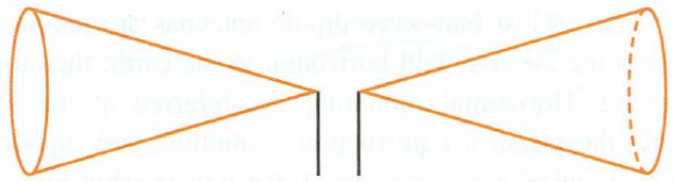
# DIPOLE ANTENNA VARIANTS

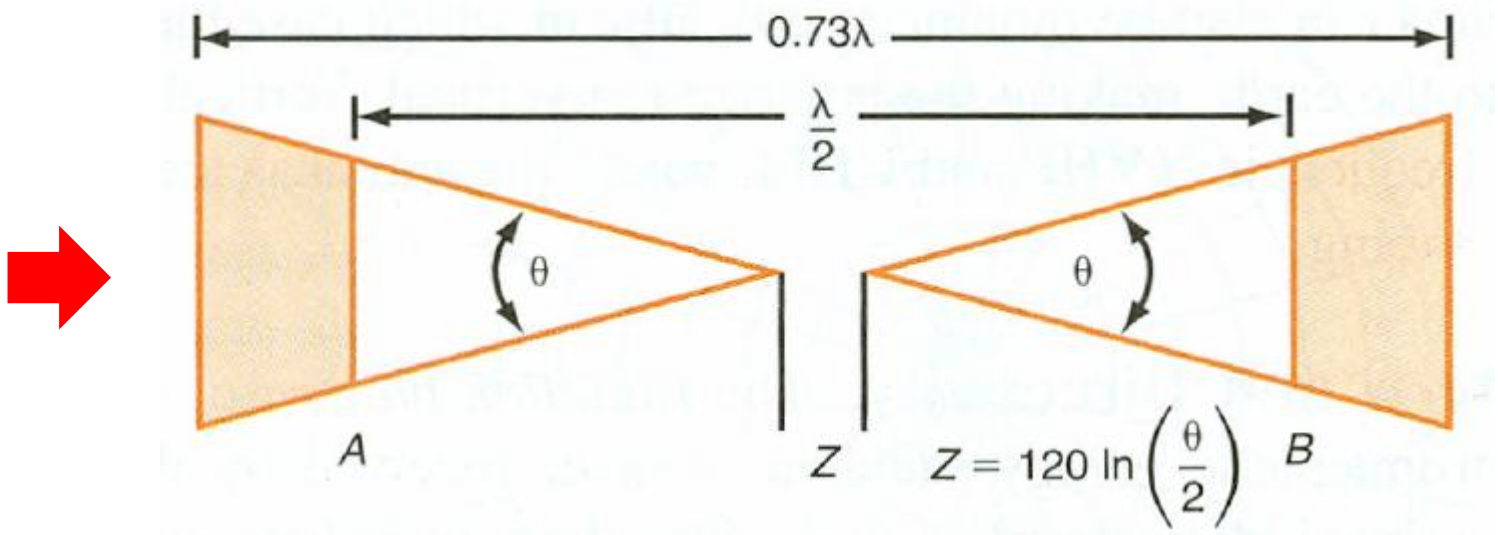
**ECE 523E – ANTENNA ENGINEERING & RADIO WAVE PROPAGATION**

**Thursday, 05 October 2023**

# CONICAL DIPOLE ANTENNA

1. In the last session, we saw that one can increase the bandwidth of a dipole antenna by using a thicker wire.
2. This technique can be extended to increase bandwidth further by using conductors that are flared further to form a conical structure.
3. Cones are shaped such that the coloured area is equal to the unshaded.





# PARAMETERS OF CONICAL DIPOLE ANTENNA

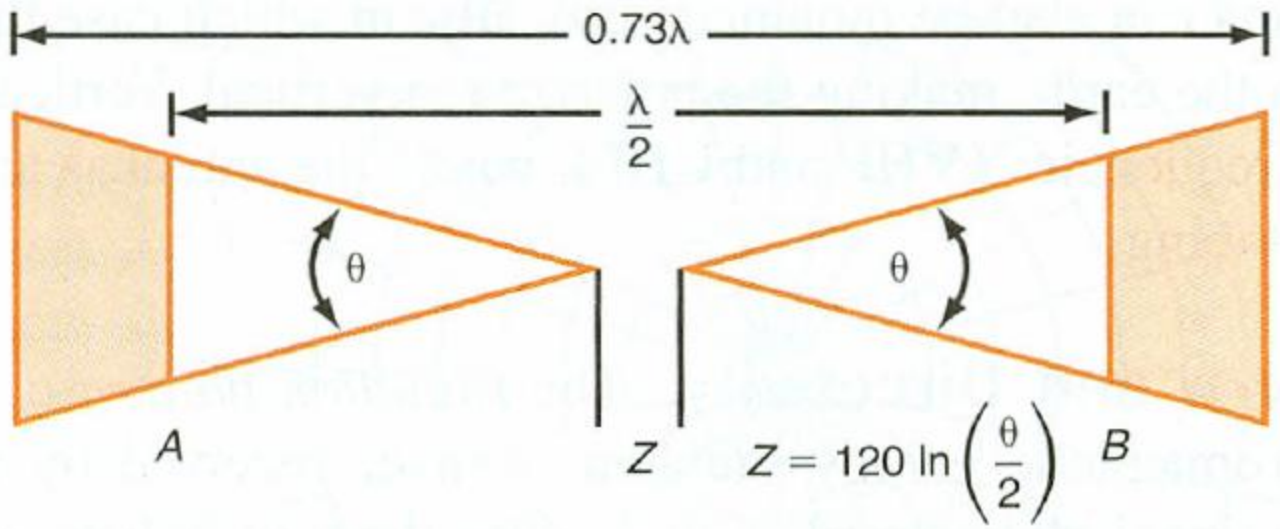
1. The centre impedance of the conical dipole at resonance is given by:

$$Z = \ 120In\left(\frac{\theta}{2}\right)$$

2. **The impedance of a conical dipole is much higher than that of a basic dipole (73 Ohms).** Therefore the antenna is connected to a coaxial cable by using an impedance matching network.

