Sound-- Wireless Microphones!

WIRELESS MICROPHONE THEORY
Quote: "There is nothing in the world worse than a cheap wireless system," Hosch says. "It's scary when your future is hanging on a $ 1.98 battery. Anytime you can, you should get someone to use a wired mic over a wireless system." Scheirman adds, "and just remember that even the best wireless microphone system, a $10,000 system, is almost as good as a mic cable." (From TCI, May 1993, page 25).

A wireless microphone system is a small-scale version of a typical commercial FM broadcasting system. In a commercial broadcasting system, a radio announcer speaks into a microphone that is connected to a high-power transmitter in a fixed location. The transmitted voice is picked up by an FM receiver and heard through a speaker or headset.

In a wireless microphone system, the components are miniaturized but the same principles apply. The transmitter is small enough to fit into the microphone handle or into a small pocket-sized case. Since the microphone and transmitter are battery powered, the user is free to move around while speaking or singing into the mic. The transmitted voice is picked up by a receiver that is wired to a speaker.

Two types of microphones are available with wireless mic systems: the handheld mic, with a transmitter in its handle; and the lavalier mic, which is small enough to be concealed as a lapel pin or hung around the neck. Lavalier mics are wired to miniature body-pack transmitters, which fit into a pocket or clip onto a belt. There is also a transmitter, designed by Lectrosonics, which accepts any three-pin XLR input and acts as a
Wireless microphones are widely used today in television and video production. They eliminate the need for stage personnel to feed cables around cameras, props, etc. For location film production, as well as ENG (Electronic News Gathering) and EFP (Electronic Field Production), wireless mics make it possible to obtain usable first take sound tracks in situations that previously required post-production dialogue looping. The cost saving can be significant.

Handheld mics are used by performers on camera where they provide the freedom needed to move around the stage and gesture spontaneously. They are used by speakers and entertainers who need to pass the mic from one person to another. In concerts, hand-held wireless mics permit vocalists to walk and dance around the stage and even into the audience without restriction and with no chance of shock in the event of rain.

Lavalier mics are used in game shows, soap operas and dance routines. They eliminate the need for boom mics and help to alleviate visual clutter. Lavalier mics are used by MCs, panelists, lecturers, clergy, stage actors, and dancers because they can be concealed easily and provide hands-free mobility. Some lavalier transmitter models have high impedance line inputs that accept cords to create wireless electric guitars.

Technology in the early 1970s introduced the integrated circuit compandor which was incorporated into wireless mics to reduce noise. At about the same time, the FCC authorized the use of frequencies in TV channels 7-13 for wireless mics. Thus the wireless microphone's most serious problem, radio interference from other services, was virtually eliminated. Later, the application of diversity reception minimized the
problem of dropouts (transmission losses due to cancellation of radio waves), greatly improving system reliability.

Today's wireless mics perform almost as well as conventional wired mics. In the 1980s, wireless mics were manufactured with an improved dynamic range and smaller transmitters, a result of better compandor integrated circuitry and advanced circuit design techniques. A variety of standard microphones with different sound characteristics is available.

There are no international standards for wireless mic radio frequency allocations. Performance is not controlled for transmitter power limits, frequency stability, or RF bandwidth occupancy. Wireless mics could therefore, theoretically, operate at any frequency. Certain frequency bands are more commonly used. In the United States, the FCC regulates the operation of wireless mics at specified frequency bands.

**WIRELESS PROBLEMS**

Transmission Loss
There is a calculated transmission loss between transmitter and receiver through use of an isotropic antenna. Less transmitter power is required for an equivalent signal strength at the receiver as frequency is lowered. One problem with wireless microphones is the difficulty in designing antennas that are small but efficient in the VHF low-band area. However, for the VHF high-band, small and efficient antennas are practical.

Interference from other radio services is the major problem at both VHF and UHF. The only clear channels available are the unused TV channels in a given location and the "B" channels. For touring groups the TV channels become a problem, as a clear TV channel in one city may not be clear in another. Therefore, the "B" channels are recommended for this
Purpose. [The "B" channels are specific frequency bands designated by the FCC for wireless mics.]

Dropout
Loss of reception at the receiver of a wireless mic due to radio wave cancellation called multipath reflection is usually referred to as dropout. This problem has several possible sources. Dropout characteristics are different between VHF and UHF frequency bands. The dropout zones are much shorter at UHF where rapid flutter is often heard.

Loss of reception may also be caused by a transmitter being too far away from the receiver. This may be corrected by relocating either the transmitter and receiver antennas closer to each other.

The power of a signal received by an antenna is a critical factor in causing dropout. When examining practical solutions and limitations in alleviating dropout, it is important to consider that not all of the power transmitted will reach the receiver. A wireless mic transmitter radiates power in many directions simultaneously, depending on the specific mechanical configuration of the antenna system. This makes the transmission vulnerable to many types of interference.

System performance is degraded by path losses due to interfering objects between the transmitter and receiver, such as other equipment or people, as well as by the position of the transmitter antenna and interfering signals due to multipath reflections.

Several paths can occur when the environment in which the wireless microphone is operating contains objects such as cameras, lighting equipment, or stage props made of metal or other materials that reflect...
radio signals. Due to phase differential of the arriving signal, the resultant signal can be enhanced or totally cancelled, causing multipath dropouts. These path losses affect the total power received at the antenna. Multipath cancellation is the most common cause of dropout.

