Review

- Wavelength in meters = 300/Freq in MHz

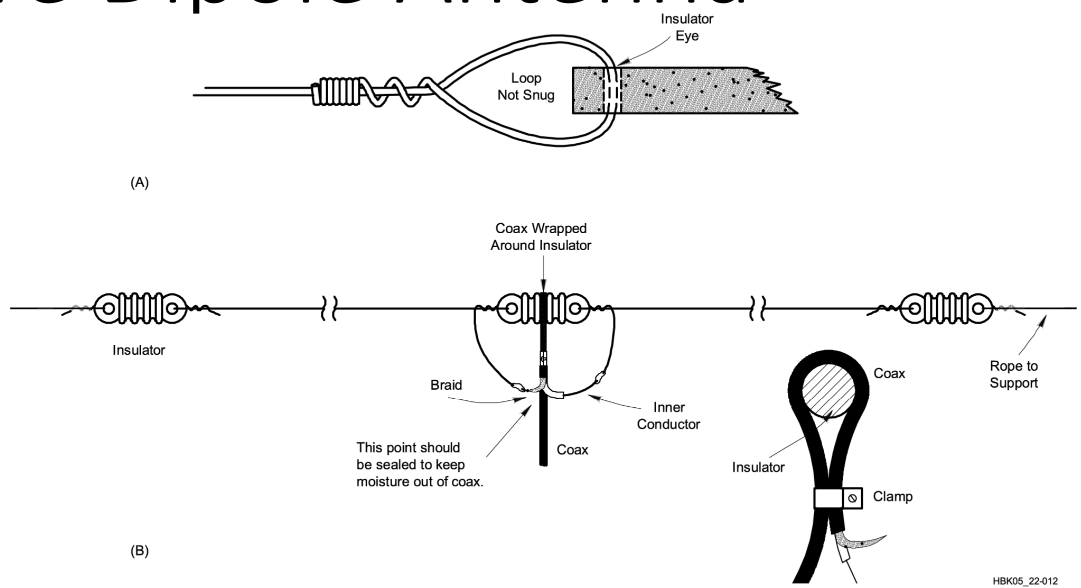
or

Wavelength in ft = 983.6/Freq

MHz

- Velocity factor is multiplied times the wavelength for coax cable.
- Resonance is when Capacitive reactance (X_C) = Inductive reactance (X_L)
- Reactance has a real component and an imaginary component (-j X_C or j X_L)
- Power = Voltage * Current (E*I)
- Voltage = Current * Resistance (I*R)
- Power is also = I*I/R or $= I^2$*R

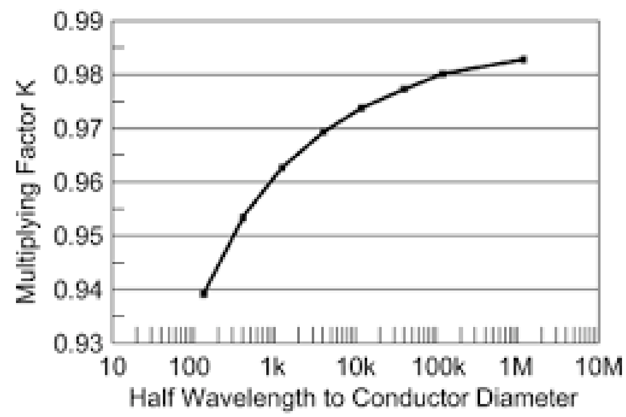
The Half-Wave Dipole Antenna



- Start with excess length (492 * K / f in MHz) and adjust

- The K factor is based on length of wire to wire diameter ratio.