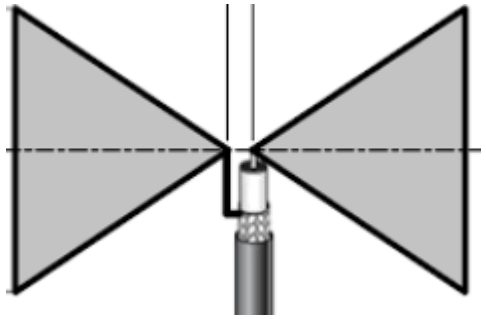
3. **Conical dipole antenna offers very high bandwidth** and can maintain a constant impedance and gain over 4:1 frequency range, e.g. 250MHz to 1GHz.

4. **Conical dipoles are expensive and difficult to manufacture.**

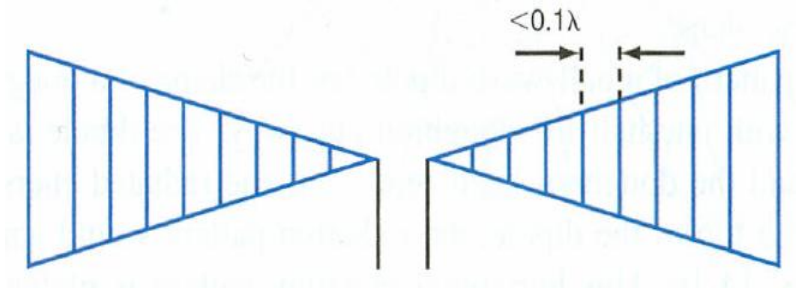


# BOW-TIE ANTENNA

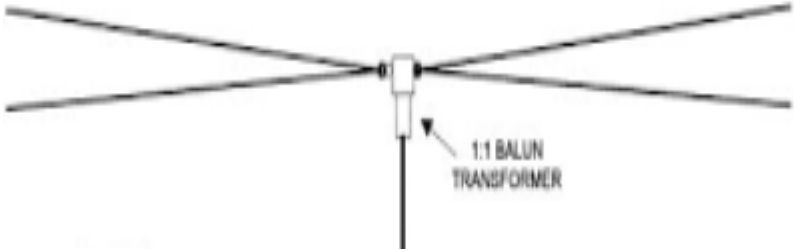
1. A **bow-tie antenna** is a two-dimensional conical dipole made in the form of a triangle or bow-tie.
2. **A bow-tie** can be made from a **flat aluminium sheet**; **grillwork of conductors** to reduce wind resistance but the spacing must be less than $0.1\lambda$; or wires without a grill.



**(a) Aluminium sheet bow-tie antenna**




**(b) Bow-tie antenna with grill**

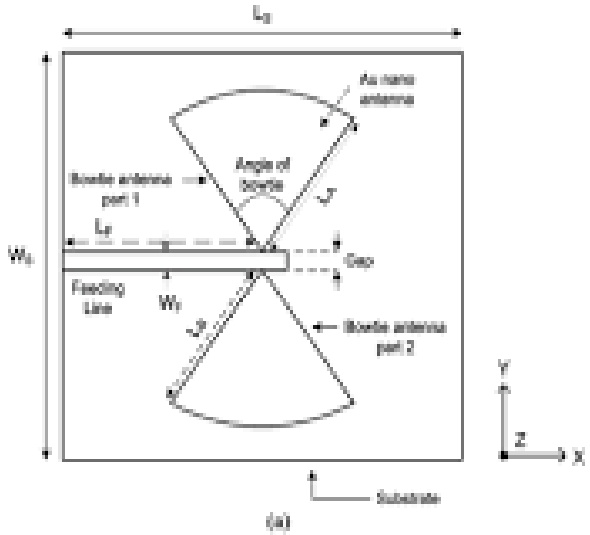



**(c) Bow-tie antenna made from rods without grill**

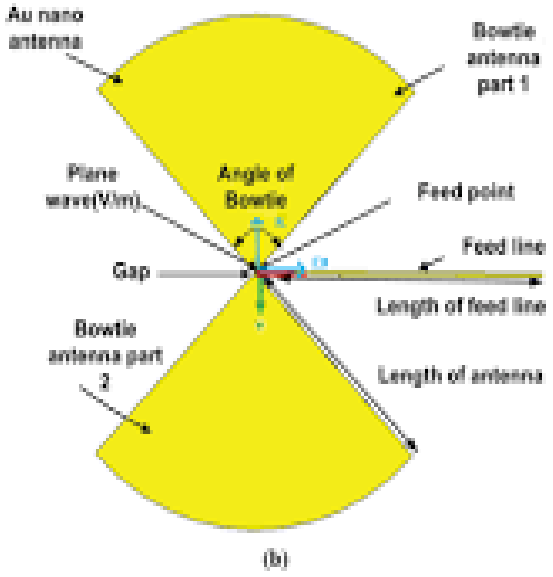
# WHY DO WE NEED BOW-TIE ANTENNAS?

1. **Dipole Antenna** antenna design is specified by the length - the length should be equal to a half-wavelength at the frequency of interest.
2. Hence, if you want your antenna to radiate at 300 MHz, you will design an antenna with length

