Wireless-Microphone Application Techniques

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1.0 Introduction

Wireless microphones have become increasingly an accepted part of modern sound installations and a vital component of a great many systems. They are widely used in houses of worship, schools, auditoriums, conference and meeting rooms, stadiums, clubs and a variety of similar situations. Virtually any public gathering where sound-system coverage is advantageous offers the opportunity for effective use of a wireless microphone system.

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Furthermore, wireless microphones can greatly enhance the effectiveness and appeal of a performance or presentation, as well as convey a very desirable image of professionalism. Consequently, their use has grown rapidly in recent years and they are now routinely specified for new installations. Many users are also adding wireless microphones to existing systems as a means of enhancing their usefulness at relatively low cost.

As a result of these trends, sound professionals must be prepared to offer wireless solutions for a variety of diverse applications. However, while there is a wide array of equipment available, product specifications are often confusing and their purpose and meaning unclear. Terminology used in wireless microphone brochures and instruction manuals is likely to be quite different from that in similar documents for other types of audio products.

The basic technology used in wireless microphones is also substantially different from audio technology in many respects. Information is often scarce, especially practical help on avoiding potential problems and solving common problems. Much of this situation is due to the wireless industry not having devoted nearly enough effort to training and education. This document is intended to fill some of this gap by providing practical, immediately useful information about installing and operating wireless microphones.

Fortunately, the audio industry has reached a general consensus on some of yesterday's issues. For example, for reasons that are now widely understood, 49 MHz wireless equipment has all but disappeared from the professional market. For the most part, the merits of diversity systems and audio processing have been placed into perspective, although debate as to the best implementations continues. Although the meaning of some wireless specifications remains obscure, understanding them is not essential to successful application of the systems. Most audio professionals have, by trial and error or some other means, arrived at working decisions in regards to the selection of equipment.

In spite of this, a lack of solid information in regards to application issues has left a number of audio professionals and wireless users alike uncomfortable about using wireless microphones. The origins of many problems are often mysterious, as are the possible solutions. If the cause of a certain problem is unclear, how is it to be avoided in the future? Even the simple desire to do a top-notch job sometimes leads to frustration. What really is the best way to install a remote antenna, for example? And if problems do arise, where can information and assistance be found?

This short discussion of wireless microphone application techniques is an attempt to cover some of the basics of the practical usage of these systems. The emphasis is on the nuts and bolts of getting the best performance out of wireless, not on the technology itself. It tries to answer, in relatively nontechnical terms, many of the most commonly asked applications questions. All but the most experienced audio professionals should find it useful.

2.0 Selecting Frequencies

Government Policy and Regulation

Wireless microphones, like all radio frequency equipment, operate in defined frequency ranges and on specific frequencies. Usually, the frequency ranges available for wireless use are dictated by government policy and regulation. This is an important concept because the choice made by the government usually has little to do with how well the equipment will perform or how cost effective it will be. That is, the responsible government agency is likely to be primarily concerned with following broad policy guidelines, minimizing conflicts between different categories of radio frequency users and avoiding potential interference. For much the same reasons, most governments place strict requirements on technical performance, effectively dictating many of the detailed product specifications.

If the resulting equipment costs more than desired or has lower performance and is less useful than manufacturers and users would like, this is little concern to the government. Thus, design and manufacture of wireless microphones and other RF equipment has much more to do with what is permitted than what is possible.

Government policy also dictates who may use specific frequency ranges. That is, frequency ranges assigned for use by one class of wireless user may not be available to other classes of users. For example, in the United States, those involved in broadcasting and TV/film production have access to some frequency bands that are not available to general wireless users, and vice versa. Once again, governmental policy rather than technical issues are likely to affect strongly the choices of wireless users.

It should also be recognized that the detailed technical requirements imposed by the government, which vary widely from one frequency range to another, may greatly affect actual performance. That is, any presumed theoretical advantages of the UHF frequency ranges over the VHF frequency ranges for a particular application (or vice versa) may be wiped out by the technical requirements imposed by the government. Consequently simplistic decisions such as “to go to UHF because it is better” may well turn out to be wrong on several counts.

UHF Versus VHF

Presently there is widespread debate as to the relative merits of UHF operation versus VHF operation. Even putting aside the issue of whether or not UHF operation is allowed for a given class of wireless user, the situation is far from straightforward. Both ranges offer some advantages over the other, especially for specific applications. In addition, there are actually several UHF frequency bands used around the world and their relative usefulness varies rather widely.

Unfortunately, the UHF versus VHF question has to some degree turned into a competitive issue. That is, not all wireless manufacturers offer UHF equipment, or may not offer some specific type of UHF system. In this case, UHF operation might be played down for promotional reasons. On the other hand, companies offering UHF equipment may over-promote UHF operation because major competitors either don’t offer UHF equipment or don’t offer a specific type of UHF equipment. Thus, it might be wise to qualify recommendations on this issue before acting upon them.

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The relative maturity of UHF equipment is also an issue. That is, only one of two generations of UHF equipment exist, while VHF high band operation has been a fact for nearly 20 years. For this reason, comparisons based strictly upon theoretical considerations might be of limited validity for some time into the future. Despite all of this, some useful generalizations are possible. Although opinions are quite likely to vary somewhat, and debate will probably continue for some time to come, the relative advantages and disadvantages of UHF and VHF are as follows:

Advantages of UHF:

- Fewer systems in use, more frequencies available; interference much less likely.
- Higher power allowed under United States regulations; at full power, range can be better than equivalent VHF systems.
- Antennas smaller, easier to conceal; high-gain antennas for receivers more practical.
- Most current development effort going into UHF; typical UHF systems are of recent design and have latest features.

Disadvantages of UHF:

- More expensive than VHF for equivalent performance and features.
- Audio quality does not match best VHF systems.
- Generally not quite as easy to use as comparable VHF systems; operation is more technical for certain applications.
- Antenna distribution networks frequently needed; these are more complex and expensive than similar VHF equipment.
- At full authorized transmitter power (United States), battery size or operating life might be problems.

Advantages of VHF:

- VHF systems less expensive, more product choices, many price and performance levels available. (continued next page)
- VHF systems somewhat easier to use, more forgiving of application errors or poor conditions.
- Less complex, potentially more reliable, easier to maintain.
- Antenna distribution networks easier and less expensive to implement than for UHF.

Disadvantages of VHF:

- Many more existing systems, fewer frequencies available, chances of interference by other wireless considerable higher than for UHF.
- Due to limited frequency availability, larger facilities may run out of usable frequencies.

At the risk of oversimplification, the above can be summarized thus: VHF systems are recommended unless interference or frequency congestion are, or likely will become, problems. The higher costs and minor disadvantages of UHF systems are justified when interference or congestion are a problem, and for certain specialized applications.

Operating Frequency

Once the frequency range has been selected, it is then necessary to select a specific operating frequency. During the course of selecting and installing a wireless microphone, a frequency must be picked by someone, somewhere. Even if the choice is dictated by that unit being the last one in stock, a choice has been made. Because frequencies are in incredibly short supply and there can never be any more, they must be reused over and over again. Wireless microphones, especially VHF systems, share frequencies with a huge number of other radio users, including a great many of the other 300,000 or so wireless-microphone users. Therefore, frequency selection is extremely important, especially to the satisfaction of the end user.

It is sometimes claimed that there are special frequencies set aside for wireless microphones which cannot be used for other purposes. Although there is a germ of truth to this, the statement is basically untrue. In the United States, there are eight special frequencies in the 169 to 172 MHz range identified for wireless microphone use. These frequencies are just slightly different from the normal frequencies in this band (171.105 MHz as versus 171.100 MHz, for example). This small difference is, however, for the purposes of reducing interference to other users of this band, caused by low power wireless transmitters. The reverse is not true; the small frequency difference is of no help whatsoever in protecting the wireless system from the other users.

In reality, these special frequencies (only four of which can be used at one location) are not protected in any way from other licensed users of frequencies, in this range. In addition, relatively few countries make special provisions for wireless microphone frequencies, and even then the frequencies are usually shared with other services. Thus, wireless microphones are forced to coexist with other authorized uses of the spectrum, a fact that greatly affects the selection and use of all types of wireless equipment.

Although frequency selection doesn't have to be complicated (especially when the wireless manufacturer is prepared to assist), a few basics need to be observed. At least 25,000 or 30,000 wireless systems are sold each year in the United States alone on the same five or six frequencies. For a number of reasons, it is convenient for the manufacturers to supply one of this small number of frequencies when they can. Therefore, if the end user already has one or more wireless systems, the chances of it being on one of the five or six most common frequencies is relatively high. Much the same applies to most other countries as well. Providing a wide selection of different frequencies presents a number of technical and logistic problems to manufacturers, and many attempt to standardized on a short list of a few selected frequencies.

Two wireless systems cannot operate on the same frequency in the same locality without major problems. Users will experience whines, warbling tones, loud howls similar to feedback and other problems that will make the audio of both systems more or less unusable. Duplicating an existing frequency is, then, a sure recipe for trouble. Thus, the first order of business is to avoid using a frequency already in use at the location.

This also illustrates why it is so very important to determine if there are any other wireless systems are in the vicinity. In this case, vicinity generally refers to the same building or facility. However, wireless systems can interfere with each other at distances up to 2500 feet (750 meters) or so. While it might be impossible to determine accurately the existence of other wireless systems over this large an area, let alone their frequency, it can be worth an effort. For example, if a system is being installed in a facility and another similar facility is down the street, it might be wise to make an inquiry.

If no other wireless systems are existing in the facility or the immediate area, frequency selection becomes fairly simple. In the United States, most manufacturers have lists of frequencies that work in all areas of the country (sometimes called traveling frequencies, although that is not their primary purpose). These are almost always four of the special wireless frequencies, which are legal and licensable for most users. The situation outside of the United States is generally more complicated and varies widely from country to country. However, manufacturers or distributors generally provide listings of acceptable frequencies by geographical area.

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The lists provided by the wireless manufacturers may include frequencies within various TV channels. In the United States and several other countries, these frequencies may be licensed if the facility is involved in some form of TV or film production, broadcasting, cable television operation, and certain other activities. Quite often, the rules are not too strict; for example, a house of worship that videotapes services for later playback at a nursing home would probably qualify. If the user qualifies, these TV channel frequencies are good choices, as the chances of interference are considerably less than for frequencies shared with two-way radio systems and other communications services.

TV Channels

If TV channel frequencies are used, the selection should be made from channels not used in the local area. That is, if one of the local TV channels is channel 8, frequencies from channels 7 or 9 should be chosen. In a given area, adjacent TV channels are never used, so both channels 7 and 8 or channels 8 and 9 cannot be in the same city. Normally, users of VHF systems need only to be concerned about channels 7 through 13. The channel designations may vary in other countries, but the same general rules apply. That is, for VHF wireless systems, it is almost always safe to ignore low band VHF TV channels (below 88 MHz) and UHF TV channels. Conversely, VHF TV channels can usually be ignored for UHF wireless systems.

