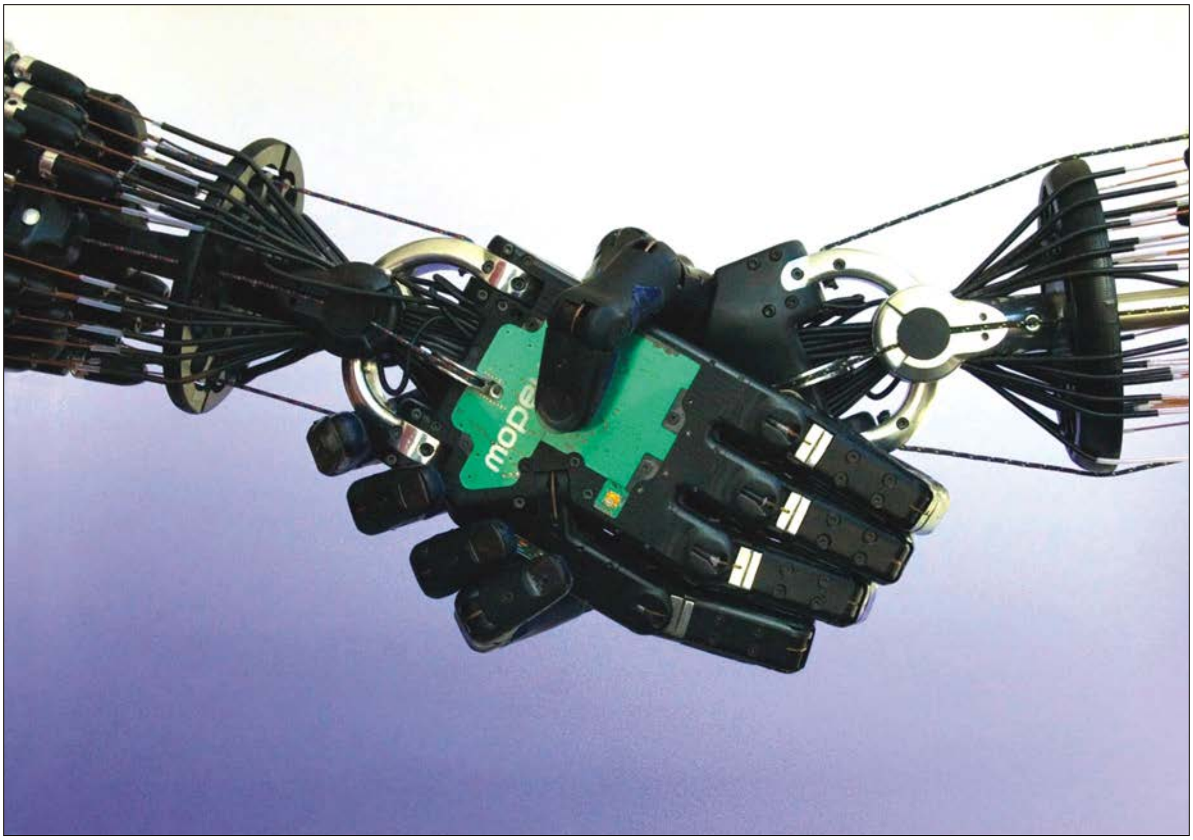

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Research Article

Effect of Climate Change on Satellite Communication Links in Malaysia

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Abstract

Communication through satellites remains as one of the most important aspects in telecommunication field. Satellite communication links operating at microwave frequency range at Ka or Ku band often used in rural or other areas where optical fiber communication links are absent. However, microwave links tend to suffer losses due to hydrometeors such as rain. One of the parameters of measuring the performance of satellite links is rain height. Higher rain height results higher losses for the satellite links. With the climate change occurring globally, rain height changes as it depends on the temperature on the surface level. This study studies the effect of climate change to rain height and ultimately to losses incurred at satellite links in Malaysia. The reanalysis data from National Oceanic and Atmospheric Administration has been used to quantify rain heights.

