SHURE

AUDIO SYSTEMS GUIDE

THEATER PERFORMANCES

INTRODUCTION

Proper microphone selection and placement in theater applications can dramatically improve and reinforce the impact of the action and emotion on the stage. From large Broadway shows to small community stages, any theater experience relies on having good sound to emotionally connect with the audience. In acoustically amazing venues, simply projecting the voice may be all that is necessary for everyone to hear. That was how it was done for hundreds of years before the development of modern sound reinforcement. Now, in modern larger theaters and for more complex productions, microphones and sound reinforcement systems have become absolutely necessary.

While the physical design of the theater environment and its acoustic qualities must be considered in the design of a sound reinforcement system, the topics we will focus on in this book include microphone selection and placement for both wired and wireless microphone systems. This text will examine how microphones, both wired and wireless, can be used to ensure that every word is heard while taking into account the complexities of costuming or staging. Some of the text in this booklet is borrowed from several of Shure Incorporated's Applications Bulletins and educational booklets which can be found on the Shure Inc. website, www.shure.com. It also contains new material, which covers microphone techniques specific to theater productions. These techniques can be useful in all theater applications regardless of venue size.

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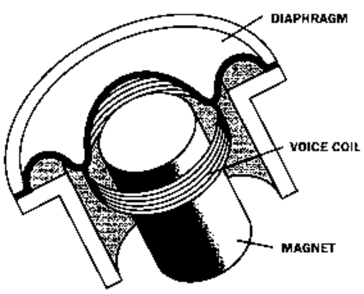
I. MICROPHONE DESIGN

A microphone is a type of transducer, which is a device that converts one form of energy into another. A microphone captures acoustic energy and converts it into electrical energy. The electrical energy produced is the electrical representation of the acoustic sound wave. This energy is then transferred to the next device in the audio chain through the microphone cable, or via a wireless system, which sends the audio signal through space using radio waves. There are several types of microphone designs that perform this task using different methods. For our purposes in this guide, we will concentrate on the two most common types of microphones used in professional audio today, dynamic microphones and condenser microphones.

DYNAMIC MICROPHONES

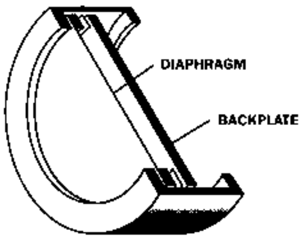
Dynamic microphones use an assembly consisting of a thin diaphragm, a voice coil, and a magnet. As sound waves strike the diaphragm, which is usually made of a very thin plastic, it causes the attached voice coil to vibrate within the magnet's field. This action, known as electro-magnetic induction, generates the electrical representation of the sound wave. This miniature electric generator is a very simple design, yet it is a very cost-effective way of creating an audio signal. Dynamic microphones tend to be more resistant to rough handling, humidity, and temperature change. They can also handle extremely loud sounds and are almost impossible to overload. For these reasons, dynamic microphones are widely, though not exclusively, used in live sound reinforcement.



Dynamic Microphone

CONDENSER MICROPHONES

Shure Condenser microphones use an assembly consisting of a diaphragm and an electrically charged backplate. The assembly is essentially a capacitor, which is a electronic device that can store a charge. In this design, a thin layer called an insulator separates the metal or metal-coated backplate, which is rigid, and the diaphragm, which is flexible. When the condenser element is charged, an electrical field is created between the diaphragm and the backplate. The charge is proportional to the space between them. As sound waves strike the diaphragm and cause it to vibrate, the spacing in between the two surfaces varies, affecting the electrical charge in the assembly. This fluctuation creates the electrical representation of the sound wave.



Condenser Microphone

There are two common types of condenser microphones, and they are distinguished by the method used to charge the element.

Electret condenser microphones have a permanently charged backplate. Electret microphones typically require a small amount of DC voltage (often around 5VDC) to power the FET electronics in the circuit in order to amplify the very small voltage created and produce a useable sound. When using electret microphones with wireless systems, this supply voltage comes from the wireless transmitter itself. There are also preamplifiers available to connect an electret lavalier to a traditional XLR cable which supplies phantom power.

Non-electret, or "externally biased" condensers also require power to charge the backplate. This power is usually supplied also by phantom power, normally from a mixer, preamp, recorder, or similar. Phantom power is normally supplied over the same XLR cable the microphone is connected to. The name "phantom power" was coined because the power seems to come out of 'nowhere' since there is only one cable connected to the microphone which carries audio as well as power.

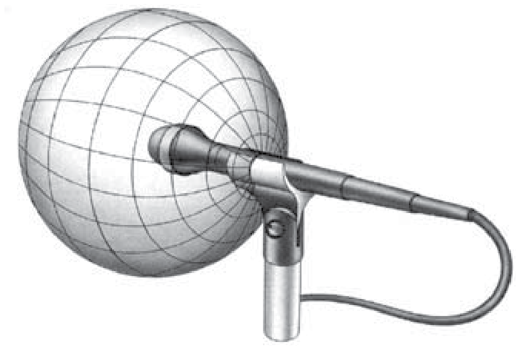
All condensers have active circuitry incorporated into the design, which is required to supply a usable voltage level to the next audio device, and also to convert the microphone output to low impedance.

Because of their design, condenser microphones can be considerably more expensive than dynamic microphones. They are also more sensitive to temperature, dust, rough handling and humidity changes. Even with these caveats, condensers provide a great advantage over dynamics in theater applications for a couple of reasons. First, condensers can be made much smaller than dynamics, making them much easier to hide in costuming. Secondly, they generally have much better frequency response and higher sensitivity. This makes condensers better-suited for overhead or boundary microphone techniques where the microphones are placed much further from the performers.

MICROPHONE DIRECTIONALITY

Whenever you are choosing a microphone for an application, it is important to consider its directionality, sometimes referred to as its polar pattern or pick-up pattern. There are several directional patterns available, the primary being omnidirectional, unidirectional, and bi-directional. A microphone's directional pattern is usually illustrated on its specification sheet or user guide by a polar graph that shows the microphone's sensitivity to sound arriving from different angles. The graphs show the "receiving" end of the microphone at 0 degrees.

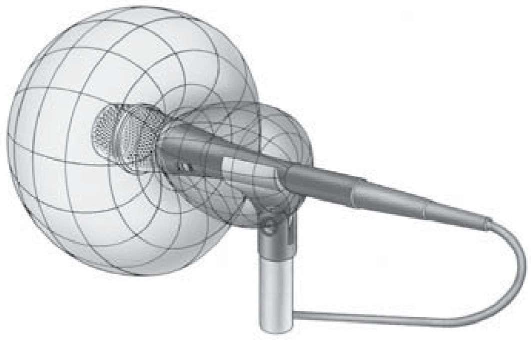
An **omnidirectional microphone** has equal sensitivity at any angle. Sounds are reproduced equally whether arriving at 0 degrees (on axis) or at 180 degrees (the rear of the mic). The important thing to remember is that omnidirectional microphones will pick up ambient or room sound as well as the sound you intend to amplify or record. This can contribute to feedback issues in a live sound reinforcement system. Feedback is the unwanted, high-pitched squeal or howl produced when sound from a loudspeaker is picked up by a nearby microphone and re-amplified. For this reason, omnidirectional microphones are often used for direct recording and theater applications (most productions rarely employ onstage monitor loudspeakers, so omnidirectional microphones are acceptable). The vast majority of lavalier microphones used in theatre are omnidirectional.



