Interference Evaluation Between Wireless Systems on a Tier 5 border

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Executive Summary

The goal of this report is to evaluate the different interference mitigation methods that exist to reduce the risks of interference along Tier borders especially in the context of a proposition of authorizing mid band frequency (3.5 GHz and 3.8 GHz for example) licences under the Canadian Tier 5 territory boundaries. It is a given that by subdividing the spectrum in smaller tiers such as Tier 5s, the risk of interference between operators on either side of the tier borders can exist. This already exists between international operators along the Canadian/American border or between operators at the borders of two Tier 4 or Tier 3 service areas. Nevertheless, this interference can be reduced by using different mitigation techniques, such as, modifying the orientation of the antenna, (i.e., applying a more aggressive down tilt for sites along the borders, aligning antenna azimuths[1] so that energy is directed away from the neighboring tier, or reducing the antenna height), reducing the transmission power of these sites, changing their antenna aperture or using massive MIMO antenna configurations, which will be the norm for 5G operations.

These are techniques that have been used throughout the industry and an example of this can be found in many places along Tier and international borders. We have chosen Windsor as an example to show how various mitigation techniques are applied by Canadian operators along the border as to protect American operators serving Detroit. Indeed, the sites located on Riverside Dr. W, near the Detroit River currently have two sectors pointing parallel to the Detroit River while the third sector is pointing towards the Windsor area resulting in minimal RF energy being directed towards Detroit. In addition to azimuth considerations, power reductions and aggressive tilting is also used by Canadian operators on their side of the border. In fact, interference coordination between operators using the same spectrum along a border is a regular occurrence in the wireless industry. Furthermore, interference mitigation is already implemented in the design phase of new site deployments in a proactive way by operators as it is their obligation to protect each other's licenced areas from interference.

To avoid using mitigation techniques, an appropriate distance between a new site and any given border can be considered. In the section Coverage Distances, there are guidelines that suggest a distance must be maintained between the site and the tier border by comparing the height and tilts of the antenna located on this site. If the site is less than 14.3Km away from the tier border, than an appropriate height and tilt must be considered to avoid any interference with nearby tiers. If the height and tilt cannot be achieved than further mitigation techniques must be applied.

The mitigation techniques used across the industry to reduce interference are:

- Down tilting antennas
- Reducing antenna heights
- Reducing the transmit power
- Reorient the antenna azimuths
- Change antenna model (e.g. 60HPBW to 30HPBW)
- Roaming on existing networks
- Deploying small cells

[1] Azimuth: antenna direction where the 0° points directly towards the north and an azimuth of 90° would orient the antenna towards the east. Azimuth are the direction to which the antenna is beaming its maximal signal.

The following tables summarize the results obtained with these interference mitigation techniques on a real site deployment along a tier border. The first table gives an appreciation of the potential reduction of the interference area in the neighboring tier for each mitigation technique individually. The second table shows the results when all techniques are applied. When applying one mitigation technique, the resulting interference will be reduced by 12% to 77% depending on the scenario or mitigation technique used. By applying multiple mitigation techniques (two or more techniques), a cumulative interference reduction will be obtained. The interference reduction for multiple mitigation techniques can range from 57% to 100%. When applying all mitigation techniques, the resulting interference will be reduced by 84% to 100% depending on the scenario or type of configuration.

Table 1: Summary of results per interference mitigation technique

Mitigation technique	Resulting interference reduction range
A 10 deg down-tilt	37% to 77%
Azimuths parallel to border	34% to 76%
Operating at half power	21% to 46%
A 10 m height refuction	12% to 37%
Use of a mMIMO antenna Vs a standard antenna	30%

Table 2: Summary of results when all mitigation techniques are applied

Combinations of all mitigation techniques	Resulting interference reduction range
Standard antenna	84% to 100%
mMIMO antenna	87.4 % to 100%

It's a given that in some cases it will be difficult to eliminate all the interference caused by sites on each side of a border between two coordinated licensees. Even as operators are obligated to use these techniques in their site deployment design, some residual interference could remain and may be experienced by the affected network subscribers by a reduction in throughput and a potential increase in latency but not an elimination of service. This will be mostly observed in fringe coverage areas of the affected network.

It is understood that all these mitigation techniques have an impact on the operator trying to offer service within their licenced Tier. We could easily understand that if interference from a site is reduced or eliminated in a neighboring tier, then the resulting coverage from these mitigated sites will also be reduced in those directions. To remedy this, a densification approach using small cells along the borders where coverage is needed would be a viable technical solution while keeping the interference at a minimum on the operation of neighboring tiers. By implementing a typical small cell deployment at around 100 m away from tier borders, the coverage would be sufficient to supply the service level desired by the operator. Another remedial action would be using existing low band or mid bands frequencies that are already giving coverage in these areas which incumbent operators have a supply of or to roam off an existing provider's network as presently mandated by the CRTC.

Similarly, a tabu table such as table 7 and table 8 used for macro sites can be done for small cell scenarios. This would allow the designer to deploy the small cells at respectable distances from a licensed tier border, and from each other to avoid interference (within another licensed tier or within its own tier). Furthermore, these mitigation techniques specified above can also be used for small cell scenarios. This would allow the coverage to stay within a licensed tier and not cross over to the neighbouring tier, and reduce interference from sites that may be placed on high terrain or close to another micro cell. In summary, we have shown through simulation that mitigation techniques are effective and are in fact already largely used by operators to control interference on areas they aren't licensed for.

1 Introduction

This report was requested by Cogeco in order to complete a coverage and interference analysis at the border of Tier 5 regions. The goal of the mandate is to perform RF coverage studies using mid-band frequencies, such as the 3.5 GHz and the 3.8 GHz, to determine the impact of interference on nearby tiers when positioned close to the border of these tiers under study. Once the impact is determined, mitigation solutions are proposed to reduce or eliminate the interference that would exist along the border of the Tier. In our evaluation, we considered the 3.5 GHz band characteristics as it has a slightly greater range than that of the 3.8 GHz one.

The study shows that the interference caused by a 3.5 GHz system can be easily mitigated using a combination of techniques seen in the following section. Thus, allowing the licencing of mid-band or mmWave channel blocs at a more local level (Tier 5) than a Regional, Provincial or National level (Tiers 1, 2, 3 and 4). Indeed, the propagation distances at higher bands such as 3.5 GHz are relatively short to the distances achieved in lower bands. This limited range results in less interference on neighboring competing services and thus allows for smaller territory subdivisions for competitive licencing purposes.

Furthermore, the extensive use of small cell technology to deliver 5G NR services in addition to mMIMO technology, will also result in reduced or more targeted cell coverage and additional control of resulting interference between competitive neighboring networks. This technology helps in ensuring that interference can be completely mitigated along tier borders between neighboring operators using the same spectrum even for Tier 5 localised areas.

The following report presents the various techniques presently available to wireless operators to ensure the interference is controlled within their own network and on neighboring tiers between different operators. These techniques include:

- Down tilting antennas
- Reducing antenna heights
- Reducing the transmit power
- Reorient the antenna azimuths
- Change antenna model to smaller apertures (60HPBW to 30HPBW)
- Using mMIMO beamforming antennas
- Roaming on existing networks
- Deploying small cells

The following section will present in greater detail the different scenarios that the mitigation techniques will resolve and an example along the Detroit River will show some of these techniques already in use.

2 Methodology

To evaluate the complexity of coordination in order to minimize interference along Tier 5 borders between neighboring operators using the same spectrum in adjacent tiers, we looked at the proposed draft Tier 5 subdivision map available through ISED Canada website “Service Areas for Competitive Licensing”[2]. More specifically we looked at a specific Tier 5 (5-285), assumed to be a newly licensed Area for operator B, with respect to three of its neighboring Tier 5 (5-284, 5-286, and 5-293) assigned operators. We than extracted from the ISED Canada Spectrum Management System[3] the sites from an existing incumbent mobility service provider (Bell Mobility) within the four Tier 5 regions selected. We assumed that the sites within each of the Tier 5 regions were operated by 4 independent licensed operators in the 3.5 GHz Band and looked at scenarios where operator B (5-285) has to protect the border from interference in service areas of operators A (5-284) as well as of C (5-286) and D (5-293). Seeing as the mitigation techniques are the same along any border, we focused on scenarios of interference on Tier 5-285 on Tier 5-284. Each scenario will be evaluated using a standard MIMO antennas and mMIMO.

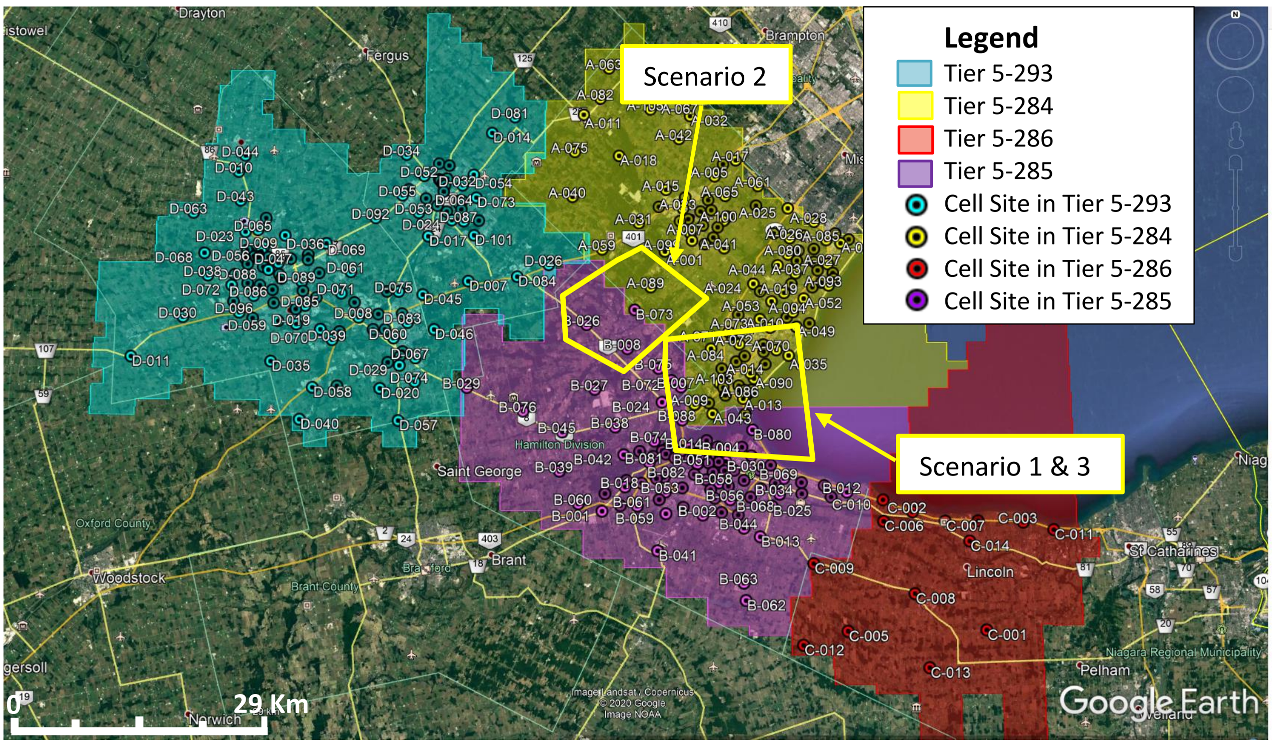


Fig 1: Map of existing sites within tiers 5-284, 5-285, 5-286 and 5-293

The scenarios that were considered are presented in the following pages. They are:

1. Scenario 1 – Site in Tier 5-285 located at the border with Tier 5-284
2. Scenario 2 – 2 Rural sites in Tier 5-285 located 3 km from Tier 5-284 border
3. Scenario 3 – 1 Suburban site located close to the Lake Ontario facing Tier 5-284
4. Scenario 4 – Small Cell evaluation along a border

[2] Service areas for competitive licensing : https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf01627.html#tierMap
[3] Spectrum Management System : https://sms-sgs.ic.gc.ca/eic/site/sms-sgs-prod.nsf/eng/h_00010.html

2.1 Scenarios

The first scenario can be seen in Fig.2. The site B-088, circled in yellow in the figure below, is along the tier border of 5-284 and 5-285. The orientation of each sector is depicted by orange arrows. The land is mostly residential with trees, commercial-industrial, grassland and forest.

The existing parameters of this site are:

Table 3: Scenario 1 Existing Parameters

Sites	B-088		
Sector	1	2	3
Height (m)	29.3	29.3	29.3
Azimuths (°)	70	170	315
Tilt (°)	0	0	0
Max Power (dBm)	49		
Frequencies (MHz)	700/850/1900/2100/2600		
Model	RHHTT_65A_R4		

Looking at this site configuration, it can be expected that interference from the operation of a 3.5 GHz 5G NR system would create interference in Tier 5-284 as one of the site sector is directed toward that Tier.

Fig 2: Scenario 1 Map with site B-088 interfering on tier 2-284

The 2nd scenario can be seen in Fig.3. The sites B-026 and B-008 are located around 3km away from the tier 5-284/5-285 border. These sites are marked by yellow circles. The orientation of each sector is depicted by orange arrows. The terrain surrounding these sites is somewhat flat and rural, open, grassland and forest.

The existing parameters of this site are:

Table 4: Scenario 2 Existing Parameters

Sites	B-008			B-026		
Sector	1	2	3	1	2	3
Height (m)	44	44	44	27.2	27.2	27.2
Azimuths (°)	0	140	270	45	160	280
Tilt (°)	4	4	4	2	2	2
Max Power (dBm)	49					
Frequencies (MHz)	700/850/1900/2100/2600					
Model	DBXNH_6565A_A2M					

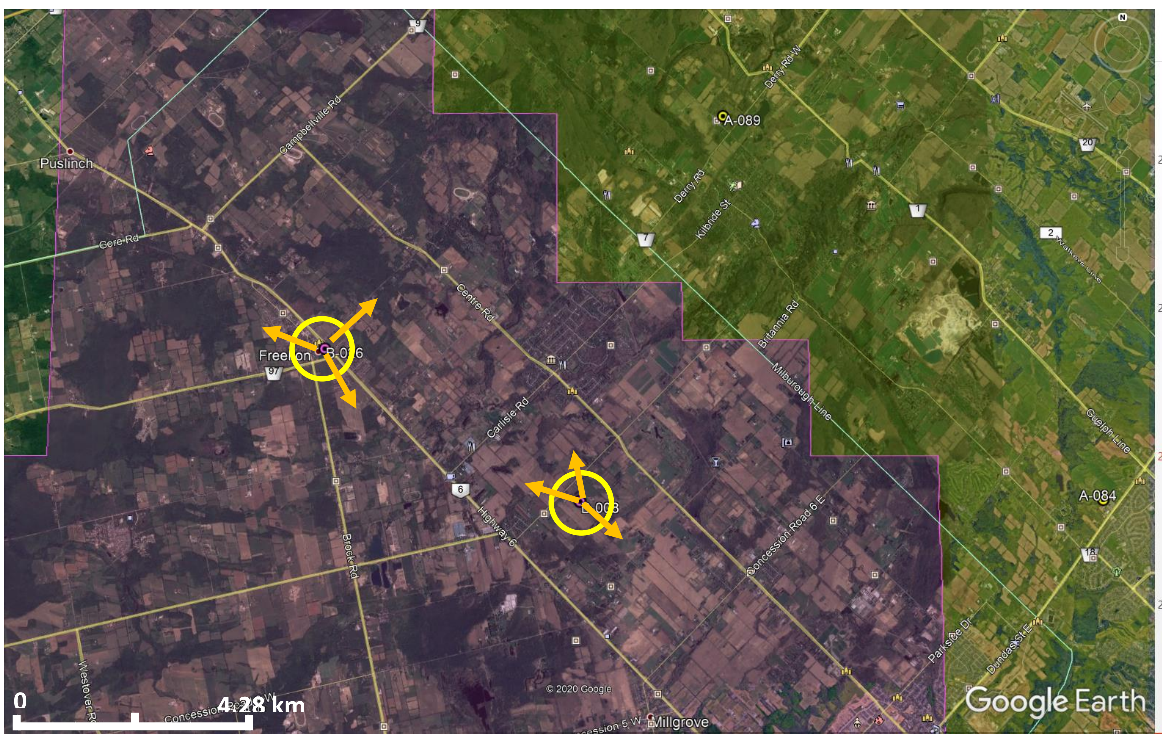


Fig 3: Scenario 2 Map with sites B-026 and B-008 interfering on tier 2-284

The 3rd scenario can be seen in Fig.4. The site B-010 is located near the Hamilton harbour where there is a body of water separating the site being studied and tier 5-284. The site B-088 is circled in yellow and the orientation of each sector is depicted by orange arrows. The terrain surrounding this site is in-land water, industrial and suburban. This type of scenario observes the interference impact from a new site located across a body of water to a neighbouring tier.

Table 5: Scenario 3 Existing Parameters

Sites	B-010		
Sector	1	2	3
Height (m)	71	71	71
Azimuths (°)	0	120	240
Tilt (°)	0	0	0
Max Power (dBm)	49		
Frequencies (MHz)	850/1900/2100 /2600		
Model	SBNH_1D4545A		

Fig 4: Scenario 3 Map with site B-010 interfering on tier 2-284

The 4th scenario can be seen in Fig.5. This scenario consists of 4 small cells located on either side of a simulated suburban tier border. These sites are 100m from the tier border and the terrain surrounding these sites is a residential terrain with a few trees.

The typical small cell parameters involving these sites can be seen in the table below:

Table 6: Typical Small Cell Parameters

Sites	B-005	B-043	B-058	B-015	B-090	B-091	B-092	B-093
Height (m)	10							
Azimuths (°)	0							
Max Power (dBm)	40							
Frequencies (MHz)	3500							
Model	Kathrein 80010431 (omni antenna)							

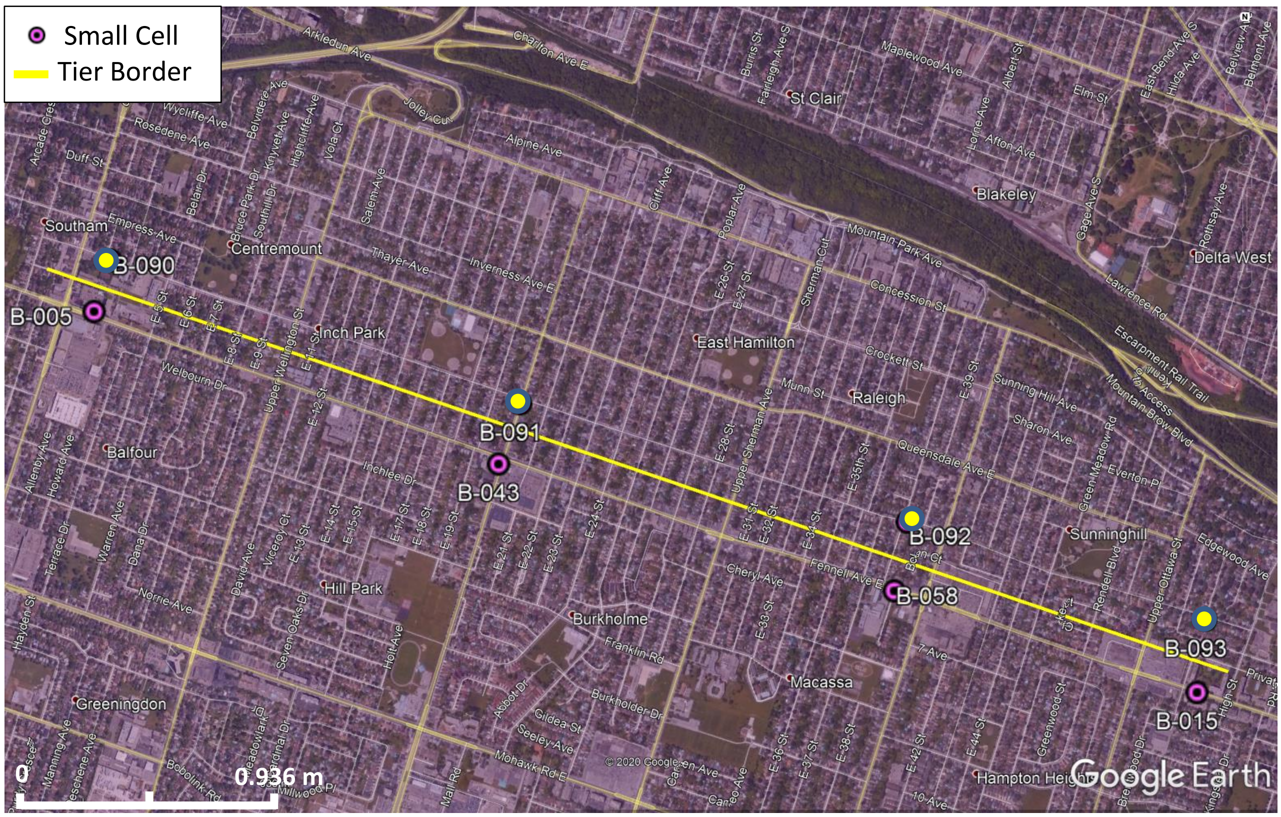


Fig 5: Small Cell Map Scenario

2.2 Simulation Tools

Now that the different scenarios have been addressed, a strong simulation tool is used to observe the impacts when adding a 3.5GHz NR system to an already existing network. Mentum Planet 7.4 is capable of analyzing the interference and coverage after inputting the above transmit parameters. Planet has a generic propagation model within its software that is excellent for macro/micro-cellular evaluation and very good for mm-Wave evaluations. Planet's generic propagation model considers the absorption loss for each clutter for a given frequency and creates an accurate and realistic propagation simulation. Furthermore, YRH has terrain elevation files and clutter data that complement the propagation model by providing 30m accuracy with regards to ground elevation and clutter/obstacles. The elevation and clutter files used by YRH are "YRH_Ontario_30m_heights" and "YRH_Ontario_30m_clutter". For the end user, the received antenna is an omni located 1.5m above ground. Using these parameters and the mitigation techniques seen in the next section, the interference and coverage impact can be observed.

2.3 Mitigation Techniques

To reduce interference in a nearby tier, the following mitigation techniques were considered:

Table 7: Mitigation Techniques

Mitigation	Antenna used	
	Standard X-POL	**mMIMO Beamforming**
Antenna model	Kathrein 80010603	Ericsson mMIMO AIR6449
Down-Tilt	10 deg	20 deg
Height reduction	10 m	10 m
Power reduction	50% (-3 dB)	50% (-3 dB)
Orientation	Parallel to border	Parallel to border
Antenna apperture	HBW of 30 deg (Kathrein 800 10251)	NA

Typically a three sector 60°HPBW configuration, such as the Kathrein 80010603 antenna, is used throughout the industry to supply a coverage across a desired area. (See Annex A for Kathrein 800 10603 technical specifications). However, when not using an appropriate down tilt, height, power, and orientation can lead to interference within the network. If there is still interference after adjusting these parameters, then an antenna swap would be another method to mitigate the interference. Swapping a 60° HPBW to a 30° HPBW would cause the propagation to go further in distance but be narrower along the propagation. This would cause the propagation to interfere with fewer sites along the sides of the antennas and add coverage at a longer distance. It should be noted that this antenna can cover a further distance and this may lead to interference at a further location if additional mitigation techniques aren't used. For the studies done in this report, the Kathrein 800 10251 antenna was used as the 30° HPBW antenna. (See Annex B for Kathrein 800 10251 technical specifications) The 1900 to 2100MHz band was altered to add a 3500MHz antenna model into Planet.

Inevitably with the use of 3.5GHz NR wireless systems, mMIMO beamforming configurations will be used. Beamforming allows the transmitted signal to be focused or propagated to a certain area that needs coverage. This allows devices to be able to receive signals in places that would be either obstructed or further away. Furthermore, a mMIMO beamforming configuration would reduce interference because it is not broadcasting the signal in directions that are not needed. The beamforming antenna model used for the mMIMO configuration analyses is the Ericsson mMIMO AIR 6449. (see Annex C for Ericsson AIR 6449 technical specifications) Mentum Planet's method to simulate a beamforming configuration is to apply multiple antenna patterns with different tilts inside the antenna model. Once the simulation is completed, a smart selection is conducted by the software to select the best pattern with regards to the location of the population density. When applying a 10° down tilt for a mMIMO network, the results would be the same because the smart selection picked an antenna pattern that would be sufficient to combat the tilt applied to the antenna resulting to a similar result. By applying a 20° down tilt, the smart selection would not be able to select a pattern that would result in a similar coverage for the population density. Instead the smart selection would likely pick the highest up tilted pattern to achieve the best coverage possible. Please note that for a standard configuration, not mMIMO, the generic down tilt used across the industry is about 10°.

To circle back, these mitigation techniques specified and the appropriate setup of sites located nearby tier borders, nearby macro sites or even nearby international borders are seen throughout the industry today. An example of such mitigation techniques can be seen in Windsor to reduce interference across the Detroit River. More often than not, one mitigation technique will not be sufficient to reduce the interference to a respectable level. Especially if the site is located beside a neighbouring tier. Thus the combination of multiple mitigation techniques will often be needed to reduce the interference level to an adequate level. However, the use of these mitigation techniques will also cause the coverage to decrease. For example: adding a down tilt to an antenna will cause the interference to reduce, but it will also cause the coverage to reduce. A coverage and interference criteria needs to be properly established to validate if the coverage and interference levels are acceptable.

2.4 Coverage and Interference Criteria

To acquire a good coverage across the area in LTE or 5G NR systems, the RSRP should be greater than or equal to -100 dBm. Any value less than -100 dBm will cause users to have packet loss or dropped calls. It should be noted that -100 dBm would allow a good exterior received signal but due to the high frequency being used, a larger than 10 dB drop is to be expected when observing in-building coverage through housing materials such as wood, concrete or commercial building material with metal and polarized windows especially affecting higher range frequencies such as those above 2.5 GHz. For this reason, a threshold of -95 dBm of RSRP level is considered to be the target design signal strength for a mobile receiver located at 1.5m above ground. This is considered as an acceptable outdoor reception threshold by the industry and one of the many cellular network design coverage criteria.

A way to combat this coverage dilemma at higher frequencies is to add more macro/micro sites to cover the same territory as existing lower band sites. However, this increases the risk of interference between sites. Parameters that will raise the risk of interference are: distance between sites, insufficient antenna tilts and/or antenna azimuths, high transmit power and high antenna heights.

SINR (Signal-to-Interference and Noise Ratio) and RSRQ (Reference Signal Received Quality) are quantitative indications of signal quality. For the SINR, if the received signal is greater than the addition of Interference and Noise, then the signal quality would be "good". If the received signal is much smaller than the addition of Interference and Noise, then the signal quality would be poor. The minimum required SINR used in the industry is 5 dB. An excess of interference would be the result of having an SINR of 5 dB or less. Hence if the RSRP signal strength is -95 dBm, interference from cross-border sites would start being problematic when their RSRP reaches -100 dBm at the border. . If the RSRQ is “low”, the quality of the data transfer or phone call would be “low”. Latency would increase and data transfer rates would suffer because of reduced modulation resulting in a poor user experience in the low SINR affected areas.

In light of the above, to avoid mitigation and interference along nearby tier borders, an RSRP coverage guideline has been created to determine the heights, tilts and distances needed. For this analysis, the power used is an 80W transmit power. By adjusting the heights and tilts, the -100dBm RSRP coverage distance can be determined. It should be noted that once the antennas reached a certain tilt, the coverage will either maintain the same distance or even increase due to the antenna side lobes. Thus, this table also determines the range of the tilt that may be used on future sites to avoid over tilting the antennas.

If the distances in the guideline are not maintained, then the mitigation techniques seen in the previous pages must be considered to avoid interference. If one of the mitigation techniques is not adequate enough to reduce the interference, then progressive mitigation would need to be applied. Progressive mitigation would be the addition of a different mitigation strategy to reduce interference. If the interference is still too high, then a third or fourth mitigation technique would need to be applied until the interference is sufficiently reduced.

Similarly, interference from neighboring sites or sectors within the same network is dealt with by using these mitigation techniques. These techniques can be used by operators coordinating their deployment along any Tier or international border they share. In an LTE/5G network where the spectrum is reused at every site using orthogonal coding mechanisms, it is clear that the interference is impacting the coverage of a dominant site/sector (or best serving sector when using a simulation tool such as Mentum Planet) Typically the dominant site is the site with the higher RSRP level and is usually the existing site when considering a new deployment. If the site is the second best serving site/sector, than it is the interfering site while another site is acting as the dominant site. Hence the idea is to limit the coverage and interference coming from sites in a given tier into a neighboring tier in such a way that their contribution of a first and second best serving sector is eliminated on the other side of their licensed Tier border. This would effectively reduce the risk of contributing to the SINR levels within the protected tier. When considering an example of an international border. The site located at the south of the border would limit its coverage and interference so that the first and second best serving sectors would not be seen at the north of the border. This would be similar when considering two licensed tiers located next to each other. Additionally, an example of the techniques previously mentioned to limit the coverage/interference can be seen along the Canadian and American border, near the Windsor and Detroit area.

2.5 Example

One example that proves that operators use the methodology presented in the previous pages are the sites along the Detroit River located in Windsor. Telus, Freedom Mobile, Rogers Wireless and Bell Mobility have about 50 sites located nearby the Detroit River and these existing sites have a configuration in place to reduce interference within the city of Detroit. The information regarding these site parameters were taken from Innovation, Science and Economic Development Canada's database. The next few maps show the location of the sites and the direction in which the antennas are pointing at.

