clean the mast thoroughly with a good paint thinner, TSP or solvent, then apply a suitable coating. Two coats of a quality cold-galvanizing paint, such as the *LPS* or *Rustoleum* products, works well as do a number of marine coatings. I've tried the *Hammerite* coating and it doesn't adhere very well; it flakes off when you're working on the mast. It contains glass flakes and doesn't seem well suited to our mast application. Other steel coatings such as epoxies are available and are worth looking into especially those for marine service. Put a cap on the top of the mast to keep water out and you'll be all set.

Steps

If you're going to have more than one antenna on your mast, at some point you're going to want to be able to work on the top antenna. If it's out of reach, you'll need some steps to climb the mast. The simplest one is made out of two or three-inch steel angle iron or aluminum and a length of 15 to 18 inches is ideal. Drill two holes to take a two-inch U-bolt (if you have a two-inch mast) and install the steps at convenient distances up the mast. Install them with saddles if possible and they'll be both safe and comfortable. You may either leave them up permanently or just put them on when you need them. I always carry a couple of steps in my toolbox because I never know when I might need them. A word to the wise, file down the ends and edges of your angle iron step so that you don't gouge yourself accidentally. Welded steps are good too, just more work. If you weld steps onto the mast, weld one on each side of the mast so that you can stand and work for as long as you need.

Parking your antenna system

There is much debate on how you should park your antennas in order to minimize wind damage. Some say pointing the elements into the wind gives you the strongest material (the boom) for the wind to work against, others say that the opposite. The maximum wind load is when either the boom or the elements are at a 45 degree angle to the wind so obviously that's to be avoided. If your tower and antenna system is engineered and built to the weather conditions you'll encounter, you'll probably be okay no matter which way they're pointed. If not, be sure your homeowner's insurance is paid up and cross your fingers when those big storms roll in.

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Coaxial cable

These days it's easy to spend hundreds of dollars on coax. The price of copper hasn't gone down in recent memory; if it's been some time since you've bought any, sticker shock may well set in.

When selecting coaxial cable, there are four major areas of electrical characteristics to consider. These are attenuation, VSWR, power ratings and shielding.

Attenuation

Attenuation is the measurement of signal loss in a cable as a result of inner conductor loss, outer conductor loss, dielectric loss and radiation loss. About 90% of the attenuation comes from the inner and outer conductor loss, while about 5% to 7% is from the dielectric loss.

Attenuation may be expressed in the form of a percentage of transmission efficiency.

Total Attenuation	Efficiency
1.5 dB	**71%**
3.0 dB	**50%**
6.0 dB	**25%**

In other words, with 3 dB of attenuation, 100 watts out the back of the radio results in 50 watts at the antenna. This attenuation works on receive also; a 3 dB loss means that the received signal loses half of its signal strength as well.

Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio of the maximum voltage amplitude to the minimum voltage amplitude in a transmission line. Lengthy, authoritative tomes concerning transmission lines and loss are available to the reader and lie outside the scope of this book. For many amateurs, an SWR of less than 1.1:1 is the only acceptable reading. Other authorities have different ideas and regard high SWR as little more than a nuisance. You know which camp you're in. Sometimes variations of conductor and dielectric diameters are introduced during the manufacturing process which would affect the VSWR. These abnormalities look like bumps, corrugations or other irregularities that are visible on the jacket. These irregularities typically come when one manufacturing roll-end is spliced onto the end of another.

Power ratings

Power ratings come in two categories; peak power and average power rating. The peak power rating is limited by a voltage breakdown between the inner and outer conductors and is independent of frequency. The average power rating is governed by the safe long-term operating temperature of the dielectric material and decreases as the frequency increases.

A cable with a solid dielectric will handle higher power than a cable with a foam dielectric. *RG-8/U* with a solid dielectric will handle 5000 volts maximum while the same cable with foam dielectric only has a 600 volt rating.

Many amateur transmitter duty cycles are so low that substantial overload is permissible on current peaks so long as the SWR is relatively low, such as less than 2:1.

Shielding

This is the ability to keep unwanted signals out and wanted signals in. Most high grade coax has 96% shield while BELDEN *9913* and its relatives have 100% shield. If you don't mind hearing from your neighbors occasionally, less shielding may be worth the bargain price. Otherwise, stick to the good stuff; remember, you get what you pay for.

Connectors

Considerations should be given to connectors as well. Not only the type (*UHF/PL-259, N*-type, etc.) but also the material is important. The connector material becomes a factor over time as the material oxidizes. Gold or silver oxides are conductive while nickel oxides are ferromagnetic and can cause non-linearities and IMD problems. Silver connectors should be your long-term choice. They also take solder more easily than their nickel-plated cousins.

So far as peak power handling ratings of connectors, both UHF and *N*-types are rated at 2.0 kV DC voltage with a peak power of 10KW at a VSWR of 1.0. Anyone who's tried to run 5KW into *RG-8/U* with *PL-259*'s on it will tell you that those figures are probably optimistic.

For VHF/UHF or even serious HF applications, *N*-type connectors are the preferred ones. They have slightly less insertion loss than *PL-259*'s but their main advantage is that, unlike *PL-259*'s, they are waterproof; there is a rubber O-ring gasket between connectors that insures that no water can get in. They're more expensive and you'll have to stock up on adaptors, elbows, barrels, etc. but it might just be worth it. For VHF/UHF applications, it is a given that you should use them.

Velocity factor

The speed of RF travelling through coax is determined by the dielectric material used in the core. Solid polyethylene, such as used in *RG-213,* will slow the signal to 66% the speed of light.

Impedance

Although coaxial cable can be manufactured for any impedance value from 35-ohms to 185-ohms, the most common coaxial cable impedance used by amateurs is 50-ohms. Transmitters, low-pass filters, amplifiers and antennas are generally designed for 50-ohm unbalanced operation. The reason for the 50-ohm characteristic is that it is a compromise between low attenuation (75-ohms) and power handling capability (30-ohms).

Bending radius

A normal amateur installation will create bends and turns in the feedline run. Bending coax is acceptable as long as the minimum bending radius is not violated. A typical bending radius is a multiple of the coax diameter. For example, a common spec for RG-8 minimum bending radius is 4 inches, which is a multiple of 8 (1/2" OD X 8). There is a bending radius parameter for all coax cables so do your homework and treat the coax with care. Coax with more rigid shield materials will have a larger bending radius.

RG-8/U vs *RG-213*

The most common coax used for amateur applications is *RG-8/U.* Although one brand of *RG-8/U* is basically the same as any other brand, there is often a significant difference in the quality and cost of the materials and in the manufacturing consistency and quality. As with many other things, with coax you get what you pay for. The easiest way for manufacturers to cut the cost of their coax is to cut down the amount of copper braid in the shield. A shield coverage of 97% indicates a high-quality coax, but if you can see a lot of dielectric showing through the braid, it's probably a lower grade coax. *RG-8/U* has a cellular polyethylene (or foam) inner dielectric and a black PVC jacket.

Many amateurs insist on using *RG-213/U* which, although it is slightly lossier that *RG-8/U,* offers two significant benefits. First, *RG-213/U* is a designation that can only be used by cables manufactured to the military specification for that cable, both for materials as well as manufacturing processes. This results in a more consistent product that doesn't have sloppy splices in the middle of it. Using *RG-213/U* minimizes this kind of potential problem.

Another advantage of *RG-213/U* is that the jacket is made from non-contaminating PVC unlike regular *RG-8/U.* Any cable used outdoors is subject to years of sunlight abuse. The UV radiation from sunlight causes a chemical reaction with the standard PVC jacket material and the chloride from the jacket material (polyvinyl chloride, remember?) starts to migrate, or leach, toward the inner dielectric and through the copper braid. Not only does the braid get all gummed up, but also it degrades the performance of the coax and it only gets worse over time. In an extreme case, the chloride will coat each strand of braid and actually insulate each strand from the others. You'll have continuity on each strand but not from one to the other. The SWR of the coax (not the antenna) will rise over time due to this feedline degradation and you'll have to replace it. If you are in the Sunbelt or are at a higher than average elevation, the non-contaminating jacket is probably mandatory. In the cloudy Pacific Northwest, it is not as critical for long-term reliability.

A disadvantage of RG-8 with foam dielectric is that the foam will cold flow over time. That is the center conductor will actually move in the dielectric over several years. This usually isn't a big deal if you don't have any significant bends in your RG-8, but does become a problem if you've wound a coaxial choke balun for your antenna and it's in full sunlight. In that case the cable gets hot enough to soften up.

Many hams consider only the BELDEN brand of cables. BELDEN is recognized as a quality manufacturer of many different kinds of professional cables and typically their prices are higher. Other manufacturers offer competing products and are often many times less expensive. In addition to COLUMBIA and TIME cable products, there are other brands that are worth a look. Don't be afraid to consider other brands to save some money.

Connectors and jumpers

Feel free to use as many connectors as you want in a feedline – the loss is very small. From EE school lab work by Gary Nieborsky, K7FR, his measured connector loss is 0.008 dB or less per connector so the only things you have to worry about is using the right connectors and making sure that there is no water incursion, which is the biggest factor in amateur coax failures.

Cheap dBs?

What does all this mean? To a ham with a tribander at fifty-feet, probably not a whole lot. Just use good coax and enjoy operating. But if you want to improve your signal, you might want to dig a little deeper.

The first thing to consider is to use larger diameter cable, specifically CATV or other hardline. This will significantly decrease your attenuation. A contester and DX'er, Paul Reiter, WY7I, gave himself a boost in RF output by installing 72-ohm CATV hardline up to his antenna. He started getting terrific comments from DX stations about his loud signal and attributes it (correctly) to his reduced transmitted signal loss (attenuation) by using the big hardline. By the way, he was feeding a *TH7DX* with a short jumper of *RG-8* after leaving the 72-ohm hardline. It makes for slightly increased SWR, but the higher signal and efficiency more than make up for the slight feedline impedance mismatch.

Free CATV roll-ends from your local cable company are always welcome, but let's suppose that you are trying to decide if real live ANDREW *Heliax*® is worth the investment. Let's also suppose that your run is going to be 250 feet from the antenna to the output of your RF source. Here are several typical configurations:

Cable Type	Total Loss dB at 30 mHz
RG-213 with *PL-259*'s	3.45
RG-213 with *N* connectors	3.33
RG-8 foam (*8214* type) with *PL-259*'s	2.45
RG-8 foam with *N* connectors	2.33
ANDREW *Heliax* ½" with *PL-259*'s	1.17
ANDREW *Heliax* ½" with *N*-connectors	.96
ANDREW *Heliax* 7/8" with *PL-259*'s	.94
ANDREW *Heliax* 7/8" with *N*-connectors	.60

It's obvious that the upgrade from *RG-213* with *PL259*'s to ½" *Heliax* with *N*-connectors is worth almost 2.5 dBs. Many DX'ers and contesters say that a 1 dB change is worth chasing; that would make this a most worthwhile improvement!

The next improvement you make to your station might well be to upgrade your feedlines and take advantage of the gain (actually reduced attenuation) involved. This is something that will benefit QRO'ers and QRP'ers alike. Of course, the free cable TV hardline is an attractive alternative. But even if you purchase the coax new, the economics still make sense.

Hardline connectors

There have been dozens of schemes over the years to use plumbing hardware or other materials to fabricate something that you can plug a *PL-259* into. Some of the ideas seen seem simple and reliable while others are not. If you're going to do it yourself, stay away from dissimilar metals and make certain the connection is waterproof. Otherwise my recommendation is to buy and use the connectors from the manufacturer. You've already saved a ton of money by getting the hardline free, now spend a bit to get some good connectors. If you can only afford one, get one for the end out in the weather and fabricate the one in the shack. That should minimize your potential problems.

Burying coax

There are several reasons why you might choose to go to all the work of burying your coax. One is that direct burial cable is virtually free from storm and UV damage, and usually has lower maintenance cost than cable that is out in the open. Another reason might be aesthetics; a buried cable will be acceptable in almost all communities. Also, being underground does a great job of de-coupling the feedline that minimizes inter-station interference as well as RFI.

Although any cable **can** be buried, a cable that is specifically designed for direct burial will have a longer life. The best cable to use is one that has a high-density polyethylene jacket because it is both nonporous and will take a relatively high amount of compressive loads. In some direct burial cables, an additional moisture barrier of polyethylene grease may be applied under the jacket; this allows the material to leak out, thus "healing" small jacket penetrations.

Here are some direct burial tips:

1. Because the outer jacket is the cable's first line of defense, any steps which can be taken to prevent damage to it will go a long way toward maintaining the internal characteristics of the cable.

2. Bury the cable in sand or finely pulverized dirt, without sharp stones, cinders or rubble. If the soil in the trench does not meet these requirements, tamp four to six inches of sand into the trench, lay the cable and tamp another six to eleven inches of sand above it. A creosoted or pressure-treated board placed in the trench above the sand prior to backfilling, will provide some protection against subsequent damage that could be caused by digging or driving stakes.

3. Lay the cable in the trench with some slack. A tightly stretched cable is more likely to be damaged as the fill material is tamped.

4. Examine the cable as it is being installed to be sure the jacket has not been damaged during storage or by being dragged over

sharp edges.

5. You may want to consider burying it in plastic pipe which is then used as a conduit. Be careful to drill holes in the bottom of the pipe at all low spots so that any moisture can drain out.

6. It is important that burial is below the frost line to avoid damage by the expansion and contraction of the earth during freezing and thawing of the earth, and any water surrounding the buried cables.

While PVC pipe provides a mechanical barrier, water egress is practically guaranteed - you can't keep it out. It'll either leak in directly or will condense from moisture in the air. Use the perforated type so that any water will just drain out harmlessly.

Here's a handy reference table of coax losses for amateur bands. Thanks to Frank Donovan, W3LPL, who put it together and made it available.

Table 1 - Coax Types and Attenuation
Cable Attenuation (dB per 100 feet)

	1.8	3.6	7.1	14.2	21.2	28.4	50.1	144	440	1296
LDF7-50A	.03	.04	.06	.08	.10	.12	.16	.27	0.5	0.9
FHJ-7	.03	.05	.07	.10	.12	.15	.20	.37	0.8	1.7
LDF5-50A	.04	.06	.09	.14	.17	.19	.26	.45	0.8	1.5
FXA78-50J	.06	.08	.13	.17	.23	.27	.39	.77	1.4	2.8
3/4" CATV	.06	.08	.13	.17	.23	.26	.38	.62	1.7	3.0
LDF4-50A	.09	.13	.17	.25	.31	.36	.48	.84	1.4	2.5
RG-17	.10	.13	.18	.27	.34	.40	.50	1.3	2.5	5.0
LMR-600	.10	.15	.20	.29	.35	.41	.55	.94	1.7	3.1
SLA12-50J	.11	.15	.20	.28	.35	.42	.56	1.0	1.9	3.0
FXA12-50J	.12	.16	.22	.33	.40	.47	.65	1.2	2.1	4.0
FXA38-50J	.16	.23	.31	.45	.53	.64	.85	1.5	2.7	4.9
9913	.16	.23	.31	.45	.53	.64	.92	1.6	2.7	5.0
LMR-400	.16	.23	.32	.46	.56	.65	.87	1.5	2.7	4.7
RG-213	.25	.37	.55	.75	1.0	1.2	1.6	2.8	5.1	10.0
RG-8X	.49	.68	1.0	1.4	1.7	1.9	2.5	4.5	8.4	13.2

Table 2 - Coax Types and Attenuation Cable Attenuation (feet per dB)

	1.8	3.6	7.1	14.2	21.2	28.4	50.1	144	440	1296
LDF7-50A	3333	2500	1666	1250	1000	833	625	370	200	110
FHJ-7	2775	2080	1390	1040	833	667	520	310	165	92
LDF5-50A	2108	1490	1064	750	611	526	393	227	125	69
FXA78-50J	1666	1250	769	588	435	370	256	130	71	36
3/4" CATV	1666	1250	769	588	435	385	275	161	59	33
LDF4-50A	1145	809	579	409	333	287	215	125	70	39
RG-17	1000	769	556	370	294	250	200	77	40	20
LMR-600	973	688	492	347	283	244	182	106	59	33
SLA12-50J	909	667	500	355	285	235	175	100	53	34
FXA12-50J	834	625	455	300	250	210	150	83	48	25
FXA38-50J	625	435	320	220	190	155	115	67	37	20
9913	625	435	320	220	190	155	110	62	37	20
LMR-400	613	436	310	219	179	154	115	67	38	21
RG-213	397	279	197	137	111	95	69	38	19	9
RG-8X	257	181	128	90	74	63	47	27	14	8

Table 3 - Coax Types and Attenuation Feet Required for 1 dB Advantage LDF5-50A vs:

	1.8	3.6	7.1	14.2	21.2	28.4	50.1	144	440	1296
LDF7-50A	2500	1430	1250	910	715	625	475	279	158	90
RG-17	1666	1430	1110	770	560	475	420	120	60	30
FXA12-50J	1250	1000	770	525	435	355	255	120	75	40
9913	935	590	455	320	280	220	150	85	53	29

Table 4 - Coax Types and Attenuation Feet Required for 1 dB Advantage LDF4-50A vs:

	1.8	3.6	7.1	14.2	21.2	28.4	50.1	144	440	1296
RG-17	-	-	-	-	-	-	-	220	90	40
FXA12-50J	-	-	2000	1250	1100	835	625	250	145	65
9913	1430	1000	715	500	455	345	235	135	75	40
RG-213	618	434	306	212	171	146	106	58	29	14

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Weatherproofing

The primary purpose of weatherproofing is to keep out moisture and contaminants from your coax electrical connections. Whether it's rain or condensation, water in a connector cable can put you off the air.

Electrical tape

Every amateur installation has many feet of electrical tape used outdoors in a variety of applications. The '3 rolls for $1' hardware store specials are **not** recommended for demanding outdoor use, particularly for weatherproofing. *Scotch* (TM) *Super 88* is just about mandatory. Besides being conformable to 0°F (-18°C), it will perform continuously in ambient temperatures of up to 220°F (105°C) and it is UV resistant. The data sheet says it provides "moisture-tight electrical protection" and it retails in the $4 to $5 range. Another *Scotch* tape, *Super 33+*, is another "premium grade, all-weather vinyl insulating tape" with many of the same properties and specs as the *Super 88*. The only difference is that *Super 88* is slightly thicker than *Super 33+ (10 mils for 88 vs. 7 mils for 33+)*. Both tapes are easily applied at low temperatures, and will even stick to a wet aluminum antenna boom.

Another specialized tape is the SCOTCH *130C Linerless Rubber Splicing Tape.* This is a fairly thick (30 mils vs. 7 mils for *Super 33+*) tape, is intended for high-voltage splices and is moisture-sealing. 3M makes many products for demanding electrical use - these are just several of them. You may have your own favorite.

Weatherproof connector joints

Properly sealed connector joints will be very effective and reliable in maintaining electrical and mechanical integrity. Here's how to do it:

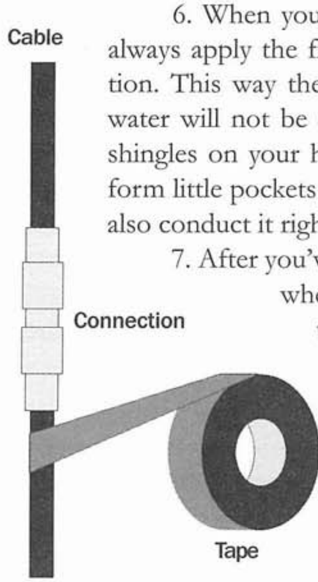
1. Install and solder the connector correctly on the end of the coax. If you've done dozens of connectors, you know how to do it. If you're not sure, have someone check your work and don't scrimp on the solder. For the best results, you may want to use silver solder on your outdoor connections.

2. Always use two pairs of pliers or channelocks when seating the connector to a female *SO-239* or barrel connector. Hand tightened connections are **not** tight enough! Do not crimp or deform the connector.

3. Apply two wraps of premium electrical tape (*Scotch 33+* or *88*).

4. Apply a layer of vapor-wrap material. Avoid *CoaxSeal* if possible, as it cracks and dries out as it ages. Do not put *CoaxSeal* directly on a connector; the connector will be unusable once it is removed. You will have to cut it off and throw it away because the *CoaxSeal* changes your *PL-259* into a gooey mess. By putting one or two wraps of tape over the joint first, your connector will be protected from the vapor-wrap and it will look as good as new if you ever have to take it apart. To remove, simply take your razor knife, slice down the joint and peel off the weatherproofing. Vapor-wrap is simply a butyl rubber material that comes in rolls or sheets and does an excellent job of isolating the joint from the elements. A better vapor-wrap is the commercial vapor-wrap variety, such as Andrew or db Products. It won't stick to connectors and comes off easily and is handled by Champion Radio Products.

