ATKINS

Electromagnetic Fields Study

Highlands & Islands Enterprise
Western Isles
Connected Communities Broadband Network
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Glossary of Terms

EMF	Electromagnetic Field
FWA	Fixed Wireless Access
GSM	Global System for Mobile Communications
ICNIRP	International Commission on Non-Ionizing Radiation Protection
NRPB	National Radiological Protection Board
PDH	Plesiochronous Digital Hierarchy
RF	Radiofrequency
SDH	Synchronous Digital Hierarchy

EXECUTIVE SUMMARY

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The aim of the Western Isles *'Connected Communities'* project, a multi-agency initiative combining private and public sector organisations, is to deliver high performance broadband connectivity to residences, businesses and public sector organisations located across the six main populated islands of the Western Isles of Scotland.

Utilising radio as the predominant transmission medium, the communications infrastructure shall comprise a medium/high capacity microwave radio network spanning the islands of Lewis, Harris, North Uist, Benbecula, South Uist and Barra, linking various community nodes located throughout the Western Isles to a central hub site in Stornoway. At each of the community nodes, fixed wireless access technology will provide high, medium and low bandwidth connectivity to network subscribers.

A study was commissioned by the Connected Communities project team to compare electromagnetic emissions from this proposed network against health and safety guidelines as defined by the ICNIRP and the UK NRPB.

The independent expert group on mobile phones, under the Chairmanship of Professor Sir William Stewart recommended that the UK Government adopt the ICNIRP guidelines and this study demonstrates that the emissions from the proposed network will be significantly less than the limits prescribed.

1 INTRODUCTION

1.1 Purpose and Scope

The main objective of this document is to demonstrate, using methods sanctioned by the UK's NRPB, that the implementation of the Connected Communities broadband network shall not, when considered in isolation, result in the exposure of the general public to adverse levels of electromagnetic fields.

There are two main sources of radiofrequency electromagnetic fields within the proposed Connected Communities broadband network: terrestrial point-to-point microwave radio equipment and broadband fixed wireless access radio equipment. Both shall be evaluated, and the power densities of the associated electromagnetic fields calculated.

The power density data shall be compared with reference levels contained within both national and international published guidelines, and EC Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC). Compliance with such reference levels ensures the protection of humans against the established health effects of exposure to electromagnetic fields. Such a comparison, therefore, shall demonstrate that the electromagnetic fields likely to be generated by the Connected Communities broadband network pose no known threat to the health of the general public of the Western Isles.

1.2 Background

There exists a general consensus amongst organisations responsible for the provision of guidance on exposure to electromagnetic fields, as follows (Mann *et al*, 2000):

a) Heating can occur as a consequence of exposure to electromagnetic fields at telecommunications frequencies.
b) The established adverse effects on people's health occur at exposure levels where heating would be expected to occur.
c) Exposures should be restricted to avoid the established effects of exposure to electromagnetic fields.
d) There is no convincing evidence that adverse effects can occur as a result of exposure within the current protection guidelines.

As Mann *et al* (2000) assert, the views of the NRPB and ICNIRP form part of this consensus.

In view of the above, a number of different national and international organisations have published guidelines for the protection of the general public from exposure to electromagnetic fields. It remains a matter for policy makers to determine which set of guidelines should be adopted (Mann *et al*, 2000), however, this document shall consider the three most important sets of guidelines in this particular instance, namely:

- NRPB Restrictions on human exposure to static and time varying electromagnetic fields and radiation (1993)
- ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz) (1998)
- EC Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999)

The full text of the ICNIRP guidelines and EC recommendation can be found in Appendices A and B respectively.

2 EXPOSURE LEVELS – METHOD OF CALCULATION

2.1 Overview

There are several different approaches to calculating the exposure of a person to EMF in the vicinity of a transmitting radio antenna. In general, the simpler the calculation used, the more conservative the outcome and the greater the compliance distance that will result (Mann *et al*, 2000). (Compliance distance is the distance from a transmitting antenna beyond which basic EMF exposure restrictions are not exceeded.)

Sections 2.2, 2.3 and 2.4 below describe the methods used to calculate exposure to EMF in this particular instance.

