Impact of DTT networks in 600 MHz on WS (White Space) channel availability in UHF TV bands

Note by BBC and Arqiva

Executive Summary

This note contains the results of the analysis of WS channel availability, in four different scenarios of coexistence with DTT networks in the UHF TV bands and with three different potential WS Device (WSD) protection ratio (PR) curves.

Using the key data point of 50 MHz WS spectrum availability and 20 dBm WS power, which is comparable to WiFi powers and bandwidths in domestic routers, the results are as follows:

Scenario (all 8 MHz WS channels counted discretely)*	**% UK households served WiMax PR** (50 MHz/20dBm)	**% UK households served WiFi PR** (50 MHz/20dBm)	**%UK households served WiFiI PR** (50 MHz/20dBm)
32 UHF TV channels no WS or DTT in 600 MHz	5%	0%	42%
39 UHF TV channels WS in 600 MHz no DTT in 600 MHz	6%	0%	48%
39 UHF TV channels WS in 600 MHz with two DTT multiplexes in 600 MHz from 25 sites	2%	0%	27%
Post-700 MHz clearance	0%	0%	3%

*In all cases there are the six DTT multiplexes in channels 21 to 30 and 39 to 60 at their post DSO frequency plan which are analysed plus any DTT multiplexes in 600 MHz dependant on the scenario except in the post 700 scenario which represents an illustrative six multiplex plan using only channels 21 to 48.

The next set of results looks at the number of contiguous 8 MHz channels available. The results are summarised in the table below for the 20 dBm WS power and assume a requirement for two groupings of three contiguous 8 MHz channels (2 x 24 MHz). The choice of three contiguous 8 MHz channels allows a 20 MHz telecommunications technology to sit inside these channels. And, by pairing two groups of three contiguous channels, it would be possible to support applications requiring 2 x 20 MHz assignments.

Scenario (all 8 MHz WS channels counted as triples)*	% UK households served WiMax PR (50 MHz/20dBm)	% UK households served WiFi PR (50 MHz/20dBm)	%UK households served WiFiI PR (50 MHz/20dBm)
32 UHF TV channels no WS or DTT in 600 MHz	4%	0%	26%
39 UHF TV channels WS in 600 MHz no DTT in 600 MHz	4%	0%	36%
39 UHF TV channels WS in 600 MHz with two DTT multiplexes in 600 MHz from 25 sites	2%	0%	18%
Post 700 MHz clearance	0%	0%	2%

*In all cases there are the six DTT multiplexes in channels 21 to 30 and 39 to 60 at their post DSO frequency plan which are analysed plus any DTT multiplexes in 600 MHz dependant on the scenario except in the post 700 scenario which is an illustrative six multiplex plan using only channels 21 to 48.

In all of the scenarios considered WS channel availability increases if the WSDs use a modulation scheme that coexists well with DTT receivers by being designed to produce very low out of band emissions. The “WiFiI” (WiFi Improved) protection ratio availability calculations demonstrate the levels of the availability which could potentially be achieved by using such modulation characteristics. See main body for further details.

Introduction

This paper looks at the availability of WS channels interleaved with DTT services in the UHF TV bands against four scenarios and three different possible protection ratio curves depending on WSD applications which are subsequently deployed.

In the first three scenarios six DTT multiplexes are present using the post Digital Switch-Over (DSO) frequency plan. In scenario 4 an illustrative post-700 MHz clearance frequency plan has been assumed (based on initial work carried out on behalf of Ofcom). This assumes that six DTT multiplexes would need to be compressed into the 27 channels which would remain available for television broadcasting. Whilst this illustrative spectrum plan is helpful in looking at potential future WS channel availability, very substantial further work is required to confirm that such a frequency plan would continue to deliver acceptable levels of DTT coverage and capacity in the event of the enforced clearance of 700 MHz. The development of such plans is expected to take a period of several years to complete and will be dependent on a range of domestic and international considerations. For the avoidance of doubt, the publication of these availability calculations should not be treated as an acceptance on the part of Arqiva or the BBC that this illustrative frequency plan would meet the requirements of the UK DTT platform.

1. Scenario 1 models the number of WS channels in UHF TV channels 21 to 60 without 600 MHz (31 to 37), known as the 32 Channel case, no 600 MHz availability
2. Scenario 2 models the number of WS channels in UHF TV channels 21 to 60 with 600 MHz for White Space known as 39 Channel case, no DTT
3. Scenario 3 models the number of WS channels in UHF TV channels 21 to 60 with two DTT multiplexes in Channels 31 to 37, known as the 39 Channel case, with DTT
4. Scenario 4 models the number of WS channels in UHF TV Channels 21 to 48 with the six multiplexes, 3 Commercial (80 sites) and 3 Public Service (Greater than 1100 sites), known as the post 700 MHz clearance perspective

WS availability curves have also been calculated for three different levels of protection ratios:

1. WiMax use based on current protection assumptions.
2. WiFi use based on current protection assumptions.
3. A ‘WiFi Improved’ (WiFiI) case based on WiFi use with current protection assumptions up to +/-9 channels and only an overload protection level of 0dBm beyond that. This gives a likely best case estimate of TVWS availability based on potential future technical WSD improvements although it may be practically difficult to fully achieve this performance.

For this third technology scenario, the protection ratio assumptions are:

		WiFiI Protection ratio in dB						
DTT received power in dBm		**-70**	**-60**	**-50**	**-40**	**-30**	**-20**	**-12**
Channel offset Δf (8MHz)	Δf = ±1	-40	-38	-34	-31	-25	-15	-7
	Δf = ±2	-47	-47	-43	-33	-25	-15	-7
	Δf = ±3	-38	-34	-32	-32	-22	-12	-4
	3 < |Δf| < 9	Interpolate linearly in dB between f=±3 and f=±9						
	Δf = ±9	-39	-39	-36	-29	-19	-9	-1
	Δf >= ±10	-70	-60	-50	-40	-30	-20	-12

Table 1 Improved WiFi protection ratios (WiFiI)

The model developed by the BBC uses the same methodology and the reference geometry currently being used in the TVWS project, which includes:

1. Geographical availability based on populated 100m x 100m pixels
2. 1% location degradation to DTT signal sets the threshold for the permissible WSD power
3. DTT and WSD antennas at same 10m height outdoors and when the DTT receiver and WSD are in the same pixel a distribution of coupling losses is used in the calculation when they are not in the same pixel the DTT antenna pattern is taken into account.

The results simulations set out in this report should be treated as preliminary:

- The final technical parameters for coexistence with DTT are based on a range of initial assumptions about WSD technology choice and discussions are continuing in the TVWS project on different reception geometries. The current simulations have been made for number of different WSD technology approaches.
- The model only takes into account the need for WSDs to coexist with DTT, and not PMSE services.

The results are presented in a graphical form with aggregated number of 8 MHz channels along the horizontal axis and percentage of the total households which would receive a service on the vertical axis. A family of curves is produced each curve being for a different WS power.

A good reference point for comparison is the 20 dBm curve as this is close to the WiFi powers used in domestic WiFi wireless routers (17dBm).

The first set of results are for non contiguous 8 MHz channels, the channels do not have to be adjacent to each other in the spectrum band to be counted. The second

set of results are for groups of channels that have to be adjacent in the spectrum band to be counted.

Results

Non Contiguous 8 MHz channels – WiMax protection ratios

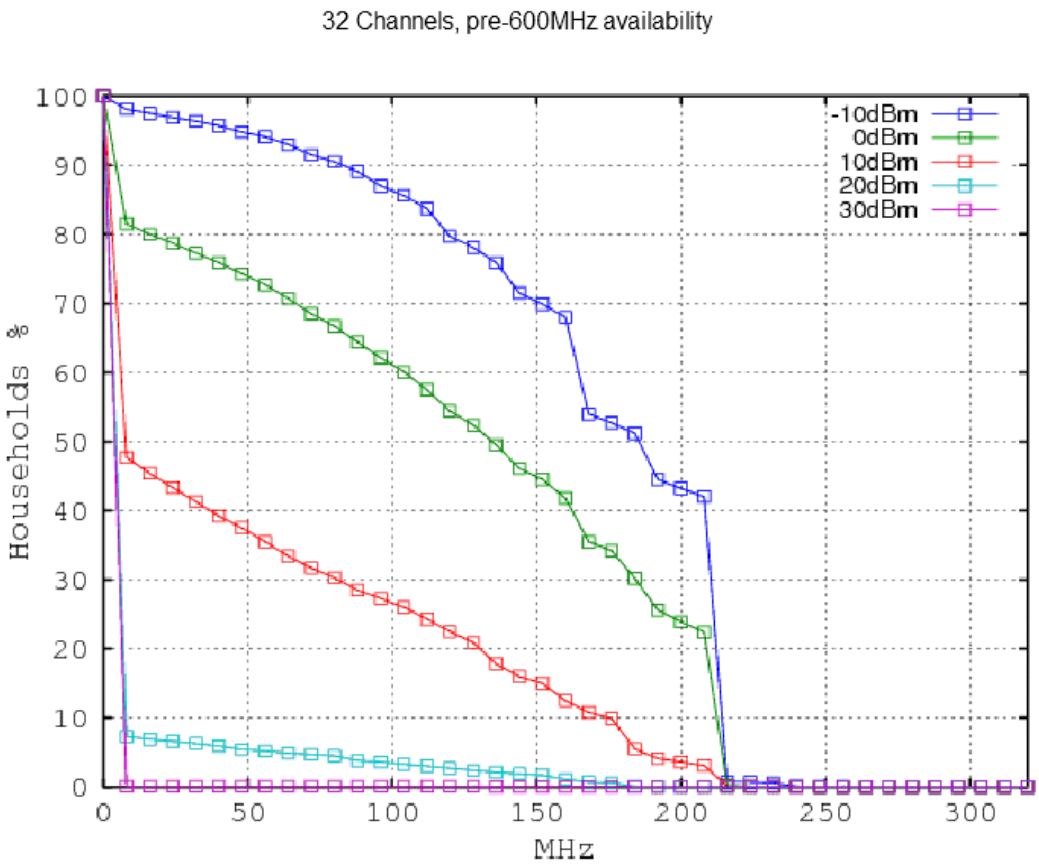

Figure 1: 32 Channels, no 600 MHz – WiMax PR

Figure 1 shows the number of households served against WS (WiMax) spectrum availability for a range of WS (WiMax) powers with no DTT or WS (WiMax) services in the 600 MHz band. For the 20 dBm/50 MHz point there are just over 5% of households which would get a WS (WiMax) service.

