Information & Communication Technologies Authority

Consultation Ref: ICTA/01/18

CONSULTATION PAPER ON THE OPENING OF 700 MHz AND 800 MHz BANDS FOR IMT-ADVANCED

18 June 2018

Explanatory memorandum

Considering that:

1) the ICT Authority has as one of its functions, under section 18(*p*) of the Information and Communication Technologies Act 2001, to *"allocate frequencies and manage, review, and, where appropriate, reorganise the frequency spectrum"*;
2) the ICT Authority has as one of its objects, under section 16(*g*) of the Information and Communication Technologies Act 2001, to "*further the advancement of technology, research and development relating to information and communication technologies through modern and effective infrastructure taking into account the convergence of information technology, media, telecommunications, and consumer electronics*";
3) The Authority has received expressions of interest to operate International Mobile Telecommunications (IMT-Advanced) systems in the frequency band 694 – 790 MHz and 790 – 862 MHz ("the frequency bands of interest");
4) The 694 – 790 MHz band is under the National Spectrum Allocation Plan allocated to the BROADCASTNG service, whereas the 790 – 862 MHz band is allocated to the MOBILE service on a primary basis;

The Information and Communication Technologies Authority resolves to:

1) make available for public consultation the Consultation Document Ref: ICTA/01/18;
2) invite views, contributions, and comments on the Consultation Document.

GUIDELINES ON RESPONDING TO THIS CONSULTATION

G.1 All comments are welcomed; however it would make the task of analyzing responses easier if comments were referenced to the relevant question numbers from this document. The questions are listed together at ANNEX A.

G.2 You are invited to send your written views and comments on the issues raised in this document to the **Executive Director, ICT Authority, 12th Floor The Celicourt, Celicourt Antelme Street, Port Louis**, or by email to icta@intnet.mu, at latest by 16h00 on 20 July 2018.

G.3 Should you be including confidential information as part of your responses, you are requested to clearly identify the said confidential materials and to place same in a separate annex to your response.

1.0 Introduction

The World Radiocommunication Conferences held in 2007 (WRC-07) and in 2012 (WRC-12), allocated the upper part of the UHF band, namely 790-862 MHz, commonly known as the 800MHz band to the Mobile Service in Region 1. WRC-15 allocated an additional 96 MHz between 694 MHz and 790 MHz, commonly known as the 700MHz band, to the Mobile Service in Region 1 with a view to enhancing mobile broadband capacity. These frequency bands are also referred to as the first and second digital dividend bands respectively.

The digital dividend is the result of the digital compression techniques that are used nowadays for digital television. These compression techniques allow the transmission of several (up to six, depending on the coding and modulation scheme used) standard television channels of acceptable quality in the radio-frequency spectrum previously used by single analogue channels[1].

The frequencies liberated by the broadcasting service possess superior signal propagation characteristics as compared to those located above 1 GHz. These frequencies are particularly well suited for mobile applications as they provide cost-effective coverage solutions and excellent in-building propagation.

The compatibility between the Mobile Service, in particular based on Long Term Evolution (LTE), and broadcasting receivers operating in the 470 – 862 MHz band has been studied extensively since the WRC-07 decision. A number of reports at the level of CEPT, ITU and national regulatory authorities have been published to that effect. Today, according to a report published in April 2018 by the Global mobile Suppliers Association (GSA), the 800 MHz band is the second most popular band after the 1800 MHz band for the deployment of LTE[2] with 175 commercial networks deployed in 79 countries. According to the same report, the 700 MHz band is listed as the fourth most popular band among mobile operators.

The aim of this consultation document is to present the current situation in Mauritius and assess the readiness of both the 700 MHz and 800 MHz bands for assignment to Public Land Mobile Network (PLMN) Licensees. This document assesses the conditions for coexistence of the Mobile Service and the adjacent Broadcasting Service within the Mauritian context. The findings made on the basis of a compatibility study made specially for Mauritius is presented together with its limitations at Annex B. From these findings, it is clear that the effect of the Mobile Service on digital broadcasting reception is highly dependent on the technical characteristics of receivers deployed, the use of distribution amplifiers (boosters) and the DTTB received signal levels within the Mauritian territory. Moreover, it is noted that in Mauritius, the installation of television reception systems may not always be done by a professional. As such, the height of the receiving antennas, the type of antennas used, the antenna pointing as

[1] http://www.itu.int/net/itunews/issues/2010/01/27.aspx
[2] GSA, Spectrum for LTE-Snapshot, April 2018

well as the cabling installation may all contribute to the interference which a televiewer may experience due to the coming into operation of an LTE base station in the vicinity of his dwelling.

This paper further considers the different mitigation techniques that may be applied in order to cater for interference caused by an LTE network on digital television reception. These mitigation techniques include the use of filters within the television receive chain, as well as the use of base station filters and reduced transmitter power. This paper also reports on the risk of interference between the Mobile Service using LTE and wireless microphones and other Short Range Devices.

Finally, the paper proposes options and their associated conditions for cost effective approach to the opening of the frequency bands for Mobile Services.

2.0 The DTTB Plan and Digital Dividend for Mauritius

The analogue switch off in Mauritius took place on 17 June 2015, in line with the commitment taken at the Regional Radio-communication Conference 2006 (RRC-06). At the time of the switch-off, the DTTB plan had already catered for the first digital dividend band.

Following the WRC-15 decision to allocate the 694 – 790 MHz band to the Mobile Service, the Authority engaged into coordination meetings with the French Administration in order to reach agreement on a new DTTB plan for both Mauritius and Reunion Island. An agreement to that effect was signed in October 2017.

In accordance with the said plan, all television broadcasting stations have to operate in accordance with the new plan at latest by 30 June 2019. Hence as from that date, television broadcasting in Mauritius will operate only within the 470 – 694 MHz band. Consequently, the 694 – 862 MHz band will be fully allocated to the Mobile Service. Figures 1 and 2 below show how the spectral occupancy of the 700 MHz and 800 MHz bands will evolve after 30 June 2019 from the current situation. Figure 3 shows the LTE800 and LTE700 band plans with respect to the spectral occupancy after 30 June 2019.

In order to facilitate the introduction of LTE in the said frequency bands, the Studio to Transmitter Links, which are currently in operation, will have to be migrated to the Broadcasting band between 470 – 694 MHz. Furthermore the CDMA2000 network which, according to the understanding of the ICTA has a declining customer base, will be required to be switched off. The CDMA2000 customers would then be migrated to similar services rendered through other technologies operating in other frequency bands assigned to the operator.

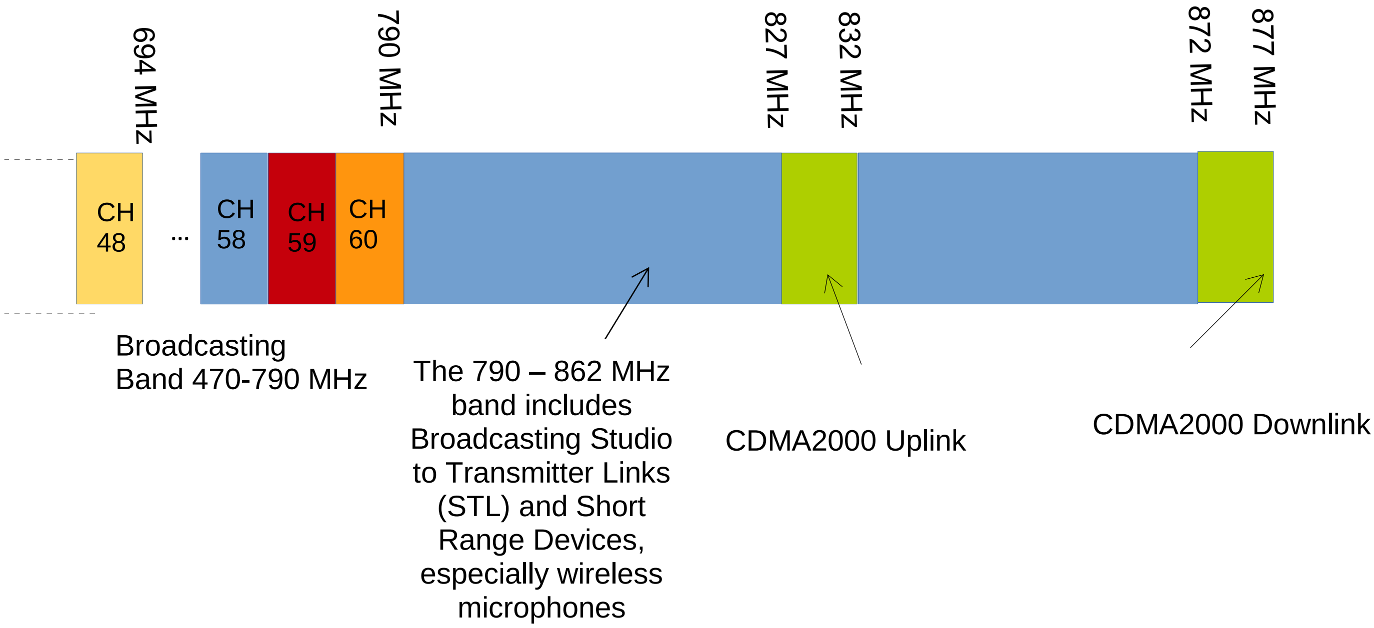


Figure 1: Current 700 MHz and 800 MHz Spectral Occupancy

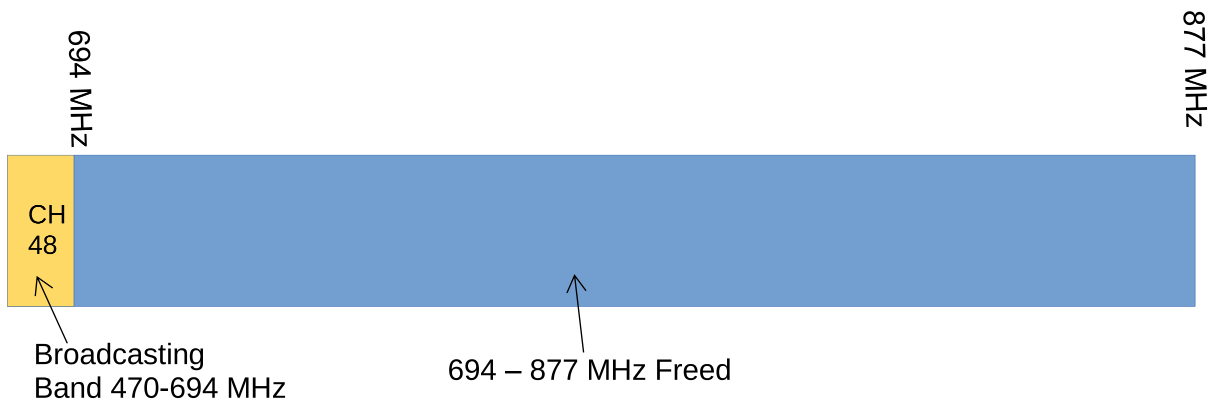


Figure 2: 700 MHz and 800 MHz Spectral Occupancy after 30 June 2019

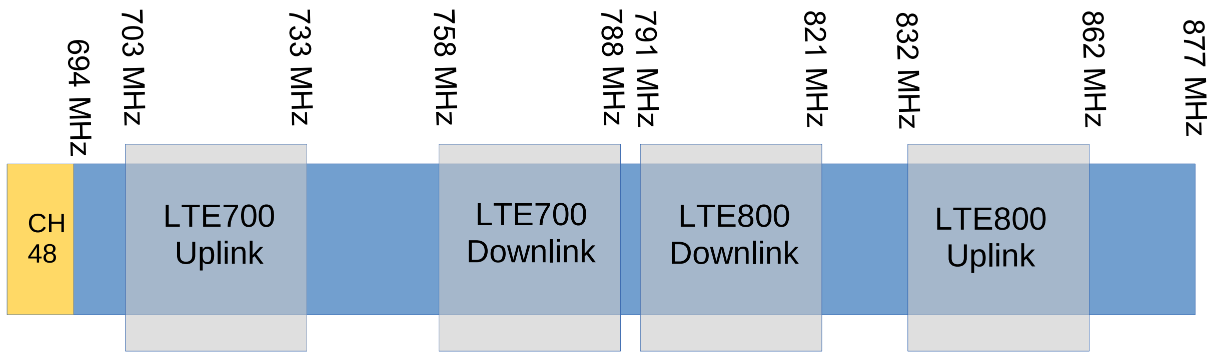


Figure 3: 700 MHz and 800 MHz Band Plans

3.0 Co-Existence Issues for Mobile Services in the 700 MHz and 800 MHz bands

The operation of Mobile Services under the PLMN Licence in the 700 and 800 MHz bands are subject to two main co-existence issues. Firstly with the adjacent terrestrial broadcasting services and secondly with Short Range Devices (SRD), including wireless microphones which have traditionally been operating in the broadcasting band between 470 MHz and 862 MHz and also in the 863-865 MHz band.

3.1 Co-Existence issues with DTTB Installations

Two options are being considered in this consultation paper, namely option 1: opening of the 800 MHz band in the first phase and 700 MHz band in the second phase which may only be after 30 June 2019 and option 2: opening both bands at the same time after 30 June 2019. These options which will be considered in turn have been formulated on the basis of the coexistence study carried out by the ICTA and which is included for reference at Annex B. Option 1 will be presented as two sub-options, namely option 1a and option 1b.

