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Analysis of Cross-Ocean Microwave Communication Systems Using Point-To-Point, Space Diversity and Hybrid Diversity Configurations

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Abstract —Microwave communication is still important to use in the backhaul network of telecommunications systems because it can reach remote areas that are difficult to reach by cable technology. One of the implementations is cross-ocean backhaul communication which is widely applied in the archipelago. So, to reach the remote areas, proper backhaul network planning is required. A point-to-point microwave transmission network can be a solution to reach remote areas of islands separated by oceans. The problem that occurs is that the multipath fading on the ocean route is quite large so that to overcome this we need a diversity technique. There are various diversity configurations such as space, frequency, and a combination of both or Hybrid. Based on the simulation and theoretical calculations, concluded that point-to-point configuration producing the quality of communication below the standards set by the ITU-R (ITU-T G.821). The use of space diversity and hybrid diversity provided a significant increase in the quality of communication both in terms of availability, un-availability, and fading margin.

Index Terms—Microwave, cross-ocean, space diversity, hybrid diversity, availability

I. Introduction

Information and communication technology in Indonesia is developing rapidly. Statistics Indonesia noted that users of ICT services increased by 63.53% in 2019 [1]. Also, in terms of quality, the development of ICT technology is getting faster, for example, 4G services can provide download speeds of up to 100 Mbps [2]. Therefore, proper infrastructure planning is the key to the equitable deployment of ICT in Indonesia [3].

The challenge is Indonesia has a very large archipelago, thus requiring good telecommunication network planning from access to backhaul. The deployment of a backhaul network using optical fiber has been implemented by the Indonesian government through the Palapa Ring project [4]. However, not all remote areas can be covered by optical fiber, so microwave technology can be used in these conditions. The microwave radio communication network still has an important role in the even distribution of ICT infrastructure in Indonesia, because it can reach all places that are impossible to reach using cable technology. So, to overcome the interference obtained from geographical conditions, it is necessary to design an appropriate microwave link [5].

The implementation of microwave network deployment can reach remote areas across the ocean. For example, in Pekajang Island of Riau Islands Province, which was originally an isolated area of ICT services, now people can enjoy ICT services because it uses VSAT satellite technology as a backhaul network [6]. However, microwave communication technology can be used as an alternative in the area by connecting it to the nearest microwave network on Bangka Island. Also, the advantage of using microwave communication is that it is cheaper to deploy than satellite technology [7].

In general, microwave communication systems use a point-to-point configuration where there are two antennas, namely a transmitter which functions as a medium for sending signals, and a receiver that functions as a medium for receiving signals [8]. However, the most common problem in microwave communication is multipath fading. Multipath fading is a disturbance caused by multiple trajectories so that the transmitted signal is reflected by objects such as houses, buildings, trees, vehicles, and other objects between the sender and the receiver. Another disturbance that occurs in microwave communication is the influence of the atmosphere in the form of signal absorption and refraction [9].

So, to overcome the interference that occurs in microwave communication, the techniques commonly used are diversity configurations [10]. Diversity is a technology that is applied to the reception of a communication system which is basically to overcome the effect of fading that occurs in the microwave communication pathway and the operation of this system is carried out by two or more systems simultaneously to improve the quality of the received signal [11]. Examples of technique diversity are space diversity, frequency diversity, and hybrid diversity [7].

The main quality indicators for microwave networks are Availability and Un-availability [6]. Availability measures the reliability of a communication system while Un-availability calculates the length of time the system fails in a certain period, either annually or monthly. Both

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indicators are influenced by many factors such as geographical conditions of the area, frequency usage, and specifications of the equipment used. The quality of microwave communication has been standardized by the International telecommunication Union on recommendation ITU-R G.821-G827, this recommendation applies to both short-haul and long-haul routes [5].

A study entitled "Analysis of Microwave Communication Network Planning on Ocean Topography Using Space Diversity" by Arrizky Ayu Faradila Purnama, concluded that the link budget value of the planning using space diversity technique has better results than that of the plan without space diversity technique. The results of this study indicate that the use of the space diversity technique is proven to be able to increase the reliability value of the network [12]. Meanwhile, another study entitled "Design of a Digital Microwave Transmission System Backhaul Network Using Frequency Diversity in the Riau Islands Region" by Yosy Rahmawati published in the Techno Journal concluded that the design of a microwave transmission system using a frequency diversity is feasible to be implemented because it has a system reliability value above the threshold based on ITU-R G.827 and F.1703 standards [13].

So, the author wrote a paper entitled "Analysis of Cross-Ocean Microwave Communication Systems Using Point-To-Point, Space Diversity and Hybrid Diversity Configurations". This paper is the result of research from a design carried out using point-to-point, space diversity, and hybrid diversity configuration models which are simulated using the Pathloss 5.0 application, in a cross-ocean communication system between Pekajang Island and Bangka Island. Then analyze and compare the results of the simulation and observe changes in microwave communication quality parameters such as Availability, Unavailability, and fading margin.

The paper consists of the following sections. In section II, we describe the Research Method. Section III discussing about the Result of the simulation and the analysis. In Section IV describe the discussion. In Section V describe the conclusion of the research.

