Digital Dividend (Interference Analysis of Mobile WiMAX, DTT & DVB-H Systems)

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ÆGIS spectrum engineering

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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 adjacent band interference issues associated with the possible use of the released/interleaved spectrum by wireless broadband systems, DTT and DVB-H systems.

Among wireless broadband systems, IEEE 802.16 has been considered in the work carried out by Aegis. IEEE 802.16 is a family of standards defining the physical and medium access control layers for the wireless metropolitan area network and is often referred to as WiMAX. The 802.16 standards describe various modes of system operation. These include fixed/mobile, line-of-sight/non-line-of-sight, TDD/FDD and licensed/license-exempt bands. Channel bandwidths from 1.75 MHz to 10 MHz are defined in various air interfaces standardised in 802.16. In this study, system characteristics of mobile WiMAX are taken to be representative of wireless broadband technologies that might be implemented in the released/interleaved spectrum.

Adjacent band interference scenarios have been analysed using the Monte Carlo method where probability density functions for various system parameters are used to generate random samples. The probability of interference is then determined by comparing calculated wanted and unwanted signals at a victim receiver in each trial against an interference criterion. Interference scenarios have examined interference from base stations to base stations, subscriber stations to subscriber stations, base stations to subscriber stations and subscriber stations to base stations.

Results of the adjacent band sharing between the mobile WiMAX and DTT systems show that:

- Mobile WiMAX base station TX interference into DTT probabilities averaged over the DTT coverage area are 42.8% for 0 MHz and 11.9% for 1 MHz guard band. These figures could be significantly less if the real distribution of the population were to be taken into account.
- The mobile WiMAX subscriber station TX interference into DTT RX is calculated to be well below (some 40 dB) the wanted power levels at the DTT coverage edge when interference statistics from a wide area are considered.
- The analysis of a single interference entry from a mobile WiMAX subscriber station TX into a DTT RX located nearby indicates that the required minimum

separation is 27 m for 7 MHz guard band and 70 m for 0 MHz guard band when the DTT RX is at the DTT coverage edge and the interference is through the DTT RX antenna boresight.

- Interference from DTT TX into mobile WiMAX base station RXs results in an increase in the receiver noise floor receiver floor of up to approximately 80 dB. It should be noted that the impact of interference may be reduced by avoiding WiMAX base station antenna alignment with the DTT TXs as their location will be known before the mobile WiMAX base stations are deployed. Furthermore, a better receiver filtering will reduce the impact of interference.
- Interference analysis of DTT TX into mobile WiMAX subscriber station RXs suggests that interference probabilities reduce from 1.24% to 0.35% when the guard band is increased from 0 MHz to 6 MHz.

Results of the adjacent band sharing between the mobile WiMAX and DVB-H systems show that:

- The mobile WiMAX base station TX into DVB-H RX interference analysis results in interference probabilities of 2.22% for no guard band and 0.47% for 1 MHz guard band.
- In the mobile WiMAX subscriber station TX into DVB-H RX interference scenario, the resultant CDFs of wanted and aggregate interference power show that probabilities associated with the lowest value of the wanted power and the highest value of aggregate interference (giving rise to C/I values close to the protection ratio) are very small. Therefore, as in the case of interference from mobile WiMAX subscriber station TX into DTT RX, the probability of interference from mobile WiMAX subscriber station into DVB-H RX is very small when a wide simulation area is considered.
- The analysis of interference from a single WiMAX subscriber station TX into a DVB-H RX (assumed to be operating at the edge of the DVB-H coverage area) suggests that the required minimum separation distance varies between 82 m and 212 m when the guard band varies between 7 MHz and 0 MHz.
- In the case of Interference from a DVB-H TX into mobile WiMAX base station RXs, the receiver noise floor is raised significantly (up to in excess of 100 dB).
- The interference probability due to the DVB-H TX interference into mobile WiMAX subscriber station RXs increases from 15.84% to 32.45% when the guard band is reduced from 6 MHz to 0 MHz.

1 INTRODUCTION

This report provides results of adjacent channel interference modelling between Mobile WiMAX, DTT and DVB-H systems in the UHF spectrum.

Interference scenarios have been analysed using Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) developed by European Radicommunications Office (ERO). The software is used to implement generic co-existence studies for radio systems operating in same or adjacent frequency bands.

SEAMCAT is a statistical simulation model based on the Monte Carlo method where probability density functions for various system parameters (e.g. antenna heights, powers, operating frequencies, positions of the transceivers, etc.) are used to generate random samples (also called trials or snapshots). In each trial, interfering and desired signal powers are calculated using sampled values. The probability of interference is then determined by comparing calculated wanted and unwanted signals at a victim receiver in each trial against an interference criterion, for example C/I, I/N or C/(N+I).

Main elements of a SEAMCAT interference scenario are shown in the following figure.

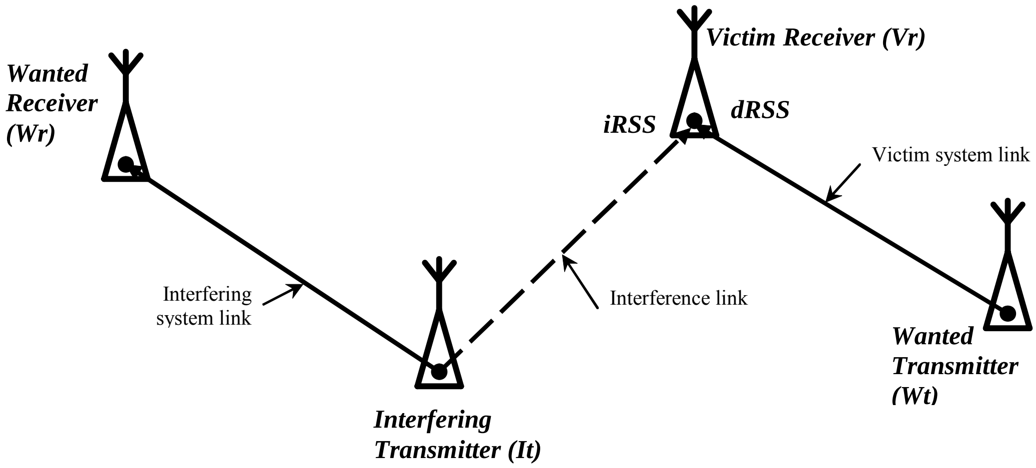

Figure 1: Main Elements of SEAMCAT Interference Scenario (Taken from SEAMCAT User Manual, http://www.ero.dk/seamcat)

In each trial, the wanted transmitter (WT) is always first positioned at the origin of the simulation area. The victim receiver (VR) and interfering link are then positioned relative to the WT according to appropriate user defined statistical rules.

For scenarios involving CDMA systems, specific simulation modules are used where non-interfered (nominal) capacity is determined before considering interfering signals. For victim CDMA systems, the interference criteria is the excess outage, i.e. the percentage of users that cannot be served as a result of interference.

For scenarios involving OFDM systems (such as mobile WiMAX), the development of specific simulation modules is not complete. Therefore, interference scenarios have been analysed using generic SEAMCAT features during the course of this study.

2 INTERFERENCE FROM MOBILE WIMAX INTO DTT

2.1 Mobile WiMAX Base Station Transmitter into DTT Receiver

2.1.1 Approach

Interference from a cluster of 9 mobile WiMAX cells is aggregated at a victim DTT RX. The victim DTT RX is located randomly within the central mobile WiMAX cell.

Repeated predictions are made as the entire mobile WiMAX 9-cell pattern is shifted from the centre towards the edge of the DTT coverage area to derive statistics for the whole DTT coverage area.

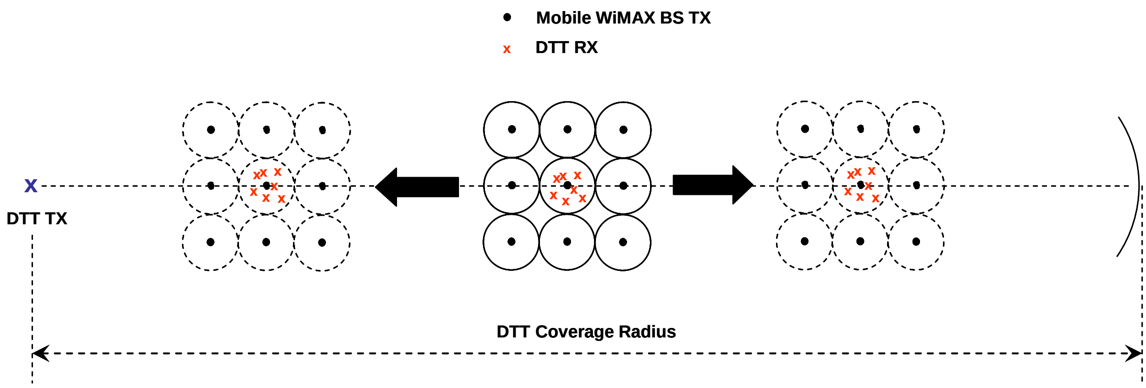

Figure 2: Interference Analysis Approach

2.1.2 Parameters

The list of assumed parameter values is shown in table below.

Frequency	586 MHz
DTT TX EIRP	72.15 dBm (10 kW ERP) (Ref: [1])
DTT TX Noise BW	7.6 MHz
DTT TX Height (a.g.l.)	100 m
DTT RX Height (a.g.l.)	10 m
DTT RX Antenna Maximum Gain	12.8 dBi (Ref: [2])
DTT RX Antenna Pattern	ITU-R BT 419-3 (Ref: [3])
DTT RX Feeder Loss	3.6 dB (Ref: [2])
DTT RX Noise Figure	7 dB (Ref: [4])
DTT RX Noise Floor	-98.2 dBm
DTT Link Minimum Required C/N	22.8 dB (Ref: [2])
DTT Link Median Path Loss Model	Rec. 1546 (Ref: [5])
DTT Link Path Loss Variations	Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6])
DTT Protection Requirement	95% of locations protected from mobile WiMAX interference at the coverage edge (Target Minimum Median Field Strength = 57 dBμV/m)
DTT Coverage Radius	30.8 km
Mobile WiMAX BS TX Maximum Power	36.3 dBm (Ref: [7,8])
Mobile WiMAX BS TX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS TX Antenna Maximum Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS TX Maximum EIRP	54.3 dBm
Mobile WiMAX BS TX Height (a.g.l.)	30 m
Mobile WiMAX SS RX Height (a.g.l.)	1.5 m
Mobile WiMAX SS RX Maximum Antenna Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX SS RX Antenna Pattern	Omni
Mobile WiMAX SS RX Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX SS RX Noise Figure	7 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	8.93 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Coverage Requirement	95% at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model *(Mobile WiMAX BS into DTT RX)*	SEAMCAT's Hata Urban Outdoor-outdoor Model with log-normal variation

Table 1: Mobile WiMAX BS TX into DTT RX Interference Analysis Modelling Parameters

The maximum mobile WiMAX BS TX EIRP (54.3 dBm) is specified for 420 OFDM subcarriers each with 10.94 kHz spacing. In simulations, it is assumed that the mobile WiMAX BS TX EIRP varies uniformly between 48.28 dBm and 53.05 dBm in order to accommodate the variable BS TX traffic loading. These values correspond to 25% and 75% of 420 subcarriers allocated to each BS TX. The bandwidth remains the same for all EIRP values as OFDM subcarriers are assumed to be randomly distributed within the entire available bandwidth.

The following figure illustrates the ERA measurement of protection ratios as a function of guard band between the DTT RX and mobile WiMAX BS TX channels. These values are used in SEAMCAT scenarios to assess the impact of interference.

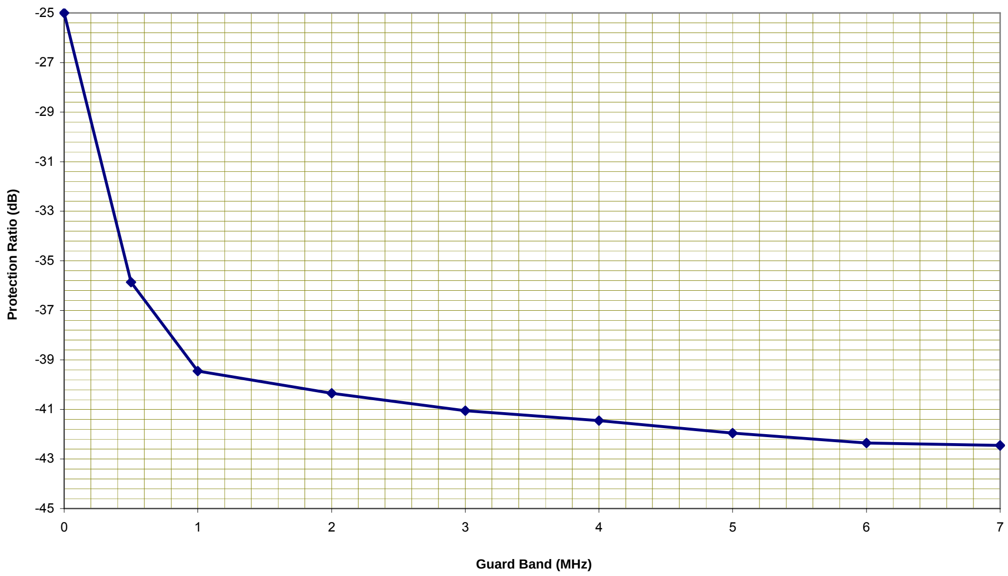

Figure 3: Protection Ratios

2.1.3 Analysis Results

Two sets of results have been derived corresponding to 0 and 1 MHz guard band between the DTT RX and WiMAX BS TX channels as the protection ratio does not vary significantly beyond 1 MHz guard band until the guard band exceeds 10 MHz. For the 0 MHz guard band case, the protection ratio is -25 dB while the corresponding value for 1 MHz guard band is -39.5 dB.