The opening the 700 MHz and 800 MHz bands requires that the following prerequisites be fulfilled:-

1. The migration of Studio to Transmitter Links (STL) operated by MCML to the 470 -694 MHz band;
2. The switching off of all CDMA2000 base stations operated by MTML;
3. Requesting SRD users operating tunable devices to retune same outside the 694-862 MHz band;
4. The conduction of field tests is required in order to confirm the extent of the interference between LTE base stations and DTTB receivers. The following are expected to be confirmed from the field tests:-
    (a) The radius around the LTE base stations where filters will have to be provided to televiewers;
    (b) The maximum EIRP the LTE base stations will be authorised to operate;
    (c) The minimum antenna height that will be authorised for LTE base stations;
    (d) The characteristics of the filters that will be required in-line with DTTB receivers/distribution amplifiers in order to effectively mitigate overload interference in DTTB receivers/distribution amplifiers;
    (e) The characteristics of the LTE base station filters that will be required in order to effectively mitigate out-of-band emission interference in DTTB receivers;
    (f) The susceptibility of DTTB receivers available on the market to interference from LTE downlink emissions in different conditions including propagation environment and DTTB received signal level;
    (g) The susceptibility of aerial installations and DTTB receivers installed within Mauritian homes to interference from LTE base stations.

For that purpose, section 3.1.2 proposes a field test methodology which is also subject to consultation.

3.1.1 Option 1a: Opening the 800 MHz band fully prior to 30 June 2019 and 700 MHz after that date

1. Option 1a enables the planning of three blocks of 10 MHz each in the band 791-821 MHz (downlink) and 832 – 862 MHz (Uplink). Given that only 1 MHz guard band would be available between DTTB Channel 60 and the lowest 10 MHz block, special care will have to be taken in regions where Channel 60 is in use, namely Coromandel, Terre Rouge and Bel Air. Additional care will have to be taken in regions where channels 52, 53, 54 and 55 are in operation as the superheterodyne DTTB receivers in these regions may suffer from N+9 image signal interference (refer to Annex B). These regions are covered by DTTB transmitters located at Chamarel, Citadelle, Coromandel, Corps de Garde, G.R.S.E, Les Mariannes, Plaine Paul and Riche en Eau.
2. Under these conditions, DTTB receivers are expected to be affected within a radius of around 600m in urban[3], 1.2km in suburban[4] and 2km in rural[5] propagation environment. These are valid under the base station assumptions made in the coexistence study and assuming that the DTTB received signal level in these regions is greater than 66 dBuV/m (refer to Annex C for coverage maps) and that receivers deployed have characteristics similar to Receiver 1 (Refer to Table 5 Annex B). With filters installed in line with those receivers, the radius of affected receivers is expected to improve only slightly if at all. This is so as Receiver 1 has sufficient dynamic range to withstand overload interference, which is the only interference mechanism these filters are capable of mitigating. Receivers with such characteristics are affected essentially by interference due to Out-of-Band emissions. For receivers with similar characteristics as Receiver 2, the affected radius is expected to be around 1.3 km in urban, 2.5 km in suburban and greater than 6 km in rural propagation environment under the same assumptions as above (Refer to Table 7 Annex B). With filters installed, these will improve to around 800m in urban, 1.4 km in suburban and 2.8 km in rural propagation environment.
3. Filters may be required beyond the radii specified above in order to cater for installations incorporating distribution amplifiers, households using receivers with inferior characteristics than what have been assumed and households with DTTB coverage below 66dBuV/m (refer to Annex C for coverage maps) or inappropriate aerial installations.
4. Additional base station filtering to be implemented in the LTE800 downlink where required. With the assumptions used in the coexistence study, it is estimated that with downlink operation in the 791-801 MHz band, an additional attenuation of 23 dB should be sufficient in Channel 60 to cater for interference due to Out-of-Band emissions. This should provide the required 21.2 dB C/N for

[3] Urban radio propagation environment are generally defined as being dominated by tall buildings, office blocks and other commercial buildings.
[4] Suburban radio propagation environment are generally defined as comprising of residential houses, gardens and parks
[5] Rural radio propagation environment are generally defined as comprising of open farmland with sparse buildings, woodland and forests.

broadcasting reception in regions with 66dBuV/m coverage or better (refer to Annex C for coverage maps). In regions with poorer coverage however or where a base station operates with higher EIRP than assumed, greater additional attenuation may be required.

3.1.2 Option 1b: Opening the 800 MHz band partially prior to 30 June 2019 and 700 MHz after that date

1. Obtion 1 b enables the planning of three blocks of 5 MHz each in the band 806-821 MHz (downlink) and 847 – 862 MHz (Uplink). In this way we would keep 16 MHz guard band between the LTE800 downlink and DTTB Channel 60. This would reduce the radius around the base station where receivers would be expected to be affected and filters required. Further, OOB emissions would be expected to be mitigated with less costly base station cavity filters. Additional care will have to be taken in regions where channels 53, 54 and 55 are in operation as the superheterodyne DTTB receivers in these regions may suffer from N+9 image signal interference (refer to Annex B). These regions are covered by DTTB transmitters located at Chamarel, Citadelle, Coromandel, Corps de Garde, G.R.S.E, Les Mariannes and Plaine Paul.
2. Under these conditions, DTTB receivers are expected to be affected within a radius of around 500 m in urban, 800 m in suburban and 1 km in rural propagation environment. These are valid under the base station assumptions made in the coexistence study and assuming that the DTTB received signal level in these regions is greater than 66 dBuV/m (refer to Annex C for coverage maps) and that receivers deployed have characteristics similar to Receiver 1 (Refer to Table 5 Annex B). With filters installed in line with those receivers, the radius of affected receivers is expected to improve only slightly. This is so as Receiver 1 has sufficient dynamic range to withstand overload interference. Receivers with such characteristics are affected essentially by interference due to Out-of-Band emissions. For receivers with similar characteristics as Receiver 2, the affected radius is expected to be around 1km in urban, 1.8 km in suburban and 4.4 km in rural propagation environment under the same assumptions as above (Refer to Table 7 Annex B). With filters installed, these will improve to around 400 m in urban, 600 m in suburban and 600 m in rural propagation environment.
3. Filters may be required beyond the radii specified above in order to cater for installations incorporating distribution amplifiers, households using receivers with inferior characteristics than what have been assumed and households with DTTB coverage below 66dBuV/m (refer to Annex C for coverage maps) or inappropriate aerial installations.
4. Additional base station filtering to be implemented in the LTE800 downlink where required. With the assumptions used in the coexistence study, it is estimated that with downlink operation in the 806-811MHz band, an additional attenuation of 15 dB should be sufficient in Channel 60 to cater for interference due to Out-of-Band emissions. This should provide the required 21.2 dB C/N for broadcasting reception in regions with 66dBuV/m coverage or better (refer to Annex C for coverage

maps). In regions with poorer coverage however or where a base station operates with higher EIRP than assumed, greater additional attenuation may be required.

The main drawbacks of Option 1 are:-

1. Operators may have to operate within a reduced channel bandwidth of 5MHz should the required mitigation of interference be considered too costly under option 1a;
2. Whereas filters to be distributed will cater for 800 MHz band operations, 700 MHz band filters will have to be distributed anew once the 700 MHz band is opened.

3.1.3 Option 2: Opening both 700 MHz and 800 MHz bands after 30 June 2019

After 30 June 2019, the 694 -862 MHz band will be fully available for assignment within both the 700 MHz and 800 MHz band plans. The downlink of LTE700 is on the upper part of the 700 MHz band, hence this provides for a guard band of 64 MHz between the lower edge of the LTE700 downlink band and the upper edge of DTTB channel 48. The coverage hole radius is expected to be similar to the results obtained for channel 58 and lower (refer to Annex B). Once an appropriate 700 MHz filter is installed in-line with the receiver or amplifier, the effect of the remaining interference due to out-of-band emissions is expected to be lower than for LTE800. This should enable the base station to operate at an EIRP higher than the one used in the simulation. Moreover, any additional base station filtering will be subject to less design constraints and less costly given the available guard band.

The main advantages of option 2 are:-

1. Filters will have to be distributed only once, hence reducing the cost of deployment;
2. A total of 20 MHz x 2 per operator will be available for assignment;
3. Sufficient time would be available for the switching off of the CDMA2000 base stations and the migration of STLs.

Q 1. Please indicate your interest, as a PLMN operator, for operating in the 700 MHz and 800 MHz bands. Kindly also indicate the time frame within which you plan to start any deployment in the said bands.

Q2. Please provide your substantiated preference with respect to Options 1a, 1b and 2 above. Please indicate any other appropriate options that may be considered.

3.1.4 Field Test Methodology

The following field test methodology is proposed:-

1. The tests to be carried out in presence of existing DTTB services.
2. Operators wishing to conduct LTE800 test will be required to apply and take out a test licence;
3. ICTA in collaboration with MCML to choose locations where tests will be carried out with respect to the criteria including the following:-
    a. DTTB frequencies received at locations;
    b. The environment (Urban, Suburban, Rural);
    c. The predicted DTTB received field strength.
4. ICTA in collaboration with MCML to conduct DTTB field strength measurements within the chosen locations in order to confirm suitability of these locations. Measurements to be carried out at 10m above ground level as specified in GE06 agreement;
5. Operators to be communicated details of the locations where tests will be authorised;
6. The operators to inform the ICTA at least 15 days prior the start of the test at a location providing information pertaining to the GPS coordinates of the LTE800 base station as well as other technical characteristics including EIRP, Block Edge Mask and antenna height. Several antenna heights may be tested in order to determine the minimum antenna height to be prescribed.
7. Several EIRP levels may be tested in order to determine the maximum EIRP to be prescribed. The operators shall therefore provide for a step attenuator so as to vary the transmitter power as and when required for the purpose of the test. The operators should also provide for base station cavity filters of different attenuations for the purpose of the test;
8. Operators to perform the tests on the frequencies provided by the ICTA for test purposes. Three traffic loads to be tested, namely 0% (idle mode), 50% loaded and 100% loaded;
9. ICTA and MCML to choose DTTB receivers and amplifiers to be tested. These receivers and amplifiers should be representative of what is available on the market;
10. ICTA and MCML to conduct coexistence field measurements around the identified locations in order to determine the coverage hole radius for each receiver under test. These results will be compared with the predictions of the coexistence study;

11. The test set-up depicted below may be used for the coexistence measurement. All measurements will be carried out at 10m above ground level as specified in the GE06 agreement.

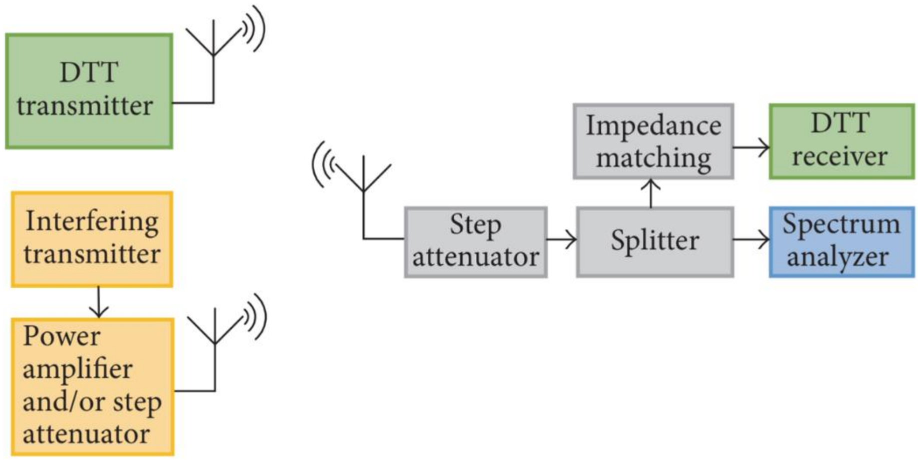


Figure 4: Test set-up[6]

12. The ICTA together with operators to undertake a nationwide communication campaign informing the public of the tests to be carried out and of the actions to be taken to report any interference complaint as well as the remedial actions to be taken.
13. Operators to inform the public within each location, at least 15 days prior, of the tests that will be carried out and of the interference potential;
14. Operators to put at the disposal of the public a hotline where complaints may be recorded. Operators to provide to the ICTA statistics pertaining to the said complaints;
15. Operators to provide filters of the determined characteristics to those televiewers who have reported interference. The operator should also provide for an antenna installer to visit the complainant to ascertain that the reported interference is due to the operation of LTE. The antenna installer should provide assistance to the complainant for installing the filter and resolving the interference. The operators should ensure that complaints are attended within 72 hours;

Q3. Please provide your general comments with respect to the proposed field test methodology;

Q4. Please indicate the maximum EIRP at which the tests may be conducted;

Q5a. For the purpose of the field test, kindly propose candidate LTE800 DTTB receiver filters, including their technical characteristics.

Q5b. Kindly also propose candidate LTE700 DTTB receiver filters, including their technical characteristics.

Q6. For the purpose of the field test, kindly propose candidate LTE800 Base Station Cavity Filters including their technical characteristics.

Q6b. Kindly also propose candidate LTE700 Base Station Cavity Filters including their technical characteristics.

