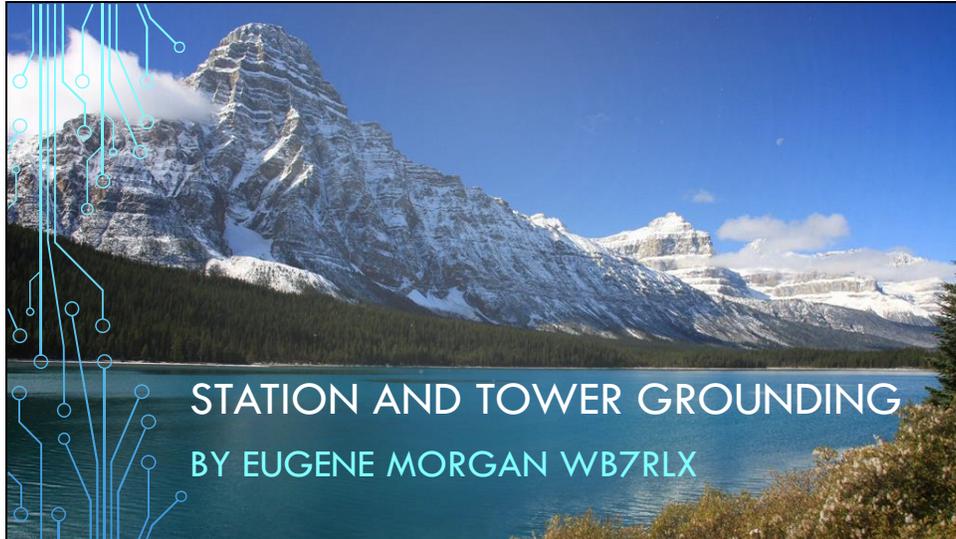
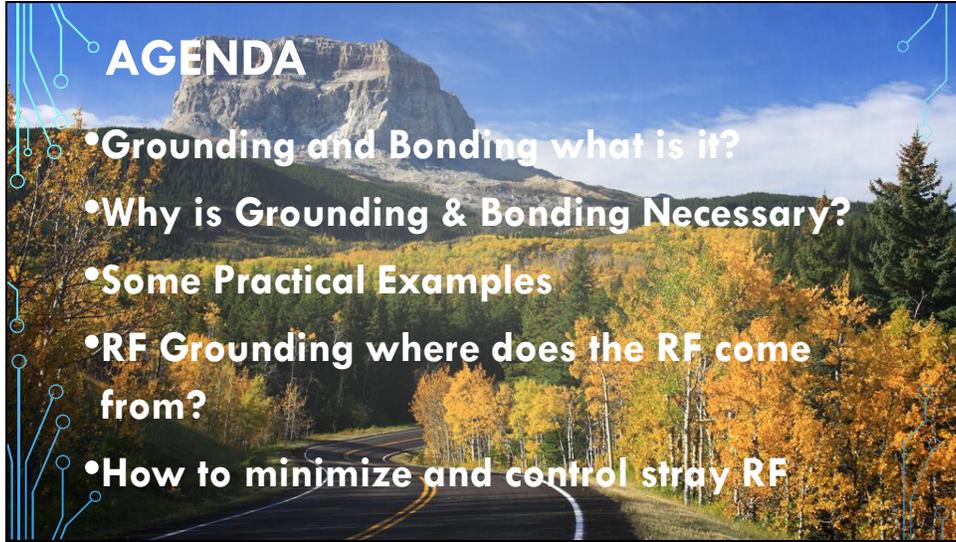


