Circuit: Jurnal Ilmiah Pendidikan Teknik Elektro
Volume 9 No. 2 March 2025 -August 2025
ISSN: 2549-3698; E-ISSN: 2549-3701
DOI: 10.22373/crc.v9i2. 30796

Arima Modeling for High-Frequency Channel Response in Equatorial Region

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Submitted: 02-06-2025 Accepted: 06-08-2025 Published: 31-08-2025

Abstract

Indonesia, an archipelagic country located along the equator, is highly vulnerable to natural disasters. At the same time, its geographical conditions require reliable telecommunications to strengthen connectivity across its many islands. One effective solution is the utilization of High-Frequency (HF) communication technology, which enables long-distance communication and supports broadcasting-based telecommunications. This approach can expand available frequency channels, making HF radio communication an important tool for disaster-prone regions like Indonesia. To optimize HF communication, researchers have developed various models of HF channel radio systems, often represented statistically and implemented through channel simulators. Among these approaches, the Auto Regressive Integrated Moving Average (ARIMA) model has been identified as particularly suitable. This is because ARIMA can handle the non-stationary characteristics of time-series data, such as those found in HF channel attenuation measurements. In the modeling process, several ARIMA configurations were tested, including ARIMA (0,1,1), (0,0,5), (1,0,0), (1,0,1), (1,0,2), and (0,0,4). From these options, two models—ARIMA (1,0,0) and ARIMA (1,0,2)—showed the closest fit to the observed data. The final selection was made using the Akaike Information Criterion (AIC), where the ARIMA (1,0,2) model emerged as the best. This model provides the most accurate representation for predicting HF channel attenuation, supporting more reliable telecommunications systems for Indonesia.

Keywords: *Archipelago, Channel Simulators, Radio Communication Systems*

Abstrak

Indonesia meruapakan wilayah yang dilintasi oleh garis khatulistiwa. Indonesia juga tersusun dari beberapa pulau dan merupakan daerah yang rawan terhadapat bencana alam. Dengan perkembangan teknologi memungkinkan wilayah kesatuan Indonesia untuk saling terhubung satu dengan yang lainnnya yaitu dalam hal telekomunikasi khususnya melalui penggunaan frekuensi tinggi (HF). Salah satu teknologi yang dapat mendukung hal tersebut adalah dengan menggunakan teknologi telekomunikasi dengan basis broadcasting. Dengan teknologi tersebut dapat meningkatkan frekuensi kanal yang baru. Salah satunya adalah dengan menggunakan kanal radio High Frequency (HF). Para peneliti banyak melakukan penelitian terhadap kanal radio HF baik dalam bentuk uji statistik, desain dan implementasi dengan kanal simulator. Salah satu model yang dapat digunakan dalam implementasi tersebut adalah dengan pemodelan Auto Regresive Integrated Moving Avarage(ARIMA). ARIMA dapat dimodelkan berdasarkan karakteristik dari redaman kanal HF non-stasioner terhadap waktu. Hasil pemodelan

ARIMA yang diperoleh adalah model ARIMA (0,1,1), (0,0,5), (1,0,0), (1,0,1), (1,0,2), dan (0,0,4). Dan dua model yang mendekati adalah ARIMA (1,0,0), dan ARIMA (1,0,2). Salah satu model ARIMA terbaik dipilih berdasarkan kriteria AIC terkecil. Model ARIMA terbaik adalah model ARIMA (1,0,2).

Kata kunci: Kepulauan, Kanal Simulator, Sistem Komunikasi Radio

Introduction

Indonesia is an area traversed by the equator. This geographical condition provides great potential for utilizing natural energy sources such as solar and wind. In terms of renewable energy, wind power offers various types of wind turbines capable of generating high-quality renewable electricity [1]. The shape of Indonesian territory is an archipelago. Indonesia is a region prone to natural disasters [2][3]. With the development of technology, it is possible that the islands can be connected. Telecommunication technology is developing very rapidly. As the telecommunications sector expands, it faces increased threats from sophisticated criminal activities [4]. So it is possible to increase the need for new frequency channels. HF radio communication systems have the advantages in propagation that they can reach long track distances and communication systems is to increase noise immunity, which allows increasing the range of the system [5], is easy to implement. However, it is cheaper than satellite communication systems, but HF radio communication systems are influenced by the increase in channel width and radio frequency [6], [7]. However, a high-frequency prediction method is required to ensure accurate forecasting of channel behavior [8].

