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Executive Summary

In June 2011 Ofcom published a consultation on coexistence of new services in the 800 MHz band with Digital Terrestrial Television (DTT) [1]. This sets out Ofcom's approach to the release of the 800 MHz band for new mobile services following completion of the switchover from analogue to digital television. Following this digital switchover (DSO), high powered mobile base stations will operate close in frequency to the spectrum used for DTT, which could affect the ability of some people to receive digital services.

The potential for interference from base stations to DTT receivers has been studied extensively by Ofcom and the results of these studies were made available in a technical report published alongside the consultation [2]. One area of consideration was the effect of interference on households that use amplifiers in their TV installation to boost and distribute the received digital signals. Amplifiers are susceptible to interference as they can be easily overloaded if signal power at their input exceeds a certain threshold, resulting in loss of reception of all DTT services.

Amplifiers are typically found in the following types of TV installation:

- Communal aerial systems: These typically have a single aerial on the roof which is connected to a launch amplifier that boosts the received signal level before distributing it to different outlets, e.g. in flats or other communal dwellings. Communal systems that provide access to DTT services only are known as master antenna TV (MATV) systems.
- Domestic installations with amplifiers: These tend to be single properties that use a variety of amplifier installations to boost and distribute the DTT signal, including mast head, booster and set-back amplifiers.

This report builds on the earlier analysis undertaken by Ofcom of the potential for interference into different types of amplifier used in communal and domestic installations [2]. Conducted measurements were undertaken to establish the performance of a cross-section of TV distribution amplifiers when subjected to base station emissions, for different wanted DTT signal levels and frequency offsets. The measurements were then repeated to determine the degree of interference mitigation that might reasonably be expected through the use of in-line filters installed prior to the amplifier.

The results show that without any mitigation there is the potential for masthead and indoor amplifiers to degrade the C/I protection ratios of the two DTT receivers under test. The LTE base station causes interference via two main mechanisms:

- In-block LTE signals (LTE Block A) producing overload of the amplifier/TV under test;

- Out-of-block LTE signals (LTE emissions falling into adjacent DTT channels), causing interference directly into the receiver's wanted signal under test.

When the interference is caused by LTE base station in-block signals the main cause of picture failure is due to amplifier overload, which appears to occur when the peak interference level exceeds the amplifier's input 1 dB compression point. When this happens the amplifier is driven at least partly into saturation, resulting in non linearity of the signal and complete loss of DTT picture.

When the interference is caused by LTE base station out-of-block signals the main cause of picture failure is due to emissions falling within the wanted DTT channel and causing interference directly to the DTT receiver, rather than amplifier overload. In this case the best C/I performance that can be achieved with the DVB-T mode used in testing is determined by the Adjacent Channel Leakage Ratio (ACLR) of the LTE signal:

- For an adjacent TV channel leakage power of 0 dBm / 8 MHz relative to an in Block A 10 MHz LTE signal of 59 dBm a minimum (best) C/I protection ratio of -43 dB can be achieved for channel 60;
- For an adjacent TV channel leakage Power of –10 dBm / 8 MHz relative to an in Block A 10 MHz LTE signal of 59 dBm a minimum (best) C/I protection ration of -53 dB can be achieved for channels 59 and below.

When filters are introduced to mitigate the adjacent channel base station interference the C/I protection ratios are improved for both receivers:

- The insertion of the professional filter prior to the masthead amplifiers restored the C/I performance of both DTT receivers to -43 dB for channel 60 and -53 dB for channels 59 and below;
- The insertion of the domestic filter prior to the indoor amplifiers restored the C/I performance of Rx1 to -43 dB for channel 60 and -53 dB for channels 59 and below, in all but a few cases;
- The domestic filter improved the C/I performance with Rx2 by around 11 to 14 dB. Previous measurements have shown that Rx2 is more prone to LTE interference than Rx1, requiring higher C/I protection ratios. In this case the filter did not provide the same improvement as for Rx1.

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Abbreviations List

ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CCDF	Complimentary Cumulative Distribution Function
C/I	Carrier-to-Interference
DSO	Digital Switchover
DTT	Digital Terrestrial Television
DUT	Device Under Test
DVB-T	Digital Video Broadcast - Terrestrial
EIRP	Effective Isotropically Radiated Power
FEC	Forward Error Correction
iDTV	Integrated Digital Television
LTE	Long Term Evolution
MATV	Master Antenna Television
NF	No Failure
RBW	Resolution Bandwidth
TOI	Third Order Intercept

1. Introduction

In June 2011 Ofcom published a consultation on coexistence of new services in the 800 MHz band with Digital Terrestrial Television. Alongside this consultation Ofcom published the results of a practical field trial undertaken in the Tamworth area to quantify the impact of interference from high-power LTE base stations to television services using channels just below 790 MHz [3].

During the field trial the project team were approached by members of the public reporting interference to domestic TV reception. Subsequent investigation at a communal dwelling indicated that the interference appeared to be due to overload in the distribution amplifiers of the Master Antenna TV (MATV) system, and this was confirmed by the successful addition of mitigation filtering. Other reported problems, relating to individual domestic installations, also appeared to be due to overload effects in masthead or distribution amplifiers. These amplifiers are typically used either to improve the reception of DTT services in areas of poor coverage, or to boost and distribute signals to several receivers in a home.

In response to these concerns Ofcom commissioned ERA Technology to undertake laboratory measurements of amplifier overload performance for a range of devices typically found in communal and domestic installations. The amplifiers were chosen from a representative list identified in a report from ManderCom [4]; three commercially available masthead amplifiers were selected and three indoor amplifiers.

The previous Ofcom Technical Report in June 2011 [2] identified two categories of amplifier installations in its analysis. These were "communal aerial systems" (CAS), and "domestic installations with amplifiers" (DIA). The results of this study will be incorporated into further analysis work in those areas.

The masthead amplifiers would normally be professionally installed as roof climbing would be involved, and gains should be preset accordingly in advance. The assumption for these tests is that the professional installation would have correctly adjusted gains and the output signals to the TV would be separately regulated as well.

The indoor units could be installed by the general public and would be sitting in a domestically accessible area. The assumption for these tests is that these units would be run at maximum gain unless they had to be backed off due to overload picture failure.

The amplifiers were connected to two different types of integrated digital television (iDTV) receiver, representing equipment with good and typical performance identified from previous testing undertaken by ERA [5]. The actual units identified in this report as Rx1 and Rx2 were identified as Rx1 and Rx4 respectively in the earlier work.

The amplifiers were subjected to interference signals obtained by recording the emissions from 800 MHz base station equipment developed by a leading LTE equipment vendor. The base station was configured for both idle and fully loaded traffic conditions.

The measurements were repeated to ascertain the degree of interference mitigation that might reasonably be expected from in-line filters installed prior to the amplifier under test.

The results are presented as Carrier-to-Interference (C/I) protection ratios calculated at the point where interference results in visible degradation to viewed picture quality (the appearance of macroblock artefacts) on the receiver. C/I performance is a measure of amplifier overload, defining the permitted level of interference for a given wanted signal level and frequency offset; the higher the C/I value the more sensitive the amplifier is to overload effects, potentially resulting in a loss in reception of digital services.

2. Test Set-Up

2.1 Amplifiers under Test

Some initial amplifier testing was undertaken during the earlier field trial work and the results are detailed in the Ofcom Technical Report published in June 2011 [2]. The items under test in this report are additional different models to extend the information available.

The amplifiers under test were selected from a list of commercially available devices presented in a report on "masthead and indoor amplifiers for TV signal reception and distribution" prepared for Ofcom by ManderCom [4]. The main characteristics are summarised in Table 1.

Table 1: Summary of Amplifier Characteristics

Identifier	Type	Frequency Range (MHz)	Gain (dB)	Inputs	Outputs
Amplifier 1	Masthead	470 - 862	25	1	1
Amplifier 2	Masthead	470 - 862	3 - 12	1	1
Amplifier 3	Masthead	470 - 862	25 - 34	1	1
Amplifier 4	Indoor	470 - 862	16	1	4
Amplifier 5	Indoor	FM, VHF, UHF	10 - 20	1	4
Amplifier 6	Indoor	47 - 862	10 - 20	1	1

The amplifiers were initially characterised in terms of:

- Gain flatness: The variation in amplifier gain across the operating frequency band of interest;
- Input 1 dB compression point: An amplifier maintains a constant gain for low-level input signals. However, at higher input signals the amplifier will go progressively into saturation and the gain will decrease. The 1 dB compression point (P1dB) is the point at which the input signal level causes the gain to drop by 1 dB from its small signal value;
- Third order intercept point (TOI): The TOI point is another measure of the amplifier's linearity. For every 1 dB increase in input signal level, the third order products will increase by 3 dB. Note that TOI is an extrapolated result of intermodulation distortion products at the amplifier output and is not directly measurable.

The results are included in Appendix A and summarised in the tables below.

Table 2: Amplifier Performance for Masthead Amplifiers

	Amplifier 1	Amplifier 2		Amplifier 3	
		Low Gain	High Gain	Low Gain	High Gain
Gain at 796 MHz dB	24.4	-1.6	11.2	25.3	34.3
Input P1 dBm	-19	0	0	-14.5	-21.5
TOI dBm	17	9.5	26	19	20

Table 3: Amplifier Performance for Indoor Amplifiers

	Amplifier 4	Amplifier 5		Amplifier 6	
		Low Gain	High Gain	Low Gain	High Gain
Gain at 796 MHz dB	18.5	5.3	16.7	11.9	20.0
Input P1 dBm	-2.5	-2.2	-13.5	1	-7
TOI dBm	26.5	15.5	14.5	22.5	22.5

In areas which are served by high levels of DTT signal it is expected that professional installers will, where possible, set the gain of the amplifier to optimise signal performance. This means the amplifier is set to a point at which the gain is set to as high a level as possible whilst protecting the output of the amplifier from excessive signal powers. This would be coupled with subsequent post amplifier signal splitting and levelling to result in a uniform working signal level of typically -50 dBm at the TV receiver input.

To represent this practice in the measurements a back off equation for the amplifier gain representative of what may be used by an installer in a real life situation was employed; this equation is as follows:

Back-off = Amplifier Rating – De-rating Value – Power Variation (post switchover)

Where:

De-rating value is given by:

10log (n-1) (where n is the number of DTT multiplexes)

Power variation is given by:

Post digital switchover 7 dB below original analogue vision carrier

2.2 DTT Receivers

DTT receiver performance when subjected to 800 MHz LTE base station interference was evaluated in a previous study from ERA Technology published in July 2011 [5]. From this study two iDTV receivers were selected, considered to represent good and typically performing models currently available in the UK market.

Receiver 1 in this report is also receiver 1 in the July 2011 report, and receiver 2 in this report was receiver 4 in the earlier work.

Both receivers used in the study were initially characterised with, and without, a domestic filter in order to provide a benchmark for the amplifier results. Their performance is included in Appendix B.

2.3 Mitigation Filters

To investigate the possible mitigation against the effects of amplifier overload Ofcom commissioned some prototype filters; two of which were subjected to detailed testing and are shown in the figures below. These are referred to in this report as a "professional" filter, for use with masthead amplifiers, and a "domestic" filter for use with indoor amplifiers. The expectation is that the "professional" filter would be used in MATV and similar installations, and the "domestic" filter more universally wherever required, but most frequently in an indoor environment with installation by the general public. In both cases these units are in prototype housings and not in a production engineered final product format.

The rejection of each filter for Block A (791 – 801 MHz) is shown in Figure 3.

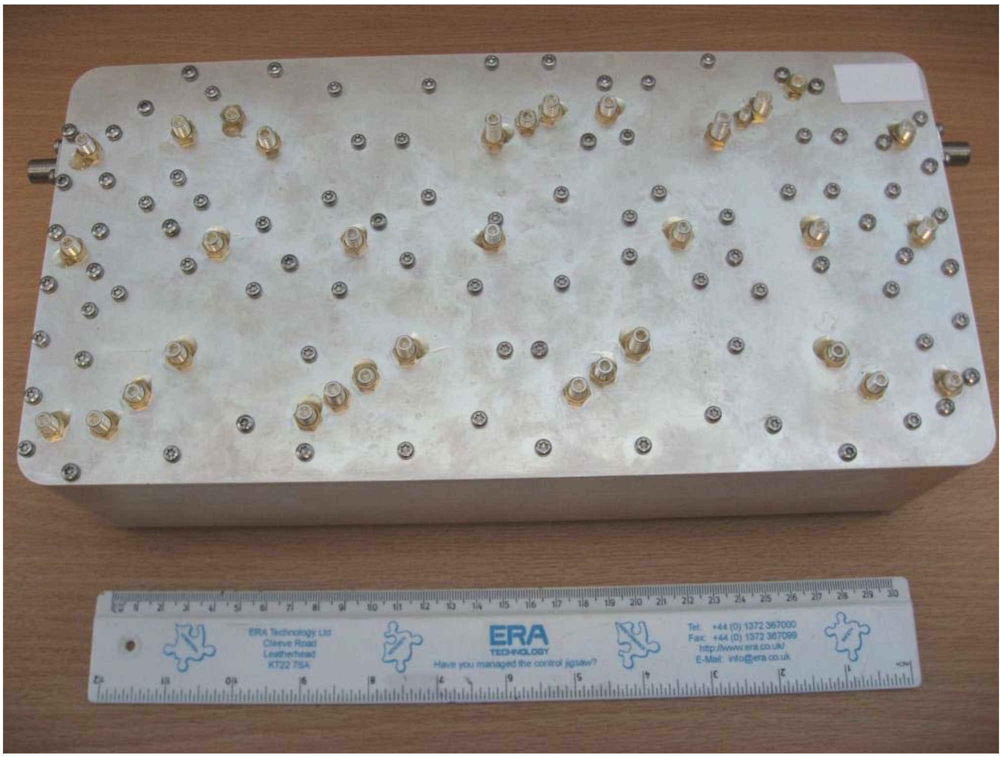

Figure 1: Prototype professional filter for use with masthead amplifiers

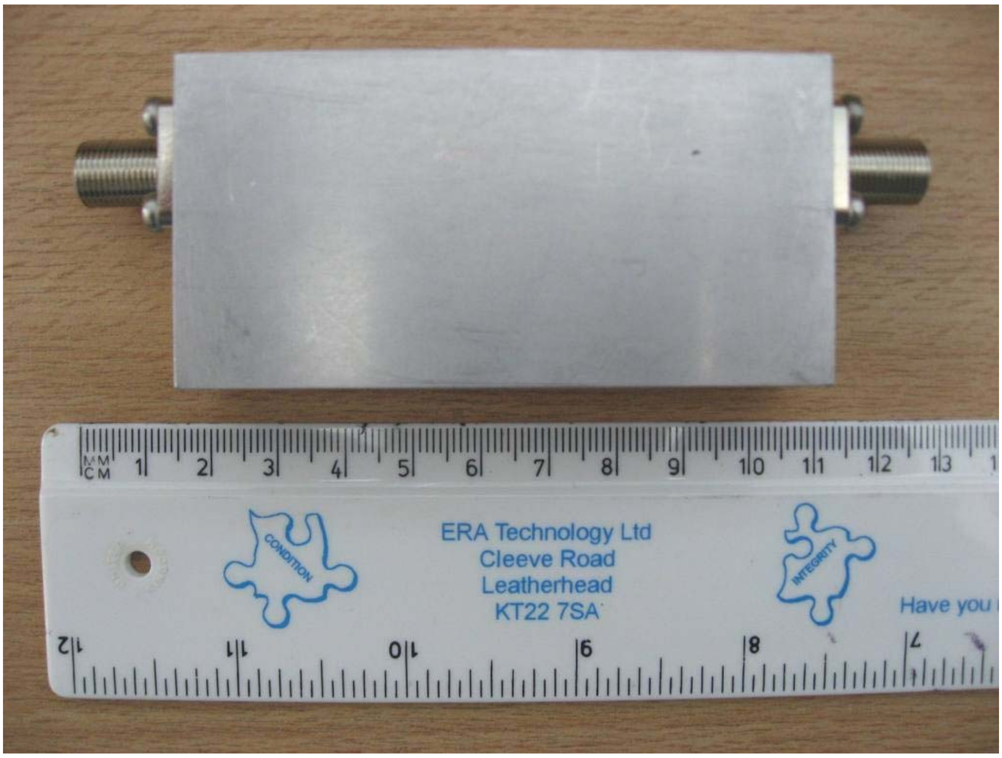

Figure 2: Prototype domestic filter for use with indoor amplifiers

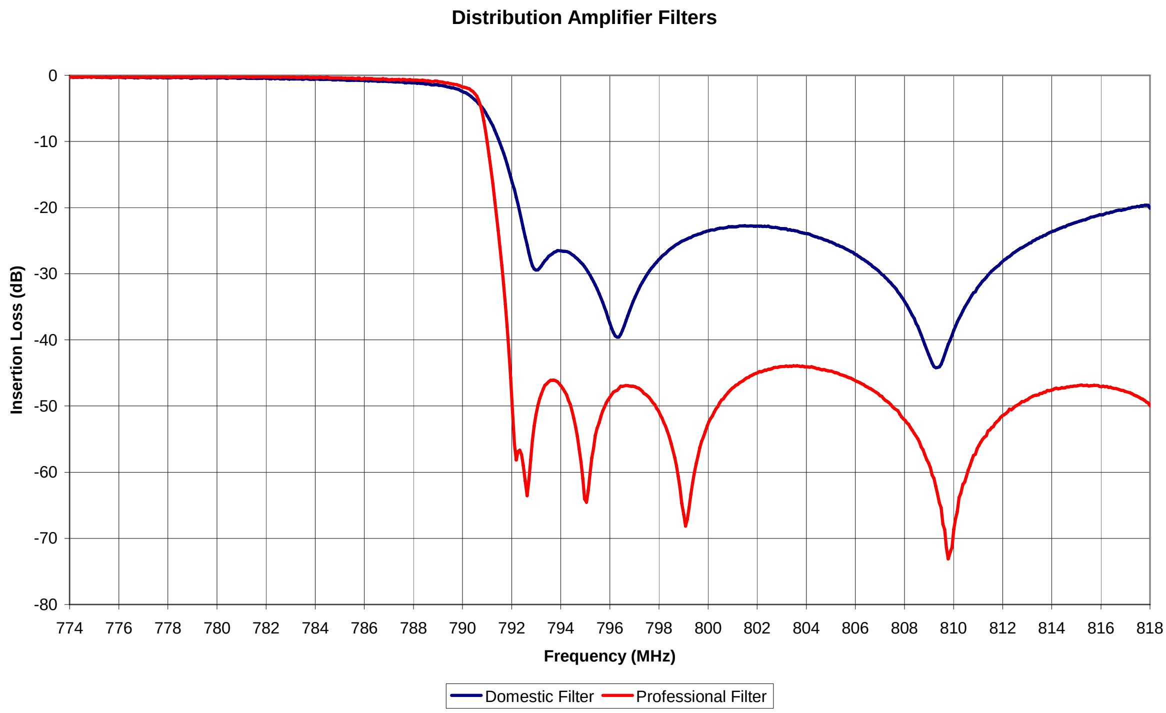

Figure 3: Filter rejection in Block A (791 – 801 MHz)

The difference between the domestic and professional filter performance can be measured in several critical areas, these are:

- Insertion loss across DTT channels;
- Sharpness of corner;
- Rate of roll off;
- Rejection across LTE channels.

Insertion loss and rejection are summarised in the table below:

Table 4: Filter insertion loss

Insertion Loss (dB) at:	Professional Filter	Indoor Filter
786 MHz	0.5	0.8
790 MHz	1.8	2.6
791 MHz	8.4	5.6
> 792 MHz	50.6	16.3

As can be seen from Figure 3, the main difference between the two filters is the sharpness of the corner at 790 MHz, rate of roll off across the 1 MHz guard band (790 – 791 MHz) and the depth of rejection across LTE Block A (791 – 801 MHz).

The major operational difference between the two filter types will be shown by any energy in the LTE signal in the 1 MHz guard band together with any internal LTE signal frequency occupancy control within the first 1 MHz of the 791 – 801 MHz Block A allocation.

2.4 Wanted Signal

The wanted DTT test signal was produced by a Rohde & Schwarz signal generator configured for DVB-T transmissions based on ETSI standards EN 300 744 [6]. The key parameters are summarised in Table 5.

Table 5: DVB-T system parameters

Parameter	DVB-T1
Multiple access	COFDM
Modulation	64-QAM
Forward error correction	2/3
FFT points	8 k
Guard Interval (μs)	7 ($^1/_{32}$)
Data rate (Mbit/s)	24.1
Channel bandwidth	8 MHz

All measurements were based on the non-critical DVB-T mask described in ETSI EN 302 296 [7] as shown in Table 6. The resulting spectral emissions of the wanted signal are compared with the ETSI non-critical mask in Figure 4 below, measured in a 5 kHz resolution bandwidth (RBW).

