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# **Spread Spectrum Technology and Wireless Microphone Systems**

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**A report on spread spectrum RF techniques  
as applied to wireless microphone systems  
based on currently available devices and  
technological capabilities.**



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## What is Spread Spectrum?

Spread spectrum is a special communications technique that deliberately uses much more RF bandwidth than necessary to transmit a signal. A sophisticated receiver processes the wide bandwidth RF signal to recover a much lower bandwidth version of the original signal, from which the desired data or audio information can then be efficiently extracted. This technology is of interest due to the noise-like properties of the transmitted signal and the several unique properties of the “processing” circuitry in the receiver.

Spread spectrum was originally developed by the military to improve the security of sensitive radio communications. The technology has been under active development by military and government agencies in the US and elsewhere for over 30 years. Huge sums of money have been spent on researching, designing, developing and deploying spread spectrum systems for a wide range of applications. Although there are several non-communications uses of spread spectrum, much of the focus has been on securing communications. This technology offers three main advantages for secure radio communications; it is more difficult for the adversary to detect, it is considerably harder to recover the information once the transmission has been detected, and it is resistant to intentional jamming.

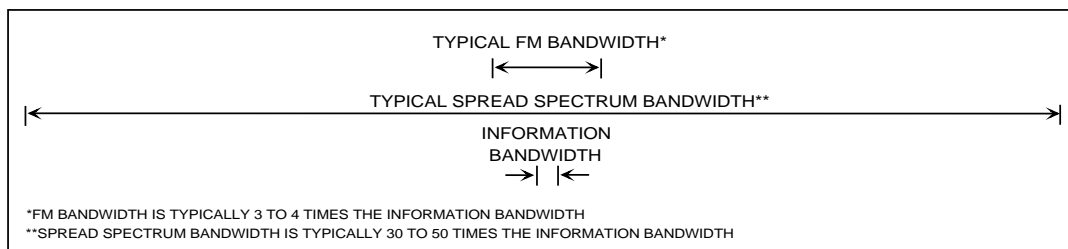


Figure 1 - Spread Spectrum Bandwidth Usage

None of these three general advantages of spread spectrum technology are of particular importance in wireless microphone systems, however. Even the jamming resistance is not very significant, since there is a large practical difference between random interference and intentional jamming. Instead, spread spectrum has become of interest in wireless microphones largely because various US Government policies that have resulted from the critical shortage of allocated radio frequencies. This technology is being heavily promoted by the Government as one means of providing wider access to radio communications by the general public and industry.

One of these new policies is to allow use of unlicensed spread spectrum transmitters in the 902 to 928 and 2400 to 2483.5 MHz bands, provided that the equipment employed has been pre-approved by the Government. Within these frequency bands, approved spread spectrum equipment may be used by anyone, at any time, for any legal purpose, subject only to some very minor conditions. Not only does this allow access to radio frequencies by many who could not previously qualify, it eliminates the often substantial effort and expense of the licensing process. For these and many other reasons, spread spectrum technology is being rapidly adopted for a wide range of private, commercial and industrial applications.

## Why Use It?

Contrary to some popular misconceptions, spread spectrum technology does not generally offer any particular technical advantages over conventional FM techniques for wireless microphone systems. In fact, with the one exception that digital transmission is allowable in spread spectrum systems, the reverse is almost always true. As it turns out, the design of spread spectrum wireless microphone systems that achieve the level of performance routinely expected of even relatively inexpensive FM systems is quite challenging. Some of the difficulties result from the technology itself, while others are related to the harsh RF environment in the 902 - 928 MHz and 2400 - 2483.5 MHz bands.

The obvious question then becomes: “Why use spread spectrum?” The answer goes back to the issue of government policy. A high percentage of potential wireless mic users do not qualify for licensed operation in the VHF and UHF TV bands, or the special 944 - 952 broadcasters band. Other than spread spectrum, their options are more or less limited to the eight special wireless mic frequencies in the 169 - 172 MHz range. Only four of these frequencies can be used at the same time, and they are very often overcrowded and interference prone. Spread spectrum offers, at least in theory, a way around this problem.

