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Extracted atmospheric impairments on earth-sky signal quality in tropical regions at Ku-band

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ABSTRACT

Atmospheric condition variations were shown to have a major effect on the earth sky signal quality at Ku band. Moreover, such variations increased in the tropical regions as compared to temperate areas due to their different weather parameters. With the increase of recent satellite communication technology applications throughout the tropical countries and lack of information regarding the atmospheric impairments analysis, simulation and mitigation techniques, there is an ever increasing need for extracting a unique and accurate performance of the signal quality effects during highly natural tropical weather impairments. This paper presents a new method developed for proper analysis with distinctive and highly realistic performance evaluation for signal quality during the atmospheric conditions variations in 14 tropical areas from the four continents analyzed based on actual measured parameters. The method implementation includes signal attenuation, carrier to noise ratio, symbol energy to noise ratio, and symbol error rate at different areas and different modulation schemes. Furthermore, for improvement in analysis in terms of covering more remarkable regions in tropics, the paper provides new measurements data with analysis for certain region in tropics used as a test bed and to add measurement data of such area to the world's data base for future researchers. The results show a significant investigation and performance observation in terms of weather impairments in tropical regions in general and each region in that area in particular regarding the signal attenuation and error rates accompanied for several transmission schemes.

1. Introduction

As the desire for more data to be sent with respect to time in satellite communication, the higher frequencies began to gain much more interest. As a recent trend, Ku band is typically used especially in high quality and advanced applications multimedia transmissions because of its wide bandwidth, and less noise effect compared with other higher bands like Ka and V bands. Consequently, the rain attenuation at Ku band, which is the main considered frequency band in this paper, has a paramount impact on signal attenuation in space, followed by clouds, water vapor and oxygen as a minor effect on signal level variation.

The atmospheric phenomena cause two types of fluctuations on the transmitted signal, namely the fast and slow fluctuations (Adhikari et al., 2012). The former is typically caused by rapid variations at the signal level due to the irregularities of the refractive index in the troposphere. This variation is referred to as tropospheric scintillation. On the other hand, the latter is normally caused through the absorption and scattering of the signal by the particles, especially water droplets, in the link between the station on earth and the satellite.

The abovementioned atmospheric impairments effects on the earth sky communication quality increase the need for developing prediction models through researches in order to predict the atmospheric fade level as well as proposing proper fade mitigation techniques (FMT). Several researchers have tried to analyze the atmospheric effects on the transmitted signal level (Bryant et al., 2001; Crane, 1996; Dissanayake et al., 1997; Ramachandran and Kumar, 2007; Yamada and Karasawa, 1994). Despite a small inaccuracy percentage, they have been able to build well formulated models for a better expectation of the phenomena the impact according to the parameters related.

Recently, extracting an exclusive and accurate performance of the signal quality effects during highly natural tropical weather impairments has turned into a growing demand due to the fact that modern satellite communication technology applications are being increasingly demanded in tropical countries and that there is a scarcity of information regarding the atmospheric impairments analysis. This paper presents integrated aspects to improve

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the evaluation and analysis of atmospheric effective parameters on the signal quality at Ku band in tropical regions. The integrated aspects include (i) presenting a new method which has been developed to extract the atmospheric impairments out of other impairments affecting signal quality, (ii) obtaining actual atmospheric and geographical parameters of substantial tropical regions, and finally, (iii) supplying the specified database with the first measured data of a remarkable region in tropics.

2. Methodology

The signal transmitted or received from GEO satellite passes through 4 atmospheric layers; Troposphere, Stratosphere, Mesosphere, and Thermosphere. The significant impairments on Ku band signal occur on the lowest layer, the Troposphere, which contains the rain, clouds, and water vapor. It needs to be asserted that the impairments analysis done can be classified into two methods, Atmospheric impairments on the single site method that can be referred to (AI-SS), and Atmospheric impairments on multisite (AI-MS). In the former the researchers use the analysis method to obtain the weather parameters effects on specific region or site using variable transmission parameters such as different elevation angles and/or frequencies. Therefore, they use fixed geographical parameters with specific atmospheric parameters related to this region. On the other hand, in the (AI-MS) method, researchers tried to analyze and compare the rain impairments in different regions in tropics, nonetheless, they use different transmission parameters like elevation angles and frequencies while these two parameters have major effects on the attenuation value during the bad weather especially at high rain rates periods. The next subsection will discuss the transmission parameters variations and the reason behind presenting a new analysis method, the Extracted Atmospheric Impairments on Multi Site (EAI-MS) method, for proper indications and recordings of the atmospheric effects in tropics.