As a general rule, distant TV channels may also be ignored. That is, stations more than 75 miles (120 km) away can often be ignored. The radius may need to be greater if the distant station is very powerful or transmits from a very high elevation. The radius can be smaller if the distant station is a low power educational station or if the terrain is mountainous. However, very flat terrain may also be a problem; the radius of concern may need to be increased to 125 or even 150 miles (200 to 250 km) if over featureless terrain or open water. Caution should also be exercised if the wireless system is itself at a high elevation—in the penthouse of a tall building, for example. In this case, the radius must be extended considerably, in some situations by a factor of up to two.

In any case, it is always wise to avoid using frequencies close to the picture or sound carriers of distant TV channels. If the distant station later increases power or moves its transmitting antenna, problems may arise after months or years of trouble-free operation. Temporary problems may also arise during periods of freak weather or during times of high solar activity. Similar caution should be exercised with portable equipment, as it is always possible that the system will eventually be used at a higher elevation, or at some location closer than expected to the remote transmitter.

If frequencies are chosen from the manufacturer's list of compatible frequencies and no other wireless systems exist, frequency selection is complete. However, the presence of even one frequency not on the list can cause serious problems. This is because certain combinations of frequencies are not compatible; that is, they do not work well together. In some cases, the problem is simply that two of the frequencies are too close together. When this occurs, one or both of the wireless receivers will not be able to "reject" the signal from the other close-by system and will fail to work properly. Even if there are no major problems, the audio signal from the wireless receiver may not go off when the associated transmitter is turned off, resulting in a loud and very objectionable burst of noise.

Intermodulation

Another problem with frequencies that are not compatible is interference caused by RF intermodulation, or "intermod." Certain combinations of frequencies can cause interference to another frequency, especially when the signals are strong. Under these conditions, mixing of two frequencies can cause the appearance of a third frequency inside the wireless receiver. If this third frequency happens to be near the assigned frequency of the receiver, it will detect this signal and generate an output. The results range from being undetectable to severe interference, depending upon the signal levels involved, the design of the receiver and other factors.

One important type of intermodulation problem is caused by the second harmonic of one signal, mixed with another signal, and appearing on a third frequency. That is:

(2 × Freq #1) – Freq #2 = Freq #3

For example, assume that a wireless receiver is tuned to 171.305 MHz, one of the special United States wireless frequencies. If transmitters on two other of the special wireless channels, 171.105 and 171.905 MHz, are present, a problem is likely to result:

(2 × Freq #1) - Freq #2 = Freq #3
2 × 171.105 = 342.210
342.210 - 171.905 = 170.305

In this example, the use of the combination of 171.105, 171.905 and 170.305 MHz is shown to be potentially troublesome; that is, this combination is not compatible.

Note also that all three frequencies are on the list of eight special United States wireless microphone frequencies assigned by the government. This illustrates why not all eight frequencies can be used in one area, as well as the risks in making assumptions about frequency combinations. Often, it is assumed that frequencies assigned by government agencies will work well individually or in combination. The actual situation is usually the reverse; there is usually little rationale for the choices other than a uniform frequency spacing, and neither intermodulation problems or other difficulties are taken into account.

In the above example, 342.210 MHz is not actually received at the antenna; it is generated in the receiver electronics. A strong signal at 171.105 MHz will cause a small amount of harmonic distortion in the receiver RF amplifier, resulting in the generation of the 342.210-MHz signal. If a strong 171.905-MHz signal is also present, an output at 170.305 MHz will appear, quite possibly interfering with the signal from the actual 170.305-MHz transmitter. How serious the problem will be depends upon the design of the receiver and how strong the various signals actually are. This particular type of interference is called third-order intermodulation, and is the most serious form of the problem. Many other types of intermodulation exists, as do some similar problems caused by other troublesome frequency combinations.

Two very important points are that even one extra incompatible frequency can cause a significant problem, and combinations that will cause problems are not often obvious. In addition, problems may not show up immediately for any number of reasons, including simply that the incompatible combination isn't used for some time. This is why ignoring existing frequencies or using frequencies not on the manufacturer's list of compatible frequencies is risky.

Frequency Selection

Assuming that there are existing frequencies not on the manufacturer's list of compatible frequencies or more systems are needed than is covered by the list, what is to be done? Although the problem can be approached on a trial and error basis, this is not cost effective, can be very time consuming and simply may not be effective, especially if a large number of systems are involved.

The best solution is to obtain the assistance of the equipment manufacturer or distributor. Virtually all major manufacturers have computer programs to check random combinations of wireless systems quickly for compatibility problems. Given an accurate list of all existing frequencies and the location, the manufacturer should be able to suggest quickly an adequate number of fully compatible frequencies. However, as with the published list, it is extremely important that the list of existing frequencies be complete. Even one missed frequency can cause significant problems to one or more of the other systems.

Manufacturers and dealers are sometimes asked to come to the site and perform a site survey to determine which frequencies are clear. This is usually impractical for a number of reasons, one being the expense involved. In addition, the survey is not likely to be effective, as each candidate frequency should reasonably be monitored for at least several days. Obviously, time and equipment limitations will almost always make this impractical. Equally important, intermod problems will usually not be found by monitoring, and they are as likely to cause problems as anything else. While the idea of finding clear frequencies that will always work perfectly is certainly attractive, the idea is not very realistic.

Another approach is to review published frequency allocation lists to find frequencies that are not allocated in a particular area. The idea is to find clean frequencies that are not used by anyone else, at least in your area. Aside from the issue of intermod, the idea has another major failing. Namely, the 162 to 174 MHz frequency band is allocated to government agencies on an international basis. These frequencies are often heavily used by the military, national security or police organizations and governmental agencies and departments.

Certain of these agencies, such as those dealing with national security and crime prevention, decline to have their frequency allocations published, for obvious reasons. Therefore, the available listings often show little usage for what are actually some very active frequencies. Aside from the frequency not actually being clear, there is the possibility of problems with the wrong government agency. Although most countries are somewhat more tolerant of wireless microphones than was once the case, interfering with government communications is still ill-advised.

Frequency selection is usually simple and straightforward. For most smaller installations, the use of manufacturer's listings of compatible frequencies will be all that is needed. Only larger installations and those that have a number of existing frequencies present any difficulty. In this case, the wireless microphone manufacturer or distributor is, by far, the best source of assistance.

It is extremely important to make sure that the manufacturer has all of the required information, especially a complete listing of all existing frequencies. It is also important to avoid simplistic approaches such as magic clear frequencies, frequencies that always worked before, frequencies that worked well somewhere else and the like. With a systematic approach and perhaps a little help from the manufacturer or distributor, problems should be minimal.

3.0 Interference Control

Although interference in wireless microphone systems is relatively rare, it can be very disconcerting when it does occur. Electric interference is not terribly unusual in audio systems, but the nature of wireless interference is markedly different from the usual problems. Consequently, audio professionals sometimes feel ill-equipped to deal with any problems that do arise. As with other wireless microphone applications issues, however, a small amount of knowledge and a systematic approach will go a long way towards smoothing the path to success.

Frequencies

The most important single factor in controlling interference is proper frequency selection. As was discussed above, problems with incompatible frequencies may not be immediately apparent and, in fact, may not appear for some time after installation. This may lead to the belief that a particular problem is being caused by external influences ("interference"), rather than by poor frequency selection. This is another reason why it is important to take care in initially choosing frequencies for all of the wireless systems.

In spite of proper frequency selection, interference will still sometimes occur. There are various causes, each requiring a different solution. A key issue is determining for certain that the problem is external to the wireless installation (that is, that it really is interference), rather than some other type of problem. It is very common for wireless equipment to be blamed for various unrelated audio problems, especially when the wireless equipment is new. Because the wireless system or systems are both new and vaguely mysterious, there is a natural tendency to attribute the latest problem to them. It is often very useful simply to plug in a wired mic temporarily in place of the wireless to isolate a problem. This simple step can often save a great deal of time that might otherwise be wasted looking for a nonexistent wireless problem.

Interference Sources

The next step is to determine what type of interference is being experienced. If a voice is heard, for example, it will be helpful to determine the source. Is the voice another wireless system, a broadcast station or from another type of radio service? If either another wireless system or a broadcast transmission is present, the frequency selection is likely at fault. Possibly, an existing wireless system was overlooked, or one of the systems is on a frequency that is incompatible with the frequencies of the other systems. Solving the interference problem will usually require identifying the error or oversight responsible and making any necessary changes.

On the other hand, if the interference is from another radio service (police, fire, taxi and the like), direct interference, intermodulation or spurious outputs may be the problem. With direct interference, the offending transmitter is either on or very near the wireless frequency. This problem is more likely if the wireless system is using the special wireless frequencies or other frequencies shared with two-way radio communications. With intermodulation, the other radio service might be causing an intermodulation problem with other frequencies present, such as other wireless or TV channel carriers.

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Spurious outputs from communications transmitters arise from the process of generating the transmitted frequency. In most systems, a signal is generated at a relatively low RF frequency and multiplied to the desired output frequency. For example, a transmitter on 168 MHz might first generate a signal at 10.5 MHz, then multiply this signal by a factor of 16 to obtain 168.0 MHz. Because the filtering will be imperfect, small outputs at 15 times 10.5 MHz (157.5 MHz) and 17 times 10.5 MHz (178.5 MHz) will also be present at the transmitter output. If the transmitter is a high power design, these outputs can be fairly strong, perhaps 1 to 10 milliwatts. A wireless receiver on or near 178.5 MHz could then experience interference from the spurious output of this transmitter, especially if it is located nearby.

The majority of problems with spurious outputs are due to poorly maintained or defective transmitters.

Unless the offending transmitter is very near, the spurious signals from properly maintained transmitters will not often bother a wireless system that is in use. However, if the receiver is on but the wireless transmitter is not powered, the spurious signal can cause the receiver squelch to open. This usually results in very loud noise output from the wireless system. Misadjusted or defective transmitters, on the other hand, can literally transmit watts of power on the spurious frequencies, causing major interference. In this case, TV broadcasts and other radio services may also be affected.

As a practical matter, however, it doesn't make a great deal of difference whether the interference is due to direct frequency conflict, intermodulation or spurious transmitter outputs (even from a defective transmitter). Because wireless microphone usage is almost always secondary to most other uses of radio frequencies, the wireless system is the one that must make the accommodation. Due to the proliferation of all types of radio equipment, few governments are able to police the radio spectrum in any effective way.

