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A SATELLITE LINK-LIKE BIT ERRORS MODEL BASED ON THE RECEIVED SIGNAL LEVEL FOR LINK SIMULATOR'S NOISE IMPLEMENTATION.

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1 Introduction

Both changes in speed and protocols in data transfer via satellite links will be an attraction for various services and will extend the terrestrial network to remote areas without the need for costly and limited terrestrial network. However, high frequency satellite links are subject to climatic impairments, especially rainfall. In varying weather conditions, these links show wide variations of bit errors and could not allow the achievement of reliable communication.

In some existing systems, these problems are solved by providing the system an extra power margin. At these frequencies and above, the link margin is about 10-20dB. If this supply power is provided for a long period of time, the considered system will turn to be inefficient. It seems therefore important to conduct some experiments in order to develop new protocol or improve existing one for an efficient and reliable data transfer.

The non-permanent access to satellite links for experimental purposes can be supplied by indoor apparatus or computer software that generates test conditions approximating actual or operation conditions. Up to now, some satellite link simulators are being developed [1]. These simulators use an Additive White Gaussian Noise (AWGN) to generate the channel error which is not generally the case for satellite links under climatic effects.

The intent of this paper is to present and evaluate an efficient bit error generation algorithm based on the statistical analysis of the received signal level in practice. This algorithm is one of the key points for developing a satellite link simulator suitable for the design of today and future communication links[2].

2 VSAT's System and Data Collection

The experimental system used for the data acquisition consists of 3 Very Small Aperture Terminal (VSAT) system, the JCSAT-1B communication satellite and one rain gauge.

These stations are located in Hakozaki Campus of Kyushu University, Fukuoka and are being used to conduct several experiments for earth-satellite link clarification in Ku-band (14/12 GHz) since 1997. The VSATs and the rain gauge are installed on top of 2 buildings and separated by about 200 m as shown in Figure 1. In this paper, these 3 stations are called: Station JI, Station JII, and Station Z. One of these VSATs is used for data transmission to the satellite and all of them receive the returned signal. The modulation mode is the QPSK with coding rate $r = 1/2$ and the transmission rate is 64 Kbps. The experimental system observes and records the received signal level every 0.2 second, the occurred bit-error every 2 seconds and the rain intensity every second.

The analyzed data are bit-error and received signal level. They have been collected within 2 years (2001-2002) from June to September. In our analysis, we also used the rain intensity provided by the rain gauge to assure that the attenuation of signal level is due to the local rainfall (Figure 2).

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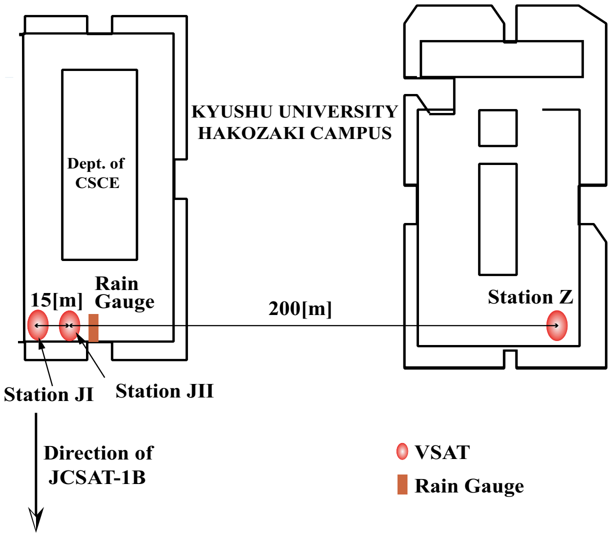

Figure 1: Experimental system's location.

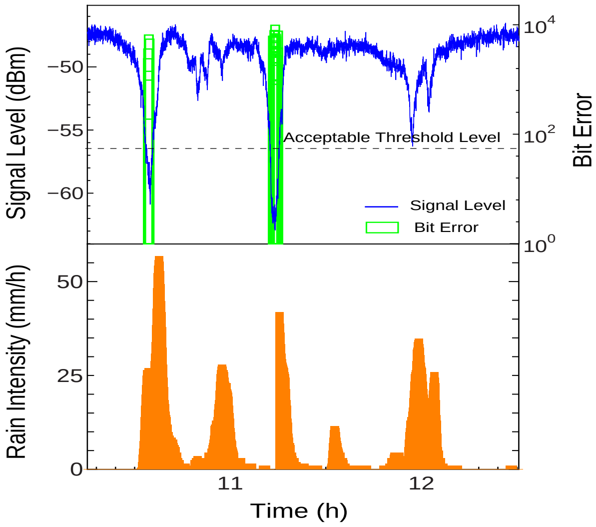

Figure 2: Bit-error and signal level cause-and-effect relation under rainfall.

3 Description of the statistical model

In the bit error generation, it is important to determine when and how many bit-errors occur. We use two main parameters for these estimations: the threshold signal level and the coefficient of variation.