Solutions
*Use a high gain receiving antenna at the mix position: High gain antennas can improve the signal-to-noise ratio, and may thus reduce fades and dropouts if they are due to weak. Signal cancellations will not be aided. high gain receiving antennas are generally also a bad idea because: (a) the transmitter is constantly moving around with the performer so the antenna would have to be continuously re-aimed, and (b) much of the received radio signal is actually caught on the bounce from walls, props, etc., so even if one stood offstage and aimed a beam antenna at the performer, it could be aiming at the wrong target.

*Place the receiving antenna(s) and receivers near the mic(s) and run audio signals back to the mix position: With wireless mics, an alternative is to place the receiving antenna(s) on or above the stage, run a moderate length of antenna cable to a nearby wireless mic receiver, and then run a standard audio cable between the receiver's audio output and the mixer's input. Most receivers provide line level outputs that are ideal in this situation. This keeps the mic transmitting antenna(s) and the receiving antenna(s) reasonably close, which optimizes the RF S/N ratio.

*Diversity reception: In some wireless microphone installations, it may be impossible to locate a single antenna to eliminate multipath dropout or signal fading. The technique that has been adapted for wireless microphones to minimize multipath dropouts is called diversity reception. This is the application of two or more receiving antennas to receive signals
that have been diverted into more than one path (multipath). The idea, in
general, is that if the signal is weak at one antenna, it will probably be
stronger at the other, at any given instant. Diversity reception enhances the
performance of a wireless mic system. It is usually effective, although
nothing will guarantee a total absence of dead spots. There are a number of
different ways to accomplish diversity reception, and each manufacturer of
wireless microphones tends to favor one approach or another. The
conditions required to achieve this reception are:
*a single transmitter source
*uncorrelated, statistically independent signals
*multiple receiving antenna systems.

This success of any diversity reception system depends on the degree to
which the independently received signals are uncorrelated. If a diversity
reception system cannot produce uncorrelated, statistically independent
signals, then diversity reception does not exist.

Implementation of a diversity reception system can be accomplished in
several ways, but all system implementations have the need to combine the
received, independent signals in some method. The major drawback with
any multiple reception diversity system is cost. Combining techniques are
chosen based on cost and the degree of improvement required. The less
predictable or less closely related the signals, the more significant the
benefits of the diversity system.

There are various techniques of diversity reception based on the exact
method for processing and extracting the transmitted signals. Space
diversity is the technique most commonly used for wireless mics. Space
diversity can be implemented in many different ways, but the three basic
requirements of diversity reception mentioned earlier must be satisfied.
Two or more receiving antennas are required and must be at least one half wavelength apart (typically three feet). The amount of separation determines the degree of the uncorrelated signals. Polarization diversity is a method of space diversity in which the antennas on the receiving system are placed at angles to each other in order to capture the uncorrelated, independent signal. Each antenna provides an independent path that is selected or combined to produce the desired signal improvement. These selecting and combining methods of processing the independent signals are shown below:

In space diversity the incoming signal with the best signal-to-noise ratio is selected from the two or more antennas used. The signal selection can be accomplished either prior to or after audio detection.

Another method of signal improvement is that of combining the incoming independent signals. The two methods of doing this are called maximal ratio combining and equal gain combining. In maximal ratio combining, independent signals are combined in order to derive the maximum signal voltage/noise power ratios from each of them. A modification of this approach is equal gain combining in which all incoming signals are set to an average constant value.

Clearly, the maximal ratio combining method offers the best possibility for improvement over a non-diversity system, although it is the most difficult to implement. Wireless mics typically use selection or equal gain combining diversity. The choice is based on greatest reduction of the probability of dropouts. Any of the selection/combining techniques can be implemented in the pre-detection or post-detection stage of the receiver.

MULTIPLE WIRELESS SYSTEMS
A wireless microphone requires system design and analysis consistent with the channels and particular design being used. When using multiple wireless mics, the following interference sources must be considered:
* transmitter spurious emissions,
* transmitter and receiver inter-modulation, and
* splatter

Spurious signals are generated within the transmitter due to mixing products created in multiplying the crystal oscillator to the carrier frequency. These mixing products, if the fall within the bandwidth of the receiver, will be heard as squeals or chirping sounds. The spurious outputs of the transmitter are discrete spectral signals (splatter), and typically cannot be removed easily once a transmitter is designed.

Transmitter intermodulation (IM) occurs when a carrier frequency from another source is coupled into the output stage of a transmitter and becomes a second signal source. The transmitter IM products will overwhelm the receiver and will be recognized as acceptable signals, thus creating the chirping and squeals and overall sensitivity degradation.

**WIRELESS MOUNTING**
In the case of concealed mics, either suspended round the neck or clipped to clothing, three things are vital:
1] The material must not generate static electricity-- this tends to rule out silk garments. Clothes with metal supports can also cause problems.  
2] The antenna lead must be straight and firm-- not allowed to bend and break, it is best taped to the skin.
3] The mic itself should be as near the mouth as possible-- unless specified otherwise most neck mics and omni-directional and will generate feedback if the gain is really turned up-- which it might need to be if the mic is
buried at chest level. Small cardioid pickup capsules are available but they can lose some frequency response which might need some correcting at the mixer. Since these mics are tiny they can also be concealed in wigs, and in all locations need frequent cleaning to remove perspiration and make-up.

CLOTHING NOISE & WIND NOISE
One of the ever-present difficulties in hiding lavaliers under wardrobe is clothing noise. In actuality, there are two different causes of "clothing noise": contact noise and acoustic noise.

