Red-M

WP2 Final Report – Field Measurement Results for Ofcom 3G Rollout Assessment

Prepared for

Ofcom
OFFICE OF COMMUNICATIONS

Date: 16th October 2007
Authors: Andy Barnard, Bachir Belloul
Document Ref.: RED_CON_1602
Version: Issue v1.3

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WP2 Final Report – Field Measurement Results for Ofcom 3G Rollout Assessment

Prepared for:	Mark Austin, Ofcom
Author(s):	Andy Barnard, Bachir Belloul
Checked by:	Steve Leach
Report Date:	20th September 2007
Doc. No.:	RED_CON_1602
Version No.:	Issue 1.3
Contact Details:	Graylands, Langhurstwood Road, Warnham, West Sussex. RH12 4QD E: info@red-m.com tel: 01403 211 100

Version History		
Version	**Date**	**Comments**
Issue 1.0	20th September	First Version Released for Ofcom comment
Issue 1.1	24th September	Update following review and incorporating Ofcom comments
Issue 1.2	27th September	Re-order columns in Table 1 and Table 2 so that operator pseudonyms are consistent with Table 3 and Figure 9.
Issue 1.3	16th October	Removed Fig9 and updated Table 3 with Op4's latest data. Minor corrections.

About Red-M
Red-M is a wireless professional services company that provides consultancy, audit, design, implementation, systems integration and management services. Through its services, Red-M provides insight into the benefits and challenges of current and future wireless technologies and creates mission critical wireless networks that are delivered to requirements, right, first time.

The company's capabilities span all wireless technologies including Cellular (2G, 3G & GSM-R) PMR, Wi-Fi and WiMAX, and its customers include Airwave, BAA, British Land, Bullring, Network Rail and Ofcom.

Red-M has successfully completed 1000s of radio projects including over 300 major wireless systems in a range of diverse and challenging locations, including corporate buildings (e.g. Canary Wharf), most of the major airports in the UK (Heathrow), large shopping centres (Meadowhall), key UK sporting venues (Millennium Stadium), train stations (Waterloo), and hospitals (Bristol).

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Executive Summary

This document reports on the results of a measurement campaign undertaken to support Ofcom's benchmarking exercise to assess the validity of their approach to the analysis of mobile network operators' 3G rollout obligations.

The measurements were conducted following a methodology that was developed by Red-M in a previous work-package. The approach is in essence to:

- Determine the areas where Ofcom and operator models produce contradictory predictions of coverage at the defined level – the 'combined marginal' areas.
- Design a drive test passing close by population centroids.
- Report on the results of comparisons of model predictions with measured results.
- Calculate the 'hit rate' of P.1546-2 for the areas driven, by comparing the predicted signal strengths at the centroids with measurements.
- Perform a linear prediction process to predict the signal strength at the population centroids near the drive routes.
- For the areas that have been driven, calculate population coverage, using the 2001 census data.
- Use the hit-rate to estimate population coverage in the combined marginal areas that have not been driven.

The conclusions of this exercise are broadly that:

- P1546 predictions of signal strength are significantly worse than the measured values, although P1546-3 outperforms P1546-2 by 0.6dB on average
- The mean difference between predictions and measurements is very consistent across four of the five operators
- Comparisons with available operator model predictions have shown that operator model predictions are significantly better than P1546-2 or P1546-3, with one operator achieving close to zero mean offset.
- The Hit rate of the Ofcom P1546 model can be improved by applying a correction factor of +8dB, corresponding to the mean prediction error deduced from measurements.
- This corrected measure can be used for population coverage estimates with a reasonable degree of accuracy, and the resulting measure compares very closely with the coverage estimates of most of the operators.
- The corrected measure can be applied to estimate population coverage outside the benchmarking area.

Detailed conclusions, operator by operator containing actual population coverage results are given in the Appendices. For reasons of confidentiality, these results are not given in the main report.

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Disclaimer

Whilst Red-M use best-in-class methodologies and practices to ensure accurate gathering of all wireless systems present on the bands of interest within the environment, the principles of radio propagation and technology protocols mean that in certain circumstances wireless elements may not be detected as part of any measurements. These measurements are only true and accurate for the conditions encountered at the time of any survey. Red-M therefore accepts no liabilities for any omissions.

Red-M requires customer sign off against any design works and any subsequent implementation works will be against the agreed design. This may involve some compromises against the original requirements where some requirements may be mutually exclusive.