5. Apply two or three layers of tape over the vapor-wrap.



Drawing 1: The proper way to put the final wrap on vertically running coax joint.

6. When your coax joint will be running vertically, always apply the final layer of tape in an **upward** direction. This way the tape will overlap in such a way that water will not be conducted into the tape laps (like the shingles on your house). Tape wrapped downwards will form little pockets that will not only trap the rain but will also conduct it right into your joint.

7. After you've torn or cut the tape, do not stretch it when applying the final few inches. Let the tape relax, **then** attach it. If you put it on under tension, it will "flag" which is the technical name for that loose tape end that is flapping around in the breeze.

8. Paint the whole joint with a protective layer; e.g., clear acrylic spray paint. That joint should never fail. (Some people like to use ScotchKote but it's meant for buried applications and is not UV resistant so it'll flake off in a year or two.)

Shrink-fit tubing

Although shrink-fit tubing has been available for years, a new wrinkle for coax joints is shrink-fit tubing with glue impregnated along the inside. As you apply heat to the shrink-fit, it shrinks while the glue melts and oozes inside between the fitting and the tubing. It not only keeps the tubing from slipping, but it also fills in the voids in the joint and provides an additional seal. It's an expensive alternative (approximately $1 per inch) but is very simple to use and remove if necessary.

Feedpoints

The feedpoint of your yagi or wire antenna should also be weatherproofed. For commercially made baluns, just use the methods described above. For wires attached to feedpoints or dipoles, just do the best that you can. For bare nut and bolt connections, you can put a little ball of vapor wrap over the connection. That'll do an excellent job of weatherproofing it. You'll probably have some dissimilar metals so I would be sure to use only stainless steel hardware and some type of appropriate antioxidant on the connection. Also, use silver solder if you have to solder anything.

Silicon caulking

I never put silicon caulking material (RTV - room temperature vulcanizing) on anything that needs to conduct electricity, especially antennas or coax joints. Silicon cures by absorbing moisture out of the air. It also releases or outgasses a solvent material (acetic acid) during the curing process. This is that 'greasy' feeling that you get after handling silicon that's been curing for awhile. What you wind up with is a connector that not only is absorbing moisture but also is giving off a solvent that will migrate into your connector and cause it problems—a double whammy! If you must use RTV, use the aquarium type or Dow Corning *3145 RTV Adhesive Sealant* for best results and reliability. This RTV doesn't have the outgas problem.

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Rotators

Rotators may be categorized as one of those necessary evils—sometimes you can't live with them and you can't live without them. While rotators enable us to turn our directional antennas in a desired heading, they are frequently the weakest link in many antenna systems. Anytime you have an electromechanical device such as a rotator, you have a number of scenarios for failure—and usually at a most inconvenient time!

Brakeless wonders

At the bottom of the rotator totem pole are the "brakeless wonders." These are rotators designed primarily for TV antennas or lightweight amateur arrays; they don't have a brake built into them. Instead of a brake, they typically have some way of adding resistance to applied wind forces, such as a cork pad. These rotators include the Hy-Gain by Telex *TR44, CD45*, the Yaesu *G-450XL* and the now defunct Alliance *HD73*. Small tribanders and VHF/UHF antennas are suitable applications for this class of rotator. The lack of a brake means they will turn in the wind, but they will give reasonable duty for the price for modest installations.

HAM-IV'S and *T2X Tailtwisters*

Larger loads need a rotator with a real live brake to hold the antenna when the wind blows. The entry level rotator here is the HY-GAIN *HAM IV*. It has a solenoid operated brake and will generally handle big tribanders or small stacks. Its bigger brother, the *T2X Tailtwister,* is a physically stronger rotator for a larger dollar investment. The added strength of the *T2X* comes from larger body castings, and it also contains more ball bearings to accommodate heavier loads. Internally, the parts are the same for both the *HAM IV* and the *T2X;* same motor, same gears, same almost everything.

The good news is that the *HAM IV/T2X* have become the de-facto standards for American hams. This means all towers are built for their bolt pattern. This also means parts are readily available and you can even make repairs yourself. And that means you can find them just about everywhere, including your local ham radio flea market.

The bad news is that the weaknesses and fixes for these rotators are well documented; e.g. indicator potentiometers and brakes. These rotators are very sensitive to voltage drop so be certain to use the recommended wire sizes or put up with the resultant problems. An emergency first aid kit for these rotators should include a few fuses - there are two - and a spare motor starting capacitor.

Other rotators

Hy-Gain also manufactures the HDR-300. This is an off-the-shelf transmission with a 1 rpm motor. Hy-Gain adds the brake and indicator/control system and you get a medium duty rotator with a couple of limitations; the splined output shaft and the brake effectiveness are both troublesome

Craig Henderson, N8DJB (www.rotordoc.com), is one of the leading Hy-Gain rotator repair guys in the country. After fixing hundreds of them, he has come out with his own rotator - the CATS RD-1100. It's well engineered, robust and has a smaller footprint than the T2X, making it suitable for Rohn 25G installations.

Mike Staal, K6MYC, through his company M² ANTENNAS, produces the *Orion OR-2800* rotator. It features a worm gear design and a digital control box with presets and computer interface. A large antenna system, such as a stack of monobanders, is a candidate for an Orion. This is a simple, powerful rotator but has a user unfriendly control box and the mast clamp has 2 fatal problems – clamp teeth that only give less than an estimated ½ sq. in. of mast contact area and dimpled fastener surfaces that eventually flatten out, permitting the mast to slip. These two design flaws will let the clamp loosen up. In my almost 20 years of tower work I've installed dozens of these rotators and virtually 100% of them loosened up over time.

The TIC GENERAL *Ring* rotators have been out for over ten years and offer a unique solution to the problem of turning an antenna around a tower on a sidemount. They have not yet established themselves as the ultimate answer to sidemounting antennas.

A recent entry into the side-mounted rotator category is the Orbital Ring Rotator by Rich Bennett, K0XG (www.K0XG.com). Like all of his products, it is a very robust device with a large capacity.

Recent entries in the rotator market include the AlfaSpid – an impressive little rotator with a worm gear drive imported from Poland – and the Prosistel line of Big Boy worm gear drive rotators manufactured in Italy that have medium to heavy-duty capacity.

Japanese rotators

Japanese rotators are impressively designed and manufactured, and have made a dent in the US market. They seem to suffer fewer problems in the reliability area compared to other rotators, however repair and parts availability has been their weakness. Another minor drawback is that you need metric tools to work on them. Although the self-centering clamshell mast clamp that many of these rotators use is an innovative design, most of them are made from cast aluminum pot metal and can be easily broken during normal installation. YAESU, EMOTO and CREATE rotators were all imported from Japan, but the Yaesu are the only ones currently available. The Yaesus have established themselves as reliable rotators with nice analog control boxes, an adjustable preset on most models, and a rotation overlap that gives 450 degree coverage.

Prop pitches

Many serious antenna systems have been built around prop pitch rotators. Having an incredible 9,576 to 1 gear reduction and built to military specifications, prop pitch motors have proven themselves to be reliable as well as robust. They are the transmissions from propeller driven aircraft and primarily from World War II. They were the motors that changed the pitch of the propellers and are behind those round cans that stick out of the middle of the propellers.

Many have been up for twenty years or more and are still operating. The biggest problem these days is that the supply is dwindling. You won't find them at every hamfest anymore but they are still available if you go looking. With the decreased supply comes increased cost. When you consider the alternatives, an investment of $1,000 or more in a prop pitch doesn't seem outrageous. Considering what other new heavy duty rotators sell for, you can get a rotator that will turn your house if necessary and will last for years for about the same amount of money. Nothing else comes close.

With a prop pitch, you'll have to supply the power and the directional indicator. The power is fairly easy; you need 28 VDC at at least 10 amps. Although 28 VAC can be used, DC is much easier on the motor. You can use 14AWG or similar wire with little voltage drop (not a big deal with prop pitches); simply use the three wires for left and right rotation. Be sure to put bypass capacitors on the brush leads or you'll have your own spark generator trashing the bands everytime you turn your antenna.

The indicator problem also has an easy solution. Although it's impossible to get a prop pitch at a flea market for under $100 anymore, you can still get selsyns for $5 and less. A selsyn is a mechanism consisting of two units connected by wires where turning one of the two will turn the other one the same amount. After you've found a compatible pair (same number of wires with same voltage and connections), fabricate a mounting arrangement that will secure the tower selsyn close to the mast. Mounting it upside-down will prevent water from running down the output shaft into the selsyn itself. Hose clamps will be quite handy for this part of the operation.

You have two choices for coupling the selsyn to the mast. One method is to have two identical gear sprockets; one on the mast and the other on the shaft of the selsyn. The only tricky part is getting the sprocket around the mast. Another way is to mount a pulley onto the selsyn shaft that is the same diameter as the mast. Then all you need to do is put a belt of some sort around both of them. I've seen long springs used, as well as good sized fishing line, to provide the linkage. Another option is to use a small belt of some kind. As long as it is fairly impervious to weather and UV proof, just about any arrangement will work.

Rather than fabricating your own controller, the Green Heron RT-21 will work with virtually any rotator and is also user friendly. It is computer compatible and has many nice features.

An easier way to use a prop pitch is to buy one all ready to from Kurt Andress, K7NV. His work is gorgeous and it comes complete and ready to use. A Green Heron control box and custom mast clamp are also available. www.k7nv.com

Rotator loading

Rotator manufacturers have found that the square footage of an antenna doesn't accurately reflect the loads placed on a rotator.

Table 1 - Rotator Specs

Rotator	Rotating Torque, in.-lb.	Brake Torque, in.-lb.
Create RC5-1	500	6000
Create RC5-3	500	6000
Prosistel 641D	570	3135
Hy-Gain Ham IV/V	800	5000
C.A.T.S RL-1100	800	4000
Yaesu G-800	950	3450
Yaesu G-1000	950	5200
Hy-Gain Tailtwister	1000	9000
Prosistel 2051D	1255	7125
AlfaSpid RAK @ 12V	1400	14,000
Create RC5A-2	1400	13,000
Create RC5A-3	1400	13,000
AlfaSpid RAK @ 18V	1800	14,000
Create RC5B-3	1910	17,000
Prosistel 61D	2150	16,530
Yaesu G2800DXA	2170	21,700
M2 Orion 2800	2800	17,000
AlfaSpid RAK @ 24V	3240	14,000
Hy-Gain HDR300	5000	7500
AlfaSpid Big RAK @ 12V	5000	24,000
TIC Ringrotor 1022D (1 motor)	6500	6500
Prosistel PST 61DHP	7640	16,530
TIC Ringrotor 1032D (1 motor)	7881	7530
Prosistel 71D	7980	30,400
AlfaSpid Big RAK @ 18V	> 8000	24,000
TIC Ringrotor 1022D (2 motors)	11,500	6500
TIC Ringrotor 1032D (2 motors)	13,467	7530
Small prop pitch	16,000	Unknown but robust

The problem is that a square footage figure doesn't represent the torque or rotating moment. Two antennas with the same surface area could put drastically different loads on the rotator. As a result, two rotator manufacturers have come up with their own method of calculating rotator loading. HY-GAIN uses a measurement called "Effective Moment," which is defined as the product of an antenna's weight (or mass) and its turning radius. YAESU's "K-Factor" is the same as the HY-GAIN "Effective Moment." Use this calculation to more accurately select the proper rotator for your installation.

Rotator torque

While the above rotator ratings have to do with antenna wind loading, the rotator must have sufficient starting torque to start the mast and antenna system into rotation. It must also have sufficient braking torque to hold the antenna in the wind.

More nuts and bolts

It's probably not surprising that most rotator failure problems are caused by overloading. Big winds produce big forces on the whole antenna system; a lot of these forces travel down the mast to the rotator. People ask if they should pin their rotator through their mast with a long bolt, to prevent the mast from turning in the rotator during a wind storm. What happens if you do is that now you'll find the **next** weak point in your system, and it's usually an internal gear or part.

The Yaesu rotators do come with a bolt for pinning the mast while other manufacturers say that pinning the mast will void the warranty so use your best judgment and experience to decide whether to do it or not.

By the way, if the wind does turn your antenna out of alignment, simply point the antenna when it's parked in a direction such that the next windstorm will blow it back into alignment. You know what your prevailing wind direction is, just use the wind to put your antenna back where it belongs.

Thrust bearings

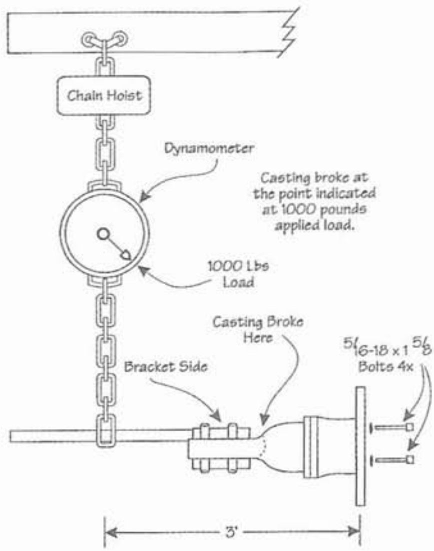
The purpose of a thrust bearing is to bear the vertical and horizontal load of the mast and antennas of the system. Use only outdoor rated thrust bearings. You'll recognize these as being galvanized or made from aluminum. Do not use any bearing made for indoor use, such as machinist pillow blocks or wheel bearings. Generally, do not use any bearing that uses a single Allen screw to secure the shaft. The Allen screw and the bearings will rust and seize in a few short years and you'll have a stuck antenna system and a genuine repair problem. If you're not sure, just leave the bearing out in the backyard for a few weeks and see what happens. If no rust appears, you can probably use it. If you do get rust spots, throw into the recycle bin. This will save you a lot of future anguish.

A word of warning

There is one primary rule when it comes to rotators; **never** install a rotator that is more than five years old without having it inspected and refurbished. If all you have to do is grease the bearings, you'll still be doing yourself and your rotator a favor. Any older rotator is a time bomb waiting to go off—and fail. Don't believe the guy at the flea market where you bought it who told you it had just been "rebuilt". Go through it yourself or have someone capable go through it. Don't say you haven't been warned!

Rotator destruct test

Back in the 90's I was working at the Hy-Gain factory in Lincoln, NE, and we had a customer that wanted to know how much bending stress a TailTwister (T2X) would take, so we put one in the lab and found out. The drawing shows the test set-up, and it went to 3,000 foot-lbs. before the rotator neck broke. That's a lot of force.



Drawing 1: Hy-Gain lab destruct test lab set-up.

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Installing beams

After you've invested a significant amount of time, energy and money putting up your tower, next comes the challenge of getting your new flamethrowers mounted on the top of the installation. Big yagis are a handful, whether they're on the ground or up in the air. Installing them on a tower can be a long and arduous undertaking.

While there are various ways to rig an antenna for hoisting, two methods are normally used.

Sling rigged

Once again we use our old friends, the nylon slings as chokers. I prefer to use long slings (six-foot or more) for rigging the boom. Install one sling on each side of the center mounting point of the antenna with two or three wraps around the boom; then bring them together so that the pick point is right above where the boom plate will attach to the mast. This assures that the antenna is balanced and will arrive in the correct mounting position. Using two slings on the boom enables you to hoist the beam up into position horizontally. Even if the antenna is mechanically off balance, you can adjust the slings so that it will remain basically horizontal. With antennas that have the elements mounted above the boom (such as M^2 and SteppIR), the antenna will attempt to "turtle," or flip over, if given the chance. You can minimize that tendency by tying the slings with opposite wraps (one around the boom in one direction, the other wrapped in the other direction).

Lifting torque arm

A lifting torque arm (LTA) is a long plate which attaches vertically to the boom of the antenna with U-bolts and is the attachment point for the haul line. The long (18 to 24 inches) size of the LTA acts as a torque arm to keep the boom horizontal. The longer the LTA, the more torque it will exert; also the more clearance you'll need up at the mast in order to get it into position. The main drawbacks of the LTA are that the LTA will be offset from where the boom mounting plate is (a major hassle if you're the person on the tower that has to wrestle it into place) and it doesn't do a very good job with an out-of-balance load.

A similar device is called a tiller. It can be shorter than the LTA and extends parallel up the tramline. The upward end of it slides along the tramline via a carabiner or other clamp thus holding the beam in a pre-determined attitude, typically where the elements will clear the top guywires or any other potential obstructions. It can be as simple as a 2-4' long piece of angle U-bolted to the boom.

Hoisting the antenna

Unless otherwise noted, the boom of the antenna should always be horizontal when lifted. The "dead lift" is simply pulling the horizontal antenna straight up the tower. On a self-supporting tower, this is the easiest way to do it. With a guyed tower, you can spend a lot of effort threading the antenna through the guy wires, a technique Tom Schiller, N6BT, describes in his book "Array of Light" the "wig wag" technique. It brings the antenna up horizontally but then threads it through the guy wires. This is very useful where you don't have enough room for a tramline system or have some other limitations. I use it occasionally and it's a nifty alternative.

Another variation is the "boom vertical dead lift." This is also a lot of work and you must still thread the antenna through the guys.

Also, you must tip the antenna back to horizontal once it's up to its mounting position. I've never used this technique and it certainly does have its limitations.

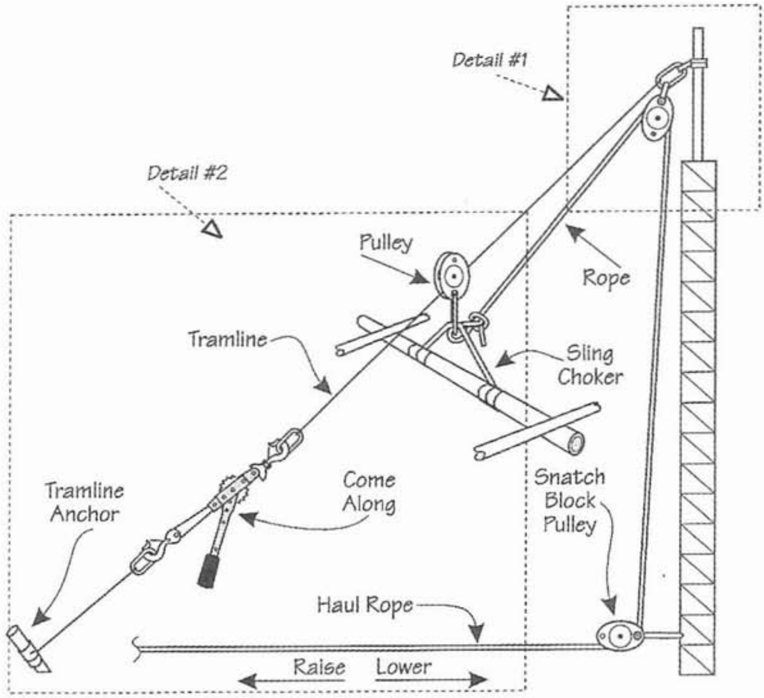
Another option is to assemble the antenna at the top or on the tower. For large arrays, this can be quite useful, particularly if you can pivot the boom during assembly. Again, this involves a lot of work - let's face it, they're all a lot of work! - and a special antenna mount that will allow the antenna to pivot.

For some installations, "skyhooks" may be the only practical solution. These are typically the most dollar intensive. Cranes with 140-foot jibs can cost $150 or more per hour. Helicopters can be just the ticket for some installations. They run around $500 per hour in the Pacific Northwest but can often accomplish a very difficult installation quickly; they can thus become cost effective. Two things you must keep in mind when working with helicopters; their downdraft creates a terrific amount of static electricity; you'll need some way to bleed off the charge or you'll get zapped. It's not dangerous but it's a jolt. Also it only takes around fifteen-pounds pressure to move a chopper. Remember, it's in equilibrium when it's hovering and it doesn't take much to move it. Just grab the load and pull it to where you want it. Left, right, up, down—it's an easy maneuver. An exciting maneuver, but an easy one. Hot air balloons are also used occasionally with some success, but can present problems on days that are not virtually windless.