Omnidirectional Microphone

A **unidirectional microphone** is most sensitive to sound arriving on axis and less sensitive to sound as it moves off axis. Unidirectional microphones can allow higher gain levels from the sound system before feedback becomes a problem. There are two primary types of unidirectional microphones. Cardioid microphones exhibit an upside-down, heart-shaped pattern with a 130-degree pickup angle in front. Sound is greatly attenuated at 180 degrees and is sometimes referred to as the null point. **Supercardioid microphones** exhibit a narrower pickup angle of around 115 degrees in front and therefore are even less sensitive to ambient sounds. This can provide still higher gain before feedback. However, they do have some sensitivity directly rear of the microphone at 180 degrees, making placement even more critical. Any unidirectional microphone can be very effective in an application with a high level of undesirable ambient sound. This is of great benefit when trying to achieve maximum gain before feedback.

Cardioid (Unidirectional) Microphone



Supercardioid Microphone

Since unidirectional microphones pick up less ambient sounds than omnidirectional microphones, they can be used in situations where you may need to mic a sound source from a slightly farther distance, yet still maintain the direct to ambient mix of an up close omni. Unidirectional microphones tend to lose high frequency sensitivity first as the sound source moves further off axis. Because of this, the sound may become "muddy" and less bright when the mic is not pointed directly at the sound source. Unidirectional mics also exhibit proximity effect, which is an increase in bass response as the sound source moves closer to the mic. This may cause the sound source to sound "boomy" or "bassy". Depending on the application, this may or may not be desired. Omnidirectional microphones do not exhibit proximity effect and are less susceptible to wind and breath noise. This is an important thing to consider when choosing mics for an outdoor performance.

Bi-directional microphones are most sensitive at 0 degrees and 180 degrees, while being least sensitive at 90 degrees (at the sides). These microphones are also known as "figure-8" microphones. The coverage angle at either front or back is about 90 degrees. These mics are used mainly for pickup of two opposing sound sources. They are often used in certain stereo recording techniques and are incorporated in the design of an MS (mid-side) stereo microphone. They are rarely used in live sound reinforcement or theater applications.

II. MICROPHONE SELECTION AND PLACEMENT

Choosing the proper microphone for any given application can also be based on several other factors not yet discussed: price, quality, and especially in theater, physical size and color. Whichever microphone is chosen, it is the first step towards an effective sound system. The goal of any sound reinforcement system is to project the program material to an audience in a manner that allows the person furthest away from the performance area to hear sufficiently. An efficient system will allow enough amplification to occur before audio feedback is a problem. You may often hear the term "gain before feedback" which refers to this principle. Feedback can be devastating to any production and severely distracting to the audience and the talent, not to mention the damage it can do to the sound system and your hearing. The system's efficiency can be greatly affected by room acoustics, system components, and the performers themselves, but there are several ways to minimize feedback. Solutions include: making the room less reverberant by treating it with absorptive materials, moving the loudspeakers further away from the microphones, and using unidirectional microphones. Some of these solutions are sometimes costly and not practical for smaller venues with limited resources. One of the most effective ways of minimizing feedback is to move the microphone closer to the sound source. In theater applications when it is not practical to use a typical handheld vocal microphone, the use of either a lavalier or headset microphone will best allow you to "close mic" the performers. Most modern lavalier and headset designs are lightweight and discreet. Both do an excellent job of increasing potential gain before feedback. Boundary microphones and overhead microphones can also provide good performance. These mics do not get as close to the sound source and, therefore, may not provide the same amount of potential gain, however, they can be less expensive in the long run and still quite inconspicuous. Let's look at each of these types of microphones, their physical qualities, and the techniques involved in their use.

Theatrical productions are moving to wireless microphones for many reasons, but most importantly – better sound quality. Wireless mics provide better isolation and a more consistent sound especially when it concerns EQ and volume.

LAVALIER MICROPHONES

TwinPlex™ TL46 Lavalier Microphone

Lavalier microphones are made of small elements, usually condenser, designed to be mounted via clip or pin to clothing. They are generally connected to an XLR terminated pre-amp assembly, or for wireless applications, they are be terminated with a variety of connector types. The design of these mics makes them inconspicuous enough to be used in TV broadcast, video production, and of course, theater. Early designs used large dynamic elements and were usually hung around the neck on a lanyard. Contemporary designs almost exclusively use electret condenser elements. They can now be as small as a few millimeters in diameter and weigh only an ounce or so (not including the pre-amp assembly). They are often available in several colors such as black, white, cocoa, and tan. Lavaliers can be mounted with an array of mounting clips or pins; some include a magnet mount that will avoid creasing or putting holes in clothing. The same small capsules that are used in lavaliers are often used for wire frame headset microphones as well.

In an effort to make lavaliers as flexible as possible for different mounting positions, manufacturers have made some lavaliers available with swappable frequency response caps. These caps do not alter any circuitry; rather, they alter the high-frequency (treble) response of the mic in one of two ways. They either provide acoustic resistance to the opening of the cartridge, which attenuates the natural high-end frequency response, or they create an acoustical chamber on the front of the cartridge, which enhances the high-end frequency response of the microphone. Note that only omnidirectional microphones are available with this feature as the acoustical characteristics of unidirectional microphones cause them to sound worse when used with response shaping caps.

Lavaliers allow you to place the mic much closer to the actor's mouth than other microphone types, which increases gain before feedback. Lavaliers, therefore, allow you to minimize pick up of room noise, stage vibrations, and other unwanted sounds. They are also more easily hidden and less cumbersome than larger microphones. When used with wireless systems, they give performers almost unlimited mobility.

In theater applications where a lavalier is preferred, omnidirectional condensers are the most popular. It is true that using unidirectional microphones is one of the general rules to minimizing feedback due to their rejection of off-axis sounds; however, an omnidirectional in these applications is still very effective because of the improved proximity to the performer's mouth. This distance stays consistent as the performer moves around the stage when using wireless lavaliers. An actor which moves around a lot, will have minimal volume fluctuations when using and omnidirectional mic compared to a directional mic. Omnidirectional microphones do not exhibit proximity effect, reducing the need to cut low frequency response at the mixer. Another advantage omnidirectional mics have, is that the frequency response of the mic stays consistent even if the sound source is off axis, or if the mic is in an unusual position. This is an important attribute given that mic technique in theater productions involves the creative positioning of the microphone on a performer. Wardrobe may not allow for the usual lavalier positioning on the chest. Often times, the lavalier may be hidden in the performer's costume, or planted in a wig or hairline. While indoor theatre applications may not be affected as much by wind, it is useful to know that omnidirectional microphones pick up less wind noise than their directional counterparts.

Let's examine some lavalier techniques that will help get the best performance out of your microphones:

PLACEMENT

- It is suggested to place the mic center on the hairline first (if possible). The result will be a natural sound with minimal additional EQ. If the hairline is not an option, try placing the mic above the ear. This can be useful especially with an actor wearing a hat or who has no hair.
- Before placing a lavalier on or near the hairline, consult with the wigmaster to determine the best method to hold it in place. Discuss which actors are wearing hats and when with the costume dept. Mics and cables can be secured in the hair using clips, comb clips, bobby pins, or even elastic headbands. You can also sew them into wigs or barrettes. If the actor will be wearing glasses, the mic can be mounted on the temple area of the glasses. A small piece of clear tape should hold it steady.
- If placement above the ear is best for your production, you can construct an "ear clip" using a hanger, pipe cleaner, florist's wire or purchase a pre-made clip. Make a loop on the end that goes over the ear to hold the microphone cartridge. Then, form the wire around the back of the ear and curl the opposite end up around the front of the earlobe to until there is 1/4 of an inch exposed. Cut any excess wire. For added comfort, and to hold the cable, slide some snug fitting surgical tubing or apply heat shrink tubing over the microphone cable and wire.

