Adequacy of Protective Distribution System (PDS) Raceways for Equipotential Bonding

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Abstract:
Raceways for secure communications cabling are designed to provide a robust mechanical pathway for the cabling installation that originates at the secure communications hardware (i.e., servers, routers, etc.) and maintains its structural integrity to access boxes to desktops and other end-user locations. Some of these pathways consist of electrical metallic tubing (EMT), rigid steel conduit (Type RMC), and proprietary hardware by specific manufacturers. The inherent design of these pathways can be a deterrent to tampering due to the internal/external secure locking mechanisms but can also give visual indications where suspected tampering may have occurred.

However, ongoing uncertainty exists as to the bonding capabilities of the proprietary systems versus the EMT or Rigid systems. This paper is intended to provide the data and conclusions on the testing and other comparisons to the most prevalent Protective Distribution System (PDS) pathway systems with a specific focus on reputable pathway systems (e.g. Holocom, Inc.).

Bonding resistance measurements were made to determine the extent of conductivity across sections of each raceway. Furthermore, additional data will be presented to suggest that these raceway systems can afford flexibility as an equipotential plane for all telecommunications systems, and not just for secure communications systems.

The Importance of Telecommunications Bonding

The purpose of electrical bonding is to minimize the voltages between metallic objects when the following events occur:

1. A ground potential rise (GPR) during a lightning strike event,
2. A phase-ground fault within the ac electrical distribution system,
3. Dissipation of electrostatic charges,
4. Electromagnetic interference (EMI/RFI) due to transient or non-linear signals transmitted from an unwanted source.

To achieve this, an effective design of an equipotential plane is the desired outcome for any telecommunications bonding infrastructure; whether it is a secure data center or a simple telecommunications space in a commercial building.

Measurement Criteria

Most industry-related personnel anecdotally use the **National Electrical Code** as the authority to determine if metallic items are properly bonded. However, there is no **NEC** requirement for a resistance value nor testing the bonding resistance between metallic objects since it assumes that the mechanical integrity of the connections should be sufficient if the manufacturers' proper torque settings are used when securing their hardware connections.

For telecommunications system designers, a heavy reliance is placed on the ***Telecommunications Industry Alliance (TIA) TR-42.16 Engineering Committee on Premises Telecommunications Bonding and Grounding,*** which produces a document called ***TIA-607 (Generic Telecommunications Grounding (Earthing) and Bonding for Customer Premises)***. This document is often cited where the effectiveness of a bonding infrastructure is discussed. The document calls for a bonding resistance of 100 milliohms, or 0.1 ohms. This ohmic value is intended to be measured using the testing and design practices set forth by ***Building Industry Consulting Services International (BICSI)*** and ***National Electrical Contractors Association (NECA)***.

To further analyze the conductivity, the two-point measurements were made with, and without, the internal powder-coating to determine if the bonding resistance was improved with steel-to-steel connections, thereby not relying on the incidental bonding between metallic items.

Testing Procedure

The procedure to measure bonding resistance is known as a 'two-point' test method, which is similar to a continuity test often performed with standard volt-ohm-milliammeters (VOMs). This procedure is recommended by the ***Institute of Electrical and Electronics Engineers (IEEE) Standard 1100-2007 (Emerald Book) – Recommended Practice of Powering and Grounding Electronic Equipment***.

Type of Metering Instruments Used
For the purposes of this paper, three types of testers were used to measure the bonding resistance of the raceway system:

1. A micro-ohmmeter with a resolution of fifty (50) microohms,
2. A ground impedance tester to determine the bonding resistance to the ac equipment grounding system and,
3. Two types of earth ground testers that have the ability to reject stray ac and dc currents.

The laboratory use of an ohmmeter was considered as part of the test procedure. However, this type of meter was discounted due to the fact that these devices have proven to provide false readings in situational environments where AC or DC current may be present on the bonding infrastructure. Earth ground resistance testers utilize internal circuitry that is inherently immune to the effects of DC and AC current.

Bonding Resistance Test Planes
Resistance measurements were conducted in two fashions:

1. Between metallic portions of the Holocom PDS raceway where exterior paint and interior powder-coating remained on the surface of each section of the raceway or interconnectors and,
2. Between metallic portions of the Holocom PDS raceway where the interior powder-coating was removed.

All measurements were made where the steel sections abutted with each other while various interconnectors were used to section these sections. The various connectors included straight, forty-five (45°), intersection, three-way, and ninety-degree (90°) connectors or internal/external connectors.