Using a tramline

In my opinion, tramming is usually the only way to go. A tram system is where the load is suspended below the tramline and I use it for most antenna raising projects on towers, and even on trees. This is **not** the technique that uses two ropes stretched out parallel with the antenna sitting on top of two lines running from the ground to the tower - that's the trolley technique. That method is a real headache; the ropes are difficult to equalize and they'll oscillate, the beam gets real tipsy as you get to the top of the trolley lines and there's a lot of drag resistance as you pull the antenna up the ropes. This is a method to be avoided!

My preference is to use one steel tram line with the antenna suspended below the tram wire. You'll need three pulleys, a haul line,



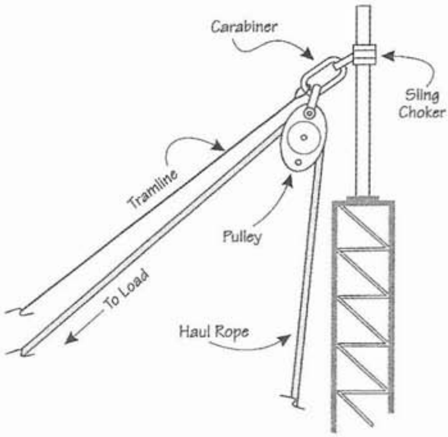
Drawing 1: Tramline schematic.

a length of wire rope for the tram line, an anchor on the ground and miscellaneous slings and carabiners. First, secure a sling choker on the mast about three feet above the place where the antenna will be mounted. Use two or three wraps and bring the choker through itself as described earlier.

Clip a carabiner or shackle to the tail of the sling. Then clip a pulley into the carabiner. Bring up one end of your tram line and clip it into the same carabiner.

Run your haul rope from below, through the back of the pulley, then out the front in the direction of your ground anchor. You may lower the end of the haul rope directly to the ground or you may clip your haul-rope end carabiner onto the tram line and let it slide down the wire. Small diameter aircraft cable or wire rope such as 1/8" or 3/16" is sufficient to take the static load of just about any amateur antenna.

You may have to drop one or two of the guy wires closest to



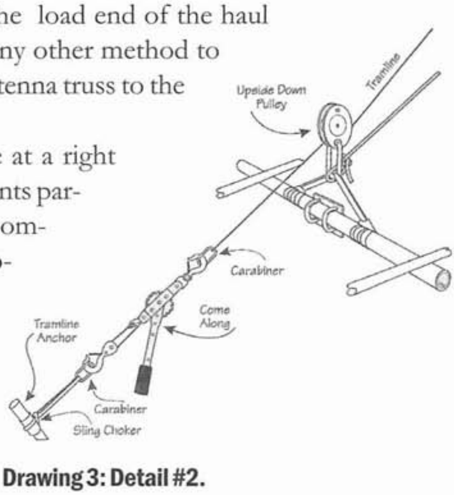
Drawing 2: Detail #1.

the antenna tram path if the antenna is going to be installed close to the top of the tower. This goes for any wire antennas also. These should be detached at ground level.

You'll need to secure the other end of the tram line to an anchor. You can use a tree, a fence post, a car (be careful not to scratch the finish), a stake driven into the ground or any other convenient strong point. This is when you'll want to use your come-along and your cable gripper. Tighten the cable until most of the slack is taken up. **Do not overtighten;** you could damage your mast. If the sling on the mast is now high enough to create a significant moment of force on your mast (more than four or five feet), back guy it with another wire line or rope in the opposite direction, then anchor it to a convenient spot.

Attach the tram pulley on the tram line. Turn the pulley upside-down (as the antenna will be suspended from the tramline) then clip in the load end of the haul line. After using slings or any other method to truss the antenna, lift the antenna truss to the tram pulley and clip it in.

The boom should be at a right angle to the tram line (elements parallel to the line) with the boom-to-mast bracket pointed toward the mast ready to accept u-bouts. At this point, the haul rope should be attached to the tramline pulley. It goes up through the pulley on the



Drawing 3: Detail #2.

mast, then down the tower to the ground. The third pulley may be used at the bottom of the tower to change the direction of the haul rope from vertical to horizontal. This is a classic snatch block arrangement and will make pulling the haul rope easier.

Next, attach any tag lines. I prefer ¼" polypropylene because it's light and stiff enough that it won't typically get hung up on any clamps or hardware sticking out on the elements. Tie the end to the boom at a convenient spot that you can reach when you need to untie it. Wrap the tag line around an adjacent element two or three times. You can add one or two wraps of electrical tape to hold it in place on the element to keep the fulcrum out on the element and away from the boom. The tag line will pull easily through the tape when you're done.

The tag line may occasionally get hung up on an element hose clamp, or something else. If you can't reach it with something long to free it, just lower the antenna, then tram it back up again. Doing this is only a minor inconvenience because everything is rigged; it's just a matter of lowering it, then hauling it back up again — a five-minute job.

When it's time to launch the antenna, have someone on your ground crew pull the haul line while you and another person help the antenna off the ground. Once the antenna is launched, the tag line person can guide it as it goes up.

Having the antenna suspended beneath the tramline keeps the antenna from twirling around on the way up. Another advantage is that tramming will let you run the antenna up off the ground so you can run any on-the-air tests you'd like. Just attach a run of coax before you lift the antenna. To make any adjustments, lower the antenna, make the changes and pull it up again. The tramline being inline with the elements may cause interaction or will actually touch the tramline — that will throw your measurements off. Make measurements with the boom 90° to the tramline if possible (elements parallel to the tramline).

I use the tagline to pull the elements down so that they'll clear the guys (you pull them down on one side of the boom and the ones on the other side go up - sometimes almost vertically). You'll be pulling against the haul rope so don't pull too hard on the tagline. The tagline is used to move the boom so that the antenna will be in the proper mast-mounting orientation. You want the boom-to-mast plate to wind up at the mast so the boom and elements have to be aligned so that that happens.

Someone must be on the tower to guide it when the antenna gets close to the tower. One or more elements will inevitably snag on the tower, guys, wire antennas or anything else in the vicinity. Once the antenna has cleared all obstacles and if everything was rigged correctly, the antenna should mate right up to the mast. It doesn't always happen on the first try, but it's nice when it does. Put the mast bracket clamps or hardware together and it's done. You probably took two hours to rig the tram but only ten minutes to get the antenna up on top once everything was correctly rigged.

To take antennas down, rig everything the same way, then lower the antenna down the tram line. The only thing to look out for is to make certain that the haul line goes behind the boom before it goes through the mast pulley. Once you've used this technique, you'll likely use it again.

24
GROUNDING

Lightning Axiom: The probability of a given structure or system being struck by lightning is directly proportional to its value.

Lightning Corollary: If two structures or systems of equal value are next to each other, the one that will be struck by lightning is the one for which replacement parts are no longer available.

The thoroughness of this chapter is possible by the invaluable contribution of Jim Brown, K9YC, a consultant for audio and video systems
www.audiosystemsgroup.com

What is Grounding?

The word "ground" when used in the context of electrical engineering has multiple meanings. Although all are valid uses of the word, these multiple meanings have led to major confusion, misunderstandings, and bad advice. The first three of these meanings apply to practices that make our systems safe though they have nothing to do with how well they work. How we respond to these meanings of the word "grounding" are defined by building codes, which carry the force of law.

A connection to earth

The first and most obvious of those meanings is an electrical connection to earth. The sole purpose of the earth connection is electrical safety – it provides a discharge path for lightning, and for voltage and current transients that may be present on power system wiring.

Power system grounding

A second common use of the word "ground" is the connection of one conductor of the mains power system to earth. This "grounded conductor" is called the "neutral," and serves as the return for mains power. This earth connection is called the "system ground" (or "system bond"), and it must be made at one, and only one point in any power ***system***. Most residences and offices have only one power system – power that enters the building is simply distributed by circuits wired in parallel at one or more breaker panels to as many lighting fixtures, appliances, and outlets as are needed. A "system ground" connection must be made in the first breaker panel within the premises, and virtually all breaker panels include a large screw called a "bonding jumper" to make the connection. [Caution: if your system includes more than one breaker panel, make sure that the bonding jumper has been removed from all but the first panel. One bonding jumper is required. More than one bonding jumper on the same system is illegal, and creates serious problems.]

A bond can be defined as a low impedance connection that is mechanically and electrically robust. At frequencies above a few hundred Hz, the impedance of virtually any conductor is dominated by inductance, not resistance. Bonding conductors should be "beefy" so that they don't melt, and as short as possible so that they have low inductance.

The power system equipment ground

A third common use of the word "ground" is the bonding together of exposed metal parts of all equipment connected to the power system, including the earth connection in the breaker panel. This connection is called the "equipment ground," (or safety ground) and is carried by the green wire and the third (round) pin in standard power cords and outlets. The function of this connection is also safety – it provides a solid current path certain to blow a fuse (or trip a breaker) if the "hot" conductor somehow shorts out to the exposed metal. Note that this equipment ground (the "green wire") is specifically NOT permitted to carry load current. If the equipment ground carries current, something is wrong! Load current is carried by the hot conductor and must be returned on the neutral.

Ground as a signal reference or reference plane

A fourth common meaning of the word "ground" is "a reference plane" against which electrical potential is measured. This may be "circuit common" in a piece of electronic gear, or it may be the chassis of an automobile or aircraft. Viewing this reference plane as a single point is a convenient, but dangerous, fiction – a fiction because all circuit wiring has some finite length, and thus inductance and resistance. There is also capacitance between signal wiring and common. Indeed, the combination of signal wiring and the associated circuit return forms an inductive loop, may form resonances, and behaves as a transmission line at some frequencies.

Shielding is not grounding

Old wives tales have grown up around the mistaken concept that "grounding" is somehow important to prevent RF interference, spurious signals, and noise. Nothing could be further from the truth – indeed, a connection to earth is neither necessary nor even useful in preventing RFI or noise. Many people mistakenly talk about the connection of cable shields as "grounding." It is not – it is shielding. Shields do not need to be grounded, but they do need to be continuous, and all wiring that penetrates the shield need to be RF-bypassed to the shield. At unshielded equipment, shields should be bonded to the point where the power system equipment ground is bonded to circuit common.

Another old-wives tale is that a connection to earth somehow makes an antenna work better. A study of virtually any text on antennas shows this to be wrong. Certain types of antennas, notably most verticals, need a conductive plane to serve as the return for the antenna's electrical and magnetic fields and to complete the electrical circuit. The earth's surface is typically a poor conductor, so except for salt water, it serves that function very poorly – any current flowing in the lossy earth will cause power to be lost as heat. A vertical antenna can be made to work quite efficiently by placing a highly conductive plane under it (like a radial system), so that the return for both the antenna's fields and its current is a low resistance like copper rather than the lossy earth. It does not matter whether this conductive plane makes contact with the earth! The earth does, however, play an important part in how our antennas work – the earth in the far field from the antenna reflects waves radiated from the antenna and reinforces them to form the "main lobes" of the antenna's vertical pattern.

Lightning

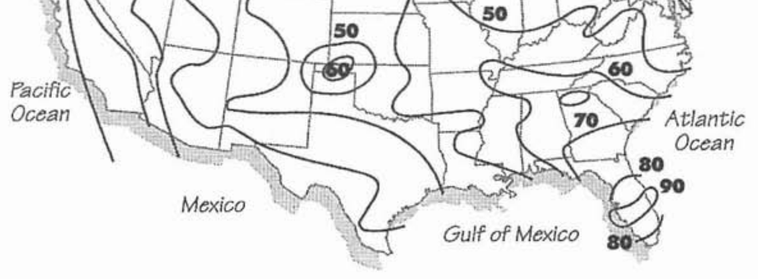
Lightning is the most obvious transient disturbance from which we want to protect ourselves and our equipment. Lightning storms are compelling and awesome forces; many of us have seen what destruction they can cause. Each year over 400 persons are killed by lightning. Several hundred more suffer from injuries caused by lightning such as burns, shock and other damage to the body's more vulnerable parts. Fifty percent of all strikes will have a first strike of at least 18,000-amperes of current while ten percent will exceed 65,000-amps. It'll take a lot less than that to destroy your radio equipment or to cause bodily harm.

Lightning is caused by the atmospheric friction caused by winds that rub clouds together. This friction creates a cloud with a charge similar to what happens when you rub a balloon on your hair; they're both full of static electricity. These charged clouds can be either positively or negatively charged; it doesn't matter which because the results are the same.

Imagine one of these charged clouds drifting through the sky. It will be dragging a shadow of that charge below it across the earth. It is this shadow that is looking to either take on more electrons or give up electrons in order to get back to a neutral charge. It is looking for an object that reaches up towards the cloud that will help it transfer the charge. That object could very well be your tower system, or the wiring inside your home.

Air acts as an insulator, but breaks down (that is, arcs over) at some high voltage. The arc-over is a huge current pulse with a fast rise time and short duration. Each lightning pulse reaches its maximum level within about two to five microseconds. Any short duration pulse consists of an infinite number of harmonics, the relative strength of which is determined by the rise time of the pulse and the impedance of the current path. It is a major mistake to think of lightning as DC. Yes, there's a DC component, but data collected by the IEEE (Institute of Electrical and Electronic Engineers) shows that most of the energy in a lightning strike is in the MF spectrum (300 kHz-3 MHz). So when designing a ground system for lightning protection, we need to avoid inductance!

In addition to the very high voltages and currents that cause damage, the ionized air from a direct hit may reach a peak plasma temperature of 60,000°F; it's no wonder that it can cause so much destruction.



Drawing 1: Lightning days per year in U.S.

Lightning activity varies widely from one part of the earth to another. Most of the benign West Coast has five or fewer lightning days per year while areas of Florida have over ninety. Even with a low average number of five lightning days in Western Washington, there may be as many as 800 lightning strikes in one day in King County alone. Even in a moderate zone such as Nebraska with forty days-per-year, I'll never forget one active Fourth of July storm—the lightning barrages made it seem as though I was in a war zone!

The Earth as part of a ground system

The earth is important as a reference plane because it's sitting there ready to accept the charge (and the associated energy) from lightning. Although we know it is round, we can think of the earth as a plane of infinite size. The earth's conductivity varies widely, depending on the chemistry and geology of the soil (or rock) and its moisture content, from fairly good to very poor. The conductivity of the soil, measured in ohm/cm of resistivity, has much to do with how quickly and how well the earth conducts and disperses lightning strike currents. Conductivity can even vary a lot between points that are very close together for a variety of reasons, both natural (the presence of rocks, streams, earth stratification) and manmade (excavation, land filling, building structure, buried pipes). Soil with high resistance can be treated with chemicals to increase its conductivity, but this is not a permanent solution; the ground must be re-treated every year or two as the chemicals deteriorate and wash away. Special hollow electrodes that allow you to add chemicals to can be purchased and installed. The chemicals in these devices must also be replenished periodically. There may also be environmental concerns with some of these chemicals.

Lightning Protection

The most fundamental elements of lightning protection are:

1. A low impedance path for lightning to our reference plane (earth) that does not include our house or ham station. This path is provided by earth electrodes.

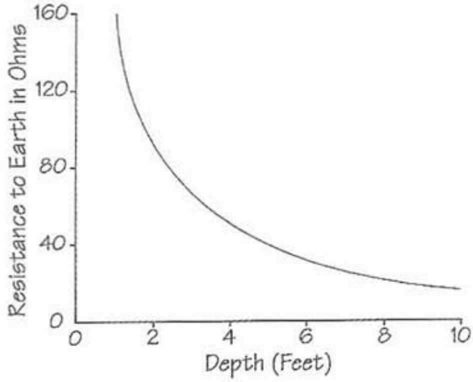
2. Common bonding of our equipment so that, in the event of a lightning strike, the potential difference between equipment

is minimized

3. Protection devices on power, signal, and control wiring that is connected to our equipment.

Earth Electrodes

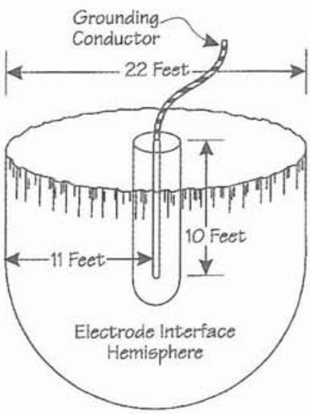
An earth electrode is an electrical connection to the soil, whether intentional or unintentional. A ground rod is an example of an intentional connection – what building safety codes call a "made" electrode. The larger the building, the more likely it is to have various unintentional connections to earth – structural steel, conductive cold water pipe, conductive gas pipe. We can reduce the impedance to earth of an electrode by increasing the surface area in contact with the soil, but this is not a linear increase. For example, doubling the rod's diameter decreases the impedance to earth by only about 10%.



Drawing 2: Ground electrode depth resistance.

Driving a rod further into the ground also decreases the resistance to earth. In the simple case where earth conductivity varies little with depth, doubling the rod length reduces the resistance to earth by approximately 40%. After driven to a depth of ten-feet, additional decreases in resistance are very small and incremental; so in this average situation, ten-foot long ground rods are plenty. If, however, conductivity at the surface is poor but improves with increasing depth, longer ground rods may still reduce resistance significantly.

Multiple ground rods interact with each other due to the mutual inductance between them. If there were no mutual inductance, the impedance of four rods in parallel would be simply one fourth the impedance of a single rod. In reality, mutual inductance causes the total impedance to earth of multiple rods to be somewhat greater than this simple parallel analysis would suggest. One way to look at how this mutual inductance affects the combined impedance of multiple rods is to think of a rod as creating a hemisphere-shaped volume that depends on its size, and that the volumes of adjacent rods should not overlap. Using this analysis, it has been shown that for maximum effectiveness for a given amount of buried copper, the spacing between rods should be about 2.2x the rod length.



Drawing 3: Electrode interface hemisphere.

This analysis is also oversimplified – it works for DC and the low frequency components of lightning, but it fails to consider the inductance of the wire that interconnects the ground rods. At 1 MHz, the inductive reactance of 22 ft of #6AWG copper is about 70 ohms, so spreading out the electrodes is not quite as beneficial as it might appear.

Ufer grounds

Concrete can be a good electrical conductor or good insulator, depending on its formulation. Most concrete used in construction is a fairly good conductor. A ***Ufer*** ground (named for its inventor, Herbert Ufer) is an electrical conductor encased in conductive concrete to form a made electrode. Ufer grounds tend to be very good grounds – that is, they have a relatively low impedance to earth – because they have a much larger surface area than a simple rod. Structural steel within a concrete foundation acts as a Ufer, including a ham radio tower sitting on concrete that is electrically conductive – if a robust connection is made to a conductor inside the concrete.

Tower grounding

A Ufer ground can be formed by bonding a tower to the rebar internal to the concrete tower base. The rebar cage should be tied together (some rebar can be brazed) so that arcing does not occur during a lightning strike. If all this is done properly, a tower taking a lightning strike is unlikely to explode or crack the concrete base.

Multiple earth electrodes can be wired in parallel to further reduce the total impedance of the connection to earth. In a typical tower installation, the Ufer electrode formed by the concrete base with its structural steel should be augmented by one or more driven copper rods connected to each leg of the tower. The impedance can be further reduced by using multiple rods on each leg in a hub and spoke arrangement. As we will learn later, this combination of electrodes must be bonded to all other ground electrodes associated with our building.

Ground system impedance

The National Electrical Code *(Article 250, Part 4)* calls for a made electrode (ground rod) at a building's service entrance of a certain size. If, depending on soil conditions, that rod has a resistance to earth greater than 25 ohms, a second made electrode must be added. That's all! In other words, NEC does not place much emphasis on the impedance to earth. The IEEE *Green Book (Recommended Practice For Grounding, ANSI/IEEE Std. 142-1982)* calls for a target resistance of 5 ohms where highly sensitive electronic communications equipment is installed. The cost of achieving this rather low resistance value will depend on soil conditions, and the resistance of a grounding system may not fall nearly as much as you would like in proportion to the time and money invested. You must determine how elaborate and effective (and costly) your grounding system will be. And remember – NEC doesn't think it's a big deal.

The good news is if you follow our recommendations for tower grounding and properly bond it to the power system's ground electrodes, you will probably have a fairly low resistance to earth. A good on-the-ground radial system for your vertical will reduce the impedance at higher frequencies even further. Although there may be some resonance effects (the capacitance of the radials and the inductance of the wire to the electrodes), these tend to be fairly low Q resonances because the earth is so lossy.