Contact noise is the result of garments rubbing directly against either the mic capsule itself or the leading few inches of cable (equally sensitive to friction). Contact noise can usually be controlled-- if not completely eliminated-- by careful positioning and taping down of the mic and cable.

Begin by securing the clothing on both sides of the mic capsule. This can be done by sandwiching the mic between two sticky triangles of cloth camera or gaffers tape. Form these triangles by folding a few inches of 1" wide tape corner over corner, similar to folding a flag.

By immobilizing the mic between both layers of clothing, you have eliminated the possibility of either layer of clothing rubbing against or flapping onto the microphone.

If the lavalier must be positioned between skin and clothing, or attached directly to skin, then a professional medical/surgical tape should be used against the skin.

Once the mic capsule has been secured, the next step is to form a strain
relief for the thin cable. Make a small loop just under the mic capsule. In the case of very sensitive mics, such as the ECM-77 and MKE 2, make the loop go around twice. Tie a small thread of camera tape (sticky side out) to preserve the loop. Tie the loop loose enough so that it can "breathe" (change diameter to absorb tugs).

Apply a few inches of tape along the cable below the loop. Any tension on the cable will be absorbed by the garment, rather than by the microphone (which is somewhat isolated by the floating loop).

When using an external "tie clip," it is still important to think it terms of creating a strain relief. Loop the thin cable up and under the tie clip, forming a semi-circle, and passing through the wide hinge of the clip. Continue the loop behind the garment, and bring the cable around downward, thus completing the circle. As the cable loops downward, it should be inserted between the jaws of the tie clip and the back of the garment. Hide the balanced of the cable behind the wardrobe.

Not only is this arrangement more pleasing to the eye than a dangling cable, but the floating loop of cable isolates the mic while the grip of the tie clip serves as a strain relief.

Acoustic clothing noise is the sound generated by the clothing itself as garments or layers rub against each other when the actor moves. Noise is much more prevalent from synthetic fabrics than from natural cottons or wools. There is no simple remedy, only prevention, so it is wise to consult early with the wardrobe department.

However, here are a couple of tricks that may help. Anti-static sprays, such as Static Guard (tm), will reduce static electric discharge, clinging, and
reduce friction. Dry silicon spray lubricants sometimes help, but be careful of staining. Stiff or starched clothing can be softened with water or alcohol (make sure the colors don't bleed). Saddle soap, silicon, or light oil can take the bite out of hard leather.

Another noise problem common to lavaliers is that of wind noise.

Manufacturers usually supply small foam or metal mesh windscreens with their lavaliers, but these are usually more effective against breath pops than against outdoor gusts of wind.

Lavaliers used under clothing have the advantage of being partially shielded from the wind, but may still require added protection.

Clothing rubbing against windscreens can be extremely noisy, so that great care must be taken when using hidden lavaliers out of doors. Surrounding the windscreen with sticky tape and securing it to both layers of clothing, as you would a bare mic, will reduce the friction noise. However, the tape may destroy a foam windscreen when it is removed! Inexpensive, expendable foam windscreens can be made by wrapping the mic in acoustafoam; or by pulling the foam booties off of video cleaning swabs.

Cheesecloth over a mic works very well against wind. Another Hollywood variation is to snip the finger tips off of children's woolen gloves, and pull the wool tips over a lavalier wrapped in foam or cheesecloth.

**WIRELESS BODYPACK APPLICATION**

Without question, the most difficult aspect in using radio mics is correctly attaching them to the body of the actor or actress.
Actors have never been amenable to the idea of welding a body-pack directly to their skin, so...

Body pack transmitters can be hidden almost anywhere. The most common sites include the small of the back, rear hip, inside thigh, ankle, pants pocket, and inside chest pocket of a jacket, or in the heroine's purse. When talent is wearing a scant bathing suit, for example, radio mics can sometimes be hidden under straw hats, or even on the back of the neck under long tresses of hair. Leg warmers provide a convenient place to hide radios when dealing with exercise attire.

There are a number of ways transmitters may be secured. Belt clips work fine under a jacket or loose top. Special pouches or pockets can be pinned (or permanently sewn) into wardrobe. Sometimes it is possible to merely hang the unit with a safety pin that has been taped onto the transmitter casing. Specially constructed elastic belts can be worn around the waist, thigh, calf, or ankle. Transmitters can also be held in place by elastic bandages.

Anytime camera and gaffers tape is used, special care must be taken not to tape directly to skin or delicate wardrobe. Fold the tape over itself to form a non-adhesive strip to wrap around first. Better yet, use some sort of liner, such as a strip of cloth, wide gauze, or even a length of toilet paper.

Avoid placing the transmitter directly against the skin, since perspiration does not get along well with fragile electronics. Many mixers have found that unlubricated condoms provide excellent protection from excess perspiration, rain, or water spray. Normal-size condoms work fine, just stretch them out a bit before rolling them onto the body-pack.
Kai's note: when buying condoms for wireless mic body-packs, buy the large size. For some kicks, buy some cigarettes, No-Doz, and Tylenol at the same time and watch the cashier's reaction. By the way, you'll actually use the Tylenol, No-Doz, and cigarettes (if you smoke) during the production runs, so they aren't just entertainment.

Care should be taken in securing the flexible transmitter antenna cable. To prevent the antenna from being torn from its connector the first time the actor moves or bends over, use a rubber band to provide elastic strain relief. Attach one of the rubber band to the tip of the antenna. The free end of the rubber band can be safety-pinned to the clothing or taped in place (use medical tape on skin). Thus, the antenna can be maintained reasonably straight (a little bit of slack is okay) yet protected against tearing. Avoid running the antenna directly against the skin, since body moisture tends to interfere with (absorb) the outgoing signal.

