An Coimisiún um
Rialáil Cumarsáide
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Update on 2.3 GHz and 2.6 GHz co-existence analysis reports (Documents 19/59d and 19/59c)

A report from Plum Consulting London LLP

Consultant Report

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Update on 2.3 GHz and 2.6 GHz co-existence analysis reports (Documents 19/59d and 19/59c)

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About Plum

Plum is an independent consulting firm, focused on the telecommunications, media, technology, and adjacent sectors. We apply extensive industry knowledge, consulting experience, and rigorous analysis to address challenges and opportunities across regulatory, radio spectrum, economic, commercial, and technology domains.

About this study

This study for ComReg identifies the co-existence considerations and associated technical conditions and interference mitigation approaches for the 2.3 and 2.6 GHz bands.

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1 Introduction

On 18 June 2019, ComReg published its consultation Document 19/59R, on the Proposed Multi Band Spectrum Award for the 700 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz Bands. As part of this consultation ComReg published two reports from Plum Consulting:

- Document 19/59c: a report analysing the potential compatibility and co-existence measures necessary to facilitate the co-existence of future Wireless Broadband (WBB) networks in the 2.6 GHz band with aeronautical radars in the 2700 – 2900 MHz (the 2.7 GHz Band); and

- Document 19/59d: a report analysing the potential compatibility and co-existence measures necessary to facilitate the co-existence of future WBB networks in the 2.3 GHz band with Eir’s RurTel network, and wireless local area networks (WLANs) in the 2.4 GHz band (i.e. Wi-Fi).

This report details the further work undertaken by Plum since the publication of the two reports published as part of ComReg Document 19/59R. This report is structured as follows:

- Section 2 analyses the responses received to the ComReg Document 19/59R consultation and in particular those relating to documents 19/59c and 19/59d.

- Section 3 provides a brief overview of the field trials at the Shannon ATC radar site which were undertaken to determine the susceptibility of the aeronautical radar operating at 2.7 GHz (S-band) to interference from new communication networks in the adjacent 2.6 GHz band. These fields trials were also conducted to confirm the assumptions and conclusions of the compatibility analysis undertaken in Document 19/59c which were based on the Belgian testing[1] parameters.

- Section 4 provides updated interference plots for the STAR2000[2] radars at Cork, Dublin and Shannon based on the results of the field trials (see, ‘Plum radar measurements (final report)’, dated 13 December 2019 (Document 19/124d). In particular, changes to the radar antenna performance have been implemented to provide more accurate representation of the interference contours.

- Section 5 includes a new interference plot for the TA10 radar at Dublin Airport (‘Radar Head 2’) which aims to provide an indication to ComReg of the compatibility and coexistence impact between MFCN deployments and this operating radar if this service remains in operation longer than previously anticipated. The analysis in this report uses the protection criterion obtained from the Belgian testing of the TA10 radar.

- Section 6 provides an updated compatibility analysis for the 2.3 GHz band based on updated information of the RurTel network provided by Eir on 31st October 2019 and subsequently on 5th December 2019. In particular the Kerry RurTel system has been decommissioned and updated information provided on the Galway and Donegal networks.

- Section 7 presents the final recommendations made by Plum and provides, where appropriate, an update to those recommendations made in ComReg Documents 19/59c and 19/59d.

[1] The Belgium measurements are described in the report “Study of the Performance Degradation of the Belgian S-band Air Surveillance Radars due to the Interference of Upcoming 4G Technologies”, available on the website of the Belgian regulator, BIPT: https://www.bipt.be/en/operators/radio/rights-of-use/terminated-allocation-procedures/study-of-the-performance-degradation-of-the-belgian-s-band-air-surveillance-radars-due-to-the-interference-of-upcoming-4g-technologies

[2] Thales STAR2000 radars are operated by the IAA in Dublin, Shannon and Cork.

2 Consultation responses

2.1 Introduction

There was a total of 11 responses to ComReg's consultation on the "Proposed Multi Band Spectrum Award: Including the 700 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz Bands" (Document 19/59R).

There were four inputs that related to the studies undertaken by Plum with regards to the 2.3 GHz and 2.6 GHz bands:

- Ericsson noted that the technical conditions in Annex 12 of Document 19/59R for the 2.6 GHz (also 2.1 GHz) band did not seem to address Active Antenna Systems (AAS) as they refer to EC Decisions updated in 2008 and 2012.
- Imagine, Three and Vodafone commented on the use of the 2.3 GHz band for RurTel deployments.

These are addressed in the following sections.

2.2 Ericsson comment on Active Antenna Systems

"As a general comment on the technical conditions as set out in Annex 12 for the 2.1 GHz and 2.6 GHz bands; they do not seem to address AAS (Active Antenna Systems) as they only refer to the EC Decisions that were last updated in 2008 and 2012.

Noting that these technical conditions have been updated to include technical conditions for AAS, which resulted in the newly approved ECC DEC (06)01 and ECC DEC (05)05 respectively for the bands 2.1 GHz and 2.6 GHz, and noting that the related CEPT Report 72, which constitutes the basis for the planned update of EC DEC 2012/688/EU and 2008/477/EC, Ericsson encourages ComReg to include the technical conditions for AAS as set by ECC DEC (06)01 and ECC DEC (05)05 into Annex 12."

Plum's response

The comment from Ericsson relates to the technical conditions and not the sharing study undertaken by Plum. However, with regards to AAS, Plum's study on sharing with radars (Appendix A of Document 19/59c) notes that the subject was still under study. The work on AAS is now concluding and in the case of co-existence with radars:

CEPT Report 72 (published on 5 July 2019) says:

"*Concerning the LRTC (BEM), for the 2.6 GHz frequency band:*

Moreover, measures applicable at national level, such as pfd limits in order to protect the various types of radars above 2700 MHz would remain applicable, noting that it may be more complex for operators to comply with the pfd limit since AAS systems cannot be fitted with additional external filters. "

Draft ECC Report 308 (agreed for public consultation at the ECC meeting 2 – 5 July in Sofia, Bulgaria) says:

"*Measures for the coexistence with other services; radar >2700MHz; with respect to non-AAS:*

There is possibility of higher interference for AAS compared to non-AAS for sectors pointing towards such other services stations for frequencies close to the upper edge of the DL band where the beam is still more likely to be beamformed. When AAS is not pointing towards such other services stations (i.e. outside ±60 degree of AAS antenna boresight), AAS is not expected to cause more interference than non-AAS BSs."

Hence, although not raised by any respondents Plum's analysis and recommendations still apply.

2.3 Imagine's comment on RurTel deployments

"Ref 6.52

While technically it may be appropriate to consider interference issues the approach taken here is significantly disproportionate to the underlying service. To consider effectively sterilising significant portions of the national geography and 20MHz of valuable spectrum to provide basic telephony to c. 87 customers is excessive in the extreme. Almost any other approach would be more acceptable than this given the time, effort and cost that will be needed to engineer, implement, monitor and police such an arrangement. We strongly suggest a revised approach to this issue including the provision of a hard deadline to provide alternative service to these 87 customers.

Ref 6.58

We believe the best approach here is to give Eir a hard deadline to execute a shutdown of the network."

Plum's response

The Plum study identified potential co-ordination areas based on available RurTel parameters as described in Appendix A.2 of Document 19/59d. These parameters were derived from data provided by ComReg and Eir[3]. It is noted that Eir did not comment on the validity of the assumptions in their response to Document 19/59R.

The analysis has since been updated based on information provided by Eir on 31st October 2019 and 5th December 2019. The Kerry RurTel system has been decommissioned and the Galway and Donegal networks revised.

The outcome of the studies does not mean that in practice there may be significant sterilisation of portions of the national geography but does require additional analysis / network planning by the winning bidder to address possible interference until the RurTel services have transitioned out of the 2.3 GHz band.

2.4 Three's comment on RurTel deployments

"The use of this band by Eir to provide Rurtel services to a very small number of customers presents a number of issues for the award of the band…. In Figure 10 of the consultation document, ComReg presents exclusion/coordination zones that would be required around the Rurtel stations. These are surprisingly large considering the number of customers served, and in fact a substantial part of the geography of Ireland is within the coordination zones."

"In the meantime, Eir should be required to reduce the bandwidth used by Rurtel to the minimum required. Donegal has the highest number of users at just 77. Even though some repeaters may be required, it seems

[3] See correspondence between ComReg and Eir in Document 19/59f

difficult to justify the use of a full 20 MHz in any of the three locations. Eir should be required to reduce this bandwidth to the minimum necessary, and to justify that bandwidth in each location."

Plum's response

The sharing analysis is based on available parameters for the RurTel system as described in Appendix A.2 of Document 19/59d. These parameters were derived from data provided by ComReg and Eir[4].

The analysis has since been updated based on information provided by Eir on 31st October 2019, in particular the Kerry RurTel system has been decommissioned and the Galway and Donegal networks revised. Due to the nature of RurTel systems, Plum understand that unless the sites are decommissioned the RurTel bandwidth cannot be reduced and is currently operating from 2307-2327 MHz.

In relation to reducing coordination areas, Plum note further comments were received from Eir on 5th December 2019, it was considered by Plum that this information would not impact the output of the modelling completed to date, in particular as no revised equipment parameters were available and this was one key area of uncertainty. The use of detailed technical parameters for specific sites in the modelling may lead to an amendment of the co-ordination zones but currently there is no basis for further amending the outcome of the Plum analysis.

2.5 Vodafone's comment on RurTel deployment

"Change B. Remove Uncertain Transition in the 2.3 GHz band.

10. The current proposed auction design has a number of complications generated by issues in the 2.3GHz band. These complications are principally related to the current use by eir of parts of this band for the legacy Rurtel Service. A very valuable portion of spectrum is being made unavailable in a large geographic area of the country for an unspecified time. In Kerry, for example, this spectrum is being used to serve 2 customers. This is an extreme example of inefficient use of spectrum.

Plum's response

The sharing analysis is based on available parameters for the RurTel system as described in Appendix A.2 of Document 19/59d. These parameters were derived from data provided by ComReg and Eir[5].

The analysis has since been updated based on information provided by Eir on 31st October 2019. The Kerry RurTel system has been decommissioned and the Galway and Donegal networks revised.

Plum note further comments were received from Eir on 5th December 2019. It was considered by Plum that these would not impact the output of the modelling completed to date, in particular as no revised equipment parameters were available and this was one key area of uncertainty.

The use of detailed technical parameters for specific sites in the modelling may lead to an amendment of the co-ordination zones.

[4] See correspondence between ComReg and Eir in Document 19/59f
[5] See correspondence between ComReg and Eir in Document 19/59f

3 Field trials at Shannon ATC radar

In considering the approaches taken in the benchmark countries and the analysis and recommendations from Plum in Document 19/59c, ComReg proposed to implement the following mitigation measures to ensure coexistence between aeronautical radars operating in the 2.7 GHz band and new MFCN base stations in the 2.6 GHz band:

- Implementation of filtering at the impacted radars to address interference due to blocking and intermodulation; and
- Implementation of a pfd limit of -145 dBW/m^2/MHz at the antenna of the radar receiver, to address MFCN spurious emissions.
- An additional pfd limit of -83 dBW/m^2 at the antenna of the radar receiver[6] if the radar is unfiltered at time of deployment of MFCN base stations to address in-band blocking and intermodulation effects[7].
- Implementation of a 1 km co-ordination zone[8] from the radar to provide additional protection from MFCN base stations.

In Document 19/59R, ComReg proposed as an additional step to this study, in cooperation with the IAA, to conduct field measurements for adjacent channel coexistence to better inform the above recommendations.