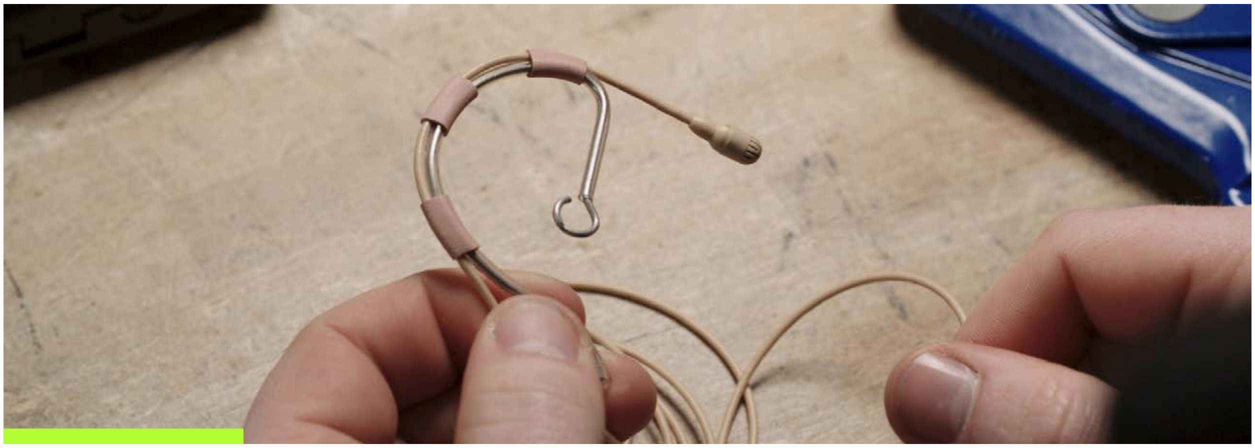

Hairline Placement


Tie Clip Placement

KEEPING THEM STABLE

- Never use gaffer tape to affix cable to the skin. The glue on this tape can cause skin irritation and may be too sticky. As an alternative you can use surgical tape, spirit gum, medical adhesive, or clear bandage tape. 3M brand Transpore™ or Tegederm™ are industry standard medical tapes used for hold cables to actors heads and necks. It's a good idea to have an actor use "skin Prep" alcohol wipes to clean the skin area first and making the tape hold the cable even when the actor sweats during a performance.
- Be sure to provide strain relief for the cable. When mounting a lavalier on the head, the cabling at the point at which the

neck bends needs to be the most secure. Make sure there is slack or a sudden movement can pull the microphone out of place. Again, surgical tape is the best choice for securing the cable to the neck. For example, if you're taping the actor's left side, have them turn their head far right for the extreme range of motion to make sure they have enough slack.



CARE AND MAINTENANCE

- Be careful not to get makeup or hairspray into the grill or the element. Use a makeup cap or similar to protect the mic whenever possible. Any makeup or hairspray that gets inside can alter the frequency response or worse, destroy the element altogether. Do not use liquid or soap to clean the mic; this can be more damaging than the makeup. It is generally best to replace the grill of the mic if it becomes covered with makeup. Some lavalier microphones have replaceable caps and grills. If you must attempt to clean the mic, hold it upside down and brush it lightly with a soft brush or cloth. This will help prevent residue from getting down into the element. To clean adhesives off of the cable, you can use a mix of warm distilled water and no more than 10% alcohol. Check with the manufacturer for any specific cleaning methods for their microphones in order to maximize the life of the microphone.

- It is not uncommon for a microphone capsule to "sweat out", which occurs when the cartridge becomes drenched with perspiration and ceases to work properly. In many cases, this is temporary. Many top theatre productions will use a double-mic technique on their top talent to avoid interruptions during the performance. Some newer lavalier microphones contain a hydrophobic coating that repels water. To remedy a capsule which shows signs of "sweat out," shaking the sweat out of the element can often be effective. If more maintenance is necessary, the microphone can be placed in an airtight box containing a silica gel packet. The silica gel packet will absorb moisture in the box. To avoid sweat out, you may try to not use a windscreen. Also, try to move the mic off the actor's skin and also out of hair and beards where sweat can collect.

- Sweat can drip down the cable to the capsule. To prevent this, you can affix a small cotton or gauze patch around the cable in an inconspicuous position. Some manufacturers offer "sweat rings" on their lavalier mics, which are small plastic or rubber collars that hug the cable and keep moisture from dripping into the capsule. Many will use a what is known as a Hellerman sleeve to try and avoid this.

- To ensure sweat doesn't enter the connector and cause an electrical short, make sure that the connector has a rubber flex-relief and that it fits snuggly around the cable so that there is no opening for the sweat to drip into the connector. Sweat which finds its way into the connector can result in corrosion and subsequently, a poor electrical connection. You may also add a drip-loop near the connector, which will route the sweat down the loop instead of into the connector. Adding a small piece of heat shrink tubing around the cable and over the solder contacts can help close a gap between the cable and the flex-relief, or add an additional level of assurance in active performances. Some types of connectors offer improved water/sweat resistance and further protection against corrosion. You can also use neoprene mic pouches to keep sweat off the pack. Some wrap the transmitters in dry condoms-wrapped and taped shut.

- The day-to-day maintenance of your microphones should include drying them thoroughly in a cool, dry space after each use. In cases where your microphones are being used extensively in unusually harsh environments like the outdoors, in direct sunlight, in extreme humidity, or any combination of the three, it might be prudent to obtain an airtight box as mentioned above to store and dry your microphones overnight. Try to use shoe bags that are made of a mesh material that promotes good air flow so they can dry. Putting a fan on them will help this process. This is a frequent practice at theme parks and on Broadway.

- Storage of a lavalier microphone is important to ensuring long-lasting performance. When putting the microphone away for storage, it is advised to not wrap the lavalier cable around the wireless transmitter pack tightly. Wrapping the cable tightly around the transmitter can put undue stress on the cable in the same areas, especially near the connector. Over time, this can lead to breakage of the cable in those spots. A better alternative is to gently wind the cable up into a uniform circular coil. Ask the actors to please not wrap them. A common way to store wireless bodypacks with lavaliers in theatre is to use a shoe bag which is designed to hang from a door/closet. Each shoe pocket can hold a transmitter with lavalier neatly and organized for the next use.

GETTING THE BEST SOUND

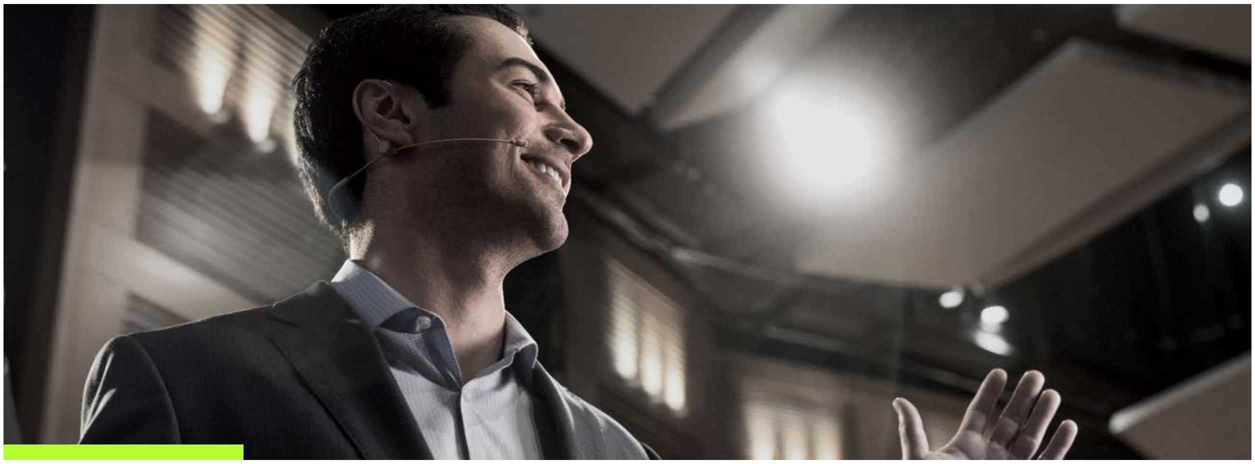
- If the microphone cable is run inside of clothing, tape the cable to the fabric to prevent contact noise, which is caused by cable and clothing rubbing together. Consider sewing a "channel" or "tube" of fabric on the inside of the costume to prevent excess rubbing against the cable. It is common to try and place the mics so actors can change costumes quickly without the mics getting in the way. Some prefer to attach the mic to the actor directly, while others prefer to embed the mic/transmitter combo in the costume itself.

