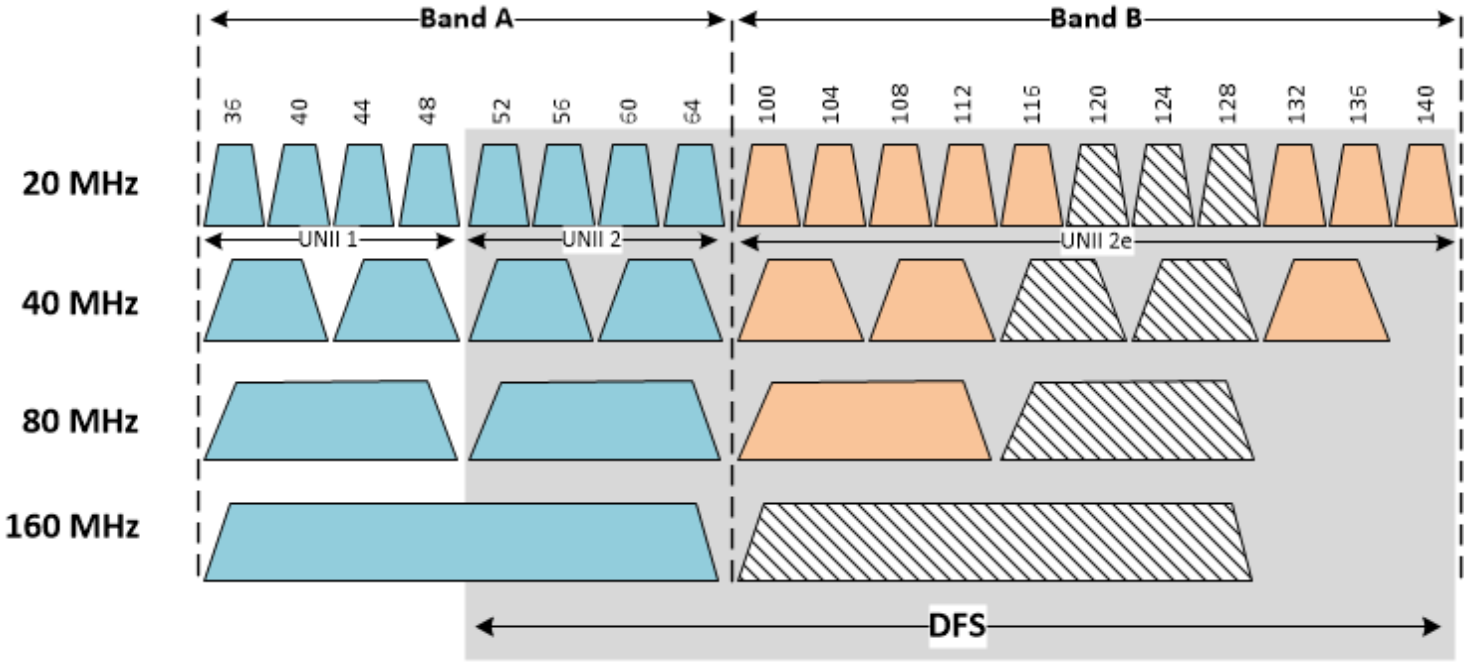
Bowden Networks

White Paper

# Unlicensed 5GHz Wi-Fi Spectrum in the UK (Feb 2015)



## Forward

Welcome to the second edition of my white paper on usage of the 5GHz band within the UK. I decided to update this document as I have had a few enquiries about the validity of the information presented, as time has moved on since version 1 was released in August 2013.

Unfortunately, there have been no changes in the spectrum available for Wi-Fi networks within the UK, so all information within the original paper is still valid. However, I thought it would be useful to add in some additional considerations now that the 802.11ac standard amendment has been ratified and there is growing adoption of 802.11ac Wi-Fi equipment.

There appears to be growing recognition of the need for additional spectrum within the 5GHz band for the UK, following the publication of OFCOM's report: "The future role of spectrum sharing for mobile and wireless data services - Licensed sharing, Wi-Fi, and dynamic spectrum access" There will hopefully some clarity around any new spectrum to be made available within the UK following the ITU World Radiocommunication Conference in November 2015.