1. Introduction

The 3G licensees have an obligation to provide a telecommunications service to an 'area where at least 80% of the population live' by the 31st of December 2007. Ofcom reiterated in the 3G Rollout obligations statement published on the 27th of February 2007 that it expects all 3G licenses to meet the requirements for rollout as stated in their licences. This statement summarised the conclusions of the 2006 consultation in which Ofcom proposed three basic methods to assess compliance, being

- engineering analysis by Ofcom
- physical field strength measurement by Ofcom or an agent
- operator self-declaration (either based on prediction, measurement or a combination).

Ofcom intends to use a methodology based on engineering analysis backed up by measurements in the field to verify the results as necessary.

Red-M was asked by Ofcom to propose a suitable measurement methodology to support their objectives and subsequently asked Red-M to undertake a series of measurements in a benchmarking area of 100km by 100km in the South West of England. Red-M's recommended measurement methodology has been described in a separate document[1].

This report documents the application of the methodology described in [1] to the benchmarking area, and gives measurement results for each operator. Following processing of the measurements to map them to the 100m by 100m prediction grid, comparisons are made between measurements and both P1546 predictions and Operator predictions. In the areas measured, the data interpolation technique described in [1] has been applied to enable a measurement estimate of population coverage to be made on all population centroids within the measurement area[2].

Ofcom have requested that data shared with them in confidence by the mobile operators remains in confidence. In order to meet this requirement, this report has been structured with confidential data contained in appendices, one for each mobile operator. Only high level and aggregated data is contained in the main body of the report. A final appendix, for Ofcom only, contains overall conclusions from the measurement campaigns with identifiable comparisons of operator data.

[1] WP1 Final Report: 'Field Measurements to Assist Ofcom to Verify the Approach to the Assessment of 3G Operator Rollout, issue 1.3' by Bachir Belloul and Andy Barnard.
[2] All population centroids where the error estimate for the interpolation technique is better than ±3 dB.

2. Summary of Measurement Methodology

The measurement methodology developed by Red-M and described in [1] considered how to determine the errors due to measurement. These errors are due both to basic accuracy of the scanning receivers proposed, and also due to the requirement to take a large number of samples in a local area to remove the effects of 'fast fading', whilst maintaining the integrity of the measured signal.

The methodology also proposed how to plan a measurement campaign to help determine the accuracy of the models used during the benchmarking process. The approach described in [1] is in essence to:

1. Determine the areas where Ofcom and operator models produce contradictory predictions of coverage at the defined level – the 'combined marginal' areas (see Figure 1).
2. Target clusters of these areas with high population density.
3. Design a drive route passing close by population centroids, with density suitable for linear prediction methods.
4. Collect and report on drive test measurements.
5. Process measurements to give a measured value corresponding to the prediction grid's 100mx100m pixels.
6. Compare measurements with predictions, for example to give mean prediction errors.
7. Calculate the 'hit rate' of Ofcom's predictions using the P.1546-2[3] model for the areas driven, by comparing the predicted signal strengths at the 100m pixels measurements.
8. Report on model 'hit rate' for both Ofcom and operator models.
9. Perform a linear prediction process to predict the signal strength at the 100m pixels covering population centroids that are close to the drive route but that have not been directly driven.
10. Report on linear prediction results.
11. For the areas that have been driven, use this data to calculate population coverage, using the 2001 census data.
12. Report on population coverage.
13. Use the hit-rate analysis to estimate uncertainty in the population coverage figure for the combined marginal areas that have not been driven as part of the benchmarking exercise.

The measurement campaign outlined in this document has been carried out over an extensive area covering a range of terrain types typical of where people live, and it is therefore it is considered that the conclusions in this report can be applied not only within the benchmarking area, but also elsewhere in the UK.

[3] Subsequent to the publication of [1], Ofcom produced predictions according to P1546-3, and comparisons have also been made against this model.

3. Application of Process to Determine Drive Routes in the Benchmarking Area

Data supplied by Ofcom from the Mobile operators and the corresponding predictions from Ofcom using P1545-2 was assessed to determine the 'combined marginal area' for each operator. The definition of 'combined marginal area' is illustrated by Venn diagram in Figure 1 – area (A + B) is the combined marginal area.

Operators supplied data in a variety of different forms, but all could be processed to provide the coverage contour defined by Ofcom (CPICH level predicted to be -110dBm or greater). Some data was not available until after the drive testing was complete, and drive test routes were chosen based on the subset of data that was available at the time of route planning.