Table 6: 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

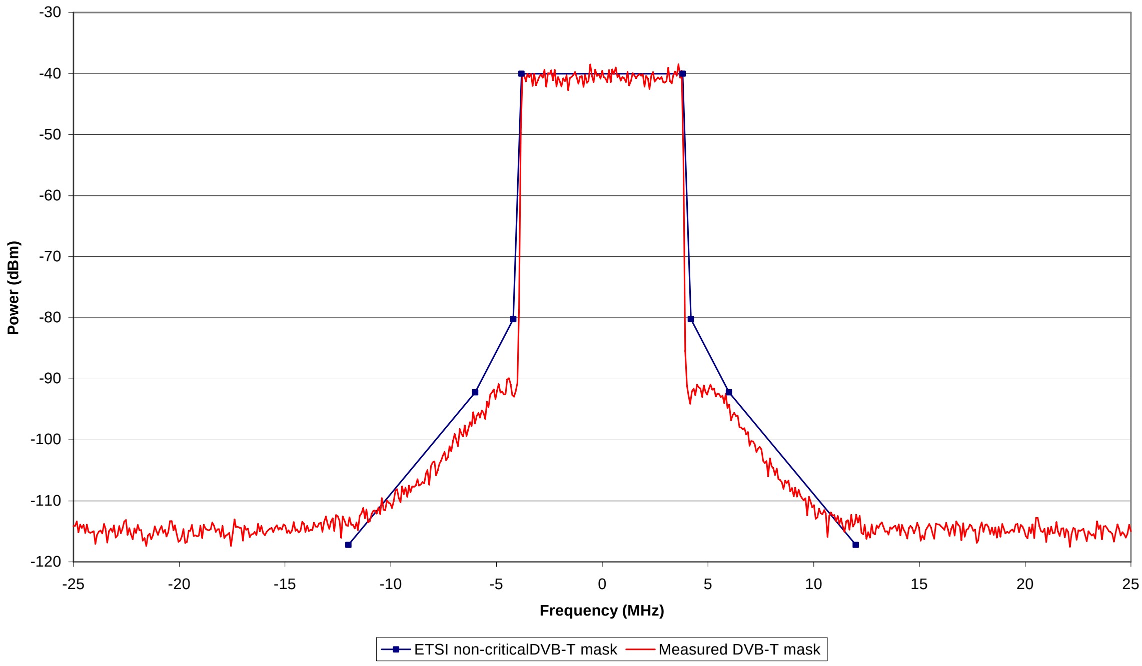

Figure 4: DVB-T wanted non-critical transmitter mask

2.5 Interfering Signal

The base station signals used in the testing were recorded directly from an equipment vendor's 800 MHz test network; the base station was configured for both maximum traffic loading (i.e. 100% loading) and idle conditions (i.e. no traffic only control telemetry on the base station, giving rise to time-discontinuous or "bursty" emissions). In each case the resource block allocation and sub-frame usage were adjusted automatically by the vendor's base station scheduler. The base station was configured for QPSK modulation and 10 MHz channel bandwidth as described in Appendix A of ETSI TS 136 104 (3GPP TS 36.104) [9].

Table 7: LTE base station signal parameters

Parameter	Value
Multiple access method	OFDMA
Duplex	FDD
Channel bandwidth	10 MHz
Allocated resource blocks	Allocated dynamically depending on traffic
Channel modulation	QPSK
Sub-frame length	1 ms
Number of OFDM sub-carriers	12 (per resource block)
Sub-carrier bandwidth	15 kHz
Code rate	1/3

Measurements were undertaken with the base station frequency centred on 796 MHz, occupying the frequency range 791 – 801 MHz (Block A) for a 10 MHz bandwidth signal.

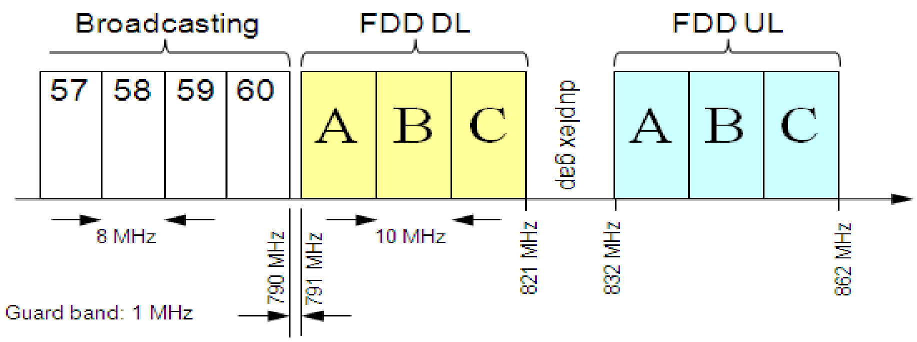

Figure 5: LTE and DTT Frequency Allocations

The recorded base station signals were replayed through a signal generator and the out-of-block emissions were adjusted to comply with the minimum requirements for Case A operation specified in ECC Dec 2010/267/EU [8].

Table 8: Base station out-of-block EIRP limits

Case	Frequency range	Condition on base station in-block EIRP, P dBm/10 MHz	Maximum mean out-of-block EIRP	Measurement bandwidth
A	470 – 790 MHz	P ≥ 59	0 dBm	8 MHz
		36 ≤ P < 59	(P-59) dBm	8 MHz
		P < 36	-23 dBm	8 MHz

Out-of-block power refers to the power radiated by a transmitter outside its channel bandwidth. The signals have been adjusted to the worst-case, assuming that base station emissions just meet the maximum mean out-of-block EIRP requirement over DTT channel 60, given in Table 8.

For DTT channels 59 and below, the maximum mean out-of-block EIRP was set to (P-69) dBm, i.e. a further reduction of 10 dB on the channel 60 emissions. The out-of-block EIRP was generated using an AWGN noise source from a signal generator and combined with the LTE in-block signal. The test setup is shown in Figure 6 and the resulting spectral emissions are shown in Figure 7 and Figure 8.

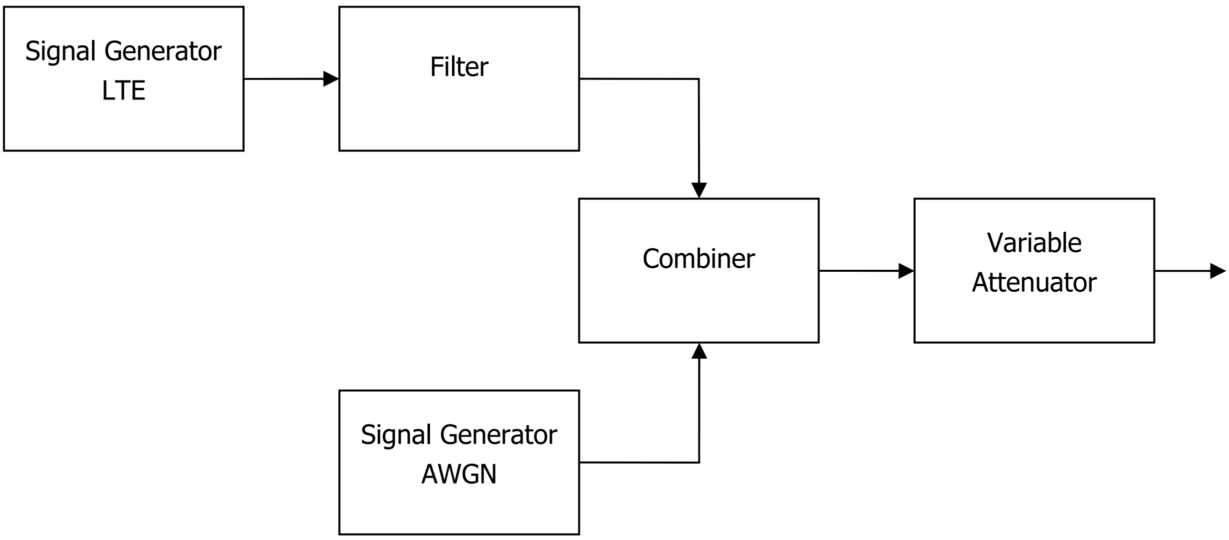

Figure 6: Generation of LTE base station interferer

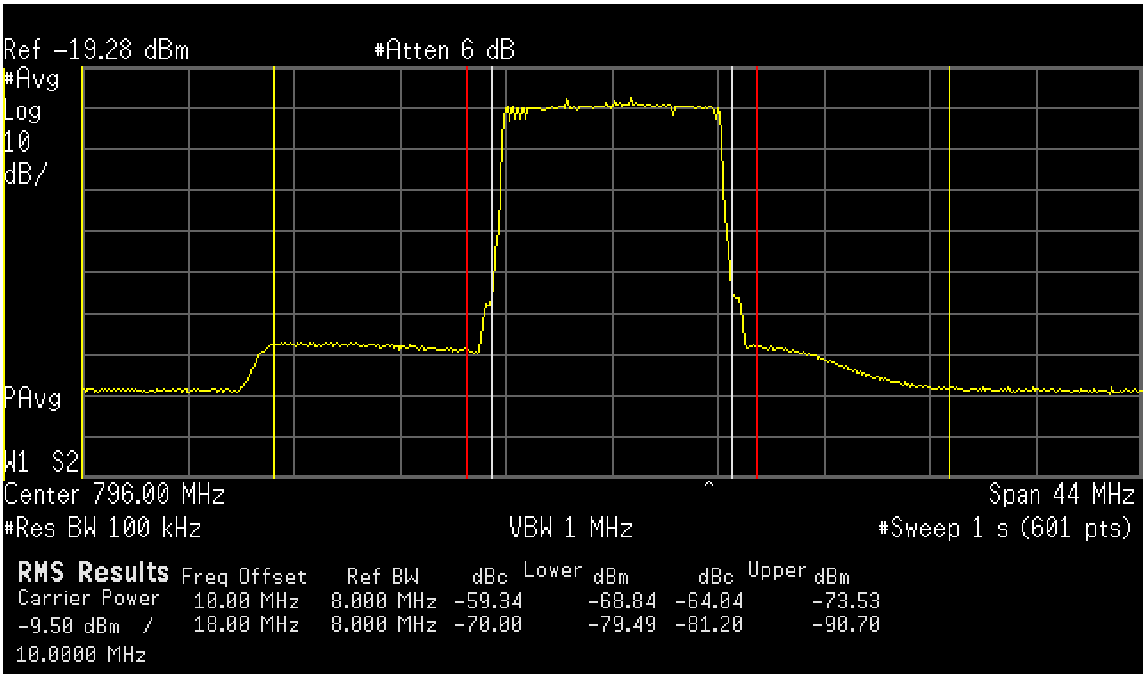

Figure 7: LTE base station emission under fully loaded traffic conditions

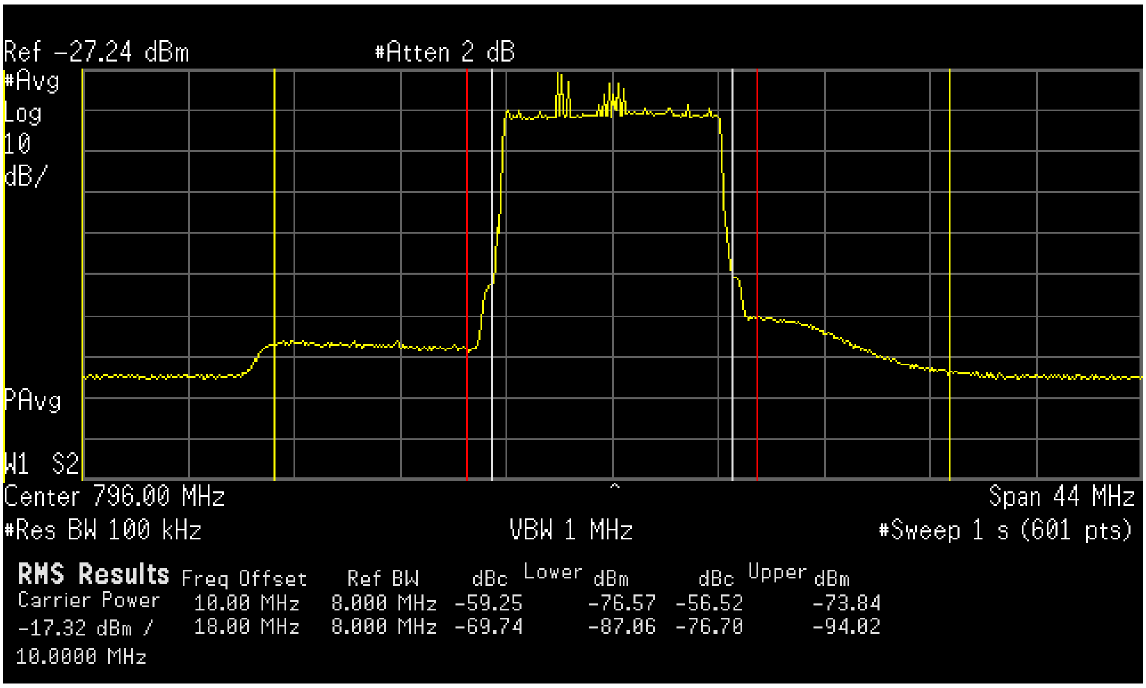

Figure 8: LTE base station emission under idle traffic conditions

It can be seen from the figures above that the out-of-block power in DTT channel 60, measured in an 8 MHz bandwidth, is -59 dBc (equivalent to 0 dBm assuming an in-block EIRP = 59 dBm).

The relative emissions for fully loaded and idle traffic conditions are compared in the figure below. It can be seen that the average power of the base station under idle conditions is lower than when the base station is fully loaded with traffic (by around 8.3 dB). Although the average power of the base station signal reduces with traffic, the peak power remains the same as for the fully loaded signal.

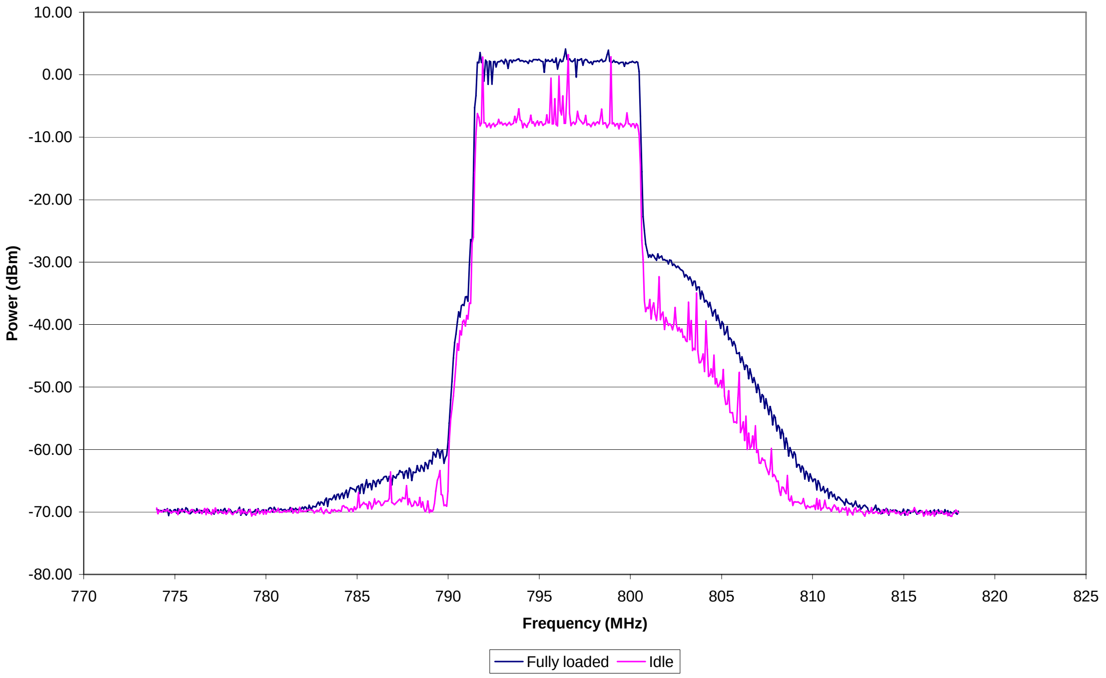

Figure 9: Comparison of fully loaded and idle base station emissions

Complimentary Cumulative Distribution Function (CCDF) curves, showing the peak-to-average power relationship for both idle and fully loaded traffic conditions are included in Appendix D.

2.6 Failure Criterion

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 (Viterbi). At the receiver end, 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 such digital systems usually results in an abrupt "cliff-edge" effect in the presence of interference when compared to analogue systems. The Digital TV Group[1] publishes the D-Book, which includes degradation criteria to be used when assessing interference to digital systems. The different DVB-T receiver degradation criteria taken from the D-Book are compared in Table 9 below.

Table 9: 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 x 10^{-4} after Viterbi decoding, corresponds to the Quasi Error Free criterion in the DVB-T standard, which states "less than one uncorrelated error event per hour".

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

However, as noted in the D-Book, there is often no direct way of identifying BER or transport stream errors for commercial receivers. In this case Picture Failure is the only means of assessing the interference effects.

The PF point was identified by visual observation as shown in Figure 10 below, which shows the onset of Un-Correctable Errors 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 Picture Failure point.

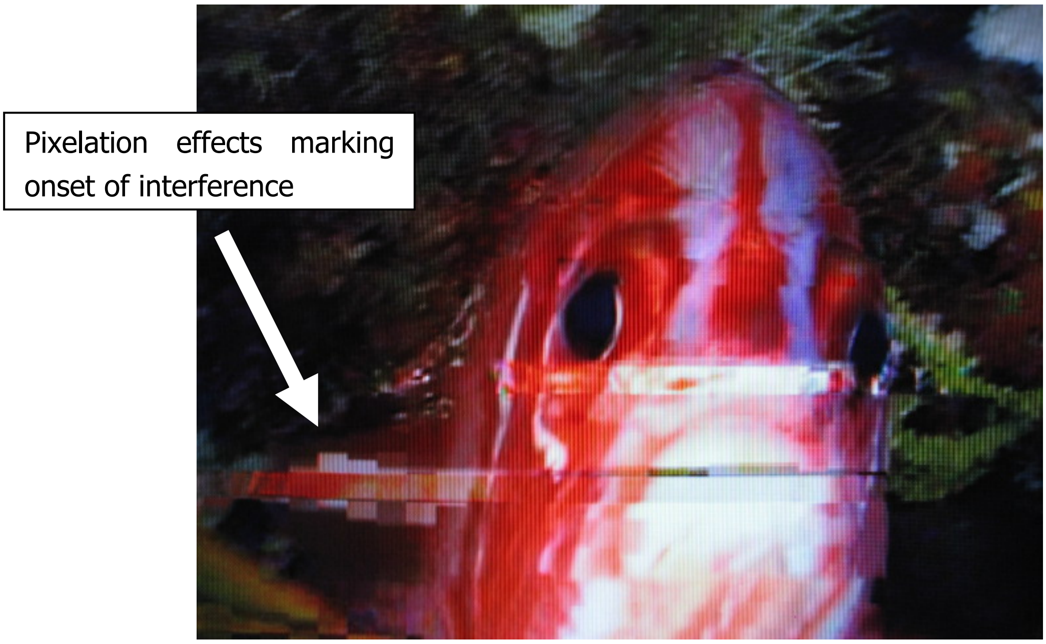

Figure 10: Received picture showing onset of interference

3. Results

In the following section results are presented as the Carrier-to-Interference protection ratio at the onset of interference, both with and without the in-line mitigation filters. Results were obtained for the following test scenarios:

Table 10: Summary of test scenarios

Factor	No.	Variability
DTT Receivers	2	Good and Typical Receiver Performance
Amplifiers	6	Masthead and Indoor Amplifiers
Amplifier Gain Settings	2	Maximum and back-off (according to back off equation)
Interfering Signals	2	Fully Loaded LTE (max EIRP = +2.5 dBm / 10 MHz), Idle LTE (max EIRP = -5.5 dBm / 10 MHz) in Block A
Wanted Signal Level	6	-70, -60, -50, -40, -30, -20 dBm into DUT
Channel Offsets	6	Co-channel, and Channels 60, 59, 58, 57, 51

Results for the first, second and third adjacent channels (Ch 60, 59, 58) are summarised in the following sections and C/I protection ratio curves for other frequency offsets are included in Appendix C.

Cases where the interfering signal power was not sufficient to create a picture failure are marked as NF (No Failure) in the tables. The maximum power available for the interfering signal was:

- Fully Loaded LTE max EIRP = +2.5 dBm / 10 MHz
- Idle LTE max EIRP = -5.5 dBm / 10 MHz

In the case of amplifier 1 operating under maximum DTT signal (C = -20 dBm) the level of C was sufficient to drive the amplifier into saturation and cause failure before any interference was applied. These cases have been marked with a dash in the tables.

The results for receiver 1 are summarised in Table 11 to Table 16 and results for receiver 2 are summarised in Table 17 to Table 22.

