

Grounding Guidelines for Safe Deployment of Mast and Equipment by Dr. John M. Tobias, PhD, PE

1. Introduction.

In many of the applications for the BlueSky Mast, it will be necessary to provide an electrical grounding means for the mast. The BlueSky Mast can also be used to provide a zone of protection of lightning. This guide provides information on how to implement the BlueSky Mast and its accessories for correct, safe, electrical grounding and lightning protection.

2. Grounding.

The purpose of earth grounding the mast is to dissipate electrical current into the earth and to keep the electrical potential (voltage) of its metal parts the same as the earth. For the purposes of lightning protection, it is necessary to channel the current into the earth in a controlled fashion. For electrical safety, the mast needs to be kept as the same voltage as its surroundings to prevent an electrical shock hazard. Grounding the mast accomplishes both.

2a. Grounding Subsystems.

For the purposes of most field equipment there are three types of grounding:

- 1) *Equipment Grounding***
- 2) *System Grounding***
- 3) *Lightning Protection***

1) *Equipment Grounding*

Equipment Grounding consists of the parts of the electrical system that connects the non-energized parts of equipment through a conductive means, like a wire or cable, back to the ground in its source of power. This ground is often called the 'green wire' but its correct name is the equipment grounding conductor or EGC. This ground serves two essential purposes. First it is a dedicated path for any fault current to flow back to the source of power and open, or trip, a circuit breaker back at that source. The second purpose is to keep the exposed parts of the equipment, that are not supposed to be energized, at the same voltage. When equipment is all connected to a common ground, their external voltage (or potential) is the same. Where there is no voltage difference, there cannot be a shock hazard.

All of the means for equipment grounding is usually built into the electrical equipment and power supply systems. However, equipment grounding could be rendered ineffective without attention to the system grounding component.

2) System Grounding

System Grounding consists of the parts of the electrical system to connect the entire system to earth. The EGC keeps all of the external parts of the equipment on the electrical system at the same voltage but the system ground keeps this voltage as close to zero as possible, thereby preventing shock hazards. Another aspect of system grounding is the electrical connection, or bonding, of different grounding systems together. This serves to keep different electrical systems at the same zero voltage, referred to the earth. The essential parts for system grounding consist of the grounding electrode and the wire that connects it, the grounding electrode conductor. Bonding conductors also serve as part of this system.

System grounding, beyond safety purposes, also contributes to the performance of many signals and computer systems. In many of these systems, having a zero-voltage reference is critical for correct operation. Also, it helps to drain effects from electromagnetic interference (EMI.) A good system ground will accomplish this.

3) Lightning Protection

Lightning Protection is similar to system grounding. It electrically connects parts of structures or equipment that may receive a lightning strike to grounding electrodes that are dedicated to delivering the lightning current into the earth. Like the other forms of grounding, part of this grounding system prevents the travel of lightning current by electrical connection, also called bonding, of different equipment.

Each of these parts work in concert to prevent electrical hazards in the form of short circuits, over current events and electrical shocks.

2b. Implementing System Ground.

The Surface Wire Grounding Kit (SWGK) for the BlueSky Mast utilizes a radial system. Three radials, 25 feet long with five stakes attached to each radial are used. In order to get the best results, place all of the radials and stakes as far apart as possible. Using this principle, the radials are ideally installed 120 degrees apart, equally spaced about the mast, extending out straight from the mast with all of the stakes placed equally apart. (see Figure 1)

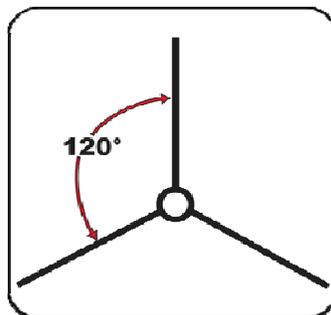


Figure 1 - Optimal Deployment of Grounding Radials

However, it is sometimes not possible to achieve this ideal placement due to deployment constraints and alternate installation techniques are acceptable as long as the radials and stakes are placed as far apart as possible. (see Figure 2)

