8
Building an Outdoor Node

There are many practical considerations when installing electronic equipment outdoors. Obviously, it has to be protected from the rain, wind, sun, and other harsh elements. Power needs to be provided, and the antenna should be mounted at a sufficient height. Without proper grounding, nearby lightning strikes, fluctuating mains power, and even a light winds in the proper climate can annihilate your wireless links. This chapter will give you some idea of the practical problems you will be up against when installing wireless equipment outdoors.

Waterproof enclosures

Suitable waterproof enclosures come in many varieties. Metal or plastic may be used to create a watertight container for outdoor embedded equipment.

Of course, equipment needs power to work, and will likely need to connect to an antenna and Ethernet cable. Each time you pierce a watertight enclosure, you provide another potential place for water to seep in.

The National Electrical Manufacturers Association (NEMA) provides guidelines for protection of electrical equipment from rain, ice, dust, and other contaminants. An enclosure with a rating of ***NEMA 3*** or better is suitable for outdoor use in a fair climate. A ***NEMA 4X*** or ***NEMA 6*** provides excellent protection, even from hose driven water and ice. For fixtures that pierce the body of an enclosure (such as cable glands and bulkhead connectors), the International Electrotechnical Commission (IEC) assigns an ingress protection (IP) rating. An ingress protection rating of ***IP66*** or ***IP67*** will protect these holes from very strong jets of water. A good outdoor enclosure should also provide UV protection to prevent breakdown of the seal from exposure to the sun, as well as to protect the equipment inside.

Of course, finding NEMA or IEC rated enclosures may be a challenge in your local area. Often, locally available parts can be repurposed for use as enclosures. Rugged plastic or metal sprinkler boxes, electrical conduit housings, or even plastic food containers can be used in a pinch. When piercing an enclosure, use quality gaskets or o-rings along with a cable gland to seal the opening. UV stabilized silicone compound or other sealant can be used for temporary installations, but remember that cables flex in the wind, and glued joints will eventually weaken and allow moisture to seep in.

You can greatly extend the life of a plastic enclosure by providing some protection from the sun. Mounting the box in the shade, either beneath existing equipment, solar panel, or thin sheet of metal specifically for this purpose, will add to the life span of the box as well as the equipment contained inside.

Before putting any piece of electronics in a sealed box, be sure that it has minimal heat dissipation requirements. If your motherboard requires a fan or large heat sink, remember that there will be no airflow, and your electronics will likely bake to death on the tower. Only use electronic components that are designed to be used in an embedded environment.

Providing power

Obviously, DC power can be provided by simply poking a hole in your enclosure and running a wire. If your enclosure is large enough (say, an outdoor electrical box) you could even wire an AC outlet inside the box. But manufacturers are increasingly supporting a very handy feature that eliminates the need for an additional hole in the box: ***Power over Ethernet*** (***POE***).

The 802.3af standard defines a method for supplying power to devices using the unused pairs in a standard Ethernet cable. Nearly 13 Watts of power can be provided safely on a CAT5 cable without interfering with data transmissions on the same wire. Newer 802.3af compliant Ethernet switches (called ***end span injectors***) supply power directly to connected devices. End span switches can supply power on the same wires that are used for data (pairs 1-2 and 3-6) or on the unused wires (pairs 4-5 and 7-8). Other equipment, called ***mid span injectors,*** are inserted between Ethernet switches and the device to be powered. These injectors supply power on the unused pairs.

If your wireless router or CPE includes support for 802.3af, you could in theory simply connect it to an injector. Unfortunately, some manufacturers (notably Cisco) disagree on power polarity, and connecting mismatching gear can damage the injector and the equipment to be powered. Read the fine print and be sure that your injector and wireless equipment agree on which pins and polarity should be used for power.

