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CHANNEL MODEL FOR SATELLITE COMMUNICATION LINKS ABOVE 10GHZ BASED ON WEIBULL DISTRIBUTION

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Abstract:

Current satellite communication networks will work at frequencies above 10GHz for transmission and reception of signals. At these frequency bands, the most prevailing fading mechanism is rain attenuation. In this paper, a unique channel prototype, a synthesizer for generating rain attenuation time series for satellite links operating at 10GHz and above is offered. The proposed channel prototype modifies M-B model since it generates rain attenuation time series that follow the Weibull distribution. The novel dynamic model is based on the first-order Stochastic Differential Equations (SDEs) and deliberates rain attenuation induced on a slant path as a Weibull-based stochastic process. Moreover, the theoretical terminologies for the computation of the exceedance probability of hitting time random variable are presented.

Key words – SDE, Weibull, M-B model.

1. INTRODUCTION

The growing demand for high data rate services and the insufficiency of the spectrum lead to the employment of high frequency bands such as Ka and Q/V bands for the operation of satellite systems. At operating frequencies above 10 GHz rainfall is the prevailing fading mechanism since it causes the highest attenuation among the other atmospheric effects. Due to the high values of rain attenuation for small time percentage, though still critical for high availability systems, the adoption of a fixed power margin as a countermeasure of rain attenuation is not the optimal solution. Therefore, Fade Mitigation Techniques (FMTs) must be introduced into the system. Such techniques include the Adaptive Coding and Modulation (ACM) technique and the power control. For the estimation of the FMTs, time series synthesizers are needed. Time series synthesizers are also useful for system evaluation in case that investigational rain attenuation time series are not available. In, the M-B model, a time series synthesizer, has been proposed based on SDEs assuming that rain attenuation follows the lognormal distribution and that the rate of change of rain attenuation is proportional to the instantaneous value of rain attenuation. The methodical solution of the SDE proposed it has been given. The application of SDEs to communication systems is presented. However, it is shown that rain attenuation can be also described with the Weibull distribution. Recently, the experimental results have been shown that the Weibull based model of gives much better expectation than other prediction models. Furthermore, apart from the generation of time series, one of the metrics that are required for the depiction of rain attenuation dynamics is the hitting time measurements. Hitting time statistical properties have been used for the advance of an analytical method for the calculation of the rain attenuation active parameter, as well as, their application for the optimization of FMTs. The contribution of this prototype is the development of a new rain attenuation time series synthesizer and the calculation of its hitting time distribution. The basic conventions are that first-order statistics of rain follow Weibull distribution and that the rate of change of rain attenuation is proportional to the instantaneous value of rain attenuation. These new theoretical results, given in this proposal, are

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methodical and can be used for the development and the ideal design of next generation FMTs and new protocols for broadband satellite communication networks operating above 10GHz.

2. CLOUD ATTENUATION

The liquid water content of clouds is the physical cause of cloud attenuation. Prophecy models for this particular attenuation factor have been developed within the framework of ITU-R and elsewhere. The fig.1 depicts attenuation values due to clouds and fog exceeded for a certain range of probabilities. Here, attenuation refers to the turbulences made due to the clouds which results in a loss of data communication or a severe distortion in signals. A novel method to have a better efficiency against cloud attenuation has been proposed. The proposed prototype has been considered as a pictorial representation in order to obtain the main aspects of the prototype, which solves the issue of accomplishing higher data rate during disturbances. The ITU-R model was selected as the underlying prediction method for generating the model, which resembles the three frequency bands examined in this study.