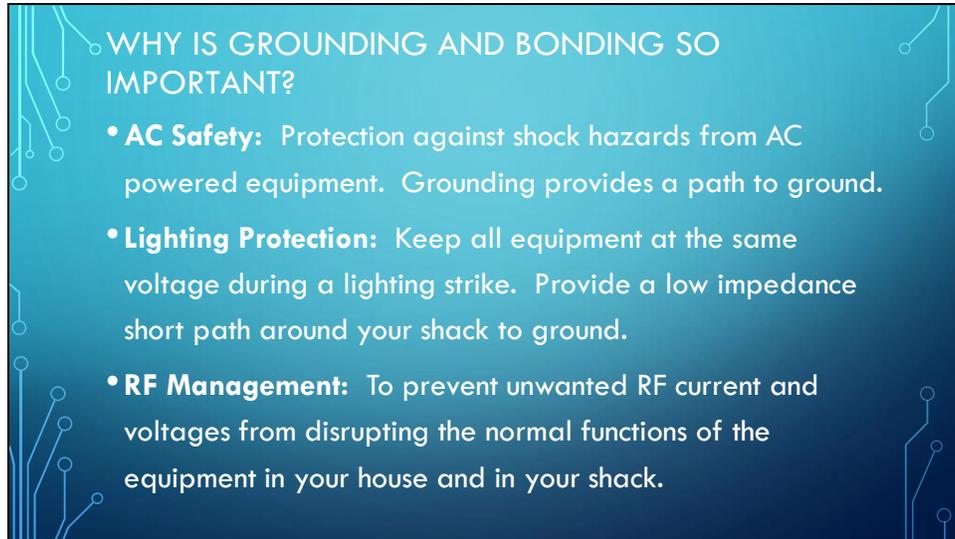
Slide 1





AGENDA

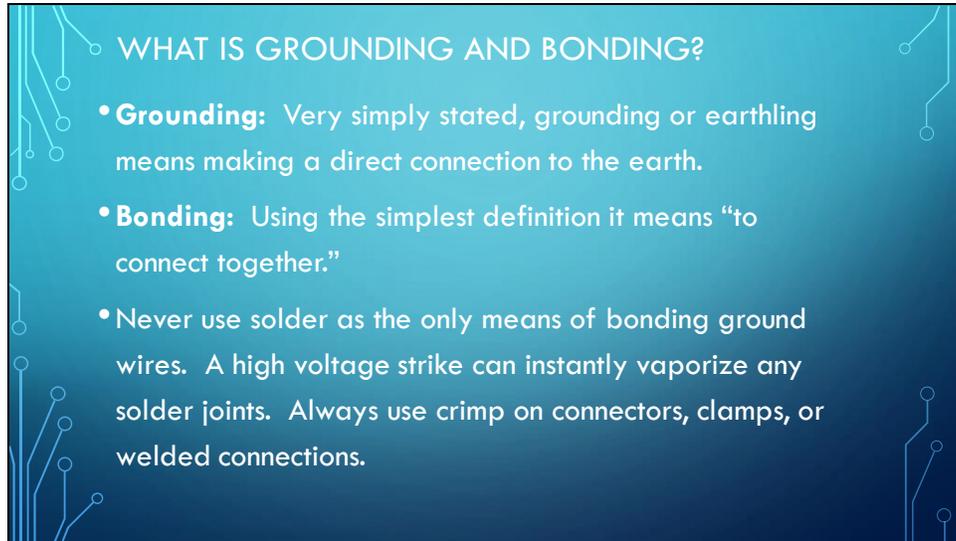
- **Grounding and Bonding what is it?**
- **Why is Grounding & Bonding Necessary?**
- **Some Practical Examples**
- **RF Grounding where does the RF come from?**
- **How to minimize and control stray RF**



WHY IS GROUNDING AND BONDING SO IMPORTANT?

- **AC Safety:** Protection against shock hazards from AC powered equipment. Grounding provides a path to ground.
- **Lighting Protection:** Keep all equipment at the same voltage during a lightning strike. Provide a low impedance short path around your shack to ground.
- **RF Management:** To prevent unwanted RF current and voltages from disrupting the normal functions of the equipment in your house and in your shack.

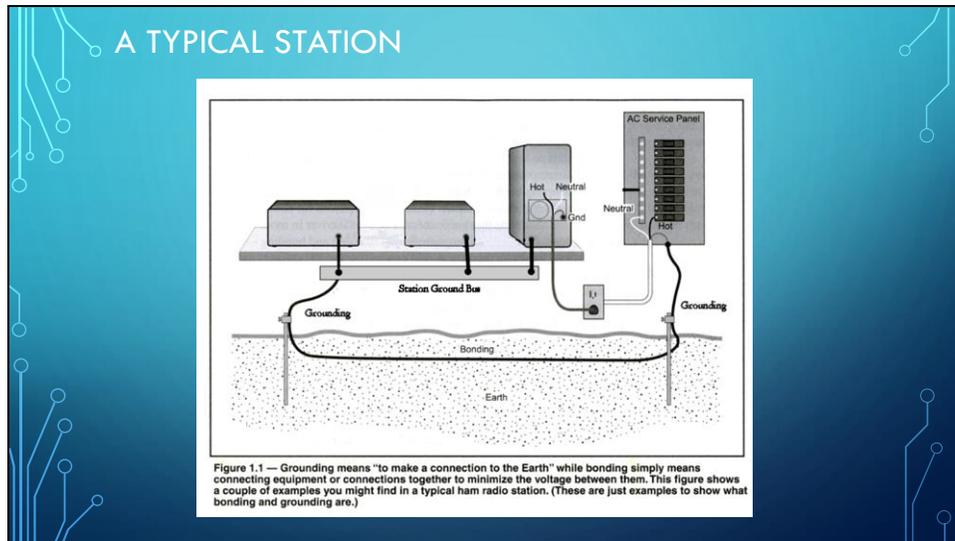
We are not going to cover AC Safety aspect in this presentation. Primary reason is AC Safety relies heavily on having a proper grounding system in place so we will focus on that. Also note that much of the wiring in your house has been done to address safety concerns. So we will focus our attention to Lighting Protection and RF Management.



WHAT IS GROUNDING AND BONDING?

- **Grounding:** Very simply stated, grounding or earthing means making a direct connection to the earth.
- **Bonding:** Using the simplest definition it means “to connect together.”
- Never use solder as the only means of bonding ground wires. A high voltage strike can instantly vaporize any solder joints. Always use crimp on connectors, clamps, or welded connections.

Grounding can have a much broader context when talking about electronics. What we are focused on in this presentation is equipment grounding specifically.

