ERA Technology Ltd, Cleeve Road
Leatherhead, Surrey, KT22 7SA, UK
Tel: +44 (0) 1372 367000 • Fax: +44 (0) 1372 367099
info@era.co.uk • www.era.co.uk

ERA Business Unit:	ERA Technology Ltd
Report Title:	**Conducted Measurements to Quantify DVB-T Interference into DTT Receivers**
Author(s):	B Randhawa, S Munday
Client:	Ofcom
ERA Report Number:	2007-0631
ERA Project Number:	7G0403801
Report Version:	Final Report

ERA Report Checked and Approved by:

M Ganley
Head of EMC Group

October 2007

Ref: BR/vs/62/04038/Rep-6189

© Copyright ERA Technology Limited 2007
All Rights Reserved

No part of this document may be copied or otherwise reproduced without the prior written permission of ERA Technology Limited. If received electronically, recipient is permitted to make such copies as are necessary to: view the document on a computer system; comply with a reasonable corporate computer data protection and back-up policy and produce one paper copy for personal use.

DOCUMENT CONTROL

If no restrictive markings are shown, the document may be distributed freely in whole, without alteration, subject to Copyright.

ERA Technology Ltd
Cleeve Road
Leatherhead
Surrey KT22 7SA
UK
Tel : +44 (0) 1372 367000
Fax: +44 (0) 1372 367099
E-mail: info@era.co.uk

Read more about ERA Technology on our Internet page at: http*://www.era.co.uk/*

Summary

In December 2006 ERA Technology Ltd undertook a measurement programme on behalf of Ofcom to quantify 3G and WiMAX mobile interference into DVB-T receivers [2].

Following on from this work, additional measurements have been undertaken to enable Ofcom to gain a fuller picture of the performance of a large range of digital terrestrial television (DTT) receivers that are available in the UK market, and the likely performance of these receivers against digital video broadcast – terrestrial (DVB-T) interference.

A total of fifteen DTT receivers were tested to determine their required carrier-to-interference (C/I) protection ratios in the presence of DVB-T interference for a range of channel separations from N-11 to N+11 channels away.

<u>DVB-T interference into fifteen DTT receivers</u>

The test results for the measured C/I protection ratios for DVB-T interference into fifteen DTT receivers showed that:

- Receivers 2, 5, 6, 7, 9, 14 and 15 were considered as having typical operating performance.
- Receivers 1, 3 and 4 were considered as having the worst performance.
- Receivers 8, 10, 11, 12 and 13 were considered as having the best performance.

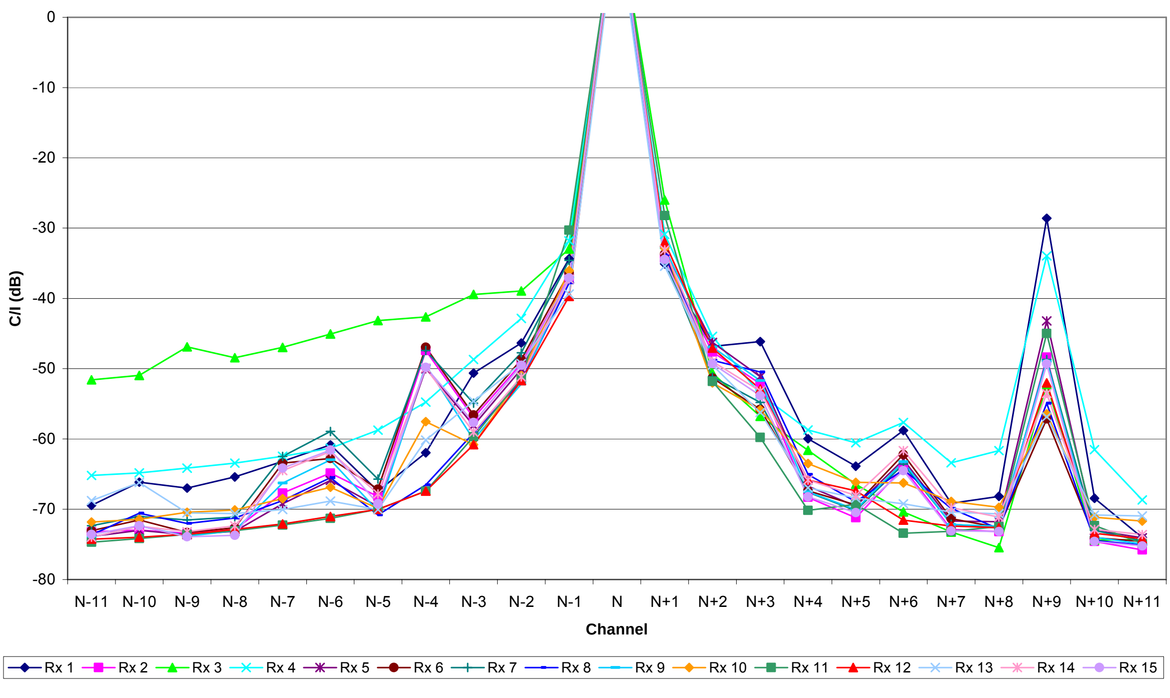


Figure 1: C/I protection ratios for DVB-T interference into fifteen DTT receivers

© ERA Technology Ltd

The results also revealed that receivers 2, 5, 6, 7, 9, 14 and 15 were more susceptible to DVB-T interference at N-4, with protection ratios levels comparable to those measured at the N+9 image channel. Also, the measurements showed that these typically performing receivers were slightly more susceptible at N±6 than compared to other channels but 12 to 17 dB more immune than at N-4 and 15 to 20 dB more immune at N+9. Further investigation revealed that all of these typical performing receivers had the same generic processor and RF modulator box inside the casing.

From the figure above, it can be seen that the N+9 image C/I values vary as much as 20 dB between Receivers 1 and 9 and 28 dB between Receivers 1 and 13. Also, apart form the N-4 susceptibility, Receiver 1 has very similar characteristics when compared to a typically performing receiver.

The average measured C/I protection ratio for all fifteen DTT receiver at adjacent channels N-1 and N+1 were -35.9 dB and -32.7 dB respectively. The average measured C/I protection ratio for all fifteen DTT receivers at N+9 channel separation was -48.6 dB.

From these results, three receivers (representing typical, worst and best case performance) were selected for more detailed analysis to establish:

- The effect of changing the wanted signal level to investigate the overload points for adjacent channel interference.
- The effect of changing the modulation from 64-QAM to 16-QAM for the interfering signal.
- The effect of operating at different frequencies within 470 – 862 MHz in order to ascertain whether the DTT receivers are more sensitive at the higher or lower end of the spectrum.

<u>Effect of changing wanted signal level</u>

Conducted interference measurements were performed to quantify the effect of changing the wanted 64-QAM DVB-T signal level in order to determine the overload points of a worst, typical and best performing receiver. The receivers were subjected to adjacent (N+1) channel interference using a 16-QAM DVB-T signal. Measurements were performed for wanted channels of 36 (594 MHz) and 62 (802 MHz).

The results showed that under suitable receiver operating conditions, i.e. for wanted signal levels of -73 to -53 dBm, the protection ratios measured were reasonably flat within 2 to 3 dB, whatever the level of the interfering signal.

However, if the wanted signal level exceeded a received power threshold of -50 to -40 dBm, the receiver started to lose its ability to discriminate against interfering signals on the

© ERA Technology Ltd

adjacent channels. Resulting in less power required for the interfering signal relative to the level of the wanted transmission to cause the onset of degradation to the received picture.

Effect of changing modulation scheme

Conducted measurements were carried out to determine the effect of changing the modulation scheme of the wanted signal from 64-QAM to 16-QAM for channel 39 (618 MHz).

The results showed that by changing the modulation of the received wanted signal to 16-QAM, a lower protection ratio of 3 to 5 dB is required compared with 64-QAM results. Thus, revealing that a DTT receiver is more tolerant to interference, when operating under a 16-QAM modulation scheme compared to a 64-QAM modulation. This is expected as the 64-QAM modulation requires less amplitude and/or phase transitions to change symbol states compared to the 16-QAM scheme and therefore requires less interference to cause demodulation errors in the DTT receiver.

Effect of changing tuned receiver frequency

A sample of tests were performed at different frequencies within the 470 – 862 MHz band to ascertain whether the DTT receivers were more sensitive at a higher or lower frequency range of the spectrum. Measurements were performed for channel 22 (482 MHz), channel 30 (546 MHz) and channel 59 (778 MHz) for a worst, typical and best performing receiver.

The results show that the receivers performance is broadly similar regardless of operating channel, except for N+5 channel separation for Receivers 1 (worst quality) and 13 (best quality). The results showed that Receivers 1 and 13 were more susceptible to interference at N+5 when operating at higher channel numbers.

This effect was investigated further for Receiver 13 by measuring the required C/I protection ratio at N+5 with the receiver operating on different channels. The results show that the C/I protection ratio of -68 dB, is approximately constant for channels below channel 47. However, for channels above 47 the required C/I protection ratio at N+5 increases steadily to approximately -59 dB at channel 64.

ERA TECHNOLOGY

© ERA Technology Ltd

This page is intentionally left blank

© ERA Technology Ltd

Contents

© ERA Technology Ltd

Tables List

Page No.

Figures List

Page No.

© ERA Technology Ltd

© ERA Technology Ltd

Abbreviations List

BER	Bit Error Ratio
C/I	Carrier to Interference
COFDM	Coded Orthogonal Frequency Division Multiplexing
DDR	Digital Dividend Review
DTT	Digital Terrestrial Television
DVB-T	Digital Video Broadcasting - Terrestrial
FEC	Forward Error Correction
MUS	Minimum Usable Signal
PF	Picture Failure
PMSE	Programme Making and Special Events
QAM	Quadrature Amplitude Modulation
QEF	Quasi Error Free
RBW	Resolution Bandwidth
UCE	Uncorrectable Errors
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications Systems
VBW	Video Bandwidth

© ERA Technology Ltd

1. Introduction

Ofcom announced on 17 November 2005 the beginning of its Digital Dividend Review (DDR) – the project, which will examine the options arising from the release of spectrum afforded by the digital switchover program. The available spectrum includes the spectrum released by analogue switch off – the ultra high frequency (UHF) spectrum in bands IV and V (470 – 862 MHz) with the exception of the spectrum reserved for the six digital terrestrial television (DTT) multiplexes [1].

Digital broadcasting is roughly six times more efficient than analogue, allowing more channels to be carried across fewer airwaves. The plans for digital switchover will therefore allow for an increase in the efficiency with which the spectrum is used – including the potential for a large amount of spectrum to be released for wholly new services.

Ofcom estimates that the digital switchover program will release up to approximately 112 MHz of spectrum in the UHF band for new uses. The UHF band is prime spectrum, because it offers a technically valuable combination of capacity (bandwidth) and range. This part of the spectrum is much sought after for a whole range of services likely to be used by millions of people every day.

The potential future uses of this spectrum are wide ranging and include: broadband wireless access, cellular mobile (for example, UMTS and systems beyond IMT-2000), private mobile radio, further terrestrial digital television services (including standard definition television, high definition television and local digital TV), mobile digital multimedia (including mobile television), and services for programme making and special events (PMSE).

The diagram below details the spectrum that will be assigned to six DTT multiplexes post switchover and the spectrum available after switch over.

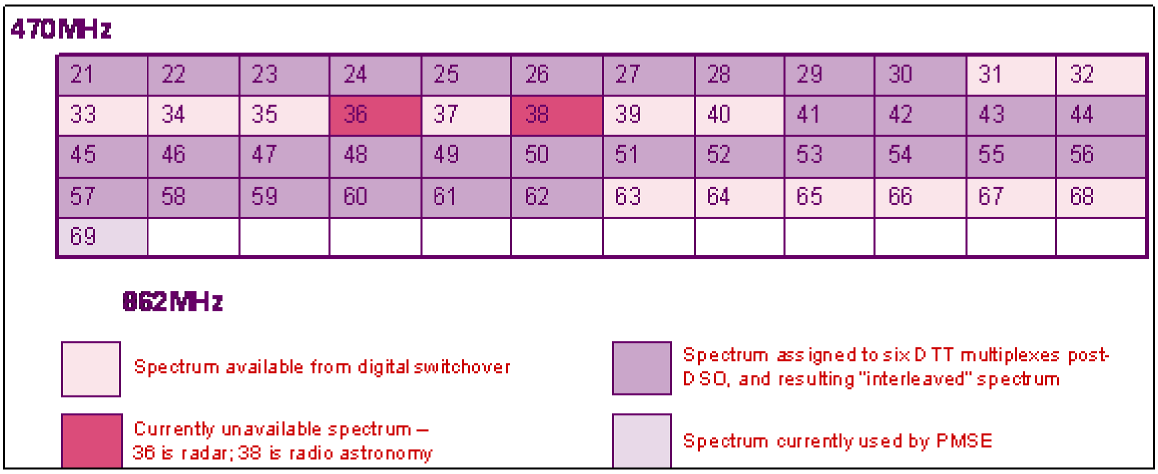


Figure 2: Outline of band plan for 470-862 MHz

© ERA Technology Ltd

After switch-over, fourteen channels are expected to become completely clear in the UK and available for new uses. New use of channels 31, 40, and 63 have the potential to cause adjacent channel interference to some of the spectrum assigned to the 6 DTT multiplexes. The use of all but channel 40 of the available spectrum has the potential to cause interference due to the DTT image channel at N+9. For example, channel 22 has the potential to be interfered with by the use of channel 31 as it is 9 channels away

As part of the DDR, ERA was asked by Ofcom to investigate the potential interference to Digital Video Broadcast-Terrestrial (DVB-T) receivers from UMTS and WiMAX mobile transmitters for adjacent and N+9 channel separation. The results of this initial work were presented in a report to Ofcom in December 2006 [2].

Following on from this work Ofcom have commissioned further measurements on a broader range of DTT receivers in order to gain a fuller picture of the potential for interference from DTT transmissions. This report presents the results of conducted measurements performed on fifteen receivers commonly available in the UK to characterize their performance in terms of the required carrier-to-interference (C/I) protection ratio for a range of frequency offsets from co-channel to N±11 channel separations.

2. Objectives and Scope of Work

The objective of the work was to enable Ofcom to get a fuller picture of the performance of a large range of DTT receivers that are available to consumers, and the likely performance of these receivers against DVB-T interference. The programme of work is detailed below:

- To perform measurements of DVB-T interference into 8k 64-QAM DVB-T for fifteen receivers operating on channel 39 (618 MHz) for frequency separations up to N±11 channels.
- From the above results, choose a selection of receivers that are representative of different performance levels (i.e. typical, best-case and worst-case performance) for further testing to investigate:
    - The effects of changing the wanted signal level to investigate the overload points of the receivers for adjacent channel interference.
    - The effects of changing DTT service level from 64-QAM to 16-QAM modulation.
    - To perform a sample of tests at different frequencies within 470 – 862 MHz to ascertain whether the DTT receivers are more sensitive at a higher or lower frequency range of the operating UHF spectrum.

