MC/193

Study to Determine the Potential Interference from TDD LTE into WiFi

Test Results

Issue 3

April 2014

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Change History

Version	Date	Change Details
1	15/07/13	First formal release
2	16/09/13	Additional tests of five WiFi devices Corrected errors in calculation of MUS and related parameters in issue 1
3	15/04/14	Removed DUT 4 results following retest. The results of this device are now given in the accompanying ‘Additional Test Results’ document MC/SC1050A/REP001/2

Contents

1 INTRODUCTION

This document is an appendix to the main report (Wagstaff *et al*, 2013) on the potential for TDD LTE in the 2.3 GHz band to interfere with WiFi services in the 2.4 GHz band. It contains the detailed graphical results for each of the WiFi Devices Under Test (DUT) together with comments on the interpretation of the results.

Issue 2 of this document contained the results from an additional series of tests and corrects errors in the post-processing found in issue 1.

The additional tests were:

- DUT 12 Mobile phone MP2 retest
- DUT 18 Mobile phone MP4
- DUT 19 Tablet TB3
- DUT 20 Mobile phone MP5
- DUT 21 Mobile phone MP6

These additional tests were conducted after the main report (Wagstaff *et al*, 2013) was produced. With Ofcom's agreement that report has not been updated. The additional tests have not significantly affected the conclusions of the main report.

Issue 3 of this document removed the results of DUT 4 Mobile Phone MP1 after a retest. The new results for this device will be given in an updated version of the 'Additional Test Results' report (Wagstaff, 2014)

1.1 Interference points

The main report (Wagstaff, 2013) describes the two interference points used for the analysis of the results. These points, 1 Mbps and 90% throughput, are indicated in this report where appropriate, and are marked on the throughput versus C/I plots as illustrated below:

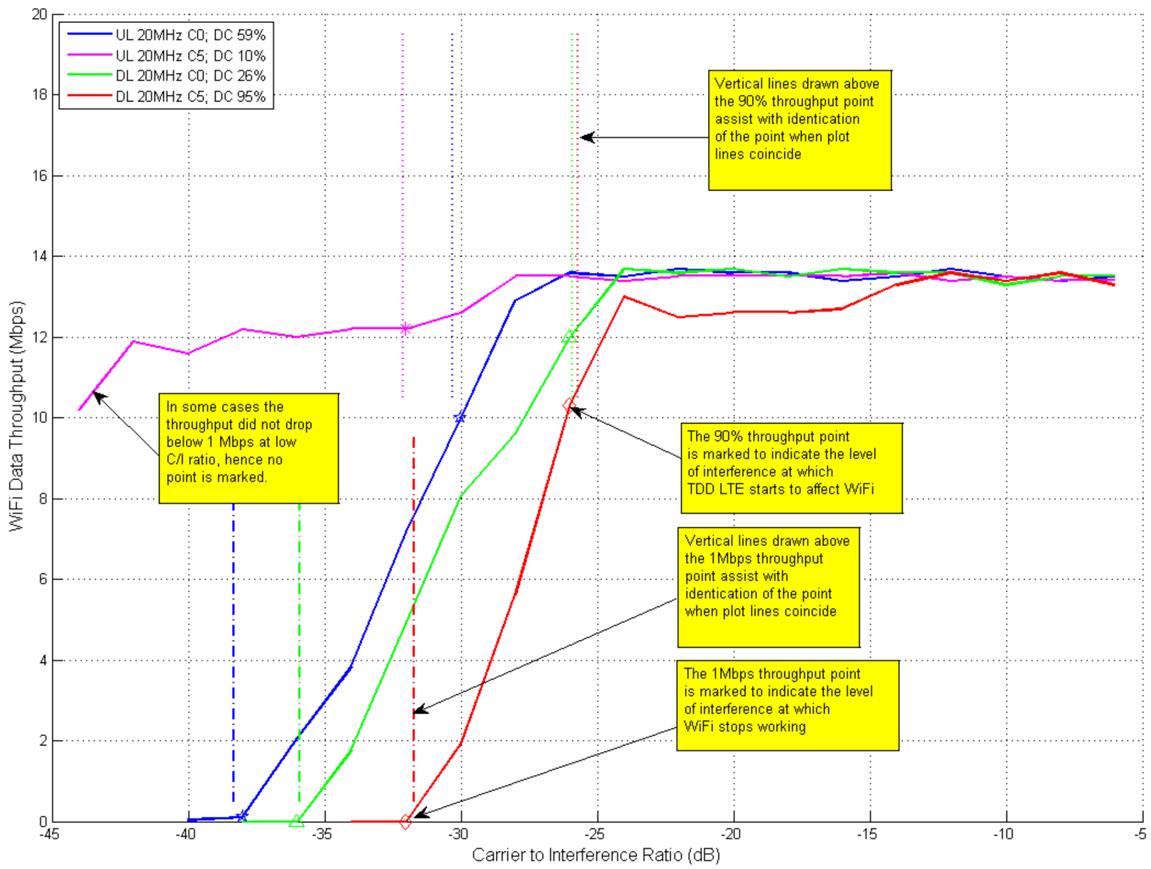


Figure 1: Marking of 1Mbps and 90% throughput points

Note that the 90% throughput point is also commonly referred to as the 'knee', because it is the point at which throughput starts to drop on the throughput versus C/I plot. It is also sometimes referred to as the point at which throughput has dropped by 10% rather than 90% throughput.

The throughput versus C/I plots illustrate the effect of specific interference signals on a DUT for a specific WiFi channel at a specific carrier level above the DUT MUS. The interference points measured for all of the interference signals and WiFi channels used for testing a DUT are grouped together on the Summary plots:

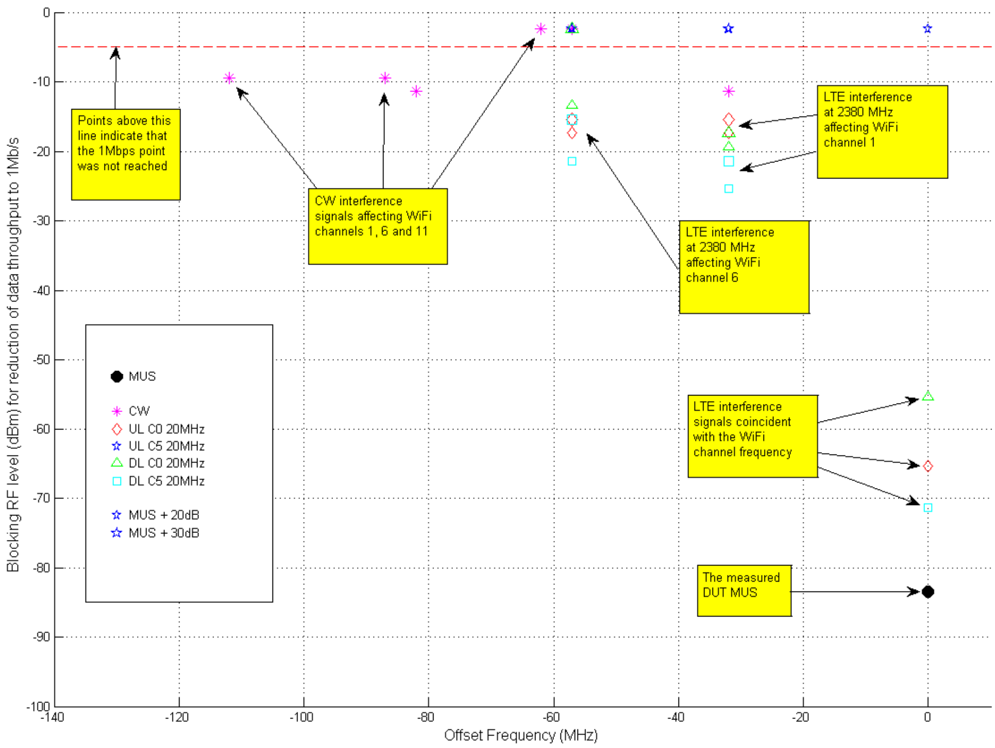


Figure 2: Example of Summary Plot capturing 1 Mbps interference points

A similar “Summary at Knee” plot is provided for analysing the 90% throughput interference points.

An algorithm for extracting these two points has been developed and has been used to show the 1 Mbps and 90% points in this document. The algorithm is not completely reliable, because the C/I versus throughput curves are not always straightforward to interpret and the definitions of the two points do not always give results that are what the human interpreter would expect. For this reason it is recommended that any use of these figures should be visually checked to ensure that the results are commensurate with the analyst’s expectations.

1.2 DUT numbering

In order to maintain anonymity of the devices considered, details of the DUTs themselves are contained in a separate document (Biggs, 2013) which will not be published beyond MASS and Ofcom.

Each DUT was allocated a serial number (e.g. DUT 1) for the purposes. Additionally each DUT was later allocated a group number (e.g. HR1 for a home router) to clarify what type of DUT was being tested. Both numbers are given in this report and either can be used to uniquely identify a DUT.

2 TEST CONFIGURATION

Device Type / ID	DUT #	Test Type	Test Started	Test Completed	Test Script Version	Test Configuration	MUS
Home router HR1	2	2	10/06/13	11/06/13	120	2	-95.4dBm
Home router HR2	6	2	12/06/13	13/06/13	122	2	-98.0dBm
Home router HR2 (test 2)	6	3	02/07/13	02/07/13	149	9	-85.1dBm
Home router HR3	9	2	18/06/13	18/06/13	124	5	-93.0dBm
Home router HR4	14	2	26/06/13	26/06/13	139	5	-91.8dBm
Laptop LP1	1	1	16/05/13	23/05/13	77	1	-91.2dBm
Laptop LP2	3	2	24/06/13	24/06/13	137	6	-90.8dBm
Tablet TB1	5	2	03/06/13	09/06/13	107	1	-95.3dBm
Tablet TB2	15	2	26/06/13	27/06/13	139	7	-90.6dBm
Tablet TB3	19	2	21/08/13	22/08/13	153	11	-89.2dBm
Mobile Phone MP2	12	2	21/06/13	21/06/13	134	6	-89.5dBm
Mobile Phone MP2 (re-test)	12	2	19/08/13	20/08/13	153	11	-82.7dBm
Mobile Phone MP3	16	2	28/06/13	28/06/13	145	8	-89.8dBm
Mobile Phone MP4	18	2	20/08/13	21/08/13	153	11	-90.7dBm
Mobile Phone MP5	20	2	23/08/13	24/08/13	153	11	-86.8dBm
Mobile Phone MP6	21	2	27/08/13	27/08/13	153	11	-88.9dBm
Multimedia dongle MD1	17	2	27/06/13	27/06/13	139	5	-85.8dBm
Outdoor Hotspot OH1	7	2	14/06/13	14/06/13	124	5	-94.8dBm
Outdoor Hotspot OH2	8	2	17/06/13	17/06/13	124	5	-95.1dBm
Outdoor Hotspot OH2 (test 2)	8	3	03/07/13	03/07/13	149	9	-87.1dBm
Outdoor Hotspot OH3	10	2	19/06/13	19/06/13	128	5	-87.5dBm
Outdoor Hotspot OH4	11	2	20/06/13	20/06/13	130	5	-88.6dBm
Outdoor Hotspot OH5	13	2	25/06/13	25/06/13	139	5	-92.1dBm

Table 1: Test Configuration Details

Key

DUT # — Device Under Test ID. See MC/SC1050/REP004 for actual device details

Test Type
1 — Full set of “Essential” tests
2 — Reduced set of “Essential” tests
3 — Additional tests agreed with Ofcom

Test Configuration
1 — Iperf client; ZyXEL router; DUT as Iperf server. RF Amp 1
2 — Iperf client; EnGenius bridge; DUT; Iperf server. RF Amp 1
3 — Iperf client; EnGenius bridge; DUT; Iperf server. RF Amp 1; 20dB attenuators to reduce noise floor
4 — Iperf client; ZyXEL bridge; DUT; Iperf server. RF Amp 2; 10dB attenuator to reduce noise floor
5 — Iperf client; ZyXEL bridge; DUT; Iperf server. RF Amp 2; 6dB attenuator to reduce noise floor
6 — Iperf client; ZyXEL router; DUT as Iperf server. RF Amp 2; 6dB attenuator to reduce noise floor
7 — Iperf client; ZyXEL bridge; DUT; Iperf server. RF Amp 2; 6dB attenuator to reduce noise floor
8 — Web Server; ZyXEL router; DUT as Media Client. RF Amp 2; 6dB attenuator to reduce noise floor
9 — Iperf client; ZyXEL bridge; DUT as Iperf server. RF Amp 2

10	Iperf client; Long cable; ZyXEL router; DUT as Iperf server. RF Amp 2; Long cable
11	Test configuration for additional devices. Iperf client; ZyXEL router; DUT as Iperf server. RF Amp 2; 6dB attenuator to reduce noise floor
MUS	minimum magnitude of wanted WiFi signal required to produce a response in the DUT in Channel 1

3 AGGREGATED TEST RESULTS

This section contains the aggregated results for all DUTs tested in Ofcom's Baldock chamber test facility.

The main features of the aggregated plots are:

- The x-axis values are the absolute RF level of blocking in dBm, for either 1Mbps or 90% throughput;
- The y-axis represents either the frequency offset in MHz when separated on the basis of offset frequency, or else dB above MUS when separated on the basis of wanted level;
- The distribution of blocking levels over the grouped DUT and modulation types is represented as a box plot. The box plot represents the range, median and inter-quartile points;
- Protection distance scales are included for a LTE BS of +60dBm EIRP and three attenuation indexes. An attenuation index of 2 corresponds to a minimum coupling loss in free space;
- A protection distance scale is included for a LTE UE of +23dBm EIRP. This is minimum coupling loss in free space only;
- The plot shown in Figure 3 is for all DUT, both modulation types and all wanted levels against frequency offset;
- The plot shown in Figure 4 is for all DUT, the lower duty cycle modulation type and all wanted levels against frequency offset;
- The plot shown in Figure 5 is for all DUT, both modulation types and all offsets against wanted level;
- Plots of both modulation types and all offsets against wanted level are then provided for the six types of DUT, with separate graphs for each of the two interference points (1 Mbps and 90%), in Figure 6 and Figure 7.

Note that these aggregated plots have not been updated for issue 3 of this document. The results of DUT 4 have not been removed. This is not expected to significantly affect the main conclusions.

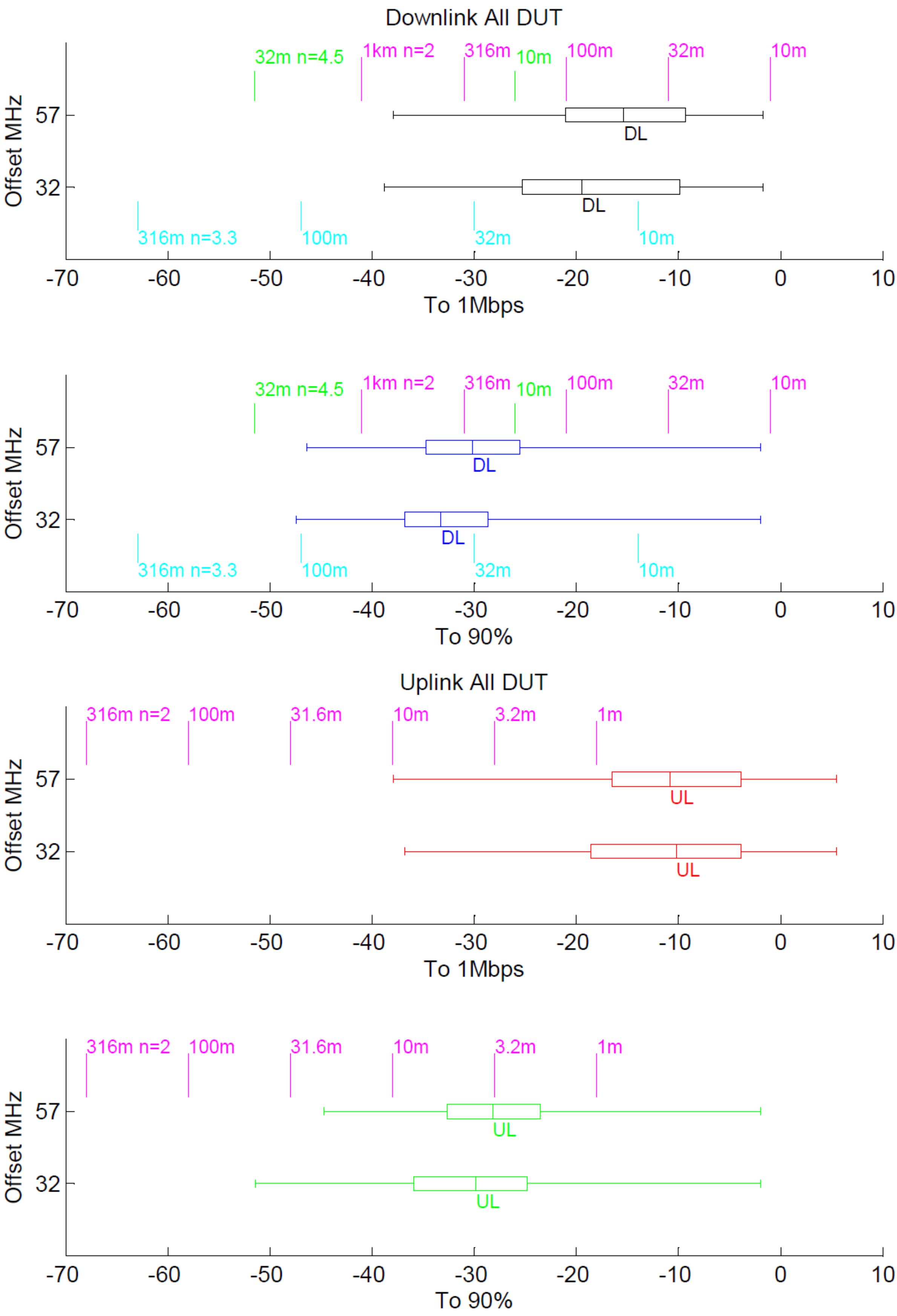


Figure 3: TDD LTE power levels causing disruption to WiFi (all DUTs)

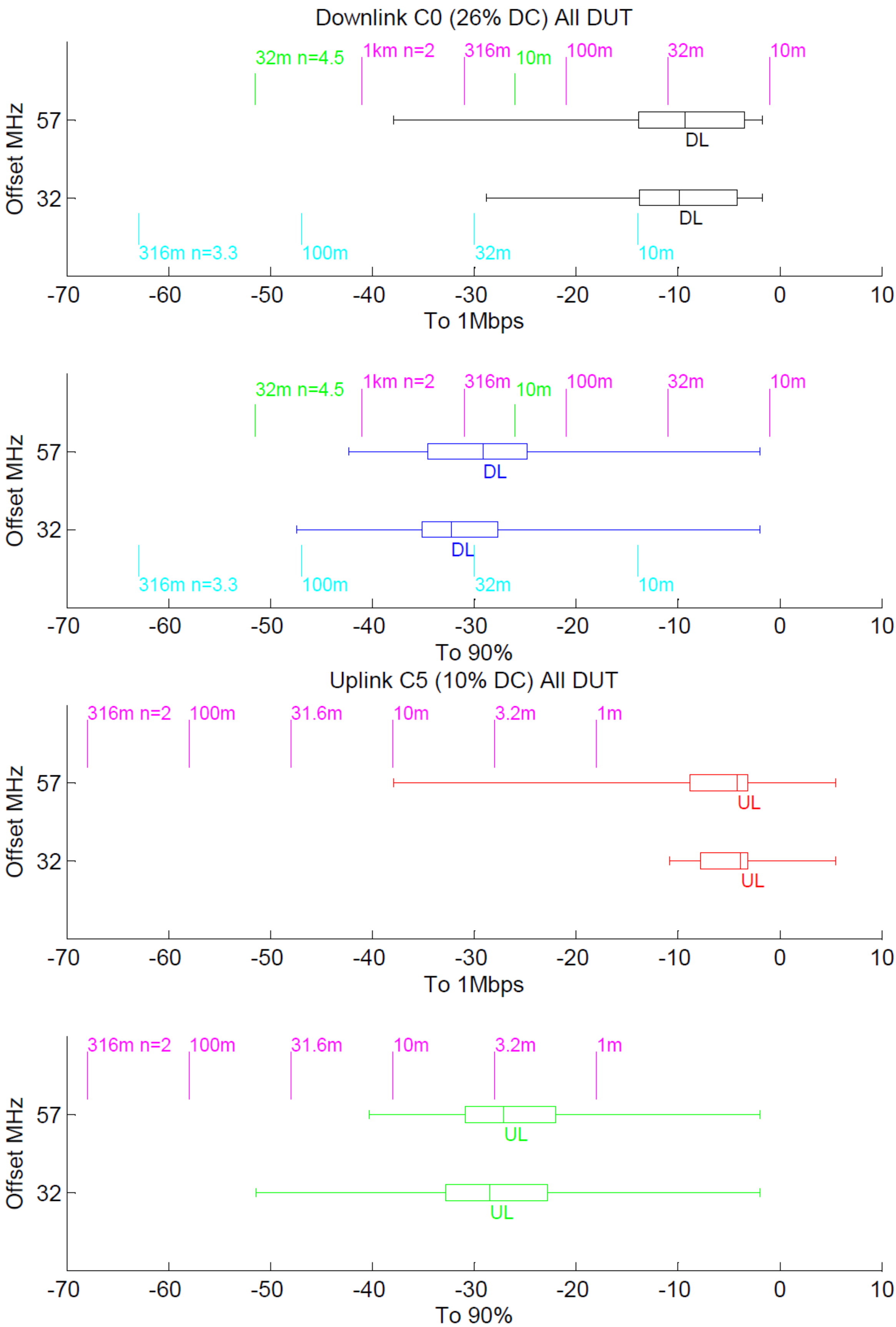


Figure 4: TDD LTE power levels causing disruption to WiFi (all DUTs, low duty cycle TDD LTE only)

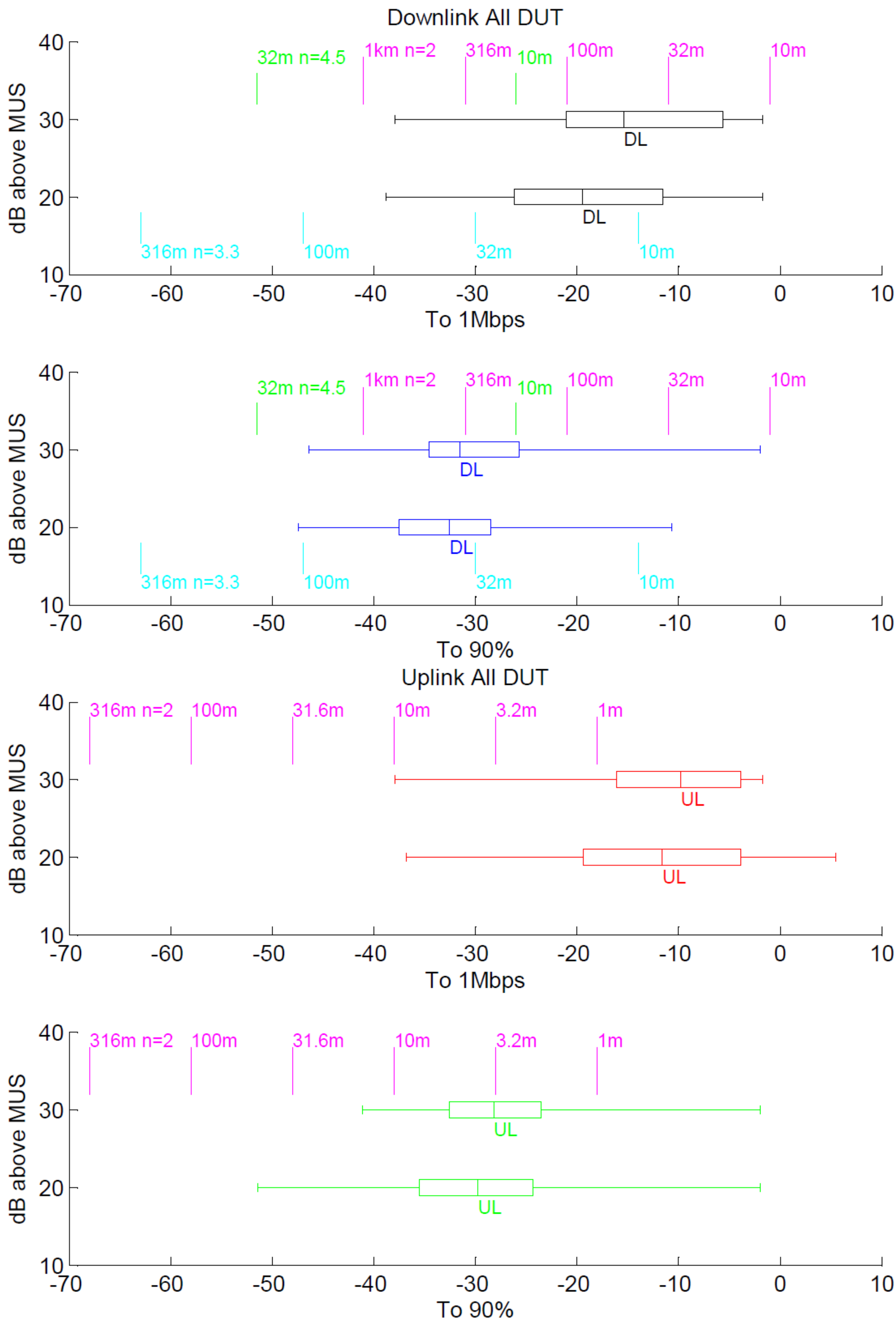


Figure 5: TDD LTE power levels causing disruption to WiFi at different WiFi levels (all DUTs)

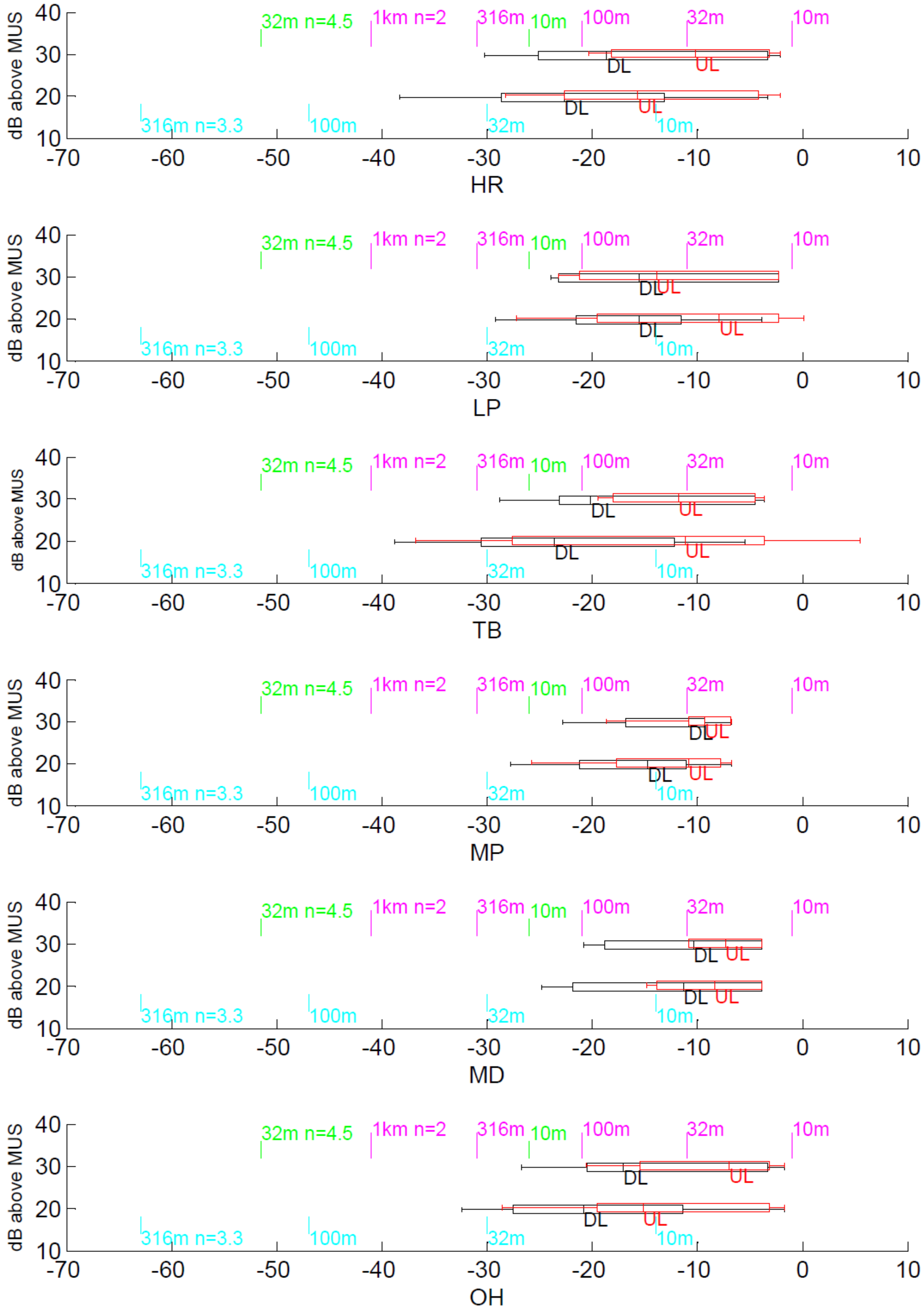


Figure 6: Level above MUS versus TDD LTE EIRP for different DUT types at 1Mbps point

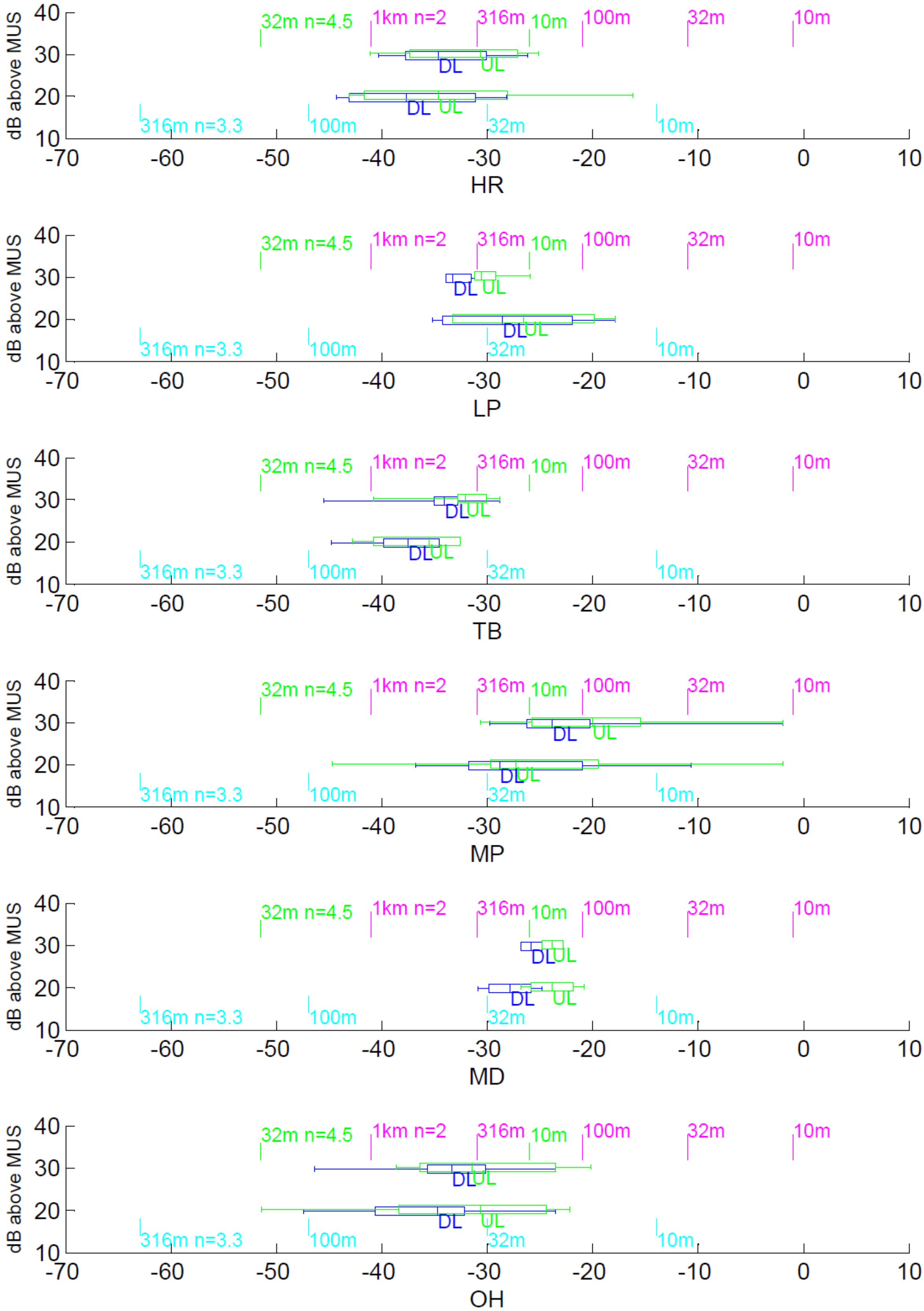


Figure 7: Level above MUS versus TDD LTE EIRP for different DUT types at 90% point

4 DUT TEST RESULTS

This section contains the detailed results for each individual DUT tested in Ofcom's Baldock chamber test facility.

The CW and LTE test settings used for the majority of the tests (Test Type 2) are specified in the Test Parameters section of the main report (Wagstaff, 2013).

The additional test settings used for Test Type 1 (for DUT1) and Test Type 3 (DUT6 and DUT8) are stated in the relevant section for each DUT in this document.

All tests were performed with copolarised antennas. It was established during testing that the WiFi antennas generally used vertical polarisation. To avoid using special test jigs to hold devices in the vertical position, the devices were placed flat on the turntable in the chamber, and the test antenna polarisation was adjusted to match the device orientation.

4.1 Home Routers

4.1.1 Home Router HR1 (DUT 2)

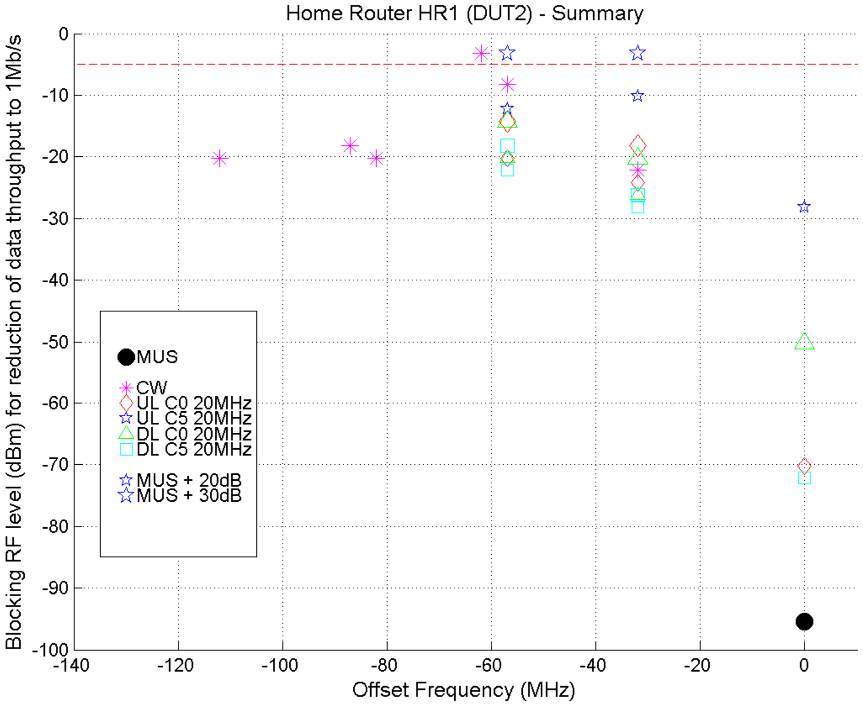
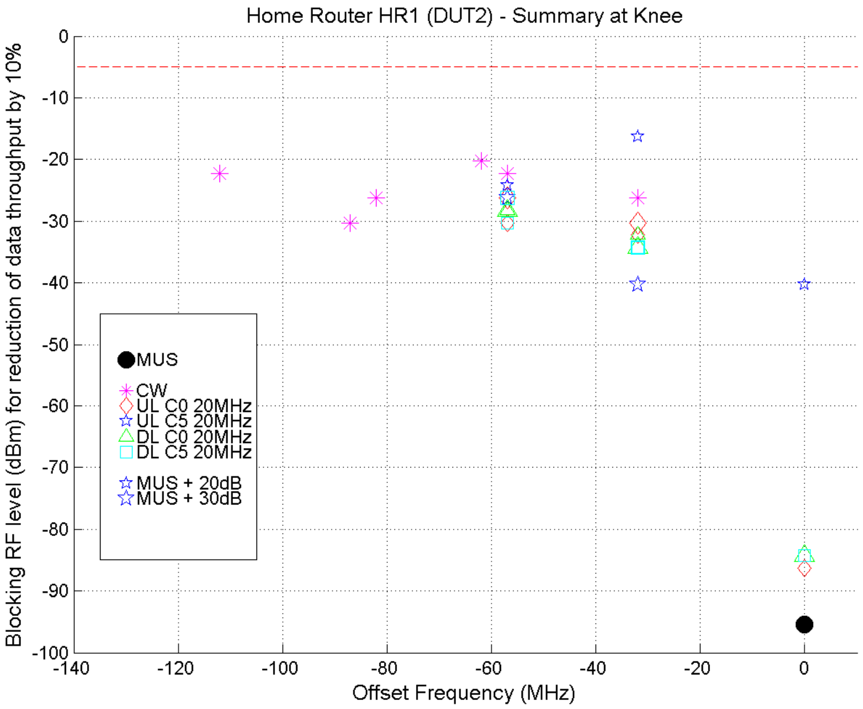


Figure 8



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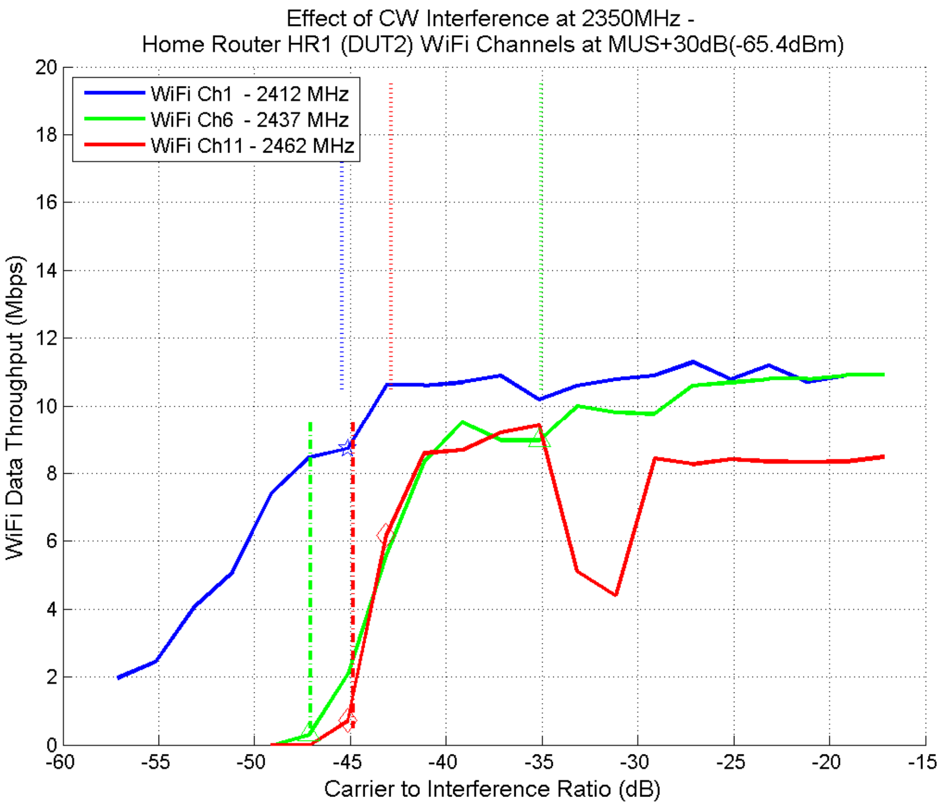

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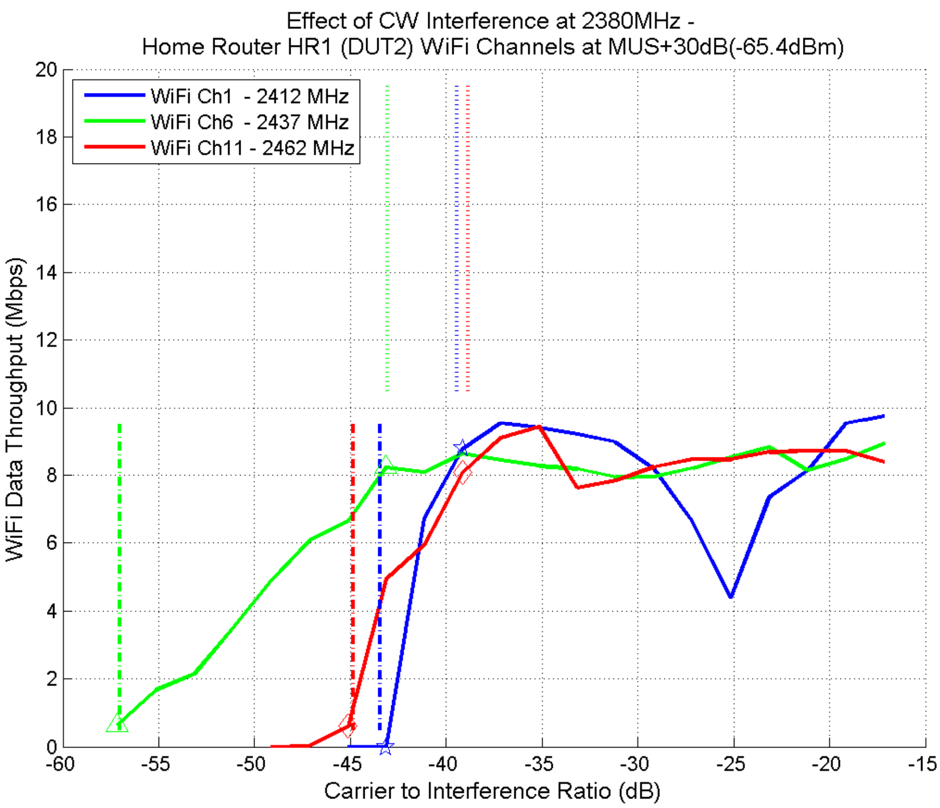

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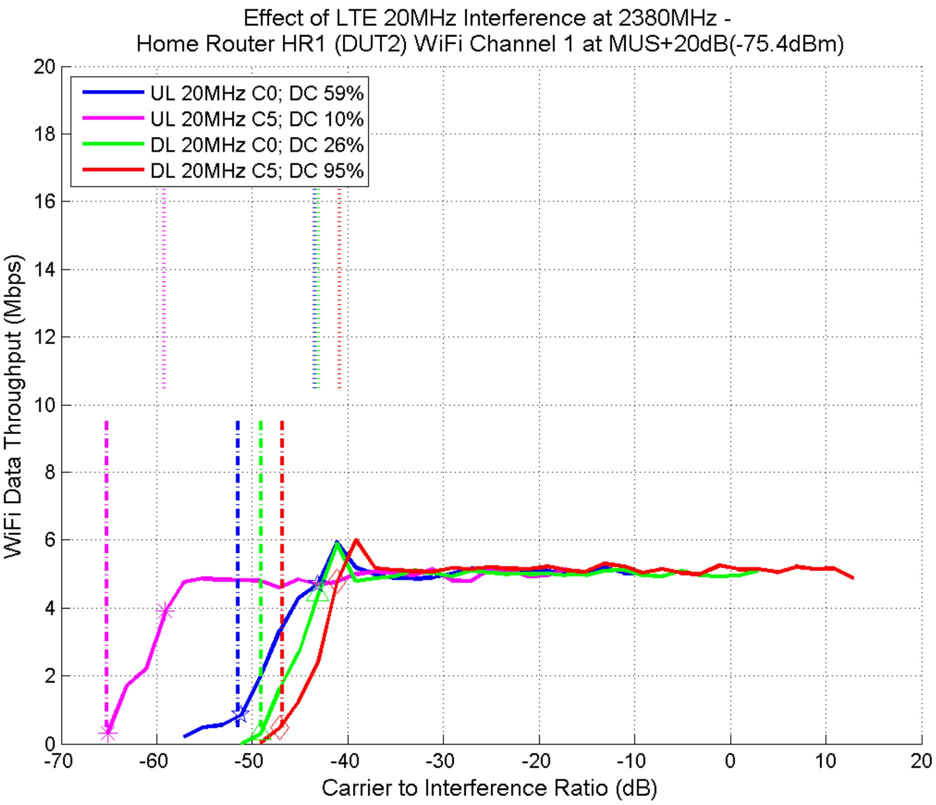

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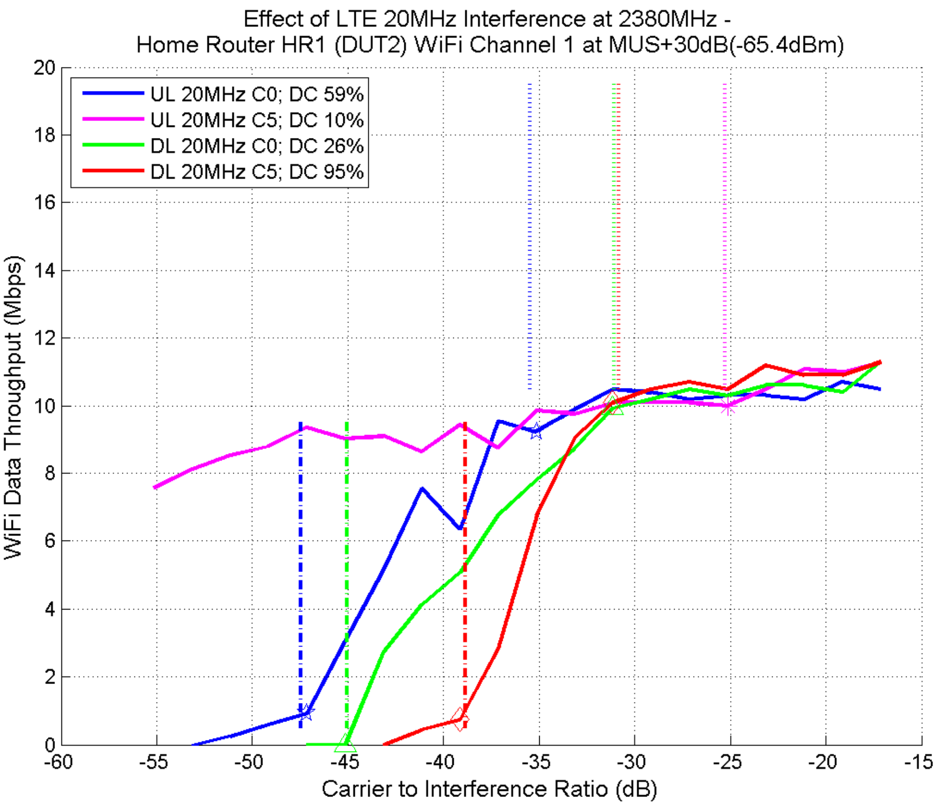

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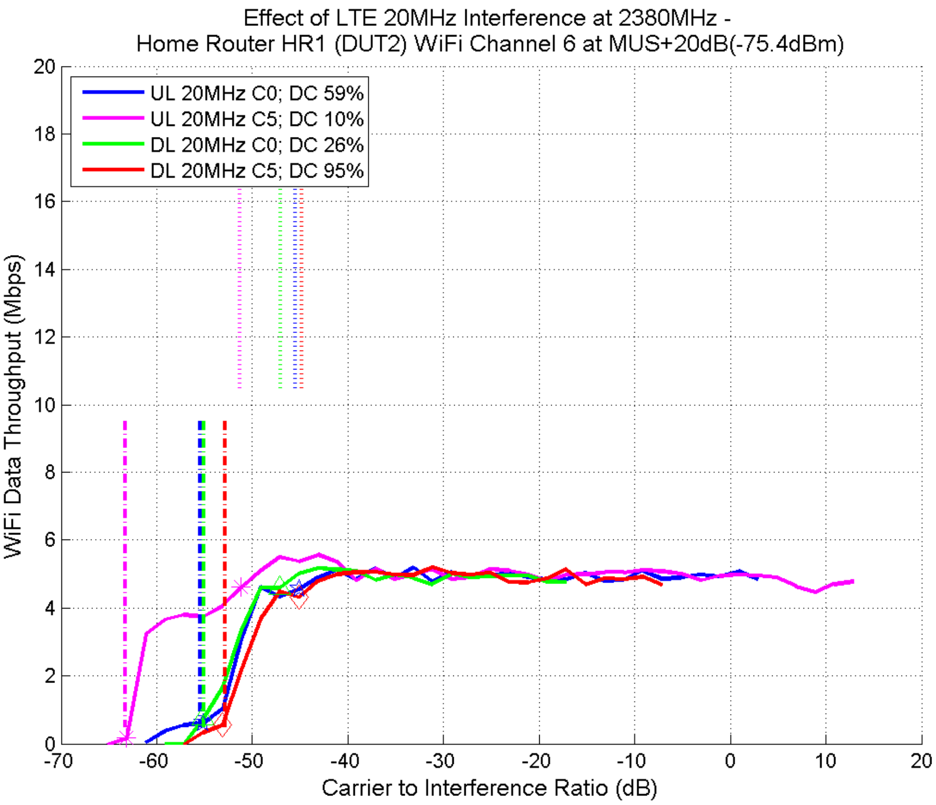

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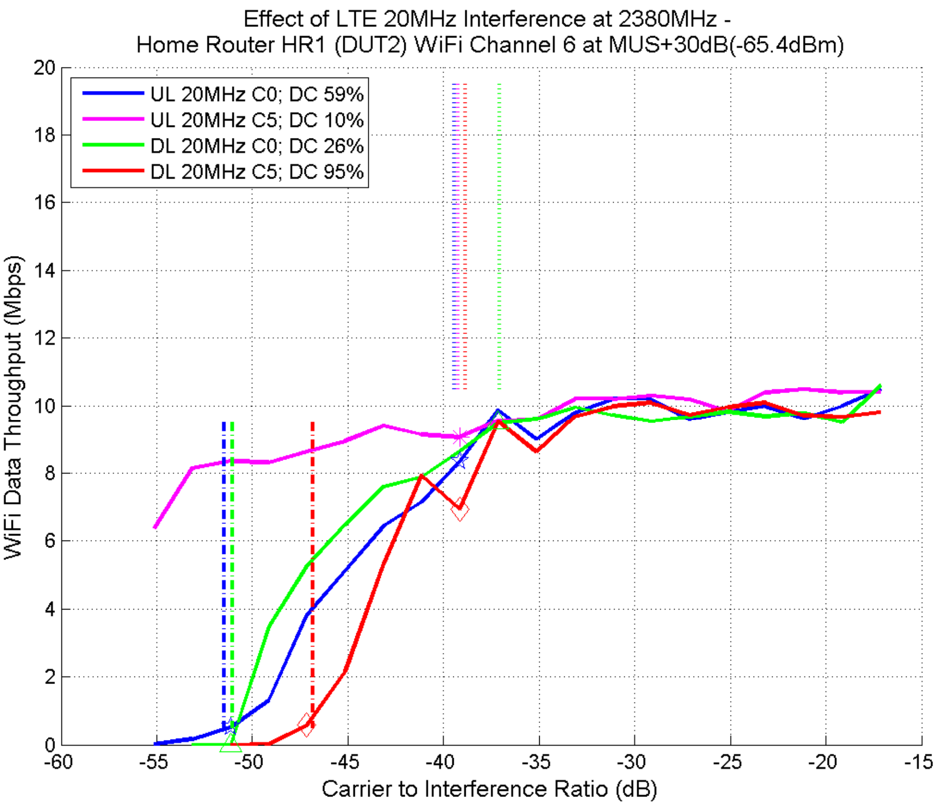

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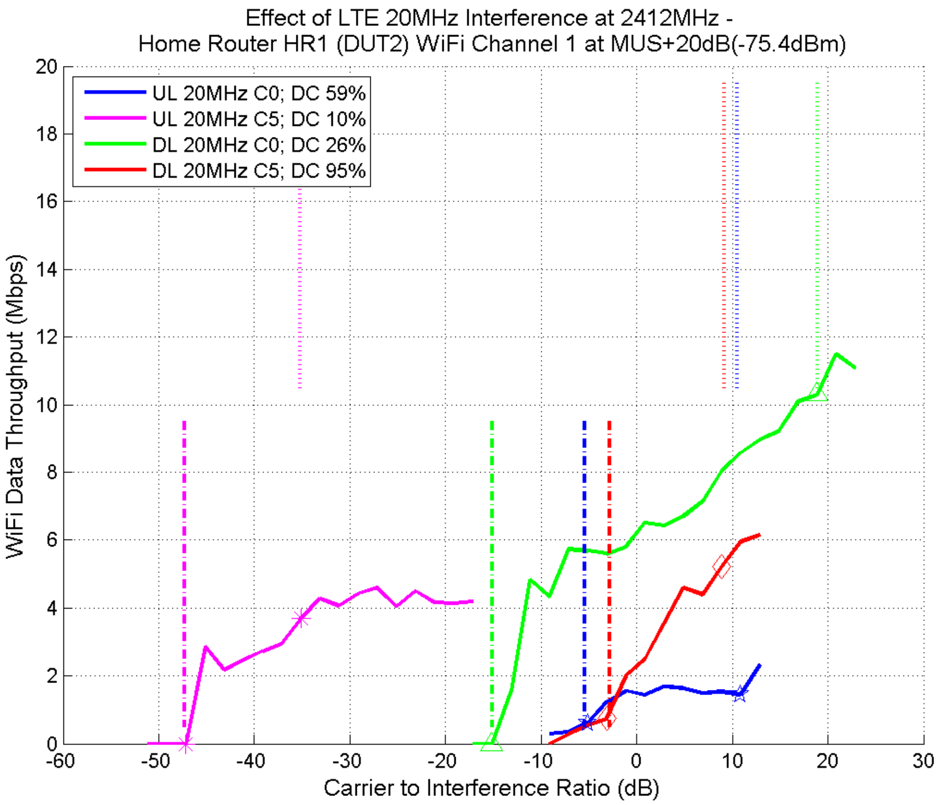


Figure 16

Observations

- This DUT was vertically polarised and approximately omnidirectional.
- Throughput can be seen to be poor, although this may have been limited by the EnGenius test device which was later replaced.

4.1.2 Home Router HR2 (DUT 6)

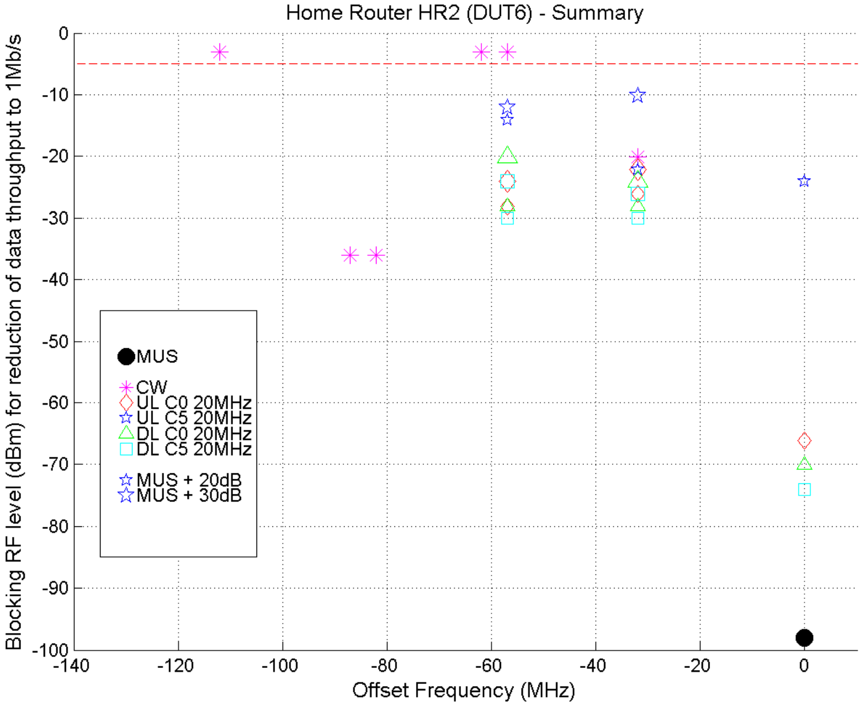


Figure 17

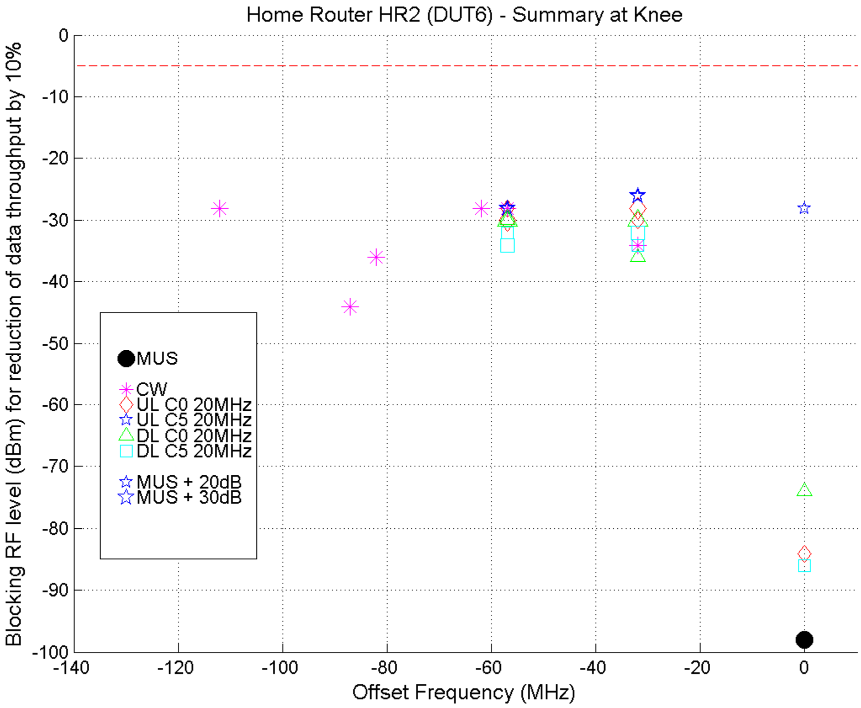
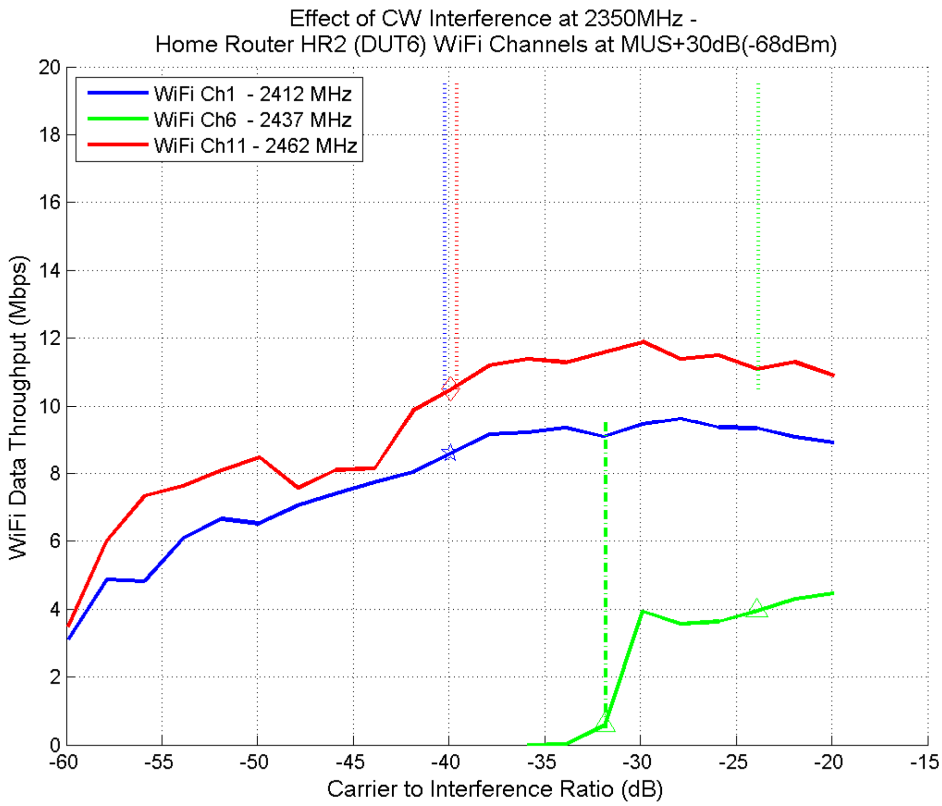


Figure 18



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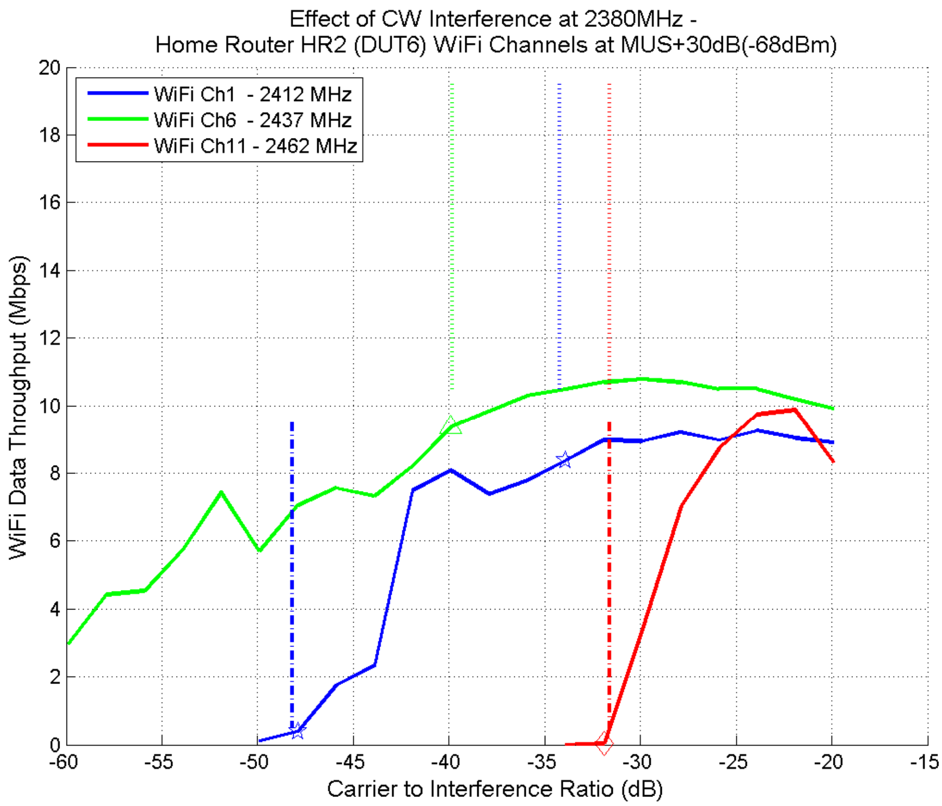

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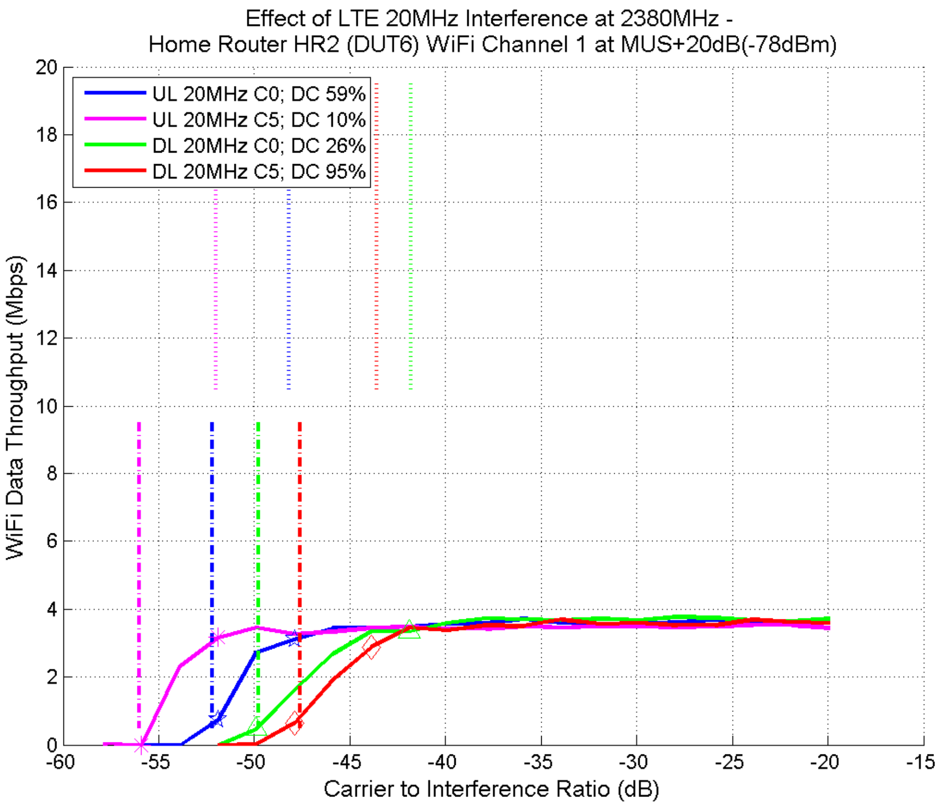

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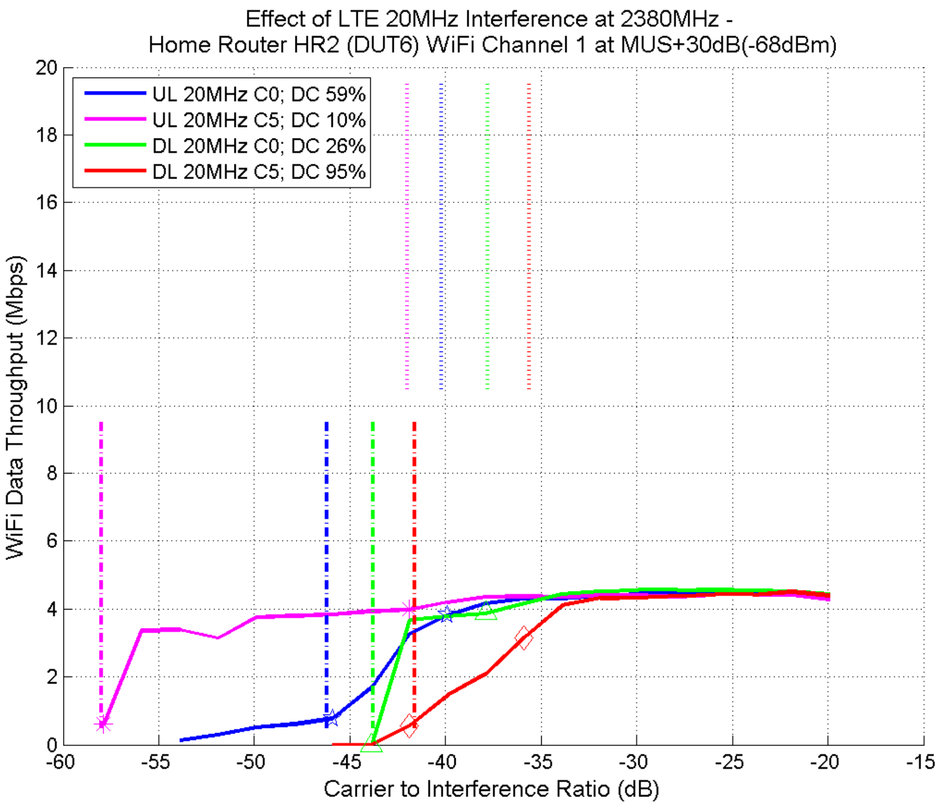

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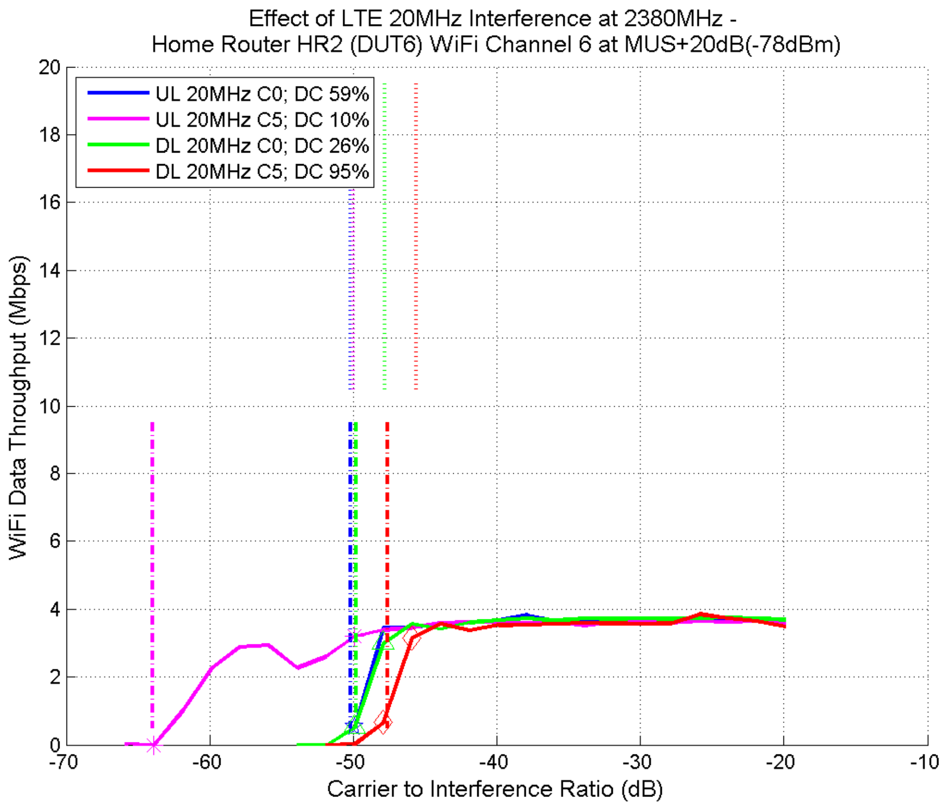

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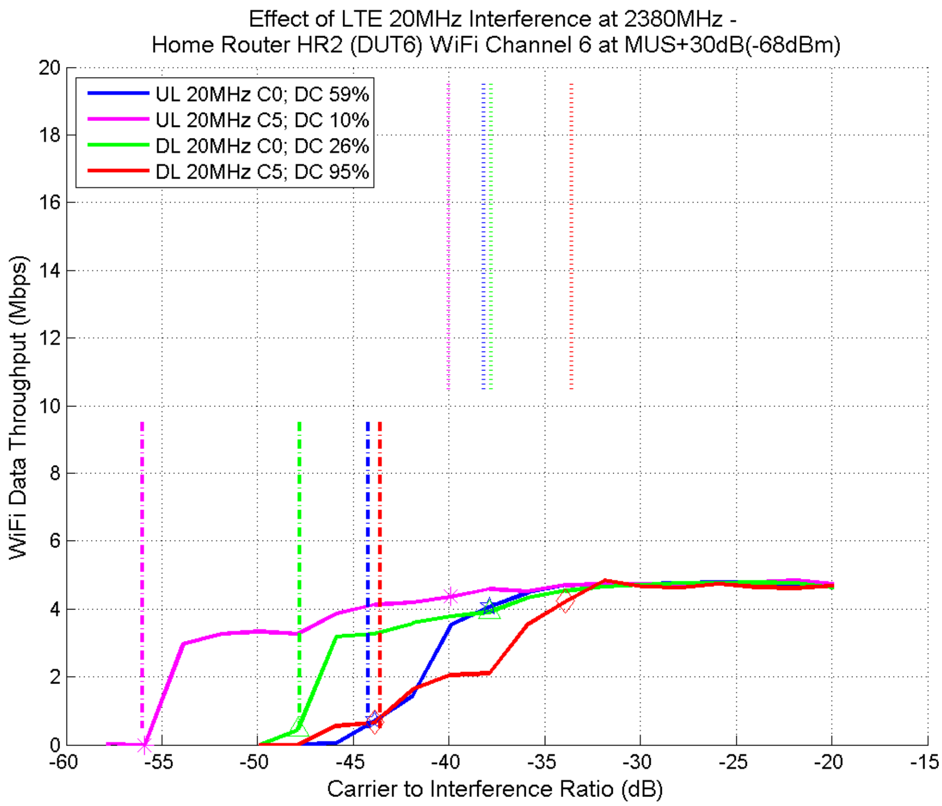

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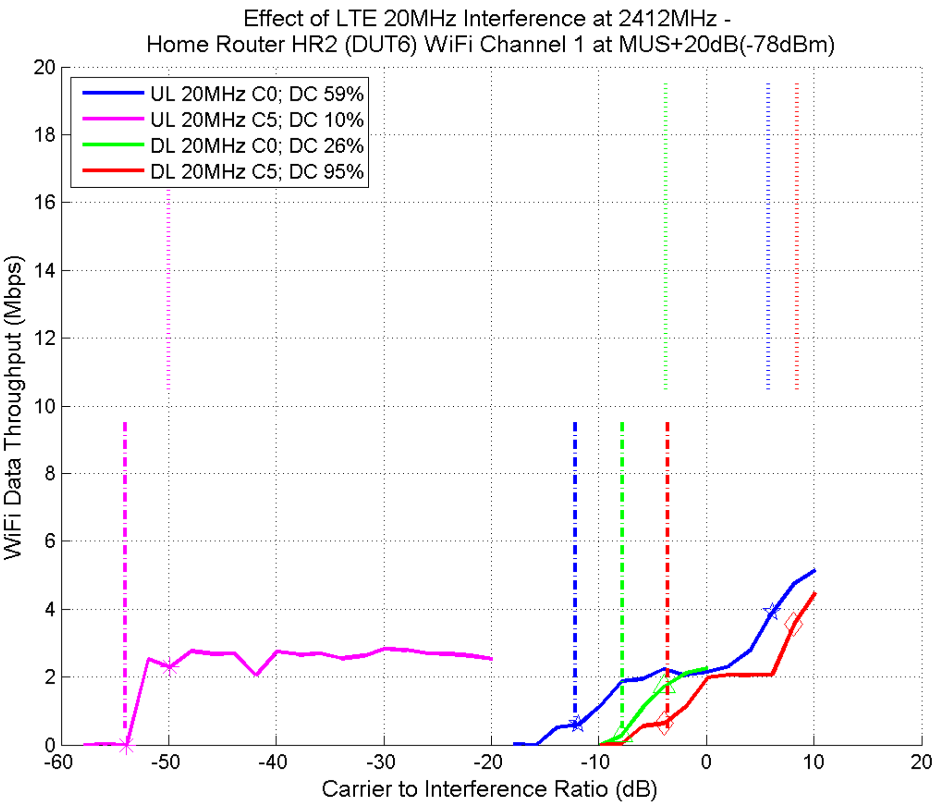


Figure 25

Observations:

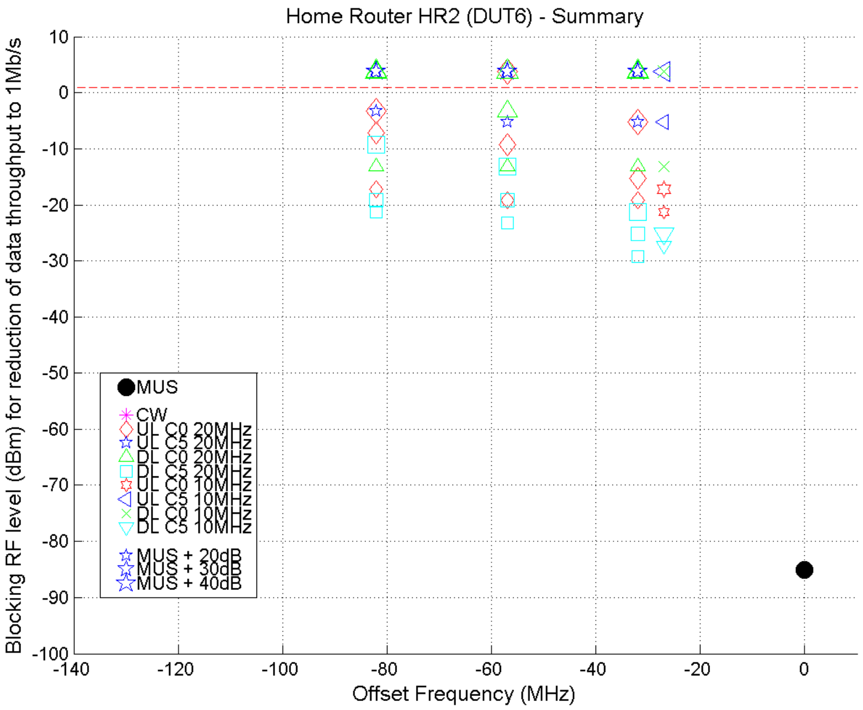
- Throughput can be seen to be poor, although this may have been limited by the EnGenius test device which was later replaced.
- To eliminate the effect of the EnGenius, additional tests (see the following section) were performed on DUT6, using home router HR1 in client bridge mode as the test device injecting the Wi-Fi signal.