Although policy varies widely between countries, many governments are not inclined to become involved in disputes between two parties, especially two commercial users. Only problems affecting large numbers of radio or TV users will attract any attention, with first attention going to problems affecting broadcasting. Even then, corrective action may take many weeks, if not months. Unfortunately, even interference caused by a defective transmitter is not likely to result in any action, especially if only a wireless user is affected..

In reality, the probability of obtaining any type of effective corrective action from the other party is often quite low, even when the problem clearly is not the fault of the wireless system. Accordingly, the best course of action when this type of interference is experienced is to change the frequency of the wireless system (or to exchange it for one on another frequency). In making such a change, an attempt should be made to isolate the problem, especially if the presence of an unknown existing frequency is suspected. With the information gained, the chances of running into a second, related problem are greatly lessened. While the problem described is relatively rare, such situations do arise from time to time.

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In rare instances, for no readily apparent reason, a specific frequency or a specific frequency combination simply will not function properly in a certain location. While there is most certainly a valid reason for the problem, it is often not worth the time and effort that would be required to isolate its cause fully. Usually, changing out one or two of the wireless systems for ones on other frequencies is the fastest and easiest solution, and the one which will most quickly resolve the problem. Because this type of situation does arise occasionally, it is best to work with a wireless manufacturer or distributor who will provide the necessary support, including changing frequencies or exchanging systems if it becomes necessary.

In this regard, there probably isn't anything wrong with the wireless system that is experiencing the problem. This sort of difficulty is not often the result of defective equipment, although lower quality, less sophisticated equipment will generally be more susceptible than higher quality gear. Rather, it is the result of extremely heavy use of all radio frequencies and the existence of literally millions of transmitters operating in the same general frequency range as wireless systems. In addition, the declining ability of most governments to police the radio waves effectively has resulted in an increasing number of unlicensed, uncontrolled radio transmitters. While it might be comforting to blame the wireless equipment manufacturer for these problems, it is most likely unwarranted.

Electrical Equipment

Although not often encountered these days, faulty or poorly designed electrical equipment is sometimes a source of interference to wireless microphone systems. At one time, this variety of interference was probably the most common type and frequently became a serious problem.

However, this is no longer true for several reasons. One reason is the move of wireless equipment to the 150 to 216 MHz VHF frequency range or the even higher UHF frequency range, where such interference is less likely. Another reason is that advances in circuit design have made modern wireless receivers significantly less susceptible to this type of noise than was the case for earlier designs.

Poorly designed and poorly maintained electrical equipment is not as common as it was in past years. Manufacturers of electrical equipment must now design their products to avoid the generation of high levels of electrical noise, both to satisfy government requirements and to make them acceptable to their customers. Users of heavy electrical equipment are also much more likely to maintain it properly than in the past, as complaints by the public are far more common and more likely to get serious attention by the authorities.

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Electrical noise is generated primarily by electrical discharges and arcing, including insulation breakdowns, arcing of relay and switch contacts, worn rotating contacts on electrical machinery, spark plugs on automobiles, high-voltage breakdowns, and the like. In larger cities, especially in industrial areas, there will usually be a fairly high ambient RF noise level due to the accumulated effects of electrical noise from many minor sources. For wireless microphone systems without some type of audio processing, this ambient RF noise will cause a noticeable amount of audio noise. With the audio processing in virtually all modern systems, however, the effect is normally negligible. More serious are periodic high-intensity noise bursts, usually caused by defective electrical equipment or by high-energy electrical switching. In some cases, very large amounts of electrical energy are involved, and even the best wireless equipment will be affected. However, this situation is quite rare.

For interference caused by electrical equipment, the quality of the wireless microphone receiver is a major factor in determining how susceptible the system will be. Well designed receivers, which have narrowband RF front ends, a high degree of IF selectivity, and good limiting characteristics, are less affected than poor designs. Operating frequency is also a factor; this type of noise is most severe at low frequencies and falls off rapidly with increasing frequency. Therefore, equipment operating at 49 or 72 MHz is much more likely to be affected by electrical noise than are systems in the 150 to 216 MHz range or higher. In severe cases of interference, however, no system will be able to operate satisfactorily. When this happens, there is little choice but to correct the external source of the problem.

When serious interference due to electrical noise is encountered, it's usually caused by defective, damaged, overloaded or poorly maintained electrical power equipment. Only very rarely does properly operating equipment create any problems. Fluorescent lighting fixtures are a particularly good example of this. Fixtures in good working order almost never generate noticeable interference. However, defective units can generate surprising amounts of RF energy, creating significant problems. The only solution is, of course, to repair the fixture itself.

Much the same situation is true of other types of electrical equipment. When interference is encountered, it is usually not continuous and it is almost always possible to match the occurrence of the problem with the operation of a specific piece of electrical equipment. That is, the wireless problem can be matched to the cycling of the heating/air conditioning system, the operation of an individual motor, the turn on/turn off of a particular bank of fluorescent lights, or the use of a certain item of electrical equipment. Once the problem item has been identified, corrective action is usually fairly simple. Often, a little routine maintenance by an electrician is all that is required.

Lighting Equipment

Lighting systems are also potential sources of interference. The potential for interference varies with the type of lighting. For example, incandescent lighting is almost never a problem unless dimmers or electronic controls are used. Both dimmers and electronic controls, especially older designs, are frequently a source of interference and should be checked in the event of problems. As mentioned above, defective fluorescent lighting equipment can become a serious problem, but correctly operating units will rarely cause any trouble.

Certain types of industrial lighting equipment, especially mercury vapor and sodium vapor systems, can be troublesome. Most of the problems will occur during the start-up cycle for these types of lights; the interference caused by normal operation is usually minimal. Therefore, they are rarely a problem unless a unit is defective and repeatedly goes through the start-up cycle.

Since neon lighting equipment is regaining popularity and is sometimes used in clubs and on sets, many users are concerned about its interference potential. While neon tubes do create an increase in ambient RF noise similar to that found in industrial areas, severe interference is rare. When problems are encountered, they are almost always due to arcing or corona in high-voltage distribution wiring. Corona is sometimes difficult to detect visually, even in near-total darkness, but can be heard clearly in quiet surroundings. Both arcing or corona, if present, will probably have to eliminated in order to obtain good results with wireless systems.

Occasionally, problems with neon systems are caused by the use of electronic dimmers, because the tubes become electrically very noisy when operated near the point where they extinguish. Cabling between the dimmer controller and the transformer, and between the transformer and the neon tubes, is also an occasional source of problems, especially when electrical grounding is deficient. Due to the very high voltages used in neon systems, the tubes can also directly induce interference into cables and sensitive circuits. This includes the audio circuits in the wireless transmitter, so the microphone, microphone cable and transmitter should be kept at least 24 inches (60 cm) away from the tube.

When problems with neon systems are experienced, any arcing or corona should be eliminated first. If there are any residual problems, dimmers and electronic controls should next be checked for proper operation. Proper grounding of the neon equipment, especially the high-voltage transformer, very often greatly improves the situation. Finally, the wireless-system receiving antennas should be placed as far away from the neon tubes as possible while still being reasonably close to the transmitters. This approach will maximize the desired signal from the transmitter while minimizing the interfering signal.

Digital Equipment

Digital equipment of all types can be a source of interference to wireless microphone systems. Items such as digital effects generators, digital delay devices, control computers (including personal computers in the area) and microprocessor based instrumentation all have the potential to create problems. Wireless receivers mounted directly on portable TV cameras are sometimes affected by the digital circuitry in the camera. Specific models of cameras and certain types of accessories are also known to be more troublesome than others, so compatibility testing of camera and wireless is usually an excellent idea.

Older digital equipment, designed before the current regulations on interference generation were in existence, is considerably more likely to be troublesome than new equipment. Current governmental rules generally require that such equipment sold today pass fairly stringent standards for spurious outputs. Older equipment, on the other hand, was largely unregulated and some manufacturers were extremely careless in regards to the emission of interference. Maintenance problems in digital equipment, such as loose or missing covers, can also cause substantial increases in the amount of interference produced.

Interference from digital equipment is of two types, clock harmonics and general wideband noise. The first type occurs when a wireless system operates on a harmonic of a clock frequency in the digital device. Because very fast logic and a large amount of circuitry are both typical, harmonic outputs may extend into the microwave frequency range. Even if the digital system is fully in conformance with current emission regulations, a sensitive wireless receiver tuned to a frequency near one of the harmonics will likely have problems, especially if it is physically near the digital device.

"Interference from digital equipment is of two types, clock harmonics and general wideband noise."

The problem may only appear as a failure of the receiver squelch circuits to shut off the receiver audio when the transmitter is turned off. In more severe cases, the audio will be impaired, either by the presence of one or more tones or by high-level noise outputs. Generally, moving the wireless receiver and its associated antenna away from the digital device will improve the situation, as the interference level falls off rapidly with distance. Even so, the permissible level of spurious output for digital equipment is far above that capable of affecting a sensitive wireless receiver. If the wireless frequency is directly on the clock harmonic, there may be little that can be done except change the wireless frequency or eliminate the digital device.

"Digital devices may also create interference on the shared ac power lines in audio equipment installations."

The second type of interference caused by digital equipment is broadband noise, generally resulting from switching of the digital logic in the device. Personal computers and other computing devices are especially prone to generating this form of spurious emission. This type of noise is usually regulated by governments and new equipment typically must pass standardized tests before being offered for sale. Even so, broadband noise from digital devices can cause at least minor problems for wireless microphone systems. In most cases, severe problems will be experienced only if the wireless receiver is mounted immediately adjacent to the digital device. Even 1 or 2 feet (.3 to .6 meter) of separation will often resolve any problems.

Digital devices may also create interference on the shared ac power lines in audio equipment installations. In this case, separate power sources for the wireless equipment (and other sensitive audio equipment) might be necessary. Power-line filters, such as are used in the better quality power protective devices sold for use with personal computers, are sometimes helpful in solving this particular problem. However, the most effective solution is to use only modern digital equipment conforming to the more stringent emission standards now typical. In the United States, this means equipment with full FCC approvals (both Class A and Class B); similar standards apply in other countries. It is also almost always very helpful to separate the wireless equipment from the digital equipment as best possible.

Squelch Operation

Another interference problem sometimes considered by end users as an equipment defect is opening of the receiver squelch when the transmitter is turned off. With sensitive wireless receivers, very small spurious signals can cause the receiver squelch to open up, usually resulting in an extremely noisy output. This is not really an equipment defect; because a signal is actually being received, it just isn't the one wanted. Of course, the receiver squelch can be adjusted to require a much larger signal to be present before the squelch opens, but this sacrifices wireless system operating range, perhaps by as much as a factor of four.

