ZÉN and the art of using WIRELESS MICROPHONES

by
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Consider these three challenging audio problems; what do they have in common?

Rose Bowl — New Years Day, 1981. Prior to the game, six skydivers, unfurling a gigantic American flag, free-fall from several thousand feet above the playing field. As they descend, the skydivers sing "The Star Spangled Banner" over a live NBC network telecast.

Entertainment Parks. As the floats in a feature parade wind along their way, various instrumental versions of the same tunes emanate from them . . . in unison.

Radio City Music Hall. The all-new live entertainment format takes the form of a musical extravaganza. Up to 15 performers sing and dance not only on stage, but also from the wings, and even amidst the audience.

The common denominator? Sound technicians in each of these performance settings relied upon wireless microphones to solve a critical application problem that prevented the use of trailing mike cables.

The above examples illustrate some of the creative and diverse ways in which wireless microphones are currently being used. In fact, the application spectrum for the wireless mike is growing rapidly, and solutions to installation difficulties follow close behind.

First, let's examine the three prior applications to see in greater detail how the use of wireless mikes was implemented.

Rose Bowl

For 10 years, Bill Mayhew of Mayhew and Company (North Hollywood, California) has been selling, renting and installing wireless mikes. He deals with stage, screen and broadcast users. Recently, he rented six body-pack wireless systems to NBC for the pre-game live telecast, plus a seventh system for use by the referee during the Rose Bowl game itself.

Interestingly, even though transmitter-to-receiver distances were well in excess of standard equipment specifications, only standard systems were used. In other words, no additional transmitter power boosters or special antennas were employed. Transmitter power, however, was switched to the higher setting, 100 milliwatts. Both the skydivers and the referee were served by an antenna diversity system using three dipole antennas (Figure 1). Antennas were mounted at the highest possible points in the stadium structure, assuring line-of-sight reception. They were also oriented in two planes, perpendicular to the action. Antenna diversity was not used primarily to prevent radio dead spots (more on this later), but rather to ensure the best reception over the long transmission distances.

The wireless mike system used by the Rose Bowl referee was also modified slightly.

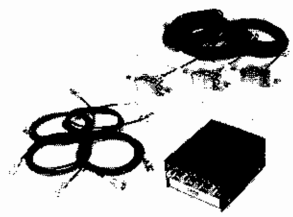

Figure 1

MOST COMMONLY ASKED QUESTIONS ABOUT WIRELESS MICROPHONES

1) Will my receiver pick up CB or FM radio transmission?

Professional wireless systems that operate in the VHF "Hi-band" radio-frequency spectrum (150 to 216 MHz) are immune from CB and FM radio interference. Economy "Lo-band" wireless microphones (30 to 50 MHz) *can* pick up CB calls. Tuneable systems in the commercial 88 to 108 MHz FM band often drift, and are overwhelmed by commercial stations — especially in large, radio-congested cities. Although there is no such thing as an absolutely clear channel, touring VHF Hi-band users, such as The Osmonds, have reported hundreds of problem-free shows in dozens of cities.

2) Can two or more transmitters operating on a single frequency be used with one receiver?

No. The receiver, seeking the strongest signal, will "hunt" uncontrollably from one transmitter to another. Each transmitter/receiver combination must be on its *own* frequency, and such frequencies must be carefully selected to ensure compatibility with the other systems. Always consult the manufacturer when using multiple systems.

3) Since they cost more, are UHF systems necessarily better than VHF systems?

UHF wireless systems (400 to 470 MHz; 900 to 950 MHz) are attractive in situations where so many VHF wireless mikes are currently in operation, that interference is inevitable. However, they offer no advantages in range, dropout immunity or other radio or audio properties. UHF systems cost more simply because UHF design, components, manufacturing and testing are more challenging than VHF design. Ironically, they sometimes suffer from interference in situations where a VHF system would not.

4) Can I use any microphone element with my wireless?

Yes. Some pocket transmitters are even able to provide switchable 1.5 V bias power for electret elements; other condenser mikes will need their own power supplies if phantom power requirements are different.

5) Do I need a Federal Communications Commission license to operate my wireless?

Some frequencies can be used by anyone; no license is required. Others can be used by anybody, but a license is required. Still others can be licensed only by broadcasters or filmmakers. It only requires filling out a form; no test is required. Consult the manufacturer.

6) Does the audio volume slowly fade as the transmitter-to-receiver distance increases?

No. The audio signal stays constant out to the limits of transmission range, even though the *radio* signal strength is decreasing.

7) I hear other radio signals only during dropouts — is this interference?

No — hearing other radio signals during a dropout is normal, and can happen if the ratio of these background signals is high compared to the transmitter signal (now weakened by the dropout). If you hear noises or other signals during normal, healthy transmission, that's *true* interference, and a different frequency must be selected.

8) To prevent receiving background radio noise, can I set my receiver "squelch" control at maximum?

Yes, but it reduces the operating range of the system. Always set the receiver squelch just slightly higher than the strongest background radio noise level for best compromise.

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 (Reprinted with permission from Recording Engineer/Producer) April, 1981

Instead of using the transmitter on-off switch, a separate switch was provided for the mike element. This was done for two reasons. First, because turning a transmitter off causes a "pop" — it's the nature of the beast — and all wireless systems have this imperfection. Second, problems occur with FM radio systems, which are used in all professional systems. Difficulties exist even if operation is in the VHF or UHF bands, rather than in the commercial FM radio band. The receiver will seek out and lock on to the strongest signal it detects; if the transmitter is turned off, the receiver may well pick up other radio transmissions, such as mobile business radios.