© ERA Technology Ltd

3. Measurement Methodology

This section presents the system parameters, measurement set-up and test procedure.

3.1 Wanted System Parameters

The DVB-T wanted signal was generated using a Rhode & Schwarz (R&S) MPEG-2 measurement generator and R&S TV test transmitter. The MPEG encoder was used to convert a moving video display into the correct format required by the DVB-T TV transmitter. The transmitter, comprising of an input data stream, forward error correction (FEC) encoder, modulation source and carrier, was used to generate the wanted signal at the required frequency.

The DVB-T system parameters used in the interference measurements are shown in the table below.

Table 1:
DVB-T system parameters

DVB-T Parameter	I	II
Modulation	64-QAM	16-QAM
Error Coding Rate	2/3	¾
Guard Interval (μs)	7 ($^{1}/_{32}$)	7 ($^{1}/_{32}$)
Data rate (Mbit/s)	24.1	18.1
Channel raster (MHz)	8	8

The DVB-T transmitter masks described in ETSI EN 302 296 [3] are shown in the table below. All measurements were based on the non-critical mask.

ERA TECHNOLOGY

© ERA Technology Ltd

Table 2:
DVB-T transmit masks

Offset (MHz)	Critical mask dBc	Non-critical mask dBc	Relaxed non-critical mask dBc	Ref bandwidth (kHz)
+/-3.8	32.8	32.8	32.8	4
+/-4.2	83	73	67.8	4
+/-6	95	85	85	4
+/-12	120	110	110	4
+/-20	120	110	110	4

The wanted signal level was initially set to 50 dBµV/m. This field strength is equivalent to a received power level of -73 dBm for a 75 Ω system, measured in a 7.6 MHz bandwidth. This is equivalent to operating 7 to 10 dB above the minimum sensitivity of the receiver.

For the more detailed analysis the wanted signal level was varied in order to determine the overload points of the receiver under test, when subjected to interference on the adjacent channel.

Measurement results are given as C/I protection ratio versus channel spacing. The measurements were performed between N-11 and N+11 channels in one channel increments (8 MHz) from a centre frequency of 618 MHz (channel 39) on all fifteen receivers.

For the more detailed analysis on three of the receivers, centre frequencies of 482 MHz, 546 MHz and 778 MHz were also investigated, representing channels 22, 30 and 59.

A summary of the parameters used in both the initial and detailed testing is shown in the table below.

Table 3:
Summary of parameters for initial and detailed analysis

Parameter	Initial testing	Detailed testing
No of receivers tested	15	3
Modulation scheme	64 QAM	64 QAM, 16 QAM
Wanted signal level (dBm)	-73	Various
Channel number N	39	22, 30, 59

© ERA Technology Ltd

3.2 Interfering System Parameters

The unwanted DVB-T signal was simulated using an Agilent E4438C signal generator, using the test parameters given in Table 1 above, and used to interfere with the wanted signal into the DTT receivers.

Measurements were performed with the interferer using both 64 and 16-QAM modulation.

3.2.1 Requirement for filtering

The out of band emission levels of the unwanted signal was filtered by a 4-pole UHF filter to conform more closely to the transmission mask set by EN 302 296. The effect of using a filter on the transmit spectrum is shown in the figure below.

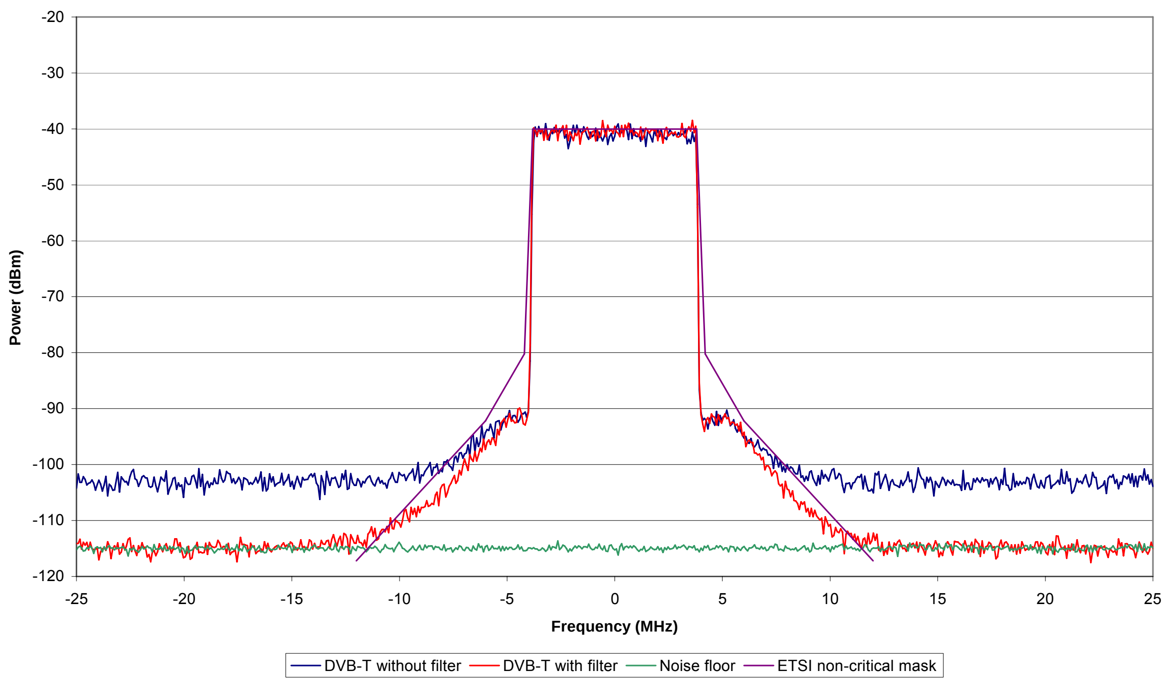


Figure 3: DVB-T interfering signal with and without filter measured in a 5 kHz resolution bandwidth

Without the band pass filter the noise from the signal generator masks the true protection ratios which can otherwise lead to erroneous results for large frequency separations (greater than N+2 channels) between the wanted and unwanted signals. This finding was also observed in an input to CEPT ECC TG 4 by TDF [5].

The characteristics of the filter used for the in the test set-up producing the interfering signal is shown in the figure below:

© ERA Technology Ltd

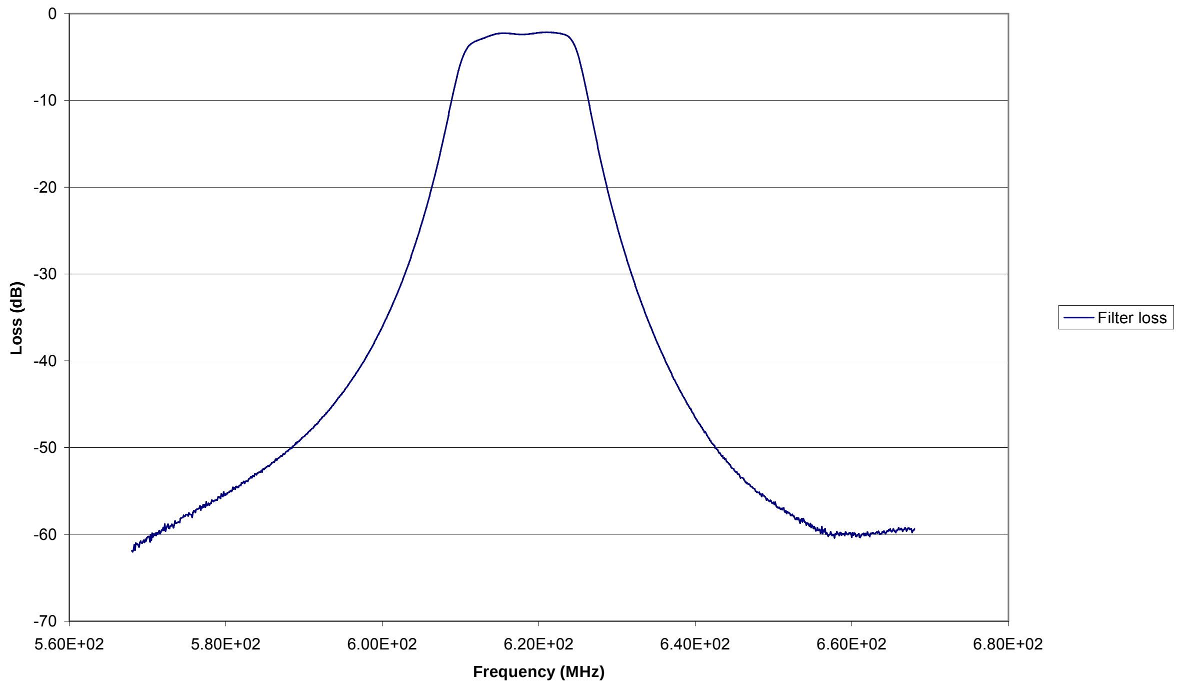


Figure 4: Characteristics of 4 pole UHF band pass filter used on the interfering signal

3.3 Interference Criteria

DVB-T systems use coded orthogonal frequency division multiplexing (COFDM), which spreads the information over a large number of orthogonal carriers. Forward error correction (FEC) is then applied to improve the bit error ratio (BER). In many digital systems the data to be transmitted undergoes two types of FEC coding; Reed Solomon and convolutional coding. At the receiver the pseudo-random sequence added at the transmitter by the convolutional encoder is decoded by the Viterbi decoder, followed by Reed Solomon decoding for parity checking.

The error protection employed by digital systems results in an abrupt “cliff-edge” effect in the presence of interference when compared to analogue systems. The Digital TV Group[1] (DTG) publishes the D-Book [4] which includes degradation criteria to be used when assessing interference to digital systems. The different DTT receiver degradation criteria are compared in the following extract from the D-Book.

---

[1] The Digital TV Group is the industry association for digital television in the UK. See http://www.dtg.org.uk/

© ERA Technology Ltd

Table 4:
D-Book comparison of degradation criteria

Criterion	Description	Comments
REF_{BER}	Post Viterbi BER=$2x10^{-4}$	BER can be very erratic with some types of impairment (e.g. impulsive inference), so an accurate measure can be hard to achieve. A measure of BER is often not available (e.g. in a commercial receiver).
UCE	No un-correctable Transport Stream errors in a defined period.	Probably the most useful measure, but unfortunately this is often not available (e.g. in a commercial receiver).
UCE Rate	A measure of the number of UCE in a defined period.	Sometimes normalised to 'Error Seconds' (Used for 'mobile' applications).
PF	"Picture Failure". No. of observed, (or detected) picture artefacts in a defined period.	This is what the consumer sees and cares about. There is always access to a 'picture' in a commercial receiver. However, when testing demodulators alone, MPEG decoding and picture display is not always available.
SFP	"Subjective failure point"	Essentially the same as PF

The reference BER, defined as BER = 2×10^{-4} after Viterbi decoding, corresponds to the quasi error free (QEF) criterion in the DVB-T standard, which states "less than one uncorrelated error event per hour". However, as noted within the D-Book, there is often no direct way of identifying BER or transport stream errors for commercial receivers. This was found to be the case for all fifteen of the receivers under test and so picture failure (PF) was the only means of assessing the interference effects.

The PF point was identified by manual observation. The figure below shows the onset of un-correctable errors (UCE) used to determine the failure point. The onset of a complete picture failure, i.e. no reception, could be observed with a 1 to 2 dB increase in the interfering signal from the PF point.

© ERA Technology Ltd

Figure 5: Received picture showing onset of interference

3.4 Test Procedure and Equipment Set-Up

The test set-up used to perform the conducted DVB-T interference measurements is shown in the figure below.

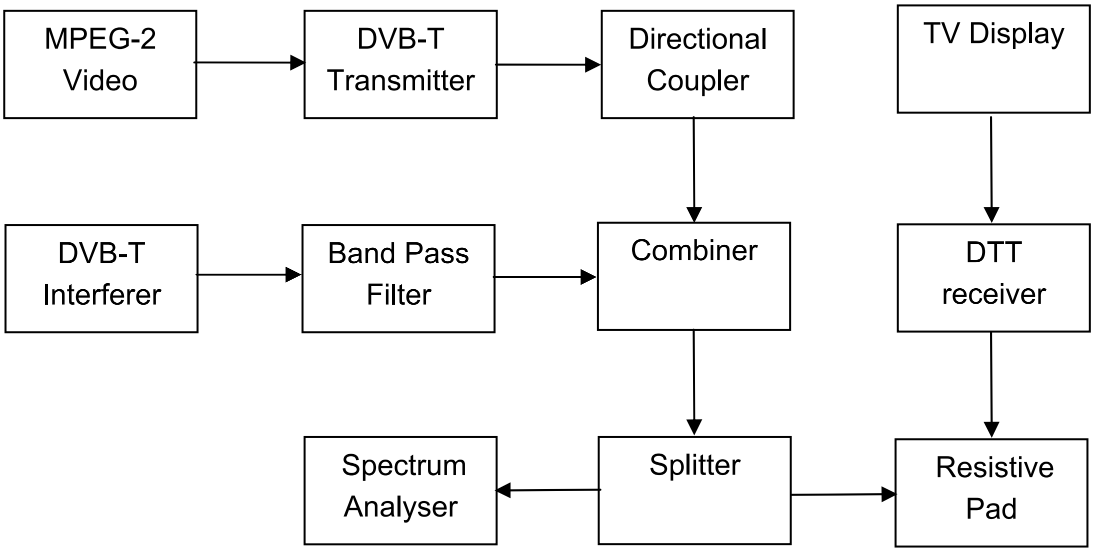


Figure 6: Measurement set-up for DVB-T interference into a DTT receiver

© ERA Technology Ltd

The following test procedure was used to measure the C/I protection ratios using the conducted set-up shown in the figure above:

1. For each digital receiver tested, the wanted signal level was set to the required power level ‘C’ given in Table 3, at a channel frequency of N-11.

2. The wanted channel power level ‘C’ was recorded using a spectrum analyser in a channel power bandwidth of 7.6 MHz. The spectrum analyser was set to RMS detection with a resolution bandwidth (RBW) of 100 kHz and a video bandwidth (VBW) of 1 MHz.

3. The signal generator transmitting the interfering DVB-T signal was initially set to a signal level –20 dB below the noise floor of the spectrum analyser.

4. The signal level of the DVB-T interference ‘I’ was then adjusted at the signal generator to achieve the required degradation of the received quality of the decoded MPEG signal.

