Wired, Optical, and Wireless Communications Book

Outside Plant Chapter

What is the Outside Plant

The first topic to consider is what is the outside plant? In general outside plant connections are those exterior to a building. Typically these are used to connect one building to another. This type of connection can be completed using wired media or a wireless connection.

Standards and Codes

Adherence to applicable standards and codes is required for any network construction project. A standard is used to provide guidelines for the type of material to use, as well as suggested installation practices. Notice that a standard is not a requirement. A standard is designed to achieve a basic level of performance. While it is true that many extant networks function without applying these standards, eventually they are overwhelmed by errors when the load on the network increases to a level such an ad hoc network cannot sustain. Troubleshooting is then very difficult. Time is wasted attempting to determine how the network was constructed.

Codes were created to protect lives and property. Ignoring codes leads to legal liability at the least. Often work must be redone when an inspection reveals lack of compliance. A code is a requirement. The authority having jurisdiction or AHJ decides what codes to require. In most cases this will be a city government. Some areas, such as rural areas, may not have as many codes in their jurisdiction. Nevertheless, the commonly adopted codes should be adhered to, even if they are not required.

An outside plant installation must be done following the applicable codes and standards in case of an accident or dispute. Failure to conform to these provisions leaves the organization open to a claim for damages due to negligence.

Project Planning and Management

Whereas the network manager may install a cable or two inside a building, outside plant projects are complex and costly enough to call for outside assistance. If the project is complex enough, then a complete network design is called for. In addition to the usual network design steps detailed in the top down network design process, outside plant projects require coordination with other entities to arrange right of way, locate existing utility lines, and secure required permits.

Once the planning phase is completed the resulting decisions must be rendered on paper in the form of lists of material and work prints. Ensure these specifications and drawings include:

> Obstacles, such as existing utilities, traffic, future building construction, landscaping, safety during construction, access to the site for heavy equipment, and future maintenance requirements

Right of way easements

Detailed plans for structures, conduits, poles, and so forth

Media specifications

Keep in mind the expected life of an outside plant installation is 30 years. Much will change in that length of time. As discussed below running cable through a set of vaults, manholes, and conduits is the most expensive up front option, in the long run it is the most flexible as the media may be updated as required.

Issuing a Request for Proposal

Once the project planning is complete someone must be hired to perform the work. As discussed in the chapter on requests for information, proposals, and quotes this document must include detailed statements as to the work expected. The sections typically included are:

General description of the work to be performed

List of specific tasks

Reports required

Required certifications or qualifications

Timing

Security requirements

Work site restrictions

Glossary of terms

More specifically the general statement of the work describes the job in broad terms. For example, you might state that two buildings are to be connected to each other using direct burial fiber optic cable that requires boring under a city street. This general statement allows prospective bidders to judge if they are interested. This type of general statement can be used in a Request for Information as well.

The list of specific tasks provides a detailed description of each separate part of the project. For the direct burial fiber optic cable you would specify whether it is singlemode or multimode. If multimode cable is called for, then whether it is 50/125 or 62.5/125 in size would be stated. This assumes you know what you want to have installed. If not, then you would specify the performance requirements such as the ability to carry 55 Mbps of traffic.

Some projects may be large enough that they call for formal status meetings on a regular schedule, then an audit after completion. Others may only require periodic verbal updates. Either way you should state what is expected.

Some jobs require specific qualifications. For example, engineering work should be done by a Professional Engineer licensed by the state. The configuration of the equipment might call for someone certified on that equipment. In all cases you should use designers and installers who have passed the appropriate BICSI examinations at a minimum.

Clearly state when work may commence. Also clearly state by what date work must be completed. Failure to do so leaves too much discretion in the hands of the contractor who does not have to live with the mess an uncompleted project produces.

Does your facility have any security requirements that would prevent work from being started? Must workers undergo a background check? Many governmental permits require someone on site at all times who can speak to any governmental inspector who might appear. Anything along these lines should be clearly stated to prevent delays and added cost.

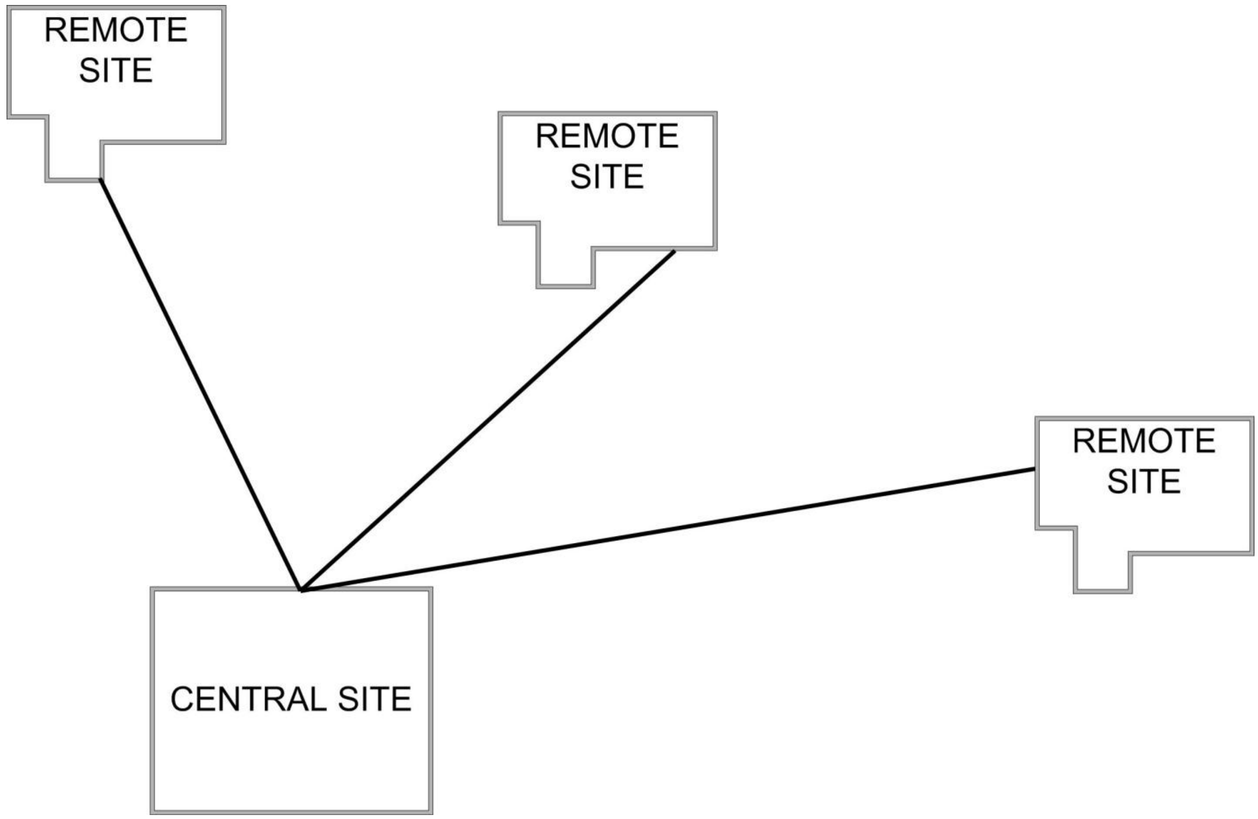
Likewise, any restrictions on access to the site need to be included. For example, using a jack hammer to remove concrete during class hours would not work for a school.

Finally to be sure everyone is talking about the same thing; define all technical and legal terms in a glossary. The less anything is left open to interpretation the better.

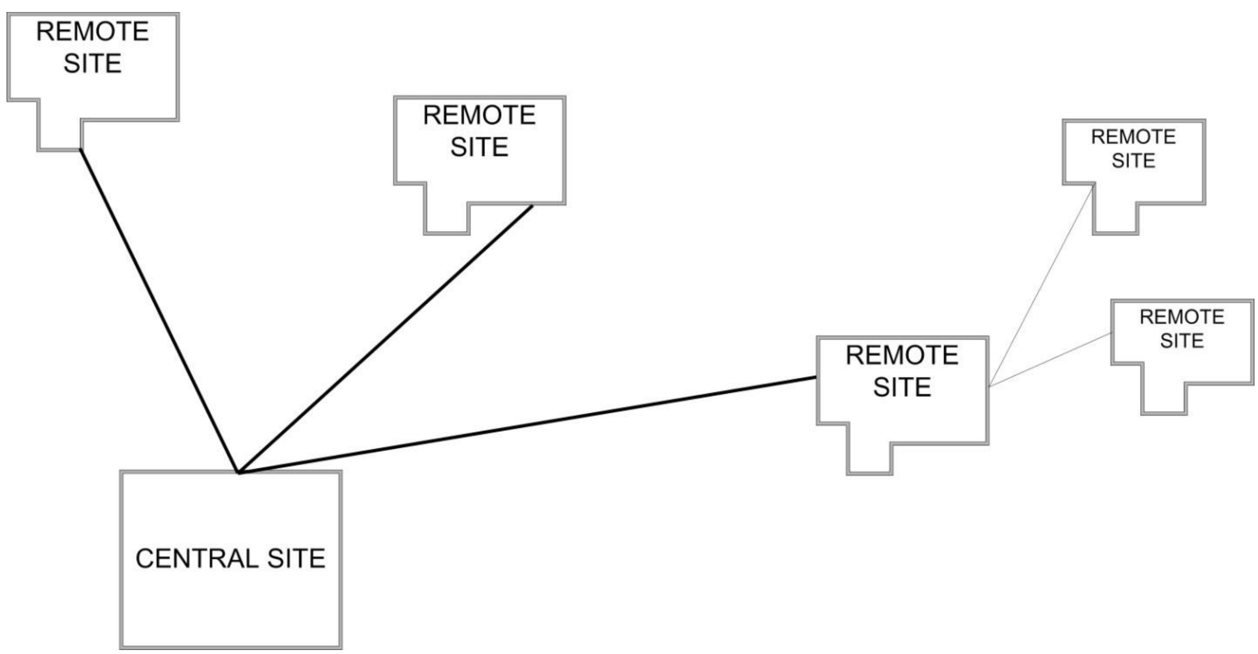
Topologies

Topology is the method selected for the layout of the connections between points. Possibilities include:

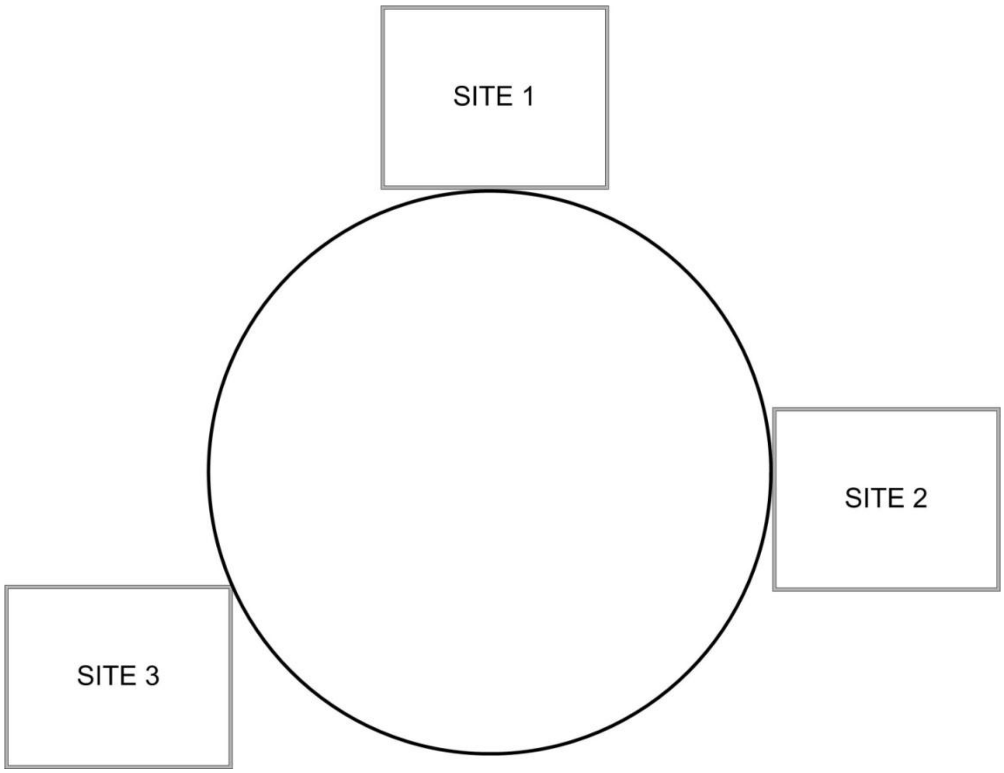
Star



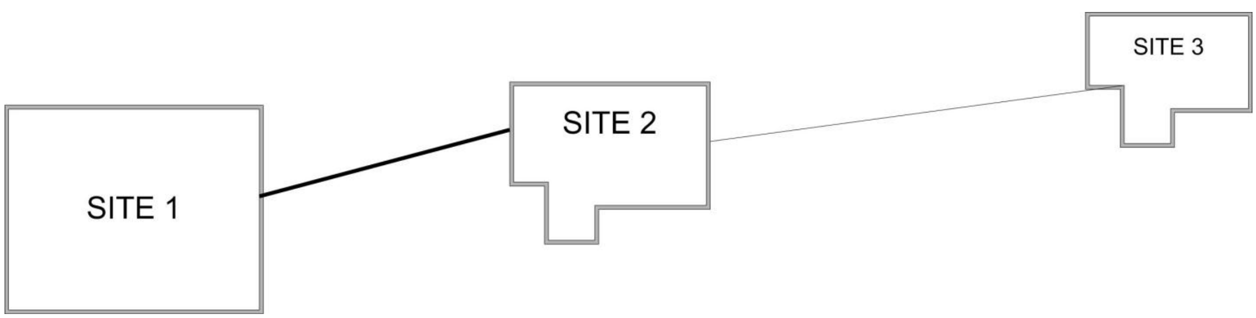
Multiple Star



Ring



Bus



For the outside plant a star topology is the most commonly used. In this design all connections radiate out from a central site.

In the multiple star all connections still radiate out from a central site. But in addition one or more of these remote sites also serve as the central site for an additional star pattern. This design is used when the distance from the first central site to the furthest location exceeds the maximum allowable distance.

For the ring topology the connections form a solid ring connecting all sites in turn.

In the bus arrangement the connections proceed from the first location to the second then to the third and so on.

Redundancy

As the outside plant is often beyond the direct control of the user, redundancy in the connection is desirable. This can be accomplished by:

Using physically diverse routing

Using alternate technologies

With physically diverse routing two cables are run between each location. These two cables can be in a straight line between the locations, just physically separated, or they can be part of a ring topology.

Alternative technologies can combine a primary link with a redundant link using a completely different method. For example, a single fiber optic cable might connect two buildings in a campus environment. In case this link were to be cut, then a wireless connection using either radio frequency or free space optics could be installed as a backup connection.

Adding Capacity

Once the infrastructure is in place changes in the end point equipment can be used to increase the capacity of the connection without changing the installed cabling. Multiplexing is the easiest way to accomplish this.

A common method of multiplexing over a fiber optic cable is Coarse Wavelength Division Multiplexing (CWDM). Using CWDM eight channels, instead of just one, are transmitted over a single cable. These eight, individual channels are created by using a different color or wavelength for each channel.

Grounding and Bonding

Proper grounding and bonding is required for safety and performance. The National Electrical Safety Code (NESC) requires all cable shields, support strands, and other non-current carrying metallic parts to be grounded. This applies to end points and each junction point.

Grounding of a device is done by connecting the device to an effective electrical ground. What constitutes an effective electrical ground depends on the installation. For a building it is the ground connection for the electrical power supply from the utility company. In the case of a tower, as discussed below, a ground field may have to be constructed for the site.

Bonding refers to the interconnection of the various conductive parts so that they are all at the same electrical potential. Devices are not attached to the bonds. The devices are attached to the grounding system, which is then attached to the ground field. An effective bond requires a cable of sufficient size to maintain less than 40 V along its entire length. The bond between the telecommunications ground system and the electrical power ground system must be by at least a 6 AWG size conductor.

In addition to basic grounding, protective devices are required when the line or equipment will be exposed to lightning induced currents or be near high voltage sources. High voltage in this case is anything more than 300 V. The amount and type of protection is determined by whether the line or device is considered to be exposed or unexposed. Just because something is under a cover does not mean it is not exposed. If some other part that connects to it is exposed, then it may be as well. Protectors may be fused or fuseless.

In general each location will have its own ground field. Ground fields should not be connected to each other via the media being installed unless the two ground fields are also properly bonded to each other.

Pathways

In outside plant installations the media can be wired or wireless. In the case of wired media the cable can be installed underground or aerially. Wireless media can be radio frequency or infrared based.

Underground Installation Methods

If the installation is underground there are several alternatives available. To have fiber optic cable installed outside a utility contractor is normally used. They will use one of two basic methods to run the cable. The two basic methods are:

Cut and replace or trenching

Directional boring

In cut and replace a trench is dug through whatever is in the way between the two points to be connected. If just dirt is there, it is a simple process. If concrete or asphalt is there, then it must be removed and then replaced.

Cut and replace can be accomplished using one of three methods:

Trenching machine

Backhoe

Specialized plow

To do cut and replace the surface is removed if required, such as a concrete in a parking lot, then a trench is dug using a backhoe or trenching machine. Once the cable is laid and the dirt put back in place the dirt must be compacted. Compacting is done by a machine designed for this purpose. It just compresses the dirt so a dip in the surface does not develop later on. This is especially important when a public street is crossed. Typically, the jurisdiction will have an inspector test the compaction to ensure it meets requirements before the concrete or asphalt is put back in place. If the test fails the dirt is left to sit or be compacted again, then the test is performed again. All of this of course takes time and disrupts traffic. So cities require that trenching be done in small sections so as to impede traffic as little as possible. Such a requirement slows the rate of the job and therefore raises the cost. In general cities do not like cut and replace.

Boring then has become a popular alternative. To bore, a backhoe is used to dig a single hole at each end of the cable run. The boring machine is then used to bore a small tunnel, about 6 inches for most fiber runs, from one hole to the other. A pipe is run through the tunnel and the cable is threaded inside the pipe. The usual distance between the two holes is a few hundred feet, when doing utility work like this. This method is not foolproof. Problems encountered include dirt or rock that is difficult to bore through and potholes from shifting of the dirt.

Directional Boring Machine

Direct Burial Cable

Regardless of the method used to dig into the earth, the cable must be of a type that can withstand the harsh environment. Direct burial cable in particular must be able to resist moisture, compression loads, and animal activity. There are several different designs for direct burial cable. All of which are suitable for most uses.

As discussed the burial depth is affected by the requirements of the local jurisdiction, the type of cable being buried, the depth of the 50 year frost line, and the presence of any other cables. In general direct burial fiber optic cable should be at least 1 meter below ground.

In addition to the fiber optic cable a tracer wire should be installed along with the fiber cable. This is required as direct burial fiber optic cable cannot be easily detected from above ground.

Underground Cables

If the cable is run through a conduit installed underground, then it is referred to generally as underground cable. In contrast to direct burial cable this type does not require the extensive physical protection. Installing cable in conduit makes it easier to add additional cables, as well as change the cable for a new type. There are several types of underground cable.

Underground cables are run through ducts. These must be large enough for the cable itself, additional cables, and most important large enough for a pulling eye attached to the cable. The pulling eye on the cable is used to pull the entire bundle of cables through the duct. In general this duct should be at least 1.5 times the diameter of the cables.

Aerial Installation Methods

Aerial installations are a common site across the country. Replacing aerial installations after a storm is also a common occurrence. Therefore, an aerial run must always account for the expected wind and ice loads. These loads define the type of pole, the cable and support strands to be used, and the way equipment such as access points are mounted to the poles. For the poles themselves there is a classification system based on the transverse breaking strength of the pole. The size and type of pole then also dictate the depth to which the pole must be placed. This can be quite deep. Even though you may have the right to install the poles on the surface, keep in mind that you must consider the subsurface even with an aerial installation.

Clearances from other cables attached to the poles as well as over any objects that the route crosses must be accounted for. In some cases this will limit your ability to use an aerial link.

Aerial cabling must be installed properly since the cable is open to the environment and also often shares the pole with other utilities such as telephone or electricity. Most importantly aerial cable must have a means of strain relief to support the hanging cable. This is accomplished in one of three ways. First by installing a messenger strand, usually a stainless steel cable with high weight support strength. The messenger is installed first with the fiber being lashed to it for support. Second, the messenger may be built into the fiber optic cable itself to make installation easier. This type of cable is sometimes called figure eight cable based on the cross section appearance. Lastly, if it is available the cable can be overlashed to an existing support cable.

Typically poles are 35 feet in length. They are set 10 feet into the ground. At the ends guy wires must be installed to balance out the strain the messenger cable introduces. Poles are usually 225 feet apart.

Right of Way Issues

These days right of way can be a major problem. If you own the right of way, then the only problem will be the appearance. If you do not own the right of way, you may find the owner is reluctant to have their property disturbed.

In this case public right-of-way will have to be used. Most governmental entities, especially cities, will allow the easement area that runs along the edge of the street to be used for a fee. This is the same place water and sewer lines run. There will be rules about when and how this is done. Most cities have come to prefer boring over cut and replace when you cross their property or easements.

Dealing with the government can also lead to delays. A permit is typically required. Such a permit often must be approved by the city council. This can require several readings to allow for public input. All of this can take several months. Further, several sets of detailed engineering plans must be submitted for approval at the same time.

Regardless of where the cables are placed clearances must be maintained from other pipes and cables. For gas, water, and oil the clearance is at least 6 inches when crossing and 12 inches when parallel.

