Antennas and Antenna Placement for Wireless Audio, Explained and Demystified

RF VENUE™

Introduction

In wireless audio, perhaps no topic inspires as much awe and uncertainty as antennas and their placement. Novice wireless users tend to either underthink or overthink — even agonize over — their antenna decisions. If you operate or are responsible for a wireless audio system — wireless mics, in-ear monitors (IEMs), or both — you need to understand some core antenna concepts.

> **This ebook will help you gain confidence when buying and using your antennas; fortunately, it's not as complicated as you might think!**

First, we will look at *remote antennas* and how to place them. Most IEM transmitters and mic receivers come with one or two whip antennas for mounting directly on the device. These are fine for small, single-channel systems, but their range and versatility are limited. For systems with multiple channels or that cover a larger area, you need remote antennas. They are "remote" as they are not mounted on the receiver or transmitter, but instead are placed in a more optimal location and their signals are conveyed to/from the equipment via coaxial (aka coax) cabling.

We'll also explore *wireless accessories* — the devices and components needed to use your antennas. These include distribution devices that allow multiple wireless mic receivers to share a diversity pair of antennas and combiners that merge signals from multiple IEM transmitters into a single antenna.

So, let's jump in!

What's inside?

Choosing an Antenna

No one wants a speaker's voice to drop out during an event, or a musician to get a blast of noise into their ears during a performance.

That's why choosing an antenna is important. Fortunately, there are usually several suitable choices, which you can further refine by selecting a few preferences.

Let's start with a few rules of thumb:

- For wireless mic receivers, you need two antennas (called a diversity pair).
- For multiple wireless mic channels, use distribution to feed the antenna signals to the receivers.
- For IEMs, you need one antenna.
- For multiple IEM channels, use a combiner to sum the transmitter signals into a single feed to the antenna.
- Most situations benefit from using directional antennas instead of omnidirectional or non-directional ones. (We'll explore this later.)
- While it is important to choose properly, there is often more than one "right" way to do something.

Why use two antennas for mics?

Modern professional wireless mic systems use a concept called diversity reception, which boosts reliability and performance.

A wireless mic system comprises two main components: the transmitter — which can be a handheld unit used by a singer or lecturer, or a bodypack unit with a lavalier mic worn by an actor, minister, et al. — and the receiver. The link in between is a radio wave emitted by a small antenna either on or built into the transmitter. The radio wave carries the audio as a frequency-modulated signal. This is the wireless part of the setup, because it does the job ordinarily handled by a mic cable.

The challenge of wireless audio is getting the radio waves from the transmitter to the receiver reliably and without interruption so the audio will sound good and be free of noise or dropouts.

While it's possible to get pretty good reception with one antenna and a simple receiver, in live production, a worship service, or anywhere else we use wireless mics, "pretty good" isn't good enough.

We need perfect reception — or as close to perfect reception as we can possibly get. To make it more interesting, we're dealing with transmitters that are moving about, so we might have great reception in one spot but not in others. Diversity reception can help.

A diversity receiver uses two antennas and, most often, either switches antennas (switching antenna diversity) or has two RF sections (true diversity, where each antenna and RF section signal path is a backup for the other), and the audio comes from the side with the better radio signal. In either case, we only have a problem if neither antenna can get a good signal. The improvement in reliability is sizable, which is exactly why we use a diversity pair of receiving antennas.

Why use directional antennas?

With its single element, a vertical whip antenna is simple and generally omnidirectional in a horizontal plane around it. That means it picks up (as a receiving antenna) or emits (as a transmitting antenna) in all horizontal directions around it.

This omnidirectionality limits its usefulness for mic reception because it does not focus on where the performance is and cannot ignore interference from other directions. As a transmitting antenna for IEMs, it spreads the RF energy in all directions, which dilutes its coverage of the performers who need the IEM signals.

Directional antennas are somewhat more complex because their elements are arranged so that signals will reinforce in certain directions and cancel out in undesired directions (similar to directional microphones that you would use for stage vocals and instruments).

Directional antennas are typically more useful for mics and IEMs because we can aim them so they're more sensitive where they need to be and less sensitive in other directions. In other words, we can get more of what we want and less of what we don't want. Directionality can also help increase the range of reception and transmission.

Common types of directional antennas used for wireless audio are:

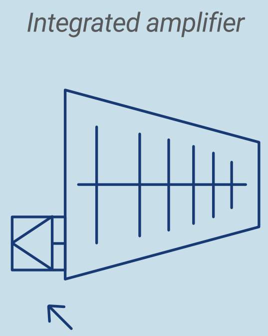
- Log-periodic directional arrays (often called paddles or fins)
- Helical antennas
- Panel antennas with a backplane

Helical antennas tend to be highly directional and more tightly focused, while panel/backplane antennas tend to have broader coverage patterns. Paddles are usually somewhere in between.

