Path Profile Analysis of a LOS System Using 3-D Digital Map

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Abstract:

Exponential growth of mobile communications, radio links and wireless networks has increased interest in many topics in radio propagation. Much effort is now devoted to refine radio propagation path-loss models for urban, suburban, and other environments together with substantiation by field data. Diffraction of a radio wave front occurs when the wave front encounters an obstacle that is large compared to the wavelength of the ray. The actual amount of obstruction loss is depended on the area of the beam obstructed in relation to the total frontal area of the energy propagated and to the diffraction properties of the obstruction. The objective for the system designer is to provide sufficient clearance of the obstacle without appreciable transmission loss due to the obstacle. The degree of intersection between the obstacle and the first Fresnel zone gives a good measure for obstruction loss.

Remote sensing technologies (satellite images, aerial photography, and image processing) give attractive facilities which can be sacrifice to determine the topography differences and the path profile between any two points on the image of the area under test.

Merging these facilities with the principle of wave propagation (First Fresnel Ellipsoid) represent the proposed idea of this paper. Data of path profile extracted from 3D remote sensing image by using ERDAS IMAGINE was used and analyzed by MATLAB tools to test the validity of any suggested path.

Keyword: *Attenuation, line-of-Sight, Propagation, Remote Sensing.*

1. INTRODUCTION:

Propagation is the study of how radio waves travel from one point to another, and can be a fascinating part of ham radio. When signals travel directly from the transmitting antenna to the receiving antenna, this is referred to as line-of-sight propagation [1].

The radio wave did not follow the natural curvature of the earth. Earth's curvature is a direct block to line-of-sight communication. When enough distance separates the two radio stations so that their antennas fall behind the curvature, the earth itself blocks the transmitted signals from the receiver [2].

There are certain radio frequencies, which can travel only in the line-of-sight. This means that higher the antenna of the radio transmitter, greater the distance covered by its transmission. That explains why television transmission towers are made as high as possible [3]

Buildings, hills, and airplanes easily reflected radio wave signals, so some of your signals reach the other station by a direct path and some may be reflected [1]. When reflections occur, it is possible to contact other stations by pointing your antenna toward the reflecting object rather than station you are trying to contact [1].

A propagated ground wave takes three separate paths to the receiver. They are the direct wave, the ground-reflected wave, and the surface wave, the effectiveness of ground waves depends on the radio frequency, transmitter power, transmitting antenna characteristics, electrical characteristics (conductivity and dielectric constant) of the terrain, and electrical noise at the receiver site. Low and very low frequencies are propagated much better by surface path than are higher frequencies [5].

The direct wave is the ground-wave component that travels directly from the transmitting antenna to the receiving antenna. In terrestrial communications, the direct path is limited by the distance to the horizon from the transmitter. This is essentially line-of-sight distance [5].

It can be extended by increasing the height of the transmitting antenna, the receiving antenna, or both. The direct path is also useful for extraterrestrial communications.

The ground-reflected path reaches the receiving antenna after being reflected from the ground or sea. Upon reflection from the earth’s surface, the ground wave undergoes a 180°-degree phase shift.

Since the reflected path travels longer reaching its destination, a phase displacement somewhat greater than the 180°-degree shift caused by reflection results. The net result near the ground is a weakening of the phase displacement somewhat greater than the 180°-degree shift caused by reflection results.

The net result near the ground is a weakening of the direct wave. This weakening is roughly equal to the strength of the reflected wave

When the direct path and the ground reflected path is called the space wave [4].

The surface wave reaches the receiving site by traveling along the surface of the ground surface wave can follow the contours of the Earth because of the process of diffraction. When a surface wave meets an object and the dimensions of the object do not exceed its wavelength, the wave tends to curve or bend around the object [6]

2. Free Space Propagation:

The basic concept in estimating radio transmission loss is the loss expected in free space, that is, in a region free of all objects that might absorb or reflect radio energy. This concept is essentially the inverse-square law in optics applied to radio transmission [3].

Reliable microwave communication necessitates a clear line of sight between the terminals, with the further requirement of first Fresnel zone clearance at all points on the intervening ground. Under these conditions the signal strength will be near the free-space value, except for possible ground reflections and atmospheric [3].

Consider a radio link consisting of an isotropic transmitting antenna and a receiving antenna with effective area Ar. Since a hypothetical isotropic antenna has the same radiation intensity in all directions, the power flow per unit area at a distance d from the transmitter is:

$$P_o = P_t / \left(4\pi d^2\right) \quad (1)$$

Where:

P_t = transmitted power

d = distance between terminals

Assuming a plane wave front at a receiving antenna, the space loss is given by:

$$P_r / P_t = A_r / \left(4\pi d^2\right) \quad (2)$$

Where:

P_r = received power

A_r = effective area of the receiving antenna

A_t = effective area of the transmitting antenna

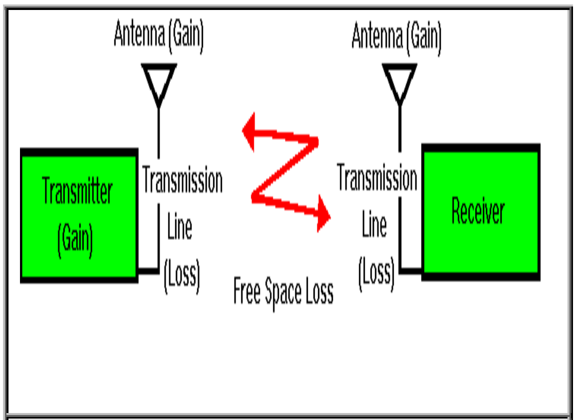


Figure (1) General Radio Frequency Link

If the isotropic transmitting antenna is replaced by a transmitting antenna with effective area At, the received power will be increased by the ratio At/Ai, and the expression for space loss becomes:

$$P_r / P_t = \left(A_r A_t\right) / \left(4\pi d^2 A_i\right) \quad (3)$$

The effective area of an isotropic antenna with no loss is given by:

$$A_i = \lambda^2 / 4\pi \quad (4)$$

Where, λ is the Wavelength.

Hence:

$$P_r / P_t = \left(A_r A_t\right) / \left(d^2 \lambda^2\right) \quad (5)$$

In Figure (1) the transmitters and receivers must compensate for loss of signal strength in free space.

3. Atmospheric effects:

The concept of free space transmission assumes that the atmosphere is perfectly uniform and nonabsorbent, and that the earth is either infinity far away or that its reflection coefficient is negligible [7].

In a practical line-of-sight communication system, the received signal will be near the free space value. When the wave is propagated in the atmosphere and near the ground, the free space transmission equivalent is modified through various causes such as atmospheric refraction, reflection, etc [8].

Under normal atmospheric conditions, terrain has two effects on the propagation loss of a microwave radio system:

* Trees, buildings, hills, or the earth can block a portion of the microwave beam to cause an obstruction loss (in addition to the free space attenuation) [3].
* A very smooth section of terrain or water can reflect a second signal to the receiving antenna. The reflected signal may arrive out of phase with the direct signal, resulting in additional attenuation from signal cancellation (interference) [3].

Radio line of sight and optical line of sight are different. Even over a smooth earth with no obstructions, radio line of sight is limited by the earth's curvature. Radio wave
Propagation extends beyond optical line of sight. So, for radio line-of-sight calculations, the earth's radius is taken to be 1.333 times or 4/3 the normal radius. This produces a flatter earth between two fixed points [9].

In order to achieve true line-of-sight propagation (free space) the true line-of-sight path between two fixed antennas must clear from any obstruction by more than the distance required for optical line of sight [10].

4. Fresnel Zone:

Fresnel zones in propagation shown in Figure (2) can be defined as ellipsoids of revolution whose focal points are the transmitting and receiving antennas, and which include all points from which a wave radiated by the transmitter is reflected to the receiver with a path length difference equal to a whole number of half a wavelength as compared with the direct geometric path between the two antennas [10].

Fresnel zones result from diffraction by the circular aperture. The most important region to consider is what is called the first Fresnel zone ("fre-nel") [11].

You can think of this zone as an ellipsoid (3 dimensional ellipses like a rugby ball) with the transmitter at one end and the receiver at the other.

The thickness of the ellipsoid at the midpoint is about $(d\lambda)^{1/2}$ [12].

Any obstacles that protrude more than 40% into the volume of the space defined by the ellipsoid will have a detrimental effect on the received signal strength [3].

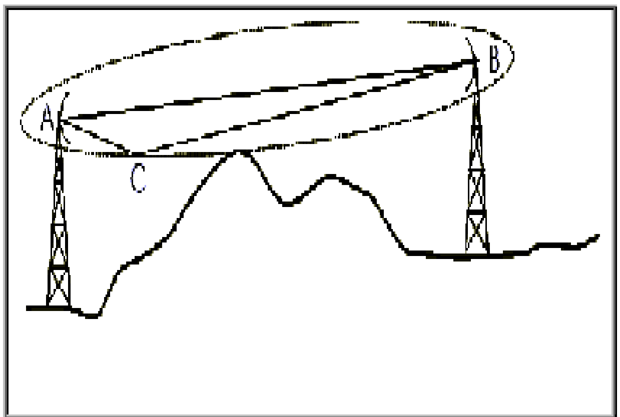


Figure (2) Fresnel zone

One demonstrates that the effective part of the energy is radiated within the first Fresnel ellipsoid that is the one from every point of which a wave is reflected with a path length difference of half a wavelength in the respect to the direct path [2].

Consequently, it is sufficient to raise the aerials so that the first Fresnel zone is clear of obstructions by ground obstacles.

In order to facilitate the analysis of phenomena produced by ground interception of part of the direct radiation, we must apply the notions introduced by Fresnel in optics [10].

Let a broad ridge be situated at distances d1 and d2 from the transmitter T and the receiver R, respectively, at a height h below or above the optical line of sight, as shown in Fig(3a) and (3b).

