MICROWAVE RADIO LINK DESIGN FOR THE EXTENSION OF THE POINT-OF-PRESENCE (POP) BANDWIDTH

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Abstract— **This study conducted a design simulation for a microwave radio link for the extension of the bandwidth from the Point-of-Presence facility. The microwave radio link design was simulated using the Pathloss tool and the modulation technique of 128 QAM modulation. Different antenna dimensions of 1.8m, 1.2m, and 0.6m were used in order to perform design simulations to correlate stated variables that are characterized for the microwave link. Based on the design simulations, Design Simulation 3 with the smallest antenna dimension of 0.6m resulted in a minimal link unavailability of 0.08 minutes and had the highest link availability of 99.99998%, which translates to a reliable radio link that is within the reference of the acceptable range of values for link availability. As the dimensions of the antenna were changed, there was a significant change in the link unavailability time. Small diameter antennas are favorable to use, when possible, because of their small aperture for wind and tower, which results in considerably less tower leasing costs.**

Keywords: Point-of-Presence, QAM modulation, Pathloss tool, Microwave Radio Link, Link Availability, Link Unavailability

I. INTRODUCTION

Point-of-Presence (PoP) facilities are established to serve as a data bandwidth distribution point for identified receiving points. It is a demarcation point, access point, or physical location at which two or more networks or communication devices share a connection (Yang, et al., 2016). Its primary focus is to distribute bandwidth within adjacent and nearby receiving points, but due to the growing demand for reliable internet connectivity, it is also designed to cater to other middle and last-mile links through microwave radio technology or microwave link.

A microwave link is a communications system that uses a microwave radio beam to transmit information between two locations, ranging from just a few meters to several kilometers (Hanafi, et al., 2016). Microwave radio transmission is used in point-to-point communication systems on the surface of the Earth, in satellite communications, and deep-space radio communications. Other parts of the microwave radio band are used for radars, radio navigation systems, sensor systems, and radio astronomy [3]. In order to design a point-to-point microwave link system, there are several technical choices that need to be considered in designing a link, for instance, the microwave line-of-sight link, the link budget, and the free-space path loss on the link analysis.

Microwave communication is cost-effective, can be rapidly installed, can cross complicated terrains, and is an efficient means to connect two or more wireless points over a variety of terrains and space, where continuous runs of cable or fiber-type transmission lines would not be practical or even possible (Yang, et al., 2016). The design of a reliable microwave link requires a lot of complex computations. Studying the effect of all the different design aspects is crucial for the communication system in designing the path profile, link budget, fade margin, and all other parameters.

This study will design a point-to-point microwave radio link for the bandwidth extension from PoP within acceptable link availability with given probable attenuations, different antenna dimensions, and a specific modulation technique that are evaluated per design simulation with provision of frequencies and prediction of the link unavailability time. For this study, the Point-of-Presence facility located in Cauayan City will be used for the design of the microwave radio link that will gradually establish a network through propagation of microwave radio technology to identified adjacent and nearby receiving points.

II. METHODS

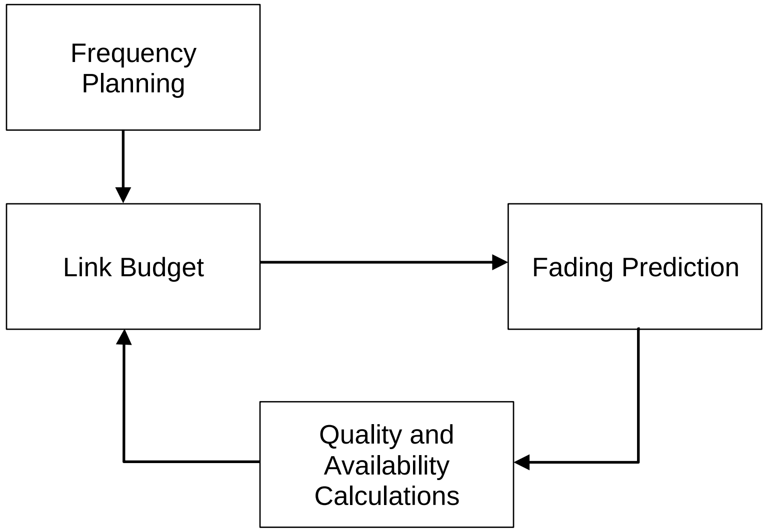


Figure 1. Microwave Radio Link Design Development

Figure 1 shows the iterative process in the design of a microwave radio link that goes through many redesign phases before the required quality and availability are achieved (Dengia, et al., 2017). In order to provide an optimal communication for a microwave radio link design, various design simulations in this study were based on modeling different radio link solutions with different antenna dimensions, a specific modulation technique, and other microwave link parameters needed for the establishment of the link within the acceptable range of values for a reliable microwave radio link design.