II. Research Method

A. Research Design

This study analyzes the quality performance of microwave communication links using point-to-point configurations, space diversity, and hybrid diversity implemented across the ocean between Pekajang Village, Riau Islands Province to Air Jukung Village, Bangka Belitung Province. This link extends up to 71.29 km using a 2 GHz radio frequency and vertical polarization. The design of the microwave network and link budget using Pathloss 5.0 software. The data used to simulate the design of this microwave network are data longitude, latitude, elevation, antenna height from both sites, antenna type data, microwave radio, and data transmission lines. Meanwhile, the dependent variable is the microwave link performance indicators such as availability, un-availability, and fading margin as illustrated in Fig. 1.

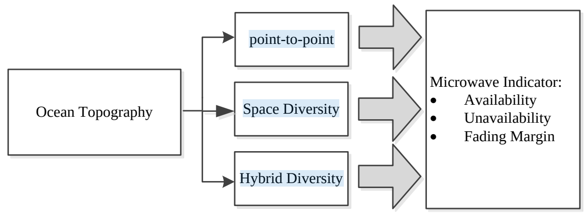

Fig. 1. Variables of research

B. Microwave Radio Communication System

Microwave radio communication is a transmission medium through air channels to transmit information from source to destination without a barrier or Line of Sight. The basic propagation mechanism is Line of Sight (LOS), which is a radio wave path that follows the line of sight, which means that there is no obstacle between the transmitting antenna and the receiving antenna, which obstructs the path of the microwave propagation, as described in Fig. 2 [3].

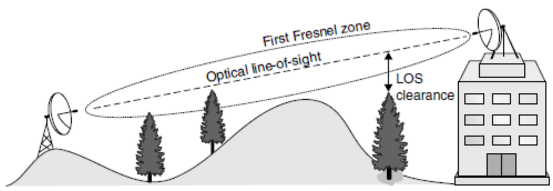

Fig. 2. Line of sight propagation [14]

The important thing to consider in designing microwave communication is multipath fading. This causes signal dispersion, which is a problem in high bit-rate digital LOS links [9]. Multipath fading is the dominant fading mechanism for frequencies lower than 10 GHz. A reflected wave causes a phenomenon known as multipath, meaning that the radio signal can travel multiple paths to reach the receiver. Typically, multipath occurs when a reflected wave reaches the receiver at the same time as the direct wave that travels in a straight line from the transmitter, it causes signal degradation at the receiver [3].

Multipath fading can occur due to many things, including terrain effects and atmospheric effects. Terrain effect is an effect caused by a barrier or obstacle blocking the Line of Sight area in microwave radio communications [14]. The phenomenon that occurs in the terrain effect includes reflection, diffraction, and scattering. While the atmospheric effects a variety of weather and climatic phenomena such as air temperature (temperature), air humidity, rain, and wind incidence which influences the reliability of microwave communication. Phenomena caused by atmospheric effects include signal absorption, signal refraction, ducting and signal attenuation caused by rain [10].

C. Link Budget Calculation

The calculation of the link budget is needed to determine the suitability between design and theory. Then, the parameters of the link budget calculation are as follows,

a) Antenna Gain

Antenna gain measures the antenna's ability to transmit the desired wave in the intended direction [10]. Antenna gain can be found by the following equation

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

where f is the frequency in GHz, d is the diameter of a parabolic antenna in meter, and η is antenna efficiency in percentage.

b) Free Space Loss

Free Space Loss is the attenuation which directly proportional to the square of distance and frequency and gives the free-space loss that represents most of the total attenuation caused by wave propagation effects [9]. The frequency and distance dependence of the loss between two isotropic antennas is expressed in absolute numbers by the following equation

$$FSL = 92{,}45 + 20 \log D + 20 \log f \quad (2)$$

where D is the distance in kilometers and f is the frequency in GHz.

c) Effective Isotropic Radiated Power (EIRP)

EIRP is the maximum power of the microwave signal emitted from the transmitting antenna, which refers to the isotropic antenna [15]. EIRP is obtained by adding up the output power of the transmitting antenna with the antenna gain then subtracting the loss or it can be written as an equation,

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

d) Isotropic Received Level (IRL)

Isotropic Received Level (IRL) is the value of the isotropic power level received by the receiving station. This IRL value is not the value of the power received by the system or the decoding circuit, but it is the value of the receiving power level of the receiver station antenna. To get the received power value at the receiving antenna, the IRL value must be obtained first [16]. The IRL value is obtained from the equation,

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

e) Received Signal Level (RSL)

Received Signal Level (RSL) is the power level received by the decoding processing device. The RSL value is influenced by the line losses at the receiving antenna and the gain of the receiving antenna [17]. The RSL value can be calculated with the equation

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

f) Hop Loss

Hop loss is the difference or difference between gain and loss on a microwave link. Gain is the gain value at the sender and receiver, while loss is the amount of free space attenuation and attenuation such as extra attenuation and atmosphere (water vapor and oxygen) [9]. By considering the microwave link, the amount of Hop loss is expressed by the equation

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

g) Fading Margin

Reserved power is used to maintain an acceptability level above the threshold level [9]. This power reserve is often referred to as the fading margin. In systems without diversity, the fading margin can be calculated by the equation

$$FM = RSL - R_{x\ Threshold} \quad (7)$$

h) Availability

The system reliability measure is often referred to as availability [3]. Ideally, all systems should have 100% availability. But it is impossible to fulfill it because in the system there must be unavailability. Availability can also be defined by the system's ability to provide services. [3].

$$Av_{path} = (1 - UnAv_{path}) \times 100\% \quad (8)$$

Meanwhile, unavailability can be expressed by the equation,

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

where parameter a is the earth's roughness factor, b is climate factor, D is the distance in Km, f is the frequency in GHz and FM is Fading Margin in dB.