Two-way radio systems solve this problem by having the transmitter send a low-frequency tone along with the audio. If this tone is not present, the squelch will not open. While this approach is effective, audio response must be limited to 300 Hz on the low end, and the audio quality also suffers in other ways. Wireless microphone systems using high-frequency tones are also available, but because of government regulations and some technical considerations, these too usually involve at least some sacrifice in audio quality and operating range.

A few systems employ another technique to address this problem, one that does not involve the transmission of a tone. In this technique, two separate squelch circuits are present. One responds to received RF signal level in the usual manner. The second squelch circuit looks for high-frequency audio components and certain types of noise that indicate that interference, not the desired transmitter signal, is being received. Even when the RF signal level is very high, the secondary squelch circuit can prevent squelch gate opening if interference is present. This effectively prevents the highly annoying loud noise bursts that are typical of interference.

" . . . automatic mixers work well with wired microphones but are very susceptible to noise and interference from wireless microphones."

Both techniques have some limitations, but both are capable of solving the basic problem in most circumstances. The use of systems with one or the other type of circuitry is especially recommended in installations employing automatic microphone mixers. Increasingly popular for simple installations, automatic mixers work well with wired microphones but are very susceptible to noise and interference from wireless microphones. Because in such installations an operator is rarely present, interference noise from wireless equipment usually represents a system failure. Unfortunately, there are relatively few practical alternatives to a receiver with secure squelch circuits in this type of installation. The most effective is simply to ensure that the wireless transmitter is turned on before the automatic mixer, and that it remains on until the automixer is turned back off. In reality, this may prove difficult to enforce.

The problem is less troublesome in systems not using automatic mixers. This is fortunate, because most wireless systems do not have the necessary special squelch circuitry. Experienced sound mixers are aware of the potential problem and are careful to fade the wireless audio when the transmitter is not in use. Less experienced mixers may not remember to take the necessary preventative measures. Generally, the best approach is to educate the end user to anticipate that this situation can occur and to recommend that the receiver audio be turned off whenever the transmitter is not on.

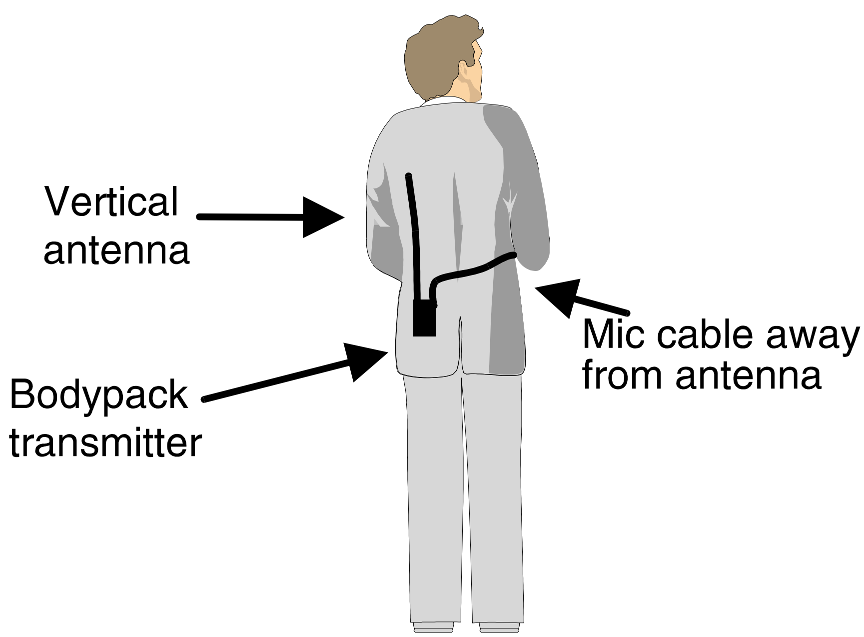
4.0 Transmitting Antennas

Few areas of wireless microphone technology are as foreign to the typical audio professional as are antennas, and few generate as many questions. Even experienced wireless users are often uncomfortable about the proper use of antennas and how they affect the results obtained. There is considerable justification in this, as antenna theory is difficult and the typical wireless application represents far less than the ideal situation shown in the textbooks. Fortunately, effectively using wireless antennas is much easier than understanding them. By keeping in mind just a few key points, very good results can easily be obtained.

Bodypack Antennas

One of the most frequently asked questions regards the orientation and positioning of the antenna on the bodypack transmitter. Although most instruction manuals advise the vertical orientation, questions arise as to how much performance might be lost with another orientation. To answer this, it is first important to place the whole issue in proper perspective. Essentially, if certain basic mistakes are avoided, the orientation of the transmitting antenna is only important if the maximum possible operating range is needed. Because this is not usually the case, some flexibility can normally be permitted.

The desires and needs of the person wearing the transmitter must also be considered. Obviously, there are very real limitations on what can be asked of many persons who will wear wireless equipment. For example, methods that might damage clothing or be even mildly uncomfortable might not be acceptable. Other techniques, commonly used with professional performers, might well offend the modesty or dignity of many persons. Thus, practical considerations must often take precedence over the optimum technical solution.



". . . the best way of wearing the antenna is with the transmitter located near the small of the back, with the antenna extended upwards to the lower neck area."

Although circumstances may dictate other methods, the preferred method is to orient the antenna vertically and as high on the body as possible. The vertical orientation is best, largely because it allows the maximum extension of the antenna wire. A location high on the body is preferred because this placement will improve range under virtually all conditions. It is also best to locate the transmitter on the back so that it won't be shielded by the arms.

Thus, the best way of wearing the antenna is with the transmitter located near the small of the back, with the antenna extended upwards to the lower neck area. However, the microphone cable is an integral part of the antenna and must also be considered. This is because the transmitter itself it far too small to balance the active antenna element, forcing the mic cable to assume a part of this role. Because of this, insofar as practical, the mic cable should be extended in the opposite direction from the antenna.

If the transmitter is being worn on the small of the back, the mic cable should extend down below the body of the transmitter, along one hip and then back up the front of the wearer's body. No matter the actual transmitter orientation, it is of primary importance to keep the antenna and the mic cable well separated. Bundling the antenna and mic cable together can reduce the range to as little as 10% of normal. In effect, this electrically shorts out the antenna, greatly affecting performance. Much the same is true if the antenna is bent in such a way as to lie against the transmitter body; the antenna should extend directly away from the transmitter body. It is, however, quite acceptable to position the mic cable next to any part of the transmitter body.

Attachment of the antenna in such a manner as to keep it well extended is important. For the example above, the recommended technique is to attach a sturdy rubber band to the end of the antenna and to use a safety pin to attach the rubber band to the clothing. This provides the stretch and give necessary for comfortable wearing, without allowing the antenna to sag. It is sometimes also useful to tape the mic cable to the transmitter body on the side away from the antenna, if both come out of the same end of the unit.

Antenna Placement

Problems sometimes arise when antenna conductors and mic cables are incorporated directly into theatrical costumes. The costume designer and seamstresses are often not aware of the necessity of separating the antenna and the mic cable, with the result that both cables end up together somewhere within the overall costume. Other problems with costumes can occur, one common one being the use of fabrics with metallic coatings or metallic threads. This type of material can be an excellent RF shield, greatly reducing the range of a wireless transmitter worn beneath the costume. When problems are experienced with costumed performers, careful attention to the costume details is highly advisable.

For more casual wearing of a bodypack transmitter, several approaches can be recommended. When a transmitter is worn in a suit-coat pocket, the antenna wire is best positioned back over the shoulder, with the mic cable running downwards inside the coat. When worn on a belt, it is most convenient to allow the transmitting antenna to hang down from the waist. However, this placement always reduces range, as compared to running the antenna upwards, because the antenna height will be reduced. If the transmitter is worn on the belt, the antenna should hang down away from the transmitter case, even if this means mounting the transmitter upside down. Allowing the antenna to dangle down next to the transmitter case is likely to reduce range considerably more than will wearing the antenna lower.

A bodypack transmitter may also be worn horizontally around the waist. In this case, where the antenna is inherently less effective than when fully extended and straight, it is especially important to separate the antenna wire and the mic cable. Even so, the typical range is likely to be significantly less that for most of the other possible techniques. Obviously, in this situation, the shorter antenna lengths typical of UHF equipment will be at less of a relative disadvantage than for VHF antennas. This is also true of transmitters worn on the belt, although for a different reason. Because effective antenna height is frequency dependent, UHF transmitters will generally suffer less performance loss when worn this way than will VHF units.

Many other methods of wearing a bodypack are possible, especially in professional entertainment applications. With any technique, the important factors to consider are: extension of the antenna and mic cable; separation of the antenna and mic cable; a location high on the body; and an approach which takes into account the needs of the wearer. In many instances this last factor, as well as artistic and visual considerations, might be more important than any of the other factors.

In this case, use of techniques such as diversity reception and high-performance receiving antennas might be advisable to offset any range problems that might occur.

When transmitting antennas are worn close to the body, a significant loss of efficiency results. Depending upon a number of factors, the effective range will be reduced to one-half to one-fifth of that which would be achieved by a free-standing, isolated transmitter. The actual loss depends upon whether or not the body is between the transmitting antenna and the receiving antenna, body size and mass, and several other factors. The antenna pattern is also altered; the effective orientation of the antenna usually tilts forward through the vertical plane of the body. This affects the optimum orientation of the receiving antenna, as will be discussed later.

The proximity of the antenna to the skin is also a significant factor, especially when significant perspiration is present. There is some evidence that individual body chemistry may play a role as well, although hard data seems to be lacking. Spacing the antenna even a few millimeters away from the body is known to improve range significantly, especially if the wearer is perspiring freely. This is because the body, and especially perspiration, is somewhat conductive and tends to short out the antenna.

The antenna should not become wet if in direct contact with the body. In such situations, wearing the transmitter outside one or more layers of clothing, especially bulky items, will improve range. In extreme cases, the use of surgical rubber tubing or the equivalent to keep the antenna dry and slightly away from the body might be advisable.

Handheld Transmitters

Because handheld transmitters are not worn close to the body and thus are not greatly affected by the various body effects, it might be assumed that they will be more efficient than bodypack transmitters. Other things being equal, this would be true. However, handheld transmitters, at least in the VHF range, are far too short to be efficient as antennas. For example, at 180 MHz, a full size antenna is about 33 inches (84 cm) long. Because the length of a typical handheld transmitter is only 10 to 12 inches (25 to 30 cm) or so, there will be a significant loss of efficiency.

For UHF handheld transmitters, the length of the transmitter body is considerably closer to optimum than for VHF transmitters. For units with internal antennas, part of this advantage is offset by the RF absorption of the hand. UHF designs with external antennas, although sometimes lacking in esthetic appeal, are relatively efficient in comparison to other types of transmitters.

