# Analysis of Rain Attenuation Effects on The Communication System Quality of The Merah Putih Satellite VSAT IP Services Using C-Band and Extended C-Band Frequencies on The Bogor-Sorong Communication Link

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**A B S T R A C T**

The objective of this research is to analyze the impact of rain attenuation on the quality of the Merah Putih satellite communication system on VSAT IP services at C-Band and Extended C-Band frequencies on the Bogor-Sorong communication link. The objective is to analyze the impact of precipitation intensity on rain attenuation by comparing the Crane Global Model and the ITU-R P.618-14 Model. The aim is to identify the most suitable rain attenuation model based on the outcomes of the link budget. The result indicates that an increase in rain intensity and frequency produces a proportional rise in rain attenuation and vice versa. The ITU-R P.618-14 model is the most appropriate for this research, creating a more optimal link budget value. This is indicated by the C/N total parameter value for the C-Band frequency, which is 15.605415 dB, and for the Extended C-Band frequency, which is 15.655086 dB. The Eb/No parameter value for the C-Band frequency is 10.58852 dB, while the Extended C-Band frequency is 10.63819 dB. Moreover, the ITU-R P.618-14 Model yields a comparatively lower BER parameter value, which is $2.1849\times10^{-6}$ for the C-Band frequency and $2.0742\times10^{-6}$ for the Extended C-Band frequency.

## 1. Introduction

Rainfall intensity represents a primary factor impacting the amount of rain attenuation in the propagation of wireless communication systems, including satellite communication systems such as VSAT IP. Rain attenuation is defined as a condition whereby raindrops cause the absorption and scattering of electromagnetic waves, reducing the signal power of the communication system. Rain attenuation can be known mathematically by using rain attenuation prediction modeling. The efficacy of diverse rain attenuation prediction models has been the subject of extensive research. The previous research presented an analysis of the impact of rain attenuation on Ku-Band frequency in VSAT systems, with Telkom 3S as the utilized satellite. This research compares two models for predicting rain attenuation: ITU-R P.618-5 and the Simple Attenuation Model (SAM). The previous study was limited in scope, focusing only on the Ku-Band frequency. This limitation is because other frequencies, such as C-Band and Extended C-Band, are also used in satellite communication systems. Therefore, further research is needed to analyze the effect of rain attenuation on the quality of satellite communication systems at these frequencies on rainfall data limited to 2023 obtained from BMKG. In this research, two types of rain attenuation modeling are analyzed to identify the most suitable: Crane Global Model (CGM) modeling and ITU-R P.618-14 modeling. Both models have different characteristics, and the use of both aims to determine the effect of rain intensity on rain attenuation and to compare the suitability of using the Crane Global Model and ITU-R P.618-14 modeling for this research.

## 2. Literature review

Previous research (Sabrina et al., 2021) examined the calculation of rain attenuation value predictions in Lhoksumawe City using several models, including ITU-R P. 618-5, Simple Attenuation Model (SAM), and ITU-R Modification. This research found that each rain attenuation model used has a different attenuation value because it is influenced by rainfall, parameter values, and the use of coefficients in this research, whose values are based on the frequency and type of polarization. Based on the calculation results, the ITU-R P.168-5 modeling produces the lowest rain attenuation value. This research concluded that the higher the rainfall intensity and frequency, the higher the rain attenuation value.

Rain attenuation research (Setyawati, 2023) uses several modeling techniques, including ITU-R P.618-5, Global Crane, SAM, and ITU-R Modified. The objective of this research is to analyze and predict rain attenuation. The rainfall data used in this research was collected from November 2022 to February 2023 and obtained from the BMKG Mopah Merauke Meteorological Station and the Kemayoran Meteorological Station. The results of this research indicate that the ITU-R Modification modeling is the most effective approach for representing rain attenuation.

Another research (Ma'ruf, 2021) is concerned with the impact of VSAT antenna diameter and rain attenuation on the performance of Ku-Band and C-Band frequencies in VSAT services. The rain attenuation modeling used is the ITU-R P.618-5. In this research, the performance of VSAT services is based on the Eb/No parameter value. The result is that a VSAT antenna diameter of 1 meter is the most effective antenna size at both Ku-Band and C-Band frequencies. The results of the rain attenuation prediction calculations in this research show that rain attenuation significantly affects communication networks operating at Ku-Band frequencies. This is indicated by the attenuation value produced at the highest rainfall intensity of 145 mm/h, which is approximately 35.37 dB. Conversely, communication with C-Band frequencies is not significantly affected. The resulting attenuation value under the same rainfall conditions is only approximately 2.25 dB.

In this research (Annisahajar, 2020), rain attenuation was calculated using two models, the ITU-R P.618-5 and the Simple Attenuation Model (SAM). The two models were analyzed to identify the most suitable for this research. The link budget is calculated to achieve optimal conditions for each rain attenuation modeling application, taking into account the BER value by the standard. This research shows that SAM modeling is the most suitable for this research, as it produces optimal signal parameter values compared to the ITU-R P.618-5 model. In SAM modeling, the C/N value is 13.789 dB, the Eb/No value is 11.570 dB, and the BER is $7.994 \times 10^{-7}$.

