HF OPERATORS

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WHY YOU NEED A CURRENT BALUN

by

John White
VA7JW

14 Oct 2015 rev 1

What is a Balun ?

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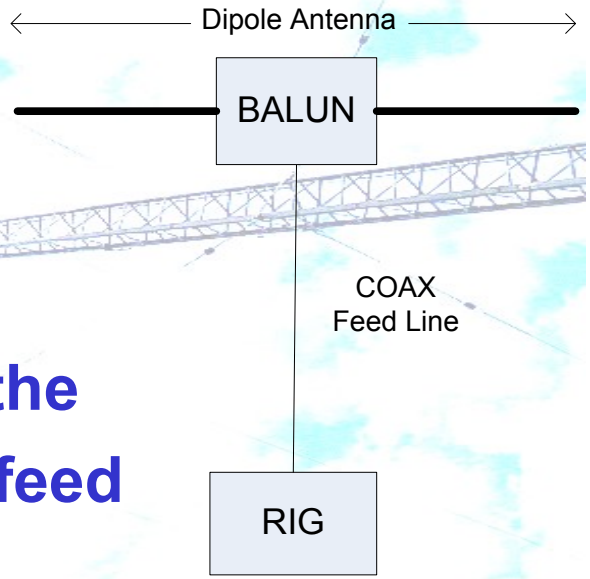
- A BALUN is a device typically inserted at the feed point of a dipole-like antenna
  - wire dipoles,
  - Yagi's, quads, loops etc.
- Not used for Vertical antennas
- Provides an interface between the coax feed line and the antenna feed point



What Does It Look Like

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- Typically a cylindrical tube or a rectangular box
- Has supporting eye bolts
- Antenna connection terminals
- PL-259 Coax cable connector
- Easy to use

Supporting Eye-Bolt

Eye-Bolts for Antenna wire connection

Coax Connector for PL-259

Two Types of Balun

- . . - . - - . - - . . . . - . . . . - . - - . . . - . . . . - .

- Two types of Baluns, Electrically different
- Look identical outwardly
- The Current Balun – is the topic of discussion
- The Voltage Balun – is NOT USEFUL for resolving the problems presented here
- <u>Ensure the balun label states it is a current balun</u>. If a balun is to remedy issues discussed herein, it must be a Current balun

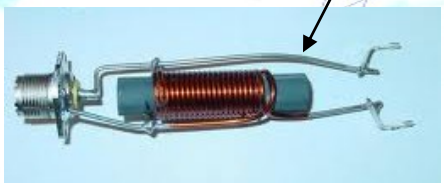
What's Inside the Balun

- - - • - • - - • - - - • • - • • • • - • • - - • • • • • - - • • • • • - -

- A transformer-like structure using a ferrite "core", or ferrite beads threaded on the coax
- Ferrite is a magnetic material designed for use at radio frequencies

Ferrite Beads

Windings on different styles of ferrite cores



Ferrites threaded on coax cable

What Does the Balun Do

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1. Matches a BALanced antenna to UNbalanced coax connection, hence the name BAL-UN
2. Provides impedance matching between coax characteristic Z and antenna feed point Z
3. Prevents RF currents from flowing on the coax which will radiate, or conduct RF into the shack
4. Reduces / eliminates RF-in-the-Shack problems

Balance to Unbalance

- • - • - - • - - • • • • • • - • - - • • • - • • • • • - •

- Coax cable is an Unbalanced cable system
  - the braid (a.k.a. shield) is connected to “ground” at rig
- Dipole antennas are balanced systems
  - the antenna has no reference to “ground”
  - the antenna & feed point terminals are “floating”
- Connecting unbalanced to balanced will cause the coax cable to radiate – very undesirable

- Visit W8JI for detailed explanation RE balanced and unbalanced circuits
  http://www.w8ji.com/common_mode_current.htm#Dipoles_and_Common_Mode

Impedance Matching

– • – •   – – • –   – • •   •   • • • –   •   – – • • •   – •   • • •   • – •

- Provides fixed impedance matching ratios
- 1:1 impedance ratio, 50Ω to 50Ω for resonant dipoles such as Vee’s, trap, multiband, Yagi’s ..
- 4:1 impedance ratio, 50Ω to 200Ω for other resonant antennas such as folded dipoles, off center fed dipoles, loops..
- Other less common ratios exist up to 12:1

Feed Line Radiation

– • – •   – – • –   – • •   •   • • • –   •   – – • • •   – •   • • •   • – •

- Feed lines are not intended to radiate RF
- Purpose of the coax is transport Tx and Rx signals between the Rig and Antenna. These signal currents are kept INSIDE by the coax (shield)
- If RF is flowing on the OUTSIDE of the coax braid, (for whatever reason) the feed line will radiate, systems may not work properly due to RF-in-the-Shack
- A Current Balun will, by its design, suppress RF currents flowing on (not within) the coaxial cable

What is RF-in-the-Shack

- - - • - • - - • - - - • • • - • - - • • • - - • • • • - -

- On transmit … typical symptoms
  - reports of distorted Tx audio?
  - does the PC do unexplained things?
  - do you get “tingles” when touching the equipment ?
  - worse yet – do you get electrical shocks?
  - do these things change when you alter station wiring or change bands?
  - did you “fix” it by adding or changing grounds or altering shack wiring?
- Then you likely have RF-in-the-shack. RF TX currents are being conducted via coax into the shack, invading wiring & affecting equip. performance

System Analysis

- • - • - - • - - •• • • • • - • - - • • • - • • • • • - •

- Need to understand how the station components interact with each other with respect to the RF environment

A. Differential and Common Mode Currents defined

B. Coax cable – a shielded feed line or a “wire”

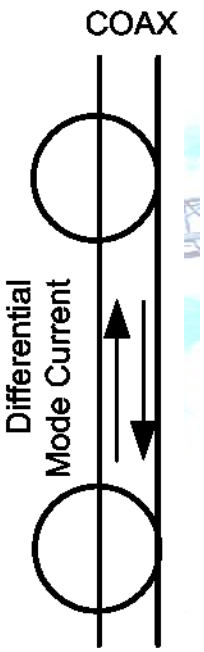
C. Grounds – what are they, actually?