3.1 Summary of Results for Receiver 1

Table 11: Summary of results for Receiver 1 with masthead amplifiers (Ch 60)

	DTT Level (dBm)	Rx1 C/I (dB)	Amplifier 1 (dB)			Amplifier 2 (dB)			Amplifier 3 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-43.0	-31.2	-38.8	-42.2	-27.3	-42.8	-42.6	-33.9	-36.1	-42.1
	-60	-43.4	-28.8	-31.2	-42.7	-18.3	-41.7	-42.8	-32.0	-28.0	-42.5
	-50	-42.3	-26.9	-23.1	-41.6	-10.9	-39.1	-42.6	-29.6	-20.4	-42.6
	-40	-38.1	-25.0	-15.1	NF	-7.4	-32.5	NF	-18.9	-21.1	NF
	-30	-29.5	-24.0	-6.1	NF	-5.8	-24.3	NF	-15.7	-14.3	NF
	-20	NF	-	-	-	-2.8	-17.2	NF	-14.7	-5.3	NF
LTE Idle	-70	-40.3	-36.7	-33.4	-42.9	-33.5	-36.5	-43.1	-40.1	-29.8	-43.2
	-60	-42.7	-35.5	-25.1	-43.1	-24.3	-35.7	-43.2	-39.3	-20.7	-43.7
	-50	-39.8	-33.9	-16.0	-42.6	-16.8	-33.2	-42.9	-35.3	-14.7	-42.8
	-40	-31.0	-30.8	-9.3	NF	-14.3	-25.7	NF	-25.8	-14.2	NF
	-30	-23.9	-30.3	0.3	NF	-11.7	-18.3	NF	-22.6	-7.4	NF
	-20	NF	-	-	-	-9.9	-10.1	NF	-21.8	1.9	NF

Table 12: Summary of results for Receiver 1 with indoor amplifiers (Ch 60)

	DTT Level (dBm)	Rx1 C/I (dB)	Amplifier 4 (dB)			Amplifier 5 (dB)			Amplifier 6 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-43.0	-28.4	-41.6	-42.2	-28.4	-41.6	-41.7	-28.1	-41.9	-42.2
	-60	-43.4	-18.2	-41.8	-42.2	-23.3	-36.8	-42.4	-21.0	-39.0	-42.9
	-50	-42.3	-14.3	-35.7	-41.8	-21.1	-28.9	-42.3	-16.9	-33.1	-42.0
	-40	-38.1	-11.0	-29.1	NF	-18.1	-21.9	-38.2	-13.9	-26.1	-42.3
	-30	-29.5	-8.9	-21.0	NF	-16.0	-14.0	NF	-12.1	-18.0	NF
	-20	NF	-7.0	-13.0	NF	-14.0	-6.0	NF	-10.6	-9.4	NF
LTE Idle	-70	-40.3	-29.3	-40.7	-43.1	-32.9	-37.1	-43.3	-32.1	-38.0	-42.9
	-60	-42.7	-22.0	-38.0	-43.3	-29.4	-30.6	-42.9	-27.0	-33.0	-43.0
	-50	-39.8	-20.6	-29.4	-43.0	-26.7	-23.3	-38.1	-23.9	-26.1	-42.0
	-40	-31.0	-17.7	-22.3	NF	-24.5	-15.5	-33.5	-21.0	-19.0	NF
	-30	-23.9	-15.9	-14.1	NF	-23.0	-7.1	NF	-18.0	-12.0	NF
	-20	NF	-13.0	-7.0	NF	-20.7	0.7	NF	-16.1	-3.9	NF

Table 13: Summary of results for Receiver 1 with masthead amplifiers (Ch 59)

	DTT Level (dBm)	Rx1 C/I (dB)	Amplifier 1 (dB)			Amplifier 2 (dB)			Amplifier 3 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-50.8	-27.2	-42.9	-53.0	-19.1	-50.9	-52.5	-28.6	-41.4	-52.9
	-60	-50.5	-25.3	-34.7	-52.7	-11.4	-48.6	-52.6	-26.7	-33.3	-52.9
	-50	-49.1	-23.9	-26.1	NF	-6.1	-43.9	NF	-24.7	-25.3	NF
	-40	NF	-24.0	-16.1	NF	-2.6	-37.5	NF	-16.3	-23.9	NF
	-30	NF	-23.9	-6.1	NF	0.1	-30.1	NF	-14.6	-15.4	NF
	-20	NF	-	-	-	1.1	-21.1	NF	-12.7	-7.3	Nf
LTE Idle	-70	-45.8	-32.9	-37.1	-52.9	-25.3	-44.6	-53.4	-34.4	-35.6	-53.6
	-60	-42.8	-31.6	-28.9	-52.7	-17.6	-42.4	-52.8	-32.6	-27.4	-52.6
	-50	NF	-29.9	-20.1	NF	-12.2	-37.8	NF	-30.6	-19.4	NF
	-40	NF	-29.8	-10.2	NF	-9.7	-30.3	NF	-22.9	-17.1	NF
	-30	NF	-30.1	0.1	NF	-7.6	-22.4	NF	-20.2	-9.8	NF
	-20	NF	-	-	-	-7.9	-12.1	NF	-19.7	-0.3	NF

Table 14: Summary of results for Receiver 1 with indoor amplifiers (Ch 59)

	DTT Level (dBm)	Rx1 C/I (dB)	Amplifier 4 (dB)			Amplifier 5 (dB)			Amplifier 6 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-50.8	-20.7	-49.3	-52.2	-20.9	-49.1	-52.4	-22.7	-47.2	-52.9
	-60	-50.5	-11.4	-48.6	-52.9	-17.2	-42.8	-52.5	-13.9	-46.2	-52.6
	-50	-49.1	-9.4	-40.6	NF	-15.3	-34.6	-50.1	-10.9	-39.1	-51.2
	-40	NF	-7.0	-33.0	NF	-14.2	-25.8	NF	-9.9	-30.1	NF
	-30	NF	-5.9	-24.0	NF	-14.0	-16.0	NF	-9.3	-20.7	NF
	-20	NF	-5.3	-14.7	NF	-13.0	-7.0	NF	-8.6	-11.5	NF
LTE Idle	-70	-45.8	-26.5	-43.6	-53.2	-27.0	-43.0	-52.7	-28.9	-41.0	-52.5
	-60	-42.8	-16.7	-43.3	-52.5	-23.6	-36.4	-52.9	-22.8	-37.2	-52.7
	-50	NF	-15.2	-34.8	NF	-21.3	-28.6	NF	-16.9	-33.2	NF
	-40	NF	-12.9	-27.1	NF	-20.2	-19.8	NF	-16.0	-24.0	NF
	-30	NF	-11.6	-18.4	NF	-20.9	-9.1	NF	-15.0	-15.0	NF
	-20	NF	-12.8	-7.2	NF	-21.0	1.0	NF	-15.6	-4.4	NF

Table 15: Summary of results for Receiver 1 with masthead amplifiers (Ch 58)

	DTT Level (dBm)	Rx1 C/I (dB)	Amplifier 1 (dB)			Amplifier 2 (dB)			Amplifier 3 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-50.6	-24.2	-45.8	-51.9	-19.2	-50.8	-52.2	-25.8	-44.2	-52.7
	-60	-51.6	-23.4	-36.6	-52.6	-9.4	-50.6	-52.7	-24.6	-35.3	-52.8
	-50	-51.0	-22.9	-27.1	NF	-3.3	-46.6	NF	-23.7	-26.3	NF
	-40	NF	-22.9	-17.2	NF	-0.8	-39.2	NF	-14.0	-26.0	NF
	-30	NF	-23.9	-6.1	NF	1.1	-31.1	NF	-11.7	-18.4	NF
	-20	NF	-	-	-	2.0	-22.0	NF	-10.7	-9.3	NF
LTE Idle	-70	-46.7	-31.0	-39.1	-52.8	-24.8	-45.1	-53.3	-32.8	-37.2	-52.9
	-60	-48.9	-29.9	-30.7	-52.7	-14.3	-45.7	-52.7	-31.4	-28.6	-52.9
	-50	NF	-29.0	-20.9	NF	-10.3	-39.7	NF	-29.7	-20.3	NF
	-40	NF	-28.9	-11.1	NF	-8.8	-31.1	NF	-21.0	-19.0	NF
	-30	NF	-29.9	-0.1	NF	-7.7	-22.3	NF	-19.8	-10.3	NF
	-20	NF	-	-	-	-7.9	-12.1	NF	-19.7	-0.3	NF

Table 16: Summary of results for Receiver 1 with indoor amplifiers (Ch 58)

	DTT Level (dBm)	Rx1 C/I (dB)	Amplifier 4 (dB)			Amplifier 5 (dB)			Amplifier 6 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-50.6	-19.7	-50.3	-52.8	-19.0	-51.0	-52.4	-20.7	-49.3	-52.0
	-60	-51.6	-9.4	-50.6	-52.9	-15.26	-44.7	-52.4	-11.8	-48.2	-51.8
	-50	-51.0	-7.5	-42.5	NF	-13.2	-36.8	-50.1	-9.9	-40.1	-51.1
	-40	NF	-6.0	-33.9	NF	-12.2	-27.8	NF	-8.9	-31.1	NF
	-30	NF	-4.9	-25.1	NF	-13.0	-17.0	NF	-9.4	-20.6	NF
	-20	NF	-5.1	-14.8	NF	-12.0	-8.0	NF	-8.6	-11.4	NF
LTE Idle	-70	-46.7	-22.6	-47.4	-53.2	-24.4	-45.7	-52.6	-25.5	-44.5	-53.1
	-60	-48.9	-15.8	-44.7	-53.2	-21.3	-38.7	-53.1	-18.1	-41.9	-52.6
	-50	NF	-13.4	-36.6	NF	-20.5	-29.9	NF	-15.6	-34.4	NF
	-40	NF	-12.1	-27.9	NF	-20.3	-19.7	NF	-15.9	-24.1	NF
	-30	NF	-11.7	-18.4	NF	-20.0	-10.0	NF	-15.1	-14.9	NF
	-20	NF	-11.2	-8.7	NF	-19.9	-0.1	NF	-15.5	-4.6	NF

3.2 Summary of Results for Receiver 2

Table 17: Summary of results for Receiver 2 with masthead amplifiers (Ch 60)

	DTT Level (dBm)	Rx2 C/I (dB)	Amplifier 1 (dB)			Amplifier 2 (dB)			Amplifier 3 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-41.1	-35.1	-34.8	-42.2	-30.9	-39.1	-42.7	-36.2	-33.8	-42
	-60	-39.8	-28.1	-31.9	-42.7	-25.4	-34.6	-42.8	-33.3	-26.7	-42.6
	-50	-34.5	-26.2	-23.3	-41.7	-13.8	-36.2	-42.6	-29.7	-20.3	-42.8
	-40	-29.3	-24.0	-15.9	NF	-9.4	-30.6	NF	-19.9	-20.1	NF
	-30	-22.9	-23.2	-6.8	NF	-5.7	-24.3	NF	-15.7	-14.3	NF
	-20	-15.5	-	-	-	-2.8	-17.2	NF	-14.8	-5.2	NF
LTE Idle	-70	-31.0	-42.5	-27.5	-40.9	-39.8	-30.2	-42.8	-43.3	-26.7	-40.3
	-60	-31.4	-34.3	-25.7	-42.2	-32.3	-27.7	-42.8	-39.9	-20.1	-39.7
	-50	-27.4	-33.7	-16.3	-41.4	-20.6	-29.5	-40.5	-36.6	-13.4	-39.0
	-40	-22.7	-30.4	-9.6	NF	-16.5	-23.5	NF	-26.6	-13.4	NF
	-30	-14.7	-29.6	-0.5	NF	-12.5	17.4	NF	-22.4	-7.6	NF
	-20	-8.8	-	-	-	-9.9	10.1	NF	-21.6	1.6	NF

Table 18: Summary of results for Receiver 2 with indoor amplifiers (Ch 60)

	DTT Level (dBm)	Rx2 C/I (dB)	Amplifier 4 (dB)			Amplifier 5 (dB)			Amplifier 6 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-41.1	-34.6	-35.4	-42.2	-33.5	-36.5	-41.6	-35.2	-34.8	-42.2
	-60	-39.8	-24.4	-35.7	-42.2	-26.3	-33.7	-42.4	-27.0	-33.0	-42.8
	-50	-34.5	-16.3	-33.7	-41.8	-21.2	-28.8	-41.4	-17.8	-32.2	-42.1
	-40	-29.3	-11.9	-28.1	NF	-18.1	-21.9	-38.2	-14.9	-25.1	-39.9
	-30	-22.9	-8.9	-21.1	NF	-16.0	-14.0	NF	-12.0	-18.0	NF
	-20	-15.5	-7.0	-13.0	NF	-14.0	-6.1	NF	-10.6	-9.4	NF
LTE Idle	-70	-31.0	-42.6	-27.4	-25.6	-40.2	-29.8	-29.2	-42.1	-27.9	-23.5
	-60	-31.4	-31.4	-28.5	-22.2	-32.8	-27.2	-24.5	-34.2	-25.8	-22.2
	-50	-27.4	-23.3	-26.7	-18.3	-27.8	-22.2	-24.0	-25.5	-24.5	-21.5
	-40	-22.7	-18.9	-21.1	-18.8	-25.5	-14.5	-24.9	-21.8	-18.2	-21.2
	-30	-14.7	-16.1	-13.8	-21.4	-23.1	-7.0	-21.8	-18.8	-11.2	-21.9
	-20	-8.8	-12.8	-7.2	NF	-20.7	0.7	NF	-16.5	-3.5	NF

Table 19: Summary of results for Receiver 2 with masthead amplifiers (Ch 59)

	DTT Level (dBm)	Rx2 C/I (dB)	Amplifier 1 (dB)			Amplifier 2 (dB)			Amplifier 3 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-48.9	-27.2	-42.9	-53.0	-21.2	-48.8	-52.5	-28.5	-41.5	-52.8
	-60	-48.8	-25.1	-34.9	-52.6	-17.4	-42.6	-52.7	-27.6	-32.3	-53.0
	-50	-44.4	-24.2	-25.8	NF	-6.1	-43.9	NF	-24.8	-25.2	NF
	-40	-36.3	-23.0	-17.0	NF	-3.5	-36.5	NF	-17.1	-22.9	NF
	-30	-27.9	-23.2	-6.8	NF	0.1	-30.1	NF	-14.7	-15.4	NF
	-20	-18.3	-	-	-	1.1	-21.1	NF	-12.7	-7.4	NF
LTE Idle	-70	-40.1	-34.4	-35.6	-51.8	-30.9	-39.0	-53.4	-36.7	-33.4	-51.4
	-60	-38.6	-31.7	-28.3	-52.6	-24.7	-35.3	-52.6	-33.6	-26.4	-52.0
	-50	-35.1	-29.7	-20.3	NF	-15.1	-34.9	NF	-31.5	-18.5	NF
	-40	-29.3	-30.3	-9.6	NF	-10.3	-29.7	NF	-23.0	-17.1	NF
	-30	-22.1	-29.4	-0.6	NF	-7.5	-22.4	NF	-20.5	-9.6	NF
	-20	-12.5	-	-	-	-7.7	-12.2	NF	-19.6	-0.4	NF

Table 20: Summary of results for Receiver 2 with indoor amplifiers (Ch 59)

	DTT Level (dBm)	Rx2 C/I (dB)	Amplifier 4 (dB)			Amplifier 5 (dB)			Amplifier 6 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-48.9	-25.7	-44.3	-52.2	-23.9	-46.1	-52.4	-25.8	-44.2	-52.9
	-60	-48.8	-13.4	-46.6	-53.0	-18.2	-41.8	-52.4	-17.8	-42.3	-52.7
	-50	-44.4	-9.4	-40.7	NF	-15.3	-34.6	-50.0	-10.9	-39.2	-51.2
	-40	-36.3	-6.7	-33.0	NF	-14.3	-25.7	NF	-9.9	-30.1	NF
	-30	-27.9	-5.8	-24.1	NF	-14.0	-16.0	NF	-9.3	-20.7	NF
	-20	-18.3	-5.1	-14.8	NF	-13.0	-7.1	NF	-8.6	-11.5	NF
LTE Idle	-70	-40.1	-36.5	-33.5	-39.2	-32.5	-37.5	-41.8	-35.7	-34.3	-36.5
	-60	-38.6	-25.6	-34.4	-35.8	-25.8	-34.2	-37.2	-25.2	-34.8	-36.0
	-50	-35.1	-17.3	-32.8	-38.9	-22.3	-27.6	-37.1	-18.8	-31.3	-34.6
	-40	-29.3	-14.2	-25.7	NF	-21.1	-18.9	NF	-16.7	-23.3	NF
	-30	-22.1	-11.8	-18.2	NF	-21.0	-8.9	NF	-16.5	-13.6	NF
	-20	-12.5	-11.9	-8.1	NF	-19.7	-0.3	NF	-15.5	-4.6	NF

Table 21: Summary of results for Receiver 2 with masthead amplifiers (Ch 58)

	DTT Level (dBm)	Rx2 C/I (dB)	Amplifier 1 (dB)			Amplifier 2 (dB)			Amplifier 3 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-49.6	-30.0	-40.0	-51.8	-28.2	-41.8	-52.1	-32.7	-37.3	-52.7
	-60	-42.8	-24.3	-35.8	-52.6	-20.3	-39.7	-52.8	-26.7	-33.3	-52.7
	-50	-38.5	-22.2	-27.9	NF	-10.3	-39.7	NF	-23.7	-26.3	NF
	-40	-38.0	-22.1	-17.9	NF	-1.7	-38.3	NF	-13.9	-26.1	NF
	-30	-29.7	-23.2	-6.8	NF	1.2	-31.2	NF	-11.7	-18.4	NF
	-20	-19.3	-	-	-	1.1	-21.2	NF	-10.7	-9.3	NF
LTE Idle	-70	-45.0	-36.8	-33.2	-53.1	-34.1	-35.8	-53.2	-39.6	-30.3	-52.9
	-60	-35.8	-29.6	-30.4	-52.5	-28.1	-31.9	-52.7	-32.7	-27.3	-52.9
	-50	-31.4	-28.8	-21.3	NF	-17.3	-32.6	NF	-29.6	-20.4	NF
	-40	-30.2	-28.6	-11.4	NF	-8.9	-31.1	NF	-20.9	-19.1	NF
	-30	-23.8	-29.5	-0.5	NF	-7.9	-22.1	NF	-19.6	-10.4	NF
	-20	-13.6	-	-	-	-7.7	-12.3	NF	-18.6	-1.4	NF

Table 22: Summary of results for Receiver 2 with indoor amplifiers (Ch 58)

	DTT Level (dBm)	Rx2 C/I (dB)	Amplifier 4 (dB)			Amplifier 5 (dB)			Amplifier 6 (dB)		
			Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I	Amp I	Amp C/I	Filter C/I
LTE 100%	-70	-49.6	-31.6	-38.4	-49.4	-30.0	-40.0	-51.4	-31.7	-38.3	-48.1
	-60	-42.8	-21.3	-38.7	-49.9	-20.2	-39.8	-51.4	-21.7	-38.3	-49.8
	-50	-38.5	-12.5	-37.5	-50.6	-15.3	-34.7	-49.2	-11.9	-38.1	-49.2
	-40	-38.0	-6.0	-34.0	NF	-13.2	-26.8	NF	-9.9	-30.1	NF
	-30	-29.7	-4.9	-25.0	NF	-12.9	-17.1	NF	-9.4	-20.6	NF
	-20	-19.3	-5.1	-14.9	NF	-11.9	-8.1	NF	-8.6	-11.4	NF
LTE Idle	-70	-45.0	-38.5	-31.5	-42.0	-38.7	-31.3	-47.6	-39.0	-31.0	-40.5
	-60	-35.8	-28.6	-31.4	-42.7	-26.7	-33.3	-47.1	-28.5	-31.5	-42.0
	-50	-31.4	-19.4	-30.6	NF	-21.6	-28.4	-45.0	-18.8	-31.2	-43.1
	-40	-30.2	-12.9	-27.1	NF	-19.9	-20.1	NF	-15.8	-24.1	NF
	-30	-23.8	-12.0	-18.0	NF	-19.9	-10.1	NF	-15.3	-14.7	NF
	-20	-13.6	-11.1	-8.8	NF	-19.8	-0.2	NF	-15.5	-4.5	NF

3.3 Analysis of Results

Interference mechanisms

ECC Dec 2010/267/EU defines limits for both in-block and out-of-block EIRP emissions (see Table 8, section 2.5). The emissions assumed in this study are shown graphically in Figure 11.

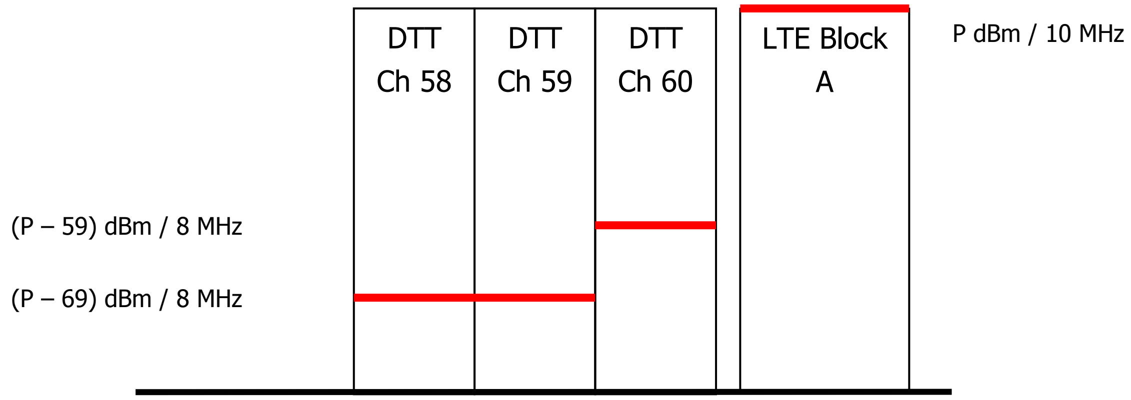

Figure 11: Graphical representation of LTE emissions

The level of out-of-block EIRP emissions are set at a constant value of either (P-59) dBm / 8 MHz for channel 60, or (P-69) dBm / 8 MHz for channels 59 and below.

Picture failure occurs via two main interference mechanisms:

- In-block LTE signals (LTE Block A) producing overload of the amplifier/TV pair under test;
- Out-of-block ACLR signals (LTE emissions falling directly into DTT channels), causing interference directly into the wanted signal of the receiver under test.

Overloading of the amplifier is a result of the main LTE in-block EIRP and the amplifier/TV pair's Adjacent Channel Selectivity (ACS). The amplifier could be subjected to possible high levels of LTE base station power. In certain conditions this can cause the amplifier to go into compression.

