Ground Is A Myth!

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What Is A Ground?

* Haven't you wondered?
* Have you just accepted it?
* Does it have meaning at all?
* Seen on schematics
  * but what does that mean?
It's about a reference point

- Ground is an arbitrary zero reference (circuit)
- Might be an energy state
- Might be a common connection
- Implies stability
- Or, perhaps …
It's about the earth

- Physical objects in contact with earth
- Earth's charge state
- Distance from the center of mass
- Gravitational potential energy
Ground and Gravity

- Gravitational potential energy
- $mgh$, but what is $h$?
- Referenced to what?
- Center of mass
- Earth's surface
What if there’s no earth?

• Then there’s no reference
• Newton’s law of gravitation still applies
  • distance and masses
• Just like voltage / E-field

\[ F_1 = F_2 = G \frac{m_1 \times m_2}{r^2} \]
Let’s go back to Voltage

- Electric Potential
- Mark your relative position in an E-field
- Says something about Work and PE
- conservative field
- path independent
Is there a ground for Voltage?

- Just the difference in position in an E-field
- Where is zero?
- Shift in focus
- Maybe at the edge of the universe
What about Current?

* Is there such a thing as ground for current?

* Time rate of change of charge

* Featured in Maxwell

* Since it’s a derivative, there is no reference point

Current = time rate of change of charge \( \frac{dQ}{dt} \)

\[ \oint \vec{H} \cdot d\vec{L} = I + \oint \frac{\partial \vec{D}}{\partial t} \cdot d\vec{A} \]

\[ \nabla \cdot \vec{J} = \frac{\partial \rho}{\partial t} \]
Circuits and Ground

* Common reference
* Chassis connection
* Shielding
* Current return path
Digital & Analog Ground

* Split system into two
  * one noisy, high current
  * one quiet, low current

* How do we re-join these?

* What if there's a voltage differential?

* “ground loop”
Ground Currents

- Current return path
- Most common use
- If the ground has finite resistance
- Delta V along path
- It’s no longer a reference

What’s this voltage?

What’s this voltage?
Ground and AC

- Very tricky!
- Must be the zero reference for all time
- Signals changing with time: \( V(t), I(t) \)
- Consider with three (or more) phases
Diversion: Phasor Notation

- Vectors used to represent:
  - Voltage, Current, Impedance
  - magnitude
  - phase
- Vectors can rotate with time
  - angular velocity, rad/sec $\rightarrow \omega$
  - Complex plane, $e^{-j\omega t}$
- Only for monochromatic signals
- Vector sums simplify calculations
Phasors and Impedance

- You might recognize this from ham exams
- Differential equations become algebra, geometry
- See VIRLCW talk
- Again, only one frequency
- Do not over-apply
Adding Phasors

- Decompose into their X and Y components
- Real and Imaginary
- Add these separately
- Resultant components are the new vector
- Tip+Tail, Parallelogram, Tail-Tail
Delta and Wye (Y)

* Delta is un-referenced
* Wye has a reference, or neutral signal
  * no current if phases balanced
  * is this ground?
* Transformable
* How to “ground” a Delta?
Split Phase and Neutral

* What is the neutral?
  * center tap
  * is this ground?
  * Driven by one phase, isolated - no "ground"

Earth ground?

Magnetic isolation

Gnd?

EXAMPLE USA
V1, V2 = 120 Volts
V1 + V2 = 240 Volts

EXAMPLE EUROPE
V1, V2 = 230 Volts
V1 + V2 = 460 Volts
Neutral and Grounding Conventions

- Connected to earth in some way?
- What is the resistance?
  - generally a poor conductor
  - variable: salt, water
- Can we still be hurt?
  - sure
Ground Fault Interruptor

- A workaround
- Looks at current balance
- Doesn’t really reference “ground”
- Infers flow to ground, but could be anywhere
- What is ground?
Ground Conductivity

* Even in the best conditions: 100s of Ohms

* Worst conditions: 100,000s Ohms

* Is this useful or meaningful?

* Is this safe?

Understanding Ground Resistance Testing - AEMC Instruments
Let's Increase the Frequency

- What is different at HF?
- More coupling, but to what?
- Does this do anything for performance?
- Does this do anything for safety?
Let's Increase the Frequency

- What is different at VHF?
- Even more coupling, but to what?
- Does this do anything for performance?
- Does this do anything for safety?
But don’t Antennas Need a Ground?

* Balanced antenna needs nothing
* Symmetrical structure favors nothing
* Match doesn’t indicate “ground”, though it appears assymetric
* pattern shift
What about Ground Planes?

* Creates a mirror for the single radiating element
* More compact
* Easy to use vertically polarized
* Radials might be on the earth
* Is that really a ground?
* Do you need them to be there?
  * no
Baluns connect to Ground, right?