The logical solution to this problem seems to be to permanently leave the transmitter switched on, and either turn down the received audio at the board (just like a regular wired mike, right?), or have the user (like our friend, the referee) turn his microphone on and off. But sometimes, being human, even referees forget, so control at the board is usually preferable.

While explaining this Rose Bowl application, Bill Mayhew recalled another story connected with a stage version of *Gone With The Wind* at the Dorothy Chandler Pavillion, in Los Angeles. Here, the burning of Atlanta was recreated. Live fires were used to heighten the stage illusion, and the flames spooked one horse. A wireless-equipped Rhett Butler finished his scene, walked to the wings, and told a stagehand (and, unwittingly the audience), "That horse is scared --- less!" When the actor realized his *faux pas,* he decided to eliminate the problem in successive shows. As a result he turned off the transmitter on his way offstage and — you guessed it — produced a resonant "pop" followed by background radio crackle. From then on, Bill recommended leaving the transmitter on, taping over the switch so the talent couldn't get at it, and turning the sound down at the board in order to eliminate unwanted surprises. He reasons that the cost of leaving the transmitters on is cheap compared to the price of embarrassment.

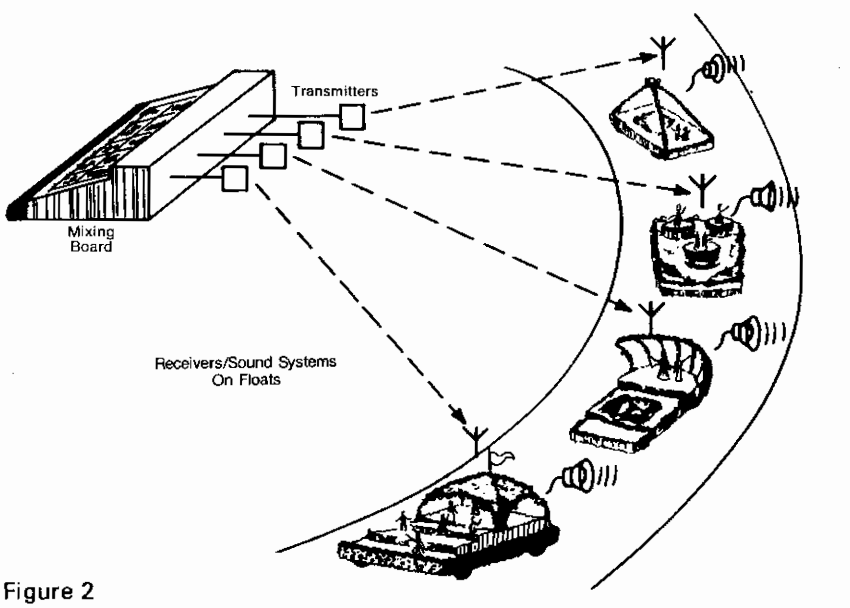

Figure 2

Theme Parks

Most major entertainment parks have used wireless mikes for years. More recently, they have incorporated such technology into their parade spectaculars. This was done to solve a specific problem: synchronization of music between floats. Formerly, separate tape players and sound systems were used on each float. Since there was no way to synchronize the music between floats, this caused a conflict of sound, especially when two floats were equidistant from a particular point along the parade route.

Audio technicians solved the problem by feeding individual synchronized music tracks to several transmitters — brass to one transmitter, rhythm track to another, strings to a third, and so on (Figure 2). Each transmitter was operating on a separate radio frequency, sending its track to a receiver and sound system mounted on each float. In this way, a fully-synchronized music program could be fed to all the floats in unison. More than one curb-side spectator has wondered, "How do they all play together like that?"

Incidentally, this same technique has been used in other major parades, including the Orange Bowl Parade. Imagine the extraordinary demands that the length of such parade routes place on the reliability of a transmitter-to-receiver radio link. Another parade application uses wireless microphones to beam the music and announcers' comments from one side of the street to sound systems located on the other side, thus eliminating overhead mike cables that might interfere with taller floats. This same technique is often used to extend communications or PA messages around race courses or across bodies of water (across the Potomac River, for example, during the unlimited Hydroplane Championship Races).

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What are some of the installation considerations in setting up jobs like these? According to Bill Mayhew and associate, Ken Keeney, antenna selection and placement are crucial for maximizing transmission distances. Ken Keeney advises the replacement of the small, 18-inch, "quarter-wave," flexible wire transmitter antenna with a half-wave, dipole antenna, thus giving a "free" 3 dB boost in effective radiated transmitter power. (This is equal to doubling transmitter power, without cutting battery life by half.) He also uses such dipoles on each of the receivers for improved reception. He keeps the antennas high, away from metal, and polarized in the same direction — usually vertical.

As Bill Mayhew added, "If we have slight indications of interference from another radio source, and we don't have time to change systems, sometimes changing polarity will help." He says that when the interference is from commercial FM or mobile business radios, both of which radiate from vertical antennas, he orients the transmitter and receiver antennas horizontally. For TV station interference with horizontally radiated signal patterns, system antennas are mounted vertically. This trick gives several additional dBs of rejection for unwanted signals.

Another recommendation is to bring out the antenna cable perpendicularly from any dipole antenna, at least three feet to prevent distorting the "field" of the antenna. This can sometimes mean success in marginal radio-frequency situations.

Radio City Music Hall

When Laurence and Robert Estrin were contracted to completely refurbish the original (1932) sound system at Radio City Music Hall, in New York City, they included one of the most extensive wireless mike networks presently to be found in a permanent installation. The Estrins now have their own company, Best Audio, in Hollywood, California, but did the job while Larry was president of Filmways Audio Group, also of Hollywood. The Radio City assignment encompassed one of the most extensive re-designs the Estrins had tackled, and yet the total upgrade was completed in just 30 days.