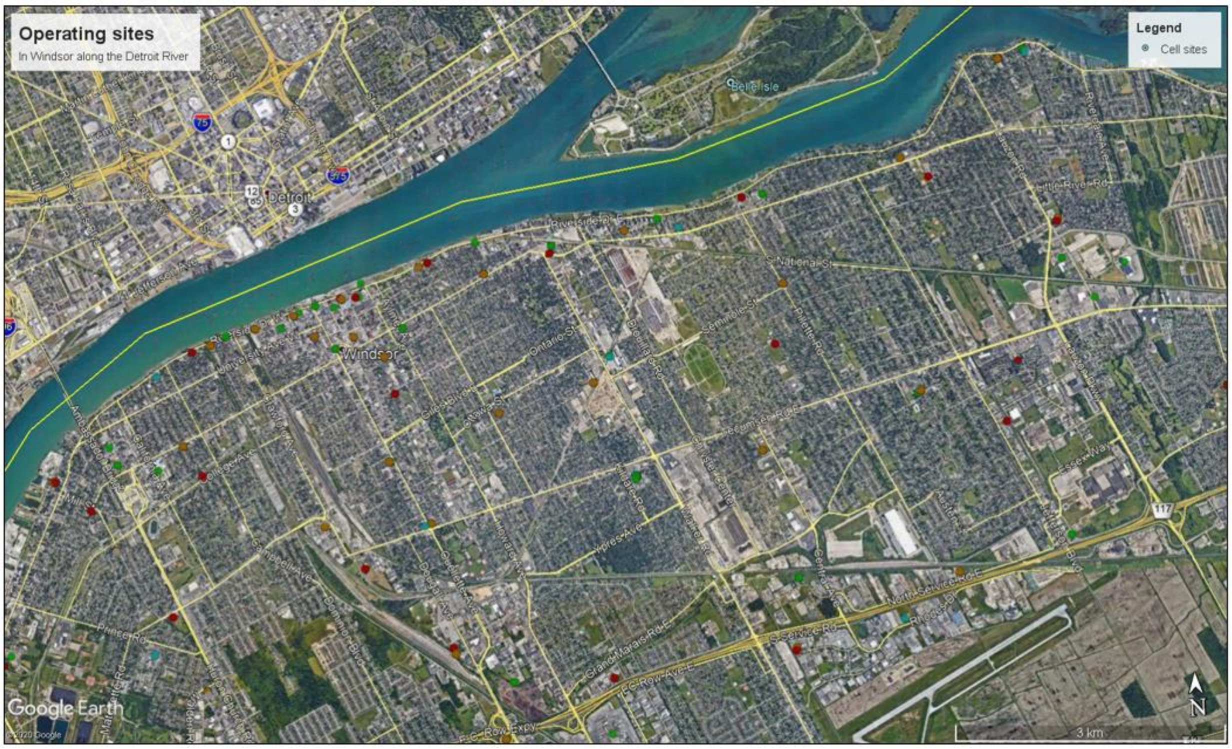


Fig 6: Windsor Map with existing mobility site locations

Fig 7: Windsor Map with cell site antenna orientations

The main observation is that the sites located along the Detroit River have their antennas pointing parallel to the river, while a third sector would be pointing away from Detroit and towards the city of Windsor.

It's noted that the closest site pointing towards Detroit is located at approximately 400 m away from the river. Although the antennas of that site are positioned at a heights between 72 m and 88.1m, the operator has configured the antennas of the sector pointing towards Detroit to have a down tilt of 6° to 15° and a max transmit power of 80W. The sectors that are pointing towards the Detroit River are using these frequencies: 872.5MHz, 1937.5MHz and 2137.5MHz.This site is circled in red on the map shown in Fig.7. Furthermore, this site configuration and mitigation scenarios are done for frequencies that propagate much further than the 3.5 GHz band. Indeed, the sites located along the river have channels operating between 700 MHz and 2.6 GHz, yet the interference seems to be sufficiently controlled between the international operators on either side of the border.

The site configurations along the Detroit River and within central Windsor is seen below. The sites near the river are the sites seen no further than 200m away from the Detroit River. Similarly, cellular sites that are applying azimuth mitigations can be seen no further than 200m away from the River. Further inside-Windsor sites are located 450m to 1Km away from the Detroit River and already at such a small distance mitigation techniques don't seem to be systematically used. The site circled in red in the above map is located only 400m away from the river.

Nevertheless, looking at the sites in the Windsor area, we can find sites with aggressive tilts between 30° to 60°. The operator of these sites is Telus and it seems that they use an aggressive down tilt to mitigate interference to cross border systems. Other max and average values can be seen in the Windsor summary table below.

Table 8: Windsor Summary Parameters

	Sites Near River	Sites in Windsor
Distance to border	< 450 m	➢ 450 m
Azimuth Delta to border	±70°	0°
Average Power	34.2 W	39.8 W
Max Power	79.4 W	158.5 W
Average Tilt	8.5°	17.65°
Max Tilt	35°	60°
Average Height	41.2 m	35.7 m
Max Heigth	66 m	85 m

Analysing the table above it can be concluded that along the border the operators have a clear design intent of protecting the international border with azimuths, power reductions and tilts that reduce interference on the Detroit side of the border. In addition, as sites are increasingly removed from the border we see that sectors are pointing towards Detroit but the tilting is very aggressive to try and contain the energy on the Canadian side of the border. Looking at this real and implemented scenario it's clear that interference mitigation techniques are used in the design of the Canadian networks and that these methods work for all bands in licensed in that area from 700 MHz to 2500 MHz. This is done in a proactive way when designing the coverage from each site and through coordination, tilting and power adjustments could be further applied to ensure that the interference is minimal after implementation. Today, electric tilts are remotely adjusted using the RET (Remote Electric Tilt) technology and power adjustment as well by remote control of the power parameters.

By comparing the riverside sites and the in-land sites located in Windsor, the half power reduction and azimuth orientation are the main techniques used to minimize the interference along the international border. Now, to better understand these mitigation techniques in the four scenarios that were presented in the previous sections, the mitigation techniques are applied to the typical and mMIMO configured sites and their reduction of the 2nd best server (interfering server) contribution are measured to quantitatively depict the impact of applying one or multiple mitigation techniques to reduce interference

3 ANALYSIS AND RESULTS

In this sections, we will look at the impact that the mitigations could have on reducing the interference that sites could cause from one side of a Tier border to the other side of that border. Typically we assume here that two concurring operators would be licensed with the same spectrum on either side of the border. Before evaluating the reduction in interference each mitigation technique could have on interference, we looked at what interference is caused by the sites mentioned in the first three scenarios when operated with the parameters found in the ISED Canada Database within an existing Bell Mobility network. We then looked at the concept of proposing a cross-border design constraint guideline in a form of a distance taboo table depending on antenna height and tilt for antennas pointing directly towards a tier border ensuring that -100 dBm at 3.5 GHz wouldn't go beyond a Tier border. Thirdly, we applied mitigation techniques for the interfering sites in the three scenarios and compared the reduction of interference to the one that is caused using the published ISED site configuration. Finally we evaluated the method of using a microcell deployment scenario along a border in a suburban area as a method to bring coverage while minimizing interference.

As shown for each of the scenarios detailed below, interference from these sites exists and could be extensive if interference mitigation measures are not applied. Also, it should be noted that the original site configuration for the sites in these scenarios was that of an operator with sites on both sides of the border.

3.1 Interference Scenarios

3.1.1 Scenario 1

In this scenario, we looked at the interference caused by a site configured with a sector pointing towards a Tier border. In each of the scenarios, the active interfering site(s) in Tier 5-285 has a purple circle around the site. In Fig.8, Site B-088 causes interference on 1.544 Km^2 of the area within tier 5-284 (where it's second best server and causes SINR to be < 5dB on 5-284 best server coverage). This site is located very close to the tier border (< 1km) and there is a sector pointing directly on the nearby tier.

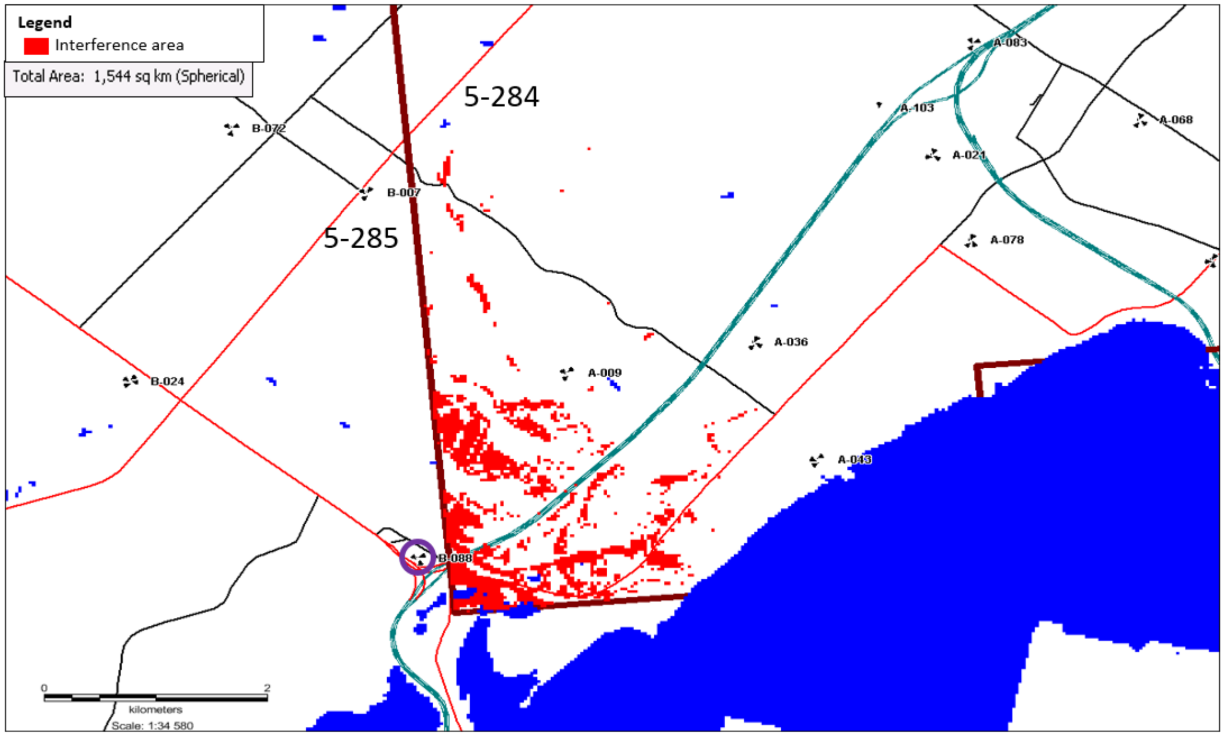


Fig 8: Scenario 1 B-088 original ISED published configuration interference impact

3.1.2 Scenario 2

In this scenarios, the sites are located at approximately 3 km from the tier border and have sectors pointing towards the border. In Fig.9, sites B-026 and B-008 cause interference (where it's second best server and causes SINR to be < 5dB on 5-284 best server coverage) on 5.136 Km^2 of the area within tier 5-284.

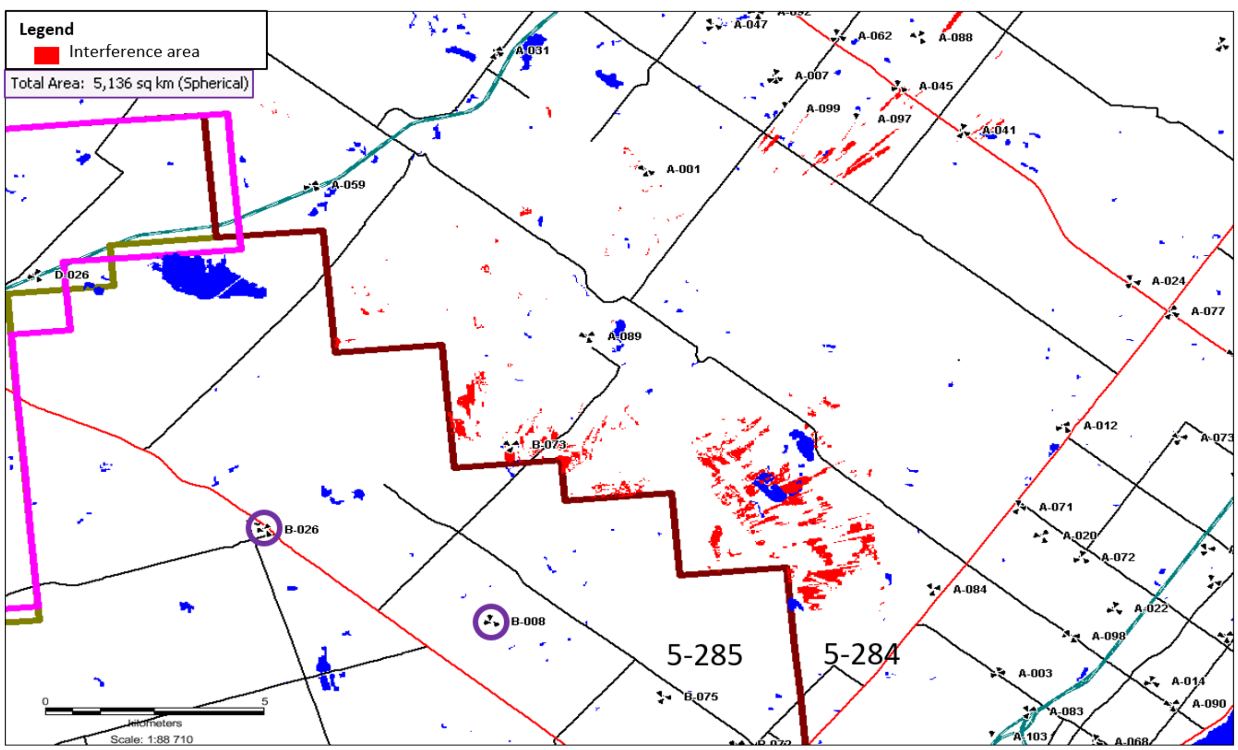


Fig 9: Scenario 2 B-026 and B-008 original ISED published configuration interference impact

3.1.3 Scenario 3

Similarly, In Fig.10, the site B-010 causes interference (where it's second best server and causes SINR to be < 5dB on 5-284 best server coverage) on 1.213 Km^2 of the area within tier 5-484. This site has a sector pointing directly at the nearby tier and is separated by a mass of water. The mass of water has no clutter that would attenuate the 3.5 GHz signal.

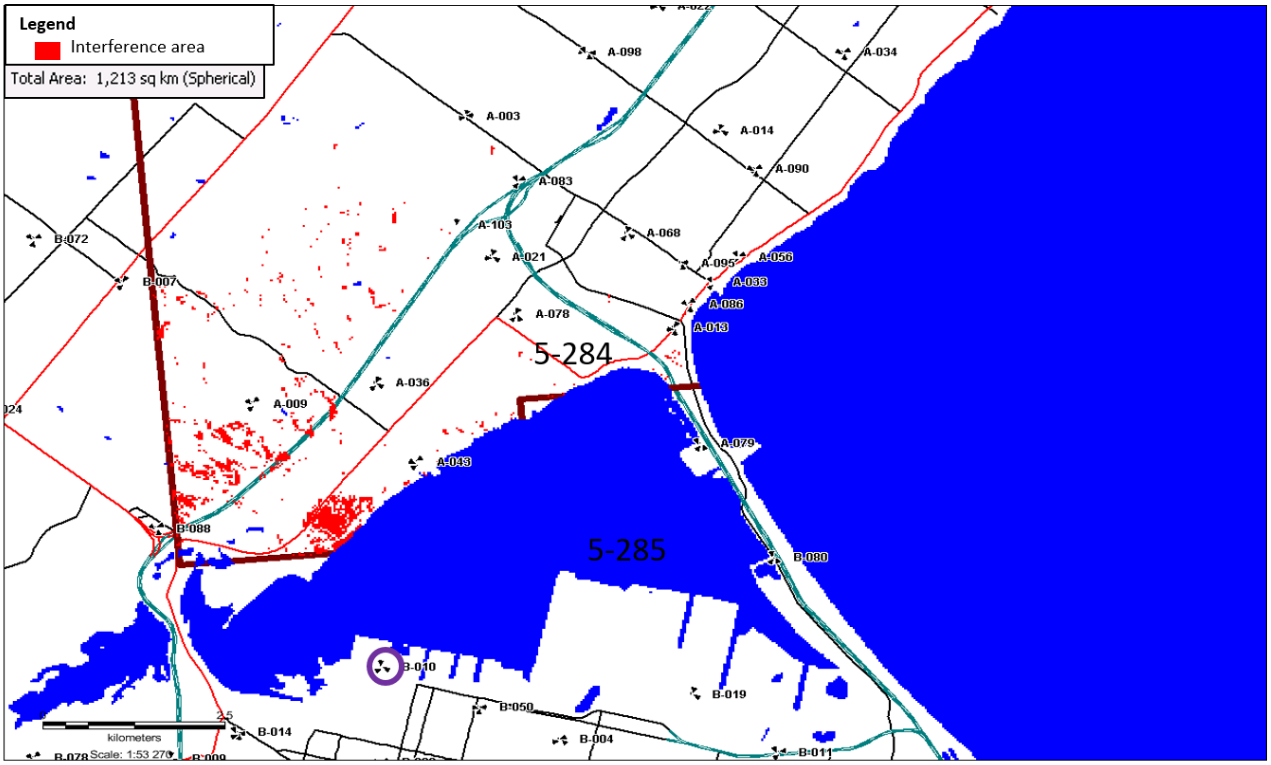


Fig 10: Scenario 3 B-010 original ISED published configuration interference impact

3.2 Coverage Distances

Although the mitigation techniques in the previous section are all ways to reduce the interference impact on nearby licensed tiers and interference within its own/existing tier, these mitigation techniques also reduce the coverage needed. This section will consider the impact that heights and tilts would have on the RSRP coverage when applying different combinations of these parameters. For this analysis, an RSRP coverage of -100 dBm is considered with a typical transmit power of 50W being used. The heights considered for this analysis are heights in-between 30 to 70m, with increments of 10m between each analysis. These are typical macro site tower heights that are used across the industry. The down tilts considered ranges from 0 to 30°, with increments of 2° between each analysis. Typically, the down tilts used for LTE sites are generally 0° to 15°. The coverage distance was calculated from the site propagating to the end of the main -100dBm RSRP signal. For this type of analysis, the clutter is mostly, an open, rural and flat terrain to try and reduce variables that would cause the coverage to be reduced (worst case). By applying different types of clutter such as urban, suburban, urban core and forested, the coverage would be less than the values seen in the heights and tilts vs coverage tables seen on the next page. The tables 7 and 8 on the next page also compare the typical antenna configuration coverage with a MIMO configuration coverage. Please take note that only one site was simulated at a time for both the typical and MIMO configuration. This allows the antenna pattern selection tool for the mMIMO to consider a pattern that would cover the largest area (most users) without considering other mMIMO sites. In a mMIMO deployment, the beamforming algorithm of a given sector will increase its tilt as to reduce its contribution (seen as noise and interference) in an area already covered by another more dominant site/sector.

These heights and tilts vs coverage tables can be used as a general guideline and eventually perhaps an industry accepted model as to when mitigation techniques would need to be considered. By, first locating the distance between a new site and the area that needs to be covered, the corresponding height and tilt parameters can be found in tables 7 and 8. If these parameters cannot be respected, the mitigation techniques must be considered.

For example, from table 7 it can be seen that a site having a standard MIMO antenna height of 70m would need to be located at more than 14.2Km from a tier border when applying no tilt to ensure that it's signal would be less than -100 dBm at the Tier border. This would theoretically allow for the SINR>5 dB criteria mentioned previously. Similarly, it could be seen by looking at the table that applying a 6 degree down tilt would reduce that distance by a factor of 1.9 and an 8 degree down tilt would reduce that distance by a factor of 3.9.

Using the same concept with a mMIMO antenna in table 8, it can be seen that the results are similar in terms of propagation distances for a -100 dBm signal when comparing height and antenna tilts.

It can be noted that the shortest propagation distance is 0.8 Km and that is with a down tilt of 30°. Using a higher down tilt will have minimal additional impact due to the coverage plateauing. It can be seen when considering down tilts of 16° to 30° that the coverage difference is very minimal with a difference of 0.7 Km. This is due to the antenna tilt pointing too low causing the antenna pattern side lobes to be the dominant factor in its coverage.

Table 9: Standard MIMO antenna configuration antenna height and tilt vs -100 dBm coverage range

Typical Site Configuration																
Antenna Height (m)	30 m															
Antenna Down tilt (°)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance (Km)	10.6	10.3	6.7	6.4	2.8	2.1	2.1	2	1.5	1.4	1.4	1.3	1	1	0.9	0.8
Antenna Height (m)	40 m															
Antenna Down tilt (°)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance (Km)	12.1	11.8	10	6.5	3.1	2.2	2.2	2.2	1.6	1.2	1.2	1.2	1	1	0.9	0.9
Antenna Height (m)	50 m															
Antenna Down tilt (°)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance (Km)	13.3	13	12.3	7.1	3.2	2.2	2.2	2.2	1.6	1.2	1.2	1.2	1.1	1.1	1	0.9
Antenna Height (m)	60 m															
Antenna Down tilt (°)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance (Km)	14.2	14.1	13.3	7.2	3.5	2.3	2.3	2.2	1.7	1.4	1.4	1.3	1.1	1.1	1	1
Antenna Height (m)	70 m															
Antenna Down tilt (°)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance (Km)	14.2	14.1	13.3	7.4	3.6	2.3	2.3	2.3	1.8	1.4	1.4	1.3	1.2	1.1	1.1	1.1

Table 10: mMIMO antenna site configuration height and tilt vs -100 dBm coverage range

mMIMO Site Configuration																
Antenna Height	30 m															
Antenna Downtilt	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance	10.7	10.7	7.04	6.5	3	3	2.8	2.3	1.6	1.4	1.4	1.4	1.3	1.2	1	1
Antenna Height	40 m															
Antenna Downtilt	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance	12.3	12.1	10.6	6.5	2.7	2.7	2.7	2	1.3	1.3	1.3	1.3	1.1	1.1	1	1
Antenna Height	50 m															
Antenna Downtilt	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance	13.9	13.7	12.5	7.1	2.7	2.7	2.7	2	1.4	1.4	1.4	1.4	1.2	1.1	1.1	1.1
Antenna Height	60 m															
Antenna Downtilt	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance	14.2	14.2	13.3	7.2	3	2.8	2.8	2.1	1.4	1.4	1.4	1.4	1.3	1.2	1.1	1.1
Antenna Height	70 m															
Antenna Downtilt	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Propagation Distance	14.3	14.3	13.3	7.4	3.2	2.9	2.9	2.3	1.6	1.4	1.4	1.4	1.3	1.2	1.2	1.2

3.3 Reducing interference with mitigation

This section will analyze the implementation of the mitigation techniques using Mentum Planet simulations to reduce the interference impact in the three scenarios specified in the previous sections. This action would be required if the guidelines seen in table 7 and table 8 are not met. This is likely to occur if a sector addition is done on an existing site and the height requirements are limited to what is vacant in the existing site. These mitigation techniques can also occur if a network needs to be optimized to reduce mitigation when a new site is added. For these scenarios, the typical and mMIMO configurations would follow the same parameters seen in section 2.1 and the mitigation techniques listed in section 2.3. The interference maps are inserted in Annex E through Annex G as reference. Fig.8, Fig.9, and Fig.10 seen in the previous sections has determined that with the addition of a 3.5GHz NR system to existing sites, the interference area would be 1.544Km^2, 5.136Km^2 and 1.213Km^2 with respect to the scenario 1, 2 and 3 analyses. However, please note that the use of a mMIMO beamforming deployment would already cause a reduction in interference by a third or even a half depending on the scenario it has been implemented. By observing Fig.11, Fig.12 and Fig.13 below, the interference would be 1.01Km^2, 3.425Km^2 and 0.688Km^2 with respect to scenarios 1, 2 and 3. Hence, by keeping the same parameters and deploying a mMIMO beamforming antennas for a 3.5 GHz deployment, the interference has been reduced 30 to 50% of the total interference seen in a typical configuration. As stated in the methodologies section, this is caused by the beamforming characteristics to only give a signal to users in need and to not broadcast like a typical macro configuration.

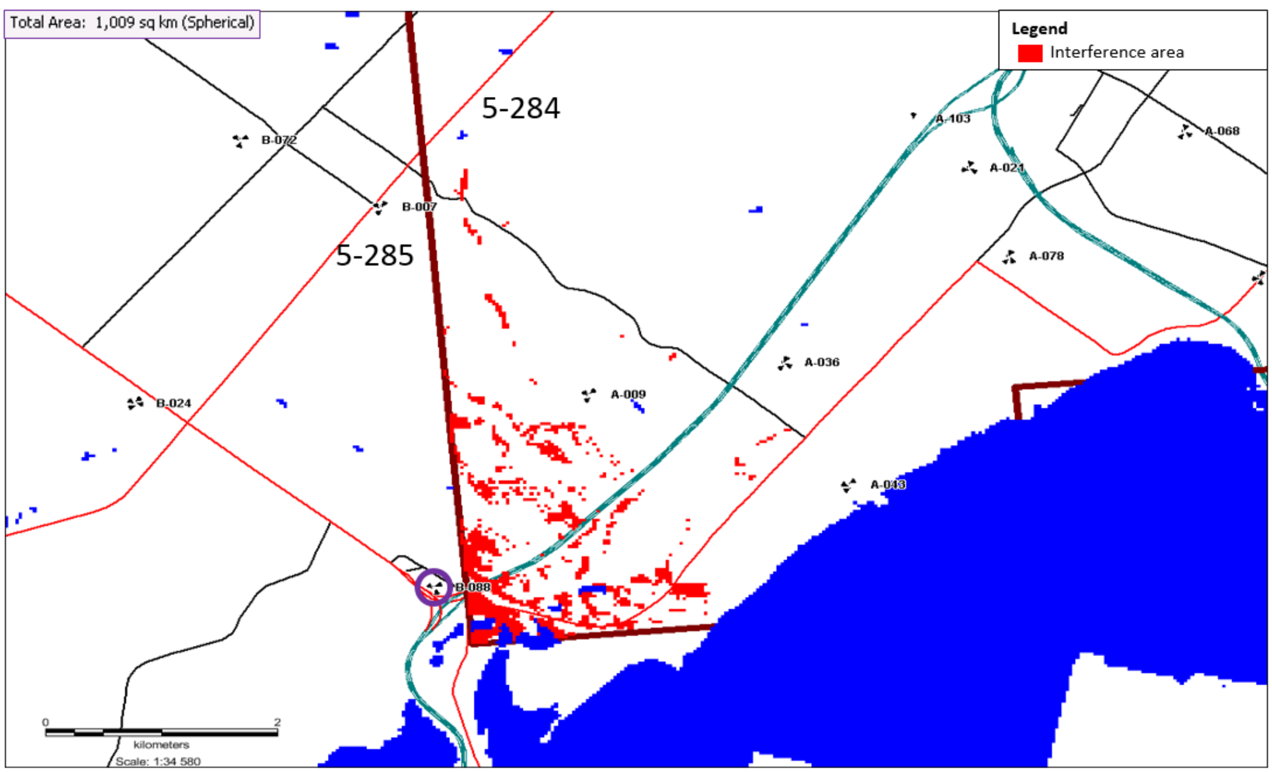


Fig 11: Scenario 1 B-008 mMIMO configuration

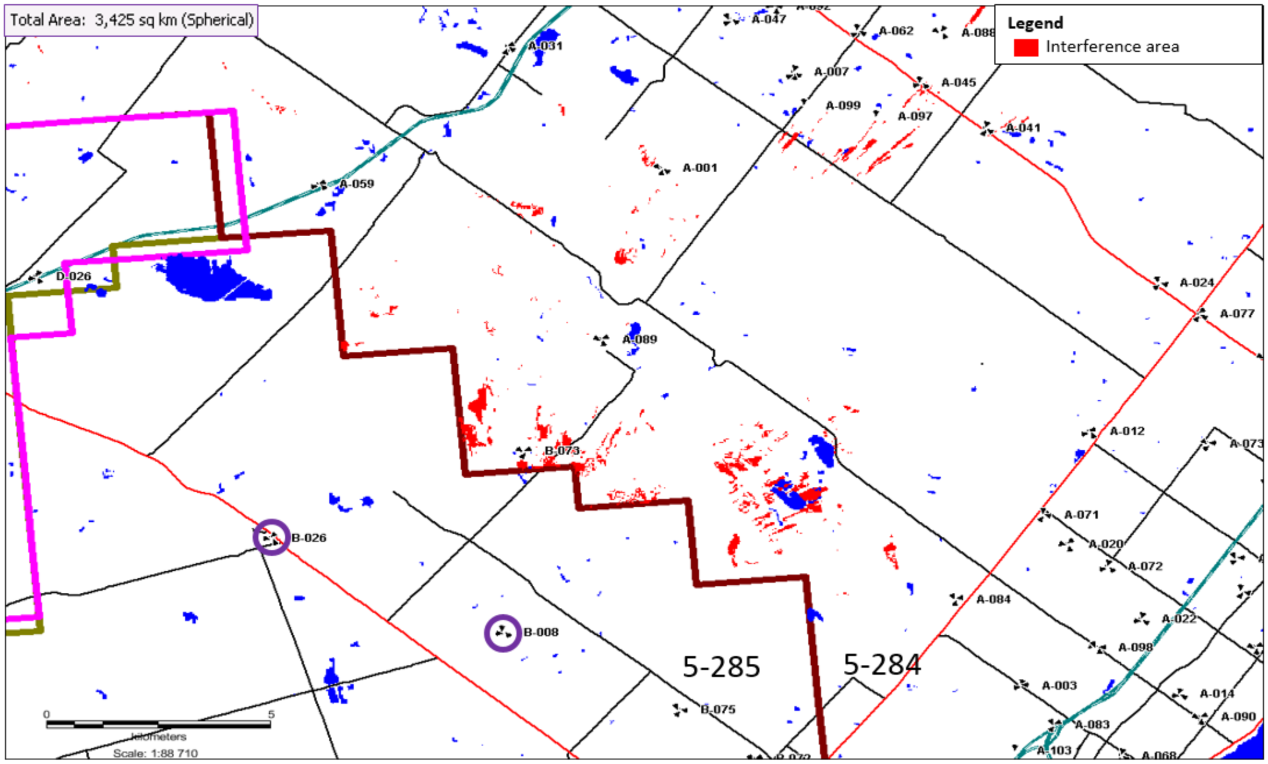


Fig 12: Scenario 2 B-026/B-008 mMIMO configuration

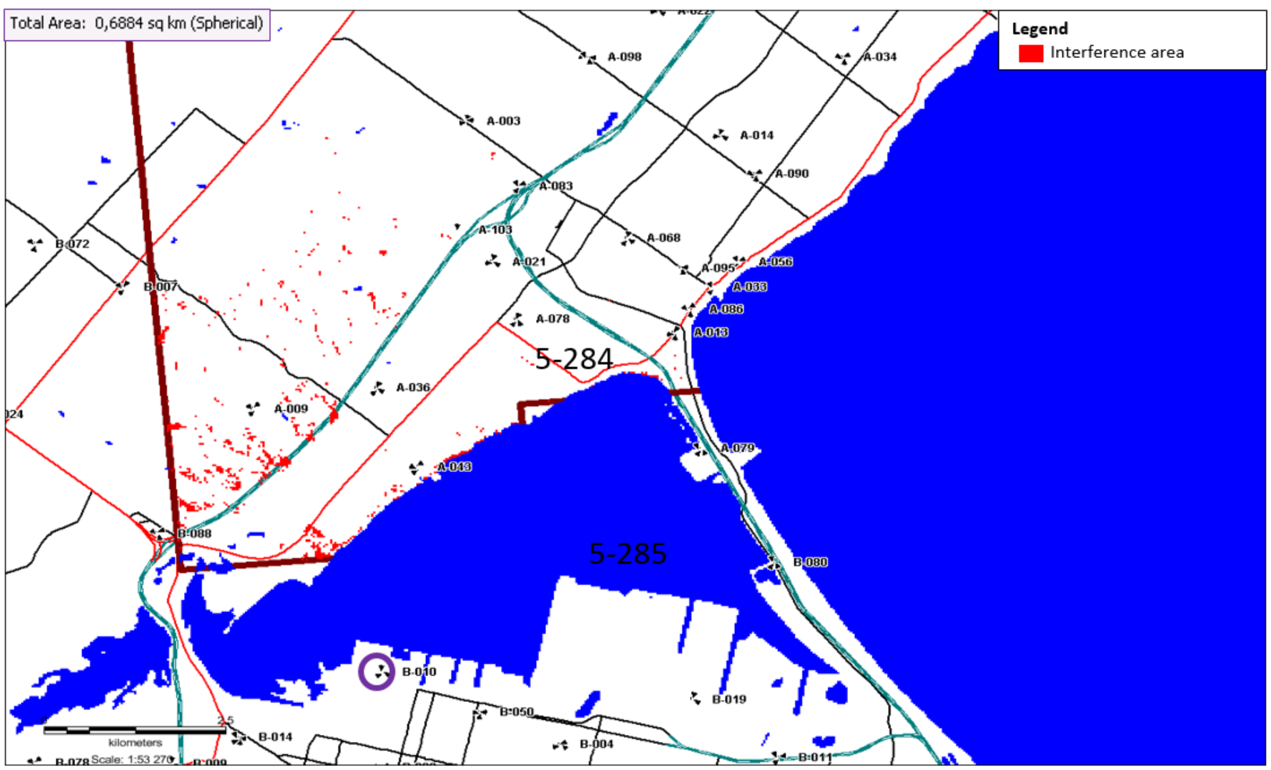


Fig 13: Scenario 3 B-010 mMIMO configuration

3.3.1 Downtilt Mitigation

For this section, a 10° down tilt has been added to a typical configuration. In Fig. E.1 (Seen in Annex E), the interference has been reduced by 37% in which the remaining interfering area is 0.969Km^2 for scenario 1. For scenario 2 seen in Fig. E.2, the interference has been reduced by 68% and the remaining interfering area is 1.638 Km^2. Finally, for the third scenario seen in Fig. E.3, the interfering area is reduced by 77% and the remaining interfering area is 0.276Km^2. It should be noted that the reason why the scenario 1 has a lower reduction compared to the other two scenarios is related to the distance of the sites with regards to the border. For scenario 1, B-088 is located at approximately 300m away from the neighboring licensed tier border. As for scenario 2 and scenario 3, the closest site is located 1.5Km away from the neighboring tier border and this plays a significant part in the reduction of interference when applying a tilt. Similarly, this can be seen in the coverage vs heights and tilts tables 3 and 4 seen in the previous section.

