RADIO COMMUNICATIONS IN TODAY'S COMPLEX RF WORLD

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INTRODUCTION

This paper explores the use of unlicensed RF spectrum for wireless production communications. We will look at why UHF communications is becoming increasingly problematic in production environments. We will also explain the benefits of using unlicensed spectrum as well as the associated challenges. In addition we will address Frequency Hopping Spread Spectrum and other critical digital RF technologies and techniques that may be employed to overcome those challenges.

Why is UHF based communications a problem?

Reliable wireless communication is absolutely essential in today's fast-paced broadcast and live production markets, but licensing requirements, radio spectrum reallocation and the wide variety of devices competing for clear spectrum have created an array of problems for system administrators and end users throughout the world. The traditional UHF spectrum that has been widely used for wireless intercoms is becoming increasingly crowded and more difficult to use.

The FCC in the United States, as well as many other agencies around the world have reallocated UHF spectrum for uses other than traditional broadcast TV and associated secondary low power auxiliary devices. In the US, approximately 100MHz of formerly available 700MHz spectrum has been auctioned to communications companies like AT&T and Verizon. These companies are building out infrastructure to use this spectrum for personal communications and mobile media applications.

In addition FCC Chairman Julius Genachowski said in October 2009, that there is a "looming spectrum crisis". Speaking at a telecommunications industry meeting in San Diego, Genachowski underscored the growing spectrum crunch by noting that in recent years the FCC has authorized a three-fold increase in commercial spectrum while many observers have anticipated a thirty-fold jump in wireless traffic. In an interview for C-SPAN's Communicators series on November 20, 2009, the chairman said that there were a lot of ideas being offered up about what the commission could do to address the need for more spectrum. "We haven't said anything about which ideas were the best". He also said the FCC would be looking at government and commercial spectrum, but that there were "no easy pickings on the spectrum chart, and hard choices to make." Even the most optimistic outlooks call for large amounts of spectrum to be reallocated from the UHF spectrum for use in averting this crisis. Several commentators have speculated that much of this spectrum will need to come from existing UHF broadcast television.

While available UHF spectrum is decreasing, a growing number of devices are competing for its use. Production demands are driving the need for more wireless microphones, wireless IFBs and other UHF wireless devices. To add to the problem, plans are moving full speed ahead for whitespace device implementation in the remaining UHF TV spectrum. There can be no debate; the UHF spectrum is becoming more and more difficult in respect to the use of low power wireless devices.

UHF SPECTRUM OVERVIEW

There are many characteristics of the UHF spectrum that make it uniquely suited for use in many various applications. Next we will briefly look at some of the properties of the UHF spectrum and some common devices that typically utilize it.

UHF spectrum characteristics

The UHF spectrum is technically defined as extending from 300MHz to 3000MHz. For our purposes however, we will focus on that portion of the UHF spectrum between 450MHz and 806MHz as this portion of the spectrum has traditionally been used for wireless microphone and wireless communication equipment. Generally speaking, UHF frequencies have excellent propagation characteristics. They penetrate walls fairly well and are less susceptible to multipath fading than other portions of the RF spectrum. Also, because the length of UHF waves is not particularly long, between one and two and a half feet, antenna size is very manageable.

UHF low power auxiliary devices

UHF low power auxiliary devices such as wireless microphones, wireless IFBs and wireless intercom systems have been in use for decades. The core technology hasn't changed significantly in many years. Generally, these devices are now frequency agile within a portion of the UHF spectrum. Typically the operational frequency of the device can be adjusted between 18 and 24 MHz in 25kHz steps. They almost always utilize analog FM technology. These devices incorporate transmit power levels of between 50mW and 250mW. Devices that implement this type of technology have operational requirements and limitations that must be understood for successful deployment. Generally speaking, the minimum frequency separation between transmitters must be at least 500kHz. In addition, careful attention to intermodulation interference must be given when selecting frequencies for collocated use. Because of this, frequency coordination has become a particularly significant challenge for UHF users at large shows or events. Frequency coordination software programs have helped this task to some degree but these

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programs are complicated and expensive and require significant RF knowledge and experience by operators. Additional challenges for frequency selection when using wireless intercom systems is the required separation between transmit and receive frequencies. Typically this separation must be at least 90MHz. This is primarily due to a phenomenon known as desensing. Desensing occurs when a transmitter is physically located near a receiver. Desensing dramatically lowers the receivers ability to detect the desired transmission thus limiting range and performance. Because of this, wireless intercoms require two portions of spectrum to be available and separated by a fixed frequency range.

