MICROWAVE ATTENUATION STUDIES DUE TO RAIN FOR COMMUNICATION LINKS OPERATING IN MALAYSIA

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Abstract
Attenuation due to rain is an important constraint in the designing of the microwave communications links operating in Malaysia especially at frequencies above 10 GHz. In recent studies, the ITU-R proposed models for the prediction of rain attenuation give a good estimation for the microwave propagation loss caused by rain for the temperate regions but it underestimates the rain attenuation prediction for the tropical regions. This paper studies the rain attenuation prediction models for the design of microwave terrestrial line-of-sight (LOS) systems and the results of this investigation.

1. Background

Microwave links are revolutionizing the wireless communications system via radio frequency (RF) transmission medium in personal and telecommunication services in Malaysia. The conventional microwave link is normally employed in SDH (Synchronous Digital Hierarchy) and PDH (Parallel Digital Hierarchy) backbone terrestrial communication systems. Typically, it is very suitable for very high bit rate and large area coverage. In the designing of a microwave link [1], there are several design points to be considered, they are (1) system reliability, (2) economical design, (3) present and future frequency selection, (4) minimization of the number of new microwave sites, and (5) flexible and multilevel systems.

However, microwave links render the system susceptible to all kinds of path attenuation, in which the microwave propagation is affected by changes in the lower atmosphere. The presence of hydrometeors such as rain, fog, water vapor and oxygen in the radio wave path, especially for these microwave links, which employs line-of-sight propagation, can produce an extremely significant effect in the energy absorption.

With respect to the hydrometeors energy absorption, the path loss due to rain attenuation has been recognized as a major obstacle in the design of microwave communication links operating at frequencies above 10 GHz [2]. In tropical areas such as Malaysia, where excessive rainfall is a common phenomenon throughout the year, rain attenuation is more significant in causing propagation losses and can severely degrade the radio wave propagation at centimeter or millimeter wavelengths. Moreover, rain attenuation restricts the path length of the microwave communications links and thus limits the usage of higher frequencies for terrestrial line-of-sight (LOS) communications systems.

Typically, the effects of rain on the design of microwave terrestrial line-of-sight (LOS) communication link that relies on the propagation of electromagnetic waves can be measured from the lowest 10 km of Earth's atmosphere [3]. To determine the total path attenuation, the microwave path loss due to rain attenuations must be added with the free-space loss (FSL) while considering the anticipated rain rates [4]. The rain rate is usually measured in millimeters per hour. According to [5], a rain at rate of 100 mm (4 inches) per hour or greater is considered as heavy rain. The rain rate is generally governed by the size and shape of the raindrops. The path loss normally varies with both the raindrop size distribution (RSD) and rain rate. In addition to this, the rain rate has a nonuniformity profile. Moreover, the size of the rain cell (rain – occupied area) will be considered along the microwave link. The heavier the raindrops, the smaller will be the rain cells.

Rain attenuation effects have been studied worldwide over the past years and various models for solving the problem have been offered. Nevertheless, at present time, the continuing research is required in the field of designing the reliable microwave communication links, as the higher bandwidth capability links are in demand. This is due to the increasing preferences in the 1 to 10 GHz frequency bands, spectral congestion is occurring at these lower microwave frequencies. This has forced the radio telecommunications engineers to look forward to the feasibility in using frequency bands above 10 GHz. As mentioned earlier, the path attenuation due to rain plays a significant role at frequencies higher than 10 GHz, considering all these factors; it is obvious that the knowledge of path attenuation due to rain is required [6].

2. Experimental Results

This section is devoted to the development of MATLAB program for computing rain attenuation data. This section also discusses the investigation using the PATHLOSS software.

2.1 MATLAB Prediction Program '*Rainsoft.m*'

A software application package is required to calculate and predict the path attenuation due to rain. The whole program source code was written in C and compiled under MATLAB 6.1. It is a console application that uses one command window for the displaying prompt text in real time. The C language is chosen for its versatility and speed when it is complied.