Given the critical shortage of usable radio frequencies and the ever-increasing demand for more, it appears quite unlikely that the Government will assign more frequencies for use by wireless microphones.

Wireless microphones are not viewed as being a critical communications service that greatly impact the public’s welfare and safety. In addition, highly visible users such as broadcasters, film and TV producers and related activities can license and use frequencies in unused VHF and UHF TV channels. For other types of potential users whose needs are not satisfied by the eight special VHF wireless frequencies, the Government has made available spread spectrum operation in the 902 - 928 and 2400 - 2483.5 MHz bands.

In reality, much the same situation applies to the communications needs of literally hundreds of other private, commercial and industrial groups, as well as the general public. All of these are being encouraged to make use of the same two spread spectrum bands to satisfy their needs. The incentives are legal access to the radio spectrum, even if significantly limited, and convenient unlicensed operation. The plan appears to be working; new applications are appearing almost daily and new spread spectrum equipment is being introduced at an amazing rate.

However, the total magnitude of the usage planned for these two spread spectrum bands is not generally well-known at present. Taking this into account, it is clear that wireless microphones will be sharing these bands with a huge number of other spread spectrum devices. It is also highly likely that in

most major population centers, congestion will begin to seriously limit wireless system performance within a relatively short period of time. Thus, the attraction of easy unlicensed wireless operation is more than offset by the reality that anyone and everyone has the same free access.

Another consideration is that spread spectrum technology has some significant limitations for one-way, real time communications in harsh RF environments. This is especially true when very high audio quality is required. Contrary to popular misconceptions, spread spectrum technology does not greatly reduce or eliminate interference. Rather, interference is *tolerated* by spread spectrum systems. Audio quality or digital error rates gradually deteriorate in the presence of interference, but “acceptable” communications quality can be maintained until interference is severe. The problem is that “acceptable” quality for professional wireless microphones is vastly different from “acceptable” cordless telephone or two-way radio quality.

Another common misconception is that spread spectrum offers a virtually unlimited number of communications channels. In the case of wireless microphones at least, the reverse is actually true. That is, far more conventional FM channels will be available in a given RF bandwidth than is possible with spread spectrum. There are a number of other significant limitations for spread spectrum wireless microphone systems as well. As a practical matter, it appears likely that spread spectrum wireless systems will be used not because of any advantages they offer, but rather because this is often the only available option.

### **Interference and Unlicensed Operation**

The issues of interference and unlicensed operation are of critical importance in spread spectrum wireless microphone systems. Audio problems caused by interference are a major concern of most wireless users, which often drives the price of the system used, the brand of equipment purchased, frequencies and operating band, operating techniques and many other decisions. Very often, considerable effort is expended in coordinating frequencies, reconfiguring equipment and testing systems to provide the maximum amount of protection from interference. Career opportunities might even be affected by the ability to achieve reliable and consistently interference-free operation.

Virtually all currently available wireless microphone equipment is based upon FM technology. Even if the equipment is synthesized, it operates on a single specific frequency at any given time. The avoidance of interference is based upon selecting frequencies that will not be in use by anyone else in the immediate area during the performance or event. Care is also taken to avoid intermodulation problems caused by predictable interactions between frequencies in use. Success will be achieved when the necessary information is available, the appropriate measures taken and the situation controlled. This is the fundamental reason for frequency coordination.

The situation with spread spectrum is completely different. Anyone using a spread spectrum RF device that meets the necessary technical requirements and which has been pre-approved by the government is free to use it at any time and in any place, without a license. Spread spectrum systems either operate on a large number of different frequencies in rapid

succession, or occupy an extremely wide bandwidth that can include the output of large numbers of other systems. In other words, the situation is completely uncontrolled.

