RF Shielded Enclosure Grounds: A Review

CHARLIE SNOW
Independent Consultant, Chandler, AZ

Engineers and technicians must be cognizant of the terms used in discussions on grounding.

BACKGROUND

Grounding is the most abused and misunderstood term used in the electrical and electronic designs and specifications for RF shielded enclosure installations. It seems that almost every engineer, no matter what the specialty or discipline, has a different mental picture of the reason for and the method of grounding that must be employed for a successful and safe installation. Even the identifying nomenclature employed may well differ from engineer to engineer, and from job site to job site. This article is an attempt to define the more commonly used terms associated with grounding an RF shielded enclosure.

First, readers should understand that the safe and proper installation of an enclosure involves two primary grounding considerations. The first consideration is the electrical neutral or common return to the center tap of the secondary of the main power transformer (Figure 1). The second is the very low impedance path for the electrical grounds, commons or neutrals that lead to an earth ground (Figure 2).

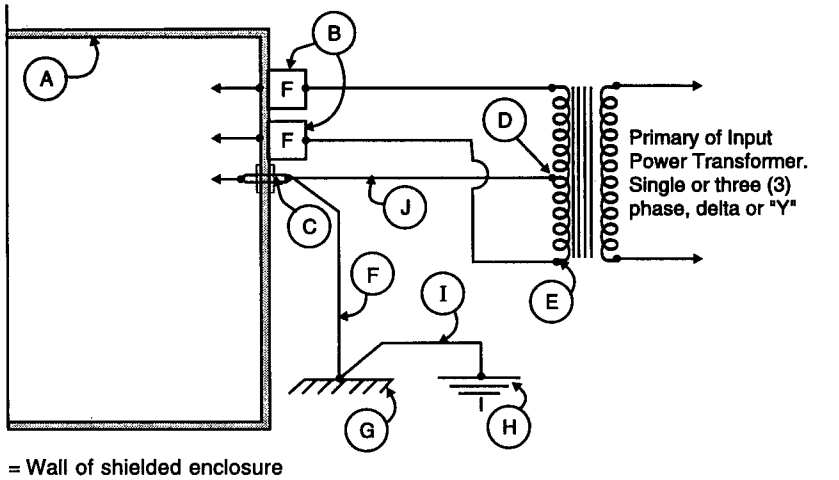
There are other needs for grounding or creating common connections from the shield enclosure to some type of ground or to other shields (Figure 3). In some instances, the connections may be made to equipment or stations outside the enclosure. However, under no circumstances may these be used in place of the primary electrical or the electronic grounding circuits.

Specific requirements usually call for the connections to be attached to the ground stud on the shielded enclosure (Figure 4). The specifications may also call for connections to be passed through a power-line filter for external access and attachment. Both of these procedures are safe and effective. If the enclosure has power-line filters on the ground(s), then the enclosure itself still must be properly attached to the building electrical ground system. Designers must always bear in mind the fact that a shielded enclosure is an electrical box as described in the National Electrical Code (NEC). As such, it must be properly grounded in the same manner as all other electrical boxes.

DEFINITIONS

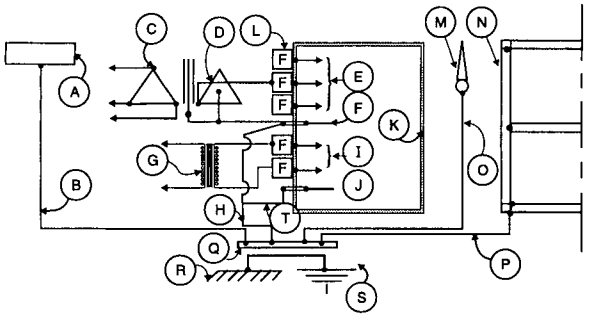
Following are some of the more common identifying names and phrases associated with shielded enclosure grounding.

Bonding: the very low resistance connection of ground studs, ground wires, terminals, etc., that are found



A = Wall of shielded enclosure
B = Power-line filters
C = Ground stud
D = Center tap of the power transformer secondary
E = Secondary phase
F = Very low resistance wire from the ground stud to the counterpoise
G = Counterpoise
H = Earth ground
I = Very low resistance wire connecting the counterpoise to the earth ground. Note that wire F first goes from the enclosure ground stud directly to the counterpoise. The wire I then connects the counterpoise to the earth ground.
J = Very low resistance wire connecting the ground stud to the power transformer center tap secondary. This is also known as the green wire, the neutral and the electrical common.