If your wireless equipment doesn't support power over Ethernet, you can still use the unused pairs in a CAT5 cable to carry power. You can either use a ***passive POE injector***, or simply build one yourself. These devices manually connect DC power to the unused wires on one end of the cable, and connect the other end directly to a barrel connector inserted in the device's power receptacle. A pair of passive POE devices can typically be purchased for under $20.

To make your own, you will need to find out how much power the device requires to operate, and provide at least that much current and voltage, plus enough to account for loss in the Ethernet run. You don't want to supply too much power, as the resistance of the small cable can present a fire hazard. Here is an online calculator that will help you calculate the voltage drop for a given run of CAT5 : *http://www.gweep.net/~sfoskett/tech/poecalc.html*

Once you know the proper power and electrical polarity needed to power your wireless gear, crimp a CAT5 cable only using the data wires (pairs 1-2 and 3-6). Then simply connect the transformer to pairs 4-5 (usually blue / blue-white) and 7-8 (brown / brown-white) on one end, and a matching barrel connector on the other.

Mounting considerations

In many cases, equipment can be located inside a building, provided there is a window with ordinary glass through which the beam can travel. Normal glass will introduce little attenuation, but tinted glass will introduce unacceptable attenuation. This greatly simplifies mounting, power, and weatherproofing problems, but is obviously only useful in populated areas.

When mounting antennas on towers, it is very important to use a stand off bracket, and not mount the antennas directly to the tower. These brackets help with many functions including antenna separation, antenna alignment and protection.

Stand off brackets need to be strong enough to support the weight of the antenna, and also hold it in place on windy days. Remember, antennas can act like small sails, and can put a lot of force on to their mounts in strong winds. When estimating wind resistance, the total surface of the antenna structure must be considered, as well as the distance from the center of the antenna to the point of attachment to the building. Large antennas such as solid dishes or high gain sectorial panels can have considerable wind load. Using a slotted or mesh parabolic, rather than a solid dish, will help reduce the wind load without much affect on antenna gain. Be sure that the mounting brackets and supporting structure are solid, or your antennas will become misaligned over time (or worse, fall off the tower entirely!)

Mounting brackets must have enough clearance from the tower to allow for aiming, but not too much clearance that the antennas become too hard to reach if any service or maintenance is required.

Figure 8.1: An antenna with a standoff bracket being lifted onto a tower.

The pipe on the standoff bracket that the antenna will be mounted on needs to be round. This way the antenna can be pivoted on the pipe for aiming. Secondly, the pipe must also be vertical. If it is being mounted on a tapered tower, the standoff bracket will have to be designed to allow for this. This can be done using different lengths of steel, or by using combinations of threaded rod and steel plates.

As the equipment will be outside for all of its service life, it is important to be sure that the steel used is weatherproofed. Stainless steel often has too high a price tag for tower installations. Hot galvanizing is preferred, but may not be available in some areas. Painting all steel with a good rust paint will also work. If paint is chosen, it will be important to plan a yearly inspection of the mount and repaint when necessary.

Guyed towers

A climbable guyed tower is an excellent choice for many installations, but for very tall structures a self supporting tower might be required.

When installing guyed towers, a pulley attached to the top of a pole will facilitate the tower installation. The pole will be secured to the lower section already in place, while the two tower sections are attached with an articulated joint. A rope passing through the pulley will facilitate the raising of the next section. After the cantilever section becomes vertical, bolt it to the lower section of the pole. The pole (called a gin pole in the trade) can then be removed, and the operation may be repeated, if required. Tighten the guy wires carefully, ensuring that you use the same tension at all suitable anchoring points. Chose the points so that the angles, as seen from the center of the tower, are as evenly spaced as possible.

Figure 8.2: A climbable guyed tower.

Self-supporting towers

Self supporting towers are expensive but sometimes needed, particularly when greater elevation is a requirement. This can be as simple as a heavy pole sunk into a concrete piling, or as complicated as a professional radio tower.

Figure 8.3: A simple self-supporting tower.

