THE BROADCAST BRIDGE

Improving Comms With 5GHz

Essential Guide

EG

ESSENTIAL GUIDES

Introduction

As broadcasters strive for more and more unique content, live events are growing in popularity. Consequently, productions are increasing in complexity resulting in an ever-expanding number of production staff all needing access to high quality communications. Wireless intercom systems are essential and provide the flexibility needed to host today's highly coordinated events. But this ever-increasing demand is placing unprecedented pressure on the existing lower frequency solutions.

The 5GHz spectrum offers new opportunities as the higher carrier frequencies involved deliver more bandwidth for increased data transmission. In excess of twenty-five non-overlapping channels, each with a bandwidth of typically 20MHz, demonstrates the opportunity this technology has to outperform legacy systems based on lower frequencies such as DECT in the highly congested 2.4GHz frequency spectrum.

Although 5GHz shares the RF spectrum with Wi-Fi, use of 5GHz is not limited to Wi-Fi, and vendors dedicated to streaming reliable audio over the airwaves instead focus on optimizing transmission for audio. Specifically, this means keeping latency low and maintaining accurate audio delivery. Audio streaming intercom solutions are based on a specific 5GHz use-case to maintain high quality audio, as opposed to Wi-Fi which provides for the generalized data delivery solution and with it potentially increased latency and dropout.

RF technologies such as OFDM (Orthogonal Frequency Division Multiplexing) further improve the robustness of transmission. Rather than transmitting on one frequency, lower symbol rate audio data is spread across multiple carriers to help protect against multi-path interference and reflections, essential for moving wireless handsets or highly dynamic environments.

As 5GHz appears in the SHF range, it displays some interesting beneficial characteristics associated with this band, specifically directionality. This allows engineers to direct narrow beams and steer them to make better use of the available power. Furthermore, interference with nearby transmissions on the same frequency is reduced allowing frequency reuse.

The concept of constructive interference provides signal amplification for certain relative signal phases through constructive interference. The superimposition effect can be used to make the best use of the available transmitter power to deliver the optimal signal.

Understanding the intricacies of concepts such as short-range devices, dynamic frequency selection, and transmitter power control are key to designing the best RF intercom delivery system possible, especially when working internationally.

All this combines to make 5GHz the ideal band for reliable high-quality intercom. The directional capabilities provide greater control when planning RF coverage and blind spots can be filled using specific directional antennas.

Tony Orme.

Broadcasters rely on clear and reliable communications now more than ever, especially when we consider how many multimillion-dollar live sports events that are broadcast annually. Our reliance on intercom continues to increase and the 5GHz band provides new opportunities to further improve live broadcast production.

Tony Orme
Editor, The Broadcast Bridge

© The Broadcast Bridge 2020

Improving Comms With 5GHz

By Tony Orme, Editor at The Broadcast Bridge

Radio frequency licensing authorities throughout the world have been applying pressure on broadcasters and their related services to reduce their RF spectrum allocation to allow cellular phone operators to continue to expand their coverage and provide improved services. Intercom plays a critical role in broadcasting, especially for live productions using RF mobile intercom systems, and their reliability and quality are critical.

Within the confines of a studio, production staff who tend not to be too mobile are able to work within the confines of a wired beltpack and desk mounted intercom panels. However, even with Power over Ethernet (PoE) systems, the cumbersome restrictions of trailing cables often prove to be prohibitive. To overcome this, intercom vendors started to use RF solutions within the 1.9GHz and 2.4GHz spectrums.

Vendors using the 1.9GHz and 2.4GHz also had to compete with users of Digital Enhanced Cordless Telecommunications (DECT) phones, and other devices such as mobile telephones, 2.4GHz lighting controllers, access points, Bluetooth, cordless phones, and Wi-Fi routers.

© The Broadcast Bridge 2020

Early adopters of these frequencies were able to use them without much interference, but as the use of other devices increases, the airwaves can become clogged.

Congested 2.4GHz

The 2.4GHz spectrum falls under the international unlicensed ISM (Industrial, Scientific, and Medical) band. The ITU (International Telecommunication Union) defined the use of this spectrum back in 1947, a long time before Wi-Fi and other users were ever considered. Although there is some variance between countries, generally, a bandwidth of 100MHz is allocated to this band providing only three or four 20MHz non-overlapping channels to be allocated (assuming a 5MHz guard band).

