Test Report: Adjacent Channel Interference from Higher Powered 700 MHz UE into Broadcast TV below 694 MHz

Addendum post Freeview Laboratory testing

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Summary

The results and investigations undertaken at the Freeview Laboratories in Lane Cove, Sydney are presented and conclusions reached. This report is a collaboration between Grant Willis (Telstra), David Lee (Telstra), David Searle (FreeTV), Stephen Farrugia (BAI), Steven Naumovski (BAI) and Jack He (Freeview Labs). Thanks go to everyone involved for making this possible.

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01 Introduction

Following the investigation undertaken by Telstra that led to the report titled “Adjacent Channel Interference from Higher Powered 700 MHz UE into Broadcast TV below 694 MHz”, it was agreed after discussions with representatives from the broadcasting industry to undertake some further experimental investigations to revisit some of the conclusions reached by Telstra. This was undertaken in December

2024 using the facilities of the broadcasting industry at the Freeview test laboratory in Lane Cove, Sydney.

1.1. Requested changes to the Registration Exemption Threshold

The mobile operators are seeking changes to the ACMA registration exemption limits currently defined in the 700 MHz spectrum licences.

Telstra is particularly seeking the ability to introduce high power UE equipment (Power Class 1) into the Australian market, specifically with a view to supporting improved cellular broadband access for the emergency services.

- This requires that the registration exemption limit be raised to 39dBm EIRP

In addition, Telstra is seeking to have the regulations normalised to address the current (uncontrollable) practice of network customers attaching gain antennas in both mobile and fixed scenarios to 700 MHz devices.

- This requires that the registration exemption limit as a minimum be raised to 37 dBm EIRP to support the fixed Yagi use cases.

The following chart shows the relative levels of each type of network usage.

Legend

- Existing ACMA Registration Exemption Limit (23 dBm EIRP)
- Minimum required extension to cover existing Power Class 3 device 3GPP operating range without external antennas (25 dBm EIRP)
- Antenna Gain addition on top of Power Class 1 and 3 UE TX Power
- Power Class 1 additional peak transmitter power (31 dBm +2 dB / -1 dB)

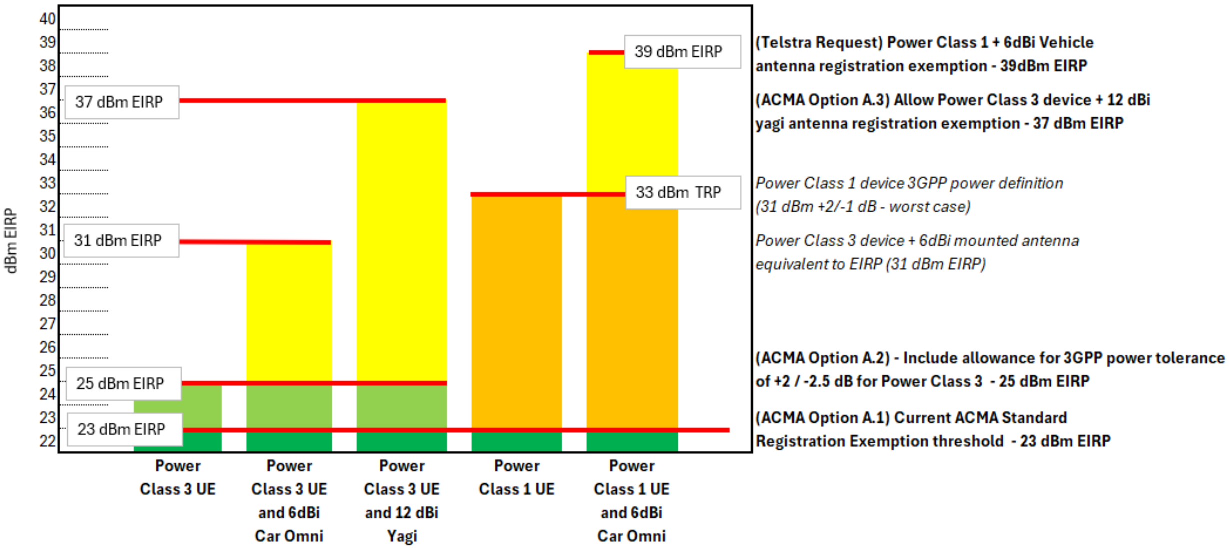

Figure 1 – Exemption requirements for different operating modes

The references to the ACMA Options relate to the 700 MHz band open ACMA consultation which opened December 19th 2024.

02 Matters under further investigation

It was agreed that clarity would be sought on what the dominant interference generation mechanism actually is (is it receiver blocking/selectivity or is it out of band emissions from the LTE-UE).

Telstra and the broadcasting industry representatives also agreed to investigate the following:

- Resolve the notable ~10dB discrepancy in receiver sensitivity reported by Telstra from the Surrey Hills laboratory testing conducted by Telstra and the testing the TV industry carried out in 2023 during a separate project where they sampled 33 different TV makes and models.
- Explore why such unintuitive protection ratio variations were found during Telstra's testing and how they compare to a wider selection of TV receivers. The broadcasters expected PR's to be fairly linear, except in the overload and threshold zones.
- Perform the testing with multiple TV signals simultaneously, as this is what TV receivers and retransmission child-sites are presented with in the real world. Naturally Ch's 49-51 are our main interest. Freeview's lab facility can produce these 3 signals simultaneously and test many TV's also at the same time.
- Revisit the impact of different LTE UE traffic behaviours on the severity of the noted interference

The broadcasters had raised the potential for generating multiple UE signals, with traffic on them to simulate the bursting nature of interference to TV signals. Unfortunately, the practicalities of developing a suitable test setup to support this were unable to be met with existing equipment.