5. The power level of the interferer was measured in the channel bandwidth of the receiver using RMS detection, a RBW of 100 kHz and a VBW of 1 MHz.

6. The C/I protection ratio was calculated from Steps 2 to 5.

7. Steps 2 to 6 were repeated for each of the channel frequencies between N-10 to N+11.

Note: a standard scart lead was used to connect the DTT receiver to the LCD display. Also a directional coupler was used to avoid any interaction between the output stages of the unwanted signal generator and the wanted TV generator signals at the combiner stage. The receiver bandwidth associated with the DTT receivers is 7.6 MHz and a spectrum analyser was used to measure the channel power in the receiver band as well as to measure the power of the interfering DVB-T signal.

4. Results

A total of fifteen DTT receivers were tested to determine their required C/I protection ratios in the presence of DVB-T interference for a range of channel separations from co-channel to N+11 channels away.

From these results, three receivers (representing typical, worst and best case performance) were selected for more detailed analysis to establish:

- The effect of changing the wanted signal level to investigate the overload points for adjacent channel interference.

© ERA Technology Ltd

- The effect of changing the modulation from 64-QAM to 16-QAM for the interfering signal.
- The effect of operating at different frequencies within 470 – 862 MHz band, in order to ascertain whether the DTT receivers are more sensitive at the higher or lower end of the spectrum.

The conducted test case scenarios and the parameters used are summarised in Table 5 below.

Table 5:
Summary of test scenarios

Scenario	Wanted signal (dBm)	Wanted modulation	Interfering modulation	Wanted channel	Interfering channel
C/I protection ratio (15 receivers)	-73	8k 64-QAM	8k 64-QAM	39	N±11
Effect of changing wanted signal level (3 receivers)	-80 to -10	8k 64-QAM	8k 16-QAM	36 62	37 63
Effect of changing modulation (3 receivers)	-73	8k 16-QAM	8k 64-QAM	39	N±11
Effect of changing tuned receiver frequency (3 receivers)	-73	8k 64-QAM	8k 64-QAM	22 30 59	N+11 N±11 N±11

Note: When testing for a wanted signal centered on channel 22, the frequency offset was limited to N+11 channels due to the lower cut-off frequency of the filter used on the interference source.

4.1 C/I Protection Ratios

Figure 7 below shows the C/I protection ratios for all fifteen receivers tested. Individual plots are included in Appendix A.

The results show that:

- Receivers 2, 5, 6, 7, 9, 14 and 15 could be considered as having typical operating performance.
- Receivers 1, 3 and 4 could be considered as having the worst performance.
- Receivers 8, 10, 11, 12 and 13 could be considered as having the best performance.

© ERA Technology Ltd

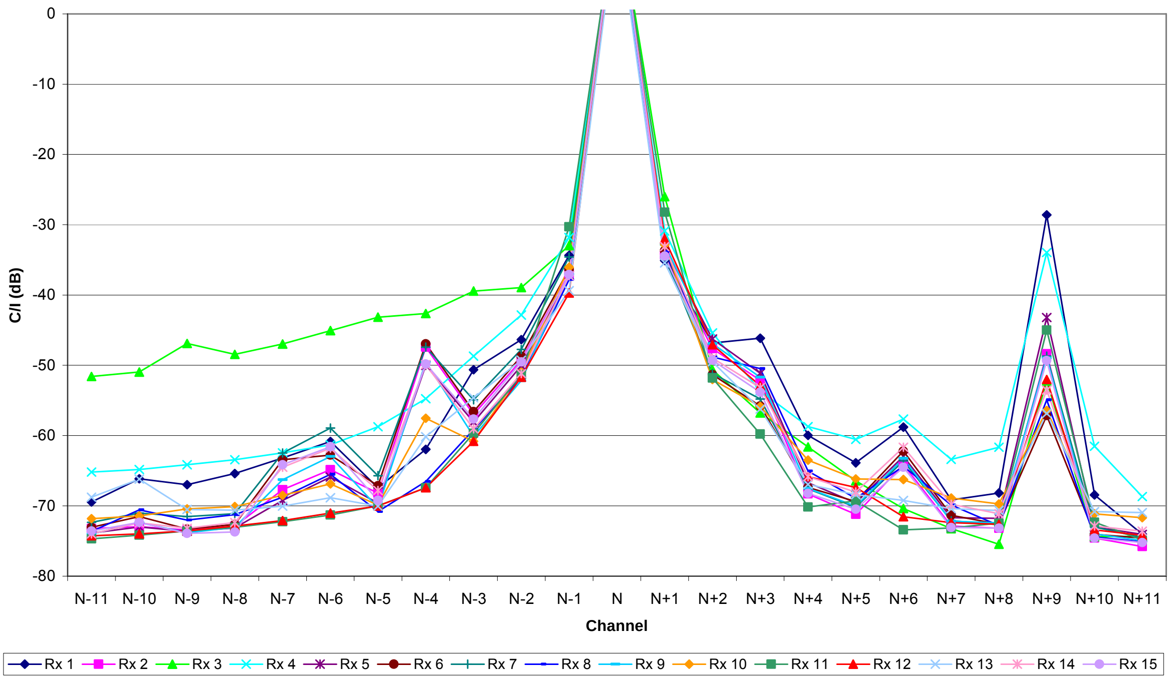


Figure 7: C/I protection ratios for DVB-T interference into fifteen DTT receivers

The figure above also reveals that receivers 2, 5, 6, 7, 9, 14 and 15 are more susceptible to DVB-T interference at N-4. The levels observed on the N-4 channel for these receivers, are comparable to the N+9 level measured for all fifteen receivers (see Table 6). The average measured C/I protection ratio for all fifteen DTT receivers at N+9 channel separation was -48.6 dB. The average measured C/I protection ratio for all fifteen DTT receiver at adjacent channels N-1 and N+1 were -35.9 dB and -32.7 dB respectively.

© ERA Technology Ltd

Table 6: C/I protection ratios at N-1, N+1 and N+9 for all fifteen receivers

Receiver	C/I @ N-1 (dB)	C/I @ N+1 (dB)	C/I @ N+9 (dB)
1	-34.37	-35.09	-28.61
2	-36.96	-34.33	-48.38
3	-32.98	-26.01	-52.26
4	-31.83	-30.88	-33.96
5	-37.17	-33.16	-43.22
6	-36.32	-33.69	-57.16
7	-34.61	-34.53	-48.69
8	-37.79	-33.78	-54.92
9	-37.03	-32.83	-48.96
10	-36.06	-32.84	-56.42
11	-30.3	-28.22	-44.99
12	-39.72	-32.01	-52.03
13	-39.39	-35.42	-56.87
14	-37.25	-33.1	-53.53
15	-37.08	-34.46	-49.33

Also from Table 7, it can be seen that these typically performing receivers are slightly more susceptible at N±6 than compared to other channels but 12 to 17 dB more immune than at N-4 and 15 to 20 dB more immune at N+9. Further investigation revealed that all of these typical performing receivers had the same generic processor and RF modulator box inside the casing.

© ERA Technology Ltd

Table 7: C/I protection ratios for receivers with typical receiver operating conditions

Receiver	C/I @ N-6 (dB)	C/I @ N-4 (dB)	C/I @ N+6 (dB)	C/I @ N+9 (dB)
2	-64.86	-47.42	-64.16	-48.38
5	-65.92	-50	-62.96	-43.22
6	-62.79	-46.94	-62.21	-57.16
7	-58.95	-47.41	-63.62	-48.69
9	-62.99	-49.53	-63.26	-48.96
14	-61.8	-49.89	-61.68	-53.53
15	-61.58	-49.82	-64.5	-49.33

From the results of Figure 7, it can be seen that Receiver 3 is the anomaly for the all receivers tested. It has very poor immune qualities to DVB-T interference for negative channel offsets compared with the measured C/I protection ratios for positive channel offsets.

The figure below shows the protection ratios for Receivers 1, 9 and 13, representative of worst, typical and best performance respectively:

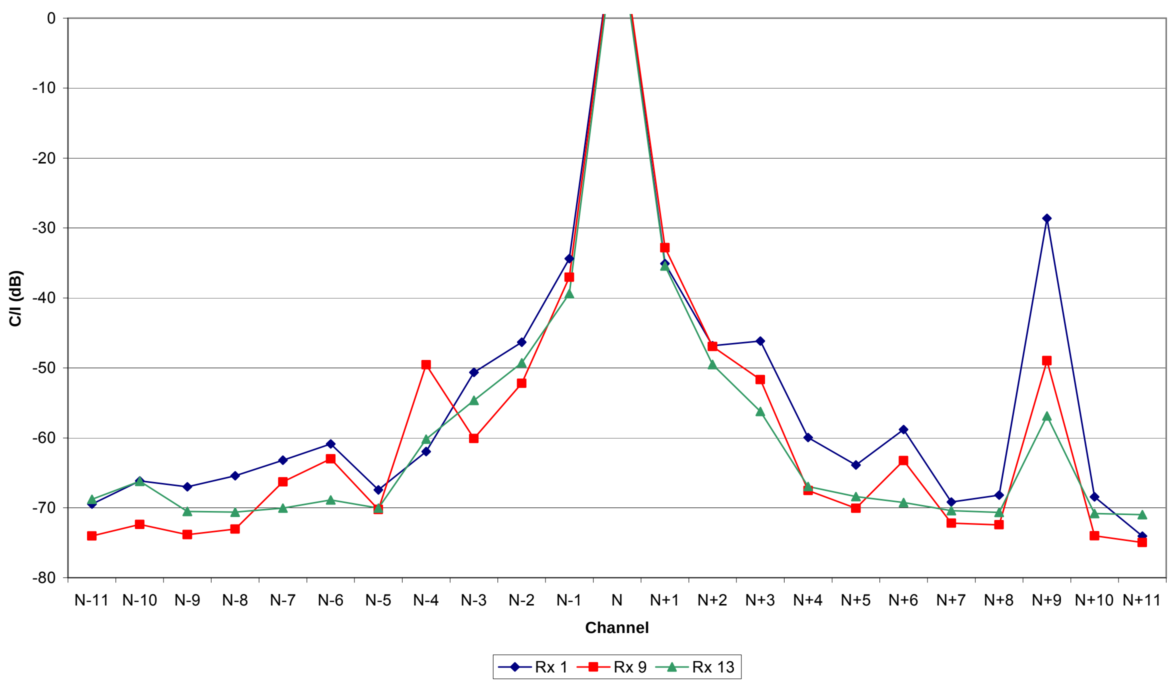


Figure 8: C/I protection ratios for worst, typical and best performing DTT receivers

© ERA Technology Ltd

From Figure 8, it can be seen that the C/I values on the N+9 image channel vary as much as 20 dB between Receivers 1 and 9 and 28 dB between Receivers 1 and 13. Also, apart from on the N-4 channel, the worst receiver, Receiver 1, has very similar characteristics to the typical receiver, Receiver 9.

4.2 Effect of Changing Wanted Signal Level

The following results quantify the effect of changing the wanted 64-QAM DVB-T signal level in order to determine the overload points of a worst, typical and best performing receiver. The receiver were subjected to adjacent (N+1) channel interference using a 16-QAM DVB-T signal. Measurements were performed for wanted channels of 36 (594 MHz) and 62 (802 MHz).

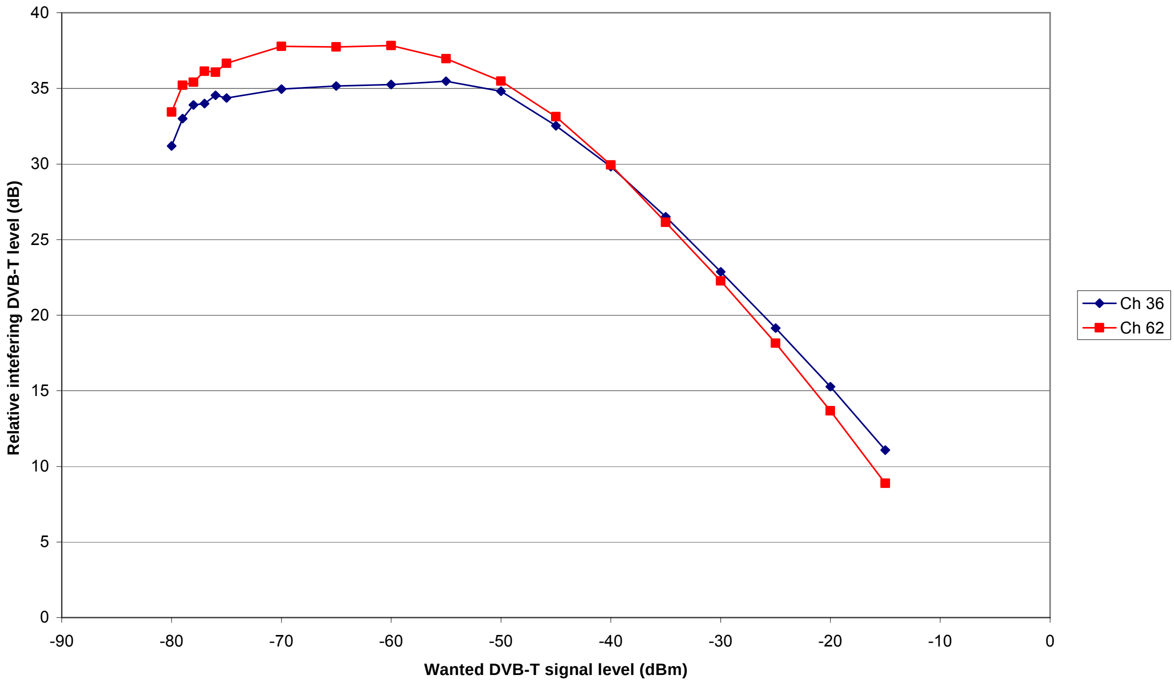


Figure 9: Maximum relative level of adjacent channel DVB-T (16-QAM) signal for the worst performing receiver

