HF OPERATORS

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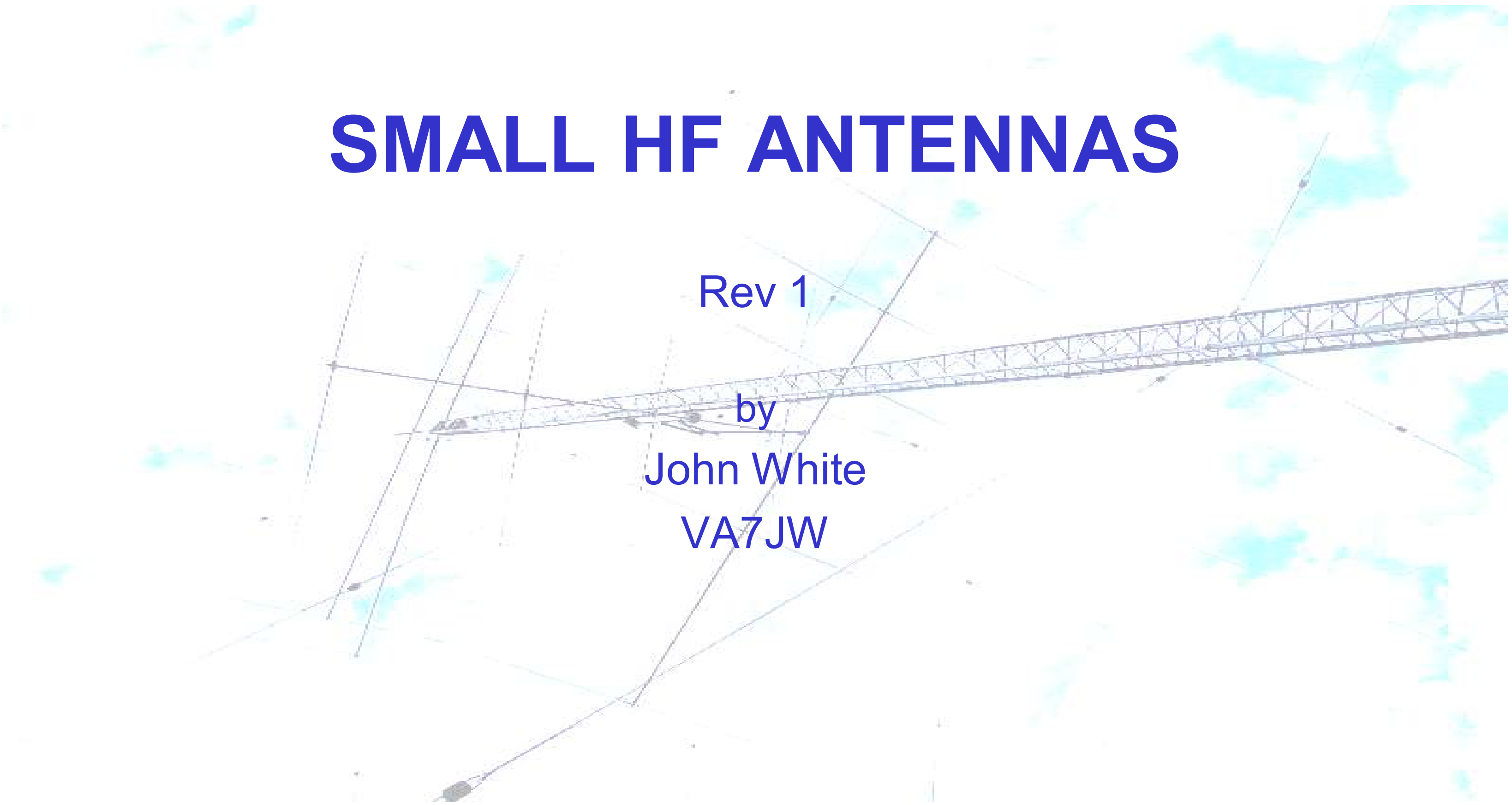


SMALL HF ANTENNAS

Rev 1

by
John White
VA7JW

Antenna Problems

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

- Big or Small – always problems ….
- Affects all - Single family, apartments, condo's, high rises, etc …
- The Small Space and Big Antenna Dilemma
- Today's Urban Constraints
  - Covenants and Gated Communities
  - Restricted lot size
  - City Bylaws
  - Boards of Variance
  - Strata Rules
  - Neighbor complaints of unsightly "structures"

What to Do?

