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PATH ATTENUATION CALCULATOR FOR RAIN FADE

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ABSTRACT

Rain as a weather phenomenon is one of the things that greatly affects propagation of radio waves. Above 10 GHz, the attenuation brought about by the interaction of the propagating waves and the rain droplets becomes significant for both terrestrial radio links and satellite links. For this reason, rain attenuation models have been developed to aid in planning purposes for network implementation. The models use statistics to predict the attenuation that is caused by specific amount of rain and also the type of rain. This means that different regions will have different levels of attenuation due to the fact that they experience different types and amount of rain. A couple of models exist including the ITU-R, Moupfouma model, Crane attenuation model and other localized models depending on the geographical area that research data collection and extensive analysis has been conducted on and a comprehensive set of values and factors have been determined that can aid in estimation of attenuation due to rain. This paper seeks to provide a viable means by which a transmission engineer can be able to know the attenuation per kilometer due to the various models. This is achieved by designing a software calculator that provides the output of the attenuation per kilometer (dB/Km) while taking an input of rain rate for the different models available. The calculator is based on visual basic platform and works with forms.

KEYWORDS: path attenuation, calculator, rain fade

1. Introduction

The study of the effects of hydrometeors, especially rain on signal propagation in recent years has been at the forefront due to the congestion of the lower frequency bands. Higher capacity communication channels are needed for today's high speed transmissions and this is only achievable by using higher frequency bands. The only drawback is that as the frequency of propagation increases, the attenuation due to rain becomes more and more significant (Yeo, Lee & Ong, 2014).

The atmosphere above the earth's surface is composed of layers which have different properties and composition. The two main regions that exist are the homosphere which extends up to about 80 km above the earth's surface and the heterosphere, which extends onwards from the homosphere.

The homosphere is divided further into three other layers, the troposphere, the stratosphere and the mesosphere. The troposphere is the region that is most important to radio engineers dealing with terrestrial radio links. The troposphere extends from the earth's surface to about 18 km above the equator while for the poles it extends to 8 km. The troposphere is

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characterized by a regular decrease in temperature known as the lapse rate of about -6^{o} [C/Km]. The troposphere is also where most weather phenomenon including formation of clouds and rain (Gordon, Ozuomba, & Kalu, 2015).

In the troposphere, the electromagnetic waves which are propagating are influenced by:

1. Gas composition of the atmosphere.
2. Precipitation such as rain, snow or hail.
3. Litho meteors such as dust, smoke and sand.

The International Telecommunications Union Radio communications sector (ITU-R) located in Geneva manages the electromagnetic spectrum. It publishes frequency allocation tables on a regular basis that divide the spectrum into separate bands for each service that utilizes radio waves for communication. The table of allocated frequencies is integrated into the various communications regulations depending on the geographical regions and countries (Gordon, Ozuomba, & Kalu, 2015).

For frequencies of more than 10 GHz, the attenuation due to rain becomes significant. This occurs because as the wave passes over an object that has dielectric properties which defer from the medium surrounding it, absorption and scattering of the energy occurs. The energy which gets absorbed heats up the material that absorbed it. The energy which is scattered relates to the wavelength of the incident wave (Shrestha & Choi, 2017).

As the frequency increases, the wavelength reduces to a point where the wavelength is smaller than the diameter of a raindrop. This means that the incident wave is completely absorbed by the drop and this is the reason why with higher frequencies, attenuation due to hydrometeors increases significantly.

Radio wave propagation is defined as the transfer of energy by electromagnetic radiation at radio frequencies (Hashiguchi, Hashiguchi, Vonnisa, & Abubakar, 2018). Radio waves propagate via several different physical mechanisms. In free space a wave propagates without meeting any obstacle. Attenuation here is by virtue of scattering of energy of the wave as it propagates. Radio waves can also propagate by means of reflection. Waves are reflected at surfaces according to Snell-Descartes law (Shrestha & Choi, 2018). The reflection can be specular which occurs when the reflecting surface is perfectly smooth plane that is also homogeneous or the reflection can also be diffuse which takes place on a rough surface.

