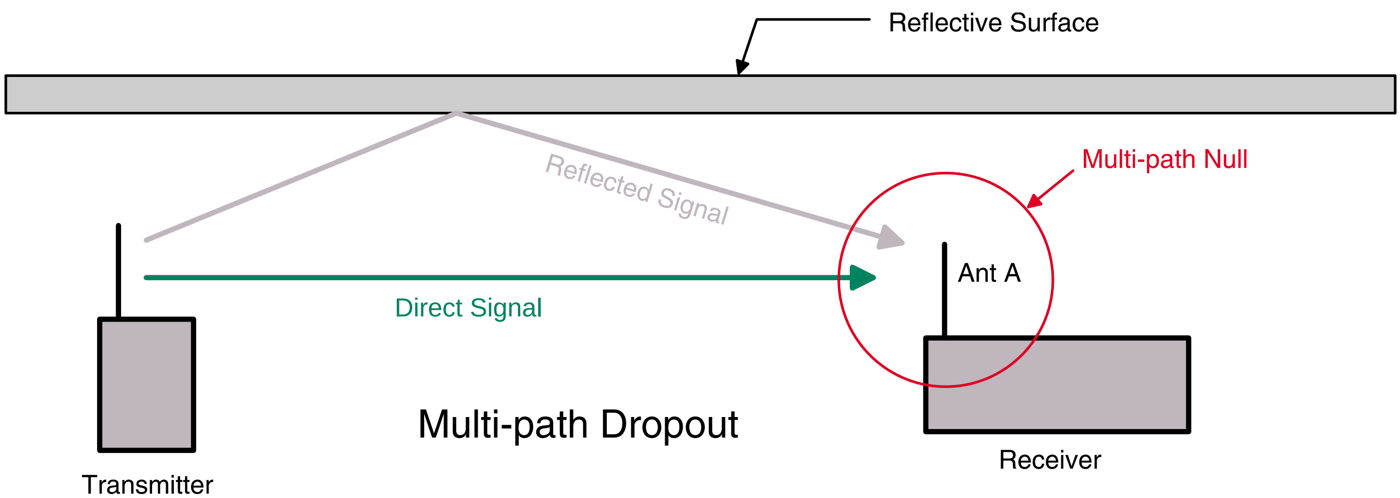
DIVERSITY RECEPTION

The term "diversity" is one of the most widely misunderstood concepts of wireless systems. This word stems from the root word "diverse," meaning "not correlated." As it applies to wireless microphone receivers, the term simply refers to the use of two antennas to eliminate "dropouts" caused by multi-path phase cancellations (multi-path nulls).

A multi-path null is illustrated below. In this example, the signal from the transmitter reaches the receiver antenna via a direct path and a reflected path. The reflected signal path is a bit longer than the direct path, causing the two signals to be out of phase when they mix together at the receiver antenna. The resulting weak signal causes what is known as a "dropout."

