Wireless Microphones

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This document provides a crash-course on wireless microphone technology, concepts, and terminology and is designed as a companion to (not a substitute for) the user's manual of the Sennheiser Evolution series wireless microphone system. This document might help learning to use this wireless mic kits a little easier. This is a work in progress, therefore, please send me your comments, suggestions, and corrections. I look forward to your feedback. — David.

Introduction

There is some mystery surrounding wireless microphone systems and how they work, but the best way to think about them is that you're operating a small radio station. The electrical energy from the microphone is modulated by the transmitter into radio frequency (RF) and then demodulated by the receiver back into an electrical signal which is fed into your mixer or camera.

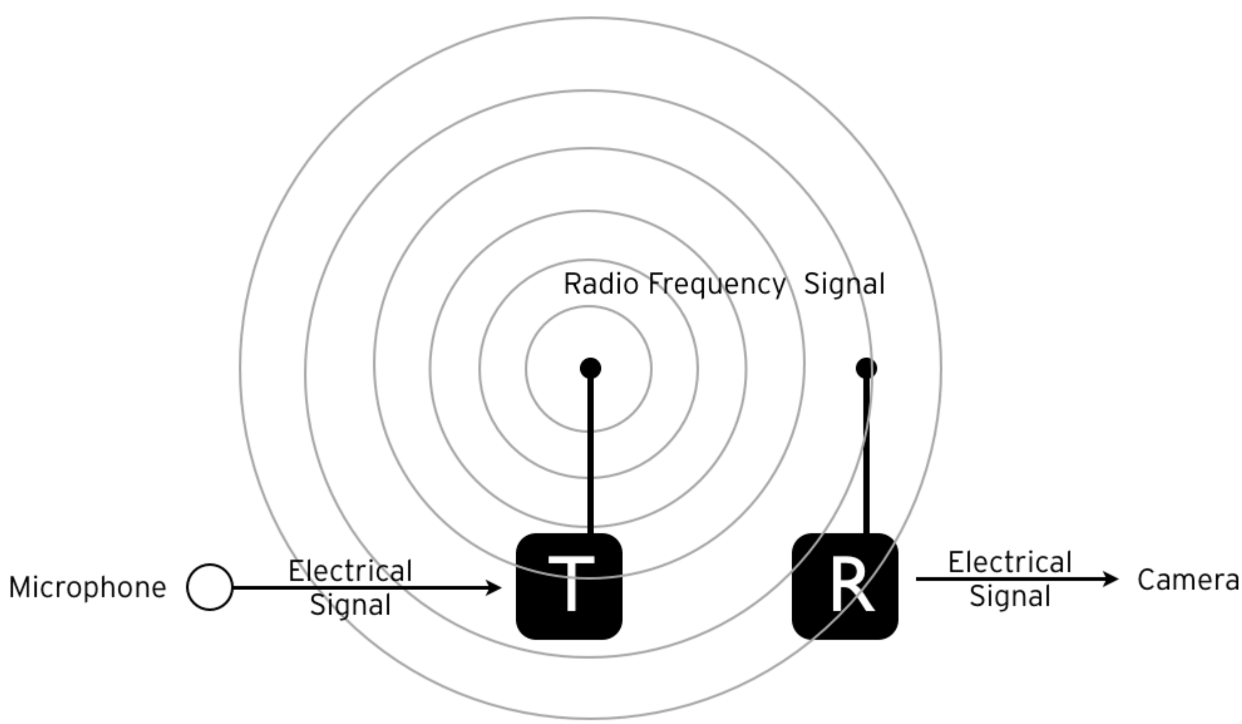
Wireless system features

Diversity. Better models have true diversity reception (two separate receiver modules each with its own antenna). This eliminates dead spots caused by phase cancellation which is caused when direct and reflected signals arrive at the transmitter out of phase. The newer G3 series of Sennheiser wireless mics (which bagan shipping the summer of 2009) features an adaptive diversity system using the audio cable as an antennae.

Compander. A compander is a technique used to improve the dynamic range of the audio signal. It compresses the audio signal in the transmitter to lift it above the inherent noise floor of the radio frequency link. The signal is then expanded by the receiver.

Microphone gain adjustment. Most wireless systems offer adjustable microphone gain on the transmitter in order to accommodate different level sources. This helps to avoid clipping.