These differences in directionality are not critical in most applications, but they can be significant in certain situations. For example, to pick up a wireless mic signal from across the length of a football field, you'd be wise to use a diversity pair of helical antennas. If you're operating IEMs from the wing of a stage, an antenna with a broader pattern would usually work best.

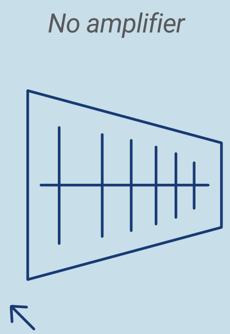
Active or passive antennas?

ACTIVE ANTENNAS
Active antennas have built-in amplifying circuitry to boost received signals. Because of this circuitry, they need external power, usually from a plug-in power supply or a DC bias voltage provided via coax cable. They are commonly used with mics but can't be used for IEM transmission.



**Both have same antenna elements*

PASSIVE ANTENNAS
Passive antennas have no amplifying circuitry and do not need external power. They work equally well for transmitting or receiving.



It might seem like a no-brainer to opt for active antennas, right? Well, no. If anything, they should rightly be considered as a last resort because they can introduce more problems than they solve.

Amplification boosts the noise floor along with the signal, and also unavoidably adds some noise as well. Too much gain can push the amplifier circuitry — and the active circuitry downstream in the distro and receivers — into non-linearity (similar to clipping when you overdrive an audio circuit). This causes intermodulation, which increases the RF noise floor sharply and creates artifact signals that can interfere with the desired signals, causing audio dropouts, noise, and/or severe distortion.

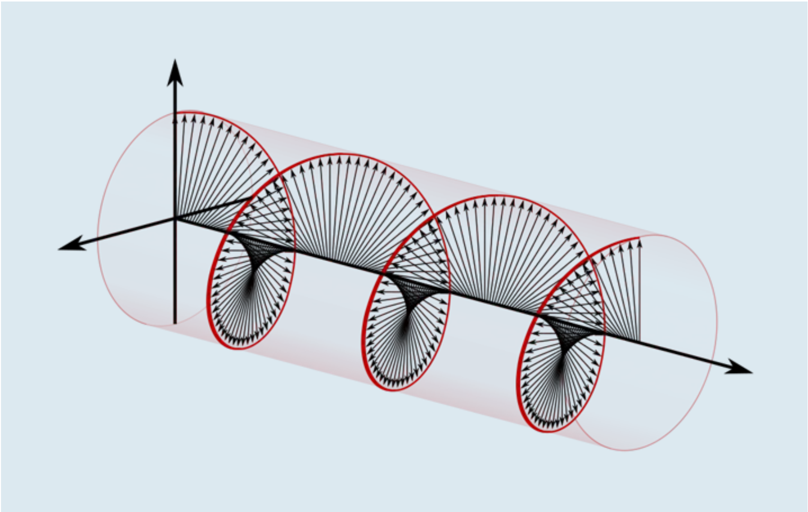
It's usually better to use passive antennas and perhaps have in-line RF amplifiers on hand for those occasions where you need some signal boost. Applications that benefit from active antennas or in-line amplifiers typically involve systems that require a long coaxial cable run (generally over 100–150+ feet).

Since coaxial cable is inherently lossy (you don't get all of the signal out of it that you put in), an active antenna can make up for some of that loss, but with the tradeoff of more noise.

A Look at Polarization

Polarization of RF signals and antennas had been a long-neglected aspect of wireless audio technology.

We define the polarization of a radio wave by the orientation of its electrical field, which is in turn determined by the orientation of the transmitting antenna.



In the world of wireless mics, these are simple, single-element whip antennas, usually either a short piece of wire (as on most bodypacks and some handheld units) or a linear element within the housing (as most modern handheld transmitters use). Note that we cannot control or predict the position or orientation of these antennas because people who are moving about are holding or wearing them.

Now, if the receiving antennas are of a single polarization, like a whip or paddle, this may present a problem because they are fixed in position. If they are parallel to the transmitting antenna — that is, if they are aligned with the signal's electrical field — they should receive the signal fairly well. But when the signal's polarization is angled differently than the fixed polarity receiving antenna (because of how the talent holds or wears the transmitter, for instance), the receiving antennas become far less effective.

Fixed, single-polarization antennas cannot adapt to the off-angle polarization of the signal. In practice, whips or paddles are good for about 300° of all the possible angles of polarization, and they drop off sharply as the mismatch angle approaches 90°. This phenomenon is commonly called a *polarization cross-fade*. This is largely why, even with the industry's decades of diversity reception experience, sound system operators still struggle with dropouts when using a traditional arrangement, such as two vertical paddles or two whip antennas.

Innovators at RF Venue recognized that while spatial diversity is good, it can be improved by considering polarization as well. This can be done with a diversity pair of two circularly polarized antennas, or with a co-located pair of cross-polarized antenna elements, one vertical and one horizontal.

