

# **Interleaved Spectrum Planning Study**

**Final Report**

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Prepared for Ofcom  
by  
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Wireless



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## Summary

NGW on behalf of Ofcom have carried out an assessment of the availability of interleaved spectrum, for DTT applications, at 71 post DSO broadcasting stations. The assessment was based on version 5.5 of the UK plan and an interpretation of potential European interference based on information contained within the GE-06 frequency plan.

As part of the study NGW have had to develop a methodology for defining how a service is protected and where such a service should be protected. The method can be seen as successful as the introduction of interleaved services at 71 stations has had a negligible impact on overall UK coverage.

Introduction of any new DTT service using a channel within spectrum used by the main multiplexes will have an impact on the coverage of co-channel and possibly adjacent channel multiplexes. As there are no agreed rules for assessing the impact of such services, NGW have developed a definition of where a station serves, the digital preferred service area (DPSA). The purpose of the DPSA being to protect the station offering the best of a combination of a 3PSB service and the greatest number of commercial multiplexes.

Using the DPSA combined with a permissible increase in the protected field strength (PFS) of PSB multiplexes of 0.5dB and an increase in the PFS of commercial multiplexes of 1.0dB the availability of spectrum at 71 sites has been assessed. Templates for each station have been derived that show the restrictions required on a channel to protect coverage on the main multiplexes.

The theoretical maximum coverage of a network of 71 stations using interleaved channels and the derived theoretical templates with an ERP of 10kW at main stations and 1kW at relay sites has been calculated, Table 1.

Modulation scheme	Theoretical maximum Coverage of 71 interleaved stations households	71 stations percentage of UK
QPSK 2/3	21,504,356	81.83%
64QAM 2/3	16,857,312	64.15%

Table 1 :Theoretical Maximum Coverage of the 71 Interleaved Spectrum Stations

The theoretical overall impact of the 71 site interleaved network on the main multiplexes is minimal, Table 2.

	V5.5 coverage households	V5.5 percentage of UK	V5.5 + 71 Interleaved stations households	V5.5 +71 percentage of UK	Impact on v5.5 coverage households
3PSB	25,906,370	98.58%	25,906,080	98.58%	-290
6CORE	23,794,798	90.55%	23,792,538	90.54%	-2,260

Table 2 : Comparison of the coverage of the Main multiplexes pre and post the introduction of interleaved channels

Though the impact on overall coverage is very small, there could be a significant impact on the gross coverage of stations in overlap areas assuming the use of the full

theoretical antenna templates, power and heights. This is an inevitable consequence of introducing interleaved applications.

## **Introduction**

As part of the Digital Dividend Review (DDR) being carried out by Ofcom, National Grid Wireless (NGW) was commissioned to assess the availability of interleaved spectrum for use by new DTT services. The study was to include details of the coverage achieved and the impact the identified interleaved channels would have on the six main DTT multiplexes.

The assessment was to:

- Use the latest version of the DSO plan and European interference based on GE-06.
- Use the UK planning model (UKPM).
- To protect the DSO plan – NGW to define what “protect” means.
- Initially identify one channel at the 71 specified existing broadcasting stations.
- Not make any assumptions about the use of existing or planned infrastructure
- Only consider UHF channels +2 above and -5 below aerial group used by the main multiplexes at the station being assessed.
- Include all UHF channels at the 10 largest stations.

To meet Ofcom’s brief with respect to protection of the DSO plan NGW have developed a definition of which services will be protected, what protection means in terms of a permissible increase in interference and where these services will be protected.

The rules developed for defining and protecting services have then been used to assess the restrictions on interleaved channels, within the receive aerial group of the station being examined. Having assessed each applicable channel, the best with respect to its potential theoretical coverage was chosen for further assessment.

For each station the potential theoretical coverage has been predicted and the impact on the main multiplexes of a full 71 site interleaved network has been calculated.

This report and its associated appendices detail the results of the study NGW have carried out on behalf of Ofcom assessing availability of interleaved spectrum and its impact on the six main multiplexes.

## Methodology

There is unlikely to be a single answer to the question of what protection of the DSO plan means. Rules can be based on protecting each station, protecting regional and national coverage, the 3PSB services, the maximum number of multiplexes, gross coverage etc. However, though these rules can be used to dictate which stations a postcode database should point viewers at, ultimately the majority of viewers will watch the station that provides the greatest, usable choice. On this premise it seems prudent to base protection of the network on protecting the station that provides the viewer with the greatest choice.

Using viewer choice as the guide, NGW have specified for any given location which station should be protected, the digital preferred service area (DPSA), and have developed a set of planning rules for limiting the increase in interference to a station within the DPSA.