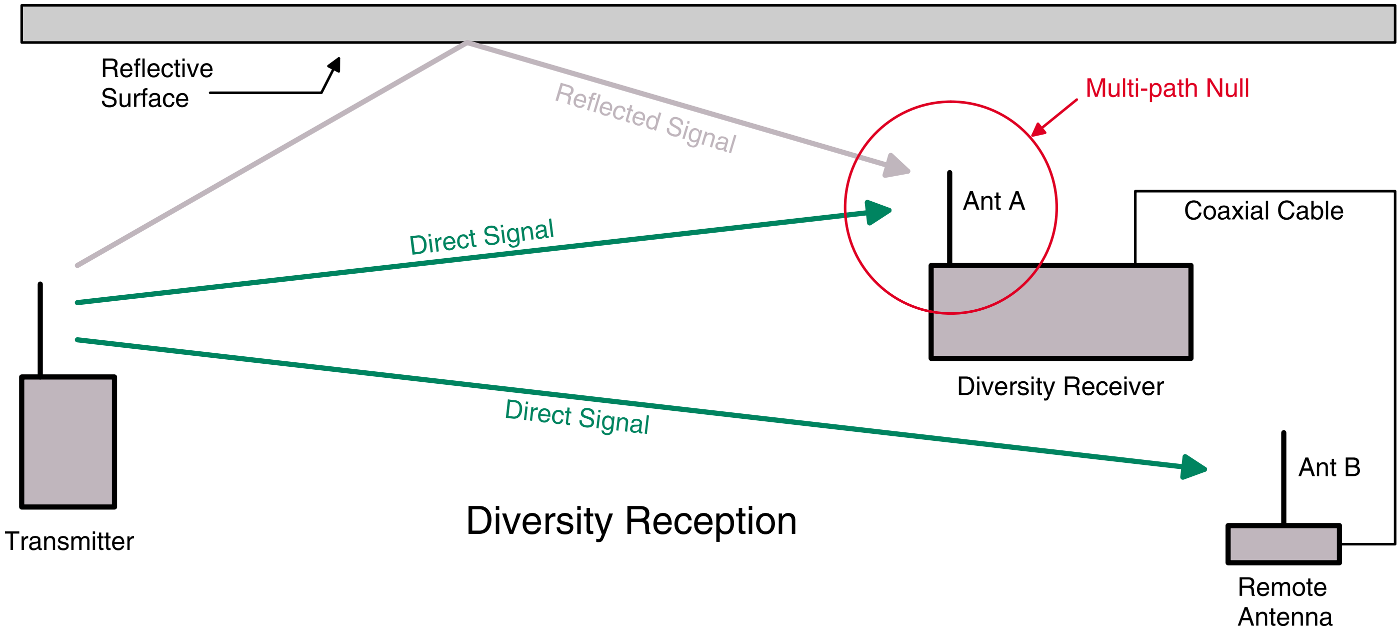


The most common type of dropout might more appropriately be called a "noise up," where the receiver audio output remains open during a multi-path null, and brief hiss, clicks, pops or other noise can be heard momentarily along with the audio. A complete loss of the audio can also occur if the multi-path null is deep enough to cause the receiver to squelch. VHF dropouts usually sound more like a momentary swishing or hissing sound, sometimes along with a buzzing sound. UHF dropouts are more shorter in duration than VHF due the the higher frequency and shorter wavelength, sometimes sounding more like a pop or click.

Multi-path conditions that cause dropouts are very common indoors, since the output of a wireless transmitter radiates in all directions and bounces off of many types of surfaces in the room. In reality, a wireless system operating in a room will be generating perhaps hundreds of reflections around the room, but the system continues to operate since the direct signal is normally stronger. Metal is an especially good reflector, so multi-path conditions also occur outdoors, since the transmitter signal can be efficiently reflected from cars, trucks, trailers, metal building surfaces, etc.

Dropouts occur when the transmitter and receiver antennas are in a particular location relative to each other. Moving the transmitter or receiver to a different location can oftentimes reduce or eliminate the dropouts. Other objects that move around the room, like people's bodies, also alter the reflected and direct signals and can make dropouts either more or less prevalent.

The wavelength of radio signal carriers at VHF frequencies ranges from about 5 to 6.5 feet long. At UHF frequencies, the wavelength ranges from about 12 to 20 inches. The point is that the "dropout zone" (the location where a dropout occurs) will be larger at VHF frequencies than at UHF frequencies, so antennas have to be moved farther with a VHF system than with a UHF system to alleviate dropouts. This also means that locating and being able to identify a dropout zone during a walk test is a bit easier with a VHF system than with a UHF system.



In this simplified illustration of diversity reception, the signal arriving at antenna A is largely cancelled by a multi-path null, leaving little signal left for the receiver. The signal at antenna B remains strong and provides adequate signal for the receiver to produce a usable audio signal to noise ratio.

Note that the illustration shows antenna B as a “remote” antenna connected with coaxial cable. The spacing between the antennas must be at least 1/2 wavelength of the operating frequency to ensure that the antennas are receiving uncorrelated (“diverse”) signals to gain the full benefit of diversity reception.

Imagine what would happen if antenna B was also mounted on the receiver. If the system was a VHF design, there would be a strong chance that the multi-path null would occur simultaneously at both antennas. What would be the benefit of trying to switch back and forth between two antennas that are picking up the same signal? The difference between the two signals would be either nonexistent or so minimal that it would not have any effect on the reception. At UHF frequencies with the shorter wavelengths, there might be enough space between the antennas to achieve some benefit of diversity reception when two antennas are mounted on the receiver.