Achieving a reliable microwave link availability for the study is one of the most important parameters in designing a link. A widely used reference for high-capacity link availability is 99.999%, often known as "five-nines." This means that the link would experience outages for 0.001% of the time, or about 5 minutes in a year. This is often known as carrier-class availability, because it has long been the telecom operators' benchmark for wired and wireless telecommunications (Wells, 2010). The selection of the suitable antenna in this study also determined the economical aspect of the design of the microwave radio link. It is worth discussing these interesting facts revealed by the results of Liang and Yu (2015), in which it is estimated that the sharing of sites and antenna can reduce 20 - 30% of Capital Expenses, 25 - 45% of Capital Expenses can be saved if the whole radio network is shared, and the sharing of all the assets would decrease Capital Expenses by an additional 10%.

The study conducted three design simulations with different antenna dimensions of 1.8m, 1.2m, and 0.6m using the Pathloss tool and modulation technique of 128 QAM modulation in order to perform different schemes to correlate stated variables that are characterized for the microwave link.

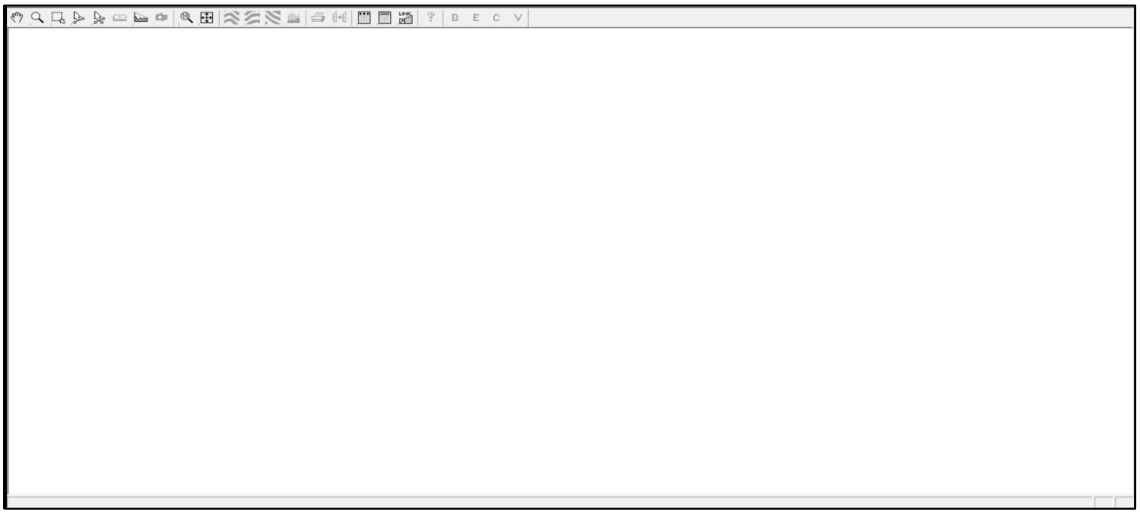


Figure 2. Pathloss Tool (Coordinates and Terrain Data)

Figure 3. Pathloss Tool (Transmission Analysis)

Shown in Figure 2 and Figure 3, is the graphical user interface of the Pathloss tool where coordinates, terrain data and transmission analysis are simulated and other redesign phases in designing a microwave radio link.