[6] Source: https://www.hindawi.com/journals/wcmc/2017/1563132/

3.2 LTE800 and LTE700 Uplink to DTTB receiver Interference

Considering the DTTB band plan prevailing currently, the lower edge of the LTE800 uplink band is separated from the upper edge of DTTB Channel 60 by 42 MHz. After 30 June 2019, the separation will increase to 138 MHz. Some studies have shown that despite the 42 MHz separation, the DTTB receiver features as well as the presence or absence of a masthead amplifier in the receiving chain may heavily influence, in specific circumstances, the DVB-T signal QoS perceived by the user when subjected to LTE uplink transmissions[7]. Other studies have concluded that there is low probability of interference between the LTE800 uplink and DTTB receivers[8]. These studies have shown that even the worst DTTB receiver tested did not suffer from picture degradation until the mobile handset, radiating maximum power, was placed within 1.4 metres of the receiving equipment[7]. According to these same studies the interference could be remedied by moving the handset away from the DTTB receiving equipment[7].

In the case of LTE700, however, the lower edge of the uplink band is separated by only 9 MHz from the upper edge of Channel 48. Nonetheless, according to measurements carried out[9] DTTB reception only very rarely suffer from interference from handsets. It is noted nonetheless that a combination of very specific circumstances including poor TV receiver, poor quality aerial installation with high system gain, an antenna system pointing towards an area with high mobile use and weak DTTB signal level, may result into interference from the LTE700 uplink[9]. Similar conclusions are presented in other studies on the coexistence of DTTB and mobile broadband[10].

Such cases of harmful interference may be mitigated effectively by the use of a filter with a moderate 5dB discrimination between the DTTB band and the LTE700 uplink band[9].

Q7. Please provide your comments/views with respect to LTE700 and LTE800 Uplink interference to DTTB.

3.3 Co-Existence issues with PMSE (Wireless Microphone) in the 470 – 862 MHz

Programme Making and Special Events applications (PMSE) is the term used to describe handheld or body worn radio applications used for real-time presentation of audio-visual information or recording. These include wireless microphones. These devices traditionally operate in conformity with European standards in the 470 – 862 MHz. Over the years the ICTA has type approved about twenty such devices. Moreover, recently the ICTA has started issuing licenses to operate PMSE devices in this frequency band.

[7] https://www.itl.waw.pl/czasopisma/JTIT/2015/4/74.pdf
[8] https://www.ofcom.org.uk/consultations-and-statements/category-2/second-coexistence-consultation
[9] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/101655/700-MHz-Coexistence-Study-of-mobile-uplink-interference-effects-upon-DTT-reception.pdf
[10] https://www.hindawi.com/journals/wcmc/2017/1563132/

These devices may be tuned in order to operate in the broadcasting white spaces within their band of operation. PMSE devices operate on a secondary basis in the 470 – 862 MHz band. This means that they should not cause interference to primary services and should accept interference from these primary services.

The allocation of the 694 – 862 MHz to the Mobile Service will reduce the tuning range of the PMSE devices by 168 MHz. Moreover with this allocation PMSE devices will have to coexist with LTE base stations as well as User Equipment. The CEPT Report 32[11] provides recommendations on the best approach to ensure the continuation of existing PMSE services in the 470-862 MHz band.

In order to address the interference issues which PMSE device users may experience after the coming into operation of Mobile Services in the 700 MHz and 800 MHz bands, the Authority intends to give prior notice to these users to retune their equipment so as to restrict their operations within the 470 – 694 MHz band.

It is to be noted that other PMSE devices operate without licence in the 863-865 MHz band. The 1 MHz separation between 862 MHz and 863 MHz will ensure that PMSE operating in the said band are not interfered with by the operation of the mobile communication networks according to CEPT Report 32.

Q8. Please provide your comments/views with respect to LTE700 and LTE800 interference to PMSE.

3.4 Co-Existence with other SRDs

Short Range Devices (SRDs) operate in the 862 – 870 MHz in close proximity with the LTE800 uplink band with a guard band of 1 MHz in between. SRDs are unlicensed devices used for a plethora of applications including alarms, door openers, medical implants and RFID. SRDs operate on a non-interference and non-protection basis. ECC Report 207[12] provides a comprehensive analysis of the adjacent band co-existence of SRDs and LTE around the band edge of 862 MHz.

The major effects identified in ECC Report 207 are[13]:-

1. Receiver blocking: The SRD receiver is unable to operate in the presence of a strong signal on a nearby frequency;
2. Out of band energy from the LTE User Equipment (UE): Since this appears within the bandwidth of the SRD receiver it cannot be filtered. It can prevent the operation of SRDs, especially in cases of low wanted signals.

Q9. Please provide your comments/views with respect to LTE700 and LTE800 interference to other SRDs.

[11] https://www.ecodocdb.dk/download/7aafc49a-17c7/CEPTREP032.PDF
[12] https://www.ecodocdb.dk/download/bae9a812-55c7/ECCREP207.PDF
[13] http://www.etsi.org/deliver/etsi_tr/103200_103299/103288/01.01.01_60/tr_103288v010101p.pdf

3.5 Cost Implications

The options presented above, including the proposed field tests have cost implications which have to be addressed. The main cost implications are as follows:-

1. Refarming costs to be incurred by MCML in order to migrate the STLs as well as the broadcasting transmitters outside the 694 - 862 MHz band;
2. Interference mitigation costs to be incurred by operators. This includes the cost of additional filtering at the base stations, the cost of providing filters to households and the cost of the communication campaign;
3. Field Test costs to be incurred by:-
   a. operators regarding equipment to be tested and interference mitigation measures;
   b. ICTA and MCML regarding the receivers to be tested and the measurements to be carried out and;
   c. ICTA and the operators regarding the communication campaign;
4. Costs to be incurred by PMSE and other SRD users in order to mitigate any interference to their system operating on non-interference and non-protection basis.

As regards the costs to be incurred by operators, it is noted that should option 1 be favoured, the operator to whom the lowest frequency block is assigned will have to incur higher costs compared to the operators to whom the two higher blocks are assigned in order to mitigate interference to the Broadcasting receivers. It is therefore proposed that, where all three PLMN operators have a common interest to deploy networks in the 800 MHz band, these PLMN operators work out a common solution in order to share the interference mitigation costs equitably.

Q10. Please provide your comments on the costs identified above, indicating any other costs that has not been identified;

Q11. Please provide your views on the proposal for equitable interference mitigation cost sharing among operators

3.6 Conclusion

This consultation paper has considered different coexistence issues related to the operation of the Mobile Service, particularly LTE, in the 694 – 862 MHz band. Particular emphasis has been laid to coexistence between LTE downlink and DVB-T reception in the 470 – 790 MHz (Pre-30 June 2019) and in the 694 – 862 MHz (Post-30 June 2019). It has been concluded that the introduction of LTE base stations within the coverage area of DVB-T transmitters will result in coverage holes. The interference may be partially mitigated through the installation of an appropriate filter in line with the DVB-T receiver or distribution amplifier as the case may be. In order to completely mitigate the interference, additional LTE base station filtering may be required, together, in some cases, with a reduction in transmitter power. Given that a new DTTB plan will enter into force as from 30 June 2019 and that thereafter the 694 – 862 MHz will be fully available for the Mobile Service, two options have been considered. In the first option, only 15 MHz x 2 is proposed to be made available in the 800 MHz band to operators in the short term once Studio to Transmitter links have been migrated out of the band and and CDMA2000 base stations have been switched off. This would provide sufficient guard band between the Mobile Service and Broadcasting, hence facilitating the mitigation of interference. In the second option, the full band is made available after 30 June 2019. One of the main advantages of this option is that filters will be provided to televiewers only once, whereas if option 1 is adopted, filters will have to be provided on two occasions, given that the same filters cannot cater for both LTE700 and LTE800 interference. A field test is proposed to be carried out in order to obtain a real life assessment of the interference between LTE and DVB-T. This paper has proposed a field test methodology accordingly. Finally, the potential interference issues between LTE uplink and DVB-T as well as between LTE and Short Range Devices, including wireless microphone, have been highlighted.

ANNEX A: LIST OF CONSULTATION QUESTIONS

Q 1. Please indicate your interest, as a PLMN operator, for operating in the 700 MHz and 800 MHz bands. Kindly also indicate the time frame within which you plan to start any deployment in the said bands.

Q2. Please provide your substantiated preference with respect to Options 1a, 1b and 2 above. Please indicate any other appropriate options that may be considered.

Q3. Please provide your general comments with respect to the proposed field test methodology;

Q4. Please indicate the maximum EIRP at which the tests may be conducted;

Q5a. For the purpose of the field test, kindly propose candidate LTE800 DTTB receiver filters, including their technical characteristics.

Q5b. Kindly also propose candidate LTE700 DTTB receiver filters, including their technical characteristics.

Q6. For the purpose of the field test, kindly propose candidate LTE800 Base Station Cavity Filters including their technical characteristics.

Q6b. Kindly also propose candidate LTE700 Base Station Cavity Filters including their technical characteristics.

Q7. Please provide your comments/views with respect to LTE700 and LTE800 Uplink interference to DTTB.

Q8. Please provide your comments/views with respect to LTE700 and LTE800 interference to PMSE.

Q9. Please provide your comments/views with respect to LTE700 and LTE800 interference to other SRDs.

Q10. Please provide your comments on the costs identified above, indicating any other costs that has not been identified;

Q11. Please provide your views on the proposal for equitable interference mitigation cost sharing among operators

Annex B: Co-Existence Study between LTE800 Downlink and Digital Terrestrial Television Broadcasting (DTTB)

1.0 Introduction

In order to assess the co-existence between LTE800 and DTTB, the Authority has undertaken a study by making use of the Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT). This software tool is based on the Monte-Carlo simulation method which is developed within the frame of the European Conference of Postal and Telecommunication administrations (CEPT). The aim of this tool is to use statistical modelling of different radio interference scenarios for performing coexistence studies between wireless systems operating in overlapping or adjacent frequency bands. Whereas the co-existence study has been limited to LTE800, it is considered that the results of same may also be applied to LTE700 as well.

2.0 Definitions used in Co-Existence study

1. Protection Ratio

The ITU Radio Regulations (RR1.170) defines protection ratio as 'the minimum value of wanted-to-unwanted signal ratio, usually expressed in decibels, at the receiver input, determined under specified conditions such that a specified reception quality of the wanted signal is achieved at the receiver output'

2. Location Probability

Location probability is the probability that within a given (small) area, a field strength level is exceeded at a required percentage of points within that area.

3. Receiving location

The first level of coverage (smallest unit) is a receiving location; A receiving location is regarded as being covered if the level of the wanted signal is high enough to overcome noise and interference for a given percentage of the time.

4. Small area (pixel) coverage

The second level of coverage is a 'small area' or 'pixel' (typically 100m by 100m). In this small area the percentage of covered receiving locations is indicated. A pixel is called covered if a given percentage is reached. For example 95% for fixed DVB-T reception according to the GE06 agreement.

5. Coverage area

The third level of coverage is the coverage area of a station, or a group of stations, is made up of the sum of the individual small areas in which 95% (fixed reception) of coverage is achieved.

6. **Coverage area loss**

The coverage area loss describes the loss of covered area if an additional interfering source is added. The coverage area loss represents the percentage of loss area relative to the originally covered area.

7. **Coverage holes**

A coverage hole is an area within the existing broadcasting coverage are which is no longer covered due to the introduction of a new interference source (such as a mobile uplink or downlink transmitters). An area is no longer covered when, due to the introduction of an additional source of interference, the reception location probability within that area no longer reaches (or exceeds) 95%.

3.0 Simulation Methodology

1. A pixel of 100m x 100 m is positioned within a DTTB coverage area;
2. At each simulation run (event), DTTB receiver location is randomly positioned, following a uniform distribution, within this pixel. The directional antenna of each receiver is made to point towards the DTTB transmitter in order to ensure maximum received signal strength;
3. An LTE800 seven site cluster (each site has three sectors) is positioned such that the distance between the base station of the central site and the pixel is varied. The pixel is positioned on the bore sight of the nearest LTE800 sector antenna. No Multiple Input Multiple Output (MIMO) antenna has been considered in this study. The system layout is illustrated in Figure B1 and the pixel positioning is illustrated in Figure B2:-

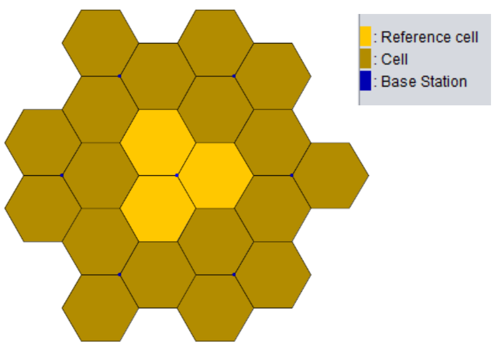


Figure B1: System Layout

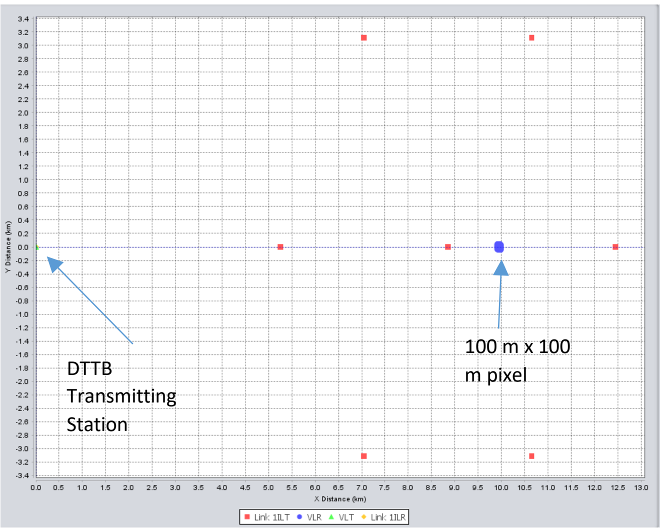


Figure B2: Pixel positioning

4. The above steps is repeated for each pixel;
5. For each pixel position, the Interference Received Signal Strength (IRSS) at 95% of locations is determined from the Cumulative Distribution Function (CDF) of IRSS generated by SEAMCAT for each pixel as shown in Figure B3 below;