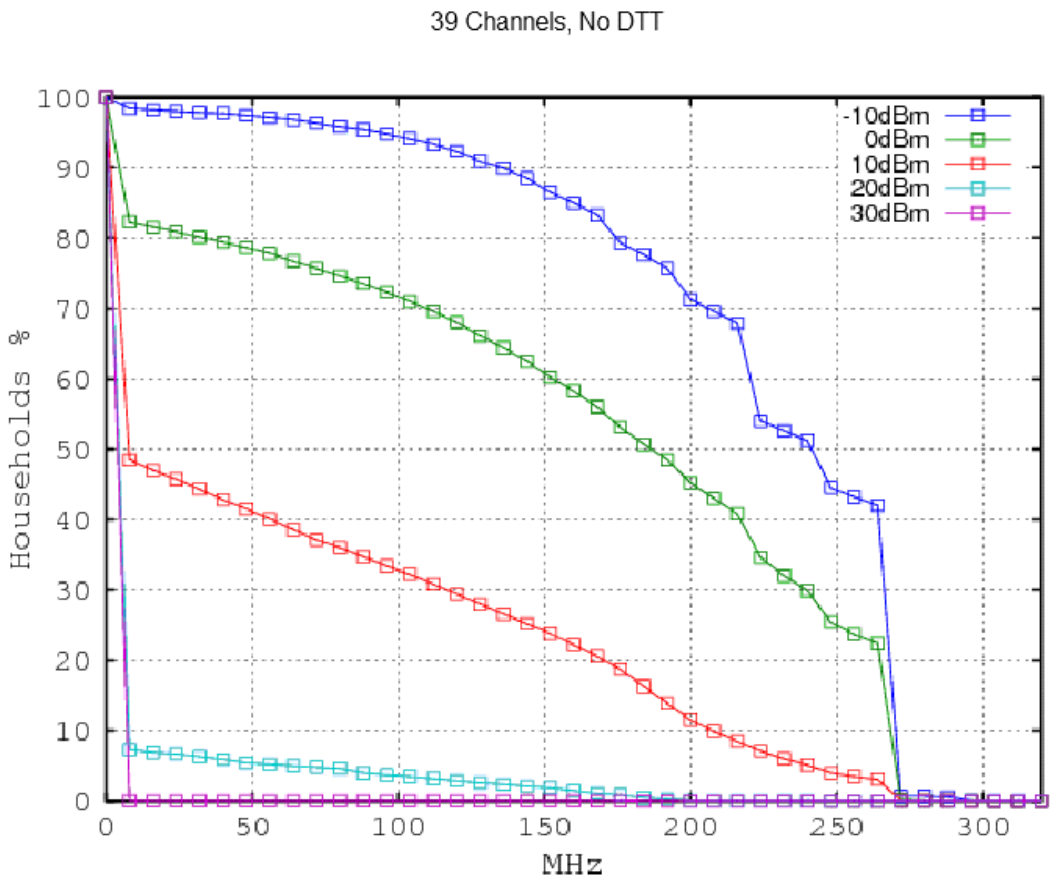

Figure 2: 39 Channels, no DTT – WiMax PR

Figure 2 shows the availability of WS spectrum where the 600 MHz spectrum is brought into play and is available for WS (WiMax) only and WS (WiMax) also uses the interleaved spectrum in the rest of the UHF TV band. For the 20 dBm/50 MHz point this analysis shows that 6% of households would get a WS service.

39 Channels, with two DTT multiplexes

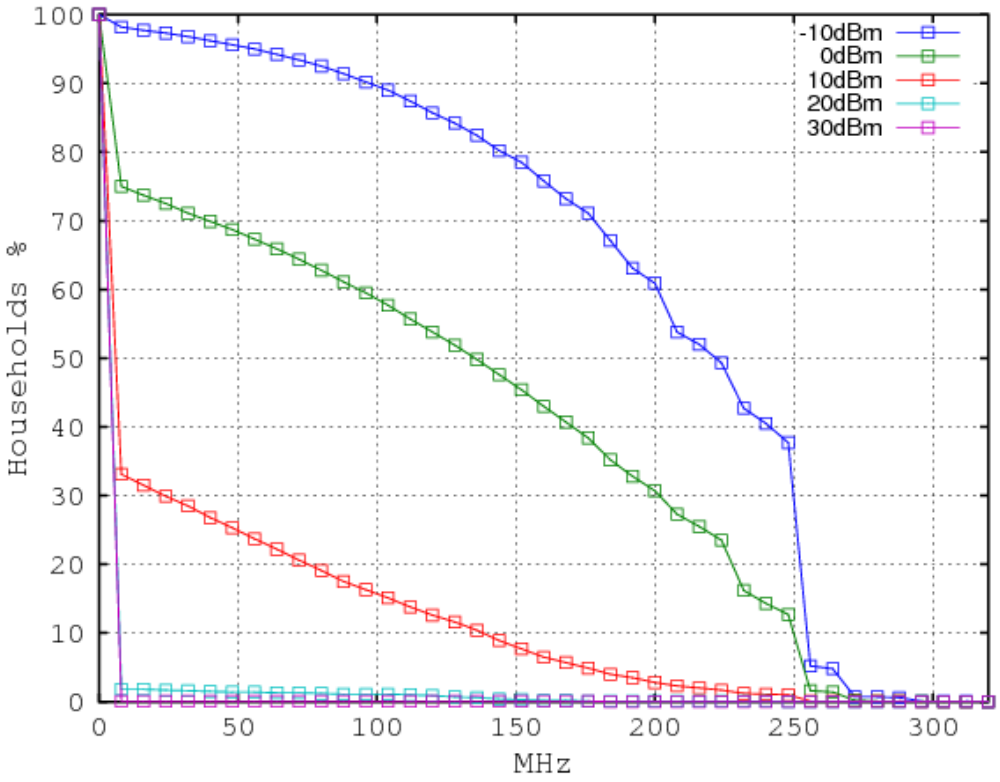

Figure 3: 39 Channels, with two DTT multiplexes – WiMax PR

Figure 3 shows the availability of spectrum for WS (WiMax) by households when two DTT multiplexes are introduced in the 600 MHz band. The two new DTT networks comprise of the top 25 sites in terms of population served. The WS (WiMax) channels are interleaved between the DTT channels between UHF TV channels 21 to 60. For the 20 dBm/50 MHz point 2% of households could be served by WS (WiMax) services.

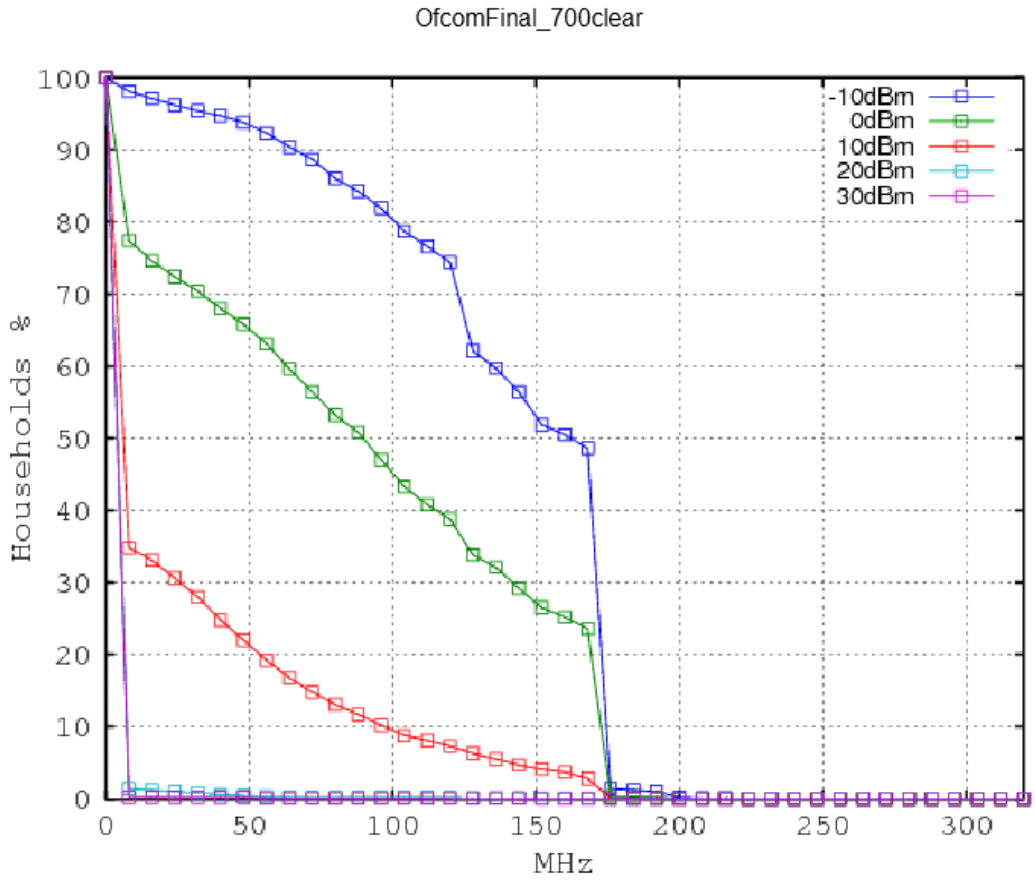

Figure 4: Channels 21 to 48, 3 Commercial DTT Multiplexes (80 sites) and 3 Public Service Multiplexes (greater than 1100 sites) –WiMax PR

Figure 4 shows the availability of spectrum for WS by households when six DTT multiplexes based on an illustrative frequency plan for UK DTT in a post 700 MHz cleared environment. The three commercial multiplexes operating from the 80 high power sites to give 90%+ population coverage. The three public service multiplexes are running from over 1100 sites across the UK to deliver 98.5% population coverage. For the 20 dBm/50 MHz point the analysis shows 0% of households would get a WS (WiMax) service.

Scenario (Channels discrete and or contiguous)	Percentage of households served for 20 dBm/50 MHz	Percentage change to when compared to 32 channel case
32 Channels, no 600 MHz – WiMax PR	5%	-
39 Channels, no DTT – WiMax PR	6%	+1%
39 Channels, with two DTT multiplexes – WiMax PR	2%	-3%
Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiMax PR	0%	-5%

Table 2 for the four scenarios modelled using the WiMax protection ratio curves, the UK population who would get 50 MHz of spectrum at 20 dBm for WS services.

