

Grounding, Bonding, and Shielding

OR

**What is the Fastest Way to Start
an Argument With Engineers?**

J.R. McGee
Founder and CEO
The X-Stream Leadership Group

Major Points of References

- **NFPA / NEC (Article 100 and Article 250)**
- <https://www.arrl.org/files/file/RFI/Thompson%20Noise.pdf>
- <https://www.iqsdirectory.com/articles/emi-shielding/rf-shielding.html>
- www.HamRadio.me

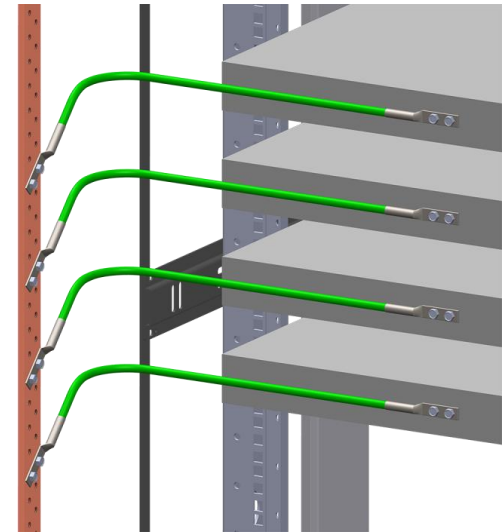
Definitions

- **Grounding:**
 - **Grounding is the electrical system's connection to the ground itself. Article 100 of the NEC defines ground as “the earth.”**
 - **Section 250.4(A)(1) states that grounded electrical systems “shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.”**



Bonding

- **Article 100 of the NEC defines bonded (bonding) as “connected to establish electrical continuity and conductivity”**
- **Bonding metal parts, such as enclosures and raceways, ensure that they are all continuous on an **E**ffective **G**round-**F**ault **C**urrent **P**ath (EGFCP) that references back to ground (earth)**
- **The EGFCP helps operate devices such as circuit breakers and fuses or ground-fault detectors in ungrounded systems.**



Reason For Bonding

- In grounded systems, it is important to bond the equipment grounding conductors to the system grounded conductor to complete the EGFCP back to the source of electricity
- The conductivity of the EGFCP is critical for protective devices to work properly
 - This speaks to why we scrape the paint from contact surfaces of metallic enclosures to make our electrical system bonding connections
 - Removing the paint, as required in Section 250.12, provides for a better connection and conductivity path.



Is There a DIFFERENCE?

- **In the 2020 edition of the NEC, the language “or bonded” was added to Section 250.12, which now reads “Nonconductive coatings ... on equipment to be grounded or bonded shall be removed ...”**
- **This further emphasizes that grounding and bonding are not the same but work together to ensure the safety of the electrical system.**

Purpose of All This...

- First and foremost is the safety of personnel within a building
- Ensuring the proper grounding and bonding of the electrical system could very well be the reason an employee within the building avoids an unintended shock and can go home that night. It is that important
- Other items that could be negatively affected by improper grounding and bonding are sensitive equipment and low-voltage signals
- RFI is PARTICULARLY affected by Grounding, Bonding, and Shielding

Burnie & Les



"Hold on Burnie, don't try that yet. I think I figured it out."