Radio Link Design by using Pathloss Tool

Pathloss program software requires exact geographical coordinates of radio link end points by using Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) information of the Earth, which is a high-resolution digital topographic database of Earth. The program calculates line-of-sight status and link budget by taking into account free space loss, rain loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss or path attenuation, as a definition, is the reduction in power density of an electromagnetic wave as it propagates through space. It is a major component in the analysis and design of the link budget of a telecommunication system. Other than free space loss and rain loss, path loss is also influenced by terrain contours, environment, propagation medium, the distance between the transmitter and the receiver, and the height and location of antennas.

Path loss normally includes propagation losses caused by the natural expansion of the radio wave front in free space, absorption losses when the signal passes through media not transparent to electromagnetic waves, diffraction losses when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena.

The signal radiated by a transmitter may also travel along many different paths to a receiver simultaneously; this effect is called multipath. Multipath waves combine at the receiver antenna, resulting in a received signal that may vary widely, depending on the distribution of the intensity and relative propagation time of the waves and bandwidth of the transmitted signal. The total power of interfering waves in a Rayleigh fading scenario varies quickly as a function of space, which is known as small-scale fading. Small-scale fading refers to the rapid changes in radio signal amplitude in a short period of time or travel distance.

Path Loss Radio Link Design

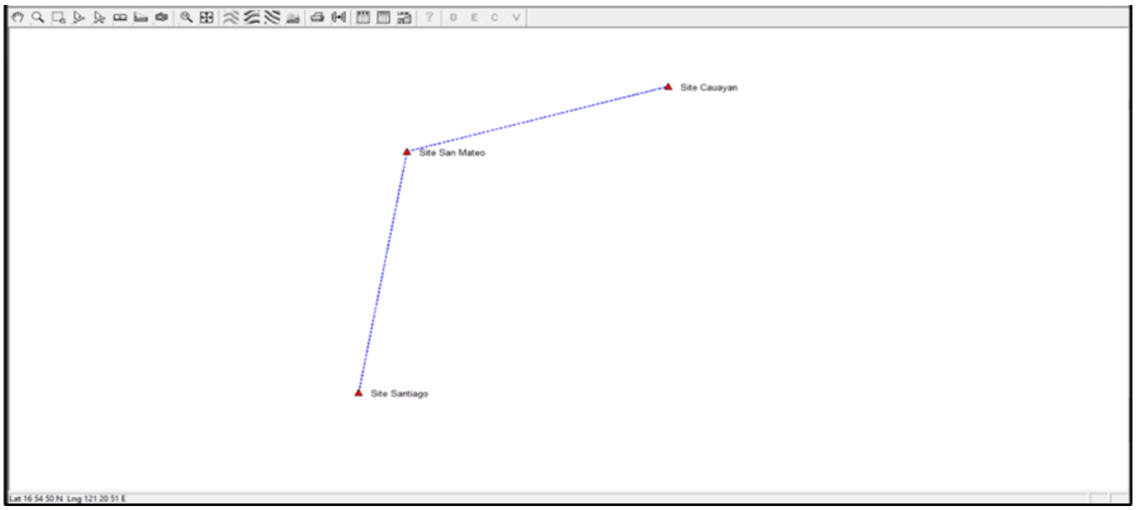


Figure 4. Link Definitions in Pathloss

The geographical coordinates for two sites are entered into the Pathloss tool, as Site Cauayan and Site San Mateo, by using their Latitude and Longitude values, and the sites are connected to establish a link, as presented in Figure 4.