$$L = \frac{1}{2} \times \frac{3\times10^8}{300\times10^6} = 0.5 \text{ M}$$

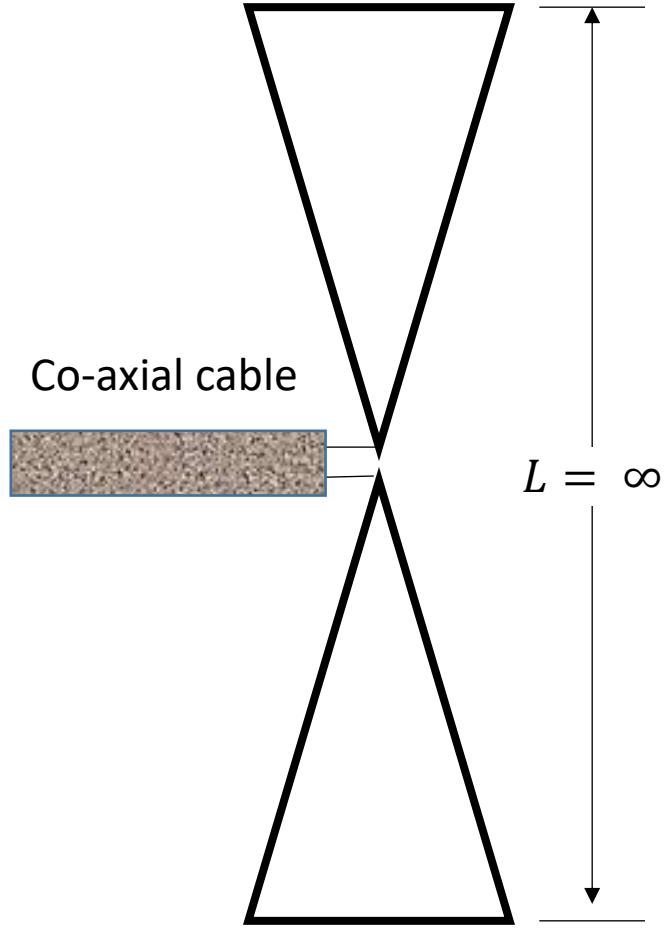



3. Suppose we also want the antenna to radiate well at 200 MHz and 400MHz?
4. The Half-wavelength dipole won't work well because it is defined in terms of length. We therefore require another type of antenna that is defined according to another variable other than length.
5. One solution is to use a bow-tie antenna that is specified in terms of angles and not length.

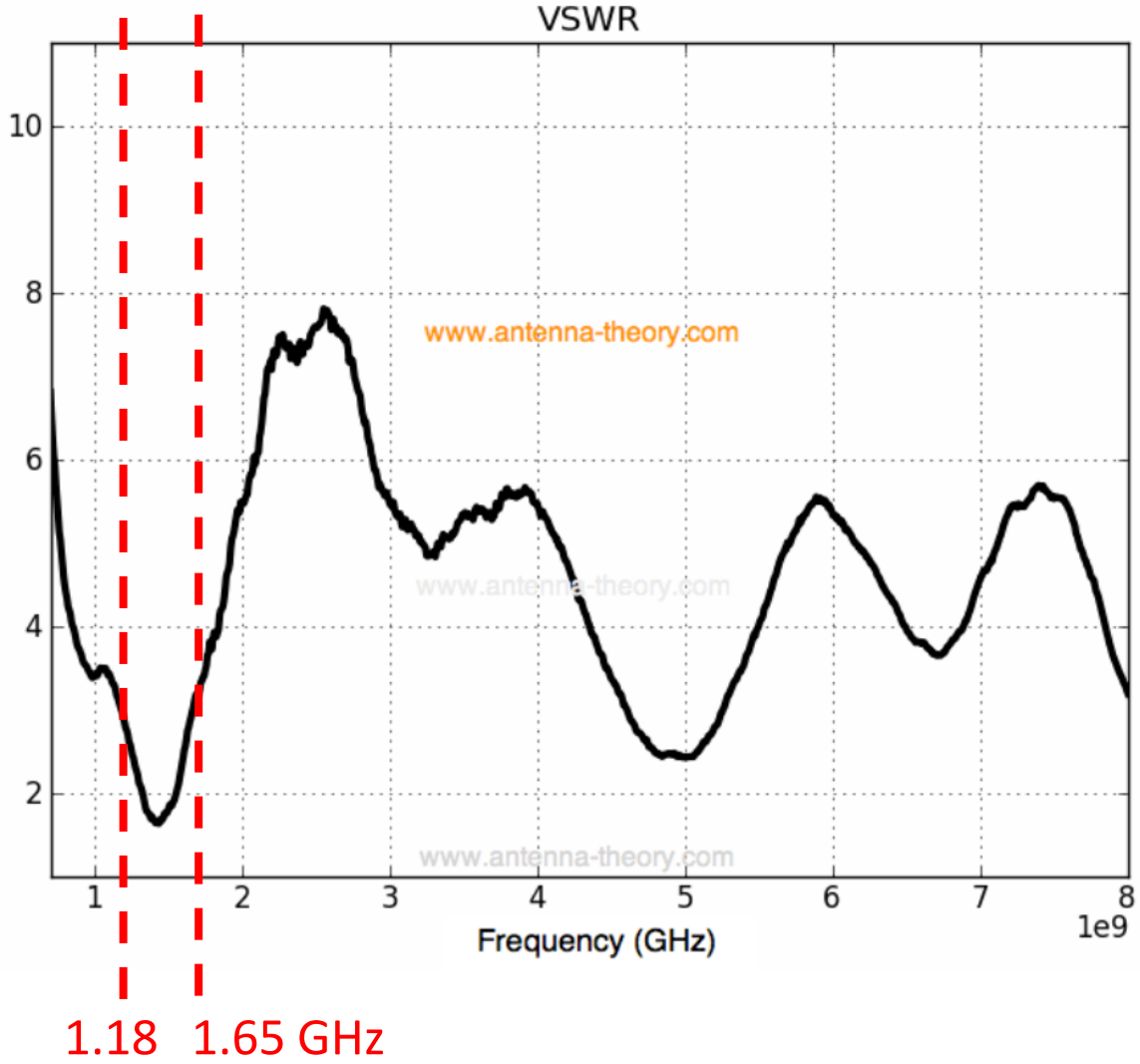


# INFINITE BOW-TIE ANTENNA

1. Infinite Bow-tie antenna is infinitely long in both directions, so that wavelength never comes into the equation.
2. Theoretically, the antenna  has an infinite bandwidth because it looks the same at all frequencies.
3. In practice, the antenna is clipped at some distance from the centre hence its name bow-tie antenna (or butterfly antenna, or a biconical antenna)



# BOW-TIE VOLTAGE STANDING WAVE RATIO (VSWR)




L=76.5mm

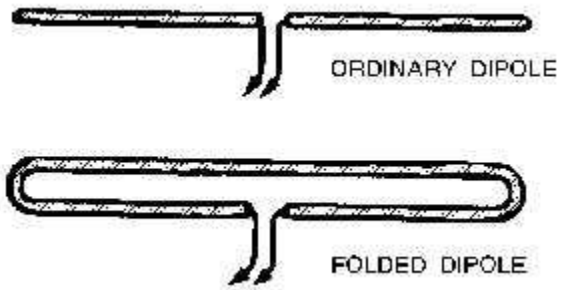
$$f = \frac{c}{2\times L} = \frac{3\times 10^8}{2\times 0.0765} = 1.96GHz$$

