UK radiowave propagation measurement data for frequencies below 6 GHz

Information about the data files

Publication Date: 2 August 2019

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1. Overview

Propagation measurement data collected by Ofcom between 2015 and 2018 has been released under our open data policy. We are making this data available so that academia and industry can benefit from the data in analysis of their own propagation models. This document provides the technical parameters and describes the format of the measurement data files.

The data collected – in brief

We have collected propagation measurement data in seven areas of the UK: Boston, London, Merthyr Tydfil, Nottingham, Scar Hill, Southampton and Stevenage. The measurements are representative of the diverse topography of the UK.

A continuous wave (CW) transmitter was deployed at a fixed location and the mast-mounted antenna was clear of local obstructions. The transmitting antenna was at 17 m above ground level (or 25 m for London).

The receiver was installed in a car and collected measurements of received power in the surrounding area. The receiving antenna was at 1.5 m above ground level.

The measurements were made at six frequencies between 400 MHz and 6 GHz.

Background

In 2015, a propagation measurement campaign was initiated by Ofcom to capture statistically significant propagation measurement datasets across the diverse topography of the UK for six frequencies below 6 GHz. The aim of the study was to assess the UK specific performance and applicable frequency ranges of propagation prediction methods, including ITU-R P-series Recommendations, and identify areas of improvement.

The campaign was completed in 2018 following collection of data at seven locations in the UK: Boston, London, Merthyr Tydfil, Nottingham, Scar Hill, Southampton and Stevenage. The locations are representative of the diverse topography of the UK and are shown in Figure 1.

The measurement data has been included in the ITU Study Group 3 (Radiowave Propagation) databank.

Figure 1: Propagation measurement areas

2. Methodology

The campaign employed a high-power narrowband methodology to capture mobile measurements at six frequencies (449.425, 915.950, 1802.50, 2695.00, 3602.50 and 5850.00 MHz) using typical parameter ranges of mobile networks in the UK. The measurement frequencies were chosen to be representative of current and future mobile systems. Non-operational licences were granted for these frequencies and the spectrum was monitored to ensure that it was clear of other activity. The transmission power levels enabled us to capture data over significant distance ranges of up to 25 km. The narrowband signal reduced the risk of interference with adjacent services.

A CW transmitter was deployed in a mobile laboratory with a 20 m pump up mast. At all sites the transmit antenna was raised to a height of 17 metres. In London the van was parked on a raised structure which facilitated an overall 25 metre antenna height. The receiver equipment was installed in a car (Ford Focus Estate) fitted with a 1 x 1 m roof-mounted steel ground plane and further calibrated to ensure minimum impact to the receive antenna radiation patterns. The car was also fitted with a CAN Bus speed interface to enable the distance travelled to be supplied to the receiver.

To reduce data collection time, the lower frequency bands were paired (449.425/915.950 MHz and 1802.50/2695.00 MHz) and data collected simultaneously with multiple Rhode and Schwarz CW scanners. The higher frequencies (3602.50 and 5850.00 MHz) were collected individually with the addition of low noise amplifiers to optimise the dynamic range. Omni directional vertically polarised transmit and receive antennas were used for all frequencies.

The measurements were distance triggered and the data was averaged on export from the receiver using the Lee method as described in Recommendation ITU-R SM.1708 to remove multipath effects. The Lee criteria parameters are given in Table 1. It should be noted that for the 5850.00 MHz measurements, the maximum number of samples within the 40 wavelength distance that could be collected was 35, limited by the maximum pulse rate available from the CAN Bus interface which gives a minimum distance interval of 5.8 cm.

Detailed equipment configuration and technical parameters for each measurement site are given in Annex 1.

Table 1: Lee criteria for multipath removal

Frequency (MHz)	Wavelength (m)	40λ (m)	Number of samples	Sample distance (m)	Max speed (m/s)	Max speed (mph)
449.425	0.67	26.73	50	0.53	267.26	597.84
915.950	0.33	13.11	50	0.26	131.15	293.37
1802.50	0.17	6.66	50	0.13	66.59	148.96
2695.00	0.11	4.45	50	0.09	44.53	99.60
3602.50	0.08	3.33	50	0.07	33.31	74.52
5850.00	0.05	2.05	35	0.06	29.30	65.55

Quality assurance

Prior to selection a survey visit was made to each measurement area and a number of candidate sites were evaluated with regard to repeatable access for van location, security and suitability of the environment. During these site assessment visits the spectrum was monitored to ensure there was no local use of the measurement frequencies.

To ensure consistency and quality of the measurement data daily line-of-sight calibration checks were undertaken and the transmitter equipment output was monitored and found to be stable during the data collection time periods.

At Merthyr Tydfil and Scar Hill equipment failures resulted in changes to the link budget. Any invalid data was discarded, and some measurements were modified to ensure that the link budget information presented in this document can be used to correctly establish measured basic transmission loss. Further information is available in Annex 1.

3. Propagation measurement areas

The aim of the measurement campaign was to collect propagation data across the diverse topography of the UK. Descriptions of the environments of the seven measurement areas are given below.

Boston This area in Lincolnshire has flat terrain with hills rising to the west of the transmitter location. The environment is predominantly open with sparse vegetation and three small towns within the service area of the transmitter.

London Significant areas of urban, dense urban and high urban environment.

Merthyr Tydfil This is a large town selected specifically because the surrounding area is mountainous. The peaks of the hills rise to greater than 750 m above sea level from the transmitter location at approximately 325 m. There is sparse urbanisation with some village and suburban areas.

Nottingham A city in an area with rolling terrain. There are urban areas to the south-east and south-west of the transmitter location with a scattering of suburban and village areas to the north-west.