2.2 Inverse Square Law

At sufficiently large distances from a transmitting antenna, in what is termed the 'far field', it is possible to calculate the power density of a plane wave, S, using the inverse square law:

(1) $$S = P_{rad}G \ / 4\pi d^2$$

where P_{rad} is the maximum power radiated by the radio in Watts, G the linear antenna gain and d the distance from the antenna in metres.

The 'far field' of an antenna is dependent upon the antenna type and the wavelength of the transmitted radio wave.

2.3 Parabolic Antennas

The maximum power density of a plane wave generated by an antenna, S_{max}, occurs in what is termed the 'near field', and can be calculated using the following formula:

(2) $$S_{max} = 16\pi P_{rad} / G\lambda^2$$

where λ is the wavelength in metres.

The boundary between the near and far fields for parabolic antennae can be calculated as follows:

(3) $$D_{far} = G\lambda / 8\pi$$

Calculating the maximum power density of a plane wave using equation (2) represents a conservative approach which cannot underestimate power density in the near field (Mann and Wheelton, 2000).

2.4 Sector Antennas

Were the power density in the near field of a sector antenna to be calculated using equation (2), the value would be greatly overestimated. As such, it is better to use equation (1) to calculate power density and identify the minimum safe distance from the antenna at which exposure guidelines would not be exceeded. However, it is important to note that this method will also overestimate power density within one metre of a sector antenna (Mann and Wheelton, 2000).

3 LIMITING EXPOSURE TO EMF

3.1 Biological Basis for Limiting Exposure

The following is a short excerpt from the ICNIRP guidelines (the full text of which can be found in Appendix A) concerning the biological effects of electromagnetic fields with frequencies in the range 100 kHz – 300 GHz:

> Available experimental evidence indicates that the exposure of resting humans for approximately 30 min to EMF producing a whole body SAR (specific energy absorption rate) of between 1 and 4 W kg^{-1} results in a body temperature increase of less than 1 °C. Animal data indicate a threshold for behavioural responses in the same SAR range. Exposure to more intense fields, producing SAR values in excess of 4 W kg^{-1}, can overwhelm the thermoregulatory capacity of the body and produce harmful levels of tissue heating……The sensitivity of various types of tissue to thermal damage varies widely, but the threshold for irreversible effects in even the most sensitive tissues is greater than 4 W kg^{-1} under normal environmental conditions.

In view of the above, both NRPB and ICNIRP have established basic restrictions on exposure to electromagnetic fields based upon specific energy absorption rates (SAR). Both organisations state that protection against adverse health effects requires that these basic restrictions are not exceeded.

However, SARs are not easily measurable in people, therefore both the NRPB and ICNIRP have introduced alternative means of evaluating exposure to electromagnetic exposure based upon field strength and power density. These alternative means give rise to *investigation levels* in the case of NRPB, and *reference levels* in the case of ICNIRP. Compliance with the investigation and reference levels ensures that the associated basic restrictions are not exceeded.

3.2 NRPB Guidelines

3.2.1 Basic Restrictions

The NRPB guidelines advise basic restrictions on the specific energy absorption rate to ensure that harmful temperature rises do no occur in the body. Compliance with NRPB guidelines is demonstrated by showing that none of the basic restrictions is exceeded (Mann *et al*, 2000).

SAR averaged over the body and over any 15 min period	0.4 W kg^{-1}
SAR averaged over any 10 g in the head or fetus and over any 6 min period	10 W kg^{-1}
SAR averaged over any 100 g in the neck and trunk and over any 6 min period	10 W kg^{-1}
SAR averaged over any 100 g in the limbs and over any 6 min period	20 W kg^{-1}

Table 1 *– NRPB basic restrictions on exposure to electric and magnetic fields (10 MHz – 10 GHz) (Source: Exposure to Radio Waves near Mobile Phone Base Stations, Mann et al, 2000)*

3.2.2 Investigation Levels

The NRPB investigation levels are provided in Table 2. The investigation levels provide a benchmark, facilitating direct comparison with calculated exposure levels in order that compliance (or otherwise) with the NRPB basic restrictions may be confirmed.