## Background

I decided to put this brief white-paper together as I found it quite challenging to find definitive information about how the 5GHz band is used within the UK for unlicensed, 802.11 ("Wi-Fi") communications. There are plenty of Wi-Fi text-books around that talk about spectrum allocation and usage restrictions in the USA, but there are few that detail the regional regulations that apply in other parts of the world.

As I am based in the UK, I decided to investigate the specifics of the 5GHz band in my home country. As I had to do quite a bit of detective work to find this information, I thought that putting it all together in one place for everyone's benefit would be useful.

Before we launch in to this exploration of the 5GHz band, I want to outline a caveat around the information presented here. As with everything else in the world of IT (*particularly Wi-Fi networks, as I write this*), things change (often, rapidly).

Please ensure that you do your own investigation and verify the information sources that I reference in this document. There may be changes in regulation and changes to spectrum allocation that may render some of this information obsolete by the time you read this document.

I will endeavour to keep this text up to date, but please do your own due-diligence to verify this information. Contravention of RF spectrum regulations is at best annoying and at worst dangerous (for instance, if you affect emergency services or medical equipment). There is always the possibility of financial penalty to consider too in extreme cases.

## Introduction

Wi-Fi networking text books generally describe the unlicensed RF spectrum that is used by Wi-Fi networks. They describe how the 2.4GHz and 5GHz bands are used for Wi-Fi networking, talking at length about the 'ISM' and 'UNII' bands. The terms 'ISM' and 'UNII' are RF band definitions used within the USA. The same *frequencies* may be used in other parts of the world, but in the UK those terms are not used to describe those same areas of RF spectrum.

(*Just to clarify, I'll frequently use the term "Wi-Fi networks" in this paper. I am specifically talking about wireless networks that adhere to the 802.11 standard. They utilize "unlicensed" radio frequency spectrum (i.e. you don't need to purchase a license to use the RF channels that the wireless network occupies). These are also known as "wireless LANS" (WLANs) or "radio LANs" (RLANs).)*

A typical Wi-Fi text book will often describe in detail how the 2.4GHz band is divided up in to eleven 5MHz channels (channels 1 through to 11) in the USA. They will go on to describe that in other parts of the world there are different numbers of channels used due to differing regional regulations. There are often examples that show how the 2.4GHz band is divided in to 13 channels for much of Europe and 14 channels in Japan (with perhaps a few other regional variations thrown in for good measure).

So, most people get a good feel for how 2.4GHz operates in their region from off-the-shelf text books.

However, when the discussion turns to 5GHz, things are a little less clear. Most texts talk about how the 5GHz band is divided up in to a number of "UNII" bands. There are UNII bands 1,2,3 and 2e. Each of them has varying usage (indoor/outdoor) and power restrictions. Depending on which book you read (and when it was written) around 23 channels are available in the USA in the 5GHz band.

But, a quick inspection of any manufacturer's data-sheet for their access point shows that although there is support for 23 5GHz channels in the USA, there are only 19 channels supported in the UK.

When I first started researching this topic, the question in my mind was: "OK, we seem to have fewer channels than the USA, perhaps we don't support one of those UNII bands for some reason?" However, it soon became clear that the UNII band definitions are pretty much meaningless in the context of UK RF spectrum usage.

Interestingly, although many text books describe the 2.4GHz band for other global regions, they pretty much ignore 5GHz in anywhere other than the USA. I'm guessing this is due to the significant variation and complexity of 5GHz band usage around the globe compared to 2.4GHz.

## Regulatory Bodies

In the USA, the regulations that apply to the use of unlicensed Wi-Fi bands are controlled by a single body: the FCC. However, in Europe, the situation isn't quite so clear-cut.

Spectrum usage in the UK is regulated by the UK's own spectrum regulator: Ofcom. However, Ofcom is also involved with and subject to the European Regulatory body: ETSI. This is mainly through the ETSI ERM (Electronic Radio Matters) working group. This relationship is used to try to ensure harmonisation of standards between the European standards defined by ETSI and UK spectrum usage.

### Ofcom

In the UK, we have Ofcom for the regulation of all wireless communications. To quote from their web site:

"*Ofcom is the communications regulator. We regulate the TV and radio sectors, fixed line telecoms, mobiles, postal services, plus the airwaves over which wireless devices operate*."

They provide information and guidance for RF spectrum usage within the UK, including unlicensed wireless LANs.