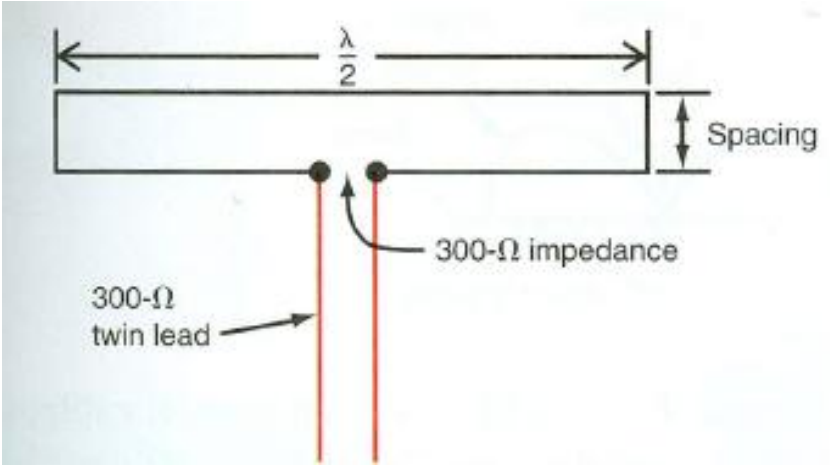
Resonance frequency, $f_c = 1.5\ GHz$

We can the half-power points
$f_1 = 1.18$ and $f_2 = 1.65$
Fractional Bandwidth $= \frac{1.65-1.18}{1.5} = 31\%$

# FOLDED DIPOLE ANTENNA

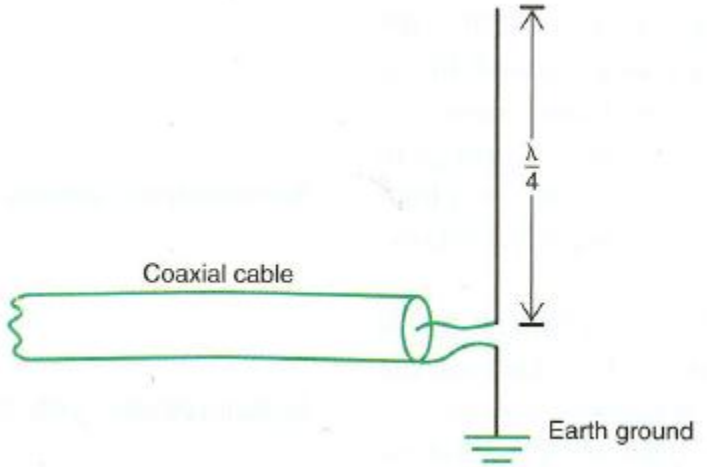
1. A folded dipole is a popular variation of the half-wave dipole.
2. The impedance of a folded dipole is 300 Ohms.
3. **The spacing between the two parallel conductors is not critical** but varies from 1” in low frequency antennas to 3” in high frequency antennas.
4. **The folded dipole offers higher bandwidth than the standard half-wave dipole.**



# ONE QUARTER WAVE LENGTH OR GROUND PLANE ANTENNA

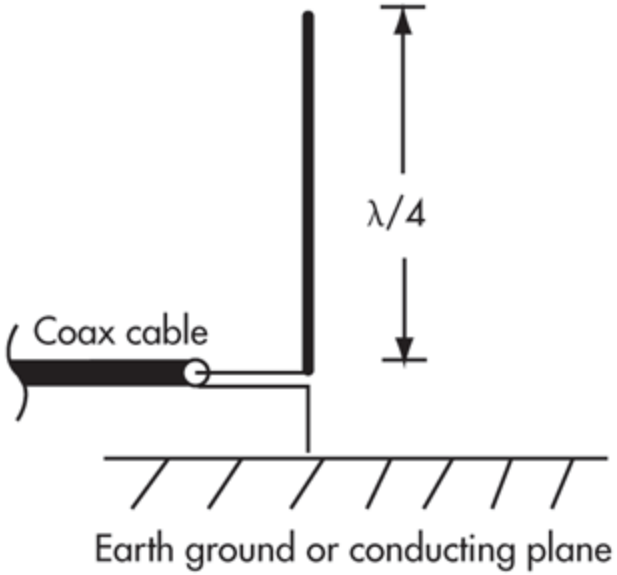
1. **The Quarter wavelength Vertical or Ground Plane Antenna** (also called Marconi Antenna) is similar to a vertical mounted dipole with the exception that it is shorter, i.e quarter wavelength.
2. **The antenna is usually fed with a coaxial cable** with the centre conductor connected to the vertical radiator while the shield is connected to earth/ground.
3. **The earth acts provides an electric mirror** which effectively completes the other quarter wavelength.
4. The result is a vertically polarized omnidirectional antenna.