4.1.2.1 Additional Out of Band Tests

The WiFi and LTE settings for the LTE additional out-of-band (OOB) tests for DUT6 are shown below:

WiFi Receiver Sensitivity	WiFi Channels	LTE Channel Bandwidth	LTE Frequency Offsets	LTE Frame Structure
MUS +20dB, +30dB, +40dB	1, 6, 11	20MHz	2380MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB, +30dB	1	10MHz	2385MHz	UL_C0, UL_C5, DL_C0, DL_C5

Table 2: Additional OOB Test Settings for DUT6



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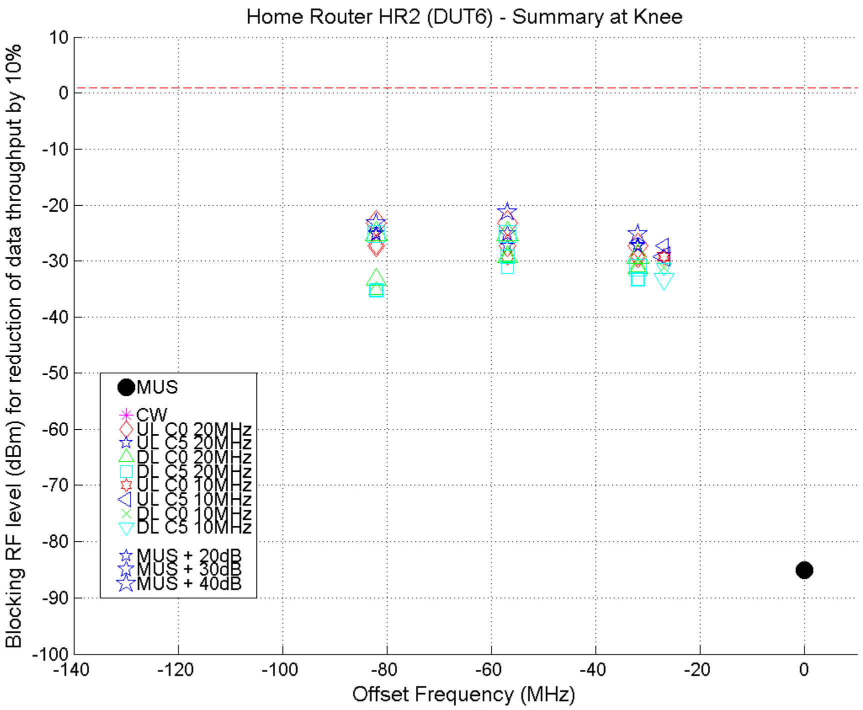

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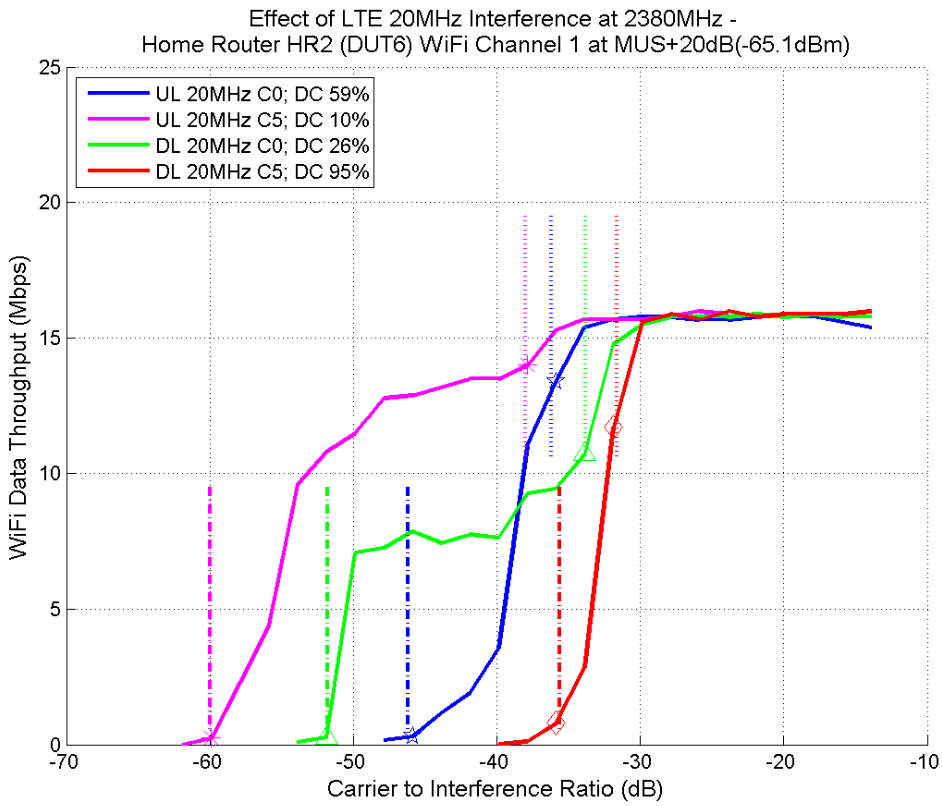

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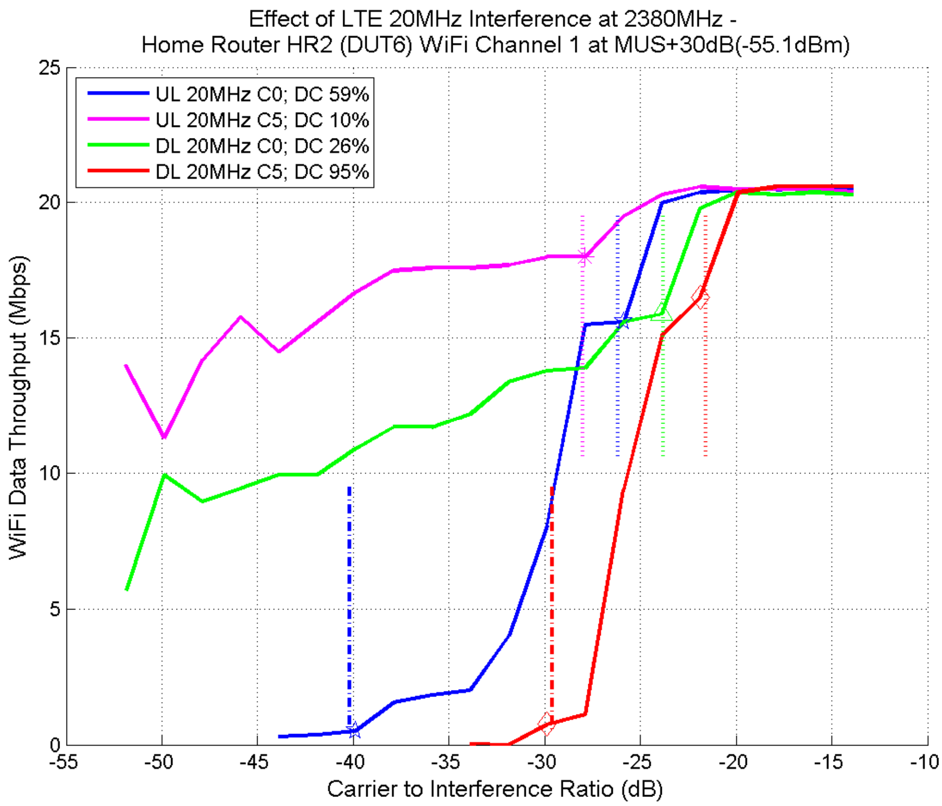

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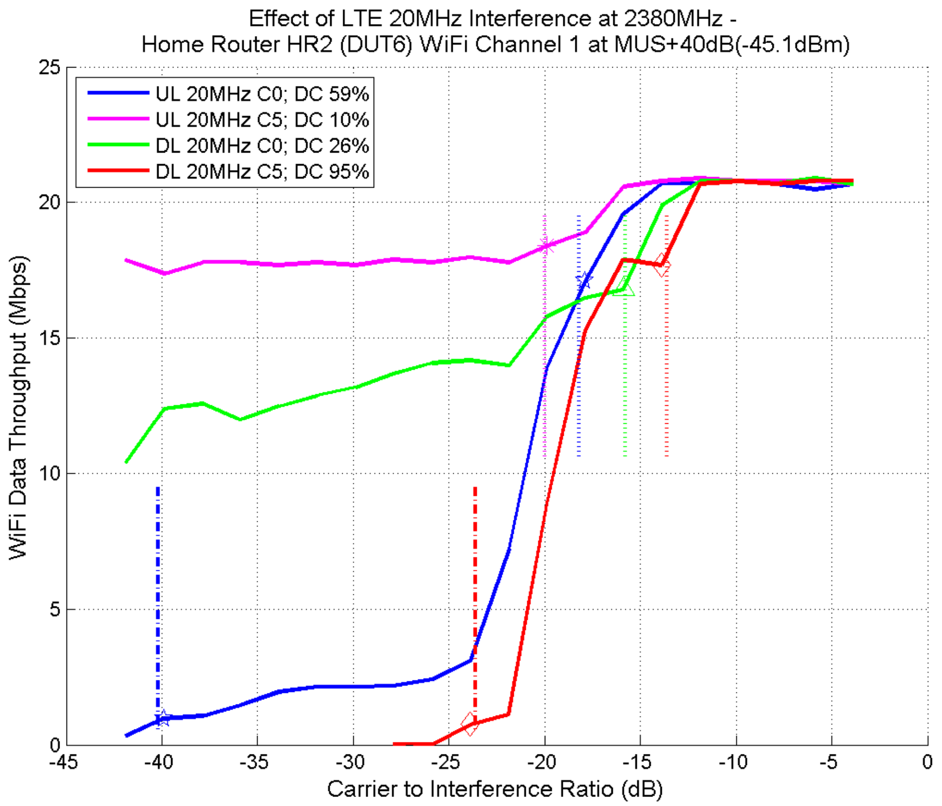

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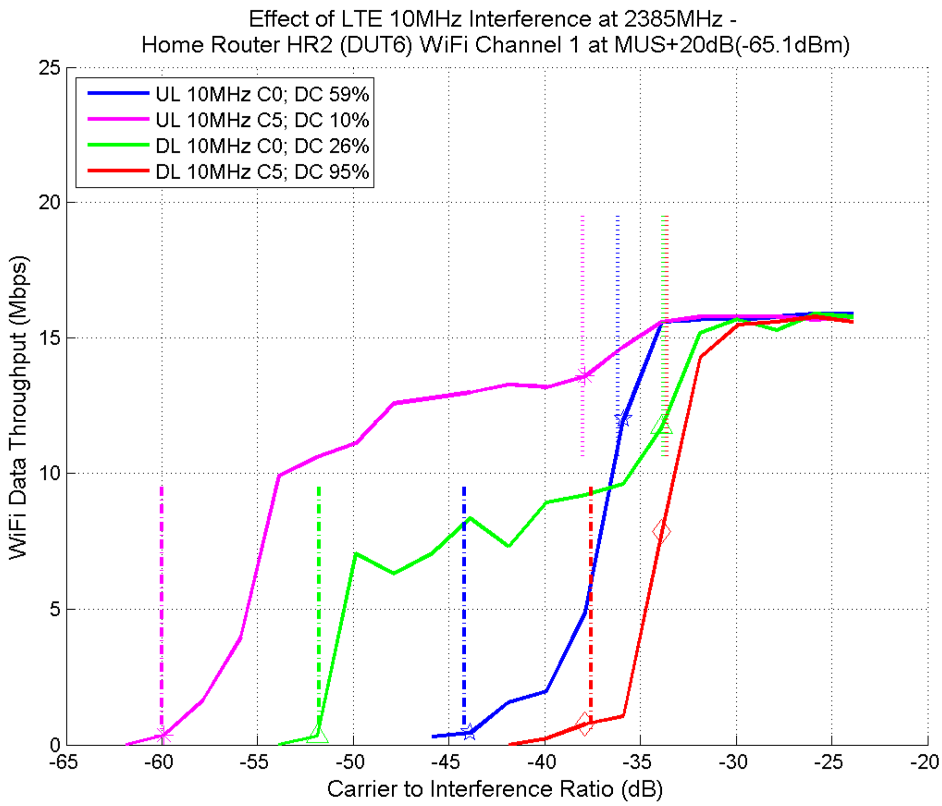

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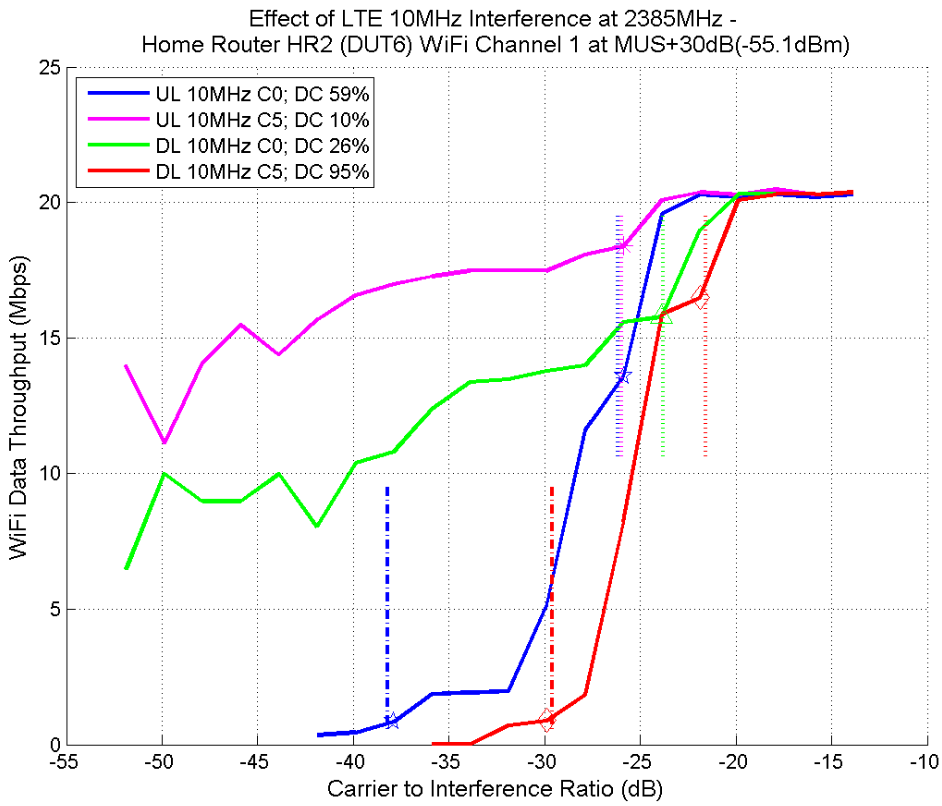

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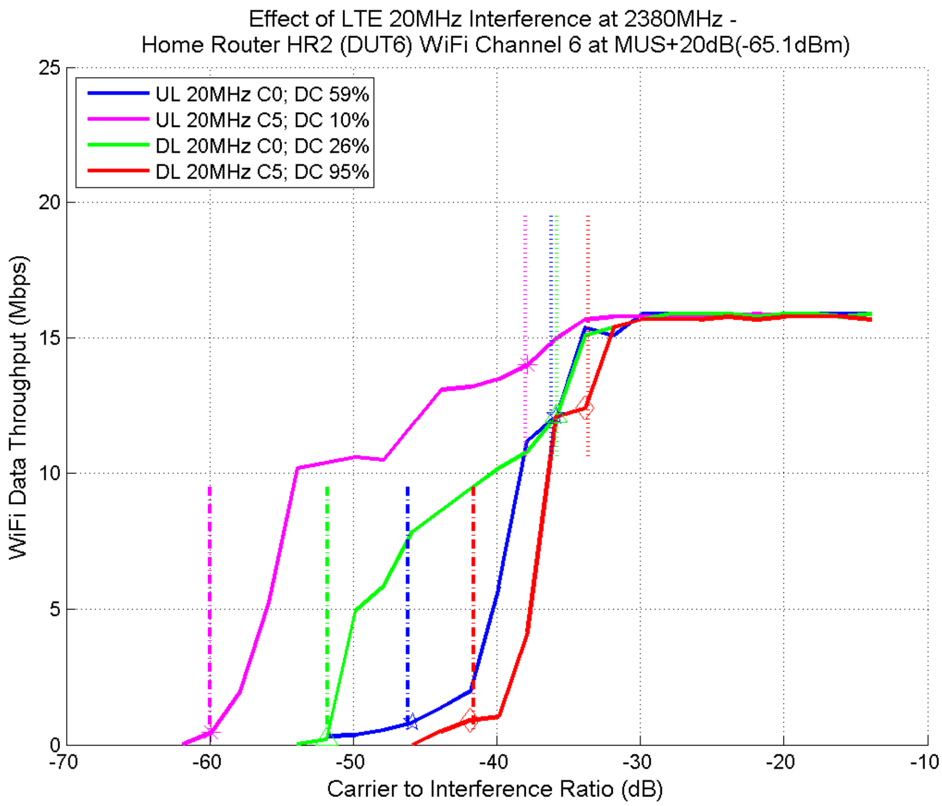
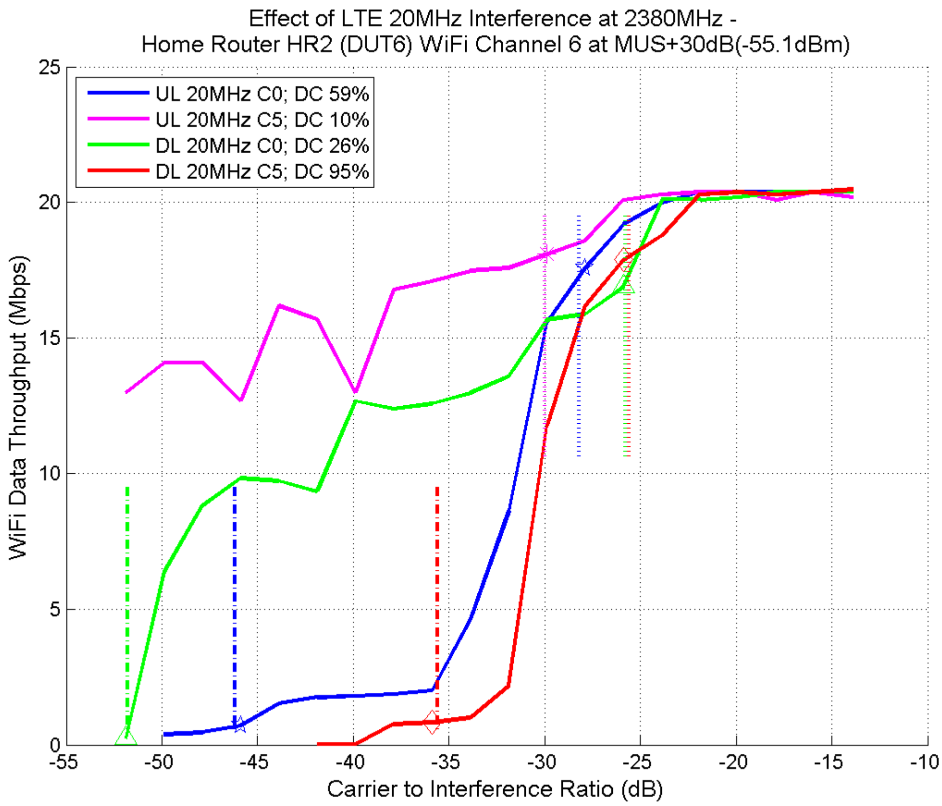


Figure 33



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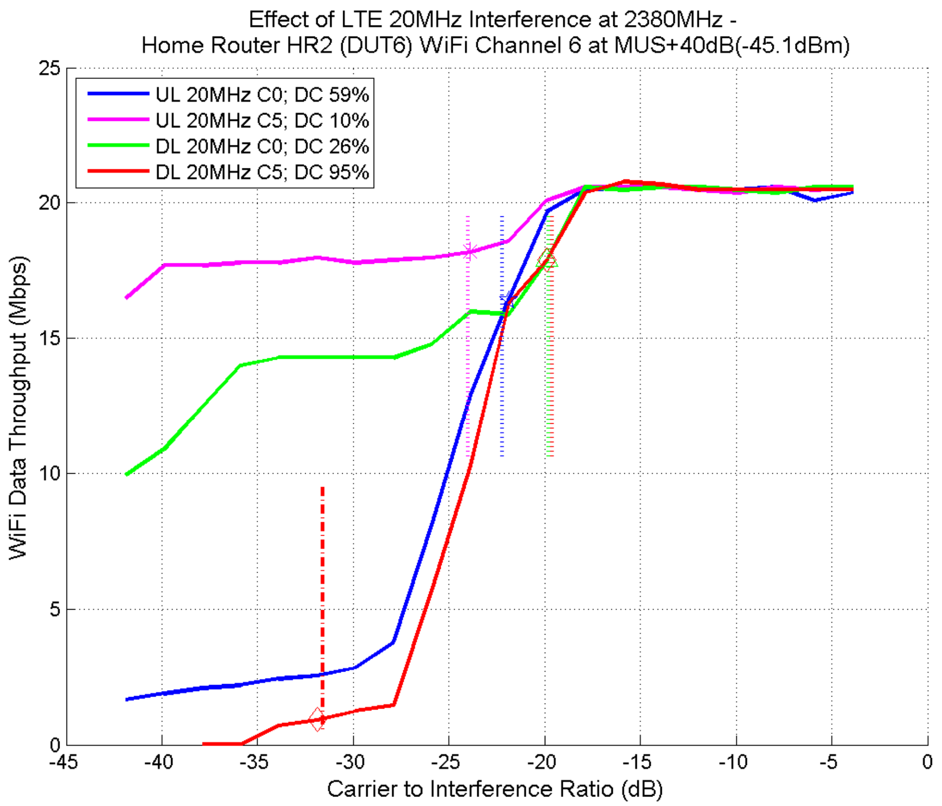

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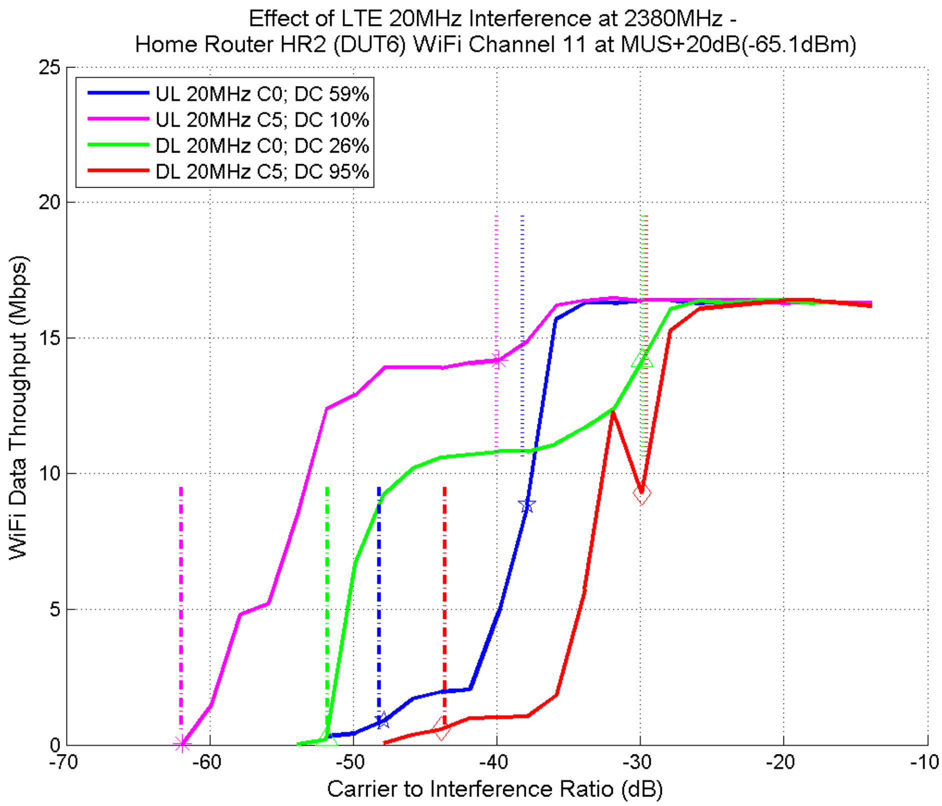

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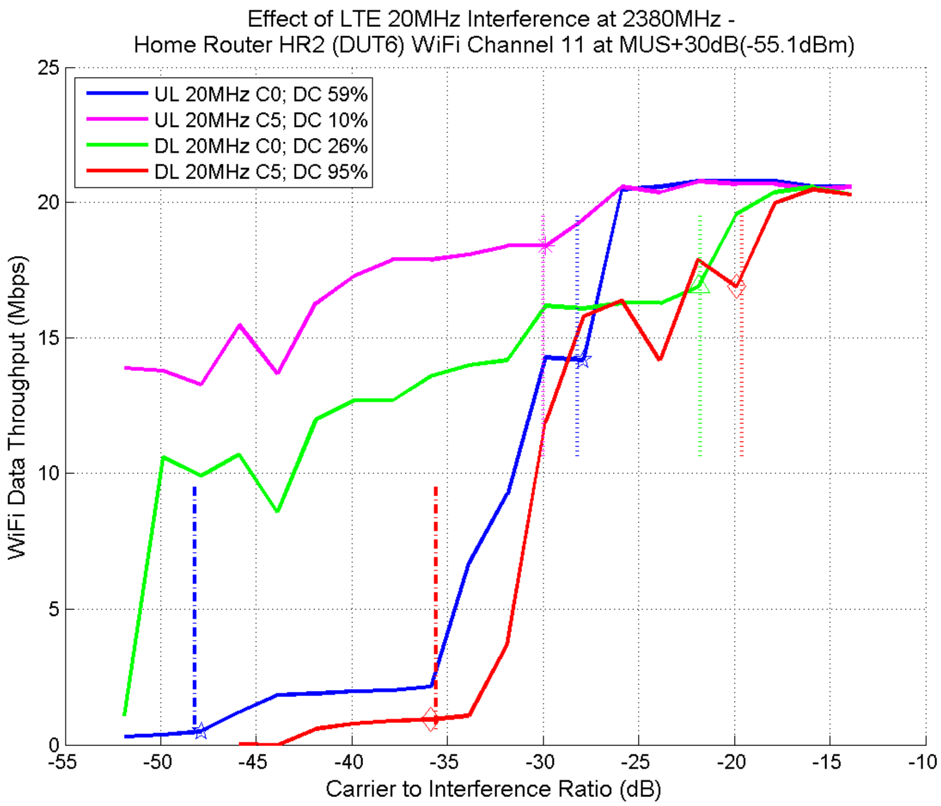

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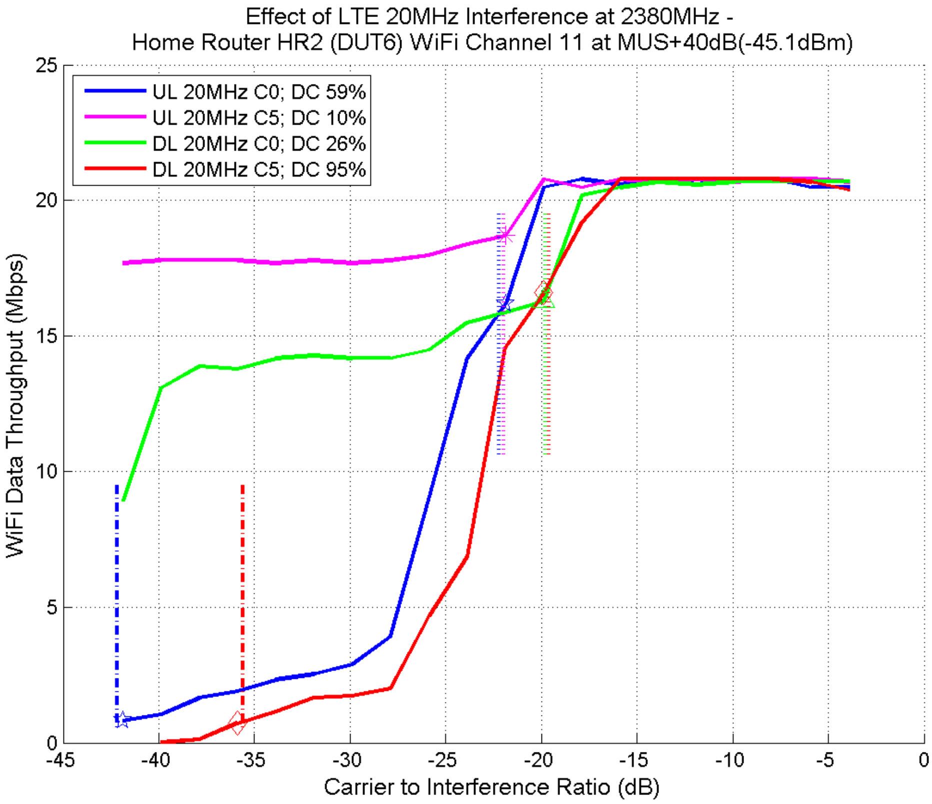
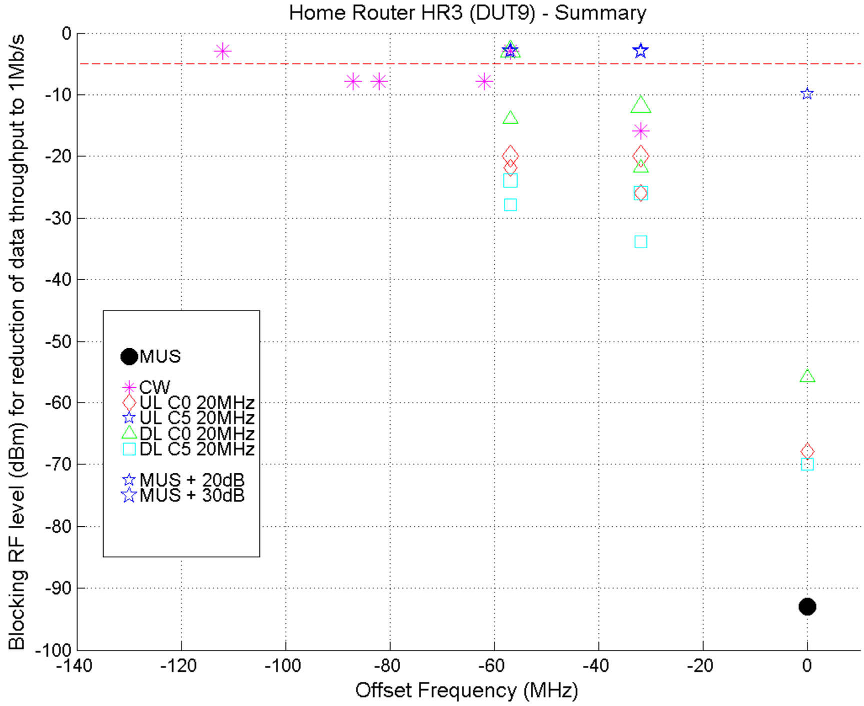


Figure 38

Observations

- At offsets greater than 50MHz, the blocking is independent of the offset frequency.
- At MUS +40dB, the expected improvement in blocking is achieved with respect to the MUS +20dB and +30dB results.
- Overall WiFi data throughput is in line with expectations following replacement of the EnGenius test device.

4.1.3 Home Router HR3 (DUT 9)



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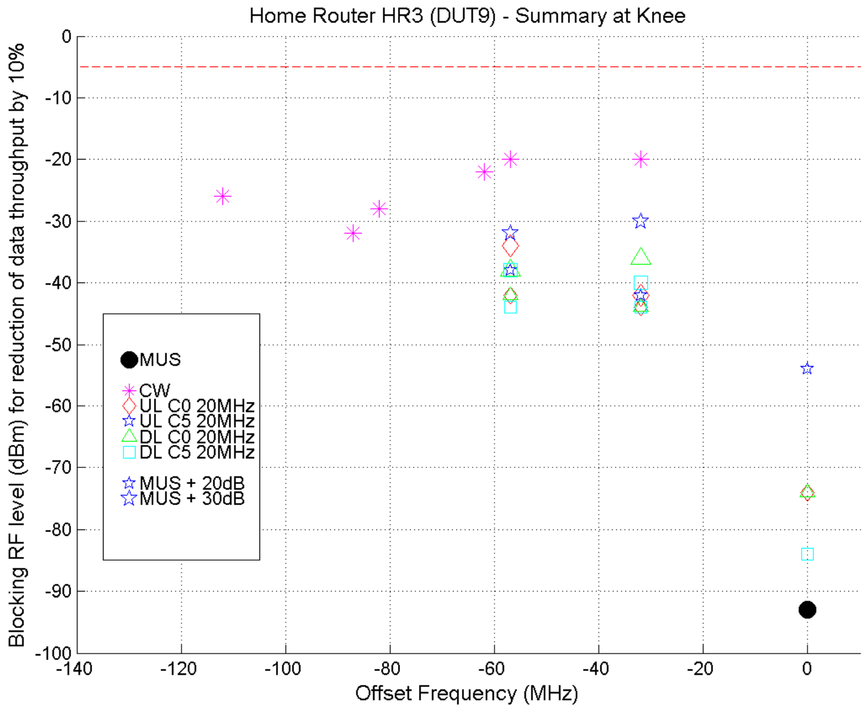

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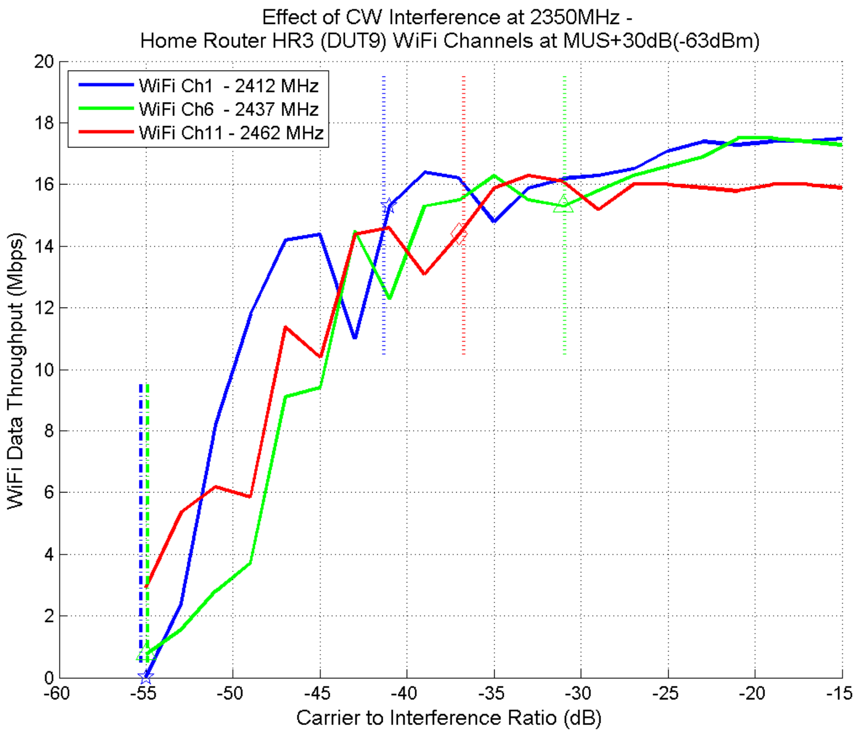
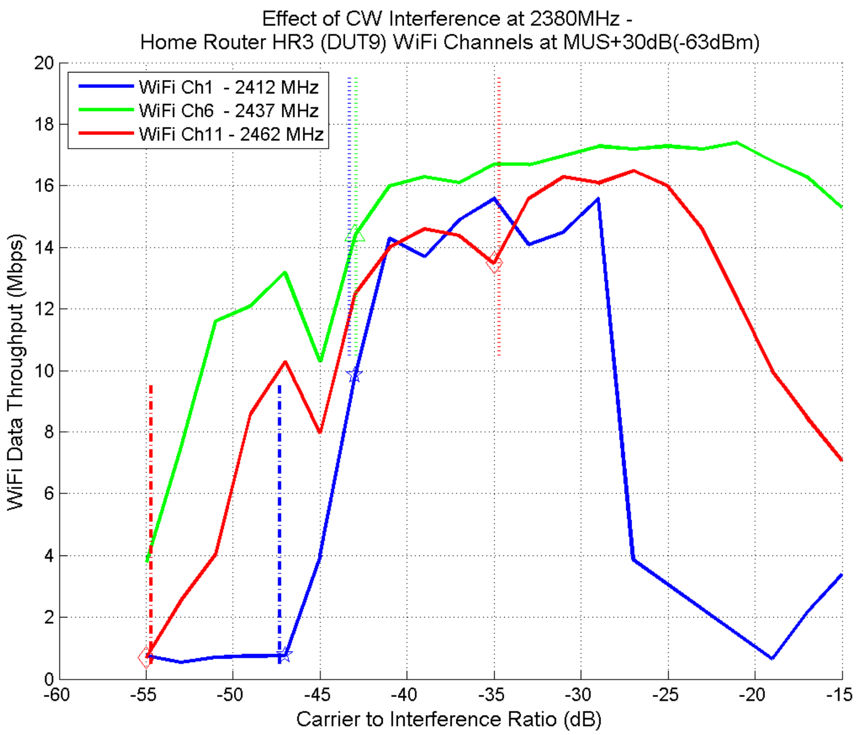


Figure 41



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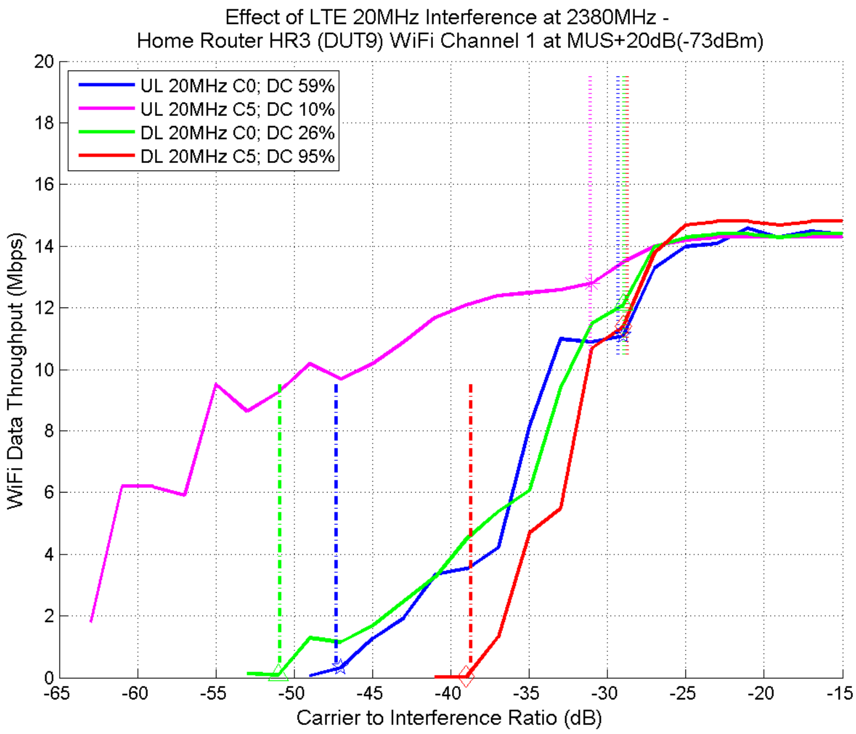

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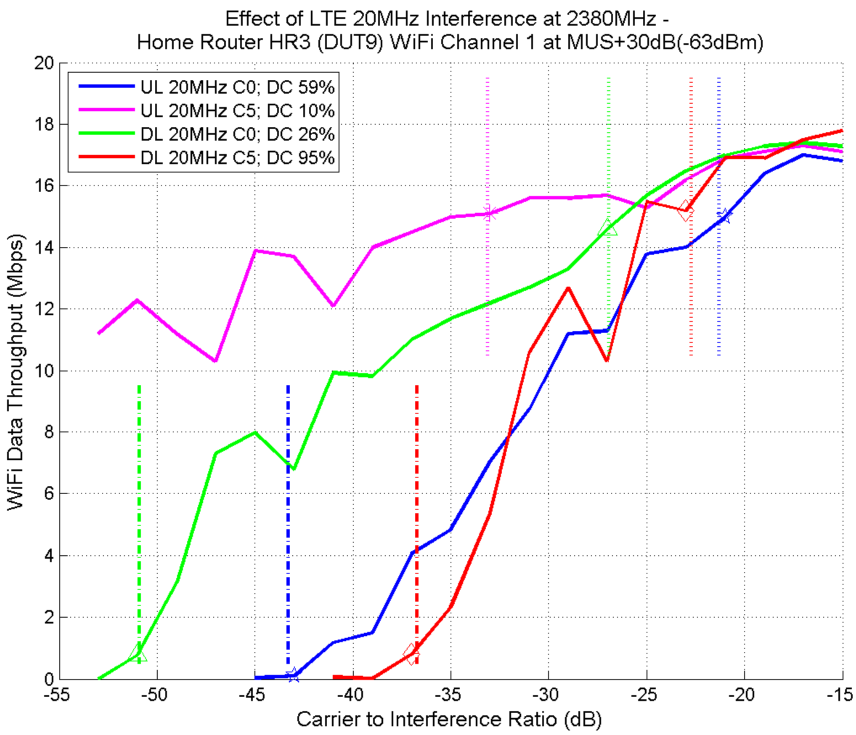

Figure 44

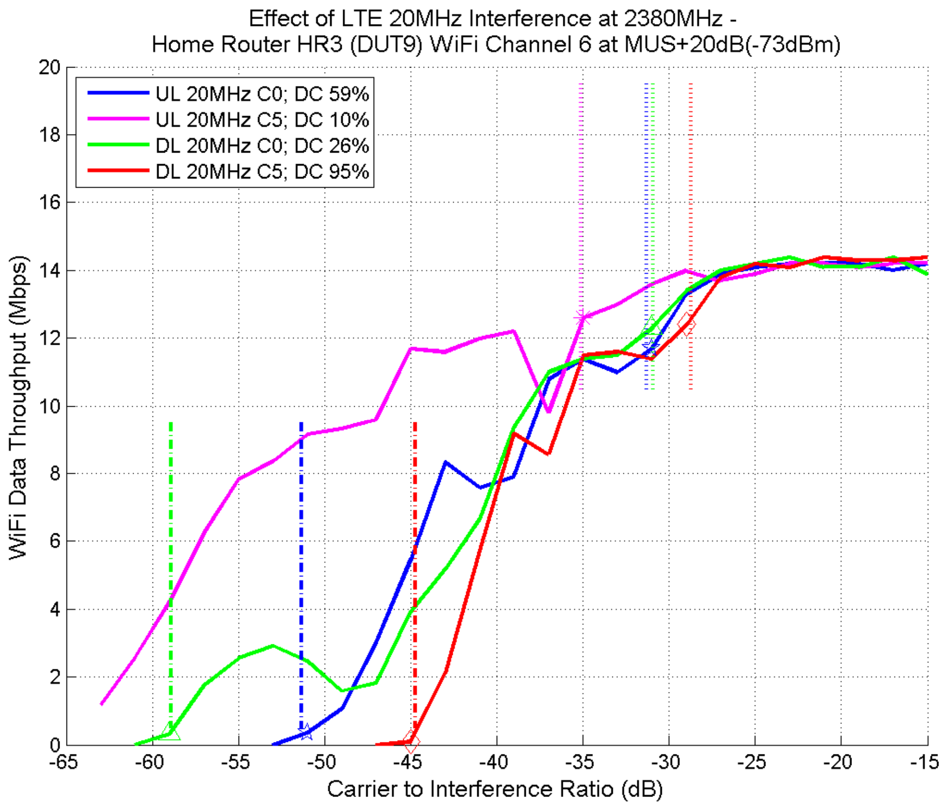

Figure 45

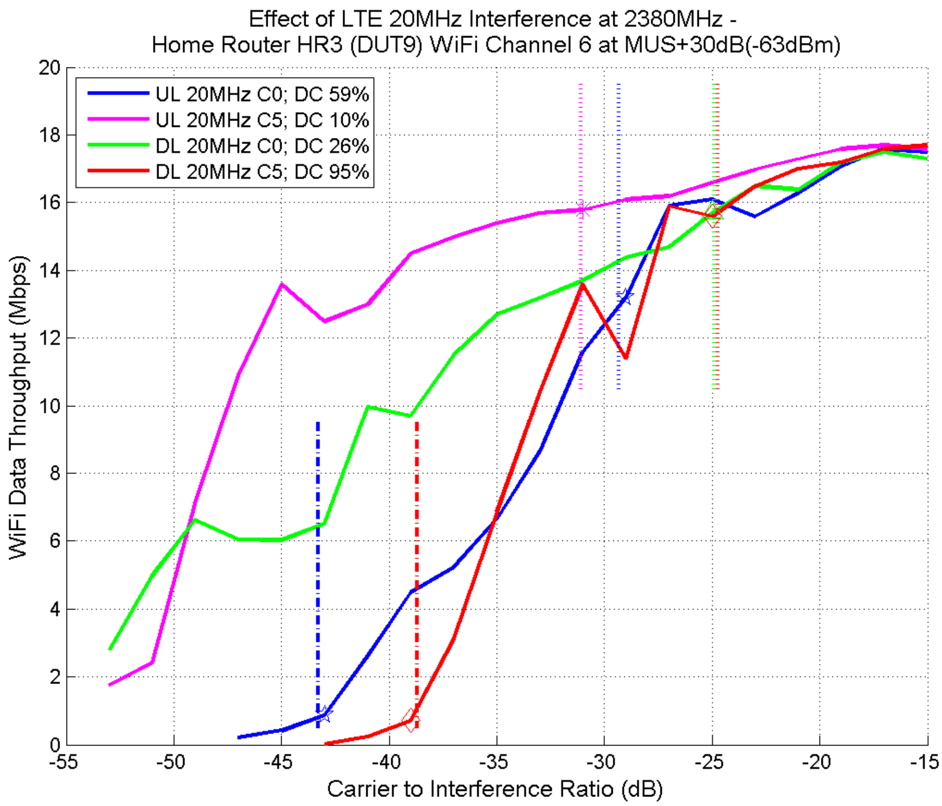

Figure 46

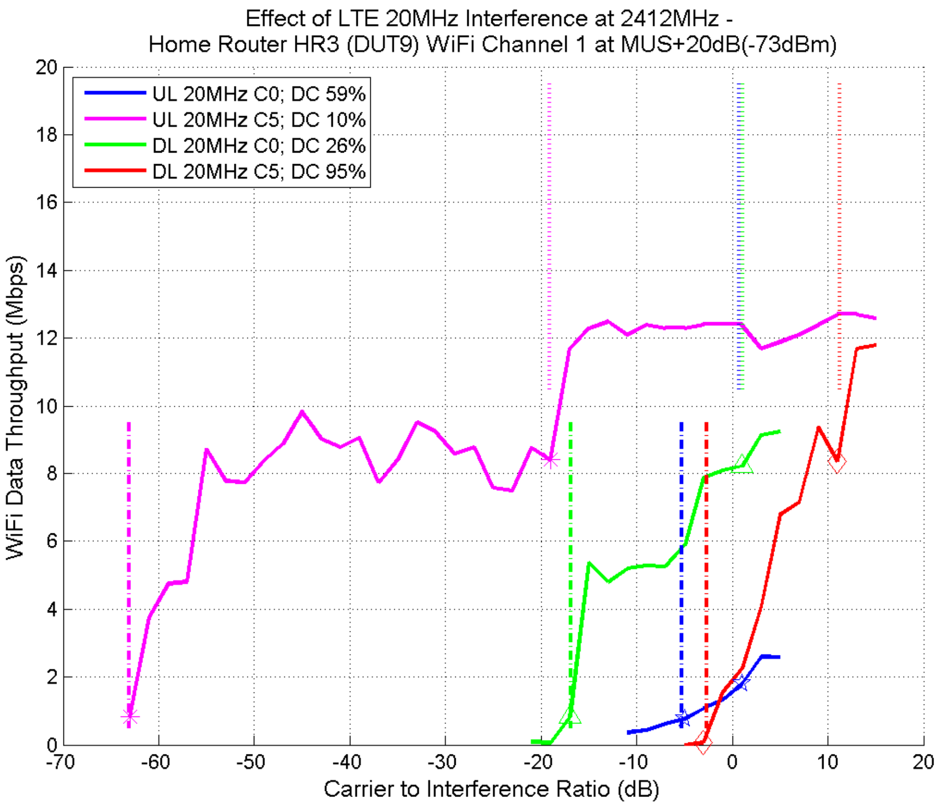

Figure 47

Observations

- The CW throughput test results at 2380MHz (Figure 42) showed very low throughput at the lowest interference power levels. A conjecture for this behaviour, which is seen elsewhere, is that rate adaptation in some devices can lead to an increase in data rate when structured interference is detected. This behaviour has not been investigated in detail.
- The CW test results were not used in the post-processing analysis of the DUT.

4.1.4 Home Router HR4 (DUT 14)

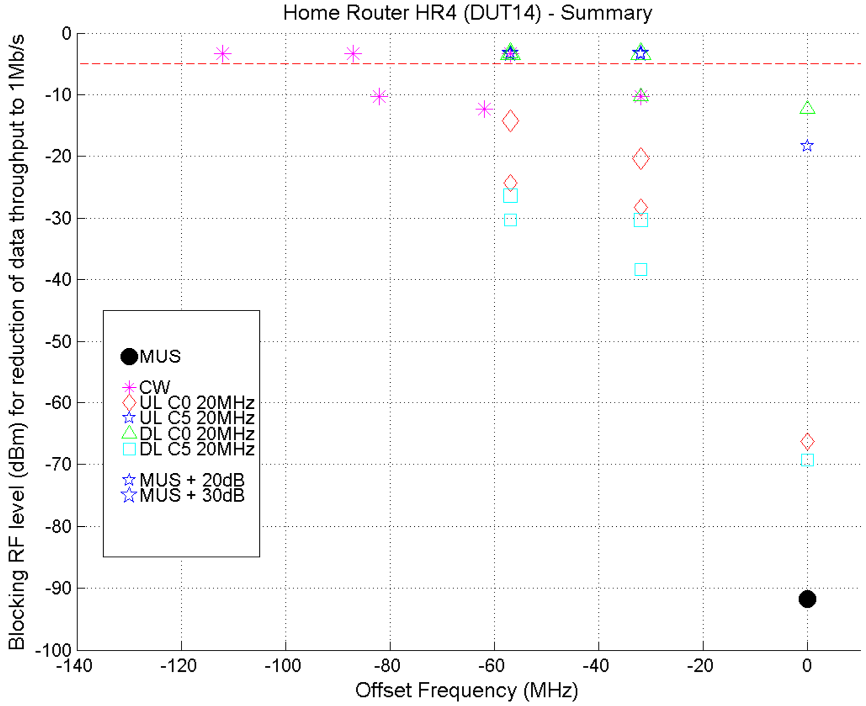

Figure 48

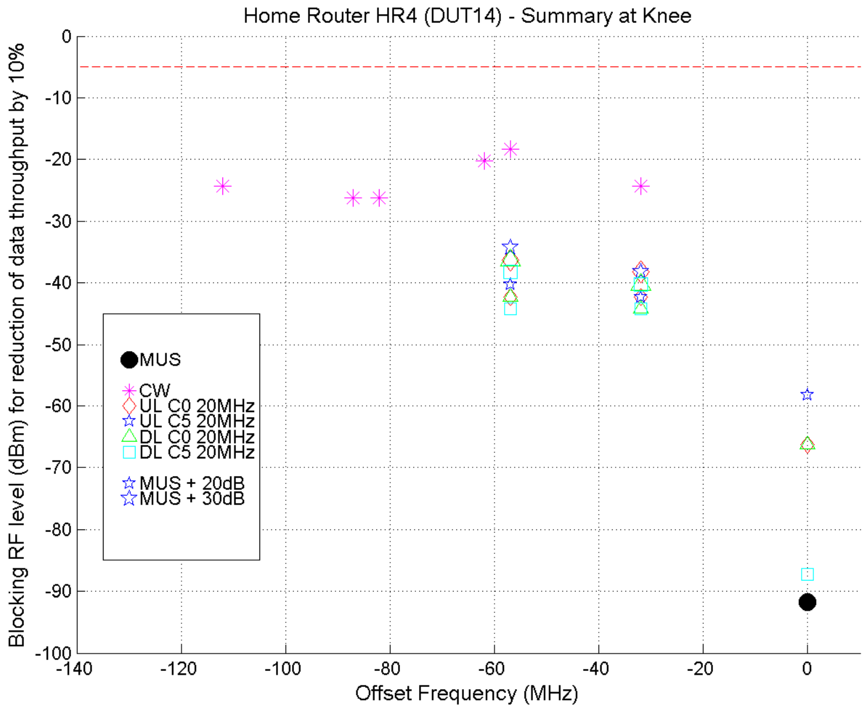

Figure 49

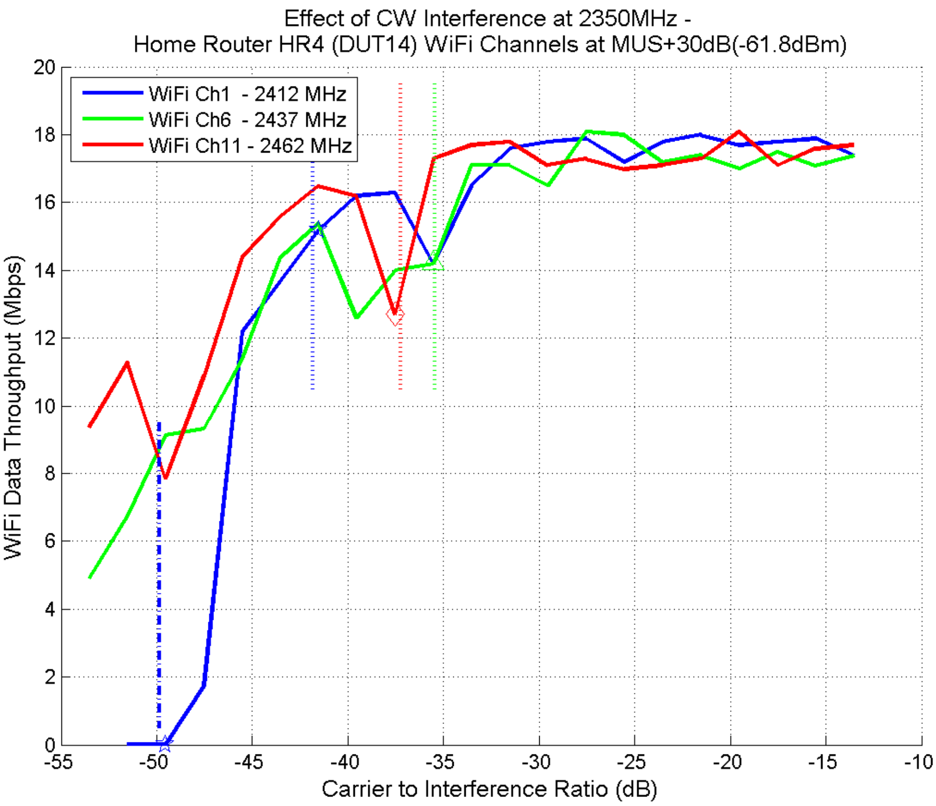

Figure 50

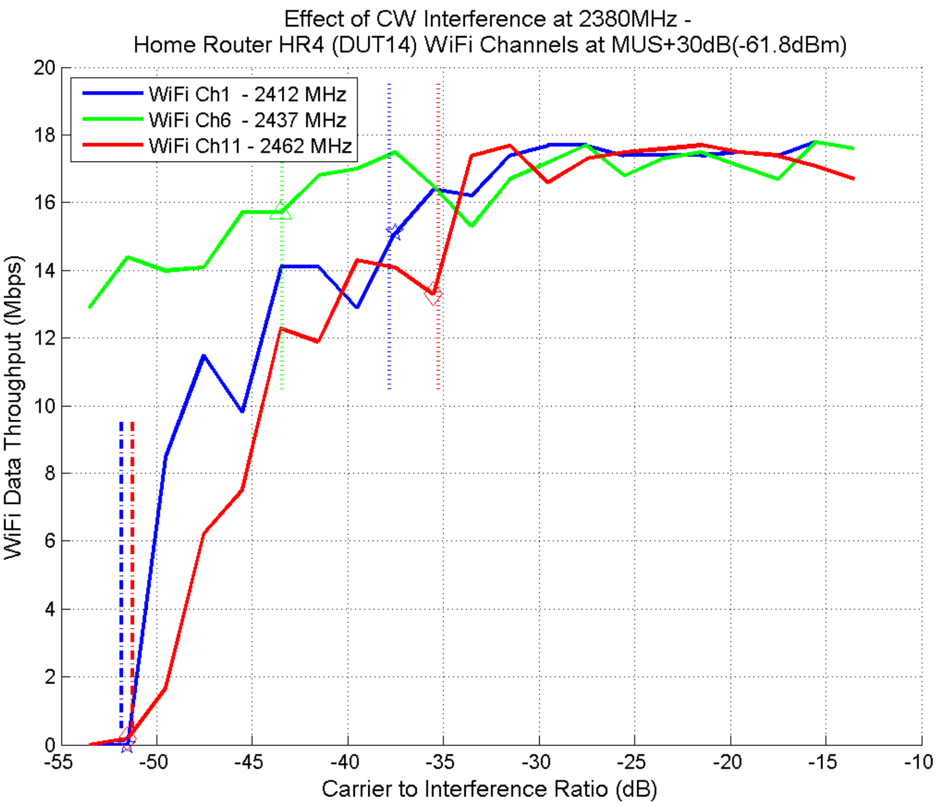

Figure 51

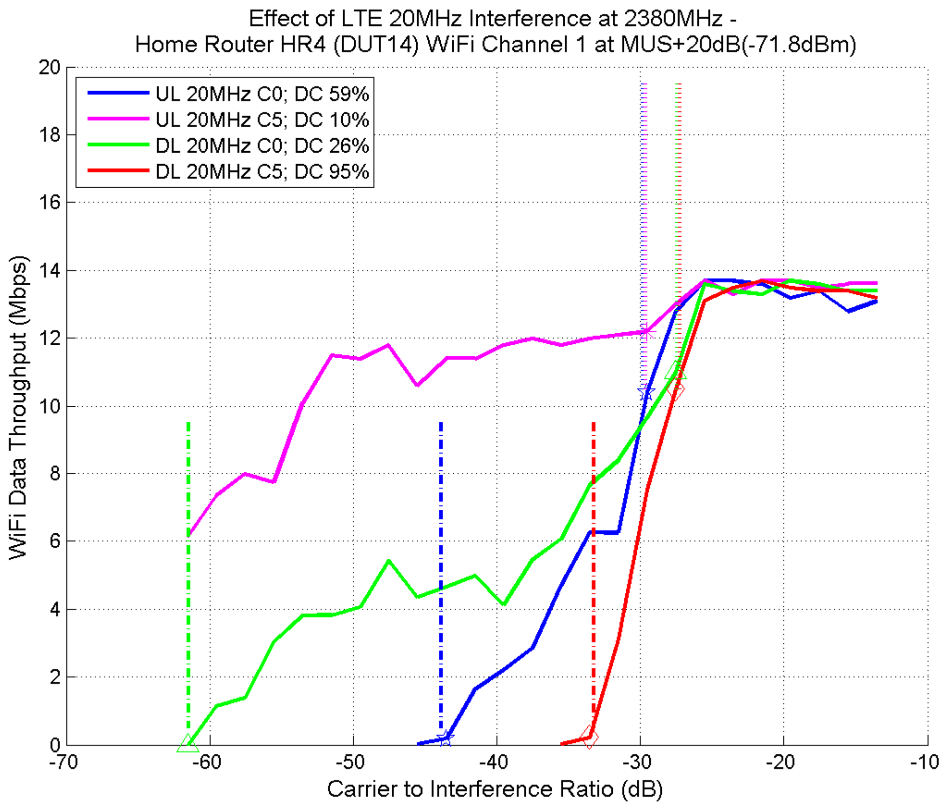

Figure 52

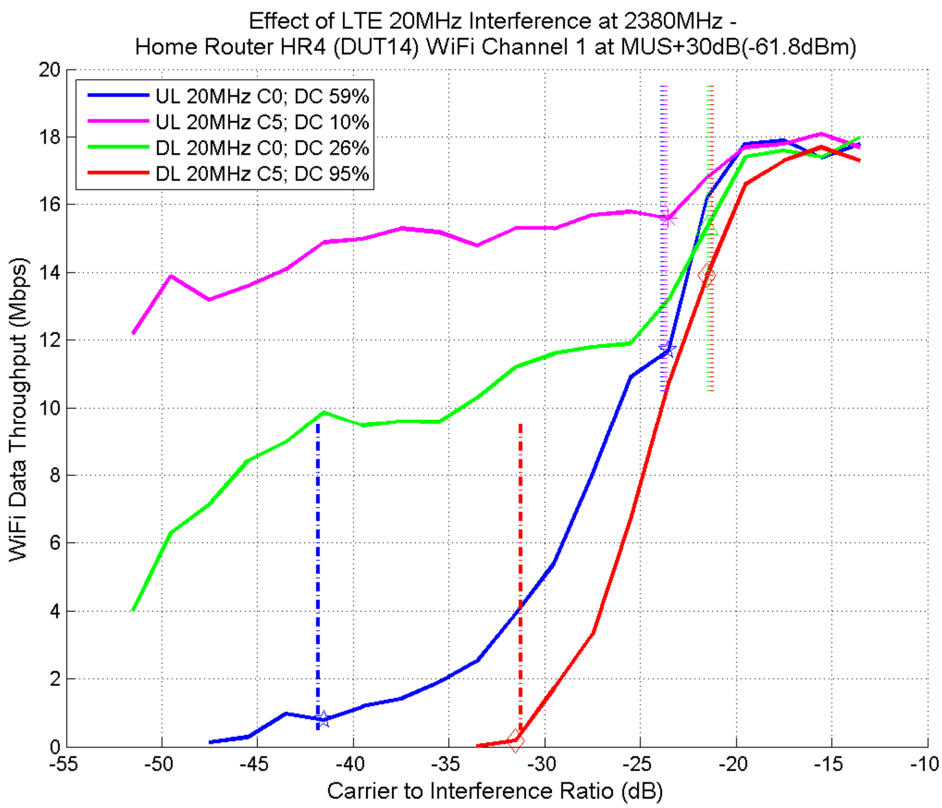

Figure 53

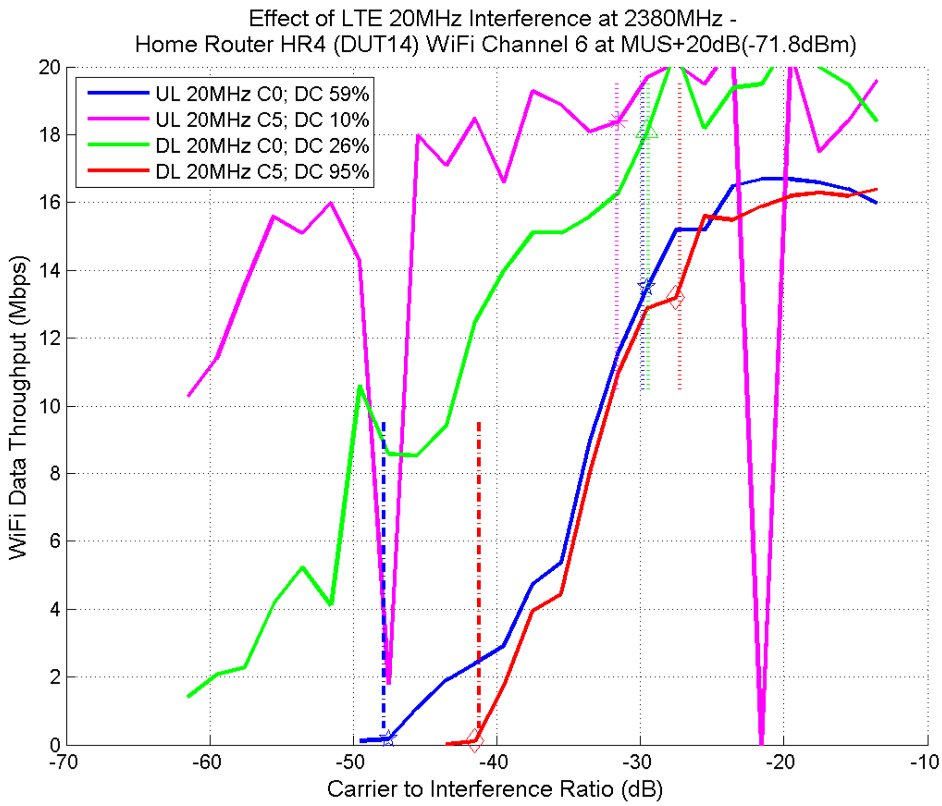

Figure 54

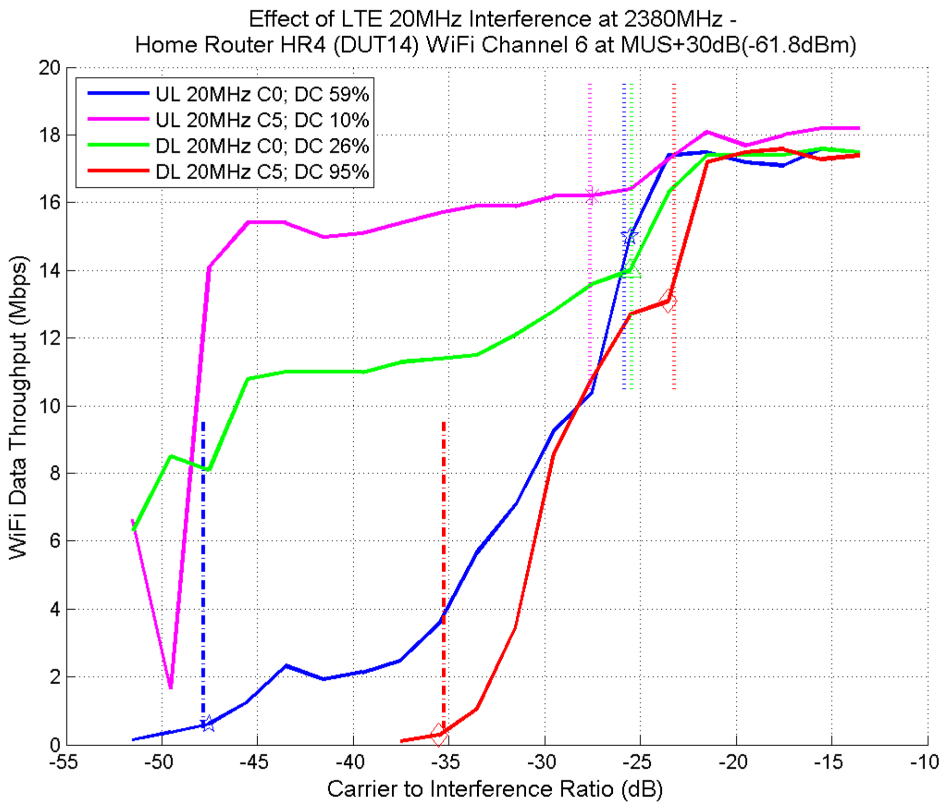

Figure 55

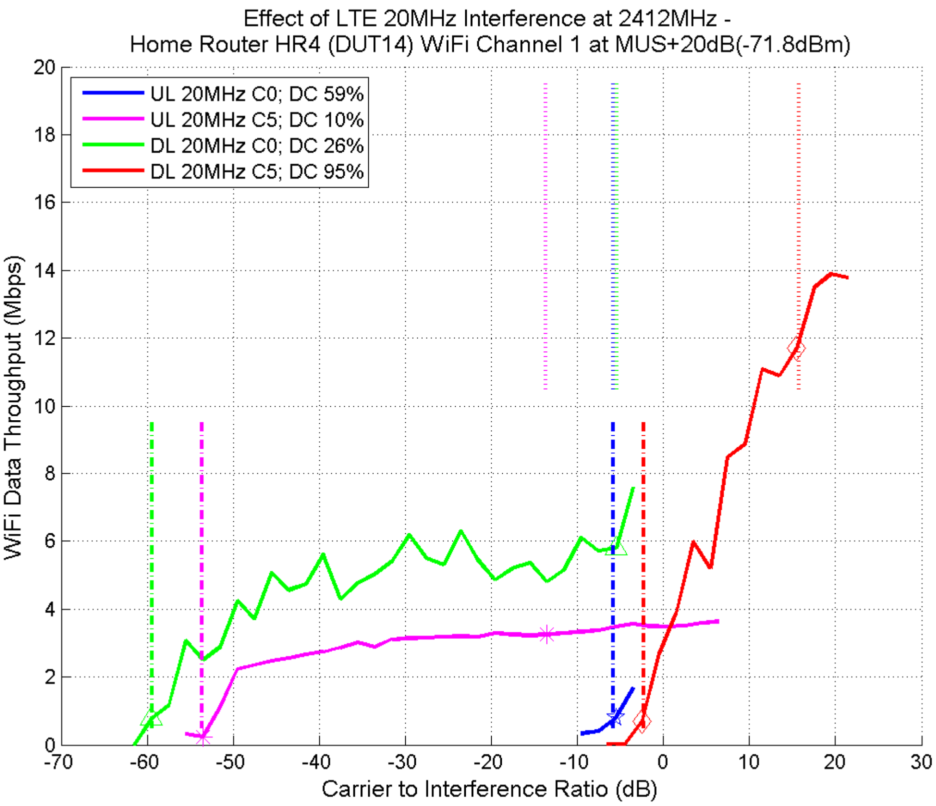

Figure 56

Observations

- In Figure 56 there is a marked difference in behaviour of the DUT when the duty cycle is high compared to when it is low. When the duty cycle is low it appears that the DUT can manage to maintain traffic throughput at higher interference levels, but throughput is not maintained when the duty cycle is higher. The most likely explanation for this difference in behaviours is that the DUT is managing to successfully transmit packets in the gaps between the interference packets. This conjecture is given further credence by observing that the behaviour is seen when the interferer is co-channel, which is when signal structure is more likely to be detectable by the WiFi receiver