Originally the use of 36 to 40 wireless units was envisaged, but the extreme radio-frequency congestion in Manhattan bode ill for such an installation. Eventually, as many as 15 Dynamic Expansion systems were used simultaneously in productions of *Snow White,* and *A New York Summer* (Figure 3). To solve the problem of interference between wireless frequencies, a computer was used to determine frequency compatibility.

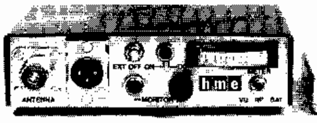

Figure 3

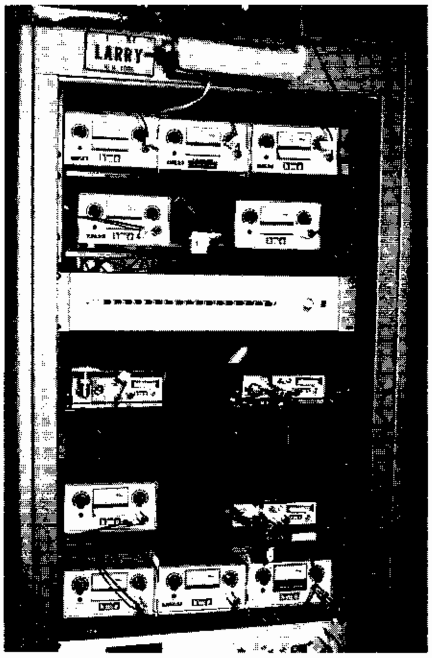

Figure 4

According to Tim Kerr, a freelance audio engineer who was instrumental in installing the systems, between two and three days were required to successfully install the diversity antennas (three diversity systems were used together), and to locate the receivers so they would not "talk" to each other. This consideration is often overlooked by engineers who, for neatness, stack together all the receivers next to their audio console. This is unwise, because all wireless receivers radiate local oscillator radio signals that can interfere with each other; a distance separation of two feet between receivers is desirable in multiple installations (Figure 4).

At Radio City, diversity antennas were needed because of the enormous amount of steel on stage (resultant problem to be discussed later). The Hall's facilities include a rotating stage, on-stage elevators, and a bandstand, motorized and moveable from the rear of the stage to the front. Antennas were placed on the floor behind the footlights, as well as stage left and stage right, suspended from the proscenium. This meant antenna cable runs of between 100 and 125 feet; RG-8 and antenna amplifiers were used to boost the signal to the diversity boxes.

Tim Kerr also found that the transmitters were being overdriven by the combination of loud singers and hot electret mike elements. Changing to lower output microphones helped, but Tim still had to contact engineers at HM Electronics, who devised a front-end adjustment to handle outputs from different mike elements. This feature has since found its way into the company's standard line of wireless microphone product; its main benefit comes from the transmitter's ability to handle a wide range of input signals.

Similarly, a special four-stage RF filter — also a standard option now — was designed at HME to enable the 15 systems to be used together. A benefit of Radio City's steel structure is the attendant aid in preventing interference from radio sources outside the building from reaching the wireless mikes.

In addition to the major challenges of the RCMH set-up, some minor demands were also encountered. For example, the Seven Dwarves' costumes (*Snow White* production, of course) caused problems. Their beards brushed over the mike elements and caused noise. Strange but true, the dilemma was solved by mounting the mike elements in their nostrils — the masks' nostrils, actually. Also, antennas had to be wired up their backs because the Dwarves kept stepping on the 18-inch flexible transmitter antennas.

This brings up an interesting point regarding transmitter antenna placement. The most commonly accepted method is to mount the antenna at waist level, and run the antenna up the back or over the shoulder. This should make it parallel with the receiver antenna, which is also usually mounted vertically. Alternate, recommended locations for the transmitters include the armpit or crotch, with the antenna run down the arm or leg. To hold the antenna in place, a rubber band should be tied at the free end, the antenna and rubber band then run up the back, and a safety-pin used to hold the other end of the stretched rubber band to the clothing (Figure 5).

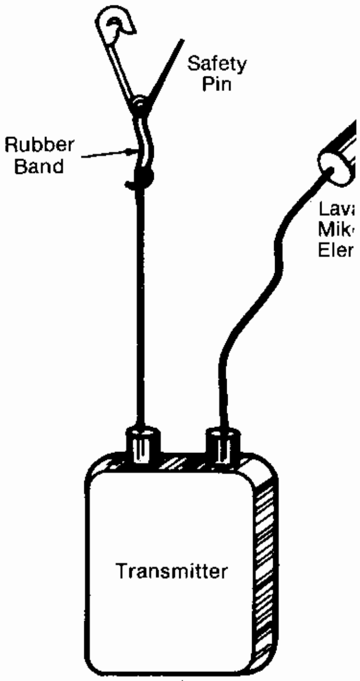

Figure 5

In addition to the Dwarves' peculiar trouble, a second problem encountered at Radio City was static-popping caused by electric motor brushes, SCRs (as in dimmers), and inadequately-suppressed engine ignitions. Such interference entered the receivers through the AC power lines into which they were plugged. Since the noise was found to be AC-line coupled, it went away when the antenna diversity boxes were powered by batteries instead of mains power supplies.