The handheld transmitter antenna is usually quite inefficient, offsetting any advantages of the lack of significant body effects. Consequently, range will generally be similar for both types of transmitters. The exceptions are UHF units with external antennas or when a particularly inefficient antenna design is used for the handheld, as is sometimes the case. In this latter situation, range might be significantly less than for a similar bodypack transmitter.

5.0 Receiving Antennas

Orientation

The question of orientation also comes up frequently in regards to wireless receiving antennas, especially when diversity is used. For nondiversity systems, the antenna orientation should be the same as for the transmitting antenna. In most cases, this means the vertical position. For diversity operation, the recommended orientation is with the two antennas approximately at right angles to each other, preferably with each one at about a 45 degree angle from vertical. When using two whips on a diversity receiver, they should form a "V," similar to TV rabbit-ear antennas. This provides as much separation as possible between the two antennas, desirable for maximizing diversity performance.

Orienting the two antennas at right angles optimizes reception of the polarized radio-frequency signals from the transmitter. Radio waves have a property known as polarization. That is, RF signals transmitted from a vertical antenna are vertically polarized, while signals transmitted from a horizontal antenna have horizontal polarization. This is significant because horizontal antennas are inefficient in receiving vertically polarized signals and vice versa. As was mentioned above, the human body tends to tilt the polarization of radio waves transmitted from a body-worn antenna forwards through the torso. Thus, even if the antenna is worn in the vertical position, the polarization of the radio wave will not be vertical. In addition, whether the polarization of the signal is seen as clockwise or counterclockwise from vertical depends upon which side of the body faces the receiving antenna. By orienting the receiving antennas to either side of vertical, both conditions are accommodated.

Do not make too much of these considerations. First of all, in a typical indoor environment where RF signals are reflected from many different surfaces, polarization losses are not high. Thus, a single vertical antenna is not at a major disadvantage in respect to a diagonally mounted antenna. Secondly, in a typical application, dropouts due to multipath propagation are a more significant consideration than obtaining the absolute maximum range. Finally, the most important consideration of all is to avoid mounting the antenna or antennas in such a way as to degrade performance seriously. Some relatively common mistakes in mounting and positioning of antennas can reduce range to less than 20% of what it should be. This is far more serious than a minor loss due to less than optimum receiving-antenna polarization.

Height

The height of the receiving antenna is also important. If obtaining maximum range is a consideration, the antenna should be mounted quite high, well above the height of the transmitter. There are several advantages to this, including the fact that the receiving antenna can look over the top of persons and objects near the transmitter. Another advantage of a high mounting location for the receiving antenna is that over extended distances less of the RF energy will be absorbed by the ground (or floor), increasing range.

RF Path

In the VHF and UHF frequency ranges, maintaining a clear, unobstructed path between the transmitter and the receiving antenna is very important. Often referred to as being "line of sight," a clear path helps ensure that the radio waves will not be blocked by objects in the way or reflected away from the receiving antenna. The electrical field of an antenna is always considerably larger than the antenna itself. Consequently, unlike light, even objects not directly in the path of the RF signal can distort the antenna pattern, affecting performance. Pattern distortion can cause range to be much less than expected, especially in certain directions.

It is recommend that receiving antennas be mounted with their center at least 8 feet (2.5 m) above the surface upon which the wireless user will stand. This will usually require the use of a dipole, ground plane or similar type of remote antenna. Alternately, the receiver can be placed on a shelf or other support at this height to allow use of whip antennas. However, it may then be more difficult to use the receiver. Further elevation of the antennas might be advantageous in many circumstances, especially outdoors and when a very long operating range is required. Golf courses, stadiums and sports playing fields are good examples; an antenna elevation of 30 to 60 feet (10 to 20 meters) might be necessary for best results in such situations.

Indoors, a lower location might be necessary if the antennas will be too close to the ceiling, especially if the ceiling contains metal. For example, the common acoustic tile ceiling is supported by a metal grid structure, and the wireless antenna must not be placed too close to the metal supports. Close proximity to all metal objects, such as furniture, lighting fixtures, scaffolding, electrical cables, structural members, aluminum window frames and equipment cabinets must be avoided.

> **"Because of the higher frequencies, UHF systems require considerably less antenna spacing for good diversity operation than do VHF systems."**

Whip and dipole antennas require at least an 18 inch (0.5 m) spacing from metal surfaces. Ground-plane type antennas need proper spacing above the ground-plane, but may be in close proximity to metal below the ground plane elements. Other types of antennas might require greater separations or special mounting techniques; consult the manufacturer's instructions for details.

In view of the small separation, the effectiveness of using two receiver-mounted whip antennas for diversity receivers is often questioned. Whether or not good results will be achieved depends to a considerable degree upon the type of diversity being used. Phasing types of diversity require greater spacing than is typically provided on receivers for proper operation, but will work to a limited degree. For true (dual-receiver or space) diversity systems, reasonably good diversity reception can usually be obtained.

Because of the higher frequencies, UHF systems require considerably less antenna spacing for good diversity operation than do VHF systems. The effect is inversely proportional to frequency; for example, for roughly equivalent performance, a 500 MHz system needs about one-third the antenna spacing as for a 170 MHz system.

Although maximum diversity effect for VHF systems requires a spacing of at least 6 to 10 feet (2 to 3 m), the diversity performance of receiver-mounted whips is almost always adequate to prevent dropouts if the operating range is not extreme. This is because a multipath null zone (the most usual cause of dropouts) at VHF frequencies is only about 2 inches (5 cm) in size. Thus, an antenna spacing of 5 or 6 inches (12 to 15 cm) is adequate to allow the receiver to avoid a dropout. If the operating range is greater than 200 feet or so (60 meters), or if the operating environment is difficult (such as marginal line of sight conditions, many reflecting metal surfaces present or moving vehicles within range), the use of widely spaced diversity antennas is recommended.

Common Problems

In respect to whip antennas, one mistake is so common that it is deserving of special note. This is the practice of using a whip antenna at the end of a cable. Quite often, the need arises to locate the antenna remotely from the receiver. Because a whip antenna is usually already available, a cable is purchased and the whip is connected to the end of the cable. Unfortunately, this arrangement results in a very inefficient antenna and should never be used. Operating range will often be less that 25% of what was obtained with the whip attached to the receiver. The reason for the problem is that an antenna has two halves, a radiating element and the balancing element.

Although the balancing element can take many forms, it must be present for the antenna to work properly. When the whip is simply attached to the end of the cable, there is no real balancing element and efficiency suffers greatly.

If a whip is to be used remotely from the receiver, a ground plane or the equivalent is required. This is a large metal surface directly connected to the outer shield of the RF cable at the antenna that then serves as the balancing element for the whip.

Another common problem arises when wireless systems are mounted in equipment racks. If the antennas connections are at the rear of the receiver, problems are almost certain to arise unless remote antennas are used. Even when the antenna connectors are on the front of the receiver, problems are likely if the whip antennas usually supplied with the system are used. Such antennas often end up only an inch or so (3 to 4 cm) away from other equipment in the rack. Efficiency is very poor under these conditions, especially in certain directions, due to antenna pattern distortion.

Worse, if several receivers are mounted together, not only will the antennas all be near the other equipment, they will be in close proximity to each other. Electromagnetic coupling between adjacent antennas will further distort the patterns, sometimes reducing range by as much as 90% in some directions. The coupling can also create various interference problems by allowing RF energy from one receiver to leak into another. This is especially true of lower cost units that typically are not as well shielded as more expensive receivers.

Most wireless systems are supplied with some type of wire whip antenna. This type of antenna is inexpensive and rugged and has relatively good performance if properly used. Often, however, the need arises to locate the antenna remotely from the receiver. In this case, manufacturers offer other types of antennas such as dipoles, more complicated types of whips (such as 5/8-wave whips), ground-planes (a whip with an attached ground-plane structure) and various types of directional antennas (such as yagis and log periodics).

Dipole Antennas

Dipole antennas have two identical elements that serve to balance each other. Consequently, they work well at the end of cables and do not need a ground plane. Dipoles also have slightly better performance than whips and provide somewhat better operating range. Special types of whips, such as the 5/8-wavelength design, also offer better performance than a simple whip antenna, but have the same ground-plane requirements. That is, unless a special grounding adapter (such as a microphone stand mount) is used, very poor performance may result. The ground-plane antenna is simply a whip antenna with an attached ground-plane structure, usually with downward tilting rods serving as the ground plane. Properly used, dipoles, 5/8-wavelength whips and ground-plane antennas all have roughly equal performance.

Yagi and Log Periodic Antennas

For more demanding or specialized applications, various types of more sophisticated antennas are sometimes used. In situations demanding operation at extreme ranges, yagi or log periodic antennas are often used. These are antennas with several active elements, which results in gain, meaning that they intercept more signal than simpler designs. They typically allow operating ranges of from two to four times that which can be achieved with a simple whip antenna. However, this is achieved by making them directional; that is, they are much more efficient in one direction than in other directions. Typically, best performance will be achieved over an angle of from about 30 degrees to about 90 degrees, depending upon the design. This directional property is sometimes an advantage and sometimes a drawback, depending upon the application.

In some instances, the directional nature of such antennas can be used to suppress unwanted interference. That is, if the back of a directional antenna is pointed towards the interference source, and the front towards the wireless transmitter, the desired signal will be increased and the interfering signal level decreased. Typical antennas of this type provide 5 to 10 dB of gain and roughly equivalent signal rejection off the back. Thus, it is possible to increase the desired signal by 5 to 10 dB and simultaneously decrease interference by 5 or 10 dB, providing 10 to 20 dB in overall improvement. However, this requires that the directional antenna be mounted more or less directly between the interference source and the transmitter, which often is not feasible.

Most directional antennas require a matching transformer to connect them to RF cables; this device may or may not be included. Commonly available matching transformers typically have TV type “F” connectors, necessitating some sort of adapter connector or cable. Most such antennas resemble standard TV antennas, in fact, one of the better units that can be used for VHF wireless is actually designed for TV. This is the Winegard YA-6713 (similar older models were the AK-6713 and the K5-713), a TV channel 7 through channel 13 yagi that is inexpensive (around $30.00 in the United States) is not excessively large and has quite good performance. Other TV antenna companies offer somewhat similar designs.

“The most important concern is maintaining a clear and unobstructed path between the receiving antenna and the transmitter.”

Comparable models are available for UHF systems operating in the 500 to 800 MHz range, which corresponds to the UHF TV channels in most countries. UHF systems operating outside of this range should use the special purpose antennas offered by wireless manufacturers. Most companies active in UHF wireless systems offer some type of high performance antenna, often highly optimized for the application. Some include RF line amplifiers integrated into the antenna, which might or might not be an advantage for a particular application.