4.2 Laptops

4.2.1 Laptop LP1 (DUT 1)

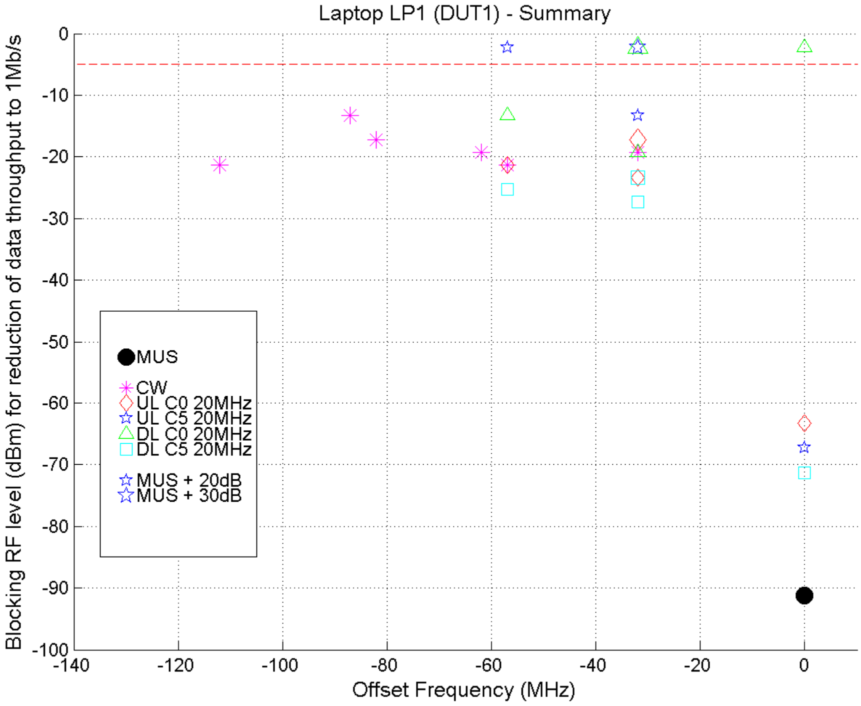

Figure 57

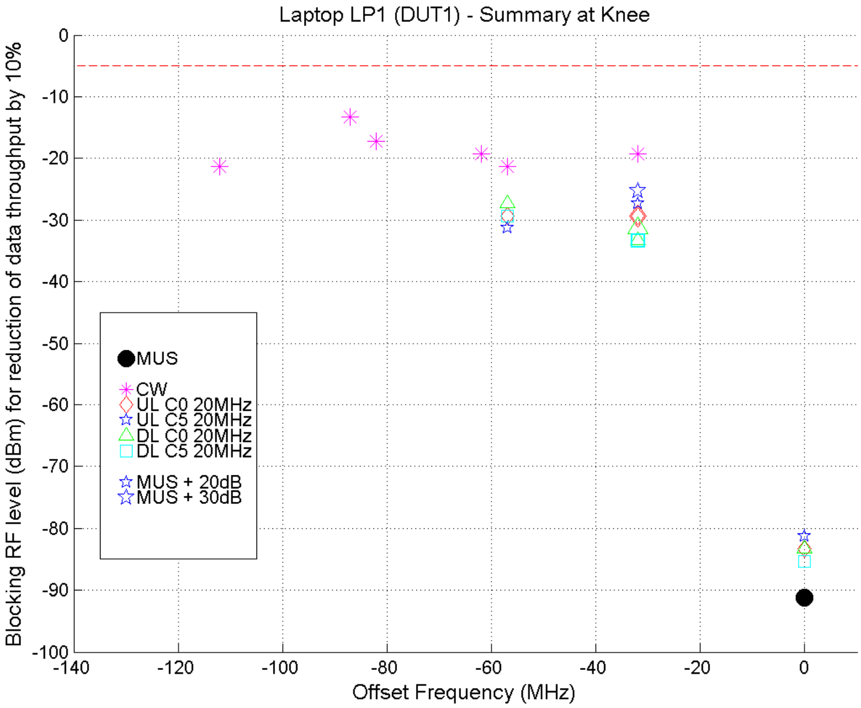

Figure 58

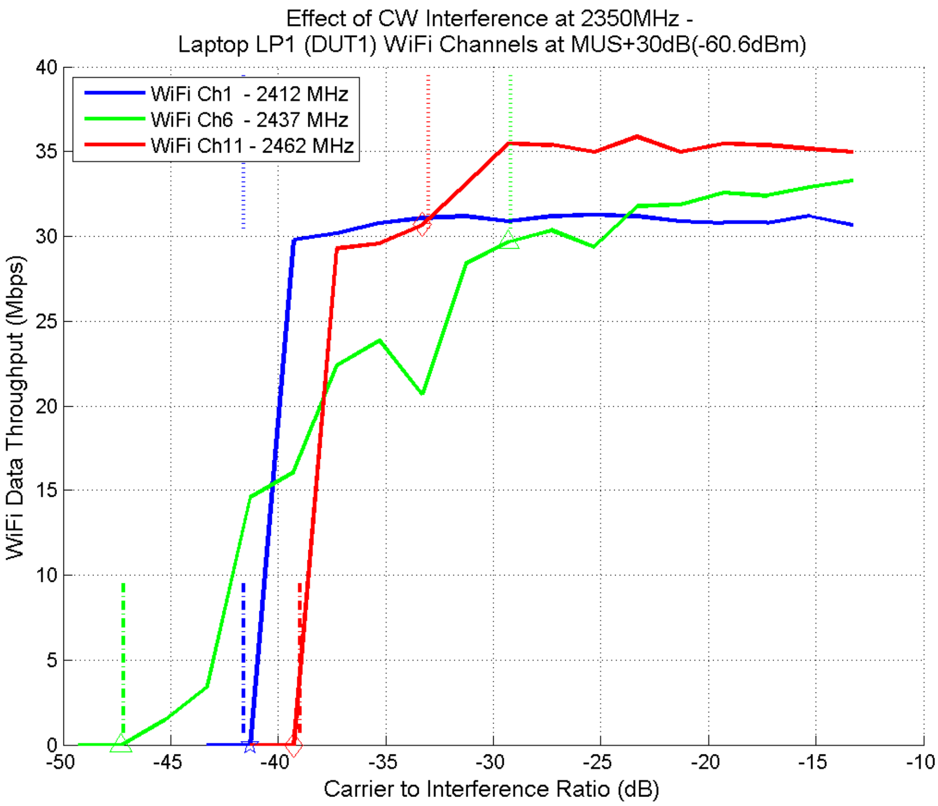

Figure 59

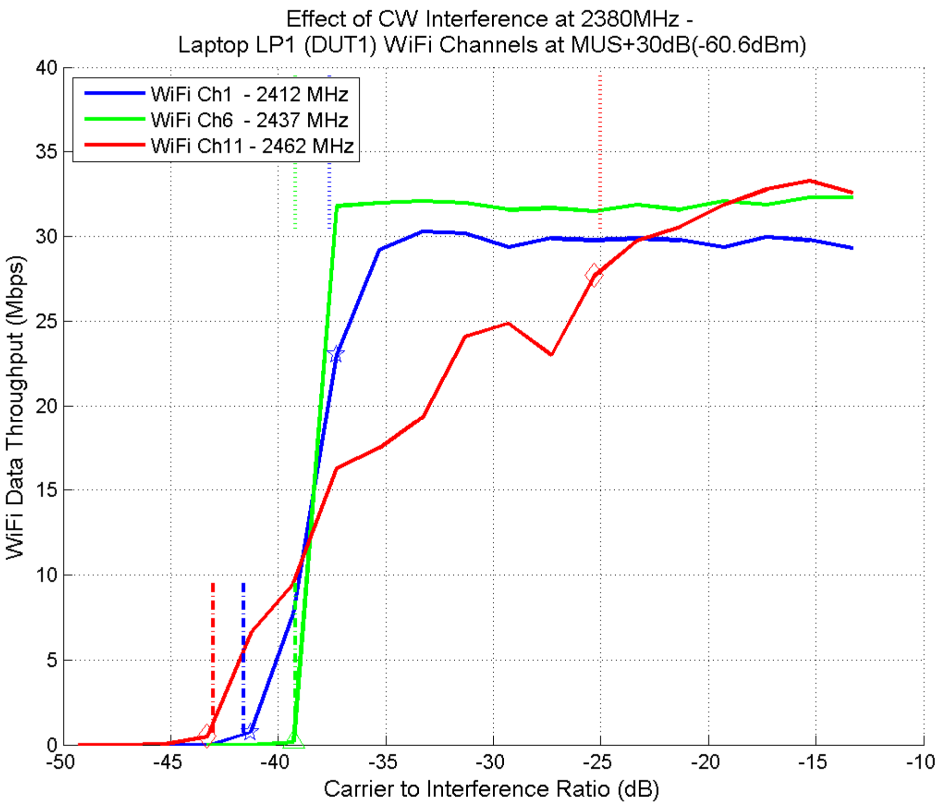

Figure 60

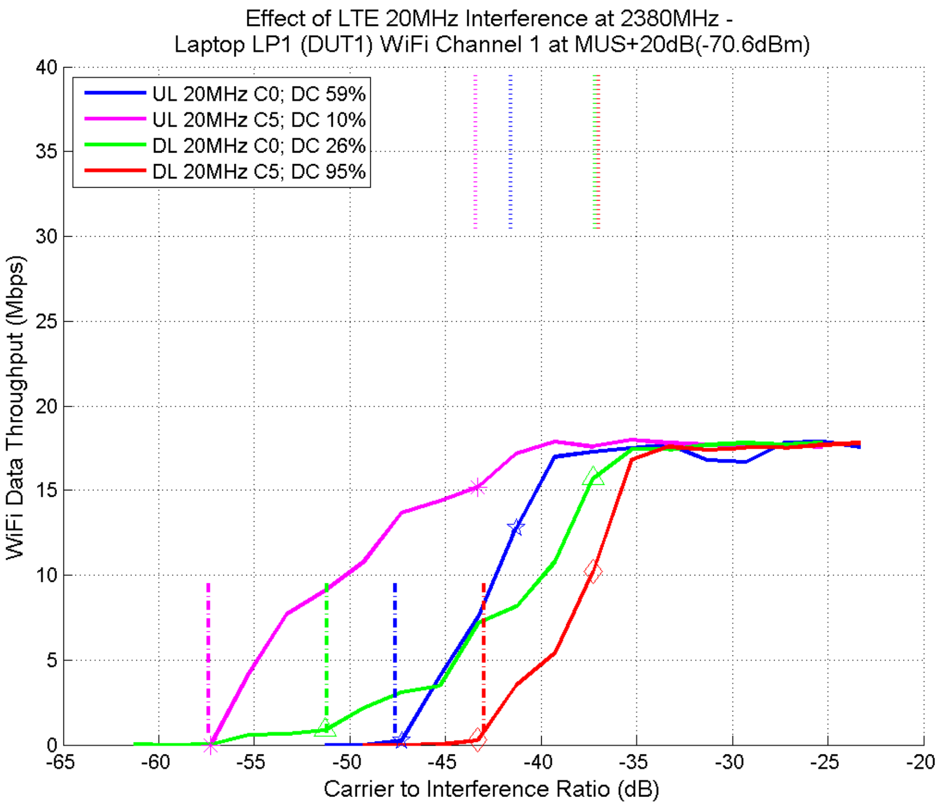

Figure 61

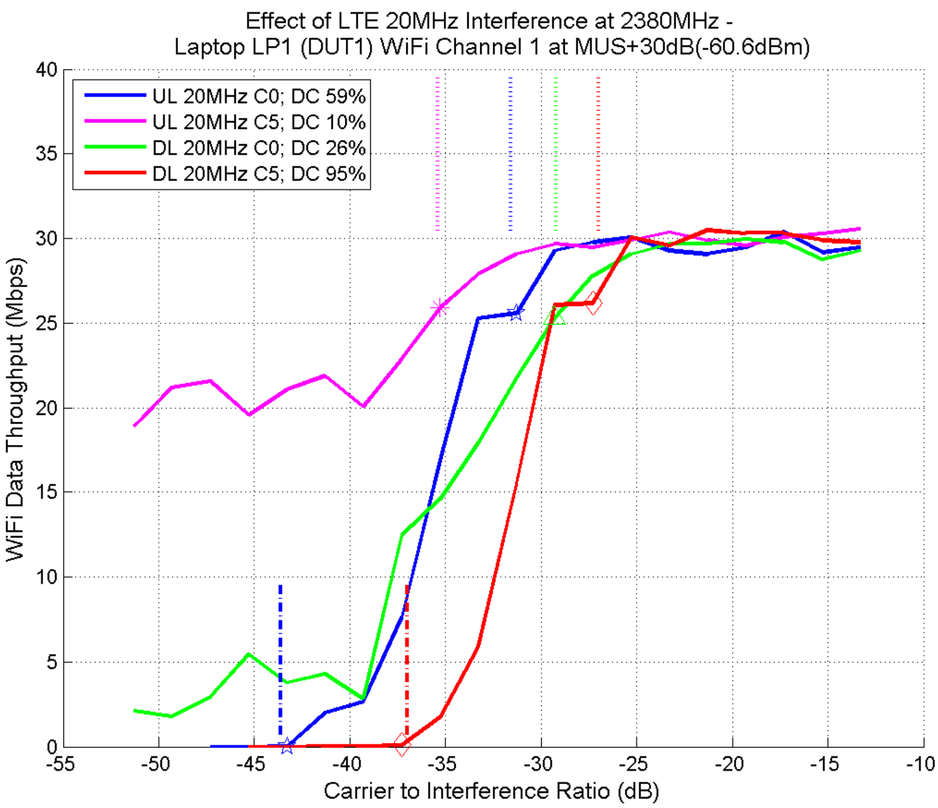

Figure 62

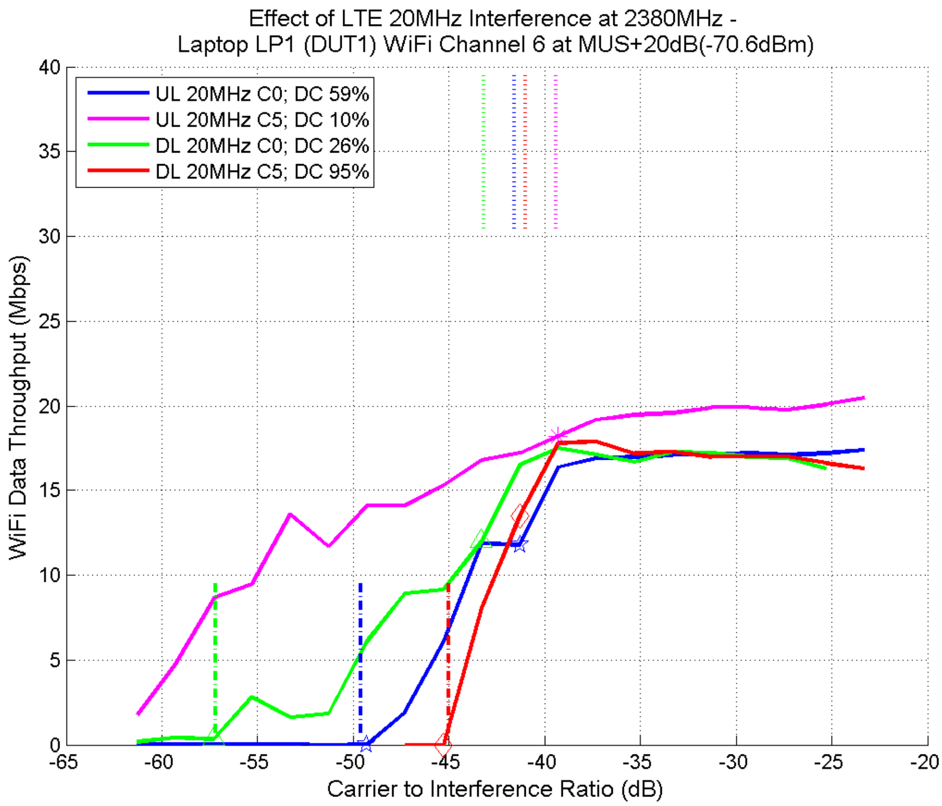

Figure 63

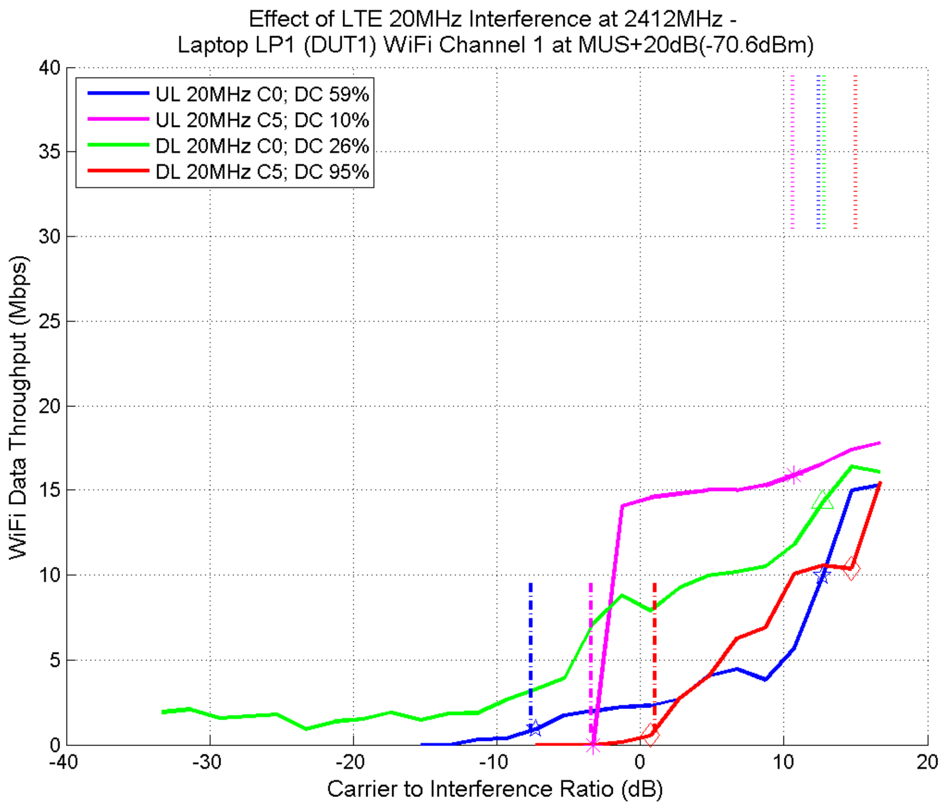

Figure 64

4.2.1.1 Additional Tests

The WiFi and CW settings for the full set of blocking and selectivity tests performed for DUT1 (Test Type 1) are shown below:

WiFi Receiver Sensitivity	WiFi Channels	CW Frequencies
MUS +30dB	1, 2, 3, 6, 11, 13	2350MHz, 2360MHz, 2370MHz, 2380MHz, 2390MHz, 2400MHz, 2410MHz

Table 3: CW Test Settings for DUT1

The WiFi and LTE settings for the full set of LTE out-of-band (OOB) tests for DUT1 (Test Type 1) are shown below:

WiFi Receiver Sensitivity	WiFi Channels	LTE Channel Bandwidth	LTE Frequency Offsets	LTE Frame Structure
MUS +20dB	1, 2, 3, 6	10MHz	2375MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB	1, 2, 3, 6	10MHz	2385MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB, +30dB	1	20MHz	2350MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB	6	20MHz	2350MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB, +30dB	1, 3	20MHz	2360MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB	2, 6	20MHz	2360MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB, +30dB	1, 3	20MHz	2380MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB	2, 6	20MHz	2380MHz	UL_C0, UL_C5, DL_C0, DL_C5

Table 4: OOB Test Settings for DUT1

N.B.: The LTE OOB throughput versus C/I results for WiFi channels 1 and 6 at 2350MHz and 2380MHz are presented in the preceding section, to be consistent with the presentation of the other DUT (Test Type 2) results, and are not replicated in this section.

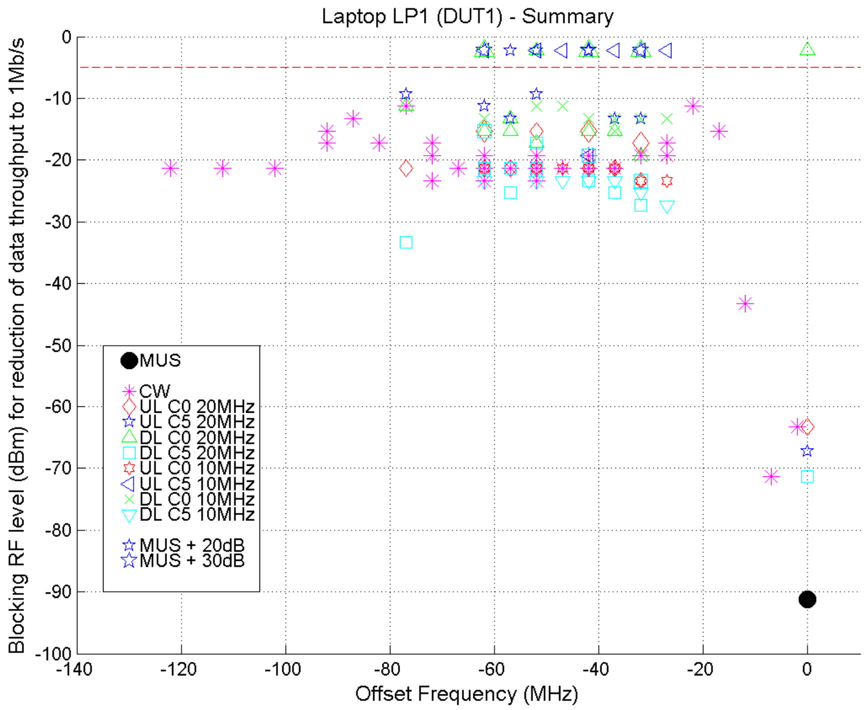

Figure 65

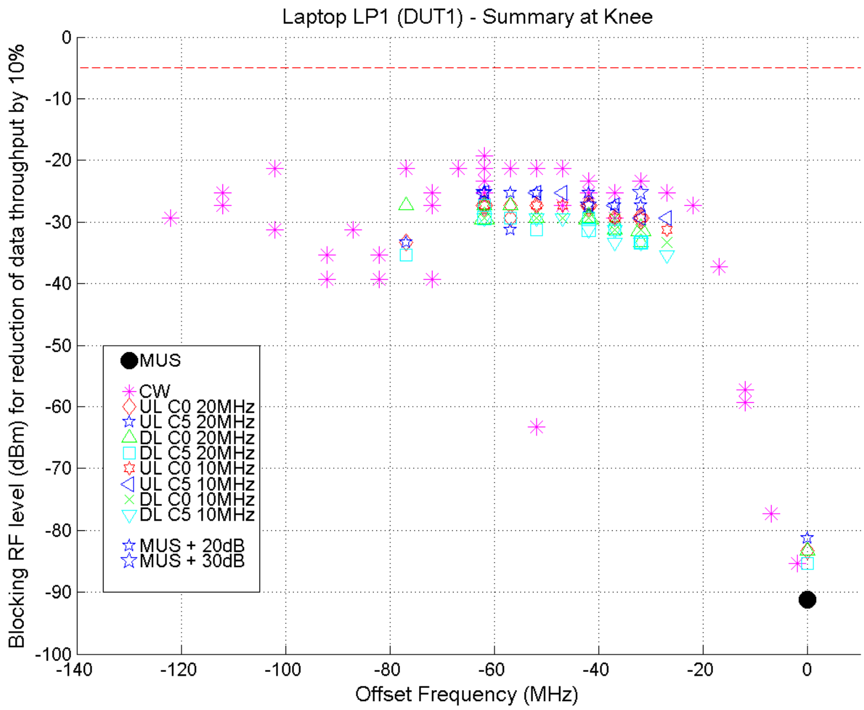

Figure 66

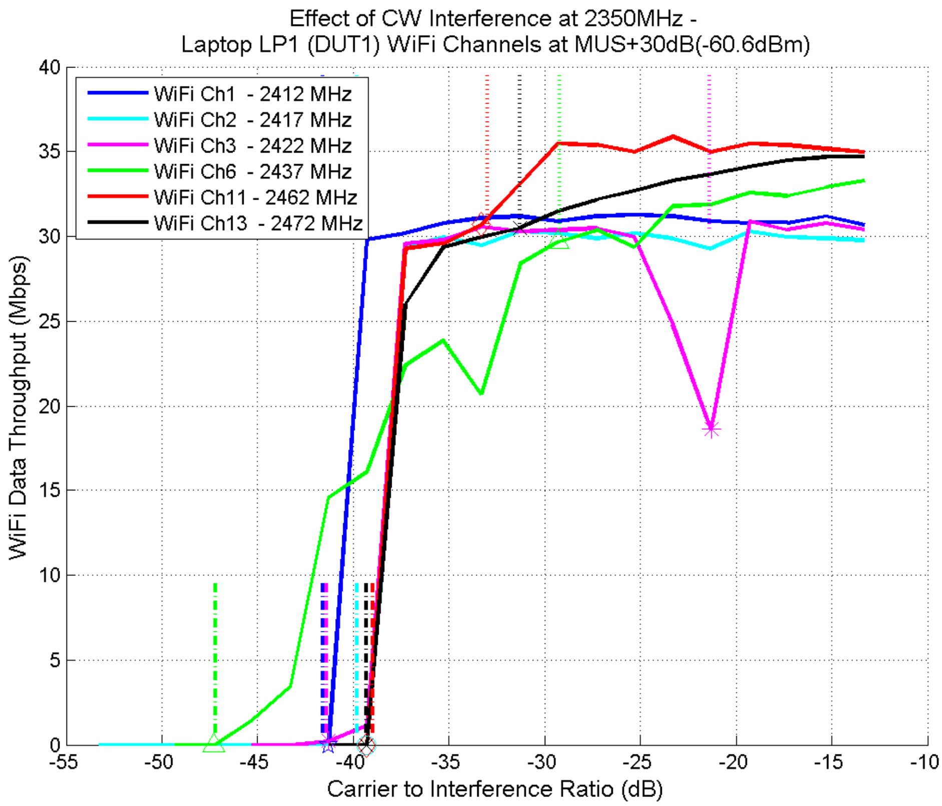

Figure 67

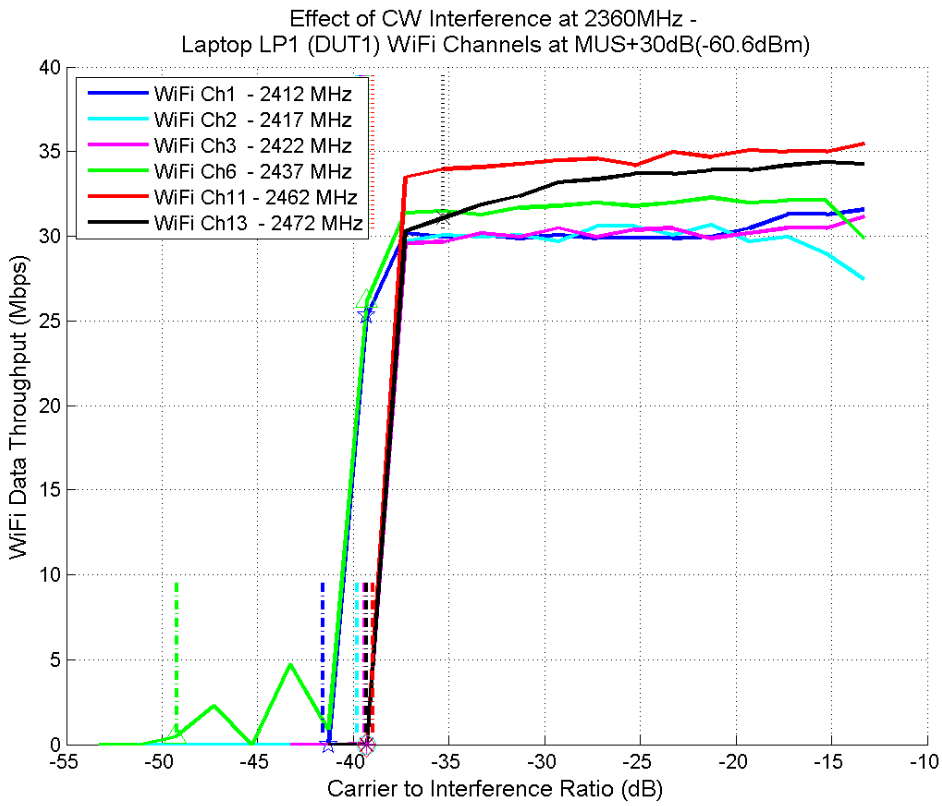

Figure 68

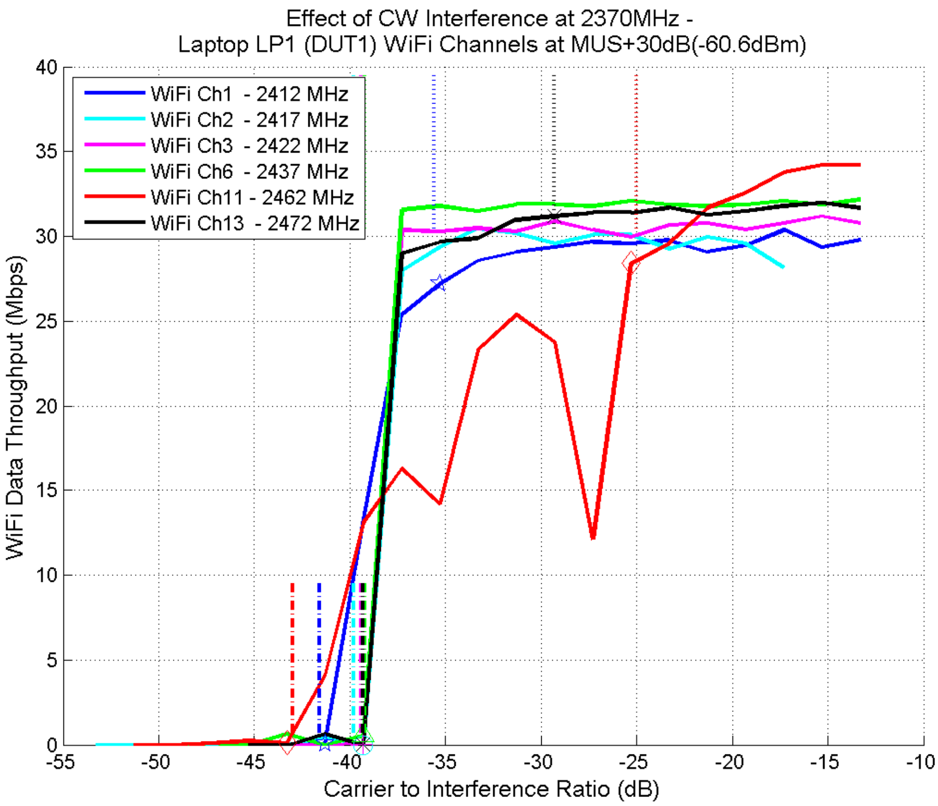

Figure 69

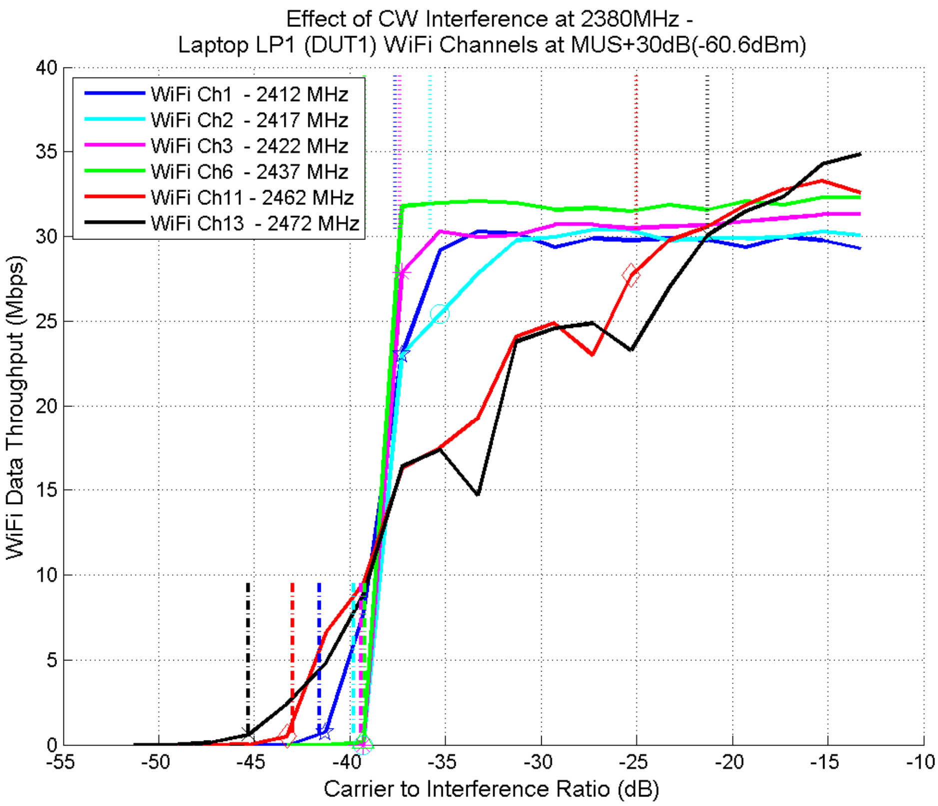

Figure 70

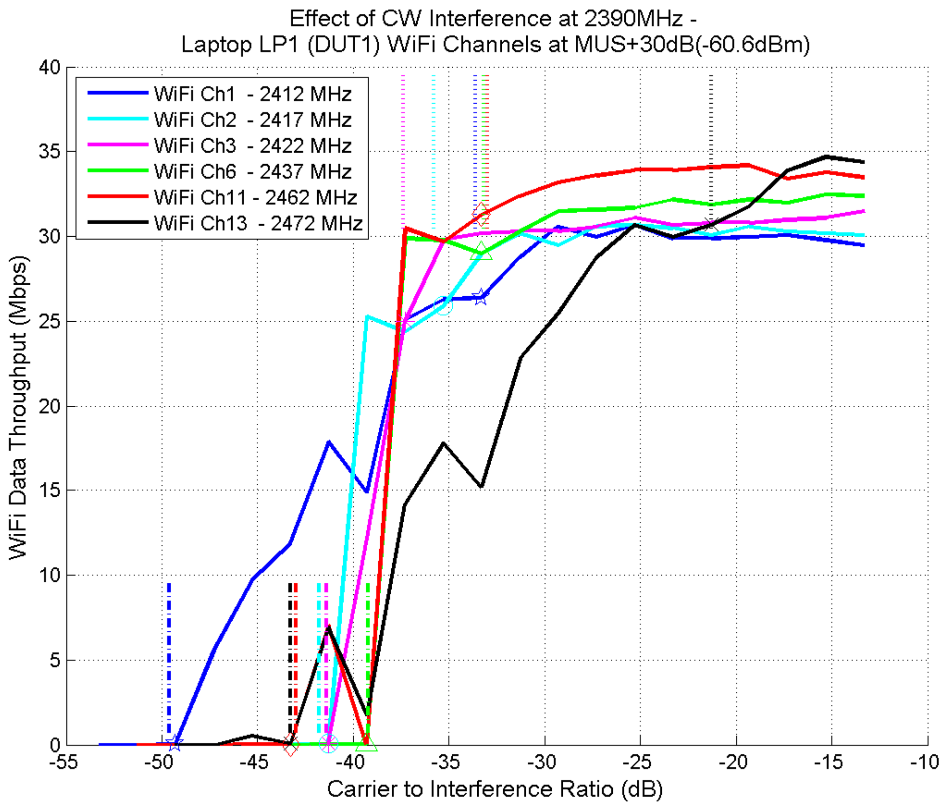

Figure 71

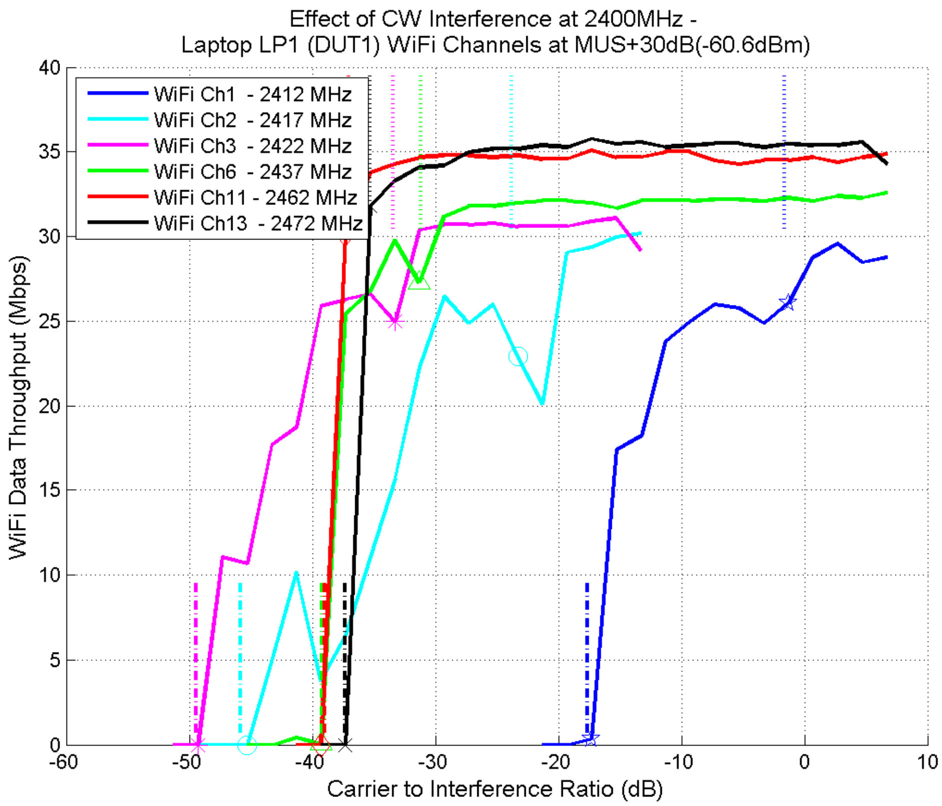

Figure 72

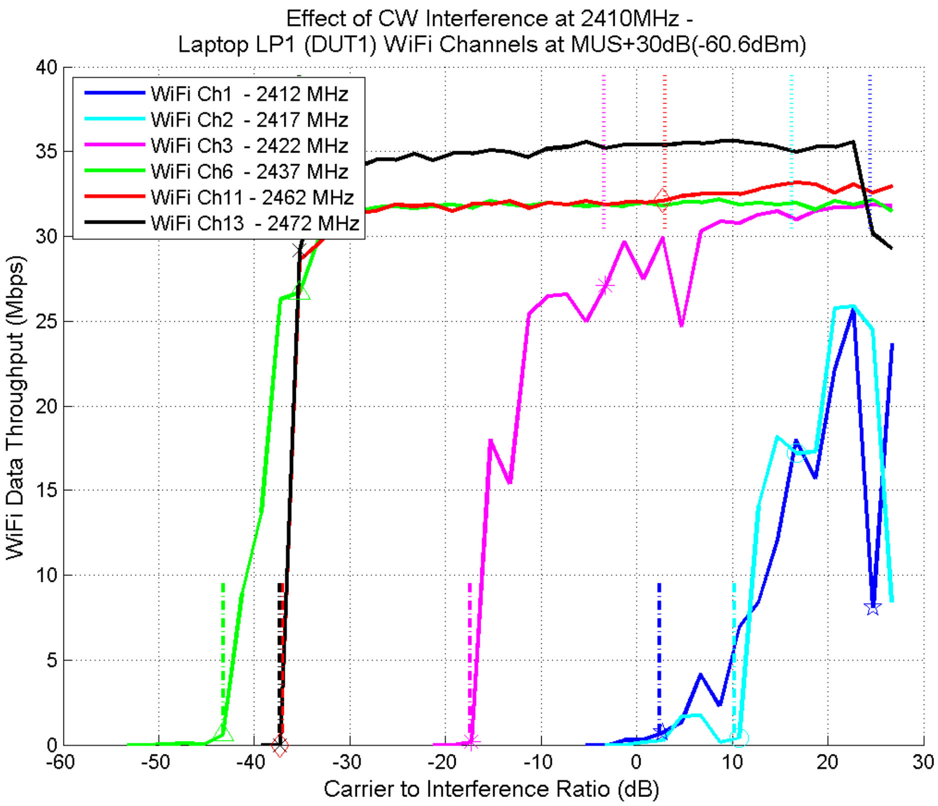

Figure 73

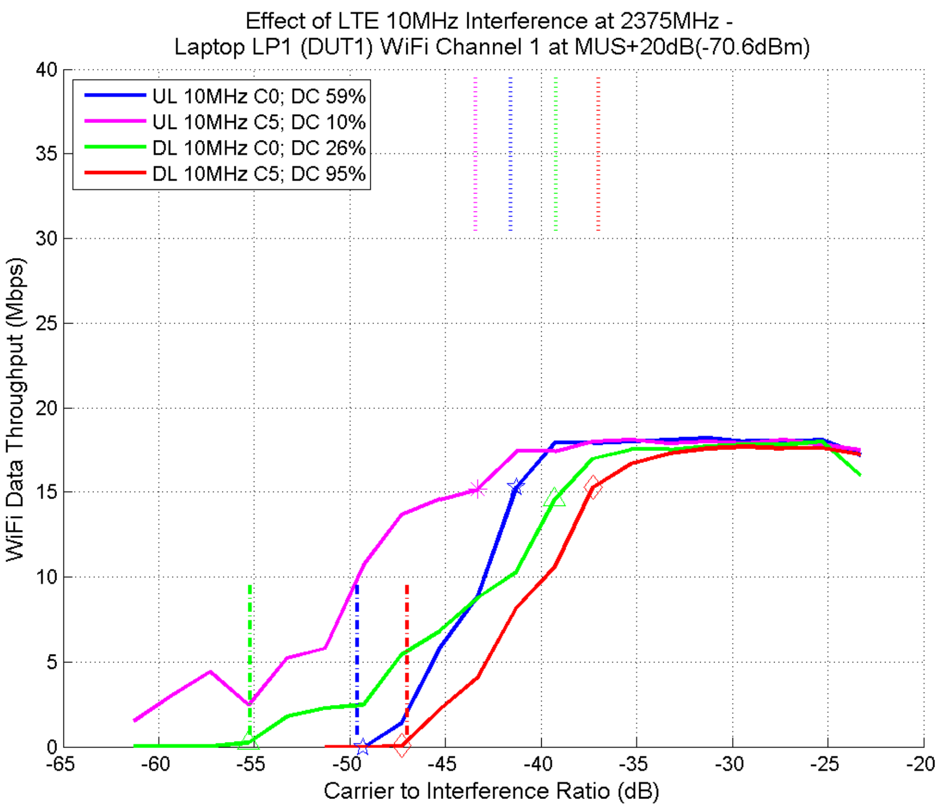

Figure 74

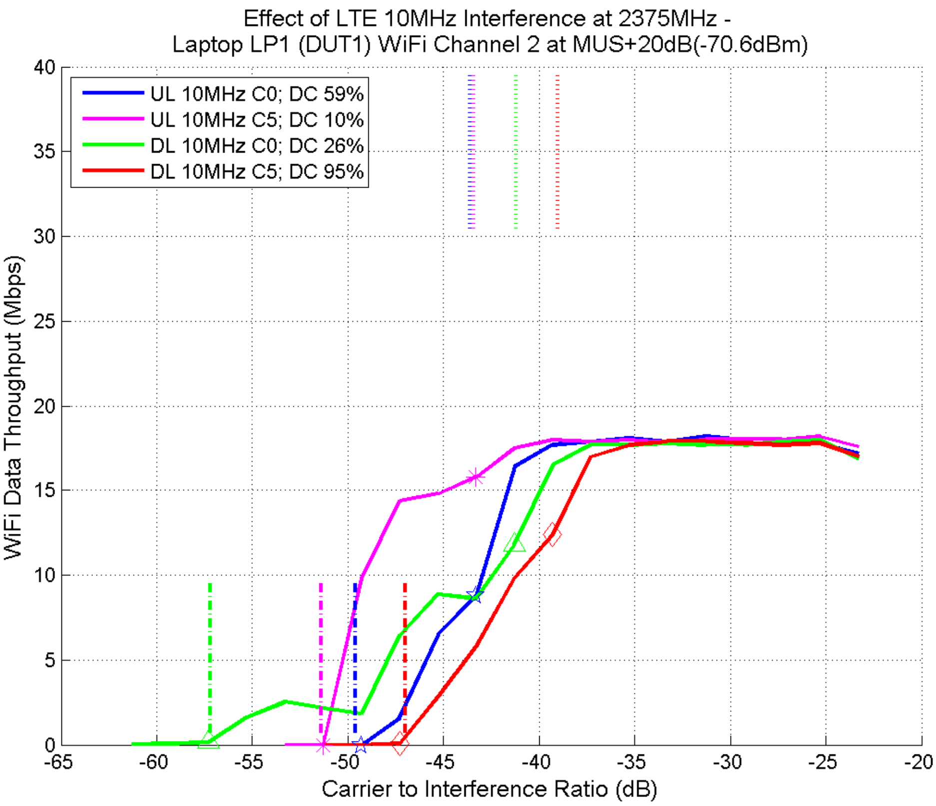

Figure 75

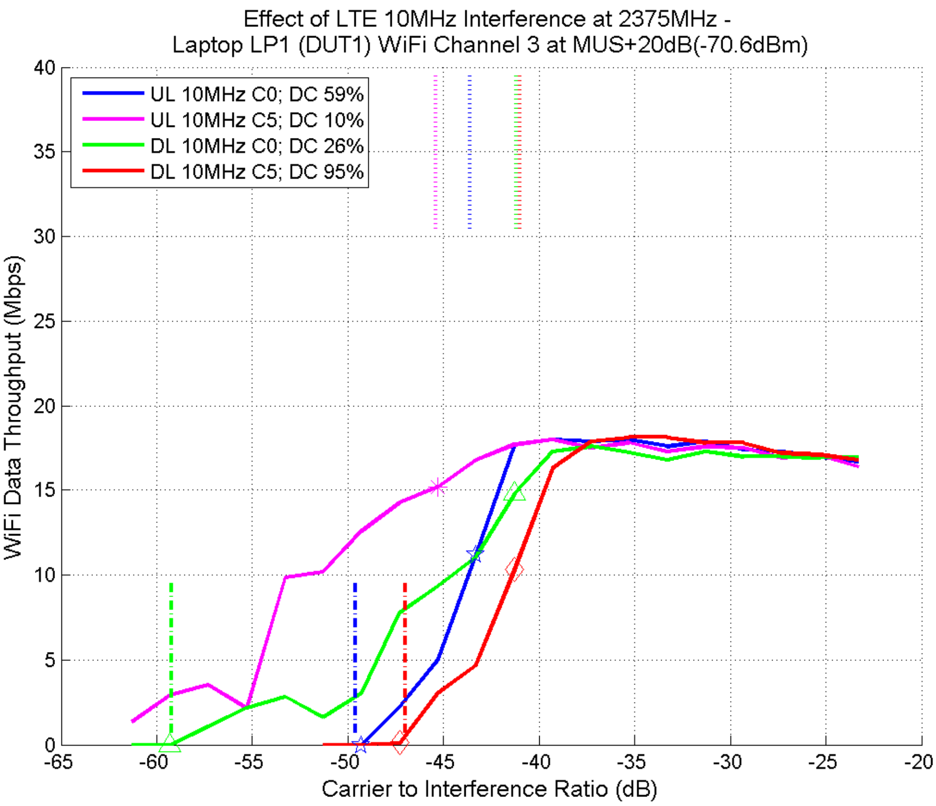

Figure 76

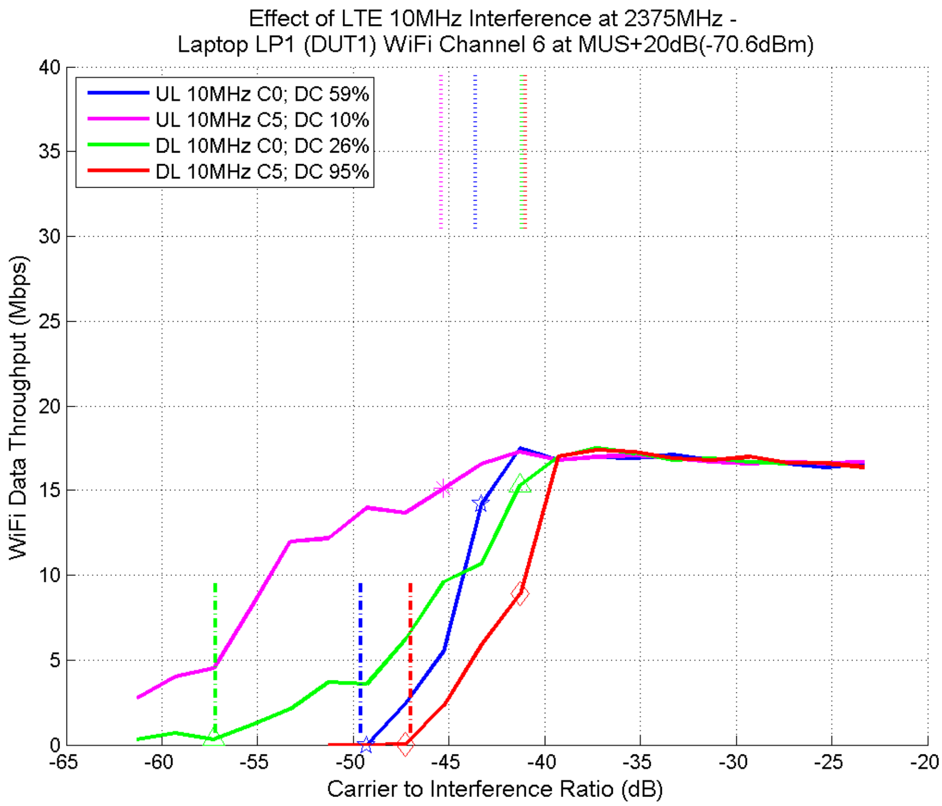

Figure 77

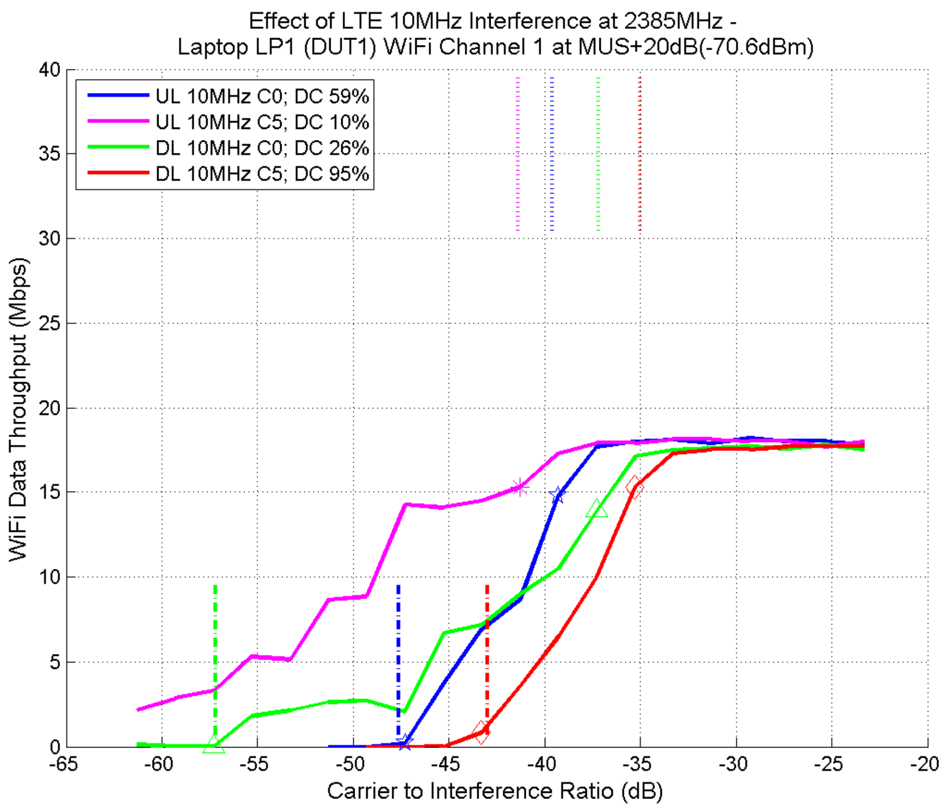

Figure 78

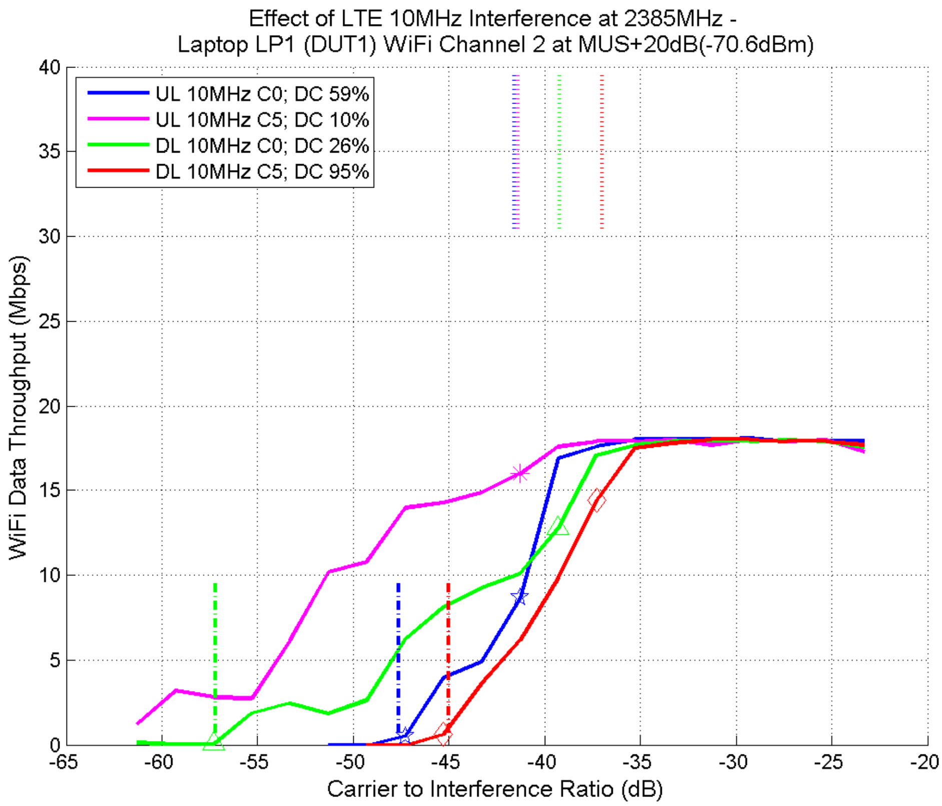

Figure 79

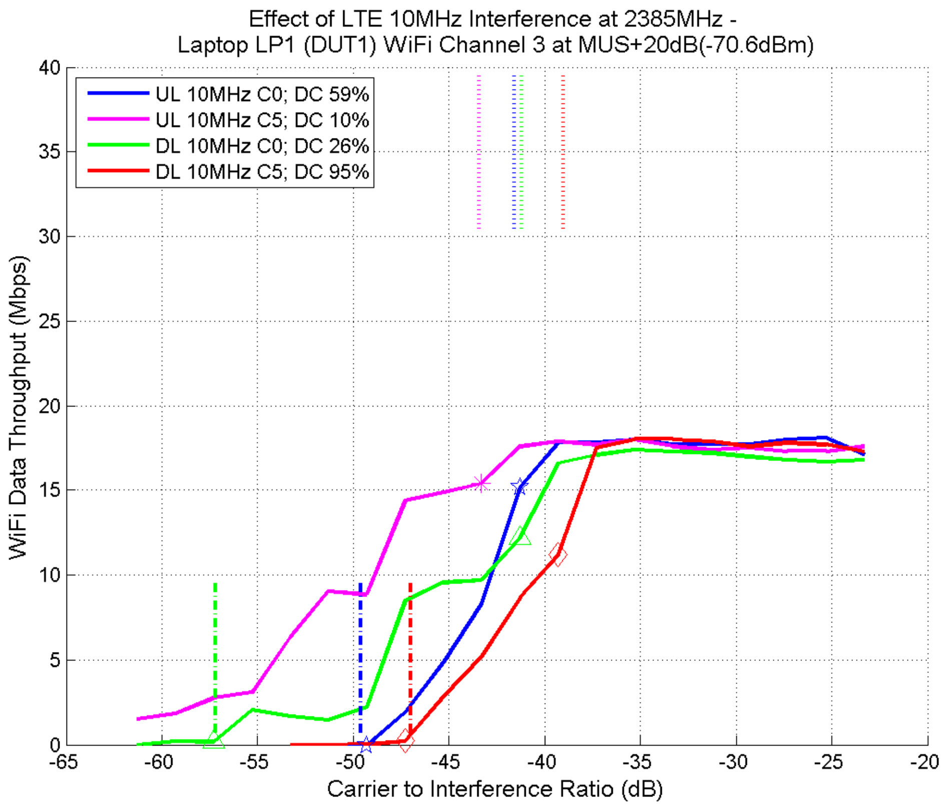

Figure 80

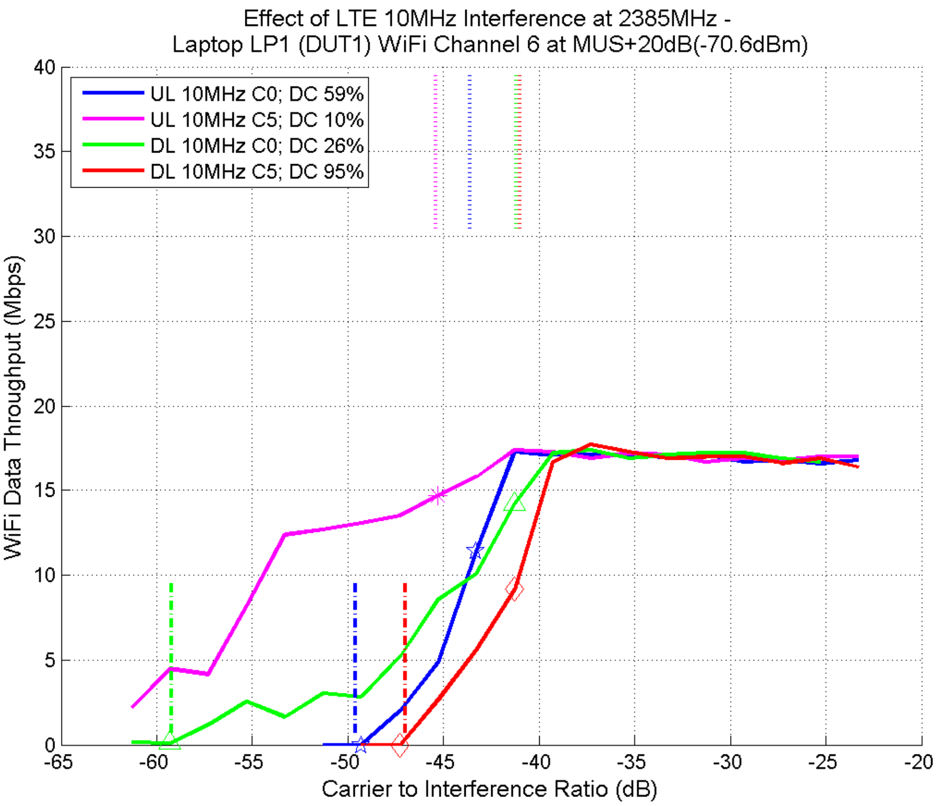

Figure 81

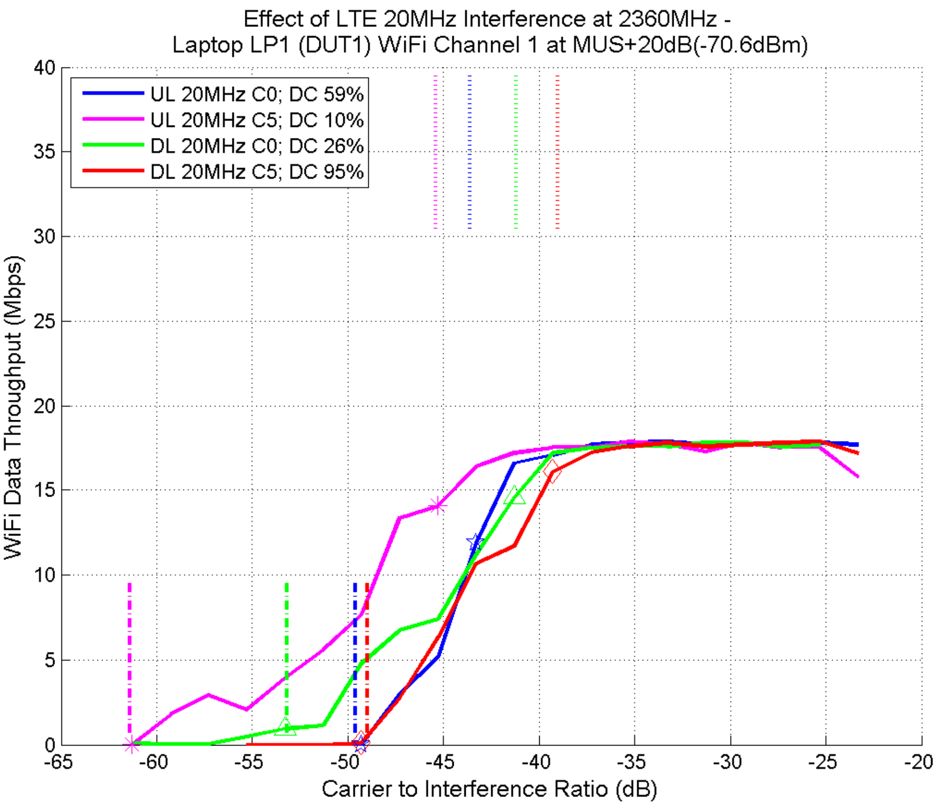

Figure 82

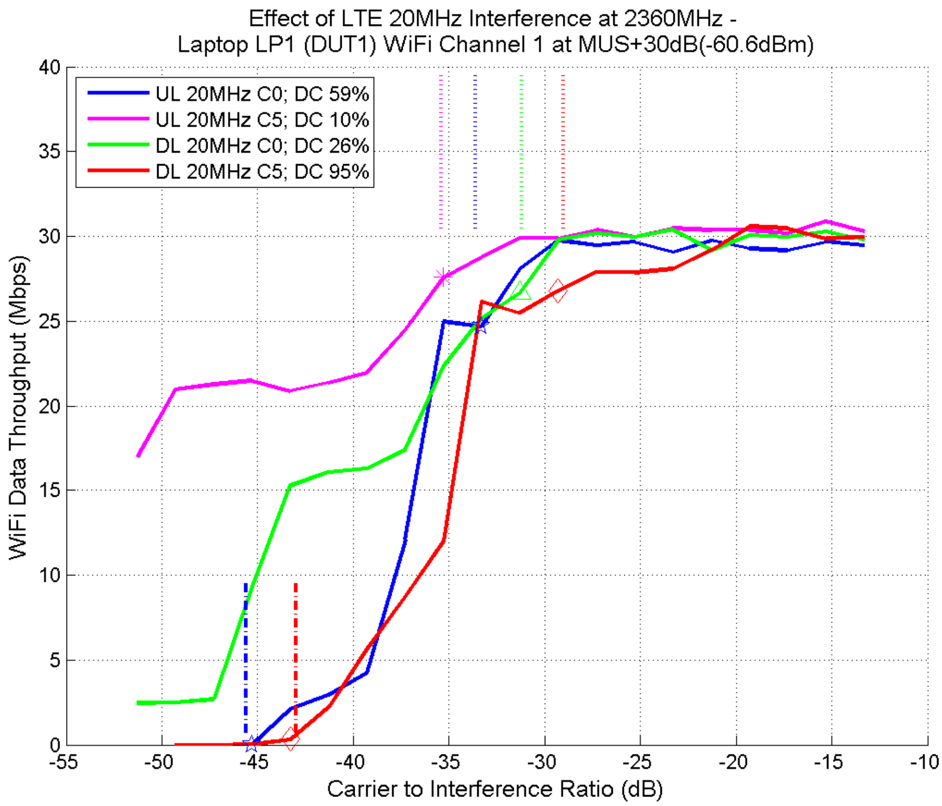

Figure 83

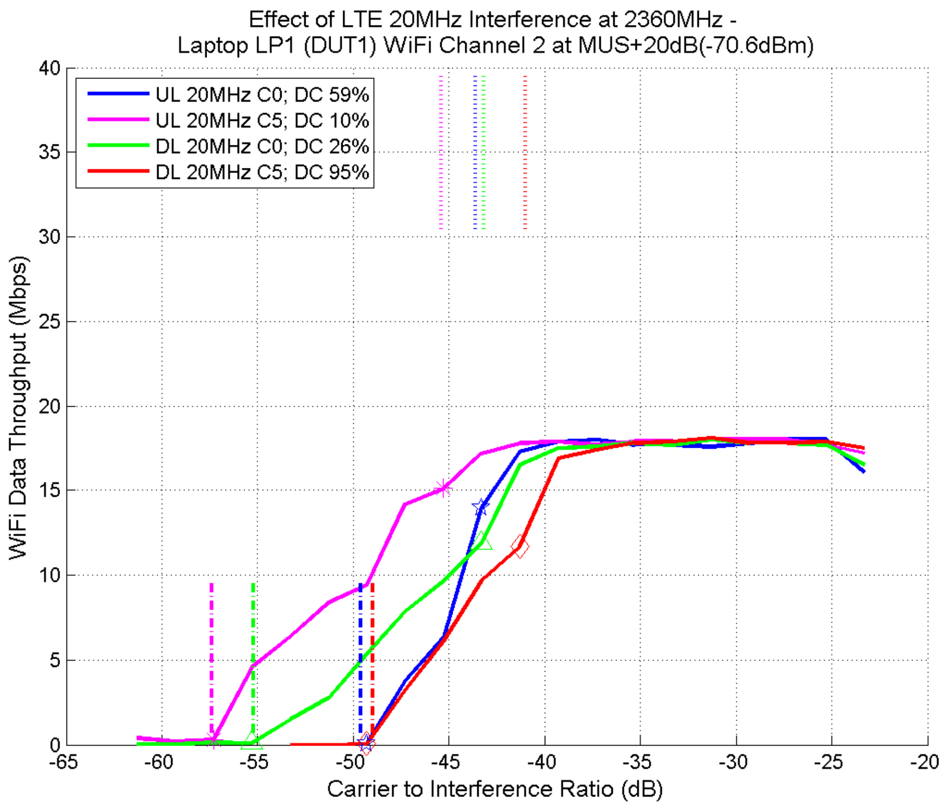

Figure 84

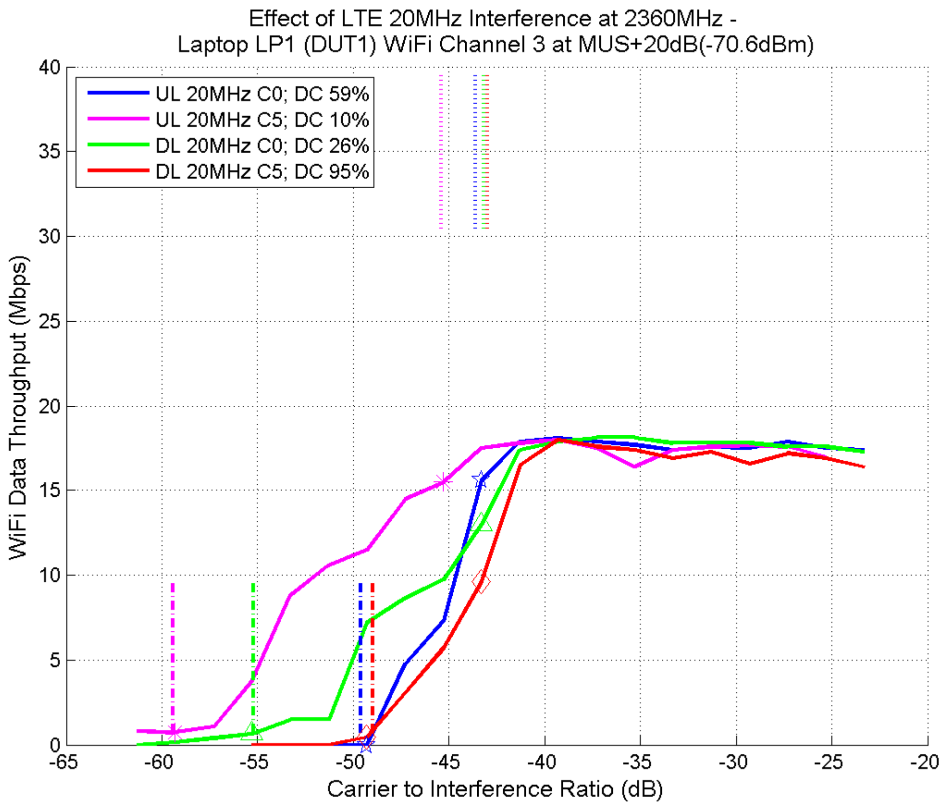

Figure 85

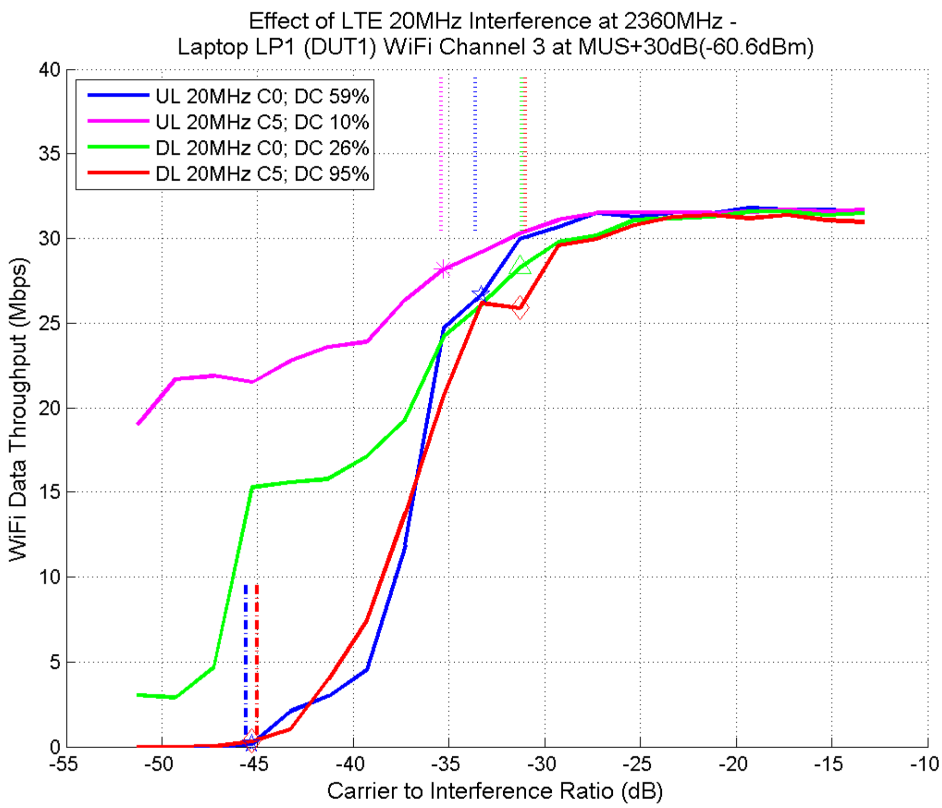

Figure 86

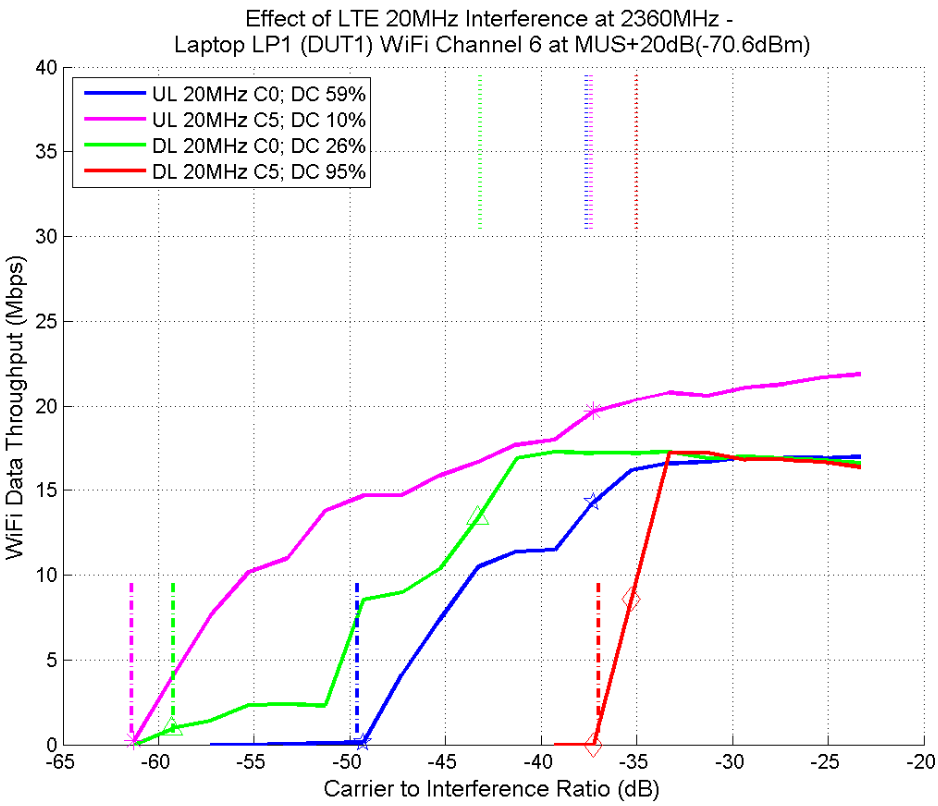

Figure 87

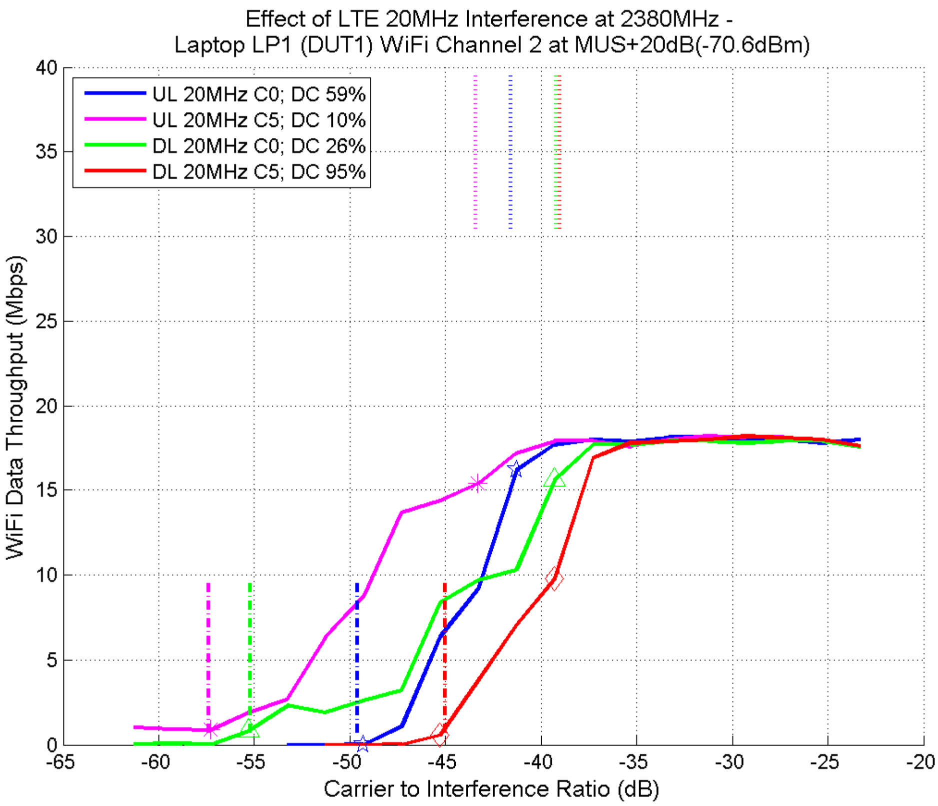

Figure 88

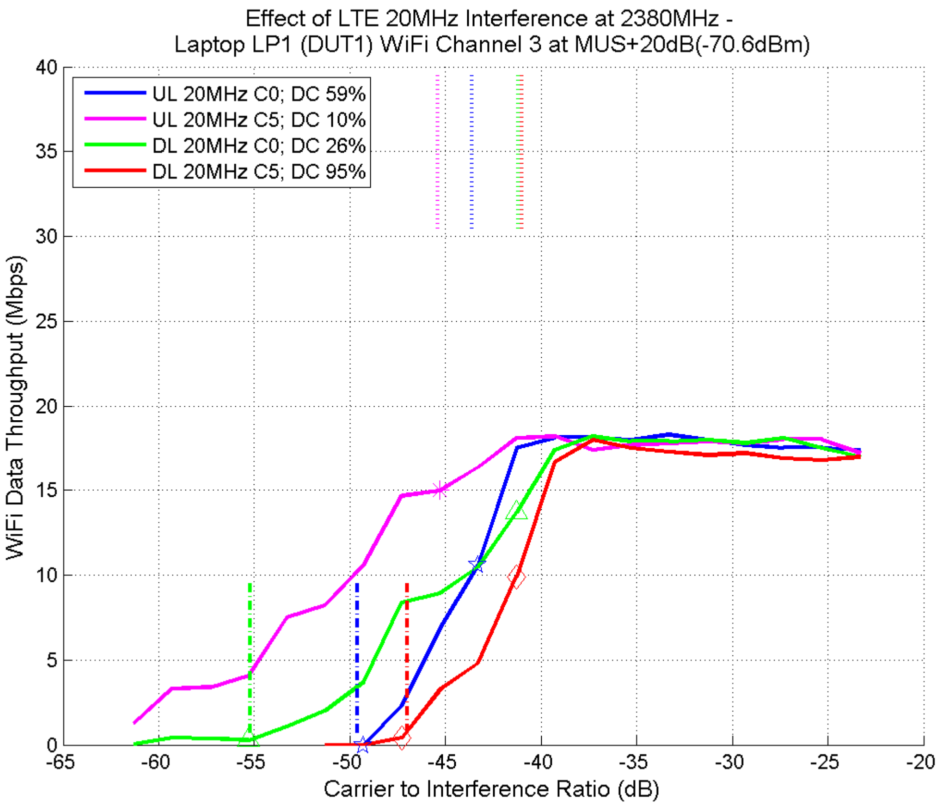

Figure 89

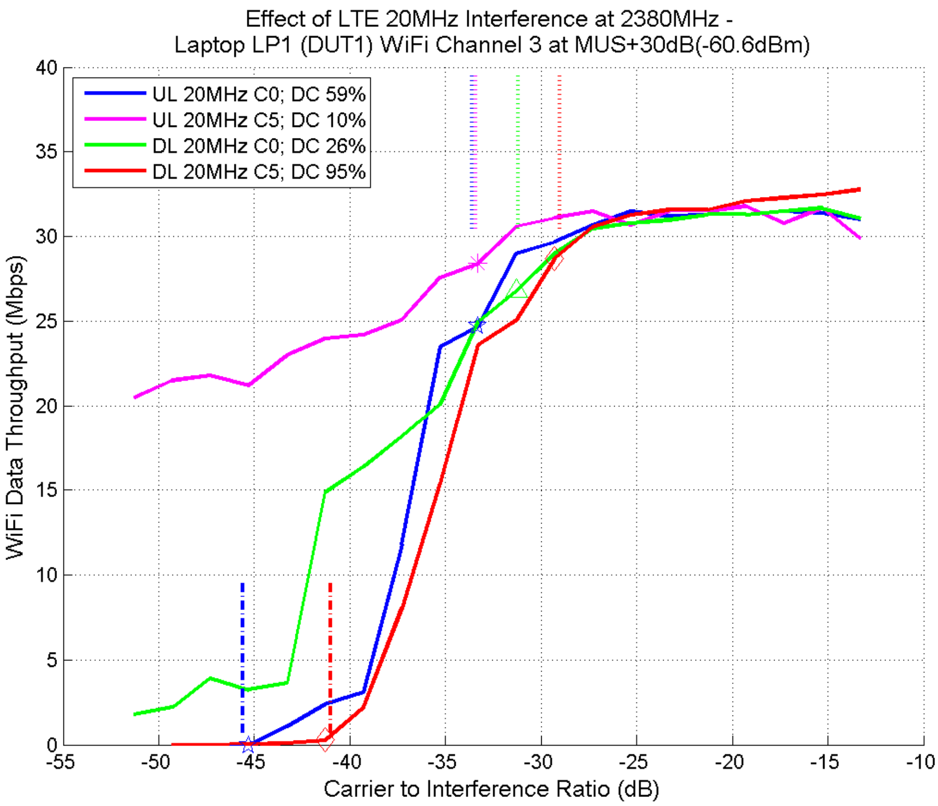

Figure 90

Observations

- The additional tests performed for DUT1 show that, for offsets greater than 50MHz, the blocking is independent of the offset frequency.
- The additional tests performed for DUT1 show that the 10MHz bandwidth LTE transmissions exhibit the same characteristics as the 20MHz bandwidth transmissions.

