

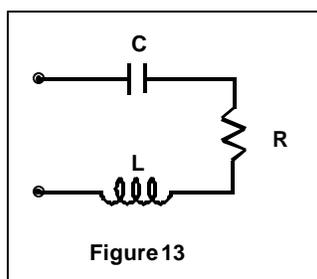
Dipoles For Dummies

(As well as all the rest of us without a PhD in electromagnetics)

Part 3 -- Advanced

If you followed the discussion so far, you are now ready to move to the advanced class. Here we will determine the impedance of a dipole antenna. The impedance is important because it affects the ability to couple energy into the antenna structure. Interestingly, many antenna books do not bother to calculate this.

Referring to Figure 2 (in Part 1), we can see that one of the elements of the antenna impedance will be a capacitor. We also know that the wire arms of the antenna must have inductance, and this inductance will be in series with the capacitance.

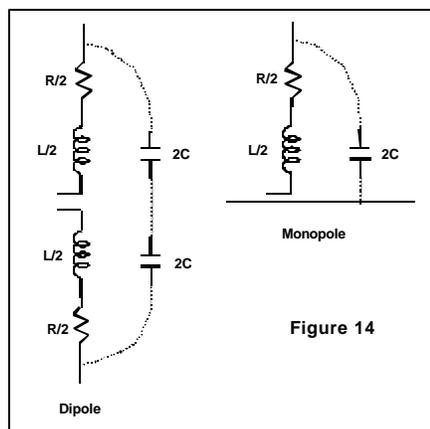


If the antenna radiates, some energy will be lost and this lost energy must be accounted for in our model. The only component that will dissipate power is a resistor; so let's add that to our model in series with the inductor and capacitor. *Therefore, the equivalent circuit for a dipole antenna becomes a series R-L-C network as shown in Figure 13.* We call the resistor the "radiation resistance" since it represents the energy that is lost as radiation.

Figure 13 clearly shows that the dipole will behave as a series resonant R-L-C circuit. At low frequencies the dipole impedance will be capacitive, at high frequencies it will be inductive, and at resonance it will be resistive.

The impedance of a monopole is one half that of a dipole. This can be seen by studying Figure 14. The inductance and resistance will be one half that of the dipole and the capacitance will be twice that of the dipole.

Below the resonant frequency the input impedance to the antenna will be large ($> 1,000$ ohms) due to the impedance of the capacitor. Above the resonant frequency the impedance will also be large ($> 1,000$ ohms) due to the impedance of the inductor. At resonance, however, the impedance will be low (< 100 ohms) since the inductive reactance will cancel the capacitive reactance, leaving just the radiation resistance. The well-known value for the radiation resistance of a thin, half-wavelength dipole is 72 ohms, for a monopole it will be half of that or 36 ohms.

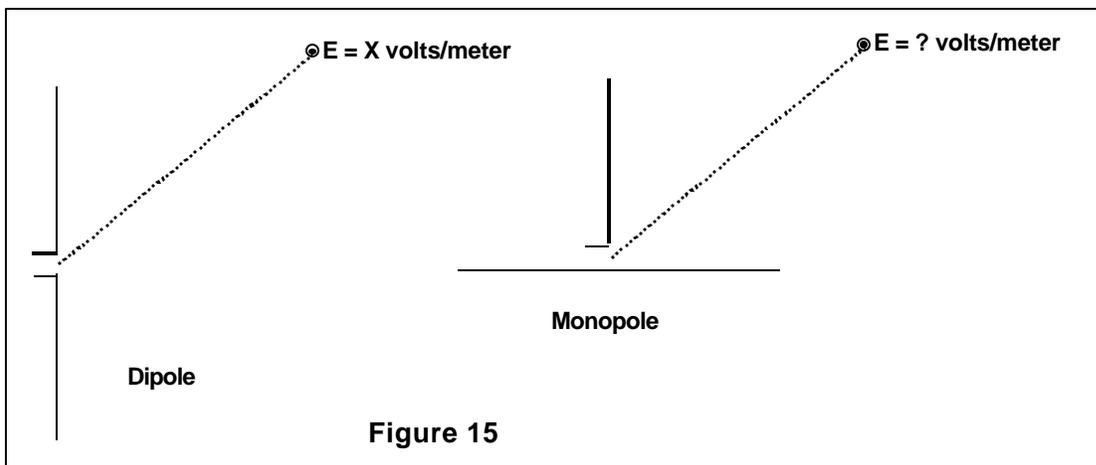


It will be difficult for the common-mode voltage (or any other voltage for that matter) to drive much current into the antenna when the input impedance is large. However, it will

be easy to push current into the antenna at resonance when the impedance is low. Therefore, dipole (monopole) resonance is important to us with respect to EMC. *At the resonant frequency it is much easier to couple energy into the antenna and it will therefore be a more efficient radiator.*

As it turns out, the resonance frequency of a dipole is related to its length, Resonance will occur when the antenna's length is approximately one half wavelength (one quarter wavelength for a monopole). Additional higher frequency resonances will also occur at frequencies that are odd numbered harmonics of the half-wavelength resonant frequency (odd numbered harmonics of the quarter-wavelength resonant frequency for a monopole). At these frequencies the radiation will be increased because of the low impedance of the antenna.

