MTA Big Lake Project

Bringing Faster Internet Service to Big Lake

FINAL REPORT

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Acknowledgements

The UAA student team would like to thank Roland O'Shea and George Dodge for their time and input on this project. Experience is hard earned and can be an irreplaceable asset when it comes to projects in the world of engineering. As young aspiring engineers, we thank Roland and George for sharing their knowledge and experience with us. It was very much appreciated.

1. Introduction

About MTA

In 1953 residents of the Mat-Su Valley found themselves wanting what the large telephone companies were not willing to provide. The Valley residents wanted a telephone network in their area but the large phone companies viewed investing in the rural Mat-Su region as more risk than reward. The determined Valley residents found their own solution and created a member owned cooperative named Matanuska Telephone Association. During this time period it was common for rural communities to create a cooperative to provide services, such as electric power and telephone, when the large for-profit companies would not provide such services. MTA's goal and purpose was not to make large profits for its member-owners but to provide them with the best possible telecommunication service at a competitive price. This is still the driving force and mission of MTA today.

62 years later, MTA is the area's most established communication provider, employing over 350 people and offering a range of products and services to include Voice, Broadband, Wireless, Business solutions, Directory service, and Digital Television. MTA's service area is greater than 10,000 square miles, spanning from Hiland Road in Eagle River to Clear Air Force Station near Anderson, Alaska [1]. Included in their service area is Big Lake. This will be the service area of focus in this report.

Much like many other rural telecomm cooperatives today, MTA has been experiencing financial challenges in the new era of communication, where there is an ever increasing consumer demand for the latest wireless products, high data consumption, and faster connection speeds. All of these translate into high costs for MTA in the form of upgrades on existing infrastructure and installation of new infrastructure.

Another factor that has a large financial impact on MTA is that the Federal Communication Commission is changing the way it supports rural telecommunication companies. The FCC manages a fund called the Universal Service Fund. The USF is a system of federal subsidies set up to support universal access to telecommunication service across the United States. Within the USF there are four constituent programs, one of which is called the High Cost Program. The High Cost Program focuses it monetary support on telecomm companies with customers located in rural and hard-to-serve areas. MTA is dependent on this program as a source of income and has made investments in high-cost rural areas with the understanding that the federal support would be there [2]. In 2011 the High Cost Program began a 6 year phase-out period and a new program called the Connect America Fund was introduced. There is some concern that the new program greatly benefits the largest telecomm companies while the smaller companies, such as MTA, are given reduced access and support.

Background

MTA is exploring its options to meet the increased demand for broadband service to its Big Lake members. Big Lake presents a problem for MTA that is also found in many other rural areas. There is a large demand for high speed internet service, but the service area is large and the population is sparse.

MTA is a legacy telephone provider and as a result many of the connections from MTA's equipment, called DSLAMs (Digital Subscriber Line Access Multiplexors), to the customer are made up of twisted copper pair conductors remaining from the days of traditional telephone service. MTA provides internet service over these twisted copper pairs quite successfully, with some of their members getting speeds of up to 30 Mbps downstream and 3 Mbps upstream. The main limitations of this network configuration include the loop length of the "last mile" and the transport capability from the core Internet Protocol network to the DSLAM. In MTA's industry, the connection from the DLSAM to the customer's location is called the "last mile".

MTA has invested in upgrades to connect most of their DSLAMs to the core network using fiber-optic cable as transport, which has a very high capability. However, in some sparsely populated areas, it is cost prohibitive to make the investment to install fiber-optic cable; as a consequence, transport to the DSLAM is provided over the existing twisted copper pair. This results in reduced capability to all members fed from these DSLAMs.

The Big Lake area has twelve DSLAMs in total. Three of the DSLAMs on the eastern side of Big Lake are served with fiber-optic transport and meet the current capability demand. The other nine DSLAMs all use twisted copper pair as transport. These are located in the northern and southern areas around Big Lake. Over the last few years MTA has focused its network design to reduce the distance of the "last mile". Now the limitation mainly resides in the inadequate transport capability of the nine DLSAMs fed by twisted copper pair.

Problem Statement

MTA has requested that UAA explore options to increase the broadband service to its Big Lake members. They have asked UAA to focus on designing a low-cost transport system that connects the nine copper-fed DSLAMs to the core Internet Protocol network. The existing copper twisted pair transport to these DSLAMs is the main limitation in this area's network capability. MTA views microwave transport as a viable option. They asked UAA to explore using microwave technology or a hybrid of fiber-optic and microwave to provide a solution to the transport problem.

Microwave technology has proven to be a successful means to transport broadband service to remote and rural regions in past projects in Alaska. GCI started a project in 2011 named the TERRA project. It is a hybrid terrestrial fiber-optic and microwave network that successfully provides broadband to around 70 remote villages across Alaska, removing the need for high-cost and high-latency satellite connections [3].

Microwave technology takes advantage of the large information carrying capacity of the Ultra High Frequency (UHF), 300 MHz to 3 GHz, and Super High Frequency (SHF), 3 GHz to 30 GHz, bands. A disadvantage of microwave is it is highly dependent on “line of sight” between the transmitting and receiving antennas. In the simplest terms, this means that microwaves cannot propagate through hills, buildings and trees with much success. This creates the need for constructing expensive towers on which to mount the microwave antennas on both ends of the link. It should be noted that “line of sight” is a relative term and factors such as refraction caused by the Earth’s atmosphere allow microwaves to propagate farther than the “visual” line of sight. To include this phenomenon in calculations, RF engineers may use a model that uses 4/3 the Earth’s actual radius.

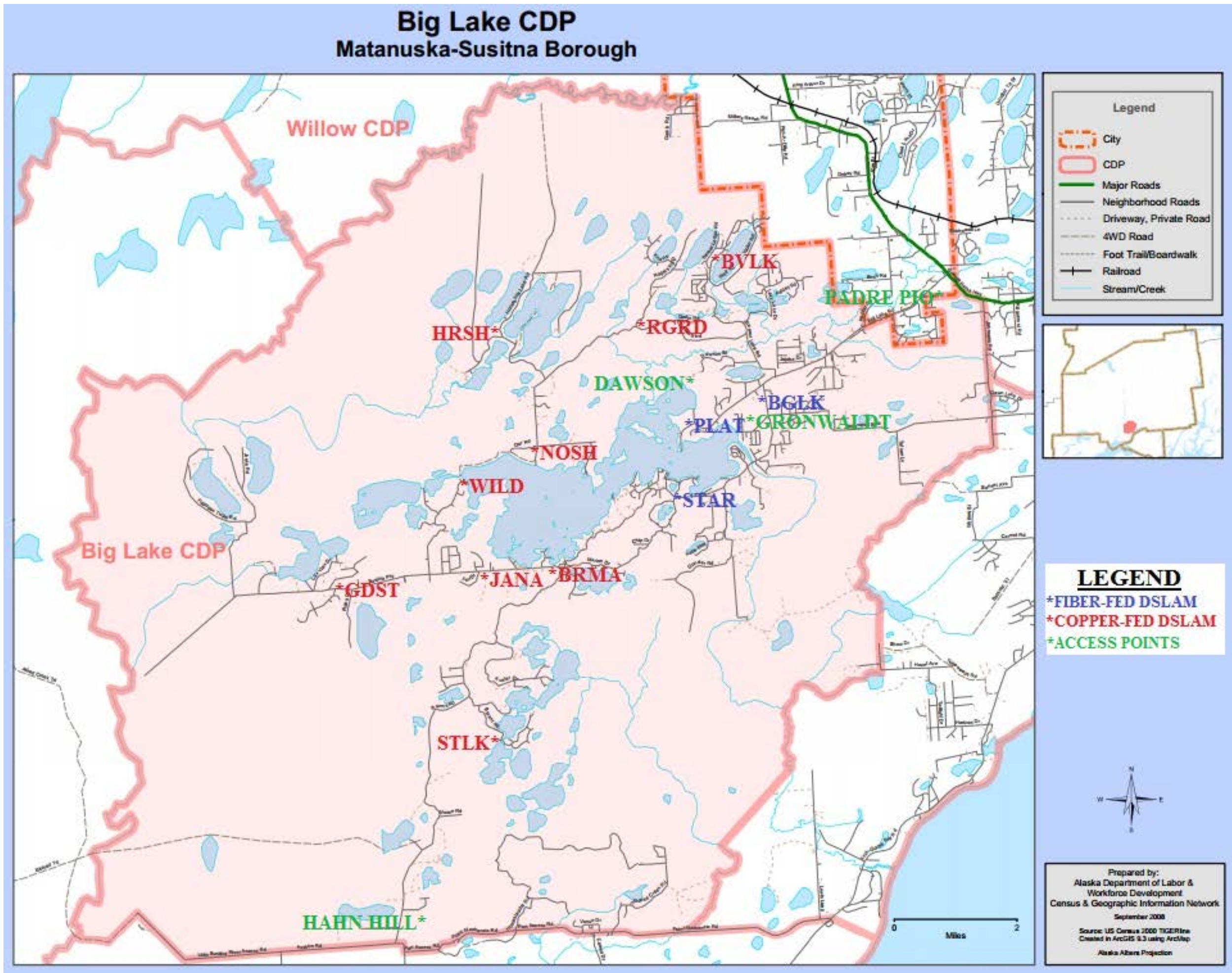
MTA designates each DSLAM with a four letter acronym called a CLLI code (Common Language Location Identifier). Table 1, shown below, displays the DSLAMs CLLI code, common name, current transport method, and location.

Table 1: Big Lake Area DSLAM Information

CLLI CODE	COMMON NAME	TRANSPORT	LATITDUE	LOGNITUDE
BGLK	Big Lake Central Office	Fiber-Optic	61°33'02.63"N	149°49'10.71"W
PLAT	PLAT DLC Cabinet	Fiber-Optic	61°32'38.65"N	149°51'15.54"W
STAR	STAR Hut	Fiber-Optic	61°31'36.08"N	149°51'54.42"W
BVLK	Beaver Lake	Copper	61°34'49.71"N	149°50'28.38"W
RGRD	Rogers Road	Copper	61°34'02.69"N	149°52'41.65"W
NOSH	North Shore	Copper	61°32'17.88"N	149°56'02.15"W
WILD	Call of the Wild	Copper	61°32'03.01"N	149°58'09.86"W
BRMA	Burma	Copper	61°30'45.03"N	149°55'37.70"W
JANA	Jana	Copper	61°30'45.17"N	149°58'09.86"W
GDST	Gold Streak	Copper	61°30'46.24"N	150°01'57.17"W
STLK	Stephan Lake	Copper	61°28'26.74"N	149°57'31.08"W
HRSH	Horse Shoe Lake	Copper	61°34'00.39"N	149°56'02.15"W

The DSLAM locations are plotted and shown on the map below, see Figure 1.

Figure 1: DSLAM and Access Point Locations in Surrounding Big Lake Area



The access points are also shown on the map in Figure 1. These access points are the locations of existing towers or monopoles that have fiber-optic connections to the core IP network. The tower names and their corresponding heights and locations are shown below in Table 2.

Table 2: Heights and Locations of Existing Towers/Monopoles[1]

NAME	OWNER	HEIGHT	LATITUDE	LONGITUDE	FCC ID
Hahn's Hill	H Services LLC	400 ft	61°25'53.68"N	149°59'53.14"W	1256358
Dawson	AT&T/MTA	190 ft	61°33'21.00"N	149°51'34.00"W	1236839
Gronwaldt	GCI/Verizon	120 ft	61°32'38.60"N	149°49'54.10"W	1264519
Padre Pio	AT&T/Verizon	120 ft	61°34'13.37"N	149°43'47.11"W	1281440
Sunset	GCI/Verizon	100 ft	61°39'12.37"N	149°35'50.43"W	1264522

[1]This data has been compiled from the FCC website. For more information visit www.fccinfo.com.

Costs estimates were provided by MTA for certain aspects of the project. MTA set a goal for the overall cost of the transport design to be at $3000 per subscriber. As stated earlier, there are 532 subscribers, this brought the goal for the total cost to $1,596,000.

Estimates were provided for the cost of installing infrastructure at various heights above ground level (AGL) to mount the microwave antennas. A summary of these costs can be seen below in Table 3.

Table 3: Tower/Pole Cost Estimates Provided by MTA[1]

HEIGHT (AGL)	TYPE	ASSOCIATED COST
60 ft.	Wooden Pole	$27,000
100 ft.	SST[2]	$136,000
150 ft.	SST	$187,000
200 ft.	SST	$265,000[3]

[1]These costs are assuming towers/poles would be going into existing MTA sites that have property ownership established.

[2] SST means self-supporting lattice tower.

[3] Cost includes mandatory obstruction lighting as required for towers at this height.

Cost estimates were also given for fiber-optic installation in terms of cost per ft. The estimate was broken down into three different installation methods as seen below in Table 4.

Table 4: Fiber-Optic Cost Estimates Provided by MTA

INSTALLATION TYPE	ASSOCIATED COST
Aerial	$15/ft.
Aerial/Buried Mixed	$25/ft.
Buried	$35/ft.

The "aerial" cost assumes that there are already poles in place, from MTA or another utility, which the fiber-optic cable could be mounted on. The "buried" cost would be used if there were no existing poles and the fiber-optic cable must be buried in the earth. The "aerial/buried mixed" cost would be used if the fiber-optic path required a mixture of aerial and buried installation.

In summary, the MTA Big Lake Project's objective is to design the lowest cost transport system that will provide MTA's Big Lake subscribers with increased high speed internet service at a minimum rate of 10 Mbps down and 2 Mbps up.

2. Preliminary Design Methodology

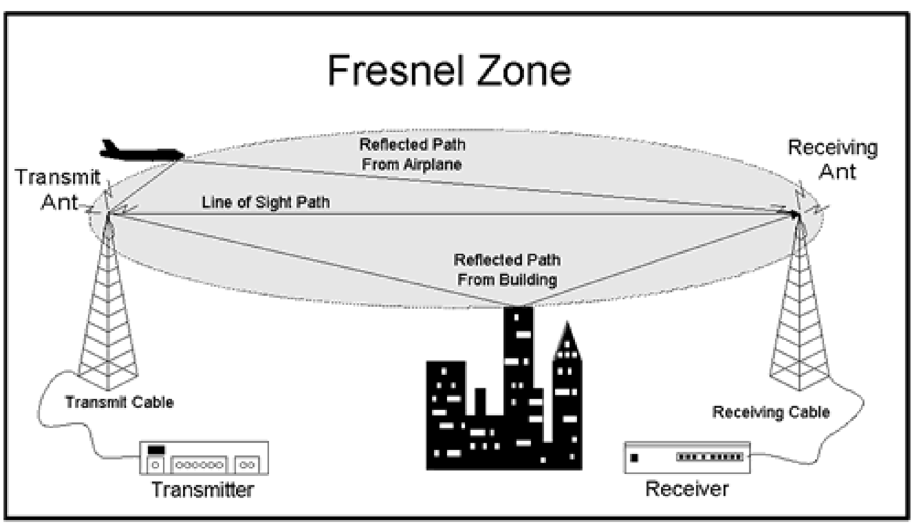
The MTA Big Lake Project was started by the project advisor Dr. Alex Hills and MTA representatives. An initial draft of the scope of work containing background information and project goals was developed by MTA (Appendix A) and distributed to the UAA student team members.

After the UAA team reviewed the draft, an initial meeting with MTA and UAA was set up to establish a relationship between the teams and to have a more detailed discussion about the project and its goals. MTA personnel involved in the meeting included:

- Eric Anderson, *Director of Engineering, Construction and Operation*
- Dennis Eby, *Internet Service Provider (ISP) Network Engineering Manager*
- Ruvin Lerman, *RF Engineer*
- Ryan Leaders, *OSP Network Planner*

After meeting with MTA, the UAA team met with Roland O'Shea, an experienced RF Engineer in Alaska. Roland had agreed to demonstrate a program called *Pathloss* that he has used in designing radio links during his professional career. The software has the ability to model what is known as the Fresnel zone of a radio link. The Fresnel zone, shown below in Figure 2, is an ellipsoid shape around the line of sight path. Due to reflection and phase shifting of the radio wave, objects inside the Fresnel zone such as buildings and trees, although not directly obstructing the line of sight path, can still considerably attenuate the received signal [4].

Figure 2: Image of a Fresnel Zone [4]



After Roland's demonstration, the team had a clear understanding as to what abilities were needed from a RF modeling program in order to be successful. For the UAA team, *Pathloss* was not an option due to the high cost of obtaining a license for the software.

The project advisor recommended a freeware program called *Radio Mobile* to aid in designing and modeling the microwave links for the Big Lake project. *Radio Mobile* was chosen due to its similar capabilities to *Pathloss* and the fact that it was freeware. *Radio Mobile* was created by Roger Coudé a RF Engineer and amateur radio enthusiast from Montreal, Quebec. He created the software and made it free to download in a dedication to amateur radio and humanitarian use [5].

After the modeling software was selected, the UAA student team worked with the project advisor to develop a work plan to follow during the development of the transport design for the Big Lake area.

Work Plan

1. Compile list of all DSLAM data provided by MTA, to include: CLLIs with their corresponding transport method and location via latitude/longitude.
2. Compile list of all access points (i.e. fiber fed towers/monopoles) provided by MTA. Collect information on these points, to include: above ground level heights and locations via latitude/longitude.
3. Make a site visit to Big Lake to take pictures of equipment and collect pertinent data, to include: tree height measurements around the DSLAM locations, verification of tower/monopole heights and visually inspect towers and monopoles for loading availability.
4. Analyze the cost estimates that were given by MTA to further understand the trade-offs between constructing towers for microwave use compared to installing fiber-optic cable runs. For example: At what distance does the cost of a fiber-optic cable run equal the cost to install a tower? Compute this comparison for different types of fiber-optic installation as well as different tower heights.
5. Using *Radio Mobile,* create links between every access point and every DSLAM using design guidelines provided by MTA's RF Engineer, Ruvin Lerman. The guidelines are as follows:
    - Select frequency of 18 GHz (Advantages: slimmer Fresnel zone and can interface with Gigabit Ethernet).
    - At first attempt, assume no refraction i.e. use flat earth model (K= 1).
    - Review Fresnel zone clearance. Fresnel clearance of 0.6 is minimum acceptable.
    - Second attempt, optimize model include refraction i.e. use a 4/3 Earth model where (K= 1.33).
    - Evaluate Fresnel zone clearance again with minimum being 0.6.
6. Create four to five preliminary designs using the "Design Approach" described in the next section.

7. Create cost estimates for each of the preliminary designs.
8. Analyze the preliminary designs and select one or two to recommend and create a list of each designs pros and cons.
9. Draft Interim Report and conduct presentation for MTA.
10. **Final Design:** Conduct tower loading availability analysis to use in detailed design.
11. **Final Design:** Conduct link budget analysis and select antennas and equipment for preferred preliminary design.
12. **Final Design:** Complete detailed design and create associated cost estimate.

Design Approach

Elevation Data

To develop our designs, the locations of the nine copper fed DSLAMS and the five access points (towers/monopoles) were mapped using the *Radio Mobile* software. The software allows the user to import elevation data from the Shuttle Radar Topography Mission (SRTM). The SRTM was an international project between NASA and NGA[6]. SRTM was a modified radar system on-board the Space Shuttle Endeavor and the data obtained from it was taken during a mission lasting 11 days in February of 2000. The SRTM project obtained elevation data with 1 arc second precision for most of the world, but only the data for the US has been made public. The remaining data of the world was released at 3 arc second precision. Unfortunately, not all of Alaska was covered by the SRTM project and as such the Big Lake area only has 3 arc second data available.

Land Cover Data

The land cover data, or perhaps more widely known as “clutter” data is used to evaluate radio paths while taking into account obstacles like trees and tall buildings. We used data from the University of Maryland Land Cover Earth Science Information Partnership.

Microwave Design

After the data was imported, all the different paths or “links” between each tower located at the different access points and all nine DSLAMs were analyzed. The 60 ft. wooden pole was the most cost effective infrastructure option to mount antennas on; therefore, all DSLAMs were originally set at an antenna height of 60 ft. The antenna height at the access points were set to their corresponding tower/monopole heights. For the preliminary designs, the assumption has been made that the microwave antennas could be mounted at the top of each tower/monopole. (The UAA team will request MTA’s guidance on this assumption for the final design development.)

Each link was then examined in *Radio Mobile*. The worst case Fresnel clearance and the distance of the link (i.e. distance between the access point tower and the DSLAM) was recorded and is shown below in Table 5.

Table 5: Microwave Link Data at 18GHz from Access Points to DSLAM Antennas set at 60 ft.
(Bold Font Indicates Fresnel Clearance Greater than 0.6)

TOWER A: HAHN'S HILL at 360 ft.		
DSLAM at 60 ft.	**Worst Fresnel**	**Distance (Miles)**
BRMA	-1.3	6.05
GDST	**2.6**	**5.70**
JANA	**3.6**	**5.66**
STLK	-2.9	3.21
WILD	0.1	7.14
BVLK	**2.7**	**11.50**
RGRD	**3.7**	**10.17**
HRSH	0.5	9.50
NOSH	**1.4**	**7.66**

TOWER D: PADRE PIO at 120 ft.		
DSLAM At 60 ft.	**Worst Fresnel**	**Distance (Miles)**
BRMA	-7.5	7.63
GDST	-2.2	10.74
JANA	0.0	8.84
STLK	-0.4	10.05
WILD	-2.8	8.28
BVLK	**2.2**	**3.74**
RGRD	**1.8**	**4.89**
HRSH	**0.9**	**7.04**
NOSH	-3.9	7.08

TOWER B: DAWSON at 190 ft.		
DSLAM At 60 ft.	**Worst Fresnel**	**Distance (Miles)**
BRMA	-0.1	3.73
GDST	-2.5	6.43
JANA	-0.5	4.69
STLK	0.0	6.52
WILD	-0.8	3.92
BVLK	**4.9**	**1.80**
RGRD	**9.5**	**1.01**
HRSH	**3.8**	**2.87**
NOSH	-5.5	2.73

TOWER E: SUNSET at 100 ft.		
DSLAM At 60 ft.	**Worst Fresnel**	**Distance (Miles)**
BRMA	-4.3	14.57
GDST	-1.3	17.31
JANA	-0.5	15.64
STLK	-1.1	17.16
WILD	-0.2	14.75
BVLK	-1.3	9.48
RGRD	-0.8	10.99
HRSH	-0.8	12.87
NOSH	-6.6	13.63

TOWER C: GRONWALDT at 120 ft.		
DSLAM At 60 ft.	**Worst Fresnel**	**Distance (Miles)**
BRMA	-4.0	3.83
GDST	-3.4	6.96
JANA	-0.4	5.03
STLK	-2.2	6.38
WILD	-0.8	4.58
BVLK	**2.9**	**2.53**
RGRD	**4.3**	**2.22**
HRSH	0.0	4.00
NOSH	-3.2	3.39

All microwave designs were made using the following algorithm:

1. Label the towers A, B, C, D, and E.
2. List all the DSLAMs that have at least 0.6 Fresnel clearance to tower A.
3. List all DSLAMs that have 0.6 Fresnel clearance to tower B, excluding any DSLAM listed in step 2.
4. Repeat step 3 for each remaining tower, or until all DSLAMs are listed.
5. For any DSLAMs not listed, find the minimum antenna height needed at the DSLAM to get 0.6 Fresnel clearance to any tower.
6. Repeat the process, starting with each tower.

This process was done for towers A-D, since none of the links to Tower E (Sunset) met the minimum 0.6 Fresnel clearance. We created four different preliminary designs using this algorithm.

Microwave/Fiber hybrid

To include a hybrid microwave and fiber transport design, a fiber run was used to replace any infrastructure at the DSLAMs that required a taller height than the 60 ft. wooden pole. This only occurred at the STLK and WILD DSLAMs. This hybrid design was considered to demonstrate the high-cost of fiber-optic cable installation compared to microwave installation. However, this might be a viable option if fiber-optic cable is planned to be installed in this area at a future date, as this would be an infrastructure investment for that future project.

3. Preliminary Design Analysis

Preliminary Designs

The following five designs were developed. Path link profiles for each link in the following designs can be found in Appendix B. It is important to note that the prices listed for each preliminary design do not include equipment costs, or any associated equipment installation costs. These costs will be examined and considered once a preferred design is chosen.

In examining the preliminary designs the factor given most importance was the estimated cost. The four designs using only microwave shared the same total estimated cost so other factors were also analyzed. These factors included: Fresnel clearance and path distance.

Tower loading availability will be another factor analyzed in the near future. As an example of the impact of the tower loading availability, while it may be determined that a design using only two access point towers is preferred, several access point towers may need to be used due to tower loading restrictions. The tower loading issue will be explored further after MTA provides information on acceptable tower loading and antenna space availability.

The preliminary design cost breakdowns can be seen below in Tables 6 and 7.

Table 6: Preliminary Design Infrastructure Costs for Microwave Only (Designs 1-4)

DSLAM CLLI	REQUIRED ANTENNA HEIGHT (0.6 FRESNEL)	INFRASTRUCTURE TYPE	ASSOCIATED COST
BRMA	65 ft.	Wooden Pole[1]	$27,000
GDST	60 ft.	Wooden Pole	$27,000
JANA	60 ft.	Wooden Pole	$27,000
STLK	90 ft.	100 ft. SST	$136,000
WILD	70 ft.	100 ft. SST	$136,000
BVLK	60 ft.	Wooden Pole	$27,000
RGRD	60 ft.	Wooden Pole	$27,000
HRSH	60 ft.	Wooden Pole	$27,000
NOSH	60 ft.	Wooden Pole	$27,000
		TOTAL	$461,000[2]

[1]This assumes a short extension could be mounted at top of wooden pole to achieve the 65 ft. AGL needed for BRMA

[2]Total includes only infrastructure costs (i.e. tower, foundation, geos, engineering, permitting). Does not include equipment costs (i.e. antennas, transmitters, receivers, and cables.)

Table 7: Preliminary Design Infrastructure Costs for Microwave/Fiber Hybrid (Design 5)

DSLAM CLLI	REQUIRED ANTENNA HEIGHT (0.6 FRESNEL)	FIBER-OPTIC CABLE DISTANCE	INFRASTRUCTURE TYPE	ASSOCIATED COST
BRMA	65 ft.	-	Wooden Pole[1]	$27,000
GDST	60 ft.	-	Wooden Pole	$27,000
JANA	60 ft.	-	Wooden Pole	$27,000
STLK[3]	-	22920 ft.	Aerial/Buried Mixed	$382,800
WILD[4]	-	15320 ft.	Aerial/Buried Mixed	$572,880
BVLK	60 ft.	-	Wooden Pole	$27,000
RGRD	60 ft.	-	Wooden Pole	$27,000
HRSH	60 ft.	-	Wooden Pole	$27,000
NOSH	60 ft.	-	Wooden Pole	$27,000
			TOTAL	$1,144,680[2]

[1]This assumes a short extension could be mounted at top of wooden pole to achieve the 65 ft. AGL needed for BRMA

[2]Total includes only infrastructure costs (i.e. tower, foundation, geos, engineering, permitting). Does not include equipment costs (i.e. antennas, transmitters, receivers, and cables.)

