Special Temporary Authority Request Orbital BTS (GSM) and eNodeB (LTE) Test

Lynk

3 October 2019

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Introduction

Note: Lynk Global, Inc. (herein "Lynk") is formerly known as UbiquitiLink, Inc.

The following document details an STA Request to the FCC by Lynk which is substantially similar in nature to a prior STA Request submitted by Lynk (when it was known as UbiquitiLink) to the FCC on April 8, 2019. This prior STA Request was granted with the call sign **W09XPA.**

The following STA Request to the FCC is for a space test that will extend for a short duration and encompass a continuation and expansion of the technical objectives of prior global tests, since these tests enabled by the ISS resupply missions are by their nature of short duration. It will, however, be substantially identical to the previous test, especially with regard to the interference discussion.

As a result, the language and structure to this document is almost a clone of the prior STA.

Following discussion with the FCC, the document specification is designed to present and conform to a general set of testing parameters. Specific testing parameters which vary on a site-by-site basis, are later specified within a single document, Attachment 1. [redacted]

The host vehicle for the payload is the Cygnus ISS resupply spacecraft. [redacted]

[redacted]

[redacted]

Applicant Description

About the Applicant

Lynk, is a Delaware corporation, incorporated in January 2017. Our management team includes veterans of NASA, Nanoracks, Orbcomm, SpaceHab, Orbital (now Northrop Grumman), Fairchild, and Neustar. Lynk is developing a last-mile ubiquitous communications solution using small satellites for standard cellular/mobile devices such as smartphones, feature phones, and cellular M2M/IoT devices.

Lynk's team consists of world leaders in nanosat markets, technology and launch.

Charles Miller, CEO, has 30 years' experience in the space industry and has been the founder or co-founder of multiple private ventures and organizations. He co-founded Nanoracks LLC; Nanoracks LLC has launched over 700 payloads making it the world leader in nanosatellite launches. Miller served as NASA Senior Advisor for Commercial Space from 2009-2012 where he advised leadership on commercial public private partnerships (PPP). At NASA in 2009, Miller managed a USG team of more than two-dozen civil servants (including representatives from AFRL and FAA) that developed a commercial partnership strategy for developing reusable launch vehicles. Miller then successfully persuaded senior NASA leadership to support a $300 million per year overguide request in the FY 2011 budget process using PPPs to develop reusable launch vehicles.

Margo Deckard, COO, is a cofounder of Lynk. Deckard has over 20 years of technical and policy experience in the space industry. Highlights include being Project Manager for the Ultra-Low-Cost Access to Space Study for the United States Air Force. This study focused on how the United States Government could leverage free enterprise to achieve low cost access to space to meet our National Security needs in the next 5 years. She also served as the Principal Investigator for NASA-funded research on the environmental impacts of space solar power (SSP), and co-authored a study for the National Security Space Office on SSP. Deckard leads Lynk's spectrum team.

Key members of our technical team include Tyghe Speidel and Dr. Joseph Bravman.

Tyghe Speidel, our Vice President of Technology & Strategy, is the inventor of the key IP enabling our orbital cell tower technology, among other patents in Lynk's intellectual property portfolio. He is a former spacecraft engineer at NASA's Jet Propulsion Laboratory (SMAP, Curiosity), and the founder and global lead of the commercial space practice at Accenture.

Dr. Joseph Bravman, our Vice President of Operations, previously was Orbital's Senior Vice President/Corporate Development, Corporate Chief Engineer, Senior Vice President of Orbital's Advanced Systems Group, and Senior Vice President for Engineering and Operations. During his time at Orbital, Dr. Bravman managed the construction of the ORBCOMM satellite constellation and Orbital's role as provider of the ORBCOMM space segment. Prior to Orbital, Dr. Bravman was Corporate Executive Vice President of Fairchild and President of its Defense Electronics division that produced avionics, satellite communications, and mission planning ground support systems.

Test Description and STA Request

Summary

Table 1 below summarizes the STA request

<table>
<tr><td>Frequencies</td><td>
The payload is capable of operating a 200 kHz GSM band carrier in one of the following bands:
<table>
<tr><th></th><th colspan="2">Uplink Portion (MHz)</th><th colspan="2">Downlink Portion (MHz)</th></tr>
<tr><th>GSM Band</th><th>Low End</th><th>High End</th><th>Low End</th><th>High End</th></tr>
<tr><td>GSM 850</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
<tr><td>GSM 900</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
</table>
The payload is capable of operating an LTE block (1.4 MHz) in one of the following bands:
<table>
<tr><th></th><th colspan="2">Uplink Portion (MHz)</th><th colspan="2">Downlink Portion (MHz)</th></tr>
<tr><th>LTE Band No.</th><th>Low End</th><th>High End</th><th>Low End</th><th>High End</th></tr>
<tr><td>85</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
<tr><td>68</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
<tr><td>28</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
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<tr><td>26</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
<tr><td>8</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td><td>[redacted]</td></tr>
</table>
[redacted]
</td></tr>
<tr><td>Locations</td><td>[redacted]</td></tr>
<tr><td>Power</td><td>[redacted]</td></tr>
<tr><td>Test Time Frame</td><td>04 December 2019 to 01 June 2020</td></tr>
<tr><td>Duration of Flight</td><td>Not to exceed 6-month period of time.</td></tr>
<tr><td>Duration of Testing</td><td>Testing will be spread over the duration of flight. No one test site will see more than 4 minutes of testing (2 tests at 2 minutes each) on any</td></tr>
</table>

	given day during the testing period. In most cases it will be substantially less than 4 minutes, and this CONOP for test density is consistent with the previous STA application.
Northrop Grumman Kill Switch Contact	[redacted]
Lynk Kill Switch Contact	[redacted]

Table 1 - Summary of the STA application request

Our extensive interference analysis (discussion in detail below) demonstrates that there is no harmful interference from this test. The interference discussion describes why there will be no harmful interference impacting the existing licensed service quality due to the presence of the satellite downlink signal. This is the result of a number of combined factors that first reduce the probability of occurrence to extremely low levels and then allow the existing device protocol to completely eliminate any residual effects to the normal operation of licensee user equipment.

During previous testing campaigns, Lynk was granted a call sign and coordinated consent with all terrestrial MNOs in the granted frequency band for testing inside the proposed spot beam. [redacted]

Detailed Description

Lynk is developing a cellular-based nanosat communications network. The service would provide GSM or LTE cellular service around the globe operating on the majority of cellular bands used globally with downlink blocks between 724 and 960 MHz using a Low Earth Orbiting (LEO) nanosat or as a hosted payload on the Cygnus ISS cargo spacecraft. The spacecraft, shown in Figure 1, would effectively act as a high-altitude cell tower. There is a need to perform testing on prototype equipment, which will provide important information regarding the performance of the links and the network/system control capabilities. Initially, Lynk desires to perform a series of very short tests in various locations in around the globe. The FCC Special Temporary Authority request seeks to test using specific spectrum ranges, using specialized equipment operating at specified power densities, at a specific area, and at times within the US and internationally.

The proposed test configuration involves hosting the communications payload on the Cygnus spacecraft (mission NG-12), which is an American unmanned cargo spacecraft developed and operated by Orbital ATK (now acquired by Northrop Grumman) and used to re-supply the International Space Station (ISS). The Lynk communications system will be packed inside the Cygnus spacecraft as part of its approximate 5,000 kg of cargo before launch (scheduled for December 2019). The Cygnus is then launched to deliver its cargo to the ISS. After Cygnus has docked with the space station, astronauts on the ISS will remove the cargo inside the spacecraft. After it is emptied, they will fill the vehicle with trash accumulated on board the station since the last re-supply mission. They will close the Cygnus hatch. Once the hatch is closed, astronauts, in a "shirt-sleeve" environment, will assemble a structural frame (which was delivered as Cargo) onto the "nose" of the Cygnus spacecraft. The Lynk communications payload will be assembled and fastened to this frame.

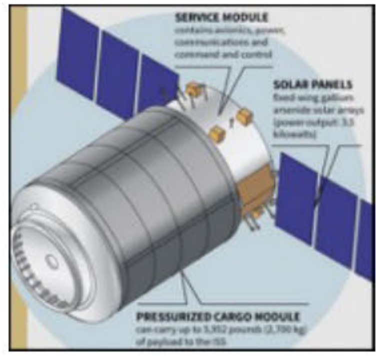
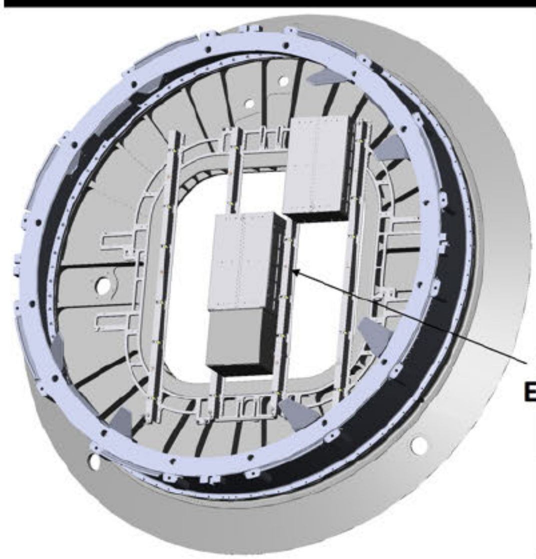


Figure 1 - Cygnus spacecraft

[redacted]

Figure 2 below depicts the Lynk payload as it will be assembled on the nose of the Cygnus spacecraft.