5GHz Solution

With all this congestion, vendors looked to the 5GHz spectrum for more space. The frequency spectrum for 5GHz under ISM regulations does vary around the world and some of the channels available fall outside of this specification, however, up to 25 channels are available, compared to three or four in the 2.4GHz spectrum.

Each channel has 20MHz bandwidth with a 5MHz guard-band. Multiple channels can be bonded together to make combined bandwidths of 40MHz and even 80MHz. The 5GHz spectrum is divided into four distinct bands; A-Lower (5,150 to 5,250GHz), A-Upper (5,250 – 5,350GHz), B (5,470 – 5,725GHz), and C (5,735 – 5,850 GHz) with restrictions for their power and location (see figure 1).

Some of the frequencies are shared with the military and other mostly weather radar services. To reduce the possibility of interference from these, DFS (Dynamic Frequency Selection) is mandated in many countries. This is a "listen then transmit" function, that is, the transmitter must first listen to the channel it wants to use to confirm it cannot detect any other traffic, and only then transmit. If other users are occupying the frequency, then the transmitter must switch to one of the other channels and repeat the procedure. If none of the frequencies are available, then it simply cannot transmit. Other non-radar devices, such as Wi-Fi access points, will not prevent usage of the channels, only specific radar patterns will, and radar is unlikely to be present in most deployments.

The SRD (Short Range Device) is a unit that may just transmit, or transmit and receive, but has a low risk of interference with other devices. This is because their power output is relatively low, or they can only work in restricted areas.

Channel Number	Frequency MHz	Band	Europe (ETSI)	North America (FCC)	Japan	Max Power	Application
36	5,180	A-Lower	Indoors	Yes	Yes	200mW/ 23dBm EIRP	Indoors
40	5,200		Indoors	Yes	Yes		
44	5,220		Indoors	Yes	Yes		
48	5,240		Indoors	Yes	Yes		
52	5,260	A-Upper	Indoors/DFS/TPC	DFS	DFS/TPC	200mW/ 23dBm EIRP	Indoor
56	5,280		Indoors/DFS/TPC	DFS	DFS/TPC		
60	5,300		Indoors/DFS/TPC	DFS	DFS/TPC		
64	5,320		Indoors/DFS/TPC	DFS	DFS/TPC		
100	5,500	B	DFS/TPC	DFS	DFS/TPC	1W/30dBm EIRP	Indoor/Outdoor
104	5,520		DFS/TPC	DFS	DFS/TPC		
108	5,540		DFS/TPC	DFS	DFS/TPC		
112	5,560		DFS/TPC	DFS	DFS/TPC		
116	5,580		DFS/TPC	DFS	DFS/TPC		
120	5,600		DFS/TPC	No Access	DFS/TPC		
124	5,620		DFS/TPC	No Access	DFS/TPC		
128	5,640		DFS/TPC	No Access	DFS/TPC		
132	5,660		DFS/TPC	DFS	DFS/TPC		
136	5,680		DFS/TPC	DFS	DFS/TPC		
140	5,700		DFS/TPC	DFS	DFS/TPC		
144	5,720		DFS/TPC	DFS	No Access		
149	5,745	C	SRD	Yes	No Access	4W/36dBm EIRP	Outdoor/FWA License Required
153	5,765		SRD	Yes	No Access		
157	5,785		SRD	Yes	No Access		
161	5,805		SRD	Yes	No Access		
165	5,825		SRD	Yes	No Access		

Figure 1 – Channel allocation of 5GHz bandwidth showing maximum power and location available and how they vary for Europe, North America, and Japan. SRD, DFS and TPC are described in the text below.

© The Broadcast Bridge 2020

Optimize Transmitter Power

To avoid interference with other devices, TPC (Transmit Power Control) is used. This system reduces the transmitted power to the minimum necessary to maintain adequate data throughput but at the same time keeping the possibility of interference to a minimum.

It is important to note that 5GHz is not 5G and it is not Wi-Fi. 5GHz is a frequency spectrum available for use under the regulations stipulated in the country it is being used in. Wi-Fi standards such as IEEE 802.11n use the 5GHz spectrum and wireless-networking routers complying with it will also use 5GHz. However, Wi-Fi does not have exclusive use of the 5GHz channels (as shown in figure-1) and shares it with other users such as broadcasters with intercom devices and earth exploration satellite services (5.255 – 5.35GHz in the UK).

