Digital Dividend:
Channel 36 issues

Final Report for OFCOM

1913/DD/R/5.0

20th November 2007

Table of Contents

EXECUTIVE SUMMARY

The phased digital switchover of television services in UHF bands IV and V is planned to take place in the UK between 2007 and 2012. Digital broadcasting is more efficient than analogue, allowing more channels to be carried in a smaller bandwidth. As a result, Ofcom estimates that the digital switchover programme will allow 112 MHz of released spectrum (14 x 8 MHz channels) to be used for other services. In addition, interleaved spectrum within the 32 channels to be used for digital terrestrial television is also, potentially, available for other uses.

This report examines issues surrounding the possible early use of Channel 36. Channel 36 is currently used for aeronautical radar while Channels 35 and 37 are used to provide Channel 5 analogue TV service in the UK.

One potential use of channel 36 would be for DVB-H (or similar handheld TV) services. In this study, simulation models have been developed to examine adjacent channel interference between DVB-H services and analogue TV. One of the implications of interference is 'hole punching' where the protection ratio (i.e. the ratio of minimum wanted to unwanted signal) requirement is not satisfied because a receiver suffers interference from a local transmitter operating on a channel adjacent to the relatively weak wanted signal. The sensitivity of punched holes to a number of parameters (e.g. antenna height, protection ratio, transmit power) has been investigated.

The results indicate that the un-coordinated provision of DVB-H services in channel 36 will cause significant levels of interference to analogue TV transmissions on Channels 35 and 37. The high probability is fundamentally due to the high field strengths required by a practical DVB-H services, coupled with a protection ratio (DVB-H into PAL system I) of some -5dB for adjacent channel operation. For an uncoordinated DVB-H network implemented using a dense network of low power transmitters, it is estimated that interference would be caused to some 3% of channel 5 analogue TV viewers.

Such interference may be avoided by ensuring that DVB-H transmitters are co-located with the analogue services. In some areas this will lead to a satisfactory DVB-H service, particularly where the analogue transmitter is located in a dense urban area (as at Croydon). In such areas, however, the DVB-H service area will be much smaller than that for the analogue service; if relay transmitters are installed to rectify this, they will cause interference to the analogue services, which (by definition) will be relatively weak in the areas where such relays might be installed.

In many other cases, however, the analogue transmission site is too far from target DVB-H coverage areas to provide a reliable DVB-H service (while the analogue coverage is satisfactory due to the greater height and gain of the domestic receive aerial).

The international co-ordination of a network of co-located DVB-H transmitters, of similar power to the analogue services with which they are sited, is likely to be very

challenging. If DVB-H services are implemented with lower-power, co-sited transmitters, co-ordination will be significantly eased, but large coverage deficiencies will remain.

After digital switchover, channels 35 and 37 will be available for other services. One of the options is to deploy DVB-T service in these channels. Therefore, further modelling has been implemented to investigate interference between DVB-H and DVB-T services. In this case the more relaxed protection ratio of DVB-T compared to PAL will result in a much lower percentage of viewers affected.

1 SCOPE

This report summarises a subset of work undertaken by Aegis Systems within a larger project concerned with issues surrounding the Digital Dividend Review (DDR). The work concerned issues surrounding the possible early release of Channel 36.

2 BACKGROUND

Currently, channels 35 and 37 are used to provide analogue TV service (Channel 5) while channel 36 is used for aeronautical radar. Channel 36 may be subject to an early release for the use of other services. One of the candidate services is DVB-H. The use of channels 35 and 37 by 'Five' is indicated in the map below, where these sites are shown in red (crosses indicate lower-power relay sites).

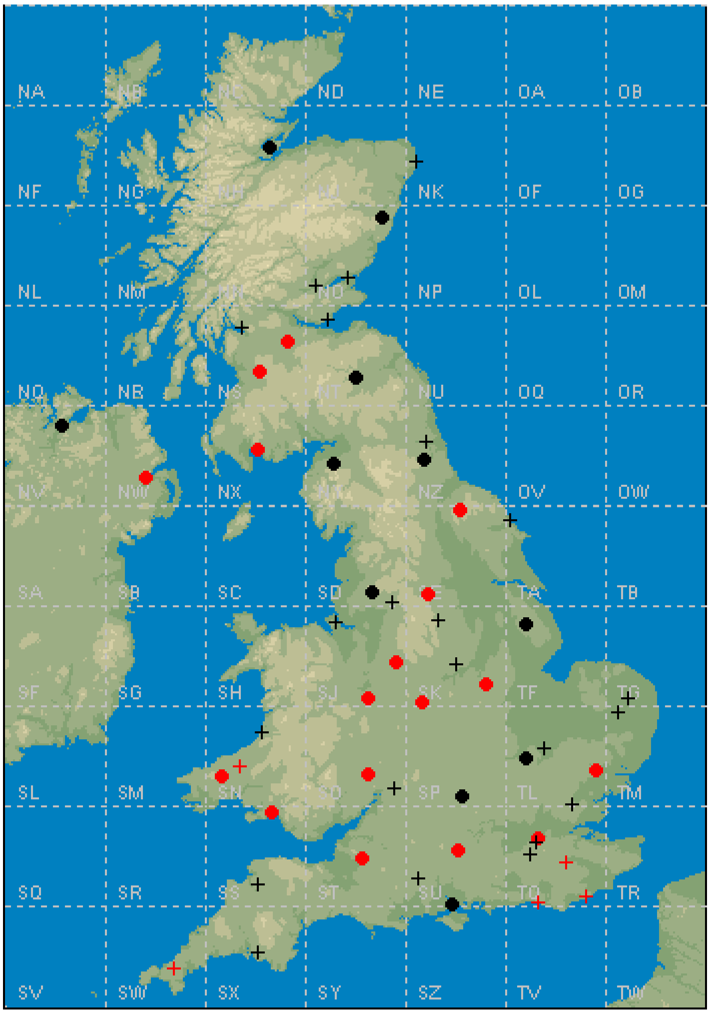

Figure 2.1: Use of channels 35 & 37 by the 'Five' network

In this study, simulation models have been developed to examine adjacent channel interference between DVB-H services and analogue TV. One of the implications of interference is 'hole punching' where the protection ratio (i.e. the ratio of minimum wanted to unwanted signal) requirement is not satisfied because a receiver suffers interference from a local transmitter operating on a channel adjacent to the relatively weak wanted signal. It should be noted that analogue TV is far more sensitive to such adjacent-channel interference than are digital systems, such as DVB-T or DVB-H (though the degradation will be more gradual with increasing interference).

When analogue TV services are withdrawn channels 35 and 37 will be available for other services. One of the options is to deploy DVB-T service in these channels. Therefore, further modelling has been implemented to investigate interference between DVB-H and DVB-T services.

To allow such co-existence studies to be carried out, it has been necessary to propose plausible scenarios for the introduction of DVB-H services, in terms of the transmitter network architecture and extent. This work has also allowed an estimate to be made of the exported field strength for which co-ordination might be sought from other administrations.

3 GENERALISED MODELLING APPROACH

Both 'deterministic' and probabilistic models have been developed to model interference between analogue TV/DVB-H and DVB-T/DVB-H services. The simulation process can be summarised as following.

- Parameters including the EIRP, noise figure, feeder loss, noise bandwidth, minimum C/N, maximum antenna gain, antenna pattern, antenna height, polarisation discrimination, protection ratio and target coverage percentage are input to the model.
- The minimum required wanted carrier level and wanted and interfering system coverage areas are calculated. The median path loss is calculated from COST 231 Hata and Rec.1546 propagation models. Outdoor signal variations and building penetration losses are represented by log-normal distributions.
- In the **deterministic** model, the simulation area is divided into pixels representing potential victim receive locations. For a given wanted and interfering transmitter separation, the wanted (C) and interference power (I) levels are calculated for each pixel. C and I are then used to derive C/I. For each pixel, C and C/I are compared against the minimum required wanted carrier level and protection ratio, respectively. In order to account for the location variability, the protection ratio requirement is increased by an amount corresponding to the joint location variability of wanted and interfering signals at the target coverage percentage assuming that the wanted and interfering signals are uncorrelated. Similarly, the minimum wanted carrier level requirement is increased by an amount equal to the location variability of wanted signal at the target coverage percentage. If both requirements are satisfied the pixel is assumed to be not affected from interference (i.e. 'successful'). If either of the requirements is not met, the pixel is assumed to be interfered (i.e. 'failed'). Successful and failed pixels are plotted to show the impact of interference (i.e. the hole punch) for the assumed wanted and interfering transmitter separation distance. The process is repeated for a range of wanted and interfering transmitter separation distances.
- In the **probabilistic** model, C and I are calculated at uniformly distributed random points within the simulation area over a number of Monte Carlo trials. At each point, variations in C and I are obtained from a log-normal distribution representing uncorrelated joint location variability of wanted and interfering signals.

In the deterministic approach, a pixel is failed if C and C/I requirements are not satisfied at the target percentage of locations within the pixel. For example, if the target coverage requirement is 95% the pixel will fail even if 94% of potential receiver locations within the pixel satisfy the C and C/I requirements. Therefore, a plot of successful/failed pixels within the simulation area may represent a pessimistic picture. In order to obtain a more realistic view, Monte Carlo trials are carried out to determine C and I variations at random potential receiver locations.

The use of the probabilistic approach enables random successful/failed receiver locations to be plotted.

3.1 Analysis of Interference from DVB-H into Analogue TV

3.1.1 Baseline Simulation Model Parameters

Assumed parameters for the baseline simulation model are summarised in the following table.

DVB-H TX Frequency	594 MHz (Channel 36)
DVB-H TX EIRP	32.15 dBW/8MHz (1 kW ERP)
DVB-H TX Height (a.g.l)	30 m
DVB-H Coverage Requirements	90 dBμV/m median wanted field strength at 10 m
Analogue TV RX Frequency	589.25 MHz (Channel 35)
Analogue TV Wanted TX EIRP	46 dBW ERP Vision peak sync
Analogue TV Wanted TX Height (a.g.l)	100 m
Analogue TV Victim RX Height (a.g.l)	10 m
Analogue TV Victim RX Antenna Max Gain	12.9 dBi
Analogue TV Victim RX Antenna Pattern	ITU-R BT 419-3 (Band V)
Analogue TV Victim RX Feeder Loss	3.6 dB
Analogue TV Victim RX Polarisation Discrimination	16 dB (Ref: RRC Report Chapter 3)
Analogue TV Coverage Requirements	70 dBμV/m median wanted field strength at 10 m
Outdoor Propagation Variation	Log-normal (μ = 0 dB, σ = 5.5 dB) (Ref: ETSI TR 102 377 V1.2.1)
Building Penetration Loss	Log-normal (μ = 11 dB, σ = 6 dB) (Ref: ETSI TR 102 377 V1.2.1)
Median Path Loss Models	Rec.1546 (Analogue TV Wanted Path) COST 231 Urban Hata (DVB-H Wanted Path) COST 231 Urban Hata (Interference Path)
Protection Ratio	-5 dB (Ref: Technical Parameters and Planning Algorithms, Joint Frequency Planning Project, Document JPP/MB/1, Version 2, July 2003)

Table 3.1: Parameters for DVB-H into Analogue TV Baseline Model

The assumed protection ratio value of -5dB is an average of the figures for DVB transmissions in the lower and upper adjacent channels (-4 and -6dB respectively). The analogue vision is, therefore, slightly more susceptible to interference than the sound carriers[1].

[1] Both the FM and NICAM sound carriers are taken into account in these protection ratio figures.

Median path losses obtained from the models used in the analysis are illustrated in ***Annex A***.

3.1.2 Baseline Simulation Model Results

Based on the assumed baseline parameters, the coverage area radius for the analogue TV and DVB-H are calculated to be 22.43 km and 1.243 km, respectively. The following figures show the failure rates obtained from the deterministic and probabilistic simulation models for a range of analogue TV and DVB-H transmitter separation distances.

In the diagram where the results from the deterministic approach are presented green points represent pixels satisfying the protection ratio requirement while red points show pixels failing to meet the protection ratio. In the case of probabilistic modelling, green points represent potential random receiver locations where the protection ratio is satisfied while red points illustrate random receiver locations failing to meet the protection ratio requirement.