[redacted]



[redacted]

Figure 2 - Illustration of the Lynk payload in both the stowed (left) and deployed (right) configuration

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

The test defined above requires authorization for the Lynk payload to transmit for no more than 4 minutes per day over any one testing site for the period from approximately 04 December 2019 until not later than 01 June 2020 (in increments of 2 minutes for each overpass). The exact dates of operation are governed by the actual date of Cygnus departure from ISS and the detailed maneuvers that occur after undocking from the ISS and deployment of other nanosats. [redacted]

The payload, and especially its transmitter, is under the strict control of commands uploaded over the Cygnus spacecraft from Northrop Grumman Mission Control or via the backup Globalstar T&C module. These commands are time tagged for execution at specific times, and consequently at specific locations and positions. The Cygnus spacecraft by virtue of its ISS mission has its position (Ephemeris and TLE coordinates) and its attitude control well established. As such the center of the spot bean depicted below will be accurately controlled and the transmission intervals precisely planned and executed. This will ensure that the transmissions will only occur over the desired test areas, and that no transmissions will occur across international borders unless authorized by both of the corresponding country regulators. The precision of this control method was demonstrated on the NG-10 prior mission. As described in the sections evaluating the potential for harmful interference, the energy outside of the main lobe of the antenna will be below the minimum signal sensitivity of user devices (-105 dBm per 200 kHz for GSM, and -106 dBm per 180 kHz for LTE). [redacted]

This base-station attached to Cygnus will transmit on the broadcast channel as its downlink and respond to any uplink bursts from specific mobile phones or modules in the testing area. [redacted] On the ground, the devices consist of existing GSM and/or LTE mobile phones or IoT/M2M modules. [redacted]

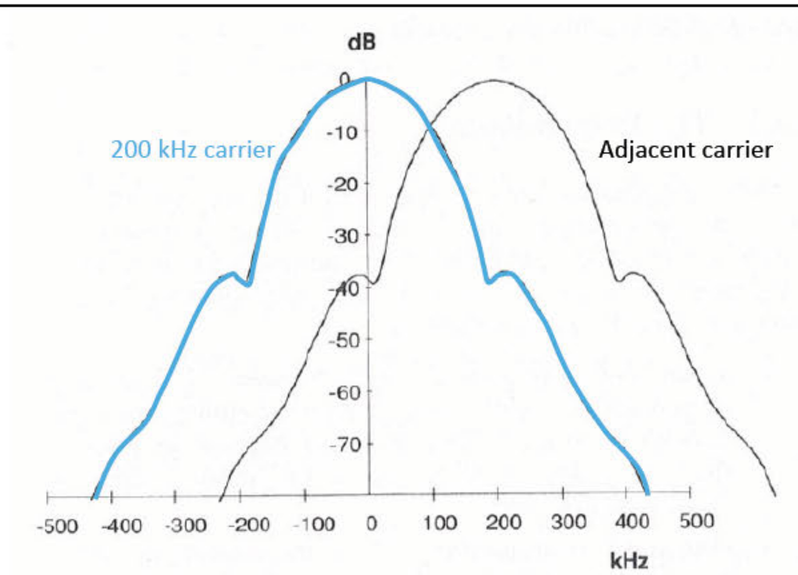
GSM communications tests will be conducted on carrier frequencies that are 200 kHz wide [redacted]

LTE communications tests will be conducted in spectrum deployment of 1.4 MHz, [redacted]

The GSM phone and module signal energy bandwidth are illustrated in Figure 5 below.

The LTE phone and module signal energy bandwidth are illustrated in Figure 6 below.

Additional information on the antennas being used and the link analyses is provided in the Appendices.



[redacted] GSM spectrum showing ACI Level in a 200 kHz channel

Figure 5 - [redacted] GSM Spectrum showing ACI Level in a 200 kHz channel

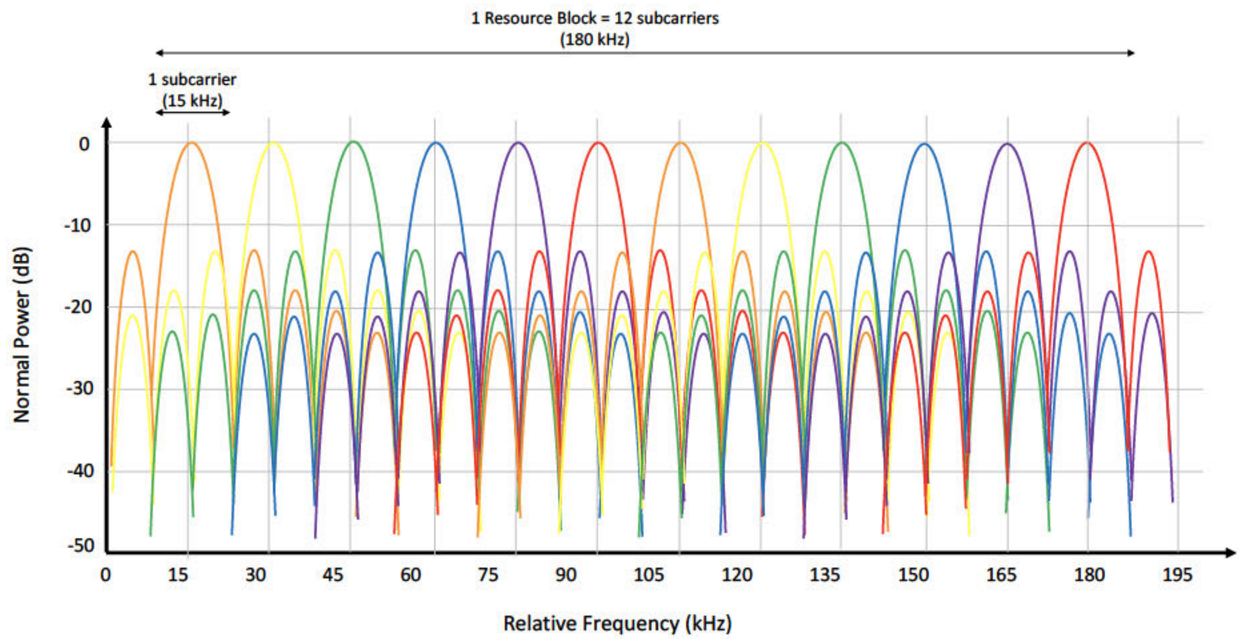


Figure 6 - LTE [redacted] Spectrum showing ACI level of 12x15 kHz subcarriers in a 180 kHz Resource Block

Table 2 below describes the general technical parameters of each ground transmitter for the Earth-to-Space link.

Table 2 - Lynk Uplink (Earth-to-Space) Transmitter Technical Parameters		
	GSM protocol	***LTE protocol***
Transmit/Receive Bandwidth	[redacted]	[redacted]
Power	[redacted]	[redacted]
Module (w/ antenna)		
Antenna: Gain	[redacted]	[redacted]
Power EIRP	[redacted] [redacted]	[redacted]
Stnd mobile phone or module		
Antenna: Gain	[redacted]	[redacted]
Power EIRP	[redacted] [redacted]	[redacted] [redacted]
Antenna Height	[redacted]	[redacted]
Radius of Operation	[redacted]	[redacted]

Table 2 - Lynk STA Request Operational Parameters

Table 3 below describes the general technical parameters of the space transmitter for the Space-to-Earth link.

Table 3 - Lynk Downlink (Space-to-Earth) Transmitter Technical Parameters		
	GSM protocol	***LTE protocol***
Channel Bandwidth	200 kHz	1080 kHz
Power (W)	[redacted]	
Antenna Gain	[redacted]	
Antenna Type	[redacted]	
EIRP	[redacted]	
ERP (EIRP – 2.15 dB)	[redacted]	
Approx. S/C Orbital Height	[redacted]	
Free Space Loss (freq dep.)	[redacted]	
Max PSD (dBm per channel bandwidth)	-92.8 to -94.5 dBm per 200 kHz	-92.8 to -94.5 dBm per 1.08 MHz (-100.25 to -102.25 dBm per 180 kHz)
Max PSD (dBm per kHz)	-116.5 to -115.5 dBm per kHz	-122.8 to -124.8 dBm per kHz
Min PSD (at edge – per channel bandwidth)	-105** dBm per 200 kHz	-114*** dBm per 1.08 MHz (-121*** dBm per 180 kHz)
Min PSD (at edge – per kHz)	-128 dBm per kHz	-143 dBm per kHz

[redacted]

*** - 105 dBm is the sensitivity of a typical GSM device (6 dB noise figure) across a 200 kHz carrier channel.*

**** - 114 dBm is the sensitivity of a typical LTE device (6 dB noise figure) across a 1.4 MHz deployment (6 RB's, or 1.08 MHz of traffic).*

Table 3 - Lynk STA request operational parameters for space segment transmitter

Table 4 below describes the general orbital technical parameters of the space transmitter for the Space-to-Earth link.