Squelch. Some models offer adjustable squelch, which silences the output when the receiver does not get a



strong or quality signal from the microphone, instead of reproducing noise.

Digital hybrid. Some advanced models (not the Evolution series, but some you might rent in the future) use a digital hybrid method that provides an improvement over traditional wireless. The transmission is still pure analog, but the compander function is handled in the digital domain. Digital signal processing (DSP) is used to enhance the audio quality and makes it possible to achieve a flatter frequency response in the audio spectrum and reduce noise and other undesirable artifacts.

Advantages and disadvantages of using wireless microphones

There are several advantages of using wireless microphone systems over a wired microphones:

- Greater **freedom of movement,** the camera (or audio recorder) can be far from the subject or actor,
- Avoidance of **cabling** and elimination of trip hazard in crowded or uncontrolled situations.

But wireless is not a panacea. There are several disadvantages to be considered:

- Increased overall **complexity** and thus an increase in the probability of problems due to the introduction of three new elements in the mix: a transmitter, a receiver, and the radio frequency link between the transmitter and receiver rather than a single microphone cable,
- Limited **range**, a balanced XLR microphone cable can be run to about 300 feet without issues, it can run through floors and between buildings without interference,
- Possibility of **interference** from other radio frequency transmissions including television stations or other wireless microphone systems,
- Limited operating time based on **battery life**,
- **Noise or drop-outs** (especially with non-diversity wireless microphone systems),
- Reduced **audio quality** (due to compression for RF transmission), and
- **Intermodulation** (see below).

Intermodulation is a major problem when operating multiple systems in one location. Intermodulation occurs when two or more RF signals mix. The solution to this problem is to manually calculate all of the possible products of the frequencies in use, or use a computer program that can do this calculation for you. Many models offer factory preset frequencies designed to avoid intermodulation, avoiding the need for any calculations when using multiple systems in your production.

Tips for successful use of wireless microphones

Read the manual, do some homework. Wireless microphones are not difficult to use, but they do require some preparation and practice for successful use. The differences can be as small as remembering to have spare batteries on hand and making sure the frequencies you are using don't conflict with each other. There are many nuances involved in using wireless microphones. They might seem like a plug-and play proposition, and in many cases they might be, but when there's a problem, it can get complicated to trouble shoot the source of the problem. More than most gear, you should really take the time to read the owners manual that comes with your wireless microphone system and practice using then in a variety of situations before using them on a critical shoot.

Batteries. Always start with fresh batteries in the transmitter and receiver. Use quality alkaline batteries, other types will have much shorter life. Plan on changing batteries every four to six hours, depending on the battery life your particular model provides. If you have a new system, keep notes to determine how much use time you can expect from a set of fresh batteries. Keep the system turned off when not in use. Weak transmitter batteries are a common cause of wireless problems, including failure, poor range, distorted audio and even interference.

Finding a usable frequency. Make sure that the frequency you are using is appropriate, legal, and will avoid the TV channels operating in the area. See the "Finding open frequencies" section later in this document. Some advanced wireless systems have a built in spectrum analyzer, making it very simple to find an open frequency. If your wireless microphone does not have one, then the best way to find a usable frequency is to turn on your receiver (make sure your transmitter stays off) and watch the signal strength indicator on the receiver display while listening with headphones. If there is no visible activity and the audio you hear is completely clean, then you can go ahead and use that channel. If you see or hear anything, then select another frequency several increments away and try again.

Antenna placement. Good antenna placement is critical for trouble-free wireless system performance. There should be a clear line-of-sight path between the transmitter antenna and the receiver antenna. Avoid transmitting through obstacles such as solid metal objects (e.g. furniture, some walls, industrial equipment). Avoid getting too close to equipment that transmits RF energy (e.g. electronic equipment like computers, old televisions sets, any lights with ballasts including fluorescent lights and neon signs). Human bodies absorb RF energy, so take that into consideration as well when placing body pack transmitters.

Camera mounting. The most convenient place to mount the receiver and its all important antenna might be on your camcorder, but it might not be the most efficient as far as the signal path. Above the camera is usually better than to the side of the camera. Camcorders can interfere with the RF signal and can produce their own RF interference of their own. If you notice that your receiver produces any noise when placed close to your camera, try moving it to find a better position.