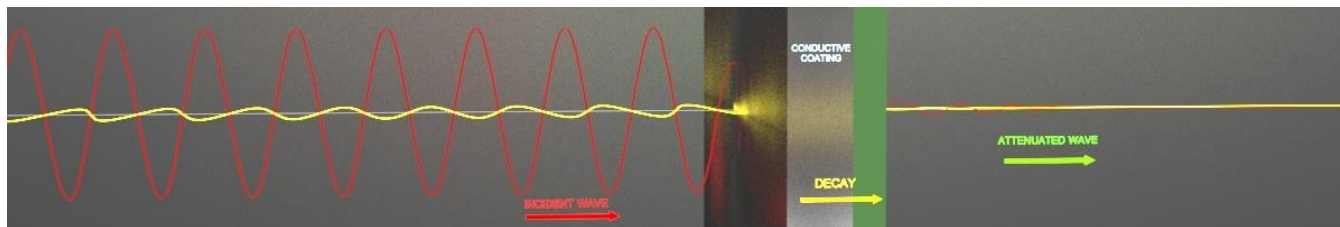
Examples



Grounding / Reference



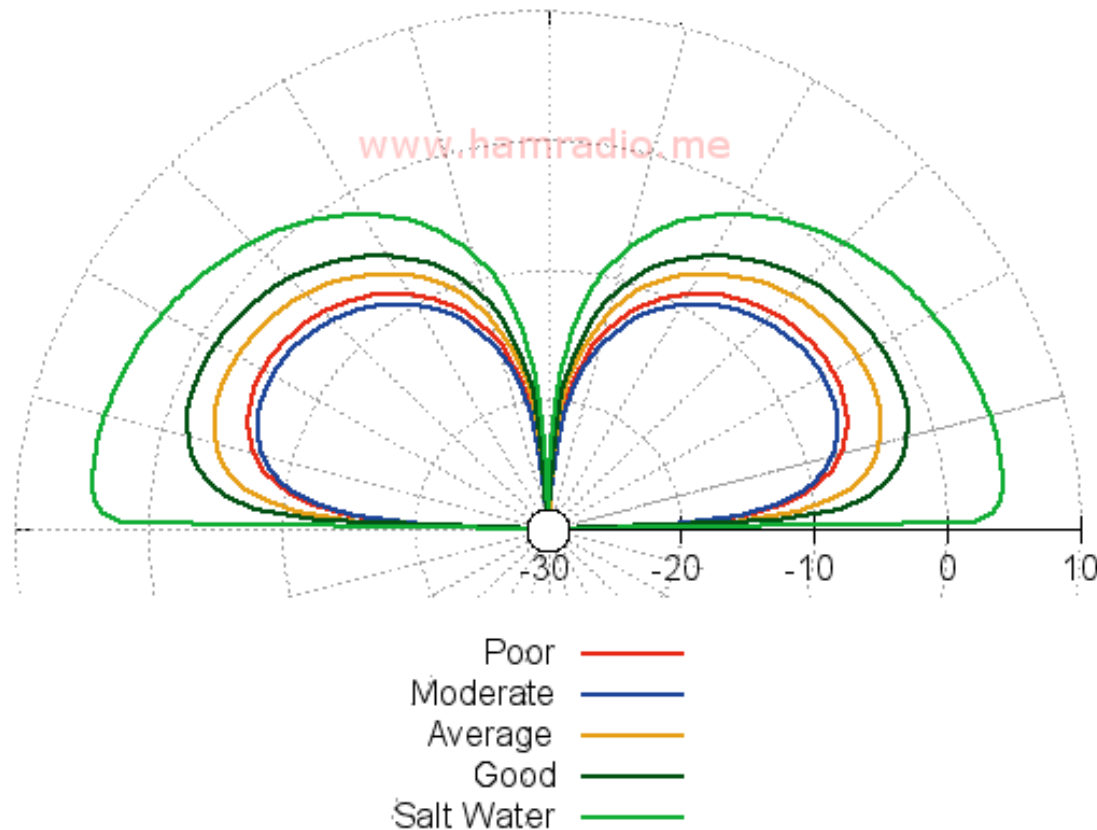
Bonding / Uniformity



Shielding / Isolation

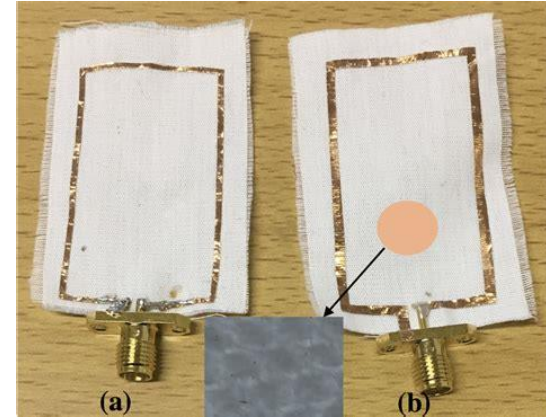
