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A Report by Plum Consulting London LLP

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Updated co-existence modelling of RurTel and aeronautical radar with Wireless Broadband (WBB) in the 2.3 and 2.6 GHz bands

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About Plum

Plum offers strategy, policy and regulatory advice on telecoms, spectrum, online and audio-visual media issues. We draw on economics and engineering, our knowledge of the sector and our clients' understanding and perspective to shape and respond to convergence.

About this study

This note is describes work undertaken by Plum as an extension to the earlier study on 2.3/2.6 GHz sharing issues.

The document includes revised interference contour predictions for the RurTel network, and predictions of the coordination area required for the proposed Star2000 radar installation in Dublin, replacing the existing TA10 unit.

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Contents

1 Protection of RurTel at 2.3 GHz

1.1 Background to Plum's RurTel Studies

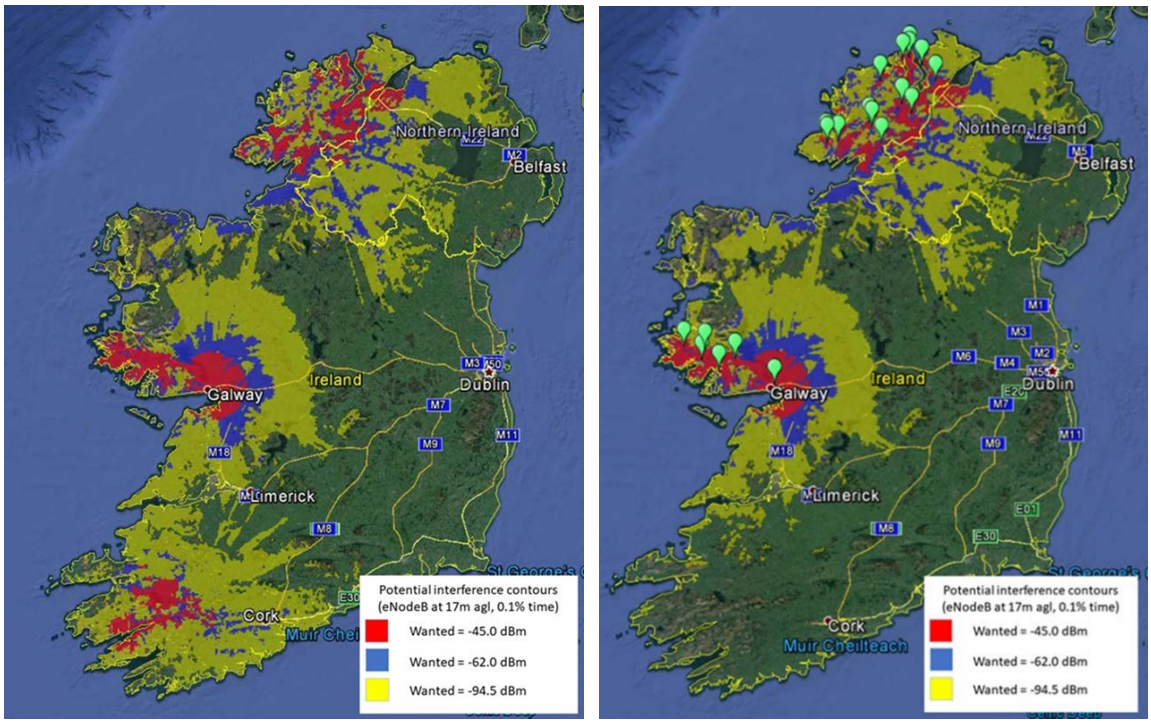
RurTel is a legacy system for the provision of public switched telephone Network (PSTN) services that was deployed in the west of Ireland in the 1990s. The system was originally used in remote areas in Kerry, Galway and Donegal.

The original Plum modelling ("*2.3 GHz Sharing Analysis*", May 2019, published as ComReg Document 19/59d) considered the constraints imposed on new services in the 2.3 GHz band by the need to protect these services, and took into account sites recorded in ComReg's licence database across all three counties. Due apparently to the age of the system, no detailed technical parameters were available from the operator, Eir, nor, unfortunately, was Eir able to provide information on the current status of the network. Plum therefore made plausible assumptions regarding the sensitivity and selectivity of the RurTel receivers and assumed that all sites in the ComReg database were active.

Given the absence of detailed system information, predictions were prepared for a number of cases; in assessing the impact of interference it was assumed that the wanted signal at each RurTel receiver was -45dBm, -62dBm or -94.5dBm (intended to represent short links, longer links and links suffering short-term deep fades). Both co-channel and adjacent channel interference was modelled, with RurTel adjacent-channel selectivity of either 40dB or 50dB being assumed.

Subsequent to the May 2019 report (Document 19/59d), Eir provided, in November/December 2019, more detailed, current, information on the RurTel network, and confirmed that the sites in Kerry had been decommissioned. The Plum predictions were re-run, excluding the sites in Kerry, and those known to have been decommissioned in Galway. These updated results were published by ComReg in Document 19/124c on 20 December 2019.

Figure 1.1: Predictions of 19/59d (May 2019, left) and 19/124c (December 2019, right)



In October 2020, ComReg conducted surveys of the 4 remaining customers in Galway. Following the results of these surveys, which indicated that these customers could be migrated to an alternative service, ComReg asked Plum to re-run the sharing analysis on the basis that the Galway network need no longer be considered. As the overall number of sites is now significantly reduced, Plum has also taken the opportunity to re-examine the detailed configuration of the network, in an attempt to define the co-ordination contours more precisely.

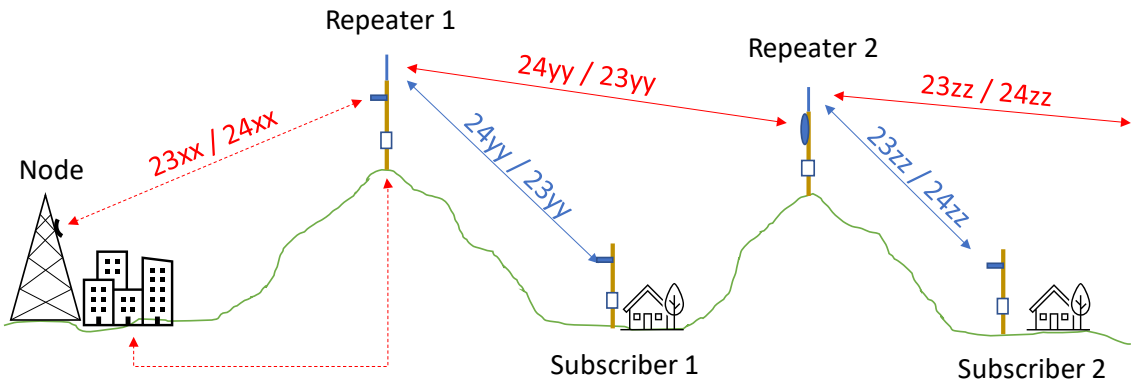
1.2 RurTel's Network Structure and Modelling Assumptions

Significant discrepancies have been found in between the licence information held by ComReg and the detailed network information provided by Eir in December 2019. In both cases, locations of some of the sites also appear to be incorrect, and these have been amended where possible[1]. There is also confusion in the naming of some sites ('Chara', 'Cara' and 'Carha' are used for one location, while 'Ballinahinch' and 'Ballyhark North' seem also to be known as 'Ballinacric' and 'Ballyheerin').