4.2.2 Laptop LP2 (DUT 3)

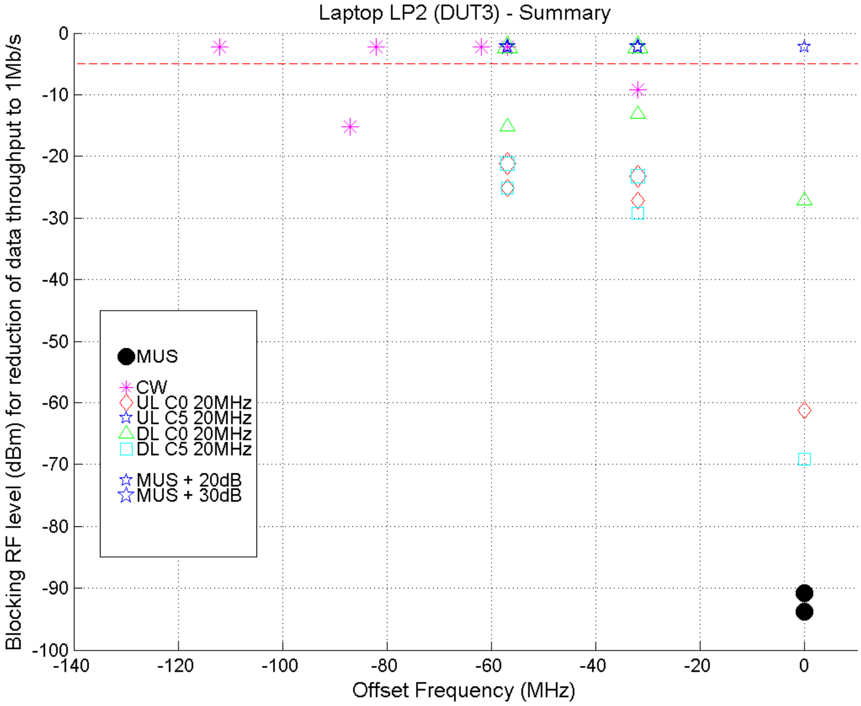

Figure 91

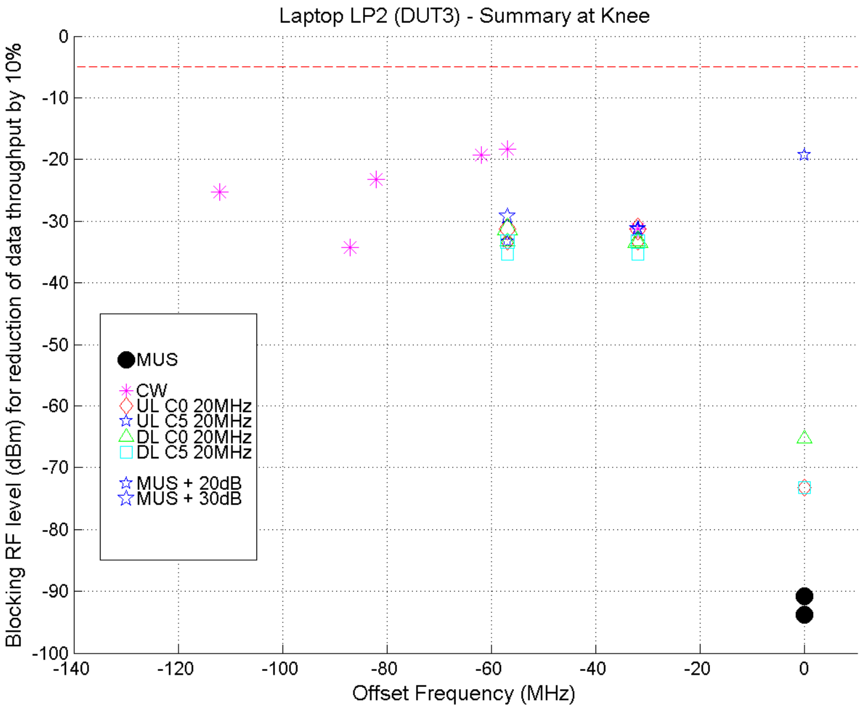

Figure 92

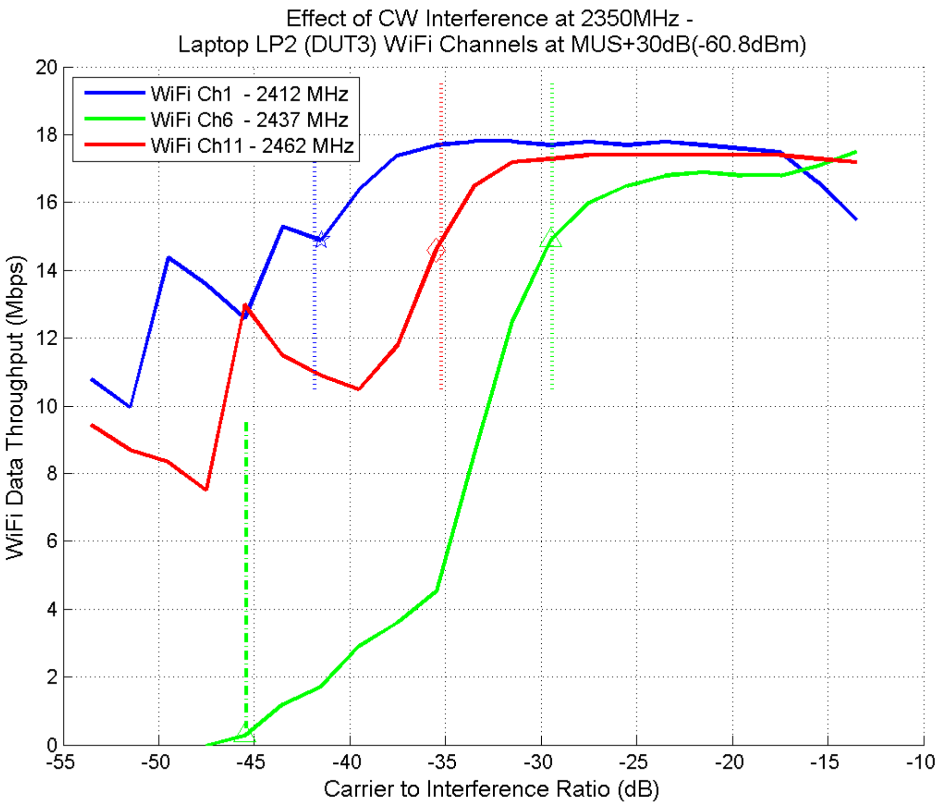

Figure 93

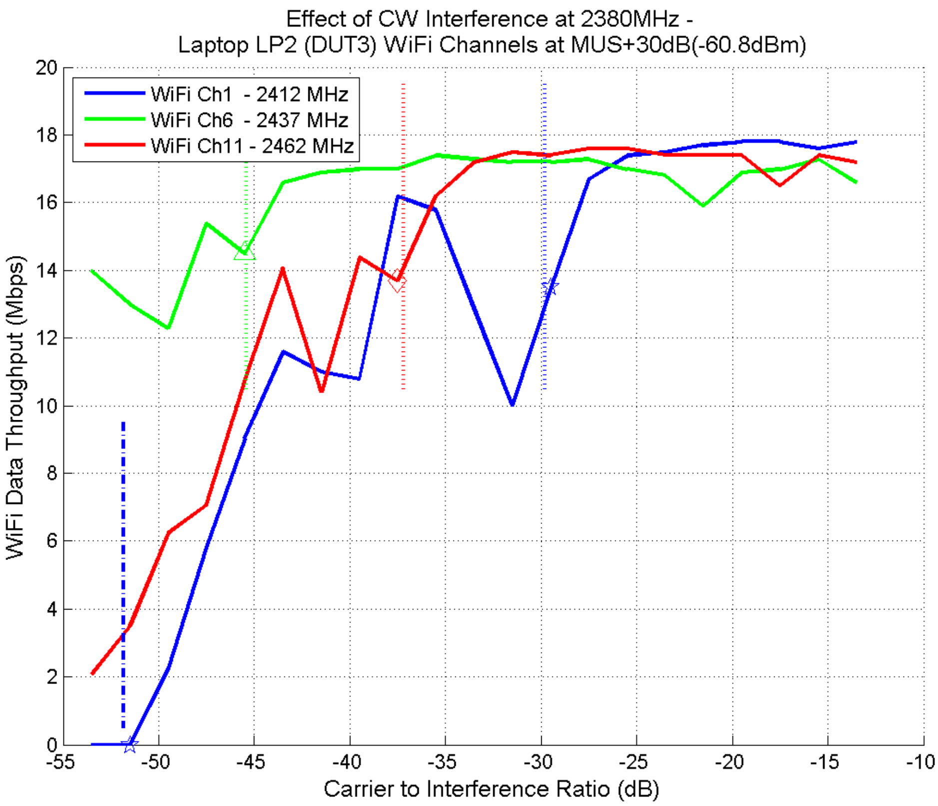

Figure 94

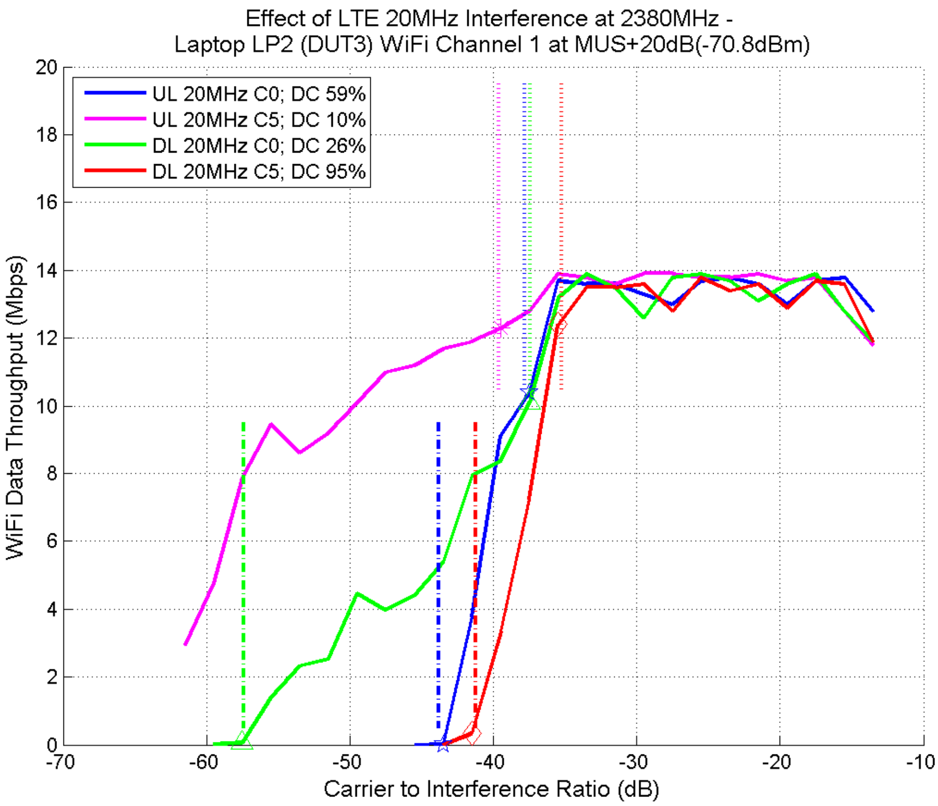

Figure 95

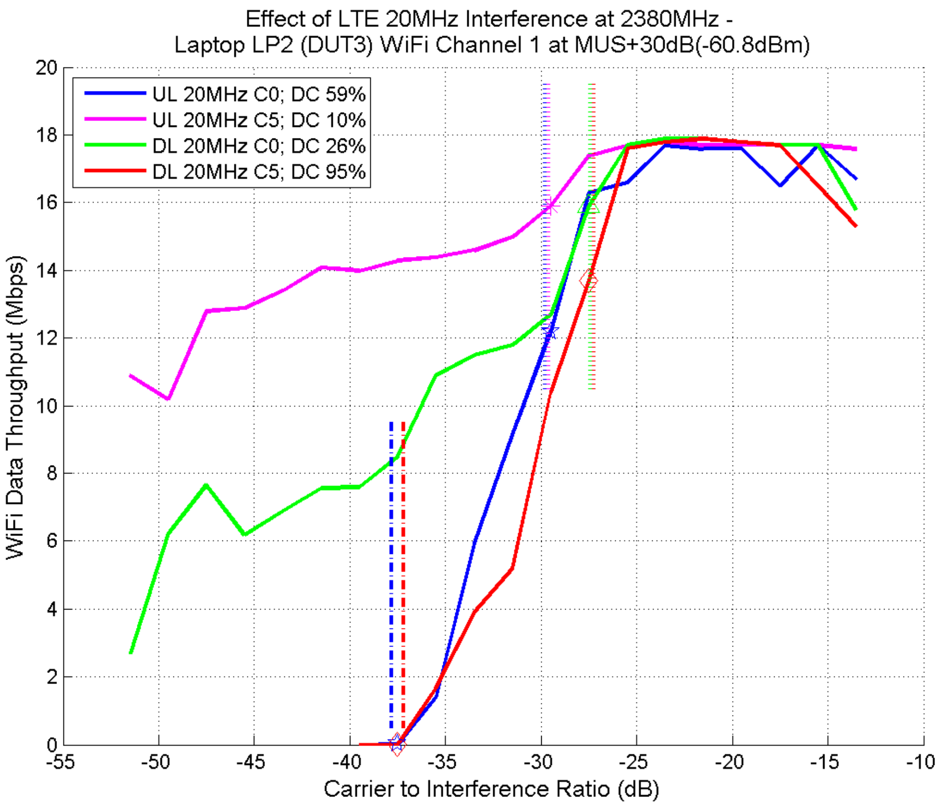

Figure 96

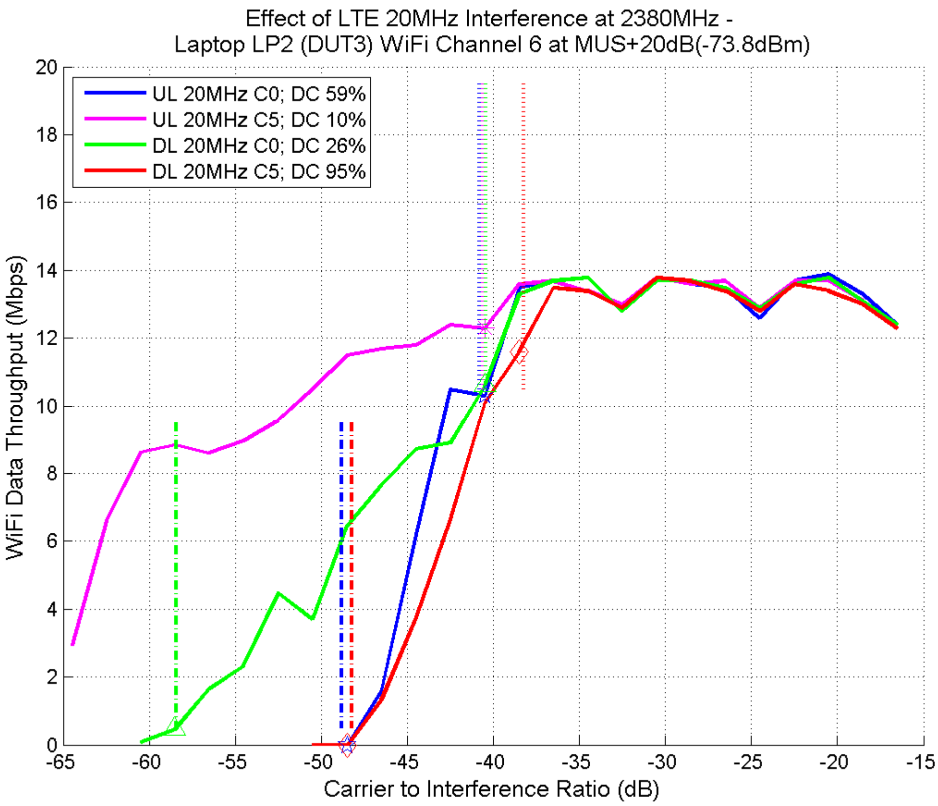

Figure 97

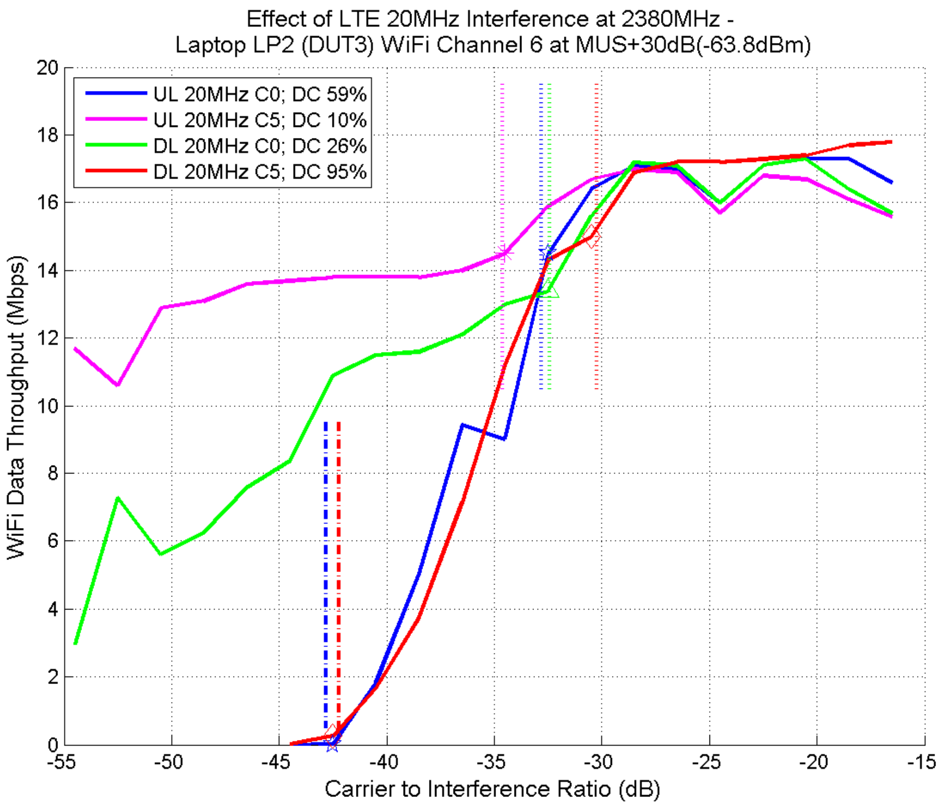

Figure 98

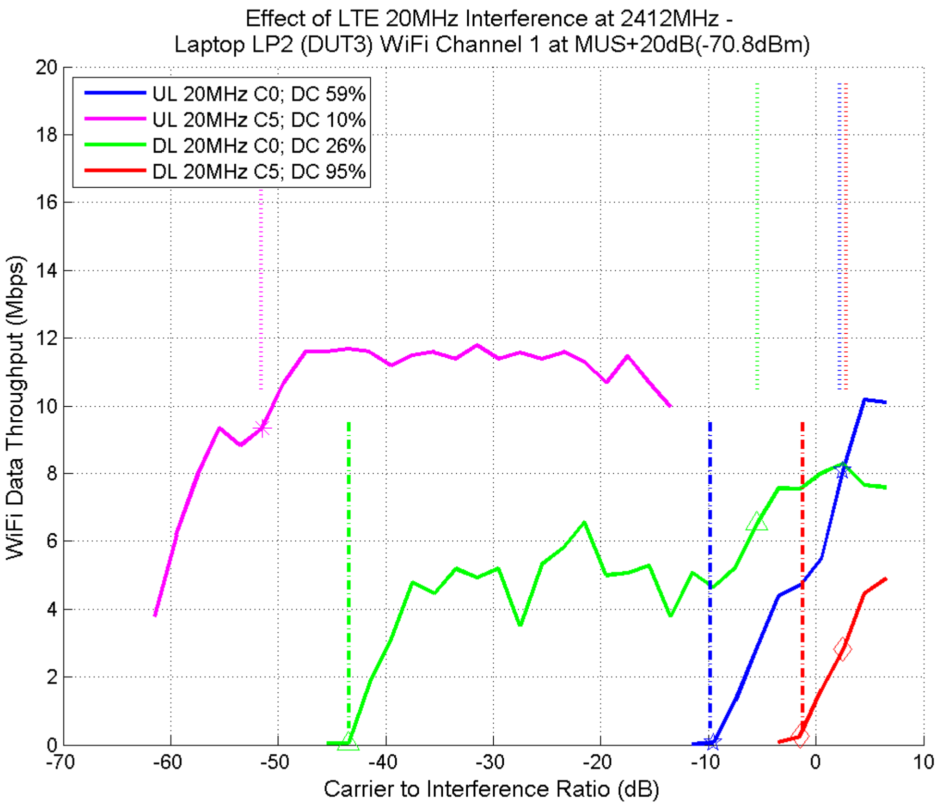

Figure 99

Observations

- The attenuation level of the wanted WiFi signal on channel 6 blocking and selectivity tests was set incorrectly by 3dB as such the test results are reflective of performance at MUS+33dB. This is not expected to significantly affect the overall conclusions.
- Receiver sensitivity tests were conducted on both WiFi channel 1 and channel 6 which resulted in marginally different MUS values present in the summary plots.

4.3 Tablets

4.3.1 Tablet TB1 (DUT 5)

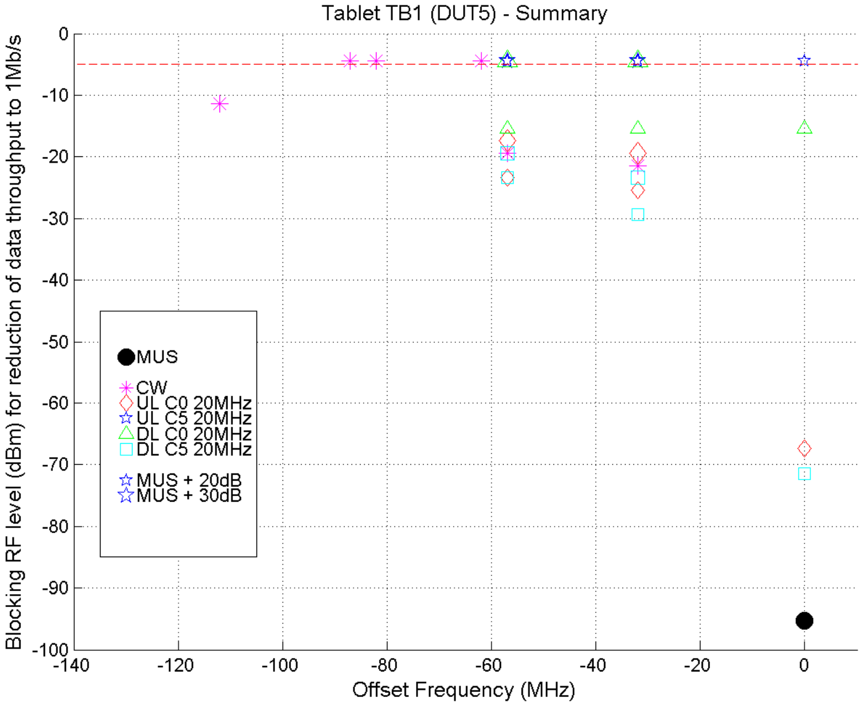

Figure 100

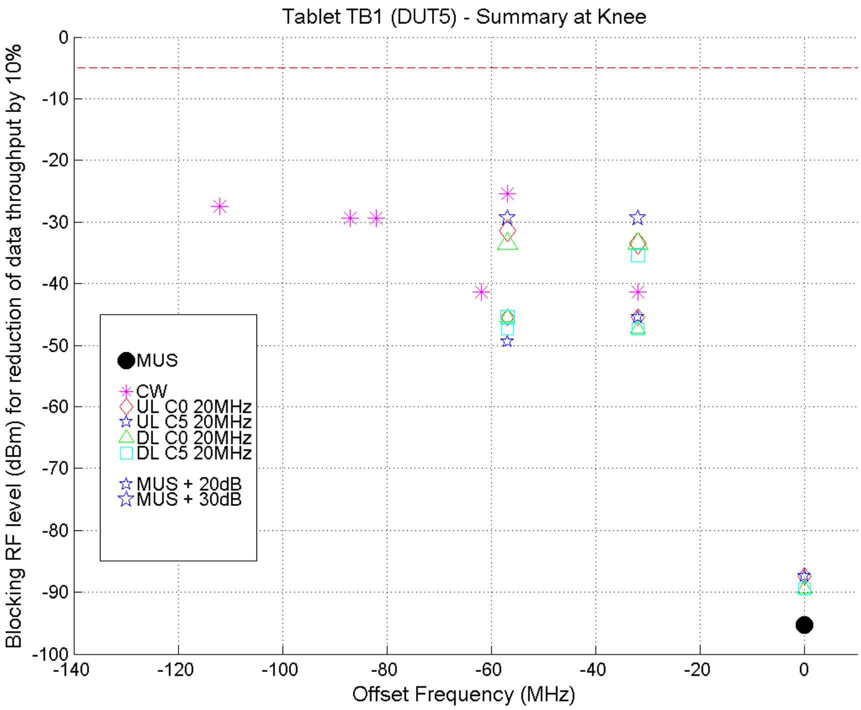

Figure 101

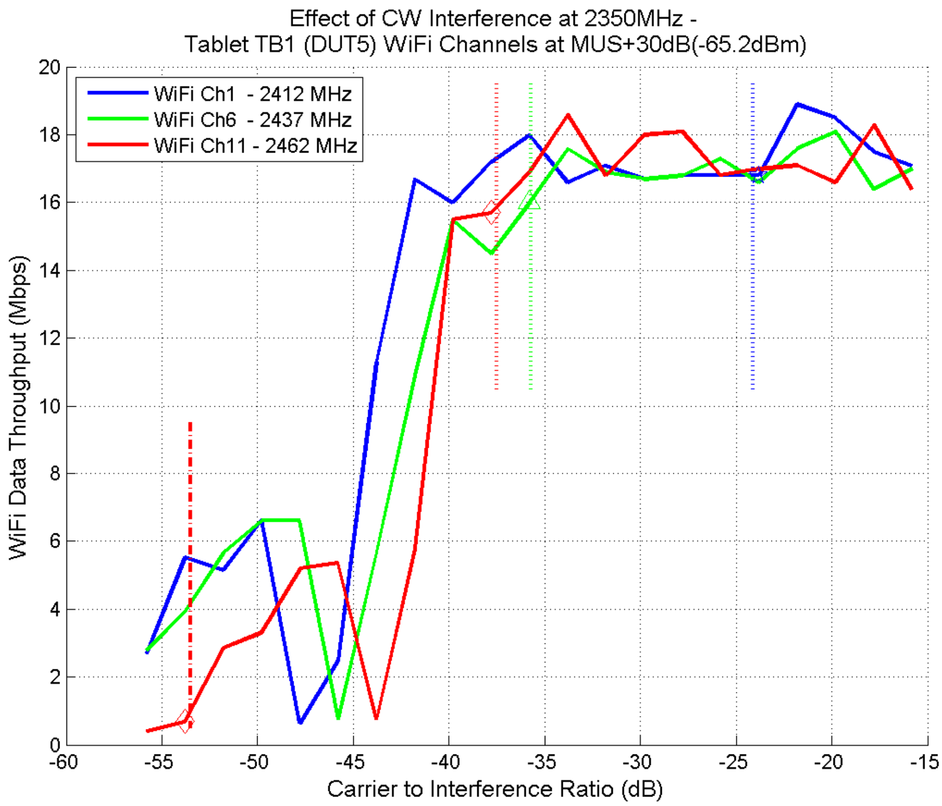

Figure 102

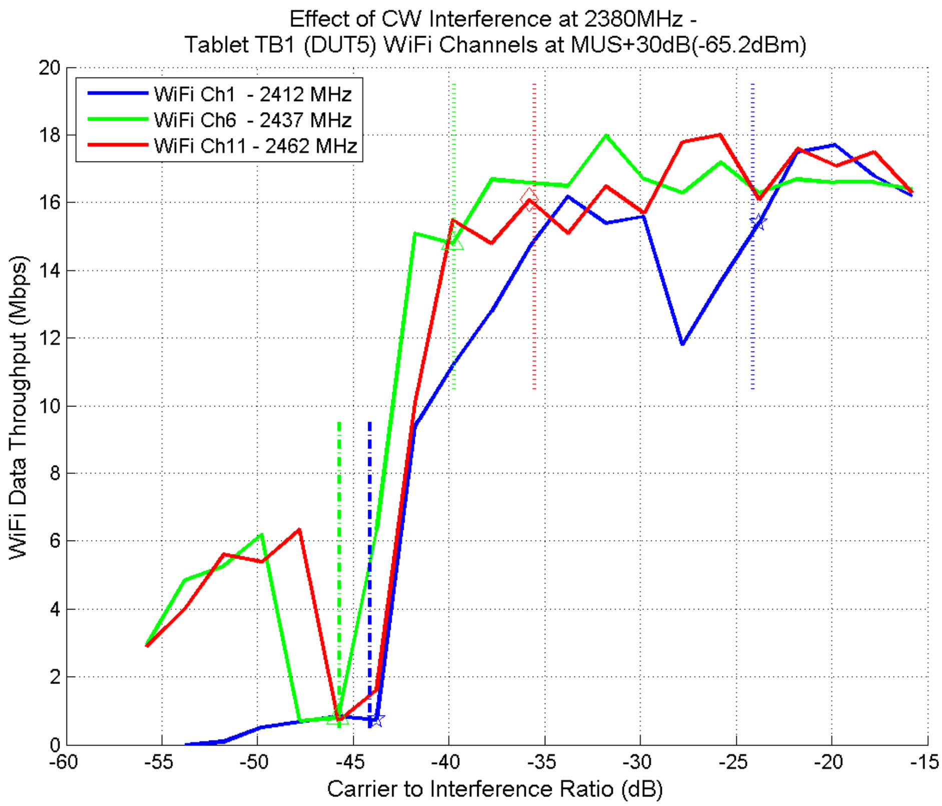

Figure 103

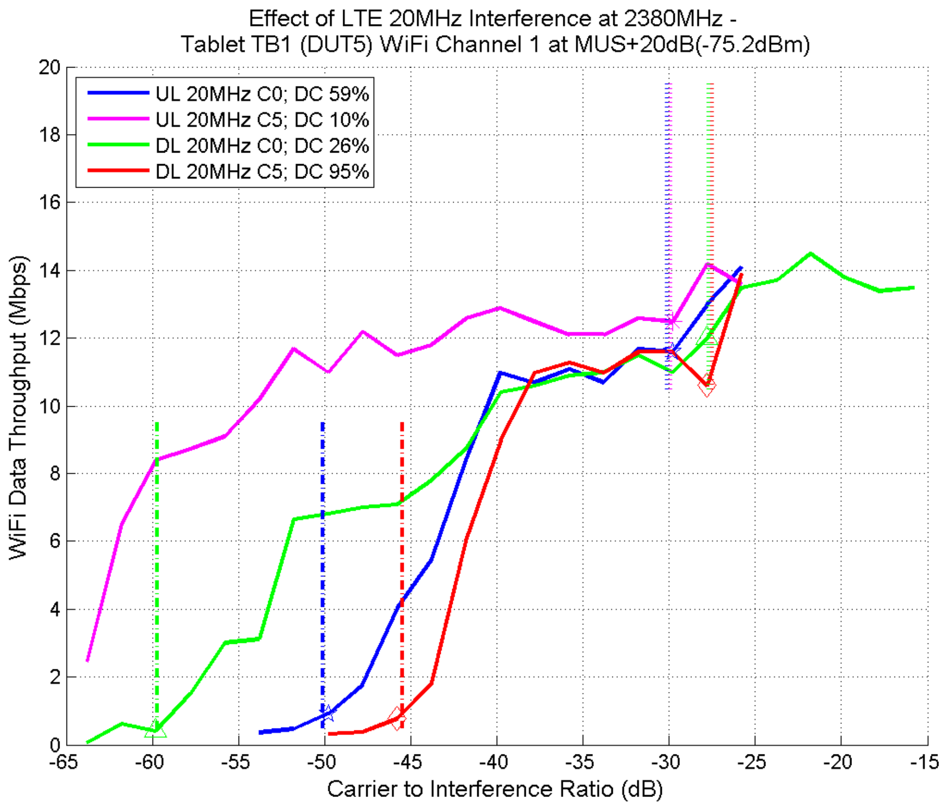

Figure 104

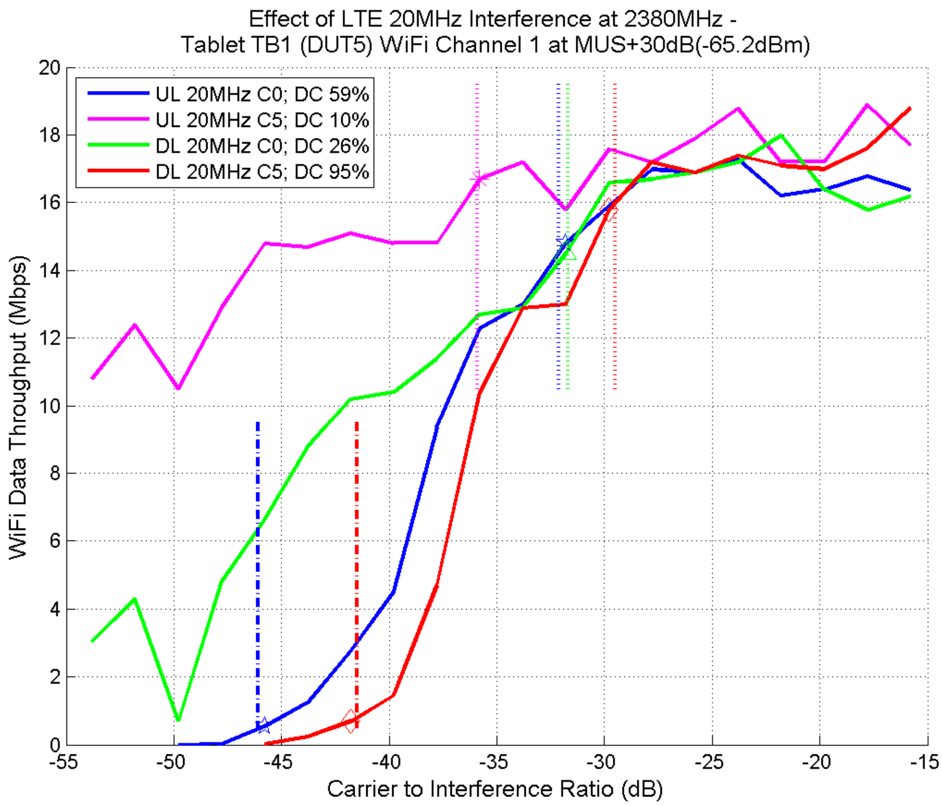

Figure 105

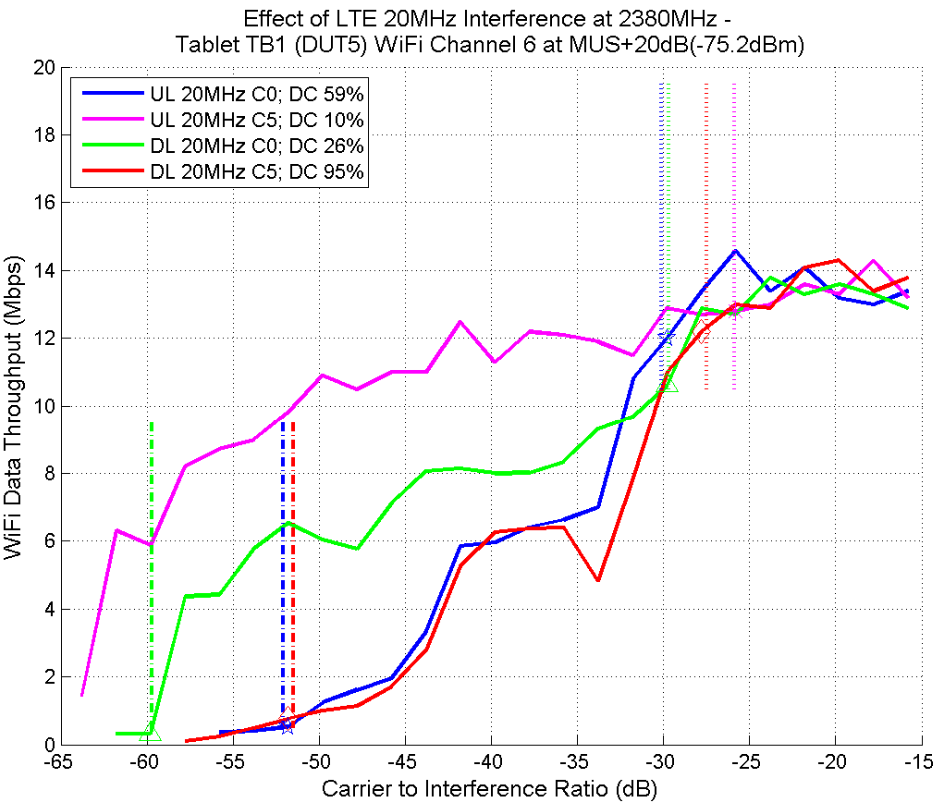

Figure 106

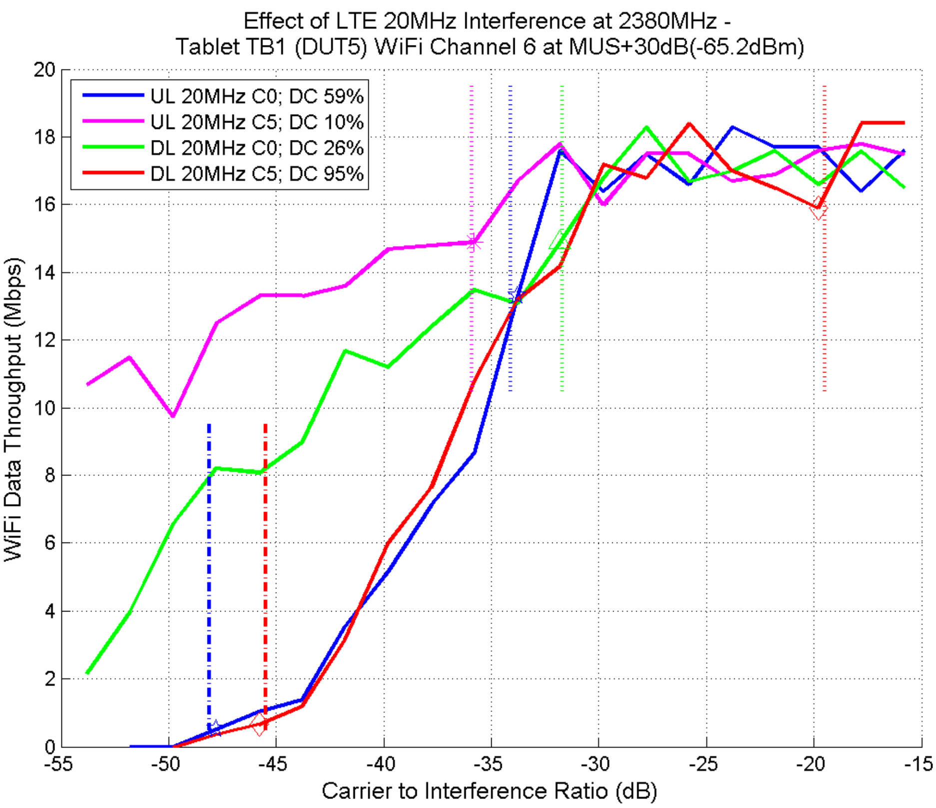

Figure 107

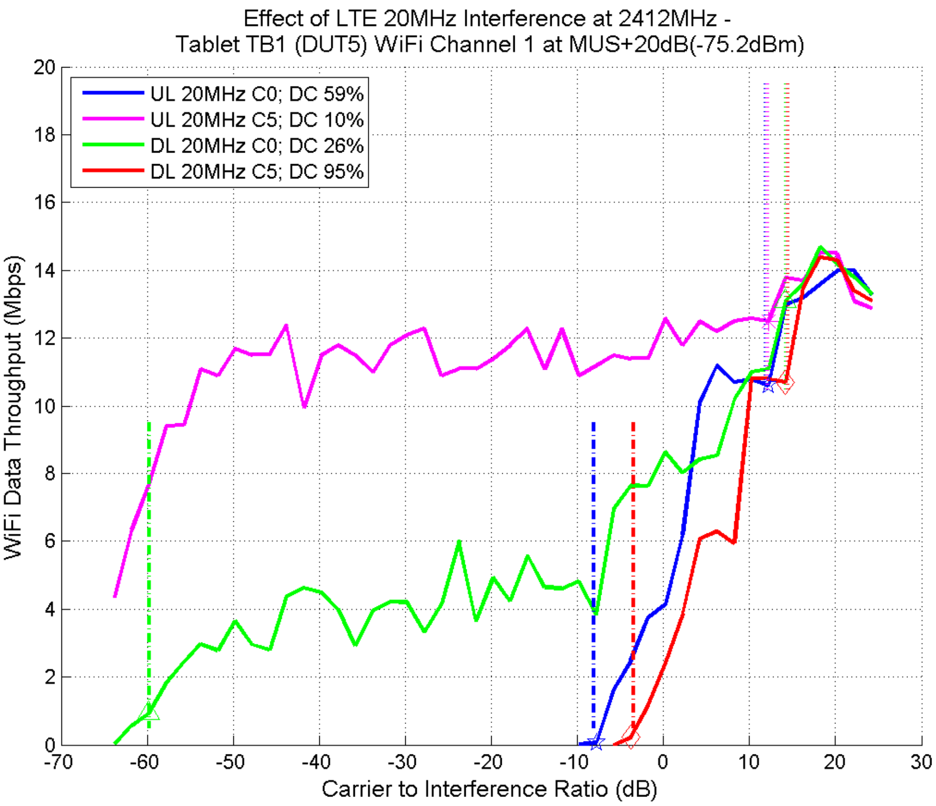

Figure 108

Observations

- Horizontally polarised when positioned horizontally on turntable.
- WiFi tablet devices are commonly used in vertical or semi-vertical position as well as flat on a table or other surface.
- In Figure 108 the DUT maintained a high throughput for the 10% duty cycle interference when applied co-channel. This is similar behaviour to that seen in other DUTs in this study.

4.3.2 Tablet TB2 (DUT 15)

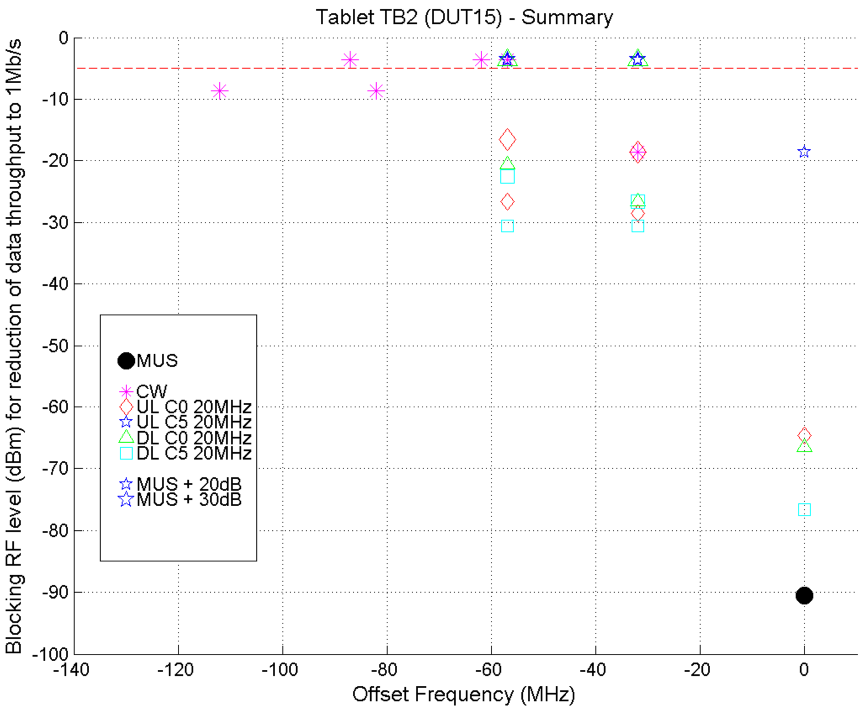

Figure 109

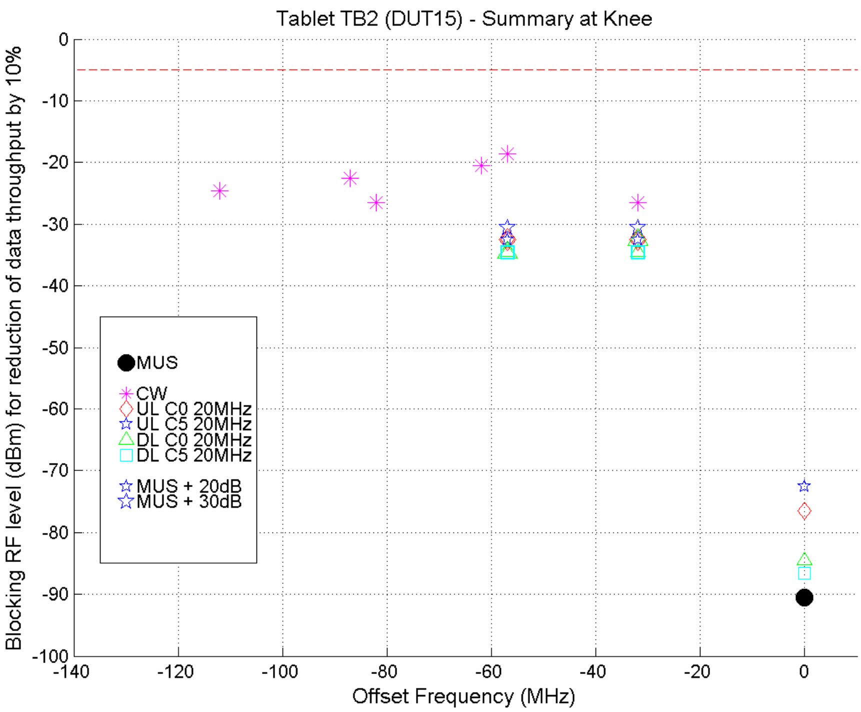

Figure 110

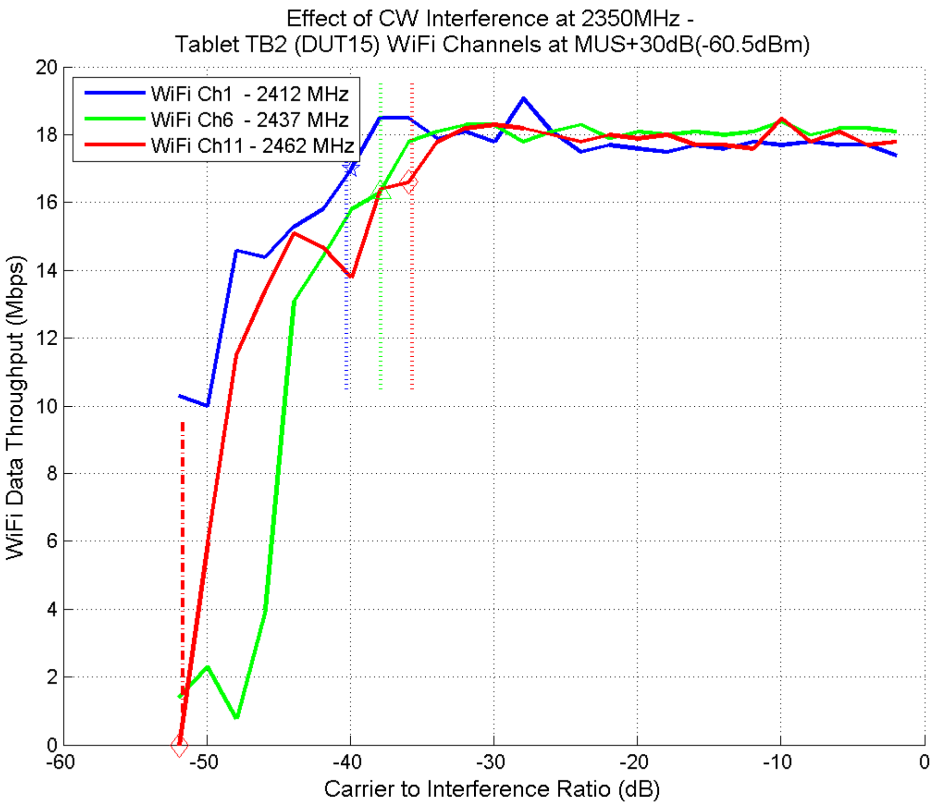

Figure 111

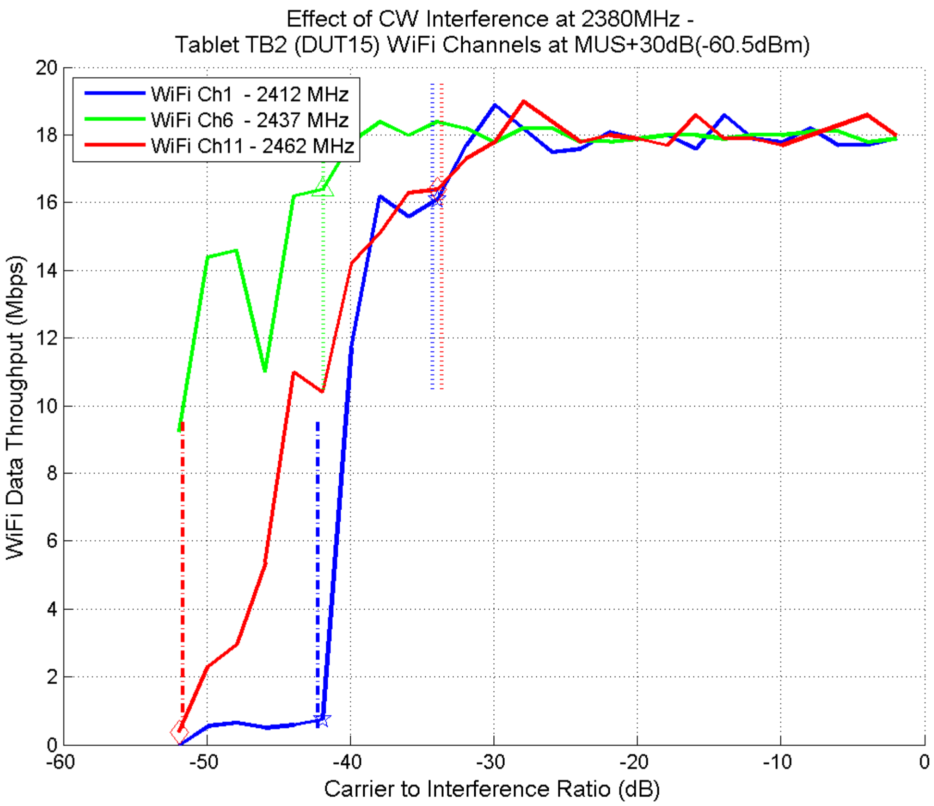

Figure 112

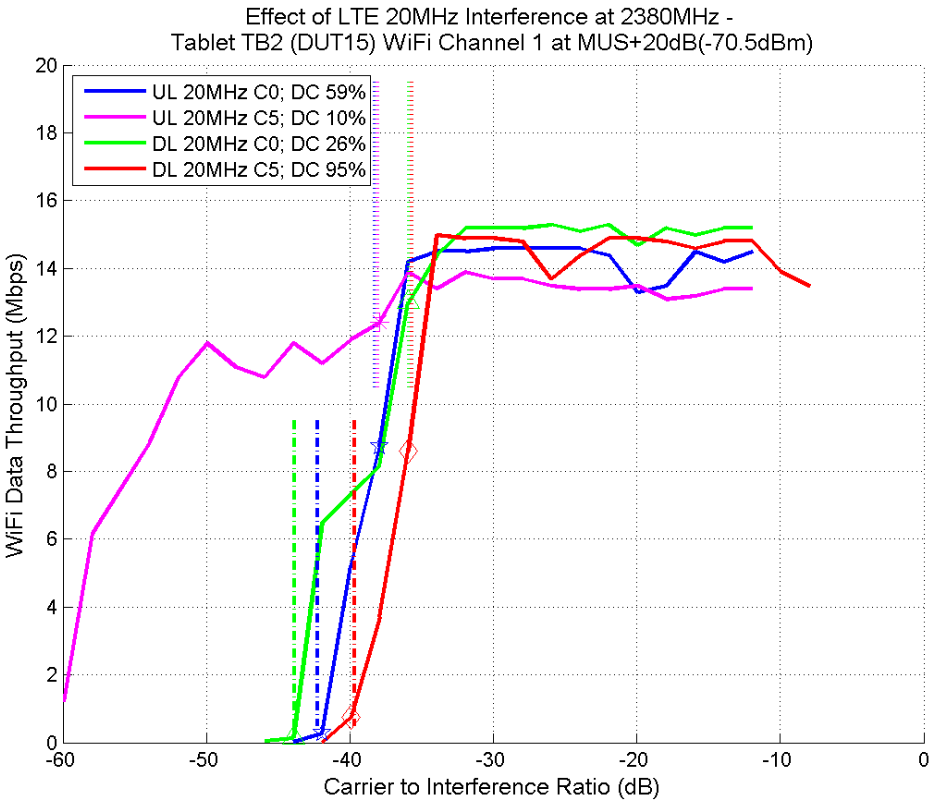

Figure 113

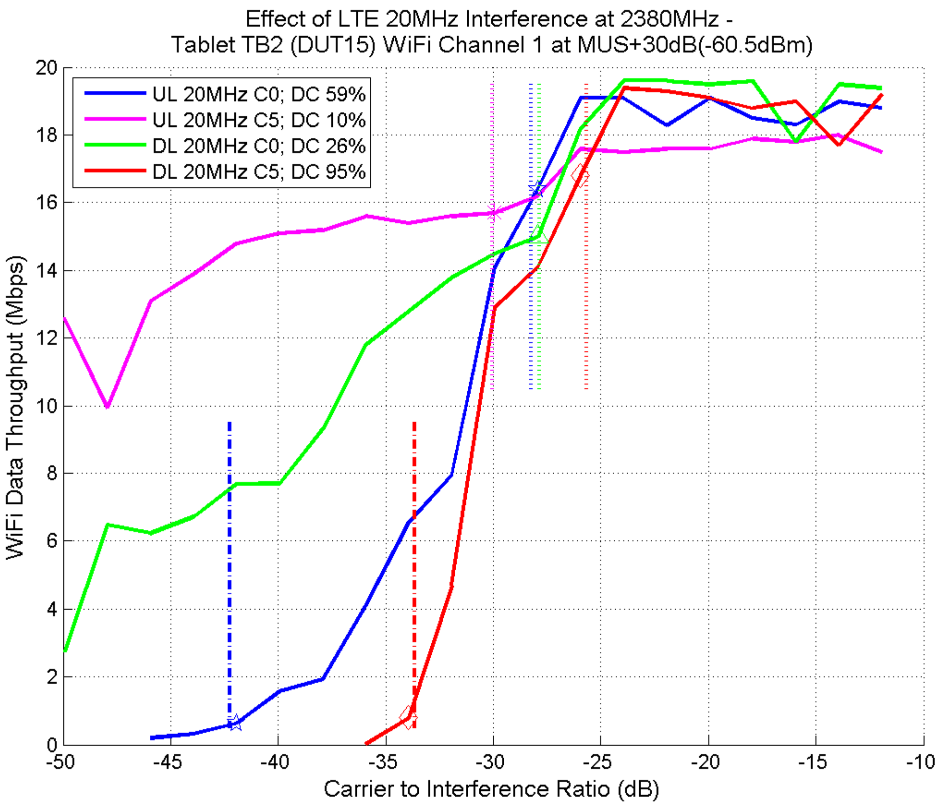

Figure 114

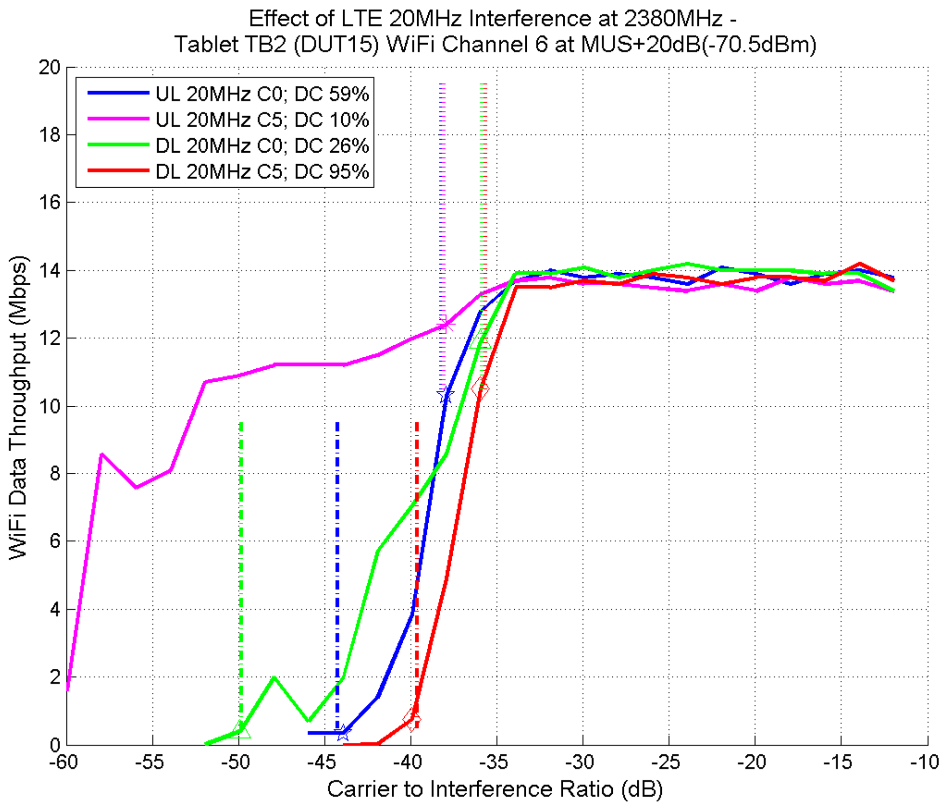

Figure 115

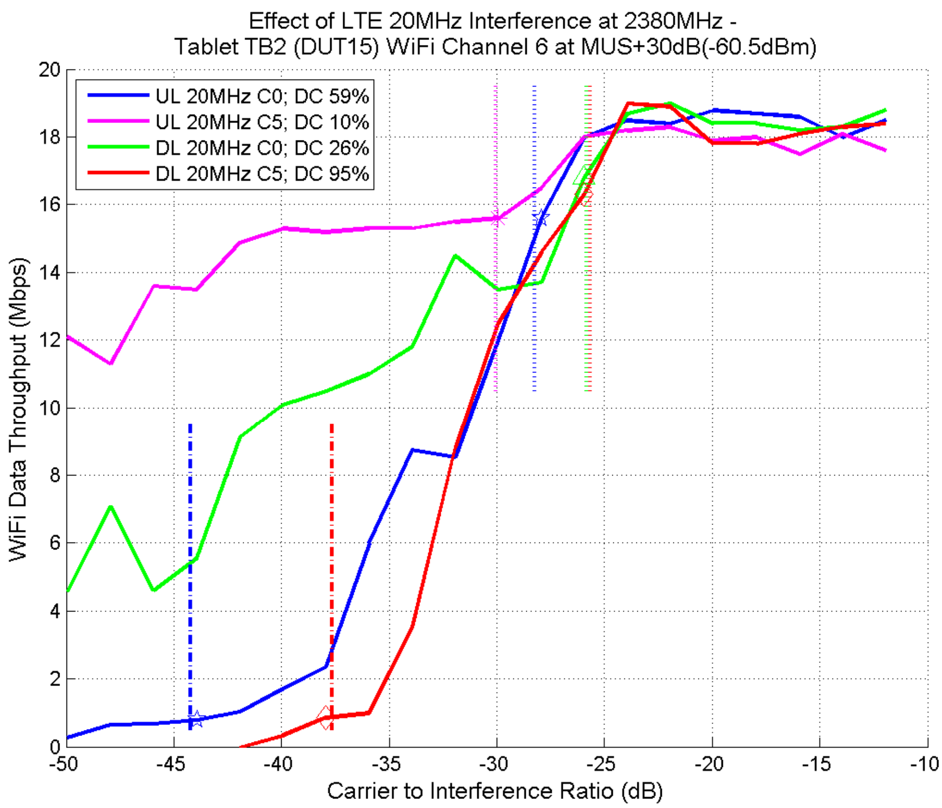

Figure 116

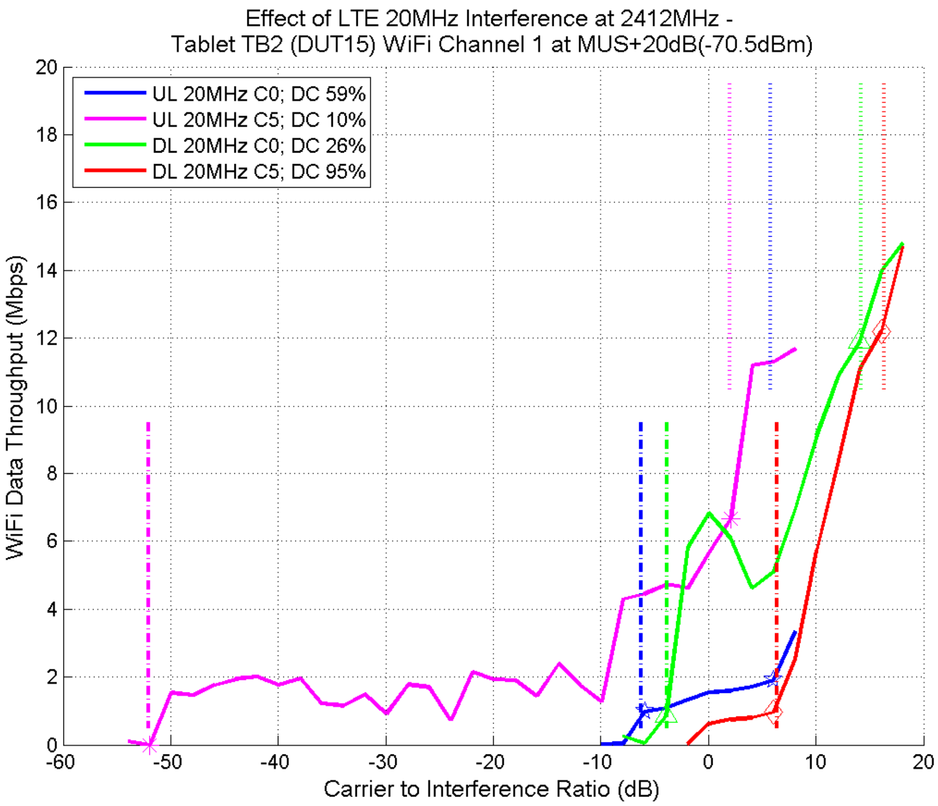

Figure 117

Observations

- Horizontally polarised when positioned horizontally on turntable.
- Tablet devices commonly used in vertical or semi-vertical position, as well as horizontally on a table or similar surface.