© ERA Technology Ltd

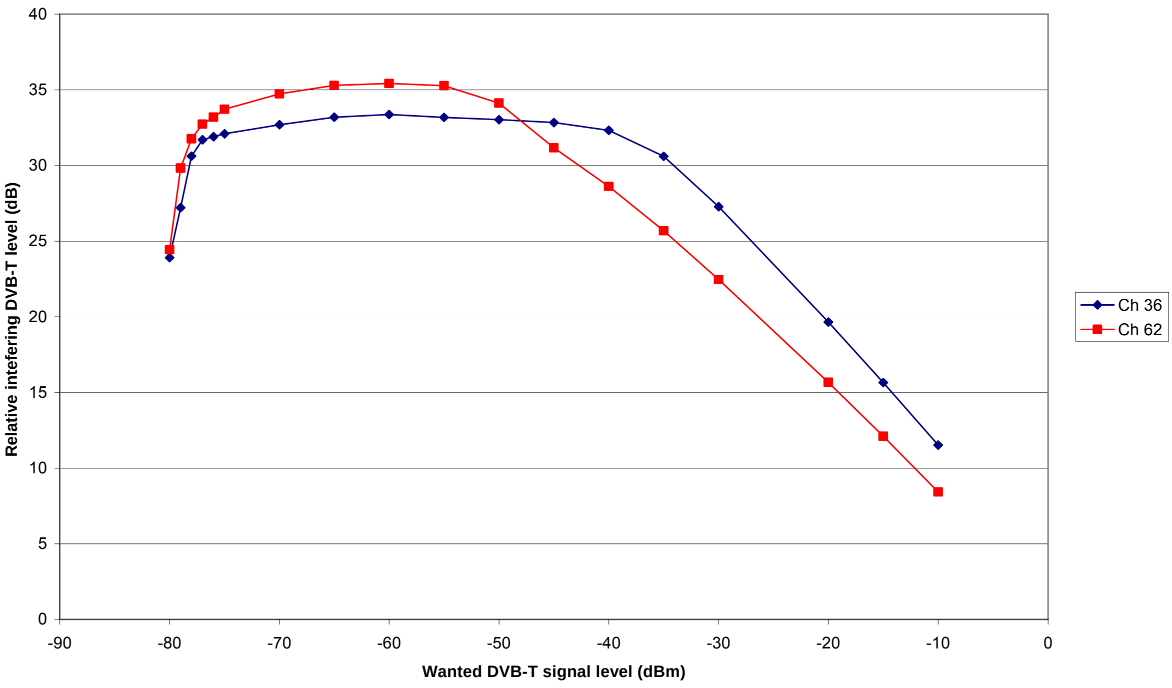


Figure 10: Maximum relative level of adjacent channel DVB-T (16-QAM) signal for typical performing receiver

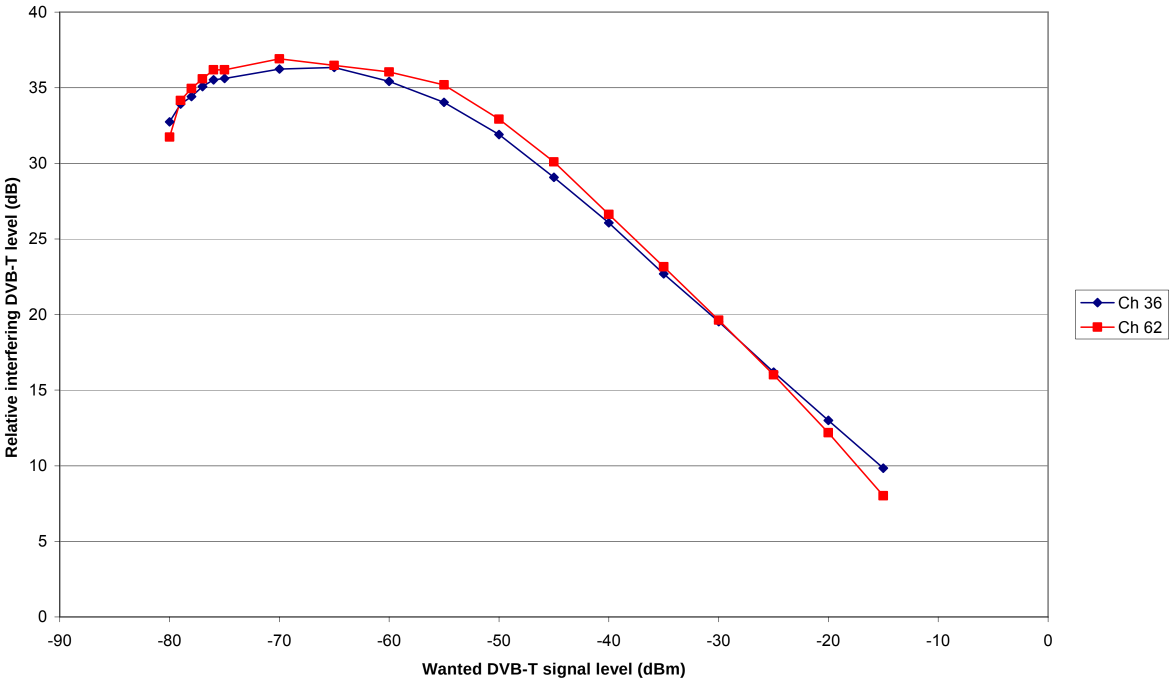


Figure 11: Maximum relative level of adjacent channel DVB-T (16-QAM) signal for the best performing receiver

© ERA Technology Ltd

From Figure 9, Figure 10 and Figure 11, it can be seen that the trend for all three different performing receivers tested are very similar. The relative level of adjacent DVB-T channel interference required to cause the onset of interference varies from 24 to 33 dB at 3 dB above the minimum usable sensitivity (MUS) to 8 to 12 dB for a wanted DVB-T signal level of -15 dBm.

The 9 dB difference between the worst, typical and best performing receivers, when tested at the lower received signal levels is most likely due to the difference in receiver quality in terms of filtering and noise figure performance.

The measured plateau for wanted signal levels between -73 to -53 dBm can be deemed as the most suitable operating conditions for all three receiver quality types, when subject to 16-QAM DVB-T interference.

The above results show that under these suitable receiver operating conditions the protection ratios measured for wanted signal levels of -73 to -53 dBm (e.g. at receiver sensitivity +10 dB to +30 dB) are reasonably flat within 2 to 3 dB, whatever the level of the interfering signal.

However, if the wanted signal level exceeds a received power threshold of -50 to -40 dBm, the receiver starts to lose its ability to discriminate against interfering signals on the adjacent channels. Resulting in less power required for the interfering signal relative to the level of the wanted transmission to cause the onset of degradation to the received picture.

4.3 Effect of Changing Modulation Scheme

The following results show the effect of changing the wanted modulation scheme from 64-QAM to 16-QAM for channel 39 (618 MHz).

It can be seen that 16-QAM modulation requires a lower protection ratio of 3 to 5 dB compared with 64-QAM and is therefore more tolerant to higher levels of interference. This is expected as the 64-QAM modulation requires less amplitude and/or phase transitions to change symbol states compared to the 16-QAM scheme and therefore requires less interference to cause demodulation errors in the DTT receiver.

© ERA Technology Ltd

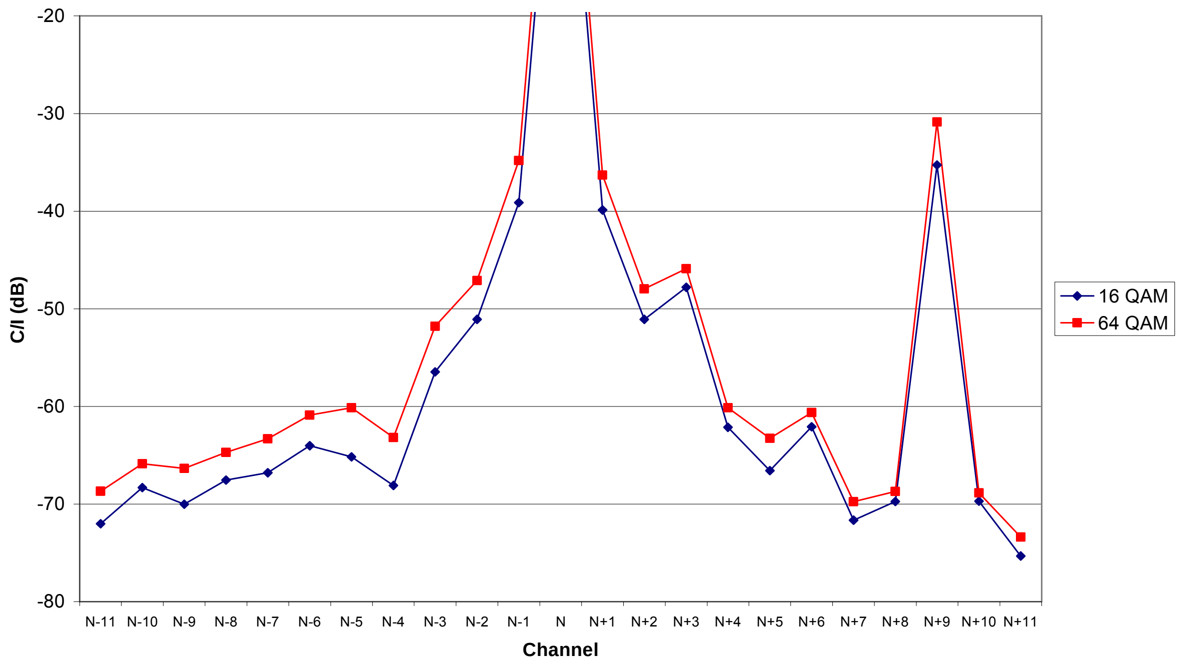


Figure 12: Comparison of 16-QAM and 64-QAM modulation schemes for worst performing receiver

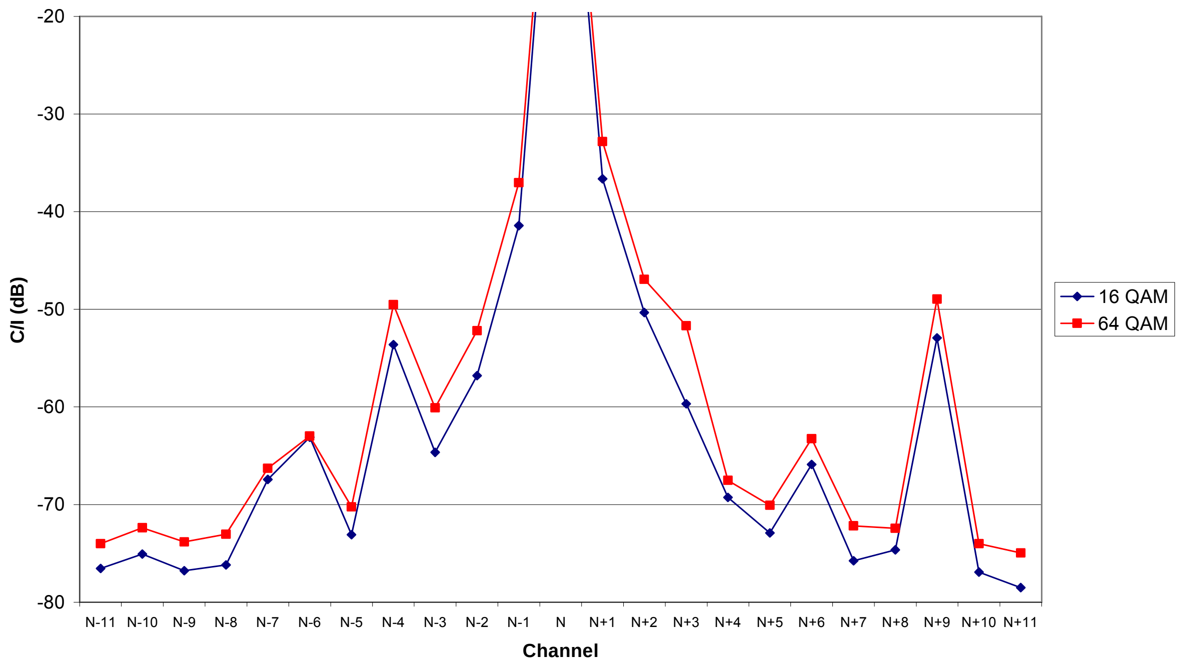


Figure 13: Comparison of 16-QAM and 64-QAM modulation schemes for typical performing receiver

© ERA Technology Ltd

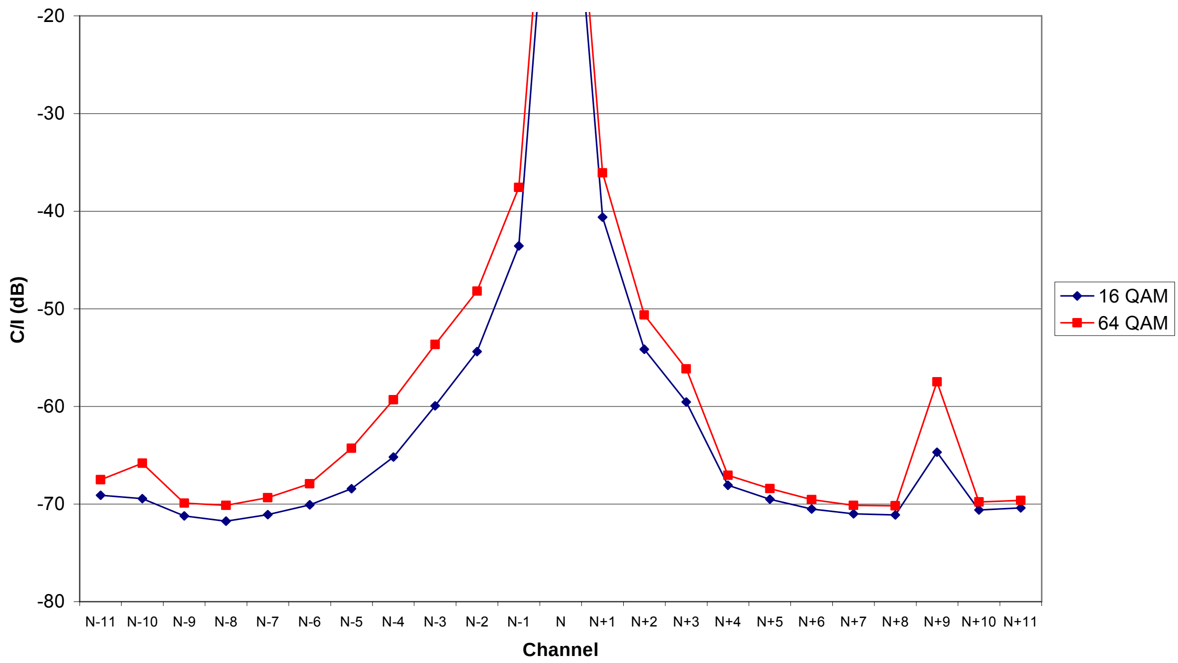


Figure 14: Comparison of 16-QAM and 64-QAM modulation schemes for best performing receiver

4.4 Effect of Changing Tuned Receiver Frequency

A sample of tests were performed at different frequencies within the 470 – 862 MHz band to ascertain whether the DTT receivers were more sensitive at a higher or lower frequency range of the spectrum. Measurements were performed for channel 22 (482 MHz), channel 30 (546 MHz) and channel 59 (778 MHz) for a worst, typical and best performing receiver.