Out-of-block EIRP emissions effectively fall co-channel with DTT multiplexes resulting in a co-channel interference scenario. Assuming that the out-of-block EIRP is interfering directly with the DTT receiver, and not the amplifier, it follows from the results that the measured best C/I performance for the DVB-T mode used in the testing is:

- For P – 59 dBm / 8MHz a minimum (best) C/I protection ratio of -43 dB can be achieved for channel 60;
- For P – 69 dBm / 8MHz a minimum (best) C/I protection ratio of -53 dB can be achieved for channels 59 and below.

The filters used within this study are designed to reduce the in-block EIRP whilst presenting minimum insertion loss to the DTT multiplexes (and hence the out-of-block EIRP that falls within them). Therefore, assuming the amplifier is not in overload, the C/I protection ratio can only be improved by a Block A filter as far as the -43 / -53 dB condition discussed above.

Amplifier compression

In general, overloading of the amplifier is caused by the peak power level of the in-block EIRP (rather than average signal power in Block A). CCDF measurements show that the peak-to-average power levels of the LTE test signals are:

- +8.5 dB under fully loaded (100%) traffic conditions
- +16 dB under idle traffic conditions

The complete CCDF curves are presented in Appendix D.

Comparing the results from section 3 with the measured performance for 1 dB compression point (section 2.1) it can be seen that C/I performance starts to degrade when the interfering signal level forces the amplifier into an overload condition.

Table 23: In-block EIRP at picture failure point

Amplifier Under Test	Input P1dBm	In-block EIRP dBm at Picture Failure		Variance, Peak to Input P1dB
		100% Peak Level	Idle Peak Level	
Amp 1	-19	-16.5 to -14.5	-16 to -13	2.5 to 6
Amp 2	0	+5.5 to +9.5	+6 to +9	5.5 to 9
Amp 3	-21.5	-16.5 to -12.5	-17 to -13	4.5 to 9
Amp 4	-2.5	+1.5 to +3.5	+3 to +5	4 to 7.5
Amp 5	-13.5	-6.5 to -3.5	-5 to -3	7 to 10.5
Amp 6	-7	-1.5 to +1.5	0 to 1	5.5 to 8

Table 23 shows that picture failure occurs when the amplifier under test is subjected to an in-block EIRP at 2.5 to 7 dB above the measured 1 dB compression point.

There are a limited number of cases where the picture failure was a function of both the in-block and out-of-block EIRP levels. In these cases it appears that the in-block power required is lower but the C/I protection ratio is higher than expected. This is the switchover point at which the dominant interference mechanism changes.

In cases where the variable gain was reduced in line with the back-off equation, there was a 1 dB increase in peak interference level at the input to the amplifier (to cause picture failure) for each 1 dB decrease in gain.

Effect of mitigation filter

The professional filter improved the C/I protection ratio for both Rx1 and Rx2 back to the theoretical best values of -43 dB / -53 dB. This is the best possible C/I protection ratio achievable and in some instances is a better performance than the DTT receiver on its own.

The indoor filter improved the C/I protection ratios for Rx1 back to the theoretical best values of -43 dB / -53 dB in the majority of cases. In a limited number of cases the amplifier experienced overload conditions resulting in a slightly lower improvement in C/I. This only occurred during channel 60 measurements at higher wanted DTT signal levels for amplifier 5 and LTE operating in idle mode.

Previous measurements have shown that Rx2 is more prone to LTE interference than Rx1, requiring higher C/I protection ratios. In the case of Rx2, the filter did not provide the same improvement as for Rx1. However, the filter still improved the C/I protection ratio by 11 to 14 dB in the majority of cases.

4. Conclusions

This study presents the results of lab based interference measurements to determine the potential for interference into different types of amplifier used in communal and domestic TV installations. Conducted measurements were undertaken to establish the performance of a cross-section of TV distribution amplifiers when subjected to LTE base station emissions, for different wanted DTT signal levels and frequency offsets. The measurements were then repeated to determine the degree of interference mitigation that might reasonably be expected through the use of in-line filters installed prior to the amplifier.

The results show that the introduction of both masthead and indoor amplifiers has a detrimental effect on the C/I performance of the two receivers considered in the test programme. There are two principal interference mechanisms that can affect the observed C/I performance:

- In-block EIRP (LTE Block A) producing overload of the amplifier under test;

- Out-of-block EIRP (LTE emissions falling directly into DTT channels), causing interference directly into the wanted receive signal under test

The results show that when the interference is caused by LTE base station in-block EIRP emissions the main cause of picture failure is due to amplifier overload, which occurs when the peak interference level exceeds the input 1 dB compression point by 2.5 to 7 dB, depending on the amplifier under test.

When the interference is caused by LTE base station out-of-block EIRP emissions the main cause of picture failure is due to emissions falling within the wanted DTT channel. In this case the measured best case C/I performance for the DVB-T mode used in testing is:

- -43 dB for a given ACLR of -59 dBc (in channel 60).
- -53 dB for a given ACLR of -69 dBc (in channels 59 and below).

There are a limited number of cases where the picture failure was a function of both the in-block and out-of-block EIRP levels. In these cases it appears that the in-block power required is lower but the C/I protection ratio is higher than expected. This is the switchover point at which the dominant interference mechanism changes.

The insertion of the professional filter prior to the masthead amplifiers restored the C/I performance of both DTT receivers to the measured best case C/I performance of -43 dB for channel 60 and -53 dB for channels 59 and below. In some cases this is better than the baseline performance of the DTT receiver on its own.

The insertion of the domestic filter prior to the indoor amplifiers improved the performance in the majority of measured cases, with Rx1 being improved to the measured best case performance of -43 / -53 dB in all but a very limited number of cases.

Previous measurements have shown that Rx2 is more prone to LTE interference than Rx1, requiring higher C/I protection ratios. In the case of Rx2, the filter did not provide the same improvement as for Rx1. However, the filter still improved the C/I protection ratio by 11 to 14 dB in the majority of cases.

5. References

[1] Coexistence of new services in the 800 MHz band with digital terrestrial television, Ofcom, June 2011 (http://stakeholders.ofcom.org.uk/binaries/consultations/dtt/summary/dttcondoc.pdf)

[2] Technical analysis of interference from mobile network base stations in the 800 MHz band to digital terrestrial services, Ofcom, June 2011 (http://stakeholders.ofcom.org.uk/binaries/consultations/dtt/annexes/Technical-Report.pdf)

[3] The co-existence of LTE and DTT services at UHF: a field trial, Aegis Systems Ltd, 4th July 2011 (http://www.ofcom.org.uk/static/research/co-existenceLTEDTTservicesatUHF.pdf)

[4] Masthead and Indoor Amplifiers for TV Signal Reception and Distribution, ManderCom, 6th June 2011 (http://stakeholders.ofcom.org.uk/binaries/consultations/dtt/annexes/Masthead-indoor-amplifier.pdf)

[5] Assessment of LTE 800 MHz Base Station Interference into DTT Receivers, ERA Technology, July 2011 (http://stakeholders.ofcom.org.uk/binaries/consultations/dtt/annexes/lte-800-mhz.pdf)

[6] ETSI EN 300 744: Digital Video Broadcasting; Framing structure, channel coding and modulation for digital terrestrial television, v1.5.1 November 2004

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

[8] European Commission Decision of 6 May 2010 on harmonised technical conditions of use in the 790 – 862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union (2010/267/EU) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010D0267:EN:NOT)

[9] ETSI TS 136 104 V8.5.0 (2009-04): LTE; Evolved Universal Terrestrial Radio Access (EUTRA); Base Station radio transmission and reception (FDD) (3GPP TS 36.104 version 8.5.0 Release 8)

