Department of Physics, Vidyasagar University

Paper No. PHS 404B.1 : Applied Analog Electronics-II (Special Paper)

Semester IV, M.Sc. Physics

Topic : Television Systems

Lecture No. 02 : Antenna Basics

Keywords : Antenna, λ/4 antenna, Marconi antenna, dipole antenna, folded dipole antenna, VHF and UHF, Diplexer, BALUN.

Antenna Basics

The basic antenna

The most basic antenna is called "a quarter wave vertical", it is a quarter wavelength long and is a vertical radiator. Typical examples of this type would be seen installed on motor vehicles for two way communications. Technically the most basic antenna is an "isotropic radiator". This is a mythical antenna which radiates in all directions as does the light from a lamp bulb. It is the standard against which we sometimes compare other antennas.

This type of antenna relies upon an "artificial ground" of either drooping radials or a car body to act as ground. Sometimes the antenna is worked against an actual ground.

Antenna Polarisation

Depending upon how the antenna is orientated physically determines it's polarisation. An antenna erected vertically is said to be "vertically polarised" while an antenna erected horizontally is said (not so surprising) to be "horizontally polarised". Other specialised antennas exist with "cross polarisation", having both vertical and horizontal components and we can have "circular polarisation".

Note that when a signal is transmitted at one polarisation but received at a different polarisation there exists a great many decibels of loss.

This is quite significant and is often taken advantage of when TV channels and other services are allocated. If there is a chance of co-channel interference then the license will stipulate a different polarisation.

Antenna Impedance

Technically, antenna impedance is the ratio at any given point in the antenna of voltage to current at that point. Depending upon height above ground, the influence of surrounding objects and other factors, our quarter wave antenna with a near perfect ground exhibits a nominal input impedance of around 36 ohms. A half wave dipole antenna is nominally 75 ohms while a half wave folded dipole antenna is nominally 300 ohms. The two previous examples indicate why we have 75 ohm coaxial cable and 300 ohm ribbon line for TV antennas.

A quarter wave antenna with drooping quarter wave radials exhibits a nominal 50 ohms impedance, one reason for the existence of 50 ohm coaxial cable.

The quarter wave vertical antenna

The quarter wave vertical antenna is usually the simplest to construct and erect.

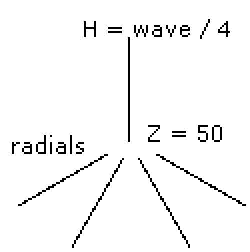

Figure 1. – A quarter wave vertical antenna with drooping radials

In figure 1 we have depicted a quarter wave vertical antenna with drooping radials which would be about 45 degrees from horizontal. These 45 degree drooping radials simulate an artificial ground and lead to an antenna impedance of about 50 ohms.

A quarter wave vertical antenna could also be erected directly on the ground and indeed many AM radio transmitting towers accomplish this especially where there is suitable marshy ground noted for good conductivity. An AM radio transmitting tower of a quarter wave length erected for say 810 Khz in the AM band would have a length of nearly 88 metres (288') in height.

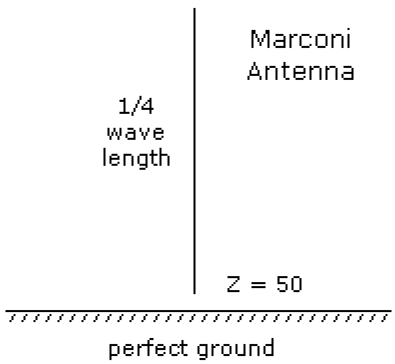

Figure 2. - A Marconi antenna

The formula for quarter wave is L = 71.25 metres / freq (mhz) and in feet L = 234 / freq (mhz). Note the variance from the standard wavelength formula of 300 / freq. This is because we allow for "velocity factor" of 5% and our wavelength formula becomes 285 / freq.

When a quarter wave antenna is erected and "worked" against a good rf ground (called a Marconi Antenna) the earth provides a "mirror" image of the missing half of the desired half wave antenna.

In figure 2 above where I have depicted the Marconi Antenna imagine a duplicate of the quarter wave antenna being in existence from the top of the ground and extending down the page. This is the mirror image.

Half wave dipole antenna

The half wave dipole antenna becomes quite common where space permits. It can be erected vertically but is more often than not erected horizontally for practical reasons. I gave quite a good example of its use in my paper on radio telescopes from my original site. I have reproduced it in figure 3 below.