For some strange reason, they use their own particular parlance for WLANs, calling them 'RLANs' (Radio LAN), rather than the usual "Wi-Fi network" or WLAN that everyone else in the world uses. Here is Ofcom's definition of an 'RLAN' in the UK:

"*An RLAN is a radio local area network. That is, it is a high bandwidth, two way data communications network using radio as the medium of transmission rather than optical fibre or copper cable and operating over a limited geographic area. RLAN operate at 2400 – 2483.5 MHz, 5150 – 5350 MHz and 5470 – 5725MHz*."

### ETSI

ETSI is a standards organisation whose role includes RF spectrum governance within the European Union. In their own words (from their web site):

"*ETSI, the European Telecommunications Standards Institute, produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.*

*We are officially recognized by the European Union as a European Standards Organization. The high quality of our work and our open approach to standardization has helped us evolve into a European roots - global branches operation with a solid reputation for technical excellence.*"

There are a number of ETSI-defined standards that govern the use of unlicensed bands (i.e. 2.4GHz and 5GHz) within the EU. Wi-Fi users within the UK are also subject to these same standards, as the UK is a member of the EU.

## Standards

Due to the governance of RF spectrum by both Ofcom and ETSI in the UK, we have to consider a couple of standards documents when trying to understand how the unlicensed 5GHz band may be used in the UK.

### IR2006

The first standard we have to look at is the Ofcom document:

"*IR 2006 - Wireless Access Systems (WAS) including RLANs operating in the 5150-5725 MHz band*"

The latest version of this document can be found at Ofcom's web site at:

http://stakeholders.ofcom.org.uk/spectrum/technical/interface-requirements/

In summary, this document details how the 5GHz unlicensed spectrum in divided up in to 2 bands in the UK: band 'A' and band 'B' (note there is no reference to the UNII bands we usually find in our Wi-Fi text books). These bands are allocated as follows:

- Band A : 5150 - 5350 MHz (channels 36 - 64)
- Band B: 5470 - 5725 MHz (channels 100 - 140)

Band A channels can only be used indoors. Band B channels may be used indoors or outdoors and may be used at slightly higher power levels, if required. Here is the summary of channel usage from the document:

| Band | Channel | Centre Freq (MHz) | Usage |
|---|---|---|---|
| A | 36 | 5180 | Indoor |
| A | 40 | 5200 | Indoor |
| A | 44 | 5220 | Indoor |
| A | 48 | 5240 | Indoor |
| A | 52 | 5260 | Indoor |
| A | 56 | 5280 | Indoor |
| A | 60 | 5300 | Indoor |
| A | 64 | 5320 | Indoor |
| | | | |
| B | 100 | 5500 | Indoor/Outdoor |
| B | 104 | 5520 | Indoor/Outdoor |
| B | 108 | 5540 | Indoor/Outdoor |
| B | 112 | 5560 | Indoor/Outdoor |
| B | 116 | 5580 | Indoor/Outdoor |
| B | 120 | 5600 | Indoor/Outdoor |
| B | 124 | 5620 | Indoor/Outdoor |
| B | 128 | 5640 | Indoor/Outdoor |
| B | 132 | 5660 | Indoor/Outdoor |
| B | 136 | 5680 | Indoor/Outdoor |
| B | 140 | 5700 | Indoor/Outdoor |

## ETSI EN 301 893

Although the Ofcom IR 2006 document defines the channels that may be used within the 5GHz band, it references an ETSI document for further clarification about how the 5GHz band may be used. This document has the rather dry title of:

"*Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive*"

This document also has the designation of: "ETSI EN 301 893 V1.7.1 (2012-06)". (Note there are several versions of this document floating around from previous incarnations. Version 1.7.1 appears to be the current (at the time of writing) ratified document.

Several channels in the 5GHz band are subject to DFS restrictions (i.e. Dynamic Frequency Selection) to ensure that Wi-Fi and radar systems using the same band

can peacefully co-exist. In brief, Wi-Fi systems have to stop transmitting and move to a new channel if radar signals are detected on a DFS controlled channel.

In addition to DFS mechanisms, there are accompanying TPC (Transmit Power Control) mechanisms which allow an access point to dictate the power levels that a client may transmit at on channels that may be used by radar systems (i.e. DFS channels).

Given the recent significant rise in the use of Wi-Fi equipment on 5GHz, DFS mechanisms are particularly interesting, as they have the potential to unexpectedly disrupt Wi-Fi systems afflicted by radar systems on the same channel.

