Case Study: Estimated changes to the number of 2G cell sites or sectors as a consequence of reduced spectrum holding at 900MHz – Part 2

Prepared for

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Version History		
Version	**Date**	**Comments**
0.1 draft	31 July 2008	Initial Version
1.0	6 August 2008	Final version

Executive Summary

Red-M conducted a 'simulated' design exercise for a single area of the UK, which was chosen to be representative of the UK as a whole, to help Ofcom build a picture of the number of additional GSM900 Macro cell sites required as the amount of spectrum available is reduced. The area chosen by Ofcom was:

- A 25km by 25km square of the south-west of England including Bristol, Bath and rural areas, containing at least 90 base station sites, with a mix of clutter representative of the UK as a whole.

The simulated design exercise was repeated five times with reducing amounts of spectrum. Starting with a baseline, spectrum was removed in 2.5MHz blocks. Blocks of 2.5MHz, 5MHz, 7.5MHz and 10MHz of spectrum were removed and the network was re-designed to meet the defined grade of service and coverage quality objectives. These objectives did not vary as the amount of spectrum was reduced.

The results show that removal of 2.5MHz of spectrum should be possible in most cases without an increase in the number of base station sites, although it may require some re-balancing of the network. Removal of 5MHz of spectrum would require a small number of additional sites to meet the traffic capacity. After that, removal of 7.5MHz and 10MHz of spectrum require increasingly-large numbers of new sites, and a completely new frequency plan. The results are more sensitive to traffic density values than to power values.

The results of the exercise are summarised in the table below.

Table 1: Overall site counts for 900MHz re-planning simulations

Scenario	Site count summary		
	Sites	Transceivers	Sites %
Bristol baseline	91	577	100 %
Bristol – remove 2.5 MHz	91	578	100 %
Bristol – remove 5.0 MHz	93	578	102 %
Bristol – remove 7.5 MHz	104	610	114 %
Bristol – remove 10.0 MHz	131	682	144 %

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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. All drawings shown in this report are indicative and are not necessarily to scale. They should not be used as the basis for system installation. Scaled CAD drawings can be requested where installation is required.

1. Introduction

Ofcom is currently considering how to implement liberalisation of 2G spectrum in the UK. Ofcom published a consultation in September 2007 which included a proposal that the existing holders of 900MHz spectrum (O2 and Vodafone) should be required to clear and release some of that spectrum so that it could be re-allocated to other parties. Ofcom's proposal was based upon their initial assessment of the costs that O2 and Vodafone would be likely to incur in clearing that spectrum.

Ofcom is currently considering the responses to that consultation and refining its estimates of the costs of clearing spectrum.

In updating their analysis Ofcom believes that a simulation exercise may be beneficial to ascertain the sensitivity of some of the costs associated with reducing the amount of 900 MHz spectrum O2 and Vodafone hold and use for their 2G networks. The outcome of the exercise would provide Ofcom with information about the number of additional sites that may be required to achieve the same capacity and coverage (i.e. maintain a broadly similar level of network quality) in sample areas of a 2G network when some amount of spectrum is cleared. Part 1 of this study simulated two areas: London (urban) and Burton (rural). This work, Part 2, simulates a 25km x 25km square around Bristol, which was chosen to give a clutter distribution as representative as possible of the whole of the UK.

2. Red-M's Approach to the Case Study

2.1 Outline

Red-M conducted a 'simulated' design exercise for a single area of the country to help Ofcom build a picture of the number of additional GSM900 Macro cell sites that may be required as a function of the amount of cleared spectrum. The area chosen was a 25km by 25km square including Bristol, Bath and countryside in the south-west of England.

The simulated design exercise was repeated five times with reducing amounts of spectrum. Starting with a baseline with 17.2MHz, spectrum was removed in 2.5MHz blocks. Blocks of 2.5MHz, 5MHz, 7.5MHz and 10MHz of spectrum were removed and the network was re-designed to meet defined grade of service and coverage quality objectives. The approach taken at each stage was to modify the baseline network, simulating a 'least cost minimum disruption' scenario where sites in the baseline network continue to exist in the reduced spectrum scenario. The sites are not moved, but some tuning of antenna down-tilt was used to control interference.

In order to make the process as realistic as possible, care was taken to identify a baseline scenario and then benchmarking the baseline against extracts of data supplied by Ofcom. Benchmark data included:

- Range of site heights.
- Number of Sites.
- Per Sector Transceiver Counts, as shown in Figure 1.
- UK clutter distribution.

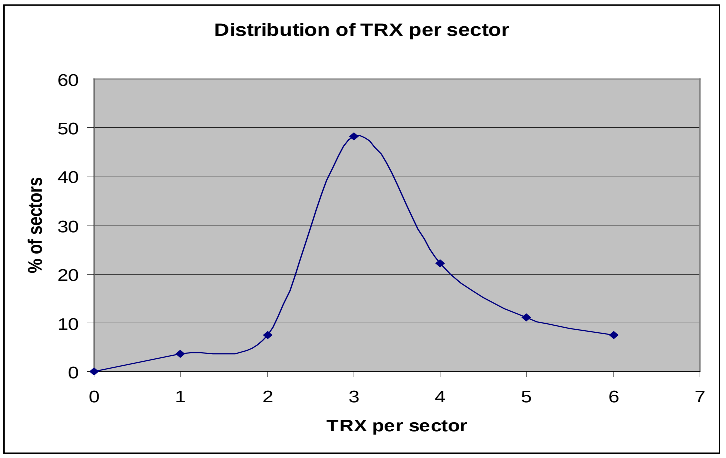

Figure 1: Example Benchmark Data of TRX counts (smoothed)

Ofcom have provided a set of clutter distribution data for the whole of the UK, and the geographic square was specifically chosen to achieve similar clutter distribution, as shown in Table 1. The "UK (80% population)" column refers to the clutter distribution of those areas in which 80% of the UK population live, and so the remote rural areas are excluded, leading to a higher proportion of urban and suburban clutter types. The "UK (geographic)" column considers the whole of the UK and lists each clutter type as a proportion of the total geographic area. The final column lists the proportion of each clutter type in the chosen area, and shows that it is reasonably representative of the UK as a whole.

Table 2: Clutter values

Clutter code	Clutter Category	UK (80 % population)	UK (geographic)	Chosen area near Bristol
0	Rural	65 %	83 %	73 %
1	Suburban	21 %	5.7 %	21 %
2	Urban	1.4 %	0.3 %	0.8 %
6	Water	1.5 %	1.4 %	0.2 %
8	Woodland	8.1 %	9.0 %	5.0 %

Of paramount importance in estimating the changes to the number of cell sites is the traffic model. 2G networks do not exhibit the 'cell breathing' phenomenon of 3G networks, and therefore cells are either:

- Coverage-Limited – a reduction in spectrum results in no change to the number of cells required, or
- Capacity-Limited – a reduction in spectrum results in an increase in the number of cells required

In practice, the Bristol baseline scenario was designed with capacity-limited sites in the city centres of Bath and Bristol, and coverage-limited sites out in the open countryside.

In order to limit the impact of 'edge effects' on the simulation results, simulations were run on a larger area (the 'computation zone' being 32km x 32km), than that for which the results are reported (the 'focus zone' of 25km x 25km).

2.2 Details of the Approach Taken

Red-M adopted the following process:

- A benchmark 2G network was designed using the 'ICS Telecom' planning tool. This network was designed to approximate a 'real' UK 2G network, with coverage probability as specified in Ofcom's technical parameters.

- The clutter database used was the "British Isles 50m Database", re-sampled to 200m.

- In order to calculate the coverage, Red-M defined a representative link budget and planning level (see section 3 below). Red-M used the COST231-Hata propagation model, enhanced with the use of terrain and clutter data and a diffraction model[1].

- A traffic model was defined (see section 4 below) by associating a traffic density (in Erl/km^2) with each type of clutter available in the clutter database.

- Results were recorded for the baseline networks. The results included coverage quality (at the respective planning levels), grade of service, site counts and transceiver counts. Graphical representations of coverage, grade of service and best server interference were produced using the planning tool.

- Once the baseline network was simulated, a paired uplink-downlink block of 2.5 MHz of spectrum were cleared of GSM carriers. The

[1] 'Deygout 1994' method with coarse integration.

network was then re-planned with additional sites as necessary and optimised to recover approximately the same capacity and coverage that it had before the spectrum was cleared. Within the constraints of the technical parameters given, re-planning/optimisation resulted in new sites rolled out, existing sites split, and the implementation of a new frequency plan[2]. Existing sites from the baseline plan were left in place, although some re-tuning of antenna down-tilt was done to help reduce interference. In a small number of cases, antennas mounted more than 20 metres above ground level were reduced in height to limit the signal spread, thus allowing better frequency re-use. Further tuning would improve the network quality, but in the interest of time, this activity was kept relatively short.

- At the end of the optimisation activity the minimum number of additional sites and sectors to provide the same coverage and capacity as the baseline was recorded. Coverage quality, grade of service, site & transceiver counts and graphical representations were recorded for comparison with the baseline network.

- A summary table was produced for the number of additional macro base sites needed to reproduce the baseline capacity/coverage as a function of the reduced amount of spectrum available.

[2] ICS Telecom's automatic frequency planning facility was used with pre-defined channel groups.

3. Propagation Modelling

3.1 Propagation model

Ofcom requested that the planning exercise used a COST231 derived propagation model. The formulation of the model available in ICS telecom is shown in equation (1):

$$Pathloss = k_1 + k_2 \times \log(d) + k_3 \times h_{mobile} + k_4 \times \log(h_{mobile}) + k_5 \times \log(h_{eff}) + k_6 \times \log(h_{eff}) \times \log(d) + k_7 \times (diffraction\_loss) + clutter\_loss \quad \ldots\ldots\ldots(1)$$

Where

- d is the distance between transmitter and receiver in km
- the values k_1 to k_7 available from a previous exercise are shown in Table 3.
- h_{mobile} and h_{eff} are the height of the mobile and effective height of the base-station in m respectively
- *diffraction_loss* is a loss term calculated using an approximation to the universal theory of diffraction using a terrain height database
- *clutter_loss* terms (available from a previous exercise) are shown in Table 4.

Table 3: Values for k_1 to k_7

K1	135.5
K2	40
K3	-2.55
K4	0
K5	-13.82
K6	-6.55
K7	0.60

Table 4: Table of Clutter Loss Values

ICS Telecom Clutter code	Clutter Category	*Clutter Loss (dB)*
0	Rural	-5.5
1	Suburban	-2
2	Urban	0
6	Water	-3
8	Woods / forest	3

3.2 Planning Levels

The following GSM Planning levels were chosen to take into account the technical parameters specified by Ofcom and recorded in Appendix A.

Table 5 - Summary of signal strength planning levels

Clutter Category	GSM 900MHz Planning level (dBm)
urban	-75
suburban / rural	-84

The associated link budgets are given in Appendix B.

4. Traffic Modelling

4.1 Modelling Process

The approach adopted for traffic modelling was to associate a traffic density (in Erl/km^2) with each type of clutter. Five main clutter types were used, corresponding to the clutter types available in the BI-50m database. They (with colours in the clutter map shown in brackets) – Rural (white), Suburban (dark blue), Urban (light blue), Water (green) and Woodland (orange), see Figure 4 .

