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Attenuation on Wave Propagation due to Antenna Height and Distance Effects

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Abstract- line-of-sight propagation is not practical for linking two points far apart on Earth but it could be suitable to link two adjacent points that are not far apart . This is due to the reason of the curvature of the Earth's surface as required by the need to communicate over long distances. Communication between two points which a fair distance apart on earth surface using two antennas will depend on the antenna heights as s well as distance between the antennas and the used frequency of transmission, taking into account the media condition separating the transmitter and the receiver, whether it is dry environment, humid or sea level.

The purpose of this paper is to find the effect of attenuation on wave propagation between the transmitting and receiving antennas, considering the length of a link, transmitting antenna height and reception antenna height under two different media conditions , humid and sea level environments. The MATLAB is the environment used to simulate the effect of the attenuation on the wave propagation taking into account the above mentioned parameters, link length and transmit and receive antenna height. The obtained results show that for the wet earth case the best antenna heights are 160 m for transmitter and 80 m for receiver and for the sea level case it is 160 m for both antennas.

Keywords— Propagation, humid, antenna, attenuation, sea level, height, distance, MATLAB

I. INTRODUCTION

Troposphere **e**xisting from the earth's surface to between 7-17 km above the earth's surface, this region of the atmosphere is the most turbulent since there is a lot of thermal movement of air. As altitude increases air temperature decreases strongly leading gases to expand due to the reduction of pressure which reduces the temperature of the gas. The most important atmospheric effects on radio wave propagation are refraction and reflection. Refraction can occur in the troposphere or the ionosphere. The altitude increase causes the refractive index of the atmosphere to decrease, which in turn leads to the bending of waves back toward the earth, this is known as Tropospheric refraction . when radio waves are "bounced" from a flat surface this is known as reflection . reflection can take one of two forms depending on the surface from which it occurs in the atmosphere: earth reflection and ionospheric reflection. wave polarization and the angle at which the wave strikes the surface control the amount of phase shift that occurs . Because reflection is not constant, fading occurs. Normally, radio waves reflected in phase produce stronger signals, while those reflected out of phase produce a weak or fading signal. In the literature there is some work has been conducted to study the effect of antenna height and other parameters on the signal attenuation. In [1] In this paper the authors studied the effect of ground wave propagation on antennas performance by using a generic planar earth model. Simulation results show that increase in antennas height and phase angle reduces the ground wave propagation loss, thereby improving the signal power quality at the receiver's end. also they concluded that any antenna located in a favourable ground with large distance and height above most obstacles like walls, heave vegetation, etc, will perform better. In [2] the authors reviewed the work that has been done by some researches on the effect of antenna height, depolarization and humidity in forest environment. They found that the gain due to antenna height is proportional to the sum of the log of both transmit and receive antenna heights i.e. increases by 20dB increase in both antennas. The depolarization effect is dependent on the frequency and the distance between the antennas, where vertically polarized wave suffer more loss than horizontal ones. Humidity increase will result in an increase of attenuation up to 24 db in the VHF range. This paper investigates the effect of attenuation on wave propagation between the transmitting and receiving antennas, considering the length of a link, transmitting antenna height and reception antenna height over wet land and sea level. The MATLAB is the environment used to simulate the effect of the attenuation on the wave propagation taking into account the above mentioned parameters, link length and transmit and receive antenna heights.

II. RADIO WAVE PROPAGATION

According to the ITU-R recommendation P-series, the main factors influencing radio wave propagation are the atmosphere and land coverings , where the atmosphere has four layers namely magnetosphere, ionosphere, stratosphere and troposphere [2]. In most applications wave propagation is affected by proximity to the earth, objects blocking the LOS and/or atmospheric effects. Hence wave propagation varies with frequency being used . Wave propagation can take many forms, Ground waves, Tropospheric wave or Sky waves, where these waves can propagate directly and its known as Line Of Sight (LOS) or indirectly known as None Line Of Sight (NLOS). During propagation the signal will suffer from reflection, diffraction and scattering from objects such as buildings or foliage. Other phenomenon affects an incident wave are refraction , absorption and depolarization. Wave propagation get affected by many factors, such as the permittivity ε of the media over which the wave propagates, the media conductivity δ, media geometry and wave polarization [3].

III. THE ATTENUATION

Electromagnetic waves suffers loss of power during transmission when it passes in a media such as atmosphere and clouds, etc. The part of the energy that is being lost due to absorption, reflection and /or scattering is due to the physical properties of the media, through which the signal has passed by, and in addition to the attenuation resulting from the propagation of waves on the surface of the earth, Attenuation can be caused by many factors but in this paper the factors that will be considered are the transmitter and receiver antenna heights and the distance between the antennas.

