

## Development of software for Ku-band signal availability due to rain attenuation

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### ABSTRACT

Ku-Band signal is often used for satellite communication mainly for direct to home (DTH) broadcasting. One of the major issues using this band is that the signal will be affected by raindrops. Raindrops absorb and scatter signal that operates at a frequency of more than 10 GHz. However, studies have been done to predict and measure the rainfall rate and rain attenuation. The rain attenuation in Ku-Band range and the rain rate were measured at satellite receiving dish, pointed towards the orbital slot 91.5 E over a one-year period in 2013. The cumulative distribution of rain rate obtained as well as a cumulative distribution of rain attenuation obtained are presented and compared with the rain prediction models. The aim is to get the best model to be used for the purpose of software development. It was found out that the DAH prediction model is fairly equitable when compared to direct satellite dish receiving measurements in Malaysia. The model provided a suitable baseline in developing a user interface software for weather prediction.

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## 1. INTRODUCTION

According to Malaysian Communication and Multimedia Commission (MCMC) on the Class Assignment no. 2 of the 2015 document [1], the Ku-Band frequencies for DTH services which have been approved and allocated in Malaysia ranges from 10.7 GHz to 11.2 GHz, 11.45 GHz to 11.7 GHz and 12.2 GHz to 12.75 GHz. Ku-Band Frequency is widely used for DTH broadcasting due to its short wavelength, which only requires a small dish receiving device. However, the Ku-Band frequencies are easily affected by rain. When Ku-Band wave passes through the atmosphere and encounter water droplets, the signals are attenuated. This attenuation is exaggerated when the droplet "hit" the wave, that is, when half of the signal wavelength is in the droplet's diameter. As a result, losses occur in the Ku-Band link [2].

There are a lot of studies and research regarding this issue. Nevertheless, none of the findings are extended to an interface that can interact with user in GUI form, also better known as software. By having software, it can help user to predict the weather that may cause an interruption of the signal. In designing of the software for rain attenuation, several factors, principally related to the weather data must be put into consideration. These factors include wind, clouds, rain precipitation and humidity. All of these factors must be considered in the software as they are the causes of signal loss for DTH broadcasting system with rain precipitation being the most crucial factor, especially at frequencies above 10 GHz [2]-[6]. Amongst the

factors mentioned earlier, rain precipitation / rainfall is more severe in Malaysia (tropical region) which is characterized by heavy rain precipitation intensity and large raindrops.

Rainfall rate indicators specified on a percent of time basis, that is the percent of time in a year or a month that the rain rate equals or exceeds a specific value is used in the rain attenuation prediction model [7], [8]. The raindrop size distribution is different according to geographical location and it can strongly impact rain specific attenuation and, therefore, total rain attenuation [9]. Since majority of the studies on rain attenuation have been conducted in Europe, it may not be sufficiently accurate to characterize the effects of attenuation on Malaysia and there is no implementation of the findings to proceed as an application for a user. Under such circumstances, an evaluation of the predictive accuracy of these models is required for designing a reliable weather forecast data.

The gist of software development is its Metadata. The Metadata is where all of the information is placed. The metadata for weather are retrieved from NOAA (National Oceanic and Atmospheric Administration) server and from MMD (Malaysia Meteorological Department). The platform for the software development is built under Linux operating system (OS). Linux is known as the most stable operating system beside Macintosh. The main difference between Linux OS, compared to others is that it requires an expert in shell command to run or use this OS. Since most of the application of Linux uses the shell command, its Random Access Memory (RAM) processing is greater than others.

Another great thing about Linux OS is its software. The Linux introduced a software center hub, where users can download the software without searching through the web and most of the software provided by Linux are free of charge. The foundation of the software development is using the Software Development Kit (SDK). The SDK that runs under Linux is called Qt. Qt is an open source software that can provide an object oriented programming using C++ language. The purpose of this project is to identify the best model and develop software that can display the weather data as for a prediction and measurement for Ku-Band rain attenuation.