For IEM transmission, the solution is to use a circularly polarized antenna to transmit to the bodypack receiver's whip antenna, which, as we know, could be oriented in any direction at any time. Suitable antennas are the CP Stage, CP Beam, and CP Architectural from RF Venue.

For wireless mics, diversity pairs can be made impervious to polarization cross-fade in a couple of different ways. One is to use two co-located antennas — one a vertical element and the other a horizontal element. Examples include the RF Venue Diversity Fin, Diversity Architectural, and Diversity Omni antennas.

These cross-polarized diversity pairs are built into a single unit. As long as the antenna has a direct line of sight to the transmitter and the range is not excessive, there will always be a usable signal on at least one of the two antennas — A and/or B — which is exactly what we need for diversity reception to prevent dropouts.

Another approach is to use a spatially diverse pair of circularly polarized antennas, such as RF Venue's CP Stage, CP Beam, or CP Architectural. This is a very robust approach. The CP Beam, which is helical and the most directional, is popular for long-range pickup, such as across an athletic field. Two CP Stage antennas at the edge of a performance stage is another popular and reliable option.

Coverage

It's helpful to picture in your mind the coverage patterns of your antennas because it will help you choose where to place or install them.

As mentioned earlier, directional antennas are most useful for wireless audio because we can focus coverage toward where we need it and away from where we don't want it.

Figure out also where the action will be, namely where the persons who sing or speak will be — on a stage, on an altar, across the floor of a ballroom, and so on. This is where you'll need to focus the antennas. Avoid placing antennas near possible EMI (electromagnetic interference) sources, including cell phones and video displays. Spectrum analysis tools can be useful in helping visualize RF noise when placing antennas.

The most directional antenna in the RF Venue lineup is the CP Beam. It has a conical pattern of about 63° in width. It's great for covering distance, like between a stage and a front-of-house (FOH) position 100 feet (30 m) away or even across an athletic field. Think of it as analogous to a medium shotgun mic or a medium floodlight. It can cover shorter distances, too, but be mindful of the angles as the coverage pattern is tight, not broad.

The CP Stage and CP Architectural antennas are less focused and, therefore, less directional than the CP Beam. Their pattern is about 120°, like a wide floodlight. This makes the CP Stage, as its name suggests, ideal for positioning atop a mic stand at a wing of the stage, where "Monitor World" typically resides in larger concerts.

The Diversity Architectural and Diversity Fin are moderately directional, and because they comprise a vertically polarized, somewhat directional antenna along with a less directional horizontal antenna, their patterns are somewhat different for vertically and horizontally polarized signals.

The Diversity Omni antenna has practically equal sensitivity to horizontally and vertically polarized signals in all directions.

Antenna Cabling

We use coaxial cable (or coax for short) to carry RF signals between pieces of wireless audio equipment, including antennas.

Use high-quality 50Ω cable with a non-conductive dielectric material separating the center conductor and shield; TV cable, typically specified as RG-6 or RG-59, has a 75Ω impedance and is not suitable for our uses.

Coax keeps RF signals inside the cable from getting out and outside signals from getting in. That's why it's advisable to use cable that is double shielded, using both foil and copper braid as the outer conductor (or shield).