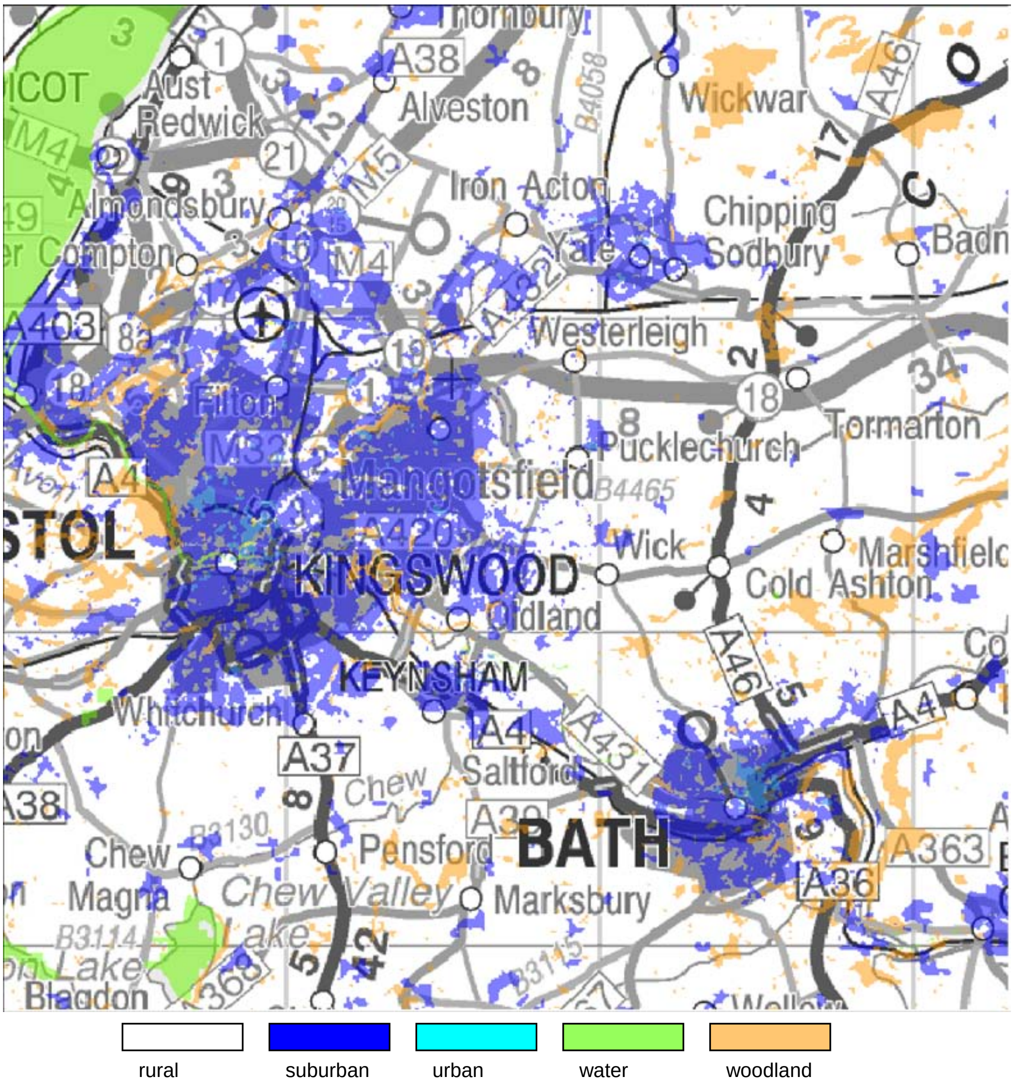

Figure 2: Bristol Clutter Map using BI-50m clutter data, (resampled to 200m)

4.2 Traffic Model

Figure 4 shows the clutter map for the Bristol focus zone. Table 6 provides statistics of the area by clutter type and gives the derived traffic density results. Population data from the UK Central Statistics Office was used to extract population densities for each postcode in the Bristol area, and the underlying geographic area was calculated by overlaying the clutter data using MapInfo. This resulted in a population per square kilometre. Specifications given by Ofcom for subscriber penetration (GSM900) and offered traffic during busy hour (20 milli-Erlangs per subscriber), were used to relate population density to traffic capacity in Erlangs per square for each clutter type. These traffic values were used in all simulations.

Table 6: Bristol Area by Clutter Type and Derived Traffic Density

Clutter Code	Clutter Type	Area, km^2	Area %	Population density (people per km^2)	Derived Erl/km^2 (900MHz)
0	Rural	458	73.2%	131	0.5
1	Suburban	130.5	20.9%	3090	11.0
2	Urban	4.9	0.8%	9600	36.0
6	Water	1.1	0.2%	-	0.003
8	Woodland	31	5.0%	-	0.05

5. Results for Bristol baseline scenario

The following figures give coverage quality, grade of service and interference plots for the Bristol baseline scenario, to meet Ofcom coverage and Grade of Service (GoS) specifications as closely as possible.

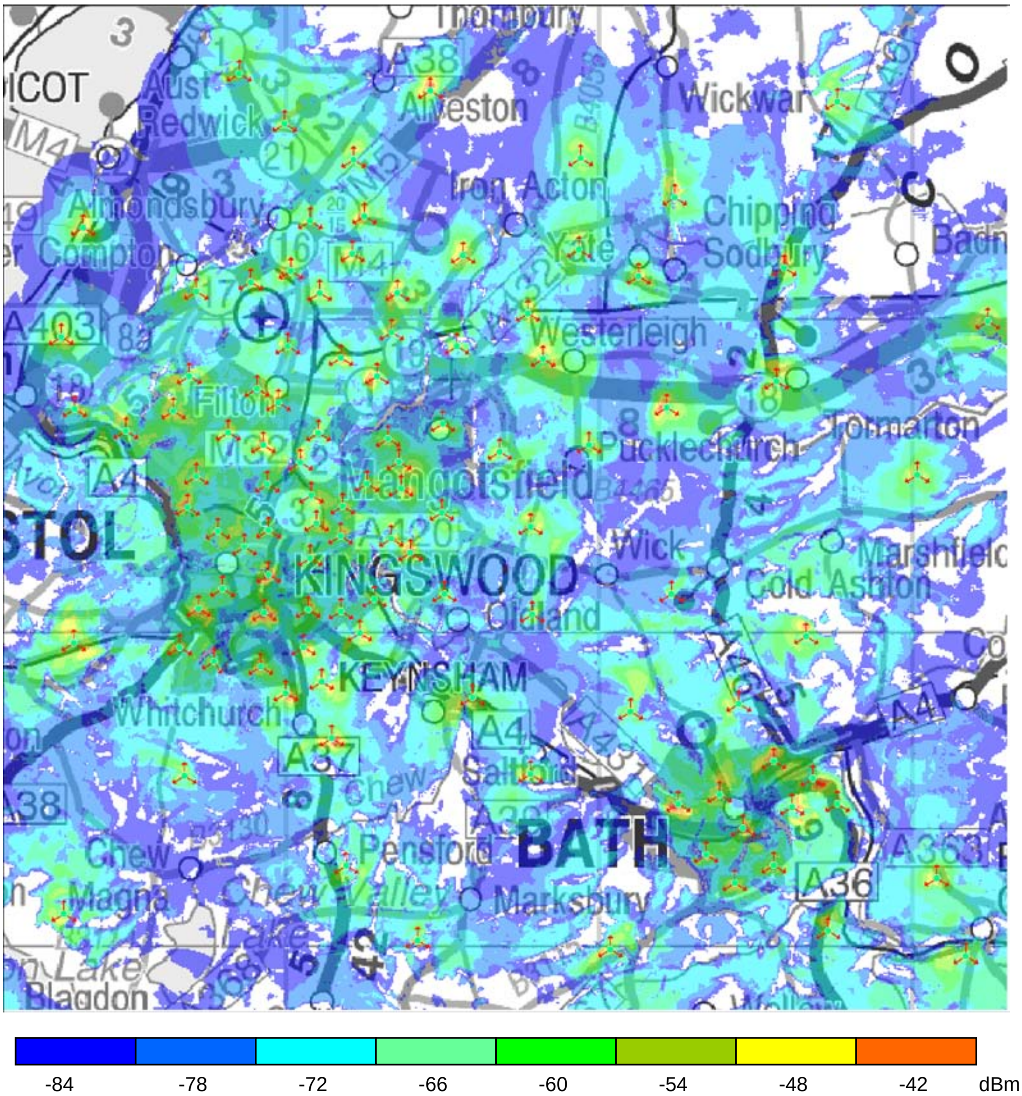

Figure 3: Base-Line Coverage for Bristol (Rural Planning Level – Dark Blue)

Table 7: Baseline Coverage (Bristol)

Clutter Code	Bristol Clutter Types	Covered Area, km^2	% Coverage
0	Rural	414	90.3
1	Suburban	125	95.7
2	Urban (at urban planning level)	4.2	85.0
8	Woodland	17.8	57.4

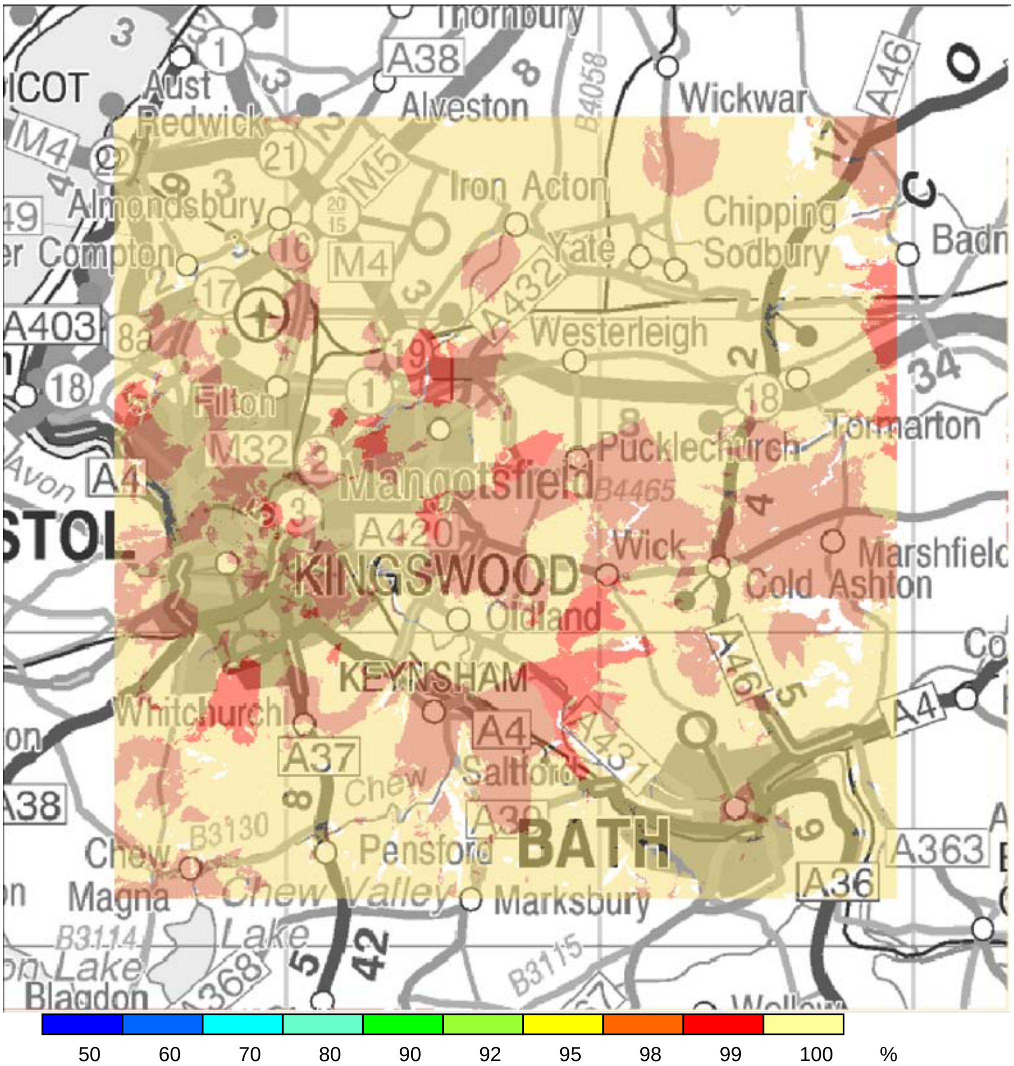

Figure 4: Baseline Grade of Service for Bristol focus zone, all exceeding 98% GoS.