4.3.3 Tablet TB3 (DUT 19)

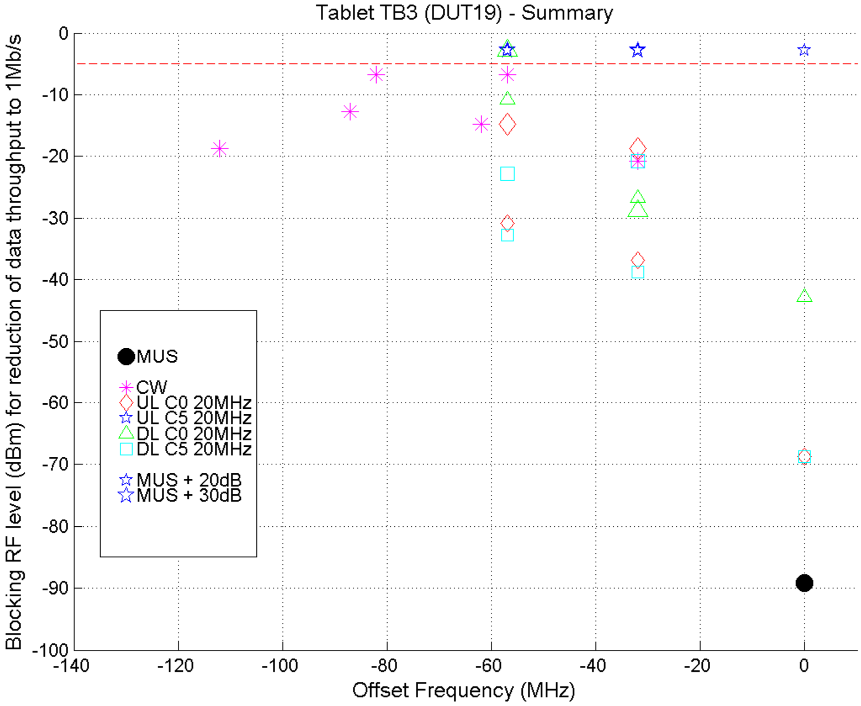

Figure 118

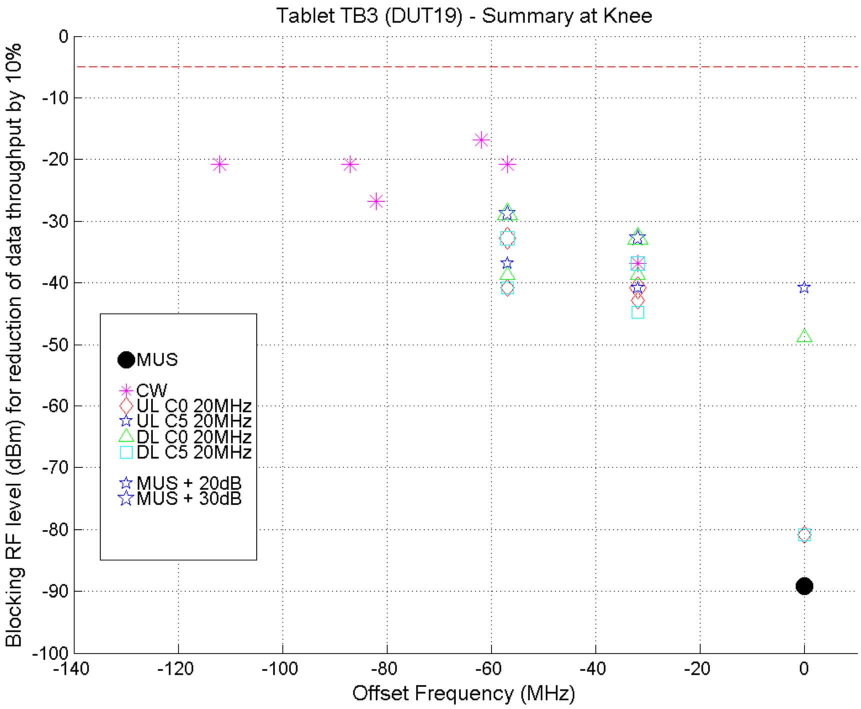

Figure 119

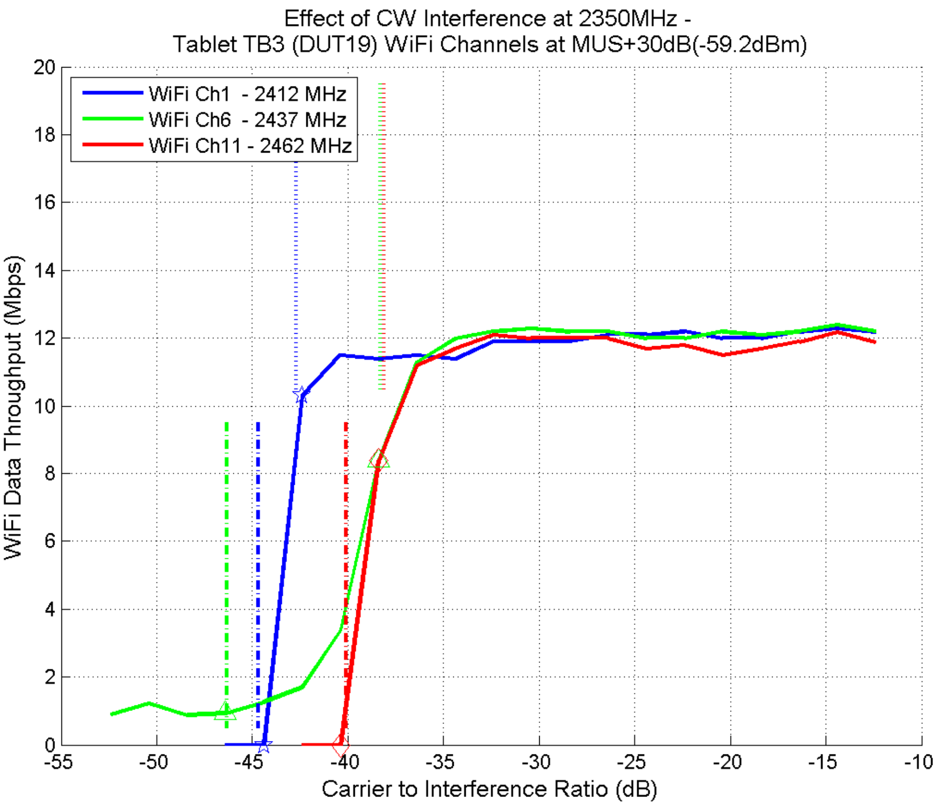

Figure 120

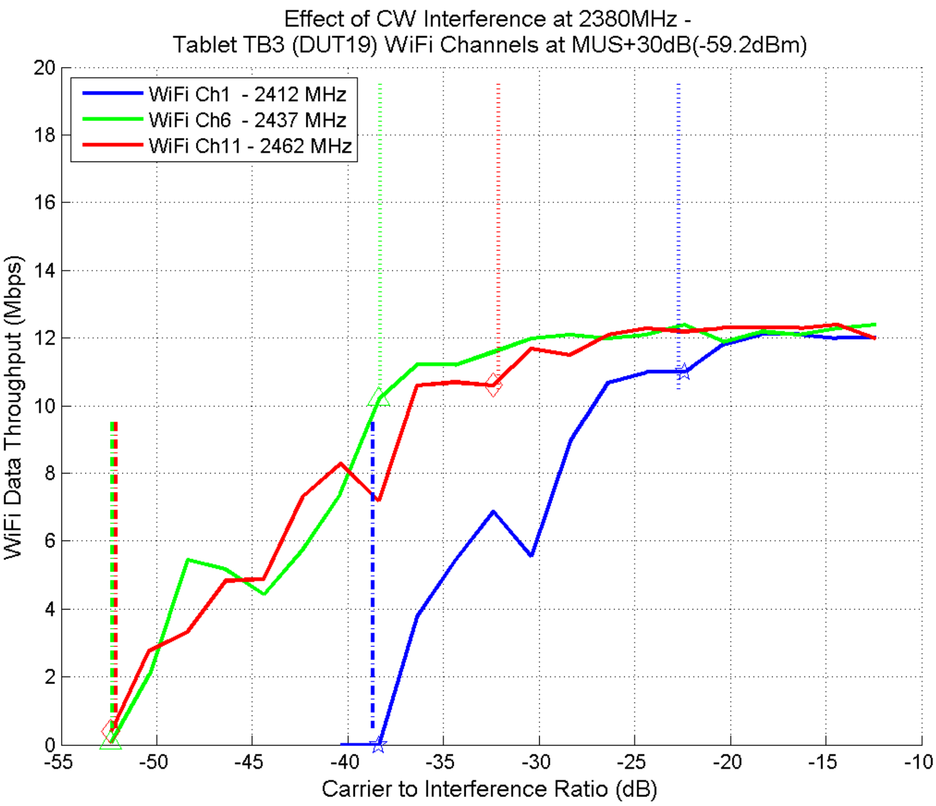

Figure 121

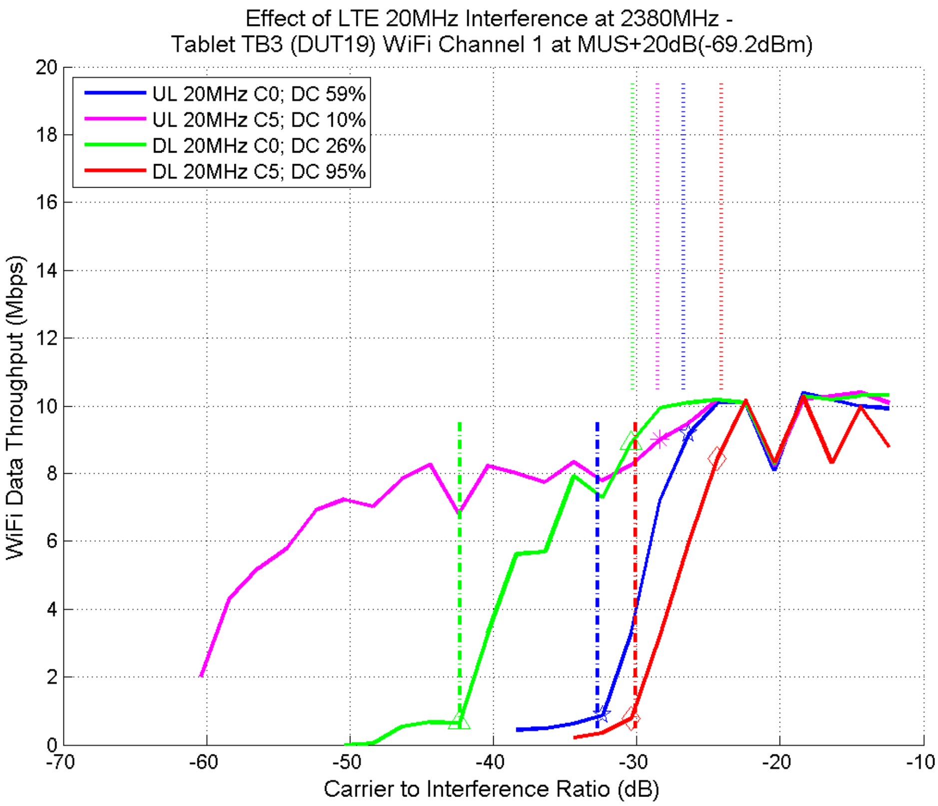

Figure 122

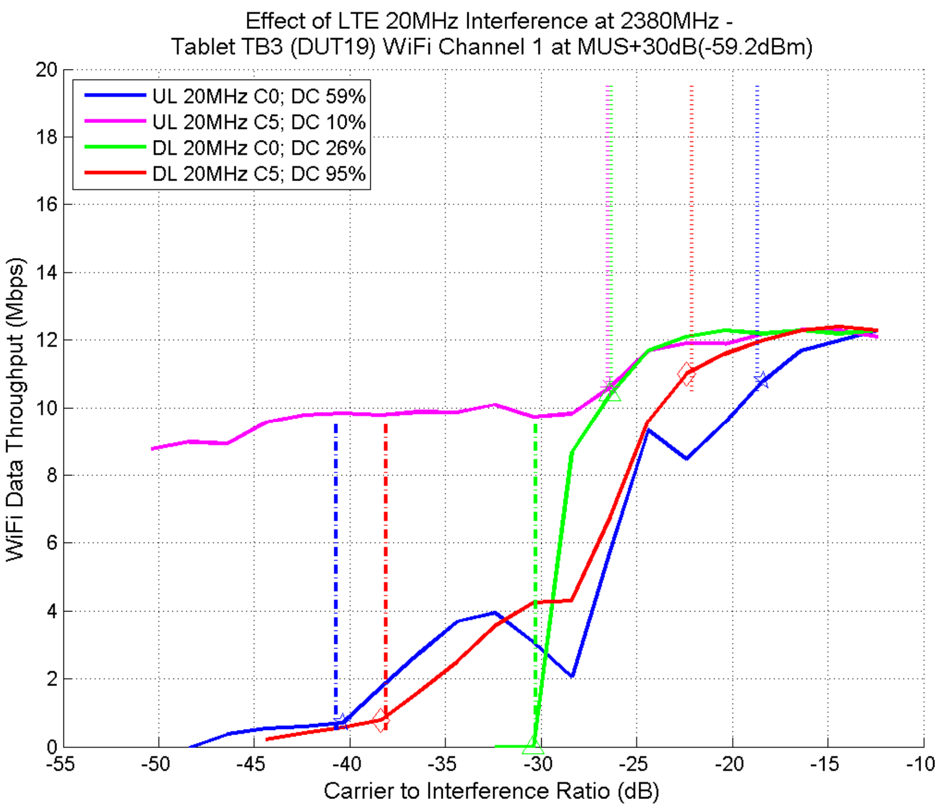

Figure 123

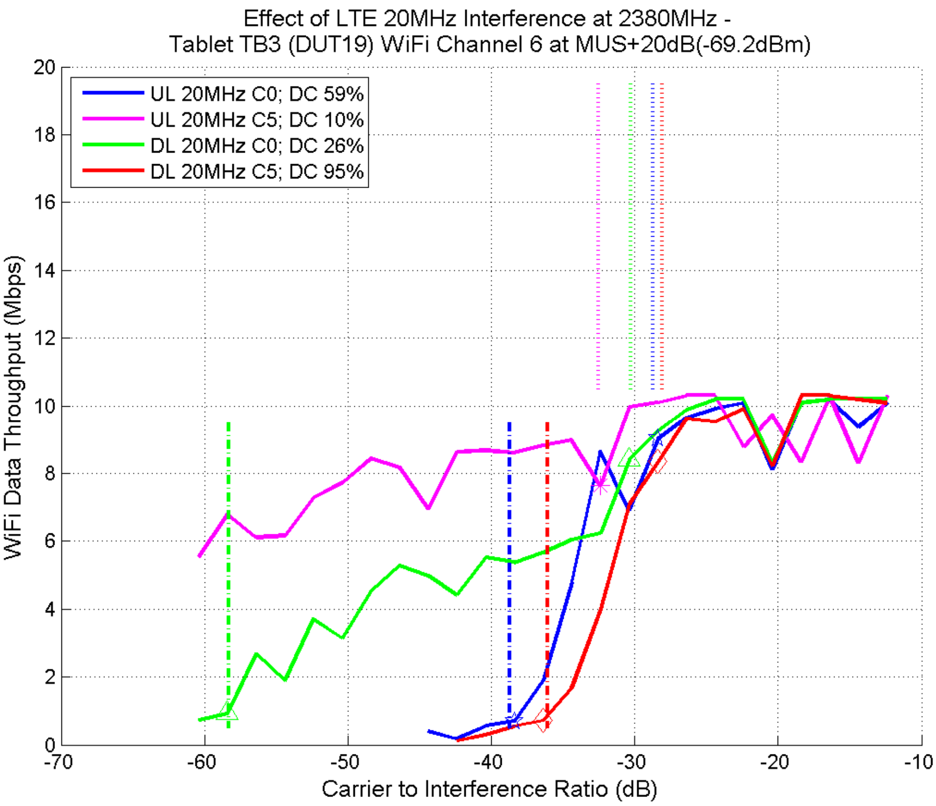

Figure 124

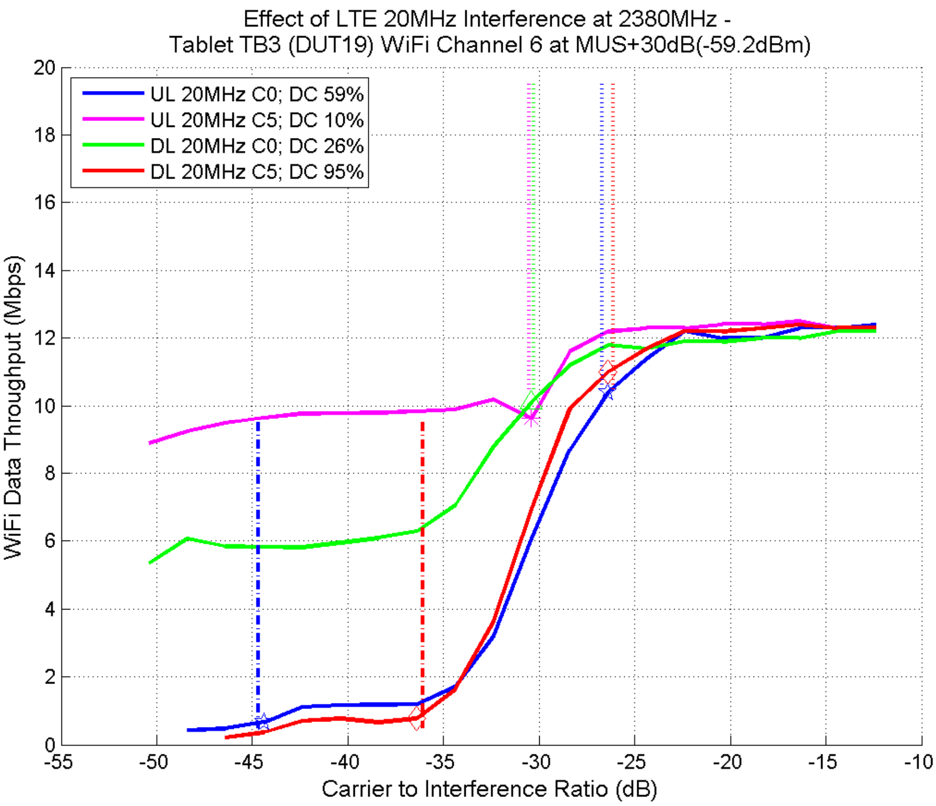

Figure 125

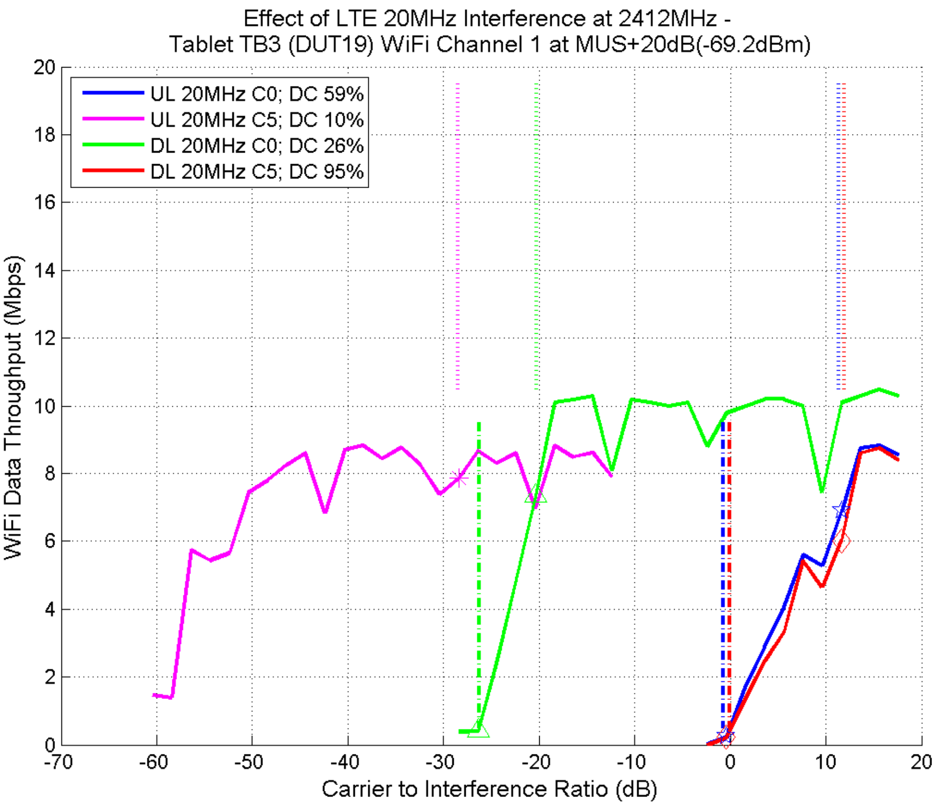

Figure 126

Observations

- Horizontally polarised when positioned horizontally on turntable.
- WiFi tablet devices are commonly used in vertical or semi-vertical position as well as flat on a table or other surface.

4.4 Mobile Phones

4.4.1 Mobile Phone MP2 (DUT 12)

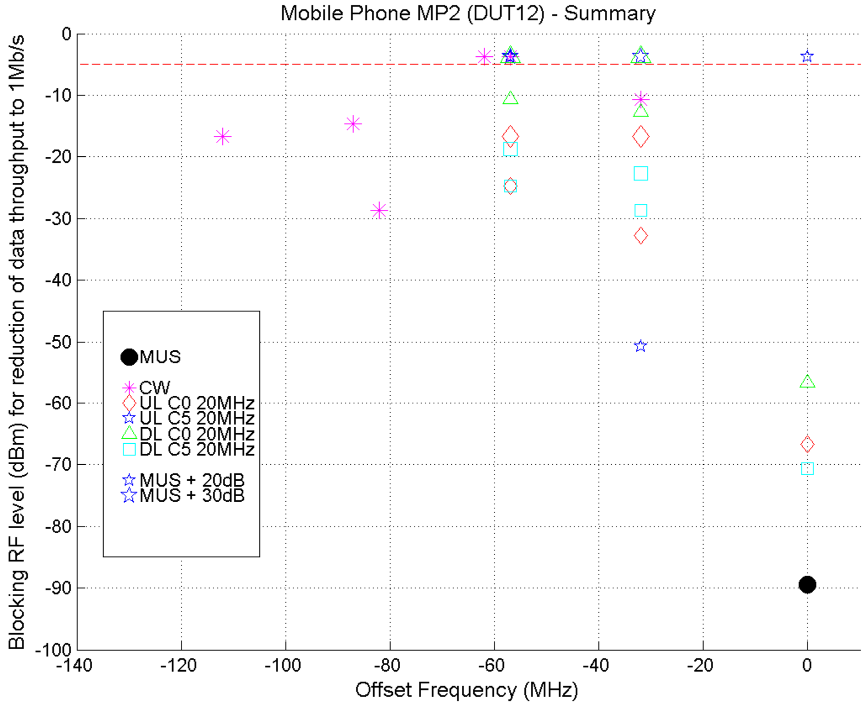

Figure 127

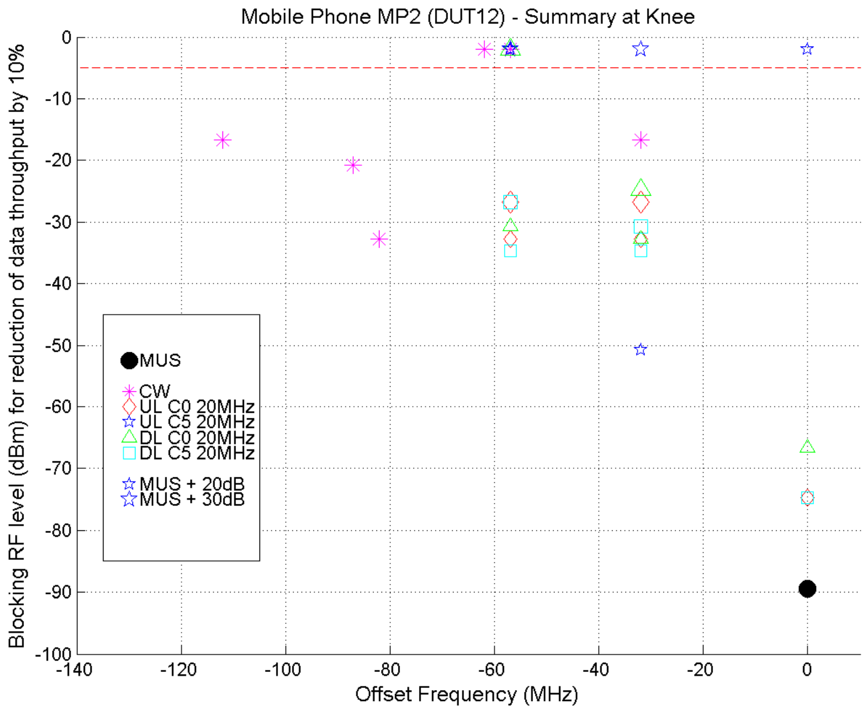

Figure 128

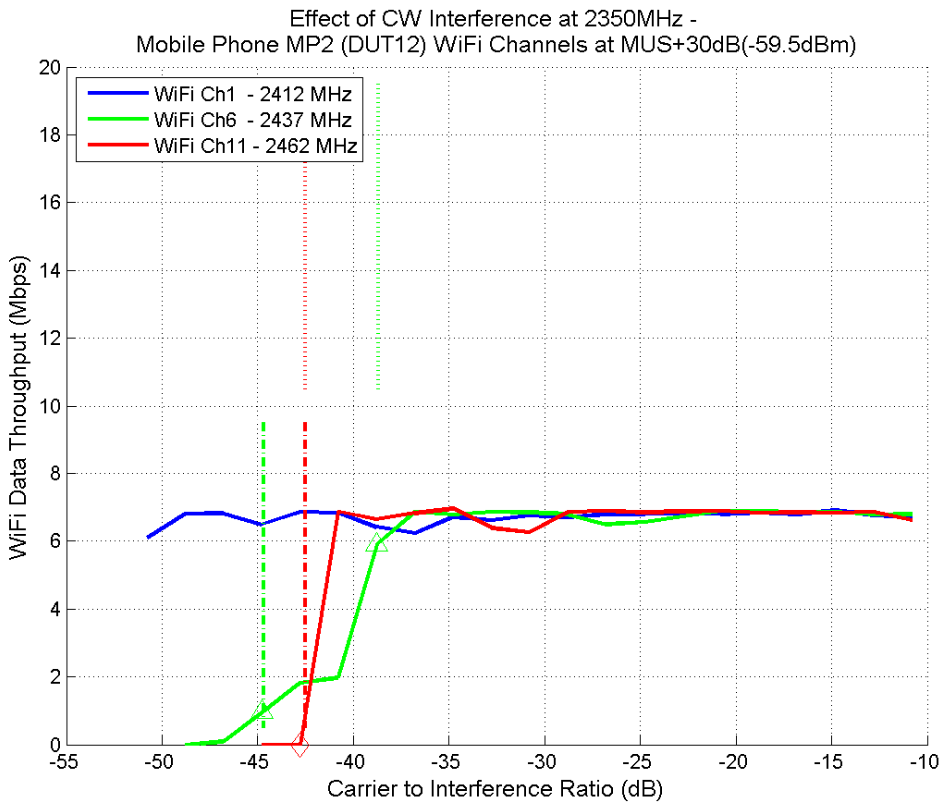

Figure 129

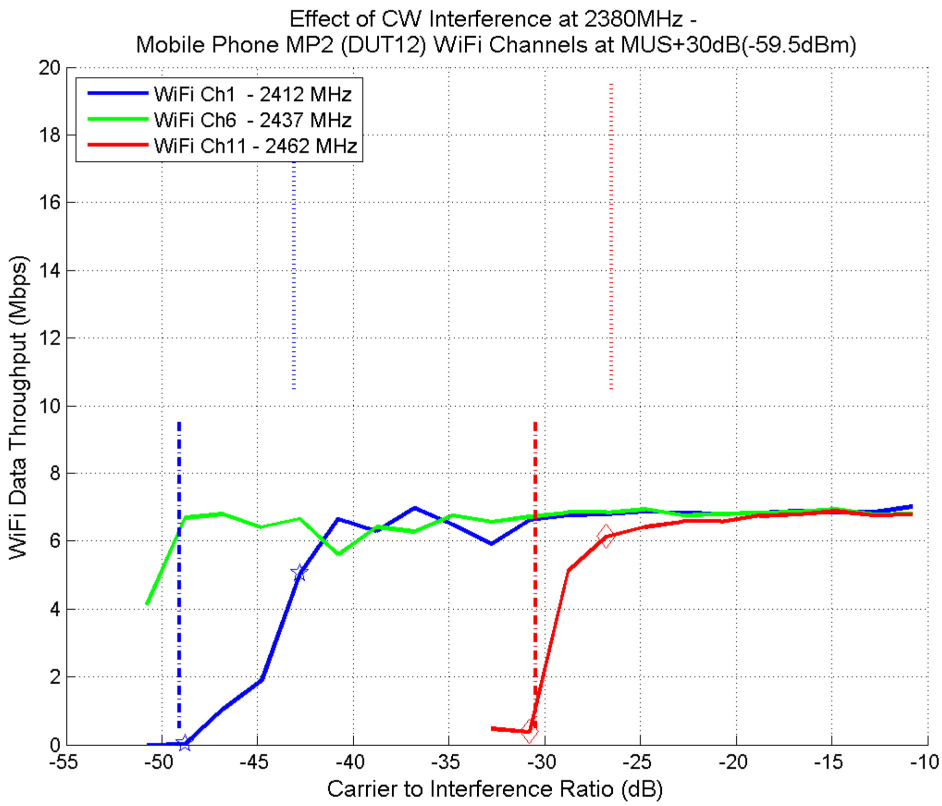

Figure 130

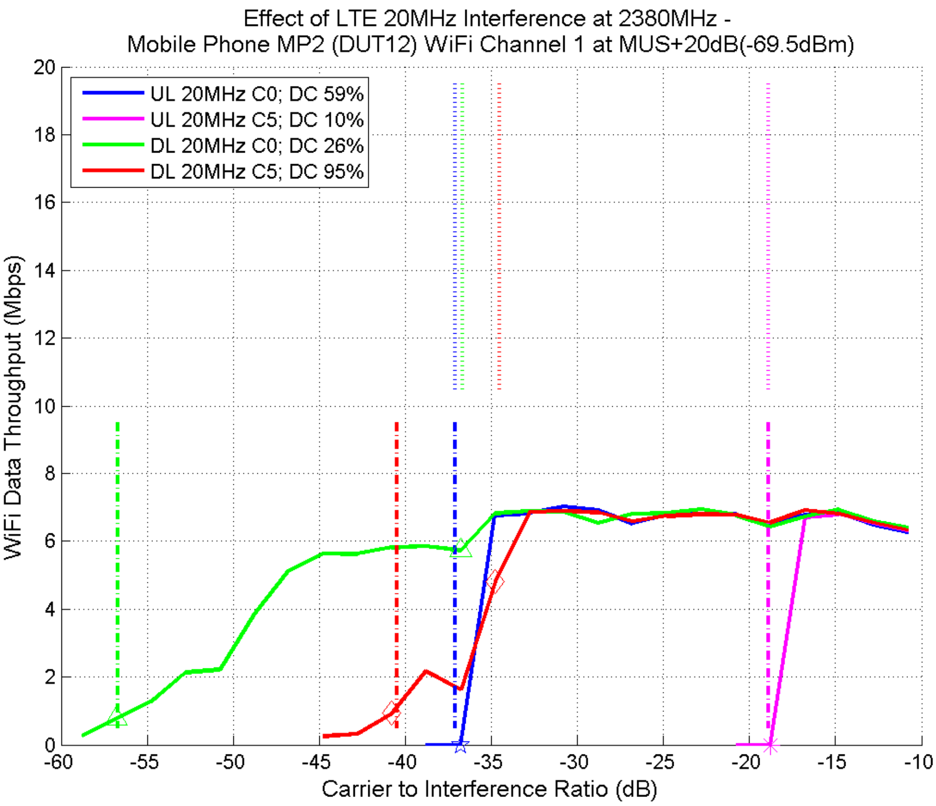

Figure 131

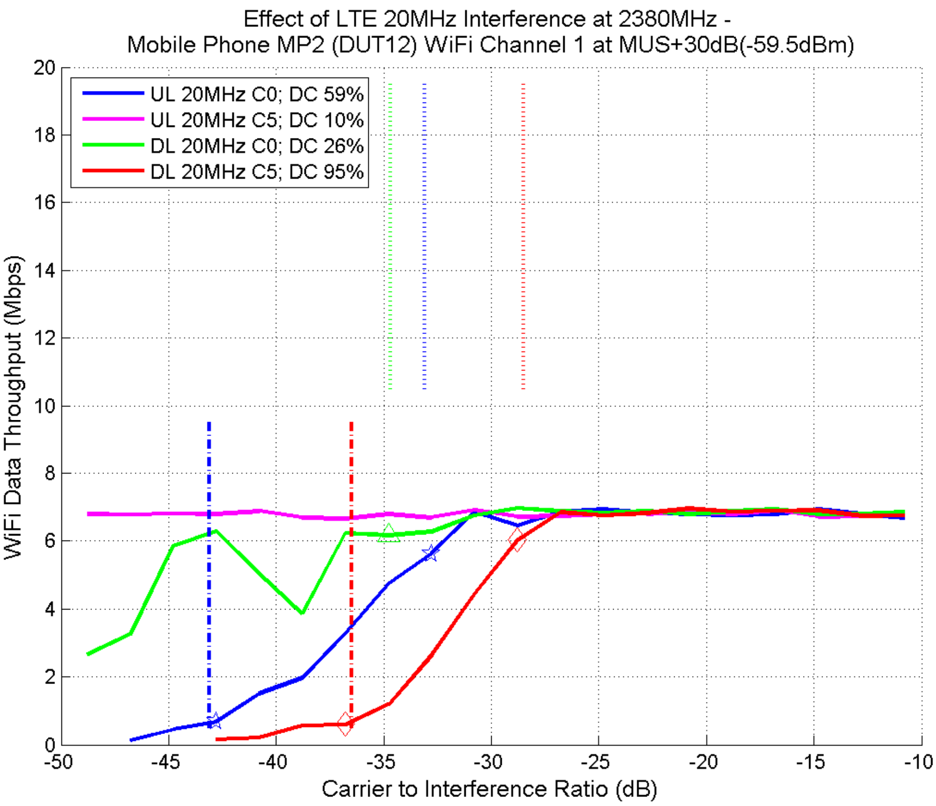

Figure 132

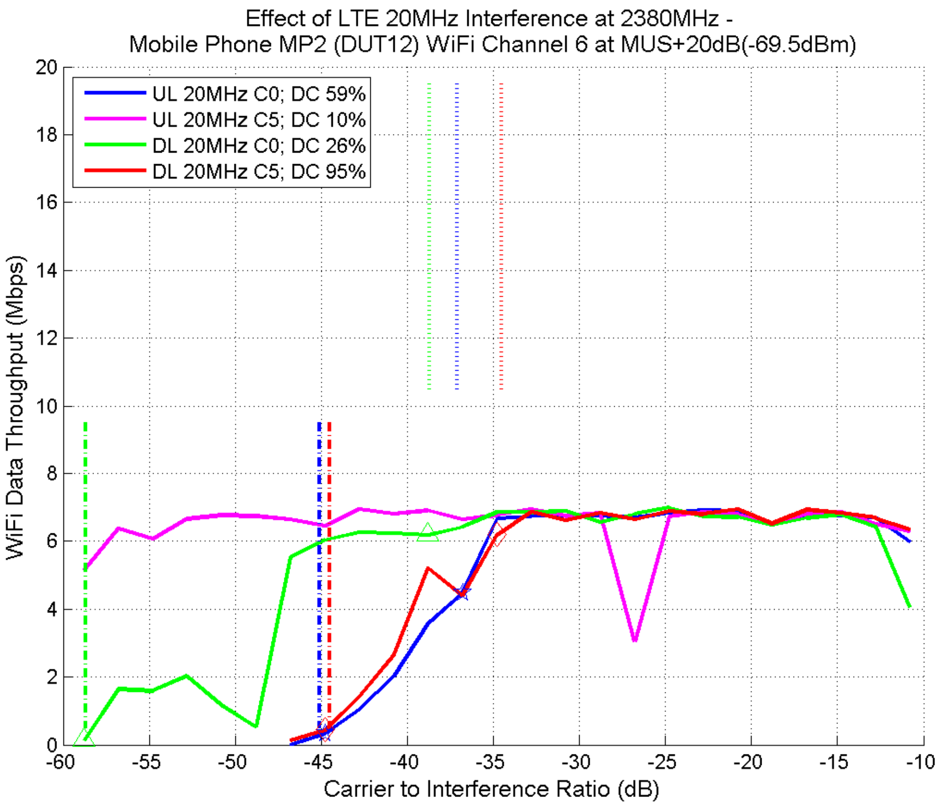

Figure 133

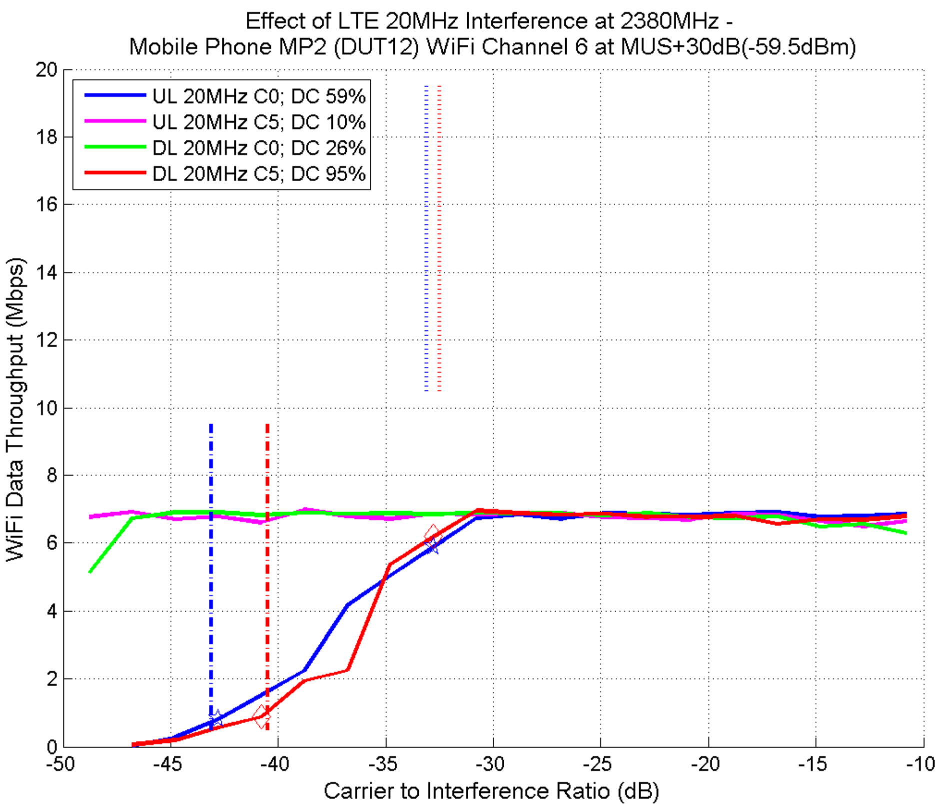

Figure 134

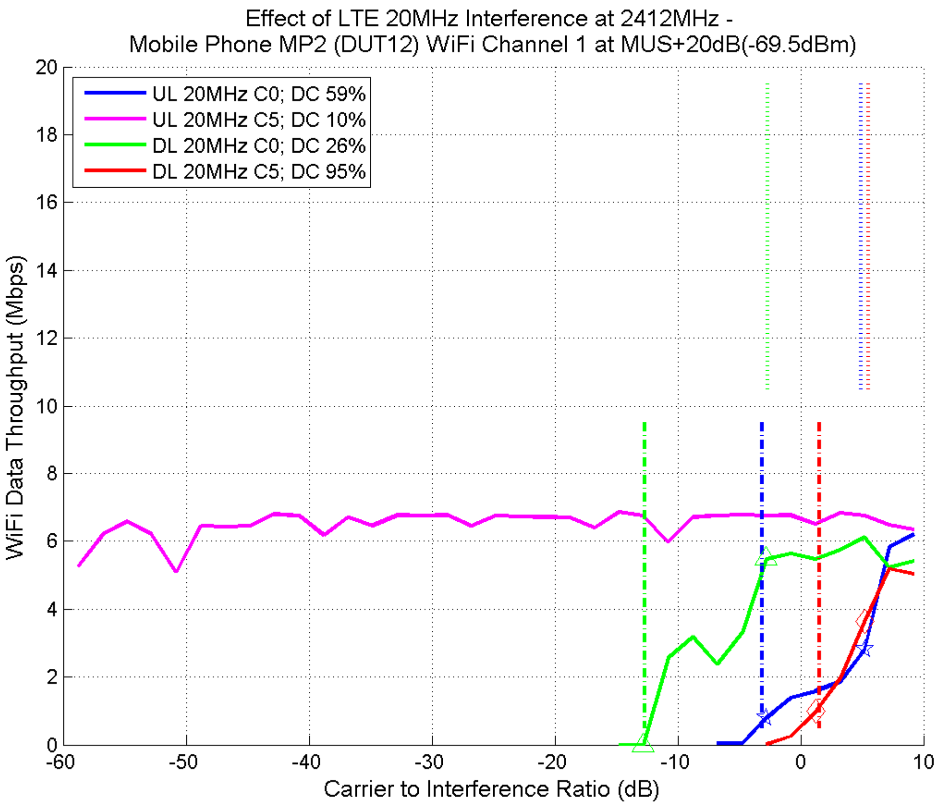

Figure 135

Observations

- Horizontally polarised when positioned horizontally on turntable.
- Mobile phone devices commonly used in near vertical position.
- Maintains high throughput for 10% duty cycle interference when co-channel.

4.4.1.1 Mobile Phone MP2 (DUT 12) Re-test

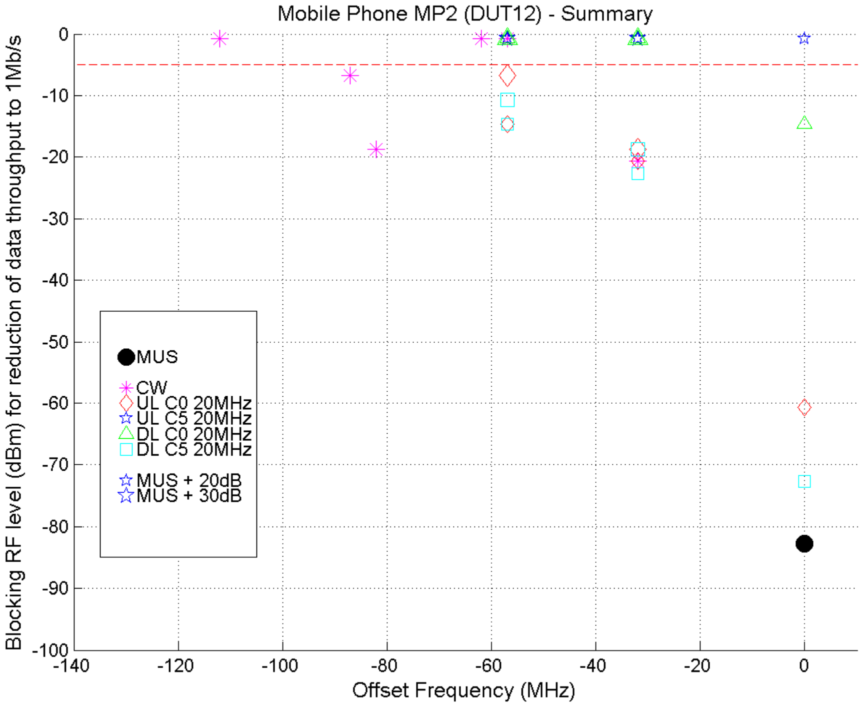

Figure 136

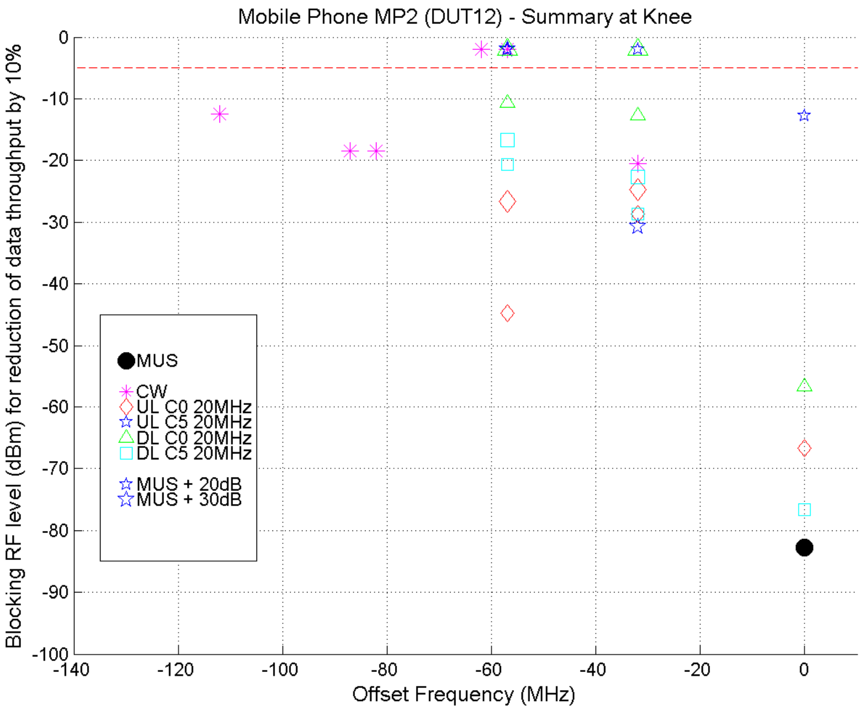

Figure 137

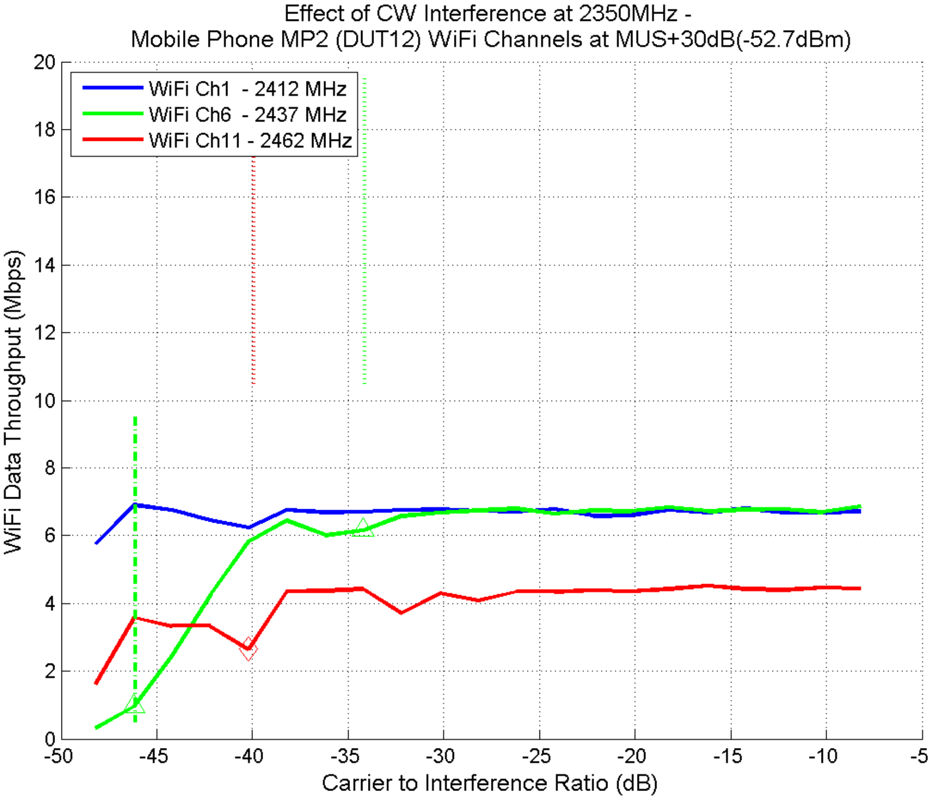

Figure 138

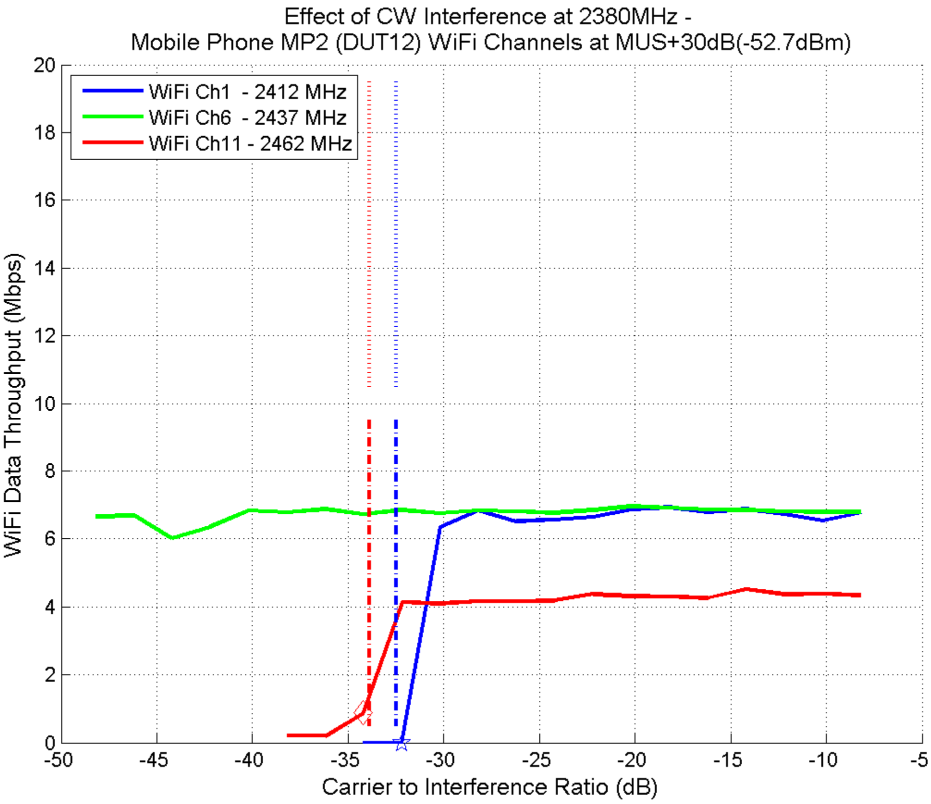

Figure 139

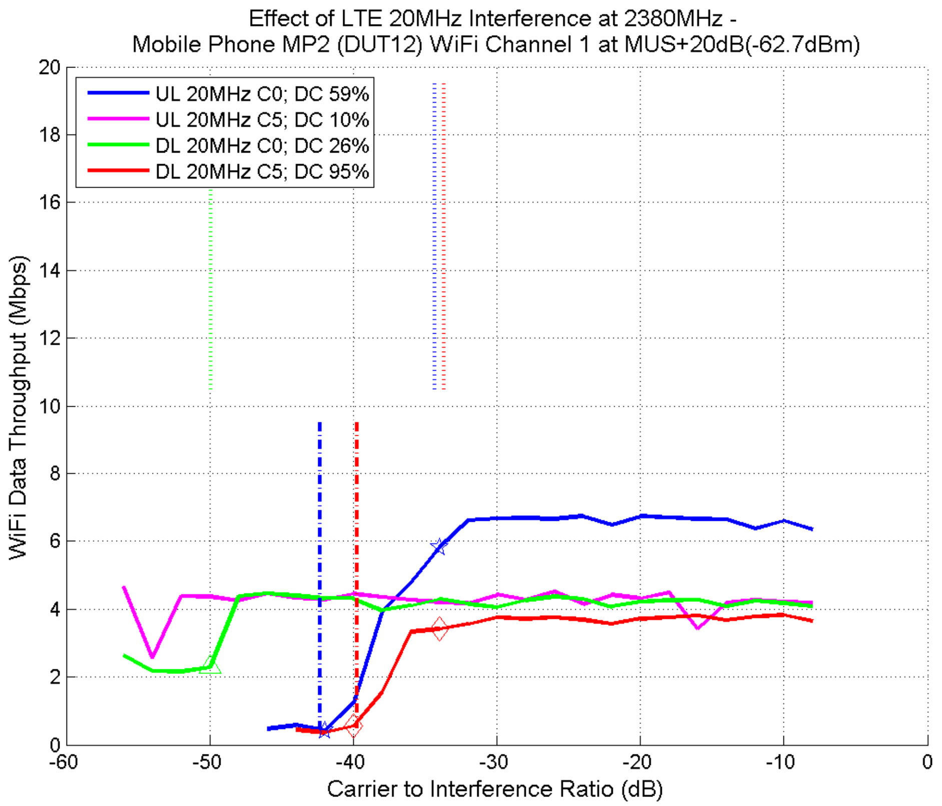

Figure 140

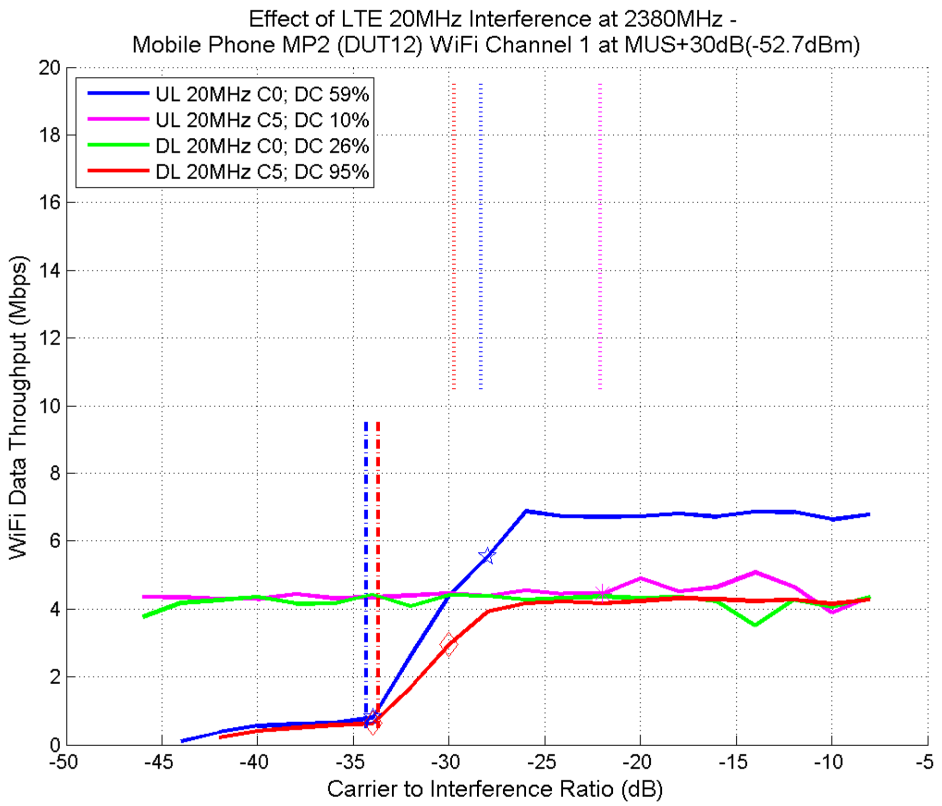

Figure 141

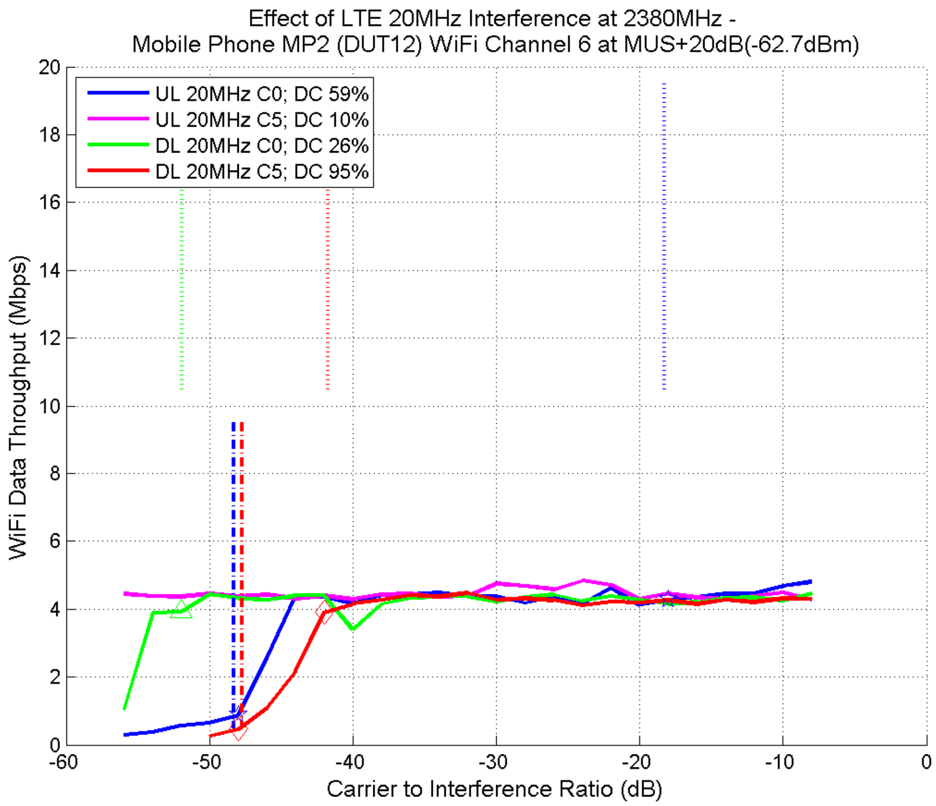

Figure 142

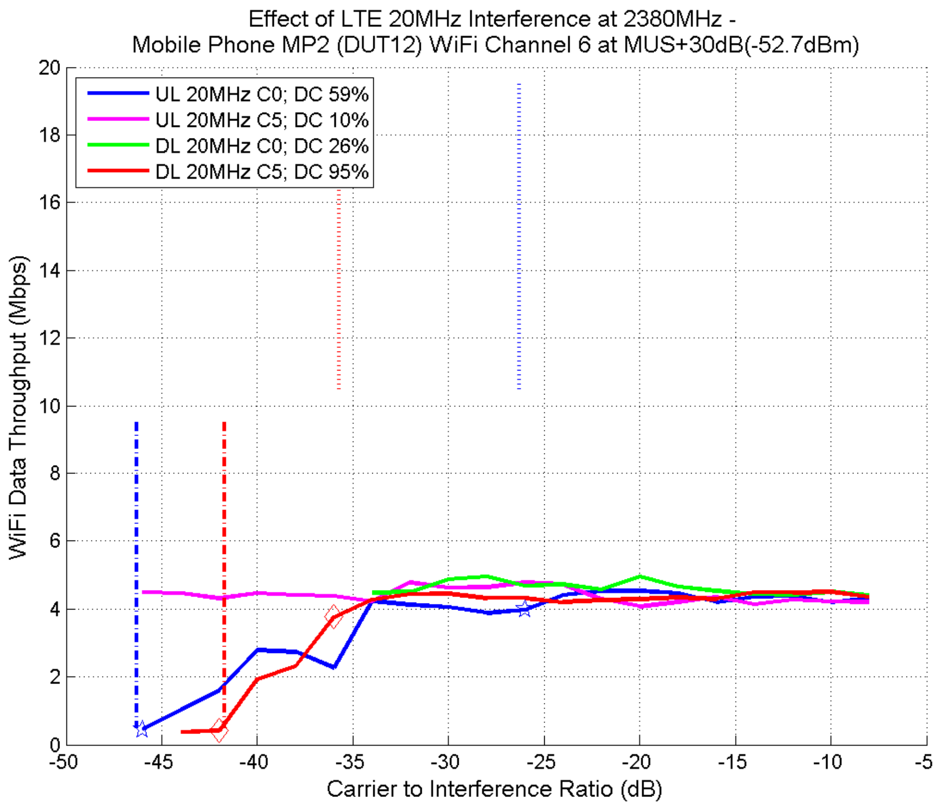

Figure 143

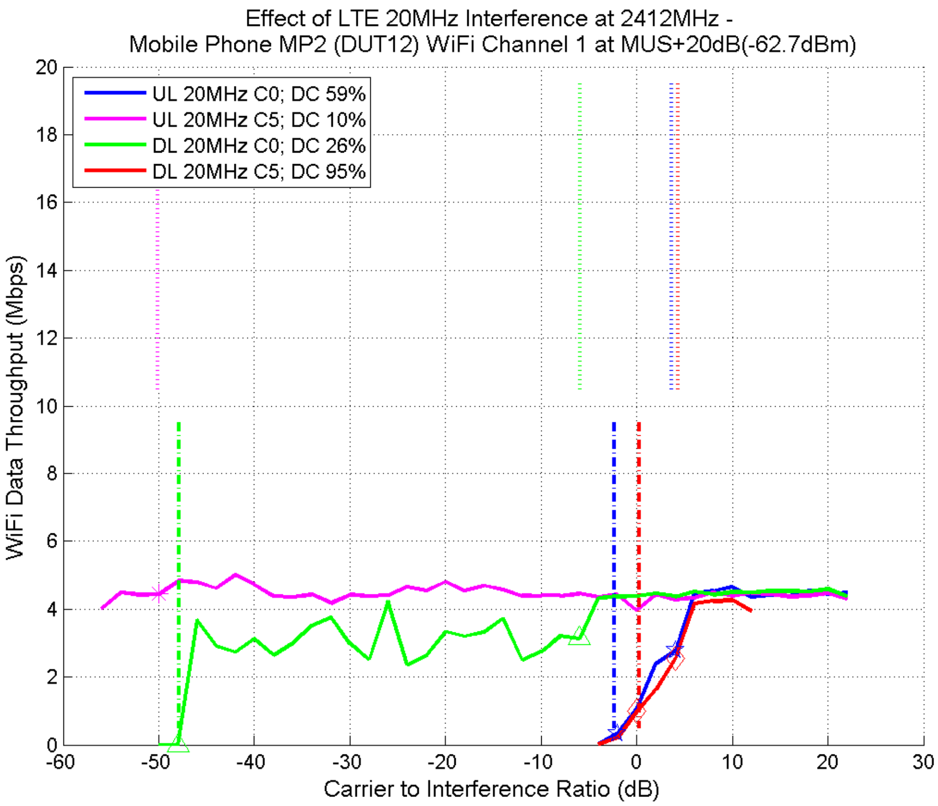

Figure 144

Observations

- The co-channel (2412MHz) test on channel 1 for an LTE Downlink 20MHz C5 interference was conducted at MUS+10dB while the other results on the same plot show MUS+20dB.
- In Figure 144 there is a marked difference in throughput between the low and high duty cycle cases. This is similar to other DUTs in this report.

4.4.2 Mobile Phone MP3 (DUT 16)

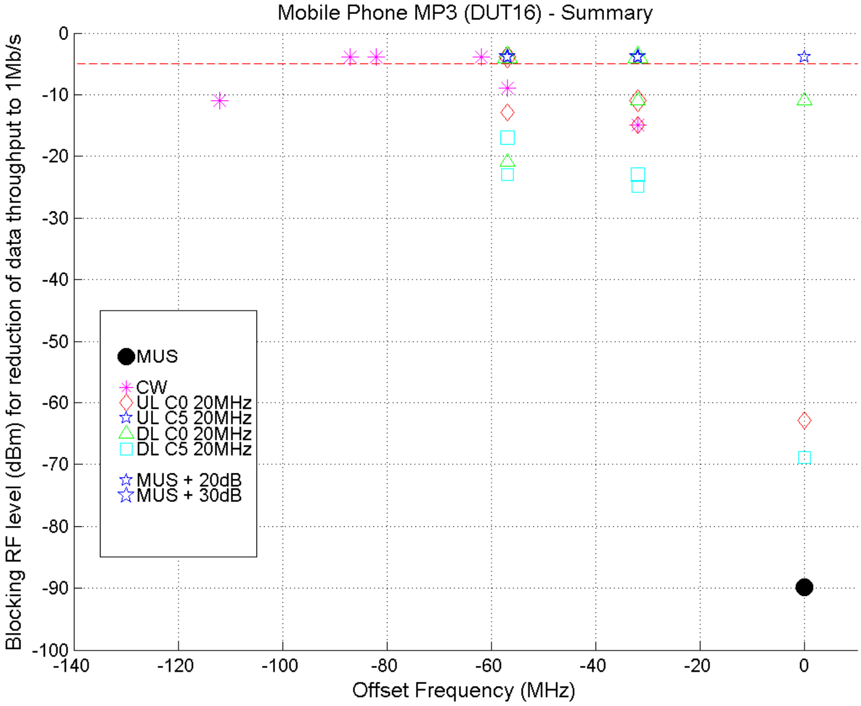

Figure 145

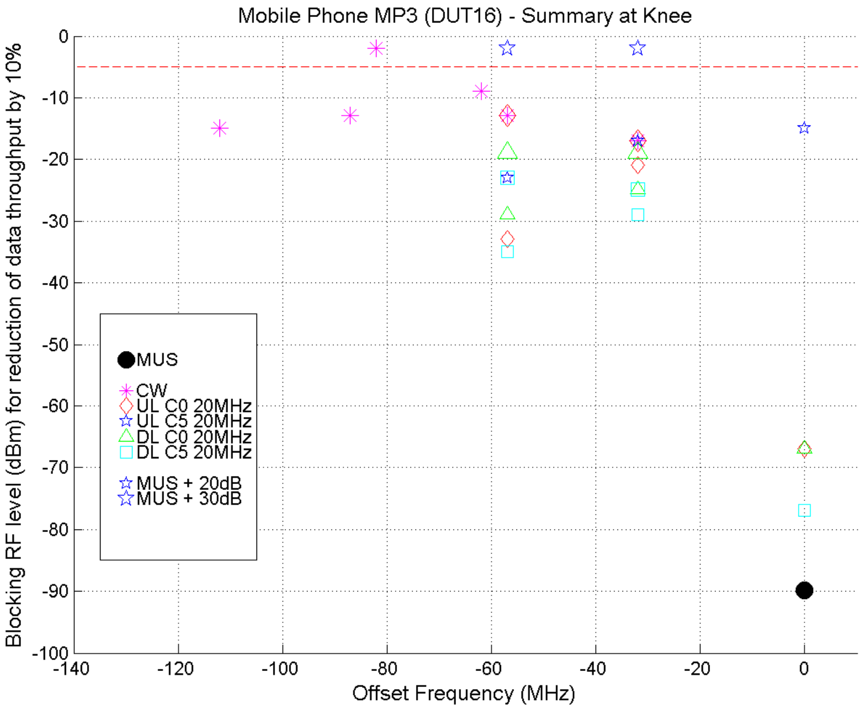

Figure 146

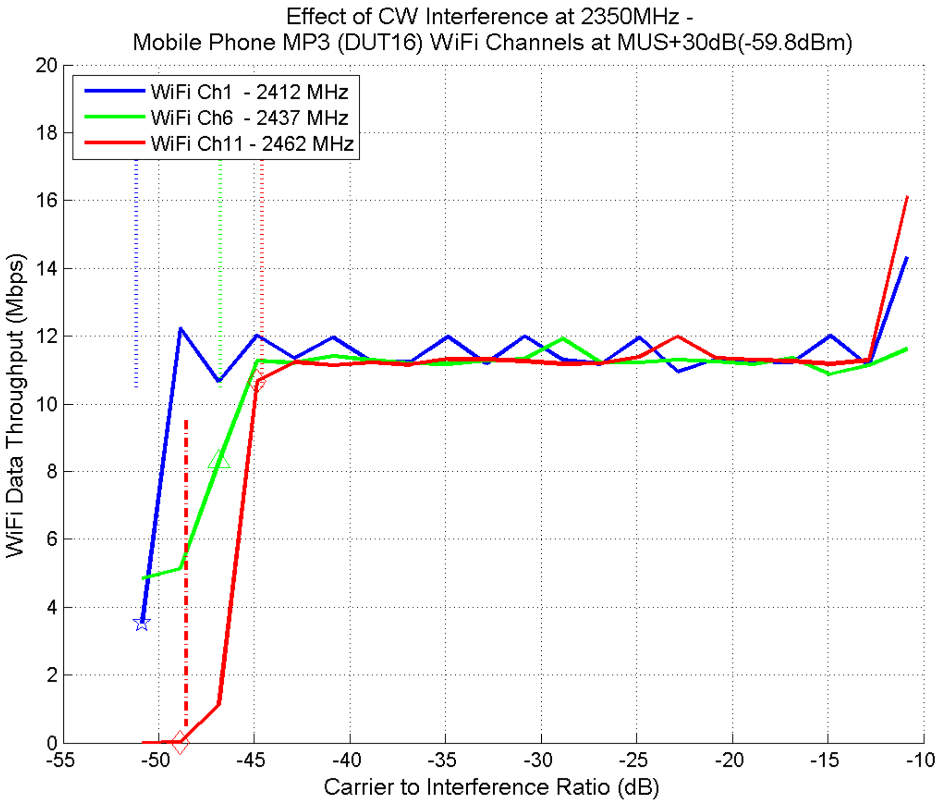

Figure 147

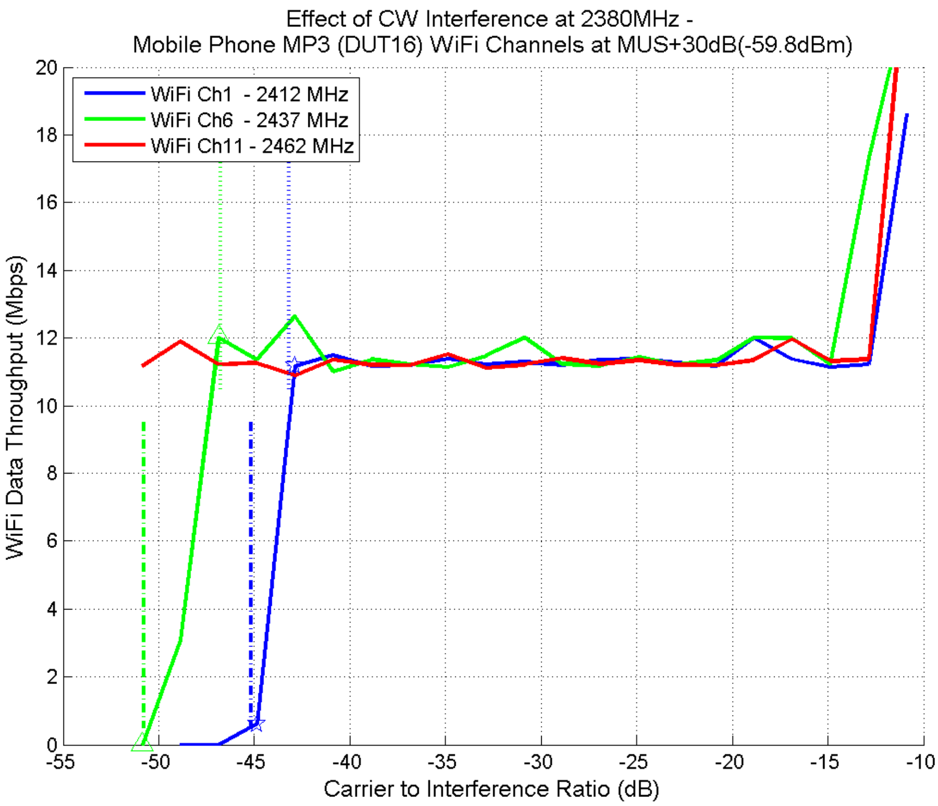

Figure 148

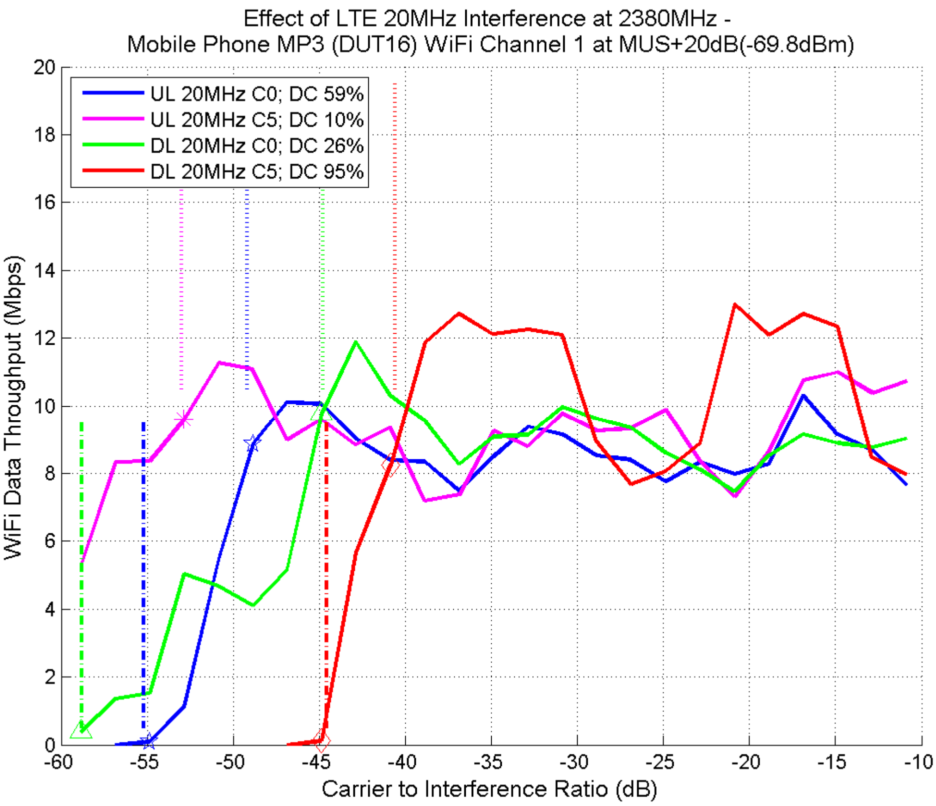

Figure 149

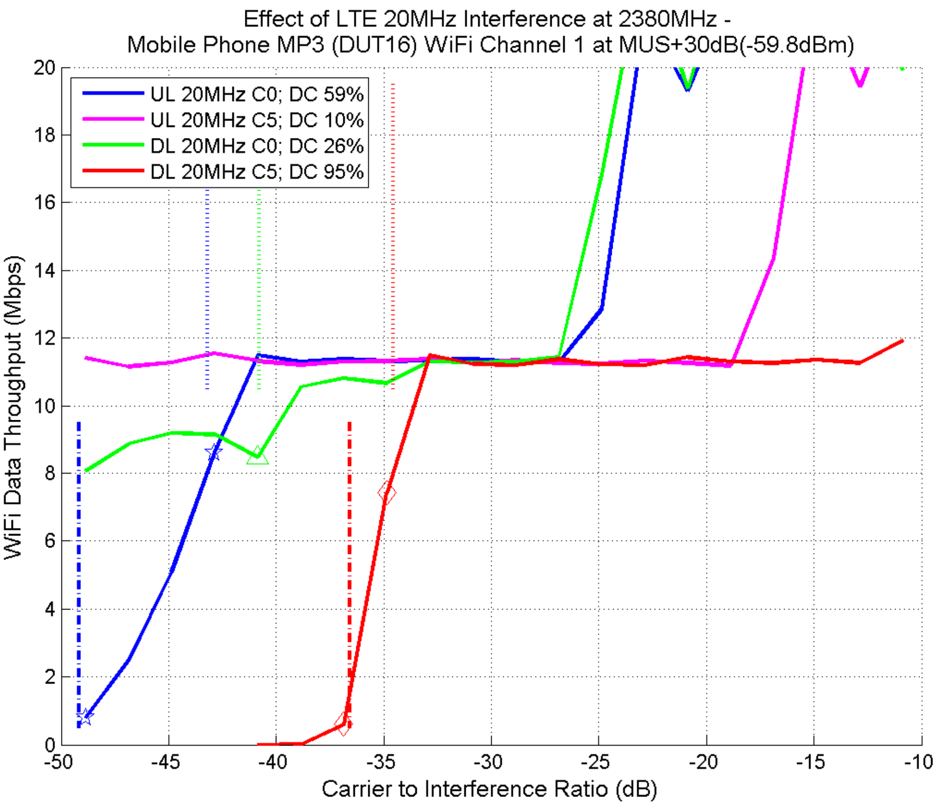

Figure 150

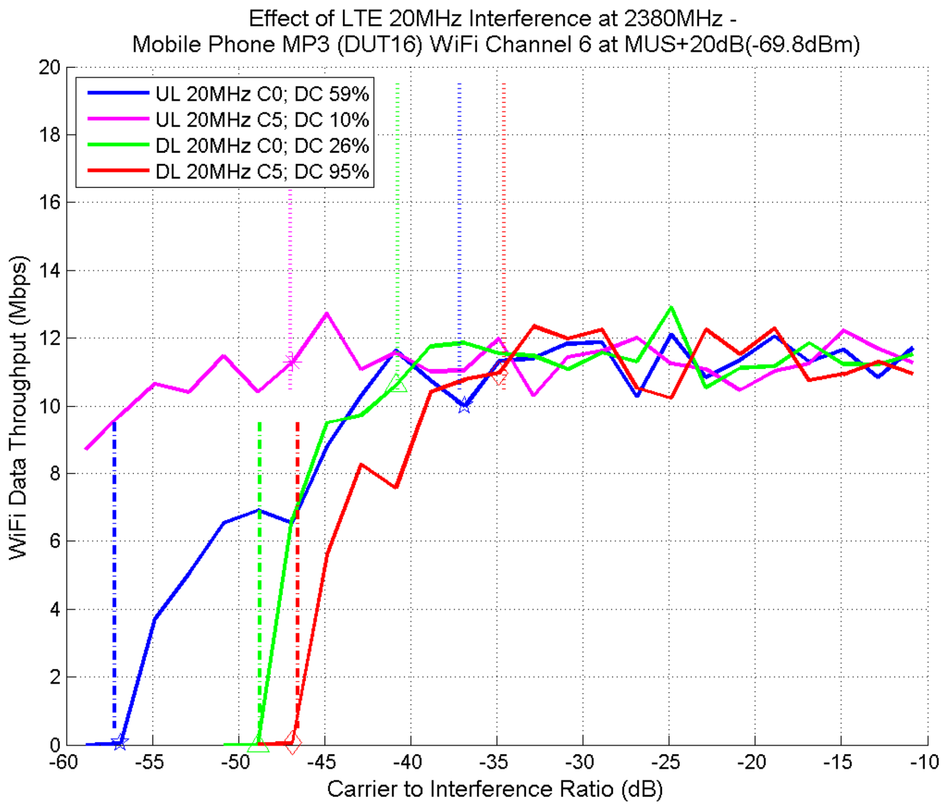

Figure 151

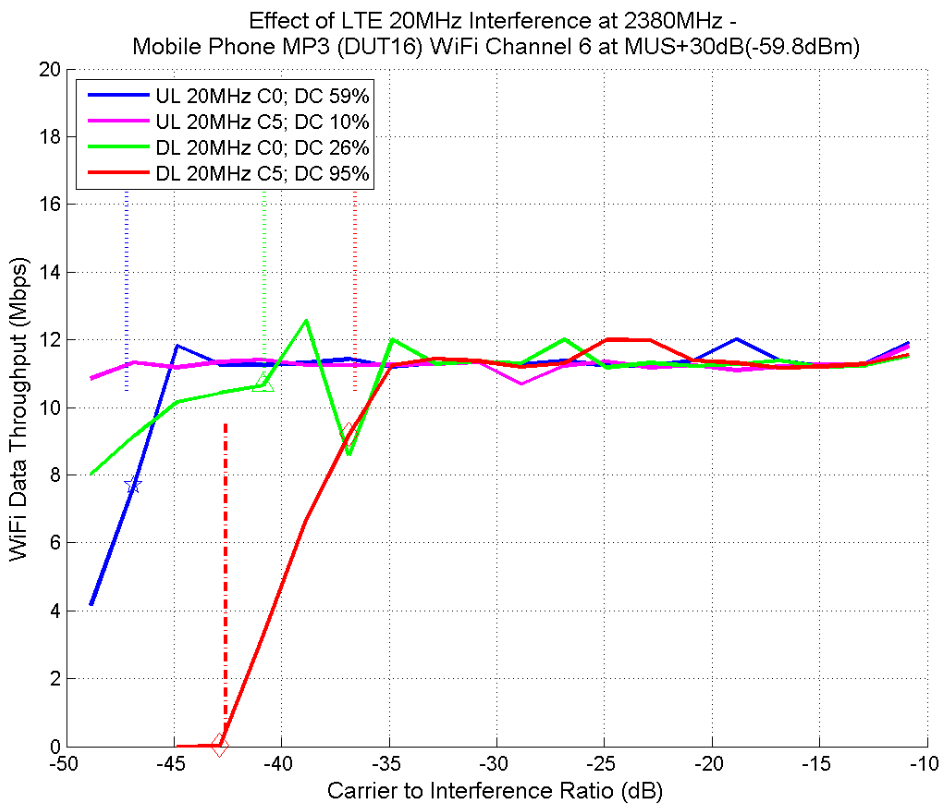

Figure 152

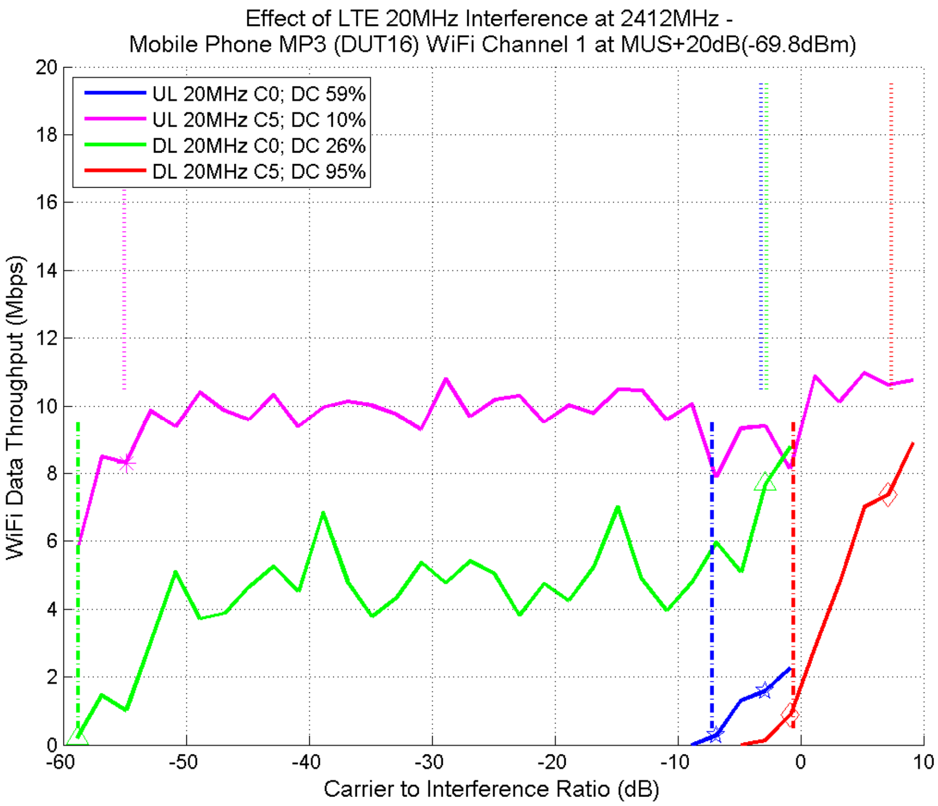

Figure 153

Observations

- Horizontally polarised when positioned horizontally on turntable.
- Mobile phone devices commonly used in near vertical position.
- Maintains high throughput for 10% and 26% duty cycle interference when co-channel.

