Airwave Propagation Analysis on Amateur Radio Frequency 10 MHz in Island Areas

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Abstract. High Frequency (HF) radio is a radio wave that works at frequencies of 3 to 30 MHz with wavelengths of 100 to 10 m, some of the mountainous areas and islands are still classified as rural areas. Rural areas are rural areas where the population is not too dense and there are no high-rise buildings. With the presence of air wave propagation for HF NVIS radio communication at a frequency of 10 MHz that can be used accurately, it can support the creation of communication systems that have effective service quality and can know the model that matches the characteristics of the area, making it easier for operators to build a amateur radio communication network. Propagation is the most important part in designing a communication network on radio waves that are traversed by having several bacterial conditions such as analyzing propagation, estimating interference, estimating cell parameters, reflection or obstacle and distance. VOACAP stands for Voice of America Coverage Analysis Program. This program is an ionospheric model that can predict the performance of HF that is expected to use empirical data. The power received for Ternate-Tidore with a distance of 15 km is 2,304 Watt, while the transmit power for Ternate-Moti with a distance of 37 km is 3,310 Watts and the transmit power for Ternate-Makian is 1,708. Sendangan for the simulation on VOACAP is 7,943 Watt for Ternate-Tidore, 5,011 Watt, for Ternate-Moti, install 3,981 Watts for Ternate-Makian, this shows that VOACAP software has a greater signal than the calculation.

Key words— NVF HF Radio, Propagation, 10 MHz Frequency, VOACAP

1. Introduction

This study aim to initiation stage for implementation Airwave Propagation Research in the Northern Maluku Islands, because of the characteristics of the archipelago and many black spots in the rural area. Alternative research is conducted to overcome technical problems in rural areas of the government of the islands [1] Propagation is the most important part in designing a communication network on radio waves that are traversed by having several bacterial conditions such as analyzing propagation, estimating interference, estimating cell parameters, reflection or obstacle and distance. The factors that must be taken into account in the planning of a radio communication network for short-distance communication are the Transmitter antenna height (Tx) and Receiver (Rx), the emitted power, the cell radius area (urban, suburban, or rural) all of which are strongly influenced by the amount of attenuation that occurs along the channel (pathloss), [1],[2] With the presence of short-wave propagation for HF NVIS radio communication can be used accurately, it can support the creation of communication systems that have effective service quality and can know the model that matches the characteristics of the area, making it easier for operators to build a HF NVIS radio communication network. HF NVIS (Near Vertical Incident Skywave) radio communication is able to overcome the skip zone so that it does not affect the quality of the beam, whether it is in the sea, swamp, beach, surrounded by puddles (floods), grasslands, dense forests, mountain slopes and so on.[3] Skip zone is an area that cannot be reached by a radio beam because the distance is too close to a certain frequency,
so that the radio waves emit into outer space. [2][4][5] In propagation modeling there are several models that are often used, such as the Okumura model, the Hata model, and Lee's model. Even so, the propagation model cannot be used to determine the propagation model in a particular area, because the propagation models are general, only discussing urban, suburban, and rural areas. While each region has characteristics of different regions. Basically, the model can be used, but it is not accurate to apply. To get an accurate model, measurements of propagation data were carried out on the islands and archipelagos, [1][6] From the results of the literature review or study, the authors did not find a propagation model for the Mountain and islands area, so the authors are interested in conducting research on the HF NVIS radio channel propagation model at a low frequency especially at the 10 MHz frequency to obtain the appropriate accurate model with the islands area.

2. Methods
The research step scheme is the beginning of the data processing planning stage of the system on the HF NVIS radio propagation and application that will be used for data retrieval. This design scheme is made based on the flow of research steps. The steps of this study are shown in Figure 1.

![Figure 1. Airwave Propagation Research Steps](image)

2.1 Radio Wave Propagation
Radio wave propagation is important for knowing the obstacles and disturbances in a mobile radio environment. The definition of wave propagation is wave propagation on propagation media. The propagation media or also commonly called the wave transmission channel can be physical i.e. a pair of conductor wires, coaxial cable and in the form of non-physical i.e radio waves or laser light[7][2][13][4] In general, one of the characteristics of radio wave propagation is attenuation, attenuation is the difference between transmit power and receiving power. This is due to changes in
channel propagation conditions during the communication process. If the minimum power that can be received by the receiver (watts) and (watts) is the transmit power and (dB) is the amount of system loss on a point to point HF radio link [8] then the total attenuation (dB) can be written as follows:

\[ A_T = P_T - P_R - L_5 \] (1)

