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 11n and 11ac standards. These are licence free bands which can be used by wifi devices.

The bands in question for the UK for license free use 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 use and Band B for indoor and outdoor Wireless Local Area Networks (WLAN).

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 5GHz Wifi devices are A and B with 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 5GHz wireless devices in the US. This means that equipment which is designed for the US market (and this can be both radio devices and antenna) might will be using frequencies incorrect for the Uk and EU. US equipment might 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 UK 5GHz. 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 more so it's far better for NLOS (non-line-of-sight) i.e. walls where it'll reflect and scatter to go through doorways or windows better.

Scatter
One of the classic problems with any 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 ☺ Ofcom have done some rough tests which show that half of the wifi signal for 2.4GHz is lost with a single brick wall. So a double brick wall would half it again so that's something like three quarters of the signal lost going through a normal house outside wall. For 5GHz it's actually worse by about 40%! So in order to get the wifi signal around a property, to reach 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 propagation around a house.

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!

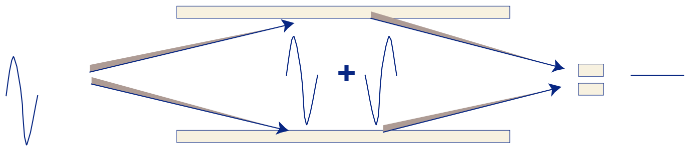
5GHz is therefore much better at getting around obstacles like walls and scattering around the inside of your house.

So although 5GHz is worse than 2.4GHz at 'going through things' the better scattering means a lot more of it is reflected from the surface of the walls so the net effect is better propagation radio.

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.

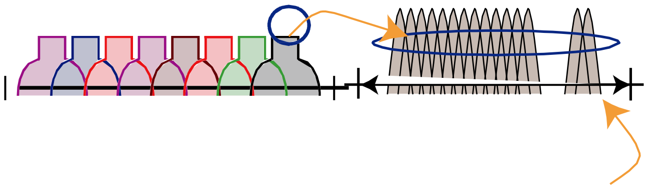


OFDM (orthogonal frequency division multiplexing) modulation is the answer. OFDM is used by 5GHz devices (and also 11g, 2.4GHz devices) and has been growing in usage due to its ability to overcome many of the signalling shortcomings of earlier WiFi technology like multi-path fades.

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….

5GHz wifi 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.



5GHz 54meg (the old 11a standard) or 11n or 11ac wifi all use OFDM to define a number of non-overlapping channels and each of these channels is divided into multiple subcarriers. By comparison the 2.4GHz ISM band used for wifi only has 3 non-overlapping channels.

A large (wide) channel can transport more information per transmission than a small (narrow) one. 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 re-transmit. Because of its high speed 5GHz wifi can accommodate this overhead with negligible impact on performance.

Water

Now the effect of water, essentially the higher radio frequency you go the more the absorption by water. So 2.4GHz is BETTER at penetrating damp surfaces or damp air! However, the higher the radio frequency the more bounce, and the wetter the surface the better the bounce. So 5GHz will bounce off damp walls better than 2.4GHz and with less attenuation (because it's not being scattered as much within the surface of the wall).

btw a common layman mistake (and I've fallen for this myself in the past) is to assume, because microwave cookers use 2.45GHz then, obviously, 2.4GHz radio waves are more readily adsorbed by water than 5GHz. I mean if it was the other way around and 5GHz was more readily adsorbed than 2.4GHz then why would you not use a higher frequency like 5GHz for a microwave cooker? Well the fact is that most microwave cookers do, in fact, use the less readily adsorbed 2.45GHz frequency. So why? Well there are a two main reasons why it's better to use a lower frequency like 2.45GHz instead of a higher frequency like 5GHz or even 10GHz (because 10GHz is even better at being adsorbed):

Well the primary reason is you need good penetration of the the food by the microwaves. Using a frequency where the microwave stops after only going half an inch into the food is NOT good for cooking the food all the way through. So although a higher frequency would be adsorbed better it would be no good at evenly heating your food. You need a lower, not so easily adsorbed, frequency for that. Actually you can see this 'overheating the outside' effect when you try to heat up liquids in a microwave cooker like a mug of tea :-) You frequently have to keep on stopping the cooking and then stirring up the tea before microwaving a bit longer.

There is also a more technical reason and that's the idea of how much energy is absorbed at each 'pass' of the microwave? The radio waves form a 'standing' wave inside your microwave oven. The width of this wave is set by the frequency. At 2.4GHz the width of the microwave is wider than it is at 5GHz (half the width at 5GHz) so for each pass of this wave over the food more energy is transferred into the food with the wider, lower frequency, wave.

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 when this frequency is used outdoors i.e. scatter and 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.

Water

Also, as discussed above, 5GHz WiFi is more readily adsorbed by water. This means, if you have two radio devices, one at 5GHz and one at 2.4GHz, then, if the air is damp, more of the signal will be adsorbed by the water in the air by the 5GHz device. You therefore need more RF power to overcome this. However, since the legally permitted power levels for 5GHz wifi are higher than 2.4GHz then this isn't an issue – not if you're doing legal power levels anyway.

Free Space Loss

This is another issue against 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 an 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 ☹ However, as mentioned above, the permitted legal power outputs for 5GHz are higher than 2.4GHz so this is more than compensated for this extra 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 licensed 5GHz band you can use outdoors for building to building linking in the UK) is 4W (36db). This compares to the 20db limit for 2.4GHz. This means, despite the 6db extra FSL (discussed above) and increased adsorbtion in atmospheric water, 5GHz WiFi still has a potential twice the 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 5Km or even 10Km and 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 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.

In essence any user wishing to setup an outdoor link for fixed or bridge links needs to first off all ensure that their radio devices conform to Ofcoms IR2006 or 2007 regulations (depending upon the frequency band used). e.g. all the EnGenius indoor or outdoor wifi products from Solwise conform to IR2006 and IR2007.

For those readers that are interested in using 5GHz Band C for fixed links then more information can be found from Ofcoms site:

Link to Ofcom faq site for 5GHz operation – Ofcom

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