Analysis of Microwave Network Design Using Back-to-Back Passive Repeaters with the Influence of Interference Based on ITU-T-G821 Standard

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Abstract**—**This paper analyzes the microwave network design which uses the back-to-back passive repeaters with the existence of interference. The microwave network design is simulated on Pathloss 5.0 software. The simulated availability results were compared to the ITU-T G.821 standard, and it shows that the simulated availability result which was produced from the interference affected, back-to-back repeater design, indicates that the availability was not reached the standard, while the other design that uses the back-to-back repeaters which were not affected by interference obtained 99.97403% availability. Although the latter design resulting in a higher availability value compared to the standard, 99.9600%, it is still not fulfilling the path availability standard, which is 99.9800%. The availability result shows that it has fulfilled the ideal condition since the value is above 99,9% and the outage time value is 0,1%. However, the availability result of the budget calculation link of using the back-to-back repeaters network design is 99.98663%, which indicates that the availability value fulfilled the ITU-T G.821 standard.

Index Terms**—**Microwave, Passive Repeater, Pathloss 5.0, Interference, ITU

I. Introduction

The microwave communication network is used to transmit information with a large capacity between point-to-point communications, such as the communication between Base Transceiver Station (BTS). Microwave communication works at high frequency between 2 GHz to 24 GHz [1].

Microwave network requires a Line of Sight (LOS) mechanism, which means that the pathway between a transmitter and a receiver should be available without any barrier or obstacles in between. The transmitted information may not be received properly at the receiver antenna if there is an existence of barriers or obstacles between them [2]. If the barriers are unavoidable then a repeater is needed to increase the quality of the signal. the passive repeater is usually used in such a scenario since it could increase the performance by producing additional gain in the middle of the path and carrying the amplified, repeated signals before reaching the receiver antenna [3].

In the telecommunication networks, an interference will always exist, and such interference could interrupt the transmitted information and give us a poor signal quality[4]-[6]. The impact of interference and obstacles in an area can be studied in a simulation in order to suggest a realistic microwave network design that meets the regulated availability standard. The link budget calculation of the proposed microwave network design is analyzed and simulated by using the Pathloss 5.0 software. The main parameters in which obtained from this study are the availability, fading margin and RSL. These parameters are needs to be ensured that they must meet the objective availability according to ITU-T-G.821 standards

II. Research Methods

The analysis in this research is based on a case study that appeared at PT APM, Bogor, Indonesia. The flow diagram of this research is shown in Fig. 1. Firstly, researchers use a realistic data such as latitude, longitude, elevation, antenna and radio data of existing sites, as the input parameters in designing the Bogor site and Cipeteuy site in the Pathloss 5.0 software and calculate the link budget between those sites.

Based on the initial data and simulation, the microwave link between the West Bogor site and the Cipeteuy site was not LOS due to a mountainous barrier. To keep the microwave link connected, a back-to-back passive repeater was placed in the highest place between these two sites.

The impact of passive repeater has been analyzed by comparing the link performance of prior implementation to the subsequent design. Further, to mimic the realistic

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network condition, the additional impact of interference to the microwave link has also been studied. The simulation results are then compared to the provisions of the ITU-T-G.821 standard. The analyzed variables are including the probability of the availability and unavailability of the microwave link. The results of this study would give the suggestion to design a better microwave network with respect to a better link performance.

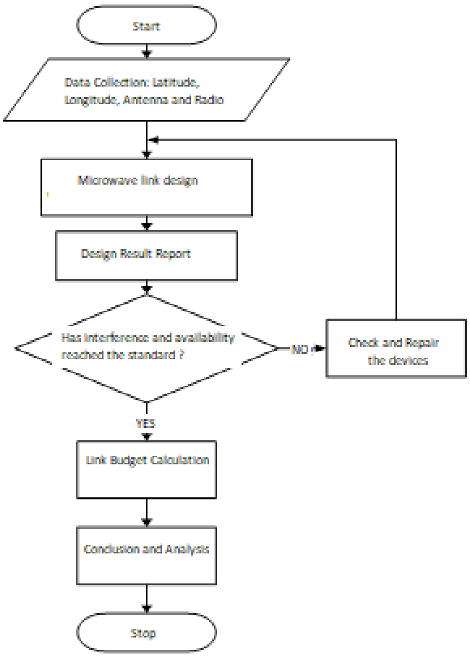

Fig. 1. Research methods flowchart

A. Research Parameters

Antenna gain is used to measure the antenna's ability to send the desired wave towards the destination. The magnitude of the antenna gain can be found with the Equation (1) [7]-[9].