As an example, the following figure illustrates the interference scenario where the mobile WiMAX 9-cell pattern interferes with the DTT RX located randomly (within the centre mobile WiMAX cell) towards the edge of the DTT coverage area of a radius of 30.8 km where it is most susceptible to interference. The SEAMCAT simulation run comprises a user defined number of trials (e.g. 20,000) in each of which a DTT RX is randomly placed within the centre mobile WiMAX cell to find an overall estimate for the probability of interference. The following figure shows an example set (comprising few hundred trials) from a total of 20,000 trails.

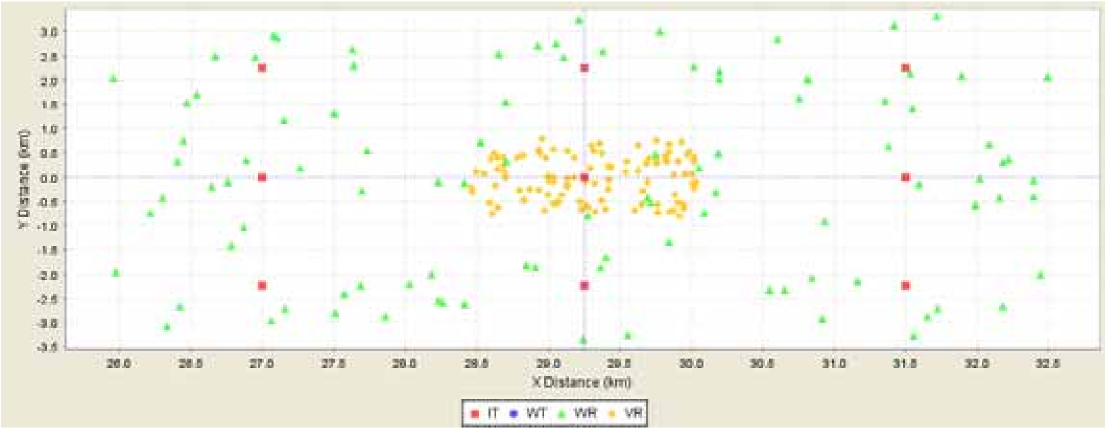

Figure 4: Mobile WiMAX BS TX into DTT RX Interference Scenario Outline from SEAMCAT (DTT RX at DTT Coverage Edge)

In the scenario outline, red points refer to interfering mobile WiMAX BS TXs while orange points correspond to a sample set of victim DTT RX random locations.

SEAMCAT generates separate wanted power and aggregate interference statistics. For the scenario considered (where a DTT receiver is assumed to operate near the edge of coverage), the reported mean wanted power is -65.61 dBm and the standard deviation is 5.56 dB. The reported mean aggregate interference is -33.9 dBm and the standard deviation is 9.92 dB. Based on these statistics, the probability of interference is calculated to be 71.2% for 0 MHz guard band and 22.6% for 1 MHz guard band using the SEAMCAT's interference calculation engine.

The following plots compare interference probabilities obtained from a number of SEAMCAT simulation runs. Interference probabilities are presented as a function of distance between the DTT TX location (i.e. the centre of the DTT coverage area of 30.8 km radius) and the centre of the mobile WiMAX 9-cell pattern.

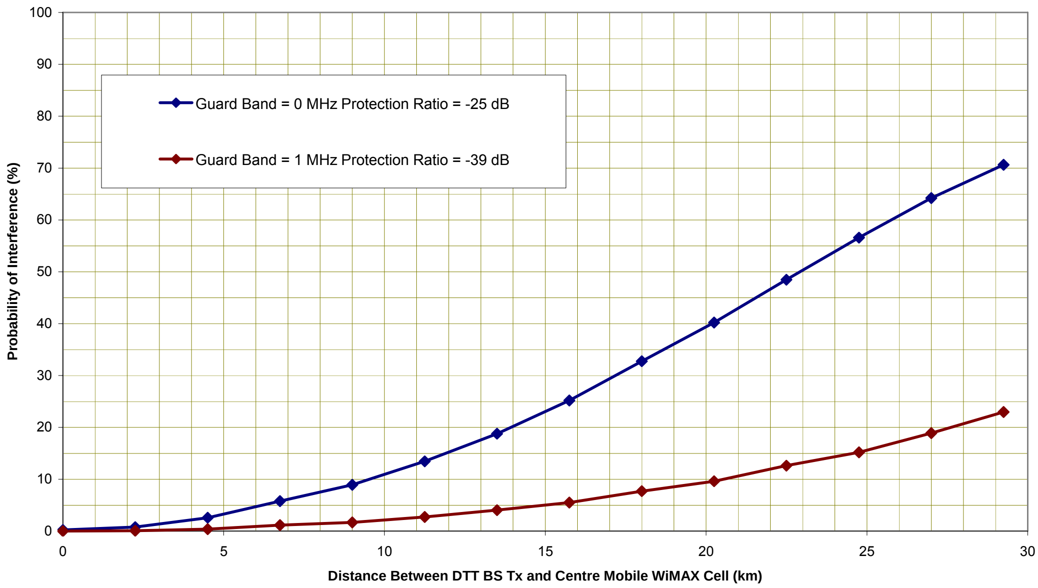

Figure 5: Interference Probabilities

Interference probabilities shown in the above figure are integrated over the DTT coverage area to calculate the overall interference probability. For the no guard band scenario, the overall interference probability is 42.8% while the use of 1 MHz guard band (which implies 14 dB relaxed protection ratio) results in 11.9% overall interference probability.

As noted earlier, the discrimination is not significantly different when guard bands between 1 – 7 MHz are considered. Therefore, for the guard bands between 1 MHz and 7 MHz, interference probabilities are not expected to be substantially different.

2.2 Mobile WiMAX Subscriber Station Transmitter into DTT Receiver

2.2.1 Approach

Interference from a population of mobile WiMAX Subscriber Station (SS) TXs operating in a cluster of 9 mobile WiMAX cells (each with three sectors) is aggregated at a victim DTT RX. The victim DTT RX is located randomly within the centre mobile WiMAX cell positioned at the edge of DTT coverage area where it is most susceptible to interference.

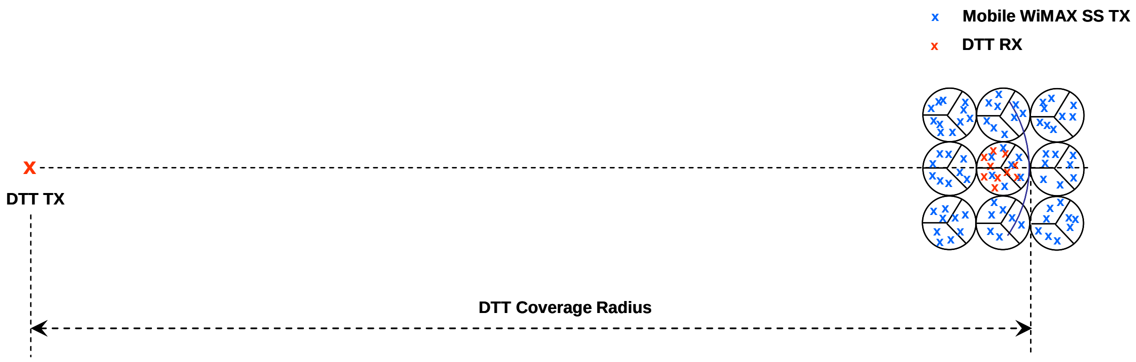

Figure 6: Interference Analysis Approach

2.2.2 Parameters

The following table provides the list of assumed parameter values.

Frequency	586 MHz
DTT TX EIRP	72.15 dBm (10 kW ERP) (Ref: [1])
DTT TX Noise BW	7.6 MHz
DTT TX Height (a.g.l.)	100 m
DTT RX Height (a.g.l.)	10 m
DTT RX Antenna Maximum Gain	12.8 dBi (Ref: [2])
DTT RX Antenna Pattern	ITU-R BT 419-3 (Ref: [3])
DTT RX Feeder Loss	3.6 dB (Ref: [2])
DTT RX Noise Figure	7 dB (Ref: [4])
DTT RX Noise Floor	-98.2 dBm
DTT Link Minimum Required C/N	22.8 dB (Ref: [2])
DTT Link Median Path Loss Model	Rec. 1546 (Ref: [5])
DTT Link Path Loss Variations	Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6])
DTT Protection Requirement	95% of locations protected from mobile WiMAX interference at the coverage edge (Target Minimum Median Field Strength = 57 dBμV/m)
DTT Coverage Radius	30.8 km
Mobile WiMAX SS TX Maximum Power	22 dBm (Ref: [7,8])
Mobile WiMAX SS TX Antenna Diversity Gain	0 dB (Ref: [7,8])
Mobile WiMAX SS TX Antenna Maximum Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS TX Maximum EIRP	21 dBm
Mobile WiMAX SS TX Antenna Pattern	Omni
Mobile WiMAX SS TX Height (a.g.l.)	1.5 m
Mobile WiMAX BS RX Height (a.g.l.)	30 m
Mobile WiMAX BS RX Maximum Antenna Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS RX Antenna Pattern	120 Degrees Sector Antenna DB878H120E-A from www.andrew.com
Mobile WiMAX BS RX Maximum Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX BS RX Noise Figure	4 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	-2.5 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Coverage Requirement	95% at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model (Mobile WiMAX SS into DTT RX)	SEAMCAT's Hata Urban Indoor-outdoor Model with log-normal variation

Table 2: Mobile WiMAX SS TX into DTT RX Interference Analysis Modelling Parameters

Assumed mobile WiMAX BS RX antenna vertical and horizontal patterns are shown in figures below.

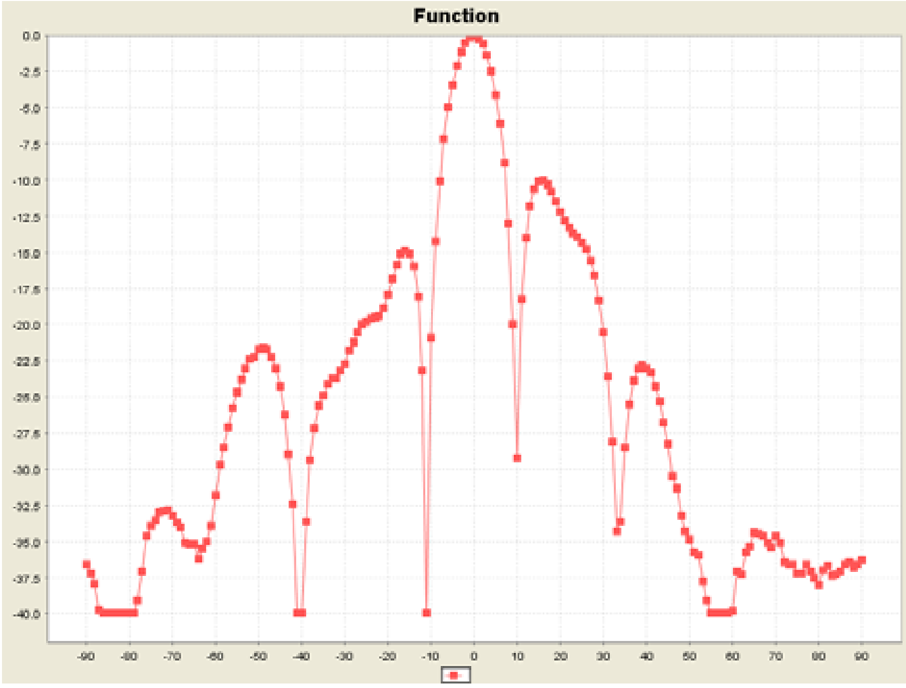

Figure 7: Mobile WiMAX BS RX Vertical Pattern (120 Degrees Sector Antenna DB878H120E-A from www.andrew.com)

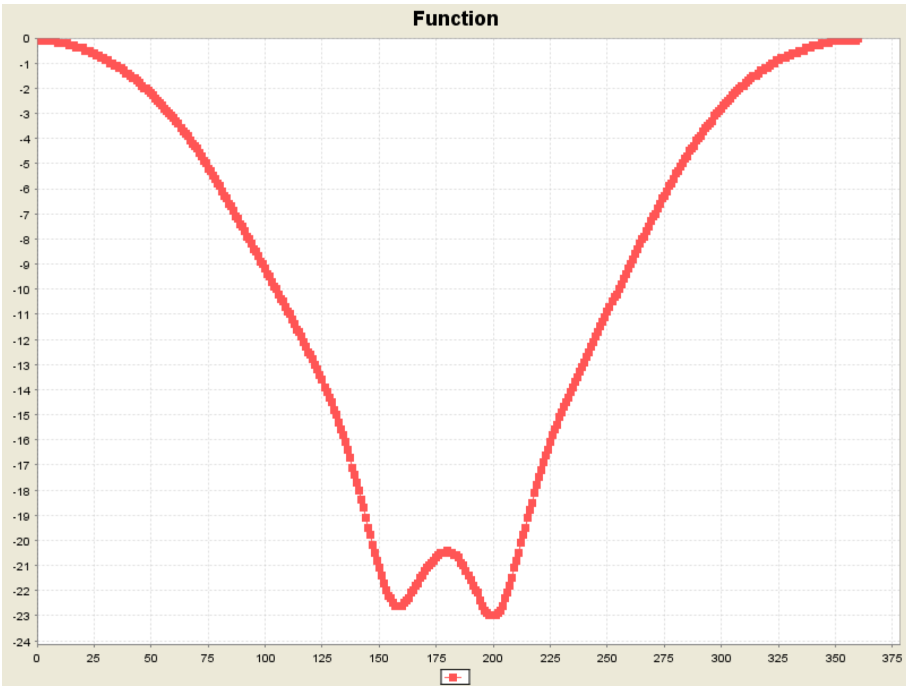

Figure 8: Mobile WiMAX BS RX Horizontal Pattern (120 Degrees Sector Antenna DB878H120E-A from www.andrew.com)

In each mobile WiMAX channel, a total of 420 subcarriers are shared among a number of mobile WiMAX SS TXs. A mobile WiMAX cell is assumed to comprise 3 sectors and each sector is assumed to use the same frequency channel (i.e. the frequency re-use is 1). At a given simulation trial, interference from 5 users in each sector is aggregated at the victim DTT RX. 5 users are assumed to share 420 subcarriers according to the following table.