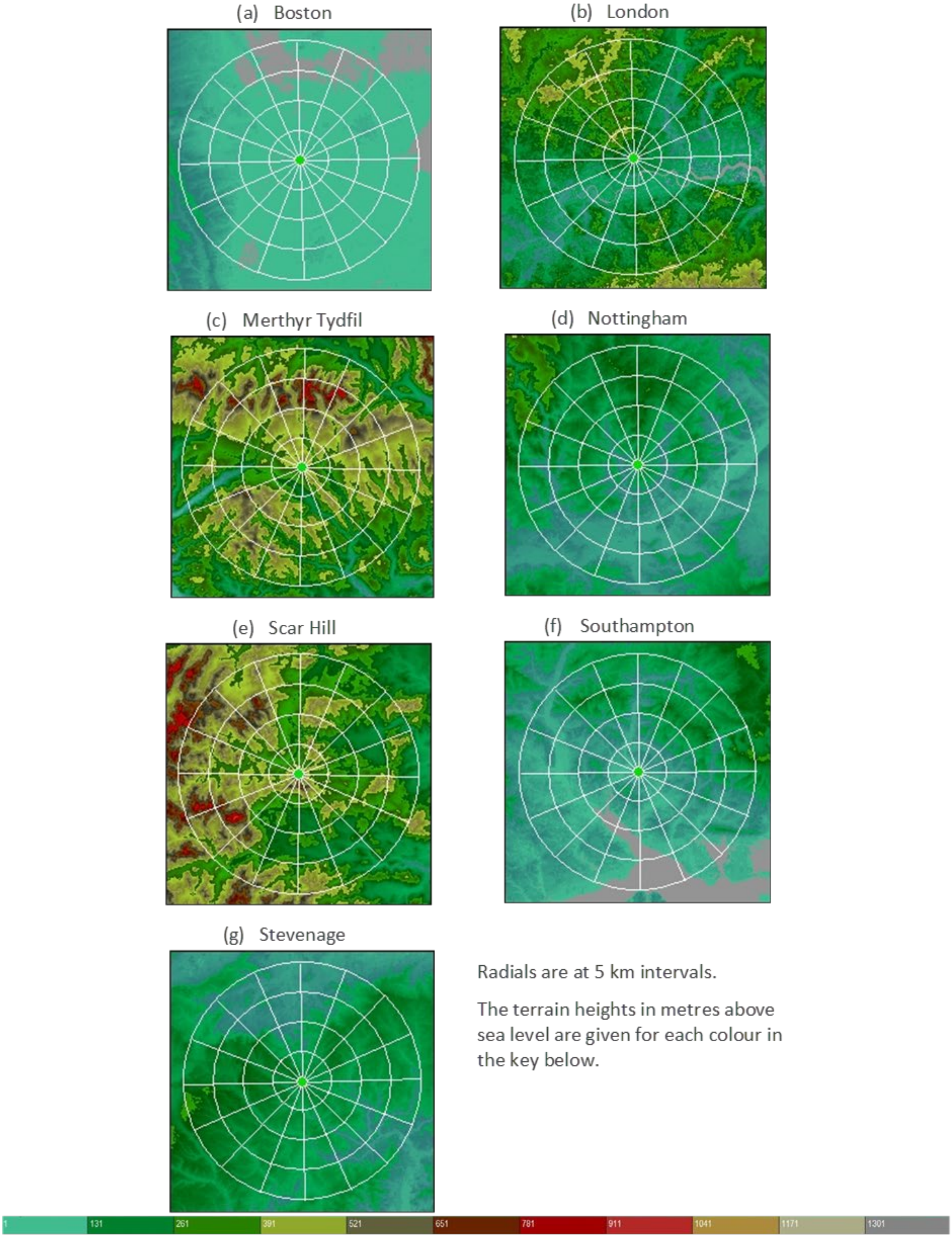
Scar Hill Located in the Cairngorms, Scotland, within mountainous terrain with dense and high vegetation. The transmitter was located close to a pine forest at a ground height of 520 m above sea level. The terrain rises to the west of the transmitter to heights of greater than 800 m. To the east the ground height falls to approximately 100 m.

Southampton A city in an estuarine area with rolling terrain. Some of the propagation paths are over water. The environment is mainly open to the north-east and the urbanisation lies to the south of the transmitter site.

Stevenage A large ‘new’ town in a fairly flat area with urban areas surrounded by suburbs and villages. This was the first area tested and the drive pattern was somewhat different to the other areas, with a high density of driving in the built-up areas of this town.

Maps of the terrain and clutter (land use) for the measurement areas are given in Figures 2 and 3 respectively.

Figure 2: Terrain heights in the propagation measurement areas[1]

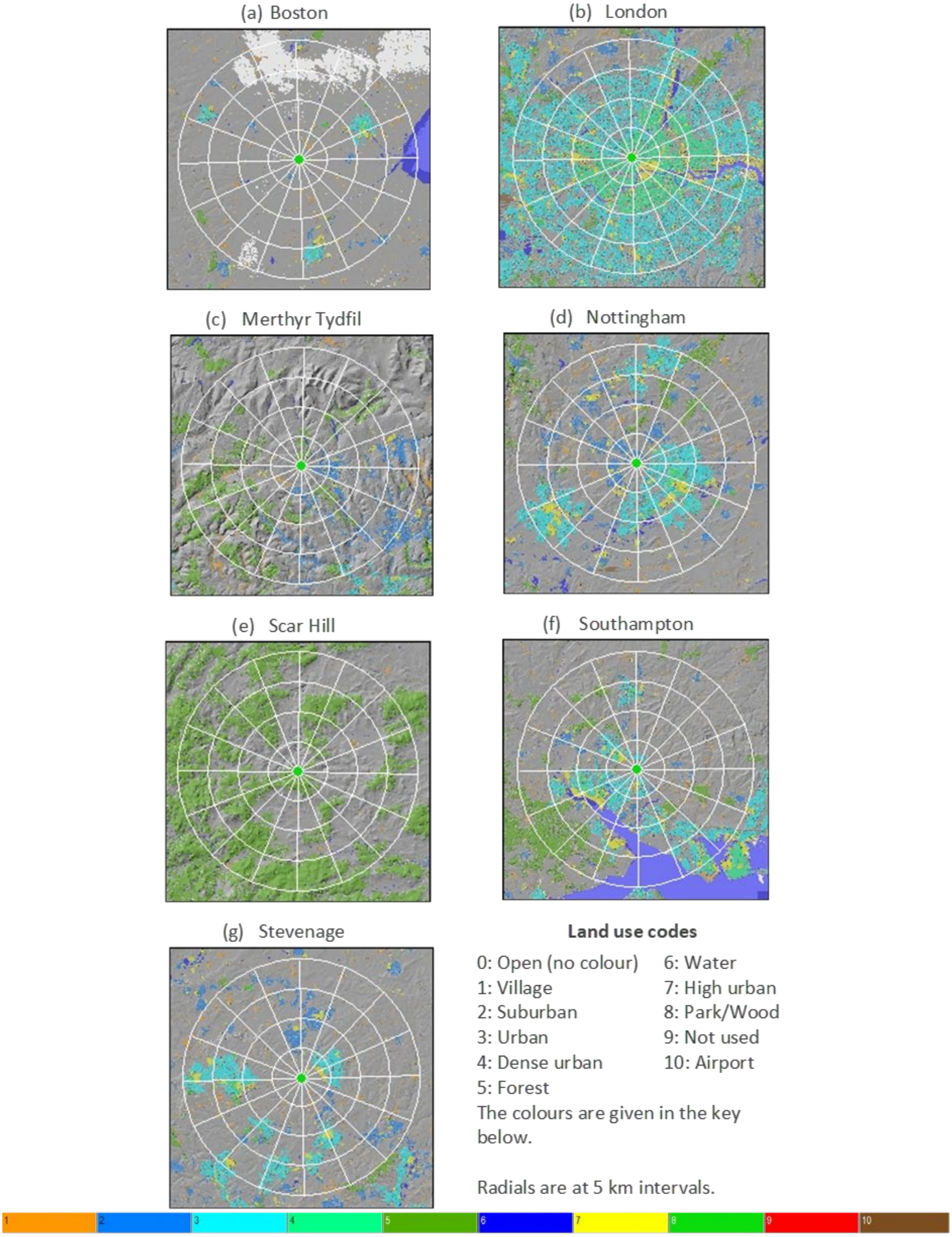


Radials are at 5 km intervals.