Our understanding of the overall structure of a RurTel network is sketched below.

[1] Typically, a site is given that is on the side of a hill with no visibility of the remote terminal; such cases have been relocated to the summit.

Figure 1.2: Indicative sketch of RurTel system



The RurTel network connects to the main network at a hub site (i.e. Letterkenny or Mulmosog). This is connected by radio to an initial hilltop repeater site. This repeater site is, in turn, connected to other repeaters. It appears that all (or most) repeaters serve a number of subscribers directly, as well as forwarding the backhaul signal to the next repeater in the chain. It seems that an omnidirectional transmit/receive antenna is used for both purposes. The next repeater in the chain will connect to the previous repeater with a directional antenna (a shrouded Yagi or a parabolic grid) and will in turn use an omnidirectional antenna to serve subscribers and provide an onward connection to the next repeater.

From Google Streetview evidence, it seems that some sites include directional antennas for both backhaul links. Subscriber stations always use a directional antenna (only shrouded Yagis have been seen). In general (there are some exceptions) the transmit/receive bands (2307-2327 MHz and 2407-2427 MHz) are swapped on each hop.

In the December 2019 data, Eir had provided the locations of many of the subscriber terminals. The decision has been taken to exclude these from our modelling because (i) these sites always[2] employ directional antennas, which limits their susceptibility to interference and (ii) by definition, these locations are generally well-screened from other radio systems.

The network data provided by Eir in December 2019 has been used to construct the assumed network routings for the remaining RurTel sites in Donegal (Figures 1.2 and 1.3). These are considered as two separate networks; (i) East Donegal and (ii) West Donegal. In the figures below all subscribers are indicated, although only one is identified using the Eir '*Sxx*' nomenclature. The geographical layout of the links is given in the appendix.

There are many remaining contradictions in the data. For example, the link from Mongorry to Barnesmore is on 2318 MHz in a dataset[3] provided by Eir in December 2019, but the frequency is shown as being used in the reverse direction in data provided[4] by Eir in 2009. The transmit frequency shown for Mongorry Hill in licence data held by ComReg[5] is 2402 MHz, which agrees with neither of the other documents. **In all such cases, we have assumed that the information in the latest, December 2019, data provided by Eir following their site surveys is correct.**

[2] Confirmed in a response by Eir to ComReg (5/12/2019): "*all the customer sites use Yagi of Grid directional antenna*"
[3] File '*Donegal Rurtel Details_final 02Dec19.xls*'
[4] Attachment to letter from Eir to ComReg dated 16/4/2009
[5] File '*RurTel as at 10092018.xlsx*' provided to Plum by ComReg

Figure 1.3: East Donegal Network

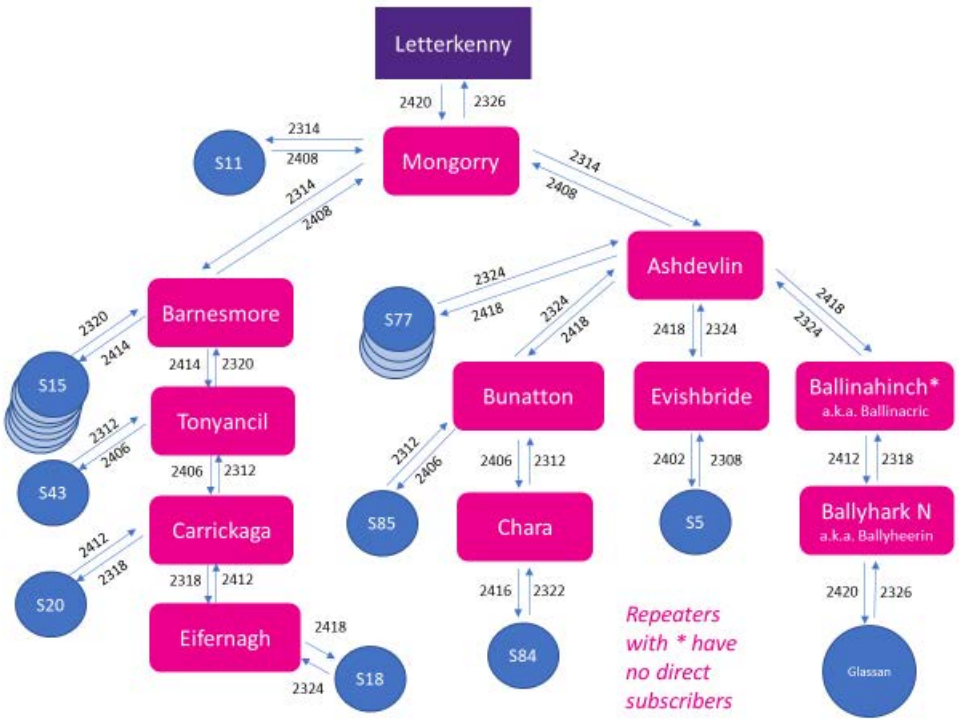
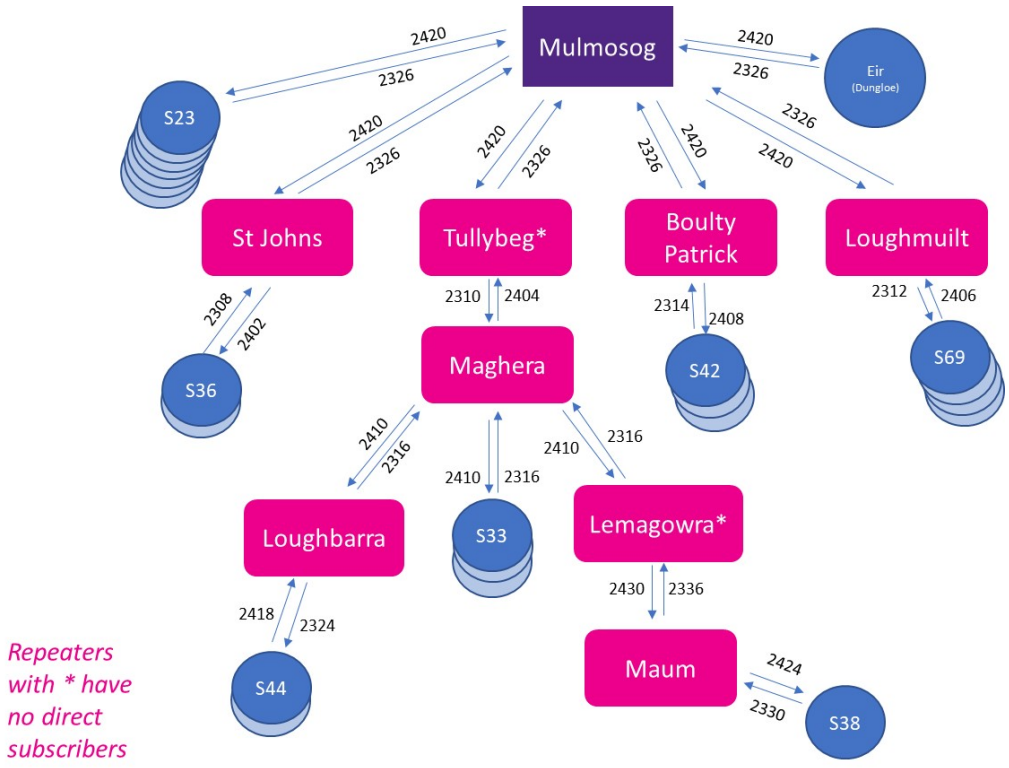
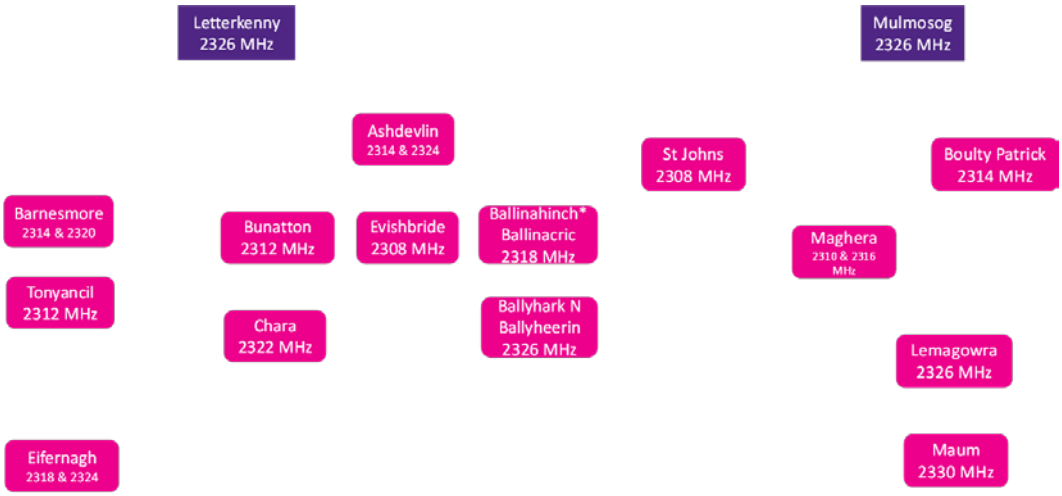