Non Contiguous 8 MHz channels – WiFi protection ratios

32 Channels, no 600 MHz availability – WiFi PR

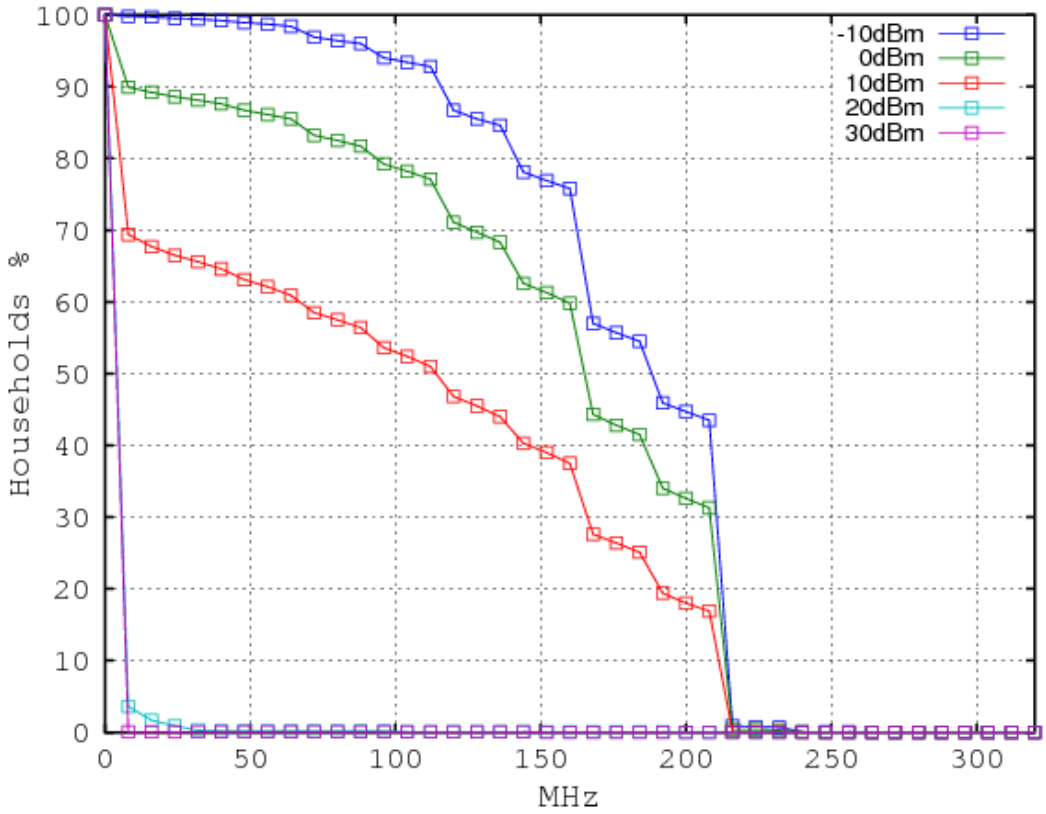

Figure 5: 32 Channels, no 600 MHz availability – WiFi PR

Figure 5 shows the number of households served against WS (WiFi) spectrum availability for a range of WS (WiFi) powers with no DTT or WS (WiFi) services in the 600 MHz band. For the 20 dBm/50 MHz point there are 0% of households which would get a WS (WiFi) service.

39 Channels, no DTT – WiFi PR

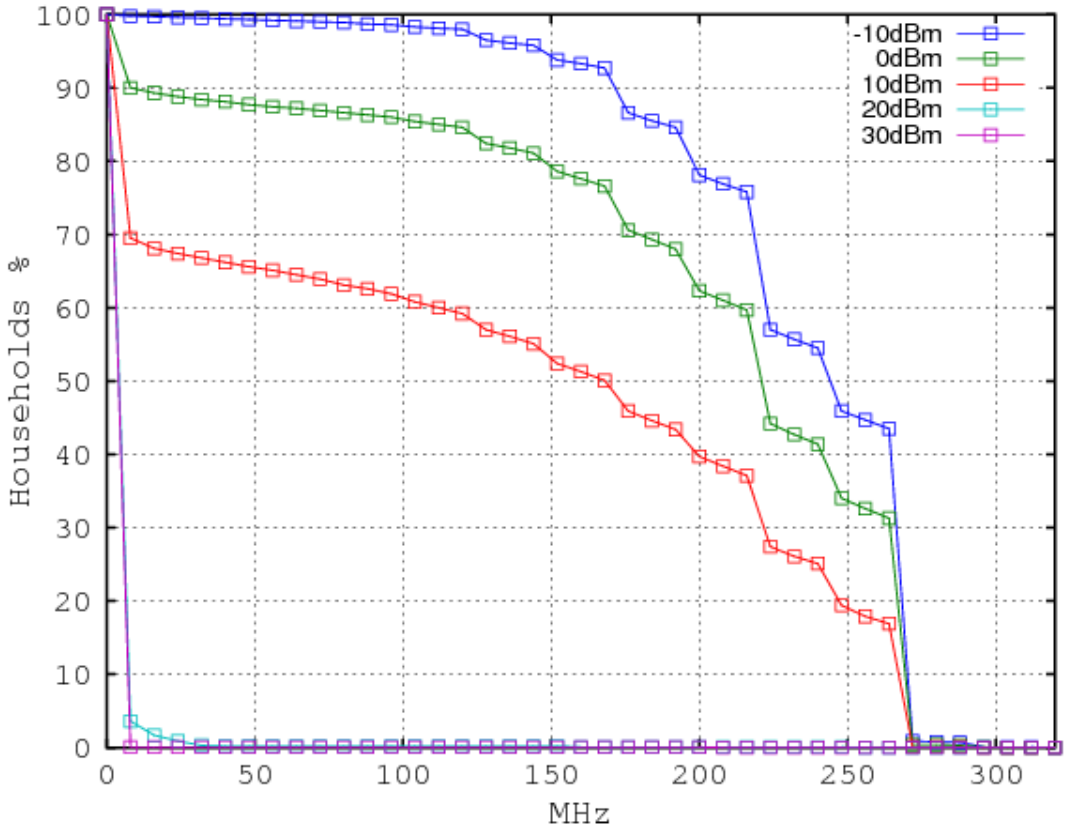

Figure 6: 39 Channels, no DTT – WiFi PR

Figure 6 shows the availability of WS (WiFi) spectrum where the 600 MHz spectrum is brought into play and is available for WS (WiFi) only and WS (WiFi) also uses the interleaved spectrum in the rest of the UHF TV band. For the 20 dBm/50 MHz point this analysis suggests that 0% of households would get a WS service.

39 Channels, with two DTT multiplexes – WiFi PR

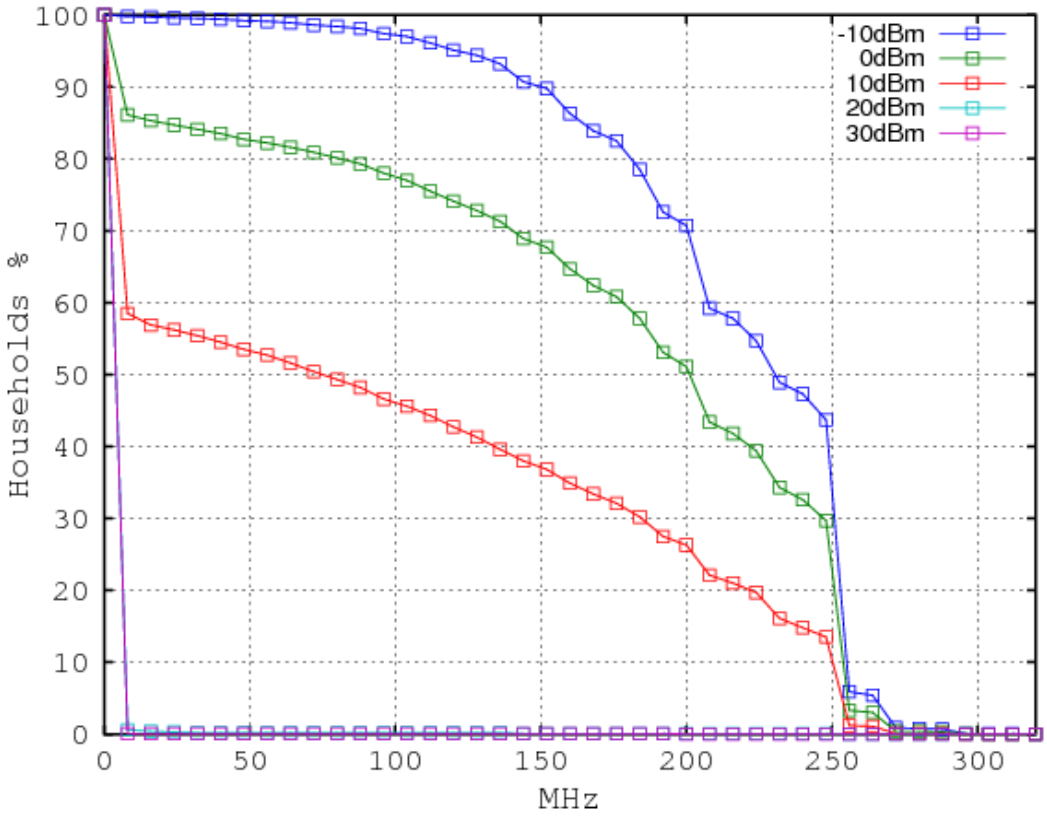

Figure 7: 39 Channels, with two DTT multiplexes – WiFi PR

Figure 7 shows the availability of spectrum for WS (WiFi) by households when two DTT multiplexes are introduced in the 600 MHz band. The two new DTT networks comprise of the top 25 sites in terms of population served. The WS (WiFi) channels are interleaved between the DTT channels between UHF TV channels 21 to 60. For the 20 dBm/50 MHz point 0% of households could be served by WS (WiFi) services.

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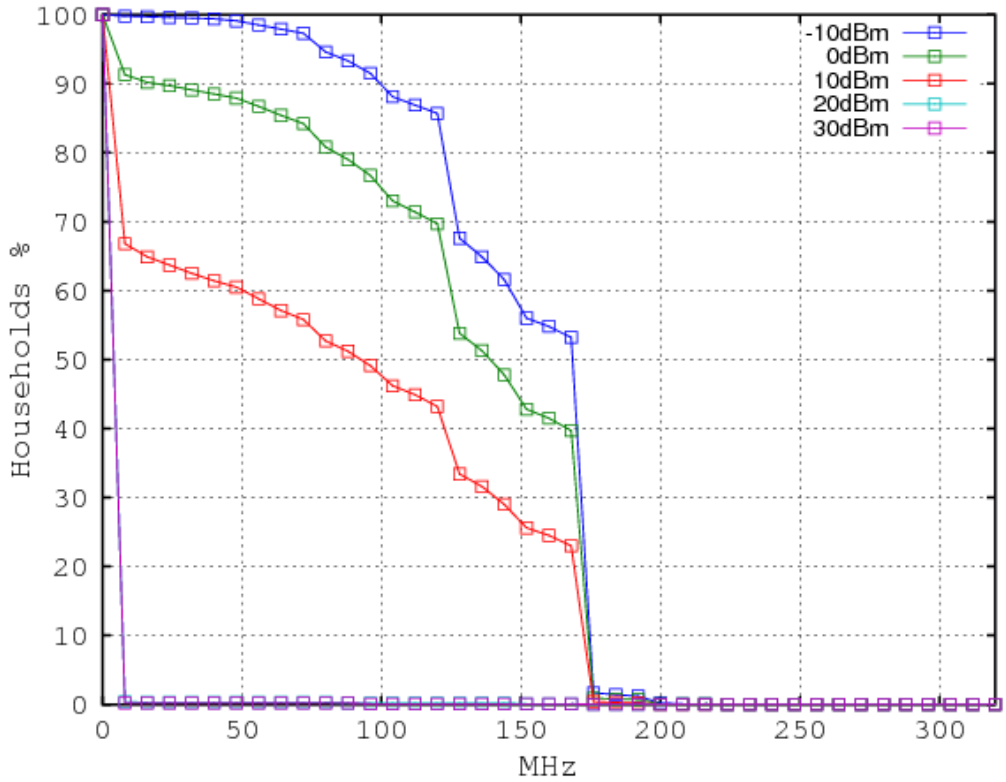

Figure 8: Channels 21 to 48, 3 Commercial DTT Multiplexes (80 sites) and 3 Public Service Multiplexes (greater than 1100 sites) –WiFi PR

Figure 8 shows the availability of spectrum for WS by households when six DTT multiplexes based on an illustrative frequency plan for UK DTT in a post 700 MHz cleared environment. The three commercial multiplexes operating from the 80 high power sites to give 90%+ population coverage. The three public service multiplexes are running from over 1100 sites across the UK to deliver 98.5% population coverage. For the 20 dBm/50 MHz point the analysis shows 0% of households would get a WS (WiFi) service.