EN 301 893 V1.7.1 dictates that: "*Radar detection is required when operating on channels whose nominal bandwidth falls partly or completely within the frequency ranges 5 250 MHz to 5 350 MHz or 5 470 MHz to 5 725 MHz. This requirement applies to all types of RLAN devices regardless of the type of communication between these devices.*"

Looking back at the channel usage table supplied by Ofcom, this translates in to channels 52 through to 140 being subject to DFS restrictions.

In addition, TPC controls are also outlined in the table below (which is an extract from EN 301 893 V1.7.1):

**Table 1: Mean e.i.r.p. limits for RF output power and power density at the highest power level**

| Frequency range [MHz] | Mean e.i.r.p. limit [dBm] | | Mean e.i.r.p. density limit [dBm/MHz] | |
|---|---|---|---|---|
| | with TPC | without TPC | with TPC | without TPC |
| 5 150 to 5 350 | 23 | 20/23 (see note 1) | 10 | 7/10 (see note 2) |
| 5 470 to 5 725 | 30 (see note 3) | 27 (see note 3) | 17 (see note 3) | 14 (see note 3) |
| NOTE 1: The applicable limit is 20 dBm, except for transmissions whose nominal bandwidth falls completely within the band 5 150 MHz to 5 250 MHz, in which case the applicable limit is 23 dBm. | | | | |
| NOTE 2: The applicable limit is 7 dBm/MHz, except for transmissions whose nominal bandwidth falls completely within the band 5 150 MHz to 5 250 MHz, in which case the applicable limit is 10 dBm/MHz. | | | | |
| NOTE 3: Slave devices without a Radar Interference Detection function shall comply with the limits for the band 5 250 MHz to 5 350 MHz. | | | | |

In summary, channels 52 through to 140 are subject to TPC controls, though the maximum power that may be used varies across the band. TPC-affected channels on UK band A are allowed to use up to 23dBm when using TPC and channels in band B may use up to 30dBm when TPC is employed.

(Note: it appears from the table above that TPC may not be required if reduced power levels are used)

Consolidating all of the Ofcom and ETSI standard data, I came up with the following tabulated data to show unlicensed 5GHz usage in the UK. (Disclaimer -

*check the current versions of the documents from both Ofcom & ETSI to verify this information*):

| Band | Channel | Centre Freq (Mhz) | Usage | Max Power With TPC | Max Power Without TPC | DFS |
|---|---|---|---|---|---|---|
| A | 36 | 5180 | Indoor | N/A | 23dBm (200mW) | No |
| A | 40 | 5200 | Indoor | N/A | 23dBm (200mW) | No |
| A | 44 | 5220 | Indoor | N/A | 23dBm (200mW) | No |
| A | 48 | 5240 | Indoor | N/A | 23dBm (200mW) | No |
| A | 52 | 5260 | Indoor | 23dBm (200mW) | 20dBm (100mW) | Yes |
| A | 56 | 5280 | Indoor | 23dBm (200mW) | 20dBm (100mW) | Yes |
| A | 60 | 5300 | Indoor | 23dBm (200mW) | 20dBm (100mW) | Yes |
| A | 64 | 5320 | Indoor | 23dBm (200mW) | 20dBm (100mW) | Yes |
| | | | | | | |
| B | 100 | 5500 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 104 | 5520 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 108 | 5540 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 112 | 5560 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 116 | 5580 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 120* | 5600 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 124* | 5620 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 128* | 5640 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| B | 132 | 5660 | Indoor/Outdoor | 30dBm (1W) | 27dBm ( 500mW) | Yes |
| B | 136 | 5680 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |
| B | 140 | 5700 | Indoor/Outdoor | 30dBm (1W) | 27dBm (500mW) | Yes |

* Not supported by most equipment in EU due to weather radar issue (see below)

In summary, this *appears* to give us 19 channels to use on the 5GHz band in the UK for unlicensed Wi-Fi.

However, when looking at the datasheet of most access points that may be deployed in the UK (well, all those that I have checked), there is generally a note that channels 120 to 128 are not supported. But, there is generally no accompanying explanation about why these channels are not available.

*This "missing channels" issue reduces the number of available unlicensed 5GHz channels in the UK to just 16.*

## The 'Missing Channels' Issue

After some research, it appears that the reason that channels 120 to 128 receive special treatment by Wi-Fi equipment manufacturers is that they occupy frequencies that are used by weather radar systems.

