Rainfall Rate Forecasting for Satellite Link Analysis

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ABSTRACT

In the satellite system design, the design processes from the initial design to launch take about 5 years and the broadcasting satellite lifetime goes over 15 years. Furthermore, global warming phenomenon causes rainfall rate to increase more and more in some regions on the earth. Consequently, at the stage of the satellite link design, we need to consider the future rain attenuation over 20 years. In this paper, we investigated a time-series system model for forecasting to consider the future rainfall rate for the satellite broadcasting service. We found that rainfall rate of the future 20 years is increasing continuously.

Key Words : rainfall rate, rain attenuation, forecasting.

요 약

위성시스템설계에서는 설계과정이 초기 설계부터 위성발사까지 약 5년 정도 소요되며, 방송위성수명은 15년 이상까지 될 수 있다. 지구의 온난화 현상은 장기적으로 지구상의 강우율을 점점 증가시키는 추세이다. 이러한 강우율 변화를 포용하기 위해서는 위성링크 설계단계에서 20년 후의 강우감쇠까지 고려하여야 한다. 이 논문에서는 위성방송서비스를 위한 미래의 강우율을 고려하기 위해서 예측용 시계열 시스템 모델을 연구하였다. 이 연구를 통하여 미래 20년 동안의 강우율은 지속적으로 증가할 수 있다는 것을 밝혔다.

Ⅰ. Introduction

Rain attenuation is a very important factor for the reliable Ku/Ka band satellite broadcasting services, and there have been many studies to mitigate the rain attenuation problem due to heavy rain. The rain attenuation is usually estimated by using the rainfall rate exceeded 0.01% of an average year [1]. The rainfall rate will be increasing gradually because the global warming phenomenon causes precipitation and total atmospheric water to increase [2]. We need to predict the rain attenuation by using the rainfall rate data during the broadcasting service period because rainfall rate is changing continuously. The satellite broadcasting service begins around 5 years later from the satellite system initial design stage, and the broadcasting satellite lifetime is about 15 years. Therefore, we need to consider the rainfall rate at least 20 years from the design for the reliable satellite broadcasting service.

We used an ARIMA (Autoregressive Integrated Moving Average) model to forecast the rainfall rate based on the rainfall rate data measured in Seoul from 1961 to 2012.

Ⅱ. Rainfall Rate Data

Rainfall rate data are measured in Seoul, Korea from 1961 to 2012. The measured rainfall intensity system will be reset every 60 minutes. It means that the rainfall rate is measured with a 60 minutes integration time and there are amount of 8760 rainfall rate data for a year.

Rain attenuation estimation needs rainfall rate exceeded 0.01% of a year [1]. Therefore, the analysis needs to find

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the rainfall rate exceeded 0.01% of the time. Since a year has 8760 hours, or 525600 minutes, 0.01% amounts to 52.56 minutes. Besides, in analysis process, it is also necessary to find the rainfall rate exceeded 0.01% of the time of two years, three years, five years and ten years. Through the observed rainfall rate data, it can be seen that the developing trend of rainfall rates of the time of two years, three years, five years and ten years is different.

From Figure 1, it can be seen that rainfall rate exceeded 0.01% of the time of a year almost has steady fluctuation trend, increasing in a year and decreasing in the next year. It has the highest point at rainfall rate of 110 mm/h in year of 1964, the second highest point at rainfall rate of 90 mm/h in year of 2000, and the two points seem to be quite different from other points. Therefore, to weaken the effect of the two highest points, it is necessary to observe rainfall intensity exceeded 0.01% of the time of two, three, five and ten years.

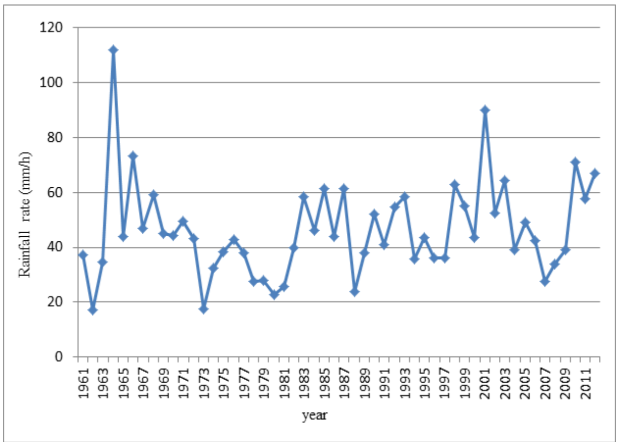

Figure 1. Rainfall rate exceeded 0.01% of the time of a year (Seoul).