## Digital Preferred Service Area

The coverage of a station can be defined in many ways. An initial approach would be to assume that the viewer will continue watching the same station that they presently use to receive their analogue services. However, with the reallocation and release of spectrum, coverage of stations in the digital network post DSO will differ slightly to that of the analogue network. Also, as 80 of the 1160 stations will offer three additional multiplexes it is likely that viewers, as they renew their existing aerials, will realign to the station offering the greatest number of multiplexes.

For this study, initially three methods were considered for defining the DPSA of stations post switchover. Each of these methods assumed that with time there would be no connection to existing analogue usage.

- A pragmatic approach based on viewers wanting to receive as many multiplexes as possible.
- A semi-pragmatic approach aimed at providing at least a 3PSB service.
- Providing the best possible PSB service irrespective of commercial multiplex coverage.

Of the three methods the second, the semi-pragmatic approach, has been adopted for this study. This definition of the DPSA ensures that 3PSB coverage is protected whilst recognising that viewers will attempt to watch a station that offers the greatest number of multiplexes.

For each location where a 3PSB service is available, coverage is assigned to a station, Figure 1. It should be noted that the definition of the DPSA does result in some 100 relay stations not being assigned coverage. As such these stations would not be protected. Ofcom has not endorsed or made any policy decisions with regards to the use or definition of DPSA.

Details of the definition of the DPSA are provided in appendix III.

## **Planning Rules for Interleaved Spectrum**

With no rules agreed within the industry for assessing the impact of applications using interleaved spectrum on the main multiplexes, NGW, for the purpose of this study, have had to develop a set. In developing the rules it was recognised that the introduction of any service in spectrum shared with the six main multiplexes could potentially result in a loss of gross coverage of co-channel and possibly adjacent channel main multiplex coverage.

Though introducing a new interleaved service will result in an impact on the main multiplexes, if this impact is limited to areas of overlap coverage where viewers are not expected to watch the affected station there will be no loss of net coverage.

After considering various methods for protecting the net coverage of the main multiplexes which depended on whether there was a choice of service in an area, a simplified method based on protecting the best service was developed.

For this study the best service was taken as a minimum a 3PSB service and the greatest number of commercial multiplexes.

NGW have had to identify, at any given location where a 3PSB service is available, which station viewers should watch the DPSA.

Having decided which locations need protecting, next the permissible increase in interference had to be decided. At any given location, receiver noise plus interference from agreed co-channel stations in the network and in neighbouring countries results in a minimum usable field strength, the protected field strength (PFS). The addition of any new co-channel interleaved application will result in an increase in the PFS. At present there is no agreed value for this increase in PFS so for the purpose of this study NGW have adopted an increase of 0.5dB for PSB multiplexes and 1dB for COM multiplexes.

The increase in the PFS is implemented on a sliding scale. For locations where the margin is low the increase in interference, effectively decrease in margin, is limited to 0.5dB and 1.0dB. In areas predicted as having a good margin of service a greater increase in the PFS is permitted.

The increase in interference has been chosen so that whilst it will be a reduction in margin it should not deprive a viewer of a service.

Details of the planning rules are provided in appendix IV.

## **Analysis of Stations**

For the purpose of this study Ofcom asked NGW to identify interleaved channels at 71 stations.

At each station, using the developed planning methods based on the DPSA and a 0.5dB or 1.0dB increase in PFS, the restrictions on each channel required to protect the main multiplexes were calculated. Restrictions were based on an ERP of 10kW at main stations and 1kW at relay stations at the height of the main multiplexes. Analysis of channels was limited to the receive aerial group +2 channels and -5 channels. From this set of channels the best, the least restricted, was selected. Restrictions for the best channel have also been calculated for half and quarter heights.

For the ten largest stations restrictions have been calculated for all available channels, ch21 to ch30 and ch41 to ch62, though channels outside the receive aerial group +2 channels and -5 channels have not been selected.

Coverage of the chosen interleaved channel based on the derived theoretical template, height, maximum ERP and QPSK2/3 modulation scheme has been calculated (Appendix II). As coverage is based on a template, maximum antenna height and ERP represents the best that can be achieved. No assessment has been made of the availability of antenna aperture or structure loading at each site. In practise maximum antenna height is not achievable as, in general, the top of the masts are fully occupied. Practical antennas, mounted lower on the structure will result in lower coverage. For each site the half height and quarter height predictions, where available, provide an indication in the reduction in coverage as the height of an antenna is lowered.

The theoretical impact on UK coverage has been assessed by modelling the UK Plan version 5.5 network along with the 71 site interleaved network (Appendix I). As the interleaved network is based on antenna templates, maximum ERP and maximum height – an implemented network, i.e. real antenna patterns at lower heights and especially at relay stations lower ERPs, will cause less reduction in overlap coverage .