**2. METHODOLOGY**

**2.1. Rainfall Rate Model**

There are many types of models to measure the rainfall rate. The selected rainfall rate model below is based on a well-known model in tropical region.

**2.1.1. ITU-R**

The ITU-R models the world into 15 different parts. The judgement made for this is based on best mean cumulative distribution experimental [10]. Percentage of rainfall rate exceeded for Malaysia is shown in Table 1.

Table 1. Annual cumulative rain rate distribution for region P

Percentage of time, %	0.3	0.1	0.01	0.001
Rainfall rate exceeded, mm/hr	16.5	41.6	120	200

\*Region P = Tropical Region according to ITU-R model (Malaysia, Indonesia and etc)

**2.1.2. VIHT (Variable Isotherm Height Technique)**

The VITH model divides the world into 8 different regions of rainfall rate [11]. The model is based on number of thunderstorm days published by Landsberg and total rain accumulation [12]. The divided boundaries were adjusted to accommodate variations in terrain, predominant storm type and motion, overall atmospheric circulation and latitude as shown in Table 2.

Table 2. Annual cumulative rain rate distribution for region H

Percentage of time, %	0.3	0.1	0.01	0.001
Rainfall rate exceeded, mm/hr	31	51	147	251

## 2.2. Rain Attenuation Model

### 2.2.1. ITU

The model was widely accepted internationally for the prediction of the rain attenuation [13]. Due to that, most developed models are compared against it for a reference point. Nevertheless, recent researches have shown that the model suits certain geographical location only.

### 2.2.2. DAH

The word DAH stands for the names of the researchers, Dissanayake, Jeremy Allnutt and Fatim Haidra. The model is also known as the USA model because it was developed in the USA. This prediction model is more or less similar to ITU-R model where the rain related input to the model is the rain intensity at the 0.01% [14]. Inhomogeneity in the rain in the horizontal and vertical directions is accounted for in the prediction. The method is applicable across the frequency range 4~35 GHz and percentage probability range from 0.001% to 10% [3].

## 2.3. Measurement

### 2.3.1. Measurement set-up

Receiver sites are located at several locations in Malaysia. Major cities were selected for this set-up. The locations are shown in Table 3.

Table 3. Receiver sites location

No.	Location	Latitude/ longitude
1	Kuantan	3.8167°N/103.3333°E
2	Alor Setar	6.1167°N/100.3667°E
3	Kuala Lumpur	3.1333°N/101.6833°E
4	Kuching	1.5600°N/110.3450°E
5	Penang	5.4000°N/100.2333°E
6	Tawau	4.2583°N/117.8944°E
7	Sandakan	5.8333°N/118.1167°E
8	Kota Kinabalu	5.9714°N/116.0953°E
9	Kota Baharu	6.1333°N/102.2500°E
10	Kuala Terengganu	5.3333°N/103.1500°E
11	Melaka	2.2000°N/102.2500°E

The receiver has a diameter of 80 cm. The receiver antenna is pointed towards 91.5 E orbital slots. The beacon frequencies start from 10.95 GHz to 12.75 GHz and are vertically polarized. The tipping bucket rain gauge with 0.5mm capacity and 1 minute integration of time is placed near the antenna location. Arrangement of the setup is shown in Figure 1.

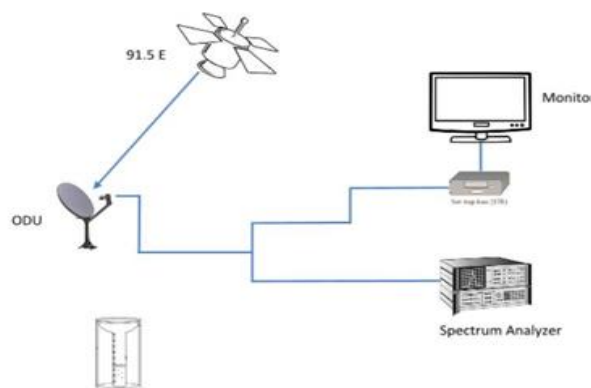


Figure 1. Measurement set-up

### 2.3.2. Software Development

Figure 2 shows the block diagram of the software architecture, interface with the data source. The metadata is gathered from NOAA and MMD. The NOAA provided the metadata in the form of GRIB file.

