

Determination of the Minimum Antenna Mast Height with Nonzero Path Inclination: Method II

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Abstract: In this paper, a second method for the determination of the minimum antenna mast height for line of site wireless communication link with nonzero path inclination and with known height of one of the antennas is presented. In the first method, (not presented here), none of the antenna height is known. In this second paper, the height of one of the antenna is known, particularly, the antenna that is above the maximum obstruction height. This places further constraint in the determination of the minimum antenna mast height for the lower antenna. In this paper, both the mathematical models and the algorithm are presented along with sample numerical example using path profile data for a 3 GHz microwave communication link with path length of 38.8876 km. The known antenna height is 20 m above the maximum height of the tip of the obstruction which is found to be 146.62 m at a distance of 14306.98 m from the transmitter. From the result, the receiver antenna height is 166.6 m and transmitter antenna height is 135.35 m whereas, the transmitter antenna mast height is 45.51 m while the receiver antenna mast height is 117.1 m the path inclination is 0.804. The ideas presented in this paper are particularly useful when a line of sight link is to be extended from an existing transmitting point.

Keywords: Microwave Communication Link, Path Inclination, Elevation Profile, Antenna Mast Height, Line of Sight Communication

1. Introduction

In wireless communication systems, Line Of Site (LOS) communication is a form of communication used when the signal, such as microwave, can travel in a straight line [1-5]. In that case, the transmitter and receiver antennas are raised and aligned to each other above the surrounding obstructions in the signal path. In order to determine the minimum antenna height for clear line of sight certain terrain and network parameters are considered; namely, the terrain elevation profile, the earth bulge, the obstruction height, the signal frequency, radius of the Fresnel zone, among others [6-11].

Basically, determination of the minimum antenna mast height is to minimize cost of construction, installation and maintenance of the mast. The higher the mast, the higher the cost. When installing a fresh LOS link, the minimum height

of the transmitter and the receiver antennas need to be determined from the available link and terrain parameters. In that case, none of the antenna height is known. The approach to determining the minimum antenna mast heights in such case is presented in method I. In this paper, the method II is presented for determination of the antenna mast height when the path inclination is not equal to zero and the height of one of the antennas is known, particularly, the antenna that is above the maximum obstruction height. This places further constraint in the determination of the minimum antenna mast height for the lower antenna.

In any case, the methods consists of mathematical expressions and algorithm for determination of the various requisite parameters along with the minimum the transmitter and the receiver antenna mast heights.

2. Theoretical Background

2.1. Determination of the Minimum Antenna Mast Height When the Path Inclination Is not Equal to Zero, ($H_t \neq H_r$) and the Higher Antenna Height (H_r) Is Known

In this analysis, a communication link (figure 1) with the

transmitter (T) and the receiver (R) at distance d apart is considered. It is assumed that the higher antenna is the receiver antenna and it is known. As such, $H_t \leq H_r$. If however, $H_t > H_r$, then the notation r for transmitter and t for receiver will have to be swapped, whereby the transmitter becomes the receiver and vice versa.

