Proceedings of
2017 4th International Conference on
New Media Studies (CONMEDIA 2017)

November 08-10, 2017 | Yogyakarta, Indonesia

IEEE Catalog Number: CFP1703X-ART
ISBN: 978-1-5090-6284-3

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Comparison Analysis Of Passive Repeater Links Prediction Using Methods: Barnett Vigants & ITU Models

Alfin Hikmaturokhman, Ade Wahyudin, Alia S. Yuchintya,
[1]Institut Teknologi Telkom Purwokerto, Jl. D. I. Panjaitan No. 128 Purwokerto 53147, Indonesia
alfin@ittelkom-pwt.ac.id

Toha Ardi Nugraha
Yogyakarta, Indonesia
Universitas Muhammadiyah Yogyakarta

Abstract— Microwave is a kind of wireless communication using radio link transmission at high frequency medium between two base stations in cellular systems. Microwave link should be line of sight (LOS) between transmitter and receiver (no obstacle). But, in the real case, there are some obstacles in microwave link between two base stations. Therefore, this paper uses a microwave passive repeater to solve the obstacle problems. The passive repeater is used to repeat information signals by changing the direction of the radio link transmission. This paper implements Barnett Vigants and ITU-R P.530-7/8 methods in passive repeater using software simulation. The difference between two methods is the availability value due to multipath and unavailability value due to rain. On a microwave transmission network using the Barnett Vigants method, resulting higher unavailability value than the use of ITU-R method P.530 7/8. The unavailability value using Barnett Vigants method obtained was 0.023%, it means the outage time of link microwave is 7244 second per year. If compared with metode ITU-R P.530 7/8 method, the unavailability was 0.000087 % or outage time system is for 26 second per year. So the availability using ITU-R P.530 7/8 method is 99. 9999133%.

Keyword-Microwave link, passive repeater, barnet vigant, availability

I. INTRODUCTION

Cellular technology is one of the most important things in communication network. Cellular technology has a system that can send the information such as voice and data from base station to users and also between base stations [1]. In order to support a good communication networks, therefore cellular system should require a microwave network design. Microwave network is a kind of wireless communication using radio link transmission at high frequency medium between two base stations in cellular technology. Microwave network design could be simulated by using microware software simulations [1]. This software is a tool for simulating the microwave radio communications. This software can be used to design the radio transmission link between base station with considering some parameters such as obstacle and radio waves in a simulated area, therefore the simulation results can be used to design as actual planning.

Radio waves can spread through in the various paths using the concept of the radio propagation mechanisms, namely Line of Sight (LOS). LOS is a path of radio waves which follows the straight line. LOS also means that there is no obstacle between the transmitter and receiver antenna. If there is unavoidable obstacle in an area, such as mountains or buildings, a passive repeater is required on the microwave networks.

This paper compares two prediction methods, Barnett Vigants and ITU Models. Those prediction methods are used to predict the microwave and which one is more accurate based on the simulation. The difference between the two methods is the value of unavailability due to multipath and unavailability value with space diversity technique.

II. BASIC THEORY

A. *Microwave Transmission*

Microwave transmission is a radio communication that utilizes frequency in the air interface as transmission medium to bring the information signals. The purpose of a microwave transmission is to transmit the information from one place to another or between base stations at high frequency [1,2].

Microwave transmission consists of two main parts, namely transmitter and receiver. In path of signals from transmitter to receiver, radio waves move through various paths and propagation mechanisms. The basic propagation mechanism is Line of Sight (LOS). LOS is the path of radio waves which follows the straight line or it means that between the transmitter and receiver antenna there is no obstacle. Fig 1 shows the basic propagation with LOS [1].

