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Communication Design in the Indonesian Archipelago: The Microwave Link between Manado-Sangihe

Endang Retno Nugroho¹, Ruliyanta¹, Rianto Nugroho^{1,2}, R.A. Suwodjo Kusumoputro¹,
Anisa Prakastia³

Lecturers, Department of Engineering and Science, National University, Jakarta, Indonesia¹

CEO of Nesindo Integration, NEC Indonesia, Jakarta, Indonesia²

U.G. Student, Department of Engineering and Science, National University, Jakarta, Indonesia³

ABSTRACT: Indonesia, which has a geographical area consisting of islands, uses microwave communication as the backbone. One of the islands in Indonesia is Sangihe Island. Construction of a communication network between Manado-Sangihe which crosses several islands using a microwave radio communication system with SDH (Synchronous Digital Hierarchy) technology. The choice of communication with microwave radio on this link is due to the current use of VSAT (Very Small Aperture Terminal) technology in Sangihe with limited capacity. Microwave systems propagate in Loss of Sight or free space, so there is no need for a physical channel in the form of cables to cross the sea. The LOS condition is the main requirement that must be met in building microwave radio communications. We did the planning using Pathloss software and the trajectory was from Manado City, Biaro Island, Siau Island, and Sangihe Island. The result of our design is to get an Availability value of 99.67%. This result is very close to the margin limit required by the ITU-T G.821 standard, which is 99.95%. To solve this problem, we use the diversity technique, and its Availability increases to 99.99%.

KEYWORDS: Microwave, Synchronous Digital Hierarchy, Pathloss, Fading Margin.

I. INTRODUCTION

According to Cisco 2016, Indonesia has the highest internet growth in the world. With Indonesia's geography, which consists of thousands of islands, to support this growth, good and sufficient infrastructure is needed[1]. Sangihe Islands Regency is a regency located in North Sulawesi Province. Sangihe Islands Regency is located between Sulawesi Island and Mindanao Island (Philippines) and is located on the lips of the Pacific Ocean. This island is located far from the center of the capital city of North Sulawesi Province, namely Manado, so that it becomes one of the obstacles in the communication process for the existing community.

For communication facilities in the Sangihe Islands Regency, cellular operators are currently still using satellite communication technology[2]–[5]. With the limited capacity of the channel, it is necessary to have an alternative communication system[3], [5].

There are several alternative communication systems that can be used Fiber Optic[6], and Microwave Radio[4], [5], [7]. Communication systems using copper and fiber optic cables will require high costs, in addition to building an underwater network, it will take quite a long time. Meanwhile, to build a microwave communication system the construction and maintenance costs are cheaper and do not require a long time[8].

The objection of this research is to design a microwave radio communication system between Manado City and Sangihe Island. In this design used SDH technology with STM-1 capacity. For the implementation process, there are 3 hops, namely the Sangihe Islands, Siau Island, Biaro Island, and Manado (North Sulawesi Island). The novelty in this research is the availability of microwave link designs in the Indonesian archipelago.

II. RELATED WORK

Microwave radio transmission system is a transmission system that uses radio waves to transmit data or information from the sender (Tx) to the receiver (Rx) with a frequency above 1GHz. Microwave transmission waves are transversal with a super high frequency (SHF, Super High Frequency) with a wavelength ranging from 0.3 to 300 cm. We did the planning using Pathloss software.

There are two types of microwave transmission systems, namely analog microwave transmission systems and digital microwave transmission systems [5]. A radio transmission system can be a hop with a maximum distance of 50km or a

backbone consisting of multiple hops with hundreds to thousands of km. The purpose of a microwave radio communication system is to transmit information from one place to another without interference [4], [5], [7], [9].

A. Wave Propagation

Wave propagation is the propagation of waves in the propagation medium. The propagation media can be in the form of physical media such as copper media, conductors, while for non-physical media it can be in the form of radio waves [10].