The '*Rainsoft.m*' is based on two rain attenuation prediction models. These are the ITU-R Rec.530 Prediction model and Global Crane Prediction Model. Although they're many available prediction models, this two are chosen because they are the most famous and mainly used in terrestrial line-of-sight (LOS) propagation links.

The program mainly uses interpolation method. By definition, interpolation is a process for estimating values that lie between known data points. In this program, the one – dimensional data interpolation is used. It is chosen because the function is widely used in the data analysis, which uses polynomial techniques.

In this case, the interpolation function used in the computation of the ITU-R rainfall intensity. The function simply returns a matrix F (0.01) corresponding to the vector in the previous command. Each column of the matrix R is a function of p, and the values of 0.01 are interpolated for each such function. The resulting matrix has the same number of rows as the length of 0.01, and the same number of columns as the matrix R. In addition to the Figure 1, the interpolation concepts are also being applied to the computation of the RSD in the rain attenuation
As the program runs down all these equations form Figure 1, the output of the desired rain attenuation result can be obtained. The exceeded attenuation due to rain is display in dB/km as the output of this program. Therefore, the rain attenuation estimation is fully completed for the ITU-R Recommendation Model. The same procedure will be taken for the computations of the Global Crane Model using the interpolation function in order to predict the path attenuation due to rain.

The developed MATLAB program has being labeled with general remarks throughout the program in order to show the task, it is assigned to perform. Since the above process is time consuming and slowed down the process of examining the attenuation results, the program has been modified to display the attenuation results for entire investigation frequency range. This is followed up by generation for the selection type of graph needed. The program provides three types of generated plots that vary on the polarization mode for the selected prediction model.

The program ends by providing user the options whether to display the comparison of the two prediction models. In this program, the comparison of the prediction models is displayed either vertical or horizontal polarization. Once the plot is selected, the graph will be displayed together with attenuation results and thus this will end the program.

2.2 PATHLOSS Prediction Software

The ultimate goal of using this PATHLOSS software is to simulate the rain attenuation values for the microwave frequencies operating in Malaysia. The PATHLOSS permits the user to investigate the radio propagation effect due to raindrop absorption in the microwave link.