Trials were carried out by Plum in 2019 at the Shannon ATC radar site to determine the susceptibility of the unfiltered Star2000 radar to interference from new communication networks in the adjacent 2.6 GHz band.

The testing confirmed that interference thresholds for two of the three interference mechanisms (intermodulation and spurious emissions) were comparable with those measured on the same model radar in Belgium in 2011 and used for interference modelling by ComReg in Document 19/59c. Although an accurate value could not be obtained for the blocking mechanism, the interference susceptibility of the radar is determined by the other two values, as these occur at significantly lower interference power levels.

The measurements have also confirmed technical characteristics such as the elevation gain pattern of the radar antenna, which were considered useful in refining existing interference predictions. Those predictions, prior to this updated report, made the worst-case assumption that interference enters the radar at the maximum gain of the antenna. In practice, some 9dB of additional discrimination is likely to be available.

A complete report of the 2.6 GHz band radar testing in Shannon is provided in the document, 'Plum radar measurements (final report)', dated 13 December 2019 (Document 19/124d).

[6] Note that the non-linearity of these interference mechanisms means that this limit is expressed in terms of absolute power rather than as a power spectral density, as for the spurious emission limit.

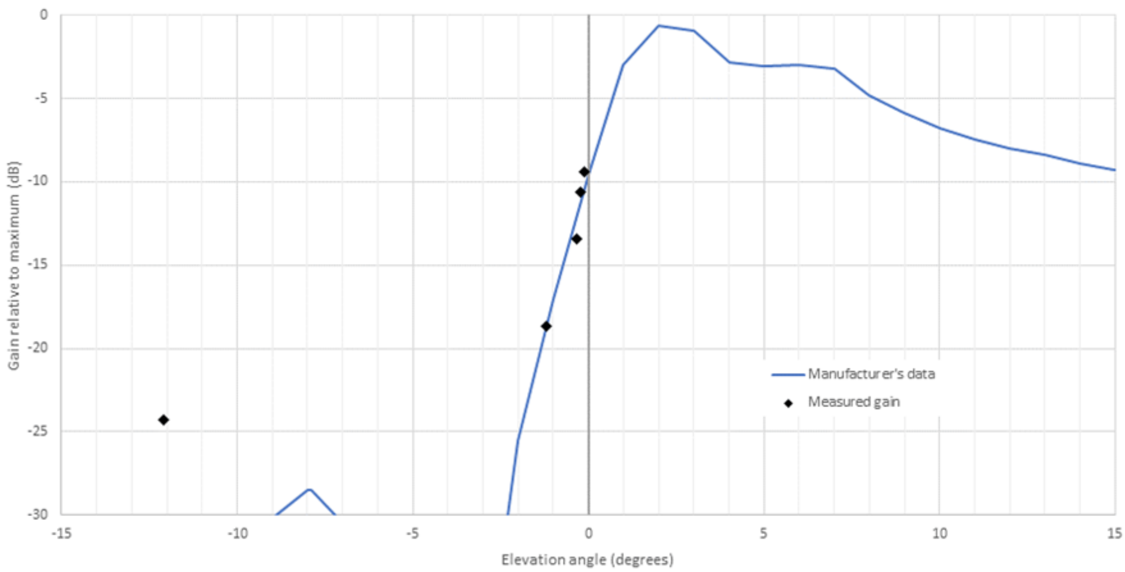
[7] Following successful installation of filters at the radar receiver, no in-band radiation limit is required as filtering at the radar receiver should address the impact of blocking and intermodulation effects at the radar receiver in the adjacent band.

[8] For example, in the UK, Ofcom has specified the coordination procedure in a "Notice of coordination procedure required under spectrum access licences in the 2.6 GHz band". https://www.ofcom.org.uk/__data/assets/pdf_file/0028/37396/im2.pdf

4 Star2000 radars revised compatibility

Following the measurement trials described in Chapter 3, the interference area predictions have been updated based on the measured radar antenna elevation pattern at Shannon shown in Figure 4.1. In addition, the antenna height at Shannon has been reduced to 17 metres from the previous 26.5 metres.

Figure 4.1: Radar elevation pattern



The representative interference threshold levels measured at the STAR2000 are shown below in Figure 4.2.

Figure 4.2: Representative Interference Threshold Levels for STAR 2000 Radars

Parameter	Threshold for STAR2000
Blocking (based on tests with an interfering 64-QAM signal)	-20 dBm
Intermodulation (based on tests with two interfering 64-QAM signals)	-44 dBm
Spurious Emissions (based on tests with an interfering 64-QAM signal)	-106 dBm/MHz

Plots presented in this section show the interference contours (i.e. the potential interference areas) calculated for the three Star 2000 radar sites in Ireland. The contours shown in green, yellow and red illustrate interference areas where the operation of an MFCN base station would not be feasible without exceeding the threshold levels shown in Figure 4.3.

Figure 4.3: Interference contours for Dublin Star2000 airport radar (0.1% time)[9]

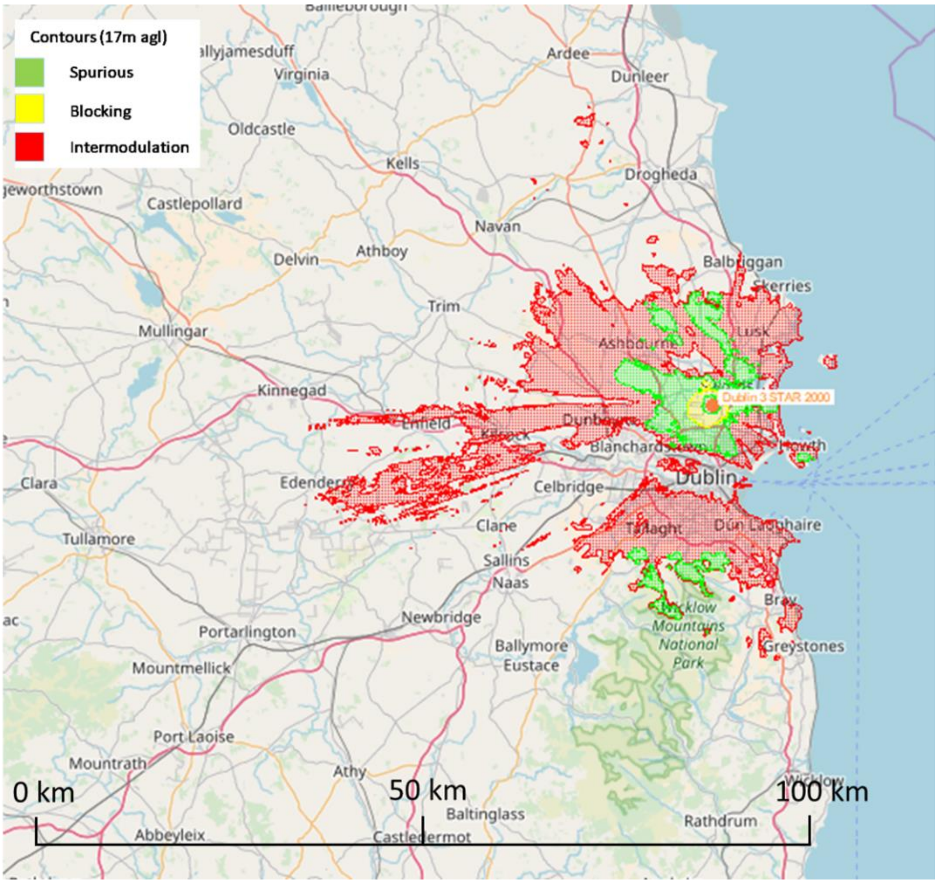


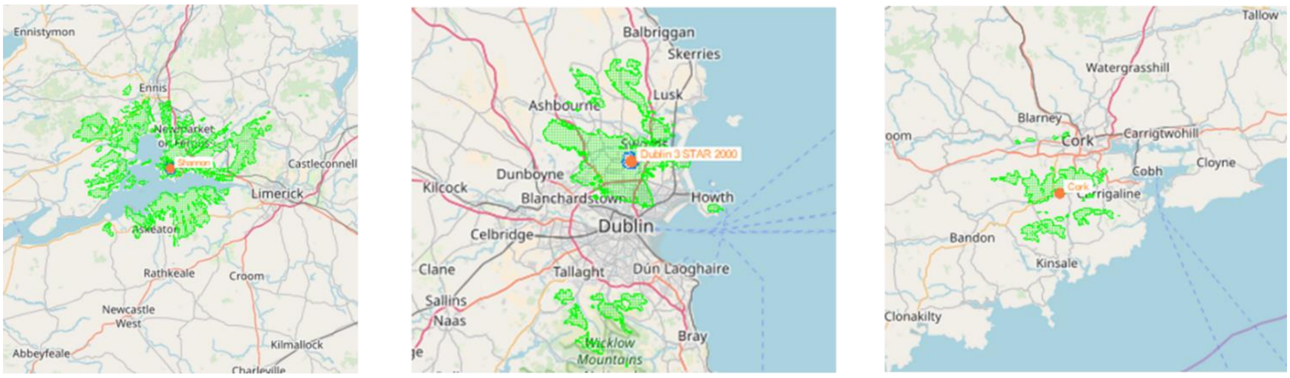
Figure 4.3 above shows that MFCN base stations could not be deployed within distances of up to approximately 50 km from the radar location without exceeding the intermodulation threshold. Similarly, MFCN base stations could not be deployed within a few km from the radar location to satisfy the blocking threshold. These distances could be reduced to the assumed 1 km coordination distance with the use of filters at the radar receiver as demonstrated in the Belgium study.

In order to meet the spurious emission threshold, MFCN base stations should not be deployed within distances up to approximately 30 km from the radar locations in a few azimuths mainly to the north and south of Dublin. However, the interference contours shown for spurious emissions assume that, in the worst case, the MFCN base station antenna gain is 18 dBi and this gain is maintained throughout both MFCN and radar bands. In practice, the gain is likely to fall to a lower value outside the MFCN operating band[10]. A plausible assumption is that the effective MFCN base station antenna gain might be only about 0 dBi, as any spurious emissions within the radar receive band will fall well beyond the design bandwidth of the antenna. This would imply that interference contours will reduce significantly at all three sites as shown below in Figure 4.4.

[9] Input document 4-5-6-7/423 into ITU-R Task Group 4-5-6-7 (10 February 2014) addressing WRC-15 states that radar interference levels should not be exceeded more than 0.1% of time and should be used in propagation models.

[10] We have however been unable to find any specifications or measurements relating to the out of band performance of MFCN antennas as, unsurprisingly, manufacturers do not provide data on performance beyond the intended operating band. To engineer a phased-array antenna with appreciable gain and a good return loss will generally imply a rather steep roll-off in gain out of band, particularly at the high-frequency end.

Figure 4.4: Comparison of 'spurious' contour with assumption of full (18dBi, green) and reduced (0dBi, blue) LTE antenna gain at radar frequency



The three plots above (Figure 4.4) show that if more realistic base station gain values are considered within the radar receiver bandwidth, distances required to protect the radar receivers are in the order of a few kilometres.