A tiny sample of newly-emerged spread spectrum communications devices includes “900 MHz” cordless telephones, a wide array of remote control devices, wireless local area networks, in-home and neighborhood computer networks, consumer and industrial video links, wireless music and public address systems, all types of short range data links, short range telephone or voice communications links, alarm systems, security system data links, industrial telemetry systems, portable wireless intercom equipment and even wireless thermostats. Aside from these new uses, several previous occupants of these bands will remain. These include vehicle location systems, other radiolocation systems, scientific and medical equipment, various types of industrial equipment, radio amateurs, governmental and military communications systems and industrial RF drying equipment.

Partially offsetting this chaos is the ability of spread spectrum systems to tolerate some amount of interference. On the positive side, it is much less likely that a single strong interfering signal will completely disable the spread spectrum system, as is possible with FM equipment. On the other hand, increasing interference will gradually degrade the performance of the spread spectrum system until it eventually can no longer function. This characteristic is of great importance in military systems, where it is often absolutely essential to get an *intelligible* message thru, often despite determined efforts by the adversary to block communication. Two-way digital data systems can also function well in a degraded mode, since errored or missing data can simply be retransmitted. Even cordless telephones can tolerate a certain degree of degradation, as they naturally have low audio quality, plus noise and other anomalies are common on telephone lines.

Professional wireless microphone systems are quite another matter, however. Audio anomalies are rarely, if ever, acceptable. Gaps in the audio will be quite noticeable, especially when they start to occur frequently. While the exact nature of the audio anomalies will depend somewhat on the implementation of the spread spectrum equipment, all systems will exhibit some degree of detectable degradation with low to moderate interference levels. Unfortunately, program quality audio is quite difficult to achieve in the presence of the more or less inevitable interference in the two available spread spectrum bands. It should be noted, however, that intercom-grade audio is far more tolerant of interference, so the technology is much more applicable to wireless intercom systems.

There are a number of circuit techniques available to suppress the effects of interference in spread spectrum systems. Two-way (bi-directional or full duplex) systems using digital audio can add error correction and detection codes to the data, allowing correction of minor errors or retransmission of unusable samples. This option would not be available in spread spectrum wireless microphones because there is no return signal path. One alternate approach to this situation would be to send redundant samples, but this imposes several problems.

One problem is that two or more successive samples can easily be lost, so it is necessary to separate the samples in time. This, of course, introduces appreciable audio delay. Even then, missing samples are still quite possible, only the probability of not losing samples is improved.

There is another problem with the redundancy approach. This is that the data rate will double. Not only will this cut the number of available wireless channels by about half, it will usually also double the signal bandwidth. This, in turn, increases the chances of interference by roughly the same degree. At the expense of ever increasing complexity, data compression or reduced-bandwidth audio coding can be employed to get the data bandwidth back down to the original value or below. However, these processing techniques not only substantially increase transmitter power consumption, they typically introduce significant time delay. Total system delays of 200 to 800 milliseconds are not uncommon for some of the more efficient algorithms. This would rarely be acceptable in a wireless mic.

There are other approaches that could be discussed, but the essential point should have been made. This is that spread spectrum is far from a cure-all for wireless mic licensing, interference, channel availability and frequency coordination problems. In actual fact, spread spectrum technology is considerably better suited to communications-grade audio systems or digital data systems than it is for professional wireless microphones.

## Types of Spread Spectrum

There are two basic types of spread spectrum systems; frequency hopping and direct sequence. Of the two, frequency hopping is the simplest conceptually. In the transmitter a frequency synthesizer is controlled by a microprocessor or a roughly equivalent controller device. The transmitter frequency is changed to a different pre-assigned channel several times per second (“hopped”). The order in which the pre-assigned channels are selected is “pseudorandom.” In other words, the channel order is seemingly random, but actually repeats itself at a defined interval. The transmitted RF carrier is itself modulated with the audio or other information that is to be sent.

At the receiver, another synthesizer and controller steps the receiver channel frequency thru the same list of pre-assigned

recover the information being sent. Small gaps will be present in the “de-hopped” signal, however, due to the time required for the receiver and transmitter synthesizers to change frequency and stabilize.