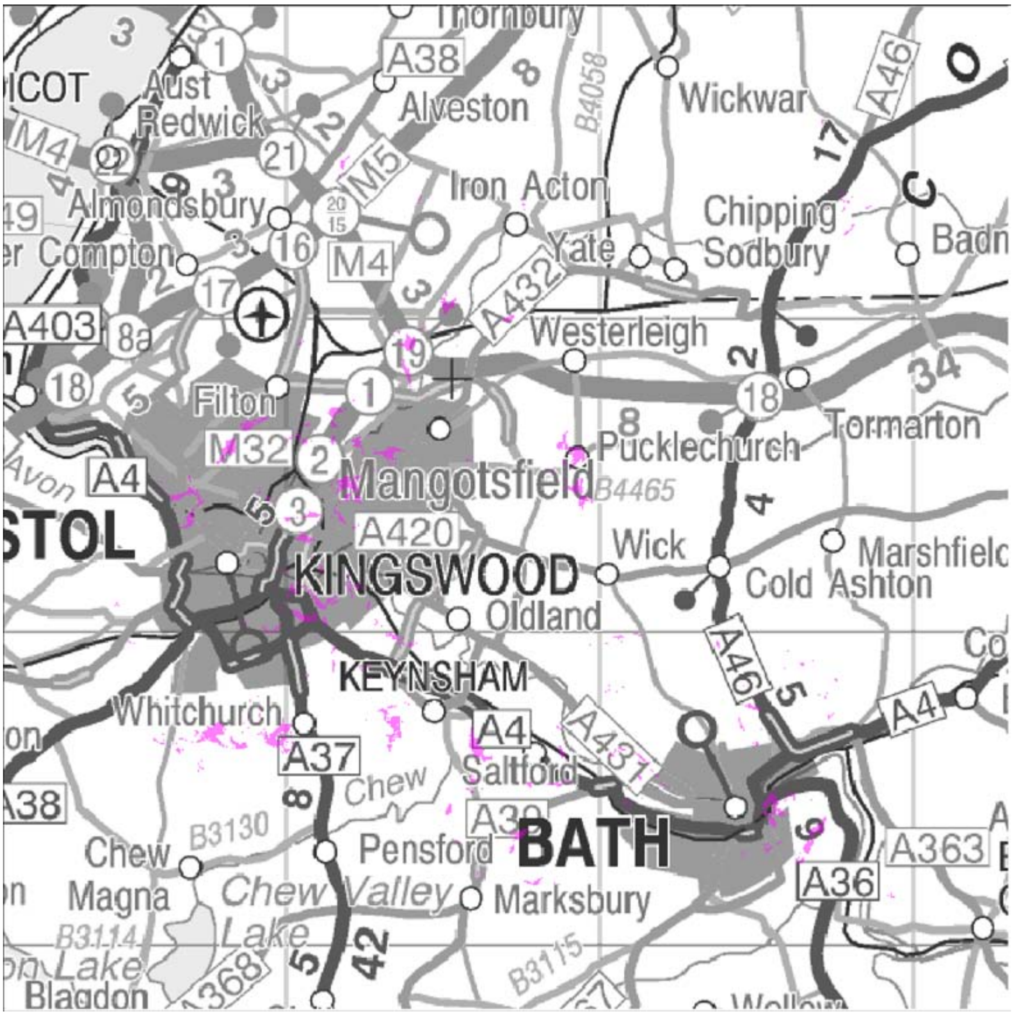

Figure 5: Baseline Interference for Bristol (Pink = Best Server Interference) Interference to <1% of the area

6. Simulation Results

6.1 Re-planning with reduced spectrum

The graphs and plots for the plans with reduced spectrum are provided in Appendix D. The results in Table 9 show that clearing of 2.5MHz of spectrum should be possible without increasing the number of sites. Some fine-tuning of antenna down-tilts are needed due to a tighter frequency re-use pattern, but in general there are sufficient channels available that this is fairly straight-forward. Any future changes to the network (e.g. traffic capacity increase due to new buildings) at this stage would still be fairly easy with some channels remaining free. Clearing of 5MHz requires a small number of extra sites in dense urban areas to help with capacity where frequency re-use becomes more difficult, and more channels are now in use due to a maximum of 4 transceivers (TRX's) per sector with a 16-group frequency plan. (It would be possible to use 5 TRX's per sector for clearing 5MHz, but this would give only 12 groups for the frequency plan, resulting in increased interference and an increased number of sites, as for the clearing of 7.5 and 10MHz). Due to the smaller number of frequency groups, clearing of 7.5MHz and 10MHz of spectrum requires a significant number of new sites, and requires efficient use to be made of every available frequency (many sectors have all channels taken), and so any future changes to the network would be more difficult to manage due to very limited options available for re-planning.

Table 8: Frequency planning details for each scenario

Scenario	Frequency planning summary		
	No. of carriers	No. of frequency groups	Max. no. of TRX's per sector
Bristol baseline	86	18	5
Bristol – remove 2.5 MHz	73	15	5
Bristol – remove 5.0 MHz	61	16	4
Bristol – remove 7.5 MHz	48	12	4
Bristol – remove 10.0 MHz	36	12	3

Table 9: Results of Frequency Clearing Simulation in the Focus Zone

Scenario	Site count summary		
	Sites	Transceivers	Sites %
Bristol baseline	91	577	100 %
Bristol – remove 2.5 MHz	91	578	100 %
Bristol – remove 5.0 MHz	93	578	102 %
Bristol – remove 7.5 MHz	104	610	114 %
Bristol – remove 10.0 MHz	131	682	144 %

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6.2 Variation analysis

In order to test the effect of varying some of the input parameters to the study, two main parameters were analysed in detail:

1. Received power level
2. Traffic load

6.2.1 Effect of varying received power level

The received power level may differ from the planning levels used in this report due to variation in propagation model, receiver height, clutter variation, building penetration loss and receiver sensitivity. To test the effect of this change, coverage was computed as the received signal strength was altered in 1dB steps from the specified values of -84dBm for suburban /rural, and -75dBm for urban. Predicted coverage values are shown in Figure 6 for the Bristol baseline scenario (all spectrum). It is seen that a 6dB drop in received signal level (equivalent to a 6dB increase in planning level for the same received signal strength) will result in rural coverage dropping from 90% to 71%, and urban coverage dropping from 85% to 63%.

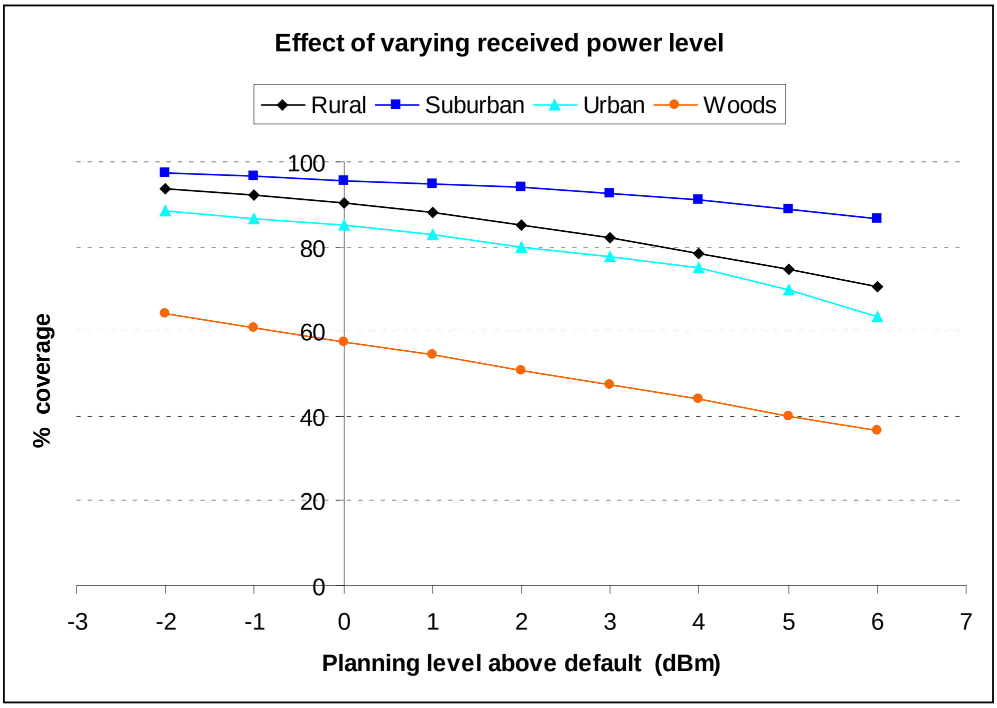

Figure 6: Effect of varying required planning level above default of -84dBm

In order to investigate the effect of a change in power on the network design, each scenario was briefly re-planned to reach the required coverage and GoS specifications, but with 3dB lower signal power. This resulted in the need for a small number of additional base station sites, see Table 10. Overall, only 5 or 6 extra sites were needed, and this was fairly consistent for all scenarios, simply to raise the coverage levels. The percentage of sites relative to the baseline for each scenario remains almost unchanged. It is therefore expected that variations in power level will not have a significant effect on the proportion of additional sites needed for spectrum clearing.

Table 10: Results of Re-planning with 3dB lower power

Scenario	Site count summary		
	Sites	Transceivers	Sites %
Bristol baseline	96	590	100 %
Bristol – remove 2.5 MHz	96	590	100 %
Bristol – remove 5.0 MHz	99	598	103 %
Bristol – remove 7.5 MHz	110	631	115 %
Bristol – remove 10.0 MHz	137	697	143 %

6.2.2 Effect of varying traffic load

The assumptions made about population densities, subscriber penetration, and busy-hour usage resulted in the values for traffic capacity in Erlangs per square kilometre for each clutter class. These assumptions have some inherent uncertainty and furthermore, towns and cities grow and users migrate over short and long time periods. Therefore it is necessary to consider the effect of variations in the traffic capacity. The traffic load in Erlangs/km^2 was varied from the default values up to increase in traffic for all clutter types, and the uncongested geographic area having at least 98% GoS was measured. It was found that at 30% extra traffic load, the uncongested suburban area drops from 99.3% to 90.7%, and the uncongested urban area drops from 99.9% to 85.9% (Figure 7).

In order to investigate the effect of a change in traffic load on the network design, each scenario was briefly re-planned to reach the required signal strength coverage and GoS specifications, but with 30% higher traffic load. This resulted in the need for an increasingly-large number of additional base station sites as shown by the results presented in Table 11.

