2.4GHz & 900MHz

UNLICENSED SPECTRUM COMPARISON

A WHITE PAPER BY INGENU

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2.4 GHZ AND 900 MHZ UNLICENSED SPECTRUM COMPARISON

Wireless connectivity providers have to make many choices when designing their technology to meet the needs of their partners and customers. One of those choices is where in the frequency band the wireless signal will operate. The choice for this is based on several different criteria. Wireless providers must balance capacity and coverage area while keeping the technology affordable. Some frequency bands are licensed and are leased to carriers as the sole users within that band. Others are unlicensed and set aside for more generic purpose and are free to use by anyone within the regulations set by the governing body.

Choosing which band to use is a balancing act. This white paper will discuss and compare two of the unlicensed bands: 2.4 GHz and 900 MHz.

WHY UNLICENSED SPECTRUM?

Through auctions, lobbying and various other methods, national governments allocate licenses for a wide range of uses. Licensed spectrum is a highly sought after commodity. In fact, one carrier recently paid $1.56 billion for 10 MHz in the 1.9 GHz to 2.0 GHz band.

For cellular communications, it is estimated that 40% of the total cost of building a network is the cost of the spectrum required. It only makes sense then to use that spectrum for the highest revenue-generating purpose. The high value of spectrum is a key reason why cellular operators are constantly migrating to newer technologies (also known as sun-setting of obsolete networks or re-farming spectrum). With the constantly increasing demand for bandwidth from human driven demands such as smart phones, tablets and streaming video, cellular providers move to the highest revenue use for this limited, expensive asset.

Unlicensed spectrum provides an alternative that comes with its own set of constraints. Governments regulate the use of unlicensed spectrum in ways that impact performance of technologies transmitting on them. For wide-area communications, the primary unlicensed bands used are 900 MHz (868 in Europe, 915 in the US) and 2.4 GHz. These unlicensed bands are free to use, but are subject to regulations and the potential interference of competing wireless signals. Technologies that can operate successfully under the regulations of these frequency bands can go to market quickly and avoid the huge costs of licensed spectrum. Even the cellular industry is beginning to test the unlicensed spectrum (Wi-Fi, call hand-off, LTE-U) to limit their spectrum costs.

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The nature of machine connectivity requires that connectivity be extremely cost-effective. Because of the sheer number of devices connected, the total cost of ownership needs to be very competitive. The extra cost of licensed spectrum already gives one strike against it. This cost, coupled with the need for machines to have a stable network for 20+ years, makes it a difficult case for cellular providers that rely on a licensed network. The demand of human-driven consumption will push the carriers to always convert older, less-efficient spectrum usage to higher throughput, higher efficiency uses. Machines and their unique needs like long battery life, no network sunsets, and coverage in distant places will never have priority on the human-centric cellular networks. So, the case for licensed spectrum doesn't optimally match the needs of most machine-to-machine (M2M) connectivity.

Thus, most Internet of Things (IoT) wide-area network providers use either the 2.4 GHz or 900 MHz bands.

2.4 GHZ TO 900 MHZ PHYSICS-BASED COMPARISON

Propagation Loss

The first place most go when comparing these two bands is propagation loss. **Propagation loss is defined as, how quickly a signal attenuates as it leaves its source.** By the laws of physics, signal attenuates more quickly at 2.4 GHz than it does at 900 MHz. This means that given the same conditions, 900 MHz propagates further. Unfortunately for 900 MHz users, this advantage doesn't translate directly to the real world as the same conditions do not exist for 2.4 GHz and 900 MHz bands. The reason they don't translate over is because of the many regulations that limit the power at which signal can be transmitted in each band. But, before we move to regulations, there is a second physics-based difference between the two bands to discuss.

Antenna Diversity

Antenna diversity is one way that wireless technologies can boost signal reception and thus overcome propagation loss. Overcoming propagation loss is another way of saying antenna diversity improves range or area covered. **Antenna diversity is using two or more antennas to improve signal reception. In order to be most effective, the antennas need to be spaced in a way that they capture the signal in unique ways to increase the probability of a reliable signal.** A typical distance between antennas is about one-quarter the wavelength. For instance, at 900 MHz, the wavelength is 33 cm (13 in.), so antenna diversity is at 8.25 cm (3.25 in.). For 2.4 GHz, the wavelength is 13 cm (5 in.), resulting in antenna diversity achieved at 3.25 cm (1.3 in.) of separation. While both bands can take advantage of antenna diversity, the 2.4 GHz band has a unique advantage in the IoT space because it allows small device sizes while still gaining a boost in signal reception.