- To raise resonant frequency, shorten each half equally



The Half-Wave Dipole Antenna

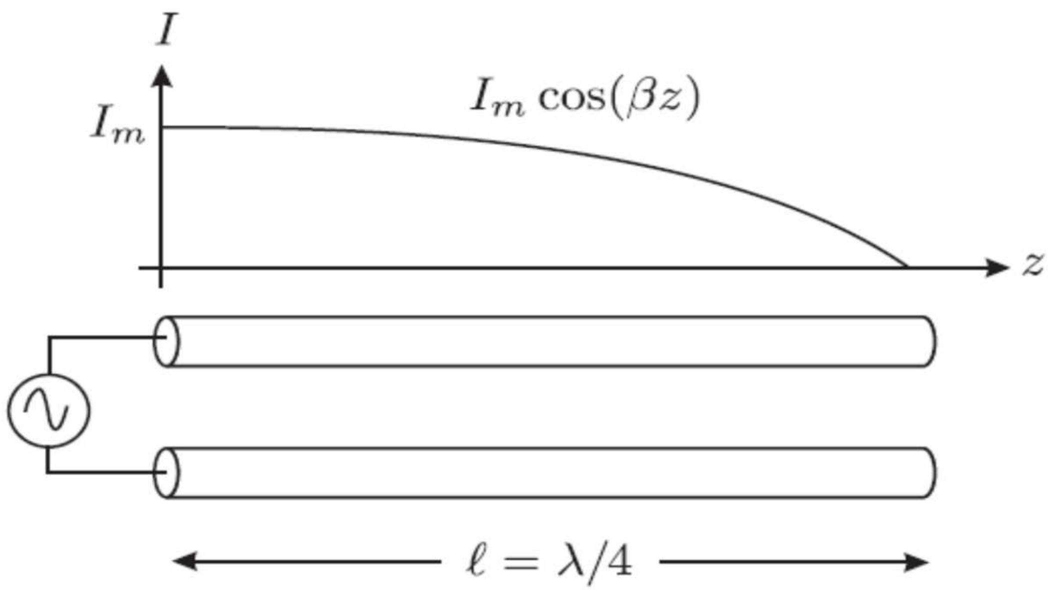
A practical dipole is the half-wave dipole (referring to the fact that it is $\lambda/2$ long). The main reason for resonance which is close to common system impedances. This, as we will see, is that the half-wave dipole has a real input impedance at resonance which is close to common system impedances.

The dipole antenna is a wire suspended above ground. You have wire which is one plate of a capacitor, air which is a dielectric and earth ground which is another plate of a capacitor. This is useful to electrically shorten a dipole antenna. This is shown at the end of the presentation.

At resonance, the dipole has a small inductive component as well since it is a "tuned" circuit.

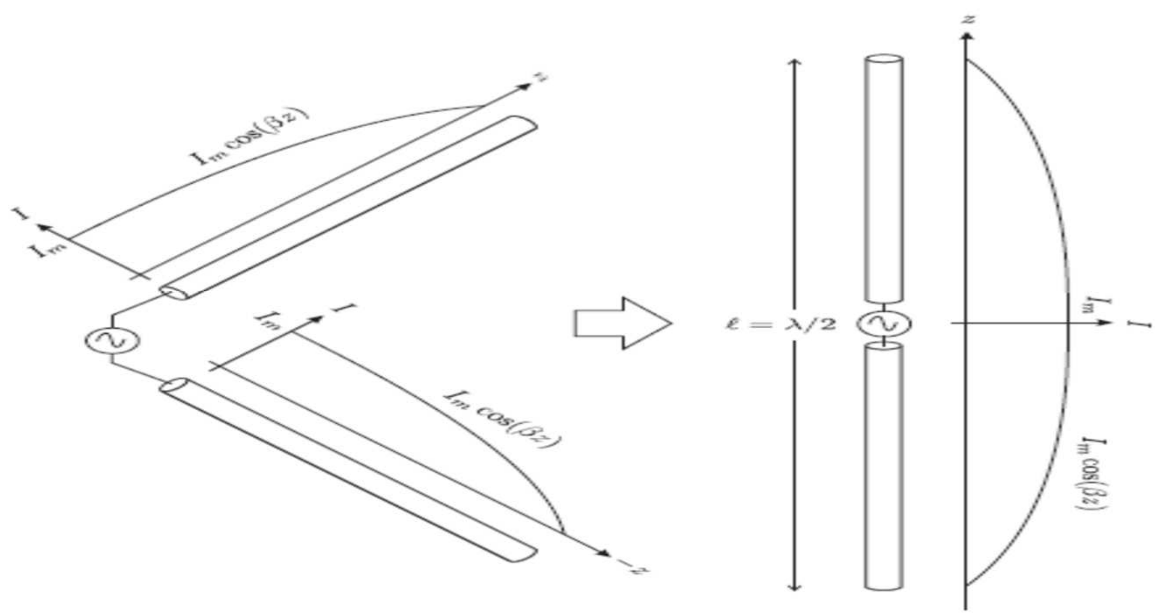
Radiated Fields

If we think about an open-circuited transmission line made of two wires, we imagine a sinusoidal current distribution set up by the standing wave along a quarter-wavelength length of line as follows:



Radiated Fields

Note that there is no current at z = λ/4 as required by the open circuit boundary condition. Now, if we “open" up the transmission line, we can essentially create a dipole that is half a wavelength long:



Radiated Fields

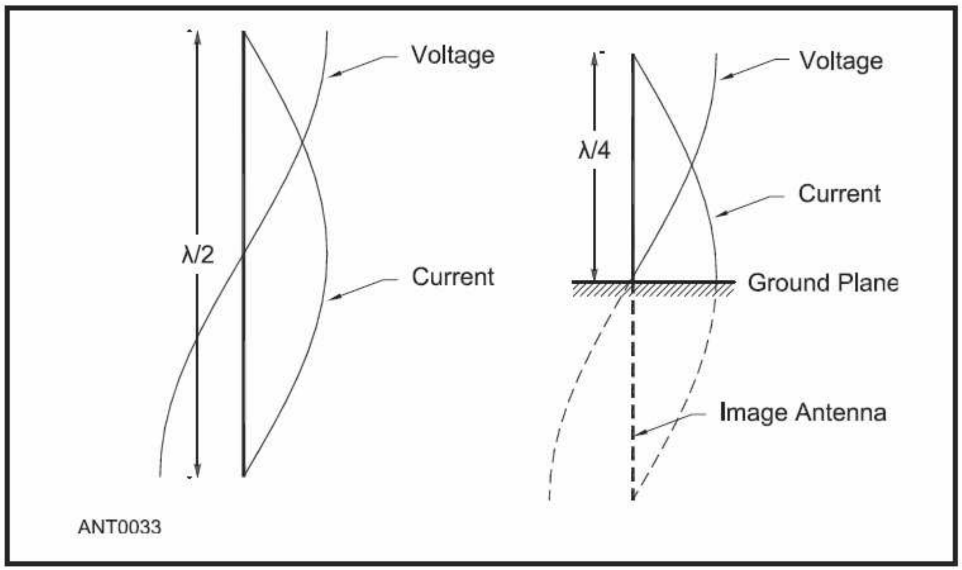


Figure 2.25 — The λ/2 dipole antenna and its λ/4 ground-plane counterpart. The "missing" quarter wavelength is supplied as an image in "perfect" (that is, high-conductivity) ground.

Dipole Impedance

For the input impedance, we anticipate both a real and imaginary part, since the near-fields of the dipole will contribute to a reactive component. The input resistance can be found as follows:

Then,

$$R_{rad} = 2W_{rad}/\mathrm{Im}^2 = 73.1280 \text{ Ohms}$$

The calculation of the reactive part of the input impedance is much more involved and beyond the scope of the discussion here. The final result for the dipole's input impedance is

$$Z_{dipole} = 73 + j42.5 \text{ Ohms}$$

Dipole Impedance

That is, the input impedance of the dipole is slightly inductive. However, there exists a “resonance“ frequency where the imaginary part of the dipole's input impedance goes to zero. This occurs at a slightly lower frequency and produces:

$$Z_{dipole} = 70 + j0 \text{ Ohms}$$

which is a useful operating point for the antenna. Common coaxial lines, such as RG-59U, have a characteristic impedance of 75 and hence can readily be connected to a dipole without impedance matching, although usually one cannot feed dipoles directly from coaxial line (more on that later).