D. Antennas – the instigator …

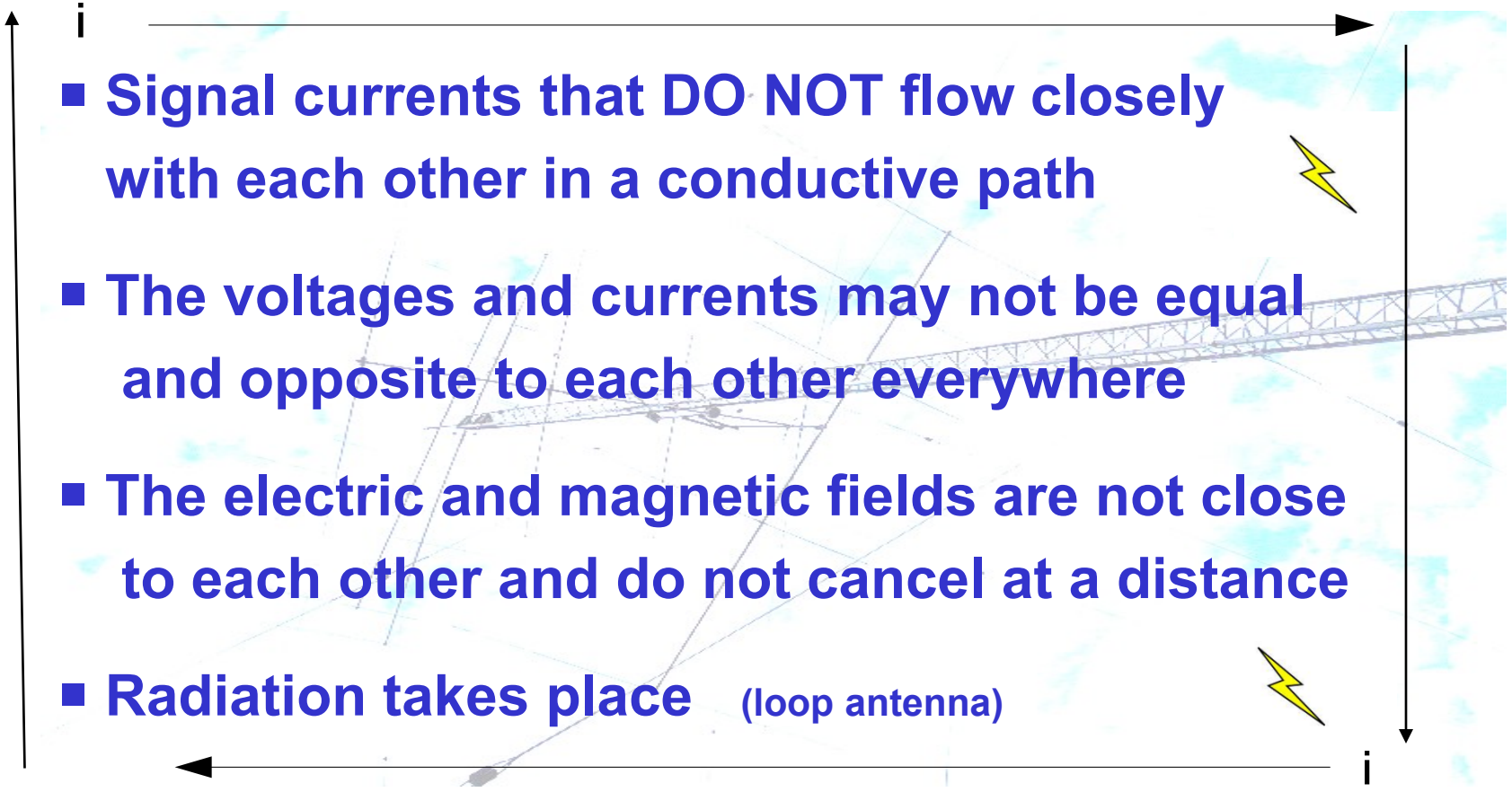
Differential Mode Current

- - - • - • - - • - - - • • - • • • • - • - - • • • - • • • • • - •

- These are signal currents that flow in two wires closely spaced with each other
- The voltages and currents are in the coax are EQUAL and OPPOSITE to each other everywhere along the circuit
- The electric and magnetic fields are very close together, are opposite to each and cancel at a distance
- No net radiation takes place at a distance



Common Mode Currents

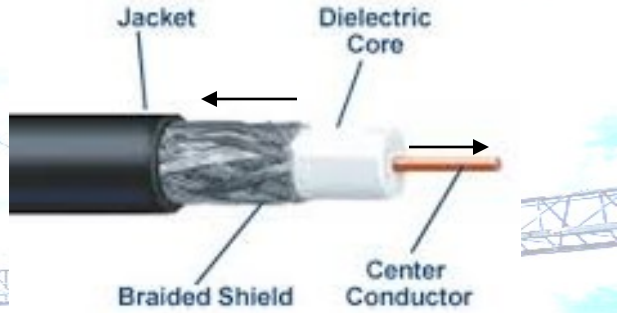


- Signal currents that DO NOT flow closely with each other in a conductive path
- The voltages and currents may not be equal and opposite to each other everywhere
- The electric and magnetic fields are not close to each other and do not cancel at a distance
- Radiation takes place (loop antenna)