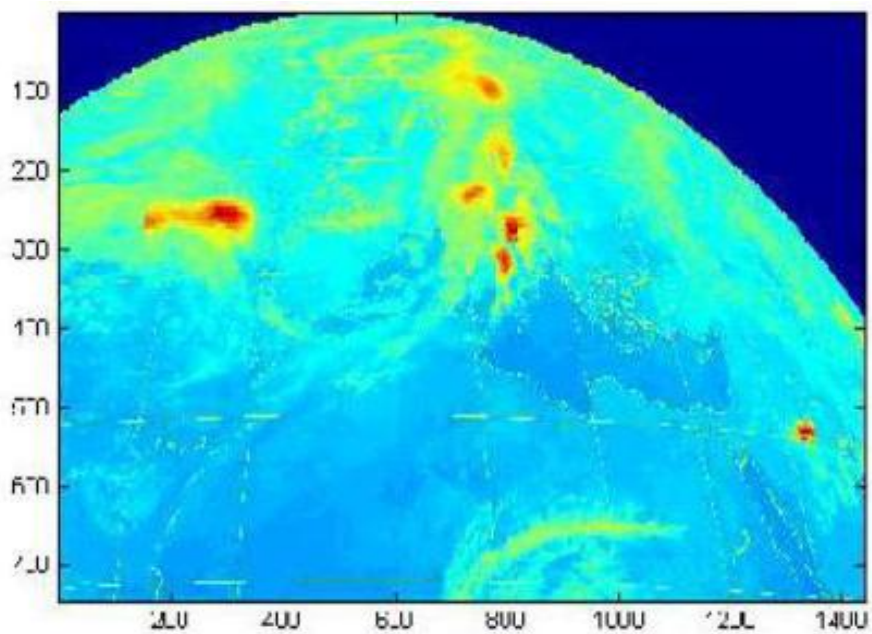

Fig.1. Illustration of cloud attenuation.

Brownian motion is a contemporary reference to a mathematical model of the random motion of particles deferred in a fluid. This category of motion was named after Robert Brown that observed it in water. Considering the Brownian motion as a standard parameter, the rain attenuation in satellite communication is further reduced. The procedures were described accurately by Norbert Wiener, and are thus also called Wiener Processes. They point out that, the process starts at zero with a probability of 1, and that the probability, that an arbitrarily engendered Brownian path be continuous is 1.The path augmentations are independent Gaussian, zero mean, with variance equivalent to the temporal extension of the increment. In satellite communication systems, accessibility is defined as the time percentage in a year throughout which the bit error rate (BER) is inferior than a certain threshold, beyond which an outage of the system occurs, although the fade margin is appropriately defined as the difference in dB between the precipitation prompted attenuation resulting in an outage and the attenuation under clear sky environments. To elaborate on the concept of availability, and illustrate the transformation from the rain attenuation distribution to the equivalent BER distribution, clear sky bit energy to noise power density ratio Eb/N0 of 12dB and a QPSK modulation scheme may be anticipated. Since the proposals, deduce that if, for example, a BER threshold higher than 10 –7 makes the system unavailable, the outage percentage for this

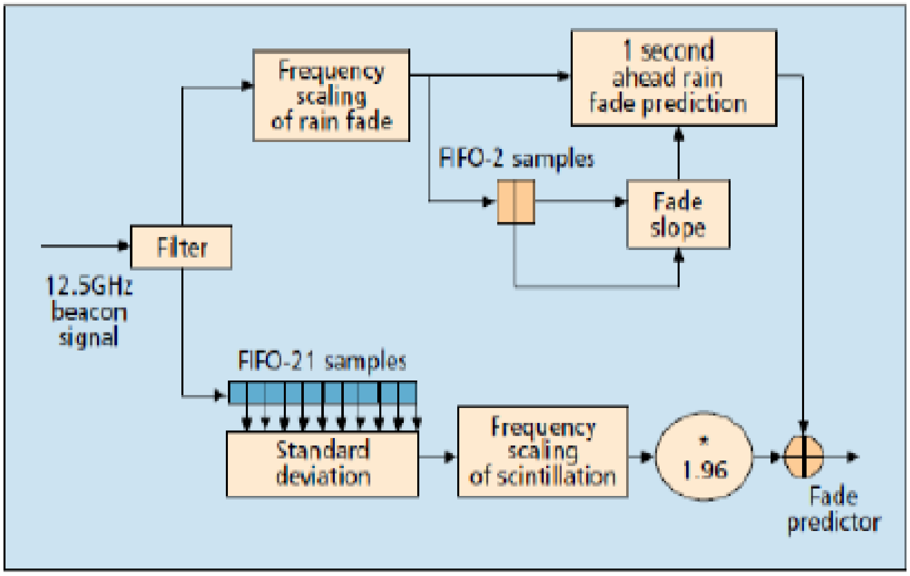

Fig.2. FMT control loop flow chart

definite satellite link will be 0.060 percent at the Ku band, 0.096 percent at the Ka band, and 0.205 percent at the V band, the assumption comes into use as shown in Fig.3. In terms of min/year this event takes place; the conforming outage times are 315.4min/year, 504.6min/year, and 1077.5min/year, respectively.

