Identification of the Best Location for High Altitude Platform Station

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***Abstract*— One of the main key issues in the exploitation of HAPS is the rain as the rain attenuation is most dominant at the frequencies above 10 GHz. The effect of rainfall is more severe in tropical regions, which are characterized by heavy rainfall intensity for long periods of the day. This paper provides a method that used to identify the best location of the HAPS stratospheric segment in peninsular Malaysia. The study was done based on ten ground stations that suffer the highest rainfall intensities on the ground. The best locations for the northern and the southern platform were found to be at Sungai Lembing (4.11° N, 102.88° E), and Tanjung Kling (2.23° N, 102.02° E) respectively. The modified ITU-R model was the used to carry out this study.**

Keywords-component; HAPS, Satellite, Rain Attenuation.

I. INTRODUCTION

The demands to providing a developed wireless communication infrastructure, to ensure high-quality communication services to the customers, has led to development of a new communications technology. The operating frequency for HAPS is 28 GHz for the downlink and 31 GHz for the uplink, where the rain attenuation will be the primary source of signal impairment for HAPS communication links [1]. HAPS technology has many advantages over terrestrial and satellite networks, especially in terms of the coverage area with highly cost effective service. The satellite cost is quite high as well as for terrestrial systems because of the many access points that are needed to cover these areas. Moreover, 258 ground terrestrial towers are needed to cover the same area covered by one HAPS segment [2]. Based on ITU-R recommendations regarding the HAPS coverage area, two HAPS platforms located at 25 kilometers altitude could cover the whole Malaysian peninsular at a minimum elevation angle of 7.5° degrees, since the length of the peninsular is 750 kilometers and the HAPS at a height of 25 kilometers can cover a diameter of 380 km at 7.5°, thus two HAPS are needed to cover 750 kilometers. For HAPS Wireless Access, the minimum elevation angle allowed to be used is 5° degrees where it is better to use a higher elevation angle in order to avoid or guard against excessive ground clutter problems.

A total of 10 different locations were selected based on the highest rain intensities. Each location has different geographical characteristics such as the base station altitude above sea level, the geo-location in terms of longitude and latitude, and the annual rainfall rate which contributes to the attenuation caused by rain. The numeric data of the geographical location (longitudes and latitudes) of this study were calculated using Google Earth software, while thirteen years statistical rainfall data with an integration time of one minute were obtained from the Malaysia Meteorological Office (MMO). The specific rain attenuation impairs the HAPS earth-space link of the selected earth stations will be predicted and analyzed with respect to the rainfall rate statistics data, signal polarization, and the elevation angle. The rain attenuation will be predicted by the modified ITU-R model, with respect to the operating frequency of the HAPS and the earth station longitude and latitude, assuming that the received signal is circular polarity at once, then in vertical and horizontal polarities. The modified model that is able to predict the earth-space rain attenuation when the signal path is either completely or partially affected by the rain will be used to predict the rain attenuation.

II. METHODOLOGY

Previously, the authors have proposed a new model that is able to predict the rain attenuation when the signal path is either completely or partially affected by the rain. The modified ITU-R model is used in this study to predict the rain attenuation, and has been presented in detail [3]. In this study, the Malaysian peninsular is divided into two distinct areas (north and south). Five earth stations were selected in each sectors based on the highest rainfall rate amounts. The distribution of the stations is shown in Figure 1.