Table 4 - Lynk Downlink (Space-to-Earth) Transmitter Technical Parameters	
Altitude and Eccentricity	[redacted]
Inclination	51.6°
Host	Cygnus, NG-11 Spacecraft

Table 4 - Lynk orbital operational parameters for space segment transmitter

Interference Mitigation

The first Lynk STA request included an interference mitigation analysis. This analysis holds true for this STA request as well. **A corresponding LTE analysis would result in the same answer of no harmful interference. The signal energy levels scale accordingly because the EIRP for an LTE eNodeB is equivalent to that of a GSM BTS.** In the case of LTE, the EIRP is spread over a wider bandwidth. As a result of better modulation and coding schemes, device sensitivities scale downward per unit bandwidth accordingly. While the data is somewhat incomplete, we have received no adverse comments from any of the MNOs who were engaged in the prior tests.

The following is a copy of the previous Lynk interference mitigation analysis (submitted to the FCC in July 2018) and granted with a previous call sign.

The engineering and spectrum team at Lynk has conducted a very detailed analysis to compute, via Monte Carlo methods, that the probability of harmful interference from this test will be non-existent.

The Lynk system shall use a specific channel licensed to Cellular One in this area. The main area of testing is in a remote portion of northeastern Arizona. Operation in a quiet area is preferred since the downlink signal from the spacecraft is very low and is intended to be the “tower of last resort”. It, therefore, should not compete with terrestrial communications. This low signal power level will preclude harmful interference in all instances. The quiet area, or zone, is outside cell tower coverage and we are purposefully selecting for an area away from cell towers for testing.

Attachment 2 is a detailed description of the Concept of Operations for this test.

Within the CONOPS description (referenced elsewhere) is information and charts illustrating the orbital path of the spacecraft and downlink beam patterns over time. It is expected that the Cygnus will be moved into the proper orbit sometime not earlier than December 04, 2019 and thus Lynk will be authorized to perform testing not earlier than December 04, 2019. The opportunity for testing will occur over at least a 2 week period. During this time, our payload will be intermittently pointed to the Earth in what are referred to as “pointing sessions”. These pointing sessions will occur approximately once per day for a duration of 6 hours (~4 orbits around the Earth) and represent our testing windows. Any location on the Earth that is underneath the Cygnus spacecraft ground track during these 4 orbits would be possible test locations for that particular pointing session.

A particular point on the surface of the Earth that meets this criterion (e.g., is directly underneath the Cygnus spacecraft ground track during these 4 orbits), would experience approximately 2 minutes of cellular connectivity centered on Cygnus’s overpass. This 2-minute time period is a testing session. The number of testing sessions within the US during a given pointing session may be on the order of 2 or 3 depending on the latitude of the location. The number of testing sessions at the location provided by Cellular One during any given pointing session is only 1. Testing at the testing location in Southwest US will occur for about 2 minutes once each day over the total mission time, approximately 6 months. Only a single 200 kHz channel will be accessed during this testing.

Since the proposed testing will occur for only up to two minutes during any particular pointing session the probability that any user’s cellular device on the ground is interfered with is incredibly low, and the probability that the user’s service is impacted is essentially zero.

The reasoning is described below and follows from a series of compounding low probability events. The various scenarios are divided into Urban, Suburban/Rural, and Remote. When needed (such as in the case of Suburban/Rural scenarios), sub-scenarios are considered in the dimensions of space (geospatial), frequency, and time.

Figure 7 below reflects a summary of the analysis in the form of a process flow. In conclusion, no matter the scenario or sub-scenario, there is no chance of harmful interference. The flowchart reads from top left to bottom right. The flow chart uses color-coded columns to indicate the dimension being analyzed along that particular point in the process flow decision line. Later in this analysis, the exact probabilities for the possible outcomes within this process flow are numerically computed.

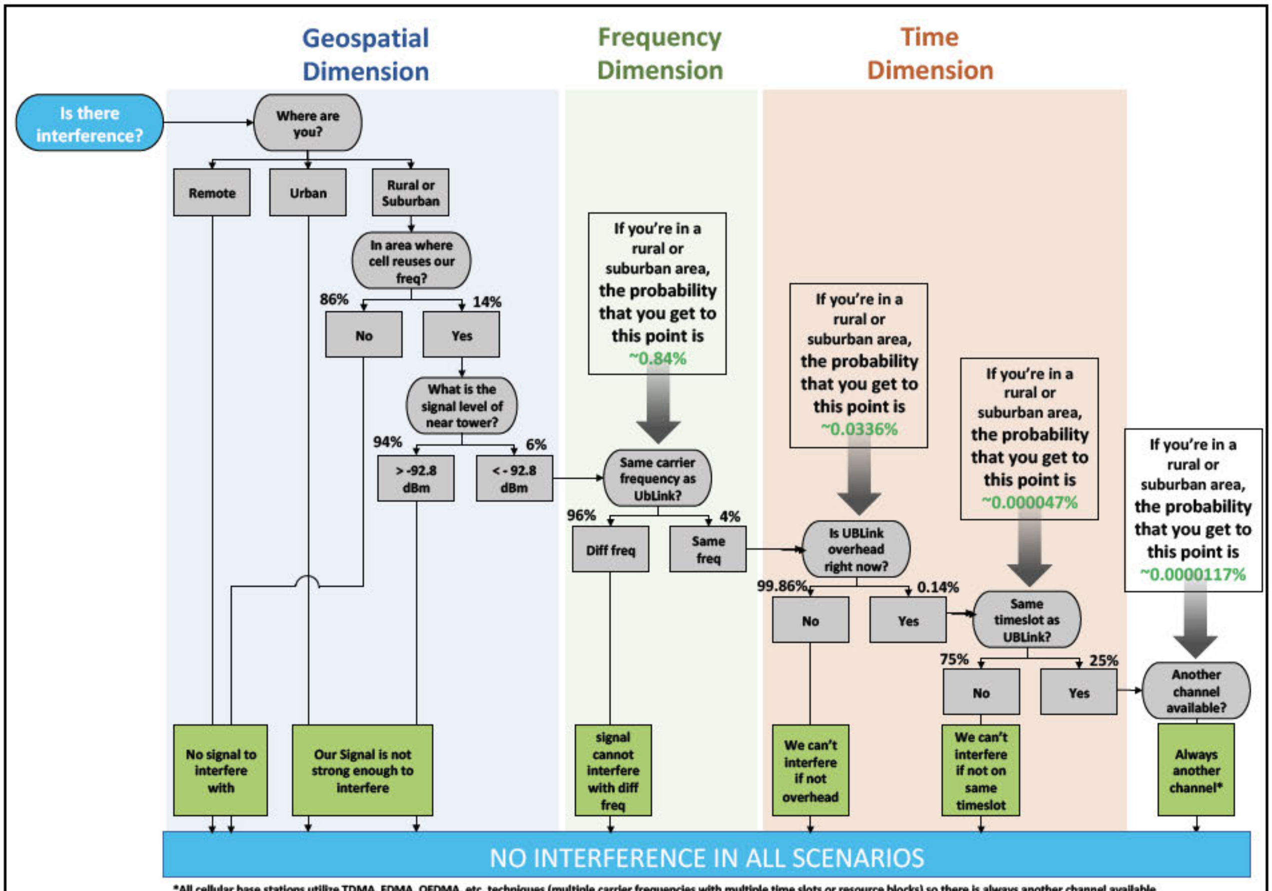


Figure 7 - Process flow illustrating that under no scenarios will the Lynk payload create harmful interference. Please see Appendix 1.1 for a full page Figure 7.

Urban Interference Analysis

There will be no impact to urban users.

Urban environments contain a large number of closely spaced towers to provide ample performance in the presence of significant multipath, shadowing, and attenuation. Additionally, towers are spaced closely in order to leverage frequency re-use and support a large number of subscribers and substantial bandwidth demands. The only locations in urban geographies where cellular signals drop to levels comparable to those from the satellite payload satellite are when attenuation from obstructions, multipath, building penetration, etc. occur. At these locations, any signal losses due to multipath, obstructions, or other attenuation will equally impact the signal from the satellite payload. Thus, there is no material case in which a customer in an urban location will suffer impeded service due to the presence of the satellite's weak signal.

In Figure 9, the urban interference analysis is conducted in columns 3 through 5 and shaded in dark blue. Urban cell radii typically do not exceed 3 km. The overlap with a neighboring cell (for handoffs); therefore, would occur at a smaller radius away from a cell tower. As indicated by the color of the cells in the 5th column, the signal energy from the Lynk payload would not raise the co-channel interference floor enough to cause harmful interference per the GSM specification for C/I when designing cellular signals for co-channel interference mitigation.

Suburban/Rural Interference Analysis

There will be no impact to users in suburban or rural geographies.

Suburban and rural users live in areas where cell edges have the greatest risk to be impacted by the power from the satellite payload because cells are generally larger and more spread-out. Although most at risk for potential interference from the Lynk payload, the following rationale details why suburban/rural geographies will experience no harmful interference. Customers will experience no harmful interference, because:

1) the potential for interference is infinitesimally small (0.0000117%), and
2) the inherent design of the terrestrial cellular network is designed to be automatically robust enough to mitigate instances of potential interference.

The terrestrial cellular network is designed to deploy the use of its spectrum to users across 3 dimensions to maximize throughput: space, time, and frequency. In other words, the spectrum is deployed geographically via expansive frequency re-use and then each cell channelizes communications across the domains of frequency and time using multiple access schemes. Therefore, in order for interference to occur, it must occur at a particular place and time/instant, and on a particular carrier frequency.

The following discussion analyses the probability of interference from the Lynk payload on the terrestrial cellular network across the following dimensions:

1) Spatial/geospatial
2) Time
3) Spectral/frequency.