Diversity circuitry implemented in a high quality receiver with excellent sensitivity will reduce or eliminate multi-path dropouts, and in some cases, increase operating range. The improvement in reception will vary depending upon the diversity methodology chosen by the designer.

The type of diversity reception circuitry chosen in the receiver design includes a number of considerations, including cost, size and weight, performance and the practicality of each circuit type for a given application.

Cost is the major criteria for designs driven primarily by market considerations. Size and weight are most important in receivers designed for field production. Performance is the primary focus in high-end studio and stage receivers. In designs aimed at motion picture production, the price of the wireless equipment is far out-weighed by the cost of perhaps even a single day of production, so audio and RF performance is the primary concern.

How the incoming signals from two different antennas are handled after they enter the receiver is what makes the difference between a good design and one that has problems. Using diversity reception makes little sense unless the receiver is a high quality design to begin with. A low sensitivity diversity receiver will often have problems in an environment where a single antenna, high performance receiver will operate without noise or dropouts. “Diversity” reception of any type will do little, if anything, for a low performance receiver. In fact, it can even make matters worse.

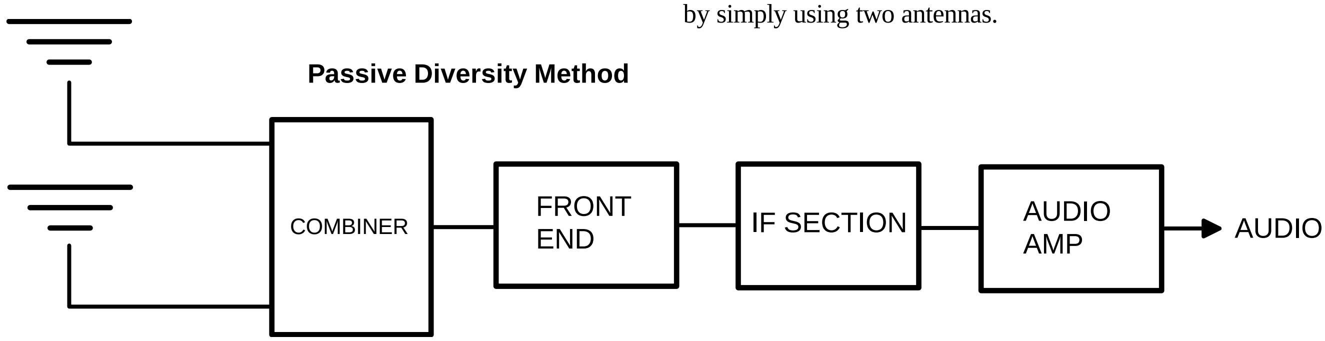
The following pages illustrate and discuss several different techniques used for diversity reception in various designs with varying degrees of success.

PASSIVE DIVERSITY

This is simply the addition of a second antenna to a single receiver, placed ½ wavelength or more away. This can be accomplished easily with an outboard combiner and a second antenna. Two combined antennas will gather more RF signal and can reduce dropouts to a small degree.

The logic behind using two antennas as opposed to one is simply "playing the odds." The chances of a multi-path "null" occurring at both antennas at the same time are perhaps less, but when both antennas have a good signal, but the signals are out of phase with each other, dropouts will still occur. Real world tests have shown that there is no real improvement in the prevention of dropouts by simply using two antennas.

Passive Diversity Method



ANTENNA PHASE SWITCHING DIVERSITY

The primary advantage of this technique is small size, which explains why this method is used in compact receivers designed for field production. Two antennas are mixed to feed a single receiver, with a phase reversal switch added to the input of one of the antennas. When signal conditions deteriorate, the phase of one of the antennas is reversed and logic circuitry then determines whether or not the switching action has improved the signal to noise ratio or not, and decides whether to latch in that position or switch and sample again. The antenna phase will remain in the better position until the signal deteriorates again, when the process is repeated.

The logic underlying this approach is this:

1) If either antenna has a strong signal, reception will be OK.

2) When both antennas have an in-phase weak signal, the signals will add to each other and provide more total RF signal.

3) When both antennas have a strong signal, but they are out of phase with each other, phase cancellation between them will reduce the signal level reaching the receiver. When this occurs, the receiver reverses the phase of one of the antennas, thus restoring the RF signal in most cases.