High power competition

UHF TV transmitters are the dominant, fixed location, high power sources of interference for low power auxiliary RF devices. Regulations require that low power devices not interfere with television reception in any way. Any device that is found to be interfering with television reception must, by rule, be turned off or relocated. In addition, as the name implies, low power auxiliary devices must accept all interference from television transmitters or other licensed users and have no recourse or remedy other than moving their own frequency or relocating. Low power devices must normally stay out of the six MHz television signal if that transmitter is within 75 miles.

White space devices

A full discussion of white space devices and the implications they may have on the UHF spectrum is beyond the scope of this paper. In brief, white spaces refer to frequencies utilized for TV broadcasts but that are not used locally in a given location. In the United States, white spaces have gained prominence after the FCC ruled that unlicensed devices that can guarantee that they will not interfere with assigned broadcasts can use the empty white spaces in frequency spectrum. The term white space is actually a misnomer because many existing devices such as wireless microphones, wireless IFBs and wireless intercom systems use this spectrum today.

There has been much discussion of how white space devices may be implemented and how they would guarantee that they would not interfere with existing broadcasts or low power wireless equipment. As of the date of the writing of this paper no decisive conclusions could be made as to if, when or how white space devices will be implemented and if so what impact they will have on low power wireless equipment use.

One point is very clear though, broadcasters are concerned about what white space devices could mean to TV broadcast production in the UHF band. On February 27, 2009, the National Association of Broadcasters (NAB) and the Association for Maximum Service Television, Inc. (MSTV) asked a Federal court to shut down the FCC's authorization of white space wireless devices. The plaintiffs allege that portable, unlicensed personal devices operating in the same band as TV broadcasts have been "proven" to cause interference despite FCC tests to the contrary. The lawsuit was filed in a United States Court of Appeals for the District of Columbia Circuit. The Petition for Review states that the FCC's decision to allow white space personal devices "will have a direct adverse impact" on MSTV's and NAB's members, and that the Commission's decision is “arbitrary, capricious, and otherwise not in accordance with law”.

This much we do know. If/when white space devices are implemented, the potential market size is staggering. The White Spaces Coalition which is fighting for white space device implementation boasts companies such as Microsoft, Google, Dell, HP, Intel, Philips, Earthlink, and Samsung. In addition several consumer groups have joined the White Spaces Coalition in an effort move white space device implementation through to completion. It seems that given this, the topic will not go away quietly.

PRODUCTION WIRELESS DEVICES CATEGORIZED

Not all production wireless devices are created equal. Spectrum allocated to wireless devices and required performance vary based on the function the wireless device performs. We will now look at various types of production wireless equipment and the requirements for each.

On-air devices

Wireless equipment that will provide audio for on-air use should be given the highest priority in any wireless plan. Wireless microphones are the primary elements here. Wireless microphones must provide broadcast quality audio with extremely low latency. Audio frequency response of at least 40Hz to 12kHz with dynamic range of greater than 90dB are required. RF hits are not acceptable and as such wireless microphones must operate with extremely high fade margins and be given the best portion of the spectrum and be protected from potential RF hits as frequencies are selected.

As it stands at this time, wireless microphone technology that is acceptable for on-air broadcast use, exists primarily in the form of analog FM, UHF technology. This means that wireless microphones are not a good candidate to move out of the UHF spectrum to help free up available UHF frequencies.

