5G Rural Integrated Testbed

Technical Report: TV White Space to Assist 5G

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Author: OLIVER HOLLAND

Technical Projects Manager, Advanced Wireless Technology Group, Ltd.

Visiting Research Fellow, King's College London

Email: oliver.holland@awtg.co.uk

Mobile: +44 7196 311973

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Executive Summary

It is very clear that many of the use cases and applications for 5G will not be viable in rural scenarios. This is because those use cases and applications rely on mm-wave spectrum to achieve sufficient bandwidth, hence capacity—noting that 5G New Radio carriers at mm-wave frequencies might be as large as 400 MHz not even considering supported aggregation options. Propagation range in mm-wave spectrum might be a few hundred metres. Deploying a base station every few hundred metres or every kilometre or so in rural scenarios will not be economically viable, as the number of customers/users per base station will be very small. Achieving 20 Gbps+ backhaul to each such base station will also not be economically viable. It is therefore necessary to maximise the use of sufficient bandwidth at the far-better propagation lower frequencies to provide good bandwidth coverage with a far lower density of base stations.

As part of the Department for Digital Culture Media and Sport 5G Testbeds & Trials Programme, this report investigates the use of TV White Space to assist 5G through opening up more spectrum at lower frequencies. Its content is based on general thoughts and analysis, as well as the experiences within the 5GRIT project of TV White Space deployments serving its use cases. Such alternative mid- and low-band spectrum might achieve propagation of several km, or 10 km or more in the case of the low-band. However, the carrier bandwidths in 5G mid- and low-bands are very small in comparison with mm-wave, and such frequencies are less amenable, or not amenable at all in the case of the low-band, to spatial reuse solutions such as beamforming. For example, the largest-bandwidth license awarded in the recent 3.4 GHz auction in the UK was only 50 MHz.

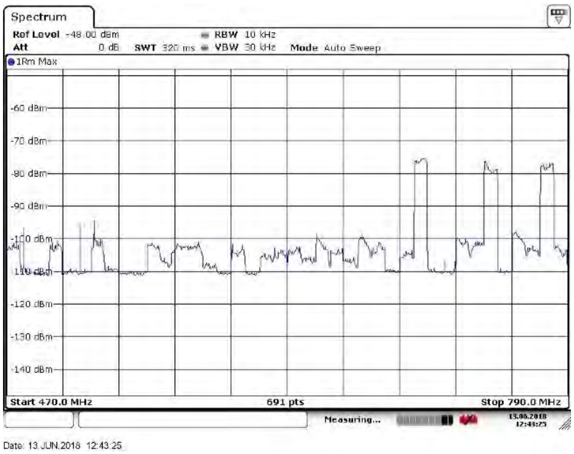
Given that all such low- and mid-band spectrum is already assigned (usually licensed), spectrum sharing is the necessary solution to open up more such spectrum. The purpose of this report is to understand the use of low-band spectrum to assist 5G through spectrum sharing, particularly TV White Space. It is noted, however, that TV White Space is just an initial example of spectrum sharing achieved through the far more broadly-applicable spectrum database-driven sharing concept, with oversight, definition and in some cases direct real-time input of the regulator. The Citizens Broadband Radio Service in the US is a further example, with many strong parallels to the operation of TV White Space frameworks. The emphasis here is that spectrum database-driven sharing in general, not just TV White Space, is the basis to achieve spectrum sharing at lower frequencies supporting 5G, and we are only investigating TV White Space as an initial example.

In Section 2 of this report, the various use cases of the 5GRIT project are described. The use cases are geared towards rural scenarios, in terms of some common rural economic activities (agriculture and deployment of drones to assist thereof, use of drones more generally, and tourism) and in terms of challenges of broadband provisioning *per se* in rural scenarios. The use cases are: “Tourism Augmented Reality”, “Agricultural”, “Rural Broadband”, and “Unmanned Aircraft Systems”.

Sections 3-6 cover the assessment of what *should* be achievable in TV White Space. In Section 3, the interference in TV spectrum is measured at the various deployment locations. Interference as experienced by TV white space devices is a vital consideration, noting that interference from distant Digital Terrestrial Television transmissions that are not meant to be covering the area can be a major issue even in some TV channels that have maximum allowed TV White Space transmission power according to the UK TV White Space framework (36 dBm, 4 W EIRP) locally. One reason for this is that the transmission power (EIRP) of Digital Terrestrial Television transmissions can be up to around 100,000 times (50 dB) higher than the 4 W maximum power (EIRP) of a white space device. It is shown in this work, however,

that there are many channels with low or zero perceived interference for most use cases. Locations/scenarios are also observed where background interference is likely to be far higher: These include high elevation, exposed, flat landscape locations, and locations next to open water such as on the edge of an island.

The following depicts such a background interference assessment, and its measurements. This is for Kirkgate in Kinross, on the edge of Loch Leven.

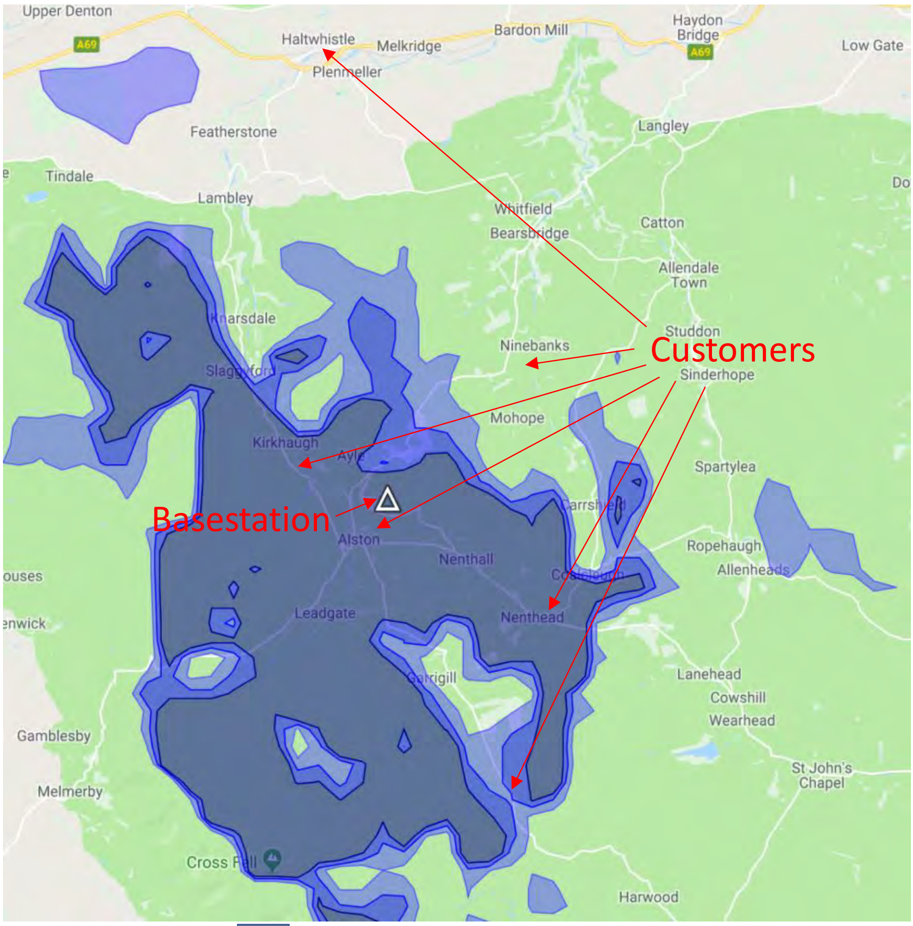


Section 4 assesses the availability of TVWS in each of the deployment locations. Such work is vital, as the availability of TVWS varies locally, sometimes moving from good availability to poor availability in only the distance of a few hundred metres, and is profoundly antenna height above ground level dependent. Moreover, there are other important considerations, such as the need for equipment to be able to transmit across multiple TV channels to achieve a reasonable bandwidth and data capacity by today's standards—especially for 5G networks/deployments as per the purpose of this report. And in many cases it will be necessary to achieve those channels contiguously to avoid the use of multiple radios on devices or other expensive radio solutions, thereby improving equipment cost-effectiveness. Hence, Section 4.5 maps availability for two of the deployment locations—including Monmouthshire County to reflect the more-recently introduced Monmouthshire deployments—particularly from the viewpoint of contiguous and non-contiguous aggregation noting that the aggregation typically has to be contiguous for aforementioned reasons. Given that these mapped areas are relatively challenged in terms of availability, it is shown that the need for contiguous aggregation can significantly reduce the number of locations in which white space devices can be deployed satisfying performance requirements. This gets worse as more channels are aggregated.

Technical requirements of the use cases are presented in Section 5 to assist decisions on available resource choices for the use cases. These are in terms of aspects such as capacity required, and the level of symmetry of the connections among others. Thence, given the TV White Space availability and background interference levels assessed in previous sections, Section 6 makes recommendations on the resource (TV channels) usage choices for the white space devices. It also depicts the predicted coverage for the scenarios, under these resource usage choices. This is achieved using a popular implementation of the Longley-Rice propagation model by the Communication Research Centre Canada. In doing so, in order to derive/map edges of coverage at three different SINR levels for each case, the received power thresholds required to realise a given SINR are adapted on a per case basis given the measured background interference levels in the chosen resources.

This work shows that almost all 5GRIT locations/scenarios achieve excellent availability, although for a small number, particularly over longer distances, there are challenges matching availabilities and resource usage choices for the downlink and uplink. It is noted here that the TV White Space devices are generally communicating on one or more contiguous TV channels in a time-division duplex fashion, so this downlink-uplink resource matching must be done. For a very small number of locations there is difficulty in achieving coverage *per se*.

As follows is an example of one of the coverage assessments. This is for Alston Moor in the North Pennines Area of Outstanding Natural Beauty as part of the analysis for the Tourism Augmented Reality Use Case.



= at least -77 dBm, equivalent to 25dB SINR

= at least -87 dBm, equivalent to 15dB SINR

= at least -97 dBm, equivalent to 5dB SINR

Section 7 discusses actual deployments. It is noted here that TVWS equipment maturity needs to be improved, hence, the deployments fall considerably short in terms of performance compared with what should be achieved per the engineering/physics of the scenarios, and many scenarios were, effectively, not beneficial to deploy because of the equipment shortfalls. Nevertheless, detailed discussion on technical reasons for this is presented, and customer feedbacks for the deployed locations, among other aspects, are covered. Moreover, it is noted again that the issues experienced in the deployments here are not because of the UK TV White Space framework or the validity of spectrum-database driven spectrum sharing to assist 5G, they are because of the equipment available in the specific case of TV White Space—for reasons such as there being a lack of economy-of-scale in the market. The spectrum database-driven sharing framework as a tool for opening up more spectrum is still of immense value.

The biggest challenge with the utilised devices is their poor ability to filter/reject high-power TV transmissions from local TV transmitters in entirely different channels from those being used for the white space communication. Such is the complexity of the UK's TV transmitter deployment structure that such cases are common, perhaps even routine, across much of the of the UK. Although speculating somewhat, we infer that the technical problem with the white space devices is almost certainly the following: Because they are dynamic spectrum devices, they are capable of tuning to a very wide frequency range (indeed, the whole of the TV band). However, their RF front ends seemingly do not filter out the TV channels they are not using, causing the power in those unused channels to overload their RFs, or alternatively they are using a higher attenuation therefore raising the noise floor. Either case can significantly reduce SINR, hence performance, as seen by the receiver.

Despite such challenges, good customer feedback was provided for the small number of deployments that it was practical to continue with, and general improvements in broadband performance through TV White Space compared with what would otherwise be achievable were observed. Such improvements were to around 10-12 Mbps throughput on the downlink on average, and 5-7 Mbps on the uplink on average. Although better, this is nowhere near the 30 Mbps+ expected; on average, performance was very approximately ¼ of that expected.

A key challenge in the use of shared spectrum is "managing" it where possible, noting that such shared spectrum access, among the new-entrant ("secondary") users, is on a license-exempt or otherwise equally-sharing (and interfering) basis. This is particularly so when using such spectrum to assist 5G, noting the highly-challenging reliability requirements in 5G and indeed increased expectations for mobile services in general. Section 8 introduces a methodology to achieve that spectrum management using only the capabilities and messaging exchanges that already exist within the UK TV White Space framework, achieved by introducing a "dummy" intermediary database that interacts and operates between the real white space devices and the real Ofcom-certified spectrum database. The intermediary database is implemented on a Raspberry PI, and the "real" white space devices are implemented as a number of virtual machines on a computer—based on the software for fully-operational white space devices within the UK TV White Space framework as created by us some years ago. Aspects of that device implementation and the database implementation are described, and the concept is shown to work in terms of the lists of resources assigned to the white space devices and partitioning of those resources among the separate devices. Further, future work on this concept is described, including the implementation and use of advanced resource management schemes based around artificial intelligence, for example, learning about changing traffic requirements and resource availabilities and acting accordingly.

Finally, Section 9 concludes this report, providing/summarising some key observations. It is noted here that due to the clearance of 700 MHz spectrum (694-790 MHz, TV channels 49-60) and auctioning for mobile broadband usage (4G LTE/5G 700 MHz) in the coming months, it is almost certain this large (96 MHz) chunk of mostly-pristine TV White Space will become unavailable to white space devices. Nevertheless, our past analysis has shown that there should still be a useful amount of white space available in most scenarios even after this event.

Table of Contents

1 Introduction and Motivation ... 11
2 Summary of 5GRIT Use Cases and Their Context ... 12
2.1 Tourism Augmented Reality ... 12
2.2 Agricultural ... 13
2.3 Rural Broadband ... 13
2.4 Unmanned Aircraft Systems ... 13
2.5 Note on Chosen Parameters ... 13
3 Interference Assessments ... 14
3.1 Tourism Augmented Reality ... 15
3.1.1 Alston Moor ... 15
3.1.2 Loch Leven ... 21
3.2 Agricultural ... 24
3.3 Rural Broadband ... 26
3.3.1 Isle of Arran ... 26
3.3.2 Bardney ... 37
3.4 Unmanned Aircraft Systems ... 38
4 White Space Availability ... 41
4.1 Tourism Augmented Reality ... 41
4.1.1 Alston Moor ... 41
4.1.2 Loch Leven ... 42
4.2 Agricultural ... 42
4.3 Rural Broadband ... 42
4.3.1 Isle of Arran ... 42
4.3.2 Bardney ... 42
4.4 Unmanned Aircraft Systems ... 42
4.5 Contiguous vs. Non-Contiguous Aggregation ... 43
5 Key Characteristics and Technical Requirements of 5GRIT Use Cases ... 44

5.1 Tourism Augmented Reality 44
5.2 Agricultural 45
5.3 Rural Broadband 46
5.4 Unmanned Aircraft Systems 47
6 Channel Usage Choice Recommendations, and Observations on Coverage and Performance 49
6.1 Tourism Augmented Reality 50
6.1.1 Alston Moor 50
6.1.2 Loch Leven 51
6.2 Agricultural 52
6.3 Rural Broadband 53
6.3.1 Isle of Arran 53
6.3.2 Bardney 56
6.4 Unmanned Aircraft Systems 57
6.5 Overall Analysis on Realisation of Use Case Requirements 59
7 Real Equipment Deployments 60
7.1 TV White Space Equipment Challenges 60
7.1.1 Reasoning around Performance Issues 61
7.2 TVWS Device Testing 62
7.2.1 Locations 62
7.2.2 Customer 1 63
7.2.3 Customer 2 64
7.2.4 Commentary and Comparison with Expected Performance 65
8 TV White Space (Spectrum Database) Resource Management Entity 66
8.1 High-Level Architecture 66
8.2 Implementation and Testing 68
8.2.1 Implementation 68
8.2.2 Testing 72
8.2.3 Ongoing and Future Work on the Management Entity 73

9 Conclusions and General Observations 75

References 75

Annex A: Detailed Lists of Available EIRPs on a Per-Location Basis 77

A.1 Tourism Augmented Reality 77

A.1.1 Alston Moor 77

A.1.2 Loch Leven 80

A.2 Agricultural 83

A.3 Rural Broadband 84

A.3.1 Isle of Arran 84

A.3.2 Bardney 90

A.4 Unmanned Aircraft Systems 91

List of Acronyms and Abbreviations

Acronym/abbreviation	Meaning
AGL	(Height) Above Ground Level
BS	Base Station
CBRS	Citizens Broadband Radio Service
CPE	Consumer-Premises Equipment
DTT	Digital Terrestrial Television
EIRP	Equivalent Isotropically Radiated Power
ETSI	European Telecommunications Standards Institute
HD	High-Definition
LoRaWAN	Long-Range WAN
MAC	Medium-Access Control
MIMO	Multiple-Input, Multiple-Output
NGA	Next-Generation Access
Ofcom	Office of Communications
PHY	PHYsical Layer
PMSE	Programme-Making and Special Events
RBW	Resolution BandWidth
RF	Radio-Frequency
SINR	Signal-to-Interference-plus-Noise-Ratio
TVWS	TV White Space
UAV	Unmanned Aircraft Vehicle
UPS	Uninterruptible Power Supply
VBW	Video BandWidth
Wi-Fi	Wireless-Fidelity
WSD	White Space Device

1 Introduction and Motivation

As part of the Department for Digital Culture Media and Sport 5G Testbeds & Trials Programme, this report investigates the use of TV White Space (TVWS) to assist 5G through opening up more spectrum at lower frequencies. Its content is based on general thoughts and analysis, as well as the experience within the 5GRIT project of TVWS deployments serving its use cases.

It is very clear that many of the use cases and applications for 5G will not be viable in rural scenarios. This is because those use cases and applications rely on mm-wave spectrum to achieve sufficient bandwidth hence capacity—noting that carriers in mm-waves can be as large as 400 MHz not even considering supported aggregation options [1]. Propagation range in mm-wave spectrum might be a few hundred metres. Deploying a Base Station (BS) every few hundred metres or every kilometre in rural scenarios to achieve such mm-wave coverage will not be economically viable, as the number of customers/users per deployment will be very small. Achieving 20 Gbps+ backhaul to each such BS will also not be economically viable in the vast majority of cases.

Alternative mid- and low-band spectrum might achieve propagation of several km, or perhaps 10 km or more in the case of the low-band. However, the carrier bandwidths in 5G mid- and low-bands are very small in comparison, and such frequencies are less amenable, or not amenable at all in the case of the low-band, to spatial reuse solutions such as beamforming. For example, the largest-bandwidth license awarded in the recent 3.4 GHz auction in the UK was 50 MHz. Given that all such spectrum below 6 GHz is already assigned (usually licensed), spectrum sharing is the only solution to open up more such spectrum (see, e.g., [2]). This must be done to maximise the use of such spectrum towards achieving sufficient bandwidth at these better-propagation lower frequencies, thus provide good bandwidth coverage in rural scenarios.

The purpose of this report is to understand the use of low-band spectrum to assist 5G through spectrum sharing, particularly TVWS. It is noted, however, that TVWS is just an initial example of spectrum sharing achieved through a far more broadly-applicable spectrum database-driven sharing framework, with oversight, definition and in some cases direct input of the regulator. The Citizens Broadband Radio Service (CBRS) is a further example with many strong parallels to the operation of TVWS frameworks. The emphasis here is that spectrum database-driven sharing in general is the basis that is being worked with and that will achieve spectrum sharing at lower frequencies supporting 5G.

This report is structured as follows. In Section 2, the various use cases of the 5GRIT project are described. In Section 3, the interference in TV spectrum is measured at the various deployment locations. Interference as experienced by TV White Space Devices (WSDs) is a vital consideration, noting that RF power from distant Digital Terrestrial Television (DTT) transmissions that are not meant to be covering the area can be a major issue even in some TV channels that have maximum allowed TVWS transmission power (36 dBm, 4 W) locally [3]-[5]. One reason for this is that the transmission power (EIRP) of DTT transmissions can be up to around 100,000 times (50 dB) higher than the 4 W maximum power (EIRP) of a WSD.

Section 4 assesses the availability of TVWS in each of the deployment locations. Such work is vital, as the availability of TVWS varies locally, sometimes moving from good availability to poor availability in only the distance of a few hundred metres, and is profoundly antenna height Above Ground Level (AGL) dependent [3]-[9]. Moreover, there are other important considerations, such as the need for equipment to be able to transmit across multiple TV channels to achieve a reasonable bandwidth and data capacity by today's standards [3]-[5]—especially as 5G networks/deployments come to the forefront as per the purpose of this report.

And in many cases it will be necessary to achieve those channels contiguously to avoid the use of multiple radios on devices, or other expensive radio solutions, thereby improving equipment cost-effectiveness. Hence, Section 4.5 maps availability for two of the deployment locations—particularly from the viewpoint of aggregation, having to be contiguous for aforementioned reasons. It is noted that currently Ofcom only allows a maximum of three TV channels to be aggregated in TVWS, and results for up to three channels being aggregated are therefore presented.

Section 5 discusses the technical requirements of the use cases and Section 6 makes resource choice recommendations based on those, also mapping coverage for the recommendations using the prior information obtained on interference levels and TVWS availabilities.

Section 7 discusses actual deployments. It is noted here that TVWS equipment maturity needs to be improved, hence, the deployments fall considerably short in terms of performance compared with what should be achieved per the engineering/physics of the scenarios, and many scenarios were, effectively, not beneficial to deploy because of the equipment shortfalls. Nevertheless, detailed discussion on technical reasons for this is presented, and customer feedback for the deployed locations, among other aspects, are covered. Moreover, it is noted again that the issues experienced in the deployments here are not because of the UK TVWS framework or the validity of spectrum-database driven spectrum sharing to assist 5G; they are because of the equipment available in the specific case of TVWS—the spectrum database-driven sharing framework as such a tool is of immense value.

A key aspect in the use of such shared spectrum is management of resource usage, noting that such shared spectrum access, among the new-entrant (“secondary”) users, is on a license-exempt or otherwise equally-shared (and interfering) basis. Section 8 introduces a methodology to achieve that spectrum management using only the capabilities and messaging exchanges that already exist within the framework, achieved by introducing a “dummy” database that operates between the real WSDs and the real spectrum database.

Finally, Section 9 concludes this report.

2 Summary of 5GRIT Use Cases and Their Context

Setting the context for rural 5G deployments, the use cases and locations in which they are deployed are briefly summarised here.

2.1 Tourism Augmented Reality

This use case involves the provisioning of capacity for digital content to enhance the experience for tourists locally. It is heavily linked to aspects for the World Around Me app [10] and provisioning for that, noting that there is often limited mobile network coverage in the areas considered. However, it also takes into account more general provisioning to tourists, which might have very significant capacity requirements.

This use case is therefore particularly for areas that have intrinsic beauty or other touristic interest for travellers. Such locations considered in this project are Alston Moor, in the North Pennines AONB, and Loch Leven in Perthshire.

2.2 Agricultural

This use case involves the provisioning of capacity to assist agriculture, both arable farming and livestock rearing. It involves the use and provisioning of communication capabilities to drones to collect images and video from the drones, and also the access to high-tech/sensing equipment on farms.

The drones might provide high-capacity video or images communicated in near real-time (e.g., for livestock investigation), and/or there might be automated uploads of images/video and other content upon the drones landing. The sensing information from farm equipment is small, although needs to be collected in near real-time over long distances and sometimes in challenging propagation conditions.

The areas considered here include a farm area of North Yorkshire around 2.5km North-East of Easingwold, and a number of farms in the Alston Moors area.

2.3 Rural Broadband

This use case involves the general provisioning of broadband to difficult-to-reach rural areas that otherwise would have no effective provisioning. The general assumption is that Next Generation Access (NGA) requirements should be achieved as defined by the UK government [11], and if not then Universal Service Offering requirements must be more generally achieved [12].

The locations considered here include a link from a BS in Bardney, Lincolnshire, to difficult-to-reach customers in a wooded area some 10 km distance away, and general broadband provisioning to the Isle of Arran, North Ayrshire. It is noted that areas such as Alston Moor and Loch Leven could also benefit and be covered by this use case.

2.4 Unmanned Aircraft Systems

The UAS use case involves the provisioning of connectivity to drones for a variety of purposes. These include user traffic communication (e.g., video/image uploads from drones, in some cases in real-time, and other, e.g., sensed data), and potentially even the control messages/data to/from drones. Of course, this is closely linked to other use cases, such as the Agricultural case which uses the drones considered here.

The key locations considered for this use case are the offices of Blue Bear Systems Research Limited [13], and an airfield nearby. However, other areas are also relevant regarding the use of drones, e.g., as defined in the Agricultural use case.

2.5 Note on Chosen Parameters

In all results given in this report, the WSD antenna height is assumed to be 7.49 m AGL. However, in terms of TVWS availability, the results should be almost always identical for all heights in the range 3.25-7.49 m. This is because there is not much, if any, PMSE (e.g., wireless mics) deployed in the areas, and this height range rounds to the discrete value for DTT protection of 5 m as calculated by Ofcom as a part of its UK TVWS framework.

If the height of a WSD is increased, there will be a degradation in availability at and above 7.50 m, and then further degradations at and above 12.50 m, 17.50 m, and 25.00 m. There will be a slight improvement in availability at heights 3.24 m and below. Further, in addition to deploying with the configuration options suggested in this report, it might be useful to experiment with horizontal and vertical polarisation of the antennas, as there might be an interference reduction by changing antenna polarisation dependent on the scenario.

More case-specific parameter choices are given in the associated sections of this report.

3 Interference Assessments

This section assesses the radio interference impinging on 5GRIT deployment locations. A series of spectrum surveys are done to investigate background interference levels, as might result from distant DTT transmitters. Only a subset of those surveys are reported here.

The utilised equipment was as follows:

- A Rohde and Schwarz FSV7 spectrum analyser.
- A Sennheiser A 1031-U wireless microphone antenna.
- A Sweex 1500VA, 900W Uninterruptible Power Supply (UPS).
- A 2m SMA coaxial RF cable.

The chosen antenna covers the range 450-960 MHz, and has been precisely characterised in our past work. This antenna is omnidirectional if mounted with the correct orientation, leading to a good certainty in the received powers through removing unknowns caused by, e.g., antenna direction and orientation. The intention was, at least in the longer-term, to use this approach to obtain a good general idea on the spectral situation in the chosen area, facilitating future work on the measurement set around, e.g., understanding propagation loss from known TV transmitters in the area and associated effects on WSDs. It is noted here that Ofcom maintains a good publicly accessible record on TV transmitters, with information such as transmission polarisation, EIRP per channel, and other factors being catalogued therein.

The drawback of this approach is that the antenna gain, hence the observable signal, might be around 10 dB less for the omnidirectional antenna than an equivalent gain for a WSD antenna. This difference might be even higher for some high gain WSD antennas. However, a spectrum analyser might anyway have around 10 dB worse sensitivity (noise figure) than a dedicated communication radio, hence the benefits of performing these measurements to understand interference in deployments at precise intended WSD locations are already eroded. It was therefore thought most beneficial to stick with the omnidirectional antenna approach for its aforementioned other benefits and potential uses, and in tandem with that perform measurements at a larger number of (in some cases elevated, or more exposed) locations to assess the interference potential.

The relevant specifications and settings used for the equipment were as follows:

- Antenna gain: 0dB, with a maximum of 3dB variation in the horizontal plane.
- Antenna height: 2.4m AGL.
- Spectrum analyser sensitivity: <-152 dBm/Hz, -155 dBm/Hz typically.
- Noise figure: 19-22 dB (at 20 °C), based on the quoted sensitivity values.
- Antenna cable loss: Variable against the precise chosen frequency, and unknown for this reason. Extremely likely to be less than 1dB at worst.
- Frequency range: 470-790 MHz.
- Reference level varying, typically around -50 dBm.
- Attenuation: 0 dB (none).
- Resolution bandwidth (RBW): 10 kHz.
- Video bandwidth (VBW): 30 kHz.

- Sweep time: 0.32 s.
- Trace mode: Max hold.
- Detector: Root-mean-square.
- Sweep values: 691.
- No preamplification.

Figure 1 provides photos of the utilised measurement equipment and configuration, in its easily-transportable setting. This "mobile spectrum measurement" configuration was used throughout almost all of the surveys reported in this document; other configurations were used in the Loch Leven case, and in other work that might be reported in later 5GRIT Deliverables if the associated locations do fall under the scope of study for the use cases.

It is noted that the "handheld" use of the antenna should have negligible or zero effect on the detected signals, given the way that the antenna was held. This "handheld" configuration was necessary due to the presence of high winds in many of the measurements/locations.