- Noise from materials in costuming rubbing together can be difficult to prevent. Synthetic materials make more noise than other materials. Consult with wardrobe to see if there is a practical way to isolate the mic and cable from noise. When in doubt, test various materials to listen to how much noise they make.

- If using a directional lavalier mic in the chest area, remember that those types of microphones exhibit proximity effect, which enhances bass frequencies the closer the microphone is to the sound source. Because the mic is much closer to a resonating chest cavity, it may sound “boomy.” You can compensate for this by using equalization to decrease the low frequencies. Employing a high pass (low cut) filter is a common approach to correcting this unwanted sound.

- Don’t be afraid to use equalization. High frequency boost can help brighten a mic that is covered by clothing or positioned in the hairline. Low frequency reduction can help reduce cable noise, breath pops, or wind noise. Experimentation is key to finding the best sound for your particular setup.

Be prepared, keep spare mics on hand. Lavalier mics may eventually need replacement in an abusive environment like theater. Sweat, makeup, and constant tugging on cables and connectors can take their toll on lavaliers. Inspect your mics before every performance by plugging them in and listening for odd noises, crackling, or degradation of frequency response. Wiggle the cables and connectors to check for loose connections. Remember that some physical damage may not be covered by the manufacturer's warranty so exercise care.



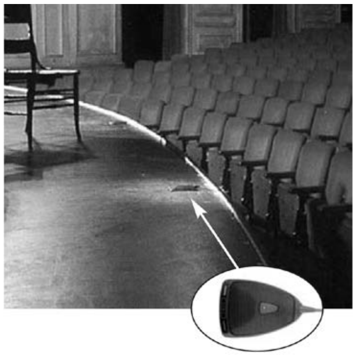
HEADSET MICROPHONES

Let's revisit the concept of micing a sound source as closely as possible to increase gain before feedback. In most theater applications, the actor's mouth is the sound source. A lavalier does a good job of close micing, especially when mounted on the hairline. However, the ultimate position would be at the performer's mouth, as it is the closest. After all, the closer you can get the microphone to the wanted sound source, the better. The best way to do this for theatre applications is with a headset microphone. While not quite as discreet as a lavalier, most modern headsets are very lightweight and comfortable for the wearer. Headsets are often available in various colors which can blend in with the performer and become nearly invisible in practical use. Many basic headsets have a frame that goes over the head. Professional quality headsets have a lightweight wire frame that sits on one or both ears and wraps around the back of the head. These headsets usually have a short boom arm that holds a condenser element at the corner of the mouth. The corner of the mouth is the preferred placement area for the headset capsule so it can be close to the sound source, but out of the way of the performer's breath (which can cause unwanted wind noise when exhaling). Condenser headsets have the required pre-amplifier assembly or are terminated with an appropriate connector for use with a wireless transmitter. There are omnidirectional headsets and unidirectional headsets, the choice of which can be determined by reviewing the characteristics of each and determining which is best for your application.

All headsets should be stable enough to maintain the microphone position at the mouth regardless of the head movements of the actors. More and more large-scale productions are using headsets, especially in high-energy musical performances; and manufacturers are consistently updating their designs to maintain the best performing mix of comfort and sound quality.

BOUNDARY MICROPHONES

Boundary microphones (also known as pressure zone or PZM microphones) are an alternative to micing each individual performer, and an alternative to overhead microphones. Boundary mics are designed to be laid flat on an acoustically reflective surface, in this case the stage itself. The surface which the microphone becomes an important part of how the microphone picks up sound. Again, these mics usually consist of condenser elements in a low-profile housing. The necessary pre-amp can be self-contained or the in-line type found in overheads. They should be placed along the lip of the stage, with a unidirectional polar pattern aiming back at the action on stage. They obviously need to be out of the actors' way as far downstage as possible. You should follow the 3-to-1 Rule with these mics as well to avoid phasing issues.



Example of unidirectional boundary microphones being used to provide area coverage for an on-stage application

The drawbacks to these microphones are some of the same drawbacks we have seen with overhead mics, primarily the distance from the sound source and the proximity to the loudspeakers. Additionally, because the microphones are on the stage, the pickup of stage noise from the actors' feet, scenery movements, etc. can also be a problem. You can alleviate some stage noise by placing a soft felt or foam pad in between the mic and the stage, and/or decreasing the low frequencies on the EQ. Small boundary microphones can be hidden in permanent scenery, as a "plant mic", such as on a table in the center of a room scene. Polar pattern for this method is dictated by the microphone's position relative to the actors.

Overhead and boundary microphones work best with experienced actors whose voices project well. People with softer voices and some children do not have the ability to project their voices enough for overhead or boundary microphones. In many cases with overhead or boundary mics you may be tempted to turn up the system volume to compensate for the increased distance from the actors, but beware that this can push the system into feedback. A headset or lavalier may still be the best answer for your production because they allow for greater gain before feedback than either overhead or boundary microphones.

OVERHEAD MICROPHONES

The microphone techniques we've been covering up to this point have involved the use of one microphone on every performer. However, this can be cost prohibitive in many smaller theaters, schools, community theater, or church pageants. An alternative method uses overhead or hanging microphones, sometimes called choir microphones. These capture sound by hanging down from above the stage. Overhead mics usually are comprised of a condenser element mounted on a short gooseneck, which then leads to a thin cable. The length of cable can be up to 20-30 feet long and ends in the necessary pre-amplifier assembly. Often times, the cable is of a thinner variety than the traditional XLR cable in order to be less noticeable. They can be found in various colors and polar patterns. A high-quality probe style or "end-address" condenser microphone can also be used, although they are quite a bit larger. There are adapters available that will suspend these more traditional microphones by the cable for overhead use and maintain their position.

Illustrative example of overhead microphone placement being used to provide area coverage

Using overhead microphones to capture sound from above can provide decent sound reinforcement, but you should be realistic as to what to expect. These microphones are further away from the sound source than even a microphone on a floor stand would be and will pick up more ambient sound than preferred. This, in addition to the possibility of these mics actually being closer to loudspeakers than to the sound source, can lead to significantly reduced gain before feedback. Another factor contributing to feedback is the number of open microphones (often abbreviated NOM) being used. The more open microphones in a sound reinforcement system, the less potential gain before feedback. Therefore, the idea to put in more mics to cover the area better or to "make it louder" will in fact worsen the situation. It is a must to use as few overhead microphones as necessary.

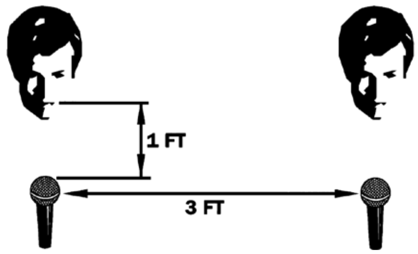
Other things to remember when using overhead microphones:

- Placement of these microphones is often dictated by the constraints of the stage set. Take into consideration when possible, the position of the actors on stage and install mics accordingly. Planned scenery for a production may make installed overheads unusable due to scenery changes, space limitations, or reflection of sound. Always aim for direct line-of-sight (LOS) from the performer to the microphone.