Talent devices

Wireless devices that provide audio to on-air talent are the next tier of wireless devices. Wireless IFB and In-Ear monitors are the primary elements in this category. These devices provide program audio and direction directly into the ear of on-air talent. These devices require high quality audio with extremely low latency. Audio frequency response of at least 80Hz to 8kHz with a dynamic range of greater than 90dB are required.

Only very occasional RF hits are acceptable when using these devices. It is important to operate with good fade margins

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and frequencies with very high expected success rates. At this point in time wireless IFB and in-ear monitor device technology that is acceptable for broadcast use exists primarily in the form of analog FM, UHF technology. This means that wireless microphones are not a good candidate to move out of the UHF spectrum to help free up available UHF frequencies.

Communication devices

As stated earlier in this paper, wireless communications is critical for successful broadcast productions. In most cases, however, these devices can tolerate a higher level of RF hits than either wireless microphones or wireless IFBs. In addition, a lower level of audio quality is usually acceptable. Audio frequency response of at least 300Hz to 4kHz is required with a dynamic range of at least 80dB. Maintaining a very high dynamic range is critical for successful communication in high noise environments. Occasional RF hits are acceptable as long as they do not compromise communications or become distracting to the user.

While most wireless intercoms in use today operate in the UHF band utilizing analog FM technology, there are other technology options that are readily available and provide high quality communications. Some of these systems also provide a higher level of features and functions. These features and functionality provide users with a more efficient and "wired-like" experience. Because of this, wireless communications make the most sense as a candidate to migrate out of the UHF spectrum when trying to free up more operational frequencies for wireless microphone and wireless IFB use.

MIGRATING WIRELESS COMMUNICATIONS OUT OF THE UHF BAND

We have now established that of the three major categories of production wireless devices, wireless communications is the best choice to migrate to a different frequency band. Now we will look at specific advantages to making that migration and what is involved.

Alternative frequency bands

If we plan to migrate wireless communications gear out of the UHF band, we must then decide to what band we will move. There are several bands that we might consider. In our discussion here, we will limit our scope to four selected bands that have the most potential for wireless communications use in broadcast production environments. In frequency order they are 902 – 928MHz (900MHz), 1880 – 1930MHz (1.9GHz), 2400 – 2500MHz (2.4GHz) and 5725 – 5875MHz (5.8GHz). All of these bands have advantages and disadvantages that need to be considered. Let's take a look at these.

World-wide operation – Availability of use for the spectrum in locations throughout the world is important for touring and rental applications. Rules vary from country to country and not all frequencies may be used in all locations.

- 900MHz – Limited availability. Acceptable for use in the USA, some South American countries and a few areas of Asia. It is not allocated for use in any CE locations.
- 1.9GHz – Acceptable in most areas of the world. Frequencies vary somewhat depending on area. 1880MHz–1900MHz in Europe, 1900MHz-1920MHz in China, 1910MHz-1930MHz in Latin America and 1920MHz–1930 MHz in the US and Canada.
- 2.4GHz – Acceptable in all areas of the world. The frequency band is basically the same worldwide with some minor variations in some locations. A few countries limit operation to a relatively small portion of the band such as France where the acceptable full power operation in outdoor applications is 2400MHz – 2454MHz.
- 5.8GHz – Is generally acceptable throughout the world, but regulations are changing frequently and it is yet to be determined where worldwide standards will land.
- Actual amount of spectrum available – The amount of spectrum that is available dictates many factors of an RF communication system. The number of collocated beltpacks, interference susceptibility, robustness of RF link and many other factors are all related to the amount of spectrum that may be used in a given location.
- 900MHz – 26 MHz
- 1.9GHz – 10 to 20 MHz depending on location. In the US only 10 MHz is available.
- 2.4GHz – 80 to 100 MHz in most locations. Some countries limit operation to less than that such as France which allows 54 MHz at full power in outdoor applications.
- 5.8GHz – 150 MHz in most locations. Spectrum allocation for this band is somewhat of a moving target at this time.