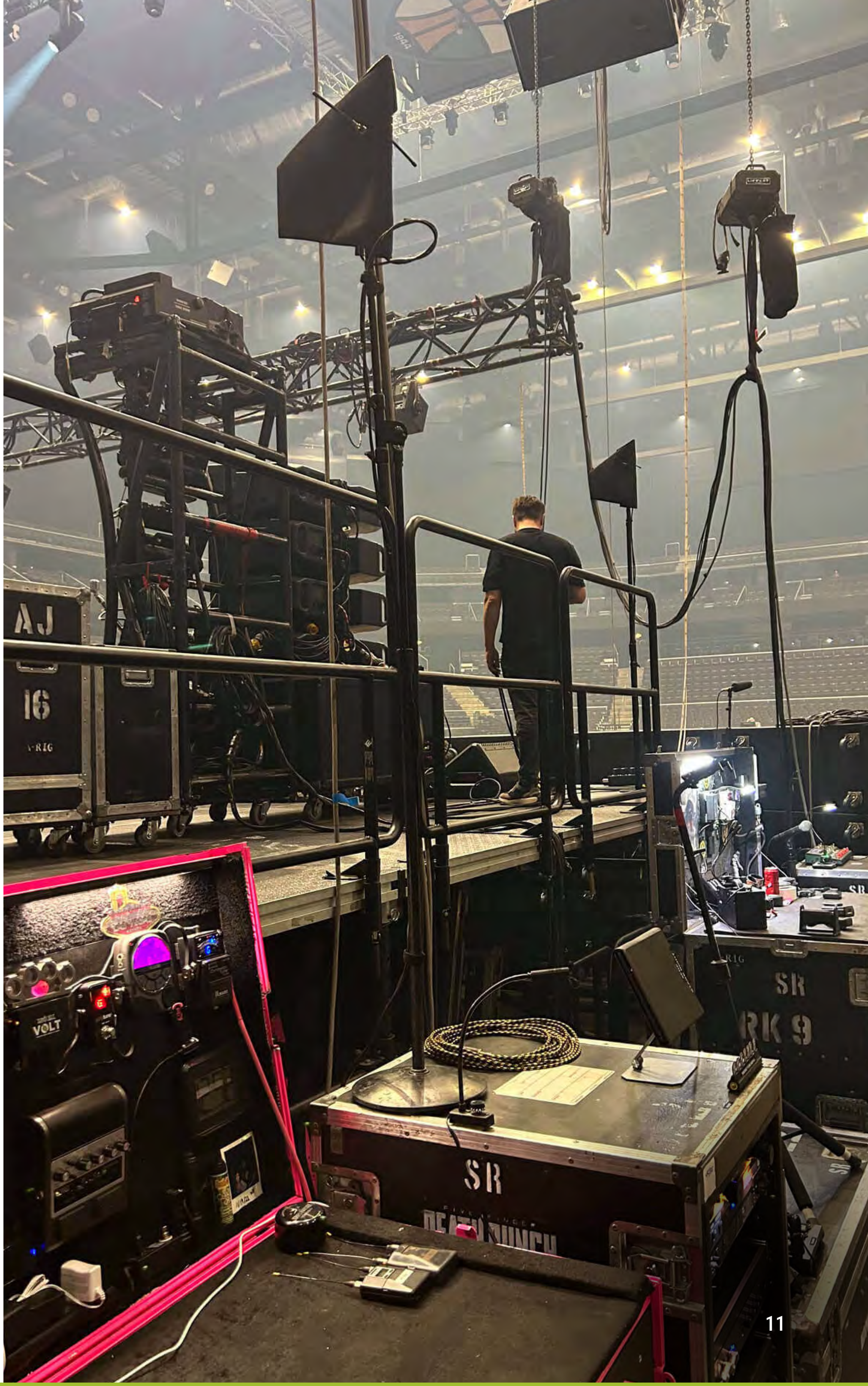
Coax cable, though, is lossy, and the losses increase with frequency. Some types of cable have more loss than others. RG-8X is a fine choice in the middle, offering good performance and price. Longer runs may require lower-loss cable like LMR-400, and short jumpers within a rack might be suitable for RG-58. These loss characteristics may be important to consider when deciding where to place antennas; sometimes it may be better to increase the antenna-to-talent distance in order to shorten the coax cables.

Placement and Aiming

Once you have a basic understanding of what the different antennas can do, you can apply them effectively in various situations.

There are several different considerations involved, including:

- The room or space (concert hall, meeting room, auditorium, football stadium, open air, etc.)
- The nature of the event (theatre, worship service, concert, lecture, athletic event, etc.)
- Where the talent or speaker is (on a stage, an altar, a dais, a field, etc.)
- The location(s) available to put antennas.
- The location of the mic receiver rack and IEM transmitter rack.



Remember, there may be more than one “best way” to place the antennas for a particular application.

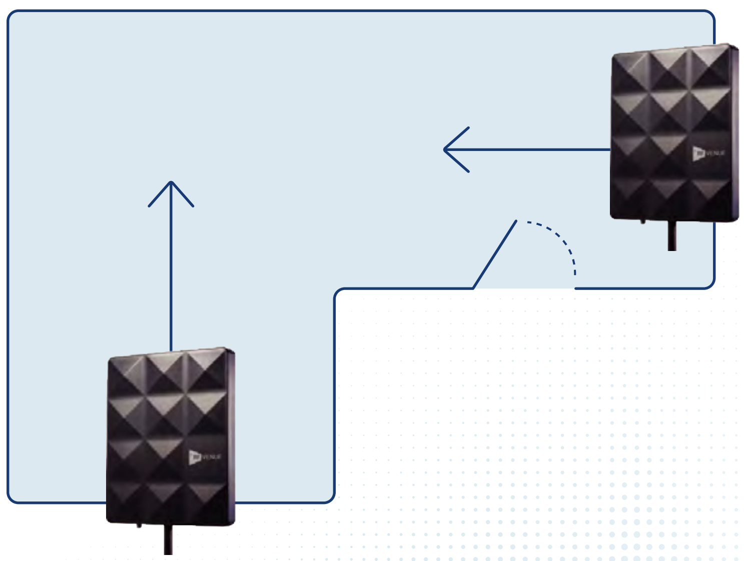
Here are some rules of thumb for placement and aiming antennas:

- Never point your IEM transmitting antenna at your mic receiving antennas. In fact, it’s a good idea to put them side by side, spaced apart by at least 6 feet (2 m).
- Aim your antennas by simply pointing them in the direction of the action.
- Locating the antennas closer to the action is generally good, but so is shortening the cable runs to the transmitter or receiver. You might have to make some trade-offs.
- A helical antenna like the CP Beam (below) is great for receiving or transmitting over longer distances.