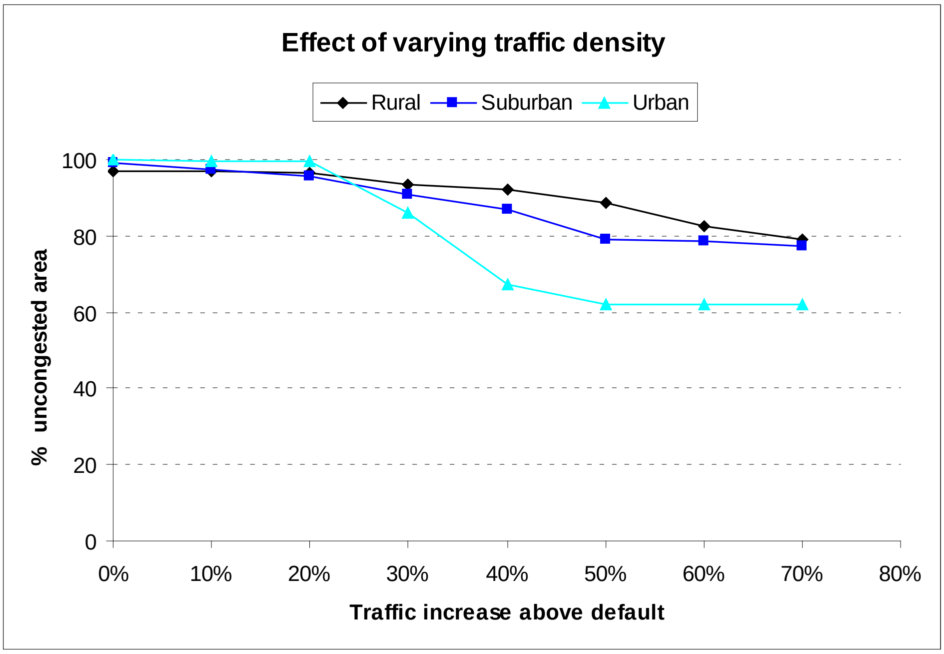

Figure 7: Effect of varying traffic load above default values

Table 11: Results of Re-planning with 30% higher traffic

Scenario	Site count summary		
	Sites	Transceivers	Sites %
Bristol baseline	97	681	100 %
Bristol – remove 2.5 MHz	97	681	100 %
Bristol – remove 5.0 MHz	98	693	101 %
Bristol – remove 7.5 MHz	118	754	122 %
Bristol – remove 10.0 MHz	148	841	153 %

Note that the "Bristol – remove 5.0 MHz" was re-planned assuming 12 frequency groups with a maximum of 5 TRX's per group for this analysis: if planned with 16 groups of maximum 4 TRX's per group, the site count would be higher. An increase in traffic may require a change in the number of frequency groups to achieve the most efficient network design within the constraints.

It is seen that urban areas are most strongly affected by the increase in and this is due to the much higher default traffic level of 36 Erlangs/km^2, compared with suburban traffic of only 11 Erlangs/km^2. As more and more frequencies are removed, so sensitivity to traffic load becomes greater.

Removal of more than 5MHz of spectrum results in a network that is substantially more sensitive to changes in traffic load.

7. Summary and Conclusions

A simulation exercise has been performed to estimate the impact of reduced spectrum on existing GSM900 networks on the assumption that the traffic handling capacity of the network needs to be maintained despite the reduced spectrum. This study focused on a square in the Bristol area, chosen to be as representative as possible of clutter types across the whole of the UK.

The results show that removal of 2.5MHz of spectrum should be possible in most cases without an increase in the number of base station sites, although it may require some re-balancing of the network. Removal of 5MHz of spectrum would require a small number of additional sites to meet the traffic capacity. After that, removal of 7.5MHz and 10MHz of spectrum require increasingly-large numbers of new sites, and a completely new frequency plan.

The simulation results are not very sensitive to reduced power (increased planning levels): a small number of additional sites is required to improve coverage, but the overall proportions of sites remain the same for all scenarios. However, the results are sensitive to changes in traffic load, and it is seen that if more than 5MHz of spectrum is removed, the number of additional sites needed to carry the increased traffic begins to increase, due to sectors becoming overloaded more quickly. As the available TRX channels are all taken in more and more sectors, so optimising channel allocation to avoid interference becomes more and more difficult.

8. References

[1] ETSI EN 300 910 V8.5.1 (2000-11) Digital cellular telecommunications system (Phase 2+) Radio transmission and reception (GSM 05.05 version 8.5.1 Release 1999)

[2] Digital Mobile Radio – Towards Future Generation Systems Cost 231 Final Report, Chapter 4.4 – Propagation Models for Macro-Cells, Thomas Kurner, E-Plus Mobilfunk GmbH, Germany

Appendix A Ofcom Technical Parameters

The Following technical parameters were supplied by Ofcom for Bristol:

- Only Macrocell sites need to be considered.
- All the available spectrum channels can be used for the simulations (17.2MHz for the baseline).
- All Cell sites use base band frequency hopping.
- Only voice capacity needs to be considered.
- Antennas are assumed to have variable electrical down-tilt.
- Maximum licensed transmit EIRP power 32dBW per carrier.
- The antenna bore-sight gain should be 16.0dBi at 900 MHz and the horizontal beam-width approximately 65°.
- GSM planning rules:
    1. Maintain a gap of 2 unused carriers (2 x 200kHz) between carriers on the same sector.
    2. Maintain a gap of 1 unused carrier (1 x 200kHz) between any used carriers on any sector on the same BTS site.
- The outdoor propagation model used to determine the coverage area from each site should be a COST231-Hata model .
- 90% coverage probability at the cell edge
- 2% blocking probability
- Spectrum is assumed to be contiguous.
- National Grid coordinates for the zone

Focus zone (25km x 25km)	x = 354500 – 379500
	y = 161500 – 186500
Computation zone (32km x 32km)	x = 351000 – 383000
	y = 158000 – 190000

Appendix B Planning Level Link Budgets

B.1 Urban Planning Level

Transmitter Parameters		**Downlink**	**Uplink**		
		BS	**MS**	**Units**	
Transmitter RF Peak Output Power	Ptx	20.0	2.0	W	max power (GSM 900 BTS Class 5 | GSM 05.05 Mobile Power Class 4)
as above in dBm	PdB	43.0	33.0	dBm	=10*log Ptx
Combiner + Cable + Connector Losses	Lcc	3.0	0.0	dB	Red-M Estimate
Tx Antenna Gain	Gtx	16.0	0.0	dBi	Red-M Estimate
Body Loss	BL		1.5	dB	1.5dB head (phone) 4.5dB waist (laptop) - ITU-R P.1238-3
Equivalent Isotropic Radiated Power	**EIRP**	**56.0**	**31.5**	**dBm**	**= Pctx + Gtx - BL**
Receiver Parameters		**MS**	**BS**	**Units**	
Receiver Sensitivity	Rx_c	-104.0	-108.0	dBm	2dB & 4dB better than GSM 5.05 reflects equipment development
Combiner + Cable + Connector Losses	Lcc	0.0	3.0	dB	Red-M Estimate
Rx Antenna Gain	Grx	0.0	16.0	dBi	Red-M Estimate
Diversity Gain	DG	0.0	3.0	dB	3dB = 2-branch MRC in AWGN environment
Body Loss	BL	1.5		dB	1.5dB head (phone) 5.5dB waist (laptop) - ITU-R P.1238-3
Required Isotropic Power	**Prx**	**-102.5**	**-124.0**	**dBm**	=Rx+Lcc-Grx-DG+BL
Maximum Allowed Path Loss	**PLmax**	**158.5**	**155.5**	**dB**	**=Tx EIRP - Prx**
Link Loss Calculation		**D/L**	**U/L**	**Units**	
Interference Degradation Margin	IDM	3.0	3.0	dB	Estimate ('Cellular Network Planning…' A.R. Mishra)
Fast Fade Margin	FFM	0.0	0.0	dB	Not Required for Rural Environment (TU50)
Building Penetration Loss	BPL	10.0	10.0	dB	Vehicle penetration loss
BPL Standard Deviation	SDbp	6.0	6.0	dB	Red-M Estimate
Location Variabilty	LV	7.0	7.0	dB	Antennas & Propagation..., S. Saunders
Total Variability	Vt	9.2	9.2	dB	=Sqrt(a^2+b^2….)
Coverage Target	Cov	90	90	%	Ofcom Technical Parameter
Shadowing Fade Margin	SFM	11.8	11.8	dB	=NORMINV(percentile/100,0,LV)
Total Planning Uncertainty	U	24.8	24.8	dB	=IDM + FFM + BPL + SFM
Allowable Propagation Loss		**133.7**	**130.7**	**dBm**	**=Plmax - U**
Planning Level	**Lev**	**-74.7**		**dBm**	**=EIRP - PL**

B.2 Rural Planning Level

Transmitter Parameters		**Downlink**	**Uplink**		Notes
		BS	**MS**	**Units**	
Transmitter RF Peak Output Power	Ptx	20.0	2.0	W	max power (GSM 900 BTS Class 5 | GSM 05.05 Mobile Power Class 4)
as above in dBm	PdB	43.0	33.0	dBm	=10*log Ptx
Combiner + Cable + Connector Losses	Lcc	3.0	0.0	dB	Red-M Estimate
Tx Antenna Gain	Gtx	16.0	0.0	dBi	Red-M Estimate
Body Loss	BL		1.5	dB	1.5dB head (phone) 4.5dB waist (laptop) - ITU-R P.1238-3
Equivalent Isotropic Radiated Power	**EIRP**	**56.0**	**31.5**	**dBm**	**= Pctx + Gtx - BL**
Receiver Parameters		**MS**	**BS**	**Units**	
Receiver Sensitivity	Rx_c	-104.0	-108.0	dBm	2dB & 4dB better than GSM 5.05 reflects equipment development
Combiner + Cable + Connector Losses	Lcc	0.0	3.0	dB	Red-M Estimate
Rx Antenna Gain	Grx	0.0	16.0	dBi	Red-M Estimate
Diversity Gain	DG	0.0	3.0	dB	3dB = 2-branch MRC in AWGN environment
Body Loss	BL	1.5		dB	1.5dB head (phone) 5.5dB waist (laptop) - ITU-R P.1238-3
Required Isotropic Power	**Prx**	**-102.5**	**-124.0**	**dBm**	=Rx+Lcc-Grx-DG+BL
Maximum Allowed Path Loss	**PLmax**	**158.5**	**155.5**	**dB**	**=Tx EIRP - Prx**
Link Loss Calculation		**D/L**	**U/L**	**Units**	
Interference Degradation Margin	IDM	3.0	3.0	dB	Estimate ('Cellular Network Planning…' A.R. Mishra)
Fast Fade Margin	FFM	0.0	0.0	dB	Not Required for Rural Environment (TU50)
Vehicle Penetration Loss	BPL	3.0	3.0	dB	Vehicle penetration loss
BPL Standard Deviation	SDbp	1.5	1.5	dB	Red-M Estimate
Location Variabilty	LV	7.0	7.0	dB	Antennas & Propagation..., S. Saunders
Total Variability	Vt	7.2	7.2	dB	=Sqrt(a^2+b^2….)
Coverage Target	Cov	90	90	%	Ofcom Technical Parameter
Shadowing Fade Margin	SFM	9.2	9.2	dB	=NORMINV(percentile/100,0,LV)
Total Planning Uncertainty	U	15.2	15.2	dB	=IDM + FFM + BPL + SFM
Allowable Propagation Loss		**143.3**	**140.3**	**dBm**	**=Plmax - U**
Planning Level	**Lev**	**-84.3**		**dBm**	**=EIRP - PL**

Appendix C Relevant Radio Planning Assumptions and their Models

C.1 Traffic Channels

A GSM system is characterised by carriers each with eight timeslots. For this planning exercise we have assumed that one timeslot on the BCCH channel is used for signalling and the remaining timeslots are used for speech. We have not assumed the use of half-rate or AMR modes which allow more than one call per timeslot.