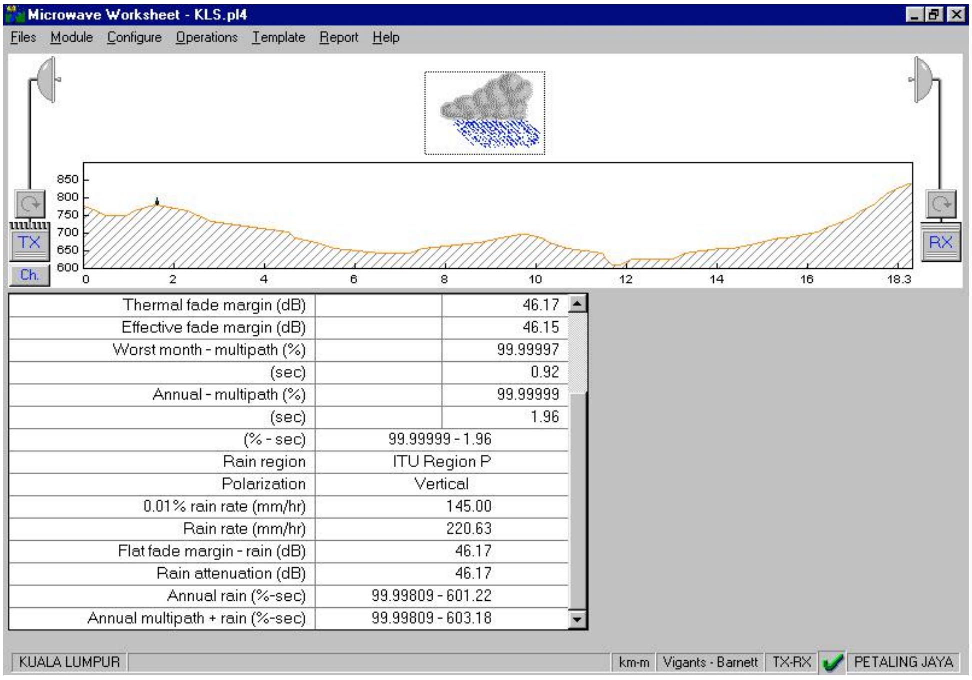

Figure 1: The PATHLOSS Sample output of the rain attenuation in the microwave link.

PATHLOSS version 4.0 from Contract Telecommunication Engineering (CTE) has organized into 10 module features and designed for 2 types of worksheets, which was Microwave and VHF-UHF worksheet. The PATHLOSS was chosen because its designed capabilities to design and investigate the analysis on the microwave link including the rain attenuation losses. Its user-friendly concept and reliable features are the prime desirable factors in selecting the software. However, due to the scope of the paper, only the effects of the rain attenuation were investigated and discussed.

The software provides two rain prediction models, which is the ITU-R 530 and Global Crane method. There are 4 rain statistics file are provided which was, Crane, Crane modified 96, ITU-R530 and Canada. The Canada rain statistics data is not applicable since the paper concentrates only on the Malaysia regions. The PATHLOSS sample output of the rain attenuation is illustrated through the Figure 1.

The Figure 1 shows the microwave worksheet from the worksheet module. Here, the worksheet deals with the outage probability due to the multi-path fading and rain attenuation. In the microwave worksheet above, the microwave transmitter dish is showed over the microwave communication link towards the microwave receiver dish. The cloud icon represents whether the rain attenuation calculation is active or inactive.

The PATHLOSS Software however, faced a number of problems. The software only gives rain attenuation results, which is based on link fade margin for the designing the communication link. Essentially, the software determines the rain rate that will take the link out of service and the probability of that rain rate. Besides this problem, the software requires various type of input parameter, which is difficult to obtain without proper agreement with those involved in the field. Although these problems were faced, the software has provided the understanding the rain attenuation effects in the designing the communication link in theory. Moreover, the effects of the propagation factor especially rain attenuation was studied through software simulation.

3. Results and Discussion

In this section, the rain attenuation prediction results are computed and analyzed. The graphs generated from various computed data results are shown together with the analysis of the results. The findings of this paper are highlighted and discussed in following paragraphs.

3.1 The ITU-R Recommendation 530 Prediction Results

The computed attenuation data of the ITU-R Recommendation 530 Prediction model are studied for the frequency ranging 4 to 400 GHz with 99.99% link availability. With the use of this ITU-R prediction model, the three RSDs that were proposed by ITU-R, Din and Ajayi are plotted as shown in Figure 2 and 3. This study is required in order to investigate which type of RSD suitable for the design of communication links operating in Malaysia.

Figure 2 shows attenuation estimation results for the vertical polarization with three different RSDs. In the vertical polarization, the generated plots show clearly that the attenuation data using the RSD proposed by Din are closer to the attenuation data computed via ITU–R ‘s RSD. However, the RSD proposed by Ajayi has estimated a much lower attenuation with respect to the Din and ITU predictions. In order to investigate the horizontal effect in the ITU-R Recommendation 530 model with the same three RSDs, the following plot was generated and illustrated through the Figure 3 below.