Figure 1.4: West Donegal network



For present purposes, we are only concerned with potential interference to receivers operating in the 2307-2327 MHz band, and as stated above we are not considering subscribers. The sites of interest therefore reduce to those shown in the figure below.

Figure 1.5: Receive sites in 2.3 GHz band (modelled in Plum predictions)

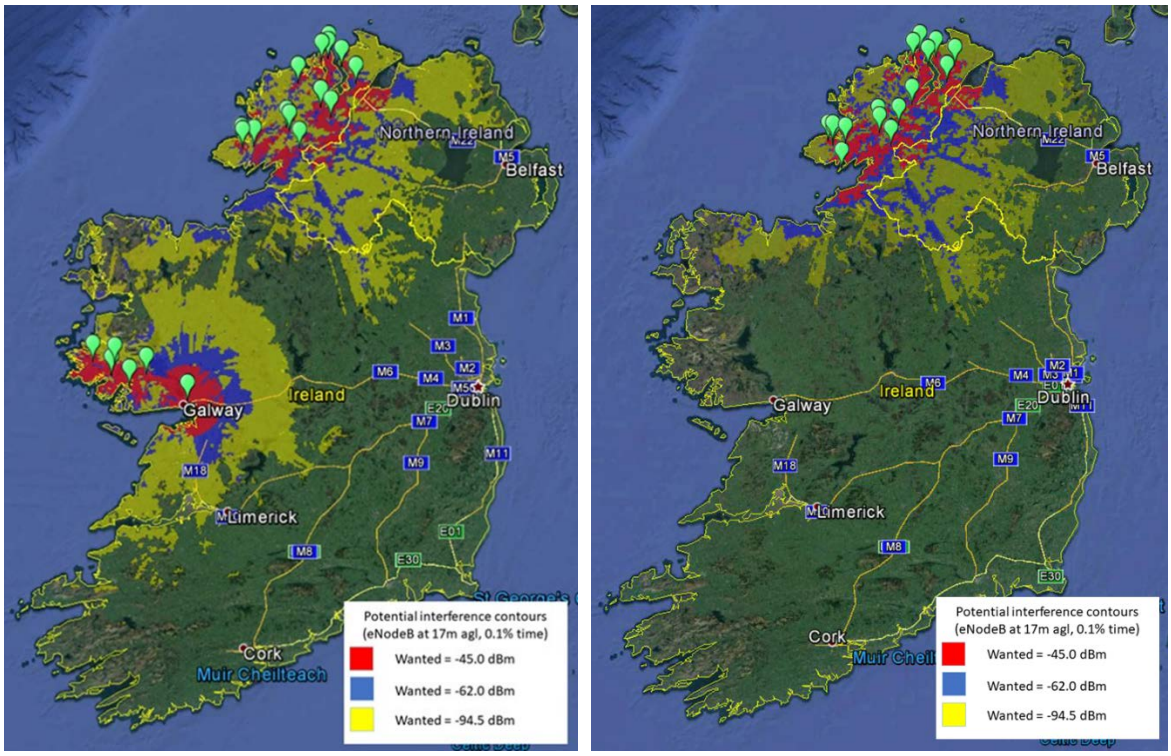


Although some of these sites will use directional antennas for receiving the backhaul from the preceding site (e.g. Maghera on 2310 MHz), they also (presumably) have omnidirectional antennas receiving subscriber signals. All sites are therefore modelled with omnidirectional antennas.

1.3 Results: discussion

The new results, for both Donegal networks, are compared with the previous iteration, in the plots below.

Figure 1.6: Prediction of 19/124c (December 2019, left including Galway network) compared with present assumption



Although there are no longer any constraints from the Galway network and differences in detail elsewhere, the overall picture in the north is substantially unchanged by the improvements in the detail of the network modelling.

We now have reasonable confidence that we are correctly modelling the currently operational network topology. What is not at all certain, however, is whether the interference parameters being applied are appropriate. Two factors are particularly uncertain:

1. Assumed level of wanted carrier: The susceptibility of a RurTel receiver to interference changes very significantly with the level assumed for the wanted carrier. Details of automatic transmitter power control (ATPC) are unknown, but it is very unlikely, given the overall nature of the system and the use of TDMA, that any ATPC is used. The data supplied by Eir suggests that the transmitter output power is fixed at 1W, and the EIRP at each site determined by the choice of antennas. The wanted signal level will then depend (i) on the link antennas and the path length (most paths appear to be line of sight); and (ii) on the instantaneous value of multipath fading.

2. Required availability of the system: At present, predictions are made for an availability of 99.9% time. This value was suggested, rather arbitrarily, in the original Plum report, as no formal planning targets have been given by either Eir or ComReg.