Figure 1. The utilised spectrum measurement equipment and configuration.

Given that the measurements were per 10 kHz RBW, to obtain equivalent power values in the 8 MHz channel and assuming a flat transmission across the whole channel, the measured EIRP levels would have to be multiplied by 800 times, equivalent to adding 29 dB.

There were some minor anomalies seen in the spectrum analyser measurements. First, there was a very slightly elevated observed power level seen on Channel 53, which appears to be an effect of internal electrical interference or an anomaly somewhere in the measurement set-up and almost certainly within the spectrum analyser itself. This inference was arrived at because it was seen roughly equally across all surveyed locations, even without the antenna connected and with other possible sources, such as mobile phones, being switched off. Second, there was a very small anomaly at the upper edge of Channel 32, which also appeared to be due to internal electrical interference with no plausible other explanation. Third, there were spikes resembling wireless microphone transmissions at frequencies 480 MHz, 512 MHz, and 519 MHz; these have been analysed and they ARE the products of intermodulation or some other spurious effects due to the proximity of mobile phones.

It is noted here that aside from these elevated powers at certain very precise frequencies or frequency ranges, such anomalies have no other negative effects on the quality of the measurements, as used for the purposes of this report.

3.1 Tourism Augmented Reality

3.1.1 Alston Moor

Figure 2 depicts the locations of measurements in Alston Moor, corresponding to the key deployment locations of interest and an extra location added as a high point to maximise the detection/assessment of interference. Figures 3-11 provide photos of the measurement locations, as well as the measurements themselves. It is noted here that there was little or no clear increase in observed power levels by moving the antenna through all possible orientations and polarisations, where we emphasise again here that this assessment was done using the Max Hold setting on the spectrum analyser.

Figure 2. Locations for Alston Moor measurements and deployments.

South Tynedale Railway

Figure 3. Photographs of the setting, and measurements at South Tynedale Railway.

Pavilion

Figure 4. Photographs of the setting, and measurements at Pavilion.

Market Square

Figure 5. Photographs of the setting, and measurements at Alston Market Square.

Hearse House

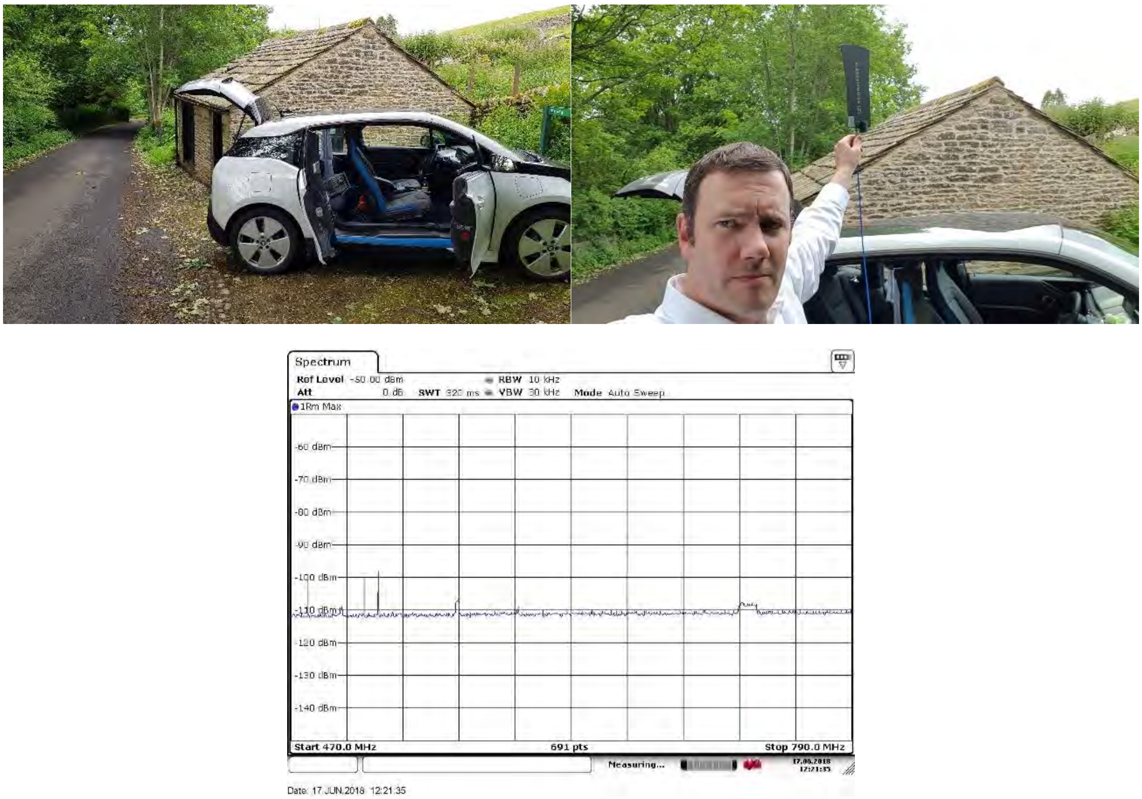


Figure 6. Photographs of the setting, and measurements at Hearse House.

High Point

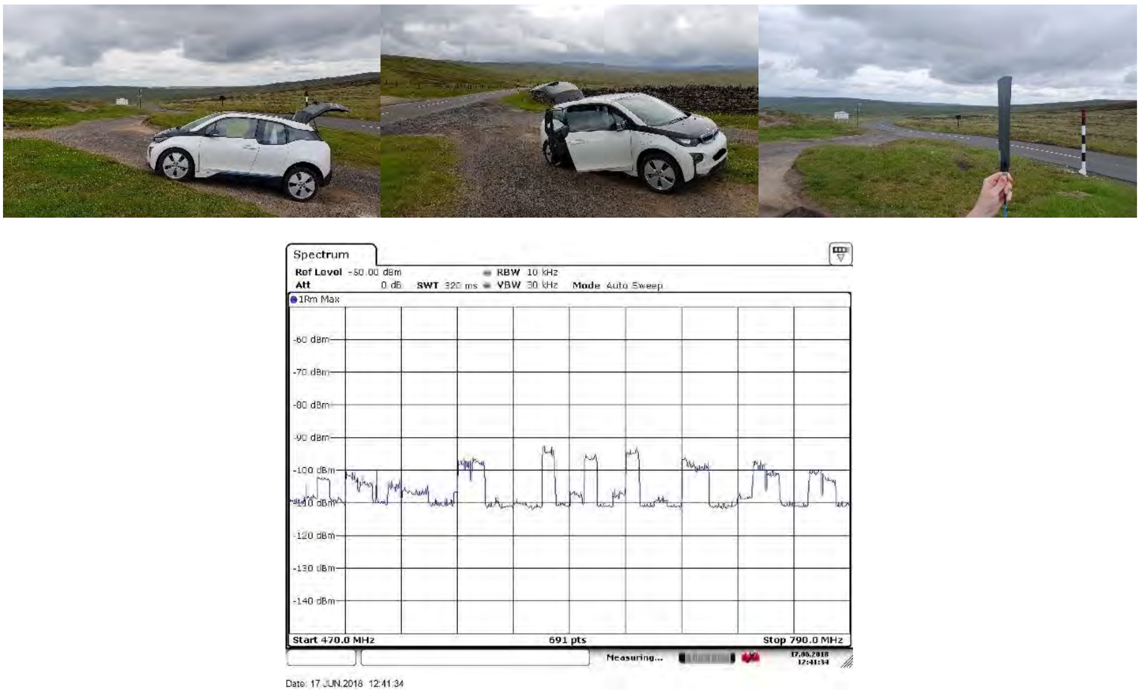


Figure 7. Photographs of the setting, and measurements at the high point.

Nenthead Mine

Figure 8. Photographs of the setting, and measurements at Nenthead Mine.

Alston Ski

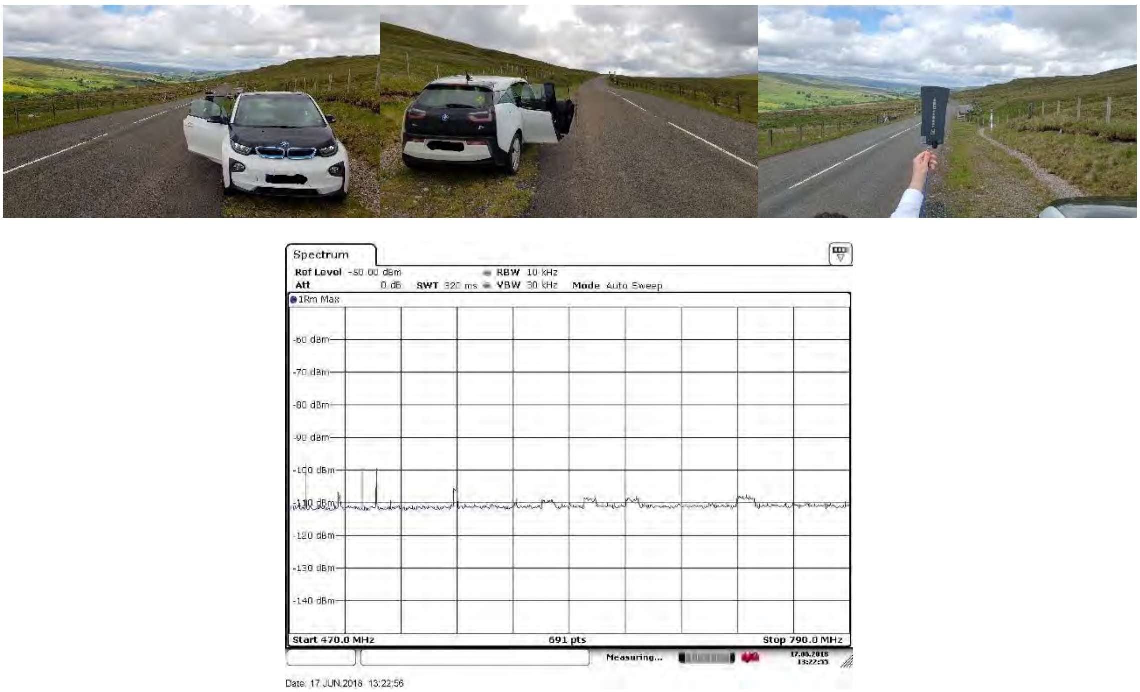


Figure 9. Photographs of the setting, and measurements at Alston Ski.

Epiacum

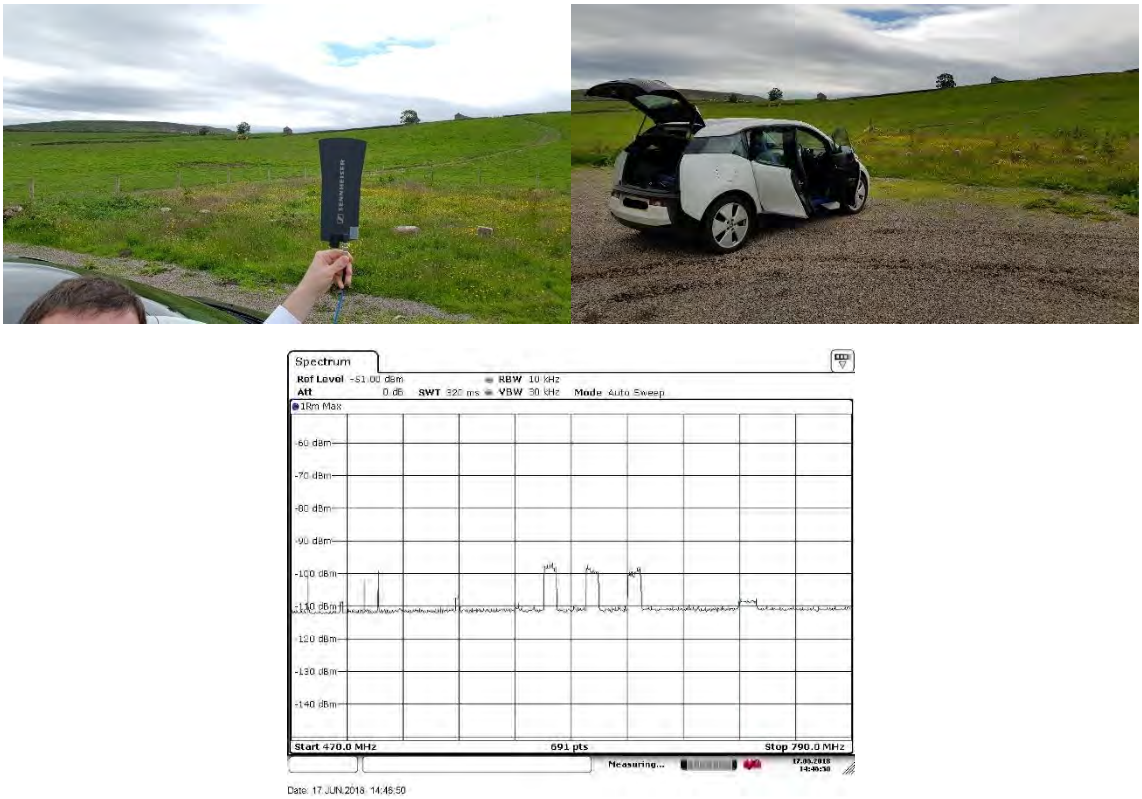


Figure 10. Photographs of the setting, and measurements at Epiacum.

Haltwhistle Station

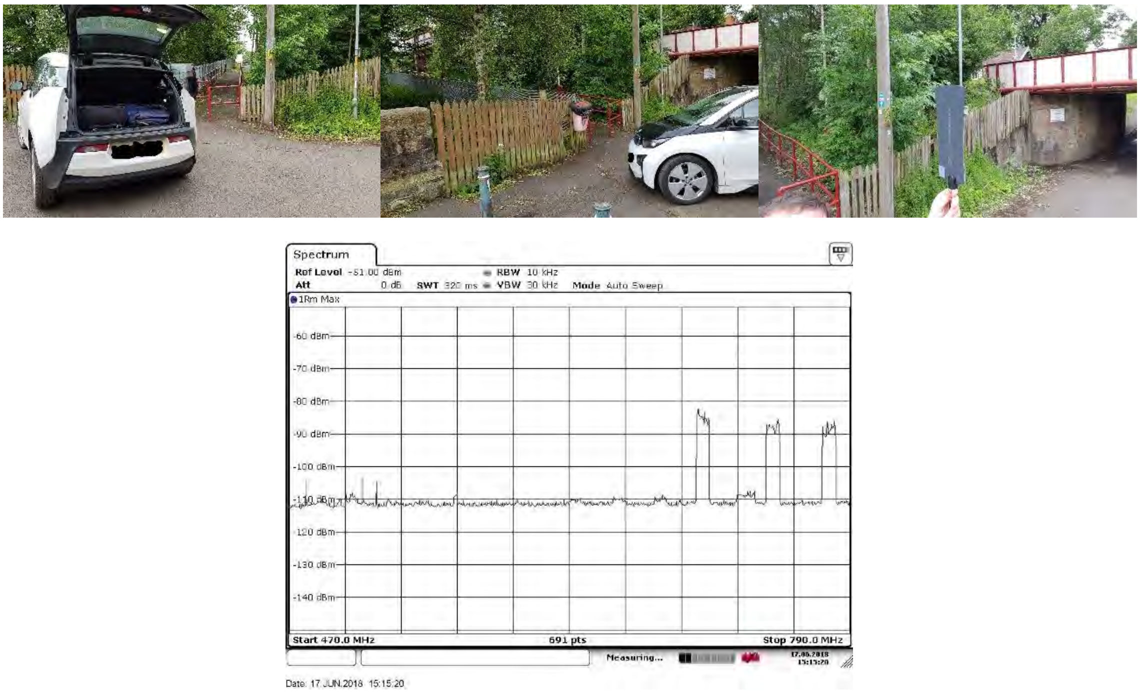


Figure 11. Photographs of the setting, and measurements at Haltwhistle Station.

3.1.2 Loch Leven

Figure 12 depicts the locations of measurements in for the Agricultural case. Figures 13-17 provide photos of the measurement locations, as well as the measurements themselves.

Figure 12. Locations for Loch Leven measurements and deployments.

Hub

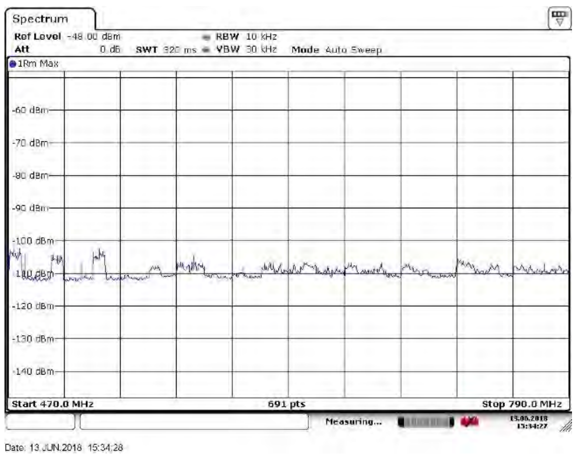


Figure 13. Photographs of the setting, and measurements at the Hub.

Boathouse

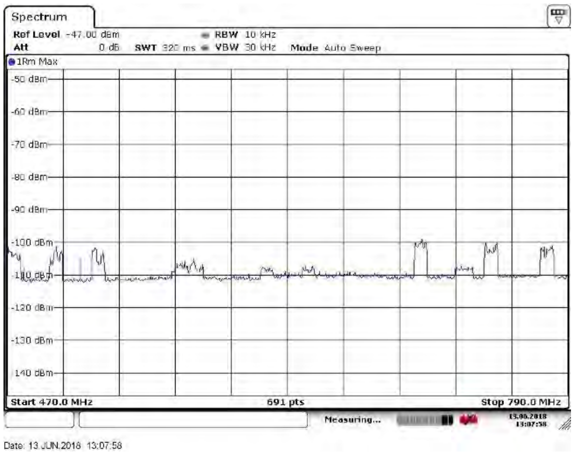


Figure 14. Photograph of the setting, and measurements at Boathouse.

Kirkgate

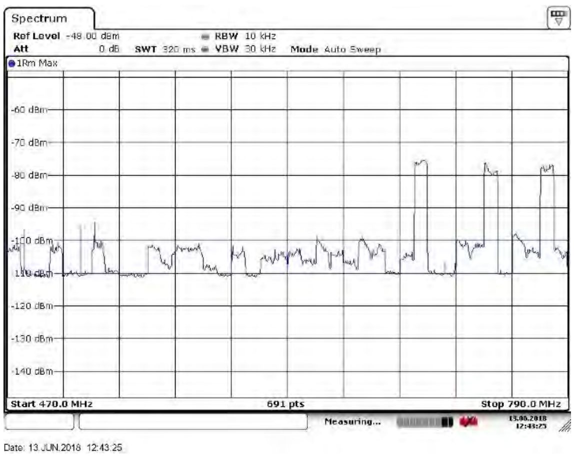


Figure 15. Photographs of the setting, and measurements at Kirkgate.

M90 J5

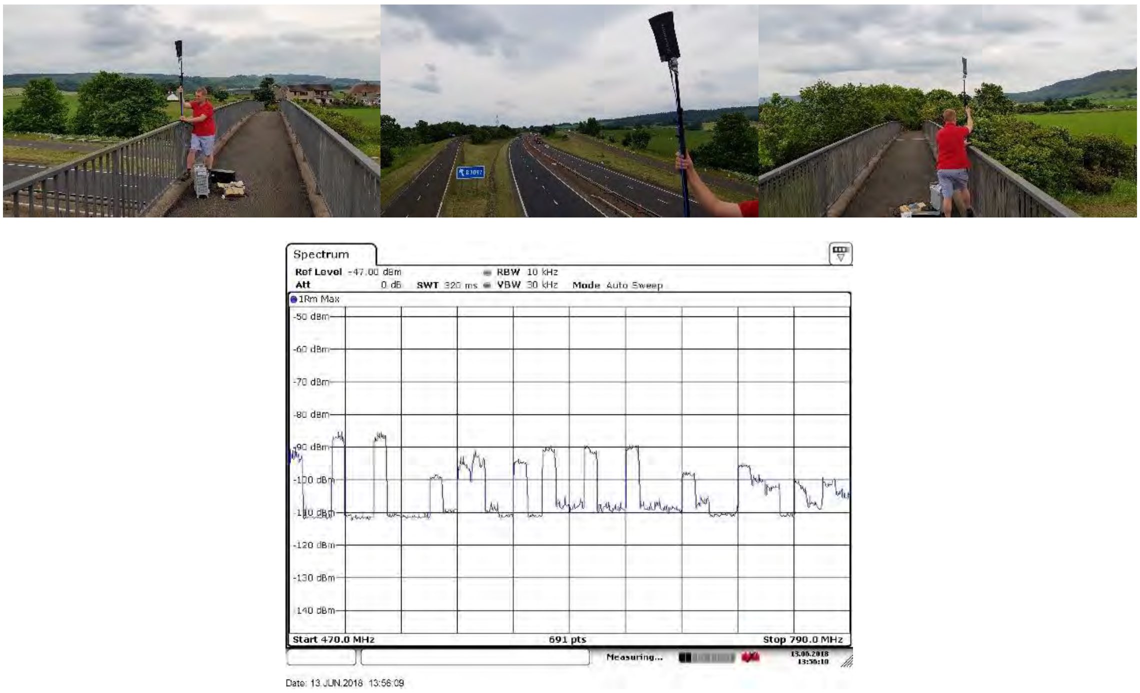
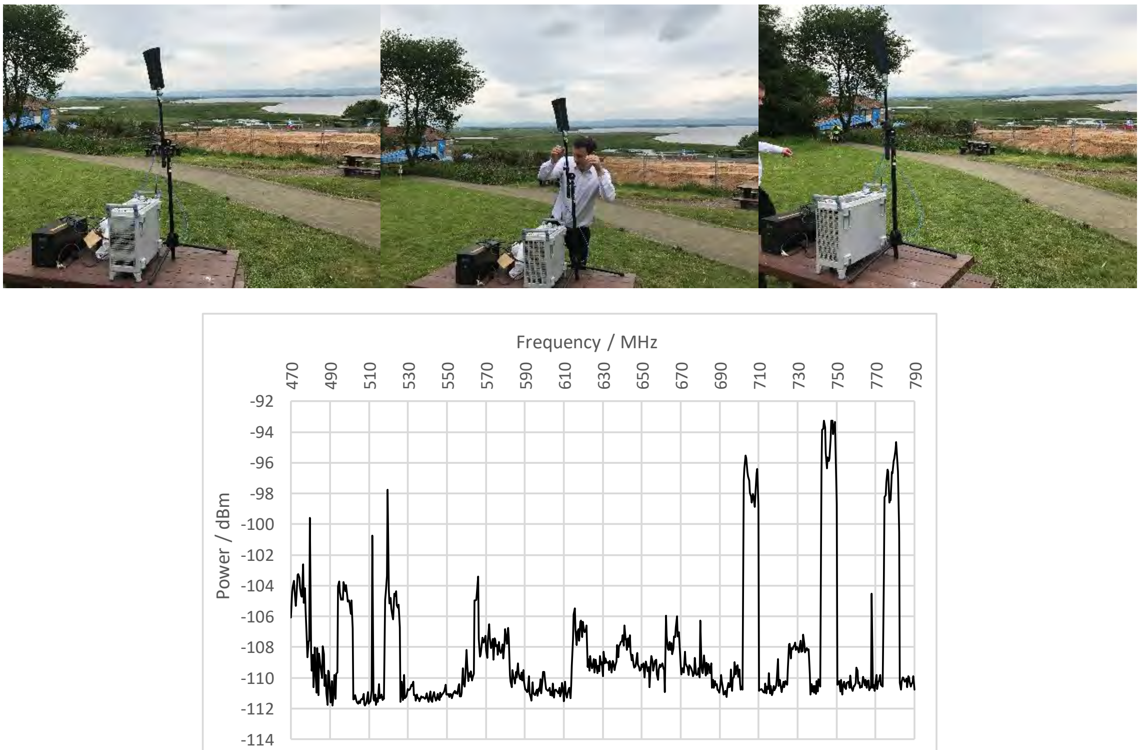


Figure 16. Photographs of the setting, and measurements at M90 J5.

RSPB



(recreated from measurement data file as spectrum analyser screenshot was accidentally not obtained in the rush to avoid approaching weather!)

Figure 17. Photographs of the setting, and measurements at RSPB.

3.2 Agricultural

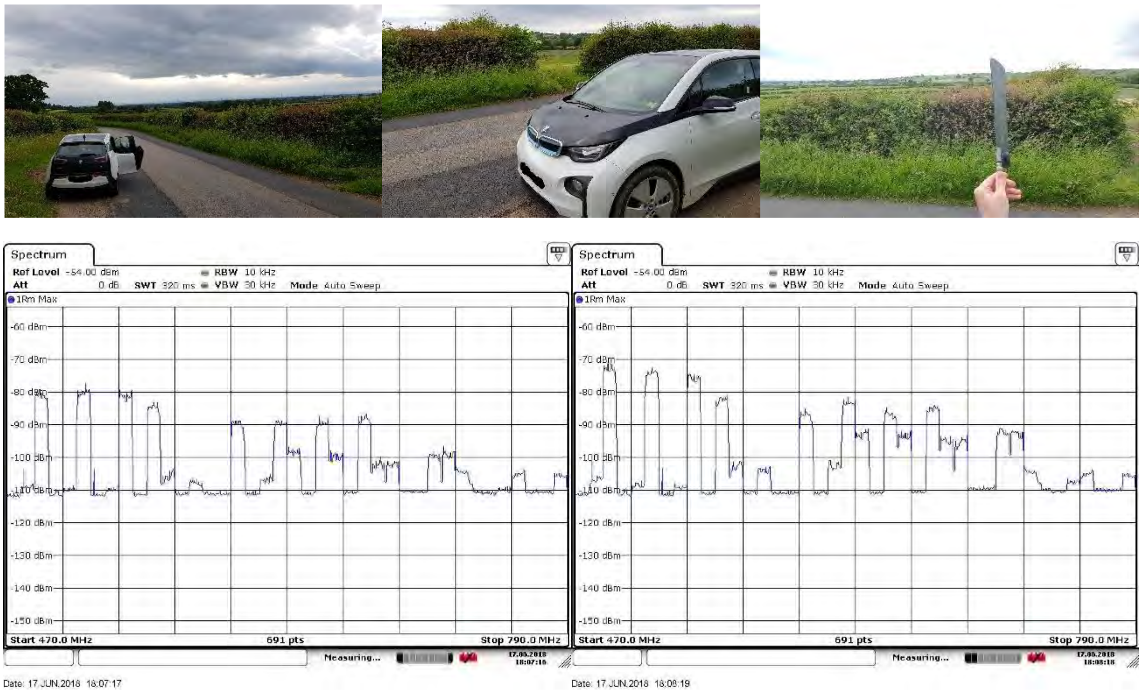
Figure 18 depicts the locations of measurements in for the Agricultural case. Figures 19-21 provide photos of the measurement locations, as well as the measurements themselves. In two of the three cases, where there was a clear increase in power levels observed by moving the antenna through all possible orientations and polarisations, both the "standard" and these "worst case" measurements are presented.

Figure 18. Locations for agricultural measurements and deployments.

Westmost Corner

Figure 19. Photographs of the setting, and measurements at the westmost corner.