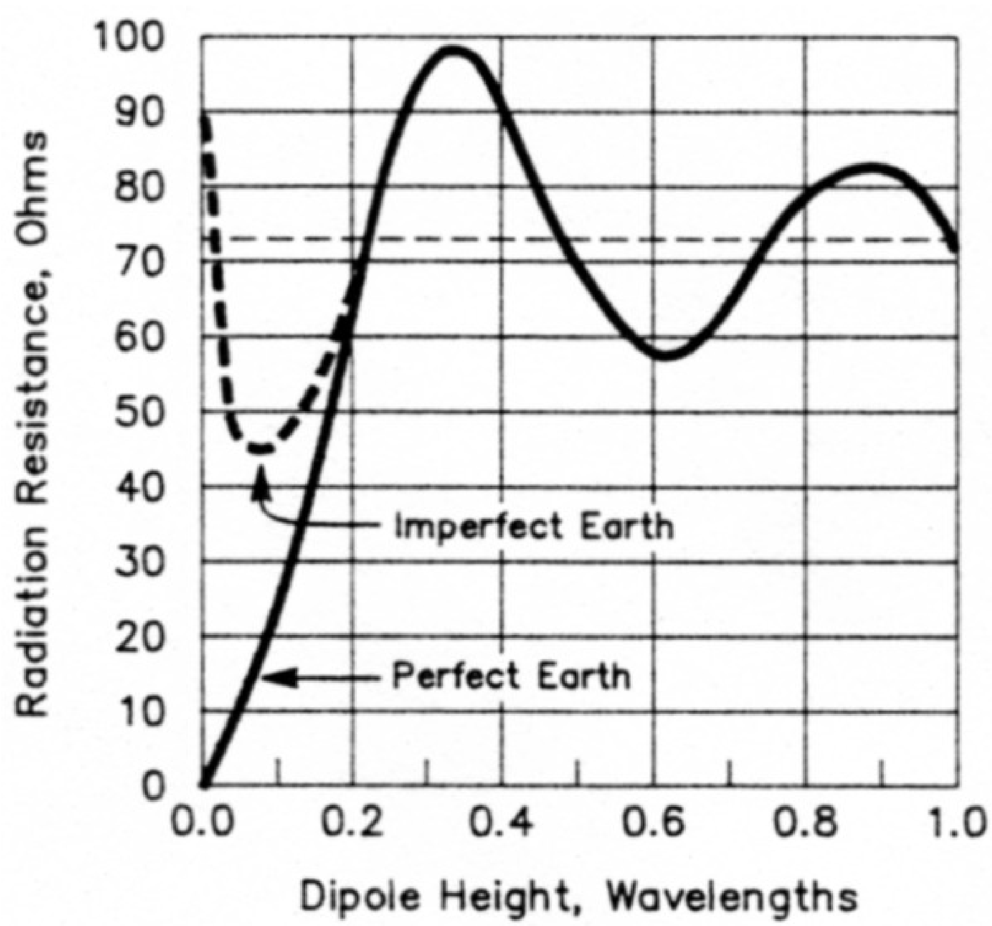
Factors that alter the dipole feed impedance

- Although the standard feed impedance of a dipole is 73Ω this value is rarely seen as the impedance is changed by a number of different factors.
- One of the major factors affecting dipoles used in the HF bands can be the proximity of the ground.
- For dipoles radiating at any frequency, if it forms the radiating element for a more complicated form of RF antenna, then elements of the antenna will have an effect. This normally lowers the impedance. It can fall to values of 10 Ω or even less. Thus it is necessary to ensure a good match is maintained with the feeder.

Dipole height above ground

- For larger dipole antennas like those used for frequencies below about 30 to 50 MHz, the height above ground can be a major influence on the feed impedance.
- At these frequencies the distance between the antenna and the ground may be only a wavelength or two in many instances. At these sorts of heights, the ground can have a major influence on the impedance, especially when the antenna is mounted horizontally as is often the case.
- It is recommended to use 1/8 to 1/4 wavelength above ground to establish a impedance near 50 Ohms to 73 Ohms.

Dipole height above ground



Formula for VSWR and reflection coefficient

Reflection coefficient Γ ,Greek letter for Gama, is defined as:

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

Z_L = The value in ohms of the load (typically an antenna)
Z_O = The Characteristic impedance of the transmission line in ohms

Calculated values are between $-1 \leqq \Gamma \leqq 1$.

Formula for VSWR and reflection coefficient

Calculated values are between $-1 \leqq \Gamma \leqq 1$.

- When value is "-1".
  Means 100% reflection occurs and no power is transferred to the load. The reflected wave is 180 degrees out of phase (inverted) with the incident wave.
- When value is "1".
  Means 100% reflection occurs and no power is transferred to the load. The reflected wave is in phase with the incident wave.
- When value is "0".
  Means no reflection occurs and all power is transferred to the load. (IDEAL)

The VSWR or voltage standing wave ratio

$$VSWR = \frac{1+\rho}{1-\rho} \qquad \rho = |\Gamma|$$

- Given that ρ, Greek Letter for Rho, will vary from 0 to 1, the calculated values for VSWR will be from 1 through to infinity. ρ is the absolute value of Γ that is it is always a positive value.