The interference susceptibility of the network is dominated by the receivers at Barnesmore, Asdevlin and Mulmosog. In an attempt to judge which of the assumed carrier levels might be most representative, simple link

budget calculations were made on the basis of the EIRP figures given in the letter sent from Eir to ComReg on 16/4/2009. In most cases, the receive antenna is unknown. Where a site is receiving from scattered subscribers, it seems likely that an omnidirectional antenna will be used, and a 6dBi gain[6] has been assumed.

Table 1.1: Estimated link budgets

Receiver	Link from	EIRP	Path length	Free space path loss	Power from 6dBi antenna
Barnesmore	Mongorry (2314)	?	27.7 km	128.6 dB	-
	Tonyancil (2320)	16 dBW	14.3 km	122.9 dB	-70.9 dBm
	2 x subs (2320)				
Asdevlin	Bunatton (2324)	16 dBW	15.9 km	123.8 dB	-71.8 dBm
	Evishbride (2324)	1 dBW	11.8 km	121.2 dB	-84.2 dBm
	Ballinahinch (2324)	1 dBW	26.3 km	128.1 dB	-91.1 dBm
	4 x subs				
Mulmosog	St John's (2326)	?	15.9 km	123.8 dB	-
	Tullybeg (2326)	16 dBW	7.8 km	117.6 dB	-65.6 dBm
	Boultypatrick (2326)	27.5 dBW	23.6 km	127.2 dB	-63.7 dBm
	Loughmuilt (2326)	1 dBW	7.4 km	117.1 dB	-80.1 dBm
	7 x subs				

The admittedly crude calculations in this table suggest that few if any of the 'infrastructure' links will approach wanted signal levels of -45dBm. The most pessimistic assumption used in the predictions, -94.5dBm, seems a reasonable value to use, allowing for multipath fading, equipment aging, etc.

Interference areas might be significantly reduced if predictions could be made for a higher percentage time (i.e. a lower system availability). Given the role of the system in providing a fixed-line replacement, and the assumed need for reliable 112/999 calls, the 99.9% availability presently used seems appropriate.

It appears as though the only way in which the predicted interference areas could reliably be reduced would be to obtain more information on the receive antennas in use at each of the three sites above. Confirmation of the transmit and receive frequencies would also be useful.

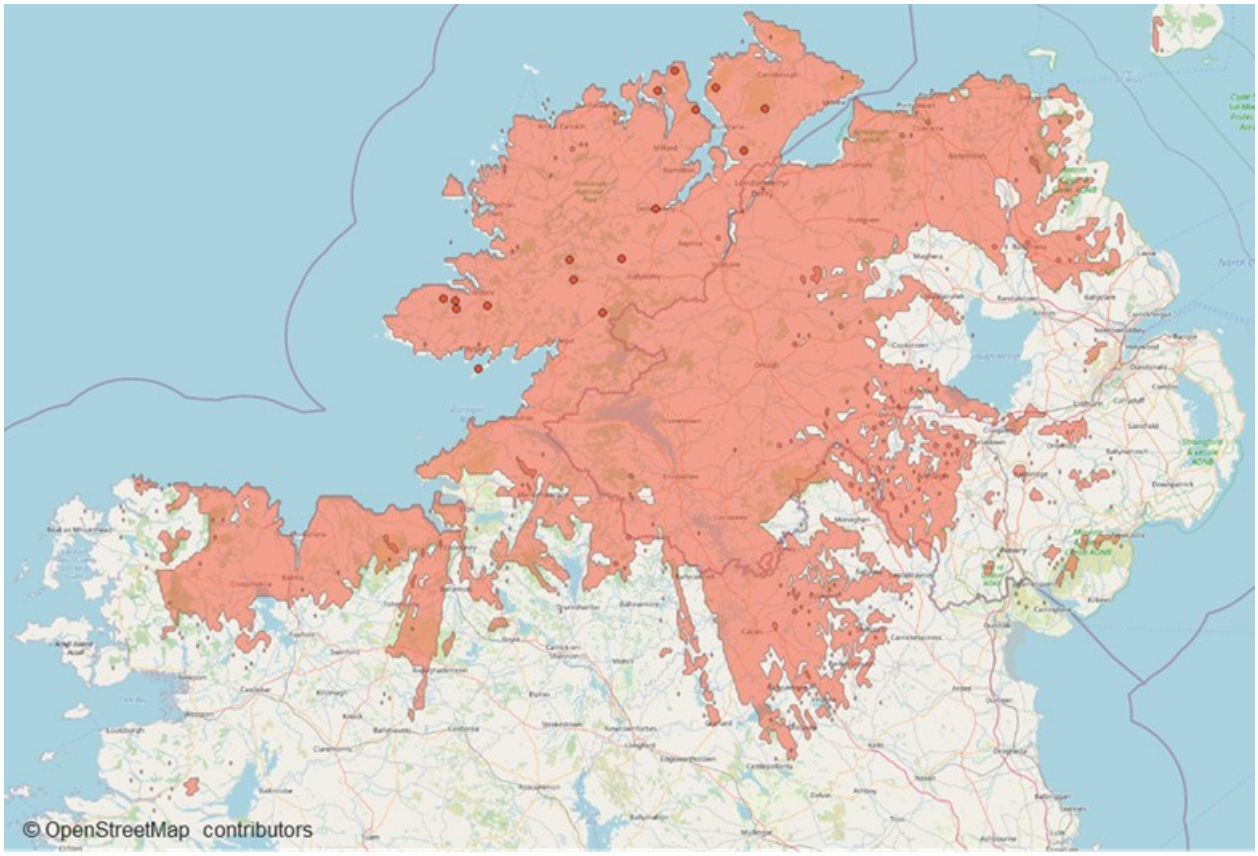
[6] Eir data suggests a feeder loss of 5dB is typical, but this has been ignored, as some antennas will have more than 6dBi gain.

1.4 Results: final co-ordination contours

Given the likely need to protect the RurTel network to wanted carrier levels down to -94.5dBm, the final results presented here are given only for that level.

The plots below relate to all operational RurTel sites in Donegal. In Appendix A, plots are provided for the individual 'East Donegal' and 'West Donegal' networks.

Figure 1.7: Overall co-ordination contour (co-channel, -94.5dBm) for both Donegal RurTel Networks



All contours have also been provided in KML and ESRI® shapefile formats.

1.5 Conclusions

Considering the further reduction of RurTel customers in Galway and the conclusions of ComReg's survey results in February and March 2020, coordination between MFCN services and RurTel in Galway is no longer applicable.

The coordination contours are still required in Donegal, as set out in Figure 1.7 above, because Eir's RurTel network provides service to 57 customers in this area. Therefore, Plum's conclusions and recommendations provided in Document 19/59d and in Document 19/124c still apply to the Donegal networks 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 area required varies with the assumed RurTel link margin, as shown in Figure 1.6, but current evidence suggests that the worst-case (-94.5dBm) assumption is appropriate for purposes of defining a coordination area that is conservative, and the supplied ShapeFiles relate to this contour only.