The transmitter antenna can be run vertically up or down from the body pack. However, if the antenna trails downward, then the transmitter should be mounted in an inverted position to avoid making a loop in the line. The transmitter antenna can also be run horizontally, such as partially around the waist. However, in these instances, the receiver antenna may need to be tilted sideways (matching the angle) to improve reception.

Under no circumstances should the mic line and antenna wire ever cross. Run the microphone cable out from the body pack in the opposite direction of the antenna. When the transmitter is mounted on the body upside-down (the antenna running downward), it is okay for the mic line to loop upward, as long as it doesn't cross the antenna.
Install a fresh battery in the transmitter every time you use it. It sounds like a detail that should be obvious, but all too often radio mic problems boil down to a weak battery in the transmitter. Change the battery frequently—every four to six hours with most brands.

**WIRELESS RECEIVER PLACEMENT**

Strive to maintain minimum distance between the transmitter and receiver. Move the receiver/antenna from shot to shot in order to achieve close and clean line-of-sight placement. Given the option, it is better to run long lengths of audio cable (from receiver to recorder) than to have long lengths of antenna cable (from antenna to receiver).

Virtually anything can interfere with good radio transmission and cause bursts of static. Check for metallic objects of any kind, such as jewelry, zippers, coins, snaps, and keys. If you cannot eliminate the metal, then at least reposition the antenna on the actor.

Carefully eyeball the path of the transmission between the actor and the receiver. Pay attention to lighting or grip stands that may suddenly have appeared. A new influx of crew members or spectators can also block the RF signal.

Examine the location itself. Check for additional electrical lines, especially coiled feeds, which can generate magnetic fields. Dimmers and special effects equipment (especially neons) are always a problem. Motors can produce interference; be aware of golf carts, forklifts, camera cranes, automobiles, and kitchen appliances.

Video and computer equipment can create strange fields. Be aware of Steadicams and other camera mounts relying on high intensity video or
radio controlled camera functions.

**WIRELESS OPERATION**
Mics with switches should never be purchased--control should always be with the operator-- but in radio mics sometimes a switch is an asset since offstage and dressing rooms conversation will be picked up by a neck mic which the performer cannot easily unplug and which the operator may have forgotten to fade out, of course he has to remember to switch it on again! Wherever radio mics are used it is vital that the mixing desk is fitted with a pre-fade listen push so that the operator can listen in to the channel before the performer goes on stage and check that all is well.
If mics with switches are used, be sure to tape over the switches so that the actor/performer does not voluntarily or involuntarily switch the mic on or off. Control should lie solely with the mixing engineer or members of the sound crew.

**WIRELESS REPAIR and TROUBLESHOOTING**
If you work with wireless mics for an extended period of time (i.e. not just one day), you are bound to come across problems.

Dead mics? Replace batteries. If the belt-pack is clearly on, check the physical connection point between the mic and the belt-pack. If the system is detachable, test the belt-pack connection with a mic that you know works.

Sometimes the mics will "thunk" on and off. The problem, other than being out of range, is usually that the battery is too lose in its chamber and is contacting on and off. Either add padding at the bottom of the battery case or adjust the battery contacts inside the body-pack.
Other problems? Check the location of the body pack on the performer. Sometimes metal objects will interfere with transmission. Check the location of the receiver. It may be too close to metal objects or sources of interference. Change the position of the antenna(s) or even the whole receiver. Other than that? Get a new wireless system. Or a new auditorium. Whichever is faster.

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The following selection first appeared in Electronic Musician, July 1993, p. 58 et al. Reprinted without permission.

THE AGE OF WIRELESS
If you're old enough, you probably remember the precursor of the modern music video. Rock groups in the late '60's and early '70's would appear on television variety shows and lip-sync their current hit wearing peace symbols, bell-bottoms, and carefully coifed hair on a stage decorated in psychedelic paisley. Ah, the good old days!

One dead giveaway that they weren't really playing was the common absence of cables leading from the guitars and even the microphones. Apparently, producers wanted a clean, uncluttered look on camera. Besides, who would notice? Everyone would be listening with rapt attention to the canned music, right?
Wrong. Armed with a little knowledge of electronics, I remember thinking how strange this looked. Even stranger, why did they stand so still once they were unencumbered by cables? I thought rock music was supposed to be wild and free. Except for Mick Jagger and Pete Townsend, most of those guys were glued to their spots. Maybe it was force of habit; after all, when they played for real, they could get hopelessly tangled up in cables if they moved around too much.

These days, live performers needn't choose between movement and music. The advent of wireless technology has freed musicians from the cable's leash. Today's concerts feature lead singers and guitarists running amok on stage while belting out their licks. Welcome to the good new days.

**TUNING IN**

The concept behind wireless technology is simple: A transmitter converts a signal into electromagnetic waves, which radiate from an antenna into the surrounding environment. The antenna on a nearby receiver detects these waves and converts them back into the original signal. This is the basis of all wireless communication, including radio, television, and satellite transmissions, as well as cordless and cellular phones.

Electromagnetic waves (also called radiation) occur at different frequencies; the entire spectrum encompasses an extremely wide range that includes the radio frequencies (RF), microwaves, infrared (heat), visible light, ultraviolet, x-rays, and gamma rays. Wireless audio transmitters convert audio signals into the RF portion of the spectrum before broadcasting them into the air using a technique called frequency modulation.