- **The ideal case is when ρ is 0, giving a VSWR of 1 or a 1:1 ratio.**

VSWR of a Dipole Antenna using a 50 Ohm transmission line

$$\Gamma = \frac{73 - 50}{73 + 50} = 0.187$$

$$VSWR = \frac{1 + 0.187}{1 - 0.187} = 1.46 : 1$$

SWR	LOSS	ERP
1.0:1	0.0%	100.0%
1.1:1	0.2%	99.8%
1.2:1	0.8%	99.2%
1.3:1	1.7%	98.3%
1.4:1	2.8%	97.2%
1.5:1	4.0%	96.0%
1.6:1	5.3%	94.7%
1.7:1	6.7%	93.3%
1.8:1	8.2%	91.8%
2.0:1	11.1%	88.9%
2.2:1	14.1%	85.9%
2.4:1	17.0%	83.0%
2.6:1	19.8%	80.2%
3.0:1	25.0%	75.0%
4.0:1	36.0%	64.0%
5.0:1	44.4%	55.6%
6.0:1	51.0%	49.0%
7.0:1	56.3%	43.8%
8.0:1	60.5%	39.5%
9.0:1	64.0%	36.0%
10.0:1	66.9%	33.1%

SWR or Standing Wave Ratio is a measurement of antenna efficiency.

When using cable of incorrect characteristic impedance

The cable / transmission line used to connect the antenna to the transmitter will need to be the correct characteristic impedance Z_O. Typically, coaxial cables are 50ohms (75ohms for televisions and satellite) and their values such as RG8 or RG59 will be printed on the cables themselves. The amount of energy reflected depends on the level of the mismatch and so VSWR will be a value above 1.

What affects dipole antennas ?

- Objects near the antenna such as houses, trees, power lines, ect
- Height above ground.
- Diameter of wire used for the dipole.
- How parallel the wires of the antenna are to the ground?
- Type of transmission line used to feed the antenna such as coax or twin lead wire.

What you do to trouble shoot antenna problems?

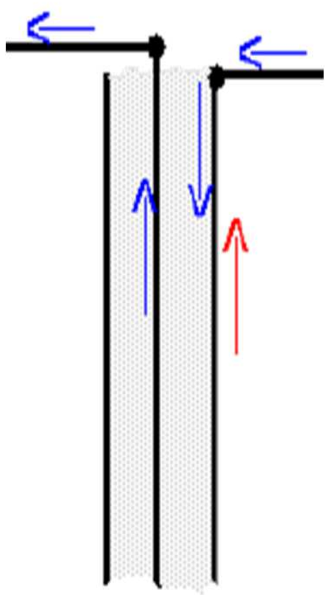
- Remember you do not get any thing for free
  - You can change the antenna feed point by changing the height of the antenna. By lowering the antenna, the feed point impedance will lower in value. This will improve the VSWR. However this will change the radiation angle to be higher.
  - If you do not have the physical space for the full length of a dipole. You have two options:
    1. You can let about 20% of the length on each end hang perpendicular to the antenna.
    2. You can add an inductor to each side of the dipole to electrically shorten it.

What you do to trouble shoot antenna problems?

- The type of transmission line you used to drive the antenna may cause issue in your radio room.
- Adjust the length and type of the coax to minimize the dB loss per foot.
- Coaxial cable, the most common feedline, delivers energy to an antenna in an unequal or "unbalanced" state. RF energy is delivered to the antenna along the center lead and inside the shield wire. In a perfect system with a 1:1 SWR there will be no current flowing on the outside coax shield at all. All RF power from your transmitter is radiated away by the antenna. However, antennas are seldom perfect and quite often there is current flowing on the shield of the coax.

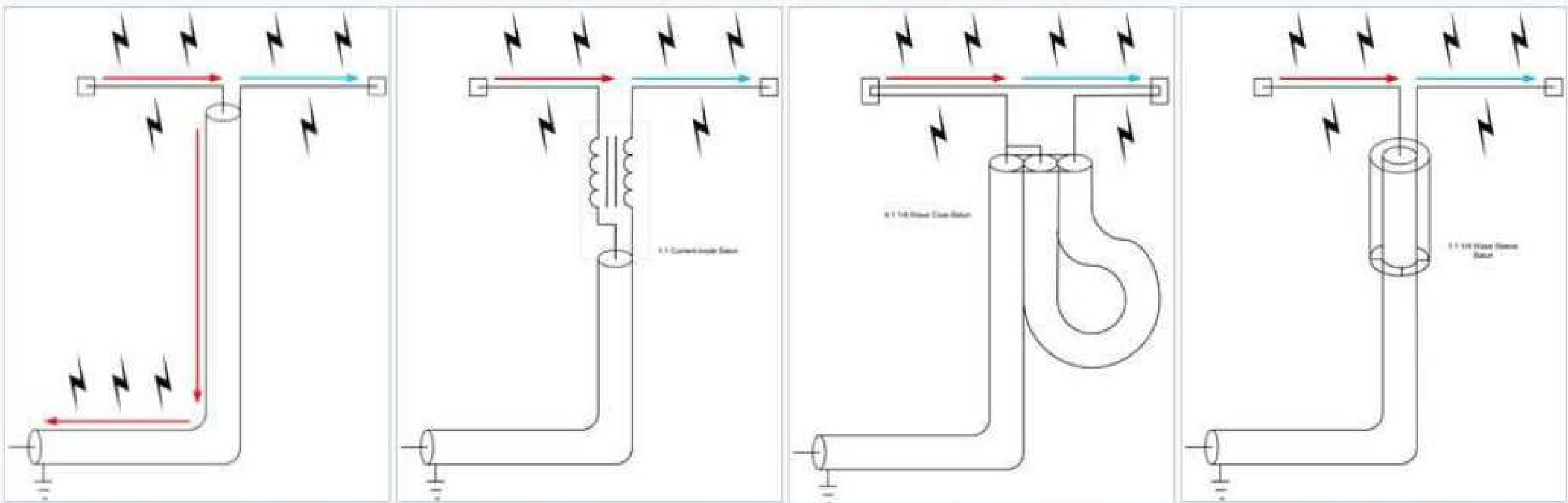
What you do to trouble shoot antenna problems?