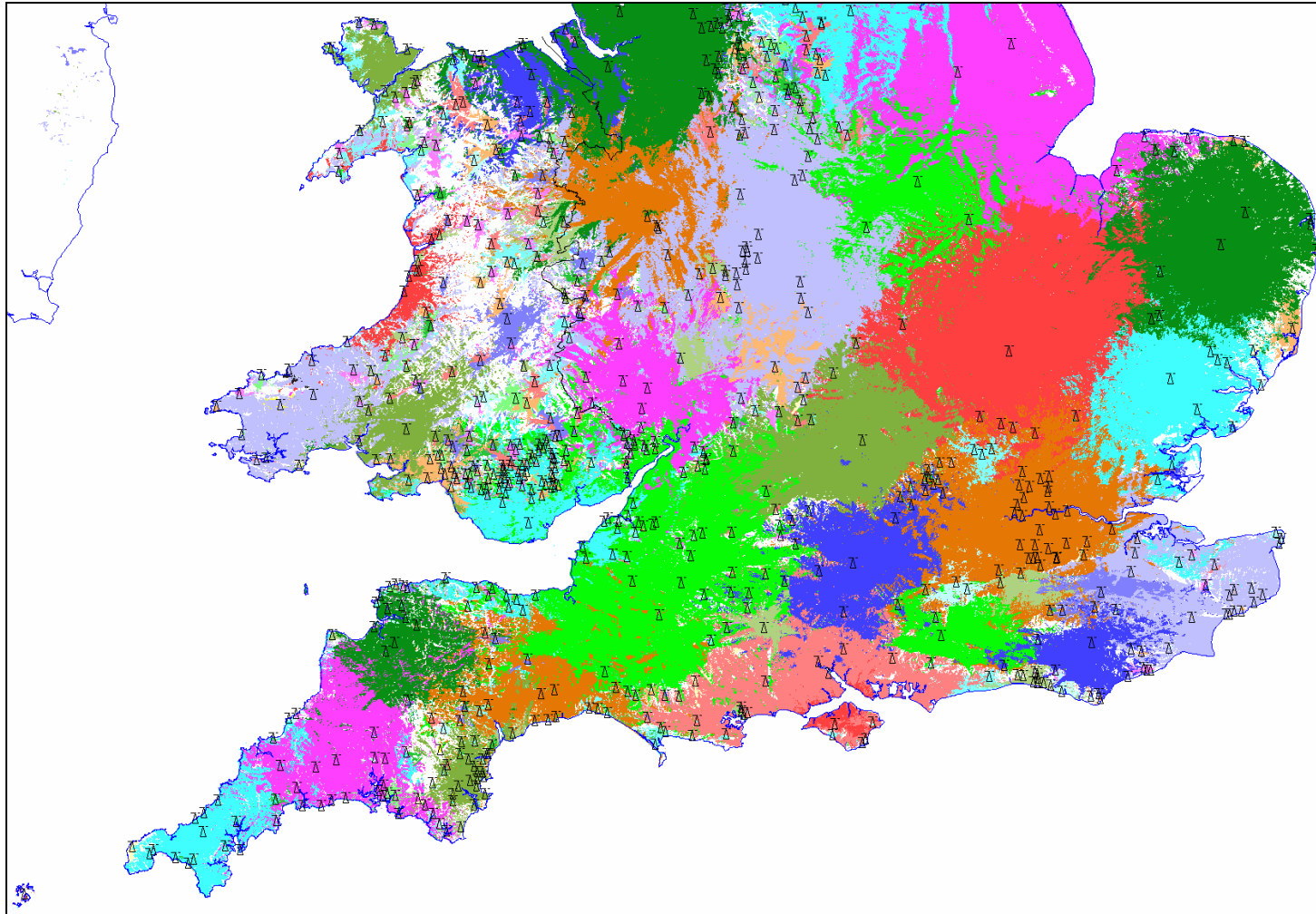


Figure 1a : Overview of DPSA Allocation

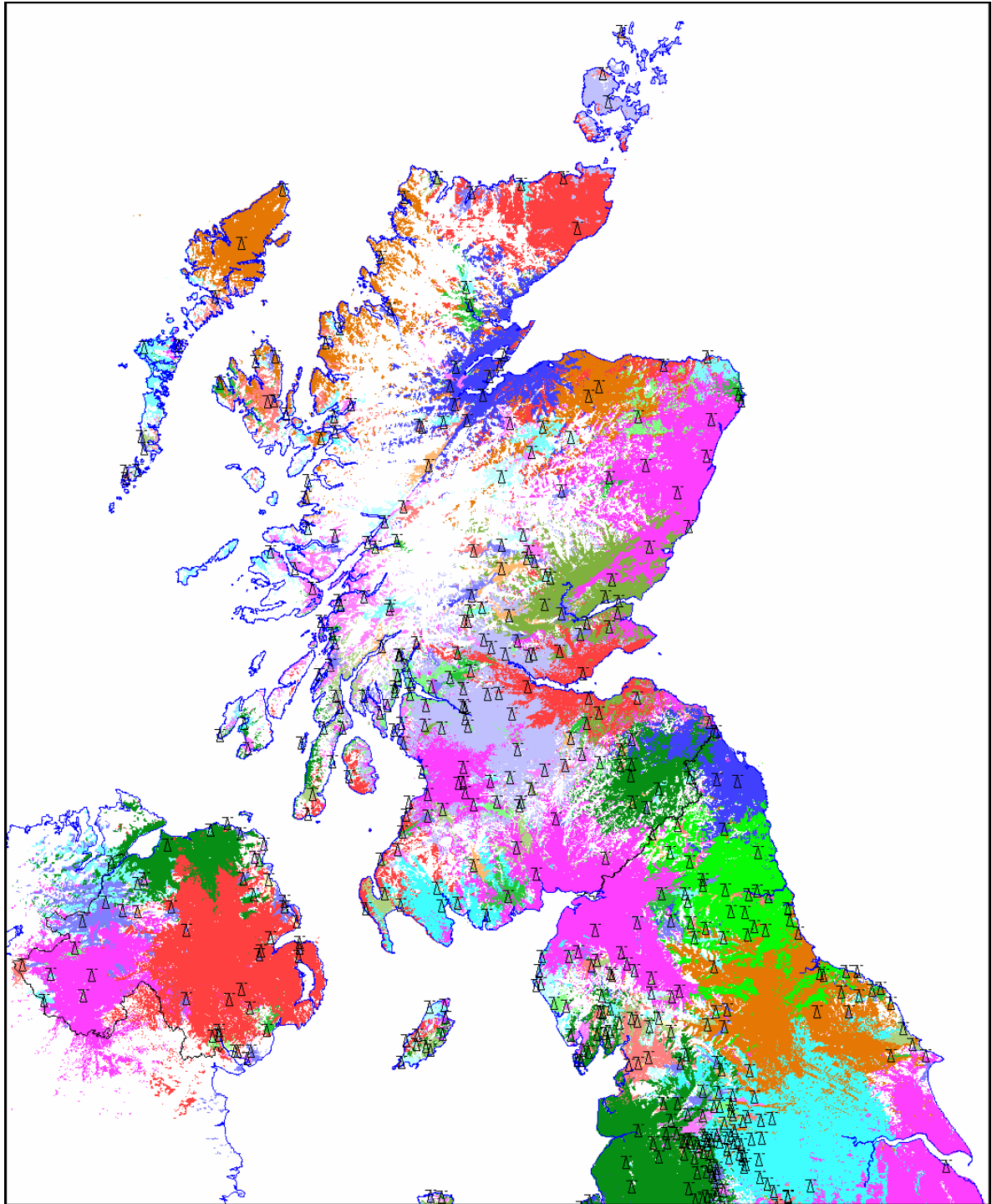


Figure 1 : Overview of DSA Allocation

## Results

Appendix I has details of the theoretical impact of the chosen interleaved channels on the main multiplexes as well as the potential theoretical maximum coverage achieved by these channels. Appendix II has details of the individual assessments carried out for each of the 71 stations considered as part of this study.

### Worst Case Impact on the Main Multiplexes

The planning rules and definition of the DPSA have demonstrated that, as designed, they protect the net coverage of the main multiplexes. The worst case potential impact to the 3PSB coverage was limited to 290 households and the worst case impact to 6Core coverage was 2,260 households, Table 3.

The UKPM uses a cut-off method to assess whether a location is classified as served or not. At some locations the increase in interference resulting from the introduction of interleaved services will result in the UKPM classifying these locations as not having a service, e.g. the 290 households. However, the planning rules are designed to limit the increase in interference to PSB multiplexes within the DPSA to 0.5dB and 1.0dB for commercial multiplexes. As such from a viewers point, those that are predicted as being impacted will suffer a degradation of margin of 0.5dB or 1.0dB which should in its self not result in a loss of service. Though digital systems degrade rapidly, at any location to receive a service reliably a degree of margin is required to allow for the dynamics of the RF channel. Consequently, a reduction of margin of 0.5dB or 1dB should not result in a loss of service. In areas where an impact is predicted it should manifest itself as a small increase in the number of glitches during periods of interference.

Though within the DPSA the increase in interference is controlled so that a service should not be lost, outside the DPSA in overlap areas no such control exists. In these areas any predicted impact may result in the ability to receive the affected station. It should however be noted that in all cases the affected service does not provide the best service – best being as a minimum a 3PSB service and the greatest number of commercial multiplexes.