For the mMIMO configurations, a 20° down tilt has been added to overcome the beamforming smart selection. By just adding a 10° down tilt, the smart selection would pick an antenna pattern that would produce a similar result to the original smart selection pattern chosen in the original configuration. In Fig. E.4 the interference area remaining for scenario 1 would be 0.657Km^2 which would mean a reduction of 37% of the original mMIMO interference area. For scenario 2, Fig. E.5, the interference reduction is almost 100%, leaving just 0.069 Km^2 of interference area. Furthermore, for scenario 3, Fig. E.6, the interference gets reduced by 80%, leaving 0.135 Km^2 of interference in the neighbouring licensed tier.

3.3.2 Height Mitigation

Another mitigation method would be to design bordering sites using smaller antenna heights. In our evaluation, we looked at the impact of reducing the height of an existing site by 10m to evaluate what does the height reduction has on resulting interference. In Fig. F.1 (Seen in Annex F) the interference for scenario 1 has been reduced by 37% in which the remaining interfering area is 0.97Km^2. For scenario 2 seen in Fig. F.2, the interference has been reduced by 26% and the remaining interfering area is 3.815 Km^2. Finally, for the third scenario seen in Fig. F.3, the interfering area is reduced by 12% and the remaining interfering area is 1.062Km^2. The height reduction didn't differ due to the lack of obstacles in these three scenarios. Reducing the height of the sites does create a reduction in coverage as seen in tables 3 and 4 seen in the previous page. However, if there is a lack of clutter or if the terrain elevation is already creating an obstruction, limiting the antenna height can have minimal effects when mitigating interference levels.

Similarly for the mMIMO configuration, Fig. F.4, Fig. F.5, and Fig. F.6 presents the interference reductions of 37%, 100% and 11% with regards to a 10m height reduction for scenarios 1, 2 and 3. These results are almost the same as the mitigation results scene in the typical configuration.

3.3.3 Half Power Mitigation

As seen in the Windsor example, the difference between the sites along the river and the sites in-land was mainly the half power reduction and orientation of the sectors. Fig. G.1 (Seen in Annex G), the use of half power causes the interference impact to be reduced to 1.213Km^2 which is a 21% interference reduction seen in the original analyses. Similarly, in scenario 2, Fig. G.2 depicts an interference reduction of 18%. This decrease results in a remaining interference area of 3.386Km^2. Furthermore, in scenario 3, Fig. G.3 depicts an interference reduction of 46%, resulting in an interference area of 0.659 Km^2.

Similarly for the mMIMO configuration, Fig. G.4, Fig. G.5, and Fig. G.6 presents the interference reductions of 18%, 100% and 40% with regards to scenarios 1, 2 and 3.

3.3.4 Azimuth Orientation Mitigation

For the second and most common mitigation technique seen in the Windsor example, the sector orientation is a common technique used. Naturally, an RF designer would orient there antennas to a specific area that needs to have adequate coverage. The designer would not orient there antennas to a neighbouring licensed tier, or in an orientation that would harm their network. By properly orienting the antennas so that they are parallel to the licensed tier border and that they are not directed towards a nearby site would be sufficient to reduce ongoing interference. As seen in Fig. H.1 (Seen in Annex H), the scenario 1 analyses would yield an interference area of 1.02Km^2, resulting in an interference reduction of 34%. For scenario 2, Fig. H.2 presents the interference reduction to be 64% and a total interference area remaining of 3.386Km^2. For scenario 3, Fig. H.3 shows the interference reduction to be 76% and the remaining interfering area to be 0.288Km^2.

Furthermore, when observing the scenarios 1, 2 and 3 maps in Fig. H.4, Fig. H.5 and Fig. H.6, the mMIMO configuration would yield inference reductions of 35%, 100% and 72% respectively.

3.3.5 Multiple Mitigation Techniques

It is common that a single mitigation technique is not enough to reduce the interference to an acceptable level. As seen in the previous mitigation techniques, there are times when there is still 60%, 80% or even 90% of the interfering area after performing a single mitigation technique. For this reason, progressive mitigation would be needed to slowly reduce the interference one mitigation technique at a time. Ideally, the combination of the mitigation techniques should eliminate the remaining interference. After applying all the mitigation techniques to scenario 1, 2 and 3, Fig.14, Fig.15 and Fig.16 show that the interference area has been reduced by 84%, 100% and 89% of the original interfering area, respectively. These figures can be seen below:

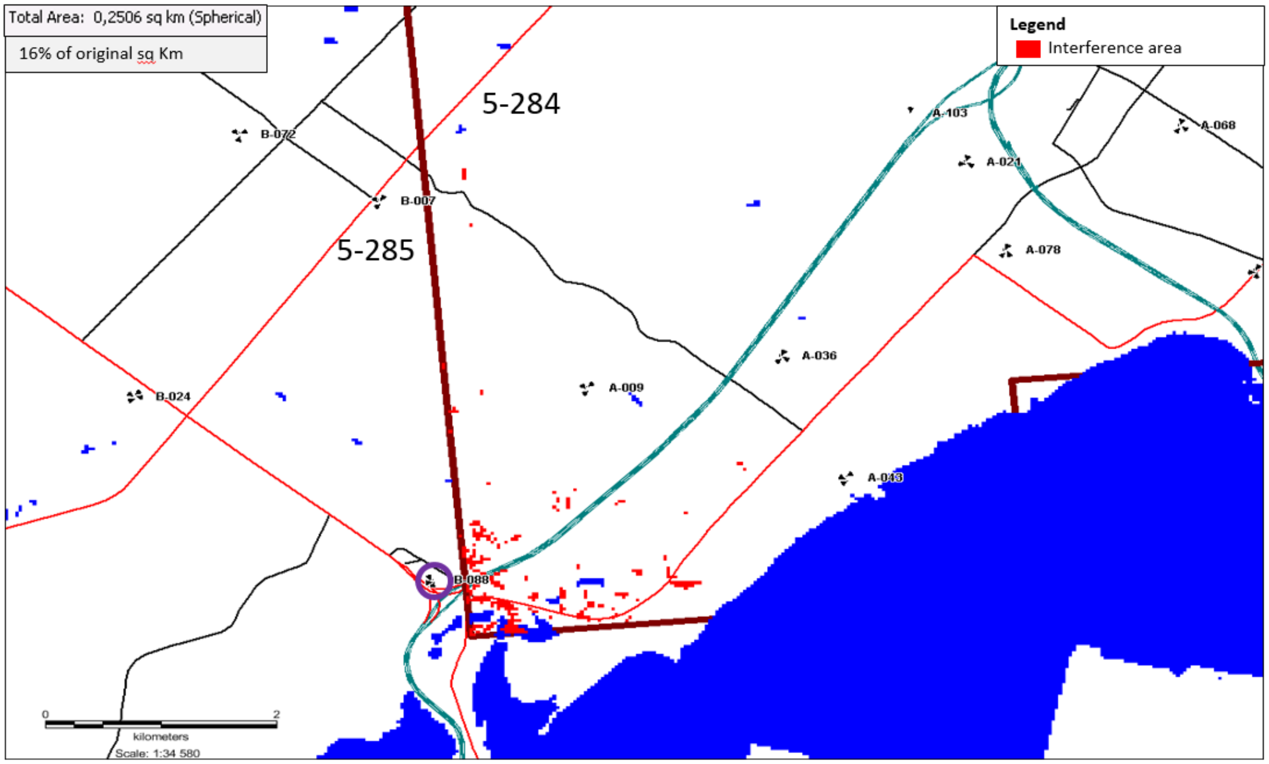


Fig 14: Scenario 1 B-008 all mitigation techniques applied

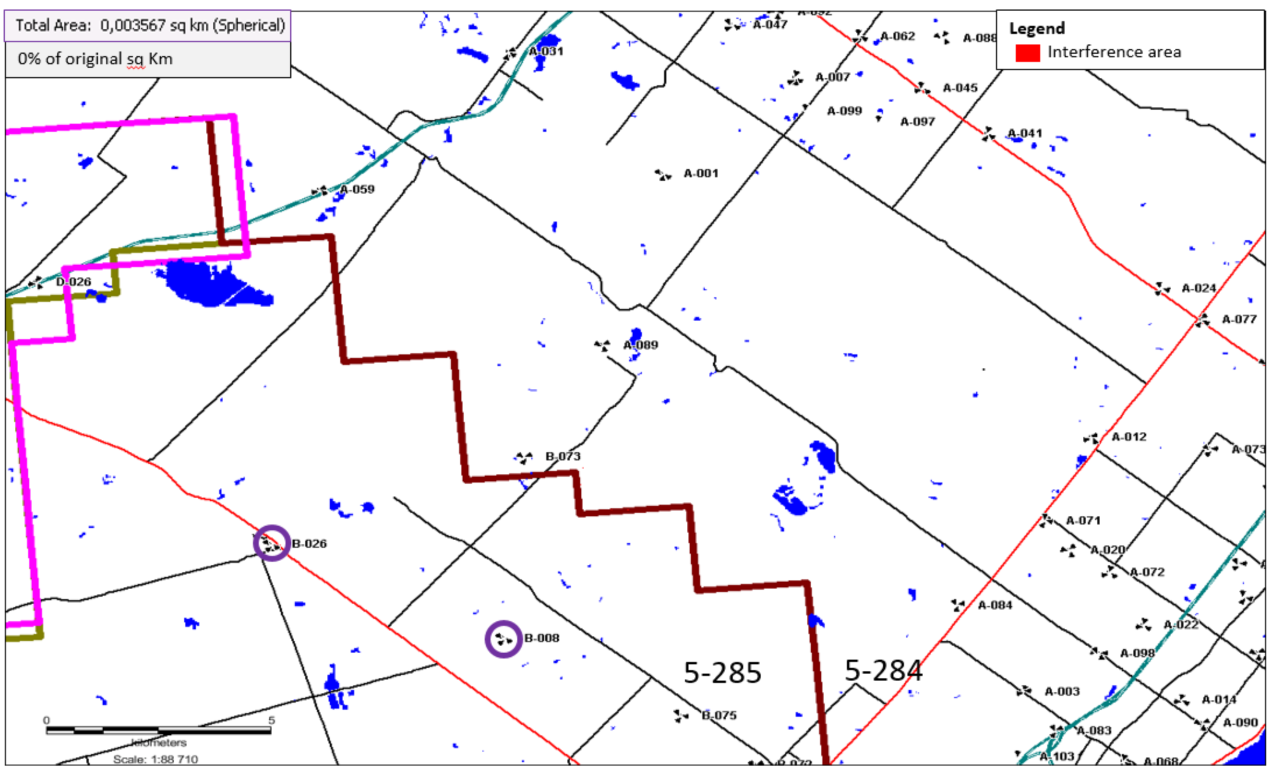


Fig 15: Scenario 2 B-026/B-008 all mitigation techniques applied

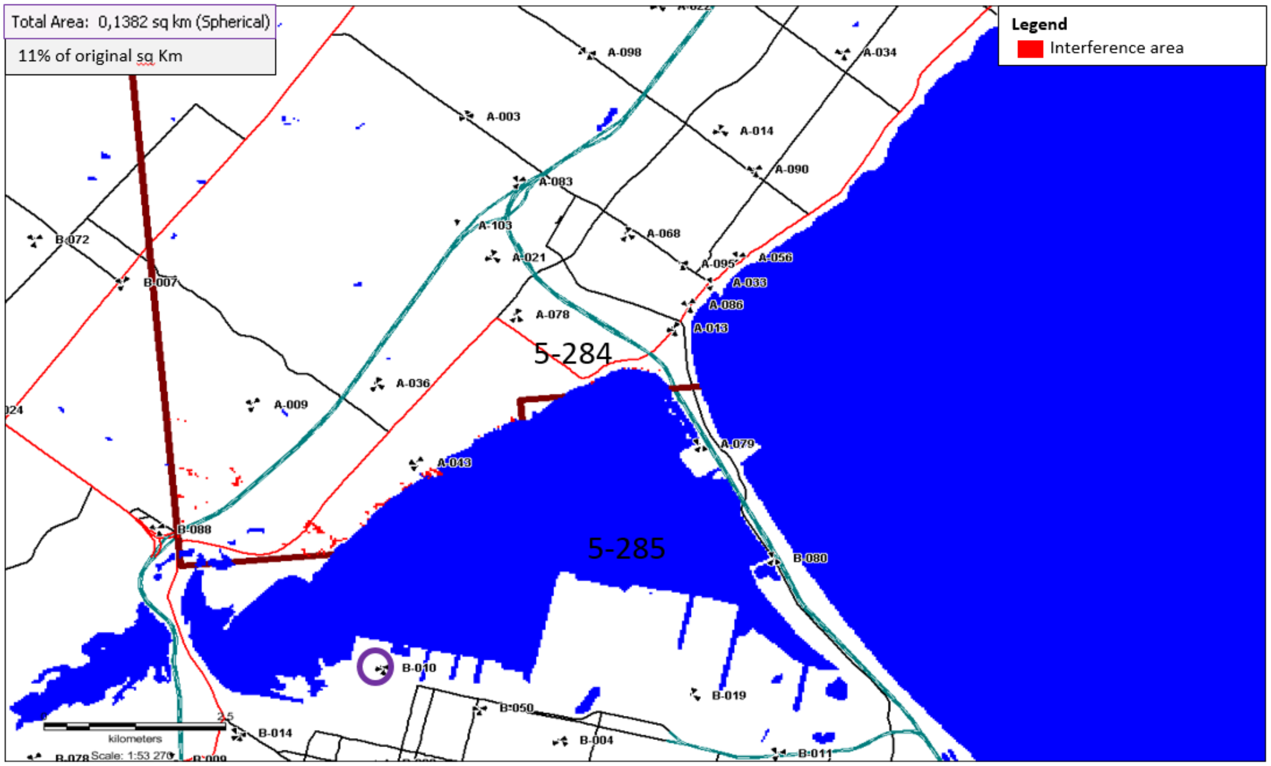


Fig 16: Scenario 3 B-010 all mitigation techniques applied

Furthermore, when applying the mMIMO configuration, Fig. I.1, Fig. I.2 and Fig. I.3 (Seen in Annex I) show that the interference area in scenarios 1, 2 and 3 have been reduced by 82%, 100%, and 96% of the original mMIMO analyses.

The remaining mitigation maps depicting the impact when applying different mitigation technique combinations is located in Annex I of this report. All the mitigation results, interference area and reduced interference percentage are summarized in the below tables 9 through 14. These tables show that a mMIMO configuration with the same parameters as a standard configuration would produce a smaller interference area due to their beamforming characteristics as compared to a standard configuration deployment. Another observation made is that by applying the correct mitigation techniques, an adequate interference reduction can be acheived depending on the scenario. Please note that these are just some combinations of mitigation techniques, while there are many different variations or combinations that would result to more or less of an interference reduction.

Table 11: B-088 typical site mitigation techniques summary – Scenario 1

B-088 Original									
	No Mitigation	Down tilt	Height	Power	Az	Down tilt + Height	Down tilt + Height + Power	Down tilt Height Power Az	Down tilt Height Power Az Ant
Interference Sq KM Area	1.544	0.969	0.97	1.213	1.02	0.658	0.526	0.275	0.251
Interference % reduced		37	37	21	34	57	66	82	84
Clutter	In-Land Water/Residential with trees/Commercial-Industrial/Grassland/Forest								

Table 12: B-088 mMIMO Site mitigation techniques summary – Scenario 1

B-088 mMIMO								
	No Mitigation	Down tilt	Height	Power	Az	Down tilt + Height	Down tilt + Height + Power	Down tilt Height Power Az
Interference Sq KM Area	1.01	0.657	0.634	0.829	0.659	0.381	0.287	0.186
Interference % reduced		35	37	18	35	62	72	82
Clutter	In-Land Water/Residential with trees/Commercial-Industrial/Grassland/Forest							

Table 13: B-026/B-008 typical site mitigation techniques summary – Scenario 2

B026/B008 Original									
	Original	Down tilt	Height	Power	Az	Down tilt Height	Down tilt Height Power	Down tilt Height Power Az	Down tilt Height Power Az Antenna
Interference Sq KM Area	5.136	1.638	3.815	3.386	1.859	1.271	0.415	0.202	0.004
Interference % reduced		68	26	34	64	75	92	96	100
Clutter	Rural/Open/Grassland/Forest								

Table 14: B-026/B-008 mMIMO site mitigation techniques summary – Scenario 2

B026/B008 mMIMO								
	Original	Down tilt	Height	Power	Az	Down tilt Height	Down tilt Height Power	Down tilt Height Power Az
Interference Sq KM Area	3.425	0.069	0.078	0.036	0.040	0.0464	0	0
Interference % reduced		100	100	100	100	100	100	100
Clutter	Rural/Open/Grassland/Forest							

Table 15: B-010 typical site mitigation techniques summary – Scenario 3

B-010 Original									
	Original	Down tilt	Height	Power	Az	Down tilt + Height	Down tilt + Height + Power	Down tilt + Height + Power + Az	Down tilt Height Power Az Ant
Interference Sq KM Area	1.213	0.276	1.062	0.659	0.288	0.228	0.172	0.144	0.138
Interference % reduced		77	12	46	76	81	86	88	89
Clutter*	In-Land Water/Industrial/Suburban								

Table 16: B-010 mMIMO site mitigation techniques summary – Scenario 3

B-010 MU-MIMO								
	Original	Down tilt	Height	Power	Az	Down tilt + Height	Down tilt + Height + Power	Down tilt Height Power Az
Interference Sq KM Area	0.688	0.135	0.614	0.413	0.190	0.112	0.086	0.025
Interference % reduced		80	11	40	72	84	87	96
Clutter*	In-Land Water/Industrial/Suburban							

3.4 Small Cell or Micro Cell solution

A small cell deployment is an option to add coverage along the tier border if the mitigation techniques seen in the previous section does not adequately reduce the interference or if the coverage is lacking, while creating minimal interference on the neighboring licensed tier or within neighboring sites. There are generally three types of small cells used in the industry today: Femtocells, Picocells, and Microcells. Femtocells are normally used for indoor applications and cover 10-50m with a transmit power of 20dBm. Picocells can be used for both indoor and outdoor applications and have a coverage radius of 100-250 m with a transmit power of 24dBm. Microcells are generally used for outdoor applications with a coverage radius of 500-2500 m and transmit power of 33-40dBm. It should be noted that a 3.5GHz NR frequency would limit the coverage radius mentioned above compared to a 700 MHz or a 1900 MHz configuration.

The Small Cell or Micro Cell technology is becoming prevalent in operator's deployment strategy. It is becoming more so with the arrival of 5G NR as to achieve its promised data rates of 10 Gbps, cells need to be positioned closer to the subscribers and near residences whether they be rural, suburban or urban. These sites would be deployed along roads on posts and lampposts or any small structure located where population is distributed. Deployment in the 3.5 GHz band and in the mmWave bands will certainly be earmarked for the 5G NR technology.

In this report we looked at a 3.5 GHz small cell scenario using a microcell configured with an omni antenna operated at 10W transmit power 10m above ground. The following map shows the small cell deployment scenario in a suburban area such as Hamilton with the yellow line representing a hypothetical tier border.

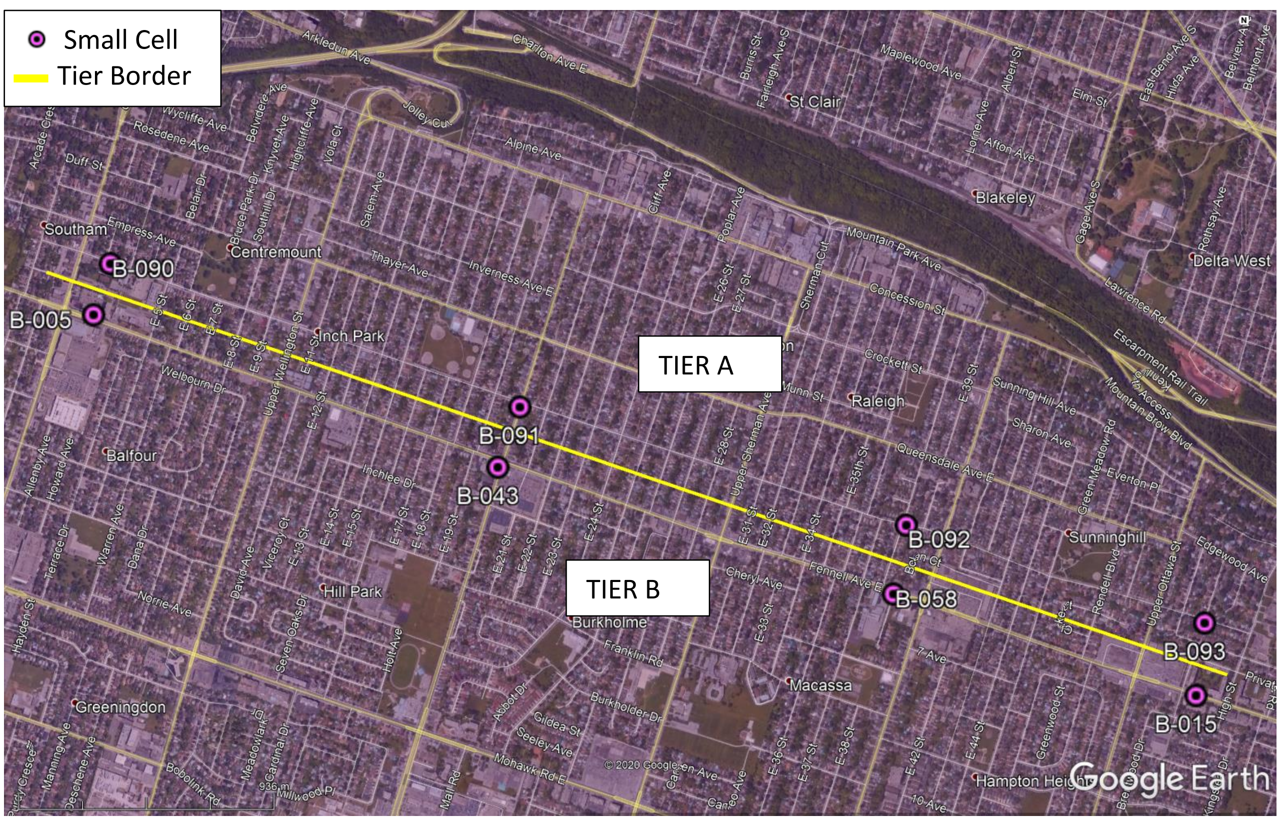


Fig 17: Small Cell Map Scenario

In the figures below, the RSRP coverage and SINR in TIER A and TIER B can be seen. When setting sites at 100 m away from the tier border, the coverage doesn't surpass -100 dBm on the neighbouring tier this can be seen in figure 17. In figure 18, the TIER A site B-091 is the only site that has a -100 dBm signal range that would go slightly beyond the tier border due to the ground elevation being a bit higher than the other tier sites. This can be mitigated with a power reduction, height reduction or 180 deg directional antenna patterns.

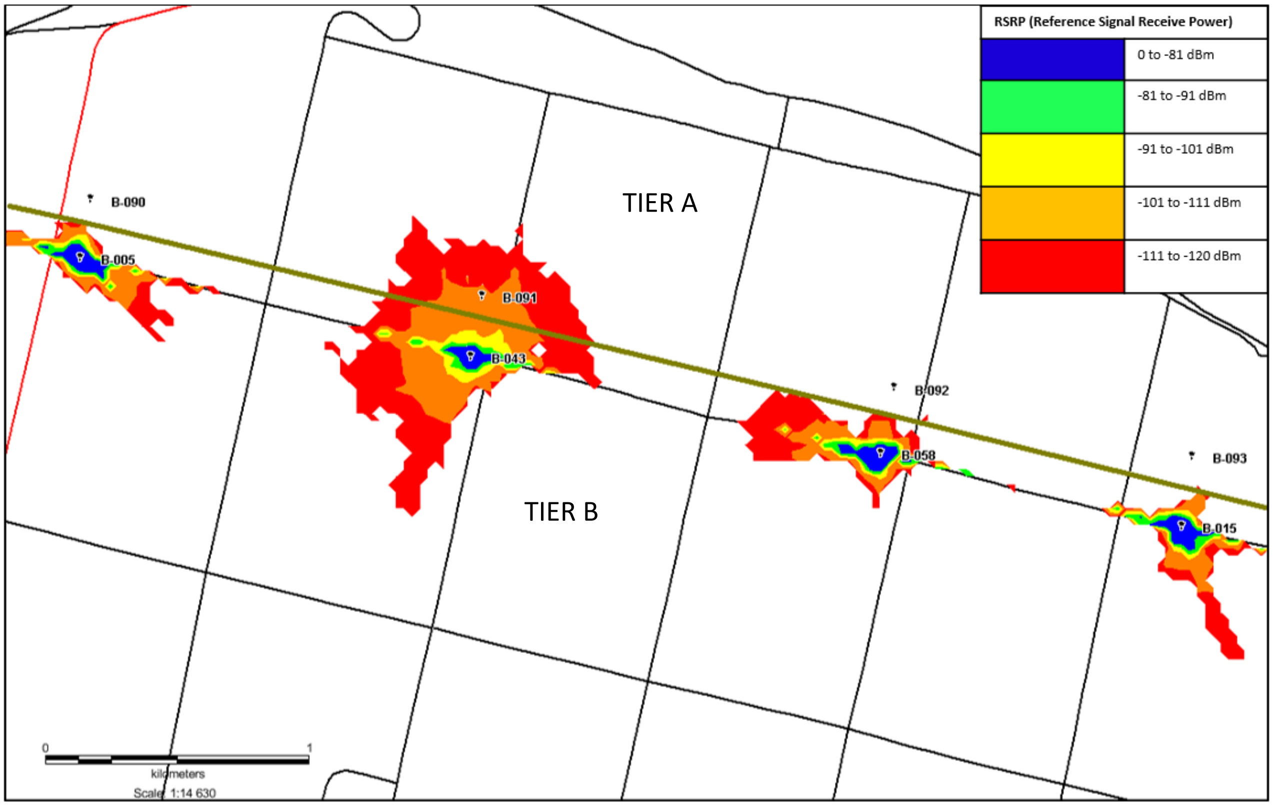


Fig 18: Small Cell lower tier RSRP coverage

The observation while comparing the SINR figure with relation to the RSRP figures is that the SINR levels are low due to the signal strength being low and it is not due to the interference levels being too high. When there is a good coverage, it can be shown that the SINR is also good and interference has minimal impact to the quality of the signal. If mitigation techniques needed to be applied to reduce the coverage to stay within a tier, it would be possible with a reduction in height, reduction in power or moving the small cell site away from the tier border. However, generally the cell coverage of these typical small cells remain good on their respective border when considering a flat terrain and mitigation is rarely needed. Similarly to the coverage vs heights and tilts table seen in the previous sections. A guide line for coverage and heights can be done with regards to a small cell deployment to minimize interference impact with regards to nearby sites and neighbouring licensed tiers.