Scenario (Channels discrete and or contiguous)	Percentage of households served for 20 dBm/50 MHz	Percentage change to when compared to 32 channel case
32 Channels, no 600 MHz – WiFi PR	0%	-
39 Channels, no DTT – WiFi PR	0%	0%
39 Channels, with two DTT multiplexes – WiFi PR	0%	0%
Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiFi PR	0%	0%

Table 3 for the three scenarios modelled using the WiFi protection ratio curves, the UK population who would get 50 MHz of spectrum at 20 dBm for WS services.

Non Contiguous 8 MHz channels – WiFi 'improved' (WiFiI) protection ratios

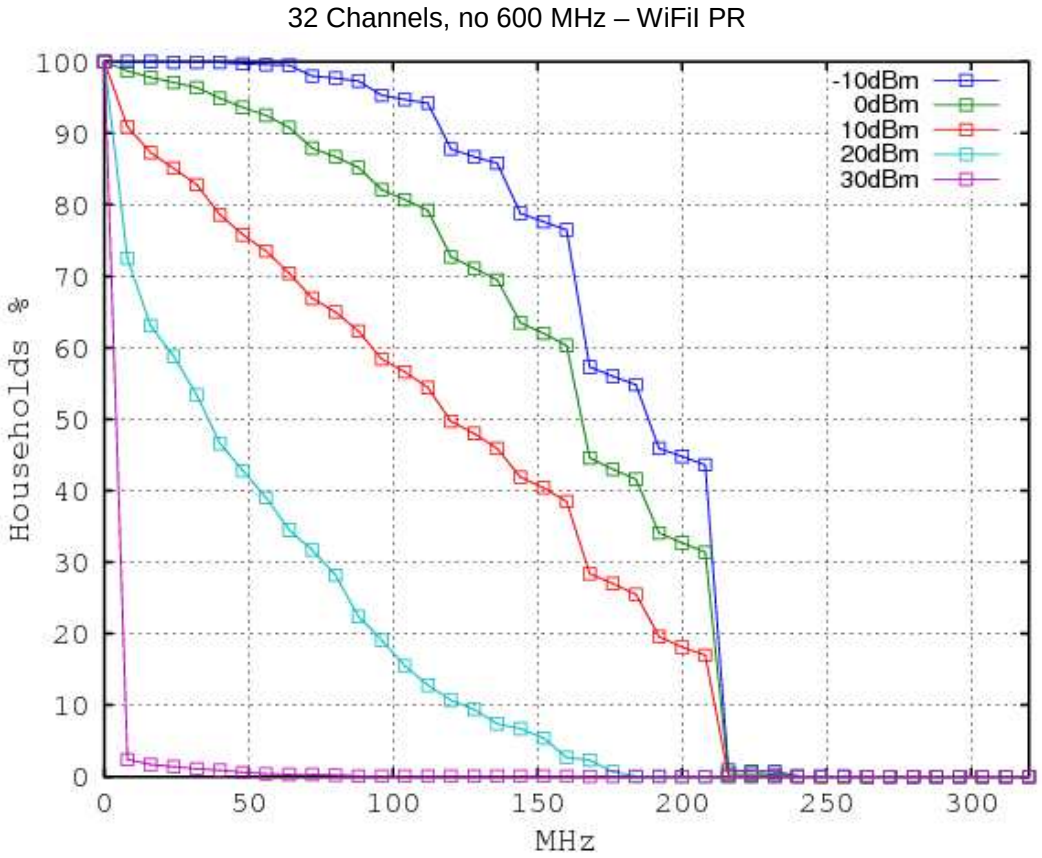

Figure 9: 32 Channels, no 600 MHz – WiFiI PR

Figure 9 shows the number of households served against WS (WiFiI) spectrum availability for a range of WS (WiFiI) powers with no DTT or WS (WiFiI) services in the 600 MHz band. For the 20 dBm/50 MHz point there are just over 42% of households which would get a WS (WiFiI) service.

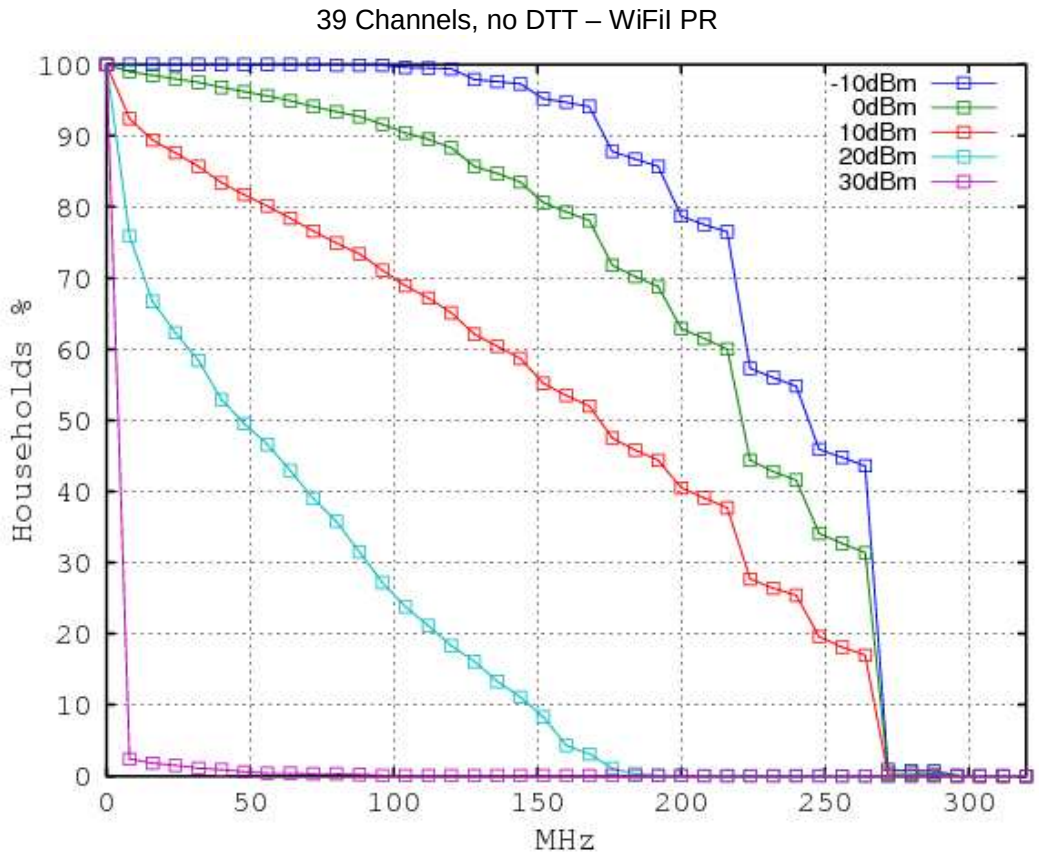

Figure 10: 39 Channels, no DTT – WiFiI PR

Figure 10 shows the availability of WS (WiFiI) spectrum where the 600 MHz spectrum is brought into play and is available for WS (WiFiI) only and WS (WiFiI) also uses the interleaved spectrum in the rest of the UHF TV band. For the 20 dBm/50 MHz point this analysis suggests that 48% of households would get a WS service.

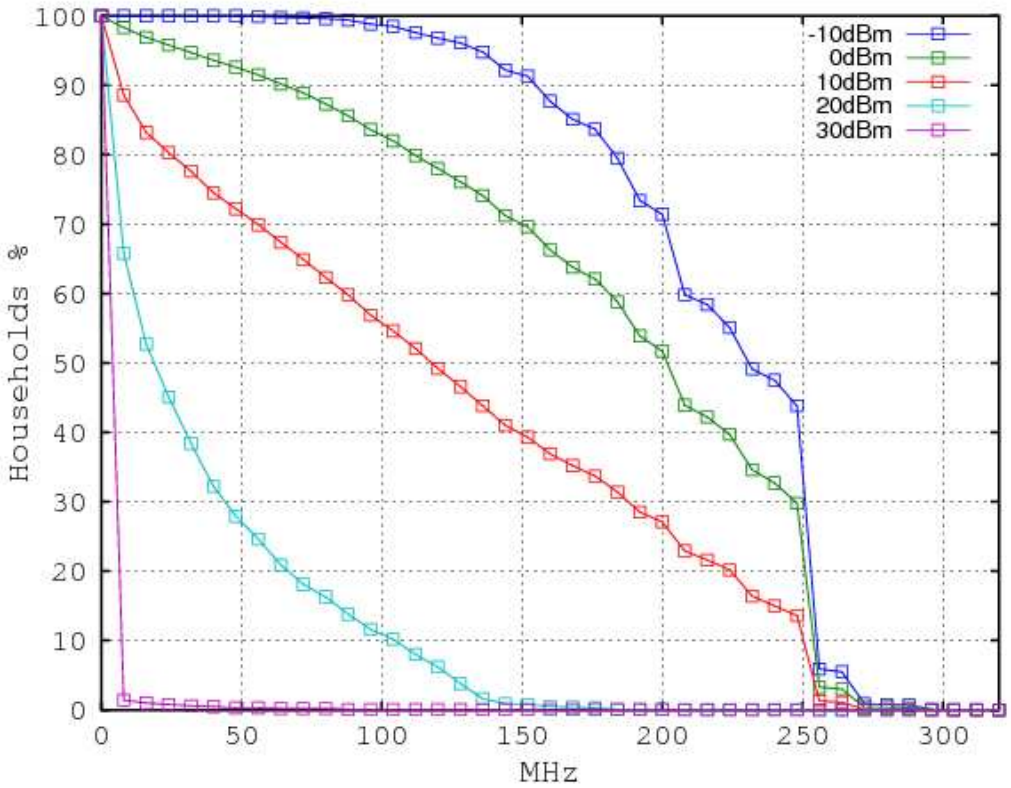

Figure 11: 39 Channels, with two DTT multiplexes – WiFiI PR

Figure 11 shows the availability of spectrum for WS (WiFiI) by households when two DTT multiplexes are introduced in the 600 MHz band. The two new DTT networks comprise of the top 25 sites in terms of population served. The WS (WiFiI) channels are interleaved between the DTT channels between UHF TV channels 21 to 60. For the 20 dBm/50 MHz point potentially 27% of households could be served by WS (WiFiI) services.