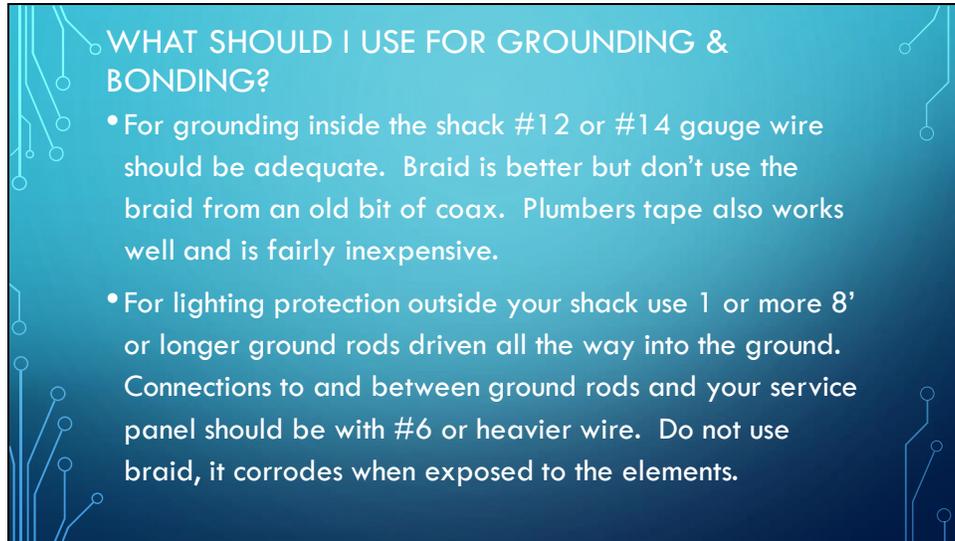


This slide shows an example of a properly connected station. Note the Electrical service and the ground rods and the station ground bus bar are all bonded together and that each piece of equipment is bonded to all the other equipment through the station ground bus. This configuration will also help to eliminate ground loops which are often responsible for humming on your signal when you transmit.

Slide 6



This slide simply shows some of the examples of grounding done by some of the hams in our club. Note in the last picture, which is my station the size of the cable running from the tower to the ground rod. The tower is also connected to two other ground rods. All three ground rods are bound together and are all connected to the common service ground on the electrical service panel.



WHAT SHOULD I USE FOR GROUNDING & BONDING?

- For grounding inside the shack #12 or #14 gauge wire should be adequate. Braid is better but don't use the braid from an old bit of coax. Plumbers tape also works well and is fairly inexpensive.
- For lightning protection outside your shack use 1 or more 8' or longer ground rods driven all the way into the ground. Connections to and between ground rods and your service panel should be with #6 or heavier wire. Do not use braid, it corrodes when exposed to the elements.

I have seen first hand examples of braid that has been use outside. Over time it corrodes. I would recommend you not use braid outside, instead use #6 or heaver copper wire or flat copper strips..

CLAMPS VERSUS WELDING

- At a minimum use grounding clamps. Avoid using stainless steel hose clamps. Ground clamp provides a better bond that will minimize corrosion.
- Exothermic Welding: When possible use exothermic welding for connections that will be underground. They will last longer and the connection will not corrode
- Outside never use aluminum wire to connect directly to a copper ground rod. Galvanic corrosion will disintegrate the connection over time and the joint will literally fall apart.



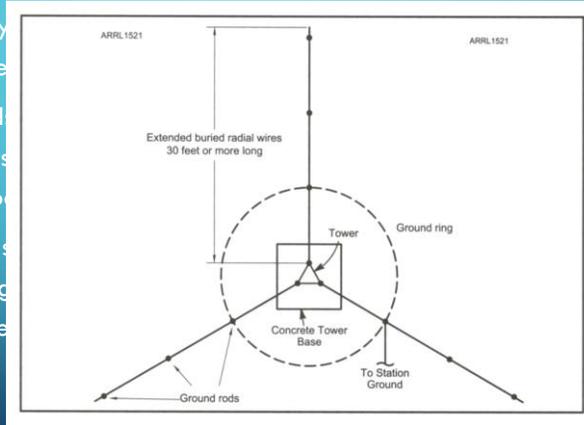
GC-style ground clamp RC-style "acorn" ground clamp



A note about galvanic corrosion. Over time galvanic action will result in the two metal components literally dissolving over time. Although in our dry Utah climate the problem is not near as bad in areas where there is exposure to salt water. There is a real problem for boaters on the Great Salt Lake. In your shack it's okay to connect copper and aluminum together as in the case of your station bus bar because the connection is not exposed to water or high humidity, but outdoors it a bad idea.

HOW MANY GROUND RODS?

- I believe currently
- Schematic of a single family dwe
- typical tower
- Place ground rods
- grounding
- tower installations
- system. Buried
- rods beyond
- the bonding
- ring are
- optional
- together and whe



o ADDITIONAL LIGHTING PROTECT FOR ANTENNAS

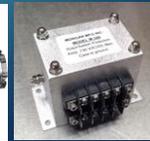
All coax should be grounded before entering the shack. There are two ways of accomplishing this.

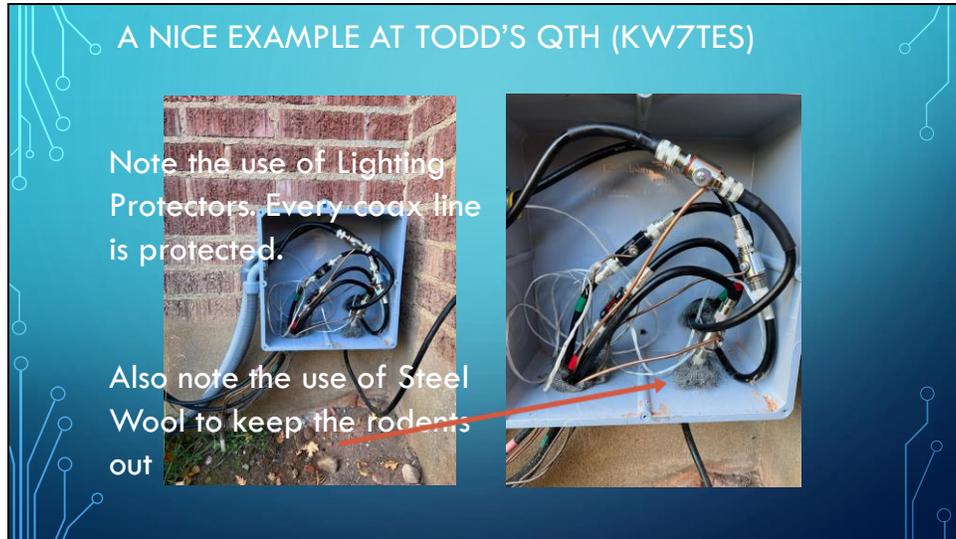


Use a Grounding Block. However this method does not ground the center conductor.