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

1. Get Permission – refer to Industry Canada CPC-2-0-03

2. Make antennas smaller

3. Hide antennas – attics, trees, around wooden fences, thin black wires …

4. Disguise antennas – flag poles, gutters, ….

5. Move

Focus on the #2 solution – Small Antennas

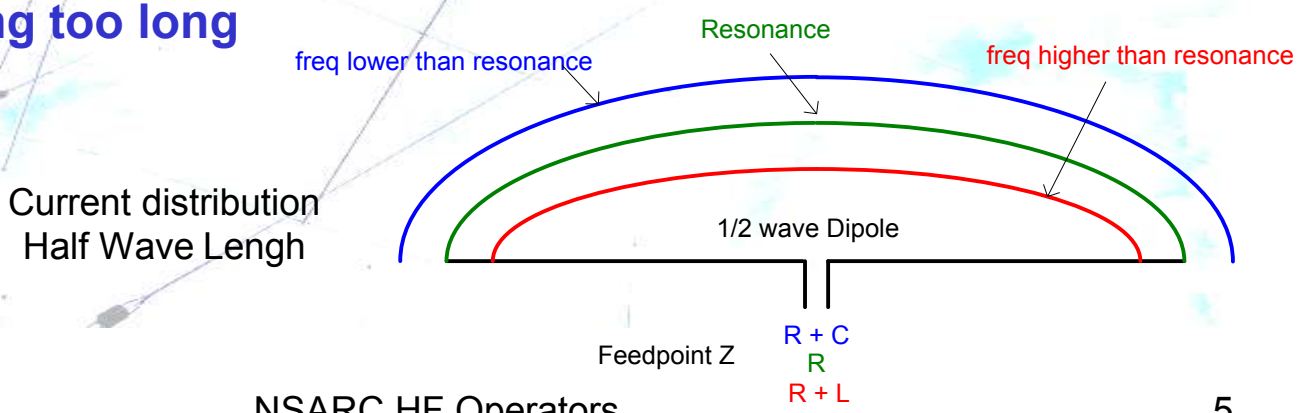
Small Antenna Characteristics

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

- Small antenna usually means SHORTER with respect to the Resonant Half Wave dipole
- Overall, antennas are characterized by
  - Bandwidth (usually VSWR < 3:1)
  - Feed point impedance (half wave dipole typically 50 ohms)
  - Gain (as much as possible over a dipole)
- Unfortunately, as the antenna becomes shorter, we get ….
  - Narrower Bandwidth
  - Lower Feed Point Impedance
  - Lower Gain
- The up side is - SMALL is better than no antenna

Antenna Basics

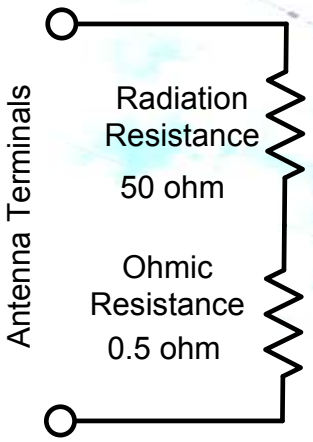
- All antennas behave as tuned circuits that possess resistance R, inductance L and capacitance C
- At resonance, L and C reactance cancel leaving only the resistive component
- At frequencies BELOW resonance, capacitive reactance appears, antenna being too short
- At frequencies ABOVE resonance, inductive reactance appears, antenna being too long



Feed Point Impedance - FPZ

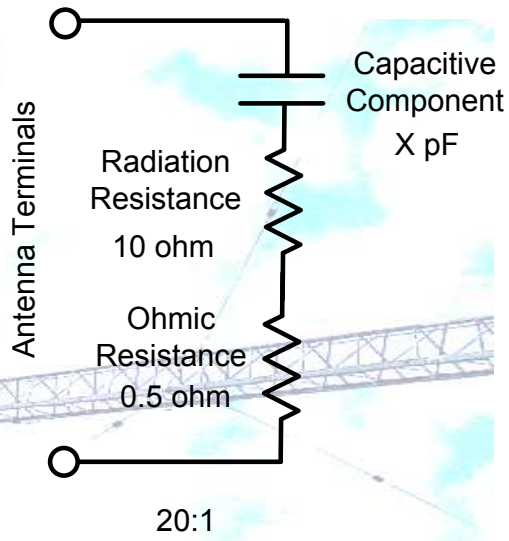
- - - • - • - - - • - - • • • - • - - - • • • - - • • • • • - -

- FPZ for a resonant half wave dipole antenna is ~ 50 ohms resistive
- Physical resistors absorb & fully dissipate energy as heat
- The 50 ohms is a hypothetical resistor that does the same thing as a physical resistor except that it dissipates the TX energy as RADIATION rather than heat
- This is the RADIATION RESISTANCE (RR)
- All antennas have real resistive loses
  - Ohmic = wire resistances typically very low
  - R wire very small compared to R radiation



FPZ with Short Antenna

- Short antennas look capacitive
  - "C" does not contribute to radiation
  - complicates FPZ
- Radiation Resistance decreases
  - complicates FPZ as well
- Ant FPZ is no longer 50 ohm resistive
  - VSWR is no longer 1:1



- To restore FPZ, coils are added to null the capacitance
  - Coil adds ohmic losses,
  - deprives RR of energy, lowering radiation efficiency i.e. gain
  - does not raise decreased value of RR

Example – Short Antenna

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

- 8 foot whip antenna (approx 1/8 wave on 20 m)
- Operating at 14.2 MHz
  - radiation resistance ~ 10 ohms
  - base coil required to resonate antenna ~ 3 uH
  - base coil typical R ~ 2 ohms
  - efficiency ~ 83% or ~ -0.8 dB (dipole / negligible S points)
- Operating at 3.7 MHz
  - radiation resistance ~ 0.3 ohm
  - base coil required to resonate antenna ~ 77 uH
  - base coil typical R ~ 20 ohms
  - efficiency ~ 1.5 % or ~ -18 dB (dipole / 3 S points)