D. Diversity

The technique used to overcome multipath fading is diversity [3]. Diversity is defined as a technique to increase system reliability by simultaneously installing two or more systems or subsystems. Diversity is more in demand by system designers compared to adding system gain because diversity is relatively cheaper. In general, 2 types of diversity are most often used, namely space and frequency diversity. However, both diversity can be combined into hybrid diversity to produce optimal improvement [14].

a) Space Diversity

This system uses one frequency, but the receiver system uses two or more antennas that are installed separately vertically with a certain distance and use one frequency, as illustrated in Fig. 3 [18]. The distance between the main antenna and the diversity antenna is obtained by the equation,

$$\Delta h = h_1 - h_2 = \rho \cdot \lambda \quad (10)$$

where ρ is a diversity coefficient with the range 100 - 200 and λ is the wavelength.

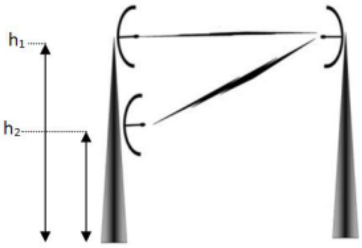

Fig. 3. Space diversity [18]

The improvement factor in the use of space diversity (I_{sd}) is obtained by the following equation,

$$I_{sd} = \frac{1.2\times10^{-3}\times\eta\times\Delta h^2\times f\times10^{(FM-v)/10}}{D} \quad (11)$$

b) Frequency Diversity

In this technique, the system operates two microwave frequencies on one antenna, both in the transmitting antenna and the receiving antenna. The information sent by the two transmitters operating at different frequencies is transmitted to one transmitter antenna. The difference in frequency (Δf) between the two frequencies is just 2% and it would be better if it is 6% different to avoid major interference [3].

The improvement factor in the use of frequency diversity (I_{fd}) is obtained by the following equation,

$$I_{fd} = \frac{0.8\times\Delta f}{f^2\times D}\times 10^{FM/10} \quad (12)$$

c) Hybrid Diversity

Hybrid diversity (HD) is an enhancement (SD+FD) of space diversity that uses frequency diversity. Hybrid diversity is the most effective of all of the diversity arrangements and is preferred in difficult propagation areas, such as those covering very long distances or transmitting over ocean. Here, one side of the link has one antenna and the other one has two antennas (SD) [14][9]. The hybrid diversity improvement factor I_{hd} is derived either from the space I_{sd} or frequency diversity improvement factor I_{fd} described previously, or using both values. Improvement hybrid diversity is obtained by selecting the highest improvement factor value between frequency and space diversity.

$$I_{HD} = I_{SD}\ or\ I_{FD} \quad (13)$$

E. Simulation Design

Microwave design simulation using Pathloss 5.0 software was carried out by performing a series of configurations, as illustrated in Fig. 4.

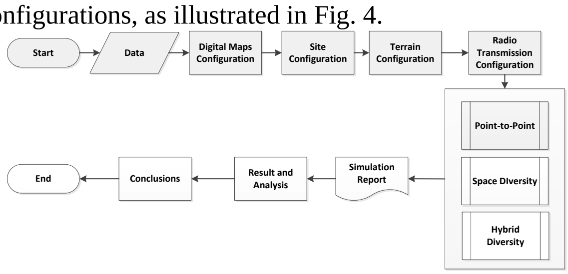

Fig. 4. Flowchart for research

a) Digital Map Configuration

The digital map used in the Pathloss simulation software uses the SRTM format. This format is capable of producing real contours in 2D and 3D, as seen in Fig. 5.

Fig. 5. Digital map of microwave links across the ocean

b) Site Configuration

At this stage, a predetermined site arrangement is carried out. These settings include the name of the location, the location of the site coordinates, and the elevation of the site, as shown in Table I.

TABLE I. RESEARCH SITE LOCATION

No	Site	Latitude	Longitude	Elevation (m)
1	Pekajang	01 09 27. 42 S	105 17 47. 78 E	111
2	Air Jukung	01 37 35. 50 S	105 44 10. 50 E	2,5

c) Terrain and atmosphere configuration

In the ocean topography, it does not have extreme terrain because the ocean stretches from one side to the other with a terrain roughness of 6.1 meters, as depicted in Fig. 6.

