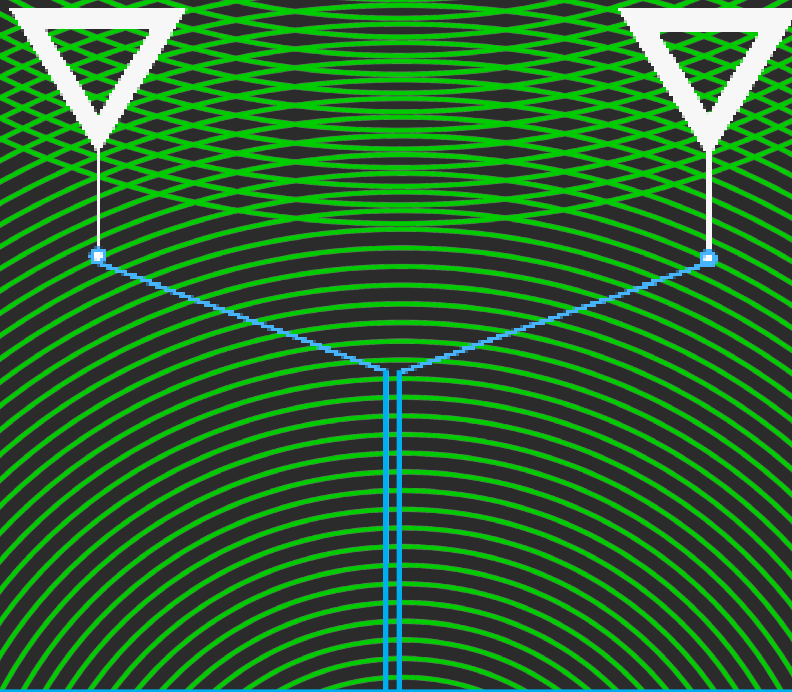


Application Notes

The Diversity Fin Antenna and Polarization Diversity



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Introduction

In most 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.

The [RF Venue Diversity Fin™](#) is a proprietary and innovative antenna design for entertainment production wireless that statistically eliminates the leading cause of dropouts in low-power wireless applications—multi-path interference. Incorporating orthogonally (perpendicular) opposed elements, a single antenna unit can now provide both cross polarization sensitivity and dual feeds for diversity wireless microphone receivers without the need to deploy two physical antennas at a calculated or estimated distance.

Background

Signal fades using low power radio in indoor environments are generally caused by either path loss or multi-path interference.

Since UHF wireless microphones are typically operated within a hundred feet of the receiver, path loss is rarely the problem, even with low power transmitters. This leaves multi-path interference as the cause of most signal fades. Multi-path is a result of radio waves bouncing around in a room, much like in an echo chamber. These “echoes” create a pattern of nulls (constantly changing as the microphone transmitter moves about), 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 as it distracts the audience and may even get production staff fired.



Diversity receivers mitigate fading 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. 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.

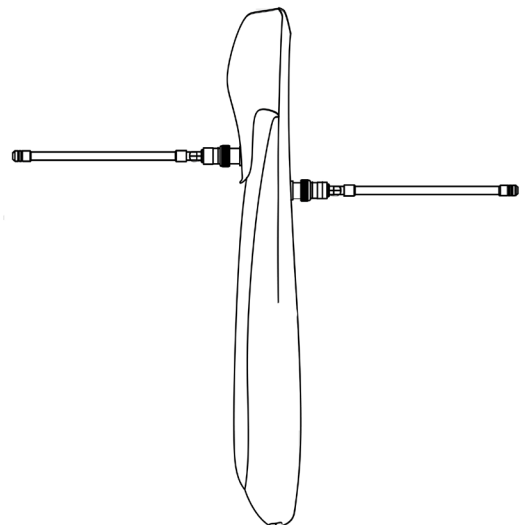
A more complex antenna diversity technique is called Maximum Ratio Combining, or MRC. In MRC systems, both antennas are active at the same time, but the ratio of the two signals is varied as a function of the signal to noise ratio. In the best-case scenario, this results in a 3dB boost in effective signal strength for a two-antenna system. 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 RF signal paths from the RX antenna to the receiver reduces the chance of a total loss of signal. In the event that the paths become correlated, where they do not vary independently, the likelihood of a total dropout increases significantly. A typical method of ensuring independent paths exist is to space two or more antennas apart by greater than a few wavelengths, and is often very effective in providing uncorrelated channels, but it can be difficult to space antennas properly in many situations.

How the Diversity Fin Works

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 Earth. The Diversity Fin uses polarization diversity across two antennas in one antenna unit to achieve the same result as spaced antennas from a single position, dramatically simplifying wireless microphone installation and setup.