The required separation distances for radars at Shannon and Cork airports are shown in the following figures:

Figure 4.5: Interference contours for Shannon Star2000 airport radar (0.1% time)

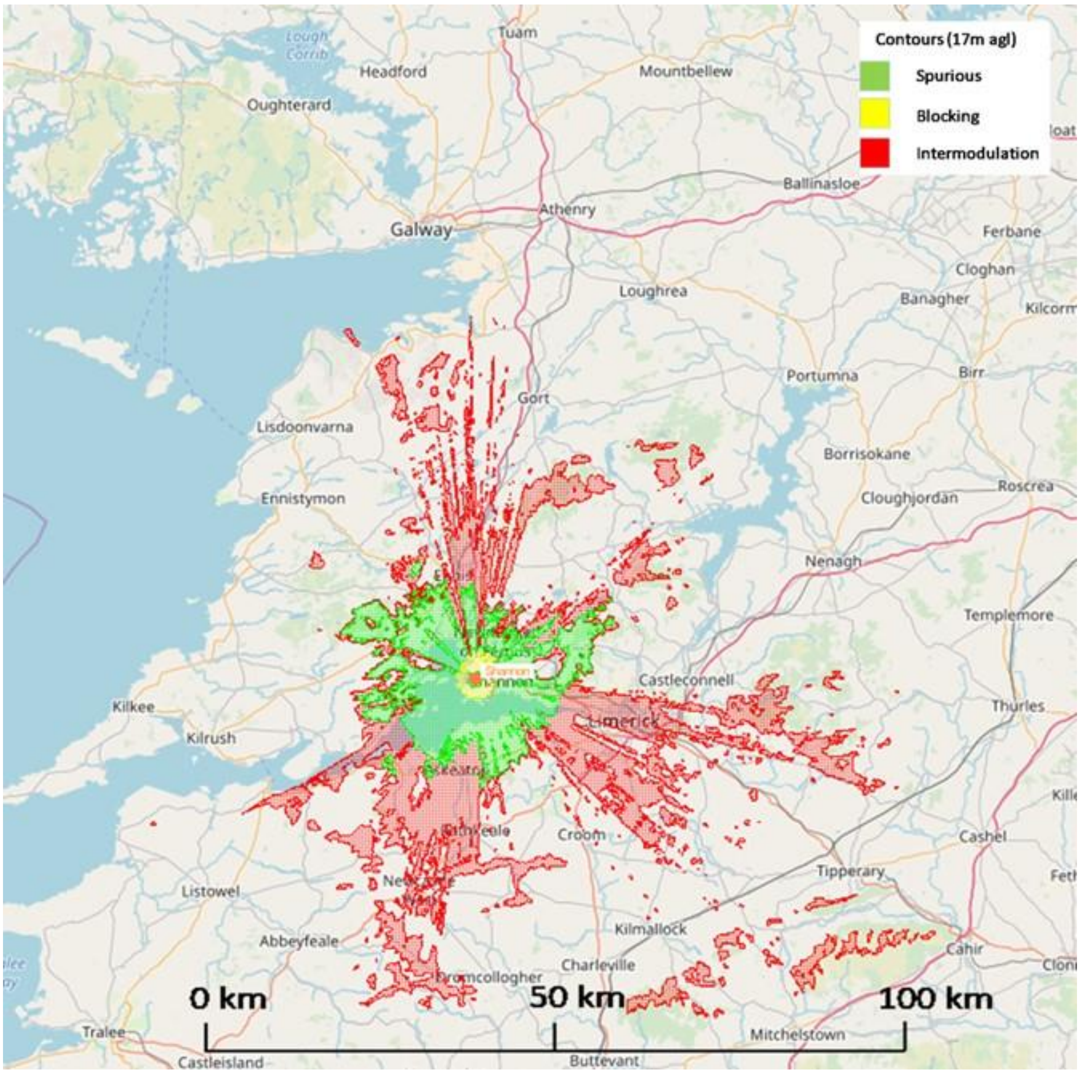
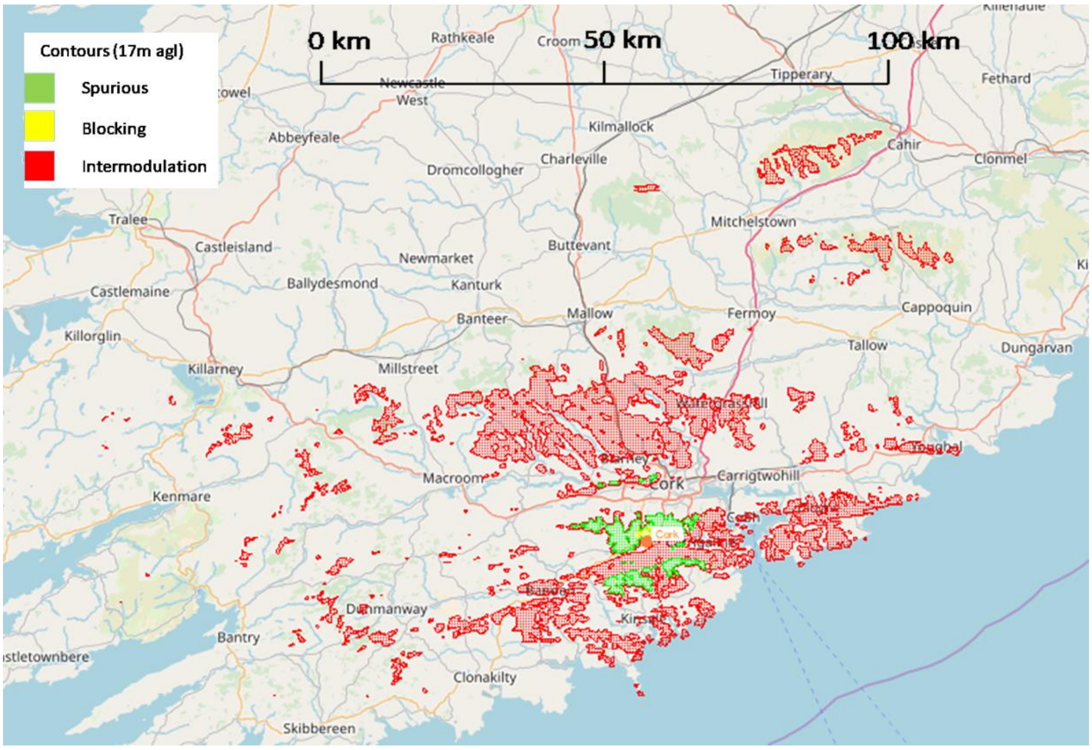


Figure 4.6: Interference contours for Cork Star2000 airport radar (0.1% time)



The figures below show the combined impact of the interference thresholds for all three sites for each mechanism in turn.

Figure 4.7 shows the potential coordination zones due to intermodulation assuming 141.5 dB loss, 0.1 percentage of time and a 17-metre base station antenna height.

Figure 4.7: Coordination zones implied by intermodulation mechanism

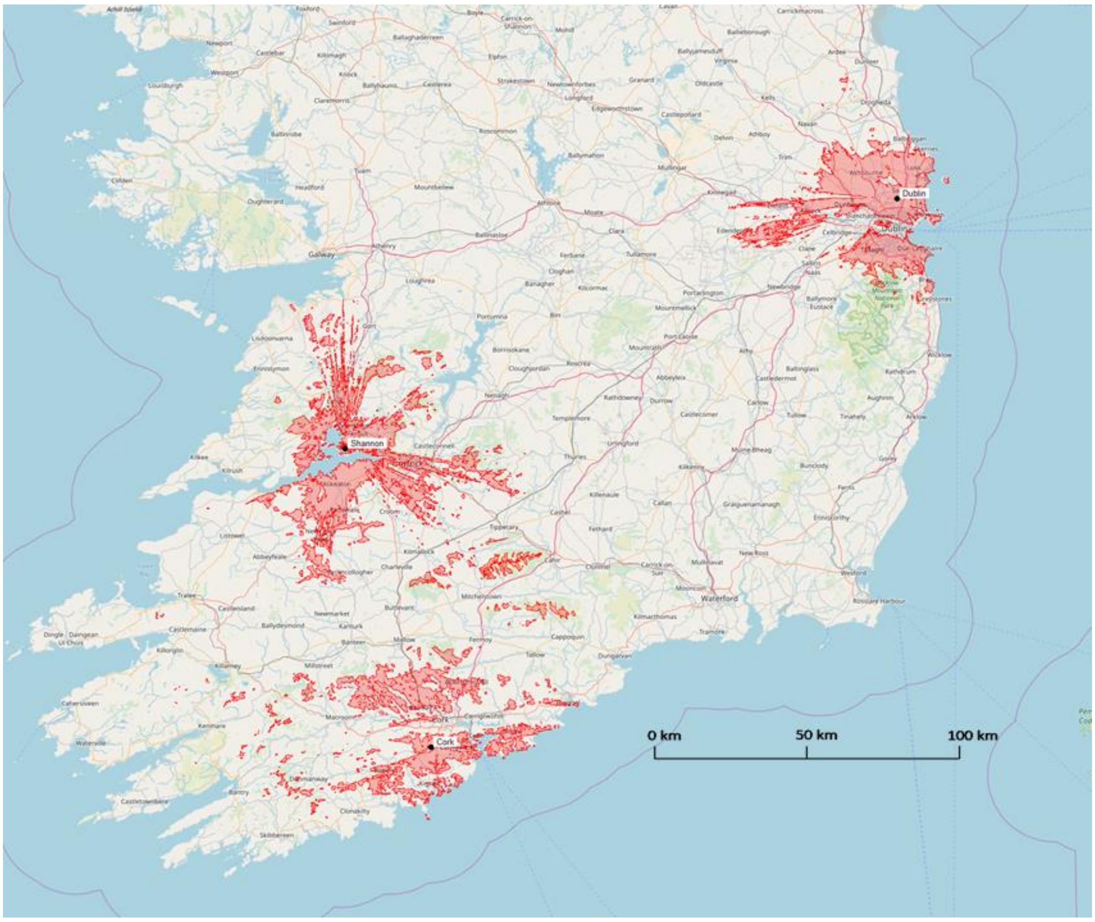


Figure 4.8 shows the potential Coordination zones due to spurious LTE emissions assuming 127.5 dB loss, 0.1 percentage of time and a 17-metre base station antenna height and 18 dBi gain.