The terrain heights in metres above sea level are given for each colour in the key below.

[1] © Getmapping plc 2015

Figure 3: Clutter (land use) in the propagation measurement areas[2]



[2] © Siradel SAS 2015

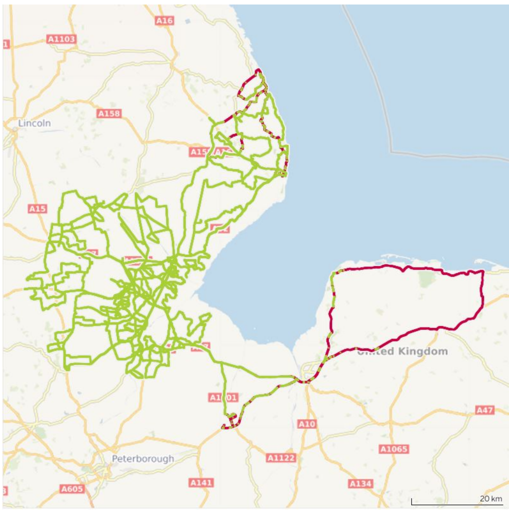
4. Measurement routes

Figure 4 shows the measurement routes for 449.425 MHz and 5850.00 MHz at each site. The local mean data points are displayed with the green/red threshold indicating 6 dB above the noise floor.

The coverage areas for 449.425 MHz are larger than for 5850.00 MHz as expected, reflecting an increase in free space basic transmission loss and diffraction loss with increase in frequency. In the case of 3602.50 MHz and 5850.00 MHz the use of high gain antennas and low noise amplifiers helped to ensure that a range of at least 10 km could be achieved.

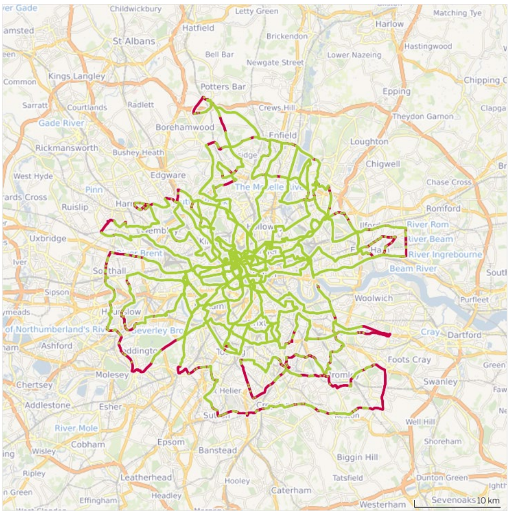
Figure 4: Measurement drive route examples[3]

(a) Boston 449.425 MHz

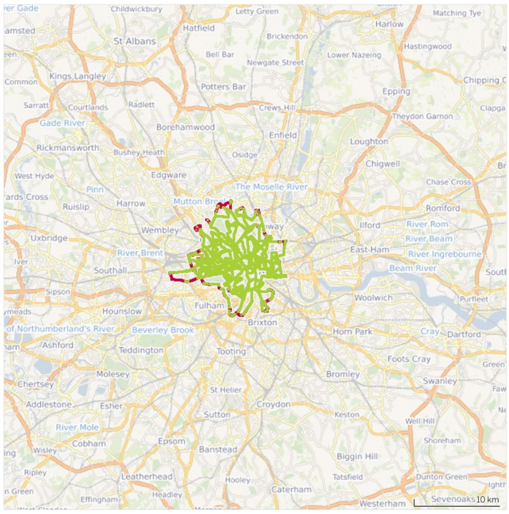


(b) Boston 5850.00 MHz

(c) London 449.425 MHz



(d) London 5850.00 MHz

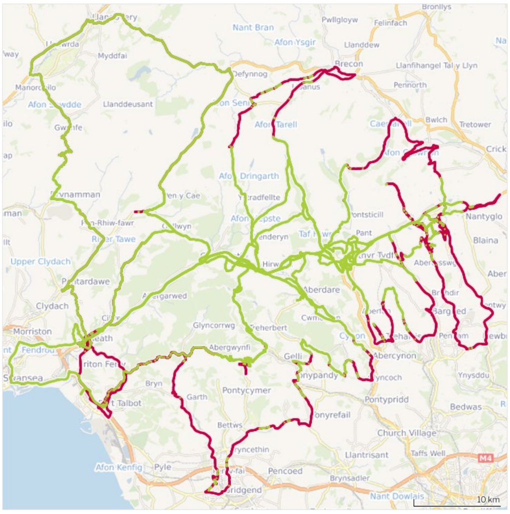


■ Above threshold level ■ Below threshold level

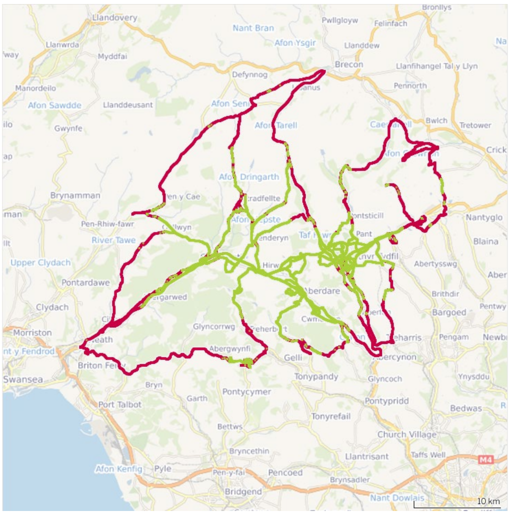
[3] © OpenStreetMap contributors
https://www.openstreetmap.org/copyright

Figure 4 (continued)