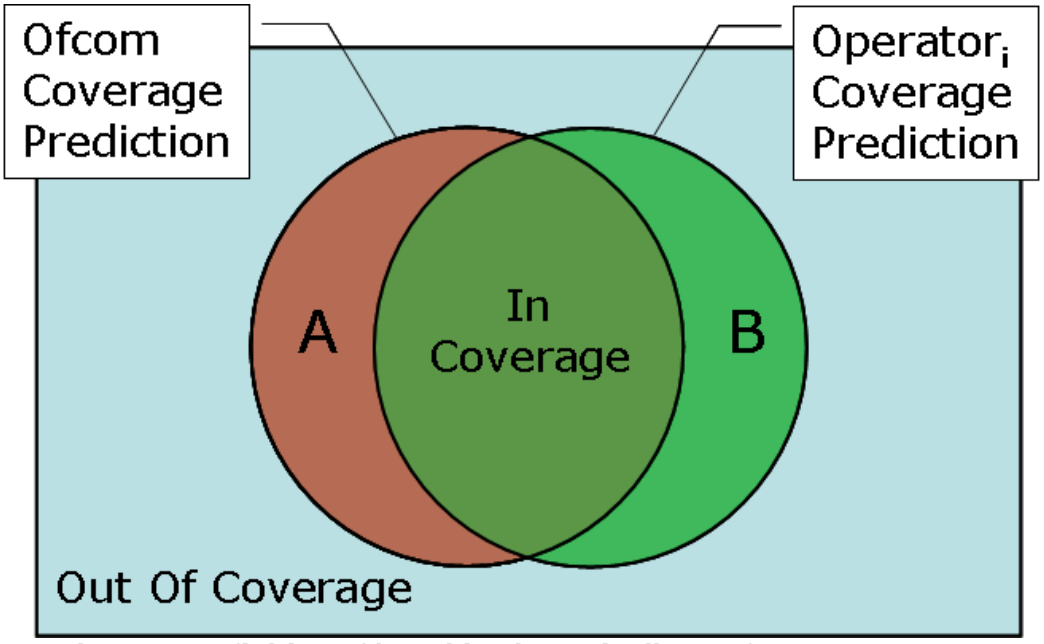

Figure 1: Definition of 'Combined Marginal' Area for one operator

Population weighted centroids for all 5 operators' aggregated 'combined marginal areas' within the overall benchmarking area are shown in Figure 2. Although this appears to include all of the benchmarking area, closer inspection of the actual operator data (contained in the appendices to this report) reveals that:

- Combined marginal areas for three of the five operators cluster geographically, and more than 50% of the combined areas for each of these operators can be driven within the 13 drive routes chosen (see detail of the 13 routes later in this section)
- The combined marginal areas for one operator cover different areas, due to the nature of the coverage of that network
- The combined marginal areas for the fifth operator are distributed almost uniformly over the benchmarking area, due to the large difference between Ofcom and operator predictions.