Bonding Resistance Test Results With Internal Powder-Coating
The results of the bonding resistance testing with interior/exterior paint and powder-coating remaining on the hardware is as follows:

- Raceway Steel sections (top cap): 350 μohms.
- Raceway Steel sections (interlock): 250 μohms.
- Raceway Steel sections (90° connectors): 250 μohms.
- Steel sections with Run End connectors: 750 μohms.
- Steel Raceway sections with 45°: 350 μohms.
- Secure Large Carrier™ Raceway w/end caps: 200 μohms.
- Secure Large Carrier™ Raceway w/Lock Kits: 200 μohms.
- Secure Large Carrier™ Raceway w/end-to-end connectors: 220 μohms.
- Secure Large Carrier™ Raceway w/pull box: 215 μohms.
- Secure Large Carrier™ Raceway w/90° internal connectors: 173 μohms.
- Secure Large Carrier™ Raceway w/90° external connectors: 175 μohms.
- Secure Mini Dukt™ Raceway w/mounting brackets: 285 μohms.
- Secure Mini Dukt™ Raceway w/three-way connector: 300 μohms.
- Secure Mini Dukt™ Raceway w/three-way reducer connector: 310 μohms.
- Secure Mini Dukt™ Raceway w/interface sleeve: <100 μohms.
- Raceway systems to lockbox: 250 μohms.

Bonding Resistance Test Results Without Internal Powder-Coating

Bonding resistance testing took place where the PDS had portions of the system removed of interior/exterior paint and powder-coating. In addition, connector plates and star washers were also used to see if the bonding resistance was improved. The results are as follows:

- Raceway Steel sections (top cap): <100 µohms.
- Raceway Steel sections (interlock): <100 µohms.
- Raceway Steel sections (90° connectors): <100 µohms.
- Steel sections with Run End connectors: 150 µohms.
- Steel Raceway sections with 45°: <100 µohms.
- Secure Large Carrier™ Raceway w/end caps: <100 µohms.
- Secure Large Carrier™ Raceway w/Lock Kits: <100 µohms.
- Secure Large Carrier™ Raceway w/end-to-end connectors: 120 µohms.
- Secure Large Carrier™ Raceway w/pull box: <100 µohms.
- Secure Large Carrier™ Raceway w/90° internal connectors: <100 µohms.
- Secure Large Carrier™ Raceway w/90° external connectors: <100 µohms.
- Secure Mini Dukt™ Raceway w/mounting brackets: <100 µohms.
- Secure Mini Dukt™ Raceway w/three-way connector: 150 µohms.
- Secure Mini Dukt™ Raceway w/three-way reducer connector: <100 µohms.
- Secure Mini Dukt™ Raceway w/interface sleeve: <100 µohms.
- Raceway systems to lockbox: <100 µohms.

The comparison between the two data sets can be seen in the graph on the following page.

Bonding Resistance (ohms) Testing Results of Holocom PDS Raceways		
Adjoining Metallic Items	**With Paint/ Powder-Coat**	**W/Out Paint/ Powder-coat**
Between Raceway Sections - Steel	350µΩ	<100µΩ
Between Raceway Sections - Steel Using Interlock	250µΩ	<100µΩ
Between Raceway Sections - Steel Using 90° connectors	250µΩ	<100µΩ
Steel Sections w/Run-End Connectors	750µΩ	150µΩ
Steel Sections Using 45° Connectors	350µΩ	<100µΩ
Secure Large Carrier™ Raceway w/end caps	200µΩ	<100µΩ
Secure Large Carrier™ Raceway w/Lock Kits	200µΩ	<100µΩ
Secure Large Carrier™ Raceway w/end-to-end connectors	220µΩ	120µΩ
Secure Large Carrier™ Raceway w/Pull Box	215µΩ	<100µΩ
Secure Large Carrier™ Raceway w/90° internal connectors	173µΩ	<100µΩ
Secure Large Carrier™ Raceway w/90° external connectors	175µΩ	<100µΩ
Secure Mini Dukt™ Raceway w/mounting brackets	285µΩ	<100µΩ
Secure Mini Dukt™ Raceway w/three-way connector	300µΩ	150µΩ
Secure Mini Dukt™ Raceway w/three-way reducer connector	310µΩ	<100µΩ
Secure Mini Dukt™ Raceway w/interface sleeve	<100µΩ	<100µΩ
All Raceway Systems To Lockbox	250µΩ	<100µΩ

Conclusions of Testing With Painted Surfaces

The testing verifies that the metal-to-metal contact of a properly installed Holocom PDS raceway provides sufficient bonding along its length. The recorded readings were well below the recommended maximum value of 100 milliohms set forth by telecommunications industry standards. These systems provide an adequate equipotential bonding plane that should be utilized for telecommunications spaces where additional bonding is desired. The highest reading recorded above was the instance where Run-End connectors abutted to the raceway ends. It is not believed that this higher resistance will impact the performance of the other sections of properly installed raceway. However, the reading of 750 µohms was still far below the recommended maximum value of 100 milliohms, and one has to consider the use of Run-Ends to be an exceptional, though incidental, bonding connection.

Conclusions of Testing Without Painted Surfaces

The testing of the unpainted and improved surfaces further enhances the conductivity between metallic sections of the PDS raceways. Where the painted surfaces exhibited very low resistances due to the properties of their metal-to-metal contact, the removal of any paint solely within the raceways themselves provides a bonding mechanism far below the resolution of the meters used in this phase of testing. Even though the Run-End connector exhibited a resistance of 750 µohms with a painted surface, the removal of paint or powder-coating had a beneficial effect by reducing the resistance to 150 µohms.