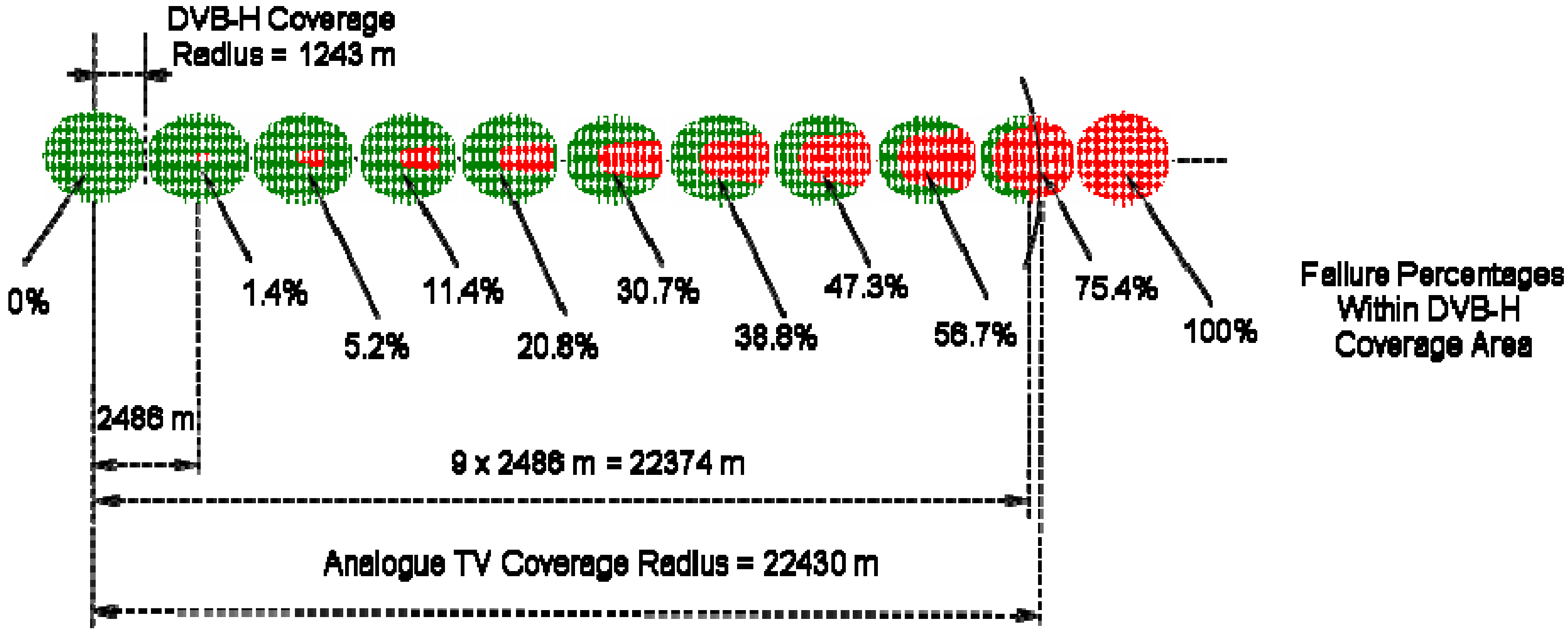

Figure 3.1: Failure Rates (DVB-H into Analogue TV, Baseline Model, Deterministic Model)

Green pixels represent discrete areas over which the protection ratio requirement is satisfied. In this case, satisfying the protection ratio ensures a target coverage of 95% across a pixel (i.e. 95% or more of users within a pixel will experience a satisfactory picture quality, as defined by a given signal to noise ratio)

Red pixels represent discrete areas over which the protection ratio requirement is **not** satisfied. As a corollary of the above, fewer than 95% of users with a pixel will experience a satisfactory picture quality.

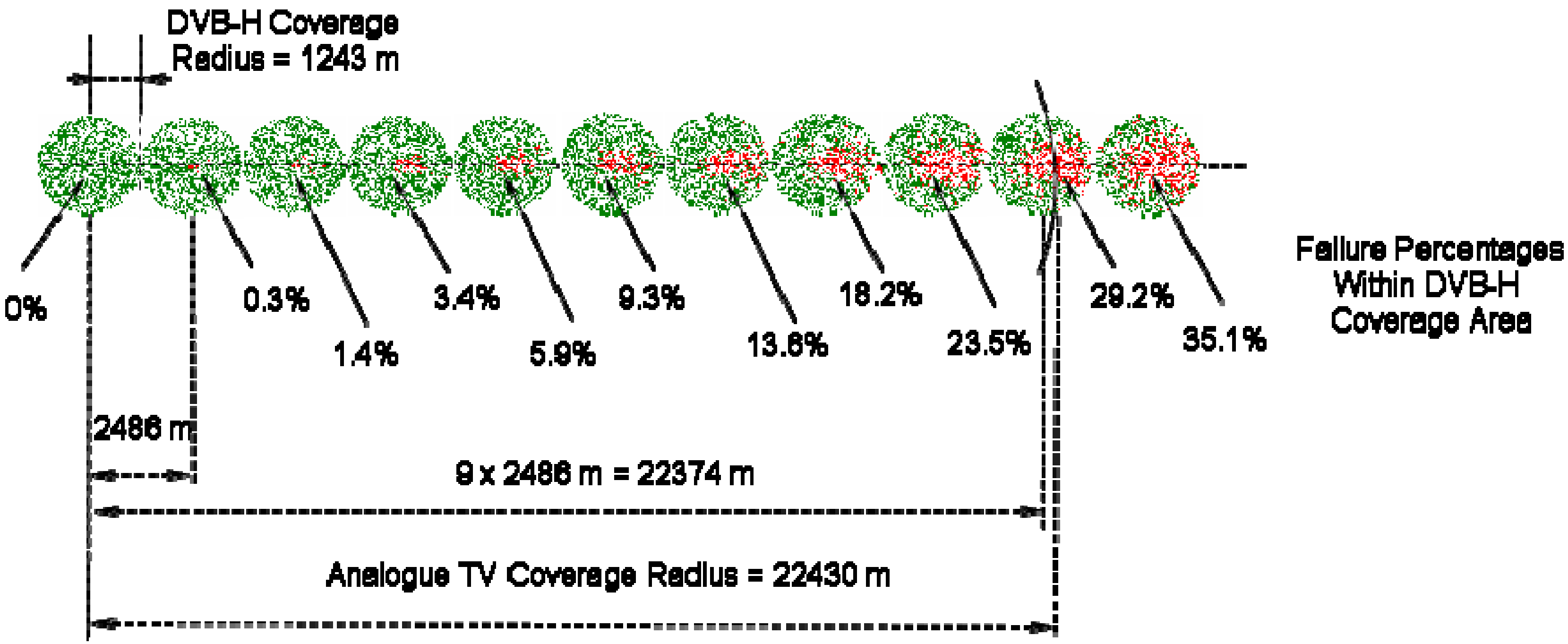

Figure 3.2: Failure Rates (DVB-H into Analogue TV, Baseline Model, Probabilistic Model)

Green points represent individual receivers at which the protection ratio requirement is satisfied. Users will experience a satisfactory picture quality, as defined by a given signal to noise ratio.

Red points represent individual receivers at which the protection ratio requirement is **not** satisfied. Users will not experience a satisfactory picture quality.

The failure rates are compared in the following figure.

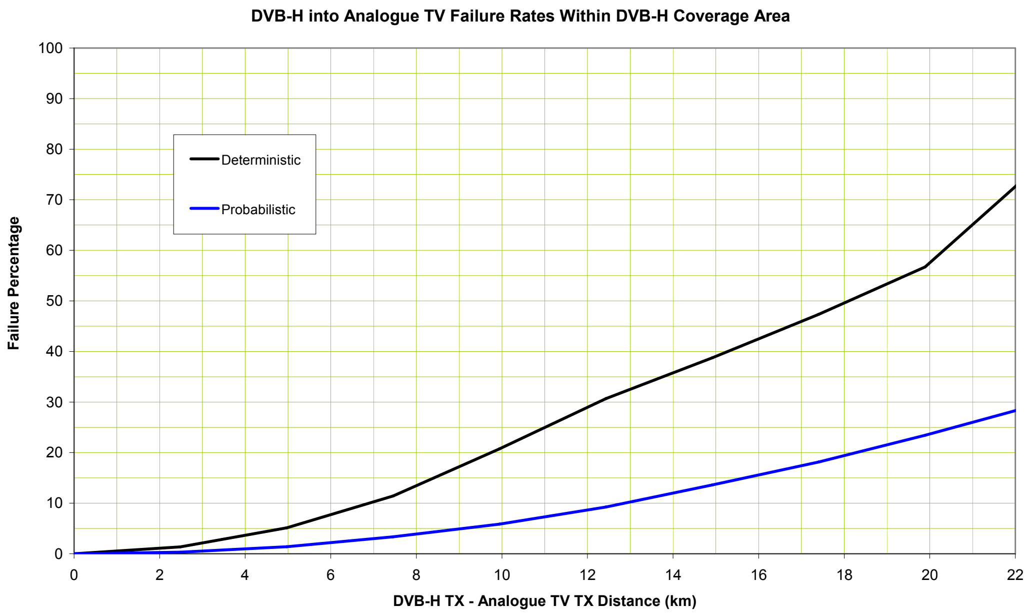

Figure 3.3: Failure Rates Comparison

In the deterministic model, when the analogue TV and DVB-H transmitter separation distance is approximately equal to the analogue TV coverage radius 75.4% of pixels within the DVB-H coverage area fail. For the same separation, the failure rate within the DVB-H coverage is 29.2% when the probabilistic model is used.

Failure percentages are integrated over the entire analogue TV coverage area to calculate the overall failure rate. The overall failure rates are 40.4% and 15.1% for the deterministic and probabilistic models, respectively.

The sensitivity of the above failure rates to a number of parameters (including antenna height, transmit power and propagation model) is examined. The results are shown in ***Annex B***. The results indicate that the failure percentage does not vary significantly when the DVB-H transmit power is increased. This is due to the fact that the increase in the DVB-H coverage area and the increase in the failed points in DVB-H coverage area are proportional when the DVB-H transmit power is increased.

3.1.3 Impact of Protection Ratio

The deterministic and probabilistic baseline models have been modified to investigate the implications of the assumed protection ratio. The following figure compares the results for the protection ratios of -5 dB & -11 dB.

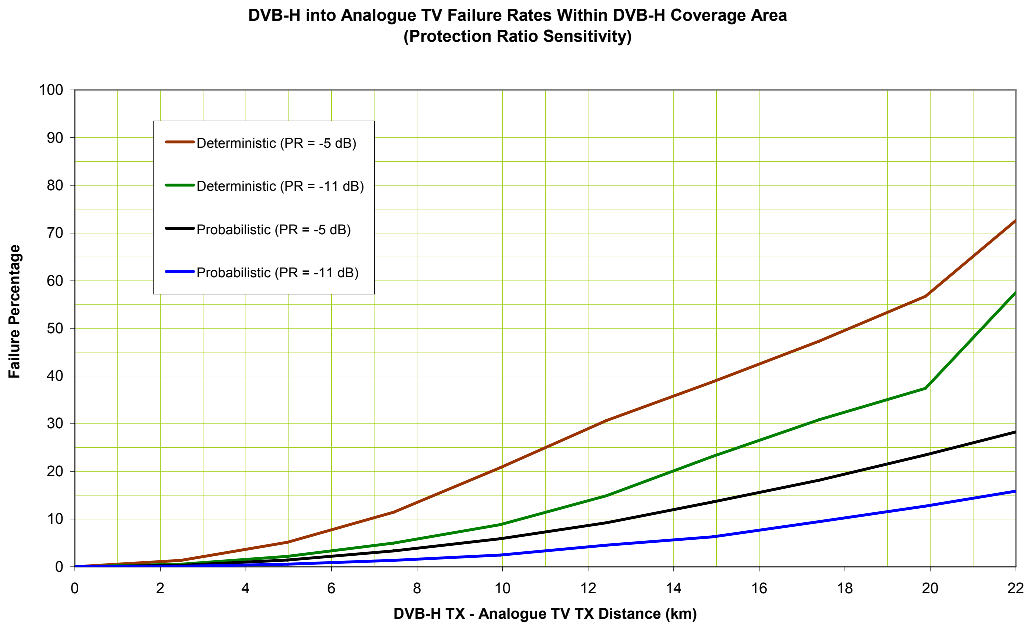

Figure 3.4: Failure Rates (Protection Ratio Sensitivity)

As expected, the relaxed protection ratio of -11 dB (which could be viewed as a reduction in picture quality of one grade) results in reduced failure rates in comparison to those obtained for the protection ratio of -5 dB.