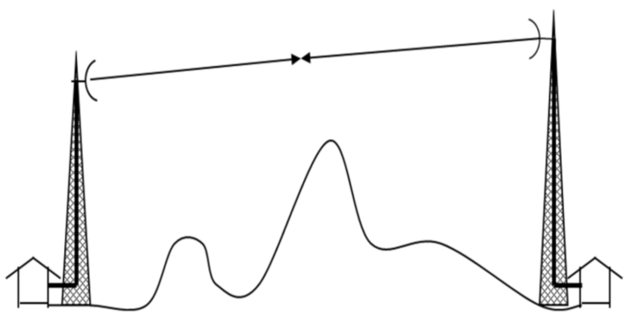

Fig. 1 LOS Propagation [1]

Repeater can be divided by two models, namely active repeater and passive repeater. The active repeater has an amplifier that can recover the signal with initial quality signals before transmitted again. Passive repeater is a kind of relay station or commonly called with microwave repeater. Microwave as passive repeater is used when microwave links are needed which have some obstacles, such as mountains or buildings. Passive repeaters are used to repeat radio signals by changing the direction of radio broadcasts without the application of electronic equipment. There are 2 main types of passive repeaters, namely passive or plane reflector and back to back antenna passive.

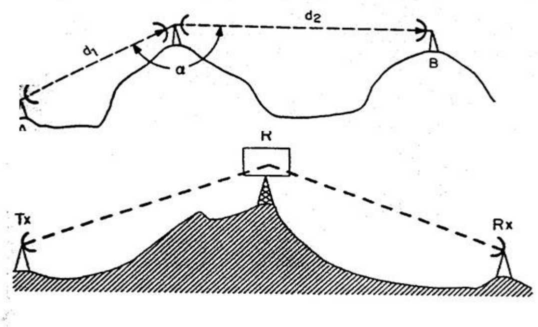

Fig. 2 Passive Repeaters [2]

Fig. 2 shows two types of passive repeater. The first type is where two antennas are placed with back to back connected by short feeder cables, these are called back to back passives antenna. The second type (bottom image) is a passive type plane reflector with a flat billboard. Metal type reflector is used to direct the signals and called a plane reflector.

B. *Back To Back Antenna*

Passive relay with back-to-back antenna consists of two antennas connected by a wave. Both antennas use a large diameter antenna. Back-to-back antenna works like a regular repeater station, without radio frequency transposition or amplification of the signal [2]

Back to back antenna is very practical. It has a large of the angle reflection. The gain of a repeater with back to back antenna is given by Eq. (1) [2]

$$G_R = G_{A1} - A_c + G_{A2}\,[dB] \quad (1)$$

GA1 is a gain from one of two antennas repeaters in dB, G_{A2} is the other antennas repeater in dB, and A_C is coupling loss (waveguide) between antennas in dB.

The calculation of back to back passive repeater is not complex. However, some issues should be analyzed in more detail, such as the advantages, the vertical distance between two microwave using parabolic antennas, signal decoupling in passive structure, and the overall effect of microwave link performance. Small gain from the back to back repeater is as a limiting factor. [3]

C. *Plane Reflector*

Plane reflector is a passive repeater to reflect microwave signals like a mirror that reflects the light. Plane reflector is placed at the top of the building. It is to support microwave link between base stations. [1,3]

The second type of passive repeater is known as a "billboard" passive repeater. The passive repeater resembles a billboard with a type of metal reflector, which shifts the microwave beam at an angle. If an angle is less than 130°, only one reflector is required. But if two paths are close between two base stations (i.e. less than 50°), a double passive reflector will be used for the case of a single reflector distance between the reflector and the important antenna terminal in the software calculation [3].

This system has some benefits of wave reduction, with dimensional choice, having a net gain greater than the parabolic antenna itself. Some mathematical analysis should be made of all possible combinations of dimensions including various curvatures for surface reflections. Usually, the limited frequency range is about 6 - to 11GHz [3]

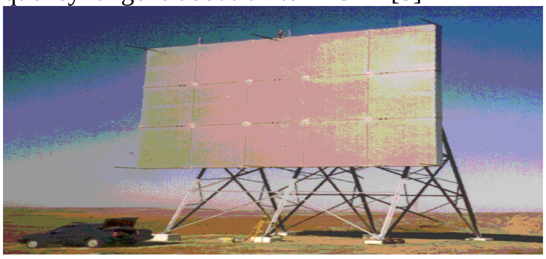

Fig. 3 Reflectors [3]

Fig. 3 shows a passive repeater reflector is a flat surface used to direct microwave signals over or around obstacles without adding external forces (or noise) to the system. A flat surface is the most efficient device that can be used to capture and transmit microwaves without additional power into the system.

