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Utilization of Trendlines in Determining Antenna Heights for Microwave Communications

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Abstract:- Telecommunication industry enabled personal and professional communications and has been a significant tool used in most businesses. Even in times od pandemic, telecommunication was instrumental in the prompt dissemination of updates, government programs, data analysis which enables the government to successfully combat the COVID 19. A microwave link is a type of communication system using a beam of radio waves to transmit information between two fixed locations. Antenna is one of the basic components of a microwave link, together with the receiver, transmitter and transmission lines. One of the common topics in microwave communications is finding the antenna heights, since the heights of the antenna defines radio horizon. There are two methods on computing antenna heights. The single obstruction method, and the double obstruction method. A feature of Microsoft office such as MS WORD, MS EXCEL, MS Power point, the trendline can be used to determine the antenna heights. Trendline is normally used to depict trends and resistances to trends. This research shows that adding some manipulations make trendline a better way to solve antenna heights, that is free of trials. It can solve any type of terrain or obstruction types present between two communicating sites. With trendline, the result is the most practical height, and the answer is always final, no trial and error required. A close-ended survey is also undertaken to determine the level of acceptability of using the process. In most of the statements, the respondent agreed on the viability of using trendline to solve for antenna heights.

***Keywords**:- Antenna Heights, Earth Bulge, Fresnel Zone, Microwave Communications, , Trendline.*

I. INTRODUCTION

Telecommunication industry has been proven to be one of the most essential industries in the country. It has enabled personal and professional communications and a significant tool used in business. In the Philippines alone, the gross value added (GVA) of information and communication industry reached Php 638.75Bn, Php 434.58 Bn for household expenditures on communication (www.statista.com, 2021). Despite the pandemic brought by the worldwide spread of COVID 19, telecommunication industry displayed resiliency and in fact, has been instrumental in the prompt information dissemination of updates, government programs, data analysis, and several activities which enable human fight the pandemic.

A microwave link is a type of communication system which uses beam of radio waves to transmit information between two fixed locations. With the use of microwave frequencies, microwave communication has been very vital in telecommunication industry and impacted broad range of industries. Microwave links carry calls on cellular phones between sites. It is also used to provide high speed wireless internet services. Telephone calls are carried over switching center using microwave. Indeed, microwave is a very powerful communication system. A simple microwave link consists of four major elements: a receiver, transmission lines, and antennas. These basic components exist in every radio communication system such as cellular telephony, two-way radio systems, wireless networks and broadcasting systems (https://ethw.org, 2018).

The transmitter produces a microwave signal that carries the information to the receiving party. The microwave signal is propagated from the transmitter into the space with the use of the antenna. A receiving antenna on the receiving party detects even a very weak signal, captures the signal and bring it to the low noise amplifier for the recovery of the original signal. The antenna height, depending on frequency used, antenna type and size, has major impact in the performance and reliability of the communication system. In general, the higher the antenna, the better its performance will be. Broadcasters invest in very high towers for greater coverage (www.electronics-notes.com, 2018). For microwave links where communication between two fixed location is necessary, antenna heights play a significant role to increase radio horizon and overcome the obstruction. High antenna necessitates the erection of large antenna towers and a bigger land area for the erection of the tower. In order to optimize the size of the tower and the and area, a practical height of the antenna is very significant.

The International telecommunications Union (ITU) recommended a formula to solve the antenna heights both for the transmitting and receiving antenna (ITU, 2008). The formula considers the earth bulge, or the bulk offered by the earth as the distance between the two communicating party increases (Arbesser-Rastburg, 2009).

The formula;

$$a = h_0 + eb + F \qquad \textit{Equation 1}$$

Where: a = antenna heights (m)
h_0 = height of the obstruction (m)
F = radius of the Fresnel Zone (m)

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Fresnel Zone (F) refers to the 3D elliptical region between the transmit and the receive antenna. The zone is dependent on the distance between the sites and the frequency used in the design (www.everythingrf.com, 2018). The formula suggests only one obstruction to be considered. It is applicable only when there is one significant obstruction or point of interest between the two sites.

There is another formula in finding the antenna heights of a microwave link, which considers two significant obstructions between two sites (Campbell_Scientific_Inc., 2016).

$$F = \frac{d_1}{D}(h_2 - h_1) + h_1 - e_{OH} \qquad equation\ 2$$

Where F = Fresnel zone (m)
d_1 = distance of the obstruction from the transmitting site (km)
D = the total distance of the communication link, distance between the two sites (km)
h_1 = the height of the first antenna above sea level (a_1 +e_1), m
h_2 = the height of the 2nd antenna above sea level (a_2 +e_2), m
a_1 = height of the first antenna from the ground (m)
e_1 = height of the elevation of the first site (m)
a_2 = height of the 2^{nd} antenna from the ground (m)
e_2 = height of the elevation of the 2^{nd} site (m)

Designers can use the same formula above but considering two different obstructions between sites. The two formulas can generate two antenna heights. This is better than the previous method of solving antenna heights because it considers two obstructions. More practical antenna heights resulted from using this method. What makes it difficult is the choice of the obstruction to be considered in the equation. One can use different combinations of the obstructions between sites. It is a real mind breaking scenario.

A trend line, often referred to as the line of best fit, is a line used to represent the behavior of the given set of data and determine if there is a set of patterns associated with the data (Cadic, 2021). In accounting, trend line can be extended to indicate a future direction. Trend line analysis is used for budgeting next or future activities, projects and is commonly used in technical analysis (www.accountingtools.com, 2022). The main objective of the study is "The Utilization of Trendlines in Determining the Antenna Heights in Microwave Communications". Specifically, it aims to aid mathematical computations with graphical presentation to lessen the burden of determining antenna heights; come up with a single answer to the problem and eliminate multiple answers and lessen the burden of determining the most practical height, and compare the result in terms of the practicality of the antenna heights computed using the three methods: Single obstruction method, Double obstruction method, and Trend line analysis. A close ended survey is also designed to determine the level of acceptability of utilizing the Trendline analysis in finding antenna heights, taking the perception from Electronics Engineering students and graduates.

II. METHODOLOGY

The ***"Utilization of Trendlines in Determining the Antenna Heights in Microwave Communications"*** is exploratory research, which aims to apply a process from one field to another field. In Radio communication, the practical height of the antenna, both the transmit and receive antennas are very important. There are several factors to considered in solving the practical height of the antenna. The earth is a sphere and the distance between two communicating parties offers a bulk known as the earth bulge. The greater the distance between the sites, the higher the obstruction will be. In addition to the earth bulge, there are several obstructions like hills, trees, houses and mountains. These earth's feature greatly affects the line of sight (LOS) propagation. Regardless of the power of the transmitter, the information cannot reach its destination when the radio communication link is blocked in between. The most effective method to overcome the obstruction is to increase the antenna height. The higher the antenna height, the easier the information reach the receiving end. Antenna height affects the propagation of the electromagnetic waves, not only the transmitting antenna. An experimental study result stated that the received signal strength is directly proportional to the height of the receiving antenna even if the transmitter has an antenna installed on a very high antenna or highly elevated areas (jimh, 2017).

