Feed Lines and Antenna   Exam Questions B-006-..........

-001 Feed line characteristics, characteristic impedance

- **A transmission line** (or feed line) is a specialized cable or structure designed to carry **alternating current of radio frequencies**, that is, currents with a frequency high enough that **their wave nature must be taken into account**.

- A **transmission line** can be **two parallel conductors** equally spaced along the length of the line **or a twisted pair** of conductors or a **coaxial cable** that is one center conductor wrapped around by continuous cylindrical conductor for the length of the cable.

- For **microwave frequencies**, a transmission line can even be a **hollow conductive tube** of uniform diameter called a **Wave Guide**.

- **Transmission lines are used to efficiently connect radio receivers and transmitters to the antenna system.**

<u>Types of Parallel Conductor feed lines</u>

See Question B-006-002-002

<u>300 ohm Twin Lead</u>

- used years ago to interconnect a TV antenna with the TV set.

Inexpensive and light weight.

<u>450 ohm "Ladder" Line</u>

- Popular for multi-band non-resonant HF "doublet" antenna.
- **Low loss under high mismatch (HI SWR) situations**

600 ohm "Open Wire" Line

- Also popular for multi-band non-resonant "doublet" HF antennas.

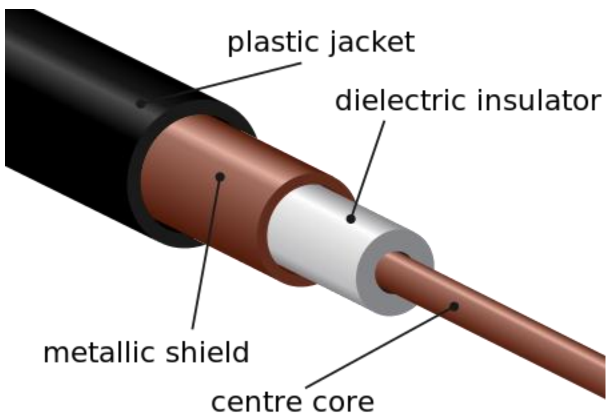
- Usually home made using plastic insulating "spreaders" and wire conductors. **See Question B-006-002-003 and -011 .**

- **Very low loss even under high SWR conditions**

- Made with 16, 14 or 12 AWG wire; handles high power very well.

Coaxial Cable

- A Coaxial Cable (or Coax) is a type of transmission line that has an inner conductor surrounded by a tubular insulating layer surrounded by a tubular conducting shield. Coaxial cable differs from other "shielded cable" used for carrying lower frequency audio signals in that the dimensions of the cable are controlled to give a precise, constant conductor spacing which is needed for it to function efficiently as radio frequency transmission line. **See Question 006-002-001**

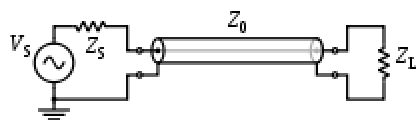


- Common types have 50 or 75 ohm impedance.

- Comes in various size diameters and types depending on power handling, attenuation characteristics, and cost.

What is the characteristic impedance of a transmission line?

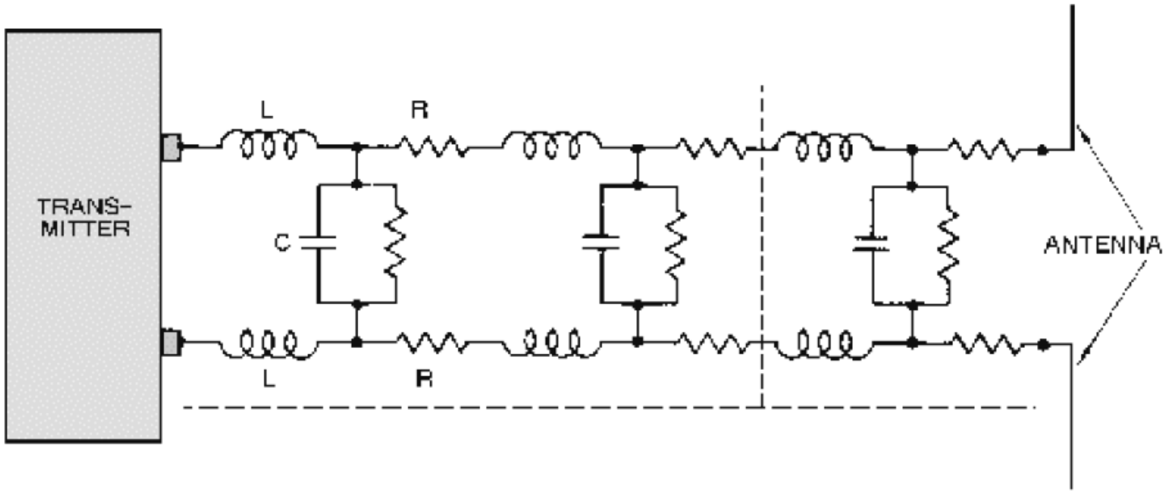
- The characteristic impedance of a transmission line is the ratio of the voltage and current of a wave travelling along the line if the line is infinitely long or if the transmission line is terminated by a load impedance equal to the characteristic impedance of the line.



- The source and load impedances above can be pure resistance and maximum transfer of power will happen provided they are both equal and equal to the characteristic impedance of the transmission line. This will be **frequency in̲dependent**. **See Question B-006-001-006**

- If the impedance terminating the transmission line differs significantly from the characteristic impedance of the line, some other value of impedance will be observed at the input of the line influenced by the length of the line. **See Question 006-001-009**

- A transmission line can be represented as the conductors of the line being a series of inductors from start to end of the line, and shunted by distributed capacitors along the line. Indeed, as well; there is slight ohmic resistance in the conductors of the transmission line as well as a very high shunt resistance from the dielectric material separating the conductors. This would give the following circuit equivalent of a transmission line be it parallel conductors or coaxial.



- Because of the progressive nature of the Transmission Line conducting the RF signal wave through it, and associated **dielectric material medium** through which the signal passes, a Transmission Line exhibits a **propagation delay**. This delay is known as the **Velocity Factor** of the transmission and is given as a **percentage (%) of the speed of light in vacuum. See Question B-006-001-007** For a transmission line to have lower attenuation, it usually has a higher Velocity Factor, all other things being equal.

"Typical" Velocity Factor of Coaxial Cable by type

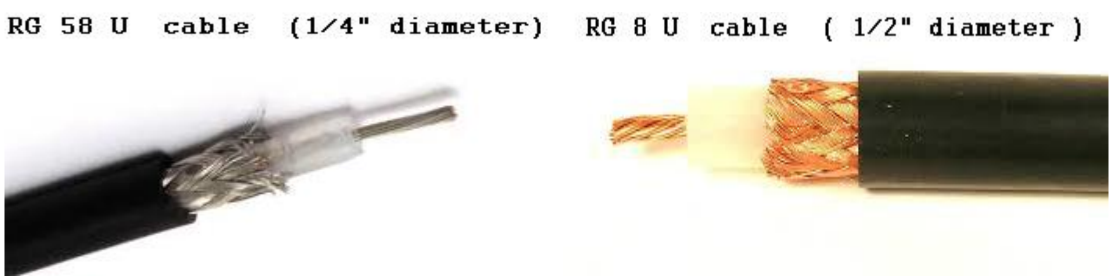
VF%	Transmission line type
95	ladder line
82	twin-lead
79	coaxial cable / foam dielectric
75	RG-6 and RG-8 coax (thick)
66	RG-58 and RG-59 coax (thin)