[3]STLK is fed from BRMA see Design 5 below for more details

[4]WILD is fed from JANA see Design 5 below for more details

The total path distance (i.e. the sum of all microwave path link distances) for the four microwave only preliminary designs can be seen below in Table 8.

Table 8: Total Microwave Path Distance for Microwave Only Preliminary Designs (Designs 1-4)

DESIGN 1		
Access Point	**DSLAM CLLI**	**Distance**
Dawson	HRSH	2.78 mi
Dawson	BRMA	3.73 mi
Dawson	STLK	6.52 mi
Hahn's Hill	GDST	5.70 mi
Hahn's Hill	JANA	5.66 mi
Hahn's Hill	WILD	7.14 mi
Hahn's Hill	BVLK	11.50 mi
Hahn's Hill	RGRD	10.17 mi
Hahn's Hill	NOSH	7.66 mi
	TOTAL	60.96 mi

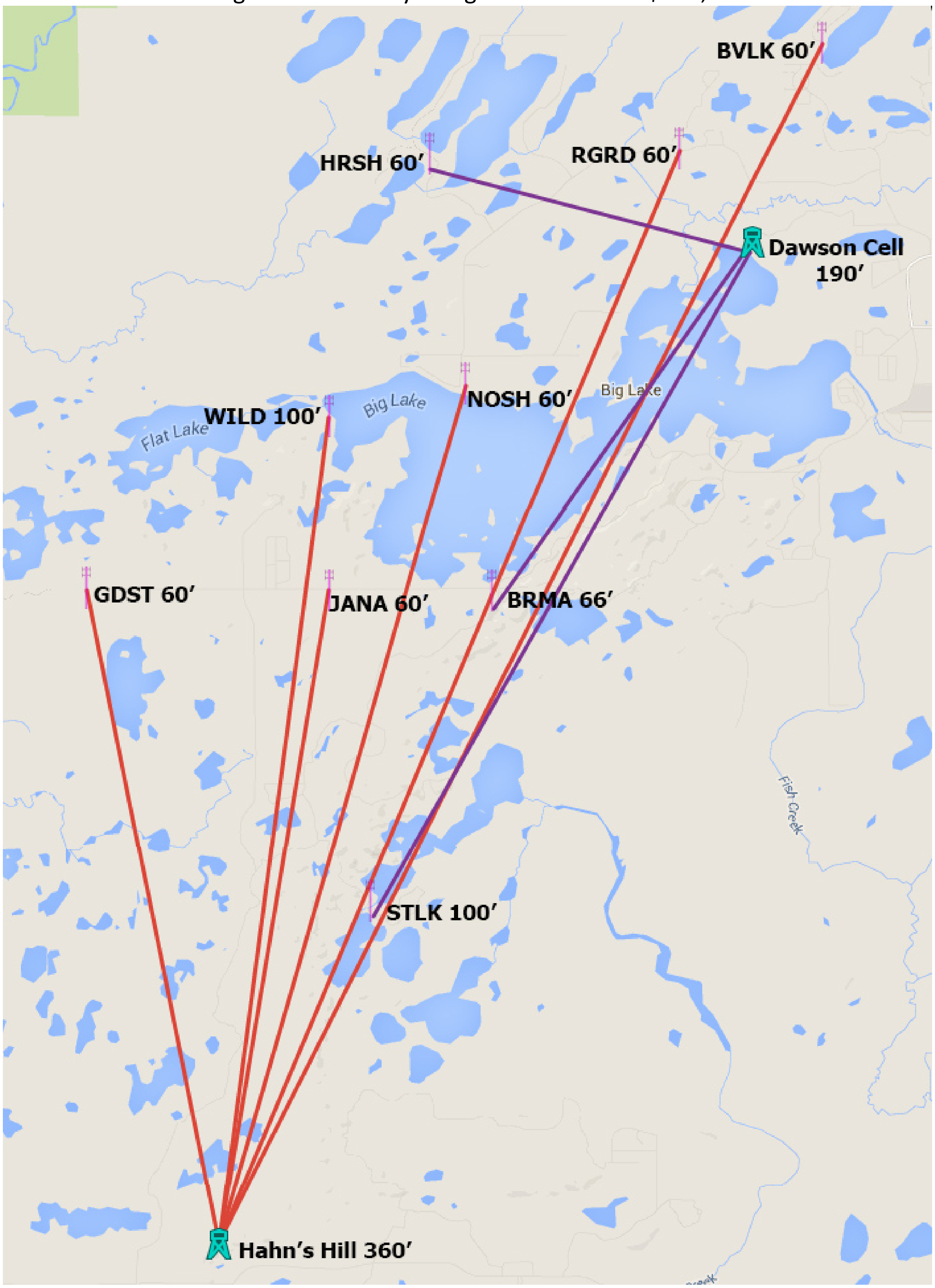
DESIGN 3		
Access Point	**DSLAM CLLI**	**Distance**
Dawson	HRSH	2.78 mi
Dawson	BRMA	3.73 mi
Dawson	STLK	6.52 mi
Padre Pio	RGRD	4.89 mi
Padre Pio	BVLK	3.74 mi
Hahn's Hill	WILD	7.14 mi
Hahn's Hill	NOSH	7.66 mi
Hahn's Hill	JANA	5.66 mi
Hahn's Hill	GDST	5.70 mi
	TOTAL	47.92 mi

DESIGN 2		
Access Point	**DSLAM CLLI**	**Distance**
Dawson	BVLK	1.80 mi
Dawson	RGRD	1.01 mi
Dawson	HRSH	2.87 mi
Dawson	BRMA	3.73 mi
Dawson	STLK	6.52 mi
Hahn's Hill	WILD	7.14 mi
Hahn's Hill	NOSH	7.66 mi
Hahn's Hill	JANA	5.66 mi
Hahn's Hill	GDST	5.70 mi
	TOTAL	42.10 mi

DESIGN 4		
Access Point	**DSLAM CLLI**	**Distance**
Dawson	BRMA	3.73 mi
Dawson	STLK	6.52 mi
Padre Pio	BVLK	3.74 mi
Padre Pio	HRSH	7.04 mi
Padre Pio	RGRD	4.89 mi
Hahn's Hill	WILD	7.14 mi
Hahn's Hill	NOSH	7.66 mi
Hahn's Hill	JANA	5.66 mi
Hahn's Hill	GDST	5.70 mi
	TOTAL	52.10 mi

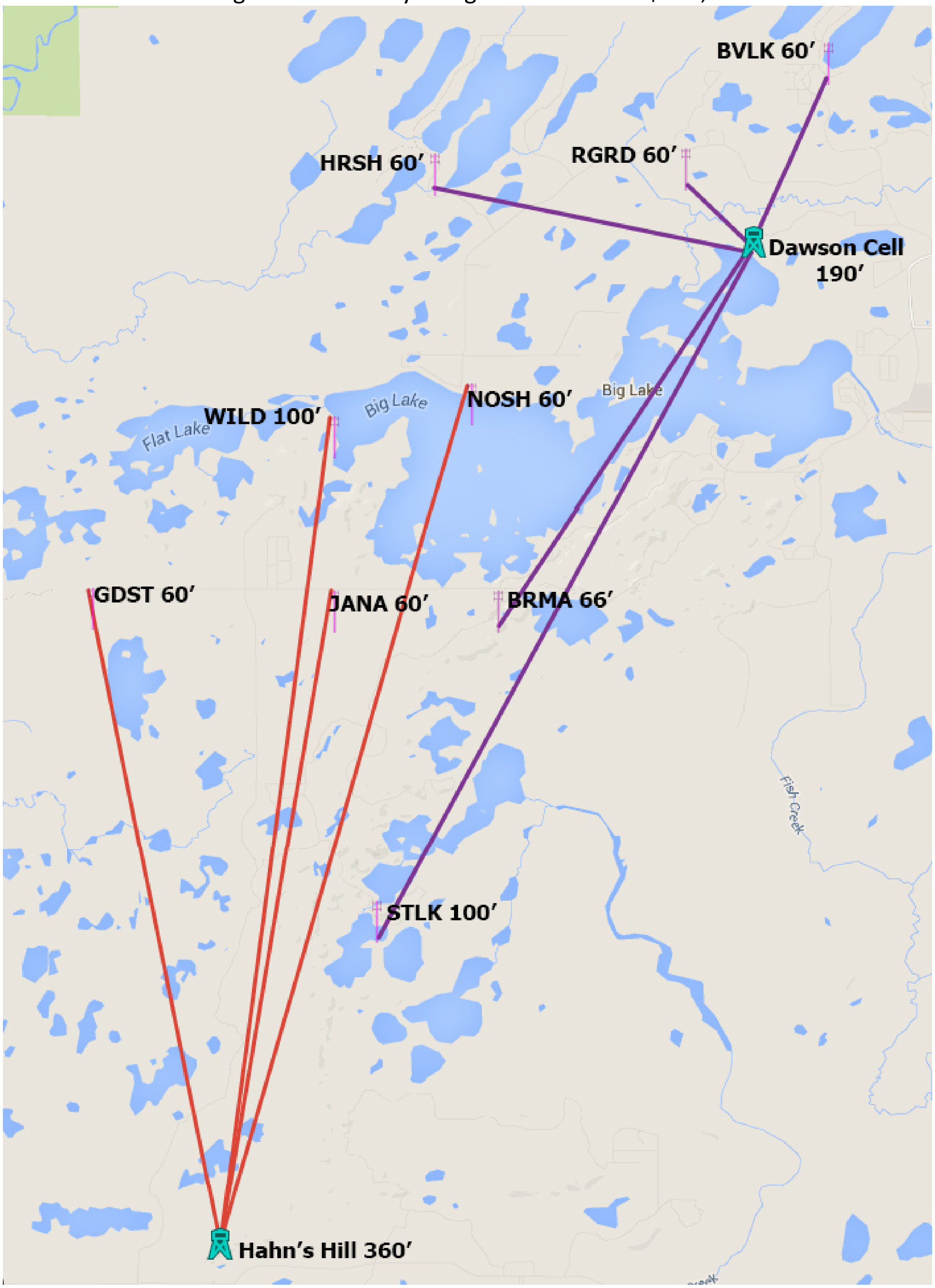
Design 1

Design 1: Preliminary Design Cost Estimate $461,000



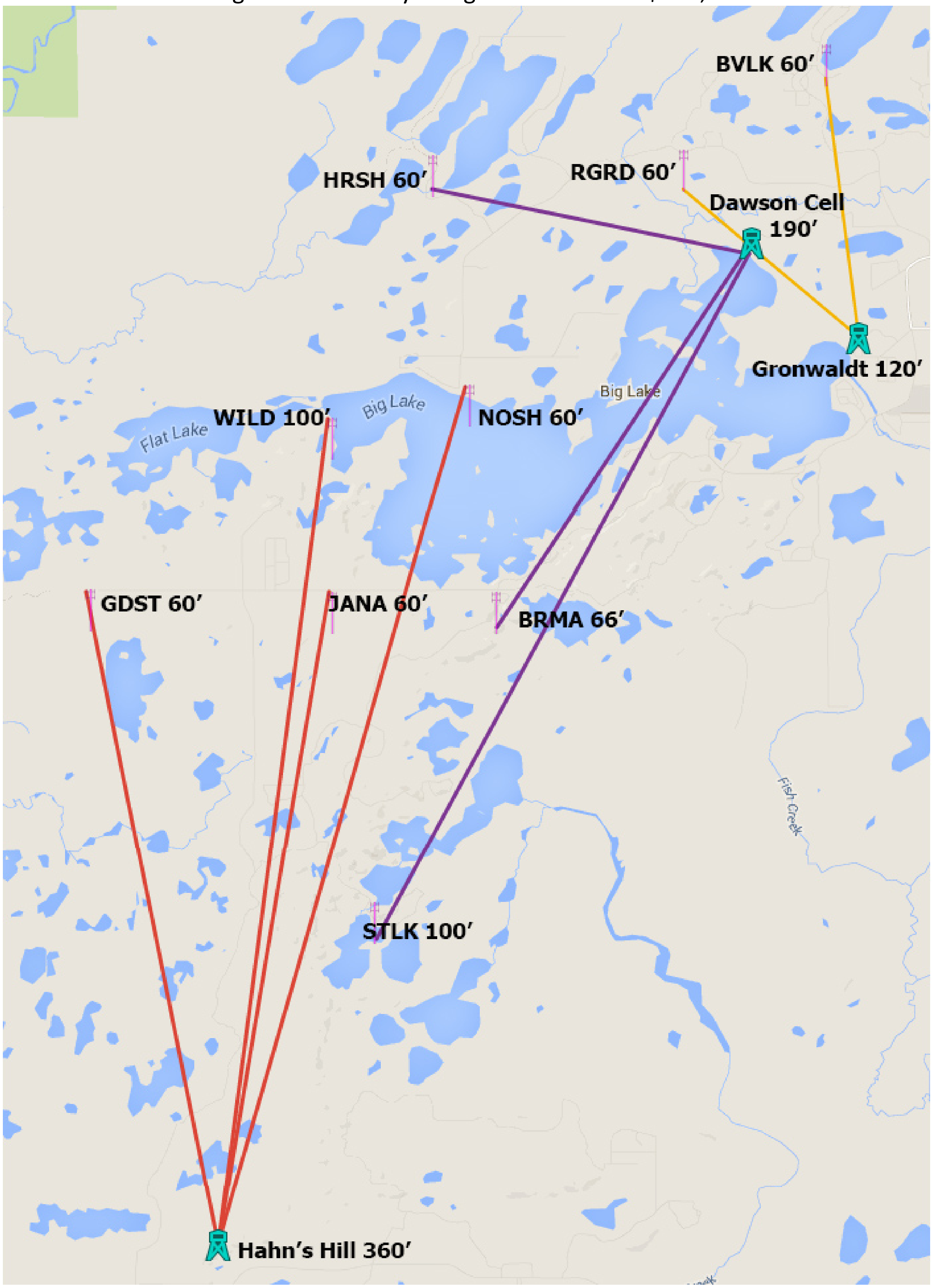
Design 2

Design 2: Preliminary Design Cost Estimate $461,000



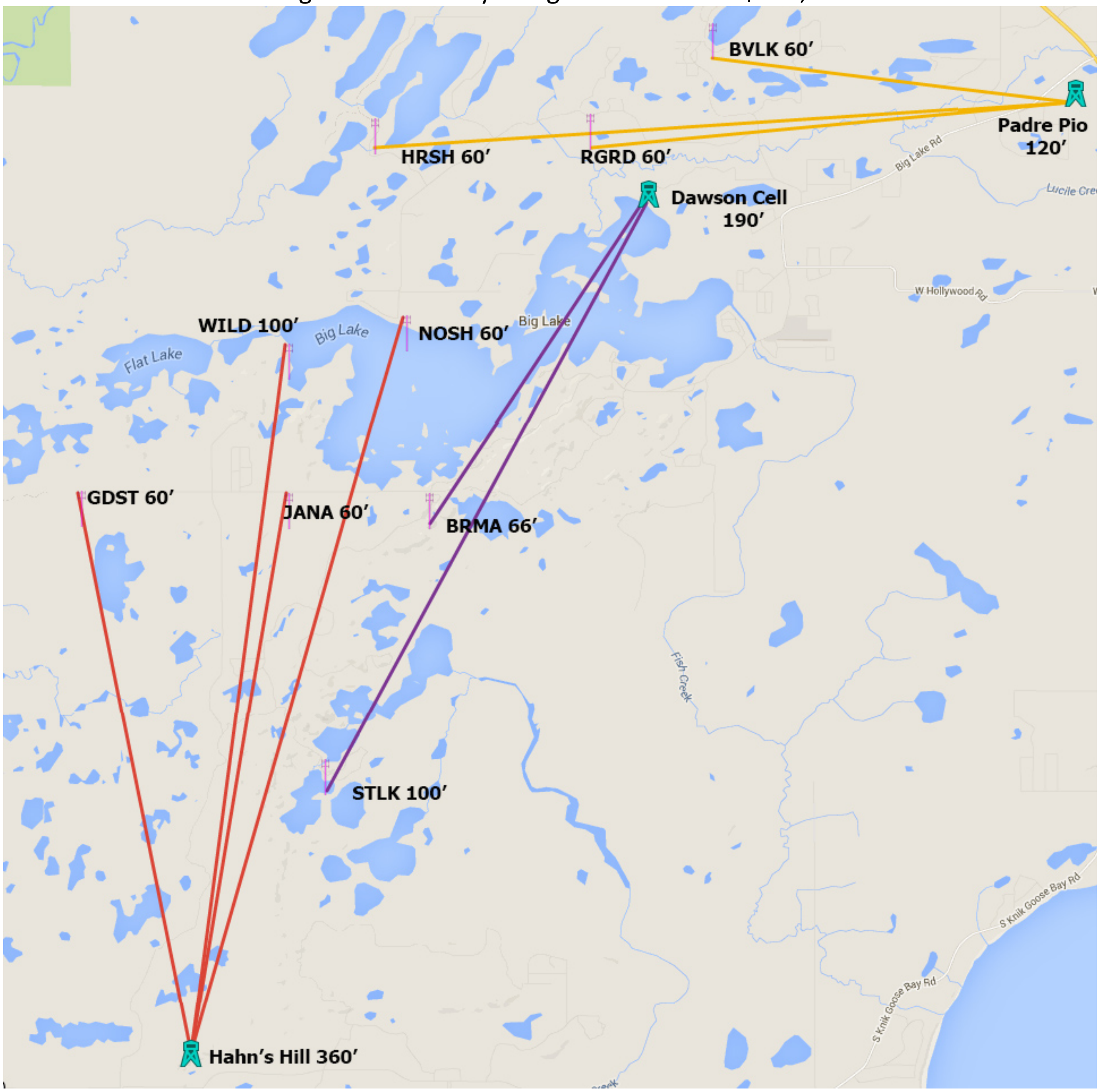
Design 3

Design 3: Preliminary Design Cost Estimate $461,000



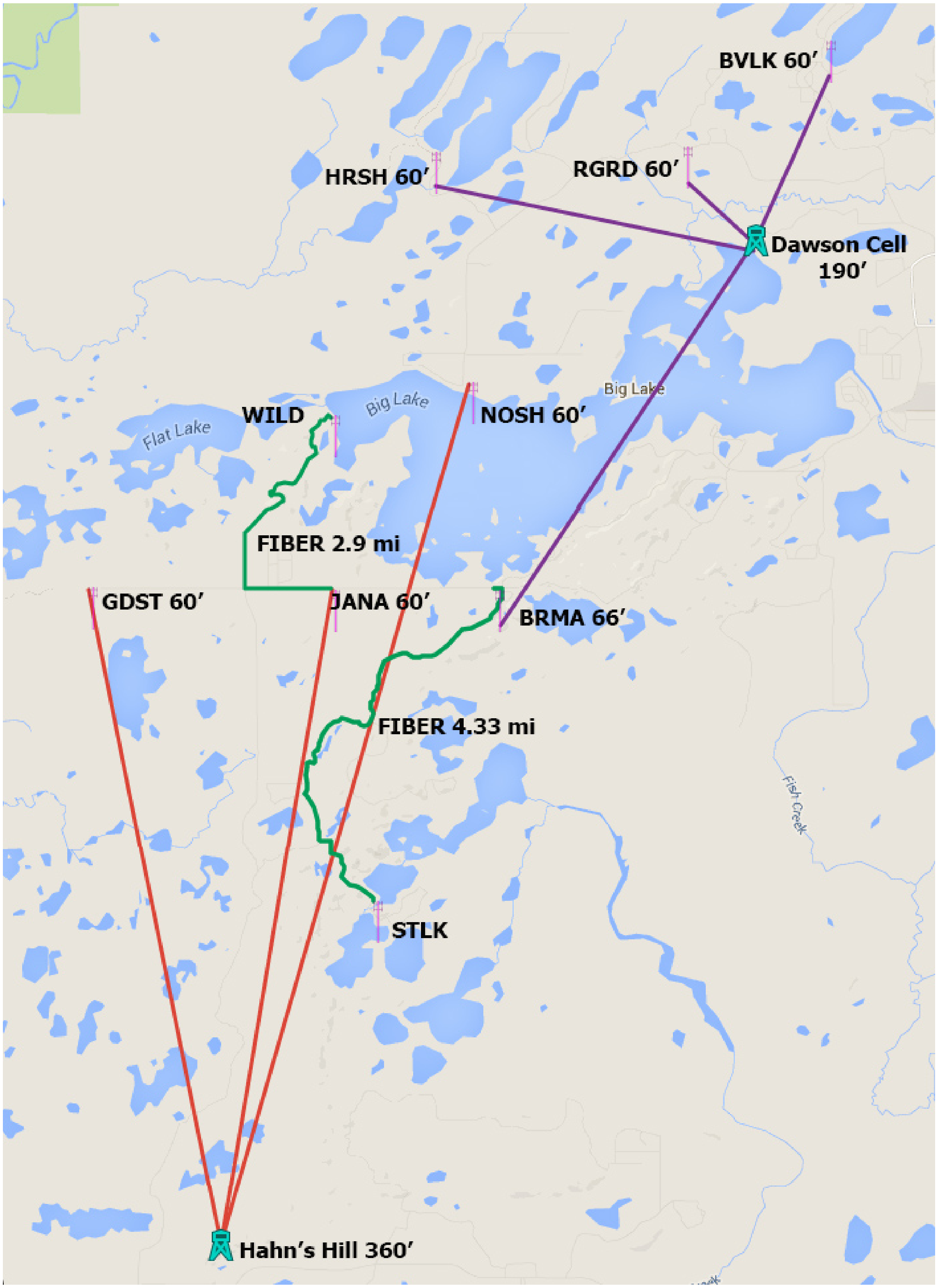
Design 4

Design 4: Preliminary Design Cost Estimate $461,000



Design 5

Design 5: Preliminary Design Cost Estimate $1,144,680 (Aerial/Buried Mixed Fiber at $25/ft.)



Preliminary Recommendations

After analyzing the five preliminary designs, we recommend the following three top designs, in the order of most preferred to least preferred. The recommendation is purely based on estimated cost, Fresnel clearance, and shortest path distance (lowest Free Space Loss).

Design 2

Design 2 is an all microwave transport solution using the Hahn Hill tower and Dawson tower access points. It is a low cost option at $461,000. The design utilizes the shortest required antenna height at the DSLAMs for proper Fresnel clearance and the shortest overall path distance, see Table 8. Tower loading availability will need to be analyzed at a future date.

Advantages:

- Low cost
- Short microwave path distances (low path loss)
- Only two access points required

Disadvantages:

- Requires building two 100 ft. towers
- Possible tower loading issues with multiple antennas per access point tower

Design 3

Design 3 is another all microwave transport solution. This design includes Gronwaldt in addition to Hahn Hill and Dawson access points. The cost is equivalent to Design 2 at $461,000. This design also utilizes the shortest required antenna height at the DSLAM for minimum Fresnel clearance and has the second overall path distance, see Table 8. Tower loading availability will need to be analyzed at a future date.

Advantages:

- Low cost
- Short microwave path distances (low path loss)
- Multiple access point towers used to minimize loading issues

Disadvantages:

- Requires building two 100 ft. towers
- Possible tower loading issues with multiple antennas per access point tower

Design 5

Design 5 is a hybrid fiber/microwave transport solution. Fiber-optic transport is clearly more expensive than microwave transport. This design has a cost of $1,144,680, but this design might be considered if tower permits may not be acquired or there are plans to extend the current fiber-optic network at a future date. The fiber-optic cable runs in this design would be an investment in the aforementioned future project. The aerial and buried hybrid cost of $25/ft. was used in the estimate as a conservative measure but much of the area has overhead power-lines.

Advantages:

- Requires only 60 ft. wooden poles.
- Futureproof-can be integrated into existing fiber network at a future date

Disadvantages:

- High overall cost
- Full fiber capacity unavailable-will be limited by microwave link

4. Final Design Methodology

Choosing a System Design

Our team held an interim project meeting with MTA on March 6th when we presented five candidate system designs. After discussion with MTA, the company and our team agreed to pursue Design 2 (see above in Chapter 3). This design was chosen because of its low cost, shorter path lengths, and because it uses only two towers, Hahn's Hill and Dawson, as access points. MTA has existing buildings, called "huts," beside both of these towers. These existing huts can be used to house microwave equipment, eliminating the need to build enclosures at these locations.

Adjustments to System Design

Access Point Tower Loading

In Design 2 four antennas are installed at Hahn's Hill, and five antennas are installed at Dawson. After the interim meeting, MTA provided us with information on space available for antennas on each tower. Hahn's Hill holds only a few existing antennas, but MTA determined that 360 ft. is the maximum height for placement of new antennas. Below 360 ft. Hahn's Hill has plenty of space available. Dawson has a number of existing antennas at and near the top, but space is available lower on the tower. Table 9 below shows availability of space for new antennas on the Dawson tower.

Table 9: Space Availability at Dawson[1]

Height	4' Antenna	3' Antenna	2' Antenna
170'	1	1	2
150'	1	2	3
140'	2	2	3
120'	2	3	4

[1]*For each height, availability is either/or, e.g., at 170' can place 1-4' or 1-3' or 2-2' antennas*

DSLAM Towers

MTA also provided new cost information for a 75 ft. tower. The use of 75 ft. towers allowed a reduction in cost for links requiring antenna heights above 60 ft. at the DSLAM. Examples are BRMA and WILD. The updated tower costs are shown below in Table 10.

Table 10: Tower/Pole Cost Estimates Provided by MTA[1]

HEIGHT (AGL)	TYPE	ASSOCIATED COST
60 ft.	Wooden Pole	$27,000
75 ft.	SST[2]	$80,000
100 ft.	SST	$136,000
150 ft.	SST	$187,000
200 ft.	SST	$265,000[3]

[1] *These costs are assuming towers/poles would be installed at existing MTA sites that have property ownership established.*

[2] *SST means self-supporting lattice tower.*

[3] *Cost includes mandatory obstruction lighting as required for towers at this height.*

Revising Antenna Heights

After tower loading and available antenna space were taken into account, we analyzed each of the path profiles again to determine antenna heights required on Dawson. All of our previous path profiles and Fresnel clearances for the links that used Dawson assumed we could use the full 190 ft. Dawson tower height. Since this assumption proved to be incorrect, all of the Dawson links were affected.