Effect of Grounding on Propagation

Antenna Pattern of 40m Monopole over various ground conditions

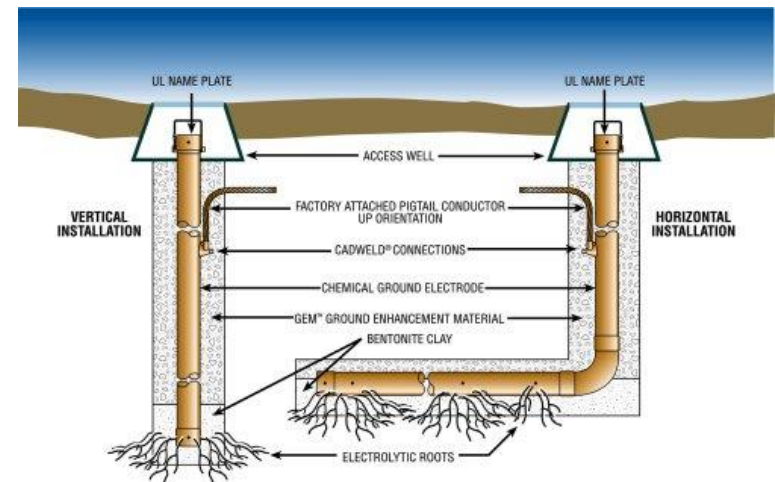
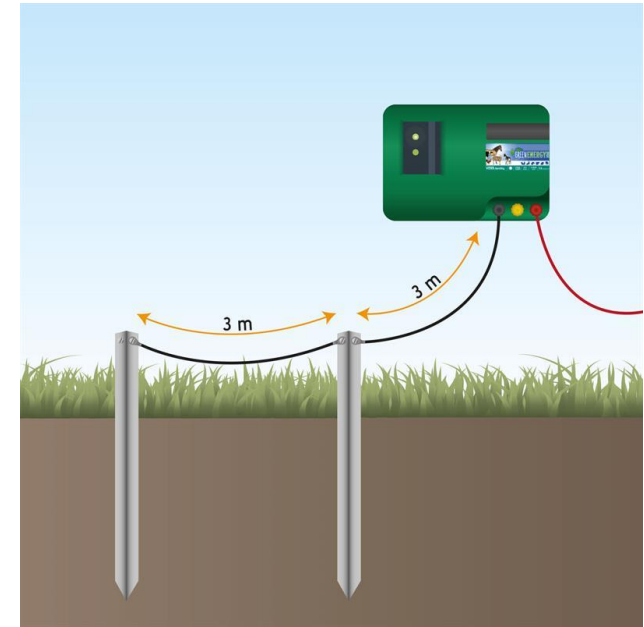
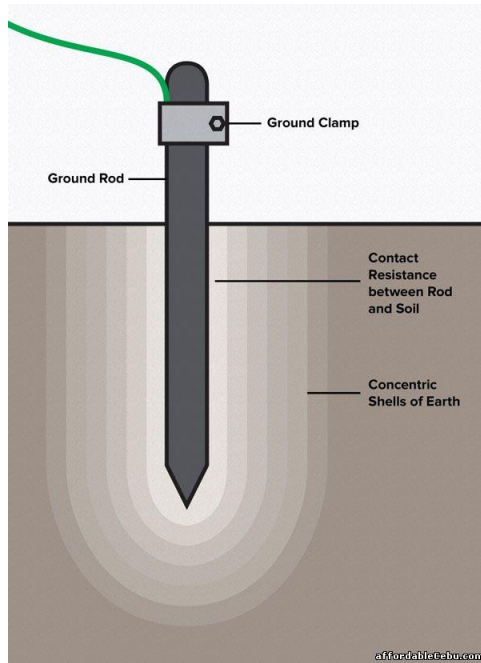