Appendix A:
Measured Amplifier Characteristics

A.1. Amplifier Gain Flatness

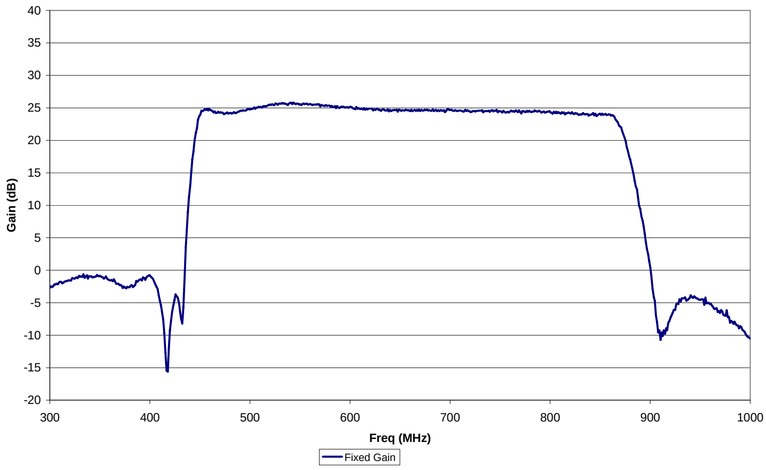

Figure 12: Amplifier 1 (masthead) gain response

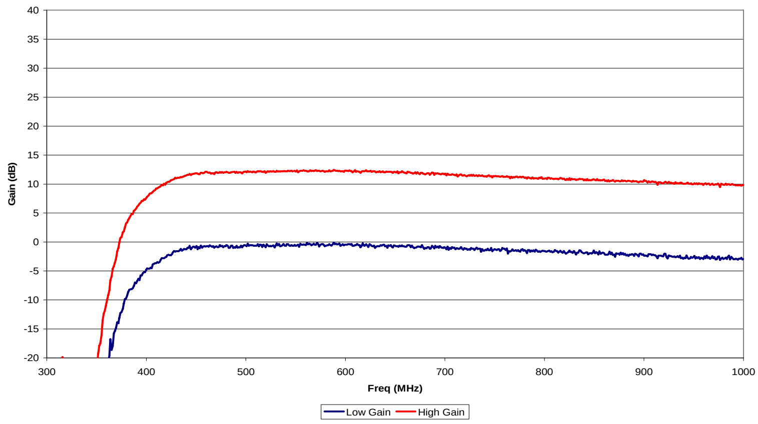

Figure 13: Amplifier 2 (masthead) gain response

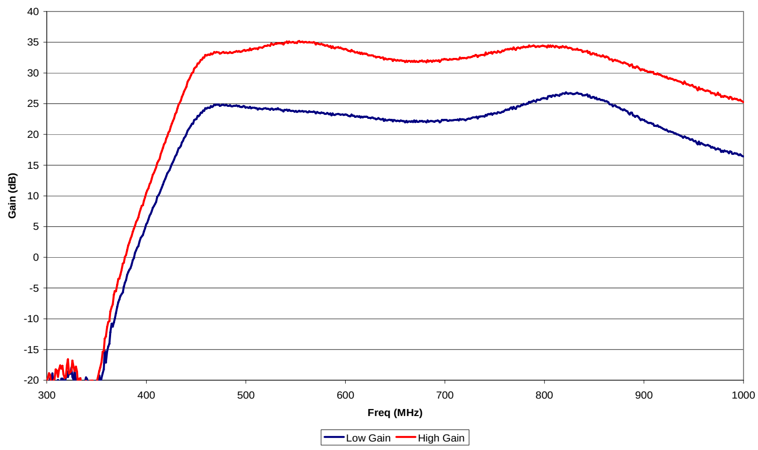

Figure 14: Amplifier 3 (masthead) gain response

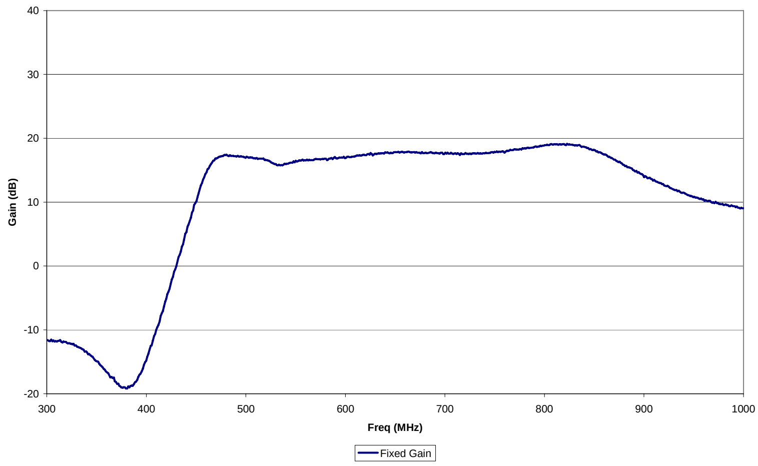

Figure 15: Amplifier 4 (indoor) gain response

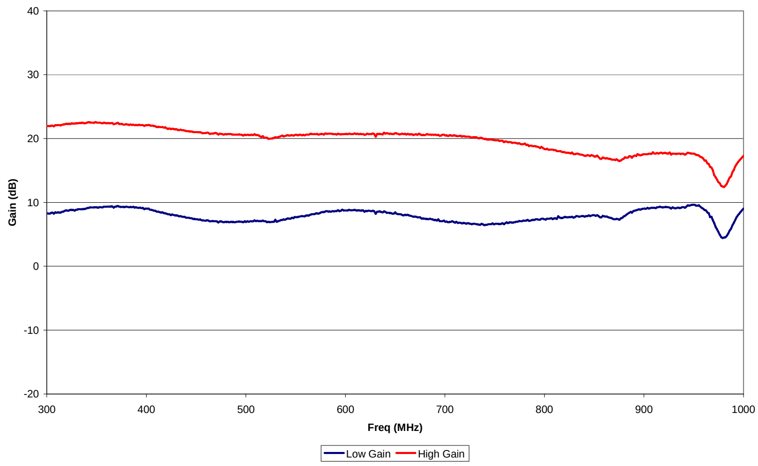

Figure 16: Amplifier 5 (indoor) gain response

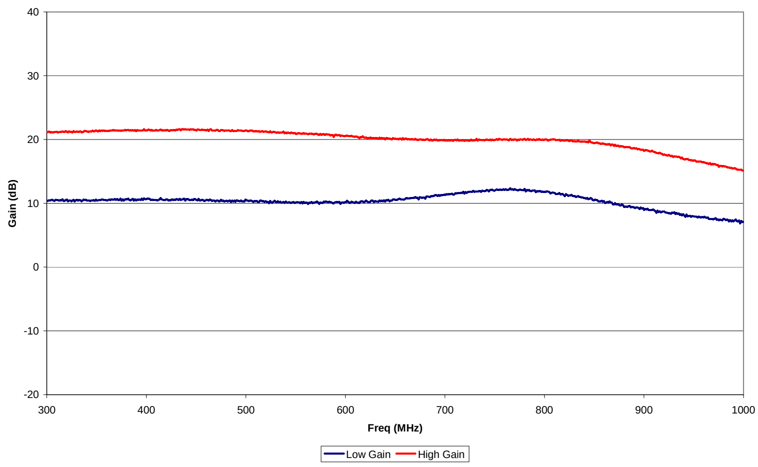

Figure 17: Amplifier 6 (indoor) gain response

A.2. 1 dB Compression Point

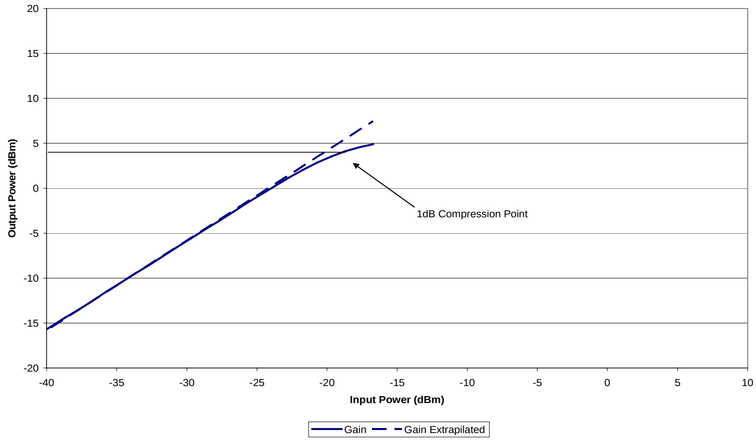

Figure 18: Amplifier 1 (masthead) 1 dB compression point

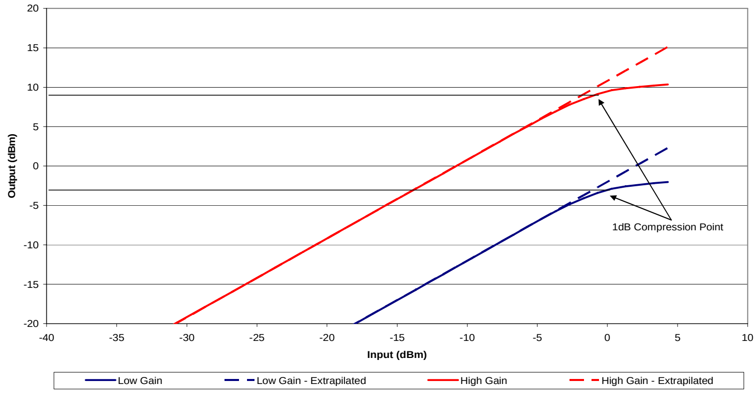

Figure 19: Amplifier 2 (masthead) 1 dB compression point

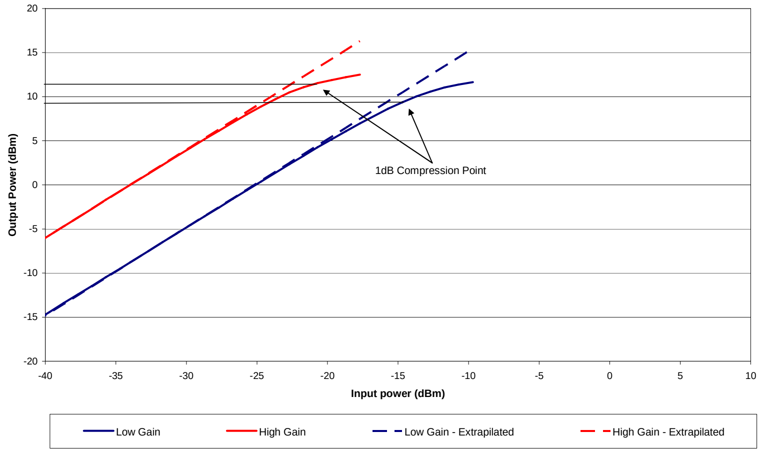

Figure 20: Amplifier 3 (masthead) 1 dB compression point

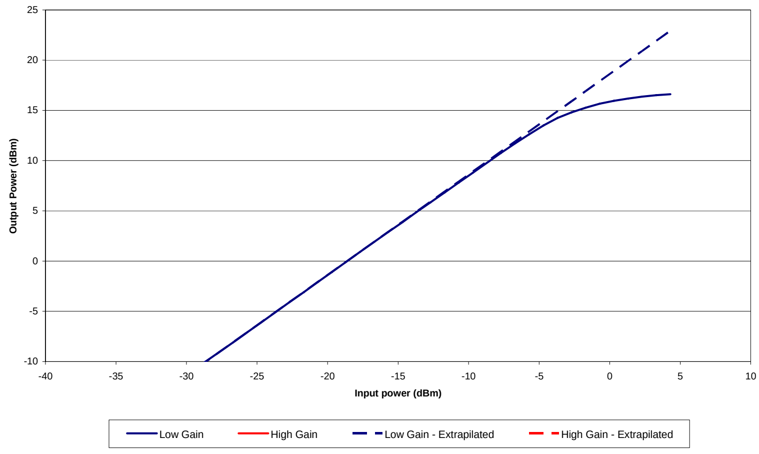

Figure 21: Amplifier 4 (indoor) 1 dB compression point

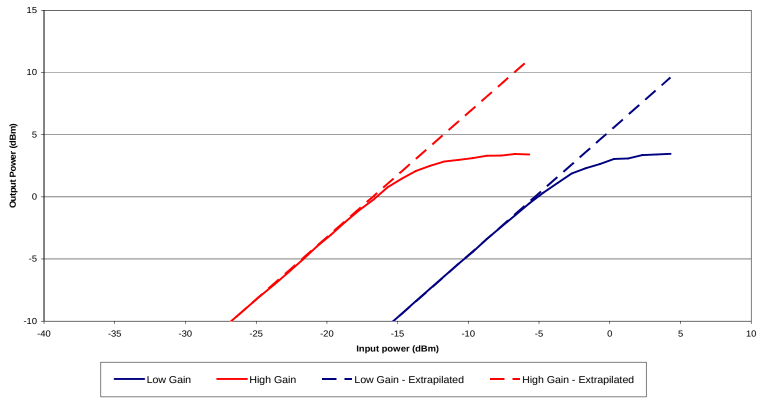

Figure 22: Amplifier 5 (indoor) 1 dB compression point

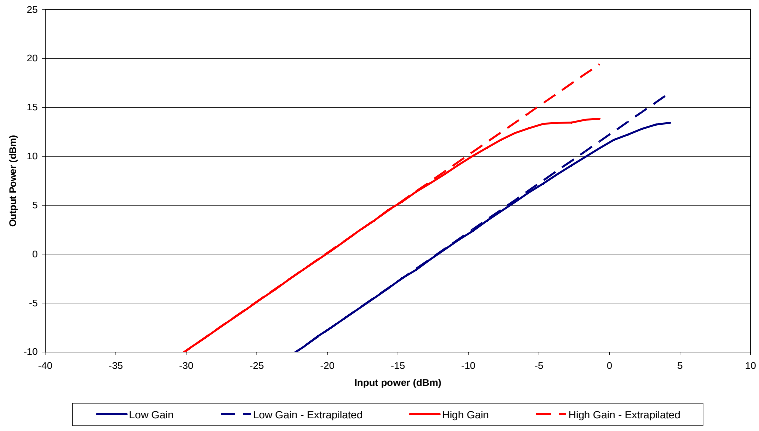

Figure 23: Amplifier 6 (indoor) 1 dB compression point

A.3. 3rd Order Intercept Point

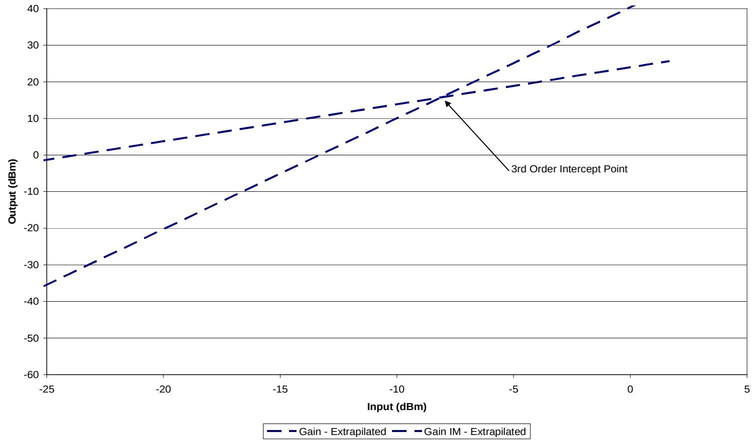

Figure 24: Amplifier 1 (masthead) 3rd order intercept point

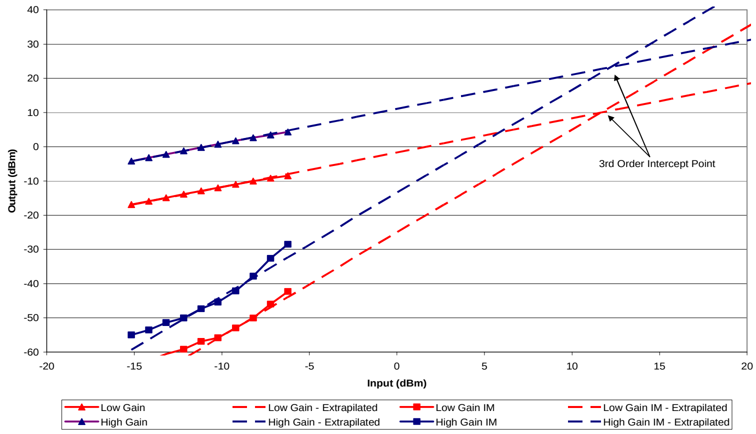

Figure 25: Amplifier 2 (masthead) 3rd order intercept point

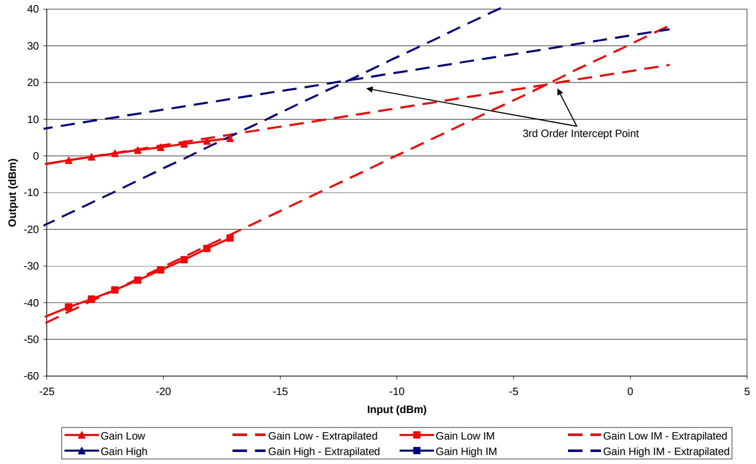

Figure 26: Amplifier 3 (masthead) 3rd order intercept point

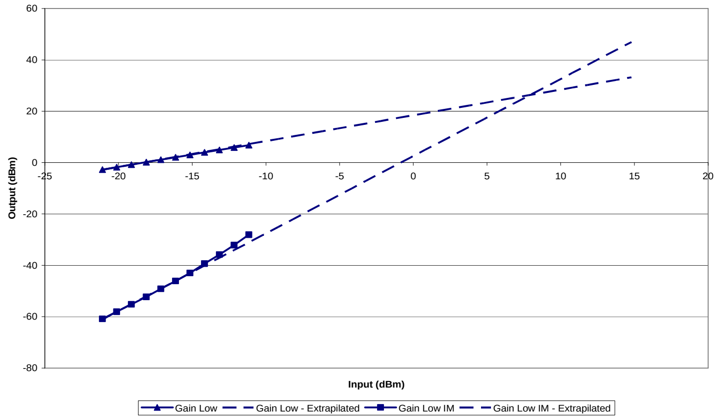

Figure 27: Amplifier 4 (indoor) 3rd order intercept point

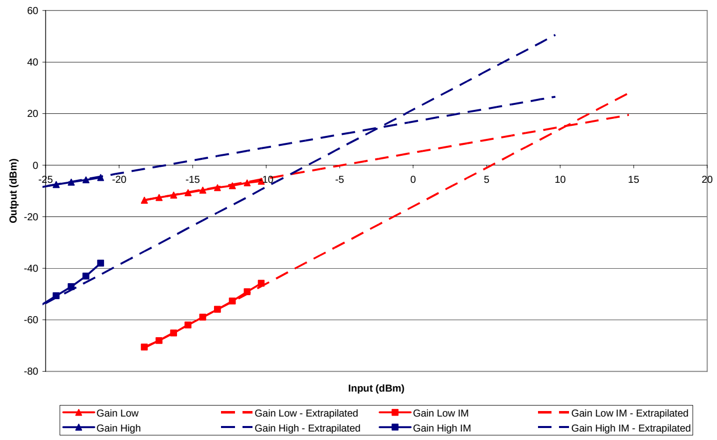

Figure 28: Amplifier 5 (indoor) 3rd order intercept point

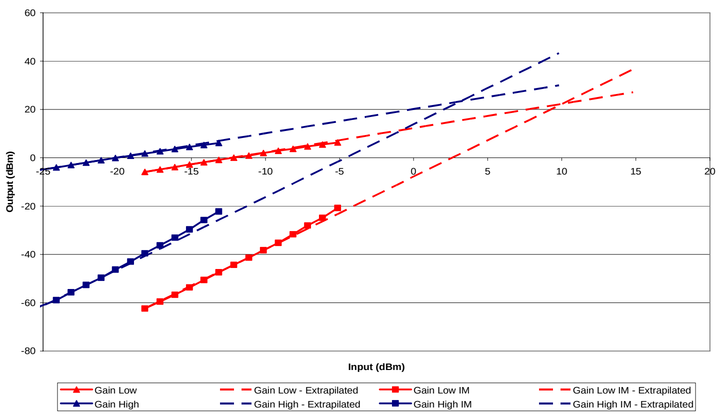

Figure 29: Amplifier 6 (indoor) 3rd order intercept point

Appendix B:
DTT Receiver Performance

B.1. DTT Receiver Performance

The two DTT receivers used in the study were initially characterised with, and without, a domestic filter in order to provide a benchmark for the amplifier results. Their performance is shown in the figures below.