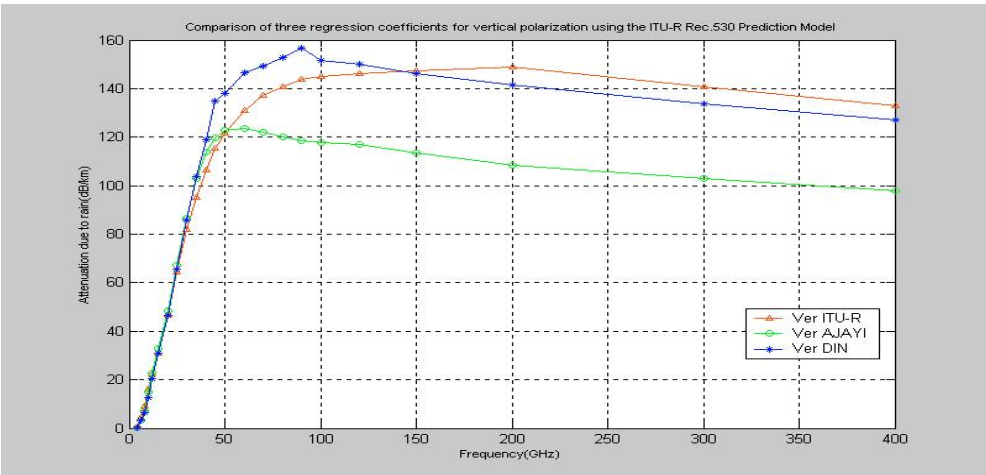

Figure 2: Comparison of three RSDs for ITU-R Recommendation 530 in the vertical polarization.

Based on the plotted Figure 3 above, it can be noted that the trend of the predicted attenuation results are similar with those shown in Figure 2, but at slightly higher attenuation values. At this point, it is obvious that all the three RSDs in the ITU-R prediction model estimates higher attenuation in the horizontal polarization compared to vertical polarization computations.

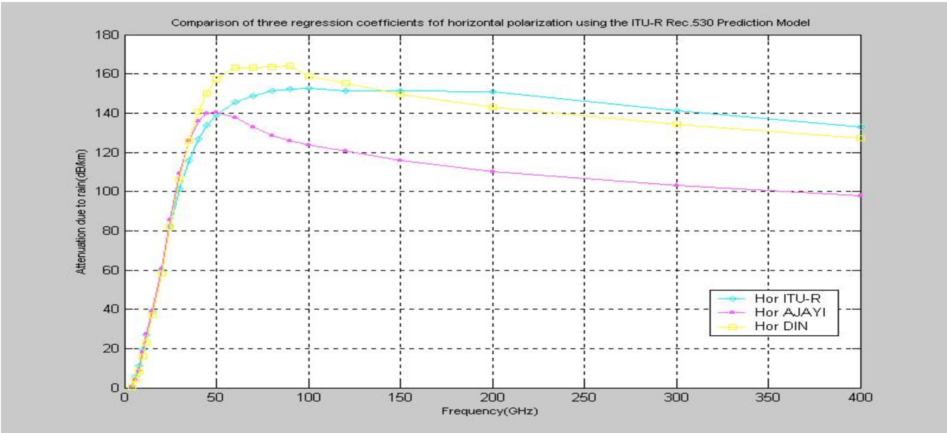

Figure 3: Comparison of three RSDs for the horizontal polarization with the use of ITU-R Rec.530 Prediction Model.

3.2 The Global Crane Prediction Results

The computed attenuation data of the Global Crane prediction model are also analyzed to study for the frequency ranging 4 to 400 GHz with 99.99% link availability. Using the three different RSDs as used in the previous section, the attenuation due to rain results are plotted as shown in Figure 4 for the vertical and Figure 5 for horizontal polarization. With the use of this Global Carne prediction model, the type of suitable RSDs will be identified for the communication links operating in Malaysia.

