Pointers on using the 5GHz WiFi bands

Legalities

In the UK , there are two main types of radio devices that use the 5GHz frequency bands. The most common are those devices that conform to the 11a standard. These are licence free bands which can only be used by devices which are part of a mobile network i.e. you cannot use these bands for bridging between stationary points.

The bands in question for UK 802.11a equipment are 5150-5350 MHz (Band A), 5470-5725 MHz (Band B). The higher band, 5725-5850 MHz (Band C), is a licensed band to be used for the Installation of Fixed Wireless Access (FWA) services between stationary points. Bands A and B have been granted licence exempt status for use by public and private users with Band A for indoor mobile/nomadic and Band B for indoor and outdoor Wireless Local Area Networks (WLAN).

Please note that this differs from the 802.11a bands used in the USA. In the USA 11a equipment also uses the range 5.725GHz to 5.825GHz (Band C). However, the permitted power levels for use in the USA are much lower than the UK: The "low" band, 5.15 – 5.25 GHz, has a maximum of 50 mW (UK 200mW). The "middle" band is 5.25 – 5.35 GHz, with a maximum of 250 mW (UK 1W). The "high" band is 5.725 – 5.825 GHz, with a maximum of 1 W (UK 4W but licensed). For both these reasons (frequency range and power) it is NOT advisable to use 5GHz radio device imported from or destined for the US market.

The operational requirements for equipment operating in the 5GHz bands are stipulated in Interface Requirement IR 2006. It contains the following conditions:

Band A (5150-5350MHz)	**Band B (5470-5725 MHz)**
All devices must comply with ERC Decision 99(23) and IR 2006 (including Transmit Power Control (TPC) and Dynamic Frequency Selection (DFS)). All devices must be part of a mobile/ nomadic network Max EIRP 200mW Indoor use only.	All devices must comply with ERC Decision 99(23) and IR 2006 (including Transmit Power Control (TPC) and Dynamic Frequency Selection (DFS)). Max EIRP 1W Indoor and outdoor use permitted.
Band C (5725-5850MHz)	
All devices must comply with IR 2007. Max EIRP 4W with a PSD not exceeding 23dBm/MHz Transmit Power Control (TPC) and Dynamic Frequency Selection (DFS) are mandatory Fixed Service Operations only	

Aside: In the EU and UK, the bands for 11a devices are A and B. Band C frequencies are used for licensed site bridging. Just to confuse things a bit more, the frequency range for Band C

(5.725-5.850Ghz) is also used for 11a devices in the US. This means that 11a equipment which is designed for the US market (and this can be both radio devices and antenna) will be using the wrong frequencies. US equipment will be set to use the frequencies which, in the UK, are allocated for licensed Band C equipment so take care with grey market equipment!

Back to 11a. To use Band A and Band B equipment must conform to ERC Decision 99(23) and IR 2006 which include two key operational requirements i.e. Transmit Power Control (TPC) and Dynamic Frequency Selection (DFS). These are covered by the IEEE 802.11h standard.

Please ensure you select the correct antenna and radio device to suite the operating band you are going to use.

The Channels

These are the channels used in the 5GHz Band A, B and C ranges:

Channel	Frequency/GHz	Band (A,B)	Maximum EIRP
36	5.18	A	200mW
40	5.20		
44	5.22		
48	5.24		
52	5.26		
56	5.28		
60	5.30		
64	5.32		
100	5.50	B	1W
104	5.52		
108	5.54		
112	5.56		
116	5.58		
120	5.60		
124	5.62		
128	5.64		
132	5.66		
136	5.68		
140	5.70		
149	5.745	C	4W
153	5765		
157	5785		
161	5805		

Notes on Indoor Use

First off, for indoor use, 5GHz radio is **much** better suited than the older 2.4GHz band. This is because it reflects and scatters better and isn't as readily adsorbed by moisture.

Scatter

One of the classic problems with 2.4GHz WiFi radio is 'it don't go through walls!'. It will, to some extent, penetrate thin wood or plasterboard (assuming the plasterboard is not foil backed) but not bricks-n-mortar ☺ Therefore, in order to get around a property, reaching the various rooms, WiFi largely needs to reflect off the walls and ceilings and get into the rooms via the door ways (and the windows). Therefore, the better the WiFi reflects or scatters then the better the transmission around a house or property.

Now, the higher the frequency the better the scatter.