Bonding Earth Electrodes

All earth electrodes that lightning might view as associated with our house or ham station must have an effective low impedance bond between them. The impedance to earth of a ground system will be the parallel combination of all earth electrodes (ground rods, building steel, tower footing, cold water pipes, radials), plus the inductance of the wire connecting them. The capacitance between a big radial field and the earth can be a significant component of lowering that impedance in the 300 kHz – 3 MHz region where the energy of lightning is concentrated. It is this parallel combination of earth electrodes that must be bonded to the power system neutral and equipment grounds at the service entrance.

All building codes require that all ground electrodes, whether made or unintentional, be bonded together. This includes metallic water pipes and building steel. But some or all of a plumbing system may be non-conductive due to use of plastic pipes, so it should not be depended upon for grounding.

Lightning induced surges

So far, we've mainly thought about lightning current induced directly into our antennas, especially our tower. This is only a small part of the problem. While your chances of taking a direct hit are relatively small, it is quite common for destructive transient spikes to be induced in wiring. When current flows, the resistance of conductors produces a voltage drop. Lighting will induce voltage along a wire, and it will induce current in any closed loop. The actual strike that induces this voltage and current may be quite distant, even miles, away.

Other power system transients (surges)

In addition to lightning-induced surges on power lines, there are also voltage and current spikes caused by the connection and disconnection of very large electrical loads and transmission lines. The power company tries to minimize these transients, but the do happen, especially when things are going wrong – for example, when there's a power failure of some sort.

Currents induced by lightning and these power system problems on power lines, telephone lines, cable TV systems, flow along those cables to your house. The function of ground system bonding, lightning arrestors, and surge protectors is to prevent these voltages and currents from causing damage.

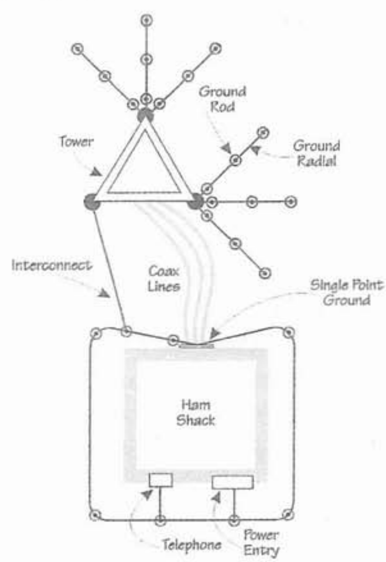
Lightning often induces very large currents in the earth. Because the earth is resistive, there can be very high voltages present between earth electrodes driven at points that only a few tens of feet apart – for example, on opposite sides of your home! That's why it's critical that all earth electrodes be bonded together. If they were not, the points within your home where those electrodes were connected could have high voltages between them, and any equipment at those locations that was interconnected would much more likely be damaged.

It's also important to realize that no matter how hard we try, none of these bonding connections are perfect. They all have resistance and inductance by virtue of their length. To be most effective these connections should be short (to minimize inductance) and beefy (so that they are less likely to melt before they discharge the voltage). It is important to run all bonding conductors as much in a straight line as possible, and to avoid sharp turns. Lightning sees a sharp turn as extra inductance, and will try to jump around it to find a different path to the earth that what you intend. That jump from where you want it to go to where lightning wants to go is called a "side flash," and is another way that lightning can cause damage.

In general, the connection to earth protects us from direct hits. Bonding and surge protection devices protect us from everything else.

Ground system bonding

An effective lightning protection system has two key elements. The most obvious is a good earth electrode system, but it's not the most important. The most critical part of any grounding system is really the overall architecture of how all the equipment and ground electrodes are bonded together. In other words, we



Drawing 4: Grounding system.

need to pay careful attention to where lightning currents flow, and where lightning voltages might appear within our system. Our objective is to minimize the difference in potential between different points in our system, between one piece of equipment and another. It is these differences in potential that cause arcing and destructive equipment failures.

For most installations, some variation of a "Single Point Ground System" is the best approach. A SPGS collects all antenna cable shields and earth electrodes at some common point before the cables enter the building. Remember, you're trying to keep the lightning energy outside where it will be conducted into your earth electrode system. The tower, cable shields, mains power system, and protectors for telephone lines, tv cables, etc. should all be bonded to this common point, thus reducing the potential differences to a minimum and protecting the operator and equipment.

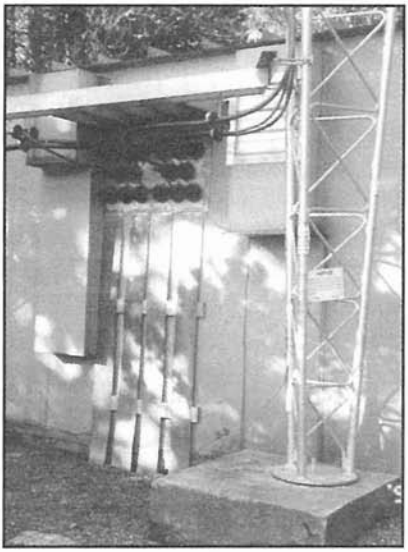


Photo 1: The building entry business end of a commercial Single Point Ground System. Note the feedlines going in and the four runs of copper strap to the earth ground.

The SPGS is facilitated by a bulkhead entry panel, a beefy plate punched so that you can mount lightning protectors for you antenna system and ground system wiring. Antenna cable shields are attached to this plate; straps from the plate run down and connect to the earth electrode system. Buried wire used in grounding systems should be solid copper and #6 AWG minimum. Sharp bends in the grounding system should be avoided because they introduce additional inductance. For ground wires, a radius of six-inches is the absolute minimum. Remember, you want the lightning surge to find the path of least impedance to ground and to dissipate harmlessly.

Lightning protection companies will try to sell you a beefy copper plate with big standoff insulators. Does this need to be copper, currently a rather expensive metal? Not really – any metal that avoids dissimilar metal issues and doesn't oxidize is fine. This leaves out aluminum, but stainless steel works. And standoff insulators aren't necessary.

Shack on upper floors

Another one of those "old wives' tales" is that somehow a radio shack on a higher floor will have all sorts of problems with noise and RF interference "because it cannot be grounded properly." Aircraft radio systems work fine with no earth connection at all, and the transmitters for many FM and TV broadcast stations are located on the top floors of skyscrapers.

Steel frame construction

A building with a steel frame and concrete foundation will generally have a pretty low impedance to earth, because the frame provides multiple low impedance paths to that foundation, which acts as a massive Ufer earth electrode. If your shack is in a building with a steel frame, bond everything to that frame – power system, telephone system, cable TV, and all antennas. When possible, try to bond all of this equipment to a single point on the building. If your antenna is on the roof, bond it to the roof at the highest place you can conveniently do so. Again, the multiple, beefy paths through building steel to the earth provides an excellent discharge path for lightning.

Buildings without steel

In a building without a steel frame, you've got to provide your own ground bonding. No problem – just follow the SPGS rules. Power, telephone, and cable TV should all enter the building as close as possible to a single point near ground level, have their grounds bonded together, and have those grounds tied to the earth electrode system. Likewise, antenna feedlines should run to a common point as close as practical to the power system bonding point, be bonded to that point, and then run to the shack. This simple concept applies whether the shack is in the basement or on the third floor!

Power, telephone, cable TV, ham station on opposite sides of a building without steel

This situation often happens, and any solution is a compromise. A good start is one or more good earth electrodes at each point where there is cable entry, with all electrodes bonded together by the shortest practical path. Don't limit your options to a star configuration. More parallel paths are better than only one path. Most authorities advise that the path should not run through your building. On the other hand, if the path you provide around the perimeter has too much inductance, lightning may find its own lower impedance path by jumping (arcing over) from one conductor to another through your building, causing mischief along the way.

National Electrical Code

In North America, building codes generally require that an electrical installation conform to the National Electrical Code (NEC). A few cities (including Chicago, Los Angeles) have their own codes that are generally similar to NEC. These codes apply to premises systems – that is, buildings and facilities connected to mains power. They do not apply to systems that are strictly portable – for example, a motor generator in a vehicle, and they do not apply to power distribution systems outside buildings (that is, the power company's wiring). They do apply to a portable generator or solar system that is connected to premises wiring. Some industrial systems, such as those running heavy equipment are exempt from some of these requirements.

The bonding requirements of standard building codes like the NEC are based on solid engineering. They have been formulated and refined over the years by some of the best engineering minds on the planet, including many who are very aware of the RF implications of the requirements. There is no conflict between these grounding and bonding requirements and excellent performance of audio systems and radio transmitting or receiving systems. Those who advocate separate, unconnected grounds for power and radio systems or audio systems are simply wrong.

You may be surprised to learn that amateur radio stations are covered by the NEC; they even have their own section under *Article*

810 - Radio and Television Equipment. In this section are specifications for everything from size of receiving antenna conductors (#14 hard drawn copper or #17 copper-clad steel for spans of 35 to 150 feet, #12 hard drawn copper or #14 copper-clad steel for longer spans), to the requirement for an antenna discharge unit on the lead-in of an outdoor antenna, and the minimum size of the station grounding protector wire (# 10.) These requirements are specifically aimed at safety.

Many consider copper clad steel a truly awful material, and strongly prefer hard drawn copper. Ordinary copper wire can be hard drawn by connecting one end to an immovable object (e.g. a telephone pole or tree) and the other to a car bumper or comealong, then pulling ("drawing") it.

Zone of protection

It is well established that high objects will protect things around them. This 'zone of protection' may be visualized as being somewhat cone-shaped, with the tip at the top of your tower system and the size of the circular cone base radius equal to twice the height of the antenna system. In other words, your tower and antenna system will protect your house and other property if it happens to be within the zone of protection.

Lightning rods

The lightning protection system should start with a lightning rod a minimum of two feet above the top antenna. This should be a galvanized rod (like your galvanized tower) and should be clamped to the mast or another topmost part of the structure. It should have a point at the top of the rod.

On-tower equipment

Everything on the tower should be bonded to it. This includes the rotator and the shields of all cables. Tower-mounted antennas don't normally require any additional bonding because they are mechanically and electrically bonded to the tower through their mounting hardware. This is also true for most other tower hardware and appurtenances. Ideally all non-coaxial cables (control cables, power cables) should be twisted pairs but this isn't really possible. PolyPhaser (www.wrblock.com) and I.C.E. (www.iceradioproducts.com) both manufacture an 8-wire protector for rotator control cables. Coax cables should have grounding pigtail kits to ground the outer shields. There are commercial versions available that use mechanical bonds. Make sure that your pigtail ground joint is weatherproofed.

Cables can be shielded by running them in steel raceway (a combination of steel conduit and junction boxes). To provide much shielding, the raceway should be continuous from the top of the tower to the shack. The EMT should be bonded to the tower at both ends and at intermediate points. While a real pain to install, cables run inside the tower are somewhat better protected as the tower steel acts like a Faraday cage.

Installing ground rods

The preferred material for a ground rod is typically copper clad steel. The copper coating is more for corrosion resistance than conductivity. The best way to drive a ground rod is with a weighted slide hammer specifically designed for that purpose. Using a water hose inserted into the ground to evacuate a hole for a ground rod is not recommended; it generally results in a much higher resistance because the rod is not in direct contact with dense soil as is a driven rod. Other methods include using a fence-post driver or rotary hammer with ground rod head.

The corrosivity of the soil is another issue. You can measure the pH of your soil with a spa or swimming pool tester and that'll tell you whether your soil is acidic or alkaline. For acidic soils (e.g. most of the eastern US), you want to go with galvanized rods because the soil acids will attack the copper. If your soil is alkaline you want to avoid galvanized, tin or aluminum rods.

Ground electrodes don't necessarily need to be vertical rods. If rocky soil makes installing vertical rods difficult, consider multiple shorter rods, or burying ground rods horizontally. The main reason for going deep below the surface is to get to in contact with more moist (lower resistivity) soil. Horizontal installation of ground rods at a depth of 36 inches provides essentially the same resistivity as an equal length rod installed vertically. The top of the installed ground electrode should be below the frost line.

Making Bonding Connections Outdoors

As discussed in *Chapter 10,* you know the importance of using antioxidants pastes, avoiding dissimilar metals and having good electrical and mechanical connections. This is especially true for grounding systems. There are only two acceptable grounding system connections. The first is a mechanical compression, or crimp, joint. You'll need an industrial type crimper since you'll be working with large wire sizes, and you'll need medium to large crimping forces. Two metals that are being joined with a crimper should be joined with enough force that the two metals actually exchange materials and bond under pressure. Another style of compression joint uses a nut and bolt mechanical force to make the connection. Mechanical connections joining a ground wire to a ground rod can be made with a proper mechanical clamp. Don't forget to use an antioxidant on all of these connections.

Uninsulated copper or steel braid oxidizes very quickly when exposed to the elements, and should never be used outdoors. Large diameter solid copper or wide copper strap is a far better bonding material for outdoor applications. Pieces of flat copper strapping may be joined with stainless steel nuts and bolts along with antioxidant paste. The minimum size for copper strapping is 1.5 inches wide and 0.0159 inches thick (26 gauge).

The second and best method, the one used in almost all outdoor commercial grounding systems, is an exothermic process. This method uses heat and chemical reduction to produce a permanently reliable joint. One of the biggest providers of exothermic bonding equipment is the ERICO COMPANY; as their equipment is called *Cadweld,* these connections are commonly called *Cadweld* joints. To make a *Cadweld* exothermic joint, you need a mold and shots of the chemical material. Each mold is for a specific application (ground wire T connection, round member tower leg, flat plate, etc.) so you typically need several molds to do everything. For amateur use, just the one mold for wire T connections would suffice. If you are going to do more than one grounding system, or are going to do a professional (and effective) job on your own grounding system, this would be a very worthwhile investment.

You first prepare the wire for the joint, then clamp on the mold. Next, pour the shot of copper oxide and aluminum powder into the mold and ignite the charge with a lighter. The initial ignition gets the shot hot enough so that it burns away the oxides and deposits copper around the joint. The larger cross section of metal increases the surface area and decreases the joint resistance. It also avoids any dissimilar metals problems. The result is an extremely reliable and long-lasting joint. After it extinguishes, then cools, you remove the mold and move on to the next joint. Don't *Cadweld* directly to tower legs. They are relatively thin walled and hollow; the heat from a *Cadweld* joint may put a hole in your ROHN *25G* or *45G* leg. Use a mechanical joint in this case.

Connecting a copper ground wire directly to a galvanized tower member is discouraged since the 2 materials are pretty dissimilar metals and are far apart on the galvanic scale. Use of a thin sheet of stainless steel between the two materials will give you a better permanent connection. Polyphaser makes a nice copper to galvanized tower leg ground clamp called the TK. It is a SS hose clamp with small sheet of SS tacked onto it. It comes in 3 different sizes for different sized tower legs.

Unacceptable bonding methods include using a hose clamp on a ground rod and silver soldered connections. While using silver solder is encouraged for outdoor antenna connectors, one surge of lightning current (and heat) will melt the silver solder and break your ground connection.

Guy anchors

Uninsulated guy wires can conduct a lightning surge and should be grounded as well. Do not use copper wire for guy wire grounding because of dissimilar metal corrosion and subsequent damage. Bond the guys to the ground wire and terminate the ground wire to a ground rod that is connected to the grounding system. If you take a lightning hit on your uninsulated guy wires, the strike will probably weld your turnbuckles together. If you are using insulators on your guy wires or PHILLYSTRAN nonconductive guy cable, you've already eliminated this potential problem.

Cables

Cables in tower installations should be bonded in three places; 1) to the top of the tower (or where the cable terminates) of the cable run, 2) to the tower or the ground system at the bottom of the cable run before it turns and goes horizontally over to the building and 3) at the building entrance to the single point grounding bulkhead plate. This will reduce the potential differences in these conductors and lessen the chance for arcing and other lightning damage.

A coaxial cable shield ground must conform to the same general specifications as the grounding system; no dissimilar metals, and it must be attached by a compression type clamp. If your coax has a copper shield, such as most *RG-8* types, you will need a copper grounding strap body, which must be attached with enough compression to assure a good electrical connection without damaging the coax.

One of the few grounding kits available which meets these criteria is offered by the ANDREW CORPORATION; one of the largest manufacturers of commercial RF transmission lines, antennas and other communications products. Their kit for ½" cable includes not only the copper grounding strap and compression installation tool, but also weatherproofing butyl rubber tape and wide electrical tape to seal the finished joint. While ANDREW kits are specifically designed for their *Heliax* cables, they will work equally well with *RG-8* type cables. They provide inexpensive insurance for your tower and grounding system installations. These kits have become the industry standard; they use the best available materials and components.

Surge protectors

Surge suppression devices are designed to prevent damage to equipment caused by current or voltage spikes on cables that connect to equipment. There are two fundamental types – shunt mode, and series mode.

Shunt mode suppressors conduct the lightning current, hopefully diverting it away from the protected equipment (and often onto the equipment ground conductor). Gas discharge tubes and metal oxide varistors (MOV's) are the most commonly used shunt mode suppression devices. At low voltage, they look like an open circuit, but conduct when the voltage exceeds a certain threshold.

Series mode suppressors block the lightning current by adding a high reactive impedance (an inductor) in series with the lightning current. The energy in the lightning strike is stored in the inductor, then discharged slowly (and thus harmlessly) back into the power line. SurgeX manufactures products of this type for professional use. (www.surgex.com) Zero-Surge (www.zerosurge.com) makes series-mode products for the computer market, Brick Wall (www.brickwall.com) for the home hi-fi market.

Disadvantages of Shunt Mode Suppressors

When a shunt mode suppressor conducts a lightning strike to the equipment ground, the IR drop in the "green wire" raises the potential between the equipment ground at the "protected" outlet and other "grounds." Consider two pieces of gear plugged into different outlets, with signal wiring between them. One of them has a shunt mode suppressor, the other does not. Or perhaps they both have suppressors, but they see different lightning currents and have different lengths of green wire to "earth." In either situation, the difference in potential between the two equipment grounds can be thousands of volts for the instant of the strike, and one or both of those pieces of equipment is likely to experience a destructive failure.

Shunt mode suppressors degrade and/or eventually fail, as they absorb some finite amount of energy. They may fail shorted or open. It is not practical to test for a degraded or "failed open" condition. As a result, it easy for a shunt mode device to have failed and offer little or no protection, but you don't know it.

Shunt mode suppressors also conduct non-destructive noise spikes to the equipment ground, and the resulting noise current can radiate and be picked up on antenna systems.

Advantages of Shunt Mode Suppressors

Shunt suppressors are much cheaper than series mode suppressors. They are the only practical method for protecting signal circuits and for protecting an entire building (that is, a "whole house suppressor" at the service entrance).

Advantages of Series Mode Suppressors

Series mode suppressors reliably protect equipment on branch circuits without causing destructive failures on equipment on other circuits.

Disadvantages of Series Mode Suppressors

They are larger and more expensive than shunt mode suppressors, and it is not practical to build series mode suppressors with capacities larger than about 30A.

Recommended Surge Suppression Strategy

Install a "whole house" suppressor at the service entrance as your first line of defense against lightning coming in on the power line, and other power line faults. Use series mode suppressors on branch circuits (that is, between the breaker panel and equipment) to control lightning induced on branch circuit wiring. Never use shunt mode suppressors (MOVs) on branch circuits.

Use shunt mode devices only in parallel with the RF inputs of sensitive equipment that cannot be protected in any other manner (antenna inputs, inputs of telephone equipment, computer network equipment, etc.) All shunt mode protection devices (telco, ethernet, etc.), MUST use the star ground as their ground.

Universally recommended, lightning surge protectors for coaxial cable have different designs, cost and effectiveness. Each manufacturer claims that their designs and products are superior. Polyphaser and Industrial Communication Engineers, Ltd. (I.C.E.) are the most professional when it comes to design and testing because most of their products are designed and sold for professional and industrial applications. Go over their literature and decide which one will meet your needs and budget.

Anything that uses an air gap to keep lightning currents out of coax is probably not worth installing – by the time the charge builds up to the point where the current arcs across the gap, the damage has already been done. Humidity, temperature and manufacturing tolerances also affect the ability of the gap to work. Some types of arrestors use simple gas tubes that are good for one discharge, and then must be replaced once they have taken a charge.

Cable TV and telephone lines

Installers of Cable TV and telephone systems are often careless about grounding for their surge protectors. It's your house – make sure that they are bonded directly and effectively to the SPGS. When new lines are being installed, make sure that they enter the building immediately adjacent to the power system so that they can have a short path to the power system ground.