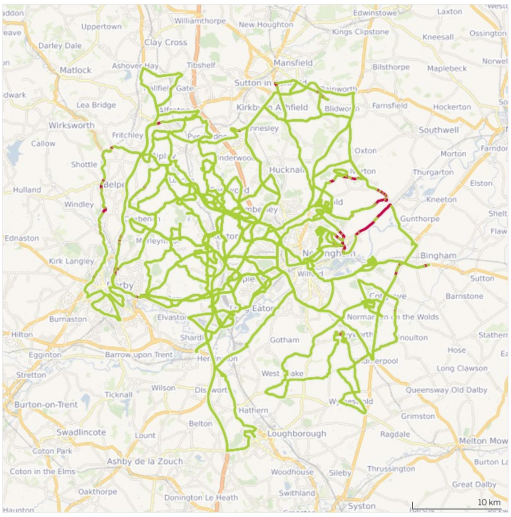
(e) Merthyr Tydfil 449.425 MHz



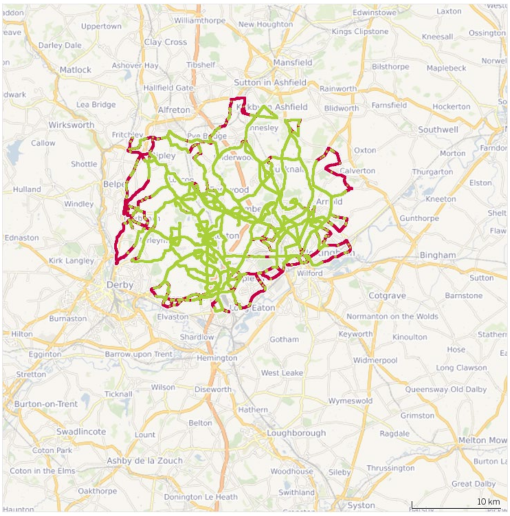
(f) Merthyr Tydfil 5850.00 MHz



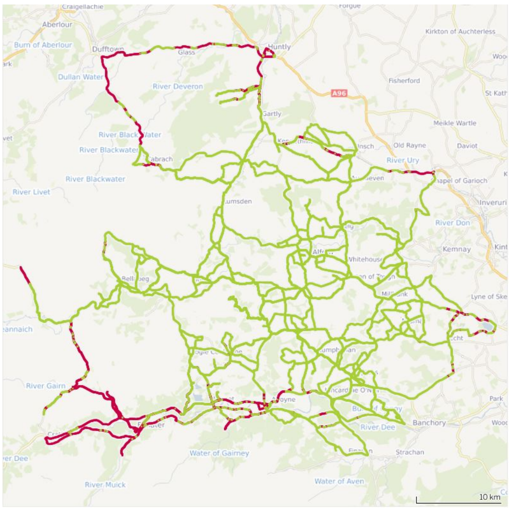
(g) Nottingham 449.425 MHz



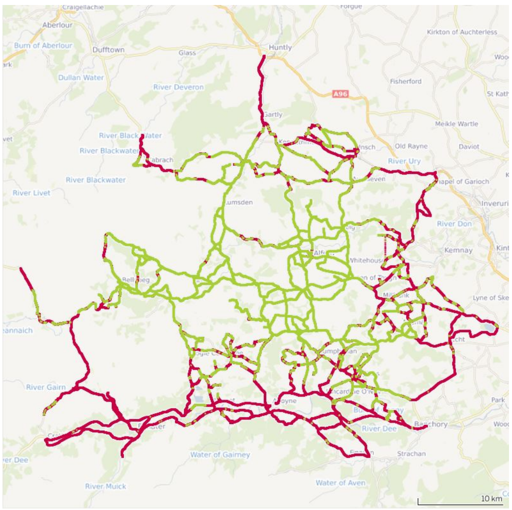
(h) Nottingham 5850.00 MHz



(i) Scar Hill 449.425 MHz

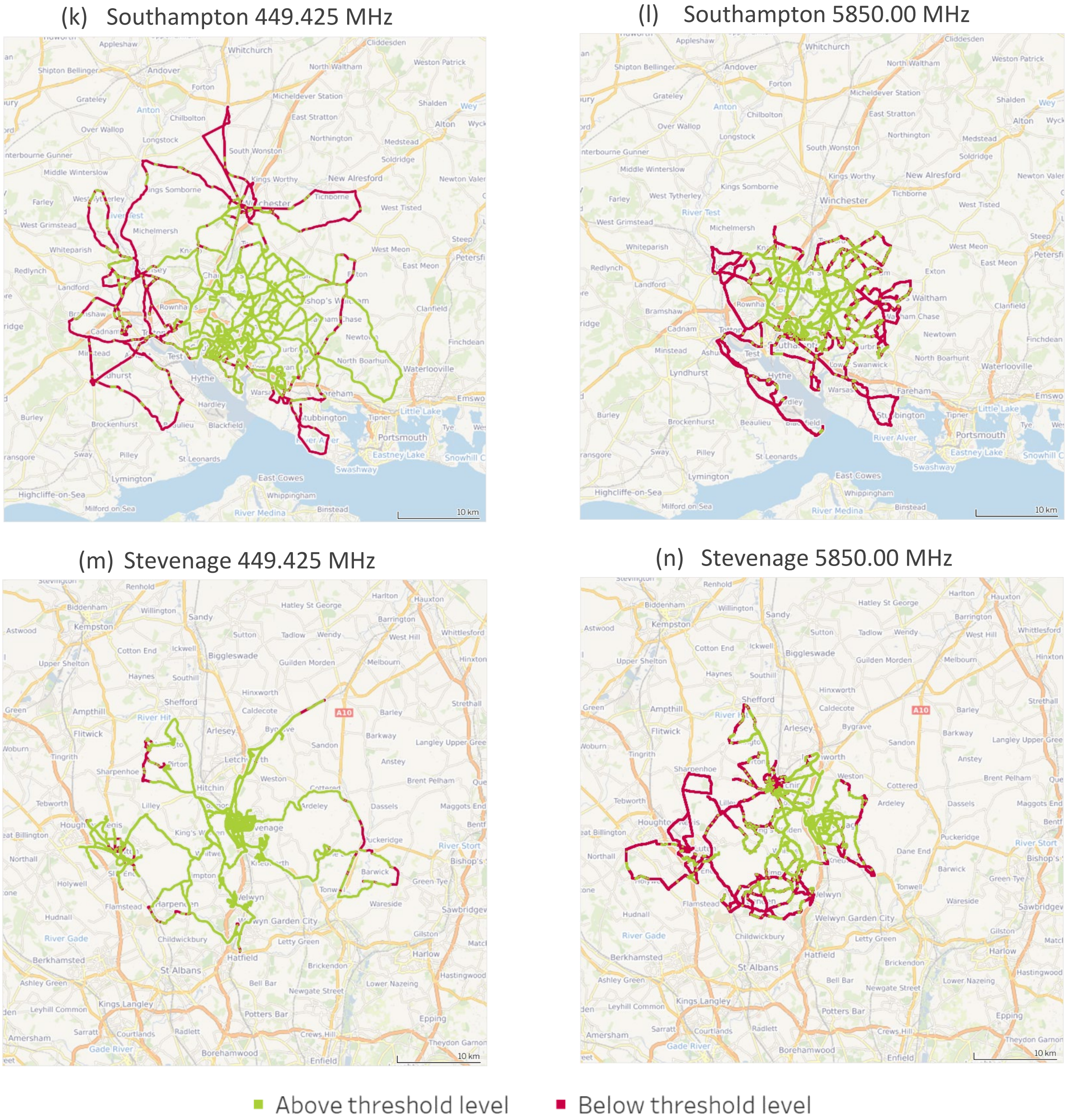


(j) Scar Hill 5850.00 MHz



■ Above threshold level ■ Below threshold level

Figure 4 (continued)



5. Measurement data file format

The measurement data is provided in csv files, one file per frequency for each measurement site. The first 10 rows of the file header data contain data relating to the measurement scenario and data. A description of the header data is given in Table 2.