	V5.5 coverage households	V5.5 percentage of UK	V5.5 + 71 Interleaved stations households	V5.5 +71 percentage of UK	Worst case theoretical potential Impact on v5.5 coverage households
PSB1	26,041,592	99.10%	26,041,236	99.09%	-356
PSB2	26,008,270	98.97%	26,007,333	98.97%	-937
PSB3	26,016,709	99.00%	26,013,973	98.99%	-2,736
COM4	24,379,842	92.77%	24,373,766	92.75%	-6,076
COM5	24,348,610	92.65%	24,346,493	92.65%	-2,117
COM6	24,420,188	92.93%	24,414,064	92.90%	-6,124
3PSB	25,906,370	98.58%	25,906,080	98.58%	-290
6CORE	23,794,798	90.55%	23,792,538	90.54%	-2,260

Table 3 : Comparison of the coverage of the Main multiplexes pre and post the introduction of interleaved channels

Though there is little impact to the net coverage of the network, the degree of overlap between some transmitters is reduced. There are potentially up to 288,377 households impacted in the gross coverage of the PSB2 multiplex from Bilsdale. However, this worst case impact would only occur if all those households have aerials directed towards Bilsdale. In reality the number of affected households is likely to be much smaller as most households would not have aerials directed at Bilsdale (which carries Tyne Tees programmes) and would instead prefer to watch Yorkshire regional programming from the Emley Moor, Belmont or Sheffield transmitters. Even those households choosing to watch Tyne Tees may not notice any degradation in the service. There is no impact within the DPSA, Figure 2.

The potential impacts on the overlap coverage of the six main multiplexes are worst case predictions as they are based on theoretical antenna templates and maximum powers and heights. In reality, the impacts should be lower (for example the tops of masts are generally fully occupied) and there are various mitigation strategies that can be used, including:

- Use of alternative channels for the new interleaved service, though this may result in lower coverage
- Practical antenna patterns.
- Lower antenna heights
- Lower powers
- Allowing less interference to the overlap areas of the six main DTT multiplexes than currently assumed in the planning rules.