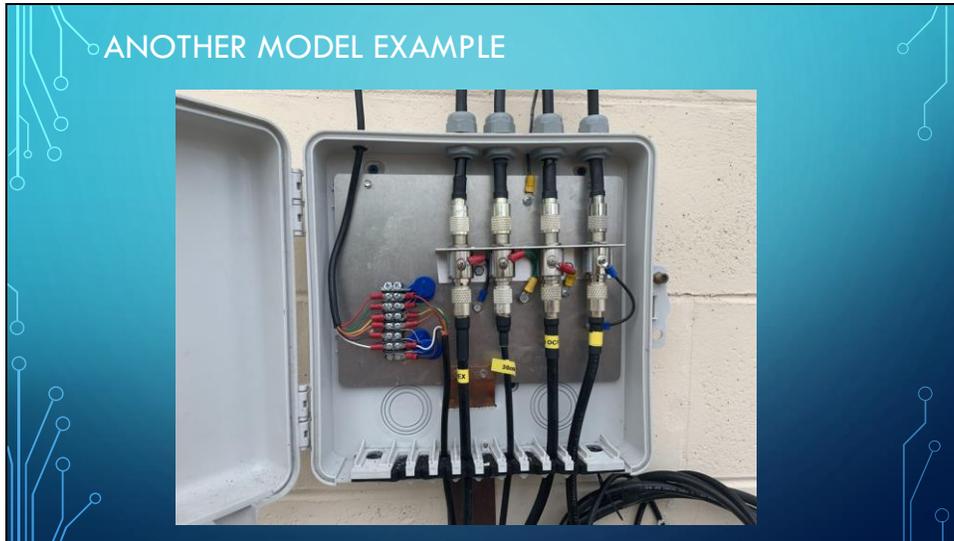
o ADDITIONAL LIGHTING PROTECT FOR ANTENNAS

Using a lightning arrester is the better approach.
It grounds the center conductor and allows static
electricity to bleed off as well





This is a good example of protecting your shack from surges from entering the shack. Todd has installed a lightning Arrestor on every bit of coax in his shack.



This is a model example. Note how the rotator wires are also protected.



This picture is of the entry point into the Mount Ogden building. On the inside of the building EVERY coax line is protected with a Lighting Arrester. They do not overlook lighting protection here. It's understood that a lightning strike is a certainty. Through the use of proper grounding they have turned a high probably risk into a low impact event. This is lighting protection done right.

○ NOW WE HAVE A GOOD GROUNDING SYSTEM OUTSIDE WHAT DO WE DO INSIDE THE SHACK?

- Implement a Single Point Ground Strategy.



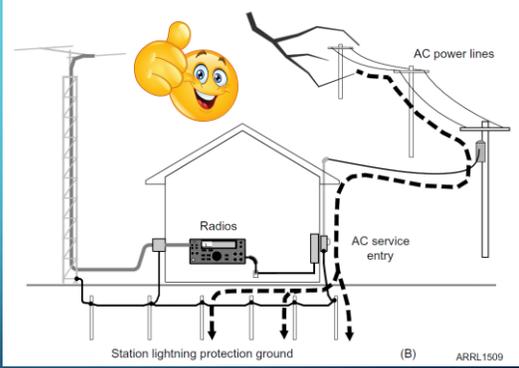
This slide shows a typical bonding buss for a station with ALL equipment connected to a single buss. You can use a copper pipe or a length of aluminum angle attached to the rear of your desk or wall. The key to keep the cable between your equipment and the common bus as short as possible. #14 gauge wire is usually adequate. You can also use wire braid. You do not want to “daisy chain” equipment. Each piece of gear needs to have a direct connection to ground otherwise a ground fault in any one piece of equipment can take out all the other equipment.



This slide shows the outside of my shack. The white and black wires go to the single point grounding bus on the electrical service panel. The other wires go to additional ground rods that I added. The single point grounding buss on the service panel also connects to other ground rods. I will be adding one additional ground rod to my system and replacing all exterior grounding wire with #6 wire. I currently have 4 ground rods outside my shack.

KEY TAKE AWAY REGARDING LIGHTNING PROTECTION

- You do not want lightning going through your shack on its way to ground!