- Because the Inductive and Capacitive Reactance behave inversely proportional one versa the other to frequency change, the **characteristic impedance of the transmission line is independent of the frequency of the wave**. Also, the characteristic impedance of the line is not affected by the length of the line. **See Question B 006-001-003**

- In practical terms, the characteristic impedance of a parallel transmission line is determined by the diameter and separation of the conductors with minor influence by the dielectric material in between. **See Questions B-006-001-002 and -008 and -010**

- In the case of a **coaxial transmission line, the characteristic impedance** is primarily determined by the **Ratio of the Diameters** of the inner conductor and the outer shield conductor. Therefore, providing the **inner vs outer diameter ratio** is the same, many different outer diameter widths of coaxial cables can have the same characteristic impedance. **See Questions B-006-001-004 and -011**

- **<u>Parallel conductor transmission line is easily influenced by nearby metallic objects upsetting the balance in the line</u>. Coaxial cable is not so influenced** and therefore can be routed almost anywhere without affect. It can also be **<u>buried underground</u>** providing the outer plastic jacket of the cable is impervious to moisture and the chemistry of the soil. **See Questions B-006-001-005 and B-006-003-001 and -002 and -003.**



Two popular coaxial cables are RG 58, (1/4" diameter), and RG 8, (1/2" diameter). The thinner cable RG 58 has higher attenuation per unit length than the RG 8 but both have the same characteristic impedance of 50 ohms. Both these coaxial cables are flexible and have **"braided"** outer shielding conductors. **See Question B-006-002-008** .

- Different types of Coaxial Cable of different diameters may all be 50 ohm characteristic impedance. **See again, B-006-001-004**

<u>Not</u> your typical ham coax install.

Heliax Coaxial Connector Kit

- Heliax Cable is called "hard line" and is not too flexible. It is very durable and low loss and used primarily for commercial installations.

Attenuation of Transmission Lines

- Transmission Lines, be they parallel conductors or coaxial cable have power loss and proportionally, **the longer the cable, the greater the loss.**

- The **loss of the transmission line** is also proportional to the frequency of operation; the **<u>higher the frequency, the higher the power loss.</u>**

- The power loss, or **attenuation**, for a given cable type is stated at various frequencies as **<u>dB of power loss per unit length.</u>**

- **Parallel conductor feed lines generally have lower losses and a higher velocity factor.**

- Low loss coaxial cables tend to be wider in diameter, have low loss dielectric such as polyfoam, and may even use air dielectric with a spiral of insulating material to keep the centre conductor properly centred.

Common coaxial cable types used for amateur radio:

Attenuation (dB per 100 feet)

Coax Cable Signal Loss (Attenuation) in dB per 100ft*								
Loss*	**RG-174**	**RG-58**	**RG-8X**	**RG-213**	**RG-6**	**RG-11**	**RF-9914**	**RF-9913**
1MHz	1.9dB	0.4dB	0.5dB	0.2dB	0.2dB	0.2dB	0.3dB	0.2dB
10MHz	3.3dB	1.4dB	1.0dB	0.6dB	0.6dB	0.4dB	0.5dB	0.4dB
50MHz	6.6dB	3.3dB	2.5dB	1.6dB	1.4dB	1.0dB	1.1dB	0.9dB
100MHz	8.9dB	4.9dB	3.6dB	2.2dB	2.0dB	1.6dB	1.5dB	1.4dB
200MHz	11.9dB	7.3dB	5.4dB	3.3dB	2.8dB	2.3dB	2.0dB	1.8dB
400MHz	17.3 B	11.2dB	7.9dB	4.8dB	4.3dB	3.5dB	2.9dB	2.6dB
700MHz	26.0dB	16.9dB	11.0dB	6.6dB	5.6dB	4.7dB	3.8dB	3.6dB
900MHz	27.9 B	20.1dB	12.6dB	7.7dB	6.0dB	5.4dB	4.9dB	4.2dB
1GHz	32.0dB	21.5dB	13.5dB	8.3dB	6.1dB	5.6dB	5.3dB	4.5dB
Imped	50ohm	50ohm	50ohm	50ohm	75ohm	75ohm	50ohm	50ohm

*** Note:** Coax losses shown above are for 100 feet lengths. Loss is a length multiplier, so a 200 ft length would have twice the loss shown above and a 50 ft length would have half the loss. This multiplier factor is why you should keep cable installation lengths between radios and antennas as short as practical!

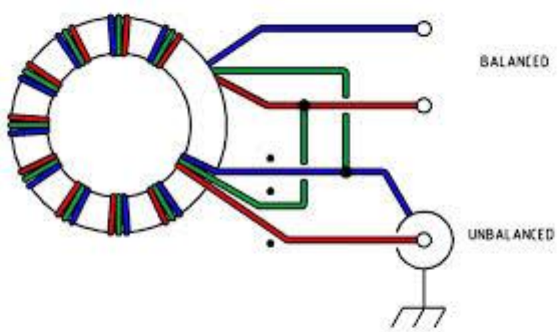
	LMR-1200	LMR-900	LMR-600	1/2" Superflex	LMR-400	Belden 9913F7	9914	RG214 RG213	LMR-240	Belden RG8X	LMR-200	LMR-195	RG-58/U
Frequency/Size	**1.200"**	**0.870"**	**0.590"**	**0.520"**	**0.405"**	**0.405"**	**0.400"**	**0.405"**	**0.240"**	**0.242"**	**0.195"**	**0.195"**	**0.195"**
30 MHz	**0.209**	**0.288**	**0.421**	**0.561**	**0.7**	**0.8**	**0.8**	**1.2**	**1.3**	**2.0**	**1.8**	**1.8**	**2.5**
50 MHz	**0.272**	**0.374**	**0.547**	**0.730**	**0.9**	**1.1**	**1.1**	**1.6**	**1.7**	**2.5**	**2.3**	**2.3**	**3.1**
150 MHz	**0.481**	**0.658**	**0.964**	**1.29**	**1.5**	**1.7**	**1.7**	**2.8**	**3.0**	**4.7**	**3.9**	**4.0**	**6.2**
220 MHz	**0.589**	**0.803**	**1.18**	**1.58**	**1.8**	**2.1**	**2.1**	**3.5**	**3.7**	**6.0**	**4.8**	**4.8**	**7.4**
450 MHz	**0.864**	**1.17**	**1.72**	**2.32**	**2.7**	**3.1**	**3.1**	**5.2**	**5.3**	**8.6**	**6.9**	**7.0**	**10.6**
900 MHz	**1.27**	**1.70**	**2.50**	**3.41**	**3.9**	**4.4**	**4.5**	**8.0**	**7.6**	**12.8**	**9.9**	**9.9**	**16.5**
1,500 MHz	**1.69**	**2.24**	**3.31**	**4.57**	**5.1**	**6.0**			**9.9**		**12.7**	**12.9**	

Balun

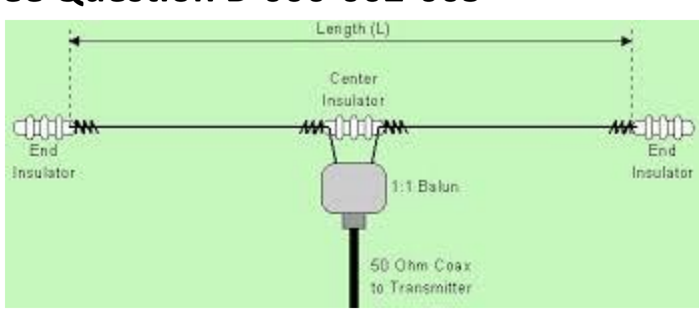
- A Balun is an electrical device that **joins a balanced line** (one that has two conductors with equal currents in opposite directions, (*such as 450 ohm ladder line*) to an **unbalanced line** (*one that has just one conductor and a shield ground, such as a* ***coaxial cable***). The term **Balun** is derived by combining ***bal**anced* and ***un**balanced*. **See Question B-006-002-004** .