The problem with this approach is:

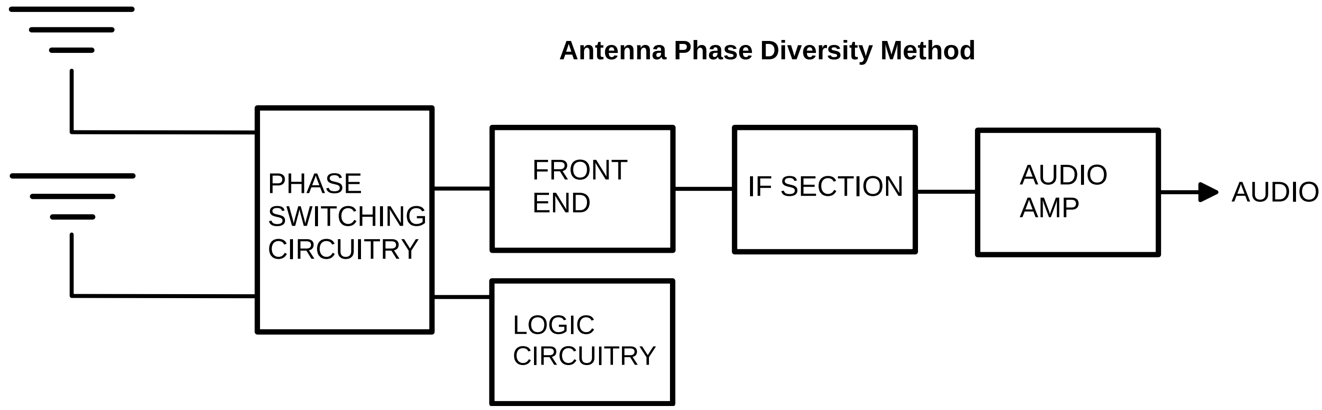
1) The receiver doesn't react until it is already in trouble.

2) There is always the possibility that switching phase will make a marginal problem worse.

3) Since the switching circuitry is in the RF signal path and is triggered only at low RF levels, it can produce a "click" when the switching occurs.

A special adaptation of this diversity technique is a microprocessor controlled algorithm called SmartDiversity™ offered by Lectrosonics in compact receivers. Embedded firmware in the receiver controls the diversity sensing and switching circuitry based upon an analysis of RF level and the rate of change of RF level. The firmware determines the optimum timing for switching and sampling to minimize dropouts and eliminate noise in the audio that could be caused by the switching activity. This "intelligent" algorithm also integrates with the SmartSquelch™ firmware in these receivers to employ "opportunistic" sampling and switching. The system will take advantage of brief squelching activity to switch, then sample and determine the best antenna phase setting while the audio is being muted by the squelching system.

Antenna Phase Diversity Method



AUDIO SWITCHING DIVERSITY

This approach uses two separate receivers, selecting the audio output of one of the receivers. It is quite effective at overcoming dropouts, but only provides a minor improvement in operating range. The switching action is usually triggered by comparing incoming RF levels and switching to the receiver with the stronger RF signal, which usually produces a better signal to noise ratio in multi-path conditions.

This method is often called "true diversity" by some manufacturers, seemingly to discredit other diversity techniques and place a particular receiver model in a more competitive position in the market. This technique is a valid approach to implementing a diversity receiver, but suffers from some inherent limitations just like other diversity techniques.

First of all, the physical size of two receivers is greater than a single receiver (common sense). Given that the physical dimensions of the front-end filters and circuitry in a high quality receiver are limited to a certain minimum size due to the frequency wavelength, this design is impractical for compact receivers intended for field production. In addition, two receivers require more power than one, which imposes another limitation to using this approach to diversity reception on a compact, battery powered receiver. In order to implement this technique in a compact, battery powered receiver, serious compromises must be made in the circuit design to reduce the physical size and power requirements.