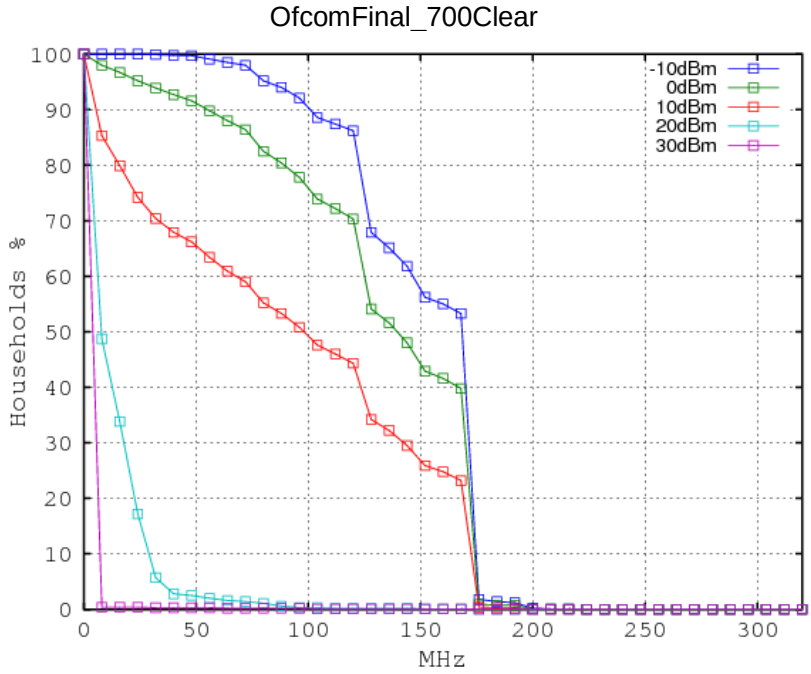

Figure 12: Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiFiI PR

Figure 12 shows the availability of spectrum for WS (WiFiI) by households when six DTT multiplexes based on an illustrative frequency plan for UK DTT in a post 700 MHz cleared environment. The three commercial multiplexes operating from the 80 high power sites to give 90%+ population coverage. The three public service multiplexes are running from over 1100 sites across the UK to deliver 98.5% population coverage. For the 20 dBm/50 MHz point there are potentially 3% of households that would get a WS (WiFiI) service.

Scenario (Channels discrete and or contiguous)	Percentage of households served for 20 dBm/50 MHz	Percentage change to when compared to 32 channel case
32 Channels, no 600 MHz – WiFiI PR	42%	-
39 Channels, no DTT – WiFiI PR	48%	+6%
39 Channels, with two DTT multiplexes – WiFiI PR	27%	-15%
Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiFiI PR	3%	-39%

Table 4 for the four scenarios modelled using the WiFiI protection ratio curves, the UK population who would get 50 MHz of spectrum at 20 dBm for WS services.

Contiguous 8 MHz channels – 32 Channels no 600 MHz – WiMax protection ratios

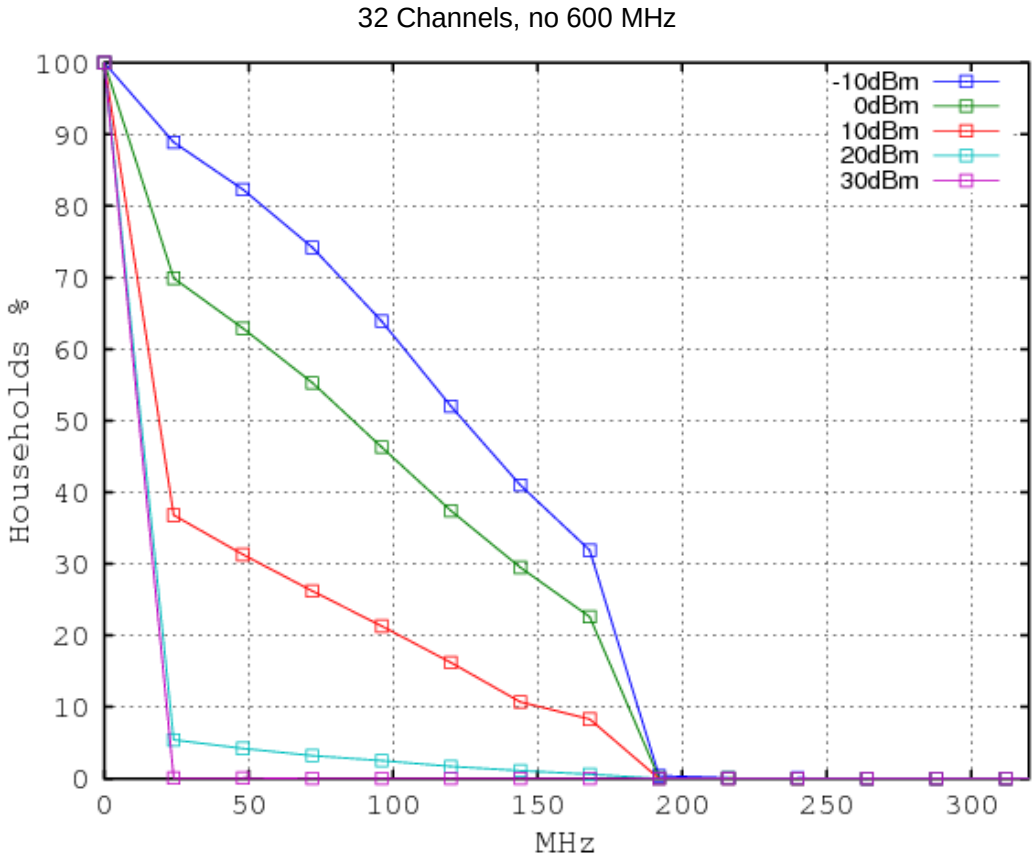

Figure 13: 32 Channels no 600 MHz, percentage of house holds served by 3 adjacent 8 MHz channels – WiMax PR

Figure 13 shows the number of households served against WS (WiMax) spectrum availability for a range of WS (WiMax) powers with no DTT or WS (WiMax) services in the 600 MHz band. For the 20 dBm/50 MHz point there are 4% of households which would get a WS (WiMax) service. This is two pairs of three contiguous 8 MHz channels (48 MHz)

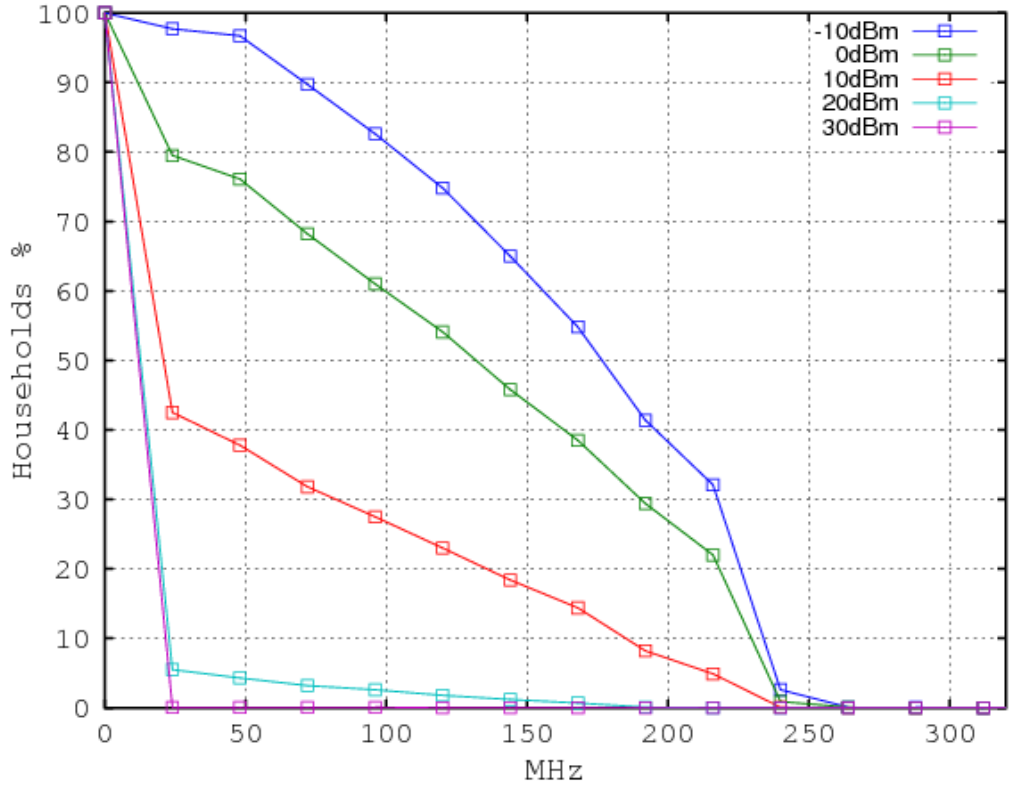

Figure 14: 39 Channels, no DTT – WiMax PR

Figure 14 shows the availability of WS (WiMax) spectrum where the 600 MHz spectrum is brought into play and is available for WS (WiMax) only and WS (WiMax) also uses the interleaved spectrum in the rest of the UHF TV band. For the 20 dBm/50 MHz point this analysis suggests that 4% of households would get a WS service. This is two pairs of three contiguous 8 MHz channels (48 MHz)

39 Channels, with two DTT multiplexes

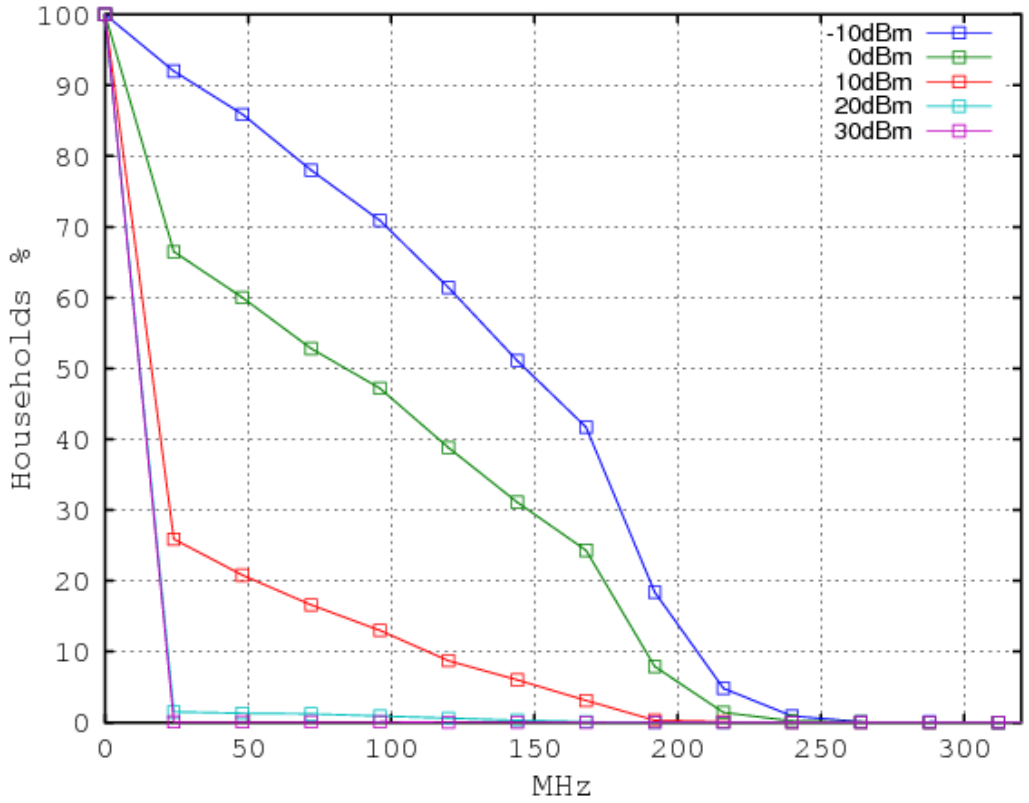

Figure 15: 39 Channels, with two DTT multiplexes – WiMax PR

Figure 15 shows the availability of spectrum for WS (WiMax) by households when two DTT multiplexes are introduced in the 600 MHz band. The two new DTT networks comprise of the top 25 sites in terms of population served. The WS (WiMax) channels are interleaved between the DTT channels between UHF TV channels 21 to 60. For the 20 dBm/50 MHz point 2% of households could be served by WS (WiMax) services. This is two pairs of three contiguous 8 MHz channels (48 MHz)