Everyone is familiar with FM radio, which works in exactly the same way
as wireless audio systems. An audio signal is fed into a transmitter, which varies, or modulates, a carrier frequency above and below its nominal value in a pattern that corresponds to the audio signal. The receiver, which must be tuned to the same carrier frequency, extracts the modulated information and converts it back into an audio signal.

The FCC approves, assigns, and licenses specific radio frequencies for a variety of uses. The frequencies available for wireless systems differ from place to place depending on local television, radio, and other signals. If you try to operate a wireless audio system on a frequency already occupied by another signal, interference may render your system unusable.

Most wireless audio systems offer a selection of frequencies to choose from; if one doesn't work due to excessive interference, you can try another one. In addition, most wireless audio manufacturers offer a frequency coordination service that identifies locally used frequencies.

**STRIKE UP THE BAND**
There are several bands of frequencies in the RF region assigned to wireless audio and other applications. In an ironic twist of terms, the VHF (very high frequency) bands occupy the low end of the region. These bands include low (49 to 88 MHz), mid (150 to 174 MHz), and high (174 to 216 MHz).

The audio portions of television channels 2 through 6 use the low VHF band; wireless auditory assistance for the hearing-impaired uses 72 to 76 MHz. Cordless phones, radio-controlled toys, walkie-talkies, and other consumer products use 49 MHz, which doesn't require a user license from the FCC. Making equipment that works in this band is inexpensive, but few wireless audio products use it because it's so crowded. The mid band
is also quite crowded with industrial and government signals. In 1988, however, the FCC allocated eight frequencies in the mid VHF band that can be licensed by commercial users of wireless audio systems, including musicians, churches, theaters, etc.

The best price/performance ratio for wireless audio systems is in the high VHF band, but broadcasters use it extensively (it carries television channels 7 through 13). These frequencies can propagate through walls and sets, making them well-suited to live performance work. However, only broadcasters and video production companies can legally license this band.

The high end of the RF region is called UHF (ultra high frequency). UHF equipment is more expensive to produce, but more frequencies are available for wireless systems. UHF signals can be transmitted with greater power, which increases the operational range between a transmitter and receiver. However, this draws more current, reducing battery life or requiring a larger, heavier battery. In addition, these signals are reflected more easily, which is a blessing and a curse. Although the reflections can extend the operational range, they also contribute to some forms of interference.

The low UHF band encompasses 450 to 614 MHz, although the FCC forbids its use between 608 and 614 MHz for wireless mics. The UHF mid band, which has been approved for wireless use, extends from 614 to 806 MHz. Wireless audio systems don't use the low UHF bands much, but crowding in other bands will soon lead manufacturers and users to seek licenses for these frequencies. The newest generation of cordless phones shares the high UHF band (806 to 960 MHz) with several wireless audio systems. The 902 to 928 MHz region of this band is license-free.
Most VHF and UHF wireless audio systems multiply the frequency of a crystal oscillator until they reach the desired carrier frequency. However, a new technique called frequency synthesis uses electronic oscillators to directly generate UHF carrier frequencies. Frequency synthesis can help reduce the problem of interference by providing a greater selection of frequencies. However, these systems generally require more power, which, once again, translates to larger, heavier batteries. Examples of these systems include the Nady 950GS (40 channels in the 800 MHz range) and Samson UHF Synth series (74 channels in the 800 MHz range).

DON'T GIMME NO STATIC
As we mentioned earlier, RF signals at nearly identical frequencies can interfere with each other. This interference, called heterodyning, results in a windy or whistling noise that sometimes exhibits a repetitive beat pattern. Manufacturers generally select frequencies that don't coincide with radio or television frequencies, but other sources of RF radiation abound, especially in performance venues. These include digital music and sound gear, computers, fluorescent and neon lighting, and large motors and generators. Walkie-talkies used by backstage security personnel can also cause problems. Broadway represents the worst-case scenario, where almost every theater up and down the street uses wireless audio systems.

Intermodulation is another form of interference. In this case, a receiver picks up two dissimilar frequencies that interact within the electronic components to produce sum and difference frequencies, which also results in a windy or whistling noise. With a careful receiver design that includes high rejection and narrow input filters to attenuate other signals other than the intended carrier, this effect can be reduced. Unfortunately, receivers that offer several channels must have filters wide enough to accept all
specified frequencies, which increases the possibility of unwanted signals entering the system.

In order to minimize both types of interference, frequency coordination is essential. Everyone using wireless systems in a venue, including on stage artists and technical crews, must select their frequencies so that they don't interfere with each other, or don't coincide with other local RF sources. This is always difficult, and sometimes impossible, when many wireless systems are in use at once.

Another common problem is dropout, in which the signal fades or disappears into a sea of static noise. This inevitable when the transmitter is too far away from the receiver, so it's important to minimize the distance between them as much as possible. The practical range of a wireless system depends on many factors, including transmitter power, type of antenna, and environment.

Among the most common obstacles to RF are walls, sets, scaffolding, lighting grids, and bodies. Solid metal objects tend to cast a "shadow" in the presence of short-wavelength UHF signals; if the receiver antenna is located in this shadow, a dropout is likely. However, nearby surfaces reflect UHF signals more easily, which might allow the signal to reach the antenna around the obstacle.