Propagation characteristics – How a particular frequency of RF wave moves through the electromagnetic spectrum and how it interacts with obstacles and other impediments is important because it will impact things such as range and RF link reliability. Generally speaking, the higher in frequency you go, the more difficulty an RF wave has in penetrating obstacles such as walls, human bodies and foliage. 900MHz acts more like traditional UHF systems while 5.8GHz has a much higher rate of signal loss due to attenuation and scattering. This affect makes use of the 5.8GHz spectrum very difficult for body-worn devices such as wireless intercom beltpacks. 1.9GHz and 2.4GHz both strike a balance between the two and offer propagation characteristics that are suitable for body-worn devices, although not as advantageous as UHF.

Regulatory constraints – Regulations for a given spectrum are important as they impact things like allowable transmitter power, modulation techniques, interoperability requirements and other elements that can have a significant impact on RF system performance and feasibility. Rules governing the

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use of 900MHz, 2.4GHz and 5.8GHz mandate that devices utilize spreading techniques or other radio technology that ensures the spectrum can support multiple users simultaneously. While this complicates radio design, it helps to ensure that the spectrum is available for all users even when there are many radios in a given location. 1.9GHz has somewhat similar requirements and also limits the use of that spectrum to voice communications.

Competition for spectrum use – The number of other devices that are competing for a given spectrum can have a great impact on RF link success.

Licensing requirements – The necessity of licensing for use of radio equipment in a given spectrum is a particularly polarizing issue. It has been said that operating broadcast production wireless equipment in a non-licensed band would greatly reduce the chance of success due to the increased competition from other non-licensed devices. This is not necessarily so as even in the current licensed UHF band the presence of unlicensed radios is rampant. The existing UHF spectrum regulations require that all users of low power secondary auxiliary devices obtain a license. The regulations also limited the ability for non-broadcast entities to obtain a license to operate radio equipment in this band. These regulations, however, have done very little to control the use of wireless microphone and wireless in-ear monitors by bands, churches, industrial and corporate users. So using a band that requires licensing does not necessarily ensure that the spectrum will remain free of non-licensed user interference. All four of the bands that we are discussing here offer license free operation in the areas for which the band is approved for use.

Considering all of the factors involved with selecting a suitable area of the spectrum to operate wireless intercom equipment, the most advantageous band of operation is the 2.4GHz band. This area of the spectrum offers a good blend of available spectrum, propagation characteristics and regulatory factors.

In review, the 2.4GHz frequency band is a globally accepted portion of the RF spectrum that is available for unlicensed use virtually anywhere, world-wide. In the US the 2.4GHz ISM band is 2400MHz to 2483.5MHz. Elsewhere in the world the band can vary slightly and can go as high as 2495MHz in certain countries.

Regulations governing the use of this band throughout the world require that all devices that operate within the 2.4GHz band use technologies that minimize interference and promote cooperative use of the available spectrum. This allows multiple devices to operate within the band with minimal interference or reduction of range and performance. This stands in stark contrast to older analog UHF radio technologies that have traditionally been used for wireless intercom systems in the past. This means you can pack a whole lot more users into a much smaller RF band while still maintaining a high quality RF link. There is also the added benefit that all of this comes without any complicated, time consuming frequency coordination.

UHF wireless intercom systems are spectrally inefficient

Typical UHF analog wireless intercom systems utilize an RF infrastructure that utilizes multiple frequencies per wireless intercom beltpack. Depending on type, a UHF wireless intercom system with 8 beltpacks would utilize between 12 and 16 discrete UHF frequencies. Additionally, groups of these frequencies would need to be separated by large amounts of spectrum to avoid desensing.

Migrating an eight beltpack wireless intercom system as mentioned above can open up space for up to 16 wireless microphones and/or wireless IFBs just by doing a frequency for frequency replacement. In reality even more wireless microphone and/or wireless IFBs could be used as these devices do not have the ridged frequency separation requirements that wireless intercom devices do. This is significant to virtually any RF plan in a broadcast production environment. Because of this fact, and because most broadcast production environments continually require higher numbers of wireless microphones and wireless IFBs, finding a way to relocate wireless intercom equipment has become a major priority for many facilities.