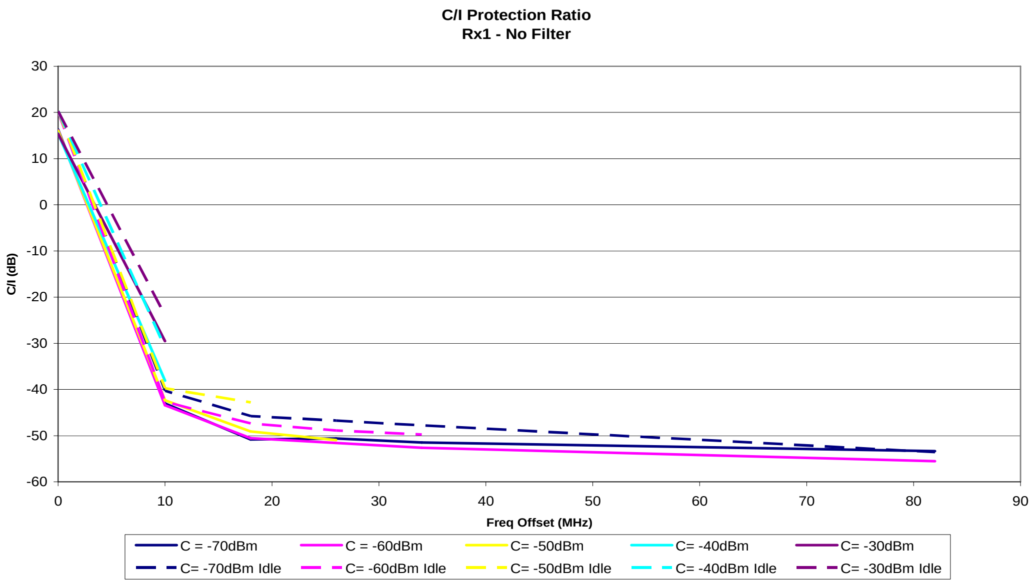

Figure 30: DTT Receiver 1 performance without filtering

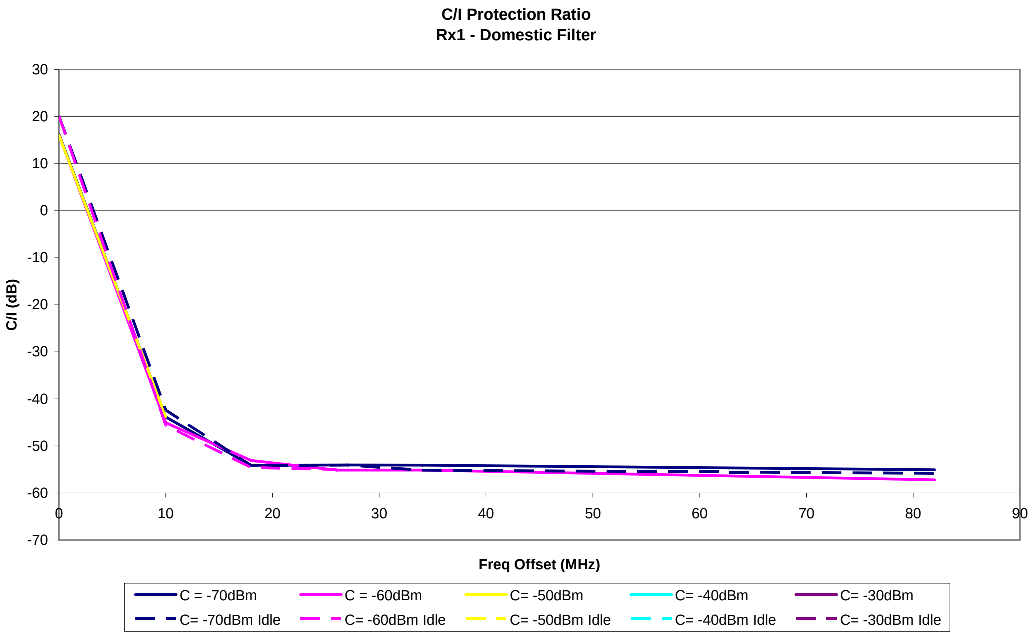

Figure 31: DTT Receiver 1 performance with filtering

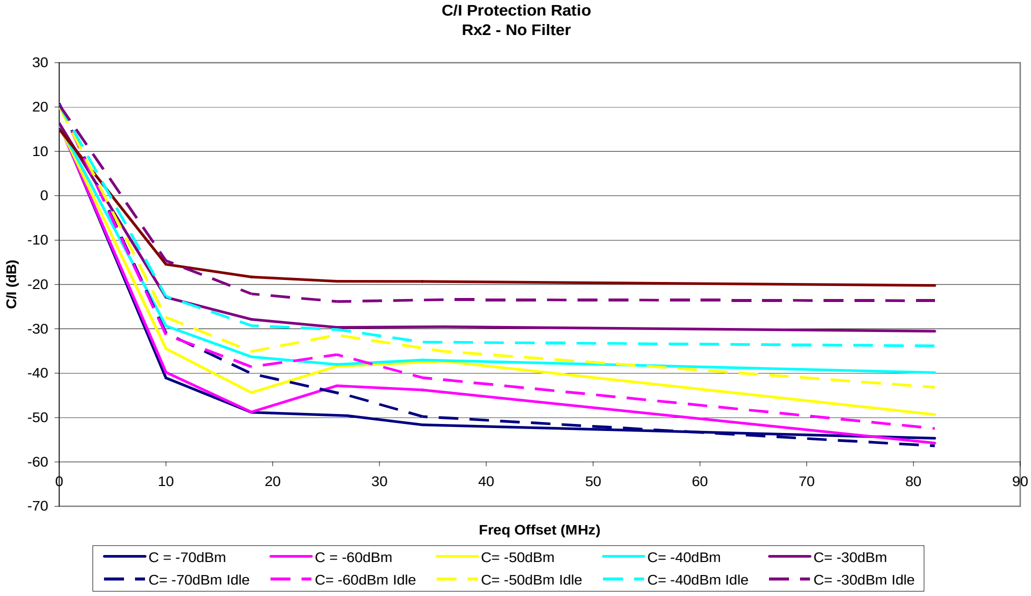

Figure 32: DTT Receiver 2 performance without filtering

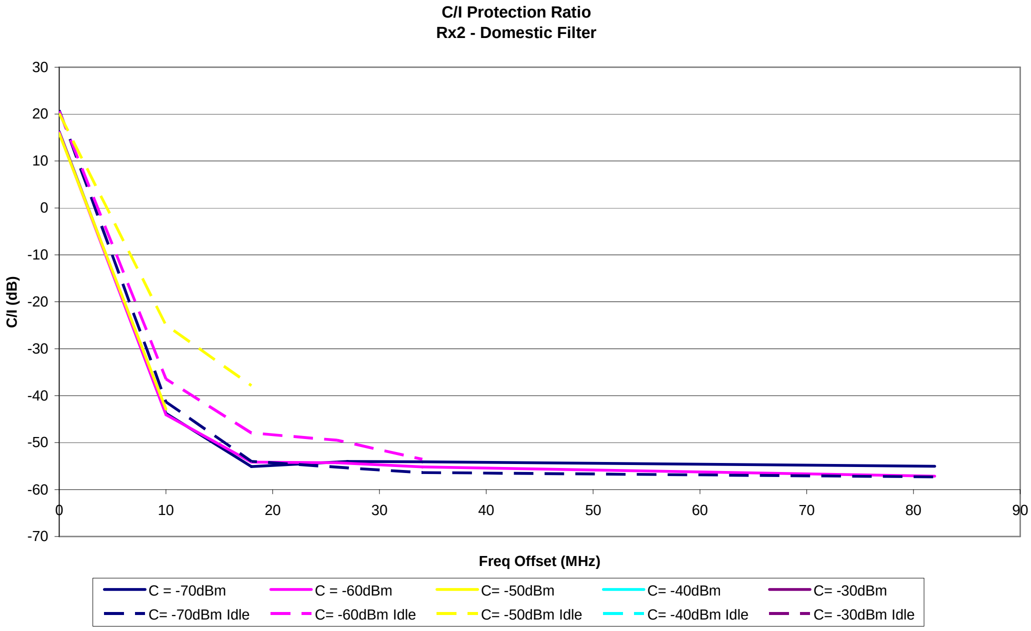

Figure 33: DTT Receiver 2 performance with filtering

Appendix C:
Amplifier C/I Protection Ratio Curves

C.1. C / I Protection Ratios for DTT Receiver 1

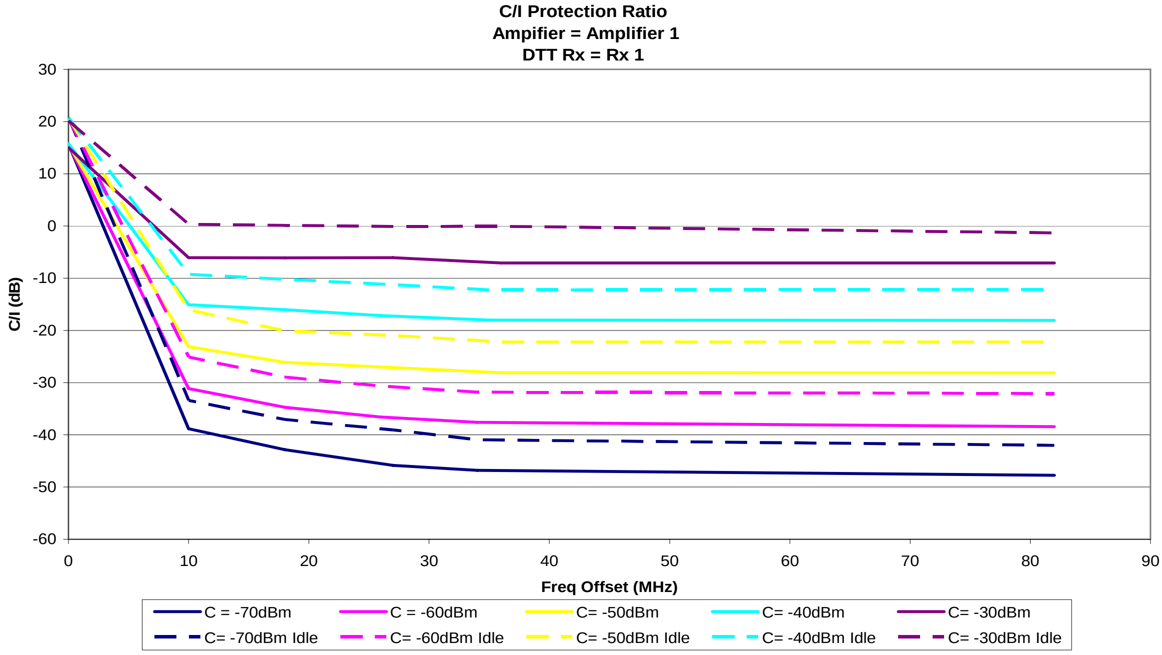

Figure 34: Amplifier 1 (masthead) with Rx1, without the use of filtering

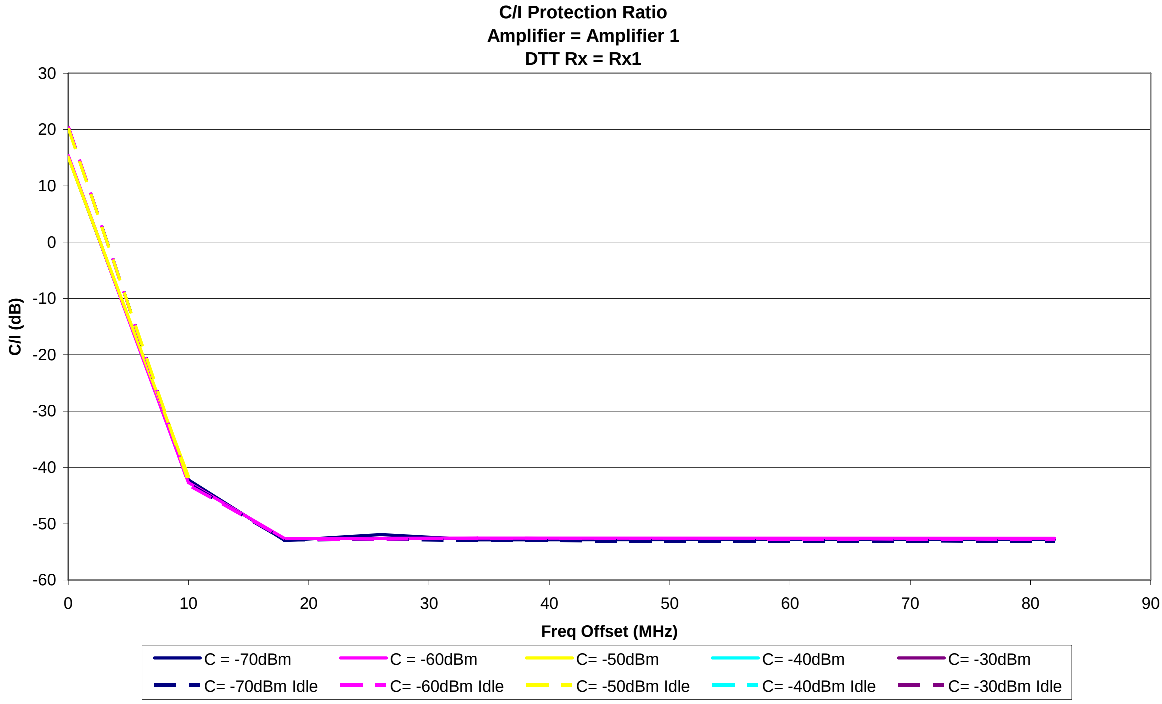

Figure 35: Amplifier 1 (masthead) with Rx1, with filtering

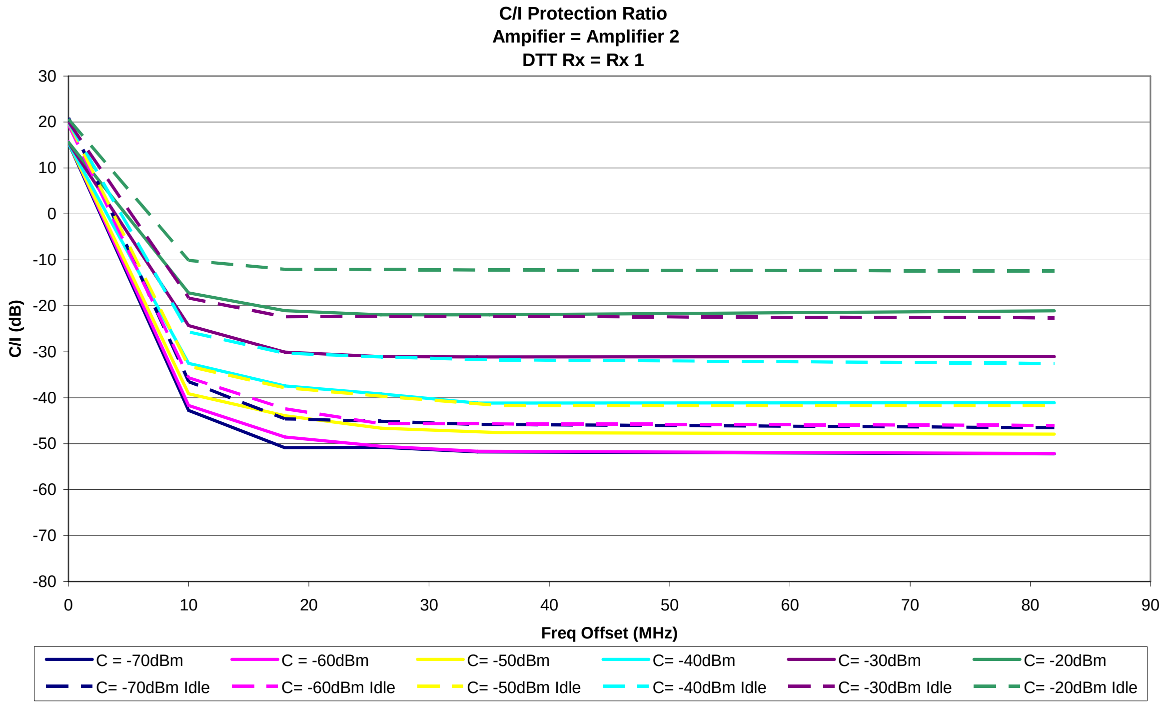

Figure 36: Amplifier 2 (masthead) with Rx1, without the use of filtering

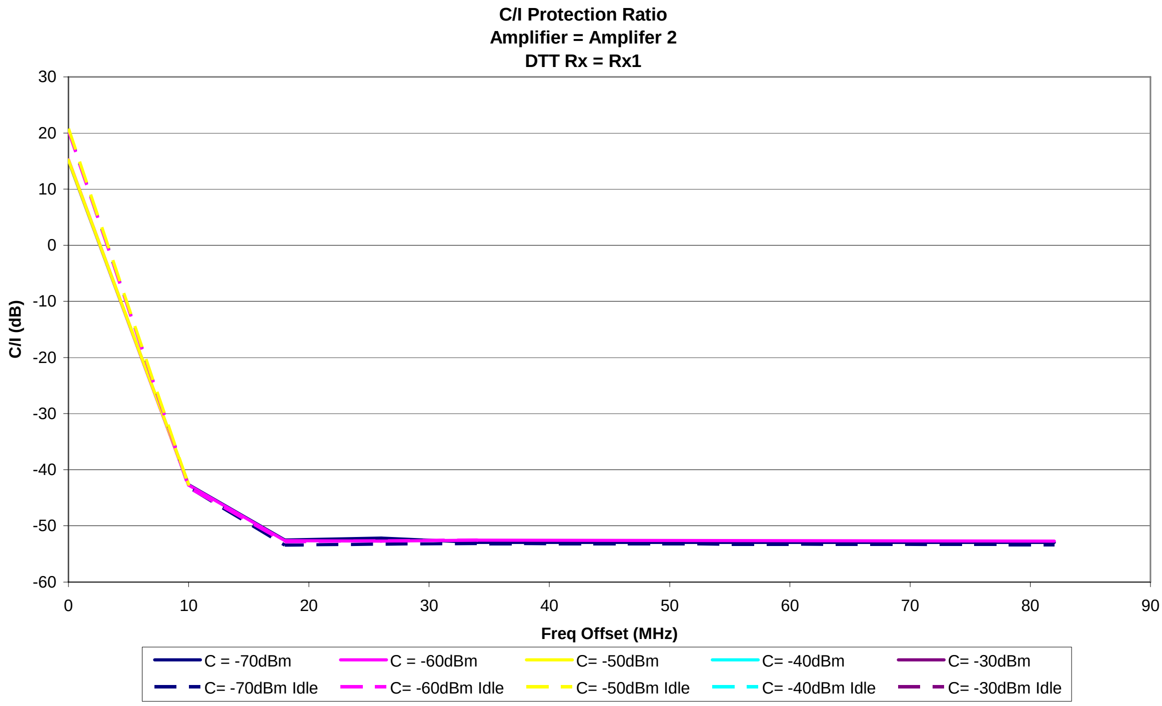

Figure 37: Amplifier 2 (masthead) with Rx1, with filtering

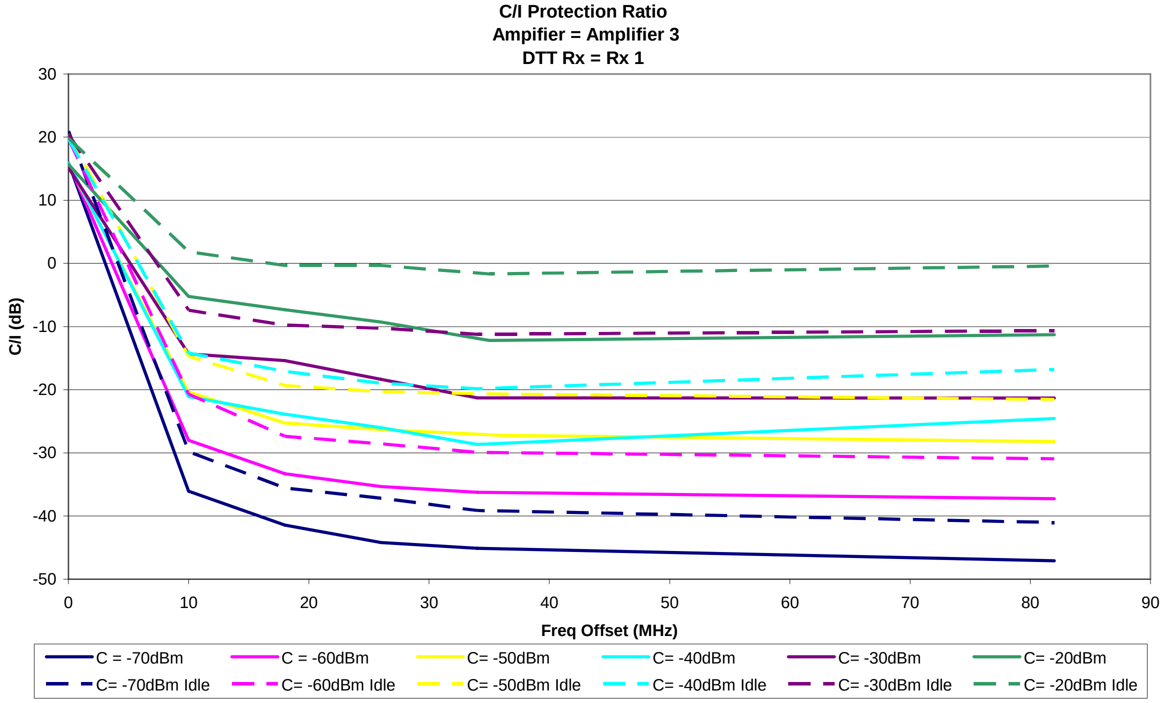

Figure 38: Amplifier 3 (masthead) with Rx1, without the use of filtering

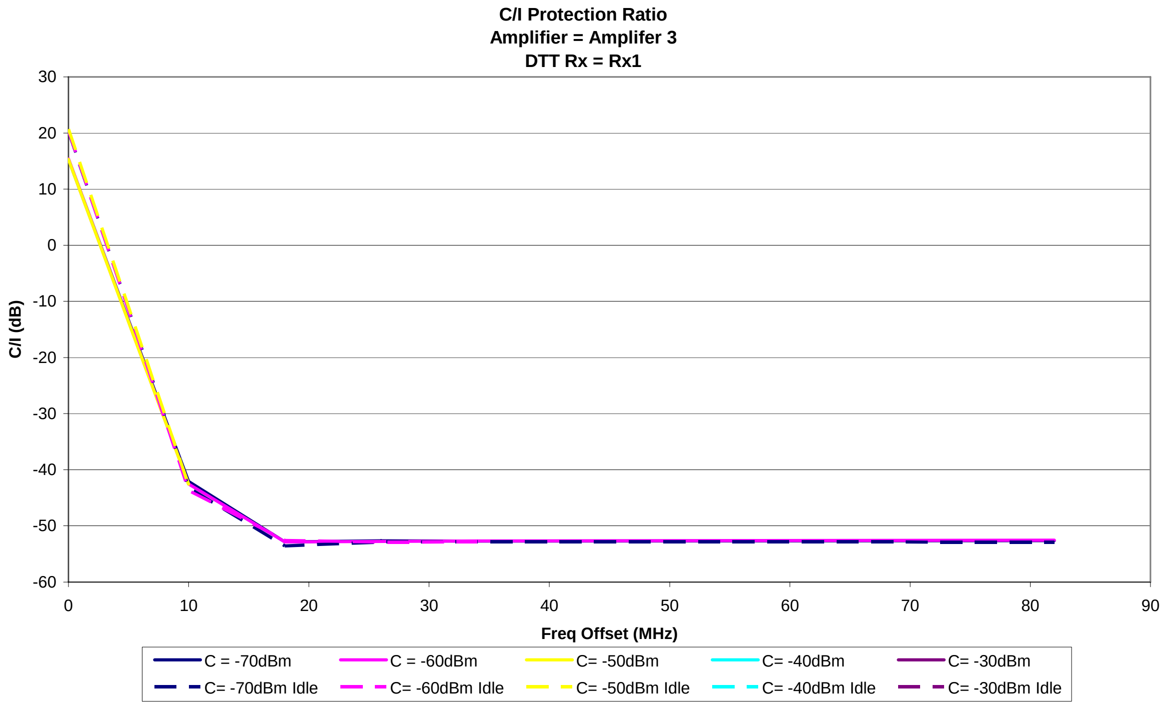

Figure 39: Amplifier 3 (masthead) with Rx1, with filtering