Damping free space or free space propagation is attenuation that occurs when the signal emitted is directly received by the receiving antenna so that there is no loss caused by the obstacle. The following is the equation of attenuation offree space [8]

\[ F = 32.4 + 20 \log d + 20 \log f \] (2)

Where:
\[ d = \text{Distance between transmitter and receiver (km)} \]
\[ f = \text{Work frequency (MHz)} \]

The link budget calculation is intended to be able to calculate or plan the power requirements so that the received signal quality meets the desired standards.

\[ P_R = P_T + G_T + G_R - L_T \text{ (dBW)} \] (3)

Where:
\[ P_R = \text{Receiver power (dBW)} \]
\[ P_T = \text{Transmit power (dBW)} \]
\[ G_T = \text{Transmit antenna gain (dB)} \]
\[ G_R = \text{Receiver antenna gain (dB)} \]
\[ L_T = \text{Total loss} \]

2. 2 Model of Outdoor Wave propagation

Based on how to make outdoor wave propagation models are divided into three main categories: [9]

a. Deterministic Model: a model created based on the relationship between an equation and the event that occurs, so that if given the same input it will produce the same output. Example: Parabolic equation.

b. Empirical Model: A model created by comparing statistically an equation with data from observations, experiments, or experiences. Example: Hata-okumura, Walfisch-Ikegami.

2. 3 Model Lee

Lee propagation model derived from experimental data carried out in several cities of the world. Model Lee was first formulated as a prediction of the received signal level (Received Signal Level) based on transmit power and antenna gain to be used at a frequency of 900 MHz. [10]

2.4 Lee Model COST-231.

European Co-operative for Scientific and Technical Research (EURO-COST) formed a working committee COST-231 to create a model of enhanced or expanded Hatta. Path attenuation model proposed by COST-231 in this form of the equation:

\[ L = 46.3 + 33.9 \log h_L - 13.82 \log h_R - t(h_R) + (4.9 - 6.55l) \log d + C_M \ldots \] (4)

2.5 Model Welfisch-Ikegami

The empirical model is a combination of the model created by J. F. Walfisch and Ikegami. This model can be used accurately on the parameters, as follows:

- Frequency \( = f (800...2000 \text{ MHz}) \)
- Transmitter height \( = h_{TX} (4...50 \text{ m}) \)
- Height of receiver \( = h_{RX} (1...3 \text{ m}) \)
- The distance between the transmitter and receiver \( = d (20...5000 \text{ m}) \)

2.6 Model Hatta

is a form of empirical equation from the path damping curve made by Okumura, the refore this model is more often referred to as the Okumura-Hata model. The Hata prediction equation for urban areas is:
\[ P (d) = 69.55 + 26.16 \, f + 10(f) - 13.82 \, l_t \, 10 \, h_t - a(h_r) + (44.9 - 6.55 \log 10 \, h_t) \, l_t \, 10 \, d \]  
\[ (5) \]

Where:
- \( f \) = Frequency of work between
- \( l_t \) = BTS transmitter effective antenna height around
- \( h_t \) = MS receiver antenna effective height around
- \( d \) = The distance between Tx - Rx (km)
- \( a(h_r) \) = The correction factor for the effective height of antenna receiver as a function of the area being served.

2.7 Model Free Space Loss
Model Free Space Loss is an unhindered free propagation model. The waves emit freely to an unlimited distance without being absorbed or reflected. In the propagation of free space, the path conditions of electromagnetic waves use an isotropic antenna. The formulas used are:
\[ P = 32.45 + 20 \, l_t \, 10(d) + 20 \log 10 \, f \]  
\[ (6) \]

Where:
- \( d \) = Distance between BTS to MS
- \( f \) = Frequency

2.8 Model Egli
Model egli is a propagation model for radio waves. This model is very suitable for use at 3MHz-3GHz frequencies and is usually used when in LOS conditions between the sending and receiving antennas.
\[ p0 = 40l_t \, 10 \, d - 20l_t \, 10 \, h_t - 10 \log 10 \, h_r \]  
\[ (7) \]

2.9 Model Ecc-33
Model ECC-33 developed by the Electronic Communication Committee (ECC) from its original measurements by Okumura and modified so that its assumptions are closer to fixed wireless access (FWA) systems. Path loss using the ECC-33 prediction model can be defined as follows: [12][13]
\[ P (d) = A + A_i - G - G \]  
\[ (8) \]

2.10 HF NVIS Radio Analysis
Analysis of data processed in software (VOACAP) Voice of America Coverage Analysis Program, namely opening VOACAP software that required propagation mode by setting the transmitter location coordinate point and location of the dancer, in this simulation the transmitter location was in the location of the campus III Khairun University Ternate City North Maluku. While the location of the recipient is in three kepulaan locations and there are mountains that are difficult to reach signals, namely the first area is Aryana net gamtufkantidorisland, while the second area is Tafaga, moti island and the third is Tahane Island Makian area[10][14][2][15][13]