In addition, (Nurdiansyah & Mauludiyanto, 2017) researched the effect of rain attenuation on C-band and Ku-band frequencies on VSAT TV communications in the Surabaya area. Rain attenuation calculations use several models, including ITU-R P.618-5, Global Crane, Simple Attenuation Model (SAM), and ITU-R Modification. The appropriate rain attenuation model is used based on the calculation of the percentage error of each model used. Based on this research, the rain attenuation modeling that is suitable for C-band frequencies is the Crane Global Model. Meanwhile, for Ku-band frequencies, the ITU-R Modification.

In this research (Igwe et al., 2019), five models of rain attenuation are analyzed, including the Simple Attenuation Model (SAM), the Svjatogor Model, the Gracia-Lopez Model, the Bryant Attenuation Model, and the ITU-R P.618-9 Model. The findings of this research indicate that the ITU-R P.618-9, Gracia-Lopez, and Bryant Attenuation Model have the most optimal performance for the North Central Nigeria region. Attenuation due to rain is calculated to be between 14 dB and 16 dB at an elevation angle of 55°, between 15 dB and 16 dB at an elevation angle of 42.5°, and between 20 dB and 22 dB at an elevation angle of 23° for Ku-Band frequencies. At Ka-Band frequencies, the rain attenuation varies between 33 dB and 37 dB when the elevation angle is 55°, between 33 dB and 37 dB when the elevation angle is 42.5°, and between 42 dB and 48 dB when the elevation angle is 23°.

This research (Ikhmal et al., 2021) evaluates ten rain attenuation prediction models for satellite communications in Malaysia at C-Band, Ku-Band, and Ka-Band frequencies. The ten rain attenuation prediction models include ITU-R, Ramachandran, Yeo, DAH, Yamada, SAM, Bryant, Crane Global, Brazil, and Garcia Lopez. For C- Band, the Yamada and Garcia Lopez models show good prediction performance. Meanwhile, the Crane Global, SAM, and Ramachandran models performed best in the Ku-Band. The SAM and Ramachandran models also show good predictions in Ka-Band.

This research (Yussuff & Akinboyewa, 2021) analyzes the effectiveness of several rain attenuation prediction models at 17 GHz and 45 GHz frequencies for terrestrial communications on Lagos Island, Nigeria. The four main models tested are ITU-R P.530-17, Da Silva Mello, Crane Global, and Moupfouma. The results show that the ITU-R P.530-17 model produces predicted values closest to the actual measurement data, followed by the Crane Global model. The Moupfouma model has the worst performance at 17 GHz, while the Da Silva Mello model has the worst performance at 45 GHz.

### *2.1 Rain Attenuation Model*

Rain attenuation is a concern in satellite communications. It causes significant signal attenuation (Delfina Abdurrahman et al., 2020). Rain attenuation models predict the amount of rain attenuation a communication signal will receive when passing through rain. This research uses two rain attenuation models, the Crane Global Model and ITU-R P.618-14, to analyze the effect of rain attenuation on the quality of satellite communication systems. Both rain attenuation models used in this research will be analyzed to identify the most suitable model based on the values of the C/N, Eb/No, and BER parameters.

#### *2.1.1 Crane Global Model*

The Crane Global Rain Attenuation Model is one of the models used to predict the rain attenuation of radio signals at microwave frequencies. R. K. Crane developed the model. This modeling uses geophysical data to determine the rain intensity at a point, the change in rain intensity along the signal path, and how altitude affects the attenuation of the signal by rain at a location. The model can also estimate differences in calculations from year to year and from site to site. (Louis J. and Ippolito Jr., 2008). The following equation can be used to obtain the value of rain attenuation (Ha, 2003).

For $0 < D \leq d$

$$A(p) = \frac{a\,R(p)^b}{D}\left[\frac{e^{ubD}-1}{ub}\right] \quad \text{......1)}$$

For $d < D \leq 22{,}5$ km

$$A(p) = \frac{a\,R(p)^b}{D}\left[\frac{e^{ubD}-1}{ub} - \frac{X^b e^{vbd}}{vb} + \frac{X^b e^{vbD}}{vb}\right] \quad \text{......2)}$$

For D > 22,5 km, calculate A(p) with D = 22,5 km, and the rain rate R'(p) at the probability value

$$p' = \left(\frac{22{,}5}{D}\right)p \quad \text{......3)}$$

Where,

Ap = Rain Attenuation (dB)
Rp = Rain Intensity (mm/h)
D = Surface Project Length (km)
$a$, b = Spesific Attenuation Coefficients
x, v, d, u = Empirical Constants

### *2.1.2 ITU-R P.618-14*

The ITU-R P.618-14 Rain Attenuation Model is used to predict the rain-attenuation of radio signals at microwave frequency attenuation. The model was first approved by the ITU in 1982 and is continually updated as rain attenuation models are better understood and additional information becomes available from various global sources. Since 1999, the ITU-R model has been based on the DAH rain attenuation model, named after Dissanayake, Allnutt, and Haidara. (Louis J. and Ippolito Jr., 2008). This model was developed by the International Telecommunication Union (ITU). The following equation can be used to obtain the value of rain (ITU-R RECOMMENDATION P.618-14, 2023).

$$A = \gamma_R L_E \quad \text{......4)}$$

Where,
A = Rain Attenuation (dB)
$\gamma_R$ = Spesific Rain Attenuation (dB/km)
$L_E$ = Effective Path Length (km)

## *2.2 Link Budget Calculation*

The link budget calculation in this research uses two methods: the manual calculation using mathematical equations and the calculation using SatMaster Pro software. This is to determine the accuracy of the calculations obtained from manual calculations by comparing them with the results of calculations using SatMaster Pro software. In this research, selecting the appropriate rain attenuation model is based on good communication signal quality, where the parameters that can be used to evaluate the signal quality include C/N, Eb/No, and BER.