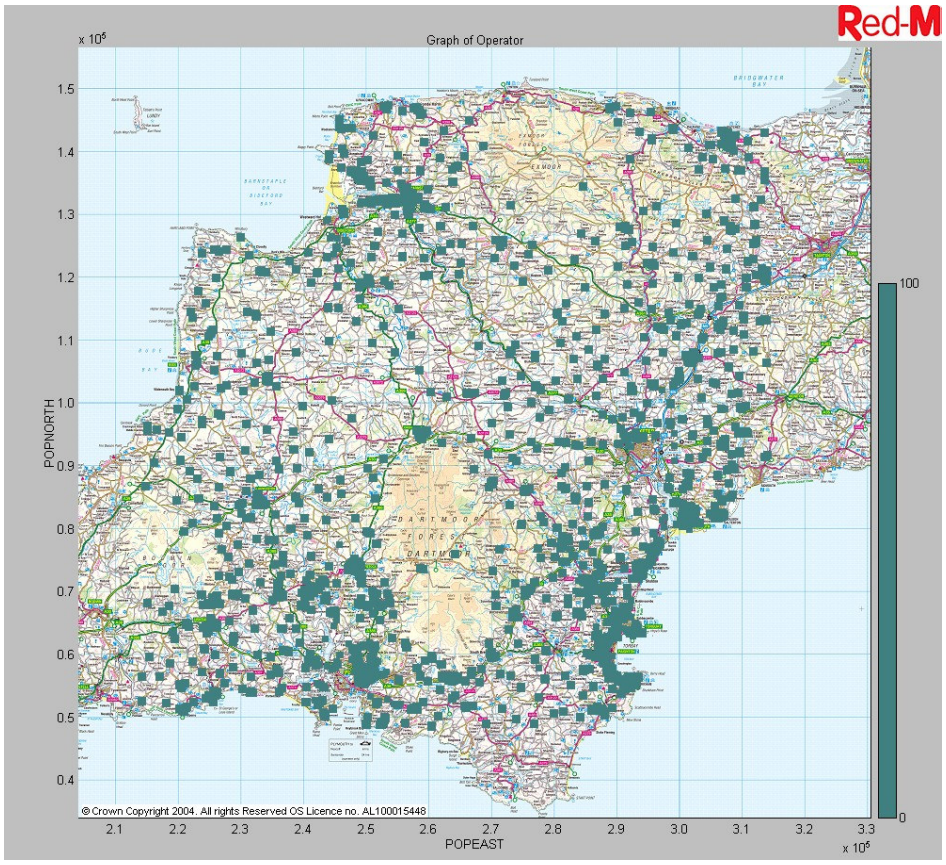

Figure 2: Population Weighted Centroids for Combined Marginal Areas (All Operators Combined)

Thirteen drive routes were chosen, in the areas shown in Figure 3. The drive routes were concentrated in the following areas:

i. Plymouth
ii. Tavistock
iii. Ivybridge
iv. Brixham
v. Paignton
vi. Torquay
vii. Newton Abbot
viii. Bovey Tracey
ix. Dawlish & Teignmouth
x. Exmouth & Budleigh Salterton
xi. Exeter (North)
xii. Braunton
xiii. Wellington (West)

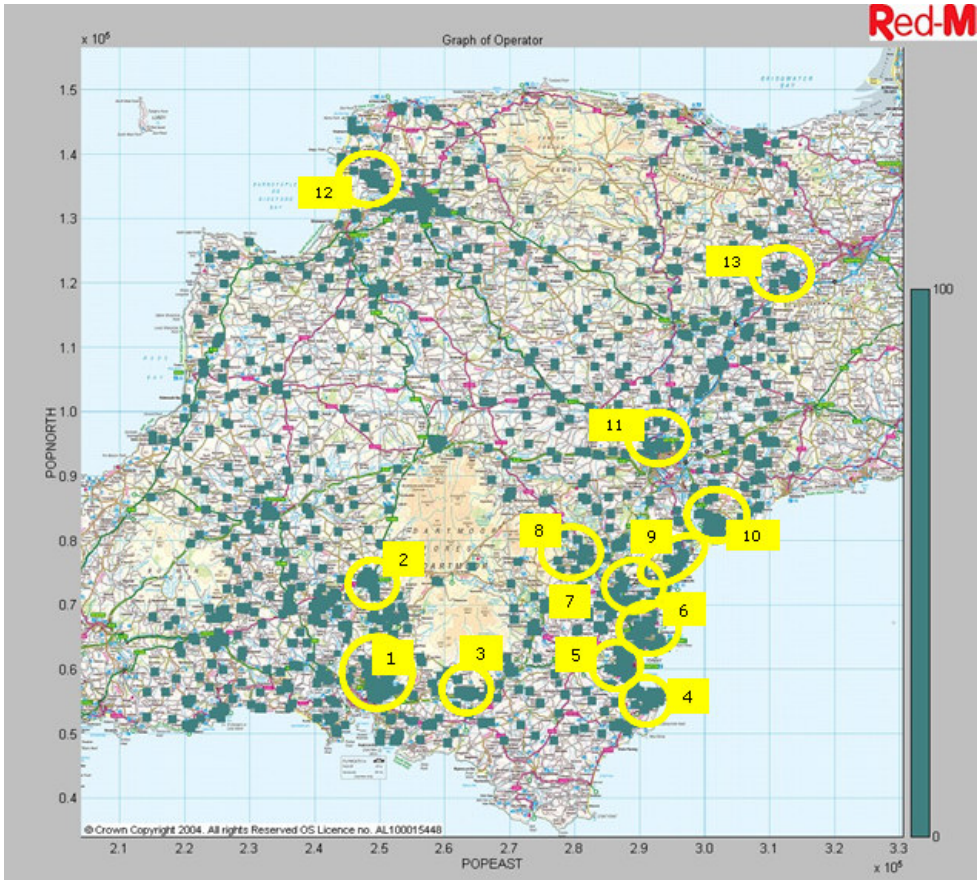

Figure 3: Thirteen Drive Routes were selected for the benchmarking

For each of these selected areas routes were driven according to the density required, which was established during the definition of the measurement methodology.