To throw some maths in….

$$Scatter \propto 1/\lambda^4$$

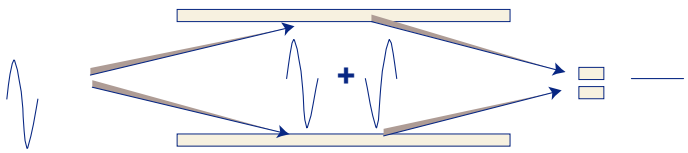
So, comparing 5.1GHz ($\lambda = 0.059m$) with 2.4GHz ($\lambda = 0.125m$) then 5.1GHz scatters 20 times more than 2.4GHz!

5GHz is therefore much better at getting around obstacles like walls and scattering around the inside of your house. At the same time the penetration of radio increases with frequency so, compared to 2.4GHs, 5GHz WiFi will actually penetrate walls/ceilings to a higher degree. Although this doesn't mean that 5GHz will pass through two-brick walls it will go through materials like plaster board or wood with less attenuation than 2.4GHz.

OFDM (orthogonal frequency division multiplexing)

One of the problems with signal scatter is reduced signal quality due to multi-reflection effects like multi-path fades. Multipath can be likened to an acoustic echo – RF reflections received by the radio from multiple, indirect paths. The echoes, though attenuated from the main path (if there is one), are delayed in time. The distribution of echoes over time, or delay spread, create intersymbol interference (ISI), a condition where the delayed energy from one transmitted data symbol begins to corrupt the symbol next arriving along a faster RF path. Another consequence of multipath is fading. As waves of the same frequency, the radio is sensitized to peaks and valleys of power that are created by the overlapping waves. Depending on how the signals overlap, they can either augment or cancel each other out.:

Multipath interference occurs when reflected signals cancel each other out. 802.11a uses a slower symbol rate to minimize multipath interference.

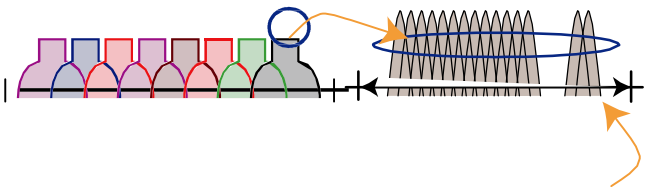


OFDM (orthogonal frequency division multiplexing) modulation is the answer. OFDM is used by 5GHz devices (and also 11g, 2.4GHz devices) and has been growing in usage due to its ability to overcome many of the signalling shortcomings of earlier WiFi technology like multi-path fades.

The next bit is a bit technical (and, if I was honest, a bit beyond me ☺) and could be skipped if you want: Just take it for granted that 5GHz WiFi devices have OFDM technology which improves the radio signal indoors:

Technical bit….

802.11a uses Orthogonal Frequency Division Multiplexing (OFDM), an encoding scheme that offers benefits over spread spectrum in channel availability and data rate. Channel availability is significant because the more independent channels that are available, the more scalable the wireless network becomes. The high data rate is accomplished by combining many lower-speed subcarriers to create one high-speed channel.



Eight channels in lower 5-GHz band One Channel (detail) 20-MHz

Each carrier is

-300kHz wide

802.11a uses OFDM to define a total of 8 non- overlapping 20 MHz channels across the 2 lower bands; each of these channels is divided into 52 subcarriers, each approximately 300 KHz wide. By comparison, 802.11b/g uses 3 non-overlapping channels.

A large (wide) channel can transport more information per transmission than a small (narrow) one. As described above, 802.11a utilizes channels that are 20 MHz wide, with 52 subcarriers contained within. The subcarriers are transmitted in "parallel", meaning they are sent and received simultaneously. The receiving device processes these individual signals, each one representing a fraction of the total data that, together, make up the actual signal. With this many subcarriers comprising each channel, a tremendous amount of information can be sent at once.

With so much information per transmission, it obviously becomes important to guard against data loss. This is accomplished by using Forward Error Correction (FEC). At its simplest, FEC consists of sending a secondary copy along with the primary information. If part of the primary information is lost, insurance then exists to help the receiving device recover (through sophisticated algorithms) the lost data.

This way, even if part of the signal is lost, the information can be recovered so the data is received as intended, eliminating the need to retransmit. Because of its high speed, 802.11a can accommodate this overhead with negligible impact on performance.

Water

The other major factor is adsorption by water and moisture. 2.4GHz is very close to the O-H frequency and, of course (remember your O level chemistry ☺), water is full of O-H bonds. To put that into layman's terms, water REALLY adsorbs 2.4GHz WiFi. On the other hand 5.1GHz is only slightly adsorbed by water. This means that 5.1GHz will actually penetrate wet or damp objects a lot better than 2.4GHz e.g. green (new) wood, and also walls or ceilings which are not 100% dry (very few walls in a house are 100% dry).