Figure 2 shows the received signal level impairments as a function of time during rainfall. It can be divided into two regions[2]: 1) The upper region of the threshold level, which, although faded, does not cause any bit-error for about 95% of time. 2) The lower region, where any fluctuation of the signal levels randomly produces a certain amount of bit-error which can be best estimated only statistically[3].

We consider the bit-error generation algorithm. Let $(\tilde{BE}_i,\, Sl_i)$ be a set of point where $\tilde{BE}_i$ is the occurred bit error and Sl_i is its corresponding signal level. The obtained scatter plot can be expressed as the following equation[3].

$$\tilde{BE}_i = m\left(Sl_i\right) + \epsilon_i \tag{1}$$

where the regression curve $m\left(Sl_i\right)$ is the conditional expectation of the number of bit error at Sl_i, and ϵ_i is a normal distributed random parameter. The $m\left(Sl_i\right)$ is obtained by applying on the set $(BE_i,\, Sl_i)$ of the raw data the moving average described by equation(2) and fitting the obtained result with the second degree polynomial[4].

$$m\left(Sl_i\right) = \frac{1}{N}\sum_{j=-k}^{k} BE_{i-k} \qquad\qquad i \geq k \tag{2}$$

where $N = 2k + 1$ is the window size. The ϵ_i is obtained by applying $BE - m\left(Sl_i\right)$ to the raw data.

We observed that, although the signal level is lower than the threshold level, bit-errors do not occur continuously. Moreover, some rare bit-errors are shown in the upper part of the threshold level. In order to locate the appearance of the bit error, we introduce the coefficient of variation (COV), which measured the variability of Sl in relation to its mean for a short period of time ΔT, and describe it by the following equation:

$$COV = \frac{\mathrm{std}\left(Sl\right)_{\Delta T}}{\langle Sl\rangle_{\Delta T}} \times 100\% \tag{3}$$

where std $(Sl)_{\Delta T}$ and $\langle Sl\rangle_{\Delta T}$ are the standard deviation and the average of the received signal levels during the lapse ΔT, respectively.

Applying the equation (3) on our received signal level, we observed that when the signal level is lower than the threshold level, bit-errors occur only if the conditional equation (4) is verified.

$$COV \leq COV_{\max} \tag{4}$$

The $COV_{\max}$ is obtained by estimating the highest value of COV below which bit-errors occur. In the upper part of the acceptable threshold level, we observed that bit-errors generally occur following the equation (5).

$$\frac{COV_i - COV_{i-1}}{T_i - T_{i-1}} \gg 1 \quad [\mathrm{s}^{-1}] \tag{5}$$

The threshold level has been estimated to be -57.67 dBm, the $COV_{\max} \approx 15$ and the window size 41 in our experimental system.

4 Evaluation of the model using the received signal level

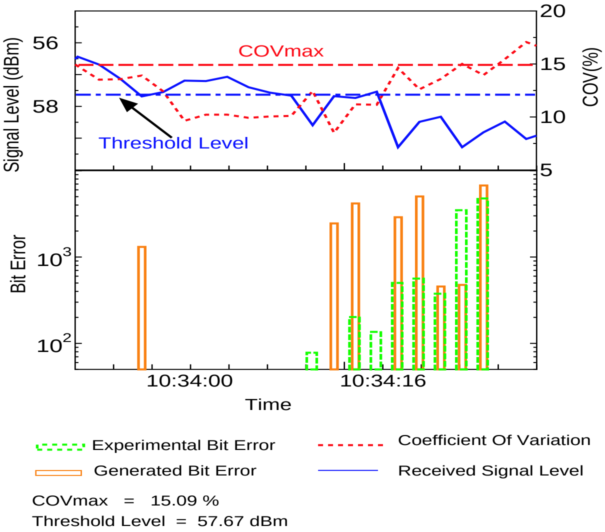

Figure 3: Short period simulation of our algorithm.

We generated bit-errors for a short period using the received signal level according to the proposed algorithm. Figure 3 compares our result to the corresponding experimental bit-errors. We can observe that, although the bit error is extremely random in position, their appearances are well located. Furthermore, we produced bit-errors in almost the same range in size.

We did a long time simulation of the bit-error generation during the period of study to test our algorithm in a statistical point of view. Figure 4 displays the distribution of bit-errors at the three stations. In these figures, we compare the result of our simulation to the raw data distribution and the lognormal fitting of the raw data. The figures indicate that our result is close to the fitted curve. Figure 5 shows the percentage of time exceeding abscissa of the bit-error. Due to the random behavior of the bit error on satellite link, it is really difficult to generate a bit-error with the same distribution as the raw data. We can observe that the simulated results well agree with those from raw data except for the region below about 3,000 of bit-errors. The difference comes from the fact that our model has been developed by using bit-errors that occured during rainfall; it means that the algorithm cannot generate small size bit-errors, which are produced by a random fluctuation of the links. Therefore, the algorithm will be able to be improved by the addition of an AWGN algortihm for the generation of such a small size bit-error.