The Government has specified that spread spectrum systems that are to be approved for unlicensed operation must hop at least 10 times per second and that there be at least 50 available channels (75 in the 2400 - 2483.5 MHz band). Higher hopping rates and more available channels will normally improve the system’s ability to tolerate interference. Because of the gaps in the de-hopped signal in the receiver, the recovered information will also have short sections missing. Depending upon the design, the gaps will be short as 10 or 20 microseconds, or as long as 5 or 10 milliseconds. For audio, either the effects of the missing sections must be accepted or the design must be fundamentally changed to use some form of digital coding.

Synchronization of the receiver with the transmitter is a complicated process. Even with sophisticated software algorithms and high performance hardware, the process can require significant time, during which no information is being received. Synchronization delays will be experienced upon initial turn-on and after any signal dropout; for some inexpensive designs this can require a second or more. Even for good designs, synchronization can be slowed by heavy interference and other frequency hopping systems in the area. This is especially true if the other hopper uses many common RF frequencies.

Additional spread spectrum “channels” can be obtained by using different pseudorandom hopping sequences and the same channel frequencies. That is, the order in which the transmitter hops to new frequencies can be changed. Similarly, the same hopping sequence can be used with a different set of RF frequencies. This is the source of the claim that “thousands” of channels are available. While this is somewhat true, it can also be quite misleading. Use of different sequences will only ensure that a receiver will not synchronize with the wrong transmitter. If frequencies are shared or relatively close together, however, there will be severe interference each time two transmitters randomly switch to the same RF frequency. This and several other factors limit the number of *simultaneously usable* “channels” in a given area to a surprisingly small number, as few as two or three for the 902 - 928 MHz band, for example.

Direct sequence spread spectrum makes use of the noise-like properties of pseudorandom digital sequences. The idea is to spread the energy contained in a narrow-bandwidth RF signal over a much wider bandwidth for transmission. This is accomplished by means of a

phase modulator driven by the digital pseudorandom sequence. The phase modulator distributes the energy in the original RF signal over a bandwidth proportional to the clock frequency of the sequence, usually 500 kHz or more. Thus, the amount of energy present at any one frequency within the bandwidth is quite small.

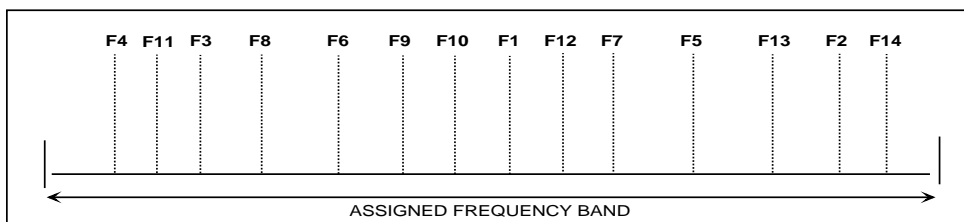


Figure 2 - Frequency Hopping Spread Spectrum

channels in the same order as for the transmitter. Once the transmitter and receiver are “synchronized”, meaning that they both change to same pre-assigned channel at the same time, the received signal will be “de-hopped”. That is, the recovered signal will be at a fixed frequency which can be demodulated to

In the receiver, a synchronized pseudorandom sequence identical to the one in the transmitter is generated and applied to a phase modulator along with the received wideband RF signal. If the two pseudorandom generators are precisely synchronized, the phase modulation will be removed from the received RF signal, producing a replica of the original narrowband RF signal. That is, the widely distributed energy in the signal received from the transmitter will be collected and reassembled into its original narrow bandwidth form.