B. Fresnel Zone

The Fresnel zone or Fresnel zone is the locus of indirect signal points in the form of an ellipse on the radio path, where the wave is limited by indirect waves which have a different length path with the direct signal, which can be calculated using Equation 1 [11].

$$F_1 = 17.3 \sqrt{\frac{d_1 d_2}{f d}} \quad (1)$$

C. Altitude Correction

Altitude correction is needed because in the process of describing the condition of the spherical earth, this influences the height of the obstacle along the trajectory as in the Equation 2 [12].

$$h_k = \frac{d_1 d_2}{12.75 x K} \quad (2)$$

where:

h_k = height correction (m) to sea level

K = curvature factor of the earth (constant)

d_1 & d_2 = distance (Km) from the terminal to the obstacle course.

D. High Clearance

High Clearance is the distance between the main axis of the radio wave trajectory and the peak of the obstacle. For the Line of Sight (LOS) requirements to be met, the magnitude of the obstacle height must be calculated at the point where the highest obstacle is located, as given in Equation 3 [12].

$$h_c = \frac{h_1 d_2 + h_2 d_1}{d} - h_k - h_s \quad (3)$$

where:

h_c = obstacle height (m) above sea level

h_1 = height of the 1st antenna (m) above sea level

h_2 = height of the 2nd antenna (m) above sea level

h_k = height correction (m) to sea level

h_s : obstacle height (m) above sea level

d_1 & d_2 : distance (Km) from terminal to obstacle course

E. Link Budget

The nominal receiving signal level is used to indicate how much power the receiving antenna can receive. The link budget calculation is given in Equation 4.

$$R_{SL} = P_t + G_{Total} - L_{Transmission} \quad (4)$$

R_{SL} = received power level (dBm)

P_t = transmission power (dBm)

G_{Total} = the total gain of the antenna Rx and Tx (dB)

$L_{Transmission}$ = transmission attenuation (dB)

F. Free Space Loss

Free space loss is the attenuation of the signal resulting from the LOS (Line of Sight) path that passes through free space (air) without any obstacles that cause reflection or diffraction. Free space loss propagation is used to predict the received signal level when Tx and Rx have a direct path so that the attenuation characteristics along the path are obtained without any barrier data, this is given in Equation 5.

$$FSL = 32.44 + 20 \lg f + 20 \lg D \quad (5)$$

where:

FSL = free space attenuation (dB)

D = track distance (Km)

f = frequency (MHz)

G. Transmission Attenuation

The propagation of the signal will experience degradation caused by atmospheric conditions, the earth's surface, and attenuation in the transmission line. To calculate the transmission attenuation, Equation 6.

$$L_{\text{Transmission}} = FSL + L_b + L_f + L_{\text{rain}} + L_{\text{atm}} + L_o \quad (6)$$

where:

FSL = free space loss (dB) attenuation

L_b = attenuation at the transmitter and receiver branching line (dB)

L_f = attenuation of transmitter and receiver feeders (dB)

L_{rain} = rain attenuation (dB)

L_{atm} = the propagation atmospheric attenuation (dB).

H. Atmospheric Attenuation

Based on the recommendation of ITU-R P.676.3 the atmospheric attenuation can be calculated by Equation 7.

$$L_{\text{atm}} = I_{\alpha} \times d \quad (7)$$

where:

$I_{\alpha} = 0.0524$ dB/Km

d = track distance (Km)

I. Rain Attenuation

Based on the recommendation of ITU-R P.837-2, the rainfall condition in Indonesia is 145 mm/hour, then the rain attenuation can be calculated by Equation 8.

$$L_{\text{rain}} = IR \times d_{\text{eff}} \quad (8)$$

where:

$IR = K \times R^{\alpha}$

$d_{\text{eff}} = d \times r$

$r = \frac{1}{1 + d/d_o}$

$\alpha = 1.322$

$d_o = 7.810$

K = Climate Factor

R = Rainfall

J. Fading Margin

Fading Margin is the difference between the nominal received signal level and the minimum received signal level (threshold), which corresponds to the desired Bit Error Rate (BER). Flat Fading Margin (FFM) is calculated to overcome errors caused by thermal noise.