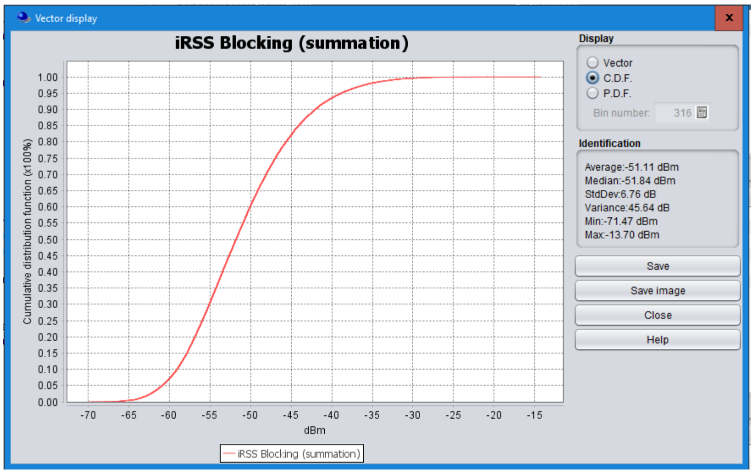


Figure B3: CDF of IRSS

6. From 5., the IRSS may be plotted against distance between the base station of the central LTE800 cell and each pixel position;
7. From 6., the Carrier to Interference ratio (CIR) in 95% of the locations within each pixel may be calculated for the following DTTB received signal levels: -70 dBm (56 dBuV/m), -60 dBm (66 dBuV/m) and -50 dBm (76 dBuV/m);
8. In order to determine the Coverage Hole Radius (CHR), Protection Ratio (PR) data for DTTB receivers should be used. The LTE800 cluster may be expected to cause a reduction in the DTTB coverage in

cases where in 95% of locations, the CIR for a pixel is smaller than the PR of the DTTB receivers in operation within the pixel;

9. Based on the above methodology, expected CHR may be determined for each DTTB coverage area in Mauritius. This is expected to provide an indication of the area around an LTE base station where filters may need to be distributed. This is also expected to provide an indication on the regions where DTTB coverage is affected but where filters are not expected to be a solution due to low DTTB received signal levels. This analysis is also relevant in deciding on the field tests that are expected to be carried out by operators as part of this planning process;

4.0 LTE800 Downlink to DTTB receiver Interference Mechanisms

LTE800 and LTE700 downlink interactions with DTTB receivers involve three main interference mechanisms that have to be considered and studied. These are:-

(1) DTTB Receiver Overload Interference;
(2) DTTB Receiver Adjacent Band Interference;
(3) N+9 image Interference

4.1 DTTB Receiver Overload Interference

In order to understand this interference mechanism Figure B4 below will be considered. Figure B4 depicts the Front-end of a superheterodyne DTTB receiver (also referred to as Can tuner) where the Radio Frequency (RF) is converted to in Intermediate Frequency (IF) by means of a Local Oscillator. It is to be noted that receivers may also be built by using a different RF Front-end architecture known as the Zero-IF architecture (also referred to as Silicon tuner) where no conversion from RF to IF is necessary.

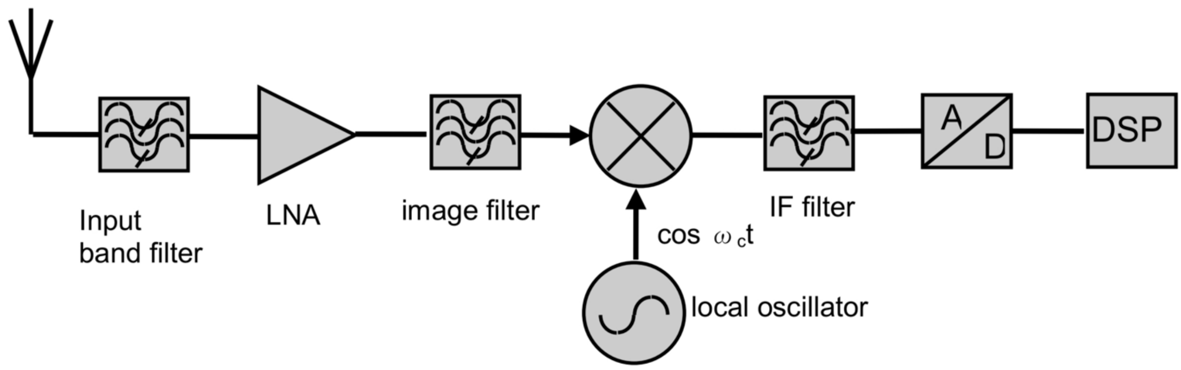


Figure B4: Front-end of superheterodyne Receiver

Figure B4 shows that the second element in the receive chain after the antenna is a so called RF Filter. This may be a band-pass filter with a passband covering the full DTTB band between 47 – 862 MHz. Hence, this architecture design will allow LTE800 downlink emissions at frequencies between 791 – 821 MHz and LTE700 downlink emissions between 758 – 788 MHz through. Should the LTE800/LTE700 downlink signal strength entering the DTTB receiver be strong enough, this may drive the Low Noise Amplifier into compression. The effect is attenuation of the wanted received DTTB signal strength, reduction in the Carrier-to-Noise ratio below what is required, hence leading to image degradation or even total image loss. It is to be noted that some receivers are more prone to overload compared to others. This is usually dependent on the dynamic range of the LNA and other non-linear components implemented within the receiver.

DTTB receiver overload interference is likely to occur in the immediate region around the LTE800/LTE700 base stations. This type of interference may be addressed relatively easily through the use of appropriate filters that will filter out the LTE800/LTE700 downlink signal.

4.2 DTTB Receiver Adjacent Band Interference

Adjacent band interference is a linear type interference that occurs due to the leakage of low-level out-of-band emission from the LTE800/LTE700 base station into the pass-band of an adjacent DTTB channel.

This interference mechanism is especially prominent in areas where the DTTB received signal strength is relatively low. Further, in those areas, this interference may affect receivers further away from the LTE800/LTE700 Base station as compared to the overload interference.

A further characteristic of this interference mechanism is that it cannot be addressed with the use of filters. This is so as the interference is present within the wanted channel itself in the form of a broadband noise whose effect is to reduce the Carrier-to-Noise ratio below the minimum required for proper demodulation.

4.3 N+9 Image Interference

The N+9 image interference is inherent to Can tuners only due to the conversion of the RF signal to an IF signal through the mixing process with a local oscillator signal as explained above.

The mixing process produces two IF signals, namely one signal at a frequency resulting from the sum of the RF and Local Oscillator frequency and an image signal which is the difference of the RF and Local Oscillator frequency. The image signal is filtered out by the IF filter.

In the same way, two RF frequencies separated by nine DTTB channels (72 MHz offset), when passing through the mixer of a Can tuner will produce the same IF. Assuming that the IF of a Can tuner is 36 MHz, the Local Oscillator frequency has to be tuned to 758 MHz in order to receive channel 61. Should DTTB channels 61 (centre frequency 794 MHz) and DTTB channel 52 (centre frequency 722 MHz) be received by such a receiver at the same time, both RF will produce the same IF at 36 MHz and hence the two signals will interfere with each other. This situation is usually avoided in DTTB planning.

In the case of LTE800, however, given that block adjacent to Channel 60 operates at 796 MHz, the N+9 interference will occur in the DTTB receiver in regions covered by channel 52. The same interference will occur between channel 53 and 54 and the LTE800 second adjacent block operating at 806 MHz and channel 55 and the LTE800 third adjacent block operating at 816 MHz.

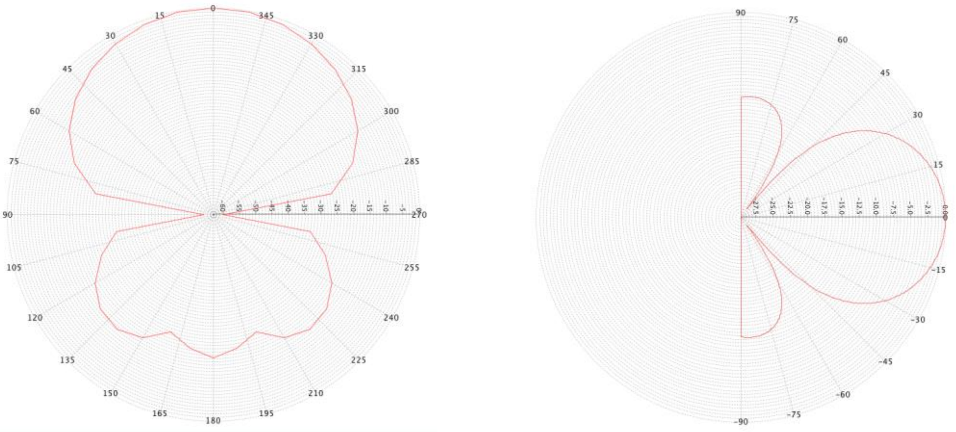
Whereas the liberation of the 694 – 862 MHz band will eliminate this problem for LTE800, the problem may persist for the lowest LTE700 block operating at centre frequency 763 MHz and Channel 48.

5.0 DTTB Simulation Assumptions

The specifications for DTTB receivers for Mauritius have been defined and published on the MCML website[14]. In general, according to the published specifications, the terrestrial front end should fully comply with the ETSI EN 300-744 standard.

For the purposes of the simulation, the following assumptions have been adopted:-

- Minimum wanted signal level: -70 dBm (56 dBuV/m);
- Receiver sensitivity:- -79 dBm
- DVB-T variant:- 64QAM ¾
- Minimum C/N in Rician Channel for 64 QAM ¾:- 21.2. DB
- Location Probability:- 95%
- Antenna peak gain:- 11 dBi
- Antenna height:- 10m
- Receive Antenna Radiation Pattern:-



Horizontal plane radiation pattern DVB-T receiving antenna

Vertical plane radiation pattern DVB-T receiving antenna

Figure B5: Antenna Radiation Pattern for DTTB antenna

[14] http://www.multi-carrier.net/English//DOCUMENTS/SPECIFICATIONS%20FOR%20SET%20TOP%20BOXES%20(STB).PDF

5.1 DTTB Receiver Protection Ratios with respect to LTE800 Interference

As specified at point 8 of section 3.1.1.2, DTTB receiver protection ratios with respect to LTE800 interference is essential in order to estimate the Coverage Hole Radius (CHR).

Several measurement studies have been carried out under the aegis of CEPT and ITU in order to determine the performance of DVB-T receivers in the presence of LTE800 interferers. The result of these studies have been published in ECC Report 148[15] for CEPT and Report ITU-R BT.2215-6[16] for the ITU. These studies specify performance in terms of receiver protection ratios and overloading thresholds.

Two of the most cited studies of the same kind had been commissioned by the UK regulator, Ofcom, in 2011[17] and 2012[18] respectively from ERA Technology. The first study pertained to the assessment of LTE800 Base Station interference into DTTB receivers and the second study pertained to television distribution amplifier performance when interfered with LTE800 Base Station including mitigation filter testing.

The objective of the 2011 study was to carry out laboratory measurements on a range of DTTB receivers in order to derive their protection ratios under operating conditions including DVB-T and DVB-T2 operating modes, various wanted signal levels at the input of the receiver, interference from time variant LTE base station signals representing fully loaded and idle traffic conditions and different frequency offsets from the LTE base station operating frequency. The 2011 study considered 13 receivers of different types (integrated Digital TV (iDTV), Personal Video Recorders (PVR) and Set-top boxes (STB)). These receivers consisted of a mix of Superheterodyne tuners and Zero-IF tuners.

The objective of the 2012 study was to undertake further laboratory measurements of indoor and outdoor TV distribution amplifier overload performance for a range of devices typically found in communal and domestic installations in the UK. The amplifiers chosen for the measurements were connected to two of the iDTV receivers tested in the 2011 study. The measurements were also repeated to ascertain the degree of interference mitigation that in-line filters installed prior to the amplifiers would bring. The results were also presented in terms of protection ratios calculated at the point where interference results in visible degradation to viewed picture quality.

The studies carried out for Ofcom are quite unique and provide valuable input to the coexistence study at hand as they have also considered the effect of TV distribution amplifiers. It is recognised however that the receivers tested are not necessarily the ones that are currently in use in Mauritius specially given that the latest report was published six years ago. Nonetheless, it is believed that applying the results from these studies to the Mauritian context has the merit of:-

[15] https://www.ecodocdb.dk/download/c041605d-e8a0/ECCREP148.PDF
[16] https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-BT.2215-6-2016-PDF-E.pdf
[17] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/33939/ite-800-mhz.pdf
[18] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/28073/era.pdf

1. providing valuable indication of the order of the potential interference to DTTB receivers;
2. assisting in designing the requirements for field tests;
3. providing valuable indication of the expected field tests results.

It is to be noted however that in order to use the PR values measured in the abovementioned study in the Mauritian context, a correction factor of 2.8 dB should be applied for fixed reception[19]. This is so as the DVB-T variant used in the study is 64-QAM 2/3 whereas the variant used in Mauritius is 64-QAM ¾.