Coaxial Cable

- - - • - • - - • - - - • • - • • • • - • - - • • • - • • • • • - •

- Connects Rig to Balun to Antenna
- Center Conductor
  - carries TX signal “up”
  - carries Rx signal “down”
- Insulation layer dielectric)
- Outer braided conductor provides return path
- Center conductor and braid are close to each other
- Braid often referred to as the Shield



Signals in the Coax

- • - • - - • - - • • • • - • - - • • • - - • • • • • • • • - •

- The Tx / Rx RF signals flow INSIDE the coax just as one would expect water to flow completely inside a pipe (and stay that way – no leaks)
- These are Differential Currents and do not radiate
- Furthermore, the signal current on the braid can not flow out through the braid to escape and conduct on the outside surface of the braid and radiate, due to the Skin Effect

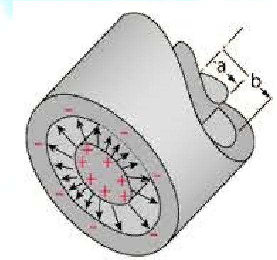
Containment of Signal

-•-• --•- -•• • •••- • --••• -• ••• •--•

- Signal currents set up electromagnetic fields, inside the coax, between the surface

  of the center conductor and the surface

  of the braid



- Due to <u>Skin Effect</u>, the signal currents are confined to the inside of the coax

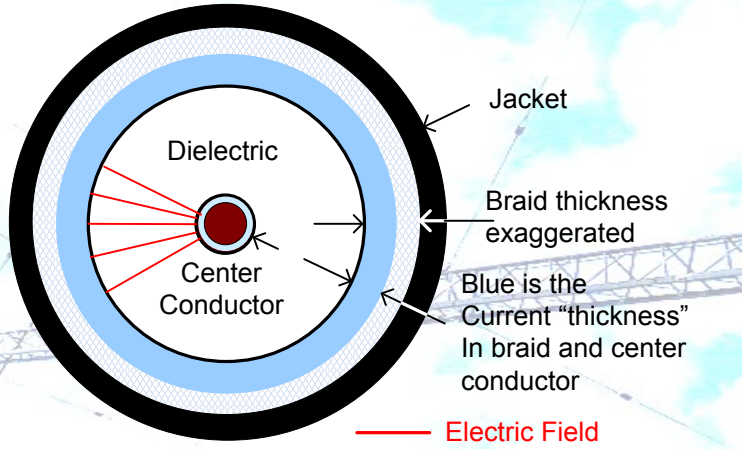
- RF current from outside sources will flow on the outside surface, of the braid, unable to penetrate

- Shielding ability works both inwards and outwards

What is Skin Effect ?

- - • - • - - • - - • • - • • • - • - - • • • - • • • • - -

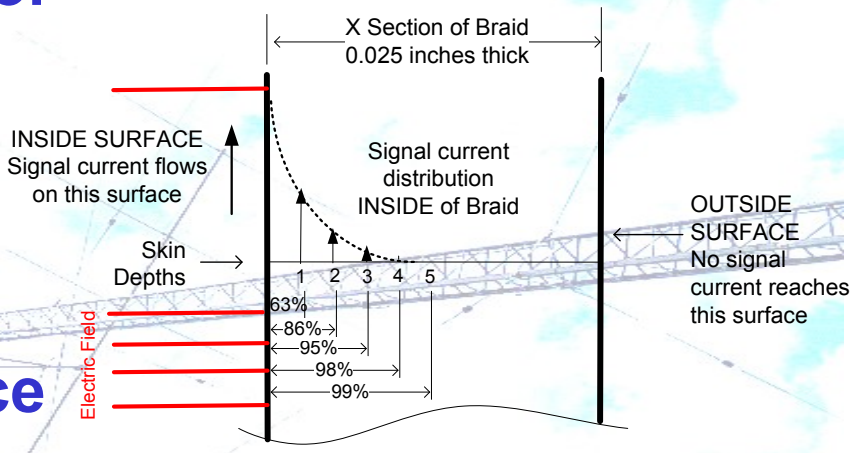
- DC currents flow evenly through the X Section of a conductor
- AC currents do NOT flow evenly through the X section of the conductors



- Most current flows close to the surface
- The higher the AC frequency, the more crowded the current flow becomes to the surface. Note that no current gets thru' to outside of the braid

Skin Depth

- AT RF, current flows extremely close to the surface of the conductor
- At 1.8 MHz, 99% of the current is contained within 0.01 inch of the braid surface



- At 30 MHz, depth is 0.0024 inch
- Signal inside the braid never reaches the outside of the braid as thickness of 0.025” > 2x skin depth

Why is this Important?

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- Skin depth makes coax “work” as a shielded cable
- Tx signals cannot escape and are delivered to the antenna
- Only Rx signals picked up by the antenna are delivered to the receiver. Undesired RF outside the coax cannot penetrate inwards
- However, RF currents do/can flow on OUTSIDE of the braid independently of the inner currents

Grounds - 2 types

- • - • - - • - - •• • • • • - • - - • • • - • • • • • - •

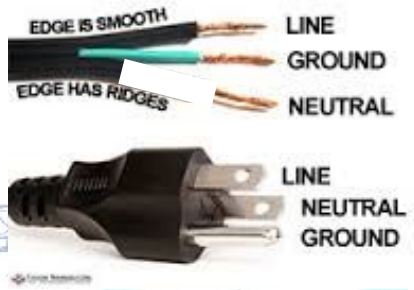
1. EARTH ground
   - consists of a metallic rod driven into the earth to protect operators from (deadly) shock hazard
   - i.e. AC power faults, static discharge, lightning ..