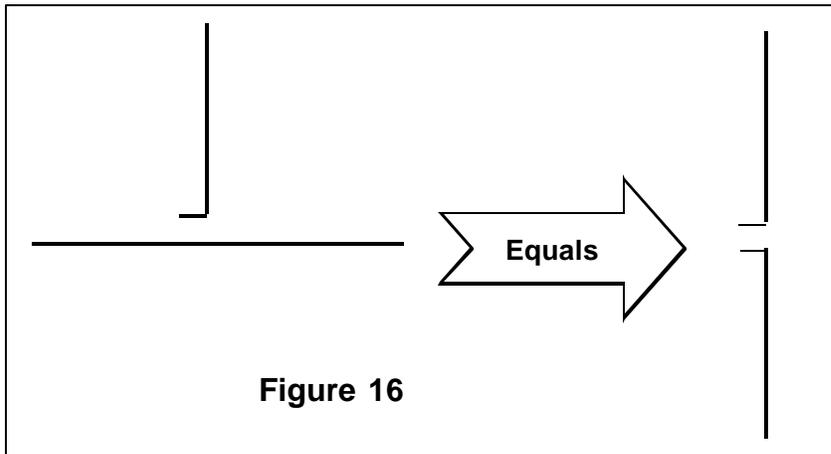
Last but not least, let's compare the performance of the dipole and monopole as radiators. For example, let's say that I measure the field at a point in space d -meters from and at a 45-degree angle to the axis of a dipole. How will this compare to the field measured at a similar point away from a monopole of one half the length and carrying the same current? This is depicted in Figure 15.



To answer this we can use the theory of images. The easiest way to understand the theory of images is to consider something that we are all familiar with, a mirror. After all, light is electromagnetic energy similar to what we have been discussing, except of a different frequency.

If you look into a mirror (a reflective surface) what do you see. You see yourself! If you move three steps back from the mirror, what does your image do? It also moves three steps back. Therefore, a mirror produces an image of you, and the image is located as far behind the mirror as you are in front of the mirror. The same thing happens with a monopole above a reference plane (a reflective surface). A reference plane produces an image of the monopole as far below the plane as the antenna is above the plane.

Saying it slightly differently, the field produced at any point in space in the upper hemisphere, by a conductor perpendicular to a reflective plane is equivalent to the field that would be produced by the original conductor plus a second identical conductor located an equal distance below the plane as the original conductor is above the plane, but without the plane present. Figure 16 shows this equivalence.



Therefore, the answer to our original question is that as long as we limit ourselves to considering the fields in the upper hemisphere (above the reference plane), *the monopole and the dipole produce the exact same field.*

I hope by now that you have a much better intuitive understanding of dipole and monopole antennas, and why they are important to EMC engineering. Note also, that we have done it all without using any mathematics or writing any equations.

Let's summarize what we have covered:

- A dipole antenna requires two parts.
- The magnitude of the radiation will be proportional to the dipole current.
- A dipole antenna does not require a ground to work.
- A monopole is just a dipole in disguise, and also requires two parts.
- The way to make a dipole antenna radiate is to have an RF potential between two pieces of metal.
- The way to prevent radiation is not to have a potential difference between the two halves of the antenna.
- The internal circuit reference (ground) of a product should be connected to the chassis as close to where external cables terminates as possible.

- The polarization of an antenna represents the orientation of the electric field produced by the antenna.
- The effective height of an antenna is defined as the ratio of the voltage induced into the antenna to the magnitude of the incident electric field.
- Adding metal (capacitance) to the end(s) of a dipole or monopole antenna will increase their radiation efficiency
- A PCB should be mounted as close to a metal chassis as possible, and have its ground connected directly to the chassis.
- A plastic enclosure should include a metal reference plane.
- The equivalent circuit of a dipole (or monopole) is a series R-L-C circuit.
- At its resonant frequency, it is much easier to couple energy into an antenna and, therefore, it will be a more efficient radiator at its resonant frequency.
- Antenna resonance will occur when each arm of the antenna is one-quarter wavelength long.
- Multiple resonances will occur that are odd numbered harmonics of the resonant frequency.
- A monopole and dipole both radiate the same field.

If you would like to learn more about antennas, you might consider our new one-day “Antenna Theory Simplified” class. In it we do use mathematics and write equations. However, we use circuit theory (not field theory) to develop simple and accurate circuit theory models for the dipole and loop antennas, which provide the participants with an intuitive understanding of antenna operation. Comparing the models to know field theory results then validates the circuit theory models developed. Other antenna structures such as the Yagi, Log Periodic, Biconical, and Bilog are also discussed.

For more information on the class look on the Henry Ott Consultants web site under In-Plant EMC Training and then click on One-Day EMC Seminars, or go directly to www.hottconsultants.com/one-day.html.

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