There are several equations used in link budget calculations that determine the overall performance of the satellite communications system:

## *2.3 Carrier to noise power ratio (C/N)*

The carrier-to-noise power ratio (C/N) is the ratio of the carrier signal power to the received noise power. In satellite communication systems, there are three types of C/N, which are C/N uplink, C/N downlink, and C/N total (Larasati, 2021).

*a. C/N uplink*

C/N uplink is a calculation to find the C/N value on the transmission path from the direction of the ground station, which has the function of a signal transmitter, to the satellite, which has the function of a signal receiver (Bloom & Reenen, 2007).

$$\left[\frac{C}{N_o}\right]_U = [EIRP]_U - [Losses]_U + \left[\frac{G}{T}\right]_U - [k] - [B] \quad \text{......5)}$$

*b. C/N downlink*

C/N downlink is a calculation to find the C/N value on the transmission path from the direction of the ground station, which has the function of a signal receiver, to the satellite, which has the function of a signal transmitter (Maini & Agrawal, 2011).

$$\left[\frac{C}{N_o}\right]_D = [EIRP]_D - [Losses]_D + \left[\frac{G}{T}\right]_D - [k] - [B] \quad \text{......6)}$$

*c. C/N total*

C/N total is a calculation to find the C/N value on the uplink and downlink transmission path. The C/N total value is obtained by summing the C/N uplink and the C/N downlink values (Roddy, 2006).

$$\left[\frac{C}{N}\right] = \left[\left(\frac{C}{N}\right)_U^{-1} + \left(\frac{C}{N}\right)_D^{-1}\right]^{-1} \quad \text{.......7)}$$

Where,
C/N = Carrier to Noise (dB-Hz)
EIRP = Effective Isotropic Radiated Power (dBW)
G/T = Gain to Temperature (dB/°K)
Losses = Attenuation Total (dB)
k = Boltzmann's Constant (-228,6 dBW/K/Hz)
B = Noise Bandwidth (dB/Hz)

2.4 Energy Bit to The Noise Power Density (Eb/No)

Eb/No is an essential parameter in digital communication systems that evaluate and compare system performance. Eb refers to the energy per bit of information, while No (N-zero) is the noise level within one Hz of the frequency bandwidth (Meutia et al., 2022). Basically, Eb/No is the ratio of signal energy per bit to noise (Aprian et al., 2019). The equation to calculate the Eb/No value is as follows (Penttinen, 2015).

$$\frac{E_b}{N_o} = \frac{C}{N} + 10\ log\,\frac{BW_{occ}}{R_b} \quad \text{.......8)}$$

Where
Eb/No = Energy Bit to The Noise Power Density (dB)
C/N = Carrier to Noise (dB)
$BW_{occ}$ = Bandwidth Occupied (Hz)
$R_b$ = Data Rate (bps)

*2.5 Bit Error Rate (BER)*

BER is the ratio of bit errors, or bits with errors, to the total number of bits received in a transmission (Setiadi et al., 2021). The lower the BER value, the better the communication link quality. BER indicates how often data must be retransmitted due to errors that occur (Aldha Rasjman Sayoga et al., 2021). The equation to calculate the BER value is as follows (Louis J. and Ippolito Jr., 2008).

$$BER = \frac{e^{-\left(\frac{E_b}{N_o}\right)}}{\sqrt{4\pi\left(\frac{E_b}{N_o}\right)}} \quad \text{.......9)}$$

Where,
BER = Bit Error Rate
Eb/No = Energy bit to the noise power density (dB)

*2.6 SatMaster Pro*

The SatMaster Pro software calculates the link budget for uplink and downlink communication. In this research, the results of the link budget calculation using the SatMaster Pro software are compared with the manual link budget calculation using mathematical equations. The parameter data in the input command uses data obtained from the Satellite Master Control of PT Telkom Satellite Indonesia in Bogor.

## 3. Method

### *3.1 Research Process*

Several steps in the research process must be completed in sequences to achieve the desired results. The following flowchart illustrates the sequence of steps in the research process.