Table 2: Measurement file header description

Header row	Field	Description	Example
1	Site name:	Name of the transmitter site location.	London
2	Site latitude (deg):	WGS84 Latitude position of the transmitter in decimal degrees.	51.530 5
3	Site longitude (deg):	WGS84 Longitude position of the transmitter in decimal degrees.	-0.133 99
4	Frequency (MHz):	Frequency of the measurement in MHz.	449.425
5	Tx antenna height (m):	Height of the transmitting antenna in metres above ground level.	25
6	Adjusted e.i.r.p. (dBm):	Equivalent isotropically radiated power of the system in dBm taking into account system gains and losses.	40.3
7	Rx antenna height (m):	Height of the receiving antenna in metres above ground level.	1.5
8	System noise floor (dBm):	System noise floor in dBm.	-122
9	Number of records:	Number of measurement records in the file following the header rows.	31 838
10	Header information for the subsequent data, formed of five columns:		
	Date (dd.mm.yyyy)	Date of measurement ‘dd.mm.yyyy’ where ‘dd’ is day, ‘mm’ is month and ‘yyyy’ is year.	
	Time (hh:mm:ss)	Time of measurement ‘hh:mm:ss’ where ‘hh’ is hours, ‘mm’ is minutes and ‘ss’ is seconds.	
	Rx Latitude (deg)	Latitude position of the receiver in decimal degrees.	
	Rx Longitude (deg)	Longitude position of the receiver in decimal degrees.	
	Local mean measurement (dBm)	Local mean received signal level at the receiver after Lee averaging in dBm.	

The adjusted equivalent isotropically radiated power (e.i.r.p.) taking account of the system gains and losses is provided so that the data can be converted into basic transmission loss. The adjusted e.i.r.p. values for each site and frequency are given in Table 3. Full link budget information is provided in Annex 1 for both the transmit and receive paths. Technical characteristics vary due to the replacement of components during the measurement project and the monitored output level from the amplifier.

Table 3: Adjusted e.i.r.p. (dBm)

Frequency (MHz)	Boston	London	Merthyr Tydfil	Nottingham	Scar Hill	Southampton	Stevenage
449.425	40.6	40.3	40.6	35.8	40.6	35.2	35.5
915.950	47.3	47.3	47.3	48.9	46.9	48.2	49.7
1802.50	47.5	48.0	45.5	48.5	47.4	46.7	48.7
2695.00	46.7	47.6	46.7	48.4	46.7	46.8	48.4
3602.50	70.0	70.0	70.0	70.2	70.0	70.2	70.5
5850.00	92.6	92.5	91.6	92.3	92.2	92.5	92.2

6. Measurement data files

During the measurement campaign over 8.2 million data points have been collected over six frequencies and seven sites as detailed in Table 4. No data filtering or thresholding has been performed on the dataset provided and no data points have been removed. We would recommend, however, that a 6 dB margin relative to the receive system noise floor is applied when using the data to ensure that errors due to the presence of the receiver noise floor are not introduced. The noise floor figures are given in Table A1.2.

Table 4: Measurement record count

Frequency (MHz)	449.425	915.95	1802.50	2695.00	3602.50	5850.00	Total/site
Boston	68 816	140 310	219 956	328 564	464 646	620 907	1 843 199
London	31 838	64 923	73 362	109 687	168 111	156 496	604 417
Merthyr Tydfil	39 055	78 946	177 774	265 719	307 932	435 613	1 305 039
Nottingham	46 538	94 791	175 492	261 967	217 181	300 408	1 096 377
Scar Hill	70 414	143 541	223 944	334 261	472 569	622 049	1 866 778
Southampton	37 543	72 785	91 705	135 969	197 879	284 407	820 288
Stevenage	38 177	77 842	69 630	104 101	169 901	248 524	708 175
Total/frequency	332 381	673 138	1 031 863	1 540 268	1 998 219	2 668 404	8 244 273

The measurements are provided in the csv files published with this document.

A1. Technical parameters

Transmitter equipment parameters

The transmitter equipment configuration for the dual frequency setup used in London is shown for the 449.425/915.950 MHz frequency pairing in Figure A1.1. An equivalent configuration was used for the other sites and for 1802.50/2695.00 MHz. The configuration for 3602.50 MHz used in Nottingham is illustrated in Figure A1.2. An equivalent configuration was used for the other sites and for 5850.00 MHz. Table A1.1 gives the transmit path link budget parameters for each site.

Figure A1.1: Transmitter equipment configuration diagram for 449.425/915.950 MHz in London