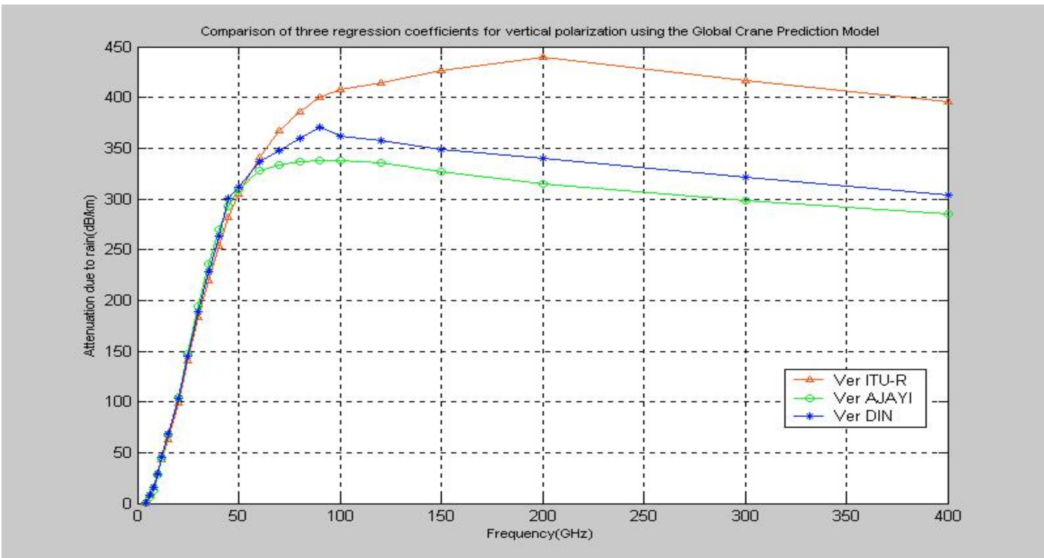

Figure 4: Comparison of three RSDs for the vertical polarization using the Global Crane Prediction Model.

Figure 4 shows attenuation due to rain prediction results for the vertical polarization with 3 different RSDs. In this prediction model, the generated plots demonstrate clearly that the attenuation data using the RSDs proposed by Din and Ajayi are almost aligned to each other with respect to attenuation result estimated from ITU-R RSDs. In other hand, the attenuation prediction results with the proposed ITU-R RSDs started to predict higher attenuation value at the frequency range of 60 GHz. For the investigation of the horizontal effect in the Global Crane model with the same three RSDs, the following plot is generated and illustrated in Figure 5 below.

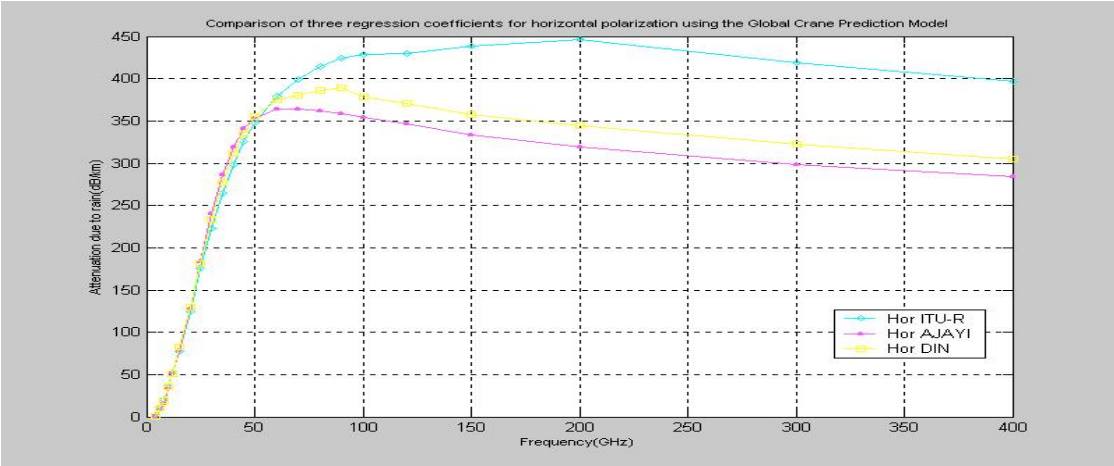

Figure 5: Comparison of three RSDs for the horizontal polarization using the Global Crane Prediction Model.

