Optimizing RF Spectrum Usage for Professional Wireless Intercom Operation

By: Tom Turkington, Vice President of Technology, Pliant Technologies

While it has never been easy to coordinate and execute wireless at large production events, as recently as ten years ago, UHF spectrum for use by production professionals was reasonably plentiful. Most productions could fit all of their wireless needs (wireless microphones, IFBs, in-ear monitors, communications, etc.) in the UHF spectrum with a little preplanning and best-practices application. Even in the most crowed RF cities, there was at least adequate available UHF spectrum to manage complex production wireless.

That isn't the case anymore. Due to multiple FCC auctions where almost 200 MHz of spectrum has been reallocated, we now have only about 1/3 of the UHF spectrum available for production wireless use. Transition of this spectrum for mobile broadband use is scheduled to be complete no later than July 3, 2020. Once spectrum has been repurposed, it becomes illegal and impractical for production wireless use.

Even under the best situations, there will be a very limited amount of UHF spectrum for use for production wireless equipment. For large events that require more than just a few wireless microphones, it is now necessary to migrate some production wireless equipment to other bands. Not all spectrum is created equal, so to achieve the best results in all categories of production wireless, it is imperative to prioritize based on operational requirements. Prioritizing wireless really comes down to placing gear in one of three categories:

- Audio that will go on-air, typically wireless microphones;
- Audio that is heard by talent, typically IFB and in-ear monitors; and
- Audio that is used for support and communications, typically wireless intercom.

Audio that will be broadcast requires maximum reliability, high fidelity (at minimum 40 Hz to 12 kHz), and extremely low latency. Zero dropouts or extraneous audio noise must be achieved. Extremely high fade margins must be maintained. Wireless microphone transmission technology, even modern digital transmission schemes, relies heavily on exceptionally clean spectrum and fixed RF frequency operation. This type of RF operation is almost always served best with UHF spectrum.

Wireless IFB, in-ear monitors, and other audio that the talent will hear are next on the list. Again, high reliability and low latency are key. A slightly lower fidelity (typically 80 Hz to 8 kHz) can be tolerated in IFB applications, while higher fidelity is still necessary in in-ear monitor work. Reliability here is slightly less crucial than with wireless microphones, but it is still very important. The occasional audio dropout can be tolerated, but, generally speaking, noise and frequent dropouts are not acceptable. This requires high fade margins and relatively clean spectrum. Again, this type of RF device is typically best served by the rules and conditions governing the UHF spectrum.

While wireless communications is critical for successful broadcast productions, in most cases, 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. Although, to avoid ear fatigue, audio frequency response of at least 100 Hz to 7 kHz is desirable. Also, dynamic range of at least 80 dB is necessary 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 many 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, which provide users with a more efficient and “wired-like” experience. Due to this, wireless communications make the most sense as a candidate to migrate out of the UHF spectrum.

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 to 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 902–928 MHz (900 MHz), 1880–1930 MHz (1.9 GHz), 2400–2500 MHz (2.4 GHz) and 5725–5875 MHz (5.8 GHz). All of these bands have advantages and disadvantages.

Worldwide Operation – Spectrum availability 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.

- 900 MHz – Limited availability. Acceptable for use in the U.S., Australia and New Zealand (with some frequency limitations), some South American countries, and a few areas of Asia. It is not allocated for use in any CE locations.
- 1.9 GHz – Acceptable in most areas of the world. Frequencies vary somewhat depending on area. 1880–1900 MHz in Europe, 1900–1920 MHz in China, 1910–1930 MHz in Latin America and 1920–1930 MHz in the U.S. and Canada.
- 2.4 GHz – Acceptable in all areas of the world. The frequency band is basically the same worldwide with some minor variations in some locations.
- 5.8 GHz – Is generally acceptable worldwide, but acceptable frequency ranges vary considerably throughout the world, making radio design challenging.

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.

- 900 MHz – 26 MHz (13 MHz in Australia and New Zealand)
- 1.9 GHz – 10 to 20 MHz depending on location. In the U.S., only 10 MHz is available. This limits the total number of wireless users significantly in this band.
- 2.4 GHz – 80 MHz in most locations.
- 5.8 GHz – 150 MHz in most locations; however, spectrum allocation for this band is still somewhat of a moving target.

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

While each band has its strengths and weaknesses, considering all factors involved with selecting a suitable area of the spectrum to operate wireless intercom equipment, the most advantageous bands are likely 900 MHz and 2.4 GHz. These areas of the spectrum offer a good blend of available spectrum, propagation characteristics, and regulatory factors. While 1.9 GHz does have some advantages, the fact that there is so little spectrum available for use greatly limits user count and sets the stage for significant system-to-system interference in large events.

In conclusion, 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. Wireless communication equipment can be effectively migrated outside the UHF band using existing technology. The 900 MHz and 2.4 GHz bands are excellent candidates for wireless communications due to propagation characteristics, regulatory requirements, and amount of actual spectrum that is available. These factors combine to facilitate better range and higher reliability of wireless devices.

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. This allows communications professionals to accommodate ever-growing production wireless requirements while ensuring high on-air reliability.