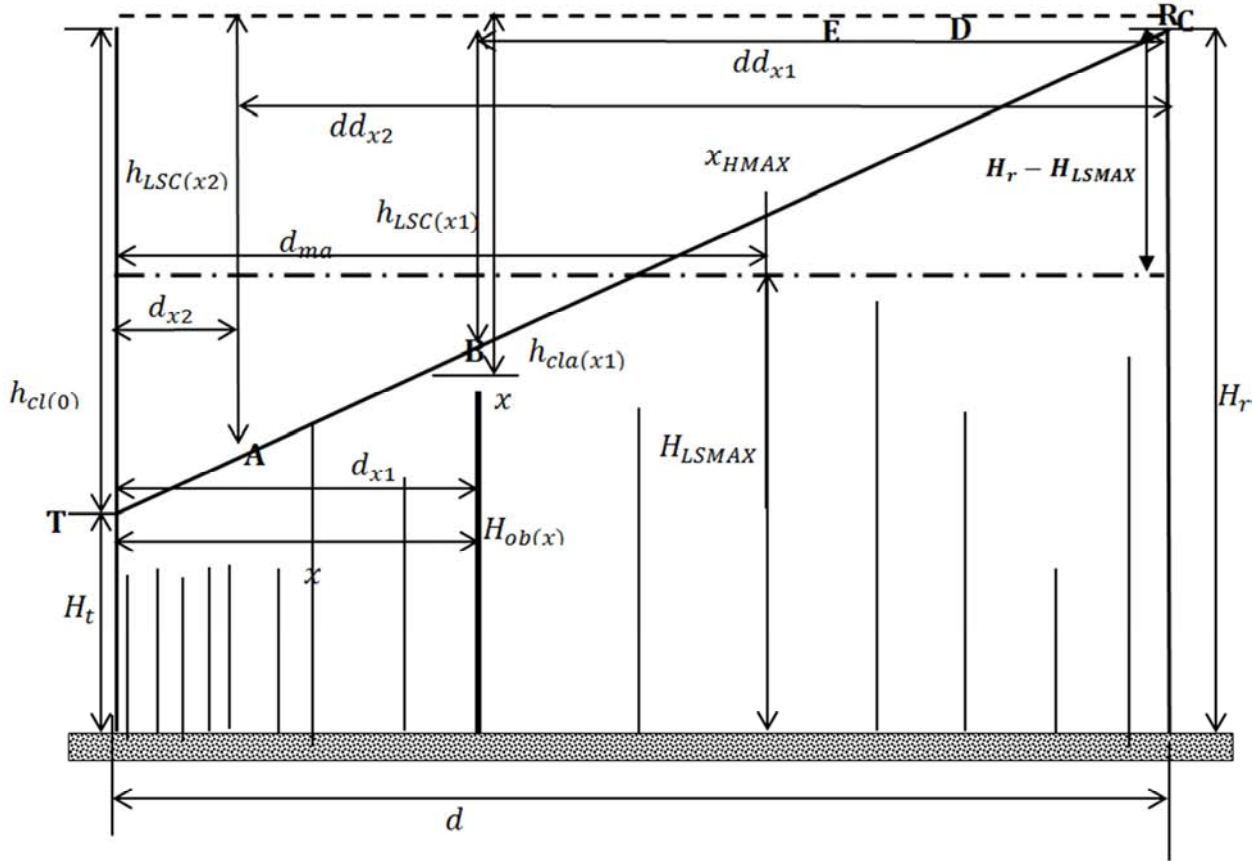


Figure 1. Model for determining the antenna mast height when the path inclination is not equal to zero.

Let $h_{cla(x)}$ be defined as the difference between the given receiver antenna height (H_r) and the obstruction height at location x which is a distance d_x from the transmitter. That means,

$$h_{cla(x)} = H_r - H_{ob(x)} \quad (1)$$

Where

$h_{cla(x)}$ is the actual line of sight (LOS) clearance height (in m) at point x .

$h_{ob(x)}$ is the obstruction height (in m) at point x measured from the ground level whereas $H_{ob(x)}$ is the obstruction height (in m) at point x measured from the sea level, where;

$$H_{ob(x)} = H_r - (h_{ob(x)} + H_{eb(x)} + H_{el(x)})$$

$H_{eb(x)}$ is the height (in m) of the earth bulge at location x between the transmitter and the receiver; it is given as [8,-10];

$$H_{eb(x)} = \frac{(d_t(x))(d_r(x))}{12.75 * K} \quad (2)$$

At the transmitter and the receiver, $d_{t(x)} = 0$, hence, $H_{eb(x)} = 0$.

$H_{el(x)}$ is the elevation (in m) at point x , which is a distance of $d_t(x)$ from the transmitter and a distance of $d_r(x)$ from the receiver.

Let $h_{LSC(x)}$ be defined as the expected line of sight height at point x . Basically, $h_{LSC(x)}$ gives the equation for line of sight in terms of H_r . At the transmitter, $x = 0$, $d_x = 0$, and $h_{LSC(x)} = h_{LSC(0)} = h_{cla(0)} = H_r - H_t$.

d_x is the distance from the transmitter to point x . In addition, let dd_x be the distance from the receiver to point x . Then, $dd_x = -d_x$. Consider two points on the line of sight at location x_1 and x_2 (where location x_1 is at a distance d_{x1} from the transmitter and a distance dd_{x1} from the receiver, Also, location x_2 is at a distance d_{x2} from the transmitter and a distance dd_{x2} from the receiver). Then, by using similar triangle (in Figure 1) on triangles ARD and BRD , $h_{LSC(x1)}$ (which is the expected line of sight clearance height at point x_1) and $h_{LSC(x2)}$ (which is the

expected line of sight clearance height at point x_2) are related as follows:

Hence,

$$h_{LSC(x_2)} = \left(\frac{dd_{x_2}}{dd_{x_1}} \right) h_{LSC(x_1)} \quad (3)$$