Investigation with consumer TV Masthead amplifiers and filters were also to be revisited.

Finally, the nature of Power Class 1 devices and their emissions was something the broadcasters wished to understand better. Unfortunately, because of the inability to use PC1 in Australia on 3GPP Band 28 at this time (as a result of the ACMA regulations in place), we do not have the necessary network software development or UE terminal equipment developments available to be able to physically explore these characteristics in a meaningful way currently.

03 Outcomes

3.1. UE Emissions Investigations

3.1.1. Power Class 3 Device Spurious Emissions Measurements

A standalone emissions measurement was made of the LTE UE device being used in the test. The results obtained are below:

Figure 2 – OOBE Measurements of a UE device conducted at Freeview Labs

It shows that at 694 MHz, for a 10 MHz UE transmission in the lower LTE network channel that the OOBE/Spurious noise is -75dB down on the peak power of the main carrier as measured in 30kHz bandwidth.

Further work undertaken by Telstra in Surrey Hills has also produced the following plots of UE OOBE/spurious performance.

10 MHz Optus UE – Nighthawk M7 device

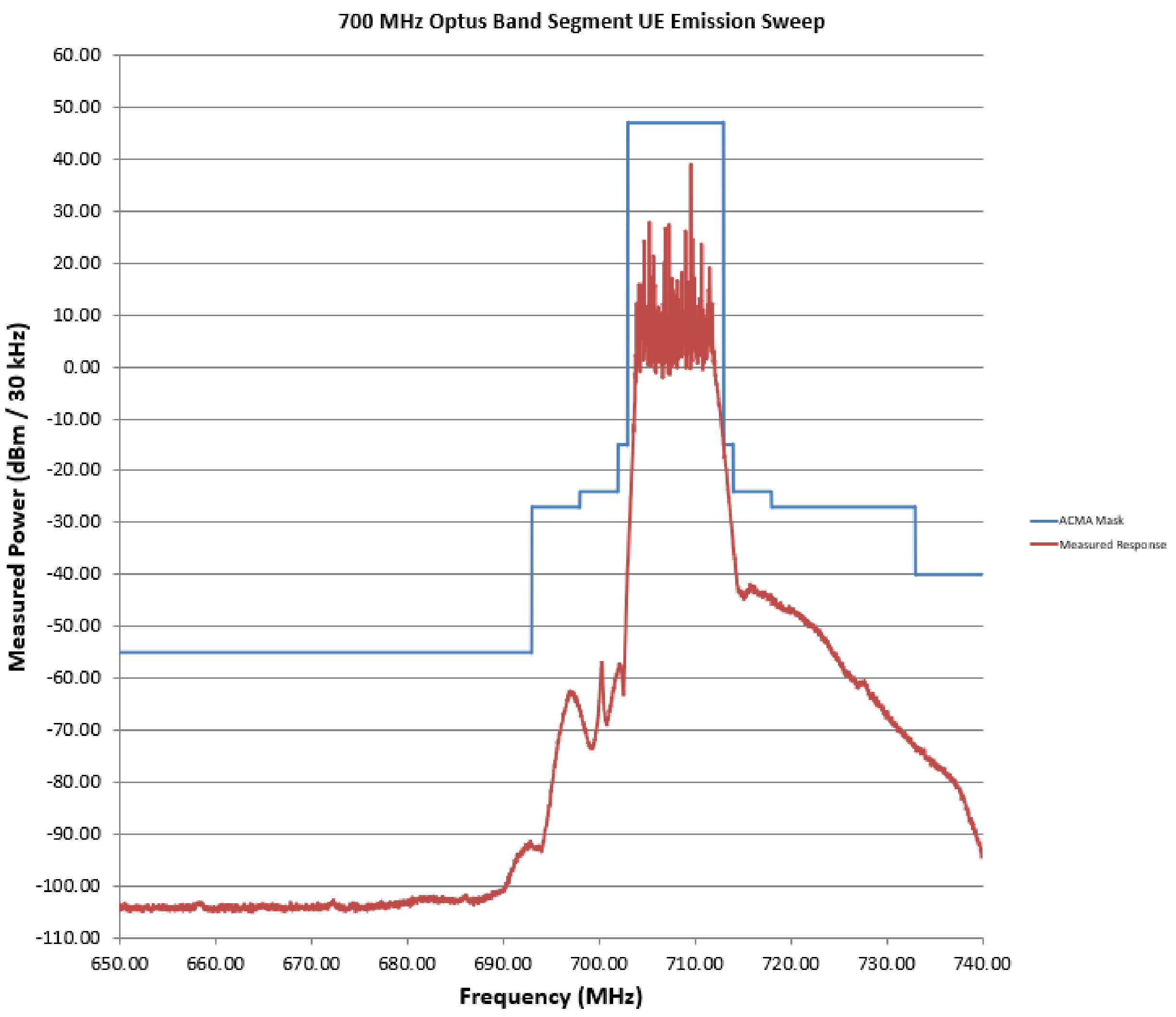

Figure 3 – OOBE Measurements of a UE device conducted at Telstra Labs

Note: The ripple in the passband between 693-700 is in part a product of the notch filter used to remove the fundamental carrier so as to reveal more of the spurious emissions below 694 MHz.