Net result: 5.1GHz is a much better WiFi solution for inside buildings.

Conclusion

5GHz is better for indoor use than 2.4GHz ☺ !

Notes on Outdoor Use

All of the factors discussed under the Indoor section about 5GHz apply equally well (if not more so) for outdoor use i.e. much better scatter and much lower adsorption by water.

Scatter

The traditional problem with 2.4GHz for outdoor use is you really need to have a clear line of site between the transmitting end and the receiving end. Because 5GHz scatters so much better then 2.4GHz then it's MUCH better at getting around buildings or obstructions in the way. It tends to do this by reflecting off surrounding buildings to reflect around the obstructions in the direct line of site. As calculated above, 5GHz scatters 20 times better than 2.4GHz. so it's really suited to non-LOS (non line of site) installations.

OFDM

If you are interested in the techy stuff then read this subject above. In either case take it for granted that 5GHz radio devices have OFDM and this improves reception in dirty signal conditions. ☺

Water

Also, as discussed above, 5GHz WiFi is much less readily adsorbed by water. This means it is much less likely to be effected by damp or wet air or wet objects e.g. fog, mist, rain, trees and other vegetation. Again, factors which make it much more suited to outdoor use.

Free Space Loss

This is one of the bad points concerning 5GHz WiFi ☹ The Free Space Loss (FSL – the amount of signal lost in the air) calculation includes a factor $20Log_{10}F$ (where F= frequency in GHz). Therefore if F is higher then the loss is higher by a factory of 20Log. In reality this equates to and extra FSL for 5GHz of 6db. Which, for the same amount of power, signal sensitivity, antenna gain etc… then 5GHz WiFi is only going to go half as far as 2.4GHz ☹ Against that the permitted power outputs for 5GHz are higher than 2.4GHz so this will tend to compensate for the extra air loss (see below).

Power

The legal permitted power outputs for 5GHz WiFi are higher than 2.4GHz. The EIRP limit for Band C (remember than Band C is the legal 5GHz band you can use outdoors for building to building linking in the UK – license required) is 4W (36db). This compares to the 20db limit for 2.4GHz. This means, despite the 6db extra FSL (discussed above) for 5GHz WiFi it still has a potential 100% extra range over 2.4GHz at the legal power limits. The actual range will depend upon factors such as signal sensitivity, and antenna gain, but, these factors being equal then 5GHz should have a greater legal range. Typically (depending upon the radio device used and bandwidth required) it should be possible to get ranges of up to 5Km or more and still stay within the legal constraints.

Fresnel zone

In our WiFi technical discussion we mention the Fresnel zone:

http://www.solwise.co.uk/los.htm

The Fresnel zone is clearance required for a WiFi beam to clear an obstruction without causing potentially degrading, diffraction effects on the signal. The height of this zone is proportional to the square root of the wavelength (sorry, more maths ☺):

$$F_N \propto \sqrt{\lambda}$$

So, the larger the wavelength (2.4GHz is about 12.5cm and 5GHz is about 6cm) then the larger the Fresnel zone. Comparing 5GHz to 2.4GHz then the Fresnel zone is about doubled. This means you require less clearance when trying to send a 5GHz signal over an obstruction compared to a 2.4GHz link.

Conclusion

5GHz is technically better for outdoor use than 2.4GHz ☺ !

5GHz and Legalities

As discussed above, there are two 5GHz bands permitted for outdoor use in the UK: These are Band B and Band C. For legal use in the UK then Band B equipment must conform to IR2006 which includes EIRP of 1W maximum. Band C equipment is for fixed links only and equipment must conform to IR2007 which also limits power to 4W EIRP.

Band C has been specifically set aside by Ofcom for building-to-building connectivity. In order that Ofcom can keep tab of 5GHz outdoor users they have implemented a licensing regime to cover Band C. In essence any user wishing to setup an outdoor link for FWA needs to first off all ensure that their radio devices confirm to Ofcoms IR2007 regulation. E.g. the EnGenius EOC-5611P product from Solwise conforms to IR2006 and IR2007.

Then they need to apply to Ofcom for a site licence; the licence is not hard to obtain and is only £50 per network (with an ongoing charge of about £1 per year per connection point) – not worth worrying about.

Further information on the legal implications of Band C usage can be found from Ofcoms site:

Link to Ofcom faq site for 5GHz operation - 5.8GHz FWA