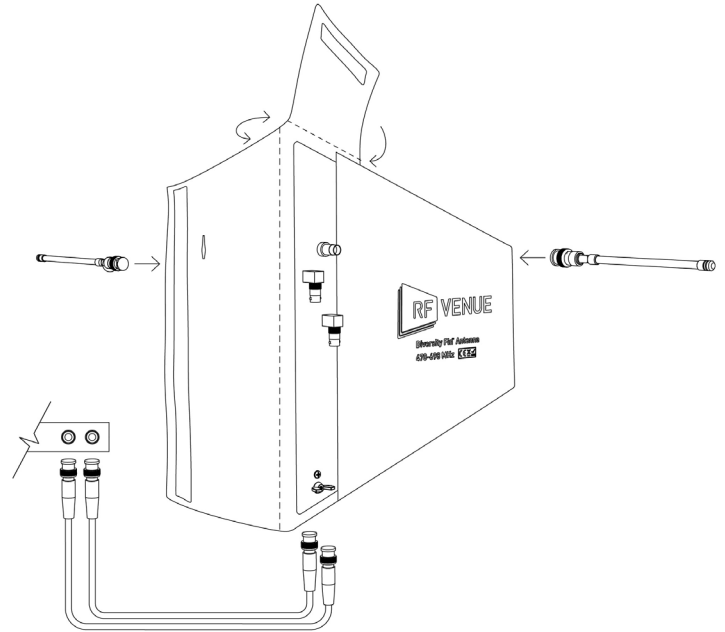
To understand how this is possible, it is necessary to understand how polarization plays a role in multi-path environments. Most small wireless devices, such as wireless microphones, generate linearly polarized radio



waves, consisting of an electric field and an orthogonally opposed magnetic field. The electric field is always pointed in the same plane as the antenna. The receive antenna must generally be oriented in the same plane as well, 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.

Mobile transmitters create and amplify what are known as “fading” conditions, especially slow fading, versus fast fading. Fading is necessary to understand how polarization plays a role in multi-path environments and the elimination of multi-path interference.

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 area¹ 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 of 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.

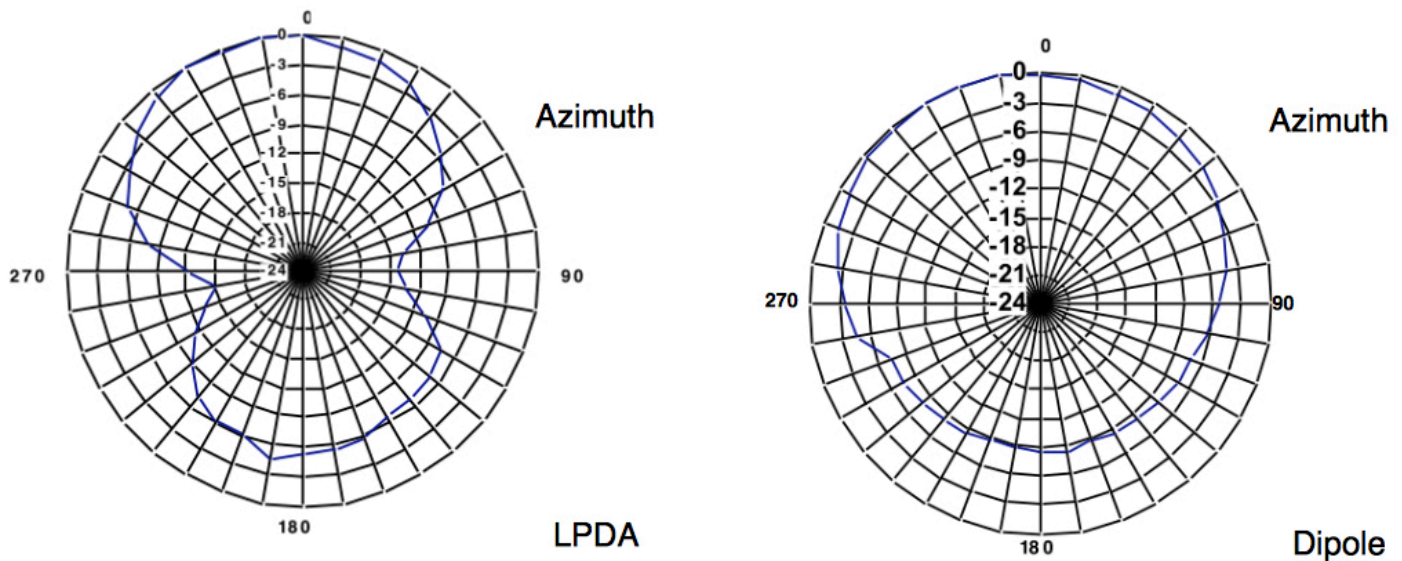


The reader may wonder why the signal does not fade in both polarizations if the antennas are at the same location. The reason is that the strength of reflections depends to a significant degree on the orientation of the wave with respect to the surface.² For a vertical wall, this means that a vertically 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 polarizations, 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 antenna³. The Diversity Fin 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. The image below 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.