Frequency Range	**Electric Field Strength (V m^{-1})**	**Magnetic Field Strength (A m^{-1})**	**Power Density (W m^{-2})**
1.55 – 300 GHz	194	0.52	100

Table 2 *– NRPB investigation levels for exposure to electric and magnetic fields (Source: Exposure to Radio Waves near Mobile Phone Base Stations, Mann et al, 2000)*

3.3 ICNIRP Guidelines

3.3.1 Basic Restrictions

The ICNIRP basic restrictions, also based upon specific energy absorption rates, are provided in Table 3. ICNIRP asserts that 'protection against adverse health effects requires that these basic restrictions are not exceeded.'

It should be noted that the influential report 'Mobile Phones and Health' published by the Independent Expert Group on Mobile Phones recommended to the UK Government that, as a precautionary approach, 'the ICNIRIP guidelines for public exposure be adopted for use in the UK rather than the NRPB guidelines'.

As can be seen from the tables, ICNIRP distinguishes occupational workers from the general public. For occupational exposure, the ICNIRP guidelines do not differ significantly from those of the NRPB. However, for the general public, ICNIRP has generally reduced basic restrictions by a factor of up to five (Mann *et al*, 2000).

Exposure Characteristic	Occupational	General Public
SAR averaged over the body and over any 6 minute period	0.4 W kg^{-1}	0.08 W kg^{-1}
SAR averaged over any 10 g in the head and trunk and over any 6 minute period	10 W kg^{-1}	2 W kg^{-1}
SAR averaged over any 10 g in the limbs and over any 6 minute period	20 W kg^{-1}	4 W kg^{-1}

***Table 3** – ICNIRP basic restrictions on exposure to electric and magnetic fields in the range 10 MHz – 10 GHz (Source: Exposure to Radio Waves near Mobile Phone Base Stations, Mann et al, 2000)*

3.3.2 Reference Levels

In common with the NRPB, ICNIRP has devised a series of reference levels with which calculated exposure levels can be compared in order to determine whether or not ICNIRP's basic restrictions have been exceeded. The ICNIRP reference levels for the frequency range 2 – 300 GHz can be found in Table 4 below.

Group	Electric Field Strength (V m^{-1})	Magnetic Field Strength (A m^{-1})	Equivalent Power Density (W m^{-2})
Occupational	137	0.36	50
General Public	61	0.16	10

***Table 4** – ICNIRP reference levels for exposure to electric and magnetic fields in the range 2 GHz – 300 GHz (Source: ICNIRP Guidelines, 1998)*

3.4 EC Recommendation 1999/519/EC

European Council Recommendation 1999/519/EC concerns the limitation of the exposure of the general public to electromagnetic fields. The basic restrictions and reference levels contained within the Recommendation are identical to those published by ICNIRP with regards to the general public (as per Tables 3 and 4 above).

4 TERRESTRIAL POINT-TO-POINT MICROWAVE RADIO

4.1 Equipment Overview

The point-to-point microwave radio links proposed for deployment in the Connected Communities broadband network typically comprise two split-mount radio units (either NEC Pasolink$^+$ SDH or NEC Pasolink PDH) and two parabolic antennae either 0.3 m, 0.6 m or 1.2 m in diameter. Each of the required point-to-point links shall operate at one of the following frequencies:

- 7.5 GHz
- 13 GHz
- 15 GHz
- 23 GHz
- 26 GHz
- 38 GHz

Table 5 below provides the maximum operating frequency and transmit power associated with each of the radio variants proposed for use in the Connected Communities network, whilst Table 6 provides the typical gain of each antenna variant.

Operating Frequency	7.5 GHz	13 GHz	15 GHz	23 GHz	26 GHz	38 GHz
Transmit Power	25.0 dBm	16.5 dBm	16.5 dBm	15.0 dBm	14.0 dBm	10.5 dBm
Maximum Frequency	7.9 GHz	13.3 GHz	15.4 GHz	23.6 GHz	27.0 GHz	40 GHz

Table 5 *– Maximum Frequencies and Transmit Powers*

Operating Frequency	7.5 GHz	13 GHz	15 GHz	23 GHz	26 GHz	38 GHz
0.3 m dia.	-	36.2 dBi	31.4 dBI	35.2 dBi	36.3 dBi	39.8 dBi
0.6 m dia.	-	42.4 dBi	37.0 dBi	40.7 dBi	41.6 dBi	44.6 dBi
1.2 m dia.	37.7 dBi	45.3 dBi	43.0 dBi	46.8 dBi	47.2 dBi	-

Table 6 *– Antenna Gains*

4.2 Calculation of Exposure Levels

Using the data contained in Tables 5 and 6 above, equation (2), contained within Section 2.3 of this report, was used to calculate the maximum power density of a radio wave transmitted by each possible combination of microwave radio and antenna. The results for each radio and antenna combination can be found in Appendix C.