With all these comparatively minor complications, it is fair to ask just how wireless mikes have been incorporated into various productions. Bob Jani, President of Radio City, aimed to metamorphize the

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shows into musical spectaculars. Such a change presented problems because the hall was designed for vaudeville performers, and as soon as the talent stepped back from the footlights the dialogue faded, and then disappeared. Even a 35-piece orchestra was muffled when it played at stage rear. Performers could not use wired microphones because cables became tangled, or were severed by the bandstand that rolls on steel wheels.

Fortunately, the wireless set-up has eliminated these problems. Performers have free run of the stage — all 9,500 square feet of it — and they can even play their parts from the audience. As Larry Estrin reports, "Since every line is important, every line must be heard, and it is!" The systems have been used twice daily for two years, and in Bob Jani's evaluation, "There is no way we could produce the types of performances we do without wireless microphones. They have added an intimacy to Radio City's big stage."

Radio City Music Hall, theme parks, and The Rose Bowl are just three examples of wireless microphone applications, and the flexibility, professionalism, and drama they can add to events.

Dropouts

Let's not kid outselves. A *perfect* technology does not exist in any field, and wireless mikes are no exception. Knowing that imperfections are part of any technological package, users like to put equipment to "the test," whatever that evaluation might be. Generally, the accepted method of evaluating a wireless system is to see how *far* it will transmit. Procedure: run out of the building with a transmitter; make a transmission; then return several minutes later and inquire whether everyone in the room heard you while you were at the drug store down on the corner buying cigarettes. Result of test: interestingly, it seems most people can walk approximately the same distance regardless of whose VHF Hi-band system they are evaluating!

This similarity is understandable since most systems radiate about the same amount of power, from the same type and length transmitter antenna, to receivers with about the same sensitivity and antenna length. Even doubling transmitter power from, say, 50 milliwatts to 100 milliwatts does not double the range; it may extend the range by 20%, but halves battery life in the process. Furthermore, the user soon discovers that the system may transmit 2,000 feet, but he has mysterious dead spots only 20 feet away from the receiver; or the system exhibits frying, sizzling, or whooshing noises during movement. In short, the user has encountered "The Dropout."

Dropouts in wireless-microphone reception are caused by the same phenomena as dropouts in an FM radio, especially in car systems, and "ghosts" during TV reception. All these media operate on a line-of-sight transmission path, rather than bending around corners like AM transmission. Such straight-line transmission makes it possible to partially or totally lose the radio link due to one of the following two cancellation effects:

1. Multi-Path Cancellation. The most common form of cancellation, noises or loss of radio signal in a car's FM tuner are of this type. A practical illustration of this occurs when a car pulls up to a stoplight in traffic, resulting in noise or transmission fade-out. Then, when the car moves forward a few feet, the signal comes back clearly. *Voila!* Multi-path cancellation. The FM station's transmitting tower is sending out its signal in all directions (horizontal polarization), and one of those radio waves bounced off a flat metal surface — the fender of an adjacent car, or the structural steel in a nearby office building. This reflected radio wave then arrived at the car's FM antenna somewhat later than the direct wave from the station's tower. Since the reflected wave is out of phase with the direct, it will totally or partially cancel out the primary wave.

This situation is analogous to the problem encountered with wireless microphones. The only difference is that with mikes, the "radio station" moves and the receiver stays in one fixed spot (Figure 6). The dead or noisy spot is know as a "null" or "dropout," and can occur regardless of how close or far apart the transmitter and receiver are. As a matter of fact, short-range dropouts are much "snappier" than long-range ones, because both primary and reflected signals are healthy; thus they "butt heads" very hard. Long-range receiver-to-transmitter situations, however, create weaker dropouts, since the bounced (longer-path) wave, which is usually much weaker than the direct wave, has to travel farther. As mentioned earlier, multi-path cancellation is the most often-encountered problem in wireless microphone installations, and is subject to varying opinions and misconceptions regarding solutions.

2. Absorption Cancellation. As its name implies, this type of cancellation is caused by the radio waves from a transmitter being absorbed by any intervening body located between it and the receiver, which can include the body of the person wearing the microphone. Incidentally, this is one good way to determine the solidity of the system's radio performance. A well-designed body-pack or hand-held wireless microphone should transmit through exterior as well as interior walls. Audio should not fade when the talent turns slowly on his heels, even out to the maximum specified range. Be skeptical of statements by the manufacturer such as, "Range up to 'X' number of feet."

As a side note on the evaluation of wireless mikes, try this exercise about 300 feet from the receiver, in line-of-sight:

1. Ball up all the flexible body-pack antenna in your hand, along with the microphone cable; talk into the mike.
2. Hold the body-pack transmitter in your hand and twirl the antenna slowly like an airplane propeller; talk into the mike while twirling.

Any radio anomalies noticed by your colleagues back at the receiver will indicate:

Case 1: The system is prone to feedback RF into the audio section, due to insufficient shielding between the audio and radio sections of the system.

Case 2: The system performance is critical with regard to polarity orientation of the transmitter and receiver antennas with respect to each other.

Diversity Reception

In summary, multi-path and absorption cancellations are the two most frequently encountered interferences. Phase cancellation can also occur, but only in relatively few and specific situations. Of the three types, multi-path cancellation is the most troublesome problem. Fortunately, the difficulty can be reduced with varying degrees of success by employing a technique called Diversity Reception. The degree of success, however, depends on the design effectiveness of the diversity scheme, and on how well the antennas are located and oriented.