Dissipaters

The theory behind dissipaters is that they dissipate any static electricity energy before it turns into a 'feeler', or small lightning bolt that precedes the primary strike. They use multiple wires in a ball configuration, or resemble a bottlebrush that sticks out into the air. When they are used in combination with a good grounding system, they are purported to effectively reduce the chances of a direct lightning strike. The theory is sound; people who use them generally endorse their effectiveness while other lightning experts tend to minimize their usefulness. Like a lot of things, they probably couldn't hurt. If your tower and antenna system includes medium or large yagis on the tower, the antennas themselves are already big enough to act as dissipaters.

What else can you do?

Another one of those old wives tales is that you can prevent lightning damage by unplugging everything – disconnect your gear from the AC outlets, remove audio cables, control cables, antenna cables, etc. You will also need to remove all ground straps in order to isolate the gear totally. Then you must hook everything up again after the storm passes. Will this protect you? Maybe, maybe not. I once lost a CD player when lightning induced enough current on internal wiring to toast the microprocessor that controls it. My non-ham friends have no antennas at all, but some have lost lots of computer gear – Ethernet boxes, computer printers, serial interfaces, even the Ethernet interfaces in their computers. In none of these cases could a nearby strike location be identified. Rather, it was voltage induced in internal wiring and the wiring between boxes.

The bottom line is that you can avoid all that bother, and most of the problems, by doing the things stated in this chapter. The better job you do on your outside grounding system, the less important interior grounding becomes. Removing the coax from the radios or switches may be only psychologically helpful because that 18,000-amp lightning surge will arc right through the thin plastic jacket on the coax to whatever path it can find to ground. If you reduce resistance and inductance to provide an easy path for surges to ground, it stands to reason that by increasing resistance or inductance you would make it more difficult for a surge to get through. An old broadcast engineer trick is to tie knots in AC power cords; the theory being that the increased inductance from the knot will discourage surges past the knot. Somehow I doubt it.

25

Building a single tower station

Back in the late 1980's I was writing an Up The Tower column in the National Contest Journal. One of my columns was called "Building A One Tower Station" and I was going to update it for this book. Back in those days there weren't the number of choices of towers and antennas that there are now and there wasn't as much information available to the average amateur. But now with the internet and much more in the way of resources available, it's a much bigger topic with hundreds of possible choices. So instead of rehashing everything that's found elsewhere in this book, I'll just hit the high points. And if you use the information in this book to help you plan your installation, you're way ahead of the game anyway.

Go with what you've got

Don't let perceived limitations hold you back. If you've got trees – use them. There are lots of competitive antennas (including wire yagis) mounted in trees.

If someone gives you a used antenna – put it up, even if it's at 20 feet.

Throw up some wire. A move to a new QTH and no antennas led me to install a multi-band dipole fed with a single coax feedline that was only a few feet above my roofline. "Wires work!" is the comment in my logbook. It was exciting to get on the air and it was even more satisfying to do it with simple wire antennas.

Do your homework

For starts, read what you can and talk to your buddies about their experiences and suggestions.

The best resource for tower and HF antenna questions is the TowerTalk internet reflector. It's a very active group with lots of knowledgeable folks in its almost 2000 members. To subscribe, send an email to towertalk-request@contesting.com with <subscribe> in the subject and you'll be all set. Over 13 years worth of archives are available at www.contesting.com. I don't think there's a single tower or antenna topic that hasn't been covered!

Two books that'll help you make antenna decisions are the vertical and yagi comparison reports available from Champion Radio Products (www.championradio.com). Both were written by your author and H. Ward Silver, N0AX, and feature on-the-air comparisons along with the testing protocol. They are ***HF Vertical Performance - Test Methods & Results*** and ***HF Tribander Performance - Test Methods & Results 2nd Edition***.

There are a bunch of other valuable antenna books available for any frequency or complexity. Add them to your library.

And of course the Rohn catalog is invaluable. It gives you many engineering drawings and specifications and associated hardware. It's available online – www.rohnnet.com - as well as on CD.

26

Be kind to your trees

by Doug Brede, W3AS

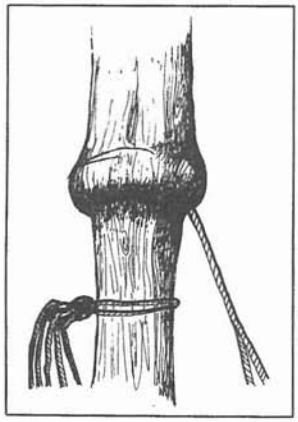
If your tree-supported antenna fell down, you'd care. Did you ever think about caring for the tree that holds up your antenna? For most hams, trees are favorite antenna supports. Many radio amateurs begin their operating careers by hanging the far end of a wire up in the family's shade tree. On Field Day, resourceful hams find a hundred and one ways to get an aerial into the air; many (if not most) of these methods involve using trees as supports or aids.

During my twenty years as a radio amateur, I've used tree-supported wire antennas almost exclusively. Some of those antennas lasted several years; most didn't. Over the years, by trial and error—and because of my trade association with arborists and horticulturists—I've gained an understanding of what can (and can't) be expected of trees as antenna supports.

There are right and wrong ways to attach and maintain your tree-mounted skyhooks over the long haul. I'll share with you some pointers from two noted horticulturists who talk about attaching wires to trees. Safety is also discussed—your safety during antenna installation, and the safety of the tree.

Trees are alive

Few antenna supports can be classified as life forms. Trees are an exception. Tree experts usually cringe when someone brings up the idea of attaching a wire to a tree—especially when connecting a chunk of wire to its midriff. The experts know that trees are made up of three basic layers: the bark, the living sapwood, and the nonliving heartwood. The bark protects the sapwood from injury. The sapwood contains the "skin and blood vessels" of the tree. If the sterile barrier between the bark and the sapwood is broken, infection can set in. Infection, if unchecked, can kill even a mighty oak within a year.



Drawing 1: Attaching ropes or wires to trees can sometimes lead to major problems for the tree. Wrapping a rope around a limb or trunk and leaving it unattended will suffocate the tree and cause a distortion of growth or the death of the limb.

Trees have the same basic problems with infection as we humans do. If a tree gets a cut or gash, infection from bacteria and fungi is bound to set in. But there's one important difference between trees and humans: "Tree wounds don't heal," says noted tree expert Dr Alex L. Shigo. "People heal; when you are wounded, you have forces that fight off the infection. Trees don't have these forces to fight off infection, and every wound will become infected."

Shigo, author of the book *Tree Biology and Tree Care* and many others, notes that trees lack an immune system that fights off infection from wounds that occur from the actions of a careless climber or the attachment of an antenna-support eyebolt. Trees treat their wounds by walling off the infected area and isolating it from the living part of the tree. "If you cut open a tree that's 2000 years old, you'll see every injury in that tree that occurred over its lifetime," says Shigo.

Whenever you wound a tree, you weaken the tree in that spot. The walled-off wood around the wound lacks the strength of healthy wood. When attaching an antenna to a tree, it's important to traumatize the tree as little as possible. This will ensure a strong, enduring connection.

Most people believe that tree paint or shellac is the best way to treat a tree wound. "Not so," says Shigo. "Wound dressing paints just protect the microorganisms." Scientific research with tree-wound preparations have failed to show any benefit to the tree.

Making the attachment

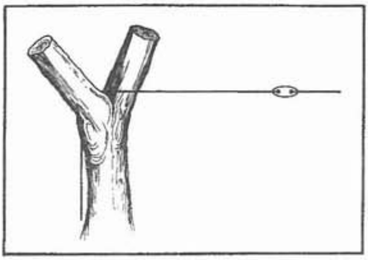
Although it's relatively easy to get a wire up into a tree, it's certainly more difficult to keep it there for the long term. Usually, annual (sometimes weekly) restringing is needed. It seems that trees "instinctively know" just when to drop a wire to the ground: during midwinter when the snow is high and the skip is long, or in the middle of a heated contest!

The bow-and-arrow method has become a standard of the wire-in-the-tree crew. But many other methods, slingshots, for example—even attaching a string to a golf ball and whacking it with a sand wedge—are common.

One of the easiest and most common ways to connect a wire to a tree is to throw a rope over a branch crotch, then tie off the loose end. This is the main method used in temporary (such as Field Day) installations.

"Doing this probably won't hurt the tree if it's done as a temporary thing," says Washington State University horticulturist Ray Maleike. But with any of these simple antenna-stringing methods, some problems for the tree (and the antenna) may develop later.

"First of all, you're not stabilizing the antenna very well with this type of setup. The other thing is that people have a tendency to forget the antenna's there. As the tree grows—as it increases in diameter—you can girdle the tree.



Drawing 2: Most hams install tree-mounted antennas by throwing a line over a branch crotch. This should be used only as a temporary installation, because abrasion of the rope and tree results. Over time, girdling may occur leading to the loss of one or more of the branches.

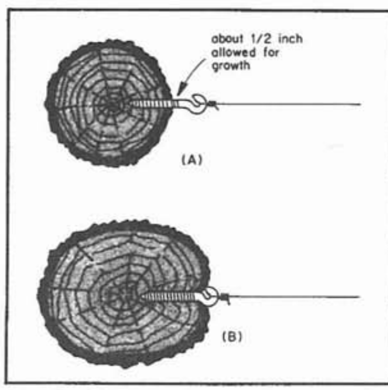
If you've got this girdling rope or wire up there, you can actually kill that portion of the tree above the wire."

Another no-no when attaching an antenna to a tree is wrapping a wire around the trunk. This strangles the veins in the sapwood the same way a noose around your neck would strangle you. "It's important not to wrap anything around the trunk," says Maleike.

Many commercial nurserymen wrap stabilizing ropes around newly transplanted saplings to keep them from falling over. Recently, however, this practice has been questioned because of the restrictions these ropes place on the growth of the tree. People forget about these ropes; some remain on trees for years after transplanting.

Encasing the stabilizing (or antenna) wire in rubber or plastic hose is not the answer either. "Wire wrapped in hose is just as injurious to the tree as the bare wire itself," says Shigo. "If you remember your basic physics, you're applying the same number of pounds of force to the tree with or without the hose." Shigo recommends that if you must wrap something around the trunk of a tree, use a wide fabric strap to do the job.

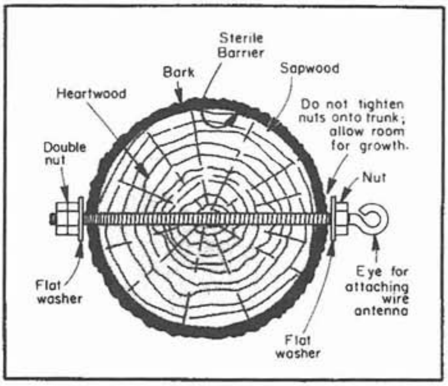
Two methods have emerged among leading horticulturists as the preferred way to attach a wire to a tree. For light antenna loads, such as the end of a dipole, a threaded eyescrew is the method of choice. Just drill a hole into the tree about $^{1}/_{16}$" smaller than the screw diameter, then twist in the eye-screw. Be certain you use a cadmium-plated eye-screw threaded for use in wood. A thread length of two or three inches should secure most antennas. Allow at least ½" of space between the trunk and the eye; this allows for outward growth of the tree with time.



Drawing 3: The best way to secure a wire to a tree is with an eyescrew mounted into the wood (A). As the tree grows and expands, however, the eyescrew will become embedded (B) and must be removed and replaced.

For stouter antennas, such as multielement wire beams, another method for securing wires to trees is recommended. This procedure involves using an eyebolt longer than the tree diameter, drilling completely through the tree, then securing the eyebolt on each side of the tree with round washers and nuts.

Drilling a hole through a tree causes much less trauma to the tree than wrapping something around it. Much of the core of a tree is dead tissue, used mainly for physical support. Although there will be some wounding of the tree at the site of the bolt or screw, such wounding will be far less than that which occurs from wrapping a wire around the trunk.



Drawing 4: For heavy antenna loads, an eyebolt passed through the trunk or limb will support more weight than an eyescrew. Allow about 1/2 inch of play between the bolt and trunk or limb. Don't tighten the bolt completely; this allows for tree growth.

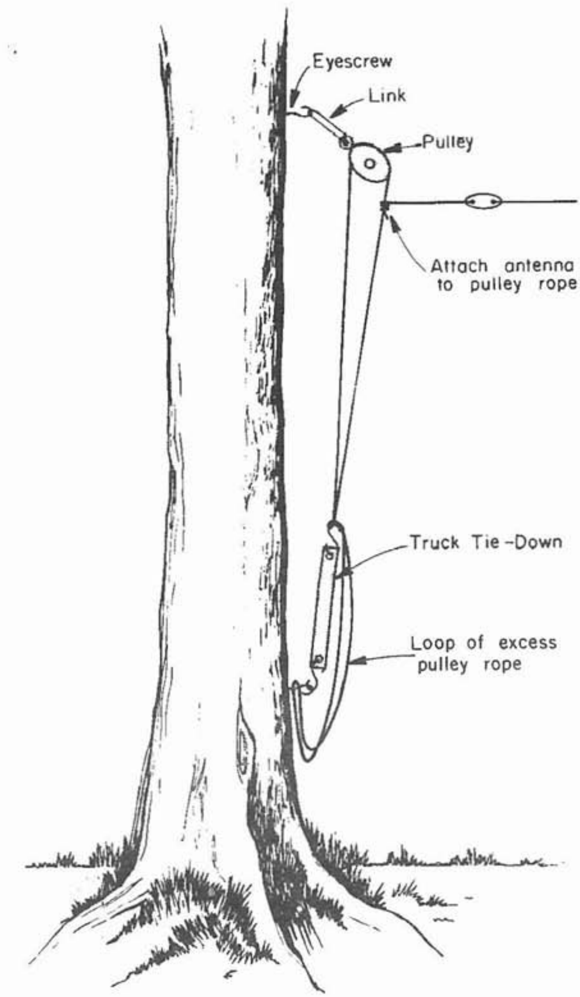
Over time, either type of eyescrew connection will have to be replaced. "If these fasteners are left on the tree for a long time, the fastener will eventually become embedded in the tree," says Maleike. "You're going to have to pull these fasteners out and replace them every now and then." Maleike recommends replacement of tree eyescrews every five to eight years as the tree matures.

Commercial arborists use drivefasteners for securing wires to trees; drive fasteners are similar to eye-screws. "These fasteners keep the wire away from the tree, allowing the tree to grow out to it," says Maleike. Drive fasteners are used for securing lightning rods and their accompanying wires to trees. The use of drive fasteners is common in the Midwest, where lightning strikes to trees are common. You may have to shop around to find drive fasteners—try calling tree-care services in your area.

It's easier to periodically service a tree-supported antenna if a pulley is used. Raising and lowering the antenna for repairs can be done without the need to climb the tree each time. I use a flexible truck tie-down to provide tension to the antenna.

Your safety in trees

A fall from a 40-foot tree is just as dangerous as a fall from a 40-foot tower. Yet, many times you see hams scaling trees with no safety equipment! Wear a tower-climbing safety belt for all tree climbs. Commercial arborists take the matter of safety one step further: They lob a rope over a tree crotch just above the height at which



Drawing 5: By using a pulley, raising and lowering the antenna for repairs can be done without the need to climb the tree. Flexible truck tie-downs can be used to apply tension to the antenna.

they'll be working. Then they tie the rope to their safety belt. The loose end of the rope can be held by a helper on the ground. Be sure to use a good quality rope that is strong enough to support your weight. Before use, inspect the rope for wear. Arborists prefer to use hemp rope rather than nylon, because hemp ropes stretch less.

When you're climbing a tree to attach a wire, always have a buddy on the ground available to fetch tools or summon help in an emergency. Be sure your buddy wears a hard hat; tools or branches dropped from even a moderate height can be dangerous. As an alternative to doing it yourself, consider procuring the assistance of a professional to install your tree antenna. A professional can clear away interfering branches and secure an eyescrew in short order. Professional tree trimmers generally work in pairs. They use a ladder or bucket truck to get up into the tree, and then they free-climb throughout the tree. A safety rope, saddle, and safety belt are worn. "A figure that I heard about how much this runs is about $50 an hour," says Maleike. Most tree tasks can be done by professionals in about an hour.

Summary

Keeping your station in good operating condition is—or should be—a fundamental practice of every radio amateur. Part of that practice includes annual inspection of your antenna system. If trees are a part of your antenna system, take a good look at them. Are you keeping them healthy?

SOME QUESTIONS AND ANSWERS ABOUT TREE ANTENNAS

Q: A CBer in my neighborhood cut the top out of his pine tree and stuck a ground plane antenna up in it. Is this an acceptable way to mount an antenna?

A: Definitely not. Not only is this a hazardous way to mount an antenna, it essentially ends the useful life of the tree. Topping of tress is strongly discouraged by professional arborists. Because topping removes the growing point of the tree, the tree recovers from the damage by sprouting numerous lateral buds around the top, which soon overrun the antenna.

Q: I've heard that if you fertilize a tree, your antenna will grow higher each year. True?

A: False. Although fertilizing is a desirable way to keep your tree healthy, it does not raise the height of your attached antenna one inch. Trees grow by extension of the apex. A wire attached to the trunk at 30 feet will still be at 30 feet 10 years later. By the way, when you fertilize your tree, use regular garden fertilizer distributed around the drip line of the tree. The fancy tree spikes you see advertised are unnecessary because most tree feeder roots are near the surface.

Q: Is there a way to slow down the growth of a tree so that it doesn't interfere with my antenna?

A: Some home-and-garden stores now stock growth regulators for trees. These products can be injected into the tree, dropped on the soil surrounding the tree, or sprayed on the leaves (follow label directions). Tree professionals can also perform this service. These growth regulators are used by some utility companies to reduce the need for tree trimming near power lines.

Q: Are certain types of trees better wire-antenna supports than others? What about hardwood versus softwoods?

A: There's little difference between hard- and softwoods in their ability to hold up antennas. Conifers, because of their shape, are nearly ideal antenna supports. Avoid the use of red oaks and silver maples, if possible, because they tend to rot easily if wounded. Avoid using poplars, too. In spite of their height and rapid growth, their branches are brittle and break easily.

Q: If I damage a tree during antenna installation, what should I do? Is tree replacement expensive?

A: If the damage is minor, your best bet is to do nothing. If it's a broken limb, saw the limb off cleanly, perpendicular to the axis of the branch. Never saw off a branch flush with the surface of the trunk, as this allows decay to set into the trunk. Using tree paint for injury repair is unnecessary (see text). In case of major tree damage, consult a trained arborist.

The answer to the second question is: Yes, tree replacement is expensive. The International Society of Arboriculture publishes a formula for calculating replacement cost of shade trees of various sizes. This pamphlet can be obtained from many tree services and libraries. Here's one point to ponder: A large, stately shade tree can add several thousand dollars in value to the property on which it sits.

Doug Brede is a former Associate Professor of Horticulture at Oklahoma State University and is now research director for a major west-coast seed company. He has written more than a hundred technical articles on landscape topics for magazines in the landscaping industry.

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Tree installations

In many parts of the country, trees offer usable, cheap antenna supports. Conifers such as pines or firs, being single-trunked, are ideal for use as antenna supports, while multi-trunked maples and cottonwoods are almost impossible to climb or use. In general, trees are not regulated, nor subject to building codes or permits. There have been three instances in Washington State where amateur tree installations have been challenged (initiated by overzealous neighbors) by building departments: in each case it was determined that the antenna in a tree was **not** subject to any building department regulations. A tree is a tree is a tree!

Wire antennas

You'll need two trees, one for each end of your wire antenna. It's very difficult to install an inverted vee in a tree because it's just about impossible to get both sides of the antenna through the branches. For attaching wire antennas, find a professional tree climber/arborist in the *Yellow Pages* or a talented buddy to install a pulley and rope system in your trees of choice. A $^{3}/_{8}$" or ½" eye lag bolt screwed into the tree with a pulley attached is the best method. Use a chain link or cold shut to attach the pulley to the lag screw eye. I prefer a non-swiveling pulley because the lay of the rope can cause the rope to turn and twist together and possibly jam the pulley. Use only metal pulleys; preferably ones made from stainless or galvanized materials. Plastic parts will either break or be damaged by UV radiation. Check your local hardware stores for usable pulleys; cheap stainless steel ones locally are available for $5 to $10 each.

Keep in mind that with pulleys and haul ropes there should be minimal clearance between the sheave and the pulley body; the rope should be larger in diameter than the clearance so that it can't get jammed in the pulley—a major annoyance. I use ¼" polypropylene rope; only a very sloppy pulley will allow it to jam. A much better option for your rope halyard is black dacron UV resistant line.