The results (Figure 11, Figure 12 and Figure 13) show that the receivers' performance is broadly similar regardless of the centre operating channel, except for N+5 channel separation for Receivers 1 (worst quality) and 13 (best quality). This effect has been investigated further in Section 4.4.1.

© ERA Technology Ltd

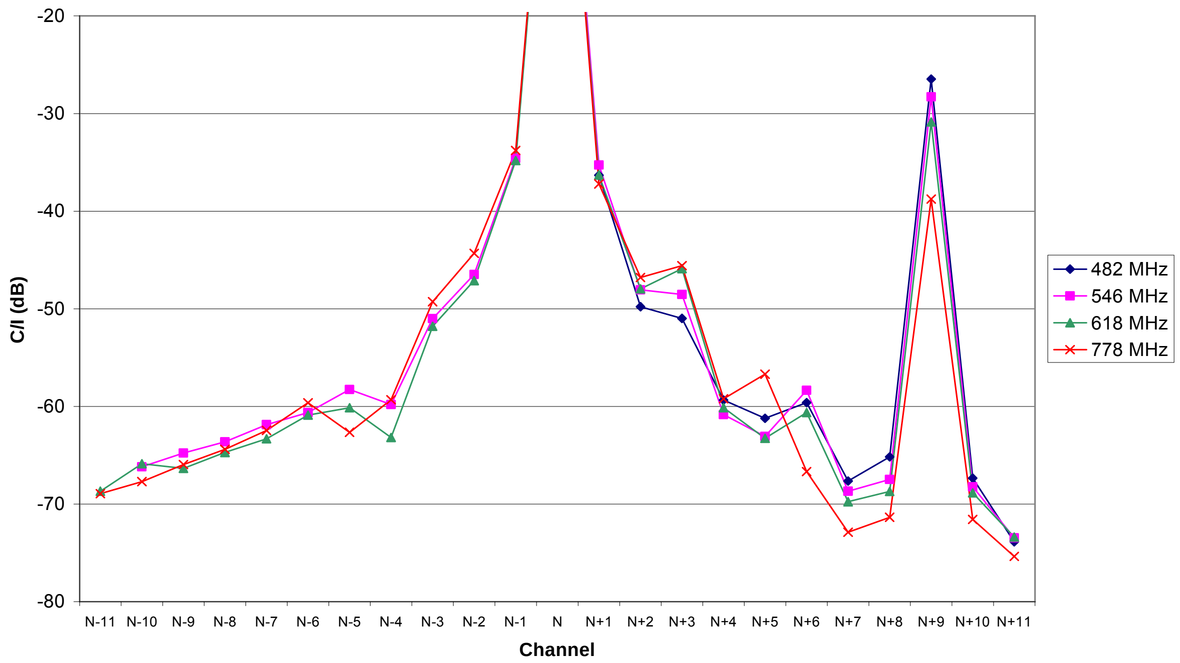


Figure 15: Effect of changing wanted frequency for worst performing receiver

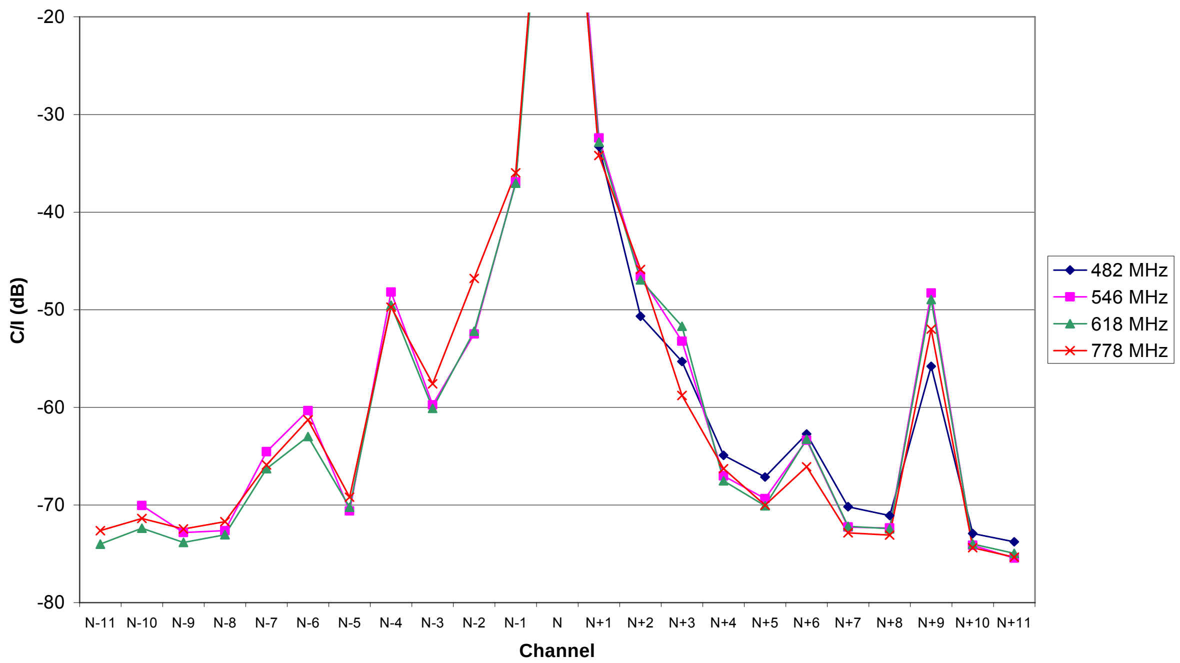


Figure 16: Effect of changing wanted frequency for typical performing receiver

© ERA Technology Ltd

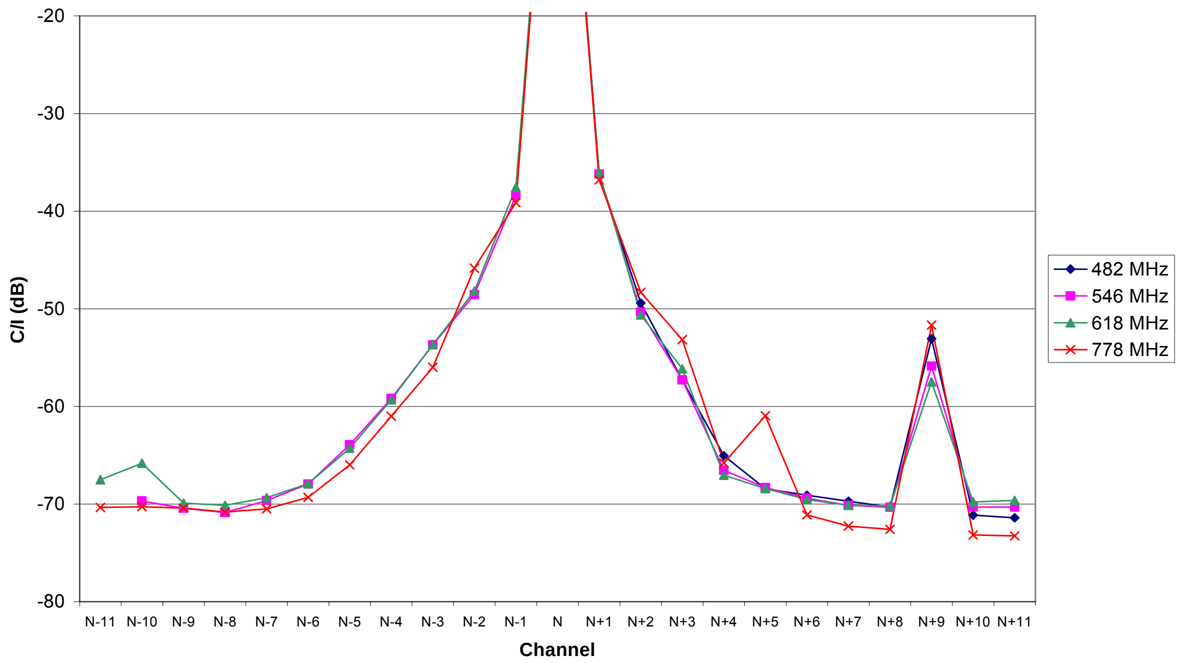


Figure 17: Effect of changing wanted frequency for best performing receiver

4.4.1 Investigation of N+5 anomaly

Figure 15 and Figure 17 above appear to highlight an anomaly at the N+5 channel separation when the receiver is operating at 778 MHz. The results suggest that receivers 1 and 13 are more susceptible to interference at N+5, when operating at higher channel numbers. This effect was investigated further for Receiver 13 by measuring the required C/I at N+5 with the receiver operating on different channels.

© ERA Technology Ltd

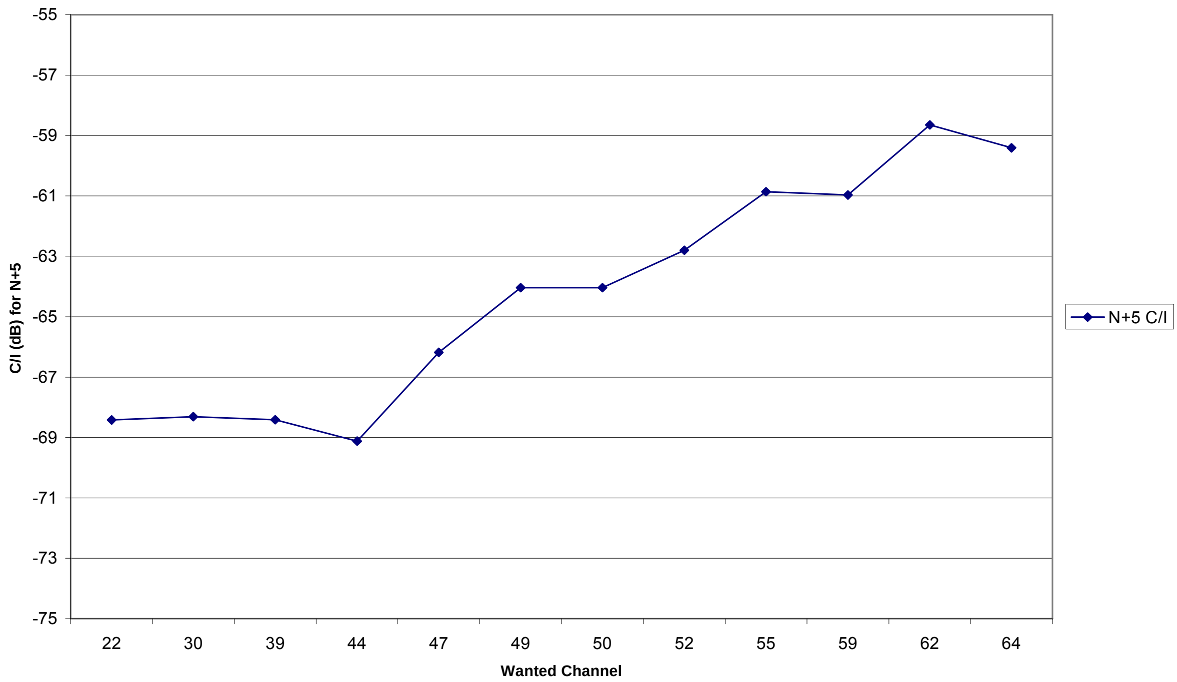


Figure 18: Variation in C/I at N+5 for receiver 13 operating on different channels

The figure above shows that the C/I protection ratio of -68 dB, is approximately constant for channels below channel 47. However, for channels above 47 the required C/I protection ratio at N+5 increases steadily to approximately -59 dB at channel 64.

5. Conclusions

A total of fifteen DTT receivers were tested to determine their required C/I protection ratios in the presence of DVB-T interference for a range of channel separations from N-11 to N+11 channels away.

From these results, three receivers (representing typical, worst and best case performance) were selected for more detailed analysis to establish:

- The effect of changing the wanted signal level to investigate the overload points for adjacent channel interference.
- The effect of changing the modulation from 64-QAM to 16-QAM for the interfering signal.
- The effect of operating at different frequencies within 470 – 862 MHz in order to ascertain whether the DTT receivers are more sensitive at the higher or lower end of the spectrum.

© ERA Technology Ltd

DVB-T interference into fifteen DTT receivers

A total of fifteen DTT receivers were tested to determine their required C/I protection ratios in the presence of DVB-T interference for a range of channel separations from co-channel to N+11 channels away. The test results for the measured C/I protection ratios for DVB-T interference into fifteen DTT receivers showed that:

- Receivers 2, 5, 6, 7, 9, 14 and 15 were considered as having typical operating performance.
- Receivers 1, 3 and 4 were considered as having the worst performance.
- Receivers 8, 10, 11, 12 and 13 were considered as having the best performance.

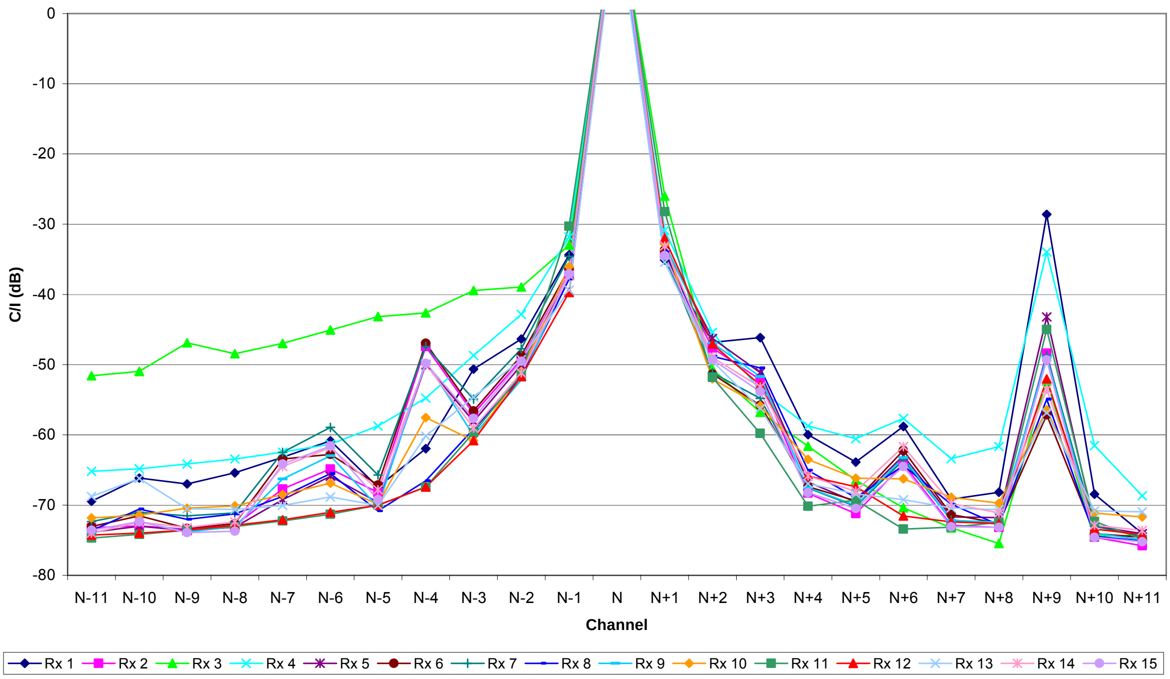


Figure 19: C/I protection ratios for DVB-T interference into fifteen DTT receivers

The results also revealed that receivers 2, 5, 6, 7, 9, 14 and 15 were more susceptible to DVB-T interference at N-4, with protection ratios levels comparable to those measured at the N+9 image channel. Also, the measurements showed that these typically performing receivers were slightly more susceptible at N±6 than compared to other channels but 12 to 17 dB more immune than at N-4 and 15 to 20 dB more immune at N+9. Further investigation revealed that all of these typical performing receivers had the same generic processor and RF modulator box inside the casing.