Figure 4.8: Coordination zones implied by spurious LTE emissions

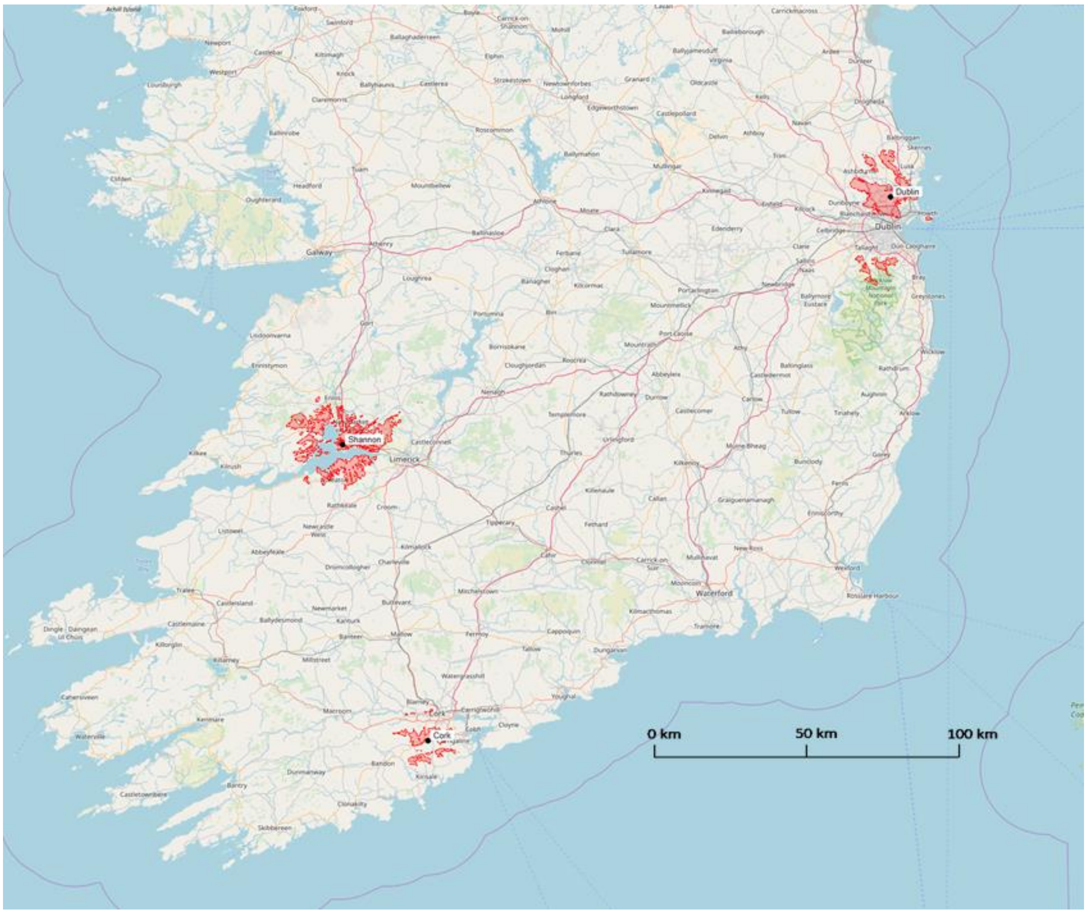
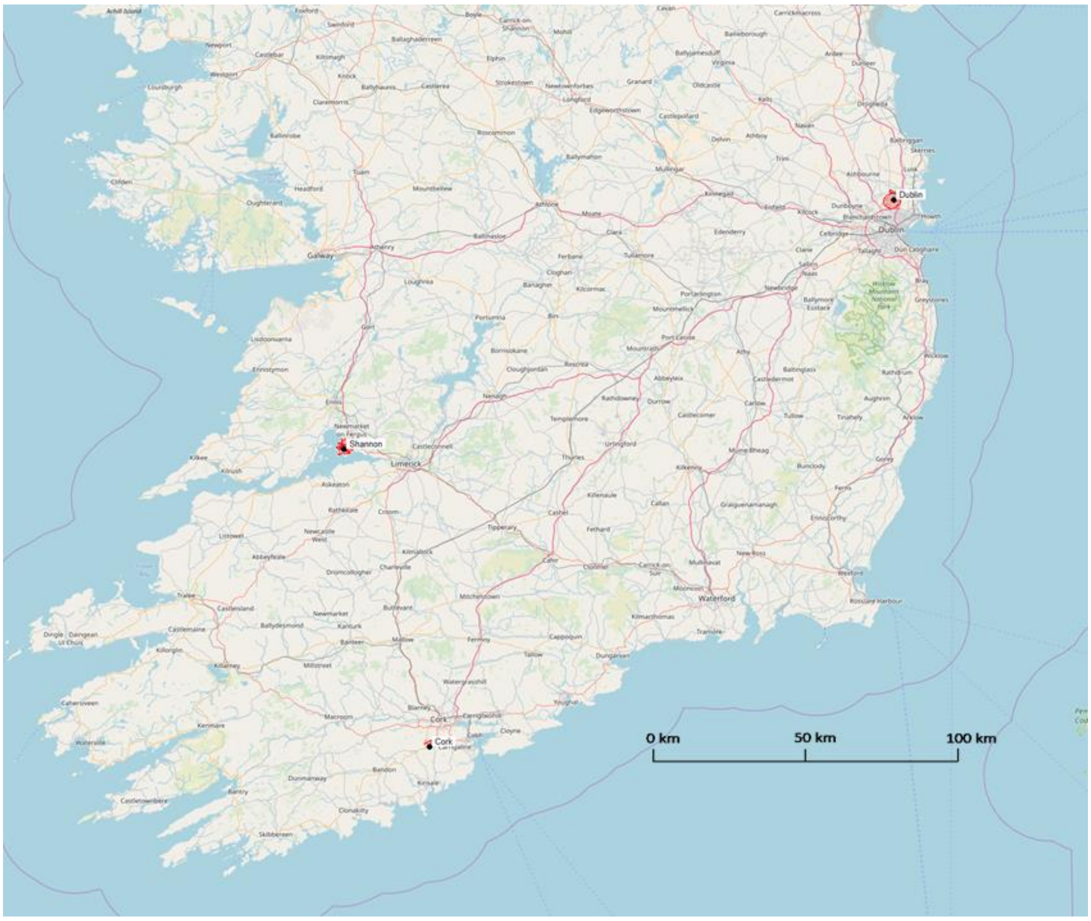


Figure 4.9 shows the potential Coordination zones due to blocking assuming 117.5 dB loss, 0.1 percentage of time and a 17-metre base station antenna height.

Figure 4.9: Coordination zones implied by blocking mechanism



4.1 Conclusions

ComReg Document 19/59c considered studies in France, Belgium and the UK which examined three primary types of interference (blocking, intermodulation and spurious emissions[11]) as a result of MFCN transmitters interfering with radar receivers. The analysis in Chapter 3 of ComReg Document 19/59c examined the potential impact of MFCN base stations on radar systems in Ireland. Based on the results of the three benchmark countries, it was concluded that a number of mitigation techniques can be applied in the Irish context to ensure potential inference from MFCN base stations to radars is minimised. These include the combination of pfd limits, implementation of filtering at the impacted radars and 1 km co-ordination zone[12] from the radar to minimise the following types of interference.

The field trial described in Chapter 3 provides confirmation of the assumptions made in Document 19/59c to reinforce the recommendations as detailed below:

[11] Blocking and intermodulation effects are the result of strong MFCN interfering signals overloading the radar receiver low noise amplifier and causing non-linearity, the lack of sufficient receiver selectivity is the key reason for this type of interference. The third type of interference relates to spurious emissions which are generated by MFCN transmitters and fall within the receiving band of the radars.

[12] For example, in the UK, Ofcom has specified the coordination procedure in a "Notice of coordination procedure required under spectrum access licences in the 2.6 GHz band". https://www.ofcom.org.uk/__data/assets/pdf_file/0028/37396/im2.pdf

- to address interference due to blocking and intermodulation and in line with mitigation techniques of the benchmark countries, radar filters should be installed on the Star 2000 Radar sites in Ireland, at Shannon, Cork and Dublin.
- to address the impact of MFCN spurious emissions, a pfd limit of -145 dBW/m^2/MHz at the antenna of the radar receiver should be satisfied by each operator[13];
- if MFCNs are deployed before radar filters are fitted, an additional in-band radiation limit is required in the frequency range of 2570-2690 MHz to address the impact of blocking and intermodulation effects at radar receivers in the adjacent band. This restriction as derived in this report is a pfd limit of -83 dBW/m^2 at the antenna of the radar receiver [14,15]. Note that the non-linearity of these interference mechanisms means that this limit is expressed in terms of absolute power rather than as a power spectral density, as for the spurious emission limit.
- to ensure protection of radars from MFCN base stations where they are operating in close proximity, a 1 km coordination zone[16] should be applied around the radars in Dublin, Shannon and Cork assuming that radar receivers are fitted with filters:
  - Inside the 1 km coordination zone, MFCN operators are required to coordinate with the radar operator, regardless of antenna gain value or compliance with pfd limit.
  - Outside the 1 km coordination zone, each potential MFCN operator is required to comply with the defined pfd limit (-145 dBW/m^2/MHz)[17].

[13] This limit is derived assuming that there are three licensed operators with equal amount of allocated spectrum. If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-140 + 10 log10 (Bandwidth(MHz) / 120)].
[14] Following successful installation of filters at the radar receiver, no in-band radiation limit is required as filtering at the radar receiver should address the impact of blocking and intermodulation effects at the radar receiver in the adjacent band.
[15] This limit is derived assuming that there are three licensed operators with equal amount of allocated spectrum. If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-78 + 10 log10 (Bandwidth(MHz) / 120)].
[16] As adopted in Belgium
[17] The compliance with pfd limits could be demonstrated by the MNOs using their own analysis tools as adopted, for example, in France.

5 TA10 radar compatibility at Dublin

As noted in ComReg Document 19/59c, from our discussions in meeting with the IAA[18], it was understood that one of the two radars located in Dublin uses an older model Thales TA 10M TD radar. This radar was planned to be decommissioned and replaced with a radar which includes the appropriate filtering to mitigate issues identified in Document 19/59c. Therefore Document 19/59c only considered the remaining three Thales Star 2000 radars used in Shannon, Cork and Dublin and assumed that the Thales TA 10M TD radar would not be in operation when MFCNs are deployed.

Since the publication of Document 19/59c, from discussions with the IAA, ComReg understands that the decommissioning of the TA 10M TD Radar has been delayed. ComReg understands that due to this delay there is the possibility that the TA 10M TD radar may remain in operation in addition to the Star2000 radars when the award commences. In light of this, ComReg has requested Plum to develop Interference area predictions for the existing TA 10M TD radar at Dublin airport to provide an indication of its impact on the 2.6 GHz band prior to its decommissioning.

The following assumptions were used for the TA 10M TD radar plot based on the values obtained by the Intersoft measurements in Belgium:

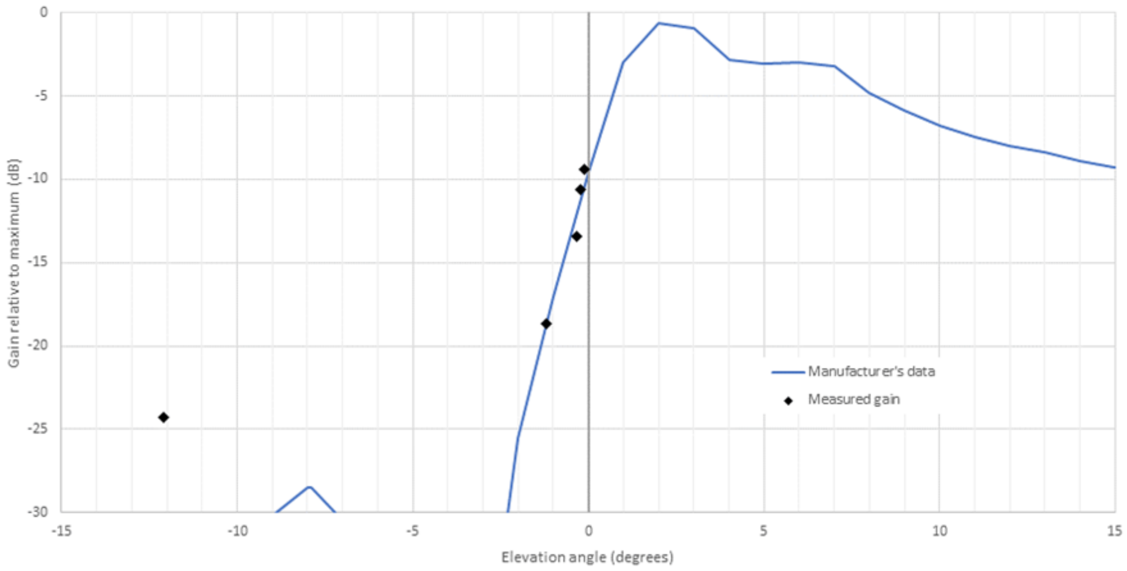
Figure 5.1: Parameters for TA10 radar

Parameter	Threshold for TA10
Blocking	- 50 dBm
Intermodulation	- 53 dBm
Spurious emissions	- 116 dBm
Antenna gain	35.0 dBi

The same radar antenna elevation pattern, as confirmed by the Shannon Star2000 installation, in the measurements described in Chapter 3 was used for this analysis. The radiation elevation pattern is shown below in Figure 5.2.