$$G = 20\log f + 20\log d + 10\log\eta + 20.4 \quad (1)$$

where

G : Antenna Gain (dB)
η : Efficiency antenna (%)
d : Diameter antenna (m)
f : Frequency (GHz)

Free Space Loss (FSL) is the attenuation that exists along with the space between the transmitter antenna and the receiver. There is no barrier in this space because the transmission itself has LOS character. The size of FSL can be calculated by Equation (2) [7]-[9]

$$FSL = 92.45 + 20\log D + 20\log f \quad (2)$$

where

D : Distance (km)
f : Frequency (GHz)

Emitted Isotropic Radiated Power (EIRP) is the maximum power of microwaves signal which emitted from the transmitter antenna or to show the effective value of the power emitted by the transmiter antenna, in other words, the power has been strengthened. EIRP is calculated by summing the output power of the transmitting antenna with the antenna gain then subtracted by loss or can be written as the Equation (3) [10], [11].

$$EIRP = P_{TX} + G_{Antenna} - L_{TX} \quad (3)$$

The *Isotropic Received Level* (IRL) is the isotropic power level value received by the receiver station. To get the value of power at the receiver antenna, the IRL value must be obtained first. The IRL value is obtained from the Equation (4), [12]-[14].

$$IRL = EIRP - FSL \quad (4)$$

where,
IRL : Isotropic Received Level (dBm)
EIRP : Effective Isotropic Radiated Power (dBm)
FSL : Free Space Loss (dB)

Received Signal Level (RSL) is the power level received by decoding processing devices. This RSL value is affected by line losses on the receiving antenna side and the receiver antenna gain. The RSL value can be calculated by Equation (5), [15], [16].

$$RSL = IRL + G_{RX} - L_{RX} \quad (5)$$

where,
RSL : Received Signal Level (dBm)
IRL : Isotropic Received Level (dBm)
G_{RX} : Gain antenna (dBi)
L_{RX} : Receiver Loss (dB)

Hop Loss is the difference between gain and loss in the microwave link. Gain is reinforcement on the both side, whereas loss is the sum of free space attenuation and such as extra attenuation and atmosphere (water vapor and oxygen). So the amount of Hoploss is expressed in Equation (6), [15], [16].

$$L_h = FSL + L_{TX} + L_{RX} + L_{Atm} - (G_{TX} + G_{RX}) \quad (6)$$

where
L_h : *Hoploss* (dB)
FSL : Free Space Loss (dB)
L_{Tx} : Transmit Loss (dB)
L_{Rx} : Receive Loss (dB)
L_{atm} : Athmosphere Loss (dB)
G_{Tx} : Receiver Antenna Gain (dBi)
G_{Rx} : Transmitter Antenna Gain (dBi)

Fading Margin (FM) is the difference between the acceptability and the minimum acceptability. Minimum acceptance or called threshold level is the threshold of power received. The relationship between fading margins and receive signal level is shown in Equation (7) [13],

$$FM = 30\log D + 10\log(a\ x\ b\ x\ 2.5\ x\ f) - 10\log UnAv_{path} - 60 \quad (7)$$

Availability is a measure of system reliability. Ideally all systems must have a value of 100%, but that cannot be fulfilled, because in a system there must be a system reliability (Unavailability) the value of availability and unavailability can be found with the Equation (8) and Equation (9)[16].

$$Av_{path} = \left(1 - UnAV_{path}\right) x\ 100\% \quad (8)$$

$$UnAv_{path} = a\ x\ b\ x\ 2.5\ x\ f\ x\ D^3\ x\ 10^{-6}\ x\ 10^{-\frac{FM}{10}} \quad (9)$$

where:
FM : Fading Margin (dB)
D : Distance (km)
f : Frequency (GHz)
$UnAv_{path}$: System Unreliability
Av_{path} : System reliability

a is the earth's roughness factor, and *b* is the climate factor, and different values are taken for different geographical and climate condition, the values for *a* and *b* are:
a : 4 ; for fine areas, seas, lakes and deserts
a : 1 ; for areas of average roughness, terrain
a : ¼ ; for mountains and highlands
b : ½ ; for hot and humid areas
b : ¼ ; for normal areas
b : 1/8 ; for mountainous areas (very dry)