- Baluns are essentially broadband RF impedance transformers. They are typically designed for 1 to 1, or 1 to 4, or 1 to 6 or 1 to 9 impedances conversions.

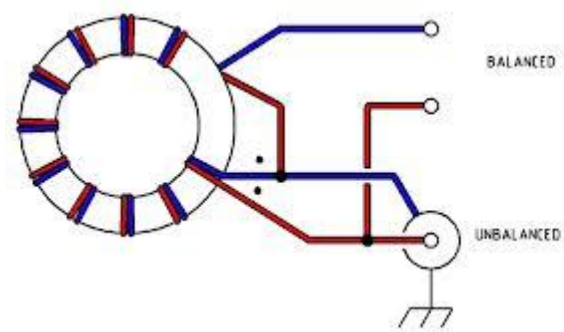
- Baluns are often wound on Toroidal powered iron cores; here is the design of a 1 to 1 Balun transformer:



- A 1 to 1 Balun can be used to some advantage to feed a 1/2 dipole antenna. **See Question B-006-002-005**



- Here is a circuit for a 4 to 1 Balun:



- The **4 to 1 Balun** could be used for impedance match a **75 ohm coaxial line to a 300 ohm twin lead transmission line**. **See Question B-006-002-010 .**

- Baluns are often part of an Antenna Tuner to provide the option of a Balanced Output to a Balanced Transmission Line.

Coaxial Connectors.

- Coaxial Connectors come in various types and sizes and have differences in terms of cost, robustness, weather and moisture tolerance and impedance continuity.

- Most HF amateur radio sets and accessories use the **common "UHF" connector** developed in WW2 era when UHF referred for frequencies above 30 MHz. UHF today means 300 MHz to 3000 MHz and the UHF connector is **not** suited for these frequencies.

- The classic **UHF coaxial "male" plug connector is the Amphenol "PL-259"** shown here with reducer:

- The PL-259 is designed to terminate the ends of RG 8 or RG 213 50 ohm coaxial cable by soldering. The PL-259 can also be fitted to smaller diameter RG 58 cable with size reduction adapters as seen above.

- PL-259 with RG 213 cable attached. **See Question B-006-003-004**

- The **mating female receptacle** for the PL-259 connector is the **SO-239 socket** as shown here:

- The SO-239 (SO for socket) is common on most HF amateur gear:

Other types of coaxial connectors:

Type N

- This is a screw-in type connector that maintains better continuity of impedance through the connection point compared to the common UHF connector. The N Type connector is therefore a good choice for VHF and UHF frequencies. The male plug has a gasket for good moisture exclusion. **See Question B-006-003-006 .**
- **Type N Female** **Mating Type N Male**

Type BNC connector

- The BNC connector is a quick connect/disconnect RF connector. It features two bayonet lugs on the female connector; mating is achieved with a quarter turn to the coupling nut. Like the N type connector, the BNC is good connector for VHF and UHF applications.

Male and Female BNC connectors

- The BNC connector was used as the antenna connector on amateur portable radio hand held equipment; this has now been superseded by the smaller **SMA** connector.

The "F" Type connector

- The "F" type coaxial connector is what we commonly see used for the domestic TV industry. The "F" connector is very inexpensive and is a threaded shell that goes on the end of coax cable using the centre conductor of the cable as the centre pin of the connector.   The TV type coaxial cable has a characteristic impedance of 75 ohms and is not used much for amateur radio.

Type SMA connector

- The SMA Type connector is sub-miniature for termination of small diameter 50 ohm coaxial cable. The SMA connector is good to frequencies up to 18 GHz.

- The SMA connector has become popular for connecting the whip antenna to amateur portable radios. **See Question B-006-003-005**

Standing Waves and Standing Wave Ratio in Transmission Lines.

- It is necessary that the source impedance (the transmitter) and the characteristic impedance of the transmission or feed line (the coaxial cable) and the load (the antenna) at the end of the cable all be the same impedance or maximum transfer of power will not occur.

- If the load impedance does not equal that of the transmission line, some of the power will be reflected back towards the source.

- In the case of a zero or infinite impedance (short or open circuit at the end of the transmission line), all of the power will be reflected back to the transmitting source. The reflected signal will be in reverse phase to the incident wave if end is shorted or in phase if the end is open.

- The degree of the reflection is determined by the amount of the mismatch of the load impedance to that of the transmission line. The resulting standing waves on the transmission line will be determined by the difference in maximum and minimum voltages of the incident and reflected waves; this will be the **Standing Wave Ratio** and can be measured with a **directional coupler** which is the basis of a Standing Wave Ratio meter instrument.

- When the **incident wave is totally reflected,** this will amount to a **1 to infinity SWR.**

- When there is an impedance mismatch between the characteristic impedance of the transmission line, the following formulas for SWR (VSWR) apply where Z_0 is the line impedance and R_L is the load impedance. Pick the formula that gives a positive number:

$$VSWR = \frac{Z_0}{R_L} \quad \text{or} \quad VSWR = \frac{R_L}{Z_0}$$

  From this, See Question B-006-005-010

Antenna Tuner and Antenna Matching

Questions B-006-006-001 to -011

- An Antenna Tuner is used to match an impedance of 50 ohms of the transceiver to that of various antennas that are not necessarily designed for the band of operation and therefore may be a much different impedance than 50 ohms.

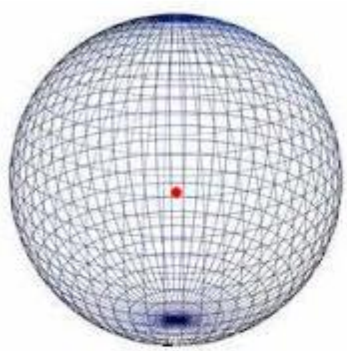
- The purpose of an **Antenna Tuner** or other impedance matching devices such as an RF impedance transformer are necessary to **<u>transfer maximum output to the antenna load</u>**.

- If the antenna is correctly matched to a transmitter, the length of the transmission line will have no effect on the matching.

- The Impedance matching ratio required of a 300 ohm antenna (for example) to a 50 ohm transceiver would be 6 to 1. This is the same as the SWR on the 50 ohm transmission line without using an Antenna Tuner or other matching device. **See Question B-006-006-011**

<u>The Basics of Antennas</u>

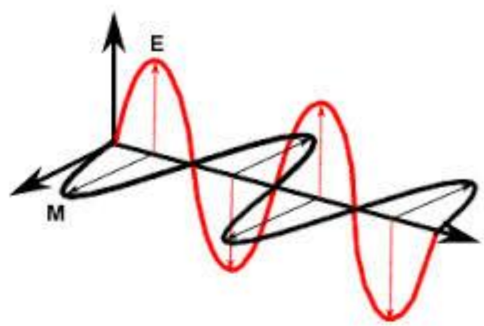
- An <u>**Isotropic radiator**</u> is a conceptual point source of electromagnetic radiation which radiates the same intensity in all directions. It has no preferred direction of radiation. It radiates uniformly in all directions over a sphere centred on the source. **See Questions B-006-007-006 and -007**



- Antenna gain can be stated in decibels relative to the theoretical isotropic radiator given by the term: **dBi**
  See Question 006-009-010 .