Wi-Fi systems have to be very careful not to interfere with those systems during their normal operation. Therefore, Wi-Fi equipment has some rather stringent, additional checks and tests imposed on it to make sure that it does not inadvertently cause any interference.

In the ETSI region (Europe), the standard EN 301 893 dictates that any channels operating in the frequency range 5.6GHz to 5.65GHz must wait an additional period of time before using channels in that range.

For most DFS-affected channels, a Wi-Fi device must generally wait for 60 seconds to verify that no radar is present before commencing operation. This means that if you power up an access point on a DFS channel, you will not see it start to broadcast signals for the first minute after power-up.

However, on the channels in the 5.6GHz to 5.65GHz range, the device (i.e. Access Point) must wait 10 minutes before commencing RF transmissions! The table below (taken from Annex D of the EN 301 893 standard) details this requirement:

**Table D.1: DFS requirement values**

| Parameter | Value |
|---|---|
| Channel Availability Check Time | 60 s (see note 1) |
| Minimum Off-Channel CAC Time | 6 minutes (see note 2) |
| Maximum Off-Channel CAC Time | 4 hours (see note 2) |
| Channel Move Time | 10 s |
| Channel Closing Transmission Time | 1 s |
| Non-Occupancy Period | 30 minutes |
| NOTE 1: For channels whose nominal bandwidth falls completely or partly within the band 5 600 MHz to 5 650 MHz, the *Channel Availability Check Time* shall be 10 minutes. | |
| NOTE 2: For channels whose nominal bandwidth falls completely or partly within the band 5 600 MHz to 5 650 MHz, the *Off-Channel CAC Time* shall be within the range 1 to 24 hours. | |

Due to this very lengthy 10 minute wait period, it seems that many manufacturers have simply chosen to withdraw support for the channels affected (120, 124 and 128).

This is a very significant limitation for those of us in Europe. With the anticipated sharp uptake in 5GHz usage around the globe, particularly as new 802.11ac equipment starts to roll out; the loss of 3 channels is quite a chunk of spectrum to lose.

In the UK we have 19 unlicensed channels to use on 5GHz for Wi-Fi. Losing 3 of those channels is a 15% loss in spectrum. This is at a time when we really need to be increasing spectrum availability to cope with the additional channel bonding opportunities that 802.11ac provides to increase Wi-Fi throughput and efficiency.

## Comparison of UNII Bands and UK Bands

Despite the clarification around the use of 5GHz channels in the UK, you may still be wondering how the various UNII bands you may read about in Wi-Fi text books map on to the UK bands.

Here is a table showing the channels and bands in use in the USA, together with the corresponding band designations here in the UK:

| UK Band | USA Band | Channel | Centre Freq (MHz) |
|---|---|---|---|
| A | UNII-1 | 36 | 5180 |
| A | UNII-1 | 40 | 5200 |
| A | UNII-1 | 44 | 5220 |
| A | UNII-1 | 48 | 5240 |
| A | UNII-2 | 52 | 5260 |
| A | UNII-2 | 56 | 5280 |
| A | UNII-2 | 60 | 5300 |
| A | UNII-2 | 64 | 5320 |
| B | UNII-2ext | 100 | 5500 |
| B | UNII-2ext | 104 | 5520 |
| B | UNII-2ext | 108 | 5540 |
| B | UNII-2ext | 112 | 5560 |
| B | UNII-2ext | 116 | 5580 |
| B | UNII-2ext | 120 | 5600 |
| B | UNII-2ext | 124 | 5620 |
| B | UNII-2ext | 128 | 5640 |
| B | UNII-2ext | 132 | 5660 |
| B | UNII-2ext | 136 | 5680 |
| B | UNII-2ext | 140 | 5700 |
| N/A* | UNII-3 | 149 | 5745 |
| N/A* | UNII-3 | 153 | 5765 |
| N/A* | UNII-3 | 157 | 5785 |
| N/A* | UNII-3 | 161 | 5805 |

* Channels not available in UK for unlicensed use

## 802.11ac Channel Planning

With the ratification of the new 802.11ac "Gigabit Wi-Fi" amendment in December 2013, interest around the he 5GHz band has grown significantly. The 802.11ac standard only defines the operation of devices within the 5GHz RF band. The 2.4GHz band is not included in the standard. Devices using the 2.4GHz band are restricted to legacy standards: 802.11n, 802.11g and 802.11b.