Reflections can also cause dropout. RF signals radiate from the transmitter's antenna in all directions. One part of the signal reaches the receiver's antenna directly, while the other parts are reflected toward the antenna from surrounding surfaces, particularly those made of metal. If the difference between the lengths of the direct and reflected paths is a multiple of 1/4 to 3/4 of a wavelength, the two signals will partially or completely
cancel each other out, resulting in a dropout. This is called multipath cancellation.

The exact locations of multipath cancellation zones depend on the relative positions of the transmitter, receiver, and reflective surfaces. In an on stage wireless audio system, the receiver and surface are generally stationary, while the transmitter is moving around with the performer. This causes the cancellation zones to move around, as well. When a cancellation zone coincides with the receiver antenna's position, the signal level drops. It's possible to map out the transmitter locations that cause cancellation at the receiver ahead of time, but it's hard to avoid these spots when you're running around during a performance.

**LOUD AND CLEAR**

Wireless receivers fall into two basic categories: non-diversity and diversity. Non-diversity receivers use a single antenna to pick up RF signals. This setup does nothing to reduce multipath cancellation, but it's inexpensive and works reasonably well with low-power transmitters over short distances (FM radios are non-diversity receivers that work over long distances, but the transmitters operate at very high power level.) The Nady Wireless One and 101, Samson VLP and Stage 2, Sennheiser VHF 1B, and Shure L3 are non-diversity systems that operate in the high VHF band.

Diversity receivers use two antennas to reduce the effect of multipath cancellation. If the antennas are placed at least 1/4 wavelength apart, it is highly unlikely that both will fall within a cancellation zone at the same instant. There are several types of diversity, each with their own ardent supporters.
Phase diversity uses two antennas and one receiver. If the signal level at the receiver drops below a threshold value, the phase of the signal from one antenna is shifted to compensate for the assumed multipath cancellation. In some systems, the phase immediately inverted by 180 degrees, while other systems continuously shift the phase according to the instantaneous signal level at the receiver. For example, the Telex FMR-100 continuously shifts the phase of one antenna to obtain the strongest possible signal.

The most common type of diversity is called switching, or true diversity. This method uses two antennas connected to their own separate receivers.

The system monitors the signal level from each antenna and uses the audio output of the receiver with the strongest signal at any given instant. This requires sophisticated circuitry to switch with no noise. Nevertheless, most high-end wireless audio systems use switching diversity to minimize multipath cancellation.

Combining diversity is a variation of switching diversity in which the audio signals from the two receivers are combined in the optimum proportion according to their relative levels. If both are strong, both are used; if only one is strong, it is used on its own. This scheme eliminates any noise that might be cause by switching from one receiver to the other. The Nady 201 and Shure EC4 and L4 receivers use combining diversity and operate in the high VHF band.

Another factor to consider is signal-to-noise (S/N) ratio. RF transmissions can achieve an S/N of no more than about 65 or 70 dB. As a result, virtually all wireless systems now use companding to improve the S/N ratio; this technology is probably responsible for the current viability of
wireless audio systems. The transmitter compresses the signal, typically with a compression ratio of 2:1. The receiver then expands the signal accordingly, which yields an S/N in the 90 to 113 dB range. Companding also extends the practical range of the system by reducing the required RF level at the receiver.

Of course, companding has its own problems. The S/N ratio from one system to another can vary by as much as 20 dB, depending on the specific design of the companding circuit. Systems with lower S/N ratios may also exhibit audible "breathing." Other anomalies include high-end and low-end roll-off, as well as increased feedback sensitivity. These problems can be reduced or exaggerated depending on factory parameters such as threshold.

APPLICATIONS
Vocal microphones are among the most common applications of wireless technology. Many manufacturers build the transmitter directly into the body of a hand-held mic. For example, the Shure Beta 58 and 87 are available in wireless versions. Another option is a headset mic, such as the Samson system with the AKG 410 used by Garth Brooks. A headset mic is connected to a body-pack transmitter attached to the performer's belt. Tiny lavalier mics are also used with body-pack transmitters for lecturers and stage actors. The receiver is connected to the house audio system with standard cables.

Guitarists are using wireless systems in greater numbers, as well. Like headset and lavalier mics, the guitar output is connected to a body-pack transmitter attached to the performer's belt or guitar strap. The receiver is connected to the guitar amp in the normal manner. Examples of wireless guitar systems include the Nady Wireless One GT, Telex R-10G and R-

Wireless audio is now in common use for electronic news-gathering (ENG). These systems include a wireless handheld or lavalier mic and a small receiver that usually mounts directly on a video camera. This receiver can be of the non-diversity type because the distance between the camera and reporter is generally very short. Several companies make ENG systems, including the Sennheiser UHF 2B, Lectrosonics Pro-Mini, Telex ENG-1, and Samson MR-1.

Other applications include wireless intercom systems for the technical crews in a venue. These systems can take the form of walkie-talkies, or headset mic/earphones with belt pack transmitter/receivers. For examples, the HM Electronics Systems 800 UHF and Telex Radiocom VHF intercom systems both accommodate up to four full-duplex (simultaneous send and receive) headset/belt-pack units with each base station.

Large performances often require several wireless mics and/or guitar systems operating simultaneously. In such applications, it's important to remember that each receiver can pick up only one signal at a time; if two or more signals are on the same carrier frequency, interference rears its ugly head.

Practically speaking, ten or twelve channels can be used together in each VHF band, while UHF can accommodate up to 40 channels simultaneously. Some wireless systems offer many more channels in a given band, but it may not be possible to use them all.