The outcomes of these observations will be discussed later in the report.

3.1.2. Extension to Power Class 1 UEs

It is noteworthy that the OOBE emission masks specified in 3GPP do not define any specific exemptions for Power Class 1, particularly relating to the requirements for OOBE below 694 MHz. It is understood that Power Class 1 devices, once they are manufactured for Band 28 LTE operation, will be required to meet the same OOBE emission limits as current Power Class 3 equipment.

3.2. TV Susceptibility Investigations

The TV susceptibility studies to be carried out aimed to extend the work Telstra did on determining the minimum tolerable LTE UE signal presented to a TV receiver before an impact was observed from the presence of the LTE UE device. The focus was on looking more closely at what happens in the TV receive signal range -75dBm to -85 dBm which had been discounted by Telstra initially due to the method for determining signal quality impact.

3.2.1. Test Setup

The test setup deployed in the laboratory for this round of testing included a sample of 11 TV receivers fed via a distribution network. This was fed with 3 concurrent TV signals – ch49, 50 and 51 combined together into one feed. The TV signal presented to the TV sets could be varied as could the UE signal.

Figure 4 – Sample test TV receivers

Figure 5 – 3 TV Transmitters on ch49/50/51

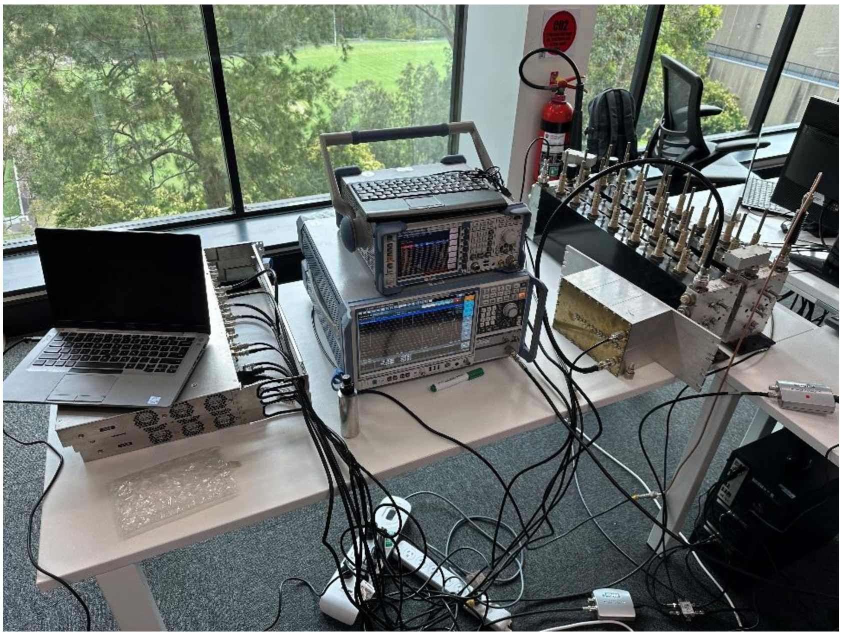

Figure 6 – TV Signal generation test setup

The 4G LTE UE Signal generation was achieved by setting up a 4G Router with an Optus SIM (to access the bottom 10 MHz of the 700 MHz band). The 4G router Tx signal was sampled using a directional coupler, followed by a circulator (to block the TV transmitter signals) and then a variable attenuator to control the level of the LTE signal presented to the TV receivers.

The LTE modem then had a separate attenuator placed in front of it to reduce the LTE network signal to the minimum, to force the UE to transmit with as few PRBs as possible and to do so at maximum signal strength. The LTE network signal behaviour was monitored using NEMO network analyser software.

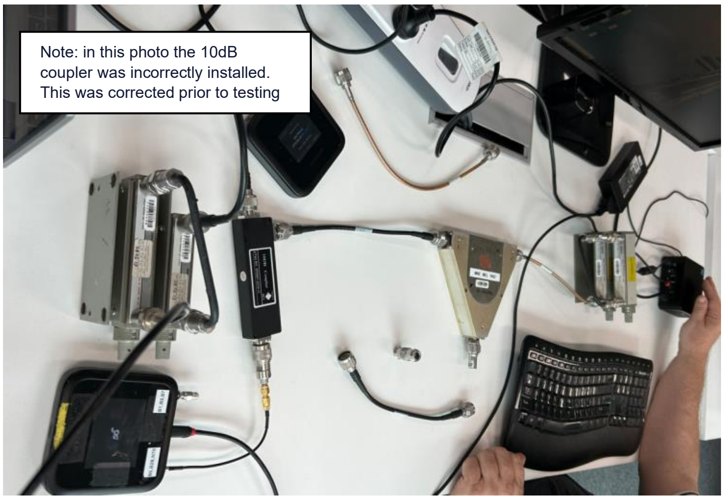

Figure 7 – LTE signal generation

Figure 8 – LTE Network Antenna

The LTE signal was then mixed with the TV transmitter signals using a 3dB coupler before being fed into a series of cascaded splitters to realise 12 common outputs.