For the back-to-back passive repeater antenna, the gain will be calculated by Equation (10).

$$G = G_{A1} - G_{AC} + G_{A2} \quad (10)$$

where:
G_{A1} : Gain of one repeater antenna (dB)
G_{AC} : Antenna coupling loss (waveguide) (dB)
G_{A2} : Gain from another antenna repeater (dB)

B. *ITU-T G.8 Standard*

The current ITU-T G.821 Standard has Availability Objective for two parameters to determine the availability of quantity in the form of an Availability Ratio (AR), which shows the ratio of time available to a communication with the total time of operation, and Outage Intensity (OI), which represents the number of outages in a communication system in the total time of operation, as shown in Fig. 2[17]. The OI can also be referred to as the average time for each outage that occurs during the total operating time. The operating time referred to is measured universally taken for 1 year.

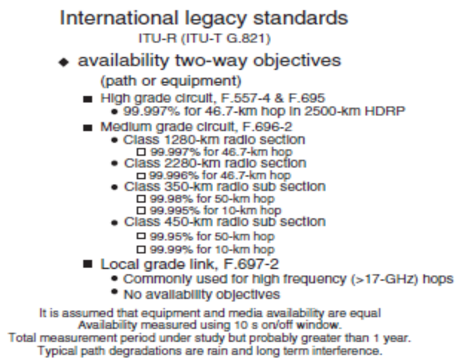

Fig. 2. International availability of objective paths per year based on ITU

Availability Ratio (AR) which used in this study is the Short-Haul Section, since it has a distance of 50 km < L_{link} ≤ 250 km. With the Hop Availability conditions 99,9600% and Path Availability 99,9800%[17].

Interference is an interaction between waves in an area. Interference can be constructive and destructive. It is refers to be constructive if the second phase difference of the waves is the same so that the new wave formed is the sum of the two waves. It is called destructive if the phase is 180 °, so the two waves eliminate each other [2], [14].

Pathloss is a tool which used to measure a loss caused by weather, soil cantilever, etc., so as not to interfere with the transmission between two interconnected antennas. Pathloss value Indicates a weakened signal level (attenuation) caused by the propagation of free space such as reflection, diffraction, and filtering. Path loss is very important in link budget calculation, cell size, or frequency design. Factors that influence the value of my level and path loss are the distance of measurement of Tx and Rx antennas, antenna height (Tx and Rx), and type of measurement area [18].

III. Results and Discussion

The design of this microwave network is based on the existing West Bogor site with the latitude of 06 34 50.88 S, and longitude 106 45 54.00 E, and site Cipeteuy with the latitude of 06 47 11.69 S, and longitude of 106 37 05.61 E. Based on the results of the design on the microwave link is not LOS due to a barrier in the form of mountains, as shown Fig. 3.

This situation was overcome by the addition of back-to-back passive repeaters antenna. In this planning the author plans a repeater placement at the coordinates of latitude 06 44 58.74 S, longitude 106 36 19.71 E. The network was designed by using Pathloss 5.0, and the simulation results are shown in Fig. 3 and Fig. 4.

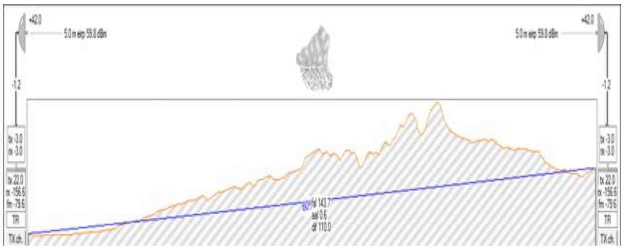

Fig. 3. Design results without repeaters

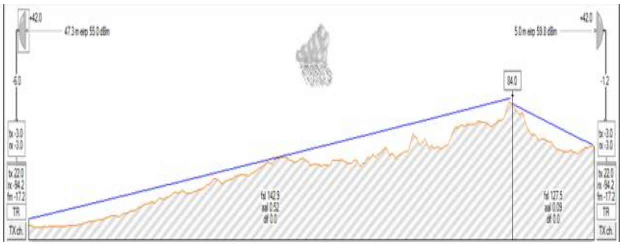

Fig. 4. Design results with repeaters

According to Fig. 4, the overall results of the network after the additional repeater are not detected, this is because of the use of microwave and radio type antennas that are not suitable, possible long distances and the presence of interference on the microwave transmission network. For this reason, interference is checked, whether the microwave transmission network that uses back-to-back repeaters has interference, checking is done using Pathloss 5.0 software.

