Avoiding Pitfalls When Selecting MIMO Antennas

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This article is intended to help readers avoid some common pitfalls associated with the selection and use of MIMO antennas.

For several years the Wi-Fi industry has been using MIMO (Multiple-Input, Multiple-Output) to increase data rates. Many new wireless networks are using MIMO technology. While this technology holds the promise of significantly improved wireless performance, every system is only as good as its weakest link. This article is intended to help readers avoid some common pitfalls associated with the selection and use of MIMO antennas.

The selection of the proper antenna for any given application is a non-trivial undertaking. Usually as system designs are nearing completion, the thought of the antenna finally arises. System designers estimate the gain that they require from the antenna and then go shopping for the best-priced or coolest-looking antenna without understanding the actual requirements that the antennas may have.

In traditional single channel communications, the standard half-wave antenna and the standard quarter-wave antennas are pretty well understood.

A basic half-wave antenna has its peak current at the center and its peak voltage at its ends. The peak current at the center is very handy since it is the antenna's lowest impendence and the perfect location to feed the antenna from our typical 50 Ohm transmission lines. We refer to half-wave antennas as Dipoles, and they are ground plane independent.

A basic quarter-wave antenna is, by definition, half of a half-wave antenna and is mounted on a ground plane and has its peak current at its lowest point and the voltage peak at its end. Again, the peak current point indicates that this point is also the lowest impendence so it can be fed at its base. So all is well – right? Well – sort of. What happened to the other half of the half-wave? It's still there! It is now in the ground plane. In the ground plane of the basic quarter-wave antenna, there are voltage peaks which are approximately one quarter wavelength from the feed point. So the dimension of the ground plane must be at least one quarter wave long to properly balance the antenna. We refer to quarter-wave antennas as Monopoles and they are ground plane dependent.

Half-Wave Blade Antenna

Half-Wave and Quarter-Wave

A half-wave design usually does not need any additional ground plane, so attaching it to, for instance, a plastic enclosure of an access point would not decrease its performance and the system designer would see the performance he is expecting. However, if the system designer chose a quarter-wave design and installed it on the same plastic enclosure, he may be surprised to see that performance is lower than he is expecting. The simple

Quarter-Wave Antenna

quarter-wave antenna requires a ground plane to work against. In the case of the plastic enclosure of the access point, there is no metal for the quarter-wave so the internal components may be substituted for a ground plane. This can cause RF current to be present on any metal that is within range, like the circuit board or the power supply leads, causing all sorts of mayhem.

If the system designer knew from the beginning that a quarter-wave antenna would be the choice for his access point, steps could have been taken during the design stages. In the case of his plastic enclosed unit, metallization could have been used that would supply the ground plane of the antenna along with shielding the electronics. Or the main circuit board could have been designed to function as the ground plane without adversely affecting the other electronics, as is typically done in cellular phones.

One of the pitfalls in applications requiring antennas is not having an adequate ground plane when required. These are pretty straightforward, but let's consider the frequency at which the access point is being designed to work. At Wi-Fi frequencies 2.4 GHz and 5 GHz quarter-wavelength is pretty small. Not so at LTE frequencies. One wavelength at 2.4 GHz is approximately 4.8 inches, at 694 MHz which is the lower end of the 700 MHz LTE band where one wavelength is approximately 17 inches long. This is quite a difference. This means that a quarter-wave ground plane would be a minimum of 1.2 inches in radius for the Wi-Fi antenna to work properly and would have to be a minimum radius of 4.25 inches for a quarter-wave antenna to work properly at LTE.

Multiple Antenna Elements

So what do all these basic antenna concepts have to do with MIMO? Well, in MIMO antennas there are multiple antenna elements. Let's look at a 3 x 3 MIMO mobile antenna for 2.4 GHz Wi-Fi. The antenna would have three separate antenna elements, each with its own feed. The elements each are simple monopole designs so they require a ground plane. In MIMO systems there is a specification called the Correlation Coefficient. This is a number from zero to one which

MIMO Surface-Mount Omnidirectional Antenna

indicates how independent the antenna elements are functioning. A Coefficient of one indicates that the antennas are working as one and will not show much (if any) date rate improvement over a single element. A low Coefficient near zero indicates that the antennas are working independently very well and will be able to increase the data rate. A Correlation Coefficient of 0.5 or less is desirable. Correlation is directly related to the spacing of the antenna elements, among other factors. An element spacing of 0.3 wavelengths is the minimum element spacing that can give a correlation Coefficient of 0.5.

Back to our 3 x 3 mobile WIFI antenna example. At 2.4 GHz, to get a correlation Coefficient of 0.5 we need to have our antenna elements spaced a minimum of 0.3 wavelengths apart. The resulting distance from element to element will be approximately 1.45 inches. When you add to that the quarter-wavelength ground plane requirement of 1.2 inches for each element, you can see that the 1.2 in radius from the single monopole now becomes, 1.45 + 1.2 + 1.2 = 3.85 inch diameter. A ground requirement like this is pretty easy to achieve, and the required antenna enclosure for the three elements can be reasonable size.