Improving line of sight. You can improve the line of sight between the transmitter and receiving antennas by locating the receiver either higher up or closer to the transmitter. Try using a non-metallic pole to hold the receiver higher if there are walls or obstacles causing interference problems.

Connections. Connect your audio with good, balanced, XLR audio cables. Some output adapters might be unshielded or unbalanced and will allow noise to enter. Use the shortest mic cable possible between the receiver output and the camera audio input.

AC Power. Hum can occur when you plug a receiver directly into an AC powered mixer, camera, or audio recorder, so use a mic cable to achieve at least a foot of distance. If that does not work, you might have to see if you can run the mixer, camera, or audio recorder off batteries rather than plugging into the AC power.

Receiver placement. If you experience interference, one thing to consider is placing the receiver closer to the subject and then running a long mic cable back to your mixer or camera.

Body-pack transmitter placement. When placing the microphone and body-pack transmitter on your subject, be careful not to allow the mic cable to cross over the antenna wire. The antenna wire on the transmitter should be kept somewhat straight. If you're using a body-pack transmitter with a flexible wire antenna, avoid letting the wire droop over itself. It's fine to invert the transmitter and have the antenna hang straight down if need be. On UHF body-pack transmitters, keep the microphone cable away from the antenna. When using VHF body-pack transmitters, don't coil or bundle the microphone cable on those transmitters for which the microphone cable functions as the antenna. When a body-pack transmitter is placed under clothing, make sure that it can be reached quickly to mute the microphone or replace the battery.

Clip-on microphones. When using clip-on microphones, position them reasonably close to the mouth. This is especially important in noisy surroundings.

Wind protection. The screen or foam wind-screen that comes with most lavalieres designed to work with wireless transmitters provide modest protection for light wind and plosives, however, in windy conditions you should use a lavaliere windjammer (available from Rycote). Note that proper operation of the lavaliere windjammer requires placement over the standard screen or foam wind screen, it does not work well by itself, there needs to be space between the artificial fur and the microphone, which the standard screen or foam provides.

Medical devices. The power output of wireless microphone transmitters is very low, and they are completely safe to use around humans and animals. However, RF energy may interfere with the normal functioning of implanted cardiac pacemakers or Automatic Implantable Cardiovertor-Defibrillator (AICD) devices. A body-pack transmitter should not be worn where it is immediately adjacent to such a medical device.

Antenna wire placement. A trick for maintaining antenna wire in a vertical position is to attach a thin rubber band to the end of the wire and then use a safety pin on the other end of the rubber band to attach it to the subject's clothing, with a little bit of slack. The rubber band will stretch to adjust for body movement, but will break instead of the antenna in the event it is tugged at violently.

Don't use a wireless mic unless you need mobility or cable free operation. Because of all the variables involved, there is always a chance of losing part of the dialog you are recording. Run microphone cables when you can, use wireless when you have to when cable-free and/or mobility is required. It's silly to use wireless microphones for a simple interview with the subject right in front of you. A wired microphone will sound better and is virtually trouble free.

What configuration? Different applications may require different microphones, a lavaliere with a body-pack transmitter or a handheld microphone with a plug-on transmitter. It's handy to have both available so you're ready for anything. Some plug-on transmitters don't provide phantom power, which might limit your microphone choices. Plan ahead.

Diversity. Use a diversity system if you can unless your working range is short, the area is uncrowded and the situation is straightforward with minimal movement through a space of camera and/or subject.

Multiple wireless microphones. If several wireless systems will be used, special precautions and procedures are necessary to avoid intermodulation. Factory presents on many models are designed to avoid these problems by maintaining proper spacing between multiple frequencies in use.

Troubleshooting interference. If you encounter interference problems, try to take a systematic approach to finding a solution. This type of problem can be very confusing unless you are methodical in your troubleshooting methodology. See the "Resolving interference problems" section for detailed information.

Checklist. Make a checklist of all the necessary supplies and accessories, there's a lot more stuff to worry about when working with wireless.

Frequencies

Just like a radio station, a wireless microphone system transmits and receives at a specific frequency, and this frequency is measured in Hertz (Hz). Hertz refers to cycles or vibrations per second. kHz stands for kilohertz or thousands of cycles per second. MHz stands for megahertz or millions of cycles per second. For example, FM radio stations transmit at a frequency between 88 MHz and 108 MHz. WBUR transmits at 90.9 MHz, and thus is heard at 90.9 on the FM dial.