We used the following process to decide which antennas would be installed at the available heights:

- We reanalyzed the five links that used Dawson as an access point and found BRMA and STLK had the lowest Fresnel clearances. It was obvious that these links would need to be at the maximum height available on Dawson, which was 170 ft.
- The reduction in antenna heights at the Dawson access point resulted in unacceptable Fresnel clearances for BRMA and STLK. To solve this problem, the reduction in height at the access point was compensated by increasing the antenna heights at the DSLAMs.
- BRMA's infrastructure was changed from a 60 ft. wooden pole to a 75 ft. tower.
- STLK was changed from a 100 ft. tower to a 150 ft. tower. (Note: An antenna height of 105 ft. was sufficient for 0.6 Fresnel clearance and 121 ft. was sufficient for 1.0 Fresnel clearance. If a 125 ft. tower is available and is more cost effective, it can be used.)
- The remaining DSLAMs (HRSH, RGRD, and BVLK) had sufficient clearance to maintain an acceptable Fresnel clearance of greater than 1.0 at any height on the Dawson tower.

Link Design Methodology

To help explain our link design process, the Dawson - BRMA link will be used as an example. The following process was used to set the design parameters for each link:

Step 1: Required Link Speed

The goal of this project was to provide MTA's Big Lake subscribers with high speed Internet service at a minimum rate of 10 Mbps on the downlink and 2 Mbps on the uplink. To calculate the required link speed for each link we looked at the number of subscribers connected to each link and multiplied this number by 10 Mbps. MTA specified an "oversubscription factor" of 5. This meant the link speed required would only need to be 1/5th of the total link speed required to give each customer 10 Mbps. This results in the following equation for link speed.

$$Required\ Link\ speed(Mbps) = \frac{((\#\ of\ subscribers) * (10\ Mbps))}{5}$$

For BRMA the number of subscribers was 79, so plugging this number into the equation above yields a minimum required link speed of 158 Mbps. The link speed was calculated for each link to determine the required modulation type and channel spacing as detailed below.

Step 2: Modulation Type and Channel Spacing

The network transmission equipment MTA specified was NEC iPASOLINK 650/250. Link speed is determined by the modulation type and channel bandwidth configured on the equipment. It was desired to keep the channel bandwidths as small as possible to conserve radio spectrum. Using the information from the iPASOLINK data sheets, found in Appendix E, we selected the modulation type and channel spacing that would give us the required link speed for each link. For the Hahn's Hill - BRMA link, we found that a modulation type of 64QAM and a channel bandwidth of 30 MHz provided a link speed of 178 Mbps. This exceeds the minimum link speed of 158 Mbps required at BRMA. Determining the modulation type and channel spacing is important not only for the required link speed, but also because it defines the transmitter power (in dBm) and receiver sensitivity (in dBm).

Step 3: Path-loss

The free space path loss depends on the distance a radio wave must travel and its frequency. The equation used to calculate the free space path-loss is:

$$Path\ loss(dB) = 36.6 + 20\log_{10}(freq(MHz)) + 20\log_{10}(distance(miles))$$

Using the distance from Dawson to BRMA of 3.73 miles, and the operating frequency of 18 GHz (18,000 MHz), gives a path loss of 133.1 dB.

Step 4: Link Budgets

A fade margin of 30 dB for each link was desirable, but any fade margin greater than 25 dB was deemed to be acceptable. Using the Friis equation in decibel form the fade margin is determined by summing all the gains/losses in a system, and then comparing the signal received to the receiver sensitivity [7].

For the nine links in the final design, our ability to optimize the link budgets was limited by the variables that we could control. These variables were the transmitter power, receiver threshold, waveguide loss, and antenna size. The transmitter power and receiver sensitivity are functions of the modulation type and channel spacing. These settings were adjusted to achieve more favorable transmitter power levels and receiver sensitivities.

The waveguide loss is a function of the length of the waveguide, and the operating radio frequency. Using the waveguide attenuation information for EW180, found in Appendix F, the waveguide loss was determined to be 6.1 dB per 100 ft. For some of the links to achieve a fade margin of at least 25dBm, the antenna height at the access point had to be decreased to minimize waveguide loss. It was also important not to decrease the antenna height by too much because a minimum Fresnel clearance of 0.6 must still be maintained for the links to perform successfully. After all other factors were optimized, the antenna size was considered.

In an effort to optimize cost, we began by placing the low cost 2 ft. antennas on both ends of all nine links. This small antenna size also has a small gain. After completing link budgets using a 2 ft. antenna (38.4 dB gain), the antenna size was increased wherever needed to meet the minimum 25 dB link margin requirement. The Dawson-BRMA link is an example. Table 11 below shows the link budget for the Dawson-BRMA link, as well as the link in the opposite direction from BRMA to Dawson. To maintain an acceptable Fresnel clearance, 170 ft. antenna height was used at Dawson. Antenna availability at Dawson was limited to two 2 ft. antennas at 170 ft. as shown in Table 9 above. This meant we could only use a 2 ft. antenna on the Dawson end of the link. To increase the link margin to acceptable levels, a 4 ft. antenna (44.4 dB gain) was placed on the BRMA tower. While the BRMA link margin is the lowest of the nine links, it still exceeds the 25 dB requirement with a 26.7 dB link margin.

Table 11: Link Budget for Dawson-BRMA link

Dawson – BRMA			BRMA - Dawson		
Transmitter Power (Dawson)	21.0	dBm	Transmitter Power (BRMA)	21.0	dBm
Waveguide Loss (Dawson)	-11.4	dB	Waveguide Loss (BRMA)	-5.6	dB
Antenna Gain (Dawson)	38.4	dB	Antenna Gain (BRMA)	44.4	dB
Path Loss	-133.1	dB	Path Loss	-133.1	dB
Antenna Gain (BRMA)	44.4	dB	Antenna Gain (Dawson)	38.4	dB
Waveguide Loss (BRMA)	-5.6	dB	Waveguide Loss (Dawson)	-11.4	dB
	--------			--------	
Received Power (BRMA)	-46.7	dBm	Received Power (Dawson)	-46.7	dBm
Receiver Sensitivity	-73.0	dBm	Receiver Sensitivity	-73.0	dBm
	--------			--------	
Link Margin (Dawson-BRMA)	**26.7**	**dB**	**Link Margin (BRMA-Dawson)**	**26.7**	**dB**

Using this strategy, we successfully designed a system where all the links have a minimum Fresnel clearance of 0.6, deliver the minimum link speed, and have a link margin of at least 25dB. In fact, over all nine links, the minimum Fresnel clearance we achieved was 90% and the minimum link margin we achieved was 26.7dB

5. Final Design Analysis

The final design topology was the same as our Preliminary Design 2, but the antenna heights were adjusted to reflect tower space availability. The revised Design 2, as shown in the figure below is our Final Design. It should be noted that the access point heights represent the full tower height, not the height at which the antenna is to be placed.

Final Design:

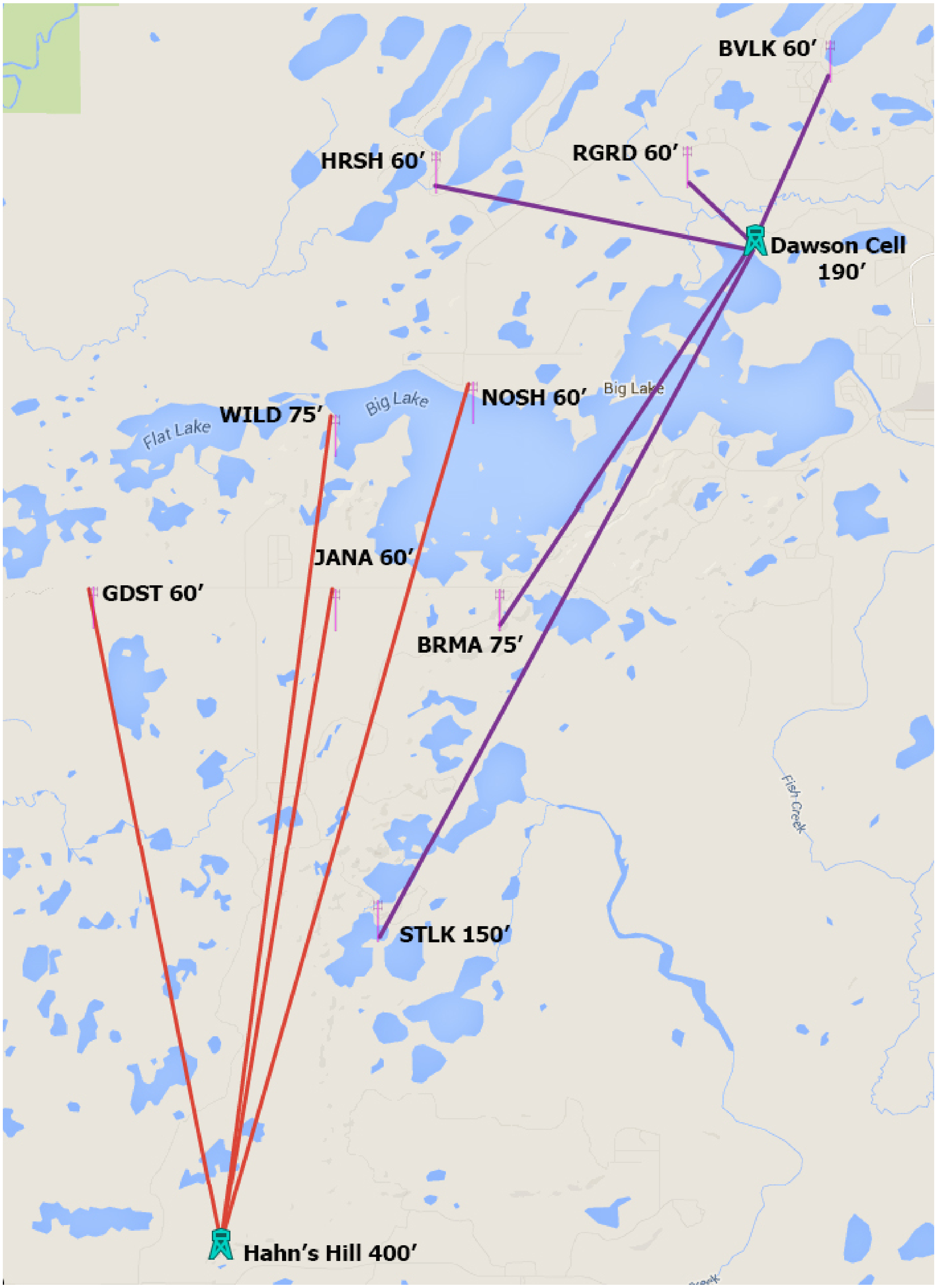


Table 12 below summarizes the antenna heights, antenna sizes, and the Fresnel clearance for each link of the Final Design.

Table 12: Antenna Heights, Sizes, and Fresnel Clearance

LINK	ACCESS POINT	ANTENNA SIZE	ANTENNA HEIGHT		DSLAM	ANTENNA SIZE	ANTENNA HEIGHT	FRESNEL CLEARANCE
Link 1	Dawson	2'	170’	-	BRMA	4'	75’	1.9
Link 2	Dawson	3'	120’	-	BVLK	2'	60’	2.1
Link 3	Dawson	2'	150’	-	HRSH	3'	60’	3.2
Link 4	Dawson	2'	170’	-	STLK	4'	150’	1.6
Link 5	Dawson	2'	150’	-	RGRD	2'	60’	7.4
Link 6	Hahn's Hill	4'	360’	-	WILD	4'	75’	0.9
Link 7	Hahn's Hill	4'	328’	-	NOSH	4'	60’	1.0
Link 8	Hahn's Hill	3'	250’	-	JANA	2'	60’	1.5
Link 9	Hahn's Hill	2'	67.25’	-	GDST	3'	60’	1.5

Table 13 below summarizes individual link costs and total estimated system cost for the Final Design. The total estimated cost of $902,888 is below the goal of $1,596,000. It should be noted that the total cost does not reflect the cost associated with performing a RF Interference Analysis.

Table 13: Estimated Total Cost for Final Design

LINK	ACCESS POINT	DSLAM	ASSOCIATED COST
Link 1	Dawson	BRMA	$123,400
Link 2	Dawson	BVLK	$68,730
Link 3	Dawson	HRSH	$69,270
Link 4	Dawson	STLK	$231,750
Link 5	Dawson	RGRD	$68,460
Link 6	Hahn’s Hill	WILD	$128,130
Link 7	Hahn’s Hill	NOSH	$74,284
Link 8	Hahn’s Hill	JANA	$71,070
Link 9	Hahn’s Hill	GDST	$67,794
		TOTAL	**$902,888**[1]

[1] *Total does not include costs for RF Interference Analysis*

The following pages contain the details of each link design, including a path profile, link capacity calculation, link budget, and detailed cost breakdown.

The lines on the following path profiles indicate: 1st: Line of sight (blue), 2nd: 60% Fresnel clearance (black), 3rd: 140% Fresnel clearance (black). The dashed line represents the minimum Fresnel clearance that occurs at any point.

Path Profiles

Dawson-BRMA

Distance: 3.73 mi

Free-space path loss: 133.1 dB

Minimum Fresnel Clearance: 1.9

<u>Dawson</u>

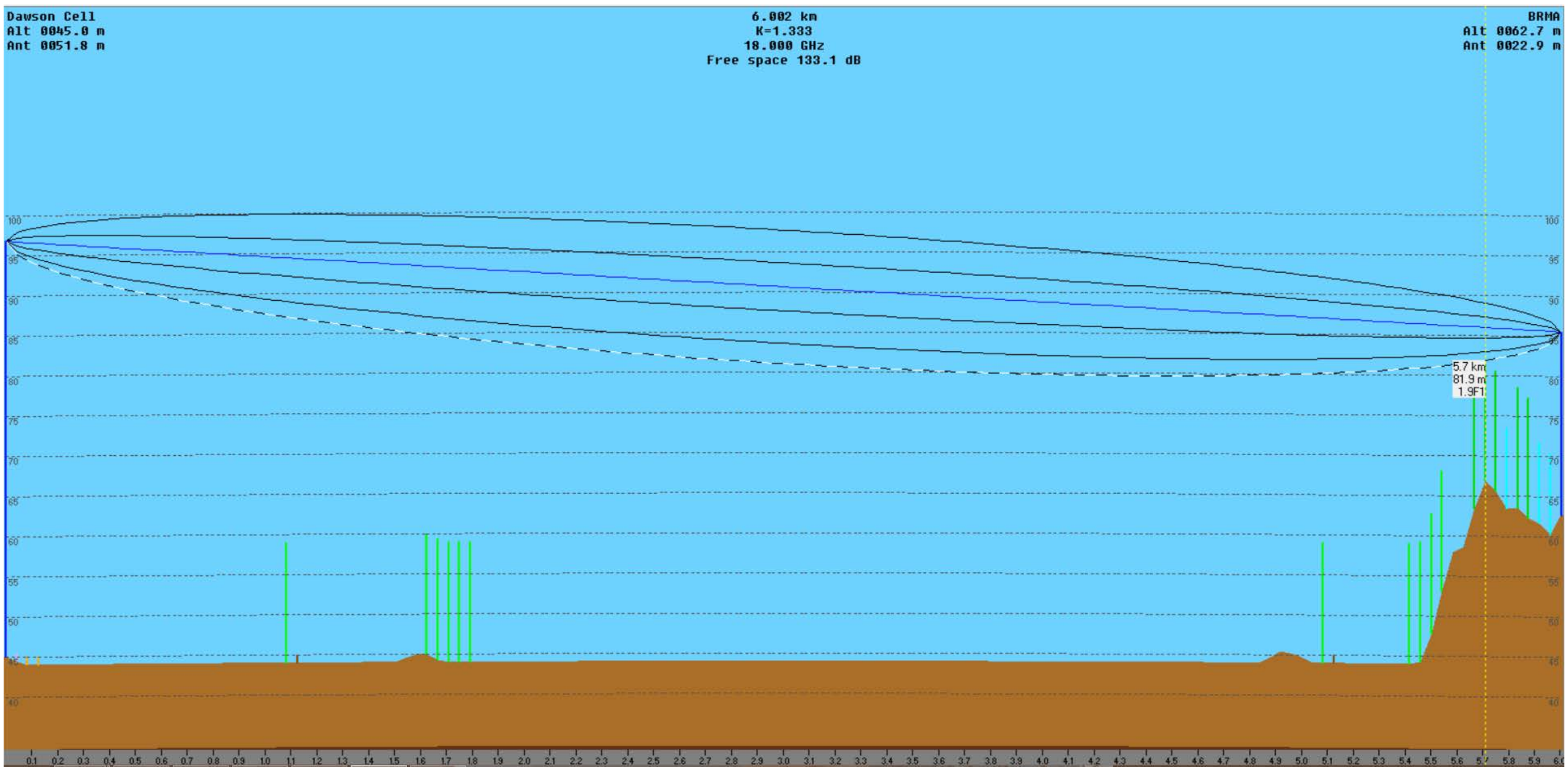
Antenna height: 170’

Existing tower: 190’

<u>BRMA</u>

Antenna height: 75’

New structure: 75’ Tower



Link Capacity:

Number of Subscribers served by BRMA:	79
Minimum Link Speed Required (Mbps):	158
Modulation Type:	64QAM
Channel Bandwidth (MHz):	30
Link Speed Delivered (Mbps):	178

Link Budgets:

Dawson – BRMA

Transmitter Power (Dawson)	21.0	dBm
Waveguide Loss (Dawson)	-11.4	dB
Antenna Gain (Dawson)	38.4	dB
Path Loss	-133.1	dB
Antenna Gain (BRMA)	44.4	dB
Waveguide Loss (BRMA)	-5.6	dB

Received Power (BRMA)	-46.7	dBm
Receiver Sensitivity	-73.0	dBm

Link Margin (Dawson-BRMA)	**26.7**	**dB**

BRMA - Dawson

Transmitter Power (BRMA)	21.0	dBm
Waveguide Loss (BRMA)	-5.6	dB
Antenna Gain (BRMA)	44.4	dB
Path Loss	-133.1	dB
Antenna Gain (Dawson)	38.4	dB
Waveguide Loss (Dawson)	-11.4	dB

Received Power (Dawson)	-46.7	dBm
Receiver Sensitivity	-73.0	dBm

Link Margin (BRMA-Dawson)	**26.7**	**dB**

Link Costs:

Access Point: Dawson

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$3,580
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: BRMA

Category	Description	Cost
New structure	75 ft Tower	$80,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,870
Antenna	4 ft. CommScope 17.7– 19.7 GHz	$2,630
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$123,400**

Dawson-BVLK

Distance: 1.80 mi

Free-space path loss: 126.8 dB

Minimum Fresnel Clearance: 2.1

Dawson

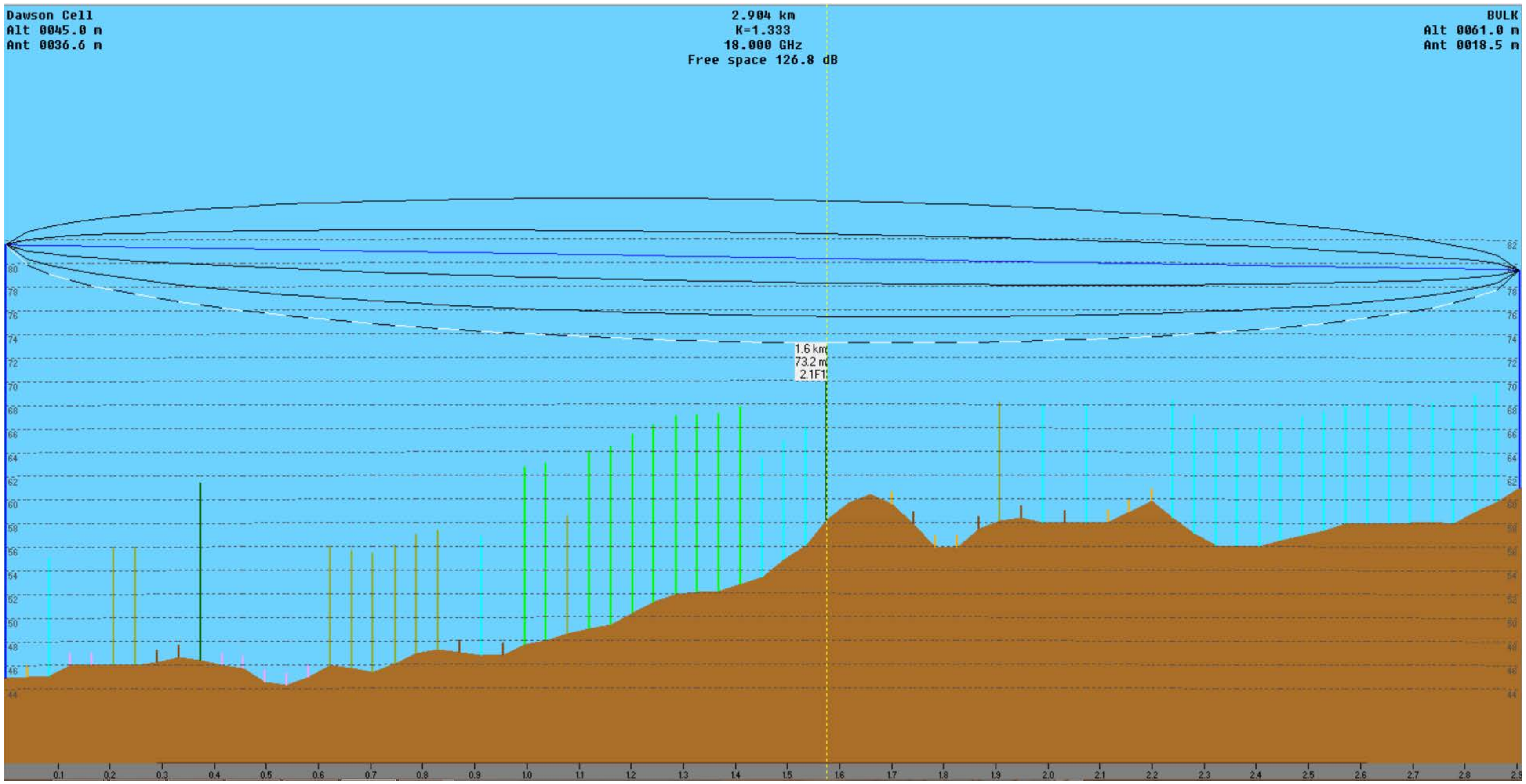
Antenna height: 120'

Existing tower 190'

BVLK

Antenna height: 60'

New structure: 60' Wooden Pole



Link Capacity:

Number of Subscribers served by BVLK:	123
Minimum Link Speed Required (Mbps):	246
Modulation Type:	128QAM
Channel Bandwidth (MHz):	40
Link Speed Delivered (Mbps):	262

Link Budgets:

Dawson – BVLK		
Transmitter Power (Dawson)	21.0	dBm
Waveguide Loss (Dawson)	-8.3	dB
Antenna Gain (Dawson)	42.7	dB
Path Loss	-126.8	dB
Antenna Gain (BVLK)	38.4	dB
Waveguide Loss (BVLK)	-4.7	dB

Received Power (BVLK)	-37.7	dBm
Receiver Sensitivity	-68.5	dBm

Link Margin (Dawson-BVLK)	**30.8**	**dB**

BVLK - Dawson		
Transmitter Power (BVLK)	21.0	dBm
Waveguide Loss (BVLK)	-4.7	dB
Antenna Gain (BVLK)	38.4	dB
Path Loss	-126.8	dB
Antenna Gain (Dawson)	42.7	dB
Waveguide Loss (Dawson)	-8.3	dB

Received Power (Dawson)	-37.7	dBm
Receiver Sensitivity	-68.5	dBm

Link Margin (BVLK-Dawson)	**30.8**	**dB**

Link Costs:

Access Point: Dawson

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$2,680
Antenna	3 ft. CommScope 17.7– 19.7 GHz	$2,130
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: BVLK

Category	Description	Cost
New structure	60 ft Wooden Pole	$27,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,600
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$68,730**

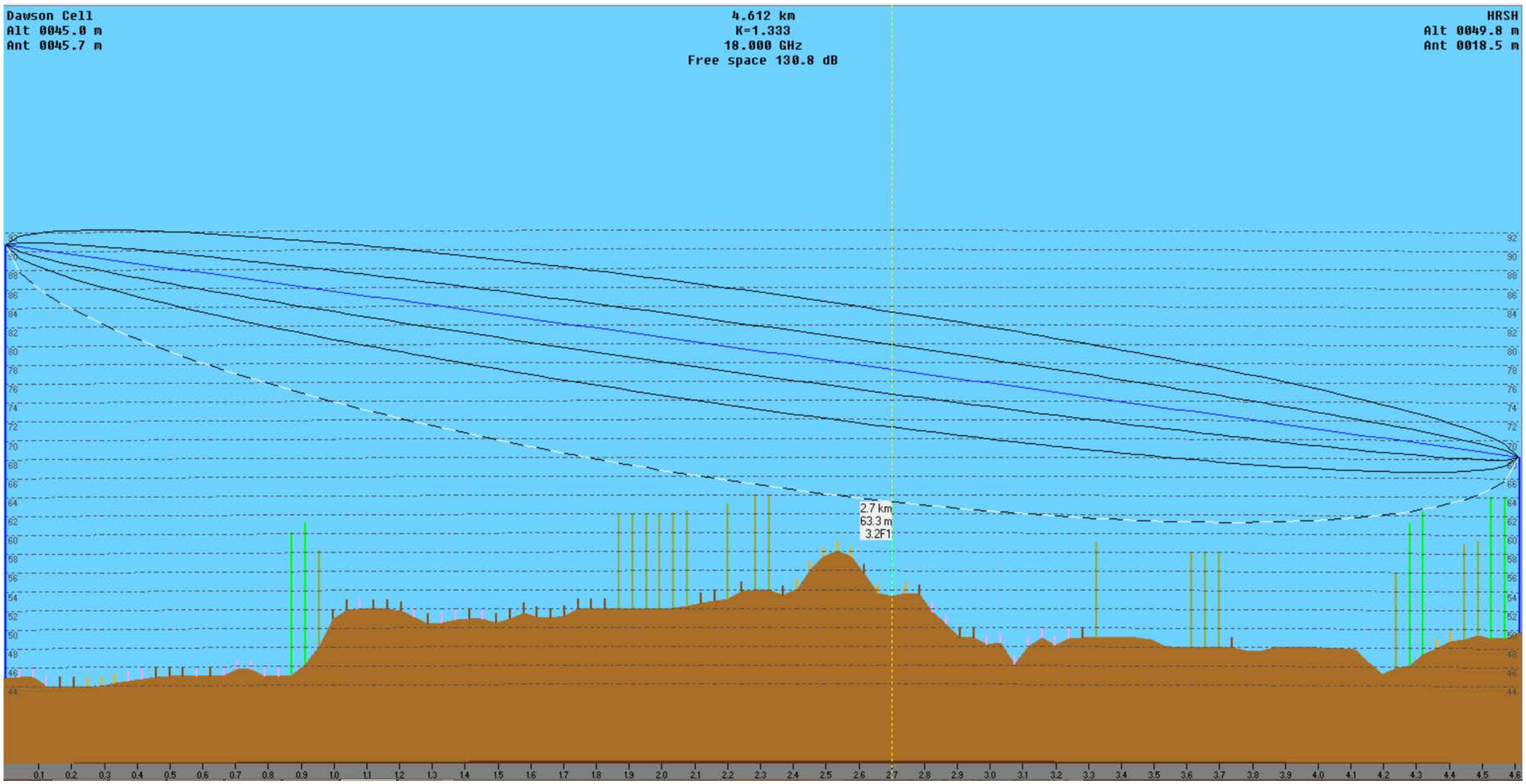
Dawson-HRSH

Distance: 2.87 mi

Free-space path loss: 130.9 dB

Minimum Fresnel Clearance: 3.2

Dawson	HRSH
Antenna height: 150’	Antenna height: 60’
Existing tower: 190’	New structure: 60’ Wooden Pole