2. CIRCUIT ground
   - refers to a common signal reference "point" that ties together all circuits inside the equipment
   - circuit ground (common) is connected to rig chassis, which is connected to Earth ground

AC Power Ground

- • - • - - • - - • • • • - • - - • • • - • • • • - • •

- AC powered equipment cord connected 115 VAC
  - Line, **black** wire, is "hot", **shock hazard**
  - Ground, **green** wire, is grounded to earth at service entrance *
  - Neutral, white wire, is power return, grounded to earth at service entrance

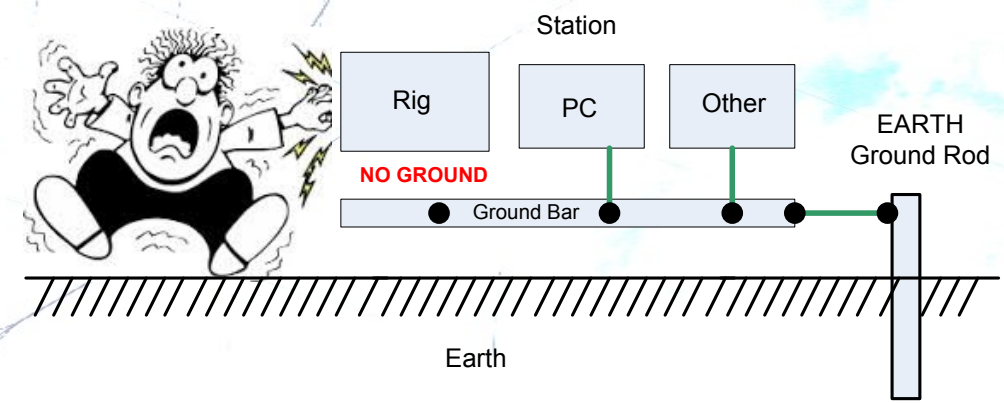


- Green wire is SHOCK HAZARD SAFETY GROUND and must never be tampered with !

The Service Entrance is where the electric power enters the house at the main circuit breaker panel. Neutral and Safety are both Earth grounded at this point. * Rig is grounded – like it or not.

Safety Ground

- AC powered electrical devices, including rigs, are SAFETY grounded by CSA code. **Don't Remove**
- You and Earth ARE conductors
- YOU could be the conductor to Earth if failure of AC wiring or lightning or static discharge occurs…



The RF Ground Myth

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- "The idea that earth / ground electrodes provide a zero impedance sink that we can use to absorb or otherwise make unwanted signals or noise go away can't possibly be true"
- "It is a total myth, pure and simple, having no basis in reality in this universe"
- "Even if it could exist, .. the unwanted current would have to come back via some other route to complete its loop"

Keith Armstrong. Cherry Slough Consultants, Stafford, UK. "Fundamentals of EMC Design" page 113, para 7.7. Interference Technology 2012