Increasing antenna heights increases the budget allocated for the erection of self- supporting antenna towers. For guyed towers, increased antenna heights would mean renting or buying larger lot for the locating the guys used to support the integrity of the antenna. The tower height should be practical to optimize the performance of the antenna and ensure that the Fresnel zone or at least 60 % of it is free from any obstruction. The difference between the terrains and presence of obstruction between the transmitting and receiving stations makes it difficult to compute the practical heights of the antenna. The ITU recommends a formula to solve for the antenna heights both at the transmit and receive stations which considers the earth bulge, Fresnel zone, distance between stations and the frequency used. The handbook also recommends to consider the effective earth's radius or k-factor (*k*). The recommended formula is easy, yet is it is not always applicable. There are lot of times that the result is impractical. The formula suggests that the height of the antenna for both the transmit and receive antennas are equal.

There are elements to consider in determining the antenna heights; the operating frequency, the distance between the two stations, the elevation of the obstructions, and the distance of the obstructions from the stations. While the frequency is one of the most significant parameters in the whole operation of radio communications, it is used in determining the radius of the Fresnel zone. The location of the obstruction is as important as the other element as it dictates the height of the earth bulge, which is added to the elevation. The vegetation is given importance by adding additional height to the elevation in the form of tree growth allowance.

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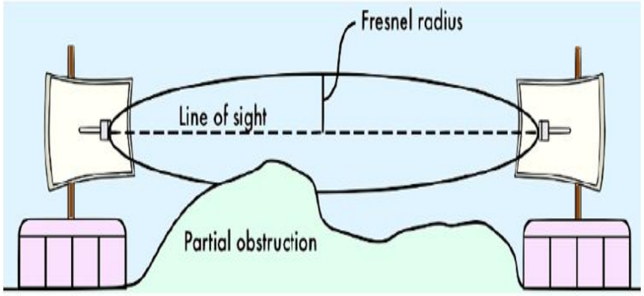

Fig 1: The single obstruction method and the Fresnel zone

Before proceeding to the actual antenna computations, it is important to solve first for the value of the earth bulge and the first Fresnel radius. The height of the earth bulge (eb) is added to the elevation of the obstruction, together with the tree growth allowance (TGA). Earth bulge(eb) is the bulk offered by the earth, owing to its curvature. This becomes higher as the distance between two station increases.

Earth Bulge can be solved by:

$$\boldsymbol{e.b = \frac{d_1 d_2}{12.75k} = \frac{d_1 d_2}{17} \qquad equation\ 3}$$

Where:
d_1 = distance of the point of consideration from site 1 (km)
d_2 = distance of the point of consideration from site 2 (km)
e.b = earth bulge (m)
k = effective earth radius multiple
also

$\boldsymbol{e.b = \frac{d_1 d_2}{1.5k} = \frac{d_1 d_2}{2}}$ **Equation 4**

d_1 = distance of the point of consideration from site 1 (mi)
d_2 = distance of the point of consideration from site 2 (mi)
k = effective earth radius multiple
e.b = earth bulge (ft)

K-FACTOR GUIDE:

K	Propagation	weather	terrain
4/3	Perfect	standard atmosphere	temperate zone, no fog
1 – 4/3	ideal	no surface layers, fog	dry, mountainous, no fog
2/3 - 1	Average	Substandard, light fog	flat, temperate, some fog
0.5 – 2/3	difficult	surface layers, ground fog	coastal
0.4- 0.5	bad	fog moisture, over water	coastal, water, tropical

Source: (Le-Ngoc, 2008)

Unlike the popular view of a Line of Sight which a clear unobstructed clear straight line. Radio frequency line of sight is defined by Fresnel Zones which are ellipse shaped areas between any two radios. The primary Fresnel zone is required to be at least 60% clear of any obstruction to ensure the highest performance of wireless link. Typically, the first Fresnel zone (N=1) is used to determine obstruction loss. The direct path between the transmitter and the receiver needs a clearance above ground of at least 60% of the radius of the first Fresnel zone to achieve free space propagation conditions. Earth-radius factor k compensates the refraction in the atmosphere. Clearance is described as any criterion to ensure sufficient antenna heights so that, in the worst case of refraction (for which k is minimum) the receiver antenna is not placed in the diffraction region. Fresnel Zone can be interpreted as [1] Radio line of sight requires no intrusions into the first Fresnel zone within the first and last 1 km next to the receiving and transmitting antennas; [2] Want no intrusions more than 40% into the first Fresnel zone at any point. (optimal clearance requires 60% of the first Fresnel zone); and [3] At least grazing line of sight must exist during adverse refraction (when k =1 or k= 0.667) (www.usna.edu, 2015).

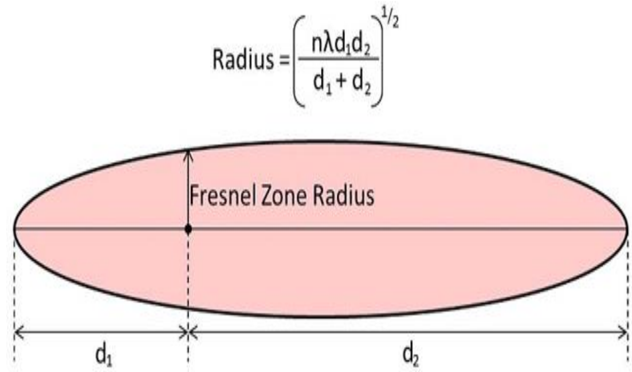

Fig 2: Formula and illustration of the Fresnel Zone Radius

From the figure, the radius of the first Fresnel zone (F_1) can be solved with the formula below.

$$\boldsymbol{F_1 = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}} \qquad equation\ 4}$$

Where
n=1 (1st)
F_1= 1st Fresnel zone (m)
λ = wavelength (m)
d_1 = distance of the point of consideration from site 1 (km)
d_2 = distance of the point of consideration from site 2 (km)

If there is a knife edge obstruction, the formula

$$a = h_0 + eb + F$$

Is very much applicable.

Another formula can be used to solve for the Fresnel zone, which can be used to solve for the antenna heights.

$$F = \frac{d_1}{D}(h_2 - h_1) + h_1 - e_{OH}$$

The formula can be used to consider at least two obstructions of interest, creating two equations which when algebraically solved will arrived to the antenna heights of the transmit and receive antenna. The problem relies on the choosing the obstruction of interest or which two significant obstructions are to be chosen (Campbell, 2016). There are parameters to consider:[1] the value of the earth bulge which is at maximum in the middle of the distance, [2] the elevation of the obstructions which varies depending on the terrains of the location, and [3] the cigar shape of the Fresnel zone which is at maximum also in the middle. Making several computations and comparing the result will result to arriving at the most practical heights of the antenna. But solving several combinations of two obstruction is burdensome.