Failure rates are integrated over the analogue TV coverage area to calculate the overall failure rate. This implicitly means that DVB-H transmitters and their associated coverage areas are tiled across the whole analogue TV coverage area. The overall failure rate for the deterministic model is 26.1% (note that the corresponding figure is 40.4% for the protection ratio of -5 dB) while the overall failure rate for the probabilistic model is 7.8% (note that the corresponding figure is 15.1% for the protection ratio of -5 dB).

3.1.4 Impact on Population

Overall failure rates calculated on the basis of an integration over the entire analogue TV coverage area provide very pessimistic failure estimates as the entire analogue TV coverage area is unlikely to be covered by households. Therefore, the implications of DVB-H interference into analogue TV households and population have been examined further with a view to obtaining more realistic failure estimates by applying a household/population database approach.

The analysis with household and population databases considers household and population distributions within Channel 5 coverage areas. The following steps outline the approach employed.

- Distance (between the analogue TV wanted transmitter and the interfering DVB-H transmitter) vs. failure rate statistics are converted into wanted field strength vs. failure rate statistics. Wanted field strengths are calculated using real world coverage plots. The area resolution for wanted field strengths is a 1 km square.

- Wanted field strengths are converted into failure rates using wanted field strength vs. failure rate statistics calculated earlier. The minimum analogue TV wanted field strength is assumed to be 70 dBµV/m. Two sets of wanted field strength vs. failure rate statistics are derived for the protection ratios of -5 dB and -11 dB.
- Household and population statistics are derived from the UK database for every 1 km square in an analogue TV coverage area.
- Total household/population failure rates are calculated by integrating the product of the failure rate and household/population at each 1 km square over an analogue TV coverage area.
- A number of household/population threshold values are used to decide whether any of 1 km squares in an analogue TV coverage area is served by a DVB-H transmitter or not. If the number of household/population is below the assumed threshold the corresponding area is excluded from the total household/population failure rate calculation.

Four example Channel 5 analogue TV coverage areas have been considered. These areas are illustrated in ***Annex C***. Results are presented in the following table. It should be noted that the households / population covered by the transmitters is slightly overestimated as the analysis has been based on transmitters considered in isolation with coverage being delineated by a field strength of 70 dBµV/m. Interference from other transmitters, which would effectively reduce the size of the coverage area, has not been taken into account. The 'household threshold' is the number of houses per square km above which a DVB-H TX would be introduced. In the most pessimistic case (zero) the analysis assumes every tile within the 70 dBµV/m contour of the coverage area is contiguously tiled with transmitters. In this case, the percentage of households or population affected is around 3.5%.

Coverage Area	Total Household & Population Covered	Household & Population Threshold	Failure Percentage (Household)		Failure Percentage (Population)	
			PR = -5dB	PR = -11dB	PR = -5dB	PR = -11dB
Croydon	5,831,070 & 11,391,080	0	3.353	1.642	3.418	1.674
		500	2.806	1.368	3.14	1.535
		1000	2.295	1.114	2.856	1.393
Mendip	1,918,636 & 3,737,143 &	0	2.96	1.425	2.947	1.418
		500	2.112	1.011	2.427	1.165
		1000	1.516	0.724	2.09	1.002
Blackhill	1,184,664 & 2,248,462	0	2.811	1.399	2.814	1.403
		500	2.385	1.184	2.606	1.298
		1000	1.808	0.895	2.376	1.183
Lichfield	3,836,983 & 7,534,122	0	3.763	1.923	3.773	1.928
		500	2.941	1.498	3.281	1.673
		1000	2.243	1.139	2.918	1.486

Table 3.2: Results of Analysis with Household and Population Databases

Failure percentages shown above are based on the probabilistic approach and the deterministic approach would lead to approximately three times higher failure rates.

3.2 Analysis of Interference from DVB-H into DVB-T

3.2.1 Parameters

The baseline model parameter values are summarised in the following table.

DVB-H TX Frequency	594 MHz (Channel 36)
DVB-H TX EIRP	32.15 dBW/8MHz (1 kW ERP)
DVB-H TX Height (a.g.l)	30 m
DVB-H Coverage Requirements	90 dBμV/m median wanted field strength at 10 m
DVB-T RX Frequency	586 MHz (Channel 35)
DVB-T Wanted TX EIRP	42.15 dBW/8MHz
DVB-T Wanted TX Height (a.g.l)	100 m
DVB-T Victim RX Height (a.g.l)	10 m
DVB-T Victim RX Antenna Max Gain	12.9 dBi
DVB-T Victim RX Antenna Pattern	ITU-R BT 419-3 (Band V)
DVB-T Victim RX Feeder Loss	3.6 dB
DVB-T Victim RX Polarisation Discrimination	16 dB (Ref: RRC Report Chapter 3)
DVB-T Coverage Requirements	57 dBμV/m median wanted field strength at 10 m (Ref: Technical Parameters and Planning Algorithms, Joint Frequency Planning Project, Document JPP/MB/1, Version 2, July 2003)
Outdoor Propagation Variation	Log-normal (μ = 0 dB, σ = 5.5 dB) (Ref: ETSI TR 102 377 V1.2.1)
Building Penetration Loss	Log-normal (μ = 11 dB, σ = 6 dB) (Ref: ETSI TR 102 377 V1.2.1)
Median Path Loss Models	Rec.1546 (DVB-T Wanted Path) COST 231 Urban Hata (DVB-H Wanted Path) COST 231 Urban Hata (Interference Path)
Protection Ratio	-30 dB (Ref: ITU-R Rec. BT 1368)

Table 3.3 Parameters for DVB-H into DVB-T Baseline Model

3.2.2 Baseline Simulation Model Results

Failure rates within the DVB-H coverage area are derived for a number of DVB-H and DVB-T TX separation distances using the deterministic and probabilistic models. It should be noted that, for the assumed parameter values, the DVB-T coverage area radius is 30.8 km.

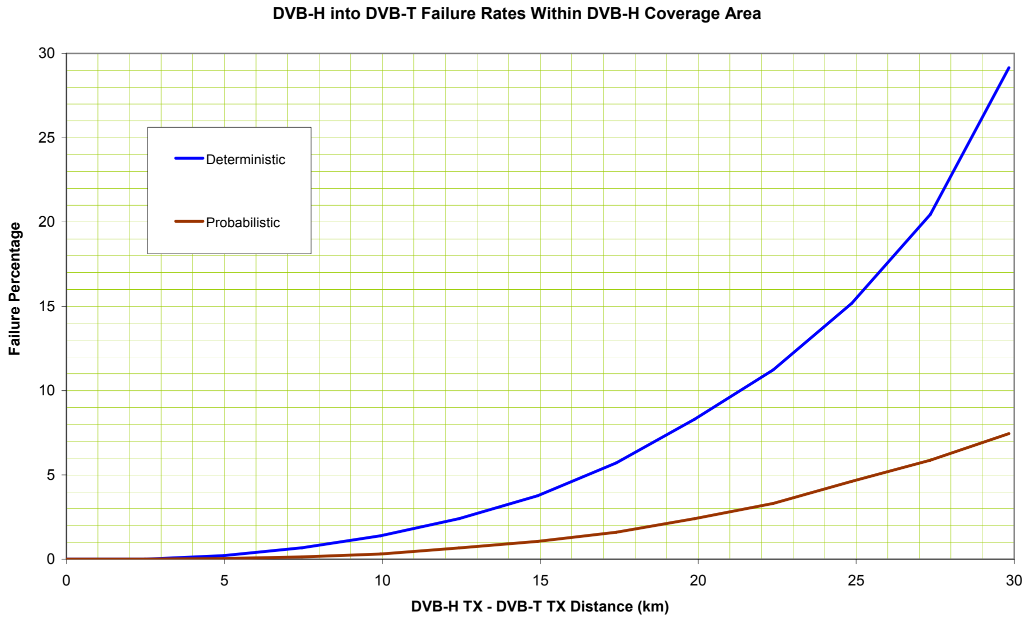

Figure 3.5: Failure Rates (DVB-H into DVB-T)

Comparing the above result with the equivalent result for the analogue TV case, it can be seen that the higher protection ratio enjoyed by DVB-T (-30 dB as opposed to -5 dB in the analogue case) makes it far more robust than PAL from an equivalent interferer.

The overall failure rate corresponding to the integration of the calculated failure rates over the entire DVB-T coverage area is 12.2% for the deterministic model and 3.4% for the probabilistic model (the corresponding figures for PAL are 40.4% and 15.1% for the deterministic and probabilistic cases respectively). These figures relate to area coverage and, like the PAL case, the percentage households or population affected will be substantially lower.

3.3 Analysis of Interference from Analogue TV into DVB-H

3.3.1 Parameters

Parameter values used for the baseline model are summarised in the following table.

Analogue TV TX Frequency	589.25 MHz (Channel 35)
Analogue TV TX EIRP	48.15 dBW/8MHz (40kW ERP)
Analogue TV TX Height (a.g.l)	100 m
Analogue TV Coverage Requirements	70 dBμV/m median wanted field strength at 10 m
DVB-H RX Frequency	594 MHz (Channel 36)
DVB-H Wanted TX EIRP	32.15 dBW/8MHz (1 kW ERP)
DVB-H Wanted TX Height (a.g.l)	30 m
DVB-H Victim RX Height (a.g.l)	1.5 m
DVB-H Victim RX Antenna Max Gain	-4.85 dBi
DVB-H Victim RX Antenna Pattern	Omnidirectional
DVB-H Victim RX Feeder Loss	0 dB
DVB-H Victim RX Polarisation Discrimination	0 dB
DVB-H Coverage Requirements	90 dBμV/m median wanted field strength at 10 m
Outdoor Propagation Variation	Log-normal (μ = 0 dB, σ = 5.5 dB) (Ref: ETSI TR 102 377 V1.2.1)
Building Penetration Loss	Log-normal (μ = 11 dB, σ = 6 dB) (Ref: ETSI TR 102 377 V1.2.1)
Median Path Loss Models	Rec.1546 (Analogue TV Wanted Path) COST 231 Urban Hata (DVB-H Wanted Path) COST 231 Urban Hata (Interference Path)
Protection Ratio	-43 dB (Ref: ITU-R Rec. BT 1368)

Table 3.4: Parameters for Analogue TV into DVB-H Baseline Model

3.3.2 Baseline Simulation Model Results

Failure rates within the DVB-H coverage area are derived as a function of analogue TV and DVB-H TX separation distances as shown in the following diagrams.

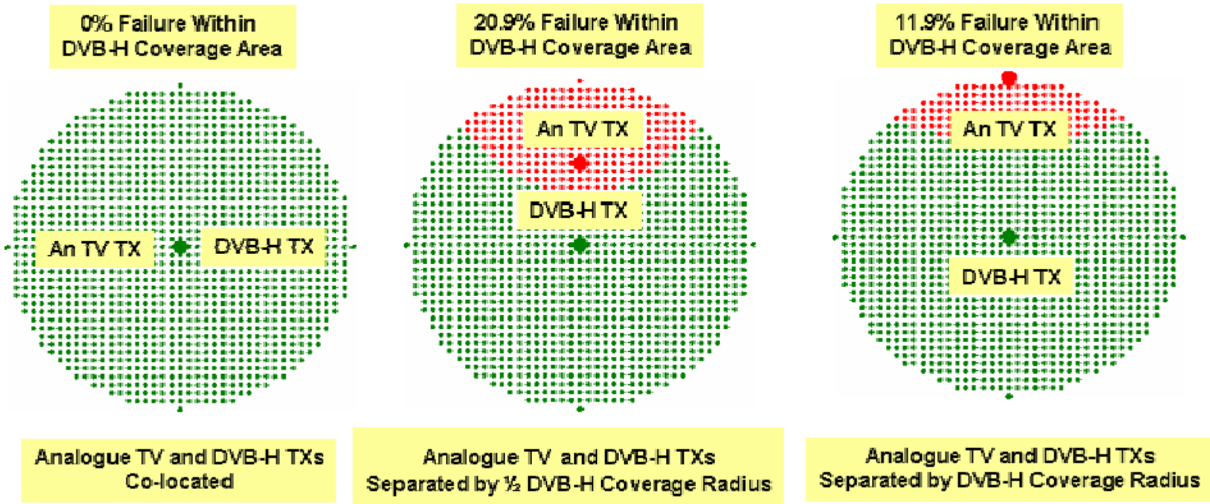

Figure 3.6: Failure Rates (Analogue TV into DVB-H, Deterministic Model)