RFI

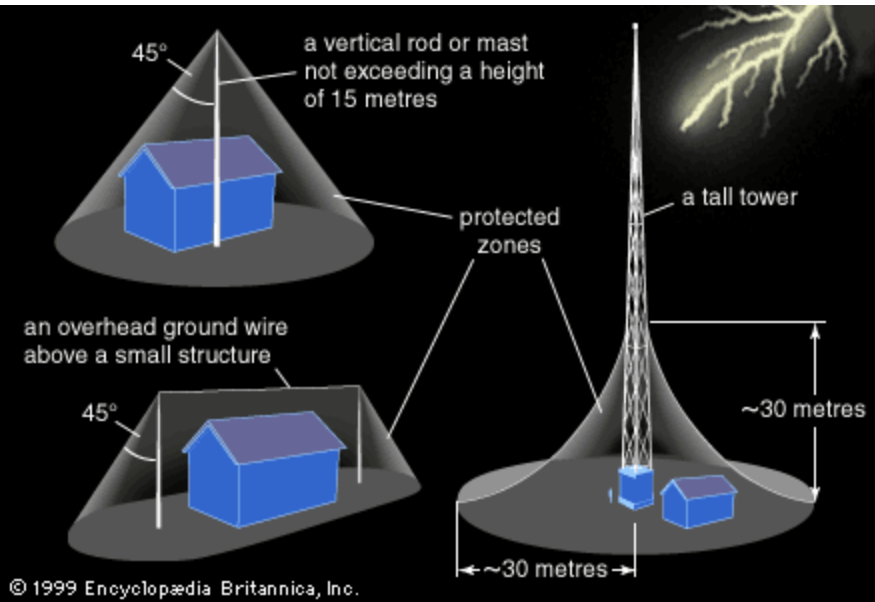
- **How Do I Know I Have a Problem?**
- **Typical Offenders**
 - Power Company
 - FCC Part 15 and Part 18 Equipment
 - USB Chargers
 - Light Bulbs and Fluorescents
 - MANY Others!
- **Your Own Personal FoxHunt**



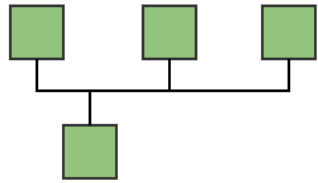
Grounding From Mild...



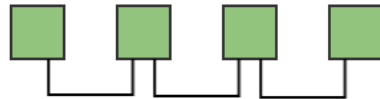
To Wild...