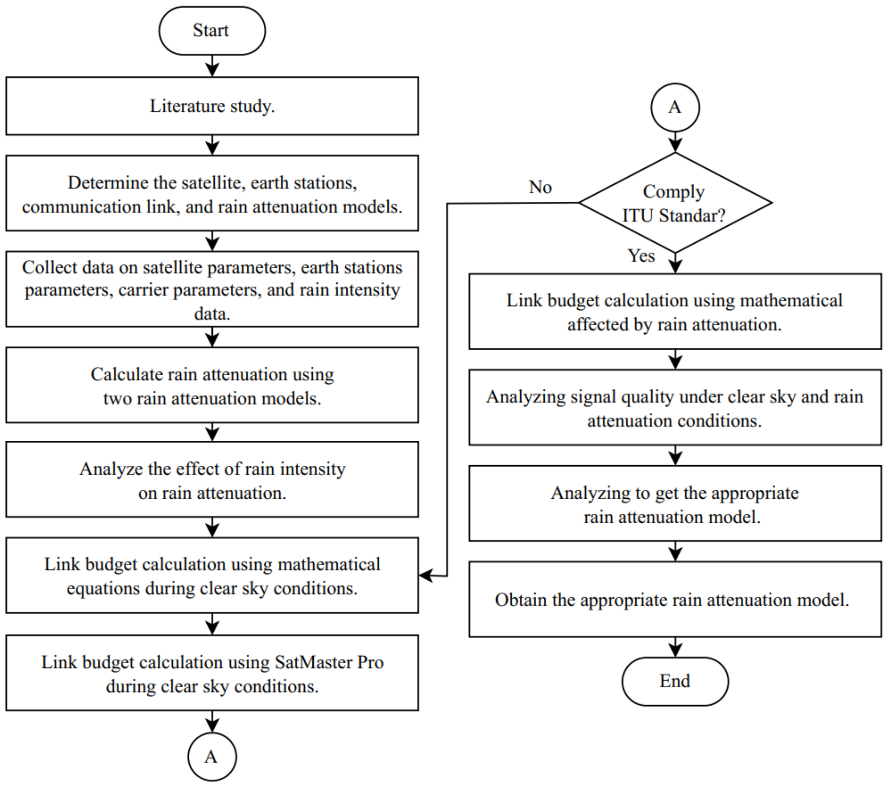


Figure 1. Research Process

### *3.2 Data*

Several data related to the research are required, including satellite communication system parameter data and rain intensity data. The required parameter data include Merah Putih satellite and carrier parameter data, sending ground station parameter data, and receiving ground station parameter data. Then, the required rain intensity data are collected from the rain intensity data in Bogor City and Sorong City. Satellite communication system parameter data was obtained from the Satellite Master Control of PT Telkom Satellite Indonesia in Bogor. The rain intensity data were obtained from the Meteorology Climatology and Geophysics Agency of Bogor City and Sorong City. These parameter data are used to calculate the link budget and identify factors affecting the quality of satellite communications.

#### *3.2.1 Merah Putih Satellite*

The Merah Putih Satellite is a communication satellite in geostationary orbit, launched on August 7, 2018, with an estimated operational functionality of over 15 years. The Merah Putih Satellite has 60 active transponders distributed between two frequency bands. The C-Band frequency band comprises 24 transponders, while the Extended C-Band frequency band comprises 12 transponders. The satellite operates at 108° east longitude (*Satellite Details - Telkom 4 (Merah Putih)*, 2018).

### 3.2.2 Carrier

The Bogor - Sorong communication link parameter data used in this research was obtained from PT Telkom Satellite. The carrier parameter data on the Bogor - Sorong communication link in this research describes the characteristics of the carrier signal sent from the sending earth station, which are the Bogor earth station, to the receiving earth station, which are the Sorong earth station. The parameter data is used for link budget calculations to determine the quality of the carrier signal and its capacity.

### 3.2.3 Sending Ground Station

The sending ground station used in this research is a ground station owned by PT Telekomunikasi Indonesia, located in Bogor, West Java. The coordinates of the sending ground station in this research are located at 106,46° east longitude and 6,32° south latitude with this data in Table 1( PT. Telkom Satelite-Data Parameter Satelite Merah Putih, 2024).

Table 1. Bogor C-Band Earth Station Parameter

| Parameter | Value | Unit |
|---|---|---|
| Location | Bogor Indonesia | - |
| Longitude | 106,46BT | Degrees |
| Latitude | 6,32LS | Degrees |
| Altitude | 173 | Meter |
| Polarization | Horizontal | - |
| Overall Availability | 99,8 | % |
| Diameter Antenna | 10 | Meter |
| Efficiency Antenna (Gain) | 60 | % or dBi |

### 3.2.4 Receiving Ground Station

The receiving ground station used in this research is located in Sorong, West Papua. The coordinates of the sending ground station are located at 131,16° east longitude and 0,52° south latitude, with this data in Table 2 (PT. Telkom Satelite-Data Parameter Satelite Merah Putih, 2024).

Table 2. Sorong C-Band Earth Station Parameter

| Parameter | Value | Unit |
|---|---|---|
| Location | Sorong Indonesia | - |
| Longitude | 131,16BT | Degrees |
| Latitude | 0,52LS | Degrees |
| Altitude | 5 | Meter |
| Polarization | Vertical | - |
| Overall Availability | 99,8 | % |
| Diameter Antenna | 1,8 | Meter |
| Efisiensi Antenna (Gain) | 65 | % or dBi |

### *3.2.5 Rain Intensity*

Rain intensity data is obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) in Bogor City and Sorong City. The rain intensity data used in this research is in Bogor City as the uplink direction and Sorong City as the downlink side. The rain intensity data used in this research is monthly rain intensity data for one year in 2023.