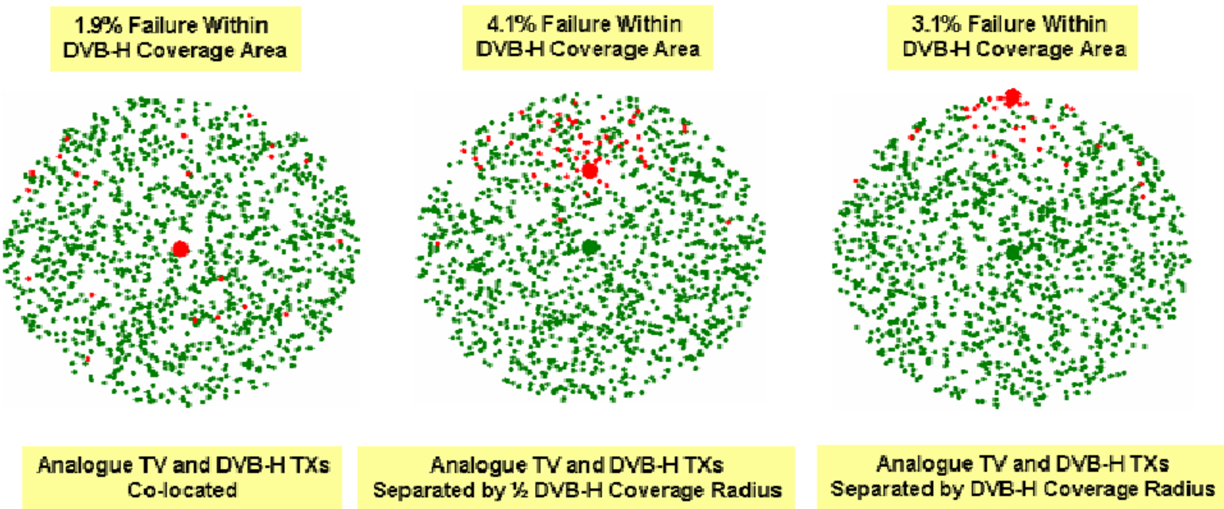

Figure 3.7: Failure Rates (Analogue TV into DVB-H, Probabilistic Model)

Further simulations have shown that the deterministic model results in 0% failure rate when the analogue TV and DVB-H TXs are separated by 2486 m (i.e. twice the DVB-H coverage radius). For the same separation distance, in the probabilistic model, the failure rate is 0.15%.

3.4 Analysis of Interference from DVB-T into DVB-H

3.4.1 Parameters

The baseline model parameters are listed in the following table.

DVB-T TX Frequency	586 MHz (Channel 35)
DVB-T TX EIRP	42.15 dBW/8MHz
DVB-T TX Height (a.g.l)	100 m
DVB-T Coverage Requirements	57 dBμV/m median wanted field strength at 10 m
DVB-H RX Frequency	594 MHz (Channel 36)
DVB-H Wanted TX EIRP	32.15 dBW/8MHz (1 kW ERP)
DVB-H Wanted TX Height (a.g.l)	30 m
DVB-H Victim RX Height (a.g.l)	1.5 m
DVB-H Victim RX Antenna Max Gain	-4.85 dBi
DVB-H Victim RX Antenna Pattern	Omnidirectional
DVB-H Victim RX Feeder Loss	0 dB
DVB-H Victim RX Polarisation Discrimination	0 dB
DVB-H Coverage Requirements	90 dBμV/m median wanted field strength at 10 m
Outdoor Propagation Variation	Log-normal (μ = 0 dB, σ = 5.5 dB) (Ref: ETSI TR 102 377 V1.2.1)
Building Penetration Loss	Log-normal (μ = 11 dB, σ = 6 dB) (Ref: ETSI TR 102 377 V1.2.1)
Median Path Loss Models	Rec.1546 (DVB-T Wanted Path) COST 231 Urban Hata (DVB-H Wanted Path) COST 231 Urban Hata (Interference Path)
Protection Ratio	-30 dB (Ref: ITU-R Rec. BT 1368)

Table 3.5: Parameters for DVB-T into DVB-H Baseline Model

3.4.2 Baseline Simulation Model Results

The following diagrams illustrate the simulation results.

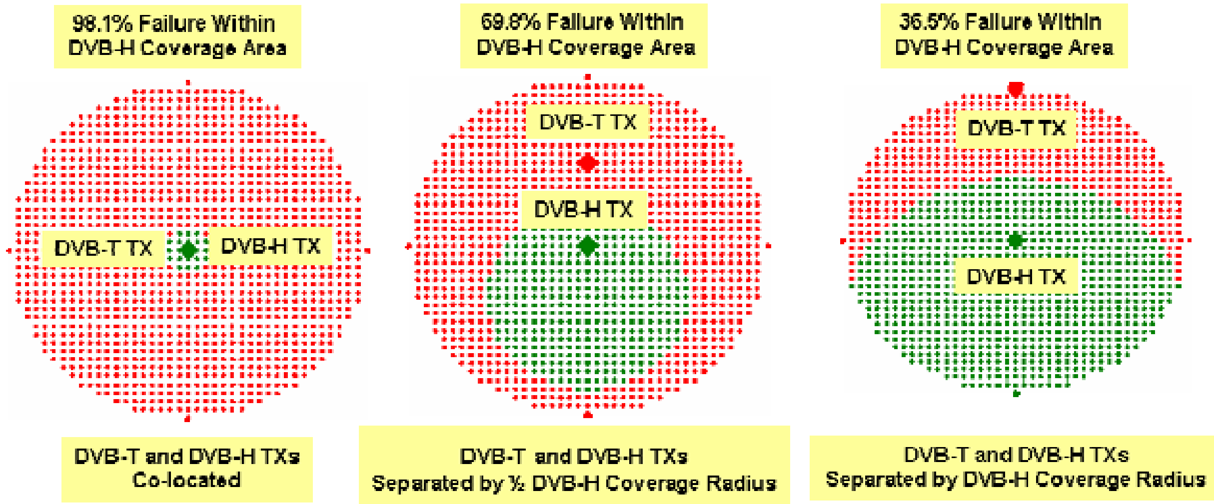

Figure 3.8: Failure Rates (DVB-T into DVB-H, Deterministic Model)

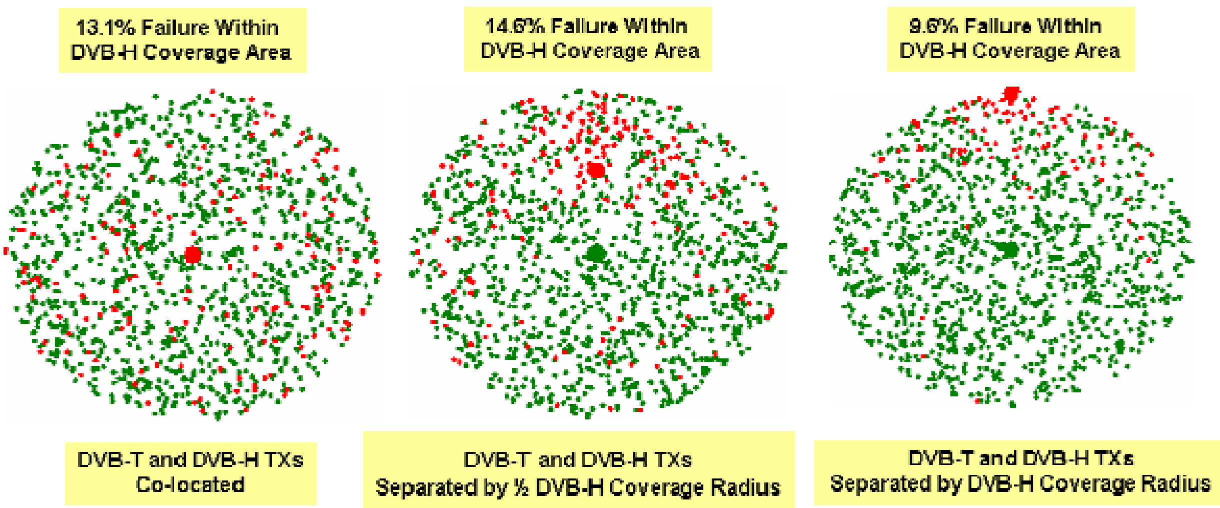

Figure 3.9: Failure Rates (DVB-T into DVB-H, Probabilistic Model)

When the DVB-T and DVB-H TXs are separated by 3.73 km (i.e. three times the DVB-H coverage radius) the deterministic model results show 0% failure rate. In the probabilistic model, the failure rate is less than 0.1% when the separation is greater than 4.97 km (i.e. four times the DVB-H coverage radius).

When considering the co-located deterministic case in Figure 3.8 above, it would normally be expected that there should be complete pixel failure across the whole area or no pixel failure at all depending on the protection ratio required and the relative powers of the two transmitters. The assumption behind this expectation is that the path loss on the wanted and interfering paths is the same and therefore the ratio of the wanted and interfering powers at a receiver is the same across the whole area.

However, due to different assumed transmit antenna heights (noting that DVB-T has been assumed to have a wide area coverage and DVB-H a much more local coverage) the propagation model differs on the wanted and interfering paths to the extent that the signal decay slope changes differently on the two paths. Given that operation with respect to the wanted signal is near the margin (i.e. close to the protection ratio requirement) this leads to an apparently anomalous result whereby the differing signal decay slopes lead to a cross over in the ratio of wanted to interfering signal strengths and hence a mix of failure and success. If the transmit antenna heights had been the same this effect would not have arisen.

4 'REAL-WORLD' COMPATIBILITY ASSESSMENT

4.1 Low-power DVB-H network (Berkshire)

Section 3 of this report presents the results of a statistical model with which the impact of DVB-H transmissions on adjacent channel analogue services is assessed. As an alternative way of visualising the issues, this section presents the results of a modelling exercise based on a specific geographical area.

The 'Five' service is transmitted from the Hannington transmitter station in Berkshire on Channel 35, at a power of 60kW (the other four services are radiated at +6dB from a higher aerial). This site provides a service to the towns of Reading Newbury, and Basingstoke, and beyond. The central part of the service area is shown in Figure 4.1.

Figure 4.1: Location of Hannington transmitter

A hypothetical DVB-H network has been assumed to use the transmitter sites indicated in red, to serve the main urban areas. It is assumed that these transmissions are on Channel 36, that all sites use an ERP of 1kW from an omnidirectional aerial at 30m a.g.l., and that they operate as an SFN.

The coverage obtained from this network is indicated in Figure 4.2.

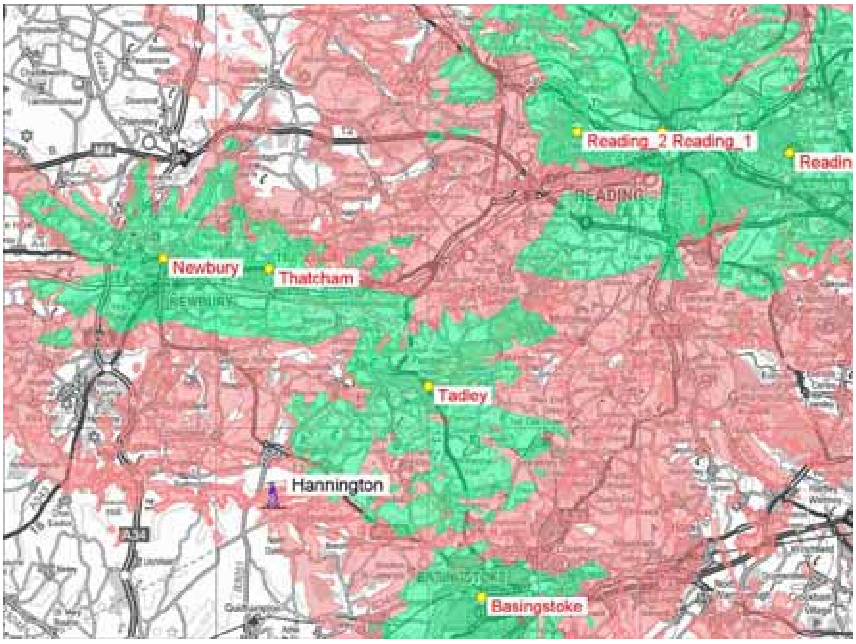

Figure 4.2: Coverage from hypothetical DVB-H network

The contours in Figure 4.2 are at 90 dBμV/m (green) and 70 dBμV/m (red), with the green contour corresponding to indoor coverage and the red contour to an outdoor service.