Link Capacity:

Number of Subscribers served by HRSH:	69
Minimum Link Speed Required (Mbps):	138
Modulation Type:	32QAM
Channel Bandwidth (MHz):	30
Link Speed Delivered (Mbps):	148

Link Budgets:

Dawson – HRSH

Transmitter Power (Dawson)	21.0	dBm
Waveguide Loss (Dawson)	-10.2	dB
Antenna Gain (Dawson)	38.4	dB
Path Loss	-130.9	dB
Antenna Gain (HRSH)	42.7	dB
Waveguide Loss (HRSH)	-4.7	dB

Received Power (HRSH)	-43.6	dBm
Receiver Sensitivity	-76.0	dBm

Link Margin (Dawson-HRSH)	**32.4**	**dB**

HRSH - Dawson

Transmitter Power (HRSH)	21.0	dBm
Waveguide Loss (HRSH)	-4.7	dB
Antenna Gain (HRSH)	42.7	dB
Path Loss	-130.9	dB
Antenna Gain (Dawson)	38.4	dB
Waveguide Loss (Dawson)	-10.2	dB

Received Power (Dawson)	-43.6	dBm
Receiver Sensitivity	-76.0	dBm

Link Margin (HRSH-Dawson)	**32.4**	**dB**

Link Costs:

Access Point: Dawson

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$3,220
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: HRSH

Category	Description	Cost
New structure	60 ft Wooden Pole	$27,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,600
Antenna	3 ft. CommScope 17.7– 19.7 GHz	$2,130
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$69,270**

Dawson-STLK

Distance: 6.52 mi

Free-space path loss: 138.0 dB

Minimum Fresnel Clearance: 1.6

<u>Dawson</u>

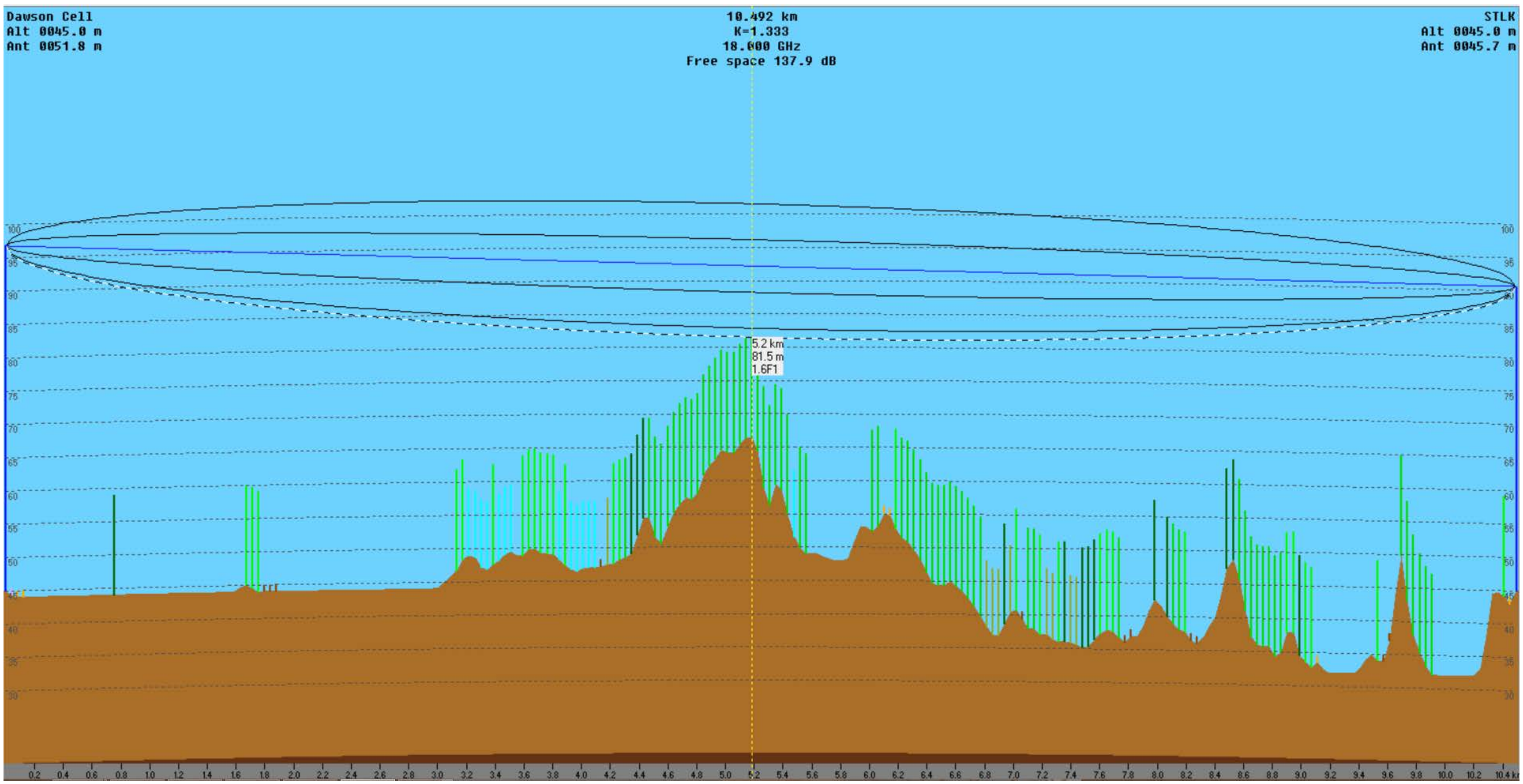
Antenna height: 170’

Existing tower: 190’

<u>STLK</u>

Antenna height: 150’

New structure: 150’ Tower



Link Capacity:

Number of Subscribers served by STLK:	31
Minimum Link Speed Required (Mbps):	62
Modulation Type:	QPSK
Channel Bandwidth (MHz):	40
Link Speed Delivered (Mbps):	75

Link Budgets:

Dawson – STLK

Transmitter Power (Dawson)	24.0	dBm
Waveguide Loss (Dawson)	-11.4	dB
Antenna Gain (Dawson)	38.4	dB
Path Loss	-138.0	dB
Antenna Gain (STLK)	44.4	dB
Waveguide Loss (STLK)	-10.2	dB

Received Power (STLK)	-52.7	dBm
Receiver Sensitivity	-84.5	dBm

Link Margin (Dawson-STLK)	**31.8**	**dB**

STLK - Dawson

Transmitter Power (STLK)	24.0	dBm
Waveguide Loss (STLK)	-10.2	dB
Antenna Gain (STLK)	44.4	dB
Path Loss	-138.0	dB
Antenna Gain (Dawson)	38.4	dB
Waveguide Loss (Dawson)	-11.4	dB

Received Power (Dawson)	-52.7	dBm
Receiver Sensitivity	-84.5	dBm

Link Margin (STLK-Dawson)	**31.8**	**dB**

Link Costs:

Access Point: **Dawson**

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$3,580
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: STLK

Category	Description	Cost
New structure	150 ft Tower	$187,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$3,220
Antenna	4 ft. CommScope 17.7– 19.7 GHz	$2,630
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$231,750**

Dawson-RGRD

Distance: 1.01 mi

Free-space path loss: 126.8 dB

Minimum Fresnel Clearance: 7.4

<u>Dawson</u>

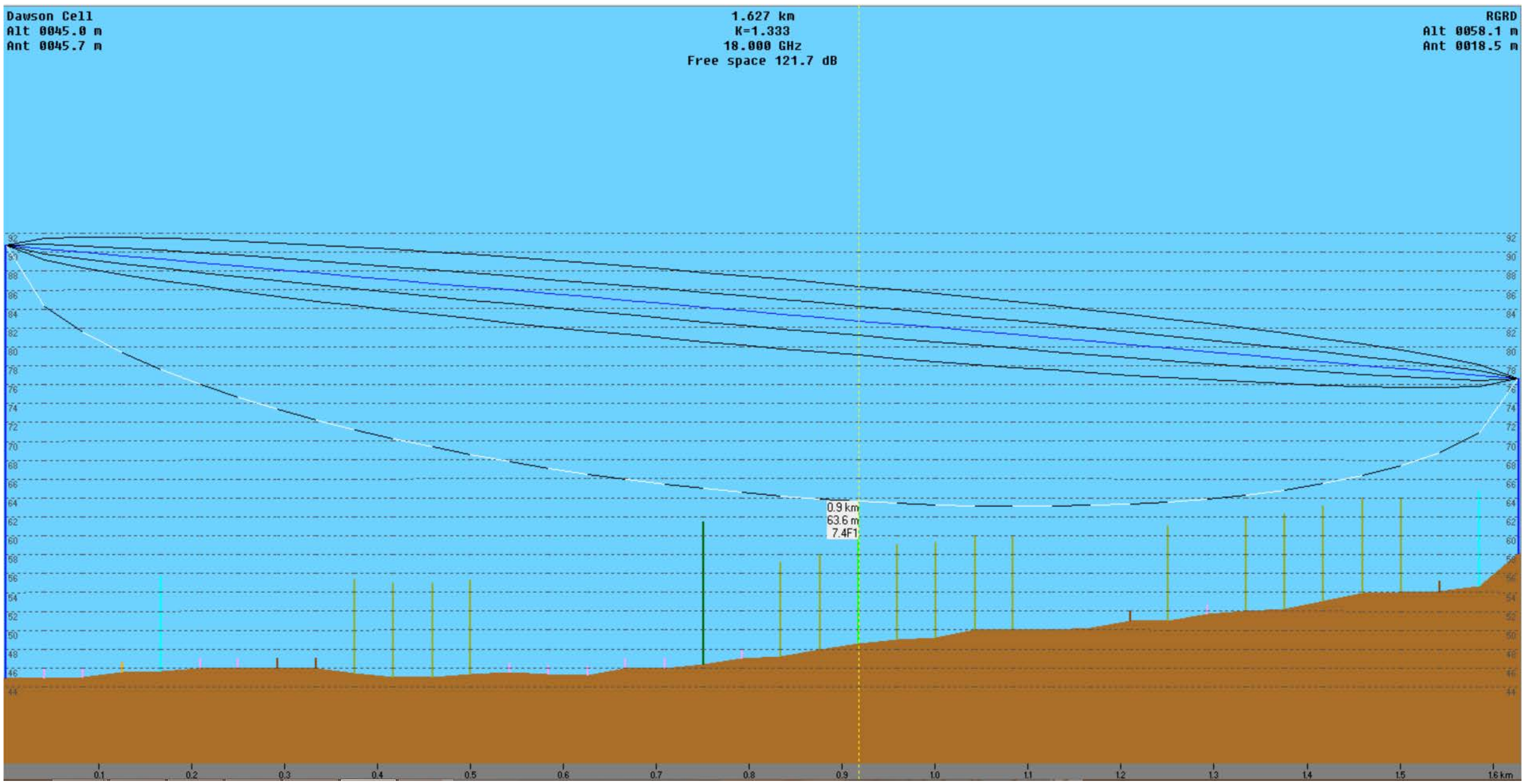
Antenna height: 150’

Existing tower: 190’

<u>RGRD</u>

Antenna height: 60’

New structure: 60’ Wooden Pole



Link Capacity:

Number of Subscribers served by RGRD:	31
Minimum Link Speed Required (Mbps):	62
Modulation Type:	16QAM
Channel Bandwidth (MHz):	20
Link Speed Delivered (Mbps):	80

Link Budgets:

Dawson – RGRD

Transmitter Power (Dawson)	22.0	dBm
Waveguide Loss (Dawson)	-10.2	dB
Antenna Gain (Dawson)	38.4	dB
Path Loss	-121.8	dB
Antenna Gain (RGRD)	38.4	dB
Waveguide Loss (RGRD)	-4.7	dB

Received Power (RGRD)	-37.8	dBm
Receiver Sensitivity	-80.5	dBm

Link Margin (Dawson-RGRD)	**42.7**	**dB**

RGRD - Dawson

Transmitter Power (RGRD)	22.0	dBm
Waveguide Loss (RGRD)	-4.7	dB
Antenna Gain (RGRD)	38.4	dB
Path Loss	-121.8	dB
Antenna Gain (Dawson)	38.4	dB
Waveguide Loss (Dawson)	-10.2	dB

Received Power (Dawson)	-37.8	dBm
Receiver Sensitivity	-80.5	dBm

Link Margin (RGRD-Dawson)	**42.7**	**dB**

Link Costs:

Access Point: Dawson

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$3,220
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: RGRD

Category	Description	Cost
New structure	60 ft Wooden Pole	$27,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,600
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$68,460**

Hahn's Hill - WILD

Distance: 7.14 mi

Free-space path loss: 138.8 dB

Minimum Fresnel Clearance: 0.9

<u>Hahn's Hill</u>

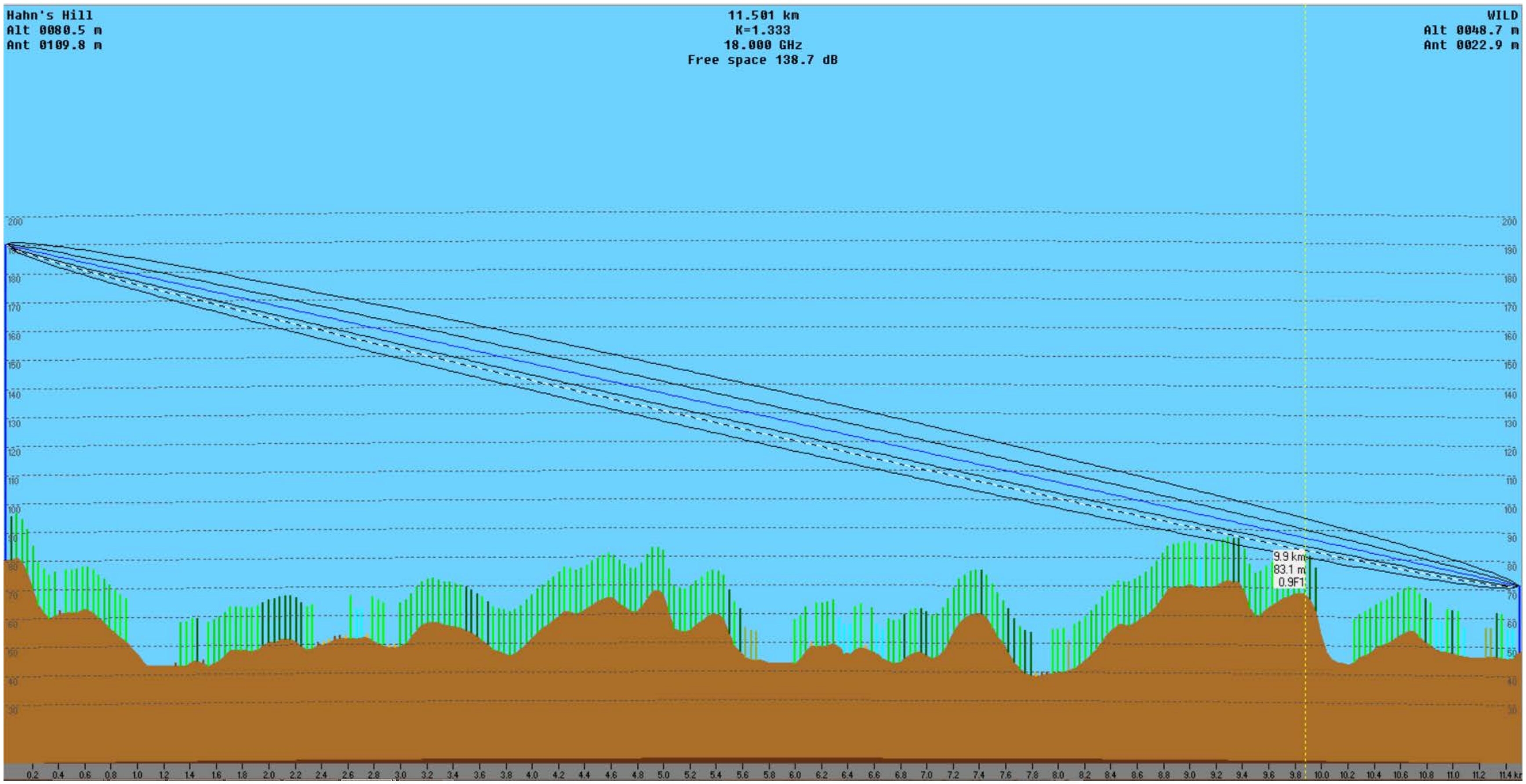
Antenna height: 360'

Existing tower: 400'

<u>WILD</u>

Antenna height: 75'

New structure: 75' Tower



Link Capacity:

Number of Subscribers served by WILD:	59
Minimum Link Speed Required (Mbps):	118
Modulation Type:	QPSK
Channel Bandwidth (MHz):	60
Link Speed Delivered (Mbps):	121

Link Budgets:

Hahn's Hill – WILD

Transmitter Power (Hahn's Hill)	24.0	dBm
Waveguide Loss (Hahn's Hill)	-23.0	dB
Antenna Gain (Hahn's Hill)	44.4	dB
Path Loss	-138.8	dB
Antenna Gain (WILD)	44.4	dB
Waveguide Loss (WILD)	-5.6	dB

Received Power (WILD)	-54.5	dBm
Receiver Sensitivity	-83.0	dBm

Link Margin (Hahn's Hill-WILD)	**28.5**	**dB**

WILD – Hahn's Hill

Transmitter Power (WILD)	24.0	dBm
Waveguide Loss (WILD)	-5.6	dB
Antenna Gain (WILD)	44.4	dB
Path Loss	-138.8	dB
Antenna Gain (Hahn's Hill)	44.4	dB
Waveguide Loss (Hahn's Hill)	-23.0	dB

Received Power (Hahn's Hill)	-54.5	dBm
Receiver Sensitivity	-83.0	dBm

Link Margin (WILD-Hahn's Hill)	**28.5**	**dB**

Link Costs:

Access Point: Hahn's Hill

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$7,000
Antenna	4 ft. CommScope 17.7– 19.7 GHz	$2,630
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: WILD

Category	Description	Cost
New structure	75 ft Tower	$80,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,870
Antenna	4 ft. CommScope 17.7– 19.7 GHz	$2,630
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$128,130**

Hahn's Hill - NOSH

Distance: 7.66 mi

Free-space path loss: 139.4 dB

Minimum Fresnel Clearance: 1.0

<u>Hahn's Hill</u>

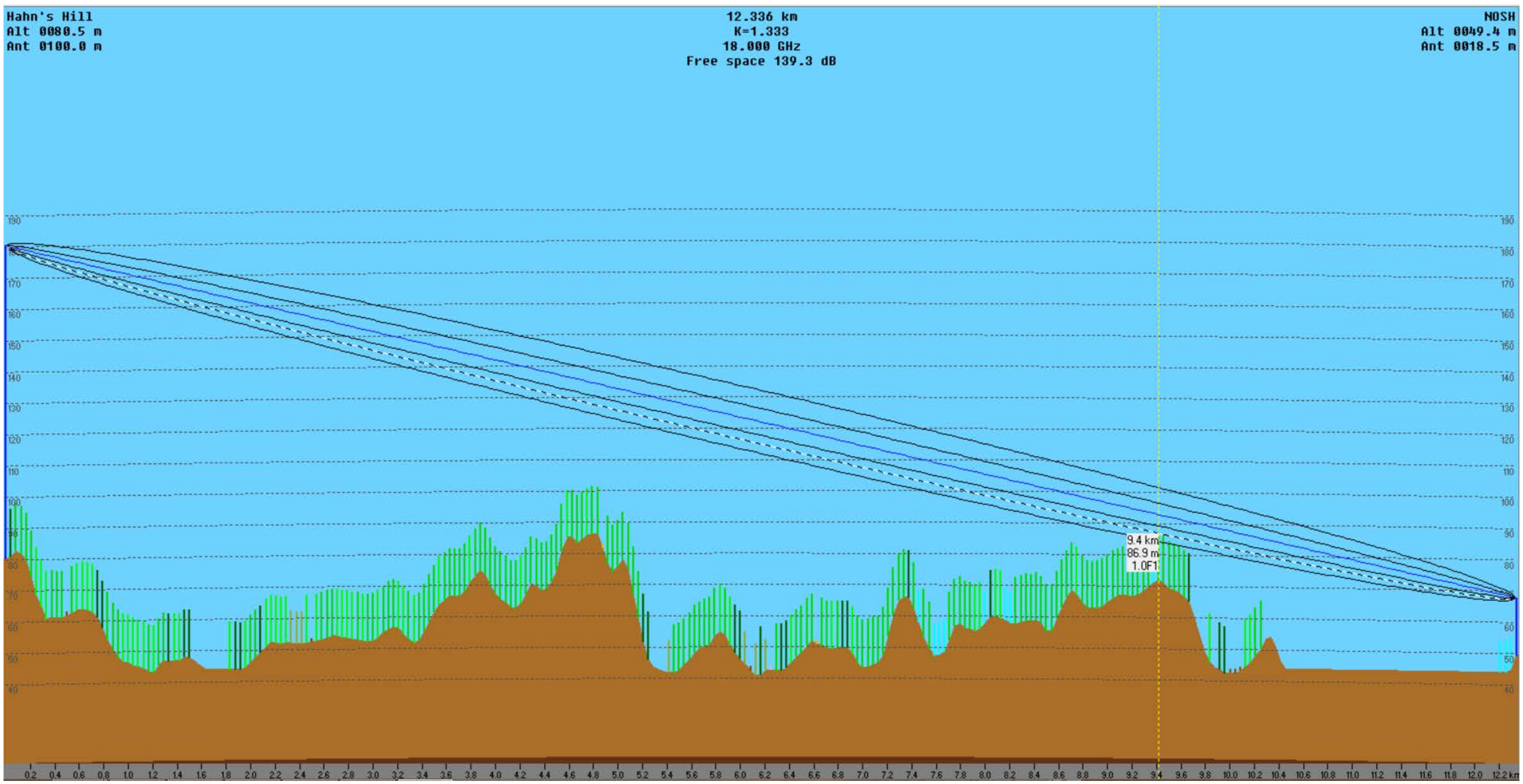
Antenna height: 328'

Existing tower: 400'

<u>NOSH</u>

Antenna height: 60'

New structure: 60' Wooden Pole



Link Capacity:

Number of Subscribers served by NOSH:	59
Minimum Link Speed Required (Mbps):	118
Modulation Type:	QPSK
Channel Bandwidth (MHz):	60
Link Speed Delivered (Mbps):	121

Link Budgets:

Hahn's Hill – NOSH

Transmitter Power (Hahn's Hill)	24.0	dBm
Waveguide Loss (Hahn's Hill)	-21.0	dB
Antenna Gain (Hahn's Hill)	44.4	dB
Path Loss	-139.4	dB
Antenna Gain (NOSH)	44.4	dB
Waveguide Loss (NOSH)	-4.7	dB

Received Power (NOSH)	-52.3	dBm
Receiver Sensitivity	-83.0	dBm

Link Margin (Hahn's Hill-NOSH)	**30.7**	**dB**

NOSH – Hahn's Hill

Transmitter Power (NOSH)	24.0	dBm
Waveguide Loss (NOSH)	-4.7	dB
Antenna Gain (NOSH)	44.4	dB
Path Loss	-139.4	dB
Antenna Gain (Hahn's Hill)	44.4	dB
Waveguide Loss (Hahn's Hill)	-21.0	dB

Received Power (Hahn's Hill)	-52.3	dBm
Receiver Sensitivity	-83.0	dBm

Link Margin (NOSH-Hahn's Hill)	**30.7**	**dB**

Link Costs:

Access Point: Hahn's Hill

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$6,424
Antenna	4 ft. CommScope 17.7– 19.7 GHz	$2,630
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: NOSH

Category	Description	Cost
New structure	60 ft Wooden Pole	$27,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,600
Antenna	4 ft. CommScope 17.7– 19.7 GHz	$2,630
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$74,284**