One type of HF radio wave propagation is the sky wave, including massive multiple-input multiple-output [9]. This type of propagation is strongly influenced by ionospheric conditions, which can affect the quality and stability of the transmitted signal. Higher frequencies cause more significant interference [10]. In this type of propagation, the signal from the transmitter is reflected by the ionosphere layer so that it can reach the receiver. With a large transmitting power, the signal on the reflected path between the ionosphere and the earth can reach a very long distance [6], [11], [12]. The high-frequency channel can be used as a frequency channel for disaster mitigation [4], [9]. In this context, optimizing the allocation and utilization of available frequencies becomes crucial. Frequency Considerations and Channel Bands take center stage, dissecting the critical spectrum domain and exploring high-frequency millimeter-wave bands for enhanced data rates [13]. This is because building an HF communication system is to build an HF communication system is very easy and does not require expensive costs. NVIS mode is considered a simple radio link during the disaster mitigation initiation process [14]. In recent decades, researchers have done a lot of modeling of HF channels with various models, generally, statistical channel modeling is designed and applied using channel simulators. One model that can be applied is the Auto-Regressive Integrated Moving Average (ARIMA) model because the ARIMA model has the characteristics that best fit the data from HF channel attenuation measurements and used multi-dimensional components [15]. In addition to its suitability for signal data, the ARIMA approach is also widely used in broader research contexts. Trends in bibliometric analysis using the ARIMA method have attracted the attention of many researchers in this field [16].

With Arima modeling, it is necessary to consider non-stationary properties in the time dimension to obtain high accuracy, so it is suitable for data that has non-stationary properties [17]. Arima modeling in other telecommunication fields has been done a lot. It is expected that from this modeling, a model can be obtained that can be able to describe the stochastic characteristics of HF channel variations and can be used in the simulation and evaluation of HF communication systems. In particular, this technology achieves optimal diversity gain in high mobility scenarios and has appealing properties in high-frequency communication [18]. The Hf channel modeling used in this study is based on measurement data in Indonesia's equatorial area. Data calculation in the form of a time domain will be modeled in univariate time series modeling, AR, MA, and ARIMA models.

Method

Figure 1 shows the flow chart of the research method. The method is the RSL (Receive Signal Level) value obtained from the measurement of the HF channel response with the placement of the Transmitter at 05°16 15" North latitude and Receiver at position 95° 16' 15" East longitude. The data is processed with Minitab and SAS Software. Then perform ARIMA modeling by generating RSL data, calculating the distribution model, and testing statistics with the Kolmogorov-Smirnov goodness of fit test, and finally selecting the model. Essentially, the Kolmogorov–Smirnov (KS) is a non-parametric statistical test used to assess whether a dataset follows a particular probability distribution [19].