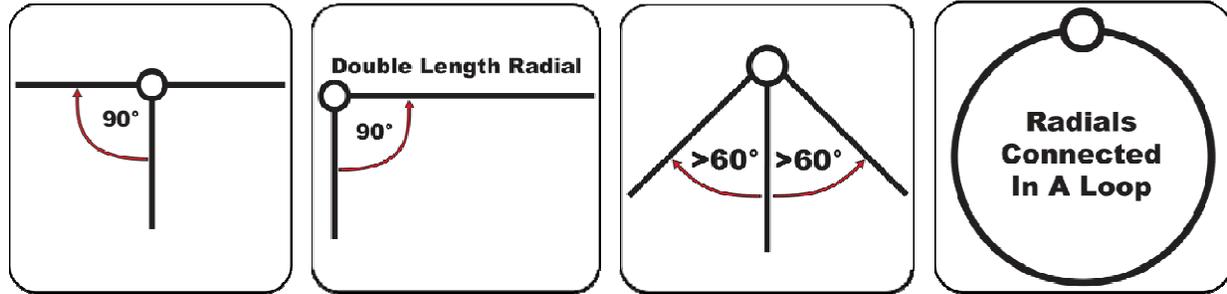


Figure 2 - Alternate Deployment Configurations of Grounding Radials

When deploying the radials avoid sharp bends in the radials, separation angles of less than 45 degrees and avoiding placing the stakes less than twenty inches apart. (see Figure 3)

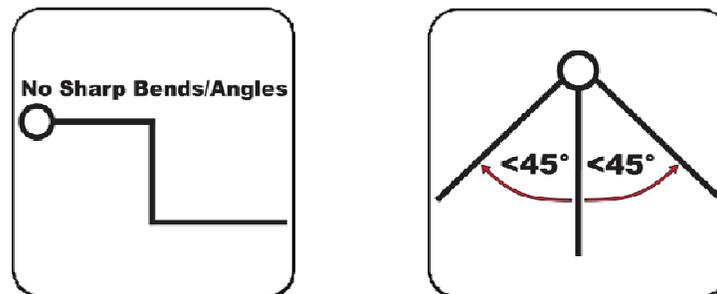


Figure 3 - Configurations to Avoid

For the purposes of **lightning protection**, it is not recommended to ‘daisy chain’ the radials into one long wire extending away from the mast. This is because such an arrangement will put all of the current from a lightning strike onto one ground path and can decrease the survivability and performance of the grounding system. Also, a single linear arrangement will tend to maximize the area on the ground that the current is injected into.

However, if the likelihood of lightning is small, a linear arrangement is permissible as it will ground the mast for electrical purposes adequately. (see Figure 4)

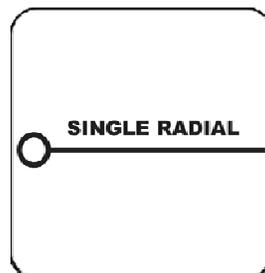


Figure 4 - Daisy Chained Straight Radial - Adequate For Electrical Grounding Only

Step Potential - A hazard of any grounding system used for lightning protection arises from a voltage that is induced nearby on the surface of the earth when the lightning event occurs. This is called step potential, and can cause a serious electric shock to persons in the vicinity. It occurs for only a fraction of a second but can result in voltages of tens of thousands of volts, enough to cause serious injury. Another hazard is flashover, where the lightning event can arc over to a nearby object. Both effects can (and do) occur when personnel or livestock gather near a tree that is struck by lightning, usually causing injury or death.

The only way to completely avoid either hazard is to be in an improved shelter, enclosed vehicle or building. Otherwise, hazards from step potential and flashover can be minimized by keeping at least six feet from lightning protection systems and their grounding systems.

2c. Selection of an Earth Grounding Electrode.