Hahn’s Hill - JANA

Distance: 5.66 mi

Free-space path loss: 136.8 dB

Minimum Fresnel Clearance: 1.5

<u>Hahn’s Hill</u>

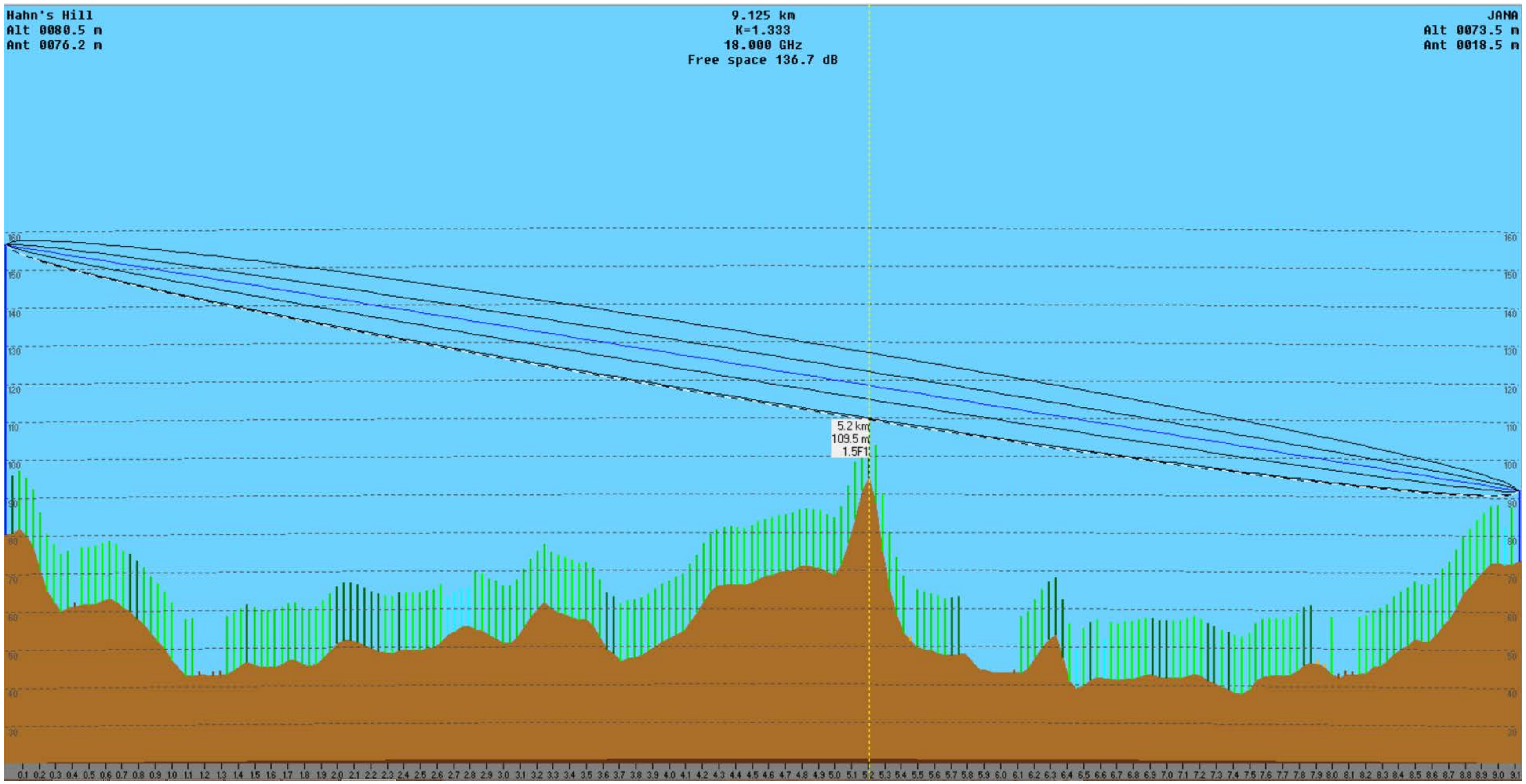
Antenna height: 250’

Existing tower: 400’

<u>JANA</u>

Antenna height: 60’

New structure: 60’ Wooden Pole



Link Capacity:

Number of Subscribers served by JANA:	25
Minimum Link Speed Required (Mbps):	50
Modulation Type:	QPSK
Channel Bandwidth (MHz):	30
Link Speed Delivered (Mbps):	58

Link Budgets:

Hahn's Hill – JANA

Transmitter Power (Hahn's Hill)	24.0	dBm
Waveguide Loss (Hahn's Hill)	-16.3	dB
Antenna Gain (Hahn's Hill)	42.7	dB
Path Loss	-136.8	dB
Antenna Gain (JANA)	38.4	dB
Waveguide Loss (JANA)	-4.7	dB

Received Power (JANA)	-52.6	dBm
Receiver Sensitivity	-86.0	dBm

Link Margin (Hahn's Hill-JANA)	**33.4**	**dB**

JANA – Hahn's Hill

Transmitter Power (JANA)	24.0	dBm
Waveguide Loss (JANA)	-4.7	dB
Antenna Gain (JANA)	38.4	dB
Path Loss	-136.8	dB
Antenna Gain (Hahn's Hill)	42.7	dB
Waveguide Loss (Hahn's Hill)	-16.3	dB

Received Power (Hahn's Hill)	-52.6	dBm
Receiver Sensitivity	-86.0	dBm

Link Margin (JANA-Hahn's Hill)	**33.4**	**dB**

Link Costs:

Access Point: Hahn's Hill

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$5,020
Antenna	3 ft. CommScope 17.7– 19.7 GHz	$2,130
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: JANA

Category	Description	Cost
New structure	60 ft Wooden Pole	$27,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,600
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$71,070**

Hahn's Hill - GDST

Distance: 5.70 mi

Free-space path loss: 136.8 dB

Minimum Fresnel Clearance: 1.5

<u>Hahn's Hill</u>

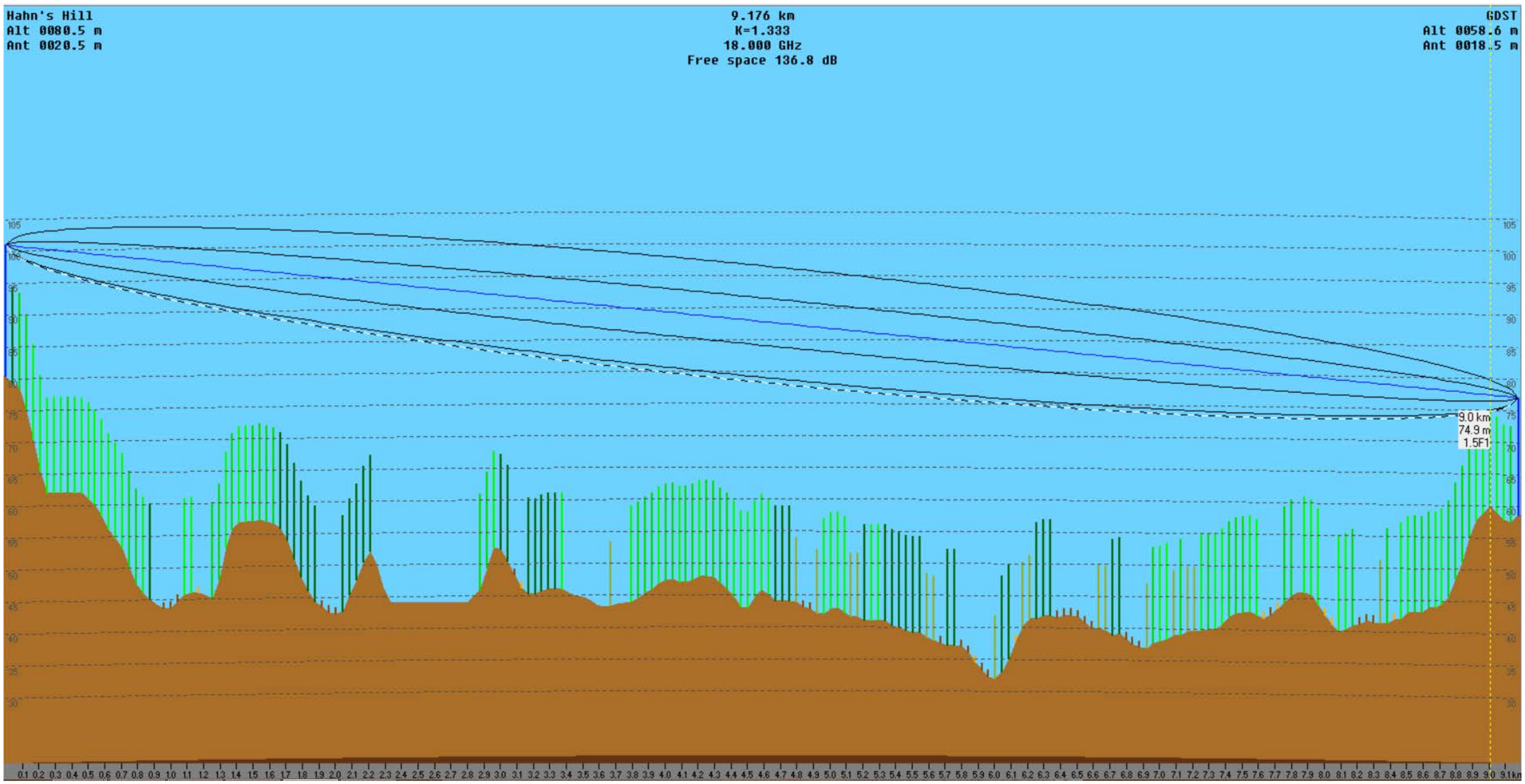
Antenna height: 67.25'

Existing tower: 400'

<u>GDST</u>

Antenna height: 60'

New structure: 60' Wooden Pole



Link Capacity:

Number of Subscribers served by GDST:	56
Minimum Link Speed Required (Mbps):	112
Modulation Type:	32QAM
Channel Bandwidth (MHz):	30
Link Speed Delivered (Mbps):	148

Link Budgets:

Hahn's Hill – GDST		
Transmitter Power (Hahn's Hill)	21.0	dBm
Waveguide Loss (Hahn's Hill)	-5.1	dB
Antenna Gain (Hahn's Hill)	38.4	dB
Path Loss	-136.8	dB
Antenna Gain (GDST)	42.7	dB
Waveguide Loss (GDST)	-4.7	dB

Received Power (GDST)	-44.5	dBm
Receiver Sensitivity	-76.0	dBm

Link Margin (Hahn's Hill-GDST)	**31.5**	**dB**

GDST – Hahn's Hill		
Transmitter Power (GDST)	21.0	dBm
Waveguide Loss (GDST)	-4.7	dB
Antenna Gain (GDST)	42.7	dB
Path Loss	-136.8	dB
Antenna Gain (Hahn's Hill)	38.4	dB
Waveguide Loss (Hahn's Hill)	-5.1	dB

Received Power (Hahn's Hill)	-44.5	dBm
Receiver Sensitivity	-76.0	dBm

Link Margin (GDST-Hahn's Hill)	**31.5**	**dB**

Link Costs:

Access Point: Hahn's Hill

Category	Description	Cost
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,744
Antenna	2 ft. CommScope 17.7– 19.7 GHz	$1,320
Installation	Equipment, Waveguide, Antenna	$4,000

DSLAM: GDST

Category	Description	Cost
New structure	60 ft Wooden Pole	$27,000
Equipment	NEC iPASOLINK 250	$13,000
Waveguide	EW180 and Flex at both ends	$1,600
Antenna	3 ft. CommScope 17.7– 19.7 GHz	$2,130
Installation	Equipment, Waveguide, Antenna	$4,000
	Total Link Cost	**$67,794**

6. Recommendations

We end with some recommendations regarding the implementation of this system design.

Channel Bandwidth/Modulation Type

As part of our final design process, we selected a channel bandwidth and modulation type for each link. Our goal for this step of the design process was to achieve a link margin of at least 25dB. We achieved this goal but used a mixture of different channel bandwidths and modulation types.

MTA may want to consider a small modification to the final design by selecting a standard channel bandwidth, e.g., 30 MHz, and using NEC's "adaptive modulation mode" on all links. This may require a recheck to ensure that an acceptable margin is achieved on all links, but the advantage will be efficiency in stocking equipment spares, all with the same channel bandwidth settings, to be used as replacements when failures occur. This should result in the need to stock fewer spare units.

Future Subscriber Growth

If MTA should decide to implement this microwave design as a long term solution for Big Lake Internet service, subscriber growth may impact the microwave link speeds used in this design. If there is substantial subscriber growth in the area served by a DSLAM, the minimum required link speed may need some readjustment. A related consideration is the possibility of the growth of the fiber-optic network that is already in place. Any planned expansion of the fiber-optic network may present opportunities that were not considered during this design process.

Wooden Pole Twist and Sway

The final microwave design utilizes six of the low cost 60 ft. wooden poles to support microwave antennas. In past meetings with MTA there was some concern expressed that "twist" and "sway" of the wooden poles might cause the antennas to move out of alignment. The 4 ft. antennas might be especially susceptible to twist or sway as they have a beamwidth of only 0.9°.

MTA may want to have a civil engineer analyze the "twist" and "sway" of the wooden poles and make recommendations on the use of guy wires, as needed. If installation of guy wires is needed but prohibited by the limits of the utility easement or by safety concerns, a solution might be to replace the 60 ft. wooden poles with 75 ft. towers. These would likely provide more stability, but replacement of six 60 ft. wooden poles with 75 ft. towers would increase the overall cost of the final design by approximately $318,000. The resultant total system cost would still be well within the original cost target.

7. References

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8. Appendices

Appendix A: Original Project Description by MTA

MTA Big Lake Project

About MTA's Network

MTA provides Internet services over twisted copper pair using ADSL, ADSL2+ and soon VDSL2. Today 70% of MTA's customers are able to get up to 30 Mbps down and 3 Mbps up using two twisted pairs with ADSL2+. Limitations of the technology include the loop length of the last mile and transport capability back to the core network.

The Last Mile

Being a legacy telephone provider the connection from MTA's equipment to the customer premise is copper cables. Each service requires two copper wires, mostly 24 gauge, which are twisted together, "twisted pair", in order to reduce cross talk among other pairs in the cable. This connection from equipment, DSL Access Multiplexor (DSLAM), to premise is known in the industry as the last mile. MTA has focused its network design on reducing the distance from its equipment and the customer premise to be around 6,000 ft. which fits the capabilities of ADSL2+ and was a cost effective way to improve services incrementally to most areas in the network. VDSL2, being deployed by the end of 2014, required shorter loop lengths, 3,000 ft. or less, in order to provide services of 50-100 Mbps down and up to 25 Mbps up. See Table 3 below for data rate versus loop lengths.

Transport

Another contributing factor in Internet service availability is the connection speed between the DSLAM and the core network. MTA connects most of the DSLAMs to the core network using fiber optic transport however in some areas the investment to place fiber is cost prohibitive therefore the transport is provided over existing twisted pair. When twisted pair is used the transport is limited by the number of pairs available and the throughput of the technology, either T1 at 1.544 Mbps per twisted pair or G.SHDSL (up to 40 Mbps) using multiple twisted pairs. Another alternative for transport is microwave, both licensed and unlicensed. Microwave is a viable solution however the cost of constructing towers can make it very expensive and is dependent on line of sight between the areas being served.

The Project

MTA serves the area around Big Lake. The DSLAMs on the eastern side of Big Lake are served with fiber and therefore have all the available capabilities. This project will focus on the southern and northern DSLAM areas around Big Lake. Services in these areas are limited by transport capacity. Currently the cost to place fiber optic cable to these sites is cost prohibitive when considering the cost of construction against the number of subscribers in the area. MTA designates each DSLAM with a CLLI, four letter acronym. The DSLAM areas this project will address are BRMA, JANA, STLK, GDST, WILD, BVLK, NOSH, HRSH, and RGRD. Details of these DSLAM areas is provided in Table 1, 2 and the attached map. On the map there are other DSLAM areas, BGLK, STAR, and ECHL, these DSLAMs all have fiber optic transport.

Project Goal

The purpose of this project is to increase service availability, providing a minimum of 10 Mbps down and 2 Mbps up that is cost effective. The existing facilities can be used, however the solution is not dependent on the use of existing facilities.

Table 1: Driving Directions and Cordinates

CLLI	ADDRESS	POLE	DRIVE DIRECTIONS
BRMA	S BIG LAKE RD	B93A	S BIG LAKE RD/JUST PAST BURMA RD/CABINET ON L
GDST	W SUSITNA PARKWAY	BL156	S BIG LAKE RD/R W SUSITNA PARKWAY/700' PAST RAINS DR/CABINET ON R
JANA	W SUSITNA PARKWAY	BL115	S BIG LAKE RD TO W SUSITNA PKWY/CABINET ON L/JUST PAST FOX DR
STLK	W BRYANT RD	BL130A-63 / DX7824	S BGLK RD/L BURMA APPOX 3.25 MI/ L BRYANT RD @ "THOMAS,FAIKS" SIGN / APPOX 3/4 MI / CABINET ON COR ON R
WILD	S CALL OF THE WILD RD	NS59 / DB6336	BGLK RD /TO W SUSITNA/R PURINGTON/TO S CALL OF THE WILD RD/CABINET ON R BEFORE BAR
BVLK	S BEAVER LAKE RD	HS23-17	BIG LAKE RD/L S BEAVER LAKE RD TO INTERSECTION WI S BEAVER LODGE RD/CABINET ON R
RGRD	W LAKES BLVD	HS41 / GD6762	BGLK RD / R BEAVER LK RD / L W LAKES BLVD / JUST BEFORE ROGERS RD / CABINET ON R
HRSH	S HORSESHOE LAKE RD	HS77 / ED5458	BEAVER LK/L WEST LAKES BLVD/R 2ND HORSESHOE LK RD/CABINET ON R
NOSH	W LAKES BLVD	NS31-1N / FB0060	BEAVER LK RD / L LAKES BLVD TO END / L @ T BEFORE BIG LAKE / L @ R.O.W-POLE LINE / CABINET ON L

BRMA	61-30-45.03 N	149-55-37.70 W	Burma
GDST	61-30-46.24 N	150-1-57.17 W	Gold Streak
JANA	61-30-45.17 N	149-58-9.86 W	Jana
STLK	61-28-26.74 N	149-57-31.08 W	Stephan Lake
WILD	61-32-3.01 N	149-58-9.86 W	Call of the Wild
BVLK	61-34-49.71 N	149-50-28.38 W	Beaver Lake
RGRD	61-34-2.69 N	149-52-41.65 W	Rogers Road
HRSH	61-34-0.39 N	149-56-36.42 W	Horse Shoe Lake
NOSH	61-32-17.88 N	149-56-2.15 W	North Shore

Table2: Number of Subscriber within the give loop lengths

DSLAM Site	<=3kft	3kft<=6kft	6kft<=10kft	>10000	Total
BRMA	17	25	15	22	79
BVLK	44	45	30	4	123
GDST	20	29	7	0	56
HRSH	21	13	33	2	69
JANA	11	13	1	0	25
NOSH	24	17	16	2	59
RGRD	2	10	5	14	31
STLK	11	14	2	4	31
WILD	5	18	18	18	59
Total	155	184	127	66	532

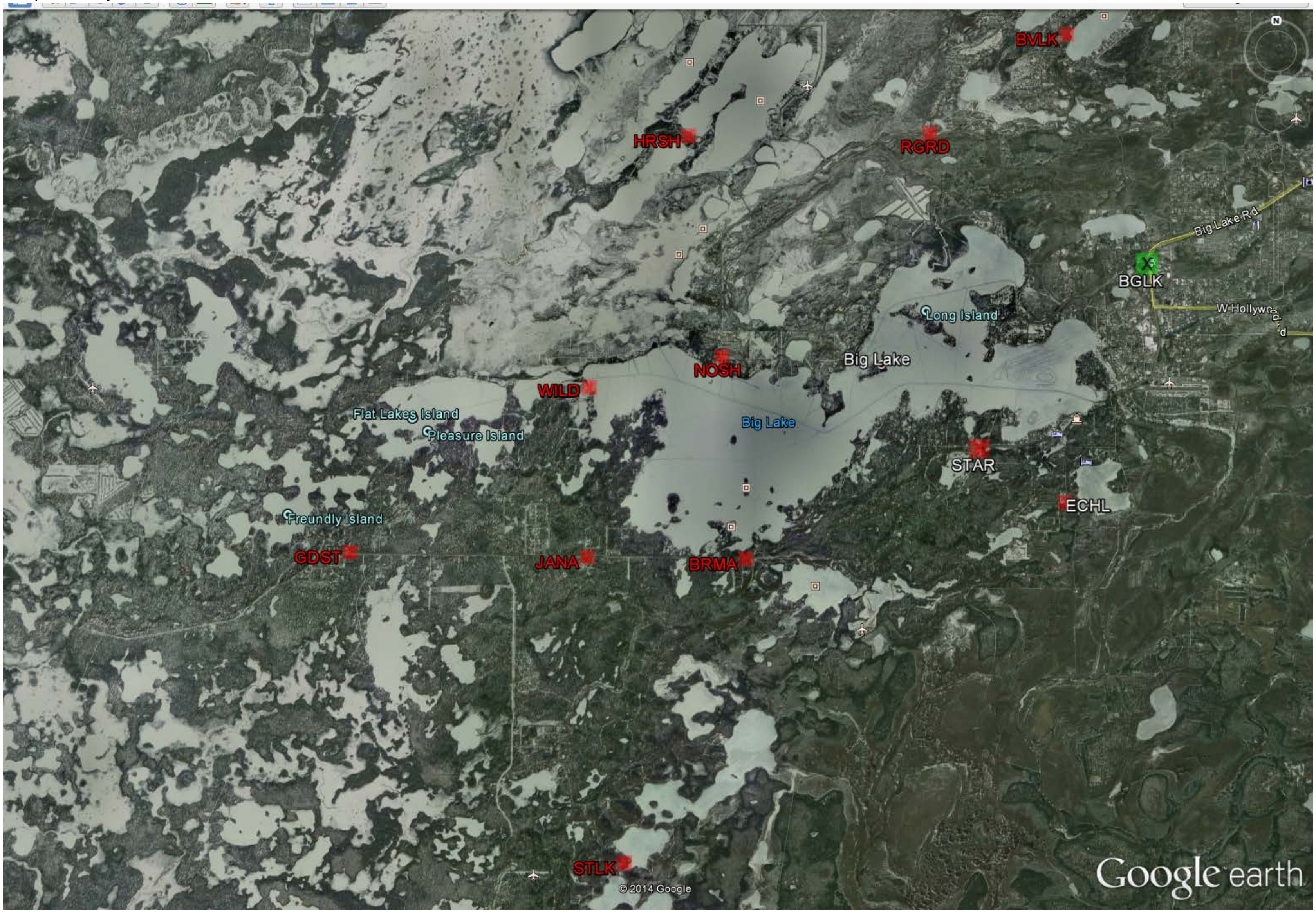
Table 3: DSL Technology Capability (Mbps)

Loop Length

Technology	<3 kft	5 kft	6kft	10 kft
ADSL2+	15	15	10	5
ADSL2+ Bonded	30	30	20	10
VDSL2	~50	X	X	X
VDSL2+ Bonded	~100	~50	X	X

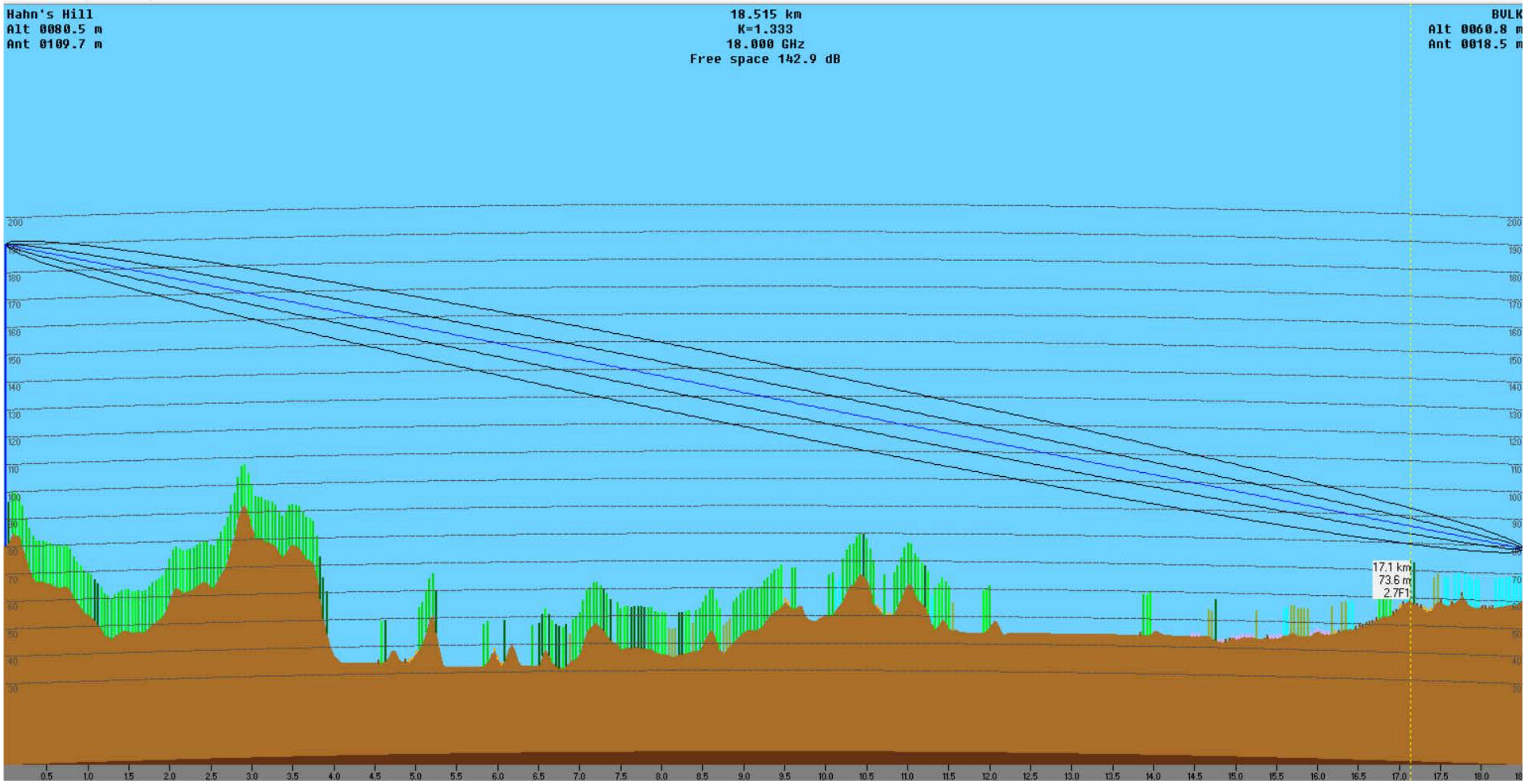
Bonded = 2 twisted pair and 2 DSLAM ports