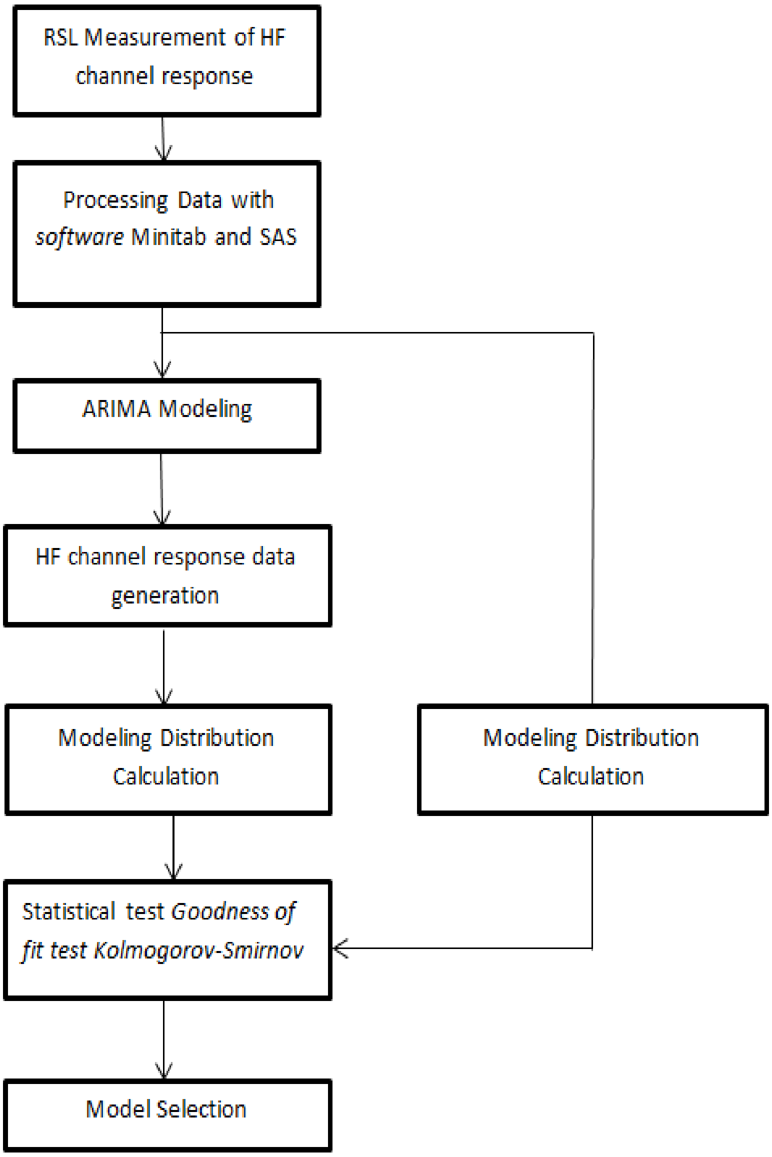

Figure 1. Flow Chart of Research Method

To get the ARIMA model, the data that has been processed by checking stationarity in variance, namely, lambda is equal to one. If lambda is not worth one, then the transformation is carried out until the lambda value is one. Furthermore, the ACF plot is checked by checking the stationarity of the data in the mean is done by observing the ACF plot. If the ACF observation has a slow declining value, then a differencing process must be carried out. And when it doesn't go down slowly, then the next step is the PACF plot. Then, ACF and PACF identification is done to determine the ARIMA conjecture model. At this stage, the suitability of the model is further evaluated through error estimation. Every time (ACF) and (PACF) for the series of estimated errors are tested and the model which satisfies the two inequalities [20].