The resulting number of available speech channels is shown in Table 12.

Table 12: Speech Channels

Number of TRXs	Number of Speech Channels
1	7
2	15
3	23
4	31
5	39
6	47
7	55
N	n*8-1

In practice a signalling dimensioning exercise is necessary to determine the number of signalling timeslots required, taking into account and balancing such events as RACH bursts, paging requests and location updates. In the current exercise this level of detail would not enhance the accuracy of the result which would remain dominated by the accuracy of the traffic models developed.

C.2 Reference Interference Limits

Reference interference limits have been taken from reference [1]. The are

- for cochannel interference : C/Ic = 9 dB
- for adjacent (200 kHz) interference : C/Ia1 = -9 dB
- for adjacent (400 kHz) interference : C/Ia2 = -41 dB
- for adjacent (600 kHz) interference : C/Ia3 = -49 dB

C.3 DTX and Power Control

C/I improvements from the use of DTX or Power control were not assumed on either the uplink or the downlink.

Appendix D Figures for Re-Planning Exercise

D.1 Bristol

D.1.1 Removal of 2.5MHz Spectrum

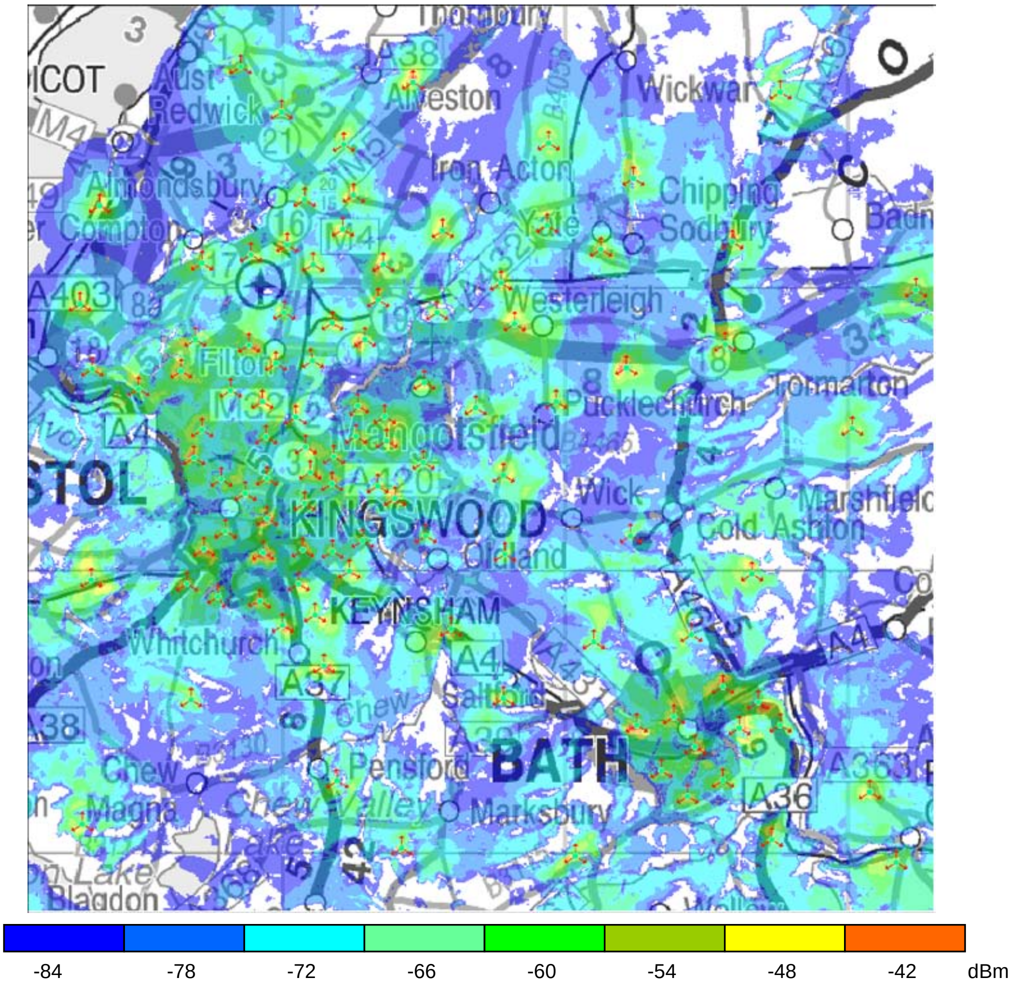

Figure 8: Coverage for Bristol with 2.5MHz Spectrum Removed

Table 13: Coverage (Bristol – remove 2.5MHz)

Clutter Code	Bristol Clutter Types	% Coverage
0	Rural	90
1	Suburban	95.7
2	Urban (at urban planning level)	85
8	Woodland	57

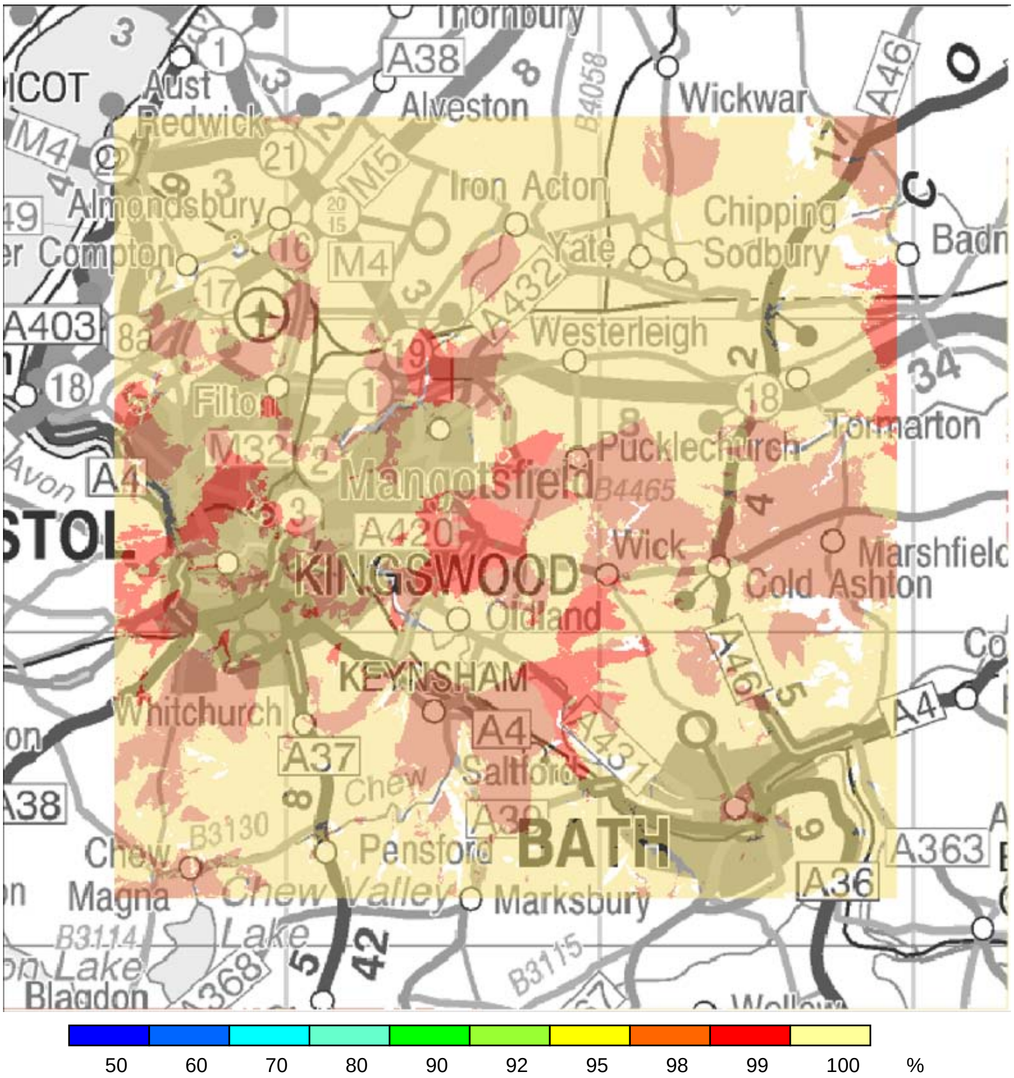

Figure 9: Grade of Service for Bristol with 2.5MHz Spectrum Removed

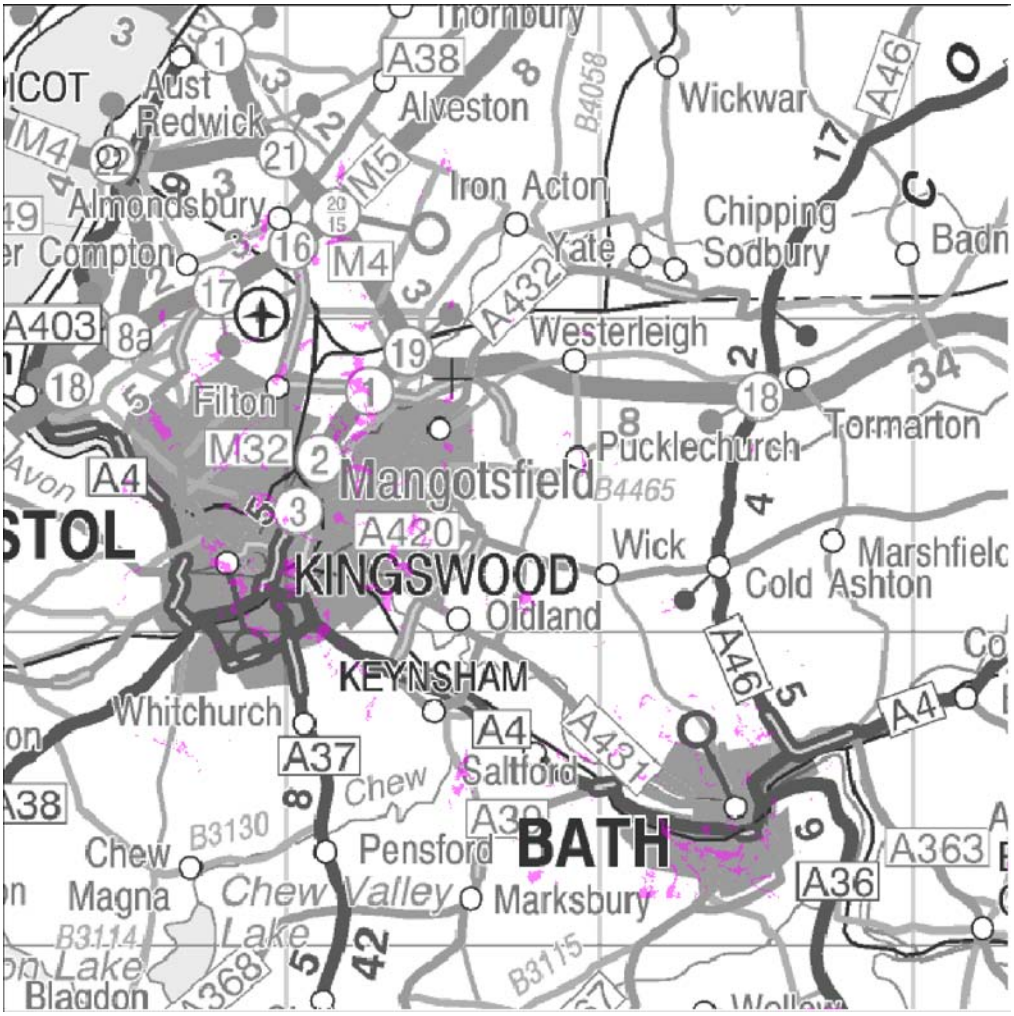

Figure 10: Interference for Bristol with 2.5MHz Spectrum Removed (Pink = Best Server Interference)

The interference area is less than 1% of the focus zone.