GRIB is short for General Regularly-distributed Information in Binary form. It is a concise data format used in meteorology to store historical and forecasted weather data. It is standardized by the World Meteorological Organization's Commission for Basic Systems. Weather forecast information is retrieved from their server and displayed in the Graphical User Interface (GUI). The GUI is based on the Geographical Interface System (GIS) for determination of the location in terms of latitude and longitude. The GIS is a system designed to store, capture, analyze, manipulate and present all types of spatial or geographical data. Information provided by GIS includes latitude and longitude, ground above mean sea level, land height and etc. Furthermore, data from MMD such as radar and satellite images are also displayed in this software. The information displayed in the GUI is as Wind, Pressure, Temperature, Cloud Cover, Rainfall and Population.

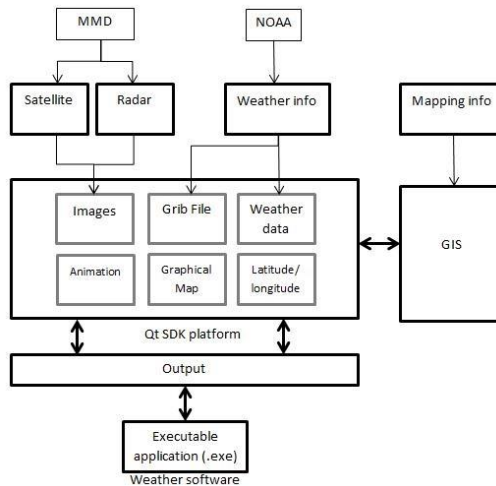


Figure 2. Software architecture

The software development starts after identifying the best prediction model. The best prediction model chosen is used only as a guideline in designing the software architecture. All input is gathered for data processing by the software. The end result of the software is to ensure output data are displayed correctly in the interface without any error. Overall flow chart of the software development is shown in Figure 3.

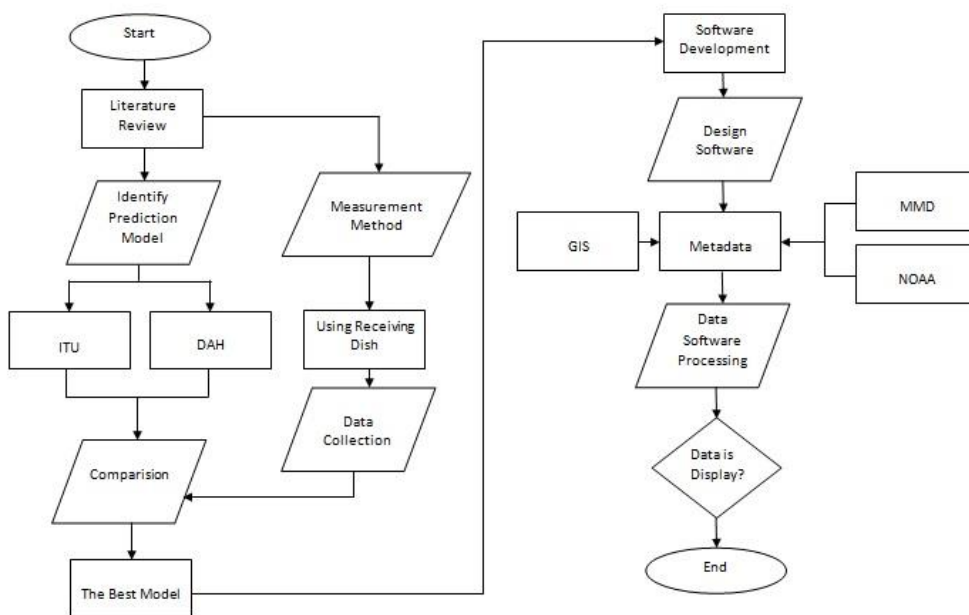


Figure 3. Flow Chart of Software Development

### 3. RESULTS AND ANALYSIS

#### 3.1. Rain Attenuation Measurement Result

Table 4 shows the result of the measurement setup in terms of attenuation (dB).