It can be noted that the 90 dBμV/m coverage extends up to 8 km in some directions from the transmitter sites. This contrasts with the theoretical coverage of 1¼ km derived earlier (see Section 3.1.2). This is attributable to the different propagation models employed. In the case of the earlier derivation, the generalised propagation model used does not allow for any free space propagation beyond a distance breakpoint in the range 40 – 300 m (depending on the heights of the transmitter and the receiver). In the terrain based case illustrated in Figure 4.2. above, the propagation model allows for free space propagation where a line-of-sight path is determined.

The impact of this hypothetical DVB-H network on the 'five' coverage area has been modelled, taking into account receive aerial directivity and polarisation discrimination.[2].

The interference has been assessed for three levels of location variability. In the first, only half of the locations within each pixel are protected, increasing to 70% and 95% in the successive plots. The higher degrees of protection require an additional 4 and 13dB[3] difference, respectively, between the mean received powers of the wanted and interfering transmissions.

---

[2] According to ITU-R Recommendation BT.412

[3] If both are taken to have a location variability of 5.5dB, and are uncorrelated.

Figure 4.3: Impact of DVB-H network on 'Five' coverage (50% locations)

Figure 4.4: Impact of DVB-H network on 'Five' coverage (70% locations)

Figure 4.5: Impact of DVB-H network on 'Five' coverage (90% locations)

It can be seen that very significant interference is experienced, even at the 50% protection level. The interference is restricted to the areas immediately adjacent to the DVB-H transmitters where the wanted field strength is high (Tadley, Thatcham) but is much larger where the 'five' service suffers additional diffraction losses or has a longer path (e.g. Newbury, Basingstoke).

4.2 High-power DVB-H network (London)

The use of low-power DVB-H transmitters has the advantage of minimising interference exported to the continent (see Section 6, below), and allows DVB-H coverage to be targeted to the most densely populated areas. Disadvantages include the very large number of sites that would be needed to institute a service, and the fact that such a network will be completely different from the existing TV network, thus maximising hole-punching problems.

In many cases, such as that of Hannington, main TV transmitters are located too far from urban areas to give efficient DVB-H coverage. This is not true for a few cases however, the most significant of which is London.

In London, Channel 5 analogue coverage is provided from the Croydon mast (all other UHF services are from Crystal Palace, a couple of kilometres to the east). A co-sited, high-power DVB-H transmitter on this mast will offer a useful degree of coverage in South and central London.

The Croydon analogue transmitter operates on Channel 37, and the primary cause of interference to the new DVB-H service would therefore be from the vision carrier and the vestigial lower sideband. Assuming that the Channel 5 transmission uses the PAL-I rather than PAL-I1[4] standard, the necessary protection ratio is -20dB. It would therefore[5] be possible to use a DVB-H power of 10kW or more (the upper limit is set at 3.2MW by the 1MW power of the analogue signal, and a -5dB protection ratio!).

Given the higher coverage limit (and the lower transmit power likely to be required by coordination constraints), the DVB-H service area will fall far short of that from the analogue transmitter, and this will necessitate relay sites in North, West and East London. Unfortunately, these sites will need (by definition) to be located in areas where the field strength from Croydon is relatively weak, which will tend to cause relatively large potential 'hole-punching'.

An example scenario is illustrated in Figure 4.6 where Croydon (at 10kW) operates in an SFN on channel 36 with Alexandra Palace (at 1kW). The coverage is plotted to contours of 70 and 90 dBμV/m.

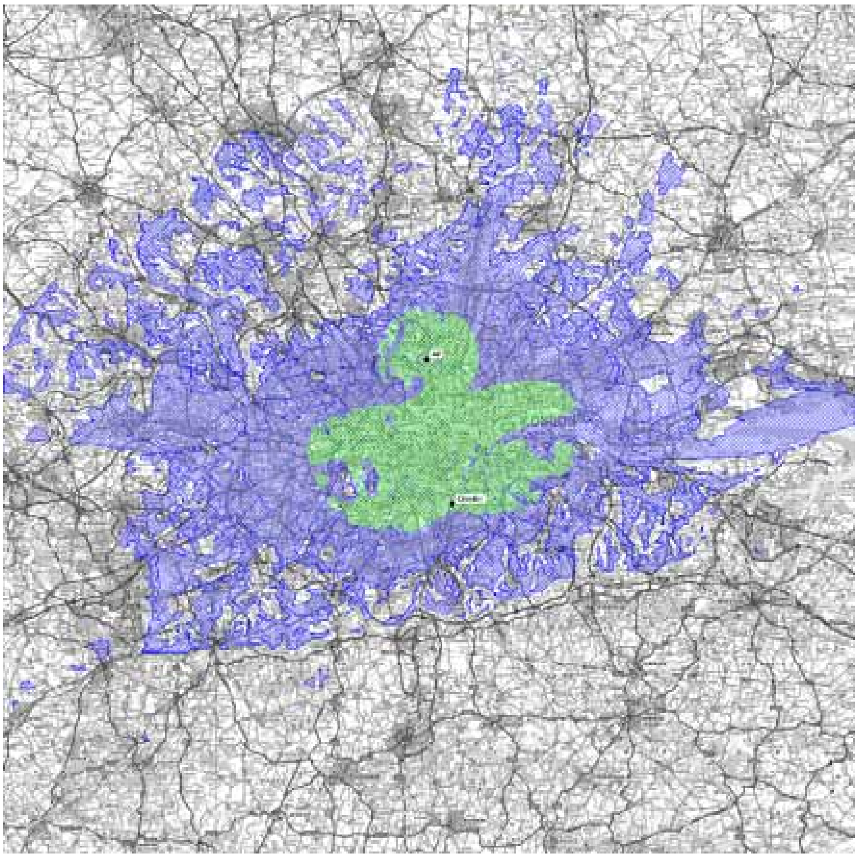

Figure 4.6: Coverage from Croydon (10kW) and Alexandra Palace (1kW)

[4] The PAL-I1 standard tightens the VSB response to improve compatibility with adjacent DVB-T services.

[5] Assuming perfectly correlated fading, which is reasonable for this co-sited case.

The impact of this network on the 'Five' analogue coverage is illustrated in Figures 4.7 – 4.9 for location availabilities of 50%, 70% and 95% (note the change of map scale with respect to Figure 4.6).

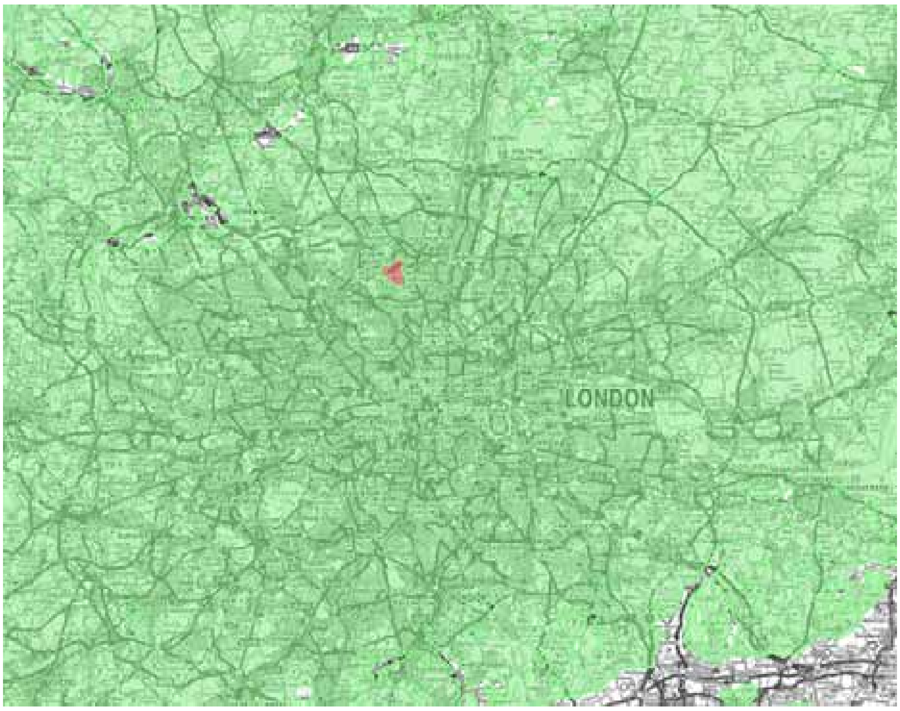

Figure 4.7: Impact from Co-sited High Power DVB-H Transmitters into Croydon Analogue Coverage (50% Location)

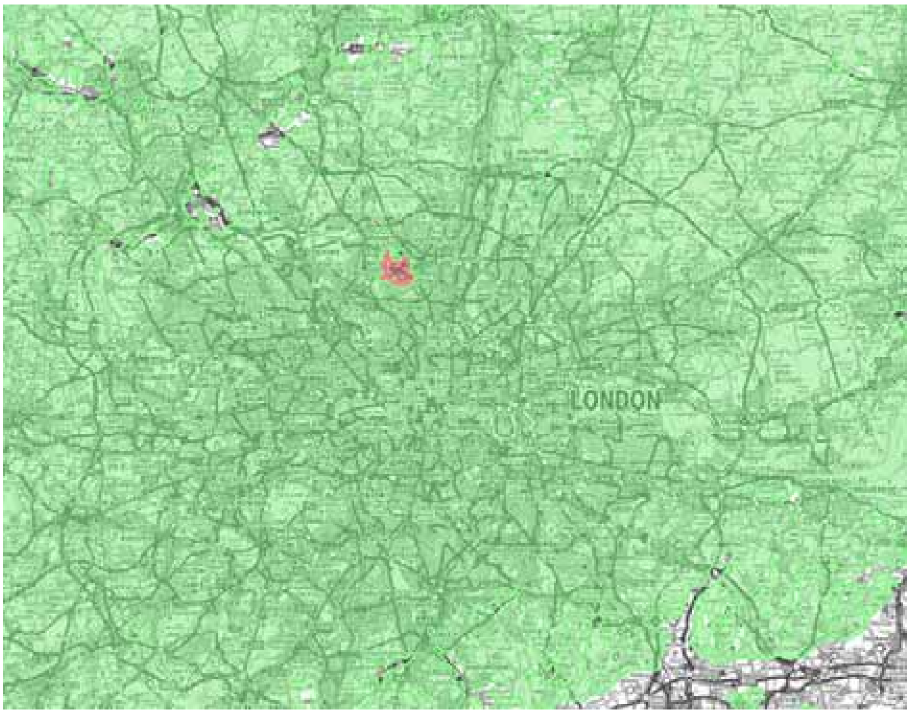

Figure 4.8: Impact from Co-sited High Power DVB-H Transmitters into Croydon Analogue Coverage (70% Location)

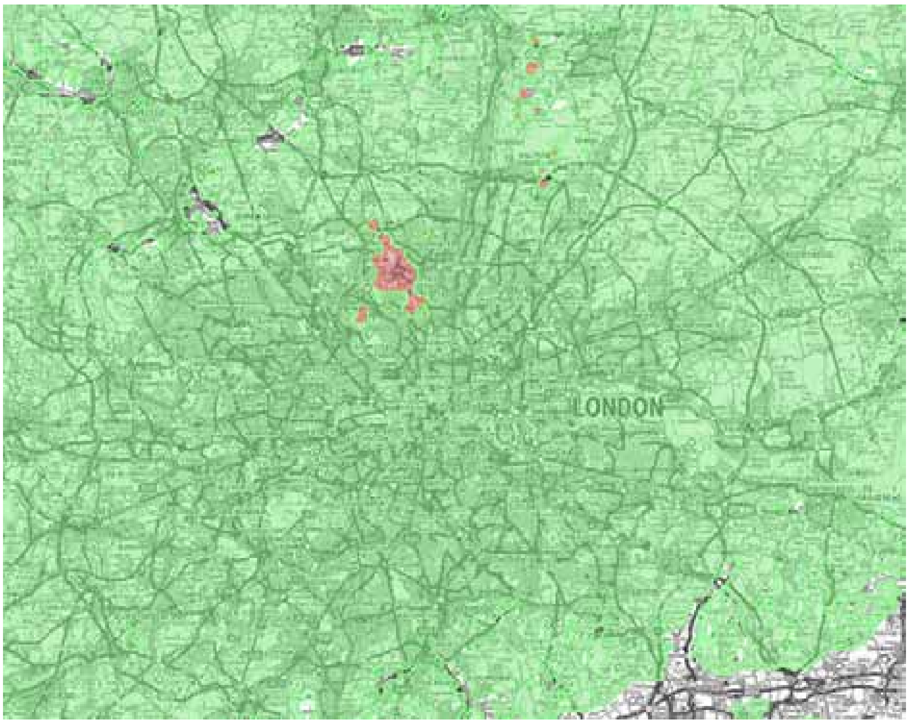

Figure 4.9: Impact from Co-sited High Power DVB-H Transmitters into Croydon Analogue Coverage (95% Location)

In considering the figures above, it should be borne in mind that the degree of hole-punching interference within London will be determined by the number and power of the filler sites necessary to complete DVB-H coverage. These, in turn, will be minimised by the use of the greatest possible power from the Croydon site.