THE TECHNOLOGY

Once a decision has been made to move wireless intercom equipment out of the traditional UHF spectrum and into the 2.4GHz band, it is necessary to select appropriate technology to ensure acceptable performance given all of the challenges of operating in an unlicensed environment. There are a multitude of wireless schemes that might be employed to accomplish the task of implementing effective, reliable broadcast production wireless communications. To explore all of these technologies is beyond the scope of this paper. As such, we will concentrate on implementation techniques of commercially available wireless intercom products as of the time of the writing of this paper. Specifically we will be discussing one implementation used in a wireless intercom system as it relates to other in-band devices that compete for use of the 2.4GHz spectrum.

Frequency Hopping Spread Spectrum (FHSS)

The two major types of spread spectrum techniques are Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS). Most devices in the 2.4GHz band utilize a form of one of these two techniques. Common 2.4GHz devices that use some form of FHSS are Bluetooth, machine to machine serial modems, wireless telephones, some wireless cameras and wireless intercom systems. Specific FHSS implementation can vary dramatically from one device to another, but the core FHSS concept is unchanged.

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First let's look at what FHSS actually is. FHSS technology seeks to use as much of the spectrum that is available over some period of time, but only a relatively small portion of the available spectrum at any given instant in time. FHSS uses relatively narrow band transmission signals that hop, or change frequency, periodically. A pseudorandom frequency hopping pattern is used to determine what frequency will be used next. This sequence must be known by both the base and the remote radio. This requires that the remote be synchronized or "paired" to the base prior to successful RF communication. In our application for this study, our specific FHSS implementation works like this. Over time the radio system uses as much of the spectrum as possible, but it only uses about 1.3MHz at one time. This narrow band signal (1.3MHz wide is actually quite narrow as compared to DSSS signals) changes frequencies, or hops, 200 times a second or every 5ms. A relatively simple modulation technique known as Gaussian Frequency Shift Keying (GFSK) in used to modulate the narrow band carrier. An optimal modulation index is selected to enhance receiver sensitivity in the presence of Gaussian or white noise and narrow-band fading.

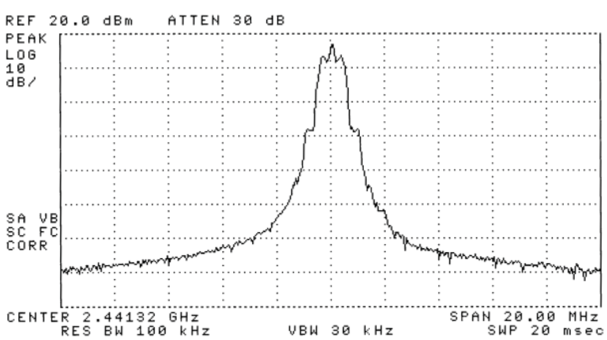

Figure 1 – Narrow band FHSS signal

Using a narrow band signal allows the wireless system to concentrate RF power into a smaller area of the spectrum at any particular moment in time. This allows the FHSS radio to maintain a reliable wireless link in the face of RF noise and interference that could otherwise be a significant problem. Additionally, changing frequencies very rapidly helps make the system less susceptible to single point external interference sources, intermodulation and multipath fading (Rayleigh fading).

FHSS is inherently a one-to-one technology and does not support multiple remote radio access. To enable multiple users on the same FHSS radio system, a technique such as Time Domain Multiple Access (TDMA) must be used. In older analog intercom systems each belt as well as the base had their own individual frequencies. This was easy to engineer, but very spectrally inefficient and very susceptible to interference and multipath fading.

By using TDMA, the base radio and all of its associated remote radios operate on the same frequency at any given moment in time. This is called multiple remote access. All of the devices on the RF link share or multiplex the frequency. First the base radio broadcasts what it has to say to each remote radio while all of the remote radios listen. Then each remote radio in turn transmits back to the base radio with its own information. Once all of this occurs the whole system changes frequencies and it happens all over again. This all takes place so fast that it seems to the intercom user that his talk and listen paths are open all of the time. The intercom user can talk and listen continuously without any interruption in either direction in true full duplex operation.