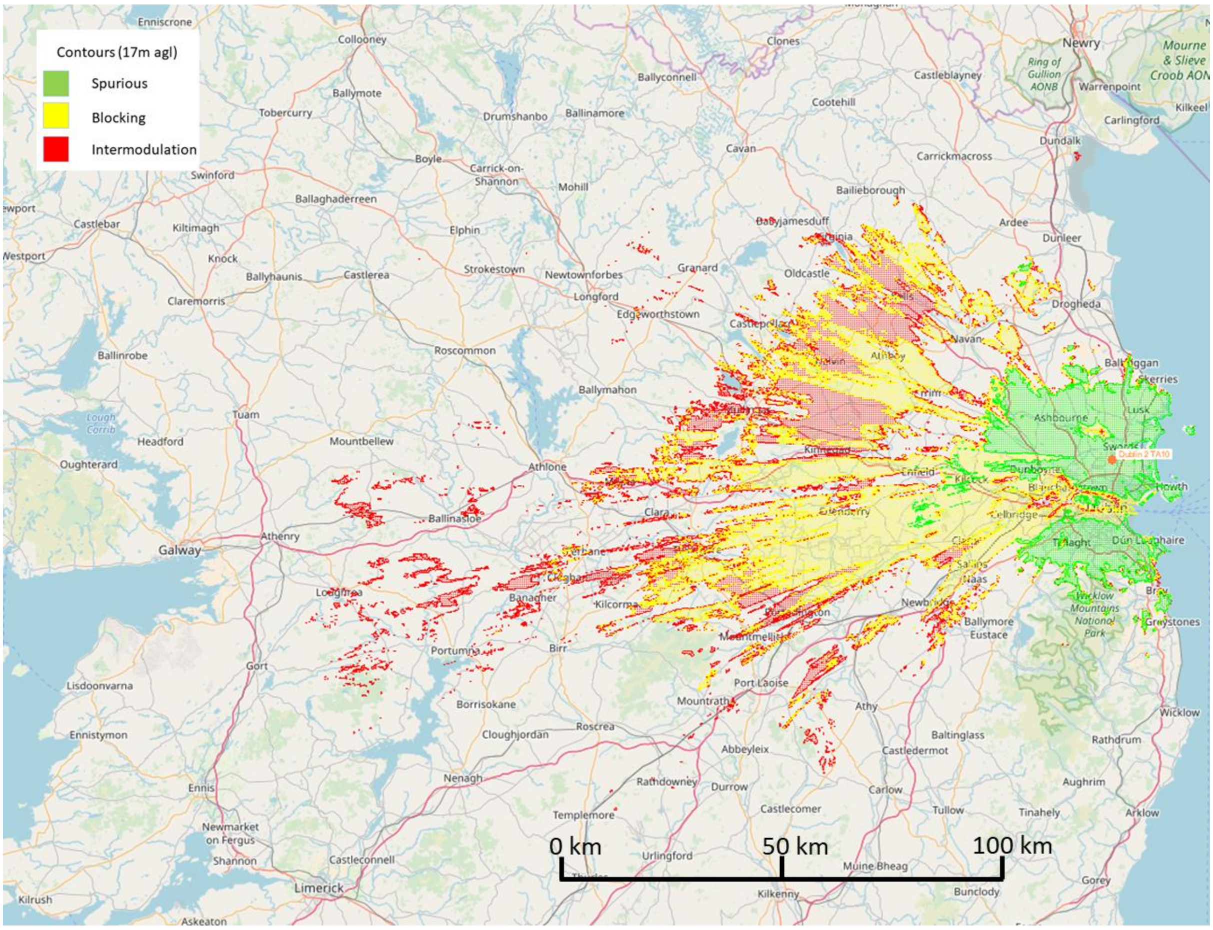
[18] ComReg and Plum met with the IAA on 25 September 2018 in the IAA offices in Shannon

Figure 5.2: Radar elevation pattern



The implications of blocking, intermodulation and spurious emissions have been examined by deriving interference contours. The results are shown in Figure 5.3 below:

Figure 5.3: Interference contours for Dublin TA10 airport radar



The interference contours (i.e. the potential interference areas) shown for each interference mechanism in green, yellow and red, illustrate interference areas where the operation of an MFCN base station would not be feasible without exceeding the threshold levels shown in Figure 5.1 for spurious, blocking and intermodulation interference mechanisms, respectively.

As seen in Figure 5.3 above, the intermodulation interference is the dominant mechanism resulting in the largest potential interference range of approximately 100 km from the radar location in several azimuths (in particular between the south west and north west of the location of the radar).

5.1 Conclusion

It can be seen that the TA 10 radar could significantly impact on deployment of MFCN in Dublin and surrounding area. In order to limit the impact of interference into the TA10 radar receiver until it is decommissioned, it is proposed that an in-band radiation limit is required in the frequency range 2570- 2690 MHz.

- Blocking and intermodulation: To address the impact of blocking and intermodulation effects at radar receivers in the adjacent band the restriction derived in this report, based on the Belgian study, for the Irish context is in the form of a pfd limit of -93 dBW/m^2 at the radar receiver antenna. This limit is derived based on the following assumptions:
  - The representative TA 10 radar blocking and intermodulation threshold levels are -50 and -53 dBm, respectively as shown in Figure 5.1. The level of -53 dBm is 3 dB more stringent than the level of -50 dBm. Therefore, this level can be used to define an appropriate pfd limit to accommodate blocking and intermodulation effects.
  - The interference entry is through the radar receiver main beam; hence the radar receiver antenna gain is 35 dBi as shown in Figure 5.1, including feeder losses.
  - The corresponding pfd level[19] is -88 dBW/m^2. This level accommodates interference from all MFCN licensees.
  - If it is assumed that there are three licensees[20] with equal spectrum allocations the corresponding pfd limit to be complied by each operator at the antenna of the radar receiver is -93 dBW/m^2.
- Spurious Emissions: The impact of MFCN base station out-of-band spurious emissions can be reduced by defining a pfd threshold at the radar receiver location. This report concludes that a pfd limit of -156 dBW/m^2/MHz at the radar receiver antenna location should be imposed to address the impact of MFCN spurious emissions. This limit is derived based on the following assumptions:
  - The TA 10 radar spurious emission threshold level is -116 dBm/MHz as shown in Figure 5.1.
  - The interference entry is through the radar receiver main beam; hence the radar receiver antenna gain is 35 dBi as shown in Figure 5.1, including feeder losses.
  - The corresponding pfd level is -151 dBW/m^2/MHz. This level accommodates interference from all MFCN licensees.

[19] Pfd (dBW/m^2) = Interference threshold at radar receiver input (dBW) – Radar antenna gain (dBi) + 10 x log($4\pi/\lambda^2$) where λ is the wavelength in meters.
[20] If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-88 + 10 log10 (Bandwidth(MHz) / 120)].

– If it is assumed that there are three licensees, with equal spectrum allocations the pfd limit to be complied with by each operator is -156 dBW/m^2/MHz[21] at the antenna of the radar receiver[22].

[21] There are a number of mitigation techniques operators can utilise to meet this limit such as, but not limited to, reducing BS E.I.R.P levels, installing more efficient antenna filters, optimising antenna orientation, increase downtilt of antenna, lower antenna height or moving base station further away from radar.
[22] If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-151 + 10 log10 (Bandwidth(MHz) / 120)].

6 Revised RurTel compatibility

Following the publication of Document 19/59R, ComReg requested further information from Eir in relation to its Rurtel Network. On 31st October 2019 Eir provided updated information on the RurTel network.

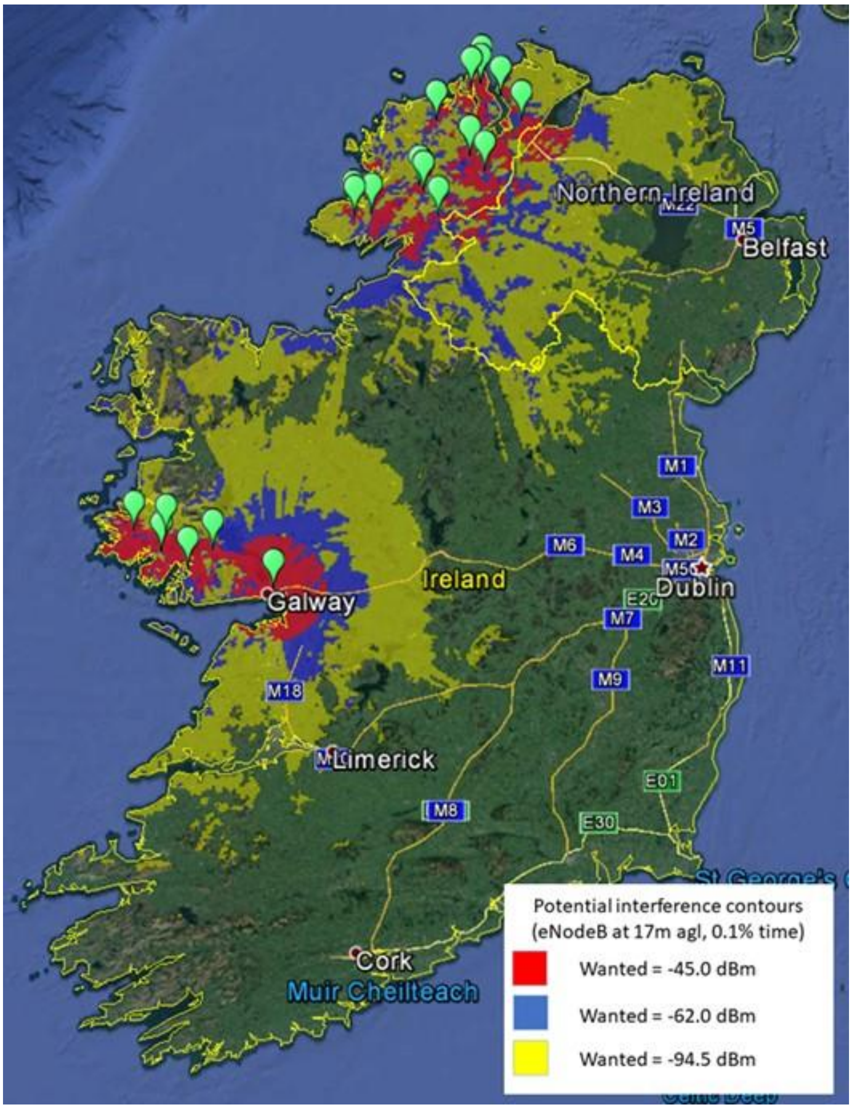
Most notably, in Kerry the RurTel system has been decommissioned and the number of base stations reduced in the Galway and Donegal networks.

Further information was received from Eir on 5th December 2019. It was considered by Plum that this information would not impact the output of the modelling completed to date in Document 19/59d and revised in this document. In this modelling, the RurTel network and equipment parameters were based on information provided by Eir[23] including two example sites. Other information such as specific base station / repeater station locations and antenna heights were obtained from ComReg licensing information. No additional information on equipment or system parameters has been made available.

The plots below show the revised composite interference contour taking into account the updated base station information from Eir in the correspondence of 31st October 2019 mentioned above. Markers for the individual RurTel base stations have also been included to provide clarity on the location of the RurTel network.

