

CHAPTER 1

INTRODUCTION

1.1 Background

Indonesia, as a maritime country and one of the largest archipelagic countries in the world, has complex issues related to the distribution of broadband access throughout its territory [3]. In addition, the population is increasing every year, triggering various problems to arise, one of which is Internet connectivity. Based on a survey conducted by the Association of Indonesian Internet Service Providers (APJII), internet users in Indonesia in 2024 reached 221,563,479 people from a total population of 278,696,200 people in 2023. The increase of 1.4% from the previous period survey [4], shows that there is an increase in economic growth in Indonesia. This increase in the number of internet users also needs to be balanced with high internet connectivity. Indonesia's diverse geographical conditions cause internet distribution to not fully reach remote areas that are classified as areas that are difficult to get internet access. To overcome this, technology is needed that can reach all parts of Indonesia, namely satellites. The use of satellites is a vital communication infrastructure in the development of technology in archipelagic countries such as Indonesia [5]. Satellite development in Indonesia is increasing, especially in broadband access. In the last 5 years, Indonesia has launched 3 GEO satellites. This shows the seriousness of the country in overcoming connectivity problems in Indonesia. One of Indonesia's GEO satellites is Satria-1. Satria-1 is an Indonesian internet satellite that has High Throughput Satellite (HTS) technology. HTS uses many narrow beams to cover a service area. The same carrier frequency is reused in many beams resulting in a high combined data rate per Hertz of assigned bandwidth [2]. By launching HTS satellites, high-speed internet, this device has the advantage of providing internet services to remote areas. HTS has a performance to channel information far better than conventional satellites. HTS can accelerate the target of broadband connections in Indonesia to remote areas so that it can accelerate the target of broadband connections in Indonesia to remote areas which will certainly increase the opportunity for Indonesia to take advantage of the benefits of digital economy with high-speed satellite internet use for schools, health centers, villages, police stations, universities, which are not served by the internet in remote areas [6]. In addition to having HTS technology, Satria-1 also has several advan-

tages, namely having a capacity of 150 giga bits per second so that it is expected to narrow the digital divide [7]. With the total transmission capacity, each service point will get capacity with speeds up to 1 mega bit per second, besides that the Satria-1 satellite can reach a wide area coverage from Sabang to Merauke, able to overcome obstacles such as mountains, hills, valleys and canyons [8]. Based on the reasons mentioned above, the Satria-1 satellite is important for Indonesia in terms of equalizing internet network connectivity.

In addition to GSO satellites, there are also non-geostationary orbit (Non-GSO) satellites that are interesting to note. Some of the main features that are the advantages of non-GSO are low propagation, small satellite size, lower signal loss compared to conventional geostationary orbit satellites [9]. One example of a non-GSO satellite is Starlink. The internet network owned by Starlink will be very useful for remote areas that are classified as areas that are difficult to get internet access [10].

As the number of non-GSO satellites increases, the use of shared frequencies between GSO and non-GSO satellites is becoming common, which can lead to more interference [11], so maintaining interference avoidance levels between non-GSO and GSO satellites is important. There is potential for co-channel interference between GSO and non-GSO systems when operating in the frequency band for fixed satellite service (FSS) at the same time [12]. Several previous studies address the analysis of interference between GSOs and non-GSOs. Previous research by Wang et al. analyzed the joint interference caused by non-GSO constellations to GSO systems, both on the uplink and downlink, based on metrics such as interference-to-noise ratio and interference probability [13]. The study describes the co-frequency interference between non-GSO and GSO large constellations, especially in OneWeb and SINOSAT-5. Based on the research [13], using 2 satellites namely SINOSAT-5 and OneWeb. SINOSAT-5 does not have HTS technology like Satria-1 while OneWeb is a low orbit constellation with fewer satellites than Starlink. Other research [12] discusses interference caused by large non-GSO constellations to GSO systems by utilizing the Two Line Element (TLE), downlink interference simulations, and observations on EPFD values. Based on [12], the downlink EPFD values performed on Starlink and Telkom-3S at Ku-Band frequencies exceed the interference limits recommended by ITU-R article 22. Furthermore, research [14] shows the positive value of C/N obtained from the link budget analysis for each link of each scenario and the estimation for the analysis of communication capacity capable of being provided by HTS is large enough to handle the needs of data services throughout Indonesia, namely 38.41-93.54 Gbps depending on environmental conditions.