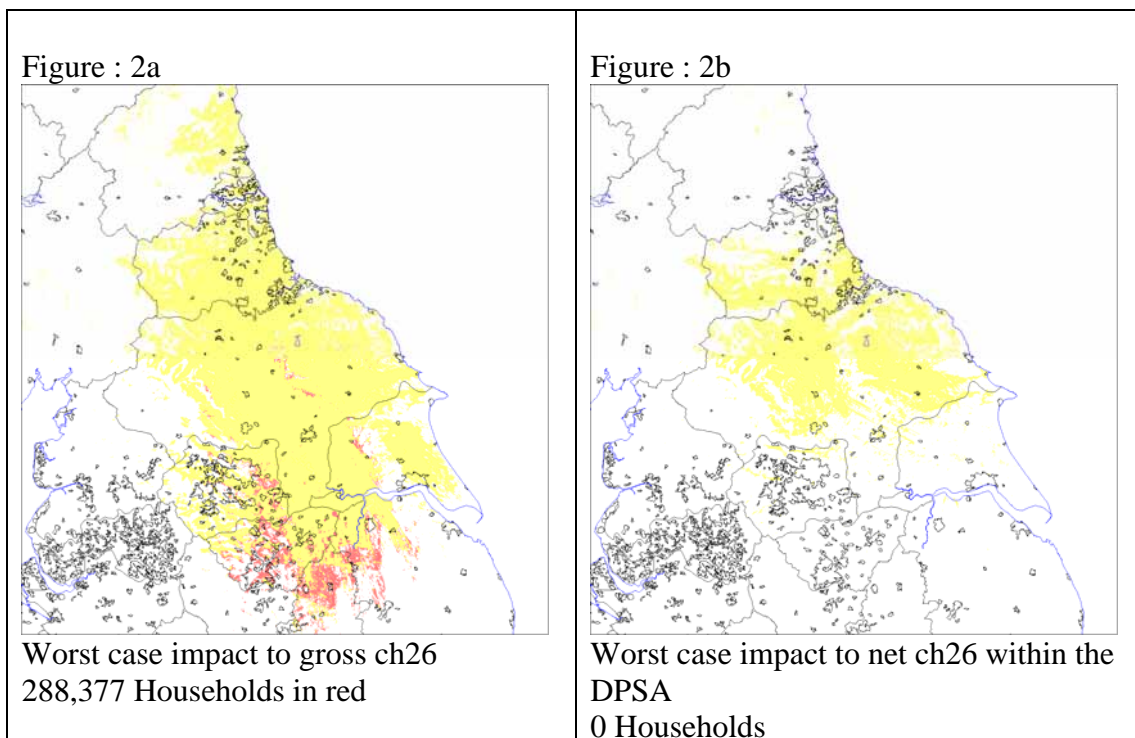


Figure 2 : Worst Case Impact of Interleaved Spectrum on Bilsdale

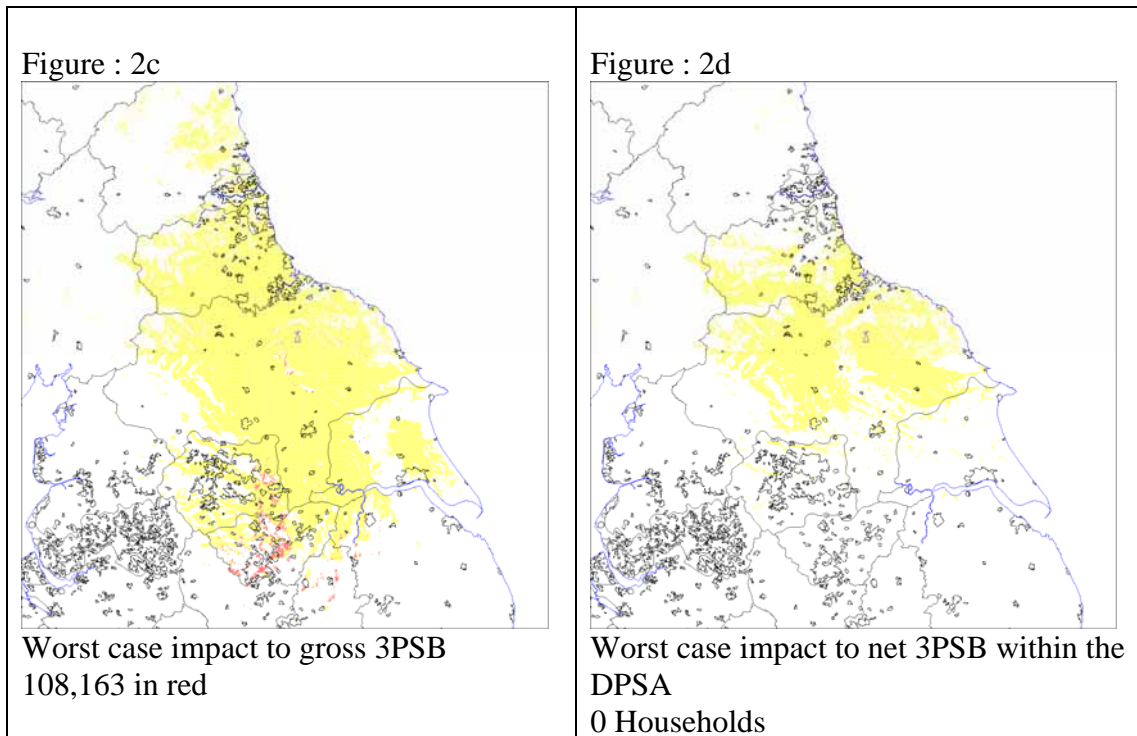


Figure 2 : Worst Case Impact of Interleaved Spectrum on Biltsdale

### Theoretical Coverage of the interleaved channels

The 71 sites allocated an interleaved channel serve over 80% of UK households if the more robust QPSK2/3 modulation is adopted. This coverage falls to a little over 60% if a higher data rate but less robust 64QAM 2/3 modulation scheme is used, Table 4. The overall UK coverage of the two modulation schemes is shown in Figure 3. The gross coverage of individual stations for these two modulation schemes is summarised in Table 5.

It should be noted that predicted coverage is based on the theoretical template and maximum ERP and antenna height associated with each of the interleaved channels. Real antennas, actual heights and ERPs will result in a reduction in predicted coverage.

Modulation scheme	Theoretical Max Coverage of 71 stations in households	71 stations percentage of UK
QPSK 2/3	21,504,356	81.83%
64QAM 2/3	16,857,312	64.15%

Table 4 : Theoretical Maximum Coverage of the 71 Interleaved Spectrum Stations

In general, the channels (within the local receive aerial group) offering the best theoretical coverage for the new interleaved service have been chosen. However, in some cases, other channels could be used, as indicated by the alternative channel templates for each station in Appendix II. Other channels may be better suited to

different coverage requirements than assumed in this study, and may also have less potential impact on the six main DTT multiplexes.