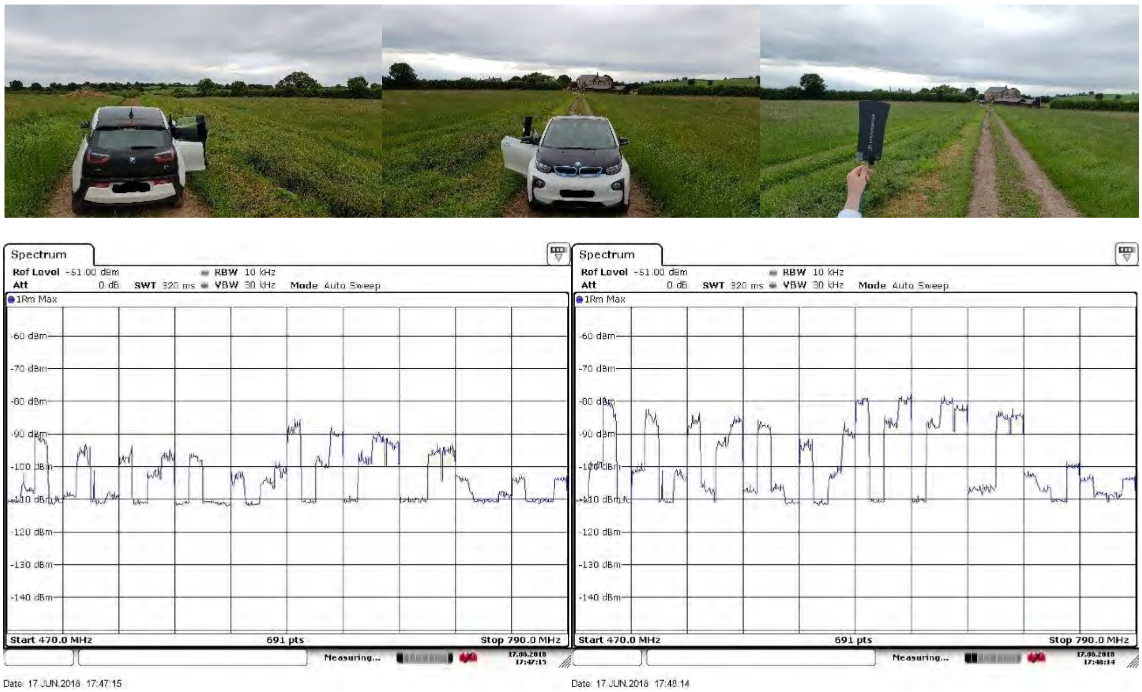
Eastmost Corner



Standard Worst Case

Figure 20. Photographs of the setting, and measurements at the eastmost corner.

Near Northmost Corner



Standard Worst Case

Figure 21. Photographs of the setting, and measurements at near the northmost corner.

3.3 Rural Broadband

3.3.1 Isle of Arran

Figure 22 depicts the locations of measurements for the Arran Rural Broadband case. Figures 23-43 provide photos of the measurement locations, as well as measurements themselves.

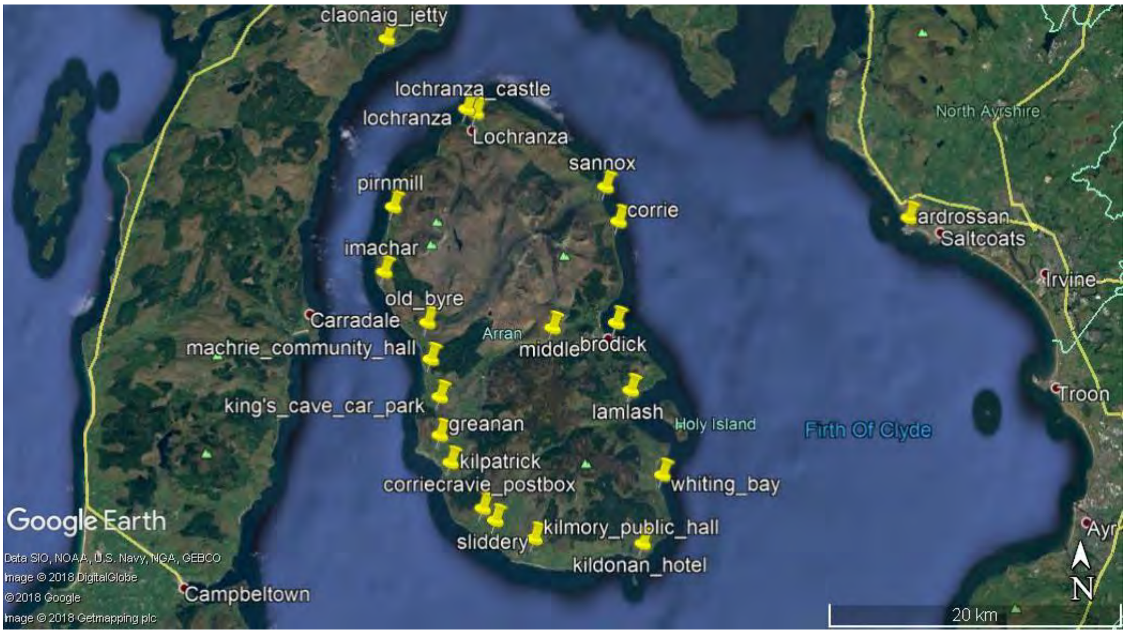


Figure 22. Locations for Loch Leven measurements, and in some cases deployments.

Claonaig Jetty

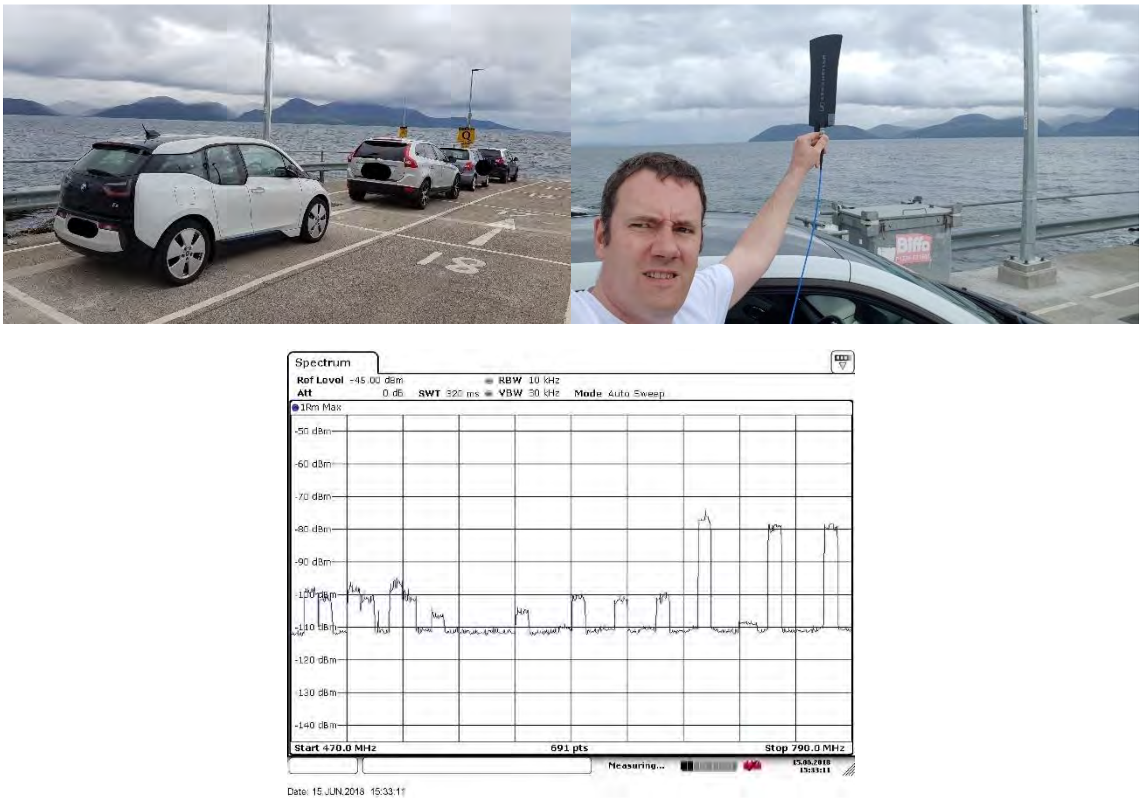


Figure 23. Photographs of the setting, and measurements at Claonaig Jetty.

Lochranza

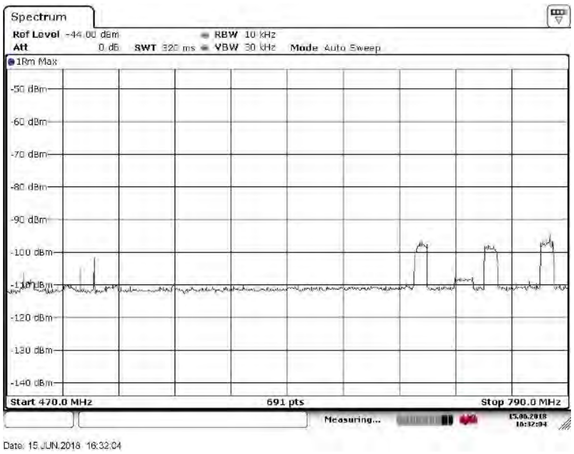


Figure 24. Photographs of the setting, and measurements at Lochranza.

Lochranza Castle

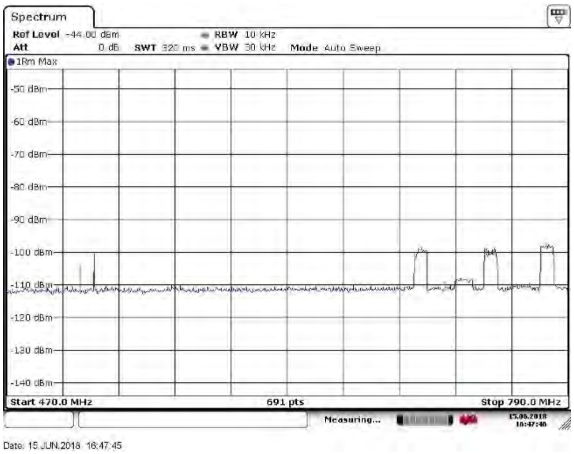


Figure 25. Photographs of the setting, and measurements at Lochranza Castle.

Pirnmill

Figure 26. Photographs of the setting, and measurements at Pirnmill.

Imachar

Figure 27. Photographs of the setting, and measurements at Imachar.

Old Byre

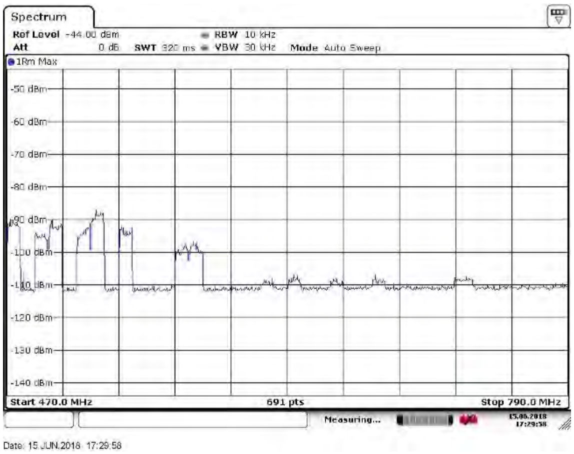


Figure 28. Photographs of the setting, and measurements at Old Byre.

Machrie Community Hall

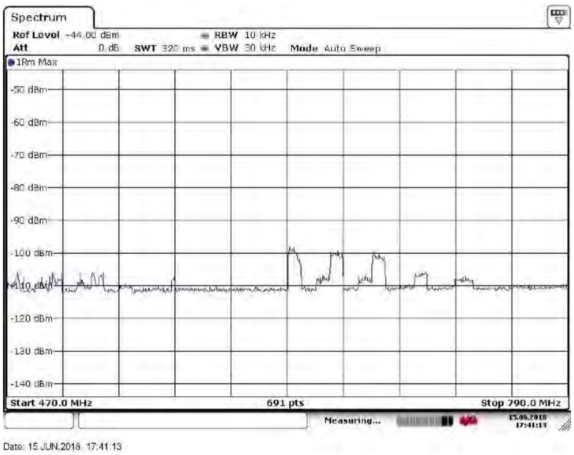


Figure 29. Photograph of the setting, and measurements at Machrie Community Hall.

King's Cave Car Park

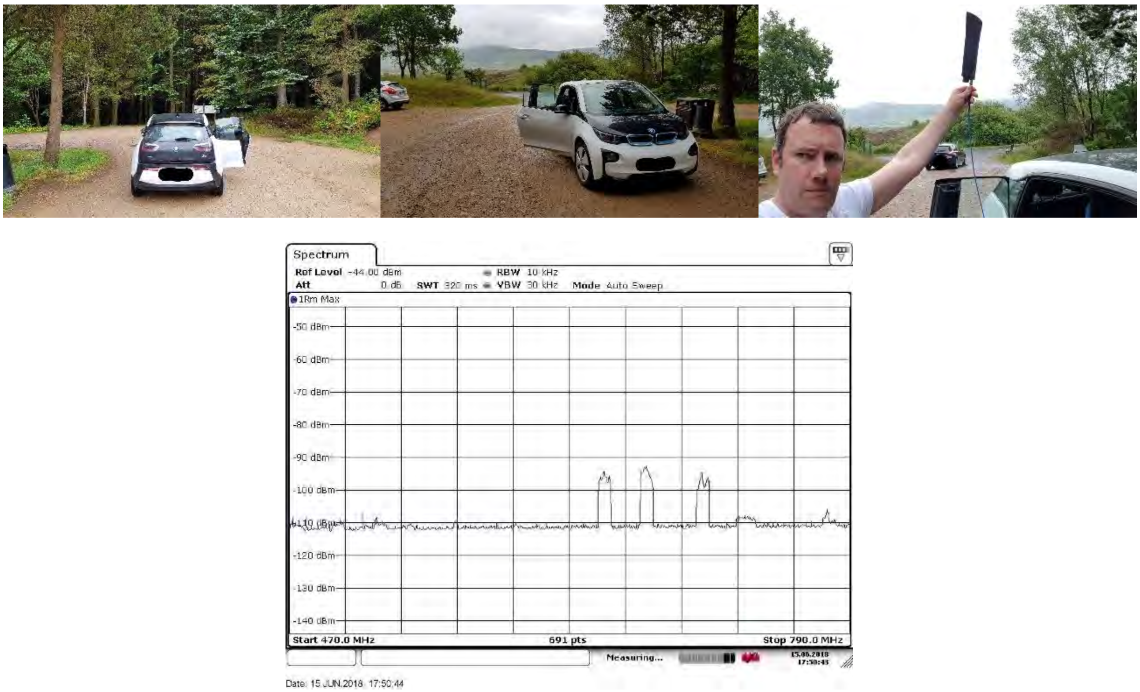


Figure 30. Photographs of the setting, and measurements at King's Cave Car Park.

Greanan

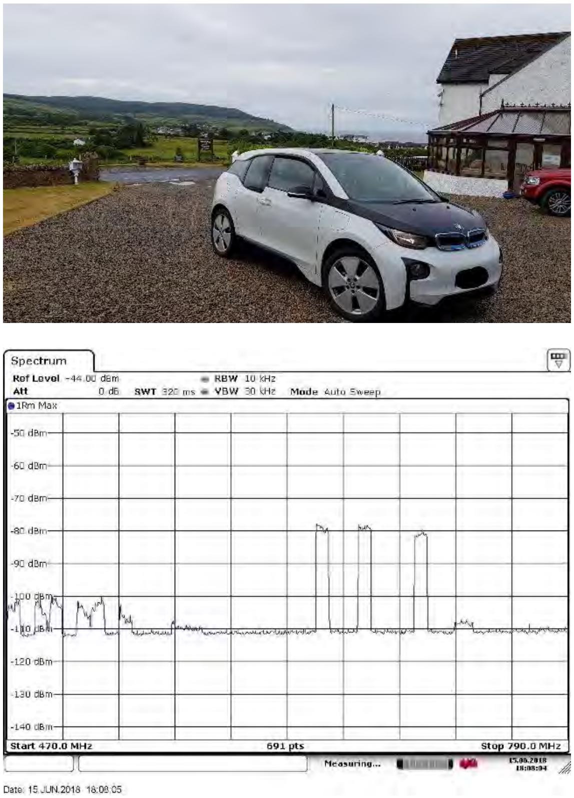


Figure 31. Photograph of the setting, and measurements at Greanan.

Kilpatrick

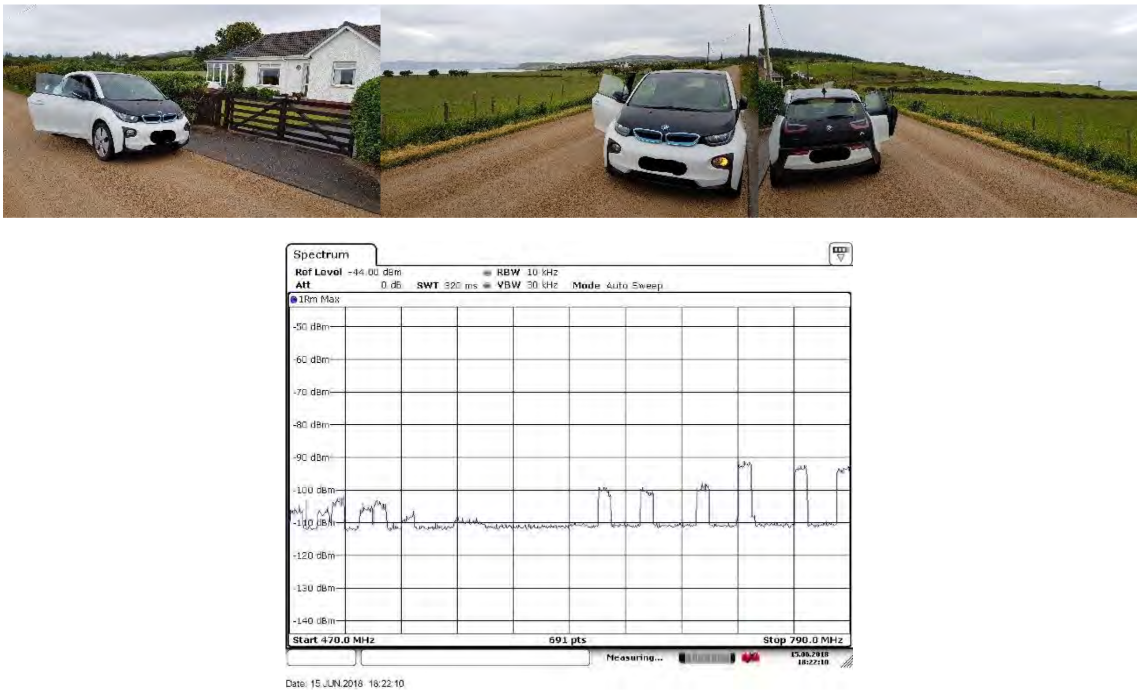


Figure 32. Photographs of the setting, and measurements at Kilpatrick.

Corriecravie Postbox

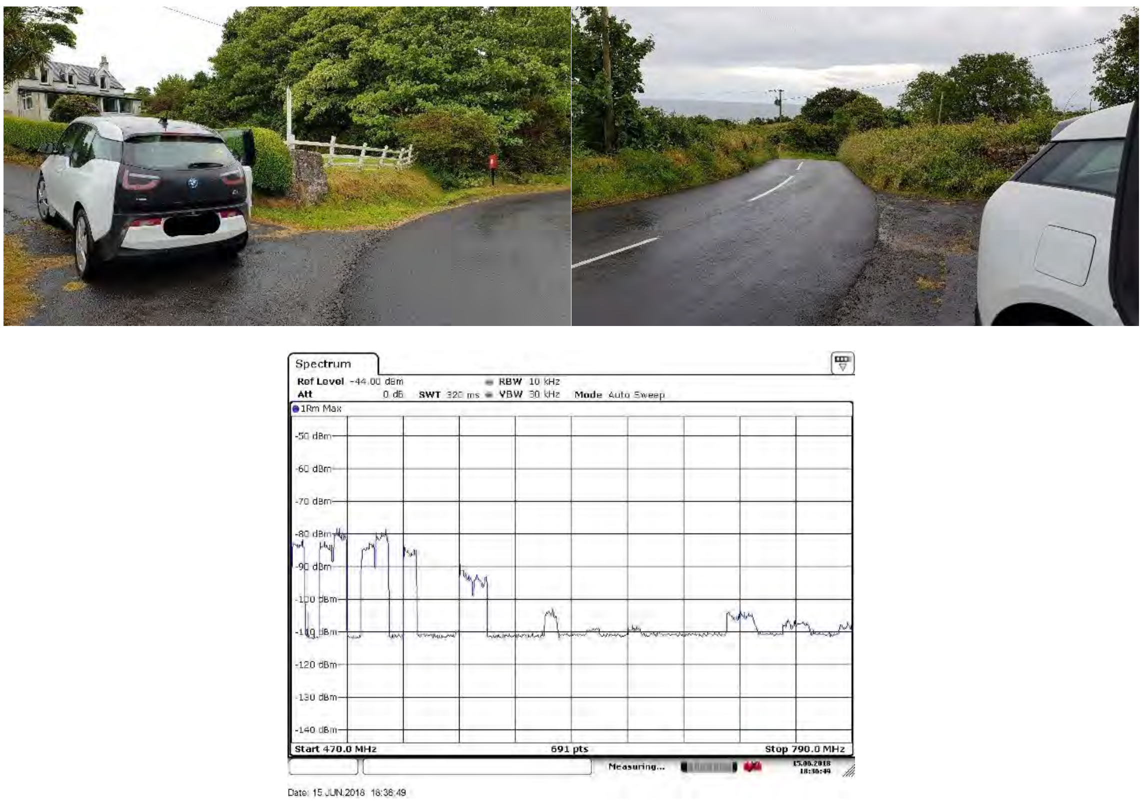


Figure 33. Photographs of the setting, and measurements at Corriecravie Postbox.

Sliddery

Figure 34. Photographs of the setting, and measurements at Sliddery.

Kilmory Public Hall

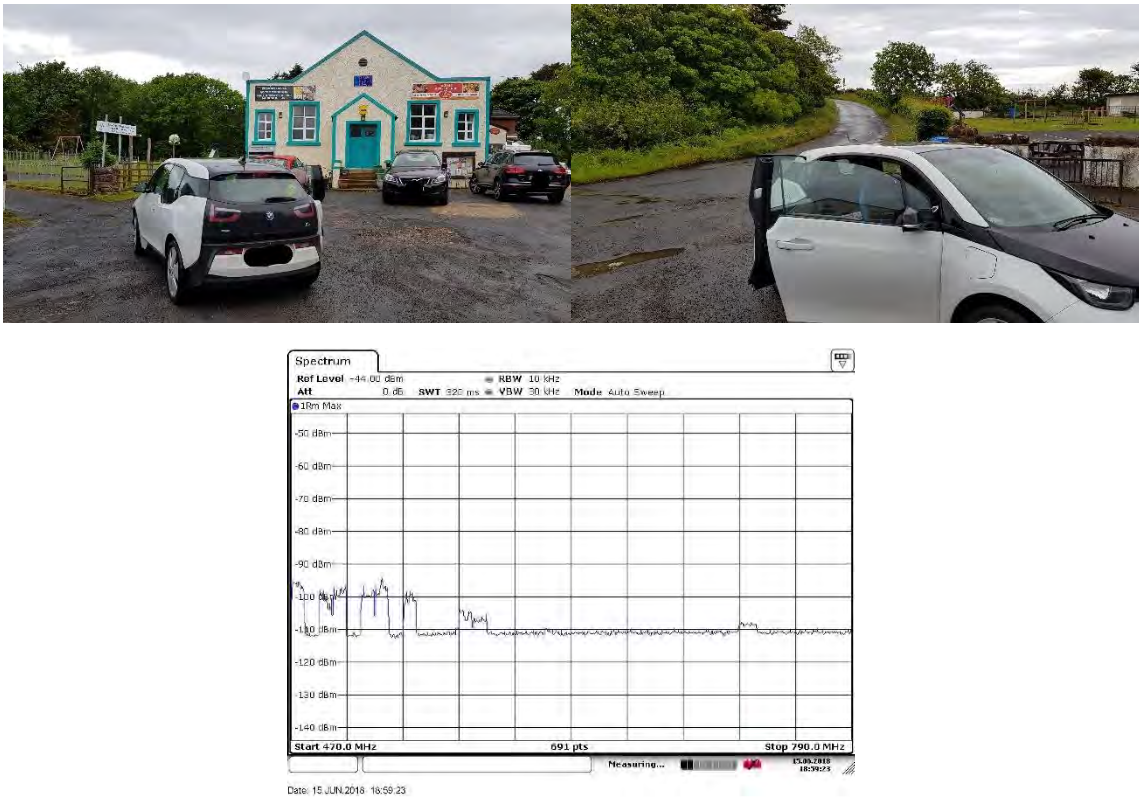


Figure 35. Photographs of the setting, and measurements at Kilmory Public Hall.

Kildonan Hotel

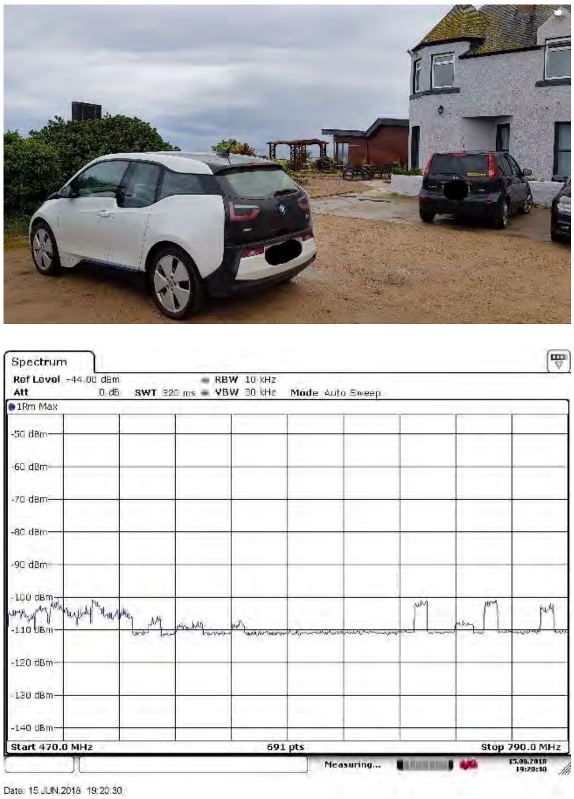


Figure 36. Photograph of the setting, and measurements at Kildonan Hotel.

Whiting Bay

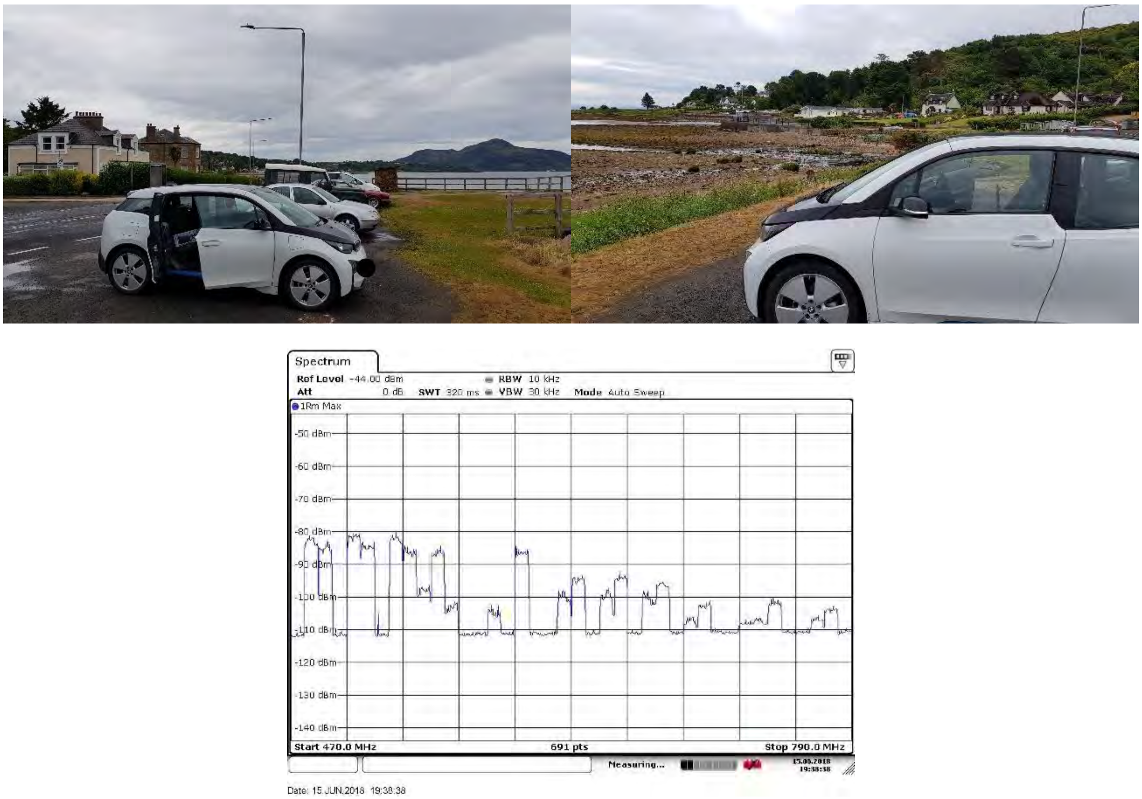


Figure 37. Photographs of the setting, and measurements at Whiting Bay.