Key words: ZDI, tele communication network, rain neight, Fade

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The backhaul in telecommunication network, which acts like a highway for data transmission, relies on cable and wireless system. For the cables type of transmission, fiber optic communication offers the fastest and most reliable data transfer, but the cost of laying down the cables and other matters related to it can be overwhelming. Hence, the use of line of sight wireless satellite links, operating at microwave frequencies for backhaul is more economical and preferable in most developing countries and rural areas[1].

Microwave links operating above 20 GHz (at Ka and Ku band) tend to suffer losses or fading of signal strength in dB due to hydrometeor events (atmospheric particles associate with water such as rain, cloud, fog and sleet). Large losses due to these phenomenons could lead to an outage, a complete loss of signal. The most dynamic and largest contributor to hydrometeor fading is rain. The International Telecommunication Union or ITU has released series of recommendations called ITU-R to address this issue, mostly through the use of mathematical models (based from historical meteorological data) for fade predictions and mitigations. Radio engineers use these models for radio planning and design, including assigning appropriate fade margins to mitigate hydrometeor fades.

Rain height is defined as the height between ground surfaces to the top layer of atmosphere where ice particles begins to melt and form rain drops. Rain height closely associates with Zero Degree Isotherm (ZDI) height and a slant path for a satellite communication link is a distance from ground stations to rain heights as illustrated in Fig. 1. The ITU[2], rain height on average is assumed to be at 360 m above ZDI due to super cooled water droplets that exist in the stratiform region. The droplets coaslesce with one another, creating heavier hydro particles and fall to earth due to gravity as rain drops. The ITU[2] also provides the yearly average of ZDI and rain height prediction and calculation throughout the globe.

However, the current model is static and does not include the climate change model. Diaz *et al.*[3] and Paulson and Al-Mreri[4] have discovered that the increase of ground temperatures over the past several decades gave rise to ZDI and rain heights in most of the regions. Higher rain heights mean higher losses since the slant path for a satellite link will be longer. In this study the correlation was observed between increasing global temperature due to climate change and the rain heights in East and West Malaysia.

Meteorological data: The NCEP/NCAR reanalysis data which provides globally gridded meteorological data by integrating global climate observations and Numerical Weather Prediction (NWP) model at 17 pressure levels from 1000-10 m bar. The reanalysis data consists of historical data back from 1948 to present at 6 h interval. The product is a joint partnership between National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) and archived by National Oceanic and Atmospheric Administration (NOAA) (http://www.esrl.noaa.gov/psd/). The temperature and geopotential heights at different pressure levels has been utilized to compute ZDIs and eventually rain heights for this study. The ZDI height can be calculated from the reanalysis data using linear interpolation between the lowest temperature-height positions decreasing through 0°C with increasing altitude as shown in Fig. 2. This technique has been used by several researchers including[1,3,4,5].

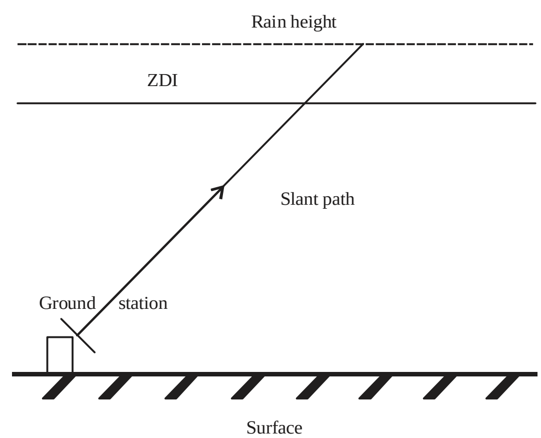

Fig. 1: Basic illustration of a typical satellite link operating at or above Ka/Ku band along with ZDI and rain height

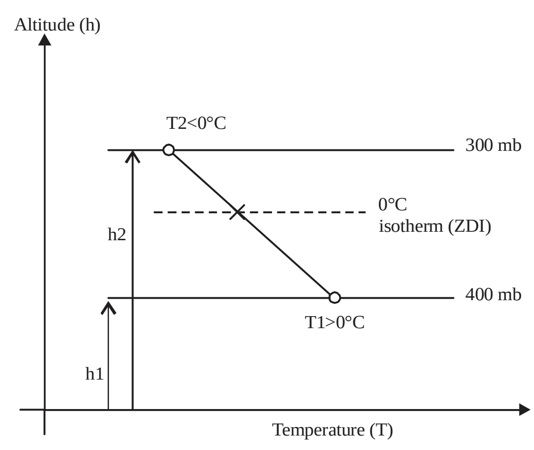

Fig. 2: Basic illustration of a calculation for ZDI and rain height where h1 and h2 are the height points and T1 and T2 are the temperature points