4.4.3 Mobile Phone MP4 (DUT 18)

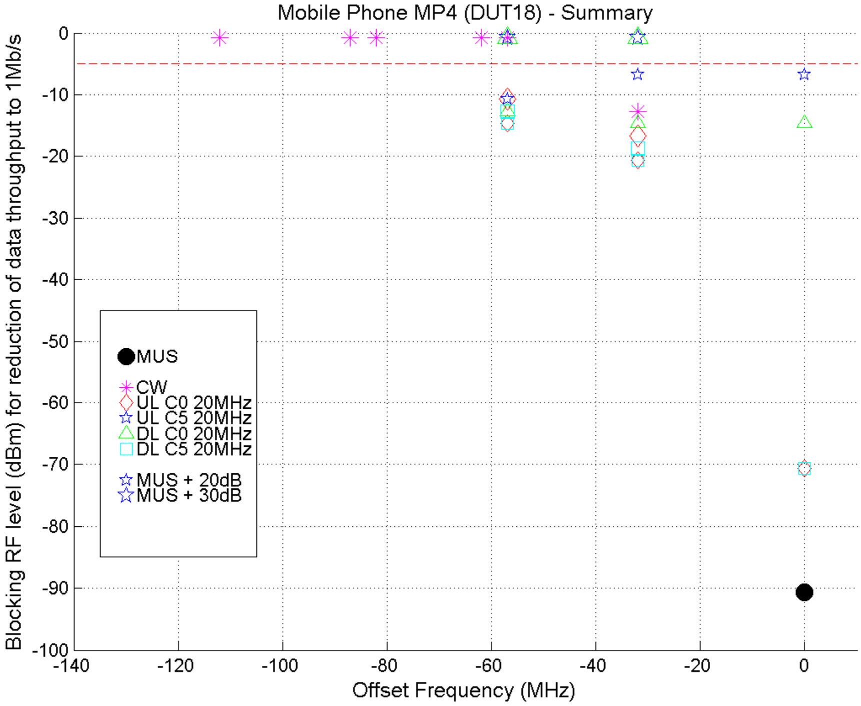

Figure 154

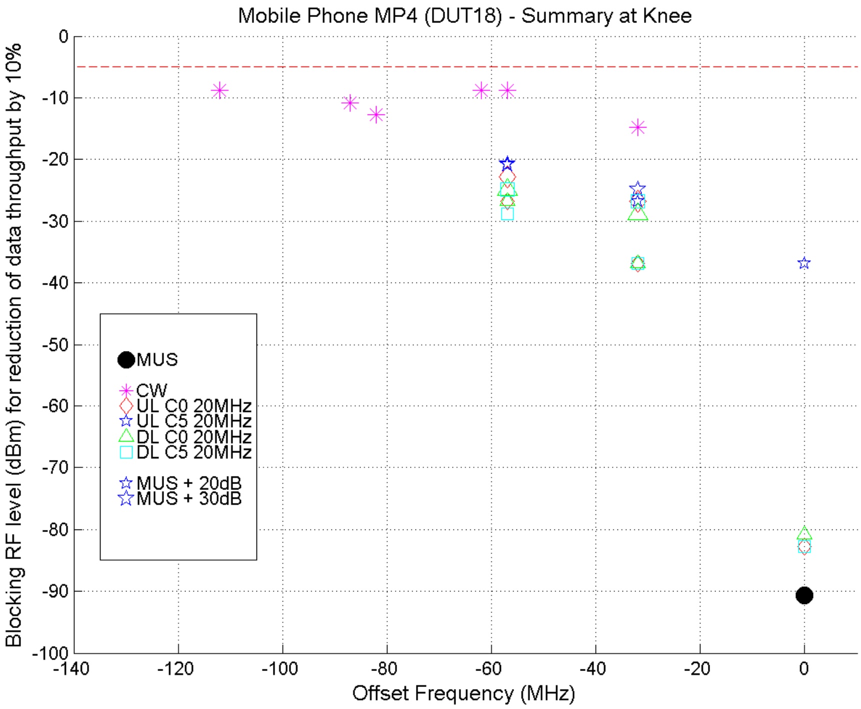

Figure 155

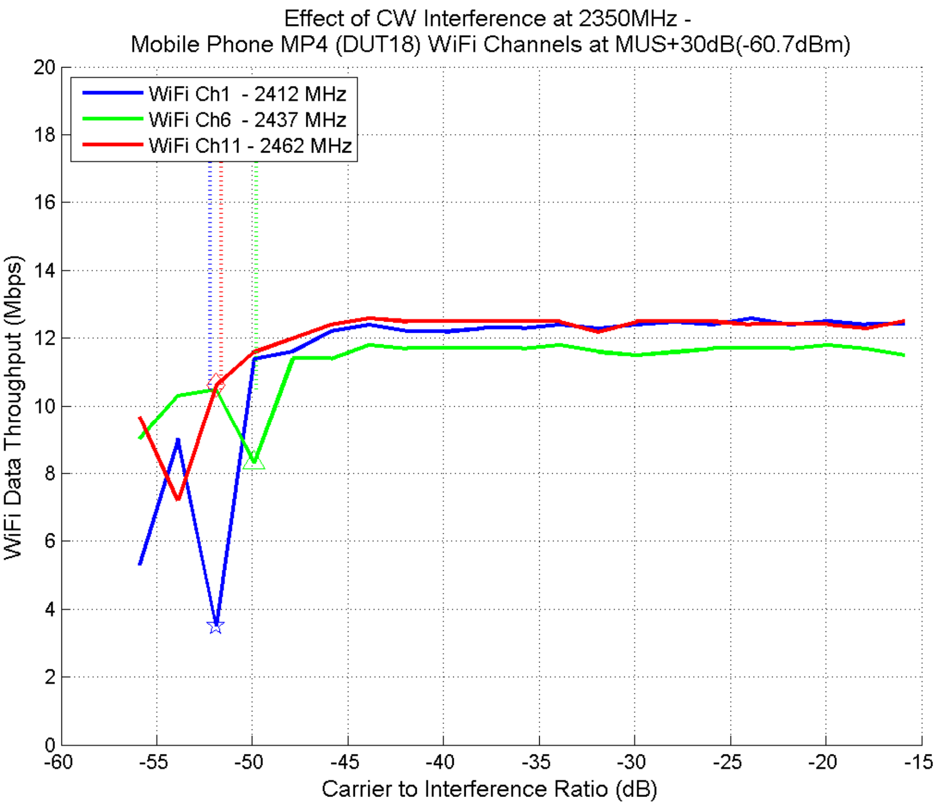

Figure 156

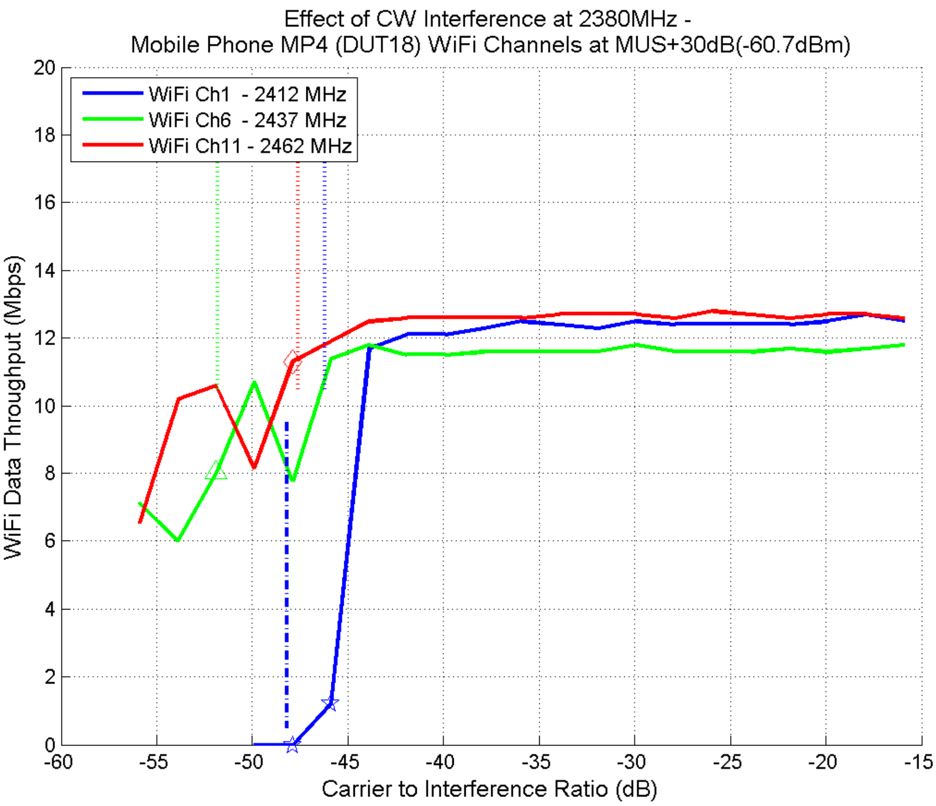

Figure 157

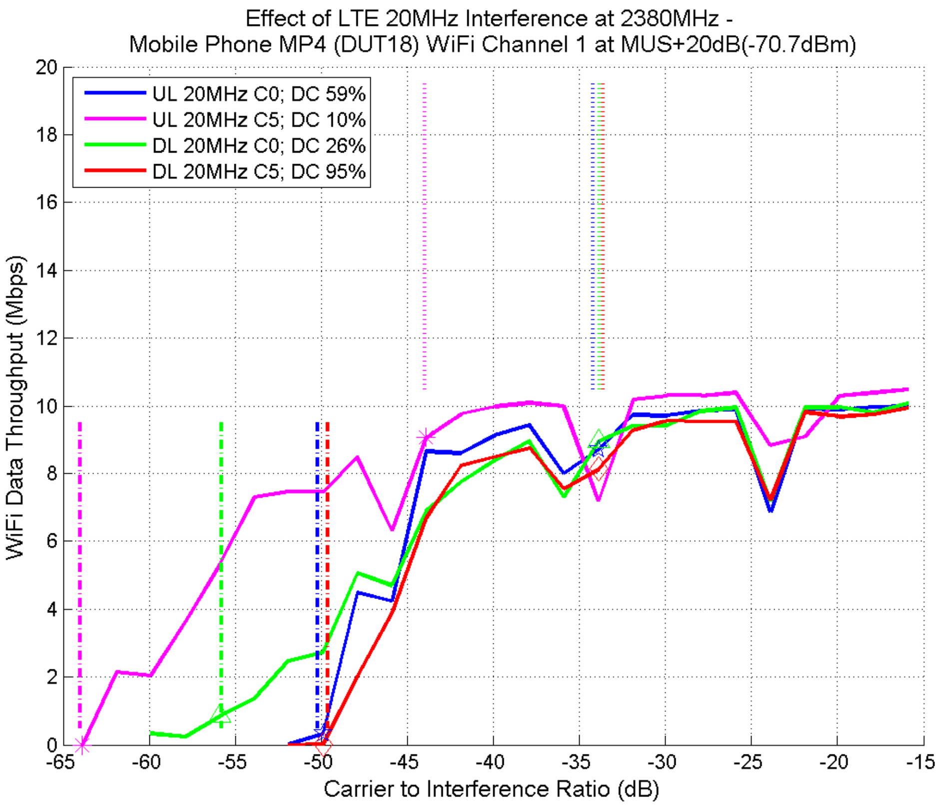

Figure 158

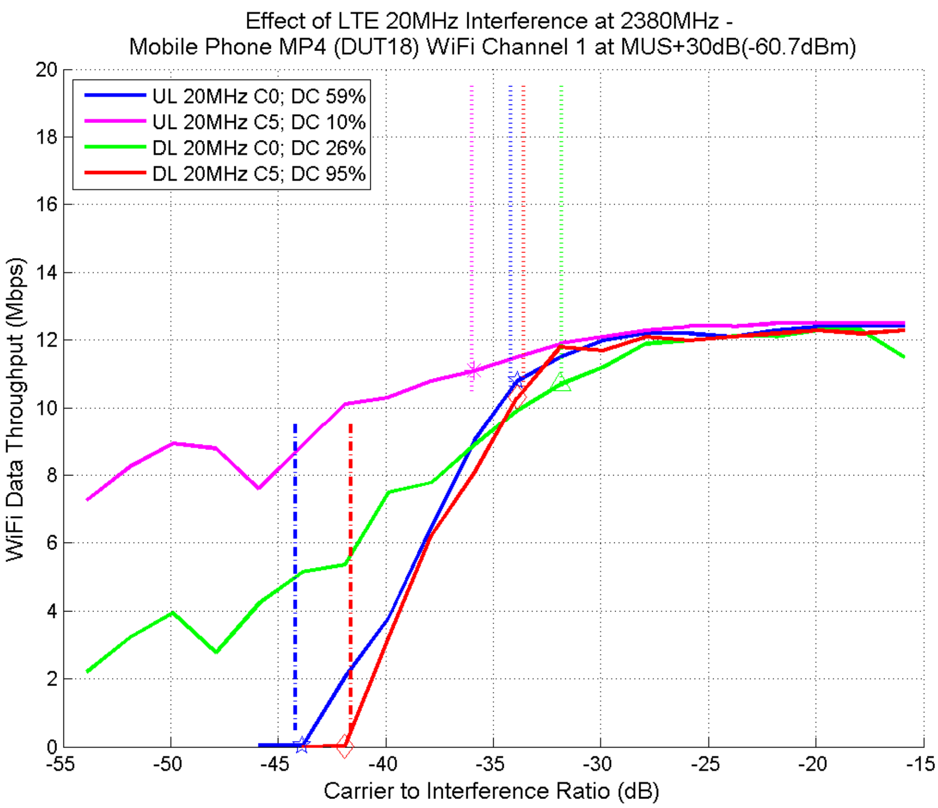

Figure 159

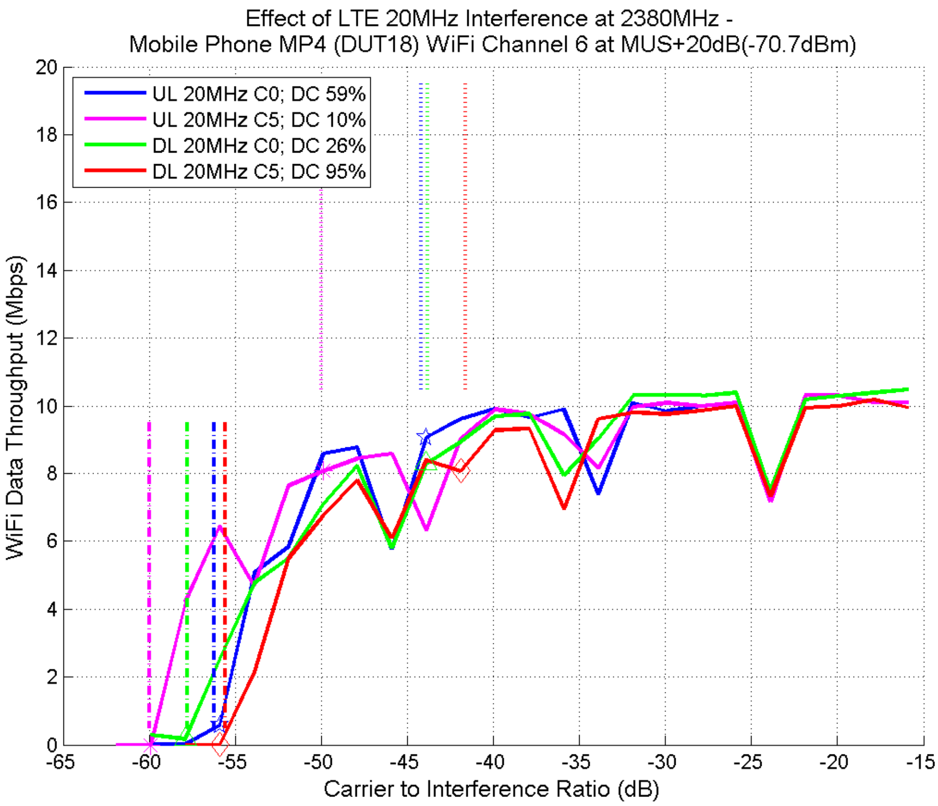

Figure 160

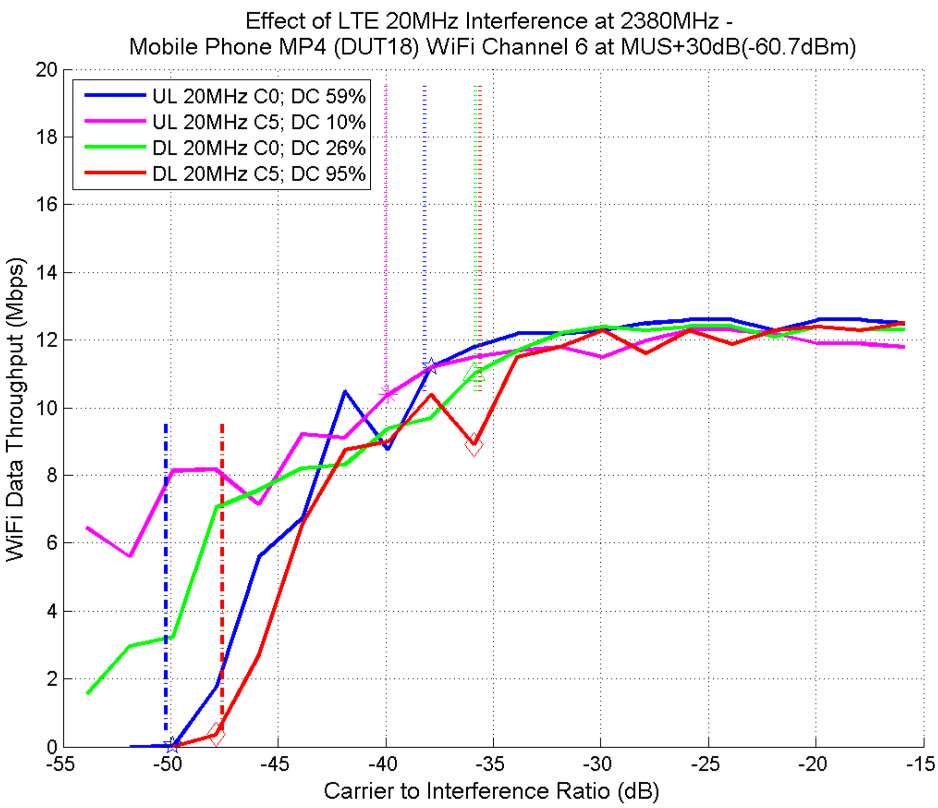

Figure 161

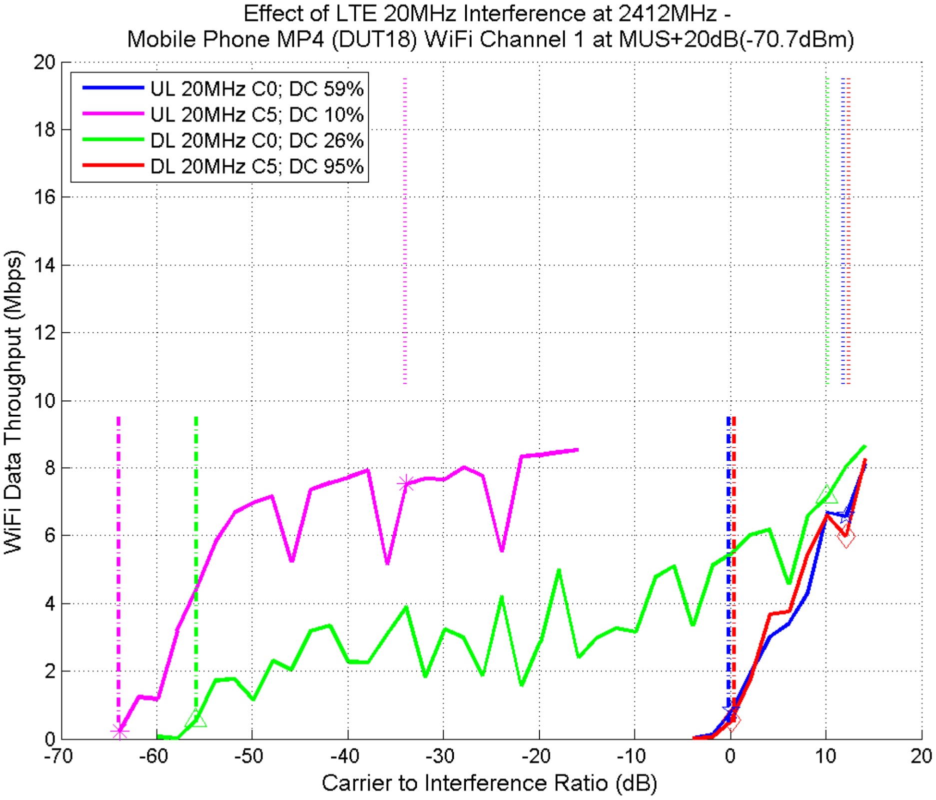

Figure 162

Observations

- Horizontally polarised when positioned horizontally on turntable.
- Mobile phone devices commonly used in near vertical position.
- Maintains higher throughput for 10% duty cycle interference in comparison with 26% duty cycle interference when co-channel.

4.4.4 Mobile Phone MP5 (DUT 20)

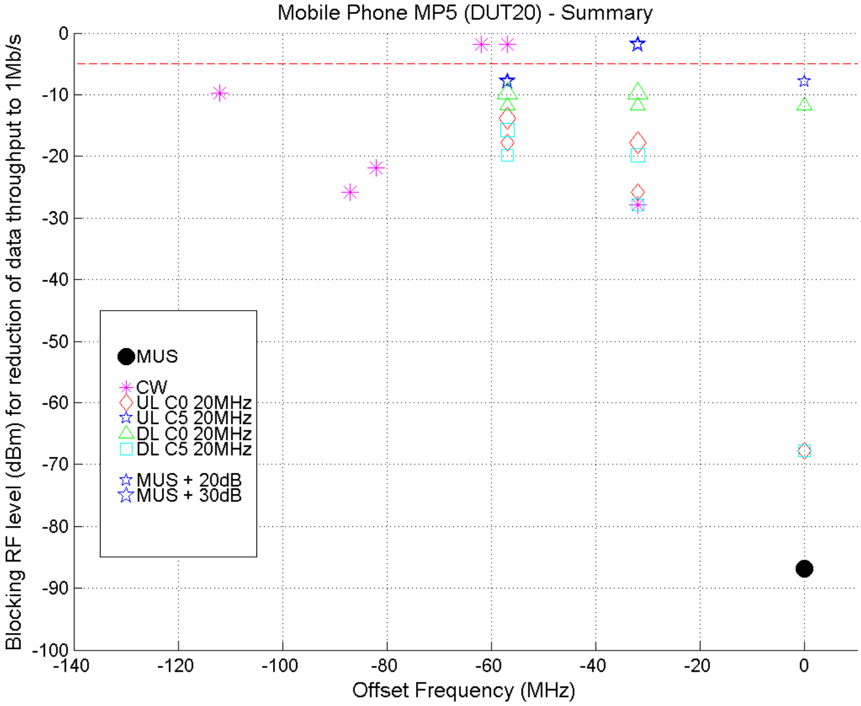

Figure 163

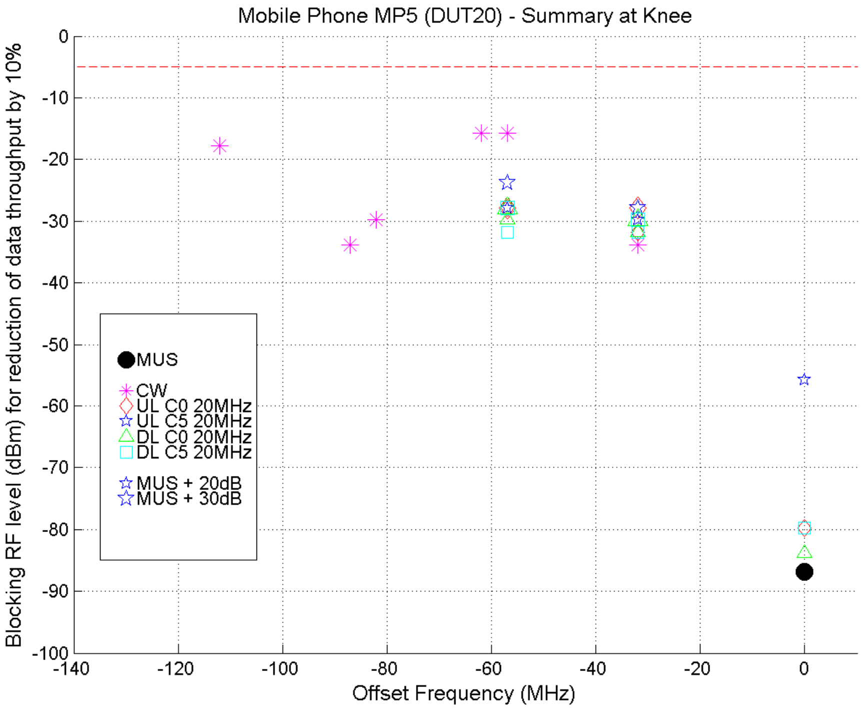

Figure 164

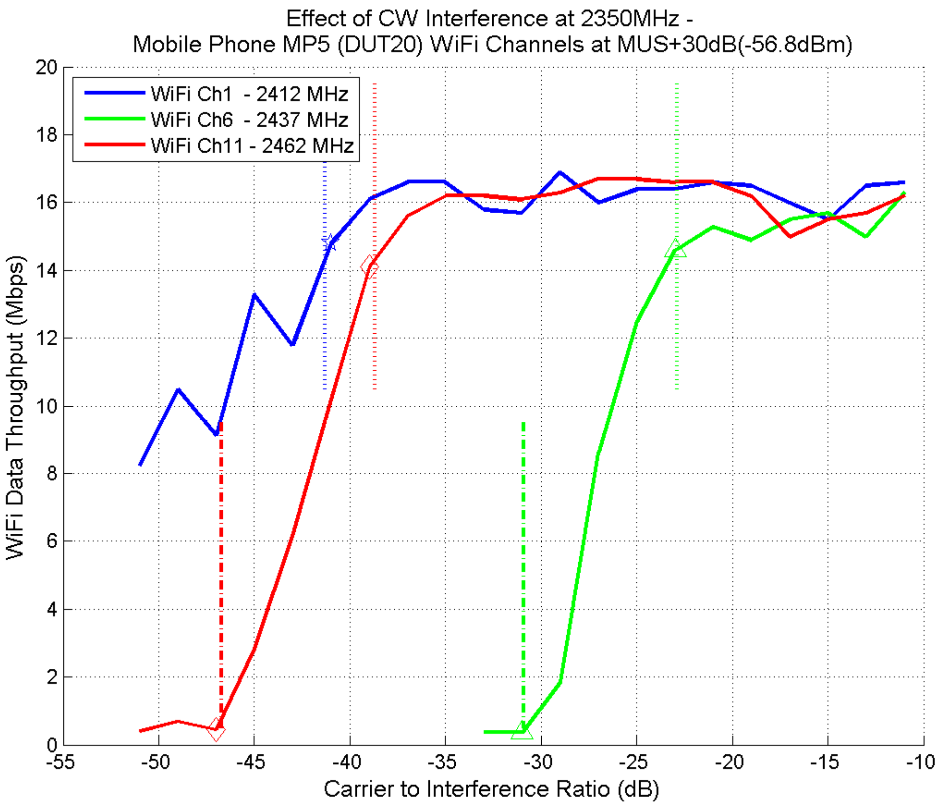

Figure 165

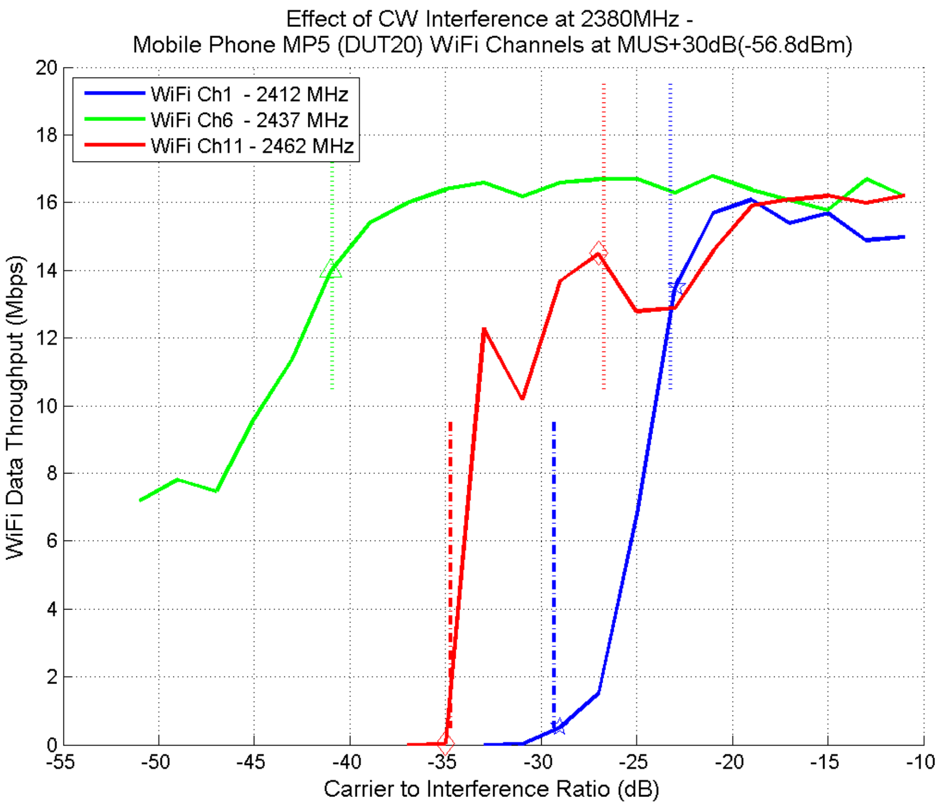

Figure 166

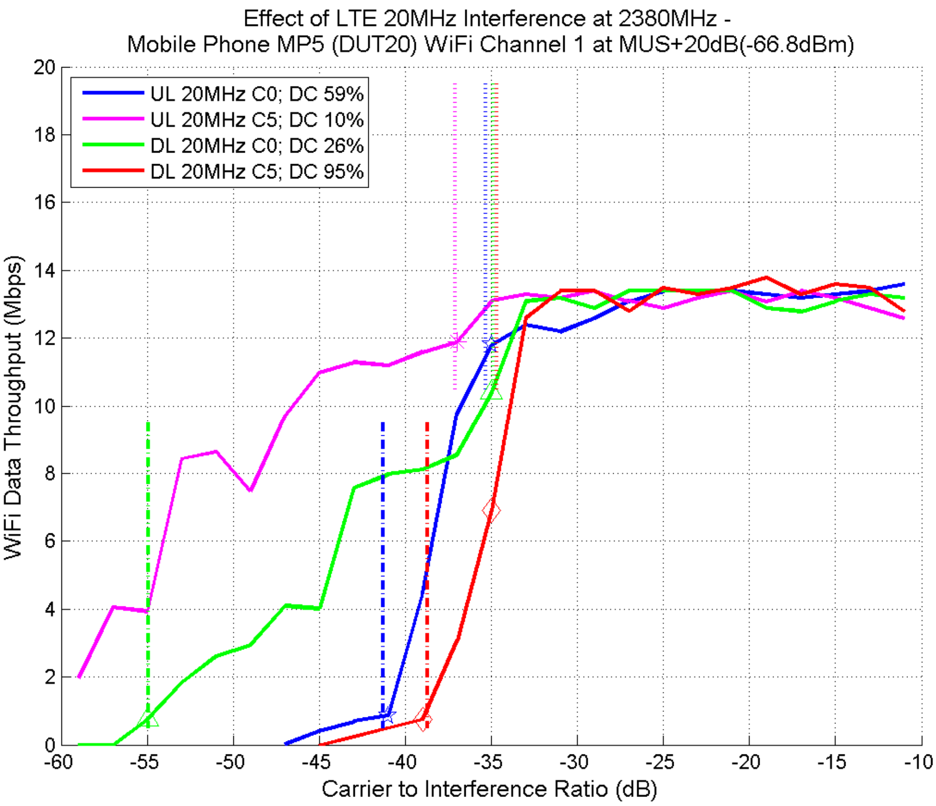

Figure 167

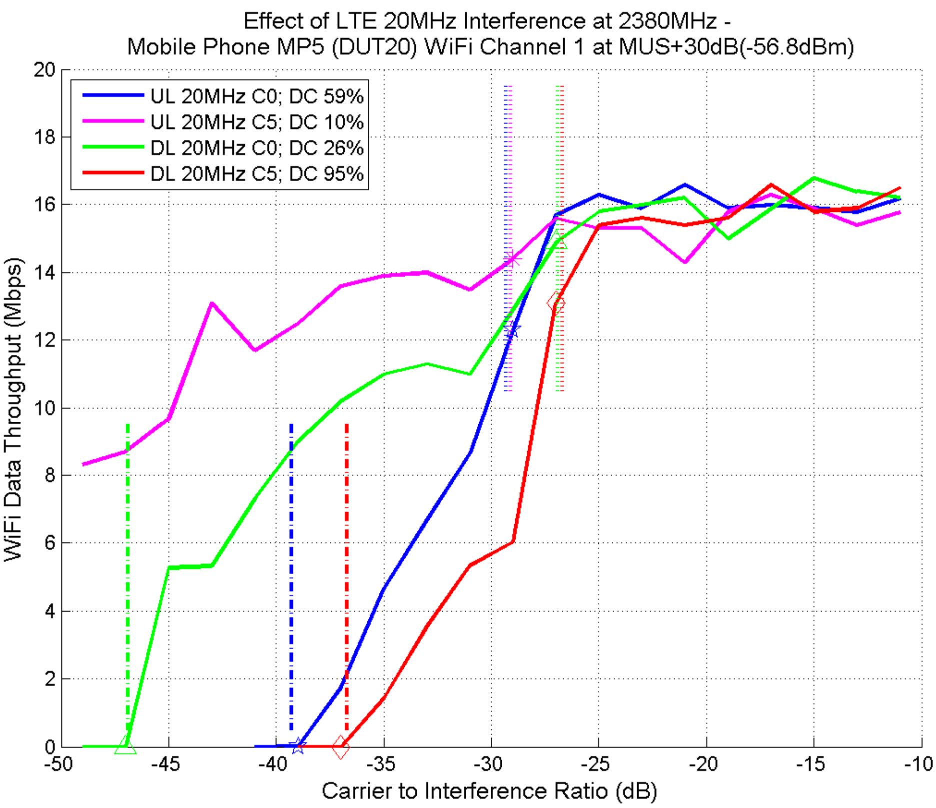

Figure 168

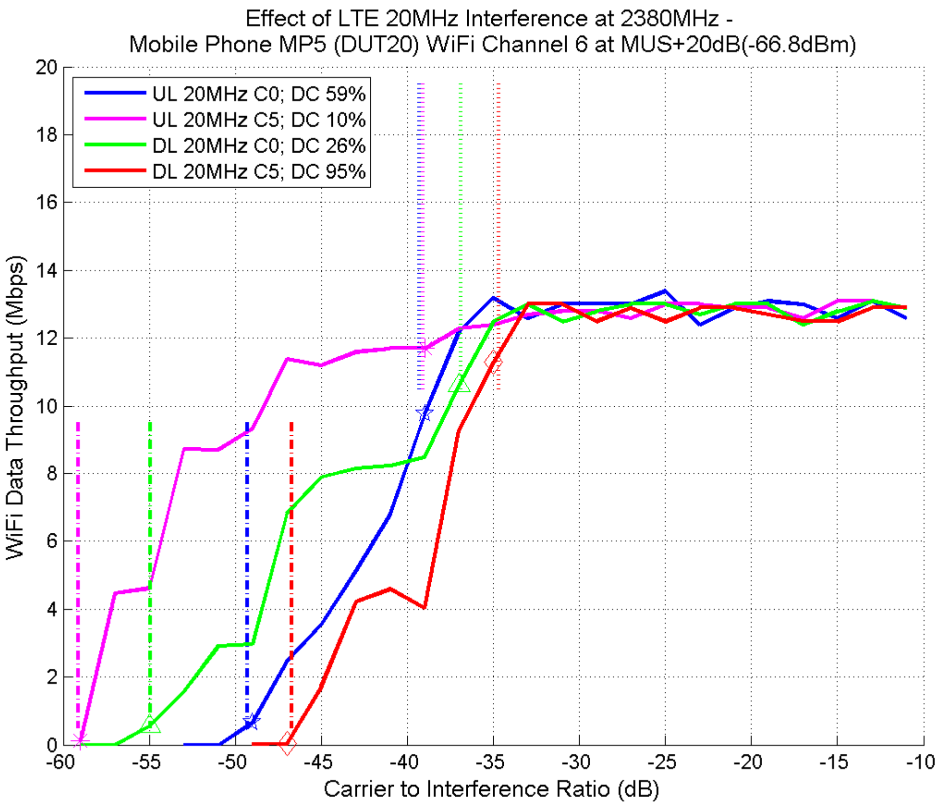

Figure 169

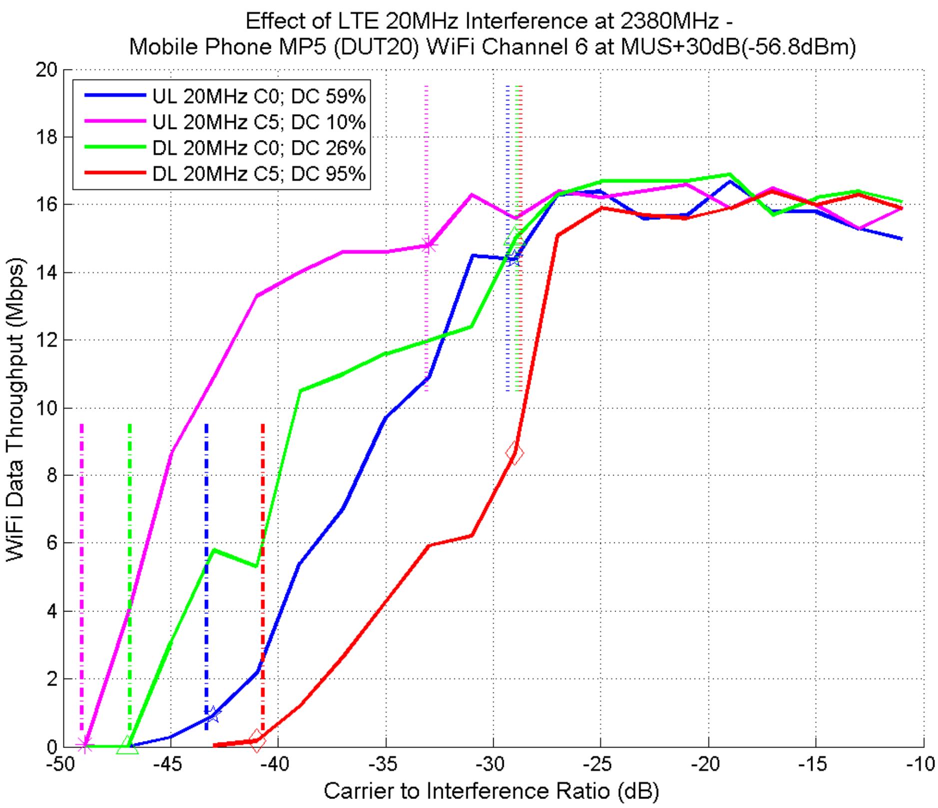

Figure 170

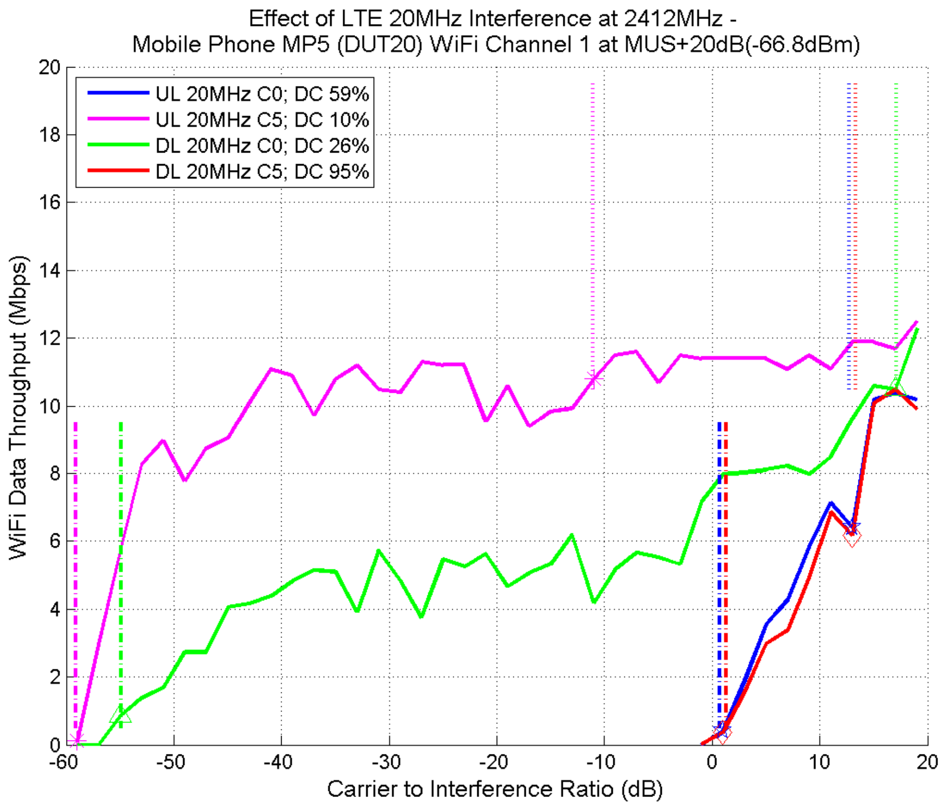

Figure 171

Observations

- Horizontally polarised when positioned horizontally on turntable.
- Mobile phone devices commonly used in near vertical position.
- Maintains high throughput for 10% duty cycle interference when co-channel.

4.4.5 Mobile Phone MP6 (DUT 21)

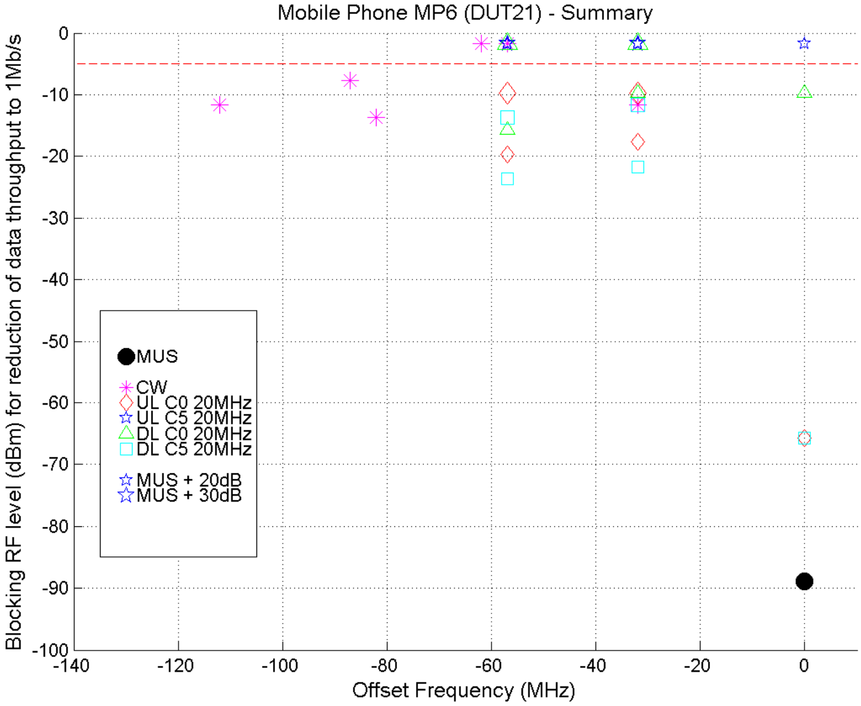

Figure 172

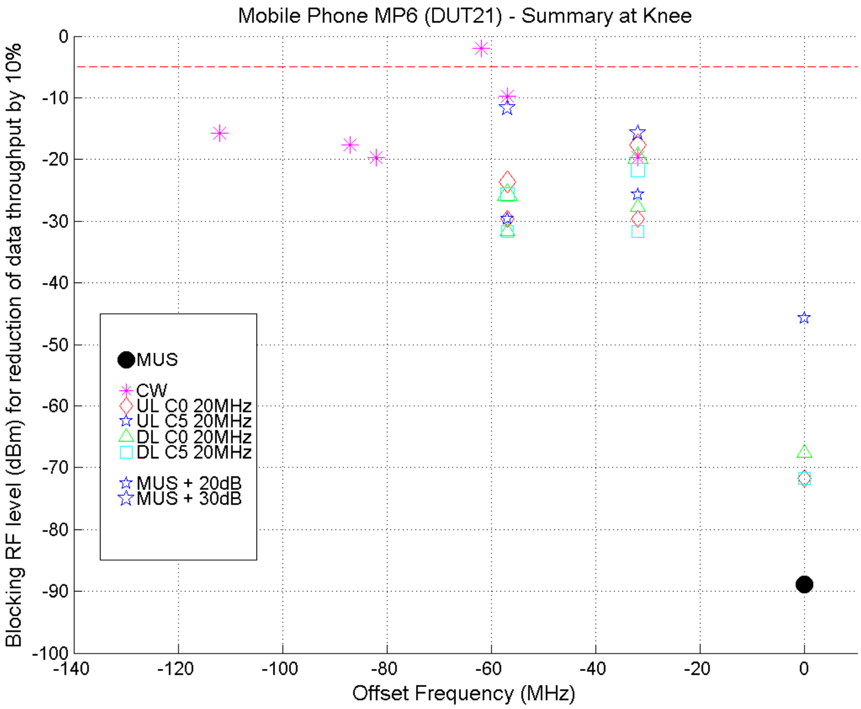

Figure 173

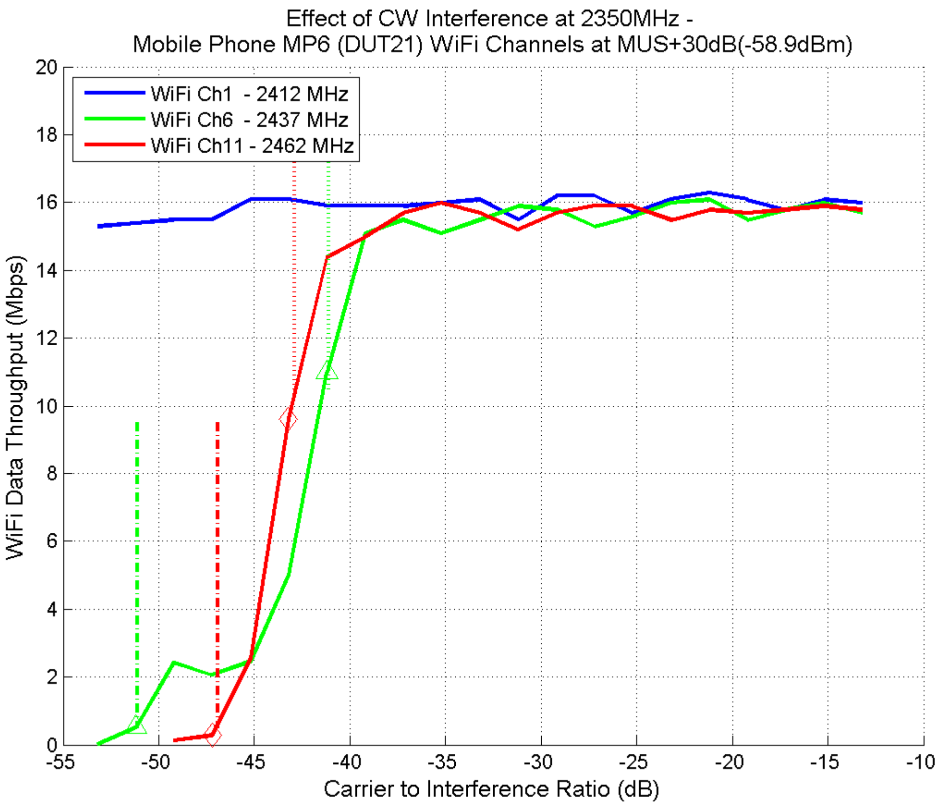

Figure 174

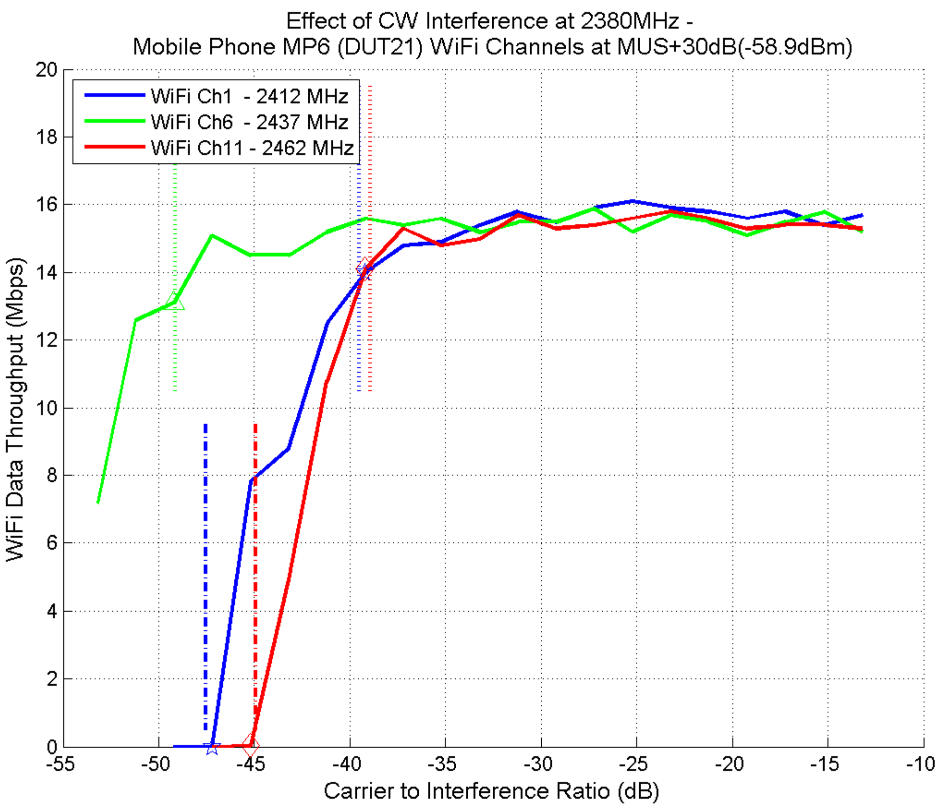

Figure 175

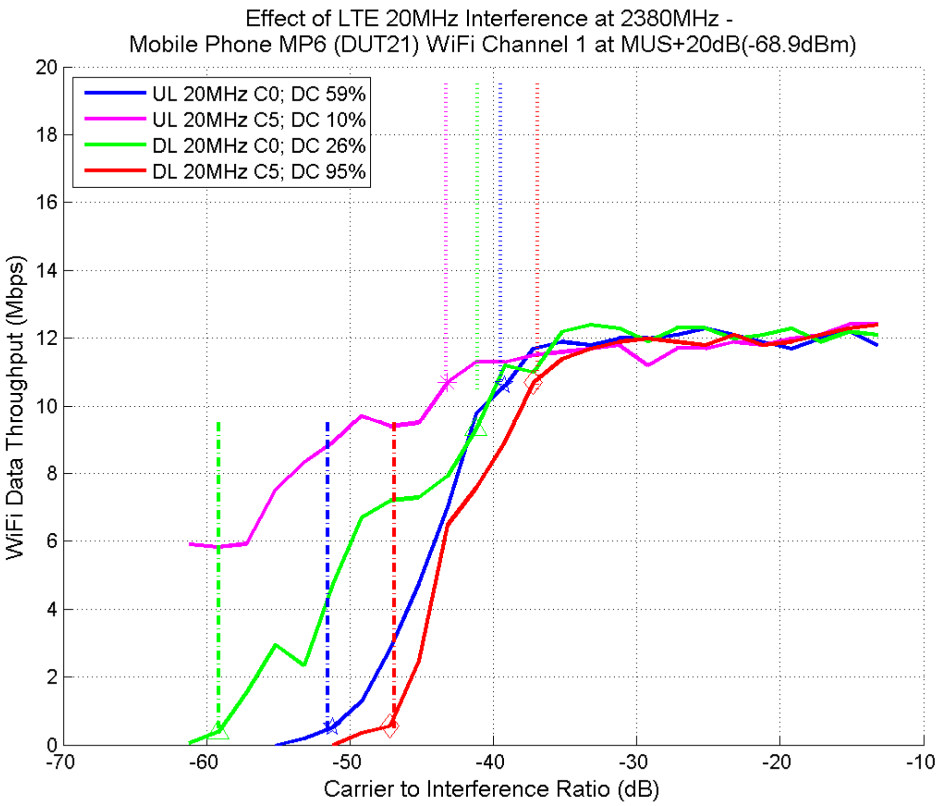

Figure 176

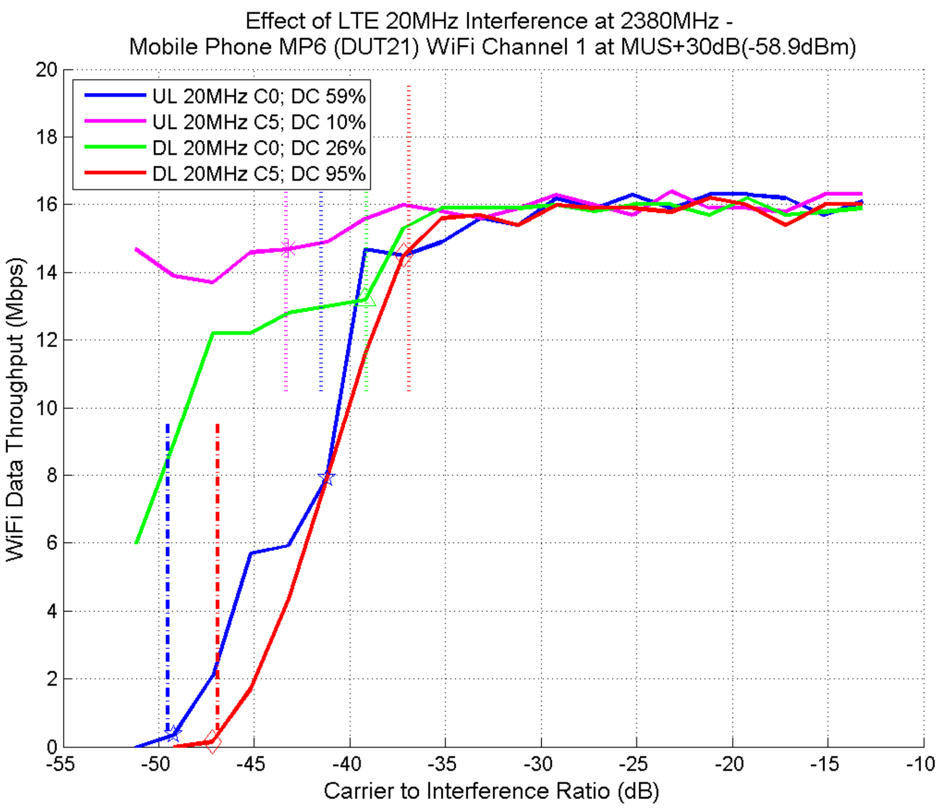

Figure 177

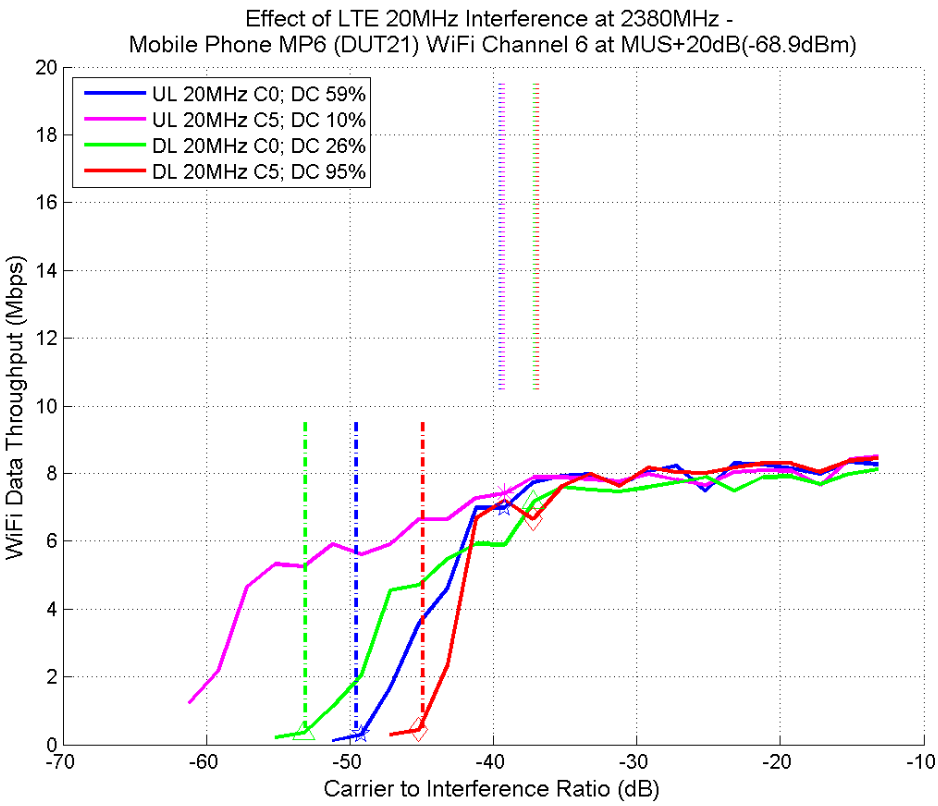

Figure 178

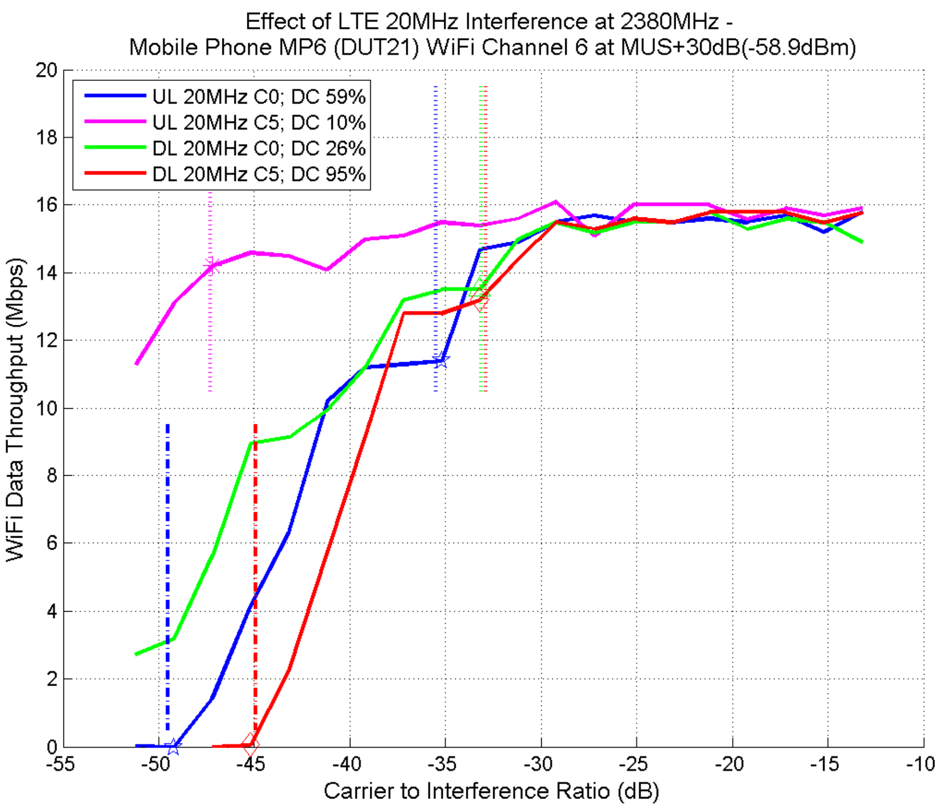

Figure 179

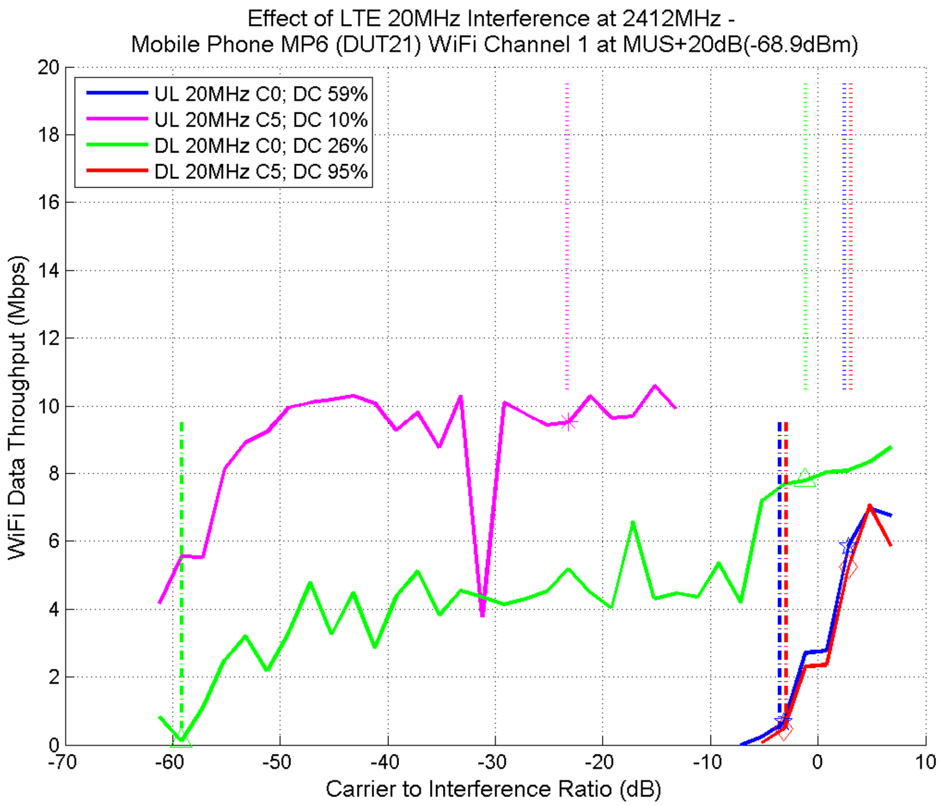

Figure 180

Observations

- Vertically polarised when positioned horizontally on turntable.
- Mobile phone devices commonly used in near vertical position.
- Maintains high throughput for 10% duty cycle interference when co-channel.