A Microsoft office application, a feature of both Microsoft Word, and Microsoft Excel is a useful tool in projecting future budget, target capacity (https://support.microsoft.com, 2022). This is known as trendline. Trendline is a dotted line used to set a pattern of the given set of data. This can be used in finding the antenna heights for both stations. The process still make use of solving the earth bulge, and the Fresnel zone. The difference is that, there's no need to solve combinations of obstructions and comparing all the results. After computing the earth bulge and applying the result to the Fresnel clearance, the data can be set for trendline analysis.

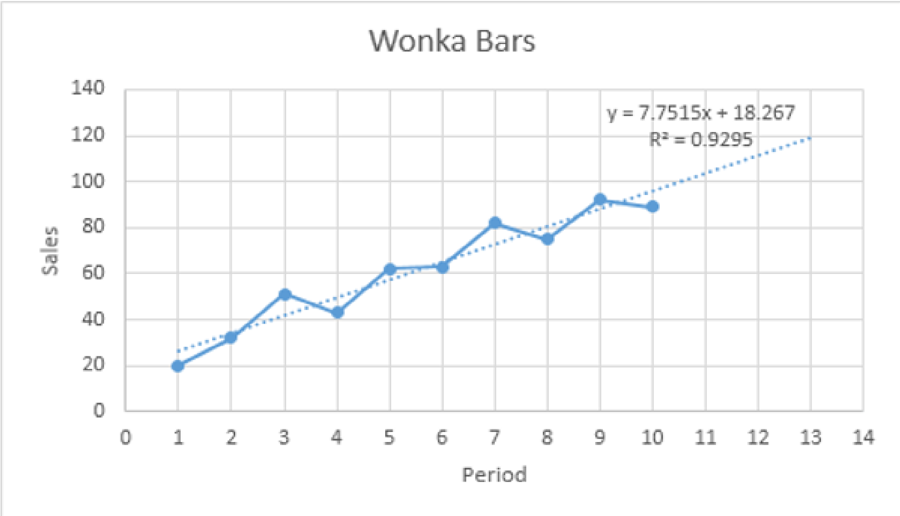

Fig 3: Example of trendline

This is a graphical analysis which is much easier than the double obstruction approach. The results of the different solutions are then compared to determine which is the most practical height. Different types of terrains are used in the comparison, to see the advantages and the disadvantages of one method over the other. Frequency is also varied for better comparison of the results.

Trendline cannot be utilized right away, there is a need to compute first for earth bulge, first Fresnel radius. There is also a need to consider the obstructions, and the tree growth allowance for better result.

Table 1: Formula used in the determination of antenna heights

	Single Obstruction Method	Double Obstruction method	Trendline Analysis
Earth Bulge (eb)	$eb = \frac{d_1 d_2}{12.75k}$	$eb = \frac{d_1 d_2}{12.75k}$	$eb = \frac{d_1 d_2}{12.75k}$
First Fresnel Radius (F_1)	$F_1 = 17.32\sqrt{\frac{d_1 d_2}{fD}}$	$F_1 = 17.32\sqrt{\frac{d_1 d_2}{fD}}$	$F_1 = 17.32\sqrt{\frac{d_1 d_2}{fD}}$
Antenna heights	$a = h_0 + eb + F$	$F = \frac{d_1}{D}(h_2 - h_1) + h_1 - h_{oe}$	Generated by the system (trendline)

Steps in using Trendline in the computations of antenna heights

1. Using the topographic map, locate the possible telecommunication site.
2. Use contour reading to identify the elevation of the sites and the space between.
3. Compute for the earth bulge of each chosen obstacle (k=4/3). Assign a tree growth allowance (TGA) for each. Compute the total elevation of the obstruction (hoe)
4. Compute the value of the 1st Fresnel and add to hoe
5. Tabulate the values of the distance @ site A and the total height,
6. Proceed with the trendline analysis from your MS WORD/ MS EXCEL Office
6.1. Click Insert » Chart » X Y Scatter » Scatter » OK
6.2. Change the data on the excel sheet with your data
6.3 Close the excel sheet to see the scattered dots based on the data
6.4. On the Word file, click the chart, then click the plus (+) sign (Chart element)
6.5. Check the Trendline box.

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6.6. Upon checking the Trendline box, a dotted line will appear
6.7. Project a line parallel to the trendline which will traverse the highest (peak) point
7. Project the height by project from the distance 0 (a1) and 13.5 (a2) to the vertical measurement
8. Repeat Step no. 3 to step no. 8, using k_e based on the figure below

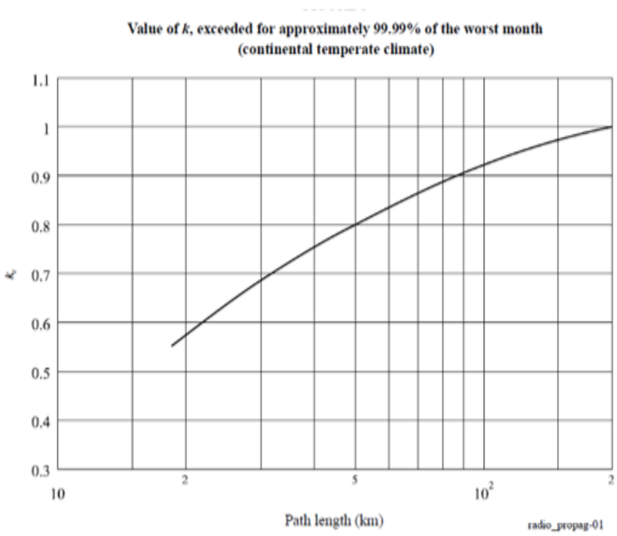

Fig 4: Value of k, exceeded for approximately 99.99% of the worst month (continental temperate climate) source: ITU Handbook

9. Based on the two results, chose the higher value of antenna heights.

There are 3 examples to be solved here for the presentation, and the results are presented alongside the results from single obstruction, and double obstruction method. The final decision, which antenna heights to be used depends on the person in-charged of finding the required height before setting up the design of the microwave communications.

The process is also presented to some professionals and other students taking up Electronics engineering who have taken the course and those who are currently taking up the course. The steps were presented to the respondents for them to try the process before filling out the survey form. There are 34 respondents; four (4) of them are already professional, working as telecoms engineers, 16 are students currently taking the course Advanced Communications Systems and Designs, where the CHED Memorandum Order (CMO) suggests the project, Two-Hop Microwave System, and 14 students who have already taken up the course during the conduct of this research.