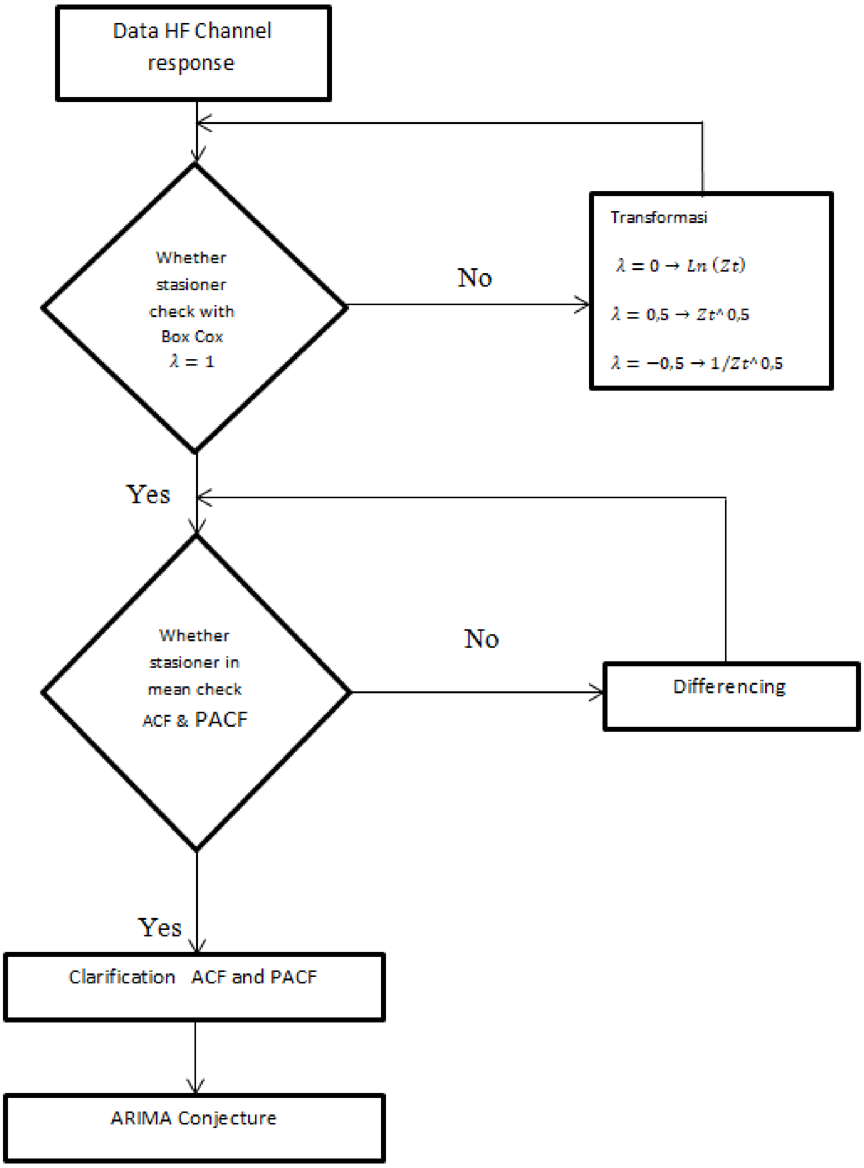

Figure 2. Flow chart of ARIMA Modeling

Then, the alleged model is inputted into the model function in SAS software. For the selection of the best model, several parameters need to be tested. That is to prove whether the parameters are significant. If the parameter is significant, the p-value <0.05 is obtained. If the p-value > 0.05, then the parameters above 0.05 must be eliminated one by one, starting from the largest to the smallest, so that all parameters have a p-value < 0.05. From these ARIMA models, one of the best ARIMA models is chosen by looking at the ARIMA model that has the smallest AIC and SBC values.

The next step is to prove whether the residuals are normally distributed. This stage of model diagnosis is carried out for the Kolmogorov-Smirnov residual normalization test with a p-value> 0.05. If it is significant below 0.05, it means that the data to be tested has a significant difference from normal data so the data is not normal. If it is the opposite, which is above 0.05, then there is no significant difference between the data to be tested and the normal data.

From the results of the best ARIMA model obtained for each HF channel attenuation event, the mean and standard deviation values are checked. ARIMA models are grouped into mean and standard deviation based on two based on mean and standard deviation, namely mean and standard deviation of large values and small values. Checking the mean and standard deviation values is done using Minitab software. Each ARIMA model calculated the mean and standard deviation values.

The best model is also seen based on the closeness of the HF channel attenuation distribution to the measured HF channel attenuation, where each ARIMA model is compared to the measurement results. The closer to each other, the better the ARIMA model. As shown in Figure 4.