ARRL Antenna Book. 21 edition. Chap 16, pg 16-5. Table 1

Operating Issues

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

- Shortened HF Antennas
  - FPZ matching issues
  - but - manufacturers typically provide built-in matching systems
  - possible need for antenna tuners (rig tuners may be inadequate)
- With High Density housing Interference more likely
  - proximity to audio, video, AM, FM, PC, Tel, etc. equipment
  - QRP to 100 watts probable max
- Safety issue
  - you and the antenna may share the same space
  - RF exposure limits need to be checked

Building RF Transparency

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

- Wooden frame structure
  - RF transparency – good
  - Embedded stucco wall mesh alter radiation patterns
  - Internal conductors acting as antennas
    - Power, telephone, cable, alarm etc wiring
    - Copper plumbing
- Concrete structure Issues
  - Rebar and metal framed windows, attenuation of signal
  - Metal 2 x 4 framing inside building
  - Internal conductors can transport RF to undesirable places within structure

High Density - Which Floor?

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

- Top floor - could be best case
  - higher is better for propagation
  - access to roof top antennas
  - short feeder runs
  - best separation from tenants, all below
- Bottom – next best location
  - access to ground mounted antennas
  - grounding systems possible
  - feeder runs OK
  - tenant spacing, top & 2 sides
- Mid floors – tough location
  - interior or balcony mounted antennas
  - tenants all around

Antenna Tuners

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

- A tuner does NOT tune the antenna
- Tuner transforms the complex impedance seen at the input of the coax feeder, to 50 ohms resistive, to meet transmitter requirement
  - facilitates maximum power transfer to antenna
- Most modern rigs have built-in antenna tuners
  - typically will match < 3:1 down to 1:1 at rig interface
- Tuning limitations may be evident if tuner cannot match the antenna / feed line impedance
- Rig tuners not well suited to off–resonant antennas

Loading Coils

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

- Loading Coils commonly used in small antennas
  - electrically lengthens the antenna shortness
  - Typically part of purchased antennas
- Cancels the Capacitive component
  - resonates the antenna
  - acts as Z matching network
  - 50 ohms

- Coil placement
  - Dipoles – one in each leg
  - Verticals –typically at bottom to half way up radiator

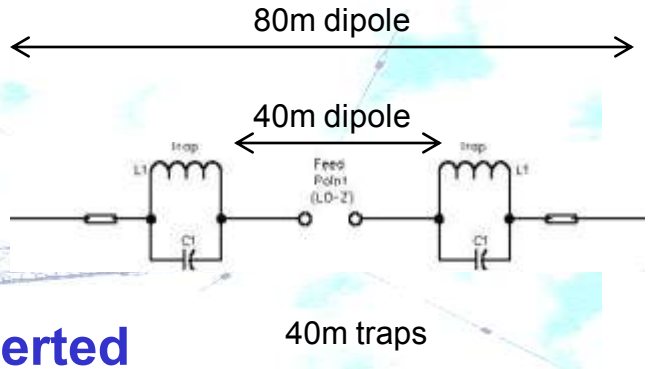
Current Baluns

- In-line coaxial current baluns keep RF from flowing on coax back into the shack
- Isolates rig / antenna from shack ground
  - MFJ-915
  - Radio Works T 4G
- Snap On chokes
  - RF Parts or DX Engineering
  - http://www.dxengineering.com/
  - http://www.rfparts.com/choke.html
- Ferrite Beads
  - Palomar Engineering model BA-8
  - http://www.palomar-engineers.com/

Traps – Multi-Band

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

- "Traps" are parallel L-C resonant devices inserted in radiating elements
- Trap is Hi–Z at a band higher in frequency than basic length
- Enables dual or multi band operation depending on how many traps are inserted
- Traps will also shorten antenna length
- Applicable to dipole's, yagi's, verticals



Products

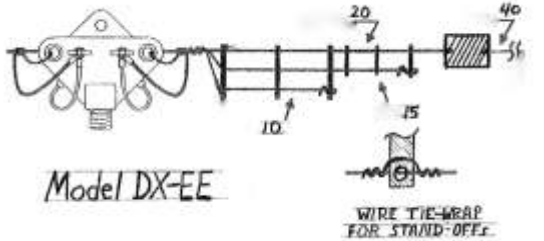
- - - • - • - - • - - - • • • - • - - • • • - - • • • • - • - •

- Many manufacturers offer shortened HF, multi-band antennas
  - resonant on specified bands, i.e. 20-15-10m etc.
  - 50 ohm feed point impedances to match 50 ohm coax
- Various configurations = dipoles, yagi's, verticals, loops
- Typically all will have some form of FPZ matching system
  - chokes, baluns, impedance transformers
  - there are losses associated with all devices
- Offerings >

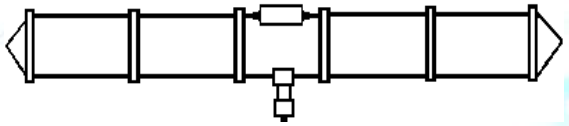
Dipole Antennas

- Shortened, loaded balanced multi-band dipoles
  - No ground issues
  - Multi band

- Alpha Delta http://www.alphadeltacom.com/
  - DX-EE 40 ft / 40 thru 10
  - Radio tuner probably OK



