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Further Analysis of Impact of Unlicensed U-NII-5 Devices on RigNet 6 GHz Backhaul Network

v1.0

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1 SUMMARY

RigNet operates a microwave network in the 6 GHz band that provides the high-reliability backhaul network for mission-critical LTE and Wi-Max broadband wireless communications serving more than 300 offshore oil and gas production platforms in the Gulf of Mexico (Gulf). On October 23, 2018, the FCC issued an NPRM[1] that proposes to authorize the operation of unlicensed devices in the band as part of the Unlicensed National Information Infrastructure (U-NII). The NPRM defines the U-NII-5 band (5925-6425 MHz) which includes the frequencies used by the RigNet microwave backbone. RigNet's backhaul network and the associated LTE and Wi-Max systems enable the operators of production platforms in the Gulf to satisfy federal regulations issued by the Bureau of Safety and Environmental Enforcement (BSEE) that require Real Time Monitoring (RTM) of offshore production facilities at onshore locations.[2] Importantly, The backbone is also the link for wireless 9-1-1 service to an on-shore Public Safety Answering Point (PSAP).

The RigNet backbone network crosses the Gulf coastline at six locations and these locations are near extensive habitations that include residences, cities, and business facilities. This report analyzes the interference to RigNet microwave receivers at these locations that would be caused by unlicensed devices. The results of the analysis demonstrate that the deployment of indoor unlicensed devices in U-NII-5 in locations near these receivers would cause interference sufficient to raise the interference-to-noise ratio (I/N ratio) on the backhaul links that cross the coastline to the extremely high levels of 25.1 dB to 42.4 dB. The backhaul links are designed to achieve very low outage times in order to meet public safety and mission critical communications requirements. To satisfy these requirements the recommended limit for the I/N ratio is -12 dB,[3] and these degradations significantly exceed this limit by 37.1 dB to 54.4 dB. (25,000 to 275,000 times). These extremely high levels of interference render the links inoperable and sever the RTM service, mission critical, and 9-1-1 communications for oil and gas production platforms in the Gulf. The disruption would prevent on-shore responses to emergencies off-shore, and jeopardize the safety of personnel on the platforms in the Gulf. The use of outdoor unlicensed devices in U-NII-5 would cause even greater interference because the unlicensed transmissions would not be attenuated by the walls of buildings or habitation structures. The analysis has additional implications for potential unlicensed device use by the 50-150 persons resident or working on

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[1] *Unlicensed Use of the 6 GHz Band*, Notice of Proposed Rulemaking, ET Docket No. 18-295, October 23, 2018.

[2] See Bureau of Safety and Environmental Enforcement (BSEE), Well Control Rule, https://www.bsee.gov/guidance-and-regulations/regulations/regulatory-reform/bsee-well-control-rule-2019

[3] See ITU-R Recommendation S.1432, and also NPRM comments by Motorola Solutions.

platforms in the Gulf. Unlicensed use on and near the platforms could cause a disruption for wireless communications served by the point-to-point link at that platform including 9-1-1 calls. For these reasons, the NPRM should therefore not be adopted and unlicensed deployment in U-NII-5 should not be permitted, either indoors or outdoors, anywhere within a 35 mile radius of 6 GHz licensed link, either on-shore or off-shore.

2 RigNet 6 GHz Backbone Network

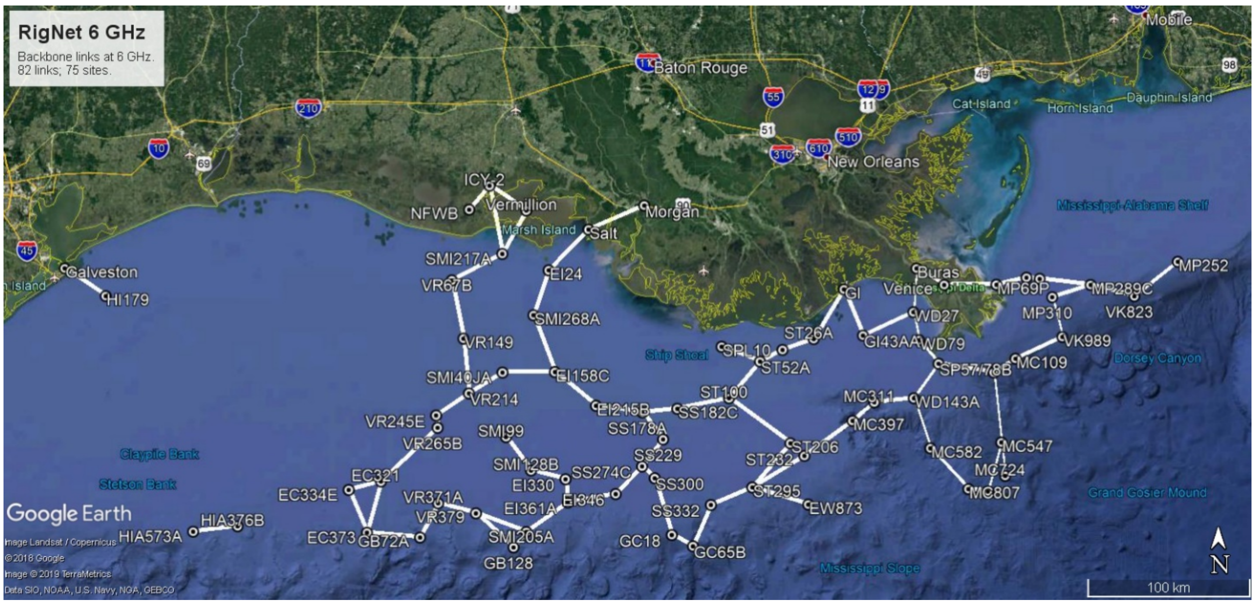

Figure 1 - RigNet 6 GHz Backbone Network

The RigNet point-to-point network in the Gulf consists of 91 sites, with 10 sites on-shore, and 81 sites off-shore. There are 75 sites that are directly connected to a 6 GHz backbone, while 6 additional sites are connected by other links, including a 6 GHz satellite link. Approximately 300 platforms surrounding the backbone are connected to the 6 GHz backbone. The 6 GHz links are shown as the white lines in Figure 1. Larger scale images of the western and eastern portions of the network are shown in Figures 2 and 3. The nodes in the network correspond to transmit and receive antenna sites. In the Gulf itself the nodes are on oil and gas platforms.

The RigNet network provides the essential backhaul network for wireless communication services to the platforms in the Gulf. This includes RTM, but also voice and data communications to personnel on the platforms, emergency 9-1-1 calls, and mission critical calls for service and assistance from on-shore facilities.