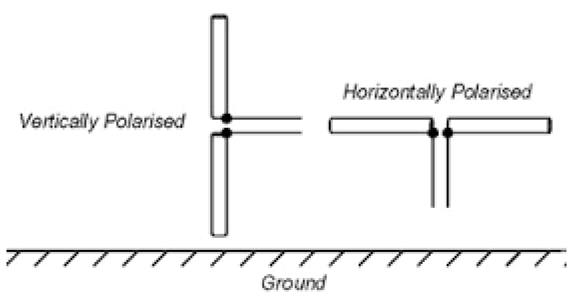
Antenna Polarization

- Antennas have two components of radiation, an **<u>Electric Field</u>** of radiation known as the "E" Field and a **Magnetic Field** of radiation known as the "H" Field. One is perpendicular to the other.



- **<u>The "E" Field radiation will determine the polarization of the antennas.</u>**

- An Antenna having the radiating elements **parallel to the surface of the earth has "Horizontal" polarization.** Conversely, an antenna having radiating elements **perpendicular to the earth's surface is vertically polarized.**



- **See Questions B-006-007-001 to -006**

- For VHF and UHF signals **where ionospheric propagation does not come into play**, **cross polarization** of antennas (transmit to receive) can result in **20 dB or more loss of signal** compared to antennas that have the same polarization. **See Questions B-006-007-008 and -010** . **It is therefore important to have antennas operating at both ends of the radio path to be the same polarization.** (For HF ionospheric propagation, same antenna polarization is not overly consequential.)

- Various common antenna types can be mounted with the elements vertical or horizontally polarized. This applies to the Yagi (beam) antenna or the dipole antenna. **See Question 006-007-009** .

Antenna Resonance and Length

- The purpose of an antenna is to convert Radio Frequency alternating current into Electromagnetic Wave Radiation and conversely change received Electromagnetic Wave Radiation back into Radio Frequency alternating current.

- The **physical length of an ideal antenna** will be a **function of the wavelength it must radiate**.

So Let's first talk about Wavelength and Frequency.

- The **speed of a radio wave** is the same as the **speed of light**. **See Question B-006-008-004 and -007 .**

- Therefore, the wavelength of a radio wave can be determined by dividing the speed of light by the frequency in Hertz or as expressed in an equation:

$$\lambda = \frac{c}{f}$$

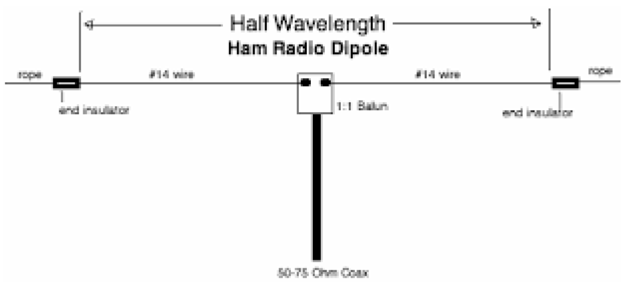
Where λ is the wavelength, c is the speed of light of 300,000,000 metres per second and f is the frequency in Hertz. This formula is simply reduced to :

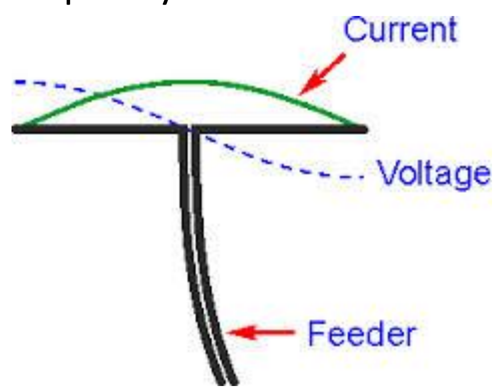
Wavelength = 300 / frequency in MegaHertz

- From this, we derive the basic wavelength name for our various amateur radio bands. *For example, the 40 metre band is from 7 to 7.30 MHz . It might appear the formula is a bit off, but amateurs gave the band names years ago when for example, the 40 metre amateur band was between 7 to 8 MHz. 300/7.5 = 40 .* **See Questions B-006-008-003 and -011 .**

- As seen by the relationship of Wavelength and Frequency, as the **Frequency increases**, the **Wavelength decreases** and vice versa.

- A half wavelength dipole antenna is a standard antenna benchmark to which the performance of other antennas are often referenced. The **half wavelength dipole is a resonant antenna** that is a <u>measured length and cut</u> to frequency .





- As seen in the right diagram above, the voltage is highest at the ends of the dipole and the current is low. At the centre feed point, the voltage is low and the current is high.

- Note the diagram to the left above, the ends of the dipole are suspended using insulators; these limit the electrical length of the antenna to a 1/2 wavelength. **See Question B-006-008-008** .

- The characteristic <u>impedance of a dipole antenna is 73 ohms</u> **in free space** when it is uninfluenced by installing close to the ground. **See Question B-006-012-004**

- To lower the resonant frequency of a dipole, the antenna must be lengthened. To raise the frequency of the antenna, it must be shortened. **See Question B-006-008-009**

- When determining the length of a 1/2 wave dipole, use the following calculations:

- **length in metres = 143 / frequency in MHz** or;
- **length in feet = 468/ frequency in MHz**

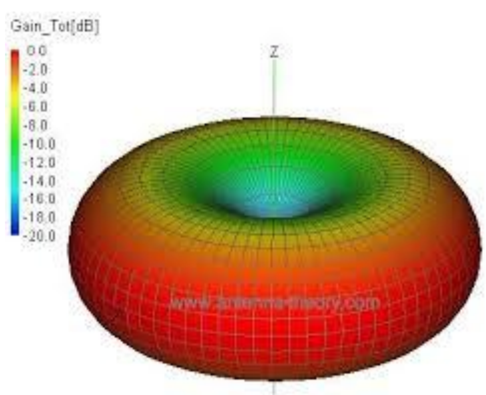
Therefore a 40 metre band, 1/2 wave dipole would be cut to length by 468 / 7.150 MHz = 65.45 feet (give or take a few inches)

- For 1/4 wave length antennas such as a mobile whip or ground plane , the above formulas can be used divided by 2 .
  See Question B-006-010-001 .

<u>**Antenna Gain, Directivity, Radiation Pattern and Bandwidth**</u>

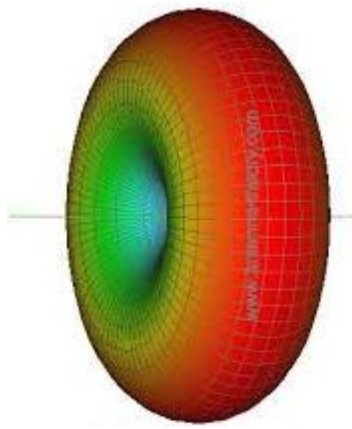
- An conceptual isotropic radiator radiates in all directions equally but most **real antennas** focus energy in certain directions and therefore have gain in those favoured directions over an Isotropic radiator.