- The worst of these conditions occurs when feeding a balanced antenna such as a dipole or loop antenna with coax. This is a natural mismatch in feed methods --balanced antenna : unbalanced feedline-- that just begs for problems.
- The illustration on the right shows the end of a piece of coax where it connects to a dipole antenna. The arrows represent a moment in time.
- The blue arrows represent antenna currents. If the antenna cannot get rid of all of the RF energy current will flow on the inside of the coax shield. This is normal and in this condition the currents are fully contained within the coax.
- However, when a balancing mismatch occurs, it is entirely possible for current to flow on the outside of the coax shield, as shown by the red arrow. This undesirable current is not contained inside the coax and can radiate from the coaxial feedline, getting into nearby electronics in very undesirable ways. This is called "common mode" current since it is actually in phase with the center lead of the coax.
- This can also happen with unbalanced antennas as well. This most often occurs where the antenna or it's support structure is not grounded or when the antenna's "ground plane" is less than adequate



What you do to trouble shoot antenna problems?

Feeding a dipole antenna with coax cable



Coax and antenna both acting as radiators instead of only the antenna.

Dipole with a current balun.

A folded dipole (300 Ω) to coax (75 Ω) 4:1 balun.

Dipole using a sleeve balun.

What you do to trouble shoot antenna problems?

- If you are having common mode current problems you will notice the SWR of your antenna system changing during a rain storm or when the coax is moved or touched. You hear frying (like bacon frying sound) noise on the receiver. In severe cases, touching your radio equipment can affect the SWR of your antenna. A very simple way to test for common mode currents is to suspend your coax away from the antenna's support structures, take a reading and then see if the SWR changes when you place it against the support structures.

Solutions for antenna problems

1. An antenna system would ideally should be a tuned system that is the feed line should be multiples of ½ wavelength and the antenna height and length of the dipole should be ½ wavelength. The antenna needs to be parallel to the earth. This is not practical in most cases.
2. Shortening the antenna physically by dropping the ends or electrically shortening by added in the dipole will also affect the band width of the antenna.
3. Using a combination of different types coax and twin lead can be used to reduce the VSWR. Coax and twin lead must be sized based on power levels being used for transmission and minimize losses in the coax cable.
4. To keep RF found getting back in to your radio room, you can use a balun to prevent currents on the coax due to impedance mismatch.

Solutions for antenna problems

5. Using a few coiled up turns of coax positioned near the antenna. The choke forms an inductor with the outside of the coax shield making it an uninviting place for current to flow. (The internal signals should not be affected). The size of the coil and the number of turns is best determined experimentally; use just enough to eliminate the problem.
6. Ground plane conditions will affect the antenna performance. You may not have control of this factor.
7. Keep the antenna clear of trees and buildings if possible as these items will affect the performance and radiation pattern of the antenna. Touching tree limbs with the antenna wires especially when it is raining may short out parts of the antenna causing the VSWR to change radically.