- B & W http://www.bwantennas.com/
  - BWD series 20 ft / 20 thru 10M
  - Radio tuner probably OK

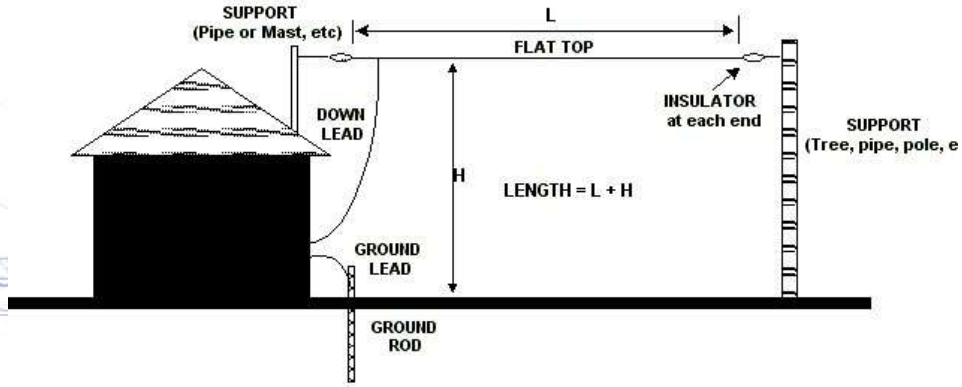


- Radio Works http://radioworks.com/
  - G5RV Plus all band
  - External tuner needed

Long Wire Antennas

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

- Random length of wire – long as possible – you build
  - string outdoors, #20 insulated black low visibility
  - need to support two ends
- Typically non-resonant
- Multi-band capability
- End feed is probably a high Z point
- Must have a tuner other than rig (LDG, MFJ, Icom. SGC)
- Must have a “ground” or counterpoise connection



TYPICAL LONG WIRE ANTENNA

Coil Loaded Dipole

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

Loading Coils (2) – “Shortner”

Balun

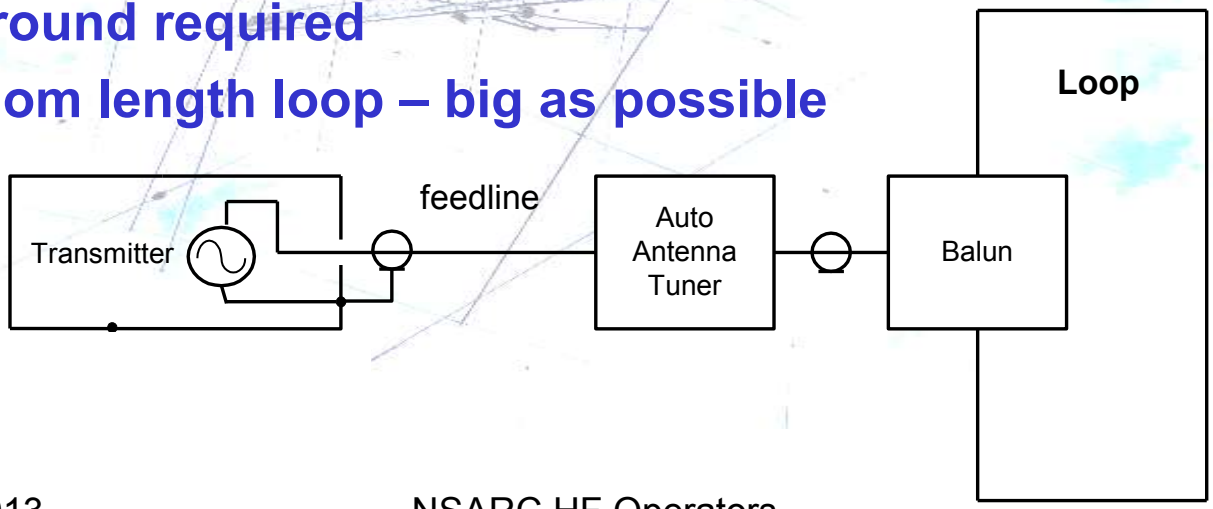
- **Single band**
- **Reduced lengths**
  - **80M dipole from 132 ft to 69 ft**
  - **40M dipole from 66 ft to 38 ft**
  - **most likely an outdoor application**
- **Radio tuner probably OK**

http://www.spiromfg.com/

Wire Loop Antenna

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

- Home made - construct wire loop
- Could reside inside dwelling - attic
- Hang horizontal or vertical on a wall
- Requires external tuner & balun
  - LDG Z-100 tuner + RBA balun
  - http://www.ldgelectronics.com/
- No ground required
- Random length loop – big as possible



Compact Dipoles

- Buddipole
  - 40 to 2 M
  - coil loaded
  - Collapsible, portable
  - 16 feet extended
  - http://www.buddipole.com/

- MFJ BigEAR
  - 40 thru 6 m
  - Model MFJ-2289

MFJ Loop Antenna

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

- Small
- 36 inch diameter
- MFJ-1786 20 thru 10 M
- MFJ-1788 40 thru 15 M
- Low noise advantage
- Inside or outside dwelling

- Includes a custom remote auto tuner- needed as loop BW is very narrow has to be retuned to follow rig frequency

Compact Yagi's

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

- Hybrid Quad
  - Model MQ-1
  - 20 thru 6M
  - 11 ft elements / <5 ft boom
  - http://www.tgmcom.com/