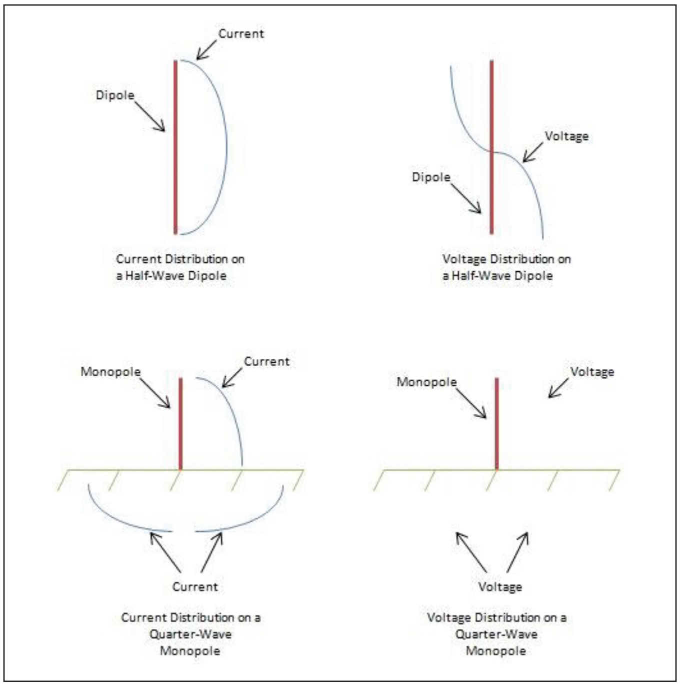
Now on to a 3 x 3 mobile LTE antenna. At 694 MHz the spacing required to get the 0.5 correlation Coefficient is 5.1 inches plus the quarter-wavelength ground requirement give us, 5.1 + 4.25 + 4.25 = 13.6 inch diameter ground plane. So the ground plane requirements for the lower frequencies become more challenging.

MIMO techniques use the fact that signals from multiple transmitting antennas, each with slightly different characteristics, will arrive at the receiving antenna at slightly different times and from slightly different directions. The old enemy of systems designers, the multi-path reflection, actually helps. The transmitters are designed to split the data stream between the various antennas and transmit them at different phases so there is an inherent delay between each transmission path. The receivers are designed to use the separate data streams to digitally reconstruct the data. The results are a data transmission which has significant increases in transmitted data rates over a conventional single data path system.

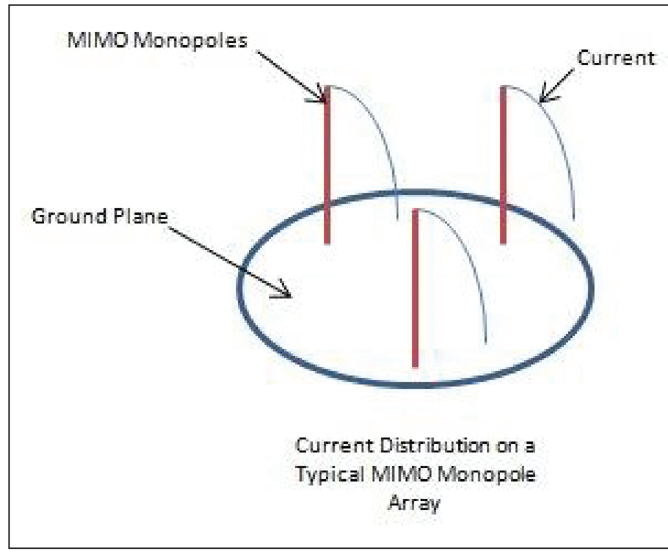
In many systems the designers have chosen not only to have the separate data paths at different times but also to have the transmission antennas at different polarizations or from slightly different antenna locations. This has multiple benefits. The first is the fact that if you are trying to communicate with a portable device you really have no control over what polarization the portable device's antennas are at. So transmitting multiple polarizations means that one of the data streams should be near the ideal polarization. Secondly, transmitting multiple polarizations also has the benefit that the multi-path reflections will be quite different for each data stream so the data will arrive at the receiver at different times.

Pitfall: The Environment

The pitfall of the multiple polarization schemes is the environment. In



Antenna Current and Voltage



Current Distribution on a Typical MIMO Monopole Array

the old two-way radio days there were many tests run to demonstrate the fact that most reflected signals tend to become vertically polarized due to the fact that most objects in the real world that are effective reflector are vertical. This actually has a benefit to mobile users that have remote antennas mount on vehicle since most mobile antennas use vertical elements. Multiple polarizations really excel in an indoor environment. The surfaces in an office or home are not predominantly metal and vertical so the polarization has a better chance of staying pure. Also, transmission distances are typically shortened so there is less chance for the polarizations to change. Spatial Segregation can also be employed. In Spatial Segregation the location of the separate transmitting antennas are different; they may also be aimed at slightly different angles. Since the locations are different, the transmitted signals will arrive at the receiver at different times so there can be data rate improvements.

For portable devices another challenge is size. Nobody wants a portable device that's 13 inches in diameter. So there are many trade-offs and pitfalls. Popular configurations for MIMO antennas used in Smart phones are: composite frame antennas, MIMO cube elements and/or Thick film Planar Inverted F's. Many proverbial hoops need to be jumped through to make these elements work. For MIMO the main challenge is getting these elements to act as separate antennas. The spacing is so close together that the elements tend to work together as one. Exotic techniques involving phasing and neutralizing are attempted to try to isolate the elements and ultimately achieve data rate increases.

MIMO technology offers great improvements in the speed of data transmission. The future will bring many more innovative antenna schemes to cope with the pitfalls. Currently, access points are commonly available with up the six separate transmission streams. Portable devices are being deployed with two and three streams. As the push for speed continues, who knows where the technology will go? Ultimately, innovative antenna designs along with system designer knowledge of antenna basics can tip the scales for successful MIMO deployments.

Author Information

Jerry C. Posluszny serves as Engineering Manager at Mobile Mark, Inc., headquartered in Schiller Park, IL. He recently celebrated his 15th anniversary with the company. Jerry has been an active Antenna Design Engineer since joining Mobile Mark and currently leads the engineering team. Previously he was employed as a Project Engineer in the medical electronics industry. He has been granted several patents in the Electronics and RF fields and holds an Amateur Extra license. He studied at The City Colleges of Chicago.