The receivers considered in this coexistence study are receivers 1 and 2 of the 2012 study undertaken by ERA Technology. The characteristic of these two filters are as follows:-

Receiver ID	DTT Transmission Mode	Receiver Type	Tuner
Receiver 1	DVB-T & T2	iDTV	Silicon (Zero IF)
Receiver 2	DVB-T & T2	iDTV	Can (Super heterodyne)

Table 1: DTTB receivers considered in coexistence study (Source: ERA Technologies[20])

The Amplifier considered in the coexistence study is Amplifier 3 (Amp3) of the 2012 study undertaken by ERA Technology. The characteristics of Amp3 is as follows:-

Identifier	Type	Frequency Range (MHz)	Gain (dB)	Inputs	Outputs
Amplifier 3 (Amp3)	Masthead	470-862	25 - 34	1	1

Table 2: Amplifier considered in coexistence study (Source: ERA Technologies[21])

The distribution amplifier filters considered in the coexistence study are also taken from the 2012 ERA Technology report. The characteristics of the filters used are summarised below:-

[19] https://www.ecodocdb.dk/download/c041605d-e8a0/ECCREP148.PDF

[20] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/33939/ite-800-mhz.pdf

[21] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/28073/era.pdf

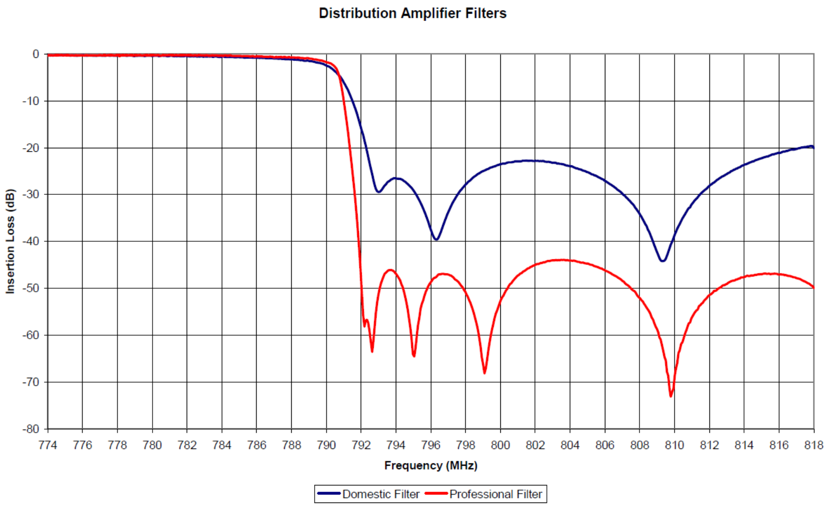


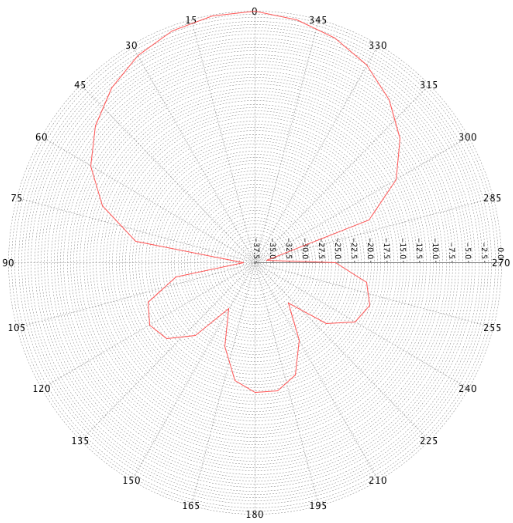
Figure B6: Distribution Amplifier Filters considered in coexistence study (Source: ERA Technologies[21])

6.0 LTE800 Simulation Assumptions

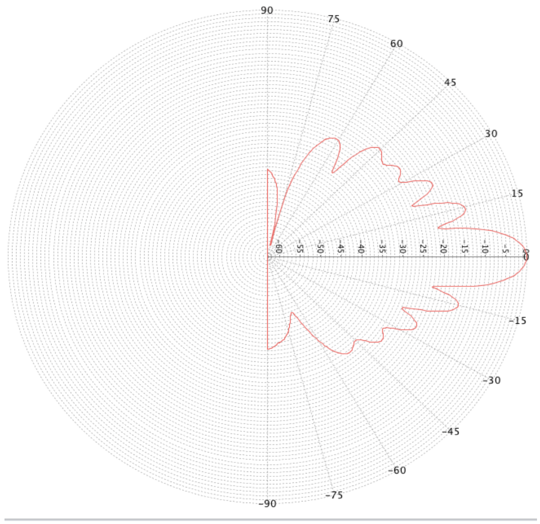
The simulation has been carried out with the following parameters for LTE800:-

- System Bandwidth: 10 MHz;
- Center Frequency of simulated LTE800 Transmitter: 796 MHz
- Base Station Maximum Transmitter power: 35 dBm (This power satisfies the Link budget as estimated in section 7.1.1.6);
- Antenna Height for each propagation environment:
  - Urban and Suburban: 30m (minimum base station height for validity of Extended Hata model)
  - Rural: 35m
- Antenna peak gain: 15 dBi
- Antenna type: Sector Antenna
- Propagation model: Extended Hata model
- Base station mode: Idle (0% LTE traffic). In the idle mode, the base station emission is bursty and therefore has the worst interference effect on the DTTB receiver.

- The Antenna radiation patterns are as shown in Figure B7 below:



Horizontal plane LTE NodeB radiation pattern



Vertical plane LTE NodeB radiation pattern

Figure B7: LTE800 Base Station Antenna Radiation Pattern

6.1 LTE800 Link Budget

In order to estimate the LTE800 cell ranges for the urban, suburban and rural cases, the Link budget below has been calculated. A downlink data rate of 8Mbps and an uplink data rate of 2 Mbps have been assumed for the purposes of the link budget. Under these circumstances, it is found that the required path loss between a UE at the cell-edge and transmitting at maximum power of 23 dBm and the Base Station is 134 dB.

Using the Extended Hata model of propagation, the cell ranges have been determined at 1.8 km for Urban environment, 3.3 km for Suburban environment and 12 km for Rural environment. These results have been considered in the SEAMCAT simulations.

Downlink Link Budget			**Uplink Link Budget**	
BS Transmit Power dBm	35.00		UE Transmit Power dBm	23.00
Number of transmit antenna elements	1.00		Number of transmit antenna elements	1.00
Number of receive antenna elements	1.00		Number of receive antenna elements	1.00
BS Antenna gain dBi	15.00		UE Antenna gain dBi	0.00
BS diversity gain/MIMO gain dB	0.00		UE Diversity gain/MIMO gain dB	0.00
BS Feeder and Connector Losses dB	4.50		UE Body Loss dB	0.00
BS EIRP	45.50		UE EIRP	23.00
Data Rate Mbps	8.00		Data Rate Mbps	2.05
Nearest performance step Mbps	8.13		Nearest performance step Mbps	5.28
Required SNR dB	4.01		Required SNR dB	1.00
Thermal Noise PSD dBm.Hz	-173.98		Thermal Noise PSD dBm.Hz	-173.98
Number of Resource blocks	51.00		Number of Resource blocks	25.00
Bandwidth per resource block MHz	0.18		Bandwidth per resource block MHz	0.18
Bandwidth for the Number of resource blocks MHz	9.18		Bandwidth for the Number of resource blocks MHz	4.50
Thermal Noise for required bandwidth	-104.35		Thermal Noise for required bandwidth	-107.45
UE noise figure dB	7.00		BS noise figure dB	5.00
UE receiver noise floor	-97.35		BS receiver noise floor	-102.45
UE Interference margin dB	4.00		BS Interference margin dB	1.00
UE sensitivity	-89.34		BS sensitivity	-100.45
Control channel overhead dB	0.40		soft handover gain	0.00
			Fast fade margin	0.00
UE Antenna gain dBi	0.00			
UE Diversity gain/MIMO gain dB	0.00		BS Antenna gain dBi	15.00
UE Body Loss dB	0.00		BS Diversity gain/MIMO gain dB	0.00
UE Required Signal Power dBm	-89.00		BS Feeder and Connector Losses dB	4.50
Downlink Path Loss	134.50		UE Required Signal Power dBm	-100.45
			Uplink Path Loss	133.9
BS Tx Power = 35 dBm	cell range (m)	height (m)		
Urban	1800	30		
Suburban	3300	30		
Rural	12000	35		

Table 3: LTE800 Link budget

6.2 LTE800 Downlink Emission Mask

The LTE800 downlink emission mask is based on the mask used in the ERA Technologies report 2012[22] which is itself based on the baseline requirements defined in the European Commission Decision of 6 May 2010[23] for DTTB Channel 60 where the maximum mean out-of-block EIRP is (P-59) dB, where P is the base station in-block EIRP. For DTTB channels 59 and below, the maximum mean out-of-block EIRP is set to (P-69) dBm. The downlink emission mask is shown in Figure B8 below.

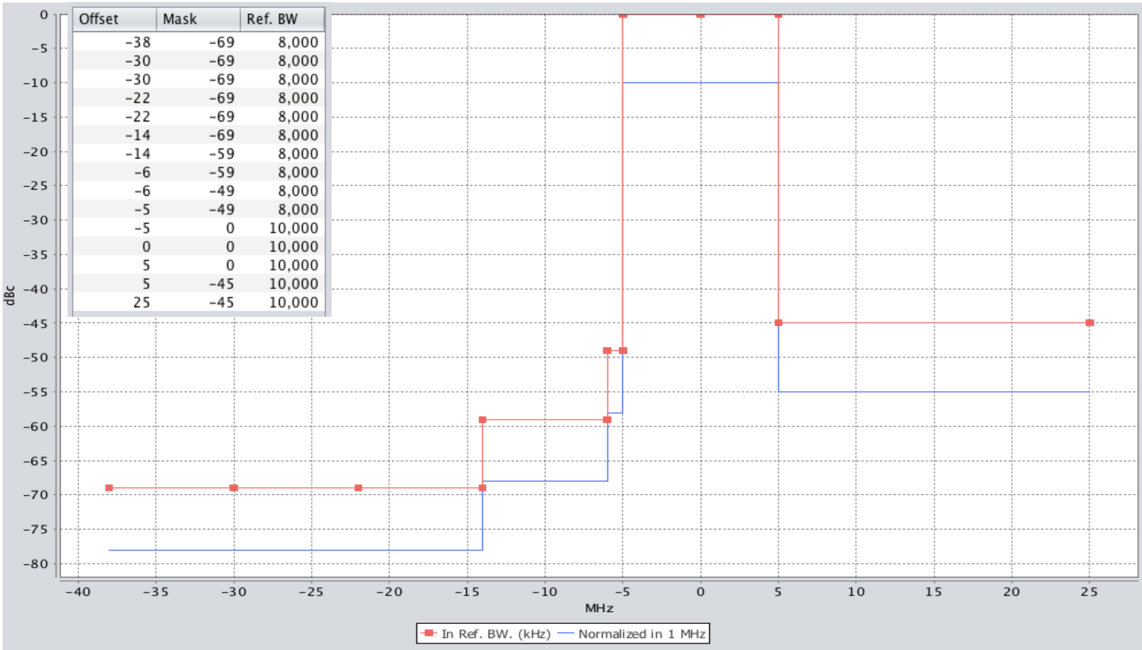


Figure B8: LTE800 Downlink Emission mask

[22] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/28073/era.pdf

[23]https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010D0267&from=EN

7.0 Results IRSS and C/I in 95% of pixel location vs pixel distance to LTE800 Base Station

This section presents the results of the coexistence study in terms of in-block Interference Received Signal Strength (IRSS) in 95% of locations within the 100m x 100m pixel against distance between the central base station in the cluster and the said pixel. The results are presented for the rural, suburban and urban propagation environments.