- G4MH Mini Beam
  - 10 /15/ 20M 3 element
  - 2M boom / 5M elements
- ZX Mini-2000 Beam
  - 10/15/20M 3 element
  - 3M boom / 3.4M elements
- Both at http://www.zx-yagi.com/mini.htm

Vertical Antennas

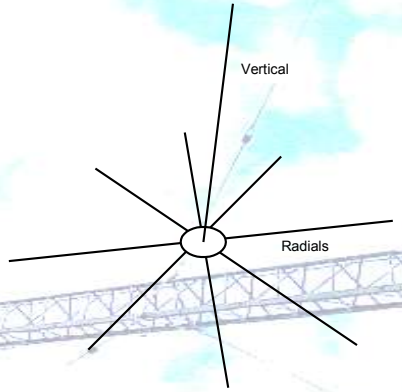
- - - • - • - - - • - - • • • - • - - - • • • - - • • • • - •

- Vertical antennas are traditionally ¼ wave long
- Must operate against a ground plane or counterpoise
- Counterpoises are non resonant, single wire
- Verticals commonly shortened for fixed or mobile use
  - Base loading – matching coils required
  - traps commonly used for fixed applications
- Copper plumbing and Safety ground wiring NOT a good choice for RF ground / counterpoise.
- Mounting possible off balconies, rooftops or at ground level

Ground Plane System

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

- A system of wires at base of vertical
  - minimum 2 per band if using multi band vertical
  - single band, 4 quarter wave are sufficient
- Lay radials out symmetrically as possible
- Bend ends to fit, no bends at base
- Lay radials on surfaces
  - roof, hold in place with bricks
  - lawns - trench and bury (staples avail from DX engineering)



Counterpoise

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

- Verticals must have another “side” to its feed point
  - Coax braid cannot be left un-terminated
- A single non resonant conductor of non-specified length connected to braid is known as a counterpoise
- Counterpoise will have RF on it and will radiate
- Undefined operation if using building copper pipe or safety ground wiring as counterpoise
- MFJ-931 Artificial Ground “tuner”
  - Helps match a short counterpoise

Vertical Capacity “Hats”

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

- Capacity “Hat” placed at top end of antenna
- Shortening the antenna gives rise to capacitance at feed point
- Introducing capacitance at the top effectively restores the length causing feed point to look resistive again
- Can be placed in middle but most effective at top

CAPACITY HAT
Not for use on antenna

Example Capacity “Hats”

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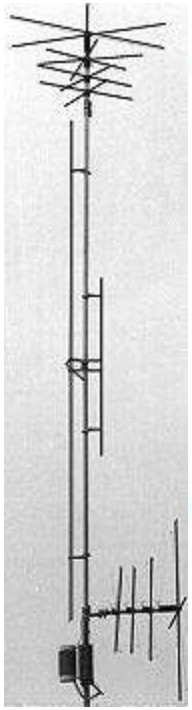


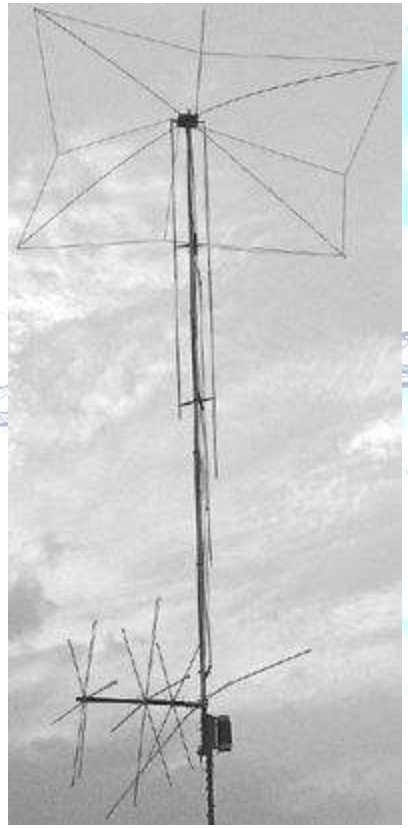
MFJ-1796

Capacity Hat

40 thru 2 M
No Radials
Feed line balun

12 feet high
24” footprint

80/40M
Needs, guys & radials
33 feet high



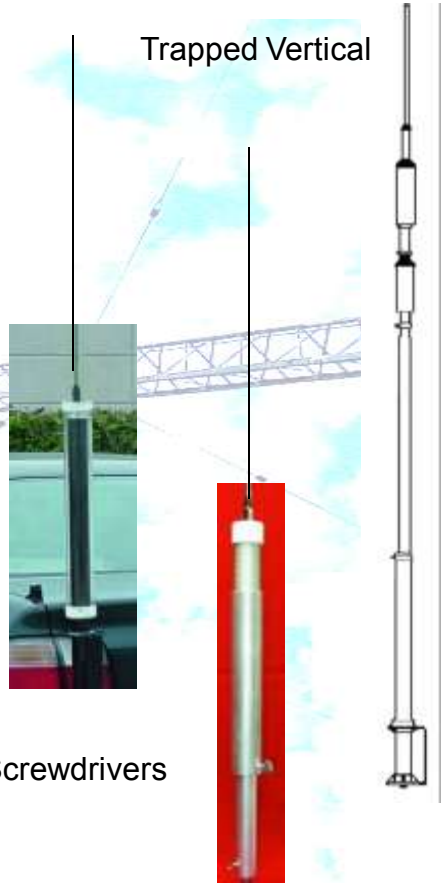
MFJ-1798

http://www.mfjenterprises.com/

Some Vertical Antennas

- Trap
  - Good for ground mount or flat roof
  - to 30 ft high
  - Requires ground system
  - Multi-band - can be 80 thru 10, 20 thru 10 etc
  - MFJ - big selection – search verticals
  - Hygain - big selection – search verticals