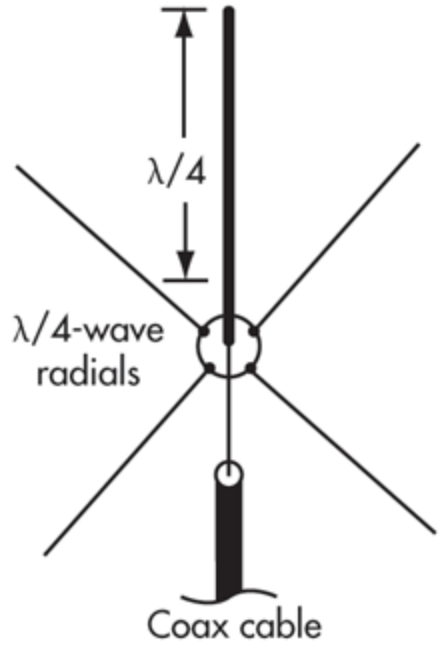


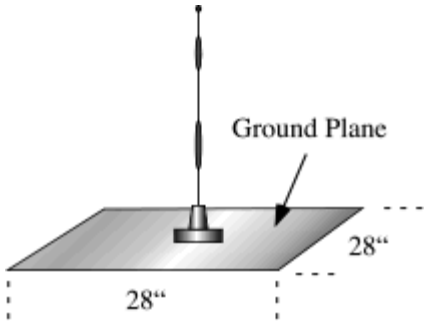



# PROVIDING A GROUND PLANE

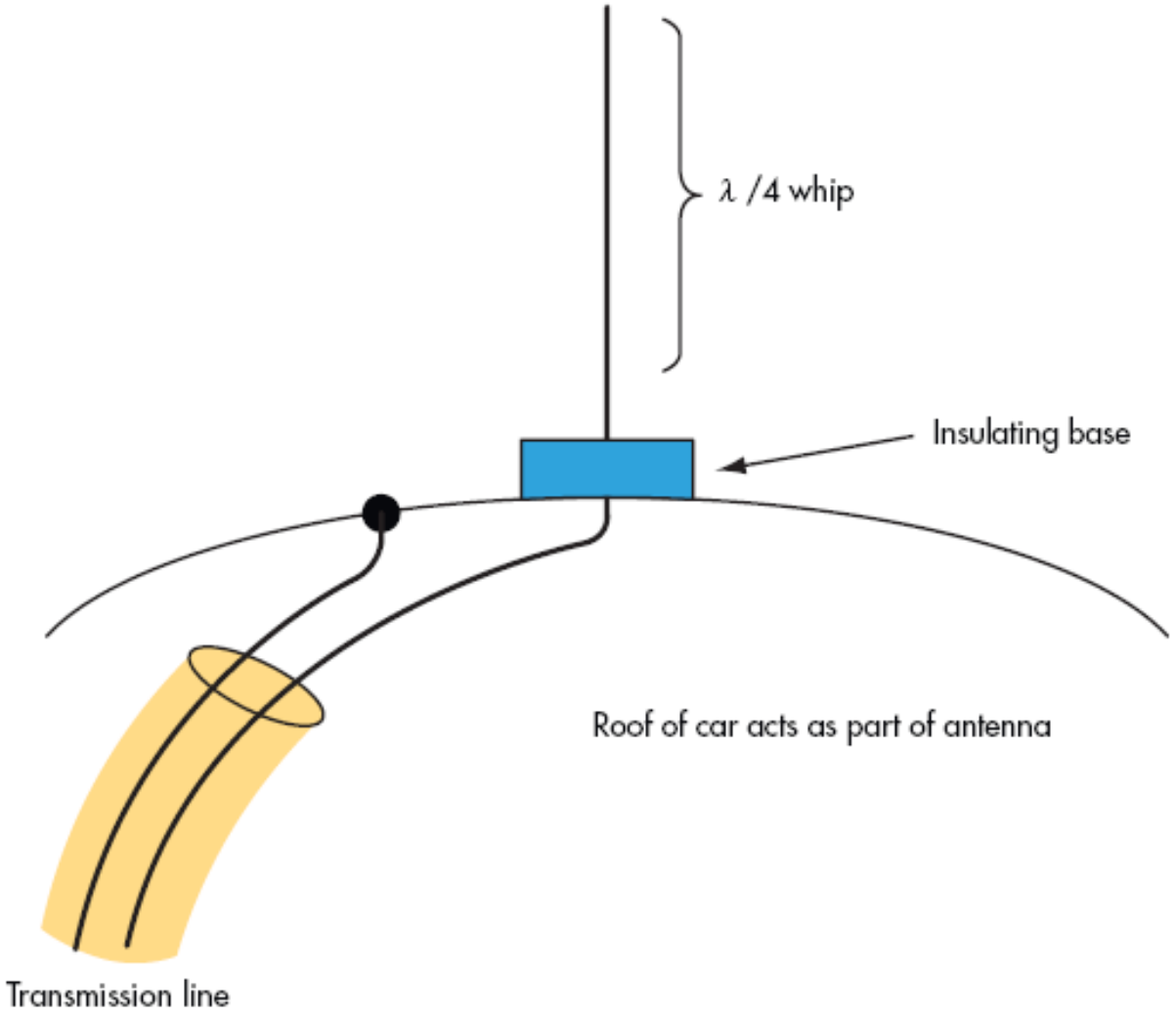
1. The effectiveness of the ground plane antenna depends on making a good conduct with the ground.
2. A good ground conduct can most of the time obtained by driving a copper rod 2 – 4 meters into the ground.
3. Where the soil has high resistance due to for instance dry soil, an artificial ground can be created by laying horizontally several quarter wavelength wires (also called radials) on or in the ground.
4. The entire ground plane collection of radials is often referred to as **counterpose**.
5. **At high frequencies**, any large flat metallic surface such as a car body can serve as an effective ground plane since the wavelength is small compared with the metallic surface.



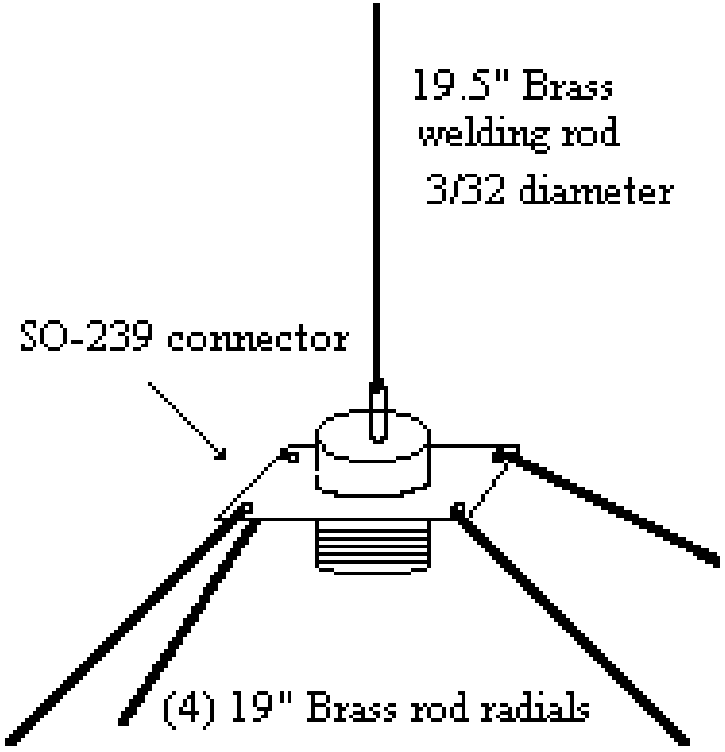



# EXAMPLE – INSTALLING WHIP ANTENNA ON A VEHICLE



# RADIATION RESISTANCE OF A GROUND PLANE ANTENNA

1. The impedance of a ground-plane antenna is one half that of the dipole, i.e 73/2 = 36.5 Ohms.
2. Just like the half-wave dipole, the impedance depends on:
   a) the height above the ground;
   b) the length/diameter ratio of the conductor;
   c) the proximity of other objects.
3. In the worst case, the impedance can drop to less that 20 Ohms for a thick conductor antenna that are close to the ground.