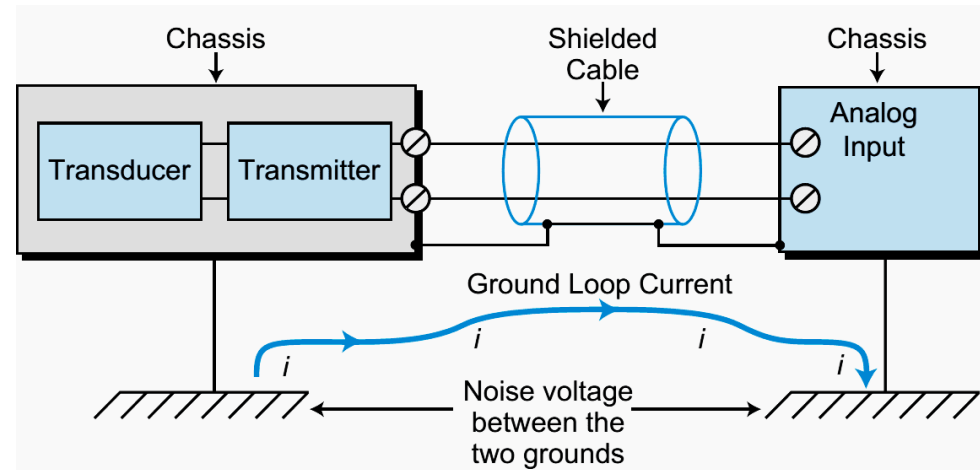
Avoiding the Dreaded Ground Loop



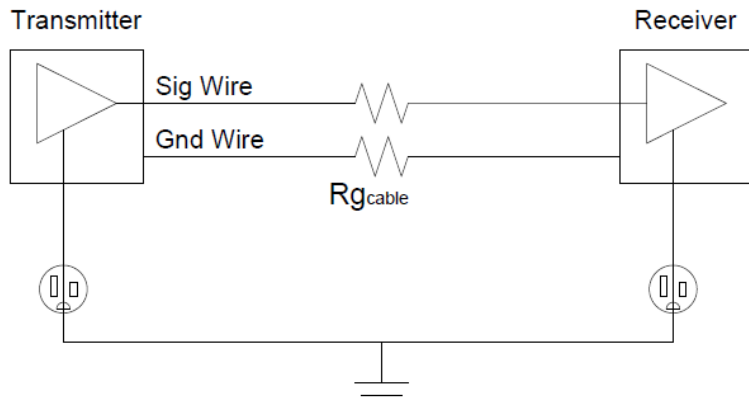
Bus topology



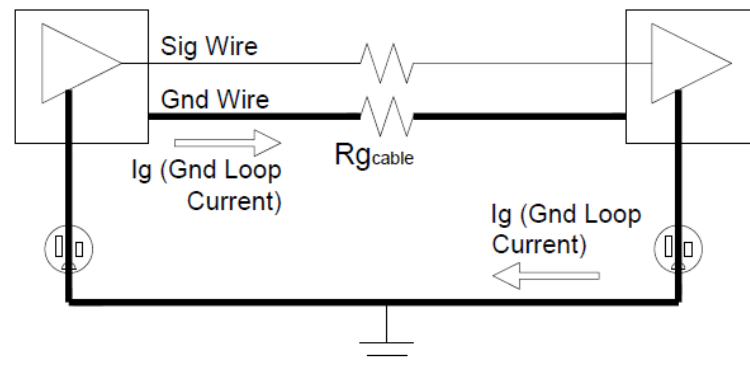