5G is a data service provided by mobile phone operators and has nothing to do with 5GHz. Generally, the frequencies used are in the range 6GHz to 100GHz (and beyond) and are entirely dependent on the country they are being used.

Moving into the 5GHz band takes us into the SHF (Super High Frequency) range as defined by the ITU and refers to the spectrum 3GHz to 30GHz. Although 5GHz only just appears in this range, SHF has some interesting characteristics we can take advantage of, especially for intercom.

Directional Capabilities

As signals increase in frequency, they become more directional and the SHF range includes the lowest frequency where the radio waves can be directed in narrow beams with convenient sized antennas. They can still be used omnidirectionally but being able to steer the beams allows us to make better use of the power available. This gives the further advantage that they will not interfere with nearby transmissions on the same frequency, allowing frequency reuse.

Although the signals can penetrate walls and objects, from about 3GHz, the signals start to reflect off hard surfaces such as the roof of a sports stadium, or concrete building. However, we can use this to our advantage.

The wavelength of a 5.580 GHz radio wave is approximately 53.8mm (2.12 inches) its half wavelength is approximately 26.9mm (1.06 inches) and its quarter wavelength is approximately 13.5mm (0.53 inches). Theses wavelengths are highly relevant as they can either increase the amplitude at the receiver or completely remove it due to the effects of the superimposition of waves.

Constructive Interference

The superimposition effect applies to any two or more waves travelling in the same medium. In this case, although the beam may be quite narrow, the transmitted waves disperse in a cone shape and spread out slightly. When an antenna is in the vicinity of a surface, such as the floor, and is close to the direction of the beam, some of the radio frequency will propagate off-axis and bounce off the floor and mix back into the signal at the receive antenna. The resulting waveform will either be increased or decreased depending on the phase of the waveforms. In other words, the two paths will arrive constructively or destructively.

Augustin-Jean Fresnel (1788 to 1827) developed the concept of Fresnel-zone analysis. This describes a shape in open space called the prolate ellipsoid (similar in shape to a rugby ball or American football) that follows the shortest path between the transmitter and receiver. The shape is divided into zones. Each zone is a function of the transmission frequency, and the distance between the transmitter and receiver antennas. Zone-1 is closest to the transmission path, then zone-2, zone-3 etc.

Polarization Effects

If a transmitter sends a signal with vertical polarization and it reflects off a horizontal flat roof, then the signal will be inverted and give 180 degrees phase shift. If the same transmitter sends a signal with horizontal polarization and it reflects off a horizontal flat roof, then the reflected signal will be in phase.

If we assume horizontal polarization for transmission and an object resides within zone-1 only, the signal will bounce of it in the direction of the receive antenna, causing a phase shift of up to 90 degrees to occur on the second signal relative to the original (due to the extra distance travelled). If a reflective object resides in zone-2 but not zone-1 then the phase shift will be between 90 degrees and 270 degrees, and for zone-3 this will be between 270 degrees and 450 degrees.

This has a very interesting effect on the signal at the receive antenna. For phase shifts up to 90 degrees, due to the superimposition of waves, the interference is constructive. This means, if a signal is reflected within zone-1 only (assuming horizontal polarization), the signal at the receive antenna will be increased. This can be seen in figure-2.

If the transmit signal is sent using vertical polarization, the effect is similar but the reflected signal phase shifts by 180 degrees resulting in the destructive and constructive interference results discussed above shifting by 180 degrees. Therefore, if the polarization is vertical and a reflection occurs in zone-1 of a horizontal surface, the reflected signal will be 180 + (up to) 90 degrees resulting in a destructive interference at the receiver.

This effect, regardless of polarization, is called multipathing.