Above: CP Beam antenna

- Don’t try to make your RF penetrate metal structures, dense wall materials, people, or other obstructions. Aim your antennas over and around them.
- In an oddly shaped room or space, try to use the antennas’ coverage patterns to your advantage. For example, if you need to cover an L-shaped room, you could use a pair of CP Stage antennas arranged as shown in the figure below.

Below: Circular polarization allows us to use spatial diversity to cover larger or irregularly shapes spaces

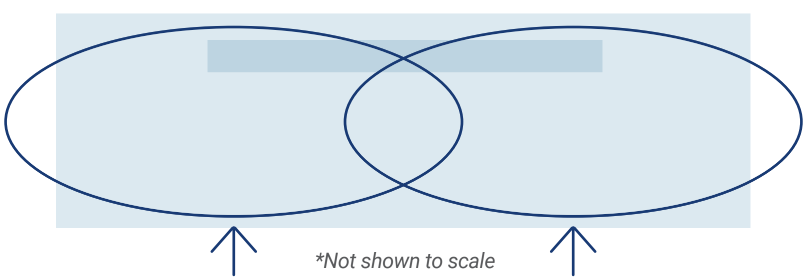


Diversity Reception: Sometimes a diversity pair does not look like a diversity pair.

Wireless microphone receivers are fitted with two antenna inputs (A and B) for diversity reception. The receiver selects between the two inputs based on signal strength.

A common practice is to use two antennas aimed at the same stage but spaced apart to provide differing lines of sight — different "views" of the RF signals from the transmitters. The idea is to accommodate the movement of talent upon the stage. In the illustration, though, the antennas are aimed straight ahead, so their coverage patterns only overlap in the very center of the stage. These antennas are spread wide and should be angled more towards the center of the stage.

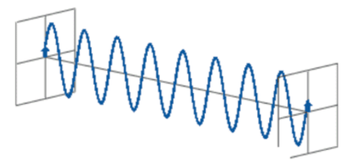
As shown in the figure below, only microphones received by both antennas in the overlapping zone would truly be served by diversity reception, while mics on other areas of the stage would be served merely by a single antenna. If these are single-polarized antennas, like vertical paddles or whips, they could still be susceptible to dropouts caused by polarization cross-fade (as described in the *A Look at Polarization* section).



Not shown to scale

A stronger option is to use a pair of co-located antennas that cover the performance space with cross-polarized antenna elements (polar diversity). A popular example is the patented RF Venue Diversity Fin antenna, which is actually a diversity pair in one unit. It pairs a vertically polarized fin — i.e., a paddle LPDA antenna — with a horizontally polarized dipole antenna in a single unit.

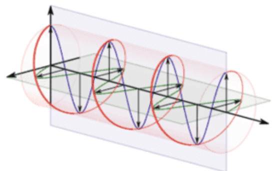
The strength of this polarization diversity approach is that, as long as both antennas have a direct line of sight to the transmitter, there will always be a good signal on at least one antenna. Any polarization angle that is bad on one antenna will be optimal on the other, so the antenna system will never be fully blind, regardless of how the talent moves, twists, or turns. Cross polarized antennas can be directional, like the vertical elements of the Diversity Fin antenna and Diversity Architectural antennas, or omnidirectional like the RF Venue Diversity Omni antenna.



LINEAR POLARIZATION

Above: Diversity Fin, Diversity Architectural, and Diversity Omni antennas

Yet another solution would be two CP Stage or CP Beam antennas as a spatial diversity pair; their circular polarization would eliminate any antenna polarization issues.

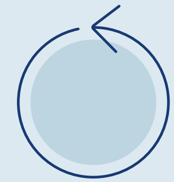


CIRCULAR POLARIZATION

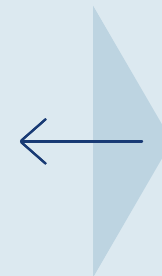
Above: CP Stage and CP Beam antennas

Typical antenna beamwidth (horizontal):