- Remember that most actors project their voice to the audience. An overhead microphone, if pointed straight down, is pointed at the top of someone's head. Speech is not as intelligible from that vantage point as the high frequency content is lost. At the same time, the microphone can be picking up both the reflected sound off the surface of the stage, as well as mechanical or air handling noise from above. When combined with direct sound, this will provide poor audio quality.

- For most reinforcement applications, you should stick with a unidirectional polar pattern. Whenever possible, you should hang an overhead mic 2 to 3 feet in front of the nearest actor downstage. The capsule should be aimed slightly upstage. These mics work best when installed 2 to 3 feet above head level. Increasing this variable will reduce your potential gain before feedback.

- Always observe the 3-to-1 Rule when spacing multiple microphones to cover a larger area. The 3-to-1 Rule states that the microphone to microphone distance should be three times the microphone to sound source distance. This will reduce interference effects such as comb filtering and phasing issues. Remember that overhead microphones will not give you the same performance as a lavalier.



III. WIRELESS MICROPHONE SYSTEMS

To achieve the ultimate in mobility and still maintain the highest potential gain before feedback requires the use of wireless lavalier microphones. In fact, some of the earliest use cases of wireless microphones were borne from needs of the theatre industry. Without wireless lavalier microphones in larger productions, movement would be restricted, scene and wardrobe changes would be difficult, and walking or dancing around stage would become dangerous. Through advances in wireless microphone technology, and the availability of more affordable systems, stage productions now have freedom of movement onstage and off. Bodypack transmitters are now easier to conceal than ever, and many wireless systems can be used simultaneously even in congested RF environments. There are rules to using wireless however, which you must follow for interference-free performance. Most of these rules pertain to frequency selection and antenna usage. Much of what has been learned about placement of mics and bodypack transmitters has been learned through years of trial and error and use in real-world situations. Every production yet to come will no doubt present unique challenges and solutions however by following some basic guidelines, you will prepare yourself for the best performance possible.

FREQUENCY RANGES

Wireless microphones are now available in a variety of different frequency ranges. As available RF spectrum becomes less available, it is important to understand the different frequency ranges available for wireless microphones as well as their pros and cons. RF coordination is a very complex topic, however we will cover the basics as it pertains to usage in theatre environments.

- VHF – (around 174 – 216 MHz) frequencies were once extremely popular in the early days of RF wireless microphones. VHF offers good performance, however due to the wavelength of the frequency being longer, antenna sizes also become longer. For the receiver antennas, this isn't a huge issue. As you can imagine, having an unsightly long antenna on the performers can become a hindrance. As UHF wireless technology became more popular and affordable, the industry has seen a decline in VHF wireless usage. More recently, as UHF frequencies are becoming more scarce due to government auctions, we are seeing a resurgence in VHF technology once again. Especially when paired with newer digital wireless microphone technology, VHF is now a more popular frequency range once again especially when UHF is not an option or too crowded.

- UHF – (around 470-616 MHz for USA) is one of the most popular and longest used frequency ranges for theatre productions. UHF offers great range and wave propagation with little output power, making it a great choice for wireless microphones. These same virtues have also made it very desirable for other uses besides wireless microphones. Since around 2009, UHF frequencies are becoming more scarce due to government auctions of these frequencies for other wireless uses (namely cellular phones). The majority of professional theatre wireless users are using frequencies in the UHF band. The largest obstacle for use of UHF frequencies are terrestrial TV broadcast stations. Wireless microphones must not use the same frequencies as local broadcast TV stations, and must operate where there are vacancies in this frequency range.

- STL (Studio Transmission Link – 941.5-960 MHz) This subset of the UHF frequencies is an option, especially for FCC license holders.

- 1.9 GHz (DECT) frequencies are popular with wireless conferencing and video applications due to their easy setup. 1.9 GHz mics are less popular with theatre applications simply due to the latency of the audio (typically around 19ms). High latency can result in an undesirable "echo" effect when used with a live sound reinforcement scenario as we often see with theatre.

- 2.4 GHz (ISM) frequencies are quite popular with users and manufacturers alike due to being able to be used in many different places internationally. These systems are often digital in nature and are easy-to-use due to automatic setup and often are license-free. The main challenge with using 2.4 GHz wireless is that many other devices, such as Wi-Fi, and other consumer devices (baby monitors, wireless video, etc.) are all trying to use this same spectrum. In a clean 2.4 GHz environment we can normally use around 8-12+ microphones. In a congested environment we may not be able to use any microphones at all.

FREQUENCY COORDINATION

Careful coordination of frequencies must be employed when operating any number of UHF or VHF wireless microphones for trouble-free performance. Wireless microphones must follow three basic rules:

1. Operate on a clean frequency to avoid interference
2. Operate with enough spacing between other signals to not have interference with each other
3. Be frequency coordinated to avoid interference from what is known as intermodulation

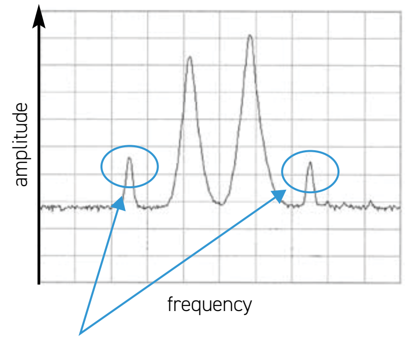
NOTE: Wireless microphones in the 1.9 GHz (DECT) and 2.4 GHz (ISM) bands typically take care of coordination automatically.

- A receiver channel can only demodulate one radio signal at a time. In other words, a wireless receiver on any given frequency can only receive a signal from one transmitter on that frequency. If there are two signals present on the same frequency, the stronger of the two may block out the other, or the output of the receiver can be unusable noise, strange sounds, or muting of the audio with digital systems. The analogy most often referred to in explaining this concept is commercial FM radio. In any city, only one station is broadcasting on any given frequency. Many receivers (e.g. car radios) may be tuned to say, 97.9FM, but only one station is broadcasting on that frequency. If you reach an area between two cities, both having stations on 97.9FM, the signal reception is poor and very noisy as both are competing for dominance to the receiver.

- Broadcast TV channels should be avoided. As mentioned previously, the great majority of wireless microphone systems operate in the UHF range and share this frequency range with broadcast television, per FCC regulations. Normally, these unused areas of spectrum in between active broadcast television stations are referred to as "whitespaces" and are where UHF wireless microphones are best operated. FCC regulations normally prohibit the use of wireless microphone systems on occupied TV frequencies. Recent FCC rule changes do permit "co-channel operation" from licensed wireless microphone users if those TV signals are weak due to building shielding; for example, indoors in a brick building. The strength of RF from broadcast TV antennas can be millions of times stronger than wireless microphone signals and will often wash out the intended RF wireless signal. If wireless microphone frequencies are on an occupied TV frequency, wireless systems will not operate reliably . Manufacturers of wireless microphones can assist you in determining your proximity to TV broadcast antennas and determine which frequencies are open for use and compatible with each other in your area. There are also internet-based tools available for determining open frequencies in your particular usage area.

- When using multiple wireless UHF/VHF microphones, each wireless system must operate on its own frequency. Each manufacturer's system has its own parameters for how close these frequencies can be located next to each other. Typically, this can be anywhere from 400 kHz to 125 kHz. Consult the manufacturer of your wireless system for exact frequency spacing parameters for your specific system.

- Frequencies chosen for multiple wireless systems in the same venue must also be calculated to avoid Intermodulation Distortion, or IMD. When multiple wireless systems are used, IMD products (frequencies) are created in addition to the specific carrier frequencies the wireless systems are tuned to. If these IMD products happen to be near or close to the frequencies selected for your wireless systems, you will have problems. IMD products can be thought of as "virtual frequencies" or "ghost frequencies" as these are unintended frequencies created by simply using 2 or more wireless systems. The more wireless systems that are used in the same area, the number of IMD products increases exponentially making it difficult to operate wireless mics unless proper frequency placement is done.