An existing tower can sometimes be used for subscribers, although AM transmitting station antennas should be avoided because the whole structure is active. FM station antennas are acceptable, provided that at least a few of meters of separation is kept between the antennas. Be aware that while adjacent transmitting antennas may not interfere with your wireless connection, high powered FM may interfere with your wired Ethernet cable. Whenever using a heavily populated antenna tower, be very scrupulous about proper grounding and consider using shielded cable.

Figure 8.4: A much more complicated tower.

Rooftop assemblies

Non-penetrating roof mount antenna assemblies can be used on flat roofs. These consist of a tripod mounted to a metal or wooden base. The base is then weighed down with bricks, sandbags, water jugs, or just about anything heavy. Using such a rooftop “sled” eliminates the need to pierce the roof with mounting bolts, avoiding potential leaks.

Figure 8.5: This metal base can be weighed down with sandbags, rocks, or water bottles to make a stable platform without penetrating a roof.

Wall mount or metal strap assemblies can be used on existing structures such as chimneys or the sides of a buildings. If the antennas have to be mounted more than about 4 meters above the rooftop, a climbable tower may be a better solution to allow easier access to the equipment and to prevent antenna movement during high winds.

Dissimilar metals

To minimize electrolytic corrosion when two different metals are in moist contact, their electrolytic potential should be as close as possible. Use dielectric grease on the connection between two metals of different type to prevent any electrolysis effect.

Copper should never touch galvanized material directly without proper joint protection. Water shedding from the copper contains ions that will wash away the galvanized (zinc) tower covering. Stainless steel can be used as a buffer material, but you should be aware that stainless steel is not a very good conductor. If it is used as a buffer between copper and galvanized metals, the surface area of the contact should be large and the stainless steel should be thin. Joint compound should also be used to cover the connection so water can not bridge between the dissimilar metals.

Protecting microwave connectors

Moisture leakage in connectors is likely the most observed cause of radio link failure. Be sure to tighten connectors firmly, but never use a wrench or other tool to do so. Remember that metals expand and contract as temperature changes, and an over-tightened connector can break in extreme weather changes.

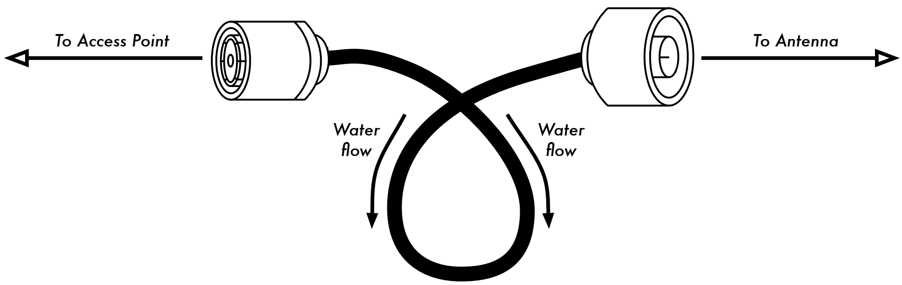

Figure 8.6: A drip loop forces rainwater away from your connectors.

Once tight, connectors should be protected by applying a layer of electrical tape, then a layer of sealing tape, and then another layer of electrical tape on top. The sealant protects the connector from water seepage, and the tape layer protects the sealant from ultraviolet (UV) damage. Cables should have an extra drip loop to prevent water from getting inside the transceiver.

Safety

Always use a harness securely attached to the tower when working at heights. If you have never worked on a tower, hire a professional to do it for you. Many countries require special training for people to be allowed to work on towers above a certain height.

Avoid working on towers during strong winds or storms. Always climb with a partner, and only when there is plenty of light. Tower work will likely take longer than you think it will. Remember that it is **extremely** hazardous to work in the dark. Give yourself plenty of time to complete the job long before the sun sets. If you run out of time, remember that the tower will be there in the morning, when you can start on the problem again after a good night's sleep.