Antenna Diversity Overcomes Propagation Loss

The 2.4 GHz has a unique advantage when these two factors are combined in the small form factor device space. **The propagation loss the 2.4 GHz band experiences due to its shorter wavelength is also the very feature than enables it to use antenna diversity to overcome said loss.** In other words, for 2.4 GHz, antenna diversity overcomes the propagation loss and is still a practical solution for small form factors. While the 900 MHz band can also use antenna diversity, it would have to sacrifice small device size, which for many applications is not an option. In the end, 2.4 GHz and 900 MHz bands come out on par in the physics-based comparison.

Of course. there are other physics related differences in transmitting signal in these two bands, but before these become an issue, government regulations usually get in the way.

GOVERNMENT REGULATION-BASED LIMITATIONS

Governments restrict the way signals are transmitted to assure proper performance of all wireless technology in their areas. These restrictions provide the rules by which wireless providers can operate. While they do give many limitations, if a provider can design a technology to take advantage of them as best as possible, they can offer unique value to device makers and customers.

There are two governing bodies we will discuss in this white paper. First is the United States' Federal Communications Commission (FCC). It's important to note that other nations also follow FCC regulations. Second is the European Telecommunications Standards Institute (ETSI) which provides the standards for

Europe and other nations who choose to use their standards as reference. We summarize how the FCC and ETSI regulate both the 2.4 GHz and 900 MHz bands in Table 1.

Equivalent Isotropically Radiated Power

One way that governments regulate radio transmissions is through controlling equivalent isotropically radiated power (EIRP). Antennas can be directional or omnidirectional. EIRP measures how much power an antenna would output if its omnidirectional signal were concentrated into a directional signal. EIRP is regulated as it helps limit interference with other wireless signals nearby.

> Governments restrict the way signals are transmitted to assure proper performance of all wireless technology in their areas.

FCC EIRP

EIRP is the addition of transmit power, antenna gain, and cable losses and can be measured with dBm (decibel-milliwatts) but is also measured in dBW (decibel-watts). As shown in Table 1, FCC regulations require that EIRP be below the 36 dBm level for both bands, but **the 2.4 GHz band has the unique ability to use 43 dBm with sectorization. Sectorization does not provide any EIRP gain in the 900 MHz band under FCC regulations.**

ETSI EIRP

In Europe, the 2.4 GHz band is allowed EIRP up to 27 dBm, depending on the application, across all 80 MHz of available bandwidth. ETSI regulates EIRP in the 900 MHz band to 250 kHz available at 27 dBm and then 1.75 MHz of band must be 14 dB or lower EIRP. While both bands may use EIRP at 27 dBm under certain circumstances in Europe, the 2.4 GHz band is able to use it across all 80 MHz of band, while the 900 MHz band only has 250 kHz of bandwidth. In clearer terms, 2.4 GHz has 320 times more bandwidth to use for 27 dBm. The severe limitation of high EIRP bandwidth in the 900 MHz band has significant performance implications when deploying wireless networks as it limits the coverage area

Modulation Techniques

Various modulation techniques are used for sending wireless signals. For the wide -area network solutions serving the IoT space, we consider utilizing direct-sequence spread spectrum (DSSS) and narrowband.

Direct-sequence Spread Spectrum

For both the 2.4 GHz and 900 MHz band, there are no legal limitations on processing gain. This means that the ratio of the spread signal to the original bandwidth can be as high as desired. This provides quite a bit of flexibility for wireless providers using DSSS modulation. DSSS can be combined with other techniques to provide robust signal in high-interference situations.

Narrowband

In FCC regulated airspace, narrowband has a 400 ms transmit time limitation for both the 2.4 GHz and 900 MHz frequencies. This means that signal sent on a given frequency can not last more than 400 ms when being sent using narrowband. This creates limitations on the flexibility of wireless providers using narrowband modulation as it doesn't allow for long message times or longer packet sizes.