If the number of antennas on stage is unwieldy, an active antenna splitter
can streamline the system. One set of antennas picks up signals from several transmitters and sends them to their respective receivers. For example, the Nady AD-4, Shure WA-404, Samson DA-4, and Telex AD-200 can each accommodate up to four diversity or eight non-diversity receivers; multiple units can be connected to serve more receivers. The Sennheiser SAS100, 200, 300, and 400 can accommodate up to six, twelve, eighteen, or 24 receivers, respectively.

Several companies offer multiple receivers in a single unit with one set of antennas. The Sennheiser EM 1046 offers up to eight switching-diversity UHF receiver modules in a single card cage and a computer monitor system. The Nady 750 offers two switching diversity, high-band VHF receivers in a single unit; up to five units can be connected for a total of ten simultaneous channels. The Samson UR5D includes two separate UHF synthesized receivers with 74 channels each.

**FREE AT LAST**

Wireless technology has broken the chains that bind musicians and actors to a fixed spot on the stage. However, this freedom has a price: Users of wireless systems must maintain a constant vigil to guard against insidious interference and dreaded dropouts. With the proper caution, however, this technology can liberate performers of all kinds to achieve new heights in aerobic entertainment.

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Here to Kai's Sound Links, including some wireless manufacturers...
Check it out!

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Hi everyone.
I'm new to the list, so don't know if you have discussed this at length or not, but here goes.
I'm putting together a wireless system (10 units) for a local Musical Theatre Group with a limited budget. I've pretty much narrowed it down to two RF units: Shure and Telex. I'm leaning towards the Shure, because I've had limited experience with both, but the Shure seemed to perform better than the Telex (although it was not a fair comparison- I was given a Low-end Telex ProStar and a middle of the road Shure SC system). But the Telex 100 or 150 looks nice too, and comes with a 3 year warrantee vs. 1 from Shure.
I'm also debating between the Countryman EWM(?) and the Sennheiser MKE-2 or the Telex equivalent. A dealer says that the Telex is 95% as
good as the MKE-2, and a lot cheaper. I know the MKE-2 is sort of an industry standard, but seems to have a reputation of sweating out more often than the Countryman. We use a Countryman table mic for a stage monitor at OSF, and they seem to take a beating (unless stage ops gets to them with paint) and lots of rain. Any input would be greatly appreciated. I am looking at reliability as being as important as sound quality. This theatre is on a limited budget, and can't afford a lot of backup units. A great sounding unit that doesn't work is not as good as a decent one that does work. Thanks in advance for your comments. BTW, this system is not for OSF.

Jeremy Lee Sound Technician Oregon Shakespeare Festival [Sent By: KingUbu@aol.com]

We have 2 Telex FMR100 systems, and during the summer, rent 6 - 10
more. In general, we have been pleased with the system (for its price range). We have lost the internal connection to the mike jack on a few of the plastic bodied belt pack transmitters. Telex uses a resistor to make the connection from the mike jack to the circuit board. Actors tend to beat mikes by rolling on them, etc, and eventually the resistor breaks. Other than that, they have held up well. I haven't worked with the Shure system. You might look at the Sony WTR 802 system. It has been highly recommended by some of our alumni as a good, mid priced system. Because it is designed as a system, it might be less expensive if you are buying enough of them.

We have used the Countryman, the Telex ELM 22 & the Sennheiser MKE-2 mikes, and by far prefer the MKE-2's. We have had sweating problems with all of the mikes, but with the MKE-2 you can remove the front (carefully) & clean makeup, sweat, etc from the windscreen. The audio quality in order would be the ELM 22, the Countryman, and the MKE-2. If you order the MKE-2's, be sure they are matched to the transmitter. They are available with a couple of different output levels. I believe the Telex xmitters require a 10db pad when using the MKE-2. Try to get at least one back up. We have never made it through a season (17 - 22 performances) without losing 2 -3 xmitters / mikes. I try to have one spare for each 6 systems, and have often used all of them.

Your welcome - if you have questions, feel free to contact me.

Jon R. Vermilye vermilye@oswego.edu Department of Theatre, 47 Tyler Hall 315 341 2138 SUNY Oswego 315 341 2999 or 3394(FAX) Oswego, NY 13126 vermilye@snyoswva.bitnet [Sent By: "Jon R. VERMILYE"]

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To: theatre-sound@pentagon.io.COM
In this posting you write:
-On Fri, 5 May 1995 KingUbu@aol.com wrote:
 --Hi everyone.
 --I'm new to the list, so don't know if you have discussed this at length or not, but here goes.
 --I'm putting together a wireless system (10 units) for a local Musical Theatre Group with a limited budget. I've pretty much narrowed it down to two RF units: Shure and Telex. I'm leaning towards the Shure, because I've had limited experience with both, but the Shure seemed to perform better than the Telex (although it was not a fair comparison- I was given a Low-end Telex ProStar and a middle of the road Shure SC system). But the Telex 100 or 150 looks nice too, and comes with a 3 year warrantee vs. 1 from Shure.

This is probably sacrilege but, I usve used Nady Mic's for years. I find the body packs to be robust. I must say that my units are NOT used daily or nitely but regularly, and sometimes in hostile envioenments.

I use the Audio Technicia directional capsule. Not the smallest but durable
and inexpensive to replace.

I haven't had any problems with resistors breaking off. I have had the packs sweat on until they stopped working, I have had actors drop them into toilets... In both cases a dry out restored operation.

The only failure point I have had has been the connection to the mini XLR.

When I wire them up, I add a shrink sleeve strain relief and that helps a lot.

I suggest you ask costumes to sew up pouches that close around the pack and hold it on the actor. I also put packs into plastic bags when necessary.