By definition, a flat fading margin is the same as fading margin, namely the ratio of the level between the nominal received signal and the minimum signal level. Calculated by Equation 9.

$$FFM = RSL - R_{x(\text{Threshold})} \quad (9)$$

where:

FFM = Flat Fading Margin

RSL = received power level (dBm)

$R_{x(\text{threshold})}$ = threshold level of the receiver's thermal noise (dBm)

K. Outage Probability for Systems without Using Diversity Techniques

Based on the recommendation of ITU-R P.530-8 to calculate the total system outage probability, Equation 10 is used.

$$P_t = P_{ns} + P_s + P_{xp} \quad (10)$$

where:

P_{ns} = the probability of outage due to non-selective fading

P_s = the probability of outage is due to selective fading

P_{xp} = probability of outage due to xp degradation

L. Non-Selective Outage Probability

The probability of outage due to non-selective fading components can be calculated by Equation 11 based on the recommendation of ITU-R P.530-8.

$$P_{ns} = \frac{P_w}{100} \quad (11)$$

where:

P_w = percentage of time where the flat fading margin corresponds to the BER that exceeds the average value for the worst month

M. Synchronous Digital Hierarchy

In the ITU-R recommendation G.708, SDH (Synchronous Digital Hierarchy) transmission is defined as a technology that has a hierarchical transport structure and is designed to transport information (payload) that is appropriately adjusted in a transmission network. SDH transmission is a digital transport network that transmits information signals from one place to another with high flexibility and can transmit SDH signals. In addition, SDH transmission has a very large transmission capacity. The standard table of SDH hierarchical levels is given in Table 1.

TABLE 1SDH HIERARCHY

Level Hierarki	Bit Rates	STM-n
1	155,52 Mbps	STM-1
4	622,08 Mbps	STM-4
16	2,5 Gbps	STM-16
64	10 Gbps	STM-64

N. Location Determination

The location determination in this plan has gone through several trials by considering road access and geography. Table 2 is a list of routes that you want to design. The purpose of determining the radio link route is to obtain data such as distance, azimuth, contours, and high points of obstacles along the path. Table 3 is a list of planned radio links. The design map is given in Figure 1. Image captured from Google Maps

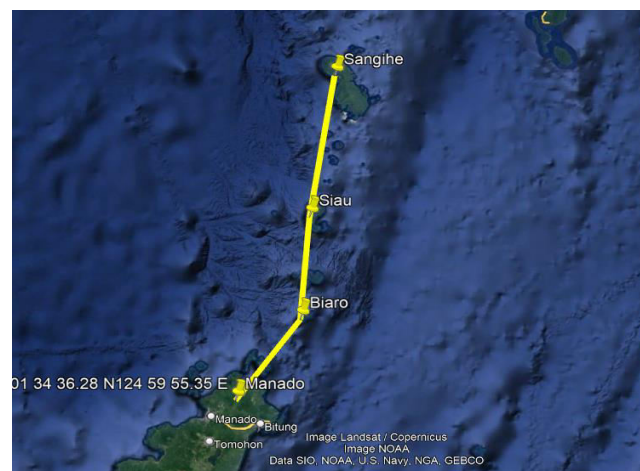


Fig. 1 Radio Link Design Map

TABLE 2DESIGN ROUTE

Site	Longitude	Latitude	Elevation
Manado	124 59 55.35 E	01 34 36.28 N	458 m
Biaro	125 20 35.98 E	02 05 07.92 N	125 m
Siau	125 22 07.32 E	02 43 09.57 N	412.3m
Sangihe	125 28 29.16 E	03 36 56.42 N	44.7 m

TABLE 3RADIO LINK DESIGN

Site-A	Site-B	Distance	Mark
Sangihe	Siau	99.81 Km	LOS
Siau	Biaro	70.14 Km	LOS
Biaro	Manado	68.08 Km	LOS

III. RESULTS

To perform the calculations, some data and radio link parameters are needed which will be calculated based on the quantities as shown in Table 4.

TABLE 4 RADIO LINK PARAMETER

Parameter	Unit	Site 1	Site 2
Site name		Manado	Biara
Distance	Km	68.08	68.08
Elevation	mASL	458.00	125.00
Frequency	MHz	6700	6700
Antenna High	m	34.5	25
Antenna diameter	m	3.6	3.6
Antenna gain	dBi	42.5	42.5
Traffic Capacity		STM ⁻¹	STM ⁻¹
Power transmits (PTx)	dBm	33	33
Threshold (10 ⁻⁶)	dBm	-74.60	-74.60
Rainfall	mm/h	145	145

A. Manado-Biara Link Budget Calculation

The path profile for the Manado-Biara site is shown in Figure 2. In Figure 2(a), the Manado-Biara line uses a frequency of 6.7 GHz with a Manado antenna height of 31.5 m and a Biara antenna of 25 m. The transmission line looks LOS because it is not blocked by the contours of the earth or the structure of the trees and according to available data, the Manado-Biara line is suitable for microwave radio transmission lines.