According to Pathloss 5.0 interference summary report, the microwave transmission network is affected by interference, because interference is affected by this design so that interference effects can be seen in Fig. 5 and report interference can be seen in Fig. 6.

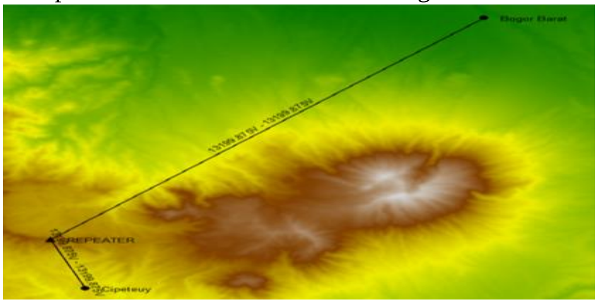

Fig. 5. Bogor Site - Passive repeater - Cipeteuy site has interference

Interference Summary Report

Coordination distance (km) 200.00
Maximum frequency separation (MHz) 150.00
Default minimum interference level (dBm) -115.00
Margin (dB) 10.00
Threshold degradation objective (db) 1.00
Total number of cases calculated 2
Calculation made on Jumat, Maret 01 2019 05:01:20

Case 1 Bogor Barat from REPEATER - 13199.875V - threshold degradatic
1-1 REPEATER to Cipeteuy - 13199.875V - correlated case
V-I distance 25.69 km
interfering level 74.84 dBm
threshold degradation

Case 2 Cipeteuy from REPEATER - 13199.875V - threshold degradation
2-1 REPEATER to Bogor Barat - 13199.875V - correlated case
V-I distance 4.32 km
interfering level 100.28 dBm
threshold degradation

Fig. 6. Report interference

It can be seen that there is the same frequency usage or the same Channel Id from report case 1, it can be seen that from West Bogor - Repeater uses frequency 13199.875V and case 2 from Repeater - Cipeteuy uses frequency 13199.875V from the same frequency usage that makes it happen influence of interference.

The Back-to-Back Repeater Antenna to Cipeteuy link has made a change in the frequency of interference in the West Bogor site for sub-band frequencies which used 128h frequency (13199.875 MHz -13199.875 MHz) to 128h (13199.875 MHz - 12974.125 MHz) by setting a frequency high (13199.875 MHz) at West Bogor site and frequency low (12974.125 MHz).

Next, the interference case in this design has been eliminated. The result of Pathloss 5.0 simulation shows the notification of "no interference case", which indicates that the microwave transmission network has not been affected by interference. This phenomenon can be seen in Fig. 7.

All the comparison of Availability or System Reliability value which generated from the microwave transmission network is shown in Table I.

Of all the results and discussions that have been conducted, it can be analyzed that the microwave transmission network in the West Bogor - Cipeteuy site designed using Pathloss 5.0 has a system failure which has caused system reliability to be poor and undetected, all due to an obstacle that makes sending signals from the transmitter antenna cannot be received by the receiver antenna because there is a barrier so that from the design results in Pathloss 5.0 obtained a report that shows that the availability value is not detected can be seen in Table II.

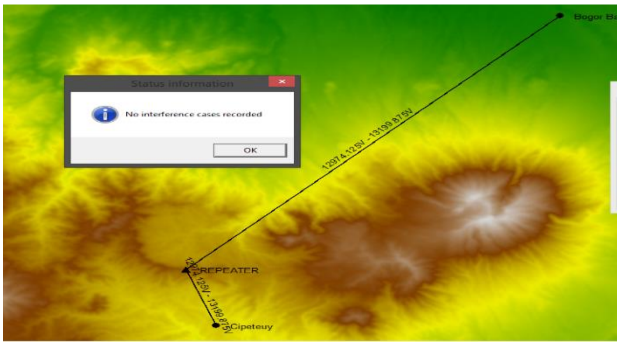

Fig. 7. Site Bogor Barat – *Passive Repeater* – site cipeteuy without interference