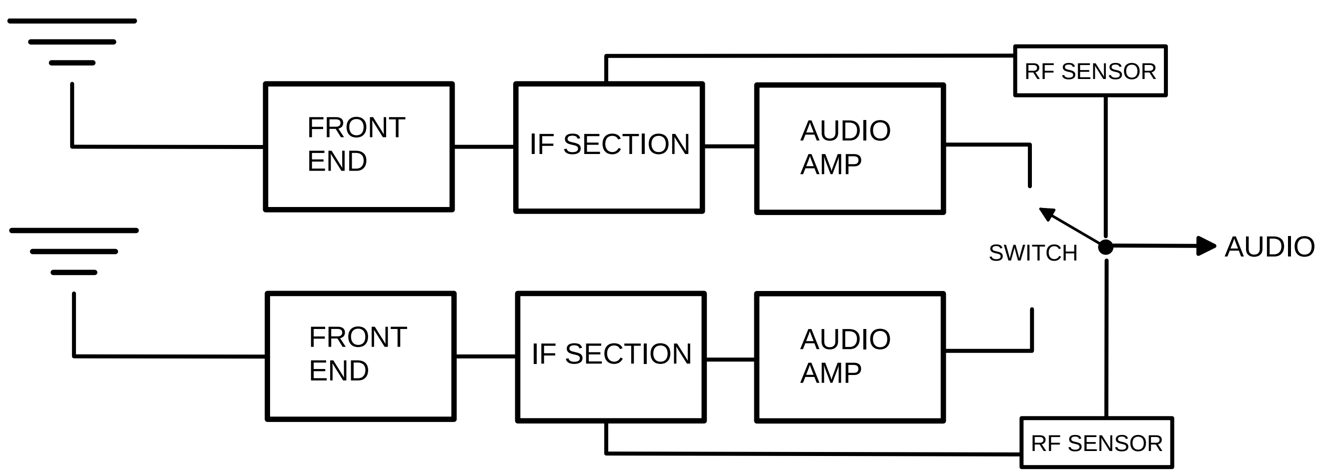
This diversity reception technique is, however, very effective at minimizing dropouts in a receiver design that is not limited by power requirements, physical size and cost. The logic behind this approach assumes that if the signal at one antenna is bad, then the signal at the other antenna is good. More often than not, this is the case, but there are still circumstances that occur where a poor signal exists at both antennas.

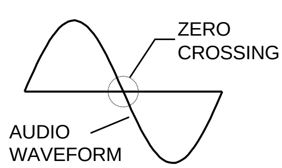
The switch from one receiver audio output to the other must occur at the "zero crossing" point in the audio signal, or a click or pop will be heard. This means that additional circuitry is needed in the receiver to determine when the audio signal is at the zero crossing point and enable the switch at that instant. In addition, the receiver audio output levels must be perfectly matched, or an audible change in level will occur when the switching takes place.

Some receiver designs handle switching so poorly that they actually interrupt the audio signal briefly, or shift the audio level when the switch occurs. You can well imagine what that sounds like when the overall RF level is low or in severe multi-path situations and the receiver is switching back and forth rapidly.

Another problem with an audio switching design revolves around the method of sensing used to trigger switching. If the switch is activated by comparing RF signal strength in the receivers, it is likely that the switch can be "fooled" by external RF signals at one antenna. For example, if an RF noise source is near one of the antennas, the receiver might think that this antenna has a stronger RF signal level and favor it in the switching. An external RF noise source produces mostly high frequency audio noise in the receiver, so this type of design could have serious problems in a typical stage setup where synthesizers or other digital equipment in use. If the receiver offers high selectivity, then using the RF signal level at each receiver to control the switching is a safe assumption.

While most of this discussion may seem negative toward this approach to diversity reception, the fact is that this technique is one of the more effective methods of reducing dropouts when it is used in a high quality receiver design.





The "zero crossing point" in the audio signal occurs between the positive and negative voltage swings when the voltage is at zero.