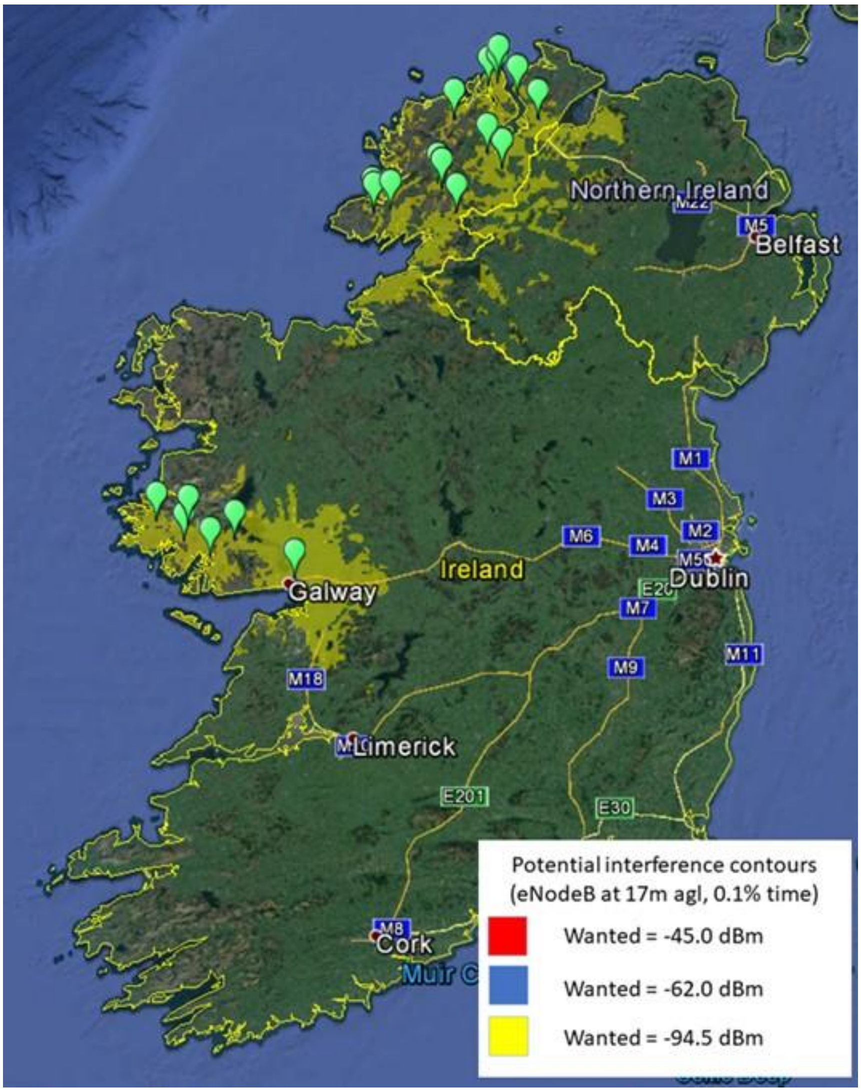
[23] Information from Eir is published in ComReg Document 19/59f

Figure 6.1: Composite Interference Contours Calculated for all RurTel BS Receivers (0.1% of time)



[Revision of Figure 2.1 in Document 19/59d]

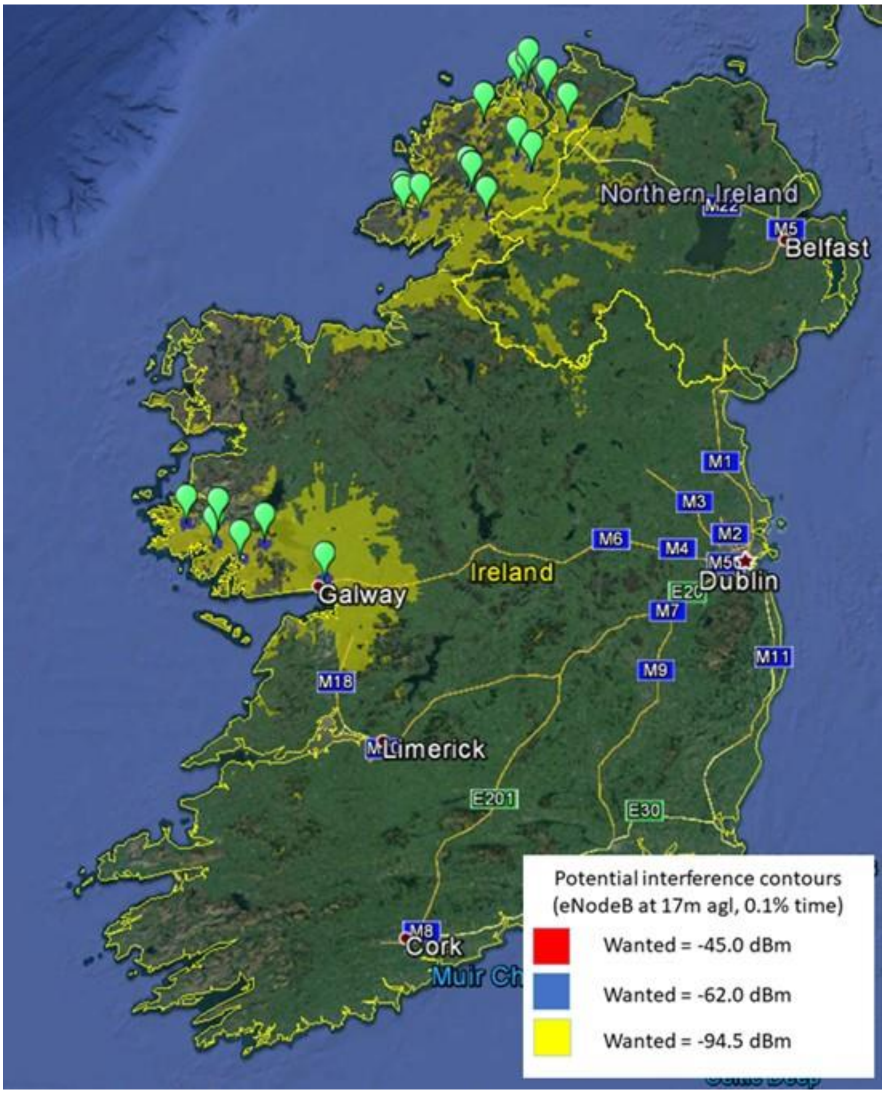
Figure 6.2: Adjacent Band Composite Interference Contours Calculated for all RurTel BS Receivers (0.1% of time, 50 dB ACS[24])



[Revision of Figure 2.4 in Document 19/59d]

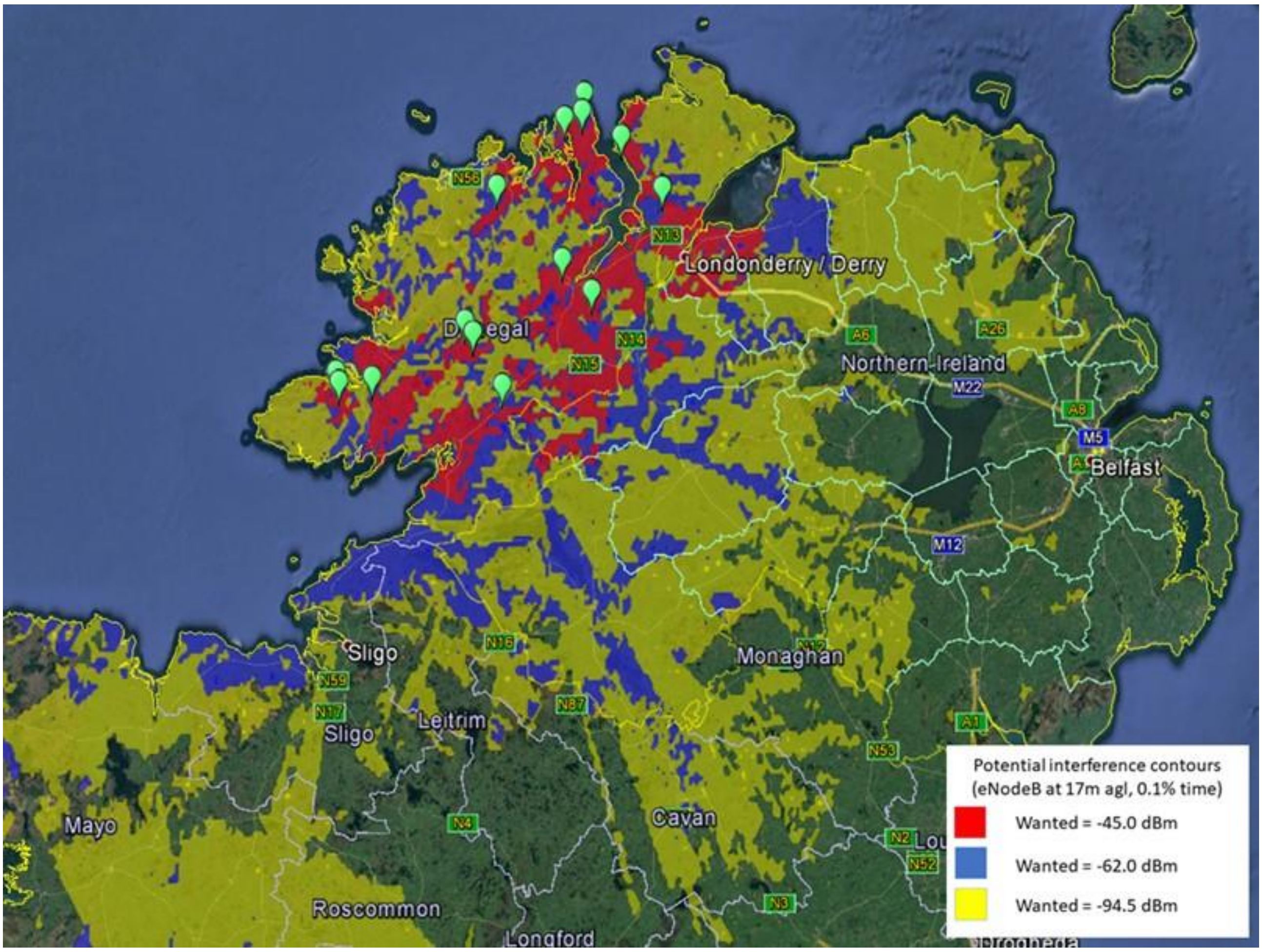
[24] Adjacent channel selectivity (ACS)

Figure 6.3: Adjacent Band Composite Interference Contours Calculated for all RurTel BS Receivers (0.1% of time, 40 dB ACS)