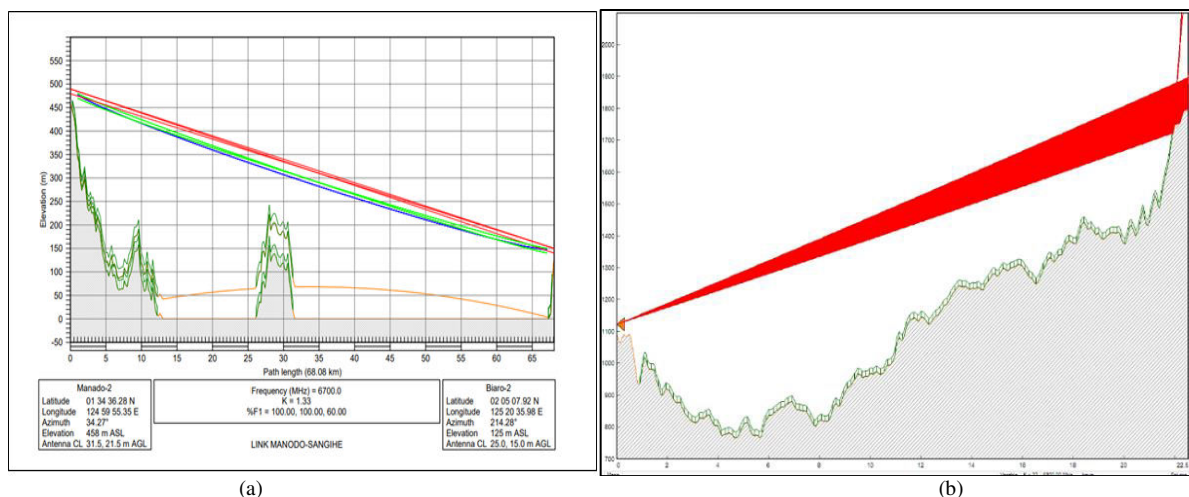


Fig. 2 Path Profile and Multipath (a) Path Profile Manado-Biara (b) Multipath Manado-Biara

In Figure 2 (b) the path of the transmission signal from the transmitter (Tx) to the receiver (Rx) does not show any multipath. Multipath is a form of interference or interference that occurs when a signal has more than one path at the time of transmission. Propagation of multipath will cause the received information to be flawed.

After going through the calculations, we get the results of the Manado Biara link design as shown in Table 5. Our first design uses a system without diversity. to improve design performance, we use diversity.

B. Bio-Siau Link Budget Calculation

The path profile on the Biara-Siau site can be described as shown in Figure 3(a). Figure 3(a) the Biara-Siau line uses a frequency of 6.7 GHz with a Biara antenna height of 27 m and a Siau antenna of 25 m. The transmission line looks LOS because it is not blocked by the contours of the earth or the structure of the trees and according to the available data, the Biara-Siau line is suitable for microwave radio transmission lines. Figure 3(b) is the Biara-Siau multipath.

TABLE 5 THE RESULTS OF THE MANADO-BIARO LINK DESIGN

Parameter	Non-Diversity	Diversity
Fresnel	12,17816 m	12,17816 m
Altitude correction	13,329 m	13,329 m
Fresnel Zone	928,71 m	928,71 m
Attenuation	155,04 dB	155,04 dB
Gain antenna	45,176 dBi	45,17 dBi
Receiving Signal Level (RSL)	-31,68 dBm	-31,68 dBm
Flat Fading Margin (FFM)	42,91408 dB	42,91408 dB
Geoclimatic Factor	4.37×10^{-4}	4.37×10^{-4}
Trajectory Slope Magnitude	4,986 mrad	4,986 mrad
Pw	0,039279	0,039279
Probabilitas Outage Non-Selective	$3,9279 \times 10^{-4}$	$4,07798 \times 10^{-6}$
Multipath Occurance	7,68372	7,6836
Multipath Activity	3,5089	3,50899 ns
Mean Time Delay	1,239056 ns	1,045 ns
Probabilitas Outage Selective	$3,58952 \times 10^{-3}$	$2,55327 \times 10^{-3}$
Probabilitas Outage Total	$3,98231 \times 10^{-3}$	$7,55803 \times 10^{-5}$
Availability	0,99601	0,99992442