The power used at Croydon will, however, be constrained both by international coordination agreements, and (possibly) by the need to avoid 'self-interference' within a UK-wide DVB-H network on channel 36.

These multiple, interdependent, constraints illustrate the degree of complexity involved in planning robust and mutually compatible services in adjacent channels.

5 MITIGATION

A number of areas can be considered with respect to mitigating the impact of DVB-H on analogue TV reception.

5.1 Mitigation by co-siting with analogue services

There need be no interference between analogue and DVB-H services if radiated from the same transmitter site, at appropriate powers.

If it can be assumed that the two signals experience exactly the same pattern of fading over the service area, the maximum power for the DVB-H service would simply be set by the required analogue protection ratio[6], taking polarisation into account. If a protection ratio of 5dB is assumed, an analogue site of 10kW ERP could support a DVB-H service of up to 30kW.

In practice, the patterns of fading will be different, on a local level, due to the slight change in wavelength, and the fact that different transmitter aerials are likely to be used. Furthermore, polarisation discrimination, if available, will have a statistical spread. It is therefore likely that an additional 'safety factor' of a few dB will be necessary between transmissions.

5.2 Critical filtering on DVB-H transmitters

It is understood that, some years ago, Arqiva undertook measurements which indicated that the use of the DVB-T 'critical' mask would reduce interference to adjacent channel analogue reception by some 10dB.

This would offer a very useful degree of mitigation, and such filtering might not represent a disproportionate expense in the context of a high power DVB-H network.

It should, however, be noted that previous work by Aegis (undertaken in a different context, and based only on theoretical or assumed receiver responses) implies that the compatibility is determined largely by the receiver response within the adjacent channel, and that significant mitigation is unlikely to be available.

Recent measurements by ERA Technology Ltd show that for some combinations of receiver, quality criterion and DVB-H interfering signal bandwidth, mitigation of up to 10 dB can be achieved by using critical filtering. However, more generally little mitigation has been shown to be achieved. This confirms the supposition that receiver selectivity dominates the compatibility situation.

[6] Interference could also occur from analogue TV to the DVB-H service, but in practice this will never be the dominant constraint.

5.3 In-line filters for consumer installations

When the original Channel Five service was rolled out on Channels 35 and 37, significant problems were experienced to and from video recorders operating, nominally, on channel 36. A major exercise was undertaken to ensure that these devices were accurately set to that channel, and ACI problems were further mitigated through the use of filters to reject signals on channels 35 or 37.

Similar filters might be used to reduce the power from DVB-H transmissions on channel 36 reaching the input of an analogue TV. The effectiveness of such filters would be limited by the need to offer a broadband rejection, where previous filters could be designed simply to notch a vision carrier.

Recent measurements by ERA Technology Ltd of a single and a double notch filter show that rejection of the order of 10+ dB (single notch) and 20+ dB (double notch) might be achieved. However the adjacent channel insertion loss reduces this mitigation significantly and the slope of the insertion loss across the adjacent channel (especially in the case of the double notch) would lead to serous viewing artefacts.

5.4 Co-sited analogue repeaters

The problem of hole-punching has been much discussed in the context of interference to DVB-T from new services such as DVB-H and cellular systems. One mitigation technique for such problems would be to co-site a small DVB-T relay with the offending transmitter.

This approach is unlikely to work in the analogue case for two reasons. Firstly, it would not be possible to operate such a relay in a single frequency network, as would be done for a digital service[7]. A new allocation would therefore need to be sought, and affected receivers would need to be retuned. Secondly, it is likely that many of the affected households would have aerials that were not aligned with the interfering transmitter. Services from a new relay would, therefore, be prone to multipath interference.

5.5 Guard bands

It would be possible to improve the compatibility between DVB-H and analogue services by operating the former in a 5 MHz, rather than 8 MHz channel, and thus introducing an extra 1.5 MHz guard band.

No measurements currently exist with which the impact of such a measure might be judged, though this would also be a straightforward addition to the measurements suggested in 5.1 above.

---

[7] The COFDM modulation scheme employed by DVB-T allows common channels to be used, whereas analogue signals would interfere with one another under the same circumstances.

5.6 Digital Switchover

While not a technique to mitigate interference, the progressive implementation of DSO will ensure that there is a diminishing population of analogue receiver to be interfered with.

The figures below indicate the current service areas[8] of analogue transmitters on channels 35 and 37, and show the reduction of coverage as the DSO progresses.

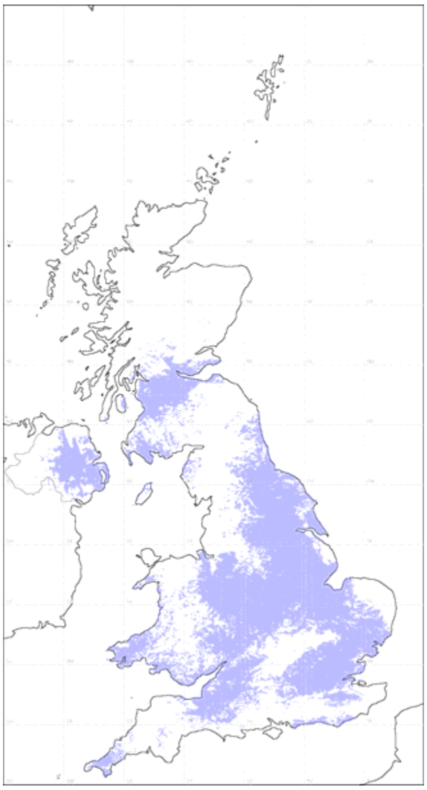

Figure 5.1: end 2007

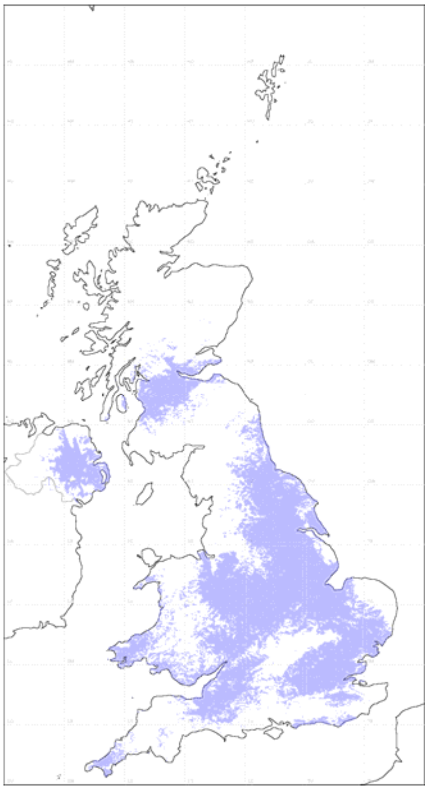

Figure 5.2; end 2008

[8] Predicted using Aegis software, and intended to be indicative, rather than definitive.

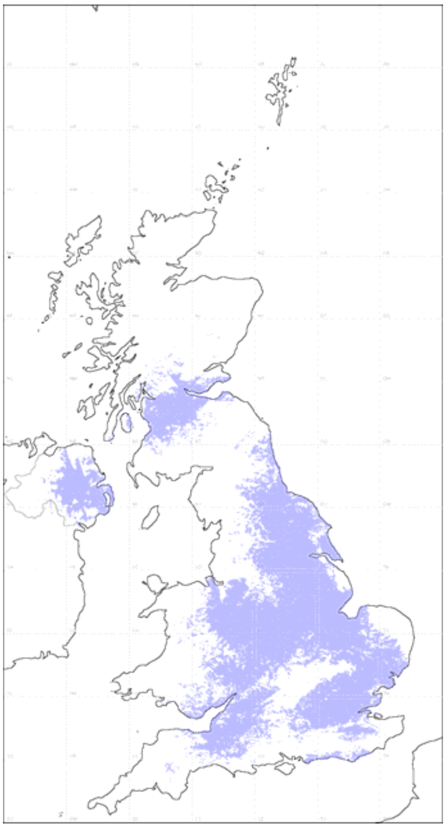

Figure 5.3: end 2009

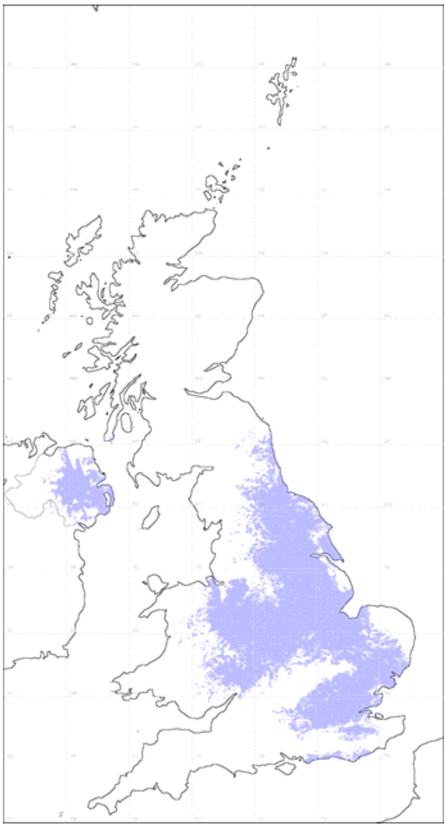

Figure 5.4: end 2010

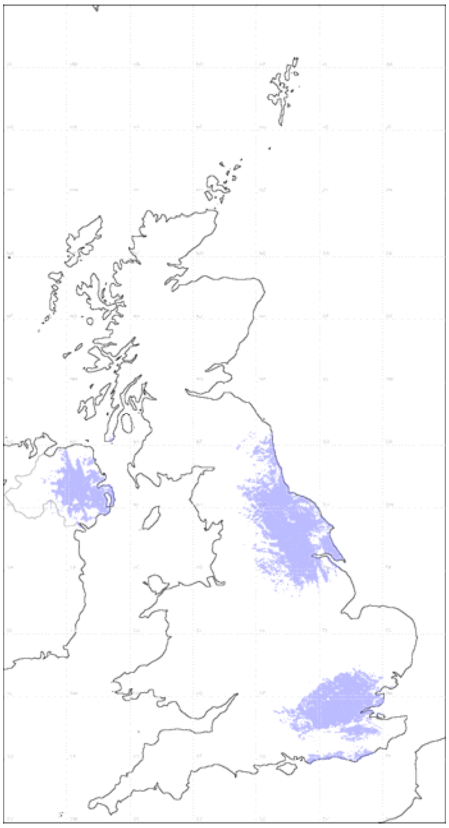

Figure 5.5: end 2011

Figure 5.6: end 2012

As shown by Figure 5.5, analogue services will continue in London until 2012, and may, therefore, need to co-exist with a DVB-H service for some years.

5.7 Impact of mitigation techniques

In addition to the mitigation factors described in the subsections above, one further factor has already been considered, namely the acceptance of a reduced picture quality reflected in the use of a less stringent protection ratio (-11 dB rather than -5 dB). This has been considered in Section 3.1.3 earlier.

Taking the relaxation in protection ratio of 6 dB already considered along with further potential relaxations in protection ratio representing some of the mitigation factors discussed in this section (Section 5), mitigation in the range up to 24 dB might be possible, but in any event certainly needs to be proven.

Using the same format as earlier, the plot below shows the failure rate[9] (for various degrees of mitigation in 6 dB steps up to 24 dB) as a function of the location of a DVB-H transmitter within the analogue TV service area (in terms of the distance between transmitters).