Ⅲ. Forecasting model

Rainfall rate is one of the most important things in satellite link design since it is a major factor to estimate rain attenuation. Satellite design takes 5 years before launching and lifetime of satellite is about 15 years [3]. Besides satellite link design requires knowledge of the mainly tropospheric, propagating properties of the space path. Attenuation, depolarization and noise temperature are most strongly influenced by rain [1]. For this reason, it is required to forecast rainfall intensities up to 30 years from initial system design stage. In general, there are three types of forecasting method: Time-series method, Casual method and Judgmental method [3]. Time-series forecasting method is based on analysis of historical data. Time-series means a set of observations measured at successive times or over successive periods. They make the assumption that past patterns in data can be used to forecast future data points. Causal forecasting methods are based on a known or perceived relationship between the factor to be forecasted and other external or internal factors. Judgmental forecasting methods incorporate intuitive judgments, opinions and subjective probability estimates. It relies mainly on individual judgments or committee agreements regarding future conditions.

Rainfall rates are observed from 1961 to 2012 year in Seoul, Korea and the purpose of the research is forecasting rainfall rate in the future. Therefore, it will be suitable to apply forecasting time-series method for these rainfall intensities. Time-series analysis provides tools for selecting a model that can be used to forecast future events. Modeling the time-series is a statistical problem. Forecasts are used in computational procedures to estimate the parameters of a model being used to allocate limited resources or to describe random process. In this paper, Autoregressive Integrated Moving Average model (ARIMA) of forecasting is presented.

The ARIMA model is combining AR and MA models. A linear time series model for response process y_t and innovations ε_t is a expressed as

$$y_t = c + \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \dots \quad + \theta_Q \varepsilon_{t-Q}$$

In lag operator notation, the model is expressed as

$$\phi(L)(1-L)^D \phi_s(L^s)(1-L^s) y_t = c + \theta(L)\theta_s(L^s)\varepsilon_t$$

The coefficients of the non-seasonal and seasonal autoregressive polynomials $\phi(L)$ and $\phi_s(L^s)$ correspond to AR and SAR, respectively. The degrees of these polynomials are p and p_s. Similarly, the coefficients of polynomials correspond to MA and SMA. The degrees of these polynomials are q and q_s. The polynomials $(1-L)^D$ and $(1-L^s)$ have a degree of non-seasonal and seasonal integration D and s. The model property P is equal to $p+D+p_s+s$, and the model property Q is equal to $q+q_s$.

Ⅳ. Results and Discussion

We use rainfall rate exceeded 0.01% of the time of five years and apply ARIMA model to forecast the rainfall rate. Different moving average parameters show different forecasting results.

Figures 2 shows the forecasted data for rainfall rate exceeded 0.01% of the time of one year by the ARIMA model. It can be seen that the forecasted rainfall rate exceeded 0.01% for one year has a steady fluctuation, and the rainfall rate is alternating every year. The pattern of the forecasted rainfall rate change is similar to that of the measured one, but it has a weak increasing trend. It can be seen that the rainfall rates exceeded 0.01% of one, three, five or ten years have a different pattern trend, as shown in Figures 2-5. Figures 3-5 show the forecasted rainfall rate for three, five and ten years which are observed from 1961 to 2012 year in Seoul, Korea by using ARIMA model.

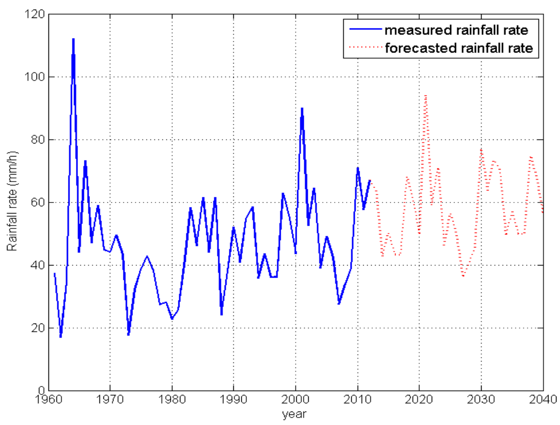

Figure 2. Forecasting for rainfall rate exceeded 0.01% of one year.