Aligning antennas on a long distance link

To properly align antennas at a great distance, you will need some sort of visual feedback that shows you the instantaneous received power at the antenna feed. This lets you to make small changes to the antenna alignment while watching the feedback tool, ultimately stopping when the maximum received power has been found.

The ideal antenna alignment toolkit consists of a ***signal generator*** and a ***spectrum analyzer***, preferably one of each at both ends of the link. By attaching a signal generator to one end of the link and a spectrum analyzer to the other, you can observe the received power and watch the effect of moving the antenna to various positions in real time. Once the maximum has been found on one end of a point to point link, the generator and analyzer can be swapped, and the process repeated for the other end.

The use of a signal generator is preferable to using the radio card itself, as the signal generator can generate a continuous carrier. A WiFi card transmits many discrete packets of information, switching the transmitter on and off very rapidly. This can be very difficult to find with a spectrum analyzer, particularly when operating in noisy areas.

Obviously, the cost of a calibrated signal generator and spectrum analyzer that works at 2.4 GHz (or even 5 GHz if using 802.11a) is well beyond the budget of most projects. Fortunately there are a number of inexpensive tools that can be used instead.

Inexpensive signal generator

There are many inexpensive transmitters that use the 2.4 GHz ISM band. For example, cordless phones, baby monitors, and miniature television transmitters all generate a continuous signal at 2.4 GHz. Television transmitters (sometimes called ***video senders***) are particularly useful, since they often include an external SMA antenna connector and can be powered by a small battery.

Video senders usually include support for three or four channels. While these do not directly correspond to WiFi channels, they permit you to test the low, middle, or high end of the band.

For 5 GHz work, you can use a video sender in combination with a 2.4 GHz to 5 GHz converter. These devices accept a low power 2.4 GHz signal and emit high power 5 GHz signals. They are usually quite expensive ($300-$500 each) but will still likely be cheaper than a 5 GHz signal generator and spectrum analyzer.

Figure 8.7: A 2.4 GHz video sender with an SMA antenna connector.

Whatever you choose for a signal source, you will need a way to display the received power level levels at the other end. While the cost of 2.4 GHz spectrum analyzers is slowly coming down, they still typically cost a few thousand dollars, even for used equipment.

Wi-Spy

The Wi-Spy is a USB spectrum analysis tool made by MetaGeek (*http://www.metageek.net/*). It features a very sensitive receiver in a small form factor (about the size of a USB thumb drive).

Figure 8.8: The Wi-Spy USB spectrum analyzer

The latest version of the Wi-Spy includes better dynamic range and an external antenna connector. It also comes with very good spectrum analysis software for Windows called Chanalyzer. It provides instantaneous, average, maximum, topographic, and spectral views.

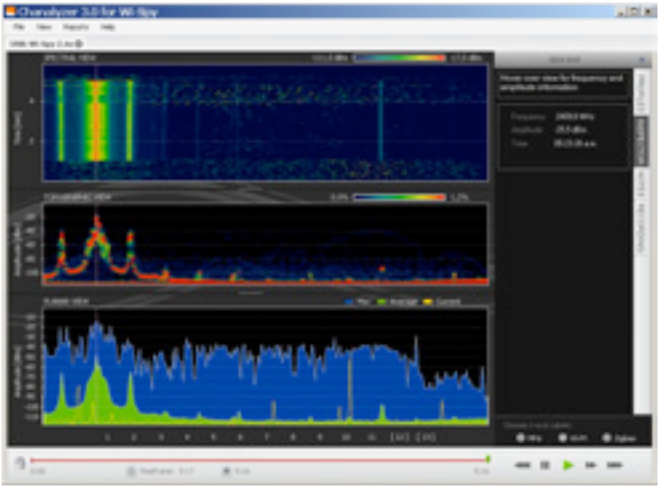

Figure 8.9: The distinctive spiked pattern to the left of the graph was caused by a high power 2.4 GHz television transmitter.