Conduit depth is typically specified by the government entity that has jurisdiction over the site. These depths may be required even if the right-of-way is privately owned. The frost line must be considered in all cases. Burial depth of cable whether in conduit or as direct burial should be below the 50 year frost line. Common depths are 24 to 30 inches. When the right-of-way goes under an area subject to vehicular traffic more depth is desirable to handle the compressive loads vehicles produce. The general guideline is 6 feet for this purpose.

Wired Media

The term recognized media means the current standards call for the use of this type of media. In most cases once the standard evolves an older type of media does not have to be removed as long as it still serves the purpose for which it was installed.

At the time of this writing the recognized wired media for outside plant use are:

Fiber Optic Cable

Singlemode fiber optic cable

Multimode fiber optic cable, both 50 and 62.5 micron sizes

Copper Cable

100 ohm balanced twisted pair copper cable

75 ohm coaxial cable

Let’s briefly review each of these cable types.

Fiber Optic Cable

Singlemode fiber optic cable is the best choice for outside plant installations. It has the bandwidth and distance ability to connect any two points to each other.

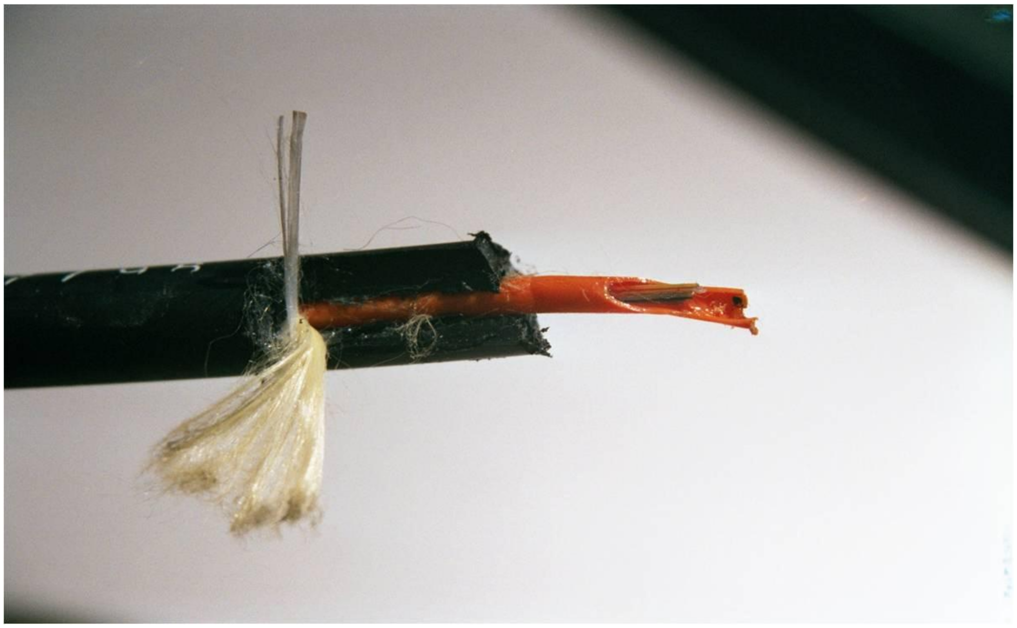
The main disadvantage to singlemode fiber optic cable is the cost of the devices to which this cable connects. A singlemode capable GBIC of SFF connector in a switch is much higher on a per port basis than a RJ-45 copper port. Nevertheless as the cost of installation is the highest single cost encountered on a campus, even if the end devices are only multimode capable, singlemode fiber should also be installed to future proof the installation.

Multimode Fiber Optic Cable

In the United States of America 62.5 um multimode cable has been the most common size. In Europe, and now in the US, 50 um multimode cable is seeing increased use. This has been common in Europe for some time, but it is new in the US.

There are two basic types of construction for fiber optic cable; loose tube and tight buffer. Loose tube construction is more common in outside plant installation due to its ability to deal with the harsher environment seen outside. Tight buffer cables are more appropriate inside of a building.

Loose Tube Fiber Optic Cable



The layout of the strands in the fiber optic cable has typically been a central core design, just like UTP cable. Increasing use is being made of ribbon style cables. The main interest in the ribbon style is the comparative ease of mass splicing a ribbon style cable.

Balanced Twisted Pair Cable

This type of cable is the common copper LAN cable, such as Category 5E or 6 UTP cable. The proper name for the cable is balanced twisted pair cable. By balanced it is meant that the signals on each of the conductors of a pair of cables are of equal value, but they have opposite polarity or phase.

In general copper cable is a poor choice for the outside plant due to the limitations it has. These include limited distance, limited capacity, and problems in balancing ground fields.

75 ohm Coaxial Cable

Coaxial cable is commonly used for audio video applications in the outside plant. It is unusual for a data connection. Although it is a recognized type, it is unlikely to be encountered carrying data unless it is for a surveillance camera managed as part of the data network.

Wireless Media

Towers

When wireless is the media of choice to connect two points in the outside plant line of sight is typically required between the two antennas. To achieve line of sight this will often require a tower or other elevated point to which the antenna can be mounted.

The easiest way to achieve this height is to use a short pole mounted on the roof of a building. In this case it achieves most of its height by being installed on the top or side of a building. This is a common way of avoiding the cost and trouble of a standalone tower. The attachment to the structure can be made using one of two methods:

Penetrating mount

Non-Penetrating mount

In a penetrating type of mount the unit or the unit's mount is bolted to the building one place or the other. For a non-penetrating mount, weight of some type is used to keep the unit still. Sand, water, and concrete blocks are commonly used for this.

If a tower is required, the size will determine the complexity of the installation. In general, towers are undesirable in urban areas. The neighbors do not like them due to their effect on the view. There are also safety and liability issues if the tower falls down. Therefore, the smallest tower possible is the best choice. Let's look at several sizes and types of towers.

As these examples show there are three basic styles of towers:

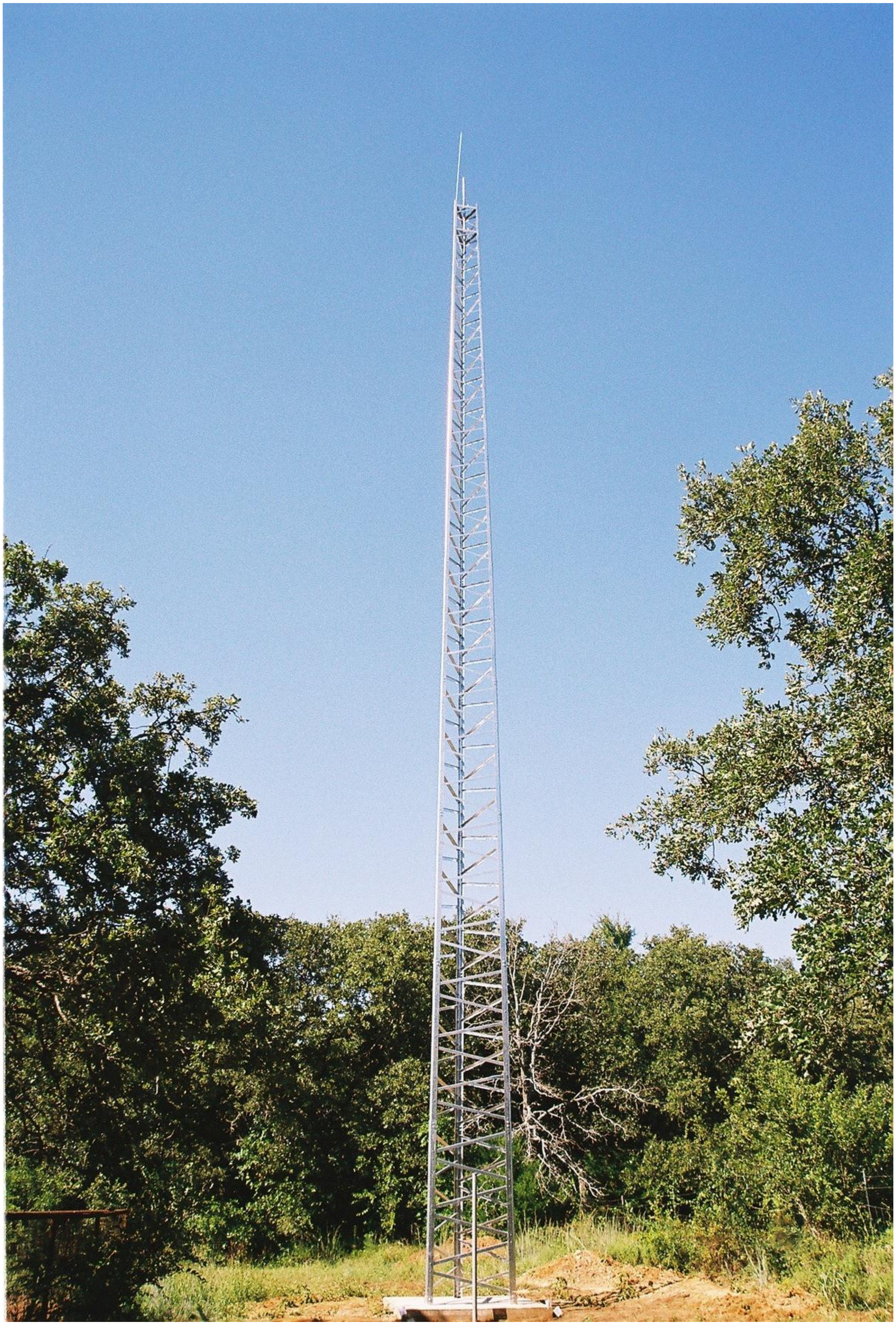
Self supporting

Guyed

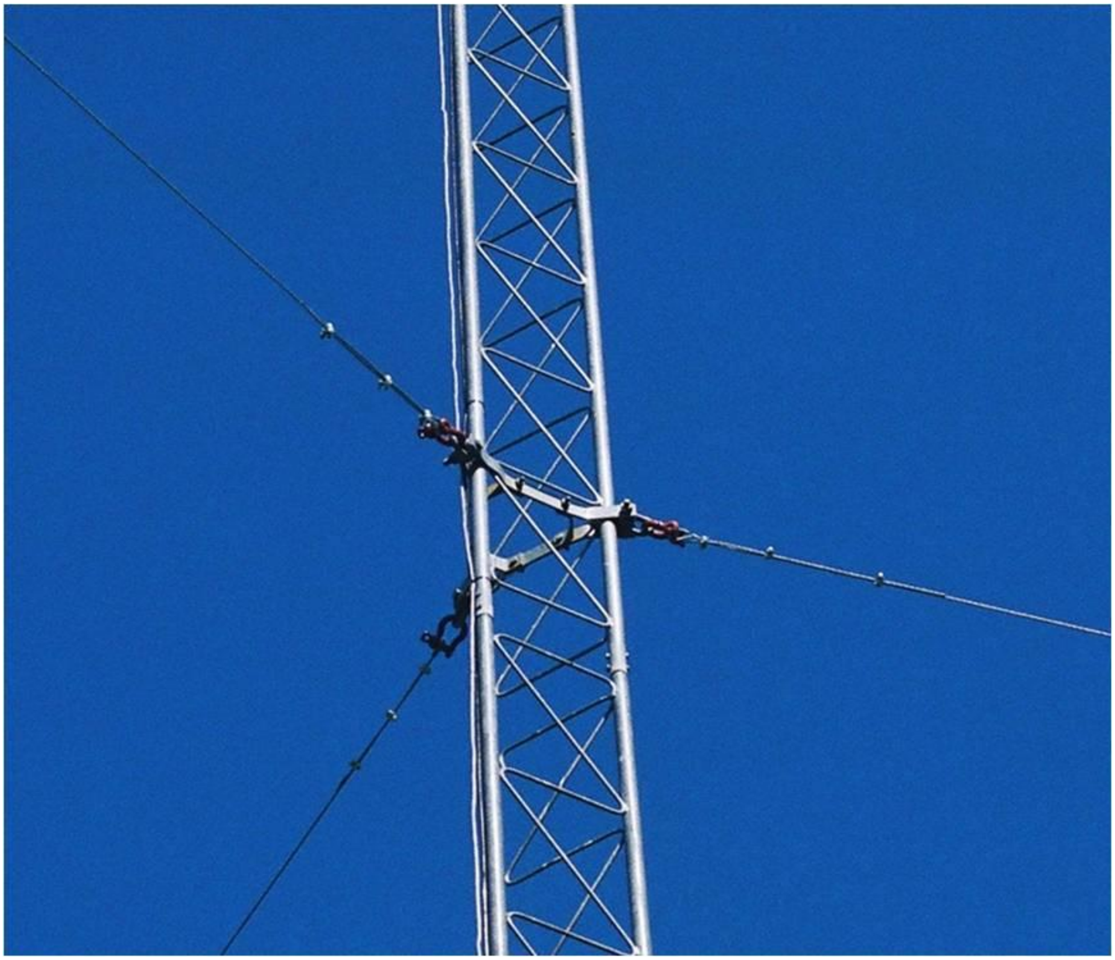
Monopoles

The requirements of the location, aesthetics, and local regulations will determine the type to use.

Medium Size Base Tower Self Supporting



Medium Size Base Tower Guyed Tower



A guyed tower is less expensive than a self supporting tower. However, more land is required for this type of tower to accommodate the guy wires.

Monopole Tower

Another type of tower is the monopole. This tower type is commonly used by cellular carriers. It is not used by most other providers due to the higher cost, unless required by the governmental entity with control over the site of the tower.

There are larger towers than these, but they are not typically used for the types of connections of interest here.

Tower Standards

The main standard for towers is the TIA -222-G “Structural Standards for Steel Antenna Towers and Antenna Supporting Structures.

Tower Database

If you prefer to rent space on an existing tower, rather than building your own, check any one of several available tower databases. Existing registered towers will have a number on a sign somewhere near them. Take this number or the location information and search for the owner. An example of this type of database is one from the FCC.

There are over 150,000 communication and broadcast towers in the United States. Many of these are owned by individuals or small companies. Each of these will have to be contacted to negotiate a lease for space on their tower or towers. There are large companies that control several thousand towers and other locations each:

ATT Communications

American Tower

Crown Castle

Pinnacle

SBA Communications

Spectrasite

Water Towers

To avoid the expense and regulatory challenges of putting up a tower, many have turned to water towers for antenna mounting. It depends on the number and distribution of these structures. However, with all structures that you do not own there will be access, cost, and interference issues to deal with. Depending on the type of water tower and the desired coverage area the antenna may be mounted directly to the top of the water tower or to the side rails. Wiring from these antennas then goes down through the hatch that is commonly at the top of a water tower.

In some parts of the world, a grain elevator is another possible site for an antenna. These tend to be quite tall, although access and electrical power supply can be an issue.

Antenna Mounting

There are several things to consider when mounting antennas on the side of a tower, or any other structure for that matter, that all center on interference with the desired signal pattern that is produced by the fact that antennas must be attached to something, and the existence of other antennas on the structure. First, the nearer the antenna is to the structure, the more distortion there is in the antenna radiation pattern. The effect of the structure on the antenna's radiation pattern can be lessened by mounting the antenna as far away from the structure or building as possible. The best place to put an antenna is at the top of a tower. But often this is not possible due to lightning protection and other devices already on the tower. On a tower an antenna can be mounted below the top, but it must set on a standoff bracket so as to move it away from the tower structure itself. In general the greater the distance the better it is. Common distances are from .3 to 1.5 m or 1 to 5 ft. A guideline of greater than one wavelength of the signal being transmitted is sometimes used, but 10 wavelengths is viewed as an even better distance. BICSI recommends these values:

2 GHz – 18 m or 60 feet

4 GHz 14 m or 46 feet

6 GHz 9 m or 30 feet

12 GHz 4.6 to 6 m or 15 to 20 feet

Second, to lessen the interference and noise from other antennas on the same structure, all of the antennas must be moved as far away from each other as possible. Since it seems that every antenna on the tower always needs to be in the same place, achieving a balance between ideal location and isolation can be difficult. The generally used guideline for this is from 1.5 to 3 meters or 5 to 10 feet of distance between any two antennas. But where did this come from? Experience in the industry has shown that this distance is sufficient for the frequencies used for wireless data networks that use low power for transmission. There are formulas for this as well. These formulas account for two factors. The first factor is the isolation gained from free space loss. In this case the free space path loss that is such a problem for wireless links is used to our advantage. The second component is the amount of overlap of the antenna radiation patterns of the two antennas. Both vertical and horizontal separation must be accounted for. For vertical separation the formula is:

dBs of Isolation = 28 + 40 X LOG(Separation Distance in Feet/(984/Frequency in Megahertz)) - Vertical Gain of Antenna 1 Towards Antenna 2 - Vertical Gain of Antenna 2 Toward Antenna 1

As the actual amount of beamwidth overlap is very difficult to determine, in most cases more than the minimum calculated distance is used. In other words, 10 feet instead of the calculated 5 feet is best. As the frequency goes down the distance goes up, as the frequency goes up the distance needed goes down. For example, to achieve 70 dBs of isolation at 900 MHz requires 13 feet, not 5. For a 5800 MHz signal, only 2 feet is needed. These simple calculations do not account for beamwidth overlap. This overlap is the difficult part to calculate. Antenna radiation patterns are available from the antenna manufacturers. However, these are idealized laboratory determined patterns. They also show a sharp cutoff at the 3 dB mark. The real cutoff is not as sharp as this would suggest. Rather the radiation falls off gradually over a much larger distance. These calculations are problematic at best. There are more sophisticated models, but these are beyond the scope or need of this work. This is why most just use the 10 foot guideline.

So far we have been considering only vertical separation. Horizontal separation is the next area to consider. In the case of a tower there is little that can be done to increase horizontal separation other than using the width of the tower and any standoff brackets. For tower mounting, antennas with very good front to back ratios are required to reduce the impact of radiation pattern overlap. When mounting antennas on a building, it is possible to use horizontal separation to our advantage. Again 5 to 10 feet is generally adequate. The formula is:

dBs of Isolation = 22 + (20 X LOG(Separation Distance in Feet/(984/Frequency in Megahertz))) – Horizontal Gain of Antenna 1 Toward Antenna 2 - Horizontal Gain of Antenna 2 Toward Antenna 1

The horizontal gain in this case is the front to back ratio as provided by the antenna manufacturer. As mentioned before an important aspect of both of these formulas is the amount of gain of each antenna toward the other, which is difficult to determine. This is why actual installations are typically done by trial and error using the guidelines as discussed.

Mounting on Water Towers

Mounting an antenna to a water tower is tricky. As these are smooth surfaces there are limited places to which an antenna can be attached. Unlike a tower that is made up of thin members to which an antenna can be readily attached, attachment to a water tower must be by welding, gluing, or by using magnets. Welding is best, but it is rarely an option as this tends to act on the metal in a way that is detrimental to the water stored inside. Welders who specialize in this must be used. Even then many water tower owners will not allow welding to the tank's surface. Unless a rail is already attached to the outside of the tank, epoxy glue is another choice. Some installations use powerful magnets to attach the antenna's bracket to the water tower.

Wind Loading

Antennas mounted on towers and poles have a wind load rating based on their surface area called the allowable projected effective area. This is important to avoid losing the antenna or overloading the tower. The manufacturer of the antenna will be able to supply the wind data for their devices. Compare this information to the main standard for wind loading, the EIA/TIA-222-G and EIA/TIA-195 standards, and a wind map. Of course the type of antenna has some effect on how much wind it can tolerate. A thin omnidirectional antenna will tolerate wind better than a parabolic dish, both due to the size and shape, and the beamwidth they each produce. The tower where the antenna is mounted has a rating. This depends on the height and whether the tower uses guy wires or not. The things hanging on the tower, such as the antennas, have an effect as well. In general the higher a device is off the ground the smaller it must be it meet the wind load requirements. The best way to be certain that the devices added to a tower will not overload it is to have an analysis done by a structural engineer with experience in this area.

Although it is difficult to do, most tower manufacturers recommend that the tower be located away from anything that be damaged by the tower as it is erected or if it falls, such as buildings and power lines. The clearance distance from any of these structures should be at least twice the height of the tower plus anything on top of the tower.

In addition to the things that hang on towers, the towers themselves have wind ratings. For example a commonly used tower that works quite well for sites that need a tower up to 100 feet or so is a Rohn 25. This tower depending on the exact model is rated for wind speeds from 70 to 110 mph. Winds come from many sources including downburst winds, straight line winds, tornados, and hurricanes. The risk in an area will determine the wind rating to use. Be sure to account for the equipment you plan to place on the tower now, in the future, and the possibility of renting space to other providers. Besides wind, keep in mind that ice hanging on the antennas and antenna mounts also has an effect on the ability of the tower, the brackets, and the antennas to remain attached. The Uniform Building Code (UBC) used in the United States of America has a section on seismic, in other words earthquake, loading on towers and their capacity to carry loads like antennas. In general the wind loading considerations are such that taking care of these also takes care of the seismic loading problem. But there is a map and table that specifies factors for seismic loading expressed as a Z factor for each seismic zone. Consult the current UBC or other local regulations for the exact application of this. A last load factor to consider is that added by people climbing the tower, the equipment they are hauling up the tower, and the tools they are using. Add the wind load, the ice load, and the temporary load and a tower may be beyond its design strength.

Tower Regulation

In the United States of America except for those towers that extend higher than 200 feet or are near an airport, regulation of towers is handled by local regulatory bodies. In the United States of America these authorities are typically cities or counties. In some cases statewide regulations may exist, but usually this sort of thing is a local concern. There are indeed concerns with towers. People object to large structures with flashing lights.