IMDs created by two transmitters

The technical explanation why IMD products are created is that non-linear circuits in wireless system designs generate weaker radio signals on various multiples (harmonics) of the intended operating frequency. To determine exactly where IMD products may be created, wireless system manufacturers have computer software that can calculate these IMD products to ensure compatibility. These software programs will place wireless microphones in clear spectrum and avoid IMD products for best performance. Additionally, manufacturers often provide pre-calculated sets of frequencies which avoid issues from IMD products. These are often pre-programmed into the receivers and transmitters as "Groups" and "Channels" or similar.

DIGITAL AND ANALOG WIRELESS SYSTEMS

Analog wireless systems have been a staple of many theatre productions since the invention of wireless microphones. They are well understood, and proven reliable for decades. With the recent shrinking of the UHF spectrum, due to recent government auctions, users are more interested than ever in getting more wireless channels into the same amount of space. Digital wireless systems are often more efficient than their analog counterparts due to a number of factors. In one 6MHz TV channel, we can typically get around 8-12 wireless analog microphones working together. In that same 6MHz TV channel, digital systems can place around 17 to 47 channels in that same 6MHz TV channel. As you can see, digital wireless systems show great ability to pack more wireless channels in the same space versus analog wireless.

Digital wireless systems often are less affected from IMD not because they are digital, but because of the way digital systems need to be engineered. Digital wireless must operate with great precision, and this means the usage of linear components which are less likely to create IMD. Digital systems also enjoy clearer sound and less coloration of the audio. As wireless microphone users are continually forced to deal with less spectrum for operation, digital systems are a welcome advancement for wireless users and are here to stay. As of the time of writing, many analog wireless systems are being discontinued in favor of their digital counterparts.

BODYPACK TRANSMITTERS

Bodypack placement is often a test of the imagination and innovation of the sound designer and wardrobe master. After all, the goal of the theatre sound designer is to hear the performer while having the technology invisible to the audience. Luckily, both lavalier microphones and wireless bodypack transmitters have continually become smaller and more advanced over the years. Bodypack transmitters of yesterday used to be big and hard to conceal. Advancements in wireless bodypack technology have made this easier to accomplish due to smaller available sizes. The smallest bodypacks are often referred to as "micro-bodypacks."

Examples of transmitters
(left to right: handheld, bodypack)

Because bodypack transmitters are now available in multiple different form factors, with a little ingenuity and creativity, they can be mounted almost anywhere. Since most come with a standard belt clip, the obvious easy option is to clip the bodypack onto an actor's clothing at the beltline or on the hip area. The standard for theatre applications is an elastic/neoprene mic belt with a pouch for the transmitter. This method keeps the pack close to the actor and avoids issues with costume quick changes. Micro bodypacks are commonly used under actor's wigs to hide the lavalier cable. When actors need to roll on their backs due to stage combat or dancing-sometimes mic transmitters are put higher up on the actors backs instead of their waist. Each situation is different, it's a good idea to have a mic fitting prior to the first tech session so that changes can be made. The small of the back can be used for placement if a fanny pack or similar harness is used instead of a clip. A bodypack can be held between the shoulder blades and under costuming using a shoulder harness made up of a pouch for the pack and a couple of loops to go around the shoulders. There are specialty-made cloth or neoprene/elastic straps, which are designed to hold bodypacks on arms and thighs. Smaller bodypacks can be even hidden in wigs or hair. Creative ways of affixing bodypacks to actors are being developed at all levels of theater every day, because every situation is unique. Tops of hats, and in wigs are some useful hiding spots.

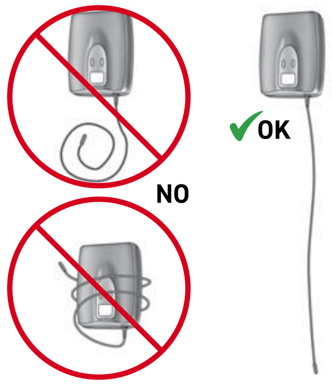
Example of portable receiver


Example of fixed receiver

When hiding wireless bodypacks, here are some useful tips to remember:

- RF signal can be blocked and reflected by metallic surfaces. This can include any costuming that has metal threading or metal plating, the extreme case being your knight in shining armor. Additionally, costumes made with polyester metallic film or other similar metallic material can sometimes cause problems due to unintended RF shielding. Wearing a bodypack under these types of materials, will severely degrade RF performance.
- Antennas of bodypacks should always be kept as clear as possible from obstructive surfaces or materials. As stated earlier, the bodypack antenna should never be curled up and stuffed into pockets. This can cause the antenna to fold and touch the housing of the bodypack itself. When this occurs, the antenna will temporarily be detuned and RF performance will suffer.

- Allow for strain relief on the mic connector and antenna, so that movement of the actor will not crimp the cable or antenna with their movements. Repetitive strain on the cable will cause failure sooner rather than later due to a broken cable. Remember to check cables thoroughly before each performance for issues.



- You can utilize the power/menu lock features of some bodypacks to make sure the actor cannot accidentally power off the transmitter during a performance, or in the case of frequency-agile systems, accidentally change the operating frequency.

- Make sure to leave the battery as accessible as possible, as you may need to do a quick change unexpectedly.

- Ask the costume department if they are using magnets for any costume pieces. Magnets can sometimes cause issues with the packs/mic elements.

- The human body is comprised of mostly salt water, and this can cause some RF transmission issues with bodypack transmitters located on or near the body. RF body absorption can decrease wireless system performance. Repositioning the bodypack or the receiving antennas (or both) can overcome this occurrence. Additionally, if an actor perspires during the performance, the actors sweat can become an issue. Antennas which come in contact with a shirt or costume that is drenched in sweat can become temporarily detuned and hurt RF performance.

- Sweat can be also potentially harmful to the electronics of a bodypack transmitter. There are many methods sound designers have used to protect bodypacks from sweat. A simple solution is to wear a Neoprene transmitter pouch when practical. While not completely waterproof, it will protect the bodypack from low-level sweat and moisture. Sometime putting the neoprene pack upside down helps to keep sweat and moisture out. Another more protective method is to use an unlubricated condom to cover the bodypack.

- As unusual as it sounds, this technique is very effective when used properly. An un-powdered, dry surgical glove can also be used. Remember that there are people allergic to latex or other materials, so check with the talent ahead of time before using any method of covering a bodypack next to skin.

- As discussed previously, it is common to double mic lead actors and any actors who may sweat a lot and/or have little to no time offstage. Having a spare transmitter and mic on the talent is the ultimate in backup reliability.

- It is a good idea to clearly label your bodypacks in some manner to identify the intended user. Any mix-ups can destroy the continuity of the show and cause the sound engineer to search for the right mixer channel to operate. You may choose to use labels affixed to the transmitters as well as naming the bodypacks in the LCD display.

- It is a good idea to label the lavs as well with actor names and the date went into service.

- Do not leave transmitters, especially analog transmitters, bunched together on a table or in a bin when they are on. Intermodulation distortion becomes more prevalent when wireless transmitters are close together. In fact, many seasoned RF techs will use aluminum bread pans (or similar) to put each powered-on transmitter in when powering up all the transmitters before a show. The bread pans will contain the RF and minimize the chance of IMD being created. Digital wireless is less likely to create IMD than analog wireless when the transmitters are close together, but it is good practice to avoid this when possible.