At the same time, any interfering signals present will have their energy redistributed in the same manner as in the spread

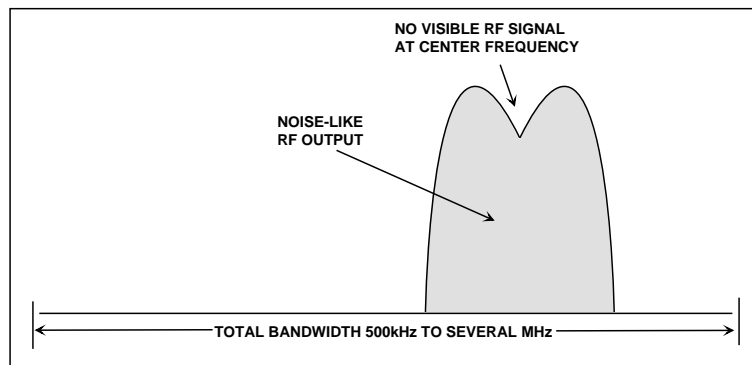


Figure 3 - Direct Sequence Spread Spectrum

spectrum transmitter. Because of the spreading of the interfering signals, very little of their energy will fall within the narrow bandwidth occupied by the desired signal. This is true even of interfering signals on the same frequency as the desired signal. Thus, within limits, direct sequence spread spectrum receivers have the ability to suppress interference. However, when high power interfering signals are present, or when there are a large number of interfering signals, the total noise energy in the receiver becomes high enough to degrade performance. This situation is expected to be common in the unlicensed spread spectrum frequency bands.

Achieving and maintaining synchronization of direct sequence spread spectrum receivers is usually even more complex than for frequency hopping receivers. Variations of the direct sequence technique, such as digitally modulating the pseudorandom code instead of the RF carrier, can further complicate the situation. Fast synchronization and re-synchronization after a dropout requires either specialized integrated circuit controllers or a fast microprocessor. Synchronizer performance in high interference RF environments, when the user is mobile, and in the presence of strong multipath is critical to the operation reliability of a system.

Frequency hopping of a direct sequence spread spectrum signal is also possible. While combining the two techniques is practical, the approach is not of particular interest in wireless mic applications for several reasons. The most significant is that the Government does not permit use of such systems in the unlicensed spread spectrum frequency bands. In addition, the acceptable alternative of changing the frequency of a direct sequence transmitter when interference becomes severe is only possible in bi-directional systems. This is because the receiver must detect the problem and command the transmitter to change frequency.

For most applications, either the frequency hopping or the direct sequence approach will usually work equally well. Although there are small differences in performance under certain circumstances, the overall performance of the two approaches is surprisingly similar. For example, spread spectrum cordless telephones are widely sold in both hopping and direct sequence configurations, yet there are no easily observable differences in operation or performance. For wireless microphones, the direct sequence technique might be slightly preferable for simple designs because it does not have the brief gaps in the data that is characteristic of hopping systems. For wireless systems which must be highly reliable and provide program quality audio, neither approach appears to have any significant advantage over the other.

## Performance Issues

The behavior of spread spectrum wireless microphone systems is substantially different from that of conventional FM wireless microphone systems. In particular, a spread spectrum system will respond in a completely different way to severe interference and low signal levels at the receiver. These differences must be understood in order to realistically and fairly evaluate the performance of a spread spectrum wireless mic system.

One area of considerable confusion is that of channel availability and capacity. It is common for spread spectrum equipment to be advertised and promoted as having "100 channels" or "hundreds of channels", or even "thousands of channels". Wireless microphone users sometimes take this to mean that dozens or even hundreds of spread spectrum wireless systems could be brought to a particular location and made to operate simultaneously. Unfortunately, this is far from the actual situation.

For spread spectrum systems, the number of "channels" reported almost always refers to the number of unique frequency and pseudorandom code combinations available. For example, if a hopper has 8 preset groups of 50 frequencies each, and 16 pseudorandom codes available, it would have 8 times 16, or 128 "channels". This does not mean that 128 such systems could operate simultaneously in one location, the actual usable number will be much lower. It does mean that if different "channels" are used for each of several systems, a receiver will usually not synchronize with the wrong transmitter and output incorrect information.

The actual maximum number of simultaneously usable systems is somewhat more difficult to determine, in part because it is greatly affected by how the information (audio or digital data representing audio) is coded and transmitted. There is a well-defined upper limit on how much information can be transmitted in a given bandwidth. This is known as "Shannon's Limit", named for its originator. Consider that spread spectrum deliberately uses much more bandwidth than necessary to transmit information, or, put another way, transmits much more information than is essential. Very simplistically, from this it can be inferred that considerably fewer spread spectrum communications links can exist in a given band than is possible with narrow bandwidth equipment.