802.11ac also introduces wider channel widths (through channel bonding) to facilitate some of the speed enhancement s that the new standard provides. Prior to 802.11ac, channel widths of 20MHz (802.11a & 802.11n) or 40MHz (802.11n) were specified. In the current 802.11ac standard, channel widths of 20MHz and 40MHz are still included, but new 80MHz channels are introduced. It is widely expected that the available channels widths will be increased further to include a 160MHz channel width when the "Wave 2" of the 802.11ac standard is introduced (in the 2015/16 time-frame).

In simple terms, doubling the channel width used by a WLAN station doubles the data throughput available (i.e. using an 80MHz channel provides twice the potential throughput of a 40MHz channel). Therefore, increasing channel widths provides a stepping stone to the "Gigabit" speeds promised by 802.11ac. Other technologies, such as multiple spatial streams, are also employed in combination with increased channel widths to provide the significant speed enhancements that 802.11ac delivers over previous standards.

Although wider channels provide us with much improved speeds, there is, unfortunately, a trade-off. As we run our WLAN channels at increased widths (e.g. using 80MHz channels as opposed to 20MHz or 40MHz channels), the number of unique channels available decreases. This necessitates more frequent channel re-use across a WLAN, and therefore generally leads to an increase in co-channel interference (CCI). This generally is a bad thing.

The available 20MHz, 40MHz, 80MHz and 160MHz channels available in the UK are detailed in the graphic below:

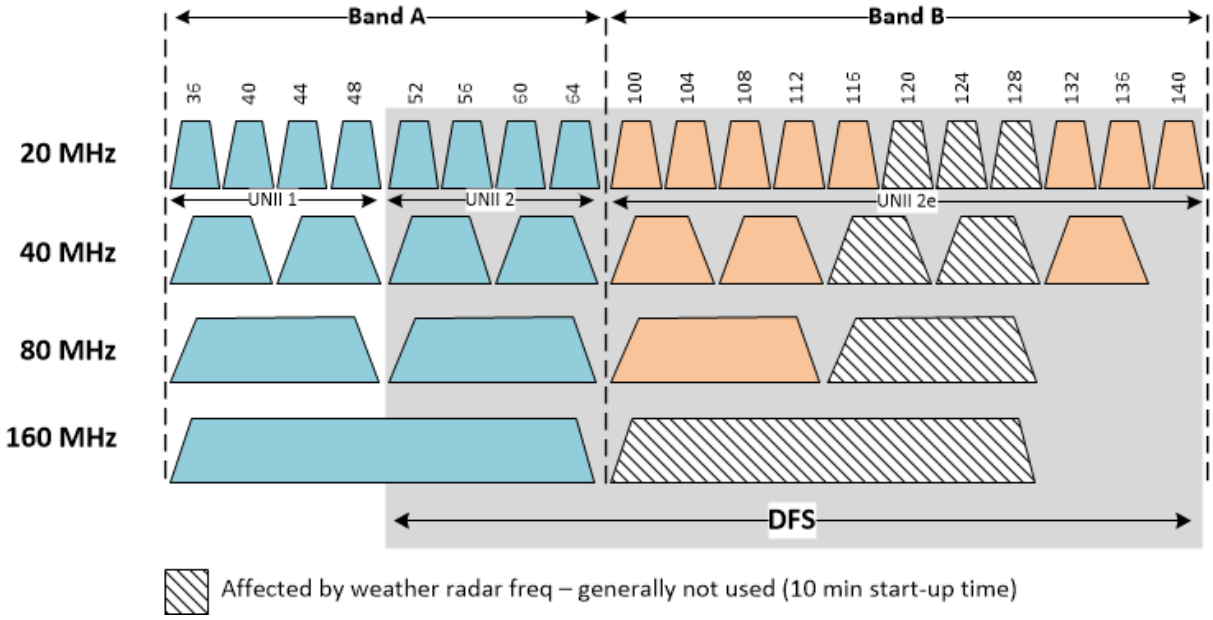



**Figure 1 - 5GHz WLAN Channels in the UK**

If we take in to account the weather radar issues discussed earlier in this document, this provides us with:

- 16 x 20MHz channels (4 not affected by DFS)
- 7 x 40MHz channels (2 not affected by DFS)
- 3 x 80MHz channels (1 not affected by DFS)
- 1 x 160MHz channels

In many instances, although we may have an 802.11ac capable WLAN infrastructure, we are currently constrained to using similar channel plans to those we had to use for the 802.11n standard. 40MHz channels still generally provide a viable option for channel planning, as we have 7 unique channels to use.