As can be seen from the table contained in Appendix C, the radio wave with the greatest maximum power density would be produced by a microwave radio operating within the 15 GHz frequency band utilising a parabolic antenna 0.3 m in diameter. The maximum power density, calculated as **4.29 W/m^2**, would occur within the near field which, in this particular instance, lies between 0 m and 1.073 m of the transmitting antenna. The power density of the transmitted radio wave reduces in the far field as the distance travelled from the antenna increases.

All other potential radio and antenna combinations would produce radio waves with maximum power densities significantly lower than 4.29 W/m^2.

4.3 Comment on Exposure Levels

At 4.29 W/m^2, the radio wave with the greatest maximum power density would not expose the general public to EMF in excess of the investigation level (10 W/m^2) prescribed by both ICNIRP and EC Recommendation 1999/519/EC. Moreover, such a power density is of the order of 23 times less than the investigation level prescribed by the UK's NRPB (100 W/m^2). It is therefore possible to deduce that the EMF arising from the point-to-point microwave radio infrastructure proposed for the Connected Communities network shall pose no known threat to the health of the general public of the Western Isles.

A further point of note with regards to point-to-point microwave infrastructure is that the successful operation of each link requires clear line of sight between transmitting and receiving antennas. As such, antennas are typically mounted at heights in excess of 5 m on either radio towers or buildings. It is therefore unlikely that any member of the general public will be exposed to the bore sight of a transmitting antenna and hence exposure to EMF arising from point-to-point microwave links is considered unlikely.

5 BROADBAND FIXED WIRELESS ACCESS RADIO

5.1 Equipment Overview

The broadband fixed wireless access radio equipment proposed for use in the Connected Communities network is the BreezeACCESS II and BreezeACCESS VL systems manufactured by Alvarion. The BreezeACCESS II system operates at 2.4 GHz whilst the VL system operates at 5.8 GHz.

A range of fixed wireless access antennas has been proposed for use in the Connected Communities broadband network. Details of the antenna variants proposed, and the associated parameters, can be found in Table 7 below. The relevant radio parameters can be found in Table 8.

Antenna Type	**5.8 GHz 120° Sector**	**5.8 GHz 90° Sector**	**5.8 GHz 60° Sector**	**2.4 GHz Omni**
Gain (dBi)	15	16	16	8
Linear Gain	31.62	39.81	39.81	6.31

Table 7 *– Antenna Parameters*

Radio Type	**BreezeACCESS II (2.4 GHz)**	**BreezeACCESS VL (5.8 GHz)**
Tx Power (dBm)	21.00	26.00
Radiated Power (W)	0.126	0.398

Table 8 *– Radio Parameters*

5.2 Calculation of Exposure Levels

Using the data contained in Tables 7 and 8 above, equation (1), contained within Section 2.2 of this report, was used to calculate the power densities of radio waves transmitted by every possible system/antenna combination. The power density of each transmitted radio wave has been calculated at discrete distances from the transmitting antennas across the range 0.1 – 10 m. The results can be found in Appendix D.

The data contained within Appendix D indicates that power density shall be greatest within radio waves produced by the 5.8 GHz BreezeACCESS VL system in conjunction with either a 60° or 90° sector antenna. However, regardless of the type of antenna and fixed wireless access system employed, the data also indicates that a person would have to stand within 20 cm of a transmitting antenna in order to be exposed to EMF in excess of both the ICNIRP and EC reference levels prescribed for the general public. Furthermore, a person would have to stand within 10 cm of a transmitting antenna before the resulting EMF would exceed the NRPB reference level of 100 W/m^2.

5.3 Comment on Exposure Levels

Figure 1 below provides a graphical representation of the power density data contained within Appendix D for a 5.8 GHz FWA system utilising either a 60° or 90° sector antenna. This represents the worst case scenario with regards to exposing the public to EMF, given that this combination of system and antenna results in the highest power density.