To determine the validity of using trendline analysis in determining antenna heights used in microwave communications, an open-ended problem solving, and close-ended survey through google form is used. This section presents the answer to the three given problems with different scenario. The results are tabulated and graphically represented. Telecom engineers actually based their judgment not only on the computation but on the graphical presentation. There is actually no exact answer as to which is the true antenna heights. As long that the First Fresnel radius is free of obstruction, the height value can be used. Practicality is the main issue in finding the antenna height. Generally, increasing antenna heights mean increasing the reliability of the system. With greater heights, obstructions are overcame; greater coverage is achieved, and the feed impedance, radiation diagram, radiation losses, distance from interference, and reduction in possibility of exposure to RF radiation are improved (Soriano, 2022). But increasing antenna heights would mean higher investments on tower erection, land area and transmission lines. The difficulty and danger during the installation. Investment also on land area is always call for choosing the practical size of the antenna. There are also local regulations on the maximum heights of structures.

Problem No. 1

In problem no. 1, the knife edge obstruction as shown in the table. Is located at a distance of 55 kms from site A.

Table 2: Problem Set No. 1; f = 5 GHz

Site A(km)	Site B(km)	Elevation(el:m)		Site A(km)	Site B(km)	Elevation(el:m)
0	15	35		8	7	45
1	14	30		9	6	35
2	13	30		10	5	40
3	12	27		11	4	36
4	11	28		12	3	46
5	10	29		13	2	50
6	9	25		14	1	55
7	8	37		15	0	45

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Table 3: Antenna heights obtained from the single obstruction method solution, double obstruction method and Trend line analysis for problem 1

Method	**Obstruction considered**	**Antenna Heights (m)**	**Remarks**
Single Obstruction Method	Km 8 (el = 45m)	a1= 38.31 a2=28.31	Good antenna heights
	Km 14 (el = 55 m)	a1= 38.26 a2=28.26	Good antenna heights
Double obstruction	Km 8 (el = 45m) Km 14 (el = 55 m)	a1= 34.34; a2=27.35	Good antenna heights
	Km 7 (el = 40m) Km 14 (el = 55 m)	a1= 19.25 a2=28.43	There is partial infringement of the Signal
Trend line		a1= 24.84 a2=37.23	free of obstruction, good antenna heights

