Chapter 1

Introduction

1.1 Introduction

Satellite communication is an important part of today's telecommunication, broadcasting, and navigation systems. The performance and reliability of satellite links are largely affected by several atmospheric parameters that attenuate the signal. Understanding and being able to accurately predict path loss due to environmental effects is required in order to design and optimize satellite communication networks. For Bangladesh, where the weather is diverse, it is preferable to model satellite path loss for enhancing the quality of satellite-based communication services.

Satellite communication path loss is caused by various factors such as free-space attenuation, atmospheric loss, rain attenuation, and cloud interference. Ground stations utilized to quantify attenuation by transmitting a dummy signal to the satellite and estimating its loss. This, however, takes resources and infrastructure on top of what is already needed. If a reliable predictive model can be established, it would eliminate the necessity of transmitting these dummy signals, thereby lessening operating expenses and boosting efficiency.

In this study, we take Bangladesh Satellite-1 and its ground base stations at Gazipur and Betbunia into account. Collecting historical attenuation data from Bangladesh Communication Satellite Company Limited (BCSCL) and relative weather data from Bangladesh Meteorological Department (BMD), a comprehensive dataset has been formed. The dataset integrates cloud, atmospheric, rain, and free-space attenuation data with various meteorological parameters. In the estimation of total accumulated attenuation, two approaches are investigated: a predictive model based on machine learning and a mathematical model. Both models' accuracy and viability are compared to ascertain their efficacy in being used as substitutes for the conventional dummy signal method. This study not only helps in the enhancement of satellite communication in Bangladesh but also offers a model that can be applied in other parts of the globe that have similar climatic conditions. By having a robust path loss model, satellite com-

munication service providers can render their networks more stable, simplify resource planning, and enhance overall service quality. The findings of this research will give valuable insights on how to mitigate atmospheric attenuation effects and offer uninterrupted satellite communication services in Bangladesh and beyond.

1.2 Motivation

The inspiration behind this research is the growing dependence on satellite communication for a number of important applications such as telecommunication, broadcasting, weather forecasting, and emergency services. It would be best to render these services more efficient, particularly in a developing nation such as Bangladesh, where satellite technology is emerging as a vital part of national infrastructure. One of the most essential satellite communications issues is attenuation of signals caused by atmospheric conditions. Conventional attenuation monitoring methods use dummy signals, which impose cost and complexity on satellite operations. By having a good predictive model, we can make these dummy signals obsolete, promoting operational efficiency and cost savings to satellite operators.

Besides, Bangladesh has diverse and extreme climatic conditions like high monsoons and humidity, which have a pervasive impact on signal transmission. A good path loss model will help mitigate the consequences of these challenges by providing real-time attenuation predictions, thus improved signal reliability and uninterrupted communication services.

The worldwide relevance of this study cannot be ignored since atmospheric attenuation is experienced by all satellite operators around the globe. The result of this study can be used as a reference for other regions of the world with the same meteorological climate, which will add to the general body of satellite communication and path loss modeling.

In general, this study is motivated by the demand for an inexpensive, dependable, and efficient means of enhancing satellite communication in Bangladesh and elsewhere. With the use of sophisticated machine learning techniques and mathematical modeling, we seek to establish a scientifically credible method of attenuation prediction for the general goal of increasing the level of performance of satellite-based communication systems.

1.3 Objective

The main goal of this research is to create an effective and precise model for predicting satellite path loss from atmospheric attenuation. Based on machine learning approaches and mathematical modeling, this research intends to establish the most appropriate method to foresee total attenuation. The main aims of this research include:

- Collecting and merging BCSCL's historical attenuation data with BMD's weather data to create a comprehensive dataset.
- Building a machine learning model to predict total accumulated attenuation based on meteorological data.
- Creating a mathematical model for predicting attenuation and comparing the precision with the machine learning model.
- Comparing the validity and accuracy of both models for determining their viability in replacement of conventional dummy signal-based attenuation monitoring.
- Providing data that can be utilized for optimizing satellite communication networks, reducing operational costs, and enhancing the performance of Bangladesh Satellite-1 and other similar systems worldwide.

Through these goals, this research seeks to play a role in the creation of a more efficient and resource-saving method of monitoring satellite communication signal attenuation.

1.4 Scope of Work

The study's importance transcends the prediction of satellite path loss—it presents a novel and globally applicable method for optimizing the performance of satellite communications. Unlike other models needing location-dependent parameters like latitude and longitude, the mathematical model proposed in this work is not geographically limited. That is, wherever a ground station is positioned or whichever country it is in, the model is still valid.
Instead of being dependent on coordinates, the mathematical model only needs to be provided with typical weather parameters like rain rate, surface temperature, surface pressure, relative humidity, cloud base height, liquid water density in clouds, liquid water temperature in clouds, uplink frequency, polarization type, and path length. All these as inputs make the model deployable anywhere on the earth without any changes, which is a huge advantage when it comes to scalability and deployment ease.
By eliminating reliance on location-specific data, this model has the potential to be a globally viable solution for satellite communication path loss prediction. Even though improvements in accuracy are still possible, the groundwork for global usability is already there. This study, thus, not only has value in the enablement of satellite communication in Bangladesh but also makes a wider contribution by providing a model that can readily be incorporated into satellite networks worldwide.