All the nodes in the 6 GHz network connect to on-shore locations through six locations: Galveston, ICY-2, Morgan City, Grand Isle, Buras, and Venice Chevron. One additional link is a satellite link to platforms connected to HIA573A. This link will be treated in

Section 3.7. The ICY-2 node connects to an office in Lafayette, Louisiana, by an optical fiber that is not shown in the figures. The coastline crossings of the 6 GHz backbone perform an essential function. If any of the six locations are rendered unusable by interference, communications from platforms to an on-shore facility would be severed for some portion of the 300 off-shore platforms, disrupting the RTM service, 9-1-1 service, emergency and mission critical communications. Even with contingencies to reroute backhaul traffic through different coastline crossings, not all data can be rerouted. Although each platform relies on local control for most emergencies, if local control is lost because of a catastrophic event on the platform, then remote action through the RTM service would be necessary. In extreme cases remote action is necessary to shut down the platform in response to the emergency.

Loss of the 6 GHz backbone link at the coastline therefore endangers life and property if there is a breakdown of a critical component on a platform in the Gulf such as on a Fire & Gas system, a faulty emergency shut down valve, or loss of automation control. Remote action could not be taken to correct the problem, nor could emergency services be provided if the communication system is rendered inoperable by interference.

3 Analysis of Coastline Crossing Sites

A closer view of the western coastline crossing sites at Galveston, ICY-2, and Morgan City is shown in Figure 2. ICY-2 is a site that is connected by a fiber optic link to Lafayette, Louisiana. The fiber link is not shown in the figures. A closer view of the eastern coastline crossing sites at Grand Isle, Buras, and Venice Chevron is shown in Figure 3. Detailed calculations of the interference caused by unlicensed devices in the vicinity of each of these coastline crossing link receivers are given in an Appendix.

Figure 2 - RigNet 6 GHz Backbone Western View

Figure 3 - RigNet 6 GHz Backbone Eastern View

3.1 *Galveston to High Island 179 Link*

The 6 GHz link from the Galveston site to High Island 179 (HI179) is shown in Figure 4. The link is 30.28 km long and the first Fresnel zone[4] is fully above the horizon, so it is a direct Line of Sight (LOS) link. Without interference and in normal operation the link exhibits a SNR margin of 26 dB for 4096QAM modulation, that is, the signal is 400x the minimum sensitivity level to provide communications. This level is needed to provide high availability in the presence of fading of the desired signal that occurs due to natural atmospheric disturbances of the long propagation path. With the further addition of spatial diversity for increased reliability, the calculated outage time of the link is a mere 103 sec in a month.[5]

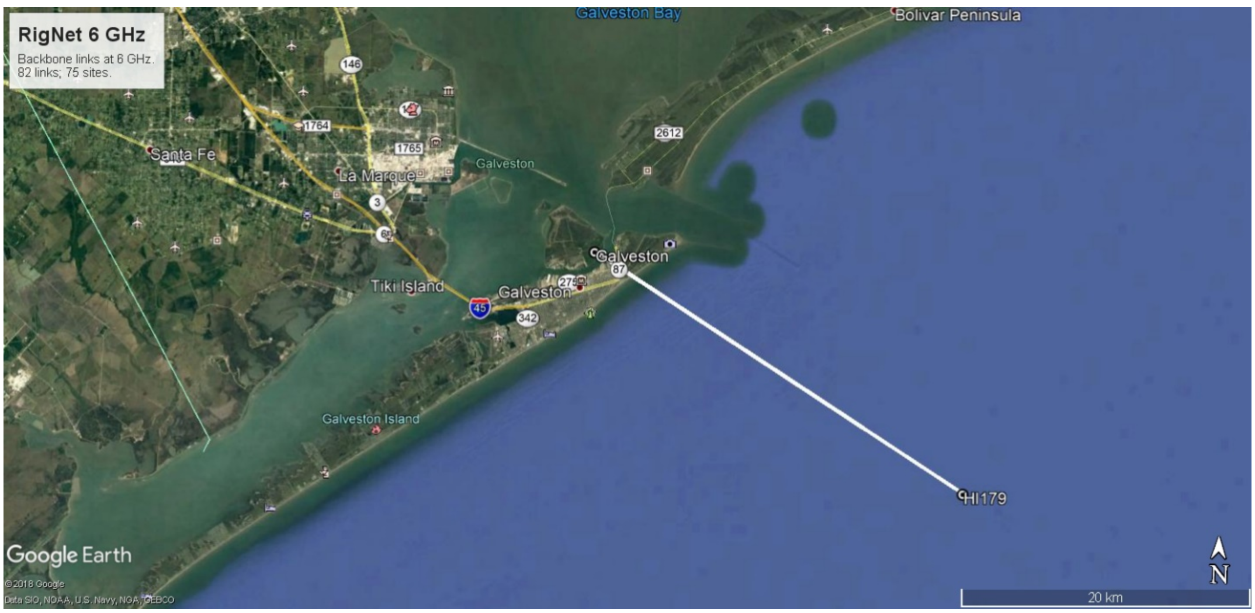

Figure 4 - Galveston to HI179 Link

A closer view of the portion of the link over the coastline at Galveston is shown in Figure 5.

The link in Figure 5 goes directly over a populated residential and commercial district. There is also a nearby hospital. All of these habitations are about 1.5 km along the LOS path to the Galveston site. Deployment of unlicensed devices in the U-NII-5 band could be indoors or outdoors along this line of sight of the link.

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[4] See Appendix in Section 6 for the discussion of the Fresnel zone and implications for Line-of-Site communications.

[5] Calculated according to Barnett and Vigants methods. See W.T. Barnett, *Multipath Propagation at 4, 6, and 11 GHz*, BSTJ, February 1972; and also A. Vigants, *Space-Diversity Engineering*, BSTJ, January 1975.

Figure 5 - Galveston Coastline

Transmissions from indoor devices would necessarily be attenuated by propagating through building walls, windows, doors, and other structural components. The ITU-R Rec. P.2109 defines probability distributions for these propagation losses, defined as Building Entry Loss (BEL).[6] The recommendation provides distributions for two kinds of buildings denoted as Traditional and Thermally Efficient. The Traditional type of buildings (exhibiting lesser attenuation) are used here to apply the BEL distributions to the coastline habitations. A Monte Carlo simulation of BEL for random distributions of devices in buildings obtains an average power level corresponding to an expectation for BEL: E[BEL] = 11.0 dB. This value can be used to estimate the received interference power at the Galveston site, or the more distant HI179 site, resulting from unlicensed transmitters in buildings in the path of the link crossing the Galveston coastline.

The analysis in Section 7.1 shows that the deployment of a small number of 6 GHz U-NII devices in the habitations along the LOS path would increase the interference (I/N) by 42.4 dB (more than 17,000 times) and render the link completely unusable. The deployment of outdoor devices would cause even greater degradation since there would not be any Building Entry Loss for the interference.

3.2 *Morgan City to Salt Point Link*

The 6 GHz link from the Morgan City site to the Salt Point site is shown in Figures 6 and 7. The Morgan City link to Salt Point passes directly over most of Morgan City and

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[6] ITU-R Recommendation P.2109, 6/2017, *Prediction of building entry loss*

parallel to highway 90. The link is 35.95 km long and the first Fresnel zone is fully above the horizon, so it is a direct Line Of Sight (LOS) link. The analysis in the Appendix in Section 7.2 shows that this link exhibits an SNR margin of 33 dB for 1024 QAM modulation, that is. the signal is 2000 times the sensitivity level. This level is needed to provide high availability in the presence of fading of the desired signal that occurs naturally due to nature of the long propagation path. With the use of spatial diversity for additional reliability, the link achieves a calculated outage time of a mere 60 sec in a month.[7]

Figure 6 - Morgan City and ICY-2 Links

[7] See footnote 5.