There is an excellent free software package for Mac OS X called EaKiu (*http://www.cookwareinc.com/EaKiu/*). In addition to the standard views, it also provides an animated 3D view, and adds support for multiple Wi-Spy devices.

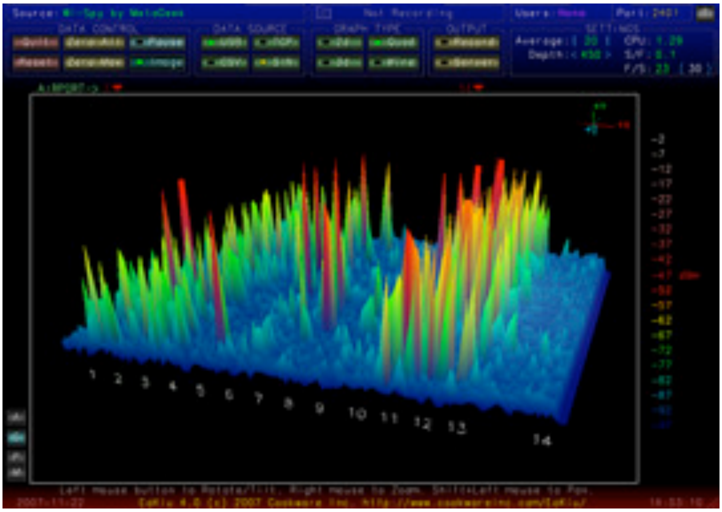

Figure 8.10: EaKiu's 3D view lets you rotate and zoom in on any part of the graph in real time. There is probably a WiFi network on channel 11, with other noise sources lower down in the band.

For Linux users, the Wi-Spy is supported by the Kismet Spectrum-Tools project (*http://kismetwireless.net/spectools/*). This package includes command line tools as well as a GUI built on GTK.

Other methods

Some wireless routers (such as the Mikrotik) provide an "antenna alignment tool" that shows you a moving bar representing the received power. When the bar is at the maximum, the antenna is aligned. With some routers, you can also enable an audio feedback mode. This causes the router to emit a loud tone, changing the pitch according to the received power.

If you don't have a spectrum analyzer, Wi-Spy, or a device that supports an antenna alignment mode, you will need to use the operating system to provide feedback about the wireless link quality. One simple method to do this in Linux is with a loop that continually calls **iwconfig**. For example:

```
wildnet:~# while :; do clear; iwconfig; sleep 1; done
```

This will show the state of all radio cards in the system, updating once every second. Note that this will only work on the client end of a link. On the access point (master mode) side, you should use the **iwspy** command to collect statistics for the MAC address of the client:

```
wildnet:~# iwspy ath0 00:15:6D:63:6C:3C
wildnet:~# iwspy
ath0      Statistics collected:
 00:15:6D:63:6C:3C : Quality=21/94  Signal=-74 dBm  Noise=-95 dBm
 Link/Cell/AP      : Quality=19/94  Signal=-76 dBm  Noise=-95 dBm
 Typical/Reference : Quality:0  Signal level:0  Noise level:0
```

You can then use a **while** loop (as in the previous example) to continually update the link status.

```
wildnet:~# while :; do clear; iwspy; sleep 1; done
```

Antenna alignment procedure

The key to successfully aligning antennas on a very long distance link is communication. If you change too many variables at once (say, one team starts wiggling an antenna while the other tries to take a signal strength reading), then the process will take all day and will probably end with misaligned antennas.

You will have two teams of people. Ideally, each team should have at least two people: one to take signal readings and communicate with the remote end, the other to manipulate the antenna. Keep these points in mind while working on long distance links.