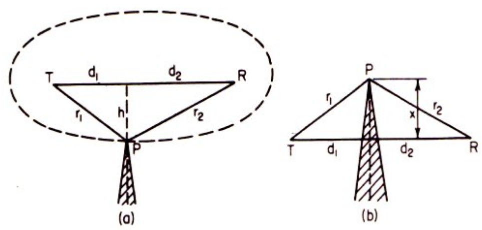


Figure (3) Effect of wide ridge

Regions of space corresponding to increased path lengths of $\lambda/2, 2\lambda/2, 3\lambda/2,$ etc., with respect to $TR = d_1 + d_2 = d$, are ellipsoids with foci T and R [3].

The nth Fresnel surface is that for which the sum of distances between the transmitter and receiver and a point on the surface of the ellipsoid of revolution (see the dotted line in Figure (3a)) exceeds by $\eta(\lambda/2)$ the distance between the transmitter and the receiver.

$$\delta = (r_1 r_2) - (d_1 + d_2) = \eta(\lambda/2) \quad (6)$$

$$r_1 = \sqrt{d^2 + h^2} = d_1\sqrt{1 + (h/d_1)^2} = d_1\left[1 + \tfrac{1}{2}(h/d_1)^2\right] \quad (7)$$

for $h/d1 \langle\langle 1$

Where:

d_1: The distance between the transmitter and the selected point.

d_2: The distance between the selected point and the receiver, $d_2 = d - d_1$.

Similarly:

$$r_2 = d_2\left[1 + \tfrac{1}{2}(h/d_2)^2\right] \quad (8)$$

Hence

$$\delta = h^2/2(1/d_1 + 1/d_2) = \eta(\lambda/2) \quad (9)$$

It is customary to express this result in terms of Fresnel zones.

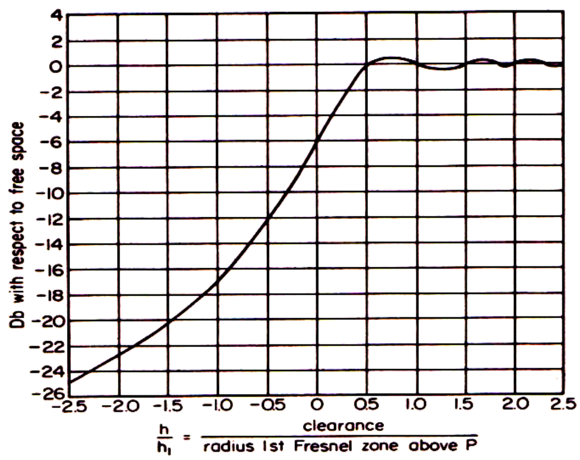


Figure (4) Relationship between attenuation and Fresnel clearance.

The necessary clearance for the first Fresnel zone is therefore given by

$$h_1 = \sqrt{\lambda/(1/d_1 + 1/d_2)} \quad (10)$$

And generally the clearances for the nth Fresnel zone are given by:

$$h_\eta = \eta\sqrt{\lambda/(1/d_1 + 1/d_2)} \quad (11)$$

Using Fresnel diffraction theory, for the "attenuation factor" (in amplitude) with respect to propagation of good clearance, the amplitude attenuation is plotted in Fig. (4) using the variable h/h1 [3]. This variable is the ratio of the clearance of the line of sight, with respect to the crest, to the clearance for the first Fresnel zone.

Figure (4): Relationship between attenuation and Fresnel clearance.

It may be seen from Figure (4) that when the ridge top is on the line of sight; there is a loss of 6 dB [11].

As the ridge goes above the line of sight, the loss increases rapidly; but as the ridge goes below the line of sight, the loss drops rapidly to zero and oscillates about ± 1 dB [3].

The received wave has a magnitude nearly equal to the free space value if the ridge is below the line of sight by an amount such as $\delta / \lambda \rangle 0.5$.

Thus, the main feature is to put the transmitter and receiver at such heights that there is at least clearance for the first Fresnel zone [13].

Terrain features in the region between the transmitter and receiver such as cliffs, buildings, vegetation, bridges, electric power lines etc. also have an effect on the propagation of the signal [13].

5. Path Profile Data Extraction:

Remote sensing technologies give attractive facilities which can be used in the domain of planning and designing of radio links. Many of the imagery satellite nowadays give the ground image in 3D in digital form, these images contains the height information for each pixel on the ground.

Many software packages were developed for image enhancement, data extraction, and data exploring. In this work ERDAS IMAGINE tool was used which is one both most efficient tool for data extraction and path profile calculation.

The selected image shown in figure (5) is a 3D satellite image of the area under test, which is a digital image for a region in United States; this image is of high resolution and high quality.