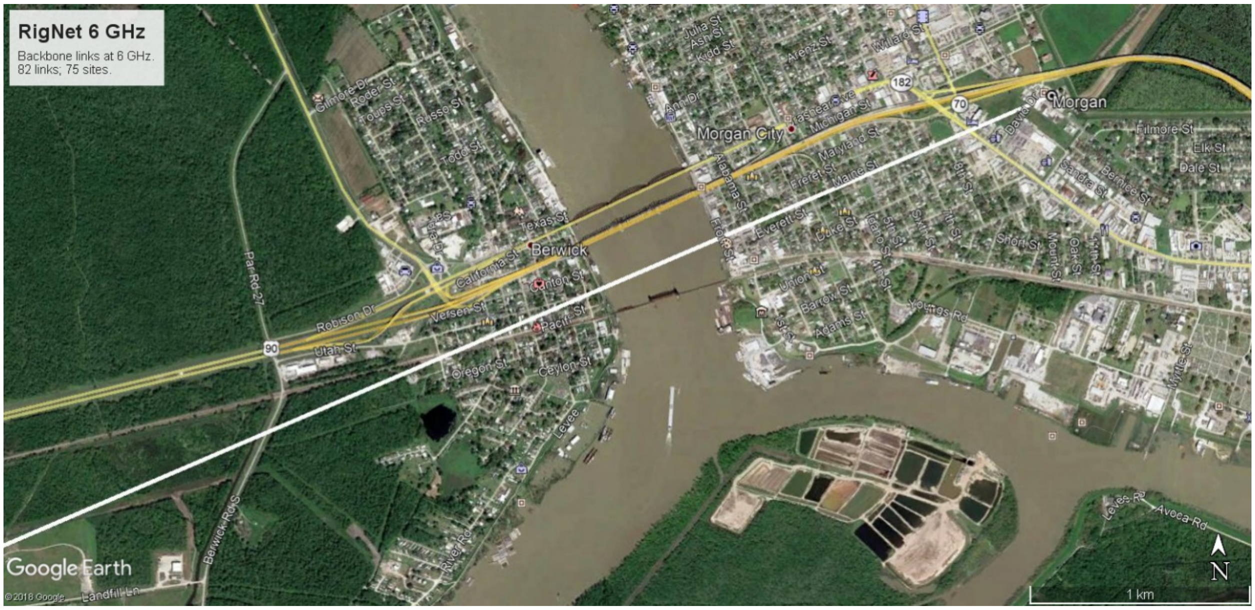


Figure 7 - Morgan City Link

The analysis in Section 7.2 shows that the deployment of small numbers of U-NII devices indoors in the habitations along the LOS path would increase the interference (I/N) by 35.3 dB (more than 3300 times) and render the link unusable. The deployment of outdoor devices would cause even greater interference since there would not be any Building Entry Loss for the interference.

3.3 *Grand Isle Links*

The site on Grand Isle (GI) has two links, one to ST26A and another to GI43AA. These are shown in Figures 8 and 9. The links are 34.45 km and 29.66 km long, respectively. The links pass directly over habitations along the coastline on Grand Isle, along highway 1, and within 1 km of the GI site. Both links are LOS with the first Fresnel zone above the horizon. The analysis in Section 7.3 shows that the GI43AA link obtains a margin of 30.8 dB with 1024QAM modulation, that is, the signal is 1200 times the sensitivity level to provide communications. The ST26A link obtains a margin of 29.6 dB with 1024QAM, or 900 times the sensitivity level. This level is needed to provide high availability in the presence of fading of the desired signal that occurs naturally due to nature of the long propagation path. With the addition of spatial diversity for additional reliability, GI43AA achieves a calculated outage time under 12 seconds per month, while ST26A achieves 27 seconds per month.[8]

[8] Ibid

Figure 8 - Grand Isle, Buras, and Venice Chevron Links

The analysis in Section 7.3 further shows that the Deployment of small numbers of U-NII devices indoors in the habitations along the LOS path would increase the interference (I/N) of the GI43AA link by 39.3 dB (more than 8000 times) and render the link unusable. Interference for ST26A would increase interference (I/N) by 37.0 dB (more than 5000 times), and that link would also be unusable. The deployment of outdoor devices would cause even greater interference since there would not be any Building Entry Loss for the interference.

Figure 9 - Grand Isle Links

3.4 *Buras Links*

Figure 10 - Buras Links

The site at Buras has two links, one to WD27 and another to Venice Chevron. These are shown in Figures 8 and 10. The links are 26.05 km and 19.30 km long, respectively. The links pass directly over habitations along the Mississippi River bank, along highway 23, and within 1 km of the Buras site. Both links are LOS with the first Fresnel zone above

the horizon. The analysis in Section 7.4 shows that the Venice link obtains 24 dB of margin with 4096QAM modulation, that is, the signal is more than 250x the sensitivity level to provide communications. This level is needed to provide high availability in the presence of fading of the desired signal that occurs naturally due to nature of the long propagation path. With the addition of spatial diversity for increased reliability, the calculated outage time is 96 seconds per month.[9]

The analysis in Section 7.4 further shows that the deployment of small numbers of U-NII devices indoors in the habitations along the LOS path would increase the interference (I/N) of the Venice link by 32.2 dB (more than 1600 times) and render the link unusable. The deployment of outdoor devices would cause even greater interference since there would not be any Building Entry Loss for the interference.

3.5 *Venice Chevron Links*

The site at Venice Chevron has two links, one to Buras and another to MP69P. These are shown in Figures 8 and 11. The links are 19.30 km and 31.38 km long, respectively. The links pass directly over habitations along the Mississippi River bank, along highway 23, and within 1 km of the Venice site. The link to Buras has been previously considered. The analysis in Section 7.5 shows that the link to MP69P obtains 27 dB of margin for 1024 QAM modulation, that is, the signal is 500 times the sensitivity level to provide communications. This level is needed to provide high availability in the presence of fading of the desired signal that occurs naturally due to nature of the long propagation path. With spatial diversity for increased reliability, the calculated outage time is 108 sec per month.[10]

[9] Ibid
[10] Ibid

Figure 11 - Venice Chevron Links

The analysis in Section 7.5 further shows that the deployment of small numbers of U-NII devices indoors in the habitations along the LOS path would increase the interference (I/N) of the MP69P link by 38.5 dB (7000 times) and render the link unusable. The deployment of outdoor devices would cause even greater interference since there would not be any Building Entry Loss for the interference.