4.5 Multimedia Dongles

4.5.1 Multimedia Dongle MD1 (DUT 17)

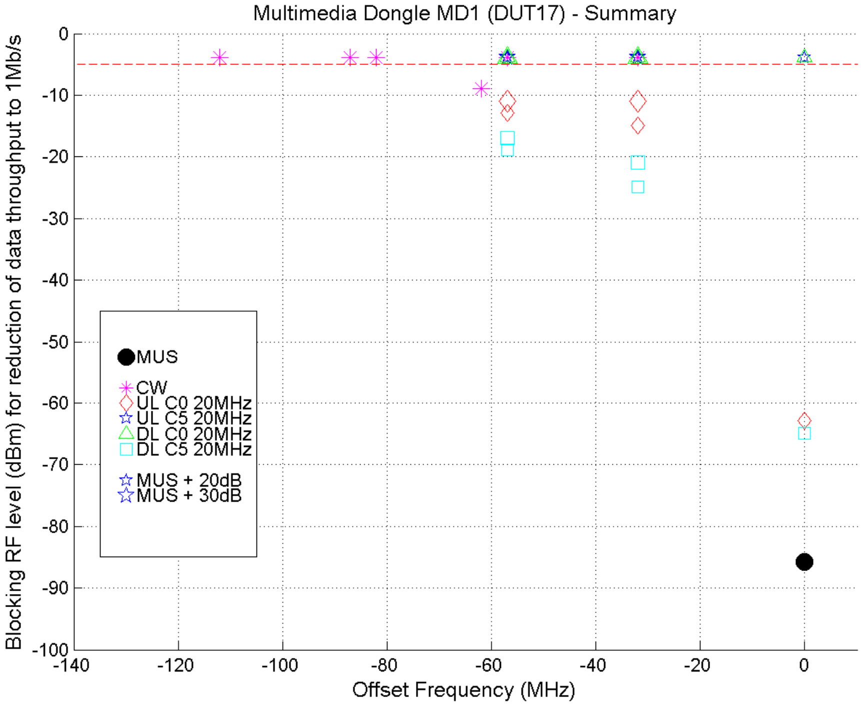

Figure 181

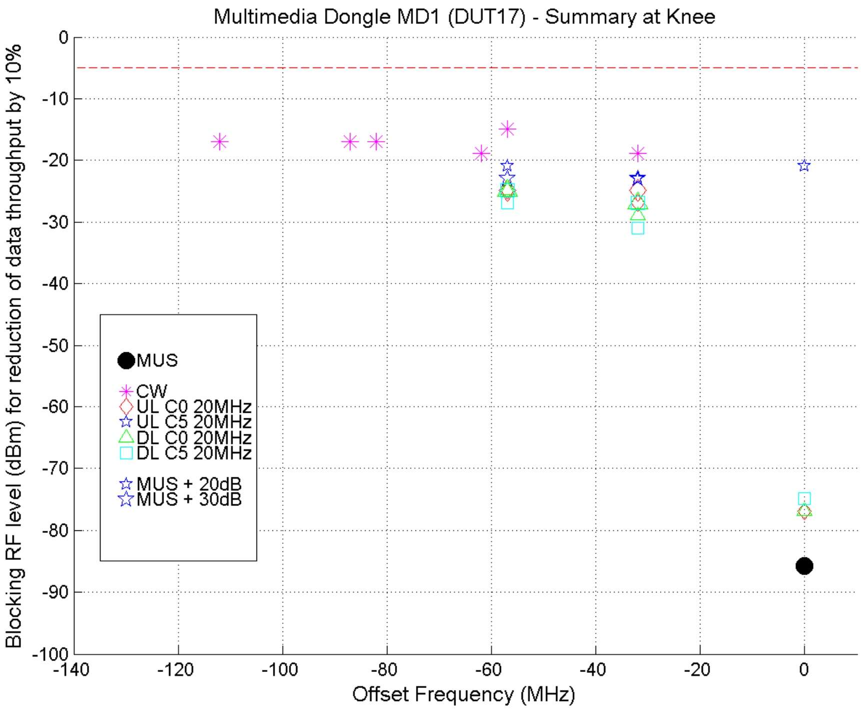

Figure 182

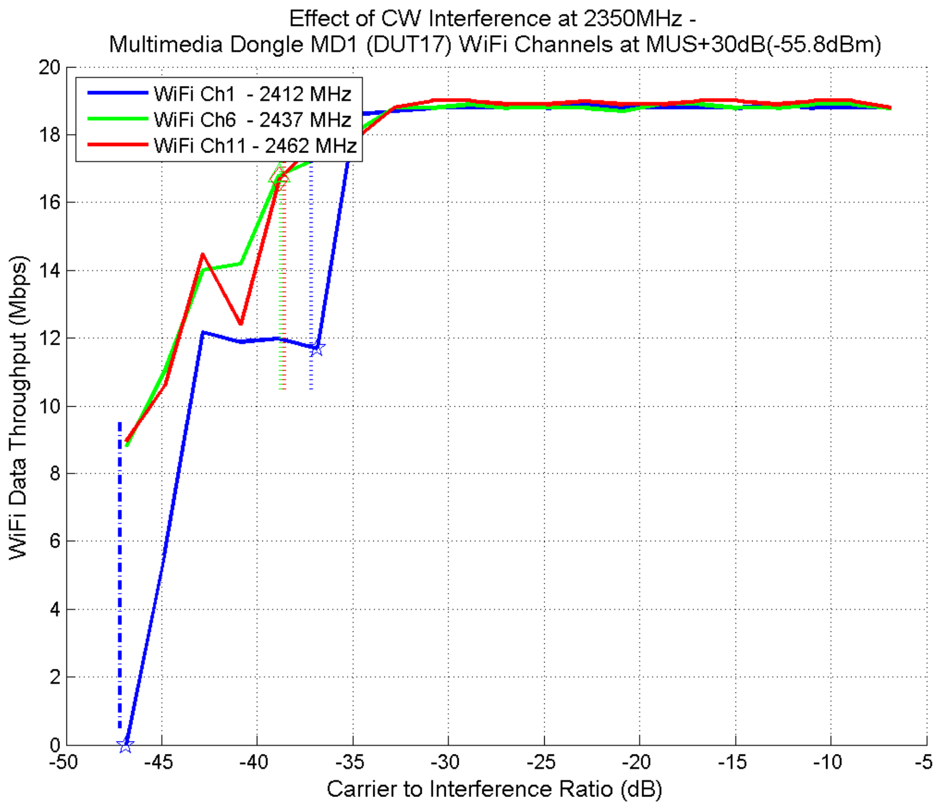

Figure 183

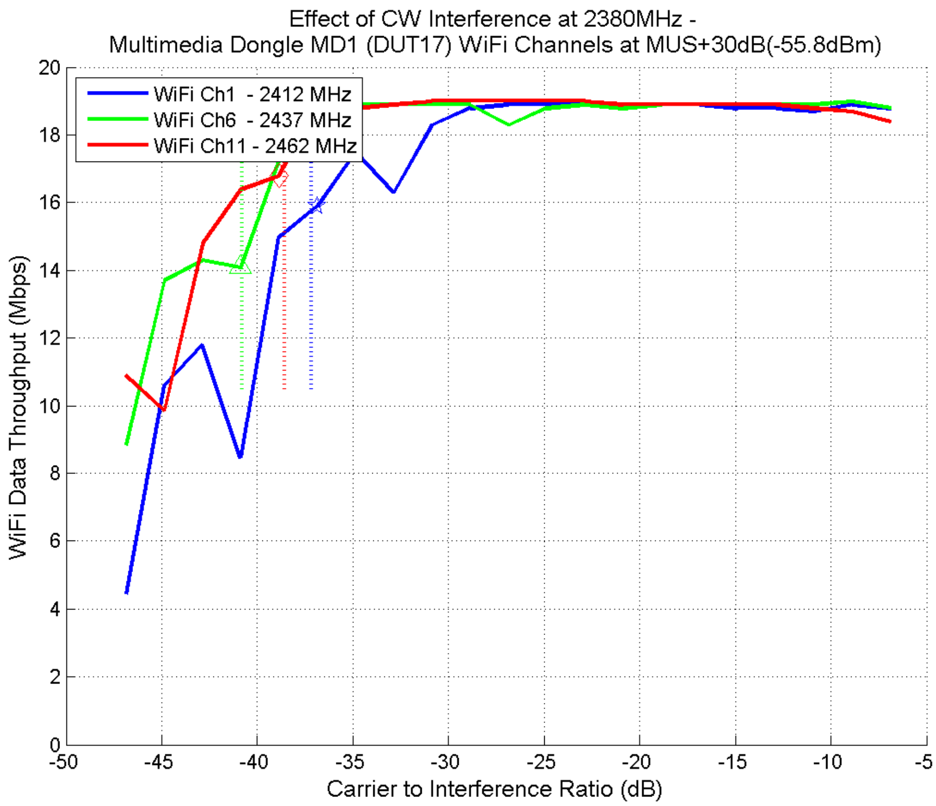

Figure 184

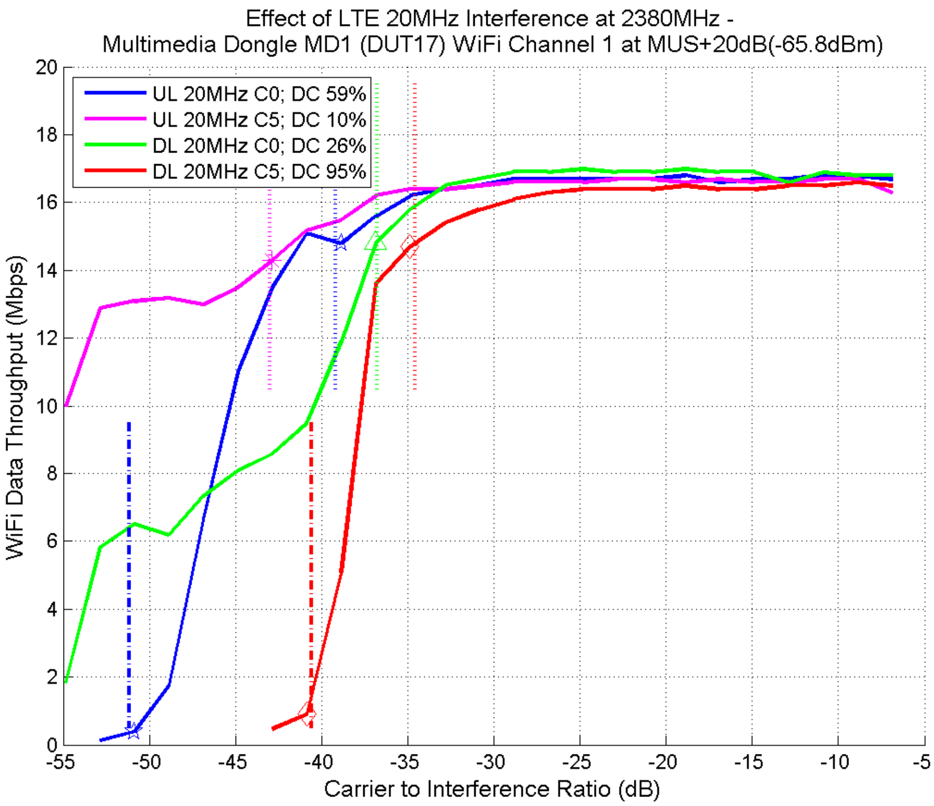

Figure 185

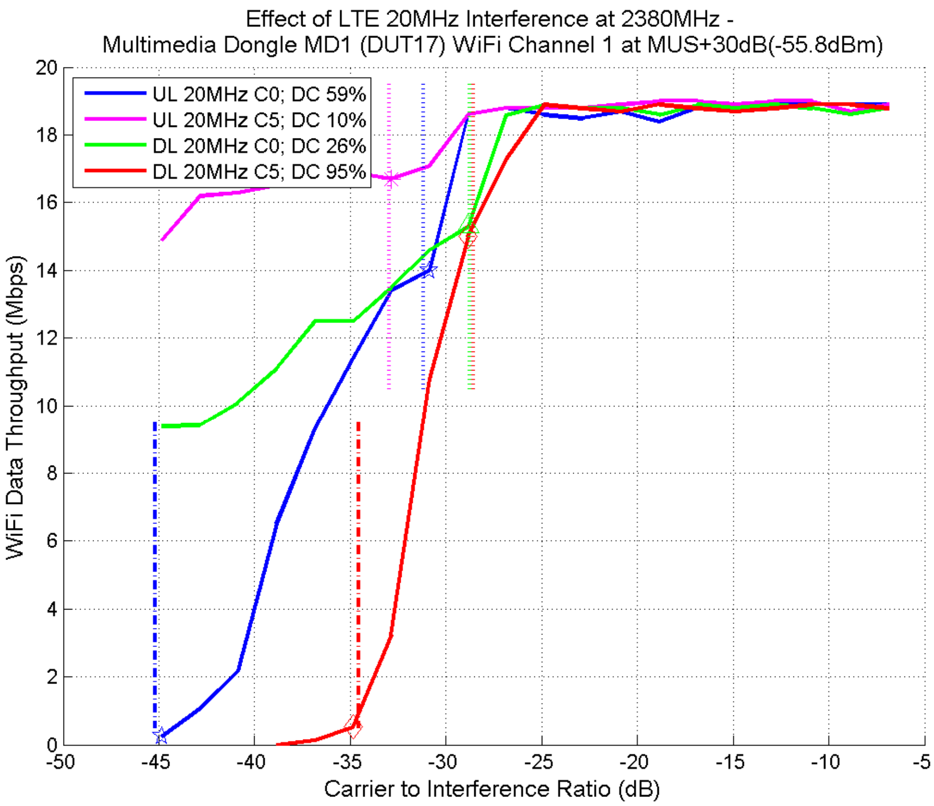

Figure 186

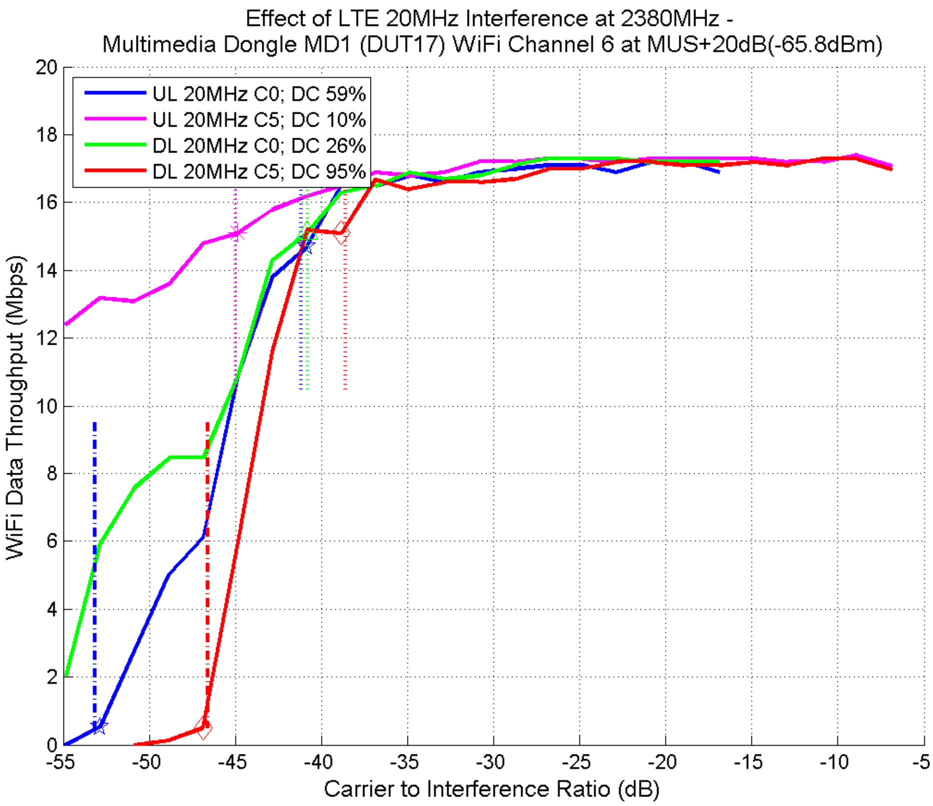

Figure 187

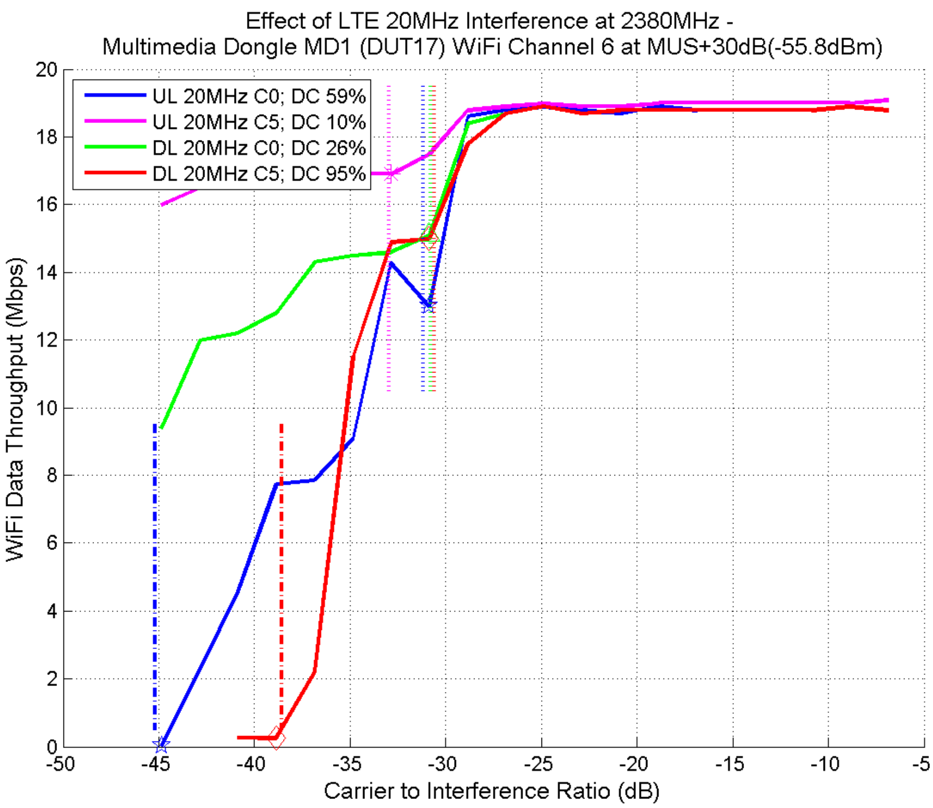

Figure 188

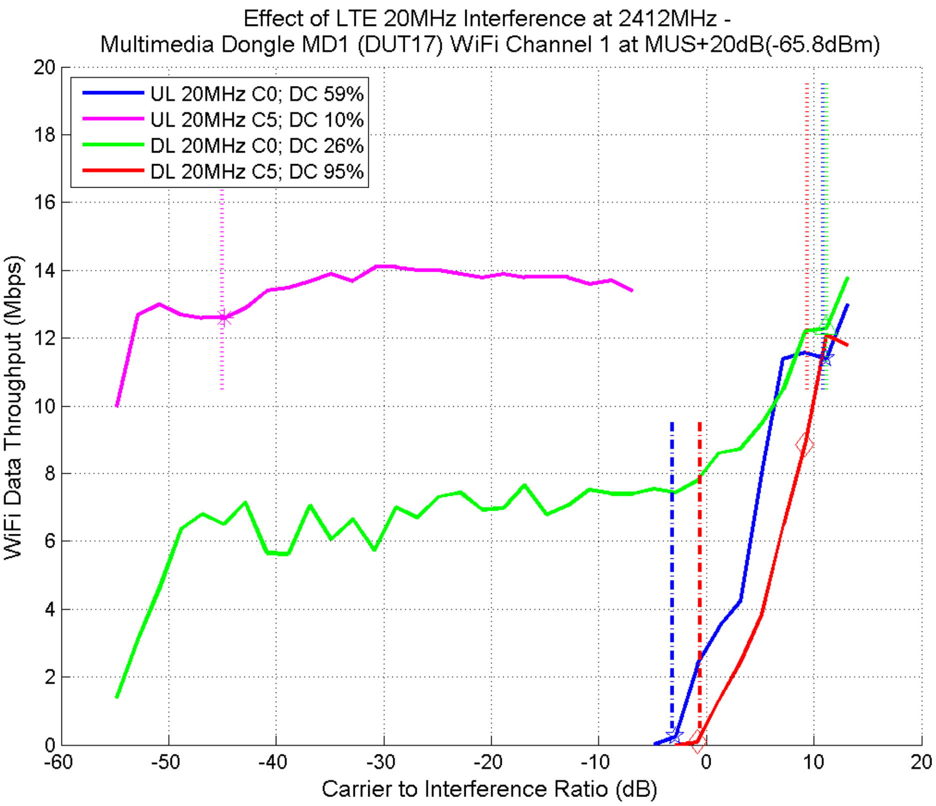

Figure 189

Observations

- Horizontally polarised when positioned horizontally on turntable.
- WiFi USB dongles commonly used in horizontal position.
- Maintains high throughput for 10% and 26% duty cycle interference when co-channel.

4.6 Outdoor Hotspots

4.6.1 Outdoor Hotspot OH1 (DUT 7)

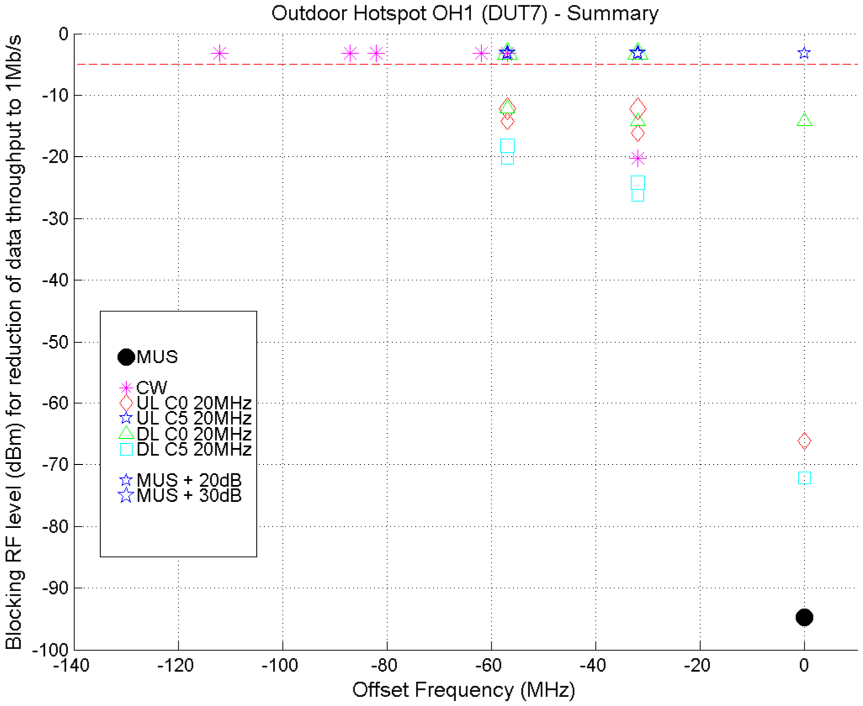

Figure 190

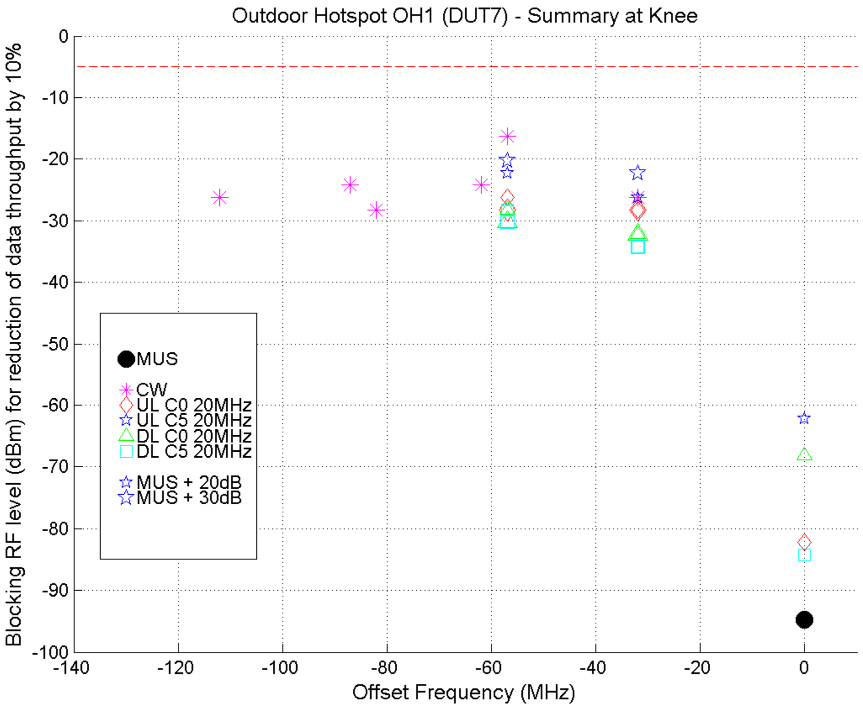

Figure 191

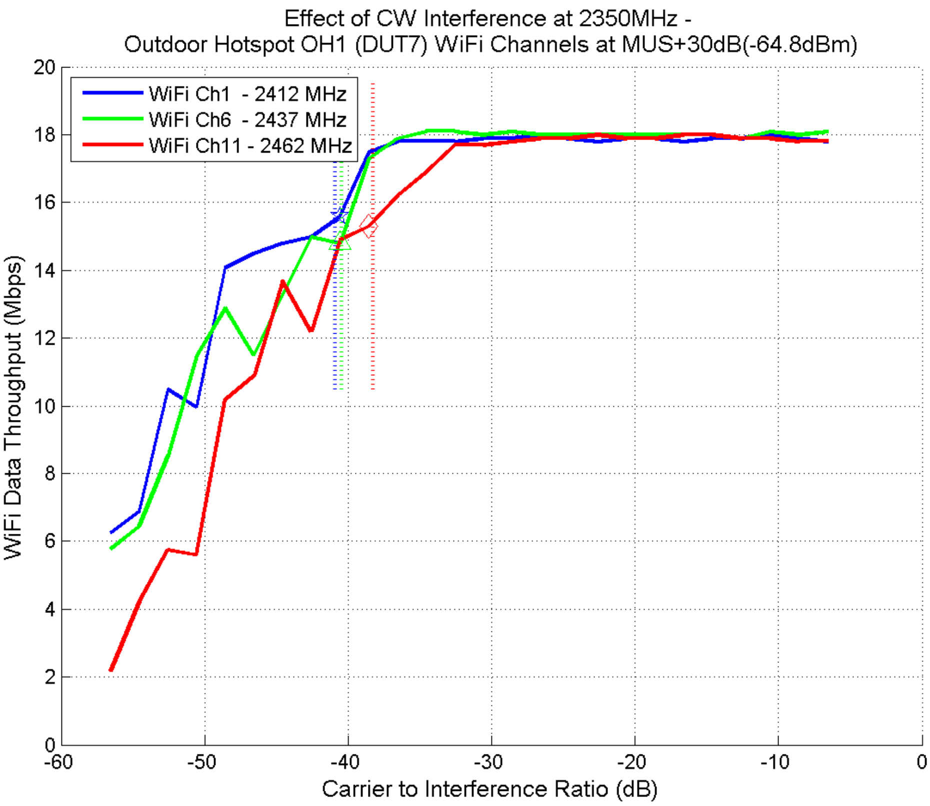

Figure 192

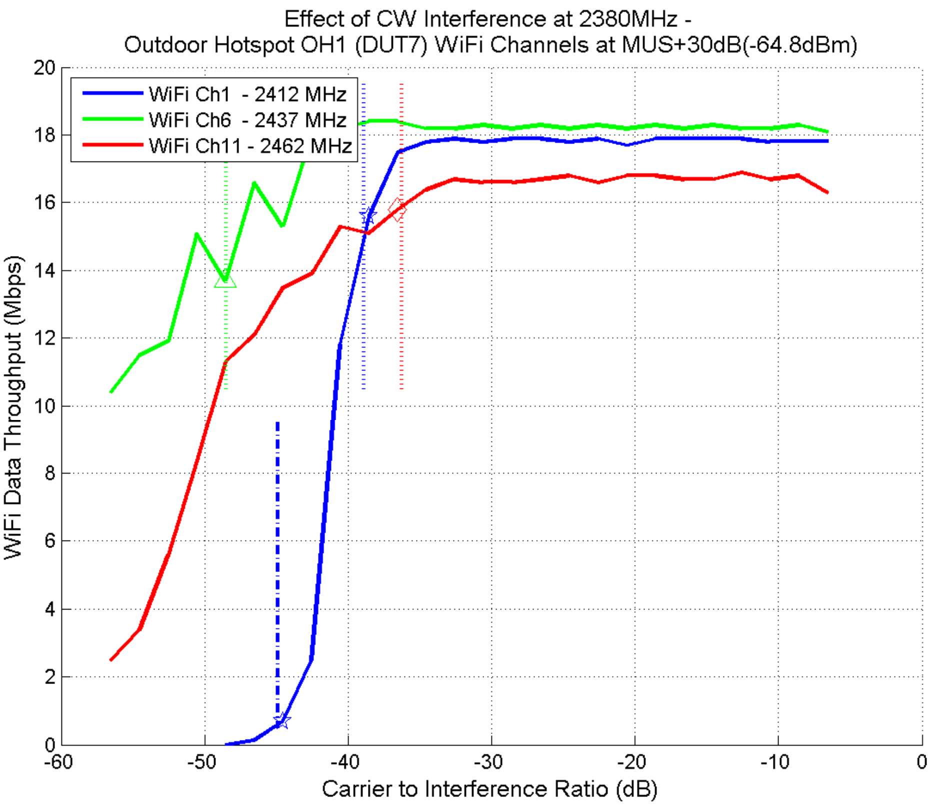

Figure 193

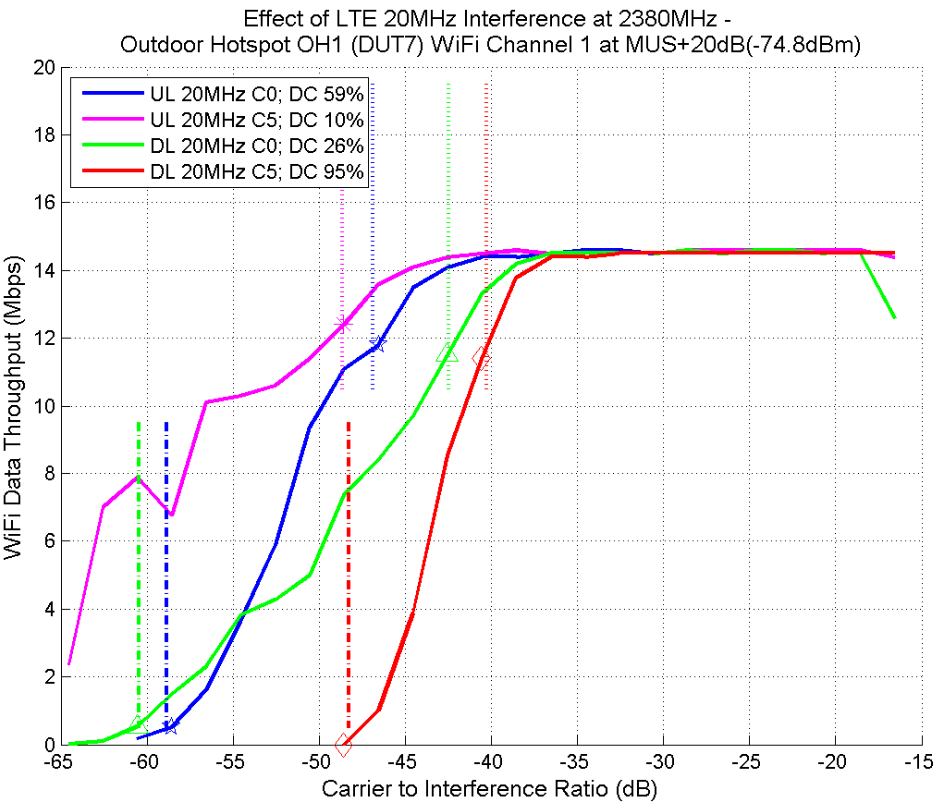

Figure 194

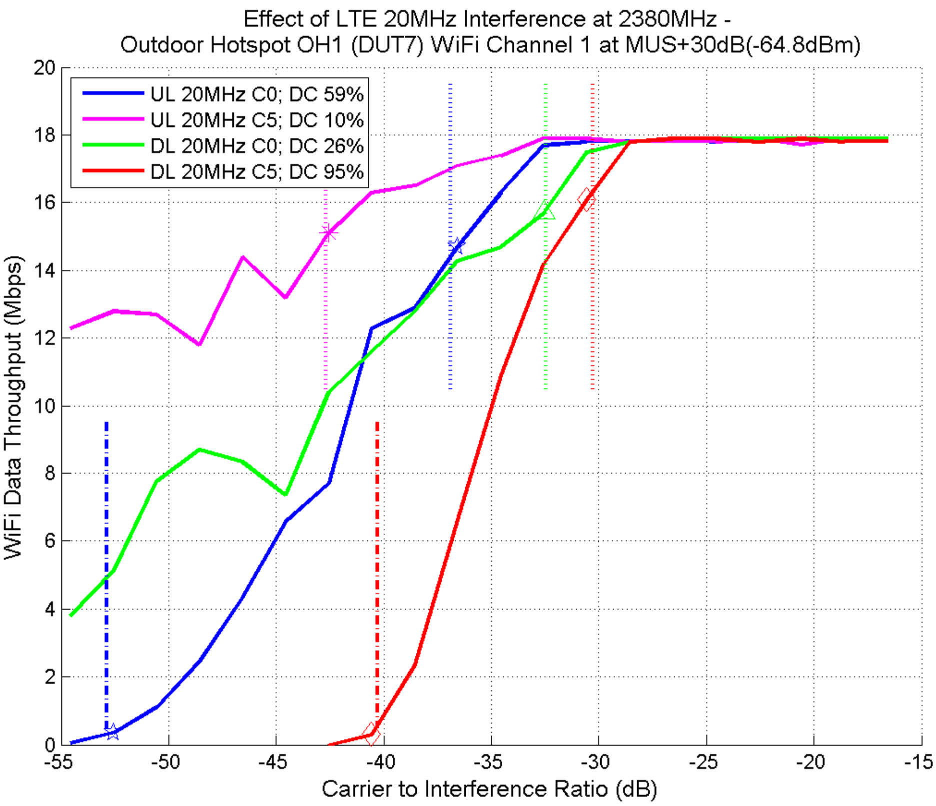

Figure 195

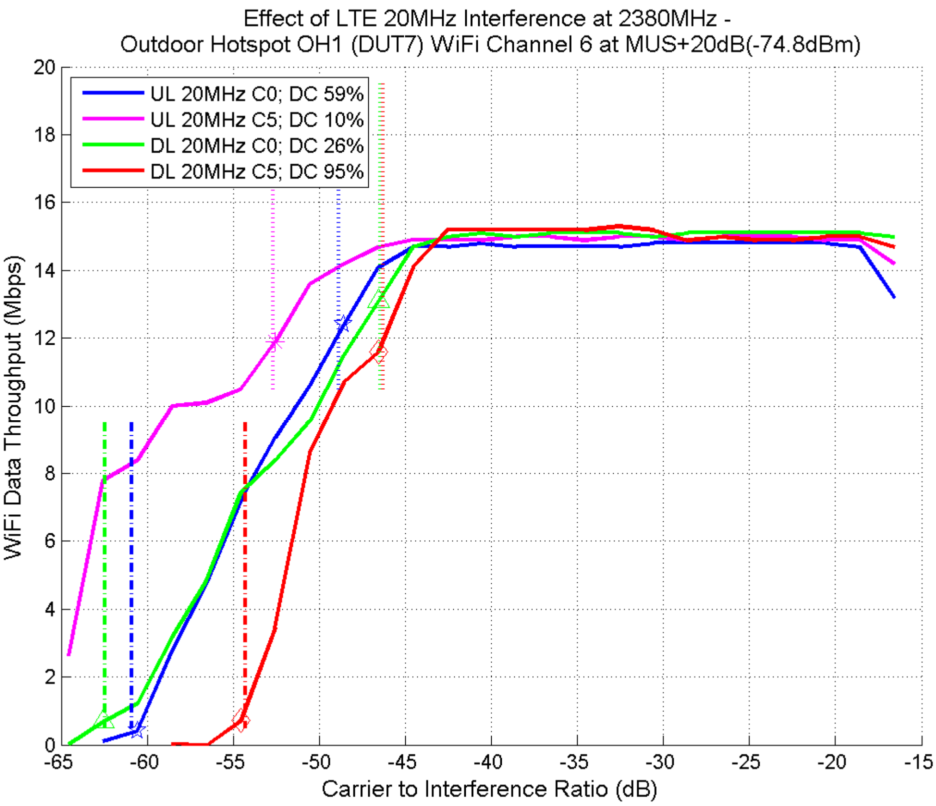

Figure 196

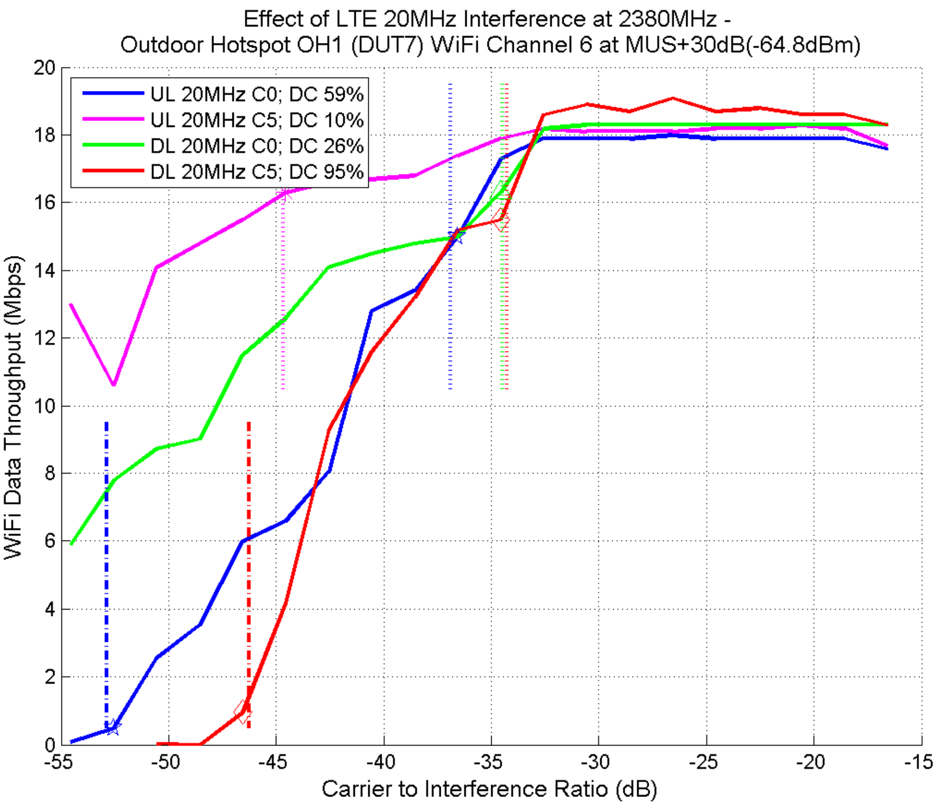

Figure 197

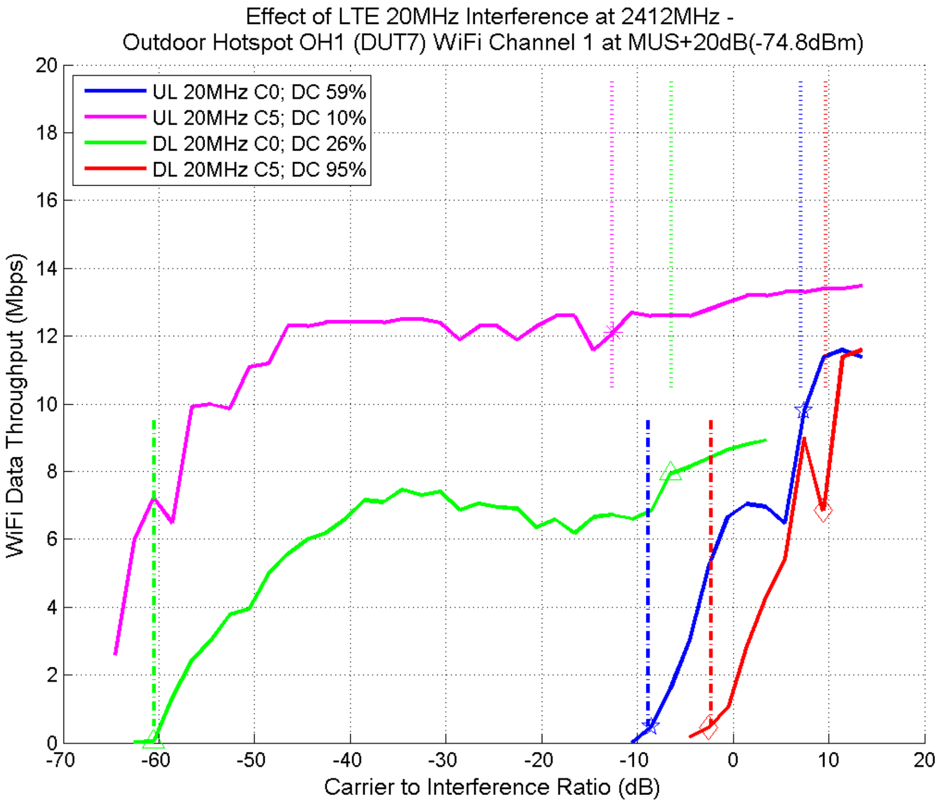

Figure 198

Observations

- Measured in vertical position and vertically polarised in operation.
- In Figure 198 the DUTs maintains a high throughput when the LTE duty cycle is lower.

4.6.2 Outdoor Hotspot OH2 (DUT 8)

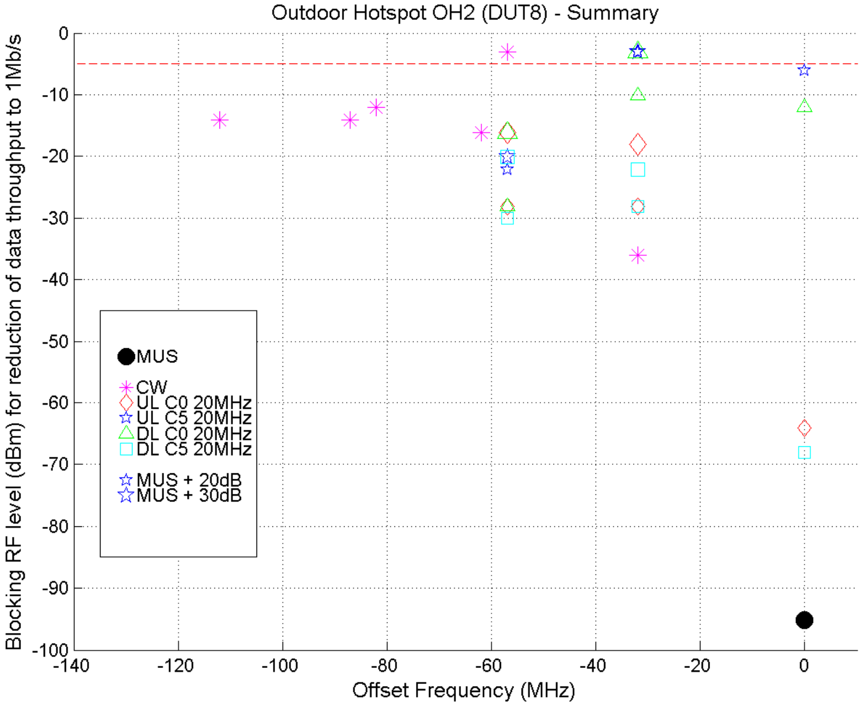

Figure 199

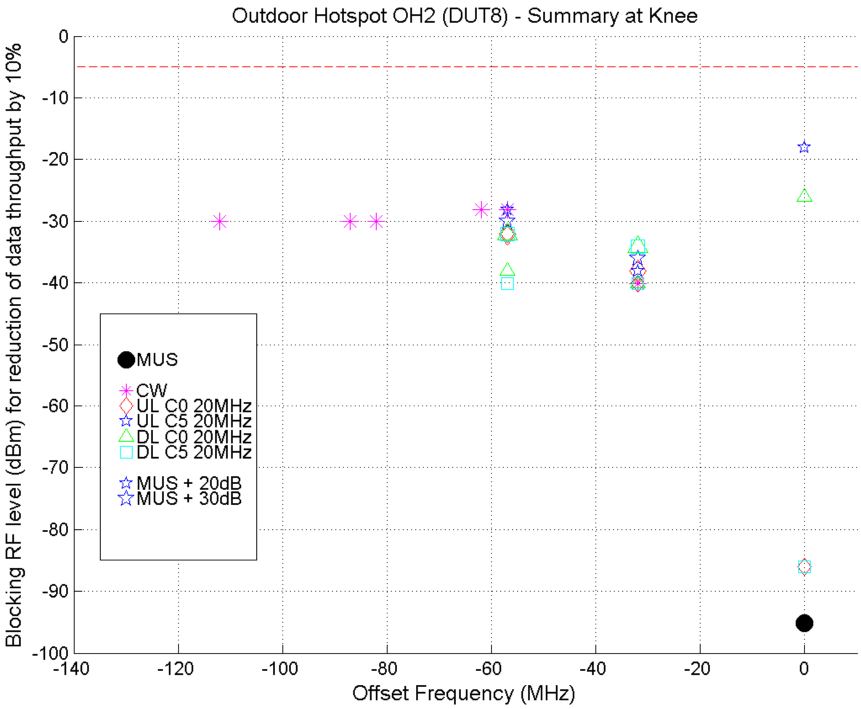

Figure 200

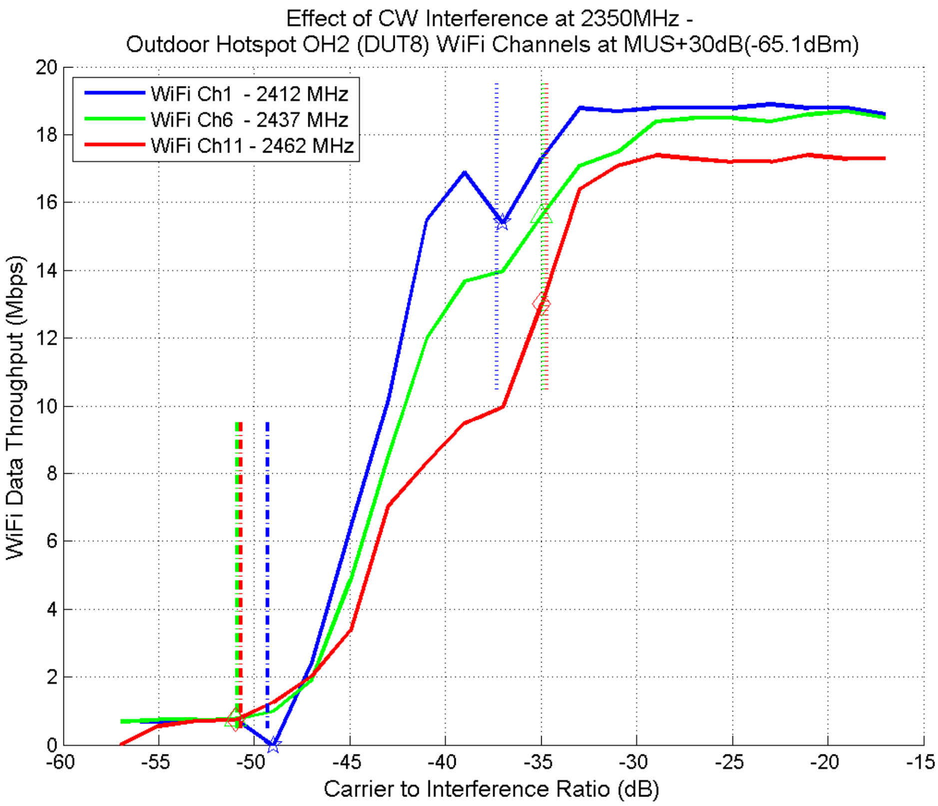

Figure 201

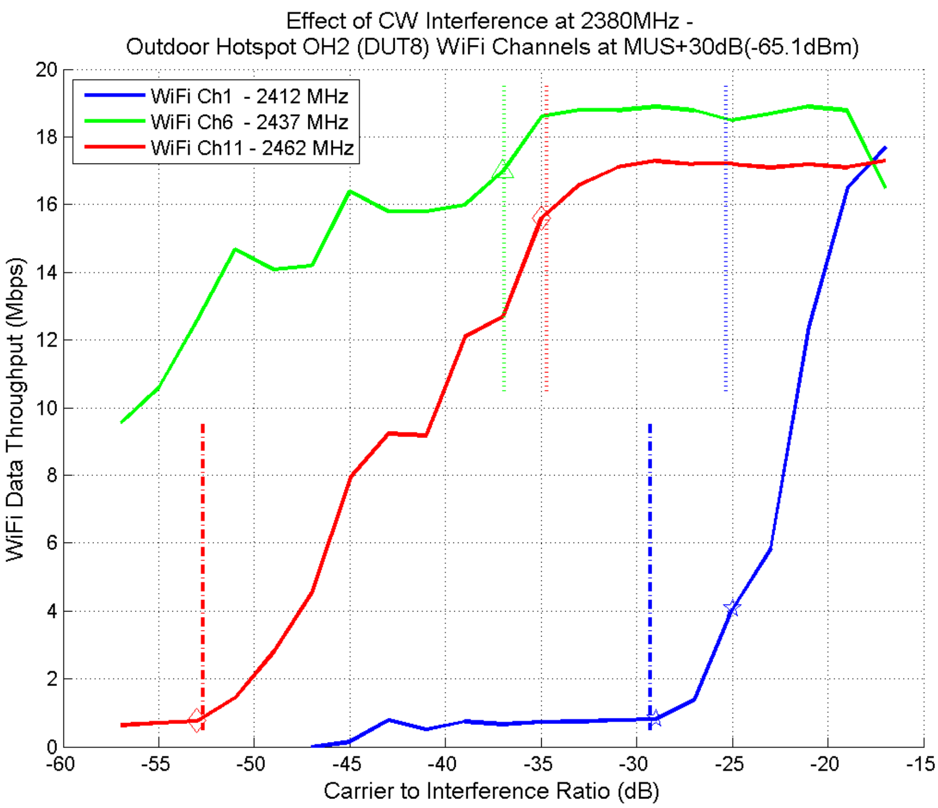

Figure 202

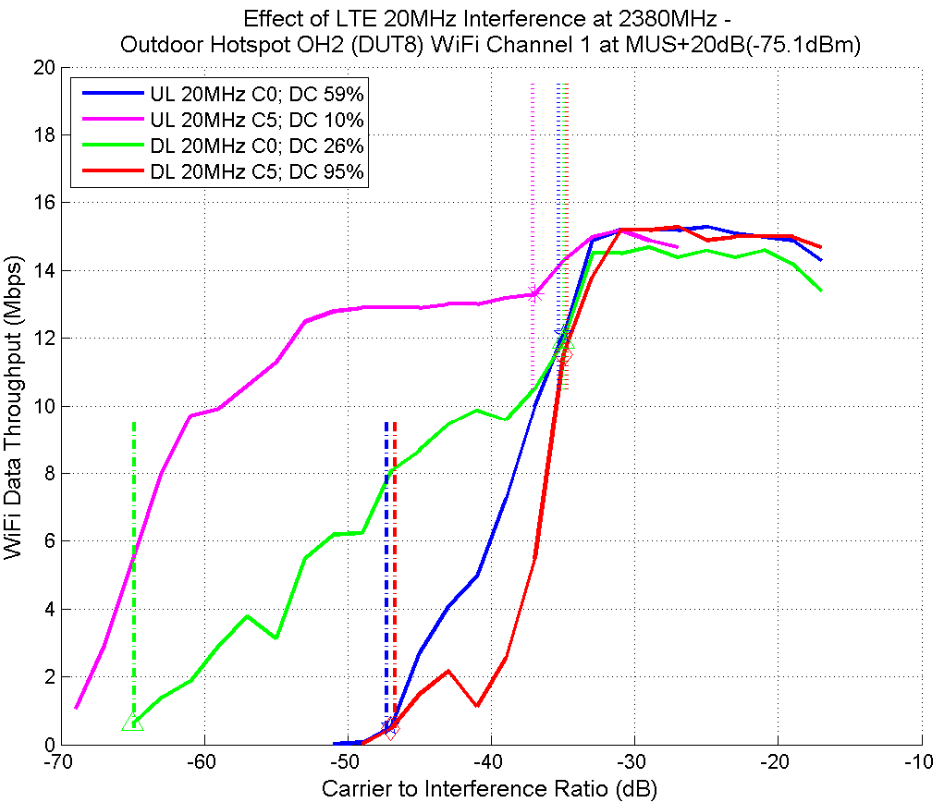

Figure 203

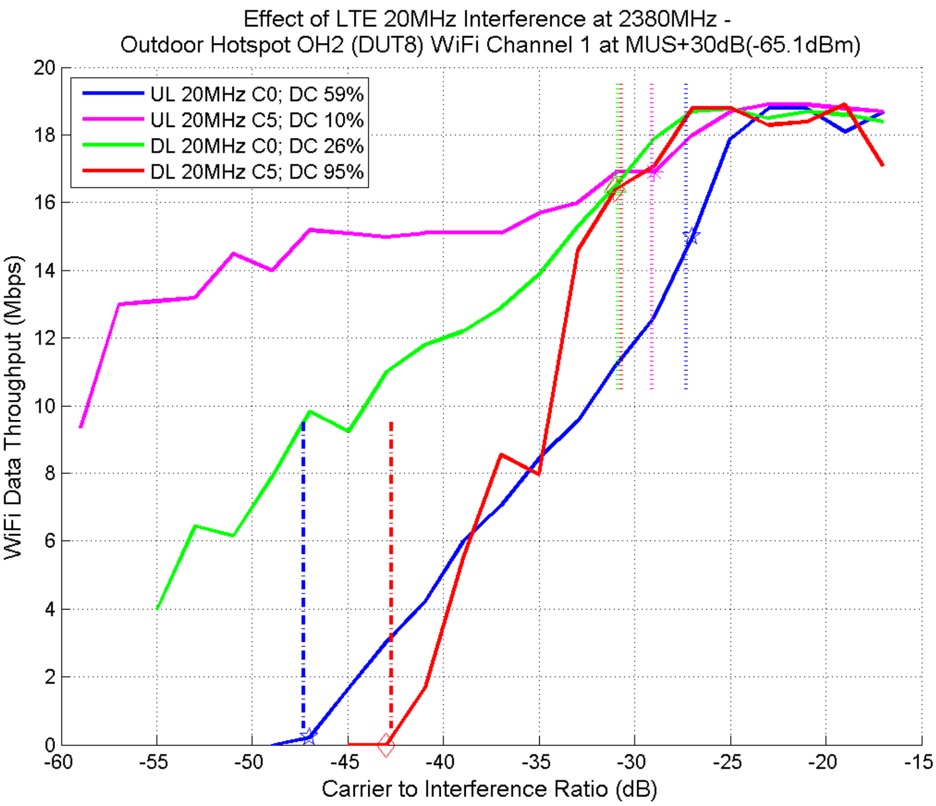

Figure 204

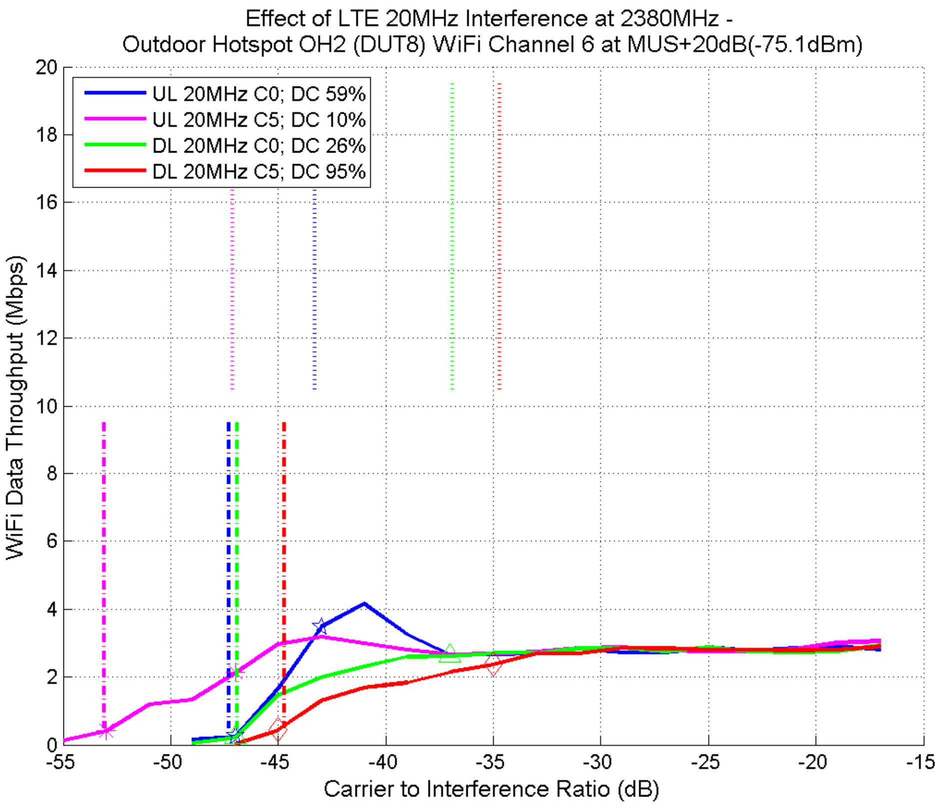

Figure 205

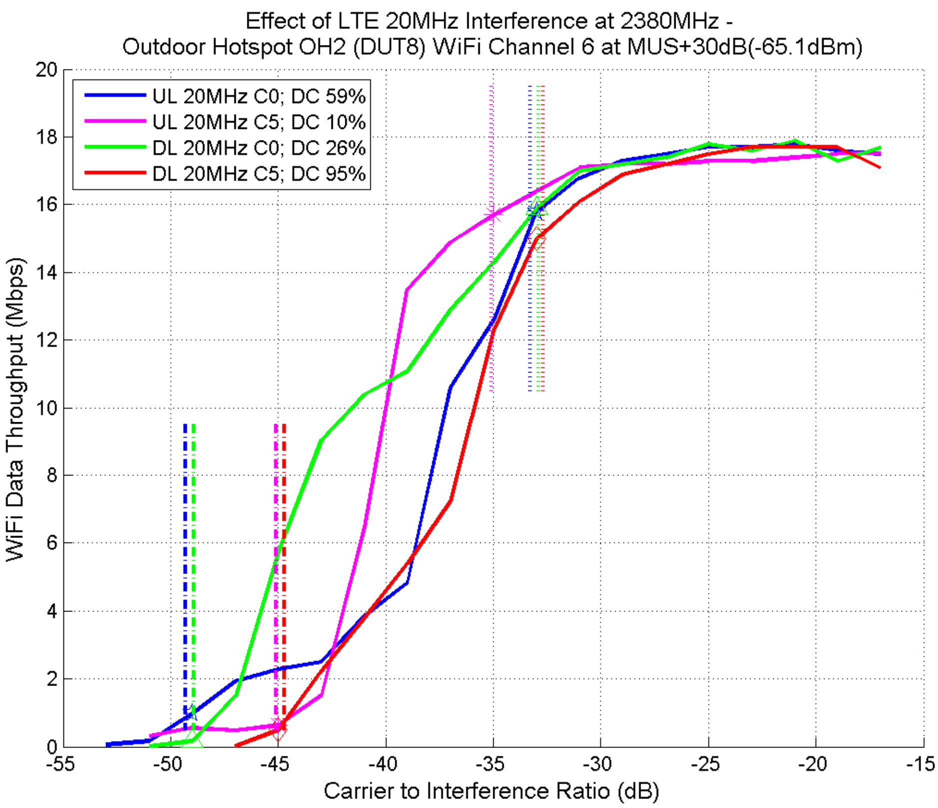

Figure 206

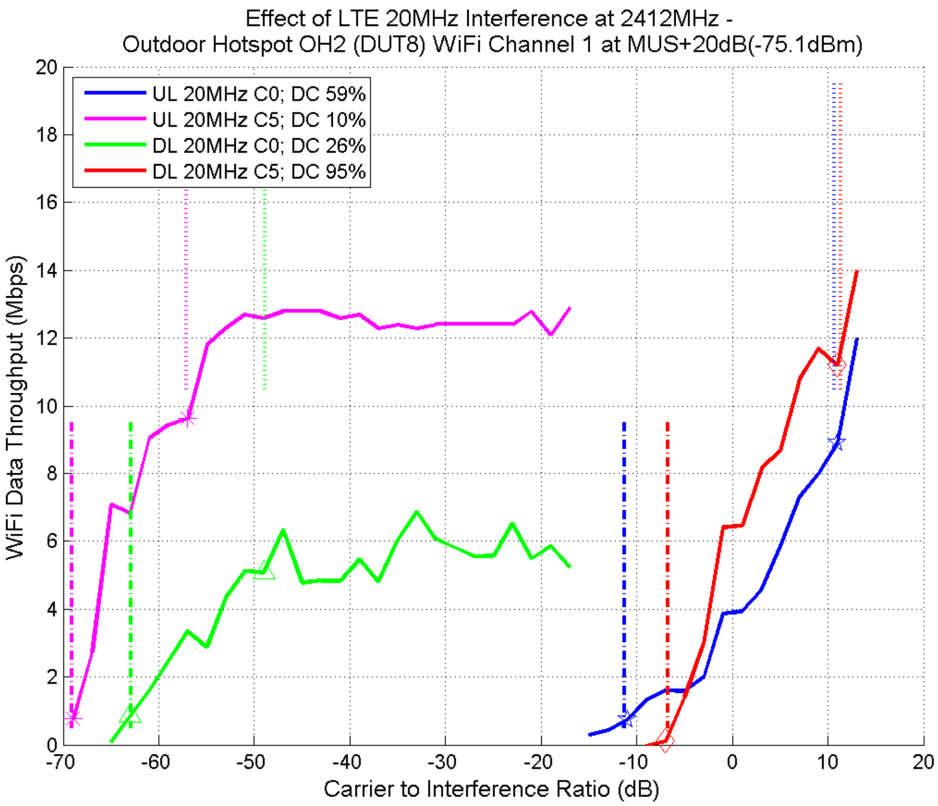

Figure 207

Observations

- Measured in vertical position and vertically polarised in operation.
- In Figure 205 the DUT shows a very low throughput, which may have been anomalous.
- In Figure 207 the DUT exhibits markedly higher throughputs when the LTE duty cycle is lower which is similar to other DUTs in this report.

4.6.2.1 Additional Out of Band Tests

The WiFi and LTE settings for the LTE additional out-of-band (OOB) tests for DUT8 are shown below:

WiFi Receiver Sensitivity	WiFi Channels	LTE Channel Bandwidth	LTE Frequency Offsets	LTE Frame Structure
MUS +20dB, +30dB, +40dB	1, 6, 11	20MHz	2380MHz	UL_C0, UL_C5, DL_C0, DL_C5
MUS +20dB	1	10MHz	2385MHz	UL_C0, UL_C5, DL_C0, DL_C5

Table 5: Additional OOB Test Settings for DUT8

The WiFi Receiver Sensitivity tests were performed on each of the three WiFi channels, to determine any variations in the MUS dependent upon WiFi receiver frequency. The MUS levels measured for WiFi channels 1, 6 and 11 are shown on the summary plots, and were used to determine the MUS +20db, MUS +30dB and MUS +40dB carrier levels used for each WiFi channel in the LTE additional OOB tests.

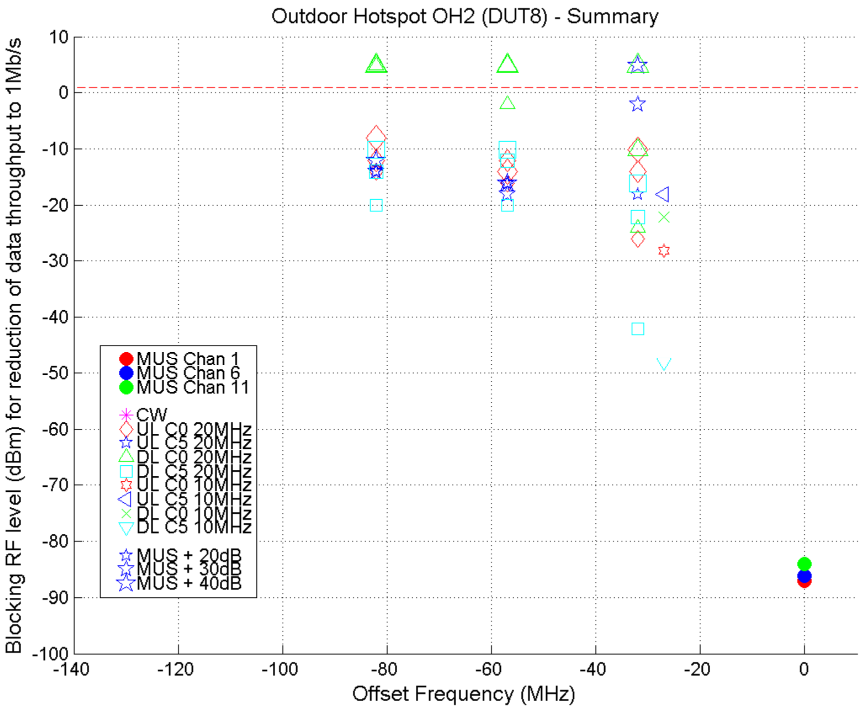

Figure 208

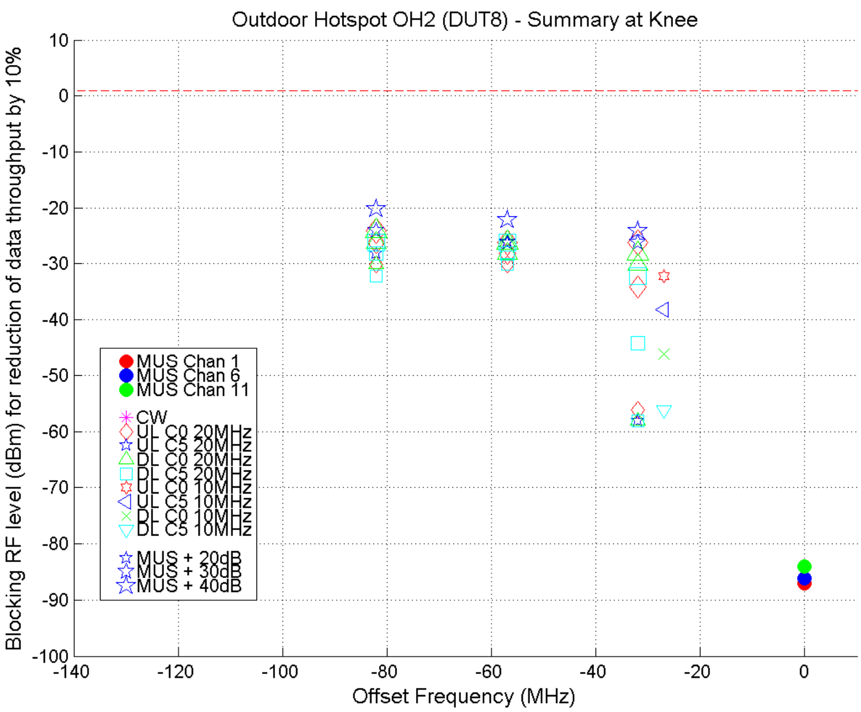

Figure 209

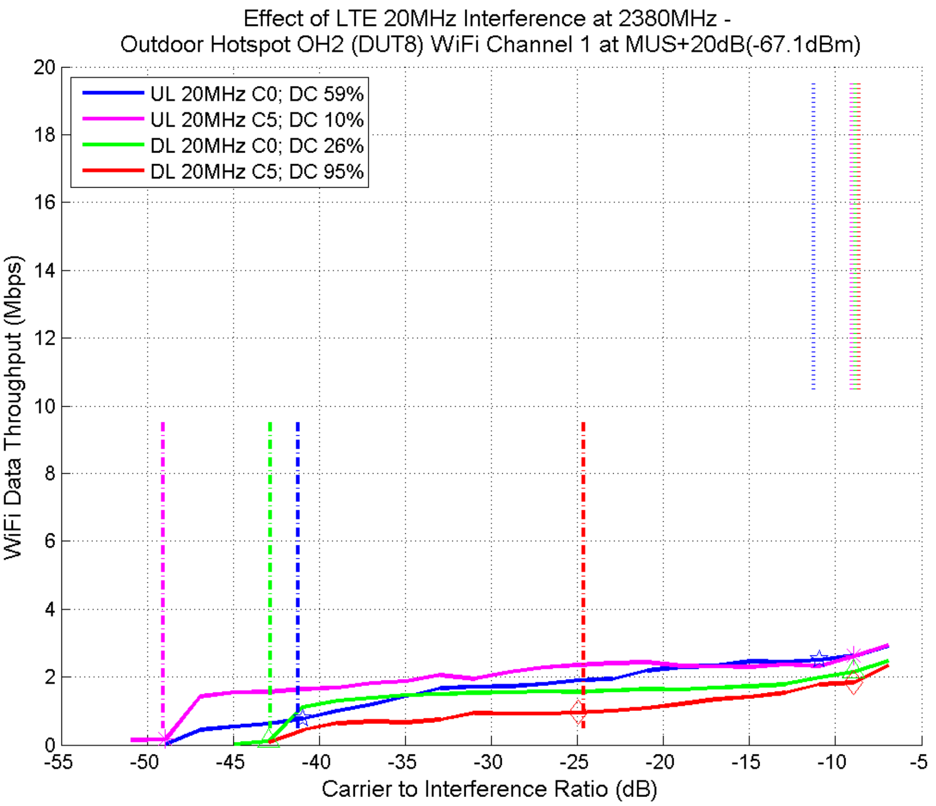

Figure 210

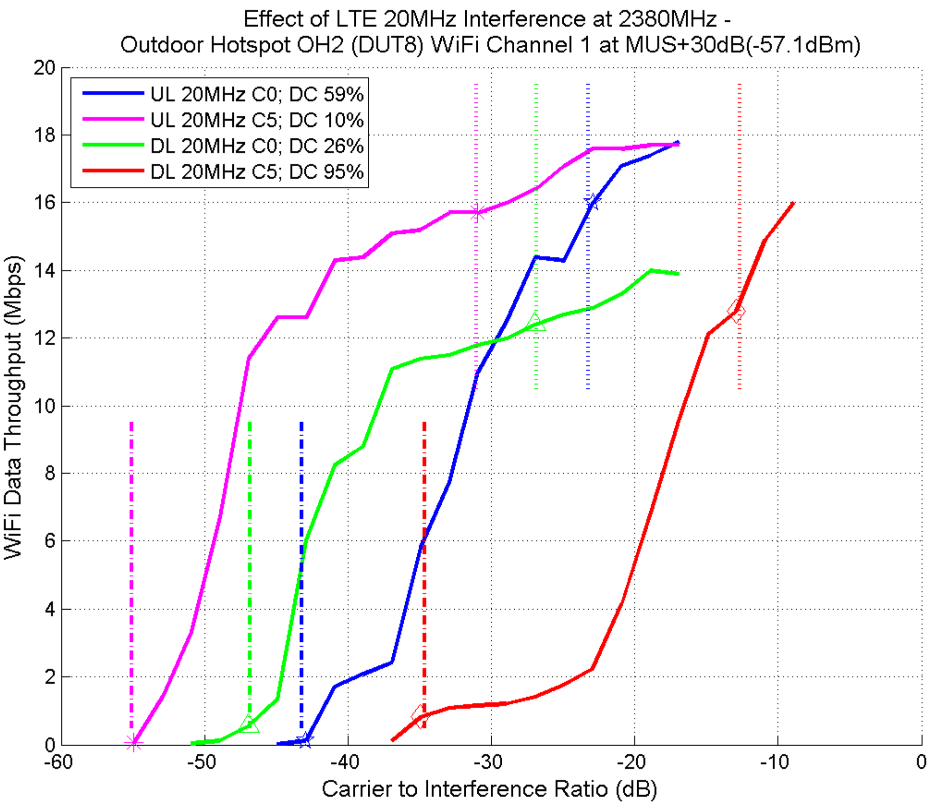

Figure 211

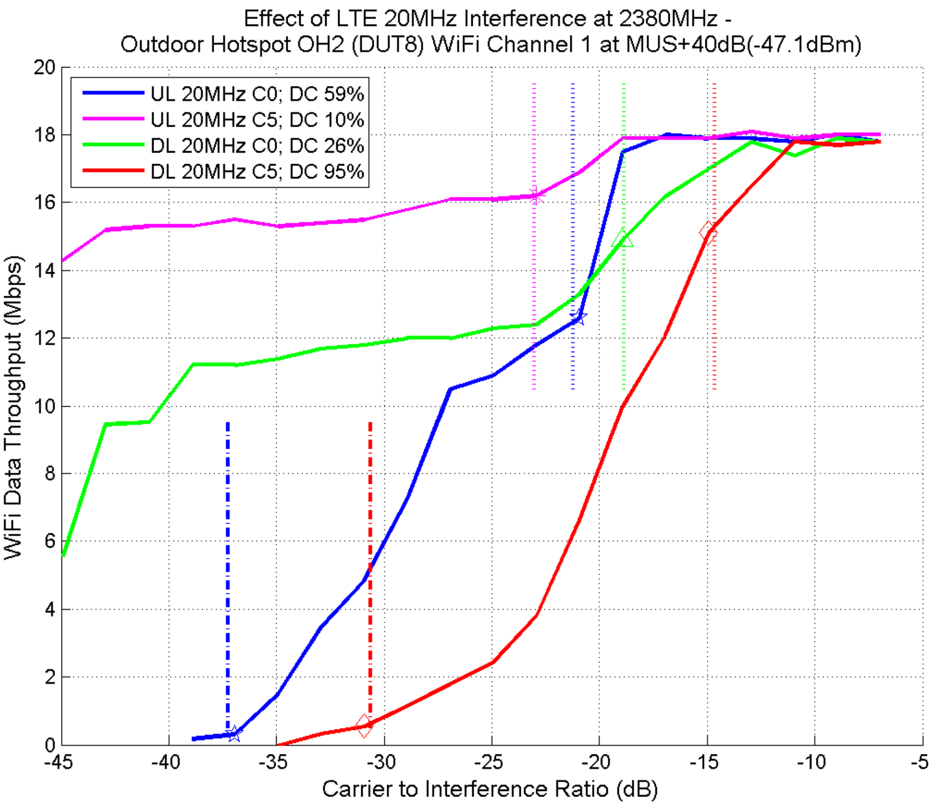

Figure 212

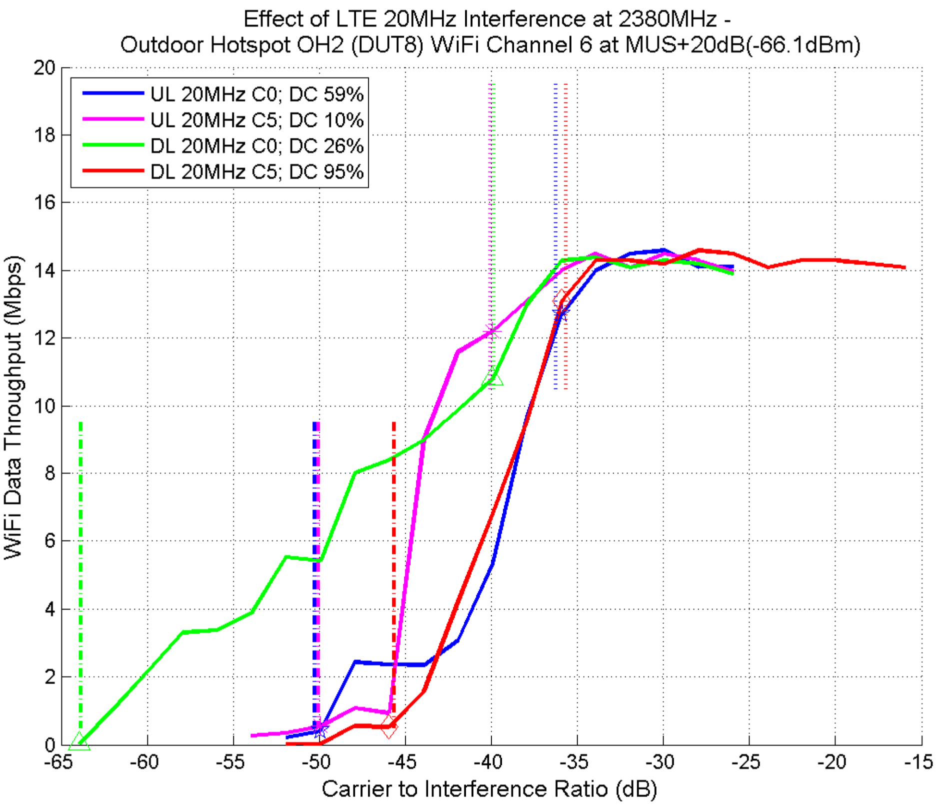

Figure 213

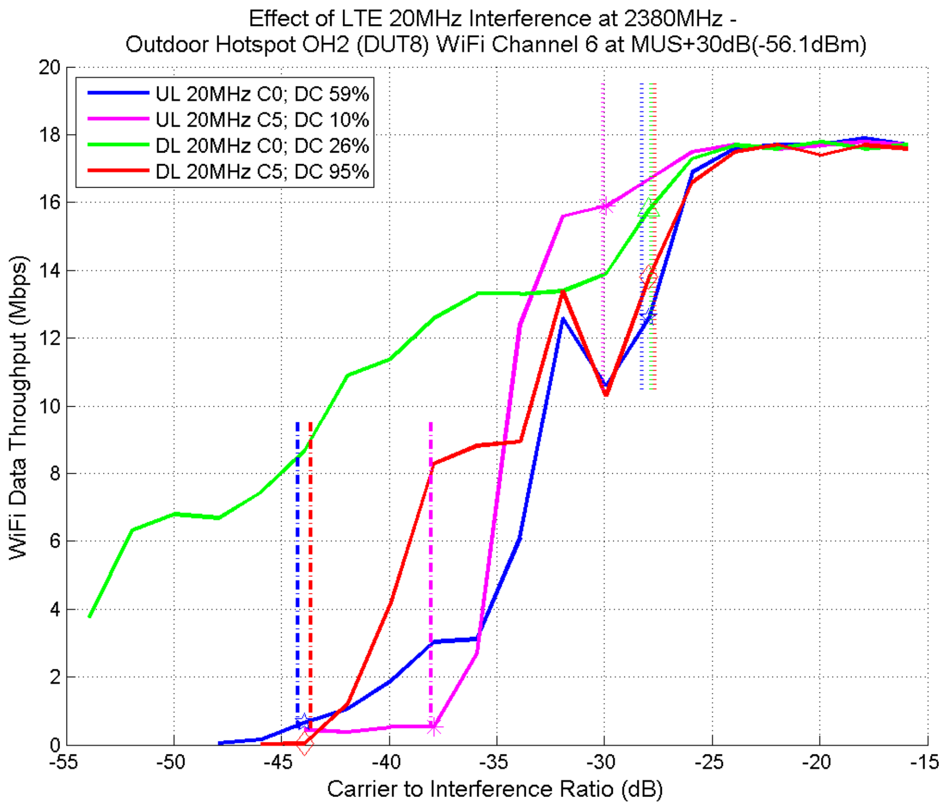

Figure 214

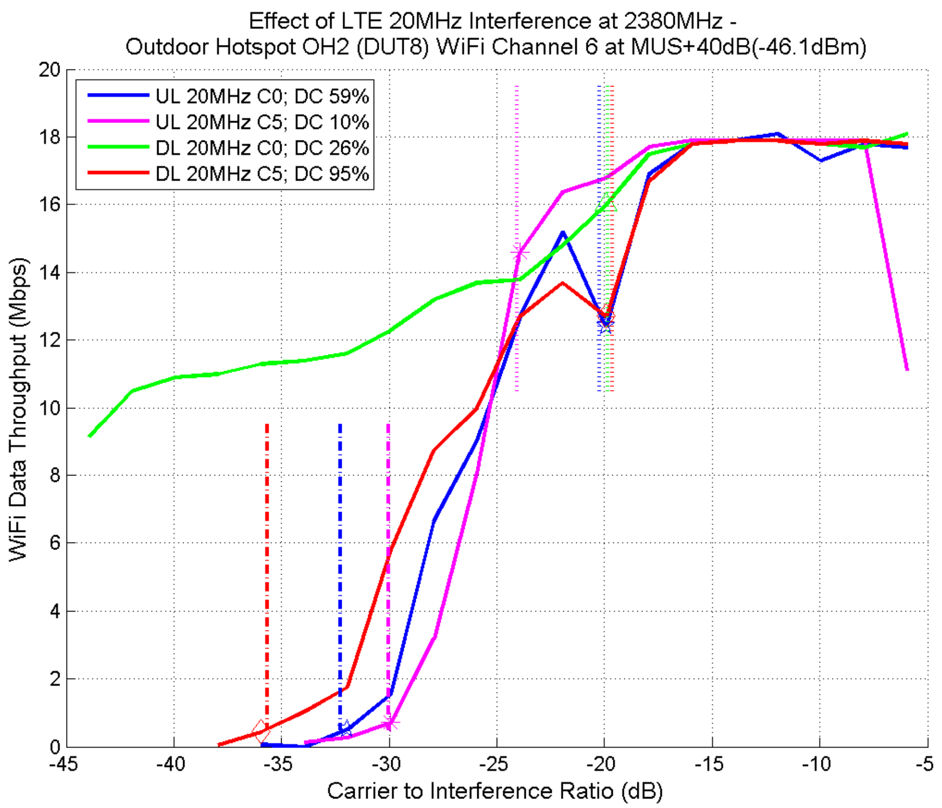

Figure 215

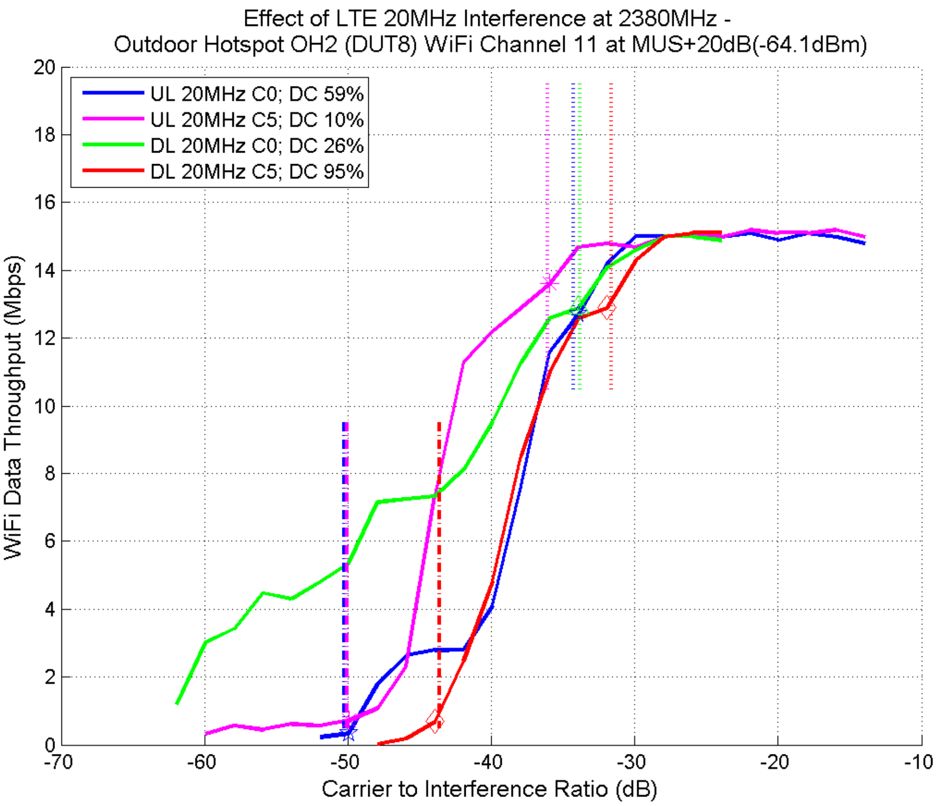

Figure 216

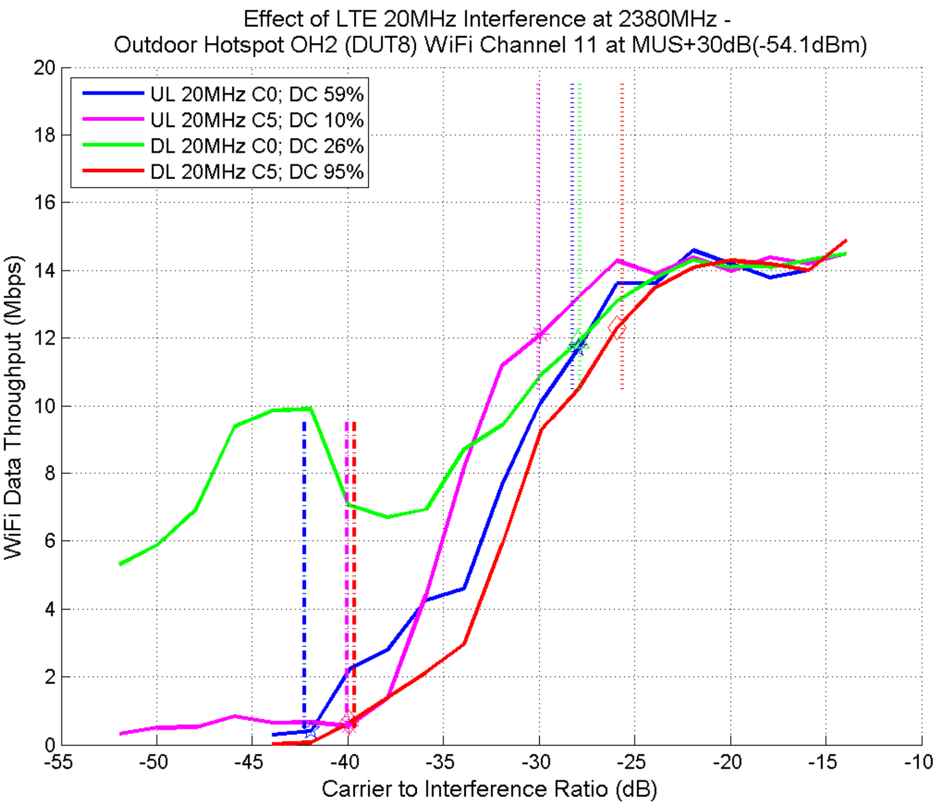

Figure 217

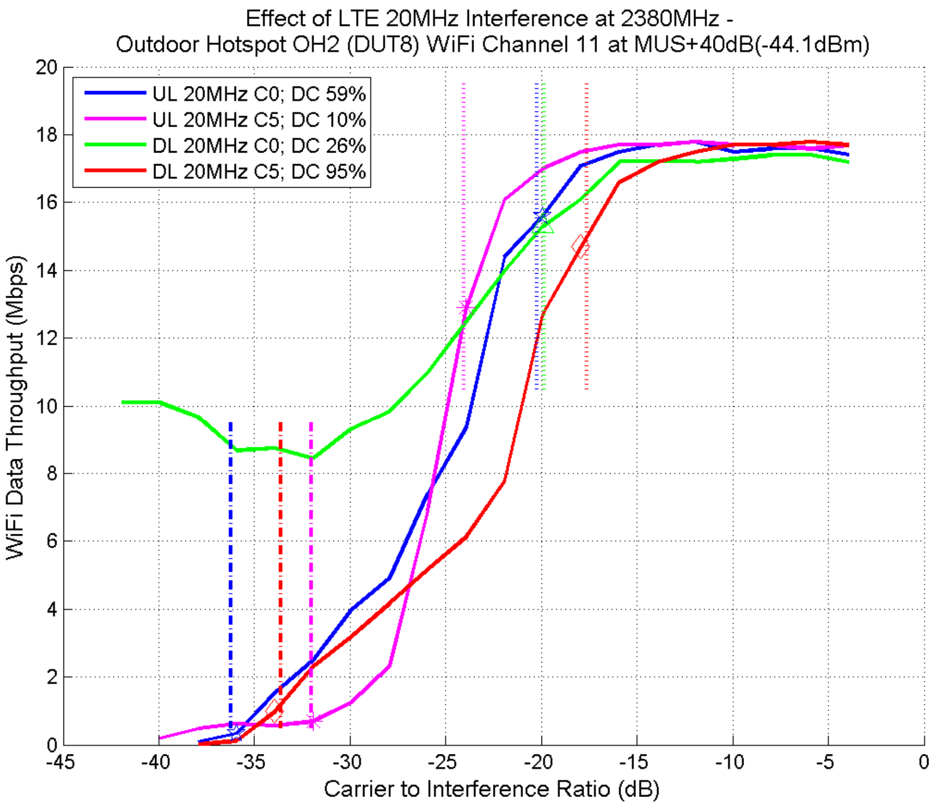

Figure 218

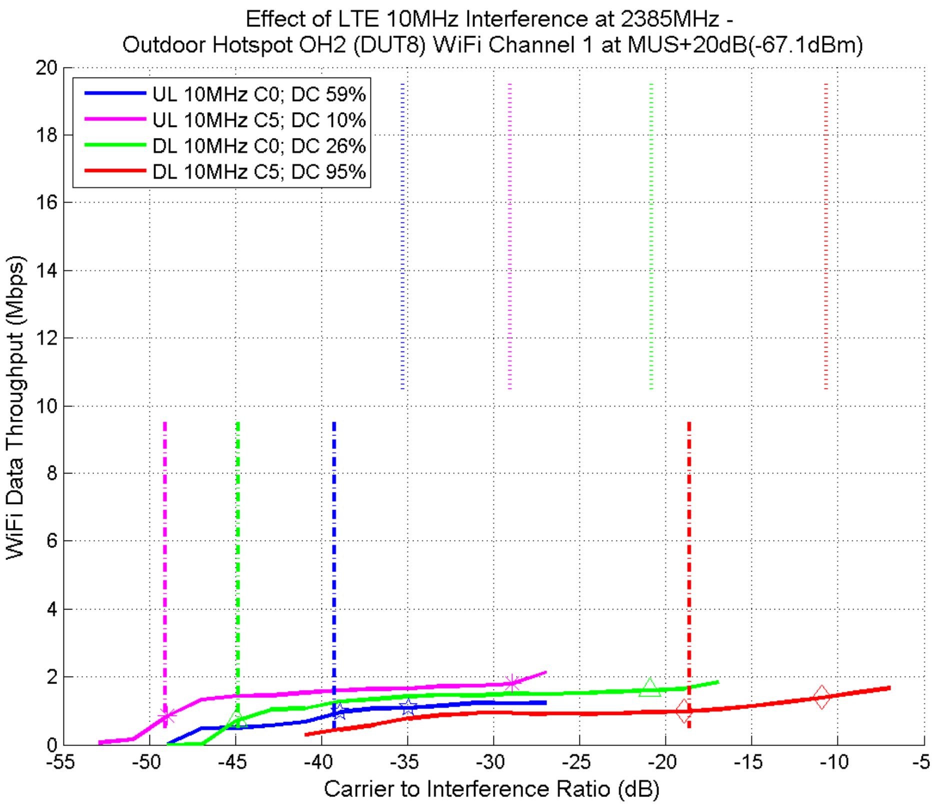

Figure 219

Observations

- The additional tests show that, at offsets greater than 50MHz, the blocking is independent of the offset frequency.
- The additional tests show that the 10MHz bandwidth LTE transmissions have the same characteristics as the 20MHz transmissions.
- The device MUS was measured independently on each of the tested WiFi channels and the tests were performed for each channel at the wanted signal levels relative to the measured channel MUS.