Frequency bands and their permitted usage are allocated by the FCC (Federal Communications Commission) in the United States. Every wireless microphone system operates on a specific frequency. The FCC dictates which frequency ranges can be used by wireless microphone systems, and these frequencies are shared with television stations, communications equipment, and the large number of wireless microphone systems that other people are using. Because of frequency sharing, there is always a chance that someone else in the area might be using their wireless system at the same frequency you are using.

If any two transmitters are operating on the same frequency, severe interference will result and the wireless system will be unusable. If the frequencies of any two wireless systems are too close together, interference is likely, and one or both systems will probably be unusable. The practical operating range of a wireless system will vary from as little as 100 feet in a crowded indoor situations to approximately 1,000 feet (300 m) under direct line-of-sight outdoors.

Diversity wireless systems will almost always have better operating range than similar non-diversity systems. Diversity receivers have two external antennas.

Professional wireless systems transmit in the VHF or UHF radio frequency bands. These bands are also used for television broadcast. The UHF frequency band provides longer range and fewer drop-outs and interference compared to systems that operate in the VHF frequency band. Equipment designed for use in the VHF band is typically less expensive, however, the VHF band is overcrowded and you have to deal with harmonics from electrical mains, fluorescent tubes, refrigerators, computers, etc. These are virtually eliminated when using a UHF system. In addition, propagation of UHF radio waves is better indoor than with VHF so RF power can be kept low, which is an advantage when using multi-channel systems.

While there are really are no "bad" frequencies (a quality wireless system in theory can use almost any frequency range) if there is other activities in a particular frequency range, then you will experience interference. Therefore, you have to find a "clear" frequency to use in order to avoid interference with other transmissions in your operating area. This is why wireless microphones come in "channel ranges" (or banks) and within those ranges you can select a particular frequency to operate with in order to avoid interference with other users in the area.

Frequency Ranges

The UHF mid range (470-806 MHz) is widely used for wireless microphones. Sennheiser G2 and G3 wireless mics are available in different channel sets:

- A: 518 to 554 MHz (U.S. TV channels 22-27)
- B: 626 to 662 MHz (U.S. TV channels 40-45)
- C: 740 to 776 MHz (U.S. TV channels 59-64, this range was reallocated by the FCC and should not be used under any circumstances for wireless microphone transmission.

The G3 series is available in a newer range:

- G: 566 to 608 MHz

Other ranges you might see listed are intended for use in Europe.

The UHF mid range range represents the newest area for wireless microphones because of the vast range (336 MHz UHF versus 42 MHz VHF) and there is very little usage by comparison with VHF. Operation is usually interference-free as long as there is no local television stations using the frequency. The FCC does not assign adjacent channel operation. This means that if a channel is in use, there will not be an adjacent channel in use within a 70 mile radius. There are often open frequencies in any given city, but actual use is governed by the FCC rules which state, "Authorized services under Part 74 of the rules include wireless microphones operated on vacant TV channels by certain entities." The FCC in the U.S. and DOC in Canada rules allow wider transmission bandwidth and greater output power for UHF transmitters, which results in better audio quality, and longer operating range. The greater total bandwidth also allows for more simultaneous operating channels than the VHF range.

While the C range (740 to 776 MHz) used to be the cleanest range within this UHF mid range (470-806 MHz) it was phased out by the FCC and reallocated for emergency services and data services. Therefore, you should not use C range equipment because it is no longer legal to use this frequency range for wireless microphones.

Sennheiser Evolution G3

Northestern's Media Studios have several Sennheiser Evolution G3 kits available for students taking selected classes. These wireless mic kits are very popular among documentary filmmakers because they strikes a good balance between price, performance, and reliability.

The G3 is a UHF wireless microphone system with good performance at a very reasonable price point. Since this system operates in the UHF frequency band, it provides longer range and fewer drop-outs and interference compared to some less expensive wireless systems that operate in the VHF frequency band.