Thirty three years worth of reanalysis data in Malaysia, from 1980-2012 were extracted from Physical Science Division under NOAA for this study. The data was extracted beginning at 1980 for the reason that the global temperature started to rise at alarming rate in the region of that period of time[6]. The rising global temperature from 1980 till now is part of the event known as "Hockey stick" as coined by some meteorologists in which the global temperature was stabilizing prior 1900s but shot up at around 1960 and 1980s.

RESULTS AND DISCUSSION

Figure 3 and 4 illustrated the increasing annual mean ZDI heights over 32 years in West (Peninsular) and East (Sabah and Sarawak) Malaysia, respectively. The least squares (LSQ) linear regression line was built-in to the annual mean ZDIs for both regions of Malaysia and found the positive slopes to be 2.11 and 1.37 m increasing per year for West and East Malaysia, respectively. These results coincide with the rising global temperature. Similar study was done by Paulson and Al-Mreri[4] have also shown the increasing ZDI due to climate change and documented the trend slopes for different regions. The results of increasing ZDIs in Fig. 3 and 4 for Malaysian regions are generally in agreement with the arguments put forth by Paulson and Al-Mreri[4].

A satellite link with operation frequency of 27 GHz, with 89 mm h^{-1} rain rate at 0.01% exceedance level, elevation angle of 50° and at 3° latitude was simulated using[7] fade model for satellite communication to study the impact of rising ZDI and rain height to satellite links. Three year samples of ZDI (1996, 2004 and 2010) from East Malaysia have been used for the annual satellite fade distributions simulation as shown in Fig. 5. The result in the Fig. 5 shows the difference of fades in dB between those three sampled years to be minute, with the differences being in the range of 0.5-1 dB at 0.001% exceedance level. However, if the fade at 0.001% exceedance level are sampled for each of the 33 years, a positive slope can be clearly seen as shown in Fig. 6 and 7 for West and East Malaysia, respectively. The slopes were found to be 0.017 and 0.0114 dB increment per year for West and East Malaysia in that order. Eventually, over the next 10 or more years, satellite link will face more significant losses in dB due to the increment of rain height. This could soon be a problem for microwave satellite links, if the fade is excessive, an outage or a complete loss of signal might occur. This issue could be resolved if radio planners integrate the increment fade slopes in their calculation,

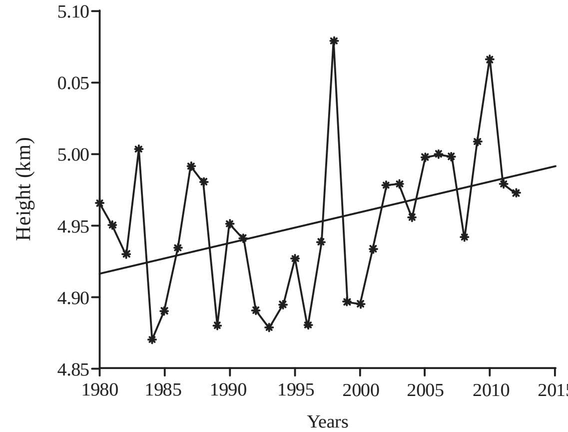

Fig. 3: ZDI trend over 33 years in West side of Malaysia (Peninsular) where the blue line indicates the actual recorded ZDI and the red line indicates the least square linear regression