The following analysis shall prove that even individually, the potential for interference along any one of the three dimensions in the cellular communications infrastructure is itself unlikely. Furthermore, we demonstrate that all 3 dimensions must be invoked at the same time in order for interference to occur for any given cellular device user in the real world.

The conclusion of the analysis below is that there is about 0.0000117 % probability that the Lynk payload will create interference to a Suburban/Rural user's *initially* chosen carrier. However, the GSM or LTE device will then automatically select another carrier should this extremely unlikely event occur, and in such regions the availability of another carrier is

nearly certain. Thus, the final likelihood of actual harmful interference impacting the service is zero.

Impact of potential interference spatially/geospatially

Spatially speaking, across the US, our analysis suggests that there is about 0.84% chance of interference.

The cellular structure relies on a frequency re-use pattern to avoid self-interference from adjacent cells operating at the same frequency. Since the test satellite operates on a single 200 KHz carrier frequency, only a fraction of the towers within the footprint could ever even be impacted. Typical frequency re-use schemes in suburban/rural geographies are on the order of every 7 or 9 towers. So numerically, the percentage of towers within a footprint that would even be sharing the same co-channel would be on the order of 14% in a worst-case scenario.

Of the 14% of tower cellular coverage areas on the ground, any impact from our payload signal would only happen at the portions of cells that represent the edge of regional coverage. Therefore, the central regions of suburban and rural locations and those that abut higher density regions (e.g., urban) would see no impact. This is represented in Figure 8 below where the design cell edges of suburban and rural towers are indicated in cases of overlap and no overlap. In geographies where cells overlap interference is mitigated, but those cells that represent the edge of regional cellular coverage or stand-alone, are subject to possible interference. The only areas that could be impacted within these cells are the slice between -92.8 and -105 dBm, which are generally areas of overlap with adjacent cells. However, at the edge of regional cellular coverage, these may be the only signals available in some geographies (where very few, or no people live). Below -105 the phones won't work, and so there can be no interference. At or above -92.8 dBm (the upper limit of the payload downlink signal energy) the tower dominates.

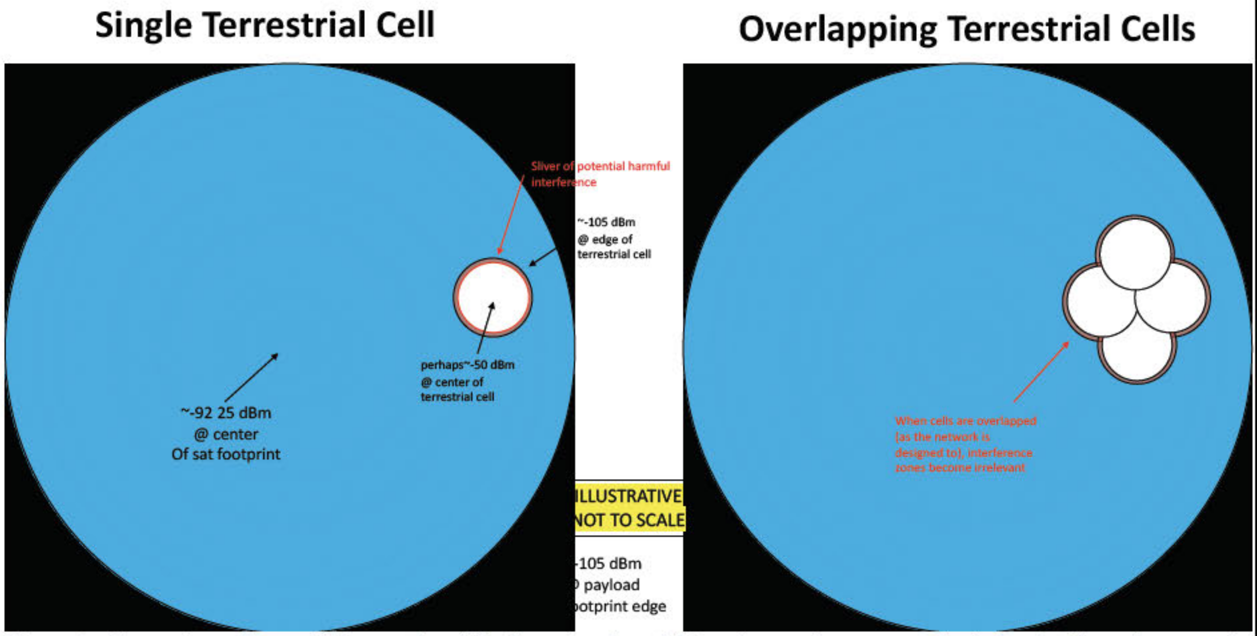


Figure 8 - Illustration of how cellular overlap defends against harmful interference from our payload signals. The only areas of possible interference are geographies where there is no continued build out of towers. Please see Appendix 1.2 for a full page Figure 8.

Attachment 2 contains a Monte Carlo simulation analysis related to the potential interference related to geospatial factors during the test. The analysis illustrates that the percentage of all land area in the US that might have access to a signal from only one tower and where the signal from that one tower is between -92.8 dBm and -105 dBm is ~6%. In other words, the theoretical possibility of interference is at most 6% of the US geography.

In conclusion, the probability that there could be interference from our payload solely enabled by the geospatial criteria is 0.84% because only 14% of towers representing the 6% of the US geography that could possibly experience interference will use the same group of carrier frequencies as the Lynk payload.

Impact of potential interference in time

Our analysis suggests that the Lynk payload can only interfere 0.035% of the time across the proposed testing period. This calculation was made based on our first mission length, which was 10 days. Although the total duration of this mission is 6 months, we will still have a finite number of pointing sessions. The number of pointing sessions has not been determined yet as this is a function of fuel and primary payloads aboard Cygnus. However, both AT&T and Verizon reported they had no interference issues. Therefore, in addition to the original calculations demonstrating no interference and no interference issues reported by major carriers, our analysis is supported. If we were to recalculate these percentages based on the longer mission, the probability would be reduced further.

Our payload will be operational over the test site for about 20 minutes total over 6 months of testing. Our first mission was 10 days long. This represents 0.14% of 10 days-time and, therefore, from a time dimension, there is a 0.14% chance that the Lynk payload could even be transmitting while over the proposed location in the Southwest US.

Furthermore, the signals from the Lynk payload will operate using the frame structures of the GSM protocol. This means that the signals from our transmitter will be transmitted in bursts in an individual timeslot across 8 potential timeslots in the TDMA frames. Our broadcast control channel (BCCH) will always occupy timeslot 1. Since we will be communicating with no more than 1 GSM mobile phone at any given point in time (to move a message from one mobile phone to the other) our downlink carrier frequency will remain quiet on at least 6 out of 8 of the downlink timeslots at all times (we will occupy timeslot 1 always and one other timeslot for the duration of moving an SMS to/from phones on the ground). Therefore, along the timing dimension, the probability that there will be interference when the Lynk payload is transmitting is 25%. In other words, there is a 25% chance that there is a burst from the Lynk payload on the downlink channel that coincides with a burst from a terrestrial cellular tower downlink channel on the same exact timeslot.

In conclusion, the temporal probability that there is interference is 25% of 0.14% or 0.035%.

Impact of potential inference in frequency

A typical cellular tower might utilize 5 MHz of spectrum. For any given cellular tower below the spotbeam that operates across 5 MHz of spectrum, 200 kHz represents 4% of the spectrum on any given tower.

Thus, the probability of interference on a spectral dimension is likely not higher than 4%.

Impact of potential inference accounting for ALL 3 factors

In conclusion, the probability that a user's device is 1) operating on a cell tower in a rural area near the test site with a cell signal lower than the signal from our payload, 2) on the exact frequency we are using for the test, and 3) at the exact time that we are overhead using it is 0.84%*0.035%*4% = 0.0000117%.

However, unlikely as that is to happen, the GSM and LTE protocols are designed to be resilient to various issues with individual carriers that may temporarily degrade performance of an individual user device with individual carriers. Should the effect occur with a 0.0000117% probability the device and its base station will simply move to another available carrier. The fact that this is only an issue at the fringes of the network, where user density is very low assures that alternate carriers will be in plentiful supply.

Thus, the final probability of harmful interference is zero.

The tests are being conducted with the express cooperation and participation of the terrestrial licensee, who believes that the Lynk service will add to the capability of their network rather than to detract from it. It is a primary objective of the Lynk test program to accumulate data to validate these assumptions and provide a design baseline for enhancements to the network aimed at delivering and improving the service.

Remote User Interference Analysis

There will be no impact to remote users:

Remote users, by definition, are those who reside in regions in which there are no towers sufficiently close to produce service. These users are enabled by the Lynk service without which they would have either no or unusable connectivity.