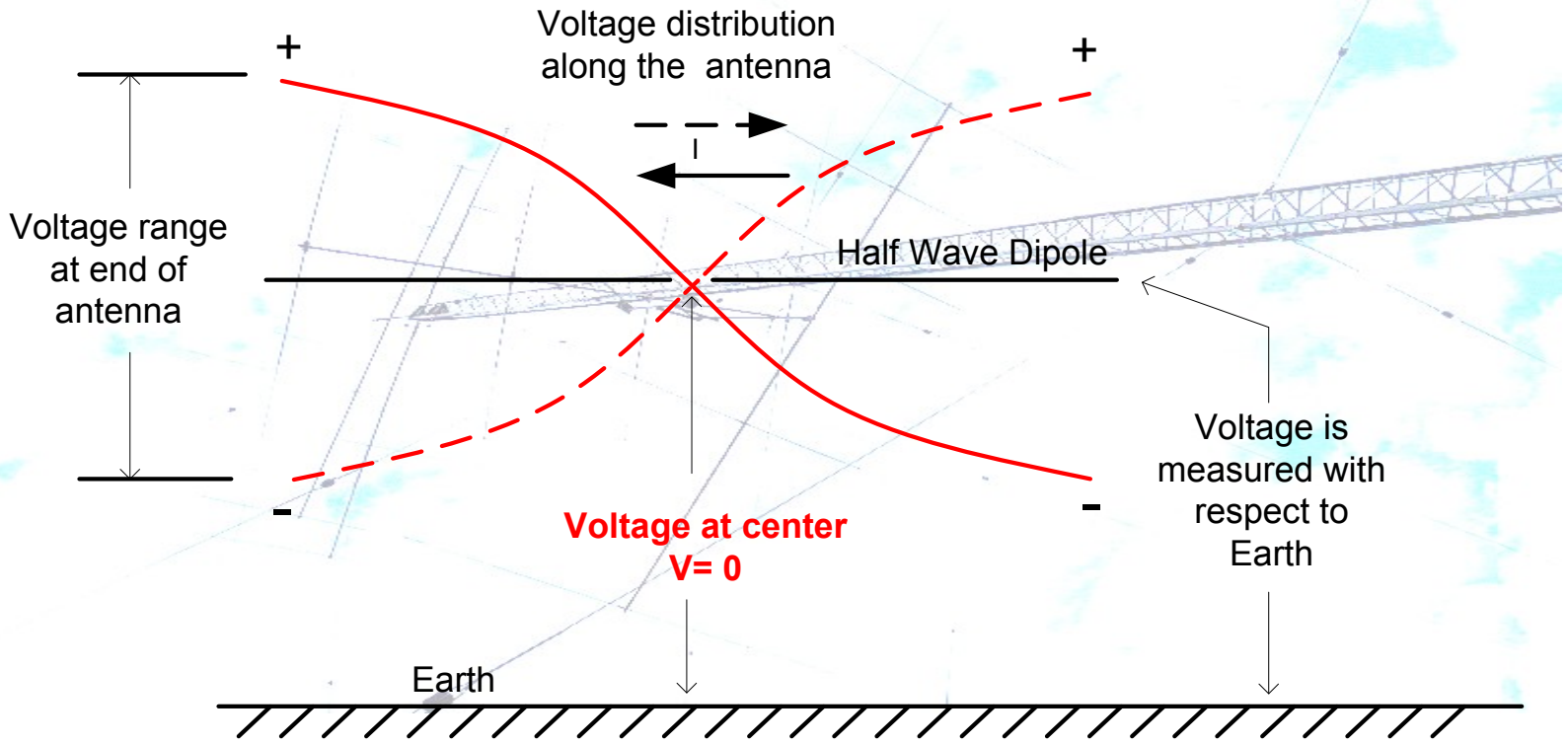
Antennas

- - - • - • - - • - - - • • - • • • • - • - - • • • - • • • • • - •

- What does the voltage distribution look like along a resonant, dipole antenna?
- Does the location of the Feed Point on the antenna matter?
- Feed point location makes no difference to the antenna as long as you match the impedance of the feed point to the Zo of the (coax) feed line
- So what is important ?

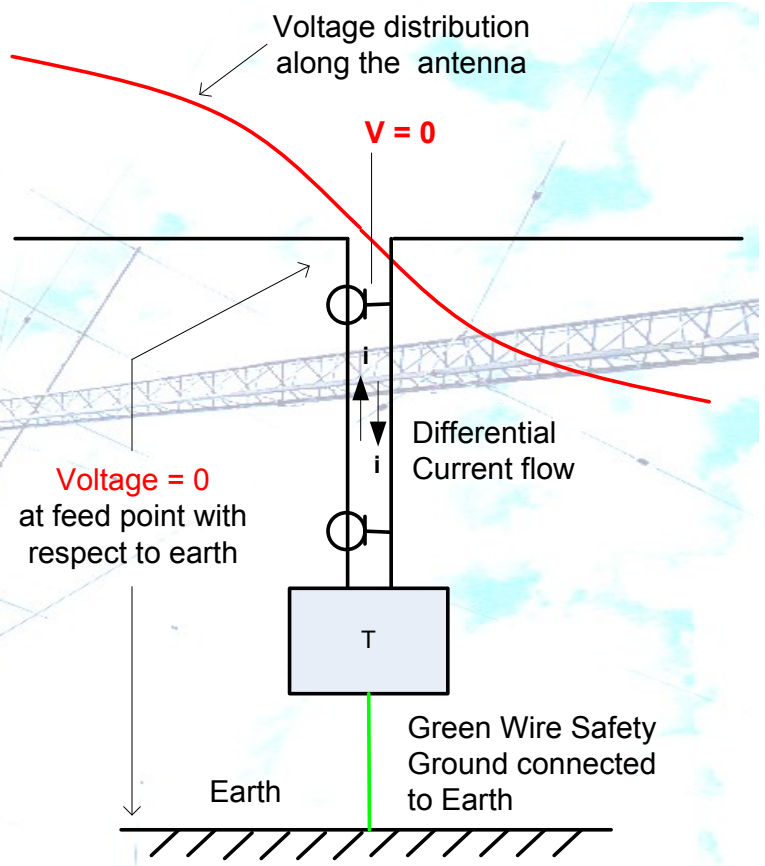
Voltage Distribution

- Resonant half wave dipole



Center Fed Dipole

- Note that **V = 0** with respect to Earth at center of dipole
- Differential mode current flow inside coax
- Things are good



Note that ...

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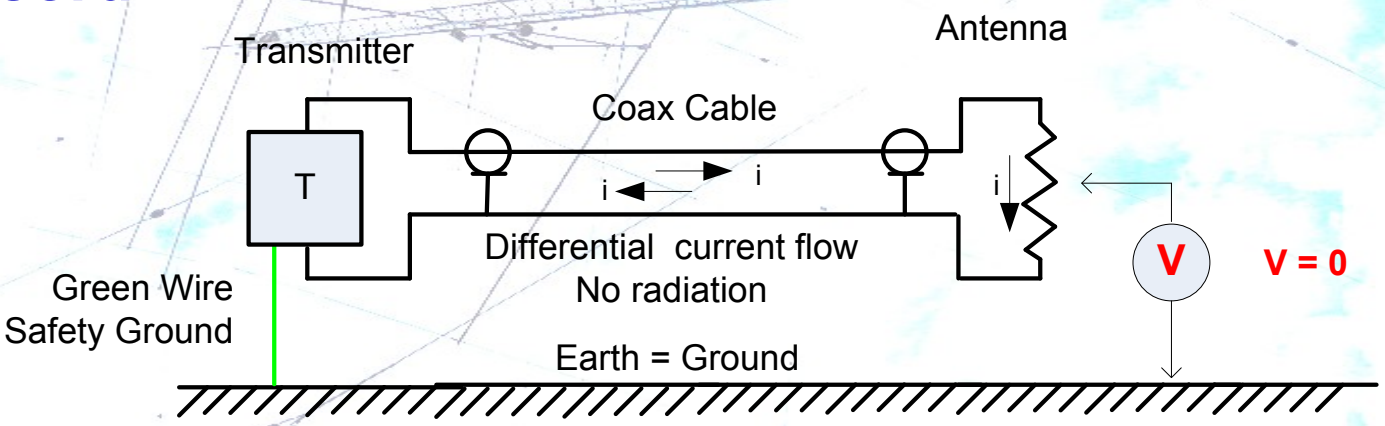
1. Voltage varies along the length of the antenna
2. The voltage along the antenna is measured with respect to Earth ground (can also be measured along the antenna, end to end, but we are not concerned about that here)
3. The voltages at the ends are high because the antenna is "open" circuit here (current = 0)
4. Voltage **V** in the center of the antenna is **zero** since the polarity reverses at the mid point, this also being the feed point