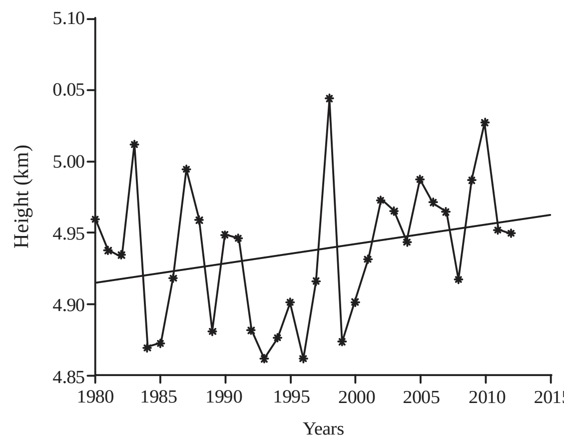

Fig. 4: ZDI trend over 33 years in East side of Malaysia (Sabah and Sarawak) where the blue line indicates the actual recorded ZDI and the red line indicates the least square linear regression

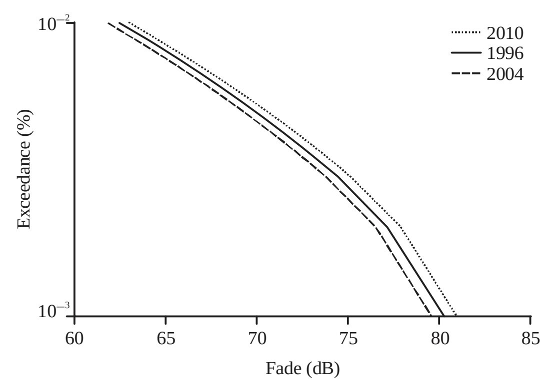

Fig. 5: Simulation of annual satellite link fade distribution with different rain heights for the year 1996, 2004 and 2010 in East Malaysia

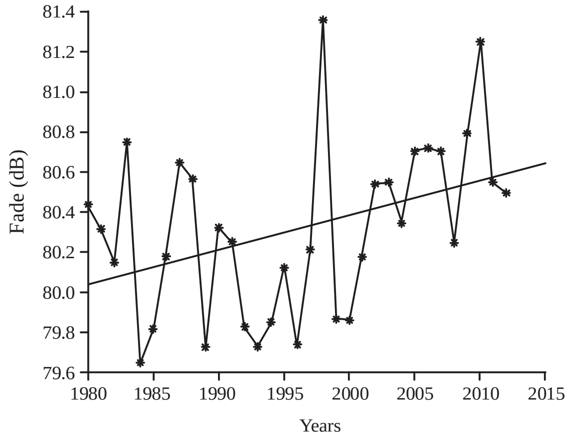

Fig. 6: Fade in dB trend due to increasing rain height over 33 years in West side of Malaysia (Peninsular) where the thin dotted line indicates the simulated fade and the black solid line indicates the least square linear regression

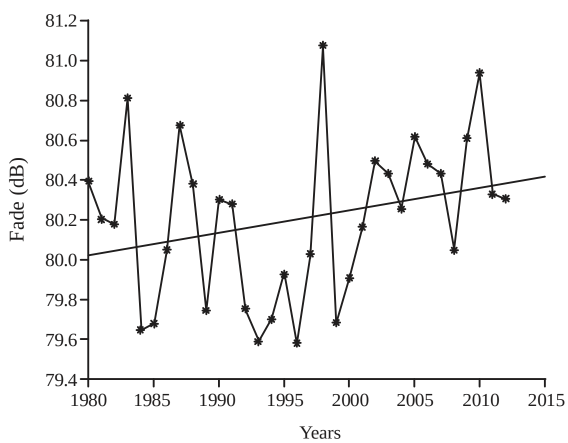

Fig. 7: Fade in dB trend due to increasing rain height over 33 years in East side of Malaysia (Sabah and Sarawak) where the thin dotted line indicates the simulated fade and the black solid line indicates the least square linear regression

particularly for the fade margin in link budget. In addition, the plan for exploitation of millimeter waves beyond 60 GHz due to current bandwidth limitations for various wireless applications including satellite links would face major challenges since an increased operation frequency for any satellite links will significantly increase the fade slopes as well.

CONCLUSION

The ZDIs and rain heights over thirty three years in West and East Malaysia have been analysed by using the NCEP/NCAR reanalysis data from NOAA. From the results, it can be concluded that the Malaysia and perhaps other regions as well, are experiencing increasing rain height and fade due to climate change. It is advisable for radio engineers to include climate change model when formulating fade model for satellite links across the globe as this would mitigate the losses incurred at those links.

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