© The Broadcast Bridge 2020

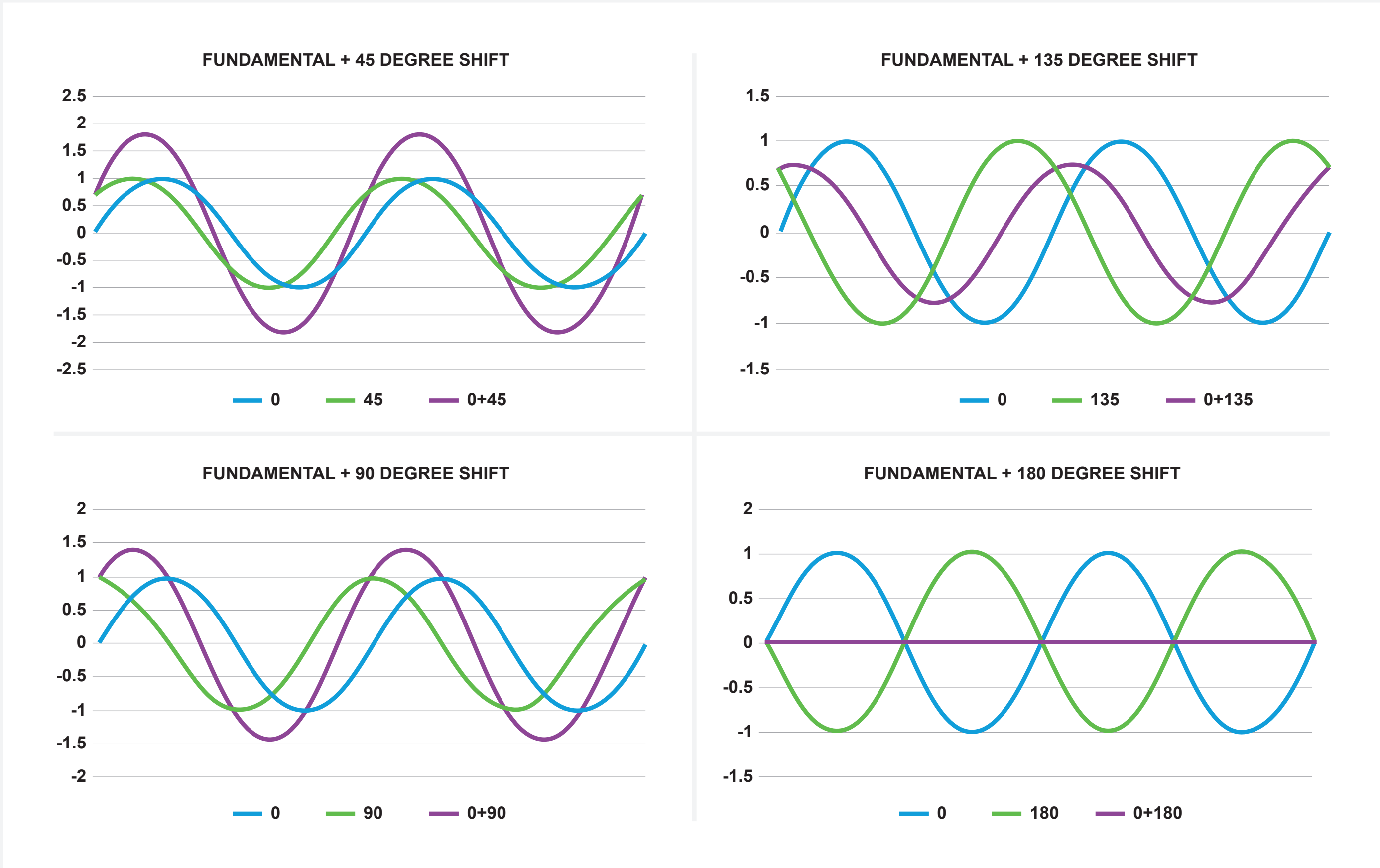


Figure 2 – top left, the blue and green signals are 45 degrees out of phase giving the construction of the purple signal (Fresnel zone-1). Bottom left, the blue and green signals are 90 degrees out of phase giving the construction of the purple signal (Fresnel zone-1). Top right, the blue and green signals are 135 degrees out of phase giving the destruction of the purple signal (Fresnel zone-2). Bottom right, the blue and green signals are 180 degrees out of phase giving complete loss of the purple signal at the receiver (Fresnel zone-2).

As we saw earlier, for a 5.850 GHz signal, the difference between the constructive quarter wavelength and destructive half wavelength is only 13.5mm (0.53 inches), so even the smallest movement at the receiver or transmitter can greatly affect the receive signal strength. Even relatively slow-moving objects can cause constructive and destructive interference in the 5GHz band. Consequently, signals of different frequencies constantly increase and decrease in amplitude depending on any relative movement and reflection.