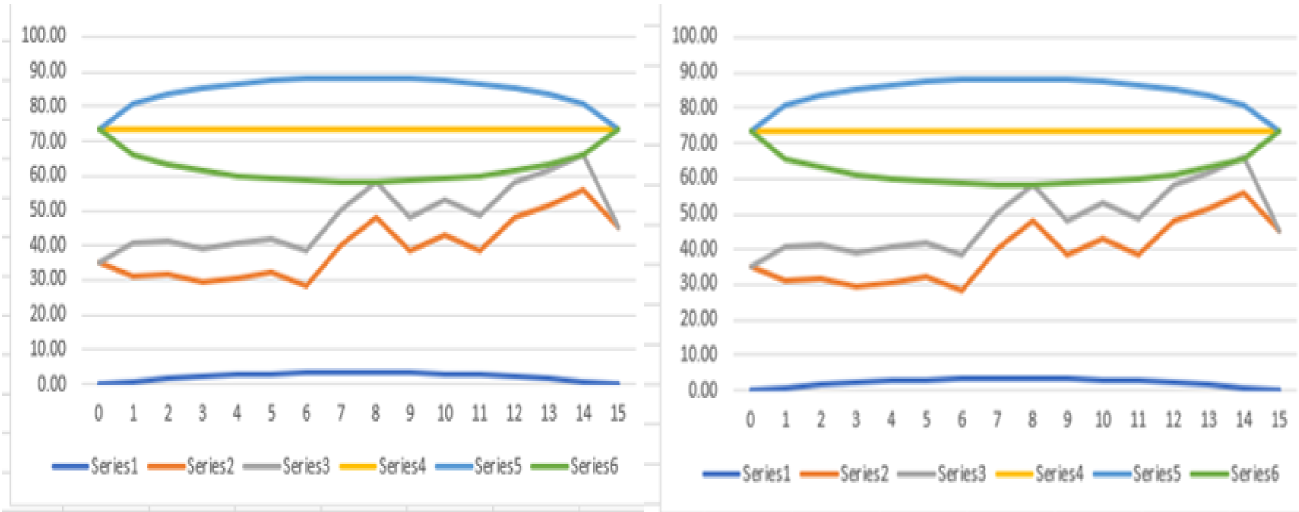

Fig 5: Single Obstruction Method Result for Problem 1

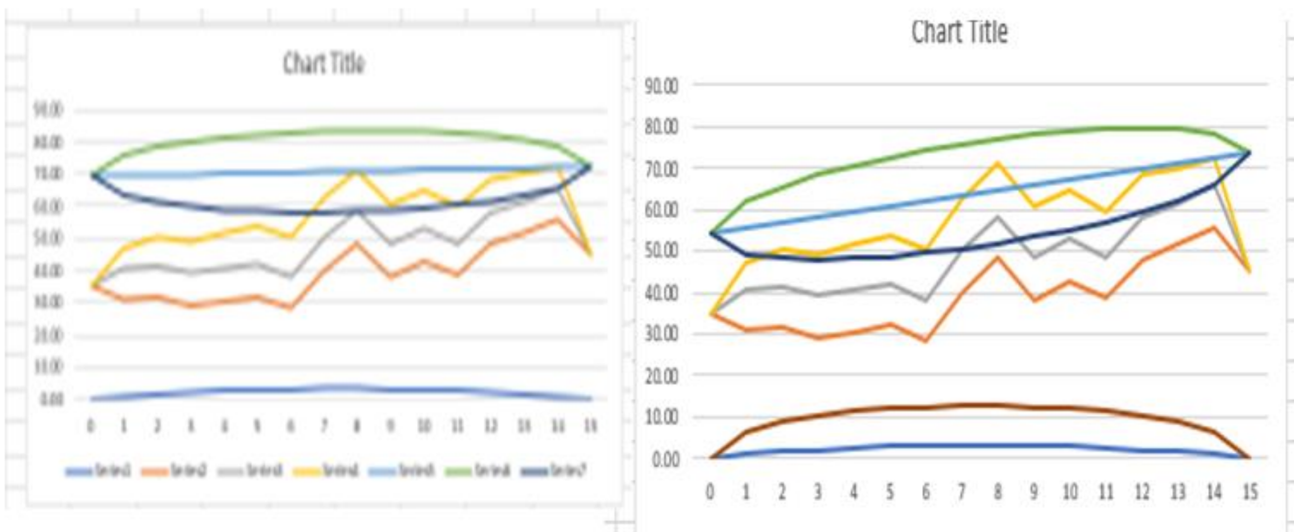

Fig 6: Double Obstruction Method result for problem 1

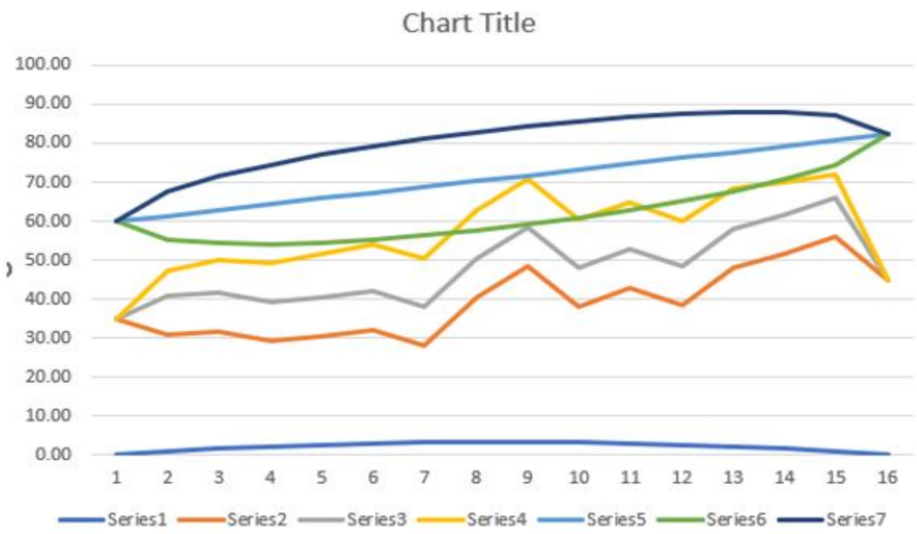

Fig 7: Trend line Result for problem 1

The antenna heights obtained from the given problem is tabulated in table 1. In problem 1, the most significant obstruction is situated 14 kms away from site A, but there is still one obstruction halfway, but a little bit lower. Using single obstruction method shows two results, considering the two most significant obstruction separately. The first Fresnel radius is clear of obstructions. In the double obstruction method, the first presentation is free of obstruction. This considers obstruction from Km 14 and Km 9. In the second result, the first Fresnel is infringed by obstruction at Km 8.

Problem 2: There are 3 significant resources in problem 2 located at km 5 from site A with an elevation of 75 m, the second obstruction at km 9 with 70 m elevation, and 75 m elevation at 14 kms away from site A.

Table 4: Problem 2, f=5GHz

Site A(km)	Site B(km)	Elevation(el;m)		Site A(km)	Site B(km)	Elevation(el;m)
0	16	40		9	7	70
1	15	40		10	6	40
2	14	30		11	5	36
3	13	27		12	4	46
4	12	28		13	3	50
5	11	75		14	2	75
6	10	50		15	1	65
7	9	60		16	0	60
8	8	45				

Table 5: Antenna heights obtained from the single obstruction method solution, double obstruction method and Trend line analysis for problem 2

Method	Obstruction considered	Antenna Heights (m)	Remarks
Single Obstruction Method	Km 14 (el = 75m)	a1= 57.23 a2=37.23	Obstruction partially shadows the signal
	Km 5 (el = 75 m)	a1= 63.03 a2=43.03	a1 is a little bit high
	Km 9 (el=70 m)	a1= 59.58 a2=39.58	a1 is a little bit high
Double obstruction	Km 8 (el = 45m) Km 14 (el = 55 m)	a1= 59.88 a2=34.98	a1 is a little bit high
	Km 9 (el=70 m) Km 14 (el = 55 m)	a1= 63.65 a2=29.44	There is partial infringement of the Signal; a1 is a little bit high
	Km 7 (el = 40m) Km 14 (el = 55 m)	a1= 65.33 a2=25.74	a1 is a little bit high
Trend line		a1= 47.62 a2=54.28	free of obstruction; a2 is a little bit high