The Circuit Diagram

- - - • - • - - • - - - • • • - • - - • • • - • • • • - • • • • • - •

- Transmitter “T” connected via coax cable to the antenna represented by a resistor (radiation resistance)
- Note transmitter is unavoidably connected to earth ground due to the Green Wire ground in the AC line cord



Note the Currents ..

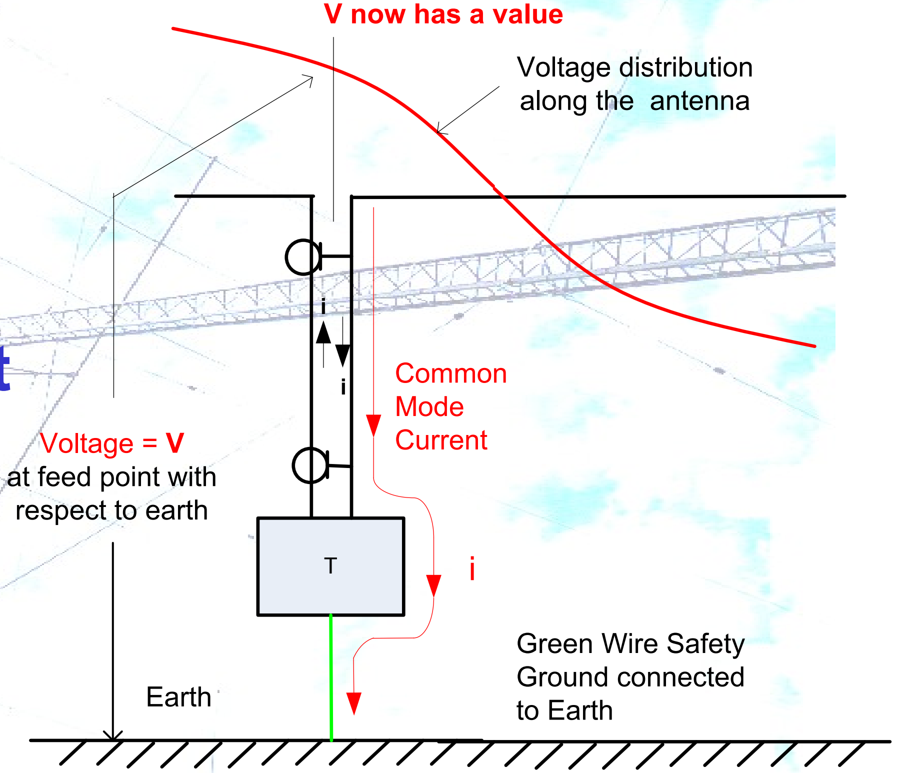
- • - • - - • - - • • - • • • - • - - • • • - • • • • - -

- Flow from the transmitter up “along” the center conductor of the coax to the antenna
- The return current comes “back” down along the INSIDE surface of coax braid due to skin effect
- Signal currents are contained within the coax
- Note that there is a) NO common mode current flow b) NO feed line radiation, c) NO current flowing in the Green wire Safety ground

Off Center Fed Dipole

- - • - •   - - • - -   - • •   •   • • • -   •   - - • • •   - •   • • •   • - •

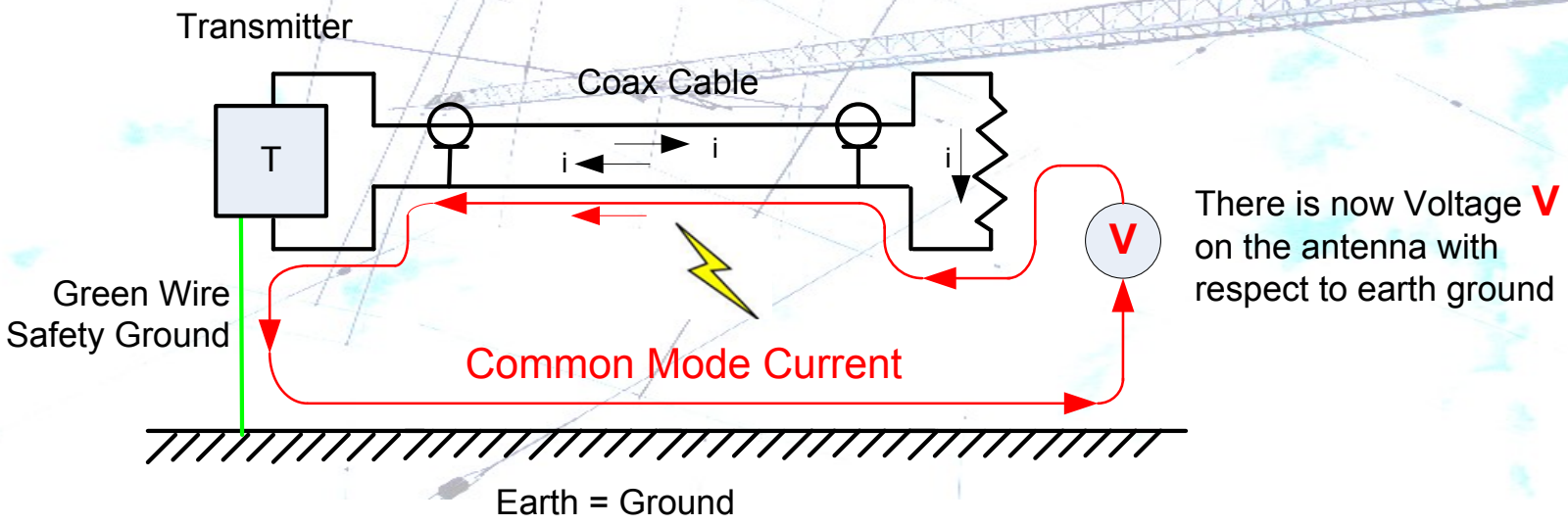
- Note that **V = now has a value** with respect to Earth
- There can now be a Common Mode current flowing on outside of coax driven by **V**
- This is bad