Radio waves can also propagate by means of transmission as they travel through a medium like vacuum, air or an obstacle without the change in frequency. Transmission can be of different types, regular transmission, diffuse transmission and mixed transmission. Waves can also propagate through diffraction which occurs when a wave impinges upon an obstacle or an aperture which has large dimensions compared to its wavelength. There are two models under diffraction; single knife edge diffraction and rounded obstacle diffraction (Gordon, Ozuomba, & Kalu, 2015). Waves are also propagated by scattering where the energy of the wave is distributed along several directions in the propagating medium.

The wave may follow different paths after it has been emitted from a transmitting antenna as it propagates to the receiving antenna. Depending on the type of obstacles that the waves comes across during their propagation, refraction, scattering, reflection and diffraction will occur leading to a myriad of elementary paths with each such path characterized at receiver level by an attenuation, a delay and a specific phase difference. This is termed as multipath propagation.

2. Methodology

The paper is done based on Visual Studio software. The program is able to produce a form in which the rain rate for a specific area, the frequency of the signal and the length of the link is input by the user. The given output is for the three selected models which are the ITU-R model, the Crane model and the rain cell growth ratio model.

The models chosen are based on the fact that the ITU-R model is the recommended model by the International Telecommunications Union (ITU), the Crane model is a model that is specifically developed for the United States of America (USA) and thus it represents a temperate climate and finally the rain cell growth ratio model is developed for Durban South Africa. This region is a sub-tropical region which is the closest in comparison to the Kenyan climate.

The pseudo-code for the program was developed as follows:

1. Takes input of frequency, rain rate and distance.
2. Uses selected model, calculate the specific attenuation.
3. Displays the attenuation.

The flowchart of the overall process is shown in Figure no.1.

The first window of the program, as seen in Figure no. 2, provides for a place where the user inputs the values of frequency, the rain rate and the length of the link that is being designed. The percentage of time that rain will exceed the given value of rain rate is also selected depending on the links specifications. This value will affect the percentage of the time that the link will be available.

When the attenuation model is selected, then more options will be visible and these will depend on the specific attenuation model selected. In the case of the ITU-R model, choices for selecting the polarization of the particular wave will appear. Also a provision for the selection of a rain rate from the map provided will be available.

The Crane model also has a map which allows the user to select the region that the planned link will be set up and thus select the rain rate that corresponds to the region. The option under each model is shown in Figure no. 3.

