FREQUENCY COMPARISON OF 900 MHz, 2.4 GHz & 5.8 GHz

As wireless devices continue to be deployed in ever increasing numbers, a number of questions can arise for developers or users. There are a number of factors to consider when choosing the appropriate wireless communications device. Potential for interference, protocol, transmit power, receive sensitivity, and bandwidth are all factors to consider. Knowing the physics behind This document outlines a few technical details about the common ISM (Industrial Scientific and Medical) bands available in the US and Canada .

ISM Bands

When looking at wireless networks, the same frequencies will keep coming up in RF chips, modules and other devices. That is primarily because those frequencies in are in the ISM bands and can be easily deployed without a specific license.

The ISM bands are open bands for communication as long as devices operating within those bands conform to certain transmission requirements and as long as they are capable of operating in that environment while accepting a reasonable amount of interference from other sources that are also operating within the same band.

In the United States the ISM bands are located at the following frequencies.

902-928 MHz (26 MHz of total bandwidth)

2400-2483.5 MHz (83.5 MHz of total bandwidth)

5725-5850 MHz (125 MHz of total bandwidth)

For simplicity the bands will be referred to as the 900 MHz, 2.4 GHz and 5.8 GHz bands.

General Characteristics of Frequencies

The frequency of a signal is inversely proportional to its wavelength and is given by the equation

$$f = \frac{c}{\lambda}$$

Where c is the speed of light (3.0×10^8 m/s) and λ is the wavelength in meters. As the frequency goes up, the wavelength gets smaller. For 900 MHz the full wavelength is 32.78 cm (12.9 inches)

For 2.4 GHz λ = 12.5 cm (4.9 inches)

For 5.8 GHz λ = 5.2 cm (2.0 inches)

Since antennas are a fraction of the wavelength -typically ¼ wave or ½ wave- 5.8 GHz components and antennas are a lot smaller than similar components at 900 MHz.

The most bandwidth is also available in the 5.8 GHz spectrum. What that means from a practical standpoint is the 5.8 GHz band can either support the largest data transfer speeds or it can be divided up to give the greatest number of channels.

The link budget of any communications system includes the transmit power, receive sensitivity and any losses. The largest losses in a system generally have to do with free space path loss and associated obstacles. Mathematically, every 6 dB of additional link budget in a system will double the range in a perfect line-of-sight application. Where there are obstacles, a good rule of thumb is that 10-12 dB are needed to double the range.

The disadvantage of higher frequencies is that for any given distance, there is a greater amount of free space path loss. Table 1 shows the calculated free space path for the ISM frequencies at various distances. Notice that 5.8 GHz has 16 dB more loss for any distance than 900 MHz.

Distance	900 MHz	2.4 GHz	5.8 GHz
100 m	71.6 dB	80.0 dB	87.7 dB
200 m	77.6 dB	86.0 dB	93.7 dB
1000 m	91.6 dB	100.0 dB	107.7 dB
2000 m	98.6 dB	106.0 dB	113.7 dB

Table 1 – Free space path loss at various distances

Table 2 shows signal attenuation in common construction materials for the various frequencies. The data in Table 2 was extracted from a 1997 NIST report (*Stone, W.C: 1997).* Note that except for some basic thin materials, 900 MHz performs better than 2.4 GHz and 2.4 GHz performs better than 5.8 GHz.

Material	900 MHz	2.4 GHz	5.8 GHz
Drywall (1/2 inch)	-0.3 dB	-0.7 dB	-0.1 dB
Plywood (Dry 1/4")	-0.5 dB	-1 dB	-0.2 dB
Plywood (Wet 1/4")	-1.5 dB	-3 dB	-1.5 dB
Glass (Typical window)	-2 dB	-3.5 dB	-0.5 dB
Lumber (Dry 3")	-2.5 dB	-4 dB	-8 dB
Lumber (Wet 3")	-3 dB	-7 dB	-14 dB
Brick 89mm	-3 dB	-5 dB	-15 dB
Brick 178mm	-7 dB	-11dB	-35 dB
Masonry Block (8")	-12 dB	-12 dB	-15 dB
Masonry Block (24")	-28 dB	-30 dB	-46 dB
Plain concrete (12")	-12dB	-16dB	-20 dB
Plain concrete (18")	-23dB	-30 dB	-48 dB
Reinforced Concrete (8")	-26dB	-32dB	-57dB

Table 2 – RF Attenuation in various construction materials.

Summary Conclusion

In order for a device to be used in given country, the frequency and modulation *must* conform to the communication rules set forth by the country's governing agency. The United States and Canada have similar rules for the frequencies discussed. For short range higher speed applications higher frequencies like 5.8 GHz will perform better simply because of the greater available bandwidth. If range or obstacle penetration are the primary concerns, than frequencies like 2.4 GHz or 900 MHz will generally yield better results.