Many other types of antennas can be used with wireless microphone systems. Manufacturers of antennas for two-way radio applications offer a wide variety of designs for special applications. In general, these antennas will work quite well and might be useful in solving a particular problem. However, they are usually designed to work only over relatively narrow frequency ranges and are rarely available for the VHF or UHF TV channel frequencies. Unlike a whip or dipole, which can work over a reasonable frequency range without a great loss of efficiency, many of these antennas perform very poorly at frequencies that are only slightly outside their specified operating range. Use caution to ensure that the antenna selected will actually cover the wireless frequencies in use.

Antenna Mounting

No matter what type of antenna is used, exercise care in positioning and mounting. The most important concern is maintaining a clear and unobstructed path between the receiving antenna and the transmitter. The receiving antenna may be concealed behind fabric, most plastics, acoustic tile and thin plywood. Good results can also be obtained through walls constructed of wooden studs and gypsum wallboard. However, some walls of this type now use metal studs, which can greatly affect performance, especially if the antenna happens to be mounted close to one of the studs. Plaster and stucco walls both usually have embedded metal wire mesh and should be avoided.

Cement block and poured concrete both usually have metal reinforcing rods inside, as do many modern brick walls. However, the rods are generally fairly widely spaced, so performance does not usually suffer too badly. In general, UHF systems will perform better through walls with widely spaced metal, due to their higher frequencies. Both VHF and UHF systems will perform poorly when there is wire mesh inside the wall. It is usually wise to look over a facility carefully to determine the construction before installing an antenna system. This simple precaution can often save a great deal of time and effort in the long run.

For VHF frequencies, there is considerable interest in antennas smaller and more convenient than standard wire whips, especially where portability is a factor. One such antenna is the helical coil antenna (sometimes referred to as a “rubber duckie” in the United States), which is perhaps one-third the length of a standard whip. Such designs, however, sacrifice considerable performance for the smaller size. While electronic circuitry can often be miniaturized without significant performance compromises, the same is not true of antennas. That is, while components can be made almost arbitrarily smaller, devices such as antennas that depend upon physical constants (such as radio wavelength) cannot.

The net result is that, while antennas whose dimensions are far less than a wavelength do exist, they are seriously less efficient than larger antennas. About the smallest antenna with reasonable efficiency is the 1/4-wavelength design, which must be about 16.5 inches (42 cm) long at 180 MHz. Antenna length is usually less of an issue at UHF frequencies. For example, a 1/4-wavelength antenna will be only 4.2 inches (11 cm) long at 700 MHz.

Of course, small antennas such as the rubber duckie are widely available for VHF use. They are usually 7 to 8 inches (19 cm) long, considerably shorter than a 1/4-wavelength whip. However, such units merely make the best of a bad situation by providing a good impedance match at the tuned frequency. This at least avoids adding matching loss to an already low efficiency. In general, even the best such designs are 4 to 6 dB less efficient than a simple 1/4-wave whip. In practical terms, the working range of a system using this type of antenna will be only 50 to 65% of that of the same system with a good quality 1/4-wave wire whip.

6.0 Antenna Systems

Cables

Frequently, antennas must be located some distance from the desired location of the receiver. In this case, coaxial cables may be used to connect the antenna to the receiver. However, coaxial cables unavoidably reduce the available signal and cut system operating range. In general terms, cables should be used only when the receiver cannot be moved to a position near the antenna or where mounting considerations require that the antenna be distant from the receiver. In most instances, better results are obtained by running a longer audio cable and using a shorter antenna cable. RF cables, particularly longer ones, should be used primarily when the advantages of a better antenna mounting location heavily outweigh the disadvantages of cable loss.

Cable loss is a particularly important issue for UHF wireless systems. The loss of standard miniature 50-ohm coaxial cables such as RG-58/U might be as high as 17 dB per 100 feet (30 meters) at 700 MHz. The use of this length of cable between the receiver and its antenna will reduce operating range to approximately 15% of normal. Therefore, it is especially important to minimize RF cable length for UHF systems. When long cable runs cannot be avoided, it is essential to select a low loss type. The constraints imposed by coaxial cable at UHF frequencies make design of antenna systems significantly more difficult than for VHF systems—one of the few major differences between the two types of systems.

One common error is the use of long RF cables to move the antenna closer to the location of the transmitter. This is usually done in an effort to improve performance. Unfortunately, the loss of the cable is quite often higher than the additional transmission loss to an antenna at the receiver. This is especially likely if a low cost cable such as RG-58/U is used; at VHF frequencies only about 80 or 90 feet (approximately 25 meters) of this type of cable will reduce the range of the wireless systems by one-half.

If the distance between the receiving antenna and the transmitter can be reduced by one-half or more by a cable with less than 6 dB of loss, performance can be improved. On the other hand, if the cable required to position the antenna to one-half of the original range has a loss of more than 6 dB, performance will suffer. For example, if the original range is 200 feet (60 m), using 100 feet (30 m) of RG-58/U (having about 7 dB of loss) to lower the range to 100 feet (30 m) will result in a loss of performance. Conversely, using 50 feet (15 m) of RG-58/U (with 3.5 dB of loss) to reduce range from 100 feet (30 m) to 50 feet (15 m) will slightly improve performance. However, since problems don't often occur at such short ranges, the real purpose of the

Cable Type	Loss per 100 ft. (dB)	Length for 15%		
Range Reduction ft. (m)	Length for 30%			
Range Reduction ft. (m)	Length for 50%			
Range Reduction ft. (m)				
RG-58	7.1	20 (6.1)	44 (13.3)	85 (25.8)
RG-59	4.9	29 (8.8)	63 (19.3)	123 (37.5)
RG-59 Foam	3.8	37 (11.3)	82 (24.8)	158 (48.3)
RG-8	3.2	44 (13.4)	97 (29.5)	188 (57.3)
RG-8 Foam	2.6	54 (16.5)	119 (36.3)	232 (70.6)
RG-11	2.9	49 (14.8)	107 (32.6)	208 (63.3)
RG-11 Foam	2.1	67 (20.5)	148 (45.0)	287 (87.4)

Table 1

Approximate cable loss factors at 200 MHz (VHF)

Cable Type	Loss per 100 ft. (dB)	Length for 15%		
Range Reduction ft. (m)	Length for 30%			

cable should be to get the antenna into a clear location. At short working distances, this is almost always more important than reducing the range.

"Cable loss is a particularly important issue for UHF wireless systems."

Obviously, the type of cable used, and the corresponding loss factor, will also affect the equation. However, lower loss cables are more expensive and usually more difficult to install. Better solutions are to use a directional antenna with gain (such as a log periodic) to extend the range or to locate the receiver nearer the transmitter and to use a longer audio cable. At UHF frequencies, the situation virtually always favors very short RF cables and directional antennas.

However, in some situations, the use of cables is difficult or even impossible to avoid. In these cases, the length of the cable should be kept to a minimum and the type of cable used selected to maintain performance. Different sizes and types of RF cable vary widely in the amount of introduced loss and, thus, the effect upon wireless system operating range. There are even significant differences between cables that would appear to be equivalent. For example; for "RG-58/U" type cables, the variation between various RG-58/U, RG-58A/U, RG-58C/U and military-specification RG-58/U cables from the same manufacturer is from 12 to 17 dB loss per 100 feet (30 meters) at 700 MHz. (Incidentally, the commercial-specification RG-58A/U is best.)

On the other hand, special low-75-loss-ohm CATV/MATV cables in slightly larger diameters are widely available that have losses as low as 3.4 dB per 100 feet (30 meters) at 700 MHz. Since 13.6 dB of extra loss will reduce operating range by a factor of about five times, this is obviously an important issue. Despite this, it is not always easy to make appropriate decisions regarding RF cable.

Although there are several ways to go about selecting a cable for a wireless installation, one of the simplest and best methods is to decide first how much performance degradation can be accepted for the wireless system. Then the required cable length should be measured, not estimated, as errors can cause significant variations in performance. Needless to say, the actual routing that the cable will follow should be used, not the point to point distance. With this information, the type of cable can be selected from Table 1 below for VHF systems and from Table 2 for UHF systems.

Some of the cables in these tables are 75-ohm types and some are 50-ohm types. Although almost all wireless microphone equipment is designed for a 50-ohm impedance, the use of 75-ohm cable is quite acceptable. While there is a small impedance-matching loss when going from 75 ohms to 50 ohms, readily available 75-ohm cables usually have slightly lower losses than do roughly equivalent 50-ohm cables. This offsets the matching losses for lengths greater than 40 or 50 feet (12 to 15 meters).

In addition, several common types of antennas have impedances closer to 75 ohms than 50 ohms, so the actual effective matching loss using 75-ohm cables may well be negligible. Because 75-ohm cable is widely used for CATV, MATV and cable TV systems, it may be both more readily available and less expensive than 50-ohm cables. For the same reason, low-loss-foam-type 75-ohm cable is usually considerably easier to obtain than the equivalent 50-ohms cables and often less expensive due to higher demand.

Although Tables 1 and 2 have entries for cable lengths that will reduce the operating range of the wireless to one-half (50%) of its normal range, an installation of this type cannot be recommended. A range reduction of about 30% should be the design maximum for any permanent installation. As can be seen from Tables 3 and 4, this limits the permissible cable length to 140 to 150 feet (43 to 46 m) or so for VHF, and only 80 feet (24 meters) for UHF, even for a high quality cable. Of course, larger and better cables do exist, but their cost is usually prohibitive. Where distances beyond about 150 feet (45 m) must be covered, relocation of the wireless receiver to a point closer to the desired antenna location is strongly recommended.

Line Amplifiers

Sometimes, however, the use of very long cables may simply be unavoidable. In these situations, it may be necessary to use an RF line amplifier (RF preamplifier) to offset cable losses. However, line amplifiers are wideband devices and do not have the ability of receivers to reject spurious signals. Therefore, there is an unavoidably increased possibility of encountering interference when using line amplifiers. Because these devices normally cover a wide frequency range (such as 165 to 220 MHz or 490 to 800 MHz), they will often receive many powerful signals in addition to the signal from the wireless system or systems. In particular, most areas have one or more TV stations on VHF channels between 7 through 13 and UHF channels between 14 and 69. (Channel assignments may vary by country.)

These transmitters are usually quite powerful and can sometimes cause overload problems in RF line amplifiers. Even if there is no serious overload, there is an increased chance of intermodulation problems. It is not unusual to encounter an intermodulation problem in an amplified system that does not exist if the same wireless receivers are used with whips. This is especially true if additional wide-bandwidth RF devices such as multicouplers (active antenna splitters) are also used.

Because of potential overload problems, it is necessary to ensure that the wireless transmitters cannot get too close to the receiving antenna in amplified systems. Normally, it is desirable to place the receiving antenna relatively close to the location where the transmitter will be used. However, operating a transmitter closer than about 20 feet (6 m) to an antenna with an attached amplifier invites problems. This is a particularly important consideration in installations where multiple wireless transmitters will be used.