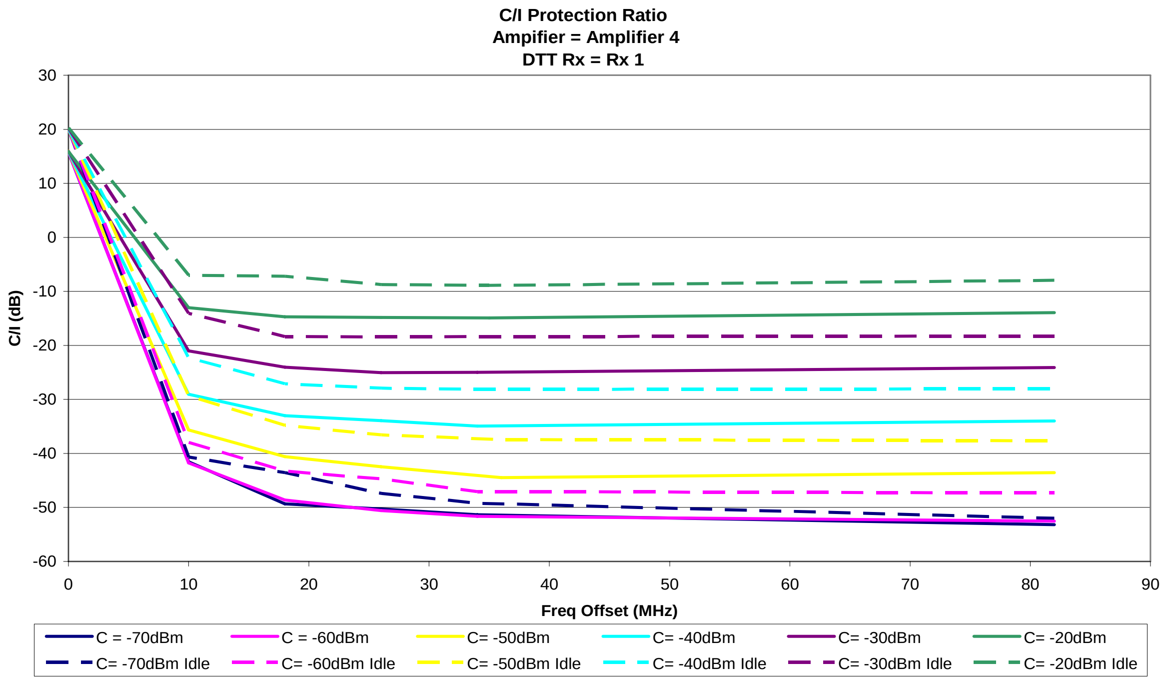

Figure 40: Amplifier 4 (indoor) with Rx1, without the use of filtering

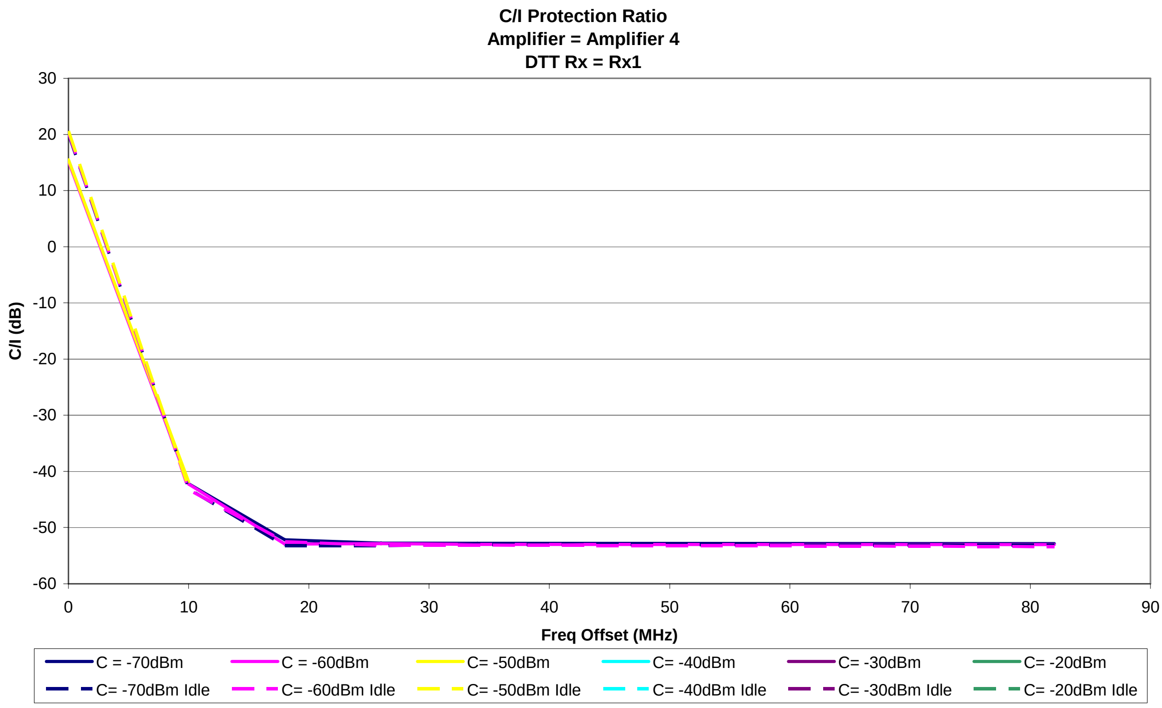

Figure 41: Amplifier 4 (indoor) with Rx1, with filtering

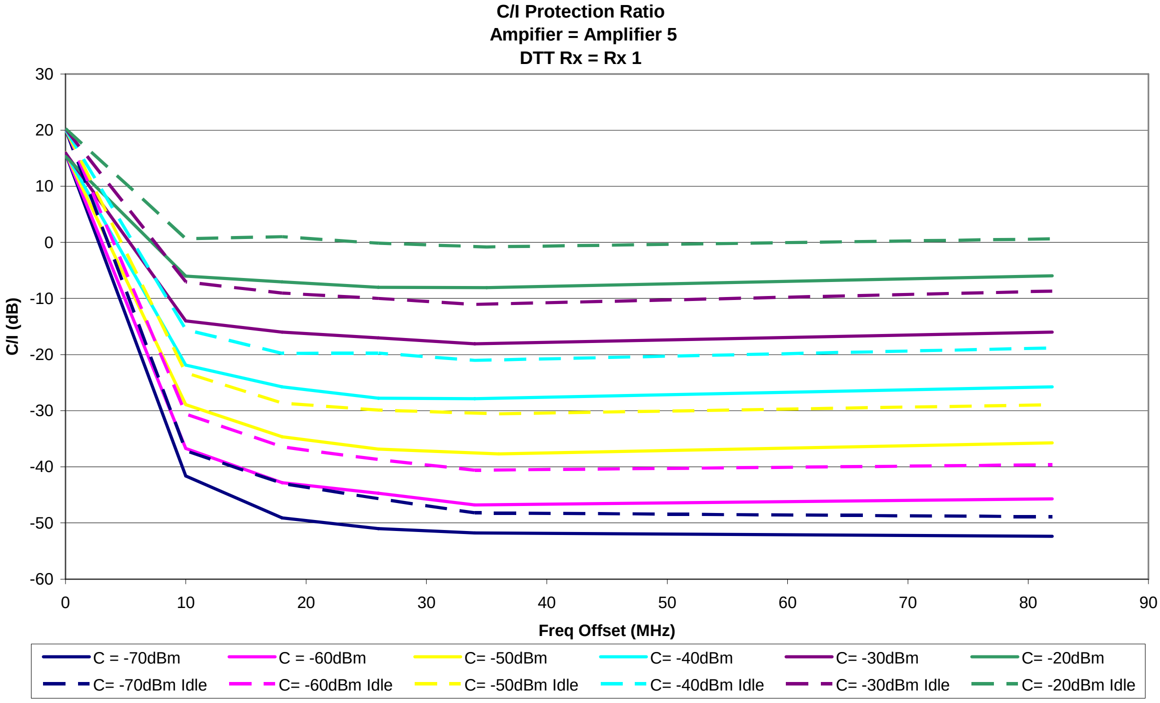

Figure 42: Amplifier 5 (indoor) with Rx1, without the use of filtering

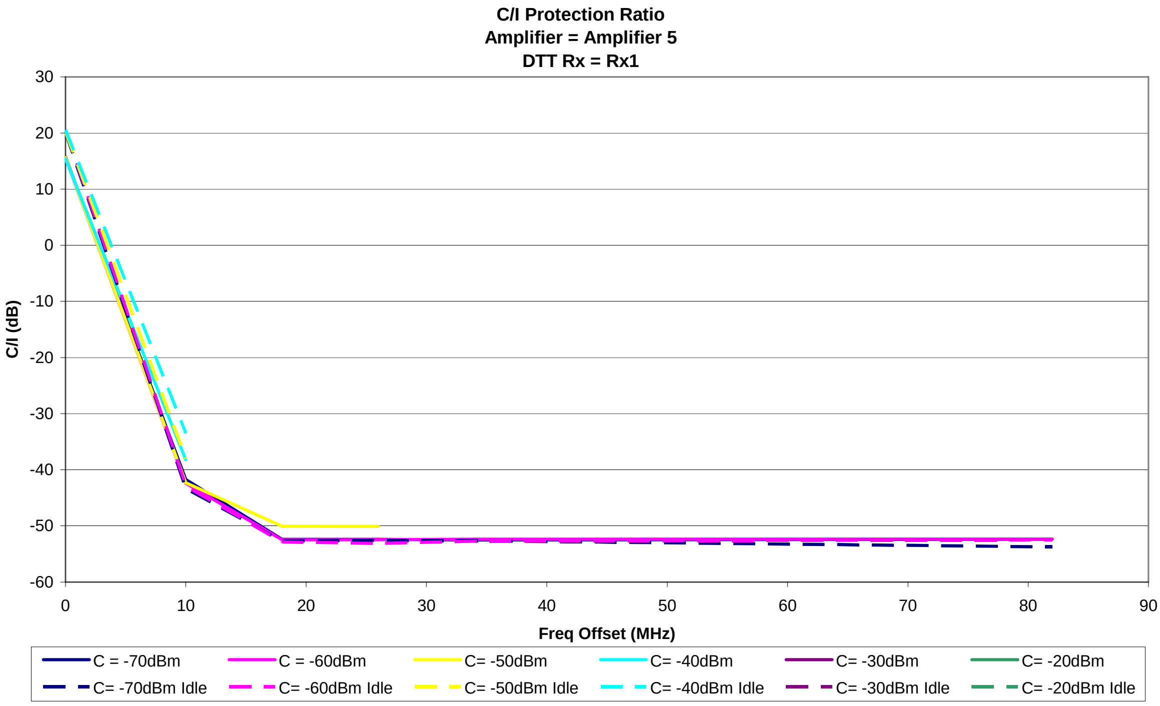

Figure 43: Amplifier 5 (indoor) with Rx1, with filtering

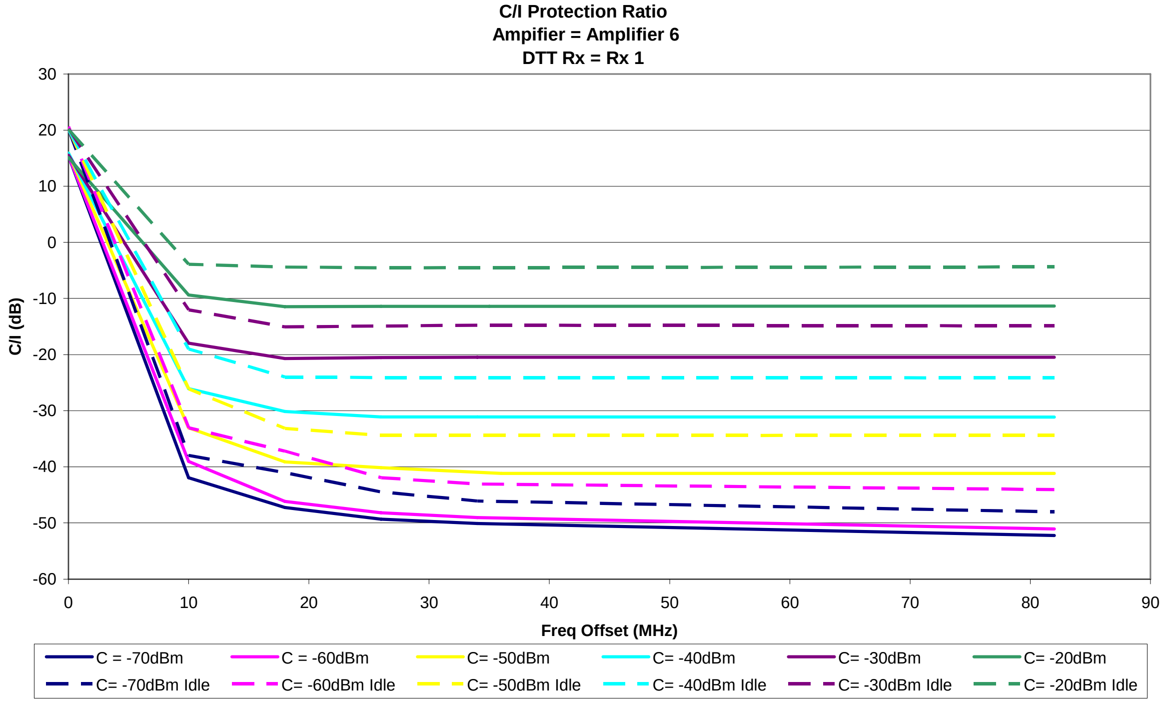

Figure 44: Amplifier 6 (indoor) with Rx1, without the use of filtering

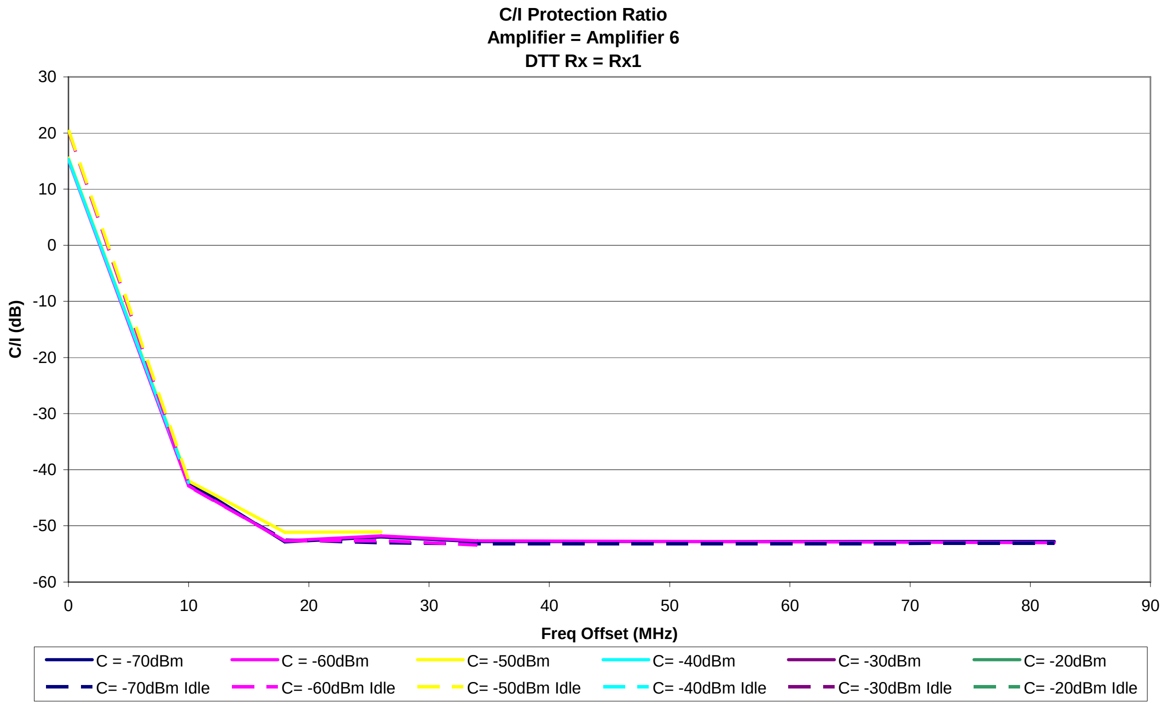

Figure 45: Amplifier 6 (indoor) with Rx1, with filtering

C.2. C / I Protection Ratios for DTT Receiver 2

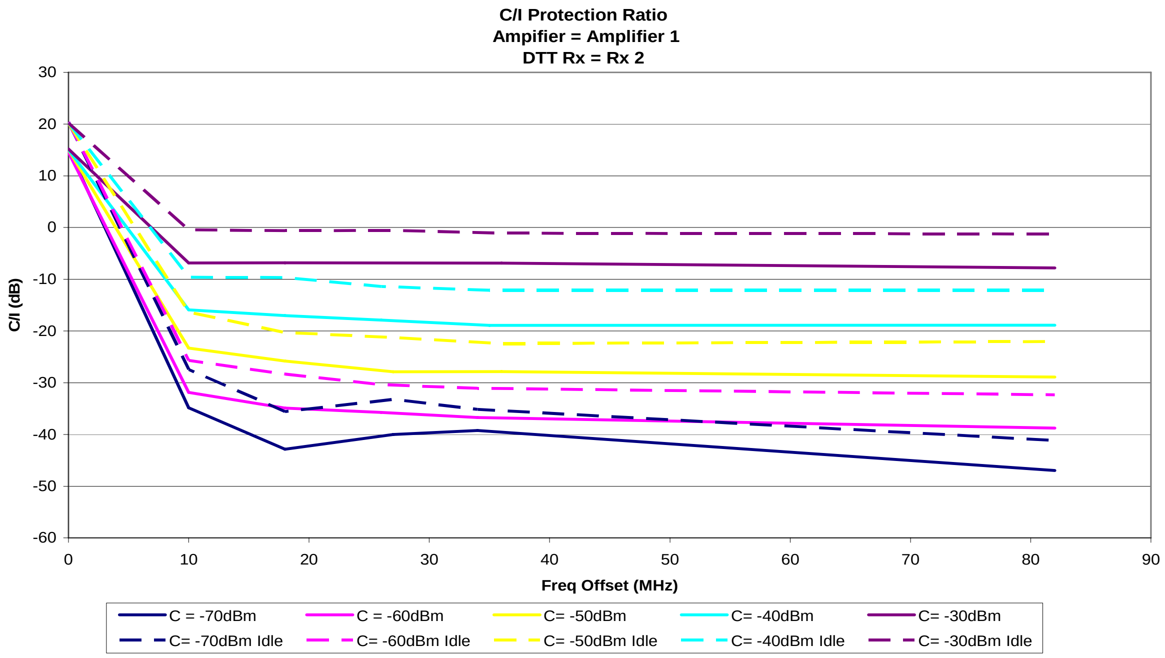

Figure 46: Amplifier 1 (masthead) with Rx2, without the use of filtering

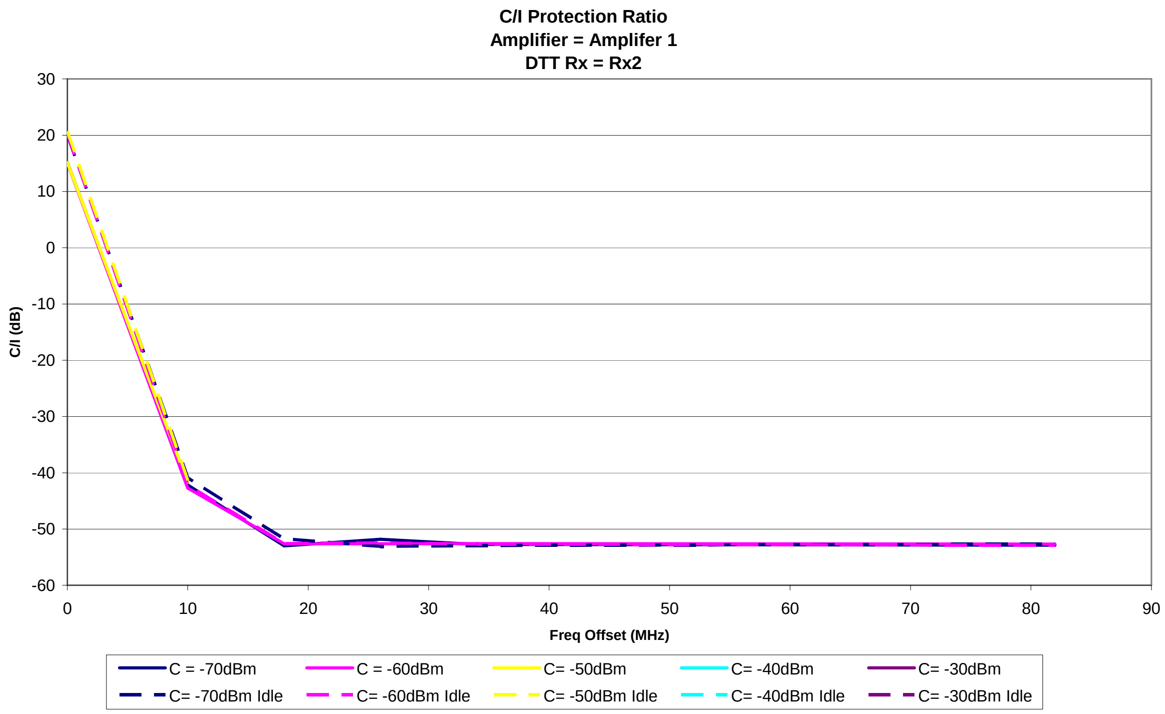

Figure 47: Amplifier 1 (masthead) with Rx2, with filtering

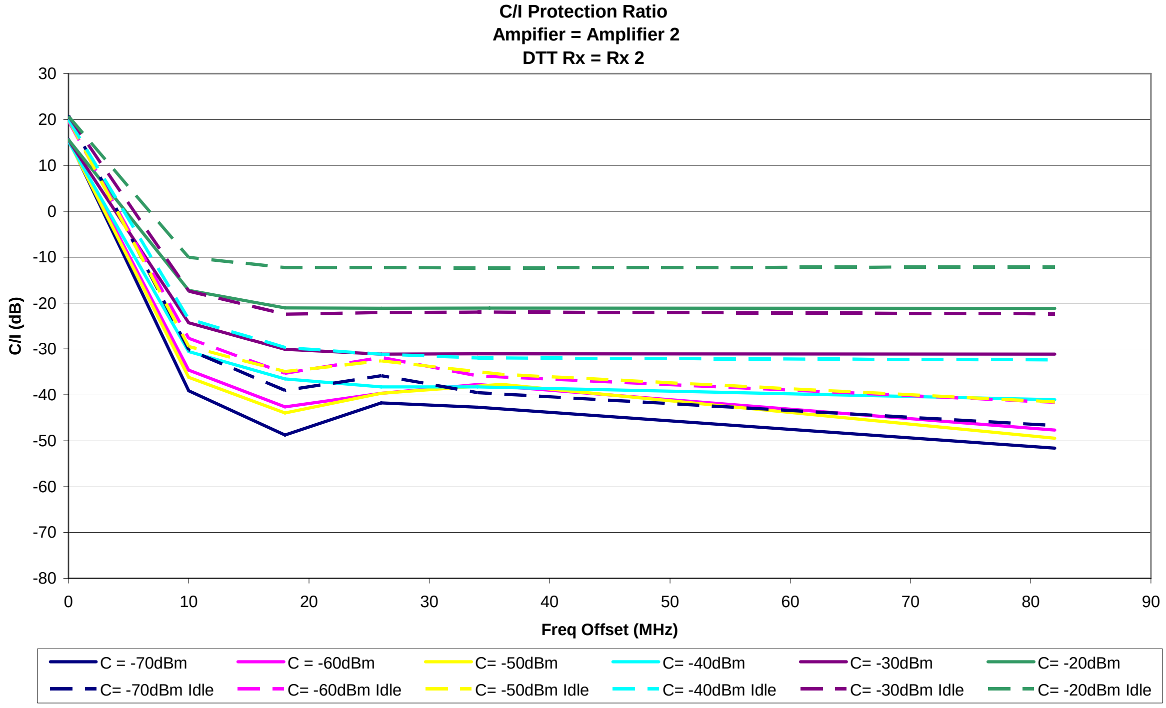

Figure 48: Amplifier 2 (masthead) with Rx2, without the use of filtering

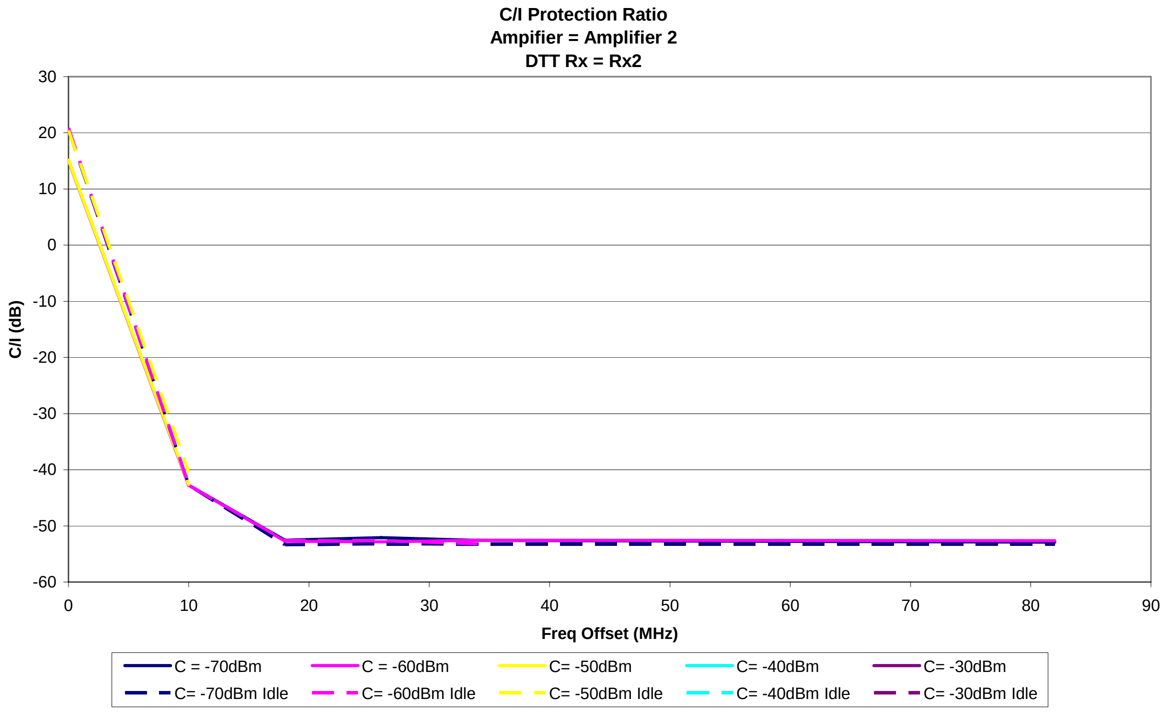

Figure 49: Amplifier 2 (masthead) with Rx2, with filtering