D.1.2 Removal of 5MHz Spectrum

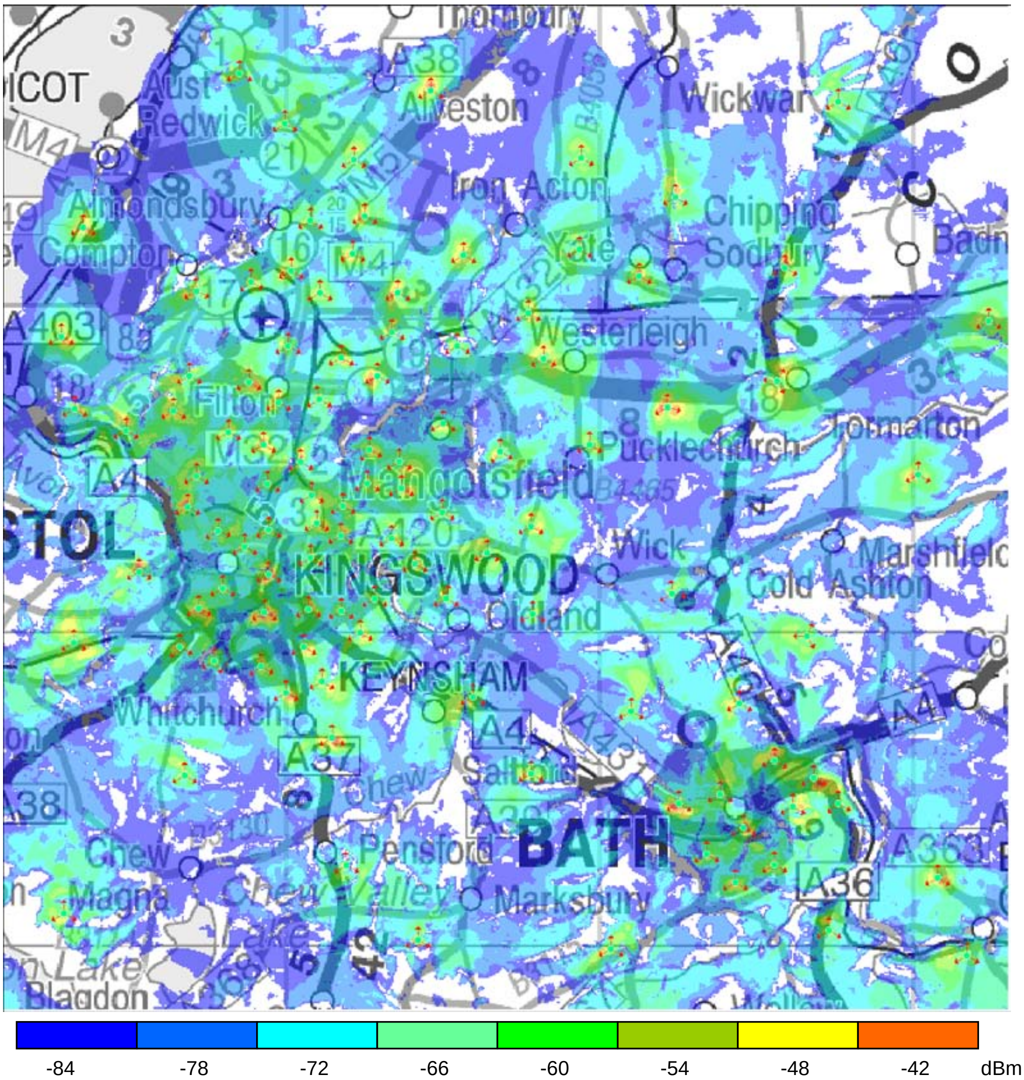

Figure 11: Coverage for Bristol with 5MHz Spectrum Removed (Rural Planning Level – Dark Blue)

Table 14: Coverage (Bristol – remove 5MHz)

Clutter Code	Bristol Clutter Types	% Coverage
0	Rural	89.9
1	Suburban	95.0
2	Urban (at urban planning level)	80.2
8	Woodland	54.5

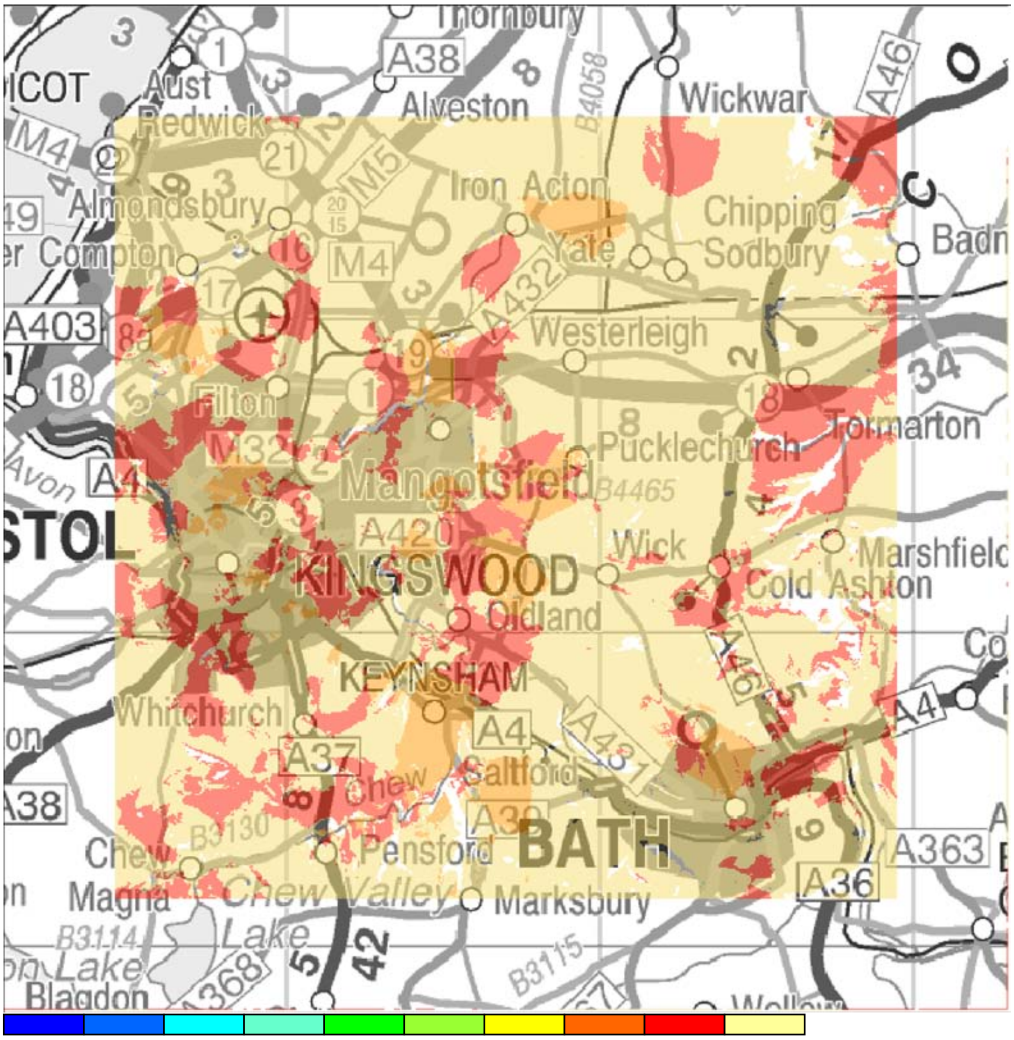

Figure 12: Grade of Service for Bristol with 5MHz Spectrum Removed

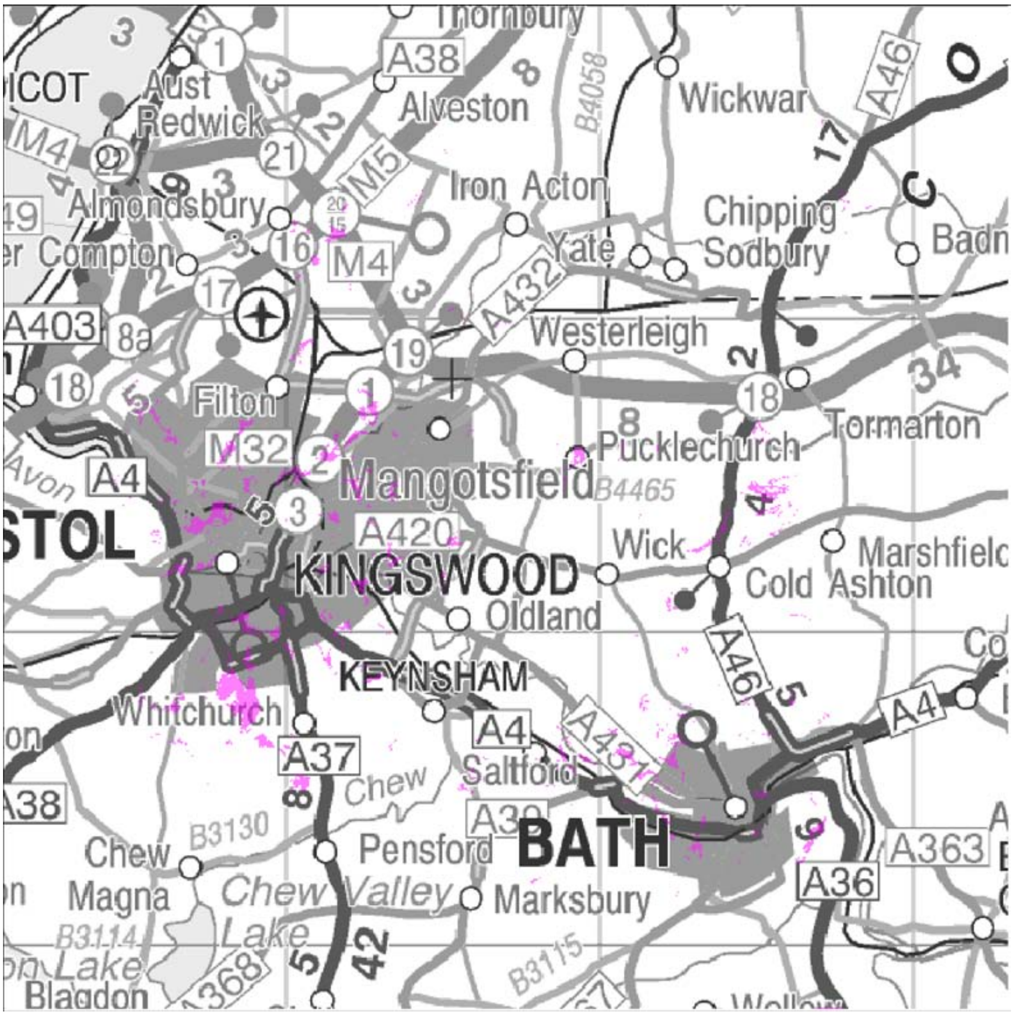

Figure 13: Interference for Bristol with 5MHz Spectrum Removed (Pink = Best Server Interference)

The interference area is approximately 1.4% of the focus zone.

