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Analysis of Rain Fade for Satellite Networks Using Multi Precipitation Estimate in Malaysia

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Abstract: Satellite networks operating above 20 GHz (Ka and Ku band) usually suffer radio signal absorption and scattering losses, mostly due to hydrometeor events such as rain. This phenomenon is called rain fade. The fading due to rain can disrupt major wireless backhaul communication and may lead to signal outages, a complete loss of signal. High frequency radio signals suffer a lot more in tropical regions such as Malaysia where more and heavier rain events are expected. In this paper, the existing meteorological data called Multi Precipitation Estimate, operated by EUMETSAT is used as a source for meteorological input to simulate rain fade effects on satellite networks in East and West of Malaysia. This paper is an extension from a previous paper, published in IEEE xplore titled "Preliminary study of EUMETSAT's Multi-Sensor Precipitation Estimate product for microwave links in Malaysia".

INTRODUCTION

It is commonly known that any hydrometeor events including rain, cloud, fog and sleet affect radio signals. The effect can be clearly seen for high frequency signals, usually above 10 or 20 GHz. The higher the frequency, the more signal losses are expected. Usually, wireless backhauls including terrestrial links (point to point) and satellite links are the most affected since they operate in high frequency region. Among these hydrometeor fading mechanisms, rain fade is the one of the most devastating fading since rains are more dynamic in terms of space and time. Rain events can typically last from few seconds to hours long and can move slowly or rapidly (Hafiz, *et. al*, 2012).

To overcome this problem, radio engineers rely on the existing mathematical and statistical models provided by International Telecommunication Union or ITU, based on historiological data, collected from rain gauges, rain radars and weather satellites to predict rain fade effects on any desired radio links. ITU provides recommendations for terrestrial links in ITU-R P. 530 and (ITU-R *et. al*, 2015) for satellite links. However, these models are limited to a single link and would not be suitable for a more complex radio links, (Hafiz, *et. al*, 2012) and (Paulson, *et. al*, 2011).

This can be easily remedied by using meteorological data to simulate any complex radio links. Since rain fade is the most devastating fading mechanism, any meteorological data that provides rainfall rate in mm/hr would be useful. There are several options to choose the source for meteorological data; this includes rain gauges, rain radars and weather satellites. Rain gauge provides the best estimation of rainfall rate since it use direct measurement of rain. Rain gauge has the best temporal sampling of rain rate, usually down to ten of seconds but the spatial coverage of rain gauge is extremely small, typically around dozens of meters. Rain radar provides larger spatial coverage at around few hundreads of kilometer but has longer temporal sampling time to about 15 minutes for every radar scan. Weather satellite offers the best spatial coverage, can be extended to globally, but depending on types of satellites, the temporal sampling can vary from 30 minutes to few hours (Hafiz *et. al*, 2014), (Hafiz, *et. al*, 2012). In this paper, the Multi Precipitation Estimate from EUMETSAT is selected to provide the source of meteorological data on rainfall rate for satellite link simulation in Malaysia.

2. <u>MATERIAL AND METHODS</u> 2.1) Multi Precipitation Estimate

Multi Precipitation Estimate or MPE is a meteorological datasets that contain numerous meteorological data including surface and atmosphere temperatures, pressures and rainfall rate. The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). an intergovernmental organization that currently manages the MPE data. The MPE measurements depend on the constellation of weather satellites called METEOSAT and can produce high spatial resolutions, with a temporal period vary from 5 to 30 minutes sample period. The MPE utilizes IR or infrared channel data and microwave based instruments called Special Sensor Microwave/Imager (SSM/I) and blends them to increase the accuracy of its estimation. The MPE also frequently uses rain gauges and radars for calibration and validation purposes. (Heinemann, et. al, 2004).

2.2) Data Collection

In this paper, three years of rainfall data from MPE were collected in West (Peninsular) and East (Sabah and Sarawak) side of Malaysia. The years are 2010,

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2011 and 2012. More years collected are to ensure little variation and stability when performing statistical calculations. The MPE product has a 30 minutes sample period with a spatial coverage from -8.0° West to 122.0° East bound longitude and 65.0° North to -65.0° South bound latitude. The Peninsular Malaysia (1.4° to 6.3° North latitude, 99.5° to 104.47° East longitude) and Sabah and Sarawak (0.79° to 7.2° North latitude, 109.4° to 119.5° East longitude) regions in MPE product are extracted for this study. (Fig 1). shows the sample of MPE rainfall data in Malaysia.