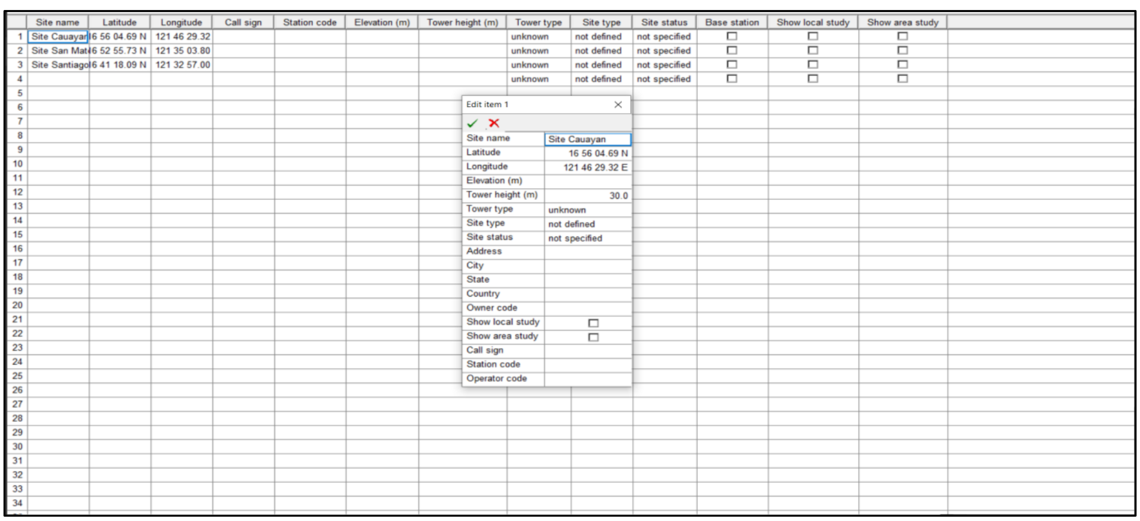


Figure 5. Generating the Path Profile and Terrain Data for Site Cauayan

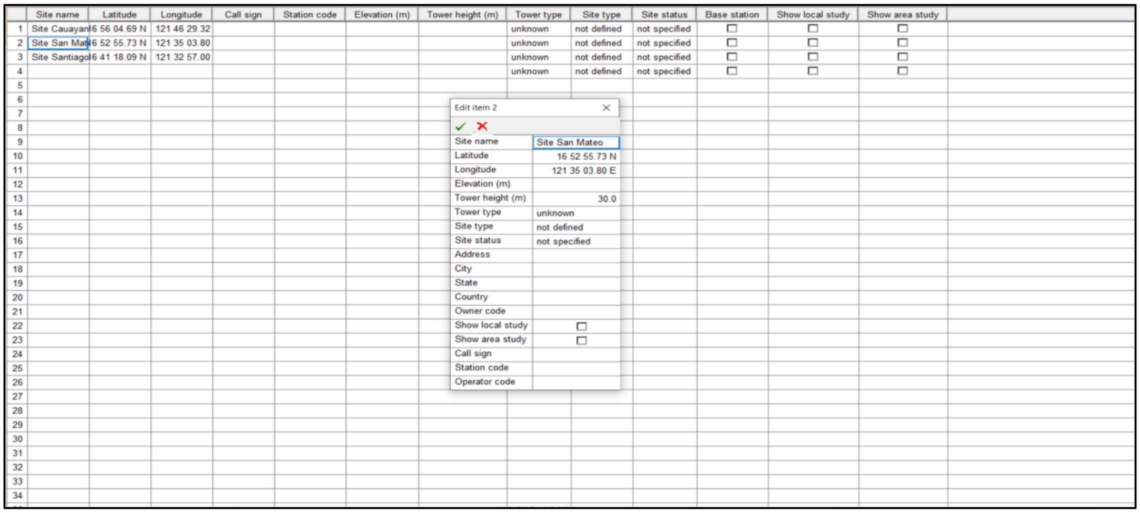


Figure 6. Generating the Path Profile and Terrain Data for Site San Mateo

Figure 5 and Figure 6 demonstrate the latitude and longitude information where the basic data for sites are being gathered.