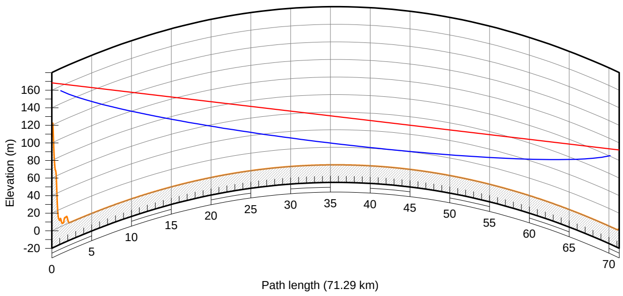

Fig. 6. Path profile of microwave links across the ocean

TABLE II. ATMOSPHERIC PARAMETERS OF MICROWAVE LINKS ACROSS THE OCEAN

Parameter	Value
Climatic factor	2
Terrain roughness (m)	6,1
C factor	6,58
Average annual temperature (℃)	26,84
Fade occurrence factor (Po)	2,86E+00
0,01% rain rate (mm/hr)	102,35

Atmospheric and rain factors are very important in microwave propagation, especially in the use of high frequencies because they can affect the signal attenuation caused by multipath fading, especially refraction and absorption of electromagnetic waves. The rain attenuation parameters use the recommended standard ITU-R P.837.5 as shown in Table II.

d) Microwave Transmission Radio Link Configuration

Microwave radio link configuration settings include antenna settings, radio equipment settings, transmission loss, and frequency channel settings. The antenna used in cross-ocean microwave transmission systems is the UHP12-19 model manufactured by Andrew. The antenna specifications are shown in Table III. While the line transmission using the EW20-25 model manufactured by CommScope. The line transmission is an Elliptical Waveguide type that works at a frequency of 1900 MHz - 2700 MHz. The advantage of this line transmission is that it has a small unit loss of 1.81 dB / 100m

TABLE III. ANTENNA PARAMETERS OF MICROWAVE LINKS ACROSS THE OCEAN

Parameter	Pekajang	Air Jukung
Antenna model	UHP12-19 (TR)	UHP12-19 (TR)
Antenna file name	a2189	a2189
Antenna gain (dBi)	35,6	35,6
Antenna height (m)	61	89,35
Antenna diameter (m)	3,66	3,66

Antenna and line transmission for space diversity configuration is used with a coefficient range between 100 λ - 200 λ with an interval of 25 λ. So, they are installed at height as shown in Table IV.

TABLE IV. DIVERSITY ANTENNA AND LINE TRANSMISSION SPACE HEIGHT OF MICROWAVE LINKS ACROSS THE OCEAN

Antenna Diversity Space	Desa Pekajang (Meter)	Desa Air Jukung (Meter)
Space diversity (ρ = 100)	46	75
Space diversity (ρ = 125)	42,25	71,25
Space diversity (ρ = 150)	38,5	67,5
Space diversity (ρ = 175)	34,75	63,75
Space diversity (ρ = 200)	31	60

TABLE V. TRANSMISSION LOSS OF MICROWAVE LINKS ACROSS THE OCEAN

Parameter	Pekajang	Air Jukung
TX line loss (dB)	1,1	1,63
Circulator branching loss (dB)	2	2
Free space loss (dB)		135,55
Atmospheric absorption loss (dB)		0,43
Net path loss (dB)	71,51	71,51

Table V shows the transmission loss parameter of the study, that generated by simulation. Atmospheric absorption loss is quite low, due to the use of low frequencies so that it has resistance to atmospheric absorption, as shown in Table V.

The radio device used in the study is MDR-4102E-C produced by Alcatel Network where this device has a capacity of up to 1DS3 with 16QAM modulation. The specification of the device is shown in Table VI.

TABLE VI. RADIO PARAMETER OF MICROWAVE LINKS ACROSS THE OCEAN

Parameter	Pekajang	Air Jukung
Radio model	MDR-4102E-C	MDR-4102E-C
TX power (dBm)	29	29
Emission designator	10M0D7W	10M0D7W
EIRP (dBm)	61,5	60,97
RX threshold criteria	1E-6 BER	1E-6 BER
RX threshold level (dBm)	-74,5	-74,5

The frequency channel used in this cross-ocean transmission system uses a frequency of 2135 MHz, vertical polarization in Pekajang Village, and 1922 MHz in Air Jukung Village. Meanwhile, the Hybrid Diversity configuration uses two frequency channels. The frequency channel used in this cross-ocean transmission system uses frequencies of 2135 MHz and 1951 MHz with vertical polarization in Pekajang Village while in Air Jukung Village it uses 1922 MHz and 2164 MHz frequencies with vertical polarization.

III. RESULT

A. *Performance of Microwave Communication Systems on The Ocean Using A Point-To-Point Configuration*

Based on the simulation results as in Table VII it is concluded that the fade margin generated on the cross-ocean microwave link using a point-to-point antenna reaches 31.99 dB. Meanwhile, the annual multipath availability of 99.86299% and annual multipath un-availability of 43206.75 seconds per year (see Fig. 7).