Figure 1. *Typical Electrical Power and Ground Circuitry.*



A = Electrical or electronic equipment that calls for grounding
B = Low resistance ground wire from the equipment to the common grounding plate (Q)
C = Primary power input of 3-phase delta
D = Secondary or primary power of 3-phase delta. Note that the delta ground is attached to the transformer plates and to the ground stud.
E = Filtered 3-phase power within the enclosure
F = 3-phase ground wire within the enclosure
G = Single-phase power primary
H = Low resistance ground wire from the 3-phase and the single-phase power at the enclosure, to the common grounding plate
I = Single-phase filtered power within the enclosure
J = Single-phase ground wire within the enclosure
K = RF shielded enclosure
L = Power-line filters, shown in 5 places
M = Building-mounted lightning rod
N = Building structural steel, electrically bonded at all joints, which calls for grounding
O = Low resistance ground wire from the lightning rod to the common ground plate
P = Low resistance ground wire from the bonded structural steel to the common grounding plate
Q = Common grounding plate, of copper or brass, mounted in a place convenient to the ground wires and the earth ground system
R = Typical earth ground system of a counterpoise
S = Typical earth ground rod or attachment
T = Single-phase low resistance wire from the single-phase power to the common ground wire

Figure 2. *Typical Building Multi-Ground Circuitry.*

throughout the grounding connection system in a shielded enclosure. All bonds must be firm, permanent, low resistance, and clean. Where conditions are prone to be wet or damp, provisions must be made to waterproof the completed connection.

Common: the return wire in an electrical circuit. It may also be called the neutral. This wire is common to the phase wire(s). Electrically, it is the center tap of the secondary of the main power transformer. This is also referred to as the green wire.

Counterpoise: the deliberately intricate buried conducting system used to transfer the electronic ground or neutral currents to an earth ground. It is also known as earth.

Dedicated Ground Wire: a ground (usually electrical) that is a very low insulated resistance wire. The wire is encased in a steel tube that is continuous from the ground stud to the ground terminus. It shall be tagged at both ends to warn others that the wire and tubing is to remain inviolate. No connections or taps are allowed along the entire length.

Earth Ground: the surrounding soil, which contains the billions and billions of coulombs in the earth which will readily accept the unwanted currents that are conducted to it by the counterpoise.

Electrical Box: As defined in the National Electrical Code, this term also identifies and includes an RF shielded enclosure. Accordingly, an enclosure must be electrically (power ground) grounded in a manner prescribed in the NEC.

Electrical Ground Point: refers to the ground stud of the RF enclosure. This is usually placed near the power-line filters. In many installations, it is the only, or single ground point.

Electrode Subsystem: varies greatly from single driven ground rods to intricate welded patterns of conductors that are buried in chemically tested earth. Chemicals may be added in the buried pattern to lower the resistivity of the system to the earth ground.

Electronic Ground: the very low impedance ground terminus for the unwanted grounding currents from electronic and/or electrical equipment that have nothing to do with the electrical neutrals.

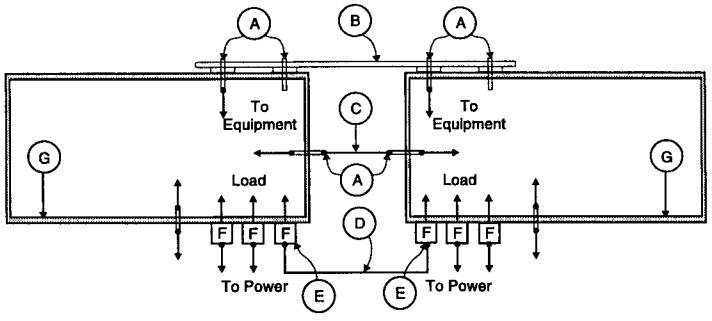
Facility Ground Feeders: the wiring that connects the enclosure to the metallic structure supports, such as the steel beams and columns, which are electrically bonded to all other metallic members of the structure. This is considered to be an unreliable grounding system, and as such is not used often.

Facility Grounding System: a complete system that includes electrodes in the earth, ground fault protection, lightning protection, and bonded steel beams. An enclosure may or may not be a part of the installation. This is commonly used as a building system of unified bonding for safety and a unipotential ground.

Floating Ground: a system whereby a low resistance wire or bus bar is distributed about the inside of an enclosure to provide a unipotential point of reference for various pieces of electronic and/or electrical equipment. Rarely does this system extend outside the enclosure. Where it must pass outside the shield, it is conducted through the enclosure wall via a power-line filter. It may well pass into an adjacent enclosure through another power line filter. For the sake of safety, it must be encased in steel conduit or troughs, except at attachment points, where standard access electrical boxes are used.

Green Wires: The ground or common colored wires in an electrical circuit. All green wires must be attached in a low resistance path to the ground point of the electrical system. This is a requirement of the NEC.

