Grounding and Bonding for Lightning protection

A typical broadcast site or ham radio station has two ground systems – tower and AC. Ground currents will flow between the two. The goal is to bond the two in such as way as to reduce or eliminate ground current flow through the equipment.

An average lightning strike will briefly produce roughly 30000 amps of current. Let's assume the tower ground system has a total resistance of 1 ohm. This would be a very well grounded site. Simple ohms law will show the entire tower ground system will rise to 30kV above true ground potential. This is perfectly fine and no damage will occur - provided that all equipment remains at the same potential.

The other ground system is provided by commercial AC power. The power grid will also provide a low resistance path to ground via the neutral conductor, the ground rods at the AC entrance panel, and ground rods at the transformers outside.

A direct lightning strike is not necessary to create a ground surge voltage. Nearby strikes can induce high currents and voltages into either system.

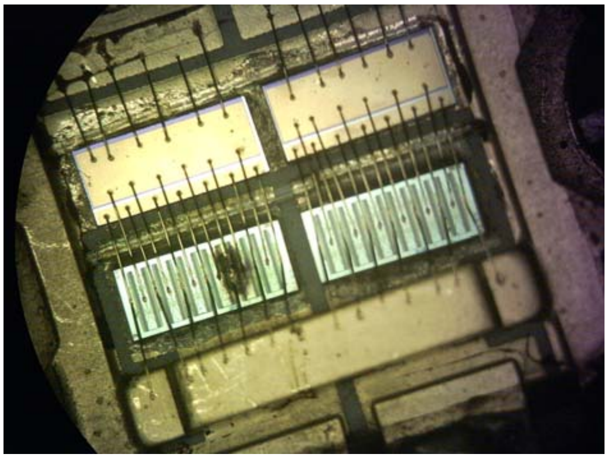
The solution to protecting the equipment is to have the tower and AC building entrances as close together as possible and well bonded to each other. Properly designed, current between the two ground systems should flow through the bonding connections - not the equipment. All equipment within the building will 'float' at whatever ground potential there is between the two. People inside the building can go along for the ride.

The easiest time to take care of grounding issues is when the site is being designed. Changes on paper are easy to make. While installing the site, a very low impedance path between the tower and AC grounds must be supplied. Transmitter and equipment AC cables should have toroid chokes placed on them to increase their inductance. Similar chokes should be placed over the RF and control cables. High inductance paths through the equipment vs low inductance paths between the two ground systems will provide maximum protection. The saying that lightning will take the path of least resistance is only partially true. Simple ohms law and current division comes into play.

The transmitter cabinet and equipment racks should be isolated from the floor. The AC ground conductor should connect to the RF connector at the top of the transmitter, and this same point carried to the bottom of the rack via an insulated wire to the site ground strap. This will prevent the cabinet and electronics inside from being part of the ground current path. Nautel uses this technique extensively in their high power transmitters.

In some sites there is a third ground system provided by the satellite receive dishes. I've seen major ongoing issues with LNB and receiver problems that cleared up immediately upon placing a heavy ground wire from the dish to the tower and building ground. It ensures the dish 'floats' at the same potential as the rest of the site and prevents high ground currents from flowing through the electronics. Prior to the ground wire installation it was difficult to keep the site on the air. Since ground wire installation there have been no problems. Another site experienced intermittent breakup as unrelated equipment was switched on or off. There were similar poor installations in which TV transmitters were repeatedly losing power supplies. Studying the grounding configuration and determining how to rearrange wiring greatly reduced the failure rate. Toroids on the satellite coaxial cables and ground blocks at the entrance point provide added protection.

Damage to components may not be immediately evident. A typical high power FET has a ceramic cover that protects hundreds of smaller FETs operating in parallel. A single surge could damage one or two of the smaller internal FETs. The transmitter AGC will compensate. Over time more and more FETs will fail and the AGC will become maxed out. The transmitter will no longer produce full power, yet no alarms will be displayed. The remaining FETs will be working harder and overall efficiency will be greatly reduced. Components weakened in this manner will eventually fail even if subsequent grounding or cooling improvements are made.