## 4. Result and Discussion

### *4.1 Analysis of Rain Attenuation Model*

The rain attenuation model analysis is carried out by comparing the rain attenuation results of the two modeling models used: the Crane Global Model and ITU-R P.618-14. Analyzing the rain attenuation model evaluates the parameters affecting the value. Based on the rain attenuation results obtained, the greater the rain intensity and the higher the frequency used, the greater the rain attenuation value produced

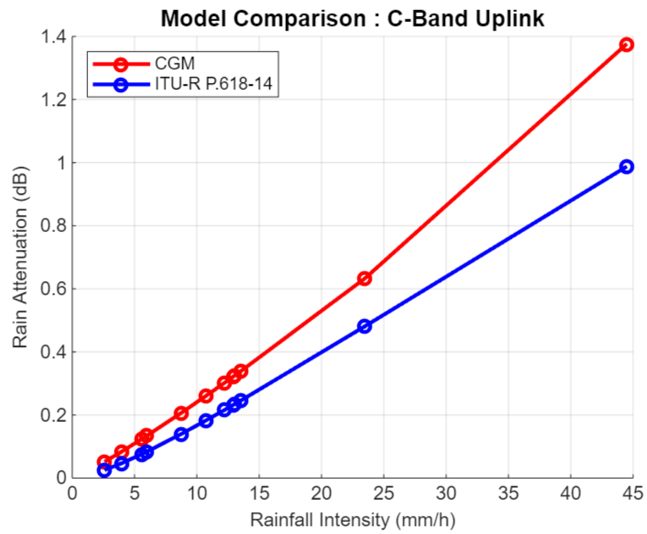


Figure 2. Model Comparison C-Band Uplink

Figure 2 shows that the two rain attenuation models used produce different attenuation values. The rain attenuation value obtained using the Crane Global Model is higher than the ITU-R P.618-14 Model. The difference is that each rain attenuation model has steps and equations that affect the value of each parameter. The difference between the two rain attenuation models from January to September and December is relatively low, but there is a significant increase in the difference in November. November has the highest rainfall intensity, with a rainfall intensity value of 44.5 mm/hour, resulting in a rainfall attenuation value of 0.989 dB. Conversely, in September, the rainfall intensity value is 2.59166 mm/hour, resulting in a rainfall attenuation value of 0.025 dB. Rain attenuation in November using Crane Global Model on uplink direction communication with C-Band frequency, the rain attenuation value is 1.377 dB. Conversely, September, with a rain intensity value of 2.59166 mm/h, produces a rain attenuation value of 0.052 dB

This is because the Crane Global Model is heavily influenced by the specific attenuation parameter, where there are two categories in determining its value, which are based on rain intensity. In November, included in the category with rain intensity > 30 mm/h, the specific attenuation value is different from other months included in the category with rain intensity ≤ 30 mm/h, resulting in a significant increase in the attenuation value. Meanwhile, the rain attenuation value in the ITU-R P.618-14 Model results remains stable as its specific attenuation value is influenced by two variables whose values are determined based on the working frequency and polarization of the antenna, which, in this condition, the frequency value and polarization type are the same.

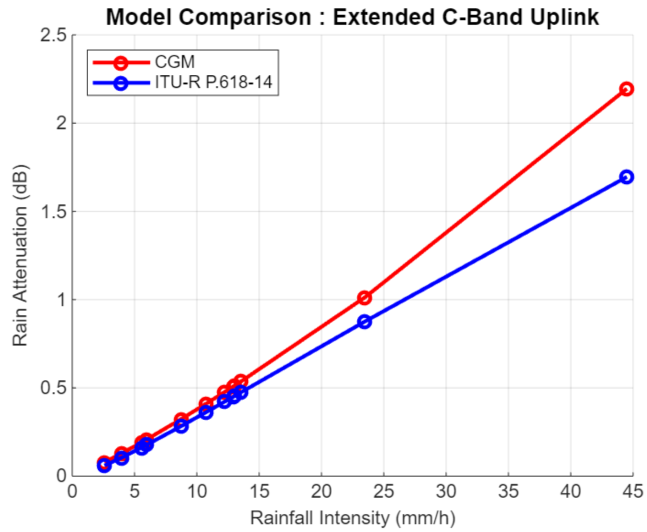


Figure 3. Model Comparison Extended C-Band Uplink

Based on Figure 3, using the Crane Global Model, the comparison at the Extended C-Band frequency results in the rain attenuation value of 2.195 dB in November. Conversely, September, with a rain intensity value of 2.59166 mm/h, produces a rain attenuation value of 0.079 dB. Rain attenuation with ITU-R P.618-14 Model the value in November 1.695 dB and September 0.059 dB.