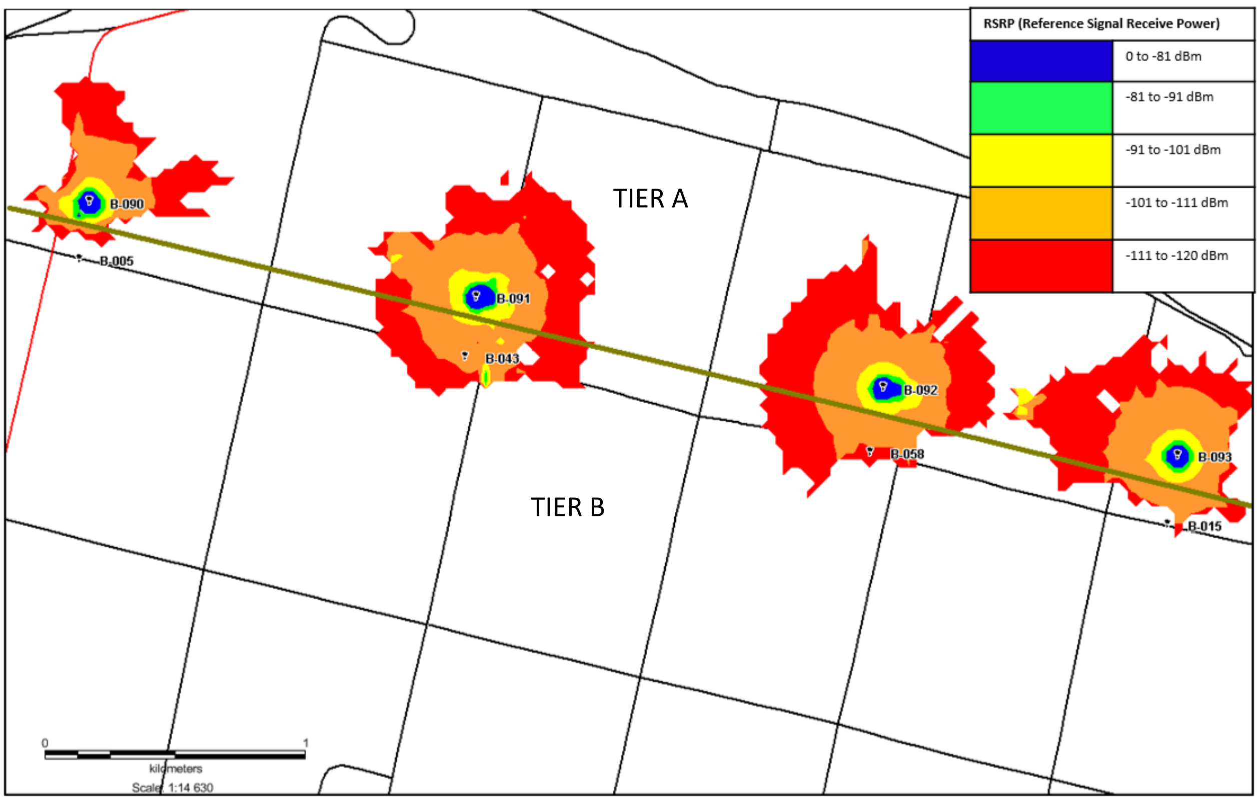


Fig 19: Small Cell upper tier RSRP coverage

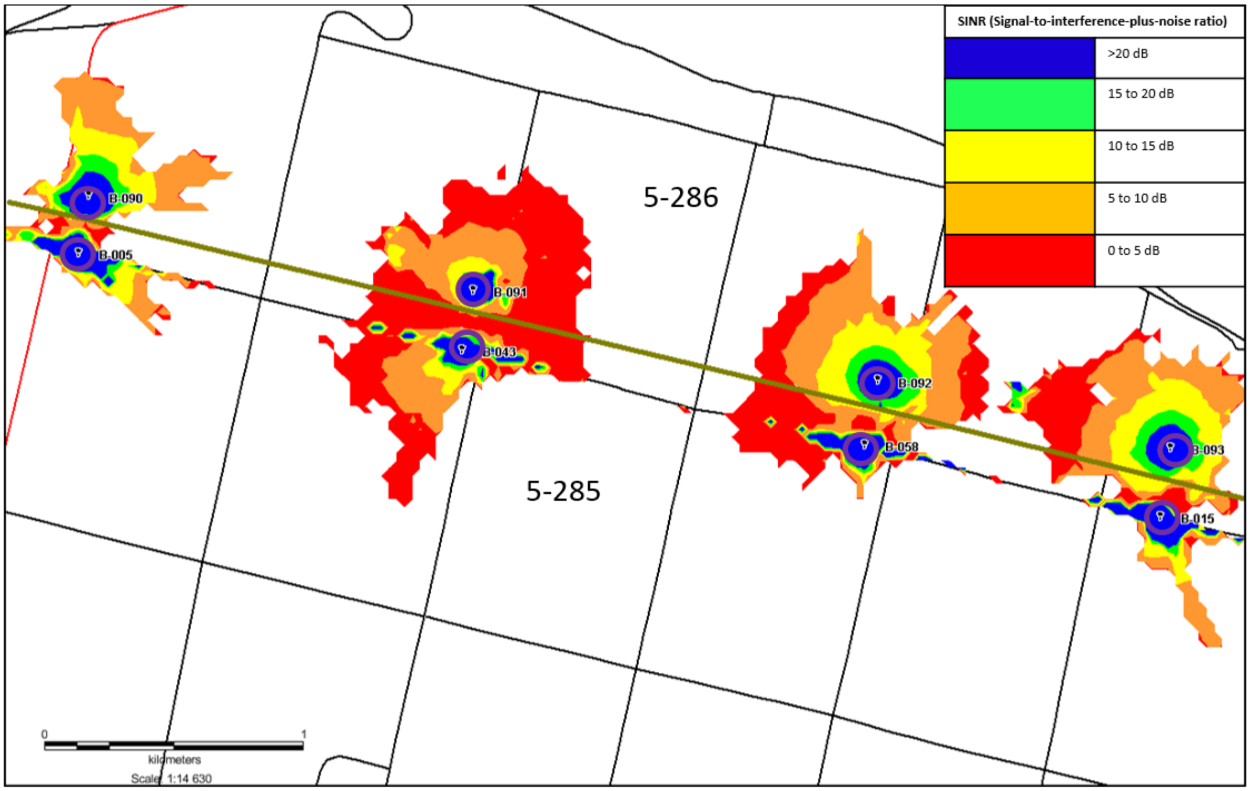


Fig 20: Small Cell SINR analysis

With respect to the deployment of small cells, the backhaul normally required is a wired or fiber connection. For this reason, many small cells have been found in highly urban - metropolitan areas (fiber) and some suburban areas (DLS, cable, and fiber). However, microcells can also use a microwave backhaul for areas that are not supported with a wired connection. In suburban areas and rural areas, microcells have been used to supply coverage needed through hub sites acting as GPON front hauls with a microwave backhaul.

3.5 Impact on Coverage

As seen in the previous sections, techniques could be applied to sites in order to limit the interference from sectors pointing towards a Tier that needs protection. It is understood that since the interference is reduced than the coverage from these sectors is reduced and therefore solutions need to be considered to ensure that operators continue offering the service their subscribers are entitled to.

Indeed, as it was quickly shown in section 3.4, using small cell technology allows the provider to have coverage in his licensed tier along the border while limiting the interference on a neighboring Tier licensed to a competitive operator. By properly spacing the small cells and adjusting the power needed a good coverage near the border can be maintained while ensure quality by maximizing the SINR across the border.

Notwithstanding what was mentioned above, when applying mitigation techniques to reduce interference along a border, the coverage will also get reduced in the areas before that border. This can be seen in the coverage distance tables presented in section 3.2. By applying a down tilt, half power reduction, lower antennas, and reorienting the antennas, the coverage and interference area will both be reduced causing areas to lack the appropriate coverage for acceptable service. A newly licensed operator could address these coverage issues by using RF Engineering and planning best practices such as densifying its coverage with smaller sites or targeting populated areas along borders with small cells. Luckily, incumbent Canadian operators have an armada of frequencies available to them other than mid-band frequencies to continue offering service to their subscribers where interference mitigation techniques are used. Indeed, the three big operators (Bell, Telus and Rogers), as well as smaller ones (Videotron, Freedom Mobile, TBay Tel…) all have licensed spectrum in the 600 MHz, 700 MHz, 800 MHz, 1900 MHz, 2.1 GHz and 2.6 GHz bands. Granted not all of them have spectrum in each of these bands but they all have spectrum licenced as Tiers 2, 3 and 4 already offering service where proposed Tier 5 licensing would authorized.

Finally, roaming on another service provider's network can also be done, and in fact is already mandated by the CRTC in decision 2017-56[4] to maintain service for a subscriber located where his chosen service provider lacks coverage. Roaming on another provider, provided that roaming agreements are in place, would allow a newly licensed 3.5 GHz 5G NR service provider to allow its subscribers to fall back on an existing incumbent network coverage thus limiting interference in areas close to tier borders by eliminating the need for macro sites in those locations.

4 CONCLUSION

This document has analysed the effectiveness of interference mitigation techniques at the border of Tier 5 licensed areas. The addition of a 3.5GHz NR system on sites that already exist in the Hamilton, Oakville, Burlington, Lincoln area near licenced tier borders would likely cause interference within its own network and within neighboring tiers. Interference has been observed by taking scenarios from sites in the tier 5-285 and propagating towards the tier 5-284 while using site parameters and locations found in the Innovation, Science and Economic Development Canada's database implementing them into a powerful RF tool such as Mentum Planet v7.4.

Furthermore, to properly dictate which techniques are needed to resolve excess interference, an industry wide observation was made. Mitigation techniques such as down tilts, antenna heights, power reduction, sector orientation and antenna swap can be seen across the industry. Such examples can be seen in the Windsor area along the Detroit River. The sites located in this area have sector orientations that are parallel to the border between Windsor and Detroit and use half the transmit power seen within in-land sites. Both these techniques and the proper use of frequency bands along the river, all avoid excess interference along international borders. When applying these techniques individually and in combination within three different scenarios, we can show that the interference areas can be reduced by at least 84% of the original standard configuration. Furthermore, with the addition of a 3.5GHz NR wireless system, the industry seems to be heading in the direction of a massive mMIMO beamforming deployment. By keeping the standard parameters such as power, height, azimuth, tilt, etc., and changing the configuration to a mMIMO beamforming configuration, the interference area reduces by at least 30 to 50% of the original standard configuration interference area. By then applying mitigation techniques to the mMIMO configuration, the interference areas are reduced by 82% to 100% of the mMIMO initial interference area.

[4] Telecom Decision CRTC 2017-56 https://crtc.gc.ca/eng/archive/2017/2017-56.htm

In light of all the mitigation techniques observed and their interference impact, it should be noted that the use of mitigation techniques will also decrease the coverage. Thus a coverage vs height and tilts analysis has been conducted to see the impact that a change of height and tilt would have on a 3.5 GHz RSRP signal. This analysis can also be used as a guideline to determine the height and tilts needed if a certain area needs to be covered. If the antenna heights are located to high or the antenna down tilts are not tilted enough, then the propagation coverage would propagate past the area needed and cause interference on already existing sites or in a neighbouring tier. However, if the heights are too low, or the down tilts are too aggressive, the propagation distance would be too low and a lack of coverage would occur on the desired site. Also, interference on the providers own network would be a result of over tilting or placing macro/micro sites too close together.

However there are other mitigation techniques that can maintain coverage and reduce interference along licensed tier borders and within one’s own licensed tier. The use of existing sites such as roaming on other providers networks or using existing mid or low frequency bands that are not 3.5GHz NR. Using sites that are already implemented can be an option to use a good coverage network while minimal interference would already be in place. The CRTC in decision 2017-56 mandated service provider’s to allow roaming on another service provider’s network to maintain service for a subscriber located where their chosen service provider lacks coverage.

Finally, instead of a macro deployment, a small cell deployment in targeted areas would be another option to maintain coverage and reduce interference. Micro cells typically give coverage range of 500m to 2.5Km depending on the frequency, topography and clutter. By implementing microcells at certain distances away from each other in their own tier or at an appropriate distance along the licensed tier border, the coverage would be well maintained while the interference can be kept at a minimal.

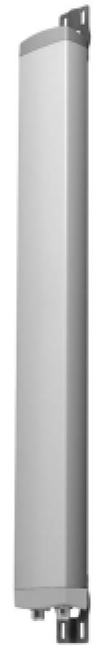
Annex A: Kathrein 800 10603 Datasheet

Panel	3300–3800
Dual Polarization	X
Half-power Beam Width	65°

Antennen · Electronic

XPol Panel 3300–3800 65° 17.5dBi 0°T

Type No.	800 10390
Frequency range	3300 – 3800 MHz
Polarization	+45°, –45°
Gain	2 x 17.5 dBi
Half-power beam width Copolar +45°/–45°	Horizontal: 65° Vertical: 7°
Electrical tilt	0°, fixed
Front-to-back ratio (180°±30°)	> 30 dB
Isolation, between ports	> 25 dB
Impedance	50 Ω
VSWR	< 1.5
Intermodulation IM3	< –140 dBc (2 x 40 dBm carrier)
Max. power per input	50 W (at 50 °C ambient temperature)
Input	2 x N-connector female
Connector position	Bottom or top
Wind load (at 150 km/h)	Frontal / lateral / rearside: 160 / 50 / 160 N
Height/width/depth	736 / 112 / 50 mm



XPol, VPol

XPol Panel 3300–3800 65° 17.5dBi 0°-10°T

Type No.	800 10603
Frequency range	3300 – 3800 MHz
Polarization	+45°, –45°
Gain	2 x 17.5 dBi
Half-power beam width Copolar +45°/–45°	Horizontal: 65° Vertical: 7°
Electrical tilt	0°–10°, continuously adjustable
Front-to-back ratio (180° ±30°)	> 30 dB
Isolation, between ports	> 25 dB
Impedance	50 Ω
VSWR	< 1.5
Intermodulation IM3	< –140 dBc (2 x 40 dBm carrier)
Max. power per input	50 W (at 50 °C ambient temperature)
Input	2 x N-connector female
Connector position	Bottom
Wind load (approx.) (at 150 km/h)	Frontal / lateral / rearside: 260 / 90 / 260 N
Height/width/depth	714 / 181 / 77 mm

Annex B: Kathrein 800 10251 Datasheet

KATHREIN
SCALA DIVISION

800 10251

35° Wideband Directional Antenna

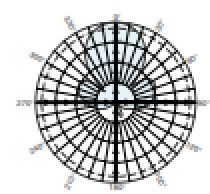
Kathrein's X-polarized adjustable electrical downtilt antennas offer the wireless carrier the ability to tailor polarization diversity sites for optimum performance. Using variable downtilt, only a few models need be procured to accommodate the needs of widely varying conditions. Remotely controlled downtilt is available as a retrofitable option.

- 0-12° downtilt range.
- UV resistant pulltruded fiberglass radome.
- DC Grounded metallic parts for impulse suppression.
- No moving electrical connections.
- Wideband vector dipole technology.
- Optional remote downtilt Control.
- Will accomodate future 3G / UMTS applications.

General specifications:

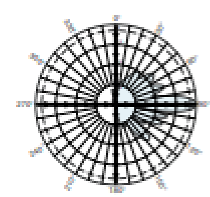
Frequency range	1710–2170 MHz
VSWR	<1.5:1
Impedance	50 ohms
Intermodulation (2x20w)	IM3:< -150 dBc
Polarization	+45° and -45°
Front-to-back ratio (180° ± 30°)	>30 dB (co-polar)
Connector	2 x 7/16 DIN female
Isolation	>30 dB
Maximum input power	300 watts (at 50°C) per input
Weight	25.4 lb (11.5 kg)
Dimensions	40.6 x 11.8 x 2.7 inches (1032 x 299 x 69 mm)
Equivalent flat plate area	4.42 ft² (0.411 m²)
Wind survival rating*	120 mph (200 kph)
Shipping dimensions	52.6 x 13.3 x 4.4 inches (1336 x 337 x 112 mm)
Shipping weight	32 lb (14.5 kg)
Mounting	Fixed and tilt mount options are available for 2 to 4.6 inch (50 to 115 mm) OD masts.

See reverse for order information.



Horizontal pattern
±45°- polarization

Specifications:	1710–1880 MHz	1850–1990 MHz	1920–2170 MHz
Gain	19.2 dBi	19.5 dBi	19.8 dBi
Horizontal beamwidth	36° (half-power)	35° (half-power)	33° (half-power)
Vertical beamwidth	9.2° (half-power)	9° (half-power)	8.5° (half-power)
Electrical downtilt continuously adjustable	0°–12° (manual or optional remote control)	0°–12°	0°–12°
Sidelobe suppression for first sidelobe above horizon Horizontal pattern	0° 6° 12° T 15 17 17 dB >18 dB	0° 6° 12° T 15 17 17 dB >17 dB	0° 6° 12° T 15 17 17 dB >15 dB
Cross polar ratio Main direction 0° Sector ±30°	 25 dB (typical) >10 dB	 25 dB (typical) >10 dB	 25 dB (typical) >10 dB



Vertical pattern
±45°- polarization

RoHS
Lead-Free

10824-A
936.2568/a

* Mechanical design is based on environmental conditions as stipulated in EIA-222-F (June 1996) and/or ETS 300 019-1-4 which include the static mechanical load imposed on an antenna by wind at maximum velocity. See the Engineering Section of the catalog for further details.

Kathrein Inc., Scala Division Post Office Box 4580 Medford, OR 97501 (USA) Phone: (541) 779-6500 Fax: (541) 779-3991
Email: communications@kathrein.com Internet: www.kathrein-scala.com

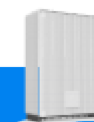
Annex C: Ericsson Air 6449 B41 Datasheet

AIR 6449

Preliminary

- 192 antenna elements, 3:1 subarray
- Up to 300W
- Up to 200 MHz Operating BW & Carrier BW
- Two 25 Gb/s SFP(C2) and Two 10 Gb/s QSFP(C1FD and C2 backup)
- -48V 45 A Two wire and three wire versions
- APC light connector and Self test push button
- Sensor support but undefined
- Size B41:
  - 841 x 521 x 217 mm (H x W x D)
  - Volume: 95 liter
  - Weight: 47 kg

PRA: July 2020

AIR or Radio Type	AIR 6488 (G2) 	AIR 6449 (G4) 	Radio 8863 
RATs supported	L, NR	L, NR	L, NR
Power capability	200W	300W	8x40W
Modulation	256QAM	256QAM	256QAM
Bandwidth (IBW/CBW)	100 MHz or 60L+60N	194 MHz	196 MHz
Tx and Rx Array	64T64R	64T64R	8 CSI-RS ports
MIMO layers (DL/UL)	16 DL / 8 UL	16 DL / 8 UL	16 DL / 8 UL
CPRI ports	3 x 10G	4 x 25G* (2x10G+2x25G)	2 x 25G*
Dimensions (HxWxD)	884mm x 520mm x 183mm (34.8" x 20.5" x 7.2")	840mm x 520mm x 210mm (33.1" x 20.5" x 8.3")	(21.5 ltr)
Weight	58 kg (128 lbs)	47 kg (103 lbs)	Approx. 21 kg (46 lbs)
Cooling	Convection	Convection	Convection
Power	-48VDC	-48VDC	-48VDC
Power Consumption	1290W	<1100W	TBD
Availability	Q2 2019	Q3 2020	Q2 2020

Annex D: Kathrein 800 10431 Datasheet

KATHREIN
SCALA DIVISION

800 10431

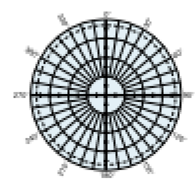
Omnidirectional Antenna

Kathrein's omnidirectional PCS/BRS antennas incorporate the quality design and attention to detail that have established our entire line of base station antennas as industry leaders. These antennas feature:

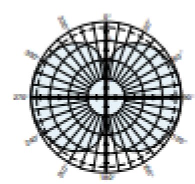
- Superior electrical performance, with low VSWR, wide bandwidth, flat frequency response, and extremely low intermodulation products.
- All metal parts of the antenna and the mounting kit are DC grounded (the inner conductor is not DC grounded).

Specifications:

Frequency range	1710–2700 MHz
Gain	2 dBi
Impedance	50 ohms
VSWR	< 1.8:1
Intermodulation (2x20w)	IM3:< -150 dBc
Polarization	Vertical
Maximum input power	50 watts (at 50°C)
H-plane beamwidth	Omni
E-plane beamwidth	78°
Connector	N female
Weight	0.33 lb (150 g)
Height	4.55 inches (115 mm)
Radome diameter	0.78 inches (20 mm)
Mounting	Mounts through a 0.63 inch (16 mm) hole to surfaces of 0.39 inch (10 mm) thick. Antenna may be inverted.



H-plane
Horizontal pattern – V-polarization



E-plane
Vertical pattern – V-polarization

Order Information:

Model	Description
800 10431	Antenna with N connector

10975-A
936.2913

RoHS
Lead-Free

All specifications are subject to change without notice.
The latest specifications are available at www.kathrein-scala.com.

Kathrein Inc., Scala Division Post Office Box 4580 Medford, OR 97501 (USA) Phone: (541) 779-6500 Fax: (541) 779-3991
Email: communications@kathrein.com Internet: www.kathrein-scala.com