Variable	Value	Units	Comments
Frequency	874	MHz	Based on highest frequency we might use
Base Station Height, Urban (hb)	30	m	An urban base station at 30 m high will have line of sight to 19.56 km away on a bald earth. Will likely be designed for 1-3 km radius
Base Station Height, Suburban (hb)	60	m	A suburban base station at 60 m high will have line of sight to 25.25 km away on a bald earth. Will likely be designed for 3-10 km radius
Base Station Height, Open Area (hb)	80	m	A rural base station at 80 m high will have line of sight to 31.95 km away on a bald earth. Will likely be design for 10-30 km radius
Base Station EIRP (dBm)	62	dBm	Based on maximum base station EIRP
Mobile Station height (hm)	1.5	m	
Minimum Usable GSM Level	-105	dBm	Per GSM spec
Ubi Sat D/L Sign Level	-93.25	dBm	From UBL link budget
Antenna Correction Factor (Ch)	0.014736029	dB	Calculated
Wavelength	0.34301	m	Calculated

		Urban			Suburban			Rural			
Distance to Base Station	Free Space Loss (for ref only)	Path Loss Lurban *	GSM Carrier level (urban)**	C/I urban (Ubi Sat)**	Path Loss Lsuburban*	Carrier level (suburban)	C/I suburban (Ubi Sat)**	Path Loss Lopen*	Carrier level (open)	C/I open (Ubi Sat)**	
(km)	(dB)	(dB)	(dBm)	(dB)	(dB)	(dBm)	(dB)	(dB)	(dBm)	(dB)	
1	91.3	126.1	-64.1	29.2	111.6	-49.6	43.7	91.8	-29.8	63.4	
2	97.3	136.7	-74.7	18.6	121.5	-59.5	33.7	101.6	-39.6	53.7	Urban cell radiuses
3	100.8	142.9	-80.9	12.4	127.3	-65.3	27.9	107.3	-45.3	48.0	
4	103.3				131.4	-69.4	23.8	111.3	-49.3	43.9	
5	105.3				134.6	-72.6	20.6	114.5	-52.5	40.8	
6	106.8				137.3	-75.3	18.0	117.0	-55.0	38.2	
7	108.2				139.5	-77.5	15.8	119.2	-57.2	36.0	Suburban cell radiuses
8	109.3				141.4	-79.4	13.9	121.1	-59.1	34.2	
9	110.4				143.1	-81.1	12.2	122.8	-60.8	32.5	
10	111.3				144.6	-82.6	10.7	124.2	-62.2	31.0	
15	114.8							129.9	-67.9	25.3	
20	117.3							134.0	-72.0	21.2	Rural/Open cell radiuses
25	119.2							137.1	-75.1	18.1	
30	120.8							139.7	-77.7	15.5	
35	122.2							141.9	-79.9	13.4	limit on GSM protocol

* Based upon Okumura-Hata Model - generally good from 1 to 20 km

** GSM C/I must be above 9 dB, GSM carrier level must be above minimum level from above. Areas where the C/I is below required and still within operational carrier levels are shown in red.

Figure 9 - Analysis of potential interference across rural, suburban, and urban cellular sites. No cell that operates within a greater honeycomb structure will be impacted; however, some regional cellular borders, where no cellular towers continued to be built out, will have signal energy that fades off at distances in excess of the coverage area design limits. These eventually may experience potential interference from Lynk's payload signal. Harmful interference will not occur as discussed above. See Appendix 1.3 for a full page of copy of Figure 9.

Frequencies of Operation

Description of Payload Band Capability and Spectrum of Operation

The flight demo will operate a cell tower in orbit that uses either a single GSM duplex carrier or a single 1.4 MHz LTE deployment carrier set at any one point in time.

[redacted]

NOTE: GSM 850 and 900 bands are synonymous with LTE bands 26 and 8, respectively.

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A duplex GSM carrier may, therefore, fall in either the GSM 850 or GSM 900 Bands.

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An LTE carrier may, therefore, fall in one of the following LTE Bands.

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The GSM 850 and 900 Bands allow for multiple power class devices. We will be using the highlighted power class level (with our baseline testing plan assumptions).

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Attachment 2 – Letter of Support, Cellular One

CELLULARONE
Live Connected

1500 S White Mountain Rd
Show Low, AZ 85901

P: (928) 537-0690
cellularoneonline.com

October 2, 2019

Author's Direct Contact Information:
(928) 537-0690 Ext. 2282
gturley@cellularoneaz.com

VIA U.S. MAIL ONLY
Federal Communications Commission
Office of Engineering and Technology
445 12th Street, SW
Washington, D.C. 20554

Attention: Chief Engineer OET

Regarding: Lynk Global, Inc., f/k/a UbiquitiLink STA for Testing of Satellite Payload

Dear Madam/Sir:

It is our understanding that Lynk Global, Inc. is seeking FCC authorization (either through an STA or an experimental license to conduct experiments with its satellite payload in the 850 and 900 MHz bands [Block & Channel designations below] at specified locations in the U.S. with standard mobile devices for a one-year period commencing approximately January 1, 2020. These tests are on a non-interference basis as part of their development process and will also lead to prospective overseas uses of this satellite payload.

As the FCC licensee for a portion of this spectrum, we have no objections to non-commercial tests for a limited period of time in our band as described below.

Frequencies	Uplink Portion: 824.2 MHz to 848.8 MHz Downlink Portion: 869.2 MHz to 893.8 MHz
Locations	Centered at 35.9498 N, 110.0844 W (Northeast Arizona, Navajo Nation)

We participated with Lynk Global on its prior test (Call Sign: WN9XQS, File No. 1247-EX-ST-2018) in February, 2019. During that experiment, SBI's network received no measurable harmful interference from the Lynk Global payload. We anticipate participating in the next experiment, will be monitoring our network for any signs of interference and will inform Lynk Global in the event we detect any harmful interference.

Sincerely,

Guy Turley
Vice President/Chief Technical Officer
Smith Bagley Inc., dba Cellular One of North East Arizona ("SBI")

cc: International Bureau, Chief

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Attachment 4 – Detailed Interference Analysis via Numerical Methods

Summary of Lynk Interference Analysis using Monte Carlo Methods

Utilized Data

https://hifld-geoplatform.opendata.arcgis.com/datasets/cellular-towers

The data provided in the link above is cellular tower locations throughout the US. It consists of cellular tower locations as recorded by the FCC, extracted from the FCC Universal Licensing System Database.

The Meta-data for the data set itself can be found here:
https://www.arcgis.com/sharing/rest/content/items/0835ba2ed38f494196c14af8407454fb/info/metadata/metadata.xml?format=default&output=html

Per the meta-data, it was last updated on December 20, 2016, by a Senior Engineer at the FCC.

It should be noted that the data set is only composed of 23,499 rows for 23,499 towers. Each row actually represents a transmitter, and some transmitters are located on the same tower (as will become evident later in this report). These 23,499 towers do not represent every cellular cell in the US and likely is only representative of macro cells. However, this is likely sufficient for this analysis as micro, pico, and femto cells don't represent likely candidates of harmful interference from Lynk as they are predominately located indoors or underground and perform over very short distances.

Data Analysis – Tower locations and distances

The data is analyzed in the MATLAB environment. A CSV file is ported into the workspace and parsed into location vectors for each tower.

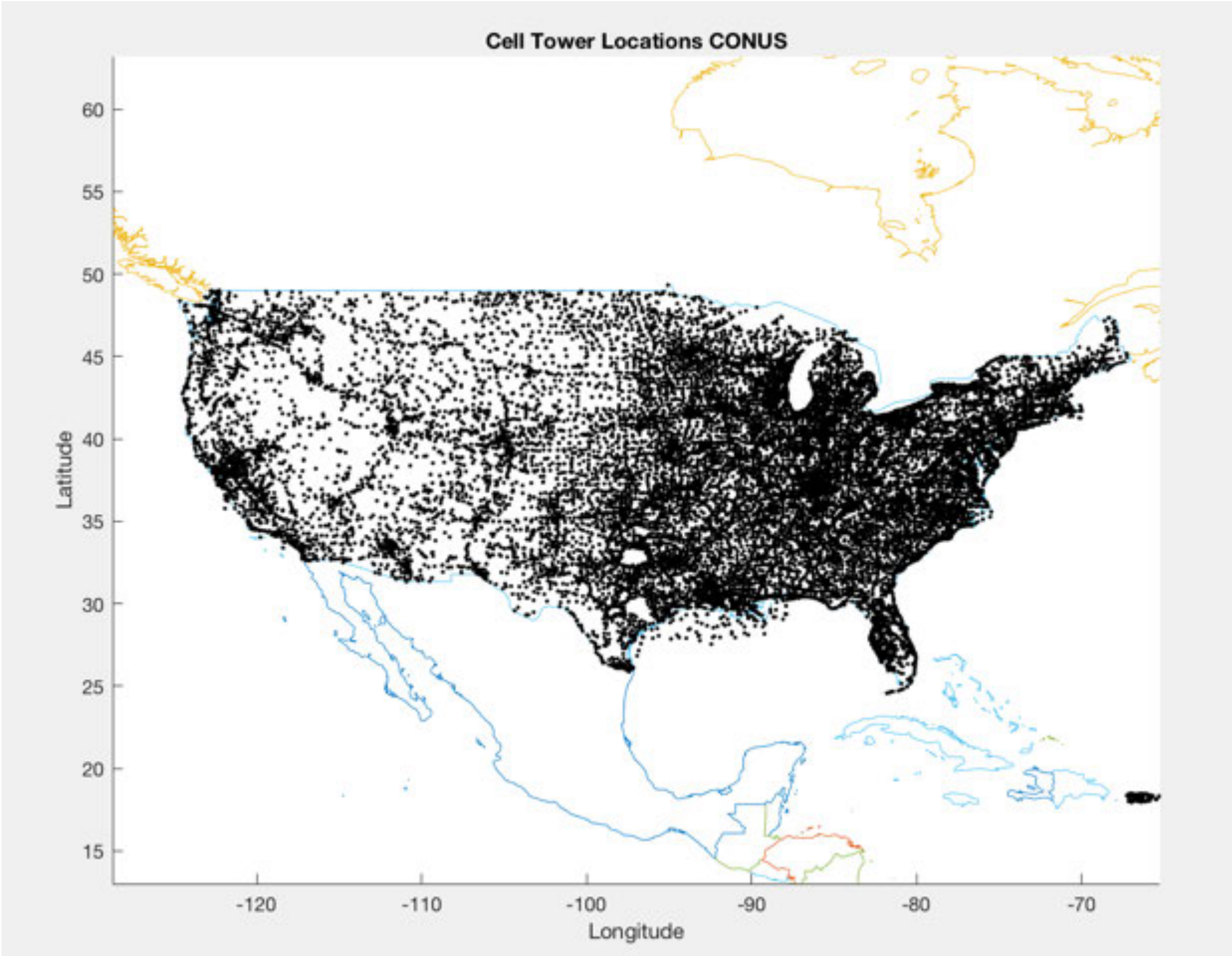

Figure 16 - The latitude/longitude positions of each cellular tower site in the FCC database

Using the latitude/longitude locations of the towers, a WGS84 Earth model is assumed to calculate the corresponding ECEF locations of the cellular towers in 3-D space (to account for the curvature of the Earth).