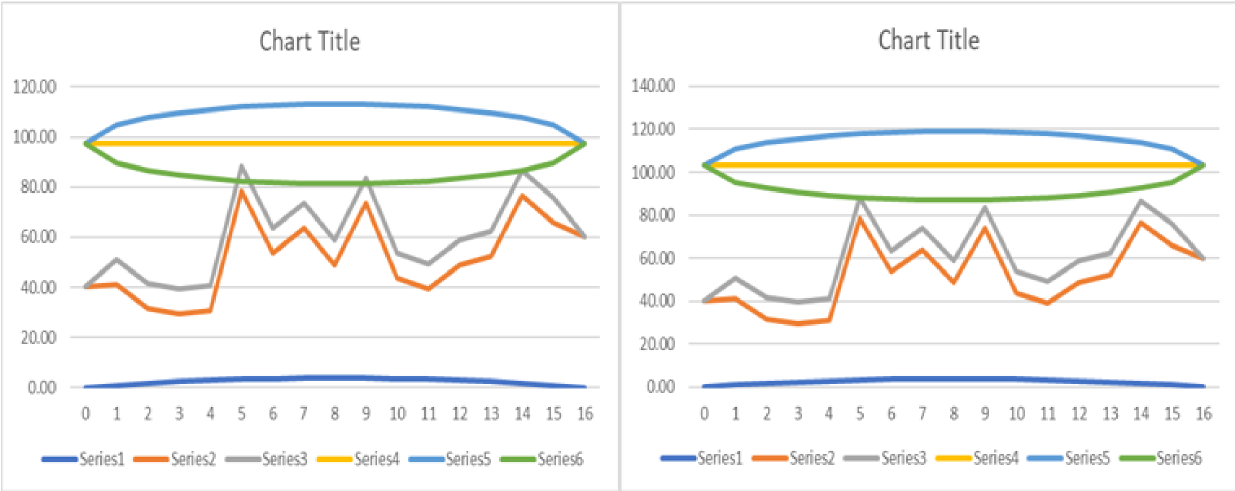

Fig 8: Single Obstruction Method result for problem 2

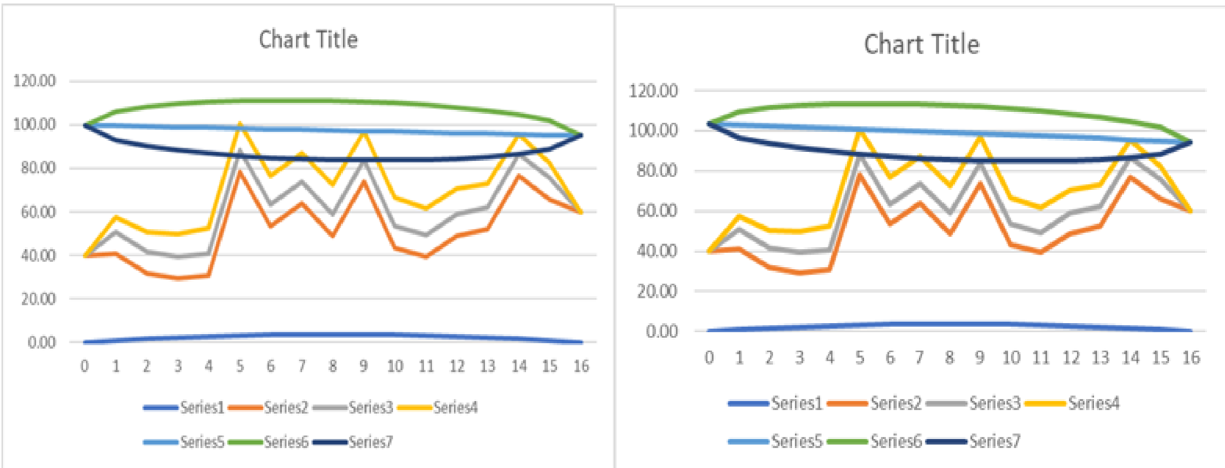

Fig 9; Double Obstruction Method result for problem 2

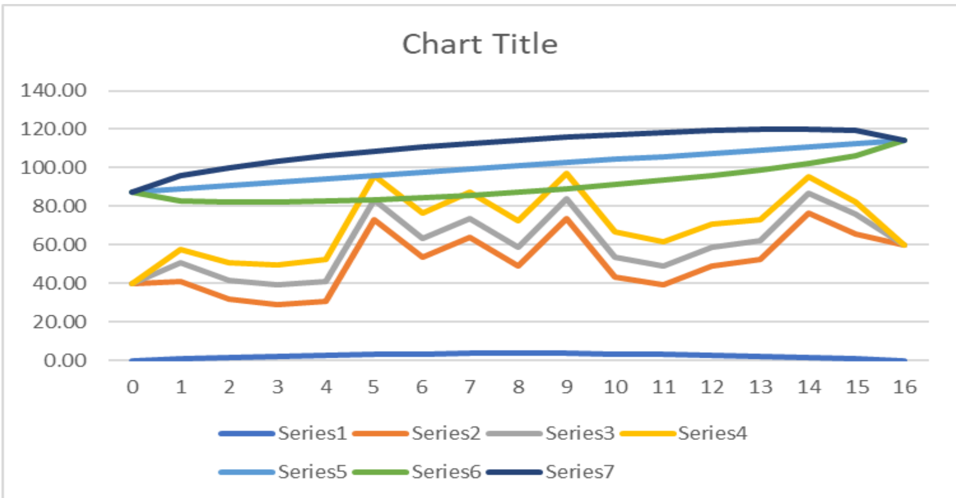

Fig 10: Trendline Method result for problem 2

In problem no. 2, there are 3 significant obstructions which is considered in determining the practical height of the antenna. When the 75 m obstruction height at Km 14 is considered, there is a Fresnel zone flouting. The infringement is caused by the radius of the Fresnel zone and the height of the earth bulge, which gets higher as it goes through the center of the communication. There is a clear path clearance when using the double obstruction method to determine the antenna heights. But the result shows an antenna height of 59.88m, 63.65 m, and 65.33m using the combinations of the three obstructions. Although higher antennas have better propagation of signals since it has overcome obstruction, there are number of things to consider which includes investment on towers, investment on land, ROI when only one antenna is to be installed, installation and maintenance costs and risks, and wind loads (www.commscope.com, 2017). The trend line result shows antenna heights lower (a_1=47.62 m; a_2=54.28m) than that of double obstruction method, yet free of infringement.

Problem 3

Problem 3 is different situation, where one side of the communication has a very high elevation compared to the opposite site. Site A is a little bit lower than the elevation of the obstruction at km 2, then the elevation become lower until the site B location.

Table 6: Problem 3, f=5GHz

Site A (km)	Site B (km)	Elevation (el:m)		Site A (km)	Site B (km)	Elevation (el:m)
0	16	220		9	7	70
1	15	210		10	6	40
2	14	240		11	5	36
3	13	200		12	4	46
4	12	175		13	3	50
5	11	150		14	2	75
6	10	75		15	1	65
7	9	60		16	0	60
8	8	45				

Table 7: Antenna heights obtained from the single obstruction method solution, double obstruction method and Trend line analysis for problem 3

Method	**Obstruction considered**	**Antenna Heights**	**Remarks**
Single Obstruction Method	Km 2 (el = 240m)	a1= 42.23m a2=202.23 m	Antenna height for site B is very high, free of obstruction
Double obstruction	Km 2 (el = 240 m) Km 4 (el = 175 m)	a1= 87.73m a2=-94.39 m	a1 is very high, a2 is negative, free of obstruction
	Km 2 (el = 240 m) Km 14 (el = 75 m)	a1= 68.09m a2=3.09 m	a1 is very high, free of obstruction
	Km 2 (el = 240 m) Km 15 (el = 65 m)	a1= 68.m a2=3.7 m	a1 is very high, free of obstruction
Trend line		a1= 66 m a2=31m	free of obstruction, a1 is lower compared to 68 m

Table 7 shows the result of using the three methods for problem 3. With single obstruction method, antenna heights for site A and site B are equal. With the elevation of site A which is very much higher than that of the elevation in site B, results to antenna height at site B of 202.23 m. This is impractical because the structure is too high to build and the wind is too strong for a heavy microwave antenna. For the double obstruction method, two results are free of obstruction and within the range. The solution which considers two obstructions near site A results to a negative antenna height (see fig. 11). The antenna height provided by the trendline analysis is still the most practical height among the three.