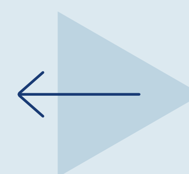
WHIP
360 degrees



PADDLE
120 degrees



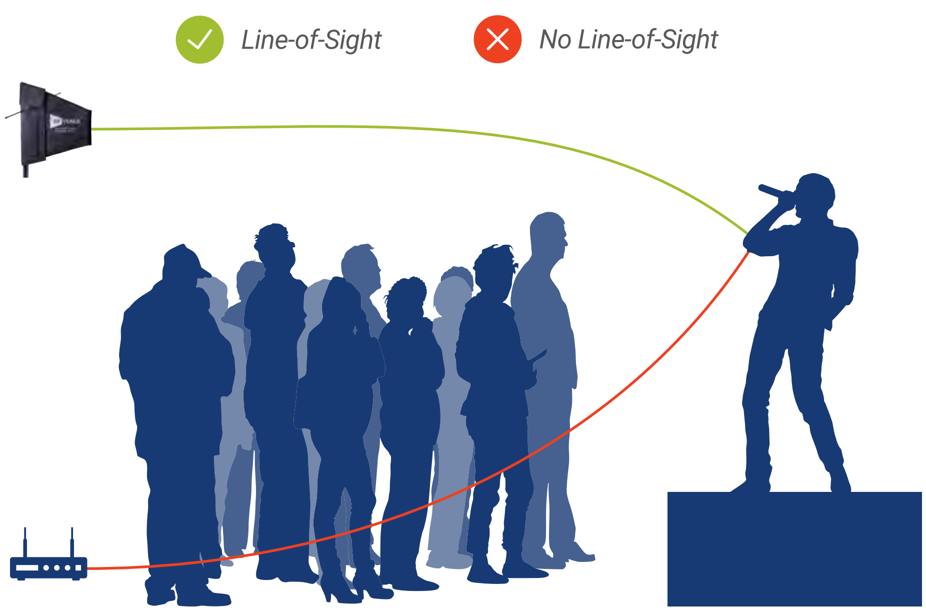
HELICAL
60 degrees in
a conical pattern



RF Venue antenna models with pattern and coverage specifications, plus recommended applications, can be reviewed using this handy chart.

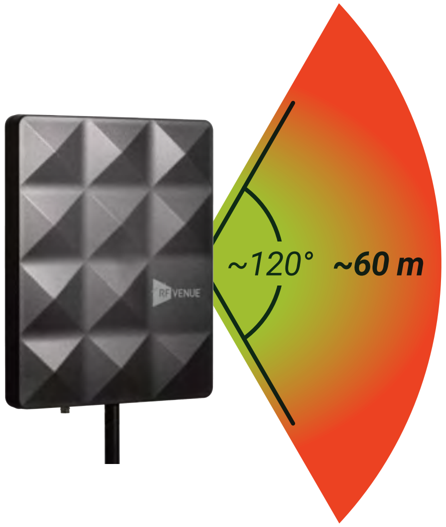
Note: Radio signals we use for wireless audio emit from their transmitting antennas in straight lines through free space. In general, effective transfer of RF energy requires a clear line of sight between the transmitting and receiving antennas.

A clear line of sight means that physical objects like walls, columns, pillars, and poles must not be in the transmission path. Yes, some walls and windows allow transmission, but all reduce levels to some degree. The heavier and denser the wall construction is, the greater it will attenuate RF signals. Note that physical objects also include people!



Let's build on the line-of-sight concept with some simple guidelines.

Although it's a rare problem, you can have too much signal. To address this, keep bodypack and handheld transmitters at least five feet (1.5 m) away from omnidirectional or whip receiving antennas to avoid overloading the distro and receivers. Similarly, keep IEM bodypack receivers at least five feet from omnidirectional or whip transmitting antennas to avoid overloading. For directional antennas, the minimum distance should be greater.

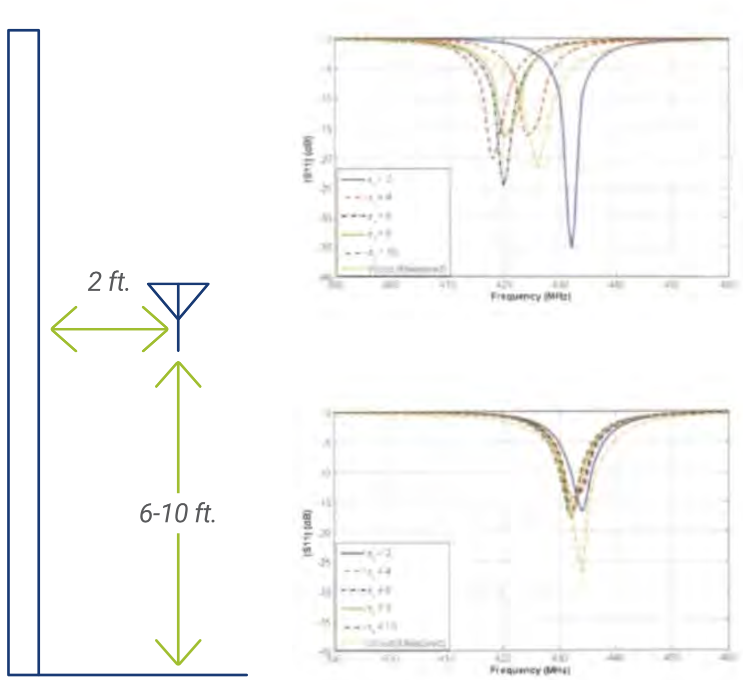


CP STAGE ANTENNA WIDTH AND DISTANCE

As a general rule, place your antennas at least two feet (60 cm) from walls and metal structures to avoid interaction with the antennas' tuning. Exceptions are antennas with metal back plates, such as the CP Beam, which can be truss-mounted. Also, RF Venue's architectural series antennas such as the Diversity Architectural and CP Architectural are specifically designed to be wall-mounted.