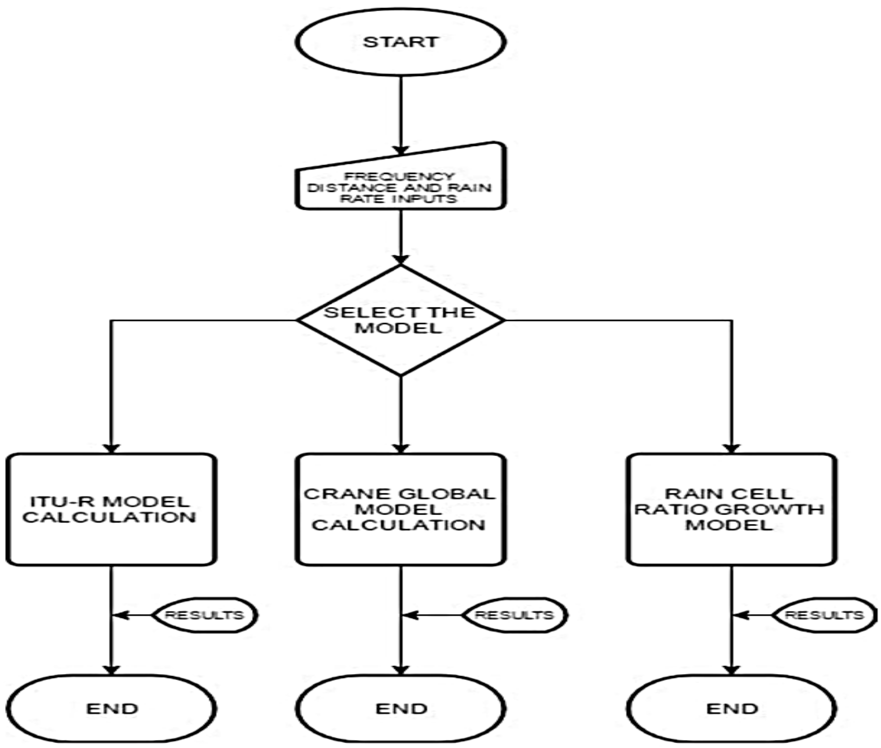

Figure no. 1: *Flowchart of the overall process*

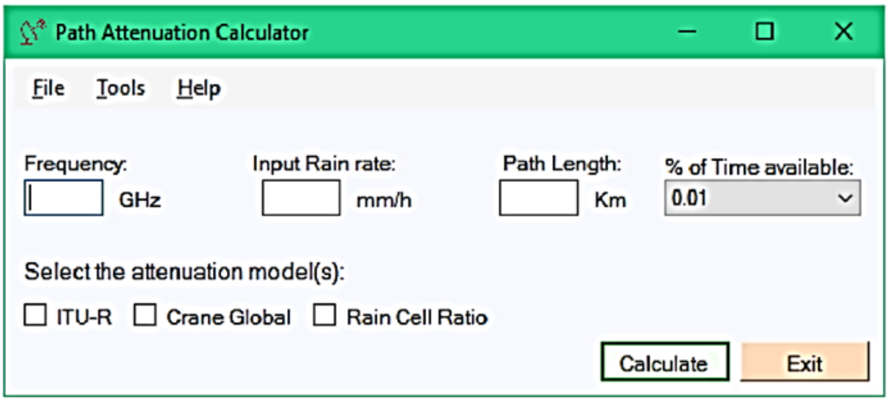

Figure no. 2: *The first window of the application*

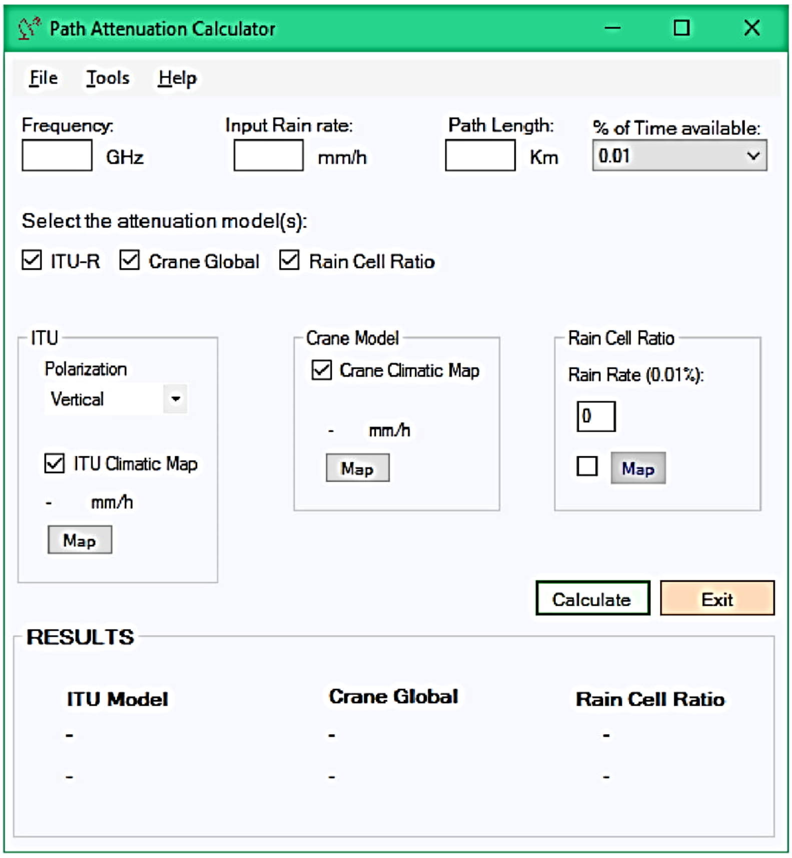

Figure no. 3: *Options under each model*

Both the ITU model and the Crane Global model provide maps that divide the world into climatic regions based on rainfall data collected. The program allows for the case of regions where the rain rate data may be unavailable that the user can select from the maps provided. The results of attenuation and specific attenuation are then displayed in the results panel shown on the main window.

3. Results

The program is able to display the results for the three models once all the inputs are in order. The output is as shown in Figure no. 4. The program also allows for the ability to plot graphs and thus compare the different model attenuation values with variation in frequency, distance or rain rate. This is shown in Figure no. 6 with parameters for plotted graph shown in

Figure no. 5. Figure no. 6 compares between two types of polarization, vertical and horizontal for ITU-R model.