1. **Test all equipment ahead of time.** You don't want to fiddle with settings once you're in the field. Before separating the equipment, power everything on, connect every antenna and pigtail, and make sure you can establish a connection between the devices. You should be able to return to this known good state by simply powering on the device, without having to log in or change any settings. Now is a good time to agree on antenna polarization (see **Chapter 2** if you don't understand what polarization means).

2. **Bring backup communications gear.** While mobile phones are usually good enough for working in cities, mobile reception can be bad or nonexistent in rural areas. Bring a high powered FRS or GMRS radio, or if your teams have amateur radio licenses, use a ham rig. Working at a distance can be very frustrating if you are constantly asking the other team "can you hear me now?" Pick your communication channels and test your radios (including the batteries) before separating.

3. **Bring a camera.** Take some time to document the location of each site, including surrounding landmarks and obstructions. This can be very useful later to determine the feasibility of another link to the location without having to travel there in person. If this is your first trip to the site, log the GPS coordinates and elevation as well.

4. **Start by estimating the proper bearing and elevation.** To begin, both teams should use triangulation (using GPS coordinates or a map) to get a rough idea of the direction to point. Use a compass to roughly align the antenna to the desired bearing. Large landmarks are also useful for pointing. If you can use binoculars to see the other end, all the better. Once you have made your guess, take a signal strength reading. If you are close enough and have made a good guess, you may already have signal.

5. **If all else fails, build your own landmark.** Some kinds of terrain make it difficult to judge the location of the other end of a link. If you are building a link in an area with few landmarks, a self-made landmark such as a kite, balloon, flood light, flare, or even smoke signal might help. You don't necessarily need a GPS to get an idea of where to point your antenna.

6. **Test signal in both directions, but only one at a time.** Once both ends have made their best guess, the end with the lowest gain antenna should make fix their antenna into position. Using a good monitoring tool (such as Kismet, Netstumbler, or a good built-in wireless client), the team with the highest gain antenna should slowly sweep it horizontally while watching the signal meter. Once the best position is found, try altering the elevation of the antenna. After the best possible position is found, lock the antenna firmly into place and signal the other team to begin slowly sweeping around. Repeat this process a couple of times until the best possible position for both antennas is found.

7. **Don't touch the antenna when taking a reading.** Your body will affect the radiation pattern of the antenna. Do not touch the antenna, and don't stand in the path of the shot, when taking signal strength readings. The same goes for the team on the other side of the link, too.

8. **Don't be afraid to push past the best received signal.** As we saw in chapter four, radiation patterns incorporate many smaller sidelobes of sensitivity, in addition to a much larger main lobe. If your received signal is mysteriously small, you may have found a sidelobe. Continue sweeping slowly beyond that lobe to see if you can find the main lobe.

9. **The antenna angle may look completely wrong.** The main lobe of an antenna often radiates slightly to one side or the other of the visual dead center of the antenna. Offset feed dishes will seem to be pointing too far down, or even directly at the ground. Don't worry about how the antenna looks; you are concerned with finding the best possible position to achieve the greatest possible received signal.

10. **Double-check polarization.** It can be frustrating to attempt aligning a dish only to discover that the other team is using the opposite polarization. Again, this should be agreed upon before leaving home base, but if a link stays stubbornly weak, a double check doesn't hurt.

11. **If nothing works, check all components one at a time.** Are the devices on both ends of the link powered on? Are all pigtails and connectors properly connected, with no damaged or suspect parts? As outlined in chapter eight, proper troubleshooting technique will save you time and frustration. Work slowly and communicate your status well with the other team.

By working methodically and communicating well, you can complete the job of aligning high gain antennas in just a short while. If done properly, it should be fun!

Surge and lightning protection

Power is the greatest challenge for most installations in the developing world. Where there are electrical networks, they are often poorly controlled, fluctuate dramatically and are susceptible to lightning. Proper surge protection is critical to not only protect your wireless equipment, but all of the equipment connected to it.