In the case of tall towers and those near airports the FAA – Federal Aviation Administration or the FCC may have an opinion on the location of the tower. To determine whether the tower falls under this requirement a form is filed with the FAA. As the FCC says:

> “The FCC has been given the authority by Congress to require the painting and/or illumination of antenna towers when it determines that such towers may otherwise constitute a menace to air navigation. “The FCC's rules governing antenna tower lighting and painting requirements are based upon the advisory recommendations of the FAA, which are set forth in two FAA Advisory Circulars. “Although the FAA's lighting and painting standards are advisory in nature, the FCC's rules make the standards mandatory. “The FCC always requires an FAA determination that an antenna tower will not pose an aviation hazard before it will grant permission to build that antenna tower. Information required on the FCC construction permit form advises the FCC staff as to whether such a tower location or height is involved. “The FAA's determination takes into consideration the location and height of the proposed tower, and its safety lighting and marking.”

The FAA form to be filed is Form 7460. The advisory circular that discusses it is AC/70/7460-1K.

In general in the US lighting or marking a tower for visibility is only required for those over 200 feet unless near an airport. If near an airport a slope requirement comes into effect.

As the FAA says:”

> “Except as provided in §77.15, each sponsor who proposes any of the following construction or alteration shall notify the Administrator in the form and manner prescribed in §77.17:

- (1) Any construction or alteration of more than 200 feet in height above the ground level at its site.
- (2) Any construction or alteration of greater height than an imaginary surface extending outward and upward at one of the following slopes:
- (i) 100 to 1 for a horizontal distance of 20,000 feet from the nearest point of the nearest runway of each airport specified in paragraph (a)(5) of this section with at least one runway more than 3,200 feet in actual length, excluding heliports.
- (ii) 50 to 1 for a horizontal distance of 10,000 feet from the nearest point of the nearest runway of each airport specified in paragraph (a)(5) of this section with its longest runway no more than 3,200 feet in actual length, excluding heliports.
- (iii) 25 to 1 for a horizontal distance of 5,000 feet from the nearest point of the nearest landing and takeoff area of each heliport specified in paragraph (a)(5) of this section.
- (3) Any highway, railroad, or other traverse way for mobile objects, of a height which, if adjusted upward 17 feet for an Interstate Highway that is part of the National System of Military and Interstate Highways where overcrossings are designed for a minimum of 17 feet vertical distance, 15 feet for any other public roadway, 10 feet or the height of the highest mobile object that would normally traverse the road, whichever is greater, for a private road, 23 feet for a railroad, and for a waterway or any other traverse way not previously mentioned, an amount equal to the height of the highest mobile object that would normally traverse it, would exceed a standard of paragraph (a) (1) or (2) of this section.
- (4) When requested by the FAA, any construction or alteration that would be in an instrument approach area (defined in the FAA standards governing instrument approach procedures) and available information indicates it might exceed a standard of subpart C of this part.
- (5) Any construction or alteration on any of the following airports (including heliports):
- (i) An airport that is available for public use and is listed in the Airport Directory of the current Airman's Information Manual or in either the Alaska or Pacific Airman's Guide and Chart Supplement.
- (ii) An airport under construction, that is the subject of a notice or proposal on file with the Federal Aviation Administration, and, except for military airports, it is clearly indicated that that airport will be available for public use.

- (iii) An airport that is operated by an armed force of the United States.
- (b) Each sponsor who proposes construction or alteration that is the subject of a notice under paragraph (a) of this section and is advised by an FAA regional office that a supplemental notice is required shall submit that notice on a prescribed form to be received by the FAA regional office at least 48 hours before the start of the construction or alteration.
- (c) Each sponsor who undertakes construction or alteration that is the subject of a notice under paragraph (a) of this section shall, within 5 days after that construction or alteration reaches its greatest height, submit a supplemental notice on a prescribed form to the FAA regional office having jurisdiction over the region involved, if --
- (1) The construction or alteration is more than 200 feet above the surface level of its site; or
- (2) An FAA regional office advises him that submission of the form is required.

The lighting may be white flashing strobe type lights or a combination of red lights and paint. There is also a requirement that notification be made to the FAA if a marking light on the tower will be out for more than 30 minutes. This means you must check the tower once every 30 minutes, which is unlikely, or implement a monitoring solution.

Local Regulations

Common local regulations include:

Zoning

Building permit

Engineering analysis

If the area where the tower will be placed is not zoned for commercial use, then a rezoning application will have to be filed. A building permit for something like a tower may require considerable supporting material. Hiring one or more engineers is also quite common. Things the engineers and inspectors will want to examine include:

Local Regulations

Structural calculations to assure the tower’s footings and wind speed survival rating is suitable for the area

A soil sample to check for suitability for the weight of the tower

A test of the concrete and bolt torques to ensure they will meet the specifications

Ground Level Tower Safety

In addition to the protection afforded to aircraft, as just discussed, the tower must be protected from ground based risks, such as someone climbing the tower. Anti-climb sections are commonly recommended to prevent unauthorized persons from climbing the tower. As lawyers are fond of signs, anti-climb warning signs and watch for wires signs should be on and near the tower. Every tower should be inspected by qualified personnel twice a year to check for security and soundness.

Tower Insurance

Liability insurance to cover at least those that climb the tower or those hurt by the tower if it falls should be acquired. The tower owner, both current and previous, can be held liable for the condition of the tower and the devices attached to it. In general a tower collapse is considered to fall under the legal doctrine of res ipsa loquitur or the event speaks for itself. This means that the mere fact that the tower collapsed is proof that somebody did something wrong. Negligence will flow to someone or at least the lawyers will attempt to send it somewhere. An insurance policy may or may not cover the loss. In some cases the insurance carrier has sought to avoid payment by proving the tower owner did not properly maintain the structure. In other cases contractors and subcontractors have sought damages based on failure of the owner to notify them of hazards the owner knew about or should have known about. This is why regular documented maintenance and inspections must be performed on these structures.

Lightning Protection

Any wireless network device mounted outside needs lightning protection. The idea is to protect the equipment and the people working with the equipment by conducting the lightning current to ground via its own isolated path, rather than by using either the equipment or the people for this purpose. In some places this type of protection is more of an issue than in other parts of the world. For example in the contiguous United States of America the number of strikes can be plotted as maps of lightning activity or Keraunic levels. Lightning protection is an important topic, but there are some disagreements on how to provide protection for towers and the equipment used both inside and outside, because lightning protection is somewhat science and somewhat art. Therefore what is included below should only be taken as a general discussion. You must hire qualified people to do the actual planning and installation work for you.

The first topic to consider is what is grounding. Standards that discuss grounding requirements include:

NEC - National Electrical Code Article 250

IEEE – Institute of Electrical and Electronics Engineers Emerald and Green books

Keep in mind that ground and earth are not the same. For example, all parts of an aircraft must be bonded to each other to help it resist damage from lightning strikes. Yet the aircraft is far from any earth when in flight. A ground then is just a common reference plane. It has nothing to do with the dirt earth is made of.

Second, ground loops must be avoided. A ground loop occurs when grounds are not all at the same electrical potential. A ground loop is caused by not using a single grounding point or not bonding multiple ground points to each other. If there are no other paths, and the potentials rise and fall together, there will be no current flow through the equipment and damage will be minimized. This is all grounds regardless of purpose, such as for electrical safety, radio frequency performance, and lightning protection. As specified by NEC Article 250-50, to avoid a ground loop a single ground point must be used or all ground points must be bonded to each other. According to BICSI bonding is the electrical interconnection of conductive parts so as to maintain a common electrical potential. To accomplish this conductors must be of sufficient size to carry the anticipated fault current and connected together in a suitable manner.

What is wrong with just letting the earth take care of this, especially if the ground rods are near each other? The problem is earth does not provide a low impedance path. For example, 100 feet, 31 meters, of No. 4 copper wire has a resistance of about 0.03 ohms. Whereas soil, depending on the type, will show a reading of 1 to 100 megohms. Further, the conductivity of soil differs depending on the moisture content and other factors.

Let’s move on to the techniques commonly used to provide protection, to the extent that this is possible, to the structures and equipment used for wireless data networks. Especially for a large tower structure, again I recommend hiring a consultant or at least discussing the project with the tower and equipment manufacturers. The main standards related to lightning protection are from the International Electrotechnical Commission (IEC). These are:

IEC 61024-1

IEC 61312-1

Also TIA/EIA-222-G, Underwriters Laboratory UL 96 and 96A, and National Fire Protection Association NFPA 780 have some information on this subject. Along with the standards the United States military has produced a two volume handbook on this. The MIL-HDBK-419A handbook uses over 800 pages to deal with all aspects of grounding and bonding regardless of purpose. Although some of the equipment manufacturers, such as PolyPhaser, do not think much of many of these standards, it is wise to consider what they have to say.

In general a lightning protection system should:

Capture the energy from the lightning strike to a know point designed to handle this amount of energy

Move this energy to ground without using the equipment to be protected to do this

Dissipate the lightning energy into the ground field

Ensure all ground points are bonded to each other

Provide additional protection for the lines providing electrical power and carrying the data back and forth

Everyone agrees on this. This disagreement is on how to do it. Everyone with an opinion on this is certain they are exactly right. Lightning protection is similar to the weather. Much is known at a high level about how weather systems work. What is missing is knowing exactly how these high level systems will act in a specific and dynamic microclimate. This is also the case with lightning protection. How lightning operates is known in general, but predicting how it will act around a specific location cannot be predicted yet.