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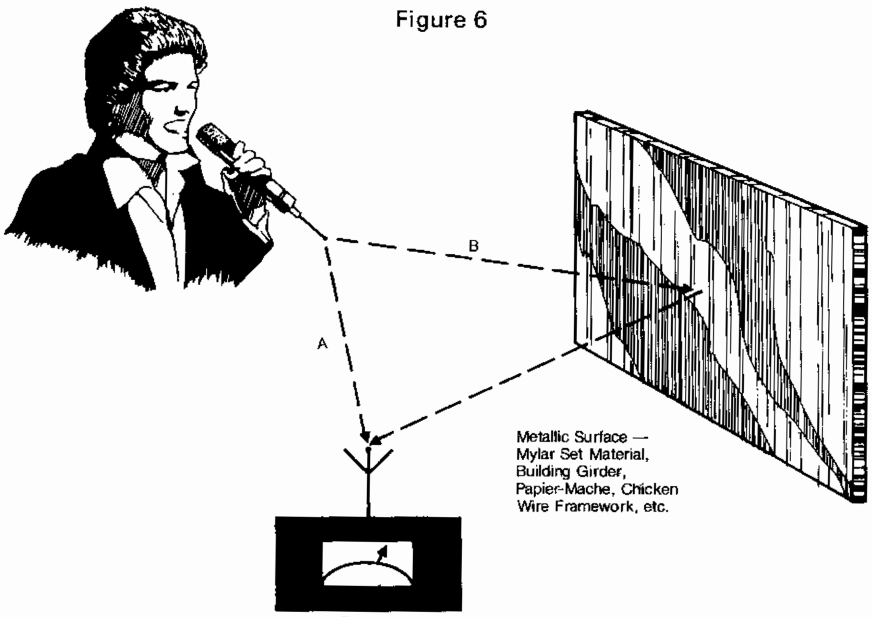
Figure 6



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Interestingly, diversity reception was not originally designed to eliminate multi-path cancellation. It was developed during World War II to eliminate "Ionospheric Fade" in round-the-world Allied military radio networks. Long-range radio travels around the globe by bouncing off the underside of the Ionosphere. Because the Ionosphere is often in a state of undulation, radio waves are scattered and/or absorbed, thus degrading reception quality. Since a relatively small area was affected, the problem was eliminated by erecting two separate receivers and antennas. The operator could then switch back and forth between antennas, and feed the stronger signal into alternate receivers.

Later designs incorporated comparator circuitry that sensed which antenna was receiving the stronger signals, and switched the output accordingly, thus obviating the need for human attention and action. The technique was well-suited to fixed-location transmitter/receiver networks, because they were located and constructed to avoid multi-path cancellation.

The emergence of microwave mobile communcations systems, such as business telephones, necessitated a re-evaluation of antenna-array techniques for signal reliability. Most of the significant research in this area was done by Bell Telephone Labs. Their theoretical models indicated that a significant increase in *multi-path-free* performance could be obtained by using "equal-gain combining" antenna diversity, as compared to the wartime "switching" diversity systems. Figure 7 shows the relative effectiveness of switching and equal-gain combining systems in reducing dropouts due to both multi-path *and* phase cancellations.

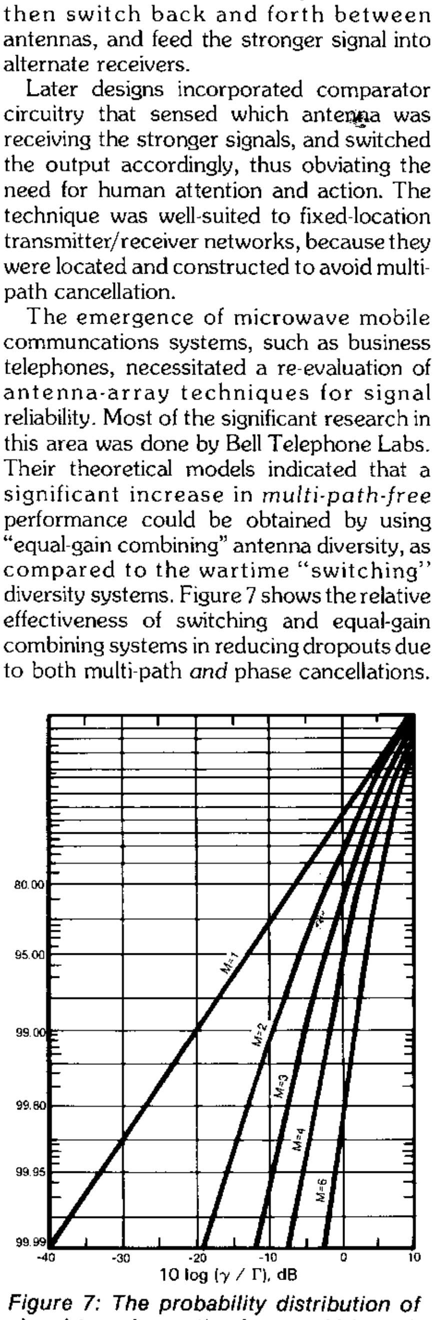

Figure 7: The probability distribution of signal-to-noise ratio for an M-branch diversity combiner. (Taken from Microwave Mobile Communications, *Edited by William C. Jakes, Jr.; John Wiley & Sons, 1974; page 322. Reproduced with permission.)*