# BENEFITS OF GROUND PLANE ANTENNA

The benefits of a ground plane antenna are:

1. Its vertical polarization;
2. Omnidirectional radiation pattern;
3. **Reduced antenna length** especially at low frequency where for instance AM transmitting stations have shorter antennas which are short, inexpensive and not obstructive.

# TECHNIQUES FOR SHORTENING ANTENNAS

1. In many applications, it is not possible to provide antennas of a full-quarter wavelength.

2. For instance, a one quarter wavelength of an antenna for a walkie talkie operating at 27 MHz will have to be approximately 9 feet.

3. To provide shorter ground plane antennas, lumped elements (inductance or capacitance) are usually added to compensate for the shortening.

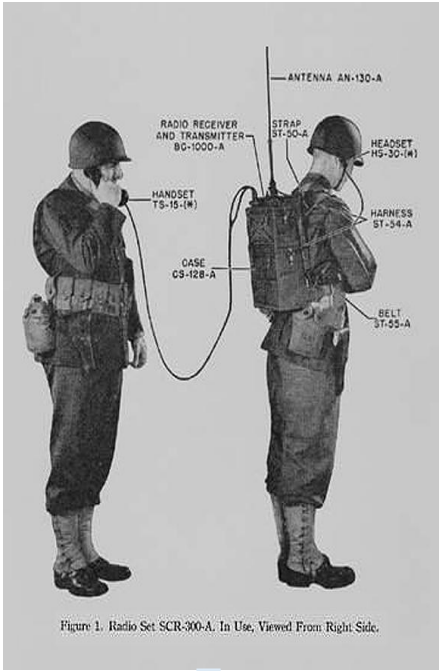
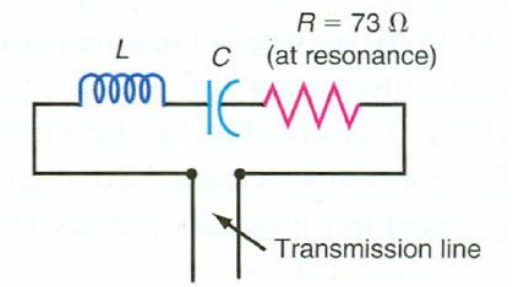


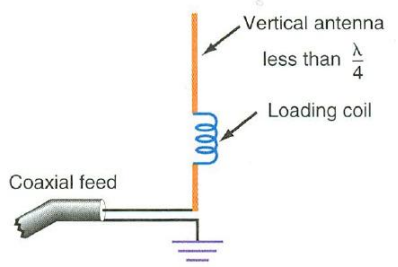
Figure 1. Radio Set SCR-300-A, In Use, Viewed From Right Side.

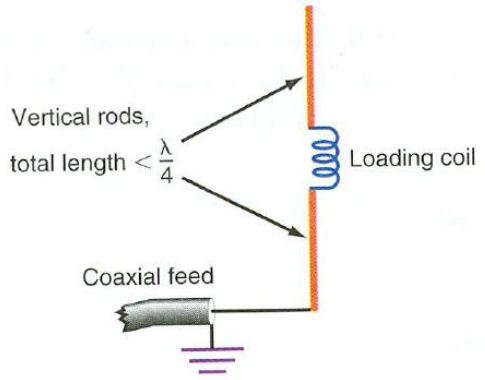


# GROUND PLANE ANTENNAS WITH LOADING COIL

1. When an antenna is made shorter than a quarter wavelength, there is a decreased inductance making the antenna to resonate at a higher frequency.
2. To compensate for this effect, a series inductor (also called a loading coil is usually connected in series with the antenna.
3. The coil can be mounted in any of the following places:
   a) At the base of the antenna, or inside a hand held unit such as a cordless phone;
   b) At the centre of a vertical conductor – used in most cellular phone antennas.
4. The coil is usually made variable so that the antenna can be tuned.