Height is good, to a point.

An important rule is to place antennas high enough off the floor to avoid obstacles (including an audience) and reduce reflections from the floor.

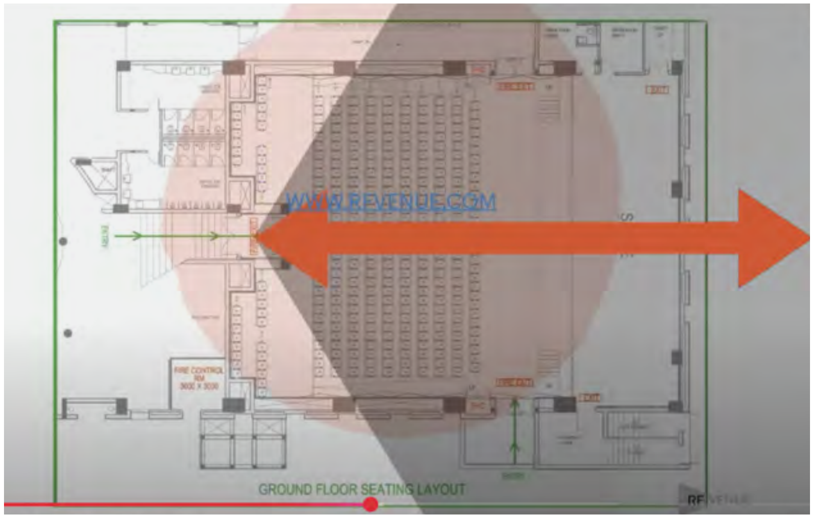


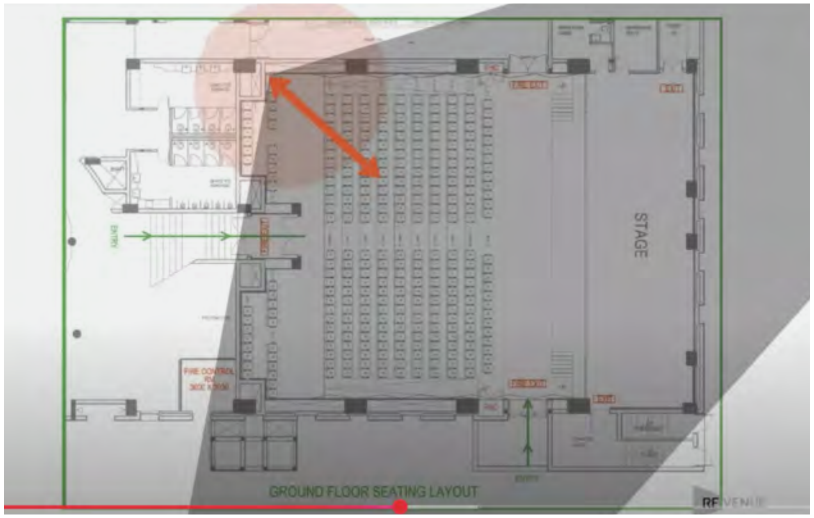
Above: Off the wall – off the deck

This ensures a good line of sight to the talent. Once you have that line of sight, there is no need for additional height unless it is to shorten the distance between the transmitting and receiving antennas.

Your talent should wear bodypack transmitters or receivers in such a way that their antennas do not come into contact with metal (on a belt or costume piece, for instance) or even bare skin. Either can cause reception problems. There are specialized belts and antenna covers available to protect bodypacks and their antennas.