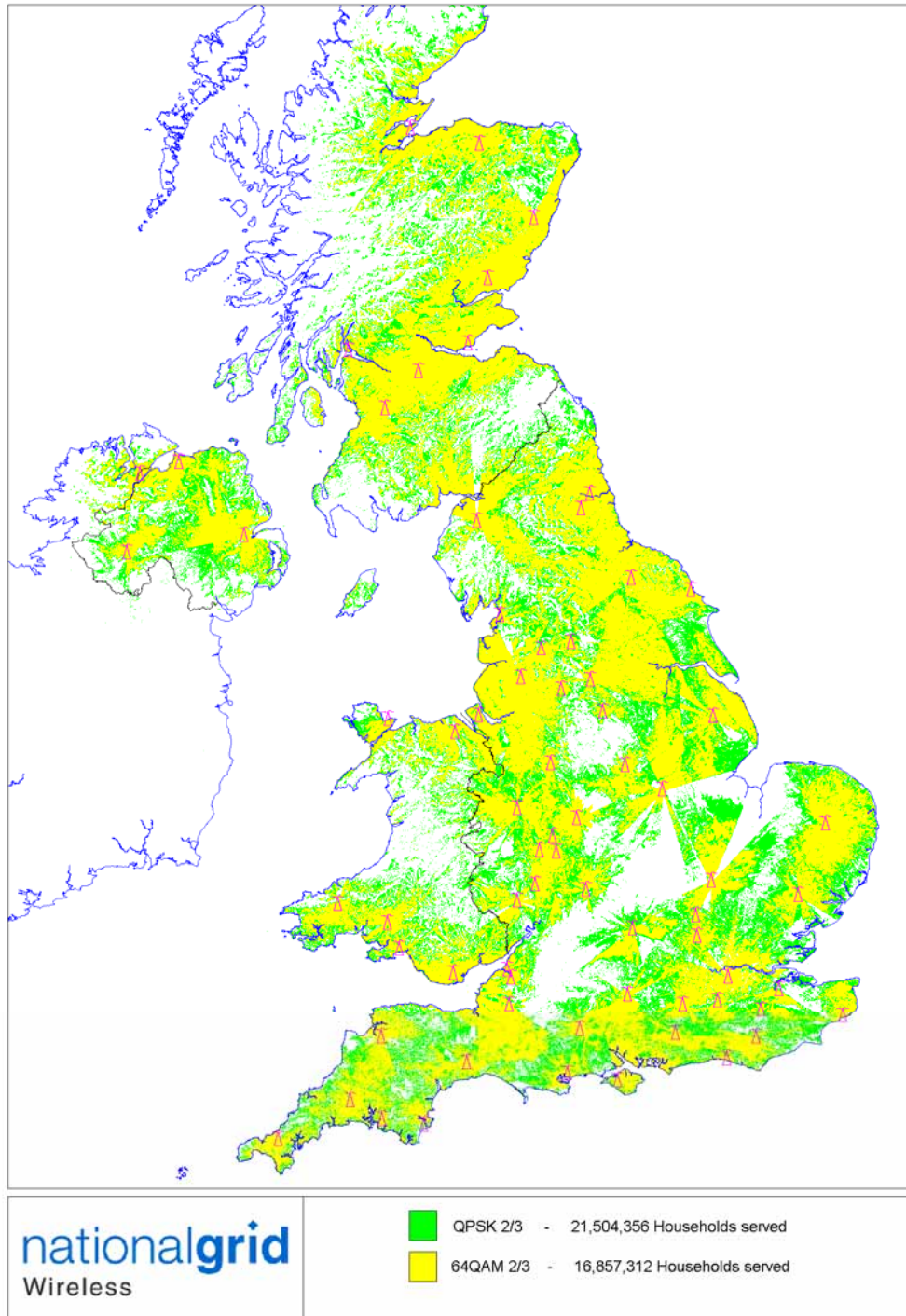


Figure 3 : Theoretical maximum UK coverage of 71 site interleaved spectrum network, 70% locations