As a means to examine the distribution of towers that might be impacted an analysis was conducted using the positions of each cellular tower to calculate the distance its nearest neighboring tower. The following represents the probability distribution function for the distance to the nearest tower, for cellular towers.

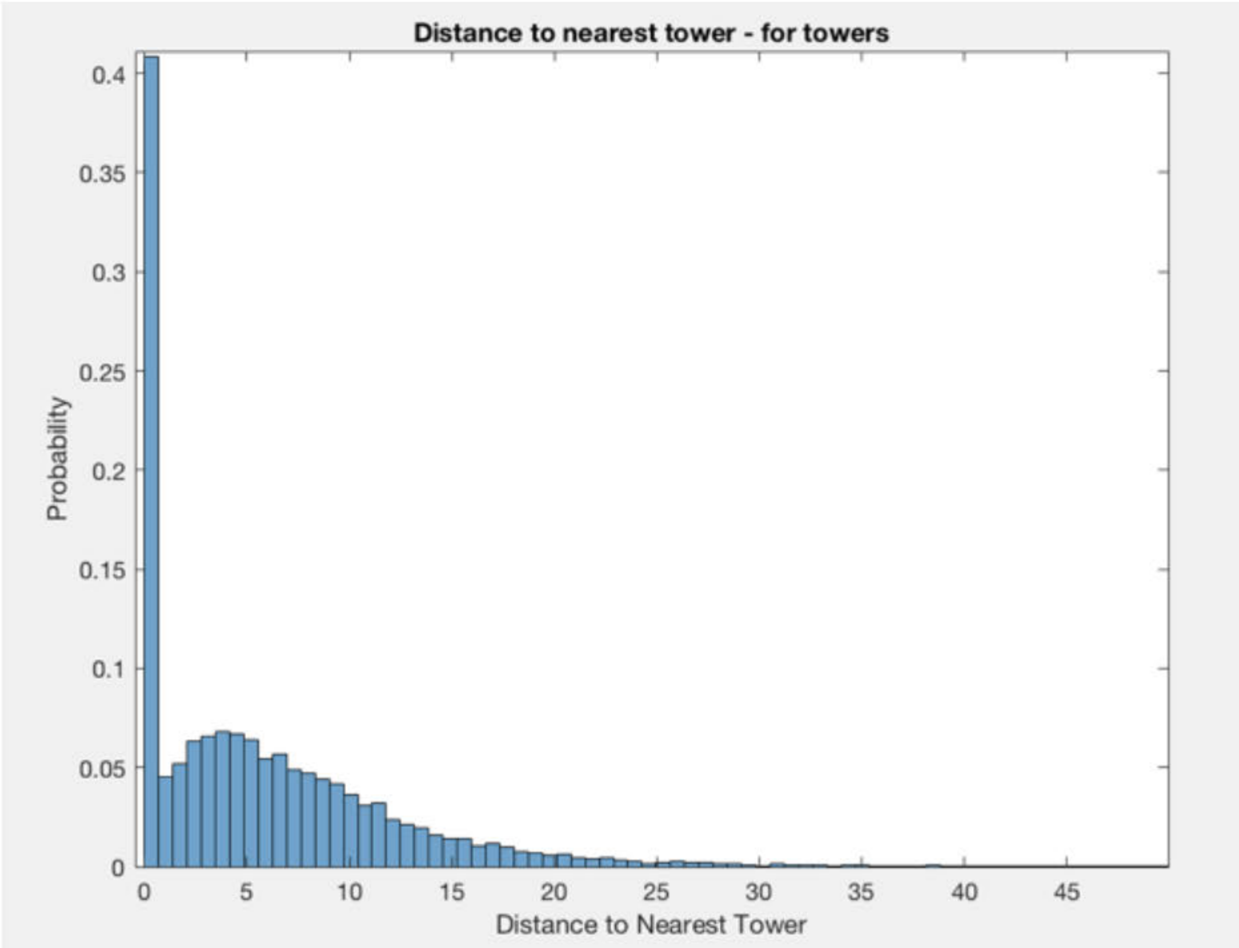

Figure 17 - For any given in cellular tower in the FCC database, the probability of the distance to the next nearest cellular tower.

Data Analysis – Monte Carlo RF Propagation Simulation

The data for tower locations were then used to generate a model for the strongest signal levels at any point across the country. Using a border file for the location of US borders, a Monte Carlo algorithm was developed to generate nearly 1 million points across the entire country. Each of these points is randomly generated (in latitude and longitude). The latitude and longitude positions are used to calculate ECEF positions for every Monte Carlo point.

Assumptions were made for critical signal propagation characteristics. The following are assumed (code snippet taken from analysis script)

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The Monte Carlo simulation points are used as the anchors for a long loop. For each point in the simulation set, the nearest cellular tower is computed. Given the distance to the nearest tower, the strongest signal energy is computed using a simplified exponential path loss model. The EIRP from the base station is assumed to be decremented by the calculated path loss estimate.

For each point, the second nearest tower is also computed, along with its distance and the signal energy from it.

Once the loop is executed, the 1 million simulation points all have a corresponding set of 4 vectors: distance to nearest tower, approximate signal energy from nearest tower, distance to second nearest tower, and approximate signal energy from the second nearest tower.

The following plots tell a revealing story:

Below is the probability distribution function of the signal energies calculated across all the Monte Carlo points in the simulation. The blue histogram represents the signal energy from the nearest, or first tower, to the Monte Carlo location point. The red histogram represents the signal energy from the second nearest, or second tower, to the Monte Carlo location point.

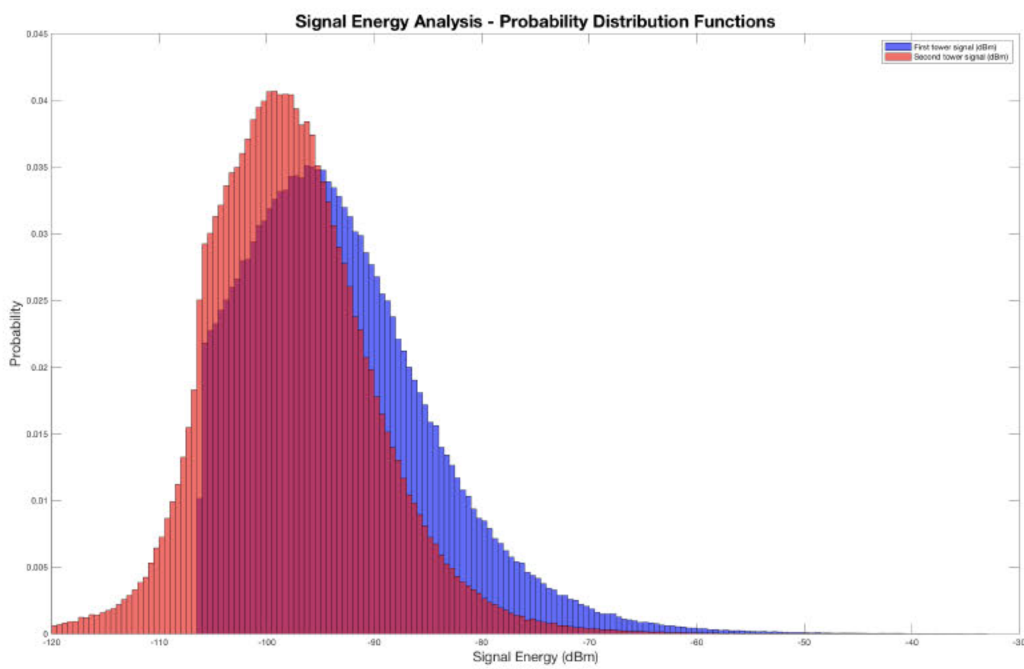

Figure 18 - Probability distribution function (PDF) of the signal energy from the nearest and second nearest tower to any location in the US per the Monte Carlo simulation model

Below is the PDF of the distance to the nearest tower and second nearest tower to all Monte Carlo Simulation points. The nearest tower is in blue and the second nearest tower is in red.

