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Enhanced satellite communication model associated with fuzzy channel

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ABSTRACT

Wireless channel prediction and impairment estimations have always been a popular area for research. Therefore, a composite model for channel induced impairments on satellite communication systems operating at frequencies above 10 GHz has been presented in this paper. Such systems show a high dependency on varying propagation characteristics due to often occurring dust and sand (DUSA) storms in the first channel (desert area), and due to rain impairments in the second channel (tropical region). Furthermore, the presented simulations for DUSA storms are based on varying levels of visibility at different altitudes along with the non-uniform DUSA particles distribution. Three-dimensional relationships are then presented for these attenuations with different weather parameters such as visibility, DUSA particles size, rainfall rate (RR), frequency, location, and propagation angle, to provide the proposed system with an enhanced view of satellite's parameters. Finally, this paper proposes Enhanced Weather Alert Control Scheme (EWACS), which supports Decision Support System (DSS), that can provide the system with more flexibility by adaptively controlling different combinations of modulation, coding, radio signal strength, frame size configuration, and data rate. This system acts to improve QoS and provides an immense support to the designer for dynamic reconfiguration of the operational satellite system parameters under different weather conditions.

1. Introduction

The time varying nature of wireless channel is based on different physical scenarios. The most significant among them are anomalous atmospheric conditions, such as rain, dust and sand (DUSA) storms, snowfall, scintillation, humidity, fog, clouds, etc. All the aforementioned weather anomalies have been researched and modeled with region specific details in several studies. The wireless channel analysis and modeling under different weather anomalies have led to much advancements in terms of achieving reliable communication, high data rates and desired QoS during weather impaired conditions. Similarly, this study leads to enhanced impairment measurements of the radio frequency signals that are being used for communication. The impairments increase considerably as operations approach higher bands of frequency i.e above 10 GHz on radio links for wide area communications with impeding channel conditions as shown in Fig. 1. A proposed methodology to model DUSA related parameters has been developed and the enhanced estimates of attenuation and signal to noise ratio (SNR) are shown in [1–8]. Weather impairments are highly dependent upon the regional characteristics. This paper proposes a study and a simulation for satellite signal propagating under DUSA storms observed in Saudi Arabia on one channel, and for rainfall storms observed in Canada on the other channel.

Researchers demonstrated that a better control for satellite signal parameters could be achieved by taking into account separately, the major weather related con-

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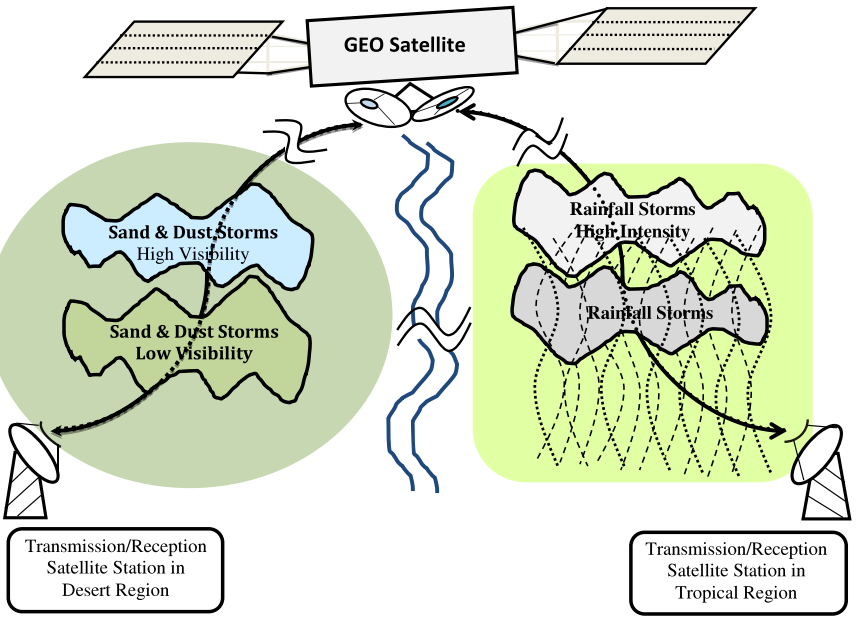

Fig. 1. End to end propagation along fuzzy channels.

tributors of signal attenuation, thus improving system performance [9–13]. Authors of [12] presented a fuzzy logic based uplink power control scheme for satellite communication under rainy weather condition. The transmitted power is adjusted based on measurements of received or reported power. The methodology yielded greater accuracy in estimating the weather-related attenuation. Therefore, this paper presents total attenuation due to rain, dust, and sand estimated for different visibility, dust particles size, rainfall conditions, frequency of operation, and elevation angle. ITU-R relied data provided the average rainfall per year for a specific location throughout the world based on statistical data collected over a decade [3].

Several models [14,10,9,11,5,3,4,2,6,12,13,8,7,15] presented individual impairments of rain or DUSA as a complex phenomenon. The behavioral and compositional characteristics of these factors from different areas around the world are uncorrelated. The authors of [15] presented phenomenon of vertical variation of visibility. In [2], another approach of adding a vertical path adjustment factor to measure DUSA attenuation was presented. Authors of [16] presented an overview for the structure of standard of Digital Video Broadcasting — Return Channel via Satellite (DVB-RCS2), which leads to adjust the return satellite signal. The impact of DUSA storms became more significant for signals having shorter wavelengths which observed more attenuation and scattering due to DUSA particles along the radio path. The effectiveness and degree of precision offered by any technical solution is dependent on proper prediction and identification of all the radio attenuation-causing factors.

During the research, it was realized that the estimations would have helped tune in channel parameters for different locations to gain a closer estimation of impeding weather conditions. The work reported in this paper was inspired by that premise. Furthermore, research thrusts have been focusing on improving QoS on satellite based networks with the use of intelligent prediction methods. The work presented in this paper should be of significant interest to the research and development community. It generalizes the concepts of [9,4,8,11,10,6,7,5] and presents a three-dimensional relationship for average DUSA particle size variations with respect to different reference visibilities and heights. Afterwards, the methods to get precise attenuation and SNR measurements have been presented based on different visibilities, frequencies and propagation angles. This scheme for modeling, estimating and proposing would be helpful to optimize the radio resources and implementing cost effective link budgets for satellite links while maintaining the end-to-end QoS requirements.

This paper provides five major contributions toward improving the operation of satellite control systems and enhancing the performance of satellite network systems. This is specifically true during severe weather conditions and for communication channels operating at frequencies higher than that of Ku band. The major contributions are:

1. An advanced presentation for layering DUSA storms based on the variation of visibility at different altitudes along with non-uniform DUSA particles distribution,
2. Migration of ITU-R techniques from the domain of improving the design to the domain of improving the operation,
3. Application of possible wireless connections among areas impacted by anomalous weather conditions,
4. Improvement of ITU-R techniques in estimating rain and DUSA attenuation more accurately at wide range of frequencies, propagation angles, visibilities, and rainfall rates (RRs),
5. An Enhanced Weather Alert Control Scheme (EWACS) for achieving improved channel performance.

The remaining sections of this paper are as follows: Section 2 presents the impact of atmospheric attenuation