The Diversity Fin™ Antenna and Polarization Diversity for Wireless Microphone Applications

by Michael Benonis

Introduction

In many wireless microphone applications, even small signal dropouts are unacceptable. Multi-path fading typically causes dropouts, rather than weak signal strength caused by too great an operating distance. One method to reduce the likelihood of dropouts is to use a diversity receiver with two antennas. While it is common practice to connect two physically separated antennas to these inputs, there are other antenna designs that achieve the same goal of reducing dropouts. One such antenna design is the Diversity Fin antenna. This white paper will explain how the Diversity Fin antenna works and what benefits it has over traditional wireless microphone antenna systems.

Background

Signal fades are generally caused by either path loss or multi-path interference. Since UHF wireless microphones are typically operated within a few hundred feet of the receiver, path loss is rarely the problem, even with low power transmitters. This leaves multi-path as the cause of most signal fades. Multi-path is a result of radio waves bouncing around in a room, much like an echo chamber. These echoes create a pattern of nulls, and if the receiver antenna is in one of these nulls, the signal is lost. While occasional signal fades might be tolerable in cellular telephone systems, any dropout is unacceptable during concerts, corporate presentations, broadcasts, or worship services because it significantly distracts the audience.

Diversity receivers help combat fades by using two antennas to reduce the odds of a total loss of signal. These receivers usually have two antenna ports and a circuit that compares the signal at each port. The receiver then either selects the better one (usually the strongest) or combines the signals with the goal of making dropouts and other undesirable sounds inaudible.

A fairly common diversity technique in wireless systems is *switched* or *selection diversity* [1]. In these systems, a sensing circuit determines the signal strength at each antenna and passes the better signal to the receiver circuit. A variant of this system forces a switch command when the selected antenna's signal drops below a preset threshold, but so-called "blind switching" can lead to poor switching decisions that result in dropouts [2].

A more complex antenna diversity technique is called *Maximum Ratio Combining*, or MRC. In MRC systems, both antennas are active at the same time, but the ratio of the two signals is varied as a function of the signal to noise ratio [1]. In the best-case scenario, this results in a 3dB boost in effective signal strength for a two-antenna system [3]. This technique is commonly used in higher-end receivers. More exotic diversity systems exist as well, including systems that use two separate transmitters on separate frequencies, but these systems are typically reserved for the most mission-critical applications and are decidedly more expensive.

All diversity techniques are based on the principle that using multiple independently variable channels reduces the chance of a total loss of signal [1]. In the event that the channels become correlated, where they do not vary independently, the likelihood of a total dropout increases significantly. A typical method of ensuring independent channels exist is to space two or more antennas apart by greater than few wavelengths, and is often very effective in providing uncorrelated channels, but it can be difficult to space antennas properly in many situations.

<u>How the Diversity Fin Works</u>

The Diversity Fin antenna uses a different approach to the problem: Rather than spacing two antennas apart, it takes advantage of the fact that radio waves are *polarized*—that is, they have a specific orientation with respect to objects in the environment. The Diversity Fin uses polarization diversity to achieve the same result as spaced antennas from just a single position, dramatically simplifying wireless microphone installation and setup.

Figure 1: The Diversity Fin Antenna

To understand how this is possible, it is necessary to understand how polarization plays a role in multi-path environments. Most small wireless devices, such as wireless microphones, generate linearly polarized radio waves. This means that the electric field is always pointed in the same direction as the antenna. The receive antenna must generally be pointed in the same direction, or some fraction of power will be ignored. While this is simple to ensure for fixed transmitter antennas, it is a problem when the transmitters are constantly in motion in a mobile bodypack or handheld form.

Cellular phone systems were a major driver of research into how UHF radio waves propagate in multipath environments where the transmitter is constantly moving. Bell Labs performed extensive research in this area [4] and found two important things: The first is that a vertically-polarized transmitter moving within a multi-path environment results in significant horizontally-polarized energy, on the order one-quarter the power of the vertical component, due to multi-path reflections that change the polarization of the signal. This is significantly different from the theoretical result where a cross-polarized receiver antenna would not see any signal. The second, more important finding was that a pair of cross-polarized antennas at the same location never resulted in a fade of more than 1 dB, on average.