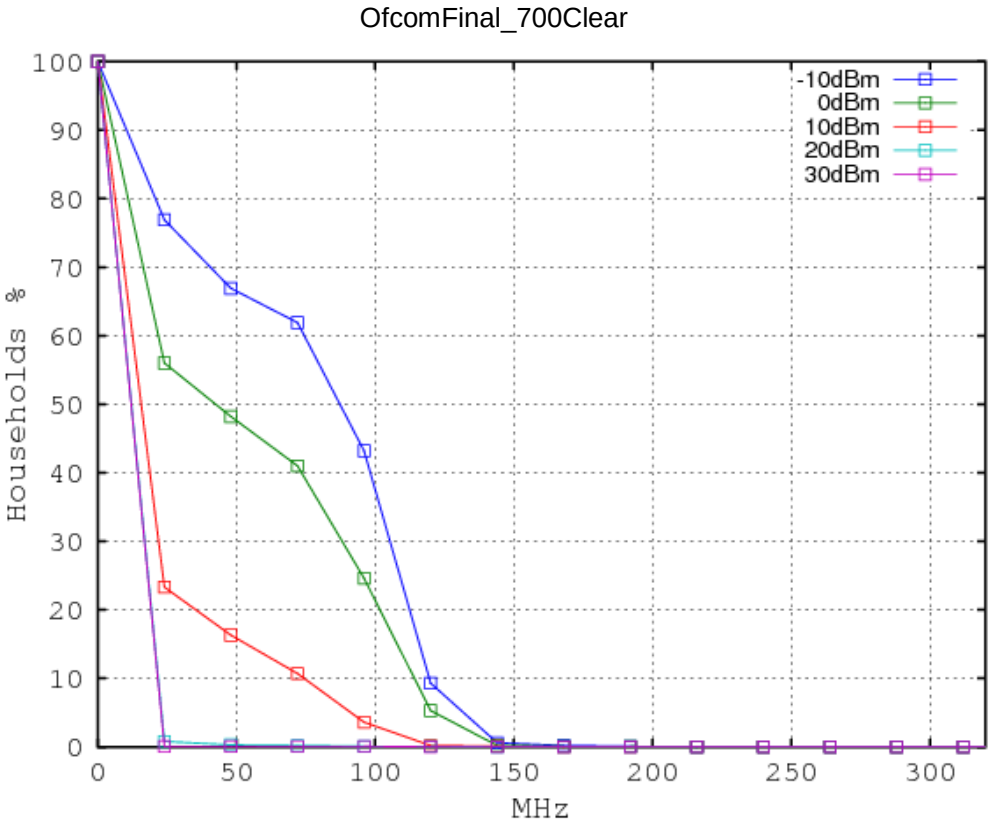

Figure 16: Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiMax PR

Figure 16 shows the availability of spectrum for WS (WiMax) by households when six DTT multiplexes based on an illustrative frequency plan for UK DTT in a post 700 MHz cleared environment. The three commercial multiplexes operating from the 80 high power sites to give 90%+ population coverage. The three public service multiplexes are running from over 1100 sites across the UK to deliver 98.5% population coverage. For the 20 dBm/50 MHz point there are 0% of households that would get a WS (WiMax) service.

Scenario (two pairs of three contiguous 8 MHz channels)	Percentage of households served for 20 dBm/50 MHz	Percentage change to when compared to 32 channel case
32 Channels, no 600 MHz – WiMax PR	4%	-
39 Channels, no DTT – WiMax PR	4%	0%
39 Channels, with two DTT multiplexes – WiMax PR	2%	-2%
Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiMax PR	0%	-4%

Table 5 for the four scenarios modelled using the WiMax protection ratio curves, the UK population who would get 50 MHz of spectrum at 20 dBm for WS services. This is two pairs of three contiguous 8 MHz channels (48 MHz)

Contiguous 8 MHz channels – 32 Channels no 600 MHz – WiFi protection ratios

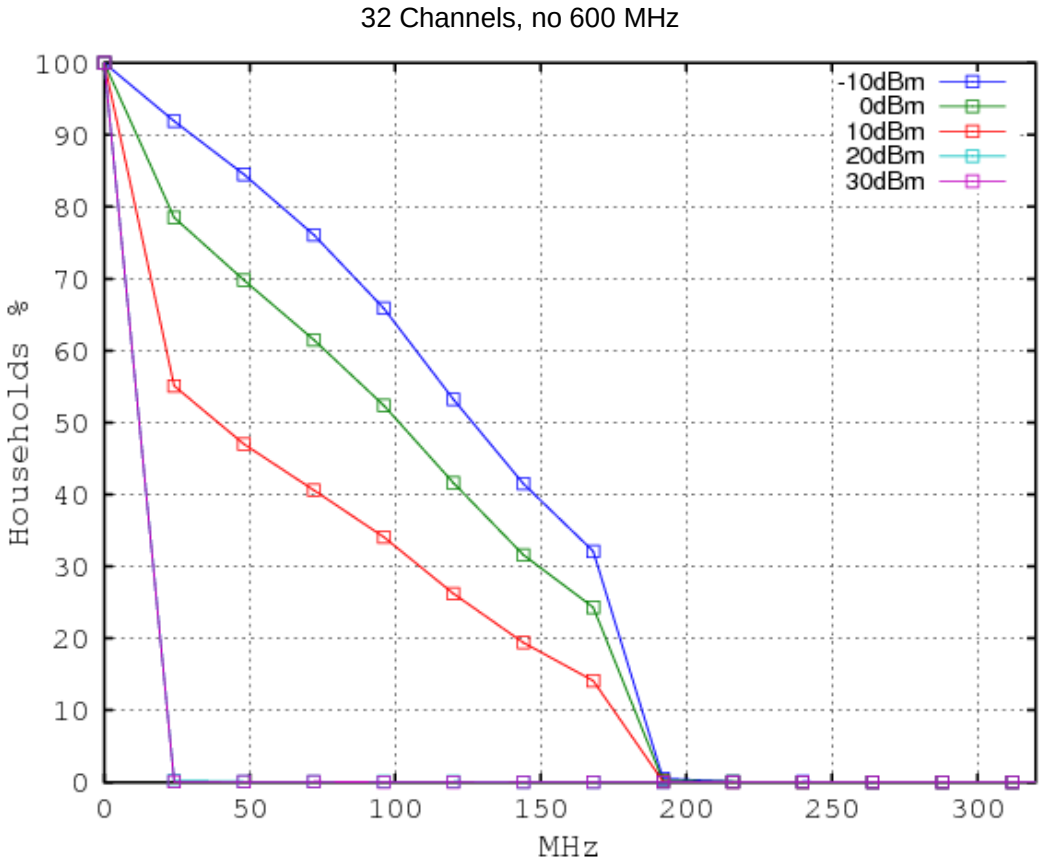

Figure 17: 32 Channels no 600 MHz, percentage of house holds served by 3 adjacent 8 MHz channels – WiFi PR

Figure 17 shows the number of households served against WS (WiFi) spectrum availability for a range of WS (WiFi) powers with no DTT or WS (WiFi) services in the 600 MHz band. For the 20 dBm/50 MHz point there are 0% of households which would get a WS (WiFi) service. This is two pairs of three contiguous 8 MHz channels (48 MHz)

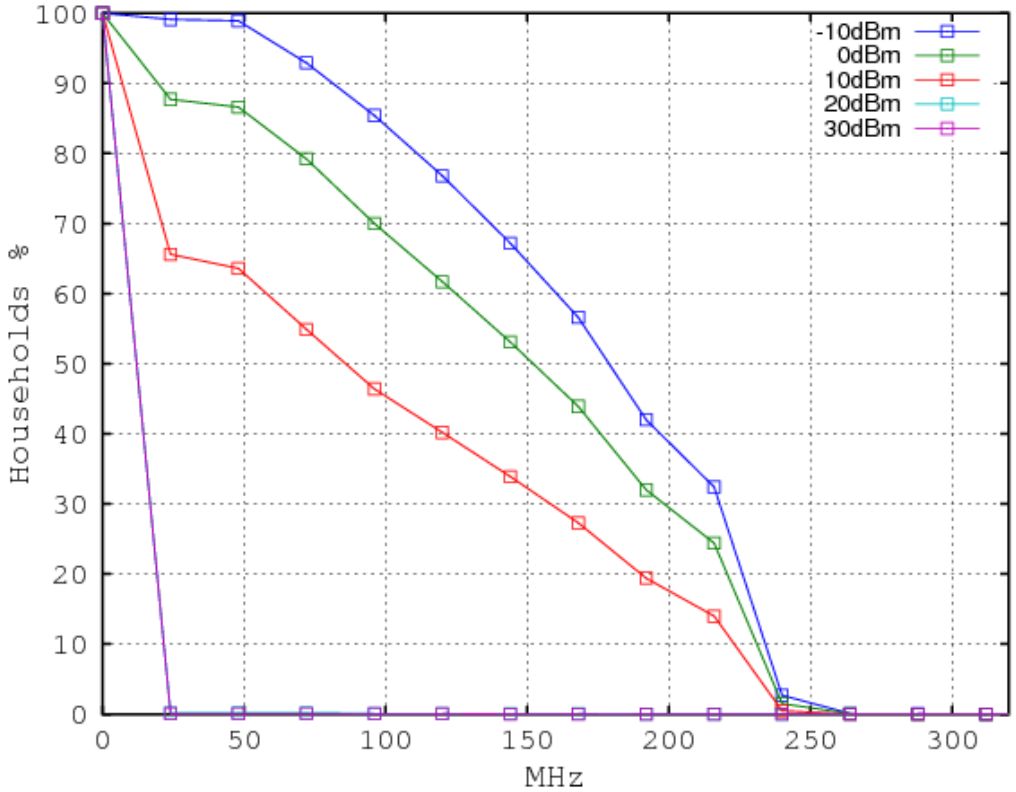

Figure 18: 39 Channels, no DTT – WiFi PR

Figure 18 shows the availability of WS (WiFi) spectrum where the 600 MHz spectrum is brought into play and is available for WS (WiFi) only and WS (WiFi) also uses the interleaved spectrum in the rest of the UHF TV band. For the 20 dBm/50 MHz point this analysis suggests that 0% of households would get a WS service. This is two pairs of three contiguous 8 MHz channels (48 MHz)