For either spread spectrum or more conventional communications techniques, the number of usable communications channels can be maximized by reducing the bandwidth of the information being transmitted. The performance of a spread spectrum system is roughly proportional to the ratio of the information bandwidth to the spread spectrum bandwidth. In other words, reducing the bandwidth of the underlying information will allow more spread spectrum links to fit into a given frequency band. Information bandwidth can also be minimized by using efficient modulation techniques and by data compression techniques.

For program quality audio, the gap in the received signal created by frequency hopping essentially dictates digital transmission of audio. Some characteristics of direct sequence systems have much the same effect. Unfortunately, transmission of high quality audio requires a data rate of approximately 750 kilobits per second. For hopping systems, elimination of the data loss due to gaps in the RF requires a further increase in data rate. For either hopping or direct sequence, achieving the required reliability probably makes redundant transmission of data samples necessary, raising the data rate to roughly 1.5 megabits per second. This can be compared to readily available communications voice encoders providing intelligible audio with as little as 24,000 bits per second

Such high data rates not only consume large amounts of the available RF bandwidth, they present some additional technical design challenges. Coding the audio into a more efficient format, such as MPEG, requires substantial processing power, processing time and battery current. The processing time delay, which can range from roughly 200 milliseconds to nearly a second, is a particular problem for wireless microphones. Faster and less sophisticated encoding techniques are available, but the data rate reduction is often relatively small, or the process is "lossy", meaning that small audio anomalies will be present.

The circuit design of the spread spectrum wireless mic system will also have a considerable effect on the number of simultaneous wireless links available. More sophisticated designs using advanced coding and modulation techniques can substantially increase the number of available links, but at a considerable penalty in cost, size and power consumption. In addition, better filtering in the receiver, overload resistant RF amplifiers and other conventional design improvements can help increase the number of links available

Realistically, for the 902 to 928 MHz spread spectrum band, the maximum number of simultaneously usable program-quality links can be expected to be in the range of from 1 to 3. For the 2400 to 2483.5 MHz band, the range will probably be from 3 to a maximum of 6 to 8 systems. Eventually, faster and more powerful encoders and decoders might be able to significantly increase these numbers. By comparison, somewhere in the range of 16 to 40 spread spectrum voice-grade channels can be accommodated in the 902 - 928 MHz band and correspondingly more in the 2400 - 2483.5 MHz band.

With spread spectrum systems, there are a series of necessary tradeoffs between the number of links available, the information bandwidth, information reliability, circuit complexity and

cost, the product's physical characteristics, and several other factors. Simply put, more simultaneous links will be available if audio bandwidth and quality are reduced, some data loss can be accepted, the product is complex and expensive, and size, weight and power consumption are allowed to increase. When the goal is maximum audio quality, total reliability, reasonable cost, and a small lightweight design with good battery life, the number of available links is only the first in a series of sacrifices. As can be seen, the performance demanded of professional wireless microphones is not necessarily a very good fit with spread spectrum technology.

A second highly significant consideration with spread spectrum is how interference affects system performance. With conventional FM wireless mic systems, if no interfering signals or intermodulation products fall on or near the operating frequency, audio quality will be mostly a function of the RF signal level at the receiver. Under the same conditions, system range will be largely a function of transmitter power, antenna efficiency and receiver sensitivity. At extreme range, the audio becomes noisy and eventually the receiver squelches. If frequency coordination was accurately done, one wireless system does not affect another.

The situation is quite different for spread spectrum wireless mic systems. For a frequency hopper, strong interference on any one of the 50 or more RF frequencies used will cause some of the transmitted information to be missed. Even with redundancy and error correction, eventually some audio is likely to be lost if interference levels are high. When data loss does occur, it generally will be random and unpredictable, without discernible cause. The situation is similar for direct sequence spread spectrum systems.