80MHz channels become far more of a challenge, as we have only 3 unique channels. Many of the historical issues associated with channel planning for traditional 2.4GHz "3 channel plan" networks will affect us when we attempt to use 80MHz channels. Levels of co-channel interference in many networks are often going to negate the speed benefits we sought by deploying 80MHz channels.

Each deployment will have to be assessed on its own merits. In well isolated environments with low numbers of APs or low levels of CCI, then an 80MHz 3-channel plan may occasionally be used. But in the majority of instances, I would expect that 40MHz or even 20MHz channels would be used to keep CCI to a manageable level.

The use of 20MHz channels for 802.11ac may seem counter-intuitive, but in areas of high density usage, particularly with many access points and client devices in

open areas, this may still provide an advantage over the use of 40MHz channels. The lower levels of CCI that 16 unique channels afford may provide a better overall performance. This is particularly true of large venues such as stadia, conference centres and lecture halls.

There may be good use-cases for 80MHz and perhaps even 160MHz channel-width usage in the home environment, but the effect on/from neighbouring networks still needs to be borne in mind. In many deployment situations, 80MHz and 160MHz width channels are simply unusable.

## The Growth in 5GHz Usage for Wi-Fi Networks

The 16 unique channels on the 5GHz band that are available within the UK are each 20MHz in width. This historically provided a good selection of channels for Wi-Fi devices using the 802.11a Wi-Fi standard. 16 'non-over-lapping' channels allowed large numbers of access points to be located in close proximity, without any real issues with co-channel interference between APs.

The advent of the 802.11n standard introduced the possibility of double-width, 40MHz channels. These wider channels helped provide some of the higher speeds enjoyed by 802.11n networks, compared to the legacy 802.11a standard. However, this reduced the number of unique usable channels available, as each 40MHz channel was formed by 'bonding' two 20MHz channels together.

Channels that are bonded together have to be spectrally adjacent (e.g. channels 36 & 40, channels 44 & 48). In the UK, we have sufficient spectrum space for 7 pairs of adjacent channels, allowing us 7 x 40MHz channels. This still provides a good selection of non-overlapping channels to use, without having to worry too much about co-channel interference if we start to pack APs in to a relatively small area.

One of the big performance gains available with the new 802.11ac standard is facilitated by expanding channel bonding even further to allow the use of 80MHz channels. This is the bonding of 4 adjacent channels.

In addition to channel bonding, there are other mechanisms available which help to boost Wi-Fi client speeds (e.g. multiple spatial streams). However, these are generally unavailable to many lower-powered tablet and smartphone devices – the very devices which are starting to dominate the population of Wi-Fi client devices. Only through the use of wider, 80MHz channels will the significant speed gains provided by 802.11ac be realised above and beyond the previous 802.11n standard.

Unfortunately, current spectrum availability in the UK only allows us to only accommodate three 80MHz channels to use with the new 802.11ac standard. As

previously discussed, there are significant limitations when considering the use of 80MHz channels.

In general, the UK is not currently well-placed to take advantage of the benefits that 802.11ac has to offer. The limited number of 5GHz channels available places the UK at a significant disadvantage compared to counties such as the USA who have well advanced plans to open up significant swathes of additional spectrum within the 5GHz band.

In short, the UK urgently requires more RF spectrum to be made available on the 5GHz band. Even in the short-term, it is fairly self-evident that the UK is heading for a spectral drought. The band will be subject to the rigorous demands of new 802.11ac networks, service provider Wi-Fi off-loading and the forthcoming tidal wave that is the "Internet Of Things" (IOT).

Hopefully, additional spectrum may be made available following the ITU World Radiocommunication Conference in November 2015.

## References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- Ofcom 5GHz standard: IR 2006 - Wireless Access Systems (WAS) including RLANs operating in the 5150-5725 MHz band: http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-policy-area/spectrum-management/research-guidelines-tech-info/interface-requirements/uk2006.pdf
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