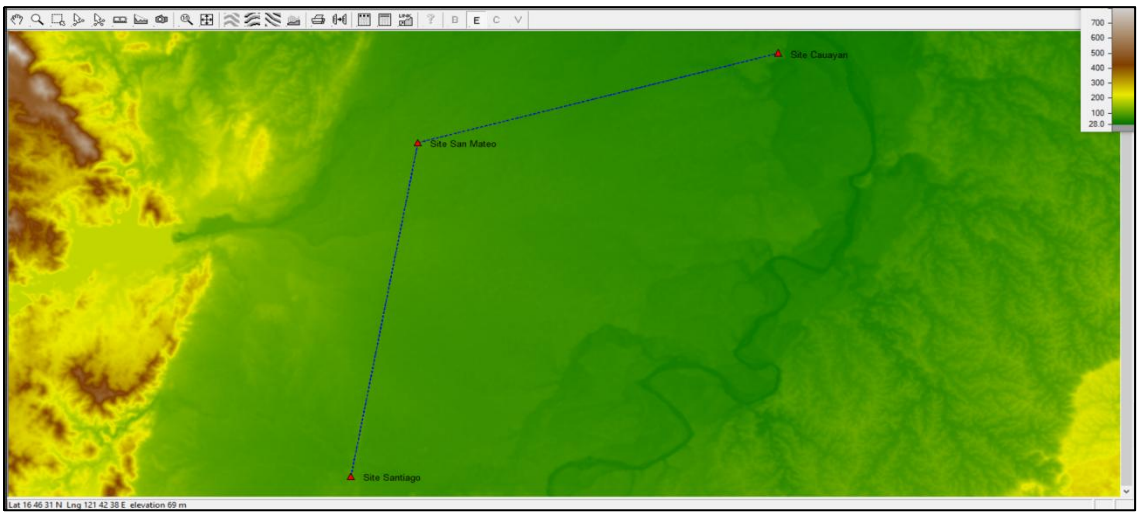
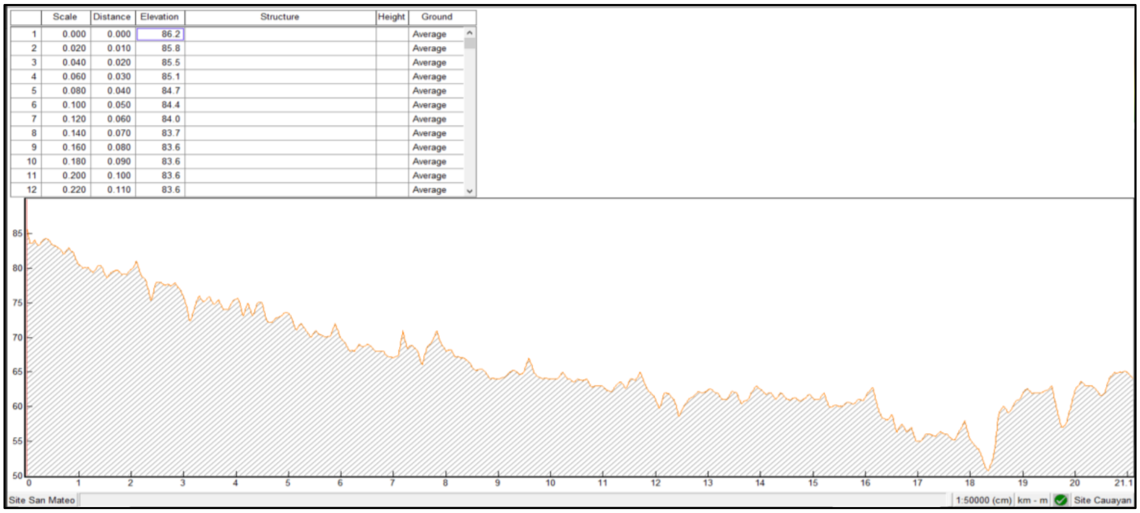


Figure 7. Terrain Backdrop and Data

The Pathloss tool shows the backdrop elevation data as presented in Figure 7. Setting the terrain data in the tool requires a downloaded Digital Elevation Model (DEM) of the Earth, in which the Shuttle Radar Topography Mission (SRTM) is used. The DEM map of the Earth is uploaded through the configuration of the geographic system of Pathloss, and SRTM is selected in the projection category that will now determine the exact site coordinates for Site Cauayan and Site San Mateo through the backdrop elevation data.



	Scale	Distance	Elevation	Structure	Height	Ground
1	0.000	0.000	86.2			Average
2	0.020	0.010	85.8			Average
3	0.040	0.020	85.5			Average
4	0.060	0.030	85.1			Average
5	0.080	0.040	84.7			Average
6	0.100	0.050	84.4			Average
7	0.120	0.060	84.0			Average
8	0.140	0.070	83.7			Average
9	0.160	0.080	83.6			Average
10	0.180	0.090	83.6			Average
11	0.200	0.100	83.6			Average
12	0.220	0.110	83.6			Average

Figure 8. Terrain Data

The Pathloss tool analyzed the exact line-of-sight status, where the profile between Site Cauayan and Site San Mateo can be geographically and tabularly seen, as shown in Figure 8. From this form, the elevation can be analyzed by adjusting the vertical measurement line from Site San Mateo to Site Cauayan to determine the location with the highest or lowest elevation.