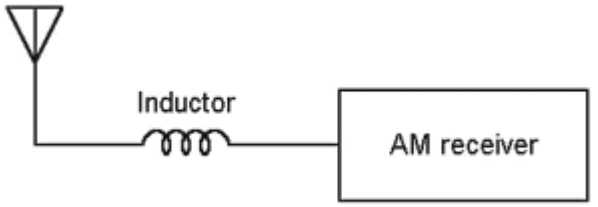



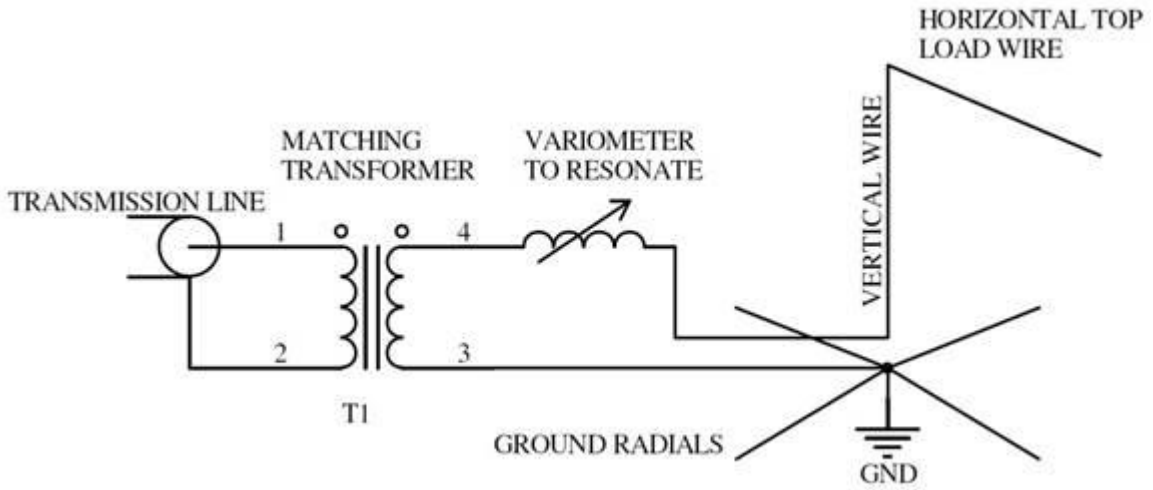
# EXAMPLES OF LOADED COIL ANTENNAS



(a) Vehicle mounted Aerial




(b) Loading Coil in AM receivers

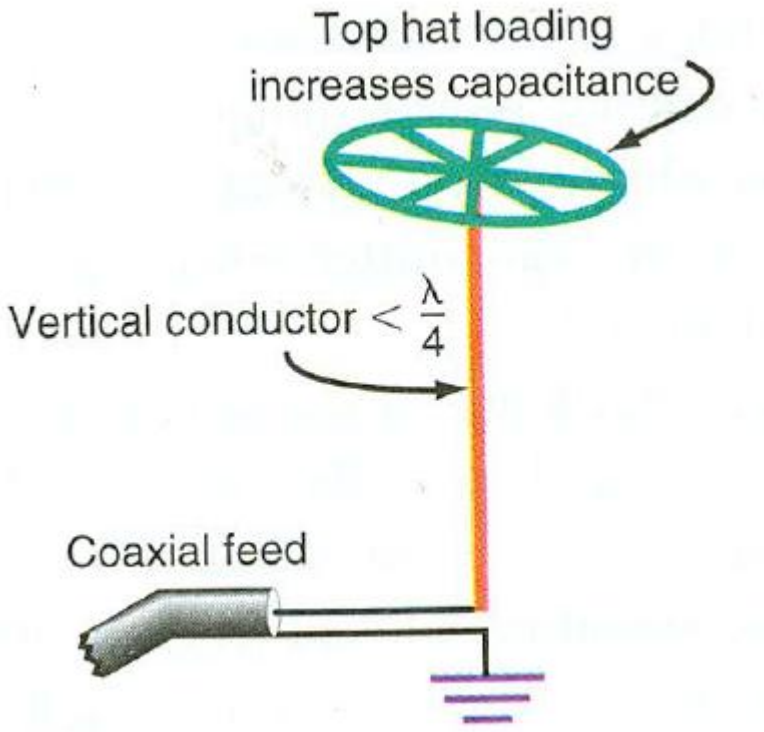



(c) Combination of inductive loading of a monopole

# INCREASING EFFECTIVE CAPACITANCE TO COMPENSATE SHORTENED ANTENNAS

1. Conductors (also called top hat) are often added at the top of the antenna to increase capacitance.

2. This arrangement is not convenient for use in portable antennas but is often used in fixed types.



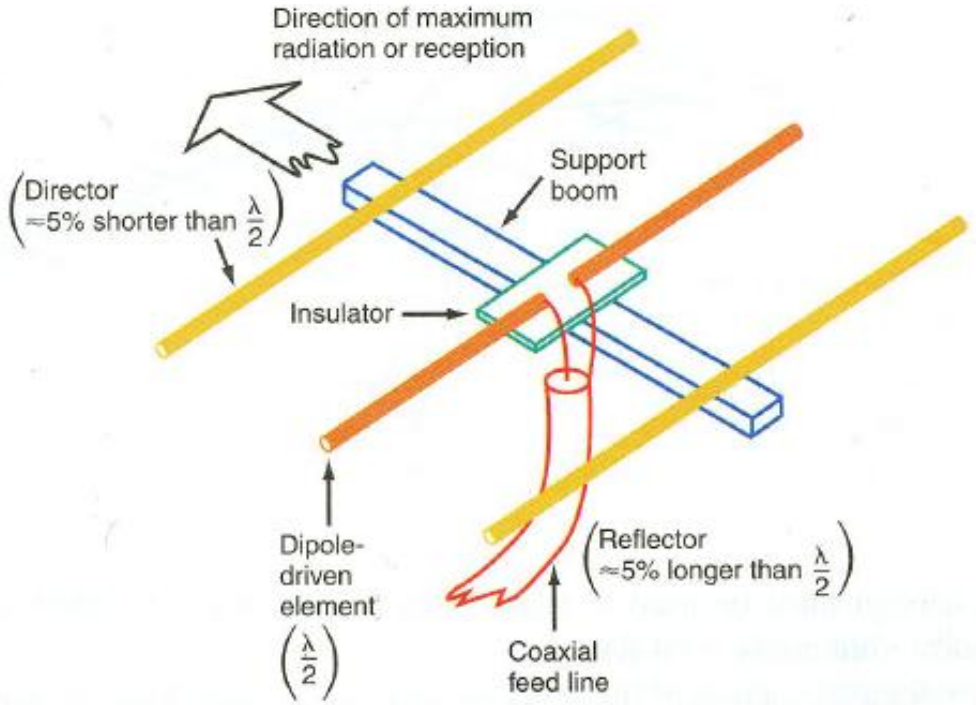
# SHORTENING OF A MAST ANTENNA USING TOP HAT

- **A mast Antenna** (or 'radiating tower') is a radio mast or tower in which the entire structure functions as an antenna.
- Mast antenna is commonly used for transmitting antennas operating at low frequencies, in the VLF, LF and MF ranges, in particular those used for AM broadcasting.
- Capacitive "top hat" is occasionally used for electrical lengthening, to allow a shorter mast to be electrically resonant.



# PARASITIC ARRAY ANTENNA

1. Parasitic array antenna consists of:
   a) The driven element usually a half dipole or some variation;
   b) Parasitic elements which are slightly longer and slightly shorter than a half-wavelength.
   c) A support boom on which all the elements are mounted.