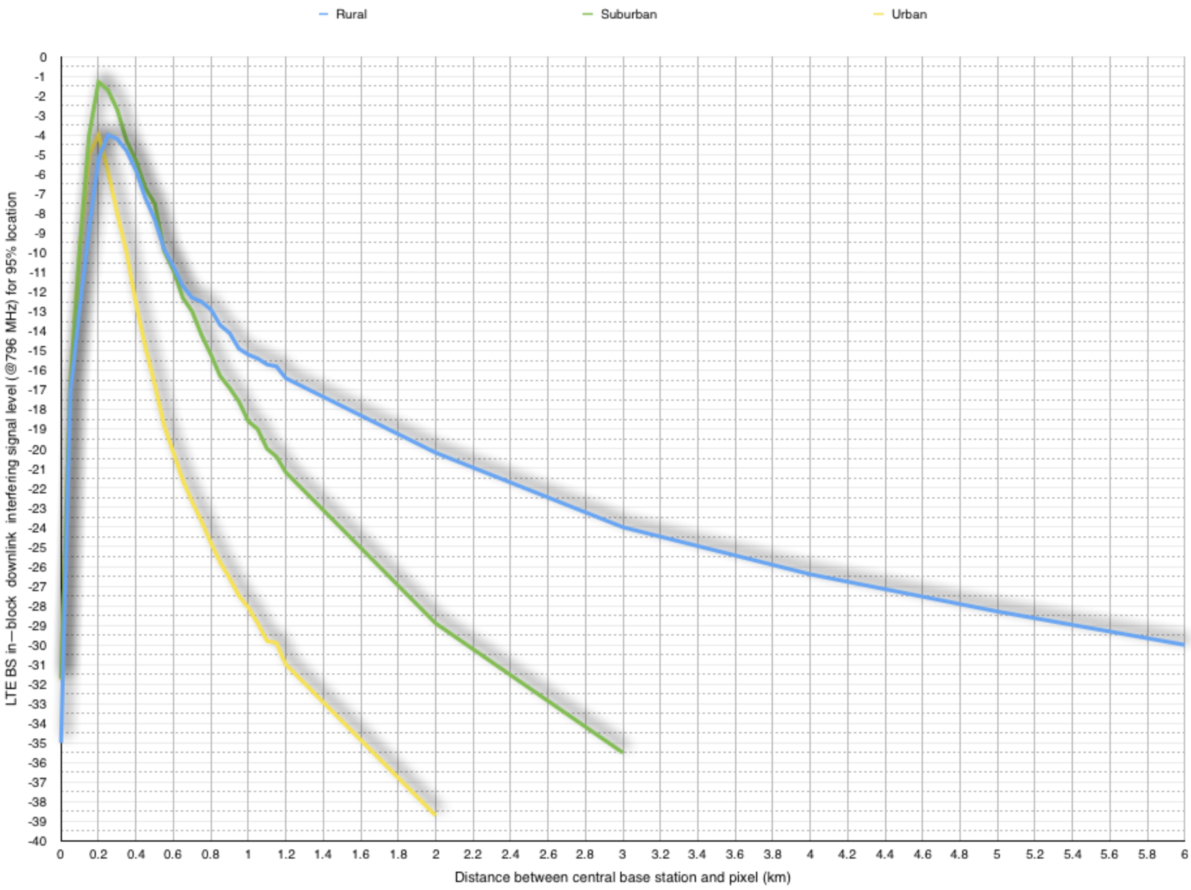


Figure B9: In-block IRSS against distance

From the above results, graphs showing the relationship between Carrier-to-Interference ratio for DTTB received signal strength of -50 dBm, -60dBm and -70dBm and distance between the central base station of cluster and pixel may be derived as shown in Figures B9, B10 and B11 below.

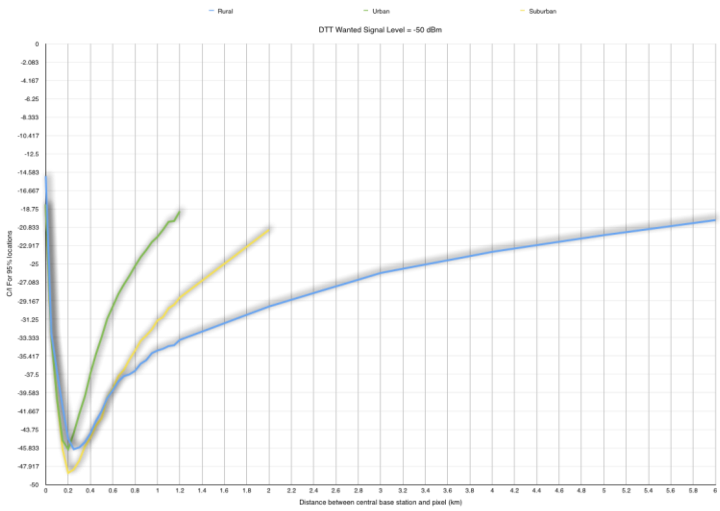


Figure B9: C/I vs distance for C=-50 dBm

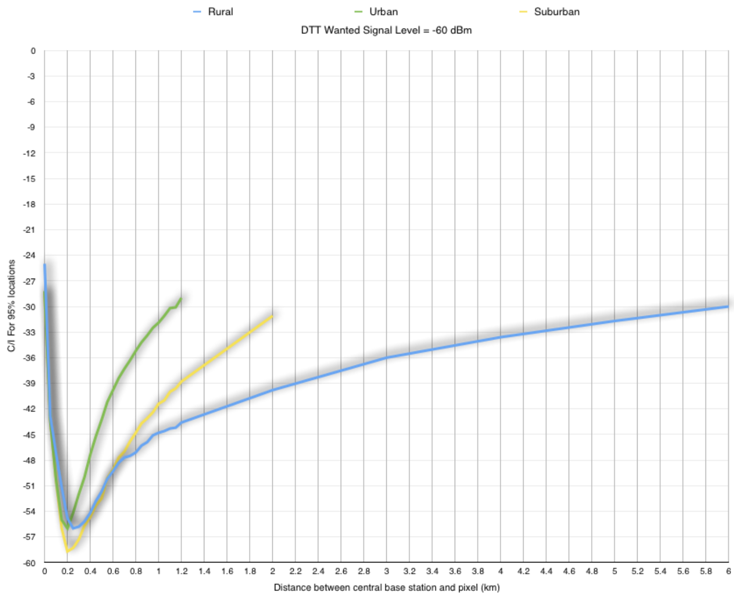


Figure B10: C/I vs distance for C=-60 dBm

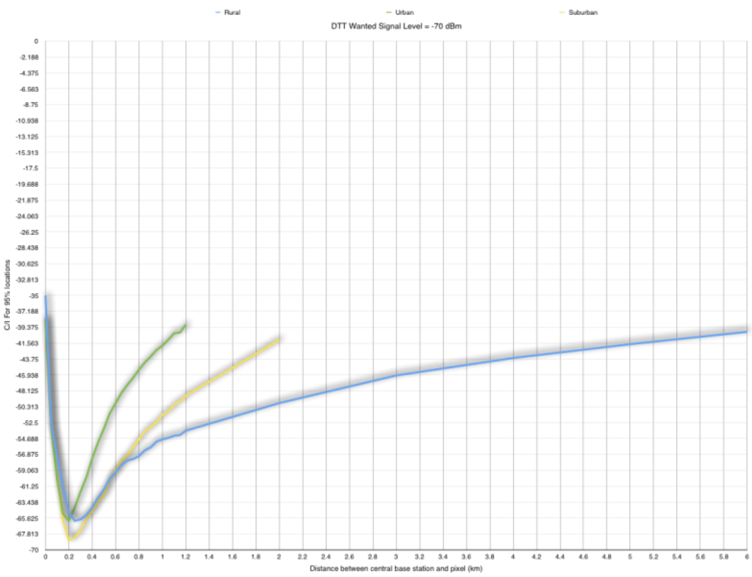


Figure B11: C/I vs distance for C=-70 dBm

Receiver 1: Measured Protection Ratio[24]

		Receiver 1 Only			Receiver 1 + Amplifier			Mitigation Technique - Filter		
Best Server coverage	**Channel No.**	**PR Receiver 1 no filter idle (-50 dBm)**	**Corrected PR Receiver 1 no filter idle (-50 dBm)**	**Interference received level (dBm)**	**PR Receiver 1 + Amp 3 no filter idle (-50 dBm)**	**Corrected PR Receiver 1 + Amp 3 no filter idle (-50 dBm)**	**Interference received level (dBm)**	**PR Receiver 1 + Amp 3 + filter idle (-50 dBm)**	**Corrected PR Receiver 1 + Amp 3 + filter idle (-50 dBm)**	**Interference received level (dBm)**
Bel-Air, Coromandel, Terre Rouge	60	-39.8	-37	-13	-14.7	-11.9	-38.1	-42.8	-40	-10
All other stations	58 and less	NF	NF	NF	-20.3	-17.5	-32.5	NF	NF	NF
Best Server coverage	**Channel No.**	**PR Receiver 1 no filter idle (-60 dBm)**	**Corrected PR Receiver 1 no filter idle (-60 dBm)**	**Interference received level (dBm)**	**PR Receiver 1 + Amp 3 no filter idle (-60 dBm)**	**Corrected PR Receiver 1 + Amp 3 no filter idle (-60 dBm)**	**Interference received level (dBm)**	**PR Receiver 1 + Amp 3 + filter idle (-60 dBm)**	**Corrected PR Receiver 1 + Amp 3 + filter idle (-60 dBm)**	**Interference received level (dBm)**
Bel-Air, Coromandel, Terre Rouge	60	-42.7	-39.9	-20.1	-20.7	-17.9	-42.1	-43.7	-40.9	-19.1
All other stations	58 and less	-48.9	-46.1	-13.9	-28.6	-25.8	-34.2	-52.9	-50.1	-9.9
Best Server coverage	**Channel No.**	**PR Receiver 1 no filter idle (-70 dBm)**	**Corrected PR Receiver 1 no filter idle (-70 dBm)**	**Interference received level (dBm)**	**PR Receiver 1 + Amp 3 no filter idle (-70 dBm)**	**Corrected PR Receiver 1 + Amp3 no filter idle (-70 dBm)**	**Interference received level (dBm)**	**PR Receiver 1 + Amp 3 + filter idle (-70 dBm)**	**Corrected PR Receiver 1 + Amp 3 + filter idle (-70 dBm)**	**Interference received level (dBm)**
Bel-Air, Coromandel, Terre Rouge	60	-40.3	-37.5	-32.5	-29.8	-27	-43	-43.2	-40.4	-29.6
All other stations	58 and less	-46.7	-43.9	-26.1	-37.2	-34.4	-35.6	-52.9	-50.1	-19.9

Table 4: Protection Ratios and In-block (796 MHz) interference received signal level for Receiver 1

The 64 QAM 2/3 protection ratios from the ERA Technologies Report[24] for Receiver 1 without filter, with Amplifier 3 and without filter and with Amplifier 3 and filter for the LTE base station in the idle mode have been corrected by 2.8 dB in order to obtain the protection ratios applicable for 64-QAM ¾.

[24] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/28073/era.pdf

Receiver 1: Estimated Coverage Hole Radius corresponding to protection ratios in Table 4

		Receiver 1 Only			Receiver 1 + Amplifier			Mitigation Technique - Filter		
Best Server coverage	**Channel No.**	**Urban CHR no filter (-50 dBm)(km)**	**Suburban CHR no filter (-50 dBm)(km)**	**Rural CHR no filter (-50 dBm)(km)**	**Urban CHR Amp 3 no filter idle (-50 dBm) (km)**	**Suburban CHR Amp 3 no filter idle (-50 dBm) (km)**	**Rural CHR Amp 3 no filter idle (-50 dBm) (km)**	**Urban CHR with filter idle (-50 dBm) (km)**	**Suburban CHR with filter idle (-50 dBm) (km)**	**Rural CHR with filter idle (-50 dBm) (km)**
Bel-Air, Coromandel, Terre Rouge	60	(0.4.0.5)	(0.7,0.8)	(0.8,0.9)	DTTB receivers with Receiver 1 characteristics in entire cell get affected	DTTB receivers with Receiver 1 characteristics in entire cell get affected	>6	(0.3,0.4)	(0.5,0.6)	(0.5,0.6)
All other stations	58 and less	0	0	0	(1.3,1.4)	(2.5,2.6)	>6	0	0	0
Best Server coverage	**Channel No.**	**Urban CHR no filter (-60 dBm)(km)**	**Suburban CHR no filter (-60 dBm)(km)**	**Rural CHR no filter (-60 dBm)(km)**	**Urban CHR Amp 3 no filter idle (-60 dBm) (km)**	**Suburban CHR Amp 3 no filter idle (-60 dBm) (km)**	**Rural CHR Amp 3 no filter idle (-60 dBm) (km)**	**Urban CHR with filter idle (-60 dBm) (km)**	**Suburban CHR with filter idle (-60 dBm) (km)**	**Rural CHR with filter idle (-60 dBm) (km)**
Bel-Air, Coromandel, Terre Rouge	60	(0.5,0.6)	(1.1,1.2)	(1.9,2.0)	DTTB receivers with Receiver 1 characteristics in entire cell get affected	DTTB receivers with Receiver 1 characteristics in entire cell get affected	>6	(0.5,0.6)	(1.0,1.1)	(1.7,1.8)
All other stations	58 and less	(0.4,0.5)	(0.7,0.8)	(0.9,1.0)	(1.5,1.6)	(2.8,2.9)	>6	(0.3,0.4)	(0.5,0.6)	(0.5,0.6)
Best Server coverage	**Channel No.**	**Urban CHR no filter (-70 dBm)(km)**	**Suburban CHR no filter (-70 dBm)(km)**	**Rural CHR no filter (-70 dBm)(km)**	**Urban CHR Amp 3 no filter idle (-70 dBm) (km)**	**Suburban CHR Amp 3 no filter idle (-70 dBm) (km)**	**Rural CHR Amp 3 no filter idle (-70 dBm) (km)**	**Urban CHR with filter idle (-70 dBm) (km)**	**Suburban CHR with filter idle (-70 dBm) (km)**	**Rural CHR with filter idle (-70 dBm) (km)**
Bel-Air, Coromandel, Terre Rouge	60	(1.2,1.3)	(2.5,2.6)	>6	DTTB receivers with Receiver 1 characteristics in entire cell get affected	DTTB receivers with Receiver 1 characteristics in entire cell get affected	>6	(1.0,1.1)	(2.0,2.1)	(5.7,5.8)
All other stations	58 and less	(0.8,0.9)	(1.6,1.7)	(3.8,3.9)	(1.6,1.7)	DTTB receivers with Receiver 1 characteristics in entire cell get affected	>6	(0.5,0.6)	(1.1,1.2)	(1.9,2.0)

Table 5: Estimated Coverage Hole Radius (CHR) corresponding to protection ratios in Table 4. CHR (x,y) means between x km and y km

Receiver 2: Measured Protection Ratio[25]