How to electrically shorten an dipole

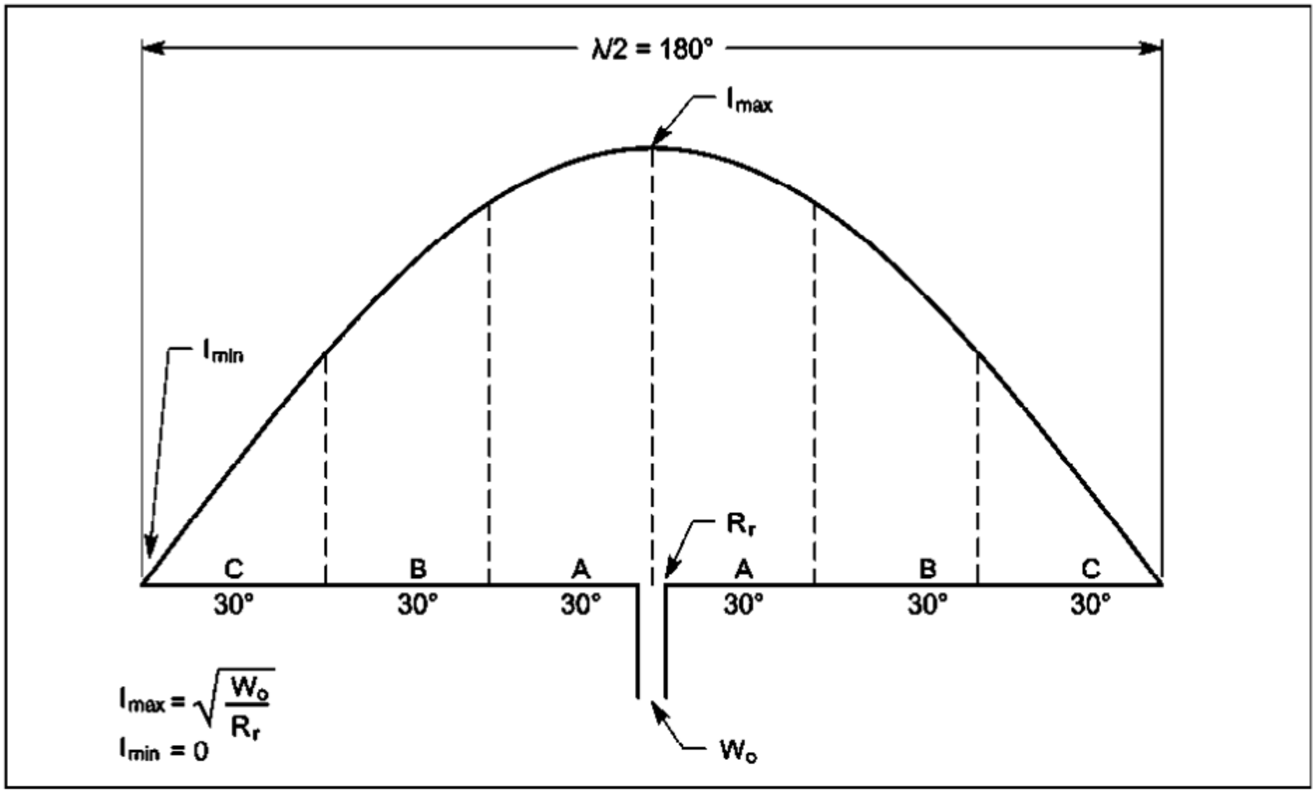


Figure 1—A half-wave dipole divided into 6 elements of 30° each. The sinusoidal current distribution is shown above the antenna.

How to electrically shorten an dipole

- To electrically shorten the dipole, observe at the 30 degree angle an impedance value is calculated and at the 60 degree angle a second impedance value is calculated. The difference between these two impedance values is used to determine the value of an inductor to be used in place of the wire between the two angular impedance values.