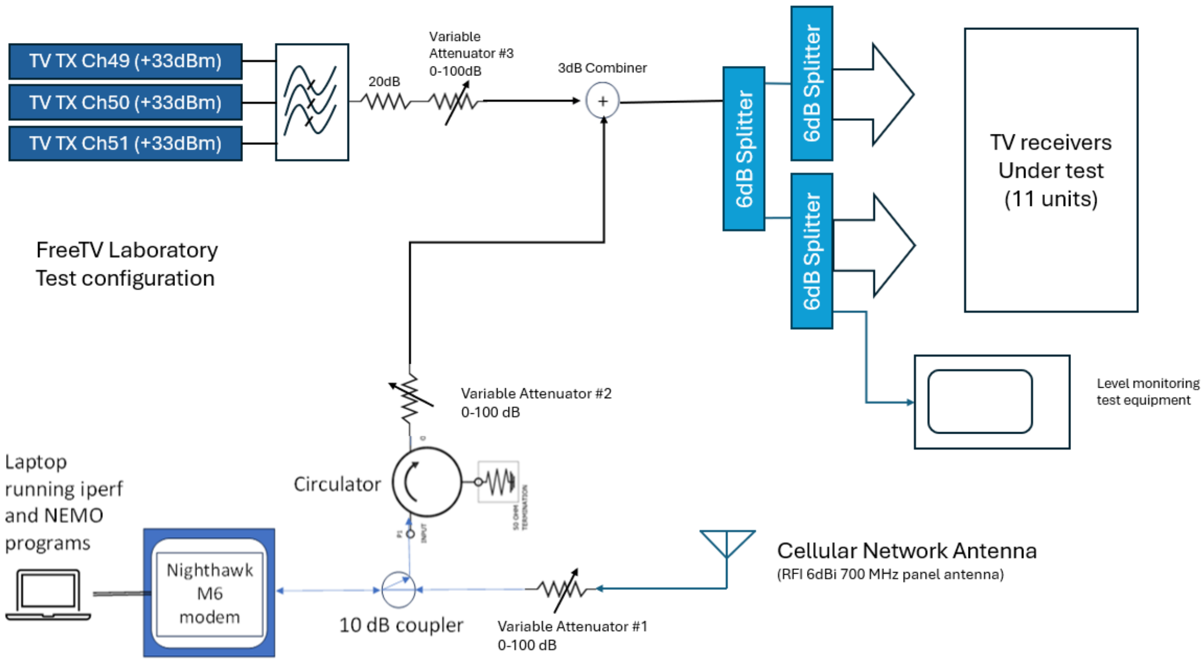

Figure 9 – Freeview Lab end to end test setup

3.2.2. TV Receiver Minimum "Impacted" signal results

The definition used by the broadcasters is that there is a noticeable image pixelation event occurring more than once in any given 30 second period, as per ITU-R BT.1368-13. This is a subjective measure where the sets are monitored by a panel of judges and when the panel agrees that the pixelation is occurring frequently enough the signal strength is recorded.

Freeview do not use the TV reported signal quality metric in these assessments.

The resulting range of receiver thresholds (dBm / 30 kHz) as determined during our joint laboratory testing were:

Minimum Discernible Signal for sample receivers (dBm)

Sample TV No	Ch51	Ch50	Ch49	90th Percentile MDS per set across channels 49-51
1	-86.3	-86.3	-85.7	-85.8
2	-85.3	-84.4	-82.6	-83.0
3	-85.3	-84.4	-84.1	-84.2
4	-86.3	-85.8	-85.7	-85.7
5	-85.8	-85.8	-85.7	-85.7
6	-85.8	-84.4	-84.8	-84.5
7	-85.8	-85.8	-85.7	-85.7
8	-86.9	-86.3	-85.7	-85.8
9	-85.8	-85.2	-85.4	-85.2
90%ile per channel	-85.3	-84.4	-82.6	