3.6 *ICY-2 Links*

The ICY-2 site has three links to: NFWB, SMI217A, and Vermillion. These are shown in Figures 6 and 12. The links are 18.60 km, 41.11 km, and 26.39 km long respectively. The ICY-2 site has a terrestrial optical fiber link to Lafayette, Louisiana. The optical fiber link is not a 6 GHz link so it is not shown in the figures. Figure 12 shows the links passing over habitations along highway 333 within 3 km of the site.

The links to NFWB and Vermillion (left and right links in Figure 12) are high enough that the first Fresnel zone fully clears the horizon. Both of these links are LOS. The analysis in Section 7.6 shows that the links obtain 28 dB and 26 dB of margin with 4096 QAM modulation, that is, the signal levels are approximately 400 times the sensitivity level to provide communications. This level is needed to provide high availability in the presence of fading of the desired signal that occurs naturally due to nature of the long

propagation path. With space diversity for additional reliability, the calculated outages or these links are 8 seconds and 119 seconds respectively per month.[11]

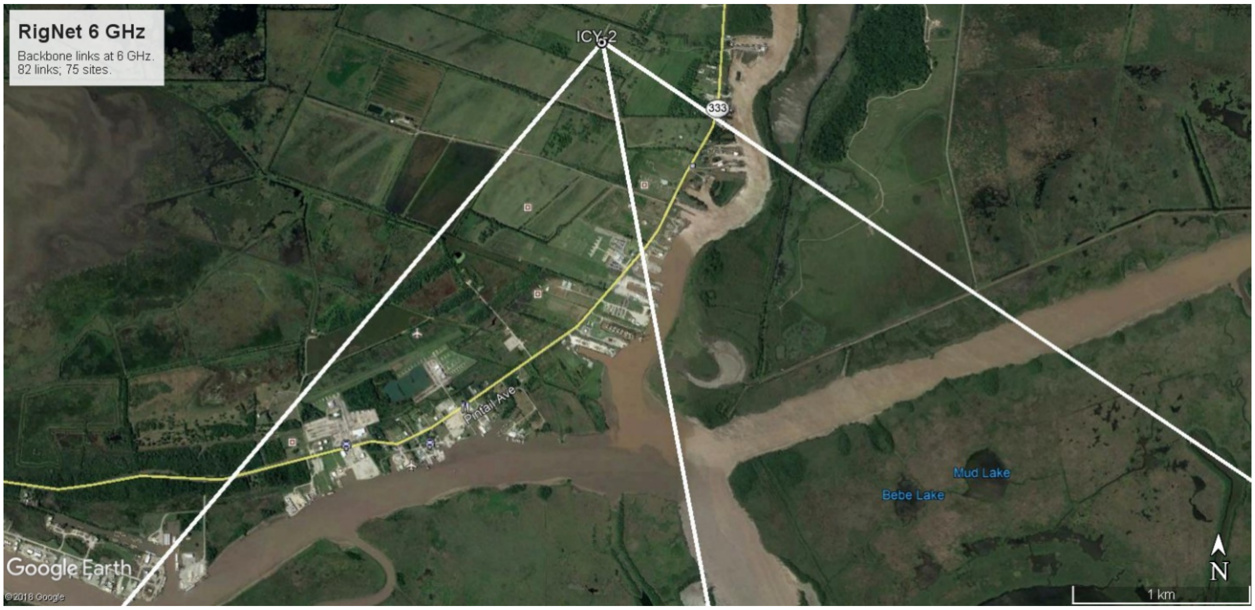


Figure 12 - ICY-2 Links

The middle link in Figure 12 to SMI217A is longer and the first Fresnel zone is slightly shadowed by the horizon so that it is 90% clear. This attenuation is insignificant for a LOS link. The analysis in Section 7.6 shows that the link obtains 32 dB of margin for 512 QAM modulation, that is, the signal level is 1500 times the sensitivity for communications. This level is needed to provide high availability in the presence of fading of the desired signal that occurs naturally due to nature of the long propagation path. With space diversity for additional reliability, the calculated outage is 58 seconds per month.[12]

The analysis in Section 7.6 further shows that the deployment of small numbers of U-NII devices indoors in the habitations along the LOS paths would increase the interference (I/N) of the three links by 25 dB, 36 dB, and 38 dB, respectively, (more than 300, 4000, and 6000 times, respectively), rendering the links inoperable. The deployment of outdoor devices would cause even greater interference since there would not be any Building Entry Loss for the interference.

[11] Ibid

[12] Ibid

3.7 *HIA573A Satellite Link*

Some High Island sites connect to on-shore facilities via a communications service through an Intelsat geo-synchronous satellite. The satellite is Galaxy 19/263 and the frequency is 6064.45 MHz, within the U-NII-5 band. Interference from U-NII devices has been detected previously in Globalstar satellites with a reported noise rise at the satellite of 2 dB due to interference.[13] This interference is the aggregate interference from all of the U-NII devices sharing the band licensed to Globalstar. It is also relevant that the observed interference occurs despite any restrictions on antenna patterns at elevation angles above 30°, as provided in the current FCC rules for the U-NII-1 band. The proposed rules in the NPRM for U-NII-5 are the same as those for U-NII-1, and similar levels of interference can be anticipated. Intelsat has commented on the NPRM in opposition to the possibility of aggregate interference to satellite services by unlicensed devices. The anticipated interference can compromise or disturb communications to the RigNet network at the satellite receiver at HIA573A, and cause inoperable communications.

4 SUMMARY OF THE INTERFERENCE ANALYSIS RESULTS

The results of the interference analysis for the six RigNet point-to-point receiver sites with communication paths crossing the Gulf coastline are shown in Figures 13 and 14 below. Figure 13 is a plot of the performance of the point-to-point links in normal operation without any interference. The Margin in the SNR, that is, the signal level in excess of the sensitivity level necessary to provide communications, and the corresponding Outage times are plotted. The large margins are necessary to achieve the desired low outage times in the presence of the propagation impairments that normally and naturally occur on point-to-point links. In general, the Outage time decreases as a strong function of the Margin (higher Margins yield lower Outage times).