3. WEIBULL BASED STOCHASTIC DYNAMIC MODEL

An extended comparative test took place considering experimental data from ITUs database of Study Group 3 (DBSG3) in order to observe the suitability of Weibull distribution for modeling the rain attenuation exceedance probability. Considering 86 experiments from DBSG3 database it was found that the RMS value of the relative error was 13.47% for Weibull distribution and 13.8% for lognormal distribution. Furthermore Weibull distribution has a lesser error probability than the other counterpart distributions which adds up to its advantage. This leads to the conclusion that Weibull distribution in many cases may describe better rain attenuation exceedance probability than lognormal distribution. This is a strong motivation in order to derive a rain attenuation synthesizer based on Weibull distribution. The rate of change of rain attenuation is considered proportional to the instantaneous value of rain attenuation, similarly with and has been verified by experimental data. Therefore, by consuming this expression, rain attenuation time series can be generated. A MATLAB file can be easily developed for the rain attenuation time series synthesis, expending the expression. Hitting time is the time needed for a stochastic process to reach a minimum or maximum attenuation threshold value, Amin or Amax, respectively, given that the value of a stochastic process is A0, with Amin ≤ A0 ≤ Amax, at the initial time occurrence t=t0. Since

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hitting time refers to a stochastic process, the prior term is a random variable. Sometimes the actualities about what are the chances over a given time period that a flood will reach or exceed a definite enormousness may need to be known. This is called the probability of occurrence or the exceedance probability. The exceedance probability may be articulated simply as the inverse of the return period let's say the value "p" is the exceedance probability, in whichever given year. For instance, for at wo year return period the exceedance probability in any given year is one over two is equivalent to 0.5, or 50 percent. We need to know the technique to calculate the exceedance probability for a particular retro of years, and not just one certain year. A one- hundred year flood is an event of flood that has a 1% probability of occurrence in whichever given year. The 100- year flood is similarly denoted as the 1% flood, since its annual exceedance probability is 1%.So, if we need to calculate the odds for a 100- year flood, over a 30-year time period, we can then use these values in the formula for the exceedance probability.

4. RESULT ANALYSIS

The theoretical expressions of hitting time statistics are compared to the statistics of hitting time derived from the generation of time series synthesizer. More particularly, for the first comparison, the statistical parameters ν and w of the Weibull distribution are calculated after fitting the CCDF of Weibull distribution to the predicted CCDF of rain attenuation. Then these two parameters are used for the generation of rain attenuation time series. The goal is to verify that the rain attenuation time series follow the Weibull distribution which was given as an input.

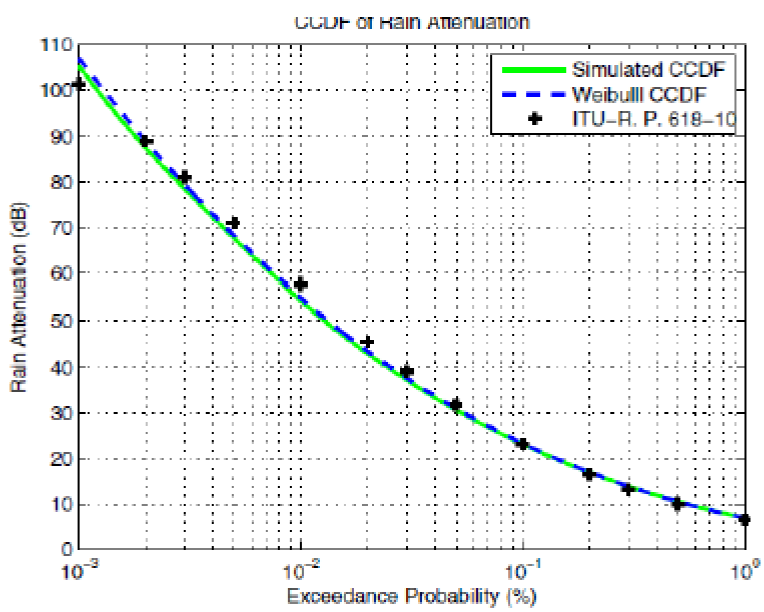

Fig.3. CCDF of rain attenuation predicted by the ITU, Weibull fitted distribution

In Fig.3, three curves of the exceedance probability of rain attenuation are shown: the predicted from ITU-R. P. 618-10, the Weibull distribution fitted to the predicted CCDF of rain attenuation and the one resulted from the time series synthesizer. The Earth station is located at a mid-latitude region in Europe; the operating frequency of the link is 40GHz and the elevation angle 20o. The statistical parameters for the Weibull distribution are w=0.41497 and v=0.3347. Also, from this Figure, it can be observed that the CCDF resulted from the time series matches exactly the Weibull CCDF.

CONSLUSION

In this paper a new channel prototype has been presented for fixed satellite communication links operating above 10GHz. Firstly, it is shown that the Weibull distribution can be used for modeling of rain attenuation exceedance probability with similar results to the lognormal distribution. Brownian motion is considered as a standard parameter. It also improves the results for fade slope statistics at high levels of rain attenuation. This is imperative for the proposal and optimization of FMTs for systems operating in tropical expanses, which are subject to high rainfall proportions. Empirical expressions for estimating the dynamics parameter as a function of the path length were obtained, that allow the synthesizer implementation without the need of experimental data.

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