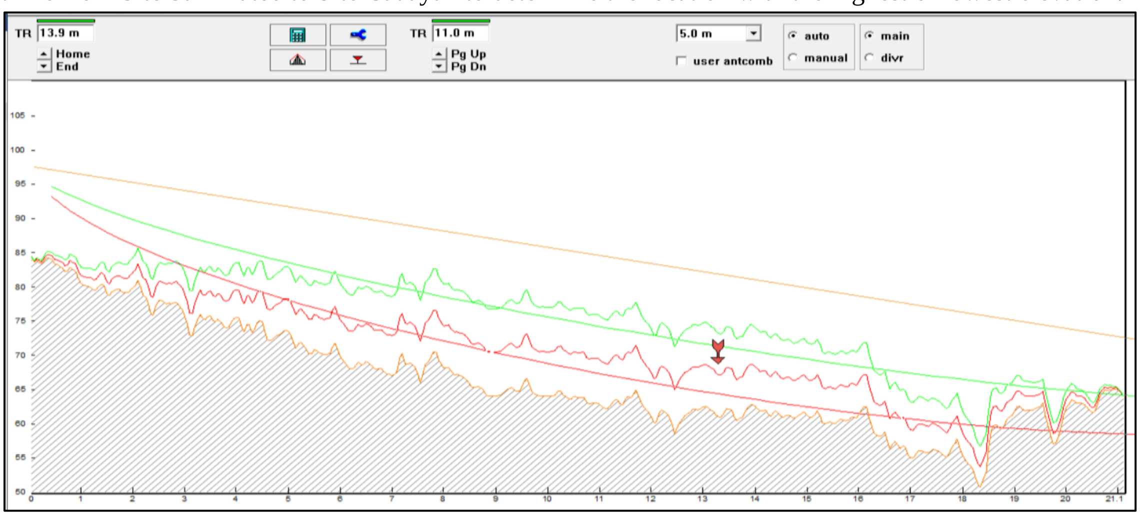


Figure 9. Antenna Heights

With further analysis, the line-of-sight status for the selected antenna heights of Site Cauayan and Site San Mateo can be viewed, as shown in Figure 9.

The antenna height parameter is editable, and depending on the tower-defined maximum height, it can be adjusted to have an optimal line-of-sight. In this study, the antenna height for Site Cauayan is taken as 11.00m, and for Site San Mateo, it is taken as 13.90m.

Path Loss Radio Link Design with Different Antenna Schemes

The overall radio link availability values with different transmission capacities are evaluated for three different radio link designs with the antenna height assumption and by changing the antenna schemes with one modulation technique. Various design simulations are studied to achieve the highest radio link capacity while still satisfying the high transmission availability values. All radio link models are based on a commercial microwave equipment manufacturer, NEC Corporation's PASOLINK product family series, which has a wide range of microwave radios that start from 4GHz to 52GHz variable spectrum.

For all radio link calculations, the Pathloss IP radio model of 8GHz NEC PASOLINK is used, and the antenna is selected from Andrew Corporation, with a frequency range from 7125MHz - 8500MHz and various diameters, but with single polarization in order to decide on the optimal design.

The multipath algorithm and rain loss related to Pathloss tool values for the selected geographical area used will be the ITU-T Region N, which is automatically selected by using the ITU algorithm Rec. ITU-R P.530-9/11 for 8GHz frequency. The rain rate data source that will be used is the ITU-R P.837-3 database.