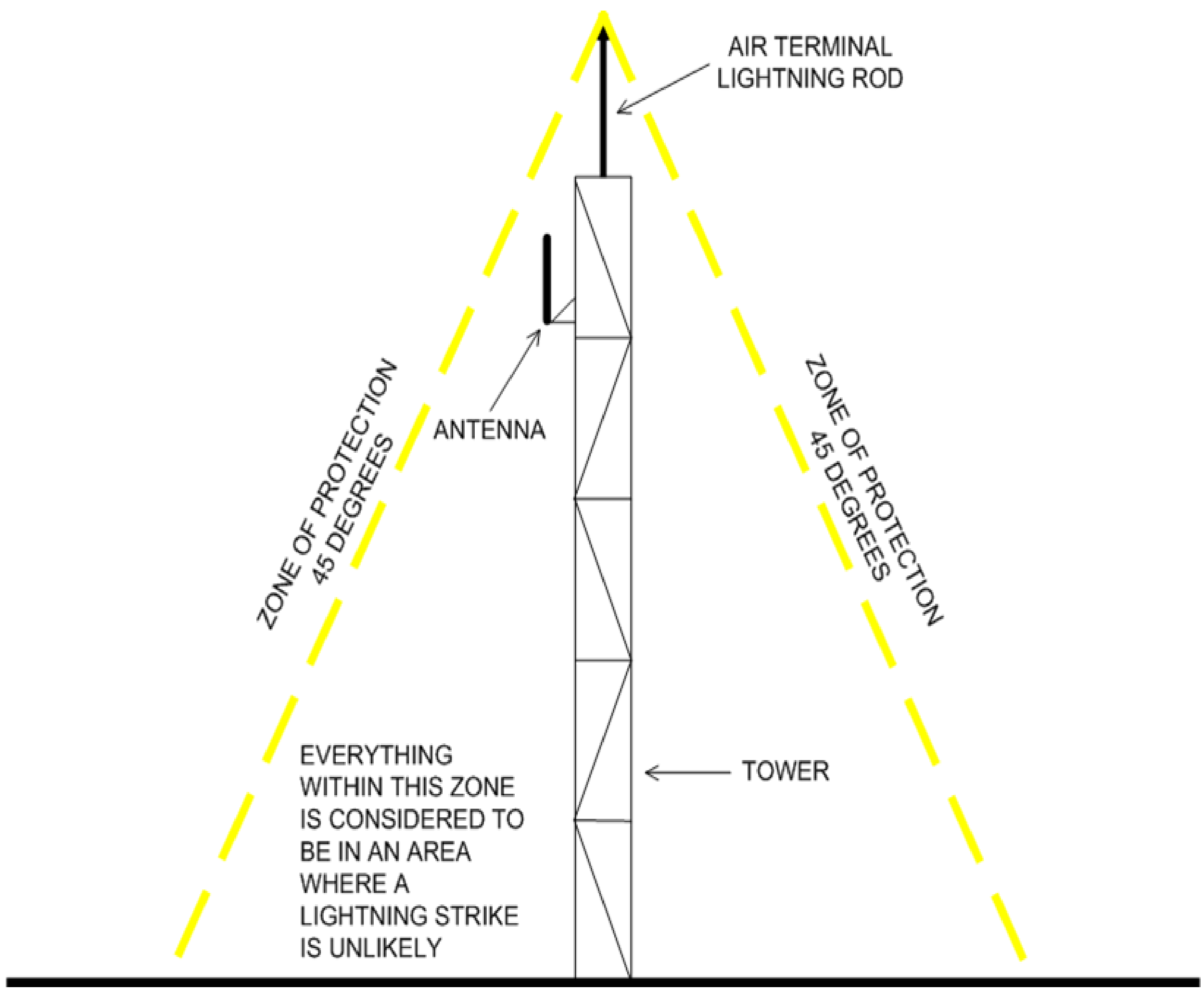
Let’s begin at the top to discuss the devices used in a lightning protection system. Basing it on standards the lightning protection for a base station tower would typically begin with an air terminal device, in other words a lightning rod, mounted to the top of the tower, extending at least two feet, about .6 meters, above all other tower hardware including the antennas. The rod is made of copper clad steel or stainless steel. This brings us to the first point of disagreement. What should the end of the lightning rod look like? Opinions range from blunt, to sharp pointed, to a brush. There is nothing definitive on this. NFPA 780-1997 is the recommended standard to follow for the installation of this air terminal device.

In the traditional approach to lightning protection from the top air terminal device a cone is assumed to extend outward at a 45 or 60 degree angle, as no one agrees on the exact angle. This should be envisioned as a cone with the top of the cone at the top of the lightning rod. Inside this zone a direct hit on any equipment mounted in the zone is deemed unlikely. In some installations the air terminal is attached right at the top of the tower. In other cases the location is determined by using a formula. This formula says that the tip of the air terminal should be at least twice the distance from the tower to the outside of the antenna that is furthest from the tower. In other words if the outside edge of the antenna is 2 feet from the outside edge of the tower, then the top of the air terminal should be at least 4 feet above the top of the antenna. For high lightning areas instead of 2 times, 5 times is used.

Move the Energy to Ground

The next step is to move the energy from the air terminal to the ground field. The cable from the air terminal to ground is another area of disagreement. One way is to use a cable that goes all the way down the side of the tower, kept off the tower by using standoffs. Each of the standoffs is grounded to the tower structure at several points as it goes down to prevent arching between this down conductor and the tower. Others ask why, just use the steel structure of the tower as arcing is sure to occur between the tower and any down conductor. Regardless of how downconductors are used or what size they are, they must all be run in as straight a line as possible. High voltage prefers to travel in a straight line. Electrons with a lot of high voltage pressure behind them do not make corners well. Damage to the conductor and surrounding structures is the common result. No bend should have an included angle of less than 90 degrees nor should it have a bend radius less than 8 inches.

If the tower utilizes guy wires and anchors for these guy wires, these should be connected as well.


AIR TERMINAL
LIGHTNING ROD
ANTENNA
ZONE OF PROTECTION
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ZONE OF PROTECTION
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EVERYTHING
WITHIN THIS ZONE
IS CONSIDERED TO
BE IN AN AREA
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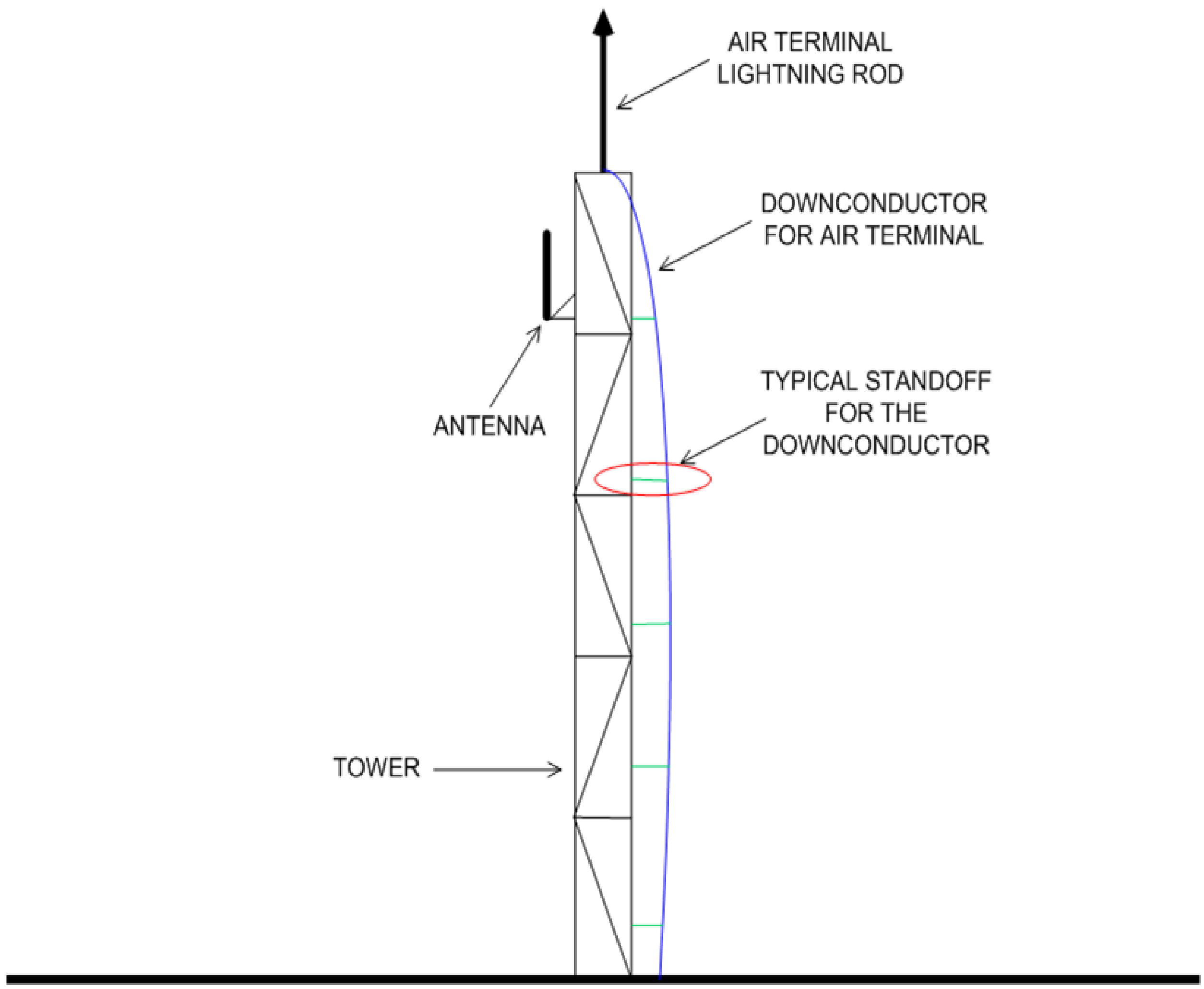
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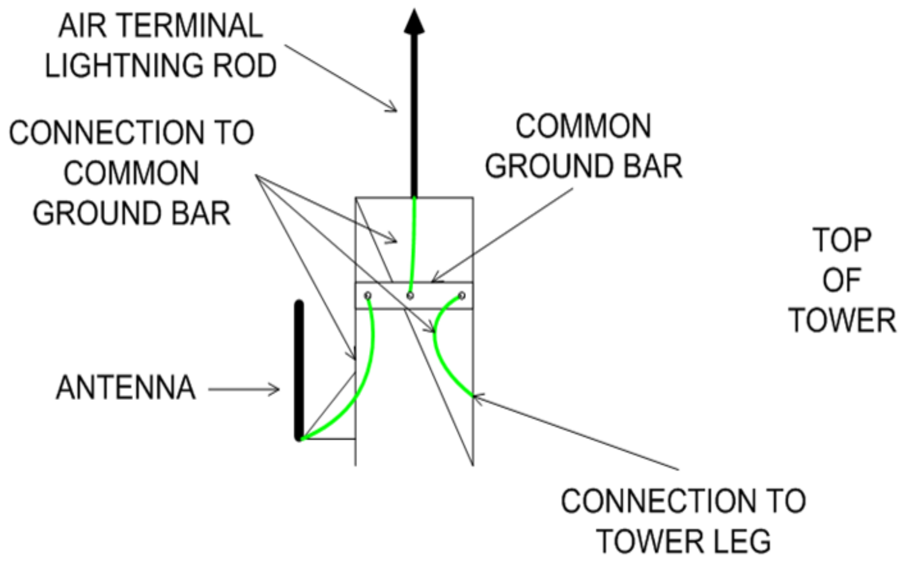
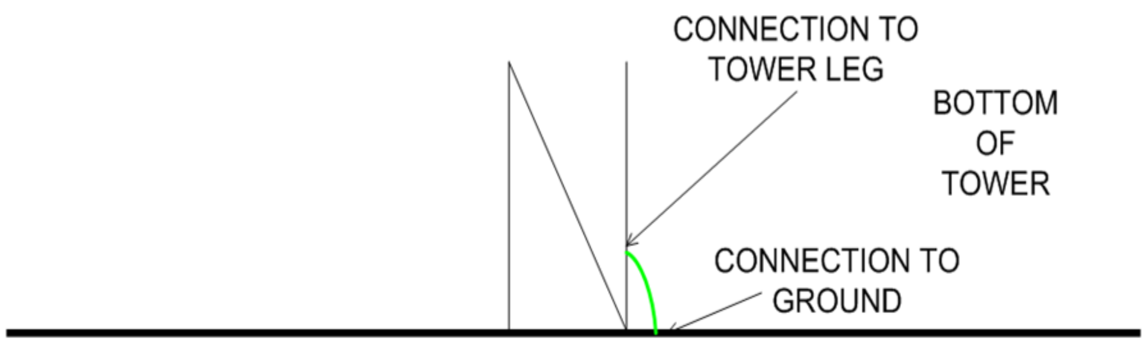
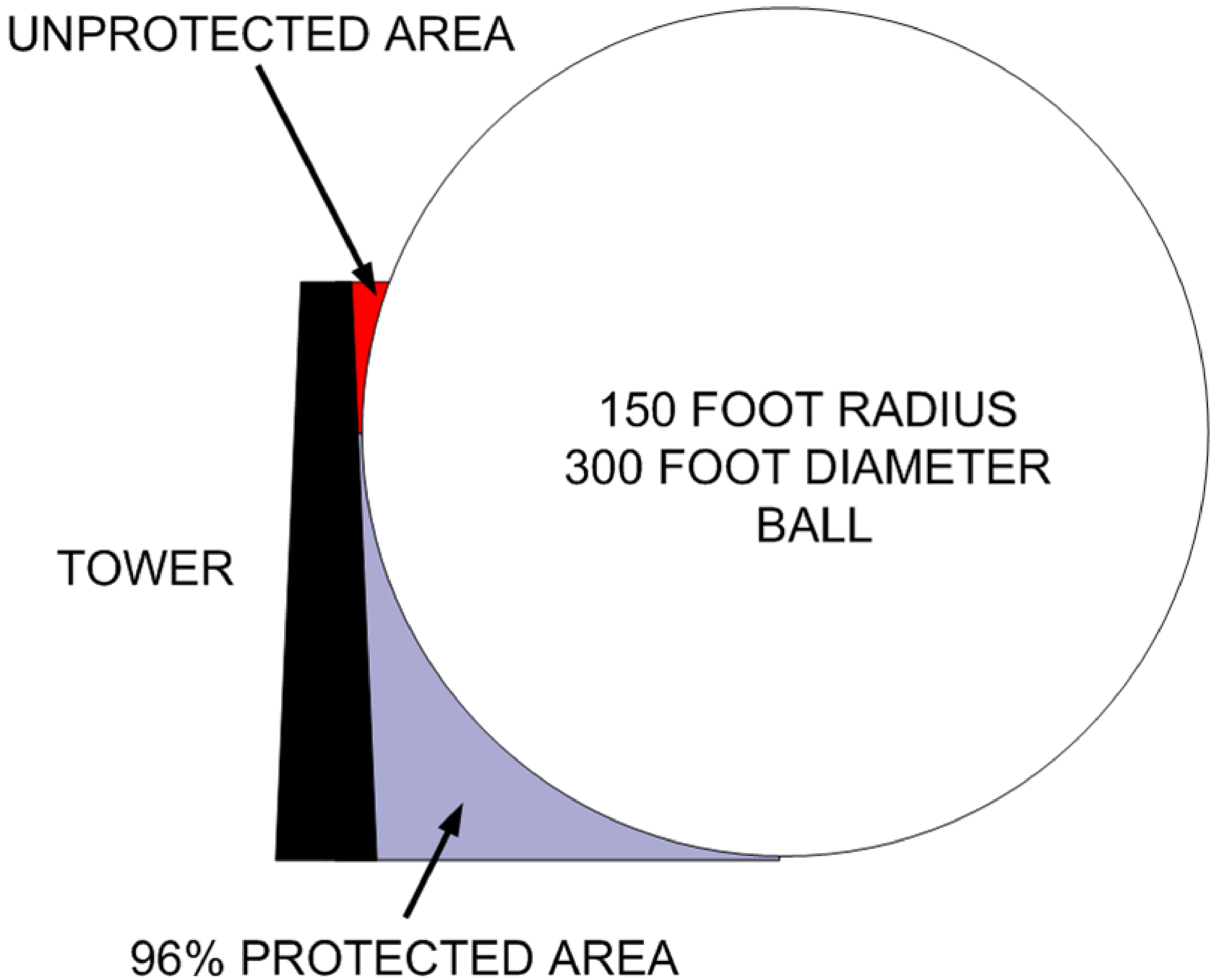