[13] See *Comments of Globalstar Inc.,* IB Docket No. 16-185, October 17, 2018

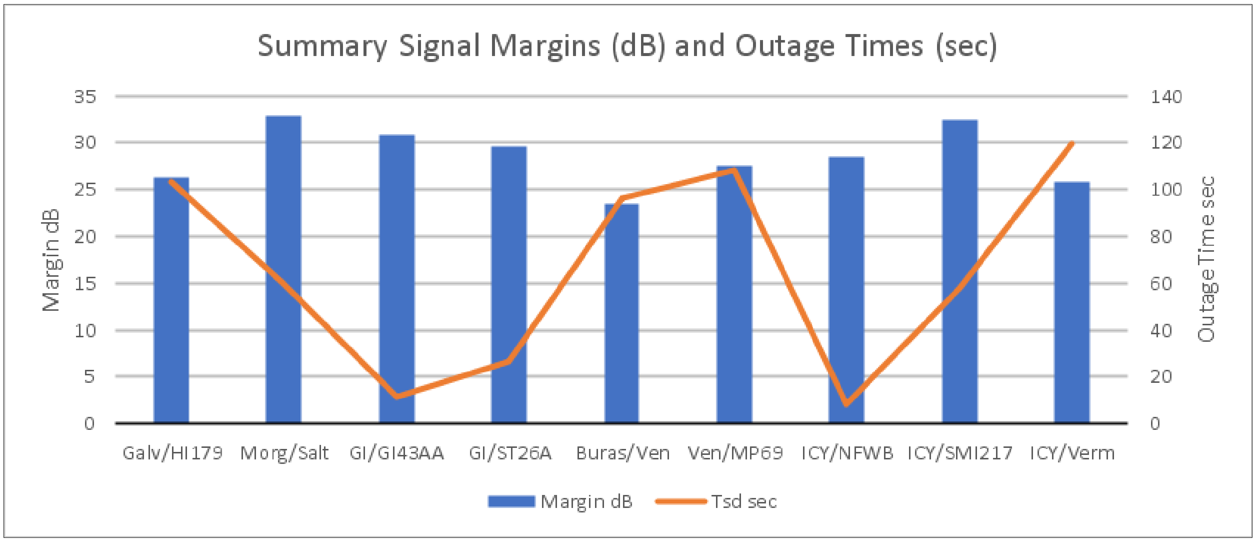


Figure 13 - SNR Margins and Outage Times

The interference I/N ratios and the amount that the I/N exceeds the recommended limit of -12 dB is plotted in Figure 14 below. For all the links, the interference will exceed the -12 dB recommendations for I/N by 37 to 54 dB, (5000 to more than 250,000 times) and in every case it will render the coastline crossing link inoperable.

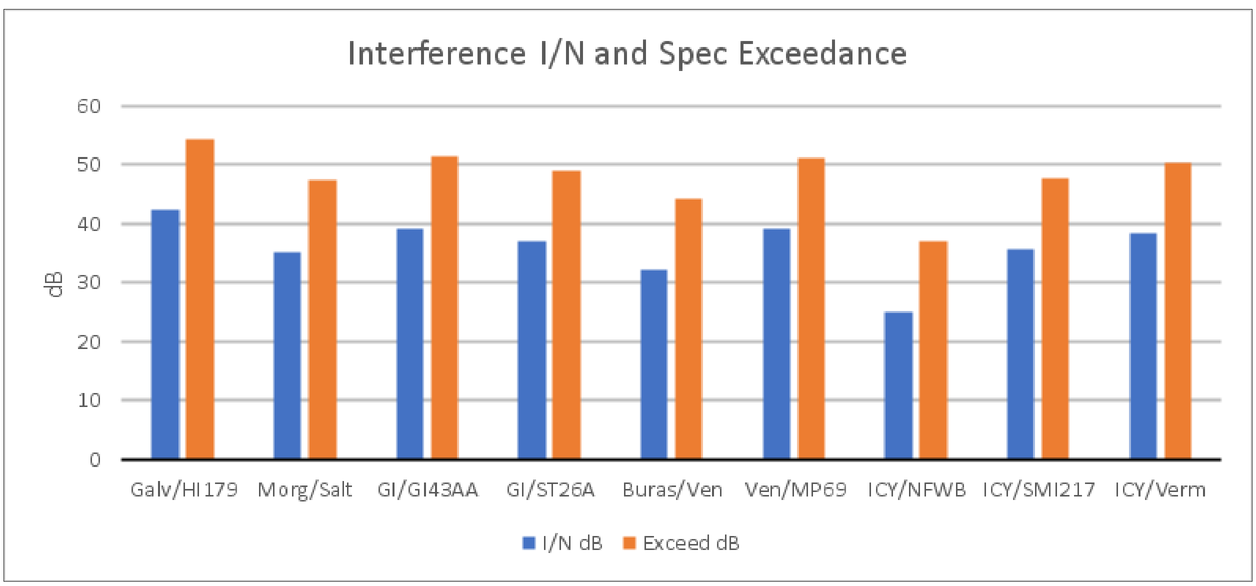


Figure 14 - Coastline Crossing Links interference (I/N) and Exceedance of Recommended Limit

While these results apply to links crossing habitations on-shore, they also apply in general to the off-shore platforms if U-NII devices are deployed there, near the victim

receivers. This case is treated in the reply comments by RigNet to the NPRM.[14] Interference from U-NII devices deployed on platforms or on marine ships with 35 miles of the platforms will generate sufficient interference to disrupt links in the 6 GHz backbone network.

5 Conclusion

RigNet operates a microwave backbone network in the 6 GHz band designated by the FCC NPRM[15] as U-NII-5 (5925-6425 MHz). The RigNet network provides essential real-time monitoring, emergency, and mission critical communication services for more than 300 offshore oil and gas production platforms in the Gulf of Mexico (Gulf). The platform operators are required to meet federal rules defined by the BSEE that require Real Time Monitoring (RTM) at onshore locations.[16] The network also provides necessary links to onshore PSAPs for 9-1-1 service, and other mission critical communications. The RigNet backbone network crosses the Gulf coastline in six locations and these locations are nearby habitations such as residences, cities, and businesses. Unlicensed operation of small numbers of indoor devices in U-NII-5 in the vicinity of these six locations would cause extremely high levels of interference, levels sufficient to raise the interference (I/N) ratio by 25 dB and 42 dB (300 to 15,000 times). In order to achieve the high levels of availability and low outage levels required, interference levels into point-to-point links are recommended to meet an interference (I/N) specification of -12 dB. The expected interference caused by indoor unlicensed devices in the vicinity of these point-to-point receivers would cause the interference to exceed the specification by 37 dB to 54 dB (5000 to 250,000 times). These interference results are summarized in Figure 14. These interference levels would render the point-to-point backbone links inoperable and sever the RTM service for oil and gas production platforms in the Gulf. The disruption would also render 9-1-1 and other emergency responses inoperable. The analysis has additional implications for potential unlicensed device use by the 50-150 persons resident or working on platforms in the Gulf. Unlicensed use on and near the platforms could also cause a disruption for wireless communications served by the point-to-point link at that platform including 9-1-1 calls. For these reasons, the NPRM should therefore not be adopted and unlicensed deployment in U-NII-5 should not be permitted, either

[14] See Reply Comments of RigNet SatCom Inc, ET Docket No. 18-295

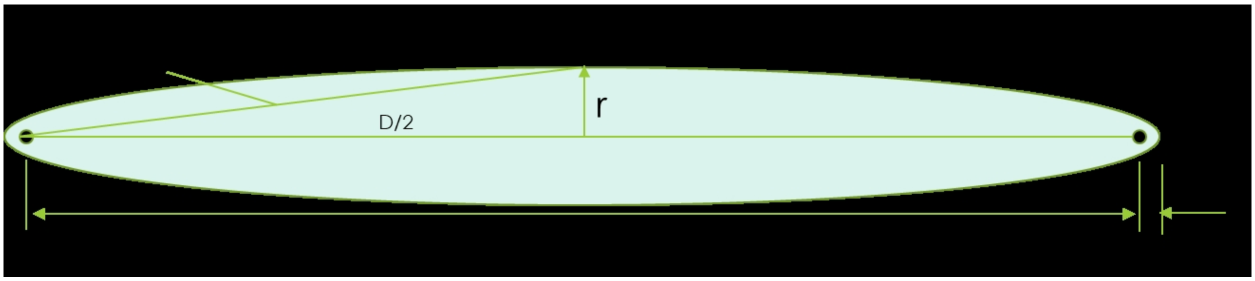
[15] *Unlicensed Use of the 6 GHz Band*, Notice of Proposed Rulemaking, ET Docket No. 18-295, October 23, 2018.