V not equal Zero

- - - • - • - - • - - - • • • • • • - • - - • • • - • • • • • - •

- There is now a voltage **V** at the feed point with respect to earth ground
- Common Mode Current now flows on outside surface of braid / shield and radiates



Note the NEW Current

- • - • - - • - - - • • • - • - - • • • - • • • - • - - • • • - - • • • • - • • • • - •

- A Voltage V now exists between the feed point and Earth ground as compared to the center fed dipole where V was 0, being center fed
- V can now drive an RF current down the OUTSIDE of the coax braid to the Rig & Shack and return through earth ground
- RF flows on the OUTSIDE of the coax, on the surface of the rig, & invading unshielded wiring
- You have RF-in-the-Shack !

What to Do!

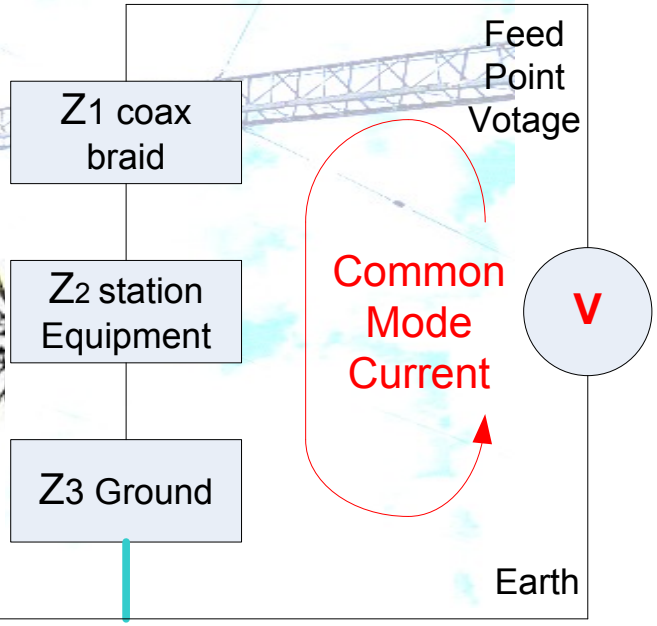
- - - • - • - - - • - - - • • • - • - - • • • - - • • • • - • • • • - •

- You cannot remove the Safety Ground to break the ground loop – that is downright dangerous
- You cannot change the voltage at the antenna which is driving undesired RF current down the coax into the shack
- What you can do is choke off common mode RF current on the coax to impede flow of RF into the shack

Circuit Impedances

- - - • - • - - • - - - • • - • • • - • - - • • • - • • • • • - -

- There will be a voltage developed across each of Z1, Z2 & Z3 but of unknown values
- RF will flow & radiate
- RF voltages develop across equipment Z's & may be felt as "tingles" and "bites" to the touch



Inserting a Hi Value Z4

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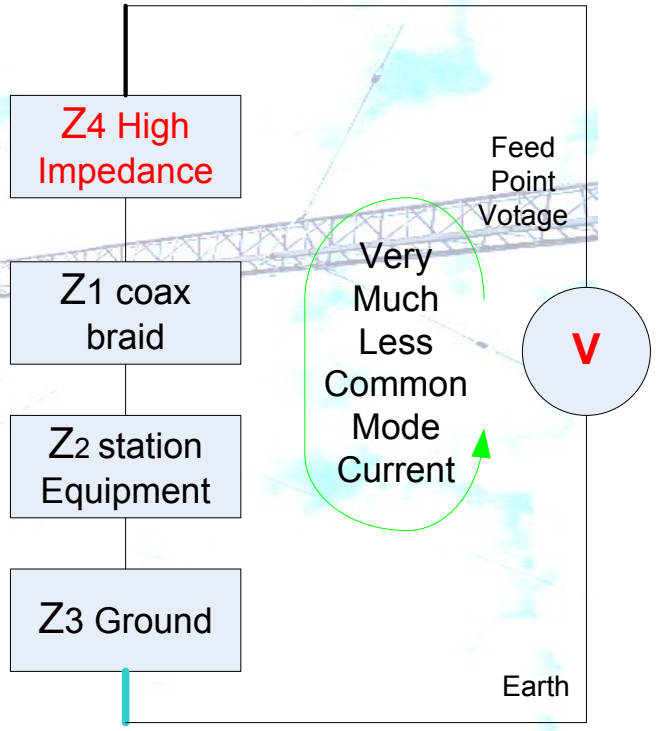
- Add Z4 – a high Impedance > Z1+Z2+Z3
- Suppresses RF loop current flowing in to Shack
- Z4 is a CURRENT BALUN installed at the feed point
- Suppresses common mode currents right where they occur, at the feed point