AC power lines

Radios

AC service entry

Station lightning protection ground

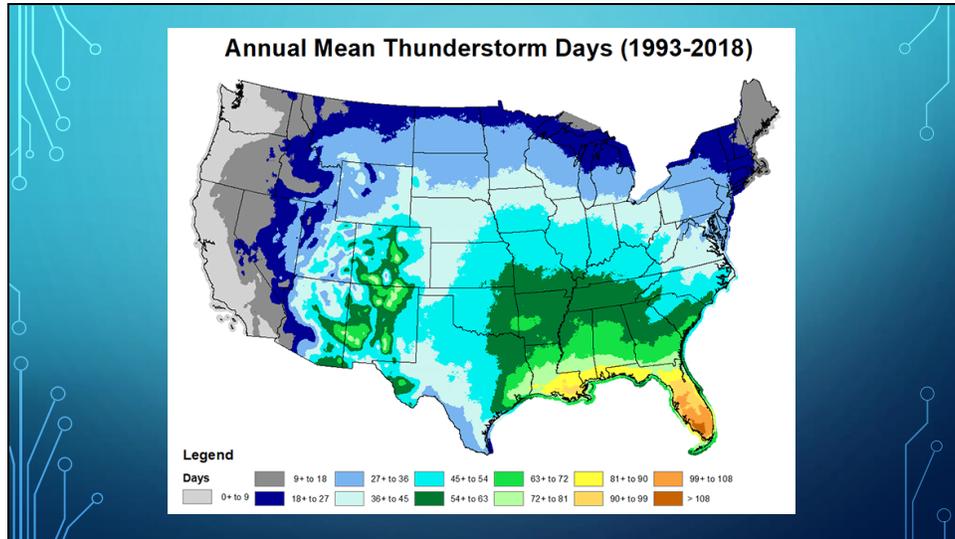
(B) ARRL1509

As you think about your ground system consider how a lightening surge would find its way to ground. You do not want it going through your shack on it way to ground. That's why it's important that you ground your antennas and rotator cable so that in the event of a lighting surge the electricity bypasses your shack on its way to ground.

LET'S GET REALISTIC ABOUT A LIGHTENING STRIKE

*How likely is
your house going
to be hit by
Lightning?*

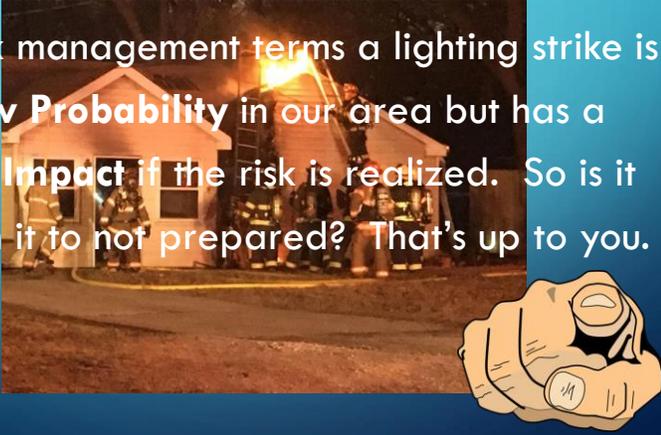




Although the risk of a lightning strike at your house is low, in some cases extremely low, a lightning strike is a high impact event. So do you really want to take a chance given the consequences if your house is struck?

LET'S GET REALISTIC ABOUT A LIGHTENING STRIKE

In risk management terms a lightning strike is a **Low Probability** in our area but has a **High Impact** if the risk is realized. So is it worth it to not prepared? That's up to you.

The slide features a blue background with white circuit-like patterns. At the top, the text 'LET'S GET REALISTIC ABOUT A LIGHTENING STRIKE' is written in white. Below this, a photograph shows a house at night with a bright lightning strike hitting the roof. To the right of the photograph, the text 'In risk management terms a lightning strike is a Low Probability in our area but has a High Impact if the risk is realized. So is it worth it to not prepared? That's up to you.' is written in white. At the bottom right of the slide, there is a cartoon illustration of a hand pointing towards the text.

I'd suggest you prepare for the worst, hope for the best, and pray that your grounding solution was well planned and implemented. You don't want to end up replacing several thousands of dollars of expensive equipment or worse yet, having to call the fire department.

AC SAFETY VERSUS LIGHTNING PROTECTION GROUND SYSTEMS

What is the relationship between these two systems? Do they complement or contradict each other? Both have similar purposes — to provide a safe path for current that would otherwise be hazardous. Done properly, the systems need not compromise each other.

The safe path for current in the ac safety ground is back to the common connection between the power system neutral and the ground conductor. The safe path for current in the lightning protection system is away from your equipment to the ground electrode and then into the Earth. As long as all of the ground electrodes of these two systems are bonded together, they do not interfere with each other and can even provide additional safe current paths.

The two systems must be bonded together at their common points — the ground electrodes. You cannot rely on the lightning protection system alone to provide ac safety and vice versa. If properly bonded, ac fault current can flow through the lightning protection ground connections back to the service entrance ground electrode and then to the neutral bus in the service entry panel. Similarly, the shared ac safety ground connections help keep all of the equipment at the same voltage so that lightning-generated currents flow into the Earth instead of between pieces of equipment. The bonding jumpers are key to both systems working to protect you and your equipment.

See: *“Ground and Bonding for the Radio Amateur”*, Ward Silver N0AX, page 1.10.