90th Percentile for all sets/all channels	-84.3

3.2.3. Impact of Fixed UE Power and decreasing TV Signal

3.2.3.1. TV Channel 49 Results

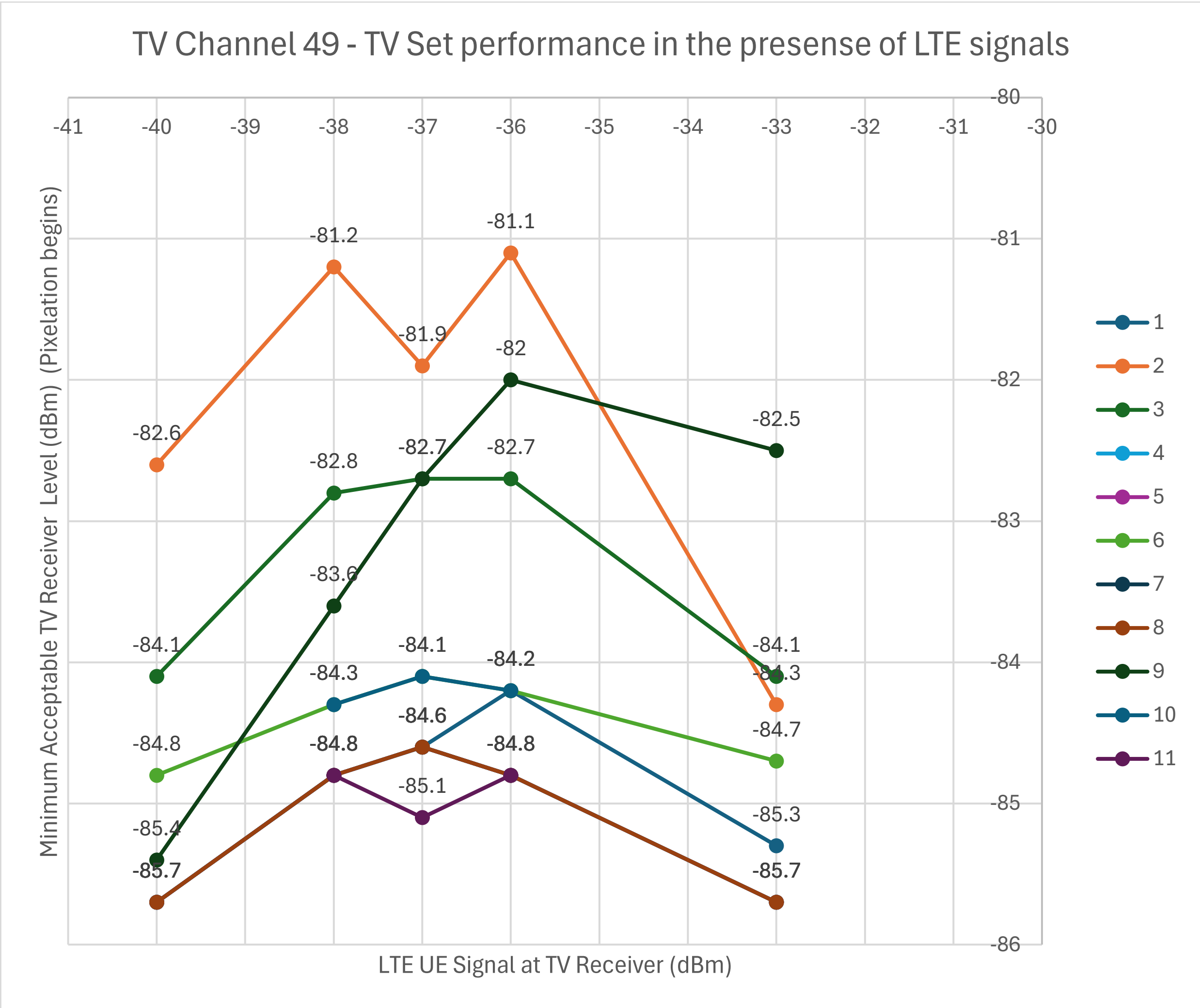

Figure 10 – Measured TV Reception performance for 11 different TV receivers on Channel 49