Therefore, it is important to further study the interference that may occur from non-GSO satellite systems to GSO satellite networks in the Indonesian region. This thesis research focuses on the Starlink Generation 2 and Satria-1 satellites at Ka-Band frequencies, analyzing the capacity degradation of Satria-1 and analyzing the regulatory aspects based on the EPFD ITU-R article 22 values. Equivalent Power Flux Density (EPFD) is a metric to ensure that geostationary (GSO) satellites and earth stations (ES) are protected from harmful interference from non-GSO systems. Article 22 of the International Telecommunications Union (ITU)'s Radio Regulations defines Equivalent Power Flux Density (EPFD) limits in order to ensure protection from harmful interference from non-geostationary (NGSO) system into geostationary (GSO) satellites and earth station (ES). The limits of EPFD is contingent upon the frequency band, time percentage, and type of receiving antenna. In the article 22 of the ITU Radio Regulation establishes the EPFD curve and the duration percentage required to safeguard the receiving antenna gain pattern against interference.

1.2 Problem Identification

The same frequency between two satellite systems, particularly non-GSO and GSO, may cause interference from one another and lead to a decrease in a Satria-1 in the quality of service or communication degradation. Based on the downlink frequency, there is a frequency overlap on the ground station and the user terminal Satria-1 due to interference from Starlink satellites. Starlink Generation 2, a constellation of Low Earth Orbit, presents an opportunity to improve connectivity. However, this satellite can cause problems by interfering with other satellites, including the Satria-1 satellite. To mitigate this risk, the ITU has established Radio Regulations, especially in article 22 that state that non-GSOs must not cause unacceptable interference and will not claim protection from GSO satellites as they already exist. The regulation also addresses the limitations of interference caused by non-GSO on GSOs, in this case, EPFD limitations for non-GSO satellites on different frequencies. Potential interference from Starlink Generation 2 affects Satria-1 on the downlink frequency of Ka-Band. For this reason, it is necessary to analyze the interference analysis from Starlink Generation 2 to Satria-1 on its compliance with the ITU Radio Regulations.

1.3 Research Objective

Based on the background and identification of the problem underlying this thesis, the research objectives can be described as follows.

1. Primary Research Objective
 - (a) Analyzing co-channel interference between Starlink generation 2 and Satria-1
 - (b) Compliancen assessment toward Article 22 Radio Regulation
 - (c) Develompent of Dynamic Model
2. Secondary Research Objective
 - (a) Evaluate the effectiveness of frequency coordination and power control mechanisms used by Starlink Generation 2 and Satria-1
 - (b) Propose technical recommendations to minimize interference between Starlink generation 2 and Satria-1

1.4 Research Question

1. What is the magnitude of co-channel interfernce between Starlink Generation 2 and Satria-1 Satellites?
2. Are both systems compliant with the Power Flux Density (PFD) and coordination limits outlined in ITU Radio Regulation Article 22?
3. How do the interference levels impact the performance of each satellite system?

1.5 Scope of Work

To focus the thesis research, several problem limitations will be applied. The following are the limitations of the research scope:

1. The satellites were Starlink Generation 2 and Satria-1
2. Focus on downlink frequency overlap in Ka-Band and Indonesia area

1.6 Hypothesis

The hypothesis in this study suspects interference caused by the Starlink Generation 2 satellite system to the satellite network on the Ka-Band frequency on the downlink and uplink side. This analysis was carried out to ensure its compliance with ITU-R radio regulations.

1.7 Research Methodology

1. Literature Study

Studying references in journals, books, and supporting articles related to interference and international and national regulations for non-GSO and GSO satellites.

2. Data Collection

Collecting data related to the 2 satellites to be studied, namely Starlink Generation 2 and GSO satellites Satria-1.

3. Technical Analysis

Identifies the technical need of interference parameters satellites can provide to consider for implementing both satellites in real-world conditions.

4. Regulatory Analysis

After conducting technical analysis and economic analysis, the next step is regulatory analysis. In this thesis research, regulatory analysis is related to the Radio Regulation issued by the International Telecommunication Union (ITU), especially article 22. This is to ensure satellite compliance with applicable regulations.