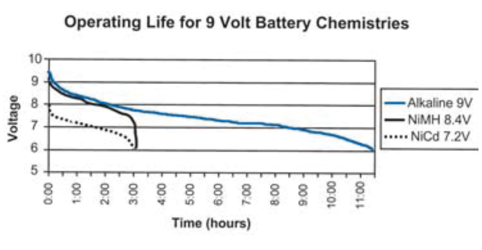
- Having a A2 listening station is very important backstage. This helps the A2 troubleshoot before actors go onstage and gives a chance to fix problems before they become major show stopping issues.

Bodypack transmitters are made with a variety of input connectors, depending on the manufacturer. Just about all transmitters will supply DC bias voltage to make condenser elements work. Using one manufacturer's wireless lavalier microphone with another manufacturer's transmitter common. To ensure compatibility of a given lavalier and wireless transmitter, it is important to ensure the "pin out" is correct. When in doubt if a mic is compatible, it is suggested to contact the manufacturer of the lavalier and/or the wireless bodypack. Many theatre users sometimes purchase a mic without a connector or rewire the proper connector on to the lavalier to match the bodypack. Do not assume that if the connector is the same between manufacturers the mic will work, as the proper wiring must be observed for proper operation as well as to prevent damage to the microphone itself.

Regarding output power of transmitters, it should be noted that output power is not only regulated by government agencies, but it is also carefully determined by the manufacturer. It is true that higher output power may increase the transmission range of the RF signal (antenna efficiency can also affect range), however higher output power can also exacerbate the likelihood of IMD being created when using multiple channels. Therefore, higher output power is not always better. With the recent advancements of digital wireless systems, lower output digital wireless systems can often outperform higher output analog systems when it comes to transmission distance. Regardless of analog or digital, lower output power will translate to longer battery life.

BATTERIES

Batteries are a very important for the operation of a wireless bodypack transmitter. If a battery goes flat during a performance, it will certainly result in a disaster. We must ensure the batteries are completely full before a performance and ensure that they will last for the duration. Battery life of a bodypack varies from model to model and manufacturer to manufacturer. Up until fairly recently, most bodypack transmitters solely used alkaline cells such as 9V, "AA" or "AAA" batteries. Before every performance, each bodypack got a new fresh battery. As you can imagine, this was costly and not environmentally friendly. Rechargeable batteries of yesterday were considered not reliable enough for professional theatre use. Recent advancements in rechargeable battery technology has not only made it a great choice for performances, but also mandatory for certain digital transmitters. The latest rechargeable battery packs now are be equipped with "smart" microchips which



Alkaline vx. rechargeable batteries

keep track of vital statistics. This may include run time until empty, time until charged, cycle count, battery health, and more. It is possible to know exactly how many hours and minutes a battery will last until it is depleted. This data can be observed at the receiver or through computer monitoring software during a performance. Having this data at one's disposal during a show increases confidence when using rechargeable batteries and is better for the environment, saves money, and is less hassle than procuring disposable batteries. Additionally, some digital bodypacks can only use rechargeable packs due to their power consumption requirements as well as their small size. Some micro-bodypacks on the market are so small that even two "AAA" batteries wouldn't fit!

RECEIVERS AND ANTENNAS

Most wireless mic receivers have detachable antennas which can either be outfitted with whip antennas or remote antennas. BNC style connectors are used most commonly and allow for either scenario. In most cases, antennas are attached to the rear of the receiver. If the receiver is to be mounted in a metal rack the antennas must be brought to the outside of the rack for best performance. Some designs allow the antennas to be moved to the front of the receiver, while others provide an accessory panel for front mounting. Again, the receiver should be mounted high enough in the rack so that the antennas are essentially in the open.

General rules concerning setup and use of receiver antennas:

- Maintain line-of-sight between the transmitter and receiver antennas as much as possible. Avoid metal objects, walls, and large numbers of people between the receiving antenna and its associated transmitter. Ideally, this means that receiving antennas should be in the same room as the transmitters and elevated above the audience or other obstructions.

- Keep the receiver antenna at a reasonable distance to the transmitter. The maximum distance is not constant but is limited by transmitter power, intervening objects, interference, and receiver sensitivity. The closer you can get the transmit antennas to the receiver antennas is better, but a minimum distance of about 10 feet is recommended to avoid potential intermodulation products in the receiver and RF overload. Ideally, it is better to have the antenna/receiver combination near the transmitter (just off stage) and run a long audio cable back to the mix position, than it is to run a long antenna cable or to transmit over long distances. It is much more difficult to run RF signals long distances through cables than it is to run audio signals long distances through cables.

- Use the proper type of receiver antenna. A 1/4-wave antenna can be used if it is mounted directly to the receiver, to an antenna distribution device, or to another panel that acts as a ground-plane. Hanging a ¼ wave antenna from a cable without a ground plane will not be effective. If the antenna is to be located at a decent distance from the receiver, a 1/2-wave dipole antenna is recommended. This antenna type has somewhat increased sensitivity over the 1/4-wave and does not require a ground-plane. For installations requiring more distant antenna placement or in cases of strong interfering sources, it may be necessary to use a remote omnidirectional or directional antenna suitably aimed.

1/4 wave and 1/2 wave antennas UHF range

- Select the correctly tuned receiver antennas. Most antennas have a specified bandwidth making them suitable for receivers operating within only a certain frequency band. When antenna distribution systems are used, receivers should be grouped with antennas of the appropriate frequency band as much as possible.

- To get the best RF reception from a diversity receiver (those with 2 antennas), the minimum separation between its antennas should be 1/4 wavelength (about 16 inches for VHF, 4 inches for UHF). The effect improves somewhat up to a separation of about one wavelength. Diversity performance does not change substantially beyond this separation distance. However, overall coverage of very large areas may be improved by further separation. The idea is that if one antenna is having trouble receiving the signal, you want the other antenna at a more favorable position.

- Locate receiver antennas away from any suspected sources of interference. These include other receiver antennas as well as digital equipment, LED lights and walls, digital effects units, lighting control systems, etc. All of these devices have the potential to emit electromagnetic interference, which can result in poor RF reception, noise, and other problems.

- Mount receiver antennas away from metal objects. Ideally, antennas should be in the open or perpendicular to metal structures such as racks, grids, metal studs, etc. They should be at least 1/4 wavelength from any parallel metal structure. All antennas in a multiple system setup should be at least 1/4 wavelength apart.

- Orient receiver antennas properly. If transmitter antennas are generally vertical, then receiver antennas should be approximately vertical as well. If transmitter antenna orientation is unpredictable then receiver antennas may be oriented up to 45 degrees from vertical. This is known as antenna polarization. Transmit and receiving antennas in the same orientation will perform best.

- Use the proper low-loss antenna cable for remotely locating receiver antennas. Typically, this is 50ohm cable for UHF wireless systems. A minimum length of the appropriate low-loss cable equipped with the proper connectors will give the best results. It is advised to use the lowest loss cable you can afford rather than trying to make up signal loss with antenna boosters.

- Antenna boosters should only be used to make up for long cable runs or other RF signal losses (from splitters etc.) Using excess boost when it is not required will actually hurt your RF system performance.

- Use an antenna distribution system when possible. This is advised when using two or more wireless systems. This will minimize the overall number of antennas and may reduce interference problems with multiple receivers. For two receivers a passive splitter may be used. For three or more receivers, active splitters are strongly recommended.

- When you perform a walk test to check your wireless, try to have any kind of video walls or LED devices turned on which will be on during the production. This will give the best 'real world' scenario as it concerns RF.

AUTOMATIC FREQUENCY SELECTION

Most wireless microphone receivers today have a "scan" feature. The scan feature will sweep the RF environment and report back to the user which frequencies are cleanest and recommended for use. The receiver scans the set of frequencies while measuring RF signal strength. The RF signal can be other RF sources such as local TV broadcast, other wireless microphone systems, or RF "noise". In any case, the manufacturer has programmed into the receiver an acceptable threshold level for RF strength from these outside sources. When the RF signal strength on a scanned frequency is below the threshold, the receiver determines that the frequency is usable. Some systems can be networked together and share the sweep data with each other. Once the user selects the suggested frequencies for the receiver(s), the transmitters must be programmed to the same frequencies. Most often, the transmitters can be programmed to these frequencies via an infrared communication link from the receiver to the transmitter.