Sennheiser offers various configurations including lavaliere, handheld, and headset microphones, body pack or plug-on transmitters, and camera or rack mountable receivers. The Northeastern kits consist of a transmitter/receiver pair and a plug-on transmitter for a hand-held mic. If you are thinking of purchasing your own, I recommend the EW100-G3 kit. It includes a camera mounted receiver, body-pack transmitter, lavalier microphone, and a plug-in transmitter, 1/8" mini output cable, XLR output cable, all in one convenient package. For all but the most demanding applications, I think you'll find that the G3 series provides a reliable RF signal and good audio quality.

The transmitter and receiver have a metal housing and sport an LCD display that provides channel and frequency information as well as battery life and signal status. You can activate the back-light by pressing on the select button of either the transmitter or receiver. The on/off button is located inside the battery compartment so there's no way the device can be inadvertently turned off.

The G3 transmitter and G3 receiver use two 1.5-volt AA batteries. As a separate accessory, Sennheiser sells a compatible rechargeable battery pack and charger. Given how common AA batteries are, it's a welcome feature that you can use AA batteries rather than a dedicated rechargeable battery pack.

Transmitters and receivers are available in one of several channel banks (A, B, G, etc.) with a 36 MHz UHF frequency range offering a total of 1,440 transmission/receiving frequencies. When you purchase one of these you have to choose a frequency range: Bank A (518 - 554MHz), Bank B (626 - 662MHz), or Bank G (566 to 608 MHz).

You might come across some old equipment that uses the C range because it used to be a popular choice for use in the Boston area since it's the range with the least amount of interference. The A and B channel banks are crowded in the Boston area, but G seems to work well in the Boston area.

The choice of specific operating frequency allows you to tune a specific transmitter and receiver pair for operation in the cleanest frequency for your specific operating area. The system is pre-configured with 4 preset channels, however the channels can be reconfigured with any of the available 1,440 frequencies within the 32MHz range in 25-kHz steps. Several systems can be operated simultaneously on the different factory-preset frequencies within a channel bank. The factory-preset frequencies are intermodulation-free. You have to be careful using a user-preset, it's possible to set up the transmitter and receiver to operate in a frequency which is not approved for wireless microphone use in your operating area.

The transmitter has a mute switch and provides an input trim to adjust for the sensitivity of the microphone in use. Both the microphone mini-jack in the transmitter and the output mini-jack in the receiver have a screw ring that when tightened will prevents the plugs from being pulled out accidentally.

While some users have expressed concern over the sound quality of the standard microphone, it's pretty good for basic documentary work. Of course, a Countryman or Tram would be preferable for high-end work, but given the price of this kit, it's unreasonable to expect Sennheiser to include a high-end lavaliere. The standard mic is "good enough" for most work.

The receiver comes with a cold shoe adapter that provides a light and convenient way of mounting the receiver on top of your camcorder. If you need to mount two receivers on a camera, the cold can easily be expanded with a T-bar accessory shoe adapter.

The plug-on transmitter allows any standard dynamic microphone with a 3-pin XLR connection to be used as a wireless microphone. The transmitter utilizes the same frequency band as the body-pack and is powered by 2x AA batteries or an optional Sennheiser rechargeable battery pack, just as with the body-pack transmitter.

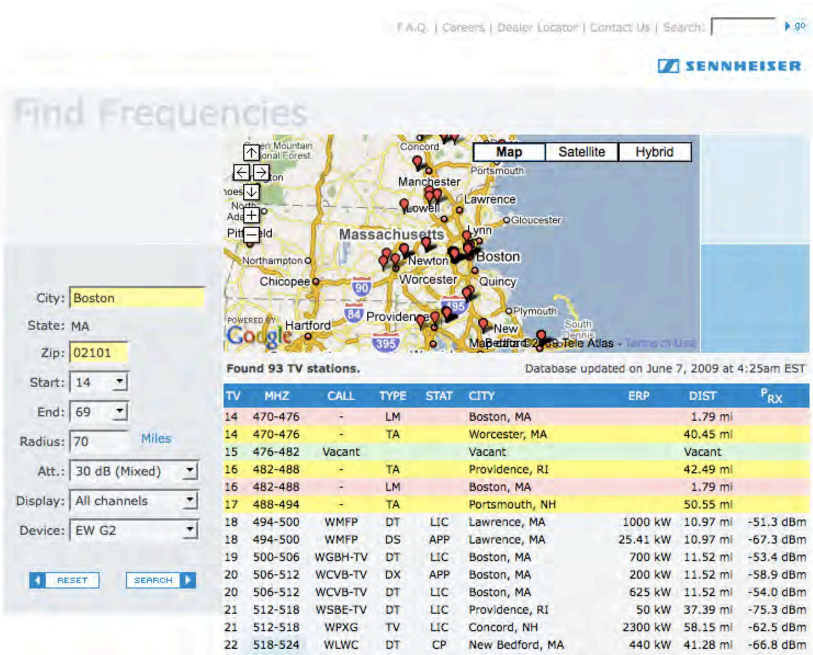
Both the transmitter and receiver have a permanently attached single flexible M3 type antenna. The effective working rage of the G3 system is between 100 and 400 feet depending on the terrain and obstructions in the area. Battery life is anywhere from five to six hours using alkaline