Let the antenna height above ground service be h m and wavelength is λ m, so this height is much larger than the wavelength (h>> λ), As shown in fig. (1):

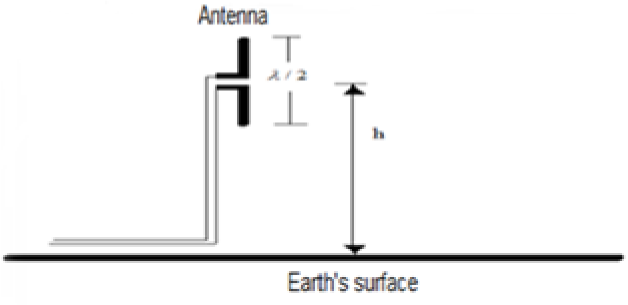

Fig. 1 antenna high above the earth's surface

Suppose that there are two antennas one for transmitting and its height (h1), and the other for receiving and its height (h2) and the distance between them is (d), consider that the ground level between the antennas flat because the distance between them is small compared to the earth radius which is (6378.1 km). Fig. (2), shows the signal paths between the antennas from transmit point to reception point and reflections that occur.

From fig. (2) it can be noted that two beams arrive at reception antenna one of them is a direct beam and the other is reflected from the earth's surface, since the beams are an electromagnetic waves this means that there are two electrical fields at reception point one of them due to the direct beam which is described by the following equation:

$$E_1 = \frac{A_1}{d_1} e^{[j(\omega t - kd_1)]} \quad \ldots\ldots (1)$$

Where A_1 is constant and described by the relationship:

$$A_1 = \sqrt{(60\, W_T\, G_T}$$

Where G_T is the transmitting antenna gain also known as attenuation factor. And the other electrical field at receiving end results from reflected beam described by the following equation:

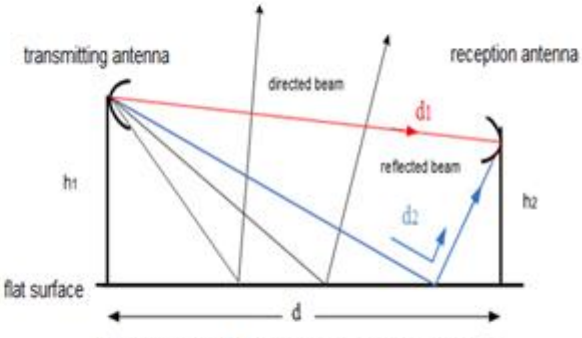

Fig. 2 signal path between trans-receiver antennas

$$E_2 = \frac{A_2}{d_2} R\, e^{[j(\omega t - kd_2)]} \quad \ldots\ldots (2)$$

Where R is the reflection factor which depends on electrical constants of earth's surface, and A_2 known from:

$$A_2 = \sqrt{60\, W_T\, G`_T}$$

Where $G`_T$ is the transmitting antenna gain from reflected beam, since the antennas heights (h1, h2) are small compared to the link length (d) it is reasonable to say that $G_T = G`_T$. The final relationship to calculate the attenuation coefficient is as follows [4].

$$G = [1 + R^2 + 2R\cos\emptyset]^{1/2} e^{(-j\delta)} \quad \ldots\ldots (3)$$

Where:

$$\delta = \tan^{-1} \frac{R\sin\emptyset}{1 + R\cos\emptyset}$$

$$\emptyset = \theta + \frac{2h_1h_2K}{d}$$

θ is elevation angle in radians
k is the propagation constant

As it is clear that the attenuation depends on the distance between antennas (d) and trans-receive antennas heights (h1, h2) respectively.

Atmospheric effects on attenuation are not taken into account because the considered distance between antennas not very large as well as the limited antenna heights.

III. SIMULATION AND RESULTS:

A Matlab (version R2015a) program was written to find the relationship between the attenuation factor and the distance between transmitter and receiver. As well as the relationship between attenuation factor and the height of trans-receive antennas (h1, h2) respectively when the distance between them is fixed while h1 and h2 are variable. It is assumed that the media in one case is a wet ground with permittivity of 10 and conductivity of 0.01 S and in the other case permittivity 81 and conductivity of 4 the propagated waves are vertically polarized.

The overall simulation results are represented in the following scenarios :

1) In this scenario the relationship between the transmitter antenna heights (80 and 160 m) and attenuation was checked at a specified heights for the receiver antenna (80 and 160 m) over a distance of 80 Km and frequency of 8 GHz Fig. (3) shows the results of this scenario.