3.2.3.2. TV Channel 50 Results

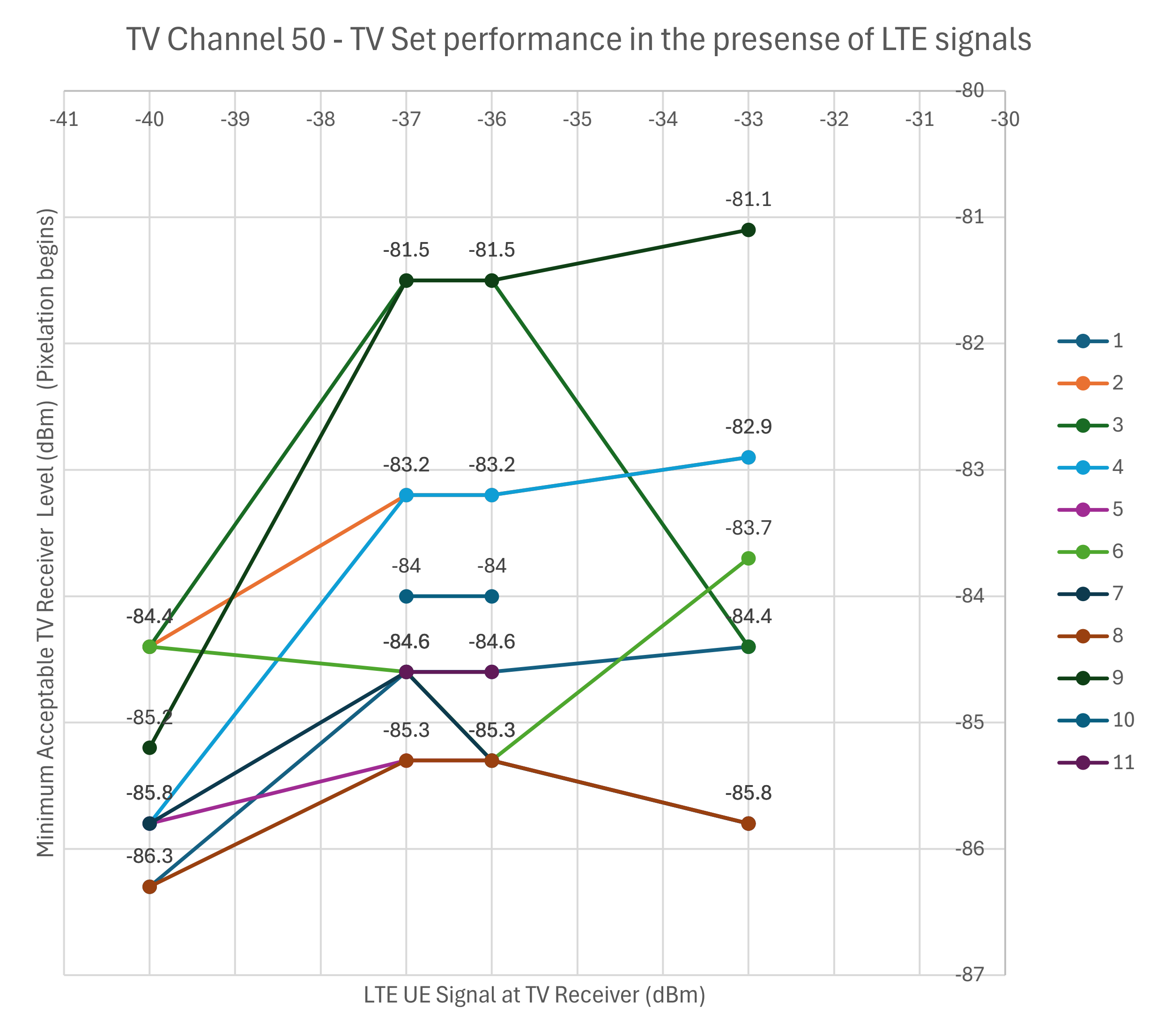

Figure 11 – Measured TV Reception performance for 11 different TV receivers on Channel 50