Note: The Sennheiser G2 series was replaced with the newer G3 system announced in 2009. The two are very similar in terms of menus and operation. The significanly new and different feature of the G3 ver the G2 is a new diversity receiver for improved performance compared to the current models.

Avoiding interference problems

When using wireless microphones, due to the nature of RF transmission, there is always a chance of interference. While some forms of interference are beyond your control, others are avoidable. Here's a list of precautions:

- Make sure that the wireless frequency you are using is not on a local TV channel (refer to the "Finding open frequencies" section).
- Check all wireless frequencies in use to make sure that two systems are not operating at the same frequency.
- Check to make sure that you don't have two wireless frequencies that are too close together. In general, 1 MHz is the recommended minimum spacing between systems.
- If a number of systems will be used at the same time, or you are working in difficult operating conditions (e.g. lots of obstacles, working around sources of RF interference), consider using better gear. Higher-end professional systems are better at rejecting interference. This is where you really hear the difference between a professional systems priced in the thousands and prosumer systems priced in the hundreds.
- Before using a system in a new location or another city, double-check for new sources of problems. Small changes in operating conditions can cause interference where none existed before.
- Check the squelch control setting on the receiver. A higher squelch setting provides better protection against interference. However, since a high setting also can cause a reduction in operating range, set the control to the lowest position that reliably mutes the interference.
- Make certain that all batteries are fresh and new. Weak batteries can make a system more susceptible to interference.



TV	MHZ	CALL	TYPE	STAT	CITY	ERP	DIST	P_{RX}
14	470-476	-	LM		Boston, MA		1.79 mi	
14	470-476	-	TA		Worcester, MA		40.45 mi	
15	476-482	Vacant			Vacant		Vacant	
16	482-488	-	TA		Providence, RI		42.49 mi	
16	482-488	-	LM		Boston, MA		1.79 mi	
17	488-494	-	TA		Portsmouth, NH		50.55 mi	
18	494-500	WMFP	DT	LIC	Lawrence, MA	1000 kW	10.97 mi	-51.3 dBm
18	494-500	WMFP	DS	APP	Lawrence, MA	25.41 kW	10.97 mi	-67.3 dBm
19	500-506	WGBH-TV	DT	LIC	Boston, MA	700 kW	11.52 mi	-53.4 dBm
20	506-512	WCVB-TV	DX	APP	Boston, MA	200 kW	11.52 mi	-58.9 dBm
20	506-512	WCVB-TV	DT	LIC	Boston, MA	625 kW	11.52 mi	-54.0 dBm
21	512-518	WSBE-TV	DT	LIC	Providence, RI	50 kW	37.39 mi	-75.3 dBm
21	512-518	WPXG	TV	LIC	Concord, NH	2300 kW	58.15 mi	-62.5 dBm
22	518-524	WLWC	DT	CP	New Bedford, MA	440 kW	41.28 mi	-66.8 dBm

- Turn off unnecessary electronic equipment and digital devices (computers, CD players, etc.). These are a relatively common cause of wireless interference, especially if located near the receiver.
- If use of computers or digital devices is necessary, keep them at least 3 feet (1 meter) away from the wireless receiver and its antennas.
- If interference does occur, see “Resolving Interference Problems” below for suggestions on solving the problem.