The figure also incorporates the reference levels prescribed by both ICNIRP and the NRPB. Additionally, the power density of radio waves transmitted by typical GSM systems operating at both 900 and 1,800 MHz have been incorporated within the figure.

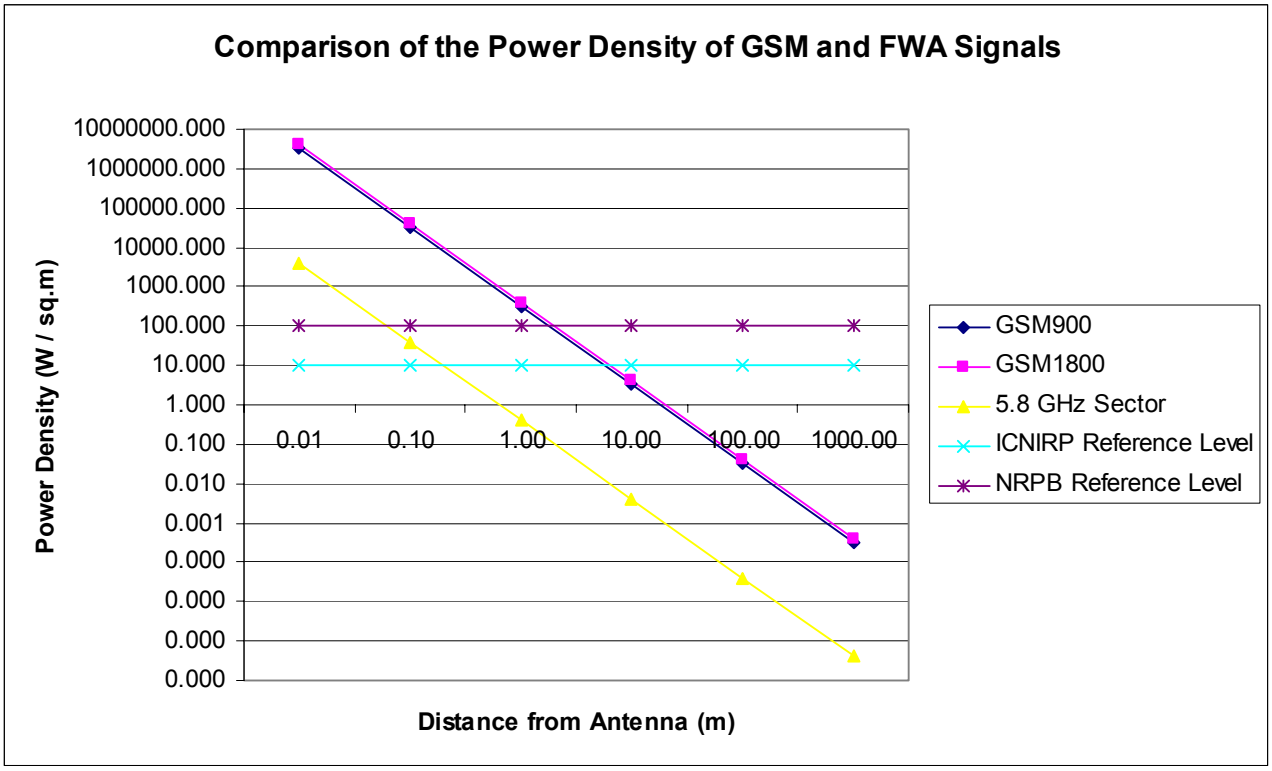

Figure 1 *– A comparison of the power density of a 5.8 GHz FWA radio wave with those of typical GSM radio waves*

In light of the data contained within Appendix D (as graphically represented in the above figure), which indicates that ICNIRP reference levels could potentially be exceeded within 20 cm of a transmitting antenna, Atkins recommends that exclusion zones be established around all FWA antenna installations. This is common practice within the radio communications industry and is necessary if members of the general public are to be protected from EMF in excess of internationally-recognised reference levels.

In light of the above figure, Atkins recommends that an exclusion zone of 1 m be established around each antenna installation. At a distance of 1 m from an antenna installation, and under worst case conditions (i.e. a 5.8 GHz FWA system utilising a 60 or 90° sector antenna), exposure to EMF would be approximately 25 times lower than the ICNIRP/EC general public reference level and approximately 250 times lower than the NRPB reference level. As such, establishing a 1 m exclusion zone could be deemed an extremely cautious measure which will ensure that, providing the exclusion zones are adhered to, the known adverse health effects of EMF are avoided.