Lamlash

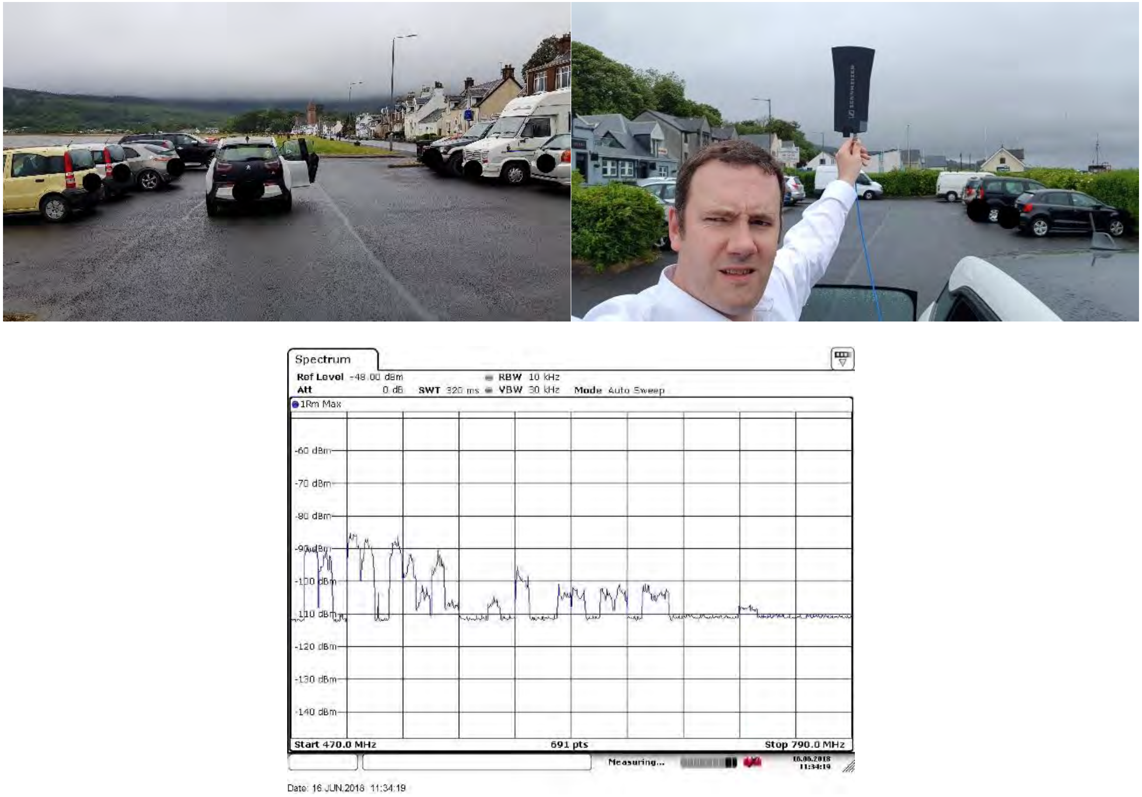


Figure 38. Photographs of the setting, and measurements at Lamlash.

Brodick

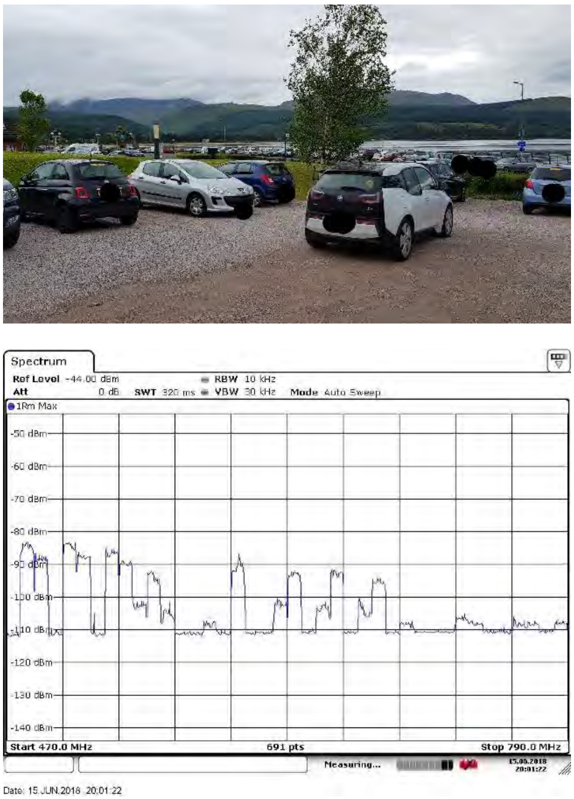


Figure 39. Photograph of the setting, and measurements at Brodick.

Corrie

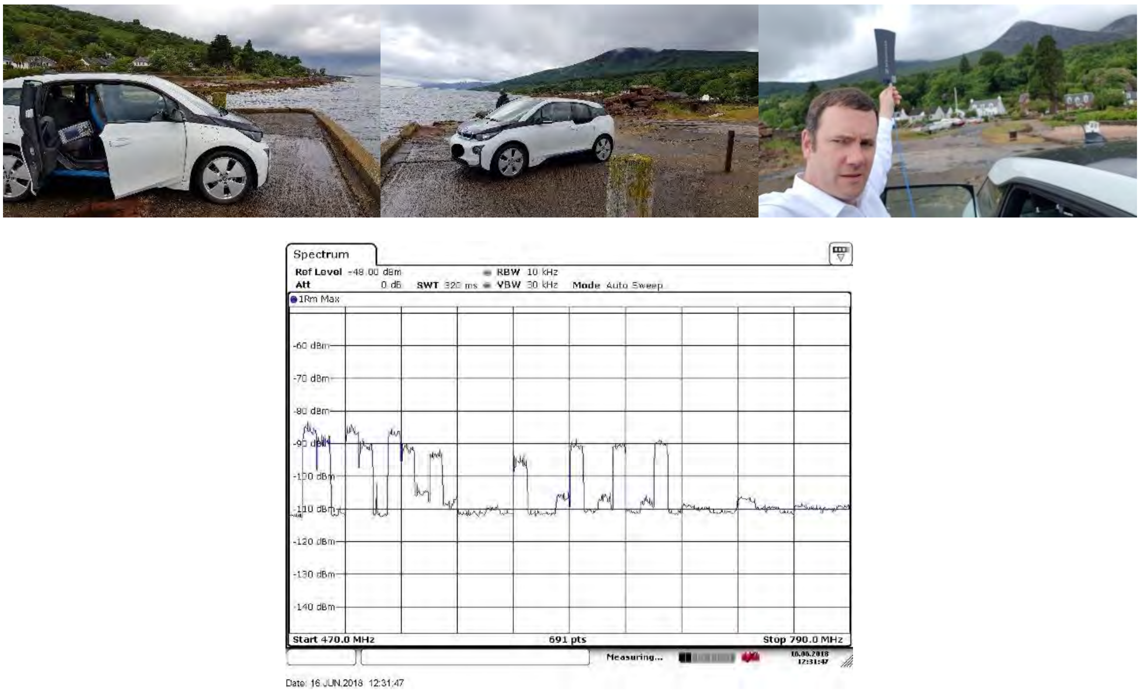


Figure 40. Photographs of the setting, and measurements at Corrie.

Sannox

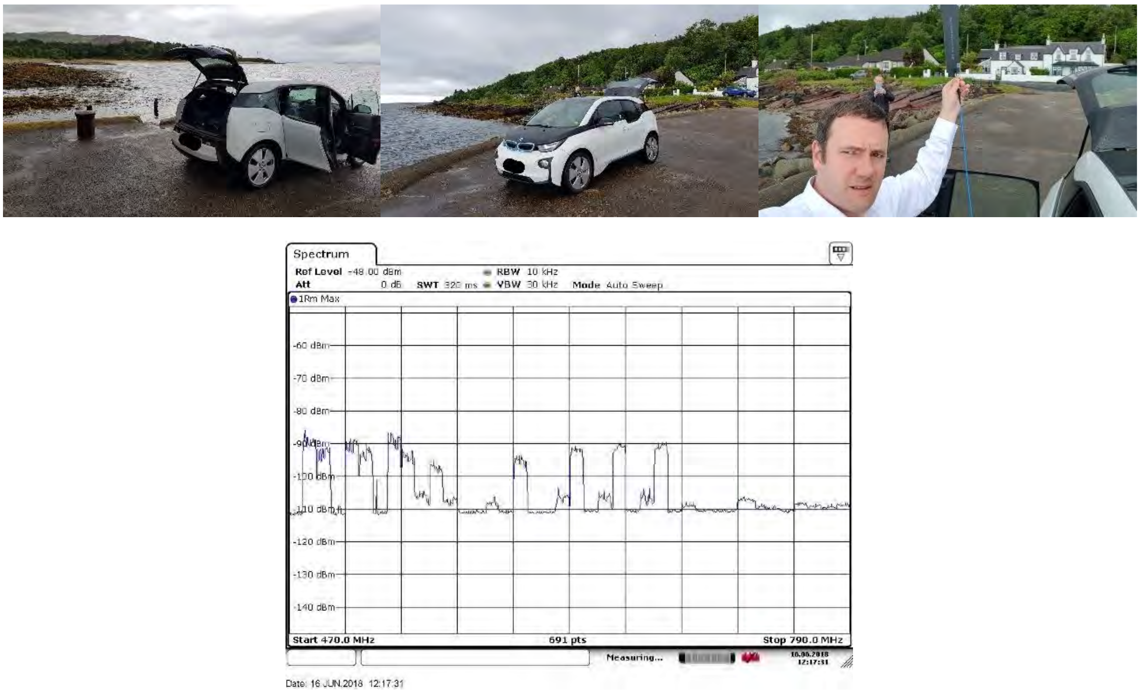


Figure 41. Photographs of the setting, and measurements at Sannox.

Middle

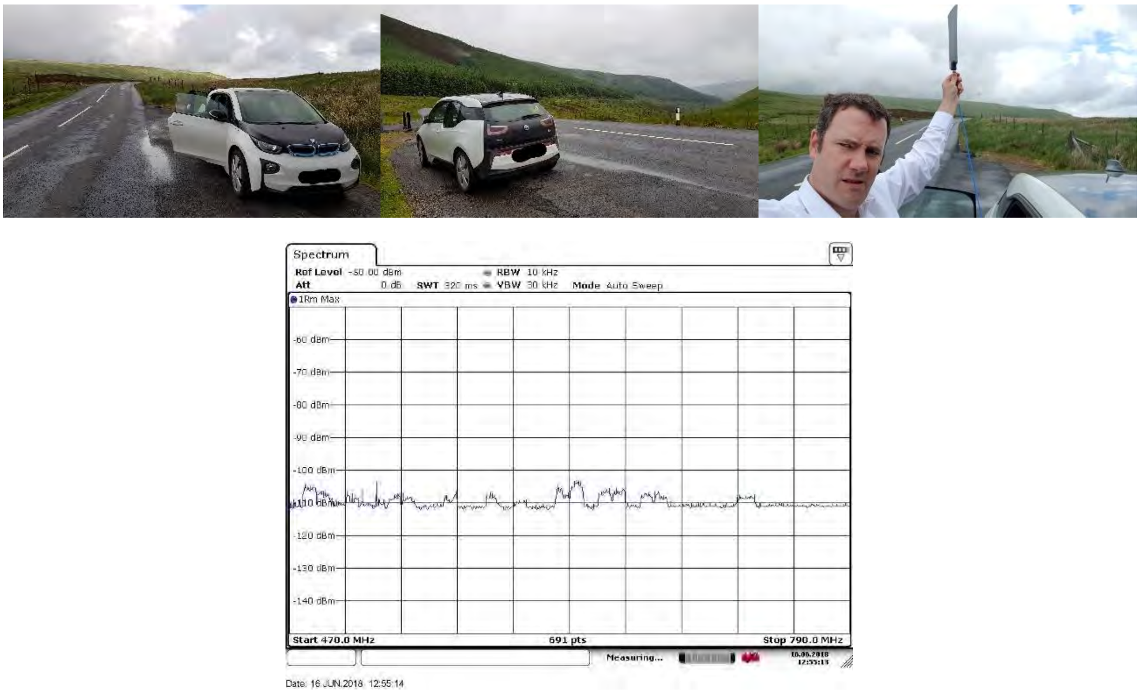


Figure 42. Photographs of the setting, and measurements at the middle of the island.

Ardrossan

Figure 43. Photographs of the setting, and measurements at Ardrossan.

3.3.2 Bardney

Figure 44 depicts the locations of measurements for the Bardney Rural Broadband case. Figures 45-46 provide photos of the measurement locations, as well as the measurements themselves. In the “Customers” location, where there was a clear increase in power levels observed by moving the antenna through all possible orientations and polarisations, both the “standard” and these “worst case” measurements are presented.

Figure 44. Locations for Bardney measurements and deployments.

Bardney BS

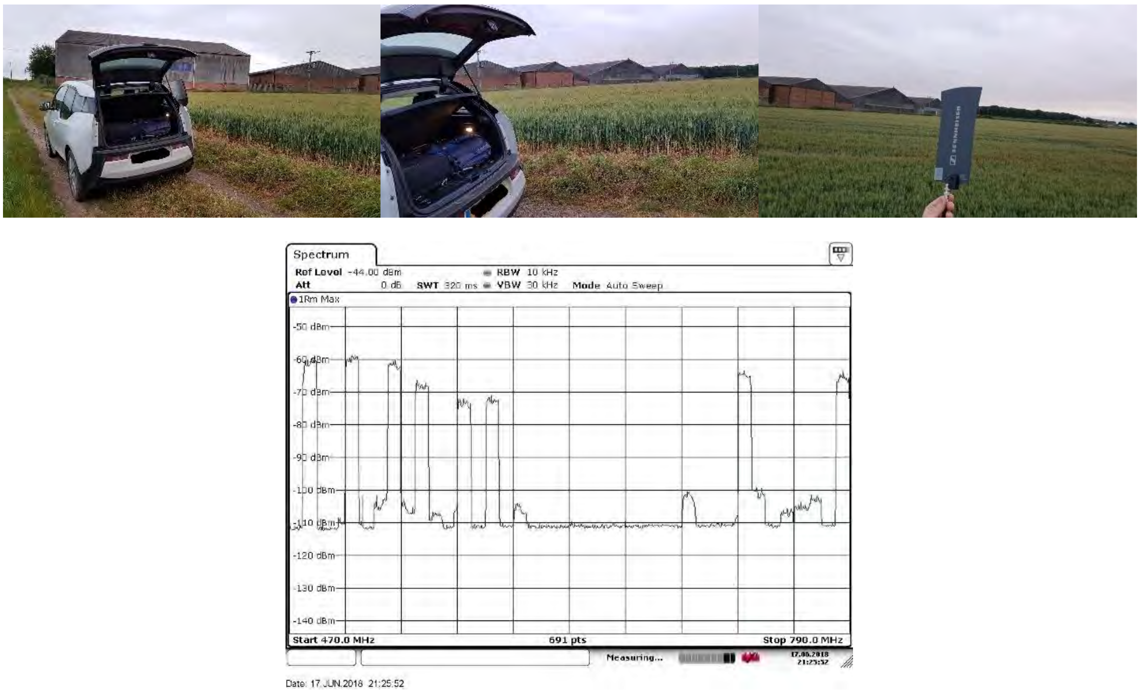


Figure 45. Photographs of the setting, and measurements at the Bardney BS.

Bardney Customers

Standard   Worst Case

Figure 46. Photographs of the setting, and measurements at the Bardney Customers.

3.4 Unmanned Aircraft Systems

Figure 47 depicts the locations of measurements in for the UAS case, for the Highfield Parc Blue Bear office, the utilised Airfield, and an extra location added as a high point with a good overview of the area to attempt to maximise the detection of interference. Figures 48-50 provide photos of the measurement locations, as well as the measurements themselves. There was, in all cases, a clear increase in power levels observed by moving the antenna through all possible orientations and polarisations, so both the “standard” and these “worst case” measurements are presented.

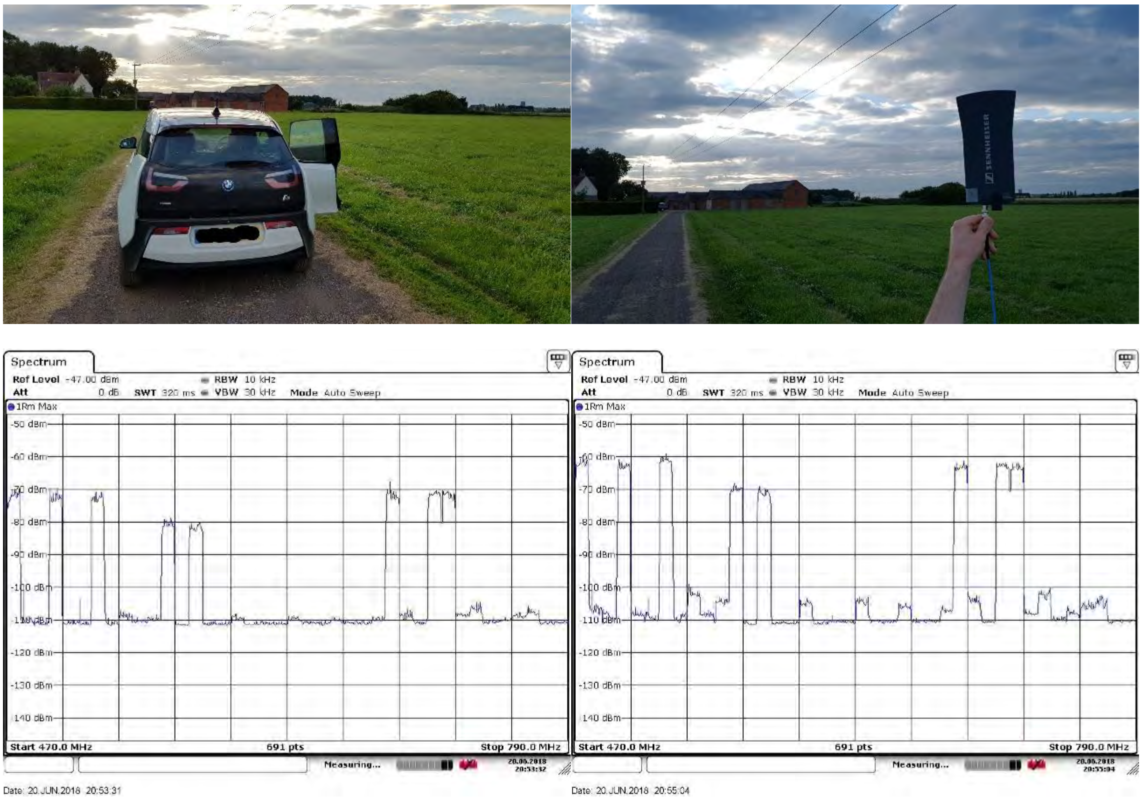
Figure 47. Locations for UAS measurements and deployments.

Highfield

Standard Worst Case

Figure 48. Photographs of the setting, and measurements at Highfield.

Airfield



Standard Worst Case

Figure 49. Photographs of the setting, and measurements at the airfield.

Extra location

Standard Worst Case

Figure 50. Photographs of the setting, and measurements at the extra location.

4 White Space Availability

In our past work, a WSD has been developed fully compliantly with the ETSI EN 301 598 conformance requirements/testing (CE marking) standard [14]. We use the logical database communication aspects of that implementation, in tandem with UK-qualified (hence, correct) Fairspectrum database access, to assess TVWS availability. Figure 51 is a snapshot of one form of GUI that we have built on top of this implementation.

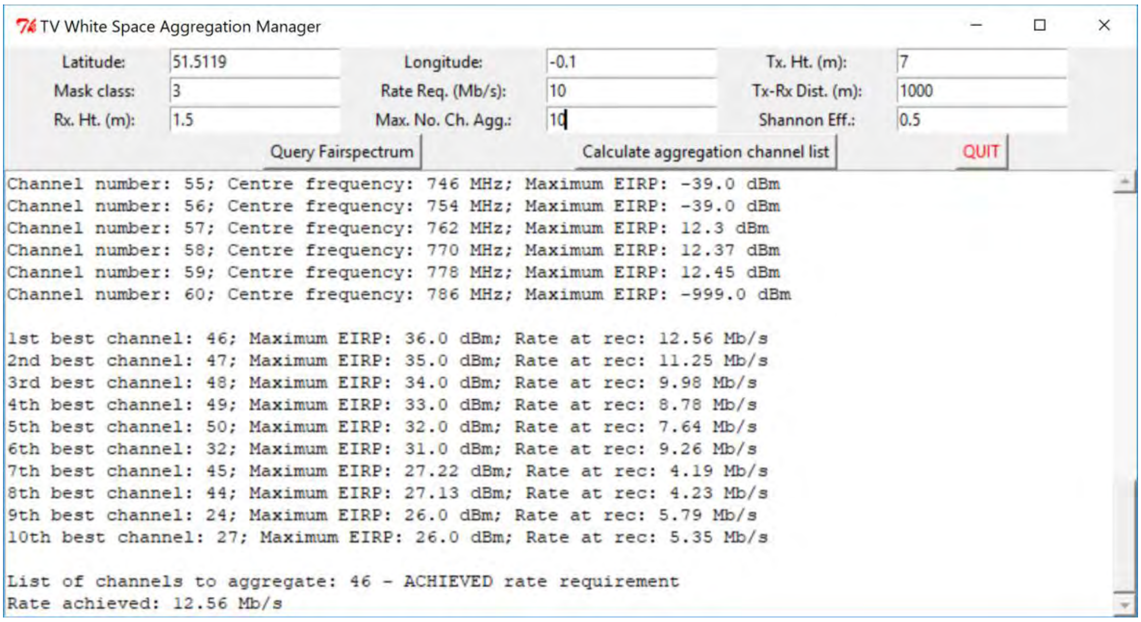


Figure 51. One form of GUI for our WSD implementation.

The following sections present the TVWS availability at the different locations, where deployment locations are only reported if they give significantly different results than other locations. At the time of doing this work and preparing this report, there was an error with Ofcom's central DTT protection work conveyed to the qualified databases, for Class 1 WSDs at some locations in the height AGL range of 3.25 m to 7.49 m. This meant that the results for Class 1 were wrong in most of our locations. This problem was reported to Ofcom; Ofcom acknowledged it and thanked us for the report, and corrected the error some time later. Class 3 results are therefore reported, despite the target WSDs for deployment being Class 1 although noting that Class 3 offers almost the same performance as Class 1, with Class 1 being only slightly better in some rare cases.

Annex A gives the (processed) results obtained from the white space database. The following subsections simply report broad per-deployment observations made from those results.

4.1 Tourism Augmented Reality

4.1.1 Alston Moor

Maximum EIRP is available on channels 51-53, only reduced marginally in some locations. Close to maximum EIRP is available in other sets of three contiguous channels. Numerous single-channels can achieve maximum, or close to maximum, EIRP at all locations. These include channels 48, 51, 52 and 53, among others.

4.1.2 Loch Leven

Channels 28-30 can serve a large proportion of locations at maximum or high EIRP. Channels 22-24 are good for some for other locations, although with significantly reduced EIRP. However, the uplink is strongly affected in many locations in striving to achieve common channels among all WSDs. Lowering the antenna to 3.24 m or lower greatly improves the situation for the uplink, especially if channels 22-24 are chosen. For the one-channel case, channel 23 appears to be good, with high EIRP throughout (downlink and uplink).

4.2 Agricultural

Channels 54-59 have maximum or close to maximum EIRP. For the one-channel case, channels 24, 27, 30, 54-59 all have maximum or close to maximum EIRP. If worse Class then best to go for 24, 58 or 59. The lower-frequency options should be selected if possible for better propagation.

4.3 Rural Broadband

4.3.1 Isle of Arran

North-West Island Coverage

Channels 47-49 and 51-53 have excellent EIRP on the downlink although relatively lower EIRPs on the uplink. This will probably not be an issue in most cases, given the asymmetrical nature of traffic and propagation characteristics of the links. Channels 32-34 are also relatively reasonable in terms of EIRP. For the one-channel case, channel 33 has at-or-close-to maximum allowed EIRP in all locations.

West/South/South-West Island Coverage

Numerous options for the downlink, all at maximum EIRP—even for low frequencies. However, the uplink is a very significant challenged due to variations at customers. Given this, a possible best choice is channels 54-56, noting that in some cases EIRP available for the uplink is significantly lower. For the one-channel case, one good choice among many is channel 52 with at or close to maximum allowed EIRP in all locations.

East Island Coverage

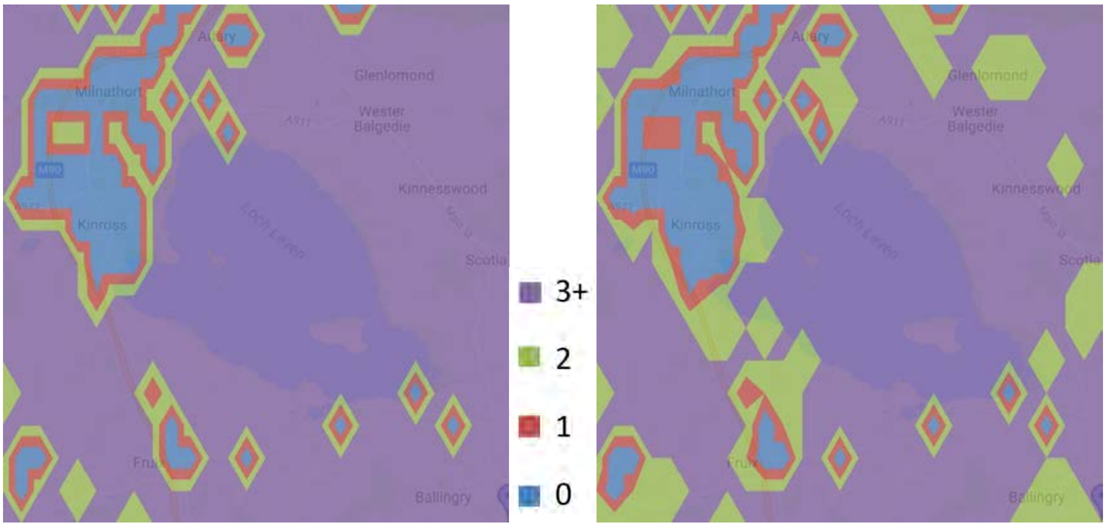
This case is by far the least problematic. Channels 50 and 52 are at or close to maximum allowed EIRP in all locations. For the one-channel case there are various possibilities, but channel 42 can be used at or close to maximum allowed EIRP in all locations.

4.3.2 Bardney

Any choice among channels 42-48, or 50-52, are with maximum EIRP in both BS and customer locations. For the one-channel case, numerous possible channels at or close to maximum EIRP exist, e.g., 23, 24, 26, 27, plus of course all the abovementioned higher-frequency (worse propagation) options.

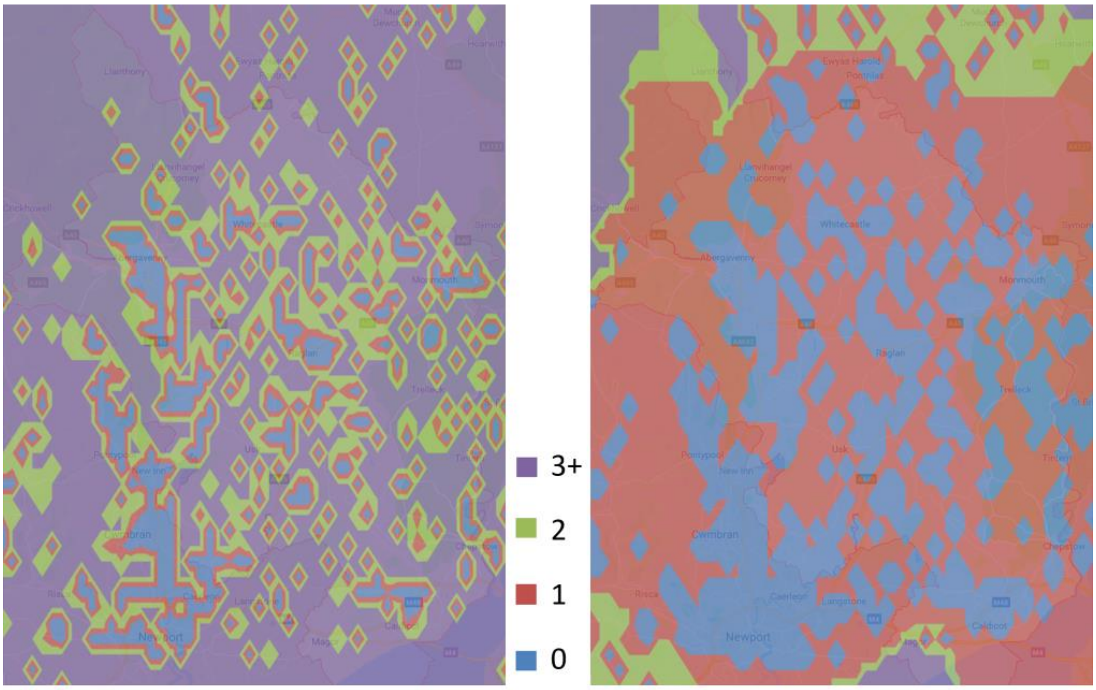
4.4 Unmanned Aircraft Systems

Channels 42-44 have maximum allowed EIRP, and channels 28-30 only 1dB lower than maximum EIRP, among some other potential options. For the one-channel case, any of the channels 42-47 are with maximum EIRP. For better propagation at lower frequencies, maximum or close-to-maximum EIRP can be achieved on channels 22, 23, 25, 26, 28-30, 33.