D. *Link Budget Calculation*

There are some parameters that will be used for link budget calculation in microwave designs, as follow:

1) *Antenna Gain*

Antenna is a device that is used to transmit information signal from transmitter and receiver. Antenna can convert information signal into an electromagnetic wave. Antenna gain can be calculated using Eq. (2) [1,3].

$$G = 20\log f + 20\log d + 10\log\eta + 20{,}4 \quad (2)$$

where G is gain antenna (dBi), d is the antenna diameter in meter, η is antenna efficiency about 55% and f is antenna frequency in GHz.

2) *Free Space Loss (FSL)*

At frequencies above 10 GHz, loss can be regarded as free space loss (FSL), free space loss is a function of frequency and distance. FSL is the attenuation that exists throughout the space between the transmitting and receiving antennas. In this space there is no barrier permitted, because the transmission itself is characterized by LOS. The magnitude of FSL can be calculated by Eq. (3) using frequency in Ghz and Eq. (4) using frequency in M hz [4].

$$FSL = 92{,}45 + 20\log(f_{GHz}) + 20\log(D_{Km}) \quad (3)$$

or

$$FSL = 32{,}45 + 20\log(f_{MHz}) + 20\log(D_{Km}) \quad (4)$$

3) *EIRP (Effective Isotropic Radiated Power)*

EIRP is a maximum transmit power from antenna isotropic, that can be expressed as follow:

$$EIRP = P_{Tx} + G_{ant} - L_{Tx} \quad (5)$$

where EIRP is Effective Isotropic Radiated Power in dBm, P_{Tx} is transmit power (dBm), G_{ant} is gain antenna (dBi), L_{Tx} is transmitter loss (dB).

4) Isotropic Received Level (IRL)

Isotropic Received Level (IRL) is the power level value that received in the antenna receiver. The value of IRL is obtained from Eq. (6) [3].

$$IRL = EIRP - FSL \quad (6)$$

5) Received Signal Level (RSL)

Received Signal Level (RSL) is signal level that received in decoding receiver. RSL can be expressed in Eq. (7) [3]

$$RSL = IRL - G_{Rx} - L_{Rx} \quad (7)$$

where RSL is received signal level (dBm) and IRL is isotropic received level (dBm). G_{Rx} is gain antenna (dBi), and L_{Rx} is receiver loss (dB).

6) Hop-loss

Hop-loss is the difference or the difference between gain and loss on microwave links. Gain is strengthening on the other side, while loss is the amount of free damping and damping attenuation such as extra attenuation and atmosphere (water vapor and oxygen). Hop-loss is expressed by Eq. (8) [4].

$$L_h = FSL + L_{Tx} + L_{Rx} + L_{Atm} - (G_{Tx} + G_{Rx}) \quad (8)$$

where L_h is hop-loss, L_{Tx} is Transmitt loss (dB), L_{Rx} is receive loss (dB), L_{Atm} is aatmosphere loss (dB), G_{Tx} is gain receive antenna (dBi), and G_{Rx} is gain transmit antenna (dBi).

7) Fading Margin

Power reserves are often called with fading margins. In a system without diversity, fading margins can be calculated by Eq. (9) [6].

$$FM = 30\log D + 10\log(a \times b \times 2{,}5 \times f) - 10\log UnAv_{path} - 60 \quad (9)$$

where a is the factor of land earth, if a = 4 is smooth, sea, lake, and dessert, if a = 1 is for the average, a = ¼ is Mountains and highlands, and b is wheatear factor, where b = ½ for hot and humid, b - ¼ for normal area, b = 1/8 for dry mountain

This paper uses the worst cases with b =1. $UnAv_{path}$ is the possibility of path unavailability because fading is still allowed. To increase the time availability, the margin link must be increased which is called fading margin. How much dB value is required, there are several approaches. The most direct approach is the assumption that fading follows the Rayleigh distribution, so that the fading margin can be used as in Table 1.