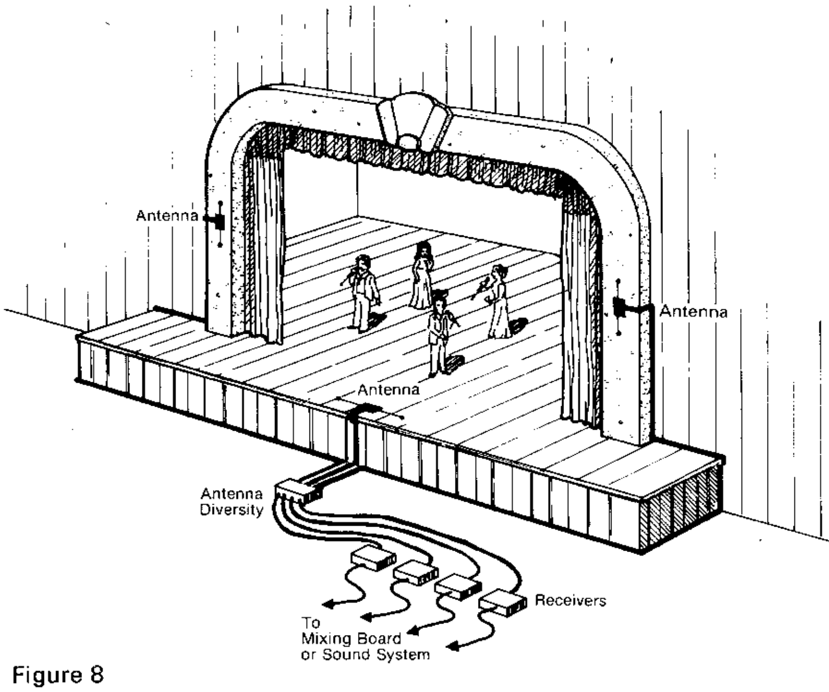

Figure 8

("M" on the diagrams indicates the number of antennas being used in each scheme.)

Consider the case of a dropout which causes a 10 dB RF (and audio) signal-to-noise degradation. Notice that for both curves, a single antenna will be drop-out free over 90% of the theoretical area coverage. Switching between two antennas further improves that figure, giving a 99% drop-out free area, as shown where M = 2 curve intersects the 10 dB SNR coordinate on the selection diversity diagram.

Use of the same two antennas is more effective, however, if they are used in an equal-gain combining diversity configuration. Bell Lab researchers found that the area immune to the 10 dB RF signal-to-noise loss figure improved to 99.3%. This figure would have been even better, but a new problem arose. In a certain number of cases, the two antennas would *phase-cancel* each other out, since they were both "on and receiving" continuously and simultaneously, not switching back and forth. The obvious solution was to increase the number of antennas in the system from two to three. Thus, the only time phase cancellation can occur is when the signals received at two of the antennas are 180 degrees out of phase and equal in strength, *and* the third signal is passing through the zero crossover point (in other words, not contributing any signal). Since a wireless system is used during dynamic situations in which the talent is usually in motion, the statistical occurrence of this condition is rare. Logically, the chances of null zones enveloping three antennas are much smaller than if two antennas were used. The end result is that the three-antenna combining system improves the −10 dB SNR figure to 99.97%. This indicated to researchers that the combining technique would theoretically eliminate 97% of the dropouts left by the switching diversity system in mobile microwave communications systems.

Since wireless microphone operational parameters are categorically similar to those involved with vehicle-based mobile radio, this technique has found successful application in this area. In fact, several hundred triple-antenna combining systems are in regular use by virtually all segments of the professional audio/entertainment industries (Figure 8). To prove the point, it is next to impossible to watch an evening of network programming, and *not* see at least one show using such a system. Dramatic series and sit-coms use body-pack systems with hidden lavalier mikes, as well as the more obvious hand-held microphones.

Related Problems With Wireless Microphones

So much for the Dreaded Drop-out. But no sighs of relief; other obstacles to perfection remain to be addressed. For instance, a low-technology item know as a battery ranked a surprising *first* on the list of wireless mike problems, according to major motion picture studios in Hollywood, where a large percentage of the above-mentioned dramas and sit-coms are produced. Here, reliability is one of the keys to cost effectiveness, since dozens of highly-paid personnel can be involved in a film shooting. Interestingly, studios indicate that over 50% of all wireless problems are not intrinsic to the basic systems. After batteries, broken wires and connectors for mikes and antenna problems ranked second and third on the list. In addition, user misapplication and incorrect operation account for a high percentage of complaints. This last item indicates the need for pointed emphasis on proper instruction in system operation. An encouraging fact of all these non-intrinsic problems is that their solutions are fairly easy and obvious.

Another important element in the motion picture industry is sound quality, since a take has to be good enough for the finished soundtrack. Even though poor sound can be used as a guide to "loop in" dialogue during post-production, looping should be avoided if possible, because the talent may be on

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location in another country when it's time to insert the required dialogue. For this reason, many actors and actresses are reluctant to write looping agreements into their contracts. If conventional mike cables can't be used in a particular scene, looping becomes a necessity, unless wireless microphones are utilized. The cost-saving and convenience of a wireless mike cannot be overemphasized here.

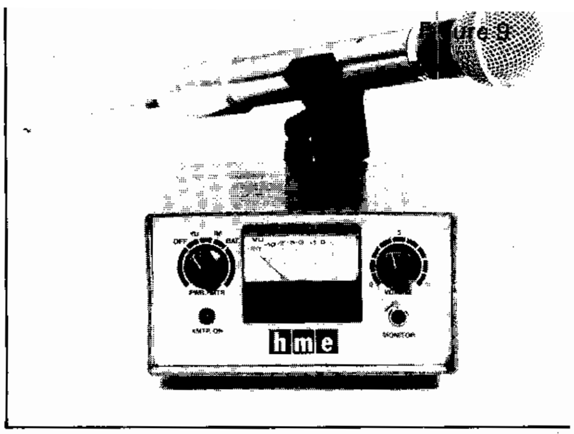
The telephoto lens in movie-making also dictated a need for wireless mikes. Boom cameras could not be used in many situations, and even wired lavalier microphones proved undesirable, since several hundred feet of cable might have to be buried or hidden at great cost.