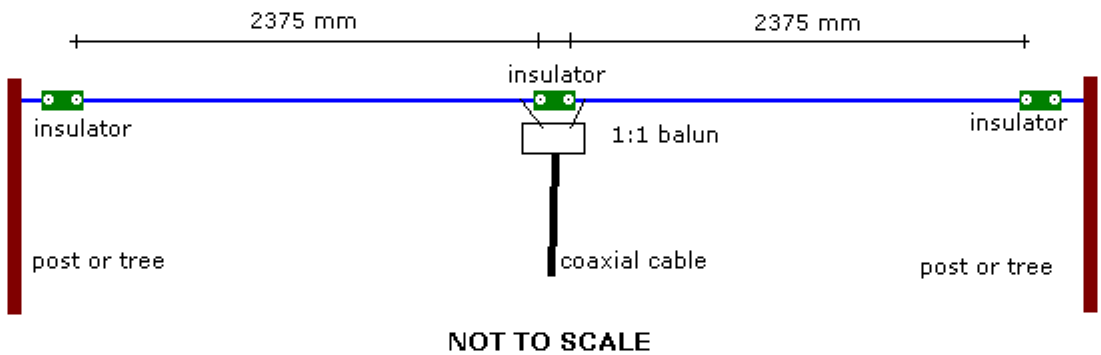

Figure 3. - Half wave dipole antenna

This particular antenna was dimensioned for use at 30 Mhz. You will note that the left and right hand halves are merely quarter wave sections determined by the formula given earlier. The input impedance (affected by many factors) is nominally 50 ohms.

As with all antennas, the height above ground and proximity to other objects such as buildings, trees, guttering etc. play an important part. However, reality says we must live with what we can achieve in the real world notwithstanding what theory may say.

People erect half wave dipoles in attics constructed of fine gauge wire - far from ideal BUT they get reasonable results by living with less than the "ideal". A lesson in life we should always remember in more ways than one.

The folded dipole antenna

The folded dipole antenna is probably only ever seen as a TV antenna. It exhibits an impedance of 300 ohms whereas a half wave dipole is 75 ohms and I'm certain someone will be alert enough to ask "why 75 ohms, if figure 3 above is 50 ohms?".

Within the limits of my artistic skills I have depicted a folded dipole antenna below.

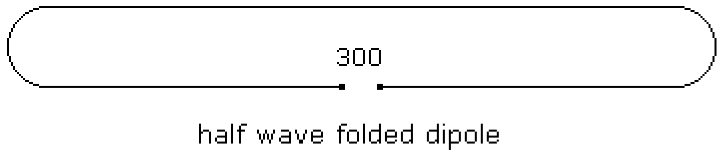

Figure 4. - Half wave folded dipole

One powerful advantage of a folded dipole antenna is that is has a wide bandwidth, in fact a one octave bandwidth. This is the reason it was often used as a TV antenna for multi channel use. Folded dipole antennas were mainly used in conjuction with Yagi antennas.

The Yagi antenna

The Yagi antenna or more correctly, the Yagi - Uda antenna was developed by Japanese scientists in the 1930's. It consists of a half wave dipole (sometimes a folded one, sometimes not), a rear "reflector" and may or may not have one or more forward "directors". These are collectively referred to as the "elements".

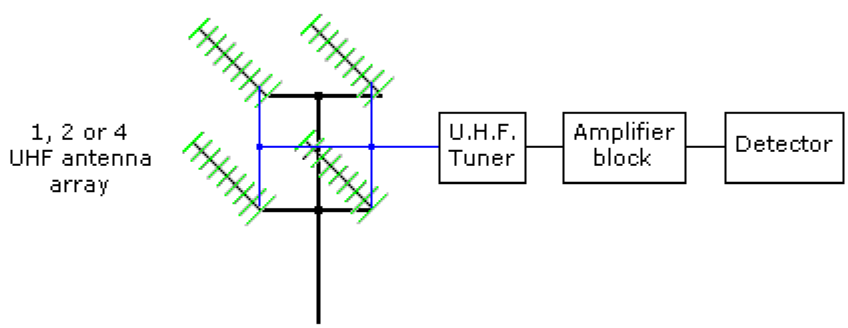

Figure 5. - The Yagi antenna

In figure 5 above I have reprinted a UHF Yagi antenna array from my radio telescopes page. You will note, not altogther clearly.

However in figure 6 below, which happens to be a photograph of a neighbour's TV antenna, I can clearly point out details of a practical Yagi antenna.