TABLE 1. REQUIRED FADING MARGIN [3]

Single Hop Propagation Reliability (%)	Required Fading Margin (dB)
90	8
99	18
99.9	28
99.99	38
99.999	48

The amount of fading margin owned by the system is the difference between receiving power and minimum power. The minimum threshold (threshold level) is the received threshold. The relationship between fading margin with Receive Signal Level is shown in Eq. (10) [6]:

$$FM = RSL - Rx_{TH} \quad (10)$$

Where FM fading margin in dB, RSL is Receive Signal Level (dBm), RX_{TH} is Rx Threshold Level (dBm).

8) Availability

The measure of system reliability is often referred to as availability. Ideally, all systems must have 100% availability. But it cannot be fulfilled, because in the system there must be system unbalance (unavailability). Availability is often referred to as reliability defined by the ability of the system in providing services.

The opposite of availability is unavailability or outage time which means system failure in providing services. The relationship between availability and outage time is shown in Table 2, while for allowable outage time tolerance for each service is shown in Table 3.

There are two commonly method for microwave links, the Barnet Vigant and the ITU-R P.530-7/8 methods. Both are methods is used to calculate the link budget especially for availability on the system. The Barnet Vigant method is a formula to obtain the system availability value of the fading margin, including the track distance factor and working frequency. The equation can be shown in Eq. (11) [7]:

$$FM = 30\log D + 10\log(6abf) - 10\log(1 - Av_{path}) - 70 \quad (11)$$

The main factor of unavailability in the system is the existence of multipath fading and the effect of rain attenuation. Consideration for system unavailability calculation due to the existence of factors that greatly affect such as the existence of multipath fading and the effect of attenuation due to the rain. Availability can be formulated by Eq. (12) [10] :

$$Av_{path} = (1 - UnAv_{path}) \times 100\% \quad (12)$$

And for unavailability can be formulated by Eq. (13) [11],[12];

$$UnAv_{path} = a \times b \times 2{,}5 \times f \times D^3 \times 10^{-6} \times 10^{-FM/10} \quad (13)$$

TABLE 2. RELATIONSHIP BETWEEN AVAILABILITY AND OUTAGE TIME [3]

Availability or reliability (%)	Outage time (%)	Outage timer per		
		Year	Month	Day
0	100	8.760 h	720 h	24 h
50	50	4.380 h	360 h	12 h
80	20	1.752 h	144 h	4.8 h
90	10	76 h	72 h	2,4 h
95	5	38 h	36 h	1.2 h
98	2	75 h	14 h	29 min
99	1	8 h	7 h	14.4 min
99.9	0.1	8.8 h	43 min	1.44 min
99.99	0.01	3 min	4.3 min	8.6 s
99.999	0.001	5.3 min	26 s	0.86 s
99.9999	0.0001	2 s	2.6 s	0.086 s

The Outage Time Tolerance for each service is defined in table 3 [3]:

TABLE 3. THE OUTAGE TIME TOLERANCE FOR EACH SERVICE [9]

Information	Tolerant	Factor
Video	100 ms	Loss of synch
Data	10 µs	Error
Voice	100 ms	Loss

9) Barnett Vigants and ITU Models.

Generally, the design of a microwave link is between 70 km and 90 km. The microwave link is in extreme obstacle and weather conditions. To overcome these obstacles, a microwave link design is required in accurately. The two predictive models commonly used for microwave links are Barnett-Vigants and ITU-R P. 530. Both prediction models have different results from unavailability caused by multipath, as well as for space diversity. The difference between the two prediction models is also observed about the unavailability caused due to rain factor [8].