Daisy chain topology



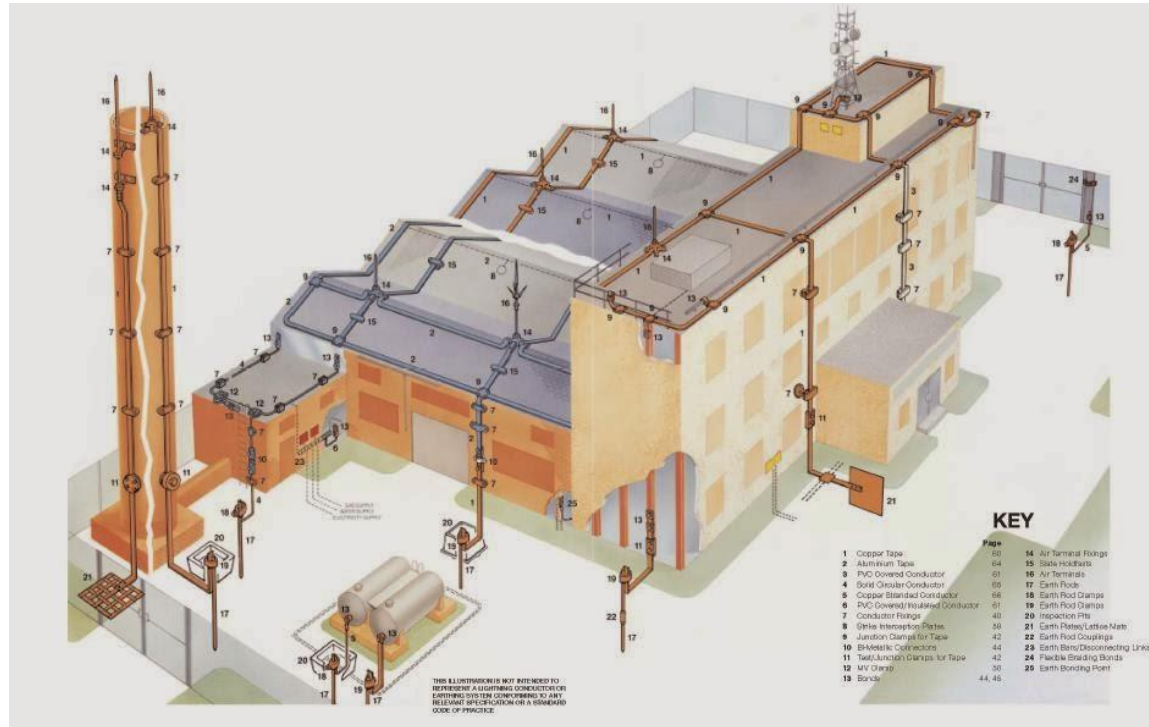
Communication Circuit



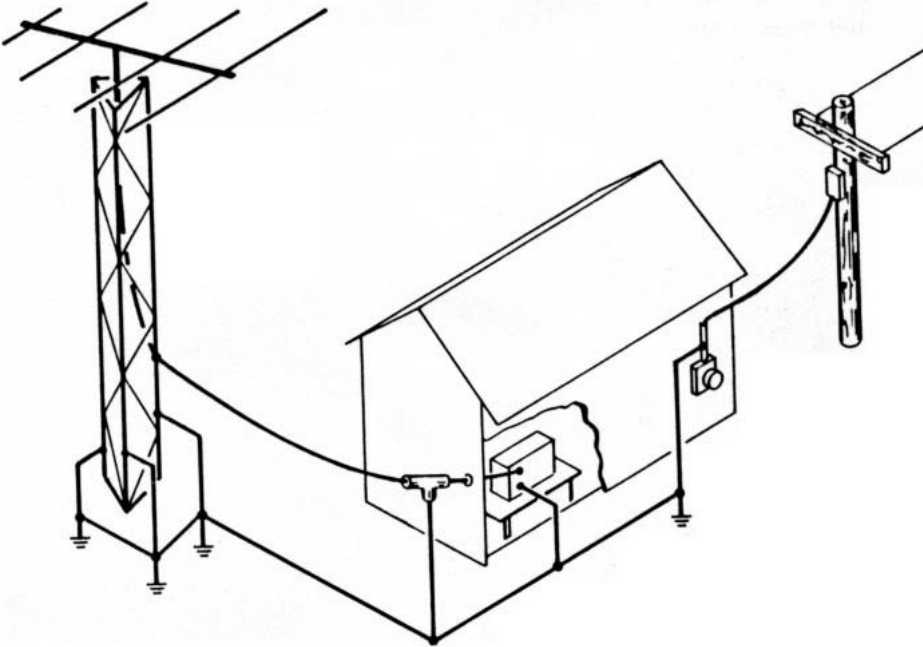
Communication Circuit with Ground Loop Highlighted