TABLE VII. THE RESULT PERFORMANCE OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A POINT-TO-POINT CONFIGURATION

Parameter	Pekajang	Air Jukung
Receive signal (dBm)	-42,51	-42,51
Thermal fade margin (dB)	31,99	31,99
Effective fade margin (dB)	31,95	31,95
Worst month multipath availability (%)	99,81732	99,81732
Worst month multipath unavailability (sec)	4800,75	4800,75
Annual multipath availability (%)	99,9315	99,9315
Annual multipath unavailability (sec)	21603,37	21603,37
Annual 2-way multipath	99,86299	

Parameter	Pekajang	Air Jukung
availability (%)		
Annual 2-way multipath unavailability (sec)	43206,75	
Annual rain + multipath availability (%)	99,86299	
Annual rain + multipath unavailability (min)	720,11	

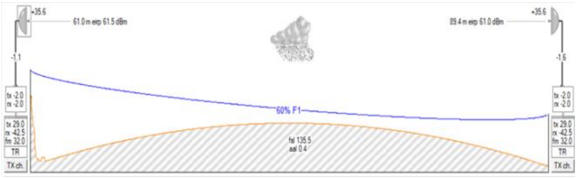

Fig. 7. The microwave communication systems on the ocean using a Point-To-Point configuration

B. *Performance of Microwave Communication Systems on the Ocean Using A Space Diversity Configuration*

In general, the radio transmission configuration of microwave space diversity is quite similar to the point-to-point configuration. The difference is the addition of antenna diversity, as shown in Fig. 8. So, there are space diversity parameters such as antenna diversity height, transmission line length, TX line loss, and net diversity. The value of each of these parameters depends on the space between the main antenna and the diversity antenna, where the antenna spacing is obtained from the multiplication of the space diversity coefficient (ρ) and wavelength (λ).

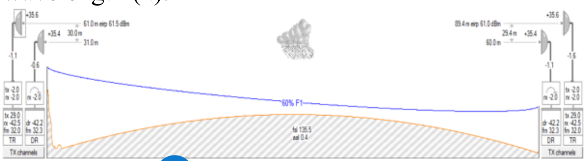

Fig. 8. The scheme of microwave communication systems on the ocean using a space diversity configuration

The simulation result for this configuration yield the fading margin is in the range of 32.06 dB to 32.33 dB as shown in Table VIII. It is concluded, the greater the space between antennas, the better the fading margin. This can be seen in the improvement of the space diversity factor shown in Table IX.

TABLE VIII. FADE MARGIN OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A SPACE DIVERSITY CONFIGURATION

Antenna Diversity	Fade margin (dB)	
	Desa Pekajang	Desa Air Jukung
Space diversity (ρ = 100)	32,06	32,06
Space diversity (ρ = 125)	32,13	32,13
Space diversity (ρ = 150)	32,2	32,2
Space diversity (ρ = 175)	32,26	32,26
Space diversity (ρ = 200)	32,33	32,33

TABLE IX. IMPROVEMENT FACTOR OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A SPACE DIVERSITY CONFIGURATION

Antenna Diversity	SD Improvement Factor	
	Desa Pekajang	Desa Air Jukung
Space diversity (ρ = 100)	12.21	11.18
Space diversity (ρ = 125)	19.07	17.78
Space diversity (ρ = 150)	27.46	25.91
Space diversity (ρ = 175)	37.36	35.55
Space diversity (ρ = 200)	48.77	46.70

The simulation result of the space diversity microwave communication quality indicator is shown in Table X and Table XI.

TABLE X. AVAILABILITY AND UN-AVAILABILITY MARGIN OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A SPACE DIVERSITY CONFIGURATION

Antenna Diversity	Annual 2-way multipath availability (%)	Annual 2-way multipath unavailability (sec)
Space diversity (ρ = 100)	99,98845	3642,01
Space diversity (ρ = 125)	99,99279	2274,17
Space diversity (ρ = 150)	99,99510	1545,94
Space diversity (ρ = 175)	99,99647	1113,90
Space diversity (ρ = 200)	99,99734	837,40

TABLE XI. AVAILABILITY AND UN-AVAILABILITY + RAIN OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A SPACE DIVERSITY CONFIGURATION

Antenna Diversity	Annual rain + multipath availability (%)	Annual rain + multipath unavailability (min)
Space diversity (ρ = 100)	99,98845	60,70
Space diversity (ρ = 125)	99,99279	37,90
Space diversity (ρ = 150)	99,99510	25,77
Space diversity (ρ = 175)	99,99647	18,57
Space diversity (ρ = 200)	99,99734	13,96

C. *Performance of Microwave Communication Systems on the Ocean Using A Hybrid Diversity Configuration*

The radio transmission configuration for microwave hybrid diversity is quite similar to space diversity configuration. The differences are the addition of one antenna diversity in Air Jukung village and the use of two frequency channels in the system, such as in Fig. 9. So, the diversity improvement factor is up to the Quad Diversity Improvement factor level as shown in Table XII.