An example drive route, showing the route taken plotted from actual measurement data, is shown in Figure 4

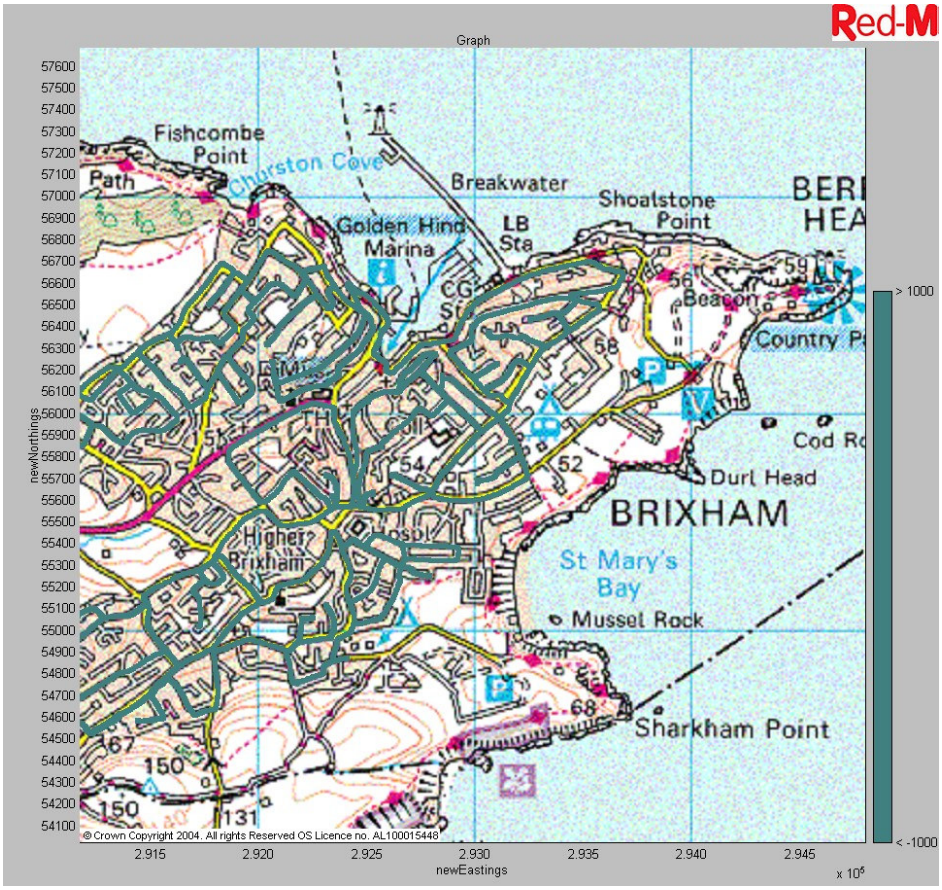

Figure 4 Extract from Brixham Drive Route (Actual Data)

4. Data Capture

The measurement configuration used during data collection was that specified in the measurement methodology and is shown in Figure 5. The receivers were set to record the UARFCNs known to be used by the operators in that area.

Measurements were made for all five operators on all routes, irrespective of whether the areas driven were in good coverage, in marginal coverage or were out of coverage for that operator.

The scanning receivers used recorded measurements only when the following conditions were met:

- CPICH Ec > ~-120dBm
- CPICH Ec / Io > ~-18dB

In addition, for reasons of accuracy related to dynamic range in the receivers, the measurement methodology specified that measurements should only be recorded when the strongest Ec measured was lower than −55dBm. In practice it was found that no measurements needed to be discarded on this ground.