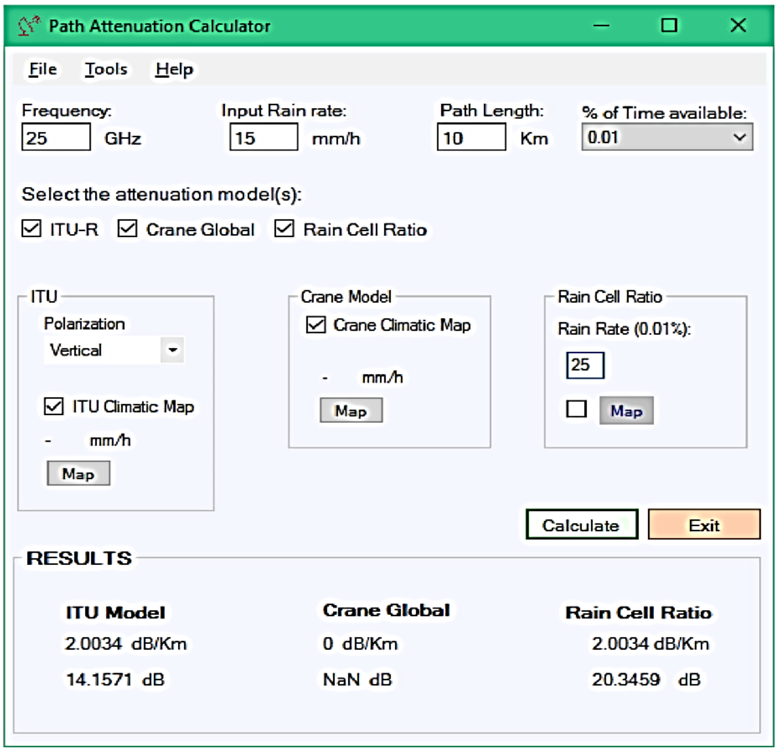

Figure no. 4: *Results of the program*

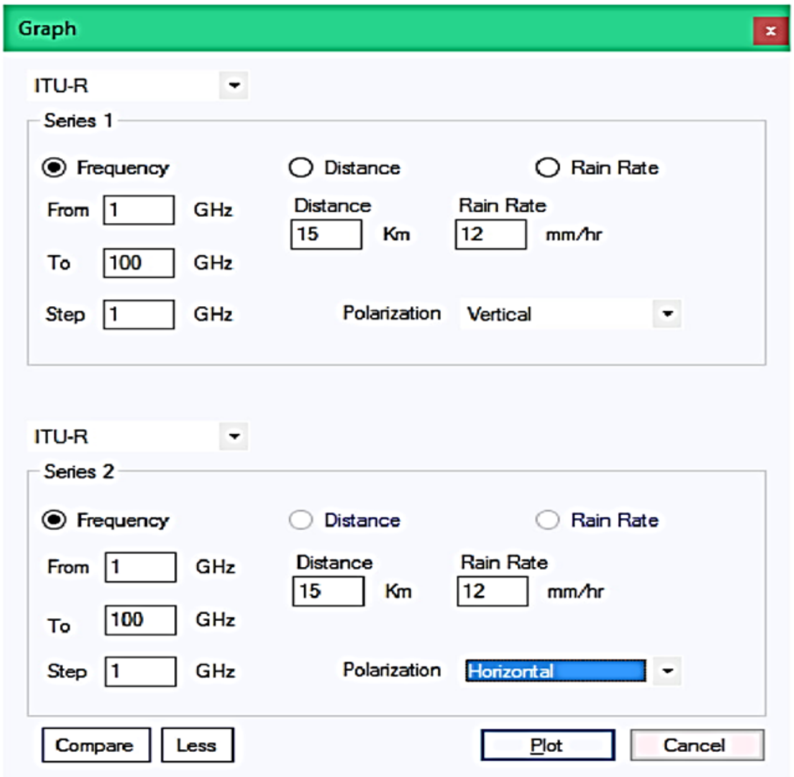

Figure no. 5: *Parameters for plotting a graph that compares the two polarizations for ITU-R model*