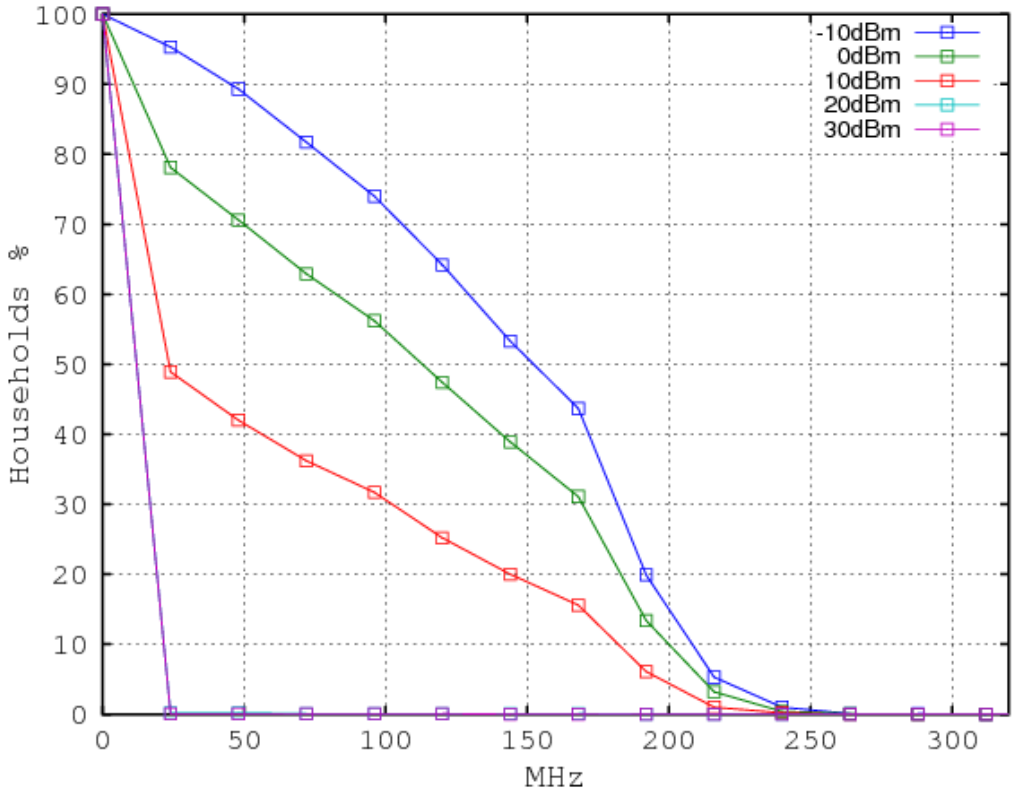

Figure 19: 39 Channels, with two DTT multiplexes – WiFi PR

Figure 19 shows the availability of spectrum for WS (WiFi) by households when two DTT multiplexes are introduced in the 600 MHz band. The two new DTT networks comprise of the top 25 sites in terms of population served. The WS (WiFi) channels are interleaved between the DTT channels between UHF TV channels 21 to 60. For the 20 dBm/50 MHz point 0% of households could be served by WS (WiFi) services. This is two pairs of three contiguous 8 MHz channels (48 MHz)

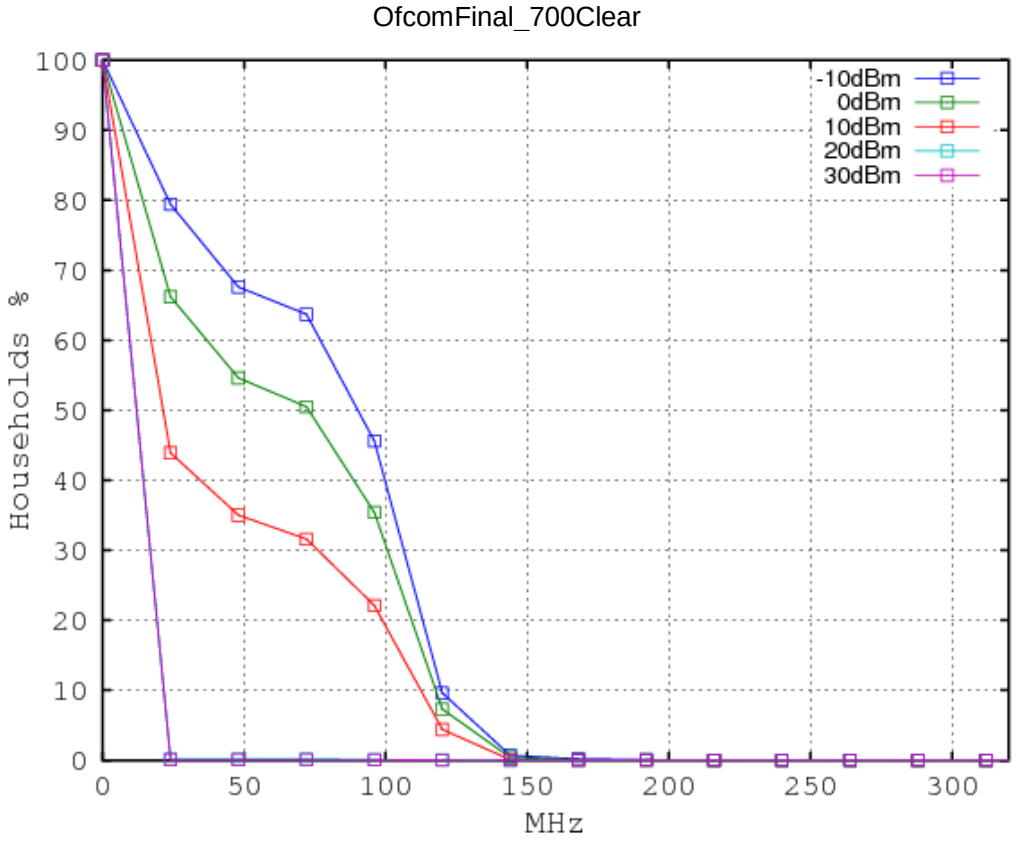

Figure 20: Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiFi PR

Figure 20 shows the availability of spectrum for WS (WiFi) by households when six DTT multiplexes based on an illustrative frequency plan for UK DTT in a post 700 MHz cleared environment. The three commercial multiplexes operating from the 80 high power sites to give 90%+ population coverage. The three public service multiplexes are running from over 1100 sites across the UK to deliver 98.5% population coverage. For the 20 dBm/50 MHz point there are 0% of households that would get a WS (WiFi) service.

Scenario (two pairs of three contiguous 8 MHz channels)	Percentage of households served for 20 dBm/50 MHz	Percentage change to when compared to 32 channel case
32 Channels, no 600 MHz – WiFi PR	0%	-
39 Channels, no DTT – WiFi PR	0%	0%
39 Channels, with two DTT multiplexes – WiFi PR	0%	0%
Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) – WiFi PR	0%	0%

Table 6 for the three scenarios modelled using the WiFi protection ratio curves, the UK population who would get 50 MHz of spectrum at 20 dBm for WS services. This is two pairs of three contiguous 8 MHz channels (48 MHz)

Contiguous 8 MHz channels – 32 Channels no 600 MHz – WiFi 'improved' (WiFiI) protection ratios

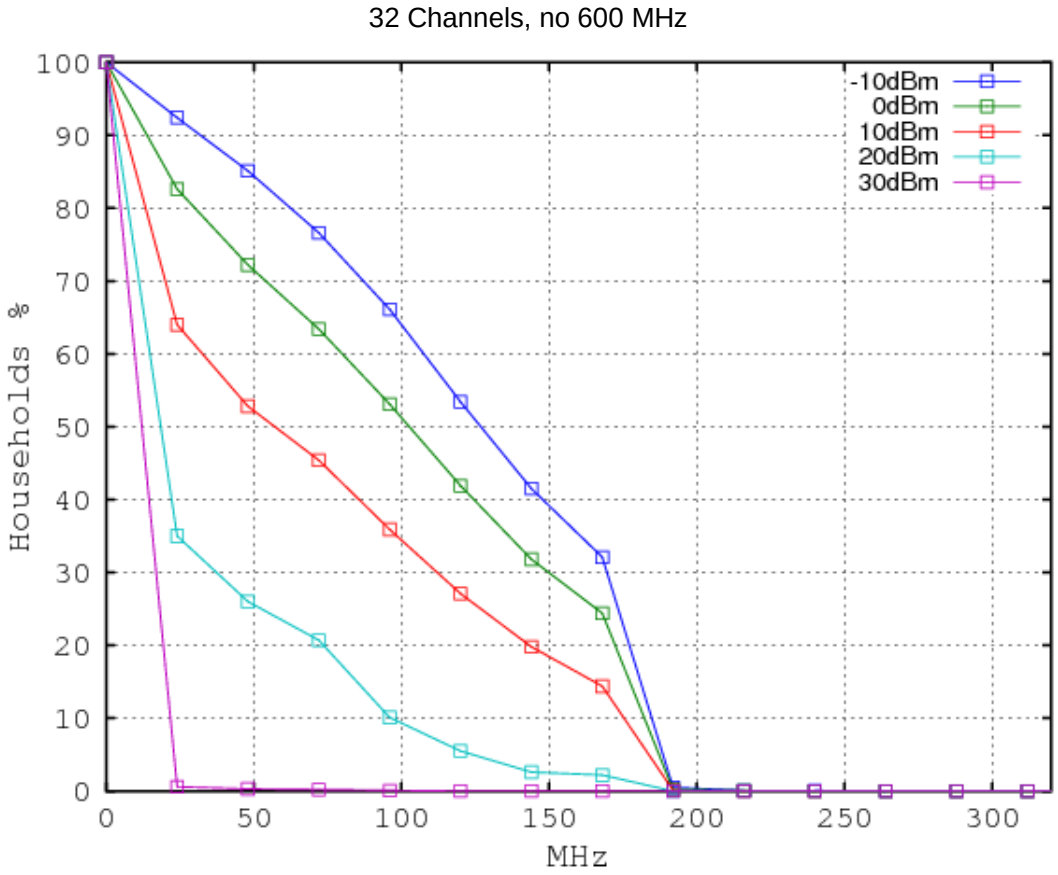

Figure 21: 32 Channels no 600 MHz, percentage of house holds served by 3 adjacent 8 MHz channels – WiFiI PR

Figure 21 shows the number of households served against WS (WiFiI) spectrum availability for a range of WS (WiFiI) powers with no DTT or WS (WiFiI) services in the 600 MHz band. For the 20 dBm/50 MHz point there are 26% of households which would get a WS (WiFiI) service. This is two pairs of three contiguous 8 MHz channels (48 MHz)