Again, the recorded readings were well below the recommended maximum value of 100 milliohms set forth by telecommunications industry standards.

Summary – Based on the acquired data during rigid testing of the Protective Distribution System (PDS) raceways, it is the conclusion of this report that the bonding resistance between all metallic components is far below the recommended maximum value of one hundred (100) milliohms set forth by telecommunications industry standards. The mechanical integrity of the PDS raceways, like those produced by Holocom, Inc., has demonstrated to be an effective equipotential bonding mechanism along its entire length. Furthermore, the measure resistances are low enough to convince the testing team that the PDS raceway can act as an equipotential plane in any room where an effective bonding infrastructure does not exist. Additional testing with retrofit hardware (bonding plates) or supplementary devices (star washers) resulted in further lowering the resistance values to values far below one hundred (100) microohms.

Other Considerations

Despite adequate bonding of the PDS raceway, there are influential factors that could put the integrity of intended signals on cabling contained within the raceway at risk. These factors could be intentional or accidental and include:

- **The lack of cable shield bonding at one or both ends of a cabling installation within the PDS raceway.** Shielded cable is intended to be bonded to a qualified reference at both ends of its path via approved hardware. In some instances, however, there may a purposeful exclusion (or removal) of the bonding mechanism due to installation personnel's misguided attempt to (a) prevent possible communication issues or (b) fix a perceived problem.

  Theoretically, removal of any shield bonds will remove the possibility of electron flow along the cable's length, thus preventing the resultant magnetic field from affecting the strength or bit structure of the signal. In reality, the removal of any bonding of a cable shield simply masks the problem. If the cable bond is removed at one end, the cable shield can act as an 'antenna', which will afford unwanted frequencies the opportunity to couple on the shield or internal cables via capacitive coupling, regardless of extraneous bonding efforts of the raceway to prevent this from occurring.

  In the case where the cables are not bonded at either end, the signal cable's metallic shielding could act as an inadvertent high inductance (often known as a 'choke') along the entire signal path. This can affect transmission of HF signals, even if they are the intended signal along that path.

  If multiple cables occupy the same raceway and some are not effectively bonded at their terminating ends, the electromagnetic compatibility (EMC) between the raceway's internal cables is impacted thus putting all cable paths at risk for signal integrity. This is primarily due the stray capacitance and unwanted inductances along their lengths.

  The above test results, however, indicate that a properly installed PDS system, could reduce, or eliminate, the effects between different cables where EMI is a concern.

- **Lack of effectively installed telecommunications bonding infrastructure.** In light of the fact that the telecommunications bonding infrastructure is never formally inspected by the Authority Having Jurisdiction (AHJ, commonly called an 'electrical inspector'), the telecommunications bonding infrastructure for some telecommunications sites may not be adequately designed, implemented, or maintained, if one is installed at all. Further complicating this is the lack of testing performed by installation personnel before sign-off or hand-off to the end-use personnel, in light of the fact that the standards specifically use testing as a verification method. Most often, there are no formal procedures in individual project plans to accomplish this. Thus, the beneficial efforts to properly install the PDS raceway can be offset if there are deficiencies in other areas of the building in the bonding infrastructure.

The measured values exhibited during the testing of the PDS raceways indicates that the raceways are a sound, logical method or method of providing a robust equipotential plane throughout the telecommunications distribution to offset existing deficiencies in a building or structure.

- **Testing of the AC Equipment Grounding System** – The ac equipment grounding systems is a part of the electrical system that provides three benefits:
    1. Maintain zero-volts on all non-current carrying metallic frames of electrical equipment, including end-use equipment.
    2. Provide an intentional path for fault current under ground fault conditions.
    3. Provide a zero-volt reference for electronic power supplies.

  The first two purposes are important to prevent electrical shock to personnel and reduce the risk of electrical fire. The provisions to meet these two requirements are contained in the governing electrical code for any jurisdiction (e.g., National Electrical Code). The third purpose is related to the steady-state performance of electronic equipment and, since it is not related to safety, it is not a concern to those who author the National Electrical Code.

  However, financial and operational investment for all end-users is impacted if deficiencies exist in its own wiring. Cord and plug-connected equipment uses the equipment ground as a reference for logic power supplies and, ultimately, the bit structure for electronic signals sent from one device to another. Compromising or failing to maintain this system can have lasting impacts that may appear to be caused by other extraneous influences.

  A concern here is that few personnel will adequately test the integrity of the equipment grounding system and the associated wiring. Conversely, too much emphasis may be placed on the integrity of the PDS raceway or other bonding infrastructures without testing the quality of the AC wiring and equipment grounding system.

Therefore, one important result of the above raceway testing reveals that the raceway system will not compensate for any improperly wired or maintained electrical system that feeds the equipment, despite its importance and relevance to the overall bonding of the cabling infrastructure.

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