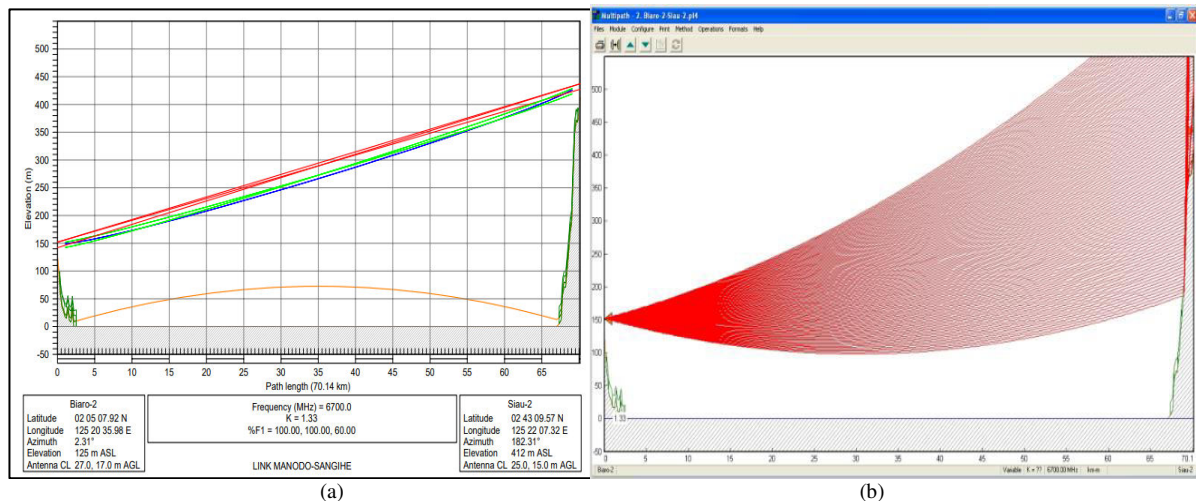


Fig. 3Path Profile and Multipath (a) Path Profile link Biaro-Siau(b) Multipath Biaro-Siau

The results of the design calculations are given in Table 6 below.

TABLE 6THE RESULTS OF THE BIARO-SIAU LINK DESIGN

Parameter	Non-Diversity	Diversity
Fresnel	7,077 m	7,077 m
Altitude correction	4,638 m	4,638 m
Fresnel Zone	17,729 m	17,729 m
Attenuation	145,880 dB	145,880 dB
Gain antenna	45,176 dBi	45,176 dBi
Receiving Signal Level (RSL)	-31,409 dBm	-31,409 dBm
Flat Fading Margin (FFM)	43,191 dB	43,191 dB
Geoclimatic Factor	4.37×10^{-4}	4.36×10^{-4}
Trajectory Slope Magnitude	4,063	4,063 mrad
Pw	0,051867	0,051
Probabilitas Outage Non-Selective	$5,1867 \times 10^{-4}$	$4,07798 \times 10^{-6}$
Multipath Occurance	10,8143	10,633
Multipath Activity	3,5089	0,692 ns
Mean Time Delay	1,276 s	1,086 ns
Probabilitas Outage Selective	$4,60208 \times 10^{-3}$	$5,438 \times 10^{-4}$
Probabilitas Outage Total	$5,12075 \times 10^{-3}$	$3,926 \times 10^{-5}$
Availability	0,994879	0,99996974

C. Siau-Sangihe Link Budget Calculation

Like the previous design, Figure 4 (a) is the Siau-Sangihe Path Profile Link, and Figure 4 (b) is the Siau-Sangihe Multipath link. Furthermore, with the same method in the previous section, we obtained the simulation results with the results in Table 7 below.