From the plotted graph above, it can be noted that the trend with this predicted attenuation results are similar with those shown in Figure 4, but at slightly higher attenuation values. Based on the two plotted figures, it is obvious that all the three RSDs in this prediction model also estimates higher attenuation in the horizontal polarization compared to vertical polarization computations.

3.3 The Comparison of Polarizations

To further understand, the differentiation of the polarization factor, an investigation is conducted on the effect of the polarization in the above mentioned prediction models. These comparisons of the polarization effect in the ITU-R prediction model are illustrated in the Figure 6.

Based on the plotted figures, it is proven that all the three RSDs in this ITU-R Recommendation 530 prediction model estimates higher attenuation levels in the horizontal polarization compared to vertical polarization predictions. This is because the horizontal polarization results in the poor resistance of the earth short circuiting the electric component of the propagate radio wave.

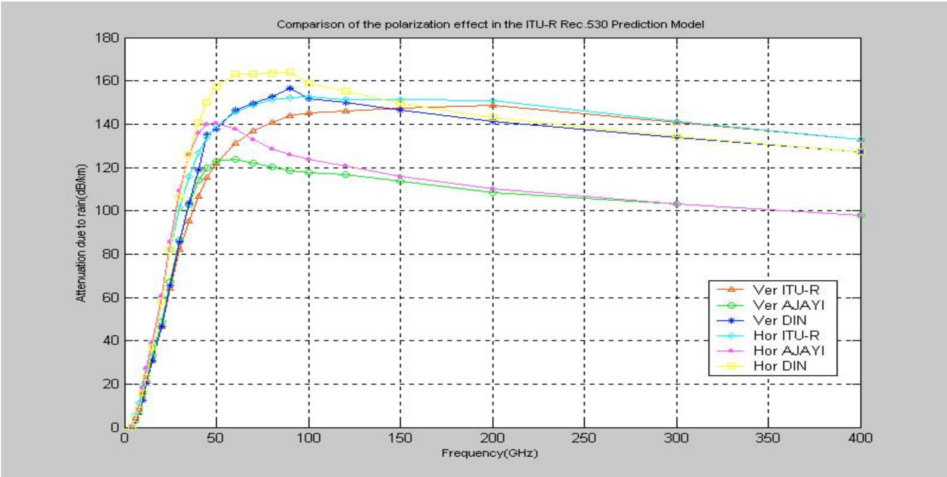

Figure 6: Comparison of the polarization effect in the ITU-R Rec.530 Prediction Model

The polarization effect is also studied in the Global Crane Prediction model as it is shown in the Figure 7.

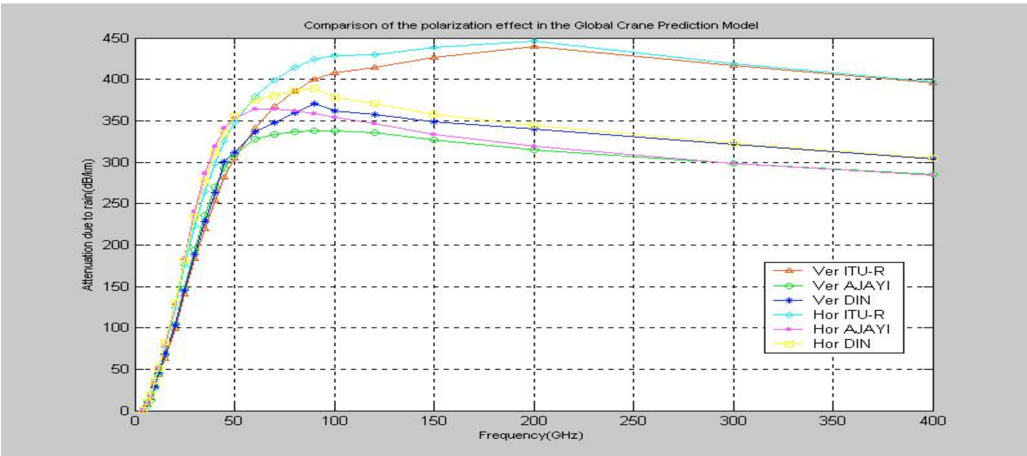

Figure 7: Comparison of the polarization effect for the Global Crane Prediction Model