OFDM Improvements

One solution to this is to use OFDM (Orthogonal Frequency Division Multiplexing). This is a form of digital modulation to encode data onto multiple carrier frequencies. The data is spread across multiple frequencies with a lower data rate so that when the sub-carriers increase and decrease, only small portions of the data transmission are affected, and these are averaged out over time.

Instead of transmitting a single high-rate data stream with a single carrier, which in itself may be susceptible to multipathing and potentially complete signal loss, OFDM uses many sub-carriers closely spaced within the same channel and transmitted in parallel. This helps alleviate the effects of multipathing and improves its tolerance to the multipathing discussed earlier. Although carriers and sub-carriers may increase and decrease in amplitude as multipathing occurs, the relatively slow changes in the data stream means these anomalies can generally be averaged out.

A guard-band between symbols stops any inter-symbol interference and further improves the reliability of the data transmission. The larger the guard-band, the longer any delay in the reflected signals can be tolerated. If the guard-band is too short, then inter-symbol interference will occur resulting in corrupted data. If the guard-band is too long, then data throughput efficiency will be compromised, and data rates lowered.

Closer Sub-carriers

Orthogonality occurs when the sub-carriers are brought closer and closer together to the point where they overlap. Interference is avoided as the spread is chosen such that the peak of one carrier coincides with the null in the adjacent carriers, thus negating any chance of channel interference.

Also, more can be done with the higher data rates and wider radio bandwidths, and this gives a higher audio bandwidth, lower latency and a lower noise floor in devices that use 5GHz.

Care must be taken when using OFDM systems as the sub-carriers have a very small tolerance for variation. Digitally controlled oscillators and DSP FFT solutions make encoding and decoding much more reliable, hence their proliferation in recent years.