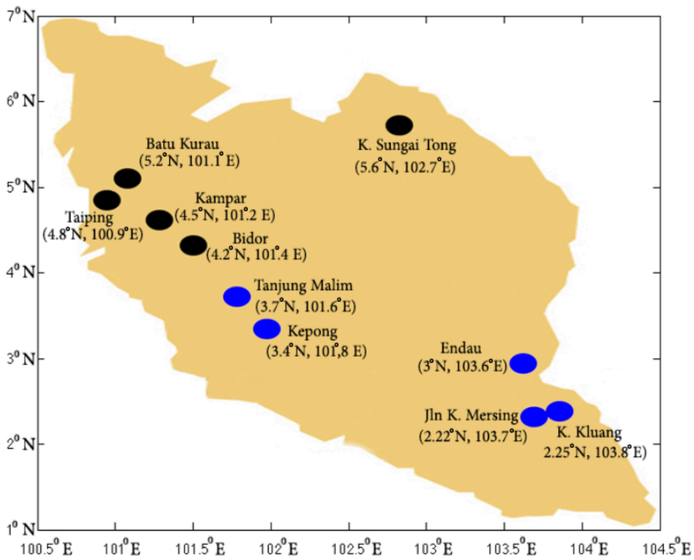

Figure 1. Locations of the earth stations

Each station will receive the line-of-sight HAPS signal at different angles, where the distance of the signal path that will be affected by the rain is dependent on the rain cell size, elevation angle, and the rainfall rate. Rain cell size is dependent on the type of rain where the precipitation can be classified into two types: convective and stratiform rain. However, in peninsular of Malaysia, the relative cell size is 1.25 km [4]. The earth stations that is covered by the first HAPS platform (ES1, ES2, ES3, ES4 and ES5) are located far away from each other. The separation distance between ES1 and ES2 is 231.23 km, 24.22 km between ES2 and ES3, 75.64 km between ES3 and ES4, and 26.57 km between ES4 and ES5. The southern ground stations that are covered by the second HAPS are separated as follows: the distance between ES6 and ES7 is 51.71 km, 234.22 km between ES7 and ES8, 46.1 km between ES8 and ES9, and distance between ES9 and ES10 is 15.2 km. All stations receive and transmit the signals with different elevation angles depending on the HAPS platform location.

III. RESULTS AND DISCUSSION

To estimate the rain attenuation contour maps, the modified model is used to predict the rain attenuation at 1.25 km rain cell size for all locations. Figure 2 shows the map of the peninsular Malaysia with the contour lines for the rainfall rate intensity of the stations of interest selected in this study. The figure depicts that the rainfall intensity varies in accordance with the geographical location. It can be seen that the station located in Taiping suffers the highest rainfall intensity ($R\_0.01$ is 145.5 mm/h), while it decreases gradually to around 126.2 mm/h at Tanjung Malim station. The figure also shows that the stations located in the northern part of the peninsula suffer from a greater relative amount of the total rainfall accumulation than those located in the southern part.

Figure 2. Rainfall rate contour lines in peninsular Malaysia

Figure 3 shows the rain attenuation contour in Malaysian peninsular, where the variation of the predicted attenuation values for each location can be seen. For a station like Taiping which experiences the highest average annual rainfall, the rain attenuation is as high as ~3.4 dB compared to Tanjung Malim station which suffers the lowest rainfall rate.

Figure 3. Rain attenuation contour lines in peninsular Malaysia

The results of the rain attenuation prediction in the northern part of the country has an average difference between the maximum and minimum value of about 2.5 dB higher compared to the southern region. Based on the results obtained, the best HAPS location has been investigated using a matrix of 10*10 for each location, which means that 100 points distributed all over each part to predict the rain attenuation at these points for each station. Each station will be represented by one matrix as shown in Figure 4. Therefore, 5 matrixes will be produced in each part.

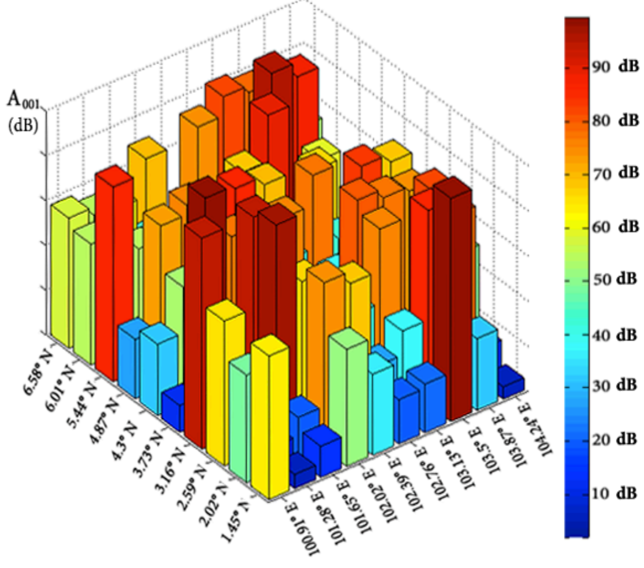

Figure 4. Rain attenuation matrix obtained for each part of the peninsular

A MATLAB code was designed to compare each element in each matrix with the elements in the other matrices located at the same matrix point, and the maximum value of the attenuation will be selected. At the end of the comparison algorithm, one matrix containing all maximum values of the attenuations will be obtained as shown in Figure 5.