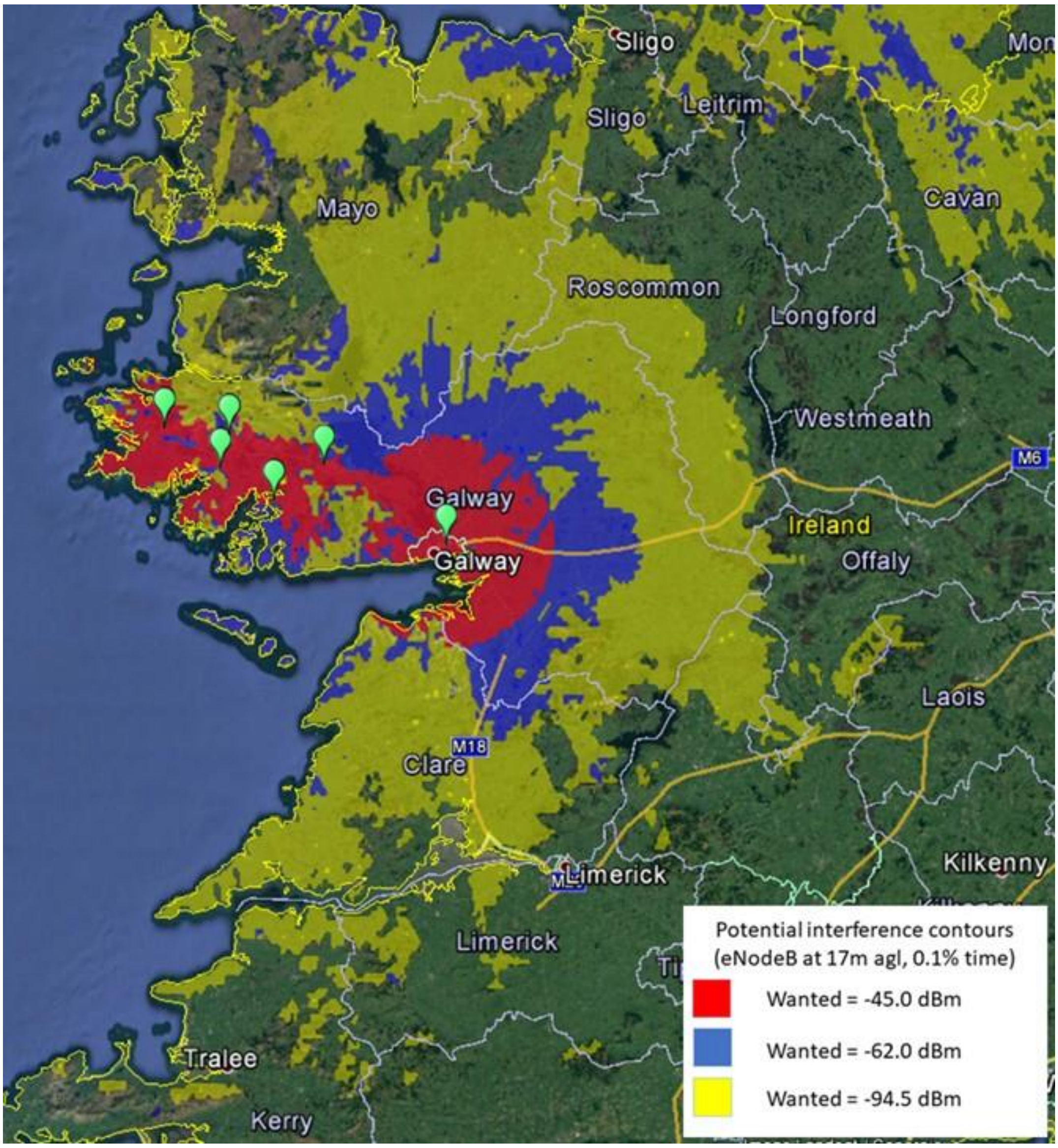
[Revision of Figure 2.5 in Document 19/59d]

Figure 6.4: Donegal Co-channel Composite Interference Contours Calculated for RurTel BS Receivers (0.1% of time)



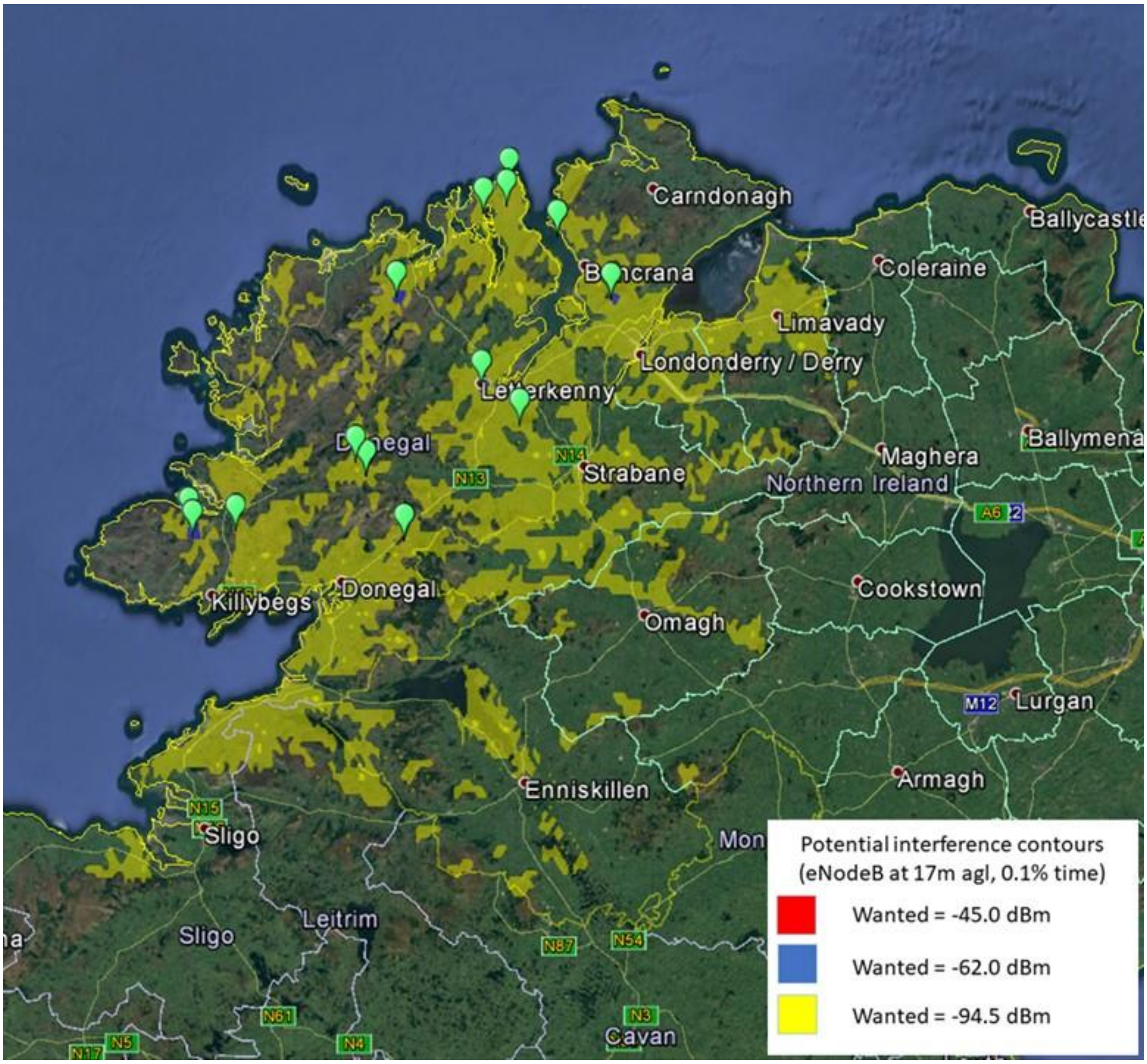
[Revision of figure B.1 in Document 19/59d]

Figure 6.5: Galway Co-channel Composite Interference Contours Calculated for RurTel BS Receivers (0.1% of time)



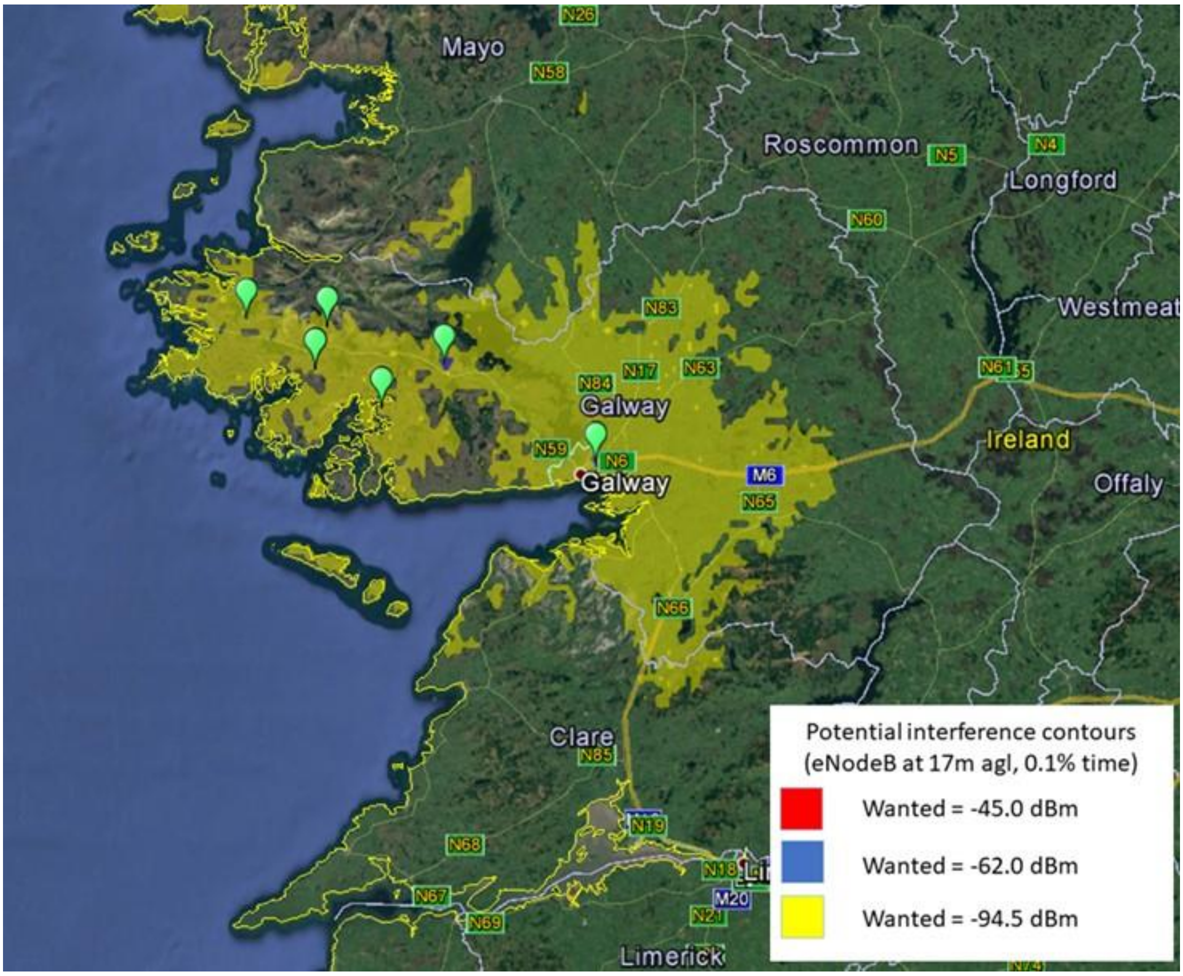
[Revision of figure B.2 in Document 19/59d]

Figure 6.6: Donegal Adjacent Channel Interference Calculated for RurTel BS Receivers (0.1% of time, 50 dB rejection)