Have your climber go up the tree until he reaches a suitable spot, then screw in the pulley. It's all but certain that the tree will have to be pruned to clear a decent window through which the line can travel. It's better to over-prune since new growth will invariably grow into the spot in just a few years. Small branches are incredibly strong and resilient and can cause major problems in any tree project or installation; they'll even prevent a yagi from turning.

Having brought the line up with him, the climber will put the line through the back side of the newly installed pulley, attach a weight to the end of the line, then throw it out in the direction that your wire antenna will take. The wire antenna must clear all branches to successfully install your antenna. When the end of the line reaches the ground, remove the weight, then tie the ends of the line together, making a loop. This is because in almost all cases it is the antenna that breaks, not the halyard. Without a loop, when the antenna breaks the end of your haul line will be at the top of the pulley and you'll have to send someone up to retrieve it. If you have a loop system, all you have to do is pull your line down and reattach your wire antenna. Tie an overhand knot for your wire attachment point where the ropes are tied together and you're ready to start hoisting.

If you're going to climb the tree yourself, you'll need sturdy boots, hardhat, a safety belt with two lanyards and tree climbing spurs. You'll need the two lanyards to leapfrog your belts around branches so that you'll be belted in 100% of the time.

In a strong wind that will get your trees swaying, you'll want to have a method that allows the trees to move without breaking the antenna. You can use a weight of some sort (cement block, plastic milk-container, a bucket with rocks, etc.) or use a rubber bungee cord (or truck tie-down as mentioned in the previous chapter).

Newer tree climbing techniques don't use steel climbing spikes as it's deemed harmful to the tree. The latest methods use a line thrown or shot over a branch and then the rope is used to climb the tree using rope ascenders like the ones used by mountain climbers. You don't even touch the trunk of the tree using this technique so it's pretty benign. There are slingshot-type devices as well as compressed air gun-types that you can use to get the line over a branch as well as the bow-and-arrow technique.

Tree climbing has even become a recreational activity similar to the way that rock climbing has. There are clubs and resources available and you can find a lot of them online. Be sure to check out the equipment and techniques and you can do this yourself.

Preparing the tree

Most tree Yagi installations require an unobstructed mounting at the top of the tree. In other words, the top of the tree needs to be removed, or topped. While arborists discourage tree topping for several reasons, in the Pacific Northwest many homeowners do it as a matter of course to reduce the size of a tree and its chances for being blown down due to a wind storm. Topping the tree, unfortunately, can't be avoided. My advice is to be as gentle as possible. This means leaving limbs and branches growing as high as possible, so that they continue to bring sap up the trunk. **Do not** strip the limbs on the upper part of the tree; with no living branches to bring the sap up, the tree trunk will quickly rot and your installation will fail.

Rotators

Beams using the techniques described below use a pipe mast for the tree mount along with a mast-mounted rotator. This requires a mast-mounting bracket to be attached to the bottom of the rotator. Since the rotator is not mounted inside a tower, which would give it its maximum strength and rating, you must be more conservative with the wind loading for mast-mounted loads by down-rating the rotator square footage capacity by approximately 50%. While the *HAM IV* from HY-GAIN has enough capacity for mast-mounting small tribanders (15 square feet inside a tower vs. 7.5 square feet when mast mounted), I usually recommend the *T2X Tailtwister* because its physical strength and design bearings have more capacity and reliability for tree installations. You want the most reliable installation possible, because if you have a rotator problem it's not as easy to replace as one mounted on a tower.


Photo 1: Mast mounted tree installation. Note horizontal brace for torque resistance.

A stress test done on a *T2X* at the factory showed that it took 1,000 pounds of force on the rotator before it broke. The rotator was plate mounted by its bottom bolt mounting holes and the top neck casting broke during this torture test. (See Chapter 22 Rotators.)

There are two mast mounting brackets available from HY-GAIN; one is a medium-duty version for their *HAM IV;* the other is a heavy-duty bracket for their *T2X Tailtwister.* Since the bolt patterns are the same, you can use the heavy-duty version on a *HAM IV* installation as well. This would be the recommended configuration. Get the recommended mast-mounting bracket if you are using other rotators also.

VHF/UHF yagis

VHF and UHF vertical antennas can be successfully tree installed. A tall tree will give your antenna coverage that may astound you. The worst part of any tree installation is that nothing is square or plumb on the tree. You might have to put up with a little lean or tilt to your installation.

The easiest way to mount a VHF vertical is on a pipe, lag screwed to the trunk at the top of a tree where it has been topped. Take an 1½" galvanized water pipe, or a size appropriate to the rotator that you're mounting, drill three or four holes in it for the lag screws, then use your $^3/_8$" × 4" or 5" long galvanized or stainless lag screws to attach it to the trunk. Without topping the tree, you must fabricate some type of standoff to get the antenna a reasonable distance from the tree trunk; plus you'll have to clear the branches up above. This is a less desirable configuration since vertically polarized VHF/UHF signals will be attenuated somewhat by the tree. Get it on top and in the clear if possible.

HF beams

Trees can be very useful for small HF triband yagis and even two-element 40-meter beams. Since a tree is a nonconductor, there is no steel tower or guy wires for the antenna to interact with. As a result, a tree-mounted HF beam is a wonderful performer. Use the same procedure described above; top the tree and use a four to five-foot section of 1½" I.D. galvanized water pipe with four ½" × 6" galvanized or stainless steel (SS) lag screws to attach it to the trunk. Notice I've moved up from $^3/_8$" to ½" lag screws. The HF beam exerts much more force on the installation than does the VHF/UHF installation, and requires stronger hardware. Be careful about using hardware store grade lag screws; you can easily twist the heads off common or ungraded lag screws. The galvanized or SS versions are generally stronger and their heads won't twist off. An improvement on the pipe-mount method is to have a horizontal flange welded onto the pipe. (See Photo 1.) This will minimize the torque related forces and increase the reliability of larger installations. Next, bring up the rotator with the control cable attached and install it on the top of the mast. Bring up and install the mast next. Again, a three or four

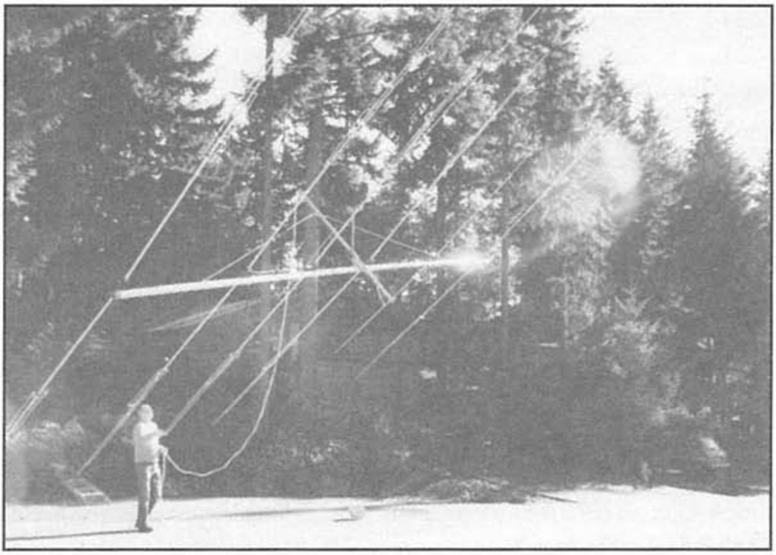

Photo 2: A big yagi for tree mounting is being launched up the tramline.

foot piece of galvanized water pipe is plenty. It's better to have it too long than too short because you may want to use the mast for a ginpole for installing the antenna; you'll want a pick point high enough above the rotator to bring up the antenna while providing enough installation clearance. Now you're ready for the antenna.

Tram up the antenna

Tree limbs make hoisting an HF beam up to the top of a tree all but impossible. The secret to getting the beam above the branches is to use the tramline and tramming technique from *Chapter 23*. Use a sling around the top of the rotator bell for your anchor and pulley attachment point; then rig your tramline as you would normally. **Do not** rig the tramline high on the mast above the rotator; it'll create a large-sized moment of force on the system and may damage your rotator or mount.

Tag line

The other key to getting the beam up is to attach a tag line to one of the elements in the middle of the boom, and use it to tip the elements upright as they approach the tree. Use a lightweight line, such as ¼" polypropylene, tie one end of the tag line to the center of the boom, then route it down the element that you want to use to pivot the antenna. Twist it around the element two or three times to give it a little extra friction, then tape the tag line to the element near the element end.

The person handling the tag line has a job that requires proper timing and finesse. Since you want the elements to go almost vertical as the beam approaches the tree on the tram line, the tag line handler should be just behind the antenna itself, so when he pulls down on the tag line, the elements go nearly vertical to clear the branches. He doesn't release the tag line until the antenna has cleared the branches and the antenna has landed at the top of the tree. As the tag line is released, the antenna should settle back to horizontal and, if done properly, should be right at the top of the rotator. It doesn't take much force to tip the antenna using the tag line; a minimal pressure is all that should be applied.

When the antenna has successfully landed at the top of the tree, the tree person can untie the tag line from the boom. The ground crew can give it a tug to pull it down. The tag line should pull right through the tape that's holding it and drop right to the ground. To

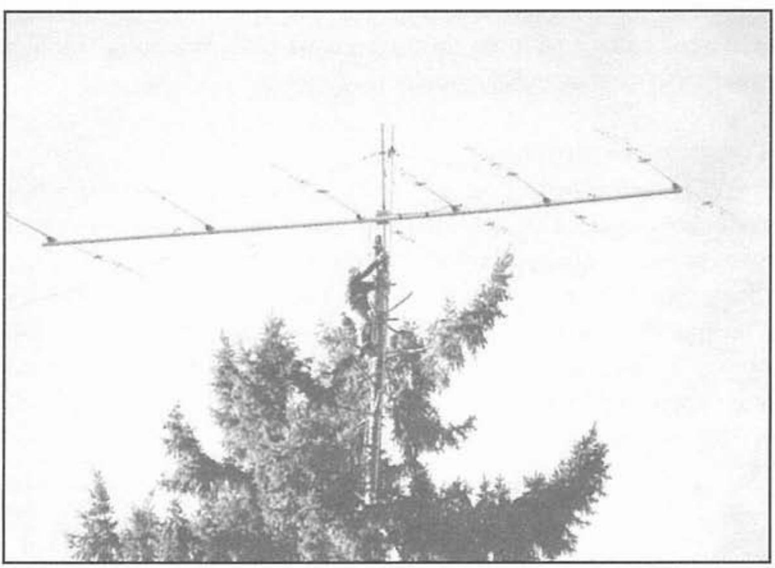

Photo 3: An aggressive tree installation. This is a KT34XA and is pretty much at the limit for this kind of installation. This antenna has been in the air for over 15 years.

insure that the tag line will run through the tape, pull it back and forth a few times while it's still on the ground to loosen the adhesive grip on the tag line.

Hoisting the antenna into place

If you've followed my advice by having your tram line secured to the top bell of the rotator, then you'll need a second step to hoist the antenna into place. Secure the antenna onto something convenient, such as another sling around the mast or rotator, then have the ground crew slack off of the tram line. When it is slack, detach it and release it back to the ground; you don't need it anymore. Before dropping the tram line, alert your groundcrew with a warning such as "I'm going to drop the cable," then "Here it comes!" or some other command. Next, remove the pulley and slings and re-rig them to the top of the mast, or at least high enough to give you adequate clearance. Reattach the haul line to the antenna bridle, then have the ground crew pull it up into position. Bolt the boom-to-mast clamp with its hardware and tighten everything. There you go; the beam's installed. Congratulations.

Securing the cables

The cables may be secured to the trunk with eye screws, nails or just about any type of standoff; then the cables can be tie wrapped (black only!) or taped to the standoff. Don't tie wrap around a limb; it's convenient but it will kill the limb. To anchor cables coming down the tree, I use fairly good-sized nails every 8-10 feet and then tie wrap the cables to the nail.

Preventive maintenance

Compared to a tower-mounted installation, a tree is relatively high maintenance. Every three to five years someone should go up and do some pruning of new growth. Little limbs and sucker branches are amazingly strong and can prevent your beam from rotating.

And, since this is a wooden structure, it should be inspected for rotting as well.

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The ten year plan

When you put time, energy and money into building a respectable tower and antenna system, you'd like it to be reliable and safe. The focus of this chapter is exactly that, what do you do to build a tower and antenna system so that no major repairs should be needed for at least ten years.

Towers

While guyed towers such as Rohn *25G* and *45G* are the most popular for amateur use, these comments will be applicable to self-supporting and crank-up towers as well. The only necessary concept for tower reliability is "DO what the manufacturer tells you to do" as far as the installation and use. Also, don't do what they don't tell you to do. In other words, follow the manufacturer's specifications **exactly** for guy anchors, base pad, materials and wind loading. According to Rohn, the most common amateur tower failure is due to overloading (a typical ham installation?). If you follow the manufacturer's specs, your chances of tower failure drop to near zero. Use the TIA or building department windspeeds for your county to determine the minimum wind speed to which you should build your system. If in doubt, over-engineer everything; if you are in a 75 MPH windspeed zone, build everything to withstand 90 MPH winds, for example. For the small incremental cost of perhaps the next larger size hardware, you'll gain a very comfortable margin of safety.

If you have any questions concerning your installation or installation plans, talk to someone who has experience in station building; I guarantee you that they'll have lots of opinions and tips for you. In fact, talk to several people. Reading this book is an excellent way to get started.

One of the most important aspects for guyed tower reliability is proper guy wire tension. Chapter 17 is an in-depth look at Guy wires and their care.

Antennas

One fact of tower and antenna ownership is that "everything has a life-span." These days, almost all commercially available amateur antennas are made out of decent materials including stainless steel hardware and high-grade aluminum tubing, but even as you're reading this, your tower, antennas and cables are deteriorating. If you build your own, don't scrimp on the materials. Use only stainless steel or hot-dipped galvanized hardware. Cadmium plating and other hardware finishes will not last the ten years that we're shooting for. Avoid them.

For wind survivability and heavy duty construction techniques, I recommend Dr. Dave Leeson's, W6NL, ex-W6QHS, book *Physical Design of Yagi Antennas.* He covers construction techniques and materials exhaustively and includes all of the technical data to back up his conclusions. There is much valuable information throughout the book. Subjects include rotators, masts, fasteners and literally dozens of other topics. You should also use antioxidants on every electrical and antenna connection.

Baluns

Baluns (balanced-to-unbalanced) – are matching devices used at antenna feedpoints to 1) balance the symmetry of antenna currents and 2) prevent, or choke, the outside of the coax shield from radiating and they are a potential problem. The HY-GAIN *BN-86* that was supplied for years for the *TH6DX/TH7DX* and others was well-known for its "fuse" capabilities. Put a little too much power through it and it opened like a fuse.

Whole books have been written on baluns and I recommend you get one to learn more about these devices.

Most baluns are out in the weather for years and do their job with no maintenance. Unfortunately they sometimes fail and there's no way to test one easily. Not only do you need special test equipment to perform a test, but also you have to get the balun off the antenna and into the shack – many times a difficult process. The only way to easily test a balun is to substitute another one and see what happens.

A circularly wound coax choke can sometimes be a more reliable choke but they need to be constructed for a certain frequency spectrum and they have specific construction parameters.

There's no magic bullet for balun reliability but many of the available commercial products work well. And you can always roll your own.

Connectors

Silver-plated connectors installed with silver solder are better in the long run. Problems that arise are generally due to poor weatherproofing, so be certain to follow all of the techniques in the Weatherproofing chapter. Never use solderless or crimp-on connectors. Always use pliers to tighten connectors; finger-tight just isn't good enough.

Coax

New coax, with a non-contaminating jacket, is the minimum for reliability.

Weatherproofing

Since inadequate weatherproofing is one of the biggest problems in station performance, follow the instructions in the weatherproofing chapter and this won't be a problem.

Rotators

Its my opinion you'll be lucky to have any rotator short of a prop pitch last reliably for ten years. Sorry. For starters, though, put in a bigger rotator than you need. The less stress you put on it will result in longer life span. The other thing that you can do is anticipate rotator failures and make their replacement an easy one-person job.

Grounding system

Because it's mostly out of sight when properly installed, a grounding system won't impress your ham friends as will your towers(s) and beam(s). Follow the techniques detailed in *Chapter 24*. Use antioxidants wherever there is an exposed electrical connection.

Hardware

Use only stainless steel (SS) or galvanized hardware suitable for outdoor use.

Wire antennas

For maximum wire antenna integrity, use a center insulator that will not only accommodate a *PL-259* as the feedline connection, but will also take the strain off of the connector as it hangs in the air. Use a black tie wrap to secure the feedline to the insulator. Stranded antenna wire or solid is your choice; both have their pros and cons. Be sure to use silver solder on all outdoor connections. Use UV resistant black dacron rope for the haul ropes.

Crank-up maintenance

Use a cable lubricant at least once a year, preferably twice. Inspect cables for obvious damage, broken strands, or rust. More information in Chapter 30.

Annual inspection

Perform a tower and antenna system inspection once a year, preferably when the weather is nice.

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REFURBISHING A TOWER

Many towers have had one or more previous lives. A used tower can often be an economical way to go, and generally will save significantly over buying all new steel and hardware.

Pre-purchase inspection

Take a long, hard look at what you want to buy before you fork over your hard earned money. Often the owner doesn't know or has forgotten the specifics relating to his tower, including manufacturer, type, etc. The main thing you're interested in is its condition. You want to see if there is any significant damage or corrosion. If any tower, including a crank-up, is in good shape, it will look like it. It will be clean and there will be little or no corrosion. Minor dents or bends that don't affect the structural integrity are usually okay. Many times these can be straightened, repaired or ignored.

In the case of corrosion, primarily rust, determine whether it is surface bleed caused by something else rusting onto the tower or whether the rust has penetrated the galvanizing. Hot dipped towers such as ROHN *25G* and *45G* have excellent rust resistance;

their galvanizing should last twenty years or more. Towers stamped from galvanized metal, such as ROHN *BX,* have thinner zinc coatings and thus have shorter service lives. Examine guy wire hardware with the same critical eye. Don't buy or reuse any badly corroded guy wire or hardware.

Crank-up towers can be yet another can of worms. The weak links for crank-ups are the cables. Be very cautious if there is any corrosion, deformities or kinks in the cables or significant rust. Recabling a crank-up can be a difficult job; contact the manufacturer for instructions and replacement cable. See that the pulleys are in good shape; they should turn without binding. The rule here is caveat emptor—let the buyer beware!

Don't forget to weigh the cost of refurbishing into the equation. It is one thing if you've got lots of time and not much money, but if you spend a month wire brushing and cold galvanizing a tower, you could be spending as much as the cost of a new tower. If you're talking to someone and they have a fifty-foot self-supporting tower but they don't know the brand, nine times out of ten it will be ROHN *BX,* not worth the effort of taking down. These are usually badly rusted and only fit for a trip to the dump.

Getting it ready

Once you get your tower home, put each section across a pair of sawhorses and go over it with your wire brush and cold galvanizing paint. For really rusted portions, use a wire brush attachment on a drill motor. Wear a respirator or mask to prevent inhaling the zinc and other materials. While it's on the sawhorses you can do a visual check for straightness by looking down each leg for anything unusual or bent. Nuts and bolts are often either missing or unusable. Get replacements **only** from the tower manufacturer's specs. Off the shelf nuts and bolts from your hardware store are probably not suitable; factory hardware has a certain grade rating that the parts must meet, while hardware store parts are likely going to be a lesser grade. Professional standards generally do not allow reuse of structural nuts and bolts on commercial towers.

As far as cold galvanizing goes, the most convenient means of application is from a paint spray can. This is a case where you get what you pay for. The cheaper ones will run and sometimes don't adhere very well. LPS makes a very good one but it's on the more expensive end of the spectrum. Welding supply stores carry good professional varieties.

Order a new base section or fixture from the factory or fabricate one. With Rohn *25G* and *45G,* you can simply sink the bottom of the first section into the concrete as you pour the base foundation. Follow the manufacturer's specifications, and the information in this book, and you'll be able to install a safe reliable system.

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Maintenance and annual inspection

Now that you've spent all that time and money on installing your dream antenna and tower system, you'll need to do periodic preventive maintenance (PM) and inspection to catch anything before it turns into a problem.