E. *Unavailability caused by Multipath*

Unavailability caused by multipath factor is a general problem in microwave link design. This situation can indicate an outage probability with diversity antenna and other techniques used to reduce the propagation effect. In this paper, there are two options for calculating unavailability in the B-V model. The parameters of the two models such as Flat Fade Margin (FFM = A), frequency (f) and distance (d). One of the additional parameters used in the BV Model is C factor, while the three additional parameters used in ITU models are geoclimatic of K factor, Link inclination | εp |, and the lowest altitude antenna (above the sea level) hL. The outage probability can be expressed in a percentage (%) as follows [8]:

B-V model:

$$P_w = \left([6.10^{-7} C f d^{3.0}] 10^{-A/10}\right) \times 100 \qquad (15)$$

ITU Models:

$$P_w = K d^{3.0} \left(1 + |\varepsilon_p|\right)^{-1.2} \times 10^{0.033 f - 0.001 h_L - A/10} \qquad (16)$$

where d is distance or microwave in kilometers, f is carrier frequency in GHz, C is a factor, K is geoclimatic factor, $|\varepsilon p|$ is link inclination (mrad) hL is antenna lower height (meter), A is flat fade margin (dB) [8].

Distance and frequency are two reasons that cause significantly differences in worst month unavailability because of multipath. In real case, the unavailability factor is influenced on distance.

F. *Diversity Methods*

The mathematic calculation in both methods is the same. Only the space diversity gain (I-sd) as Eq. (2) is the gain difference between the main antenna and the diversity antenna at the receiving end, and Eq. (16) and Eq. (17) as the equation for separating the two antennas.

B-V baseband switching systems

$$I_{sd} = 1.2 \cdot 10^{-3} \cdot \frac{f}{d} S^2 v^2 10^{A/10} \qquad (16)$$

B-V IF combining systems

$$I_{sd} = 1.2 \cdot 10^{-3} \cdot \frac{f}{d} S^2 \frac{16 \cdot v^2}{(1+v)^4} 10^{A/10} \qquad (17)$$

where S is the distance between the main antennas and antenna diversity (m), v is margin of gain antenna (dB), such as $v \leq 1$ dan $v_{dB} \leq 0$, f is carrier frequency (GHz), d is the distance of microwave link (km), A is flat fade margin (dB). For special cases: $v_{dB} = -|G_1 - G_2|$.

The value of diversity can be calculated in two difference ways, non selective and selective fading with radio signature methods. The basic formula can be used as non selective outage probability with space diversity.

III. SIMULATION DESIGN

A. *Research Instrument*

On microwave transmission network design in this research using software Planning and the data was obtained from PT. XXX in the form of point coordinates in Sumatera Barat Province, such as Latitudes, Longitudes, and elevation. Then the antenna data, radio data and rain data be set into the software as matter of observation. Latitude, longitude and elevation data has been used to create hop link, while antenna, Tx Lines and rain parameters data for input data as hop link parameters in software Planning. Data searches have been done for a week

B. *Research Location*

The locations that have been observed in accordance with the data which was obtained from PT. XXX Jakarta Selatan are in form of microwave network data between two BTS in Sumatera Barat, which are BTS Karang Tinggi and BTS Merantau as a hop link. BTS Karang Tinggi are located in point of coordinate latitude 03 44 40.00 S and longitude 102 25 25.00 E, while BTS Merantau are located in point of coordinate latitude03 24 29.00 S dan koordinat longitude 102 52 05.00 E, with distance between both BTS are 61, 82 km. the planning of site passive repeater 1 are located in latitude 03 40 11.00 S dan longitude 102 31 34.00 E , the last planning of site passive repeater 2 are located in latitude 03 34 26.00 S and longitude 102 38 53.00 E.

C. *Desain of research*

1) Data Collection Method

a. Case Study
Case study is research method which is used to accomplish this research. The case study was conducted in PT. XXX Jakarta Selatan to complete study material which be required according as research object.

b. Literature Study
On literature study which has been done in this research by obtained material data that correspond with problems using several reference from books, science journal and internet.