- Screwdriver style
  - Motorized & tuneable
  - multi-band, fully resonant 80 – 10M
  - Extends to ~ 9 ft, some shorter
  - Requires ground system
  - Ameritron SDA-110 http://www.ameritron.com/
  1. Tarheel http://www.tarheelantennas.com/home/



More Vertical Antennas

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

- Mobile Whip
  - Require ground system
  - Outbacker multi-band
    - Use Outpost tripod for ground mounting
    - http://www.outbackerantennas.com/
  -

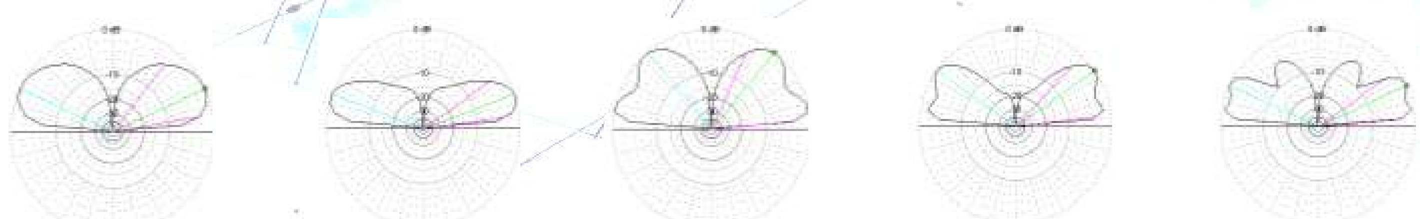
- Balcony Verticals
  - Designed for balcony mount
  - Require ground system
  - ~ 6 ft
  - multi-band 40 – 10 M
  - MFJ 1622

Radials / counterpoises generally required.

The Raised Vertical

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

- Roof mount a 16 foot 20m vertical or multi-band 20/15/10 trapped vertical with 4 radials
- Instead of exclusive traditional low angle of radiation, it will have continuous coverage ~ 10 to 60 degrees if > 16 feet above ground
- Very useful pattern for DX and "local" skip
- Not very obtrusive

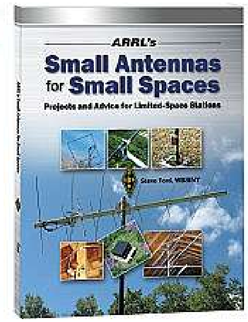


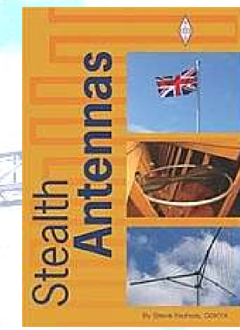
Ground level   1/4 wave   1/2 wave   3/4 wave   Full wave

Stealth Antennas

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

- Available ARRL
- Flagpole Verticals – ground mounted
- Wires lying on roof tops
  - Black insulation, small diameter
- Wires on Gable ends
  - No good under eaves with metal gutters, soffits
- Wires on Fences - Loops
- Attics for yagi’s
- VHF/UHF on short mast looks like TV antennas
- Vent pipe VHF/UHF verticals, roof mounted
  - http://www.ventenna.com/