Annex E: Down Tilt Mitigation Maps

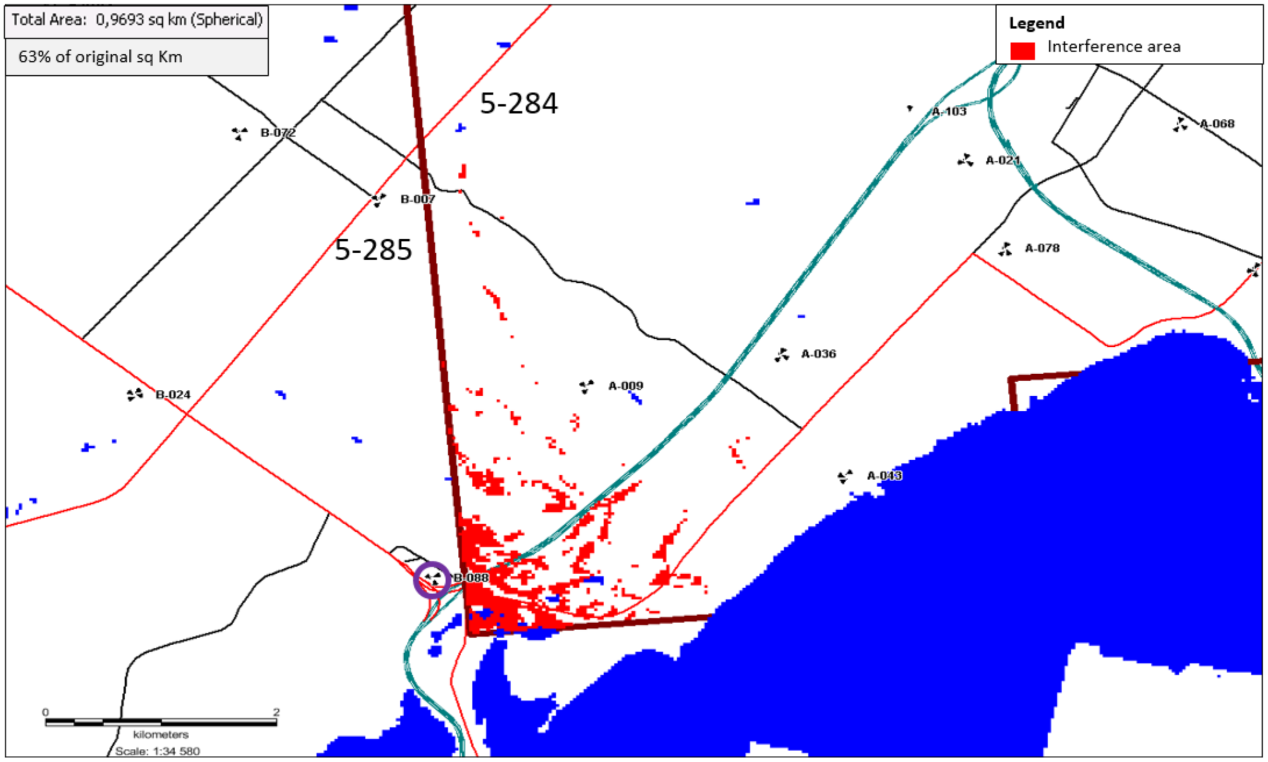


Fig. E. 1: Scenario 1 Typical B-088 10 degree down Tilt Mitigation

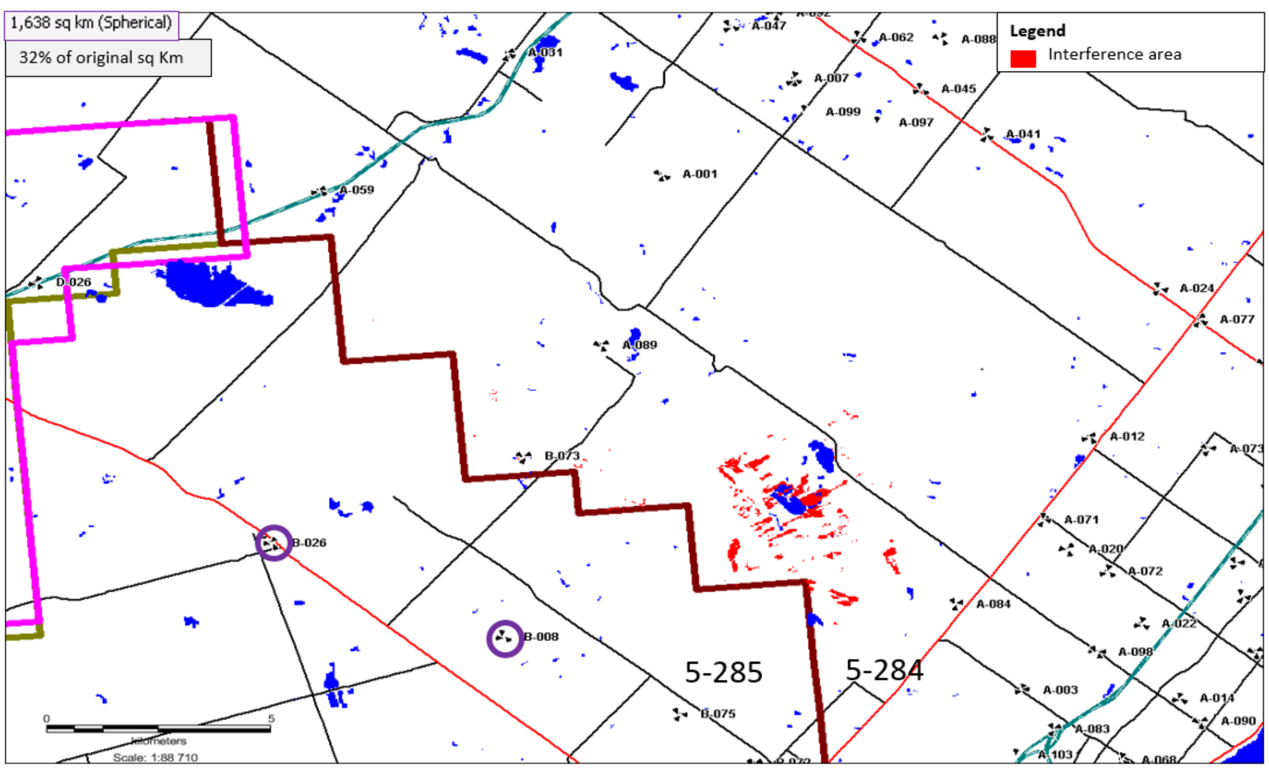


Fig. E. 2: Scenario 2 Typical B-008/B-026 10 degree Down Tilt Mitigation

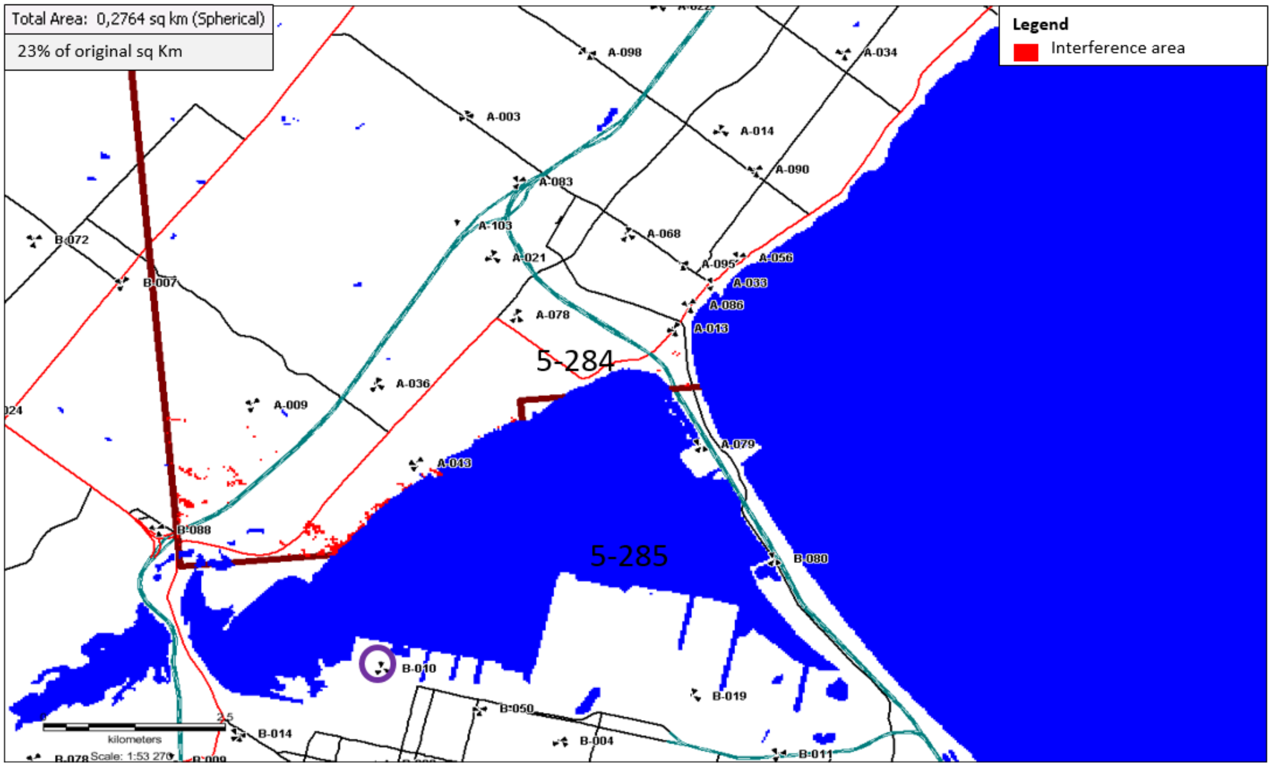


Fig. E. 3: Scenario 3 Typical B-010 10 degree Down Tilt Mitigation

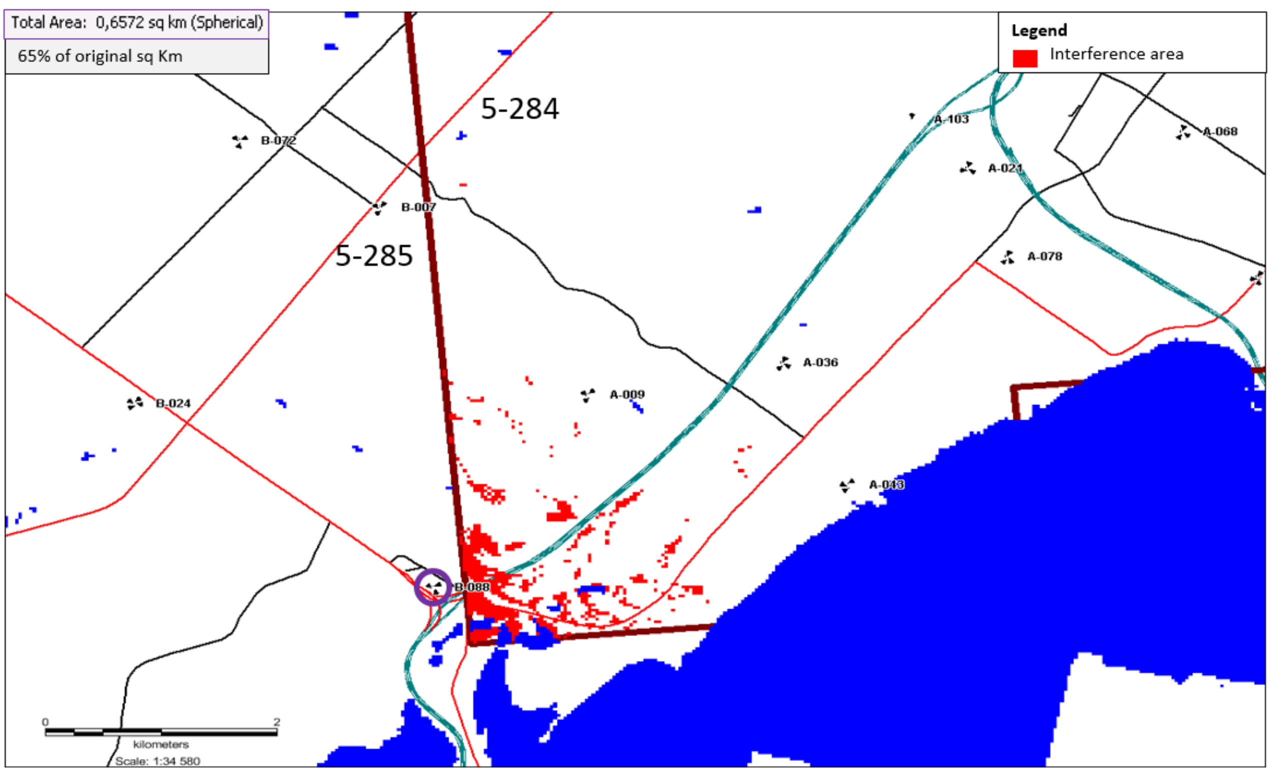


Fig. E. 4: Scenario 1 mMIMO B-088 20 degree Down Tilt Mitigation

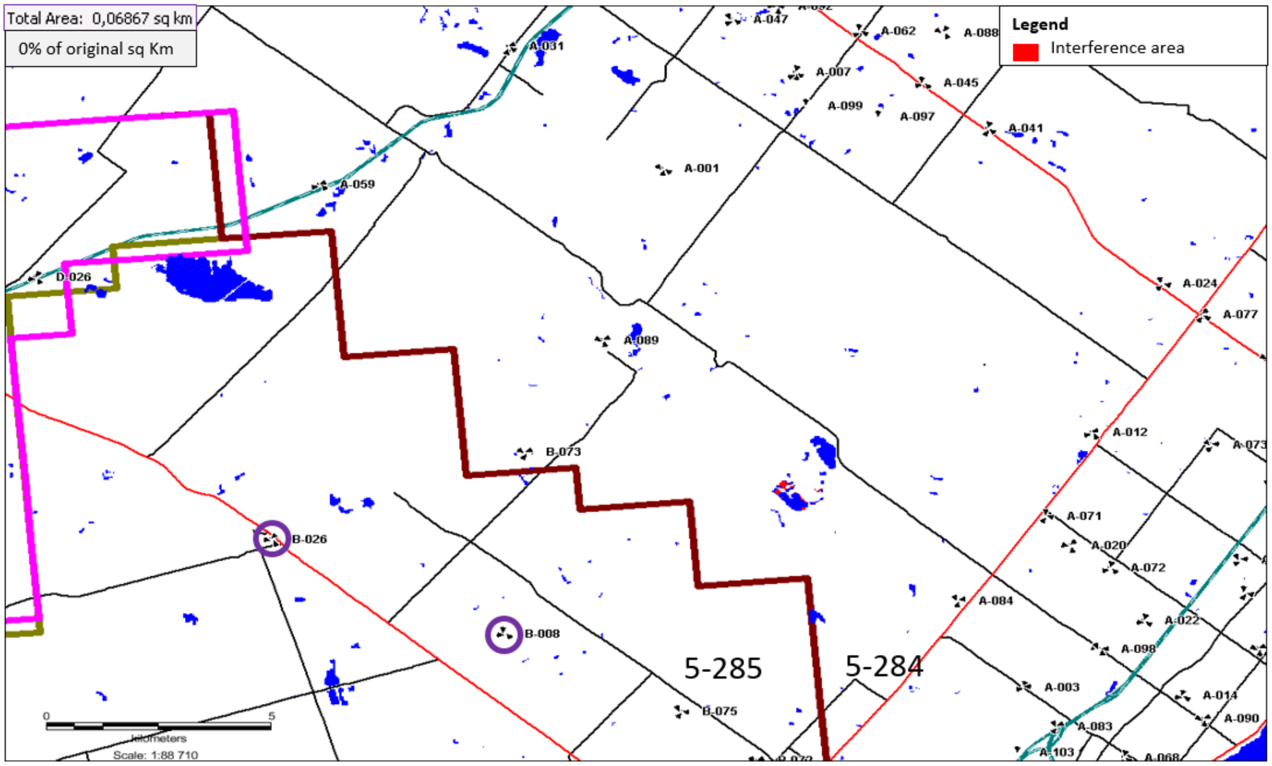


Fig. E. 5: Scenario 2 mMIMO B-008/B-026 20 degree Down Tilt Mitigation

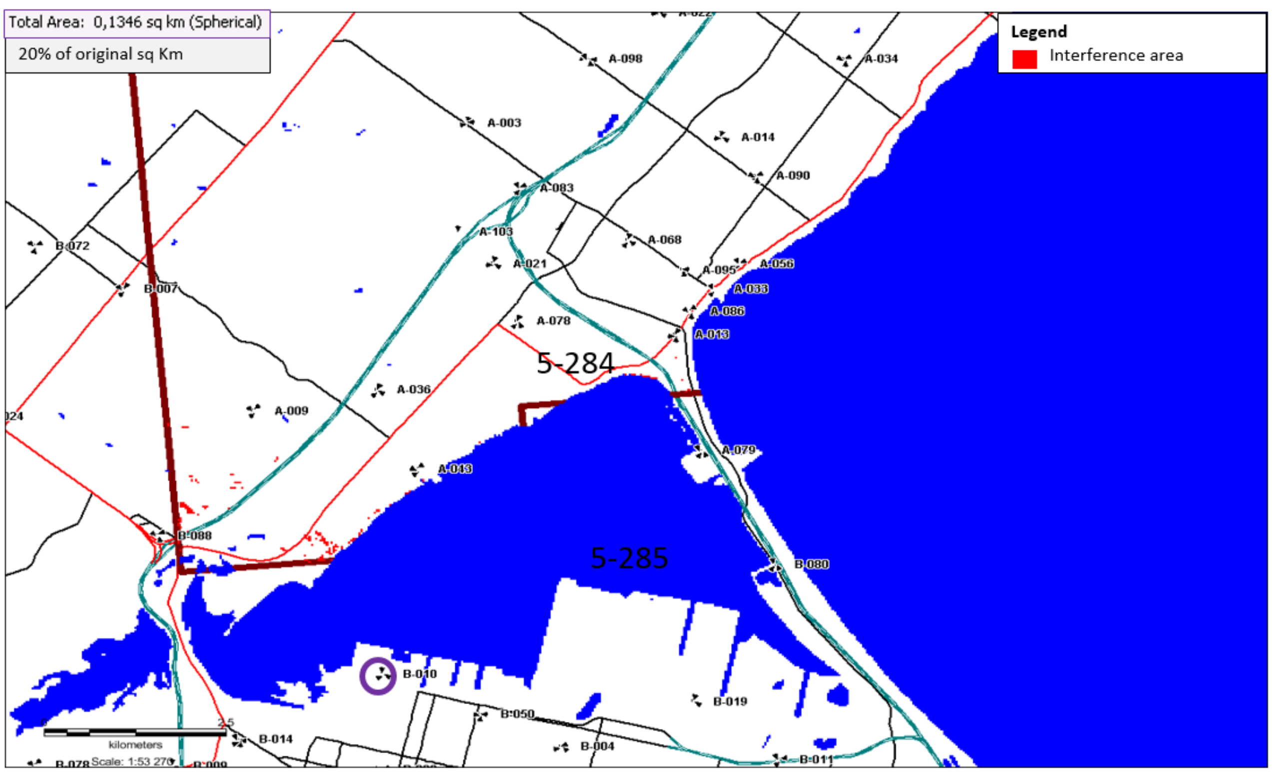


Fig. E. 6: Scenario 3 mMIMO B-010 20 degree Down Tilt Mitigation

Annex F: Height Mitigation Maps

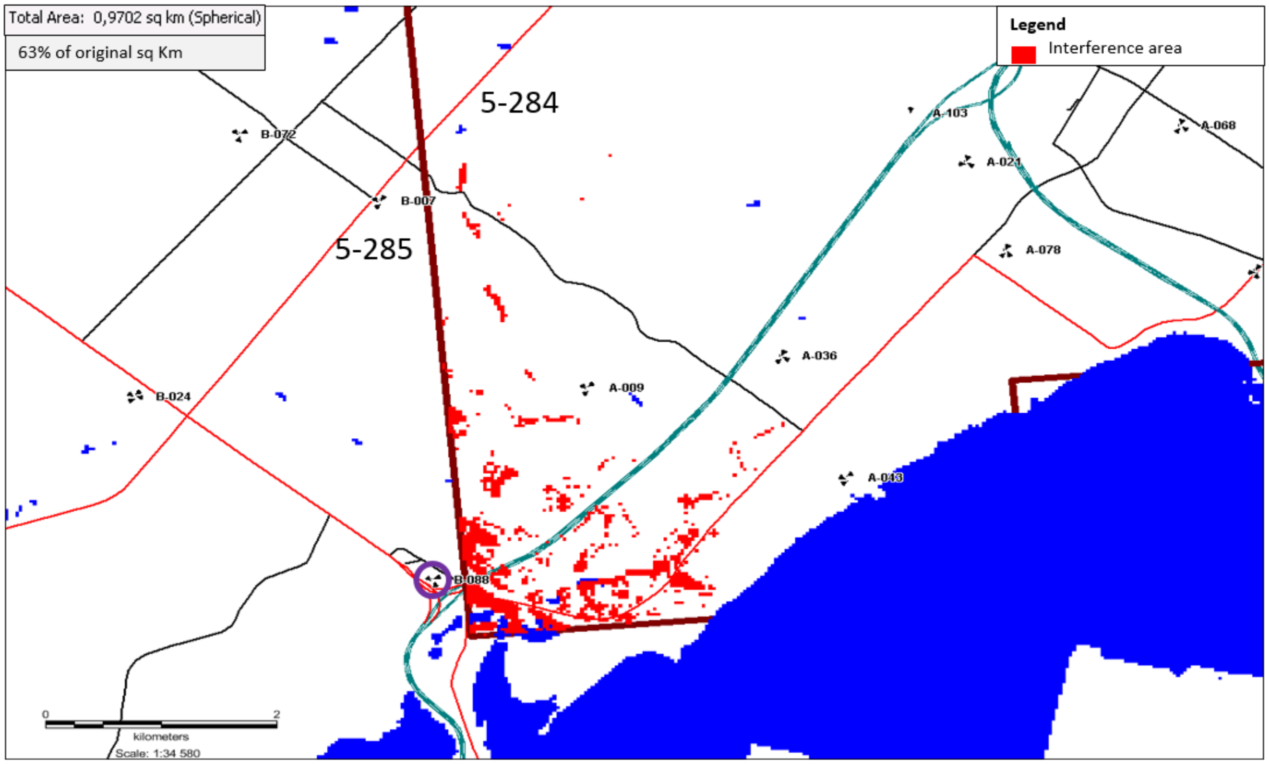


Fig. F. 1: Scenario 1 Typical B-088 10m Height Reduction Mitigation

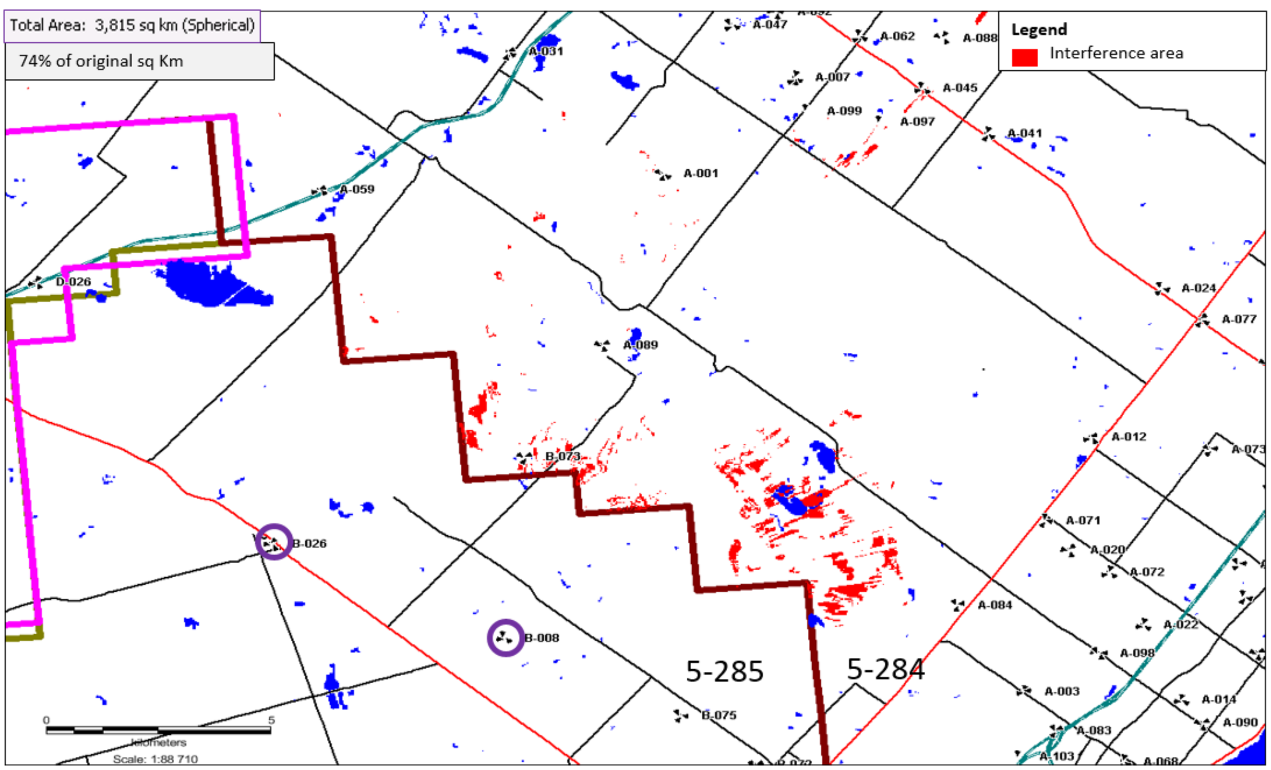


Fig. F. 2: Scenario 2 Typical B-008/B-026 10m Height Reduction Mitigation

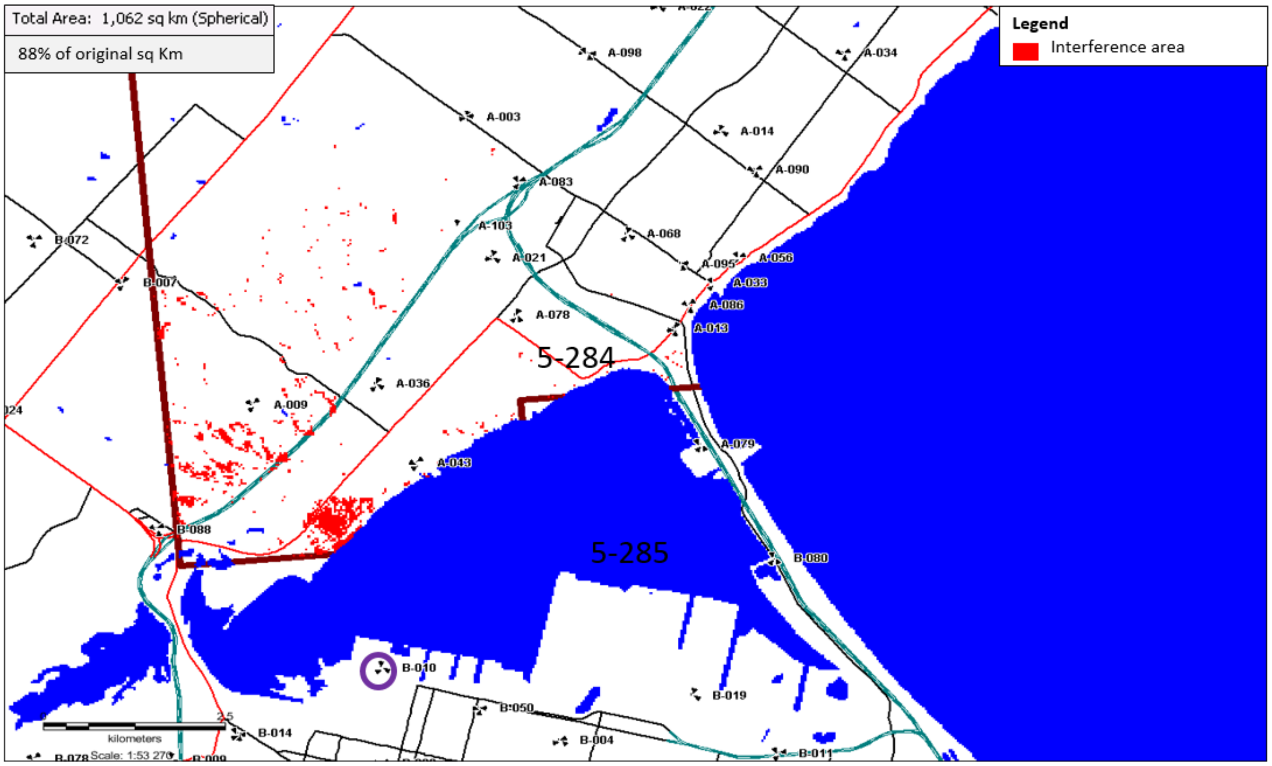