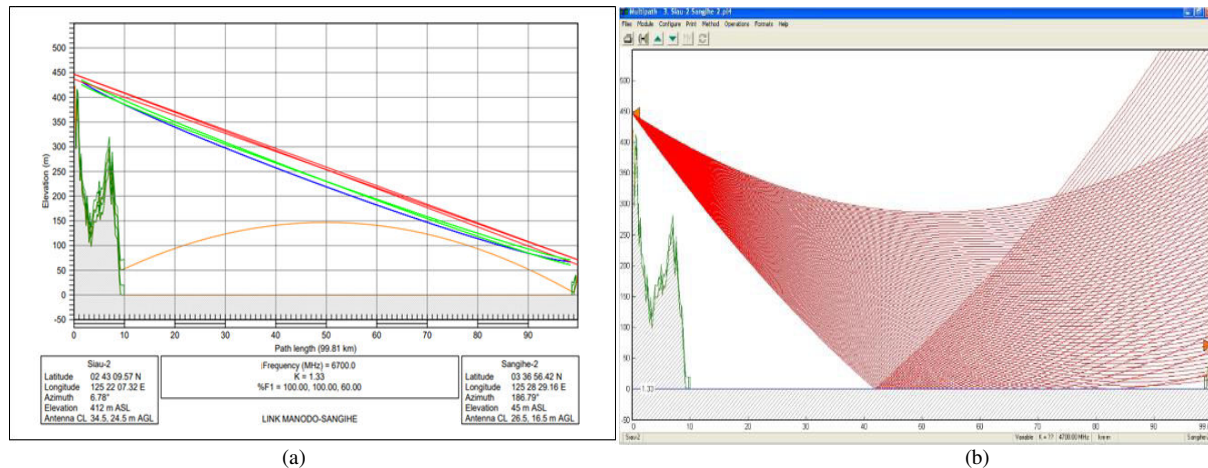


Fig. 4 Path Profile and Multipath (a) Path Profile Link Siau-Sangihe (b) Multipath link Siau-Sangihe

TABEL 7 THE RESULTS OF THE SIAU-SANGIHE LINK DESIGN

Parameter	Non-Diversity	Diversity
Fresnel	4,71414 m	4,71414 m
Altitude correction	2,928 m	2,928 m
Fresnel Zone	12,021 m	12,021 m
Attenuation	160,291 dB	160,291 dB
Gain antenna	45,17698 dBi	45,17698 dBi
Receiving Signal Level (RSL)	-36,93701 dBm	-36,93701 dBm
Flat Fading Margin (FFM)	37,66299 dB	37,66299 dB
Geoclimatic Factor	4.37×10^{-4}	4.37×10^{-4}
Trajectory Slope Magnitude	3,7604 mrad	3,7604 mrad
Pw	0,71898 dB	0,71898
Probabilitas Outage Non-Selective	$7,18985 \times 10^{-3}$	$1,050179 \times 10^{-3}$
Multipath Occurance	41,97771	41,97742
Multipath Activity	9,96578 ns	9,965744 ns
Mean Time Delay	1,816 s	1,7193 ns
Probabilitas Outage Selective	0,02189	0,0196288
Probabilitas Outage Total	0,02907	$3,8254 \times 10^{-4}$
Availability	0,97092	0,9996174

IV. DISCUSSION

In planning the communication system between Manado City and Sangihe Island using Microwave Radio, 3 hops are needed. With SDH technology currently having a standard of 8 x STM-1, the bandwidth that can be provided is 1,224 Gbps. This SDH technology adopts the 2048 QAM modulation technique[13].

The amount of availability can be increased in various ways, either by diversity, increasing the height of the antenna, or increasing the transmitter power. In this research, to increase the level of availability, then the space diversity technique is used in planning. This technique has succeeded in providing outage and availability

V. CONCLUSION

Based on the results of the design and calculation of the link budget between Manado-Sangihe using microwave radio using 3 hops, namely Manado-Biaro, Biaro-Siau, and Siau-Sangihe. To increase the availability of the designed link, diversity techniques are used. With the implementation of the SDH system, the bandwidth that can be used is 8 x STM-1, or the equivalent of 1.244 Gbps.

The result of our design is to get an Availability value of 99.67%. This result is very close to the margin limit required by the ITU-T G.821 standard, which is 99.95%. To solve this problem, we use the diversity technique, and its Availability increases to 99,99%.

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