The reader may wonder why the signal does not fade in both polarizations if the antennas are at the same location. The reason is that the strength of reflections depends to a significant degree on the orientation of the wave with respect to the surface [5]. For a vertical wall, this means that a vertically polarized wave will reflect differently than a horizontally polarized wave, and that the pattern of nulls in a room is different for horizontally polarized radio waves than vertically polarized radio waves.

Since wireless microphones transmit with randomly oriented linear polarization, the result is a constantly changing pattern of nulls in a room that is different for vertical and horizontal waves. A horizontally and a vertically polarized antenna at the same point in space are statistically independent—the key requirement for a diversity system to work effectively. More simply put, there is almost never a time when both vertical and horizontal planes will fade in the same location! Hence, an antenna with both horizontal and vertical elements dramatically reduces the chances of a fade.

This is exactly the principle behind the Diversity Fin antenna [6]. The Diversity Fin antenna combines a Log Periodic Dipole Array, or LPDA, with a perpendicularly mounted dipole antenna. The LPDA antenna is a medium gain antenna that responds to linear polarization. Figure 2 shows a plot of the antenna's gain pattern, which shows it is more sensitive to radiation from the front. In addition, it attenuates radio waves from behind, and this helps to reduce the amount of multi-path seen by the antenna, which can reduce fades.

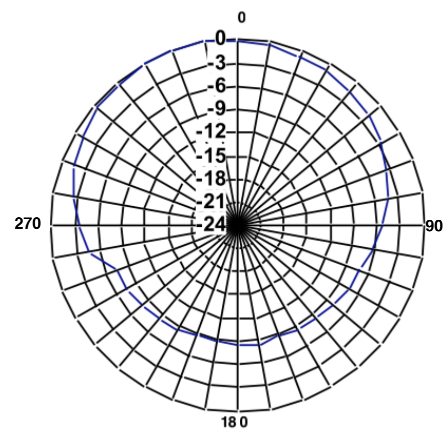

Figure 2: LPDA Gain Pattern

The dipole antenna is mounted perpendicularly to the LPDA, and responds well to radiation of the opposite polarization of the LPDA. If the LPDA is mounted vertically, then the dipole responds well to horizontal radiation. The dipole's mounting location on the LPDA affords it forward gain as well, as can be seen in Figure 3. This also helps to reduce multi-path seen by the antenna.

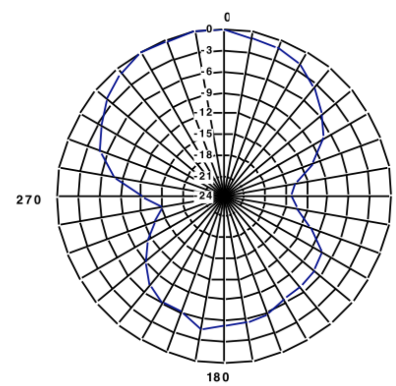

Figure 3: Dipole Gain Pattern

Because the vertical and horizontal multi-path environments are essentially uncorrelated, it is highly likely that either the LPDA or the dipole will have acceptable signal strength at any given time. The Diversity Fin has separate RF outputs for the LPDA and dipole components, and these two outputs are connected to the two antenna inputs of a diversity receiver for diversity reception. The receiver can then use diversity techniques with a single antenna system, as opposed to two spaced antennas.

Aside from the advantages of polarization diversity, the Diversity Fin's provided cover, or radome, allows the antenna to work well in the rain and other adverse conditions. This is because water cannot come directly in contact with the antenna, which may affect the pattern of the antenna. The Diversity Fin can also be folded into a compact form factor for storage and transport.

Conclusion

Wireless microphones operate in environments rich with multi-path interference that can result in deep signal fades at times due to constantly moving transmitters. It is imperative that wireless microphone systems use diversity receiver systems to avoid dropouts that are a result of fades. Diversity receive systems are based on the fundamental concept that multiple, statistically independent receive antennas exist within the environment. Traditionally, this criterion is met with two antennas spaced apart by multiple wavelengths. However, the

Diversity Fin antenna uses the novel approach of perpendicularly mounted elements held in a fixed relationship to achieve the same benefit as two antennas.

Conclusion

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