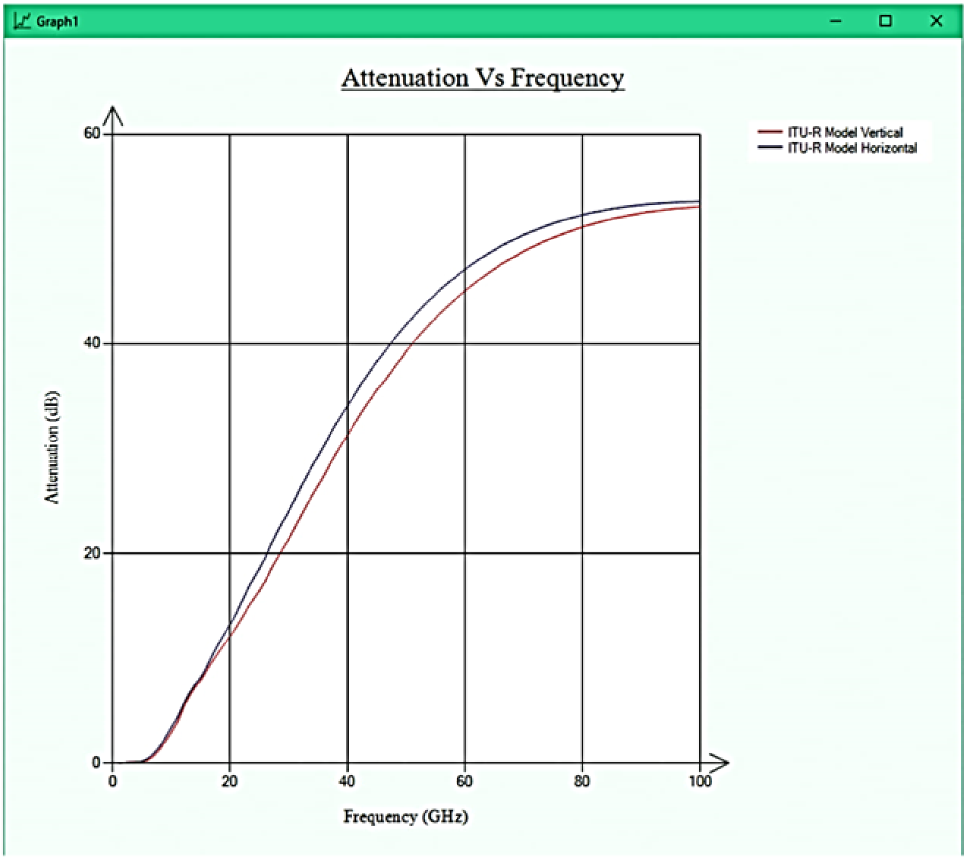

Figure no. 6: *Output of graph with parameters shown in Figure no. 5*

The Crane model has a deficiency in that the model does not provide a formula that would allow the calculation of the different coefficients required. This also has the effect of ensuring that only attenuation values for frequencies of up to 100GHz can be calculated. For the case of the rain cell growth ratio model, knowledge is needed about the rainfall breaking point. This kind of data is hard to find as it requires a lot of rainfall studies and use of disdrometers to be able to determine the rainfall breaking point of a certain area. As a substitution, the rainfall rate of R0.01 is being used instead. The ITU climatic map is used to obtain this or the value can be directly input into the provided input text box. This value also affects the attenuation values that will be found. In most cases the attenuation value will be found to be less than that given by the ITU-R when the R0.01 value is left as 0. This is contrary to the model suggested under the rain cell growth ratio.

A comparison between ITU-R model and Crane global model can be seen in Fig.8 with parameters for plotting graph is shown in Figure no. 7.