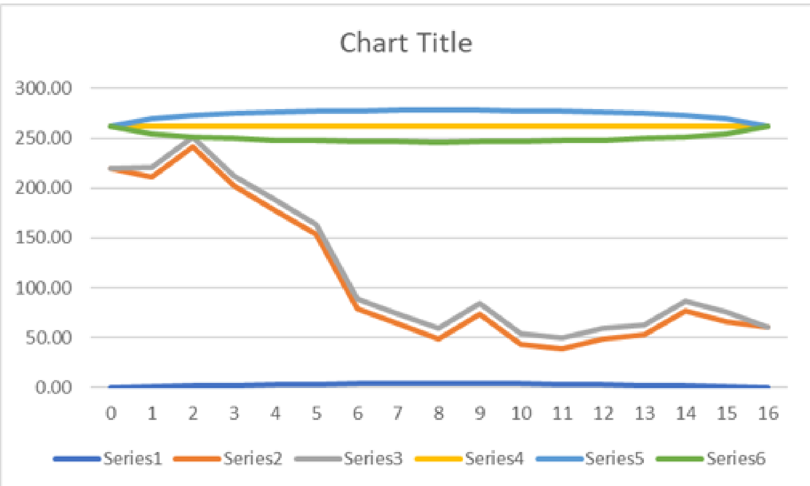

Fig 11: Single Obstruction Method result for problem 3

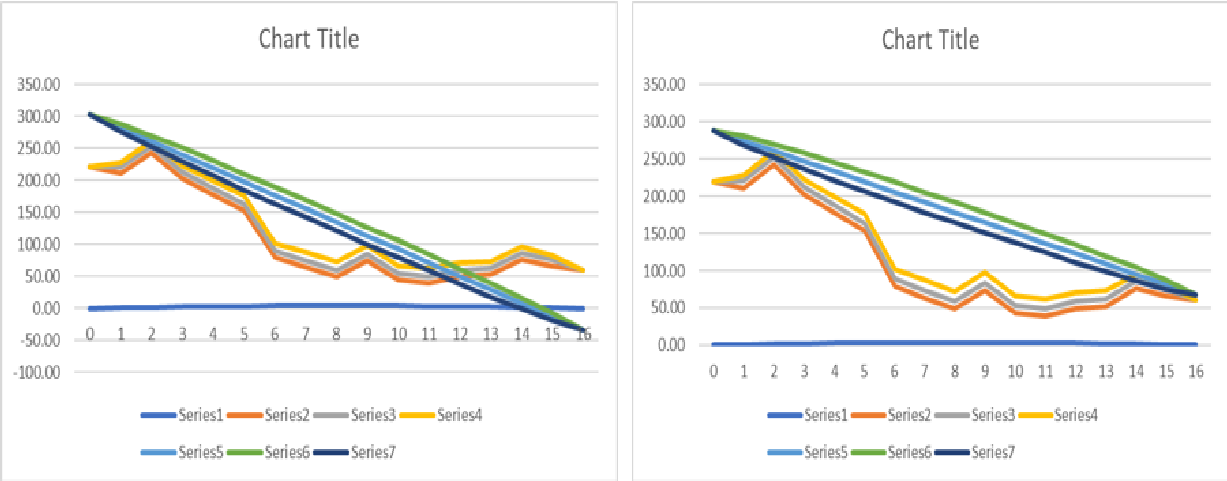

Fig 12: Double Obstruction Method result for problem 3

Fig 13: Trendline Method result for problem 3

The above figures and tables from problem 1 to 3 show that for any type of path between sites A and B, there can have different antenna heights when considering each obstruction. Wrong choice of obstruction can lead to infringement of the signals, or an impractical height of the antenna. The trendline analysis method considers all obstruction present and it only gives one result, eliminating the hassle of multiple solution and choosing the best result.

➢ *Acceptability of the Process*

Aside from solving problems related to antenna heights, a close ended survey form is distributed to the former and current ECE students from Laguna State Polytechnic University. There are 34 respondents, 4 of which were ECE graduates, who are working as telecoms engineer, and the rest are students. The purpose of the survey is to determine the acceptability of using trendline in solving antenna heights for microwave communication.

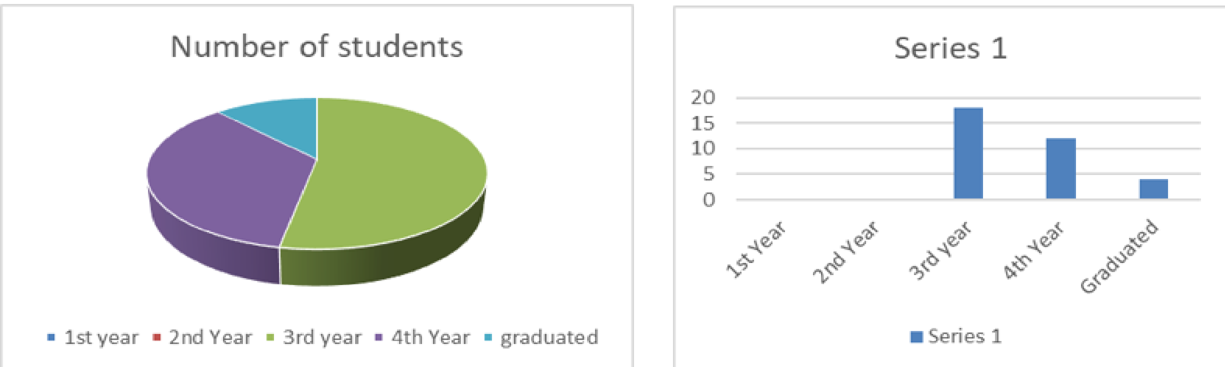

Fig 14: Academic Status of the respondents

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Figure 14 presents the academic status of the respondents. The respondents consist of 4 ECE professionals who are working in the telecommunication industries, and the rest are current ECE students. I8 of the students are currently taking the Advanced Microwave Communication Analysis and Design course, and 18 are former students of the subject but are still students. 100 % of the respondents have taken the course, Advance Communication System and Design, an elective course under telecommunication in CMO No. 101 s. 2017 and the former CMO No 24 s. 2008.

When it comes to the familiarity to the subject matter, 26 (76.5%) said that they have good knowledge on solving antenna heights, 4 (11.8%) have excellent knowledge, while the remaining 8% (4) have fair knowledge. The significant reasons in solving for antenna heights are [a] To overcome obstructions between the two communicating parties (31, 91.2%), [b] To propagate through greater distance (2, 5.9%), and [c] to propagate signals to a greater distance (1, 2.9%).

The obstruction heights (see fig. 15) are the most significant parameters need to solve the antenna heights identified by the respondents (33, 97%), followed by the distance between the two communicating sites (32, 94.1%). The next is around 70. 6% or 24 respondents indicates the importance of the frequency in the solution. While only 19 (55%) stated that location of the obstruction is also important.

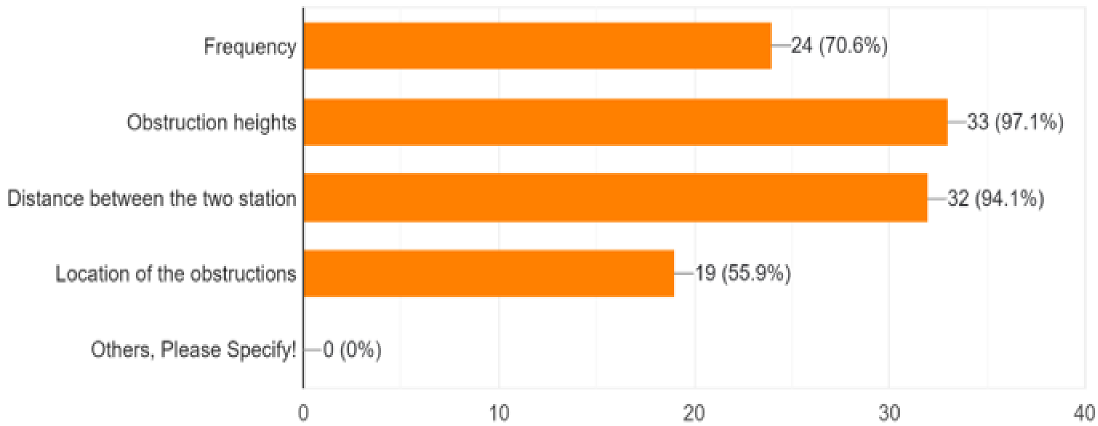

Fig 15: Parameters used in finding antenna heights

Table 16: Level of acceptance of the utilization of trendline in solving antenna heights