No.	City	Rain Attenuation (dB)		
		0.1%	0.01%	0.001%
1	Kuantan	13.9	25.9	55.7
2	Alor Setar	11.9	26.6	42.2
3	Kuala Lumpur	13.5	27.5	57.3
4	Kuching	14.8	34.3	50
5	Penang	13.7	23.5	46
6	Tawau	14.6	28.6	50
7	Sandakan	15.8	28	51
8	Kota Kinabalu	13.8	28.2	52.4
9	Kota Baharu	13.3	24.3	58
10	Kuala Terengganu	12.9	32.4	48.3
11	Melaka	13.8	27.8	43

Figure 4 (a) and (b) compares proposed measurement rain rate and attenuation features based on the measured data with the estimated rain rate and attenuation values using the prediction models.

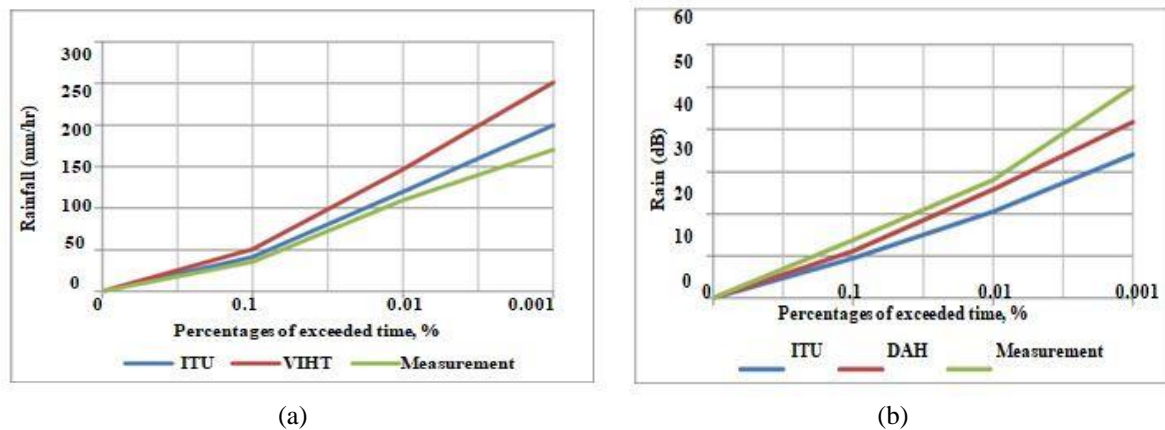


Figure 4. (a) Comparison Result for Rainfall Rate (b) Comparison Result for Rain Attenuation

From Figure 4(a), the ITU model estimation data are fairly similar to the measured rainfall rate throughout the entire percentage of time compared to the VIHT model, which overestimates the measured rainfall rate values. This is because the VIHT model lacks real rainfall rate data from Malaysia or from any tropical region. The development of the ITU model, however, was done using large amount of rainfall data gathered from this region [15]. Figure 4(b) shows that only the ITU the model overestimates the measured rain attenuation throughout the entire measurement time, whereas the DAH model follows closely to the measured rainfall attenuation data until 0.01% of time before the model starts to underestimate. The ITU rain attenuation calculation is based on the constant parameter of rain droplets. Rain droplet usually varies according to geographic area of the places. ITU model is among the pioneer models in the world, however, and it is more focused on the European region. Calculation of rain attenuation in DAH model is more precise compared to ITU model since DAH model considers the additional loss of polarizations. It shows that ITU rainfall rate and DAH rain attenuation model are the most suitable model to be used as a guideline in the software development.