3.2.3.3. TV Channel 51 Results

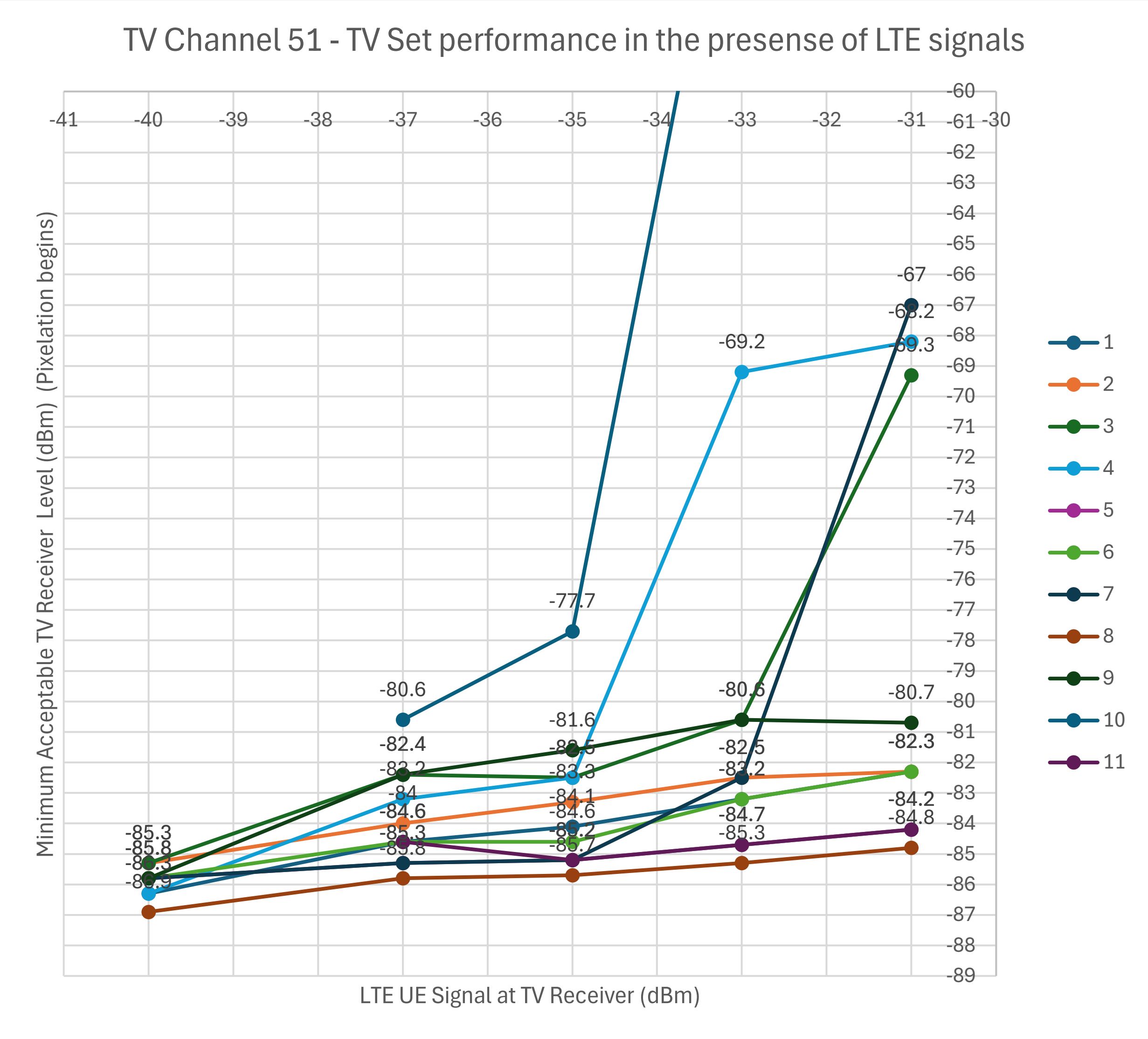

Figure 12 – Measured TV Reception performance for 11 different TV receivers on Channel 51

3.2.4. Impact of fixed TV Signal vs increasing UE power

Two tests were also conducted looking to explore what the upper limit of the UE signal could be before pixelation began.

3.2.4.1. Channel 50 Results

The first test on channel 50 was conducted with the TV receivers being supplied with a -81.5 dBm signal. This signal was determined based on the lowest signal achievable at the time of the test without any pixelation being observed on any of the active TV receivers and no LTE signal present.

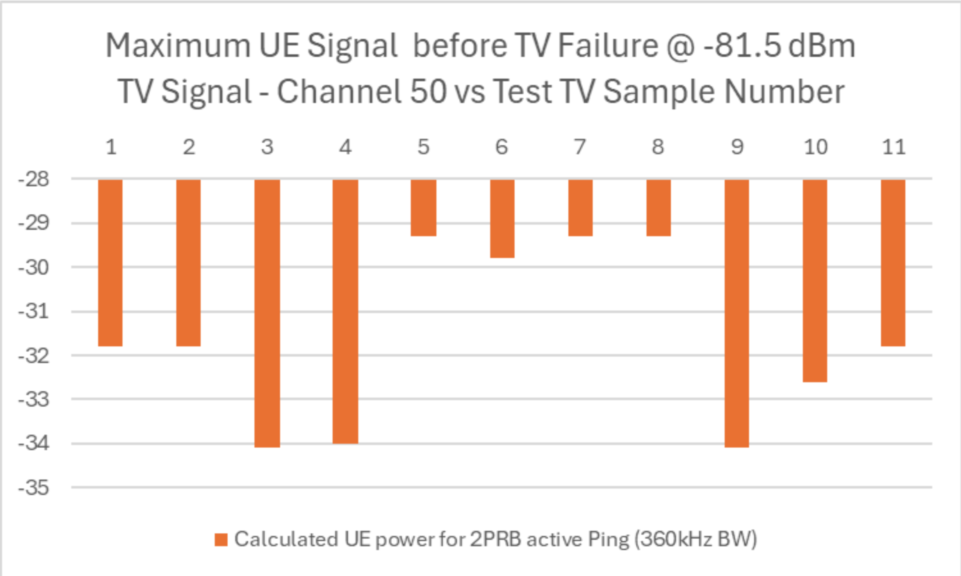

Figure 13 – UE TX power applied to a TV receiver that triggers reception failure – Channel 50

3.2.4.2. Channel 51 Results

The second test on channel 51 was conducted with the TV receivers being supplied with a -84.2 dBm signal. This signal was determined based on the lowest signal achievable at the time of the test without any pixelation being observed on any of the active TV receivers and no LTE signal present.

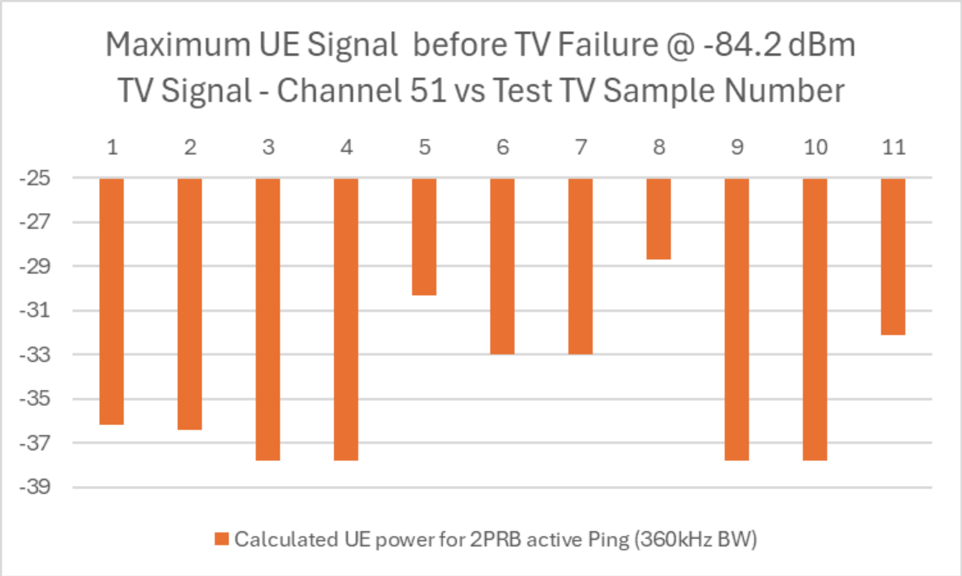

Figure 14 – UE TX power applied to a TV receiver that triggers reception failure – Channel 51

3.2.5. Impact of TV Low Noise Amplifier components

When the Freeview supplied mast head amplifier was added to the system, it was observed that the amplifier was not functioning correctly, and indeed its activation led to a minimum 10dB degradation of a TV sets ability to detect the picture, and when it did detect it, the measured MER performance of the TV signals was very poor.