Fig. F. 3: Scenario 3 Typical B-010 10m Height Reduction Mitigation

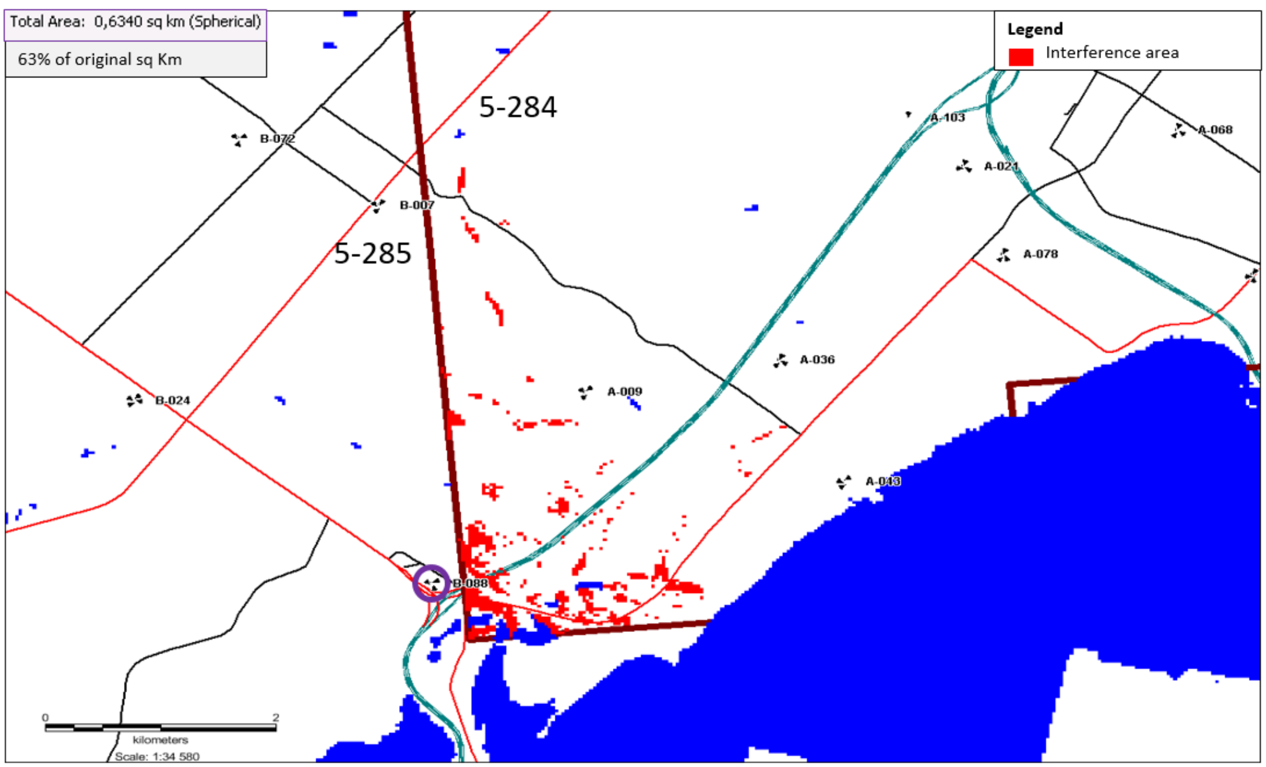


Fig. F. 4: Scenario 1 mMIMO B-088 10m Height Reduction Mitigation

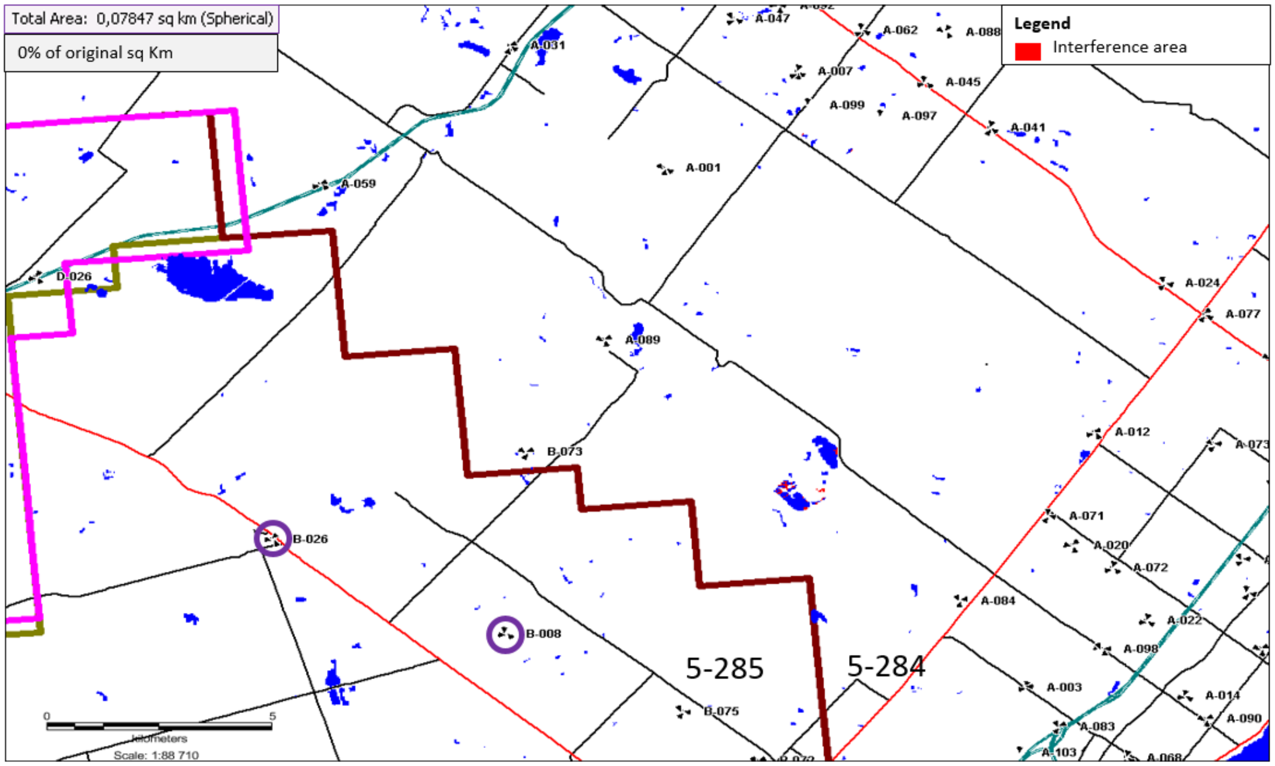


Fig. F. 5: Scenario 2 mMIMO B-008/B-026 10m Height Reduction Mitigation

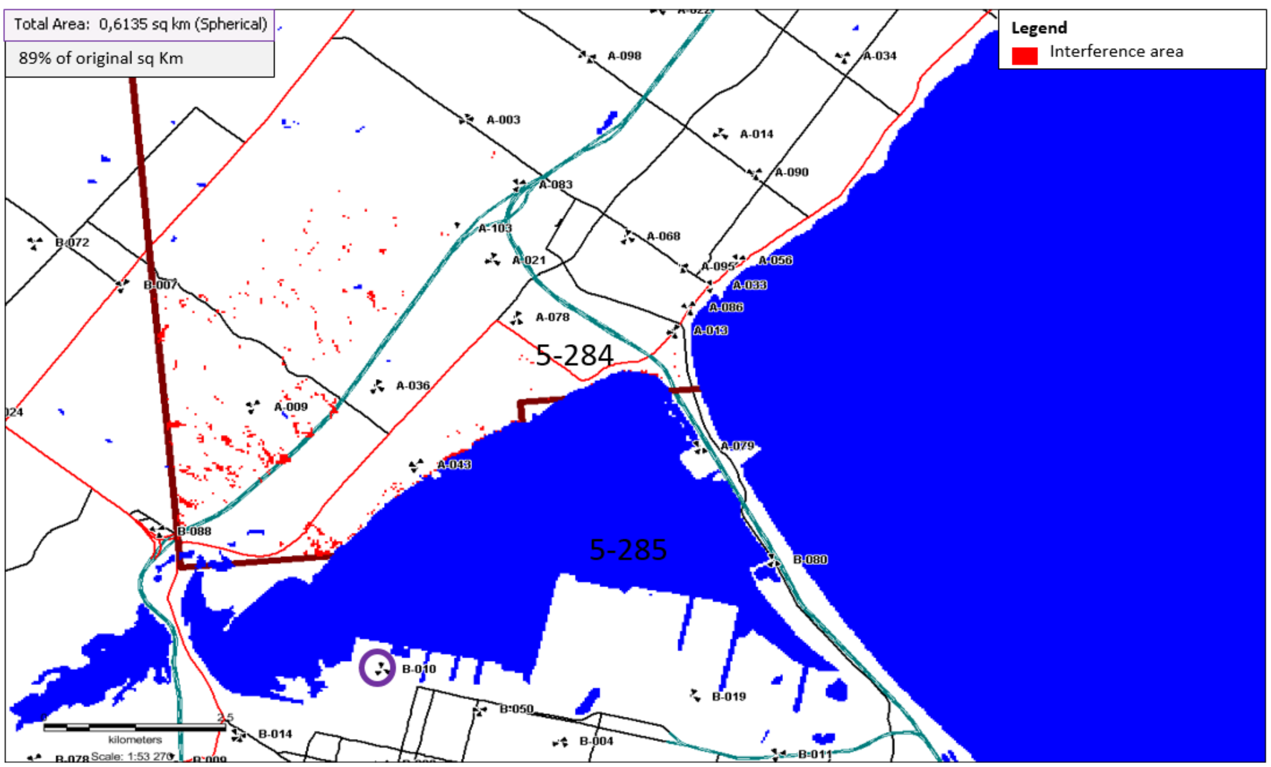


Fig. F. 6: Scenario 3 mMIMO B-010 10m Height Reduction Mitigation

Annex G: Half Power Mitigation Maps

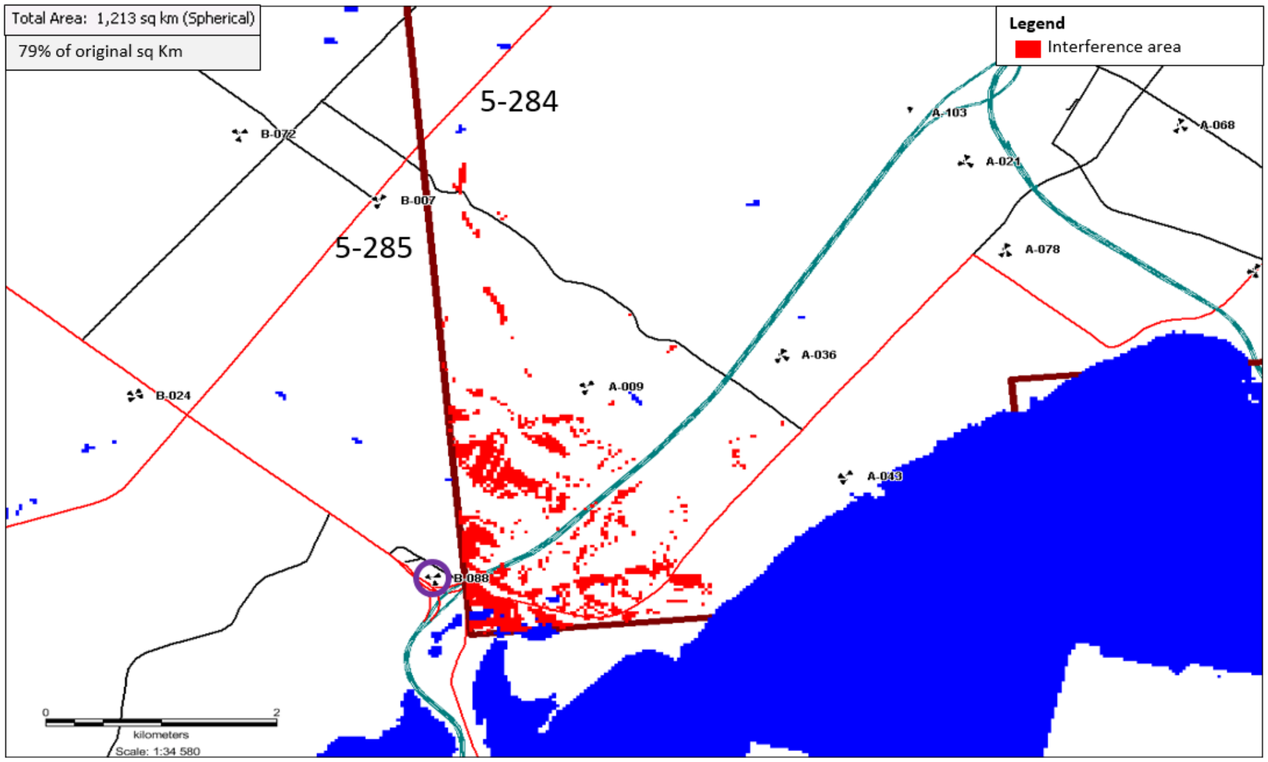


Fig. G. 1: Scenario 1 Typical B-088 Half Power Mitigation

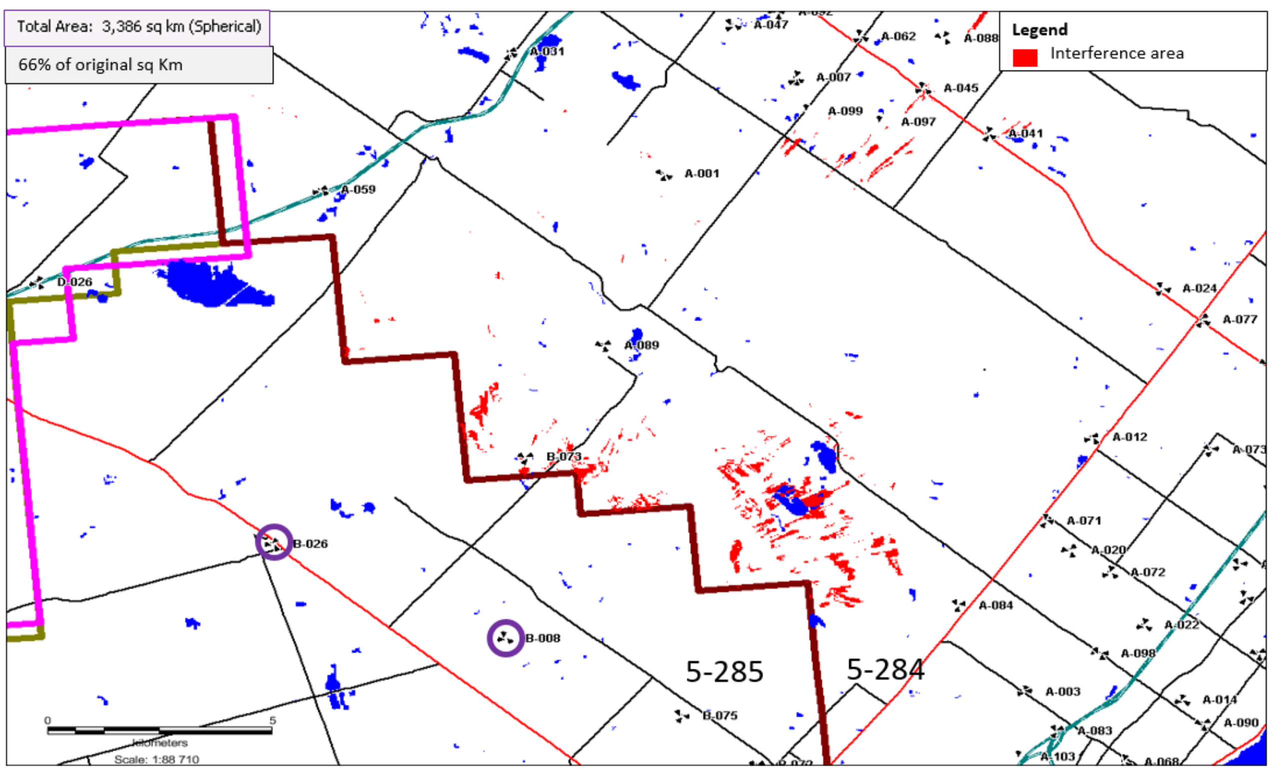


Fig. G. 2: Scenario 2 Typical B-008/B-026 Half Power Mitigation

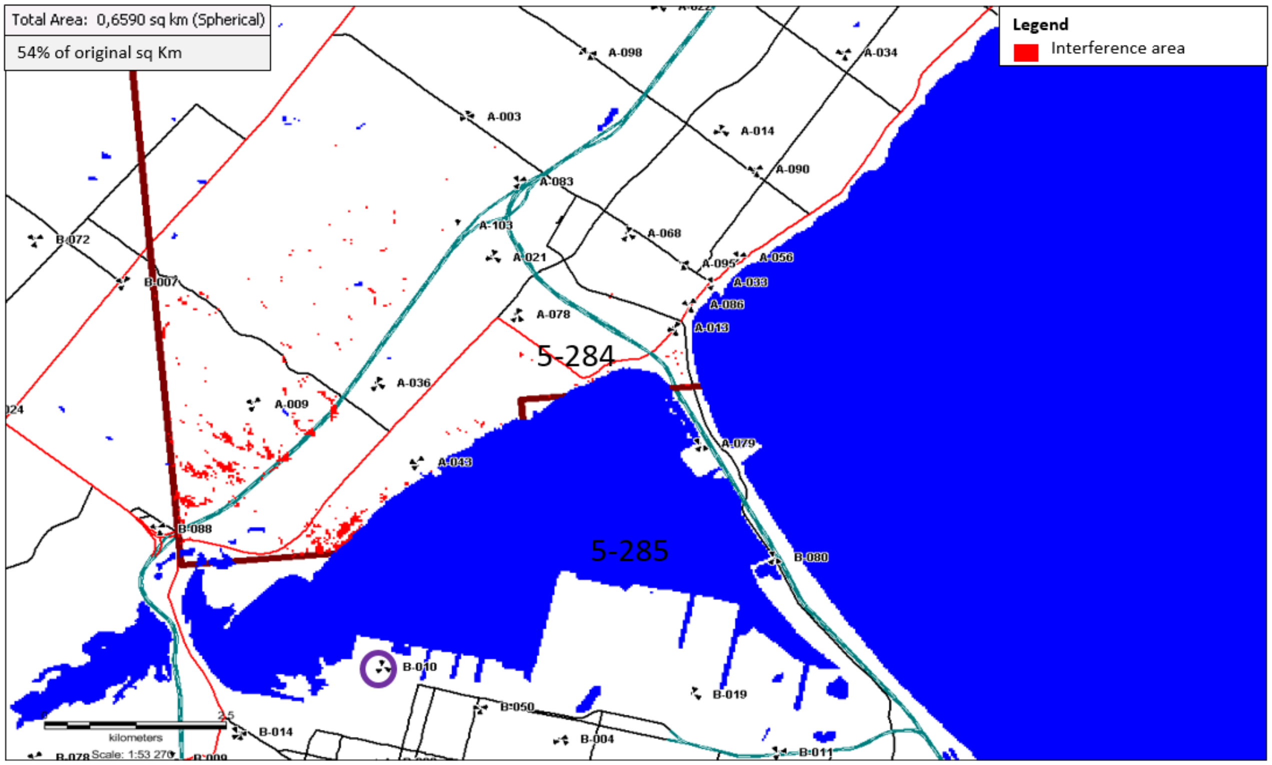


Fig. G. 3: Scenario 3 Typical B-010 Half Power Mitigation

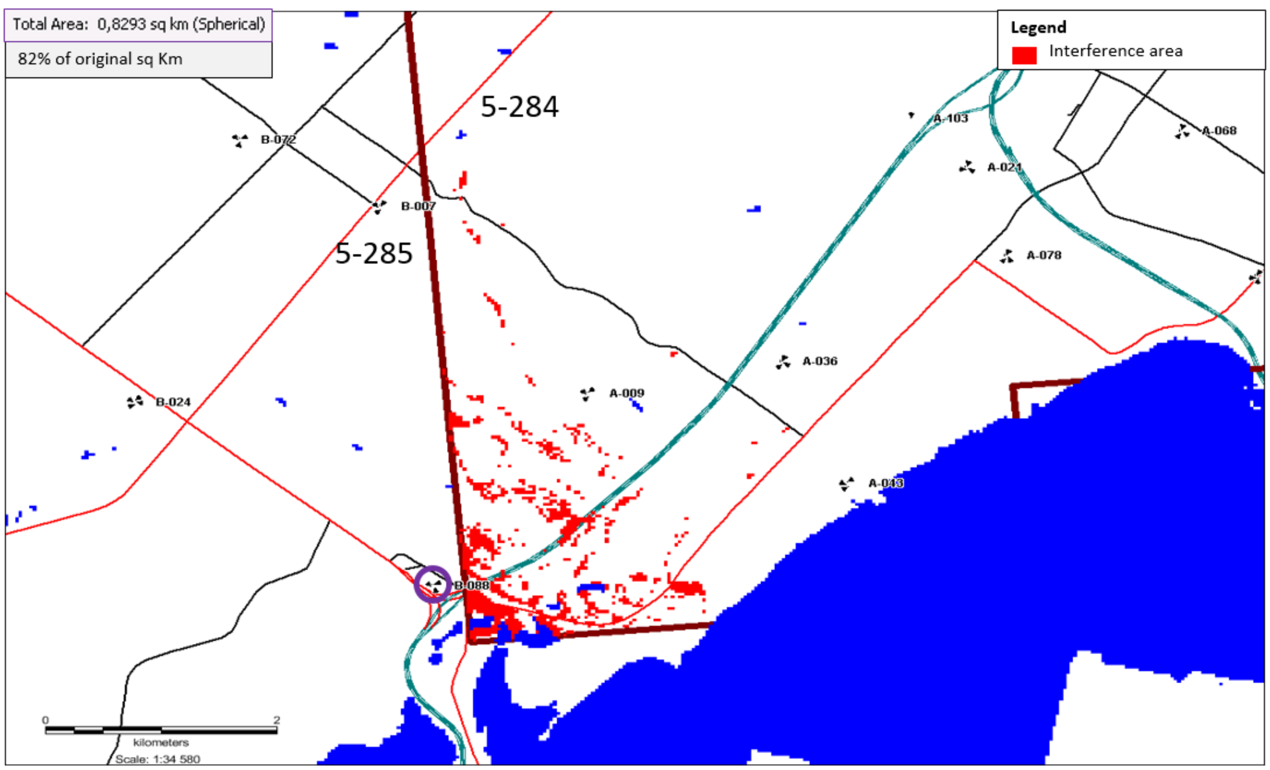


Fig. G. 4: Scenario 1 mMIMO B-088 Half Power Mitigation

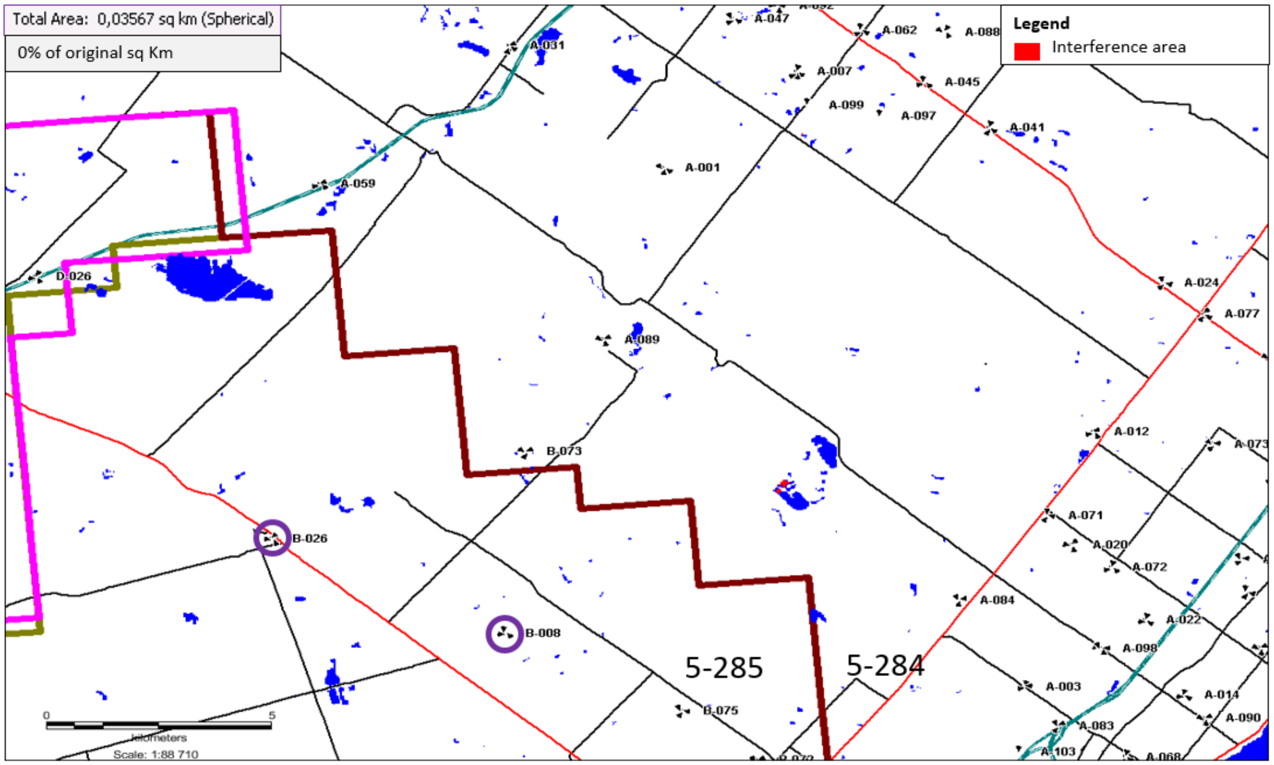


Fig. G. 5: Scenario 2 mMIMO B-008/B-026 Half Power Mitigation

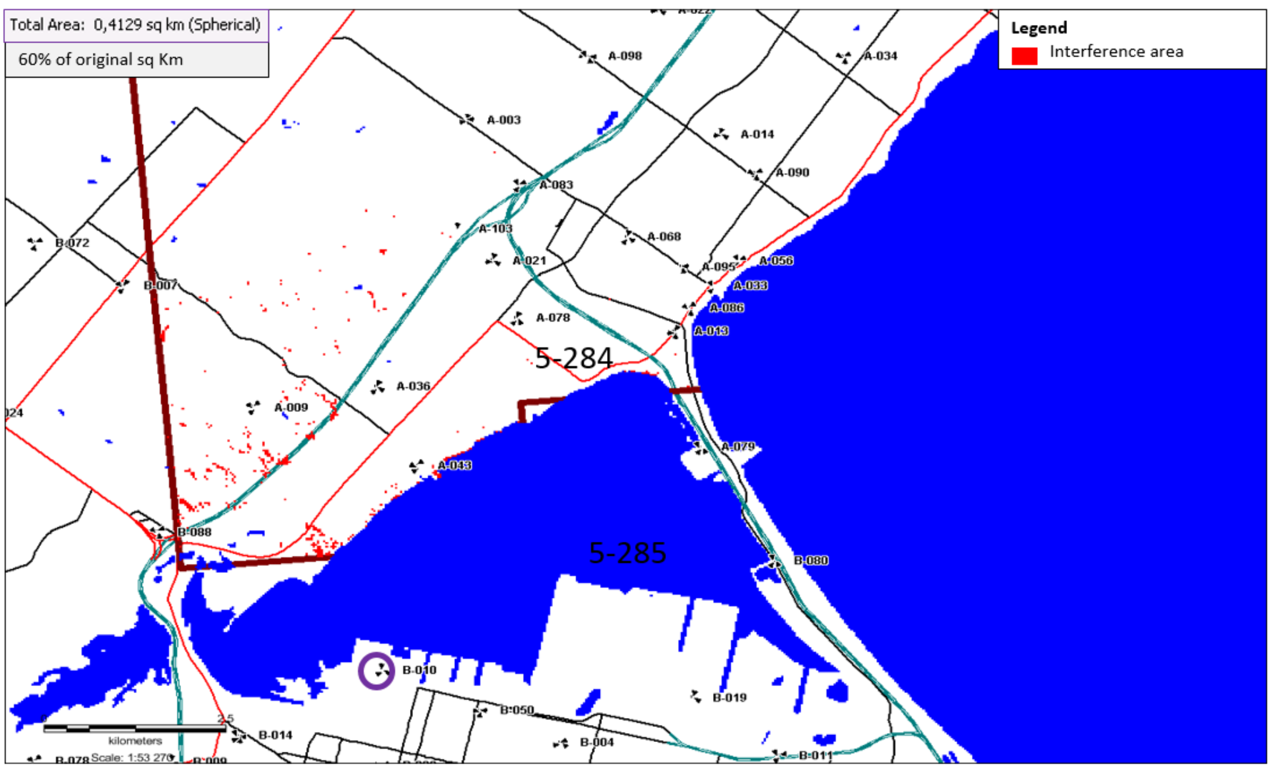