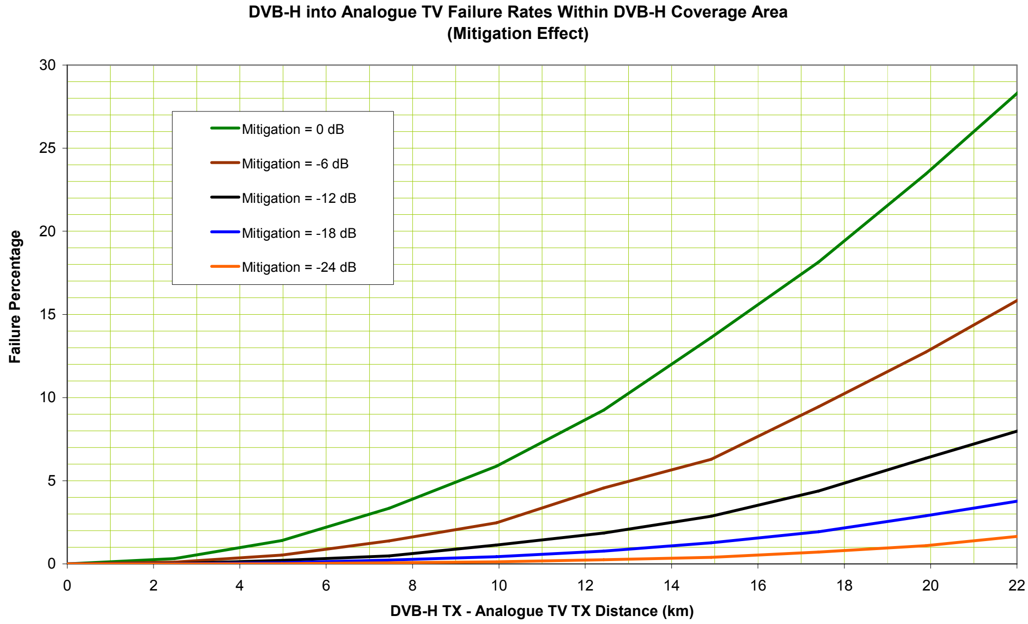

Figure 5.7: Impact of Assumed Protection Ratio

Integrating these results over the analogue TV coverage area[10] shows (Figure 5.8) how different levels of mitigation can bring the overall failure rate across the analogue TV coverage area down from nearly 15% (no mitigation) to less than 1% if 24 dB of mitigation were to be achievable.

---

[9] This is based on the probabilistic model which reflects the failure rate of individual receivers.

[10] This reflects the analogue TV coverage area being completely tiled with DVB-H coverage areas each being served by its own DVB-H transmitter.

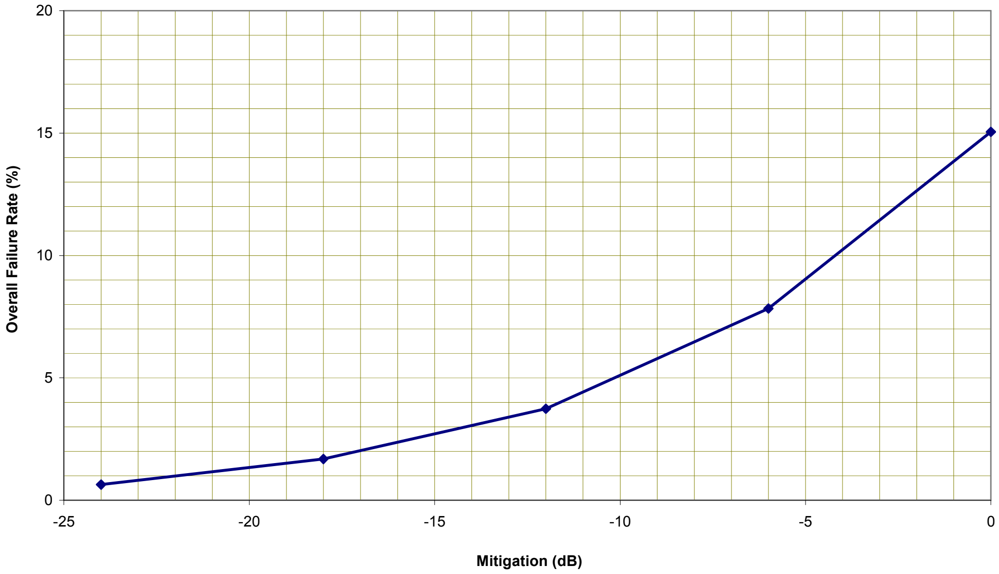

Figure 5.8: Overall Failure Rates

6 CROSS BORDER INTERFERENCE

6.1 Independent DVB-H Network

At an early stage in the development of DVB-H, some stress was laid on the possibility that DVB-H services might be transmitted using the same infrastructure as DVB-T; indeed, it is technically possible to transmit both services within the same multiplex.

With the roll-out of practical services, it has become clear that dedicated DVB-H networks are generally to be preferred. This will, particularly, be the case in the UK, where the DVB-T network is intended primarily to support rooftop reception[11] . There is therefore an enormous difference between the Rayleigh-faded channel to a low-gain terminal near the ground and the Ricean channel experienced to a directional rooftop aerial at 10m.

This difference implies that, in an unconstrained world, the DVB-H transmitter network structure would be quite different from that used to support DVB-T services. The necessarily high, uniform fields strength (in the order of 70dBuV/m and 90dBuV/m to support outdoor and indoor services respectively) would best be provided by a dense network of low power sites.

A brief exercise has been undertaken to examine the coverage and interference implications of different transmitter network options.

[11] The contrast is less marked in other countries. In the Netherlands, for example, the DVB-T network has been re-configured to target portable DVB-T reception, using a larger number of lower power transmit sites than was the case for Analogue TV. This network is more suitable for the provision of DVB-H services, and one MUX will be used to do so.

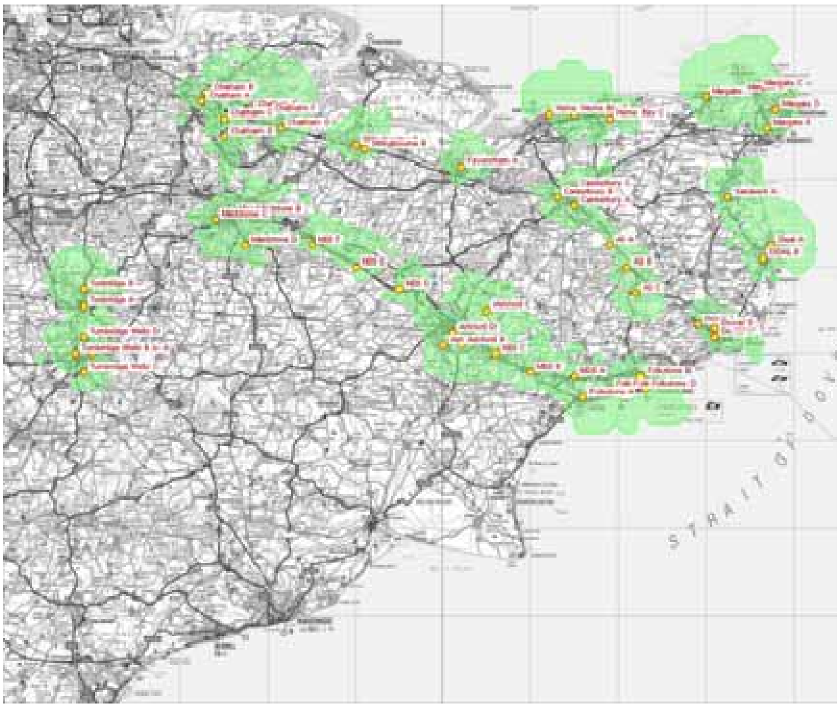

Figure 6.1: 8k SFN using 200 W sites

The network illustrated above comprises 56 sites, and was designed with the intention of providing a contiguous service in urban areas and along main transport routes within Kent. The transmitter sites are assumed to have an ERP of 200W at a height of some 20m above ground.

Such installations would probably comprise a transmitter of some 50W output power feeding a simple omnidirectional aerial, with the programme feed taken from a satellite receiver with a small (DTH-type) dish.

One advantage of such a network, operating in an SFN, is that it is capable of expansion without causing self-interference. In the network shown in Figure 2, slight self-interference was noted when using short guard-intervals in 2K mode, but none otherwise.

If the network illustrated were to be implemented on Channel 36, the potential for interference to ‘Five’ services would be limited, as that network is sparse in this part of the country, due to continental interference constraints. The coverage of the ‘Five’ network is illustrated in Figure 6.2, and is only provided from the relay transmitters at Tunbridge Wells and Hastings The 1MW transmitter at Croydon provides a service to London, but has a directional aerial to minimise exported interference so that coverage is limited to the South and East. The other analogue networks make use of additional main station sites at Bluebell Hill (30kW ERP) near Maidstone and Dover (100 kW ERP), but these have no assignment for ‘Five’.

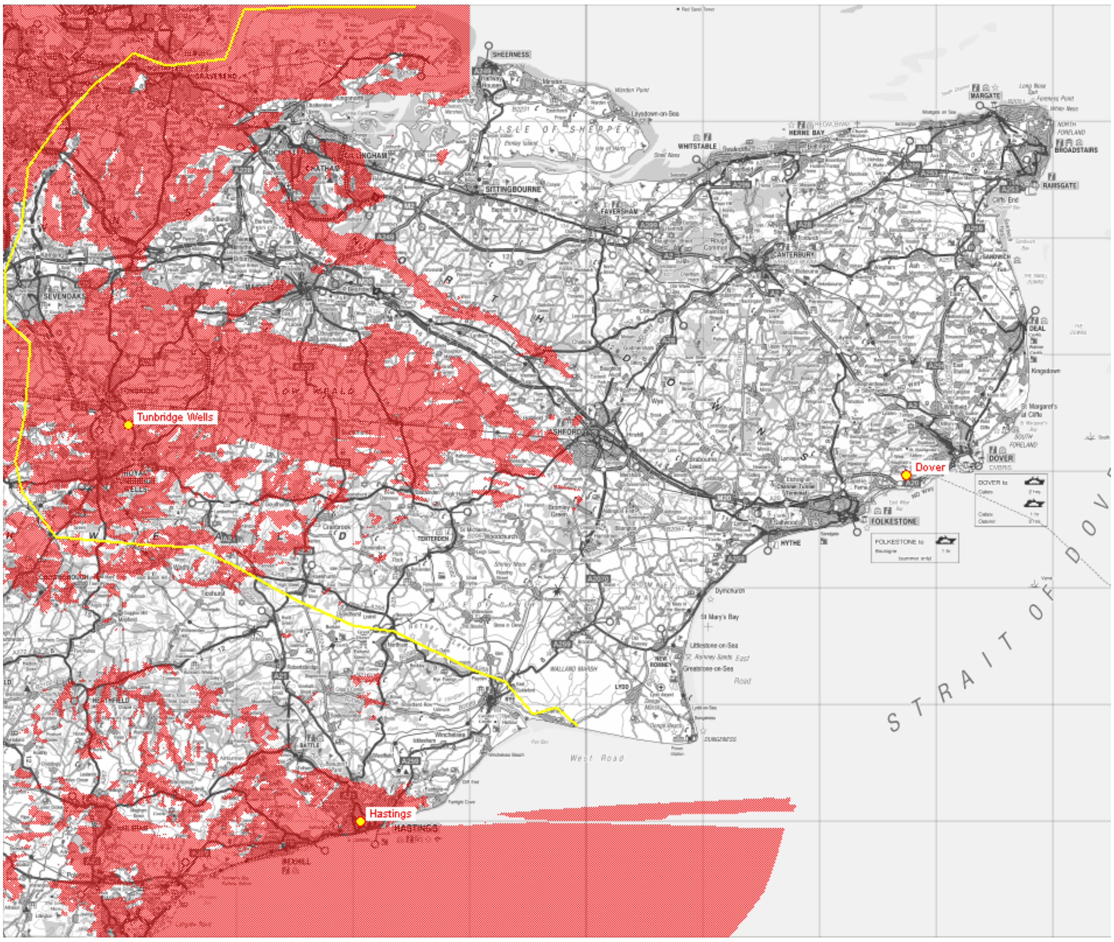

Figure 6.2: Coverage of 'Five' in Kent (Aegis estimate)

The impact of the DVB-H network shown in Figure 6.1 on the existing 'Five' service area has been predicted, and is shown below.