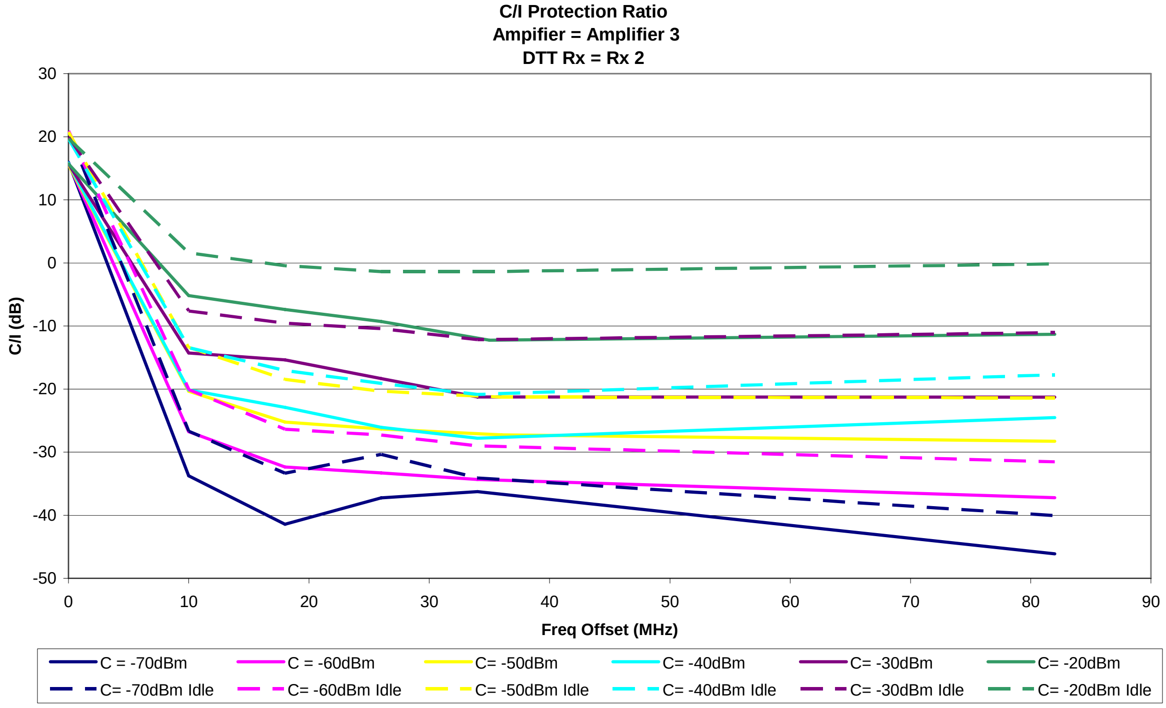

Figure 50: Amplifier 3 (masthead) with Rx2, without the use of filtering

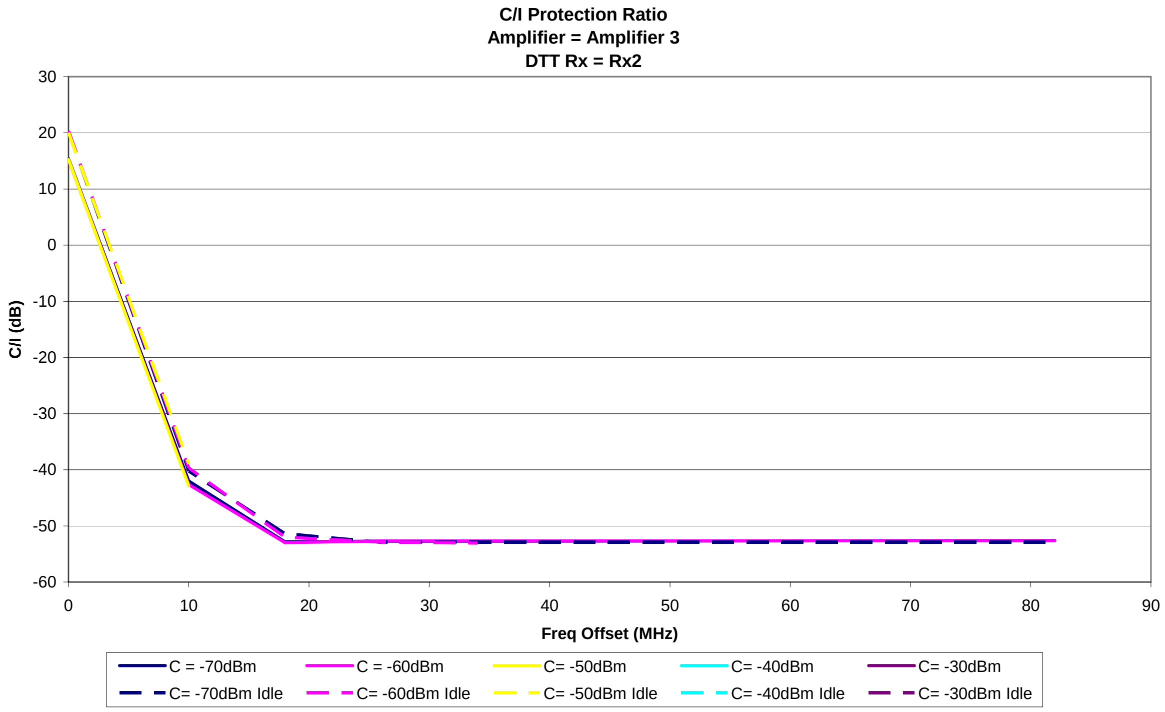

Figure 51: Amplifier 3 (masthead) with Rx2, with filtering

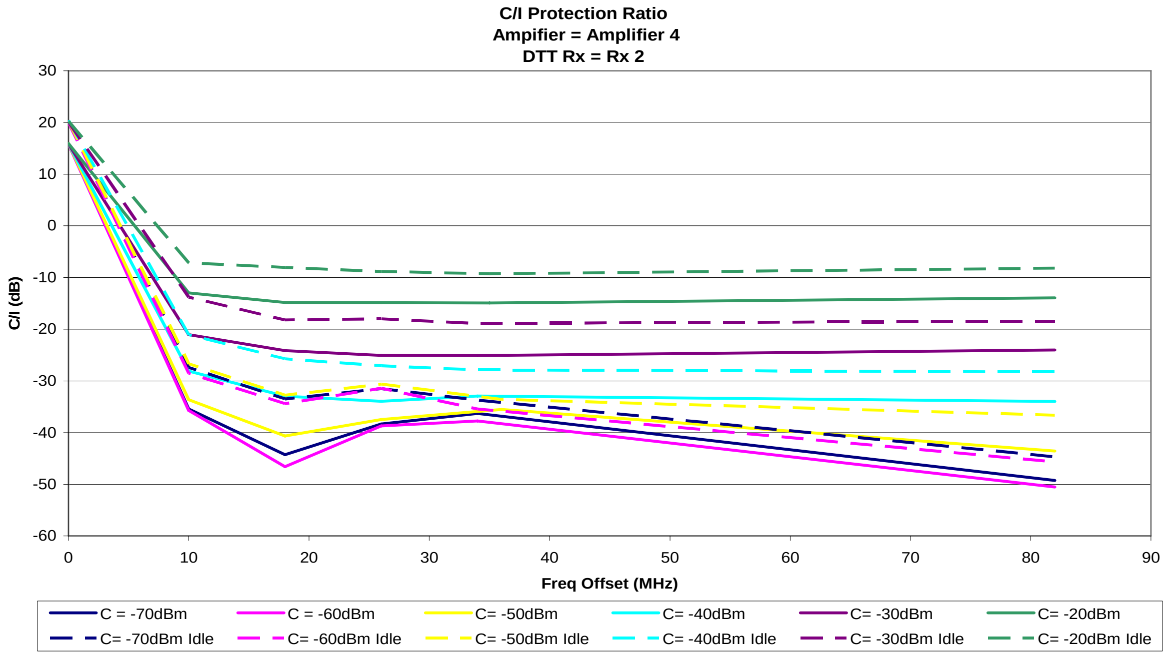

Figure 52: Amplifier 4 (indoor) with Rx2, without the use of filtering

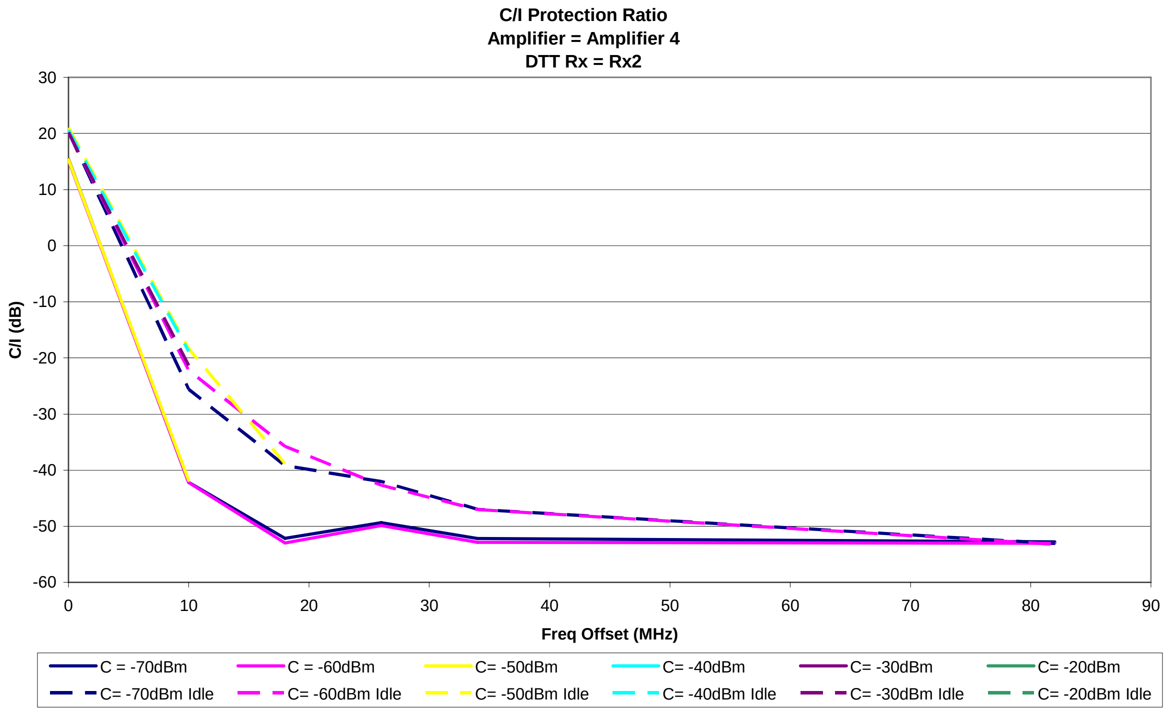

Figure 53: Amplifier 4 (indoor) with Rx2, with filtering

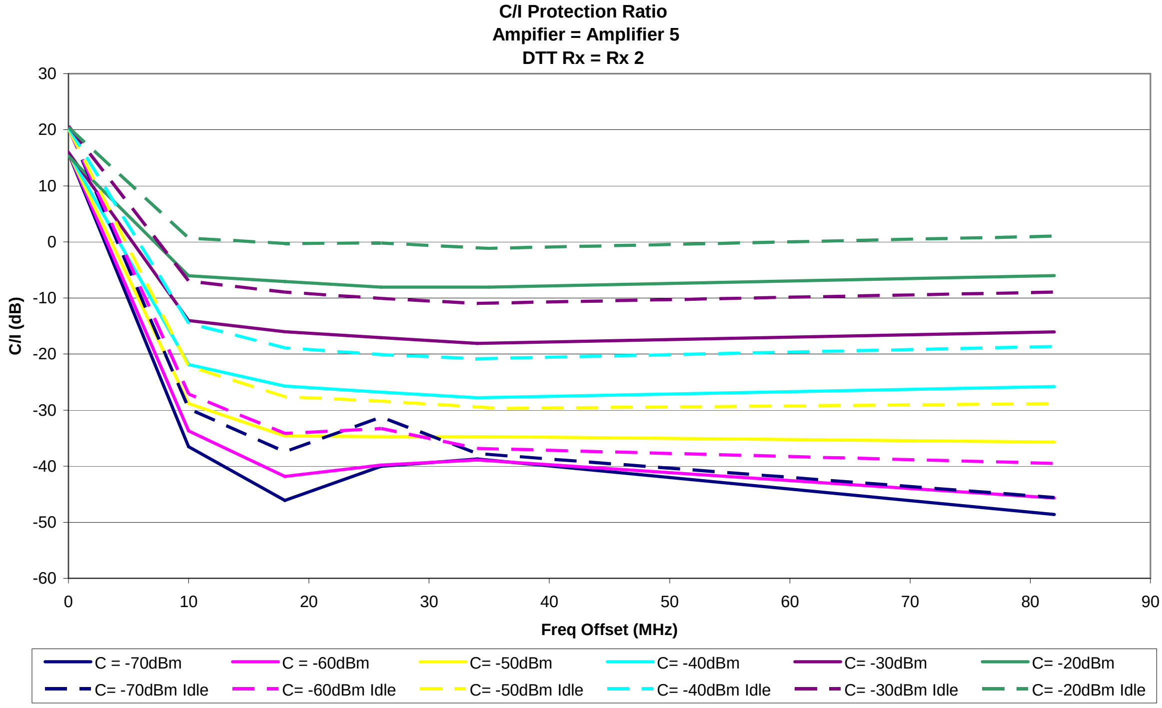

Figure 54: Amplifier 5 (indoor) with Rx2, without the use of filtering

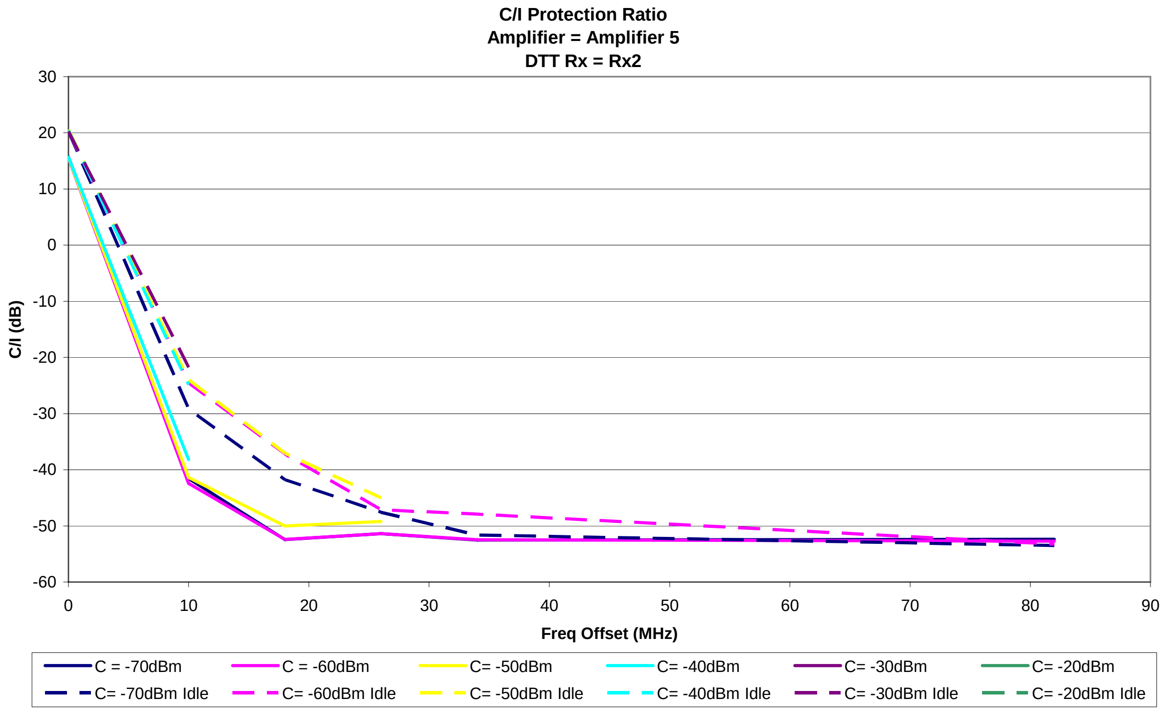

Figure 55: Amplifier 5 (indoor) with Rx2, with filtering

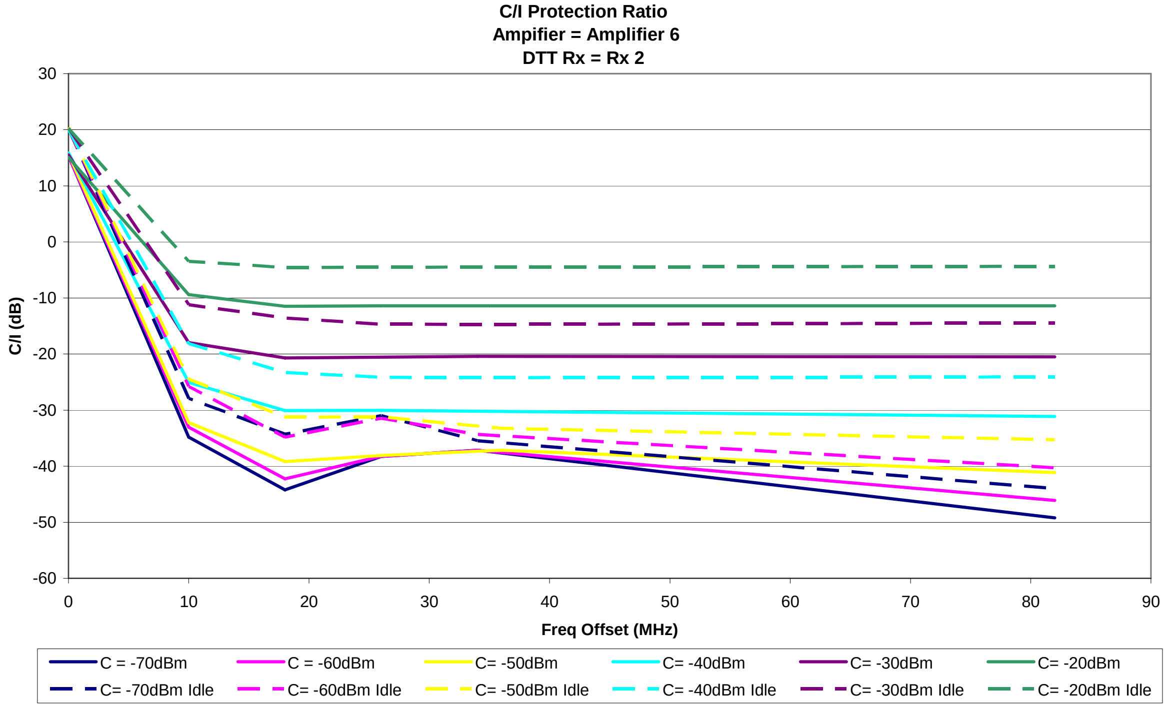

Figure 56: Amplifier 6 (indoor) with Rx2, without the use of filtering

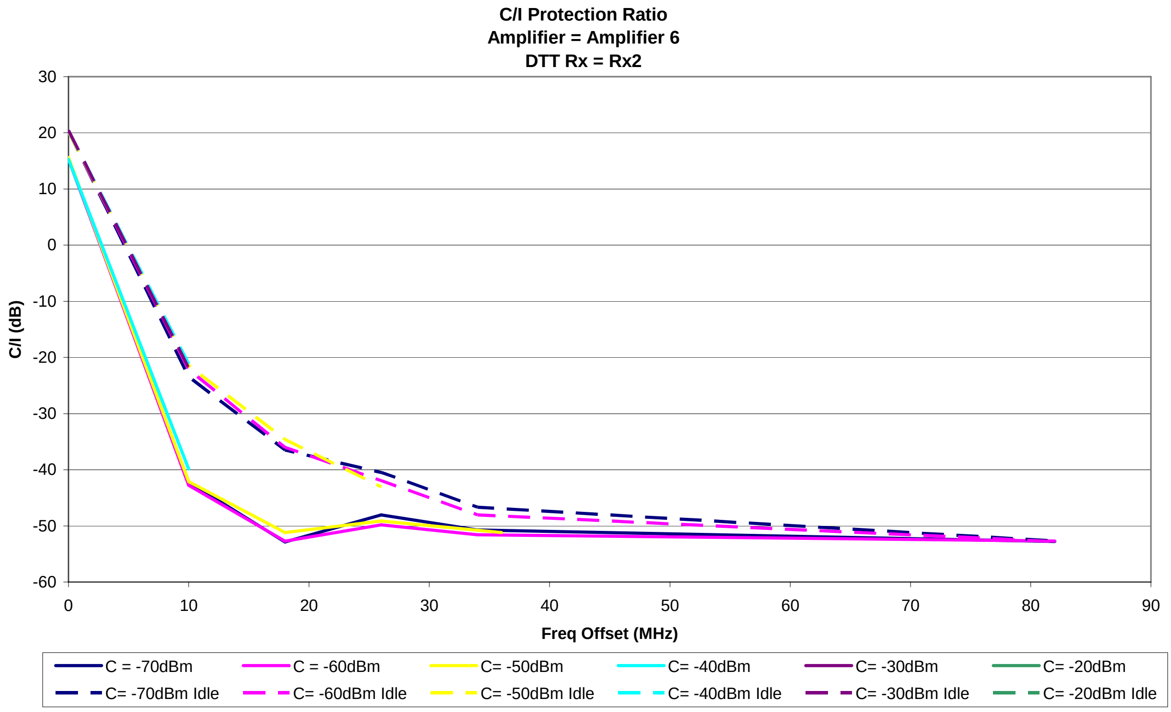

Figure 57: Amplifier 6 (indoor) with Rx2, with filtering

Appendix D:
CCDF Curves of Idle and Fully Loaded LTE Signals

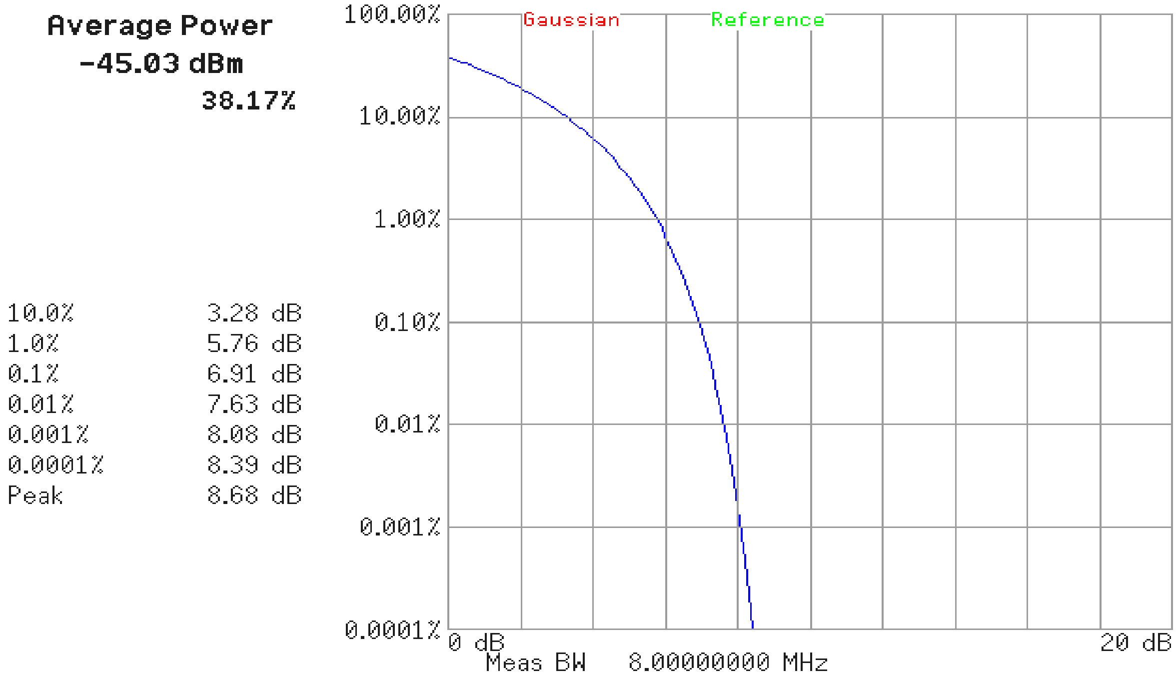

Figure 58: CCDF Measurement of LTE 100 % (fully loaded) Signal

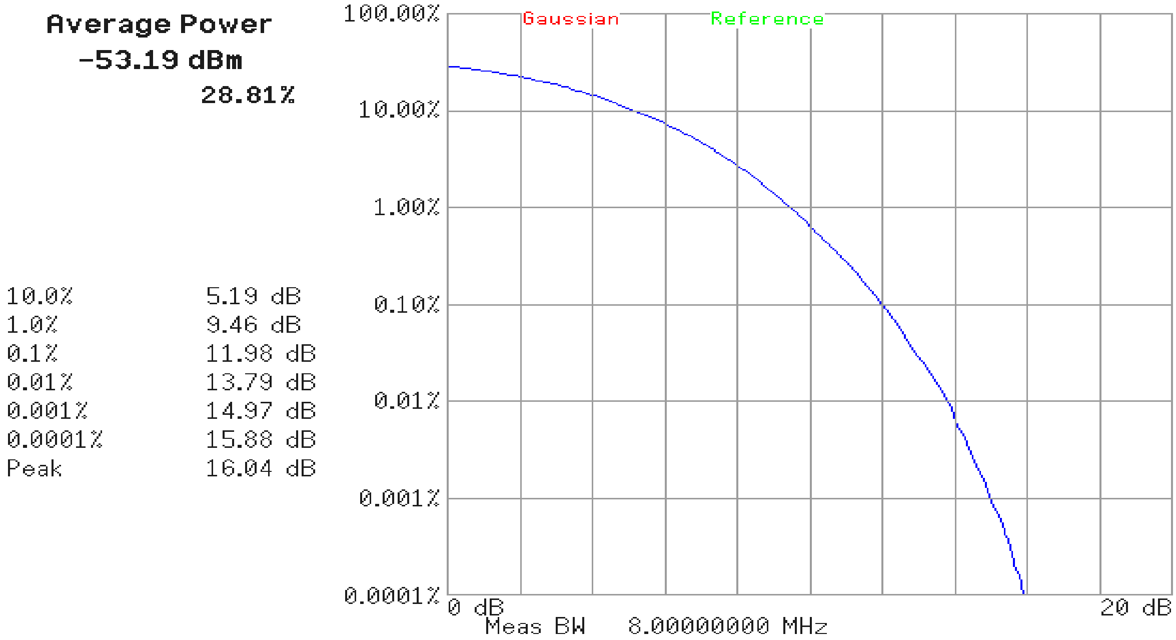

Figure 59: CCDF Measurement of LTE Idle Signal