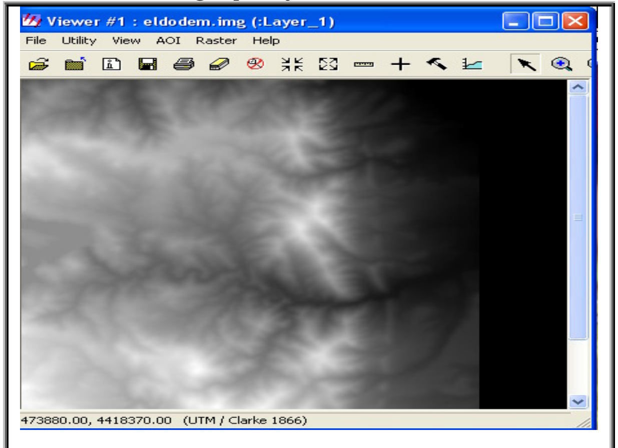


Figure (5) 3D digital map

The area of the 3-D digital map is the x axis's on the upper left side is from (0 - 468000,0 meter) the lower right side for the x axis's is from (0 - 478620,0 meter) the y axis's for the upper left is from (0 - 4427550,0 meter) thy y axis's for the lower side is from (0-4413750,0 meter) and the unit is meter. The UTM, Zone13 is the projection system and this map is spheroid in Clarke 1866.

The following steps illustrate the simulation procedure used in this work to extract the path profile between any two points on the image:

- Loading the 3D digital image shown in Figure (5) and the ERDAS IMAGINE tool to the computer shown in Figure (5).
- Use the ERDAS IMAGINE tool to illustrates the information about the 3D digital image as shown in Figure (6)

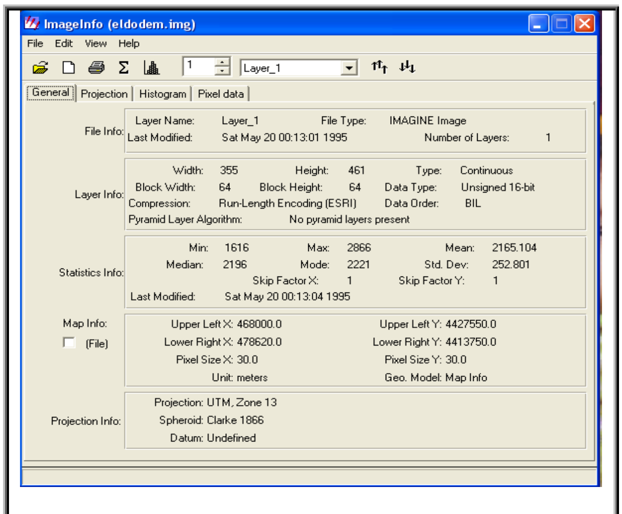
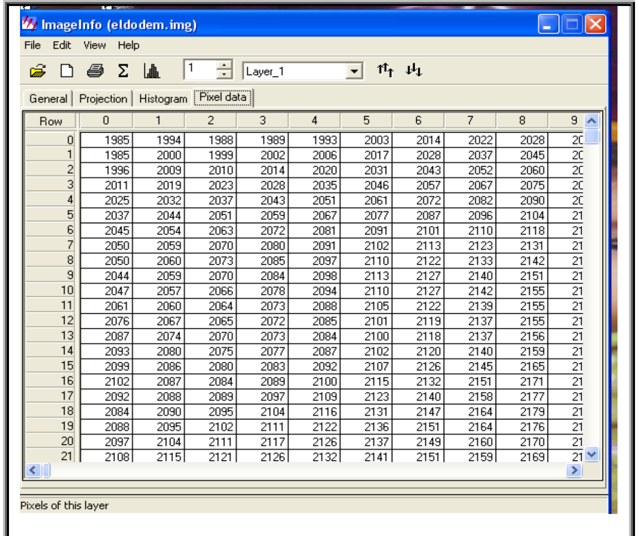


Figure (6) Image information for 3-D map

- Check the pixel data which illustrates the data file values for 3D digital map as shown in Figure (7).



Row	0	1	2	3	4	5	6	7	8	9
0	1985	1994	1988	1989	1993	2003	2014	2022	2028	20
1	1985	2000	1999	2002	2006	2017	2028	2037	2045	20
2	1996	2009	2010	2014	2020	2031	2043	2052	2060	20
3	2011	2019	2023	2028	2035	2046	2057	2067	2075	20
4	2025	2032	2037	2043	2051	2061	2072	2082	2090	20
5	2037	2044	2051	2059	2067	2077	2087	2096	2104	21
6	2045	2054	2063	2072	2081	2091	2101	2110	2118	21
7	2050	2059	2070	2080	2091	2102	2113	2123	2131	21
8	2050	2060	2073	2085	2097	2110	2122	2133	2142	21
9	2044	2059	2070	2084	2098	2113	2127	2140	2151	21
10	2047	2057	2066	2078	2094	2110	2127	2142	2155	21
11	2061	2060	2064	2073	2088	2105	2122	2139	2155	21
12	2076	2067	2065	2072	2085	2101	2119	2137	2155	21
13	2087	2074	2070	2073	2084	2100	2118	2137	2156	21
14	2093	2080	2075	2077	2087	2102	2120	2140	2159	21
15	2099	2086	2080	2083	2092	2107	2126	2145	2165	21
16	2102	2087	2084	2089	2100	2115	2132	2151	2171	21
17	2092	2088	2089	2097	2109	2123	2140	2158	2177	21
18	2084	2090	2095	2104	2116	2131	2147	2164	2179	21
19	2088	2095	2102	2111	2122	2136	2151	2164	2176	21
20	2097	2104	2111	2117	2126	2137	2149	2160	2170	21
21	2108	2115	2121	2126	2132	2141	2151	2159	2169	21

Figure (7) Pixel data for the 3-D digital map

- Insert the selected two points on the image; these points represent the suggested locations of base stations.
- Draw a line connecting the above two points as shown in Figure (8).