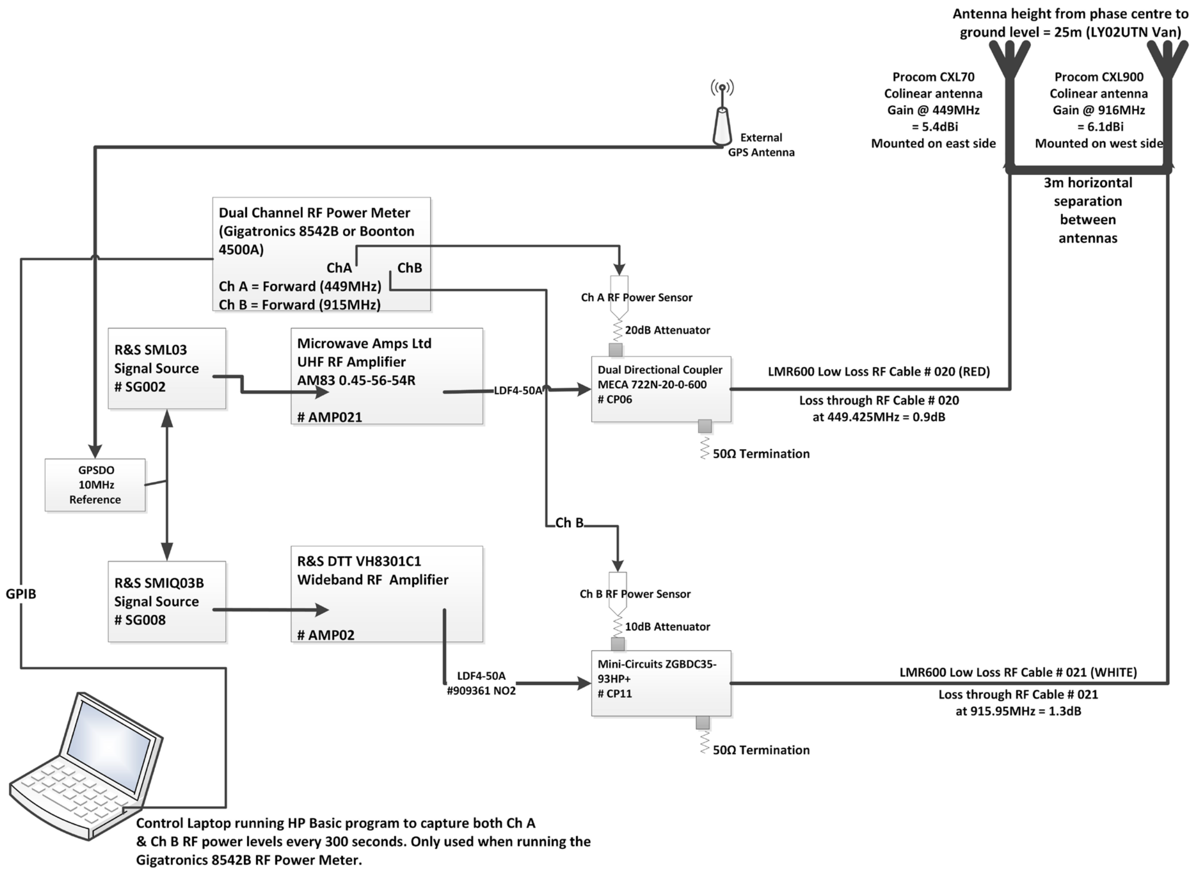


Figure A1.2: Transmitter equipment configuration diagram for 3602.50 MHz in Nottingham

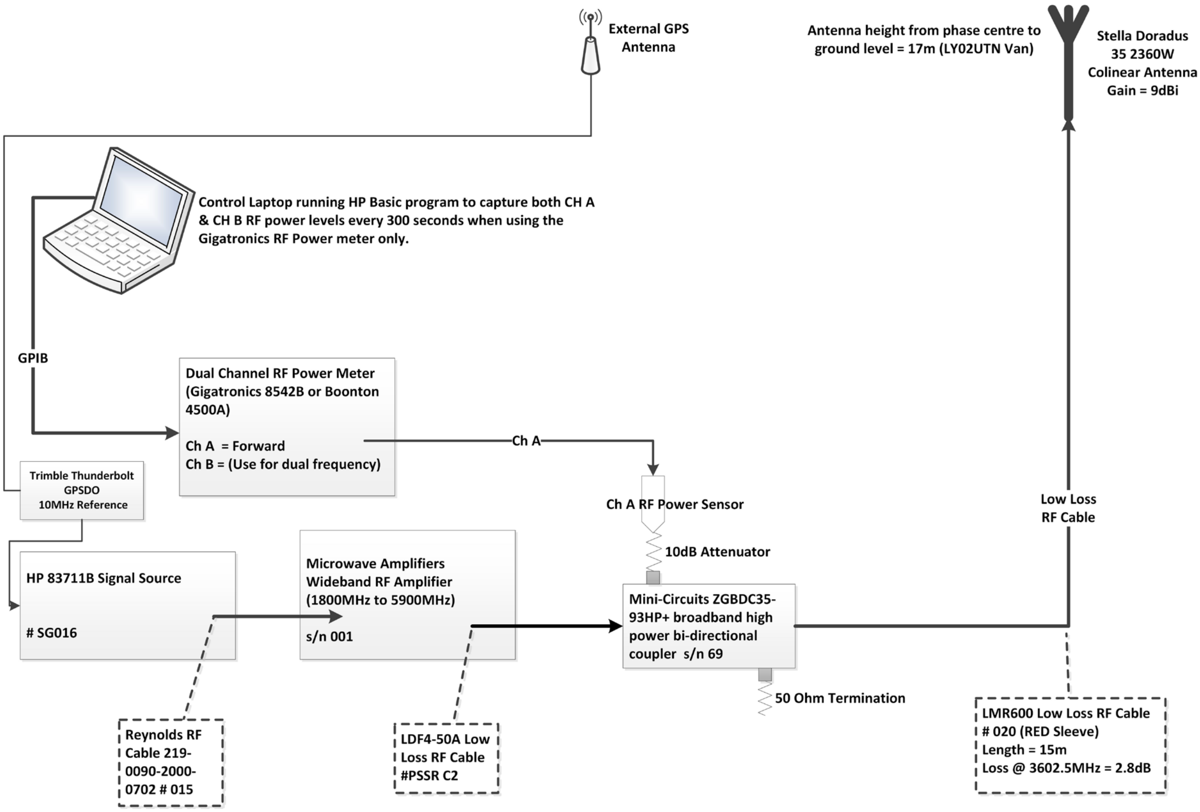


Table A1.1 Transmit path link budget

Site	Frequency (MHz)	Amplifier output (dBm)	Cable loss (dB)	Antenna gain (dBi)	e.i.r.p. (dBm)
Boston	449.425	50.9	0.9	5.4	55.4
Boston	915.950	50.3	1.3	6.1	55.1
Boston	1802.50	48.9	1.9	8.0	55.0
Boston	2695.00	49.2	2.2	9.0	56.0
Boston	3602.50	47.8	2.8	9.0	54.0
Boston	5850.00	48.9	3.9	12.0	57.0
London	449.425	50.6	0.9	5.4	55.1
London	915.950	50.3	1.3	6.1	55.1
London	1802.50	49.4	1.9	8.0	55.5
London	2695.00	50.1	2.2	9.0	56.9
London	3602.50	47.8	2.8	9.0	54.0
London	5850.00	48.9	3.9	11.0	56.0

Table A1.1 (continued)

Site	Frequency (MHz)	Amplifier output (dBm)	Cable loss (dB)	Antenna gain (dBi)	e.i.r.p. (dBm)
Merthyr Tydfil	449.425	50.9	0.9	5.4	55.4
Merthyr Tydfil	915.950	50.3	1.3	6.1	55.1
Merthyr Tydfil	1802.50	46.9	1.9	8.0	53.0
Merthyr Tydfil	2695.00	49.2	2.2	9.0	56.0
Merthyr Tydfil	3602.50	47.8	2.8	9.0	54.0
Merthyr Tydfil	5850.00	48.9	3.9	11.0	56.0
Scar Hill	449.425	50.9	0.9	5.4	55.4
Scar Hill	915.950	49.9	1.3	6.1	54.7
Scar Hill	1802.50	48.8	1.9	8.0	54.9
Scar Hill	2695.00	49.2	2.2	9.0	56.0
Scar Hill	3602.50	47.8	2.8	9.0	54.0
Scar Hill	5850.00	48.5	3.9	12.0	56.6
Nottingham	449.425	52.0	0.9	-1.0	50.1
Nottingham	915.950	50.5	1.3	7.0	56.2
Nottingham	1802.50	48.9	1.9	8.0	55.0
Nottingham	2695.00	49.2	2.2	9.0	56.0
Nottingham	3602.50	48.0	2.8	9.0	54.2
Nottingham	5850.00	48.7	3.9	11.0	55.8
Southampton	449.425	51.9	0.9	-1.0	50.0
Southampton	915.950	50.3	1.3	7.0	56.0
Southampton	1802.50	48.1	1.9	8.0	54.2
Southampton	2695.00	49.3	2.2	9.0	56.1
Southampton	3602.50	48.0	2.8	9.0	54.2
Southampton	5850.00	48.9	3.9	11.0	56.0
Stevenage	449.425	51.8	1.0	-1.0	49.8
Stevenage	915.950	51.5	1.5	7.0	57.0
Stevenage	1802.50	49.4	2.2	8.0	55.2
Stevenage	2695.00	49.9	2.9	9.0	56.0
Stevenage	3602.50	48.3	2.8	9.0	54.5
Stevenage	5850.00	48.6	3.9	11.0	55.7