In general, spread spectrum systems respond to interference first with increasing error rates, then by losing portions of the transmitted information, then finally by losing synchronization and shutting down. With a sophisticated (and expensive) design, data errors and missing samples can be accommodated up to a point, but eventually some portion of the transmission will be lost. This is not usually a major problem with voice grade communications or for many types of digital data. For professional quality wireless mics, however, where the expectation is essentially perfection, it becomes a severe limitation.

Another practical difficulty with spread spectrum systems is the so-called "near - far" problem. When two transmitters are operating in the same location, signal levels from both transmitters will vary wildly with changes in distance and multipath reflections. When the signal from the desired transmitter is weak due to multipath or distance, it is quite common for the undesired transmitter signal to be strong at the same time. In an FM system with the two transmitters operating on different frequencies, the filtering in the receivers will reject the undesired signal to alleviate interference. In a spread spectrum system, however, the receivers cannot provide filtering, due to the requirement that they must be wideband designs to accept the broad RF spectrum of the transmitted signal.

For direct sequence spread spectrum systems, using different pseudorandom sequences in each transmitter normally allows the receiver to avoid synchronizing with the wrong transmitter.

However, if the desired transmitter signal is weak, another very powerful transmitter, or one very close to the receiver, can overwhelm the discrimination provided by the different pseudorandom sequences. This will result in the receiver attempting to synchronize with the wrong transmitter, thereby losing the information from the desired transmitter, or losing synchronization entirely and shutting down.

A frequency hopping spread spectrum system can also have problems in a "near - far" situation if the two systems land on the same frequency briefly, or the stronger, undesired signal overloads or captures the wrong receiver.

### **Other Considerations**

The Government allows, at least in theory, up to 1 watt of transmitter power in the two designated spread spectrum bands. For wireless microphone systems, the actual limit is more on the order of 300 to 400 milliwatts due to some secondary requirements and the specified test methods. As a practical matter, the power consumption of digital circuitry, battery size and weight limitations, and case size constraints for wireless transmitters will probably dictate a considerably lower power output. Even so, battery costs are likely to be significant for spread spectrum transmitters, especially those operating in the 2400 - 2483.5 MHz band.

Both the 902 - 928 MHz and the 2400 - 2483.5 MHz spread spectrum bands are in the range where body absorption of RF energy is high. When a transmitter is worn on the body the actual radiated power will tend to be in the range of no more than about 20% of the rated transmitter power, and often on down to only 4% or so. With careful design, the results will be somewhat better for handheld transmitters, but considerable loss will still be encountered. Consequently, the promise of a "1 watt" transmitter greatly extending the useful range of wireless systems is mostly an illusion. Perhaps worse, fixed spread spectrum data transmission systems can use both 1 watt of power output and a high performance antenna to achieve 2 watts of actual radiated power. Obviously, this significantly increases their potential for interference.

Diversity operation is quite feasible for spread spectrum wireless systems. In fact, diversity operation may prove highly desirable, especially in the 2400 - 2483.5 MHz band. Contrary to some reports, spread spectrum does not inherently provide a form of diversity, at least not unless the transmission has considerable redundancy or some data loss can be accepted. For frequency hoppers, the idea that sending the same data at two different frequencies will protect against multipath is not entirely true. In some cases, the next frequency in the sequence might be relatively close; in other cases, multipath from another source might exist at the new frequency. Direct sequence systems are also susceptible to multipath, which can cause data errors, loss of synchronization and reduced effective range.

### **Outlook**

Despite its several limitations for use in professional wireless microphones, use of spread spectrum technology can be expected to rapidly increase. This will largely due to Government policy and efforts to promote this technology for a wide variety of miscellaneous communications applications. In addition, wireless users not qualified for licensed operation in the VHF and UHF TV bands may have little choice. Unfortunately, the Government's promotion of this technology inevitably will vastly increase usage of this technology and the designated frequency bands. Thus, interference can be expected to continually worsen, especially in the 902 - 928 MHz band. It appears likely that this band will become heavily saturated within a short period of time, particularly in heavily populated areas. The situation has already reached the point where manufacturers of industrial point-to-point data links are moving rapidly to the 2400 - 2483.5 MHz band.