As shown in the Figure 7 above, attenuation due to rain produced by the ITU's RSDs is estimated at a much higher attenuation value in the both polarization compared to those RSDs proposed by Din and Ajayi. This can be seen from the attenuation result differences of 100 dB/km at the frequency of 200GHz. The further analysis of this polarization effect in two different prediction models is explained in the following section.

3.4 Comparison of Prediction Models

After investigation on the polarization effects in one particular prediction models, the study was carried further in the analyzing of the polarization effect in two different prediction models. The results of this difference are illustrated in the following Figure 8 and 9 below.

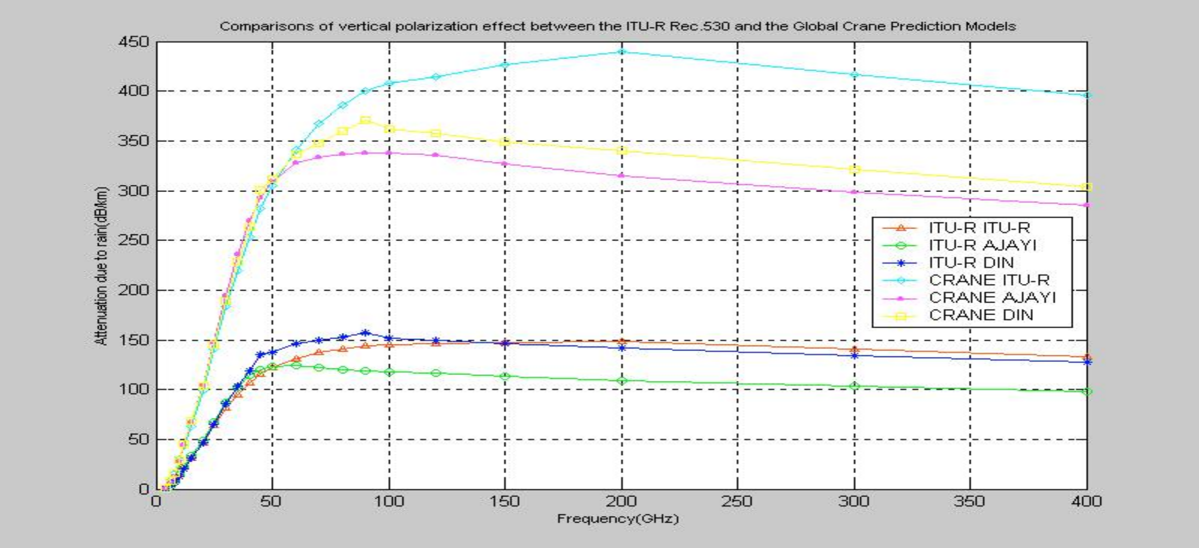

Figure 8: Comparison of the vertical polarization effect between the ITU-R Rec.530 and Global Crane Prediction Model.

From the plot above, the results clearly show that in this vertical polarization, the Global Crane Prediction model predict a much higher attenuation compared to those predicted by using ITU-R Prediction Model. This can be proven from the attenuation difference of 200 dB/km at 120 GHz for the RSDs proposed by Din .In essence, all the computation from the ITU-R prediction model indicates a much lower estimation compared to those from the Crane predictions.