Ground Stud: Usually, this is a ½" brass stud that protrudes from the inner and outer surfaces of the shield. It is held in place by flat washers and nuts. It is placed in the area of the power-line filters. There is a sufficient exposure of the protruding threads so that proper attachment can be made at both surfaces. Brass is the metal of choice because it has both strength and low resistivity.



FIRST METHOD
A =Ground studs at each shield to attach the low resistance bus bar to the shields
B = Bus bar, usually of ½" x 2" copper to provide a very low resistance between shields
SECOND METHOD
C = Low resistance wire connecting ground studs at each shield
A = Ground studs at each shield
THIRD METHOD
D = Very low resistance wires connecting power-line filters at each shield
E = Standard power-line filters on each shield, to conduct electrical power and a floating ground, from shield to shield
F = Power-line filters
G = RF shielded enclosure

Figure 3. *Three Methods of Shield-to-shield Ground Attachment.*

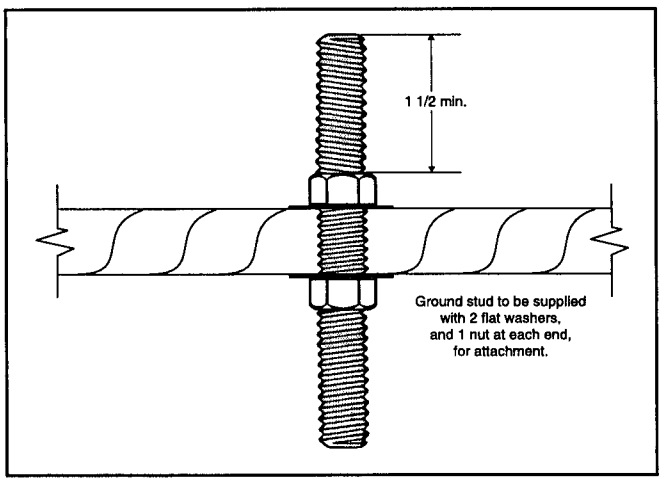


Figure 4. *Ground Stud.*

Ground Resistance Megger: An instrument to read the resistance in ohms of a grounding circuit. A ground megger is considered to be the most effective and accurate method of measuring the resistance between the earth and a ground rod or counterpoise. It is also the most repeatable.

GroundOhmer: Similar to the ground resistance megger, this instrument compares the voltage drop of a driven voltage across the ground connection to a known resistance.

Ground Rod: A common variation of an earth grounding system where a copper or copper-clad rod is driven into the earth at a convenient location. This is usually used for a lightning rod earth termination or an electronic earth ground. It is usually ½" in diameter and 8´ long, with an electrical connector at one end, and a point for earth insertion at the other end.

Grounding Hazards: Usually consist of unexpected stray ac voltages that exist between the shielded enclosure surfaces and adjacent conducting surfaces. These voltages may be internal or external to the enclosure. Dissimilar ground voltages in a single enclosure can present both inaccuracies and hazards between equipment components. This is particularly true in medical environments. Voltage differences of greater than 50 volts not only exceed the allowable limits of NEC but may well present personnel hazards.

Lightning Ground: A specified system of driven ground rods, which are connected to lightning rods, usually with #4/0 AWG wire, and measured to be less than 5 ohms from rod connection to earth ground. In many instances, this system uses a common earth ground.

Neutral: the lead that comes from the center tap of the secondary of the main power transformer. This is also the green wire, or the common. This is the return path for the phase wires after a load dissipation, back to the main distribution transformer secondary.

Off Ground Construction: a common construction type since about 1970, when it was first introduced. The theory is that all unwanted ground currents (electrical and electronic) are brought to a single point ground stud, while the shielded enclosure is kept a minimum of 1000 ohms off ground. Theoretically, this prevents the radiation of any of these ground currents from the skin of the enclosure. At the same time the ground wire is kept to the shortest length and lowest possible resistance. This is to prevent radiation from the ground wire. If needed, the ground wire can be encased in a steel conduit to minimize radiation.

RF Ground: As opposed to the electrical ground or neutral, this is the ground rod or counterpoise that is described above. In reality, this is the electronic ground that is designed for the full spectrum of low to high frequencies.

Signal Cable Ground Bus: a low resistance wire or bus bar that connects electronic and/or electrical equipment, one to another.

Single-point Ground: In this type of installation, the entire shielded enclosure is focused on the ground stud as the only point of grounding. The entire structure floats by a minimum of 1000 ohms off ground. Thus, all unwanted ground currents are kept to minimum voltage by a minimum resistance to ground. Unwanted circulating ground currents in the shield skin are all but eliminated.

Technical Ground: a grounding system for technical equipment, which is installed in parallel with any facility ground returns. These are usually found where a shielded enclosure for the technical equipment is used.

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