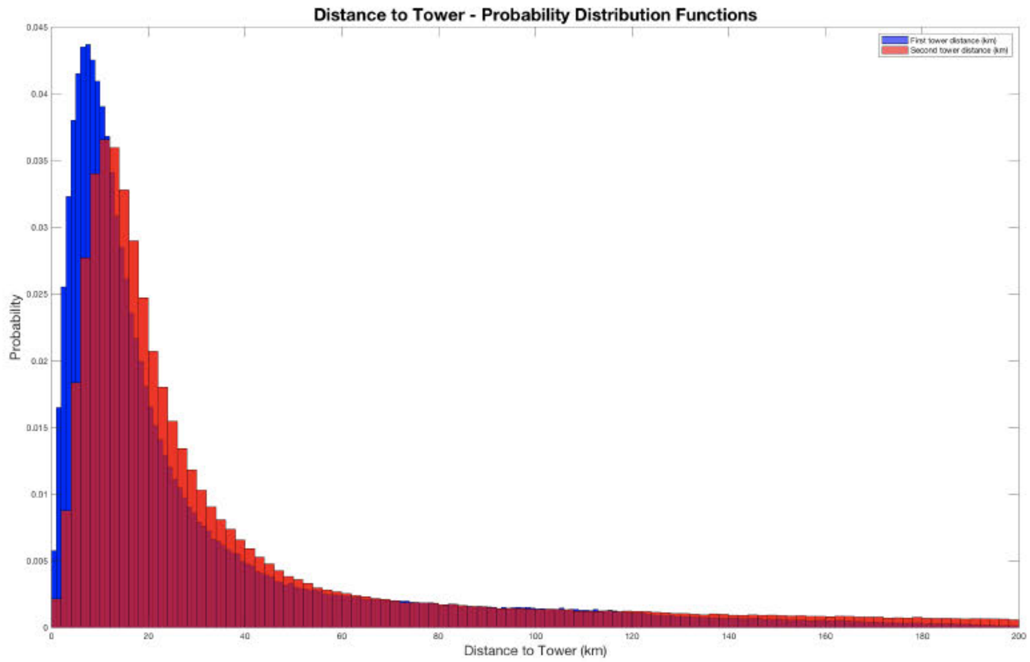

Figure 19 - Probability distribution function (PDF) of the distance to the first and second nearest tower for any location in the US per the Monte Carlo simulation model

Below is the resulting cell signal across CONUS from the simulation. Each point plotted is color-coded based on its signal energy. The color scale is from -105 to the highest signal energy calculated in the simulation. Deep blue is no connectivity.

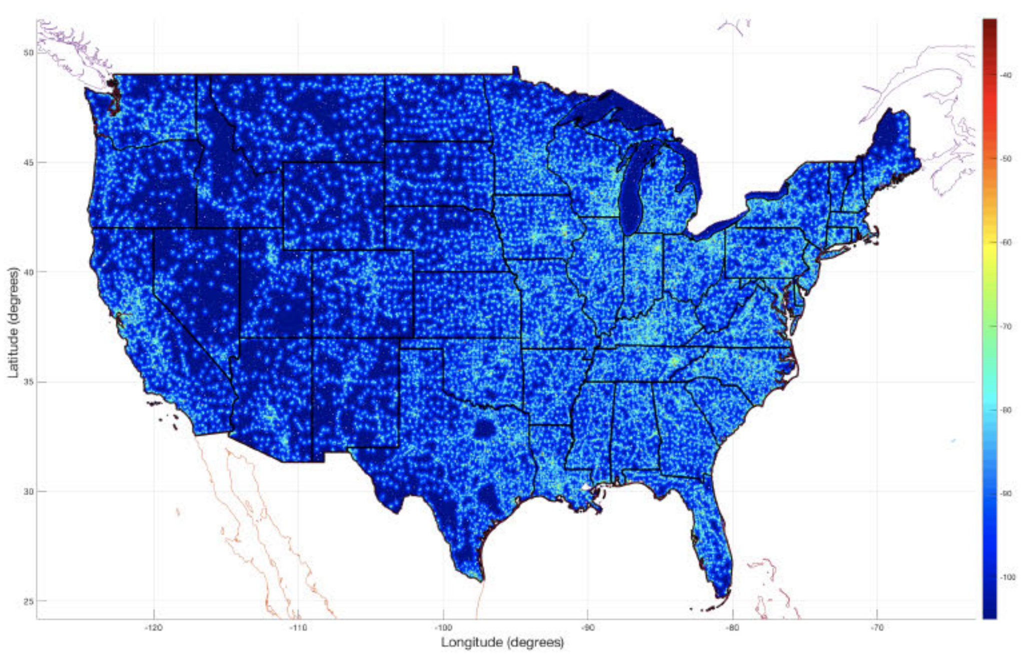

Figure 20 - The signal energy color contour map from the Monte Carlo simulation results

Below are the points in the Monte Carlo simulation which have a cell signal that the payload may interfere with (between -92.8 dBm and -105 dBm) and also have a signal from the second nearest tower that is not able to provide it sufficient service (signal less than -105 dBm). In other words, the following points represent those in the simulation that only have a connection to one existing tower that is a weak connection. Thus, the only places for potential harmful interference are shown below.

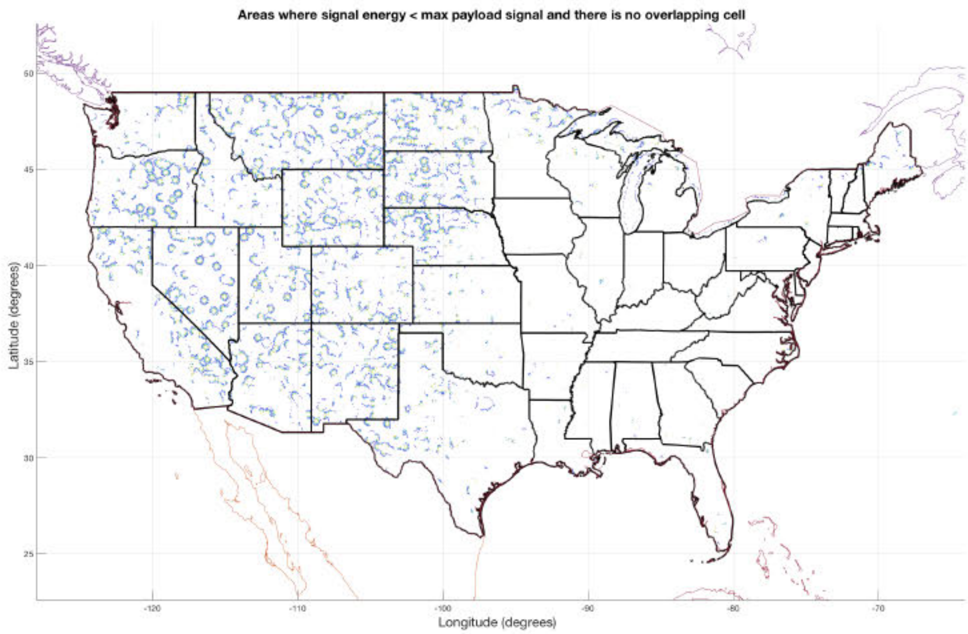

Figure 21 -Locations, or pixels in the Monte Carlo simulation, that have signal energy between the receiver minimum detectable sensitivity and the max signal energy from the Lynk payload downlink. These location represent possible areas of interference, but only if they operate on the same carrier frequency and same time.

It is also important to include the following calculation details, keeping in mind that the number of points in the simulation is exactly 967,104.

1. Number of points in coverage = 299,127
2. Number of points out of coverage = 667,977
3. Number of points w/ possible interference from Lynk = 420,108
4. Number of points w/ possible interference from Lynk and no access to at least a second tower signal = 58,944
5. Percentage of America Geographically "Covered" per this model = 69.07%
6. Percentage of America Geographically "Not Covered" per this model = 30.93%
7. Percentage of all land area with possible interference from Lynk and <u>no access to a second tower</u> = 6%