In addition to the obvious physical conveniences of a wireless system, recent improvements also give much more dynamic range than did earlier units. In fact, soundmen report that the new wireless microphone generation sometimes has *too* much dynamic range. They comment that they want the output from the new systems attenuated, because it can easily overload their mixer boards and Nagra recorders, previously considered the standard for dynamic range testing of wireless mikes. This complaint is probably a compliment to the newest advancement in wireless mikes: Dynamic Expansion.

Dynamic Expansion uses microcircuit technology to expand the dynamic range of wireless mikes to around 100 dB, with reductions in the noise floor of up to 35 dB. Some of the logistics involved include compressing the audio signal at the transmitter by a 2:1 ratio, then converting to a radio signal that is then sent to the receiver. In the audio portion of the receiver, expansion brings back the 100 dB-plus dynamic range. Any noises injected into the process in the radio link (for example, static) are reduced by the expansion process by the same 35 dB, which can be an important side benefit. The technique was developed years ago by the telephone industry to reduce background noise in long-distance telephone circuits, and goes by the more familiar label of "companding."

The challenges in designing an inconspicuous compander circuit for a wireless system are the same as in other audio signal-producing systems: freedom from noticeable noise-gating, pumping or inaccurate compressor-expander tracking. Sound mixers may have to ride gain for the first time with wireless mikes but, thanks to Dynamic Expansion, they can clearly record footsteps in the snow on the same soundtrack as an undistorted pistol shot.

The same advantage applies to broadcasters. Although they can transmit about 65 dB of program material, broadcasters do not want that material to be distorted by a wireless mike that is dynamic range-limited — even if the dynamic range capability is greater than broadcast standards. Such users want a non-limited signal that can be compressed to suit their requirements.



CASE EXAMPLES

The Osmonds

The use of Dynamic Expansion is equally attractive to live performers, but for a different reason: it lowers the background noise level of their wireless system, and therefore their overall sound system. Talking with Klay Anderson, presently with Performance Audio in Salt Lake City, provided some examples of the company's experience with wireless mikes. Two years ago Performance Audio supplied four Dynamic Expansion, hand-held wireless mikes and two cordless guitar systems to The Osmonds (Figure 9). Klay has served as soundman for about 500 stage shows worldwide: "The systems were just like a piece of wire. The Osmonds like to establish intimacy, and wireless microphones have enabled them to do that. They like a lot of interaction with their audiences."

The six members of the Osmond Family

enter from the rear of the theaters, working their way to the stage, greeting and chatting with audience members via the wireless mikes to an on-stage sound system. As Klay explains, "Often they dance out into the audience, singing and playing. There is no way they could do that with wires."

Many times The Osmonds play on rotating stages; Klay says the group are wireless for about 75% of their performance. Although they had a diversity system, he quit using it and has "never missed it." The only time dropouts occurred was during a warm-up act in front of a closed sequined curtain. Even with diversity reception, Klay experienced problems. When the curtain was opened, however, the dropouts disappeared.

Only two other problems were experienced in 500 live shows. Problem one: Donny and Alan both chipped their teeth on the hard windscreen of the Shure SM-58 heads; Klay replaced the heads with SM-57s covered with large fabric windscreens. Problem two: A zealous stagehand played a 20-second impromptu rendition of "Louie, Louie" over the stage system during Marie's solo version of "Tenderly;" seems he had picked up Donny's cordless-equipped guitar backstage, and . . .

Theater Applications

In another part of the country, Bob Cavin, chief engineer of Harry McCune Sound, San Francisco, has also had his share of wireless experiences. Liza Minelli came on stage one night with a surprise! A hand-held wireless mike seemed to be in a berserk mood, but the true culprit turned out to be a sequined dress. Moral: the sound technician should coordinate with set designers and wardrobe personnel, so that he knows the location and type of any metallic (radio-reflective) set or costume materials. While on the subject, wardrobe people ought to know by now that they should not cut off the ugly little black antennas of body-pack transmitters "for neatness!" (It has happened.) On the other hand, they could help design pockets, pouches, or straps in which to hold the body-pack.

Bob Cavin comments that perspiration from a performer can destroy in weeks the circuitry of any wireless system. As a counter-measure, he recommends liberal doses of anti-perspirant and a baggie. One major Theme Park uses condoms; buys 'em by the gross, but never tell Purchasing what they're used for. For the more conservative, it is considered doubly-safe to bag the transmitter from one end, then double back the transmitter and antenna wires from the opposite direction for a double seal (Figure 10).

On the subject of batteries, Bob Cavin and all the others interviewed said they used alkaline batteries, although the transmitters can also utilize NiCad batteries. They all felt that the uncertainty of whether or not the NiCad units were adequately charged was even more critical, when it is remembered that the life of the battery is only about 1½ hours, versus 8 hours for an alkaline. In addition, NiCad batteries have a definite service life, albeit longer than an alkaline; then they must also be discarded. Too few deep discharges shorten their lives considerably.

HM Electronics specifically recommends using only the Mallory MN1604 for several reasons. Most important, they have compatible-sized terminals, specifically on the Japanese standard. EverReady and Ray-O-Vac batteries are on the slightly larger American standard, which can make for a non-snug battery connection. Presto! Low battery symptoms. Most experienced technicians test each battery before use with a "loading" battery tester. A voltmeter that does not load the battery gives falsely optimistic readings. Also, engineering studies indicate that Mallory Duracell batteries have the lowest internal noise level. Intrinsic battery noise can get into transmitter electronics; yet another reason for HME's recommendation of the MN1604.