Fig.1. Sample image of MPE product over Asia, taken from: (http://oiswww.eumetsat.org/IPPS/html/MTP/PRODUCTS/MPE/ SOUTHERNASIA/)

3. <u>RESULTS AND DISCUSSION</u>

In this section, the three years, 2010, 2011 and 2012 of rainfall yearly distribution are presented, along with the conversion to rain fade in decibels (dB) and are compared to satellite fade distribution from ITU-R 618.

3.1) Rain Rate Distribution

(Fig 2 and 3). show the exceedance distribution in percentage against rainfall rate distribution in mm/hr for all the three years in West and East Malaysia respectively. Both figures were taken from a previous paper published earlier in IEEE explore. The figures demonstrate that the rainfall rate tends to vary from year to year, hence the need to average them out for proper statistical calculations. The rainfall rate is capped at 37 mm/hr due to hardware limitations on board the satellites.



Fig.2. Rain rate distribution in West (Peninsular) Malaysia



Fig.3. Rain rate distribution in East (Sabah and Sarawak) Malaysia

3.2) Rain Fade Distribution and Integration Time

The rainfall rate distribution obtained from MPE can be converted using the standard rainfall rate to specific attenuation formula from (ITU-R *et. al*, 2005) as shown in Equation 1.

$$kR^a$$
 (1)

Where γ is the specific attenuation, k and a are the constants that depends on the frequency operation of a link.

It is worth to note that the sample period of MPE is 30 minutes whereas the satellite rain fade distribution from ITU-R P. 618 is 1 minute. Therefore the rainfall rate distribution from MPE was converted from 30 to 1 minute integration time using a regression model as shown below in Equation 2 before translated to rain fade distribution using Equation 1. This would make the comparison more viable.

$$R_1(p) = a[R_{\tau}(p)]^b \quad mm/hr \tag{2}$$

R1 (p) and $R\tau$ (p) are the rainfall rates with 1-min and τ -min integration times respectively and exceeded with equal probability, p%, while a and b are regression coefficients. The Equ. 2, along with the regression coefficients, can be obtained from (ITU-R P. 837-5, *et. al*, 2007).

3.3) Satellite Rain Fade Distribution and Comparison

In this section, the simulated satellite rain fade distributions from MPE are compared with the ITU-R P. 618 fade model for West and East Malaysia. (Fig 4 and 5) show the comparison results. During the simulation, 20 GHz was selected to be the frequency operation of the satellite link, since it is the usually frequency range for commercial broadcasting satellite. The location of the base station transceiver was set at 100 meters above the sea level and the rain height is assumed to be 5 km at all time. Information on rain height can be obtained from (ITU-R *et. al*, 2013). The results show that the MPE's rain fade distributions are in agreement with the satellite rain fade model from ITU-R P. 618 in the lower exceedance level of 1 to 0.1% for both West and East of Malaysia. The MPE

results differ from the ITU-R at higher exceedance levels, most probably due other small hydrometeor fading mechanisms detected by the weather satellites such as cloud or fog. Regardless, most radio engineers are more concerned with the low exceedance level since high rain fades occur around this region whereas in high exceedance level usually associate with low rain fades that are negligible.



Fig.4. Satellite rain fade distribution in West (Peninsular) Malaysia



Fig.5. Satellite rain fades distribution in East (Sabah and Sarawak) Malaysia

4. <u>CONCLUSION</u>

The comparison results in (Fig. 4 and 5) shows that satellite rain fade simulations for West and East of Malaysia are in fairly agreement with the satellite rain fade model from ITU-R P. 618. This would allow the opportunities for further study and expansion to include MPE as a source of meteorological input for advance and complex satellite network simulations. Data such as MPE would allow radio engineers to identify and predict rain fade more accurately and perform more advance analysis such as the second order statistics for rain fade as opposed to rely solely on theoretical models from ITU.

4. <u>ACKNOWLEDGEMENT</u>

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