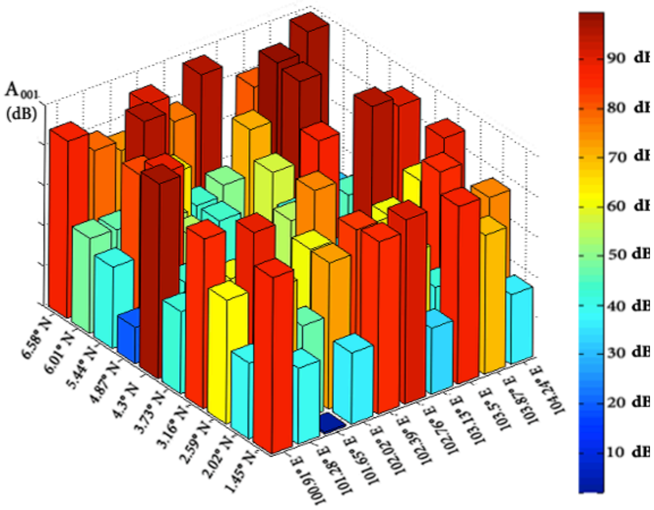

Figure 5. Maximum Rain attenuation matrix obtained for each part of the peninsular

Finally, as shown in Figure 6, the matrix element which is assigned by the lowest attenuation value will be indicated as the best location for the stratospheric segment. The best locations for the northern and the southern platform were found to be at Sungai Lembing (4.11° N, 102.88° E), and Tanjung Kling (2.23° N, 102.02° E) respectively.

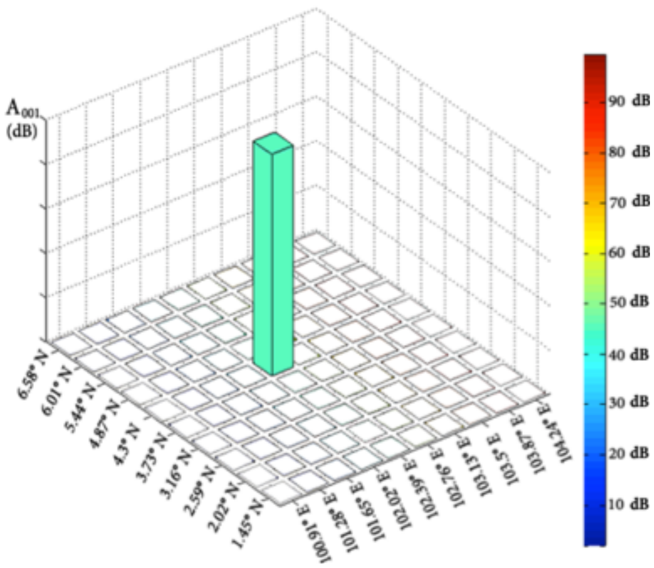

Figure 6. Rain attenuation matrix indicates the best HAPS location

The attenuation values due to the rain and free space loss of the northern part are up to 1300 dB in some points in the matrix while it is 200 dB at the most efficient location, whereas it is up to 1400 dB in the southern part but 195 dB at the most efficient location.

IV. CONCLUSION

This paper provides an overview of a mechanism that is used to identify the best location of the HAPS stratospheric segment in peninsular Malaysia. The peninsular is divided into two parts, where one HAPS segment is dedicated to each part. The best HAPS location has been investigated using a matrix of 10*10. The best locations for the northern and the southern platform were found to be at Sungai Lembing (4.11° N, 102.88° E), and Tanjung Kling (2.23° N, 102.02° E) respectively. Additionally, this method can be also used to identify the best location for Geo-stationary satellites.

V. REFERENCES

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