CHAPTER I

INTRODUCTION

1.1 Background

Today, satellite communications open up many opportunities to improve service quality and expand the reach of backhaul services in various places and times [1]. The demand for faster and more stable internet access, especially in areas without wired infrastructure, has increased interest in satellites as an efficient communication solution. With its unique ability to cover large geographic areas with minimal field infrastructure, satellites are an attractive solution to meet a variety of growing applications and services [2].

Geostationary Orbit (GSO) satellites revolve over the equator at a height of 35,678 km with an inclination nearing zero [2]. Non-GSO satellites in geocentric orbits encompass Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Highly Elliptical Orbit (HEO) satellites, which consistently operate at reduced altitudes [2]. Numerous non-GSO satellites have been recently deployed for communication reasons. The concurrent functioning of GSO and non-GSO systems within the frequency bands designated for the Fixed Satellite Service (FSS) may result in reciprocal frequency interference [3]. The Equivalent Power Flux Density (EPFD) metric is utilized to evaluate interference, ensuring the protection of GSO or earth stations from detrimental interference caused by non-GSO. The EPFD value is affected by the power flux density modified by the antenna gain of the non-GSO system and the corresponding GSO antenna. EPFD is crucial for enabling satellites to function concurrently without disrupting other systems [4].

Numerous prior research have examined the study of interference between GSO and non-GSO systems. It was observed that Starlink surpassed the downlink EPFD restrictions specified in Article 22, Table 22-1B, for the 17.8–18.6 GHz frequency range, even when assessed independently. The aggregation of all 18 ITU applications resulted in a substantial rise in the downlink EPFD limit exceedance. This analysis pertains to the GSO earth station located in Chandigarh, India [5]. Moreover, prior research indicates infractions of the ITU Radio Regulations concerning EPFD limits of 1%, 10%, and even 100% of the duration. This investigation pertains to the GSO earth station located in Fuchsstadt, Germany. Interference produced at this levels can diminish service quality and result in capacity reduction within the GSO network [6].

This study will compute the EPFD value in the downlink direction, which quantifies the possible interference from non-GSO satellite signals received by GSO earth stations [7]. When non-GSO satellites broadcast signals to non-GSO earth stations, a portion of the signal power also reaches the GSO earth station. It induces interference, potentially impacting the accessibility of the GSO network [7]. The EPFD limit is contingent upon the frequency band, time percentage, and type of receiving antenna. The Radio Regulations establishes the EPFD curve and the duration percentage required to safeguard the receiving antenna gain pattern against interference [8]. Exceeding the EPFD level will contravene Article 22 of the Radio Regulations, which stipulates that non-GSO satellite systems must not induce interference that disrupts the GSO satellite network in the fixed satellite or broadcast satellite service as mandated by the regulation [5].

The EPFD value assessment is performed utilizing the Graphical Interface Batch Calculation (GIBC) software, employed by administrators and bureaus for executing technical or regulatory evaluations of satellite networks or earth stations. To avert surpassing the thresholds established in Article 22, the ITU Radiocommunication Sector (ITU-R) formulated Recommendation S.1503, which instructs satellite operators in the creation of software for assessing EPFD restrictions [4]. Recommendation S.1503 encompasses several primary steps. Initially, ascertain the data for submission and the EPFD thresholds as stipulated in Article 22. Subsequently, the positions of the GSO satellites and ground stations utilized in the calculation are established for each process, referred to as the Worst Case Geometry (WCG). At every phase, the worst case geometry positions for the GSO satellites and earth stations are utilized to model the non-GSO satellite system for an adequate duration to acquire EPFD statistics. The computed EPFD statistics are ultimately checked against the thresholds to ascertain if the findings are successful or unsuccessful [8].

This study aims to analyze the technical and regulatory aspects of the USASAT-NGSO-3X satellite at a frequency of 10700-11700 MHz with a 0.6 m antenna. Two types of simulations are performed using the GIBC software. First is an aggregate simulation using the entire orbital shell; second, a simulation performed separately on each orbital shell. The results of these two simulations will be compared to see the EPFD value obtained and evaluated for compliance with regulatory recommendations regarding EPFD calculations.

1.2 Problem Identification

The rapid development of non-GSO satellites operating at lower altitudes than GSO satellites creates potential interference when both types of satellites share the same frequencies and services. This interference can disrupt the performance of satellite communication systems and reduce the quality of service. This study examines the USASAT-NGSO-3X satellite, part of the second generation of Starlink, which was selected based on a technical study in document 4A/94-E related to the worst case geometry issue.