	No Of Subcarriers	*EIRP (dBm)*
User 1	210	20.88
User 2	63	15.65
User 3	63	15.65
User 4	42	13.89
User 5	42	13.89

Table 3: Mobile WiMAX SS TX User Profiles

The mobile WiMAX system employs uplink power control. The power control dynamic range is assumed to be 45 dB.

The following figure illustrates the assumed protection ratios (based on the measurements by ERA) as a function of guard band between the DTT RX and mobile WiMAX SS TX channels.

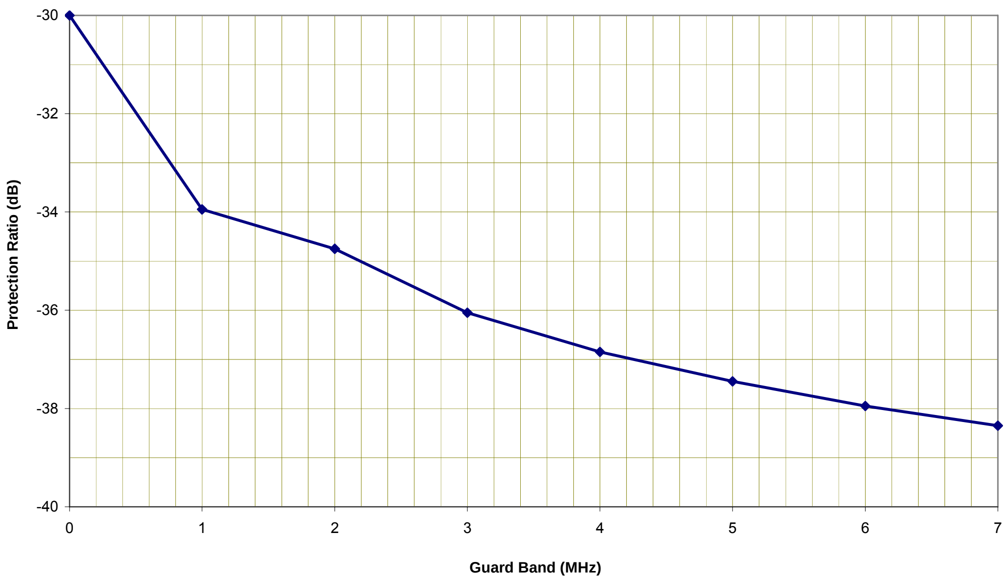

Figure 9: Protection Ratios

2.2.3 Analysis Results

The interference scenario assumes that the victim DTT RX is randomly located within the centre mobile WiMAX cell (of a radius of 1.125 km) positioned at the edge of DTT coverage area (of a radius of 30.8 km). In each simulation trial, interference from a total of 5 x 3 x 9 = 135 mobile WiMAX SS TXs is aggregated. The CDFs of wanted and aggregate interference power are shown in the following figures.

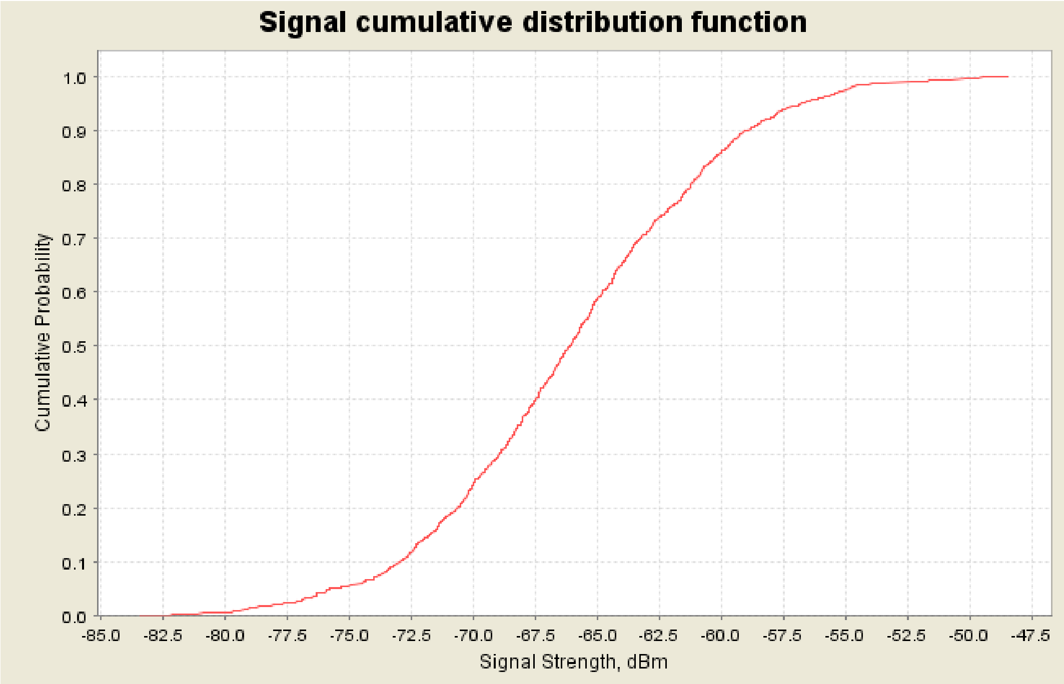

Figure 10: Wanted Power CDF at DTT RX (Mean = -66.1 dBm, Std Dev = 5.63 dB)

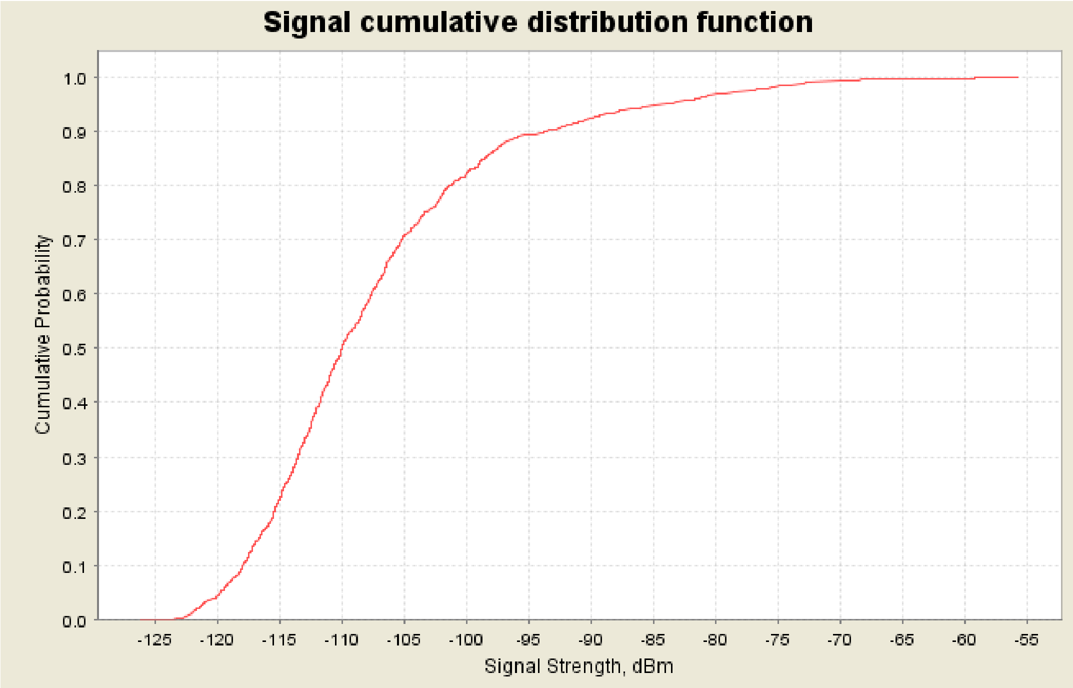

Figure 11: Interference Power CDF at DTT RX (Mean = -107.53 dBm, Std Dev = 10.58 dB)

The figures show that the wanted power is less than approximately -80 dBm for less than 1% of trials and the aggregate interference power is greater than approximately -60 dBm for less than 1% of trials. This gives rise to a C/I of less than -20 dB for less than 0.01%. As the protection ratio is -30 dB (i.e. the aggregate interference power could be as high as 30 dB above the wanted power) when here is no guard band between the mobile WiMAX SS TX and DTT RX channels, any likelihood of the protection ratio not being met is considerably less than 0.01%. SEAMCAT returns an interference probability of 0%.

While a consideration of a wide simulation area returns a very low interference probability, this does not mean that the operation of mobile WiMAX SS TXs and DTT RXs in a very close proximity will be feasible. Therefore, a further scenario is considered to examine the impact of interference from a single WiMAX SS TX (located indoors) into a nearby DTT RX (located outdoors and assumed to be operating at the edge of the DTT coverage area). Figure below illustrates the C/I variation with the distance between the WiMAX SS TX and DTT RX when the interference entry is through the DTT RX antenna boresight where the receive gain is 12.84 dBi. It is assumed that the path loss is free space and the building penetration loss is 11 dB.

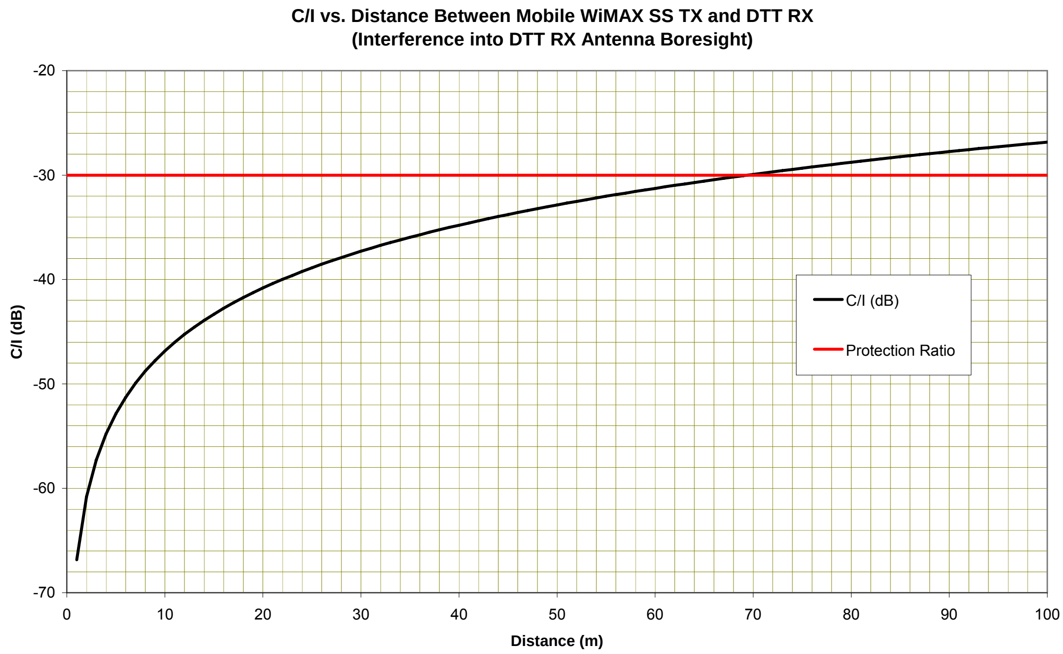

Figure 12: C/I vs. Distance Between Mobile WiMAX SS TX and DTT RX

As can be seen, the minimum required separation is 70 metres to satisfy the protection requirement of -30 dB (corresponding to a no guard band scenario). It should be noted that this separation is calculated for the DTT RX operating at the edge of the DTT coverage area. For DTT RXs operating at distances close to the DTT TX, the required separation will be reduced due to the additional margin available.

The following table shows the required separation distances for different guard bands.

Guard Band (MHz)	*Min Separation (m)*
0	70
1	44
3	35
5	30
7	27

Table 4: Guard Band vs. Minimum Required Separation Distance (DTT RX Gain = 12.84 dBi)

As mentioned earlier, the figures above are obtained for a boresight interference entry at the DTT RX (i.e. the receive antenna gain is 12.84 dBi). The following table provides minimum required distances for different guard bands for an interference entry through the receive antenna rearlobe where the gain is -3.16 dBi.

Guard Band (MHz)	*Min Separation (m)*
0	11
1	7
3	5.6
5	4.7
7	4.3

Table 5: Guard Band vs. Minimum Required Separation Distance (DTT RX Gain = -3.16 dBi)

3 INTERFERENCE FROM MOBILE WIMAX INTO DVB-H

3.1 Mobile WiMAX Base Station Transmitter into DVB-H Receiver

3.1.1 Approach

Interference from a cluster of 9 mobile WiMAX cells is aggregated at a victim DVB-H RX. The victim DVB-H RX is located randomly within the DVB-H coverage area which overlaps the centre mobile WiMAX cell.