© ERA Technology Ltd

From the figure above it can be seen that the C/I at the image channel (N+9) varies as much as 20 dB between Receivers 1 and 9 and 28 dB between Receivers 1 and 13. Also, apart from on the N-4 channel, Receiver 1 has very similar characteristics when compared to a typically performing receiver.

The average measured C/I protection ratio for all fifteen DTT receiver at adjacent channels N-1 and N+1 were -35.9 dB and -32.7 dB respectively. The average measured C/I protection ratio for all fifteen DTT receivers at N+9 channel separation was -48.6 dB.

Effect of changing wanted signal level

Conducted interference measurements were performed to quantify the effect of changing the wanted 64-QAM DVB-T signal level in order to determine the overload points of a worst, typical and best performing receiver. The receivers were subjected to adjacent (N+1) channel interference using a 16-QAM DVB-T signal. Measurements were performed for wanted channels of 36 (594 MHz) and 62 (802 MHz).

The results showed that under suitable receiver operating conditions, i.e., for wanted signal levels of -73 to -53 dBm, the protection ratios measured were reasonably flat within 2 to 3 dB, whatever the level of the interfering signal.

However, if the wanted signal level exceeded a received power threshold of -50 to -40 dBm, the receiver started to lose its ability to discriminate against interfering signals on the adjacent channels. Resulting in less power required for the interfering signal relative to the level of the wanted transmission to cause the onset of degradation to the received picture.

Effect of changing modulation scheme

Conduced measurements were carried out determine the effect of changing the modulation scheme of the wanted signal from 64-QAM to 16-QAM for channel 39 (618 MHz).

The results showed that by changing the modulation of the received wanted signal to 16-QAM, a lower protection ratio of 3 to 5 dB, was required compared with 64-QAM results. Thus, revealing that a DTT receiver is more tolerant to interference, when operating under a 16-QAM modulation scheme compared to a 64-QAM modulation. This is expected as the 64-QAM modulation requires less amplitude and/or phase transitions to change symbol states compared to the 16-QAM scheme and therefore requires less interference to cause demodulation errors in the DTT receiver.

Effect of changing tuned receiver frequency

A sample of tests were performed at different frequencies within the 470 – 862 MHz band to ascertain whether the DTT receivers were more sensitive at a higher or lower frequency range of the spectrum. Measurements were performed for channel 22 (482 MHz), channel 30 (546 MHz) and channel 59 (778 MHz) for a worst, typical and best performing receiver.

© ERA Technology Ltd

The results show that the receivers performance is broadly similar regardless of operating channel, except for N+5 channel separation for receivers 1 (worst quality) and 13 (best quality). The results showed that Receivers 1 and 13 were more susceptible to interference at N+5 when operating at higher channel numbers.

This effect was investigated further for receiver 13 by measuring the required C/I protection ratio at N+5 with the receiver operating on different channels. The results show that the C/I protection ratio of -68 dB, is approximately constant for channels below channel 47. However, for channels above 47 the required C/I protection ratio at N+5 increases steadily to approximately -59 dB at channel 64.

6. References

[1] http://www.ofcom.org.uk/radiocomms/ddr/documents/ddr_tor/

[2] RF measurements to quantify 3G and WiMAX mobile interference to DVB-T receivers", ERA Technology, December 2006

[3] ETSI EN 302 296v1.1.1 Transmitting equipment for the digital television broadcast service, terrestrial (DVB-T), 2005-01

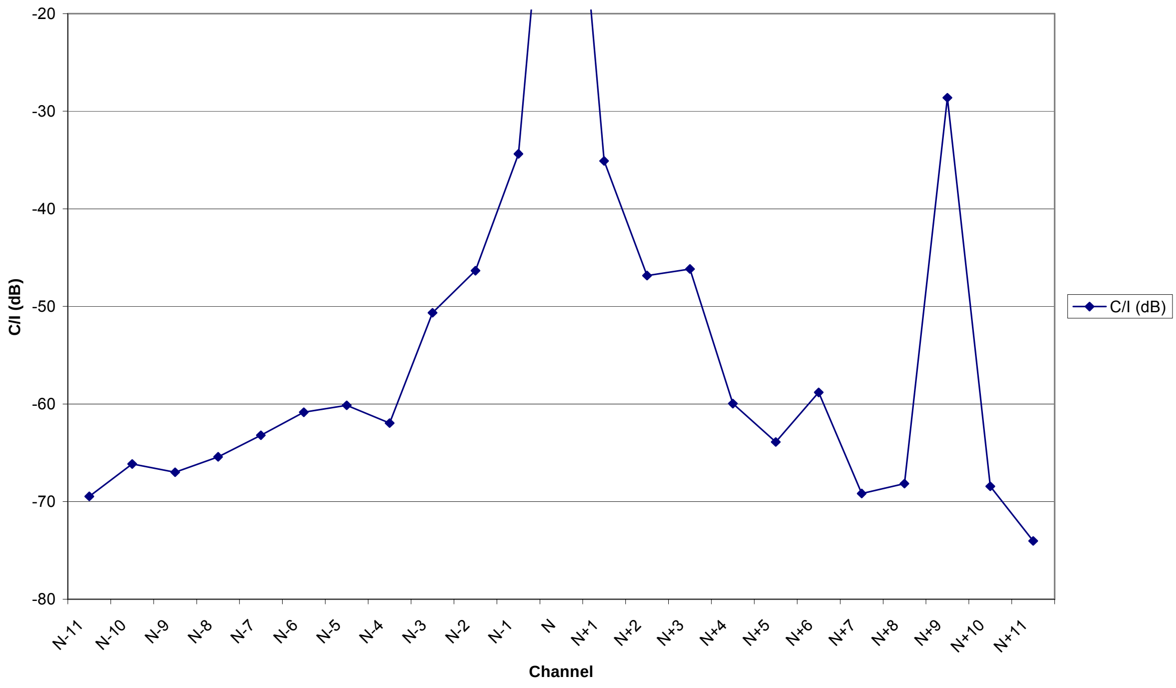
[4] The DTG D Book, Digital Television Group, 4th Ed, January 2005

[5] TG4(07)027rev3: Actual protection ratios of DVB-T receivers in the presence of interference from DVB-H