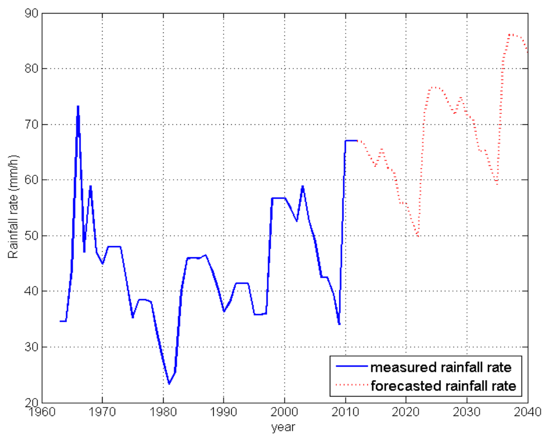

Figure 3. Forecasting for rainfall rate exceeded 0.01% of three years.

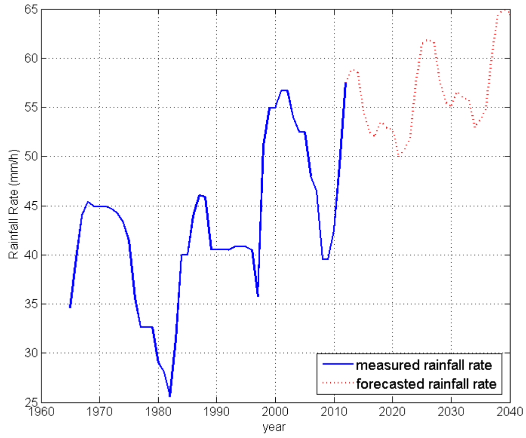

Figure 4. Forecasting for rainfall rate exceeded 0.01% of five years.

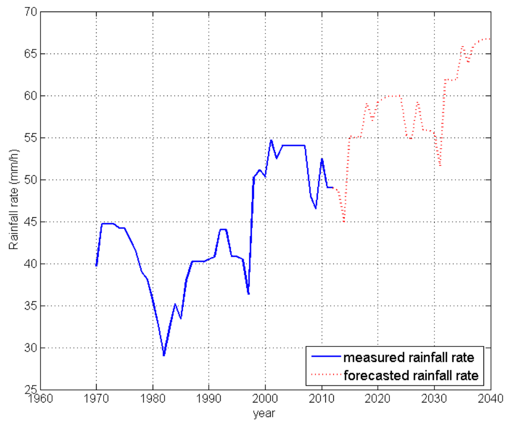

Figure 5. Forecasting for rainfall rate exceeded 0.01% of ten years.

It can be clearly observed that the resulting forecasted rainfall rates continues to grow over the forecast horizon as shown in Figures 3-5. Because this is a non-stationary process, the width of the forecast intervals grows overtime. In other words, the forecasted rainfall rate of three, five or ten years has stable growing trend and increases period by period.

ARIMA model not only contains parts for an AR and MA model, but also the extra part for differencing. The ARIMA model is ARIMA(p,d,q) where p is the order of the AR part, d is the number of times, differencing has been carried out and q is the order of the MA part. The extension allows the model to deal with long term variation better, so improves the usefulness of this modeling technique. Hence, the ARIMA is useful to difference data. This simply takes each data point and calculates the change from the previous data point. Consequently, ARIMA model using forecasting rainfall rate of the time of ten years gives the better results than using AR model.

V. Conclusion

This paper presents the rainfall rate forecasting for link analysis using the measured data for recent 30 years. Rainfall rates are measured at exceeded 0.01% of the time of one year, three years, five years and ten years. The ARIMA model gives the good results for forecasting rainfall rate exceeded 0.01% of the time of three, five and ten years. It can be concluded that rain attenuation after 30 years increases when they compared to the current ones because of the growing trend of forecasted rainfall rate in the future.

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