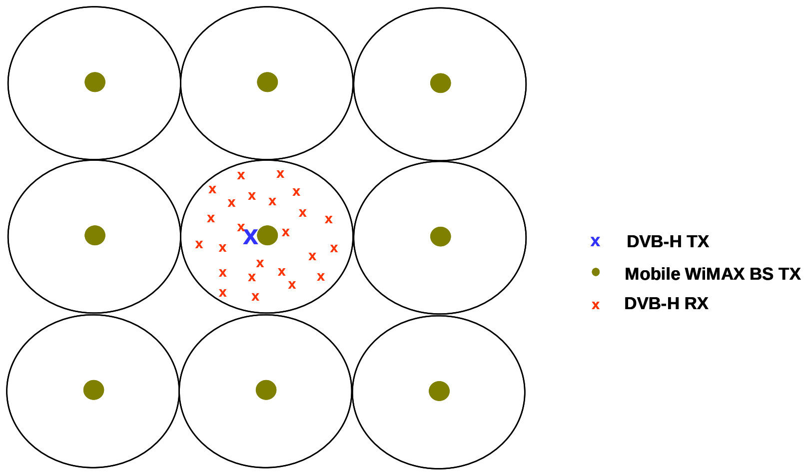

Figure 13: Interference Analysis Approach

3.1.2 Parameters

The list of assumed parameter values is shown in table below.

Frequency	586 MHz
DVB-H TX EIRP	62.15 dBm (1 kW ERP)
DVB-H TX Noise BW	7.6 MHz
DVB-H TX Height (a.g.l.)	30 m
DVB-H RX Height (a.g.l.)	1.5 m
DVB-H RX Antenna Maximum Gain	-4.85 dBi (Ref: [6])
DVB-H RX Antenna Pattern	Omni
DVB-H RX Feeder Loss	0 dB (Ref: [2])
DVB-H RX Noise Figure	6 dB (Ref: [6])
DVB-H RX Noise Floor	-99.17 dBm
DVB-H Link Minimum Required C/N	11 dB (Ref: [2])
DVB-H Link Median Path Loss Model	Hata Urban
DVB-H Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
DVB-H Protection Requirement	95% of locations protected from mobile WiMAX interference at the coverage edge (Target Minimum Median Field Strength = 90 dBμV/m)
DVB-H Coverage Radius	1.25 km
Mobile WiMAX BS TX Maximum Power	36.3 dBm (Ref: [7,8])
Mobile WiMAX BS TX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS TX Antenna Maximum Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS TX Maximum EIRP	54.3 dBm
Mobile WiMAX BS TX Height (a.g.l.)	30 m
Mobile WiMAX SS RX Height (a.g.l.)	1.5 m
Mobile WiMAX SS RX Maximum Antenna Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX SS RX Antenna Pattern	Omni
Mobile WiMAX SS RX Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX SS RX Noise Figure	7 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	8.93 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Coverage Requirement	95% at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model (Mobile WiMAX BS into DVB-H RX)	SEAMCAT's Hata Urban Outdoor-indoor Model with log-normal variation

Table 6: Mobile WiMAX BS TX into DVB-H RX Interference Analysis Modelling Parameters

The maximum mobile WiMAX BS TX EIRP (54.3 dBm) is specified for 420 OFDM subcarriers each with 10.94 kHz spacing. In simulations, it is assumed that the mobile WiMAX BS TX EIRP varies uniformly between 48.28 dBm and 53.05 dBm in order to accommodate the variable BS TX traffic loading. These values correspond to 25% and 75% of 420 subcarriers allocated to each BS TX. The bandwidth remains the same for all EIRP values as OFDM subcarriers are assumed to be randomly distributed within the entire available bandwidth.

Protection ratio levels have been measured by ERA. The following figure illustrates the measured values as a function of guard band between the DVB-H RX and mobile WiMAX BS TX channels.

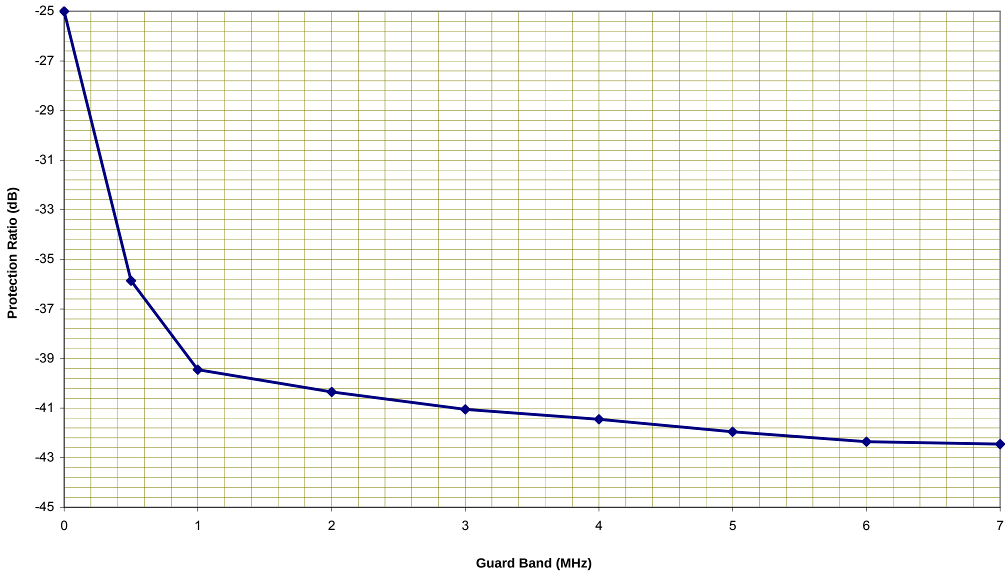

Figure 14: Protection Ratios

3.1.3 Analysis Results

Two sets of results have been presented corresponding to 0 and 1 MHz guard band between the DVB-H RX and WiMAX BS TX channels. When there is no guard band the protection ratio is -25 dB while the protection ratio for 1 MHz guard band is -39.5 dB.

The following figure illustrates example set of trials obtained from the SEAMCAT run.

Figure 15: Mobile WiMAX BS TX into DVB-H RX Interference Scenario Outline from SEAMCAT

The scenario is simulated for 20,000 trials and the above figure shows positions of scenario elements (interfering transmitter, wanted receiver, wanted transmitter and victim receiver) in 400 example trials (out of 20,000 total trials). As can be seen, the victim DVB-H RX (which is represented by yellow colour) is randomly positioned around the centre of the mobile WiMAX 9-cell BS TX pattern in each trial.

The simulation results report obtained from SEAMCAT state that the wanted power is -67.8 dBm and the standard deviation is 11 dB. The reported mean aggregate interference is -70.8 dBm and the standard deviation is 8.7 dB. Based on these statistics, the probability of interference is calculated to be 2.22% for 0 MHz guard band and 0.47% for 1 MHz guard band.

3.2 Mobile WiMAX Subscriber Station Transmitter into DVB-H Receiver

3.2.1 Approach

Interference from a population of mobile WiMAX SS TXs operating in a cluster of 9 mobile WiMAX cells (each with three sectors) is aggregated at the victim DVB-H RX. The victim DVB-H RX is located randomly within the centre mobile WiMAX cell. The DVB-H coverage area overlaps the centre mobile WiMAX cell coverage area.

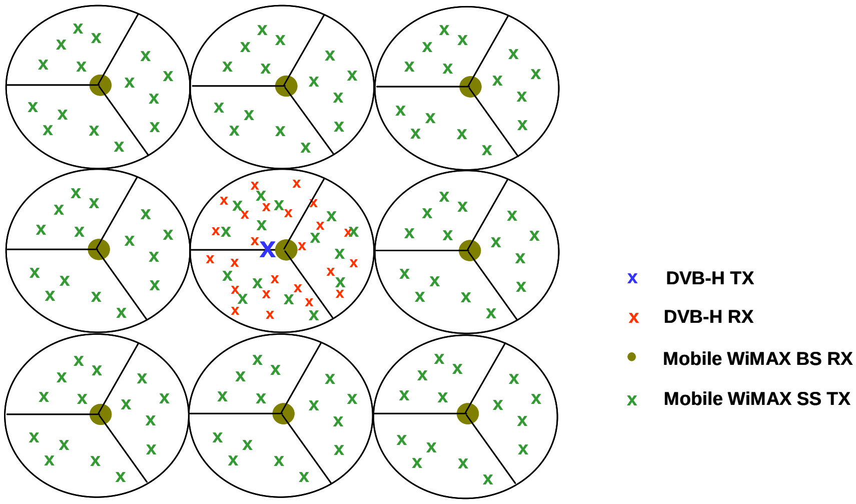

Figure 16: Interference Analysis Approach

3.2.2 Parameters

The list of assumed parameter values is shown in table below.

Frequency	586 MHz
DVB-H TX EIRP	62.15 dBm (1 kW)
DVB-H TX Noise BW	7.6 MHz
DVB-H TX Height (a.g.l.)	30 m
DVB-H RX Height (a.g.l.)	1.5 m
DVB-H RX Antenna Maximum Gain	-4.85 dBi (Ref: [6])
DVB-H RX Antenna Pattern	Omni
DVB-H RX Feeder Loss	0 dB (Ref: [2])
DVB-H RX Noise Figure	6 dB (Ref: [6])
DVB-H RX Noise Floor	-99.17 dBm
DVB-H Link Minimum Required C/N	11 dB (Ref: [2])
DVB-H Link Median Path Loss Model	Hata Urban
DVB-H Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
DVB-H Protection Requirement	95% of locations protected from mobile WiMAX interference at the coverage edge (Target Minimum Median Field Strength = 90 dBμV/m)
DVB-H Coverage Radius	1.25 km
Mobile WiMAX SS TX Maximum Power	22 dBm (Ref: [7,8])
Mobile WiMAX SS TX Antenna Diversity Gain	0 dB (Ref: [7,8])
Mobile WiMAX SS TX Antenna Maximum Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS TX Maximum EIRP	21 dBm
Mobile WiMAX SS TX Antenna Pattern	Omni
Mobile WiMAX SS TX Height (a.g.l.)	1.5 m
Mobile WiMAX BS RX Height (a.g.l.)	30 m
Mobile WiMAX BS RX Maximum Antenna Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS RX Antenna Pattern	120 Degrees Sector Antenna DB878H120E-A from www.andrew.com
Mobile WiMAX BS RX Maximum Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX BS RX Noise Figure	4 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	-2.5 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Coverage Requirement	95% at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model (Mobile WiMAX SS into DVB-H RX)	SEAMCAT's Hata Urban Indoor-indoor Model with log-normal variation

Table 7: Mobile WiMAX SS TX into DVB-H RX Interference Analysis Modelling Parameters

In each mobile WiMAX channel, a total of 420 subcarriers are shared among a number of mobile WiMAX SS TXs. A mobile WiMAX cell is assumed to comprise 3 sectors and each sector is assumed to use the same frequency channel (i.e. the frequency re-use is 1). At a given simulation trial, interference from 5 users in each sector is aggregated at the victim DVB-H RX. 5 users are assumed to share 420 subcarriers according to the following table.

	No Of Subcarriers	*EIRP (dBm)*
User 1	210	20.88
User 2	63	15.65
User 3	63	15.65
User 4	42	13.89
User 5	42	13.89

Table 8: Mobile WiMAX SS TX User Profiles

The mobile WiMAX system employs uplink power control. The power control dynamic range is assumed to be 45 dB.

The following figure illustrates the measured protection ratios (by ERA) as a function of guard band between the DVB-H RX and mobile WiMAX SS TX channels.

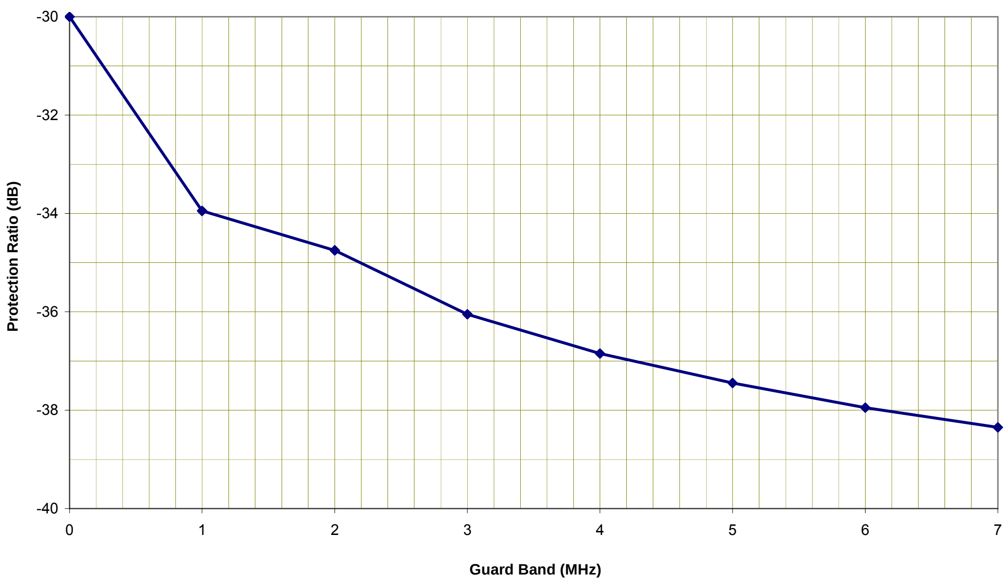

Figure 17: Protection Ratios

3.2.3 Analysis Results

In simulation trials, interference from a total of 135 mobile WiMAX SS TXs is aggregated at the victim DVB-H RX. From the resultant CDFs of wanted and aggregate interference power, probabilities associated with the lowest value of the wanted power and the highest value of aggregate interference (giving rise to C/I values close to the protection ratio) are very small. Therefore, as in the case of interference from mobile WiMAX SS into DTT RX, the probability of interference from mobile WiMAX SS into DVB-H RX is very small when a wide simulation area is considered. SEAMCAT returns 0% interference probability.