For providers in Europe, either the DSSS or narrowband technique is suitable. However, if a wireless provider is aiming to provide similar levels of service globally, DSSS has no legal limitations to inhibit its performance anywhere.

Duty Cycle

Duty cycle measures the percentage of time a signal is active. A wireless technology will choose a frame length which then makes its duty cycle the percentage of that time that it is actively sending signal. Without knowing the defined frame length, one could, over a long enough period, calculate the duty cycle by taking the percentage of time the signal is active, over the period observed. Duty cycle is regulated in combination with other factors because it keeps the air clear of unnecessary signal so that more can use the same frequency with less interference.

Application providers looking for immediate global availability of their technology should look to use the 2.4 GHz band.

In the 2.4 GHz band, there are no duty cycle limitations in either the FCC or ETSI regulated areas. And while the 900 MHz band has no duty cycle limitations in the FCC areas, it has severe limitations for those sub-bands that are used for low-power wide-area (LPWA) network providers. More specifically, those sub-bands are limited to less than a 1% duty cycle. That means that a message needs to use less than 1% active transmit signal time. Over 100 seconds, that means only one second may be used to send a message. This is a serious limit on sending anything beyond the most trivial messages using the 900 MHz band in Europe.

Bandwidth and Worldwide Availability

The 2.4 GHz band has 80 MHz of bandwidth not only in both FCC- and ETSI-regulated areas but is available worldwide. This means that application providers looking for immediate global availability of their technology without costly modifications should look to use the 2.4 GHz band. The 900 MHz band isn’t actually even the same band in FCC regions as it is in ETSI-regulated regions. In the US for instance, the 900 MHz band is 915 MHz while in Europe it is only 868 MHz. That doesn’t typically cause issues as most hardware is capable of tuning to the correct frequency when choosing between these two frequencies. However, there are gaps all around the world where there is no band close to the 900 MHz frequency. For example, China’s Sub 1 GHz band is 779-787 MHz, a far cry from the 900 MHz band.

Summary

We summarize the comparison between the 2.4 GHz and 900 MHz bands in **Table 1** starting with the physics-based limitations and then finishing with the regulation-based limitations.

Table 1. 2.4 GHz to 900 MHz Comparison.

	2.4 GHz		900 MHz	
Physics-Based Limitations				
Propagation Loss	Greater than 900 MHz		Less than 2.4 GHz	
Antenna Diversity	Achievable at 3.25 cm (1.3 in.), allows very small devices		8.25 cm (3.25 in.), small form factor not possible	
Government Regulation-Based Limitations				
	FCC	**Europe**	**FCC**	**Europe**
EIRP	36 dBm, 43 dBm with sectorization	up to 27 dBm	36 dBm, no EIRP gains from sectorization	250 kHz @ 27 dBm 1.75 MHz @ ≤14 dBm
DSSS	No limitations on processing gain			
Narrowband	400 ms transmit time limit	No limitations	400 ms transmit time limit	No limitations
Duty Cycle	No limitations	No limitations	No limitations	LPWA sub-bands <1%
Bandwidth	80 MHz	80 MHz	26 MHz	250 kHz @ 27 dBm 1.75 MHz @ ≤14 dBm
Worldwide Availability	Yes, one continuous band at 2.4 GHz		No, many countries do not have band near 900 MHz	

Overall, the 900 MHz band is much more regulated than the 2.4 GHz band. While it has less propagation loss than the 2.4 GHz band, the 2.4 GHz band has a unique ability to use antenna diversity to overcome that loss while still maintaining a small form factor. Small form factor is often an important criterion for application providers in the IoT space. All told, the 2.4 GHz band has a defensible advantage in global availability, bandwidth, duty cycle limitations and has an extra boost when combined with the DSSS modulation technique. The 2.4 GHz band also has a much higher allowable EIRP with sectorization in FCC regions, and has the ability to use the 27 dBm EIRP in Europe across all 80 MHz of band.

Ingenu's patented RPMA (Random Phase Multiple Access) technology is designed to leverage all of the advantages of the 2.4 GHz spectrum to provide unprecedented coverage, solution longevity and full-featured value.

To learn more about how RPMA can enable your application, contact us at info@ingenu.com