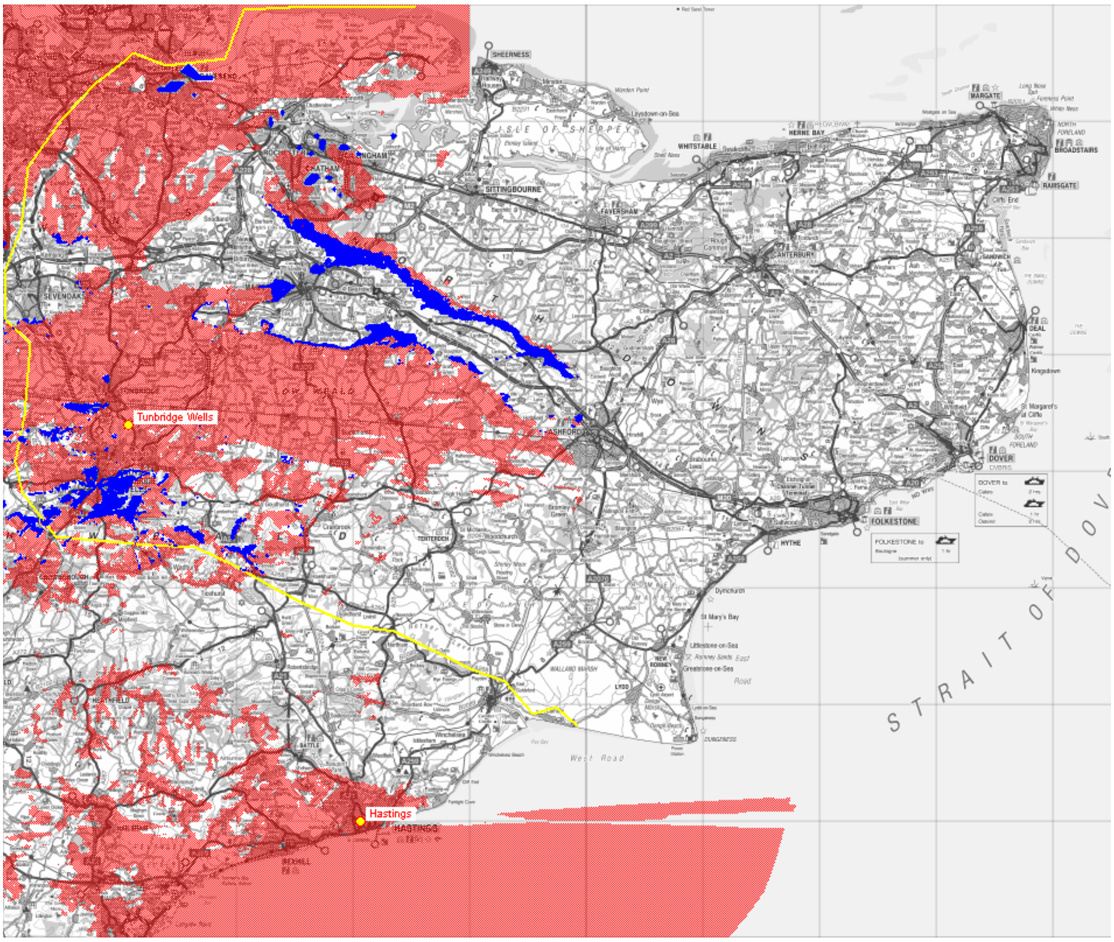

Figure 6.3: Impact of low-power DVB-H network on 'Five' coverage

It can be seen that interference (shown in blue) from the DVB-H network is limited to the immediate vicinity of the DVB-H transmitter sites, except in areas of marginal coverage. The impact on the Tunbridge Wells service is greatest, as this is co-polarised with the interference.

Figure 6.3 may be considered somewhat misleading – as no DVB-H coverage has been modelled in Sussex or London, little or no impact is shown on the coverage areas of the Croydon and Hastings transmitters. In practice, a dense DVB-H network, such as that of Figure 6.1, serving London would lead to a very significant loss of 'Five' coverage.

6.2 Co-sited DVB-H network

An obvious means by which mutual interference between the 'Five' network, and a DVB-H service on Channel 36 might be avoided would be to co-site the DVB-H transmitters at the 'Five' analogue transmission sites.

This has been modelled below, with the initial assumption that the DVB-H transmitter power is the same as that for the analogue service[12]. As the 'Five' network is sparse in Kent, it has been assumed that the main transmitter sites used by the other analogue networks are also used for DVB-H transmission. The results are shown in Figures 6.4 and 6.5 for coverage limits of 72 dBμV/m (outdoor service) and 90dBμV/m (indoor service) respectively. The aerial radiation patterns currently in use at these sites for the analogue services are indicated in Figure 6.6.

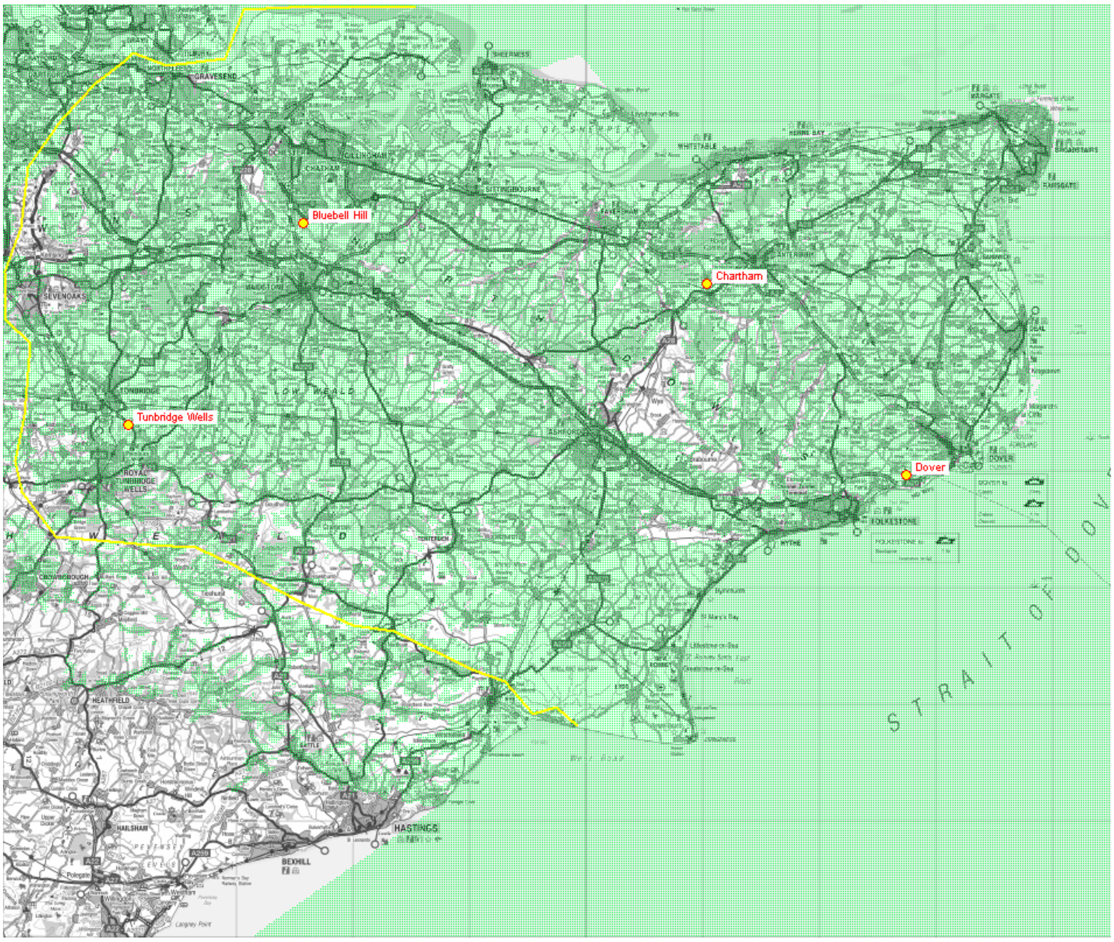

Figure 6.4: DVB-H outdoor coverage from analogue TV sites

[12] Note that this is not the usual practice in the DSO plan, where DVB-T services are generally planned at a level some 10dB below the current analogue power. The use of higher power would be justified by the more demanding DVB-H link budget.

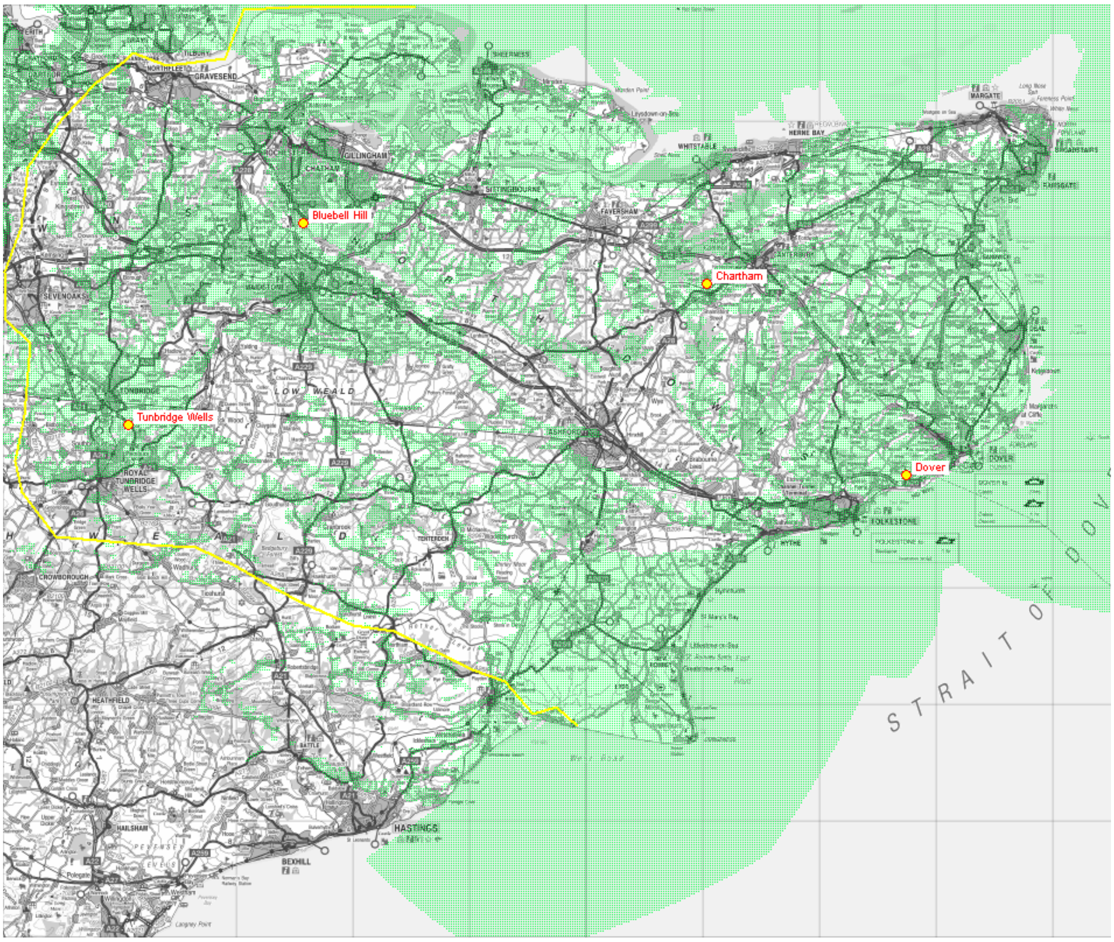

Figure 6.5: DVB-H indoor coverage from analogue TV sites

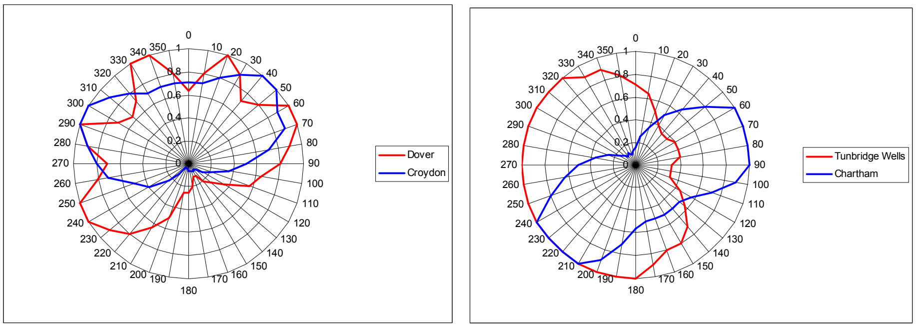

Figure 6.6: Assumed HRPDVB-H outdoor coverage from analogue TV sites

It can be seen from Figures 6.4 and 6.5 that significant coverage deficiencies remain in the DVB-H network; these may, however, be filled relatively simply by the provision of low-power 'filler' sites, operating in an SFN with the main network. The risk still exists that such fillers will cause interference to the 'Five' network, but this is only likely to impact on areas of marginal reception.

The impact of self-interference within a nationwide, high-power DVB-H network has not been modelled. Such self-interference is a constraint in DVB-T planning.