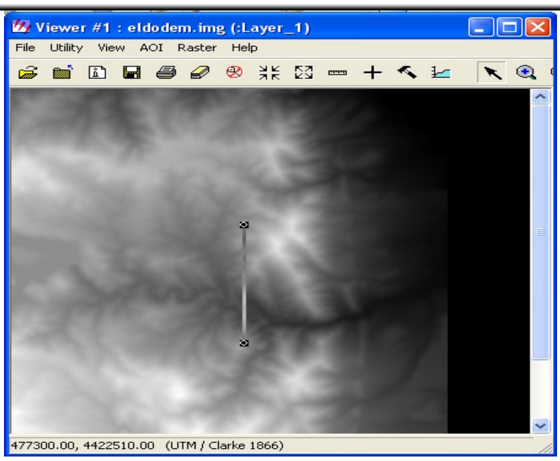


Figure (8) Selected point's locations on the 3-D digital map

- Use the ERDAS IMAGINE which gives two types of profiles (spatial profile and surface profile).
- Determine the path profile between the selected two points under test by using (ERDAS IMAGINE 8.7) as shown in Figure (9).

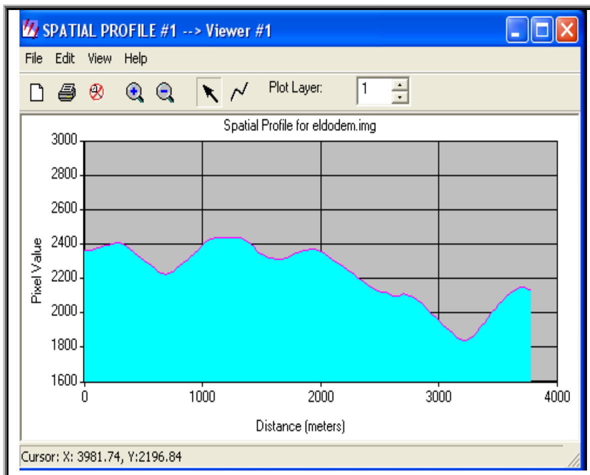


Figure (9) The path profile between the selected two points

- Determine the surface profile for the region containing the selected two points to get an idea about the topology surrounding these two points as shown in Figure (10).

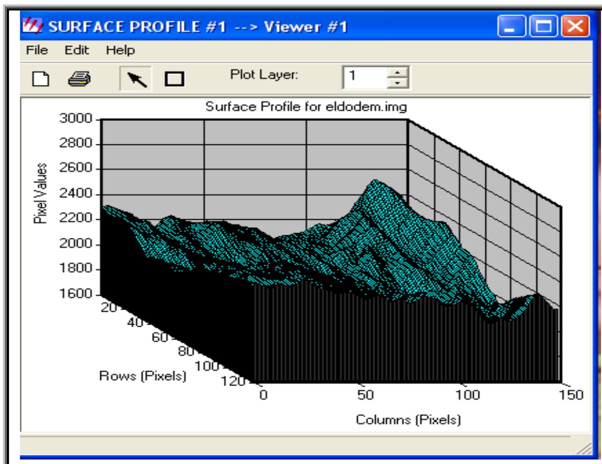


Figure (10) The surface profile for the select region

- Use the ERDAS IMAGINE tool to extract the tabular data for the path profile as shown in Table-1.