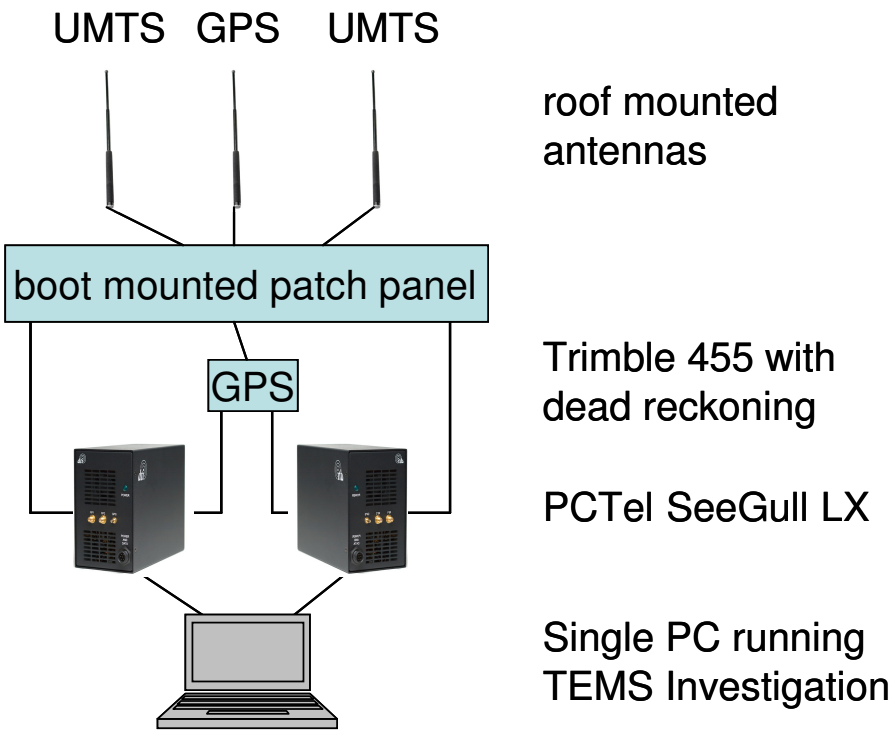

Figure 5: Measurement Configuration

5. Results

5.1 Data Pre-Processing and Mapping to Prediction Grid

The scanning receivers were set to record the top 15 CPICH scrambling codes on each UARFCN. In practice, and as expected, there were rarely more than 4 codes detected at any one time.

Data pre-processing steps were executed in the following order:

- Measurements were corrected for the antenna gains/feeder losses determined during equipment set-up
- Measurements of Ec for the individual codes were separated
- For the measurements on each code, the effects of fast fading were removed using a 'sliding window' averaging technique
- The best server was identified, if several scrambling codes were detected
- The mean of the measurements on the best server were mapped onto the 100m by 100m prediction grid.

Figure 6 shows an example of the resulting data[4] mapped to the prediction grid for the extract of the Brixham drive route shown in Figure 4. The blue crosses superimposed on the measurement grid represent the population weighted centroids. Although measurements have been deliberately made

[4] The signal strength data in Figure 6 is for illustration purposes only

close to population, there are still population weighted centroids which are in pixels that do not have a measurement result, despite being surrounded by measurements made in the immediate vicinity.

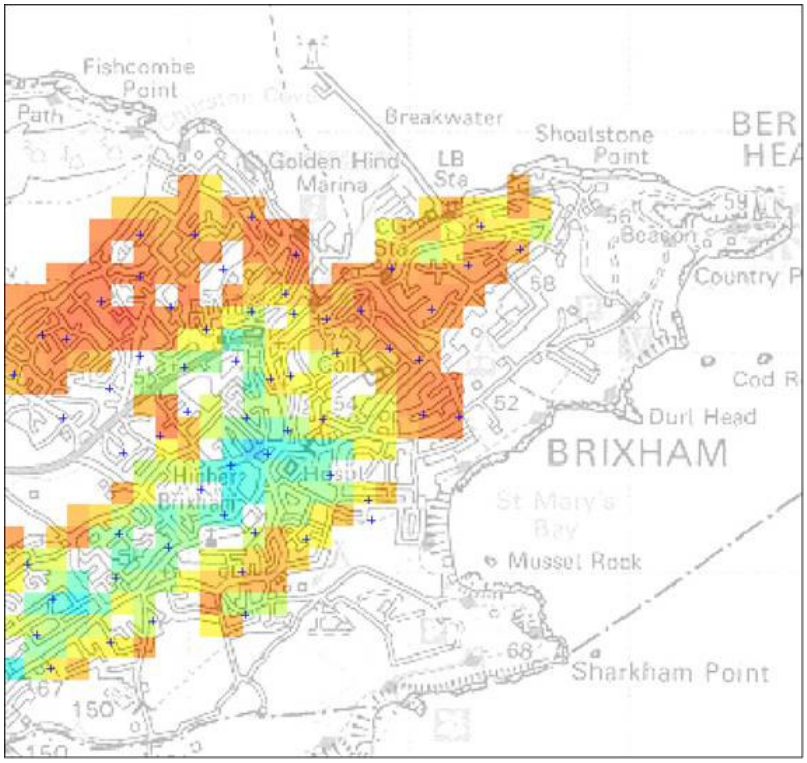

Figure 6: Measurement Points Mapped to 100m Prediction Grid

5.2 Comparison of Measurements to Predictions

The full detail of these comparisons is given in the Appendices. The summary comparison between measurements and Ofcom's P1546 predictions is shown in Table 1 and Table 2.