In spite of potential overload and intermodulation problems, the RF line amplifier must always be located at the antenna, not at the receiver. This is because once the signal has been attenuated by the cable, amplification is more or less useless. In fact, adding an amplifier at the wrong end of the cable can often actually decrease range, especially when a high quality receiver is being used.

Because of the necessity of remotely locating the line amplifiers, as well as supplying the necessary operating power and protecting them from the environment, system reliability might suffer. For example, it is not unusual for power to become disconnected accidentally from an amplifier, resulting

Length of Coaxial Cable ft. (m)	Loss of Standard RG-58/U (dB)	RF Preamp Required	Loss of					
Standard RG-8/U (dB)	RF Preamp Required	Loss of Polyfoam-Type RG-8 (dB)	RF Preamp Required	Loss of Polyfoam-Type				
RG-11 (dB)*	RF Preamp Required							
50 (15.2)	7.0	Yes	3.3	No	2.6	No	2.0	No
75 (22.9)	NR	—	4.9	Optional	3.9	No	3.0	No
100 (30.5)	NR	—	6.5	Optional	5.2	Optional	3.9	No
125 (33.1)	NR	—	8.1	Yes	6.5	Optional	4.9	Optional
150 (45.7)	NR	—	9.8	Yes	7.8	Yes	5.9	Optional
175 (53.3)	NR	—	NR	—	9.1	Yes	6.8	Optional
200 (61.0)	NR	—	NR	—	NR	—	7.8	Yes
225 (68.6)	NR	—	NR	—	NR	—	8.8	Yes
250 (76.2)	NR	—	NR	—	NR	—	9.8	Yes

Table 3. Coaxial cable loss and recommendations for use of an RF preamplifier.

Data based on 700 MHz operation

Length of Coaxial Cable ft. (m)	Loss of Standard RG-58/U (dB)	RF Preamp Required	Loss of					
Standard RG-8/U (dB)	RF Preamp Required	Loss of Polyfoam-Type RG-8 (dB)	RF Preamp Required	Loss of Polyfoam-Type				
RG-11 (dB)*	RF Preamp Required							
50 (15.2)	3.6	No	1.6	No	1.3	No	1.1	No
75 (22.9)	5.5	Optional	2.4	No	2.0	No	1.6	No
100 (30.5)	7.1	Yes	3.2	No	2.6	No	2.1	No
125 (33.1)	8.8	Yes	4.0	No	3.3	No	2.6	No
150 (45.7)	NR	—	4.8	Optional	3.9	No	3.2	No

in performance far poorer than would be the case without the amplifier. However, because there is often no recognizable major failure, the problem might go unnoticed for some time, while other equipment is blamed for any difficulties.

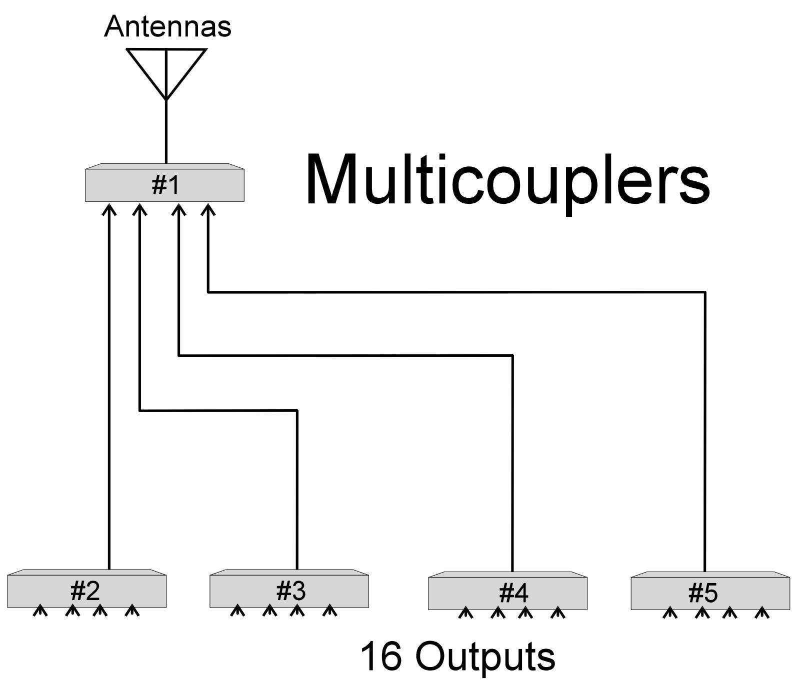
For all of these reasons, it is virtually always better to install a lower loss cable, move the receiver closer to the antenna or select a higher performance antenna if the use of a line amplifier can be avoided. Some manufacturers offer antennas with integral RF line amplifiers. Other than convenience, these offer no particular advantages over separate antennas and line amplifiers, and the same precautions apply.

Multicouplers

Oftentimes, it is desirable to have one antenna feed two or more receivers. In this case, a multicoupler (amplified signal splitter) may be used. These devices typically have four to eight outputs, allowing one antenna to drive four to eight receivers. However, multicouplers are wideband active devices much like line amplifiers and have most of the same limitations in respect to overload, intermodulation and interference rejection.

The technical characteristics of the amplifiers inside multicouplers are a major factor in performance. Inexpensive, easily overloaded amplifiers will produce far higher intermodulation levels than will the higher power, more linear amplifiers used in higher performance units. If a system with multicouplers is experiencing interference, investing in a better quality multicoupler might be wise. This is especially true if more than one multicoupler must be used in series, as when more than four to eight receivers need to be connected to one antenna.

It is also advisable to avoid multicouplers with high gain. While it may seem that higher gain would be an advantage, this is not usually the case. For a given input, higher gain amplifiers are usually more prone to intermodulation problems than are units with more modest gain. This is simply due to the fact that a higher output level will be demanded of a high-gain RF amplifier. Multicouplers with high gain might also affect receiver squelch settings, in extreme cases requiring resetting the receiver squelch circuits to get them to work at all.



Splitters

Splitters are RF signal dividers with no amplification. These devices provide a good RF impedance match to minimize signal loss, unlike simple “tee” connectors, which are often extremely lossy. Splitters can be used to divide the signal from one antenna to drive two receivers. However, it is important to realize that each two-way split will reduce the range of the wireless by about 30 to 35%. This might be acceptable in situations where the antenna cable is short and the operating range is not too long. Splitting more than two ways will reduce the operating range to less than 50% of normal and should never be attempted. Tee connectors can be far worse; depending upon the exact configuration, one receiver might experience a range loss of 90% or even more.

When both a line amplifier and a multicoupler are needed, it is possible to use both at the same time. It is also possible to use more than one multicoupler in series to drive five or more receivers. The practical limit is usually 16 receivers, with one multicoupler driving four other multicouplers, each of which in turn drives four receivers. Although some very high performance (and very expensive) units exist that can extend this limit, their cost is usually prohibitive. Using either a line amplifier and multicoupler combination or one multicoupler driving a second multicoupler will, unfortunately, further increase the possibility of encountering interference or overload. However, satisfactory operation will be obtained in most instances.

Use of more than two active devices (two multicouplers or one line amplifier and one multicoupler) in series is strongly discouraged. It is sometimes possible to configure combinations of line amplifiers, splitters and multicouplers in such a way as to avoid some of the inherent limitations. Because these solutions depend upon the characteristics of specific items of equipment, it is highly advisable to contact the manufacturer for technical assistance before proceeding.

A common question is whether or not it is necessary to terminate unused multicoupler outputs in 50 ohms. While it is always good practice to do this, whether or not it is actually necessary depends upon the characteristics of the particular piece of equipment. Leaving unused outputs unterminated might reduce the isolation of the multicoupler (the attenuation from one output to another output). Poor isolation can sometimes cause one receiver connected to the multicoupler to interfere with another connected receiver. For some units, this can be a problem even with all outputs terminated. This problem might appear when using multicouplers with inherently poor isolation or receivers with high leakage out of the antenna connector.

In the event of problems with systems using either line amplifiers or multicouplers, it is a good idea to try connecting whip antennas directly to the receiver input to see if this corrects the difficulty. In troubleshooting this type of system, don’t overlook the obvious. Line amplifiers and multicouplers are usually separately powered and it is often easy for the power to be turned off or to become disconnected. Unfortunately, this may not result in a complete system failure, so that the lost performance might not become apparent immediately.

Sometimes it is desirable to cover an unusually large area, to extend coverage to an isolated secondary area, or to satisfy some other special or unusual requirement. In a majority of cases, it will be possible to provide the capabilities desired and to achieve good results. However, a significant amount of hardware might be necessary to implement the antenna and RF distribution system properly. Purchasing and installing this equipment is likely to be expensive and mistakes will be costly. Because of this and the specialized nature of such systems, especially at UHF frequencies, it is usually best to obtain expert assistance. Often, the wireless manufacturer can provide valuable assistance. However, because it is frequently necessary to make an on-site survey prior to preparing a design or making recommendations, it might be necessary for the manufacturer to make a referral to a qualified consultant.

7.0 Installation

Aside from remote antennas and RF distribution systems, installation of wireless equipment does not differ greatly from the installation of other types of audio equipment. For example, provisions should be made for adequate cooling of the receiving equipment, especially when it will be rack mounted. Although wireless equipment is no more sensitive to heat that other types of audio equipment, wireless systems usually do have more alignment points and adjustments. For this reason, aging due to excessive heat might have more pronounced effects than for some other types of equipment.

Mounting

Mounting of wireless receivers next to digital devices such as effects generators, digital delays, microprocessor-controlled instruments and units with DSP circuitry should be avoided. Even when the digital equipment meets current government regulations for interference (and a great many older units do not), there might be problems. The government limits are usually designed to protect other equipment in the immediate area, not equipment stacked on top of the digital equipment. In addition, the government limits don't take into account highly sensitive receivers such as are found in many wireless systems.

In many cases, mounting a wireless receiver in a rack just above or just below the digital device will cause problems. Often, the wireless system will work more or less normally, but squelch operation with the transmitter off might be erratic, or the squelch might not function at all. In rare instances, the wireless audio might be affected in some manner. Whatever the nature of the problem, it can generally be fixed by simply moving the wireless receiver farther away from the digital device. Quite often, a move of only 5 or 10 inches (12 to 25 cm) will completely solve the problem.

Take particular care to keep the wireless receiver away from high-power audio amplifiers. Not only do power amplifiers produce considerable amounts of heat, some contain high-power digital switching circuitry. A growing number of modern designs employ high-frequency switching power supplies or switching power amplifier sections. Because of the high power involved, the potential exists for wireless interference. Other types of digital equipment such as personal computers and digital remote control equipment (zone control systems, for example) can also be troublesome. Although no actual problems will be encountered in a majority of installations, it is important to keep the possibility in mind in the event of difficulties with the wireless equipment.