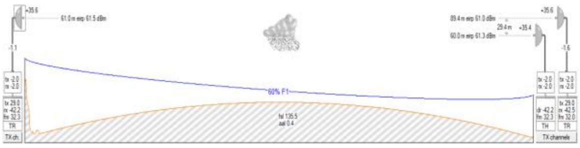

Fig. 9. The scheme of microwave communication systems on the ocean using a hybrid diversity configuration

TABLE XII. AVAILABILITY AND UN-AVAILABILITY MARGIN OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A HYBRID DIVERSITY CONFIGURATION

Antenna Diversity	Annual 2-way multipath availability (%)	Annual 2-way multipath unavailability (sec)
Hybrid diversity (ρ = 100)	99,99866	423,42
Hybrid diversity (ρ = 125)	99,99874	396,72
Hybrid diversity (ρ = 150)	99,99882	370,62
Hybrid diversity (ρ = 175)	99,99890	345,79
Hybrid diversity (ρ = 200)	99,99898	322,62

Based on the simulation, the fading margin generated in the cross-ocean microwave communication system connecting Pekajang Village and Air Jukung Village is in the range of 32.06 dB to 32.33 dB as shown in Table XIII.

TABLE XIII. FADE MARGIN OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A HYBRID DIVERSITY CONFIGURATION

Antenna Diversity	Fade Margin (dB)	
	Desa Pekajang	Desa Air Jukung
Hybrid diversity (ρ = 100)	32,06	32,06
Hybrid diversity (ρ = 125)	32,13	32,13
Hybrid diversity (ρ = 150)	32,2	32,2
Hybrid diversity (ρ = 175)	32,26	32,26
Hybrid diversity (ρ = 200)	32,33	32,33

The simulation result of the hybrid diversity microwave communication quality indicator is shown in Table XII and Table XIV.

TABLE XIV. AVAILABILITY AND UN-AVAILABILITY + RAIN OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A HYBRID DIVERSITY CONFIGURATION

Antenna Diversity	Annual rain + multipath availability (%)	Annual rain + multipath unavailability (min)
Hybrid diversity (ρ = 100)	99,99866	7,06
Hybrid diversity (ρ = 125)	99,99874	6,61
Hybrid diversity (ρ = 150)	99,99882	6,18
Hybrid diversity (ρ = 175)	99,99890	5,76
Hybrid diversity (ρ = 200)	99,99898	5,38

D. Calculation of Microwave Communication Systems on The Cross-Ocean

To validate the simulation results, it is compared with calculations based on the theories used in this study. Table XV and Table XVI show the result of fading margin and availability calculation. The simulation results must be close to the calculation to produce a valid results (see Table XVII).

TABLE XV. FADING MARGIN CALCULATION MICROWAVE COMMUNICATION SYSTEMS ON THE CROSS-OCEAN

Configuration	Fading Margin (dB)	
	Pekajang	Air Jukung
Point-to-Point	32,01	31,48
Space diversity (ρ = 100)	33,07	32,02
Space diversity (ρ = 125)	33,21	32,16
Space diversity (ρ = 150)	33,35	32,30
Space diversity (ρ = 175)	33,48	32,43
Space diversity (ρ = 200)	33,62	32,57
Hybrid diversity (ρ = 100)	33,07	32,02
Hybrid diversity (ρ = 125)	33,21	32,16
Hybrid diversity (ρ = 150)	33,35	32,30
Hybrid diversity (ρ = 175)	33,48	32,43
Hybrid diversity (ρ = 200)	33,62	32,57

TABLE XVI. AVAILABILITY CALCULATION MICROWAVE COMMUNICATION SYSTEMS ON THE CROSS-OCEAN

Configuration	Availability (%)	Un-Availability (Sec)
Point-to-Point	99,75703	74733
Space diversity (ρ = 100)	99,98515	4568
Space diversity (ρ = 125)	99,99049	2924
Space diversity (ρ = 150)	99,99340	2030
Space diversity (ρ = 175)	99,99515	1492
Space diversity (ρ = 200)	99,99629	1142
Hybrid diversity (ρ = 100)	99,99894	325
Hybrid diversity (ρ = 125)	99,99901	304
Hybrid diversity (ρ = 150)	99,99908	283
Hybrid diversity (ρ = 175)	99,99915	262
Hybrid diversity (ρ = 200)	99,99921	243

TABLE XVII. IMPROVEMENT FACTOR OF MICROWAVE COMMUNICATION SYSTEMS ON THE OCEAN USING A HYBRID DIVERSITY CONFIGURATION

Antenna Diversity	SD Improvement factor		FD Improvement factor		Quad Diversity Improvement factor	
	Pekajang	Air Jukung	Pekajang	Air Jukung	Pekajang	Air Jukung
Hybrid diversity	Not used	11,18	108,07	82,17	Not used	93,73

Antenna Diversity	SD Improvement factor		FD Improvement factor		Quad Diversity Improvement factor	
	Pekajang	Air Jukung	Pekajang	Air Jukung	Pekajang	Air Jukung
(ρ = 100)						
Hybrid diversity (ρ = 125)	Not used	17,78	109,76	83,45	Not used	101,56
Hybrid diversity (ρ = 150)	Not used	25,91	111,47	84,75	Not used	110,93
Hybrid diversity (ρ = 175)	Not used	35,55	113,21	86,08	Not used	121,81
Hybrid diversity (ρ = 200)	Not used	46,70	114,97	87,42	Not used	134,21

IV. Discussion

Based on the simulation results obtained several parameter results can be used to analyze the quality and performance of point-to-point, space diversity, and hybrid diversity microwave communication on across-ocean by taking into account the parameters of quality and performance of microwave communication include fading margin, availability, and unavailability. Then, the simulation results are compared to the theoretical calculation to validate the result.