	Mean	**Standard Deviation**	**Adjectival Description**
I know how to use trendline from Microsoft Excel MS Excel) and Microsoft Word (MS Word) and in other Microsoft Office applications	3.97059	0.83431	Agree
The formula used in solving antenna heights used in trendline is also the same formula used in other methods	3.79412	1.00843	Agree
There is no need to choose from among all the obstruction present between sites	3.23529	1.41548	Neutral
All obstruction has already been considered in the analysis using Trend line	4.38235	0.65202	Agree
The graphical representation using trendline makes the analysis easier than purely mathematical approach	4.64706	0.54397	Strongly Agree
There's always only one result using the trendline analysis	3.61765	1.10137	Agree
The result is always in the practicality range	4.02941	0.86988	Agree
The steps in finding antenna heights using trendline analysis is easy to understand	4.5	0.61546	Strongly Agree
Utilizing Trendline analysis is simpler and easier compare to Double obstruction method	4.47059	0.56329	Agree
Utilizing Trendline analysis is applicable in all forms of site terrains	4.11765	0.87956	Agree

Table 16 shows the level of acceptability as responded by 34 Electronics Engineering students and graduates. The respondents agree in most of the parameters (questions) that trendline can be utilized to determine antenna heights except in the sense of the need to choose from among the obstruction present in the problem where the respondents are neutral with a mean of 3.24 and standard deviation of 1.42, which means that the respondents are not yet sure of the given parameter. The respondents strongly with a mean of 4.5 and standard deviation of 0.615 with regards to the understandability of using the trendline analysis specially the steps. When it comes the aid of the graphical presentation upon using trendline, the respondents strongly agree with a mean of 4.65 with a standard deviation of 0.54. As Trendline is normally

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used in the projection of future budgets, demands and operation. The respondents somehow believe that the same process can be utilized in another application and that is the determination of antenna heights. The initial steps which are finding first the value of the earth bulge and the Fresnel zone radius makes the process applicable in telecommunication.

III. CONCLUSIONS

With the results of the three given problems and its relativity to the results using the mathematical approaches, the following conclusions were realized. There is a need to compute first the value of the earth bulge and the Fresnel zone radius. Both parameters have their maximum value in the middle of the distance separating the two communicating sites. Neglecting the steps will result to the infringement of the obstruction to the intended Fresnel Zone.

The difficulty of finding antenna heights depend on the bulk of the mathematical manipulation, especially when there are two or more obstruction which are difficult to identify which could affect the propagating signal the worst. With the help of the figure, generated upon plotting the points representing the obstruction, the assurance of finding antenna heights became easier.

Trendline consider every given point in the data set, which refers to all the obstruction present between the sites. For each data set combinations or given obstruction, trendline derives a unique single equation applicable for the given situation. Thus, only one solution and result are produced. This makes the system a lot easier in comparison with single obstruction method, and the single obstruction method, where multiple results are produced, and a need to pick one from among the answers the most practical.

The parallel line derived from the trendline is always adjustable to the most significant obstruction, making the signal unblocked. This feature is free from any mathematical manipulations.

Thirty-one ECE students and professionals responded to the close ended survey form distributed through google forms and drives to determine the level of acceptability of using the method. A strongly agree remark with a mean of 4.65 and standard deviation of 0.54 is given to the ease of using trendline due to the graphical aid of the application. The respondents also agree strongly with a mean of 4.5 and standard deviation 0.62 with regards to the understandability of the steps in finding antenna heights. In most questions/statements given, the respondents agreed, except in the need of choosing which obstruction are to be considered in finding antenna heights, where the respondents are neutral. The overall mean for all the statements/question is 4.02, stating that the respondents agree on the acceptability of the method.

It is recommended to still improve the method by studying trendline more deeply. Also, it is recommended also to still use the other two methods and compare the results.

REFERENCES

[1]. Arbesser-Rastburg, B. (2009). *Radiowave Propagation Information for Designing Terrestrial Point-to-Point Links.* Switzerland: International Telecommunication Union.

[2]. Cadic, E. (2021, October 10). *https://study.com/academy/.* Retrieved from https://study.com: https://study.com/academy/lesson/what-is-a-trend-line-in-math-definition-equation-analysis.html

[3]. Campbell. (2016). *Line of Sight Obstruction.* Utah: Campbell Scientific Inc.

[4]. Campbell_Scientific_Inc. (2016). *Line Of Obstruction.* Utah: Campbell Scientific Inc.

[5]. https://ethw.org. (2018, July 12). *https://ethw.org/Microwave_Link_Networks*. Retrieved from https://ethw.org: https://ethw.org/Microwave_Link_Networks

[6]. https://support.microsoft.com. (2022). *https://support.microsoft.com/en-us/office/choosing-the-best-trendline-for-your-data-1bb3c9e7-0280-45b5-9ab0-d0c93161daa8.* Retrieved from https://support.microsoft.com/en-us/: https://support.microsoft.com/en-us/office/choosing-the-best-trendline-for-your-data-1bb3c9e7-0280-45b5-9ab0-d0c93161daa8

[7]. ITU. (2008). *Handbook: Radiowave Propagation Information For Designing Terrestrial Point-to-Point Link.* Geneva: International telecommunications Union Radiocommunications Bureau .

[8]. jimh. (2017, January 13). *https://continuouswave.com/forum/viewtopic.php?t=1761*. Retrieved from https://continuouswave.com: https://continuouswave.com/forum/viewtopic.php?t=1761

[9]. Soriano, J. (2022, June 2). *https://windupradio.com/why-is-the-height-of-a-vhf-radio-antenna-important/.* Retrieved from https://windupradio..com: https://windupradio.com/why-is-the-height-of-a-vhf-radio-antenna-important/

[10]. www.accountingtools.com. (2022, February 13). *https://www.accountingtools.com/articles/trend-line*. Retrieved from https://www.accountingtools.com: https://www.accountingtools.com/articles/trend-line

[11]. www.commscope.com. (2017). *https://www.commscope.com/globalassets/digizuite/2912-microwave-communication-basics-ebook-co-109477-en.pdf?r=1.* Retrieved from https://www.commscope.com: https://www.commscope.com/globalassets/digizuite/2912-microwave-communication-basics-ebook-co-109477-en.pdf?r=1

[12]. www.electronics-notes.com. (2018, July 2). *https://www.electronics-notes.com/.* Retrieved from https://www.electronics-notes.com: https://www.electronics-notes.com/articles/antennas-propagation/installation/antenna-height.php

[13]. www.everythingrf.com. (2018, May 22). *https://www.everythingrf.com/community/what-is-the-fresnel-zone*. Retrieved from https://www.everythingrf.com: https://www.everythingrf.com/community/what-is-the-fresnel-zone

[14]. www.statista.com. (2021, October 12). *https://www.statista.com/topics/5678/telecommunication-industry-in-the-philippines/#topicHeader__wrapper*. Retrieved from https://www.statista.com: https://www.statista.com/topics/5678/telecommunication-industry-in-the-philippines/#topicHeader__wrapper

[15]. www.usna.edu. (2015, July 7). *https://www.usna.edu/Users/oceano/pguth/md_help/html/tbme7u0j.htm.* Retrieved from https://www.usna.edu: https://www.usna.edu/Users/oceano/pguth/md_help/html/tbme7u0j.htm