The impact of interference from a WiMAX SS TX into a DVB-H RX that are operating in close proximity is examined. It is assumed that the TX and RX are located indoors in the same office and the path loss is free space. In addition, the DVB-H RX is assumed to be located at the edge of the DVB-H coverage area. Figure below illustrates the C/I variation with the distance between the WiMAX SS TX and DVB-H RX. The DVB-H RX is an omni directional receiver with a gain of -4.85 dBi.

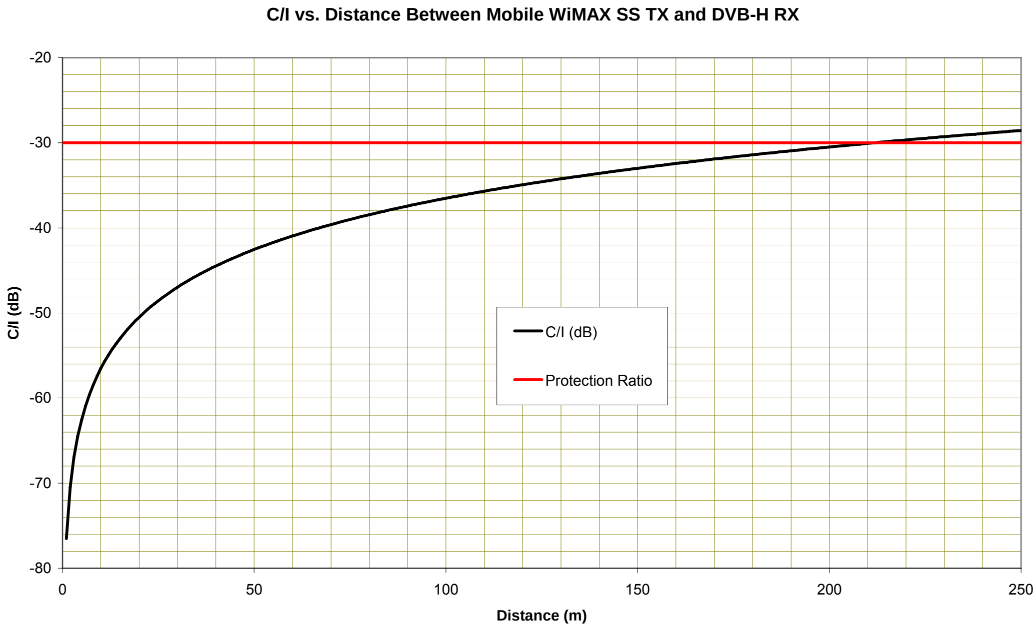

Figure 18: C/I vs. Distance Between Mobile WiMAX SS TX and DVB-H RX

In order to satisfy the protection requirement of -30 dB (corresponding to a no guard band scenario), a separation of 212 metres is required, indicating that the same room co-existence is not feasible when there is no guard band. It should be noted that this separation is calculated for the DVB-H RX operating at the edge of the DVB-H coverage area. For DVB-H RXs operating at distances close to the DVB-H TX, the required separation will be reduced due to the additional margin available.

The following table shows the required separation distances for different guard bands.

Guard Band (MHz)	*Min Separation (m)*
0	212
1	134
3	107
5	90
7	82

Table 9: Guard Band vs. Minimum Required Separation Distance

4 INTERFERENCE FROM DTT INTO MOBILE WIMAX

4.1 DTT Transmitter into Mobile WiMAX Subscriber Station Receiver

4.1.1 Approach

The sector of the mobile WiMAX cell where the victim mobile WiMAX SS RX is assumed to be operating is located randomly within the DTT coverage area (of a radius of 30.8 km).

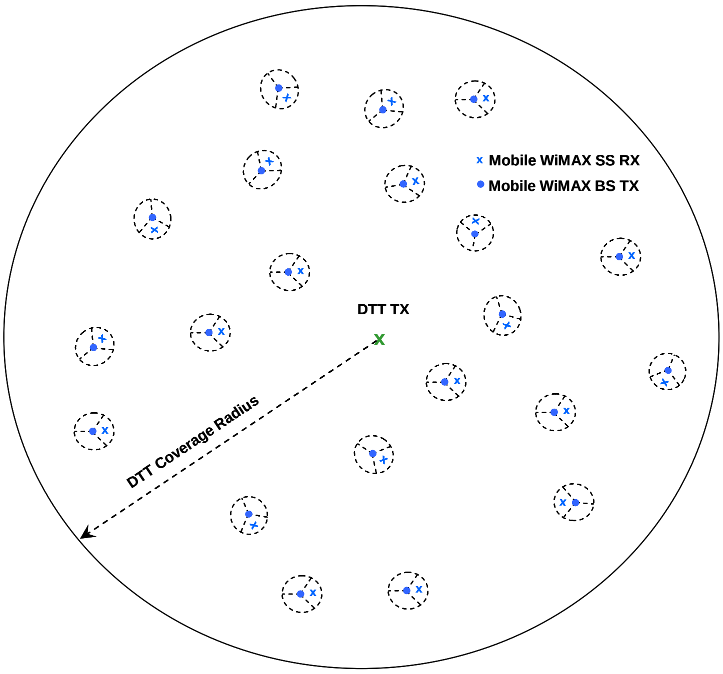

Figure 19: Interference Analysis Approach

4.1.2 Parameters

The following table provides the list of assumed parameter values.

Frequency	586 MHz
DTT TX EIRP	72.15 dBm (10 kW) (Ref: [1])
DTT TX Noise BW	7.6 MHz
DTT TX Height (a.g.l.)	100 m
DTT RX Height (a.g.l.)	10 m
DTT RX Antenna Maximum Gain	12.84 dBi (Ref: [2])
DTT RX Antenna Pattern	ITU-R BT 419-3 (Ref: [3])
DTT RX Feeder Loss	3.6 dB (Ref: [2])
DTT RX Noise Figure	7 dB (Ref: [4])
DTT RX Noise Floor	-98.17 dBm
DTT Link Minimum Required C/N	22.8 dB (Ref: [2])
DTT Link Median Path Loss Model	Rec. 1546 (Ref: [5])
DTT Link Path Loss Variations	Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6])
DTT Coverage Requirement	95% at the coverage edge
DTT Coverage Radius	30.8 km
Mobile WiMAX BS TX Maximum Power	36.3 dBm (Ref: [7,8])
Mobile WiMAX BS TX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS TX Antenna Maximum Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS TX Maximum EIRP	54.3 dBm
Mobile WiMAX BS TX Antenna Pattern	120 Degrees Sector Antenna DB878H120E-A from www.andrew.com
Mobile WiMAX BS TX Height (a.g.l.)	30 m
Mobile WiMAX SS RX Height (a.g.l.)	1.5 m
Mobile WiMAX SS RX Maximum Antenna Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX SS RX Antenna Pattern	Omni
Mobile WiMAX SS RX Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX SS RX Noise Figure	7 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	8.93 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Protection Requirement	95% of locations protected from DTT interference at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model (DTT TX into Mobile WiMAX SS RX)	SEAMCAT's Hata Urban Outdoor-indoor Model with log-normal variation

Table 10: DTT TX into Mobile WiMAX SS RX Interference Analysis Modelling Parameters

The following figure illustrates the measured protection ratios (by ERA) as a function of guard band between the DTT TX and mobile WiMAX SS RX channels.

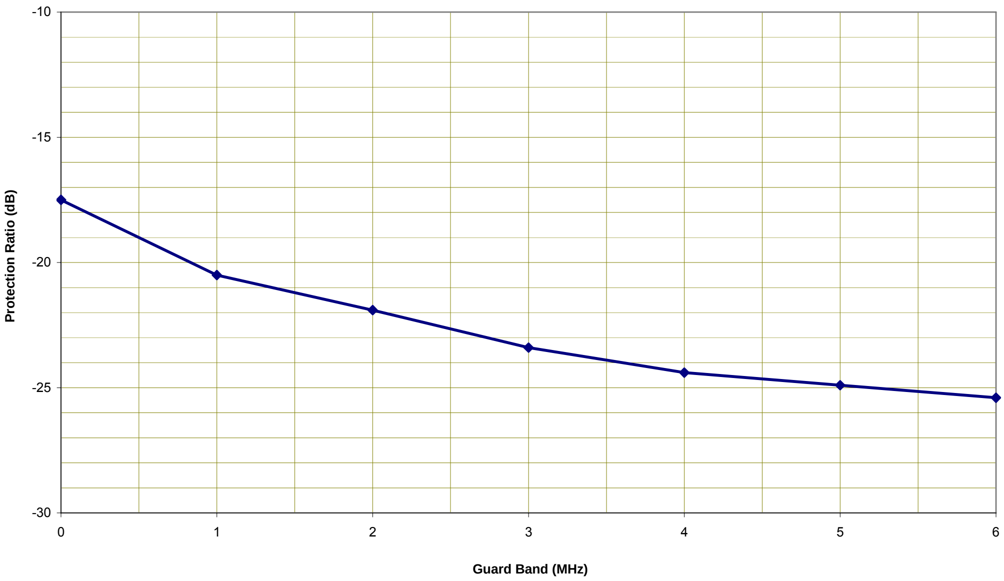

Figure 20: Protection Ratios

4.1.3 Analysis Results

An example set of positions created in the simulation is shown in following figure.

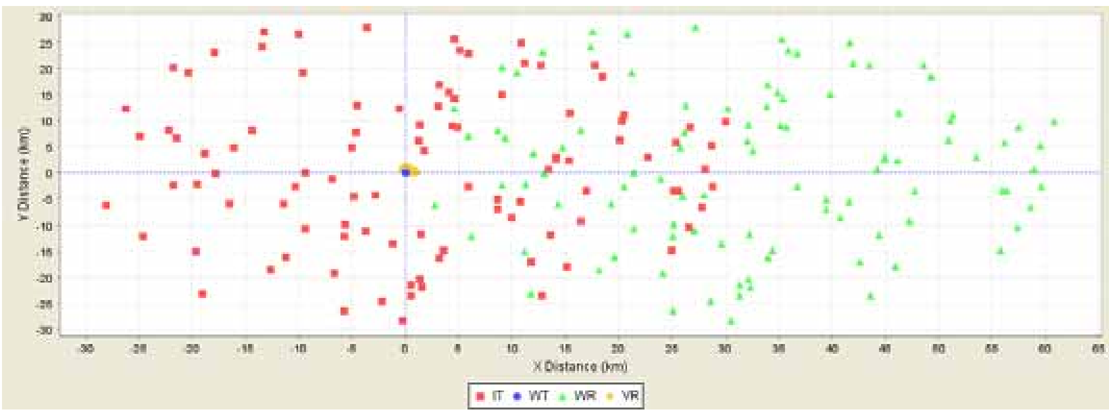

Figure 21: DTT TX into Mobile WiMAX SS RX Interference Scenario Outline from SEAMCAT

In each trial, SEAMCAT locates the wanted transmitter (mobile WiMAX BS TX) at the origin (0,0). The victim receiver (mobile WiMAX SS RX) is randomly located within the mobile WiMAX cell's 120-degrees sector (of a radius of 1.125 km). The interfering transmitter (DTT TX) is then positioned randomly within a coverage radius of 30.8 km which is equal to the DTT coverage radius. Finally, the wanted receiver (DTT RX) is located at 30.8 km distance from the interfering transmitter. It should be noted the DTT RX is included in the modelling to provide a complete interference scenario required by SEAMCAT. It does not have any significance in the interference calculations implemented during the simulations.

The following interference probabilities are obtained from SEAMCAT for a set of assumed guard bands.

Guard Band (MHz)	Protection Ratio (dB)	Interference Probability (%)
0	-17.5	1.24
1	-20.5	0.84
2	-21.9	0.61
3	-23.4	0.44
4	-24.4	0.4
5	-24.9	0.36
6	-25.4	0.35

Table 11: Interference Probabilities

The results obtained from the simulation will be pessimistic because there is an inconsistency between the modelling assumptions regarding the mobile WiMAX system and the measurements provided by ERA. The modelling assumes a 5 MHz mobile WiMAX system on the basis that such a system could conveniently use a single released channel. The ERA measurements are however based on a 20 MHz system. The channel filtering in the 20 MHz mobile WiMAX receiver will have a much slower absolute roll-off in discrimination compared to that for a 5 MHz system. The level of interference modelled for a given frequency offset is therefore likely to be 10 – 20 dB greater than it should be.

The earliest ERA measurements only extended to a frequency offset of 20 MHz (equivalent to a maximum guard band of 6 MHz as represented in Figure 20). More recent measurements, still based on a 20 MHz WiMAX receiver, have been undertaken. These are shown in Figure 22 below.