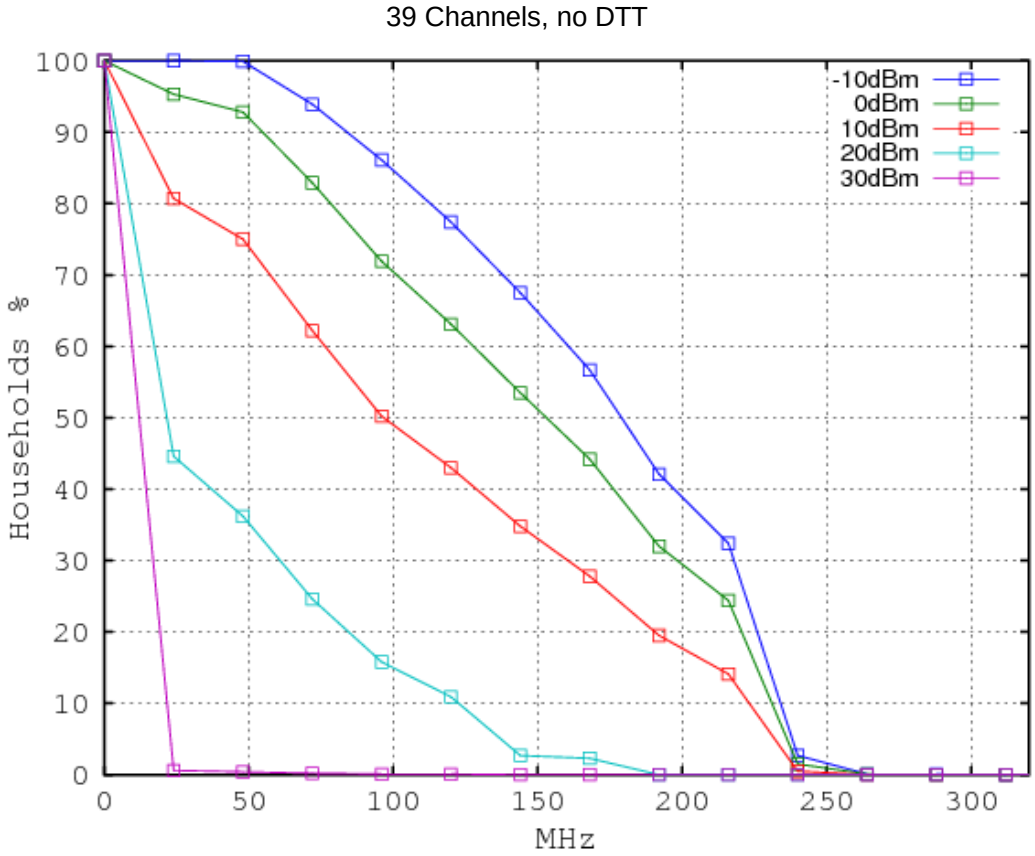

Figure 22: 39 Channels, no DTT – WiFiI PR

Figure 22 shows the availability of WS (WiFiI) spectrum where the 600 MHz spectrum is brought into play and is available for WS (WiFiI) only and WS (WiFiI) also uses the interleaved spectrum in the rest of the UHF TV band. For the 20 dBm/50 MHz point this analysis suggests that 36% of households would get a WS service. This is two pairs of three contiguous 8 MHz channels (48 MHz)

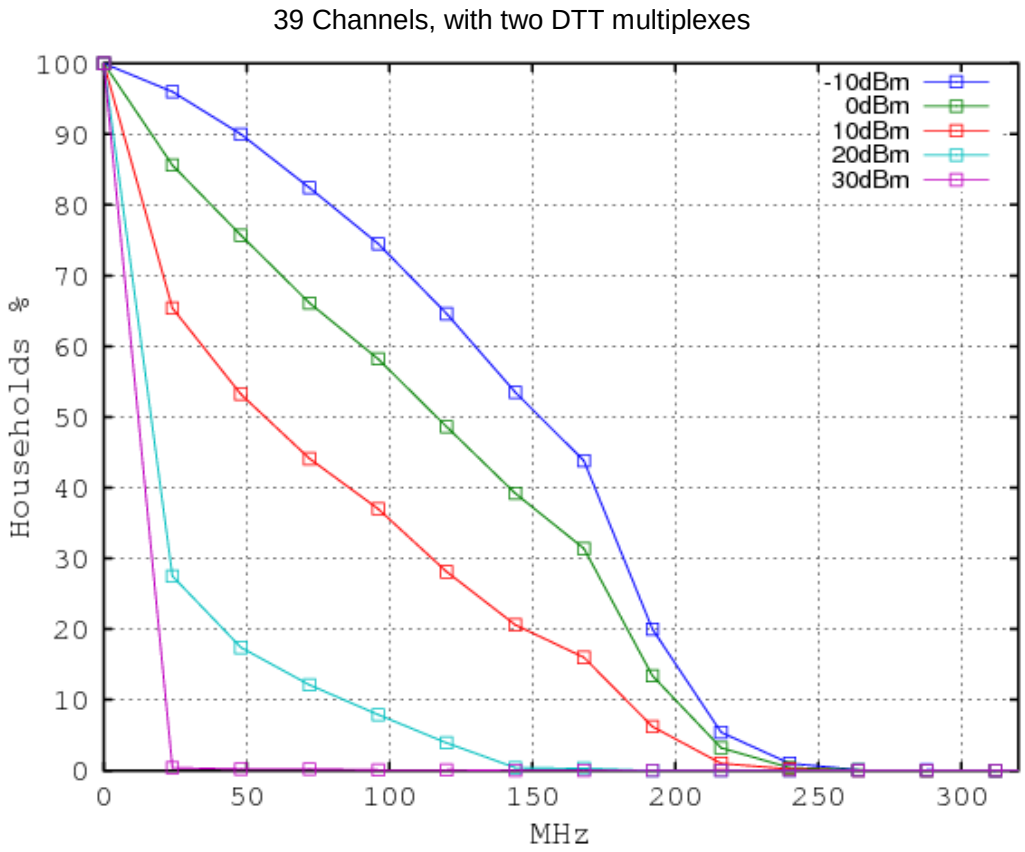

Figure 23: 39 Channels, with two DTT multiplexes – WiFiI PR

Figure 23 shows the availability of spectrum for WS (WiFiI) by households when two DTT multiplexes are introduced in the 600 MHz band. The two new DTT networks comprise of the top 25 sites in terms of population served. The WS (WiFiI) channels are interleaved between the DTT channels between UHF TV channels 21 to 60. For the 20 dBm/50 MHz point potentially 18% of households could be served by WS (WiFiI) services. This is two pairs of three contiguous 8 MHz channels (48 MHz).

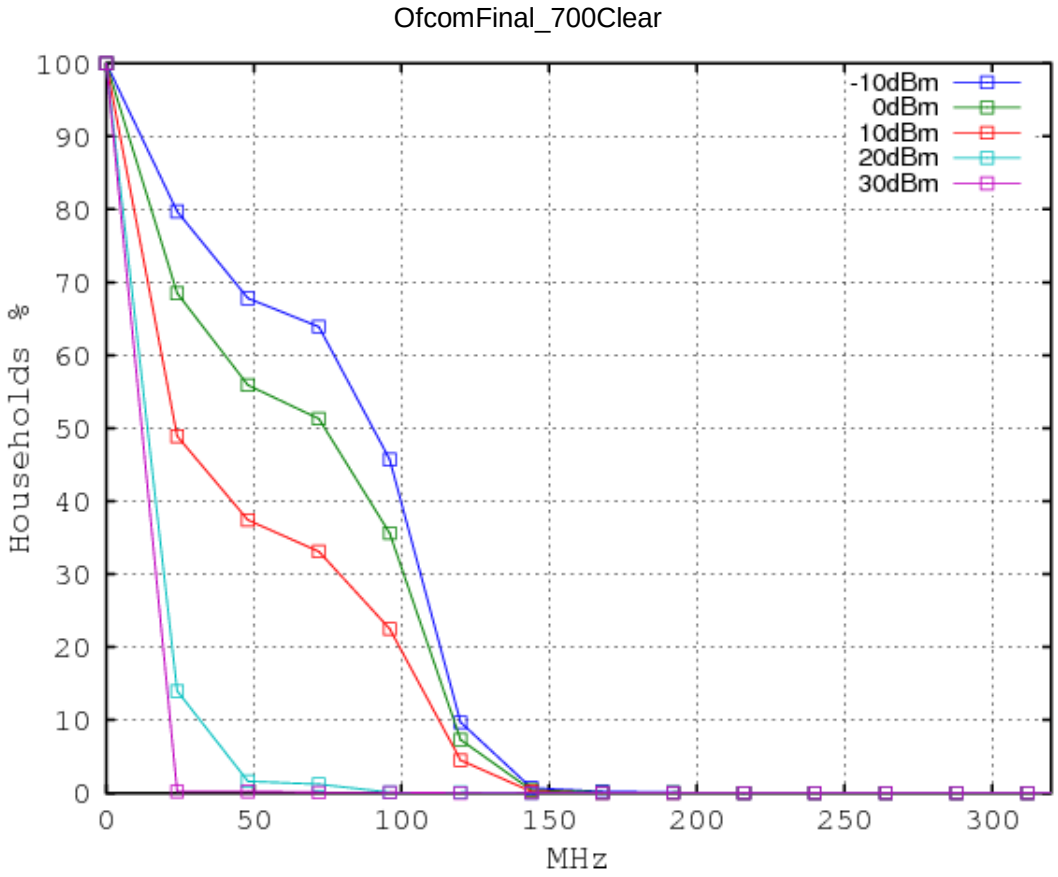

Figure 24: Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiFiI PR

Figure 24 shows the availability of spectrum for WS (WiFiI) by households when six DTT multiplexes based on an illustrative frequency plan for UK DTT in a post 700 MHz cleared environment. The three commercial multiplexes operating from the 80 high power sites to give 90%+ population coverage. The three public service multiplexes are running from over 1100 sites across the UK to deliver 98.5% population coverage. For the 20 dBm/50 MHz point there are 2% of households that would get a WS (WiFiI) service.

Scenario (two pairs of three contiguous 8 MHz channels)	Percentage of households served for 20 dBm/50 MHz	Percentage change to when compared to 32 channel case
32 Channels, no 600 MHz – WiFiI PR	26%	-
39 Channels, no DTT – WiFiI PR	36%	+10%
39 Channels, with two DTT multiplexes – WiFiI PR	18%	-8%
Channels 21 to 48, 3 Com (80 sites) and 3 PSB (greater than 1100 sites) –WiFiI PR	2%	-24%

Table 7 for the four scenarios modelled using the WiFiI protection ratio curves, the UK population who would get 50 MHz of spectrum at 20 dBm for WS services. This is two pairs of three contiguous 8 MHz channels (48 MHz)

Conclusion

In the four scenarios considered WS channel availability is improved if the WSDs use a modulation scheme that coexists well with DTT receivers and produces very low out of band emissions.