[16] See Bureau of Safety and Environmental Enforcement (BSEE), Well Control Rule, https://www.bsee.gov/guidance-and-regulations/regulations/regulatory-reform/bsee-well-control-rule-2019

indoors, outdoors, or in the Gulf, anywhere within a 35-mile radius of any 6 GHz licensed link.

6 APPENDIX: LINE OF SIGHT FIRST FRESNEL ZONE

The first Fresnel zone (F1) is a long ellipsoid that stretches between the two antennas in a microwave link. The F1 zone is constructed so that the difference between the direct path and an indirect path that touches a single point on the border of the Fresnel zone is half the wavelength.



Some simple geometry can determine that the radius of F1 in the middle is:

$$r = \sqrt{\left(\frac{D}{2} + \frac{\lambda}{4}\right)^2 - (D/2)^2} \approx \frac{1}{2}\sqrt{\lambda D}$$

For example, at 6.2 GHz, $\lambda = 4.83$ cm, and D = 30 km, we obtain r = 19 meters.

In a cross-section, the F1 zone is a circle. If the antennas at each end of the link are high enough, it is possible for F1 to completely clear the horizon, and the link is a Line of Sight (LOS) link. If the horizon cuts off some portion of the F1 cross-section, then LOS propagation will degrade.

7 APPENDIX: INTERFERENCE CALCULATIONS

The link budgets for each of the links in this report are typically represented by the link budget for the Galveston – HI179 link. After the Galveston link is explained, the other links are also listed in this appendix.

7.1 *Galveston Link*

This table shows the calculations for the Galveston – HI179 link.

Desired	HI179	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	40.19	dBi
D	30.28	km
Fc	6152.75	MHz
Lambda	0.0487	m
L.path	137.85	dB
G.rx	41.90	dBi
RX	-39.07	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	70.76	dB
QAM	4096	
Sensitivity	44.44	dB
Margin	26.31	dB
sigma	5.5	dB
p.lognorm	0.999999	
Tw	2524.73	sec
Separation	50	ft
	15.24	m
Io	24.50	
Tsd	103.06	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	100	
Activity	0.1	
BW	20	MHz
	11.43	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	1.5	km
Lambda	0.0487	m
L.path	111.75	dB
G.rx	41.90	dBi

RX.I	-67.42	dBm/MHz
I/N	42.40	dB
I+N	-67.42	dBm/MHz
SINR.rx	28.35	dB

Sensitivity	44.44	dB
Margin	-16.09	dB
sigma	5.5	dB
p.lognorm	0.00172054	

The left columns show the link budget for the* Desired *transmitter signal. It shows a margin of 26.31 dB for 4096 QAM modulation. The margin is calculated as the difference between the SNR.rx and the Sensitivity value for the given modulation. The "p.lognorm" line item shows a probability for ordinary log-normal fading for the given margin. This

is given for relative comparisons only, since it has nothing to do with the outage calculations.

The calculations for outage times follow the methods of Barnett and Vigants.[17] *The Tw line shows the calculated cumulative outage time for the worst month, without spatial diversity. Spatial diversity results in an improvement factor, Io, which is 24.50 in this link. The outage time for the worst month with spatial diversity is then the Tsd value of the last line, 103.06 seconds on this link.*

The right columns in the table show the Interference *signal effects. The interference signals are considered to be indoors, with standard 1 watt transmitters, and several factors for the distribution of the power in the spectrum. The P[ch] factor is derived from a count of 36 channels of 20 MHz each in the U-NII-1, U-NII-3, and U-NII-5 bands. U-NII devices are assumed to be multi-band devices since most devices for unlicensed sale today are advertised as multi-band. Each device will select one of the possible channels for operation, and so there is a 1/36 chance that it will overlap the channel of the victim receiver. The factor of N is the number of U-NII devices in the LOS path. The Activity factor represents the duty cycle for the U-NII device transmitter. The BW factor is the bandwidth of the U-NII transmitter, and the last line in the first block is then the power spectral density of the interference including all the factors listed above.*

The second block in the Interference column shows the propagation and path loss parameters. The E[BEL] parameter represents average Building Entry Loss (BEL) according to ITU-R Rec. P.2109, for traditional buildings. This calculation uses a Monte Carlo average of the BEL.

The third block in the interference column shows the received interference power spectral density (RX.I). This is followed by an I/N calculation, I+N calculation, and a Signal/Interference + Noise Ratio (SINR.rx). The value of N in these calculations is from the receiver block in the Desired column. This particular link is shown to have an I/N ratio of 42.40 dB. The recommended limit is -12 dB, so this exceeds the limit by 54.40 dB.

The fourth block in the interference column calculates the margin, with the interference. The interference is shown to reduce the margin of the link to -16.09 dB. Barnett and Vigants require a margin of 20 dB for a valid outage calculation. According to Barnett and Vigants, the outage time becomes too large to be calculated. In effect, margins below 20 dB have unacceptable performance for a point-to-point link. In this case the minimum valid margin requirement is missed by 36.09 dB. The p.lognorm probability is also calculated for comparison purposes.

[17] See footnote 5.

7.2 *Morgan City Link*

This table shows the calculations for the Morgan City – Salt Point link.

Desired	Salt Point	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	42.05	dBi
D	35.95	km
Fc	6019.325	MHz
Lambda	0.0498	m
L.path	139.15	dB
G.rx	42.05	dBi
RX	-38.36	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	71.47	dB
QAM	1024	
Sensitivity	38.50	dB
Margin	32.97	dB
sigma	5.5	dB
p.lognorm	1	
Tw	894.19	sec
Separation	20	ft
	6.10	m
Io	14.93	
Tsd	59.88	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	200	
Activity	0.1	
BW	20	MHz
	14.44	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	5	km
Lambda	0.0498	m
L.path	122.02	dB
G.rx	42.05	dBi

RX.I	-74.53	dBm/MHz
I/N	35.30	dB
I+N	-74.53	dBm/MHz
SINR.rx	36.17	dB

Sensitivity	38.50	dB
Margin	-2.33	dB
sigma	5.5	dB
p.lognorm	0.335716	

7.3 *Grand Isle Links*

These tables show the Grand Isle links to GI43AA and ST26A respectively.