More reports on wireless performances come from the five Broadway and other companies' productions of the award-winning musical, *Evita,* based on the life of Eva Peron. The road companies have six Dynamic-Expanded body packs (one as a spare), and triple-antenna diversity systems. All five of the principal performers use wireless mikes.

"It is a tough show to mix," says Larry Spurgeon, assistant sound designer for Abe Jacobs, renowned theatrical sound designer. Many cues must be fed to the talent, and the sound mixer must be on his toes to turn down each actor's mike at the board, to prevent the audience's hearing side comments between the performers on stage.

Larry Spurgeon has a few specific problems to overcome. For example, he found that Mylar and metal sets caused problems in Chicago, but not in Los Angeles. Antenna diversity, plus careful antenna location and mounting, solved that problem. He was careful to keep all antennas at least three feet from metallic surfaces.

Other routine precautions included having an extra system on a separate frequency compatible with the others, because "one wireless channel always has interference on it." The sound technician with each company checks batteries every night with a tester, and also walks the stage with each transmitter to test for radio anomalies. When doing so, he mounts the transmitters on the body with the antenna up the back (the way they are worn in the show), since the body can absorb radio waves. For this reason, carrying the transmitters in the hands with the antenna hanging out in space is not an adequate test.

Larry Spurgeon has also noted other factors that he feels must affect radio performance: the size of the crowd in the theater; storms; and maybe even sunspots. In short, the successful technician must deal with a myriad of possible interferences and combinations for solutions.

Some General Applications Comments

In researching and reporting on the various uses of wireless mikes as applied in different venues, many experiences, techniques and problem-solving methods came to light. Several of these comments from various professionals mentioned in this article can stand alone as worthwhile tips for anyone using the technology:

- Soundmen have reported that their transmitters were "popping." Turns out they had synthetic-fabric blouse material rubbing on the mike element itself. When it discharged, it gave off an audible "snap," which was picked up by the mike element itself, not the transmitter.
- Always expect your problem at the transmitter, rather than at the receiver. Possible culprits: the earlier-mentioned batteries; antenna/mike connectors; among others. Even suspect human error, like performers who may wad up their antennas and put them in their pockets!
- A severe dropout problem during a *Music Man* production at the Pantages Theater in Hollywood, could not even be helped by antenna diversity. The Problem: papier-mache scenery, 30 feet wide and 20 feet tall, with a chickenwire screen foundation, a structure that acted as an excellent radio reflector. What an antenna! So, reasoning that a good radio reflector should also make a good antenna, the technicians wove one of the dipoles into the chickenwire, and the other two on the apron, thus killing all dropouts.
- NBC needed to cover three locations in a building: the studio; out in the hallway; and downstairs. One antenna was placed high in each area, oriented vertically to be parallel with the body-pack antennas mounted on the actor's backs. Result: coverage of all three areas even though they were separated by building structural metal.
- Always keep the receivers on stage, close to the transmitters. Then, come out of the receiver to the board, rather than putting the receivers in the back of the room with the mixer. This is a better system because:

1) RG-8 has less loss per foot than air for sending messages; and

2) the room should have been checked thoroughly for dropouts for *each* transmitter/receiver set, and all batteries and transmitter/receiver sets checked *before* showtime.

Then there will be no need to have the RF level meters in front of the soundman; he is bound to be too busy just running sound to watch meters. And even if one of the meters does indicate trouble, what is the soundman going to do about it? Leave his board and run on stage to fix it in mid-show? Better to ensure a solid radio link by putting the receivers near the performers.

- Diversity is needed where there are reflective surfaces, indoors or outdoors. TV studios always need them because of light fixtures. Orient two antennas vertically, with one horizontal,, and at right angles to the action.
- Keep all antennas at least 18 inches away from plane metal surfaces. Be suspicious of walls; they may contain sheet metal heating ducts or steel girders. Enter The Dropout.
- Possibly lay the antennas on the floor under the stage. (Careful: the concrete floor has a steel mesh reinforcing grid called a "ground plane," which sucks the words right out of a wireless mike.) Do not worry about putting wood or other non-metallic flooring over antennas and cables.
- Make certain the antennas are at least 8 feet apart, so that two antennas don't get caught in the null spot. On the other hand, don't worry about getting the antennas a long distance apart. The intent of diversity reception is to eliminate dropouts, not extend range, although that's a side benefit. Mainly, follow the manufacturer's instructions when hooking up the antenna diversity box, and you will get no dropouts.

On the point of following manufacturer's instructions, the importance of strict adherence cannot be over-emphasized. HM Electronics has observed that such adherence is the single most important factor in ensuring success with wireless microphones. It is not important to understand the theory of mobile radio transmission and reception, but it *is* important to use the equipment properly, like any tool.

In conclusion, wireless microphones are often used because they have captured the imagination of creative artists and directors. Like never before, acts can now add drama, intimacy, power and visual stimulation. Alto Reed(!), saxophone player for the Bob Seger Silver Bullet Band, provides a perfect example of the creativity and sheer guts that can be tapped when "going wireless." Alto, like Tinkerbell, flies around in a harness on a tether wire, above the inflamed audience, playing solos with one hand, pointing skyward with the other, and never missing a note! He also plays solos while soaring skyward in a hot air balloon.

But beyond daredevils like Mr. Reed, wireless mikes are becoming equally attractive because they offer the capabilities for sound craftsmen to solve difficult miking problems. Wireless systems are tools of convenience and versatility, as well as instruments of innovation. □□□

Figure 10