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

- While noting that uncertainty still exists regarding the RurTel receiver performance (e.g. receiver selectivity) and link budgets, it is Plum's view that adjacent channel coexistence between MFCN and RurTel networks could be feasible without the implementation of coordination areas for most deployment scenarios. The uncertainty regarding the link-margin and specific frequencies at use at individual RurTel sites, however, makes it impossible to exploit such adjacency. It is therefore necessary to assume that all RurTel sites are co-channel with any MFCN deployments in frequency blocks 2-6 (2305-2330 MHz).

2 New Dublin radar site

2.1 Background to Plum's Radar Reports

ComReg document 19/59d and 19/124c contain Plum's analysis regarding compatibility and co-existence of new MFCN base stations deployed in the 2.6 GHz band with IAA's four aeronautical radars operating in the 2.7 GHz band.

There are currently two aeronautical radar sites covering the Dublin area; one of these is a Thales Star 2000 unit which, in common with those at Cork and Shannon, will be retro-fitted with a filter to protect against out-of-band interference from mobile base stations in the 2.6 GHz band[7]. Plum has produced predictions[8] for these three radar sites, showing the areas within which, the unfiltered radars would be vulnerable to interference from MFCN base stations operating at 2.6 GHz. The other site is a Thales TA10M unit which Plum considered in its analysis contained in 19/124c.

In relation to the TA10M radar unit, the IAA has indicated that this radar is due to be decommissioned; in its place, a Star 2000, with filtering, will be installed at a new site, some 13km north of the existing site. This report considers this new Dublin radar, set to replace the old TA10M radar located at Dublin Airport and for completion, the same predictions have now been made for this proposed site, as for the other three, and are presented here.

2.2 Modelling Parameters

The proposed new radar site is to be located in Tooman, Fingal, Co Dublin with coordinates 53° 33' 18.25" North, 6° 14' 59.07" West. The site is at 115m above sea level, some 50m higher than the current site.

The new STAR2000 radar at Tooman will be fitted with a filter at installation, and therefore interference as a result of blocking and intermodulation will not be a factor. Spurious emissions from MFCN base stations in the 2.6 GHz band will remain a relevant issue, similar to existing radars in Dublin, Shannon and Cork. These emissions can be mitigated by ensuring compliance with the pfd limit set out below. For comparison, the impact of the spurious emissions has been plotted below.

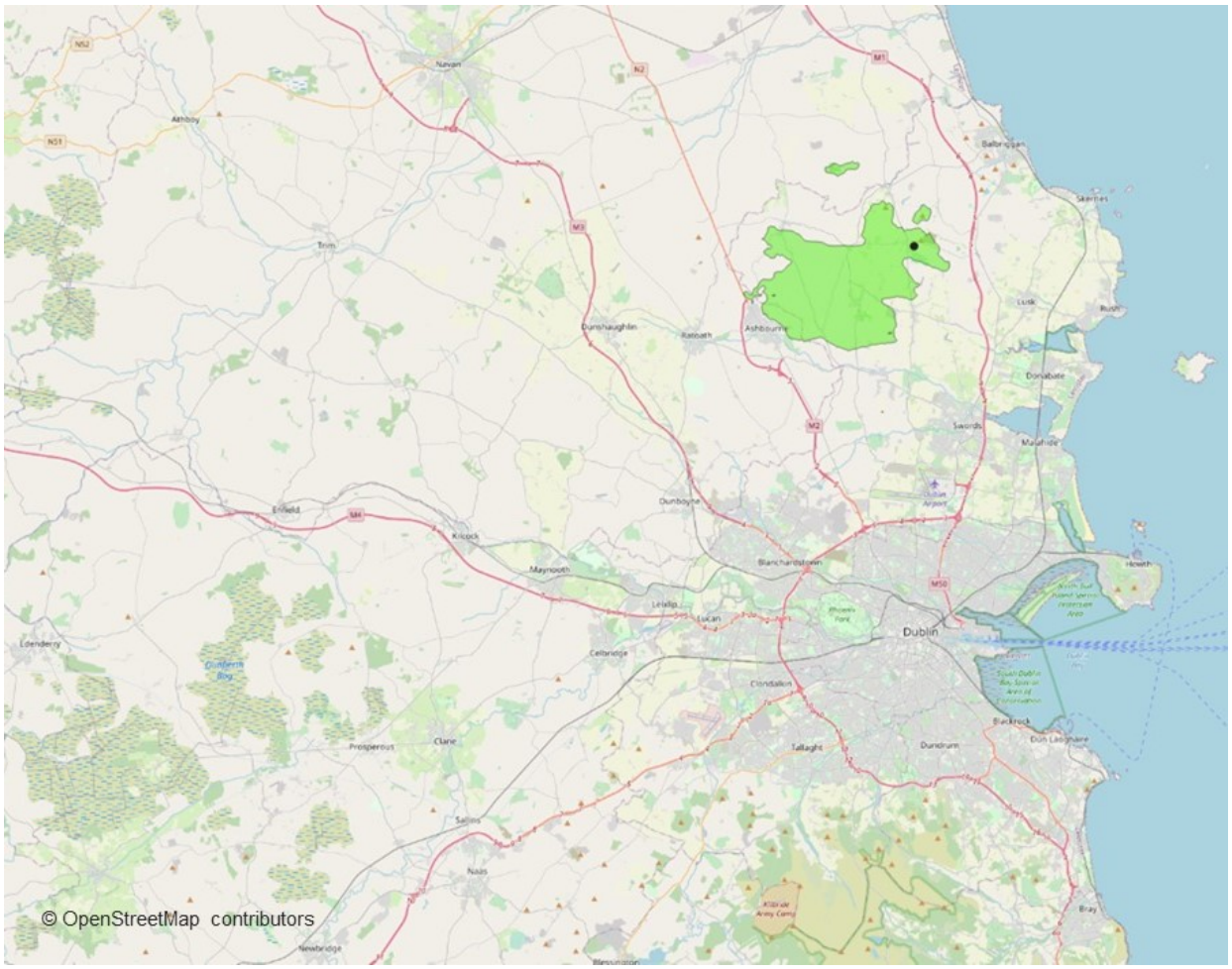
2.3 Results

2.3.1 New Tooman Radar Site

The contour showing the potential impact of unmitigated MFCN spurious emissions for the new Dublin radar is shown in Figure 2.1.