Receiver equipment parameters

The receiver equipment configuration for the dual frequency setup used in Southampton is shown for the 1802.50/2695.00 MHz frequency pairing in Figure A1.3. An equivalent configuration was used for the other sites and for 449.425/915.950 MHz. The configuration for 5850.00 MHz used in Merthyr Tydfil is illustrated in Figure A1.4. An equivalent configuration was used for the other sites and for 5850.00 MHz. Table A1.3 gives the receive path link budget parameters for each site.

Figure A1.3: Receiver equipment configuration diagram for 1802.50/2695.00 MHz in Southampton

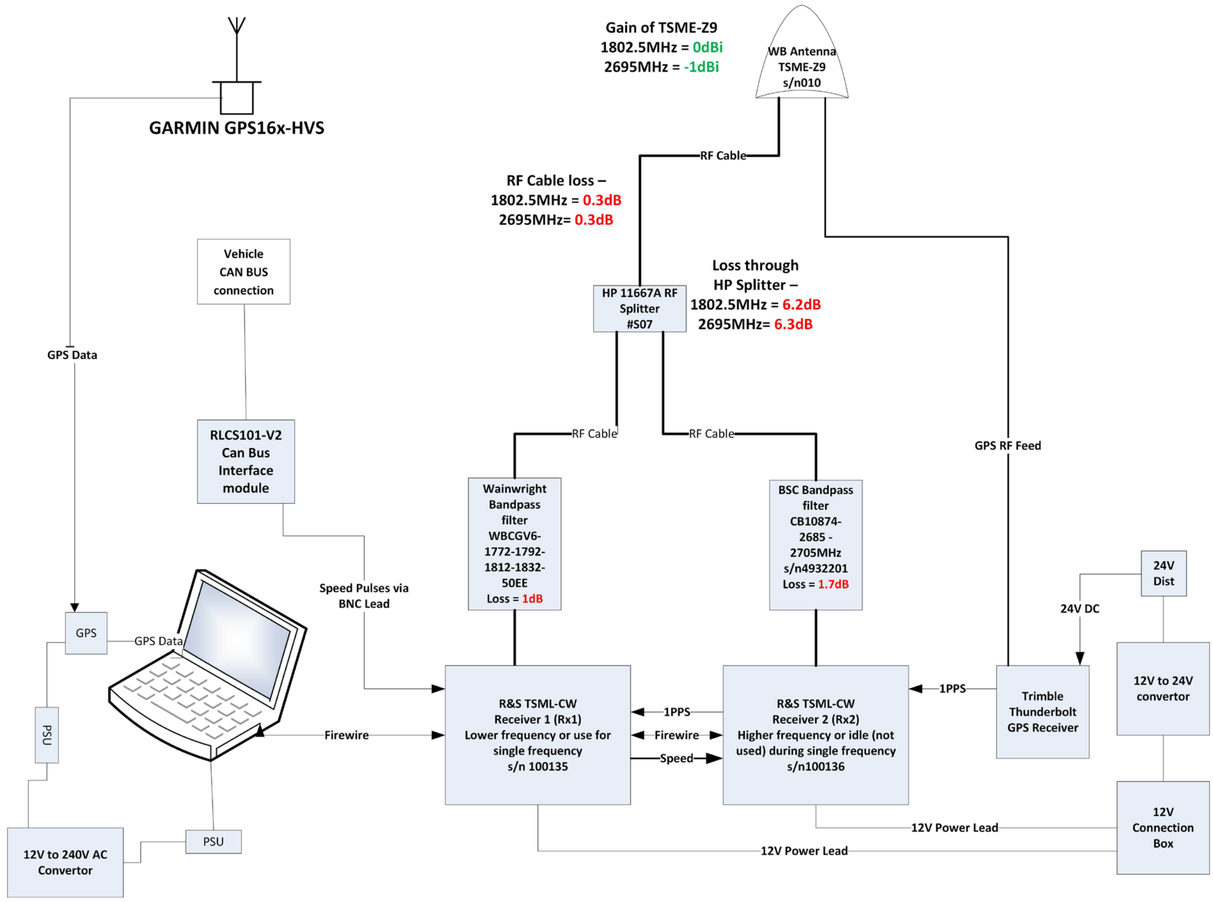


Figure A1.4: Receiver equipment configuration diagram for 5850.00 MHz in Merthyr Tydfil