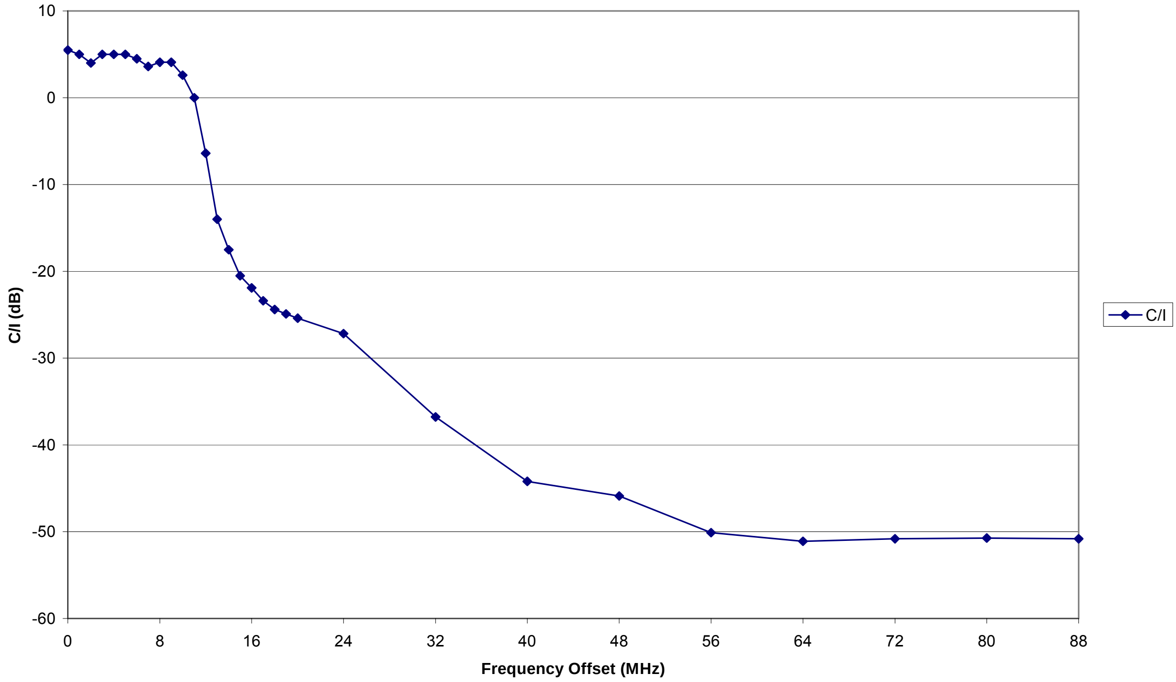

Figure 22: Extended C/I protection ratios for DTT into WiMAX

It is difficult to scale the values shown in Figure 22 as there are a number of variables involved, namely, the channel bandwidths of the interfering transmission and the victim receiver, the decay slopes of the out-of-band emissions and the receiver selectivity, and the residual level of the out-of-band emissions and the receiver selectivity.

This might lead to the assumption that the horizontal axis of Figure 22 can be scaled according to the ratio of the sum of the transmitter and receiver bandwidths (i.e. 5MHz + 8MHz as opposed to 20 MHz + 8 MHz that the measurements represent). This gives the same protection ratio with no guard band and improves the discrimination by 5 dB when a 6 MHz guard band is used. This improvement is far less than might reasonably be expected.

It is postulated that the receiver bandwidth is the dominant factor in this particular situation and it is therefore potentially more appropriate to scale according to the receiver bandwidth alone (i.e. 5 MHz as opposed to the 20 MHz that the measurements represent). On this basis the discrimination is improved by 10 dB with no guard band and by slightly more than 20 dB when a 6 MHz guard band is used.

If this improvement represents what would happen in practice with a 5 MHz receiver rather than a 20 MHz receiver, it potentially means that the probability of interference indicated in Table 11 would be an order of magnitude less.

4.2 DTT Transmitter into Mobile WiMAX Base Station Receiver

4.2.1 Approach

The victim mobile WiMAX BS RX is located randomly within the DTT coverage area. In practice, DTT TX locations may be known and BSs may be planned to avoid pointing at the DTT TXs. Therefore, the random pointing of BSs assumed in the simulation may lead to pessimistic results.

The previous simulations sought to determine the likelihood that a given link would fail. This is inappropriate for a mobile WiMAX base station, where many different links may be supported simultaneously. The interference analysis therefore aims to determine the increase in the victim mobile WiMAX BS RX noise floor due to the interference from the DTT TX.

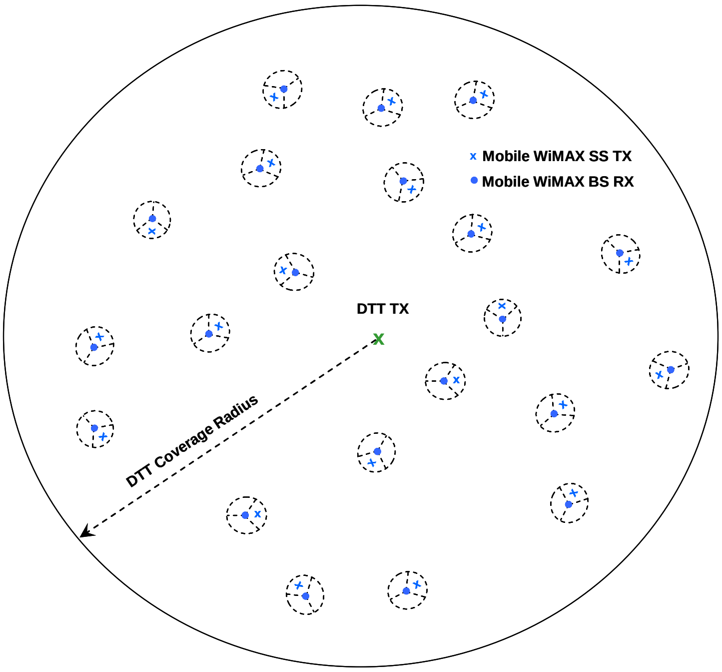

Figure 23: Interference Analysis Approach

4.2.2 Parameters

The following table provides the list of assumed parameter values.

Frequency	586 MHz
DTT TX EIRP	72.15 dBm (10 kW) (Ref: [1])
DTT TX Noise BW	7.6 MHz
DTT TX Height (a.g.l.)	100 m
DTT RX Height (a.g.l.)	10 m
DTT RX Antenna Maximum Gain	12.84 dBi (Ref: [2])
DTT RX Antenna Pattern	ITU-R BT 419-3 (Ref: [3])
DTT RX Feeder Loss	3.6 dB (Ref: [2])
DTT RX Noise Figure	7 dB (Ref: [4])
DTT RX Noise Floor	-98.17 dBm
DTT Link Minimum Required C/N	22.8 dB (Ref: [2])
DTT Link Median Path Loss Model	Rec. 1546 (Ref: [5])
DTT Link Path Loss Variations	Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6])
DTT Coverage Requirement	95% at the coverage edge
DTT Coverage Radius	30.8 km
Mobile WiMAX SS TX Maximum Power	22 dBm (Ref: [7,8])
Mobile WiMAX SS TX Antenna Diversity Gain	0 dB (Ref: [7,8])
Mobile WiMAX SS TX Antenna Maximum Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS TX Maximum EIRP	21 dBm
Mobile WiMAX SS TX Antenna Pattern	Omni
Mobile WiMAX SS TX Height (a.g.l.)	1.5 m
Mobile WiMAX BS RX Height (a.g.l.)	30 m
Mobile WiMAX BS RX Maximum Antenna Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS RX Antenna Pattern	120 Degrees Sector Antenna DB878H120E-A from www.andrew.com
Mobile WiMAX BS RX Maximum Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX BS RX Noise Figure	4 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	-2.5 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Protection Requirement	95% of locations protected from DTT interference at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model *(DTT TX into Mobile WiMAX BS RX)*	SEAMCAT's Hata Urban Outdoor-outdoor Model with log-normal variation

Table 12: DTT TX into Mobile WiMAX BS RX Interference Analysis Modelling Parameters

The following Net Filter Discrimination (NFD) values as a function of guard band between the DTT TX and mobile WiMAX BS RX channels (based on protection ratio measurements supplied by ERA) are assumed for the modelling of the victim receive noise floor increase.

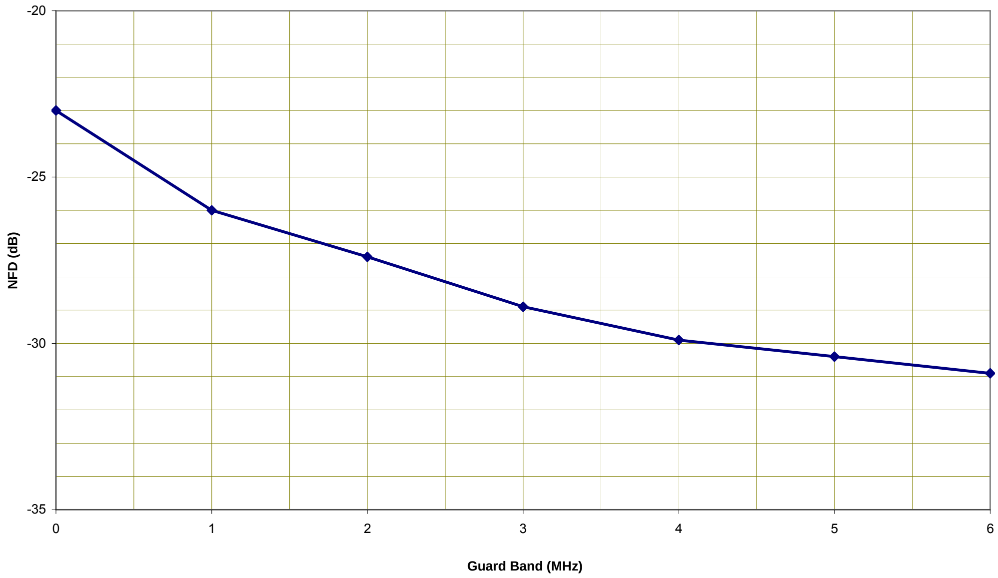

Figure 24: NFD Levels

4.2.3 Analysis Results

The following figure illustrates example set of trials obtained from the SEAMCAT run.

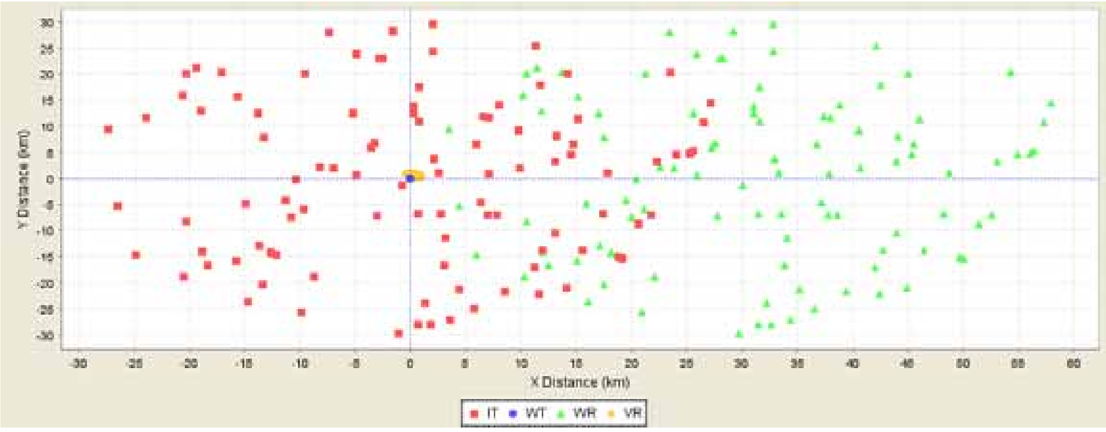

Figure 25: DTT TX into Mobile WiMAX BS RX Interference Scenario Outline from SEAMCAT

Interference power CDFs together with the receive noise floor are shown in the following figure for assumed guard band values.

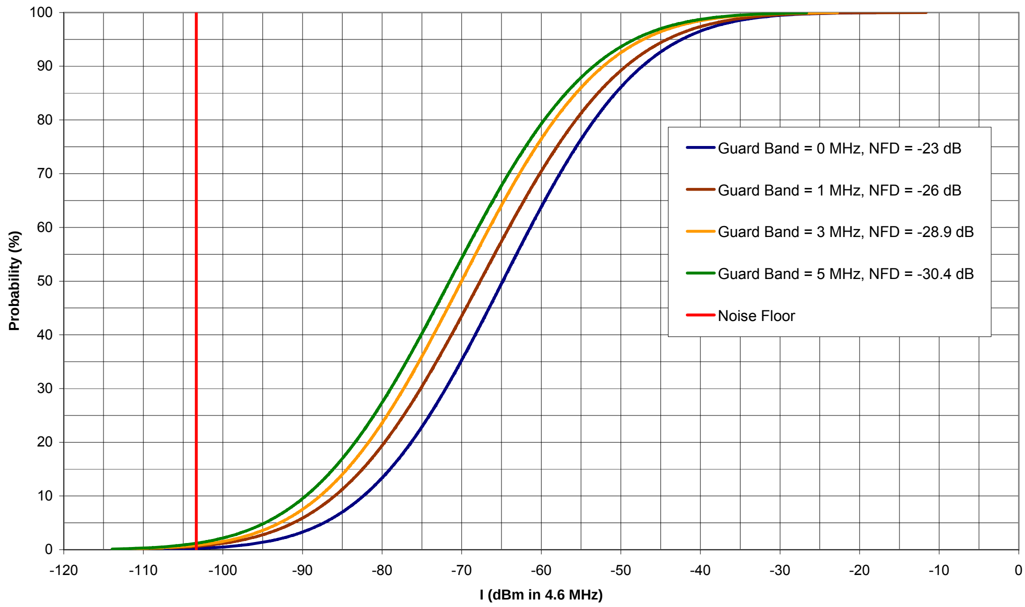

Figure 26: Interference Power CDFs

The comparison of the calculated interference values against the victim noise floor show that interference will dominate the noise floor + interference aggregation for all but very small percentages.

To check the results from the simulated scenarios, the interference from a DTT TX into a mobile WiMAX BS RX with a separation distance of 15 km is calculated by hand. At 15 km, the SEAMCAT extended Hata outdoor to outdoor urban propagation model results in mean path loss of 122.6 dB for the TX antenna height of 100 m and the RX antenna height of 30 m. Assuming that the guard band is 5 MHz and interference path is through the receiver antenna boresight, the interference is calculated from the following formula.