General maintenance

If you've followed the directives and steps described in this book you've already taken the most important steps in insuring the safety and reliability of your tower and antenna system. Following the manufacturer's specifications, using the right hardware, using antioxidants and over-engineering everything are the keys to success. At this point, you'll probably not require much in the way of general maintenance. The two most likely things that you'll need for general maintenance are a wire brush and cold galvanizing spray paint, as rust is probably the only thing about which you'll have to worry.

Annual inspection

An annual inspection is a critical part of your PM program. Most commercial companies do it religiously; many insurance companies require it as a condition of insurance coverage. An annual inspection entails examining everything in the tower and antenna system, including the ground system, concrete anchors and footings and tower structure. In addition to annual inspections, all installation should be inspected after ice storms or wind storms that exceed 60 mph. You should get in the habit of doing a quick visual check every time that you climb the tower. A log book of inspections, exceptions and repairs is a handy reference item. The information that follows is based on commercial and *EIA/TIA-222* tower inspections standards:

Tower structure

1. Check for damaged or faulty members. These are the tower legs and braces. With welded towers such as ROHN *25G* and *45G,* the members cannot be replaced without replacing the whole section; minor bends or damage that do not alter the structural integrity can usually be tolerated.

2. Check all welds for integrity.

3. Examine the condition of the finish and any corrosion. Look for rust patches; use your wire brush and cold galvanizing paint to repair it.

4. In addition to visually checking any bolted connections, you should put a wrench to at least 10% of them to check for tightness. Any loose nuts or bolts should be retightened. Also look for missing hardware and replace it immediately.

Tower alignment

1. The tower should be checked for plumb. A guyed tower is allowed a maximum deviation of one part in 400, or three inches per 100 feet. While a transit is the best way to check tower alignment, an electronic level will give you 0.1° accuracy, or a bubble level will indicate relative plumb. Even simpler is a long piece of string with a weight on the end, held at arms-length away from the tower; just sight the string along the tower leg for a very quick and fairly accurate indication of tower plumb. For self-supporting towers, the allowed declination allowed is 1 part in 250 or 4.8" in 100'.

2. Check the guy wires and guy insulators, using binoculars for the ones that aren't close to the ground or the tower.

3. Examine all guy wire and guy wire hardware including Preformed grips, turnbuckles, clamps, and clevises for damage. Make sure that all turn-

buckle safeties are intact.

4. Check guy wire tension with an instrument or another technique.

5. Examine the tower base and guy anchors. Look for any cracking of the concrete. Also look for evidence of movement in the soil of the anchor rods or base. Check for rust and/or corrosion. Excavate a buried anchor rod for twelve inches to inspect for hidden corrosion.

Antennas, cables and appurtenances

1. Inspect antenna, boom-to-mast bracket and boom truss hardware for loose or missing hardware. Test nuts for tightness.

2. Look at each feedpoint joint and coax cable joint for compromised weatherproofing.

3. Check all cables for abrasion, binding and attachment.

4. Examine all appurtenances (anything that's attached to the tower) for missing hardware or corrosion.

Grounding system

1. Do a visual inspection of the grounding system. Redo any connections that are corroded.

You should correct any problems that you discover in your inspection. If you're not sure about the seriousness of something you've found, talk to a knowledgeable buddy or contact the manufacturer for advice. When you do a tower inspection, you should have enough supplies to redo several coax connector joints if necessary, as well as a note pad and pencil to write down any discrepancies that may require further action. You'll be able to take care of most problems on the spot as well as to know what else you might need to finish the repairs. I always push and pull on antennas and appurtenances to see if anything is loose. Something might look okay but pushing on it might reveal loose hardware or some other problem.

Crank-up maintenance

Crank-up towers are complex mechanical contrivances. While some are hand cranked, many have a motor, gearbox, cables, pulleys, and limit switches - all of which should be carefully inspected twice a year.

The electric motors and gearbox are generally bulletproof and the only inspections are to check the oil level in the gearbox, the condition of the drive belt or chain (some sort of conditioner is helpful for each), and the operation of the cable drum (there are probably some Zerk grease fittings that need attention).

Pulleys are sometimes custom made by the manufacturer so you may not be able to run down to the local bearing store and buy one. Some sheaves are made by the manufacturer and then an off-the-shelf bearing is inserted in the middle. This one you probably can replace.

Pulleys need to turn and not bind so a good thing to do is to watch the pulleys if they're exposed enough while the tower is being raised or lowered and see if there are any problems.

Crank-up cables

Crank-up cables should be lubricated at least annually; twice a year would be even better. Use a cable lubricant such as PreLube 6 and be sure to check for damage while you're hanging around the tower doing the lube job. See Chapter 34 for more information.

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When something fails

Failures to your installation can come in many forms but wind is generally the common denominator. Rust, metal fatigue and overloading aren't usually a problem until the wind starts to blow. Other causes of failure could be lightning strikes, ice, vandalism or accidents.

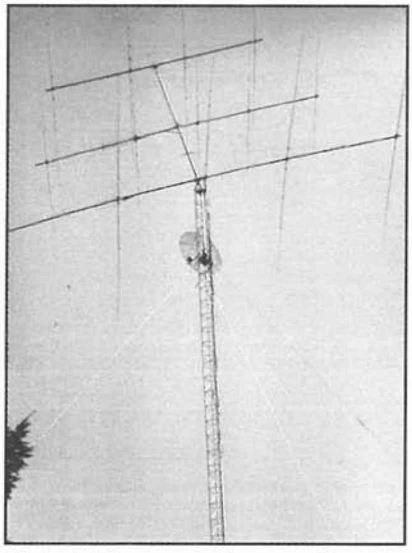

Photo 1: A bent mast. Someone should've read the Mast chapter in this book.

Assess the damage

The first thing to do is a visual inspection. Using binoculars if possible, take a look at everything from the ground to see if anything is bent or broken. If something is swinging in the wind, that's a major problem. If there is obvious damage, try to determine if it is in danger of falling. If so, evacuate the endangered area immediately and alert local emergency services. This is especially true if it looks as though it could fall on power lines, sidewalks or roadways. If you have damage that isn't an imminent danger to life or property, keep an eye on it until the storm is over to ensure that it doesn't get worse. If you have the opportunity, take some snapshots or videotape of the damage for documentation.

Prevent further damage

Your next task is to take prudent steps to prevent further damage, both to your property and to the property of others. This is not only common sense but also a requirement of the insurance company. You want to avoid or minimize the possibility of liability lawsuits for personal injury or the property damage of others. Tie anything off that you can but **do not** attempt to climb the tower!

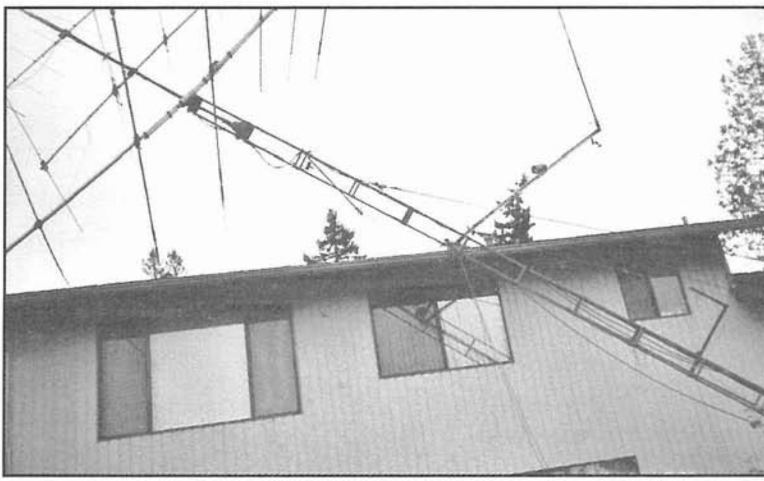

Photo 2: Oops! A potentially dangerous removal. A crane was used for safety.

File an insurance claim

After the storm is over, call your homeowner's or renter's insurance agent and notify them of the loss. Do it orally first, then follow-up with a letter. The insurance company may require a *"Proof of Loss."* They'll give you a claim number that you'll need to use in all written and verbal communications. Start a file with all your documentation, plus the other

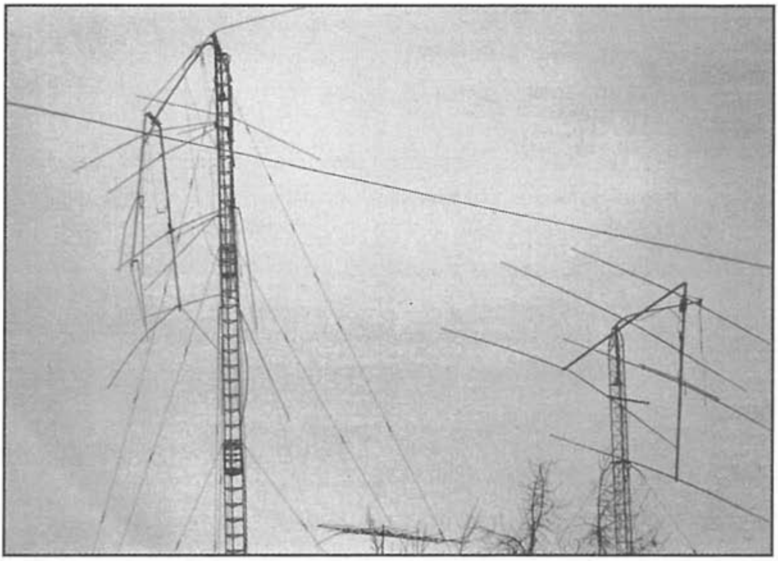

Photo 3: The big hurt. Ice damage at W7EJ.

paperwork that you'll start accumulating. Keep notes of every conversation with your insurance agent or claims adjuster with dates and times; you may have to refer to them in the future. At this point, you may want to write down all pertinent facts surrounding the loss for reference also. Send copies of your photos with your loss letter.

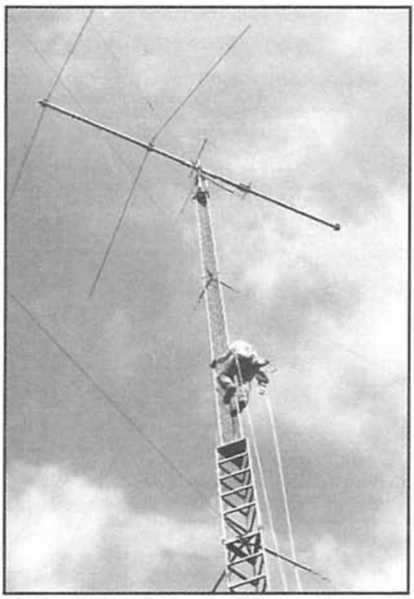

Photo 4: Wind damage. This is not going to be removed by one person on the tower because it is way out of balance.

Estimate of repairs

You'll make things very easy for your claims adjuster if you include an estimate of repair along with your letter and photos. The adjuster has probably never run into a tower loss before and would appreciate your help in getting a quote. Contact your local commercial rigger or antenna installation company and they'll give you the quote. Insurance companies will want professional workers to perform professional repairs to your loss; they expect to pay the going rate and they expect licensed contractors to do the work. Be sure that your estimate for tower repair covers **all** of the work including: dismantling damaged parts, hauling away damaged parts and disposal, clean-up, labor for reinstallation including assembly of antennas, labor for reinstallation of tower, replacing all damaged materials including hardware, cables, rotators, etc.

Don't be surprised if the estimate comes in quite a bit higher than you expect. Not only are you paying professionals to do all of the work, but a damaged tower or antenna system can be hazardous and a crane or other piece of equipment may well be needed to remove it safely.

Stay in your comfort zone

Needless to say, don't consider getting involved in the removal and repair of the damage unless you feel comfortable with it. If there is **any** doubt at all in your mind, either get the professionals in or bring in a piece of equipment such as a crane or boomtruck. One of the primary directives in this type of work is that "it has to be rigged for removal the same way that it was installed." That is, if it went in with a crane, then you need a crane to remove it. If your mast was installed by bringing it up through the middle of the tower, you probably won't be able to remove by lifting it out with a ginpole, especially if it's bent. What you **don't** do is send your nephew shinnying up the bent mast. If anything is at a precarious or dangerous angle, don't touch it—send for the professionals!

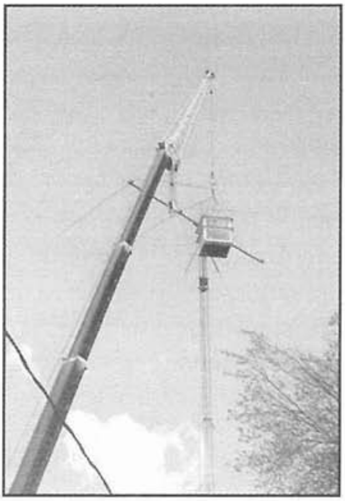

Photo 5: This is how the damaged antenna was removed. It's still a handful.

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INSURANCE

This chapter was written by Ray Fallen, ND8L, who has been an agent for The State Farm Insurance Companies since 1988.

Property insurance

There are several caveats regarding homeowner's insurance coverage as it applies to towers and antennas. First, most U.S. homeowner's policies are based upon standard language provided by the Insurance Services Office (ISO). Each company modifies that language on a state-by-state basis; so coverage that applies to towers in Ohio, may not apply to towers in Florida. Coverage may vary from company to company and on different policy types with the same company. Because of all the state-to-state differences, I can't tell you exactly how your tower will be covered, but can give you some general guidelines.

Which brings us to caveat number two...what's covered in your homeowner's policy is described in the policy itself. What's NOT covered is in the policy. Your duties following a loss are described in the policy. How the loss will be paid is, you guessed it, described in the policy. If you're picking up a pattern here, go to the head of the class. You NEED to spend time with your agent, before putting up your tower. If you've already put up your tower...what are you reading this for? Go see your insurance agent...RIGHT NOW!

Damage to towers, rotors and related antennas is covered by Dwelling Extensions, Other Structures or Appurtenant Structures coverage. The name of the coverage depends on the Insurer. For example, State Farm's Ohio Homeowner's Policy describes Dwelling Extensions as "other structures on the residence premises, separated from the dwelling by a clear space." Other structures are permanently attached to or otherwise form a part of the realty. Typically, other structures are covered for 10% (Ten Percent) of the dwelling amount, which, for most of us, would more than an adequate amount. If you're K3LR or W3LPL, that may be another story.

Remember, part of the replacement cost of a damaged tower is professional help in removal and repair, in addition to the new, replacement cost of the damaged items. In addition, fences, pole barns, gazebos, satellite dishes, detached garages and in-ground swimming pools are also considered in Dwelling Extensions, not just your tower. So add it all up and if you need more coverage, buy it is BEFORE you have a loss. Insurance companies are reluctant to sell you more coverage right after you've had a loss. In most homeowner's policies (unless you pay for more) if the damage exceeds 10% of the dwelling coverage, you pay it. So do your homework. See your agent. Ask a lot of questions.

Antennas supported by trees and ground mounted verticals are not permanently attached to the real property (sometimes much less permanently than we'd like) and, as such, are considered personal property. The good news is personal property is covered for 70 to 100% of the dwelling cost...the bad news is generally the coverage is less broad than dwelling extensions, but wind and lightning damage is usually covered. The distinction between dwelling (including dwelling extensions) and personal property coverage is: if it's nailed down, it's considered dwelling coverage...if it's not it's personal property. A Cushcraft R7 on a piece of pipe in a sack of sand mix is personal property. Eighty-feet of Universal Self Supporting Aluminum Tower in a twelve cubic yard block of six sack, rebarred concrete is a dwelling extension. No claims adjuster worth his salt will ever confuse the two.

The bottom line is this: don't ever rely on your ham radio buddies, your neighbor or your brother-in-law for advice on insurance. Call your insurance agent, bring him up to date on your installation and ask hard questions. Specifically, if my tower installation is damaged, how will it be covered? If he doesn't know, make sure he finds out and shows you, in writing (in the policy contract) how it will be covered or why it won't be. If towers/antennas are specifically excluded in the policy, what will it cost to purchase the coverage you need? Take pictures of your tower and give your agent an accurately priced inventory of your installation. Be prepared to pay the appropriate premium and sleep soundly when the north winds blow. If, on the other hand, your agent can't or won't provide you with the information you need, then go shopping for a new company or a new agent with the same company. Remember, every time you pay your premium, your agent gets paid...he OWES you that service.

Those hams renting their home still have a need for coverage. Some renter's policies (tenant's forms or HO-4s) provide coverage for personal property ONLY. Some HO-4 policies provide 10% of the contents coverage amount for building improvements, similar to the dwelling extensions coverage in a homeowner's policy. Again, forewarned is forearmed...talk to your agent. If you don't have renter's insurance...get some, especially if you have a tower up, if for no other reason than getting liability insurance (see the next section). The landlord's rental dwelling policy insurer won't pay for a tower installation that doesn't belong to the landlord, for the same reason your contents aren't covered by that policy. Maybe better to put up a G5RV and save the tower for your first house.

Liability insurance

A fundamental principle of insurance is that you buy coverage for the things you can't afford to lose. Most folks driving 1985 Yugos don't buy collision coverage...most folks driving a new Mercedes do. That beautiful new tower you're putting up is what the personal injury plaintiff's bar calls an "attractive nuisance." If one of the neighborhood kids decides to scale Mount Rohn and takes a tumble from forty feet up, you're going to get sued. You can argue about trespassing until you're blue in the face...but you're going to get sued and you're going to get sued for a lot of money. You do have some protection in your homeowner's policy. Typically, most homeowner's liability coverage is only $100,000 to $300,000. I say only, because if some reasonably competent attorney parades a teenager in a wheel chair in front of a jury...$300,000 is only a down payment and you'll be on the hook for the rest, to the extent you're collectible. You're collectible if you have a job, equity in your home or business, a checking or savings account, investments, a pension plan or any other assets. If you can afford to lose those things fine...otherwise, I would strongly encourage you to purchase at least a one million dollar personal liability umbrella policy. It doesn't cost a lot, typically less than a dollar a day, and will give you great peace of mind. After all, if you're sued for a million bucks and you lose, do you want to write the check or do you want your insurance company to write the check? Now, go back and read this paragraph again...it's very important.

Prevent further damage

Homeowner's insurance policies include a section on your duties after a loss. Specifically, you are required to protect the your property and the property of others from further damage or loss, make reasonable and necessary temporary repairs required to protect the property and keep an accurate record of repair expenditures. You obviously want to avoid personal injury or property damage lawsuits from your neighbors, but your insurance carrier doesn't expect you to put your life in danger. Tie off anything you can, but do not climb the tower! Keep track of time that you spent on the project (clean up, tie-off, etc). Your adjuster may compensate you for your time by offsetting it against your deductible. Typical rates for an insured's labor are from $6 to $10 per hour. Don't expect to be paid for time on the phone getting quotes or windshield time going to the local radio emporium, though...we're talking sweat work.

File an insurance claim

Call your insurance agent and notify them of the loss as soon as possible. Do it by phone and you may want to follow up with a short letter, fax or e-mail. Start a file documenting the claim that should include: 1) notes on conversations with your insurance agent and claims representative; 2) estimates of items to be repaired and replaced; 3) any time YOU spend actually working on the damage; 4) photographs and inventory of damaged or destroyed property 5) related claim data, such as claim number, adjuster's name/address/phone/fax/e-mail address. Get on the phone and get current street prices and availability from several vendors. If the items damaged or destroyed are no longer available, you may be entitled to replace them with items of "like kind and quality." Be prepared to document these differences and discuss them with your claims rep. Also, as my sainted grandma used to say, "Pigs get fat...hogs get slaughtered." If you can buy a new rotor/antenna/tower/whatever at a great price, turn that price in...not the list price. Most claims adjusters get real cranky (and rightfully so) if they feel a claim is being "padded." At best, it slows down the process. At worst, you may find yourself facing felony insurance fraud charges. A word to the wise should be sufficient.

One other item, in the overall scheme of things, your damaged tower (unless it's going to fall on the neighbor's house) is probably not as high on the claims representative's priority list as someone's home with major structural damage. In times of major catastrophes: hurricanes, hailstorms, tornados and the like...there's never enough time and people to get things done...be patient and be reasonable.

Before any work is done, insist that your contractor provide you with a current certificate of contractor's liability insurance (his malpractice coverage), a current certificate of worker's compensation coverage and local references. If the person is a professional, that won't be a problem. If he's a fly-by-nighter, insurance probably will be a problem...and you just don't want those headaches. If the contractor tells you that his associates are "subcontractors," tell him you want to see the "subcontractors" certificates of liability and worker's compensation insurance. Don't even consider bending on this.