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. This also helps to reduce multi-path seen by the antenna.



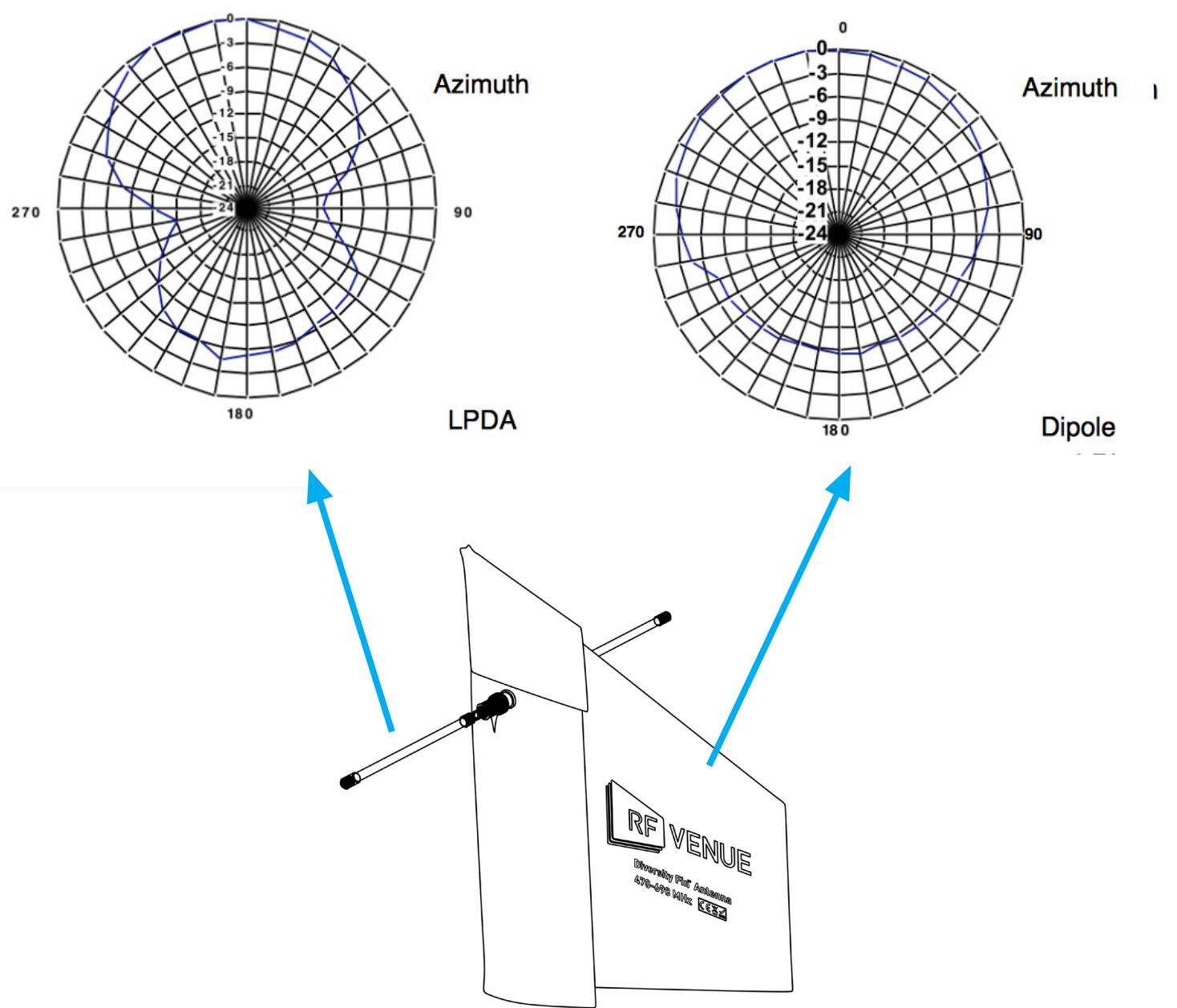
Because the vertical and horizontal multi-path environments are essentially uncorrelated, it is highly likely that either the LPDA or the dipole will have acceptable signal strength at any given time. The Diversity Fin has separate RF outputs for the LPDA and dipole components, and these two outputs 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.