From fig. (3), It can be noted that the attenuation will vary between -20 to 3dB based on antenna height change. When the receiver height h2= 80 m in the case of wet earth the attenuation fluctuates between about -18dB and 3dB when the transmitter height h1 is 80 m with an average value of -2.8 dB and the lowest values at about 45 and 73 km marks. When h2 increased to 160 m the attenuation fluctuates between about -20 dB and 3 dB with an average value of -2.5db and lowest values at the 5 and 75 km marks. . When h2 is 80 m for the sea level case the attenuation fluctuates between -7 dB to 3 dB at h1=80 m with an average value of 0.96 dB and the lowest values at the 60 and 78 km marks . At h2 of 160 m the attenuation varies between about - 5 to 3 dB when h1=80 m with an average value of 0.91 dB and lowest values at the 10 and 48 km marks.

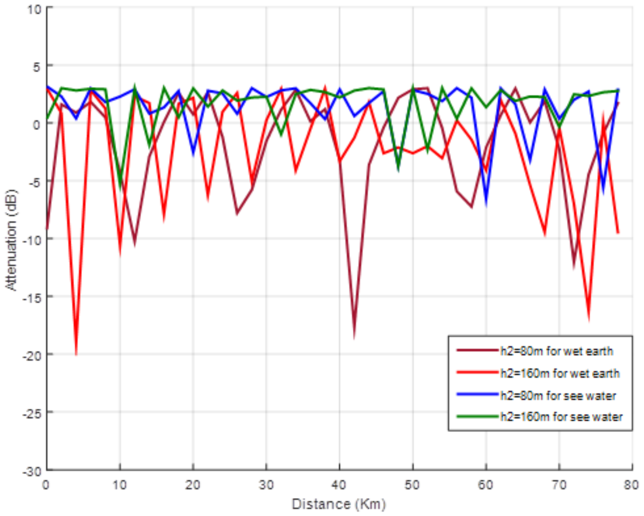

Fig. 3 the relationship between attenuation factor and distance at the height of transmitter antenna (h1=80 m) selected receiver antenna heights (h2)

2) Fig (4) shows the effect of varying distance (0 to 80 Km) on attenuation at a transmitter antenna height (h1) of 160 m and receiver antenna heights (h2) of 80 and 160 m. From the figure it can be seen that at h2=80 m for the case of wet earth, the attenuation fluctuates between -20 to 3dB with an average value of -2.57 dB and the lowest attenuation values at the 5 and 75 km marks . If h2 is increased to 160 m the attenuation fluctuates between -15 to 3dB with the lowest values at 44 and 75 Km marks with an average attenuation value of -1.56 dB. For the case of sea level When h2 is 80 m the attenuation fluctuates between -5 to 3 dB with an average value of 1.15 dB, where the lowest values of attenuation were at 12 and 37 Km marks.

At h2=160 m the attenuation varies between -10 and 3 dB with an average value of 0.86 dB where the minimum attenuation occurs at a distances of 11 and 38 Km .

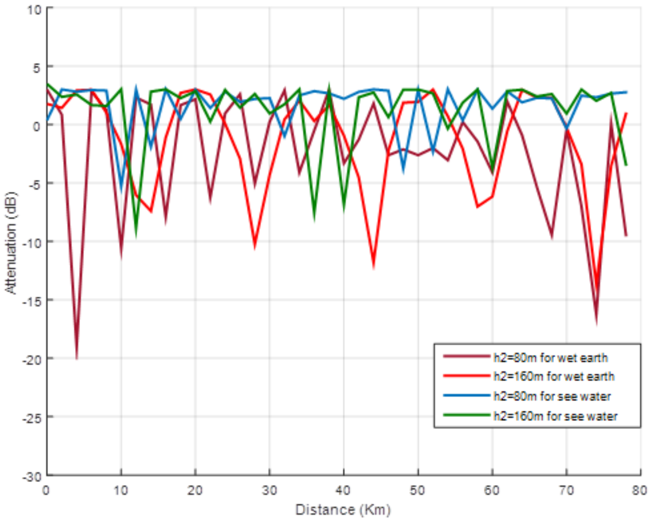

Fig. 4 the relationship between attenuation factor and the length of the link when changing receiver antenna height (h2) at h1=160m