The conclusion was that the sample amplifier was most likely faulty – which meant we were unable to conduct any testing with a mast head amplifier.

3.2.6. Impact of current TV LTE Filters on reception performance

An attempt was made to insert an LTE filter into the mix to see if that improved performance. While we observed the filter was reducing the amount of LTE signal being applied to the TV sets, and indeed the problematic set top box was finally able to receive a picture in the presence of the LTE signal, the measurements taken appear counter intuitive to the result observed.

Telstra feels therefore that given the inconclusive results obtained that no conclusion can be reached on this test. Our recommendation would be to conduct further testing, including sweeping the provided LTE filter.

04 Conclusions

4.1. UE OOBE Emissions

The UEs exceed the current requirements by quite a margin today. From these observations, we concluded in conjunction with Freeview representatives that OOBE was not the dominant impact to the quality of TV reception when in the presence of cellular user terminals.

4.2. TV Receiver Minimum "Impacted" signal results

Telstra had initially used a conservative approach of determining the failure point of a TV receiver which involved determining where the signal quality as reported by the TV receiver fell below 100%.

Having reviewed the process used for assessment by Freeview, the Telstra results have now been reassessed (ignoring the quality % indicator). The measurements made by Telstra did indeed extend down to levels approximating ~ -83dBm to -84 dBm (per 30kHz) which is like the results in the Freeview lab, however what was not recorded was what the Rx on screen quality was like at those levels for the TV receivers under test in the Telstra lab as a comparison against the Freeview method.

Telstra is happy to agree with the Freeview lab findings that show the TV receiver sensitivity is capable of lower levels than reported initially by Telstra given the revised understanding of the benchmarks to be used.

4.3. Traffic type impact validation

With the test setup, we used two traffic types.

- First, we used a sustained high throughput data transfer. This allowed the UE to achieve full power, however the energy was spread over a much wider bandwidth as more uplink PRBs were allocated to the UE.

- Second, we used a 512-byte ping once a second operating with minimal active PRBs on the LTE signal (i.e. the UE operating near cell edge). This typically meant that we were operating with only 2 PRBs on air with the full 23dBm of UE power applied to those bearers (i.e. power concentrated in <360 kHz of a 10 MHz channel). These transmissions presented a bursty traffic environment to the TV receivers

The outcome is that the TV receivers were observed to be more susceptible to the ping. This was therefore the data mode selected for the rest of the tests.

4.4. Highest acceptable LTE UE signal for error free TV reception

The Freeview lab testing sought to repeat the measurements made by Telstra that determined what the highest acceptable level of LTE UE signal injected into a TV receiver could be before an impact could be observed.

Having repeated the minimum signal strength assessments with no LTE interference, the team then proceeded to introduce LTE interference at Telstra's maximum proposed level of -33dBm to determine if that impacted the minimum signal able to be decoded by the television receivers. This was conducted using 3 parallel TV transmitters operating on channel 49 – 51.

4.4.1. Impact to Channel 49

Negligible impact observed to reception of channel 49 with an LTE interferer arriving at -33dBm at the TV set terminals.

LTE signal tested against Ch 49 TV reception	Maximum= -33dBm	1-3 dB impact on minimum receiver threshold observed with LTE signal present

4.4.2. Impact to Channel 50

Negligible impact observed to reception of channel 50 with an LTE interferer arriving at -33dBm at the TV set terminals

LTE signal tested against Ch 49 TV reception	Maximum= -33dBm	1-3 dB impact on minimum receiver threshold observed with LTE signal present

Some receivers would start presenting errors above -33 dBm while others would operate with LTE signals up to -30dBm at their input terminals without impact.

4.4.3. Impact to Channel 51

The impact to Channel 51 depended on the model of TV receiver. Four of the eleven TV receivers tested had adverse reactions to LTE test signals that were equal or higher than -33 dBm at the TV receiver terminals.

If the signals applied were reduced to -35 dBm, only 1-3dB of impact was observed against the base minimum discernible signal measured at the start of the tests.

This would support a case for setting -35dBm as the receive benchmark level for determining what a suitable revision to the 700 MHz registration exemption limits should be for the cellular network operators.

Maximum suggested LTE signal before impacts to TV reception noted for Channel 51	-35dBm

This is a recognition that given the lower receive signal capabilities demonstrated in the Freeview lab that some additional protection is required to ensure minimise any impact for TV Channel 51 reception.

05 Document control sheet

Who to reach out to if you have any queries, questions, changes or concerns.

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If you have a suggestion for improving this document, please contact the person listed above.

Issue number	Issue date	Details on the change