Placement Examples





Antennas at front of house

Mics: Diversity Fin or a pair of CP Beam or CP Stage antennas
IEMs: CP Beam or CP Stage

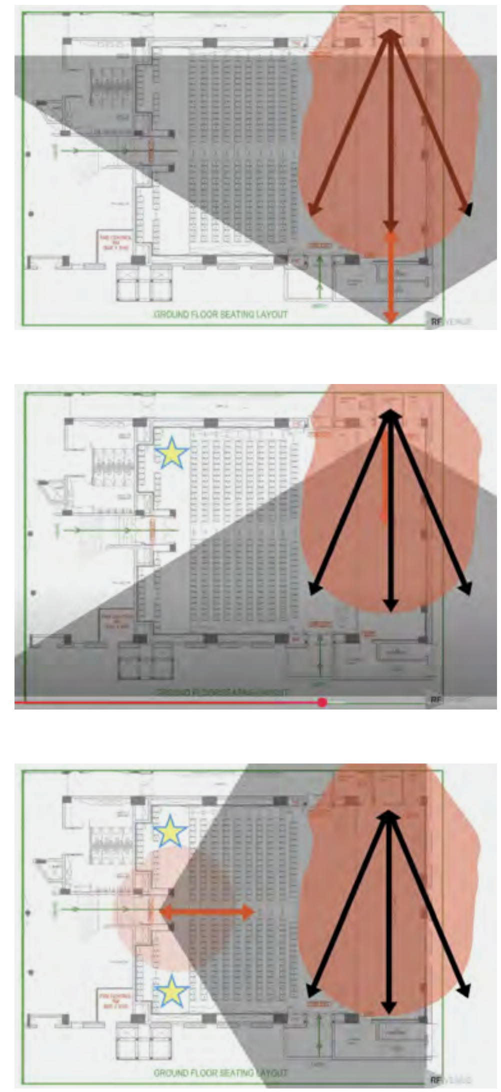
A common venue or house of worship arrangement has the stage or altar up front and the FOH position in the back. Antenna placement at FOH is often a good choice because there usually is a clear line of sight to the front and the coax cables can be short.

Antennas in rear corner

Mics: Diversity Fin
IEMs: CP Beam or CP Stage

If the antennas need to be mounted in a corner, aim them diagonally across the room to maximize coverage.

Placement Examples (Cont'd)



Antennas at stage wing

Mics: CP Stage or, alternatively, CP Beam if the stage is large
IEMs: Diversity Fin; two CP Stage; two CP Beam

A stage wing is a popular place for an IEM antenna, especially if the monitor mixer is located there. Mic receiving antennas can be located there also (with long cabling to FOH) or at FOH.

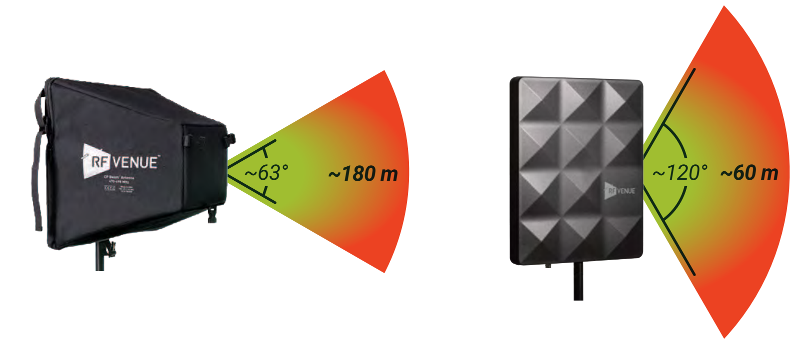
Conclusion

Perhaps because radio waves are invisible, wireless audio may seem mysterious. But if you learn some basics and develop a sense for visualizing the way RF moves in free space, you can more easily and confidently deploy wireless systems that are solid and reliable. Most situations will have more than one solution, and you'll be able to choose the direction that suits the resources you have at hand.

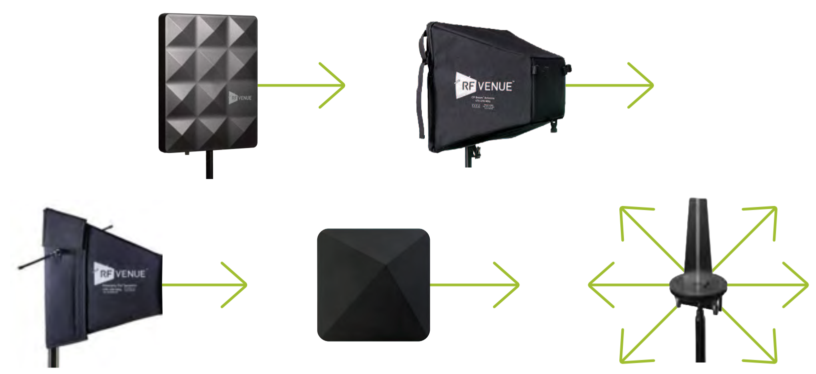
RF Venue offers a range of essentials to make wireless audio work and perform better. Many are also packaged as easy-to-order packs and bundles that include everything you need: the distribution, antennas, and cabling for smaller or larger wireless microphone or IEM channel counts.

RF Venue's innovative products address the unique challenges of RF environments, ensuring your wireless audio system operates at its best. Reach out to our team to learn more about how our solutions can elevate your audio setup to new heights.

Let's Talk



Above: Antenna beam width & distance



Above: Antenna directionality