© The Broadcast Bridge 2020

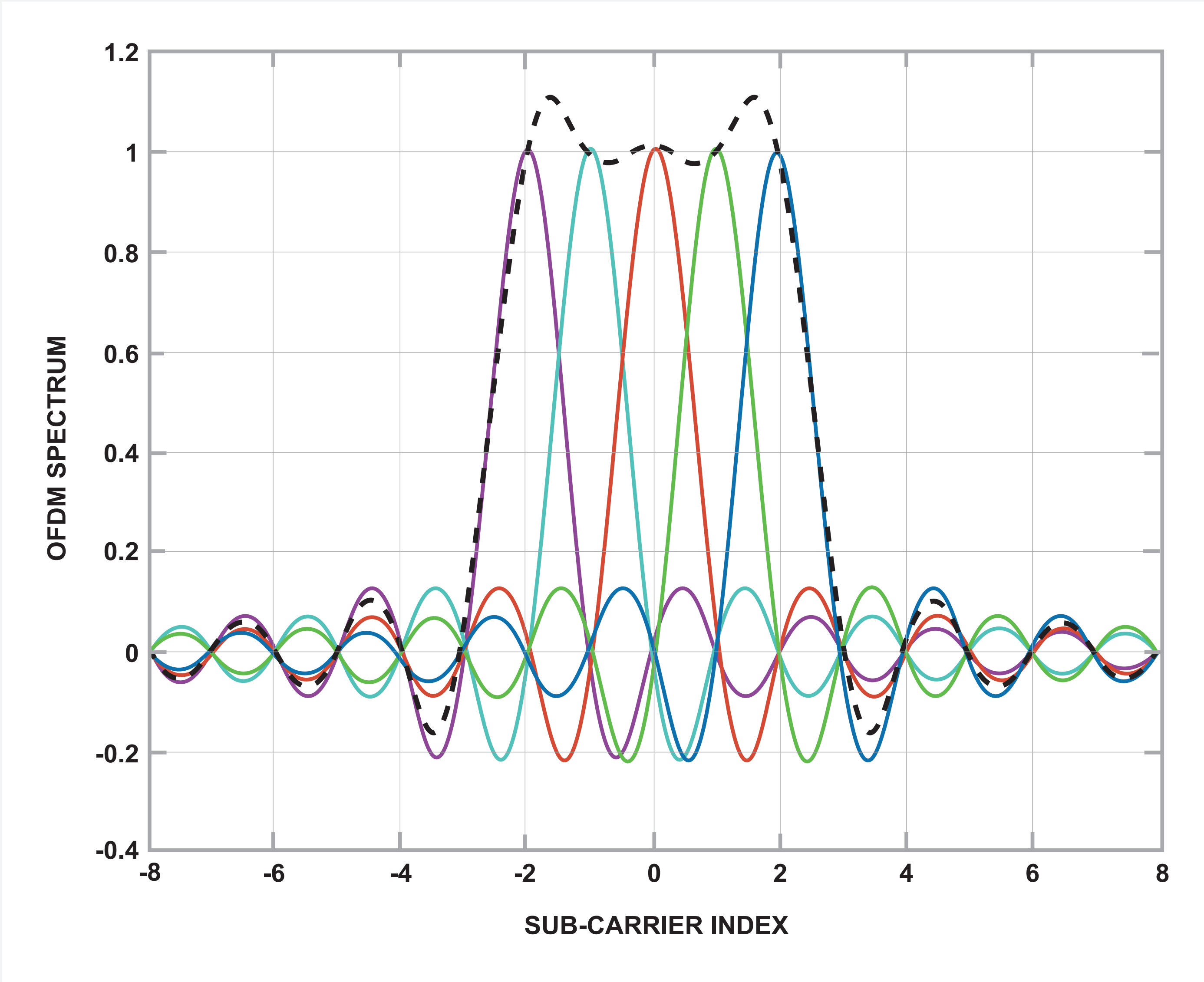


Figure 3 – multiple sub-carriers are brought together so that the peak of one sub-carrier coincides with the null of the adjacent sub-carriers, so interference does not occur. The extent of the sub-carriers forms one channel.

Broadcasters will benefit greatly from the adoption of 5GHz solutions as many more channels are available and the airwaves are relatively unused compared to the 2.4GHz band. It's also important to remember that 5GHz solutions provided by vendors specifically for broadcasting are not Wi-Fi. Intercom requires very low latency and reliable audio. Wi-Fi does not consider latency its highest priority, especially when many users want access to a computer network.

Improved RF Coverage

Furthermore, the added directional capabilities of SHF provide for greater control when planning RF coverage. Not only can omnidirectional systems be catered for, but any blind spots can be filled with specific directional antennas. Optimizing the RF energy needed further improves separation between bands to enhance resilience and remove channel interference.

Intercom is a highly specialist discipline in broadcast television and is considered by many to be the most important support service provided, especially in live productions. Production crews using RF beltpacks must be in constant communication with the studio and even the smallest outage cannot be tolerated. This is especially true in large stadiums when tens of thousands of people converge. 5GHz has the potential to massively improve communications for broadcast productions.

© The Broadcast Bridge 2020

The Sponsors Perspective

How 5GHz Boosts Digital Wireless Intercom in Broadcast Applications

By Simon Browne, VP of Product Management, Clear-Com

Wireless technologies continue to expand the creative and technical possibilities across live performance and broadcast productions.

With enhanced freedom and range, and more efficient use of the spectrum provided by digital solutions, shows are becoming more dynamic and more adventurous with deployments in increasingly complex environments such as stadiums, crowded urban areas and in venues with architectural oddities like domed ceilings. With the number of artistic, technical and logistics cues that are required for these action-packed endeavors, the use of digital wireless intercom has become even more essential.

As the range of uses for untethered, full-duplex communications continues to expand through more departments and production roles every day, much has been learned about the capabilities and limitations of existing digital wireless intercom technologies operating in the 1.9GHz and 2.4GHz bands. These areas of the spectrum have become packed with DECT and Wi-Fi -based devices used for broadcast production communications, distribution and capture — all while consumer devices continue to push for more bandwidth of their own.

Supported by

© The Broadcast Bridge 2020

Even as 1.9GHz and 2.4GHz technologies solve a multitude of problems and fulfill mission-critical roles in increasingly complex environments, the saturation of available bandwidth, constraints of legacy transmission protocols, and issues with environmental multipathing and other interference challenges have led to exploration of the possible use of the 5GHz spectrum.

The higher frequency 5GHz landscape opens up a multitude of possibilities for improvement. The increased radio bandwidth across its more than 25 wider channels (typically 20MHz each), expands data capacity, which allows for finer control, higher capacity, more robustness, flexible transmission protocols, lower latency and improved audio quality.