		Receiver 2 Only			Receiver 2 + Amplifier			Mitigation Technique - Filter		
Best Server coverage	Channel No.	PR Receiver 2 no filter idle (-50 dBm)	Corrected PR Receiver 2 no filter idle (-50 dBm)	Interference received level (dBm)	PR Receiver 2 + Amp 3 no filter idle (-50 dBm)	Corrected PR Receiver 2 + Amp 3 no filter idle (-50 dBm)	Interference received level (dBm)	PR Receiver 2 + Amp 3 + filter idle (-50 dBm)	Corrected PR Receiver 2 + Amp 3 + filter idle (-50 dBm)	Interference received level (dBm)
Bel-Air, Coromandel, Terre Rouge	60	-27.4	-24.6	-25.4	-13.4	-10.6	-39.4	-39	-36.2	-13.8
All other stations	58 and less	-31.4	-28.6	-21.4	-20.4	-17.6	-32.4	NF	NF	NF
Best Server coverage	Channel No.	PR Receiver 2 no filter idle (-60 dBm)	Corrected PR Receiver 2 no filter idle (-60 dBm)	Interference received level (dBm)	PR Receiver 2 + Amp 3 no filter idle (-60 dBm)	Corrected PR Receiver 2 + Amp 3 no filter idle (-60 dBm)	Interference received level (dBm)	PR Receiver 2 + Amp 3 + filter idle (-60 dBm)	Corrected PR Receiver 2 + Amp 3 + filter idle (-60 dBm)	Interference received level (dBm)
Bel-Air, Coromandel, Terre Rouge	60	-31.4	-28.6	-31.4	-20.1	-17.3	-42.7	-39.7	-36.9	-23.1
All other stations	58 and less	-35.8	-33	-27	-27.3	-24.5	-35.5	-52.9	-50.1	-9.9
Best Server coverage	Channel No.	PR Receiver 2 no filter idle (-70 dBm)	Corrected PR Receiver 2 no filter idle (-70 dBm)	Interference received level (dBm)	PR Receiver 2 + Amp 3 no filter idle (-70 dBm)	Corrected PR Receiver 2 + Amp3 no filter idle (-70 dBm)	Interference received level (dBm)	PR Receiver 2 + Amp 3 + filter idle (-70 dBm)	Corrected PR Receiver 2 + Amp 3 + filter idle (-70 dBm)	Interference received level (dBm)
Bel-Air, Coromandel, Terre Rouge	60	-31	-28.2	-41.8	-26.7	-23.9	-46.1	-40.3	-37.5	-32.5
All other stations	58 and less	-45	-42.2	-27.8	-30.3	-27.5	-42.5	-52.9	-50.1	-19.9

Table 6: Protection Ratios and In-block (796 MHz) interference received signal level form Receiver 2

The 64 QAM 2/3 protection ratios from the ERA Technologies Report[24] for Receiver 1 without filter, with Amplifier 3 and without filter and with Amplifier 3 and filter for the LTE base station in the idle mode have been corrected by 2.8 dB in order to obtain the protection ratios applicable for 64-QAM ¾.

[25] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/28073/era.pdf

Receiver 2: Estimated Coverage Hole Radius corresponding to protection ratios in Table 6

		Receiver 2 Only			Receiver 2 + Amplifier			Mitigation Technique - Filter		
Best Server coverage	**Channel No.**	**Urban CHR no filter (-50 dBm)(km)**	**Suburban CHR no filter (-50 dBm)(km)**	**Rural CHR no filter (-50 dBm)(km)**	**Urban CHR Amp 3 no filter idle (-50 dBm) (km)**	**Suburban CHR Amp 3 no filter idle (-50 dBm) (km)**	**Rural CHR Amp 3 no filter idle (-50 dBm) (km)**	**Urban CHR with filter idle (-50 dBm) (km)**	**Suburban CHR with filter idle (-50 dBm) (km)**	**Rural CHR with filter idle (-50 dBm) (km)**
Bel-Air, Coromandel, Terre Rouge	60	(0.8,0.9)	(1.6,1.7)	(3.6,3.7)	DTTB receivers with Receiver 2 characteristics in entire cell get affected	DTTB receivers with Receiver 2 characteristics in entire cell get affected	>6	(0.4, 0.5)	(0.9,1.0)	(0.7,0.8)
All other stations	58 and less	(0.6,0.7)	(1.2,1.3)	(2.3,2.4)	(1.3,1.4)	(2.5,2.6)	>6	0	0	0
Best Server coverage	**Channel No.**	**Urban CHR no filter (-60 dBm)(km)**	**Suburban CHR no filter (-60 dBm)(km)**	**Rural CHR no filter (-60 dBm)(km)**	**Urban CHR Amp 3 no filter idle (-60 dBm) (km)**	**Suburban CHR Amp 3 no filter idle (-60 dBm) (km)**	**Rural CHR Amp 3 no filter idle (-60 dBm) (km)**	**Urban CHR with filter idle (-60 dBm) (km)**	**Suburban CHR with filter idle (-60 dBm)**	**Rural CHR with filter idle (-60 dBm) (km)**
Bel-Air, Coromandel, Terre Rouge	60	(1.2,1.3)	(2.4,2.5)	>6	DTTB receivers with Receiver 2 characteristics in entire cell get affected	DTTB receivers with Receiver 2 characteristics in entire cell get affected	>6	(0.7,0.8)	(1.3,1.4)	(2.7,2.8)
All other stations	58 and less	(0.9,1.0)	(1.7,1.8)	(4.3,4.4)	(1.6,1.7)	DTTB receivers with Receiver 2 characteristics in entire cell get affected	>6	(0.3,0.4)	(0.5,0.6)	(0.5,0.6)
Best Server coverage	**Channel No.**	**Urban CHR no filter (-70 dBm)(km)**	**Suburban CHR no filter (-70 dBm)(km)**	**Rural CHR no filter (-70 dBm)(km)**	**Urban CHR Amp 3 no filter idle (-70 dBm) (km)**	**Suburban CHR Amp 3 no filter idle (-70 dBm) (km)**	**Rural CHR Amp 3 no filter idle (-70 dBm) (km)**	**Urban CHR with filter idle (-70 dBm) (km)**	**Suburban CHR with filter idle (-70 dBm)**	**Rural CHR with filter idle (-70 dBm) (km)**
Bel-Air, Coromandel, Terre Rouge	60	DTTB receivers with Receiver 2 characteristics in entire cell get affected	DTTB receivers with Receiver 2 characteristics in entire cell get affected	>6	DTTB receivers with Receiver 2 characteristics in entire cell get affected	DTTB receivers with Receiver 2 characteristics in entire cell get affected	>6	(1.3,1.4)	(2.5,2.6)	>6
All other stations	58 and less	(0.9,1.0)	(1.9,2.0)	(4.8,4.9)	DTTB receivers with Receiver 2 characteristics in entire cell get affected	DTTB receivers with Receiver 2 characteristics in entire cell get affected	>6	(0.5,0.6)	(1.1,1.2)	(1.9,2.0)

Table 7: Estimated Coverage Hole Radius (CHR) corresponding to protection ratios in Table 6. CHR (x,y) means between x km and y km

8.0 Analysis of results and Conclusions

As shown by the results above, the degree by which DTTB receivers operating in the 470 – 790 MHz band are expected to be affected by the introduction of LTE800 in the 791 – 862 MHz band depends on the following factors:-

1. The available guard band between the LTE800 emission and the DTTB channel being operated in a particular broadcasting coverage area. Regions within the coverage of DTTB Channel 60 have a greater potential of being affected given that only 1 MHz of guard band has been catered for;
2. The DTTB received signal level. Three levels have been considered, namely -50dBm, -60dBm and -70dBm. It is clear that those regions with higher DTTB signal levels are the ones that are expected to be less affected by both interference due to receiver overload as well as Out-of-Band emissions from the LTE800 Base Stations;
3. The technical characteristics of the DTTB receivers in use, particularly their behaviour in the presence of interference from LTE800 downlink ;
4. The use of distribution amplifiers;
5. The operating environment of the LTE800 base station. This includes the antenna height as well as the propagation environment, i.e. whether urban, suburban or rural.

The results estimated that the maximum distance between the LTE800 base station and a DTTB receiver where interference occurs to around 5km in regions under the coverage of DTTB channel 58 and lower and to more than 6 km in regions under the coverage of DTTB Channel 60. Real life interference from LTE800 to DTTB reception in France was recorded at a maximum distance of 5.77 km and an average distance of 582 m[26].

The results also show that the following mitigation techniques may be used to address the three identified interference mechanisms:-

Interference Mechanism	**Mitigation Technique**
Receiver/distribution amplifier overload	Filter to be installed in-line with amplifier or receiver
N+9 image Interference	Filter to be installed in-line with amplifier or receiver
Out-of-band emissions	Base Station downlink filtering and reduction in transmitter power of the base station

[26] https://cept.org/Documents/se-7/20816/se7-14-110_real-life_interfer-ence_-from_lte800-to-dttb