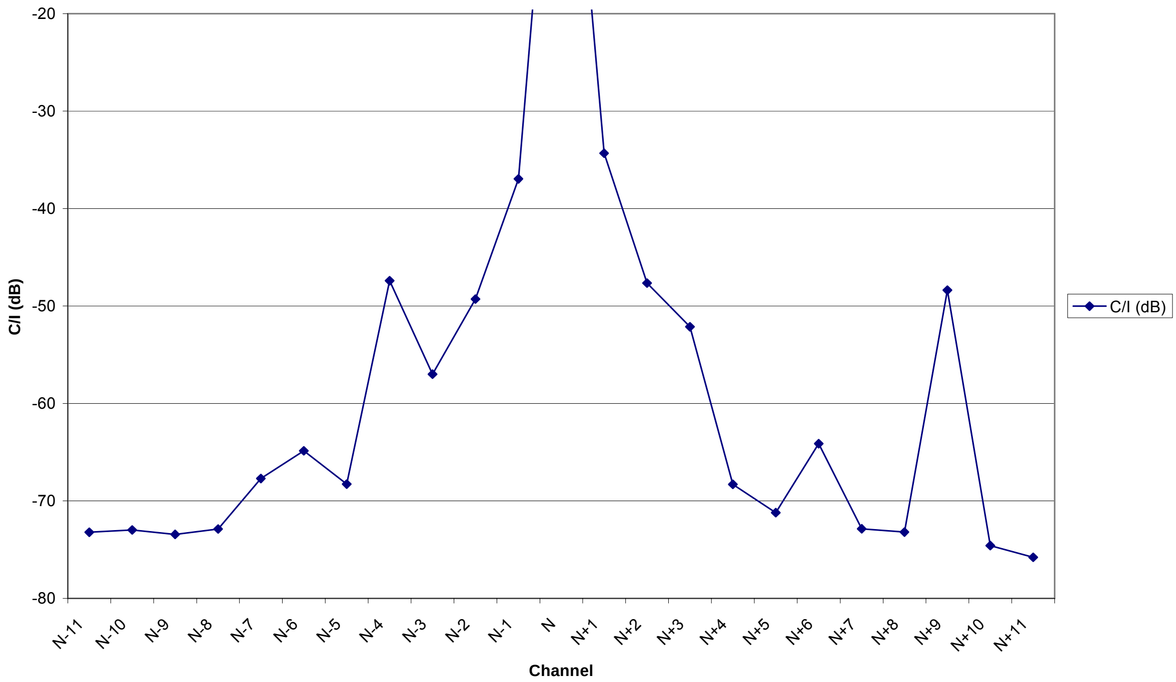
© ERA Technology Ltd

APPENDIX A
C/I Protection Ratio Plots

© ERA Technology Ltd

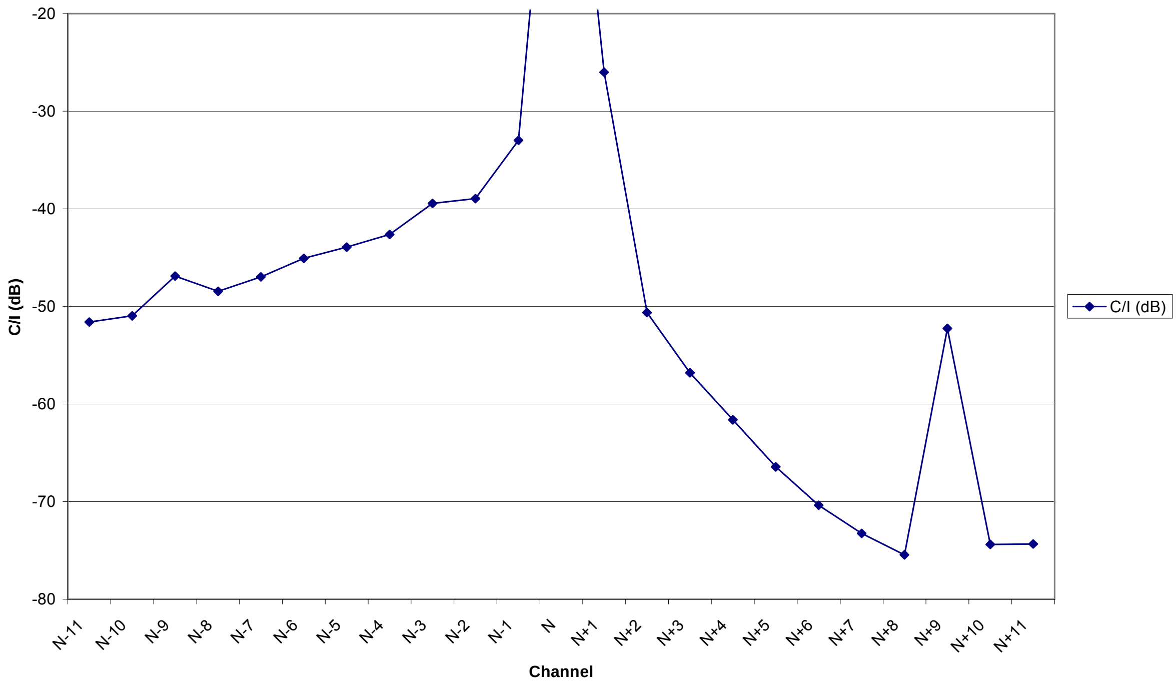


C/I Results for receiver 1

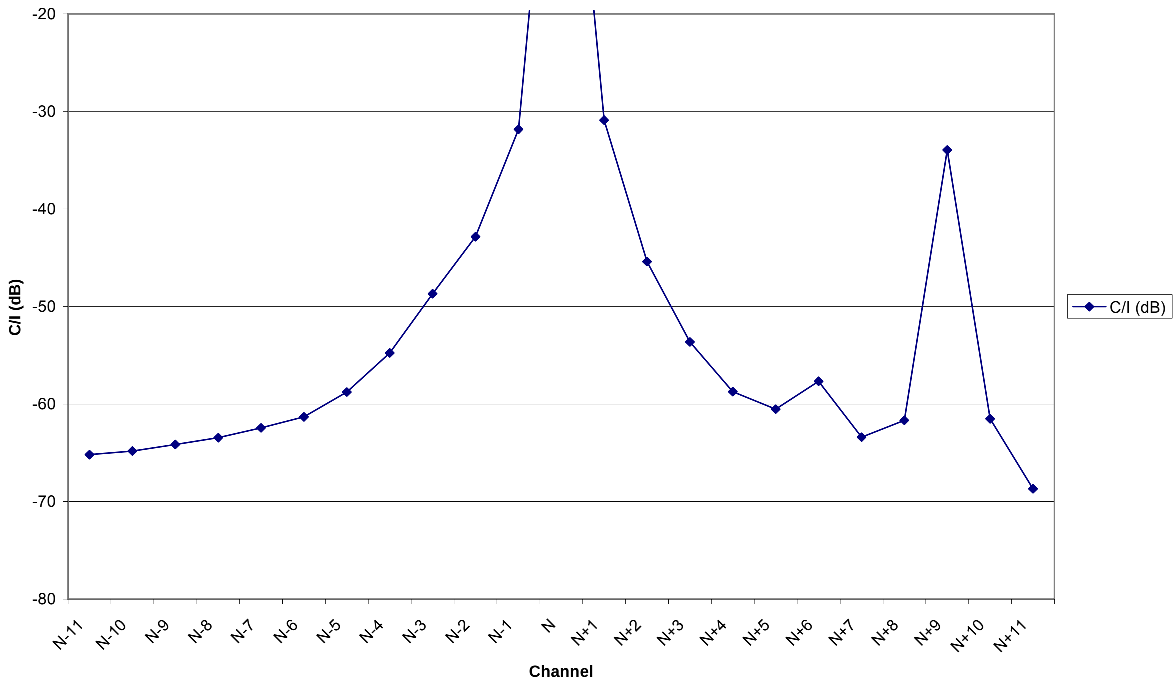


C/I Results for receiver 2

© ERA Technology Ltd

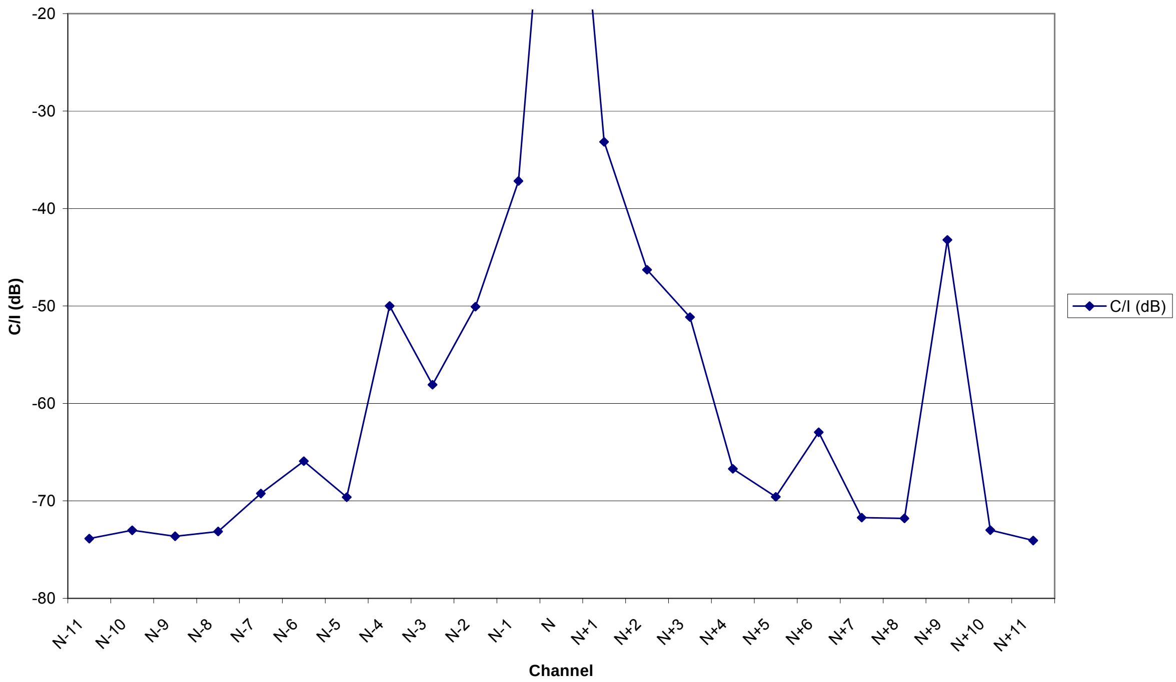


C/I Results for receiver 3

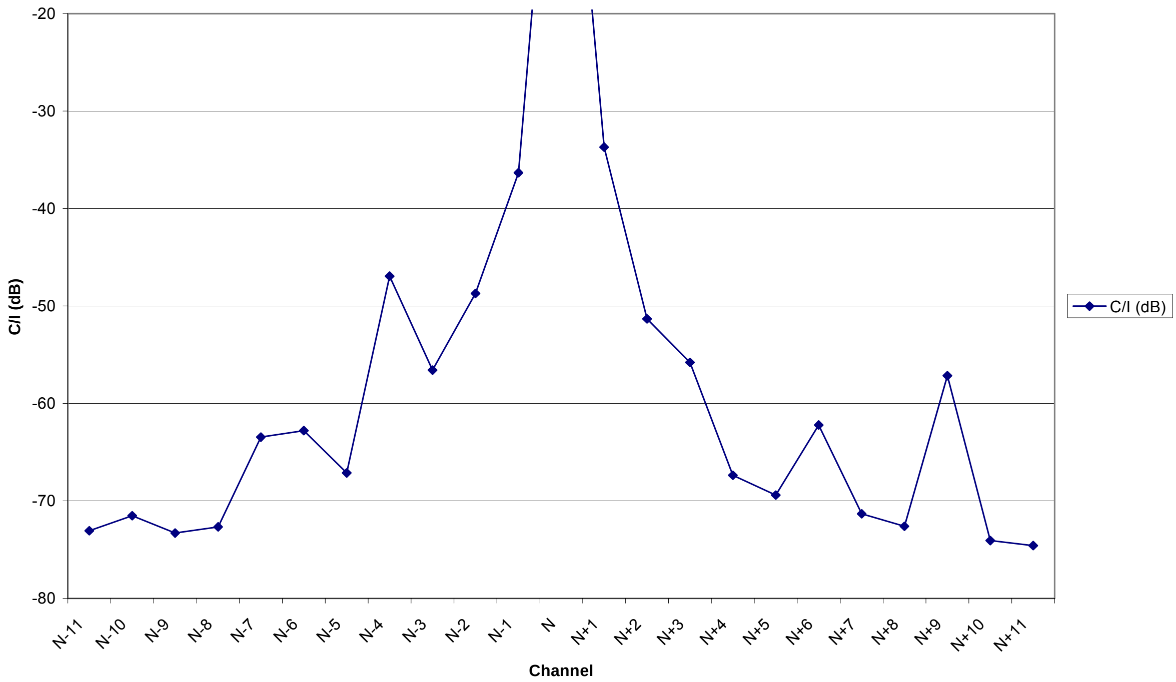


C/I Results for receiver 4

© ERA Technology Ltd

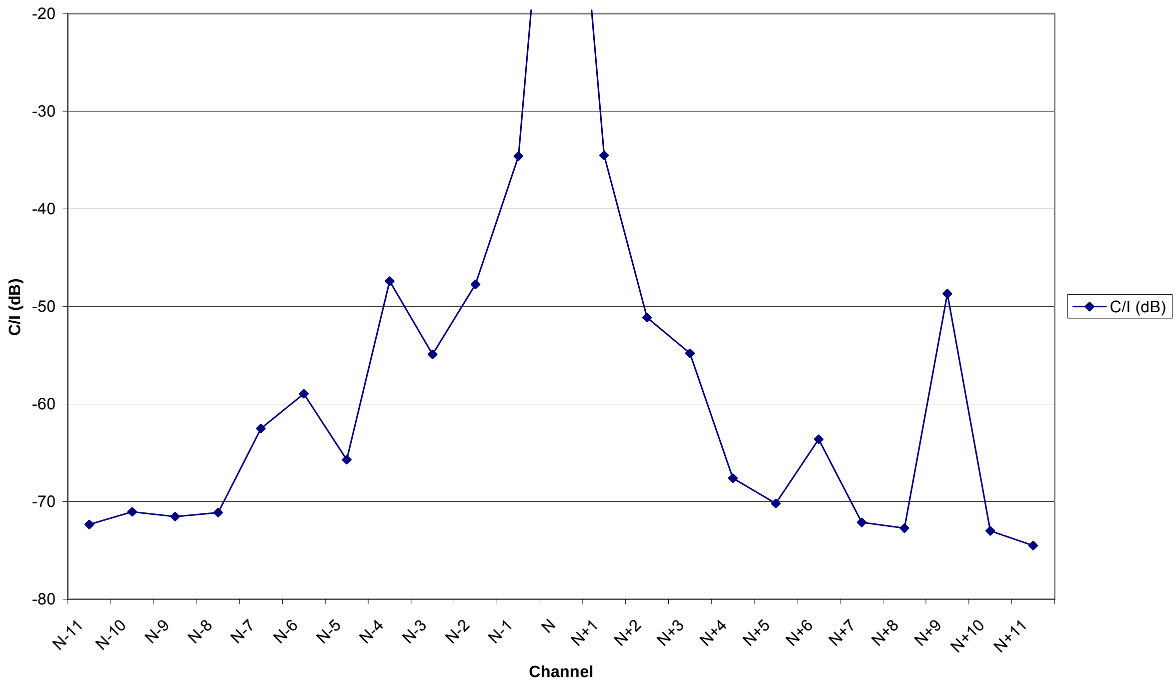


C/I Results for receiver 5

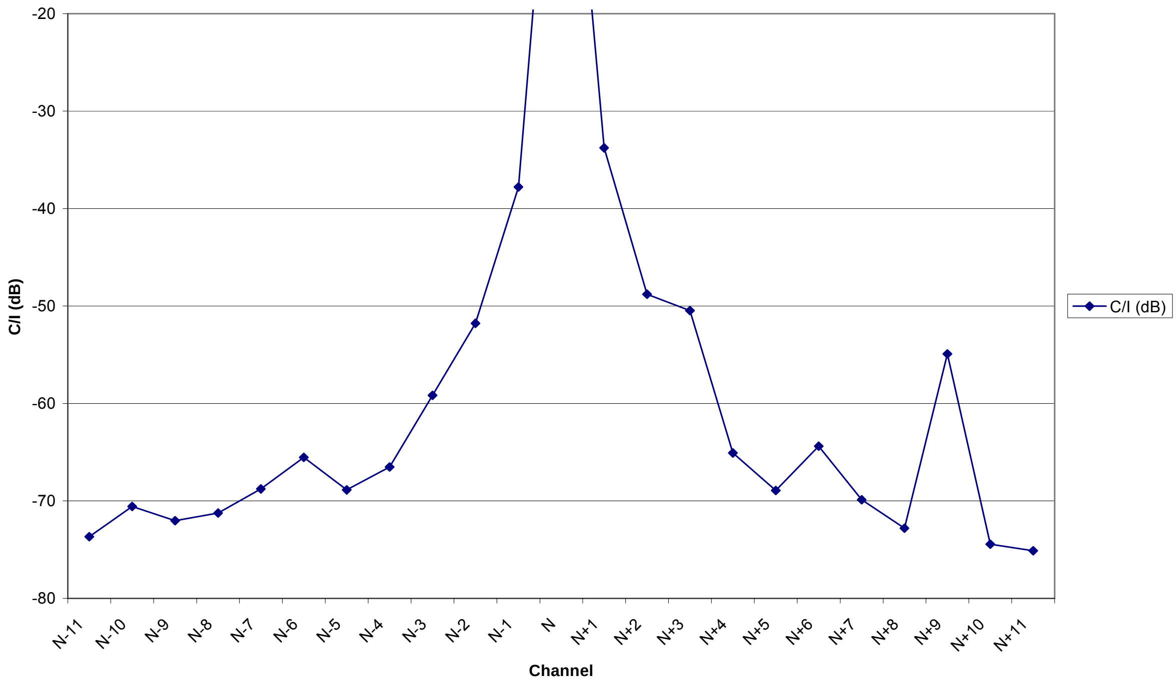


C/I Results for receiver 6

© ERA Technology Ltd



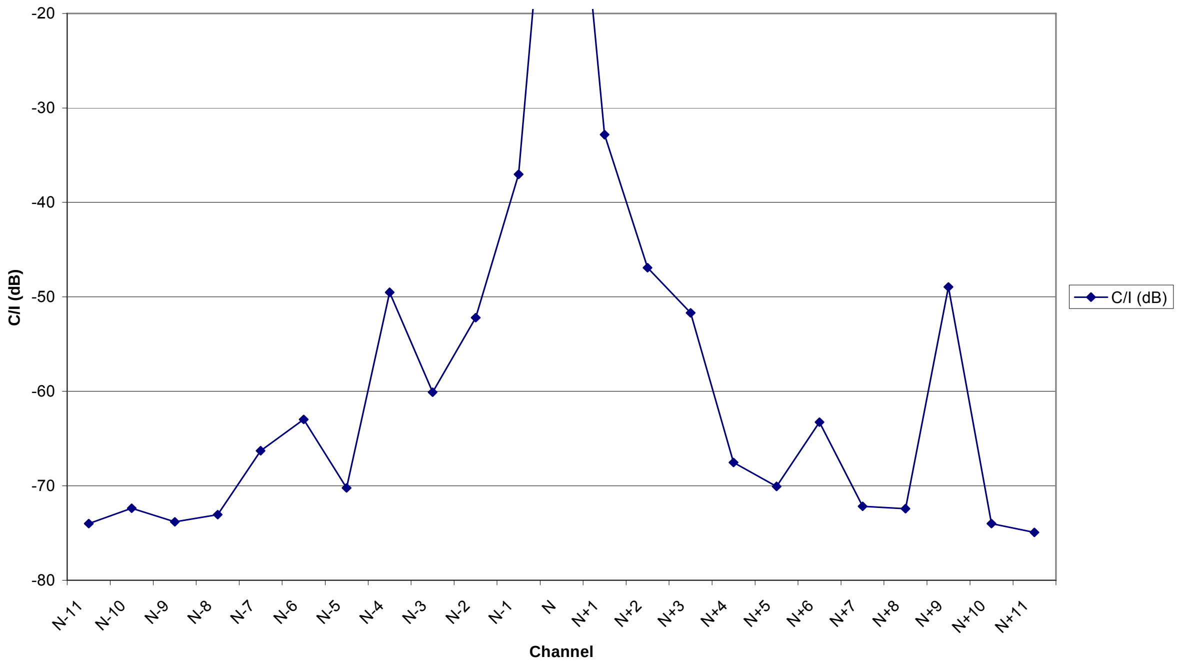
C/I Results for receiver 7



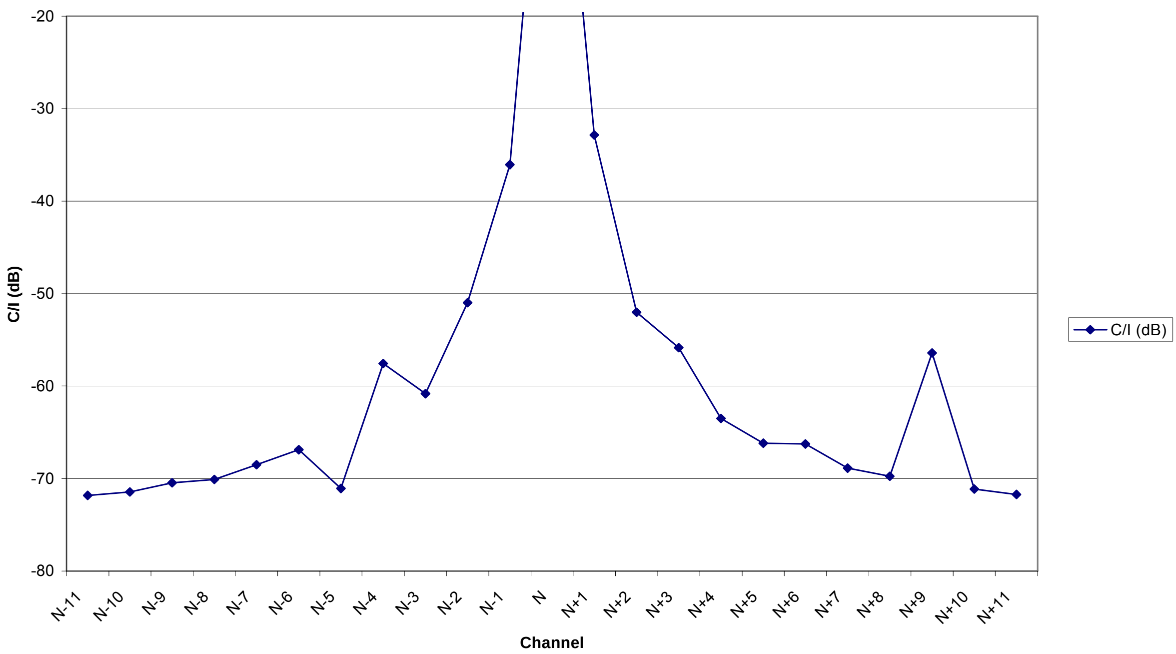
C/I Results for receiver 8

ERA TECHNOLOGY

© ERA Technology Ltd

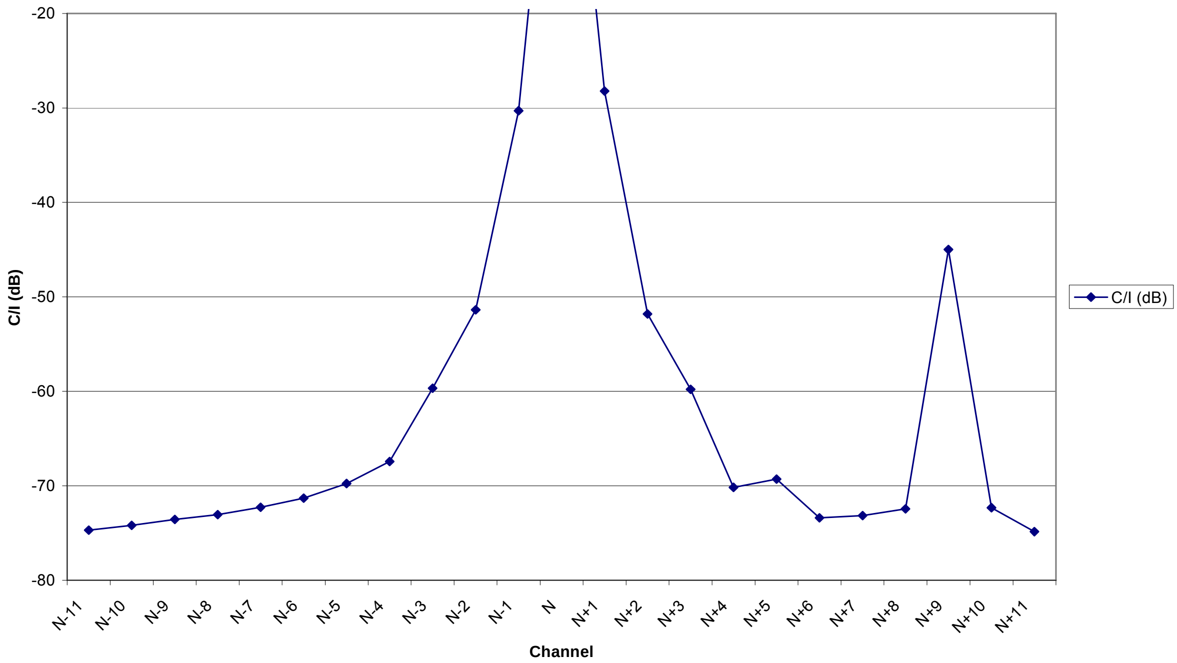


C/I Results for receiver 9