[7] See Plum report of April 2019 (ComReg Document 19/59c)
[8] See ComReg document 19/124c (December 2019)

Figure 2.1: Area of potential MFCN impact for the new (Tooman) Dublin Star2000 airport radar



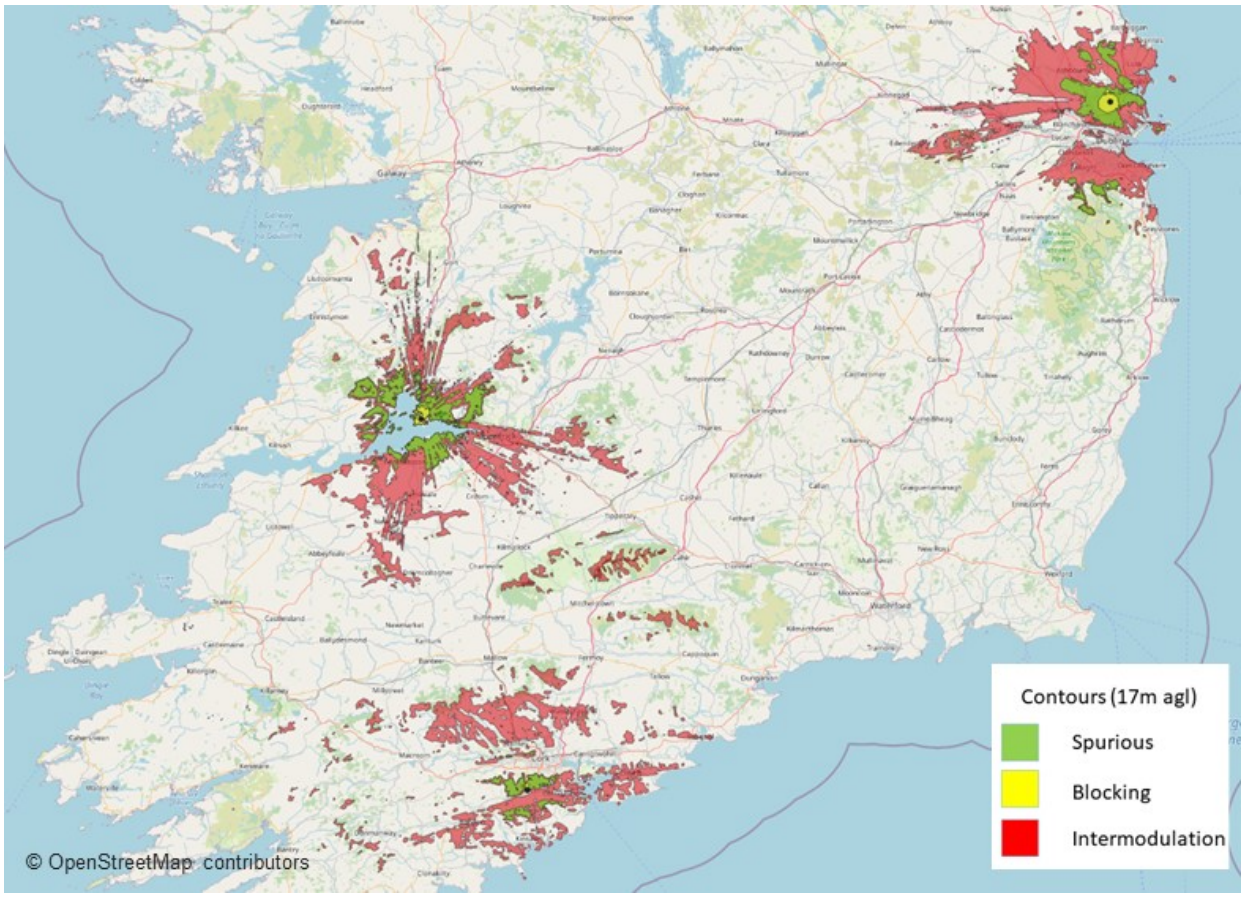
The new site is well screened by rising ground immediately to the north. The population[9] contained within the spurious emission contour is 4,176.

2.3.2 Existing and new radar sites

The areas of potential MFCN impact for the existing three Star2000 radar sites is illustrated below in Figure 2.2

[9] From Gridded Population of the World (GPW) V4.11, 2020 dataset (UN weighted). See: https://sedac.ciesin.columbia.edu/data/collection/gpw-v4

Figure 2.2: Areas of potential MFCN impact for three existing Star2000 radars



2.3.3 Recommended Licence Conditions for filtered Star2000 radars

The following maps show the potential impact areas due to the spurious emission mechanism for all four radar sites; in each case, the 1km co-ordination area is also indicated.

Figure 2.3: Dublin (Tooman) radar; potential impact of spurious emissions and 1km co-ordination zone

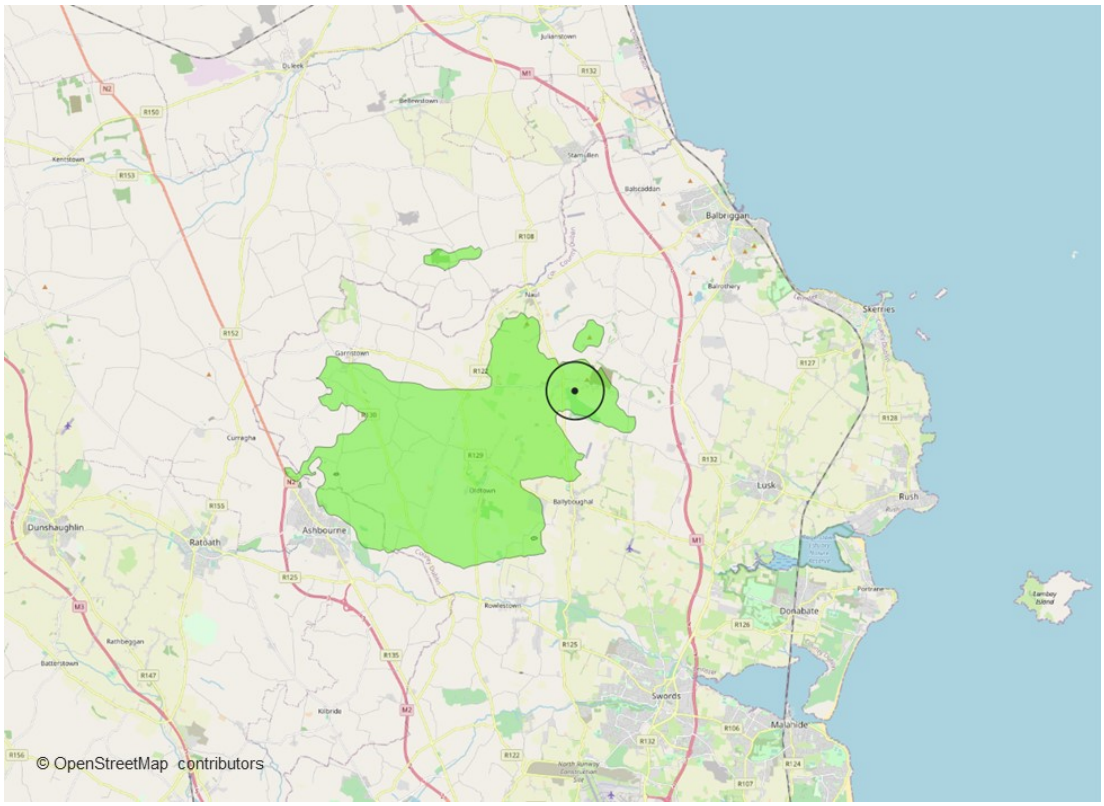


Figure 2.4: Existing Dublin radar; potential impact of spurious emissions and 1km co-ordination zone

