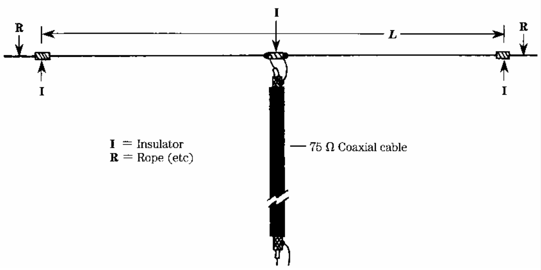
Fundamental parameters of antennas

Half wave dipole antenna



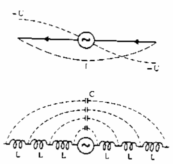
Antenna length

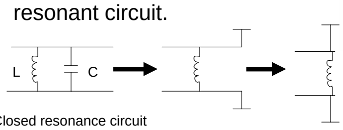
- In free space waves travel at a constant velocity of 300.000.000 meters/second.
- The RF energy on an antenna moves at a velocity considerably less than that.
- Because the antenna has dielectric constant greater than that of free space.
- A dielectric constant greater than 1 retards electromagnetic-wave travel.
- The difference in velocity changes the physical length of a half wave dipole antenna.
- The physical length differs about 5 % from the electrical length.
- This velocity difference must be taken into account when designing an half wave dipole antenna.

Electrical length: $l_e = \frac{\lambda}{2}$ Physical length: $l_m = \frac{\lambda}{2}0.95$

Resonance

- The antenna is a circuit element having distributed constants of inductance, capacitance and resistance.
- An antenna can be seen as a resonant circuit.





Closed resonance circuit

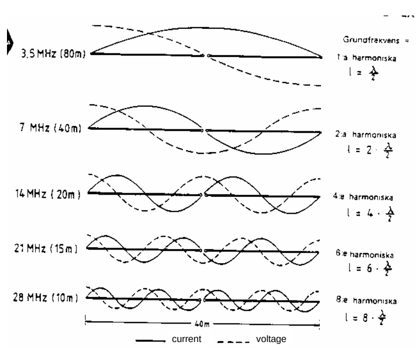
Open radiating resonance circuit

Resistive at resonance: $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$

Resonance

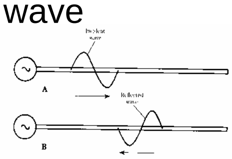
- The half-wave antenna ***is the shortest resonant length***.
- Antennas that are longer than half wave-length can also be resonant. Such an antenna is said to operate on harmonics.

Resonance harmonics



Standing wave

- The wave moving from the transmitter towards the end is called ***incident wave*** (A) and its reflection is called ***reflected wave*** (B).
- If there is only one conductor, the two waves pass each other. Electrically, the only current that flow is the ***resultant*** of both waves.
- When they ***reinforce*** the resultant is m***aximum*** and when they ***cancel*** the resultant is ***minimum.***
- In an antenna with finite length, the points where minima and maxima occurs is ***stationary***.
- Because of this effect the resultant is referred to as a ***standing wave***.



Complex voltage values for the incident wave, V_i, and the reflected wave, V_r, can be used to compute the SWR:

$$SWR = \frac{\hat{V}_i + \hat{V}_r}{\hat{V}_i - \hat{V}_r}$$

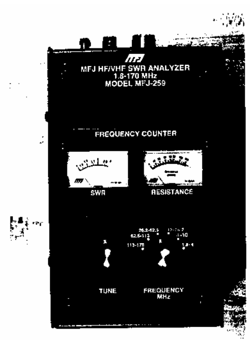
The SWR is also possible to calculate:

$$SWR = \frac{R_r}{Z_0}$$

Characteristic impedance, Z_0, and, R_r, radiation resistance

Standing wave

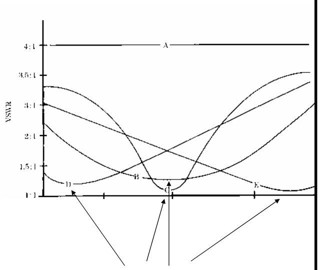
But, the most common way is to measure Standing Wave Ratio (SWR) with a SWR analyzer!



22-3 MFJ-259 VSWR analyzer.

Standing wave

- There is only one proper way to tune a dipole antenna into a specific resonance frequency.
- That is to adapt the length of the antenna elements .
- The indicator of resonance is the ***minimum point*** (not the specific value) in the voltage standing wave ratio (VSWR) diagram.



Minimum point for antennas of different length and different bandwidth.

Resistance

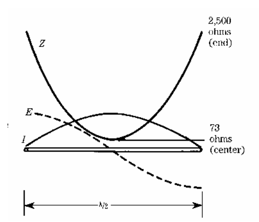
- The current flowing in the antenna must contend with ***three kinds of resistances***.
- ***Radiation resistance***, R_r, with the antenna considered as a radiator of energy, the power expended in the form of radiation can be thought of as an I^2R_r loss.
- ***Ohmic resistance***, R_0, with the antenna considered as conductor, a certain amount of energy is dissipated in the form of heat, I^2R_0 loss.
- ***Leakage resistance,*** R_l, of dielectric elements, such as insulators, I^2R_l loss. This R is usually included in the ohmic resistance

Resistance

- The purpose of the antenna is to dissipate as much energy as possible in the form of radiation.
- The energy dissipated by the radiation resistance, therefore is the useful part of the total power dissipated.
- Because the power loss depends on the ohmic resistance, this resistance should be kept as low as possible.
- In the half-wave antenna, the radiation resistance is large compared to the ohmic resistance, the half-wave antenna is therefore a very efficient radiator.
- When a half-wave antenna is fed at the center point the radiation resistance is equal to 73 ohm, the reference point is the center of the antenna at the time of peak current flow.
- The resistance is important in matching the antenna to a transmission line.