In the ITU-R Working Party 4A/94-E document, the EPFD simulation of the USASAT-NGSO-3X satellite in the worst case geometry, geometry shows results that meet the Article 22 limits at all points. However, when another simulation is performed without using the 604 km orbital shell, the resulting EPFD values exceed the allowed limits. So, a problem is found between using worst case geometry as the geometry for EPFD evaluation at the Article 22 limits and the definition of EPFD limits. It shows that it is possible to force the current algorithm to choose a specific and favourable worst case geometry to hide the resulting interference.

Therefore, an in-depth study is needed regarding the filing analysis of the USASAT-NGSO-3X satellite, both technically and regulatory. The EPFD analysis was carried out using GIBC software based on the Recommendation ITU-R S.1503-2 algorithm with the worst case geometry method. This EPFD calculation is essential to ensure satellite compliance with regulations so that interference can be avoided and satellite communications remain optimal.

1.3 Objective

The objectives can be described as follows based on the background and identification of the problems underlying this thesis research.

1. Conducting a technical analysis to examine the downlink EPFD value of the USASAT-NGSO-3X satellite at various orbital shell at altitudes of 340–614 km using the worst case geometry method in GIBC software.
2. Studying and reviewing in more depth the results of the downlink EPFD calculation against the limits set by Radio Regulations Article 22.
3. Evaluating the suitability of the worst case geometry algorithm from Recommendation ITU-R S.1503-2 to simulation result of USASAT-NGSO-3X satellite.

1.4 Scope of Work

Several constraints will be imposed to refine the thesis research. The constraints and premises of the research scope are as follows:

1. The satellite under analysis is the USASAT-NGSO-3X.
2. Technical analysis is conducted to assess interference by utilizing the downlink EPFD value at the Ku-band frequency.
3. Regulatory investigation concentrates on assessing the conformity of the USASAT-NGSO-3X satellite's EPFD value with Article 22 of the Radio Regulations, alongside an examination of the applicability of the Recommendation ITU-R S.1503-2 methodology to the GIBC software utilizing the worst case geometry method.

1.5 Hypothesis

The hypothesis of this study suspects interference on the USASAT-NGSO-3X satellite based on the EPFD value using the worst case geometry method. Simulations on separate orbital shell show EPFD values that exceed the limits of Article 22, while aggregate orbital shell simulations produce EPFD values that meet these limits. This indicates an oddity or inconsistency in the definition of worst case geometry against the algorithm used in Recommendation ITU-R S.1503-2.

In addition, in the aggregate simulation for the entire orbital shell, which should represent the envelope of each orbital shell, the simulation results do not show these characteristics. In addition, there is a mutual interaction between the number of orbital shell and the worst case geometry configuration, which causes the coordinates of the earth station and GSO satellite to shift from the individual worst case positions.

1.6 Research Methodology

The following are the methods used in this thesis research:

1. Literature Study

   This process examines the theories needed to understand and support implementation research. Related theoretical sources are obtained from books, conferences, and research journals.
2. Data Collection

   Data is obtained from the ITU website and ITU documents related to satellite operations.
3. Technical Analysis

   Identifying technical needs with EPFD parameters to further examine their compliance with Article 22 and the worst case geometry method used to determine the worst location with the highest EPFD value.
4. Regulatory Analysis

   This analysis is carried out based on the results of technical analysis that can be used as a reference for EPFD value compliance with Article 22 and the suitability of the Recommendation ITU-R S.1503-2 algorithm to the worst case geometry method.

1.7 Methodology

The methodology of compiling this thesis will be divided into several chapters as follows:

1. CHAPTER I – INTRODUCTION

This chapter will address the introduction, research background, problem identification, objectives, research scope, hypothesis, research technique, and writing structure.

2. CHAPTER II – LITERATURE REVIEW

   This chapter will delineate theoretical investigations that will substantiate and underpin this research. The theories that will be discussed are about satellite communication system, frequency allocation for space radiocommunications service, communication links, satellite orbital, non-GSO, interference, Combination in Discreate Mathematics, GIBC EPFD validation, WCG EPFD downlink, EPFD downlink, and regulatory review.

3. CHAPTER III – RESEARCH METHODOLOGY

   This chapter will outline the research methodology and the processes for data collecting and analysis.

4. CHAPTER IV – RESULTS AND DISCUSSION

   This chapter will delineate the outcomes of computations, technological evaluations, and regulatory frameworks.

5. CHAPTER V – CONCLUSION, RECOMMENDATIONS & FUTURE WORK

   This chapter describes the conclusions of the technical analysis and regulations. Then, conclusions, recommendations, and further research will be drawn.

1.8 Publication

The research discussed in this thesis book has been published at the IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology (AGERS) 2024 with the title USASAT-NGSO-3X Filing Analysis Using ITU-BR GIBC Software For Various Orbital Shells.