Map of Project Area

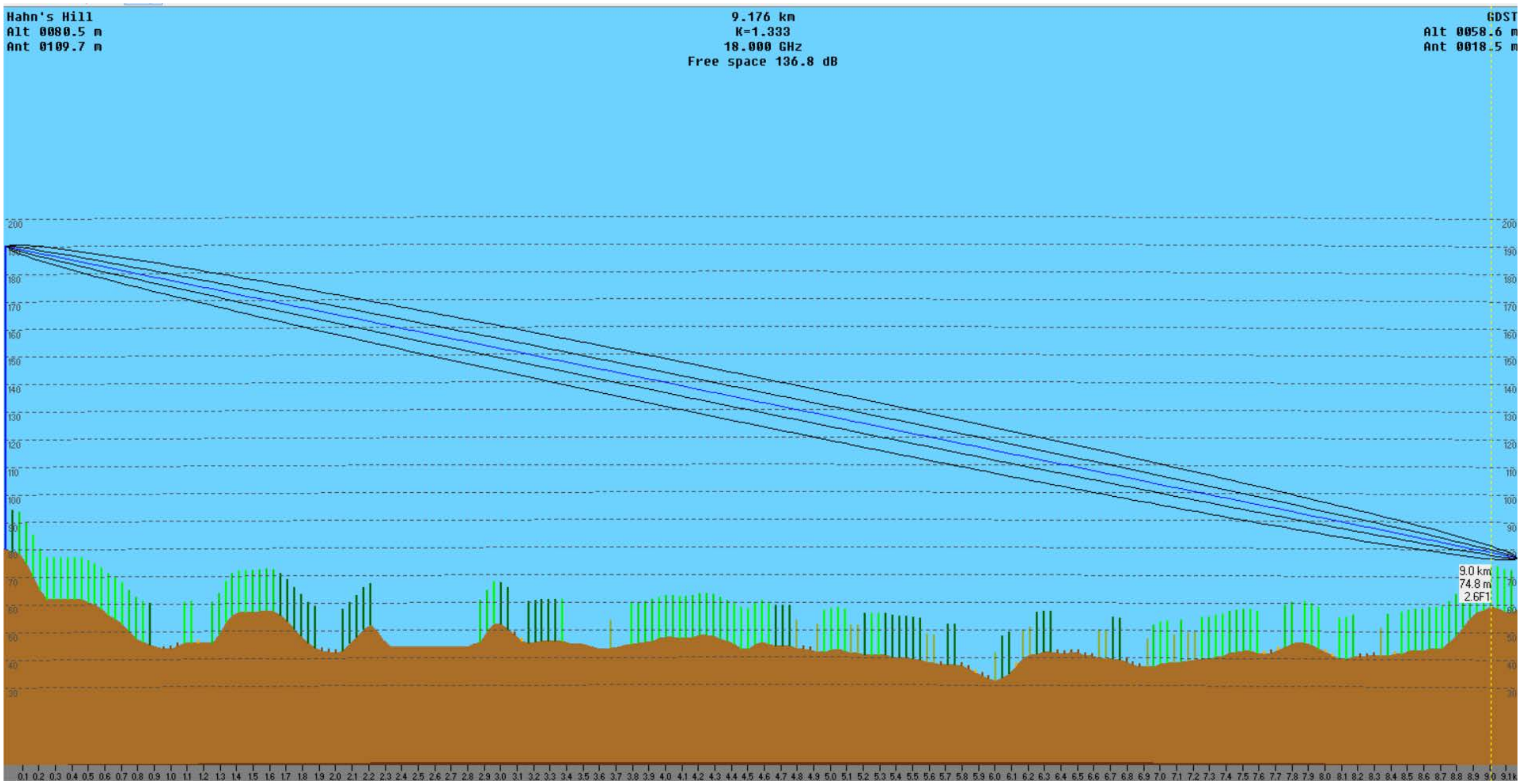


Appendix B: Microwave Path Link Profiles for Preliminary Designs

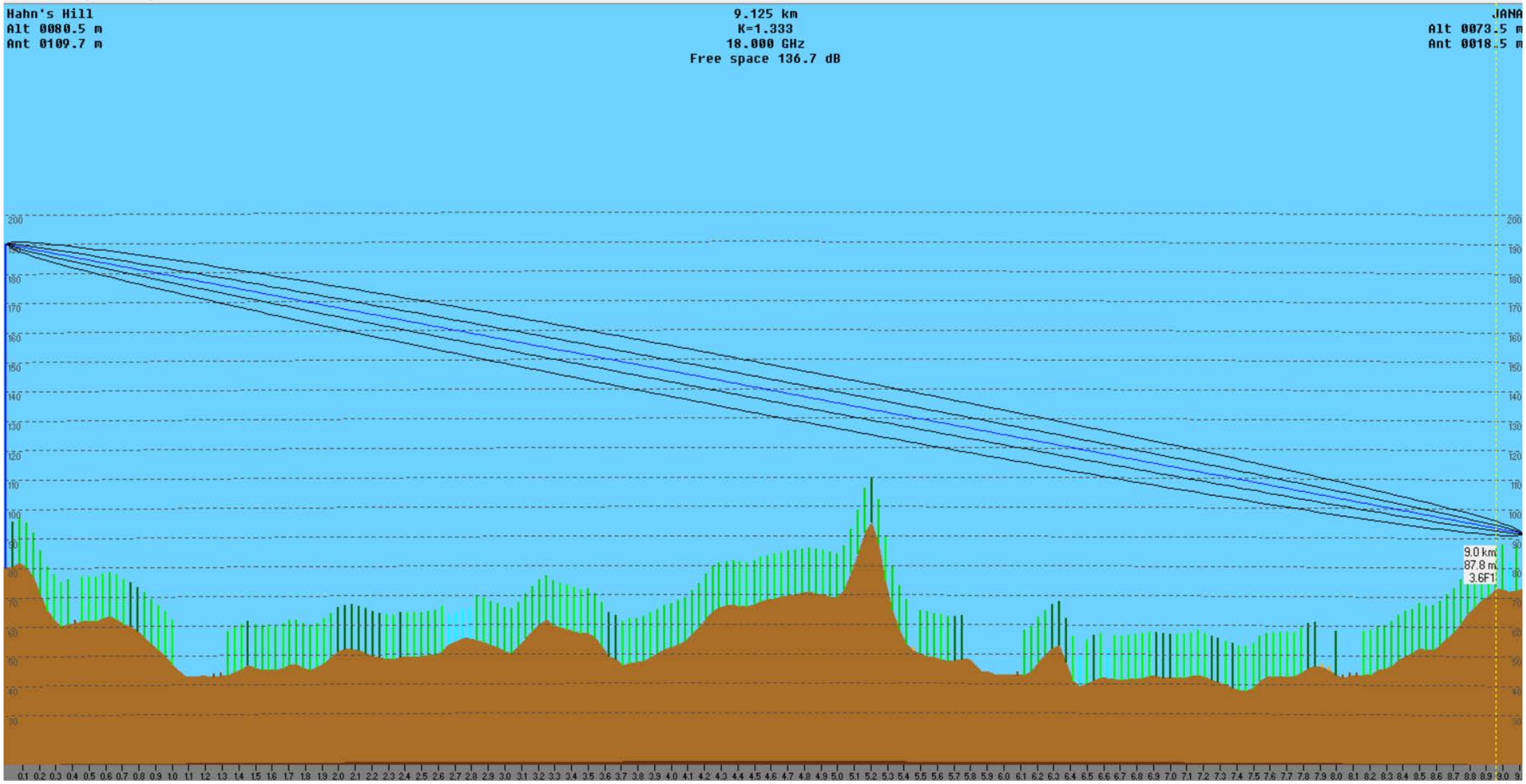
Path Profile **Hahn's Hill to BVLK**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 2.7, Path Distance: 11.5 mi.



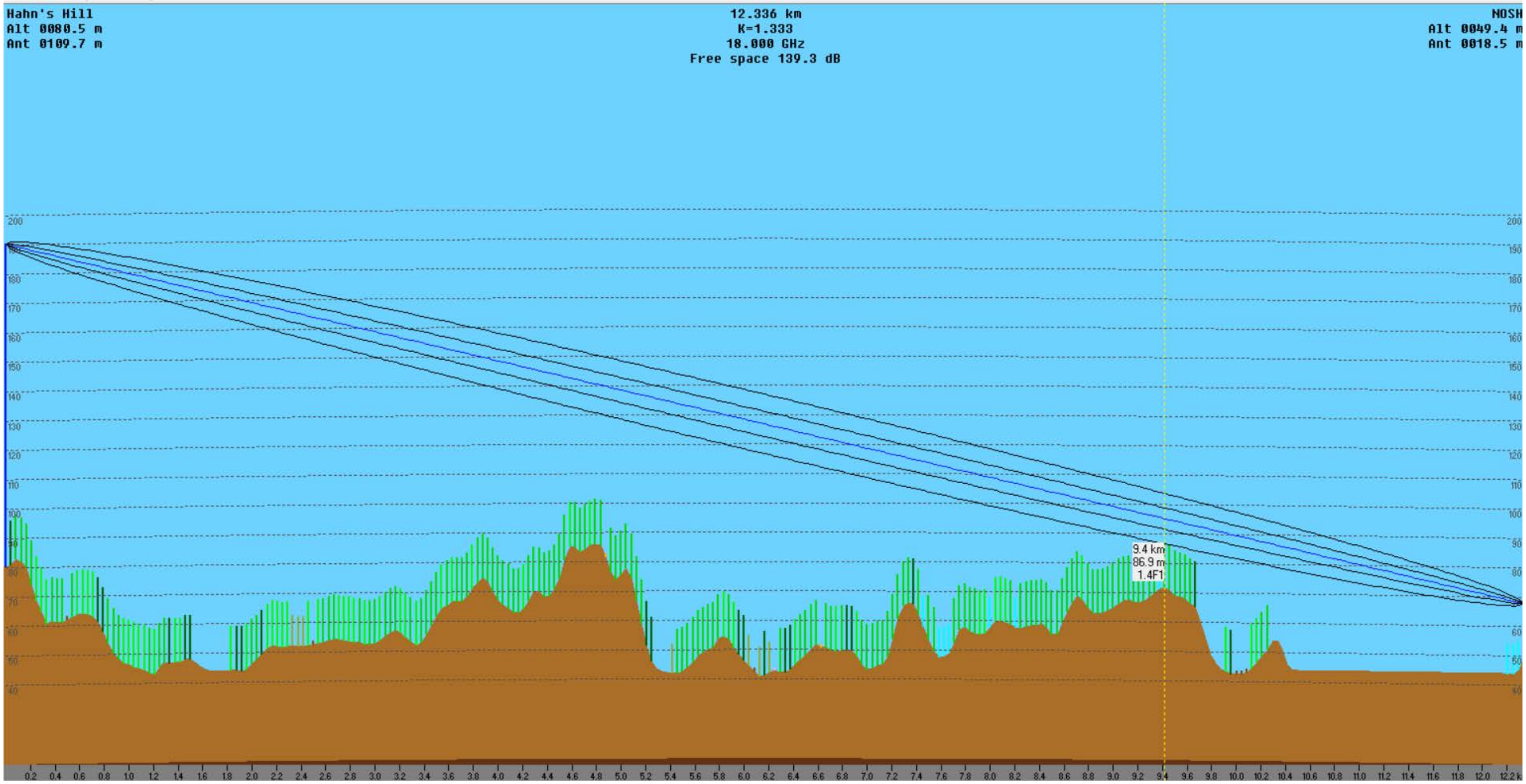
Path Profile **Hahn’s Hill to GDST**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 2.6, Path Distance: 5.7 mi.



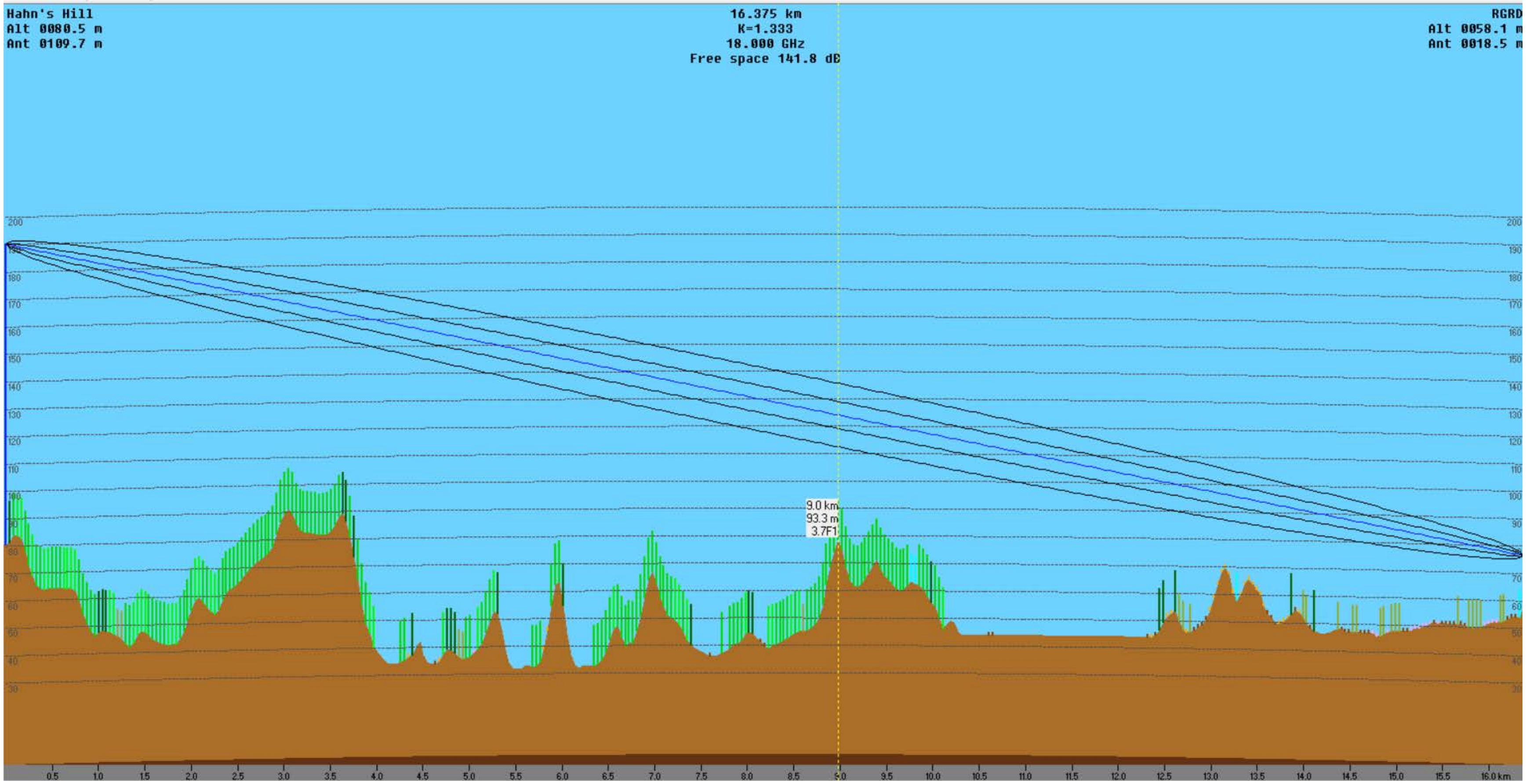
Path Profile **Hahn's Hill to JANA**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 3.6, Path Distance: 5.7 mi.



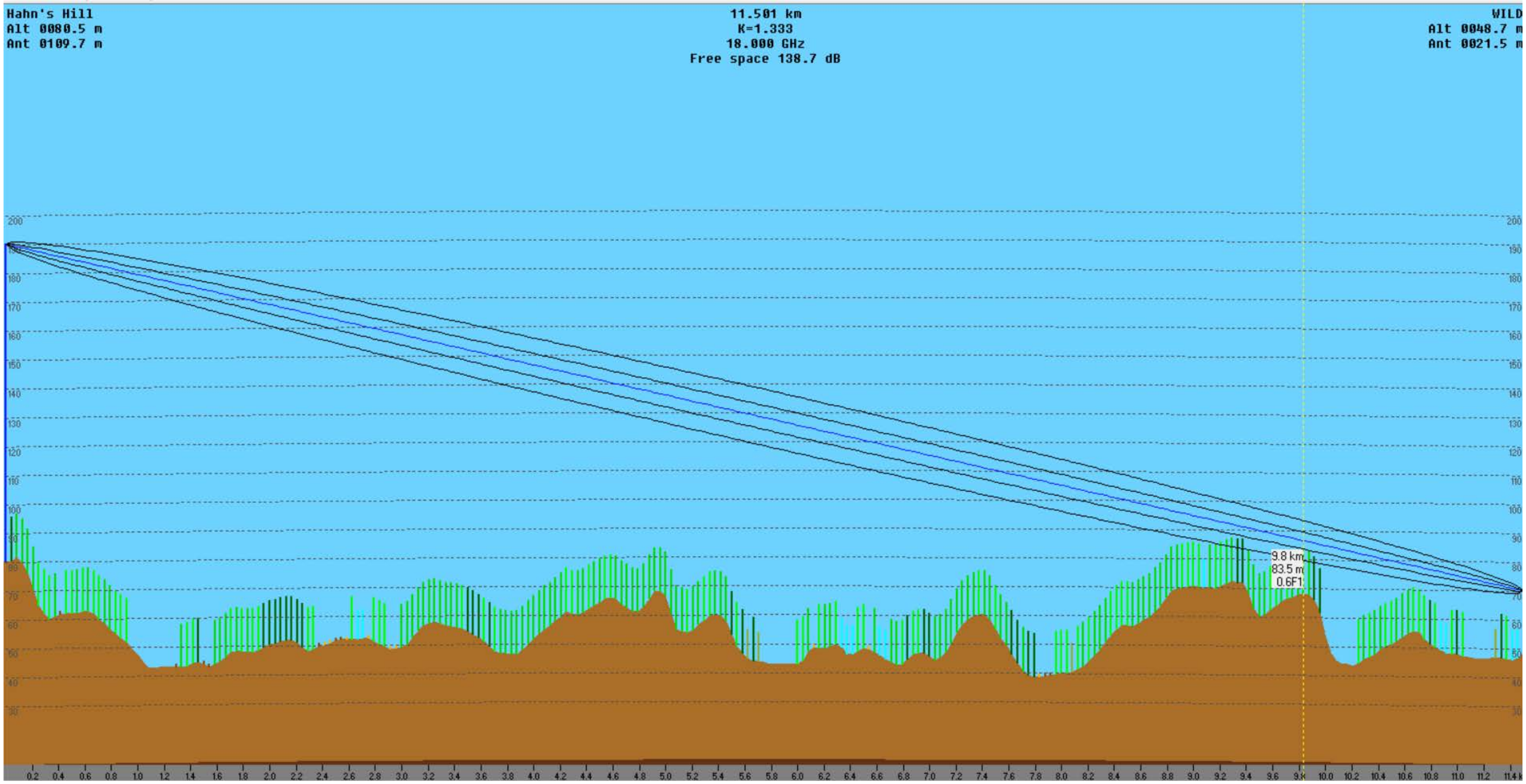
Path Profile **Hahn's Hill to NOSH**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 1.4, Path Distance: 7.7 mi.



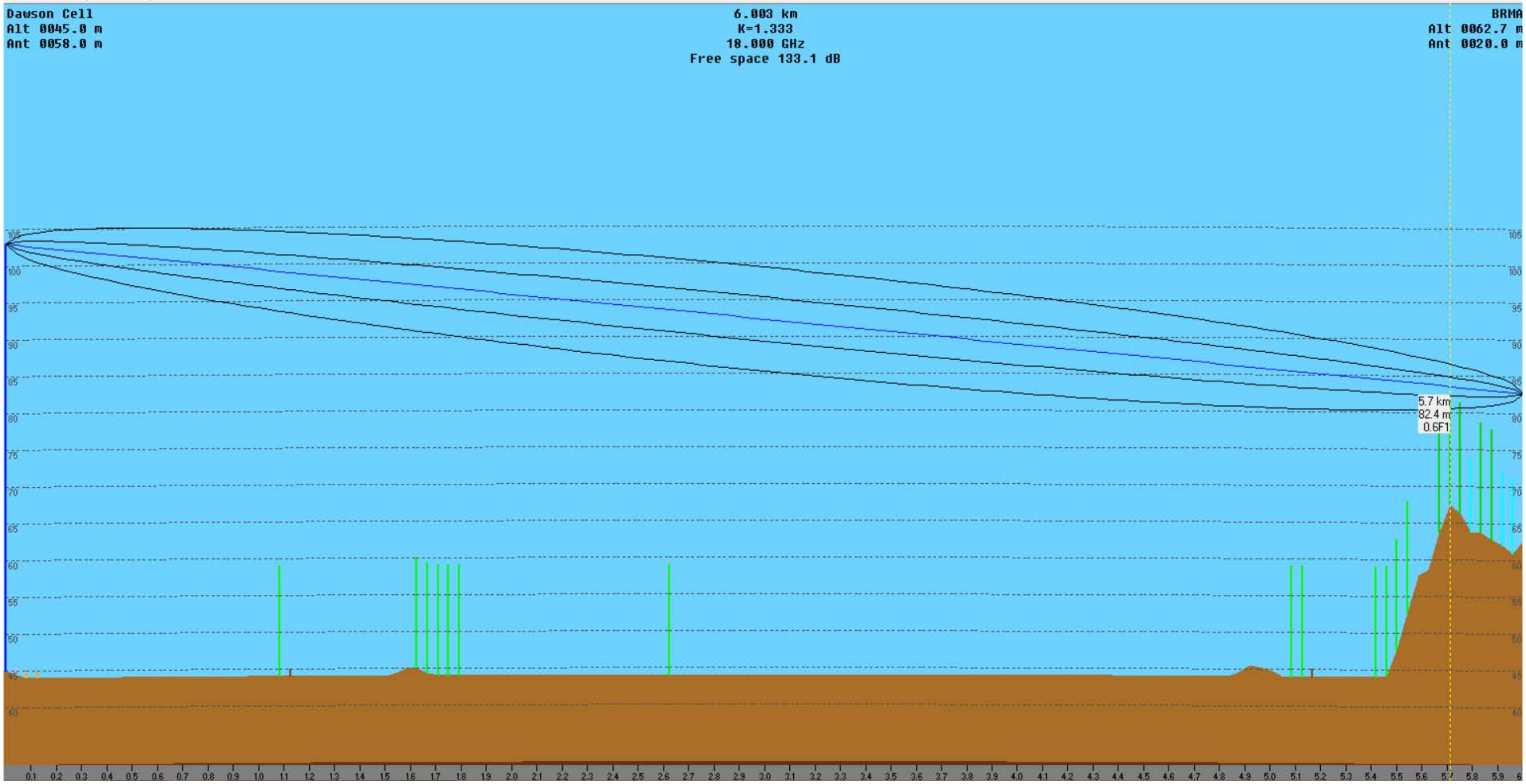
Path Profile **Hahn's Hill to RGRD**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 3.7, Path Distance: 10.2 mi.



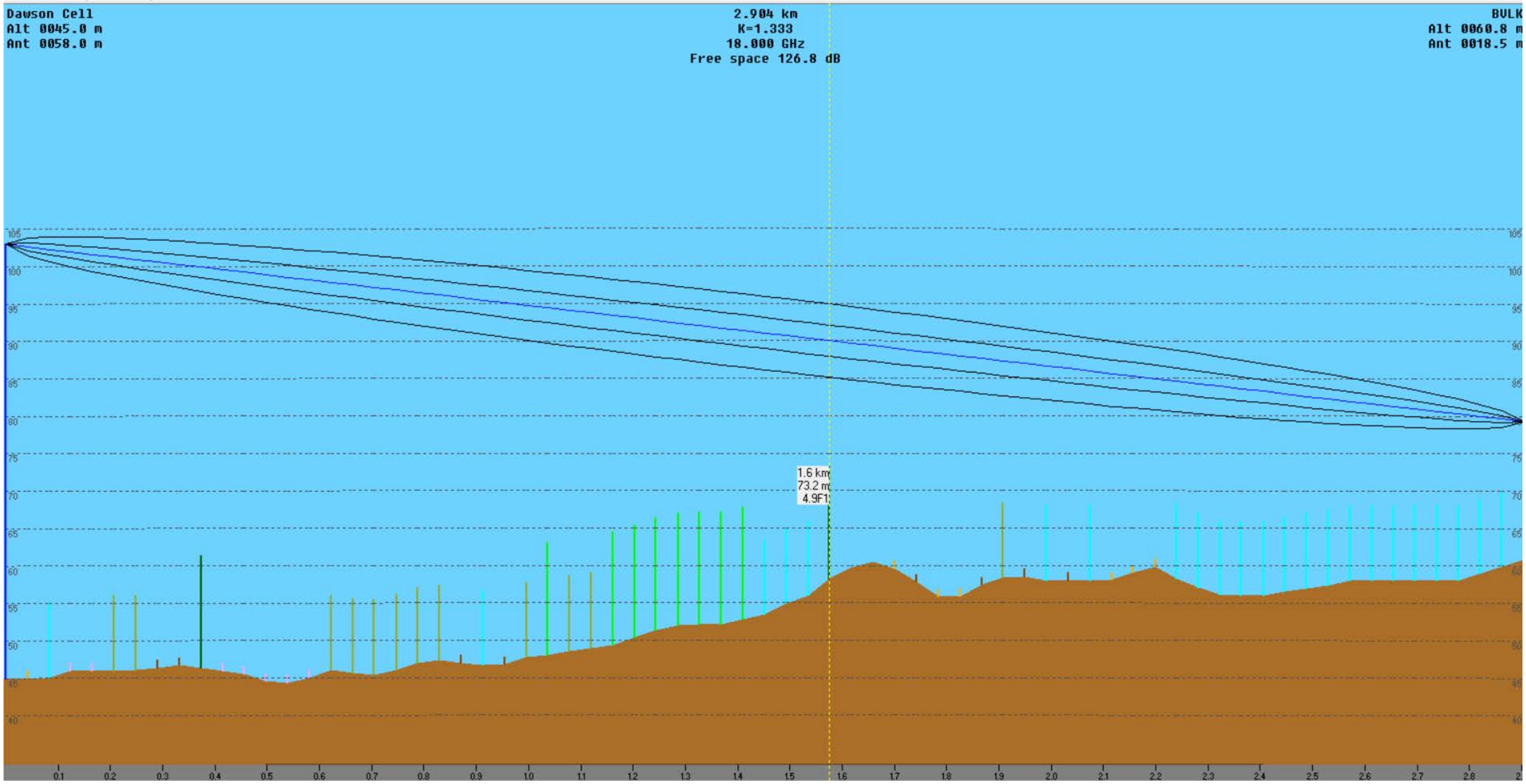
Path Profile **Hahn's Hill to WILD**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 0.6, Path Distance: 7.1 mi.