Desired	GI43AA	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	40.19	dBi
D	29.66	km
Fc	6063.8	MHz
Lambda	0.0494	m
L.path	137.55	dB
G.rx	40.19	dBi
RX	-40.48	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	69.35	dB
QAM	1024	
Sensitivity	38.50	dB
Margin	30.85	dB
sigma	5.5	dB
p.lognorm	0.99999999	
Tw	823.13	sec
Separation	50	ft
	15.24	m
Io	70.05	
Tsd	11.75	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	5	
Activity	0.1	
BW	20	MHz
	-1.58	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	0.4	km
Lambda	0.0494	m
L.path	100.14	dB
G.rx	40.19	dBi

RX.I	-70.54	dBm/MHz
I/N	39.29	dB
I+N	-70.54	dBm/MHz
SINR.rx	30.06	dB

Sensitivity	38.50	dB
Margin	-8.44	dB
sigma	5.5	dB
p.lognorm	0.062456	

Desired	ST26A	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	40.25	dBi
D	34.45	km
Fc	6137.925	MHz
Lambda	0.0488	m
L.path	138.95	dB
G.rx	40.25	dBi
RX	-41.76	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	68.07	dB
QAM	1024	
Sensitivity	38.50	dB
Margin	29.57	dB
sigma	5.5	dB
p.lognorm	0.99999996	
Tw	1755.36	sec
Separation	60	ft
	18.29	m
Io	65.38	
Tsd	26.85	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	12	
Activity	0.1	
BW	20	MHz
	2.22	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	0.8	km
Lambda	0.0488	m
L.path	106.27	dB
G.rx	40.25	dBi

RX.I	-72.80	dBm/MHz
I/N	37.03	dB
I+N	-72.80	dBm/MHz
SINR.rx	31.04	dB

Sensitivity	38.50	dB
Margin	-7.46	dB
sigma	5.5	dB
p.lognorm	0.087441	

7.4 *Buras Links*

This tables shows the Buras – Venice link and Buras – WD27 link.

Desired	Venice	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	37.65	dBi
D	19.30	km
Fc	6093.45	MHz
Lambda	0.0492	m
L.path	133.85	dB
G.rx	37.65	dBi
RX	-41.86	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	67.96	dB
QAM	4096	
Sensitivity	44.44	dB
Margin	23.52	dB
sigma	5.5	dB
p.lognorm	0.99999052	
Tw	1231.22	sec
Separation	40	ft
	12.19	m
Io	12.81	
Tsd	96.13	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	100	
Activity	0.1	
BW	20	MHz
	11.43	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	3	km
Lambda	0.0492	m
L.path	117.69	dB
G.rx	37.65	dBi

RX.I	-77.61	dBm/MHz
I/N	32.22	dB
I+N	-77.61	dBm/MHz
SINR.rx	35.74	dB

Sensitivity	44.44	dB
Margin	-8.70	dB
sigma	5.5	dB
p.lognorm	0.056888	

Desired	WD27	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	40.25	dBi
D	26.05	km
Fc	6063.8	MHz
Lambda	0.0494	m
L.path	136.42	dB
G.rx	37.65	dBi
RX	-41.83	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	68.00	dB
QAM	2048	
Sensitivity	41.47	dB
Margin	26.53	dB
sigma	5.5	dB
p.lognorm	0.999999	
Tw	1509.83	sec
Separation	40	ft
	12.19	m
Io	18.86	
Tsd	80.07	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	20	
Activity	0.1	
BW	20	MHz
	4.44	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	0.5	km
Lambda	0.0494	m
L.path	102.08	dB
G.rx	37.65	dBi

RX.I	-68.99	dBm/MHz
I/N	40.83	dB
I+N	-68.99	dBm/MHz
SINR.rx	27.16	dB

Sensitivity	41.47	dB
Margin	-14.31	dB
sigma	5.5	dB
p.lognorm	0.004646	

7.5 *Venice Chevron Links*

This table shows the Venice Chevron – MP69P link.

Desired	MP69P	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	37.65	dBi
D	31.38	km
Fc	6345.49	MHz
Lambda	0.0472	m
L.path	138.43	dB
G.rx	40.25	dBi
RX	-43.84	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	65.99	dB
QAM	1024	
Sensitivity	38.50	dB
Margin	27.49	dB
sigma	5.5	dB
p.lognorm	0.99999971	
Tw	2213.24	sec
Separation	40	ft
	12.19	m
Io	20.44	
Tsd	108.30	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	2	
Activity	0.1	
BW	20	MHz
	-5.56	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	0.25	km
Lambda	0.0472	m
L.path	96.46	dB
G.rx	40.25	dBi

RX.I	-70.77	dBm/MHz
I/N	39.06	dB
I+N	-70.77	dBm/MHz
SINR.rx	26.93	dB

Sensitivity	38.50	dB
Margin	-11.57	dB
sigma	5.5	dB
p.lognorm	0.017687	

7.6 *ICY-2 Links*

These tables show the links to NFWB, SMI217A, and Vermillion respectively.

Desired	NFWB	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	40.19	dBi
D	18.60	km
Fc	6404.79	MHz
Lambda	0.0468	m
L.path	133.97	dB
G.rx	40.19	dBi
RX	-36.90	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	72.93	dB
QAM	4096	
Sensitivity	44.44	dB
Margin	28.49	dB
sigma	5.5	dB
p.lognorm	0.99999989	
Tw	369.79	sec
Separation	40	ft
	12.19	m
Io	43.79	
Tsd	8.44	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	12	
Activity	0.1	
BW	20	MHz
	2.22	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	3	km
Lambda	0.0468	m
L.path	118.12	dB
G.rx	40.19	dBi
RX.I	-84.71	dBm/MHz
I/N	25.12	dB
I+N	-84.70	dBm/MHz
SINR.rx	47.80	dB
Sensitivity	44.44	dB
Margin	3.36	dB
sigma	5.5	dB
p.lognorm	0.729172	

Desired	SMI217A	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	41.05	dBi
D	41.11	km
Fc	6256.4	MHz
Lambda	0.0479	m
L.path	140.65	dB
G.rx	41.05	dBi
RX	-41.86	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	67.96	dB
QAM	512	
Sensitivity	35.52	dB
Margin	32.45	dB
sigma	5.5	dB
p.lognorm	1	
Tw	1565.66	sec
Separation	30	ft
	9.14	m
Io	27.11	
Tsd	57.74	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	12	
Activity	0.1	
BW	20	MHz
	2.22	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	1	km
Lambda	0.0479	m
L.path	108.37	dB
G.rx	41.05	dBi

RX.I	-74.11	dBm/MHz
I/N	35.72	dB
I+N	-74.10	dBm/MHz
SINR.rx	32.24	dB

Sensitivity	35.52	dB
Margin	-3.27	dB
sigma	5.5	dB
p.lognorm	0.275780	

Desired	Vermillion	
TX.power	1.4	W
	31.46	dBm
BW	30	MHz
	16.69	dBm/MHz
G.tx	40.35	dBi
D	26.39	km
Fc	6404.79	MHz
Lambda	0.0468	m
L.path	137.01	dB
G.rx	40.35	dBi
RX	-39.62	dBm/MHz
k	1.38E-23	J/K
T	300	K
B	1.00E+06	Hz
NF	4	dB
N=kTBF	-109.83	dBm/MHz
SNR.rx	70.21	dB
QAM	4096	
Sensitivity	44.44	dB
Margin	25.77	dB
sigma	5.5	dB
p.lognorm	0.9999986	
Tw	1971.48	sec
Separation	40	ft
	12.19	m
Io	16.52	
Tsd	119.31	sec