The Rolling Ball Concept

PolyPhaser is a major manufacturer of lightning protection equipment. They have strong opinions on what works and does not work for lightning protection. Especially for tall towers, those 150 feet and higher, PolyPhaser believes the rolling ball concept better describes what is required for lightning protection. This concept is based on research that says the typical step leader jumping distance of a lightning stroke is 150 feet. The step leader is created when updrafts in the clouds cause the charges to separate. The positive charges move upward and the negative charges move downward. This downward movement of the negative charges produces a stepped leader. This leader moves down toward earth in 150 footsteps. This creates an ionized path. The main lighting stroke is the return up this ionized path. In this visualization the zone of protection is the area under where a ball with a 150 foot radius touches the tower. Anything higher on the tower is vulnerable. Anything lower is protected 96 percent of the time. This is not 100, but 96 percent. For antennas and radios mounted in the unprotected zone, some protection can be gained by installing air terminal devices horizontally both above and below the device that stick out six inches beyond the device. This moves the protection zone out from the tower as the rolling ball can no longer touch the side of the tower. If the tower is guyed, then these guys change the protected area. The area under the guys is protected as well.

This concept looks like this:



MIL-HDBK-419A agrees to some extent with the PolyPhaser approach. Although calling for the use of air terminals it does say that structures less than 100 meters do not attract lightning to themselves. This does not mean these shorter structures are not hit, just that they do not attract lightning directly unless they are the tallest structure in the vicinity. In addition to a direct strike, any structure is susceptible to energy being directed to them from side flashes nearby

For a base station unit or antenna mounted on a high rise building, either to the building itself or on a pole mounted on the building, a connection should be made to the building's ground system. If there is a lightning rod system installed, the ground can be connected to the lightning rod system downconductors as long as the protected equipment is also on the roof. If the equipment is located on the lower floors, do not connect to any of the lightning rod system downconductors, as they will probably be at a higher potential than the building potential on that floor. The common point is the physical earth connection. A common conductor can be installed for use in connecting the floors in a building together so as to provide a path or each floor can be connected to the building's steel structure. When a lightning rod system does not exist, a connection to the steel structure of the building is the preferred method to connect a single point ground. In short concrete wall buildings there is no steel structure, only reinforcing bar in the concrete. If local building codes permit, attach the single point ground to any exposed rebar. Long inductive ground conductors dropped down the side of the building can also be used for the final earth ground connection, although this is not a very desirable method. The details on this, at least the grounding and bonding details, are contained in JSTD-607-A jointly developed by the TIA and ATIS Committee T1.This is a replacement for the EIA/TIA-607 standard. Most of this document details what must be done internally to the building to ensure the proper bonding and grounding of the telecommunications system to the rest of the buildings subsystems. By doing the grounding and bonding of the telecommunications system properly, then tying the wireless equipment to this system the wireless system is properly grounded.

Protection for Antennas and Outside Units

The protection for the antennas and any Outdoor Unit (ODU) mounted to the towers or poles is provided by their mechanical attachment to the tower or pole. Then the tower or pole, as specified here, is itself grounded. Ensure that this connection from equipment to mount is secure, thereby grounding the antenna or ODU.

Protection for Transmission Line

In addition to the indirect protection for the antenna and outdoor units mounted to the tower, the transmission cable going to these devices must also be protected. The method of protection depends on the type of cable used.

If coax cable is used such as when the antenna is at the top of the tower while the radio is at the bottom, protection for this type of cable requires the shield be attached to ground at several points. To protect the transmission line the shielding inside this cable should be connected at the top of the tower, the base of the tower, and just before the cable enters the building. Some equipment manufacturers think it should also be grounded to the tower every 25 m in one manufacturer's viewpoint and every 60 m in another's. The connections going down the tower are made using a clamp-on device. At the entrance to the structure the coax cable shield should be connected to a grounded bulkhead plate. This bulkhead has RF type coax connectors mounted on a copper plate. The copper plate is connected to earth ground using several wide copper straps. In many cases the center conductor of the coax cable will be carrying a DC current for the outdoor unit mounted up on the tower. Therefore, the outside shield should be the only thing connected to ground.

Additional protection in the form of a coax cable lightning arrestor can be added at the bulkhead mounting plate where the coax cable enters the building or other enclosure. This will remove any excessive surge voltage that may be present on the center conductor. This type of lightning protector should be installed outside the entrance to the building and should be mounted on the bulkhead plate that is properly grounded.

For ODUs mounted directly to the tower or pole up by the antenna, commonly a short transmission line is used to connect this box to the antenna. The shielding of this cable must be grounded as well. This ground should be where the ODU is mounted to the mast to direct any current down the tower or pole grounding system.

Lightning Arrestor Types

For the lightning arrestors used where the coax cable attaches to the bulkhead plate, there have been three basic types, with two still in common use. The types are:

Spark Gap

Gas Capsule

Quarter Wave Stub

The spark gap arrestor consists of two points closely spaced and directly across the transmission line. When a lightning strike occurs the high voltage will jump the gap between the two points and thereby be conducted to ground. The problem with this type of device is that it may not protect against a weak or lower voltage lightning strike, the actual breakdown voltage may vary, and constant maintenance is required. As such these are no longer used

The gas capsule arrestor is similar to the spark gap type. Its advantages over the spark gap type are a wider range of voltages over which it can operate, and a wider frequency range over which it can be used. This range is typically from DC to 2.5 GHz for the standard types, with some special types going higher. Whenever a lightning strike occurs the gas section between the inner and the outer conductor of the coaxial transmission line will spark over. This spark over ionizes the gas and it becomes conductive. This results in the energy being redirected to ground. In other words, the gas tube works like a voltage-based switch that is automatically turned on and off. This gas capsule consists of two electrodes that are insulated by a small ceramic tube. The spark over is determined by the gas properties, the gas pressure, and the electrode gap in this capsule. A small part of the energy, called the residual pulse, does go through to the network equipment. This type of protector may not operate fast enough to protect sensitive equipment. Maintenance of these units consists of testing the static spark-over voltage or just replacing the gas tube every few years. A direct hit on the site calls for the gas tube to be replaced regardless of the time period as a buildup of carbon inside the unit will result from the hit.

The quarter wave stub arrestor is a three port device. It consists of a tuned quarter wavelength shorted coaxial type transmission line that is placed directly across the actual coax transmission line. The length of the stub is one quarter wavelength of the center frequency of the range it is designed for. This device works like a bandpass filter. Quarter wave devices operate from 60 MHz to 18 GHz. A problem with this type of protector is that it cannot carry DC over the center conductor of the coax cable to a device that receives its electrical power this way. This device does not require any maintenance

When selecting a lightning arrestor there are four criteria to consider.