Fig. G. 6: Scenario 3 mMIMO B-010 Half Power Mitigation

Annex H: Azimuth Mitigation Maps

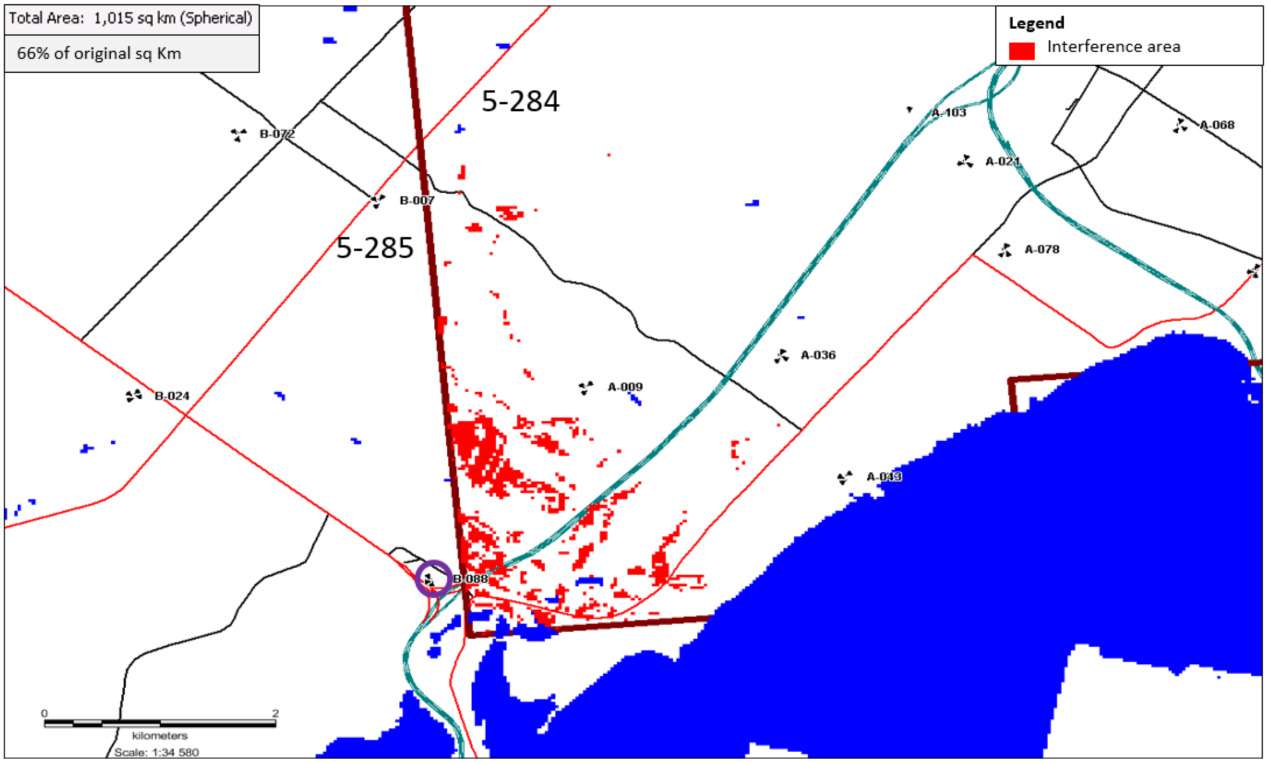


Fig. H. 1: Scenario 1 Typical B-088 Azimuth Change Mitigation

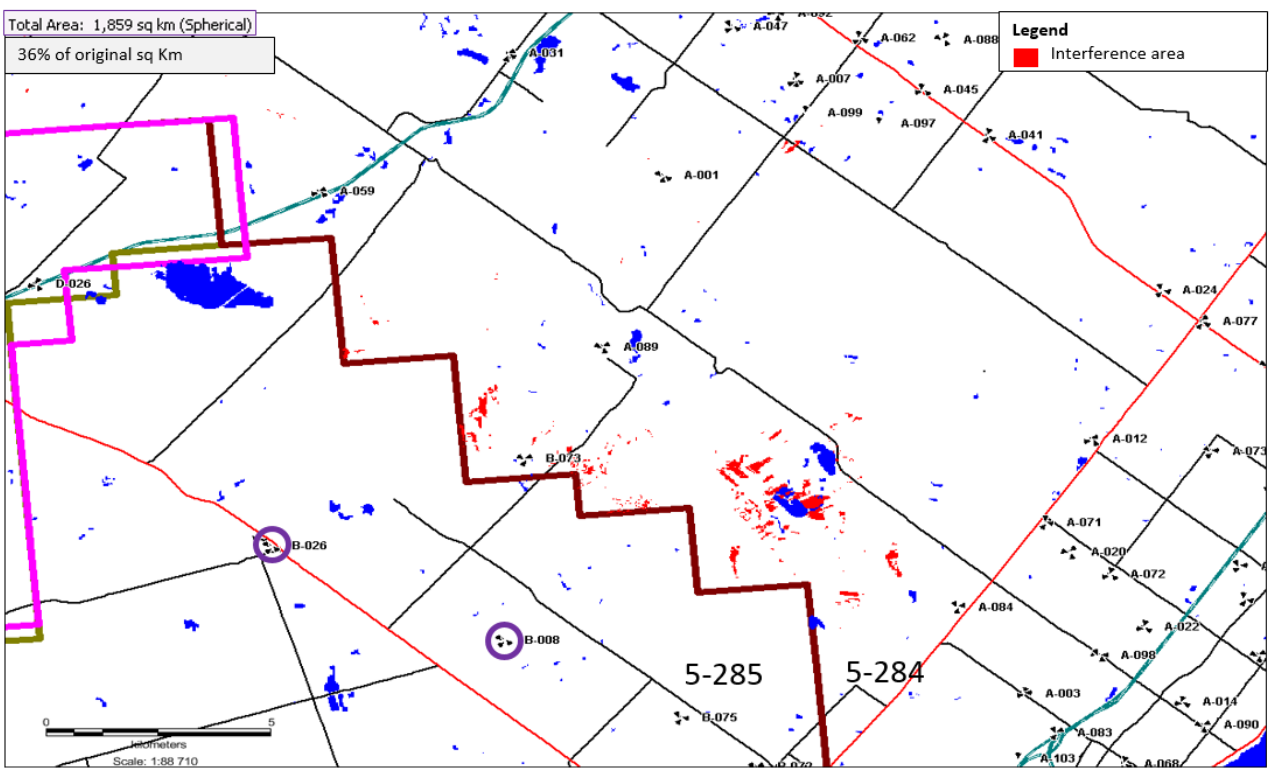


Fig. H. 2: Scenario 2 Typical B-008/B-026 Azimuth Change Mitigation

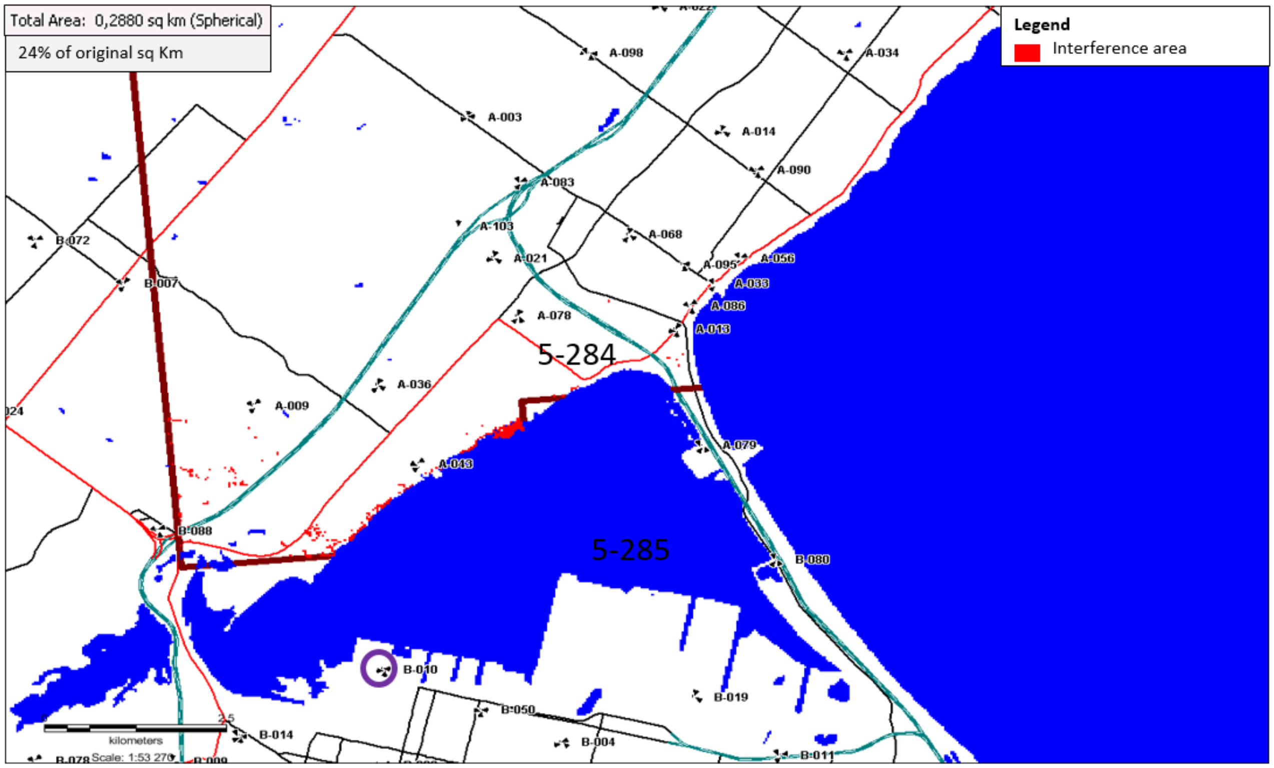


Fig. H. 3: Scenario 3 Typical B-010 Azimuth Change Mitigation

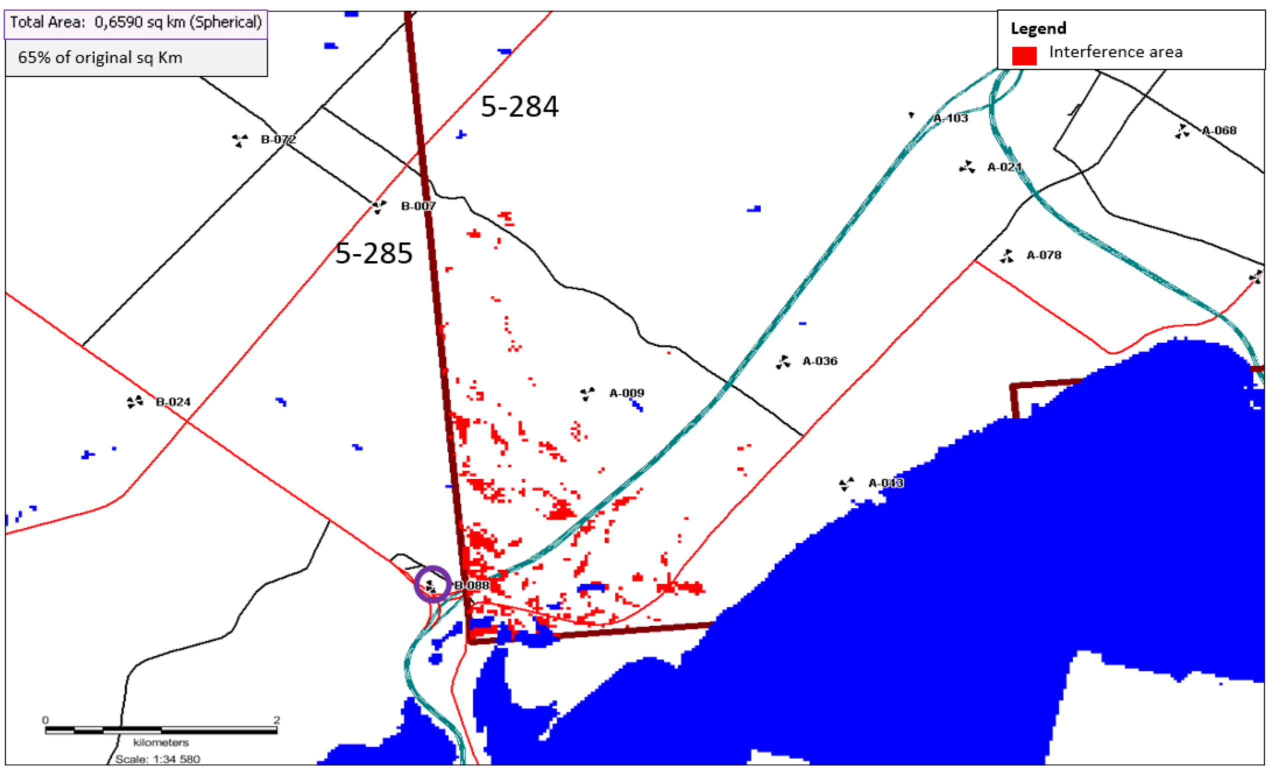


Fig. H. 4: Scenario 1 mMIMO B-088 Azimuth Change Mitigation

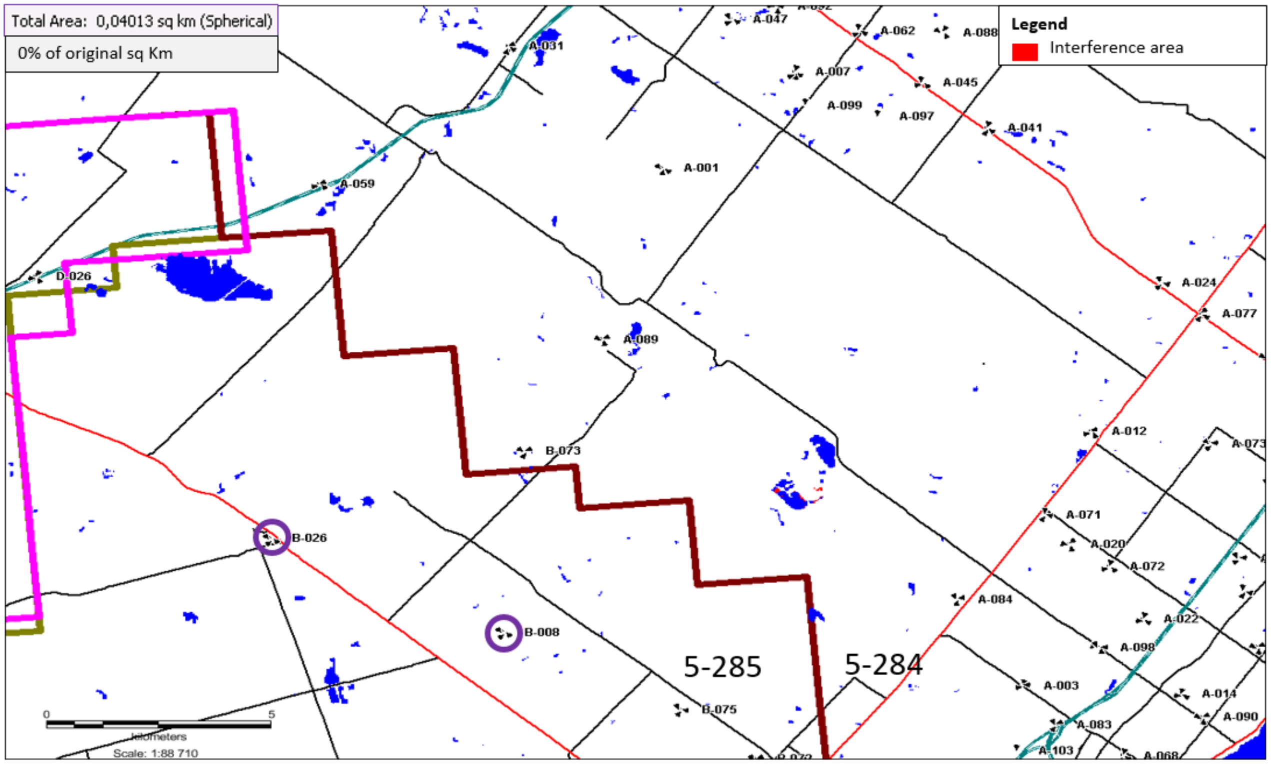


Fig. H. 5: Scenario 2 mMIMO B-008/B-026 Azimuth Change Mitigation

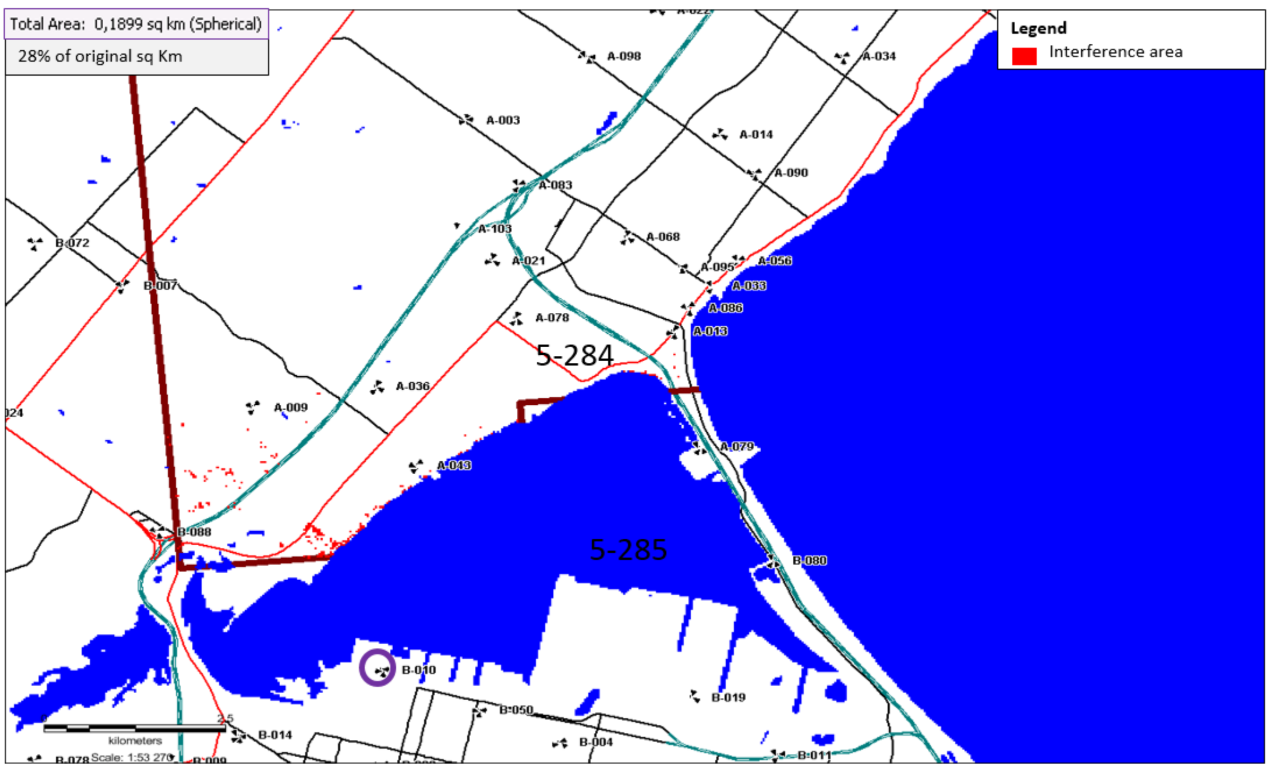


Fig. H. 6: Scenario 3 mMIMO B-010 Azimuth Change Mitigation

Annex I: Combination of Mitigation Techniques Maps

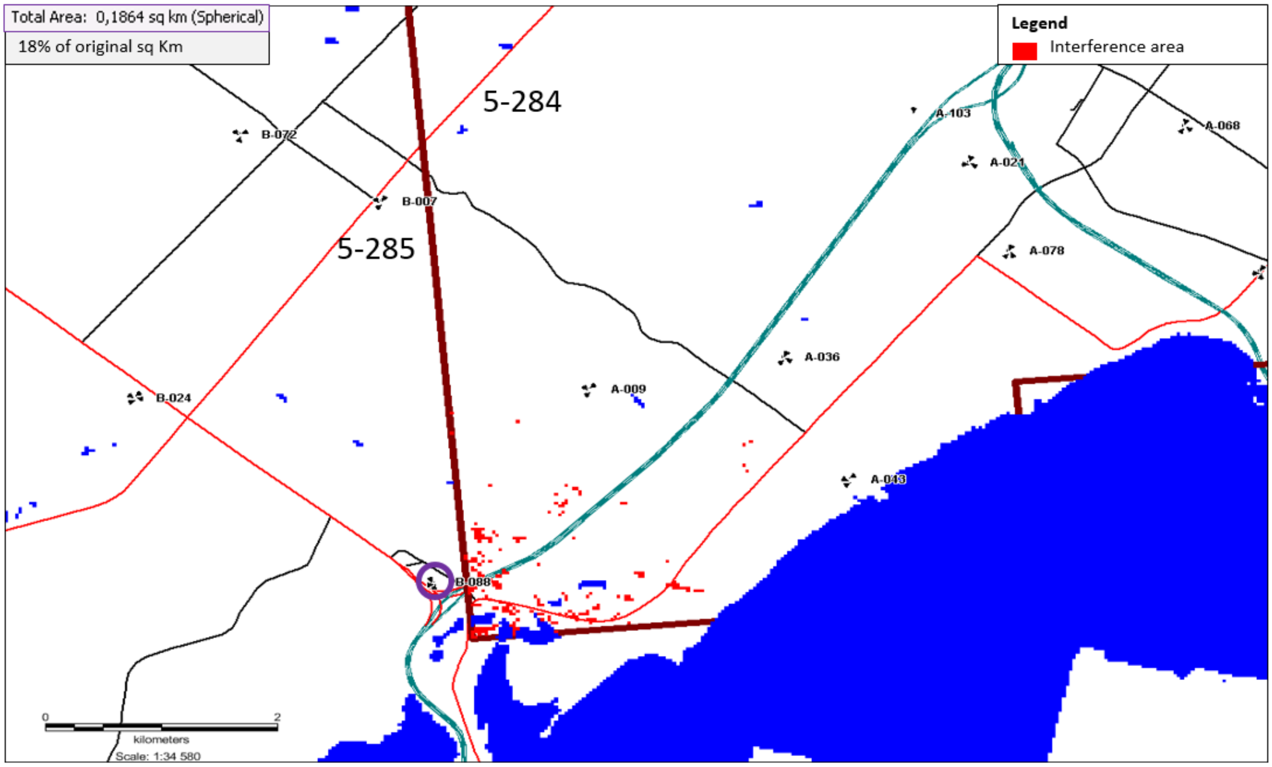


Fig. I. 1: Scenario 1 mMIMO B-088 Tilt, Height, Power and Azimuth Mitigation

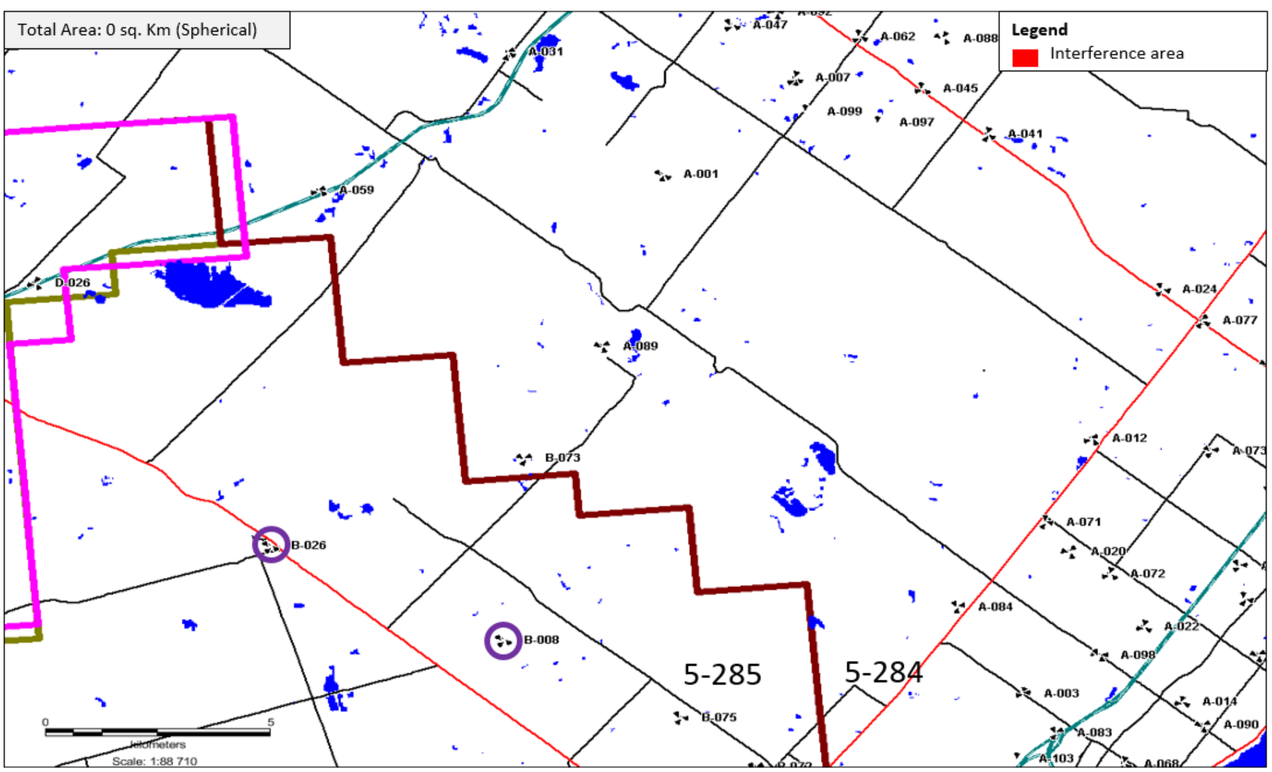


Fig. I. 2: Scenario 2 mMIMO B-008/B-026 Tilt, Height, Power and Azimuth Mitigation