A. Fading Margin Analysis of Microwave Transmission Configuration Point-to-point, Space Diversity and Hybrid Diversity in Cross-Ocean

Based on the simulation results, the fading parameter margin of Cross-Ocean Microwave Communication with a point-to-point configuration resulted in a value of 31.95 dB. The value can produce availability of 99.86299% or un-availability for 43206.75 seconds in one year. Meanwhile, the theoretical calculation results in a fading margin value of 31,48 dB, resulting in an availability of 99,75703 % or un-availability for 74733 seconds in one year. This value is very far from the standard set by the ITU-R (ITU-T G.821) where for microwave communication above 50 Km, the minimum availability value must be 99.98%. So to overcome this, the microwave communication system uses a diversity antenna configuration.

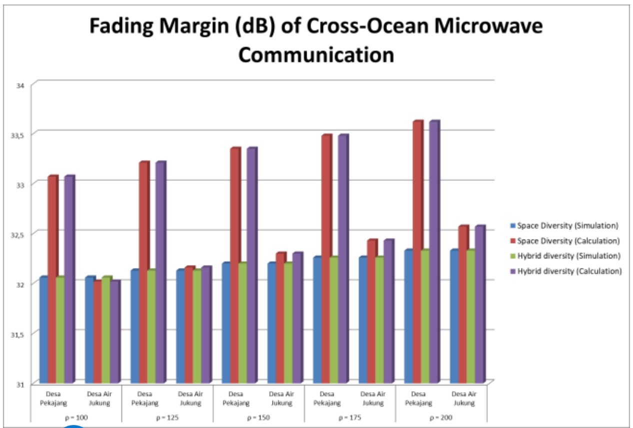

Fig. 10. Fading margin of cross-ocean microwave communication

The microwave communication configuration using space and hybrid diversity produces the same fading margin value in all the spacing settings between antennas (ρ = 100 to ρ = 200). This is because the hybrid diversity configuration will look for the best value between system space diversity or frequency diversity. Then based on the simulation and calculation results, it is found that space diversity produces the best fading margin value. So that the fading margin on both the space and the hybrid has the same value. Also, the greater the spacing between the antennas, the bigger the fading margin value is as depicted in Fig. 10.

B. Availability and Un-availability Analysis of Microwave Transmission Configuration Point-to-point, Space Diversity And Hybrid Diversity In Cross-Ocean

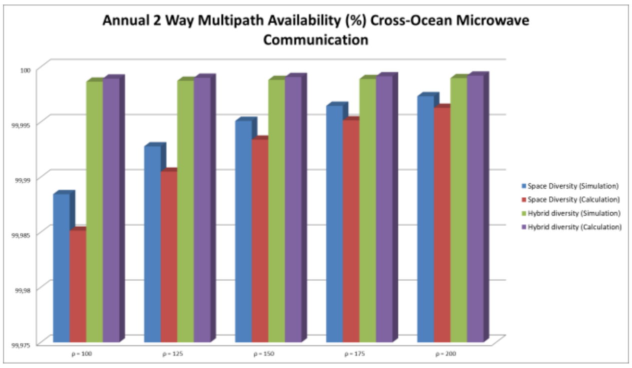

Fig. 11. Annual 2-Way multipath availability (%) cross-ocean microwave communication

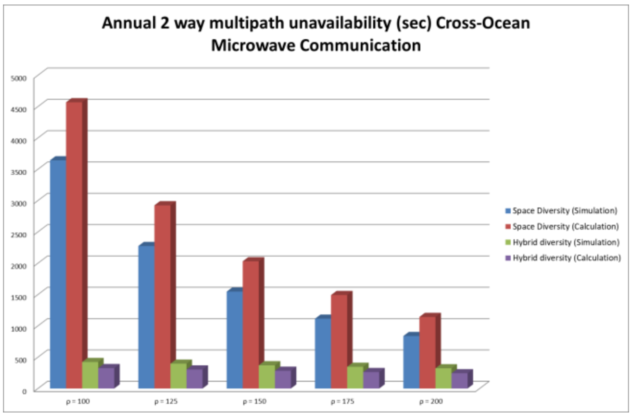

Fig. 12. Annual 2-Way multipath un-availability (sec) cross-ocean microwave communication

By using the diversity configuration it can produce a value above the standard set by the ITU. In space diversity with the closest spacing (ρ = 100), it results in

99.98845% availability or comparable to un-availability for 3642 seconds/year and increases significantly in proportion to the distance between antennas. Even the hybrid diversity configuration can produce values above 99.99% or un-availability below 500 seconds per year at all antenna distances. Likewise, the theoretical calculation produces a value that is not much different, with an average difference of up to 1%. as shown in Fig. 11 and Fig. 12.