2) Analysis Method

Analysis method that has been used between two sites is observing the availability in the hop link. The hop link is not LOS (Line of Sight) and has an effect the value of availability, so passive repeater was created between BTS Karang Tinggi and BTS Merantau. The research also compared in 2 two methods to implement this hop link planning, Barnett-vigants and ITU-R P-530 7/8 method.

3) Work Planning

Work planning of this research has been illustrated on the following flowchart Fig. 7.

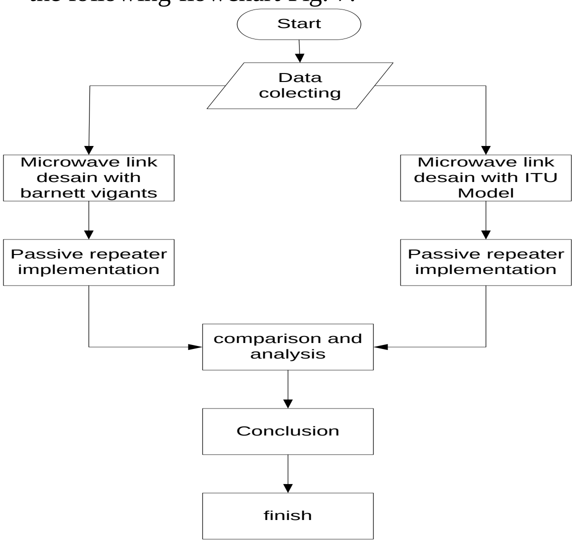

Fig. 4. System Flowchart

D. *Data Processing Design*

Microwave link is created by set all parameters into software planning such as transmission analysis, terrain data, multipath, and antenna height. The parameters which be set in transmission analysis are antenna, radio, rain and path profile. This research observed and analyzed the comparison of link microwave passive repeater design using two methods, Barnett-vigants and ITU-R P-530 7/8 models

E. *Data Analysis Design*

Analysis be conducted by comparing the link microwave passive repeater result between Barnett Vigants and ITU.R P-530 7/8 method. The use of two prediction method is to obtain microwave link planning accurately. Both of prediction methods have different result of availability that caused by multipath and also rain factor. The analysis also is done to non-line of sight microwave link, so, passive repeater was created to regenerate radio signal and change the direction of radio radiation. So, this research also analyzed the comparison passive repeater microwave link that using Barnett Vigants method and passive repeater microwave link that using ITU.R P-530 7/8 method by measuring the availability.

The microwave link was created without passive repeater using Barnett vigants. Then the Terrain data of sites was filled in terrain data menu on each microwave link to generating path profile. The antenna height was calculated in antenna height menu. For rain intensity factor was chosen the high intensity, because Indonesia is a country which have rain highly frequent. Then transmission analysis has to be adjust according the real data from the site to result availability value. Availability is a measure to reliability system. If the availability value no exist in report, it means the microwave link cannot be create, so passive repeater is needed to be created in this situation. Similar way be done to microwave link planning using ITU.R P-530 7/8. The result of microwave link planning would be compared for both of methods according the report from software Planning

.

IV. RESULT AND DISCUSSION

The analysis and result of the research are discussed about the comparison of microwave transmission network between two prediction method, Vigants Barnett and ITU-R P.530-7/8 method. The purpose of two methods on this microwave transmission network is to find the better and accurate method. On this research also will be analyzed the application of passive repeater on microwave transmission network and the comparison using link budget calculation. There is obstacle between BTS Karang Tinggi – BTS Merantau is in form of mountain, so the microwave transmission network cannot fulfill the line of sight microwave transmission network standard. Non-Line of Sight microwave transmission network can caused fail of system, because the transmitted signal cannot be received well in receiver device. This is because the signal encounter with scattering, reflection, refraction and also attenuation in path of communication.