3) In this third scenario as it can be seen in Fig (5) which shows the relationship between attenuation and frequency at various heights of receiver antenna when transmission antenna height is 80 m for the wet earth case . from the figure it can be noted that when h2=80 m the attenuation starts at about 1.5 dB at 1GHz and increases to an average value of 2.3 dB up to frequency of 4GHz and then drops down to about -4.5 dB at frequency of 6 GHz. The attenuation climbs back to about 2 dB at frequency of 7 GHz and then drops. the minimum value occurs at 6 GHz. When h2 was 160 m the attenuation starts at 1.5 dB at 1GHz and fluctuates with an average value of 2.4 dB up to the 7GHz mark and then drops very sharply to about -7 dB. The average value for this case is 0.83 dB with minimum value of -7dB at 8 GHz. For the case of sea level when h1=80 m and h2= 80 m, the attenuation starts at 3dB at the 1GHz mark and fluctuates between -2 and 3 dB with an average value of 1.19 dB and the lowest value of -2dB at 3 GHz. When h2 increase to 160 m the attenuation starts just below 0 dB at 1 GHz and then fluctuates with an average

value of 0.66dB between -7.5 and 3 dB. The lowest attenuation is at 5 GHZ with a value of -7.5 dB.

4) This scenario investigates the effect of increasing the transmitter antenna height to 160 m with receiver heights of 80 and 160 m over the same frequency range. Fig 6 shows the obtained results for this scenario. From the figure it can be clearly seen that for the wet earth case when h2=80 m , the result is the same as for the case when h1=80 and h2=160 in scenario 3. This also true for the case of sea level when h2=80 m. For the case when h2=160 in the wet earth case the attenuation starts at -3db at 1GHz and the fluctuates with an average of -0.83 dB between -3 and 3 dB, where the lowest values occur at 1 and 7 GHz.

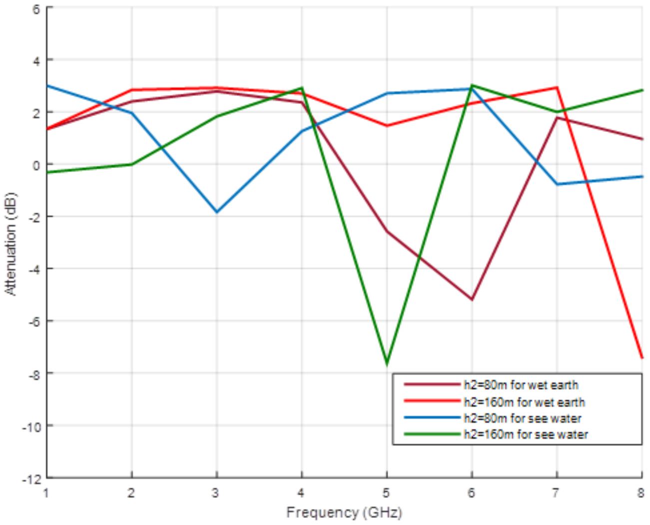

Fig. 5 the relationship between the attenuation coefficient and frequency for various antenna height h2 and h1=80 m

For the case of sea water when h2=160m. The attenuation starts at -0.5 dB and fluctuates between -10 and 2 dB with an average of -2.13 dB, where the lowest values occur at 3 and 7 GHz.

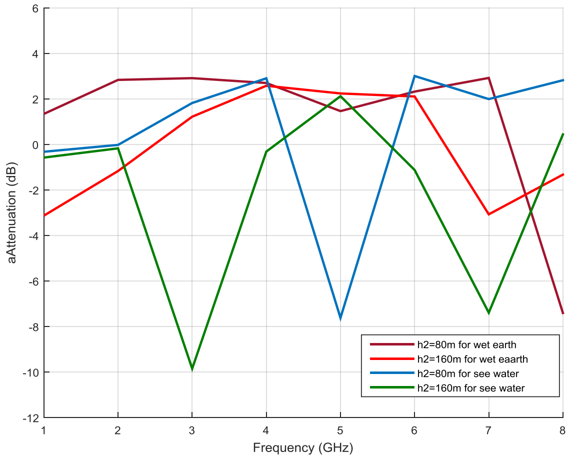

Fig. 6 The relationship between attenuation factor and the frequency when changing receiver antenna height (h2) at h1=160m

IV. CONCLOSIONS

This paper has looked at the effect of antenna heights of transmitter and receiver when they were setup on a wet earth and sea level at a distance of 80 Km between them and operating at a frequency of 8GHz on the attenuation due to LOS and reflected electromagnetic waves. Many scenarios were setup using MATLAB simulations. From the obtained results it is clear that for the effect of antenna height, for the wet earth case the best results is when h1=160m and h2=80 m, where the average attenuation was -2.57 dB and for the sea level case the best configuration is when h1=160 and h2=160 m with an average attenuation of 0.86 dB . In terms of frequency the best heights are h1=h2=160 m for the wet earth case with an average attenuation of -0.83 dB and this is also the case for the sea level environment with an average attenuation of -2.13 dB. Therefore it can be concluded that for the wet earth case the best antenna heights are 160 m for transmitter and 80 m for receiver and for the sea level case it is 160 m for both antennas.

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