Plastic around the mic capsule will also help.

I haven't had many occasions where I could put a mic in someones hair, but it does work well. My case is that my capsules are a bit large (due to the directional characteristics, and fair haired (or NO hair) talent..... :-(

[Sent By: ""D.R. Chris Christensen"" chrisc@shasta.gvg.TEK.COM]

From: KeisterA@aol.com
Date: Sat, 6 May 1995 22:32:25 -0400
Message-Id: 950506223142_109620743@aol.com
To: theatre-sound@pentagon.io.com
Subject: Re: Wireless Mics
Sender: owner-theatre-sound@pentagon.io.com
Jeremy Lee Wrote --I'm also debating between the Countryman EWM(?) and the Sennheiser MKE-2 or the Telex equivalent. A dealer says that the Telex is 95% as good as the MKE-2, and a lot cheaper. I know the MKE-2 is sort of an industry standard, but seems to have a reputation of sweating out more often than the Countryman.

Although one can not deny the MKE-2 loves to soak up sweat, there are ways to effectively extend it's life. First, buy some Dr. Shole's Mole Skin from the local drug store. Cut narrow strips from it and place them around the edge of the head of the MKE-2 screen. Obviously you don't want to cover the front of the screen. Next, get some pantyhose, and cut a sheet of nylon out of them. Soak the nylon in Scotch guard. When it's really dry, cut a small square out of it, and cover the entire MKE-2 head with it. Then use an extremely small rubber band (like those used for orthodontic work) and loop it over and over directly below the head until it is tight and holds the nylon snugly. Then trim the excess nylon away. You want the nylon tight, but don't stretch it too much, or you'll open the weave up so much it will loose it's effectiveness.

If you really want to do it right, get some O-rings from the old sennheiser body packs (the one at the mic connector) and place it in between the MKE-2 head and the nylon. This stands the nylon off the mic a bit, and aids further in keeping sweat out. It is not uncommon to use a silicon adhesive to secure this O-ring (more commonly called the Cock Ring) in place and form a water tight barrier around it's base. But be careful not to
let any silicone get into the mesh of the screen. After the show, take your MKE-2 and put it in a Zip Lock freezer bag with a dozen or so bags of Silicone gel packs (the ones that say "DO NOT EAT") and leave it in there until you pack the mics for the next show. This helps draw some moisture out of the mic. You can buy the Gel packs from any packaging supply company.

Replace the windscreens frequently. The don't cost much, and it really does help.

Also, Sennheiser has come out with a new mic, the MKE-102. It is slightly longer than a MKE-2 but the same diameter. The frequency response is virtually identical. The difference is the capsule is removable from the cable. Replacing a bad capsule is, at least, a little less expensive than the whole mic, and a lot quicker. It also comes in a configuration so the capsule is 90 degrees off the cable.

While all of these tricks may help, the mics will sooner or later go bad. If your going to use an MKE-2, you had better have a good maintenance budget for the run.

Sent by:
KeisterA@aol.com (Andrew Keister)

From: TIMPRIT@aol.com
Date: Sun, 7 May 1995 13:05:00 -0400
Message-Id: 950507130458_110007991@aol.com
To: theatre-sound@pentagon.io.com
Subject: Re: Wireless Mics
Sender: owner-theatre-sound@pentagon.io.com
Precedence: bulk
Reply-To: theatre-sound@pentagon.io.com
My experience with the MKE-102 has been somewhat different. The frequency response is actually markedly different from that of an MKE-2, with a small rise at around 4-5K that actually helps some actors with intelligibility. As Jim Bay mentioned in an earlier post, it takes a wee bit of time to eq 'em to sound like the MKE-2, but it's fairly simple & consistent.

The truly wonderful thing is that these capsules seem *far* more resistant to moisture than the ol' MKE-2. We've actually been using the same capsule on an actor who was notorious for sweating out MKE-2's for over 6 months with no problems. The only reliability issue seems to be that the Microdot connector we use on our older Sennheiser transmitters is no longer a factory-installed connector option, so we end up having them installed by our rental shop...a few have failed sooner than usual, but we've gotten that ironed out.

Sennheiser also tells me that they are now able to ship these mics in a buff version as well...previously they were only available in black.

Check these out for your next gig...I swear by 'em.

[Sent By: TIMPRIT@aol.com]
Greetings All.

I just have one thing to say about MKE 102's. GREAT!!!

I am using them now on Tommy in Toronto and Germany and they are performing quite well. Having just gone through "Producion" on Tommy a few times before, I was amazed that all through rehearsals and up until now... I have only replaced one "Wire". No capsules! Amazing!!!

Well, as for the frequency response, I was able to do a test on a character that wears two transmitters. One with a MKE 2 and the other with the 102. The results were that the input with the MKE 2 required EQ in the 500 to 1K range where as the 102 required none. The system is UPA 1-C's and there is only a small dip at 4K and 630. Like around -2db.

I think they are really cool!!! Watch out with the SK50 though, this transmitter paired with the 102 can overload in the 250hz range quite easily! Sennheiser has been made aware of this problem. You are less apt to notice it with the MKE2's due to its freq response.

Later, Jon Weston [Sent By: JWDNY@aol.com]

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For more Theatre-Sound info, check out the Theatre-Sound Web Site!

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Return to the Sound Index.

Comments, Questions, and Additions should be addressed via e-mail to Kai Harada.
Not responsible for typographical errors. Information collected from many sources. Sources are listed at the end of the Sound section.