Doesn't have to be contiguous **Has to be contiguous**

Figure 52. Availability of contiguous or non-contiguous channels with at least 30 dBm Tx EIRP for Loch Leven, Scotland, ETSI Class 3 WSD, 7m antenna height (the key indicates different numbers of TV channels available).



Doesn't have to be contiguous **Has to be contiguous**

Figure 53. Availability of contiguous or non-contiguous channels with at least 30 dBm Tx EIRP for Monmouthshire, Wales, ETSI Class 3 WSD, 7m antenna height (the key indicates different numbers of TV channels available).

4.5 Contiguous vs. Non-Contiguous Aggregation

Our past work, augmented extensively in 5GRIT to bring the understanding up-to-date with the current situation in terms of TVWS availabilities, has done a number of studies on the availabilities of TV channels for aggregation (see, e.g., [4]). It has particularly compared contiguous and non-contiguous aggregation, as one major aspect of such work—again in recognition that 8 MHz (i.e., a single channel) would simply not be enough to achieve performance expectations. Moreover, the contiguous/non-contiguous comparison is pertinent given the contiguous channel transmissions of the utilised WSDs in comparison with the non-contiguous capability of an alternative manufacturer's option on the market.

Of course, the availability of channels for aggregation increases greatly if non-contiguous aggregation is possible, through such a solution as the use of multiple radios, or perhaps a filtering approach such as FBMC or NC-OFDM to "notch out" unavailable TV channels. Using the database implementation at the time of the UK's TVWS Pilot, for example, aggregating 3 channels over this large area of England, for example, could be achieved in only 21% of locations for contiguous only aggregation being possible, and 71% of locations for contiguous or non-contiguous aggregation being possible.

Figures 52 and 53 are new work reflecting the current situation in terms of TVWS availability and matching to areas considered in 5GRIT, location-dependency is emphasised. Here, the WSD antenna height is assumed to be 7m AGL, and Class 3 WSDs apply (noting that the situation for Class 3 should be not significantly different compared with Class 1). Here comparing the case for Loch Leven and Monmouthshire in Figures 52 and 53, Loch Leven has good availability for much of the area even if contiguous-only channels area assumed. Monmouthshire has vastly-reduced availability under contiguous-only channels, such that NGA-compliance is not a possibility for the area (i.e., only one or less TV channels are available in almost all of the county), unless vastly-reduced transmission powers are used to increase availability with a very high density of BSs. The situation is vastly improved for non-contiguous aggregation being allowed though, where NGA compliance can be mostly achieved through careful placement of the BSs where there is availability of two or more channels at this high (30 dBm) EIRP.

5 Key Characteristics and Technical Requirements of 5GRIT Use Cases

This section provides some brief high-level consideration of the characteristics and requirements for the different use cases. The purpose is to develop the recommendations made in Section 5 taking into account these characteristics and requirements.

5.1 Tourism Augmented Reality

This use case is potentially very wide in terms of requirements, at the upper end being required to achieve HD, 4K, or even 360° video in near real-time. This is to augment the local environment, providing immersive reality replicated historical video as one possible example among many, to the tourist. In terms of the latency requirements, if sufficient prediction and buffering is undertaken, near-real-time should be sufficient with some seconds of latency being acceptable.

Assuming only compressed content, this would require a rate of around 5 Mbps for Full HD video, although dependent heavily on the compression mechanism and the nature of the video. For 4K video, this could increase to around 20 Mbps, again dependent on many factors. For comparison, YouTube recommends encoding options of 35-45 Mbps for 4K "standard"-framerate (24, 25, 30 fps), or 53-68 Mbps for "high"-framerate (48, 50, 60 fps). In most cases 4K should be equivalent to basic 360° video in terms of data requirement, however, it is noted that 360° video might also vary up to much higher values, potentially a bitrate of 150Mbps or more depending on quality and a number of other factors. For instance, YouTube recommends uploading 360° video with a resolution of up to 8192 by 4096 pixels, i.e., four times 4K (hence, almost four-times the bitrate of 4K) [15]. These are, of course, potential rate requirements for each single user.

In terms of providing connectivity for the sole purpose of serving the World Around Me app, as an example working it is assumed that 100 users with the app arrive to an area (within coverage scope of the BS) per hour, and 50% of them switch on the app, i.e., downloading the content provided for the area. Say there are 100 content-sets (locations) covered in the area, where each content set has a very low data amount, varying considerably although certainly less than 1 MB. There are numerous other embedded content items that are downloaded when clicked on, but nothing in excess of basic web browsing data rate. Such numbers would imply a data rate of only (100/3600)*0.5*8=0.111 Mbps as supplied by the BS. Moreover, latency in this case can be comparable to usual web-browsing, with predictive download assisting dependent on the app.

The North Pennines AONB are collecting and will provide additional information on sites (content-sets) and customer numbers likely in July 2018, and that will assist in providing precise values. In the meantime, it is not possible to give precise values for the World Around Me app—aside from estimates based on broad/sweeping assumptions such as the above. Nevertheless, it is anticipated that the key characteristic of 5G serving this app will be greater coverage/availability; required bitrate will be relatively meagre compared with the other possible considered content such as 360° video. However, should the app expand to incorporate content such as Full HD/4K and 360° video, the situation would change.

This use-case is considered to be highly asymmetrical, with very little data sent on the uplink. So the uplink is not a challenge although uplink communication capability is required. Moreover, latency and reliability should not be challenging, being achieved by the usual higher-layer mechanisms with no specific lower-layer (5G) requirements necessary.

5.2 Agricultural

For the agricultural case, the HD near real-time video as in Section 4.1 might apply in some less-common examples, e.g., where an animal has been identified as ill and closer inspection (by drone) is required. Potentially even 4K or 360° video might be useful as uploaded from drones, potentially in near real-time. As regards sensed information from the farm, e.g., from the water trough, the data requirement will be extremely small and the bitrate infinitesimal. From a 5G perspective for this latter aspect, the key benefit here is the greater coverage/availability achieved.

For other cases, e.g., surveying/enhancing arable crops, based on expert consultations internally within the project, such video (potentially HD) and photos, etc., may be included, and at peak time of the year being taken on average every 1.75 days (151200 seconds), or at $6.6*10^{-6}$ Hz. This is all non real-time, being automatically (over 5G) uploaded from the drone upon its completion of a pre-planned flight path. The number and duration of such photos and videos is highly variable, but let's say it is around 10 high-resolution (e.g., 12 MP) photos, and 100 s of 4K video. A good upper-limit could be, say, around 10 MB (80 Mb) for each such photo, and 68*100=6.8 Gb for the video, although again highly-dependent on compression. This gives a total of around 7.8 Gb data. At this frequency of only $6.6*10^{-6}$/s and a latency requirement of one day, the bitrate requirement is 51.48 kbps on average. However, if the requirement was to upload the information in, say, 1 hour after return of the drone for quick analysis, the requirement would instead be 2.166 Mbps. At the upper limit of what can be achieved with TVWS currently, safely around 50 Mbps, the information could be obtained from the drone in 156 seconds. It is noted here that current TVWS technologies might nevertheless potentially be able to achieve up to around 75 Mbps.

Other forms of more sophisticated information might apply in more advanced scenarios. They include:

- Arable farming:
  - Multi-spectral / hyperspectral imaging to identify hot-spots (whole fields, wide-area).
  - High resolution visual imagery of hot-spots (<500m radius) to understand causes of issues, e.g. gemination rates, weeds, flooding, etc.
- Livestock farming:
  - Wide-area survey (visual / thermal) in order to count livestock and image individual animals (or groups of animals).
- Infrastructure inspection:
  - Routine condition monitoring to identify safety and reliability issues. Typical surveys:
    - LIDAR.
    - Thermal.
    - Detailed visual.
- Height of drone:
  - Arable & livestock typical height: 50-100m AGL.
  - Infrastructure inspection typical height: 10-50m AGL.

The implications of those requires further inspection as the project progresses.

This use case in expected to by asymmetrical, although (*unusually*) heavily weighted towards the uplink, with the vast majority of overall capacity taken by the uplink through, e.g., user and control video and other near-real time video coming from the drones. Downlink communication is, however, clearly also required.

5.3 Rural Broadband

For the Rural Broadband case, a key target for the project is to achieve Next Generation Access (NGA) requirements [11]. A fall-back is to achieve Universal Service Offering (USO) requirements [12].

NGA requirements are that the technical solution [11]:

- Is capable of providing access speeds in excess of 30 Mbps download, not only by reference to theory and technical standards, but also by evidence of calibrated performance measurements of an existing deployment within the area of interest or an demonstrably equivalent deployment in a similar geographical environment.
- Provides at least a doubling of average download and upload access speeds in the target NGA intervention area.
- Must be designed in anticipation of providing at least 15 Mbps download speed to end-users for 90% of the time during peak times in the target area, as demonstrated by industry-standardised or reliable independent measurements.
- Must show how the solution would adapt to maintain capability and end-user experience in changes to key parameters such as increased take-up and increased demand for capacity, and be able to show using clear calculations that this is both technically and commercially viable.

- Must have characteristics (e.g., latency, jitter) that enable advanced services to be delivered, e.g., video-conferencing and High Definition video streaming to be provided to end users as evidenced by trials results not necessary obtained within the area of interest.
- Has longevity such that one might reasonably expect increases in performance within the next 7 years.

The USO requirements are [12]:

- Download speed of 10 Mbps (minimum).
  - 10 Mbps is the download speed that Ofcom has said is necessary to deliver an 'acceptable user experience', allowing for users to stream films, carry out video conferencing and browse the web at the same time.
- Upload speed of 1 Mbps (minimum).
  - Reasonable upload speeds are necessary for applications such as video conferencing and uploading large files to social media. For example, Skype recommends a minimum upload connection speed of 0.5 Mbps for a high-quality video call.
- Medium response times (latency).
  - Latency is the round-trip delay in transmission data. This is important for live applications such as live video streaming and video calls. Ofcom stated that a delay of around 1 s has a noticeable impact on user experience.
- Contention rate of 50:1.
  - Contention is the degree to which bandwidth is shared between different end users at the same network node. A contention ratio of 50:1 means that up to 50 broadband users may be sharing the same bandwidth at any one time.
- A minimum data cap of 100 GBs per month.
  - This is the limit which service providers can impose on the amount of data that users can download. In 2017 Ofcom reported that on average, UK households consumed 190 GB of data per month.

Regarding communication symmetry, this use case is asymmetrical and heavily weighted towards the downlink, per the usual requirements for broadband provisioning. The author of this report is, however, doubtful about the correctness of such government assumptions, as the uplink is becoming ever-more important and data-intensive through Cloud and Web 2.0 applications. A user's Google Photos app, for example, might conceivably upload several GB of data upon connecting to Wi-Fi over TVWS backhaul in many scenarios/locations. Fortunately, the TDD nature of TVWS equipment lends well to adjustment of the downlink/uplink ratio, and in some contexts (e.g., IEEE 802.11af) that adjustment is effectively done automatically.

5.4 Unmanned Aircraft Systems

The aforementioned requirements as per the agricultural case apply here, given that drones will be used for that. Moreover, the following additional requirements apply to the control of drones and potential other purposes:

Link distance (ground control station to drone):

- Minimum: 1.5km.
- Target: 5km.
- Stretch: 10km.

For control of drones, Blue Bear typically looks for around 4 Mbps link capacity, with a latency of 0.5 s or less—although realistically could operate with a latency of 1-2 s if necessary. Regarding link availability, the drone will continually monitor the status of the link and trigger a 'lost link' procedure (e.g., return to home) in the event of the link being lost for more than a pre-defined time (typically 3 s). In the event of the link being restored the remote pilot will have the ability to cancel the procedure and return to the mission.

For the ground control to drone (and vice versa), the following also often applies:

- Uplink for Command & Control (C2) – Note that this is flight director / autopilot commands (rather than real-time (high rate, e.g., 10Hz) servo control) containing a set of inputs such as height, heading, payload control, waypoints, vehicle status commands. These messages may be low rate, e.g., 1-2 Hz.
  - Data rate for this is infinitesimal compared with achievable capacity.
- Downlink for UA status – Similar data rate to the C2 uplink, allow the UA to report its current state, e.g. position, height, payload modes, etc. at a low rate such as 1-2 Hz.
  - Data rate for this is infinitesimal compared with achievable capacity.
- Downlink for real-time sensor data – Min requirement would be a camera image to allow First Person View (FPV) control of vehicle. Ideally this would be a Full HD 25fps image but a low res low rate image would suffice, e.g., 720p 4fps.
  - Data rate requirement for this could be considerable, potentially up to around 5 Mbps depending on scenario.

For Highfield to the ground control (Airfield), Blue Bear is hoping to investigate use of TVWS links directly to the aircraft. This enables multiple functions, including:

- Web based cooperative airspace awareness (position, speed, height, heading, ID, etc. for all aircraft within region).
- Web based satellite imagery.
- Post flight distribution of payload data, e.g., hyperspectral / multi-spectral, visual imagery for cloud-based processing. An example of this is multiple still images with a defined overlap across an area to be surveyed. For a 1 km^2 area with a 65% image overlap the number of images could be ~1,000 (each 2 MPx). For multi-spectral/hyper-spectral cameras the resolution would be lower but there would be 4-300 times the number of images (for each of the additional spectral bands).
- Relaying real-time command and control of the UA to a different location, e.g., Blue Bear offices. Performance requirements as with GCS to UA.
- TVWS tower direct to the drone – Allowing real-time command and control of the drone at different location, e.g., Blue Bear offices. Performance requirements as with ground control to the drone.

This use case is clearly highly asymmetrical biased towards the uplink, although also requires the downlink. The key characteristic of 5G (and TVWS, as a facilitator of that) that is demonstrated through the use case is greater coverage/availability, although in some scenarios (e.g., video for remote control) higher capacity and low latency is also required. Mobility of up to 30 m/s is also a concern here.

6 Channel Usage Choice Recommendations, and Observations on Coverage and Performance

This section discusses the prior interference and availability analyses, and recommends transmission channel choices given those factors. It also predicts coverage and performance.

A first important observation here is that compared with the spectrum analyser plots, a WSD might see a noise floor of around 10 dB less than the spectrum analyser, i.e., of around -121 dBm per 10 kHz bandwidth. This is because a WSD will typically have around 10dB better noise figure than the spectrum analyser. Per 8 MHz TV channel, this WSD noise floor equates to around -92 dBm (i.e., 29 dB added).

Further, it is assumed that both transmitter and receiver gains are 10 dBi, where it is noted here that WSDs generally must be time-division duplex and will use the same antenna for transmission and reception. The receiver gain means the device will see signals 10dB more powerfully than as seen on the spectrum analyser with the omnidirectional antenna. On the transmitter side, gain is already encompassed in chosen EIRP emission levels.

Taking all of these aspects into account, three threshold values of received power are derived for our coverage analyses. They are:

- -77 dBm, equivalent to at least 25 dB SINR given the abovementioned factors.
- -87 dBm, equivalent to at least 15 dB SINR given the abovementioned factors.
- -97 dBm, equivalent to at least 5 dB SINR given the abovementioned factors.

We use the Longley-Rice point-to-point model to assess coverage and performance across the deployment scenarios. The parameters used under this model are as follows:

- Transmitter height AGL: 7.49 m.
- Transmission power (EIRP): 4 W (36 dBm).
    - o Note, in almost all cases TV channels are available and chosen for which this maximum transmission EIRP can be used.
- Transmission frequency: Centre frequency of the three available/used combined contiguous channels.
- Vertical polarisation.
- Surface refractivity: 320 N-units.
- Dielectric constant of ground: 15.
- Conductivity of ground: 0.005 Siemens/m.
- Climatic zone: Maritime temperate over land.
- Confidence level: 90%.
- Time availability: 99%.
- Location availability: 90%.
- Receiver height above ground: 5m.
- Omnidirectional Tx assumed, as characteristics of possible antennas are not known.
    - o Hence, in a real scenario with directional WSD antennas, coverage will match what we present here along the axes of the (both transmit and receive) WSD antennas, but will be reduced at angles away from those axes.

The Longley-Rice implementation we have used is provided by the Communication Research Centre (CRC), Canada. It is noted that other implementations, including source code, are also freely available, an example being the GNU General Public License “RF Signal Propagation, Loss, And Terrain analysis tool (Splat!)”: http://www.qsl.net/kd2bd/splat.html.

6.1 Tourism Augmented Reality

6.1.1 Alston Moor

Considering Alston Moor, taking into account all locations together where the assumption is that one or more BSs on Mount Hooley will serve the area, the recommended channel choices are as follows:

For 3 channels, Class 3: Channels 51-53, where maximum EIRP (4 W, 36 dBm per channel) is available at almost all locations, including importantly the Mount Hooley BS. No interference as seen by the spectrum analyser; the very slight interference seen on Channel 53 appears to be an effect of internal electrical interference as discussed previously.

For 1 channel, Class 3: Channel 48 seems a good choice, with maximum EIRP throughout almost all locations. Even if dropping the spectrum mask to Class 5, maximum power still holds. Further, there is no interference in channel 48 in all locations as seen by the spectrum analyser.

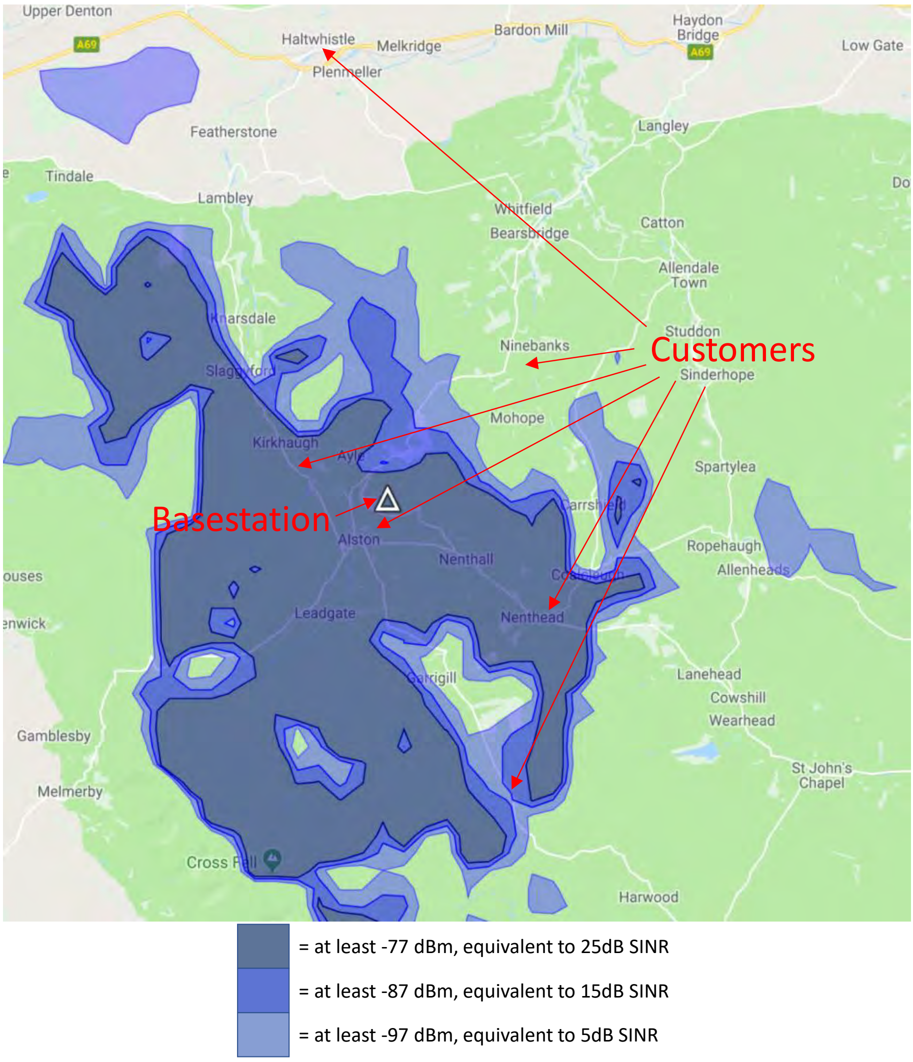


Figure 54. Predicted coverage for Alston Moor.

Given these observations, the transmission centre frequency here was set to 722 MHz, the centre of channels 51-53. Figure 54 gives expected coverage. As can be seen, all locations except Ninebanks Hearse House and Haltwhistle Station are well covered, although Alston Ski will experience a reduced SINR predicted to be at the borderline of the 15 dB threshold. It is hoped that it might still be possible to somewhat serve Ninebanks Hearse House through varying the precise location and transmitter Height on Mount Hooley.

6.1.2 Loch Leven

Considering Loch Leven, taking into account all locations together where the assumption is one or more BSs located on the Island will serve the area, the recommended channel choices are the following:

> *For 3 channels, Class 3*: Channels 28-30 can serve a large number of locations, where maximum EIRP is available in almost all those locations and interference is low or zero. Another possibility is channels 22-24 for other locations, although with significantly reduced EIRP. However, it appears to be impossible to find three contiguous channels with which all locations can be served at a reasonable EIRP—strongly affecting the uplink. The downlink, nevertheless, is excellent on channels 28-30. Further, lowering the antenna to 3.24 m or lower greatly improves the situation for the uplink, especially if channels 22-24 are chosen.
>
> *For 1 channel, Class 3*: Channel 23 appears to be a good choice, with high EIRP and little or no interference.

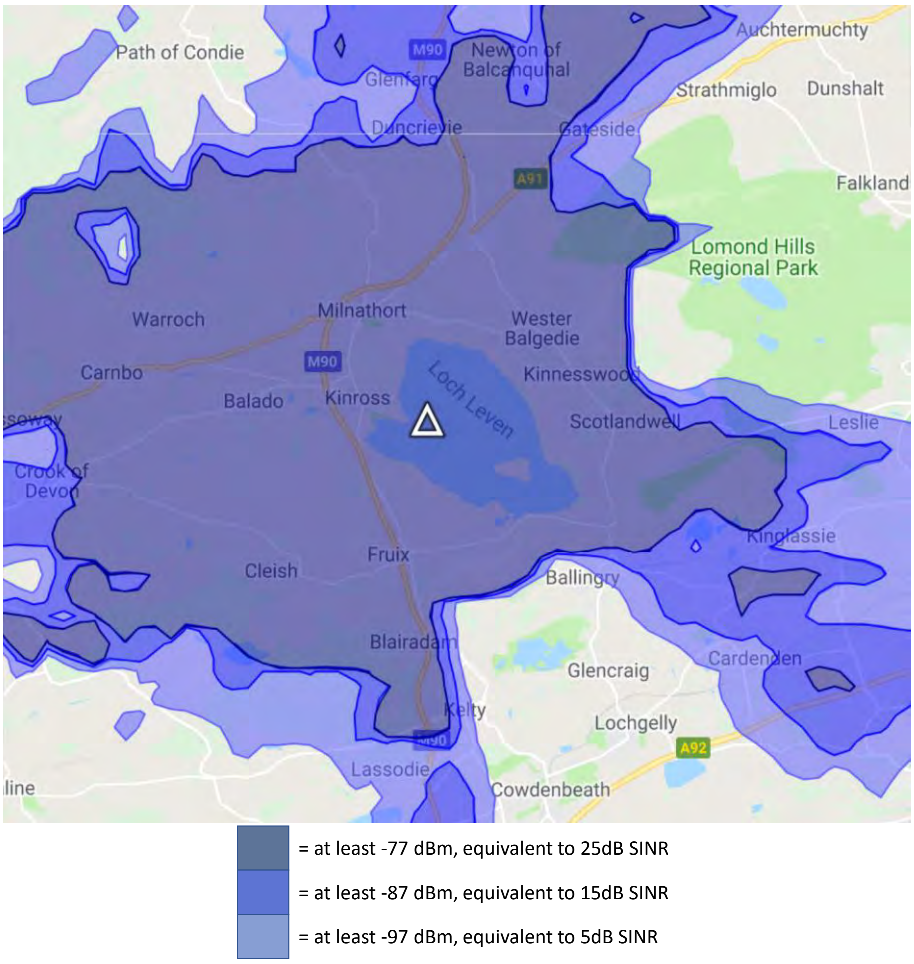


Figure 55. Predicted coverage for Loch Leven.

Given these observations, the transmission centre frequency here was set to 538 MHz, the centre of channels 28-30. Figure 55 gives expected coverage. All locations are well served on the downlink, even some considerable distance away from the Loch—although many will have issues with performance on the uplink for aforementioned reasons. Nevertheless, such are the reduced communication distances serving the Loch, and propagation, that in most cases the reduced EIRPs achievable on the uplink will suffice.

6.2 Agricultural

For the agricultural scenario, the following recommendations are made:

> *For 3 channels, Class 3*: Likely 57-59; maximum power. Quite a bit of interference still but should not be an issue at shorter distances (e.g., a few hundred metres) anticipated as needed for this.
>
> *For 1 channel, Class 3*: 24, 27, 55, 58, 59; at Class 3 all have maximum power and low interference at least as seen by the spectrum analyser. If worse Class then best to go for 24, 58 or 59, as others have EIRP reduced very slightly at worse powers.

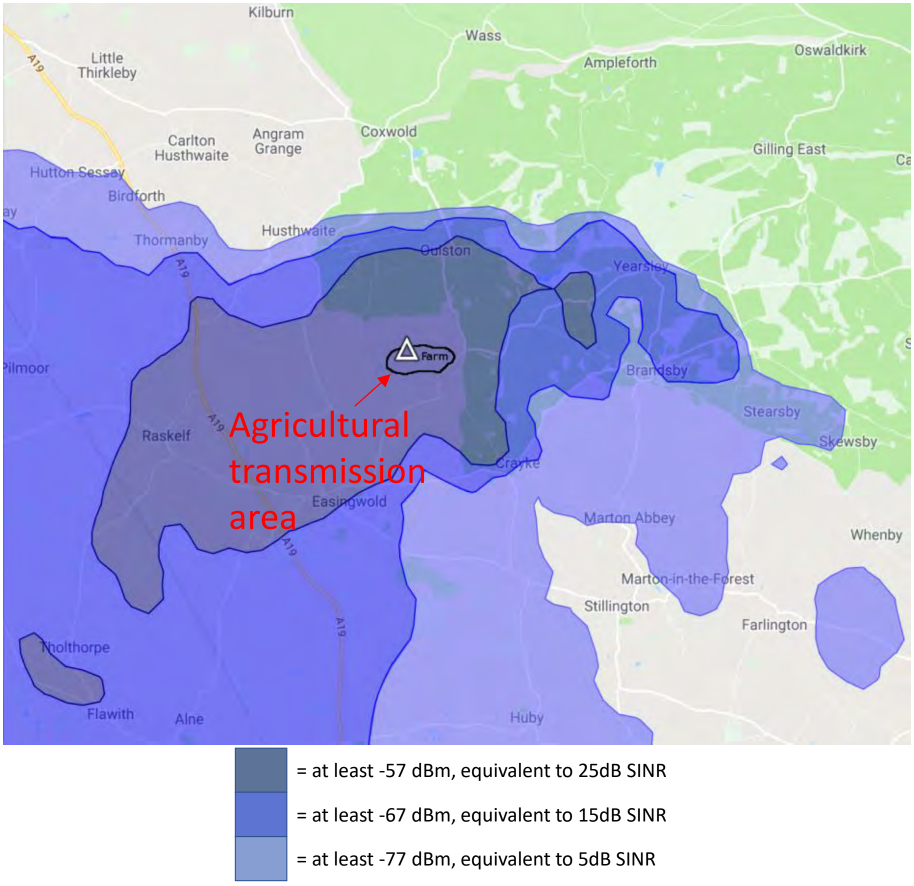


Figure 56. Predicted coverage for the agricultural case.