Fuses and circuit breakers

Fuses are critical, but very often neglected. In rural areas, and even in many urban areas of developing countries, fuses are difficult to find. Despite the added cost, it is always prudent to use circuit breakers instead. These may need to be imported, but shouldn't be overlooked. Too often, replaceable fuses are removed and pocket change is used instead. In a recent case, all of the electronic equipment at at rural radio station was destroyed when a lightning strike went through the circuit, without circuit breaker or even a fuse to protect it.

How to ground

Proper grounding doesn't have to be a complicated job. When grounding, you are trying to accomplish two things: provide a short-circuit for a lightning strike, and provide a circuit for excess energy to be dissipated.

The first step is to protect equipment from a direct or near direct lightning hit, while the second provides a path to dissipate excess energy that would otherwise cause a build-up of static electricity. Static can cause significant degradation to signal quality, particularly on sensitive receivers (VSATs for example). Providing the short-circuit is simple. The installer simply needs to make the shortest path from the highest conductive surface (a lightning rod) to the ground. When a strike hits the rod, the energy will travel the shortest path and thus by-pass the equipment. This ground should be able to handle high-voltage (i.e. you need thick gauge wire, like 8 gauge braided copper).

To ground the equipment, mount a lightning rod above the equipment on a tower or other structure. Then use a thick gauge conductive wire to connect the rod to something that itself is well grounded. Underground copper pipes can be very well grounded (depending on their depth, the moisture, salinity, amount of metal and organic content of the soil). In many sites in West Africa, pipes aren't yet in the ground, and previous grounding equipment is often inadequate due to ill-conductive soil (typical of seasonally arid, tropical soils). There are three easy ways to measure the efficiency of your ground:

1. The least accurate is to simply plug a good quality UPS or power strip into the circuit that has a ground detect indicator (a LED light). This LED is lit by energy that is being diffused to the ground circuit. An effective ground will dissipate small amounts of energy to the ground. Some people actually use this to pirate a bit of free light, as this energy does not turn an electrical counter!
2. Take a light socket and a low-wattage bulb (30 Watts), connect one wire to the ground wire and the second to the hot wire. If the ground is working, the bulb should shine slightly.
3. The more sophisticated way is to simply measure the impedance between the positive circuit and the ground.

If your ground is not efficient you will need to bury a grounding stake deeper (where the soil is more moist, has more organic matter and metals) or you need to make the ground more conductive. A common approach where there is little soil is to dig a hole that is 1 meter in diameter and 2 meters deep. Drop in a highly conductive piece of metal that has some mass to it. This is sometimes called a ***plomb***, which literally means lead but can be any heavy piece of metal weighing 50 kg or more, such as an iron anvil or steel wheel. Then fill the hole with charcoal and mix in salt, then top with soil. Soak the area, and the charcoal and salt will diffuse around the hole and make a conductive area surrounding your plomb, improving the efficiency of the ground.

If radio cable is being used, it too can be used to ground the tower, though a more resilient design is to separate the ground for the tower from the cable. To ground the cable, simply peel back a bit of cable at the point closest to the ground before it goes into the building, then attach a ground cable from that point, either by soldering or using a very conductive connector. This then needs to be waterproofed.

Power stabilizers & regulators

There are many brands of power stabilizers, but most are either digital or electromechanical. The latter are much cheaper and more common. Electromechanical stabilizers take power at 220V, 240V, or 110V and use that energy to turn a motor, which always produces the desired voltage (normally 220V). This is normally effective, but these units offer little protection from lightning or other heavy surges. They often burn out after just one strike. Once burnt, they can actually be fused at a certain (usually wrong) output voltage.

Digital regulators regulate the energy using resistors and other solid state components. They are more expensive, but are much less susceptible to being burnt.

Whenever possible, use a digital regulator. They are worth the added cost, and will offer better protection for the rest of your equipment. Be sure to inspect all components of your power system (including the stabilizer) after lightning activity.