In order to satisfy the line of sight clearance requirement at point x the following condition must be met:

$$h_{LSC(x)} \leq h_{cla(x)} - frcl \text{ for all } x = 0, 1, 2, 3 \dots n_e. \quad (4)$$

Where $frcl$ is the clearance of the Fresnel zone, n where [12-15];

$$frcl = \left(\frac{P_{(n)}}{100} \right) (r_{(n)}) \quad (5)$$

Where

$$r_{(n)} = \sqrt{\frac{n(\lambda(d_{t(x)})(d_{r(x)}))}{(d_{t(x)} + d_{r(x)})}}; \text{ for } n=1, 2, 3, \dots \text{ and } d_{t(x)} >> r_{(n,x)} \text{ and } d_{r(x)} >> r_{(n,x)} \quad (6)$$

λ in metres is given as;

$$\lambda = \frac{c}{f} \quad (7)$$

$P_{(n)}$ is the percentage clearance allowed for the Fresnel zone n , given in %. Normally, 60 % clearance of Fresnel zone 1 is required. In that case, $n=1$ and $P_{(n)} = 60\%$

Initially, $x_1 = x = 0$, and $h_{LSC(x_1)} = h_{LSC(0)} = h_{cla(0)} = H_r - H_t$. Also, at $x_1 = x = 0$, $d_x = 0$ and $dd_0 = d - 0 = d$. In essence, with $h_{LSC(0)} = h_{cla(0)} = H_r - H_t$, the line of sight clearance requirement is satisfied at $x_1 = x = 0$. Then, $h_{LSC(x_2)}$ is computed for $x_2 = x_1+1, x_1+2, x_1+3, \dots, n_e$. At each point of x_2 , the line of sight clearance requirement conduction $h_{LSC(x_2)} \leq h_{cla(x_2)}$ is evaluated. If the condition is not satisfied, then, the current x_2 becomes the x_1 (that is, $x_1 = x_2$) and the current $h_{LSC(x_1)}$ becomes $h_{cla(x_2)}$ (that is, $h_{LSC(x_1)} = h_{cla(x_2)}$). Next, $h_{LSC(x_2)}$ is computed for $x_2 = x_1+1, x_1+2, x_1+3, \dots, n_e$. When all the points from $x=0$ to $x= n_e$ are considered, the transmitter height is adjusted based on the last value of $h_{LSC(x_1)}$ which is at a distance of dd_{x_1} from the receiver. The adjustment is done as follows;

$$h_{LSC(0)} = \left(\frac{dd_0}{dd_{x_1}} \right) h_{LSC(x_1)} \quad (8)$$

$$H_t = H_r - h_{LSC(0)} \quad (9)$$

The height (in meters) of the transmitter antenna mast measured from the ground is given as $h_{t(mast)}$ where;

$$h_{t(mast)} = H_t - H_{elt} = H_r - h_{LSC(0)} - H_{elt} \quad (10)$$

Where H_{elt} is the elevation at the transmitter. The height (in meters) of the receiver antenna mast measured from the ground is denoted as $h_{r(mast)}$;

$$h_{r(mast)} = H_r - H_{elr} \quad (11)$$

2.2. The Procedure for Determining the Minimum Antenna Mast Height When the Path Inclination Is Not Equal to Zero and the Higher Antenna Height Is Known

The following algorithm states the procedure for determining the minimum transmitter and receiver antenna mast height when the path inclination is not equal to zero and the higher antenna height is known.

Step 1: Input $H_r, H_{elr}, H_{elt}, d, n_e$

Step: $H_t = H_{elt}$

Step 2: $h_{LSC(0)} = h_{cla(0)} = H_r - H_t$.

Step 3: $dd_0 = d$

Step 4: $x_1 = 0$

Step 5: For $x_2 = x_1$ to n_e Increment 1

Step: Input $d_{x_1}, d_{x_2}, H_{ob(x_2)}$

Step: $dd_{x_1} = d - d_{x_1}$,

Step: $dd_{x_2} = d - d_{x_2}$,

Step 6: $h_{LSC(x_2)} = \left(\frac{dd_{x_2}}{dd_{x_1}} \right) h_{LSC(x_1)}$

Step 7: $h_{cla(x_2)} = H_r - H_{ob(x_2)} = H_r - (h_{ob(x_2)} + H_{eb(x_2)} + H_{el(x_2)})$