IV. INTERCOM SYSTEMS

Intercom systems are communication networks designed to allow production staff to talk to one another from different areas of the venue. These systems are separate from any sound reinforcement equipment reproducing the performance but of equal importance. To monitor the performance itself, these systems can provide for an input from the main sound reinforcement system so staff can synchronize cues or other staff actions. Intercom systems most often are permanently installed systems that have individual stations located in different key areas of the venue. They are found at the front of house (FOH) mix position, spotlight positions, backstage, dressing rooms, etc. To allow two-way communication, intercom stations may have a built-in speaker/mic, or provide inputs for wearable headsets and microphones. Some stations may be in bodypack form for easy use by semi-mobile staff, or for use in portable systems. Other stations can be wall mounted, rack mounted, table top, or telephone handset type.

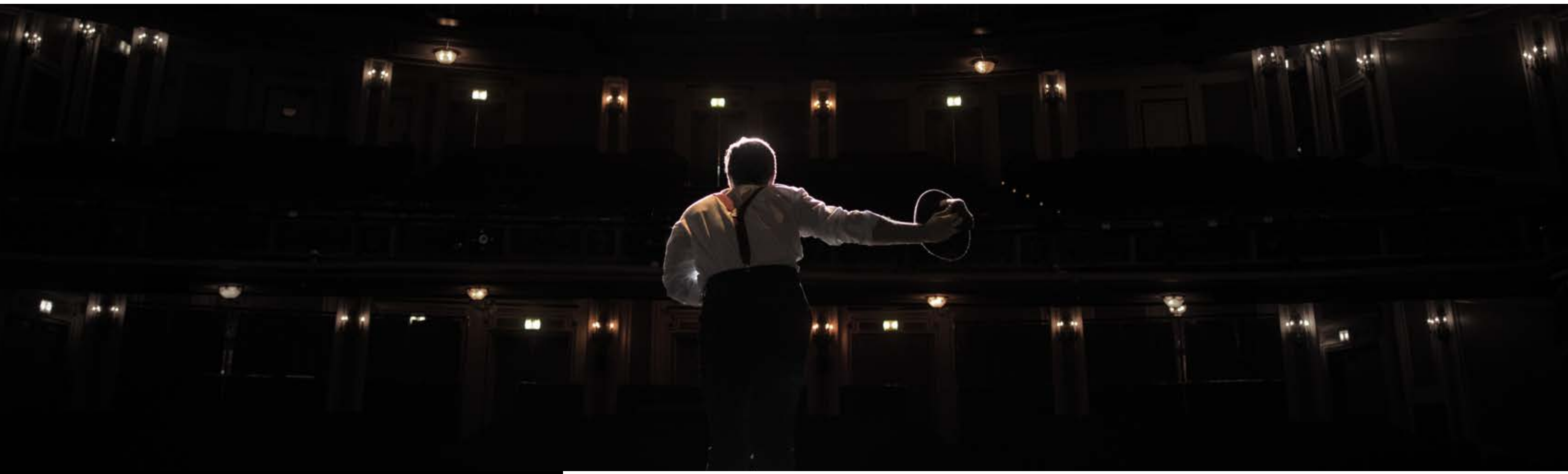
SM2 Headworn Microphone. An example of a microphone used in intercom systems

Intercoms can be configured in many different ways, from a simple 2-station system, to systems of 60 or more with digital control panels and switching systems for multiple channels. There are many wireless intercom systems available, which often can work in the same frequency range as wireless microphones. In these cases, it is important to include these wireless intercom systems in a frequency coordination to ensure that they will not interfere with the wireless microphones occupying the same RF spectrum.

V. PERSONAL MONITOR SYSTEMS

Monitor speaker wedges are commonplace for performers to hear themselves or other sounds during a performance. Additionally, wireless in-ear monitoring is very common in theatre. To understand how it works, think of a traditional wireless microphone system - in reverse. Instead of the performer wearing a mic and sending the sound to a receiver, it is the opposite. An AC powered transmitter sends audio wirelessly to a battery powered bodypack receiver which the performer wears. The audio is amplified and the performer wears one or two earpieces. In-ear monitor systems are engineered to provide full range, high quality stereo sound. In addition, the earpieces which the performers wear are designed to seal out ambient sound to provide greater control of the mix and a degree of hearing protection.

The audio source for in-ear systems is usually a combination of auxiliary mix outputs and/or direct channel outputs from the main sound reinforcement system, depending on the requirements of the listener. There may be a dedicated "monitor engineer" and separate console which sole purpose is to mix audio for the performers. It is possible to customize a different mix for individual performers if each has his or her own transmitter/receiver. In theater applications, a director's feed can be mixed into the signal the performer is hearing in-ear. The director can then talk directly to the talent to provide cues, direction, and even dialogue prompts, all without the knowledge of the audience. If there are live musicians accompanying the show, they can use personal monitors to hear director's cues as well as monitor their own performance. In addition, the sound designer will be able to improve the overall sound in the house due to not using traditional monitor loudspeakers normally used by live musicians.



VI. CONCLUSION

Theater sound design and microphone selection, wireless microphone application, and associated audio processing are undoubtedly going to continue to evolve and expand. Each new production will have a unique set of requirements and parameters that the sound designer and sound engineer will need to meet. While new technologies such as digital wireless microphones and rechargeable "smart" batteries are already being found in more affordable and user-friendly products, the core physics of audio, microphones and audio systems will remain the same.

VII. ABOUT THE AUTHORS

CRISPIN TAPIA

Crispin Tapia is an Applications Engineering Supervisor at Shure Incorporated. He has been active in the Chicago music scene for many years as a performer, and has experience in both live sound and studio recording. He has earned his B.A. in Psychology from the University of Illinois at Chicago, and a B.A. in Audio Engineering from Columbia College Chicago.

BEN ESCOBEDO

Ben Escobedo is a Senior Market Development Specialist at Shure Incorporated. Ben focuses on Professional Audio with an emphasis on Theatre and Broadcast. As an audio professional, he often presents and discusses on wireless best practices, spectrum issues, and microphone optimization. In his free time, he enjoys playing guitar and designing circuit boards for DIY guitar pedals. Ben has a B.A. in English from the University of Connecticut.

VIII. GLOSSARY

IMD – Intermodulation distortion, another name for IM.

Impedance – In an electrical circuit, opposition to the flow of alternating current, measured in ohms. A high-impedance microphone has an impedance of 10,000 ohms or more. A low-impedance microphone has an impedance of 50 to 600 ohms.

Lavalier microphone – Generally a small, condenser element worn on the chest area and mounted via a lanyard, clip, or pin.

Omnidirectional microphone – A microphone that picks up sound equally in all directions.

Phantom power – A method of providing power to the electronics of a condenser microphone through the microphone cable.

Receiver – Device that is sensitive to radio signals and recovers information from them.

RF – Radio frequency

Sensitivity – A rating to express how "hot" the microphone is by exposing the microphone to a specified sound field level.

Supercardioid microphone – A unidirectional microphone with tighter front pickup angle (115 degrees) than a cardioid, but with some rear pickup. Angle of best rejection is 126 degrees from the front of the microphone, that is, 54 degrees from the rear.

Transducer – A device that converts one form of energy to another.

Transmitter – device which converts information to a radio signal.

Wavelength –The physical distance between successive complete cycles of a wave, inversely proportional to frequency, dependent on properties of medium.