How to electrically shorten an dipole

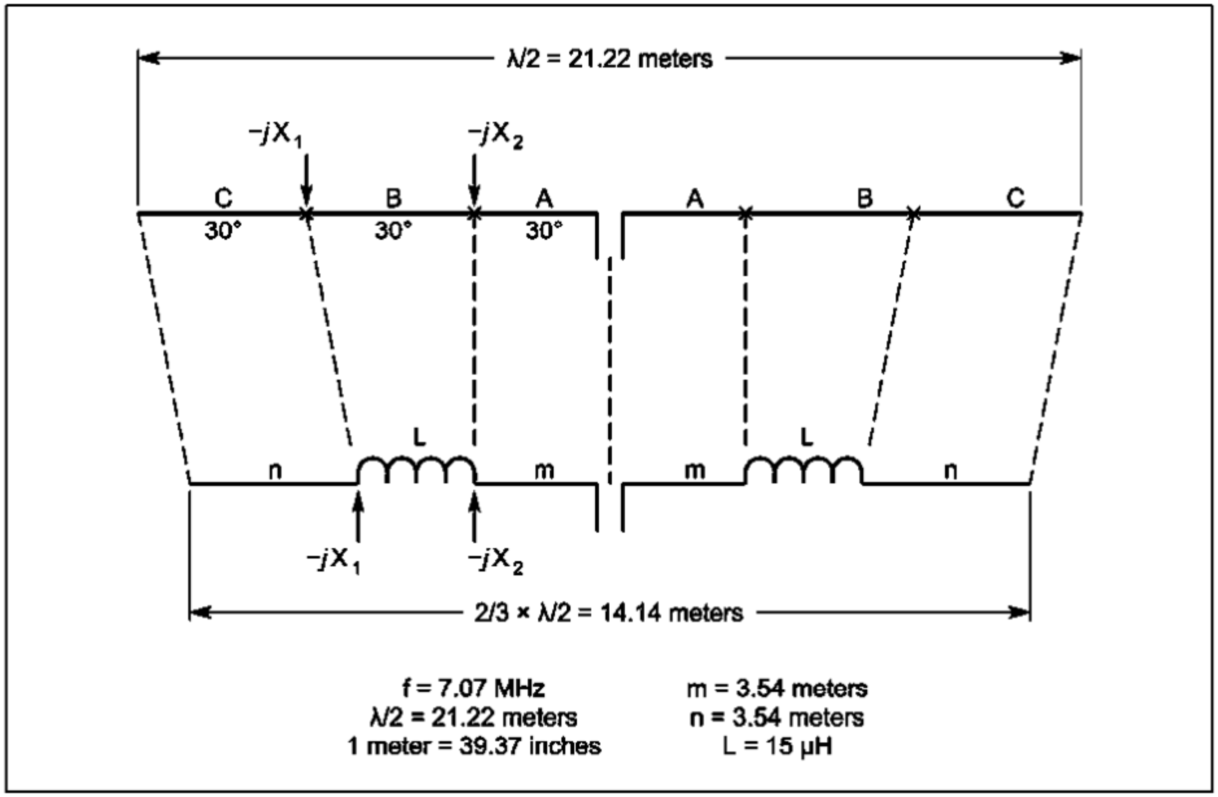


Figure 2—The first shortened example. A half-wave dipole reduced to ²/₃ of its normal length.

How to electrically shorten an dipole

Half Wave = 180 degrees   Quarter Wave = 90 degrees

Section B is the antenna section to be shortened by using an inductor.

The -j X1 and -jX2 represent capacitance for the section being shortened. In order to do this an inductor is made which cancels the capacitance for the section B.

Two formulas are used for determining the inductor value:

X = -jZo Co-tangent(Beta)   or   x= -j*Zo*cot(Beta)

Zo = 138 * log(4*h/d)   h is the height of the antenna above ground in meters.
d is the wire diameter used to make the inductor in millimeters.

-JX1= -j*Zo(Cot(X1 in degrees))

-JX2= -j*Zo(Cot(X2 in degrees))

XL= -JX2 -(-JX1)   =>   XL = jX1 - JX2

X1 = -j*Zo*(Cot(X1 in degrees))
X2= -j*Zo*(Cot(X2 in degrees))

X1 is greater than X2

How to electrically shorten an dipole

Calulations:												
Resonance_Freq		7.07	Mhz									
Wire_Length		21.21641	Meters	69.5898161	Ft	0.110509	Resistance	12 Gauge Wire	0.001588	Ohms/ft		
Height of Antenna		34.79491	in Feet	1/2 wave length at feedpoint								
Wire Diameter		2	millimeter									
Zo		597.0654	Ohms									
X1 angle		30	Degrees		n length	3.536068	in meters		0.005615	Resistance		
X2 delta angle		30	Degrees		m length	3.536068	in meters		0.005615	Resistance		
					Inductor Calculations							
-JX1		1034.148	Ohms		a	2	Form Diameter in inches					
-jX2		344.7159	Ohms		b	4	Form length in inches					
					n	27	Number of Turns					
jXL		689.4317	Ohms			339.292	wire length		1.077591			
									1.088822			
Coil Inductance		15.52001	uH		Inductor	14.87755	uH		Antenna Length	14.14427157	meters	
Center Spacing in ~ 3 inches between the two elements									Rr	50		Radiation resistance
									Rf	1.088821965	Ohms	Equivalence Resitance of all losses
									n	97.86876674	%	Antenna system efficiency