5 Conclusion

In this paper, we presented an evaluation of a method to generate bit-errors using received signal level for a local station during rainfall event. This algorithm is an important part for the development of satellite link simulator for indoor experimental purpose. From the analyzed data, we can see different characteristics between the 3 stations. That difference may be dependent on the characteristics of communication equipment at the local stations. We note that the difference could be corrected by adding on our algorithm an AWGN algorithm for small size bit-errors generation. This problem will be the purpose of further work.

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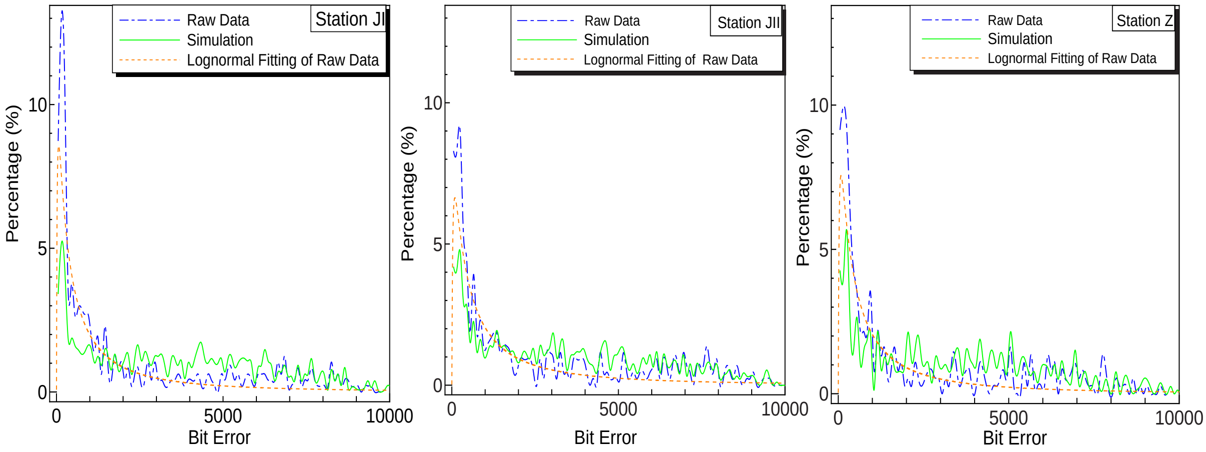
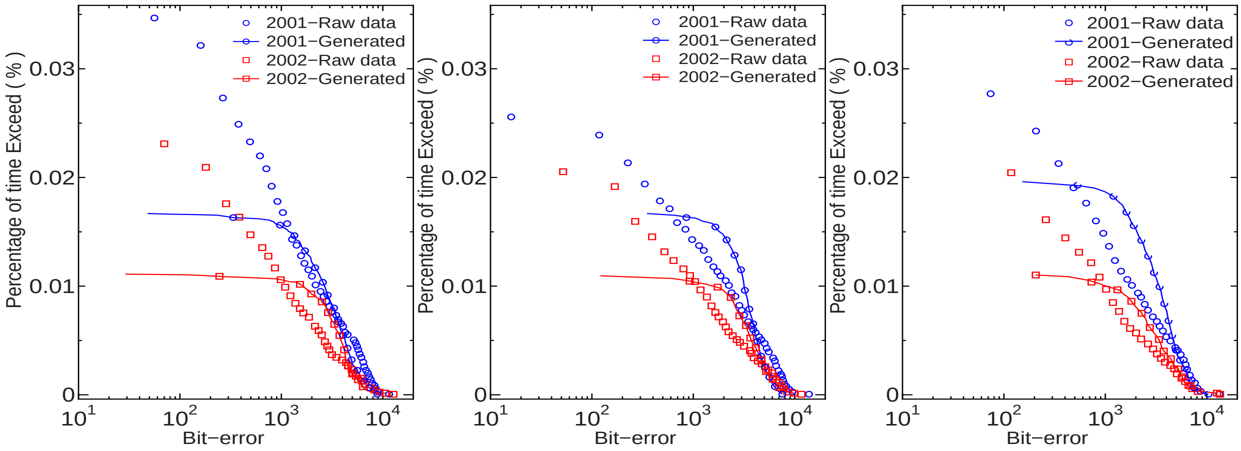


(a) Station JI (b) Station JII (c) Station Z

Figure 4: Experimental and generated bit-error distributions, where the experimental data was obtained during June to September in 2001 and 2002 at Kyushu University.



(a) Station JI (b) Station JII (c) Station Z

Figure 5: Percentage of time exceed of the experimental and generated bit-errors, where the experimental data are the same used in Figure 4.