Antenna Ideas

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

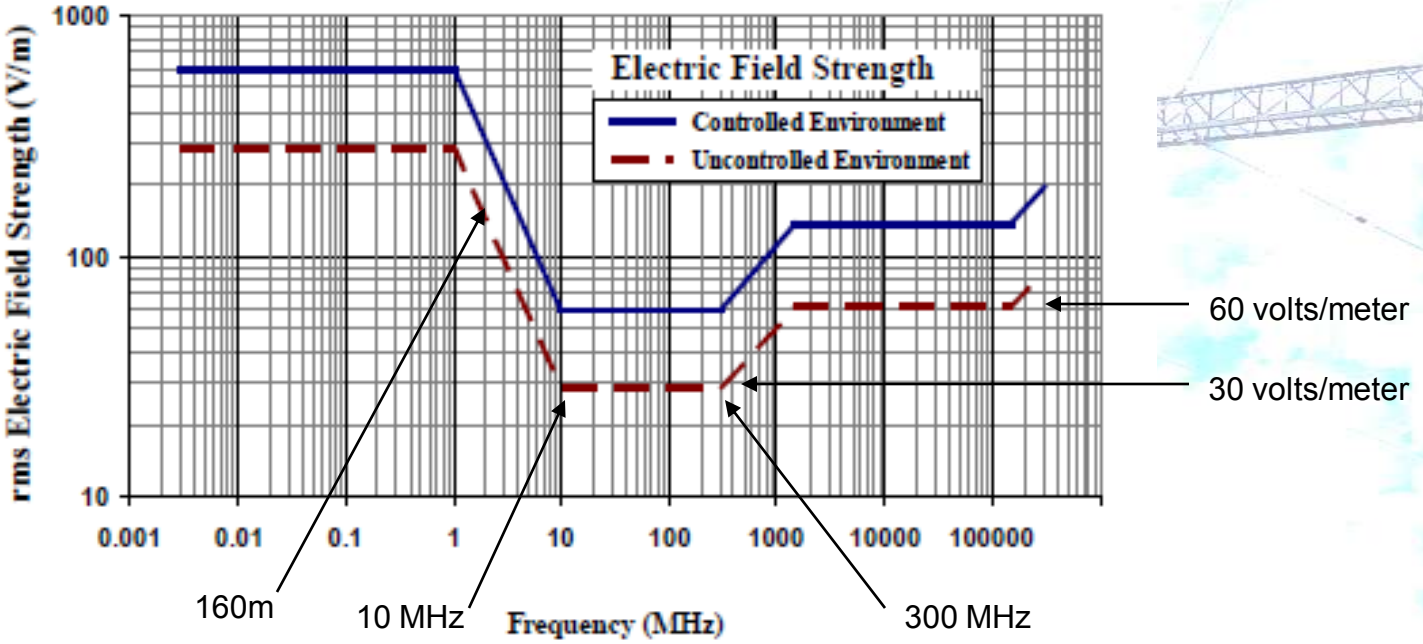
Safety

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

- Exposure to RF fields
  - RF is non-ionizing radiation
  - RF Energy is converted to heat within body
  - Body must dissipate heat that it is absorbing.
  - Safety Code 6 - Canadian Standard prescribes safe exposure levels
  - http://www.radiationsafety.ca/wp-content/uploads/2012/06/Safety-Code-6.pdf
- Exposure Factors vary with:
  - frequency
  - antenna gain
  - closeness to antenna
  - transmitter power levels
    - duty cycle SSB=20%; CW = 40%; FM, AM, RTTY, Digital = 100%
    - duration > on time / off time. 10 min on & 10 min off = 50%

Safety Code 6 Health Canada

- Dotted line applies to “us”
- Spec is max 30 volts per meter, 10 to 300 MHz
- This is a very high field strength

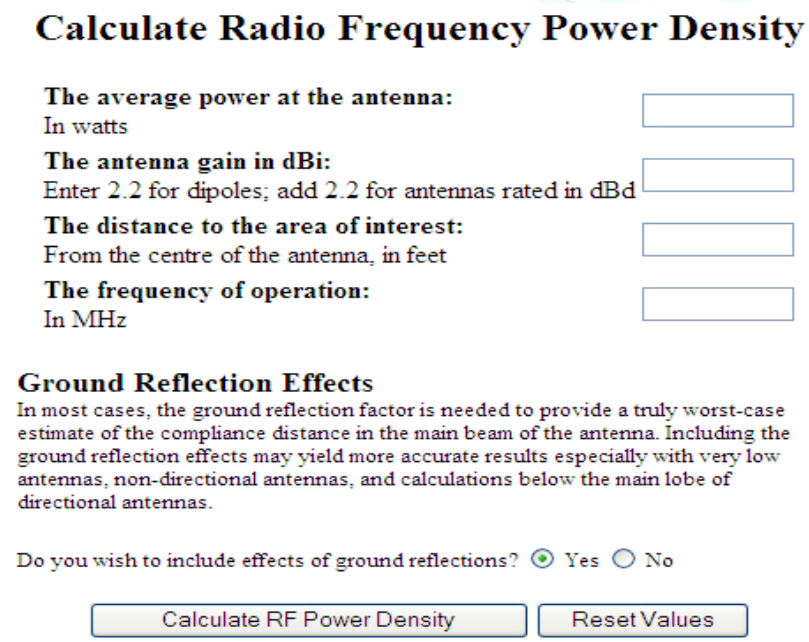


Exposure Calculation

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

This program uses the formulas given in FCC OET Bulletin No. 65 to estimate power density in the main lobe of an antenna

http://hintlink.com/power_density.htm



Examples

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

- Some sample calculations to get a “feel” for limits
- Assume 100% duty cycle – i.e. continuous carrier 100 Watts
- Antenna gain 3 dBi (slightly more than a ½ wave dipole)
- Distance from antenna 10 feet, in main lobe

	FREQUENCY MHz				
	3.7	7.1	14.2	21.3	28.3
Safe	yes	yes	yes	no	no
Required Distance	> 1.9ft	>3.6 ft	> 7.1 ft	>10.5 ft	> 14 ft

- Body more absorptive at higher frequencies

Best Practices

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

- Keep antennas at a distance
- Antenna Voltages can be very high with shortened & small antennas
- RF voltages can cause burns if antenna touched
- “Hot” grounds may occur at unknown locations if electrical (green wire) safety ground or plumbing used as counterpoise, or antenna!

Summary

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

- Visit eHam for product reviews http://www.eham.net/
- Get the antenna outside
- Consider balanced (dipoles, yagi's loops) antenna systems first as "grounding" systems not required
- Verticals and long wires require radials or counterpoise
- Long wires require counterpoise and tuner
- Keep antenna away from metallic objects
- If moving, choose antenna friendly site

Hope this provides some ideas

Appendix I
Industry Canada (I.C.)