Interference = Max EIRP + NFD – Path Loss + RX Gain + BW Correction

I (dBm in RX BW) = 72.15 dBm + (-30.4 dB) – 122.6 dB + 15 dBi + 10 log (4.6MHz / 7.6 MHz)

I (dBm in RX BW) = -68 dBm

which is in the range of interference power values shown in the above figure for the 5 MHz guard band.

As noted in Section 4.1.3, there is an inconsistency between the receiver bandwidth used in the modelling and that used in the ERA measurements. It is postulated on the basis of further ERA measurements that a discrimination of 10 – 20 dB greater than that assumed would be achieved in practice. The level of interference modelled for a given frequency offset and presented in the results above is therefore likely to be 10 – 20 dB greater than it should be.

For this particular scenario, this potentially means that the interference power CDFs in Figure 39 will be shifted 10 – 20 dB to the left. However, even with this change there is still an interference issue which will have to be tackled through coordination and/or mitigation techniques.

Potential mitigation techniques to reduce the impact of interference into BMWA BS RXs include:

- Distance (increasing path loss will reduce interference)
- Pointing (avoiding to point interfering transmitters will make use of available antenna discrimination and reduce interference)
- Filtering (better receiver filtering will reduce the impact of adjacent channel interference).

It was noted at the beginning of this section that in the modeling the mobile WiMAX BS RX is located randomly, also with random antenna pointing. In practice, coordination could be applied. If this were to be undertaken it would be expected that the distributions in Figure 26 would be compressed at the right hand end by an amount equal to the antenna discrimination obtained through coordination (assuming all BS RXs can be coordinated to the same degree). This could amount to a compression of some 20 dB.

5 INTERFERENCE FROM DVB-H INTO MOBILE WIMAX

5.1 DVB-H Transmitter into Mobile WiMAX Subscriber Station Receiver

5.1.1 Approach

The victim mobile WiMAX SS RX (assumed to be operating in a 120-degrees sector) is located randomly within the DVB-H coverage area.

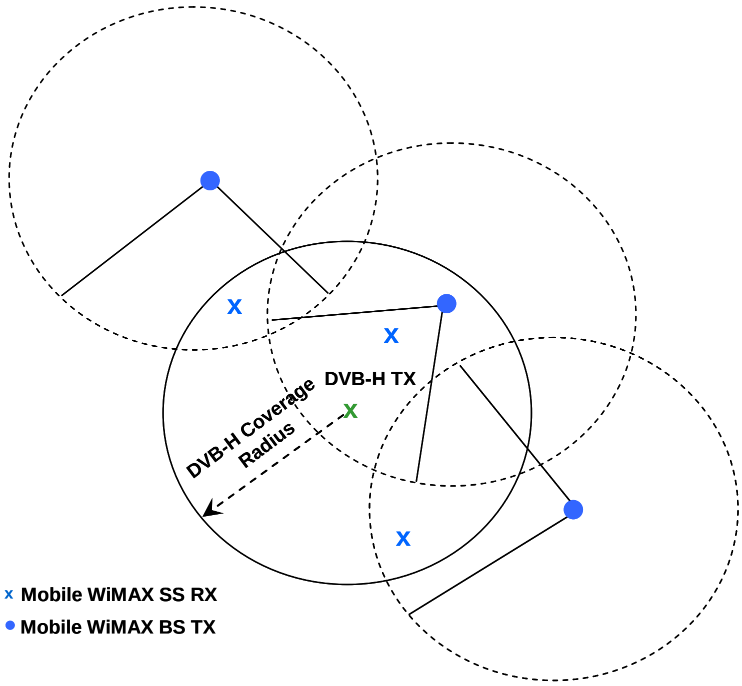

Figure 27: Interference Analysis Approach

5.1.2 Parameters

The following table provides the list of assumed parameter values.

Frequency	586 MHz
DVB-H TX EIRP	62.15 dBm (1 kW)
DVB-H TX Noise BW	7.6 MHz
DVB-H TX Height (a.g.l.)	30 m
DVB-H RX Height (a.g.l.)	1.5 m
DVB-H RX Antenna Maximum Gain	-4.85 dBi (Ref: [6])
DVB-H RX Antenna Pattern	Omni
DVB-H RX Feeder Loss	0 dB (Ref: [2])
DVB-H RX Noise Figure	6 dB (Ref: [6])
DVB-H RX Noise Floor	-99.17 dBm
DVB-H Link Minimum Required C/N	11 dB (Ref: [2])
DVB-H Link Median Path Loss Model	Hata Urban
DVB-H Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
DVB-H Coverage Requirement	95% at the coverage edge
DVB-H Coverage Radius	1.25 km
Mobile WiMAX BS TX Maximum Power	36.3 dBm (Ref: [7,8])
Mobile WiMAX BS TX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS TX Antenna Maximum Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS TX Maximum EIRP	54.3 dBm
Mobile WiMAX BS TX Antenna Pattern	120 Degrees Sector Antenna DB878H120E-A from www.andrew.com
Mobile WiMAX BS TX Height (a.g.l.)	30 m
Mobile WiMAX SS RX Height (a.g.l.)	1.5 m
Mobile WiMAX SS RX Maximum Antenna Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX SS RX Antenna Pattern	Omni
Mobile WiMAX SS RX Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX SS RX Noise Figure	7 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	8.93 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Protection Requirement	95% of locations protected from DVB-H interference at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model (DVB-H TX into Mobile WiMAX SS RX)	SEAMCAT's Hata Urban Outdoor-indoor Model with log-normal variation

Table 13: DVB-H TX into Mobile WiMAX SS RX Interference Analysis Modelling Parameters

The following figure illustrates the measured protection ratios (by ERA) as a function of guard band between the DVB-H TX and mobile WiMAX SS RX channels.

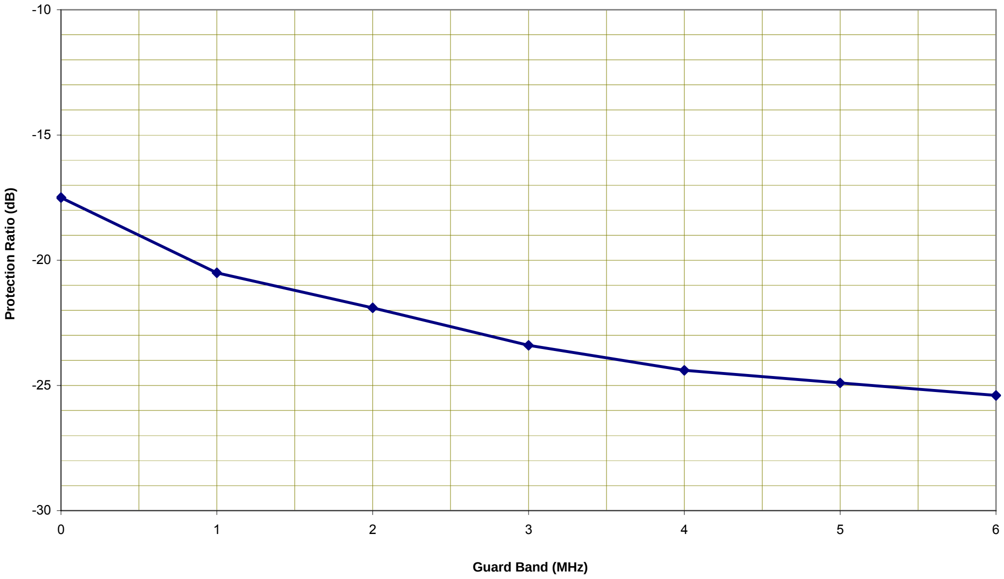

Figure 28: Protection Ratios

5.1.3 Analysis Results

Example trials obtained from the SEAMCAT run are shown in the following figure.

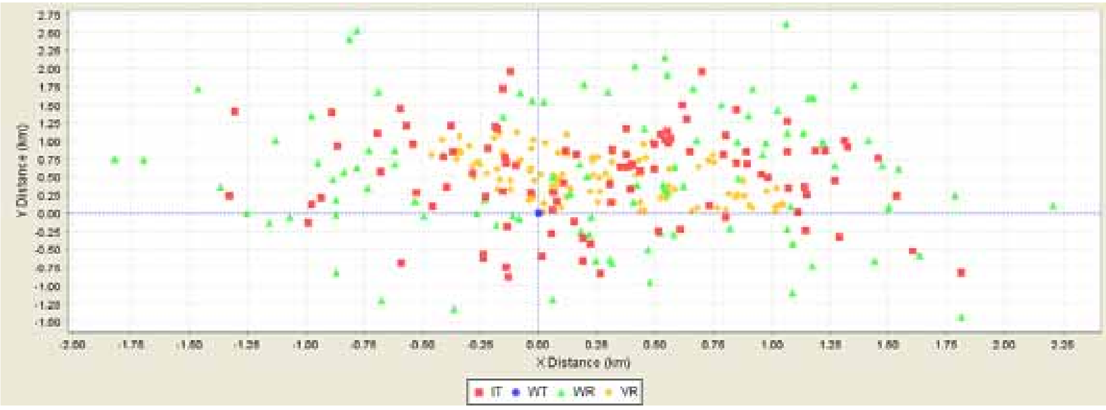

Figure 29: DVB-H TX into Mobile WiMAX SS RX Interference Scenario Outline from SEAMCAT

As can be seen, the victim receiver (mobile WiMAX SS RX) is located randomly within the mobile WiMAX sector with a 1.125 km radius. The interfering transmitter (DVB-H TX) is then located at a random distance (limited to the DVB-H coverage area radius of 1.25 km).

Calculated interference probabilities are shown in the following table.

Guard Band (MHz)	*Protection Ratio (dB)*	*Interference Probability (%)*
0	-17.5	32.45
1	-20.5	25.53
2	-21.9	22.29
3	-23.4	19.39
4	-24.4	17.59
5	-24.9	16.7
6	-25.4	15.84

Table 14: Interference Probabilities

As noted in Section 4.1.3, there is an inconsistency between the receiver bandwidth used in the modelling and that used in the ERA measurements. It is postulated on the basis of further ERA measurements that a discrimination of 10 – 20 dB greater than that assumed would be achieved in practice. The level of interference modelled for a given frequency offset and presented in the results above is therefore likely to be 10 – 20 dB greater than it should be.

For this particular scenario, this potentially means that the probability of interference is an order of magnitude less than that stated in Table 11.

5.2 DVB-H Transmitter into Mobile WiMAX Base Station Receiver

5.2.1 Approach

The victim mobile WiMAX BS RX is located randomly within the DVB-H coverage area. The interference analysis aims to determine the increase in the victim mobile WiMAX BS RX noise floor due to the interference from the DVB-H TX.

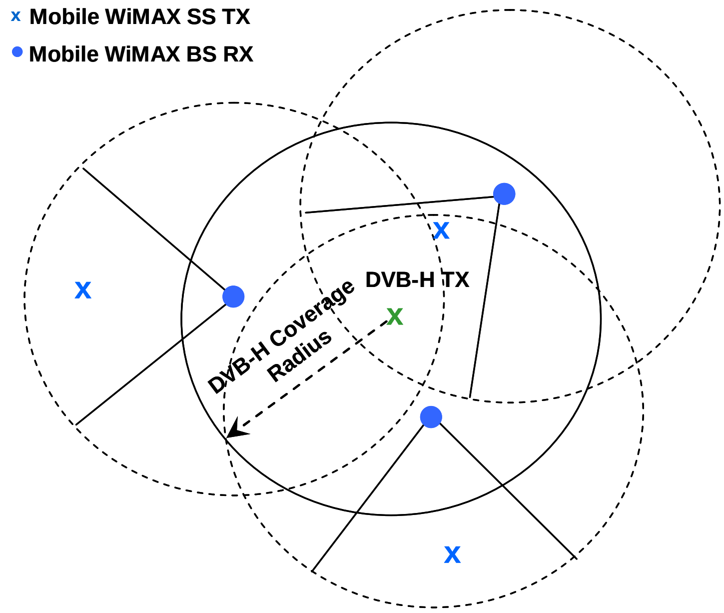

Figure 30: Interference Analysis Approach

5.2.2 Parameters

The following table provides the list of assumed parameter values.

Frequency	586 MHz
DVB-H TX EIRP	62.15 dBm (1 kW)
DVB-H TX Noise BW	7.6 MHz
DVB-H TX Height (a.g.l.)	30 m
DVB-H RX Height (a.g.l.)	1.5 m
DVB-H RX Antenna Maximum Gain	-4.85 dBi (Ref: [6])
DVB-H RX Antenna Pattern	Omni
DVB-H RX Feeder Loss	0 dB (Ref: [2])
DVB-H RX Noise Figure	6 dB (Ref: [6])
DVB-H RX Noise Floor	-99.17 dBm
DVB-H Link Minimum Required C/N	11 dB (Ref: [2])
DVB-H Link Median Path Loss Model	Hata Urban
DVB-H Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
DVB-H Coverage Requirement	95% at the coverage edge
DVB-H Coverage Radius	1.25 km
Mobile WiMAX SS TX Maximum Power	22 dBm (Ref: [7,8])
Mobile WiMAX SS TX Antenna Diversity Gain	0 dB (Ref: [7,8])
Mobile WiMAX SS TX Antenna Maximum Gain	-1 dBi (Ref: [7,8])
Mobile WiMAX SS TX Maximum EIRP	21 dBm
Mobile WiMAX SS TX Antenna Pattern	Omni
Mobile WiMAX SS TX Height (a.g.l.)	1.5 m
Mobile WiMAX BS RX Height (a.g.l.)	30 m
Mobile WiMAX BS RX Maximum Antenna Gain	15 dBi (Ref: [7,8])
Mobile WiMAX BS RX Antenna Diversity Gain	3 dB (Ref: [7,8])
Mobile WiMAX BS RX Antenna Pattern	120 Degrees Sector Antenna DB878H120E-A from www.andrew.com
Mobile WiMAX BS RX Maximum Noise BW	4.6 MHz (Ref: [7,8])
Mobile WiMAX BS RX Noise Figure	4 dB (Ref: [7,8])
Mobile WiMAX Link Minimum Required C/N	-2.5 dB (Ref: [7,8])
Mobile WiMAX Link Median Path Loss Model	Hata Urban
Mobile WiMAX Link Path Loss Variations	Outdoor Variations: Log-normal (μ= 0 dB, σ = 5.5 dB) (Ref: [6]) Building Penetration: Log-normal (μ= 11 dB, σ = 6 dB) (Ref: [6])
Mobile WiMAX Link Protection Requirement	95% of locations protected from DVB-H interference at the coverage edge
Mobile WiMAX Link Coverage Radius	1.125 km
Interference Path Loss Model (DVB-H TX into Mobile WiMAX BS RX)	SEAMCAT's Hata Urban Outdoor-outdoor Model with log-normal variation

Table 15: DVB-H TX into Mobile WiMAX BS RX Interference Analysis Modelling Parameters

The following Net Filter Discrimination (NFD) values as a function of guard band between DVB-H TX and mobile WiMAX BS RX channels (based on protection ratio measurements supplied by ERA) are assumed for modelling the victim receiver noise floor increase.