It was with knowledge of these benefits, and bountiful feedback from users of the Clear-Com's FreeSpeak II®, that the manufacturer invested in several years of engineering research for its new 5GHz FreeSpeak Edge™ digital wireless intercom. Input was gathered from all ends of the production field, including architecturally challenging stadium and convention center environments, indoor and outdoor live event venues, video-wall-laden conference centers and more.

Built from the ground up for 5GHz, FreeSpeak Edge incorporates entirely new radio technology that Clear-Com developed around a specialized, IoT-proven chipset. Leveraging 21st century technologies and the immense resource and development investments that have fueled innovation for mobile and IoT devices in recent years, Clear-Com further optimized the chipset for very low-latency audio transmission. The result is a robust 5GHz solution that prioritizes audio quality over raw data transmission.

Field tests are showing that 5GHz is expanding the possibilities for digital wireless intercom technologies in particularly challenging radio environments. After participating in field trials with FreeSpeak Edge at the Canadian Broadcasting Corporation (CBC) and the Montreal Bell Arena, Geoff Maurice of Gerr Audio comments, "As a FreeSpeak user from the very beginning, it's clear that Clear-Com has done their homework and checked all the boxes with the new Edge system - I've never heard something that sounded so good and covered so well. I look forward to deploying this system in some of Canada's most challenging RF environments."

The Bell Arena, Montreal.

Following a trial run with FreeSpeak Edge during their live streaming broadcast of Times Square on New Year's Eve Corey Behnke of Live X had this to say of the system, "New Year's Eve in Times Square is one of the most challenging radio environments, and this was the first time our field producers were able to be on a reliable comms system. It was especially helpful that it tied in with all our other systems so easily. We are often working in these very crowded wireless scenarios and it's great to know that now we have another wireless band with Edge. People using it in the field came back to say that the beltpack ergonomics and overall sound quality of Edge was very impressive."

Clear-Com's field trial program has been designed to ensure that the company can provide deployment expertise and guidance based on real-world scenarios. "As leaders in wireless intercom, we realize that there are so many unknowns, particularly when you go into a new wireless band. We have incorporated extensive field trials into our development process in order to provide our users with the confidence of reliable communication and experienced customer support they have come to expect from us," comments Craig Frederickson, Product Manager, Wireless for Clear-Com.

© The Broadcast Bridge 2020

Interference and Multipathing

In challenging environments like stadiums, crowded urban spaces and in the presence of architectural oddities like domed ceilings, digital wireless intercom can suffer from interference caused by reflections. With 5GHz, those challenges can become opportunities. Reflections, or more specifically, the multipathing they create, can be harnessed in favor of better transmission.

Through precise engineering of Orthogonal Frequency Division Multiplexing (OFDM) radio technology, the multipathing that easily propagates among 5GHz wavelengths can be transformed into “constructive interference.” As reflections help the signal propagate, the OFDM makes the transmission more robust, helping it to survive all the extra bouncing around and deliver clear audio signal.

OFDM is also used in Wi-Fi, but whereas Wi-Fi’s priority is to maximize raw data throughput, the design priority for intercom is improved audio performance and the robustness of the radio link. The radio technology is application-specific, and therefore highly optimized for transmission of real time audio, where Wi-Fi’s purpose is generic.

Multipathing can also cause limitations in propagation. So, in field tests with FreeSpeak Edge, Clear-Com has closely evaluated the transmission distances achieved by transceivers. In a standalone test in a large domed stadium, one transceiver covered the field and stands. In the empty stadium with no body blocking of RF, the signal went half-way up the tunnels.

In further testing during a game, four transceivers covered the stands and field for 40 beltpacks, while two transceivers were used for locker room and tunnel coverage.