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

- Industry Canada CPC-2-0-03
  - Radiocommunication and Broadcasting Antenna Systems
  - Client Procedures Circular
  - Defines procedures for the installation and modification of all antenna systems including amateur
- Applies to single family, detached dwelling on privately owned land, i.e. typical neighbourhood.
- Likely does not apply to strata communities, rental properties, neighborhoods with covenants or wherever an agreement prohibiting antennas was signed upon purchase.

Appendix II
Some Antenna Theory

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

- **Basic antenna forms – only 2 !**
  - **Hertzian form**
  - **Marconi form**

- **Understanding Short antennas**
  - **Properties**
  - **Behavior**
  - **Performance**

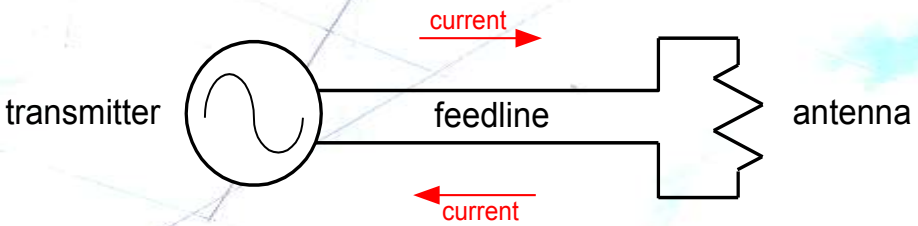
- **What type might be best depends on circumstances**

Antenna Circuit

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

- Generator – the transmitter
- Feedline – two conductors
- Antenna – two wires
- Antenna R = radiation resistance at resonance

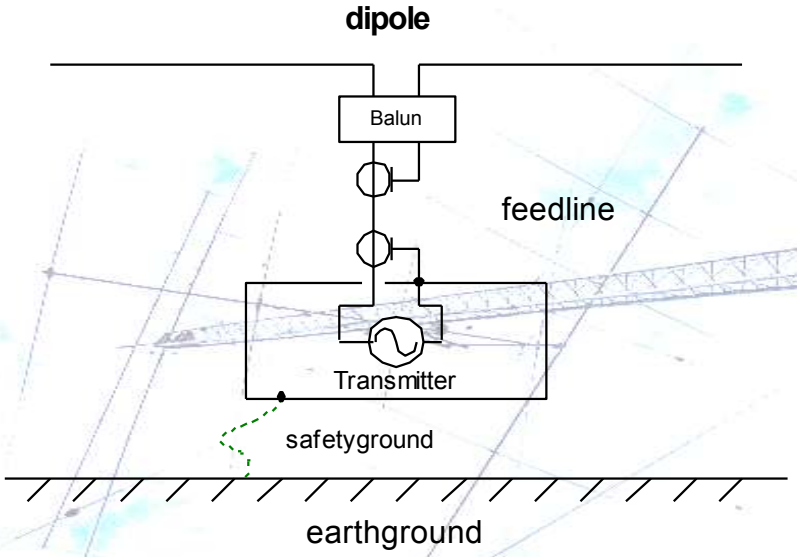
- Complete the circuit - current must flow entirely around the loop



Hertzian Antenna

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

- No earth connection required for Antenna – good!
- Antenna radiates independent of ground



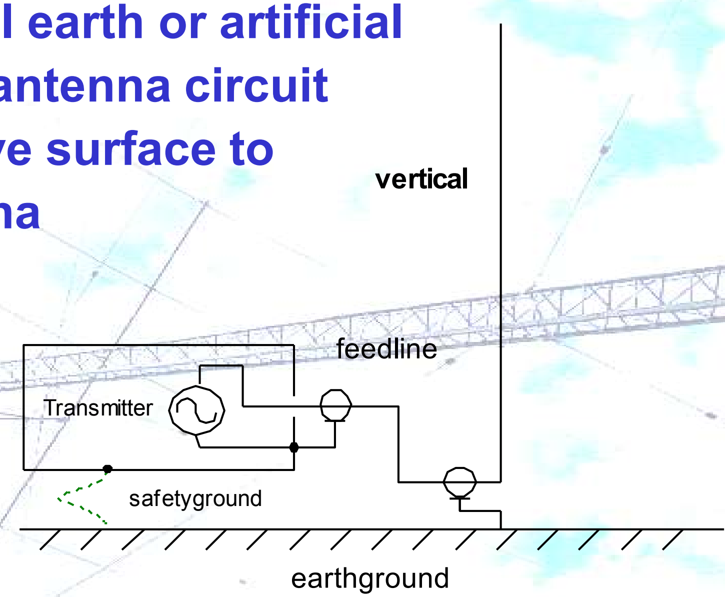
Dipole, half wave

- Rig grounded by green wire in power cord - SAFETY only
- This ground is not part of the antenna system.

Marconi Antenna

- Antenna operates "against" ground.
- Ground circuit is required – real earth or artificial
- Ground is the other half of the antenna circuit
- Ground consists of a conductive surface to mirror the top half of the antenna

Vertical quarter wave



- Rig grounded by green wire in power cord - SAFETY
- Safety ground could become part of antenna system
- Not desirable