- Autotransformer
- Classical transformer
- Both don’t care what the unbalanced side is connected to
  - typically a chassis shield
  - not earth ground
  - more about isolation than anything
Don't use the Neutral or Safety as the "Ground" !?!

* Amateur Radio Handbook says put in a ground rod
* So, we couple to the earth with a ground rod
* Big undertaking
* But why?
What about the Power Supply and Ground?

- Now what do we do?
- N grounds?
- Safety ground
- Ground rod
- RF ground
- I'm very confused!
Is your head spinning yet?

* Where is ground?
* What is zero volts?
* Ask again in an RF field
  * spatially dependent
  * temporally dependent
* induction
This is an impossible thing

- There is no ground!
- Everything is relative
- Everything is in motion
- The best we can do is differentially stabilize at certain points
So, now what?

- Shield
- Isolate
- Stabilize
Shield - Faraday

- Enclose in conductor
- Keeps fields from inducing V or I in bad places
- Changes "ground"
- Avoid leakage fields in or out
- Avoid currents in other "grounds"
- Safety, neutral

\[ \oint \vec{E} \cdot d\vec{L} = -\oint \frac{\partial \vec{B}}{\partial t} \cdot d\vec{A} \]

\[ \text{EMF} = -d\Phi_m/dt \]

\[ \oint \vec{H} \cdot d\vec{L} = I + \oint \varepsilon \frac{\partial \vec{D}}{\partial t} \cdot d\vec{A} \]
Shield: Example

- Faraday shielding between systems and subsystems
- Tight connections
- High conductivity
- Drive the E-Field to zero
Isolate

- Differential signal paths, avoid common mode
- Reduce leakage fields
- Restrict components to their primary function
- Create high impedances where current shouldn't flow
- Avoid currents in bad places

Fig 3: This is the same configuration as above with ferrite chokes added to block the alternative ground paths. Differential signal currents in the coax are not affected by the ferrite, but common-mode ground currents are blocked.
Isolation: Example

- Ferrites everywhere
- Wrap as many times as you can
- Pay attention to the ferrite mix
Stabilize

* Use low impedances
* Reduce voltage differentials
* Reduce E-field gradients / differentials
* Can be antenna enhancements
Stabilization: Example

- One wire per band
- Bundle them together
- High voltage at wire ends
- Fold over and tape
Wither Ground Rods

- Outside of lightening, you're wasting your time
- Can make things worse!
- Noise
- RF losses
- On a portable antenna: disconnect it
My 2nd Floor Station: 800 Watts

- Helically wound vertical dipole
- Tuner (manual or auto)
- AL-811H Amplifier
- IC-7600
- No ground!
But how, you ask?

- **Shielding**: all components are individually shielded
- **Isolation**: ferrites form inductive isolators keeping common mode currents from flowing
- **Stabilization**: counterpoises on all bands
What is a Counterpoise?

- A 1/4 wave monopole
- The low impedance point of an open antenna or transmission line
- Must match operating frequency
- Can be bundled
- Watch for high voltage!
Radials on the Ground

- Like a counterpoise
- Detuned by the earth
- Provide the mirror
- Should be as complete as possible: 16 to 64
- Lower loss resistance
- Remember - earth is lossy
What about the “ground” lugs?

- Connect them together
- Flat braid (low inductance)
- Connect that to the counterpoise bundle
- Stabilizes the equipment chassis within the RF fields (E-field)
- Avoid RF burn
- Connect to ground rod?
  - probably a bad idea
What Applies To Your HT?

* No apparent ground
* Where’s the other half of the antenna?
* Let’s add one
  * counterpoise
  * not a “ground”
  * several dB improvement
Lightning: A Case for Ground (sort of)

* Back to DC
* Large charge differential builds
* Covers earth's surface
* relatively wide area
* Want safe discharge
Lightning Strike

* Plasma forms from intense E-field
* Ions are conductor for charge carriers
* Charge equalizes
* Hopefully doesn’t equalize through your shack
Lightning Rod

* Sharp tip has many charge carries
* Mutual repulsion minimized
* Conducts to earth's surface efficiently
* Charge equalization
Antennas Are Like Lightning Rods

- Altitude and connection to earth's surface makes E-field intense
- Many sharp edges
- Efficient conductors
- Ought to be grounded for lightning, not RF
Should Antenna coax go to station “ground”?  

- Bad idea for lightning  
- bring that current flow inside your house?  
- likely to kill your transceiver  
- damage other gear  
- Ground the coax first through protection device  
- Do this outside or near the outside
So, what happened to Ground?

* It evaporated!
  * except for lightning
* It’s all relative
  * there is no reference
* The earth is not reliable
  * dirt is a crummy conductor
  * it’s a crummy dielectric too
What can we hams do?

* Shield our equipment from RF fields
* Isolate the various components from each other: balanced currents
* Stabilize everything within the RF field
* Ditch those ground rods (except for lightning)
* Have fun on the radio
Questions?
Thank You