The frequency range of the system

The power rating

The connector types on each end

The type of mounting

Regardless of the mounting method used, these arrestors should be installed outside the structure that houses the equipment, with a direct contact to ground, so as not to cause any unnecessary interference in the equipment to be protected when dissipating surges. The preferred mounting method is to a bulkhead plate as discussed above, as this provides the best connection to ground. If not, then the connection to ground is made by attaching a wire to a screw terminal on the arrestor and then to the ground point.

The second common type of transmission line is a UTP cable. This is being used more and more as radios are mounted at the top of the tower rather than at the bottom. An argument is currently raging over whether this UTP cable should be shielded or not.

Proponents of the use of shielded cable believe it will keep interference out of this long cable run from the equipment building to the radio at the top of the tower. Shielding in UTP is not useful for lightning protection however. For the purpose of lightning protection then there is no need to ground the shield. The means of attachment of coax is also different from UTP cable. With coax the signal itself is referenced to the shielding. The shield conductor is coupled directly into the receiver. There is also the possibility for coupling between the shield and the center conductor. It is important to ensure that the shield doesn't experience high voltages with respect to ground at the receiver. If it does, then the radio the coax cable is attached to is damaged or destroyed. Grounding the shield is required to prevent this.

UTP cable uses balanced differential signaling. The receiver is transformer coupled. There is a high degree of isolation between the cable pairs and the radio. In this case there is no need for a ground conductor. This protection device keeps the high voltages out of the radio. If shielded UTP cable is being used to keep interference out, then it should be grounded only at one end. As current cannot flow in a conductor that is grounded at one end, there is no need for large grounding straps.

Site Resistance

Once the hardware is in place something must be provided to drain the lightning current into. This was discussed in general above. Now let’s go into some details, especially as it relates to a ground field for a large tower. For a large tower, this is the concept of site resistance relative to ground mass, in other words a large area that forms a field for grounding the equipment. It is one of the most important parameters in an effective lightning protection system. You can connect the parts of a system according to the standards and fail to provide a proper ground field. As this blocks the flow of lightning current it defeats the purpose of the system of protection. The standards and guidelines - IEC 61024-1, IEC 61312-1, NFPA-78, BICSI, the IEEE, and MIL-HDBK-419A - define the required resistance differently. The IEEE and most network equipment manufacturers recommend that the site resistance be 5 ohms or less, preferably less than 3 ohms, but MIL-HDBK-419A says 10 ohms is adequate. The BICSI outside plant handbook states that the National Electric Code (NEC) calls for only 25 ohms or less. Although you can buy test instruments to measure this yourself, it is best to hire a qualified electrician or consultant to actually measure the site resistance for you for any large site. The PolyPhaser book listed in the references has a detailed discussion on how to do this. This ground field is produced by a system of grounding wires and rods that connect together so as to form a single point ground. This interconnection should be below grade and with a bare low inductance conductor. The conductor is bare copper conductor at least AWG 4, 5.9 mm, in size, with 1/0 being commonly used. This conductor should be in direct contact with the earth, no less than .45 meters or 1.5 feet below the surface. The conductor circles the structure. Then every 2.5 meters or eight feet more or less a ground rod is driven into the soil, not placed in predrilled holes. Another way uses the ground ring described and adds four to ten legs of 15 to 23 meters in a star pattern. Attached to these radials are 2.5 meter ground rods every 5 meters. These ground rods are 14 mm or 5/8 inch copper clad steel rods. The idea behind these radials and their length is to dissipate the energy out away from the structure by using the radials to carry it outward. The length is selected because any more length than this is ineffective as the energy is dissipated as much as it will be by 23 meters or so. A connection is made from this ground ring to the tower using a #8 or larger wire.

The interconnection between all the conductors is made with a device that welds the points together. This includes the ground ring to down conductors as well as the connection to the tower. This exothermic weld is created when a graphite mold around the connection is filled with copper oxide and aluminum powders. A starter powder ignites the exothermic process. The resultant molten copper is deposited into the lower mold cavity where it burns away any oxides and creates a fused connection. To ensure there is a good bond between the conductors remove any paint at the contact points. Then use an anti-oxidant compound in the connection between the lugs and the cable, as well as at the point of contact of the lugs.

The conductivity of the soil varies based on:

Type of soil

Moisture content

Temperature

Other things in the soil

The type of soil at the site of the ground system is important, with moist clay soil being the most desirable and sand the least. Moisture content is important, the higher the better. Therefore rocks are useless for a ground field. Temperature as it varies with the season of the year affects the other factors directly. The conductors for this field should be below the frost line. When fill material is used at building sites, this fill may impact the conductivity of the earth. With poor soil, improvement can be made by:

Increasing the surface area of the conductor.

Doping the soil to increase its conductivity by the use of salts, such as Epson salts, or a commercial concoction.

Also installing additional bare radial lines with ground rods which will effectively parallel the inductance and reduce the overall system inductance can help.

It is also important that all devices of the system connect to the same ground field. This means for a large site, say with a tower and its associated ground field, the ground for the rest of the equipment must be driven into the same ground area if the tower's ground field cannot be used. In addition, the fields must be bonded to each other as was already covered. This should not require any special measures as the tower and its equipment will be in the same location within a few feet of each other. For a smaller site, such as a customer location, it is best to use the ground for the electrical system installed by the electric utility company near the electric meter. Be sure that the antenna mast, lightning arrestor ground, and any Ethernet cable protection all connect to the same ground, whatever that ground happens to be. However, for a large tower with an air terminal device the ground electrodes for the air terminal on the tower must be separate from the rest of the building's electrical service. They still must be bonded to each other.

Weather Protection Devices

Some devices are made to exist outside. Other devices will need additional protection for the environment. This additional protection is typically in the form of a National Electrical Manufacturers Association (NEMA) enclosure. There are many types of NEMA boxes for indoor or outdoor use. Each one is rated by how much of the environment they keep out or filter out. The NEMA Type 3R is a common type for outdoor use. It is described by NEMA as:

> "Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, and snow; and that will be undamaged by the external formation of ice on the enclosure."

These boxes can have heaters, fans, air filters and so on. The boxes are mounted on towers, poles, or the side of a building. NEMA4X boxes are also common. These boxes provide some protection against contact with the enclosed equipment, falling dirt, rain, sleet, snow and windblown dust, splashing water hose-directed water and corrosion. They are also undamaged by external formation of ice on enclosure.

Sealing Connections

Moisture is very, very bad for connections carrying radio frequency signals. You must keep moisture out of the connections. If water gets in, forget getting it out, just replace the part. To keep it out in the first place seal connections using one of the methods discussed below. Recheck these connections on a regular basis. No one can agree on the best way to keep moisture out. Everyone does agree that it must be done. Listed next are some of the methods that have been suggested. No one method is any better than any other. Try them and use the one that works for you. The first suggestion is to spray the inside of the connector with nondielectric Bull Frog protectant. Use 3M Scotch 33+ tape on the bottom, then 3M Scotch 2210 vinyl mastic tape, another layer of 3M Scotch 33+ tape, finally a liberal - about 3mm - coat of Scotch Coat liquid, not spray. Others say forget the sprays and liquids, as they just make a mess. Do this instead. Apply a layer of 3M Scotch 33+ electrical tape, 3M Scotch 2210 vinyl mastic tape, and another layer of 3M Scotch 33+ electrical tape. The first layer of electrical tape adds a protective layer between the connector and the mastic, which is sticky. The next layer of the vinyl tape covers the mastic and keeps the gooey stuff from sticking to something it should not, as well as keeping out the water. Time Microwave, who makes LMR coaxial cable, calls for not one wrap over the mastic, but three. The first is wrapped from bottom to top, then from top to bottom, and finally a last one from bottom to top. When wrapping any of the mastic or tape, start at the bottom and wrap upward. This creates a shingling effect to help keep water out. Also be sure the tape lays down nice and flat with no bubbles or bulges. The mastic discussed above is basically a thick sticky tape. It is sticky on one side. The stick is covered with a peel off cover. This substance is about 1/8” thick. The electrical tape is any high quality tape, with 3M Scotch 33+ being a commonly mentioned brand. To remove these layers, all you need do is score a line with a utility knife and peel the butyl and outer electrical tape layer off of the inner electrical taper layer.

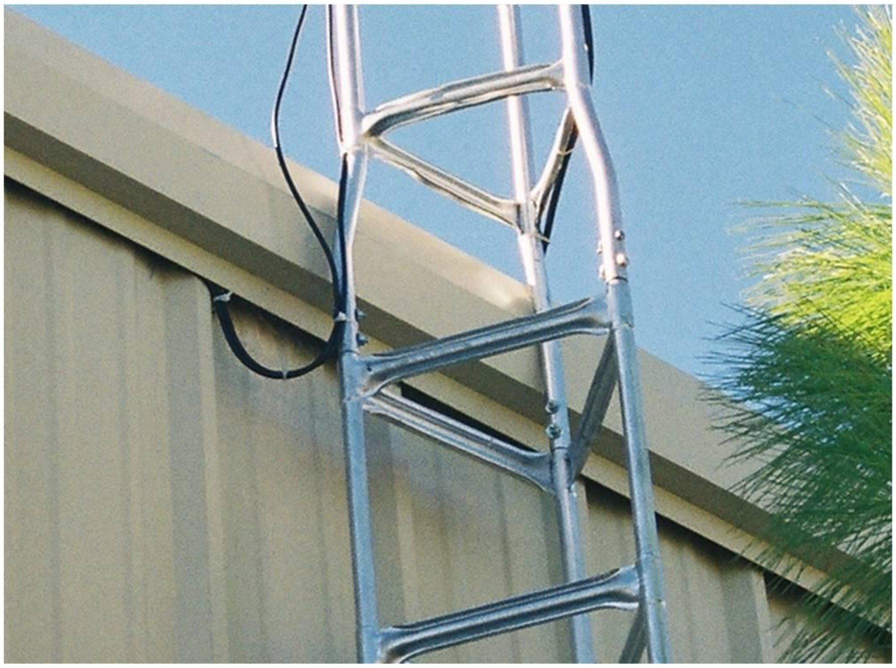
Another solution is Coax-Seal. This solution is recommended by Cisco. Coax-Seal is a putty-like material in tape form. White waxed paper keeps it from sticking to its self. Note that the first wrap comes back on itself exactly and the second turn starts the diagonal wrap. Wrap from the coax cover toward the fitting with one half overlap with each winding. The last wrap again comes straight back over the previous wrap without a diagonal. The seal is slightly sticky and should be molded by hand to remove any gaps and to ensure that all the wraps are blended together. Overtime the wraps will almost fuse together.

Regardless of the sealing method used be sure to leave any drain or vent holes uncovered. For example, many omnidirectional antennas have drain holes in the bottom near the connector. If the hole is covered, water will collect inside the antenna. This will cause corrosion and reduced performance.

Drip Loop

Besides sealing the connectors drip loops should be used before all connecting points where the cable connects to a box or wall. This is to keep the water running down away from the connection point.

Drip Loop



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