- A simple vertically oriented dipole focuses its radiation in the form of a donut around the elements in this fashion (if in free space with no external influences)

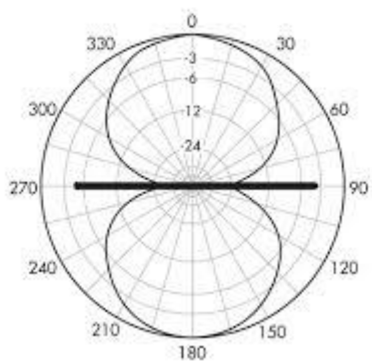


- The **gain of a dipole** over an isotropic **is approximately 2.1 dBi** in its most favoured direction in free space. Note that the radiation is greatly reduced above and below the radiating elements.

- Equally, the dipole could mounted horizontally, that is parallel to surface of the earth and the shape of the radiation pattern would look like this: (without ground influences)



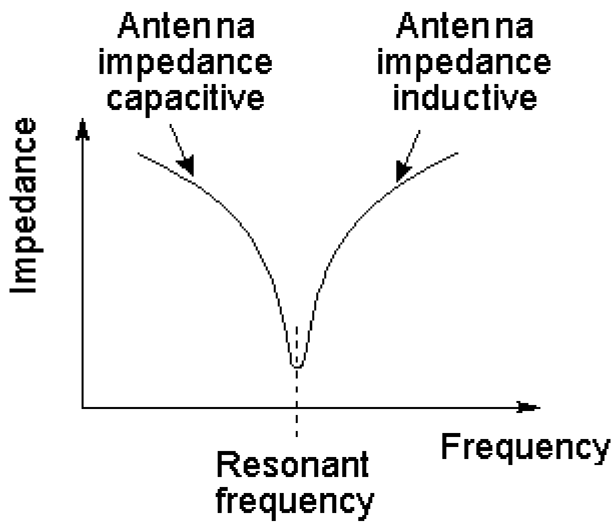
To look down on the antenna, the azimuth radiation may look like this figure 8 pattern: **See Question 006-012-003**



In the horizontal orientation, the dipole antenna radiates broadside to the dipole elements, that includes straight up and straight down. However, low HF band antennas, for practical reasons, must be erected close to the ground (1/4 wavelength above or less) and therefore, considerable distortion of the pattern may happen concentrating the radiation up and less out on the horizon.

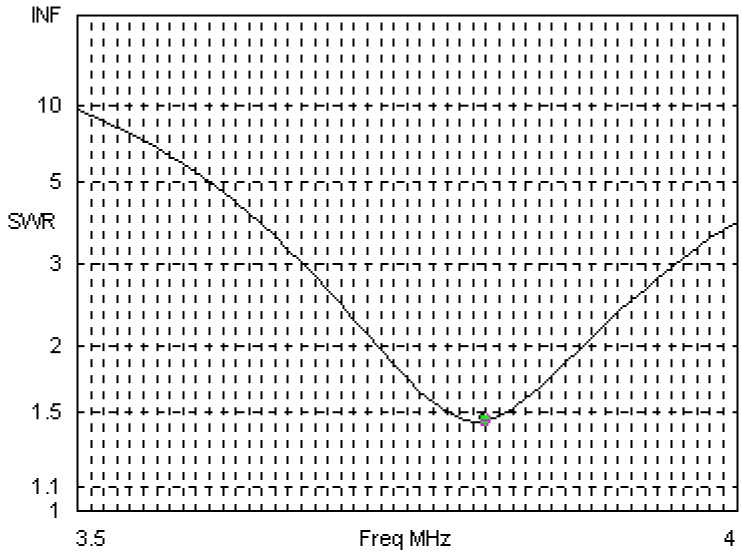
Antenna Bandwidth

- An antenna is a form of tuned circuit consisting of inductance and capacitance and as a result it has a resonant frequency. This is the frequency where the capacitive and inductive reactance cancel each other out. At this point the antenna should appear purely resistive.



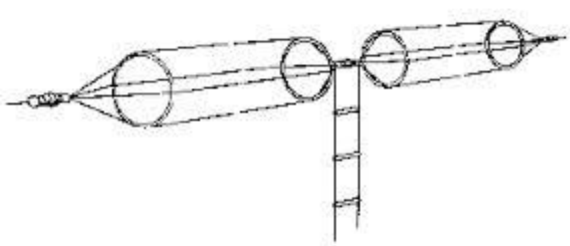
- The antenna bandwidth is the spread of frequency between which the SWR of the antenna is lower than an accepted value; eg. 2 to 1 .

Here is the VSWR sweep of a 80 metre 1/2 wavelength dipole:



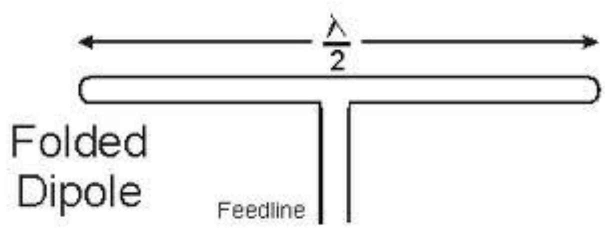
- For a resonant dipole type antenna, it generally works best when there is minimal reflected power on the feed line; this is when operating within the performance bandwidth of the antenna. **See Question B-006-009-008 .**

- Generally, the way to design a wider bandwidth antenna is to have wider elements; this may be accomplished by making a dipole using "cage" elements. or;



- By using larger diameter metal tubing when fabricating a Yagi beam antenna. **See Question B-006-009-002 .**

- Because of the thicker element size, a folded dipole generally has a wider bandwidth than a straight wire dipole.

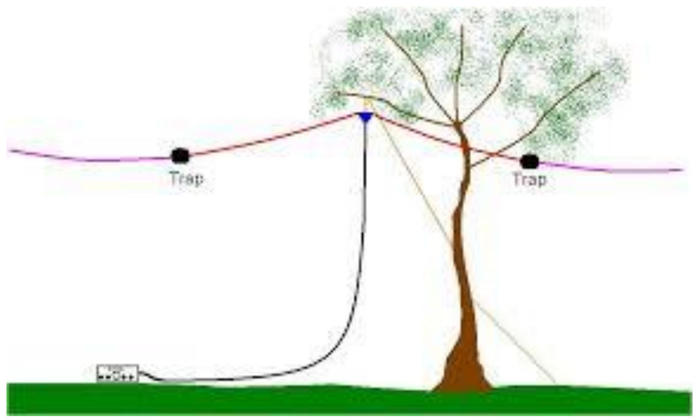


See Question B-006-012-006

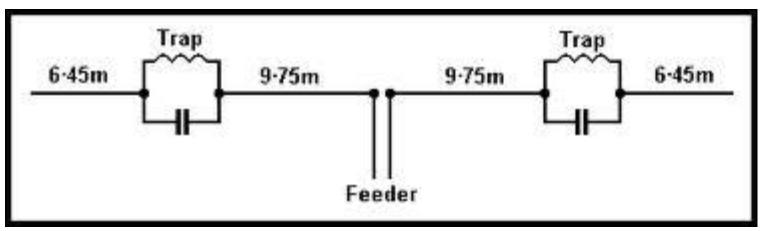
- The characteristic **impedance of a folded dipole is <u>300 ohms</u>.**
  See Question B-006-012-004

Trapped Dipole

- A trapped dipole is one means of designing a multi-band antenna. **See Question B-006-012-008**



- A more electrically descriptive picture of a trapped dipole.