If the wireless system is being permanently installed, especially in a metal equipment rack, avoid shielding or blocking of the antenna. It is almost always necessary to use remote antennas when wireless receivers are mounted in equipment cabinets. Even if the back of the cabinet or rack is open, the antennas will be in close proximity to the metal in the enclosure, as well as other equipment that might be installed. The resulting antenna patterns will be highly unpredictable, and performance is almost certain to suffer. Even when open-frame equipment racks or nonmetallic equipment cases are used, problems are likely to arise. Receiver antennas will still be in close proximity with other installed equipment or cabinet wiring. When multiple receivers are used, antenna interaction and pattern distortion will result.

"In spite of the recent trend towards heavier use of diversity systems, nondiversity systems can perform effectively in most installations. "

This and similar installation problems sometime create an unfortunate scenario where wireless performance is poor, so one or more systems are removed and returned to the manufacturer for repair. However, the manufacturer finds nothing wrong with the equipment and returns it to the owner. Of course, the problem reappears when the system is reinstalled, causing frustration all around. This is one of the reasons why it is always advisable to test a system separately, with whip antennas and out of close proximity to other systems, before returning it for repair. Often the problem might prove to be installation-related, so time will simply be lost if the system is sent off for unnecessary repairs.

Sometimes overlooked is the fact that cabling can also effectively shield an antenna, even its own cable in the case of an external antenna. Metal window frames are also often overlooked as a source of shielding, especially because it might not be apparent that they are metallic. It is worthwhile spending a few minutes examining the installation area for potential problems of this type. This simple precaution can often save substantial headaches later.

"In a surprising number of instances, interference problems in wireless systems are caused by noisy ac power."

In spite of the recent trend towards heavier use of diversity systems, nondiversity systems can perform effectively in most installations. This is especially true of fixed installations, where conditions do not often change and there is adequate time for checkout and setup.

Signal Dropouts

When nondiversity systems are used, it is almost always necessary to check the installation to make sure that there are no dropouts in the areas where the transmitter will be used. This can be accomplished by "walking" the coverage area while listening to the sound system. If any dropout problems are encountered, it does not necessarily mean that a diversity system will be needed. Unless there are a number of dropouts or they are unusually severe, it probably will be possible to correct the problem quickly without an equipment change.

If a dropout or two are experienced, the receiving antenna installation should be reexamined. Particular attention should be paid to possible blocking and pattern distortion problems caused by metallic objects. If blocking doesn't seem to be a problem, slightly relocating antenna might solve the problem. Quite often, a shift of only 5 or 10 inches (12 to 25 cm) will cure a stubborn dropout zone while not introducing any new problems. Raising the antenna is very often helpful, especially if it is not well above the level of the transmitter. If a problem persists, perhaps a better antenna, such as a dipole, or moving the antenna slightly closer to the transmitter will help. With a little experimentation (and a little experience), it usually possible to arrive quickly at a fully satisfactory configuration.

AC Noise

In a surprising number of instances, interference problems in wireless systems are caused by noisy ac power. That is, the interference enters the receiver through the ac power line, rather than through the antenna connector. Aside from noise injected on the power lines by digital devices and equipment with switching power circuits, site electrical machinery and lighting equipment can be significant noise sources. Arcing contacts, poor electrical connections, defective fluorescent ballasts and tubes, lamp dimmers, defective motors, and many other electrical devices not only can radiate noise, but also can inject noise onto the ac power lines.

Both continuous noise, such as that caused by motors and rotating contacts, and random noise bursts are commonly encountered. Wireless equipment can also be affected by high-energy transients appearing on the power lines. Because these transients are often very high in amplitude, they can couple through the power supply in the wireless receiver and affect the circuitry. Although high-energy noise bursts are almost always sporadic, their occurrence is always disruptive. If the power system at the installation location experiences this problem frequently, installing power-conditioning equipment might be necessary. Not only will this help to prevent interference, it is likely to reduce maintenance problems greatly and to extend the useful life of all equipment at the location.

When interference is experienced in a wireless system, it is worthwhile to confirm that it is not being caused by noisy ac power. If noise is present on the audio output when the receiver is squelched, it is virtually certain to be power-line noise. Burst or impulse-type noise also often enters the wireless system via the ac source. One quick way to check for the noise source is to use a battery-operated FM radio tuned to a weak station. If the FM radio does not receive the same noise as the wireless, the ac line is likely at fault.

To correct this type of problem, the best choice is changing the ac power source to one free of interference. If this isn't feasible, a combination power-line filter and surge suppressor, such as sold for use with personal computers, will often help. However, the less expensive versions of these devices have only minimal filtering and might not work very well. Better quality filters are sold by both electrical and electronics distributors. Keeping a quality power-line filter on hand for troubleshooting purposes can be a wise investment.

8.0 Bodypack Microphones

Sound Quality

Very often, users of bodypack wireless microphone systems have little or no experience with lavalier microphones. It is common for these users to be surprised by the sound quality of lavalier mics as compared to the directional handheld or podium mics that they have previously used. Typically, lavalier mics are omnidirectional and have no proximity effect. Users accustomed to directional mics might find the sound thin and lacking in bass. The high end might also be a problem. Most of the more popular wired handheld mics have a response peak in the 6 to 12 kHz range. Relatively few lavaliers have the same response, so users sometime complain about a colorless, dead sound.

For this reason, it is wise to make provisions for at least some rudimentary equalization for all but the simplest installations. If the mixer (or equivalent) does not have the required circuitry, consider using an outboard equalizer. Some of these devices are relatively noisy, however, so do not compromise noise performance with an inferior equalizer.

Complaints about excessive background noise are also common. Cardioid mics are able to discriminate against background noise because of directivity, especially when held close to the mouth. Because of this closeness, lower gain can be used, further reducing the effects of ambient noise. Lavalier mics, on the other hand, are usually omnidirectional and typically worn down on the chest or elsewhere away from the mouth. Both because of the pattern and the extra gain required to pick up the relatively distant voice, background noise can become a problem.

In addition, to some users, the typical lavalier has a hollow sound due to pickup of the time-delayed voice from acoustic reflections. Lavalier mics worn on the chest are also subject to unnatural response peaks due to chest-cavity resonances. These peaks usually occur at low audio frequencies and can substantially alter the quality of a voice. While all of these things are quite normal and very little can be done about them, prospective first-time users should be prepared in advance for the differences. This often avoids unnecessary after-installation callbacks and last minute problems.

Acoustic Feedback

For many of the same reasons, acoustic feedback might become a problem when lavalier mics are used. The sound-system design might be based, accidentally or otherwise, upon the use of closely held directional mics or podium mics which are fixed-mounted in a specific orientation. With an omnidirectional lavalier mic, the whole sound-system design can fall apart, especially if the user or users decide to take full advantage of the freedom offered by the wireless system. Since the wireless system is the only new element, it is often blamed for feedback problems if they arise. In fact, systems might be returned for repair because they cause feedback . In this situation, the use of one of the relatively few directional lavalier mics on the market might become necessary.

Many, if not most, lavalier electret mics, both omnidirectional and unidirectional, are sensitive to RF signals to some degree.

However, for several reasons, directional lavaliers do not offer the same protection from feedback as do handheld cardioid mics. For this reason, it might not be possible to provide a complete solution to the user’s problem. They also introduce yet another variable in the sound-quality issue, as they don’t sound like either a directional handheld mic or an omnidirectional lavalier. In addition, directional lavalier mics are usually appreciably more expensive than omnidirectional units, and there might be a cost impact. In any case, it might be advisable to keep one or two cardioid lavalier mics on hand to permit quick resolution of problems.

RF Sensitivity

Many, if not most, lavalier electret mics, both omnidirectional and unidirectional, are sensitive to RF signals to some degree. The amount of sensitivity varies widely from model to model, even from unit to unit. Quite often a particular unit will experience a problem at one RF frequency but not at another. The effects of the RF sensitivity range from small changes in sound quality or output level to a complete failure to operate. In most cases, the effect is noticed as a change in level or frequency response as the mic cable moves in respect to the transmitter body or the antenna. Sometimes a marked increase in noise level will also be present. If the microphone was not purchased from the wireless manufacturer, it should be carefully tested for RF sensitivity before use.

The easiest way to do this is simply to listen to the mic through the wireless system on a monitor speaker or headphones while moving the mic cable near the transmitter. The mic cable should be brought near both the transmitter case and the antenna and moved about to several different positions. If the audio level or sound quality changes when this is done, the mic is RF sensitive. Unless data was provided with the wireless system, the wireless manufacturer should be contacted for recommendations on solving the problem.

Transmitters from different manufacturers might affect mics to different degrees, as the number of mics in which problems occur increases with higher power outputs and in units with more efficient radiation characteristics. There appears to be some type of threshold at about 35 to 40 milliwatts; above this level a high percentage of all lavalier electret mics will show sensitivity under at least some conditions. In most cases, small bypass capacitors must be installed in the mic connector to prevent RF from reaching the buffer amplifier in the mic capsule.

Pin Configurations

Caution is also required when using lavalier microphones from different wireless manufacturers. There is no accepted pin configuration standard for lavalier microphones used with wireless transmitters. Units from different manufacturers, even if they use the same connector type, might not work interchangeably. In addition, a particular mic might not bear any markings identifying the type of wireless with which it is intended to be used. Often, mismatched mics might produce some output, but it is likely to be thin, distorted and weak. This problem is a potentially serious trap for the unwary.

Phasing

A final consideration is microphone phasing. Because of the way lavalier electret mics must be interfaced to the bodypack transmitters, it is not possible to reverse the phasing of the mic. Unlike a wired unit, where phasing can be changed by merely reversing two wires in the XLR connector, the wireless transmitter must take the phase supplied by the microphone capsule. This is because of the need to supply bias voltage to the capsule buffer amplifier, which requires a specific polarity and connection arrangement . Therefore, if phasing will be important, make provisions to correct it at some point later in the audio system. If the wireless receiver or mixer do not have a phasing switch, an in-line phase changer might be necessary.

9.0 Conclusion

The paragraphs above briefly cover a number of topics that will be helpful in installing and operating wireless microphone systems. In general, these particular topics were included because of frequent questions by working audio professionals or because there seem to be industry-wide problems related to them.

Hopefully, this information will prevent a few problems and speed the solution of some others. It should also help dispel some of the vague air of mystery that sometimes seems to surround wireless microphone systems. Finally, it has been said that a working professional can be very successful if he or she knows 10% of what the experts know. We believe the information we have presented is at least a good start on this 10%.