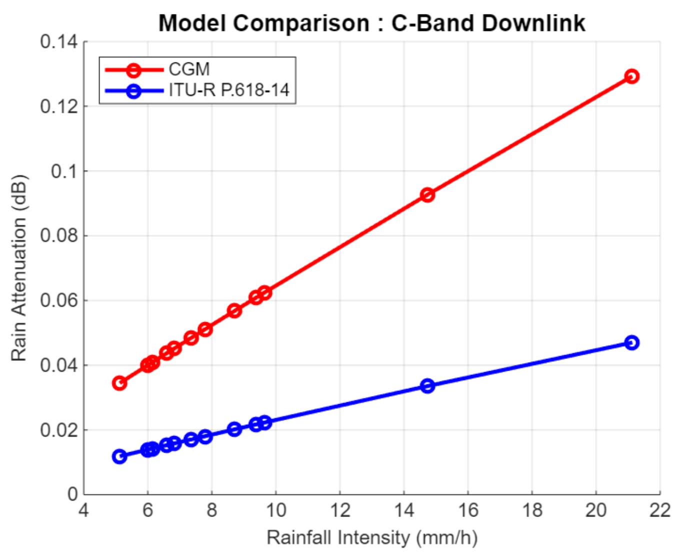


Figure 4. Model Comparison C-Band Downlink

As shown in every modeling comparison graph, the rain attenuation value for the Crane Global Model is higher than that of the ITU-R P.618-14 Model. In the Crane Global Model, the rain intensity value determines the coefficient in the specific attenuation parameter. Furthermore, there is an empirical constant parameter, where in calculating this parameter, there are four variables, each of which is influenced by the rain intensity value, and this empirical constant value is used for further calculations. Then, in determining the rain attenuation value, use an equation where the equation is also influenced by rain intensity. On the other hand, in the ITU-R P.618-14 Model, the rain intensity value only affects the specific attenuation value. Therefore, the involvement of rain intensity values in the Crane Global Model is higher than the ITU-R P.618-14 Model.

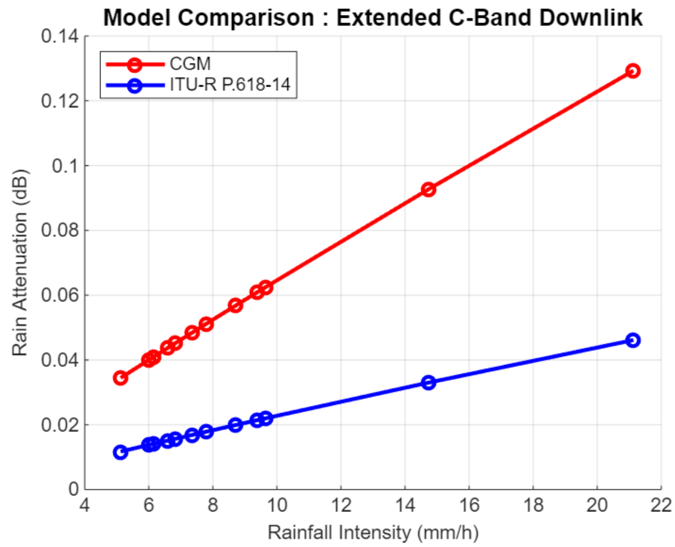


Figure 5. Model Comparison Extended C-Band Downlink

In the Crane Global Model between the C-Band and Extended C-Band frequencies, downlink communication has the same rain attenuation value because it has the same specific attenuation coefficient value. Because rain intensity is a downlink communication, both C-Band and Extended C-Band have the same value. Then, for the frequency used in the C-Band frequency of 3.620 GHz and Extended C-Band of 3.535 GHz, the two frequencies are included in the 3.5 GHz category (taking the closest frequency value). In addition, the ground station, rain intensity, specific attenuation coefficient, and empirical constant are the same, resulting in the same rain attenuation value.

### *4.2 Analysis of Link Budget Calculation*

In this link budget calculation analysis, a comparison will be made between manual calculations using mathematical equations and calculations in SatMaster Pro software. This analysis begins with uplink direction communication both at C-Band frequency and at Extended C-Band frequency, then continues with downlink direction communication both at C-Band frequency and at Extended C-Band frequency. The table shows the results of the link budget comparison between manual calculations using mathematical equations, SatMaster Pro software calculations, and ITU standards on uplink and downlink communications with C-Band and extended C-Band frequencies.

Table 3. Link Budget Uplink (C-Band)

| Parameter | Manual Calculation | SatMaster Pro Calculation | Standar ITU |
|---|---|---|---|
| Azimuth Angle | 13,724133° | 13,72° | - |
| Elevation Angle | 82,602519° | 82,34° | - |
| Slant Range | 35834,345647 km | 35834,77 km | 36.000 km |
| Free Space Loss | 199,006391 dB | 199,02 dB | 200,019 dB |
| Gain Antenna | 53,660717 dBi | 53,67 dBi | 55,883 dBi |
| EIRP | 65,013442 dBW | 64,92 dBW | 65,756 dBW |

Table 4. Link Budget Uplink (Extended C-Band)

| Parameter | Manual Calculation | SatMaster Pro Calculation | Standar ITU |
|---|---|---|---|
| Azimuth Angle | 13,724133° | 13,72° | - |
| Elevation Angle | 82,602519° | 82,34° | - |
| Slant Range | 35834,345647 km | 35834,77 km | 36.000 km |
| Free Space Loss | 199,979787 dB | 199,99 dB | 200,898 dB |
| Gain Antenna | 54,634113 dBi | 54,64 dBi | 56,856 dBi |
| EIRP | 65,986838 dBW | 65,90 dBW | 66,261 dBW |

The results of the link budget comparison between manual calculations using mathematical equations, SatMaster Pro simulations, and ITU standards on uplink communications, both C-Band and Extended C-Band frequencies, have a slight difference, so it can be said that the link budget calculations carried out are good. However, in the calculation of antenna gain, the difference produced is approximately 2 dB; this is because, in the ITU standard, the antenna efficiency value is not considered. Just like in uplink communication, the difference in results between manual calculations, SatMaster Pro simulations, and ITU standards is slight, indicating that the link budget calculations are accurate.