What Not to DO

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- Typical remedy – Change grounds. Wrong
- Review schematic - changing the value of Z3 grounding impedance does not break common mode current loop
- Simply alters locations and magnitudes of voltage and current nodes presented in the shack
- Does not address root cause
- Required action to remedy the problem is to reduce loop current by adding the Z4 impedance

The Current Balun

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- The internal electrical construction of the current balun provides:

1. A very high impedance to currents wanting to flow on the outside of the braid, thus keeping RF off the line from the feed point down downwards to the shack

2. Does not impede signal current inside the coax

- Best practice dictates: ALWAYS use a Current Balun

Ferrite Beads Z4 +

- • - • - - • - - • • • - • - - • • • - - • • • • - •

- Ferrite Beads offer additional & excellent suppression of braid currents on the coax
- Beads have NO effect on the signal inside the coax as the braid shields inside from outside
- Thread or snap the beads on to the coax to increase the braid inductance, augmenting **Z4**

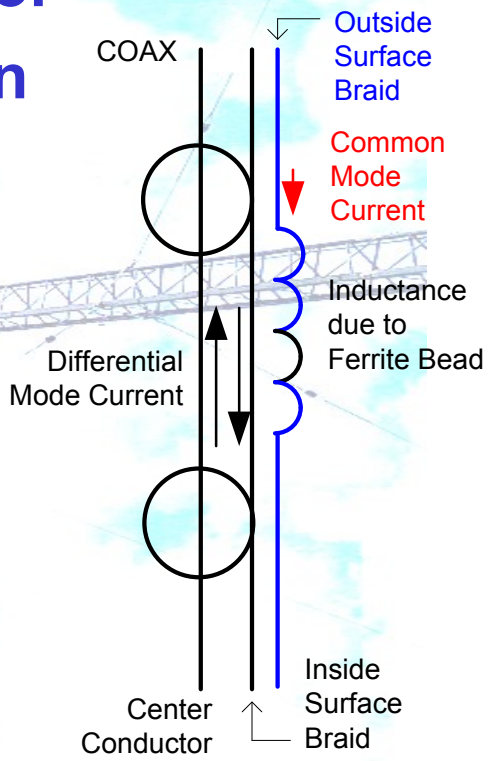
Beads

Split Snap-On

Bead Inductance

- - - • - • - - • - - - • • • - • - - • • • - - • • • • - -

- The Ferrite bead when slipped over, or snapped-on to coax forms a one turn inductor on the outer braid
- Inductance about 50-200 ohms per ferrite (dependent on ferrite material & freq)
- More than one bead often employed, to increase total impedance. 1 is not usually sufficient – as many as it takes to resolve the problem. 6 not uncommon



Coiled Coax Inductor

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- Another remedy: form a coil using 5-10 turns of the coax feed line. Creates an inductor which will also suppress current on the feed line
- Coax coil does not have as wideband rejection as ferrites due to capacitive coupling between turns

coiled coax

coax on a coil form

coil + ferrite

Antenna Induction

-.-. --.-- -.. . ....- . --... -. ... .-.

- Feed Lines will intercept RF radiated from the antenna – hard to avoid
- Also induces common mode current on braid
- This is not a current balun deficiency
- If problematic, install ferrites variously along the length of the coax to increase the common mode impedance Avoid resonant length spacing distance on coax if possible

Case Study OCF Antenna

– • – •   – – • –   – • •   •   • • • –   •   – – • • •   – •   • • •   • – •

- VE7BAV QTH, Metchosin (near Victoria)
- Off Center Fed Antenna W8JI Windom design, multi-band wire dipole, about 40 feet up
- High quality, 4:1 Z ratio, toroidal style, current balun at feed point
- About 100 feet RG-8X 50 ohm coax
- MFJ-854 clamp-on RF ammeter used to measure current on the coax

Split, hinged ferrite clamps over coax

Test Results

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- Currents as measured on coax in mA

Frequency MHz	With Balun	Balun + 8 Beads	Balun + 8 Beads + 2 turn Coax Coil
3.75	150	100	10
7.00	70	25	0
14.7	20	30	0
21.0	20	5	6
28.2	30	15	3

But my Dipole Works OK!

- • - • - - • - - • • • • - • - - • • • - • • • • - •

- If you connected the coax directly to the center of a resonant dipole, without a balun, then …
  - you connected at an exact Zero voltage point on antenna,
  - your dipole is well balanced in its physical environment,
  - the antenna legs are not close-by different objects,
  - the antenna is totally symmetrical about feed point,
  - and it hangs in a perfect straight line level above ground.
- Departure from any of the above will detune, unbalance & move the electrical zero-voltage feed point off the physical center, placing the feed line at a voltage point thus driving RF into the Shack

Summary

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- **Almost impossible to prevent common mode RF current being driven down the feed line from the antenna on to and in to shack equipment causing operational problems**

- **Remedy - choke off common mode current**
  - **ALWAYS using a current balun**
  - **put ferrite beads on the coax if problem persists**
  - **make a coax coil if problems still persist**
  - **check all coax connectors (PL-259 style) for soldered braid-to-shell integrity**

Article

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- RAC – The Canadian Amateur: May- June 2015 “Why You Need a Current Balun”. www.rac/ca
- You need to be a member of RAC to Log in to RAC. Click Downloads top left of page > Scroll down the issues of TCA. Select May-June 2015 , small pdf.
- This article has more info on how the current balun “works” than the ppt presentation.
- Alternately this can be found on the NSARC website at:

  http://www.nsarc.ca/tech_archive/Articles/Current_balun.pdf
- This Slideshow is posted on the NSARC website at:

  www.nsarc.ca/hf/currentbalun.pdf