#### 3.2. Software Development Result

From the findings, it is concluded that the ITU rainfall rate and DAH rain attenuation models are the best models to apply in Malaysia. As such, these models will be the guideline for the development of this weather software. Figure 5 shows the screen shot of the software interface.

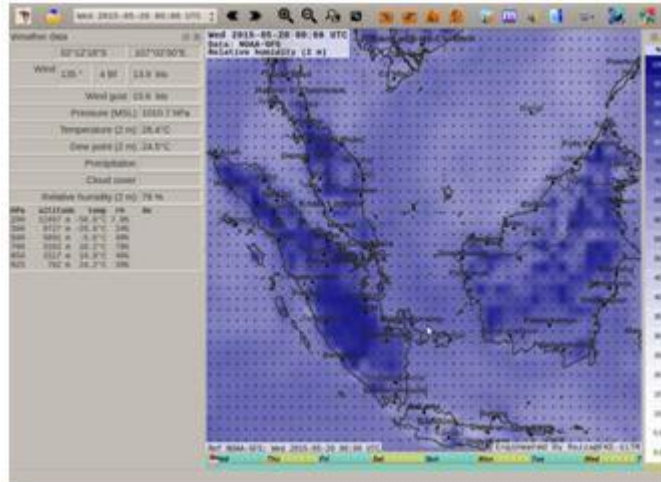
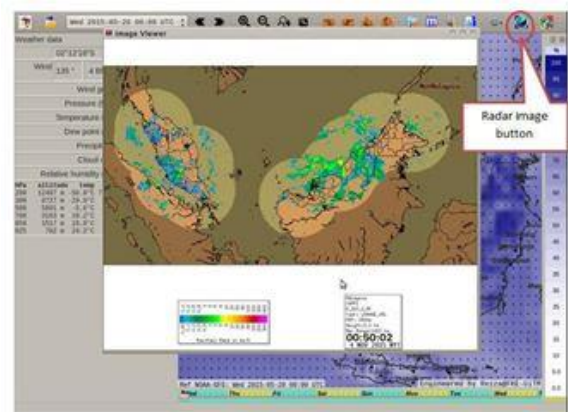


Figure 5. Weather Software Interface

The Figure 5 shows the layout of the weather software in Malaysia region. The colour tone from white to dark blue on the right hand side of the software shows the parameter of rainfall rate reading. It indicates the area for participation of rain. The software also displays other weather parameters as well. This metadata is obtained from the NOAA database. These functions run perfectly on the software. The satellite and radar images of Malaysia are successfully displayed in the software as shown in Figure 6(a) and (b).



(a)



(b)

Figure 6. (a) Satellite image from MMD and (b) Radar image from MMD

Data input from MMD is also important. The functions of the images are described as follows:

1. Malaysia Satellite Image - Satellite captures an image of Malaysia every hour. The latest image will be displayed when the satellite image icon is selected. The image shows the movement of clouds in Malaysia.
2. Malaysia Radar Image - A new image is updated every 20 minutes. The image displays the rainfall rate in mm/hr across peninsular and east of Malaysia.

**4. CONCLUSION**

Rain effect is still a major issue for Ku-Band frequencies. Even though there is a model that can predict the losses, but signal attenuation remains high and it will not assist a lot in satellite link planning. The measurement of rain attenuation and rainfall rate is used to compare the accuracy of ITU, VIHT and DAH prediction models. Overall, the ITU rainfall rate and attenuation model gave a good prediction and the VIHT

model was found to be not suitable for prediction at tropical and equatorial climates. Nonetheless, the development of this weather software will help a lot in providing real time data of the rain and advance action can be taken due to this. In summary, this project development is successful with functional software that can interact with the weather data.

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