In the horizontal polarization, the comparison of the prediction models is shown in Figure 5 illustrates a similar pattern but much higher attenuation values compared to those predicted in Figure 2. This can be noted from the same discussion point of the vertical polarization at 120 GHz where it estimates roughly a attenuation difference of 225 dB/km for the RSDs proposed by Din. There is a difference of an additional attenuation value of 25 dB/km from the previous discussion plot in Figure 5.

Although the two attenuation prediction models is computed based on the same propagation path length and the same RSDs, none of the prediction matches closely with each other.

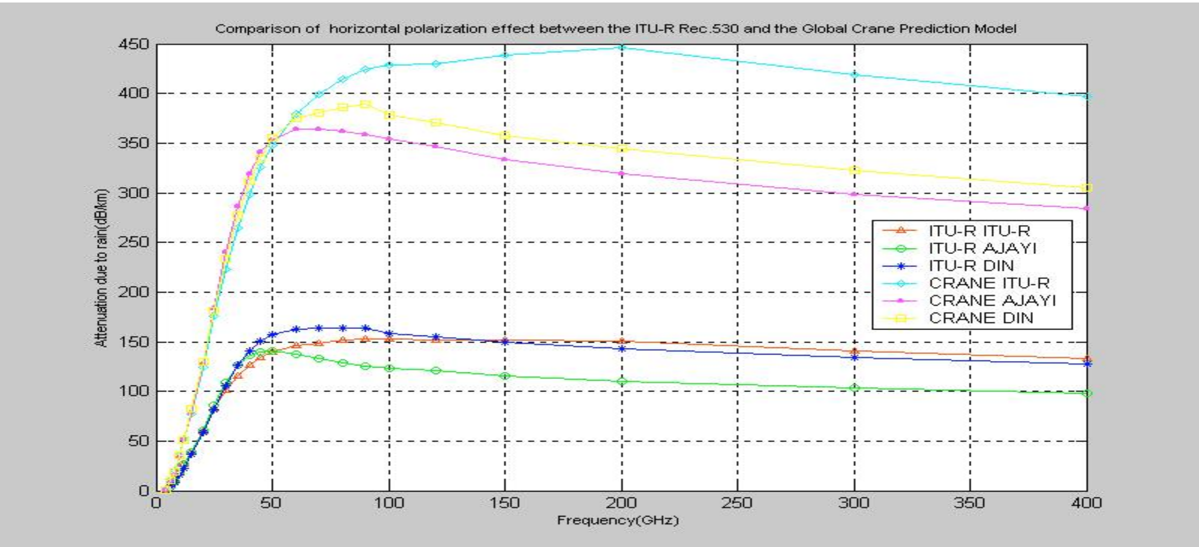

Figure 9: Comparison of horizontal polarization effect between the ITU-R Rec.530 and Global Crane Prediction Model.

The attenuation predictions using the RSDs proposed by Ajayi result in much lower predictions compared to the Din's. The attenuation predictions using ITU-R RSDs overestimate the attenuation value at microwave frequency of 60 GHz and above. As a result, the attenuation prediction using the RSDs proposed by Ajayi is suggested for the use in the designing of a communication link in Malaysia. Moreover, the horizontal polarization estimates a much higher attenuation value compared to vertical polarization. Due to this, in the designing of the reliable communication link, the vertical polarization provides a good option for engineers to consider.

In spite of these factors, the two discussed prediction models perform well in predicting the attenuation by the rain. However, the Global Crane Prediction Model has predicted a much higher estimation for the entire frequency range. This is probably because this discussed model has taken all the necessary possibilities that might occur in the attenuation estimation due to the rain. But on the other hand, the engineers propose more links to be included and thus, this will cost more money as more additional transmitters, repeaters and receivers is required. Regardless to this proposal, the ITU-R Recommendation 530 Prediction Model is preferred due to much lower prediction on attenuation due to rain with 99.99% of link availability with respect to Global Crane prediction Model. Therefore, the ITU-R Prediction Model is recommended for communication links design operating in Malaysia.

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