Direct Sequence Spread Spectrum (DSSS)

Now let's look at DSSS. DSSS technology is very different from the FHSS technology we just discussed. DSSS spreads out the available RF power over a much wider area of the available spectrum. DSSS transmissions do this by multiply the data being transmitted by a pseudorandom "noise" signal that is much higher in frequency than that of the original signal. This effectively spreads the energy of the original signal into a much wider portion of the available spectrum. As a result, at any given point in the spectrum, the total power at that particular frequency appears to be much less than if a narrow band FHSS signal was being used.

The resulting DSSS signal resembles white noise. However, this noise-like signal can be used to exactly reconstruct the original data at the receiving end, by multiplying it by the same pseudorandom sequence used to spread it originally. For de-spreading to work correctly, the transmit and receive sequences must be synchronized. This requires the receiver to synchronize its sequence with the transmitter's sequence via some sort of timing search process.

The most common 2.4GHz DSSS devices are Wi-Fi wireless LAN equipment. Wireless LAN technology comes in various forms or standards. The most common wireless network technology in the 2.4GHz band is 802.11b/g. 802.11b devices utilize traditional DSSS and 802.11g adds Orthogonal Frequency Division Multiplexing (OFDM) for greater speed.
Additional FHSS radio enhancements

In addition to baseline FHSS and TDMA technologies already discussed, a radio system must utilize other techniques to ensure that the most robust RF link is established and maintained at all times under varying RF conditions.

Redundant Data Transmit (2xTX) – 2xTX technology allows a wireless communication system to send all of the voice communication data twice, once each on consecutive hops. While this has the effect of halving spectral efficiency, it increases performance significantly by dramatically reducing Effective Packet Error Rate (EPER). The loss of one packet transmission in a harsh RF environment is common. However, because of the pseudorandom frequency relationship of the consecutive redundant packet transmission, the potential for loss of any single audio packet (2 consecutive data packet transmissions) is dramatically reduced. Some form of redun-

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dant transmission must be used in any 2.4GHz wireless communication system to maintain clear, intelligible audio even in harsh RF environments.

Dual antenna diversity – A radio system may incorporate the use of two antennas on either the base or remote radio side or both. Typically this technique is employed at the base radio side due to space and budgetary constraints. Each base radio antenna acts as both a transmit and a receive point just as it would in a single antenna design. In a dual antenna diversity design however, each packet transmission is sent out from one of the two different antennas. When combined with a redundant data transmission technique as discussed above, this approach enables the radio system to utilize spatial diversity, frequency diversity, time diversity and polarization diversity for each audio packet being sent. These diversity techniques greatly improve the chance of each audio packet being successfully transmitted and received.

Lost Packet Concealment (LPC) – Even in the best designed and implemented radio system it is inevitable that there will be some lost audio packets. The use of some form of advanced LPC technology allows some of the audio packets to be damaged or missing during transmission while still preserving the integrity of the audio that the user hears. A particularly good LPC technique utilizes an A-CELP, Algebraic – Code Excited Linear Prediction voice compression and lost packet concealment scheme. This system is a hybrid between a waveform compression and a true vocoder. The result is that it requires more than one audio packet loss (at least four consecutive data packet losses) before any interruption in audio quality occurs.

Utilizing baseline FHSS and TDMA technology along with all of the other specific techniques described above allows a well designed and implemented wireless system to work with other 2.4GHz devices without the need for frequency coordination. This enables end users to operate wireless intercom systems even in crowded RF environments without having to do the time consuming work of an extensive intermodulation and frequency selection scheme.

MAKING IT ALL WORK

The practical application of utilizing a FHSS wireless intercom system in the 2.4GHz band in the presence of other 2.4GHz devices that are competing for space requires some basic RF knowledge and a good common sense approach.