Finding open frequencies

The frequencies used for wireless microphones overlap the frequency ranges used for television transmission. For trouble free operation, you want to select a frequency that is not in use in your area for television transmission. This is easy to figure out using a page on the Sennheiser web site (www.sennheiserusa.com/findFrequency/) that provides you with a calculator and access to the FCC TV broadcast database. You can use it to find open frequency slots in your area. You enter your city or zip code and it provides you with a list of all the FCC broadcast licenses in the area so you can select a frequency to use with your wireless microphone system that will not overlap active segments of the spectrum.

The calculator allows you to adjust various parameters, including radius and attenuation. The FCC grants its broadcast licensees with a protection radius of 70 miles. Depending on your environment you have the choice to select up to 40 dB additional attenuation. For example, if you are going to use a wireless microphone inside a well shielded building you can assume 40 dB of attenuation. For operation outdoors near a TV transmitter, you should select 0dB.

The results are highlighted in various colors: Green: the channel is vacant and recommended; Yellow: the channel is either vacant with strong transmitters on an adjacent channel or occupied by a transmitter with weak signal strength in your location, operation of wireless systems should be possible; Red: the channel is being used by land mobile or radio astronomy services and not permitted for wireless microphones; Gray: the channel is being used by either an analog or digital TV broadcasting station and is likely to cause interference with your wireless system.

The calculator also provides a printer friendly view of the results. It’s a good idea to print out the results and keep it with your sound gear in the event you ever experience interference and need to switch frequencies.

Resolving interference problems

The process involved in correcting interference problems is complicated by the fact that there are several kinds of interference and each requires a different approach and a different solution. Sometimes interference problems have basic causes. You’ll want to check the following items:

- Make sure than no radio transmitters, including your own wireless transmitters and those of other wireless systems, come closer than 10 to 15 feet to the antennas of your wireless receiver. This can overload the receivers and increase the chances of interference.
- Make sure receiver antennas don’t touch or come too close to each other when using more than one receiver. Try to provide at least 10 inches of separation between any two receivers.
- Make sure that all transmitters have good batteries. Weak batteries can cause some transmitters to generate interference. If there is any doubt, install new, fresh alkaline batteries in all wireless transmitters.
- If you have a combination system (handheld + body-pack) with two transmitters on the same frequency, or two wireless systems on the same frequency, make sure that both transmitters are not turned on at the same time.

- Check the squelch setting on the receiver. A higher squelch setting provides better protection against interference. However, since a high setting also can cause a reduction in operating range, set the control to the lowest position that reliably mutes the interference.
- Turn off the wireless transmitter(s) and make sure that all receiver signal indicators go out. Listen to the audio system to see if the problem is still present. If it is, the trouble is probably not radio interference, but some type of non wireless interference. If the signal indicators do not go out, there may be squelch problems.

Make sure that the wireless system is really at fault. Try turning off the wireless receiver(s) and disconnecting the audio cables. If the problem is still present with the receivers off or with the cables disconnected, the trouble is almost certainly elsewhere, not in the wireless. The best approach is to first eliminate the most obvious causes of interference, then attempt to eliminate as many of the remaining possibilities as you can, one by one as follows:

- Reconfirm that it really is interference. If so, interference will almost always be present (in different forms) with the system transmitter either turned on or turned off.
- Make certain that two wireless transmitters on the same frequency are not both turned on at the same time.
- Check that the wireless frequency is not on a TV channel in local use.
- Check for wireless systems that are within approximately 1 MHz of the frequency of the system experiencing interference.
- Check for other obvious external sources, particularly a harmonic of an FM radio transmitter, cable TV systems and any type of radio transmitter.

Once all of above has been done, attempt to turn off other possible interference sources one by one, try to test for interference when the equipment is normally unpowered. Pay particular attention to communications and TV equipment, including cable TV gear, cordless phones and two-way radio equipment. Also carefully check out computers, printers, effects processors, lighting controllers and other digital devices.

Sometimes the cause of the interference proves extremely difficult to identify. In other cases, the cause becomes known, but it's impractical to correct the problem. In these situations, it is usually quicker and easier to change the wireless frequency once all of the simple steps outlined above have been checked.

For a more detailed discussion of interference, typical causes, and detailed troubleshooting techniques, see "Using Wireless Systems > Advanced Wireless Topics > Resolving Interference Problems" available through the link in the "References" section below.

References

This document draws upon the following excellent resources:

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Fine Print

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