Table (1) The tabular data for the 3-D

Profile Tabular Data

Point #	>	Map X	Map Y	File X	File Y	Distance	Surface Distance	(:Layer 1)
1	>	473820	4420650	194	230	0.00	0.00	1902
2		473790	4420646	193	230	30.00	30.00	1903
3		473761	4420641	192	230	60.00	60.03	1907
4		473731	4420637	191	230	90.00	90.06	1912
5		473701	4420633	190	231	120.00	120.14	1919
6		473672	4420629	189	231	150.00	150.27	1928
7		473642	4420624	188	231	180.00	180.45	1939
8		473612	4420620	187	231	210.00	210.64	1950
9		473582	4420616	186	231	240.00	240.86	1962
10		473553	4420612	185	231	270.00	271.08	1974
11		473523	4420607	184	231	300.00	301.27	1985
12		473493	4420603	183	232	330.00	331.40	1994
13		473464	4420599	182	232	360.00	361.43	1999
14		473434	4420595	181	232	390.00	391.47	2004
15		473404	4420590	180	232	420.00	421.48	2006
16		473375	4420586	179	232	450.00	451.48	2005
17		473345	4420582	178	232	480.00	481.52	2000
18		473315	4420577	177	232	510.00	511.64	1991
19		473285	4420573	176	233	540.00	541.67	1987
20		473256	4420569	175	233	570.00	571.73	1981
21		473226	4420565	174	233	600.00	601.85	1972
22		473196	4420560	173	233	630.00	631.95	1964
23		473167	4420556	172	233	660.00	662.00	1958
24		473137	4420552	171	233	690.00	692.03	1954
25		473107	4420548	170	233	720.00	722.04	1956
26		473078	4420543	169	234	750.00	752.09	1962
27		473048	4420539	168	234	780.00	782.39	1976
28		473018	4420535	167	234	810.00	812.65	1989
29		472989	4420530	166	234	840.00	842.78	1998

- Using the above tabular data for further processing using MATLAB program. Then taking the last two columns on the tabular data for drawing the path profile (2-D) by using MATLAB package Software.

6. Path Loss Calculations:

The path loss of any radio link depends on the link parameters (distance, wavelength) and the degree of obstruction of the path profile, so that it is important check the degree of obstruction before designing any radio link. This can be checked using Fresnel Ellipsoid. The following steps represent the simulation procedure used in this work to check whether the path profile between the selected two locations gives an acceptable clearance or not:

- Calculation of the Fresnel ellipsoid parameters using MATLAB package software as shown in Figures below. Figures (11), (12) and (13) shows the extracted path profile between point A and three proposed locations for point B (B1, B2, B3).

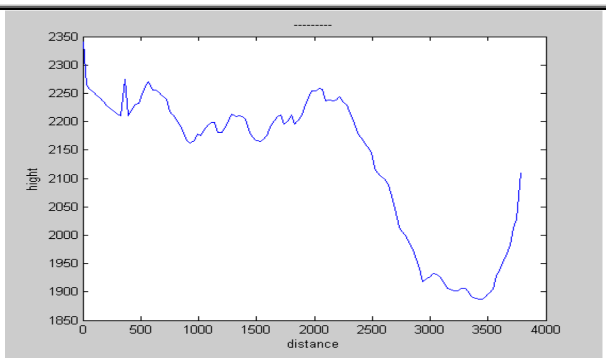


Figure (11) The extracted path profile between points A and B1

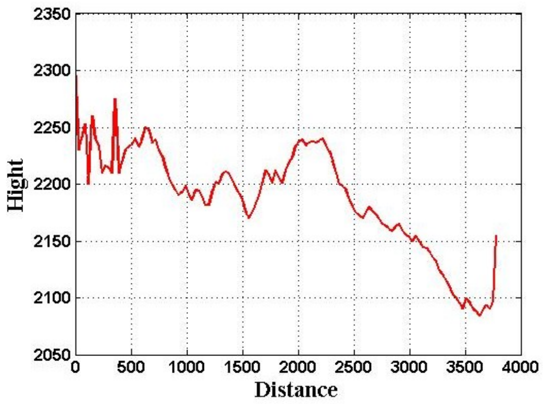


Figure (12) The extracted path profile between points A and B2

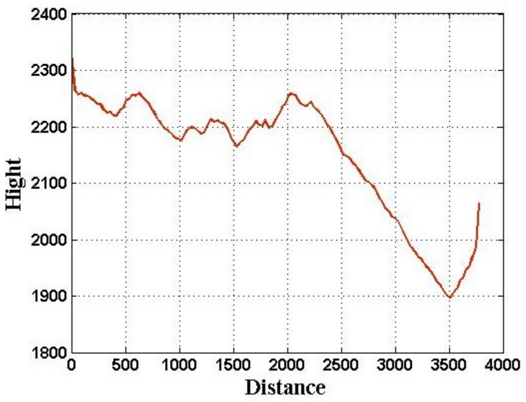


Figure (13) The extracted path profile between points A and B3

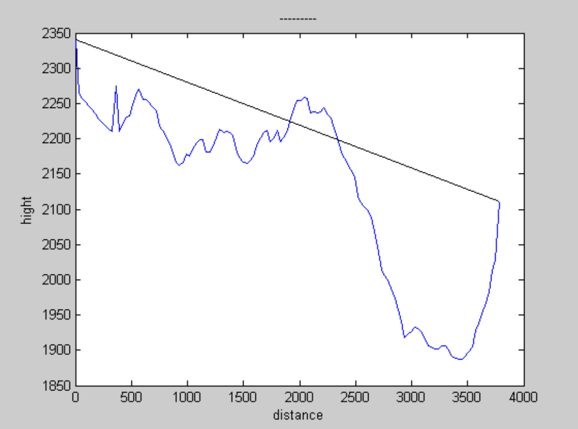


Figure (14) Line-of-sight and path profile between points A and B1.