- The traps consist of a inductor (coil) and parallel capacitor that have a resonant frequency equal to the higher operating frequency of the dipole. At resonance of the coil and capacitor, the circuit becomes a very high impedance thus limiting the length of the 1/2 dipole to that where the traps are installed. At lower frequencies, the traps add a bit electrical length to the antenna and the full length of the dipole comes into play resonating as a 1/2 wave dipole at its full length and lower operating frequency. **See Question B-006-008-010**

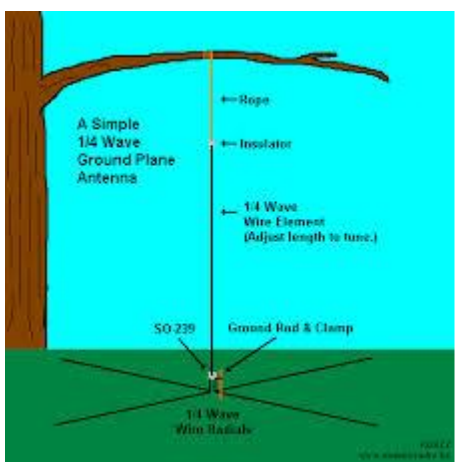
- A Multiband trap antenna may have more than one set of traps to the cover 80, 40 and 20 metre bands; there is one possible disadvantage however; such an antenna may be more prone to radiate harmonic output of an unsuppressed transmitter. **See Question B-006-012-007 .**

Vertical Polarized Antennas

- For HF operation, vertical antennas have the advantage of taking up very little real estate.

- **A simple vertical antenna is a 1/4 wave length <u>Ground Plane</u>**; such an antenna would be about 33 feet tall for the 40 metre band or 16 feet tall for the 20 metre or 8 feet tall for the 10 metre band.

- A Ground Plane antenna must work against a radial ground plane as illustrated;



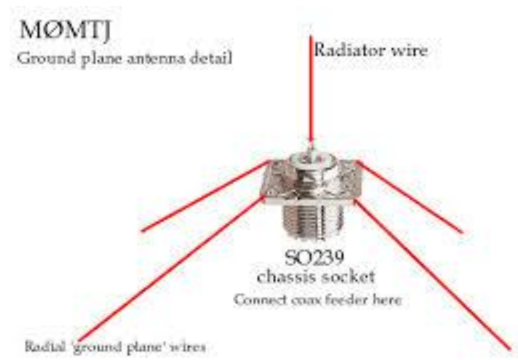
- The vertical ground plane antenna has the advantage and disadvantage of being omni-directional, it radiates equally well in all directions in the horizontal plane but it also receives interference equally well from all directions. **See question B-006-010-009**

- The vertical ground plane antenna is fed between the ground radicals and the vertical element at a low impedance.

- Like trapped dipole antennas, traps can also be used to make a multiband vertical antenna.

- An elevated 1/4 wave ground plane antennas can readily be made and mounted high for VHF and UHF work:

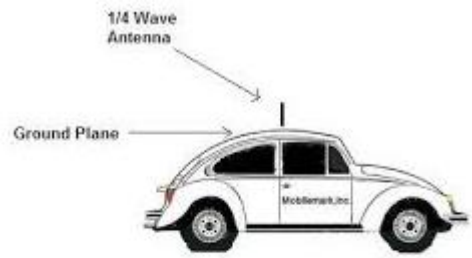
<u>2 metre band ground plane made with wire and SO-239 connector</u>



The length of vertical element and radials is approximately 18 "

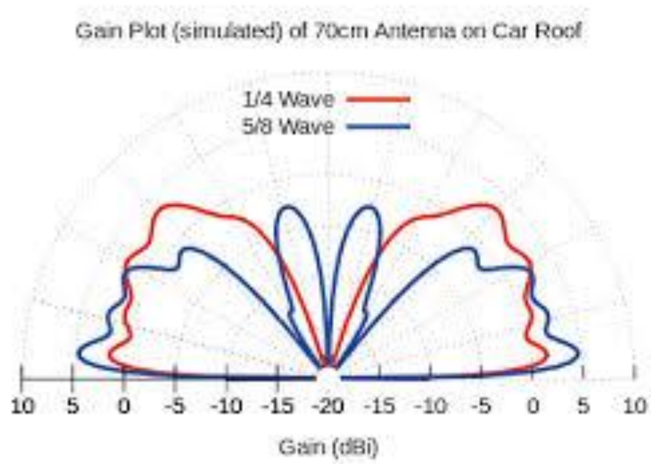
- **<u>The radials above are bent down to improve the match to the 50 ohm coaxial cable.</u> See Question B-006-010-006**

- 1/4 wave vertical whip antennas are often mounted on cars for amateur VHF FM communications; these are normally fed using RG 58, 50 ohm coaxial cable. The metal car body serves as the ground plane. A 1/4 wave whip antenna for 2 metres is about 18" long.



- Another popular type of VHF mobile antenna is the **<u>5/8 wave length vertical.</u>** This type of antenna has a low angle of antenna radiation thereby concentrating the signal out on the horizon. It offers a gain of **<u>about 3 dB over the 1/4 wave whip</u>** mobile antenna. For matching, the 5/8 whip requires a small loading coil inductance at its base. **See Question B-006-010-011** A 5/8 wave whip antenna for 2 metres is about 51" long.

Radiation Pattern comparison 1/4 vs 5/8 wavelength whip

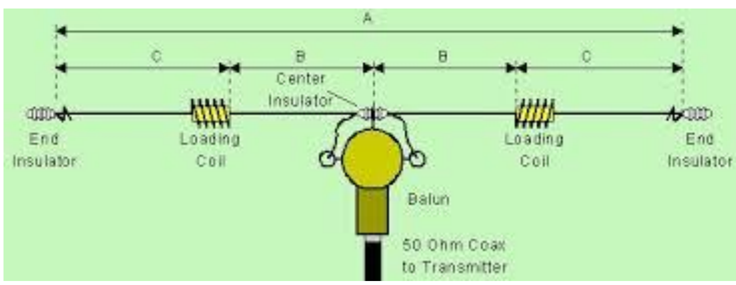


Making short antennas match

- The electrical length of an antenna can be increased by adding series inductance; this is called **loading** the antenna.

- Adding series inductance to an antenna element will decrease its resonant frequency. **See Question B-006-008-005**

- A loaded dipole is shorter than a 1/2 wavelength dipole for a given frequency of operation.



- Loading a vertical antenna is very necessary when mounting a HF antenna on a vehicle. It's rather difficult to drive around with a 33 foot tall 40 metre band 1/4 wave vertical antenna on a car.

- Some HF mobile antennas have a motorized inductor tuning mechanism to provide appropriate series inductance in the antenna element to match various HF bands.

Directional Beam Antennas

(Udo) Yagi Antenna

- The Yagi design of beam antenna is a directional antenna consisting of multiple parallel dipole elements mounted on a supporting **"boom".**

- VE3LC's rotatable Yagi antennas.

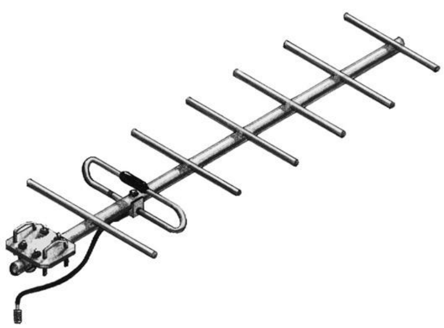
- Four stacked antennas, from top to bottom. 10 elements on 432 MHz, 15 elements on 144 MHz, 5 elements on 50 MHz, and 3 element trapped tri-band Yagi for the 20, 15, and 10 metre bands.