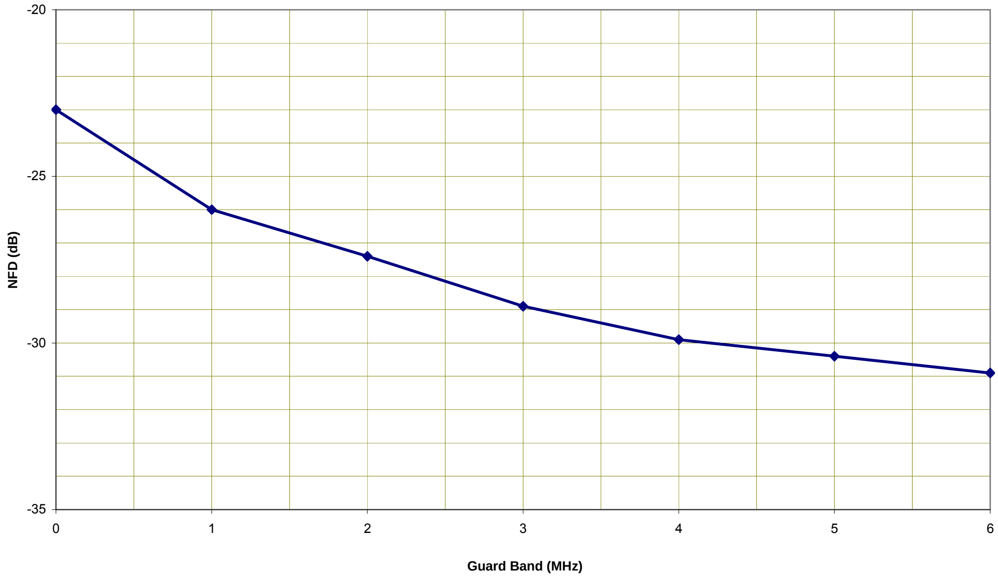

Figure 31: NFD Levels

5.2.3 Analysis Results

The following figure shows an example set of locations of simulation elements used in Monte Carlo trials.

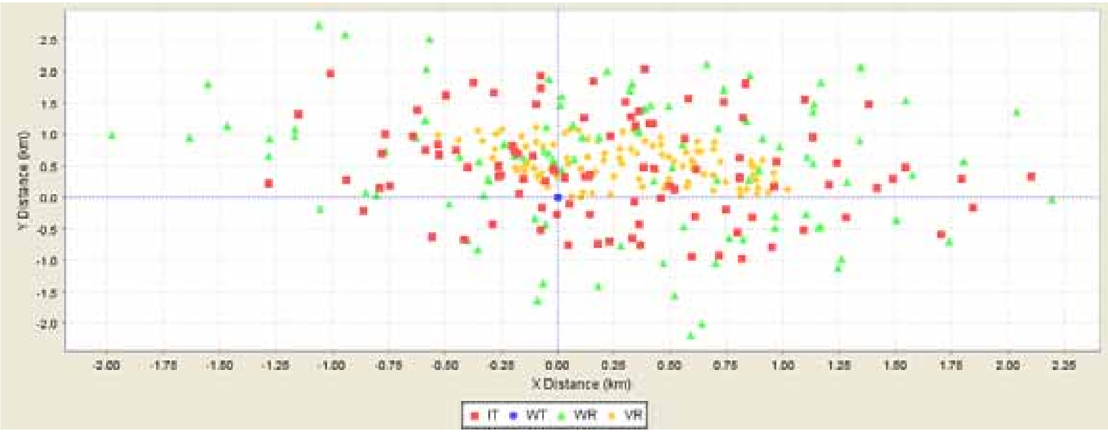

Figure 32: DVB-H TX into Mobile WiMAX BS RX Interference Scenario Outline from SEAMCAT

Interference power CDFs together with the receive noise floor are shown in the following figure for assumed guard bands.

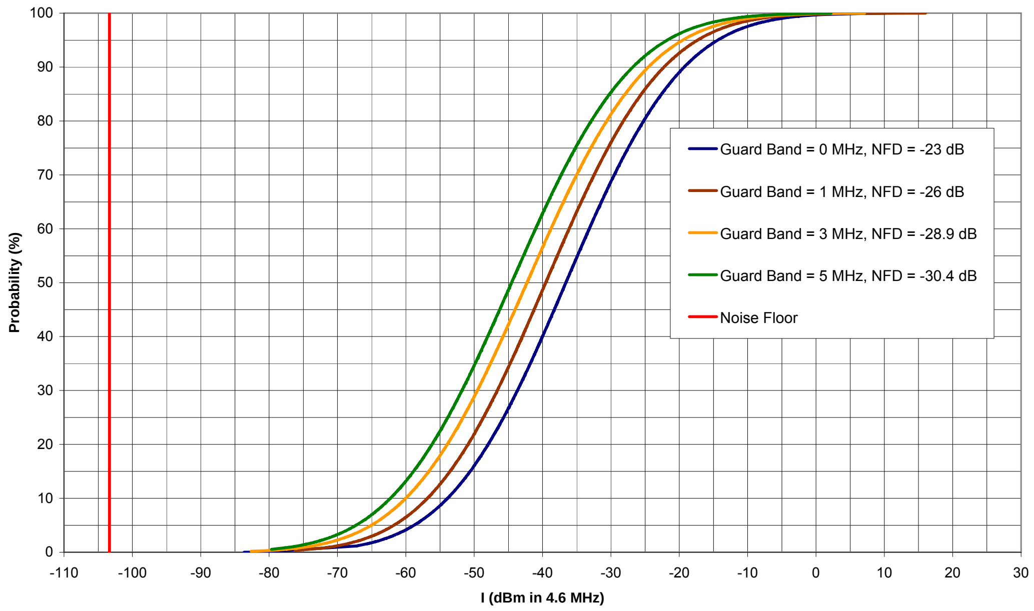

Figure 33: Interference Power CDFs

The results suggest that interference will dominate the noise floor + interference aggregation for all probabilities.

In comparison to results obtained from the analysis of DTT TX interference into mobile WiMAX BS RXs, the impact of DVB-H TX interference into mobile WiMAX BS RXs is worse even though the interferer maximum EIRP is 10 dB less than the DTT EIRP and the interferer height is 70 m less than the DTT TX height. The reason for obtaining higher interference levels from the DVB-H TX into mobile WiMAX BS RX scenario is due to the difference in DTT and DVB-H coverage areas. Interference statistics of the DTT TX into mobile WiMAX BS RX scenario are based on the victim receiver randomly located within the DTT coverage of 30.8 km radius. On the other hand, DVB-H TX into mobile WiMAX BS RX interference statistics are based on the victim receiver randomly located within the DVB-H coverage of 1.25 km radius.

As noted in Section 4.1.3, there is an inconsistency between the receiver bandwidth used in the modelling and that used in the ERA measurements. It is postulated on the basis of further ERA measurements that a discrimination of 10 – 20 dB greater than that assumed would be achieved in practice. The level of interference modelled for a given frequency offset and presented in the results above is therefore likely to be 10 – 20 dB greater than it should be.

For this particular scenario, this potentially means that the interference power CDFs in Figure 39 will be shifted 10 – 20 dB to the left. However, even with this change there is still an interference issue which will have to be tackled through coordination and/or mitigation techniques.

6 SUMMARY & CONCLUSIONS

6.1 Adjacent Band Sharing Between Mobile WiMAX and DTT

6.1.1 Interference from Mobile WiMAX into DTT

Interference analysis results obtained from sharing scenarios where mobile WiMAX BS TXs and SS TXs interfere with a DTT RX suggest that interference from mobile WiMAX BS TXs dominates the adjacent band sharing. For the assumed modelling parameters, mobile WiMAX BS TX interference probabilities averaged over the DTT coverage area are 42.8% for 0 MHz and 11.9% for 1 MHz guard band assumptions. These figures could be significantly less if the real distribution of the population were to be taken into account.

The mobile WiMAX SS TX into DTT RX scenario (where interference statistics within a wide area are considered) results in interference levels well below the wanted power levels at the DTT coverage edge (i.e. the mean wanted power is -66.1 dBm while the mean aggregate interference power is -107.53 dBm). Therefore, very low interference probabilities are expected. SEAMCAT returns 0% interference probability with no guard band.

In addition to the wide area statistical analysis, interference from a single WiMAX SS TX (located indoors) into a nearby DTT RX (located outdoors and assumed to be operating at the edge of the DTT coverage area) is examined. Results suggest that, for a boresight interference entry at the DTT RX, the required minimum separation distance varies between 27 m and 70 m when the guard band varies between 7 MHz and 0 MHz. When the interference entry is through the DTT RX rearlobes the required distances are in the range of 4 – 11 m. These distances are calculated by assuming that the path loss is free space and the building penetration loss is 11 dB.

6.1.2 Interference from DTT into Mobile WiMAX

Interference analysis of DTT TX into mobile WiMAX SS RX suggests that interference probabilities reduce from 1.24% to 0.35% when the guard band is increased from 0 MHz to 6 MHz. In the case of interference into mobile WiMAX BS RXs, the receiver noise floor is raised significantly (up to approximately 80 dB) due to DTT TX interference. Therefore, the DTT BS into mobile WiMAX BS interference scenario dominates the adjacent band sharing.

It should be noted that the impact of BS-to-BS interference may be reduced by avoiding WiMAX BS antenna alignment with the DTT TXs as their location will be known before the mobile WiMAX BSs are deployed. Furthermore, a better receiver filtering will reduce the impact of interference.

6.1.3 Conclusion

The adjacent band sharing between the mobile WiMAX and DTT services is dominated by the interference from DTT TXs into mobile WiMAX BS RXs where the receiver noise floor is raised by up to approximately 80 dB. It should be noted that the impact of interference may be reduced by avoiding to point at the DTT TXs as their location will be known before the mobile WiMAX BSs are deployed. Furthermore, a better receiver filtering will reduce the impact of interference.

6.2 Adjacent Band Sharing Between Mobile WiMAX and DVB-H

6.2.1 Interference from Mobile WiMAX into DVB-H

The mobile WiMAX BS TX into DVB-H RX interference analysis results in 2.22% and 0.47% interference probabilities for 0 and 1 MHz guard bands, respectively. The mobile WiMAX SS TX into DVB-H RX scenario interference probability is very low and SEAMCAT returns 0% interference probability when there is no guard band. These results suggest that interference from mobile WiMAX BSs is more significant than interference from mobile WiMAX SSs.

The results of analysis of interference from a single WiMAX SS TX into a DVB-H RX (assumed to be operating at the edge of the DVB-H coverage area) suggest that the required minimum separation distance varies between 82 m and 212 m when the guard band varies between 7 MHz and 0 MHz. This is based on the free space path loss assumption.

6.2.2 Interference from DVB-H into Mobile WiMAX

The interference probability due to DVB-H interference into mobile WiMAX SS RXs increases from 15.84% to 32.45% when the guard band is reduced from 6 MHz to 0 MHz. In the case of interference into mobile WiMAX BS RXs, the receiver noise floor is raised significantly (up to in excess of 100 dB) due to the DVB-H TX interference. These results suggest that both interference paths lead to significant interference probabilities.

6.2.3 Conclusion

The adjacent band sharing between the mobile WiMAX and DVB-H systems is dominated by interference from DVB-H TXs into mobile WiMAX BS RXs where the interference results in a noise floor increase of up to 100 dB.

A ACRONYMS

a.g.l.	Above Ground Level
BS	Base Station
BW	Bandwidth
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
C/I	Carrier to Interference Ratio
C/N	Carrier to Noise Ratio
C/(N+I)	Carrier to Noise plus Interference Ratio
dB	Decibel
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting – Handheld
EIRP	Effective Isotropic Radiated Power
ERO	European Radiocommunications Office
ERP	Effective Radiated Power
ETSI	European Telecommunications Standard Institute
IP-OFDMA	Internet Protocol - Orthogonal Frequency Division Multiple Access
IT	Interfering Transmitter
ITU	International Telecommunications Union
I/N	Interference to Noise Ratio
Mobile WiMAX	Mobile Worldwide Interoperability for Microwave Access
NFD	Net Filter Discrimination
OFDM	Orthogonal Frequency Division Multiplex
RRC	Regional Radio Conference
RX	Receiver
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SS	Subscriber Station
STD DEV	Standard Deviation
TX	Transmitter

UHF	Ultra High Frequency
VR	Victim Receiver
WR	Wanted Receiver
WT	Wanted Transmitter

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