III. RESULTS AND DISCUSSION

Design Simulation 1

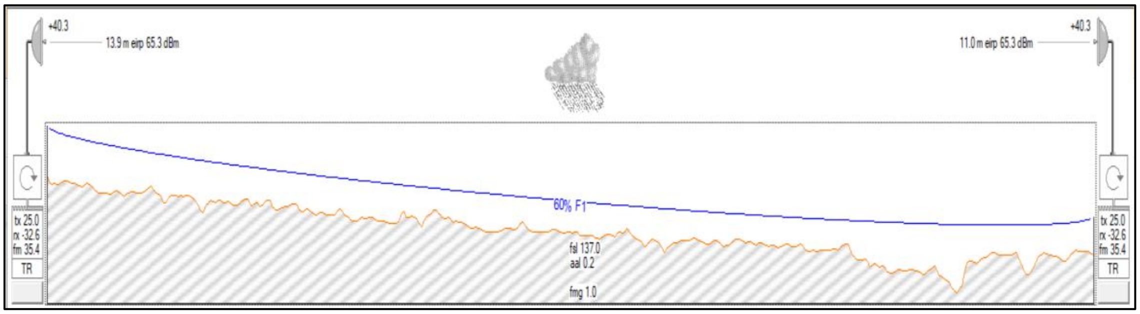


Figure 10. Transmission Analysis for 1.8m Antenna

The transmission analysis shown in Figure 10 is the result of the simulation with the NEC PASOLINK radio, using 128 QAM modulation and a 56MHz channel bandwidth, with a 1.8m antenna and a 40.3 dBm antenna gain.

Design Simulation 2

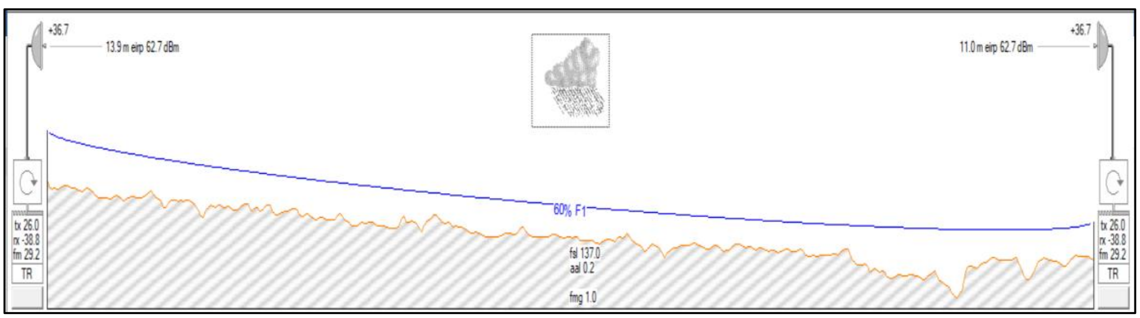


Figure 11. Transmission Analysis for 1.2m Antenna

The transmission analysis shown in Figure 11 is the result of the simulation with the NEC PASOLINK radio, using 128 QAM modulation and a 56MHz channel bandwidth, with a 1.2m antenna and a 36.7 dBm antenna gain.

Design Simulation 3

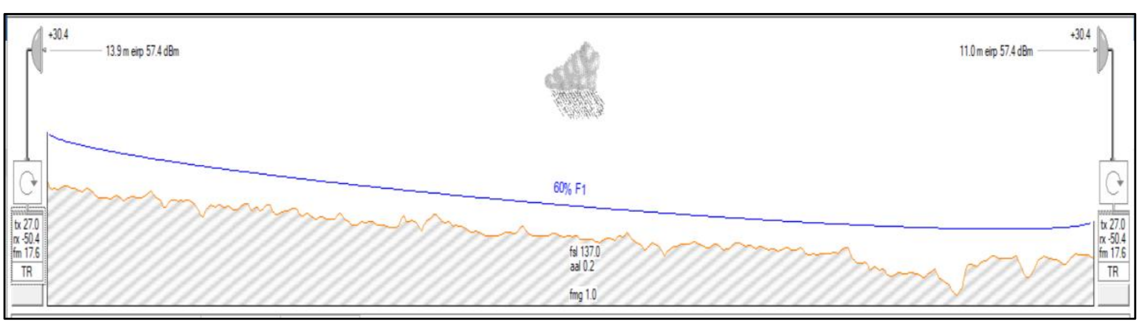


Figure 12. Transmission Analysis for 0.6m Antenna

The transmission analysis shown in Figure 12 is the result of the simulation with the NEC PASOLINK radio, using 128 QAM modulation and a 56MHz channel bandwidth, with a 0.6m antenna and a 30.4 dBm antenna gain.

