Dipoles For Dummies,

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

Part 2 -- Intermediate

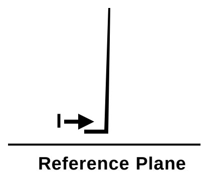

Figure 5

OK, so now we know something about how dipole and monopole antennas radiate. Let's look into the matter a little further and determine the current distribution along the length of a monopole antenna. The result will then also be applicable to a dipole, if we apply it to each arm individually.

Let's assume that we drive a current "I" into the base of the monopole antenna shown in Figure 5. The current at the top of the antenna must be zero. Therefore, the current varies from a maximum of "I" at the base to zero at the top. If the antenna is short (less than 1/10 wavelength), the current distribution will be linear from base to tip (triangular current distribution). If the antenna is long (let's say a quarter of a wavelength), the current distribution will be sinusoidal. Both of these cases are show in Figure 6.

Clearly, the antenna does not radiate uniformly along its entire length. The bottom millimeter will radiate the maximum and the top millimeter will hardly radiate at all. The average current will be 0.5 I for a short antenna, and 0.64 I for a quarter wavelength long antenna. Compared to an ideal monopole antenna (one having uniform current along its entire length), a short monopole will produce half as much radiation, and a quarter wavelength long monopole will produce 64 percent as much radiation.

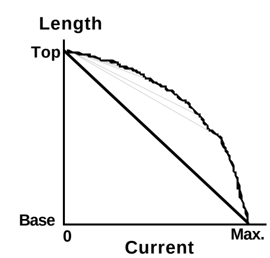

Figure 6

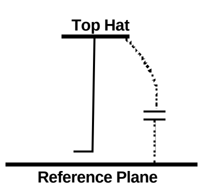

Figure 7

How could we make the antennas more efficient? By increasing the average current, that's how! That means forcing more current up to the top of the antenna. Since the current is flowing through the parasitic capacitance between the antenna arm and the reference plane, we have to do something to increase the capacitance from the top of the antenna to the reference plane.

Figure 7 shows what is often called a "top hat" or capacitive loaded antenna. By adding a large piece of metal at the top we can increased the capacitance from the top of the antenna to the reference plane and thereby increased the current flowing to the top of the antenna. The "top hat" can be a metal disk, radial wires, a metal sphere, etc. It does not matter what shape it is as long as it increases the capacitance from the top of the antenna to the reference plane.

The same approach can be used with a dipole; only in the dipole case we must apply the "top hat" to the ends of both arms. The resulting antenna is then often referred to as a "dumbbell" antenna (see Figure 8).

Therefore, we can conclude, that *adding metal (capacitance) to the end(s) of a dipole or monopole antenna will increase its radiation efficiency*. If we could achieve a uniform current along the length of the dipole we would double the radiated field in the case of a short monopole/dipole, and for the case of a one-quarter-wavelength monopole increase the radiated field by 36%.

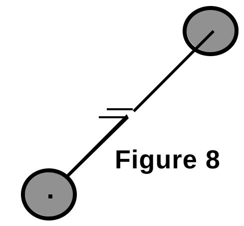
Figure 8

Two terms often used with respect to antennas are polarization and effective height (or effective length). The radiation from an antenna consists of both electric and a magnetic fields, which are perpendicular to each other. For the TEM (Transverse Electromagnetic) mode of propagation, the direction of propagation is transverse (perpendicular) to the plane containing the electric and magnetic fields. The polarization of a field is the direction of the electric field. Therefore, a horizontally polarized antenna will produce an electric field that is oriented horizontally.

An ideal (uniform current) monopole (or dipole), one meter long exposed to an electric field (with the same polarization as the antenna) of one volt/meter will pick up a voltage of one volt. The effective height of an antenna is defined as the ratio of the induced voltage to the incident electric field. Therefore, if we multiply the effective height by the magnitude of the incident electric field (in volts per meter), having the same polarization, will give the induced voltage (in volts). [OK, OK, this could be considered an equation, but I did not write the equation– I described it in words. If you want to hold me to my word about not using any equations, just ignore this paragraph.]

If the current distribution on the monopole were uniform its effective height would be equal to its actual length. For a short monopole with a triangular current distribution (average value equal to one-half the maximum current) the effective height will be one-half of its actual length.

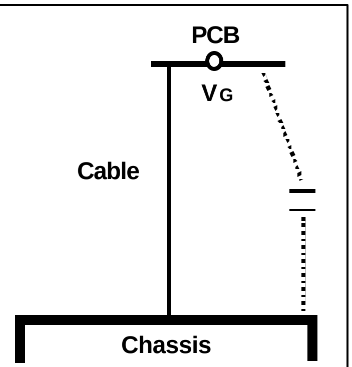

Figure 9

Again we can ask the question, what does all this all have to do with EMC? What it has to do with EMC is that you want to make sure you don't configure your product in such a way that you produce a "top hat" antenna.

Consider the product depicted in Figure 9, which consists of a PCB connected to the end of a long cable and mounted a significant distance above a metal chassis. We have just created a "top hat" antenna and the structure will radiate very efficiently. The cable is the monopole, the chassis is the reference plane and the PCB is the "top hat." *When a PCB is mounted in a product with a metal chassis, it should be mounted as close to the chassis as possible, and have its* *reference (ground) connected to the chassis.*

A similar situation exists when a daughterboard is mounted as shown in Figure 10. This is not as bad as the case shown in Figure 9 because the dimensions are usually much smaller, however, it can also, on occasion, be a problem. The solution is also simpler in this case; just connect the daughter board ground to the motherboard ground through metal stand-offs or by some other means.

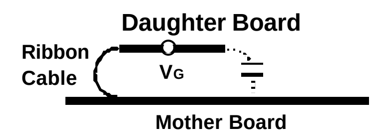

Figure 10

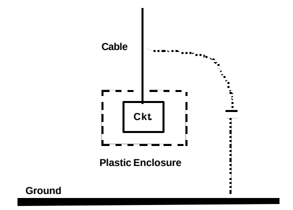

Figure 11

Figure 11 shows an interesting example. It is similar to the example of Figure 4, but this time the product is in a plastic enclosure instead of a metal box. In this situation the product does not provide a reference plane for the monopole to work against so that it will have to find something external to the product. This reference plane could be the actual ground (earth), a metal desk or table, a file cabinet, or other metal object in the vicinity of the product. In each location that the product is placed, the reference plane may be something different. Under these circumstances how do we, as part of the product design, eliminate the common-mode radiation?

This is a case where we are probably better off by intentionally providing the other half of the antenna in the product, instead of letting it be something different in each installation. One way to do this would be to add a metal plate, as shown in Figure 12, inside the bottom of the plastic enclosure and then short out the monopole to this plate. This plate does not have to be thick or heavy (metal foil will do), but it should be large. At this point the question is usually asked, how large? The answer is simple, as large as the enclosure will allow.

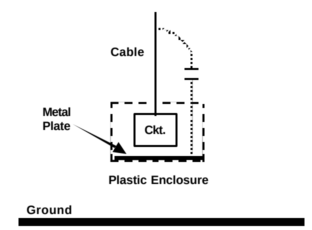

Figure 12

Therefore, we can conclude that, from an EMC engineer's perspective, every product should probably contain a large piece of metal. This can be the metal chassis, or a metal plate in the case of a plastic enclosure.