Most insurance companies will write a check for the total damages (less your deductible) when the work is completed. If you want a check prior to the start of work, the adjuster may reduce the payment for any depreciation on the damaged property (called an actual cash value or ACV settlement) and then pay the balance when the work is completed. This is consistent with the language in most policies and keeps everybody honest. Most homeowner's policies settle losses on a replacement cost basis..., which means new stuff for old...when the new stuff is purchased. Make sure you know whether your policy pays replacement cost or actual cash value BEFORE you suffer a loss. If you have an ACV policy...get it updated...right now!

Ray Fallen has been an agent for The State Farm Insurance Companies since 1988. The opinions expressed are those of the author alone, and are not those of The State Farm Insurance Companies. The coverages described may not be available or may not apply in your state, province or country. You are strongly encouraged to review your homeowner's policy and tower installation with your insurance agent to determine appropriate coverages and amounts. The pronouns "he/his" are used in a non-sexual, gender-neutral basis.

Ray's call is ND8L. He's been a ham since 1964 and is a member of the North Coast Contesters Club, K3LR's Multi-Multi team, DXCC, ARRL and the Double-O Repeater Group (N8GO). He may be reached via e-mail at: nd8l@juno.com or via the State Farm Web Page (www.statefarm.com.)

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Antennas

Although the focus of this book is towers, antennas *are* the point of the tower structure.

At the top of the pile (and the pileups) in terms of "death ray" effectiveness are stacks of big antennas. Most highly competitive stations use monoband stacks on each band (six elements over six elements etc.) for 10-, 15-, 20- and even 40-meters. At the bottom of the totem pole in terms of effectiveness are trapped, quarter-wave multiband verticals that require a good ground radial system and typically lack them.

All other antenna systems fall in between these two extremes. Full sized wire antennas will work better than trapped wire antennas, while a small beam will work circles around just about any wire setup. If you already have a small tribander, to increase your signal appreciably you'll have to at least double the boom length. In general, gain is a direct function of boom length. Just decide what's practical and affordable for you and go to work putting it all together. (For more information on antenna performance, the author and H. Ward Silver, N0AX, have published landmark antenna reports that actually compare on-the-air performance using a dipole as a reference. For copies of *HF Tribander Performance – Test Methods And Results* and *HF Vertical Performance – Test Methods And Results*, contact www.championradio.com.

Temperature cycle

An important tip relating to antenna construction is, after assembling the antenna, let it sit overnight, then retighten all of the nuts and bolts the next day. The hardware will have temperature cycled from warm to cold and warm again and some of the hardware will have loosened up during that temperature induced expansion and contraction.

Antioxidants

Corrosion is a big problem for antenna and tower systems. By using galvanized or stainless steel hardware you'll stay away from most corrosion problems. Unfortunately (or fortunately) most antennas are made of aluminum and are subject to aluminum oxidation in the element joints or or other electrical connections. Whenever you build an antenna, use an antioxidant such as the ones discussed in the corrosion chapter. Although some antenna manufacturers provide this paste with their products (FORCE 12 and MOSLEY to mention two), some manufacturers do not provide any, although they may recommend its use.

Feedline jumpers

With many beam antennas, the feedpoint is out of reach from the tower. I prefer to use a jumper, or pigtail, just long enough to reach from the feedpoint to the mast on the tower. That way, all you have to do is plug the main feedline into the jumper with a barrel connector, weatherproof it and everything's ready to go. The amount of loss introduced by an additional *PL-259* or two and a barrel connector is negligible on HF; it's not worth worrying about. You'll understand how convenient this is if you ever have to drop the antenna in the future. Just disconnect the jumper and lower the antenna. If you've connected the antenna to one long piece of coax, you'll have to work your way out to the feedpoint and disconnect it there before you can lower it. Use a jumper, it'll save you a lot of hassle.

Keeping the elements from coming apart

Most HF beams have tapered elements made up of decreasing sizes of aluminum tubing that are generally held together by compression with a hose-clamp or rivet. Here's a tip that will not only add to the mechanical integrity of the antenna but will also enhance the electrical reliability. After you've assembled the antenna with hoseclamps, tested it and are ready to install it, put a self-tapping screw or rivet through each element where the tubing overlaps. The best kind of self-tapping screws are called *TEK screws;* these have a chisel point which will start the screw in just about any material and are available in most hardware stores. Sheet metal screws tend to break off when being installed which is not a problem with the TEK screws. They are available in Phillips head as well as nut sizes for your nutdriver or cordless drill. They'll hold the elements together as well as provide a fine additional electrical connection between the different sizes of tubing. Of course you can use rivets as well as popularized by Force 12. If you're concerned about the boom twisting, you can put a few through the boom as well. These small holes can be stress risers and in some instances may cause failure. If you've got winds strong enough to overstress these small holes, chances are that the antenna will blow apart before the holes are overstressed. In *Physical Design of Yagi Antennas,* Dave Leeson, W6NL, ex-W6QHS, recommends drilling any holes (such as for self-tapping screws) on the underneath side of an element.

Speaking of Force 12 antennas and rivets, in my opinion they are a great improvement to antenna mechanical design. By replacing the traditional hoseclamps, they have reduced the cost and the weight of the antenna while eliminating a device that always seems to get hung up on something while you're trying to install or remove an antenna; that is the hoseclamp that tends to snag on guy wires, antennas, and just about anything else in the vicinity. The only complaint against rivets that I'm aware of is that in perpetually windy regions, the single row of element rivets will allow the inner piece to move enough that eventually the joint will fail and the element will come apart. In this case, or if you just want to insure more reliability, just put another row of rivets on the opposite side of the existing row. Or, in extreme cases, add two rows 120 degrees apart for a total of three and your failure rate will drop to just about zero.

Baluns

Baluns for beam antennas have a checkered history. A balun (from "balanced-to-unbalanced") is used to match a balanced load (like a dipole or driven element) to an unbalanced load (typically coax). The other purpose is to keep the outside of the coax shield from radiating and causing RFI.

From power handling limitations (the fuse syndrome) to poor mechanical and electrical design, baluns can be seen as a necessary evil. Modern baluns are designed to be "current-type" baluns as opposed to the previous "voltage-type" balun design. There are several good books available about baluns and feedlines; refer to these for more definitive information.

Another balun design is to use a coaxial RF choke. It's simply a coil made up of eight to ten turns of *RG-8* or whatever coax you're using with a diameter of six to eight inches. It's really reliable as there are no inductors to short and no toroids to saturate or burn out. The main drawback to a wound RF choke is that they can be pretty imprecise as far as being useful on the frequencies of interest. This is where having some test equipment to actually look at the choke and its parameters would be very useful. Otherwise it's a hit or miss proposition. Some antenna manufacturers provide baluns with their products, others recommend a coiled RF choke. You should follow the manufacturer's recommendations.

Split coax

Most manufacturers use some type of feed point system that will enable you to simply plug your *PL-259* directly into the feedpoint or balun. This is acceptable if you don't forget to do your weatherproofing. But a few companies want you to split the coax and feed the ends of the cable directly to attachment points on the driven element. That is, center conductor on one side and shield on the other. It works fine but the junction of the coax (the bottom of the Y) is very difficult to seal. Water will simply wick down the outer shield and into your shack unless you take great pains to weatherproof it.

There is an optional method which works on antennas such as those from CUSHCRAFT. Just connect a dipole connector to the driven element, then plug a *PL-259* into it. A dipole center connector has a female *PL-259* (an *SO-239*) embedded in a plastic material with two leads coming out to connect to the sides of the dipole. The exception to the split coax feed is the MOSLEY line of *PRO* antennas. These use a split feed, and it is very critical to successful installation of the antenna. Once again, do what the manufacturer specifies.

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Tower removal

What goes up must come down; that goes for towers and antennas as well.

Danger, Will Robinson!

I can't emphasize this enough: The MOST DANGEROUS activity around towers is removing a tower that you know nothing about. You CAN'T be too careful in this situation.

CAREFULLY inspect everything you can from the ground. Push and pull on stuff to see how secure it is. In the case of badly rusted guy wires, you may want to use temporary guys to make if safer. This is a case of "If you feel that it's dangerous - it probably is."

If you're not sure about the integrity of the tower structure and you feel uncomfortable about even climbing it - WALK AWAY. I've done this several times and never regretted it.

The removal prime-directive

The most important thing to remember in disassembling a tower and antenna system is that "it must be removed the same way in which it was installed." In other words, if it was installed with a crane, it almost certainly has to be removed by a crane. If a mast was brought up through the middle of the tower, it'll probably have to be lowered the same way.

For an undamaged antenna and tower system, just reverse the steps outlined in the installation chapter; disconnect the feedlines, rig up a tramline and lower away.

Two of the most useful tools in this phase of work are a hacksaw or hand grinder and a can of *Liquid Wrench*. Fasteners are typically thoroughly rusted and generally difficult to impossible to remove.

ROHN *25G* or *45G* sections can be difficult to take apart for a couple of reasons. If the builder didn't put any grease in the legs, they may be oxidized together. If the builder overtightened the leg bolts and ovalized the legs, the legs will be compressed together. In either case you'll need something to pry the sections apart.

The traditional method was to use a small automotive hydraulic bottle-jack and a couple of two-by-fours. This technique works fine, but you must put a leash on everything so that nothing gets away from you and falls. A *Tower Jack* allows you to pry the sections apart with relative ease. The only caution is that you may wind up bending the tower braces or popping a weld by exerting too much force with the *Tower Jack*. If that is the case, the legs may be extremely jammed and you may have to resort to the bottle jack anyway.

Of course the easiest and safest way to remove a tower is to get a crane in to lift everything. For the cost of a crane versus the chance of an accident, it's really a no-brainer. I've used a crane to lower 100' of 25G and also 90' of 45G with no problems or damage.

If you're removing a tower that you can't climb, there are a couple of options. If you've got the room to let it fall, carefully cut one set of guy wires and then pull one of the other ones to encourage it to start its downward journey. You might have to cut additional guys. A freestanding tower can be felled like a tree. Just be REAL CAREFUL in all cases.

If you don't have the room to drop it, you can use a crane to pick it up and lay it on the ground. The trick is getting up on the tower to attach the slings and the crane hook. The best thing to do is to get a crane with two hooks. You'll use one to run you up in the man-basket where you'll then attach the second hook to the slings. Have the operator put a little tension on the tower to hold it securely and then have him lower you in the man-basket. Once you're on the ground and the crane has the tower, cut everything holding it and then lift the tower up and lay it on the ground. Using a tagline will help you maneuver the tower as it's being lowered.

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Working on a crank-up

One of the touted advantages of a crank-up is the ability to bring the antennas down to roof or close to ground level where it's easier for the station owner to work on it. For this convenience, the price that you pay is the added mechanical complexity and cost of the crank-up apparatus. They can cost two to three times the cost of a guyed tower of the same height.

Another limitation is the fact that a crank-up cannot be climbed safely once it is extended. **Do not climb a crank-up tower unless it is totally nested and locked in the lowered position!** Again, all of the weight of the system is on the cable and pulley systems and if something breaks or comes loose, your toes and fingers are in the plane of the tower sections as they make their rapid descent. If the tower is jammed and won't come down, don't climb it to fix it. Get a boomtruck or crane in to lift you up to work on it. Or, better yet, get professional help.

It is possible to climb a crank-up if you can lock it into place. One method is to use three to four foot long pieces of 2x4's or pipe. Insert them at the bottom of each section through the diagonals and they'll catch each section before it can move down very far. You can also gently lower the tower until it rests on the safety pieces, thus jamming them into place and eliminating any tower movement at all. Bob Wilson, N6TV, recommends using U-bolts on a leg per section, again putting them right under the bottom of a section. Either way will give you an added safety margin.

The biggest limitation of a crank-up, in my opinion, is that all of the dead weight of the system plus any added wind loading is all supported only by the cables that hoist the tower up and down. If one of those cables breaks, and occasionally they do, the whole system makes a rapid descent until it slams into the bottom section or base pad with an incredible amount of force. Many times the tower will come through relatively unscathed but the boom of the antenna will break in half because of the sudden stop. Once the cable snaps, you must re-cable the tower to get it back into operation, if you can do it yourself. Modern crank-ups, such as those made by US TOWER, have a sophisticated system of cables, pulleys, idler wheels, jackscrews and spring-loaded hardware to make their towers move up and down efficiently and safely. Your chances of repairing a cable break on one of these towers yourself are just about nil.

Crank-up tower cables

Crank-up towers depend almost entirely on their cables to operate reliably and safely. One tower manufacturer, for example, wants you to replace the cables every 3 years. I have never seen a crank-up cable that needed to be replaced in 3 years, or even in 10 or 15 years or more in many installations. I call this a 'weasel clause', that is if something happens to your tower and you haven't replaced the cables within 3 years, the manufacturer can weasel out of any liability. You've got to understand that tower manufacturing companies are insurance-driven enterprises so they are primarily interested in limiting their liability exposure to as little as possible. That's why they have policies like that and they're not about to give you any information that may potentially cause problems.

Here are the reasons why you may want to replace your cables.

1) Damage. This is where the cable is kinked or flattened and it should be pretty obvious.
2) Rust. This means serious rust, not surface rust that can be

easily scraped off.

3) Excessive broken strands. Most crank-ups use 7x19 galvanized cable which means it has 133 strands in it. You're allowed to have six total broken strands and three in the same bundle before it's time to consider replacing the cable.

What you can do to extend the service life of your cables is to lubricate them once or twice a year with a cable lubricant. Do not use heavy grease or motor oil. They'll just attract grime and particles out of the air. Use a thin lubricant such as PreLube which is recommended by wire rope manufacturers and is distributed by Champion Radio Products (www.championradio.com). Also exercise the cables by running the tower up and down a couple of times a month and don't always leave the tower in the same spot all the time, e.g. at the limit switches. Over time the cable can take a set if it's always at the same place so leaving it at different places spreads the wear over much more of the cable.

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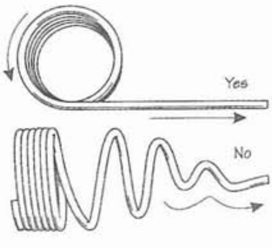
A FEW FINAL TIPS

Over the years I've picked up many tips related to tower and antenna construction. Some have been discovered easily; others were the result of hard fought trial and error. I'm passing these along so that you might avoid learning them the hard way. (If you have a tip that I've missed, please send it to me for inclusion in the next edition; you'll even get credit for it.)

1. Follow the LXC prime directive. **Do** what the manufacturer tells you to do; **Don't do** what they don't tell you to do.
2. Break every task into bite-sized chunks. In other words, do things one at a time and try to avoid doing two or more things at once. An example would be bringing up the coax feedline already attached to the beam. It adds more weight to the lift, may put the beam out-of-balance, and the cable will typically not go where you want it.
3. **Look** at your safety belt and D-ring when clipping in your lanyard. Do not assume that when you hear the click that you are secure. Always **look.**

4. For most purposes and frequencies, additional coax connectors, barrels, elbows, etc. in the line will have no significant effect on dB loss or on SWR on HF.
5. Don't use cheap hardware store electrical tape (i.e. 10 rolls for $1.99). Use only *Scotch 33+* or *Super 88*. These are far superior to anything else. A double wrap of these high grade electrical tapes is usually sufficient for weatherproofing. Expect to pay three to four dollars a roll for these excellent tapes.
6. Always take a roll of tape and a knife or razor knife when you climb a tower.
7. If you feel you must use *CoaxSeal,* wrap the joint with tape first. Then put on the *CoaxSeal.* Otherwise the *CoaxSeal* will permanently gum everything up.
8. For securing cables running up the tower, use foot-long pieces of solid #14 or #16 insulated wire. Just twist it around the cables and the tower leg; it's much easier to add or remove a cable than using tie-wraps or electrical tape.
9. Never use white tie-wraps; they'll deteriorate quickly, often in just a year or two. Black tie-wraps are better but they still eventually breakdown. The best method is to cover the tie-wrap with electrical tape insuring complete UV protection.
10. When removing cable with an axis from a roll (i.e. coax, guy cable, etc.), **unroll** it, don't uncoil it. Uncoiling will quite possibly kink it, and will not only damage the cable but also cause you unending aggravation as you attempt to get it untangled.



11. Finger-tight connections are not good enough. Use one pair of pliers or Channel-Locks to hold the connector and another pair to tighten them.
12. When putting up tubular leg towers (ROHN *25G, 45G* etc.), always grease the inside of the bottom legs. They'll go on more easily and the grease will retard corrosion growth that makes taking them apart difficult. Also, if they are new tower sections, inspect the bottom of the tower legs and the bolt

holes for excess galvanizing flash. Use a taper punch (drift pin) to clear the slag. Be careful not to enlarge the bolt holes.

13. When installing a rotator, point the rotator North (or another known direction) after testing on the ground to make beam alignment easier on the tower.
14. When hauling up rotator cable with the rotator, tie a big loop in the cable about three-feet below the rotator, then clip the loop to a carabiner on the rotator haul line to take the weight off the terminals. A large gentle loop won't damage the cable.
15. **Never** use eyebolts that have eyes that can open. Always use eyebolts that are cast or welded closed.
16. Leave three to four-feet of mast extending above the top of the highest antenna on the tower. This extra mast can then be used as a gin pole/pulley attachment point for other antenna or tower work.
17. Use **only** stainless or galvanized hardware. Avoid cadmium plated, etc. If you're not sure, leave the suspect hardware outside for a few weeks and see what happens. If it starts to rust, find some other use for it, far away from your tower.
18. Do not use machine shop type pillow-blocks for thrust bearings. These are the type which use Allen screws or set screws to secure the mast. They look like they'll work and they're relatively cheap but they will rust solid in three to five years. Use only **outdoor grade** (ROHN, galvanized, etc.) thrust bearings if you plan to ever take it apart again.
19. Use antioxidants on your metal-to-metal contacts. There are products for copper and aluminum. Use the copper ones on your ground system and use the aluminum ones when assembling your beam antennas.
20. Use a file to round the sharp edges of all plates, steps, brackets, arms, etc. to keep them from damaging you.
21. Always take extra hardware, nuts and bolts up the tower with you in case you run short or drop something. If you don't have them, you'll invariably need them.
22. Use a pigtail on beams from the feedpoint to a convenient point within easy reach of the mast. Do not attach the coax to the beam on the ground and haul up together with an-

tenna. It'll invariably be on the wrong side of something.

23. Avoid splitting the end of the coax to feed the antenna (ala CUSHCRAFT and TELREX) if possible. Use dipole center insulator so that you can use a PL-259 instead. This will prevent water from wicking down the coax.
24. Tighten all connections again the next day. Nut and bolt mechanical connections will loosen up the first time they go through a temperature cycle.
25. For a simple drip loop on your coax, take a medium sized tie wrap and attach it to the coax entry loop just before it makes your building entry. Point the tie wrap tail down and you have a quick and dirty drip loop.
26. An antenna should be removed the same way it was installed. If it went up with a crane, it'll probably have to be removed by a crane.
27. When putting something together "temporarily", always install it as though you won't be coming back; temporary sometimes means it'll be up and used for years.
28. What if you're considering a full-sized three-element 40-meter beam? You'll need a bigger tower, bigger rotator, bigger rigging talents and a bigger budget. Here's an alternative; stack two CUSHCRAFT *40-2CD*'s or XM240's. Smaller rotator, smaller hardware, smaller cost but similar gain and performance to the much bigger and more costly antenna.
29. If the wind is blowing while you're up on the tower, it may be difficult to lower the end of the rope to the ground. The first thing you can do is to attach a weight to the end of the rope; a wrench works well. Professional climbers use a bean-bag with a loop on it that's full of metal shot. If added weight isn't enough, clip the end of the haul rope carabiner into the other side of the rope. The carabiner will slide down the rope when it's lowered. You may want to also use a weight but just using a carabiner will work 90% of the time.
30. Some rotators have control cable quick disconnects, others don't. If you want to add a quick disconnect feature, the easiest thing to do is to use trailer plugs - they come in a flat 4-wire polarized configuration. Get 2 sets and install one set in one direction and the other in the other direction. This will

result in the polarized plugs being in opposite directions, preventing accidental plugging into the wrong wires.

31. One way to keep rotator control cable colors straight and consistent is to use the resistor color-code. It is: black, brown, red, orange, yellow, green, blue, violet, grey and white.
32. Antenna element hose clamps invariably catch on anything – wire antennas, guy wires, cables, etc. To minimize this annoying characteristic, wrap the hose clamp with a layer or two of electrical tape.

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