Table 1. Summary of Design Simulation Results

Microwave Link Parameters	**Design Simulation 1**		**Design Simulation 2**		**Design Simulation 3**	
Site Name	Site San Mateo	Site Cauayan	Site San Mateo	Site Cauayan	Site San Mateo	Site Cauayan
True Azimuth (°)	73.99	254.05	73.99	254.05	73.99	254.05
Vertical Angle (°)	-0.14	0	-0.14	0	-0.14	0
Elevation (m)	86.20	64.00	86.20	64.00	86.20	64.00
Tower Height (m)	30.00		30.00		30.00	
Antenna Model	VHPX4-71W		VHPX4-71W		VHPX4-71W	
Antenna Gain (dB)	40.30	40.30	36.70	36.70	30.40	30.40
Antenna Height (m)	13.90	11.00	13.90	11.00	13.90	11.00
Frequency (MHz)	8000		8000		8000	
Polarization	Vertical		Vertical		Vertical	
Path Length (km)	21.10		21.10		21.10	
Free Space Loss (dB)	137.00		137.00		137.00	
Atmospheric Absorption Loss (dB)	0.22		0.22		0.22	
Field Margin (dB)	1.00		1.00		1.00	
Net Path Loss (dB)	57.62		64.82		77.42	
Radio Model	PASOLINK+ 8G 311MB		PASOLINK+ 8G 311MB		PASOLINK+ 8G 311MB	
TX Power (dBm)	25.00		26.00		27.00	
EIRP (dB)	65.30		62.70		57.40	
RX Threshold Criteria	1E-6 BER		1E-6 BER		1E-6 BER	
RX Threshold Level (dBm)	-68.00		-68.00		-68.00	
Receive Signal (dBm)	-32.62		-38.82		-50.40	
Thermal Fade Margin (dBm)	35.38		29.18		17.58	
QAM Modulation	128		128		128	
Annual rain + multipath availability (%)	**99.99978**		**99.99991**		**99.99998**	
Annual rain + multipath unavailability (min)	**1.17**		**0.45**		**0.08**	

The design simulations summarize the radio link design results simulated with different antenna schemes of 1.8m, 1.2m, and 0.6m that provide the overall annual availability value, related free space loss, and other microwave link parameters, as presented in Table 1. The design simulation with the NEC PASOLINK radio, using 128 QAM modulation and a 56MHz channel bandwidth with the specified modulation and antenna schemes, produced Design Simulation 1 results in an overall link availability value of 99.99978%, including annual rain and multipath-related effects, which means 1.17 minutes of interruption of traffic for one year, while Design

Simulation 2 results in an overall link availability value of 99.99991% with 0.45 minutes, and Design Simulation 3 results in an overall link availability value of 99.99998% with 0.08 minutes, along with the other microwave link parameters.

Based on the results of the three design simulations with different antenna schemes and a specific modulation technique, Design Simulation 3 with 128 QAM modulation and a 0.6m antenna is considered the suitable one, with annual link unavailability of 0.08 minutes. The reason for this selection is its ability to transport data transmission traffic smoothly while at the same time allowing the use of a considerably small diameter antenna of 0.6m.

In relation to the economic aspect of the design based on the simulations, this is consistent with what has been found in the previous study of Hanafi, et al. (2016), which shows that using smaller antennas can provide up to 75% savings in tower leasing costs over a five-year period, which is sometimes equal to the cost of the radio link equipment itself. This result also ties well with previous studies, wherein the benefit of smaller antennas really cannot be understated. Going from a 1.2m to a 0.6m antenna gives about a 70% capital expenses reduction alone. Shipping, handling, and installation costs will also be reduced. For a link, this savings is doubled (Aviat System, 2022).

IV. CONCLUSION

Based on the design simulations, Design Simulation 3, with the smallest antenna dimension of 0.6m, resulted in a minimal link unavailability of 0.08 minutes and has the highest link availability of 99.99998%, which translates it to a reliable radio link that is within the reference of the acceptable range of values for link availability. As the dimensions of the antenna were changed, there was a significant change in the link unavailability time. Small-diameter antennas are favorable to use, when possible, because of their small aperture for wind and tower, which results in considerably less tower leasing costs.

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