○ NOW LET'S TALK ABOUT RF GROUNDING

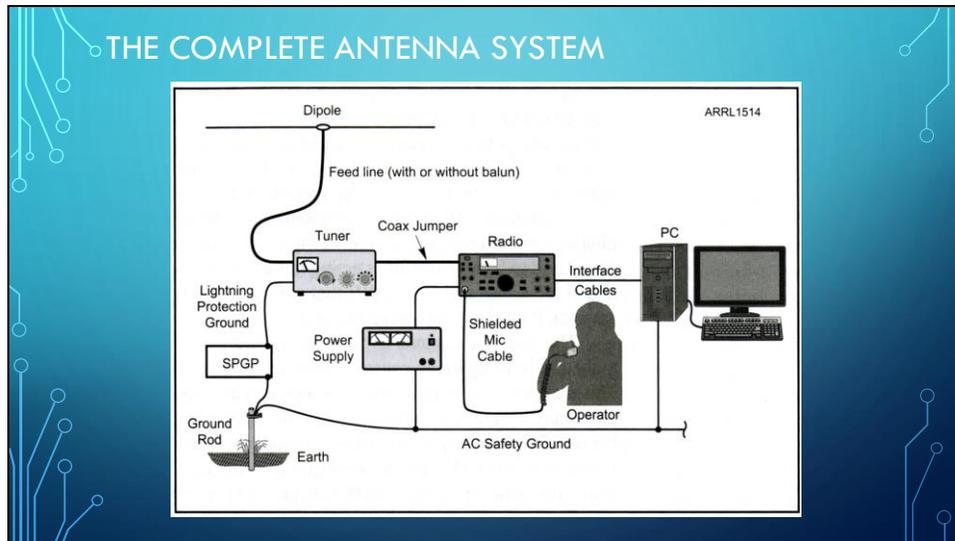
- RF Grounding is about controlling and minimizing the effect of RF. What are the effects of RF in the shack or in your house?
- In many of my articles I've referred to the effect of RF as the:

Poltergeist Effect

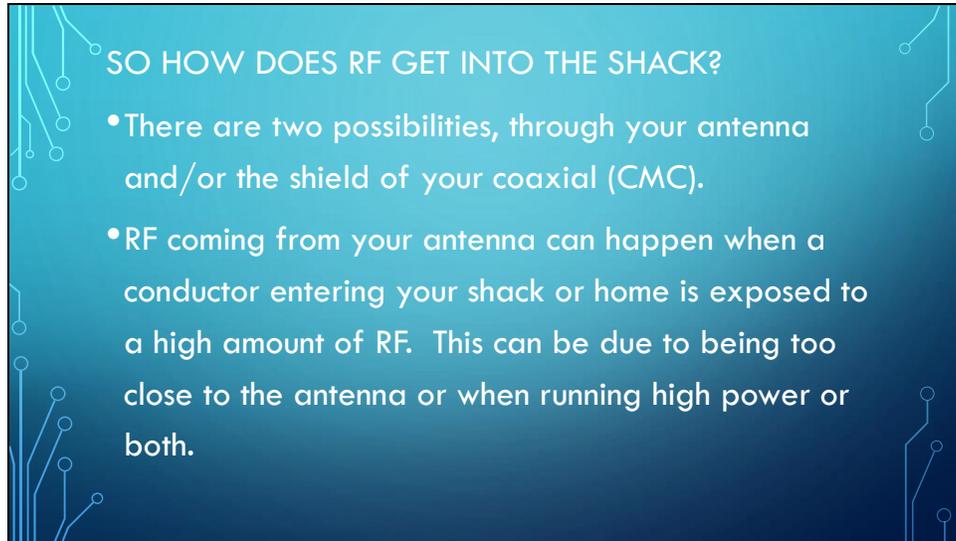
- When you transmit on certain bands some equipment will misbehave
- Indicator lights blink
- Your audio becomes distorted, speakers buzz
- The TV mysteriously turns on or off or the volume increases
- Worst case you experience an RF burn.

At this point we have talked about grounding a bonding which are both necessary steps in protecting against shock hazards from AC powered equipment and preparing for a potential lightning strike. These are two important aspects of a well-designed shack. Now let's talk about RF Grounding.

The key takeaway is RF grounding is different than electrical grounding and serves a different purpose than electrical grounding but they can work together to minimize the effect of RF in the shack.



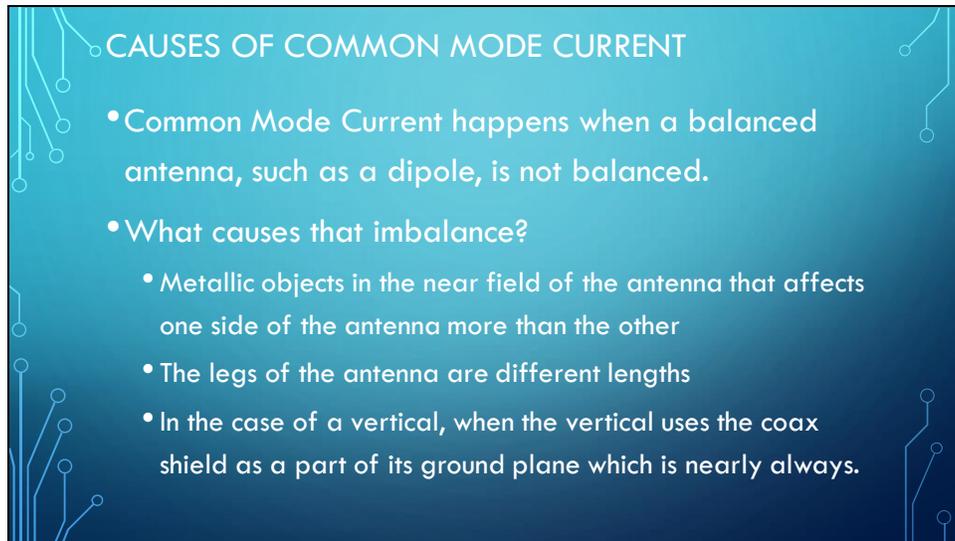
The thing to note is that RF is being introduced through two avenues: By the antenna and in some cases and as Common Mode Current. If the antenna is far enough away the RF introduced by the antenna may be so weak as to not be able to overwhelm the protections built into much of today's equipment. Common mode current on the other hand can affect any number of devices it invades. So of course one of the best things to do is try to locate your antenna away from your shack. That means you want to avoid putting an antenna in your attic if possible. If you use a vertical don't locate it a few feet from the outside of your shack. If you do locate your antenna in your attic you may find it necessary to limit your transmitter power to a few watts. It all depends on what conductors are close to the antenna. Does that length of RG6 in your attic that feeds the TV in the living room run in proximity and parallel to your attic dipole. Or how about that run of Romex that feeds the utility room where the washing machine sits dutifully waiting for that next load of laundry? Also consider, if this is the entire antenna system what RF is it picking up that I don't want it to, such as the RF coming from wall warts, LED lights, the motors various appliances, the doorbell transformer, and so on.