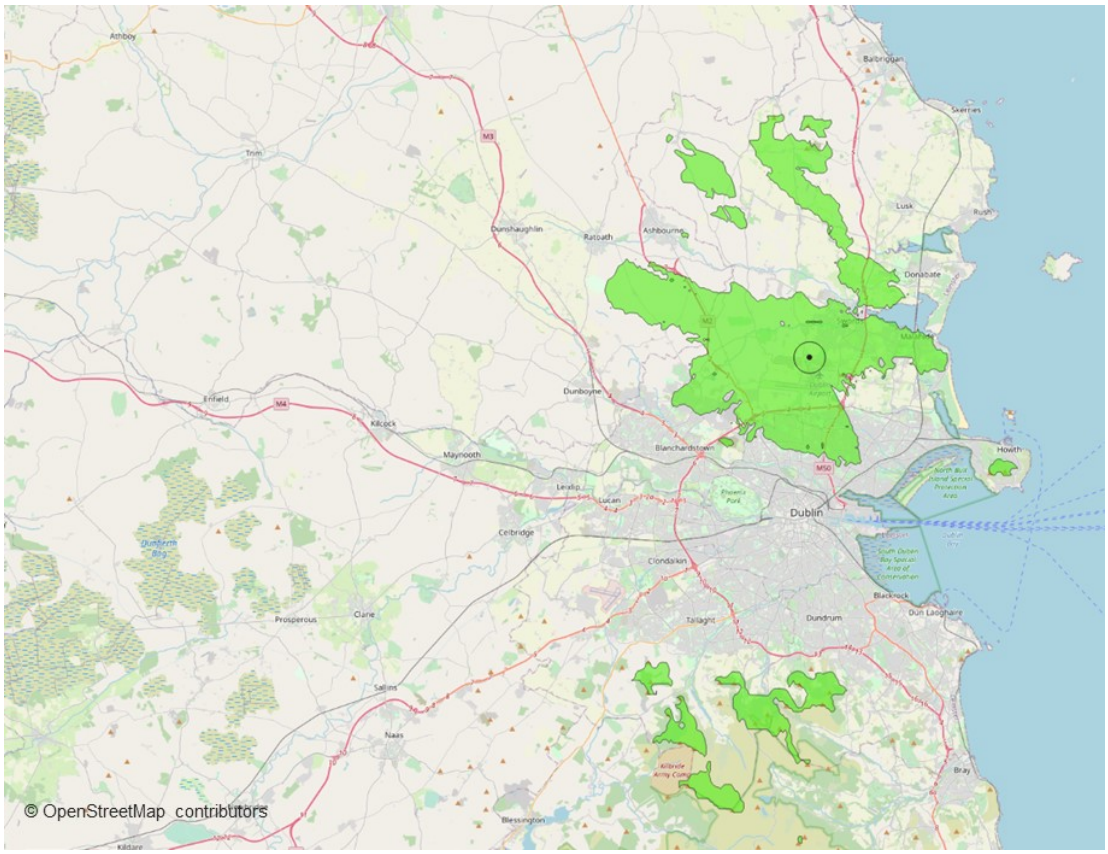


Figure 2.5: Shannon radar; potential impact of spurious emissions and 1km co-ordination zone

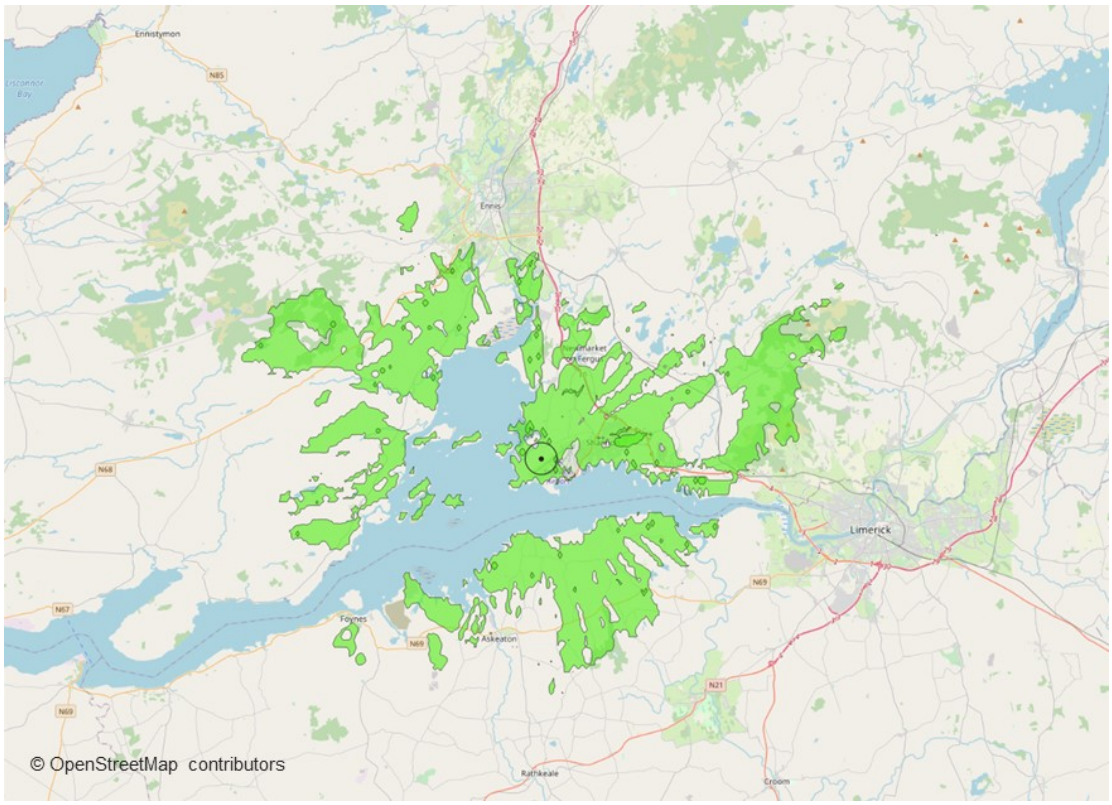
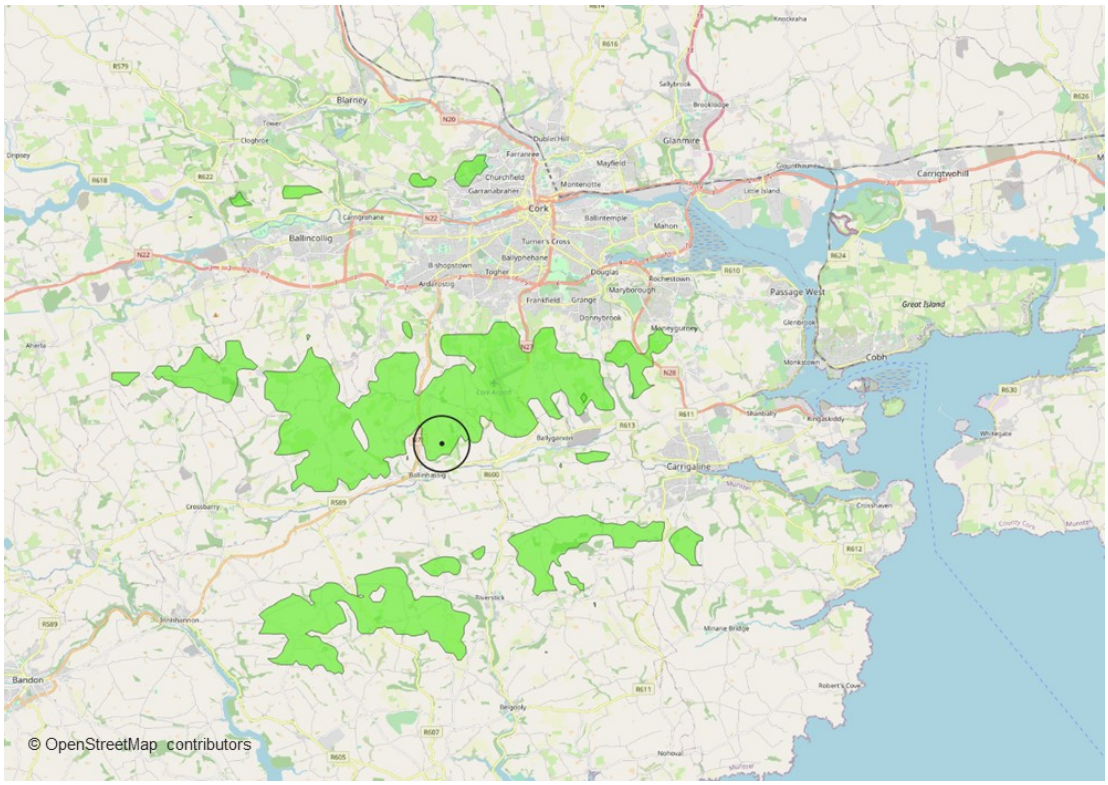