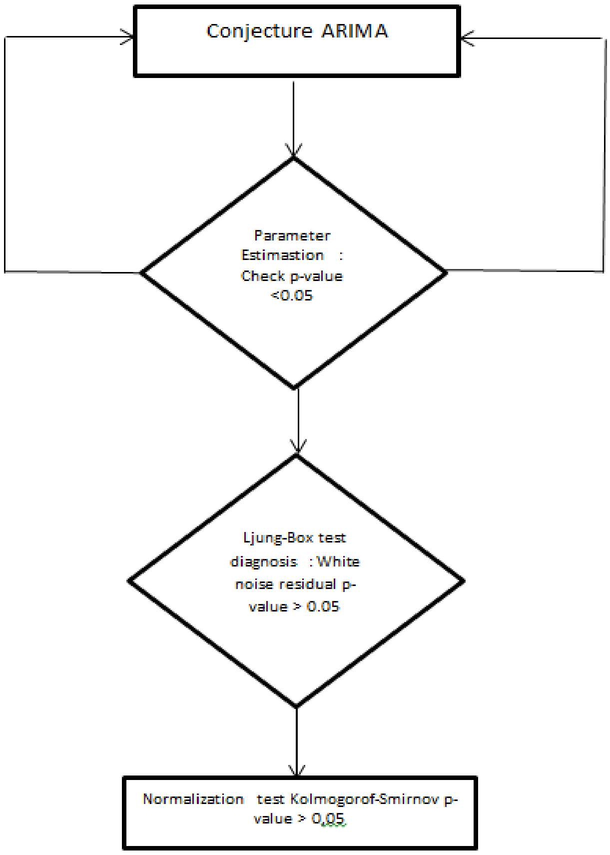

Figure 4. Flow Chart ARIMA Model Determination

Result

In this article, HF channel attenuation data are obtained, which are then used for ARIMA modeling. The ARIMA models are analyzed and selected as the best model and closest to the measurement results, which can describe the characteristics of HF channels in areas crossing the equator in Indonesia as a disaster mitigation radio channel.

Table 1. Data of HF Channel Response (RSL)

local time (WIB)	Pt	GT	Gr	Absorption Loss	Distance loss	Ground reflection loss	Antenna loss	Pr dBm	RSL
	dBm	dBi	dBi	dB	dB	dB	dB		
07:00:00	50	6	6	17	126	3	-12	-60,73	11,27
07:00:10	50	6	6	17	126	3	-12	-60,62	11,38
07:00:20	50	6	6	17	126	3	-12	-61,47	10,53
07:00:30	50	6	6	17	126	3	-12	-61,94	10,06
07:00:40	50	6	6	17	126	3	-12	-60,49	11,51
07:00:50	50	6	6	17	126	3	-12	-60,20	11,80

Table 2. Recapitulation of the HF Channel Response ARIMA Modeling

No	Event	Model of ARIMA	Sample	Event	Prob. Event
1	070122 (19:00:00-00:59:50) 290122 (01:00:00-06:59:50) 170122 (01:00:00-06:59:50)	(0,1,1)	1188	3	8,3%
2	310122 (01:00:00-06:59:50) 310122 (19:00:00-00:59:50) 040222 (01:00:00-06:59:50) 120222 (01:00:00-06:59:50) 250222 (01:00:00-06:59:50)	(1,0,1)	1980	5	13,9%
3	010122 (01:00:00-06:59:50) 030122 (01:00:00-06:59:50) 070122 (19:00:00-00:59:50) 150122 (19:00:00-00:59:50) 170122 (01:00:00-06:59:50) 210122 (19:00:00-00:59:50) 230122 (01:00:00-06:59:50) 250122 (19:00:00-00:59:50) 270122 (01:00:00-06:59:50) 020222 (01:00:00-06:59:50) 060222 (19:00:00-00:59:50) 160222 (01:00:00-06:59:50) 220222 (19:00:00-00:59:50) 260222 (01:00:00-06:59:50) 280222 (01:00:00-06:59:50) 030322 (01:00:00-06:59:50) 050322 (19:00:00-00:59:50) 090322 (01:00:00-06:59:50) 130322 (01:00:00-06:59:50) 170322 (19:00:00-00:59:50) 210322 (01:00:00-06:59:50) 270322 (01:00:00-06:59:50) 290322 (19:00:00-00:59:50)	(1,0,2)	9504	23	63,9%
4	040222 (01:00:00-06:59:50)	(1,0,4)	396	1	2,8%
5	130122 (19:00:00-00:59:50)	(0,0,5)	396	1	2,8%
6	270122 (19:00:00-00:59:50) 070322 (01:00:00-06:59:50) 110322 (01:00:00-06:59:50)	(1,0,0)	1188	3	8,3%
	Total	6	14652	36	100%

Table 2 shows a recapitulation of the ARIMA model of the HF channel response where there are six models, with a total sample size of 14252 and there are 36 events. As can be seen in Figure 5.