This transistor was still operational, could be biased, and was making power. A larger image is available. Look closely to see the power dividers / combiners to the individual FETs.
http://members.rennlist.org/warren/failedFET.jpg

A microprocessor will pack many more transistors into the package than in a typical RF FET. It will not have multiple parallel transistors. Each junction will be much smaller and more delicate. A single transistor failure could render the microprocessor useless. New transmitters will typically be fully microprocessor controlled and have a considerable amount of digital processing. This makes proper grounding and control of ground surge currents even more important.

Unless the two (or more) ground sources are properly bonded, the equipment between them can become the common jumper point. Very high ground currents may flow through the equipment possibly causing damage. The goal is to ensure that all ground systems 'float' together and remain at the same potential. The absolute voltage during a ground surge doesn't matter provided they go there together. Having things bonded together properly ensures any current between ground sources and destination will not flow through equipment. With equipment chassis isolated from ground other than via the intended ground conductor the current through the equipment is greatly reduced or eliminated.

It's not always easy to look at a site with copper ground straps running every which way and say it's done properly or to point at areas of weakness. Often ground systems are tied together in multiple places. With AC and RF entrances on opposite sides of a building it can be hard to understand how things work together.

The installation must be done properly at the very beginning. Once a system is placed on the air it is highly unlikely that you will be allowed to shut down to make improvements. Once equipment damage has occurred, grounding improvements may limit further damage, but can not fix what has already happened. Compare to buying a new car and neglecting oil changes for the first several years. Chances are you will suffer engine damage and no amount of preventive maintenance will make things better. Once the damage is done it's too late.

Continuously monitoring ground resistance is impractical and likely of little benefit. Once installed nothing should change other than thieves or vandals stealing tower ground wires. It must be replaced ASAP once noticed, but even then as long as the main system bonds are in place both ground systems will remain at the same potential. In many places I've noticed copper ground wires on tower guy anchors being replaced with galvanized steel wire. While the resistance is considerably higher than solid copper it is infinitely better than having no wire at all. The steel ground wire very seldom gets stolen. Another problem with missing grounding wires at anchor points has to do with shunting ground currents away from the concrete anchor systems. There is a possibility for a direct strike to flow through the anchor and cause cracks in the concrete. Again, having higher resistance steel is much better than having an open system after thieves steal the copper.

When installing copper wire underground, the soil type could have an effect the wire. Acidic soil will cause bare copper to deteriorate but will have little effect on tinned wire. Basic soil will have little effect on bare copper, but will remove the tin coating from the wire. (reference to acid/base may be reversed) The question becomes whether to use bare or tinned copper wire for underground installations. Consider using tinned wire anywhere underground. If the soil is acidic the tin coating will provide protection. If the soil is basic the tin coating will be removed but the copper underneath will not be affected. In either case tinned wire will provide the protection required.

I found this information online. The original source page is no longer available.

> Oxidative corrosion of copper will affect its conductivity. Electrical conductivity is a measure of a materials ability to carry an electrical current. Copper is an excellent conductor making it ideal in all electrical applications. However, in the presence of air and moisture its surface oxidizes forming a layer of copper oxides that conduct electricity very poorly. This layer is not initially a problem since the layer is very thin and actually serves to protect the underlying copper.
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> In an outdoor corrosive environment, however, the oxide layer progressively extends deeper into the copper strand and eventually oxidizes the entire thickness. The resultant decrease in conductivity severely compromises the lighting system. Landscape lighting wire is especially prone to this severe corrosion because it is a stranded wire with very thin strands. Lighting installers often see the devastation of this effect when they pull old wire from the ground and see the strands completely blackened and brittle.
>
> Tin-coating the wire protects from this type of progressive corrosion and loss of conductivity in two ways.
>
> 1. Sacrificial. The tin coating differs in electrical potential from copper in a way that causes the tin to be oxidized in preference to the copper. In other words, instead of a progressive deepening of the corrosion into the strand, the tin must completely oxidize before the copper interior is subject to corrosion.
>
> 2. Greater Conductivity of Tin Oxides. While copper oxides are very poor electrical conductors, tin oxides maintain good conductivity. This benefits the long-term conductivity of the entire wire bundle. Note: the initial conductivity of the tin coating is lower than copper, leading to a slightly higher voltage loss at time of installation. This difference is offset over time since the tin coating largely maintains its conductivity while the oxidized copper conductivity significantly decreases over time.