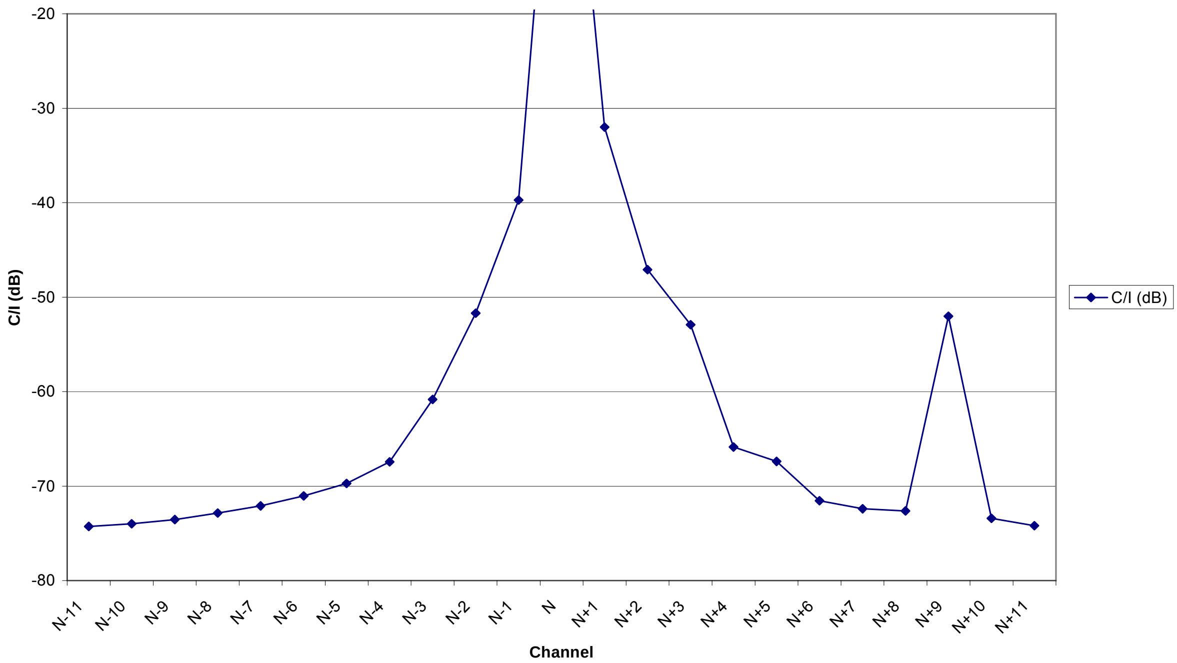


C/I Results for receiver 10

© ERA Technology Ltd

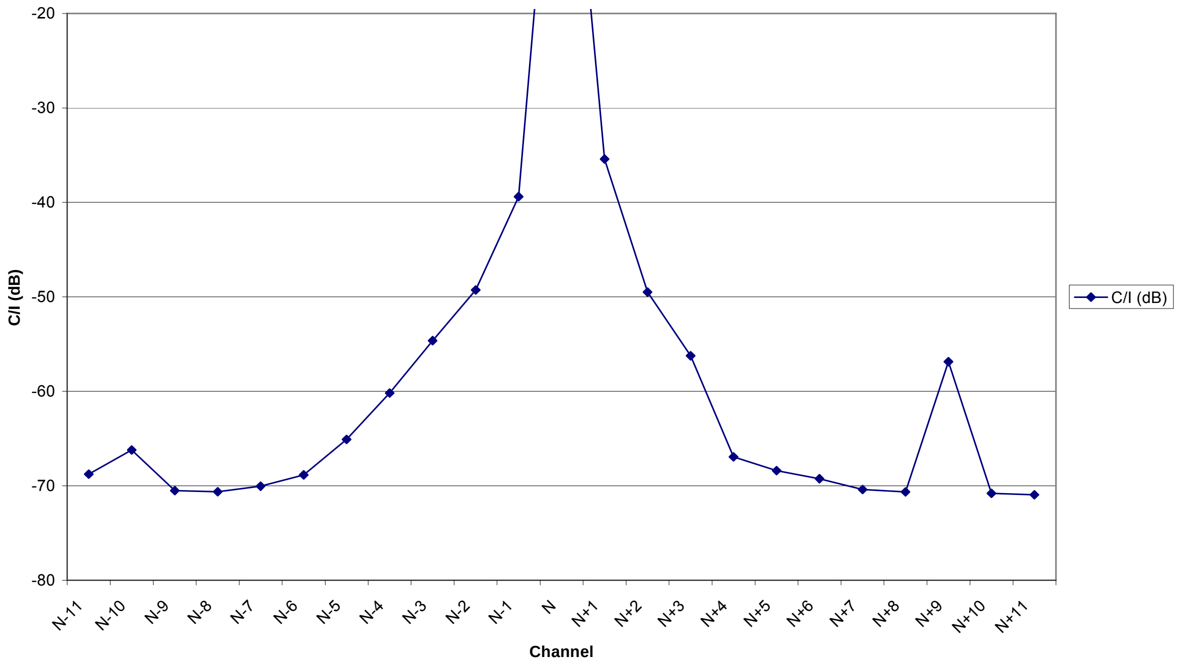


C/I Results for receiver 11

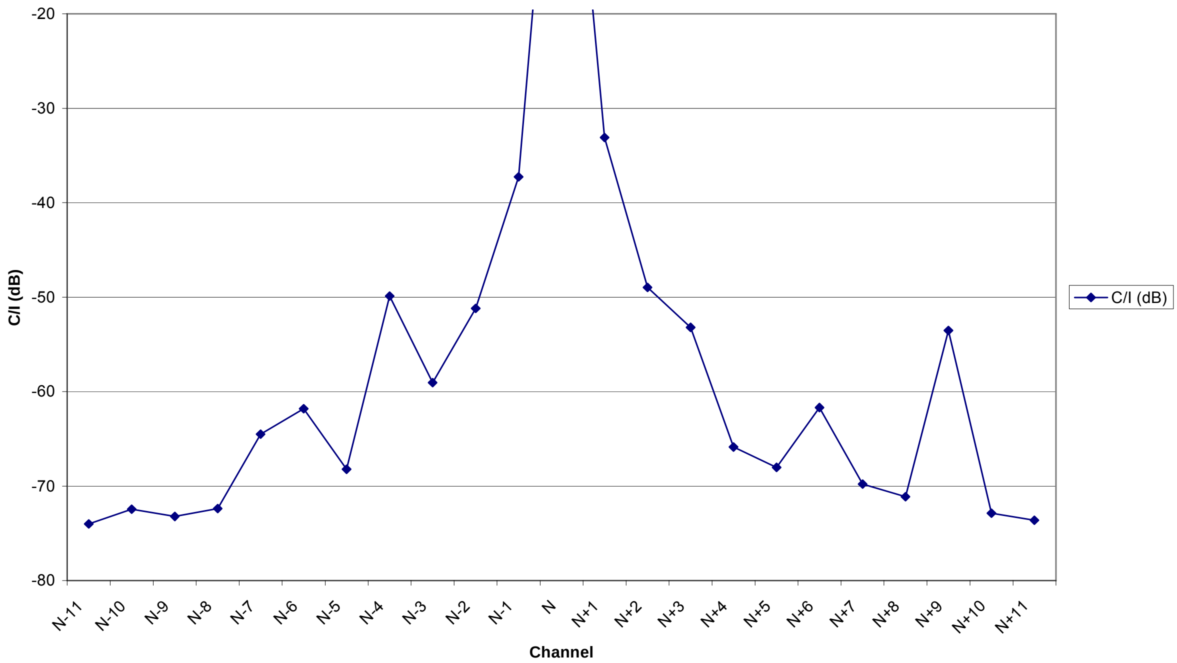


C/I Results for receiver 12

© ERA Technology Ltd

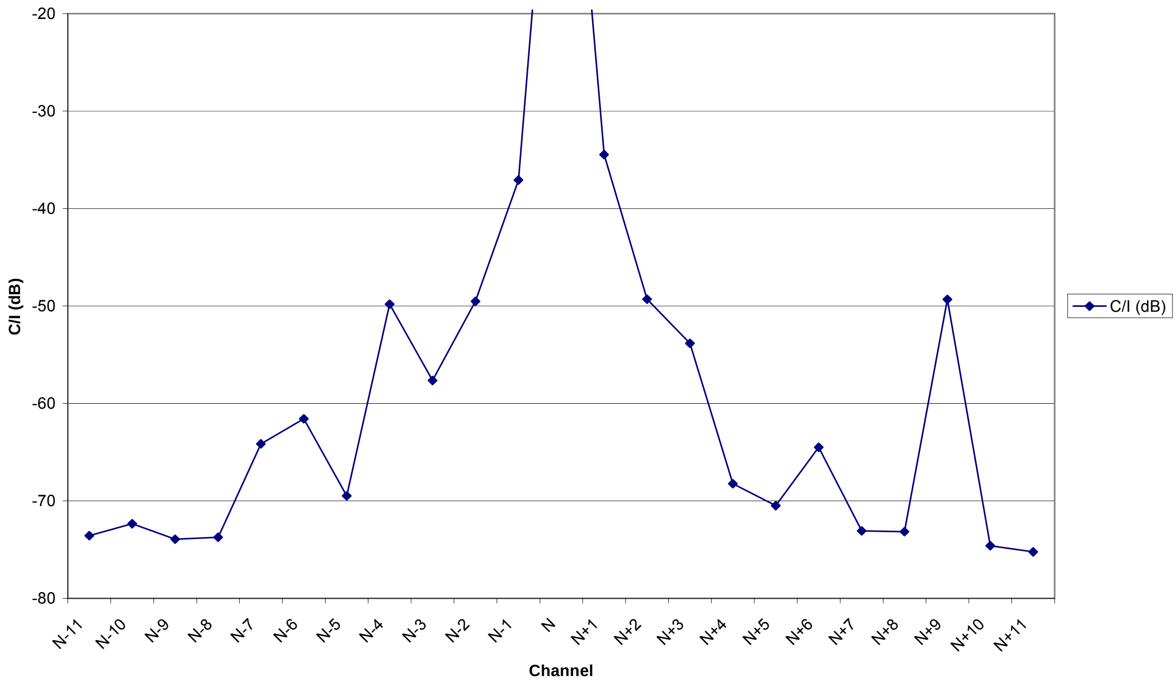


C/I Results for receiver 13



C/I Results for receiver 14

© ERA Technology Ltd



C/I Results for receiver 15

© ERA Technology Ltd

This page is intentionally left blank

© ERA Technology Ltd

APPENDIX B: Test Equipment

B.1 Test Equipment List

- Agilent E4438C signal generator
- R&S MPEG encoder
- R&S SFQ TV transmitter
- Wiltron VSWR bridge (0.5 MHz to 2 GHz)
- HP splitter (DC to 18 GHz)
- Marconi programmable attenuators
- R&S FSU-46 spectrum analyser
- DVB-T receivers
- Digix LCD TV
- 50 Ω to 75 Ω matching pad
- Standard TV scart lead

© ERA Technology Ltd