The choice of the best grounding system to install will typically depend on the soil conditions (clay, loam, sand, rock, etc.) and the location's climate (tropics, deserts, mountains, arctic, etc.). Different types of soil have different electrical characteristics. Table 1 provides a brief summary of soil types, ground qualities, and suggested types of earth grounding electrodes.

Type of Soil	Quality of Ground	Suggested Earth Grounding Electrode
Wet, organic soil	Very Good	Ground Rod, Surface Wire Ground Kit (SWGK)
Clay, loam, or shale	Good	Ground Rod, Surface Wire Ground Kit (SWGK) or Plate
Clay, loam, or shale mixed with gravel or sand	Poor	Buried pipes, building frame, or other metal object or a ground plate or several ground rods electrically connected together
Gravel, sand, stone, permafrost.	Very Poor	Buried pipes, building frame, or other metal object or a ground plate or several ground rods electrically connected together
Shallow soil	Various	Surface Wire Ground Kit (SWGK)
<p>Note: If ground rods cannot be driven to their full depth, it is generally better to use a surface wire kit. The only time the SWGK will be less suitable is when either the stakes cannot firmly stay in the soil or if the surface layer is a very high resistance compared to soil at a greater depth that could be reached by a deeply driven grounding electrode.</p>		

Table 1 - Soil Quality and Grounding

General Recommendations and Precautions for Grounding:

- 1) Before digging any holes or installing any grounding electrodes, check for any underground electrical, gas, water, or other utility lines.
- 2) Never use metal natural gas lines for earth grounding. Never use buried tanks containing flammable liquids for earth grounding.
- 3) When choosing a location for the earth grounding electrode, keep it away from locations having normal pedestrian traffic. During an electrical storm or a fault condition, dangerous voltages induced at and near the earth grounding electrode could be hazardous to personnel.
- 4) Aluminum should not be used as an earth grounding electrode.
- 5) Prior to connecting the earth grounding system, ensure that power to the system is off. This is not necessary if the system is initially self-powered, such as with an onboard generator.
- 6) Never lay system power cables or signal cables over the location of the earth grounding electrode, grounding electrode conductors, or SWGK cable. During a fault condition, step potentials at and near these components may be induced on collocated signal and power cables.
- 7) Install the earth grounding electrode at locations where ground will receive rain water (i.e., outside the drip line of shelters, etc.).
- 8) Where air conditioning units are operated near grounding electrodes, earth grounding resistance can be further improved by routing the air conditioners condensation water to the grounding electrode location via a tube or hose.
- 9) Wear gloves to protect hands when handling or inspecting grounding electrodes, conductors, and connections. Wear safety goggles when driving ground rods to protect from flying metal chips.
- 10) Where any excavation is done, such as for ground plates or buried conductors, always add water when back-filling. This will help to compact the soil and ensure good soil contact with the electrode.

3. Lightning Protection.

The BlueSky Mast may be used for lightning protection purposes when combined with the SWGK - Surface Wire Grounding Kit. To conform *exactly* to the NFPA 780 Standard (The Standard for the Installation of Lightning Protection Systems) an Air Terminal is always required at the top of the structure where lightning will be encountered. BlueSky Mast offers an Air Terminal & Top Adapter for the BlueSky Mast that can be used in conjunction with the SWGK, but again this is only required if wanting to adhere verbatim to the Standard as written for structures. The BlueSky Mast was tested and certified without use of the Air Terminal in the actual testing represented in the official grounding report.