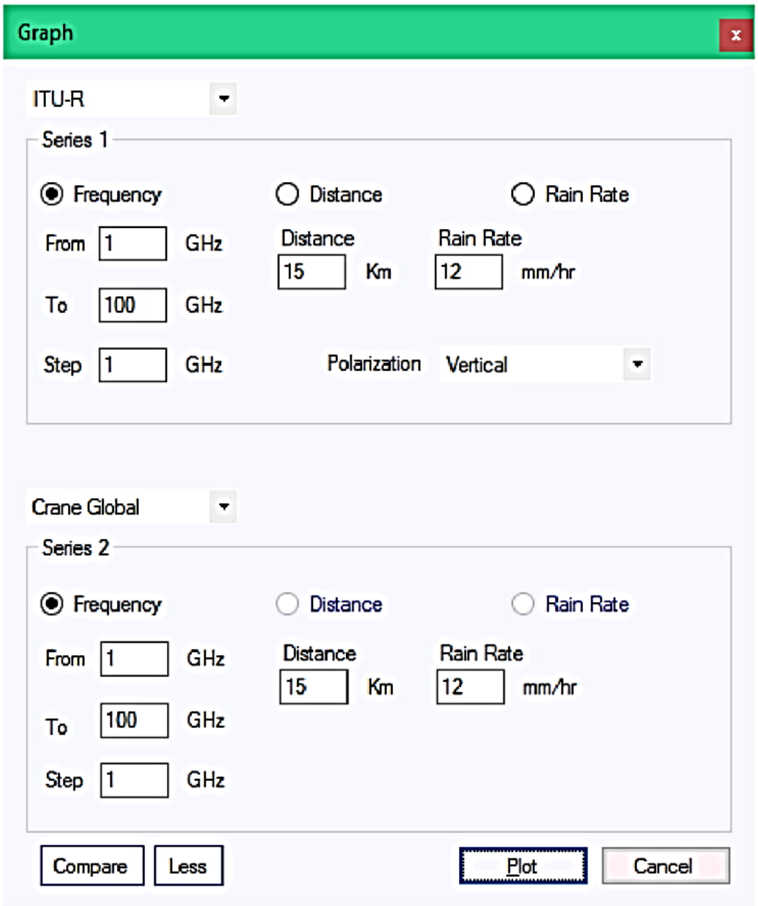

Figure no. 7: *Parameters showing input with different models*

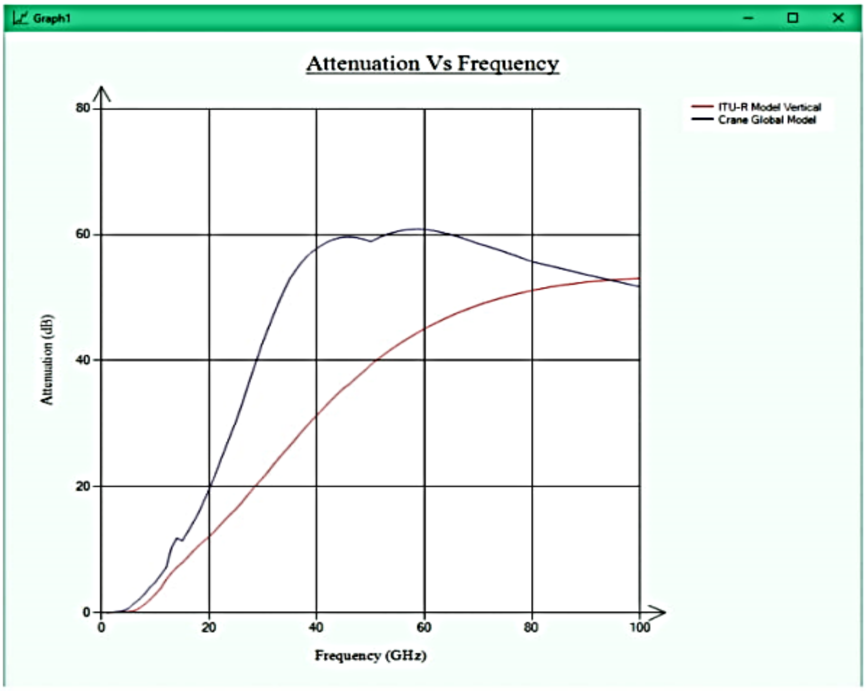

Figure no. 8*: Output for parameters shown in Figure no. 7*

4. Conclusion and Discussion

The objective of the paper was to design a path attenuation calculator for rain fade. This was done by using Visual Studio 2015 and implementing three models namely: ITU-R model, Crane global model, and rain cell growth ratio model. The models were chosen on the basis that the ITU-R model is the recommended model, the Crane global model is for temperate climates while the Rain cell growth ratio model is for sub-tropical climate which is the closest to the Kenya climate. The calculator is solely for terrestrial links.

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