4.6.3 Outdoor Hotspot OH3 (DUT 10)

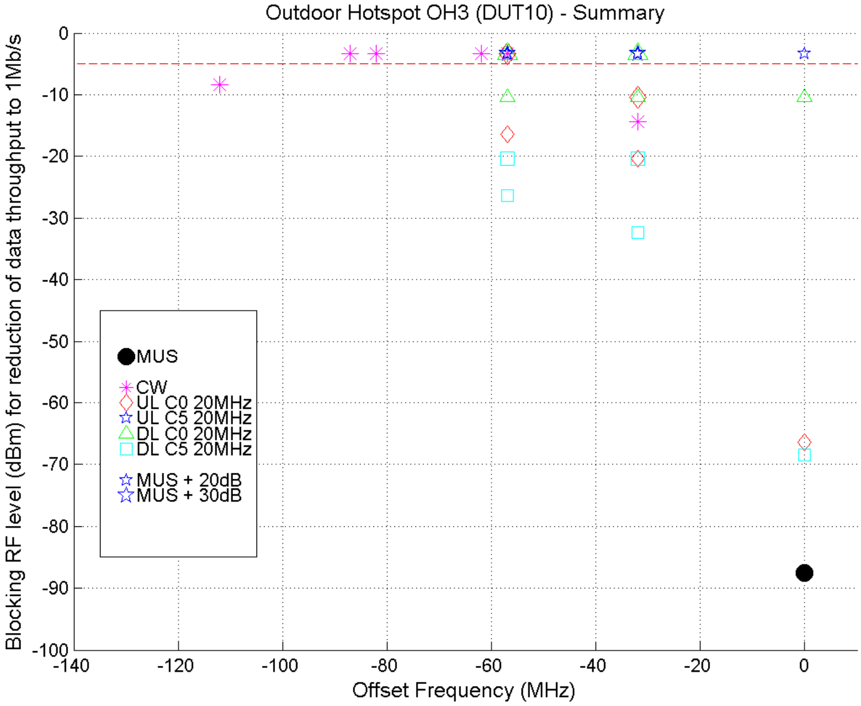

Figure 220

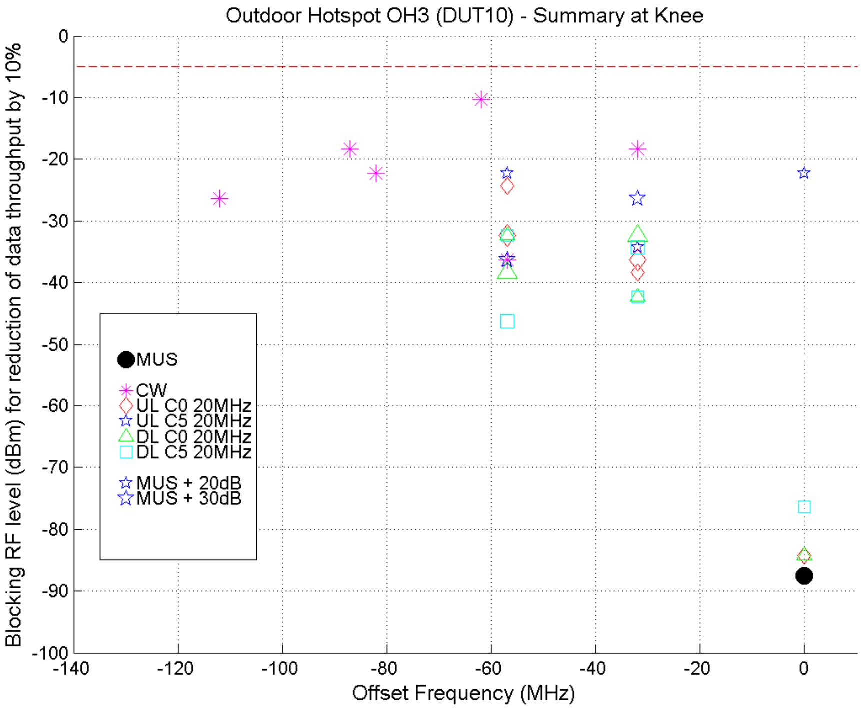

Figure 221

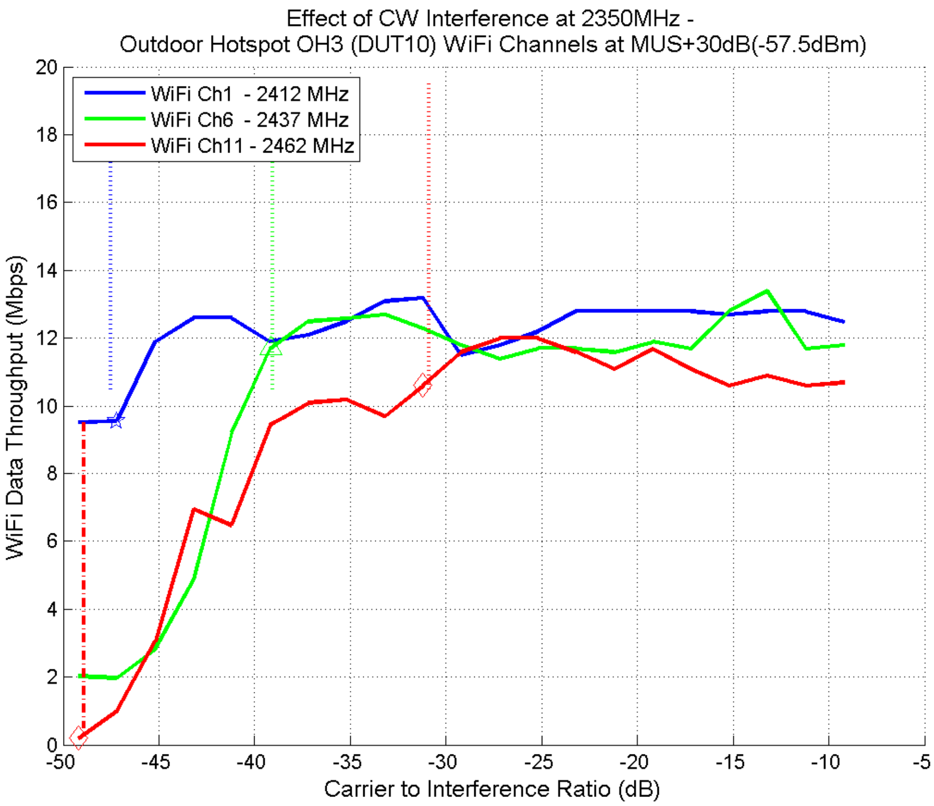

Figure 222

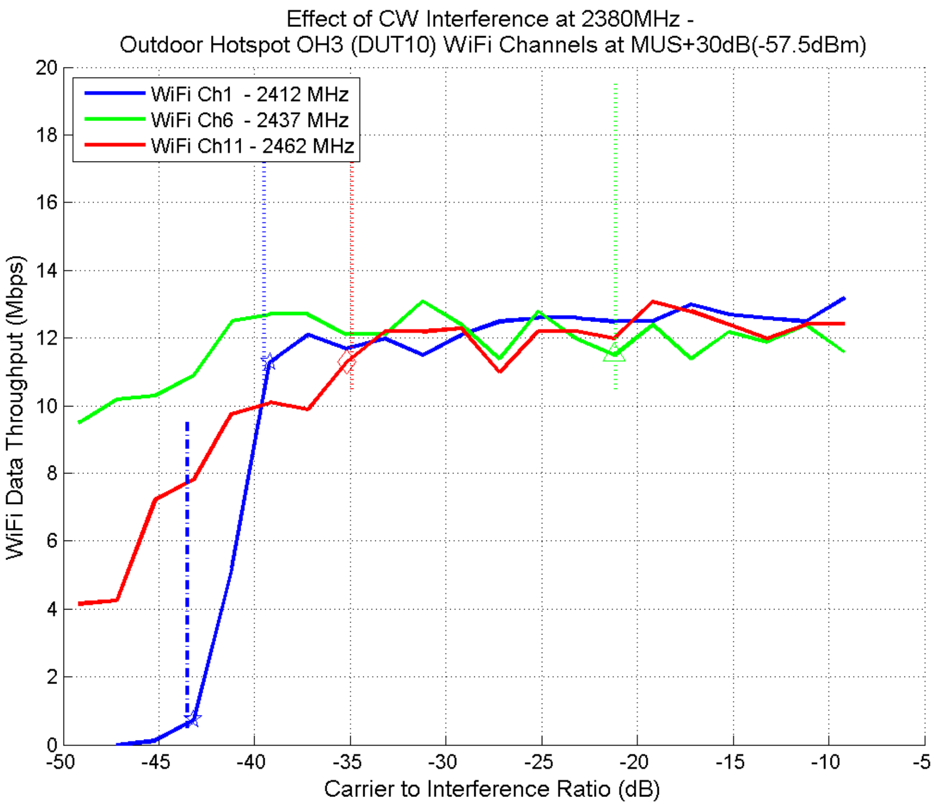

Figure 223

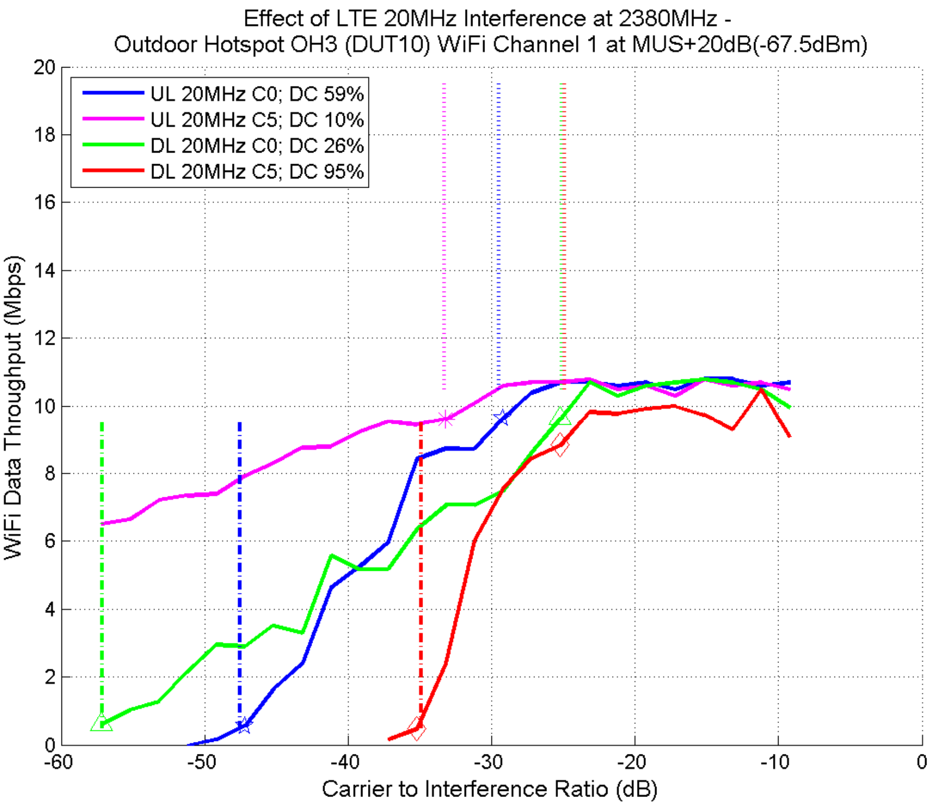

Figure 224

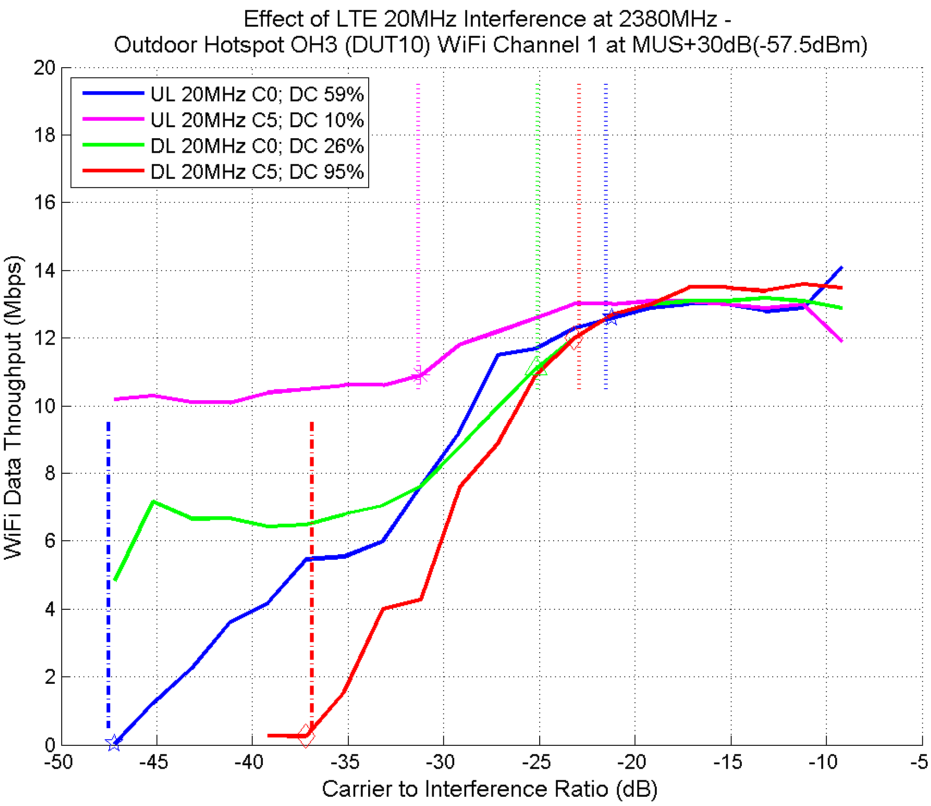

Figure 225

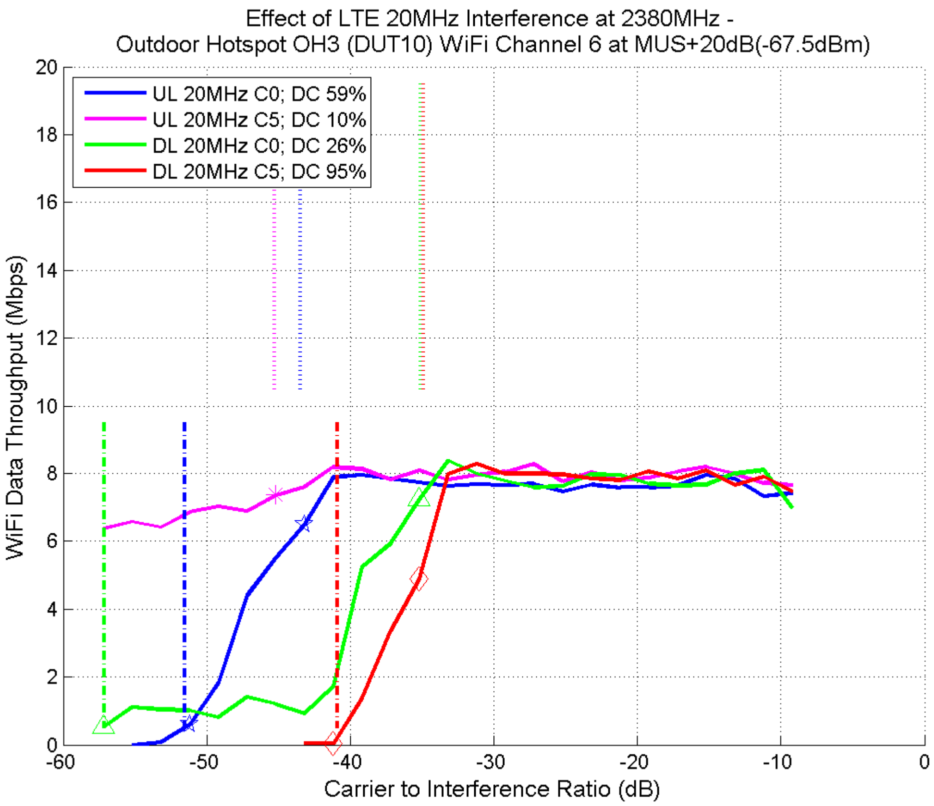

Figure 226

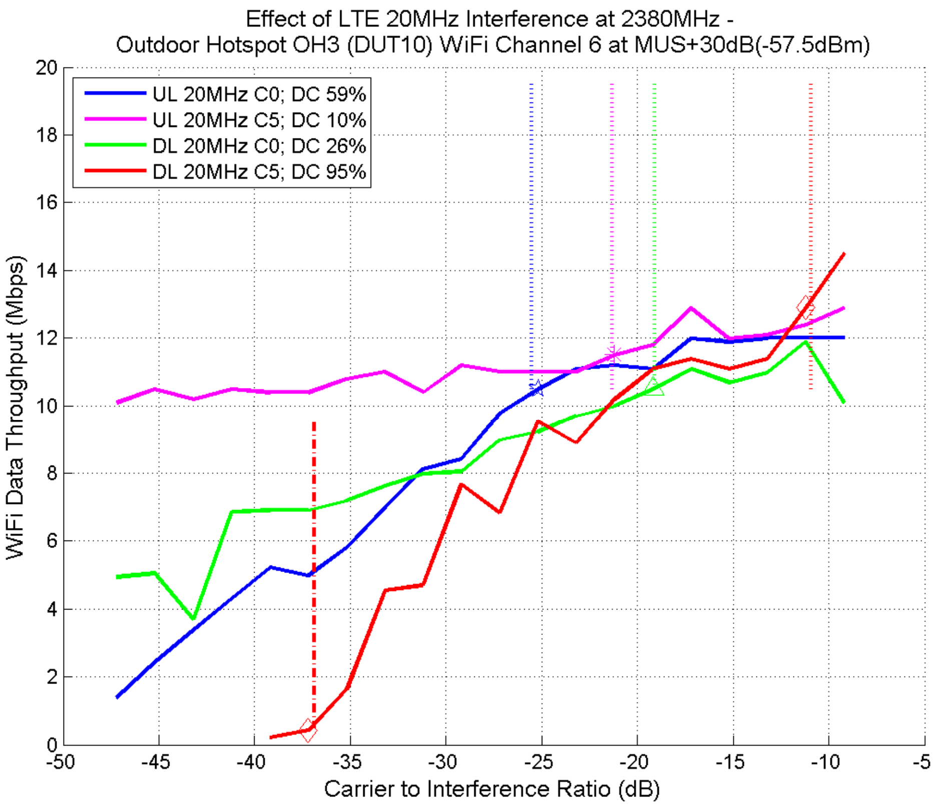

Figure 227

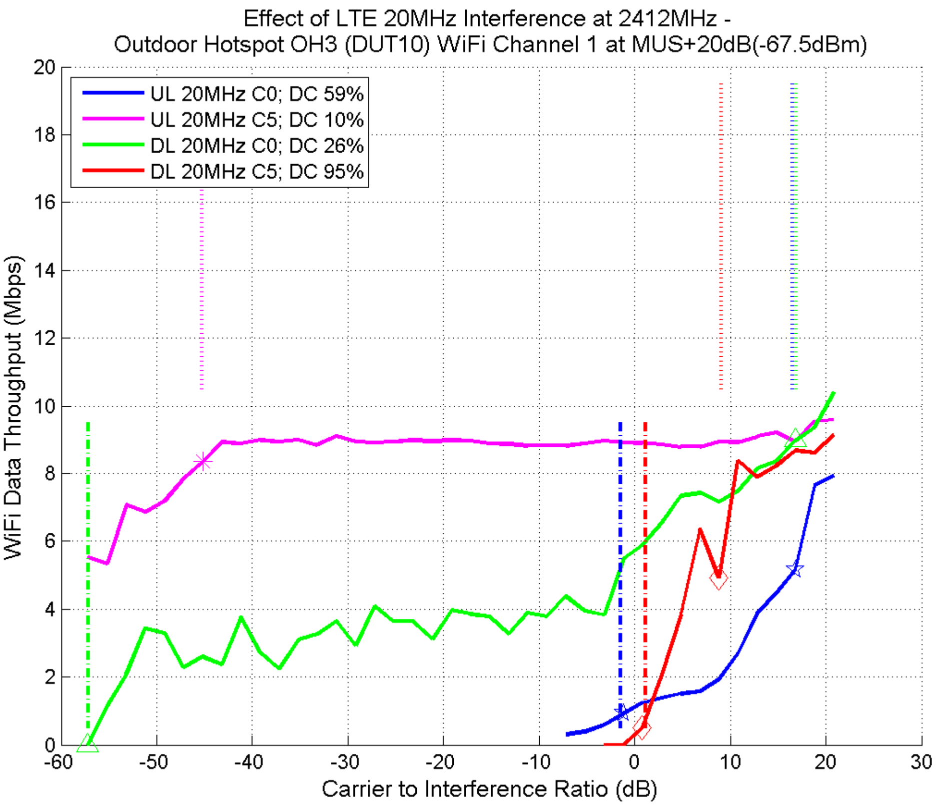

Figure 228

Observations

- Measured in horizontal position and vertically polarised in operation.
- In Figure 228 there is a marked increase in the throughout achieved at higher interference powers when the duty cycle is lower. This is similar to other DUTs in this report.

4.6.4 Outdoor Hotspot OH4 (DUT 11)

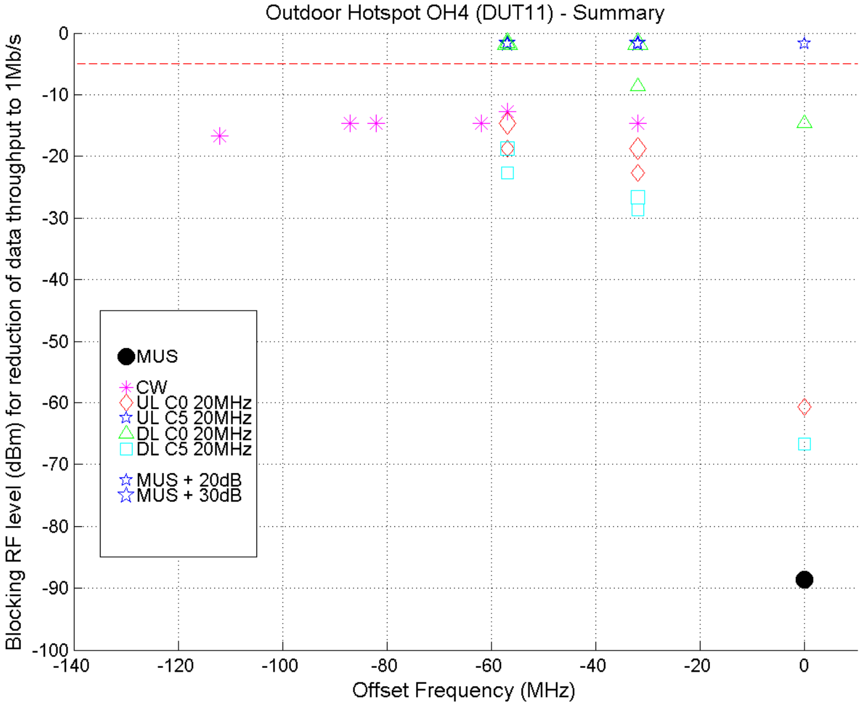

Figure 229

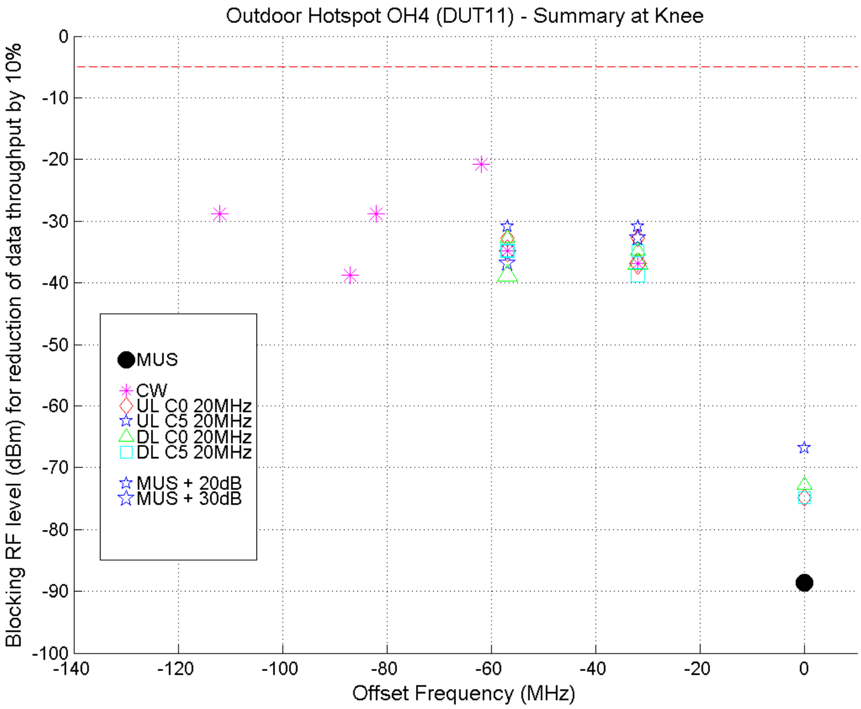

Figure 230

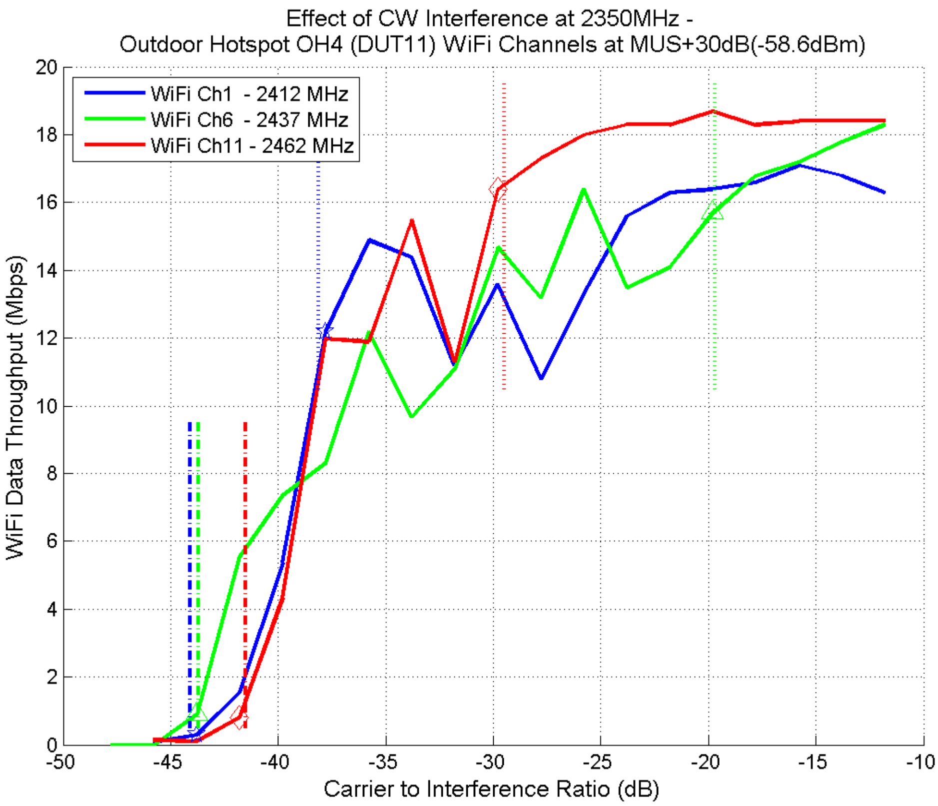

Figure 231

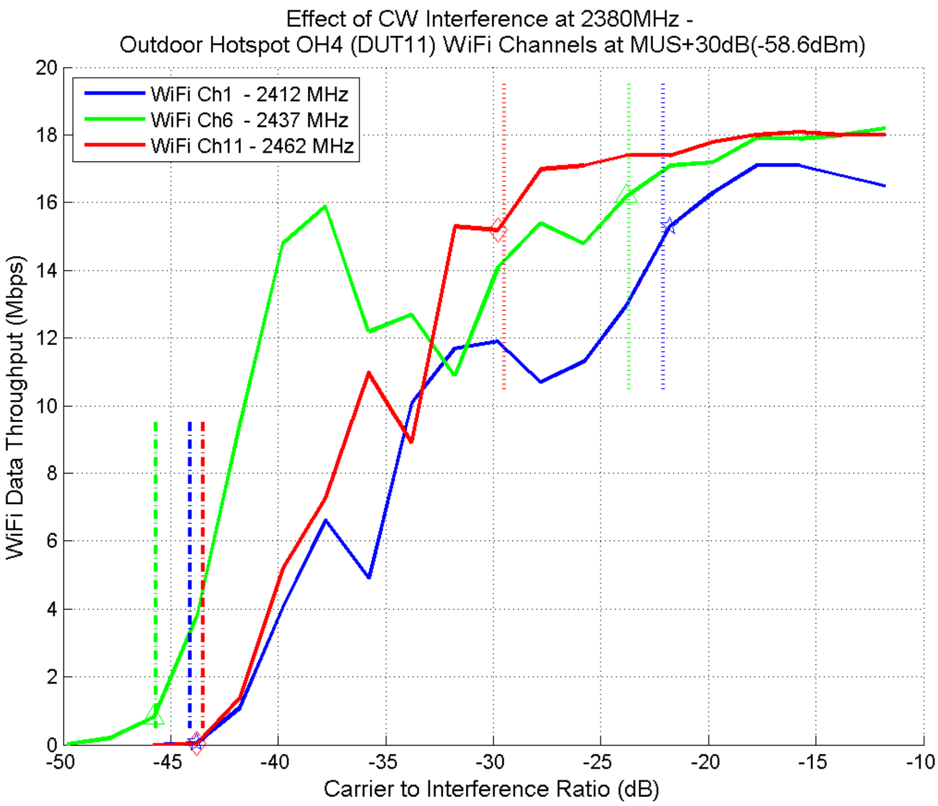

Figure 232

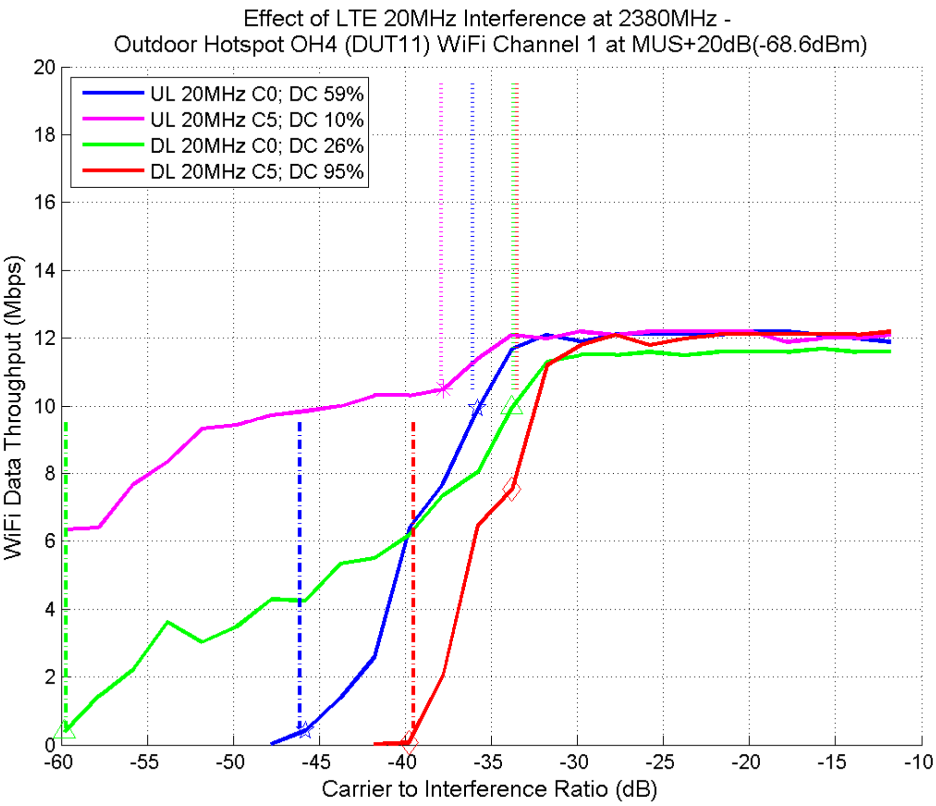

Figure 233

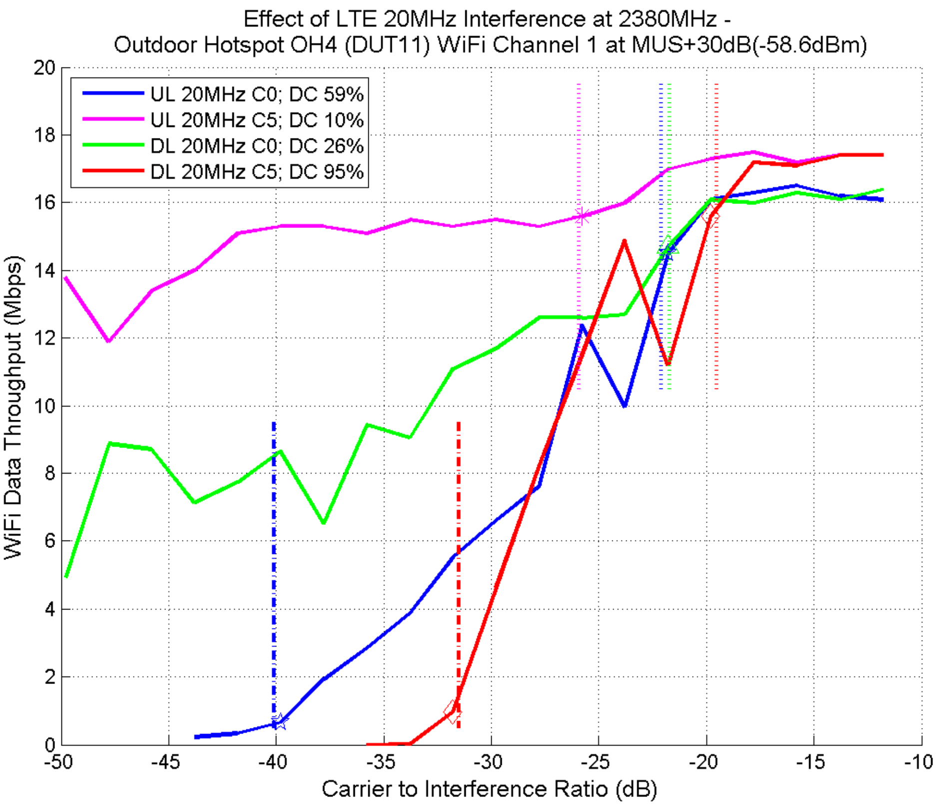

Figure 234

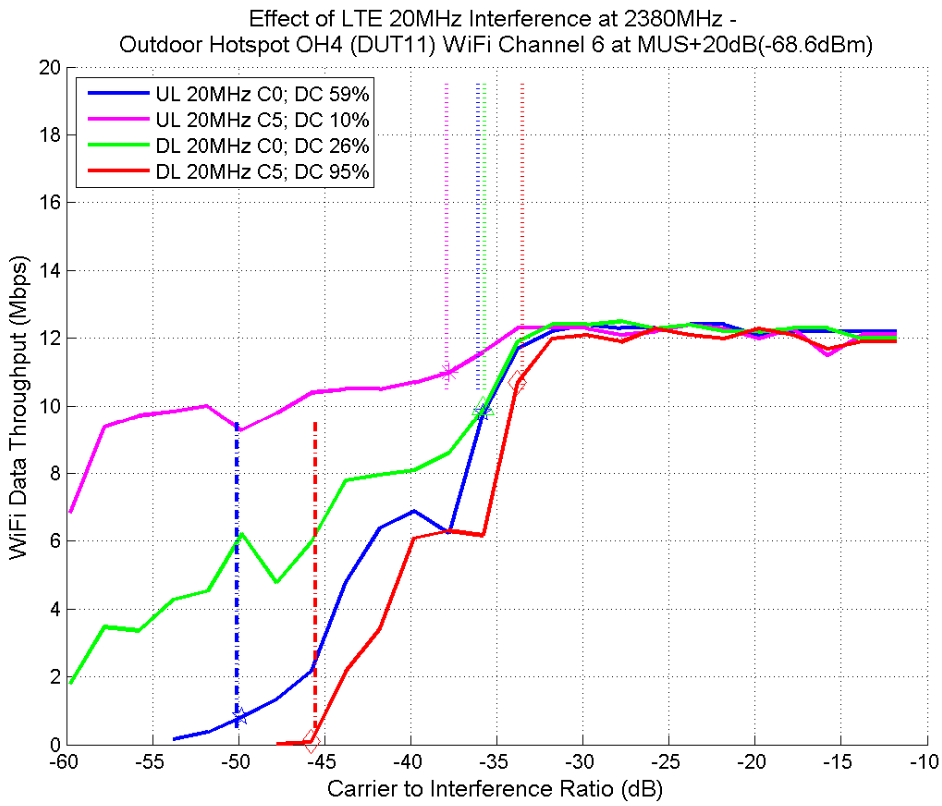

Figure 235

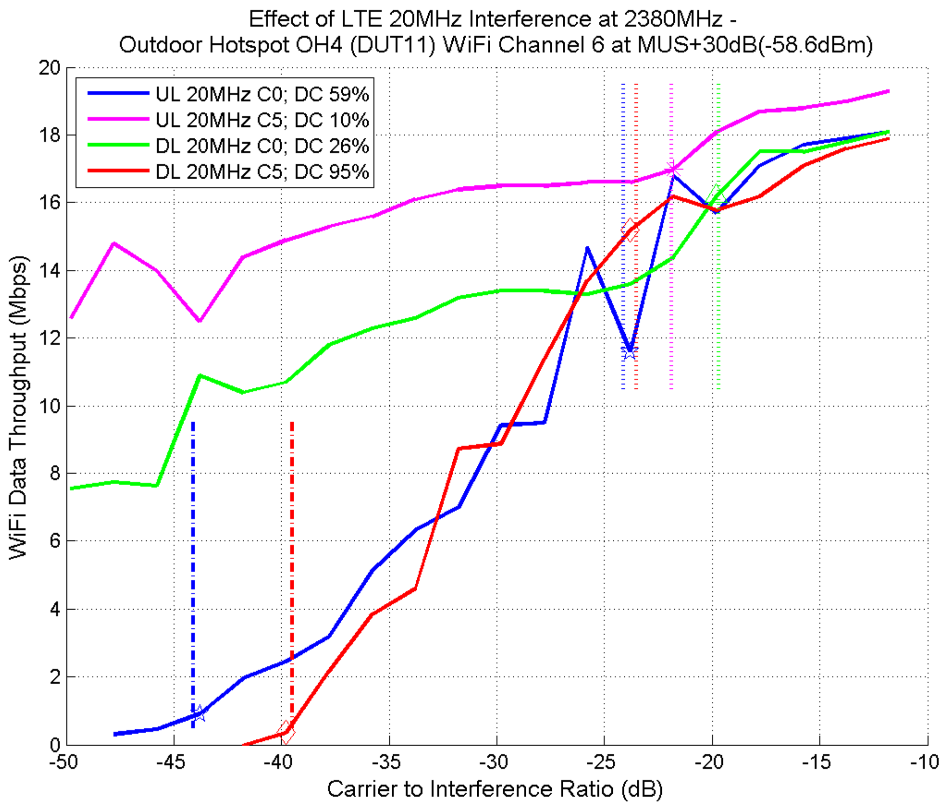

Figure 236

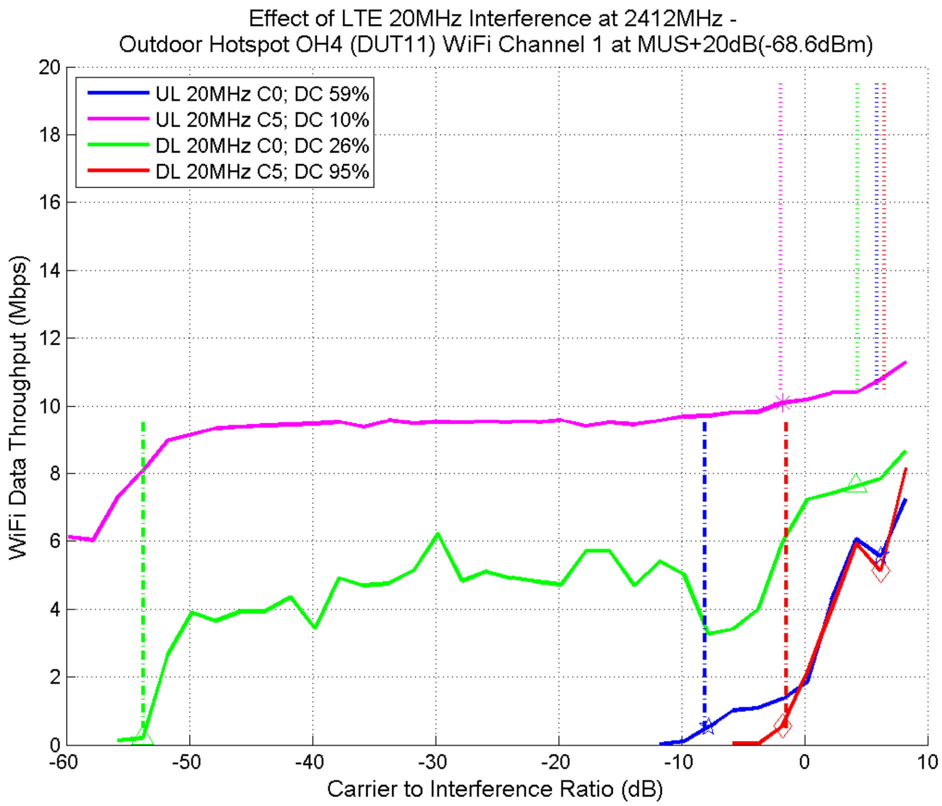

Figure 237

Observations

- Measured in horizontal position and vertically polarised in operation.
- In Figure 237 the DUT maintains high throughput for both 10% and 26% duty cycle interference when co-channel. This is similar to other DUTs in this report.

4.6.5 Outdoor Hotspot OH5 (DUT 13)

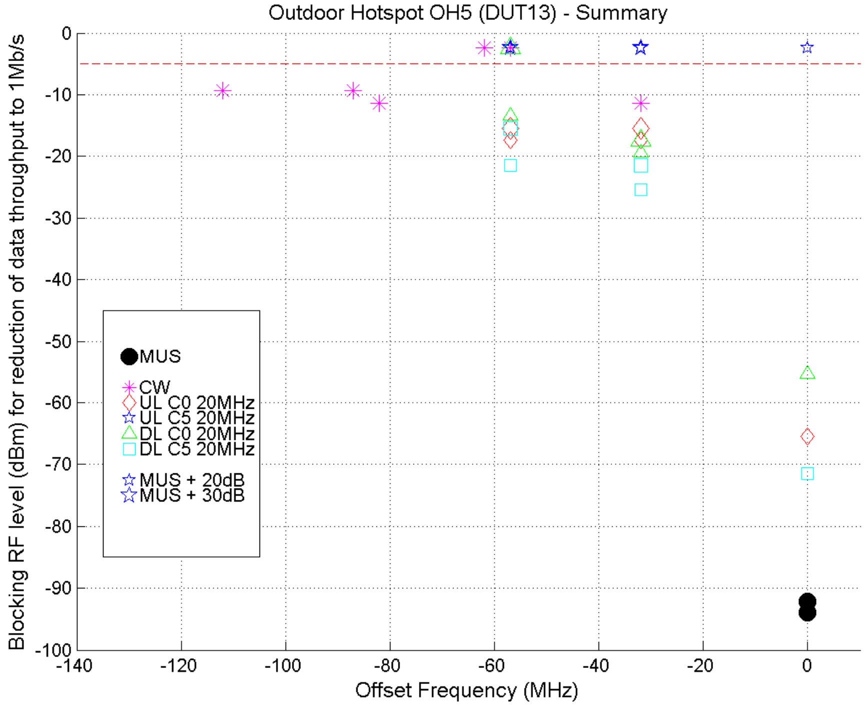

Figure 238

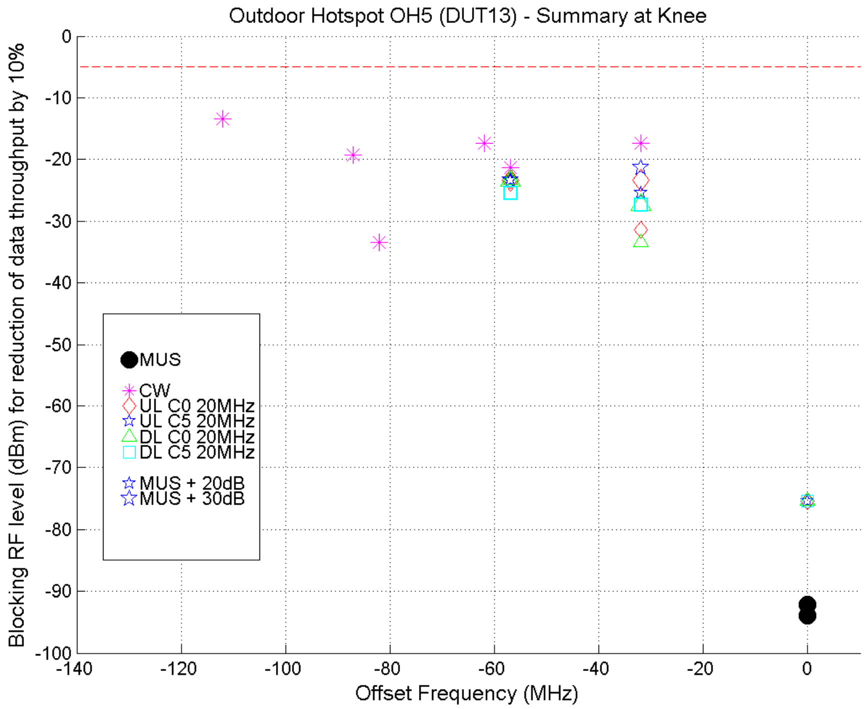

Figure 239

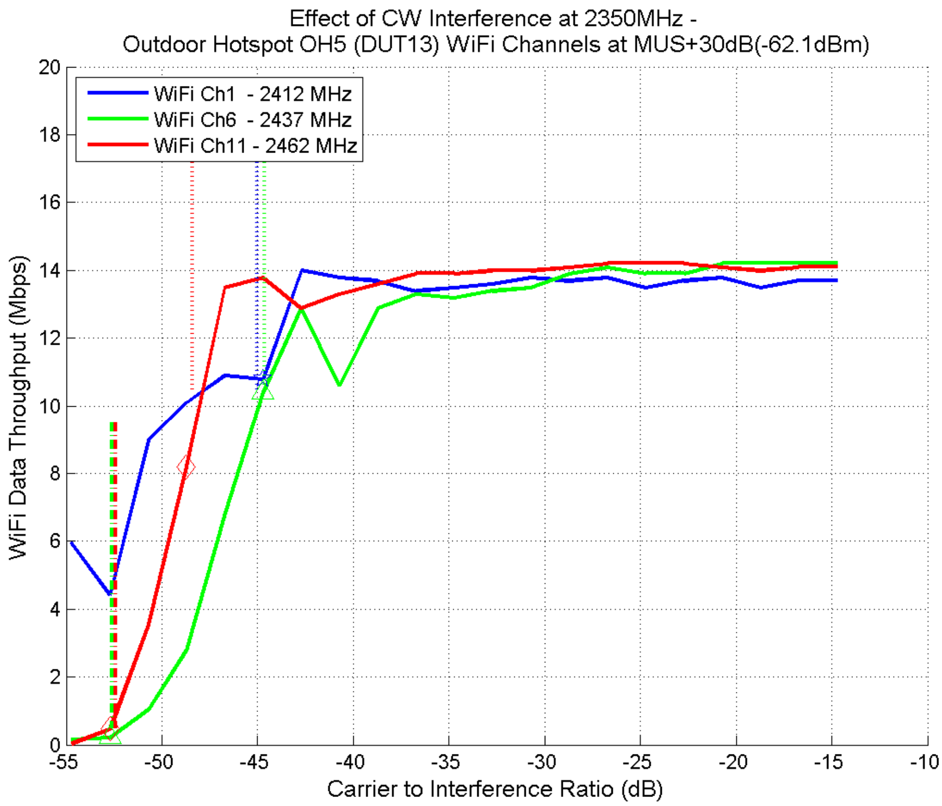

Figure 240

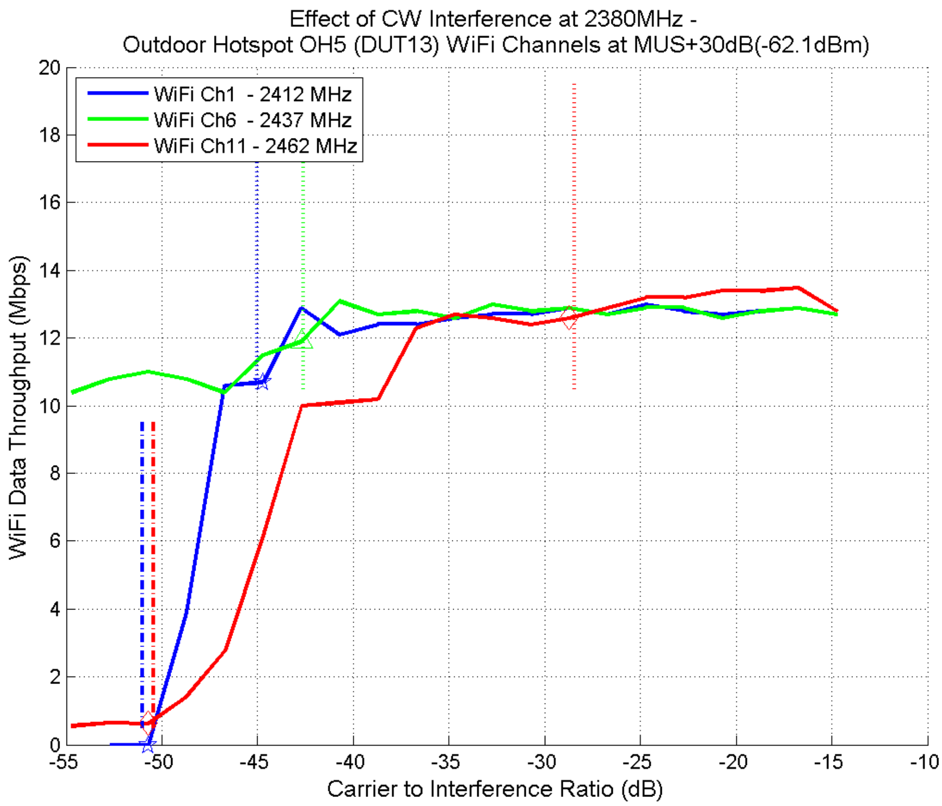

Figure 241

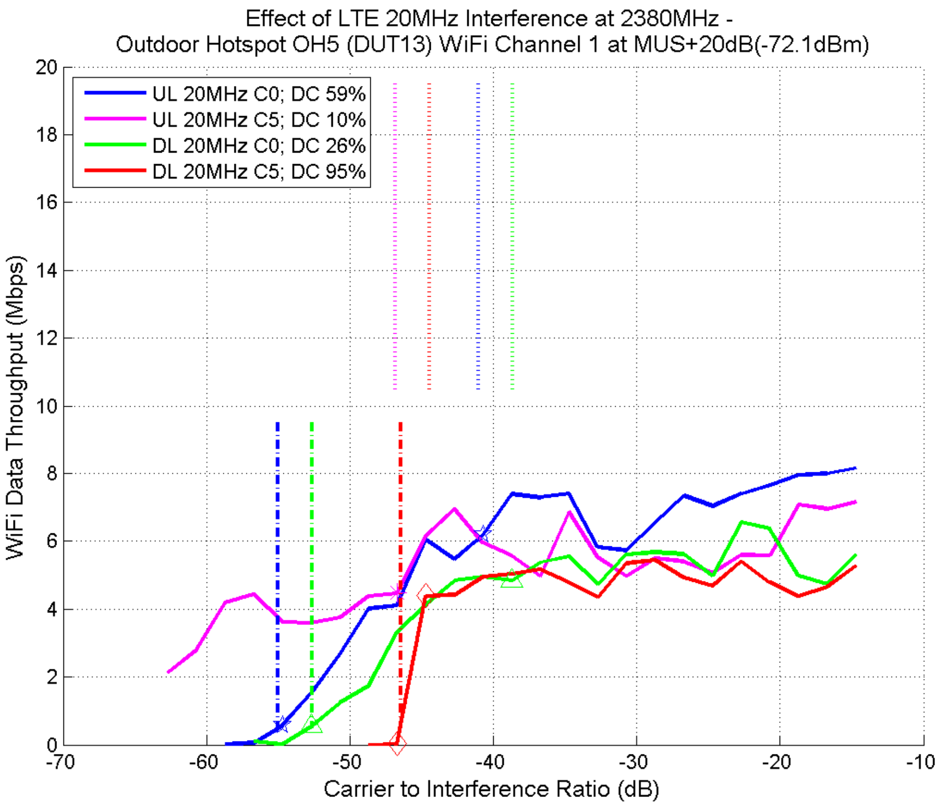

Figure 242

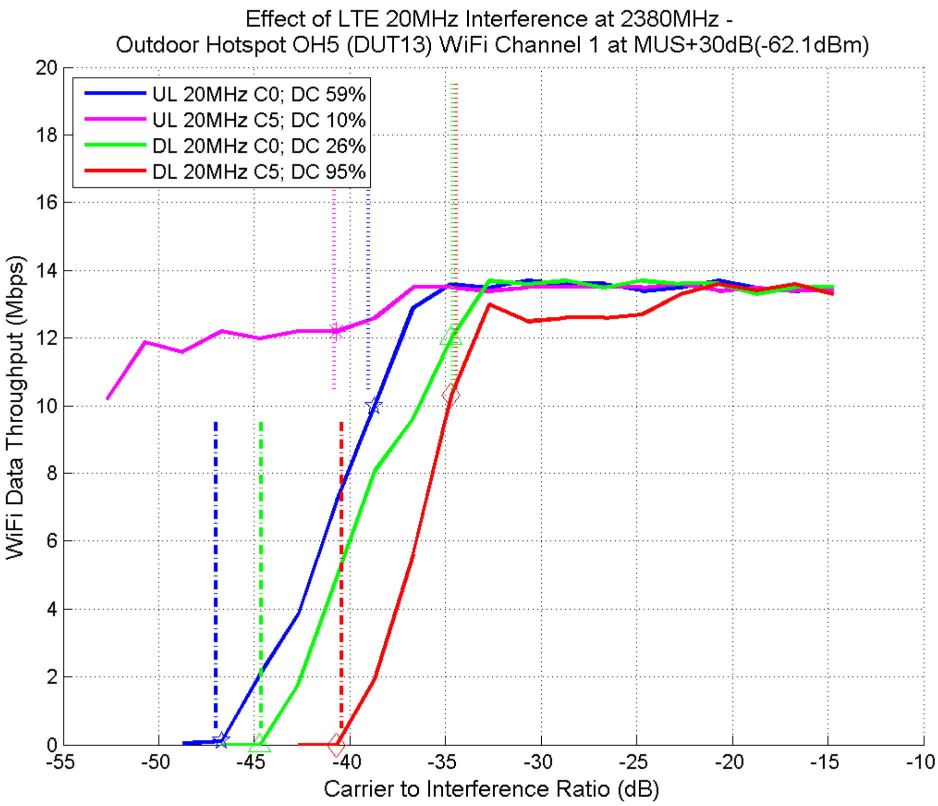

Figure 243

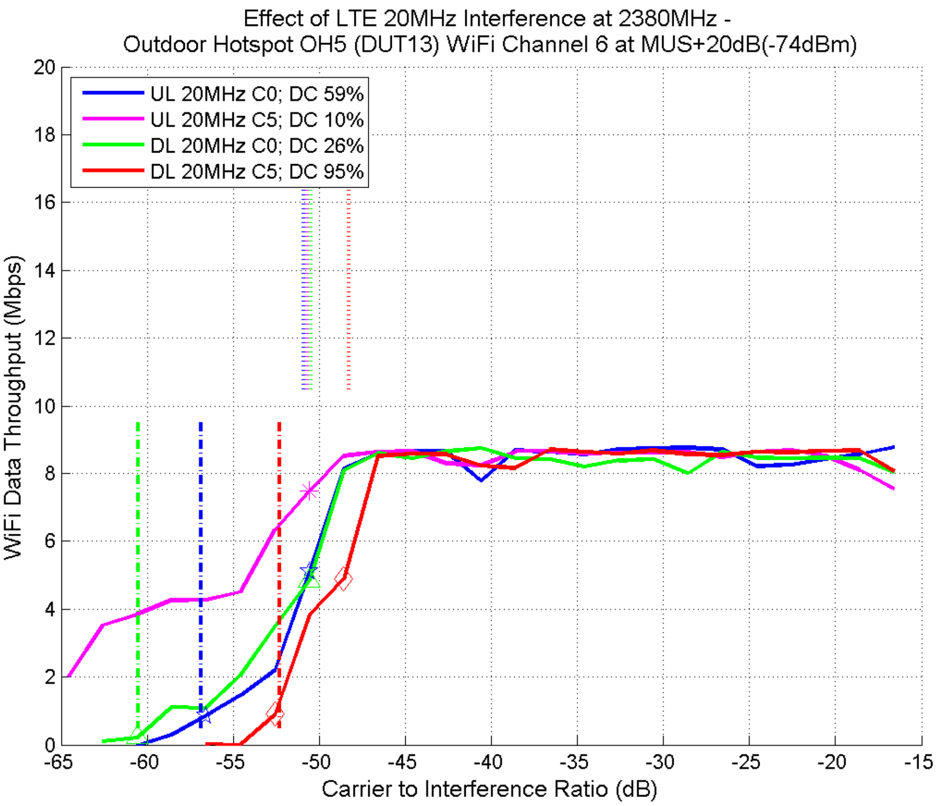

Figure 244

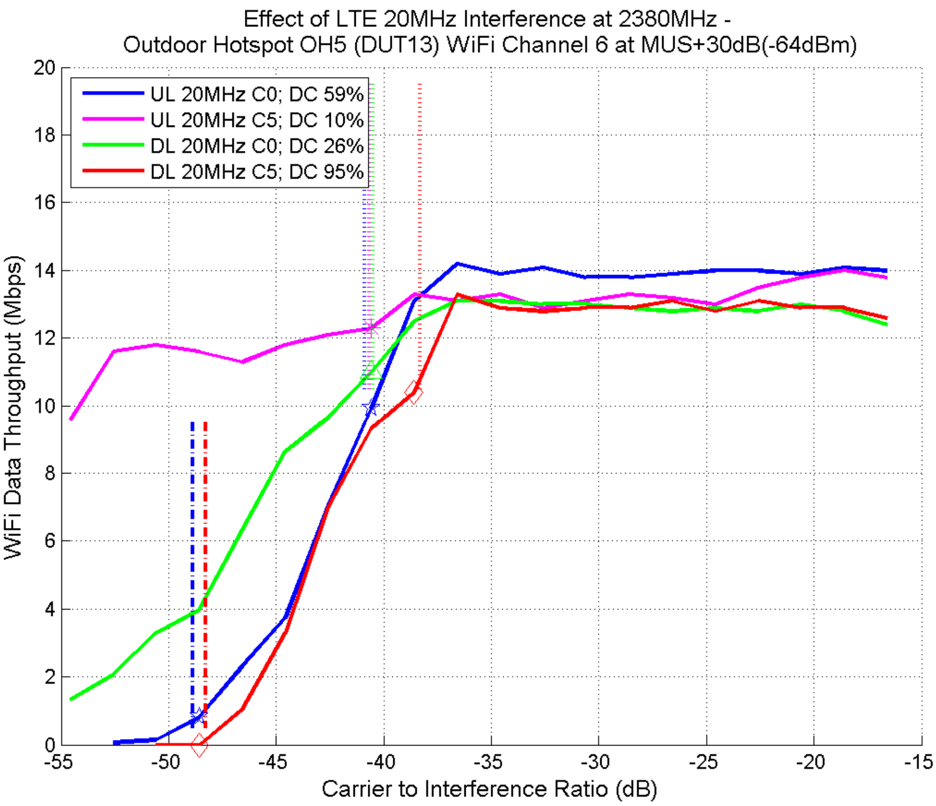

Figure 245

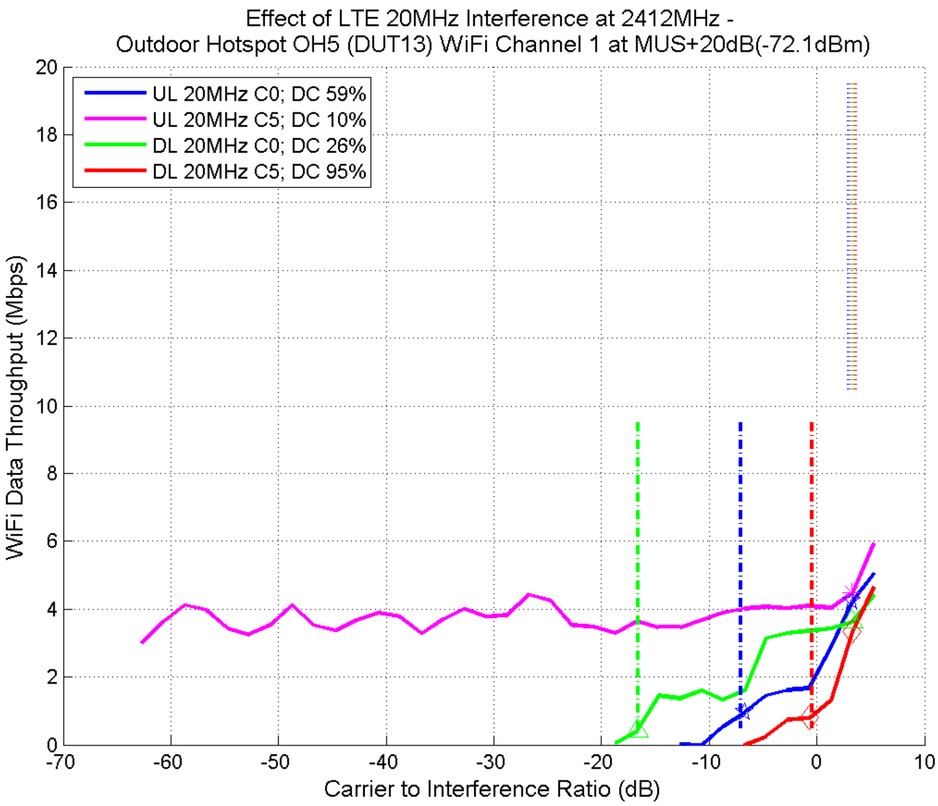

Figure 246

Observations

- Measured in horizontal position and vertically polarised in operation.
- Receiver sensitivity tests were conducted on both WiFi channel 1 and channel 6 which resulted in marginally different MUS values present in the summary plots.
- In Figure 246 the DUT maintains a relatively high throughput for 10% but not 26% duty cycle interference when co-channel.

5 ABBREVIATIONS

BS	Base Station
C/I	Carrier to Interference Ratio
CW	Continuous Wave
DC	Duty Cycle
DL	Down Link
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
HR	Home Router
LP	Laptop
LTE	Long Term Evolution
MD	Multimedia Dongle
MP	Mobile Phone
MUS	Minimum Usable Signal
OH	Outdoor Hotspot
OOB	Out of Band
TB	Tablet
TDD	Time Division Duplexing
UE	User Equipment
UL	Up Link

6 REFERENCES

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