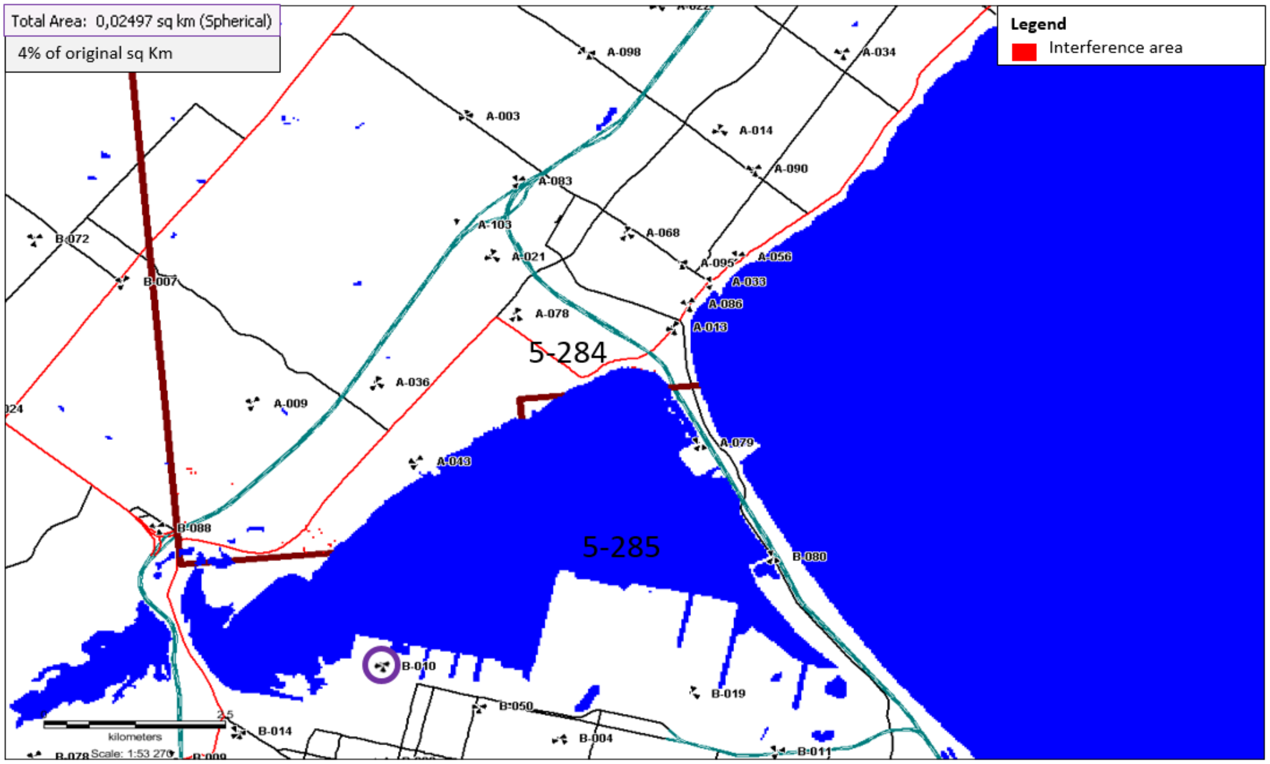


Fig. I. 3: Scenario 3 mMIMO B-010 Tilt, Height, Power and Azimuth Mitigation

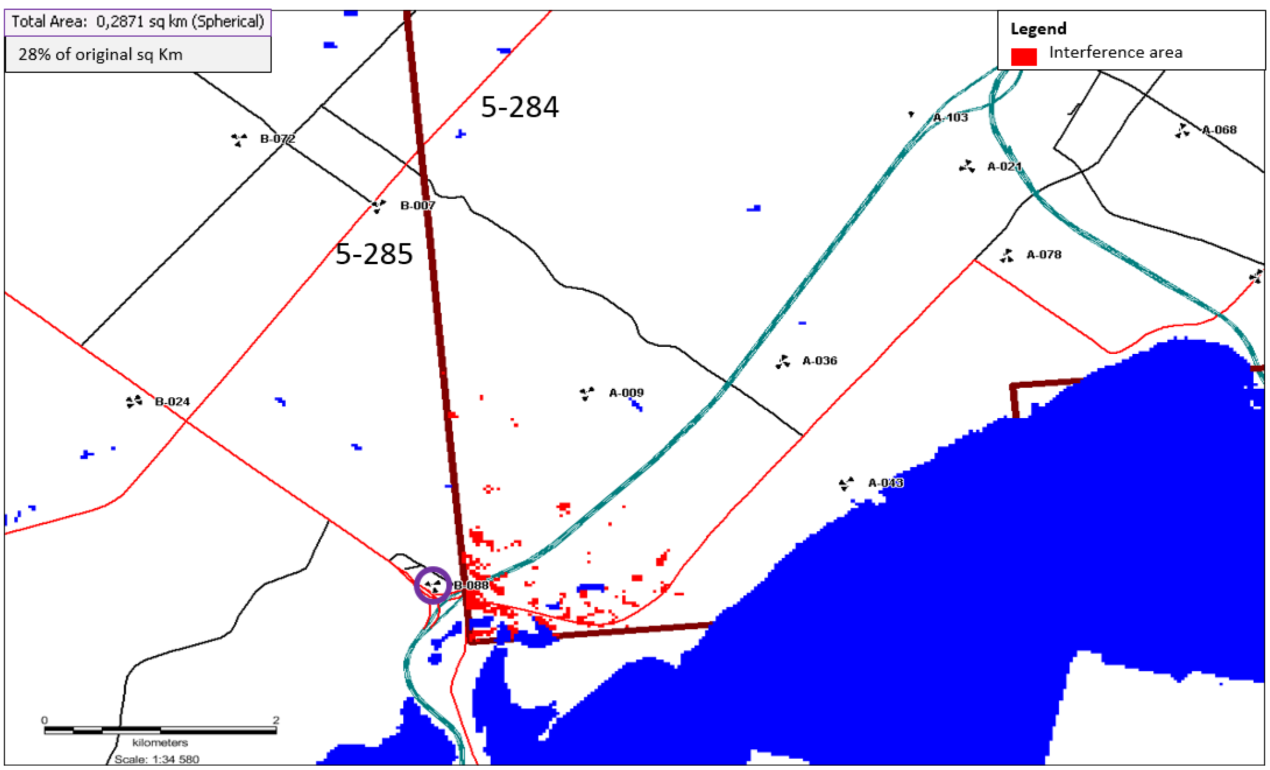


Fig. I. 4: Scenario 1 mMIMO B-088 Tilt, Height and Power Mitigation

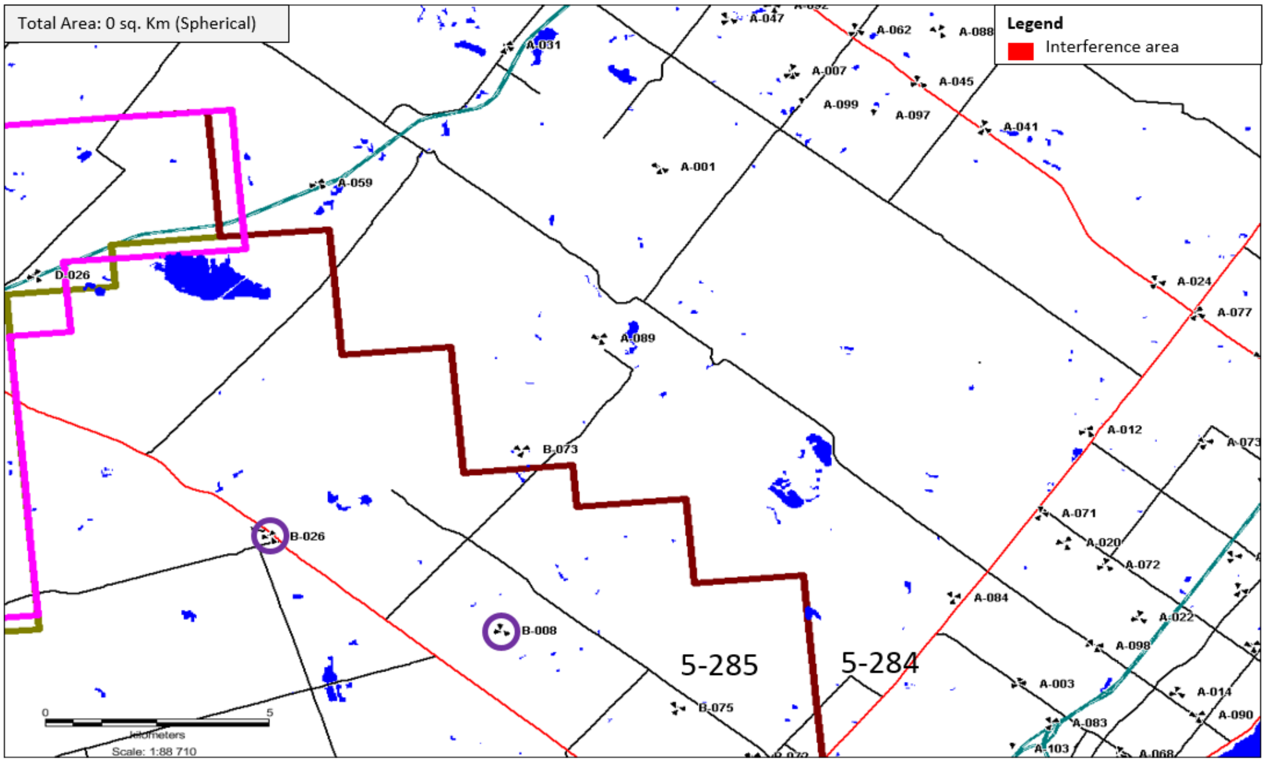


Fig. I. 5: Scenario 2 mMIMO B-008/B-026 Tilt, Height and Power Mitigation

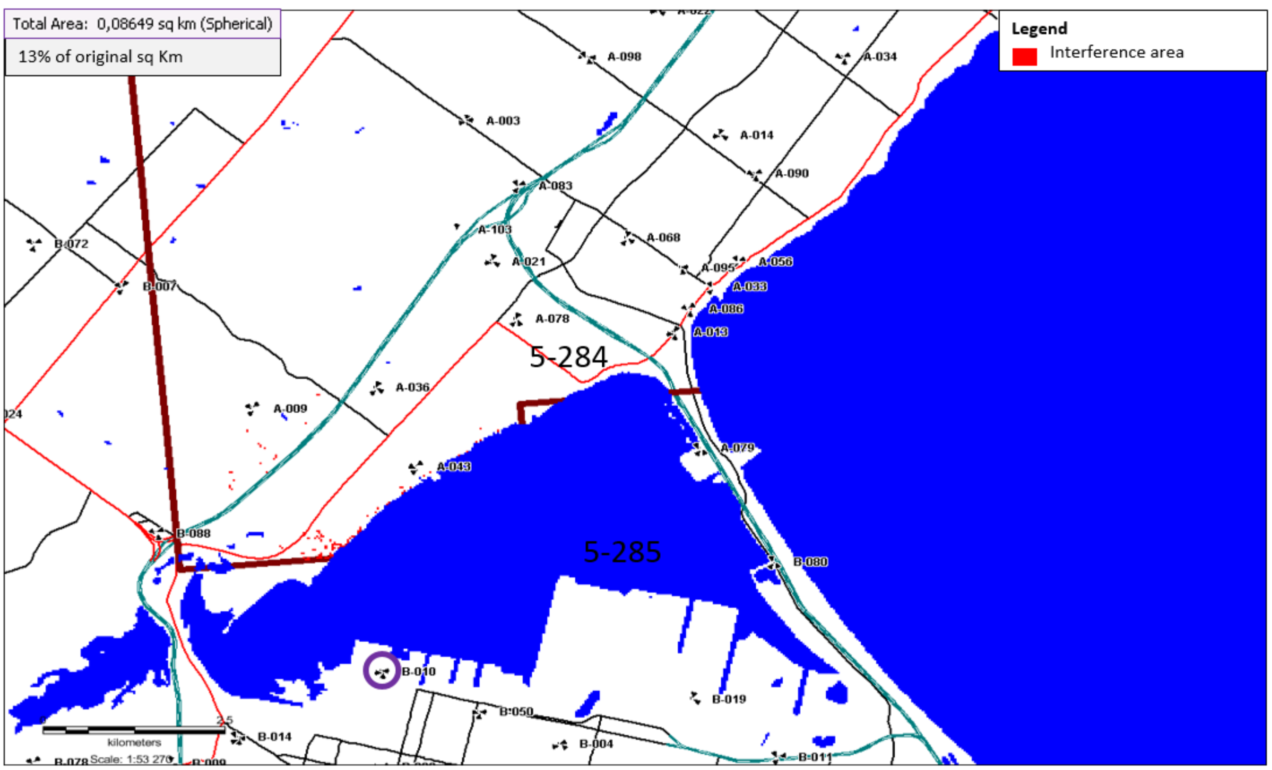


Fig. I. 6: Scenario 3 mMIMO B-010 Tilt, Height and Power Mitigation

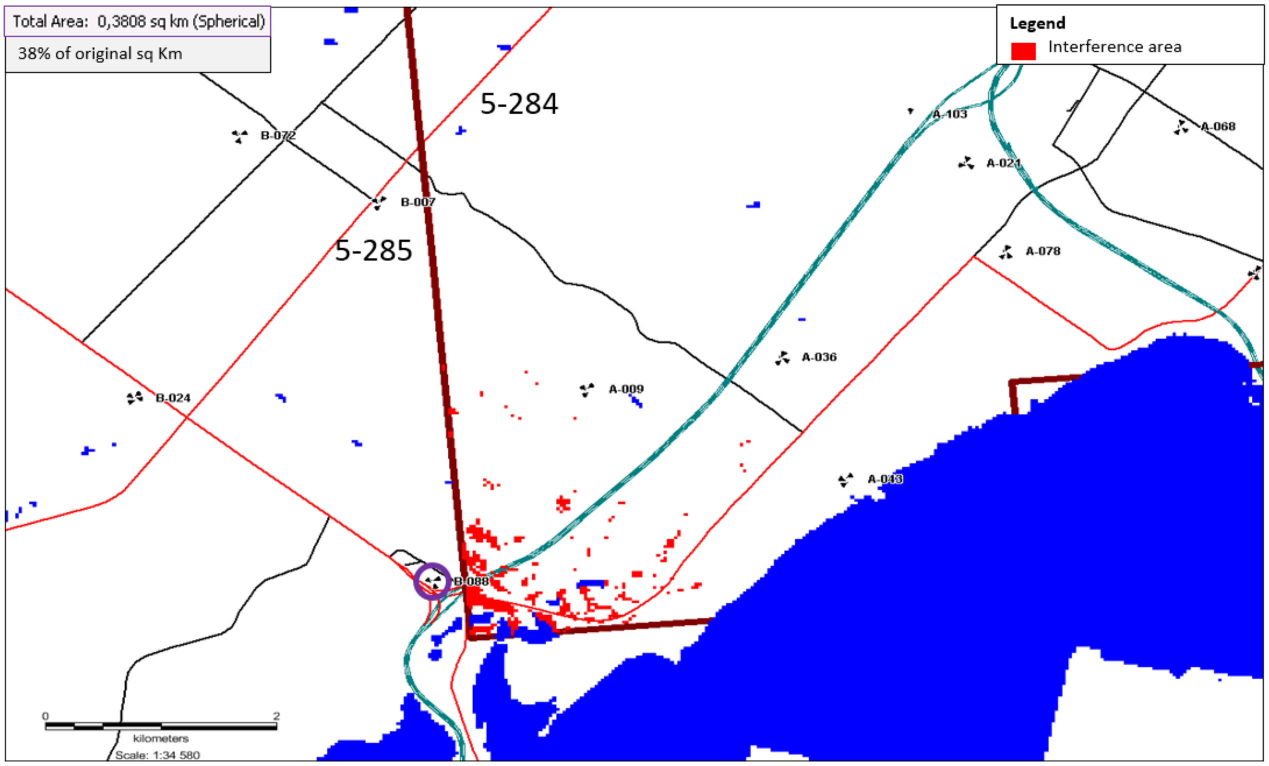


Fig. I. 7: Scenario 1 mMIMO B-088 Tilt and Height Mitigation

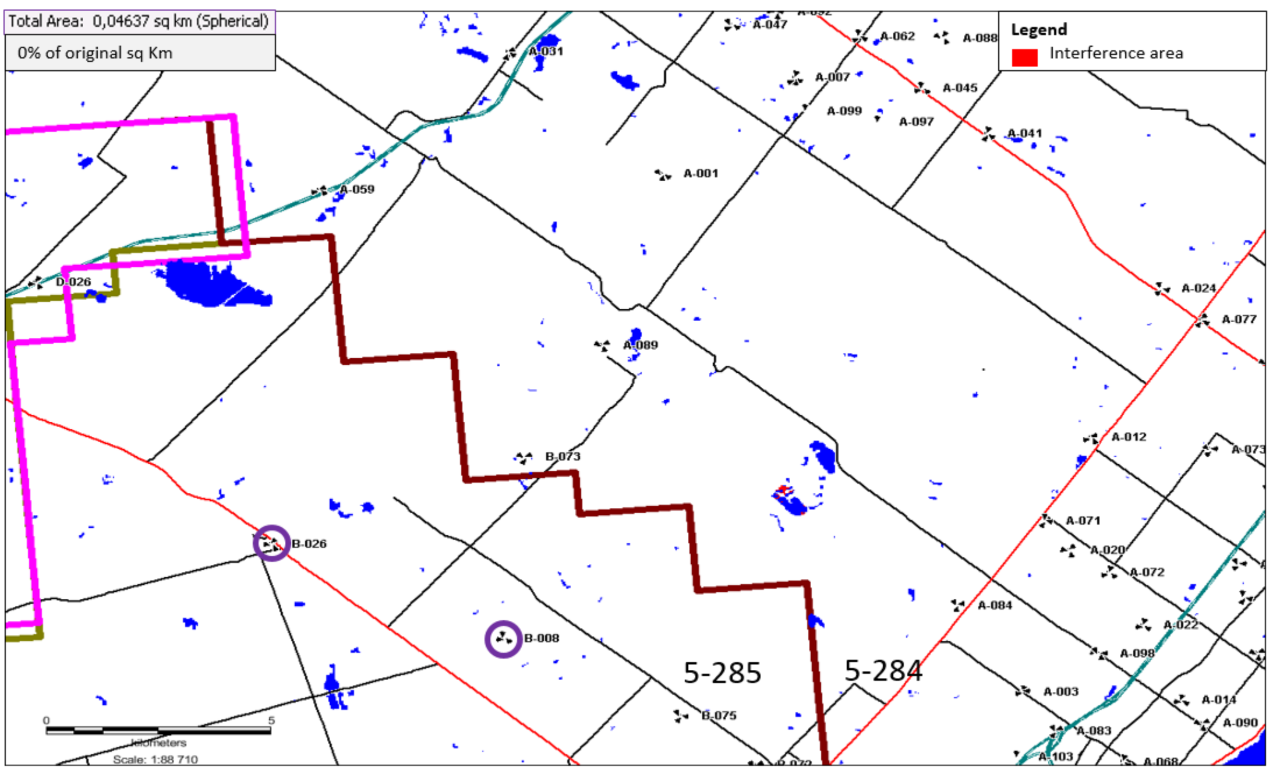


Fig. I. 8: Scenario 2 mMIMO B-008/B-026 Tilt and Height Mitigation

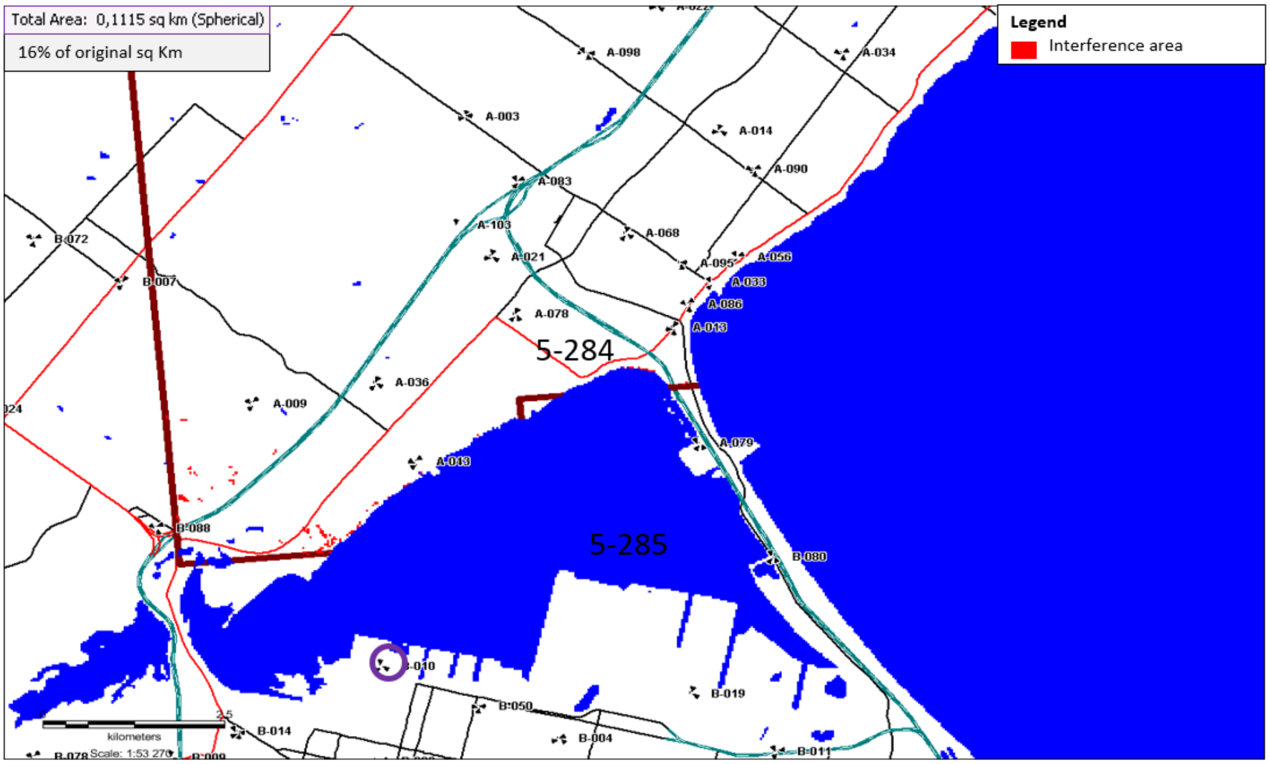


Fig. I. 9: Scenario 3 mMIMO B-010 Tilt and Height Mitigation

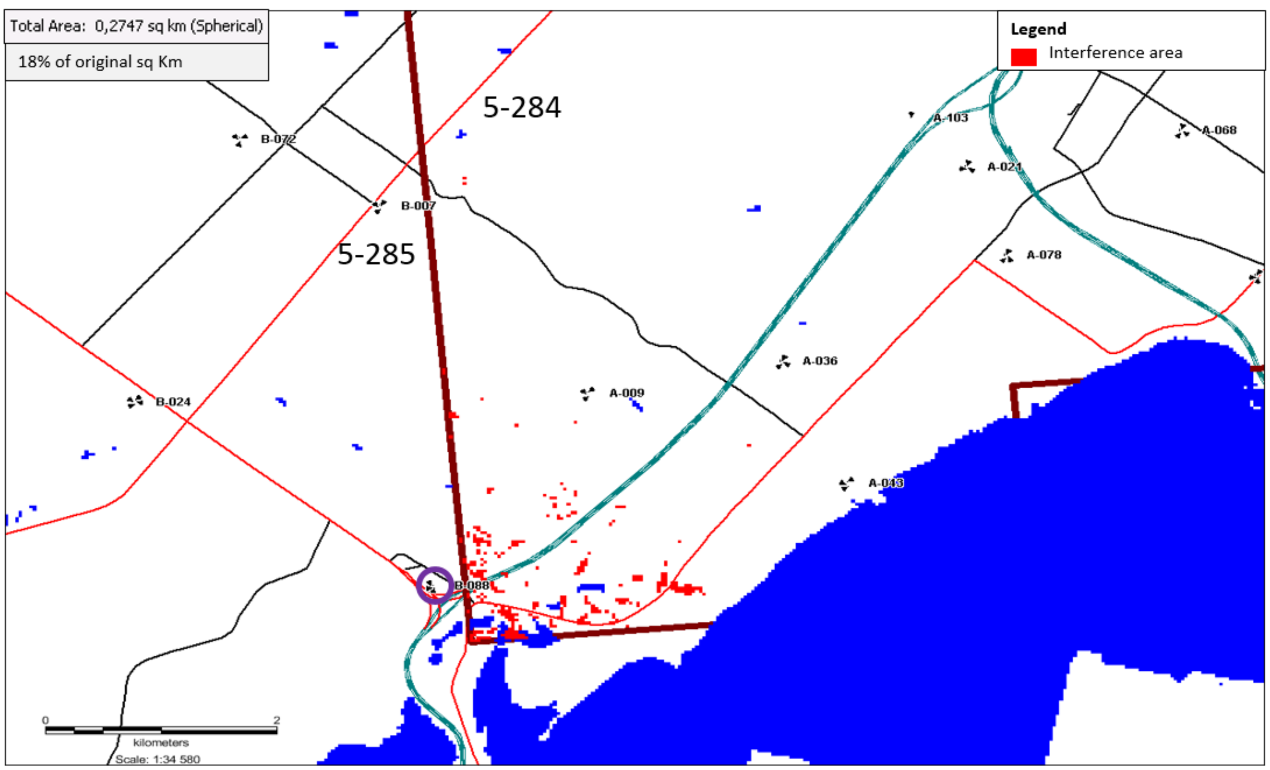


Fig. I. 10: Scenario 1 Typical B-088 Tilt, Height, Power and Azimuth Mitigation

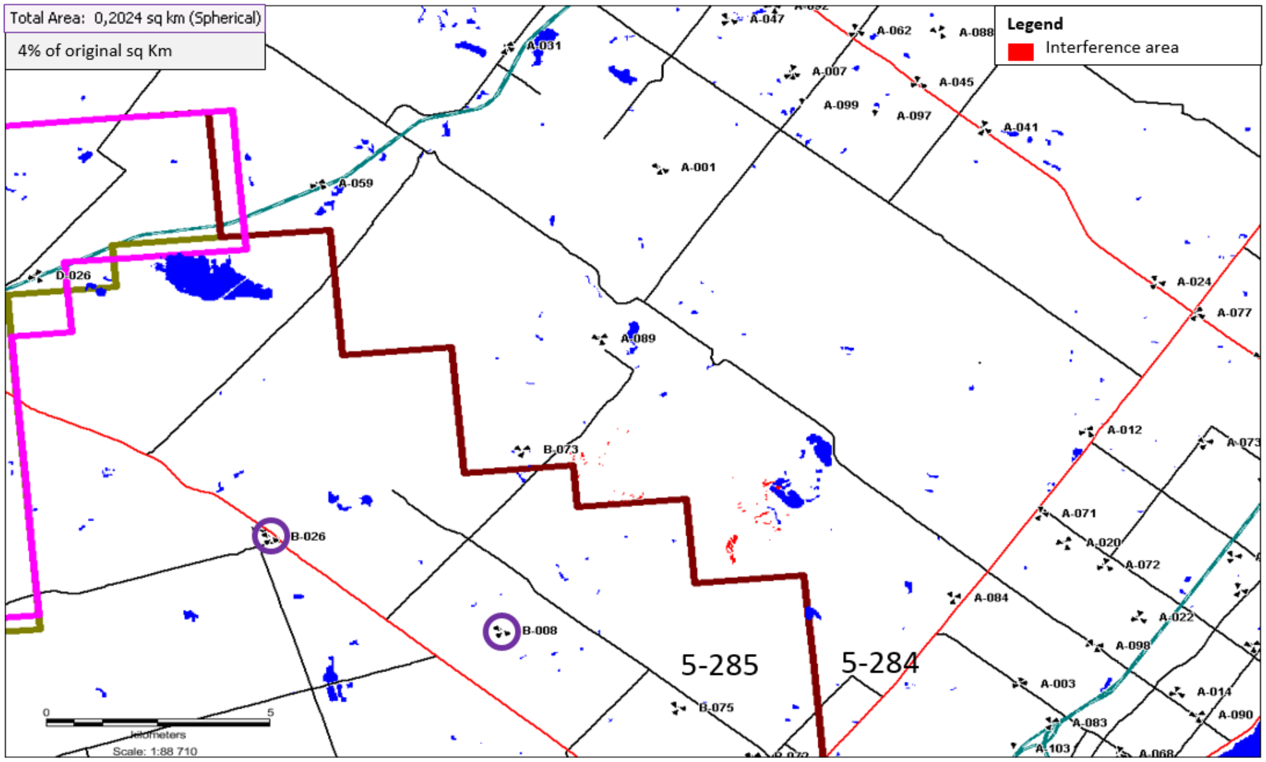


Fig. I. 11: Scenario 2 Typical B-008/B-026 Tilt, Height, Power and Azimuth Mitigation

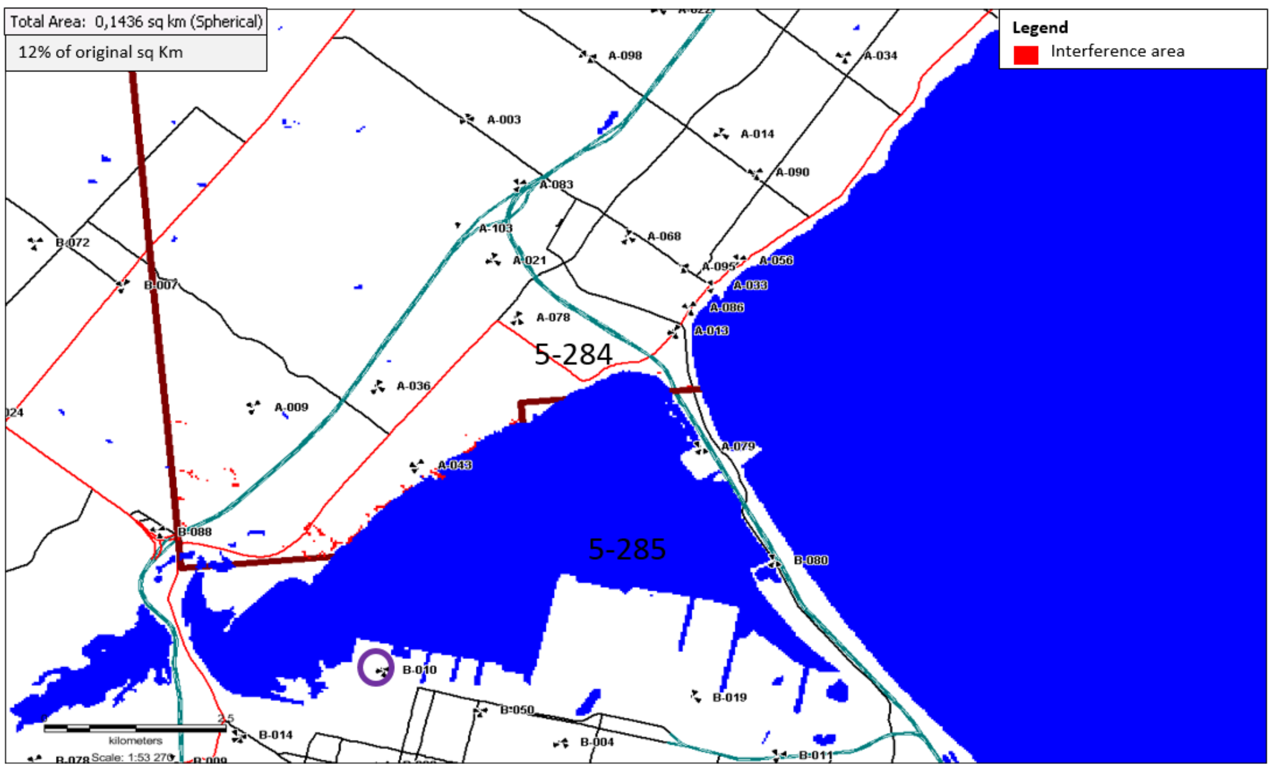


Fig. I. 12: Scenario 3 Typical B-010 Tilt, Height, Power and Azimuth Mitigation

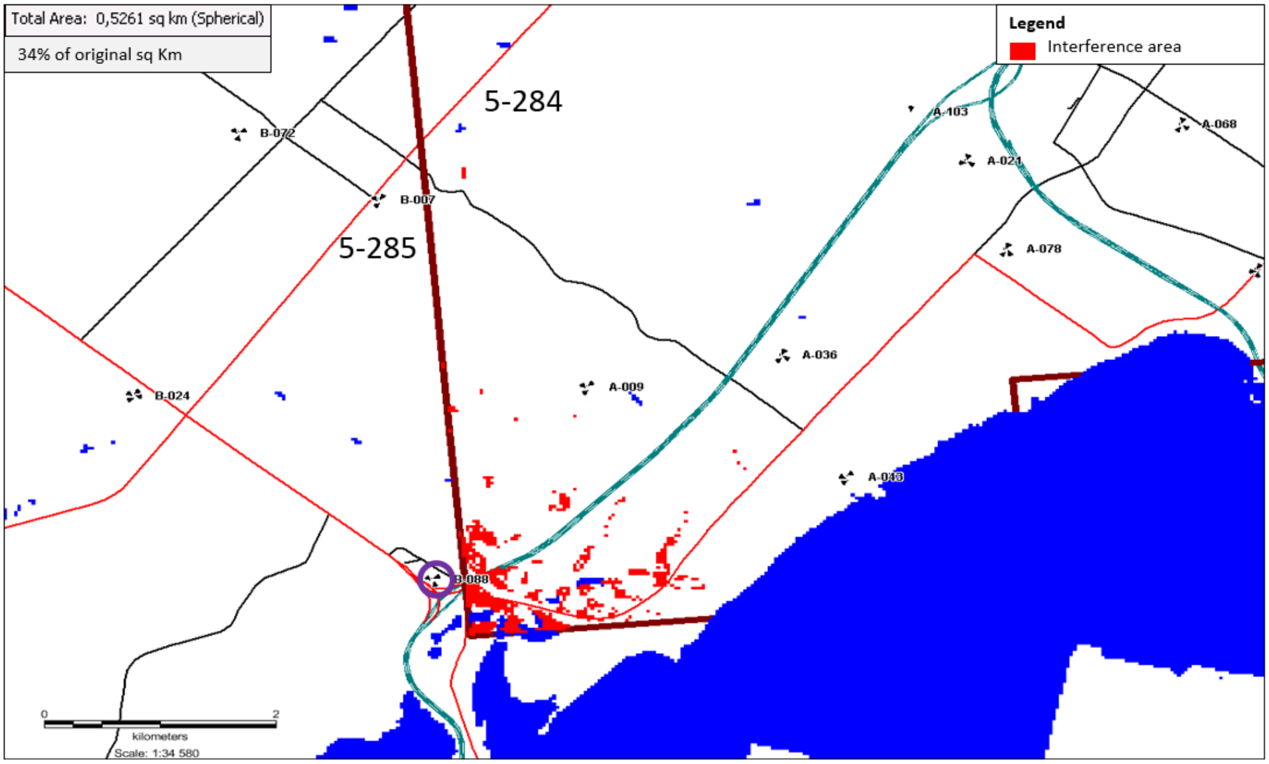


Fig. I. 13: Scenario 1 Typical B-088 Tilt, Height and Power Mitigation

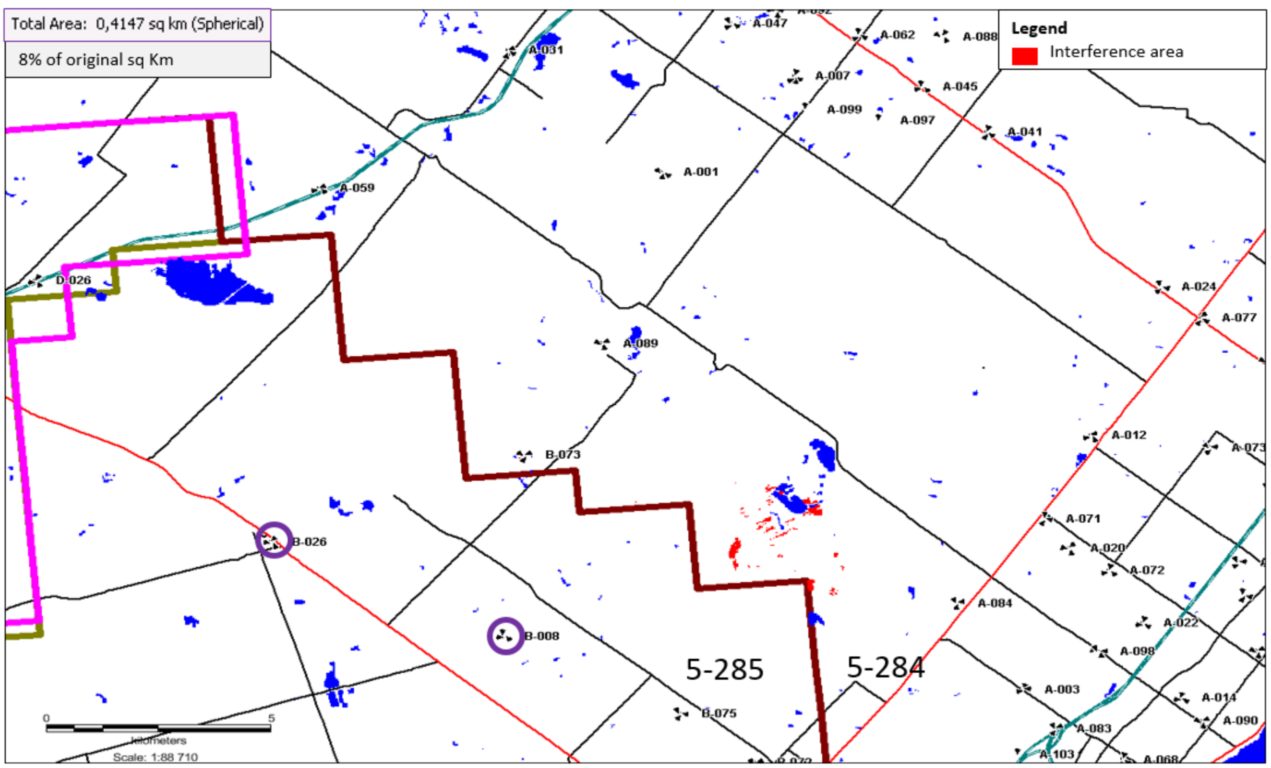


Fig. I. 14: Scenario 2 Typical B-008/B-026 Tilt, Height and Power Mitigation

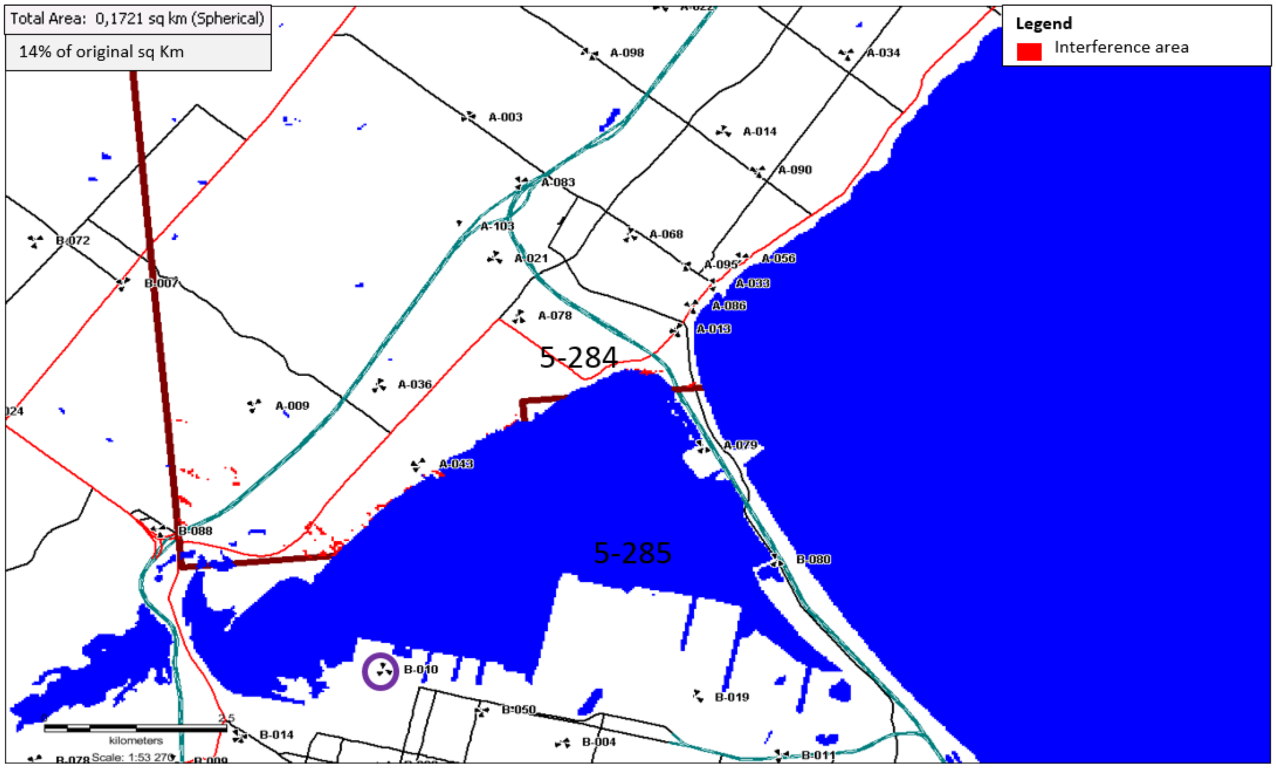


Fig. I. 15: Scenario 3 Typical B-010 Tilt, Height and Power Mitigation

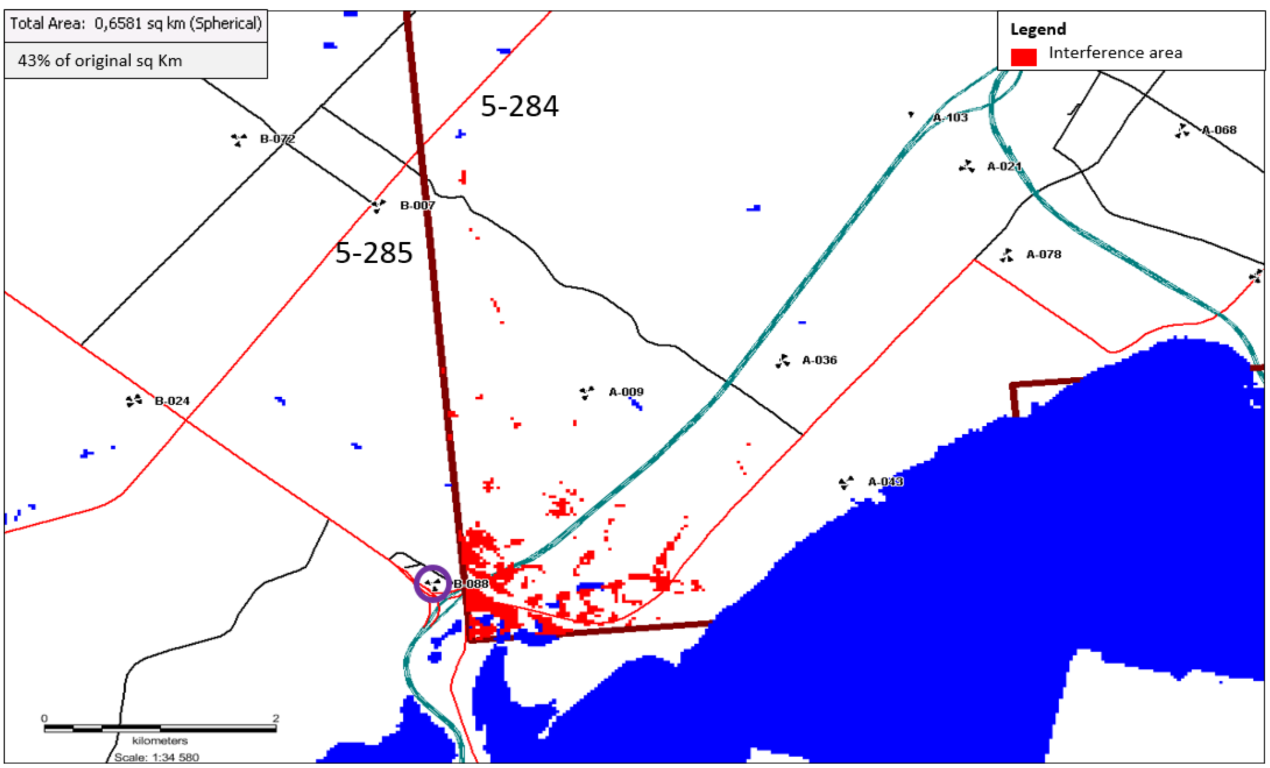


Fig. I. 16: Scenario 1 Typical B-088 Tilt and Height Mitigation

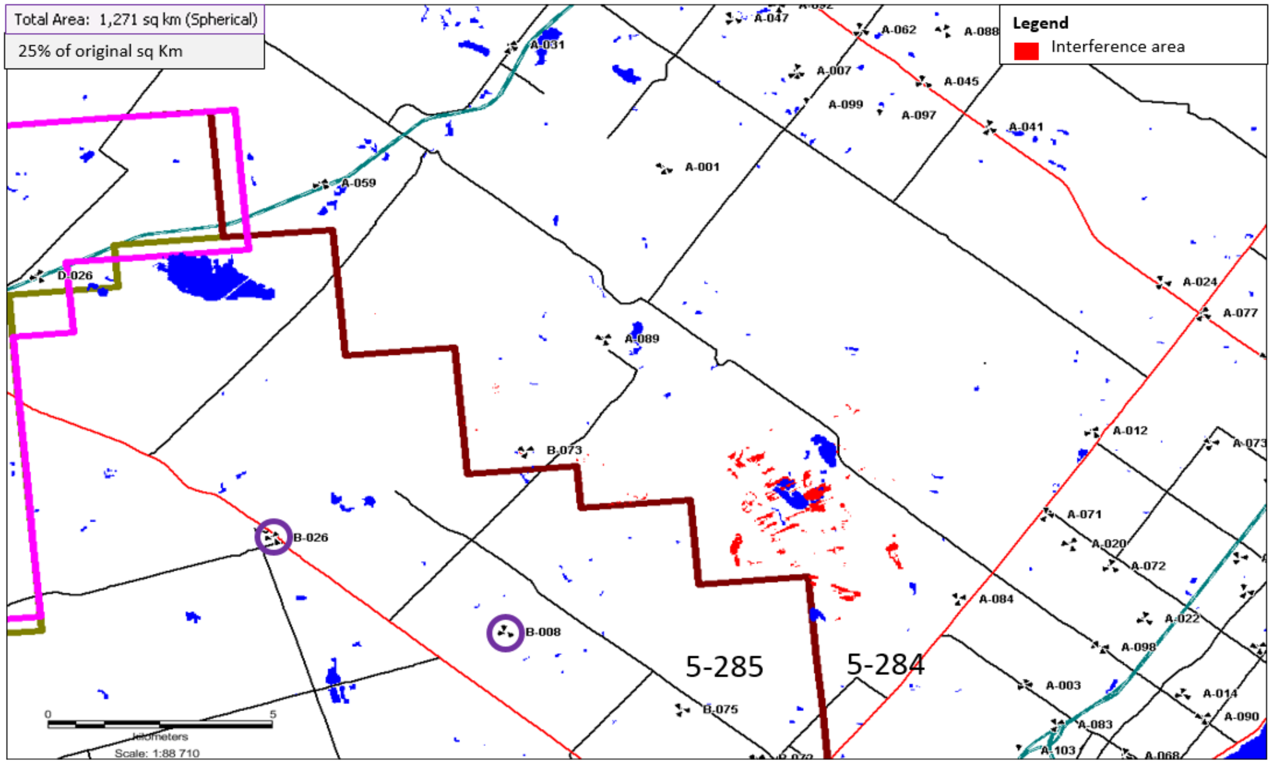


Fig. I. 17: Scenario 2 Typical B-008/B-026 Tilt and Height Mitigation

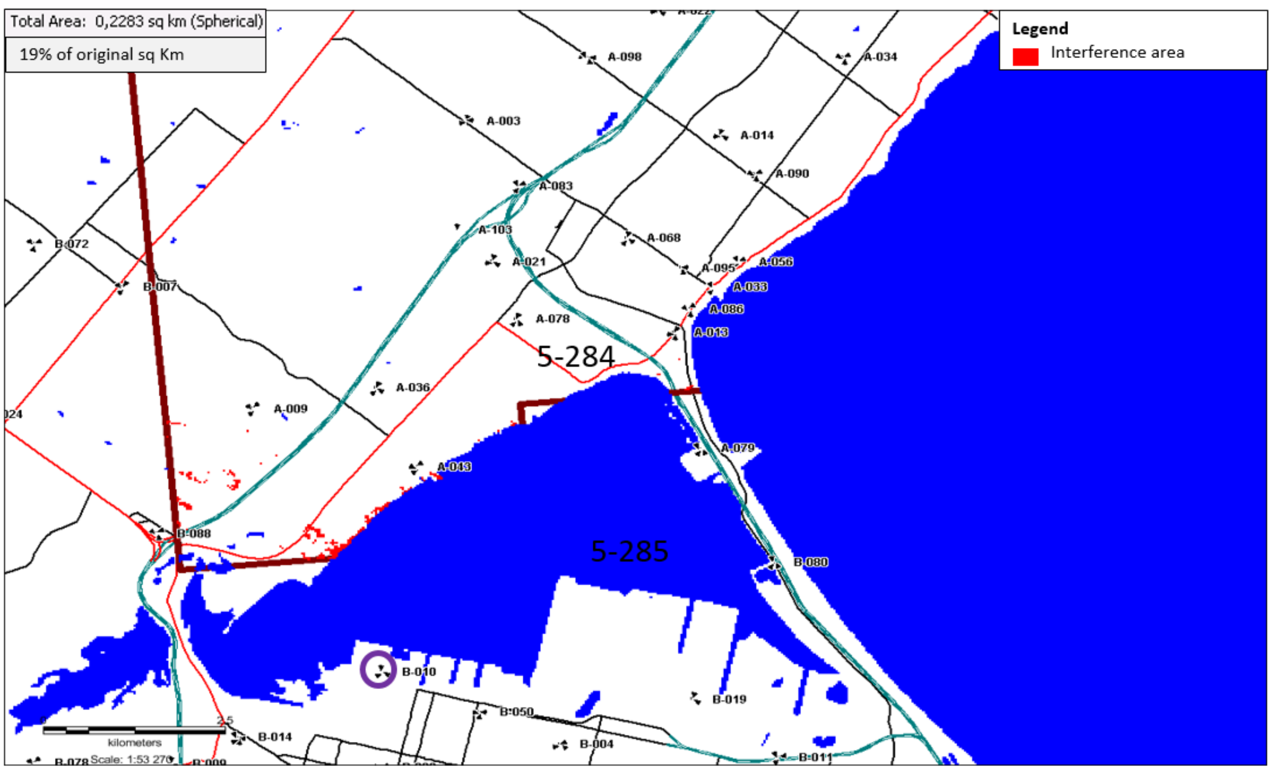


Fig. I. 18: Scenario 3 Typical B-010 Tilt and Height Mitigation