No.	Station	Ch	QPSK2/3 Households served	64QAM2/3 Households served	NO.	Station	Ch	QPSK2/3 Households served	64QAM2/3 Households served
10100	CRYSTAL PALACE	29	3931009	2940378	11300	DOVER	57	319390	110551
10101	GUILDFORD	54	721099	198172	11400	TACOLNESTON	57	387237	255428
10103	REIGATE	51	263328	105226	11500	SUDBURY	49	347461	151614
10104	TUNBRIDGE WELLS	51	64744	24468	11600	BILSDALE	24	1009412	587156
10105	HEMEL HEMPSTEAD	49	589709	194604	11700	OXFORD	49	259667	152181
10200	SUTTON COLDFIELD	51	1338947	878929	11800	LLANDDONA	51	48025	33302
10201	BRIERLEY HILL	56	159420	94398	11900	CARMEL	52	102306	59724
10202	KIDDERMINSTER	56	63891	44248	12000	BELMONT	21	655746	259550
10206	BROMSGROVE	29	260141	145829	12002	OLIVERS MOUNT	56	48148	45736
10207	MALVERN	51	246390	135830	12100	THE WREKIN	48	320660	164181
10208	LARK STOKE	48	133082	66143	12300	ANGUS	48	476080	372816
10211	FENTON	29	242279	159555	12400	SANDY HEATH	49	429123	206233
10300	WINTER HILL	56	3008009	2614006	12402	LUTON	45	166709	91727
10302	PENDLE FOREST	30	158514	111716	12500	MIDHURST	46	248723	47993
10306	SADDLEWORTH	43	290267	75990	12600	HANNINGTON	43	470400	172149
10307	STORETON	30	254806	81691	12900	PRESELY	30	70426	35605
10335	LANCASTER	30	135153	63165	13000	LIMAVADY	56	78457	52501
10400	EMLEY MOOR	45	974489	684945	13001	LONDONDERRY	51	55957	48934
10403	SHEFFIELD	26	269629	162291	13100	CARADON HILL	30	238480	134973
10407	KEIGHLEY	56	311269	122538	13105	PLYMPTON	49	114655	63753
10500	BLACK HILL	51	1395627	1158332	13200	STOCKLAND HILL	30	299435	119445
10600	WENVOE	51	718212	507821	13600	BEACON HILL	49	134122	95120
10601	KILVEY HILL	30	195114	150783	13700	CALDBECK	21	139929	109664
10700	DIVIS	30	398166	279100	13800	HUNTSHAW CROSS	51	79755	54086
10801	SALISBURY	49	90465	33410	13900	HEATHFIELD	54	158880	85062
10804	POOLE	50	255945	163476	14100	REDRUTH	55	93671	71146
10805	WHITEHAWK HILL	54	211857	137366	14500	MOEL Y PARC	30	396672	96468
10860	ROWRIDGE VP	29	767967	511251	14700	CRAIGKELLY	52	715401	623422
10900	PONTOP PIKE	56	1163999	990002	14900	RIDGE HILL	30	132457	59025
10903	FENHAM	30	646056	500919	15100	BROUGH MOUNTAIN	30	29475	18435
11000	MENDIP	55	295821	159286	15200	DARVEL	30	805318	346052
11007	BRISTOL KINGS WESTON	30	443183	230024	15211	ROSNEATH VP	48	161375	75242
11008	BRISTOL ILCHESTER CR	51	232606	162060	15300	KNOCKMORE	56	97389	61924
11100	WALTHAM	55	769427	391088	15600	ROSEMARKIE	52	89509	79000
11101	NOTTINGHAM	62	476259	284036	15800	BLUEBELL HILL	56	203385	102491
11200	DURRIS	30	412973	183405					

Table 5 : Theoretical Predicted Gross coverage of Interleaved channels<sup>1</sup>

<sup>1</sup> Note coverage is based on antenna templates and maximum ERP, real antenna patterns and actual ERP will generally result in lower coverage.

## Discussion

The planning rules can be viewed as successful from the fact that the impact of introducing a 71 station interleaved network, has had a minimal impact on the overall coverage of the UK. However, further work could be carried out particularly to the definition of the DPSA.

The impact on the main multiplexes is very much dependant on the definition of the DPSA. Though the basis of the DPSA is valid over most of the UK, analysis of the results of the study has highlighted a number of small areas where consideration might be given to improving the definition of the DPSA.

- Protection of the correct national/regional service
- Protection of overlapping services
- Protection of re-broadcast links

The DPSA currently protects the best service in North and South Wales which is often an English service from Winter Hill and Mendip respectively. Whereas viewers may elect to watch these services, the DPSA in protecting these English stations may not protect Welsh services in Wales. A similar problem occurs in England in areas adjoining North and South Wales. In these English areas coverage is assigned to Welsh stations at Moel-y-Parc and Wenvoe, and as a consequence viewers of English stations may not be protected.

The present definition of the DPSA being limited to protecting a single station at any location fails to protect overlapping coverage from stations carrying two different services. Examples of these are the regional Ridge Hill West and Storeton Wales services transmitted alongside the six main multiplexes from Ridge Hill and Storeton. In these cases as the main multiplexes offer the greatest number of services, coverage within the DPSA, where it overlaps, is assigned to the main multiplexes. As a consequence the Ridge Hill West and Storeton Wales services are not protected. In a similar manner, one of the components at stations that carry both vertical and horizontal components is often not protected.

Re-broadcast links (RBLs) are off-air feeds used to distribute programme feeds to relay stations within the network. The present definition of the DPSA may not protect the location of the relay station from an interleaved application for a couple of reasons. The present definition of the DPSA only protects populated locations, relays typically being located on remote hill tops may not have population associated with their location and thus may not be protected. If the relay location is populated and thus offered protection there is no guarantee that the location is associated with the correct station.

## **Conclusion**

A method for introducing interleaved DTT services into spectrum occupied by the main multiplexes whilst protecting the overall coverage of the DSO plan has been successfully developed.

Application of the method to 71 stations has identified viable channels that when combined as a theoretical network could provide, depending on the modulation scheme adopted, up to 80% coverage of the UK.

Though the method successfully protected overall coverage, it is based on protecting a single station. As such it would benefit from further refinement across national and regional boundaries by protecting the best service and the correct regional service.

Practical implementation of a DTT service at any one of the sites investigated would require further detailed planning to determine a practical antenna design, power and antenna height to be within the theoretical calculated design and DSO protection requirements yet to be determined and agreed.

# **Interleaved Spectrum Planning Study**

**Final Report  
Appendices I to IV**

16 November 2007

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