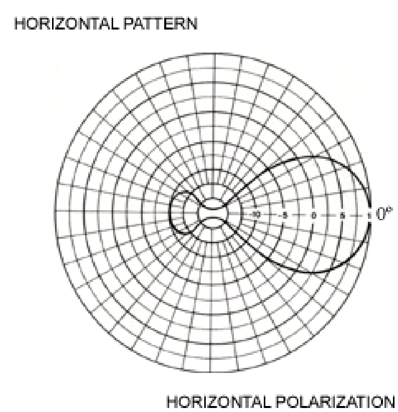
- The **Yagi** has a **reflector** at the back, **one driven** element (where the feed line is connected) and **one or more directors** facing forward. **See Question B-006-011-001**

- The reflector and directors are referred to as **<u>"parasitic"</u>** elements as they are not driven directly but obtain their radio energy by induction from the driven element. **See Question B-006-009-001**

- The structural member supporting the elements is called the **<u>"boom"</u>** .

- The picture below is a 7 element UHF Yagi with folded dipole driven element. This antenna is an "end boom" mount and can be installed with either horizontal or vertical polarization. This antenna is specified as having a 10 dBd forward gain. (dBd is gain above a reference dipole) The plot to the right is the horizontal radiation pattern of the Yagi when horizontally polarized. The Front-to-Back ratio of this antenna is given as 20 dB.





- **Note that the reflector is the longest element, and the directors are the shortest.** Some Yagi designs have the directors slightly shorter and shorter towards the front of the antenna.

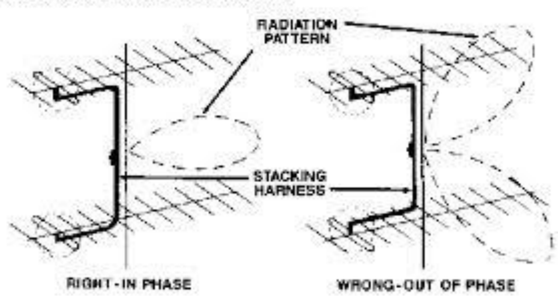
- As can be seen in the radiation pattern above, there is a minor lobe of radiation off the back of the Yagi antenna. The comparison radiation of the front major lobe to the minor back lobe is called <u>**Front-to-Back Ratio**</u> and is given as a dB difference between the front and back lobes. **See Question B-006-011-008**

- Yagi antennas have a **"Beamwidth"** specification. This refers the <u>**angular measure in degrees**</u> **between the points on the frontal radiation pattern that are 3 db less than the main lobe of radiation.**

- The element spacing is a matter of trade offs in gain, bandwidth and beamwidth. In a small 3 element Yagi antenna, 0.20 wavelength spacing between elements is a good choice. **See Question B-006-011-010**

- If two same Yagi antennas are **"stacked"** on a mast and pointing the same way and properly matched and combined onto a common feed line, the maximum increase in **gain** of the two antennas (compared to one alone) is **3 dB**.
See Question B-006-011-011 .

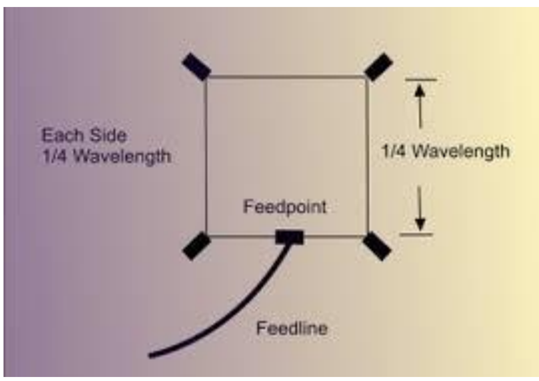
FIGURE 1. OBSERVING POLARIZATION



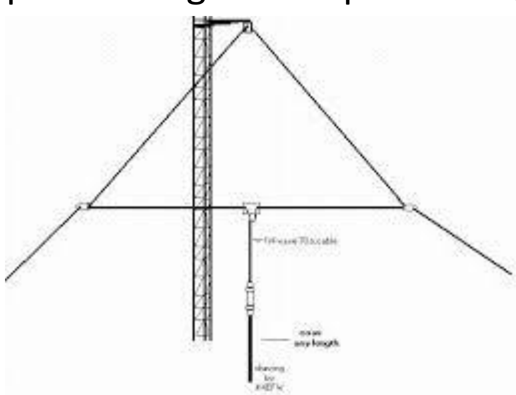
Full Wave Length Loop Antennas

- A Full Wave Length Loop Antenna can take many shapes and forms. This includes such designs as the Quad Loop, the Circular Loop, and the Delta Loop. The characteristic of all these types is the **"Loop" measures a full wavelength in circumference length** of the frequency that the antenna is designed to operate on.

- For a square Quad Loop, each side is 1/4 wavelength:

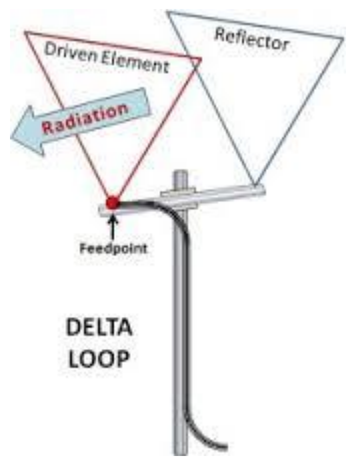


- The above antenna is fed on the bottom making it horizontally polarized. If it was fed on the side, it would be vertically polarized. **See Question B-006-013-008**
- A Delta Loop is a triangular shape and might look like this:



The above antenna is also horizontally polarized because it is fed on the bottom. There are non-conductive rope lines left and right maintaining the triangular shape of the antenna.

- **Quad and Delta and Circular Loop antennas** can be fashioned into directional beams like a Yagi antenna by adding a reflector and one or more director Loop elements.



- A two element Delta Loop, above, if properly designed and fabricated, would compare in performance to a 3 element Yagi. **See Question B-006-013-006 .**

- When any Loop type antenna is fed on the side for vertical polarization, it will display directivity based on orientation. By comparison, a vertical dipole is omni-directional in the horizonal plane. **See Question B-006-013-007**

- A symmetrical Delta Loop antenna (like an equilateral triangle) will have each side a 1/3 wavelength long **See Question B-006-013-005**