The Government has also made a preliminary assignment of another spread spectrum band in the 5725 - 5850 MHz range. It is not yet clear that this band will be usable for spread spectrum wireless microphones, as various alternatives are still under review. In any event, it will probably be at least a few years before advancing technology would make such systems truly feasible. There is also some question as to whether or not such high frequencies are practical for wireless mic equipment to be worn on the body.

With respect to the technical issues discussed above, it is important to note that spread spectrum has been the subject of intense and well-funded research for at least 30 years. It does not seem at all likely that any fundamental technology breakthroughs are on the near horizon. It is quite probable, though, that increasing demand for consumer spread spectrum products will result in less expensive components and more cost-effective designs. The negative aspect of this is that it will come at the price of additional millions of potential interference sources.

In summary, the match between spread spectrum technology and the demands of professional wireless microphone systems is not a very good one. Perhaps this will change in the future, perhaps not. At present, those qualified for licensed operation in the VHF and UHF TV bands will be much better served by using conventional FM wireless systems, particularly UHF systems. Those not qualified for the TV bands are faced with the tough choice between using the eight special VHF wireless frequencies, or becoming spread spectrum pioneers.

## **A little bit of Lectrosonics history...**

Founded in 1971, Lectrosonics began with the manufacture of portable sound systems sold under the Voice Projector<sup>®</sup> registered trademark. The first product line consisted of a self-contained lectern/sound system and two over-the-shoulder portable sound systems.

In 1975 the first wireless microphone systems were introduced to audio visual markets. The first system was a lavalier system consisting of a belt-pack transmitter and matching receiver. Soon after this, the receiver was equipped with a rechargeable battery pack to allow it to be used with the portable sound systems. A year or so later a special version of the receiver was designed to be built inside of one of the lecterns providing a completely cordless, wireless portable sound system in a lectern configuration. In keeping with the "total portability" concept, the first self-contained speaker/amplifier/wireless system was developed. The advent of wireless microphone products introduced new markets and set the stage for further product development. The first UNICHANNEL<sup>®</sup> receiver was then designed, with ultra-narrow band crystal IF filtering to eliminate interference.

By the early 1980's, wireless microphone products had come to dominate the growth of the company, leading to further investment in engineering. The first VHF high band wireless systems were introduced in 1987, taking the proven UNICHANNEL<sup>®</sup> design to a higher frequency band. The product line expanded rapidly over the following 5 or 6 years, leading to the introduction of UHF wireless systems in 1993. By 1995, Lectrosonics was the leader in broadcast and motion picture markets with a larger market share than all other competitors combined. The introduction of synthesized UHF wireless systems in 1996, with computerized monitoring and control, brings Lectrosonics literally to the forefront of technology.

In 1989 the first automatic mixer products were introduced. The first product group was the Modular Audio Processor. This group of components found homes in courtrooms, boardrooms, conference centers and distance learning applications. The most recent modular system provides room combining, automatic microphone mixing and signal processing in a very cost effective single mainframe.

1995 saw the introduction of the LecNet<sup>™</sup> product group. This series of single rack space components featured microprocessor control and computer monitoring, setup and control via a serial bus connection. The LecNet<sup>™</sup> group combined automatic microphone mixing, matrix mixing, zoned "mix-minus" sound reinforcement, automatic room equalization and and seamless teleconferencing all together in simple to operate, inexpensive packages. The automatic mixing features an Adaptive Gain Proportional Algorithm\* and the teleconferencing interface provides Adaptive Digital Echo Suppression\*.

1996 will see the expansion of the LecNet<sup>™</sup> group to include inexpensive remote control systems and further refinement of sound system automation.

Lectrosonics remains an engineering driven company. Ongoing efforts continuously produce new designs with the latest technology in electronics and mechanical engineering.

\*US Patents 5,414,776 and 5,402,500



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