D.1.3 Removal of 7.5MHz Spectrum

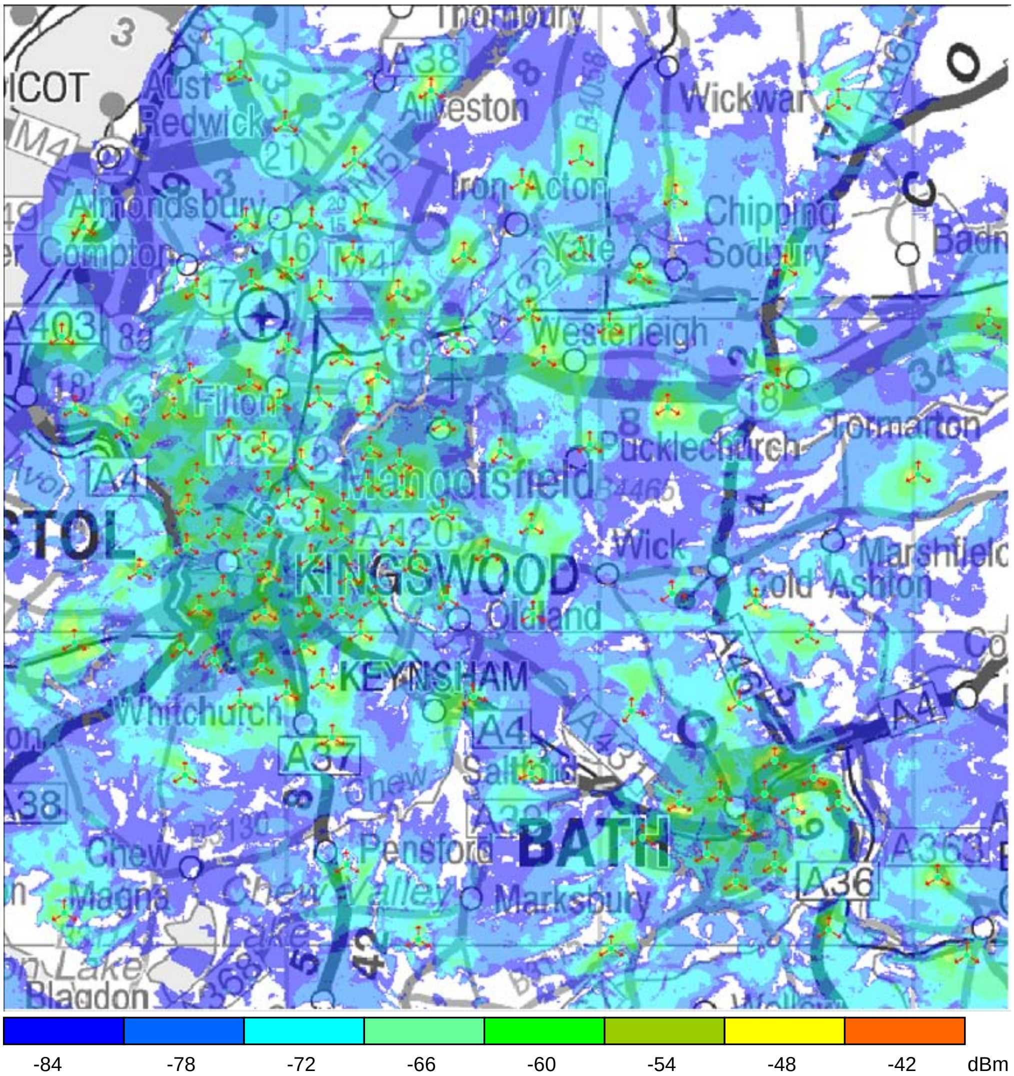

Figure 14: Coverage for Bristol with 7.5MHz Spectrum Removed

Table 15: Coverage (Bristol – remove 7.5MHz)

Clutter Code	Bristol Clutter Types	% Coverage
0	Rural	90.3
1	Suburban	96.0
2	Urban (at urban planning level)	89.4
8	Woodland	58

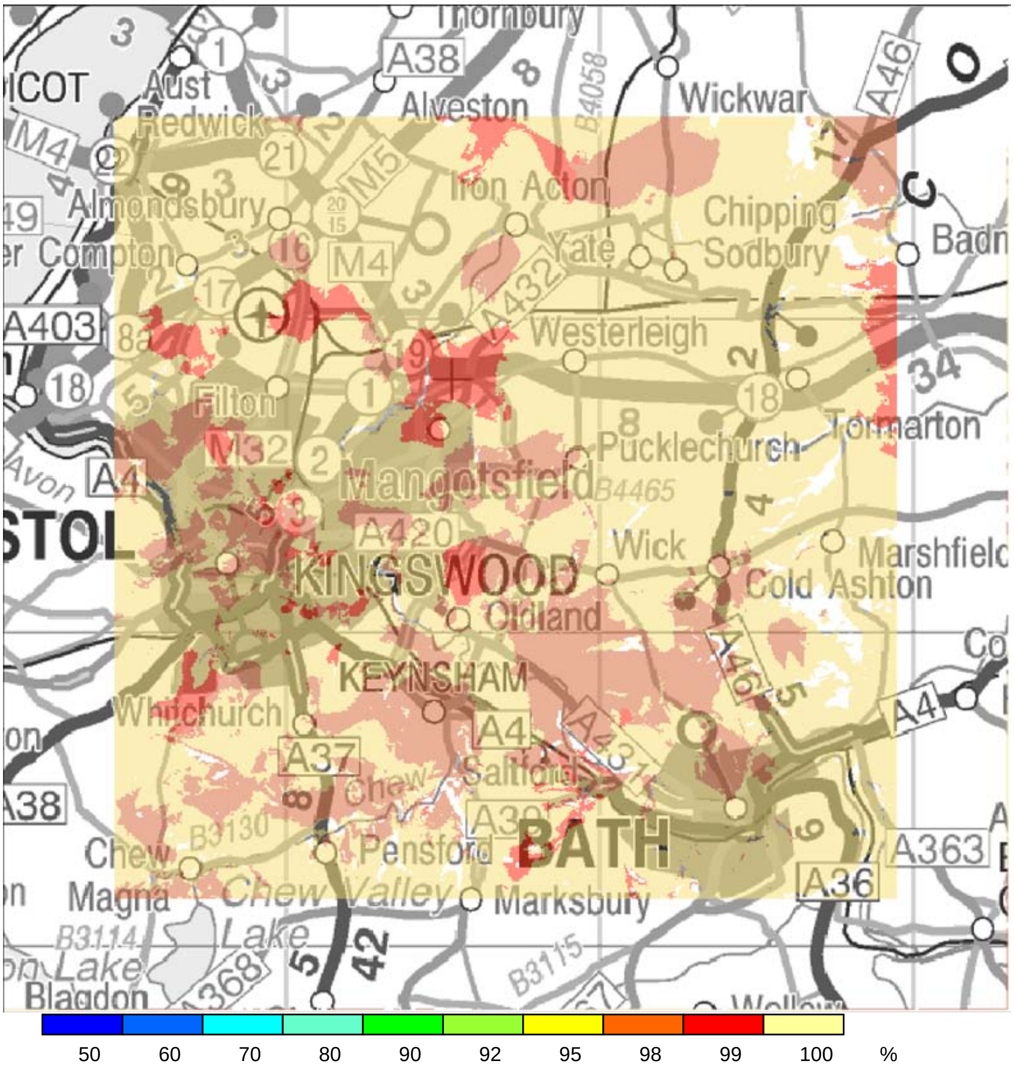

Figure 15: Grade of Service for Bristol with 7.5MHz Spectrum Removed

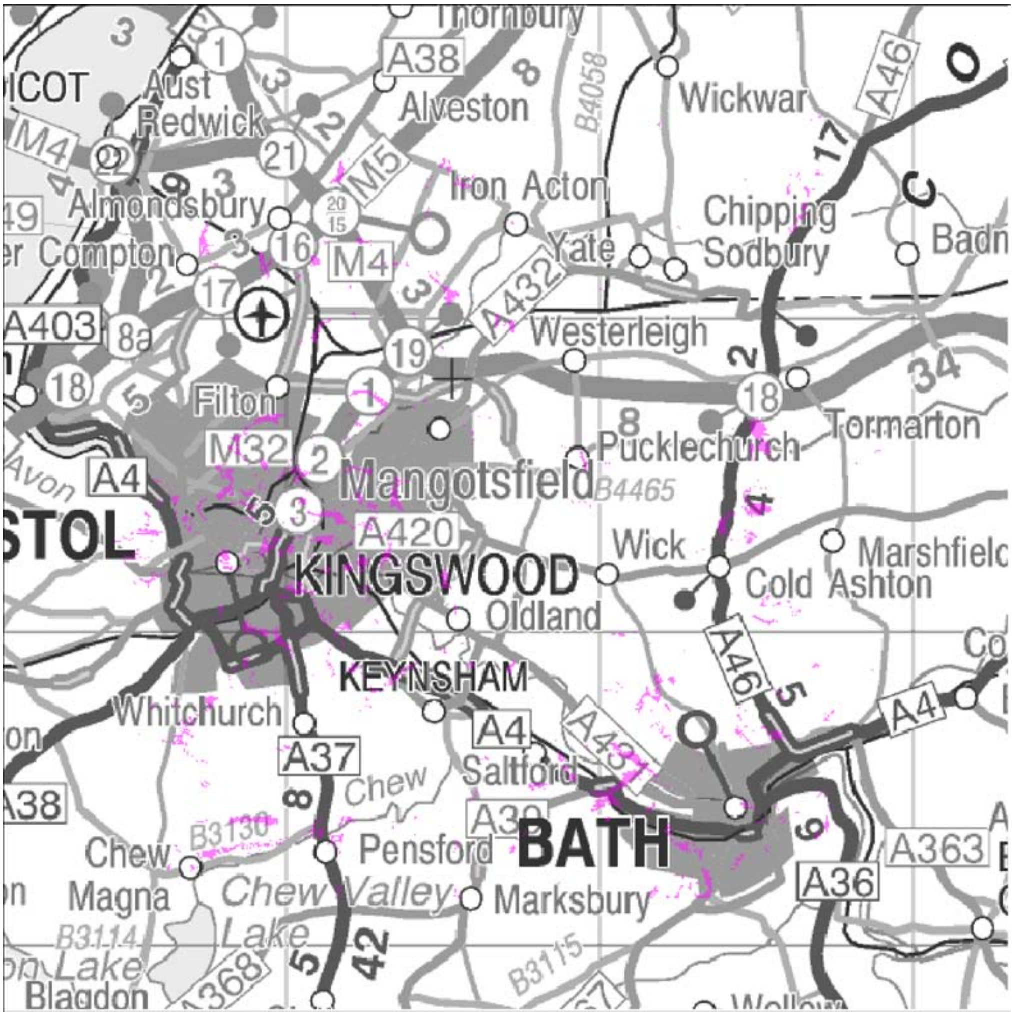

Figure 16: Interference for Bristol with 7.5MHz Spectrum Removed (Pink = Best Server Interference)

The interference area is approximately 1.4% of the focus zone.