Second Story / Remote Grounding

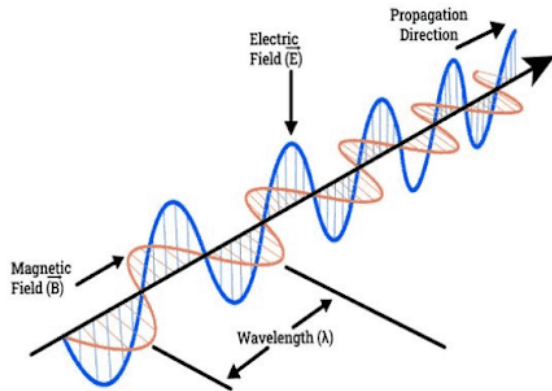


Buss Bars



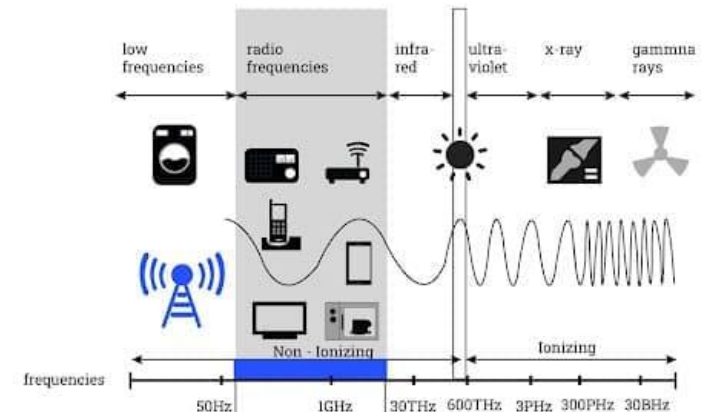
Shielding

Electromagnetic Wave



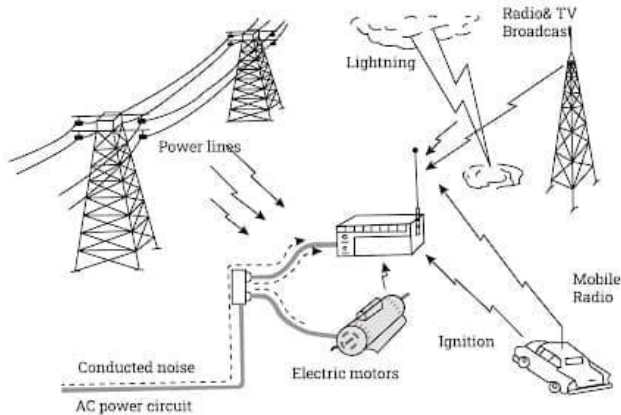
IQSdirectory.com

Radio Frequency in the Electromagnetic Spectrum



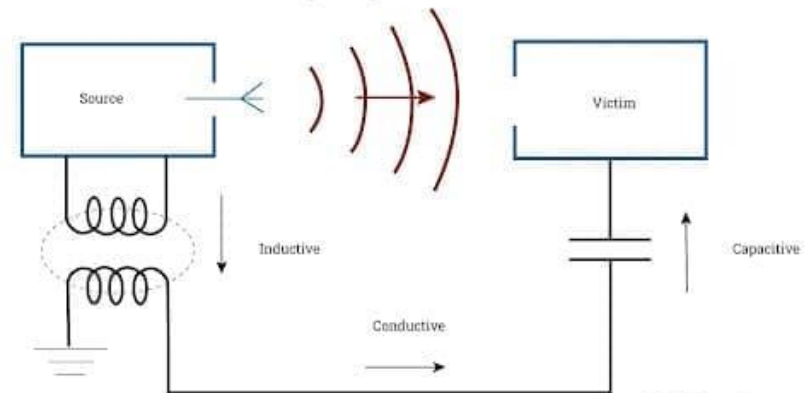
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Sources of Radio Frequency Interference



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Coupling Mechanisms



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Mobile Bonding

- **Bonding Minimizes The Leakage Of RFI Into And Out Of The Various Bolted On Parts Of The Vehicle.**
 - **It Is Not Uncommon To See A 20 To 30 Db Drop In Noise Levels Once They're Properly Bonded**
 - **Bonding Engines, Hoods, And In Some Cases Radiators, Is Important For The Same Reason**
- **On The HF Bands, Our Vehicles Act More Like A Capacitance To Ground, Rather Than A Ground Plane.**



Ground Straps

- **Fantastic DC Path To Ground...**
 - **But...**
 - **When Inductive Reactance And Capacitive Reactance In Any Given Piece Of Wire Are Equal...**
 - **At The Resonate Frequency It Becomes A Perfect Antenna Of Its Own!**



Things To Check

- **Caution Is Also Needed When Bonding The Doors, Hood And Trunk**
- **You Don't Want To End Up Drilling Through The Lid, Or Into A Wiring Harness Underneath!**
- **Keep Straps Away From Hinges, Doorstops, And Weather Seals**
- **Hoods And Trunks Should Be Strapped Across Both Hinges.**



Just When You Think You're Finished...

- **Almost Without Exception, Exhaust Systems Are Made Of A Good Grade Of Stainless Steel**
 - **Wire Brushing A Small Area For The Lug To Bite Into And Using Stainless Steel Hose Clamps To Secure The Lug Works**
 - **The Opposite End Should Be Attached To The Underframe Or Unibody Strut Work**
 - **If The Car Is Undercoated You May Have To Clean A Small Area.**



Good Enough...Ain't!

- **If Your Vehicle Is A Body On The Frame You'll Need A Bunch Of Straps To Go Between The Body And Frame**
- **As An Example, Four Separate Straps (One On Each Corner) Work Well For A Pickup Bed.**
- **Do NOT Rely On Any Factory Strap To Provide A Good Rf Ground**
 - **They're Meant Solely For DC Grounding Taillights Etc. And Are Inadequate For RF Grounding Needs**
 - **The Same Can Be Said For Factory Engine Strapping.**

Last...But Not Least...

- **Depending On The Vehicle, There Can Be Several Dozen Other Places Where Bonding Straps Will Provide A Benefit**
 - **These Include, But Are Not Limited To, Bumpers, Bumper Backing Plates, Suspension Parts, Rear Axles, Tailgates, Or Virtually Any Bolted-on Piece Of Hardware**
 - **Engines Are Also Overlooked Because Most Of Them Have Visible Ground Straps**
 - **They're For DC, So Adding Wider Ground Straps Can Help Curb Ignition Noise**

Questions?