SO HOW DOES RF GET INTO THE SHACK?

- There are two possibilities, through your antenna and/or the shield of your coaxial (CMC).
- RF coming from your antenna can happen when a conductor entering your shack or home is exposed to a high amount of RF. This can be due to being too close to the antenna or when running high power or both.

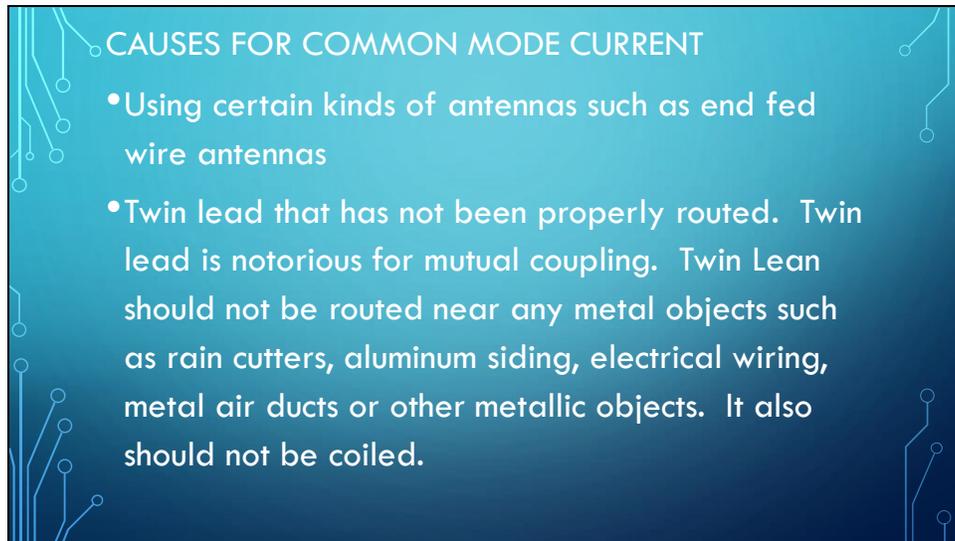
There is a way to tell where the RF is coming from. If you transmit into a dummy load and you don't see any of the effect you see when transmitting into your antenna then it's clear the RF is coming from either CMC or your antenna. If you still see the same effect when transmitting into the dummy load then it's likely that you have a bad bit of coax in the circuit or a faulty piece of equipment and/or you have a faulty ground or no ground at all.



CAUSES OF COMMON MODE CURRENT

- Common Mode Current happens when a balanced antenna, such as a dipole, is not balanced.
- What causes that imbalance?
 - Metallic objects in the near field of the antenna that affects one side of the antenna more than the other
 - The legs of the antenna are different lengths
 - In the case of a vertical, when the vertical uses the coax shield as a part of its ground plane which is nearly always.

We could make this entire discussion about common mode current but due to time we will touch on the high lights. Common mode current is cause by an imbalance in the antenna. This is a common occurrence in dipoles and vertical antennas. The imbalance can be cause by metallic objects in the near field of the antenna that affect one side of the antenna more than the other. In the case of a vertical it happens when the antenna uses the coax shield as a part of its ground plane. The unbalanced current flows down the outside of the coaxial cable looking for a path back to mother earth. On its way it can cause all sorts of issues including giving you a good RF burn.

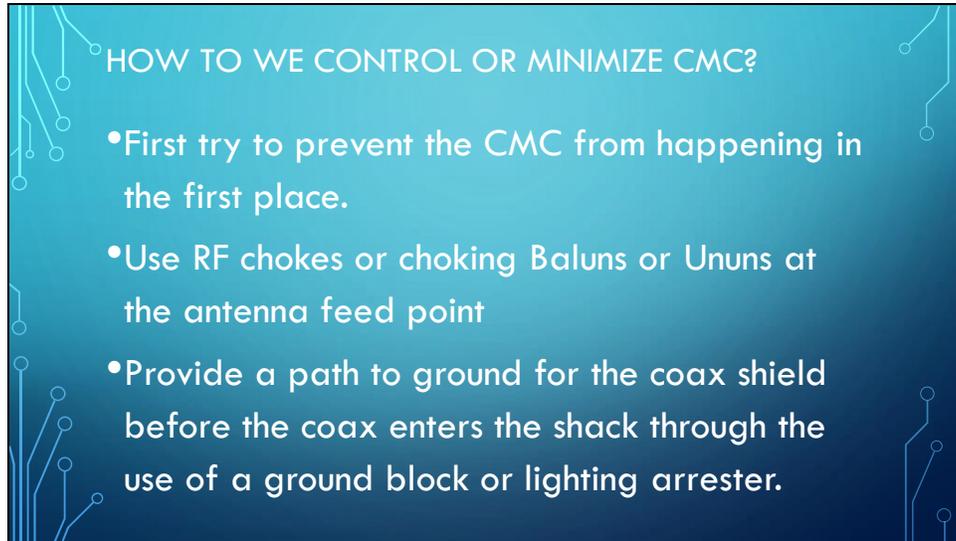


CAUSES FOR COMMON MODE CURRENT

- Using certain kinds of antennas such as end fed wire antennas
- Twin lead that has not been properly routed. Twin lead is notorious for mutual coupling. Twin Lead should not be routed near any metal objects such as rain cutters, aluminum siding, electrical wiring, metal air ducts or other metallic objects. It also should not be coiled.