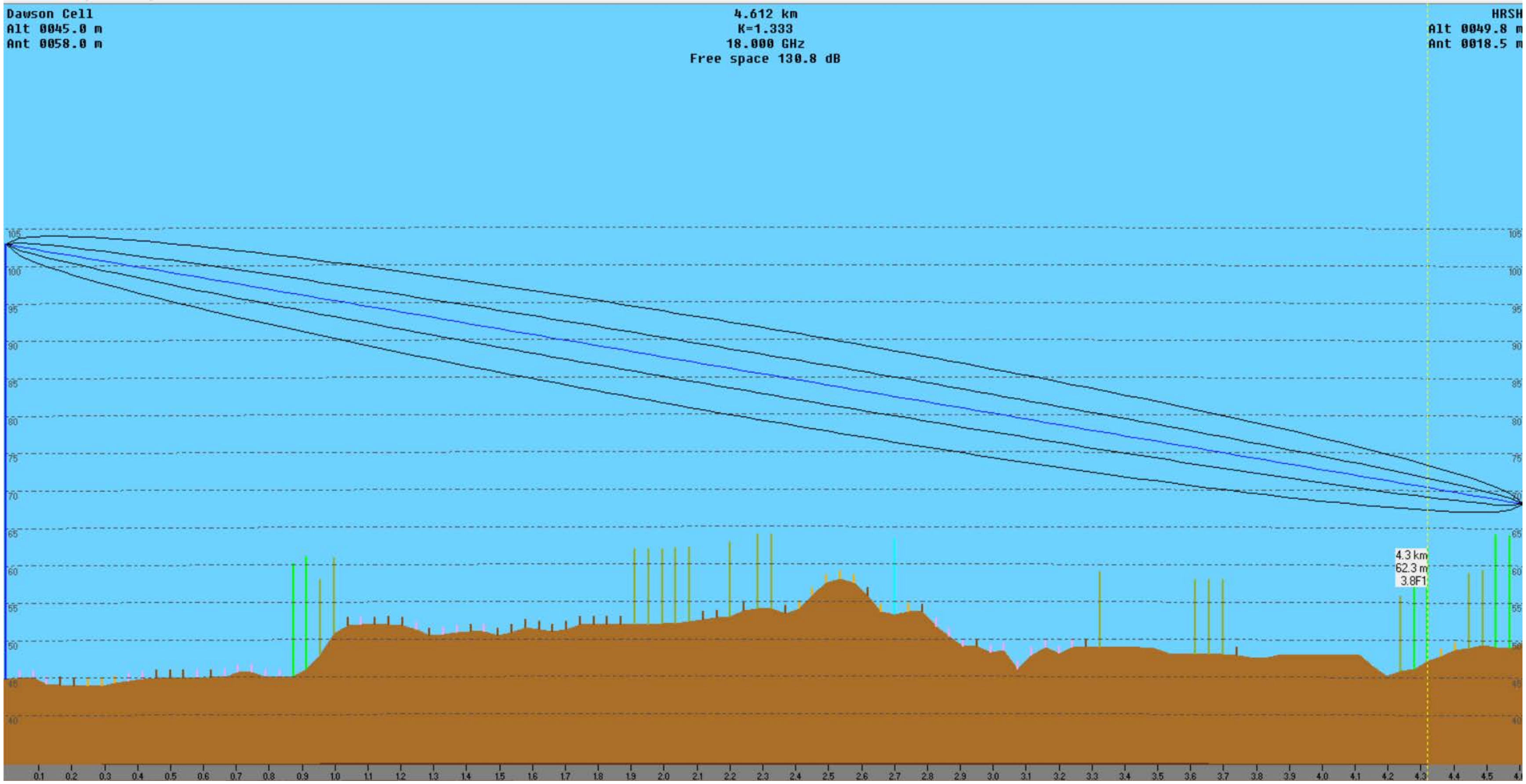
Path Profile **Dawson to BRMA**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 0.6, Path Distance: 3.7 mi.



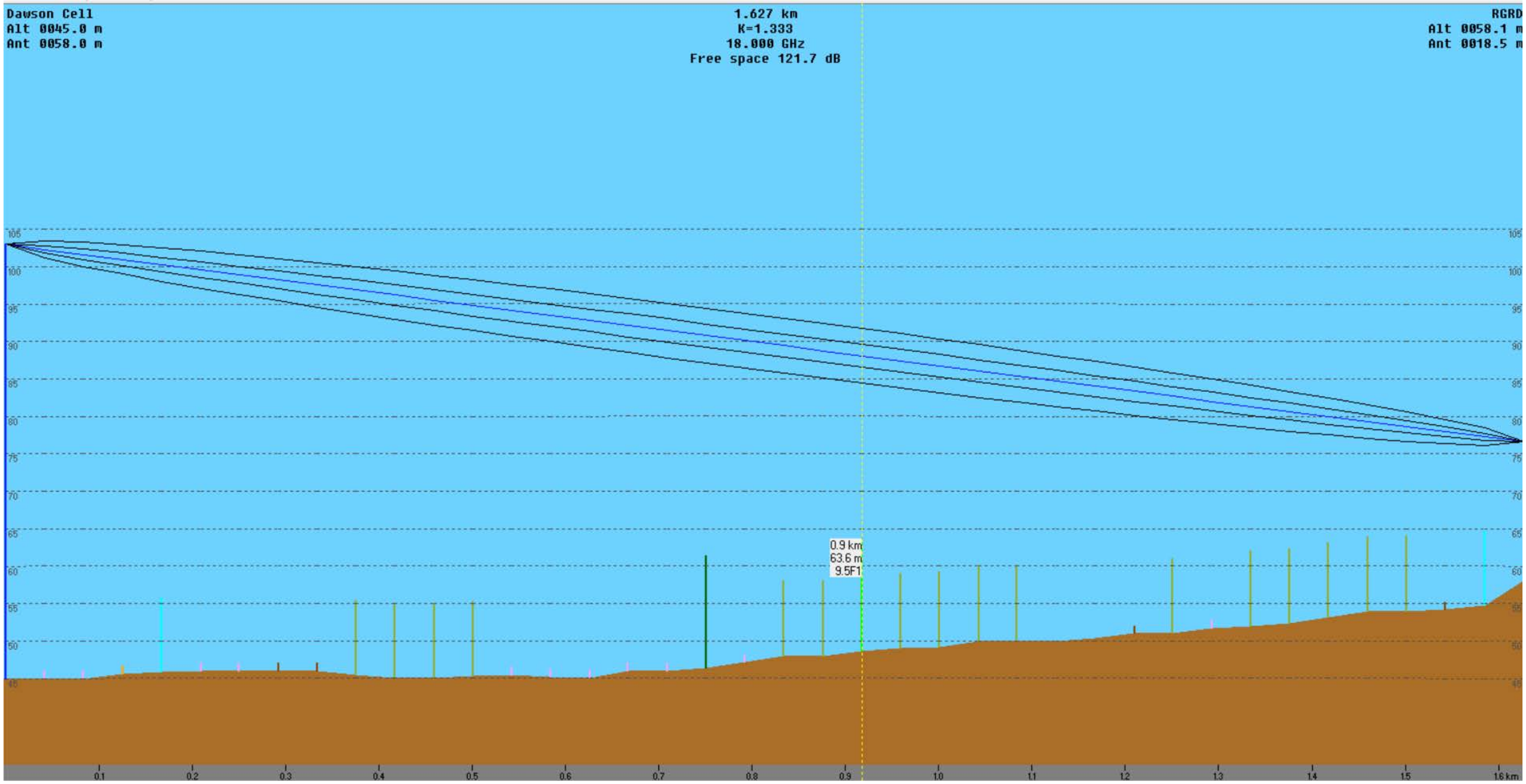
Path Profile **Dawson to BVLK**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 4.9, Path Distance: 1.8 mi.



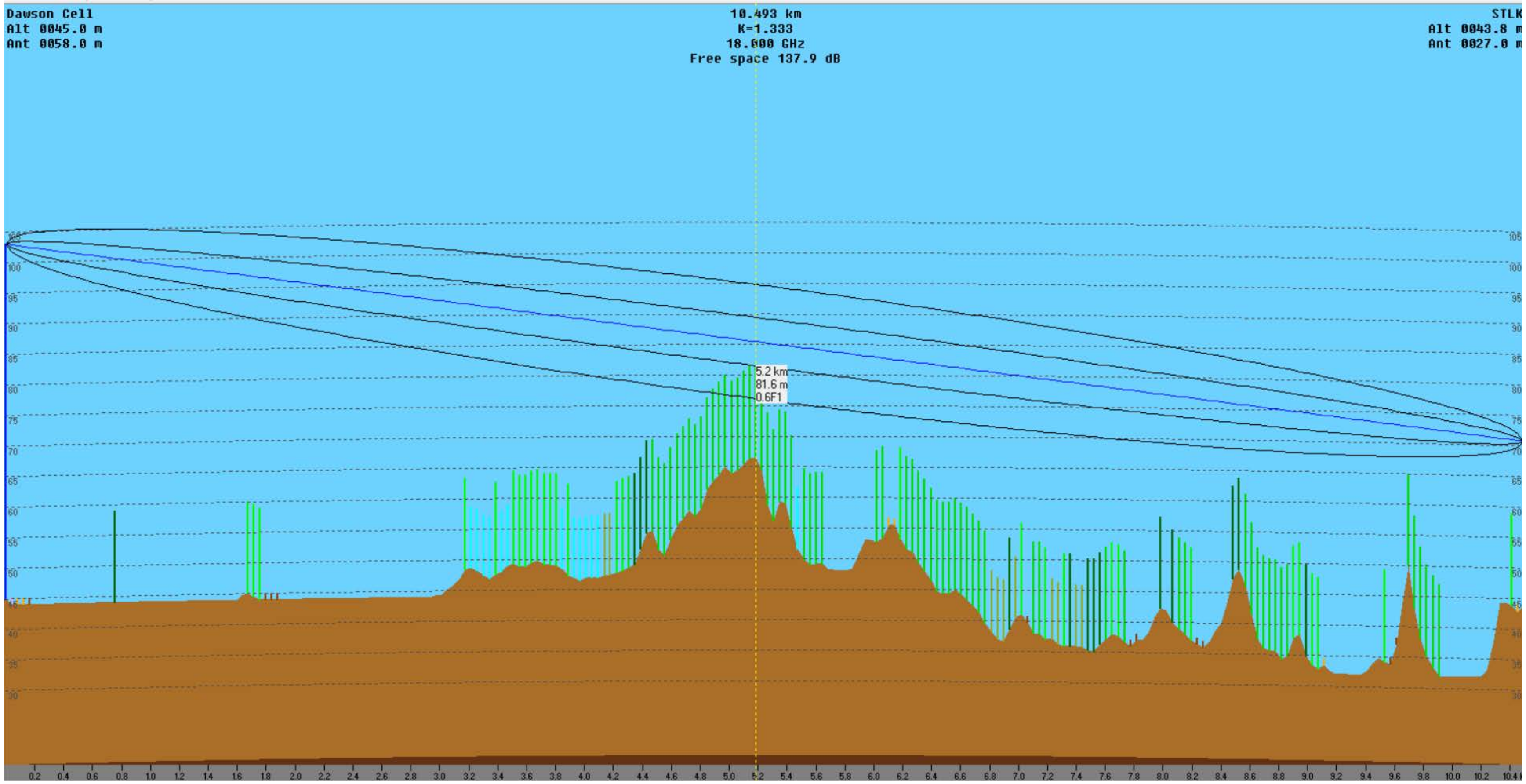
Path Profile **Dawson to HRSH**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 3.8, Path Distance: 2.9 mi.



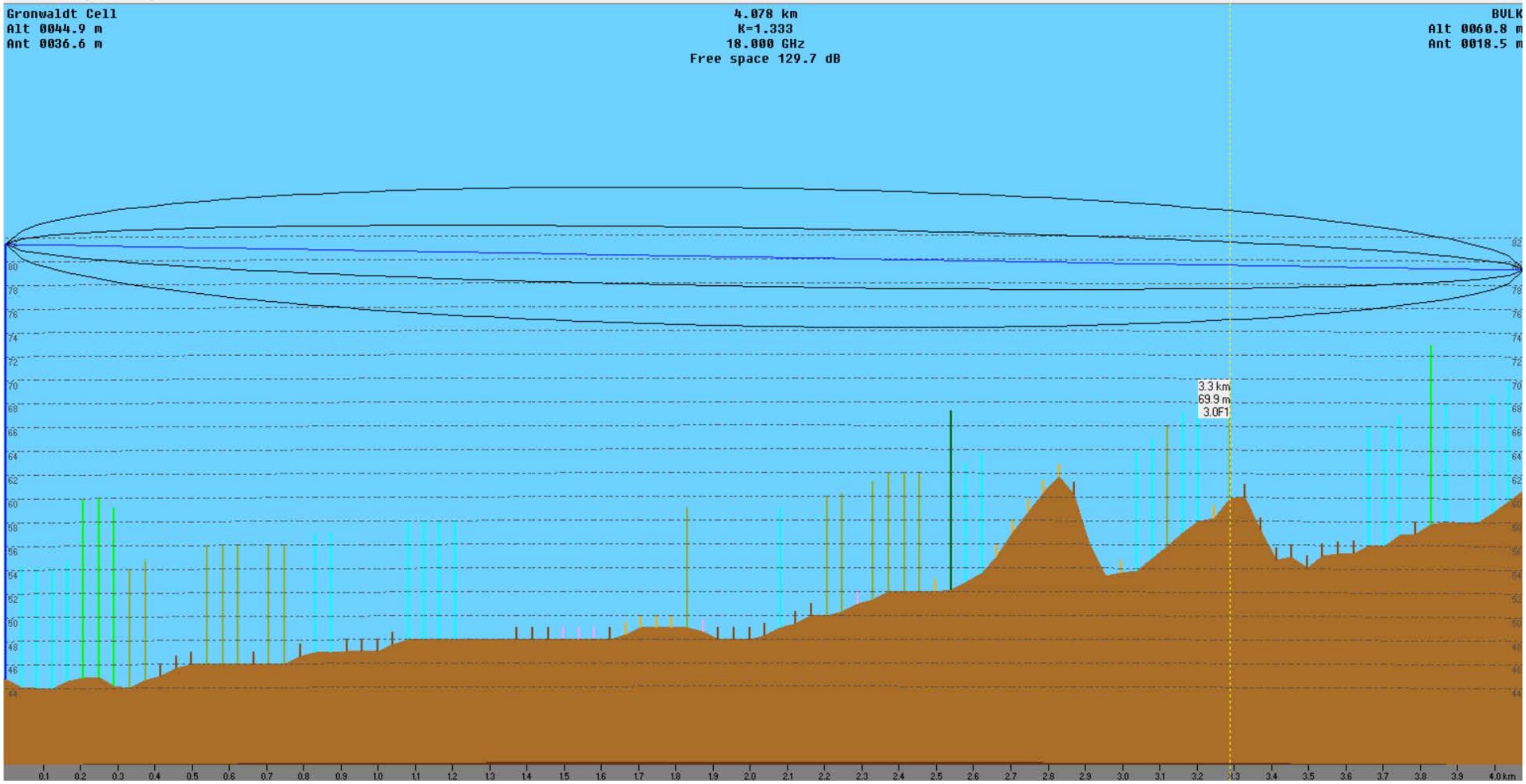
Path Profile **Dawson to RGRD**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 9.5, Path Distance: 1.0 mi.



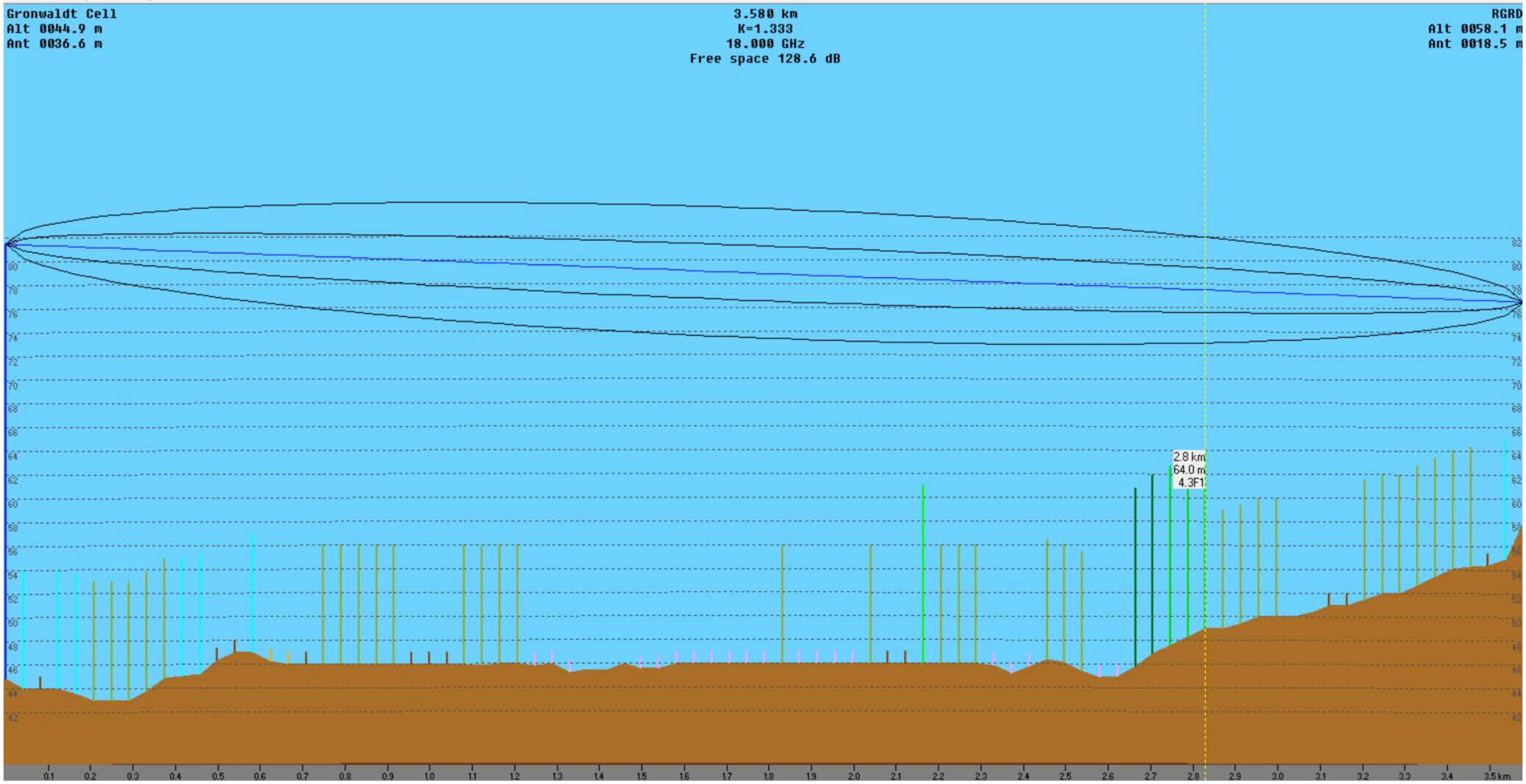
Path Profile **Dawson to STLK**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 0.6, Path Distance: 6.5 mi.



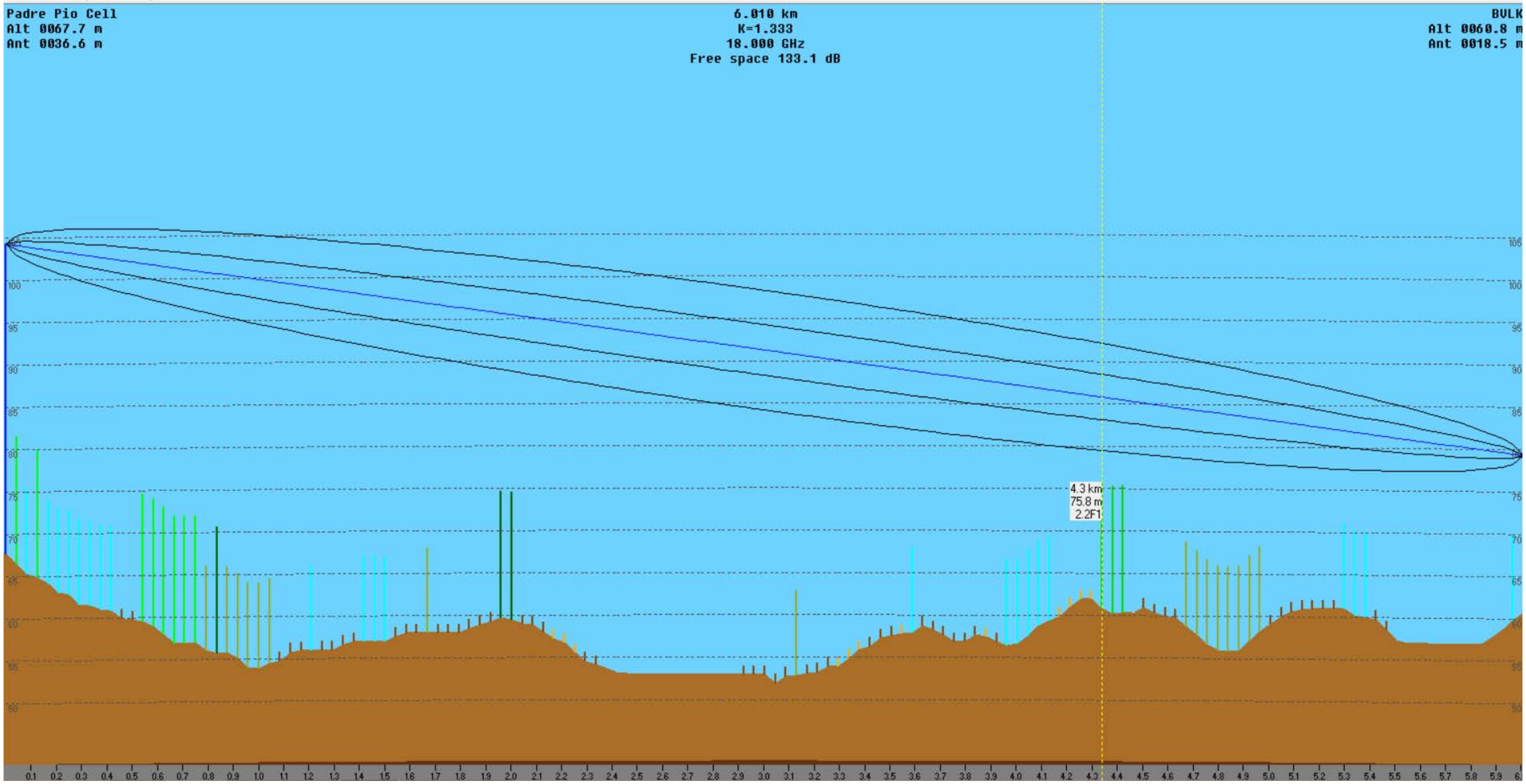
Path Profile **Gronwaldt to BVLK**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 3.0, Path Distance: 2.5 mi.



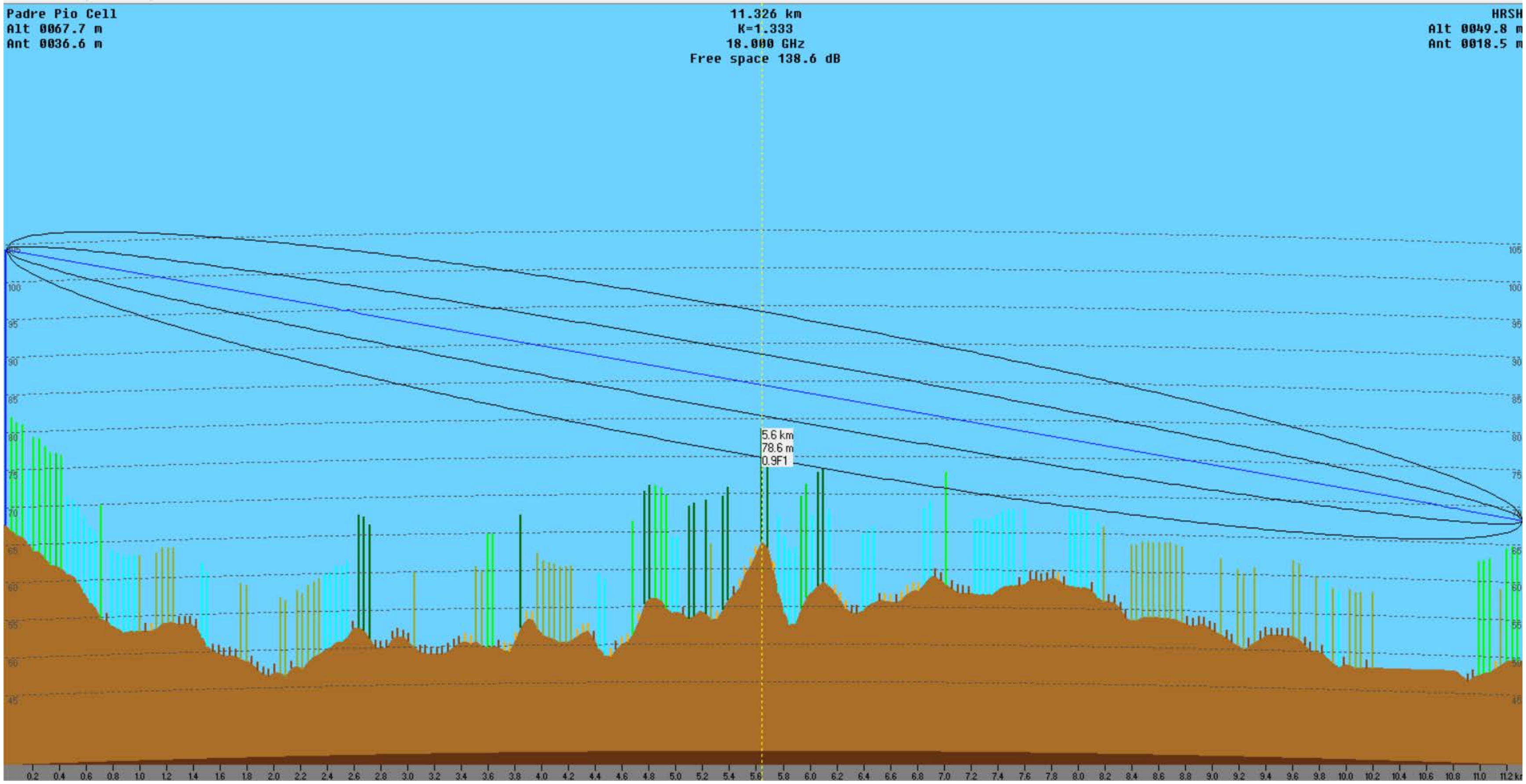
Path Profile **Gronwaldt to RGRD**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 4.3, Path Distance: 2.2 mi.