Interference		
TX.power	1	W
P[ch]	0.0278	=1/36
N	10	
Activity	0.1	
BW	20	MHz
	1.43	dBm/MHz
G.tx	2	dBi
E[BEL]	11	dB
D	0.6	km
Lambda	0.0468	m
L.path	104.14	dB
G.rx	40.35	dBi

RX.I	-71.36	dBm/MHz
I/N	38.46	dB
I+N	-71.36	dBm/MHz
SINR.rx	31.75	dB

Sensitivity	44.44	dB
Margin	-12.69	dB
sigma	5.5	dB
p.lognorm	0.010502	

7.7 *Summary of Calculations*

The Margin in the SNR and the corresponding Outage times are plotted in Figure 14 for the RigNet coastline crossing links. These results are without any interference. In general, the Outage time decreases as a strong function of the Margin (higher Margins yield lower Outage times).

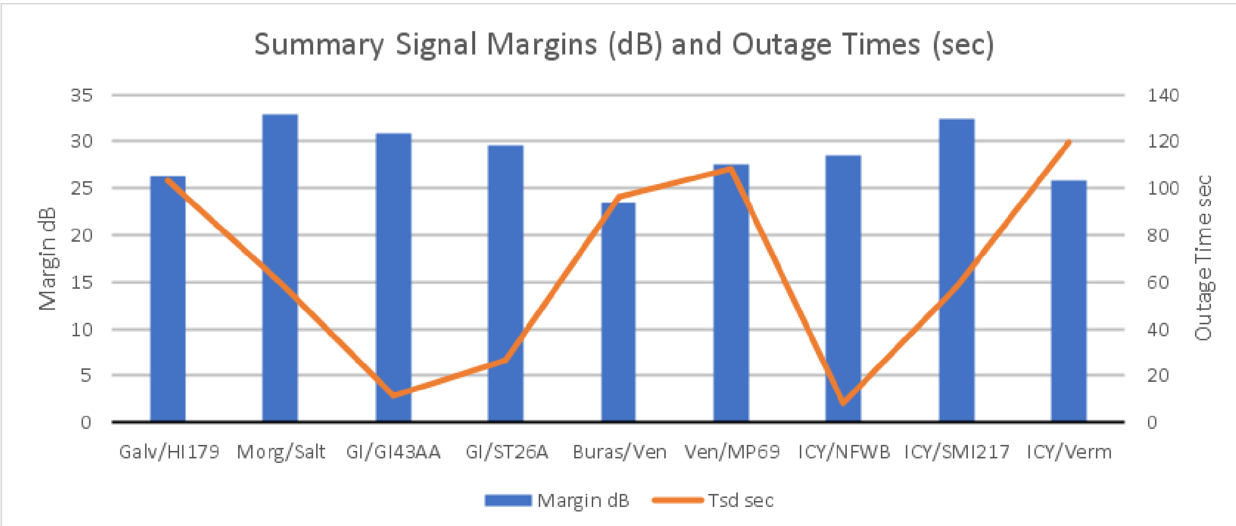


Figure 15 - Margins and Outage Times

Interference I/N and the amount that I/N exceeds a spec limit of -12 dB is plotted in Figure 15 below. Interference will exceed the -12 dB spec for I/N by 37 to 54 dB, and in every case it will render the coastline crossing link unusable.

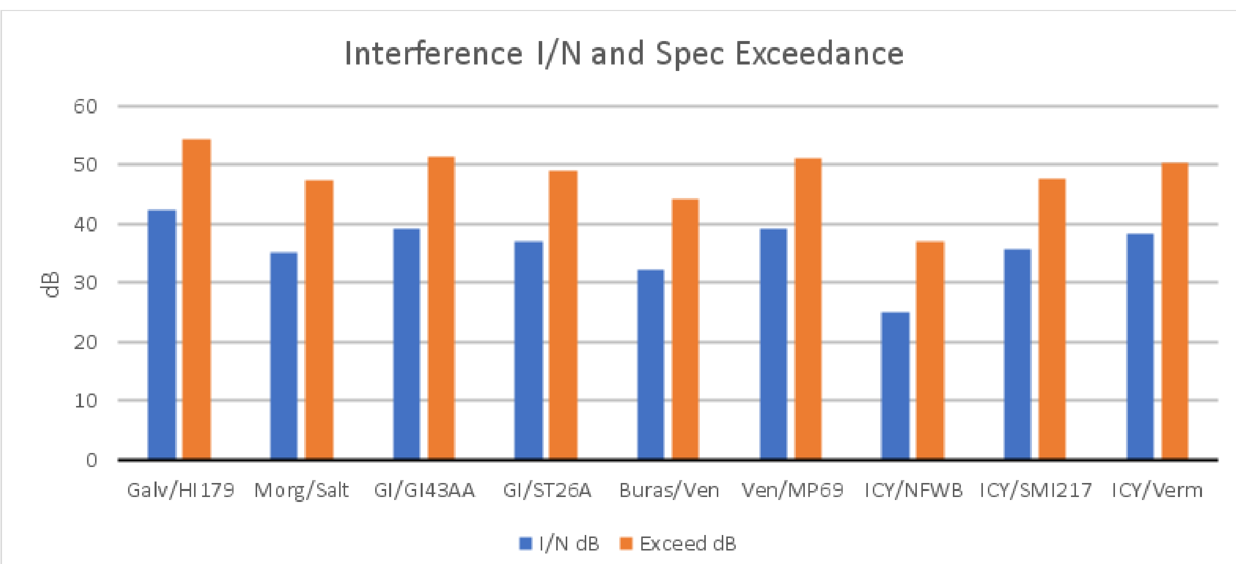


Figure 16 - interference (I/N) and Spec Exceedance

8 APPENDIX: ROBERSON AND ASSOCIATES, LLC COMPANY PROFILE

Roberson and Associates, LLC, is a technology and management consulting company serving government, commercial, and academic customers and provides services in the areas of radio frequency (RF) spectrum management, RF measurement and analysis, strategy development, and technology management. The organization was founded in 2008 and is composed of a select group of individuals with corporate and academic backgrounds from Motorola, ARRIS, Bell Labs (AT&T, Bellcore, Telcordia, Lucent, and Alcatel-Lucent), BroadView Communications, Cisco, Department of Defense (DARPA), DePaul University, Google, IBM, Illinois Institute of Technology (IIT), Illinois Institute of Technology Research Institute (IITRI), Illinois Tool Works (ITW), Massachusetts Institute of Technology (MIT), NCR, Nokia, S&C Electric, Vanu, Inc., and independent consulting firms. Together, the organization has over 1,000 years of high technology management and technical leadership experience with a strong telecommunications focus.