Table 1: Comparison of Measurements to P1546-2 Predictions[5]

	Op1	Op2	Op3	Op4	Op5	Overall Mean
MEAN ERROR						
ALL Routes	**-12.8**	**-7.4**	**-7.1**	**-7.5**	**-8.2**	**-8.61**
STDEV ERROR						
ALL Routes	**12.5**	**11.3**	**11.3**	**12.6**	**12.8**	
NSAMPLES						Total Sample Size
ALL Routes	**6857**	**6702**	**6318**	**7456**	**7354**	**34687**

[5] A negative 'Mean Error' indicates that the predicted signal strength is lower than the measured signal strength

Table 2: Comparison of Measurements to P1546-3 Predictions

	Op1	Op2	Op3	Op4	Op5	Overall Mean
MEAN ERROR (dB)						
ALL Routes	**-12.3**	**-6.9**	**-6.8**	**-7.0**	**-6.9**	**-7.99**
STDEV ERROR						
ALL Routes	**12.3**	**10.9**	**11.1**	**12.5**	**11.5**	
NSAMPLES						Total Sample Size
ALL Routes	**6857**	**6702**	**6318**	**7456**	**7354**	**34687**

In summary, the conclusion is that

- All P1546 predictions are under predicting the measured value, but P1546-3 outperforms P1546-2 by 0.6dB on average
- The difference is very consistent across four of the five operators, but one operator is an outlier[6].
- Comparisons with operator model predictions where available[7] has shown that operator model predictions are better than P1546-2 or P1546-3, with one operator achieving less than 1dB mean offset.

5.3 Hit Rate Analysis

A 'Hit Rate' Analysis was done on the measurement data, producing curves similar to the generic curve shown in Figure 7. This 'Hit Rate' can be used to assess the performance of the Ofcom and operator models in predicting in the covered population at the -110dBm threshold.

In summary, the conclusion (from the real data in the Appendices) is that

- The hit rate of P1546 is relatively poor
- This is to be expected because of the magnitude of the mean errors identified in section 5.2.
- The hit rate of the P1546 model can be improved by applying a correction factor corresponding to the mean error from measurements of ~8dB.

[6] A reason for this phenomenon is given in *Appendix F* relating to the proportion of measured pixels in combined marginal areas.
[7] Ofcom did not supply predictions for all operators, the performance of those that were supplied are analysed in the relevant Appendix to this report

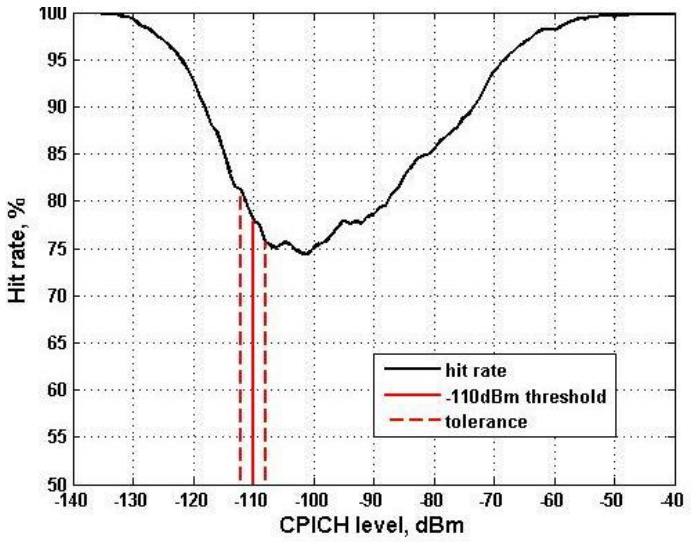

Figure 7: Generic Hit Rate Curve

5.4 Data interpolation

Interpolation was performed on the measurement data shown in Figure 6. The result is shown in Figure 8. Figure 8 shows 'measurement results' for all population centroids in the vicinity of measurements, where the interpolation technique indicates a likely variance of ±3dB from the actual measurement result.