Diversity Fin Antenna Innovation In-Depth

The underlying design of the Diversity Fin is a log periodic dipole array (LPDA, aka “shark fin” and “paddle”) tuned for the North American UHF-TV band of 470-698MHz with a half-power horizontal beamwidth of 100-110 degrees, 5-6dB forward gain, 12-15dB front to back ratio, and a nominal 50 ohm impedance. This is the first radiating/reception element terminating in a female BNC mounted to the PCB plane comprising the structure of the antenna.

The innovation places a second dipolar element orthogonally with respect to the LPDA directly on the PCB plane in the rear null. This element terminates into a second female BNC adjacent to the LPDA's. From an RF performance perspective with respect to a diversity wireless mic receiver, the orthogonally opposed antenna elements achieve the same electrical isolation between the elements as two antennas spatially separated sufficient for reactive near field isolation (a bit more than one wavelength) while being sensitive to all arriving wave polarizations with no more than 3dB cross polarization loss, regardless of where it is placed.

The forward gain of the LPDA provides for greater sensitivity when the transmitter is at distance without being overly susceptible to unwanted RF energies from the rear. Conversely, the horizontally polarized elements provide for better response when the transmitter antenna is greater than 45 degrees from vertical, and thus greatly reduces dropouts due to cross polarization.

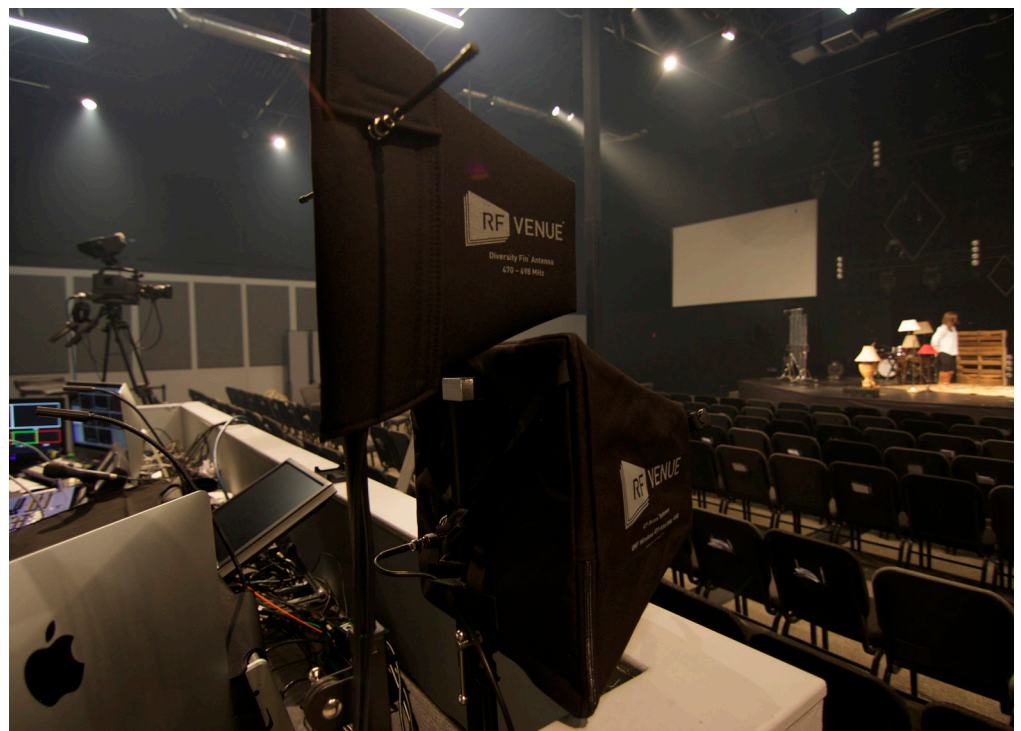


Use in the Field

So what is the practical implication and application of such a design, as it pertains to entertainment production wireless microphones? The first considerations with any antenna deployment is to determine the required coverage area(s), obstructions in the propagation path (e.g. set pieces, other performers/talent) aesthetics (camera angles, or simply visual displeasure by senior event staff) and coax path(s).

In some situations, such as TV/film location shoots and convention breakout rooms, setup and tear down time may also be a significant issue. Diversity pairs of antennas with insufficient “views” of the required coverage area, insufficient physical separation, reflective surfaces within reactive near fields or having long coax runs with excessive loss all contribute to less than acceptable signal levels at the receiver(s) during the course of the event.

Long coax runs also run the risk of damage or presenting a trip hazard. With a single antenna unit design, a single optimum location and coax path is required, deployment and removal can be achieved in less than half the time as with two antennas, and the one location presents fewer aesthetic concerns. As with all engineering designs and deployments, compromise of many factors is ever present. One key to successful operations is selecting the best tool for the application based on these factors, and the Diversity Fin is a novel tool to have among one’s antenna inventory.



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.

— About the Authors —

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