This particular antenna has been optimised for dual band operation. It is designed to pick up both VHF and UHF transmissions. Because I live in a regional of NSW in Australia, TV antennas tend to be single channel types designed either for higher gain or better directivity. Different examples will be presented later.

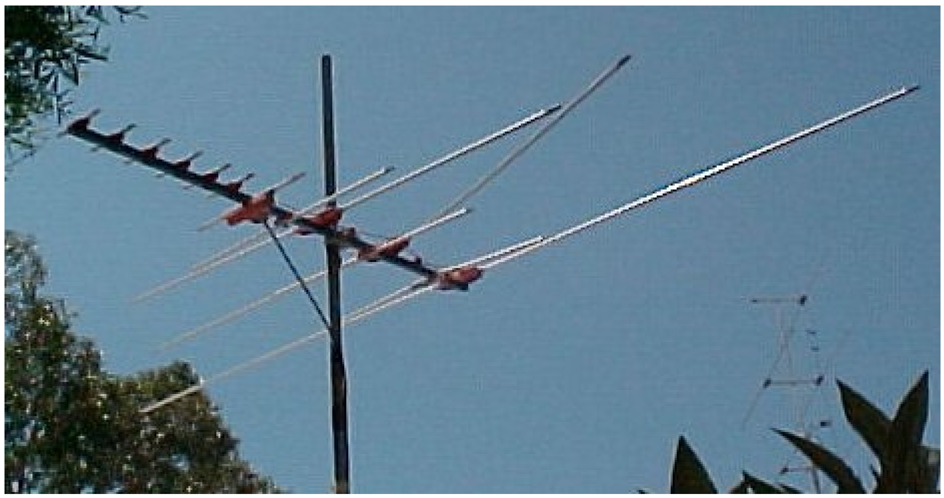

Figure 6. - A practical Yagi TV antenna

Looking from left to right on this dual band Yagi we have six UHF "director" elements which improve gain and directivity. Next is the UHF half wave dipole which could have easily been a folded dipole but is in fact a plain half wave dipole.

The next three much longer elements form a "phased array" for the VHF band. I am unsure of the function of the three remaining smaller elements, information is quite scant here but one would certainly be a UHF "reflector". Likely the other two also fulfill this function also.

Note: This is a horizontally polarised antenna and is orientated roughly NNW, 315 degrees.

You will notice the effect of very strong storms from the sea have had in bending the second larger elements. In my locality storms are a problem but not as much as roosting parrots such as large sulphur crested cockatoos.

UHF Yagi antenna

In the photograph in figure 7 below you can see a classic UHF Yagi antenna. It has a total of nineteen "elements" comprising seventeen "directors", a fancy folded dipole with a "low-noise mast head amplifier" and a "reflector".

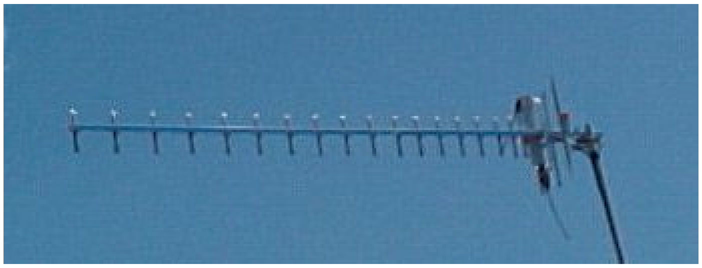

Figure 7. - a vertically polarised UHF Yagi antenna

This is a a vertically polarised UHF Yagi antenna and it is orientated WSW or 225 degrees. It does in fact pick up signals about 100 Km or 60 mile distant from Sydney.

This is the very same antenna I was suggesting to be used in the radio telescope array I depicted in figure 5 above.

Stacked half wave dipoles or a collinear array

The majority of TV antennas in my retirement village are stacked half wave dipoles. These consist of four sets of a half wave dipole and a reflector only, but mounted one above another. These antennas owe their origin to the days we only had VHF TV in the area. Surprising with the introduction of UHF they continued to function quite well in picking up UHF as well. This particular antenna is my one and I've never had the need to go to a UHF antenna. The top two elements normally are home to roosting "top knot" pidgeons, a pigeon native to Australia.

Figure 8. - Four stacked half wave dipoles collinear antenna

To the left of the photograph are the "reflectors" and to the right are the four vertically stacked half wave dipoles. The wires connecting each half wave dipole are done in a "phased way". This comprises a collinear antenna array and is so arranged for improved gain.