Figure 1 also provides the power densities of radio waves generated by typical second generation mobile phone (GSM) systems operating at either 900 or 1,800 MHz (source of reference data: Mann *et al.*, 2000). A comparison of these radio waves with those likely to be generated by the FWA component of the Connected Communities network reveals the following:

- The power densities of radio waves produced by a fixed wireless access system operating at 5.8 GHz are approximately **800** times less than those of a GSM system operating at 900 MHz, and **1,000** times less than those of a GSM system operating at 1,800 MHz

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Terrestrial Point-to-Point Microwave Radio

The maximum power density of any radio wave generated by the microwave radio component of the Connected Communities network has been calculated as 4.29 W/m^2. This is lower than the reference levels prescribed by ICNIRP (10 W/m^2), EC Recommendation 1999/519/EC (10 W/m^2) and NRPB (100 W/m^2). As such, it can be concluded that the implementation of the point-to-point microwave radio infrastructure required to facilitate the Connected Communities broadband network shall not, in isolation, result in the exposure of the general public of the Western Isles to adverse levels of EMF.

6.2 Broadband Fixed Wireless Access Radio

Following the calculation of the power densities of radio waves generated by each of the possible FWA system/antenna combinations proposed for deployment in the Connected Communities network, it is apparent that the radio wave with the greatest power density is produced by the BreezeACCESS VL FWA system – which operates at 5.8 GHz – in conjunction with either a 60° or 90° sector antenna. This equipment combination therefore represents the worst case scenario when considering the exposure of the general public to EMF.

The data contained in Appendix D and Figure 1 indicate that, under the worst case scenario described above, a person would have to stand within 20 cm of a transmitting antenna in order to be exposed to EMF in excess of the INCIRP and EC general public reference level. In order to be exposed to EMF in excess of the NRPB reference level, a person would have to stand within 10 cm of a transmitting antenna. As such, it is recommended that exclusion zones, measuring 1 m in size from the outer faces of each antenna, be established around all FWA antenna installations. Such a measure shall restrict the exposure of the general public to EMF resulting from the Connected Communities broadband network to a level that is 25 times lower than the ICNIRP/EC reference level, and 250 time lower than the NRPB reference level.

At this point it is important to remind the reader that the use of equation (1), as was the case in this instance, to calculate the power density of a radio wave generated by a sector antenna will result in an overestimation at distances of less than 1 m from the antenna (see Section 2.4). The power density data contained in Appendix D, as represented in Figure 1, which relates to distances of less than 1 m are therefore exaggerated. Hence, it is highly likely that the NRPB reference level of 100 W/m^2 will not be exceeded, even if a person was within 10 cm of a transmitting antenna. It is also possible that the ICNIRP/EC general public reference level of 10 W/m^2 may not be exceed in close proximity to the antenna. As such, the establishment of a 1 m exclusion zone around all FWA antenna installations represents a very cautious approach which, if enforced, shall ensure that the general public's exposure to EMF resulting from the Connected Communities network shall be restricted to a small fraction of even the most conservative reference levels.

To put the power densities of the FWA radio waves in perspective, a comparison was made between the strongest FWA radio wave likely to result from the FWA component of the Connected Communities network and the power densities of the radio waves generated by typical second generation mobile phone networks (see Figure 1). As Figure 1 shows, the power densities of typical GSM radio waves are considerably higher than those of the proposed FWA system (800 times higher in the case of GSM systems operating at 900 MHz, and 1,000 times higher in the case of GSM systems operating at 1,800 MHz).

It is therefore possible to conclude that, providing the recommended exclusion zones are enforced, the implementation of the FWA component of the Connected Communities broadband network shall pose no known threat to the health of the general public of the Western Isles.