Lightning protection is afforded by the ability of the mast to intercept lightning events, conduct the resulting electrical current through the ground and inject it into the ground. The mast intercepts lightning that may occur near it. This is the concept of 'zone of protection' where the installed mast provides a volume surrounding it where the lightning will not strike, instead striking the mast. This zone looks like a sphere or ball resting on the ground and on the tip of the mast. (see Figure 5)

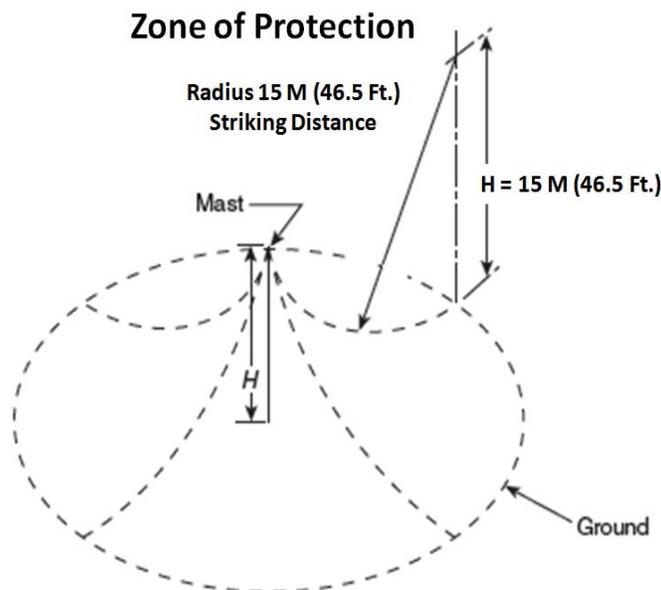


Figure 5 - Zone of Protection

The zone under the curve in the illustrations is the zone of protection. A different zone is used if the protection is for explosives and flammables. Notice that the mast will protect a conical volume approximately at a 45 degree angle from the top of the mast. Or, more simply, as far from the mast as the mast is tall, in the shape of a cone. Items in this region should not be directly struck by lightning as the mast will intercept it. However, there is still a danger of side flash and step potential near the mast and its grounding system.

Positioning equipment or systems within these conical areas will make it far more likely that the lightning event will connect to the mast rather than to the equipment, thereby protecting it from a direct lightning strike. (see Figure 6)

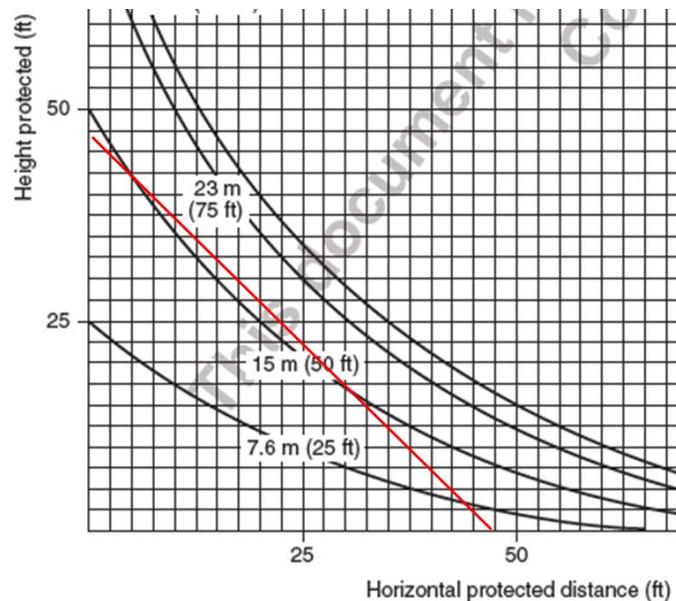


Figure 6 - Zone of Protection Height Matrix

3a. Protection for Mast Mounted Items.

Will an item attached to the mast be protected from lightning? The answer is that it will be protected from direct strike but it may not be immune to the electrical current nor to the indirect electric and magnetic fields that occur from direct lightning strikes. Since the item is mounted to the conductive mast, current may flow over the surface of the item or through the item if it is wired to another assembly. The electric and magnetic fields that occur from the high currents of the lightning event may cause damage to the electronics in any device. You will have to check with the equipment vendor for specific data concerning lightning survivability of any device.