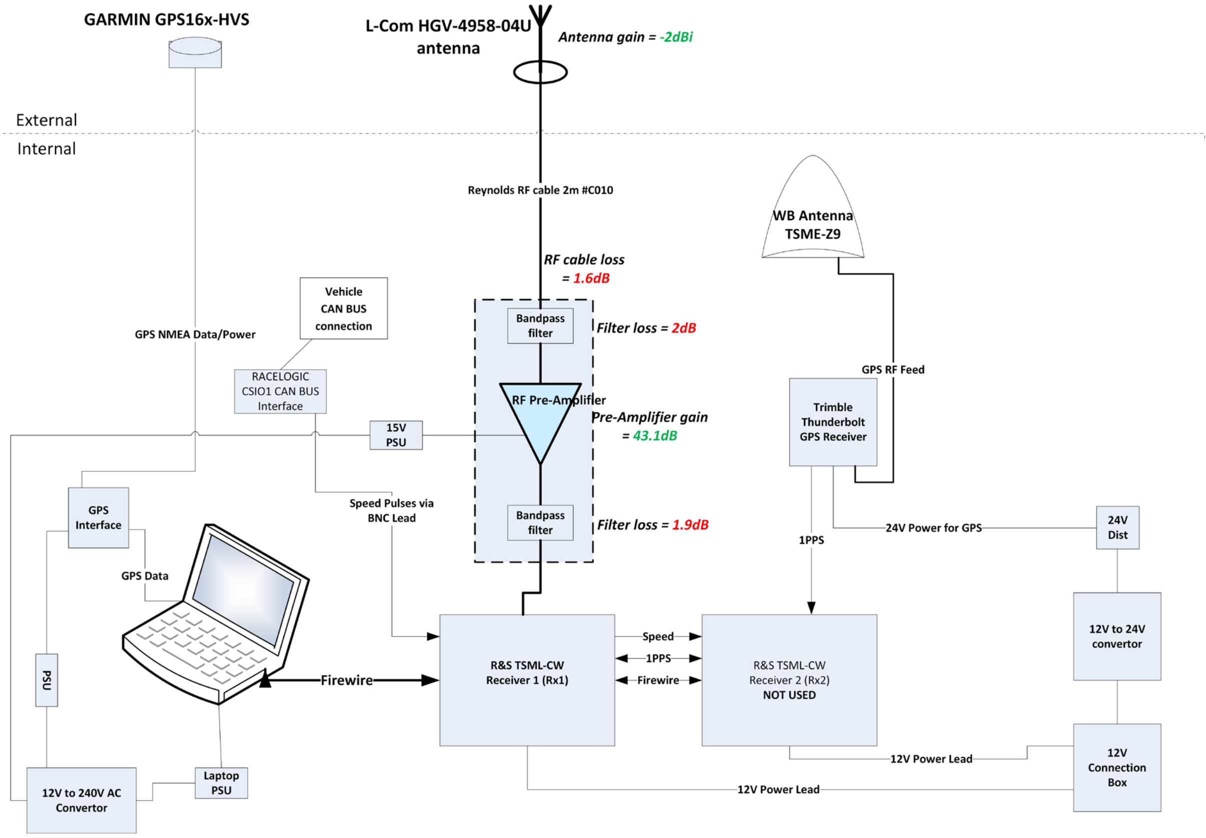


Table A1.2 Receive path link budget

Site	Frequency (MHz)	Antenna gain (dBi)	Cable/ feeder loss (dB)	External LNA gain (dB)	External BP filter loss (dB)	Splitter loss (dB)	Receive path gain (dB)	System noise floor (dBm)	Maximum measurable loss (dB)
Boston	449.425	-8	0.2	N/A	0.5	6.1	-14.8	-122	162.6
Boston	915.950	-1	0.2	N/A	0.5	6.1	-7.8	-124	171.3
Boston	1802.50	0	0.3	N/A	1.0	6.2	-7.5	-124	171.5
Boston	2695.00	-1	0.3	N/A	1.7	6.3	-9.3	-120	166.7
Boston	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.0
Boston	5850.00	-2	1.6	43.1	3.9	N/A	35.6	-91	183.6
London	449.425	-8	0.2	N/A	0.5	6.1	-14.8	-122	162.3
London	915.950	-1	0.2	N/A	0.5	6.1	-7.8	-124	171.3
London	1802.50	0	0.3	N/A	1.0	6.2	-7.5	-124	172.0
London	2695.00	-1	0.3	N/A	1.7	6.3	-9.3	-120	167.6
London	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.0
London	5850.00	-2	1.6	44.0	3.9	N/A	36.5	-91	183.5
Merthyr Tydfil	449.425	-8	0.2	N/A	0.5	6.1	-14.8	-122	162.6
Merthyr Tydfil	915.950	-1	0.2	N/A	0.5	6.1	-7.8	-124	171.3
Merthyr Tydfil	1802.50	0	0.3	N/A	1.0	6.2	-7.5	-124	169.5
Merthyr Tydfil	2695.00	-1	0.3	N/A	1.7	6.3	-9.3	-120	166.7
Merthyr Tydfil	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.0
Merthyr Tydfil	5850.00	-2	1.6	43.1	3.9	N/A	35.6	-91	182.6
Nottingham	449.425	-8	0.2	N/A	N/A	6.1	-14.3	-122	157.8
Nottingham	915.950	-1	0.2	N/A	N/A	6.1	-7.3	-124	172.9
Nottingham	1802.50	0	0.3	N/A	N/A	6.2	-6.5	-124	172.5
Nottingham	2695.00	-1	0.3	N/A	N/A	6.3	-7.6	-120	168.4
Nottingham	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.2
Nottingham	5850.00	-2	1.6	44.0	3.9	N/A	36.5	-91	183.3

Table A1.2 (continued)

Site	Frequency (MHz)	Antenna gain (dBi)	Cable/ feeder loss (dB)	External LNA gain (dB)	External BP filter loss (dB)	Splitter loss (dB)	Receive path gain (dB)	System noise floor (dBm)	Maximum measurable loss (dB)
Scar Hill	449.425	-8	0.2	N/A	0.5	6.1	-14.8	-122	162.6
Scar Hill	915.950	-1	0.2	N/A	0.5	6.1	-7.8	-124	170.9
Scar Hill	1802.50	0	0.3	N/A	1.0	6.2	-7.5	-124	171.4
Scar Hill	2695.00	-1	0.3	N/A	1.7	6.3	-9.3	-120	166.7
Scar Hill	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.0
Scar Hill	5850.00	-2	1.6	43.1	3.9	N/A	35.6	-91	183.2
Southampton	449.425	-8	0.2	N/A	0.5	6.1	-14.8	-122	157.2
Southampton	915.950	-1	0.2	N/A	0.5	6.1	-7.8	-124	172.2
Southampton	1802.50	0	0.3	N/A	1.0	6.2	-7.5	-124	170.7
Southampton	2695.00	-1	0.3	N/A	1.7	6.3	-9.3	-120	166.8
Southampton	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.2
Southampton	5850.00	-2	1.6	44.0	3.9	N/A	36.5	-91	183.5
Stevenage	449.425	-8	0.2	N/A	N/A	6.1	-14.3	-122	157.5
Stevenage	915.950	-1	0.2	N/A	N/A	6.1	-7.3	-124	173.7
Stevenage	1802.50	0	0.3	N/A	N/A	6.2	-6.5	-124	172.7
Stevenage	2695.00	-1	0.3	N/A	N/A	6.3	-7.6	-120	168.4
Stevenage	3602.50	-2	3.8	23.3	1.5	N/A	16.0	-109	179.5
Stevenage	5850.00	-2	1.6	44.0	3.9	N/A	36.5	-91	183.2

Changes to equipment

During the Merthyr Tydfil data collection for 1802.50 MHz a drop in transmitted power was observed. The data collected on that day, 28 September 2017, was discarded and subsequent data collection was undertaken with a lower e.i.r.p. Measurement values for 27 September (the only day with the higher e.i.r.p.) at 1802.50 MHz were reduced to account for the change in e.i.r.p. Therefore, the apparent noise floor level for that day at 1802.50 MHz will be lower than that for data collected after that date.

During the Scar Hill data collection at 5850.00 MHz the external LNA in the receive path failed (on 2 October 2018). The replacement external LNA had a higher gain than the original, so the 5850.0MHz measurement values following use of the replacement were reduced to account for the increase in gain. Therefore, the apparent noise floor level at 5850.00 MHz for dates after 2 October 2018 will be lower than that for data collected before that date.

The above modifications mean that the link budget information presented in this annex and the adjusted e.i.r.p. values given in Table 3 can be used to correctly establish measured basic transmission loss.