In the agricultural case, it is clear that there is interference on the chosen channels, however, the level is only approximately known on channel 57—being around 14 dB above the noise floor of the WSD. The spectrum analyser is not sensitive enough to see interference on channels 58 and 59, if any. Therefore, as an estimation, we assume that there is a 10dB on average interference above the noise floor of the WSD. Moreover, in a worst case which we assume, this interference is coming from the same direction of the intended signal, therefore, the benefits of receiver gain are eroded.

These two factors added together mean an effective decrease of around 20dB in the experienced SINR. Received power values used in this case are therefore compensated by 20dB to:

- -57 dBm, equivalent to at least 25 dB SINR.
- -67 dBm, equivalent to at least 15 dB SINR.
- -77 dBm, equivalent to at least 5 dB SINR.

As can be seen in Figure 56, even in this more challenging interference-prone scenario, the intended Farm coverage is predicted to be easily achieved. In fact, coverage at a SINR of 25 dB or more extends far away from the farm, especially to the West—over a distance of more than 5km.

6.3 Rural Broadband

6.3.1 Isle of Arran

For the Isle or Arran, it is noted that the population is almost all in coastal towns/villages around the edge of the island. Moreover, if BSs are hosted on the island they can usually cover only a small area of land, with all of the coverage otherwise going out to sea. This is due to the hilly/mountainous nature of the island, and the general shape of it, meaning that nearby areas are likely shadowed from areas that are covered. Moreover, it is noted that WSD antennas will usually be of high gain, effectively covering an angle of only, say, 30-40° from the axis of the antenna. It therefore makes sense to point the antenna at the island from outside, some distance away.

Although it is a matter of ongoing assessment, one good solution to cover Arran is therefore to set BSs on mainland locations with antennas pointing towards the West and East of the Island. For instance, the whole of the East side of the island can be comfortably covered by a BS placed in or to the South of Ardrossan, on slightly raised ground close to the coast. Most of the West side and the vast majority of the south can be covered by a BS located on slightly raised ground to the South-East of Campbeltown. The remaining area to on the North-West of the island can be covered by a BS located in or near Claonaig or Crossaig, on slightly raised ground close to the coast.

All links, except Claonaig provisioning to the North-West of the Island, are challenged by the link length of potentially 20-30 km. This could be challenging, although not because of propagation loss (noting that almost all links will be at or close to line-of-sight, so received power levels will be reasonable or good). The challenge is protocol design for the precise WSDs used, particularly whether the MAC and PHY can cope with the longer delays between transmission and reception over such distances. The validity of such options therefore needs to be tested with actual equipment. It is noted, however, that standards such as the IEEE 802.22 Wireless Regional-Area Networks standard using TVWS, are designed to cater for such transmission distances of up to 30 km. Other standards, such as the IEEE 802.11af Wireless Local-Area Networks in TVWS standard, can't operate over such distances—due to the nature of the medium-access control and the contention mechanism used. Nevertheless, assurance was received, at least for the utilised equipment, that implied such link distances would be possible.

Given the availabilities at each of these BS locations, and at served customers, the following recommendations are made.

For North-West island coverage from/near Claonaig/Crossaig:

For 3 channels, Class 3: Either channels 47-49 or 51-53. However, both have challenges with relatively lower allowed EIRP on the uplink. This will probably not be an issue in most cases, given the asymmetrical nature of traffic and the at or close to line-of-sight characteristics of links. However, this problem can be compensated by using a very high-gain antenna at the BS side if necessary, and lowering the power delivered to the antenna to still deliver the same EIRP at the BS. Also worth testing is channels 32-34, although it is noted that if the transmission is flat then the EIRP-per-channel will need to be the lowest of any of those channels. Nevertheless, we opt for channels 47-49 in this document.

For 1 channel, Class 3: Likely channel 33 is an excellent choice with at-or-close-to maximum allowed EIRP and no interference as perceived by the spectrum analyser, in all locations.

Coverage for the North-West-of-the-island case is as in Figure 57, using Channels 47-49—the centre frequency of which is 690 MHz.

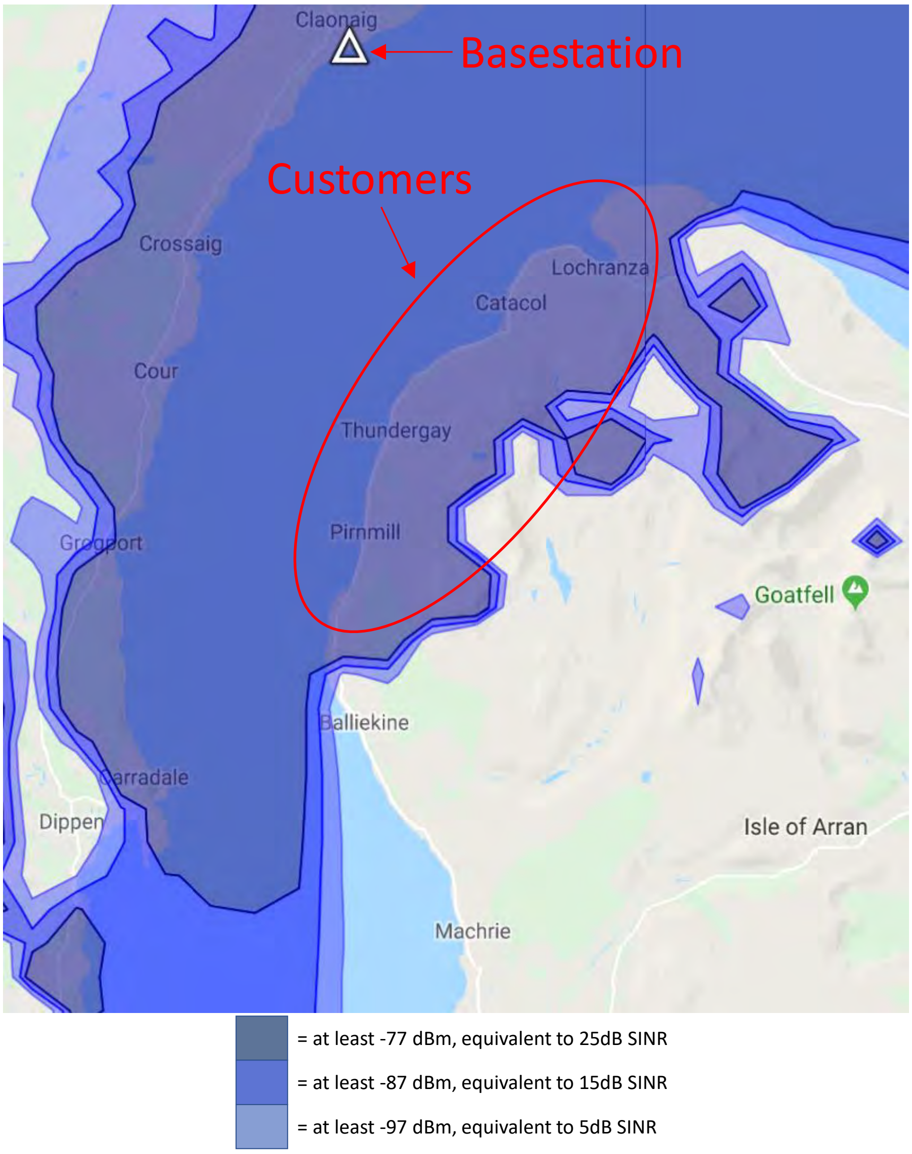


Figure 57. Predicted coverage for the north-west of Arran case.

For West/South/South-West island coverage from a coastal location towards the South-East of Campbeltown:

> *For 3 channels, Class 3*: There are numerous options for the downlink, all at maximum power—even for low frequencies. However, the uplink is a very significant challenge because of the differing TVWS availability at different customers. Given this, a possible best choice is channels 54-56, noting that in some cases EIRP available for the uplink is significantly lowered, and there is also in some cases interference on the downlink. The uplink issue can again be mitigated by using a high-gain antenna at the BS.

> *For 1 channel, Class 3*: There are numerous possible options, however, a good one is channel 52 with at or close to maximum allowed EIRP in all locations, and little or no interference as seen by the spectrum analyser.

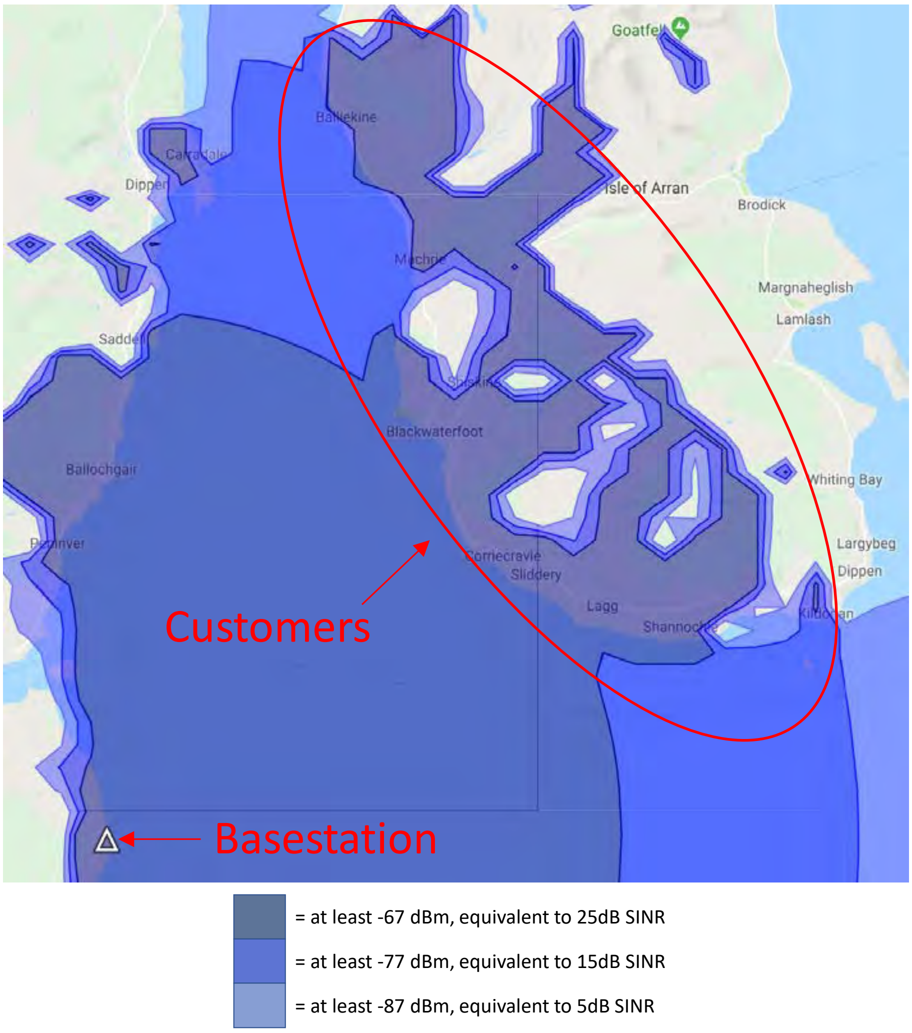


Figure 58. Predicted coverage for the south/south-west of Arran case.

Coverage for the South-/South-West-of-the-island case is as in Figure 58. This is using Channels 54-56, the centre frequency of which is 746 MHz. Moreover, although the true level of interference is hidden in many cases as it may be below the noise floor of the spectrum analyser, a 10 dB compensation for interference is assumed, giving the adjusted used values:

- -67 dBm, equivalent to at least 25dB SINR.
- -77 dBm, equivalent to at least 15dB SINR.
- -87 dBm, equivalent to at least 5dB SINR.

For East island coverage from a coastal location in or just South of Ardrossan:

> *For 3 channels, Class 3*: Channels 50 and 52 are at or close to maximum allowed EIRP at all locations, with little or no interference as seen by the spectrum analyser.
>
> *For 1 channel, Class 3*: Various possibilities, but favouring lower frequency Channel 42 can be used at or close to maximum allowed EIRP at all locations, with little or no interference.

Coverage for the East-of-the-island case is as in Figure 59. This is using Channels 50-52, the centre frequency of which is 714 MHz.

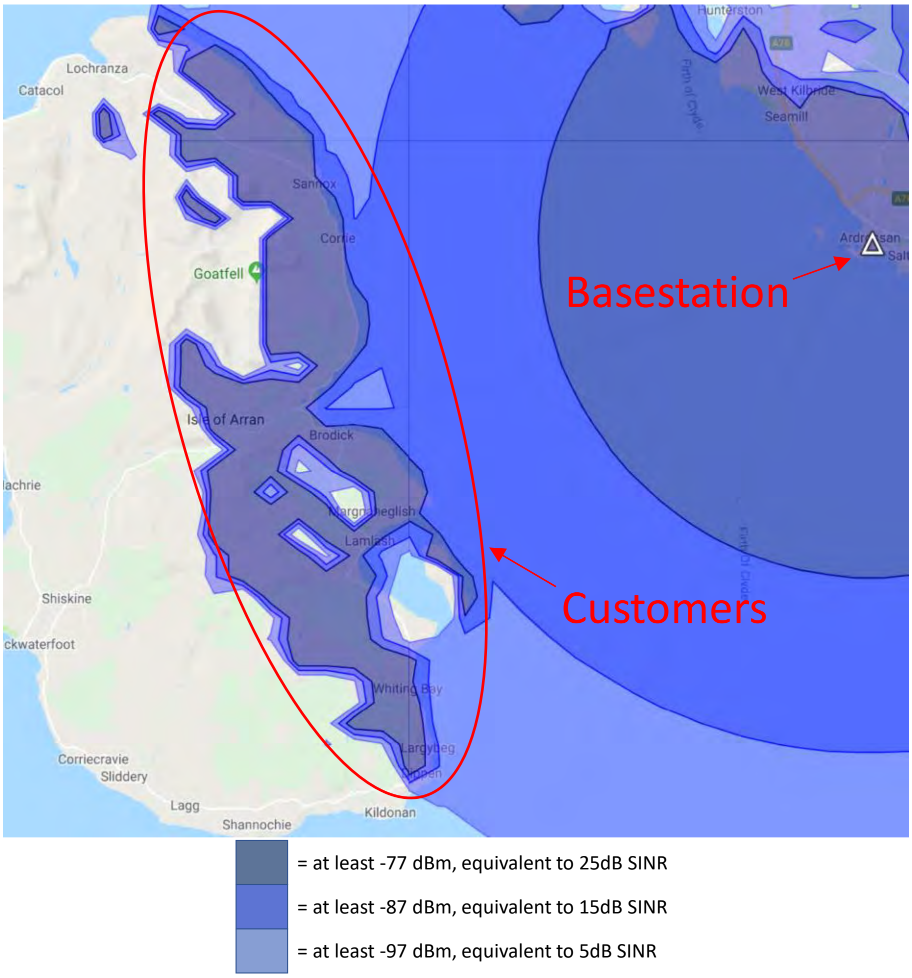


Figure 59. Predicted coverage for the east of Arran case.

6.3.2 Bardney

For Bardney, the following recommendations are made:

> *For 3 channels, Class 3*: Any choice between 42 and 48, or 50-52, are maximum power with no interference as seen by the spectrum analyser. The best choice would appear to be channels 42-44, in order to use the lowest frequency with best propagation.
>
> *For 1 channel, Class 3*: Numerous possible channels as above. Also lower frequency options for better propagation at or close to maximum power, e.g., 23, 24, 26, 27, with little or no interference. Note, channels 43-49 still at maximum power even if dropping Class 5 spectrum mask.

There is no observed interference in this case, therefore we revert back to the same situation as the tourism augmented reality case in terms of the received power thresholds in order to achieve given SINRs. Moreover, we choose and use the centre frequency of 650 MHz, being the centre frequency of the three contiguous channels 42-44.

As can be seen in Figure 60, it is predicted for the link from the BS to customers to easily be achieved at a high SINR, leading to a good modulation/coding scheme. The performance of the actual equipment would be expected to achieve a link capacity of at least 50 Mbps over the three channels combined (24 MHz) in this scenario.

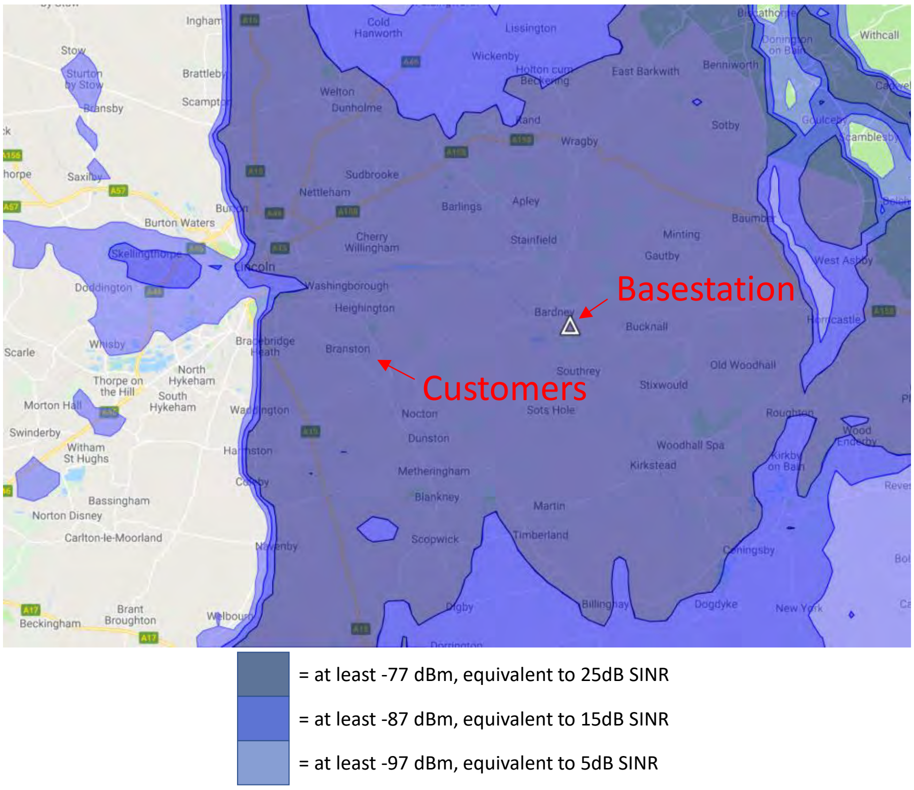


Figure 60. Predicted coverage for the Bardney case.

6.4 Unmanned Aircraft Systems

For the UAS scenario, the following recommendations are made:

For 3 Channels, Class 3: All options have some degree of interference, and there are numerous possible choices. Channels 42-44 is one possible choice as maximum allowed EIRP an relatively lower interference, although other options with similar level of interference also apply. However, this choice is lower frequency with better propagation, so we suggest it as the choice for this reason. There is alternatively an even-lower three channels, 28-30, at only 1dB lower than maximum power, however, that choice appears to have a significantly higher background interference level.

For 1 Channel, Class 3: In this case any of the channels 42-47 are worth experimenting with, all at maximum power with no interference as seen by the Spectrum Analyser. Moreover, for better propagation at lower frequency, it might be worth experimenting with some of the lower-frequency maximum power, or close-to-maximum power, channels, namely: 22, 23, 25, 26, 28-30. They all have some degree of interference. Channel 33 has no interference as seen by the spectrum analyser and is at or close to maximum power depending on which end of the link is being considered.

For the 3-channels case, the centre-frequency is 650 MHz for the contiguous channels 42-44. Moreover, there is significant interference on Channel 44, but none is seen on the other two channels. However, it is uncertain what, if anything, we might be missing below the noise floor of the spectrum analyser for those channels. Again as an approximation given these unknowns, we revert back to the same situation as the agricultural case in terms of compensated required received power thresholds in order to achieve given SINRs.

Results in the Figures 61-62 show that the link should be formed with a good SINR, predicted to be at the borderline of the 25 dB threshold.

Highfield

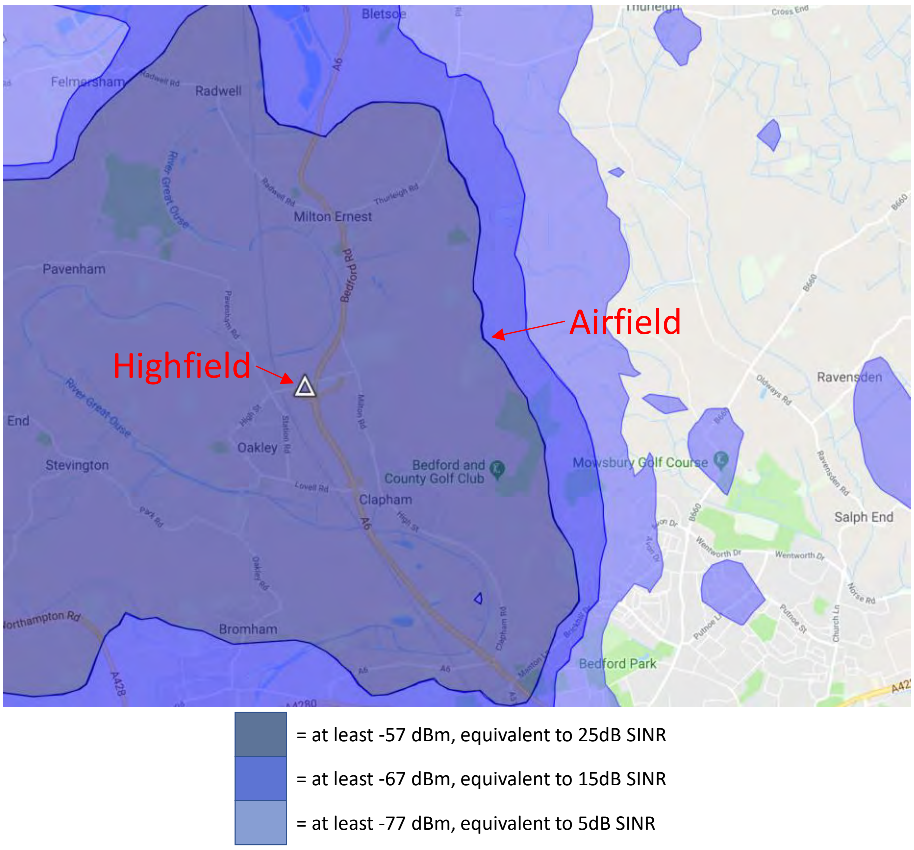


Figure 61. Predicted coverage for the Highfield case.

Airfield

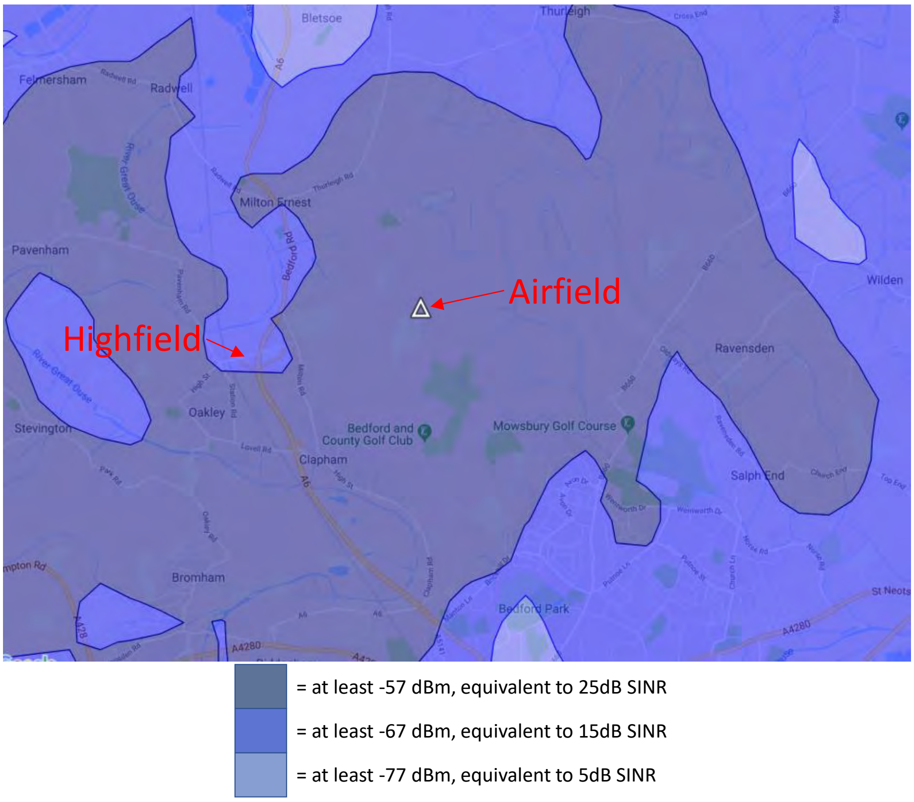


Figure 62. Predicted coverage for the Airfield case.

6.5 Overall Analysis on Realisation of Use Case Requirements

To assist the analysis here, it is noted that an SINR of 25 dB should, per channel, yield around 20 Mbps, and perhaps 25 Mbps for some radios. Rates for 15 dB SINR and 5 dB SINR should respectively drop to around 60% and 25% of that. Given that the devices are still in early stages of testing and deployment (and, indeed, still being obtained in most cases), this has been confirmed primarily by discussions and written/verbal assurances from manufacturers. There will be an update on this Deliverable later in the project that will cover such deployments and actual testing. Moreover, it is noted that the 25 dB threshold reported here is a good choice for performance, however, it might in some cases be that some of the devices actually "max out" in terms of performance at around 2-3 dB SINR more than that.

Nevertheless, in almost all cases, the requirements of the use cases should be realised. The rate that should be achieved via the 25 dB SINR threshold should be sufficient for all high-data-rate applications with the possible exception of the most challenging coding and frame rate choices for 4K and 360° video conveyed in near-real time, as well as perhaps the more challenging options for drones (e.g., near-real time multi-spectral/hyper-spectral imaging). Moreover, the raw coverage provided by TVWS is predicted to be excellent, as would be expected, comfortably serving some of the sensor or IoT-like scenarios assisting use cases such as the Agricultural case. Other requirements, such as NGA for Rural Broadband, should also be comfortably realised, at least in terms of the communication capacity and other communication requirements. The deployment should be careful, however, to not provision too many customers per BS, in order to realise the 15 Mbps 90% of the time at peak hours requirement. Further analysis on this will be undertaken.

Of course, locations in which coverage is predicted to be poor or not achieved do not realise the requirements. Currently, these are Haltwhistle Station and Ninebanks Hearse House, in Alston Moor, where the Alston Ski location is also predicted to be challenged somewhat. Through careful on-site optimisation it might be possible to improve the situation for Ninebanks and Alston Ski; however, Haltwhistle Station is predicted to be beyond reach.

Another location that looks somewhat challenged is Kildonan Hotel, in the Isle of Arran, although the deployment plan could be changed to address that—perhaps at a loss to other areas of the island. The situation would be improved if a fourth BS were added.

Reliability and latency requirements will not be challenging. Concerns around mobility can be addressed by sending batch-requests or requests with larger bounds to the TVWS databases—thereby covering a larger area in authorisation schedules.

7 Real Equipment Deployments

Prior sections of this report are related to analysis of what *should* be achievable in TVWS, undertaken in the June-July 2018 timeframe based on availability of the spectrum and other aspects at that time. This section provides an update on performance as assessed based on real deployments that have been carried out in the project towards the end of 2018.

It has become increasingly clear in undertaking this work that the development maturity WSDs needs to be improved, and they are not ideally suited for operation in most UK situations—or indeed any situations internationally where there is a complex/dense pattern of spectrum reuse by the incumbent DTT services. Here we also go into detail about some of these issues.