Annex C: DTTB Coverage Simulated with a 100mx100m resolution

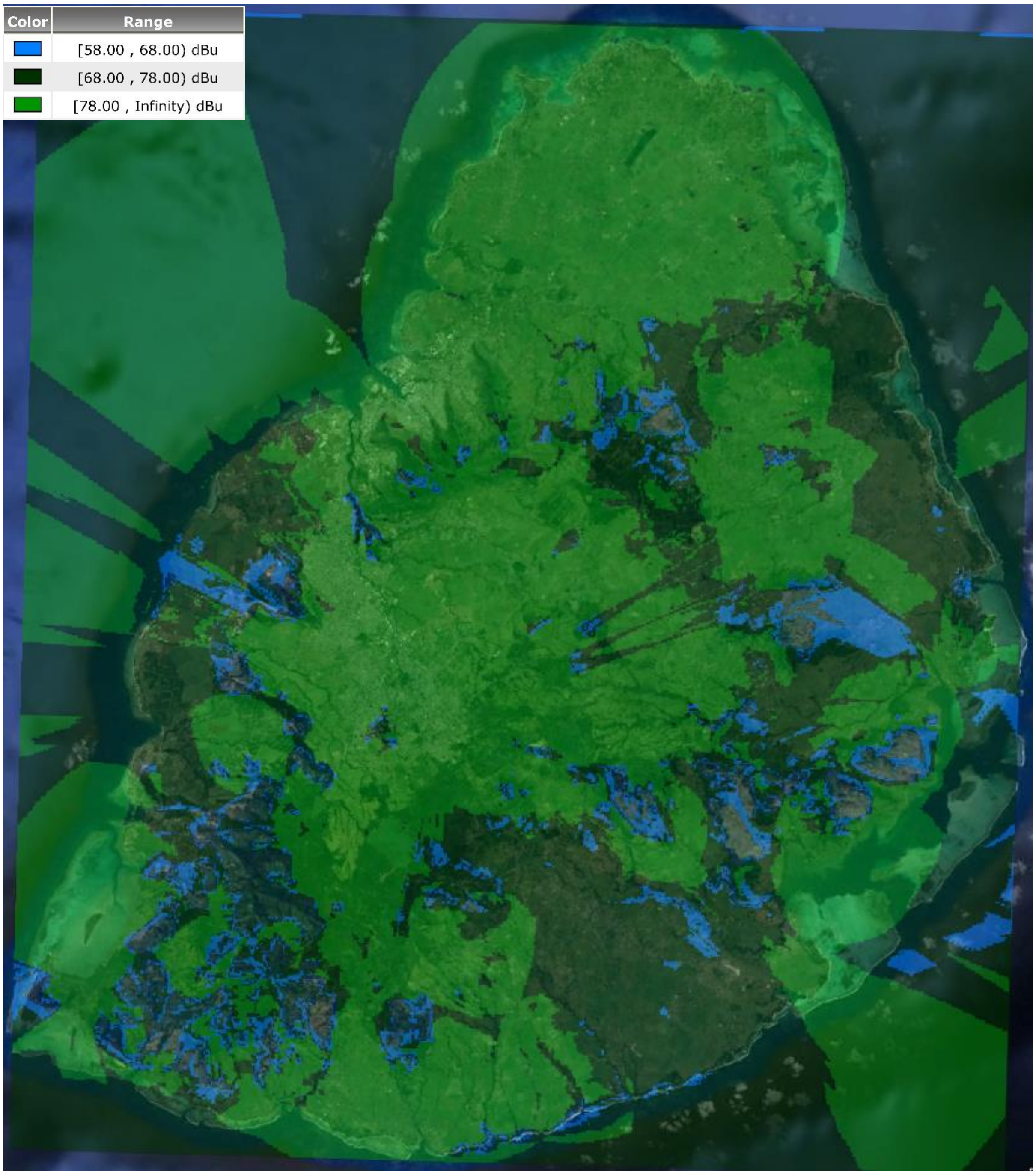


Figure C1: Simulated DTTB Nationwide Coverage

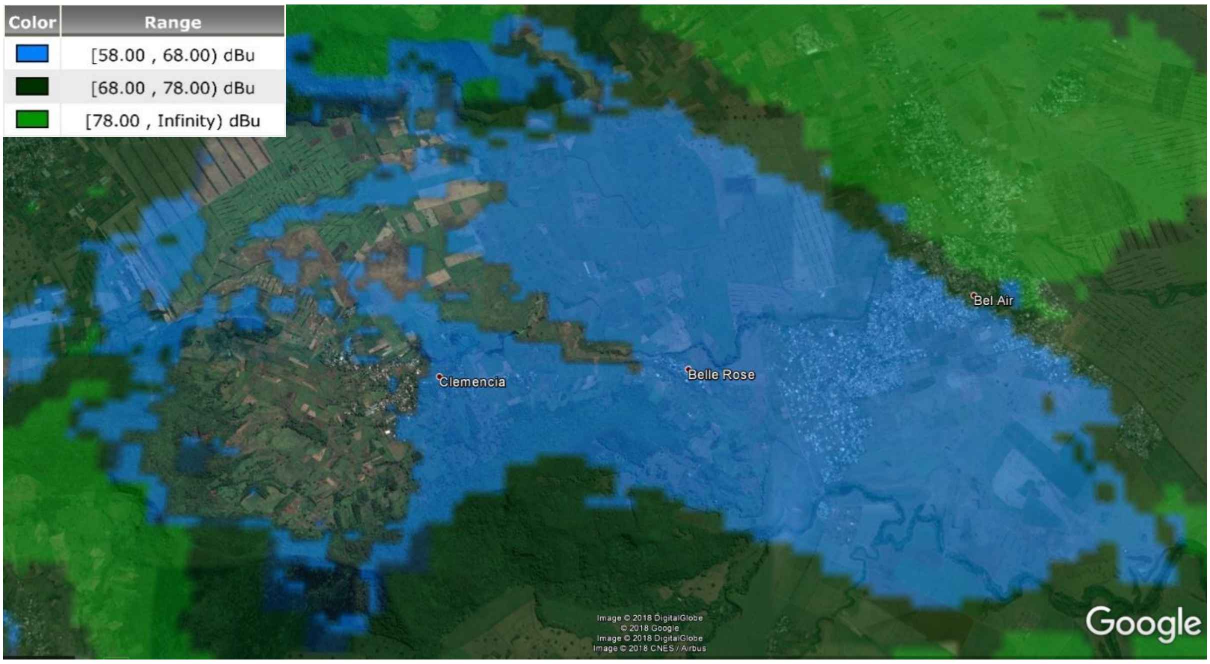


Figure C2: Regions in the East (in blue and clear) where special attention may be required according to simulation

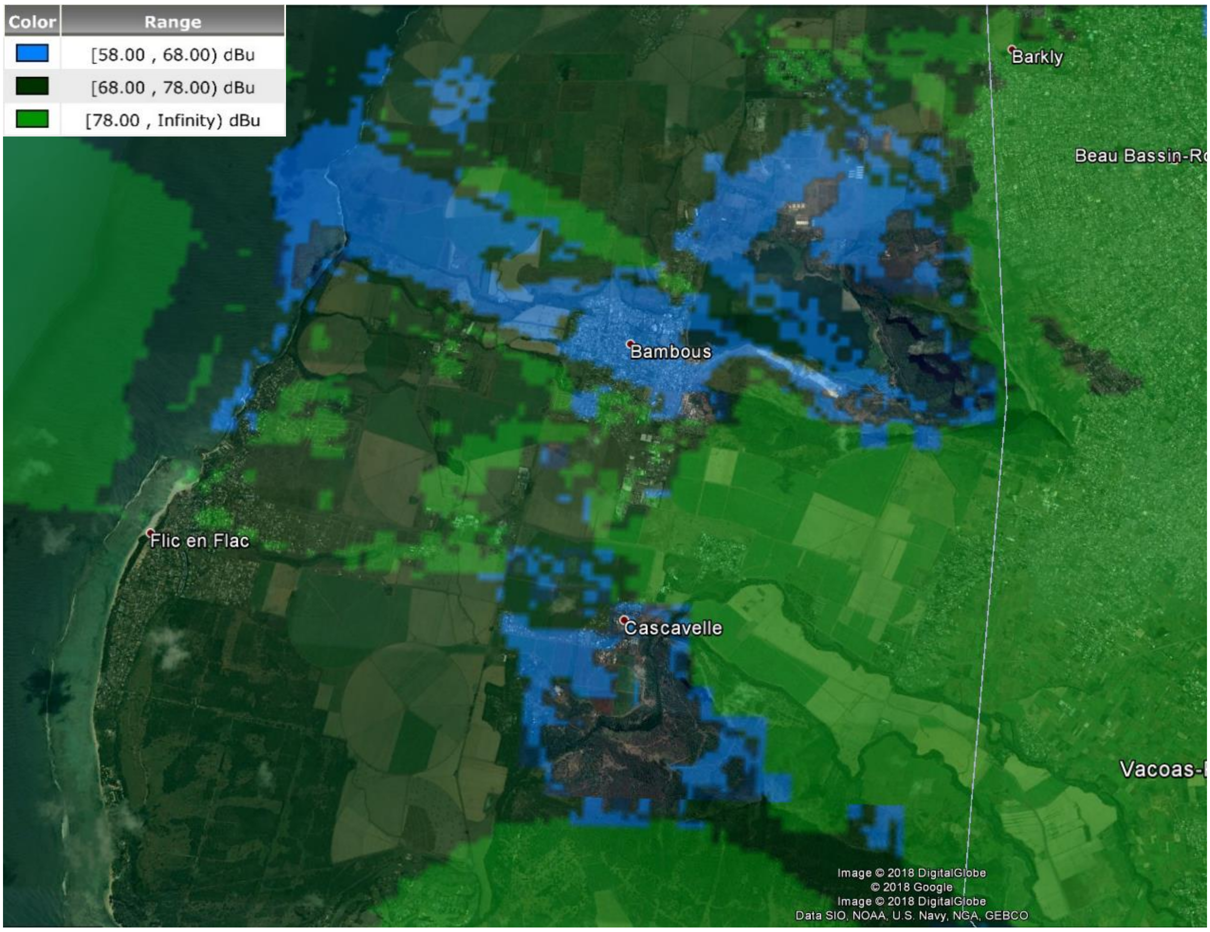


Figure C3: Regions in the West (in blue and clear) where special attention may be required according to simulation

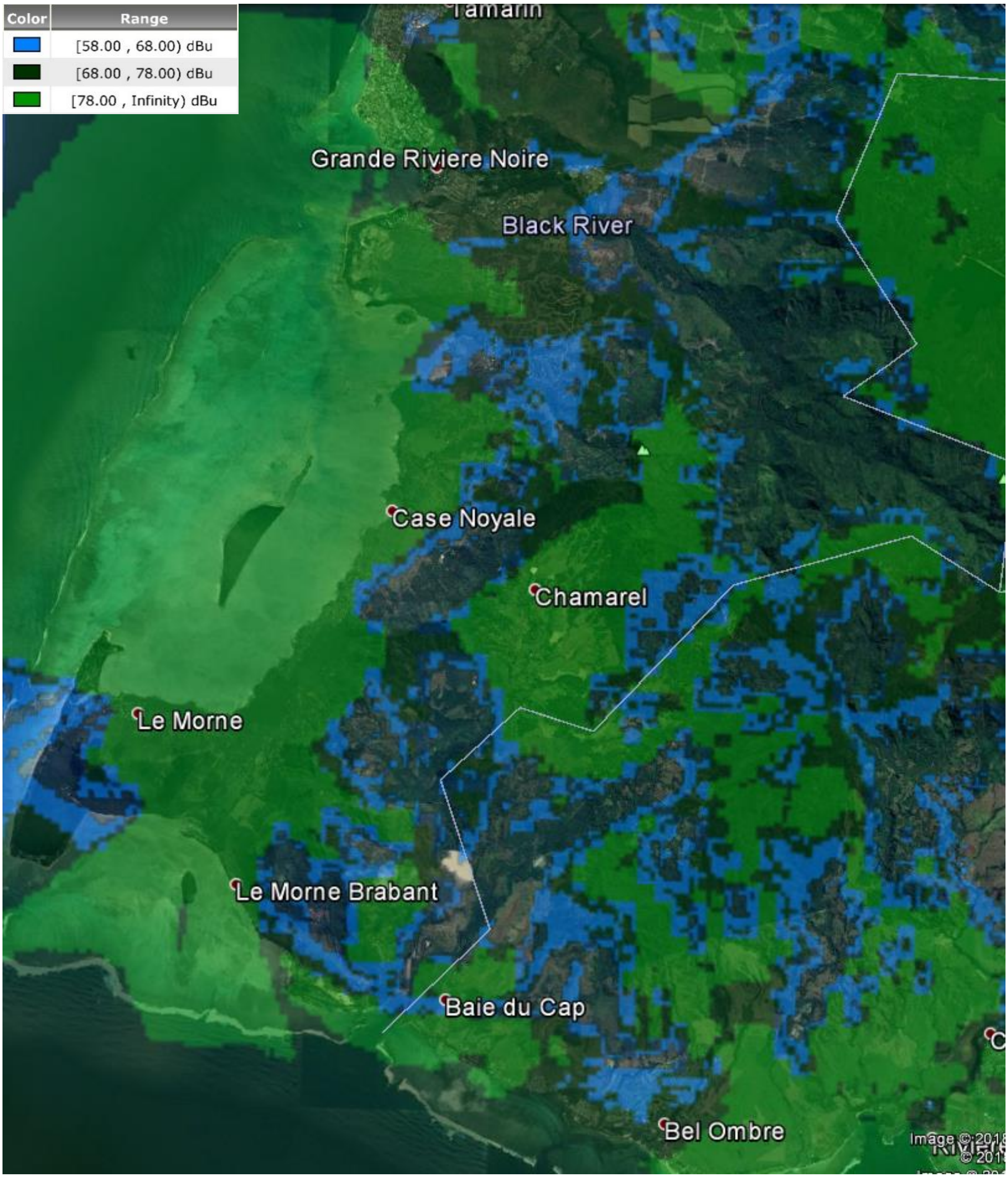


Figure C4: Regions in the South-West (in blue and clear) where special attention may be required according to simulation

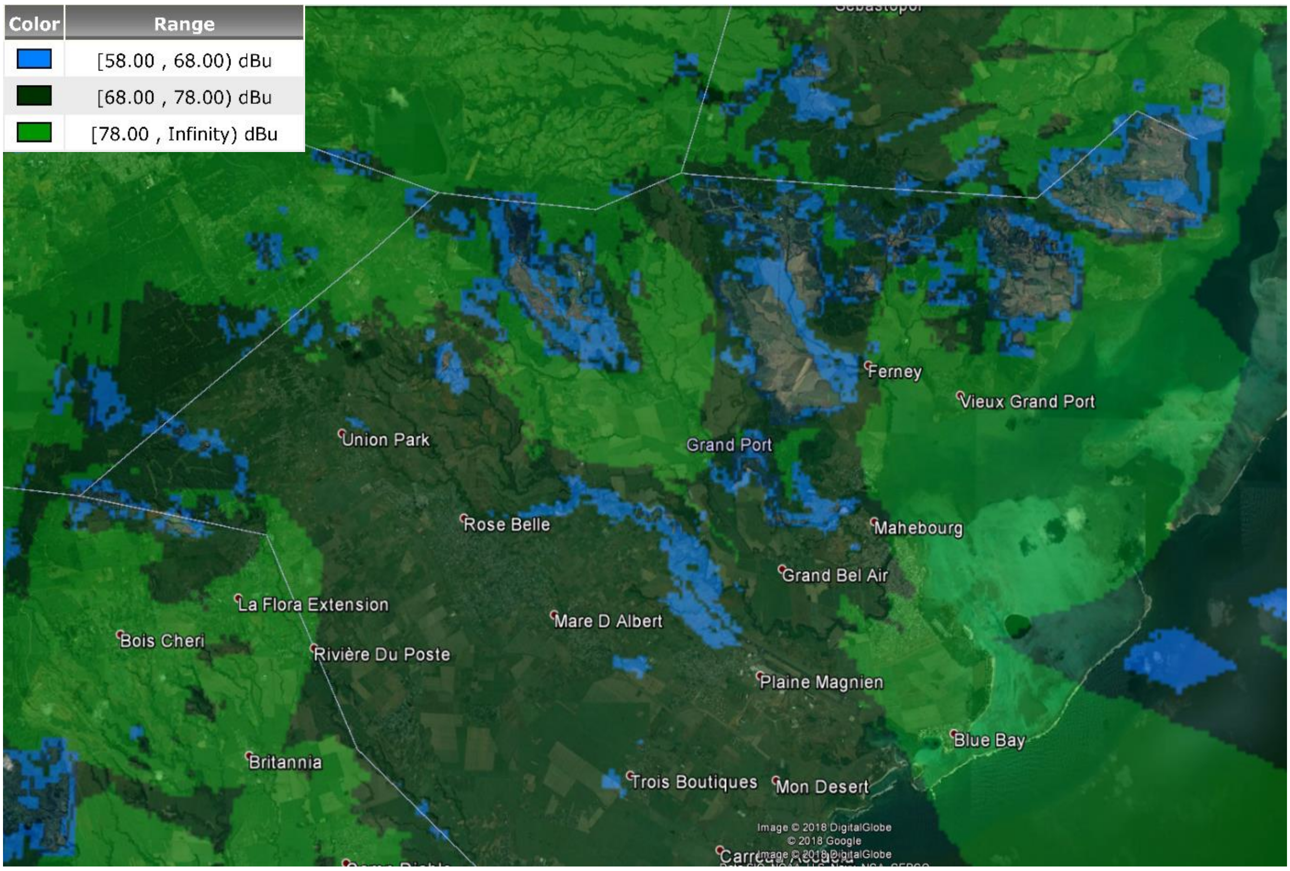


Figure C6: Regions in the South-East (in blue and clear) where special attention may be required according to simulation