Step 8: if $(h_{LSC(x_2)} > h_{cla(x_2)})$ then

Step 9: $h_{LSC(x_1)} = h_{cla(x_2)}$

Step 10: $x_1 = x_2$

Step 11: Endif

Step 12: Next x_2

Step 13: $h_{LSC(0)} = \left(\frac{dd_0}{dd_{x_1}} \right) h_{LSC(x_1)}$

Step 14: $H_t = H_r - h_{LSC(0)}$

Step 15: $h_{t(mast)} = H_t - H_{elt} = H_r - h_{LSC(0)} - H_{elt}$

Step 16: $h_{r(mast)} = H_r - H_{elr}$

Step 17: End

3. Results and Discussions

The LOS link parameters are used in the computation are; path length = 38887.6 m, frequency = 3 GHz, effective earth radius factor (k-factor) = 1.33333 and obstruction height (hob) = 10 m. The receiver antenna is assumed to be 20 m above the maximum height of the tip of the obstruction and the specified minimum LOS percentage clearance with respect to Fresnel zone 1 is 60%. Some of the elevation profile is given in Table 1. The maximum elevation of the obstruction from sea level (that is, maximum $(H_{ob(x)})$ 146.62 m and it occurred at a the distance of 14306.98 m from the transmitter. The receiver antenna is assumed to be 20 m above maximum $(H_{ob(x)})$. So, the receiver antenna is 166 m while from the results the transmitter is obtained as 135.35 m high.

In table 1 the minimum percentage clearance of 60% with respect to Fresnel zone 1 occurred at the location of the maximum height of the tip of the obstruction which is a distance of 14306.98 m from the transmitter. The radius of the first Fresnel zone at that point is 30.07 m and the LOS clearance height at that point is -18 m which gives the percentage clearance of 60% at that point. The 60% percentage clearance tallies with the 60% clearance specified at the link design stage.

Table 1. The Antenna Mast Computation Result.

x, Elevation Point	dx, Distance (m)	hel (x) Elevation (m)	Heb (x)Earth Bulge (m)	Hx, LOS Height (m)	hLsc (x), LOS Clearance height (m)	r1, radius Of The First Fresnel Zone (m)	P (x, 1), Percentage Clearance Of The First Fresnel Zone %
1	0	89.8	0	135.3	-35.5	0	-
24	1750.3	78	3.82	136.7	-44.9	12.93	-347.4
72	5403.2	92.3	10.64	139.6	-26.6	21.57	-123.5
96	7229.6	97	13.46	141	-20.6	24.26	-84.8
120	9056	94.4	15.89	142.5	-22.2	26.36	-84.4
168	12708.9	90.5	19.57	145.4	-25.3	29.25	-86.5
189	14307	97.9	20.69	146.6	-18	30.07	-60
192	14535.3	94	20.82	146.8	-22	30.17	-72.9
240	18188.1	92.3	22.15	149.7	-25.2	31.11	-81.1
256	19405.7	92.2	22.24	150.6	-26.2	31.18	-83.9
264	20014.6	89.4	22.22	151.1	-29.5	31.17	-94.7
288	21841	30.8	21.9	152.6	-89.8	30.94	-290.3
312	23667.4	23	21.19	154	-99.8	30.44	-328.1
336	25493.8	29.8	20.09	155.4	-95.5	29.63	-322.4
384	29146.7	49.9	16.7	158.3	-81.7	27.02	-302.3
408	30973.1	20	14.42	159.8	-115.3	25.11	-459.4
432	32799.5	22.4	11.75	161.2	-117.1	22.66	-516.6
480	36452.4	36.7	5.22	164.1	-112.2	15.11	-742.7
504	38278.8	29	1.37	165.5	-125.2	7.74	-1617.2
512	38887.6	48.9	0	166	-107.1	0	-

When the elevation height is subtracted from the antenna height, then the transmitter antenna mast height is 45.51 m while the receiver antenna mast height is 117.1 m. Also, given the receiver antenna height is 166.6 m and transmitter antenna height is 135.35 m, the transmitter antenna is lower than the receiver antenna. The transmitter is also below the maximum height of the tip of the obstruction which is 146.62 m high. The path inclination is $\frac{|H_r - H_t|}{d} = \frac{|166.6 - 135.35|}{38.88759} = 0.804$, where d is in km and H_r and H_t are in m.

4. Conclusion

In this paper, a second method for determination of the minimum antenna mast height when the path inclination is not equal to zero and the higher antenna height is known is presented. In the first method, (not presented here), none of the antenna height is known. In this second paper, the height of one of the antenna is known, particularly, the antenna that is above the maximum obstruction height. This places further constraint in the determination of the minimum antenna mast height for the lower antenna. In this paper, both the mathematical models and the algorithm are presented along with sample numerical example using path profile data for a line of site microwave communication link.

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