Table 5. Link Budget Downlink (C-Band)

| Parameter | Manual Calculation | SatMaster Pro Calculation | Standar ITU |
|---|---|---|---|
| Azimuth Angle | 271,215318° | 271,22° | - |
| Elevation Angle | 62,888493° | 62,89° | - |
| Slant Range | 36387,121457 km | 36387,30 km | 36.000 km |
| Free Space Loss | 194,830427 dB | 194,84 dB | 195,735 dB |
| Gain Antenna | 34,804922 dBi | 34,82 dBi | 36,679 dBi |
| EIRP | 15,476128 dB/°K | 15,19 dB/°K | 15,476 dB/°K |

Table 6. Link Budget Downlink (Ext C-Band)

| Parameter | Manual Calculation | SatMaster Pro Calculation | Standar ITU |
|---|---|---|---|
| Azimuth Angle | 271,215318° | 271,22° | - |
| Elevation Angle | 62,888493° | 62,89° | - |
| Slant Range | 36387,121457 km | 36387,30 km | 36.000 km |
| Free Space Loss | 194,624041 dB | 194,63 dB | 195,533 dB |
| Gain Antenna | 34,598539 dBi | 34,61 dBi | 36,473 dBi |
| EIRP | 15,269745 dB/°K | 14,98 dB/°K | 15,269 dB/°K |

### *4.3 Analysis of Rain Attenuation's Impact on Satellite Communication System Quality*

This analysis aims to determine the effect of rain attenuation on the quality of satellite communication systems with the Bogor—Sorong communication link at C-Band and Extended C-Band frequencies. The effect of rain attenuation is analyzed by comparing the values of signal quality parameters, total C/N, Eb/No, and BER, during clear sky conditions and during rain.

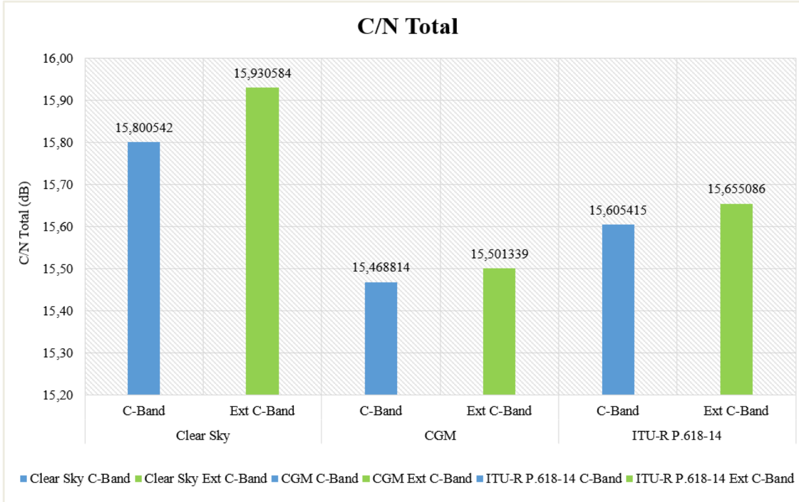


Figure 6. C/N Total Comparison Graph

Figure 6 compares the C/N total value, where the C/N total value is obtained from the accumulation between the C/N uplink and the C/N downlink. There is a decrease in the value of the C/N total parameter in the Crane Global Model and ITU-R P.618-14 Model; this is because the C/N uplink and C/N downlink parameters also decrease due to the influence of rain attenuation. From the values obtained in the total C/N parameter compared to the clear sky condition, it is clear that the most significant decrease in value occurs when the conditions are influenced by rain attenuation in the Crane Global Model with a value of 0.331728 dB at the C Band frequency and 0.429245 dB Ext C Band. Therefore, it can be concluded that the ITU-R P.618-14 Model has the best parameter values because the decrease in value is less than the Crane Global Model.