7.1 TV White Space Equipment Challenges

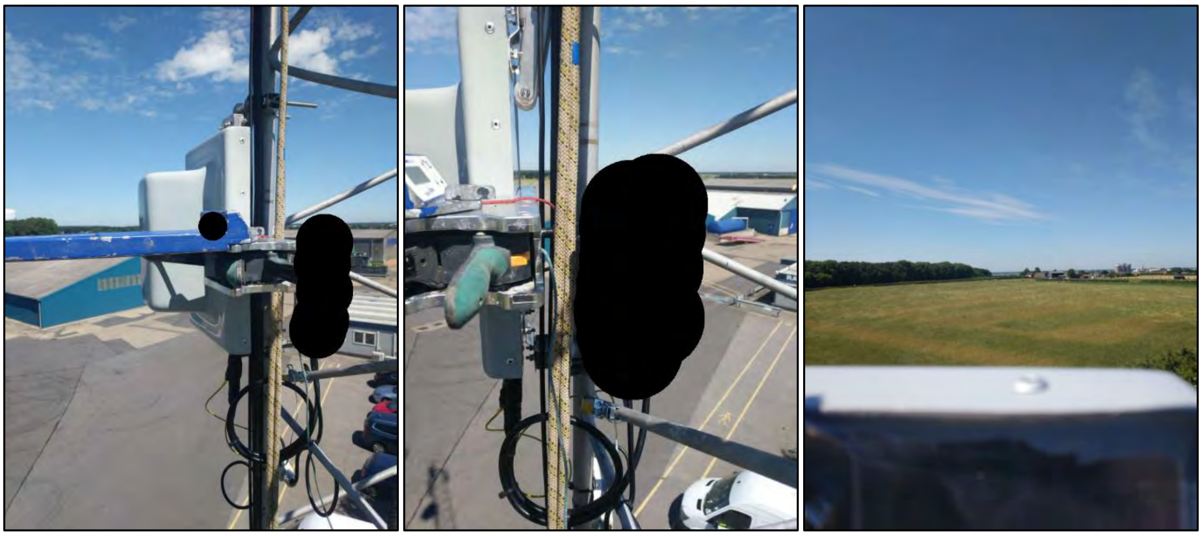
Equipment has been received from a TV WSD manufacturer (Manufacturer 1), and has been deployed and tested in a range of locations. It is noted that various options were also being investigated with another manufacturer (Manufacturer 2), however, achievement of sufficient transmission bandwidth to realise NGA compliance [11] (requiring the use of two or three concurrently-utilised TV channels, corresponding to 16 and 24 MHz respectively access spectrum) with that manufacturer would have needed multiple radios to be installed in each WSD. This was technically achievable, and the form factor of the WSDs and equipment therein (e.g., logical control board, not only at the BS side, also at the Consumer Premises Equipment (CPE) side) from Manufacturer 2 allowed it, however, it was clear that the utilised higher-layer link aggregation solution to combine the streams from the radios required further work as it was only partially working in the case of aggregating two radios, and not yet working in the case of aggregating three radios. So, Manufacturer 2 was shelved as an option—for the time being.

Deployments have therefore been made with the aforementioned Manufacturer 1's equipment. Various issues have been experienced, including:

1. Performance issues.
2. Overall functioning and usability of the WSDs, particularly configuration to work on specific networks and network structures.
3. Stability of the WSDs, e.g., requiring resetting of the WSDs after some hours.

Of the aforementioned issues, it is very difficult to know or comment on the correct functioning/usability and stability issues, as there are a range of possible inherent causes. However, a key reason behind the performance issues seems clear, as follows.

(a)



(b) (c) (d)

Figure 63. The Bardney-Longhills broadband provisioning link: (a) Plan view, (b) view of the BS side installation, (c) alternative view of the BS side installation, (d) view along the direction of maximum radiation of the BS antenna. Parts of images (b) and (c) are deliberately obscured due to potential commercial sensitivities.

7.1.1 Reasoning around Performance Issues

It is important to recognise that the UK has a very complicated and dense channel reuse in TV transmitter (DTT) deployments, covering most—if not all—of the TV channels available. It is testament to the quality and sophistication of the UK TVWS framework that often very significant white space is still made available given this [4]. Details on the TVWS framework in the UK are well covered by [3]–[5] and [14].

TVWS is very different from conventional communication systems, which typically might access a range of fixed frequencies/bands (e.g., “LTE Bands”) and can therefore be optimised for only those very specific frequencies/bands, e.g., with very precise and well-developed fixed RF filtering. Further, WSDs under the UK framework have a maximum allowed transmission power of only 36 dBm EIRP (4 W) in any given channel, whereas DTT transmitters might transmit at around 50 dB (100,000 times) higher EIRP than that in a single TV channel, in some cases.

This DTT reuse and power differential, in tandem with the very large TV spectrum bandwidth of 470-790 MHz in the UK any of which might be used by a WSD (except channels 38 and 60, to protect location-inspecific PMSE and LTE 800 respectively), creates issues. Typically, given the need to enhance the sophistication of the RFs of WSDs, the RF of a WSD will look at a much larger bandwidth than the channel or contiguous combination of (up to three, under current UK restrictions) channels that the WSD is transmitting in. Further, in other channels, even close to the intended channel for the WSD, there might be DTT transmission at far higher EIRP than the WSD. As its RF is not filtering out such channels, the WSD will also hear this very high power transmission, causing either (i) overloading the receive RF of the WSD, meaning that the waveform is clipped and power is spread across the spectrum as it sees it and causing interference to its intended signal as it sees it, or (ii) the WSD to use much higher attenuation to avoid being overloaded, causing its noise floor to rise significantly and therefore achieve a far lower SINR than it otherwise would do. The latter is much more likely.

Discussion with Manufacturer 1 has implicitly confirmed this conclusion and led to the suggestion to use fixed filters to filter out such high-power DTT transmissions in adjacent channels. This is clearly suboptimal, as it relegates this technology, which is meant to be dynamic spectrum access, to only fixed frequencies/channels within the TV band. In some cases, however, there is only one reasonable choice of TV channels that the WSD will access; in some such scenarios fixed filters might still make sense and be used as the project progresses.

Nevertheless, despite the aforementioned issues, some links have been successful enough to be tested and deployed for long enough to achieve meaningful results in the context of TVWS, including collecting customer feedback. We cover those in the following section.

7.2 TVWS Device Testing

Although far more deployments have been done, only some links have been able to be tested in a beneficial way, given the aforementioned issues. Here we cover those links and the testing of them.

7.2.1 Locations

The main viable has been the Bardney-Longhills link. Other links have been used, but not reliably established on a longer-term basis due to issues with performance/equipment.

The Bardney link to general broadband customers at Longhills is marginally less than 10 km distance, over a largely flat landscape. Figure 63(a) depicts the link on a plan satellite view; Figure 63(b)-(d) gives images of the BS installation at Bardney, including the view from the antenna along the direction of maximum radiation.

The installation characteristics were as follows:

- BS location (lat, lon): 53.203880, -0.304830.
- BS height above ground level: 17m.
- CPE locations (lat, lon—same for all customers): 53.188933, -0.451424.
- CPE heights above ground level: In the range of 5m to 15m.

Date and Time	Ping (ms)	Downlink (Mbps)	Uplink (Mbps)
13/11/2018 15:07:25	266	6.8	6.2
06/11/2018 10:32:29	162	14.1	8.5
02/11/2018 17:43:15	183	11.5	4.9
02/11/2018 15:22:23	187	14.8	8.5
02/11/2018 15:20:31	830	13.9	8.9
02/11/2018 10:36:19	203	15.0	7.6
02/11/2018 10:35:27	172	7.6	4.6
02/11/2018 10:34:38	163	13.5	6.4
02/11/2018 10:33:47	313	9.9	6.9
02/11/2018 10:31:53	298	13.6	7.2
01/11/2018 20:56:59	262	13.1	4.2
Average:	276	12.2	6.7
Standard deviation:	192	2.9	1.6
95% confidence:	< 313	> 7.6	> 4.9

Table 1. Speed test results for Customer 1, including statistical indicators and 95% confidence values. Confidence values are for there to be 95% confidence of being less than the given value for ping measurements, and more than the given value for downlink/uplink rate measurements, and are very approximate due to the low sample size.

- Polarisation: Vertical.
- Detail on utilised equipment withheld due to potential commercial sensitivities.

There are five customers served at the Longhills (CPEs) location. Two of the customers have already responded to requests to give detailed feedback and proof of performance through speed test results, which we concentrate on here. One of the other three customers has reported only throughputs that have been achieved, which are 8 Mbps and 7 Mbps respectively for the downlink and uplink.

7.2.2 Customer 1

Customer 1 gave the following feedback. Moreover, speed test results for customer 1 are given in Table 1.

> "Please find attached the speed tests done by Speedtest App on my iPhone. Also, I have attached the results by Broadband speed checker on my Macbook.
>
> My experience in the trial currently being run at Longills is largely positive.
>
> I have found that tasks such as reviewing PDF file on the net which I regularly need to do for my business is significantly faster and far less frustrating. What's particularly pleasing is the upload speed is almost that of the download speed and therefore over ten times the upload speed that I had previously, the impact of which is that I no longer have to split emails into many smaller emails and then hope that it might just send. Since this trial has started I have not had any emails stuck in my outbox.
>
> It's also pleasing to be able to use Sky to view on catch-up TV without having to plan that the previous day.

Date and Time	Ping (ms)	Downlink (Mbps)	Uplink (Mbps)
22/10/2018 19:38:00	27	7.0	0.6
25/10/2018 05:52:00	33	7.7	0.5
01/11/2018 20:59:00	30	11.2	4.1
02/11/2018 06:23:00	27	14.7	6.1
02/11/2018 06:34:00	23	14.2	6.1
03/11/2018 20:51:00	21	14.8	4.6
05/11/2018 06:18:00	39	8.5	4.9
05/11/2018 06:22:00	21	9.5	6.0
05/11/2018 06:38:00	56	9.3	3.2
05/11/2018 06:41:00	30	9.5	8.6
05/11/2018 06:50:00	29	10.5	6.6
05/11/2018 07:07:00	27	10.4	7.1
07/11/2018 20:27:00	33	9.9	6.1
07/11/2018 20:28:00	40	9.5	4.6
08/11/2018 20:46:00	30	11.5	7.3
13/11/2018 06:32:00	145	13.0	7.8
Average:	38	10.7	5.3
Standard deviation:	30	2.4	2.3
95% confidence:	< 56	> 7.7	> 0.6

Table 2. Speed test results for Customer 2, including statistical indicators and 95% confidence values. Confidence values are for there to be 95% confidence of being less than the given value for ping measurements, and more than the given value for downlink/uplink rate measurements, and are very approximate due to the low sample size.

> The reason I have only said that the experience is largely positive rather than completely positive is twofold; firstly, on occasion I have found that the speed drops right down, in one case down to just over 1meg and on a couple of others down to 2meg. (Some of these have not been captured because I had not registered on the speedchecker sites.) Secondly although 12meg is significantly faster, it is still a slow connection and in this trial we were hoping for close to 30meg."

7.2.3 Customer 2

Customer 2 gave the following feedback. Moreover, speed test results for customer 2 are given in Table 2.

> "My experience so far with Quickline has been positive.
>
> Average download speed over 10, upload reaches 8 some times which is very good.
>
> Apart from one night, I think the first night where there was a drop in the strength of the signal, every other days it has been quite stable and significantly improved comparing with our previous [company name redacted] connection.
>
> Please find attached a summary of speed tests."

7.2.4 Commentary and Comparison with Expected Performance

It is clear that this deployment has had a positive impact on customers, reflected both in terms of written customer feedback and statistical broadband performance testing results. Performance, however, is not to the level that might be expected given the bandwidth accessed by the WSDs—even taking into account the large link distance of some 10 km. Referring to Section 5.3 for example, 25 dB SINR should reasonably comfortably be achieved over the given link. This is typically equivalent to at least 20 Mbps per TV channel for the type of equipment under consideration, or at least 40 Mbps given that the particular equipment/configuration transmits in 2 contiguous TV channels. So, it is fair to say that the link is achieving very approximately 1/4 of the performance that has been predicted.

The reasons for the discrepancy might again be explained by out-of-channel interference affecting the WSD receiving RF—likely causing the device to attenuate the signal and increase the noise floor higher than it otherwise would be, exactly as explained in Section 2.1 of this report. RF filtering could improve the situation, however, it is again very suboptimal to require fixed filtering on a device that is intended to be able to dynamically access the spectrum, especially in the Bardney/Longhills location where there are in excess of 10 choices of two contiguous TV channels that might be used at maximum or close-to-maximum power allowed according to the UK TVWS framework.

This likely issue for the discrepancy was later, after our analysis and observations had arriving at this conclusion, implicitly confirmed in an email response from the manufacturer as follows:

> Same type of analysis using [redacted] tool.
>
> There are two TV transmitters to consider. The primary one at Belmont (H polarization)
>
> And the low power one at Lincoln Central (V polarization).
>
> To block out the primary signals use a filter that leaves you with channels 40-55
>
> So we can choose a channel 43 and up.
>
> With the BTS at 20m at the CPE at 15m you can use Ch 43-48 as a contiguous block. Note the grey bar is higher than the blue bar.
>
> Grey=CPE power as GOP. Blue =CPE power as SOP.
>
> So we should add a filter at the BTS to block out all the TV signals from the primary TV transmissions on Ch 22 to 35. Filter range is 40 to 55 so you will still get a bit of 53 but that wont matter.
>
> This will give a pretty clean contiguous block-according to the database that is…
>
> Note you will still get some signal from Lincoln central on Ch 41, 44, 47 but the radio will deal with that.
>
> According to [redacted] about -72dBm at the CPE & about -82dBm at the BTS
>
> So
>
> with enough height to get over ground clutter
>
> a filter on the BTS restricting to 40-55
>
> you should be able to use a bunch of channels and get good throughput. probably 45-46 best
>
> additional CPE to the SE of the BTS should be fine.

An additional email from the manufacturer for another location that was deployed under the project has confirmed the issue as being due to a TV transmitter transmitting at high power in other channels. Further to the proposed solution from the manufacturer, it is noted that such filters never have a sharp roll-off against frequency; there is always some minor effect on the intended channels in addition to insertion loss, and also some of the unintended power from other channels still gets through. The more-extensive follow-up of this filtering solution has therefore been relegated to a lower priority.

As a final note, it should be observed here that the utilised Longley-Rice path loss model in Section 6 and the associated tool, likely neglected some local clutter such as trees in particular, and this might account for at least a small extent of the performance difference.

8 TV White Space (Spectrum Database) Resource Management Entity

Here we provide detail on our developed TVWS resource management entity developed, which is fully compliant with the signalling/interactions/requirements of WSDs and Geolocation DataBases (GDBs), such as described in the ETSI EN 301 598 standard [14]. It can therefore apply to real, manufacturer-developed WSDs with a simple change of URL or IP address that the WSD is using to connect to the GDB. As well as being operational in real scenarios, this solution allows experimentation with different algorithms and means for partitioning resources. It is also compliant with spectrum database-driven spectrum sharing in general.

It is noted that GDB (GDB being the TVWS-specific name for the “spectrum database”) control is the way forward for a range of future spectrum sharing scenarios, whereby the TVWS framework matches relatively closely developments/solutions for other revolutionary solutions such as the Citizens Broadband Radio Service (CBRS) at 3.5 GHz in the US [2]. This is aside from the “freak” requirement that an “Environmental Sensing Capability” (ESC) must be used to support the GBD (or “Spectrum Access System—SAS”, in CBRS terminology) near the coasts of the US to detect navy radar, because the locations of navy radar (hence, military equipment) are not allowed to be disclosed to the GDB. Spectrum sharing regulatory efforts in other bands, such as 3.7-4.2 GHz in the US [3] and (likely, eventually) 3.8-4.2 GHz in the UK [4], among others, also have overtones of such solutions being used. Hence, the broad development of such a resource management capability is wider than just the scope of TVWS, being important for the future of spectrum management in general. What we propose is therefore a broadly-applicable concept and approach, which can be almost-directly deployed in other bands and contexts.

It is noted here that such shared spectrum is typically available to the secondary user (or tertiary user, in the case of CBRS) on a license-exempt basis, with no guarantee of spectrum quality (e.g., background interference level). This reality emphasises the need for management among the secondary (or tertiary) users being possible, in cases where the secondary user devices (e.g., their manufacturers, or operators) subscribe to being controlled by such a management entity. We present that management entity here. Moreover, we note that its functionality can be combined within 5G networks to be applicable within operator scope, likely within resource orchestration/management entities—i.e., orchestrating/managing radio resources in tandem with the more-conventionally assumed computational resources in the softwarised 5G networks of tomorrow.

8.1 High-Level Architecture

Greatly simplifying the process: WSDs can only transmit after communicating with a GDB, which informs them of which transmission powers (EIRPs) they are allowed to use in which TV channels. They then choose which channels/EIRPs they will use, among the options, and inform the GDB of their choice. Only upon receiving a confirmation/acknowledgement from the GDB of that, are they allowed to start transmitting with these chosen “operational

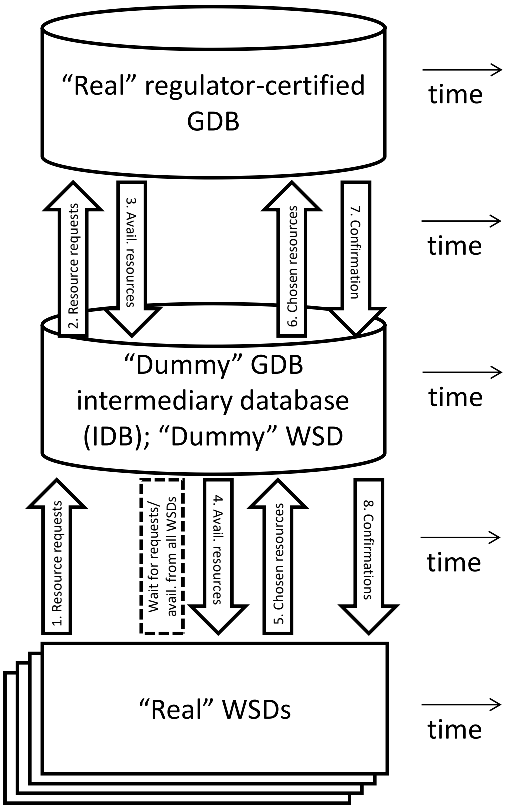


Figure 64. Architecture for the introduction of our resource management entity, including the signalling progression against time.

parameters". There is also implementation of a hierarchy and "slave" WSDs, which don't have to be internet-connected to communicate with the GDB essentially communicating through a "master" WSD, but there is no need to go into detail about the procedures for those.

Although the signalling and information/computations available to the GDB are used to protect the "primary" users, the information is mostly if-not entirely sufficient to also calculate/manage interference powers among the secondary devices. This can be very easily done by reporting back lower (or zero) powers on the channels that a management entity wishes the given WSD to not use (or indeed, use with lower power) to avoid interfering with other WSDs. This approach is valid so long as the powers reported to the WSD on a per-channel basis are not higher than the powers that would be allowed to avoid causing interference to the "primary" users. It is the approach taken here, with the exception that we leave the WSD itself untouched, and introduce an Intermediary Database (IDB) to communicate with the WSD, then manipulate the results, and return the results to the WSD that is requesting access. Hence, the IDB mimics a real WSD when communicating with the real GDB, and mimics a real GDB when communicating with the real WSD that is requesting access below it. All communication protocols, signalling and message structures are exactly the same as conventional communication between a WSD and its GDB.

This architecture and approach is illustrated in Figure 64. Here, the introduced IDB acts as a "dummy" WSD as seen by the "real" GDB, and a "dummy" GDB seen by the "real" WSDs. However, although we use the terms "dummy" GDB and WSD, they do perform exactly the same as "real" GDBs and WSDs as far as signalling is concerned. The numbering of the messages in this Figure indicates the order in which they are sent, where it is noted that message 4 is constrained or otherwise adapted for the purpose of managing resource, either:

1) The allowed powers are reduced, and/or,
2) The schedule is reduced or adapted.

It is noted here that the adapted message 4 and the therefore-adapted reporting/confirmation of chosen resources (messages 5-8) have to be compliant with the initial response from the "real" GDB and the UK TVWS framework in general.

8.2 Implementation and Testing

Here we describe the implementation and testing of the concept.

8.2.1 Implementation

The implementation is essentially based on the creation of WSD and a GDB, which we term as IDB as it serves as a resource-management intermediary between the "real" GDB and the "real" WSDs. These WSD and GDB aspects of implementation are covered respectively as follows.

8.2.1.1 WSD

The implementation is heavily based on a WSD that KCL created initially as part of the Ofcom TVWS Pilot [6]. This implements a number of procedures, all of which are necessary in order to have a valid WSD. The main purpose of the implementation was to create a "Master" WSD, as it was unclear at the time whether "Slave" WSDs would be practical because of the low transmission powers that they were authorised to use by the GBD—particularly in areas like London, which was the main focus of the work that KCL did in the Ofcom TVWS Pilot.

The procedures implemented are:

- periodic_ofcom
  - Periodically checks with the Ofcom what the author terms as "database of databases" .xml file, to confirm that Fairspectrum (the utilised Ofcom-certified database) is still authorised, and to set a timer invoking itself again according to the "refresh_rate" parameter, which specifies how often this "database of databases" has to be consulted.
- periodic_database
  - Periodically runs the procedure to check with the Ofcom-certified GDB, setting a time to invoke again according to the re-check requirement (currently 15 minutes). This invokes query_db
- query_db
  - The procedure that actually checks with the Ofcom-certified database, and returns an object with the allowed power per channel, and optionally the also aspects such as the schedule the resources can be access according to.
- notify
  - Notifies the Ofcom-certified database of the choice of parameters that the WSD has made, and waits for acknowledgement/confirmation from the database before invoking the setting of radio parameters for the WSD using set_sdr_freq.
- set_sdr_freq
  - Sets the new radio parameters (frequency, bandwidth, transmission power) that are used as a result of the choice of parameters in response to the availability indicated by the GDB. The implementation is based on a SDR, so this sets aspects such as the software gain of the SDR (for the transmission power), the mode of operation (for the bandwidth), and the frequency.

- periodic_gps
  - Periodically updates the utilised “latitude” and “longitude” parameters, and height if available (although noting that the height should be “above ground level”, whereas we optionally report “above average sea level”), used in queries of the Ofcom-certified database. This uses a well-known/supported Python GPS library with an off-the-shelf GPS dongle. The current update rate for GPS parameters is set at 1 second.
- chan_agg
  - A range of functions for the purpose of more involved decisions on which resources to select to use. Incorporates parameters such as the transmitter-to-receiver distance, path loss models, heuristics for deciding which aggregated channels to use/aggregate (hence the abbreviation “chan_agg”) in the cases where the channels have to be continuous (one radio on the device) and don’t have to be contiguous (multiple radios on a device, or a selective filtering waveform such as FBMC), among others. The output of this can trigger the “notify” parameter to the Ofcom-certified database, and the subsequant setting of the actual-chosen parameters through set_sdr_freq.
  - This function is, in effect, where the resource management decisions are also added in the case of the IDB implementation, which again is seen as a WSD from the perspective of the “real” GDB.

8.2.1.2 GDB (IDB)

Whereas at the WSD side a WSD query is manipulated to change the serial number of the WSD, spectrum mask class, latitude/longitude, height and other parameters to make the query specific to our purpose, on the GDB (IDB) side typical responses for the request, and notification, are modified.

The IDB is implemented using MongoDB, which is interacted with through JSON, similarly to all WSD device database interactions with the exception of the .xml “database of databases”. Our MongoDB implementation maintains the actual response for each device, and copies that to a “to-be-manipulated” response for each device. Consider two devices in the same or a very similar location, where the simple requirement is to give them orthogonal resources so they don’t interfere. Figure 65 portrays the actual response from the GDB, which conventionally is the same for all devices. This is a cut-down version not including the 100 kHz “spectrum density” part of the response, and only two TV channels of the response. Figure 66(a) and (b) show the allocated resources to the two devices, where it can be seen that the informed allowed power for them is manipulated (lowered) to avoid interference. This is fine to do so long as the allowed power per channel as reported by the database is left the same or lowered, not increased.

You will see in these two Figures several key aspects. First, the serialNumber is different between Figure 66(a) and (b) reflecting the two devices. Second, in both of these Figures the “eventTime” and “startTime/stopTime” represent the schedule for validity of these resources; these might be manipulated in our response as long as the indicated schedule to any WSD doesn’t go outside of the duration indicated in the original response of the database, although we don’t do that here. Finally, the “dbm” key/value pair *is* manipulated, such that the first device is only allowed to use the first channel (Channel 21) with second channel (Channel 22) being constrained to -999 dBm (effectively, zero power) and the second device is allowed to use only Channel 22 at 36 dBm. This avoids interference between the devices/links, whereas conventionally under TVWS they would likely both choose to use Channel 22 because of the higher allowed power of that channel.

```
    "result": {
        "deviceDesc": {
            "etsiEnDeviceCategory": "Master",
            "etsiEnDeviceEmissionsClass": "3",
            "etsiEnDeviceType": "A",
            "etsiEnTechnologyId": "Tech",
            "manufacturerId": "o_m1",
            "modelId": "model",
            "rulesetIds": [
                "ETSI-EN-301-598-1.1.1"
            ],
            "serialNumber": "test_olly_1"
        },
        "spectrumSpecs": [
            {
                "etsiEnSimultaneousChannelOpera": 0,
                "maxContiguousBwHz": 8000000,
                "maxTotalBwHz": 8000000,
                "needsSpectrumReport": true,
                "rulesetInfo": {
                    "authority": "GB",
                    "maxLocationChange": 0,
                    "maxPollingSecs": 900,
                    "mcwsdSupport": true,
                    "rulesetId": "ETSI-EN-301-598-1.1.1"
                },
                "spectrumSchedules": [
                    {
                        "eventTime": {
                            "startTime": "2019-01-08T03:59:49Z",
                            "stopTime": "2019-01-08T04:14:49Z"
                        },
                        "spectra": [
                            {
                                "profiles": [
                                    [
                                        {
                                            "dbm": 34,
                                            "hz": 470000000
                                        },
                                        {
                                            "dbm": 34,
                                            "hz": 478000000
                                        },
                                        {
                                            "dbm": 36,
                                            "hz": 478000000
                                        },
                                        {
                                            "dbm": 36,
                                            "hz": 486000000
                                        },
                                    ]
                                ],
                                "resolutionBwHz": 8000000
                            }
                        ]
                    }
                ]
            }
        ],
        "timestamp": "2019-01-08T03:59:50Z",
        "type": "AVAIL_SPECTRUM_RESP",
        "version": "1.0"
    }
}
```


Figure 65. Reduced example of a resource availability response from a GDB.

```
"result": {
  "deviceDesc": {
    "etsiEnDeviceCategory": "Master",
    "etsiEnDeviceEmissionsClass": "3",
    "etsiEnDeviceType": "A",
    "etsiEnTechnologyId": "Tech",
    "manufacturerId": "o_m1",
    "modelId": "model",
    "rulesetIds": [
      "ETSI-EN-301-598-1.1.1"
    ],
    "serialNumber": "test_olly_1"
  },
  "spectrumSpecs": [
    {
      "etsiEnSimultaneousChannelOpera": 0,
      "maxContiguousBwHz": 8000000,
      "maxTotalBwHz": 8000000,
      "needsSpectrumReport": true,
      "rulesetInfo": {
        "authority": "GB",
        "maxLocationChange": 0,
        "maxPollingSecs": 900,
        "mcwsdSupport": true,
        "rulesetId": "ETSI-EN-301-598-1.1.1"
      },
      "spectrumSchedules": [
        {
          "eventTime": {
            "startTime": "2019-01-08T03:59:49Z",
            "stopTime": "2019-01-08T04:14:49Z"
          },
          "spectra": [
            {
              "profiles": [
                [
                  {
                    "dbm": 34,
                    "hz": 470000000
                  },
                  {
                    "dbm": 34,
                    "hz": 478000000
                  },
                  {
                    "dbm": -999,
                    "hz": 478000000
                  },
                  {
                    "dbm": -999,
                    "hz": 486000000
                  },
                ]
              ],
              "resolutionBwHz": 8000000
            }
          ]
        }
      ]
    }
  ],
  "timestamp": "2019-01-08T03:59:50Z",
  "type": "AVAIL_SPECTRUM_RESP",
  "version": "1.0"
 }
}
```


(a)


```
"result": {
  "deviceDesc": {
    "etsiEnDeviceCategory": "Master",
    "etsiEnDeviceEmissionsClass": "3",
    "etsiEnDeviceType": "A",
    "etsiEnTechnologyId": "Tech",
    "manufacturerId": "o_m1",
    "modelId": "model",
    "rulesetIds": [
      "ETSI-EN-301-598-1.1.1"
    ],
    "serialNumber": "test_olly_2"
  },
  "spectrumSpecs": [
    {
      "etsiEnSimultaneousChannelOpera": 0,
      "maxContiguousBwHz": 8000000,
      "maxTotalBwHz": 8000000,
      "needsSpectrumReport": true,
      "rulesetInfo": {
        "authority": "GB",
        "maxLocationChange": 0,
        "maxPollingSecs": 900,
        "mcwsdSupport": true,
        "rulesetId": "ETSI-EN-301-598-1.1.1"
      },
      "spectrumSchedules": [
        {
          "eventTime": {
            "startTime": "2019-01-08T03:59:49Z",
            "stopTime": "2019-01-08T04:14:49Z"
          },
          "spectra": [
            {
              "profiles": [
                [
                  {
                    "dbm": -999,
                    "hz": 470000000
                  },
                  {
                    "dbm": -999,
                    "hz": 478000000
                  },
                  {
                    "dbm": 36,
                    "hz": 478000000
                  },
                  {
                    "dbm": 36,
                    "hz": 486000000
                  },
                ]
              ],
              "resolutionBwHz": 8000000
            }
          ]
        }
      ]
    }
  ],
  "timestamp": "2019-01-08T03:59:50Z",
  "type": "AVAIL_SPECTRUM_RESP",
  "version": "1.0"
 }
}
```


(b)

Figure 66. Example of a response manipulated by the IDB for resource management purposes.