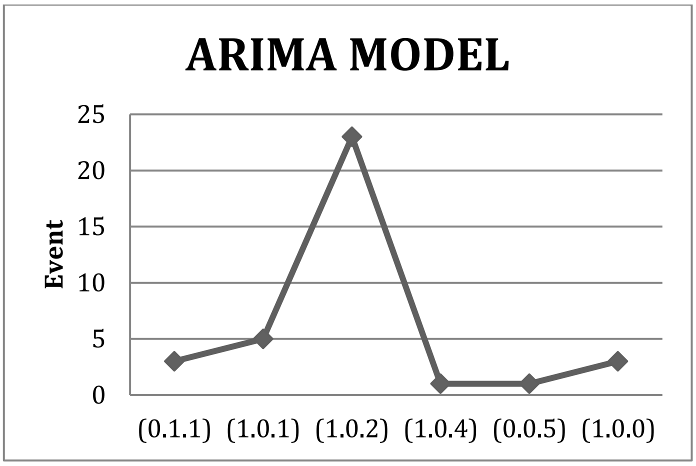

Figure 5. Recapitulation of HF Channel Response ARIMA Modeling

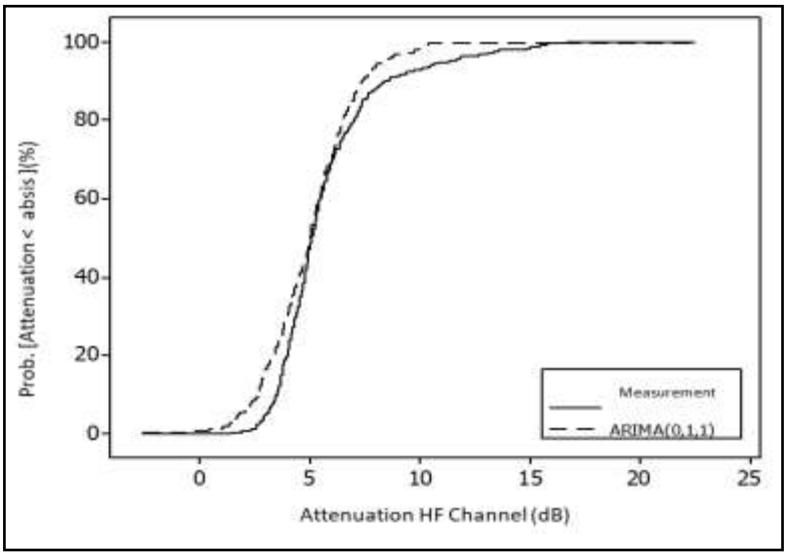

Figure 6. Arima (0,1,1) Model Result

From these data, the results of ARIMA modeling are obtained as shown in Figures 6 and 7, the figure can be seen for the Arima model (0,1,1) the generation results with modeling have values that are not the same but close. While the Arima (1,0,0) model has the same measurement value as the modeling.

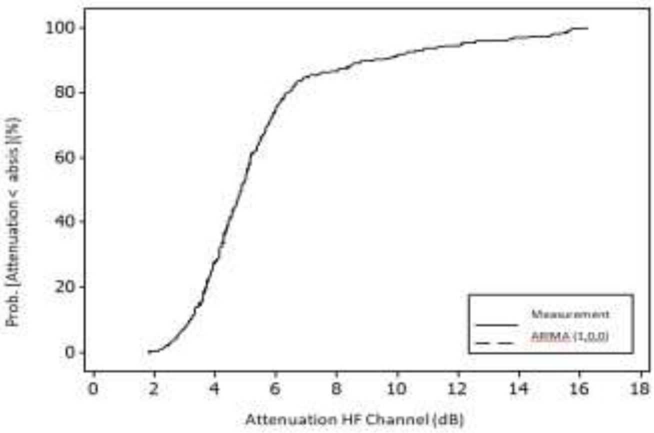

Figure 7. Arima (1,0,0) Model Result

Conclusion

From the modeling results, six ARIMA models were obtained with the greatest probability, namely the ARIMA (1,0,2) model of as many as 23 events (63.9%), then the ARIMA (1,0,1) model of 5 events (13, 9%), ARIMA model (0,1,1) by 3 events (8.3%), ARIMA model (1,0,0) by 3 events (8.3%), ARIMA model (0,0,5) by 1 event (2.8%), and ARIMA model (1,0,4) by 1 event (2.8%). The best model validation for HF channel attenuation is obtained by the ARIMA (1,0,2) model where the Mean Square Error (MSE) value is the smallest, namely 0.2004 with the most dominant number of events of 23 events (63.9%) and the model is very accurate when compared to other models because it has generated results that are close to the measurement results.

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