Typically a mast mounted device, such as a radio or antenna, is wired to a remote assembly which may include a user interface. This wired connection provides an incidental path for lightning current to travel. As such, the remote assembly can be dangerous during a lightning event. Grounding of the mast helps to minimize the current that can travel to remote assemblies. Often, these remote assemblies are equipped with surge protection devices that divert these currents to earth ground before they enter the device. We recommend checking with the specific equipment vendor for specific data concerning the lightning safety with any device or equipment.

4. Bonding

Electrical bonding is a term used to electrically connect equipment for the purpose of keeping their metal parts such as casings at the same potential or voltage. Metal casings of equipment (often called 'dead metal parts' reflecting they are supposed to be at zero voltage) are connected to ground by their design. When electrical equipment is bonded, this usually means that their grounding systems are electrically connected together. This bonding is done for the purposes of electrical safety and lightning protection. When equipment is bonded, it prevents the possibility of the 'dead metal parts' having different voltages creating an electric shock hazard. For lightning protection, it prevents sideflashes and arcing between equipment. Bond metal encased equipment and other grounding systems within 6 feet of the BlueSky mast grounding system. Many times, the BlueSky mast grounding system can be used as a common ground for other systems.* Check with local authorities and/or the equipment vendor for details concerning sharing grounding electrodes.

* National Electrical Code (NFPA 70) and The Standard for the Installation of Lightning Protection Systems (NFPA 780) generally require a discrete earth grounding electrode for an electrical system ground. This electrical system ground is required to be electrically bonded to the lightning protection system ground. However, the BlueSky mast grounding system more closely resembles a 'ground ring electrode' or a structural ground in which case the ground connections are generally permitted to be shared. We recommend checking with local authorities or the equipment vendors to determine the specific grounding requirements for your situation.

4a. Bonding Equipment to the Mast.

If the equipment is equipped with a grounding connection, it is recommended to connect this to the grounding electrode rather than the mast. This is because any electronics relying on a ground connection, particularly surge protection devices or filters, may be damaged if it is exposed to the voltage rise on the mast during a lightning strike. The voltage rise at the ground electrode connection will be less. On the other hand, antenna mountings are generally bonded to the mast just by attaching it, assuming the attachment hardware is metallic. The active components of the antenna cannot be grounded (the parts ultimately connected to the center wire of a coaxial cable) as this would short any received or transmitted signals to ground and ruin the utility of the antenna.

Under any circumstance, energy from the lightning event may damage any wiring connecting the antenna to equipment.

4b. Bonding of Collocated Equipment and Generators.

Personnel can sustain much worse injuries when contacting two metal surfaces at different potentials with bare hands (a low resistance path provided across the chest) than by contacting a surface energized to ground while wearing boots (a high resistance path to earth). For this reason, equipment located within arms length of each other (6-8 feet) must be bonded together to eliminate any hazardous voltages that may develop between them. Normally equipment connected through cord-and-plug attachment to power (for example, a three-prong plug to a standard electrical receptacle) will be grounded to a common system. However, in field use, it

is common to have equipment (notably equipment shelters and generators) with different grounding systems close together.

Bonding should be done either by running a bonding conductor (at least 6 AWG) between the two equipment or system grounding terminals. One grounding electrode can be used for more than one equipment in which case, they will be adequately bonded. This applies when two or more generators are collocated.

Don't forget to check remoted equipment for proper bonding. Often, radios and other Command & Control equipment are remoted from different systems to one central location, such as inside of a tent. Many times, each of these systems are powered by different generators. Since the earth grounding resistance for the different systems (powered by different generators) can vary, potentials can exist between the remoted equipment, if there is no electrical bonding between the systems and/or generators.

During thunderstorms, lightning flashover or arcing can occur between two or more unconnected or poorly connected metal structures that are located close to each other. Flashover between objects can cause damage to the objects and cause lethal voltage on the ground in the vicinity of these objects. To avoid lightning flashover, make sure that equipment and other metal structures (fences, masts, sheds, etc.) located within 8 feet of each other are bonded together using a heavy copper cable, at least 6 AWG. The cable lengths should be as short and as straight as practical.