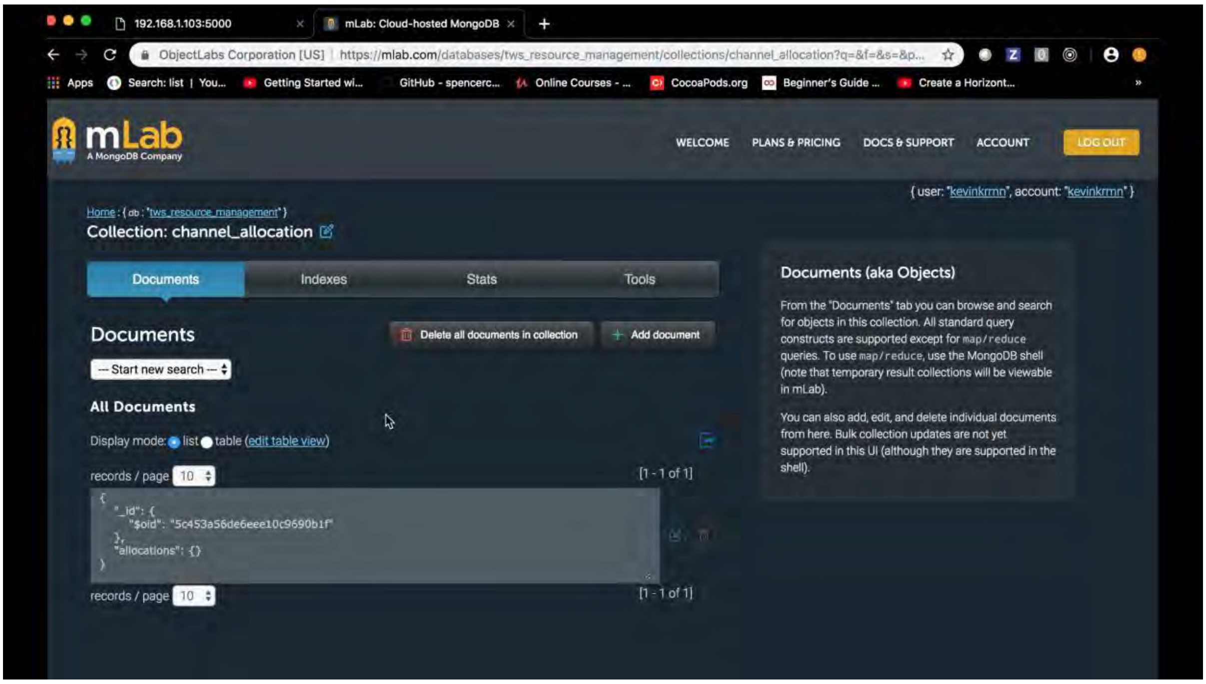
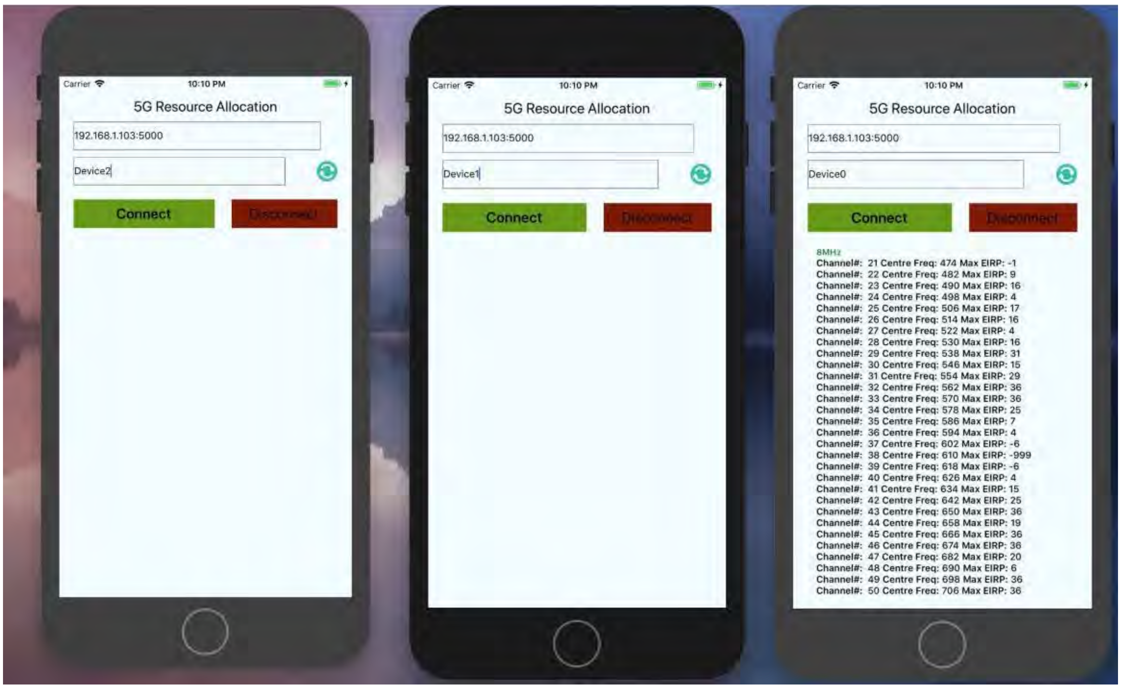


Figure 67. The MongoDB backend implementation of our IDB database.

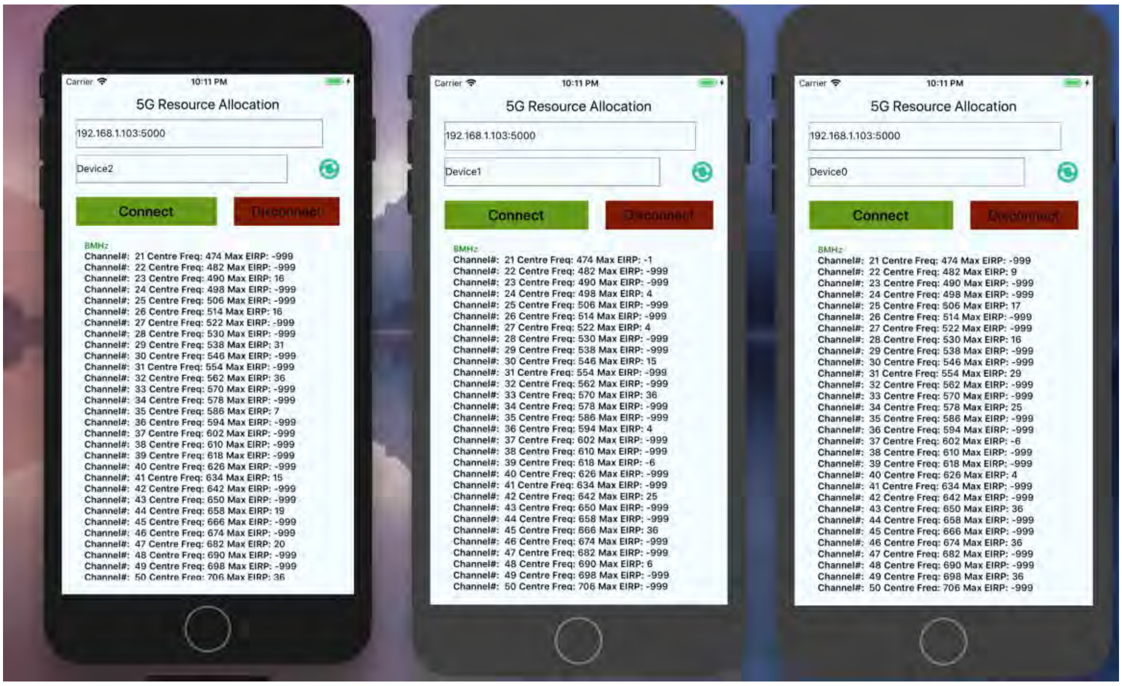
8.2.2 Testing

The concept has been developed and tested with the IDB running on a Raspberry PI 3, and a laptop implementing a number of virtual WSDs that are communicating with the IDB. Figure 67 provides a snapshot of the MongoDB-based database aspect of the IDB implementation. Figure 68 gives an example of the resource allocation for three devices using TVWS all within close range of each other. In Figure 68(a) the allocation for a single present device is seen, whereas for Figure 68(b) the equivalent allocation for three present devices is seen. It is noted that the left-most number on the mobile phone screen is the frequency of the channel edge, whereas the right number is the allowed EIRP (dBm) associated with the channel defined by those channel edges. This is as the information is structured in the actual messages between the client and the TVWS database (although other representations have been made in the KCL-developed WSD—see). This is why there is a repetition of the power levels twice each time; the lower and upper channel edge of channel 22, for example, with frequencies 478 and 486 MHz respectively, both have the same power of 9 dBm associated with them, as 9 dBm is the allowed power in Channel 22.

Analysing this Figure, referring to Figure 68(a), it can be seen that all the resources are allocated to the single present device, as the exact result from the GDB is conveyed by the IDB. However, referring to Figure 68(b) for the case where three WSDs have entered the vicinity, 1/3 of the resources are permitted to each device through the IDB constraining allowed powers to the other devices. For example, if WSD 1 is permitted transmit on Channel A with the GDB allowed EIRP for Channel A, then for WSDs 2 and 3 the permitted power for Channel A is -999 dBm, basically zero power. Likewise, if WSD 2 is permitted transmit on Channel B with the GDB allowed EIRP for Channel B, then f or WSDs 1 and 3 the permitted EIRP for Channel B is -999 dBm. And it goes on.



(a)



(b)

Figure 68. Available under our implementation as seen at WSDs.

8.2.3 Ongoing and Future Work on the Management Entity

It is noted that although this resource management framework is developed and tested/working at KCL, extensive work is still being done developing/testing and experimenting with advanced means/heuristics/algorithms for making the resource management decisions. To do that, it is necessary for the IDB to understand the resource requirement for the individual WSDs.

To these ends, it is beneficial for the IDB to know the resource requirements of the WSDs for the next resource request validity duration (currently 15 minutes in the UK TVWS framework, although can be reduced to less than that is required, without breaking the framework). An additional key-value pair has been piggy-backed on the initial TVWS resource request and periodic TVWS resource confirmation requests to the IDB to achieve this. It is acceptable to do this, as the IDB can manage the information such that if no such additional key-value pair is present, then it will handle the device as a "basic/normal" WSD thereby not breaking the UK framework and still being compliant with "basic/normal" WSDs that don't support this extra functionality.

A key capability that is being investigated to manage the resource allocations is the application of Machine Learning (ML) and Artificial Intelligence (AI). Although such technologies produce nondeterministic results and would therefore usually not be appropriate for any work in the scope of spectrum management/sharing, it is acceptable to use them in the context of horizontal sharing or sharing among secondaries if the regulatory framework permits—such as in the case of license-exempt access in general (e.g., ISM 2.4 GHz or UNII 5 GHz) or license-exempt access for the WSDs that comply with the TVWS framework. Further, resource requirement prediction through an approach such as ML/AI is strongly beneficial for reasons such as the usual WSD database-checking requirement being only 15 minutes for, e.g., "conventional" WSDs. The permitted resource for that WSD therefore should be appropriate for the next 15 minutes. This can only really-be achieved through prediction. For example, is an individual usually arrives home at 8.05pm and immediately turns on Netflix 4K while having dinner, if the WSD database-check were at 8pm without this prior knowledge then that individual might be given insufficient resources to carry then, e.g., 25 Mbps capacity of the Netflix connection—causing the Netflix experience to fail and the individual to not be satisfied. If through prediction it were ascertained that it was highly likely that the individual would return home within the next 15 minutes, more capacity could be permitted to that individual's network therefore not affecting the individual's service.

To summarise, online and future work on the resource management decisions are progressing in three phases. These are:

- Simple resource partitioning. E.g., if there are three WSDs and 3 channels, each WSD is given a different channel such that they don't interfere with each other.
- Rate-based simple resource partitioning. Here, the resources are partitioned based on the calculated rate that will be achieved at each receiver, such that all receivers are given the same "rate". This is through Shannon rate analysis based on the locations of the transmitters and receivers, and the expected path loss between each pairing over which a communication link is formed.
- Traffic-aware rate-based partitioning. In this case, the TVWS signalling is augmented to also convey a traffic requirement to the GDB before the GDB attempts to assign resources. The GDB therefore assigns resources based on the rate (traffic) requirement of different receivers.
- AI-driven rate-based partitioning. It is noted that the resource decisions might in some cases not be queried very often, particularly in the case of "real" WSDs which are only required to communicate with the GDB every 15 minutes. Prediction of the traffic requirement, based on past experience (e.g., linked to user habits per time of day, likely activities per location, etc.) is therefore useful to assign the resources as are likely to be needed, in order to reduce QoS/QoE degradation while waiting for the GDB communication and resource assignment update. This prediction has been the key initial target of the use of AI.

9 Conclusions and General Observations

This work has considered the potential for TV white space (TVWS), and spectrum database-driven spectrum sharing, to assist 5G through making more lower-frequency spectrum available. It is essential to access more such lower-frequency spectrum for many 5G use cases to be viable (or more accurately, closer-to-viable) in rural scenarios.

Most of this work is formed within the context of use cases presented in 5GRIT. It has been shown that there should be very good or excellent performance for almost all of the use cases and locations considered in 5GRIT. This is with the exception of a couple of the more-aspirational links attempted as well as a small number of longer-distance link cases where it is difficult to match resource usage availabilities on the downlink and uplink.

Real deployments with actual TVWS equipment have been covered. It has been noted that a lot of TVWS equipment is still at a relatively low-level of maturity, and for such reasons there have been issues with deployment and testing. Nevertheless, the Bardney customer broadband-provisioning link in TVWS has been viable to maintain and test on a longer-term basis, and results, particularly concentrating on two customers, have been conveyed and analysed. It has been observed here that the TVWS deployment is achieving very approximately 1/4 of the performance that would be expected; this is likely due to the poor ability of the TVWS devices to reject transmissions arising from high-power DTT transmitters in other TV channels.

Finally, a spectrum management mechanism among the new-entrant (secondary) devices, fitting well within the TVWS framework and indeed spectrum-database spectrum sharing in general, is presented. Such a mechanism is vital to achieve predictable performance in the context of such a spectrum sharing framework, particularly at lower-frequencies.

A key future consideration is that 694-790 MHz spectrum will soon become unavailable for white space devices, due to its clearance for mobile broadband (LTE 4G/5G 700 MHz) and auctioning of it likely early in 2020. This removes a lot of currently mostly-pristine (white space) spectrum. However, our prior analysis has shown that there should still be a useful amount of white space available in most scenarios after this event.

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Annex A: Detailed Lists of Available EIRPs on a Per-Location Basis

This Annex lists the processed responses as obtained from the TVWS database, corresponding to the configuration and other aspects described in Section 3.

A.1 Tourism Augmented Reality

A.1.1 Alston Moor

South Tynedale Railway

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 30.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 30.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 15.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 29.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 30.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 15.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 14.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 34.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 20.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 23.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 26.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 20.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: -29.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 24.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 24.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: -29.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 24.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 24.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: -29.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 24.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 31.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 35.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 27.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 28.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 27.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 27.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 27.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 27.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Market Square

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 29.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 30.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 16.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 29.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 30.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 16.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 35.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 15.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 33.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 19.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 23.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 26.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 19.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: -24.0 dBm

Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 29.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: -24.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 29.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 29.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: -24.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 29.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 35.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 27.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 28.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 27.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 28.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 27.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 28.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Haltwhistle Station

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: -3.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 36.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -2.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: -3.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 36.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -2.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -4.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: -2.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 36.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: -6.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 0.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 0.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: -6.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -3.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 27.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 26.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -3.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 26.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 26.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -3.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 3.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: -21.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 32.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 2.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: -21.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 32.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 2.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: -21.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Alston Ski

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 18.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 25.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 21.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 18.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 25.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 20.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 22.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 19.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 26.0 dBm

Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 13.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 24.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 24.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 11.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 27.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 30.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 25.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 30.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 26.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 24.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 27.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 24.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 27.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 24.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Epiacum

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 34.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 29.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -1.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 34.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 29.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -1.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: -2.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 36.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 25.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 25.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 28.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 25.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: -26.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 28.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: -26.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 28.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 28.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: -26.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 28.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 29.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 19.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 29.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 19.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 29.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 19.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Mount Hooley

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 35.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 26.0 dBm

Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 5.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 35.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 26.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 5.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 35.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 4.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 33.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 22.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 18.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 23.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 23.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: -4.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: -4.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 32.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: -8.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 32.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 22.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 27.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 22.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 27.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 22.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 27.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

A.1.2 Loch Leven

Hub

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 17.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 27.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 25.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 16.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 22.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 20.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 16.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 17.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 9.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 0.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -54.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 0.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 9.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 15.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 8.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: -1.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -55.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 8.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 6.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 5.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 13.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 4.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 5.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 13.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 4.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 5.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 1.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: -53.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: -3.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 10.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 5.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: -49.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: -53.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: -4.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 4.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: -50.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: -54.0 dBm

Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: -3.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Boathouse

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 13.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 28.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 27.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 13.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 23.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 22.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 13.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 19.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 11.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 2.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -52.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 2.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 11.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 11.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: -1.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 1.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -53.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 10.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: -16.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -16.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 9.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: -17.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -17.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 9.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: -17.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -17.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 4.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: -50.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 4.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 13.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 7.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: -47.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: -50.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 4.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 6.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: -48.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: -51.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 3.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Kirkgate

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 13.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 36.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 13.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 36.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 36.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 13.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 36.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -17.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 11.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 15.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 15.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 5.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -17.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: -2.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -2.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 15.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: -2.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -2.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 15.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: -2.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -2.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: -15.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 11.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm

Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: -12.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: -16.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 11.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: -12.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: -16.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 11.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

M90 J5

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -32.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 21.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 22.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -32.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 20.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 19.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -31.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 15.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 7.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: -2.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -56.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: -2.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: -33.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -33.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 6.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: -3.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -57.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: -34.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: -2.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -3.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: -34.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: -4.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -3.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: -34.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: -4.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -3.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 2.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: -52.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: -1.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 11.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 4.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: -50.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: -52.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: -1.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 4.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: -50.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: -53.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: -1.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

RSPB

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 5.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 26.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 26.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 5.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 26.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 26.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 5.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 26.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 26.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 26.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 11.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 8.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 1.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 1.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 8.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 10.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 14.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 12.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 20.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 12.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 12.0 dBm

Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 19.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 12.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 12.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 6.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: -3.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: -57.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: -3.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 6.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 6.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: -3.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: -57.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: -3.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 6.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: -2.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: -56.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Island

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 14.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 36.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 13.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 36.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 36.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 13.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 36.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -5.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 10.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 12.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 12.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 9.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -5.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 9.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 9.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 17.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 9.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 9.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 17.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 9.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 9.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: -3.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 10.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: -1.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: -4.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 10.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: -1.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: -4.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 10.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

A.2 Agricultural

Near Northmost corner

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 17.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 10.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 36.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 17.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 10.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 36.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 16.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 10.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 32.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 1.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: -28.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 25.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -28.0 dBm

Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 25.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 1.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 4.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 5.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -24.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 29.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 5.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -24.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 29.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 5.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -24.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: -22.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 30.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 27.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: -26.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: -25.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 28.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 35.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

A.3 Rural Broadband

A.3.1 Isle of Arran

Claonaig Jetty

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: -2.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: -5.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 27.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -1.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: -4.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 27.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -1.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -4.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -17.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 16.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 36.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 36.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 15.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -18.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 14.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 20.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 14.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 20.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 14.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 20.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 1.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 29.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 1.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 29.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 0.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Lochranza

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 18.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 33.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 27.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 18.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 33.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 27.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 18.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 33.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 33.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 23.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 15.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 33.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 33.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 15.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 19.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 19.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 31.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 19.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 19.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 27.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 19.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 19.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 17.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 8.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: -46.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 8.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 17.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 17.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 8.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: -46.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 8.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 16.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 7.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: -47.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Imachar

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -36.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 18.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 19.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -35.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 19.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 19.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -35.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 19.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 22.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 34.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 36.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 34.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 33.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 16.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 33.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 20.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 28.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 20.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 28.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 19.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 18.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 16.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm

Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 18.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 15.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 18.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Old Byre

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -43.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 8.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: -46.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -41.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 9.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: -45.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -41.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 10.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -44.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 10.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 19.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 13.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 4.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -50.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 4.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 13.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 14.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 5.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -49.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 5.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 0.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -49.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 5.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 0.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -49.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 5.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 14.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 0.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 23.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 25.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 21.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 28.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 30.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 21.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 30.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 30.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 30.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Sliddery

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -30.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 21.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: -32.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -29.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 22.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: -32.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -28.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 22.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -31.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 22.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 30.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 27.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 17.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -37.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 17.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 35.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 27.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 34.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 27.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 34.0 dBm

Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 27.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 9.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 9.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Kildonan Hotel

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -46.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: -4.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 4.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -45.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -3.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 5.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -44.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -3.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -45.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 9.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -3.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: -10.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 0.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -54.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: -8.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 9.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -3.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 0.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -1.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 26.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 0.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -1.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 28.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 0.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -1.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 28.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 28.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 28.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 28.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 28.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 28.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 28.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 28.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 28.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 28.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 28.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 28.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Whiting Bay

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: -33.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: -35.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 19.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -32.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: -34.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 19.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -32.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -35.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 19.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -33.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 18.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 29.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 25.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 18.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 21.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -33.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: -21.0 dBm

Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: -21.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 33.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: -21.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: -22.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 32.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: -21.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: -22.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 32.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 35.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 20.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 35.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 35.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 19.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 35.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 20.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 35.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 19.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 35.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 20.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Corrie

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: -31.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: -33.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 20.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -31.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: -33.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 21.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -31.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: -33.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 20.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -33.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 20.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 29.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 33.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 28.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 21.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -33.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 32.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 35.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 27.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 32.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 35.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 27.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 35.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 35.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 17.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 35.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 35.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 35.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 17.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 17.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 35.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 35.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 17.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 17.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 35.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Middle

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 17.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 15.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 25.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 17.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 14.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 25.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 16.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 15.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 13.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 16.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 36.0 dBm

Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 20.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 14.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 12.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 14.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 19.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 15.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 19.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 15.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 28.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 25.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 26.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 24.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 24.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 24.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 24.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Ardrossan

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 1.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: -26.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 27.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 3.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -25.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 27.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 1.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -26.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 27.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 23.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: -31.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 20.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 30.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 2.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 19.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 23.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: -30.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 22.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 9.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 22.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 9.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 22.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 9.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 36.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Campbeltown

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 27.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 28.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 28.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 27.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 29.0 dBm

Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 28.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 27.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 29.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 36.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 36.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 31.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 23.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 33.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 36.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 36.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 35.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 36.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 21.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 35.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 21.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 34.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

A.3.2 Bardney

Basestation

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 15.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 36.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 36.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 16.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 36.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 36.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 16.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 11.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 36.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 36.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 7.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 36.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 7.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 36.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 36.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 36.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 36.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 12.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Customers

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: 20.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: -17.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 34.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: 35.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: -16.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 35.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: 35.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: -16.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 32.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: -20.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 32.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: 29.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: -23.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: 29.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: -23.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: 25.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 36.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 36.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: 36.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 36.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: 36.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: 35.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: -17.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 35.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 33.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

A.4 Unmanned Aircraft Systems

Highfield

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -18.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 35.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -17.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 35.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 35.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -16.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 35.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 30.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: -22.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 30.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -22.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 30.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: -15.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 36.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 36.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: -13.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 36.0 dBm

Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: -13.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: -13.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm

Airfield

Channel number: 21; Centre frequency: 474 MHz; Maximum EIRP: -13.0 dBm
Channel number: 22; Centre frequency: 482 MHz; Maximum EIRP: 30.0 dBm
Channel number: 23; Centre frequency: 490 MHz; Maximum EIRP: 36.0 dBm
Channel number: 24; Centre frequency: 498 MHz; Maximum EIRP: -11.0 dBm
Channel number: 25; Centre frequency: 506 MHz; Maximum EIRP: 36.0 dBm
Channel number: 26; Centre frequency: 514 MHz; Maximum EIRP: 36.0 dBm
Channel number: 27; Centre frequency: 522 MHz; Maximum EIRP: -11.0 dBm
Channel number: 28; Centre frequency: 530 MHz; Maximum EIRP: 36.0 dBm
Channel number: 29; Centre frequency: 538 MHz; Maximum EIRP: 36.0 dBm
Channel number: 30; Centre frequency: 546 MHz; Maximum EIRP: 36.0 dBm
Channel number: 31; Centre frequency: 554 MHz; Maximum EIRP: 36.0 dBm
Channel number: 32; Centre frequency: 562 MHz; Maximum EIRP: -15.0 dBm
Channel number: 33; Centre frequency: 570 MHz; Maximum EIRP: 36.0 dBm
Channel number: 34; Centre frequency: 578 MHz; Maximum EIRP: -15.0 dBm
Channel number: 35; Centre frequency: 586 MHz; Maximum EIRP: 33.0 dBm
Channel number: 36; Centre frequency: 594 MHz; Maximum EIRP: -10.0 dBm
Channel number: 37; Centre frequency: 602 MHz; Maximum EIRP: 15.0 dBm
Channel number: 38; Centre frequency: 610 MHz; Maximum EIRP: -999.0 dBm
Channel number: 39; Centre frequency: 618 MHz; Maximum EIRP: 15.0 dBm
Channel number: 40; Centre frequency: 626 MHz; Maximum EIRP: 25.0 dBm
Channel number: 41; Centre frequency: 634 MHz; Maximum EIRP: 33.0 dBm
Channel number: 42; Centre frequency: 642 MHz; Maximum EIRP: 36.0 dBm
Channel number: 43; Centre frequency: 650 MHz; Maximum EIRP: 36.0 dBm
Channel number: 44; Centre frequency: 658 MHz; Maximum EIRP: 36.0 dBm
Channel number: 45; Centre frequency: 666 MHz; Maximum EIRP: 36.0 dBm
Channel number: 46; Centre frequency: 674 MHz; Maximum EIRP: 36.0 dBm
Channel number: 47; Centre frequency: 682 MHz; Maximum EIRP: 36.0 dBm
Channel number: 48; Centre frequency: 690 MHz; Maximum EIRP: -10.0 dBm
Channel number: 49; Centre frequency: 698 MHz; Maximum EIRP: 36.0 dBm
Channel number: 50; Centre frequency: 706 MHz; Maximum EIRP: 36.0 dBm
Channel number: 51; Centre frequency: 714 MHz; Maximum EIRP: -10.0 dBm
Channel number: 52; Centre frequency: 722 MHz; Maximum EIRP: -10.0 dBm
Channel number: 53; Centre frequency: 730 MHz; Maximum EIRP: 36.0 dBm
Channel number: 54; Centre frequency: 738 MHz; Maximum EIRP: 36.0 dBm
Channel number: 55; Centre frequency: 746 MHz; Maximum EIRP: 36.0 dBm
Channel number: 56; Centre frequency: 754 MHz; Maximum EIRP: 36.0 dBm
Channel number: 57; Centre frequency: 762 MHz; Maximum EIRP: 36.0 dBm
Channel number: 58; Centre frequency: 770 MHz; Maximum EIRP: 36.0 dBm
Channel number: 59; Centre frequency: 778 MHz; Maximum EIRP: 36.0 dBm
Channel number: 60; Centre frequency: 786 MHz; Maximum EIRP: -999.0 dBm