Figure 2.6: Cork radar; potential impact of spurious emissions and 1km co-ordination zone



These contours have also been provided in KML and ESRI® shapefile formats.

2.4 Conclusions

Plum's recommendations set out in Document 19/124c remain relevant and extend to the new Star2000 radar proposed at Tooman, Co Dublin. These recommendations are summarised below.

2.4.1 For STAR2000 Radars

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 existing 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[10];

[10] 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)].

- if MFCNs are deployed before radar filters are fitted, an additional in-band pfd limit[11] of -83 dBW/m^2 at the antenna of the radar receiver [12,13] 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.

- to ensure protection of radars from MFCN base stations where they are operating in close proximity, a 1 km coordination zone[14] should be applied around the radars in Dublin[15], 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)[16].

2.4.2 For the TA10-M radar

Until it is decommissioned, it is proposed that for each operator in the 2.6 GHz band:

- an in-band radiation limit is required in the frequency range 2570- 2690 MHz for:

  – Blocking and intermodulation: To address the impact of blocking and intermodulation effects at radar receivers in the adjacent band the restriction derived in Document 19/124c, 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[17]; and

- an out-of-band radiation limit is required for:

  – 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[18]. 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[19].

The recommendations above follow implementations and standards already adopted in other administrations, such as the UK, Belgium and France considered in Document 19/59d, where MFCN are currently operational in the 2.6 GHz spectrum, to protect aeronautical radar systems.

[11] 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.
[12] 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.
[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 [-78 + 10 log10 (Bandwidth(MHz) / 120)].
[14] As adopted in Belgium
[15] Applies to current radar and new and future radars installed by the IAA.
[16] The compliance with pfd limits could be demonstrated by the MNOs using their own analysis tools as adopted, for example, in France.
[17] 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)].
[18] 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.
[19] 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)].

Appendix A RurTel network geography

A.1 Network geography

Figure A.1: East Donegal network

Figure A.2: West Donegal network

A.2 Individual network co-ordination contours

Figure A.3: East Donegal network (co-channel, wanted = -94.5dBm)

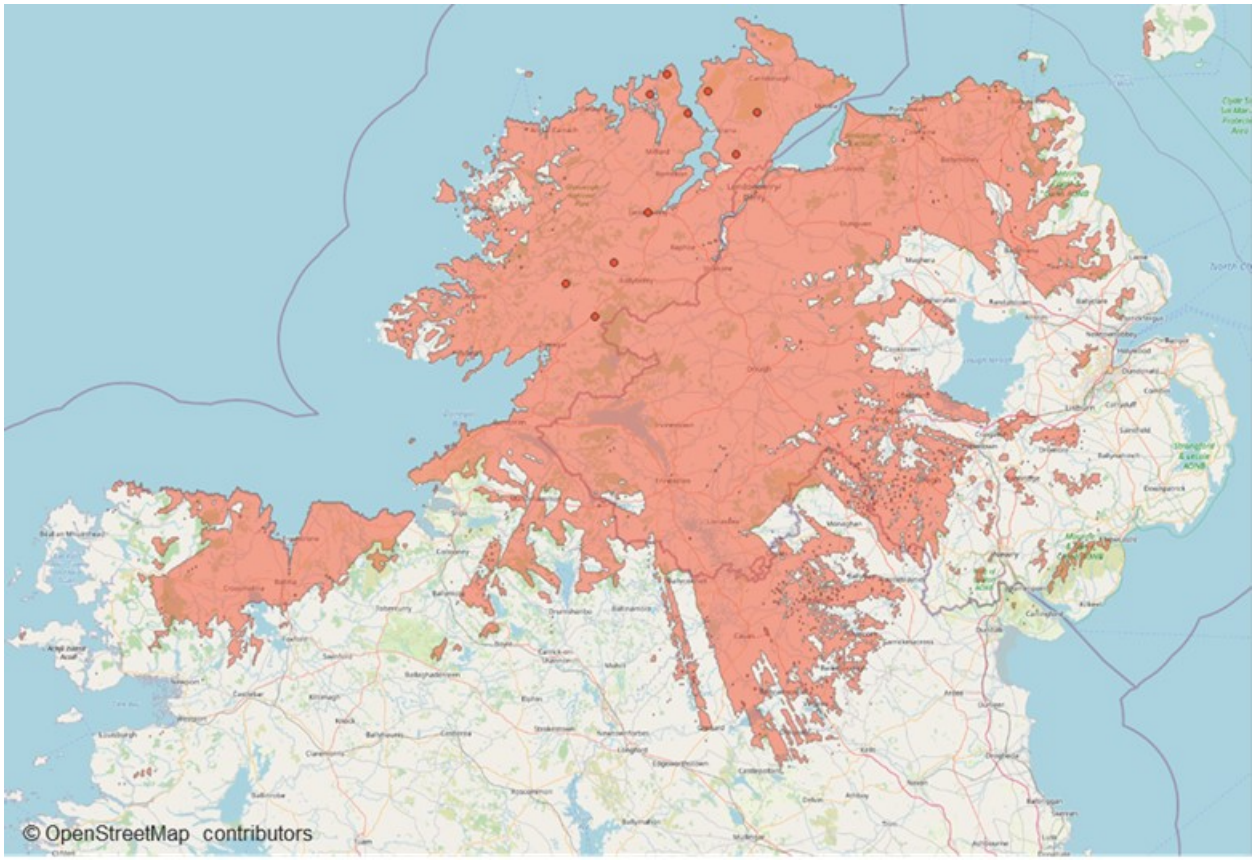


Figure A.4: West Donegal network (co-channel, wanted = -94.5dBm)