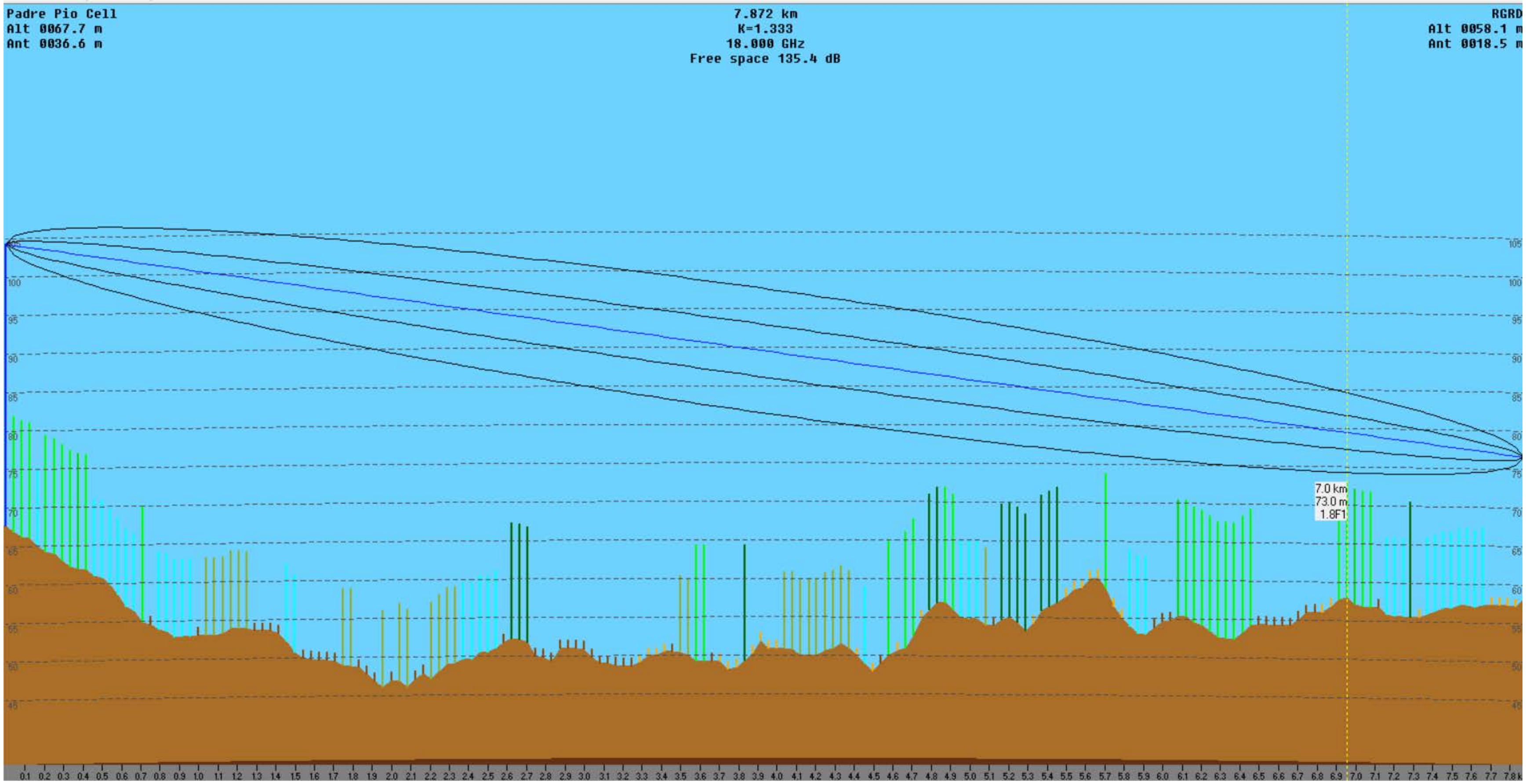
Path Profile **Padre Pio to BVLK**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 2.2, Path Distance: 3.7 mi.



Path Profile **Padre Pio to HRSH**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 0.9, Path Distance: 7.0 mi.



Path Profile **Padre Pio to RGRD**: Fresnel Zones Shown: 0.6 and 1.4, Worst Case Fresnel Clearance: 1.8, Path Distance: 4.9 mi.



Appendix C: Microwave Antenna and Waveguide Cost Estimates

2 Ft CommScope Antenna

3 Ft CommScope Antenna

4 Ft CommScope Antenna

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Click Image for Larger View

CommScope Technologies LLC - 17.7-19.7 GHz 4' ValuLine HP Low Profile Antenna

TESSCO SKU : 518131 **Mfg Part #:** VHLP4-18-3GR/C **Qty/UOM :** 1 EACH **UPC:** 729198506377

The CommScope VHLP4-18-3GR/C 4 ft ValuLine high performance, low profile parabolic antenna operates in the 17.7-19.7 GHz frequency range. The antenna is single polarized and has a UBR220 flange. The antenna features a flexible woven polymer gray radome without flash.

List: $2630.00

Your Price: $2630.00

Qty: 1

Add

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EW180 CommScope Waveguide (cost per ft.)

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Base Station Infrastructure > Cable, Connectors & Jumpers > Waveguide & Connectors > Elliptical Waveguide Cable > SKU# 432320

Click Image for Larger View

CommScope Technologies LLC - 17.7-19.7 GHz Waveguide EW180

TESSCO SKU : 432320 **Mfg Part #:** EW180 **Qty/UOM :** 1 FOOT **UPC:** 646444323208

ANDREW 17.7-19.7GHz (EW180-180) elliptical wave guide, standard jacket.

List: $18.00

Your Price: $18.00

Qty: 1

Add

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Appendix D: CommScope 18GHz Antenna Specifications

Product Specifications

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VHLPX2-18/B

0.6 m | 2 ft ValuLine® High Performance Low Profile Antenna, dual-polarized, 17.700–19.700 GHz

General Specifications

Antenna Type	VHLPX - ValuLine® High Performance Low Profile Antenna, dual-polarized
Diameter, nominal	0.6 m | 2 ft
Polarization	Dual

Electrical Specifications

Beamwidth, Horizontal	2.1 °
Beamwidth, Vertical	2.1 °
Cross Polarization Discrimination (XPD)	30 dB
Electrical Compliance	Brazil Anatel Class 2 | Canada SRSP 317.8 Part A | ETSI 302 217 Class 3 | US FCC Part 101A
Front-to-Back Ratio	66 dB
Gain, Low Band	38.4 dBi
Gain, Mid Band	38.9 dBi
Gain, Top Band	39.1 dBi
Operating Frequency Band	17.700 – 19.700 GHz
Radiation Pattern Envelope Reference (RPE)	7216B
Return Loss	17.7 dB
VSWR	1.30

Mechanical Specifications

Fine Azimuth Adjustment	±15°
Fine Elevation Adjustment	±15°
Mounting Pipe Diameter	48 mm–115 mm | 1.9 in–4.5 in
Net Weight	11 kg | 25 lb
Side Struts, Included	0
Side Struts, Optional	0
Wind Velocity Operational	200 km/h | 124 mph
Wind Velocity Survival Rating	250 km/h | 155 mph

Wind Forces At Wind Velocity Survival Rating

Axial Force (FA)	1272 N | 286 lbf
Side Force (FS)	630 N | 142 lbf
Twisting Moment (MT)	473 N•m
Weight with 1/2 in (12 mm) Radial Ice	17 kg | 37 lb

Product Specifications

COMMSCOPE®

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VHLPX3-18

1.0 m | 3 ft ValuLine® High Performance Low Profile Antenna, dual-polarized, 17.700–19.700 GHz

General Specifications

Antenna Type	VHLPX - ValuLine® High Performance Low Profile Antenna, dual-polarized
Diameter, nominal	1.0 m | 3 ft
Polarization	Dual

Electrical Specifications

Beamwidth, Horizontal	1.1 °
Beamwidth, Vertical	1.1 °
Cross Polarization Discrimination (XPD)	30 dB
Electrical Compliance	Brazil Anatel Class 2 | Canada SRSP 317.8 Part A | ETSI 302 217 Class 3 | US FCC Part 101A
Front-to-Back Ratio	71 dB
Gain, Low Band	42.7 dBi
Gain, Mid Band	43.5 dBi
Gain, Top Band	43.7 dBi
Operating Frequency Band	17.700 – 19.700 GHz
Radiation Pattern Envelope Reference (RPE)	7171
Return Loss	17.7 dB
VSWR	1.30

Mechanical Specifications

Fine Azimuth Adjustment	±15°
Fine Elevation Adjustment	±15°
Mounting Pipe Diameter	115 mm | 4.5 in
Net Weight	24 kg | 53 lb
Side Struts, Included	0
Side Struts, Optional	1 inboard
Wind Velocity Operational	200 km/h | 124 mph
Wind Velocity Survival Rating	250 km/h | 155 mph

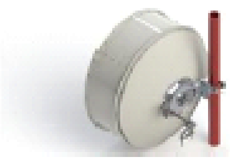
Wind Forces At Wind Velocity Survival Rating

Angle a for MT Max	0 °
Axial Force (FA)	2979 N | 670 lbf
Side Force (FS)	936 N | 210 lbf
Twisting Moment (MT)	1184 N•m

Product Specifications

COMMSCOPE®

POWERED BY ANDREW



VHLPX4-18/C

1.2 m | 4 ft ValuLine® High Performance Low Profile Antenna, dual-polarized, 17.700–19.700 GHz

General Specifications

Antenna Type	VHLPX - ValuLine® High Performance Low Profile Antenna, dual-polarized
Diameter, nominal	1.2 m | 4 ft
Polarization	Dual

Electrical Specifications

Beamwidth, Horizontal	0.9 °
Beamwidth, Vertical	0.9 °
Cross Polarization Discrimination (XPD)	30 dB
Electrical Compliance	Brazil Anatel Class 2 | Canada SRSP 317.8 Part A | ETSI 302 217 Class 3 | US FCC Part 101A
Front-to-Back Ratio	73 dB
Gain, Low Band	44.4 dBi
Gain, Mid Band	44.7 dBi
Gain, Top Band	44.9 dBi
Operating Frequency Band	17.700 – 19.700 GHz
Radiation Pattern Envelope Reference (RPE)	7062C
Return Loss	17.7 dB
VSWR	1.30

Mechanical Specifications

Fine Azimuth Adjustment	±15°
Fine Elevation Adjustment	±15°
Mounting Pipe Diameter	115 mm | 4.5 in
Net Weight	32 kg | 71 lb
Side Struts, Included	1 inboard
Side Struts, Optional	1 inboard
Wind Velocity Operational	200 km/h | 124 mph
Wind Velocity Survival Rating	250 km/h | 155 mph

Wind Forces At Wind Velocity Survival Rating

Axial Force (FA)	5326 N | 1197 lbf
Force on Inboard Strut Side	2862 N | 643 lbf
Side Force (FS)	2638 N | 593 lbf
Twisting Moment (MT)	2162 N•m
Weight with 1/2 in (12 mm) Radial Ice	74 kg | 163 lb
Zcg with 1/2 in (12 mm) Radial Ice	284 mm | 11 in
Zcg without Ice	43 mm | 2 in

Appendix E: NEC iPASOLINK 250/650 Technical Specifications

Technical Specifications

		iPASOLINK 250		iPASOLINK 650		
Frequency		5.8/L6/U6/10.5/11/18/23/24/38 GHz				
Modulation		QPSK/16/32/64/128/256 QAM				
Channel Separation	MODEM-L	3.75/5/10/20 MHz				
	MODEM-H	10/30/40/50 MHz				
AMR		Available for 30/40/50 MHz CH Sep.				
Radio Node Capability		2-Way		6-Way		
Interfaces	Base Interface	16DS1 + 2xGigE (SFP)				
	Add-on Interfaces	63xDS1				
		6xDS3 (Transmux)				
		DS1/DS3 PWE				
		8xOC3/2xOC12 (SFP)				
		2xGigE (SFP) + 2xRJ45				
Capacity (Maximum line rate with 64 byte frame size)	Modulation	Channel Size (Bandwidth)				
		10MHz	20MHz	30MHz	40MHz	50MHz
	QPSK	20Mbps	38Mbps	58Mbps	75Mbps	105Mbps
	16QAM	40Mbps	80Mbps	118Mbps	150Mbps	210Mbps
	32QAM	50Mbps	100Mbps	148Mbps	186Mbps	262Mbps
	64QAM	62Mbps	120Mbps	178Mbps	224Mbps	315Mbps
	128QAM	72Mbps	140Mbps	208Mbps	262Mbps	368Mbps
	256QAM	82Mbps	160Mbps	238Mbps	298Mbps	420Mbps
Packet Functionality		Port-based and Tag-based VLAN				
		QoS/ToS Diffserve/MPLS EXP based priority control				
Synchronization		GPS, Ethernet (SyncE/GPS/IEEE1588v2), TDM (Bits/Line)				
Radio Protection		N+0/1+1 HS/SD/FD				
BB Protection	PDH	DS1/DS3 SNCP				
	SONET	OC3 APS				
	Packet	G8032 (Ring), RTP, MSTP, LACP				
Ethernet OAM		IEEE 802.1ag service OAM and ITU-T Y.1731 PM				
Ambient Temperature		IDU: -5 to +50 Degree C; ODU:-33 to +50 Degree C				
TRP Dimensions		19.0W x 14.5H x 11.8D in				
ODU Dimensions		9.3W x 9.3H x 4.00 in				
IDU Dimensions		19.0W x 1.7H x 10.00 in		19.0W x 3.5H x 10.00 in		
Power Line Voltage		-48VDC (-40.5 to -57 VDC) +/- 20 to 60 VDC (Optional)				

Information

NEC Corporation of America

Radio Communications Systems Division
6535 N. State Highway 161
Irving, TX 75039
http://www.necam.com/rcsd

Issue: December 2010

NEC NEC Corporation of America

iPASOLINK250/650 System Paramet Rev 2.2

IAG & IAP ODU with MODEM-EH

ODU Type		IAG	IAG	IAG	IAP	IAG	IAG	IAG
Frequency Band		5.8G	L6GHz	U6GHz	11GHz	18GHz	23GHz	38GHz
Range (MHz)		5725 -5850	5925 -6425	6525 -6875	10700 -11700	17700 -19700	21200 -23600	38600 -40000
Tx Power (dBm)	(Measured at Ant. port)							
CS=5MHz	QPSK		29.0	29.0	30.0	24.0	24.0	20.0
	16QAM		27.0	27.0	27.0	22.0	22.0	18.0
	32QAM		26.0	26.0	26.0	21.0	19.0	18.0
	64QAM		26.0	26.0	26.0	21.0	19.0	18.0
	128QAM		26.0	26.0	26.0	21.0	19.0	18.0
	256QAM		25.0	25.0	25.0	20.0	18.0	17.0
	512QAM		23.0	23.0	23.0	18.0	16.0	15.0
	1024QAM				22.0			
	11bit 2048QAM				22.0			
	Minimum Output Power		-1	-1	-5	-6	-6	-5
CS=10MHz	QPSK	29.0	29.0	29.0	30.0	24.0	24.0	20.0
	16QAM	27.0	27.0	27.0	27.0	22.0	22.0	18.0
	32QAM	26.0	26.0	26.0	26.0	21.0	19.0	18.0
	64QAM	26.0	26.0	26.0	26.0	21.0	19.0	18.0
	128QAM	26.0	26.0	26.0	26.0	21.0	19.0	18.0
	256QAM	25.0	25.0	25.0	25.0	20.0	18.0	17.0
	512QAM	23.0	23.0	23.0	23.0	18.0	16.0	15.0
	1024QAM	22.0	22.0	22.0	22.0	17.0	15.0	14.0
	2048QAM				22.0			
	Minimum Output Power	-1	-1	-1	-5	-6	-6	-5
CS=20MHz	QPSK					24.0	24.0	20.0
	16QAM					22.0	22.0	18.0
	32QAM					21.0	19.0	18.0
	64QAM					21.0	19.0	18.0
	128QAM					21.0	19.0	18.0
	256QAM					20.0	18.0	17.0
	512QAM					18.0	16.0	15.0
	1024QAM					17.0	15.0	14.0
	2048QAM					17.0	15.0	14.0
	Minimum Output Power					-6	-6	-5
CS=30MHz	QPSK	29.0	29.0	29.0	30.0	24.0	24.0	20.0

1 2 3 4

	16QAM	27.0	27.0	27.0	27.0	22.0	22.0	18.0
	32QAM	26.0	26.0	26.0	26.0	21.0	19.0	18.0
	64QAM	26.0	26.0	26.0	26.0	21.0	19.0	18.0
	128QAM	26.0	26.0	26.0	26.0	21.0	19.0	18.0
	256QAM	25.0	25.0	25.0	25.0	20.0	18.0	17.0
	512QAM	23.0	23.0	23.0	23.0	18.0	16.0	15.0
	1024QAM	22.0	22.0	22.0	22.0	17.0	15.0	14.0
	2048QAM	22.0	22.0	22.0	22.0	17.0	15.0	14.0
	Minimum Output Power	-1	-1	-1	-5	-6	-6	-5
CS=40MHz	QPSK				30.0	24.0	24.0	20.0
	16QAM				27.0	22.0	22.0	18.0
	32QAM				26.0	21.0	19.0	18.0
	64QAM				26.0	21.0	19.0	18.0
	128QAM				26.0	21.0	19.0	18.0
	256QAM				25.0	20.0	18.0	17.0
	512QAM				23.0	18.0	16.0	15.0
	1024QAM				22.0	17.0	15.0	14.0
	2048QAM				22.0	17.0	15.0	14.0
	Minimum Output Power				-5	-6	-6	-5
CS=50MHz	QPSK					24.0	24.0	20.0
	16QAM					21.0	21.0	17.0
	32QAM					20.0	18.0	17.0
	64QAM					20.0	18.0	17.0
	128QAM					20.0	18.0	17.0
	256QAM					19.0	17.0	16.0
	512QAM					17.0	15.0	14.0
	1024QAM					16.0	14.0	13.0
	2048QAM					16.0	14.0	13.0
	Minimum Output Power					-6	-6	-5
CS=60MHz	QPSK		29.0		30.0	24.0		
	16QAM		26.0		26.0	21.0		
	32QAM		25.0		25.0	20.0		
	64QAM		25.0		25.0	20.0		
	128QAM		25.0		25.0	20.0		
	256QAM		24.0		24.0	19.0		
	512QAM		22.0		22.0	17.0		
	1024QAM		21.0		21.0	16.0		
	2048QAM		21.0		21.0	16.0		
	Minimum Output Power		-1		-5	-6.0		
CS=80MHz	QPSK					–		
	16QAM					–		
	32QAM					–		
	64QAM					–		
	128QAM					–		
	256QAM					–		
	512QAM					–		

	1024QAM					–		
	2048QAM					–		
	Minimum Output Power					–		
Frequency Stability		±6 ppm						
Receiver Threshold (dBm) @ BER=10-6 (Measured at Ant. port)								
Bandwidth	Modulation							
CS=5MHz	QPSK		-95.5	-95.5	-94.5	-93.5	-94.5	
	16QAM		-88.5	-88.5	-87.5	-86.5	-87.5	
	32QAM		-85.5	-85.5	-84.5	-83.5	-84.5	
	64QAM		-82.5	-82.5	-81.5	-80.5	-81.5	
	128QAM		-79.5	-79.5	-78.5	-77.5	-78.5	
	256QAM		-76.5	-76.5	-75.5	-74.5	-75.5	
	512QAm		-73.5	-73.5	-72.5	-71.5	-72.5	
	1024QAM							
	2048QAM							
CS=10MHz	QPSK	-92.5	-92.5	-92.5	-91.5	-90.5	-91.5	-90.0
	16QAM	-85.5	-85.5	-85.5	-84.5	-83.5	-84.5	-83.0
	32QAM	-82.5	-82.5	-82.5	-81.5	-80.5	-81.5	-80.0
	64QAM	-79.5	-79.5	-79.5	-78.5	-77.5	-78.5	-77.0
	128QAM	-76.5	-76.5	-76.5	-75.5	-74.5	-75.5	-74.0
	256QAM	-73.5	-73.5	-73.5	-72.5	-71.5	-72.5	-71.0
	512QAM	-70.5	-70.5	-70.5	-69.5	-68.5	-69.5	-68.0
	1024QAM	-67.0	-67.0	-67.0	-66.0	-65.0	-66.0	-64.5
	2048QAM							
CS=20MHz	QPSK					-87.5	-88.5	
	16QAM					-80.5	-81.5	
	32QAM					-77.5	-78.5	
	64QAM					-74.5	-75.5	
	128QAM					-71.5	-72.5	
	256QAM					-68.5	-69.5	
	512QAm					-65.5	-66.5	
	1024QAM					-62.0	-63.0	
	2048QAM					-58.0	-59.0	
CS=30MHz	QPSK	-88.0	-88.0	-88.0	-87.0	-86.0	-87.0	-85.0
	16QAM	-81.0	-81.0	-81.0	-80.0	-79.0	-80.0	-78.0
	32QAM	-78.0	-78.0	-78.0	-77.0	-76.0	-77.0	-75.0
	64QAM	-75.0	-75.0	-75.0	-74.0	-73.0	-74.0	-72.0
	128QAM	-72.0	-72.0	-72.0	-71.0	-70.0	-71.0	-69.0
	256QAM	-69.0	-69.0	-69.0	-68.0	-67.0	-68.0	-66.0
	512QAM	-66.0	-66.0	-66.0	-65.0	-64.0	-65.0	-63.0
	1024QAM	-62.5	-62.5	-62.5	-61.5	-60.5	-61.5	-59.5
	2048QAM	-58.5	-58.5	-58.5	-57.5	-56.5	-57.5	-55.5
CS=40MHz	QPSK				-85.5	-84.5	-85.5	-84.0
	16QAM				-78.5	-77.5	-78.5	-77.0
	32QAM				-75.5	-74.5	-75.5	-74.0
	64QAM				-72.5	-71.5	-72.5	-71.0

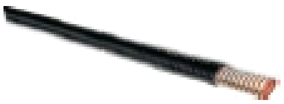
	128QAM				-69.5	-68.5	-69.5	-68.0
	256QAM				-66.5	-65.5	-66.5	-65.0
	512QAM				-63.5	-62.5	-63.5	-62.0
	1024QAM				-60.0	-59.0	-60.0	-58.5
	2048QAM				-56.0	-55.0	-56.0	-54.5
CS=50MHz	QPSK					-83.5	-84.5	-83.0
	16QAM					-76.5	-77.5	-76.0
	32QAM					-73.5	-74.5	-73.0
	64QAM					-70.5	-71.5	-70.0
	128QAM					-67.5	-68.5	-67.0
	256QAM					-64.5	-65.5	-64.0
	512QAM					-61.5	-62.5	-61.0
	1024QAM					-58.0	-59.0	-57.5
	2048QAM					-54.0	-55.0	-53.5
CS=60MHz	QPSK		-85.0		-84.0	-83.0		
	16QAM		-78.0		-77.0	-76.0		
	32QAM		-75.0		-74.0	-73.0		
	64QAM		-72.0		-71.0	-70.0		
	128QAM		-69.0		-68.0	-67.0		
	256QAM		-66.0		-65.0	-64.0		
	512QAM		-63.0		-62.0	-61.0		
	1024QAM		-59.5		-58.5	-57.5		
	2048QAM		-55.5		-54.5	-53.5		
CS=80MHz	QPSK					–		
	16QAM					–		
	32QAM					–		
	64QAM					–		
	128QAM					–		
	256QAM					–		
	512QAM					–		
	1024QAM					–		
	2048QAM				–	–		
BER = 10-3		Above value -1.0dB						
System Gain (dB) @ BER=10-6 (Measured at Ant. port)								
Bandwidth	Modulation							
CS=5MHz	QPSK		124.5	124.5	124.50	117.5	118.5	
	16QAM		115.5	115.5	114.50	108.5	109.5	
	32QAM		111.5	111.5	110.50	104.5	103.5	
	64QAM		108.5	108.5	107.50	101.5	100.5	
	128QAM		105.5	105.5	104.50	98.5	97.5	
	256QAM		101.5	101.5	100.50	94.5	93.5	
	512QAm		96.5	96.5	95.50	89.5	88.5	
	1024QAM							
	2048QAM							
CS=10MHz	QPSK	121.5	121.5	121.5	121.5	114.5	115.5	110.0
	16QAM	112.5	112.5	112.5	111.5	105.5	106.5	101.0

Appendix F: EW180 Waveguide Specifications

Product Specifications

COMMSCOPE®

POWERED BY ANDREW



EW180

EW180, HELIAX® Standard Elliptical Waveguide, 17.3–19.7 GHz, black PE jacket

Construction Materials

Jacket Material	PE
Conductor Material	Corrugated copper
Jacket Color	Black

Dimensions

Cable Volume	111.0 L/km | 1.2 ft³/kft
Cable Weight	0.22 kg/m | 0.15 lb/ft
Diameter Over Jacket (E Plane)	20.10 mm | 0.79 in
Diameter Over Jacket (H Plane)	12.40 mm | 0.49 in

Electrical Specifications

Operating Frequency Band	17.7 – 19.7 GHz
eTE11 Mode Cutoff	11.150 GHz
Group Delay	127 ns/100 ft @ 18.700 GHz 416 ns/100 m @ 18.700 GHz

Environmental Specifications

Installation Temperature	-40 °C to +60 °C (-40 °F to +140 °F)
Operating Temperature	-55 °C to +85 °C (-67 °F to +185 °F)
Storage Temperature	-70 °C to +85 °C (-94 °F to +185 °F)

General Specifications

Brand	HELIAX®

Mechanical Specifications

Maximum Twist	6.00 °/m | 2.00 °/ft
Minimum Bend Radius, Multiple Bends (E Plane)	150.00 mm | 6.00 in
Minimum Bend Radius, Multiple Bends (H Plane)	380.00 mm | 15.00 in
Minimum Bend Radius, Single Bend (E Plane)	150.00 mm | 6.00 in
Minimum Bend Radius, Single Bend (H Plane)	380.00 mm | 15.00 in

Note

Performance Note	Values typical, unless otherwise stated

Standard Conditions

Attenuation, Ambient Temperature	24 °C | 75 °F
Average Power, Ambient Temperature	40 °C | 104 °F
Average Power, Temperature Rise	42 °C | 76 °F

Product Specifications

COMMSCOPE®

EW180

POWERED BY ANDREW

Return Loss/VSWR

Frequency Band	VSWR	Return Loss (dB)
17.7–19.7 GHz	1.15	23.10

* *VSWR/Return Loss indicated is for lengths up to 300 ft (91.4 m)*
* *VSWR/Return Loss is guaranteed for factory-fit and typical for field-fit assemblies*
* *Custom length performance: Call +1-800-255-1479 (N. America), 1-779-435-6500 (Int'l.), or your local Andrew representative*

Attenuation

Frequency (GHz)	Attenuation (dB/100 ft)	Attenuation (dB/100 m)	Average Power (kW)	Group Velocity %
17.7	6.13	20.111	0.537	77.7
18.1	6.035	19.799	0.546	78.8
18.5	5.951	19.523	0.553	79.8
18.9	5.876	19.278	0.56	80.7
19.3	5.81	19.06	0.567	81.6
19.7	5.75	18.865	0.573	82.4

Regulatory Compliance/Certifications

Agency	Classification
ISO 9001:2008	Designed, manufactured and/or distributed under this quality management system