There's nothing wrong with using end fed antennas. They make a very good antenna when done properly. What that means you must use an unun AND a choke to minimize the CMC. It also helps if you can ground the other side of the UNUN provided the ground lead won't be too long. The short length of wire going to ground will be a part of the antenna.

In the case of twin lead, if you can't route it properly then simply replace it with coax and remove the twin lead altogether. Yes that could mean turning that G5RV into a multiband dipole.



HOW TO WE CONTROL OR MINIMIZE CMC?

- First try to prevent the CMC from happening in the first place.
- Use RF chokes or choking Baluns or Ununs at the antenna feed point
- Provide a path to ground for the coax shield before the coax enters the shack through the use of a ground block or lightning arrester.

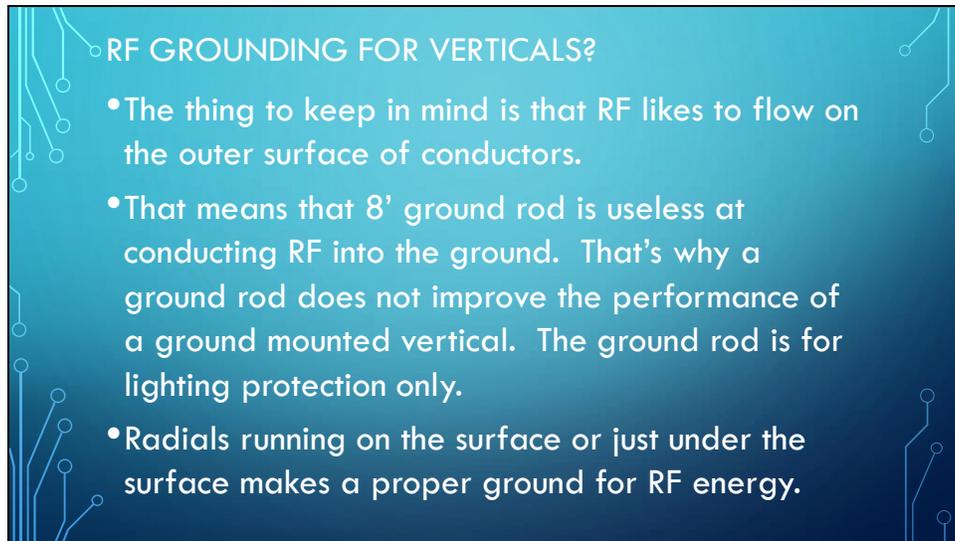
Use Baluns on balance antennas, and unun on unbalance antennas such as end fed wires. In the case of ununs always use a choke as well if the unun provides no choking. If you're into building your own chokes the best Ferrite cores or beads are the Mix 31. They provide the best choking over a broad range of frequencies from 1 Mhz to 300MHz. Note that a lot of the cores and beads bought online are from china and you never know what you are getting. If you're buying cores always know what mix you are getting.



HOW TO WE CONTROL OR MINIMIZE CMC?

- Use Ferrite rings or beads on any wire that carries electricity: USB cables, monitor cables, mouse cables, Ethernet cables, audio cables, and electrical cables.
- Keep ground wires that run from your equipment to your station ground bus as short as possible.
- If your using a ground mounted antenna lay out a proper radial field and use a choke on the feed line at the feed point of the antenna. A ground rod is of little value when it comes to CMC.

Use Baluns on balance antennas, and unun on unbalance antennas such as end fed wires. In the case of ununs always use a choke as well if the unun provides no choking. If your into building your own chokes the best Ferrite cores or beads are the Mix 31. They provide the best choking over a broad range of frequencies from 1 Mhz to 300MHz. Note that a lot of the cores and beads bought online are from china and you never know what your are getting. If your buying cores always know what mix you are getting.



RF GROUNDING FOR VERTICALS?

- The thing to keep in mind is that RF likes to flow on the outer surface of conductors.
- That means that 8' ground rod is useless at conducting RF into the ground. That's why a ground rod does not improve the performance of a ground mounted vertical. The ground rod is for lightning protection only.
- Radials running on the surface or just under the surface makes a proper ground for RF energy.

Ground rods are great at conducting DC current to ground. But they do nothing for AC current. Yes a ground rod will help dissipate CMC but the real purpose is for managing DC currents. Remember your utility power also has a connection to ground and that is why a ground rod as part of your electrical service grounding is important. It can make sure that AC circuit can be completed when there is a ground fault.

QUESTION?

For More information:

- “Grounding & Bonding for the Radio Amateur”, Ward Silver, NOAX
- NEC 810: This is an excellent PowerPoint on NEC-810 and how it applies to Amateur radio:
<https://pslara.org/docs/2.D.pdf>
- Contact your city regarding Local Building and Electrical codes, especially if you are planning to install a tower.