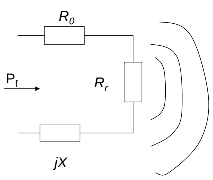
Impedance

Because the half-wave antenna has different conditions of voltage and current at different points, and impedance is equal to the voltage across a circuit divided by the current through it, the impedance will vary along the length of the antenna.



The ***impedance***, $Z_0=R+jX$, consists of both ***resistance*** and ***reactance***. If the antenna is cut to a length of exact ***resonance*** the ***reactance part is zero***, the impedance is ***purely resistive***. When the antenna is made ***shorter***, ***capacitive reactance***, $-X$, is present; when the antenna is made ***longer***, ***inductive reactance***, $+X$, is present.

Impedance



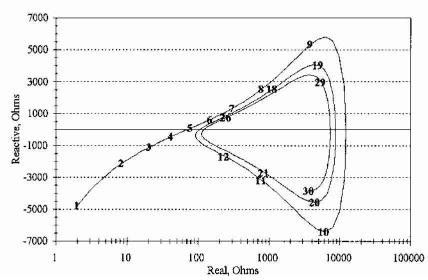
R_0=ohmic resistance (heat losses)

R_r=radiation resistance

jX= reactance mismatch between antenna and wave transmission

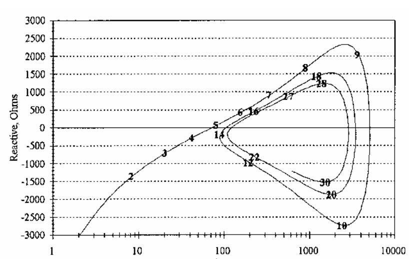
Radiated energy: $P_s=I^2R_r$

Impedance versus frequency



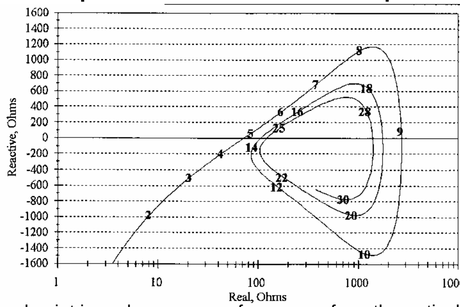
Feed point impedance versus frequency, for a theoretical 30.48 meter long dipole, made of a extremely thin wire 0.0254 mm (not realistic).

Impedance versus frequency



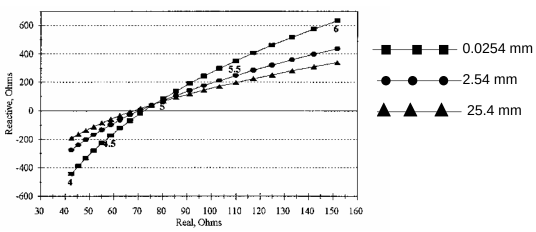
Feed point impedance versus frequency, for a theoretical 30.48 meter long dipole, made of a thin wire 2,54 mm.

Impedance versus frequency



Feed point impedance versus frequency, for a theoretical 30.48 meter long dipole, made of a thick wire 25,4 mm.

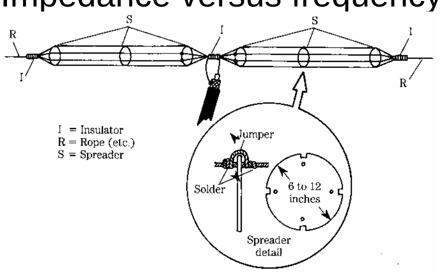
Impedance versus frequency



This graph shows an expanded portion of the frequency range around half wave resonant frequency, 4 to 6 MHz.

In this region the shape of each spiral curve is almost a straight line. The slope for a thin antenna is steeper than for a thick antenna, indicating that the antenna have a broader usable range around resonance frequency.

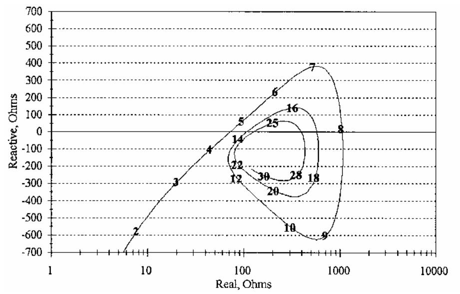
Impedance versus frequency



6-12 Cage dipole.

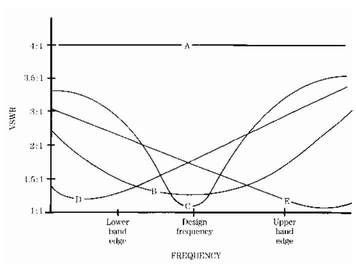
The idea of the ***cage dipole*** is to create a virtual cross sectional area that is large to create an antenna with wide-bandwidth properties.

Impedance versus frequency



Feed point impedance versus frequency, for a theoretical 30.48 meter long dipole, made of a cage dipole 254 mm, simulating a fat conductor.

Impedance versus frequency



A. Disaster antenna, high VSWR all across the band of interest.
B. Broadband antenna, matching resonance frequency.
C. Small band antenna, matching resonance frequency.
D. Resonant outside the band of interest
E. Resonant outside the band of interest.

Antenna directivity and gain