3. Resultand Discussion
From the research conducted, the determination of the location in difficult-to-reach signal areas is obtained from the calculation of LFS (Free Space Loss) using equation 2, which is shown in table 4, the results of LFS calculations.

| No | Name Island   | Distance (Km) | FreeSpaceLoss (LFS) |
|----|---------------|---------------|---------------------|
| 1  | Ternate-Tidore| 15            | 339,480             |
| 2  | Ternate-Moti  | 37            | 355,169             |
| 3  | Ternate-Makian| 54,3          | 361,832             |

After knowing the transmitter's coordinate points in each transmitter and receiver, then set July and August 2019 in UTC + 7. The transmitter and receiver system uses an isotropic antenna with 3dBi gain.[17][18] The parameters on the system are set with a noise level of 150 dBW, the minimum take
off angle is 5 (deg), required reliability on the track by 10%, the minimum S / N is - 30 dB. Figure 2. Display of VOACAP Software.

Once set parameters then click Run, select the graph it appears the data like Tangle, DELAY, WHITE, MUFDay, LOSS, DBU, SDBW, NDBW, SNR, RPWRG, REL, MPROB, as shown in Figure 3.

The results of data processing in VOACAP software began in July and August 2019 and were observed on GMT + 7, because measurements were based on the Indonesian time zone. for the frequency used in HF NVIS communication is 10 MHz, where the average elevation angle is 80 degrees, while for Ternate-Tidore area the transmit power at the minimum is -111.00 dBm, while the maximum is -53.00. Ternate-Moti the minimum transmit power is -113.00 dBm while the maximum power is -52.00 and the minimum level is -114.00, the maximum is -52.00. it can be analyzed that the farther the distance of the HF NVIS radio signal range, the less transmit power is received. Table 2 showstheresultsof HF NVIS radio data processing in theislandsandmountainsusing VOACAP Software.

| Parameter          | Ternate-Tidore | Ternate-Moti | Ternate-makian |
|--------------------|---------------|--------------|----------------|
| TANGLE (degrees)   | 87.80         | 83.40        | 80.60          |
| DELAY (milliseconds)| 0.80          | 0.70         | 0.70           |
| WHITE (km)         | 119.00        | 99.00        | 99.00          |

Figure 2. Display Software VOACAP

Figure 3. VOACAP Software Parameters.
From the calculation of the HF NVIS radio channel budget link on propagation in islands and mountains, to obtain the transmit power observed later from the results of the data verification is done with data processed in the software (VOACAP) Voice of America Coverage Analysis Program, comparison of calculation and simulation results, where the results of the dBm emission value are converted to Watts, can be seen in Table 3.

| No | Name Island | Prx (Watt) Link Budget Calculation | Prx (Watt) Software VOACAP |
|----|-------------|----------------------------------|---------------------------|
| 1  | Ternate-Tidore | 2.034 | 7.943 |
| 2  | Ternate-Moti | 3.310 | 5.011 |
| 3  | Ternate-Makian | 1.708 | 3.981 |

From table 6, it can be seen that the power received for Ternate-Tidore with a distance of 15 km is 2,304 Watt, while the transmit power for Ternate-Moti with a distance of 37 km is 3,310 Watts and the transmit power for Ternate-Makian is 1,708. Sendangan for the simulation on VOACAP is 7,943 Watt for Ternate-Tidore, 5,011 Watt, for Ternate-Moti, install 3,981 Watt for Ternate-Makian, this shows that VOACAP Software is bigger than calculation.[19][20]
From the results of calculations and simulations on VOACAP software can be analyzed that the comparison is not so much different, which means that, the smaller the transmit power received, the farther the distance of HF NVIS radio propagation communication in the islands and mountains, the HF NVIS radio propagation modeling of this communication can used, even though it is located in a difficult to reach signal area.

4. Conclusions and Recommendations
After doing the link budget calculation and VOACAP program simulation, the following conclusions are obtained:

1. Analysis of data processed in software (VOACAP) Voiceof America CoverageAnalysis Program, using the frequency of 10 MHz at a distance of 15 km, the signal transmit power at the receiver is -111.00 dBm while the link budget calculation shows that the receiver signal transmit power is -136.92 dBm.
2. Results of VOACAP program data and link budget calculation can be used for HF NVIS radio signal propagation modeling in the area of origin and use.
3. VOACAP program simulation data and calculations are not much different results, so that shows that the farther the distance of an area, the smaller the transmit power is received.

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