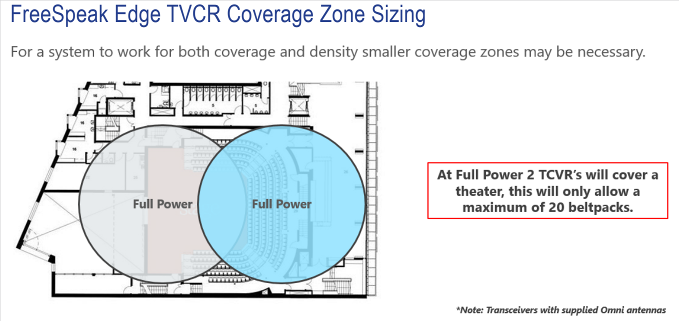
Roaming / Scalability

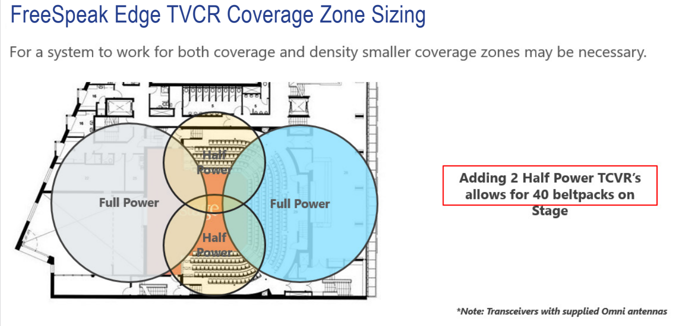
Compared to 2.4GHz technologies, 5GHz devices typically do have a shorter range compared to 2.4GHz. But that fact does allow for easier reuse of frequencies, which is ideal for high-density applications. In the relatively few cases where this might be an issue, Clear-Com’s family of products includes FreeSpeak II, which uses lower-frequency bands that can be run simultaneously to form a single, unified communications system. Overall, Clear-Com users have a lot of flexibility as they “engineer for range,” relying on a device architecture that allows for enhanced roaming across multiple transceivers, combined with deployments that maximize capabilities across spectrums.

Frequency Coordination

Another 5GHz benefit for large-scale communications is that it can be managed with frequency coordination for reduced interference. Unlike DECT technologies, the 5GHz band allow users to allocate frequencies. This Static Frequency Allocation, which is coordinated with the same methodologies as in Wi-Fi, enables technicians to dedicate channels for intercom, camera remotes, scoreboards, and other devices, improving cooperability. The remainder of channels may then be used for Wi-Fi. This guarantees the bandwidth required for intercom.

Clear-Com’s field trials are showing that even in situations where there are no free 5GHz channels, systems can still coexist with Wi-Fi on channels without hurting its performance.





Control

There are three additional controls and opportunities for fine-tuning made possible by the embodiment of 5GHz technology: Coordination, power and directionality.

Users can put their RF energy where they need it. Increased focusing capabilities allow digital wireless intercom users to narrow the likelihood they’ll interfere with other users operating in the same spectrum.

They can also tailor their system further through the reuse of channels when clean channels are hard to find, or to maximize capacity in scenarios where maximum range is not needed.

Supported by

© The Broadcast Bridge 2020

Clear-Com FreeSpeak Edge™.

This means that at a major awards event, for example, where multiple 5GHz intercoms might be used alongside various DECT-based solutions relied upon by countless outlets, it's possible to dial back the amount of radiated power and reduce interference on neighboring systems.

Additionally, in cases where transceivers can't be located near enough to the operators to use lower-power, and instead high power is needed, the antennas can be swapped out for directional antennas.

Audio Quality

The enhanced audio quality that comes along with 5GHz is due to its broad channel bandwidth, which leaves more room for audio. The result is that FreeSpeak Edge can provide up to 12kHz audio bandwidth with a lower noise floor. This enhanced audio quality and lower latency is opening up new opportunities in live broadcast where, for example, mobile announcers can use pop-up voiceover booths and a wireless beltpack for clear, full speech-band audio commentary.

Looking to the Future

With the announcement of FreeSpeak Edge, Clear-Com has solidified its position as a market leader in wireless intercom, pioneering new technologies while staying rooted in responding to the needs of its broad global customer base. By augmenting an existing product line rather than replacing it, FreeSpeak Edge can only be seen as a positive for the marketplace, providing an opportunity to capitalize on new levels of performance, audio quality, and customization now available partly due to the unique characteristics of the 5GHz band but primarily can be attributed to the innovative engineering and dedication to the customer base which is reflected in the product.

Supported by

© The Broadcast Bridge 2020

WP

WHITE PAPERS

EG

ESSENTIAL GUIDES

MEDIA

CS

CASE STUDIES

For hundreds more high quality original articles and Essential Guides like this please visit:

thebroadcastbridge.com

01/2020

Supported by

© The Broadcast Bridge 2020