Interoperation of FHSS and 802.11b/g Wi-Fi systems

There are a total of 14 Wi-Fi channels that may be used throughout the world. Only 13 of these are used in most countries. Many countries, including the United States use only 1 through 11. Each channel is 22MHz wide (versus around 1.3MHz for narrow band FHSS technology) and most of the channels overlap each other which prevents their being used in close proximity to other Wi-Fi devices. Channels 1, 6, and 11 are non-overlapping channels and are the most commonly used Wi-Fi channels for that reason. When channels 1, 6 and 11 are being used together in the same location they occupy much of the entire 2.4GHz ISM band.

The specific RF characteristics of a Wi-Fi channel vary depending on network data throughput at any given moment. When the network has very little data moving through it the RF signal appears to be lower in power and less dispersed. As data throughput approaches the maximum capability of the network the RF signal appears to be higher in power and more dispersed.

The worst case scenario for interference from or to a Wi-Fi device is when the data throughput of the Wi-Fi network is very close to maximum. The good news is that by nature of the way networks function, this doesn't happen very often. Typically this type of extremely high data throughput only happens when very large files are being downloaded or there is some other high level, constant draw demand on the Wi-Fi device. Lot's of users doing normal web surfing activities on a Wi-Fi network do not typically produce maximum data throughput conditions.

Utilizing FHSS/TDMA RF design along with the other techniques discussed earlier allows a wireless communication system to work well even in the face of extensive Wi-Fi networks. The difference in perceived power on any given frequency, at any given moment in time allows a narrow band FHSS signal to penetrate a Wi-Fi signal and be received on the other end. The 802.11b/g signal appears as background noise to the FHSS radio receiver. Just as importantly, it works the other way too. Because of the greater spreading of the RF signal in Wi-Fi networks, 802.11b/g devices typically will not see narrow band frequency hoppers as a significant interference source and will maintain over 90% of their throughput even with multiple FHSS radios present.

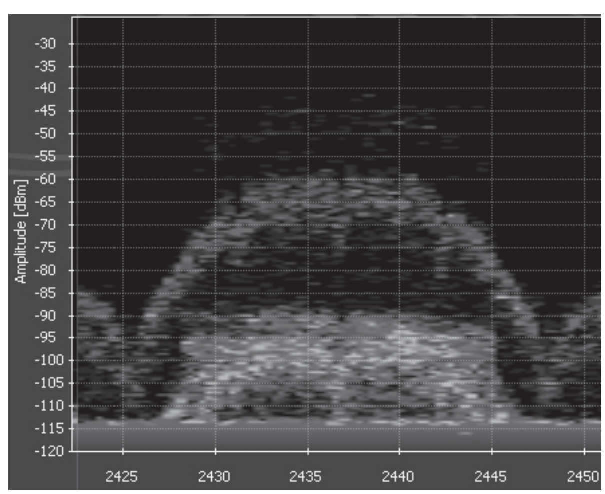

Figure 2 – 802.11b/g signal at full network throughput

As with all RF systems, the most important factor to ensuring that both wireless systems work at peak performance is to get enough physical distance between the two devices. If a

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typically powered Wi-Fi device can be kept at least 50 feet (15 meters) away from a well designed and implemented FHSS radio system's components there is an excellent chance that neither system will see any noticeable interference from the other. Of course, the more separation the better off both systems will be. Always try to separate RF systems by as much physical space as is practical.

Operating in a limited portion of the 2.4GHz band

In some cases it may be necessary or simply desirable to limit the operational band of one or more of the RF devices in the 2.4GHz band. This may be to more effectively share the band, or it may be to conform to regulations set out by governmental agencies in a specific country or region. It is the user's responsibility to select a frequency band that is legal for the country of operation. Legal 2.4GHz operation varies from country to country. Many countries allow full use of the 2400 – 2483.5MHz spectrum, but some do not.