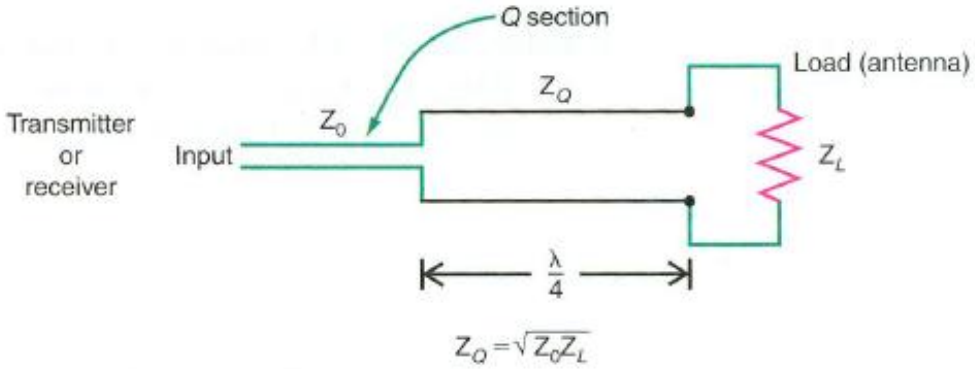


# IMPEDANCE MATCHING

1. A designer of an antenna system must ensure maximum power transfer from the transmitter to the antenna.
2. When the characteristic impedance of the transmission line matches the impedance of the antenna, the SWR becomes 1:1 and maximum power transfer occurs.
3. When impedance mismatches occur, the following can be used to correct:
   a) The length of the antenna can be adjusted to reduce SWR
   b) Impedance matching circuit such as balun, LC, L, T, or $\pi$ can be installed.
4. The ideal SWR is 1.0 but usually any SWR of below 2 is acceptable.

# USE OF Q SECTIONS FOR IMPEDANCE MATCHING

1. A **Q section** or matching stub is a quarter wavelength of coaxial or balanced transmission line of specific impedance which is connected between a load and a source for the purpose of matching impedances.
2. The Q section can be used to match one impedance to another according to the relationship:



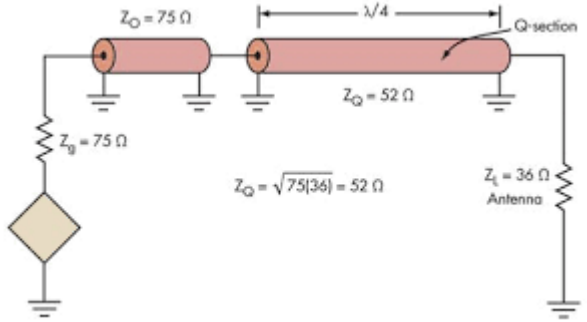

$$Z_Q = \sqrt{Z_o Z_L}$$

Where

$Z_Q$ is the characteristic impedance of the Q section

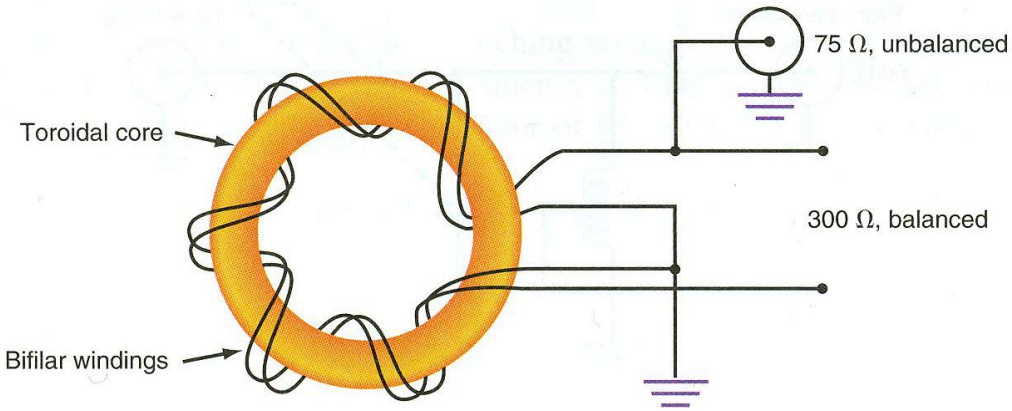
$Z_o$ characteristic impedance of the transmission line or transmitter at the input to the Q section.

$Z_L$ is the impedance of the Load

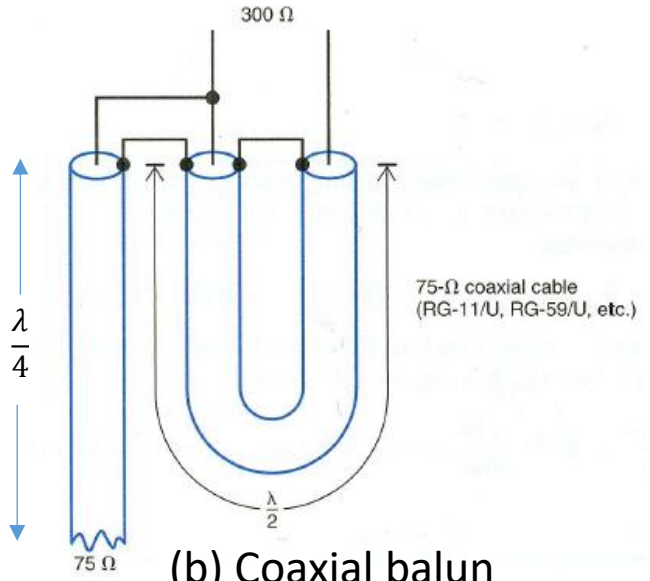


# USE OF BALUNS FOR IMPEDANCE MATCHING

1. A **balun** (**bal**ance **un**balance) is a type of transformer used for matching impedances
2. **Baluns** are usually made of ferrite core made as a toroid or rod and winding of copper wire.
3. Common impedance-matching ratios are 4:1, 9:1 and 16:1
4. Baluns can also be constructed from one-half wavelength coaxial cable



(a) Toroidal balun



(b) Coaxial balun

# USE OF ANTENNA TUNERS

1. **Antenna tuner** is a variable inductor, one or more variable capacitors or a combination of these components.
2. L, T or $\pi$ are the most commonly used antenna turners.