Note this antenna is horizontally polarised.

λ/2 Folded Dipole Antenna :

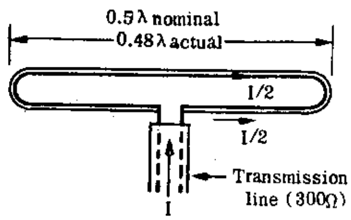

Fig. 9.14(a) Folded dipole antenna.

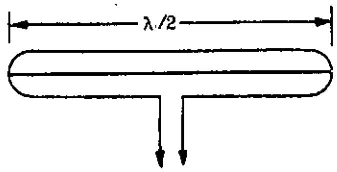

Fig. 9.14(b) High impedance folded dipole antenna.

Yagi-Uda Antena :

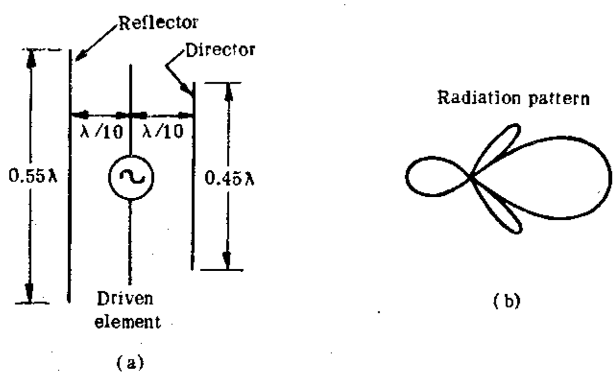

Fig. 9.18 Yagi-Uda antenna (a) antenna (b) radiation pattern

Yagi-Uda Antenna Design :

Yagi Antenna Design

The following expressions can be used as a starting point while designing any Yagi antenna array.

Length of dipole (in metres) $\approx \frac{143}{f(\text{MHz})}$ (f is the centre frequency of the channel)

Length of reflector (in metres) $\approx 152/f\,(\text{MHz})$

Length of first director (in metres) $\approx 137/f\,(\text{MHz})$

Length of subsequent directors reduces progressively by 2.5 per cent.

Spacing between reflector and dipole $= 0.25\lambda \approx 75/f\,(\text{MHz})$

Spacing between director and dipole $= 0.13\lambda \approx 40/f\,(\text{MHz})$

Spacing between director and director $= 0.13\lambda \simeq 39/f\,(\text{MHz})$

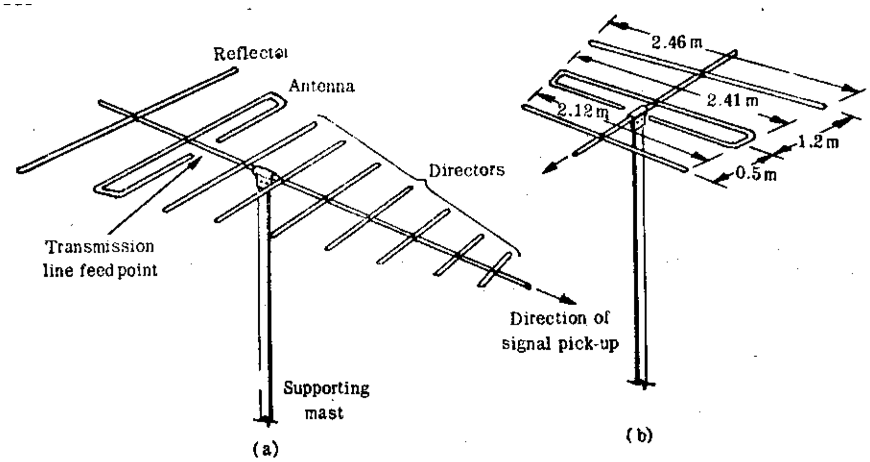

Fig. 9.19 (a) A typical Yagi antenna (b) Channel four antenna.