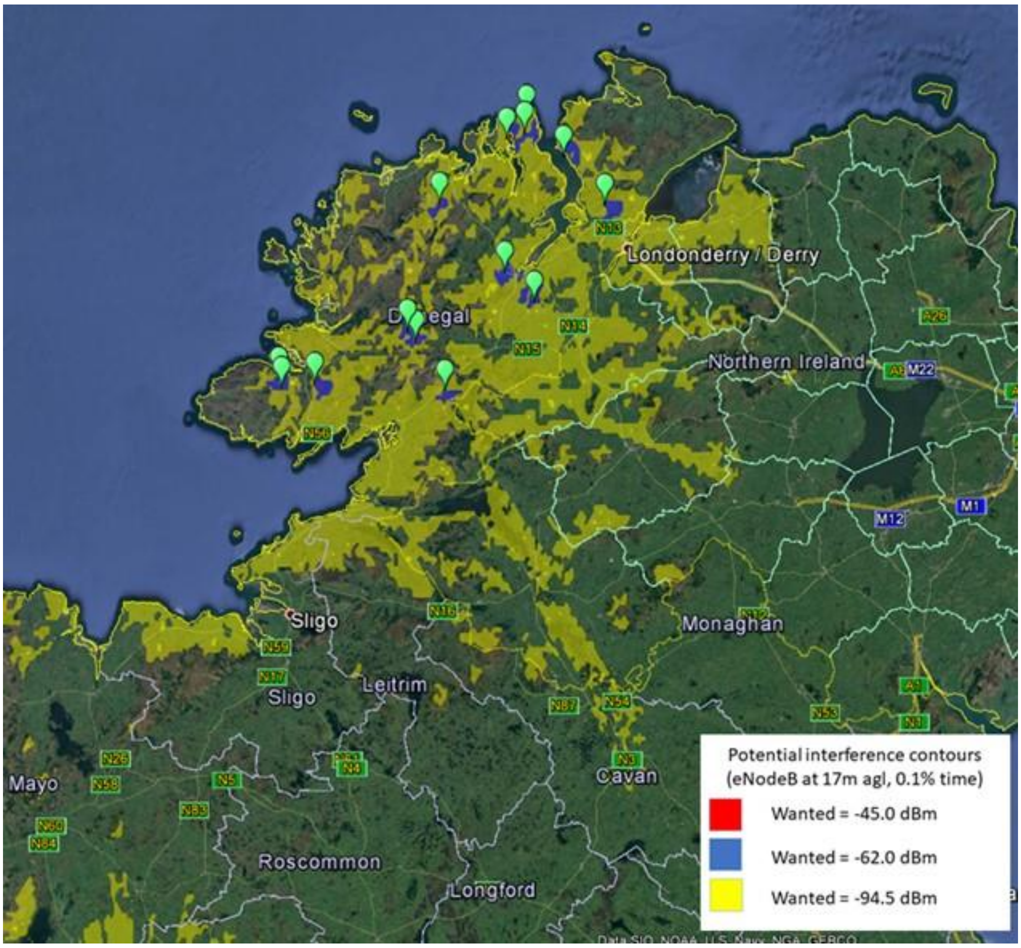
[Revision of figure B.4 in Document 19/59d]

Figure 6.7: Galway Adjacent Channel Interference Calculated for RurTel BS Receivers (0.1% of time, 50 dB rejection)



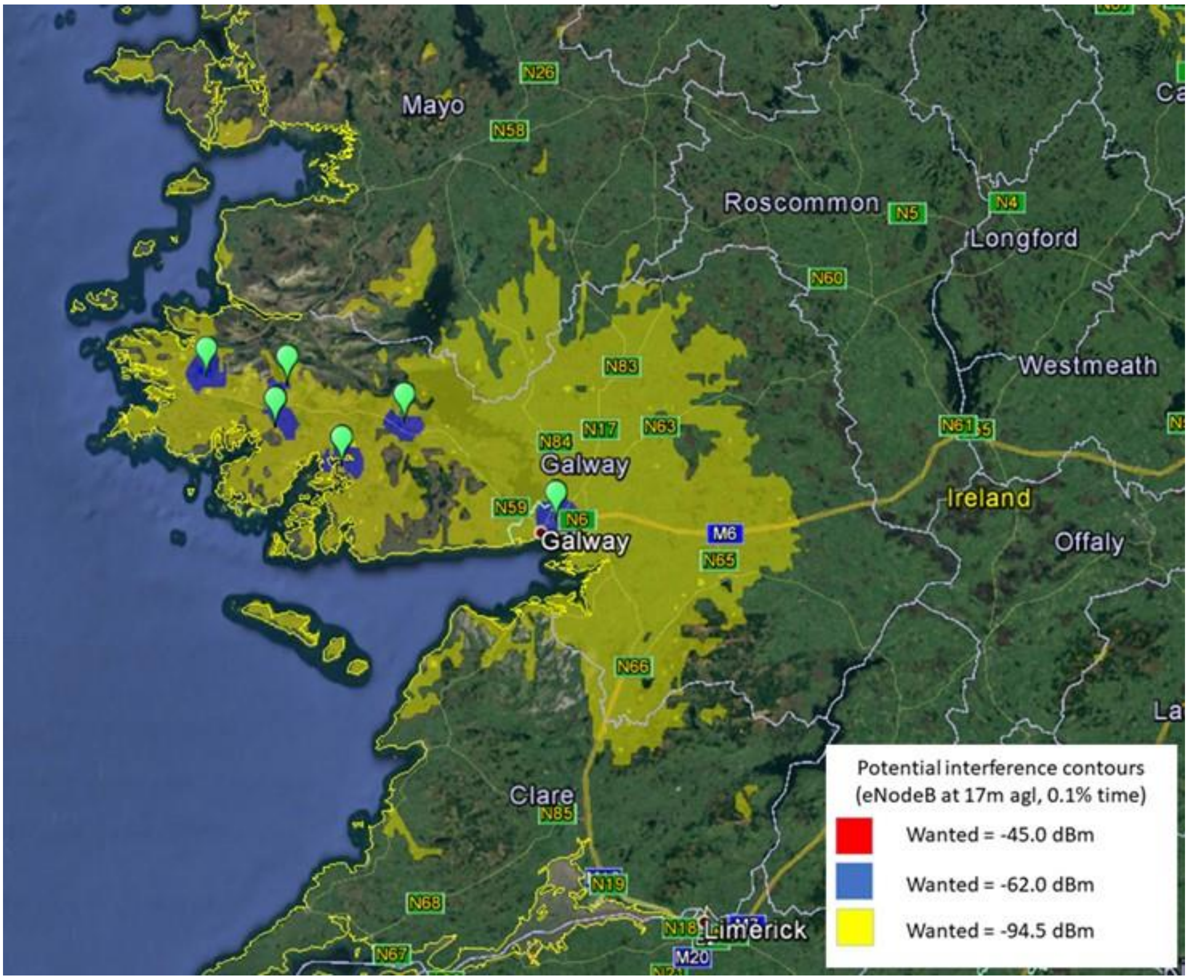
[Revision of figure B.5 in Document 19/59d]

Figure 6.8: Donegal Adjacent Channel Interference Calculated for RurTel BS Receivers (0.1% of time, 40 dB rejection)



[Revision of figure B.7 in Document 19/59d]

Figure 6.9: Galway Adjacent Channel Interference Calculated for RurTel BS Receivers (0.1% of time, 40 dB rejection)



[Revision of figure B.8 in Document 19/59d]

The population potentially impacted by co-channel interference (-94.5dBm receiver power) is as follows:

Area	Population
Galway	523,000
Donegal	292,000
All	815,000

Plum note that the removal of the two redundant sites in Galway has no impact on the overall coordination area, the limits of which are defined by the remaining sites.

6.1 Conclusions

The reduction of RurTel sites means that the area where coordination is necessary in Kerry is no longer applicable but the removal of the two redundant sites in Galway has no impact on the overall coordination area.

The conclusions and recommendations provided in Document 19/59d still apply and are summarised below:

- For MFCNs to be deployed in areas surrounding RurTel base station receivers, we would recommend that ComReg define a coordination procedure to ensure co-existence between proposed MFCN deployments and existing RurTel networks. The size of coordination areas varies with the assumed interference threshold as shown in Figure 6.1.

- In the event that the RurTel network is further reduced or retired from the 2.3 GHz band, the requirement for a coordination procedure should be assessed to reflect any changes.

In the case of adjacent channel co-existence, the results show that adjacent channel coexistence between MFCN and RurTel is likely to be feasible in practice without any coordination requirements for most deployment scenarios. However, coordination could be required for the worst-case scenarios where the RurTel wanted power is at a minimum level, as depicted in Figure 6.2 and Figure 6.3.

While noting that uncertainty exists regarding the RurTel receiver performance (e.g. receiver selectivity) and link budgets, it is our view that adjacent channel coexistence between MFCN and RurTel networks could be feasible without the implementation of coordination areas for most deployment scenarios.

7 Recommendations

7.1 2.6 GHz band and Star 2000 radars

This section provides a number of recommendations to ComReg following the conclusions drawn in Chapter 4 from the measurements undertaken at Shannon and experiences of France, Belgium and the UK included in report ComReg Document 19/59c. These recommendations are detailed below:

- to address interference due to blocking and intermodulation, filters[25] should be installed at the radars in Ireland;
- to address the impact of MFCN spurious emissions, a pfd limit of -145 dBW/m^2/MHz at the radar receiver antenna should be satisfied by each operator[26];
- if MFCNs are deployed before radar filters are fitted, an additional in-band radiation limit is required in the frequency range of 2570-2690 MHz to address the impact of blocking and intermodulation effects at radar receivers in the adjacent band. This restriction as derived in this report is a pfd limit of -83 dBW/m^2 at the antenna of the radar receiver[27,28]. Note that, unlike the spurious emission limit, this limit is expressed in terms of absolute power rather than power spectral density.
- to ensure protection of radars from MFCN base stations where they are operating in close proximity, a 1 km coordination zone[29], should be applied around the radars in Dublin, Shannon and Cork assuming that radar receivers are fitted with filters:
  - Inside the 1 km coordination zone, MFCN operators are required to coordinate with the radar operator, regardless of antenna gain value or compliance with pfd limit.
  - Outside the 1 km coordination zone, each potential MFCN operator is required to comply with the defined pfd limit (-145 dBW/m^2/MHz)[30].

7.2 2.6 GHz band and TA10 radar

In the case of the TA10 radar, if MFCNs are deployed before the radar is decommissioned, and assuming no filter is fitted, it is recommended that to address blocking and intermodulation the corresponding pfd limit to be

[25] As implemented in the UK, France and Belgium.
[26] This limit is derived assuming that there are three licensed operators with equal amount of allocated spectrum. If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-140 + 10 log10 (Bandwidth(MHz) / 120)].
[27] Following successful installation of filters at the radar receiver, no in-band radiation limit is required as filtering at the radar receiver should address the impact of blocking and intermodulation effects at the radar receiver in the adjacent band.
[28] This limit is derived assuming that there are three licensed operators with equal amount of allocated spectrum. If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-78 + 10 log10 (Bandwidth(MHz) / 120)].
[29] as adopted in Belgium
[30] The compliance with pfd limits could be demonstrated by the MNOs using their own analysis tools as adopted, for example, in France.

complied with by each operator at the antenna of the radar receiver is[31] -93 dBW/m^2 and to address spurious emissions a corresponding pfd limit is[32] -156 $dBW/m^2/MHz$.

7.3 2.3 GHz band RurTel

For MFCNs to be deployed in areas surrounding RurTel base station receivers, we would recommend that ComReg define a coordination procedure to ensure co-existence between proposed MFCN deployments and existing RurTel networks. The size of coordination areas varies with the assumed interference threshold as shown in Figure 6.1.

In the event that the RurTel network is further reduced or retired from the 2.3 GHz band, the requirement for a coordination procedure should be assessed to reflect any changes.

In the case of adjacent channel co-existence, the results show that adjacent channel coexistence between MFCN and RurTel is likely to be feasible in practice without any coordination requirements for most deployment scenarios. However, coordination could be required for the worst-case scenarios where the RurTel wanted power is at a minimum level, as depicted in Figure 6.2 and Figure 6.3.

While noting that uncertainty exists regarding the RurTel receiver performance (e.g. receiver selectivity) and link budgets, it is our view that adjacent channel coexistence between MFCN and RurTel networks could be feasible without the implementation of coordination areas for most deployment scenarios.

[31] This limit is derived assuming that there are three licensed operators with equal amount of allocated spectrum. If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-88 + 10 log10 (Bandwidth(MHz) / 120)].

[32] This limit is derived assuming that there are three licensed operators with equal amount of allocated spectrum. If there are a different number of operators and/or a different amount of spectrum allocated to each operator, the corresponding pfd limit can be calculated from [-151 + 10 log10 (Bandwidth(MHz) / 120)].