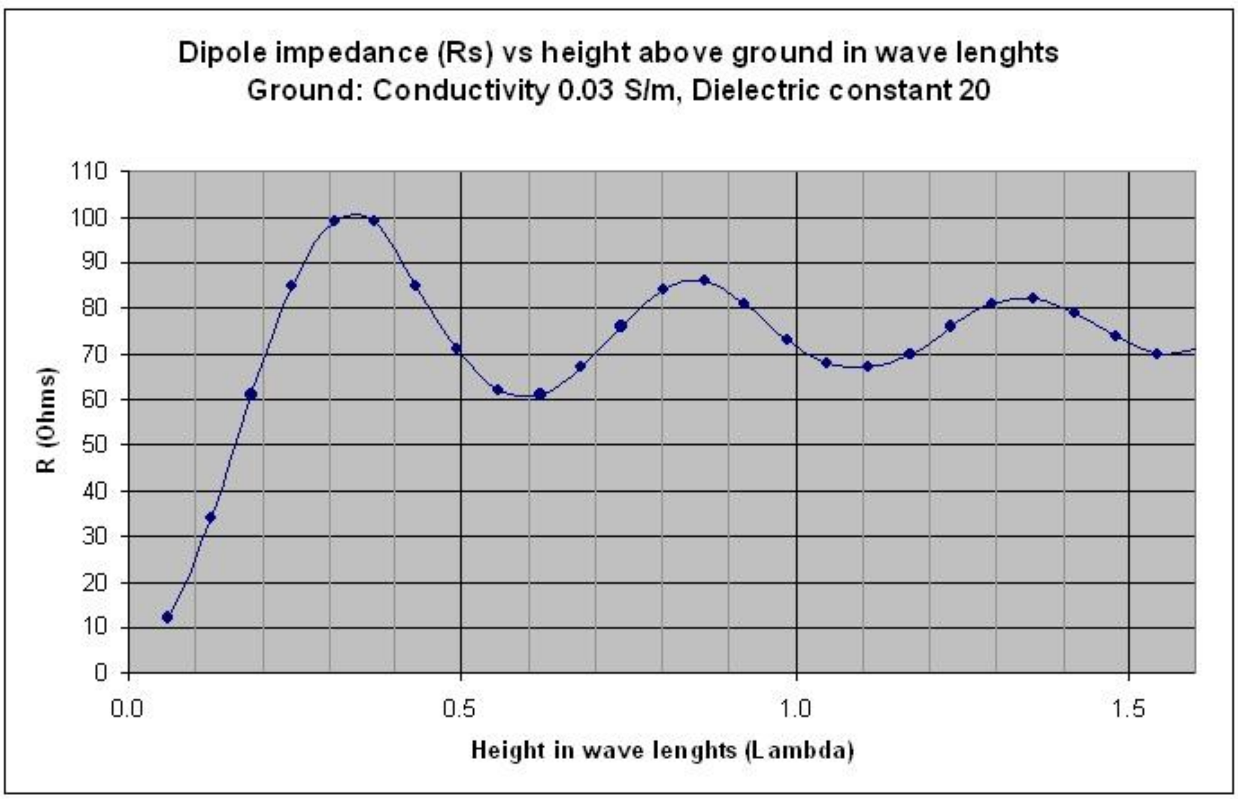
- Circular Loop Yagi with rotor to change polarization.

Loop Yagi for 23 cm (1296 MHz) band

Supplementary Information.

- The most basic wire antenna is the dipole and if cut to a 1/2 wavelength of the operating frequency will have a nominal impedance of **<u>73 ohms in free space</u>**. The impedance can be considerably influenced by the installation height above ground or anything that represents a conductive surface such as metal roofing.

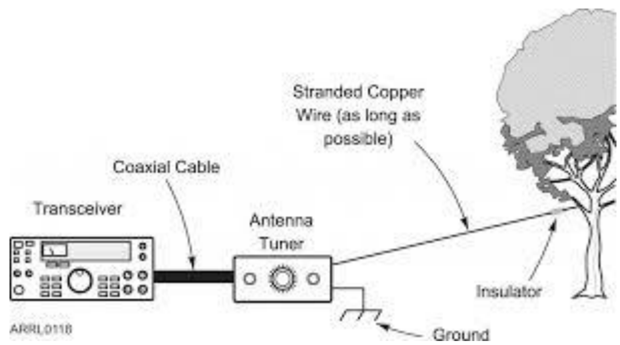
- This is a graph of the change in impedance of a dipole vs height in wave lengths above ground conductivity.



Multi Band Non Resonant Wire Antennas

- Instead of a Dipole, there are other novel wire antenna designs that can be very effective.

Random Length Long Wire antenna.



- The random length antenna must be operated against a good counter poise of wires laying on the ground. The radiating wire should be at least 1/4 wavelength for the lowest frequency band and avoid lengths that are even multiples of a half wavelength.

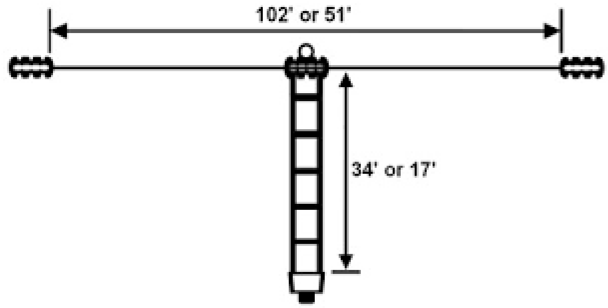
- A random wire must be connected directly into a antenna tuner for matching to 50 ohms. There is no feed line loss because there is no feed line. The grounding wires are connected to the grounding terminal of the Antenna Tuner.

- A random wire antenna is great for portable operation.

- **See Question B-006-012-002** . The equipment may be alive with RF radiation if the station and Antenna Tuner are not properly grounded with a very short wire between grounding point and the antenna tuner.

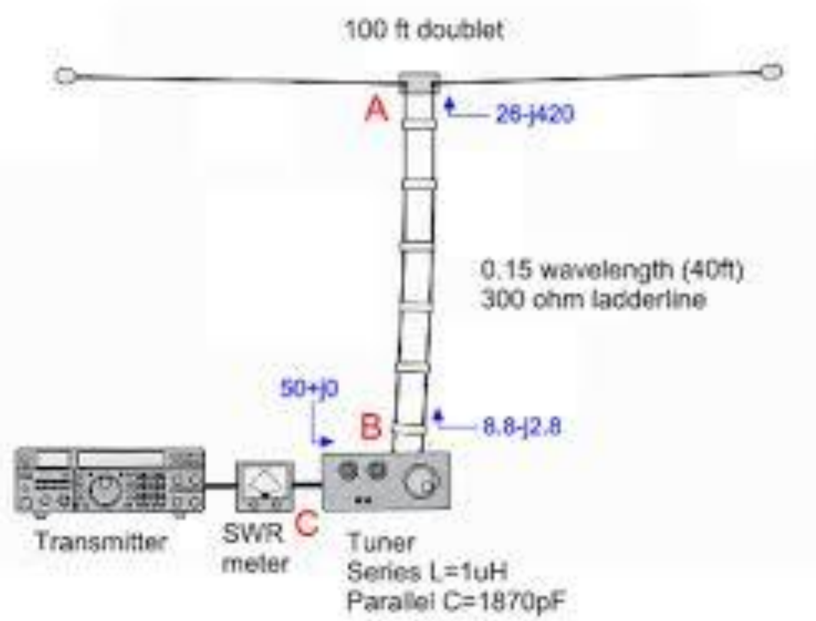
G5RV multiband antenna.

- The G5RV was designed the late Louis Varney, call sign G5RV, and is a classic amateur HF multiband wire antenna.



- The G5RV with 102' wire elements will work well on the 80, 40, 20, 15, and 10 metre bands. The feedline of 450 ohm ladder line is cut to the prescribed length shown above is a matching stub; this splices into a 50 ohm coaxial cable of whatever length is required to connect to the antenna tuner and radio equipment. At the point of connection into the coaxial cable, the impedance is relatively low for most amateur bands and any reactance is easily tuned out with an antenna tuner. The lesser lengths shown for antenna and 450 ohm feed line is for operation on 40 mtrs and up.

- Similarly, a modification of the G5RV antenna could be extending the 450 ohm ladder line from the antenna directly to the balanced connections of the antenna tuner. **This now becomes a fully balanced "Doublet" antenna.** It is a little less convenient bringing balance line into the house as it must avoid proximity to metal disturbances. High SWR on the parallel wire feed line is OK since the line loss will be insignificant and the system will still work well while tuning most of the HF spectrum.


100 ft doublet
A
26-j420
0.15 wavelength (40ft)
300 ohm ladderline
50+j0
B
8.8-j2.8
C
Transmitter
SWR
meter
Tuner
Series L=1uH
Parallel C=1870pF