Even in locations that allow full band operation you may wish to choose to limit the operational frequency bands of one or more devices. This may be the case if you would like to keep the FHSS wireless system from operating in a given portion of the spectrum to avoid a specific Wi-Fi device or some other interference source. Having said that, a well designed and implemented FHSS/TDMA wireless system as described above will very likely work well even when collocated with Wi-Fi or other 2.4GHz devices, so using as much of the band as your country of operation allows is usually the best idea. This is because the more spectrum a FHSS radio system has to utilize, the less impact single point interference sources will have.

Well designed 2.4GHz band devices should offer multiple operational bands. This allows the greatest flexibility when trying to avoid one wireless device with another. Simply limiting a wireless device to the high or low half of the spectrum probably will not give enough control of the operational band to be effective when attempting to segregate radio systems.

Antenna selection and placement

One of the most important factors in a successful RF system is the placement of the antennas relative to the desired coverage area. When using a dual antenna diversity system as described above, it is critically important that both antennas be connected and properly located for best RF performance.

Unlike older analog UHF wireless intercom systems that had dedicated transmit and receive antennas, modern FHSS systems typically have antennas that perform both transmit and receive functions. Because of this, some technicians believe it is possible to use one antenna in one location and the other in a different location. This type of antenna setup is not acceptable because it nullifies the redundant data transmission scheme employed in the most robust FHSS radio schemes. This is very important to remember when setting up FHSS radio antennas because this means that both antennas are necessary and equally important. Both antennas must be used together and properly placed at all times or RF performance will suffer.

Generally speaking, 2.4GHz wireless systems do best when the base antenna can maintain a direct line of site to the remote antenna. While this is not always possible, an attempt to set up the system with this in mind will help produce the best results.

There are some important things to remember when placing antennas for use with FHSS radio systems. Every antenna has a certain pattern of coverage for which it is useful. When using a dual antenna diversity system the patterns of both antennas need to overlap in the desired coverage area to ensure best RF results. Do not point directional antennas in two different directions and do not separate omni-directional antennas too far away from each other

Higher is almost always better when placing antennas. Maintaining a direct line of sight from the base radio antenna to the remote is the best possible scenario. The minimum acceptable application of this is to get the base antennas above head level. In many cases, the best execution is to get the base radio antennas well above the desired coverage area and point antennas directly down at the coverage area

Choose the location and orientation of antennas carefully. Omni-directional antennas should be located as close to the center of the desired coverage area as possible. Position directional antennas on the edge of the desired coverage area and point them across the area to be covered. Always make sure the antenna patterns overlap.

SUMMARY

The UHF spectrum is becoming much more crowded and will continue to do so in the coming years. Production requirements continually call for more wireless devices to complete the task. Migrating wireless microphone and/or wireless IFB equipment out of the traditional UHF band is not practical due to audio requirements and technical limitations at this time.

Wireless communication equipment can be effectively migrated outside the UHF band using existing technology. The 2.4GHz band is an excellent candidate for wireless communications due to its propagation characteristics, regulatory requirements and amount of actual spectrum that is available.

Spread spectrum technology allows multiple users to share a given portion of the spectrum effectively without significant impact on other users. Choosing the right implementation of spread spectrum technology is important to maximize operational range and to ensure a continuously robust RF link. Utilizing FHSS technology for wireless intercom systems helps to enable collocation with 802.11b/g Wi-Fi networks because

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of the complementary nature of the two technologies. To ensure a robust and reliable RF link is maintained even in harsh RF environments, other technologies and techniques must be utilized in conjunction with the base FHSS/TDMA RF scheme.

Eliminating wireless intercom from the UHF spectrum can provide a vast increase in the number of wireless microphones and/or wireless IFBs that may be operated at a given location.

ACKNOWLEDGEMENTS
The author would like to gratefully acknowledge the assistance of the following CoachComm team members:

Adam Frank – Product Specialist, Tempest
Debbie Hamby – Director of Marketing
Bob Kean – Senior Hardware Engineer
Louis Loving – Senior Firmware Engineer
Gary Rosen – Global Sales Manager, Tempest
Dennis Vaillancourt – Engineering Manager

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