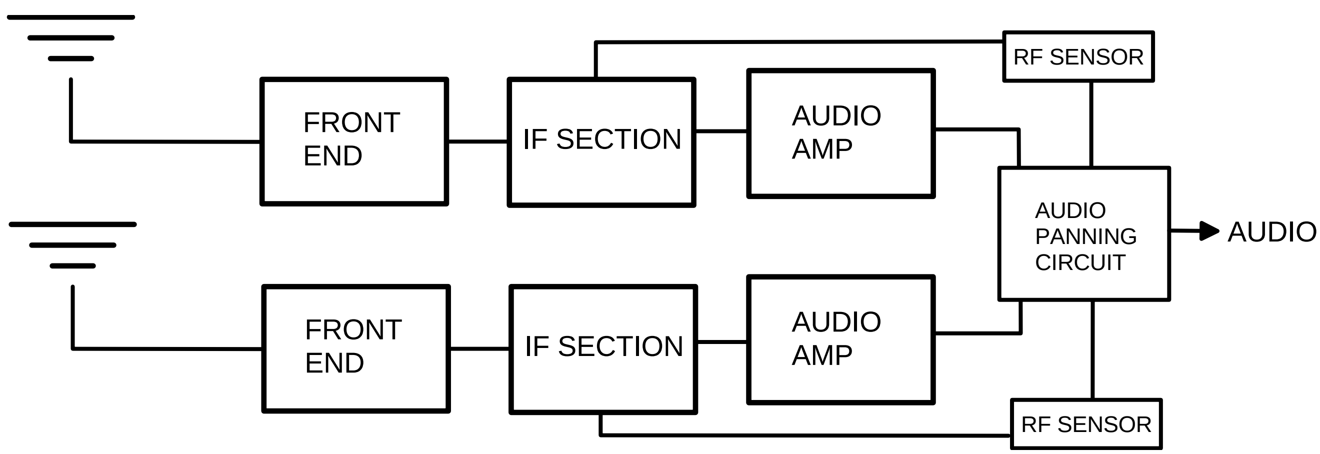
RATIO DIVERSITY (audio ratio combining)

This approach to diversity reception utilizes two separate receivers, sharing a common oscillator and audio circuitry. The audio outputs of the receivers are used simultaneously, being mixed by a “panning” circuit in a ratio controlled by the comparative RF levels at the receivers. This method anticipates dropouts long before they occur, since the comparative RF level sampling and mixing starts taking place at higher RF signal levels than in other diversity designs. By the time the signal level at one receiver drops low enough to produce noise, the panning circuitry has long since shifted to the other receiver.

The ratio combining process is similar to an audio switching diversity design, in that both techniques assume that if the RF level at one receiver is low, it will be better at the other receiver. The difference between these two techniques rests in the fact that a ratio diversity receiver utilizes both receivers simultaneously, whereas an audio switching type uses only one receiver at a time. This difference comes into play when the overall RF signal level is low and the receiver is struggling to find enough signal to produce a usable signal to noise ratio. In this situation, two antennas will gather more signal than one, and the panning circuitry in a ratio diversity receiver will continue to balance the outputs of the two receivers for the lowest noise even at very low RF levels. A switching diversity receiver will be busy selecting one or the other receiver, but not be able to use both receivers at the same time.

Another advantage to the ratio diversity technique over other types resides in the fact that no hard audio switching is used in the process. Since no switching occurs, there is no need for additional circuitry to enable switching during zero crossing in the audio signal. Output level differences in the two receivers are also less critical since no abrupt switch occurs. Lectrosonics OptiBlend™ ratio diversity circuitry is damped to provide a smooth, seamless panning action that eliminates audible artifacts of diversity operation.

When both receivers have a strong signal, their audio outputs are mixed together evenly. As the signal level drops, the panning process will begin to occur at about 40 uV. As the RF signal continues to drop, the panning action becomes more aggressive until the signal level is at about 1 uV, when the circuitry finally acts as a soft squelch and mutes both channels. As long as either antenna has at least 2 or 3 uV of signal, the receiver will continue to deliver a usable audio signal to noise ratio.



Sensitivity is another aspect of receiver performance to consider before making an assumption that a diversity design is superior by default. In the example of Comparative Squelch Thresholds shown here, the signal from the transmitter dips to a level of 5 uV due to operating range and multi-path nulls, which is not at all uncommon. A receiver that squelches at 7 uV (threshold A) in this situation will shut down and mute the audio from this transmitter signal, no matter what sort of diversity circuitry is employed. A single antenna receiver that will work to 1 uV (threshold B), however, will continue to operate and deliver usable audio.

It is always a good idea to check the sensitivity specification of any receiver being considered for purchase or rental along with the type of diversity circuitry being used in the design to get a good idea of how well the device might actually work. There are big differences from one manufacturer to another.

Comparative Squelch Thresholds