V. Conclusion

Based on the results and discussion of the research that has been done, it can be concluded as follows:

1. The microwave communication system can implement point-to-point configuration, space diversity, and hybrid diversity across-ocean waters.
2. Fading Margin is the backup power in the receiving system so that the propagated signal can be above the threshold level of the radio receiving device, so that the greater the fading margin, the better the microwave communication quality. Meanwhile, Availability and Un-Availability parameters are used to measure the reliability of microwave communication systems
3. Based on simulations and theoretical calculations, it is stated that the use of microwave communication using a point-to-point configuration producing the quality of communication below the standards set by the ITU-R (ITU-T G.821) minimum availability of 99,98%.
4. The use of diversity techniques, both space, and hybrid, provided a significant increase in the quality of communication both in terms of availability, un-availability, and fading margin.
5. In general, simulation and theoretical calculations produce values that are not much different, with an average difference of up to 1%

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Ade Wahyudin did the simulation of the Analysis of Cross-Ocean Microwave Communication Systems Using Point-To-Point, Space Diversity and Hybrid Diversity. Ade Wahyudin and Alfin Hikmaturokhman wrote the paper cooperatively. All authors had approved the final version.

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References

[1] Badan Pusat Statistik, *Statistik Telekomunikasi Indonesia 2019*, Jakarta: Badan Pusat Statistik, 2020.

[2] A. Wahyudin, N. Amalia, and I. Lindra, "Cost benefit analysis of MVNO business models for LTE 4G services in Bandung city," in *Proc. 4th Int. Conf. New Media Stud. CONMEDIA 2017*, 2017, pp. 102–107.

[3] A. Hikmaturokhman and A. Wahyudin, *Perancangan Jaringan Gelombang Mikro Menggunakan Pathloss 5*. Yogyakarta: Pustaka Ilmu, 2018.

[4] Kementerian Komunikasi dan Informatika. Sekilas Palapa Ring. *kominfo.go.id*. (2013). [Online]. Available: https://kominfo.go.id/content/detail/3298/sekilas-palapa-ring/0/palapa_ring

[5] A. Hikmaturokhman, A. Wahyudin, W. E. Rinanda, S. Pramono, A. Hidayat, and A. Sarah, "Analysis of microwave network design using back-to-back passive repeaters with the influence of interference based on ITU-T-G821 standard," *J. Commun.*, vol. 15, no. 4, pp. 318–324, 2020.

[6] A. Hikmaturokhman, A. Wahyudin, A. S. Yuchintya, and T. A. Nugraha, "Comparison analysis of passive repeater links prediction using methods: Barnett Vigants & ITU models," in *Proc. 4th Int. Conf. New Media Stud. CONMEDIA 2017*, 2017, pp. 142–147.

[7] R. L. Freeman, *Telecommunication System Engineering*, New Jersey: John Wiley & Sons, 2004.

[8] E. Oktaviasari, A. Wahyudin, and A. Hikmaturokhman, "Analisis perbandingan interferensi link gelombang mikro pada daerah urban dan rural menggunakan," in *Proc. Conference of Electrical Engineering, Telematics, Industrial Technology, and Creative Media*, 2018, pp. 178–183.

[9] G. Kizer, *Digital Microwave Communication Engineering Point-to-Point Microwave Systems*, New Jersey: John Wiley & Sons, 2013.

[10] R. L. Freeman, *Radio System Design For Telecommunications*, 3rd ed. New Jersey: John Wiley & Sons, 2007.

[11] R. G. Winch, *Telecommunication Transmission Systems, 2nd edition*, 2nd ed. New York: McGraw-Hill, 1998.

[12] A. A. Faradila Purnama and M. I. Nashiruddin, "Analysis of microwave communication network planning on ocean topography using space diversity," *Bul. Pos dan Telekomun.*, vol. 18, no. 1, p. 1, 2020.

[13] Y. Y. Rahmawati and A. Wahyudin, "Perancangan jaringan backhaul sistem transmisi gelombang mikro digital menggunakan frequency diversity dan tanpa diversity di wilayah kepulauan riau," *Techno (Jurnal Fak. Tek. Univ. Muhammadiyah Purwokerto)*, vol. 19, no. 2, p. 63, 2018.

[14] H. Lehpamer, *Microwave Transmission Networks Planning, Design and Deploymeny*, 3rd ed., vol. 53, no. 9. New York: McGraw-Hill, 2010.

[15] D. B. Liu, E. Wahyudi, and E. S. Nugraha, "Pengaruh space diversity terhadap peningkatan availability pada jaringan microwave lintas laut dan lintas pegunungan," *J. Elektro dan Telekomun. Terap.*, vol. 4, no. 2, p. 541, Dec. 2017.

[16] S. Pramono, "Analisa perencanaan power link budget untuk radio microwave point to point frekuensi 7 GHz (Studi Kasus : Semarang)," *Politek. Negeri Semarang, J. Tek. Elektro Terap.*, vol. 3, no. 1, pp. 27–31, 2014.

[17] K. C. Wan, Q. Xue, X. Liu, and S. Y. Hui, "Passive radio-frequency repeater for enhancing signal reception and transmission in a wireless charging platform," *IEEE Trans. Ind. Electron.*, vol. 61, no. 4, pp. 1750–1757, 2014.

[18] Z. H. Pradana and A. Wahyudin, "Analisis optimasi space diversity pada link microwave menggunakan ITU Models," *J. Elektro dan Telekomun. Terap.*, vol. 4, no. 2, p. 586, 2018.

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