TABLE I: AVAILABILITY WITH THE STANDARD PROVISIONS OF ITU-T-G.821 ON PATHLOSS 5.0

Parameters	Without Repeater	With Back-to-Back Repeater	ITU-T-G.821 Standard
Annual Rain Availability (%)	-	99.97403	99.9600
Annual Rain + Multipath Availability (%)	-	99.97403	99.9800

Hence, because of the poor results of the microwave transmission network at the Bogor Barat - Cipeteuy site, a repeating antenna, Passive Repeater Back to Back Antenna is added, this repeater serves to transmit the information signal, the signal sent by the repeater back to back will gain before being sent back to the receiving antenna, the Cipeteuy site. With the addition of repeaters, the gain was 84.00 dBi and the availability after using repeater back to back was 99.97403 %.

Because the influence of interference has been eliminated, the next step is to analyze the results obtained from the availability to see that the value has reached the ITU-T-G.821 standard or below standard. from table 1 it can be seen that the value of the West Bogor - Cipeteuy site system without repeaters does not meet the standards because system or availability reliability is not detected from the Pathloss 5.0 report, while the link budget calculation results in system reliability of -410428464% this value is very bad for microwave transmission systems, it can be concluded that the reliability of the system or availability of the West Bogor - Cipeteuy site without repeaters cannot be implemented because the quality of communication services is very poor. As for the results of system alignment from the Bogor site - repeater back to back - Cipeteuy from the results of the Pathloss report 5.0 the annual rain availability generated at 99.97403 % indicates that the value of the system reaches the ITU-TG.821 hop availability standard. 99.9600 %, while for annual rain + multipath availability generated at 99.97403 % this indicates that the overall system reliability value has not reached the ITU-TG.821 path availability standard with the provision of 99.98 %. But in the calculation of the link budget value in the system generated after using a repeater of 99.98663 % this indicates that the value of the calculation results or the link budget can reach the ITU-T-G.821 standard. And for the results of the comparison of the availability of the link budget calculation can be seen in Table II.

TABLE II: AVAILABILITY OF LINK BUDGET CALCULATION RESULT COMPARED TO ITU-T-G.821 STANDARD

Parameter	Without Repeater	With Back-to-Back Repeater	ITU-T-G.821 Standard
Availability (%)	-41042846	99.98663	99.9800

IV. CONCLUSIONS

There are four final conclusions which can be summarized from this research. First, according to the simulation report on Pathloss 5.0, the repeater produces a gain value of 84.00 dBi and the resulting availability is 99.974035% while the result of the calculation of the link budget availability is 99,986638%.

Second, from the report interference, it can be seen that there is an interference effect that occurs on the microwave transmission network, there are two cases, namely the use of the same frequency or the same Channel Id from the case 1 report, it can be seen that from Bogor Barat - Repeater uses the frequency 13199.875V and case 2 of the Repeater - Cipeteuy uses a frequency of 13199,875V from the use of the same frequency that causes interference.

Next, to overcome cases of interference at the West Bogor site - Passive Repeater - Cipeteuy site changes were made to sub band frequencies that used 128h frequency (13199.875 MHz -13199.875 MHz) to 128h (13199.875 MHz - 12974.125 MHz) by setting a frequency high (13199.875 MHz) at West Bogor site and frequency low (12974.125 MHz). After this is done, the case of interference in this design can be eliminated and when a simulation is carried out on Pathloss, the notification "no interference case" appears.

Lastly, the ITU-TG.821 standard that is used as a reference for availability values, availability of results reaches the standard and there is also a standard below, from the results of the design after the repeater added the annual rain availability value is 99.97403%, from this value then availability reaches the standard since the value produced is more than the ITU-T G.821 standard, which is 99.9600%, and the value of annual rain plus multipath availability is 99.97403%, this value is called the overall value and this availability value is not reached the ITU-T G.821 standard, because the standard value is 99,9800%, and the value generated from the Pathloss 5.0 report is lower than the standard value because previously in the microwave network design with the addition of repeaters the report results were not detected and the design was made below the standard, that makes the availability results below standard but can still be said to be quite good, because the availability and outage time provisions table the availability value is 99.9%, the outage time value obtained is 0.1% and damage to the transmission network is around 8.8 hours every year, 43 minutes every month and 1.44 minutes per day.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Alfin, Ade, Winda conducted the research; Subuh, Arif and Annisa analyzed the data; Alfin, Ade, Winda, Arif and Annisa wrote the paper; all authors had approved the final version.

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