Diplexing of VHF Antennas :

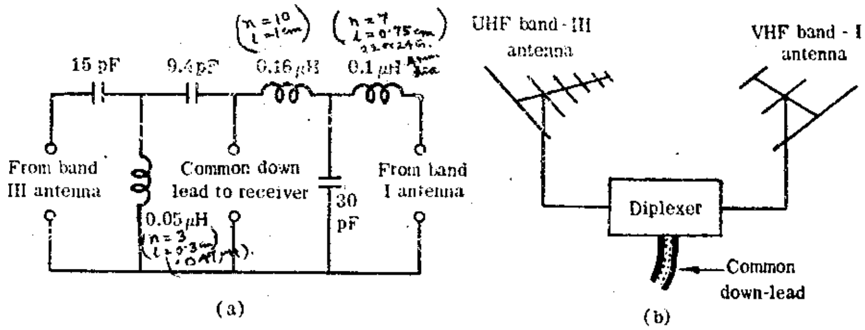

Fig. 9.20 Diplexing antenna outputs (a) diplexer network, H.P-L.P-filter combination (b) diplexer connections.

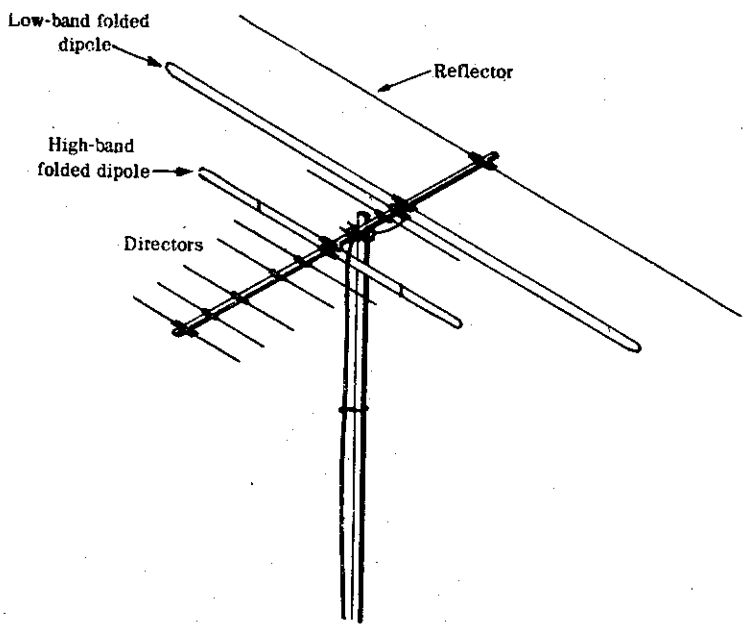

Fig. 9.22 In-line YAGI antenna array for lower and upper VHF bands.

Impedance Matching :

BALUN (BALance to UNbalance Transformer)

A balun is a device that joins a balanced line (one that has two conductors, with equal currents in opposite directions, such as a twisted pair cable) to an unbalanced line (one that has just one conductor and a ground, such as a coaxial cable). A balun is a type of transformer: it's used to convert an unbalanced signal to a balanced one or vice versa. Baluns isolate a transmission line and provide a balanced output. A typical use for a balun is in a television antenna. The term is derived by combining *balanced* and *unbalanced*.

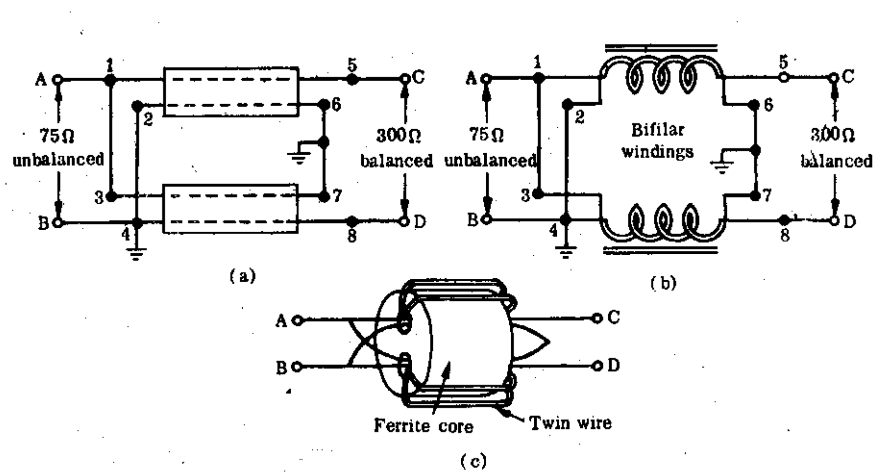

Fig. 9.32 Balun to match between 75Ω unbalanced and 300Ω balanced impedances (a) with λ/4 matching sections, (b) equivalent transformer, (c) constructional details.

Ref: Monochrome and Colour Television, by R.R. Gulathi, New Age International Publ.