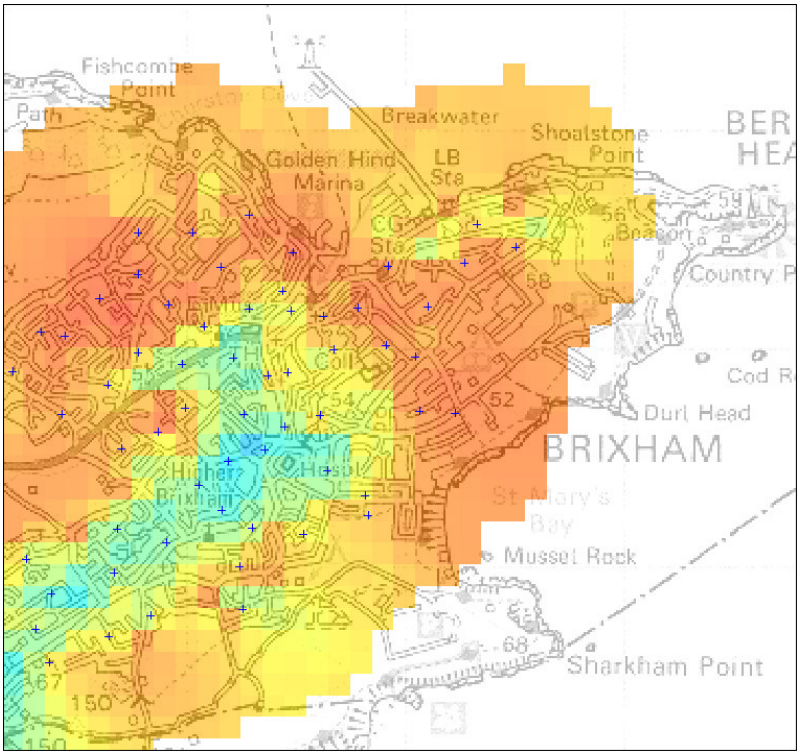

Figure 8: Interpolated Data Added to Measurement Points and Mapped to the Prediction Grid

The interpolated results have been used to give a measurement assessment of population coverage in the combined marginal areas that were measured. The uncertainty in the measured and measured/interpolated data is lower than the uncertainty in the predictions and this reduces the overall uncertainty in the assessment of population coverage.

The interpolated results were used to confirm that confining population coverage estimates to population centroids within 50m or so of a driven road does not have a significant effect on the population coverage statistics. That this is not the case was confirmed by comparing the hit rate curves based on data points including the interpolated data with the hit rate curves without this data. The use of drive tests confined to roads did not significantly alter the hit-rate distribution curves in the data measured.

Overall population coverage estimates based on measurements are given in the Appendices.

5.5 Population Coverage Assessment

Three population coverage measures were compared. They are:

- P1546-2 corrected by 8dB, which is the mean offset observed during measurements
- The population coverage predicted by each operator
- The hit rate analysis based on coverage measurements.

The hit rate analysis confirmed that 'P1546-2 + 8dB' gives a good estimation of overall population coverage. The population coverage estimate obtained as a result closely matched the population coverage predictions of most operators, as shown in Table 3.

Table 3: Population Prediction using 'P1546-2 + 8dB' compared to Operator Predictions[8]

	Op1	Op2	Op3	Op4[9]	Op5
Difference between operator prediction and 'P1546-2 + 8dB'(%)	**1%**	**-4%**	**-1%**	**3%**	**0%**

[8] Figures are expressed as a percentage of total population in the benchmarking area. A positive number means that the operator prediction of population coverage is greater than the estimate using 'P1546-2 + 8dB'

[9] Population coverage figure was revised and provided by this operator during the course of the project (see discussion in the corresponding Appendix).

6. Conclusions

The conclusions of this exercise are broadly that:

- There is a large discrepancy between the P1546 predictions of CPICH strength and the measured values collected during the surveys.
- P1546-3 performs marginally better than version P14546-2, by ~0.6dB on average.
- The mean difference between predictions and measurements is very consistent across four of the five operators.
- Comparisons with available operator model predictions have shown that operator model predictions are, in general, significantly better than P1546, with one operator achieving close to zero[10] mean offset.
- The hit rate of the P1546 model is relatively poor. This is to be expected because of the magnitude of the mean errors identified in section 5.2 of this report.
- The hit rate of the P1546 model can be improved significantly by applying a correction factor corresponding to the mean error from measurements of ~8dB.
- This corrected measure can be used for population coverage estimates with a reasonable degree of accuracy, and the resulting measure compares very closely with the coverage estimates of most of the operators.

Detailed conclusions, operator by operator containing actual population coverage results are given in the Appendices to this report. For reasons of confidentiality, these results are not given in the main report.

[10] Within the bounds of measurement error