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APPENDIX A

Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)

APPENDIX B

Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)

APPENDIX C

Radio Wave Power Density Calculations – Terrestrial Point-to-Point Microwave Radio

Upper Frequency (Hz) *a*	**Minimum Wavelength** (m) *b*	**Tx Power** (dBm) *c*	**Radiated Power** (W) *d*	**Antenna Gain** (dBi) *e*		**Antenna Gain** (linear) *f*	**Maximum Power Density** (W / sq.m) *g*	**Near Field /Far Field Boundary** (m) *h*
7.90E+09	0.038	25.00	0.316	0.3 m	-	-	-	-
				0.6 m	-	-	-	-
				1.2 m	37.7	5888.44	1.87	8.897
1.33E+10	0.023	16.50	0.045	0.3 m	36.2	4168.69	1.06	3.755
				0.6 m	42.4	17378.01	0.25	15.655
				1.2 m	45.3	33884.42	0.13	30.526
1.54E+10	0.020	16.50	0.045	0.3 m	31.4	1380.38	4.29	1.073
				0.6 m	37.0	5011.87	1.18	3.897
				1.2 m	43.0	19952.62	0.30	15.516
2.36E+10	0.013	15.00	0.032	0.3 m	35.2	3311.31	3.01	1.675
				0.6 m	40.7	11748.98	0.85	5.943
				1.2 m	46.8	47863.01	0.21	24.209
2.70E+10	0.011	14.00	0.025	0.3 m	36.3	4265.80	2.39	1.886
				0.6 m	41.6	14454.40	0.70	6.390
				1.2 m	47.2	52480.75	0.19	23.202
4.00E+10	0.008	10.50	0.011	0.3 m	39.8	9549.93	1.03	2.850
				0.6 m	44.6	28840.32	0.34	8.606
				1.2 m	-	-	-	-

a	Source: NEC Pasolink+ Digital Radio Technical Specification
b	= **a**/300000000 m/s
c	Source: NEC Pasolink+ Digital Radio Technical Specification
d	= 1 mW x (10^0.1**c**)
e	Source: Andrew ValuLine Antenna Catalogue (maximum gain used for each size/frequency combination, hence worst case scenario)
f	Linear Gain = 10^0.1**e**
g	= 16π**d** / **f**λ^2
h	= **f**λ / 8π

APPENDIX D

Radio Wave Power Density Calculations – Fixed Wireless Access Radio

Antenna / Radio Parameters					
Antenna P/N	**a**	AN1169	AN1170	AN1152	AN1062
Antenna Type	**b**	5.8 GHz 120° Sector	5.8 GHz 90° Sector	5.8 GHz 60° Sector	2.4 GHz Omni
Gain (dBi)	**c**	15	16	16	8
Linear Gain	**d**	31.62	39.81	39.81	6.31
Tx Power (dBm)	**e**	21.00	21.00	21.00	26.00
Radiated Power (W)	**f**	0.126	0.126	0.126	0.398

Distance from antenna (m)	**Power Density** (W / sq.m)			
0.10	31.680	39.883	39.883	19.989
0.20	7.920	9.971	9.971	4.997
0.30	3.520	4.431	4.431	2.221
0.40	1.980	2.493	2.493	1.249
0.50	1.267	1.595	1.595	0.800
0.60	0.880	1.108	1.108	0.555
0.70	0.647	0.814	0.814	0.408
0.80	0.495	0.623	0.623	0.312
0.90	0.391	0.492	0.492	0.247
1.00	0.317	0.399	0.399	0.200
2.00	0.079	0.100	0.100	0.050
3.00	0.035	0.044	0.044	0.022
4.00	0.020	0.025	0.025	0.012
5.00	0.013	0.016	0.016	0.008
6.00	0.009	0.011	0.011	0.006
7.00	0.006	0.008	0.008	0.004
8.00	0.005	0.006	0.006	0.003
9.00	0.004	0.005	0.005	0.002
10.00	0.003	0.004	0.004	0.002

APPENDIX E

Radio Wave Power Density Calculations – Second Generation Mobile Phone Networks

Antenna / Radio Parameters		
Antenna Type	GSM900 (typical)	GSM1800 (typical)
Gain (dBi)	17	18
Linear Gain	50.12	63.10
Radiated Power (W)	80.000	80.000

Distance from antenna (m)	**Power Density** (W / sq.m)	
0.01	3190657.026	4016799.210
0.10	31906.570	40167.992
1.00	319.066	401.680
10.00	3.191	4.017
100.00	0.032	0.040
1000.00	0.000	0.000