To solve this problem, passive repeater can be implemented between transmission line paths. The next step of microwave transmission network design is passive repeater implementation. There are two kind of passive repeater, back to back antenna and passive repeater reflector. Passive repeater that be used in this research is back to back antenna. The characteristic of this passive repeater is forwarding the information signal from transmitter antenna to receiver antenna. So, signal that have been transmitted from Karang Tinggi to Passive Repeater, when the signal was received by passive repeater, the information signal gained amplification from passive repeater antenna before resent it to Merantau. So, information signal which was transmitted to Merantau was gain amplification from back to back antenna passive repeater and was well received by the receiver BTS. While, reflector passive repeater worked as mirror which reflect signal dorm transmitter antenna to receiver antenna. When reflector passive repeater used, signal does not gain amplification, because the passive repeater only reflect the signal. On this research was implemented two passive repeater, between BTS Karang Tinggi to BTS Merantau, because the terrain topology have more than one obstacle. Table 3 is a table which explains the comparison between microwave transmission network with passing repeater and without passive repeater.

TABLE 4. MICROWAVE TRANSMISSION NETWORK WITH NON PASSIVE REPEATER AND PASSIVE REPEATER

Site	Link Budget	Vigants Barnett	ITU-R P.530 7/8
Krg Tinggi – Merantau (%)	100	-	-
Krg Tinggi - Pas Rep 1(%)	99.998	99.942	99.949
Pas Rep 1 - Pas Rep 2(%)	99.995	99.926	99.931

Pas Rep 2 - Merantau(%)	99.97	99.909	99.965
Kar Tinggi - Pas Rep – Merantau (%)	99.989	99.926	99.957

On table 3, indicates microwave transmisi network before and after passive repeater implementation. In BTS Karang Tinggi to BTS Merantau there are obstacles which cannot be avoided in form of mountains, so that a system failure and the transmitted signal cannot be received. That is proofed on table 3, according the calculation Availability value between BTS Karang Tinggi to Merantau is -2,487×1011, and the availability value cannot be detected in simulation using Software Planning with Barnett Vigants or ITU-R P.530 7/8 method. So, it can be concluded that reliable system has availability more than 99.9%, so outage time that can be occurred less than 0.01%. it means the failure system occur less than 8,8 hour every year, 43 minute every month and 1,44 minute every day on this microwave transmission network. Fig. 8 is microwave transmission network planning with passive repeater using Planning.

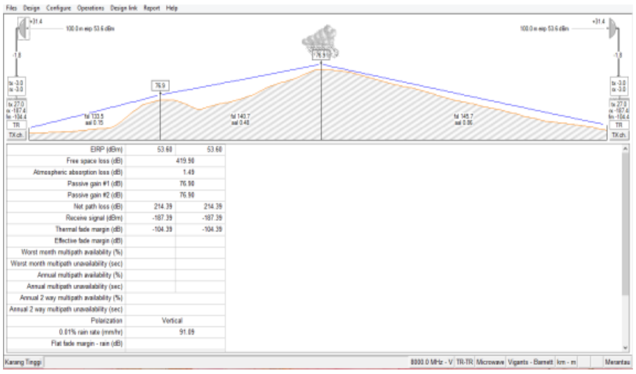

Fig. 5. Karang Tinggi – Merantau with Passive Repeater Using Software Planning.

V. Conclusion

According microwave transmission network analysis design, it's can be concluded that:

- The function of Back to back antenna passive repeater is to forwarding signal. The signal which be received by passive repeater will gain the amplification before retransmitted to Merantau site.
- There is big different result of microwave transmission network Software Planning simulation planning using Vigants Barnett and ITU-R P/530 7/8, especially about unavailability which caused by multipath factor. On a microwave transmission network using the Barnett Vigants method, resulting higher unavailability value than the use of ITU-R method P.530 7/8. The unavailability value using Barnett Vigants method obtained was 0.023%, it means the outage time of link microwave is 7244 second per year. If compared with metode ITU-R P.530 7/8 method, the unavailability was 0.000087 % or outage time system is for 26 second per year. So the availability using ITU-R P.530 7/8 method is 99.9999133%.

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