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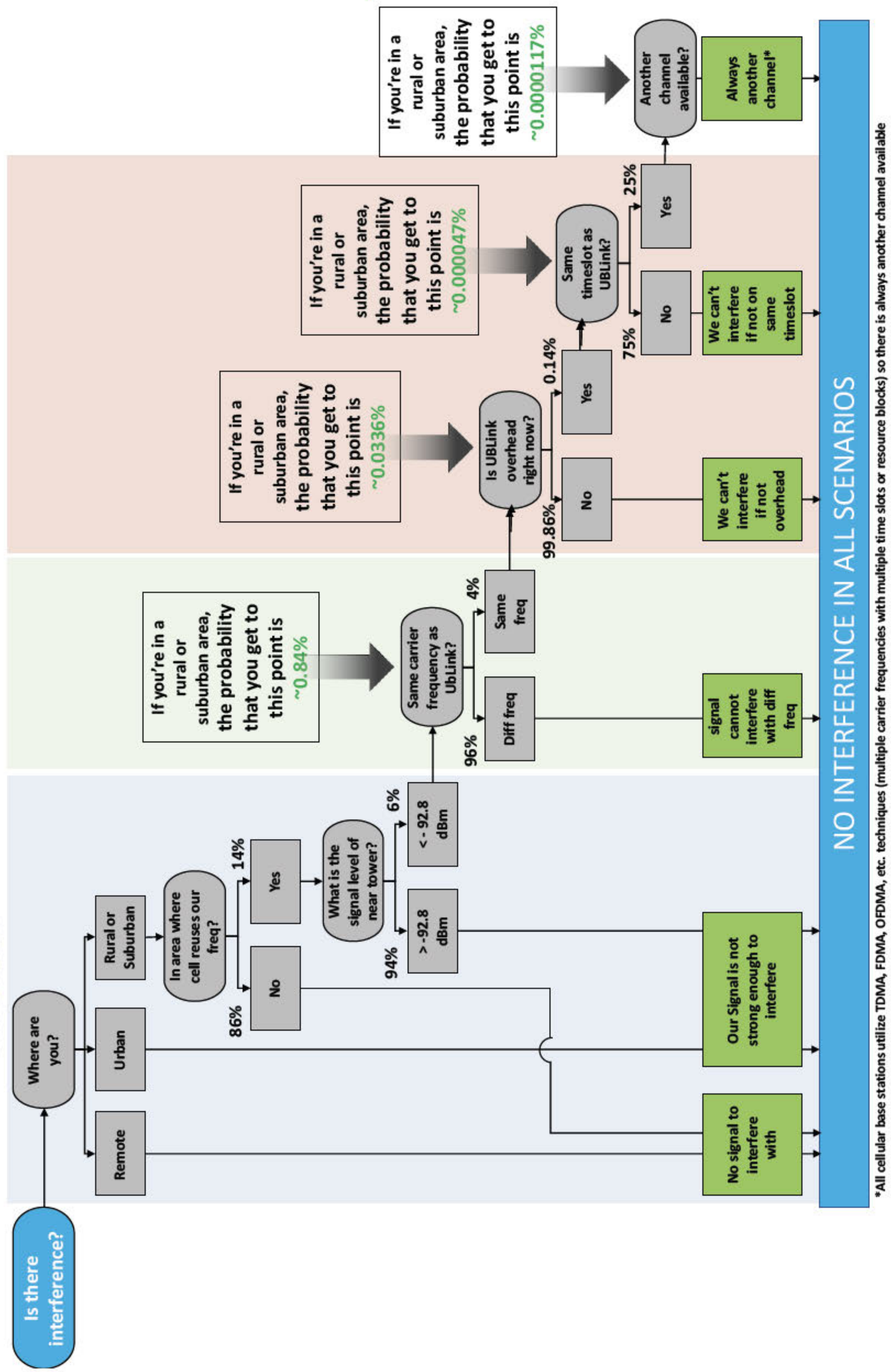
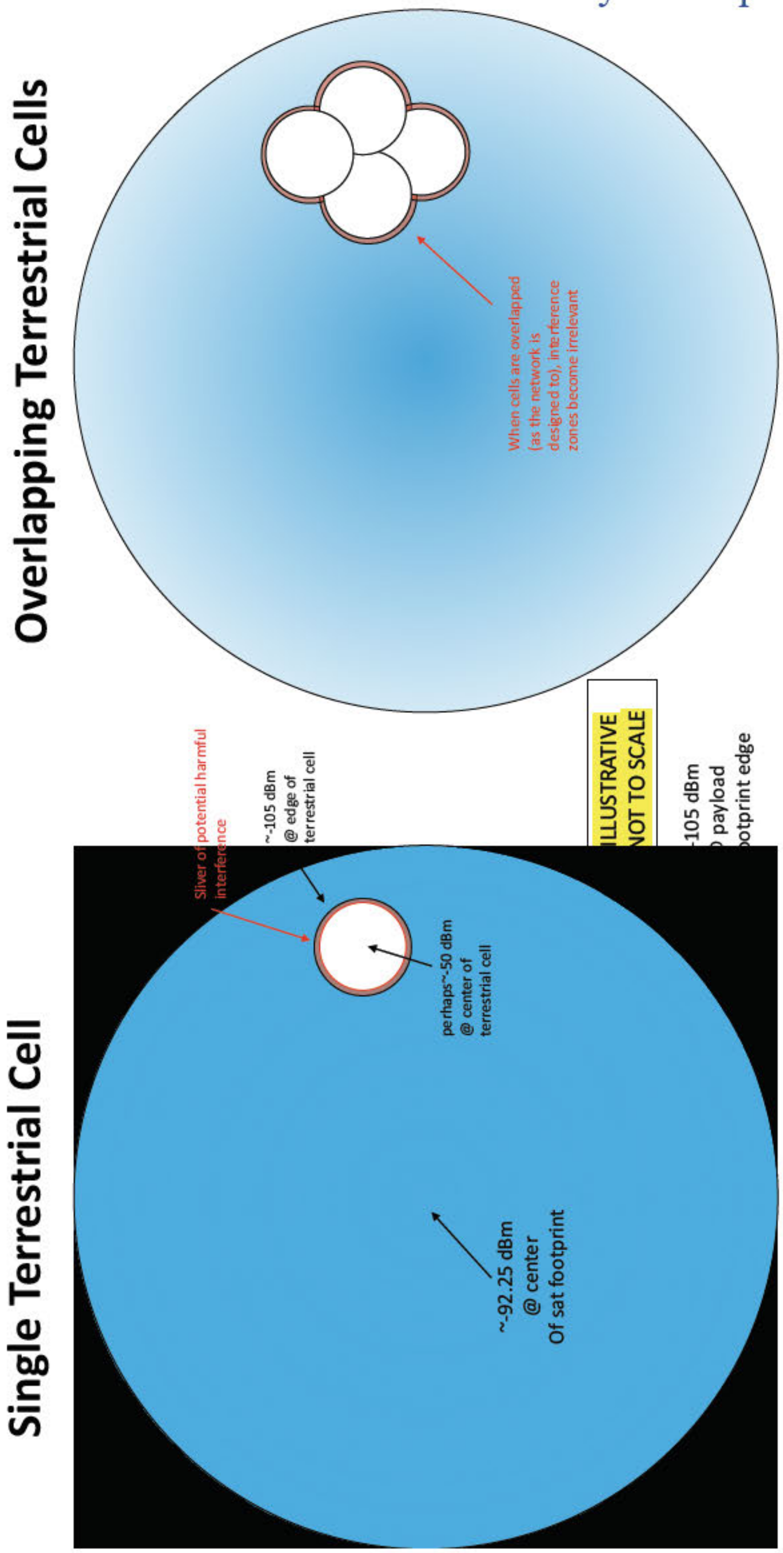
Appendix 1.1 – Interference Analysis Flow Chart



Appendix 1.2 – Terrestrial Cell Interference Analysis Graphic



Appendix 1.3 – Terrestrial Interference Analysis Table

Variable	Value	Units	Comments
Frequency	874	MHz	Based on highest frequency we might use
Base Station Height, Urban (hb)	30	m	An urban base station at 30 m high will have line of sight to 19.56 km away on a bald earth. Will likely be designed for 1-3 km radius
Base Station Height, Suburban (hb)	65	m	A suburban base station at 65 m high will have line of sight to ~28 km away on a bald earth. Will likely be designed for 3-10 km radius
Base Station Height, Open Area (hb)	80	m	A rural base station at 80 m high will have line of sight to 31.95 km away on a bald earth. Will likely be design for 10-30 km radius
Base Station EIRP (dBm)	62	dBm	Based on maximum base station EIRP
Mobile Station height (hm)	1.5	m	
Minimum Usable GSM Level	-105	dBm	Per GSM spec
Ubi Sat D/L Sign Level	-93 25	dBm	From UBL link budget
Antenna Correction Factor (Ch)	0.0147	dB	Calculated
Wavelength	0.3430	m	Calculated

		Urban			Suburban			Rural			
Distance to Base Station	Free Space Loss (for ref only)	Path Loss Lurban *	GSM Carrier level (urban)**	C/I urban (Ubi Sat)**	Path Loss Lsuburban*	Carrier level (suburban)	C/I suburban (Ubi Sat)**	Path Loss Lopen*	Carrier level (open)	C/I open (Ubi Sat)**	
(km)	(dB)	(dB)	(dBm)	(dB)	(dB)	(dBm)	(dB)	(dB)	(dBm)	(dB)	
1	91.3	126.1	-64.1	29.2	111.6	-49.6	43.7	91.8	-29.8	63.4	Urban cell radiuses
2	97.3	136.7	-74.7	18.6	121 5	-59.5	33.7	101.6	-39.6	53.7	
3	100.8	142.9	-80.9	12.4	127 3	-65.3	27.9	107.3	-45.3	48.0	
4	103.3				131.4	-69.4	23.8	111.3	-49.3	43.9	Suburban cell radiuses
5	105.3				134.6	-72.6	20.6	114.5	-52.5	40.8	
6	106.8				137 3	-75.3	18.0	117.0	-55.0	38.2	
7	108.2				139 5	-77.5	15.8	119.2	-57.2	36.0	
8	109.3				141.4	-79.4	13.9	121.1	-59.1	34.2	
9	110.4				143.1	-81.1	12.2	122.8	-60.8	32.5	
10	111.3				144.6	-82.6	10.7	124.2	-62.2	31.0	
15	114.8							129.9	-67.9	25.3	Rural/Open cell radiuses
20	117.3							134.0	-72.0	21.2	
25	119.2							137.1	-75.1	18.1	
30	120.8							139.7	-77.7	15.5	
35	122.2							141.9	-79.9	13.4	limit on GSM protocol

* Based upon Okumura-Hata Model - generally good from 1 to 20 km

** GSM C/I must be above 9 dB, GSM carrier level must be above minimum level from above. Areas where the C/I is below required and still within operational carrier levels are shown in red.

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