- Figures (14), (15) and (16) are showing the superposition of line-of-site and path profile between point A and the points under test B1, B2, B3.

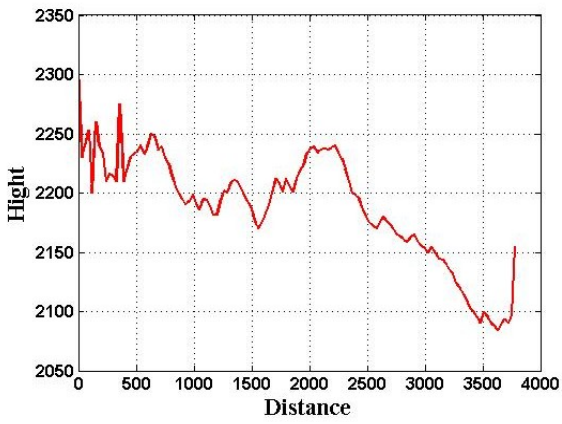


Figure (15) Line-of-sight and path profile between points A and B2.

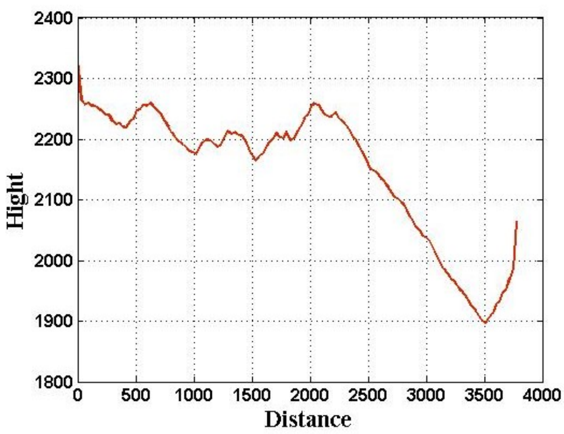


Figure (16) Line-of-sight and path profile between points A and B3.

- Superposition of the first Fresnel ellipsoid on the path profile between the transmitter A and the proposed locations (B1, B2, B3) of the receiver as shown in Figures (17), (18) and (19).

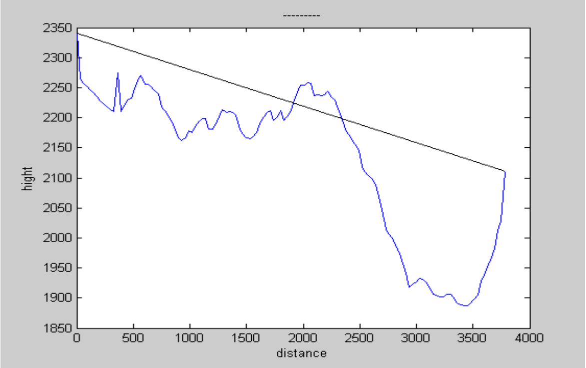


Figure (17) The First Fresnel Ellipsoid between the points A and B1.

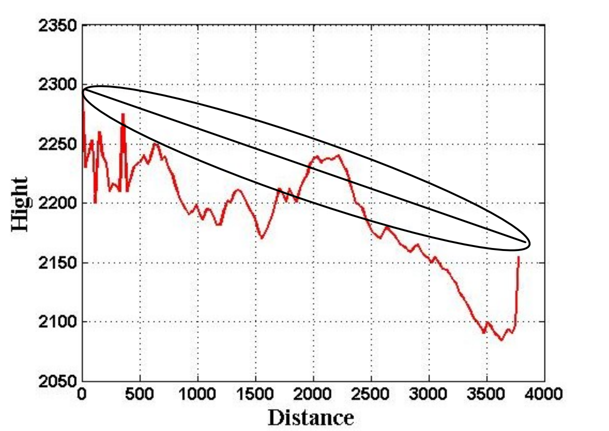


Figure (18). The First Fresnel Ellipsoid between the points A and B2.

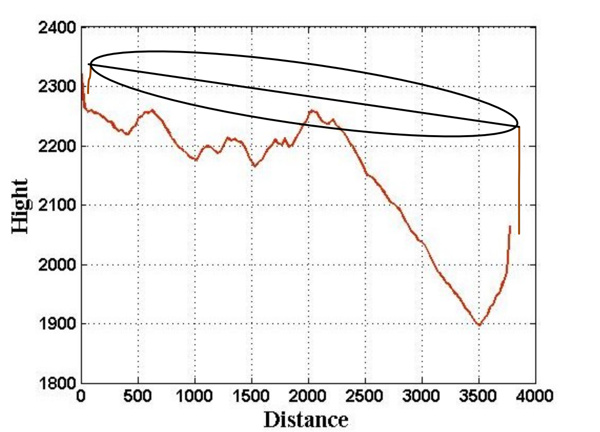


Figure (19) The First Fresnel Ellipsoid between the points A and B3.

7. Simulation Results:

The tools and parameters used in these simulations are:

- ERDAS IMAGINE Tool.
- MATLAB Tool.
- Microwave Link Parameters:

Frequency = 3 GHz (λ=0.1 meter)

Transmitter (T) and receiver (R) towers height = 70 meter.

