White Paper on Vector Diversity

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Introduction

When it comes to the saying "two are better than one", it's difficult to find a scenario where this is more true than in the context of wireless microphone antennas. We tend to think of operating range being limited by signal strength, and it is, but the distance to the first drop-out is more often dominated by the ability of the wireless receiver to cope with *multipath interference*, a phenomenon in which the same signal arrives at the same receiving antenna via multiple paths of different lengths and via different angles. Since radio signals are waves, they can either reinforce each other or cancel each other, depending on how they are combined. When cancellation occurs, there can be little or no energy at the antenna, even at relatively close range: strong signal, minus same strong signal, equals no signal!

Diversity systems overcome this problem by using multiple antennas (usually two). The basic idea is that it is exponentially less likely that destructive interference will occur at multiple antennas at the same time. What turns the science of diversity design into an art is the myriad ways that energy can be harvested and/or combined from the antennas, to optimize the receiver's performance. Ideally, all the available energy at both antennas would be combined constructively at all times. This white paper discusses some of the most commonly used types of dual antenna diversity systems, and then introduces Vector Diversity, which is able to deliver superior performance for FM (e.g. Digital Hybrid) systems, and superlative performance for all-digital systems.

Antenna Switching Diversity

The simplest type of diversity system involves using one antenna at a time. In the case of FM systems, where the act of switching antennas can introduce a slight audible "tick" in the receiver's audio, the receiver tries to switch only as necessary to escape an anticipated drop-out. In digital systems, where it is usually possible to switch silently, the receiver may switch freely, attempting to maximize the received signal. Notwithstanding its simplicity, this type of diversity system is very effective and widely used today.

Phase Switching Diversity

An improvement on antenna switching can be obtained by always combining the power from the antennas in two ways -- in phase, and out of phase -- and switching to choose the better of the two phase combinations. In most cases, energy is present at both antennas and can be constructively combined. This leads to a higher average signal strength under a given set of conditions, which translates to improved system performance.

Dual Receiver Diversity

Excellent diversity performance can be obtained if two complete receivers (radio sections) are used, one for each antenna. The two received audio signals can then be blended in proportion to the relative signal strengths at the antennas. Most of the time, a good signal is present at both antennas, in which case the audio signals combine constructively, achieving a better signal-to-noise ratio than would be possible with one antenna. At those times that destructive interference affects one of the antennas, the blend is preemptively transitioned to the other antenna, for continuous, artifact-free reception. This battle-tested type of diversity system has been called by many names, such as "true diversity", "ratio diversity" and others.

Vector Diversity

While intuitively it might seem that a dual receiver method would yield the best achievable performance from two antennas, this is not always the case. For one thing, the blending method must be implemented conservatively, in order to make sure that a fading antenna is safely removed from the mix before the audio becomes noisy. This means that the energy from both antennas can only be fully combined in the best case, where both antennas are receiving strong signals. At other times, a dual receiver diversity system is forced to use one antenna at a time.

Another subtle disadvantage of the dual receiver method comes into play when receiving all-digital signals, due to the *cliff effect*. Digital systems typically do not degrade gradually with progressively poorer signal; rather, they deliver great performance until at some point they "fall off a cliff" and abruptly sound dramatically worse. Because of the cliff effect, in all-digital modes it is possible to have a situation where the combined energy at the two antennas combined would be sufficient for good reception, yet each antenna on its own is "over the cliff" -- not individually recoverable. In this scenario, the dual receiver method falls short of the ideal.

Enter Vector Diversity. Vector Diversity works by expressing the signal from each antenna in vector form (angle and magnitude). This makes it possible to continuously rotate one of the vectors mathematically so the angles match and the signals can be combined constructively. In this way, all the energy that is available at both antennas is always fully contributing to the receiver's performance.

Lectrosonics does this by implementing two complete receivers, converting each antenna's signal to a vector at an intermediate frequency in the digital domain. These vectors are then rotated and combined optimally, then demodulated. This technique is applied in exactly the same manner for all types of modulation.

Conclusion (TL;DR)

Today's diversity reception systems all have merit, but for that little bit of extra technological magic to avoid drop-outs, vector diversity offers an optimal power combination advantage not available via any other method. When performance counts, you can count on Lectrosonics.