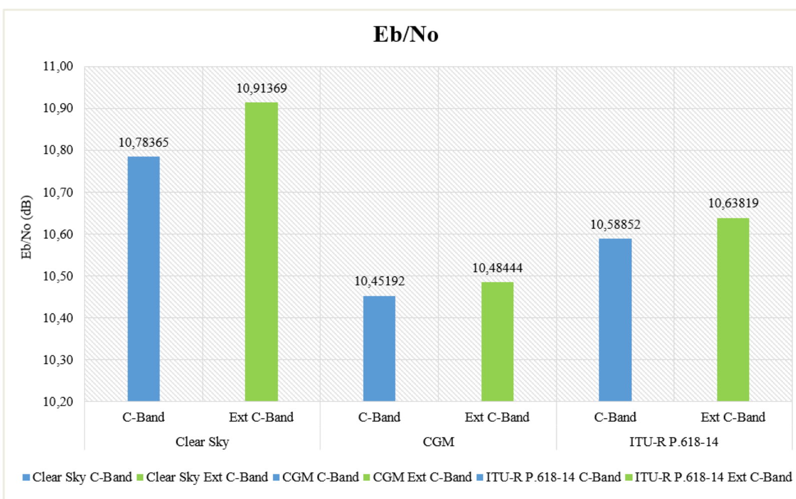


Figure 7. Eb/No Comparison Graph

The following graph compares Eb/No values under three conditions: clear sky, rain attenuation using the Crane Global Model, and the ITU-R P.618-14 Model. It can be seen from the graph that C/N total values influence Eb/No values. During rain, the C/N total values drop more in the Crane Global Model than in the ITU-R P.618-14, leading to minor Eb/No values in the Crane Global Model compared to the ITU-R P.618-14. This is because Eb/No is directly proportional to the C/N total. However, the ratio between data transmission speed and occupied bandwidth is inversely proportional.

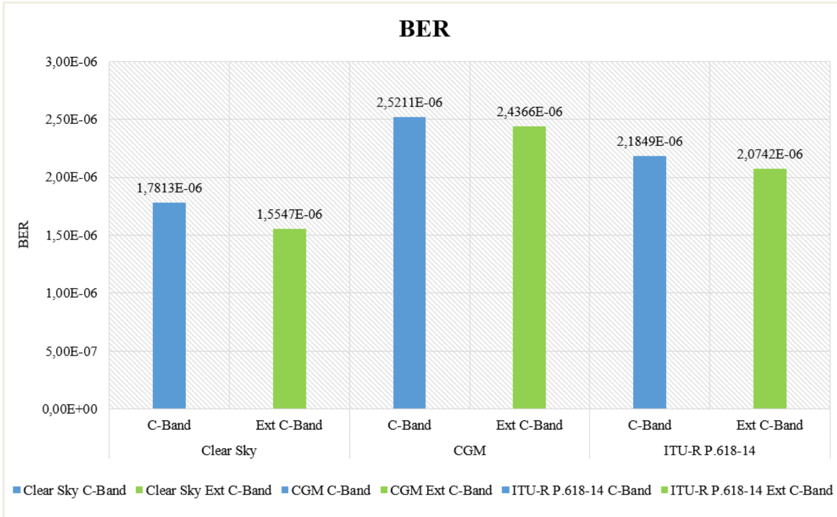


Figure 8. BER Comparison Graph

The following graph shows a comparison of BER values. Based on the graph, it can be seen that when there is rain, the BER value increases. The increase in value causes the quality of the signal transmitted to the receiving station to be poor because the greater the BER value, the greater the number of bit errors. Conversely, the smaller the BER value, the better the signal quality transmitted to the receiving station because the fewer bit errors, the more bits are successfully transmitted. So, based on the BER parameter values generated from the Crane Global Model and the ITU-R P.618-14 Model, it can be concluded that the ITU-R P.618-14 Model has the best parameter values because the increase in value that occurs is less than the Crane Global Model.

Based on the analysis of the effect of rain attenuation, it can be concluded that in this research, the appropriate rain attenuation model for the Bogor - Sorong communication link both at C-Band and Extended C-Band frequencies is the ITU-R P.618-14 Model. This is because the C/N total parameter for the C-Band frequency is 15.605415 dB, and for the Extended C-Band frequency is 15.655086 dB, the C/N total value is better because the value is greater than the Crane Global Model. Additionally, the Eb/No parameter for the C-Band frequency is 10.58852 dB, and the Extended C-Band frequency is 10.63819 dB. The Eb/No value is better because the value is greater than the Crane Global Model. Then, for the BER value, it means that the ITU-R P.618-14 Model produces a small BER value, which is better than the Crane Global Model, which is for the C-Band frequency worth $2.1849\times10^{-6}$, and for the Extended C-Band frequency worth $2.0742\times10^{-6}$.

## 5. Conlusion

The rain attenuation calculations show that the rain attenuation value obtained is directly proportional to the rain intensity value and the frequency value used. This is determined by the inverse relationship between the rain intensity and frequency; if the rain intensity and frequency values increase, the rain attenuation also increases. Conversely, as the rain intensity and frequency values decrease, the rain attenuation also decreases. Rain attenuation affects the quality of satellite communication systems, which is indicated by a reduction in the signal strength received by the earth station. The total C/N and Eb/No values in the ITU-R P.618-14 Model are higher than the Crane Global Model. The total C/N value for C-Band is 15.605415 dB, and for Extended C-Band is 15.655086 dB. The Eb/No value for C-Band is 10.58852 dB, and for Extended C-Band is 10.63819 dB. In addition, the ITU-R P.618-14 Model produces smaller BER values, namely $2.1849\times10^{-6}$ for C-Band and $2.0742\times10^{-6}$ for Extended C-Band, compared to the Crane Global Model.

The analysis of the effect of rain attenuation indicates that the ITU-R P.618-14 Model is the most appropriate for the Bogor-Sorong communication link at C-Band and Extended C-Band frequencies. This is due to the results that the C/N total and Eb/No values in the ITU-R P.618-14 Model produce higher values than those of the Crane Global Model.

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