In section V, the procedure steps and the results of the data extraction and path profile for each step was demonstrated (Figures 6, 7, 8, 9, 10, and Table-1). In section VI, the procedure steps and the results of the degree of intersection between the obstacle and the First Fresnel zone was illustrated shown in above Figures (11 - 19).

Obstruction loss caused by the intersection of the path profile with the First Fresnel Ellipsoid can be calculated by using the equation (10) and Figure (4). The attenuation for the above proposed three locations (B1, B2, B3) of the receiver is shown in Table (2).

Table (2) The attenuation factor

Case	d_1 (meter)	Attenuation (db)
First case B1	2045	-6.5
Second case B2	2225	-12.3
Third case B3	2039	- 0.3

For the above three cases the third location is the best one because it gives the better clearance. The attenuation factor was taken as validity criteria to check whether the link is accepted or not.

8. Conclusions:

For mobile and Communication networks, there are a huge number of base and control stations, so that site survey becomes impracticable. This job can be easily done by the proposed simulation. This procedure enables the designer to select the optimum numbers and positions of the base and control stations.

The accuracy of path profile and then the obstruction loss depends mainly on the height resolution of digital image used in the calculation process.

References:

[1] V. Parser, "propagation of radio waves" 1990. http://www.vigyanparsar.com/ham/ionos.htm,

[2] P. Philip, "communication system design: Line of sight and tropo-scatter system", 1979-1982.

[3] J. G. Proakis, M. Salehi, "Communication Systems Engineering" Sep 6, 2006 http://www.phptr.com/index.asp

[4] N. Rao, et al., Troposphere effects on microwave propagation in hilly terrains, Seventh International Conference on (IEE), ICAP 91, Vol.1, 15-18 Apr 1991 Page(s):58 - 62 http://www.comsoc.org

[5] J. Linmartz's "Wireless Communica- tion" Vol.1, 1996. http://people.seas.harvard.edu/~jones/cscie129/prop_models/propagation.html.

[6] B. McLarnon,"VHF/UHF/Microwave Radio Propagation"1997 http://www.tapr.org/dayton_townmeeting_1998.ht

[7] B. Fette, " RF Basics: Radio Propagation"12/10/2007 http://www.rfdesignline.

[8] H. Chan, S. Lee, "Communications planer; DSS; Mobile communications" June,1998 http://www.sciencedirect.com/science

[9] J. Ashley," Microwave path design the basics" May 1, 1998 http://mrtmag.com.

[10] E. Weissten, "wave motion-reflection and transmission", 1999. http://scuenceworld.wolfrom.com/physics/topics/reflection

[11] S. imberi, "radio wave propagation, 1977-2005 http://www.hamshack.com/propagation.html

[12] A. Drive, and Lawrence, KS," Electrical engineering training series "2004 http://www.tpub.com/content/neets/14182/css/14182_79.htm

[13] V. Parsar, "Propagation of radio waves" May 4, 2000 http://www.vigyanparsar.com/ham/IONOS.html

الخلاصة

النمو الواسع في الاتصالات الخلوية، الاتصالات الراديوية والشبكات اللاسيلكية وازدات اهميتها في العديد من التطبيقات الراديوية. كرست الان جهود كبيرة لادخال تحسينات في تصميم نمودج حساب خط البث الراديوي في المدن، الضواحي، وفي بيئات اخرى باستخدام التقنيات الرقمية ونظم المعلوماتية

ان الحيود في جبهة الموجة الراديوبة تحدث عند اصطدام جبهة الموجة لعائق بابعاد مقاربة للطول الموجي . ان مقدار الخسارة الناتجة من العوائق يعتمد على مساحة الحزمة المعائقة وعلاقتة بالمساحة الكلية للجبهة للطاقة المنتشرة وصفات حيود العائق.

ان مهمة مصمم النظام تتركز على تامين تبادل النظر بدون خسارة ملحوظة نتيجة وجود عائق قريب من مسارالقنال الراديوي،ان درجة التدلخل بين العائق والشكل البيضوي تعتبر مقياس جيد لخسارة العوائق

ان تقنيات التحسس من بعد (التصويرالرقمي بالاقمارالصناعية ، التصوير الجوي ، ومعالجة الصور) تعطي تسهيلات مشجعه حيث يمكن استثمارها لمعرفة التفاصيل الطوبوغرافية لمنطقة الدراسة وتحديد المسار الافضل للقنال الراديوي.

ان المزاوجة بين هده التقنيات والبرامجيات المستخدمة للحساب وتحديد مسار انتشار الموجات الكهرومغناطيسية يمثل المحور الاساسي لهدا البحث، حيث تم استخلاص المعلومات الطوبوغرافية للمسارات المقترحة باستخدام صورة فضائية رقمية لمنطقة الدراسة، وتحديد مواقع العوارض وحساب مقدار الخسارة ولحالات مختلفة.