The rain effect, which is the most effective phenomena on attenuation at Ku band among other atmospheric impairments, will be presented in Section 2.2, the specified subsection starting with an introduction to rain impairments in general before shrinking to tropical regions in particular. Afterwards, the previous works will be analyzed before gathering and debating the actual measured data from the previous works. Finally, the description and implementation of the newly developed EAI-MS method will take place. Other atmospheric impairments in tropics are explained in Section 2.3.

2.1. Transmission parameters effects and EAI-MS method

Transmitted signal frequency plays a major role in the estimation of effected atmospheric parameters on the signal level. For frequencies below 3 GHz, ionospheric scintillation has a remarkable effect nonetheless, this phenomenon's role will start to disappear as the frequency goes higher (Panagopoulos et al., 2004). On the other hand, for frequencies above 10 GHz, other atmospheric phenomena, such as rain and clouds, impose a serious impact on the signal attenuation (Omotosho and Oluwafemi, 2009). In addition, the oxygen and water vapor have a significant effect for higher frequencies (Zubair et al., 2011).

The elevation angle is a highly effective parameter for the atmospheric effect. Furthermore, the transmission at low elevation angle during the rain will increase the effective rain path of the signal increasing the signal power degradation, accordingly. As a result, the engineers in earth stations try to access as near satellite position as possible in order to decrease the rain attenuation during the rain events. Therefore comparing between any two regions with different elevation angle and/or frequency will not give real indication of the exact dynamic weather effect at specified regions.

Consequently, in order to restrict on the analysis of the atmospheric impairments out of other impairments for several tropical regions, a new method presented in this paper for extracting the weather parameters from the other parameters to provide actual indication of the atmospheric impairments, this can be referred to as the Extracted Atmospheric Impairments-Multi Site (EAI-MS) method. This method comprises several steps involving the aggregation of the latest actual measured atmospheric data at tropical regions in the relevant continents, in which they naturally measured using different transmission parameters and slant paths. The actual measured atmospheric parameters rather than predicted ones are used for further improvement in the signal performance assessment as will be further explained in the next subsection. The suppression of the influence of variable transmission data comes next, this is done by consolidating the transmission parameters through applying unified frequency and elevation angle for the specified regions. Then evaluating the signal performance using appropriate channel attenuation model for tropical regions (discussed later), utilizing the actual previously collected atmospheric parameters, with the suppression of the variable transmission data influence mentioned earlier. The carrier to noise ratio (CNR), symbol energy to noise ratio (E_s/N_o), are then evaluated as well as the symbol error rate (SER) for different modulation schemes.

After the implementation of this method, this research became the first to makes actual and highly realistic comparisons and analysis for the atmospheric parameters impairments on different tropical regions.

2.2. Rain impairments

Rain usually occurs at different heights above sea level depending on a region on the earth. The phenomena had a paramount effect on the received signal quality for the frequencies above 10 GHz as mentioned earlier. Rain droplets absorb and scatter the signal energy and cause its power level to attenuate to a value depending on the size, amount and the shape of the droplets the signal passes through it also results in the delay and polarization variations (Mandeep et al., 2008a).

To this date, several researchers developed rain attenuation prediction models which have gained world agreements, such as Crane (Crane, 1996), group of researchers from International Telecommunication Union-Radiowave sector (ITU-R) (ITU, 2009; ITU, 2012a), SAM (Stutzman and Dishman, 1982), and DAH (Dissanayake et al., 1997). The models were developed in the temperate regions through many years of monitoring and observations. Yet, they estimated that such models can be applied to the tropical regions. Later, some researches (Adhikari et al., 2011; Badron et al., 2011; Ojo et al., 2008; Mandeep, 2008b; Mandeep et al., 2008) proved that the aforesaid models have a significant inaccuracy level when the model was applied to the tropical regions according to the different atmospheric parameters.

Out of 100% of the time of the year, there is only a small portion that contains rainy events, usually less than 5%. ITU-R (ITU, 2009) used this percentage as a start point in their model. In order to identify the rainy conditions characteristics of any region in the world, a percentage of less than 1% of the time of the year is required to be taken into consideration. This should be the case because it contains the rainfall that causes a significant loss to the signal attenuated through. However, a heavy rain rate in tropical regions usually happens in 0.01% of the time causing a serious problem to the signal quality received because of this reason, 0.01% of the annual period of time is the most interesting percentage when analyzing the effect of heavy or highly effective