These documents regarding grounding and site preparation must be studied. By getting into the mindset of what is being said and understanding the concept rather than just reading and looking at pictures you can get an idea of what the overall goal is.

Polyphaser - Lightning Protection & Grounding Solutions for Communications Sites. (4467kB)
http://members.rennlist.org/warren/LightningProtectionAndGrounding.pdf

Broadcast Electronics - Installation Methods for Protecting Solid State Broadcast Transmitters Against Damage from Lightning and AC Power Surges (204kB)
http://members.rennlist.org/warren/ground.pdf

Nautel - Recommendations for Transmitter Site Preparation (5827kB)
http://members.rennlist.org/warren/TransmitterSitePreparation.pdf

Nautel - Lightning Protection for Radio Transmitter Stations (1530kB)
http://members.rennlist.org/warren/LightningProtection.pdf

Another critical issue is cooling. For every 10C raise in ambient temperature you can expect the life of a transistor to be half. Proper air flow over components is critical. Merely having cool room air is not enough. Look for heated air circulating within cabinets. You may have to install baffles to redirect the air or install fans to remove heated air. Walk behind the transmitter to the air intake and ensure there are no hot spots in the room. Dummy load exhaust air should not be directed toward the transmitter cold air intake. Nor should it blow directly against a wall where it could be circulated back to its intake. Direct the air parallel to a wall surface, towards the center of the room, or straight up if possible.

The latest update of this document can be found on my web page.
http://members.rennlist.org/warren/grounding.pdf

Here are other documents I'm continually working on. I'd appreciate feedback from others who work in broadcasting. It's difficult to find other technicians interested in these topics. I try to keep the latest version available for download on my personal web page.

Monitoring of transmission line pressure is standard at most sites. Unfortunately pressure alone does not ensure dehydrators are operating properly. Keeping the transmission lines dry is perhaps the most important antenna related preventive maintenance item we can perform on the ground. Sending wet air up the tower is a guarantee of trouble, especially at high power multiple carrier sites. Transmission line relative humidity is easily monitored, making moisture damage very easy to prevent.

Relative Humidity and Dehydrator operation.
http://members.rennlist.org/warren/relativehumidityanddehydrators.pdf

Construct an inexpensive and simple Dew Point Monitor
http://members.rennlist.org/warren/dewpointmonitor.pdf

I've compiled my notes and experiences working with FM combining systems into a document that I had hoped to offer as a training session. It covers combiner theory and operation as well as tuning procedures for balanced FM combiner systems. Also included is a list of tests to perform during acceptance testing or following combiner retuning.
FM constant impedance combiners. Theory and tuning
http://members.rennlist.org/warren/FMCombinerTuningAndTesting.pdf

Antenna splitter cables are often damaged by kinks or dents during installation or tower maintenance, falling ice, abrasion and metal fatigue caused by vibration, bullet holes, arcing due to dipole failure, etc. Dehydrator failures may create condensation inside the lines causing internal corrosion and contamination on insulators. A failed cable can render an antenna system unusable and it must be replaced immediately. Damaged lines should be replaced to ensure long-term reliability, especially at high power levels with multiple carriers. Included are design techniques for single cable or full harness replacements, circular and elliptical polarization, beam tilt considerations, unequal power dividers, split feed phase adjustment, and line length estimation. Splitter cable design.
http://members.rennlist.org/warren/SplitterCableDesign.pdf

I'm also working on items for HVAC routine maintenance.
http://members.rennlist.org/warren/HVAC_PM.pdf

and 3dB coupler applications.
http://members.rennlist.org/warren/3dBCouplers.pdf

Please email me with any suggestions or comments.
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"Trust those who seek the truth, but doubt those who say they've found it."

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