D.1.4 Removal of 10MHz Spectrum

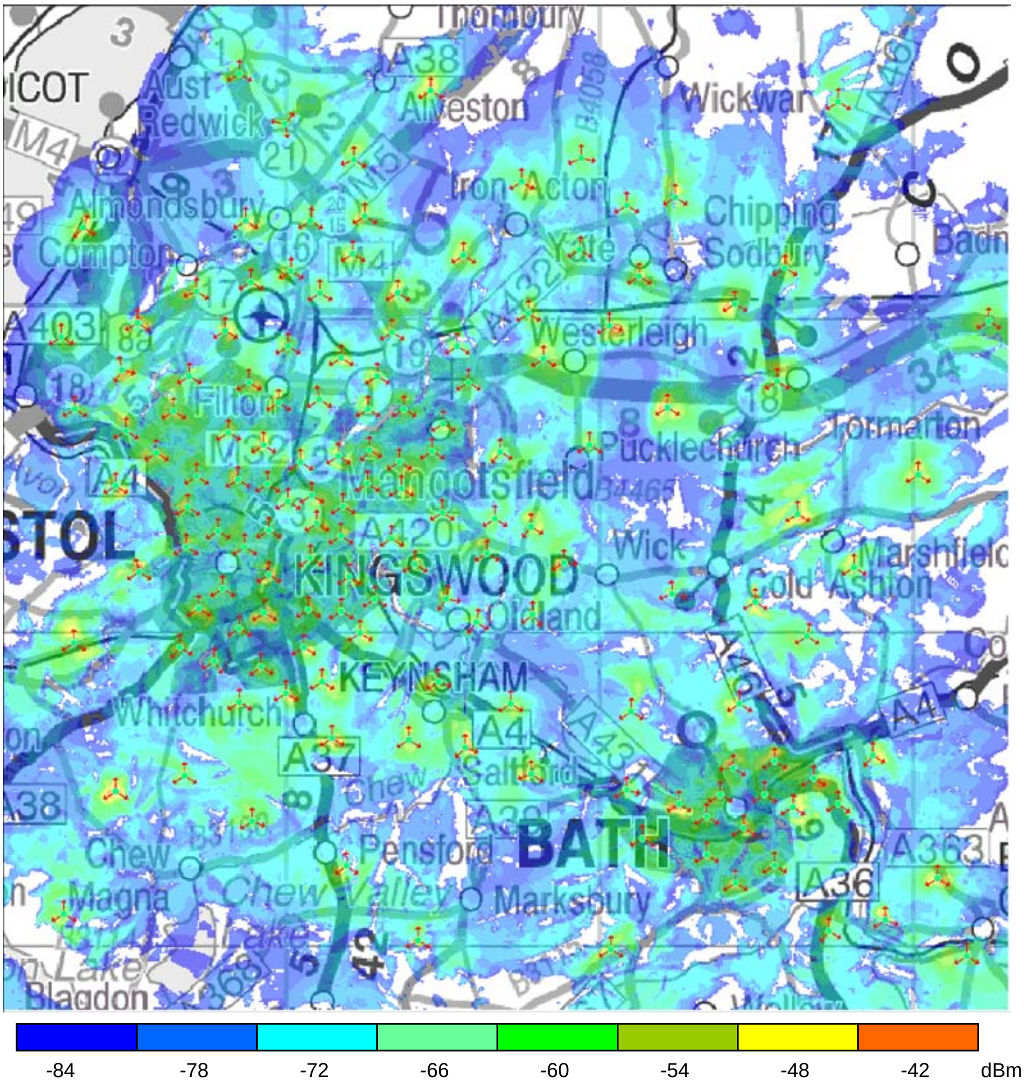

Figure 17 Coverage for Bristol with 10MHz Spectrum Removed

Table 16: Coverage (Bristol – remove 10MHz)

Clutter Code	Bristol Clutter Types	% Coverage
0	Rural	93.5
1	Suburban	97.5
2	Urban (at urban planning level)	87.5
8	Woodland	64.5

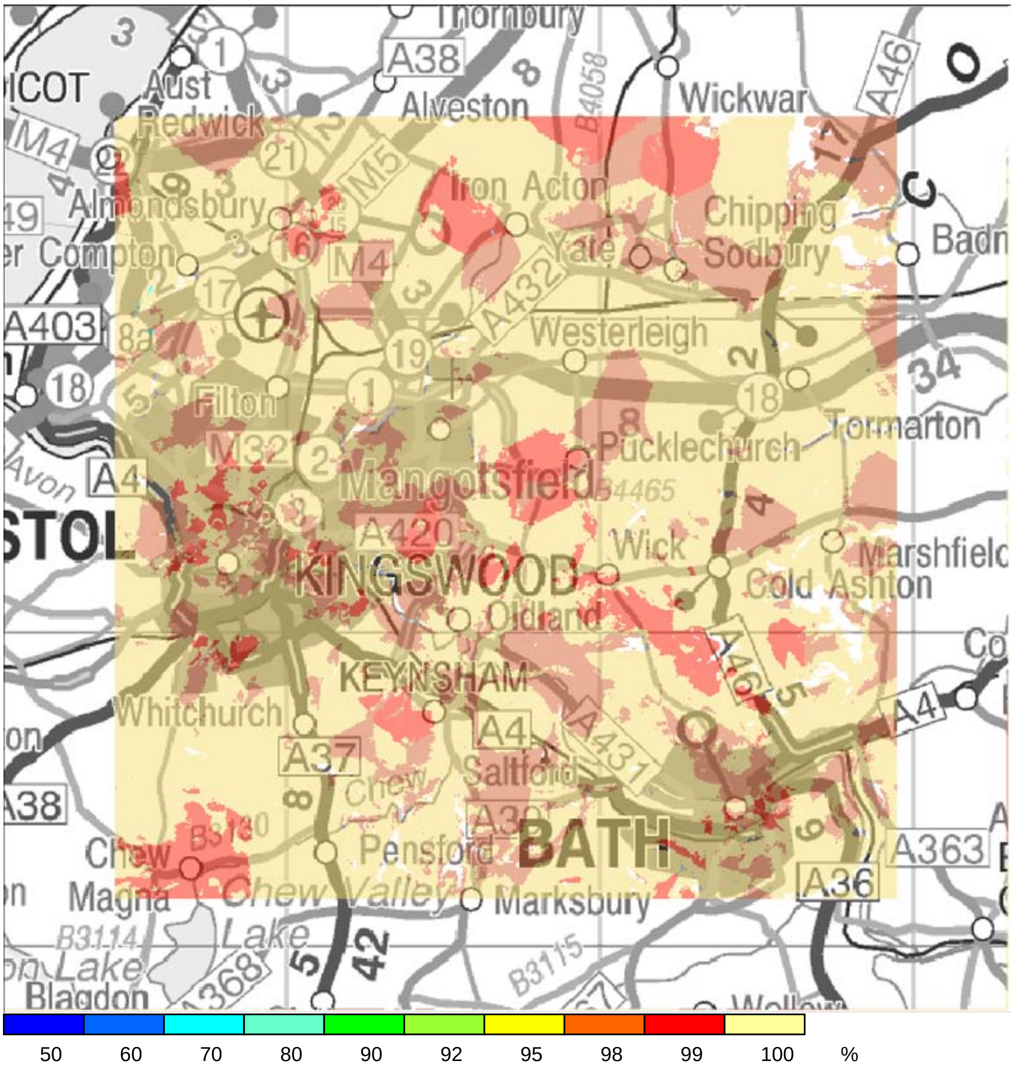

Figure 18: Grade of Service for Bristol with 10MHz Spectrum Removed

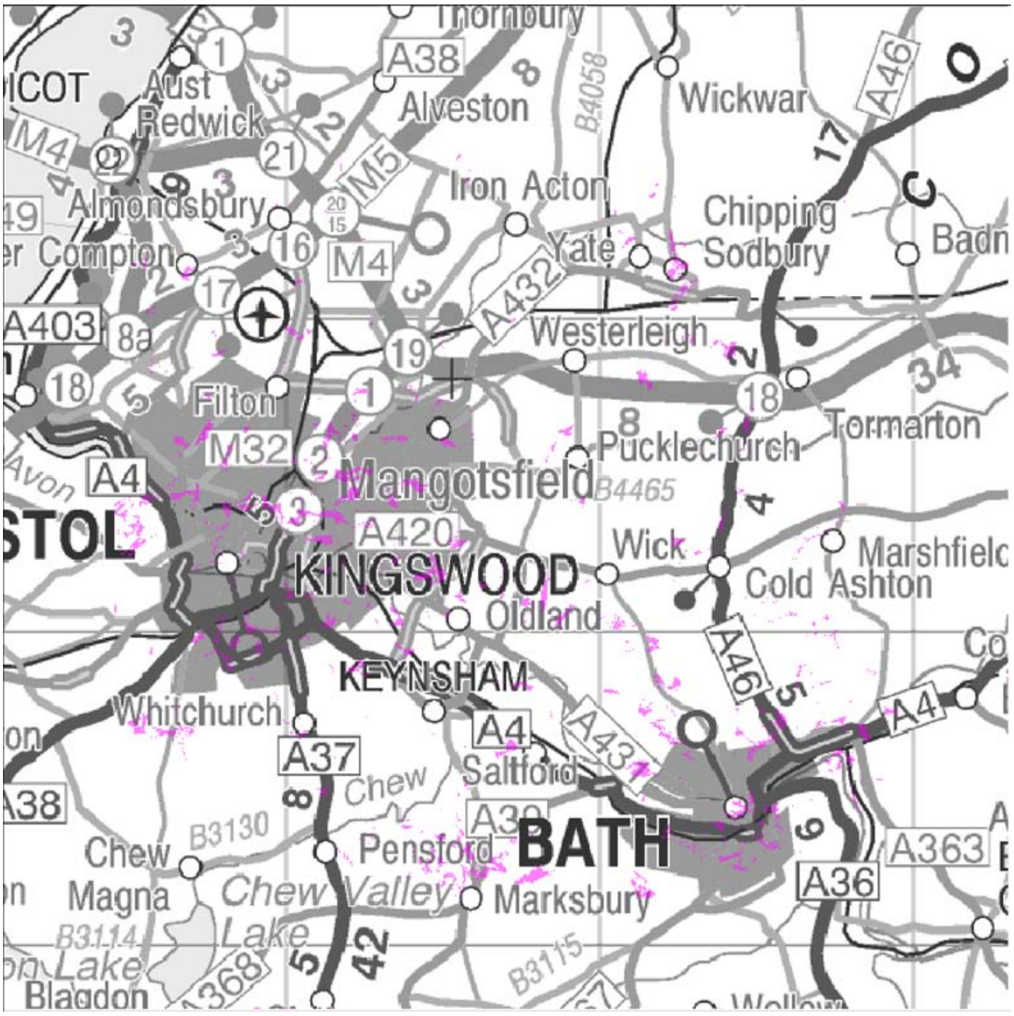

Figure 19: Interference for Bristol with 10MHz Spectrum Removed (Pink = Best Server Interference)

The interference area is less than 2% of the focus zone.