Measurement of Rainfall Characteristics and Rain-Attenuation at 38 GHz in Worst Months Affected by El Nino Signal in 1998

Won-Gyu Jang · Jae-Hoon Choi

Abstract

The measurement of unique rainfall phenomenon and rain attenuation on 38 GHz terrestrial links at South Korea in 1998 is presented. It was one of the most severe rainfall years at the measured region due to increased El Nino signal. The rainfall rate exceeded at 0.01 % was 97.4 mm/h during a worst month and annual rate was 63.5 mm/h. Experimentally measured results have been compared with some models and found that the rain attenuation by system level was underestimated by the existing prediction models. As it was measured only three months, further study and measurement of rainfall and rain attenuation in this region are needed for stable millimeter-wave system operation at all times.

Key words : Rain, Attenuation Measurement, Millimeter Wave Propagation, El Nino.

Ⅰ. Introduction

Rainfall is a well known phenomenon which causes significant attenuation on radio propagation signal level of frequencies beyond 10 GHz in a temperate region. The 38 GHz frequency band, even if rain attenuation is more severe, has been allocated to fixed point-to-point services in many parts of the world and considered as one of the suitable frequencies for point-to-multipoint multimedia services due to the large available bandwidth [1]. In 1998, there was so much rain[2] due to El Nino phenomena which had significant effects on precipitation variation at South Korea region[3]. ETRI(Electronics and Telecommunications Research Institute) and METRI (Meteorological Research Institute) had studied the characteristics of rain intensity distribution and rain attenuation prediction using the long time measured rainfall rate data[4],[5]. However, these studies mainly focused on the prediction of rainfall rate and analysis of propagation characteristics excluding the effects of system operation and the abnormal rainfall phenomena like El Nino.

In this paper, the measured results of rainfall rate and rain attenuation in 38 GHz terrestrial path at MokPo city, South Korea(Lat.: 36.48_N, Long.: 126.24_E) in the worst rainfall three months (July 98~September 98) are presented. Rainfall rate is more increased than ITU-R rain climate zone K and shows the tropical climate region characteristics which are close to rain climate zone N[6]. As precipitation was influenced by El Nino, results indicated that the rainfall rate in this region was underestimated by the ITU-R rain criterion based on experimental data from the previous temperate climates. Rain attenuation prediction data obtained by ITU-R model[7] and Global Crane model[8] were compared with measurement results for preparing the suitable prediction model in South Korea against the worst rainfall months. However, as it was performed only worst three months, further measurements of rainfall and rain attenuation in this region are needed for stable millimeter-wave system operation.

Ⅱ. Experimental Systems

In Fig. 1 and Fig. 2, the configurations of experimental system are shown. The terrestrial microwave signals at 38 GHz were received from transmitting site using a 0.6 m

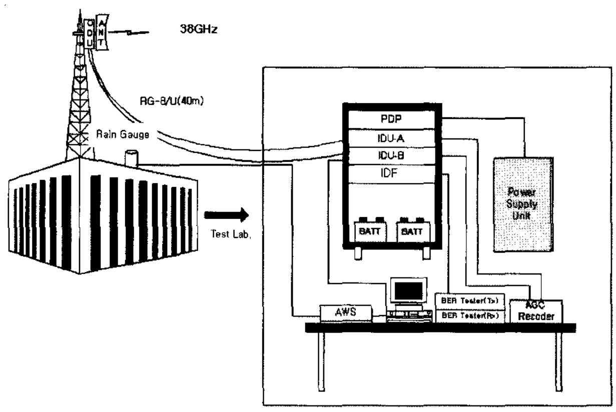

Fig. 1. Configuration of experimental system.

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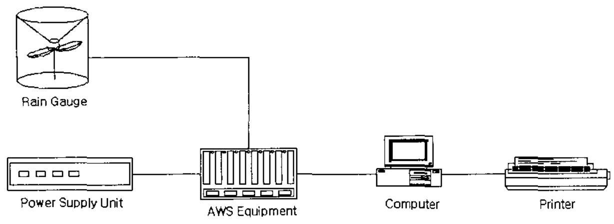

Fig. 2. Configuration of AWS system.

parabolic dish antenna. Measurements were conducted with one hop transmission system over a line-of-sight link between the two sites having distance of about 2.38 km. The detailed transmission system specifications are described in Table 1. As shown in Fig. 2, the rate of rainfall at each measurement was gathered from tipping-bucket rain gauges and sent impulse digital output to AWS(Automatic Weather Station) equipment. The total capacity of rain gauge is 900 mm/hr and resolution is 0.5 mm. Rain attenuation was measured by a form of DC voltage from system's AGC(Automatic Gain Control) port and was recorded on the AGC recorder.

In this measurement period, we gathered total of 12,400 rainfall rate data at intervals of 10 minutes. Gathered 10 minute interval data were conversed to 1 minute rainfall rate data by using the Moupfouma and Martin's proposed power law formula[9] and conversion parameters in [4]. Rainfall rate exceeded at 0.01 % was 97.4 mm/h during a worst month and it can be conversed to annual rate using the formula and suitable parameter values in ITU-R Rec. P.841, "Conversion of annual statistics to worst-month statistics" as follows:

Table 1. Experimental system specifications.

Parameter	Specifications	Remarks
Frequency Band	36.5～39.0 GHz	
Tx and Rx Spacing	1260 MHz	
Transmitter Power	> +19 dBm	
Modulation	4 FSK	
Emission Bandwidth	14 MHz	
System threshold RSL	< −80 dBm	1 × 10^{-3} BER
RSL Monitoring (AGC Range)	−40～−80 dBm	+6.1～+1.0 VDC
Antenna Type	Parabolic dish	
Antenna Size	2 feet	60 cm
Antenna Gain	> 44.3 dBi	
Main Polarization	Vertical	

$$P = p_w / Q \tag{1}$$

where P is the average annual time percentage of excess and p_w is the average annual worst-month time percentage of excess. The conversion factor Q can be calculated as

$$Q = Q_1^{1/(1-\beta)} p_w^{-\beta/(1-\beta)} \tag{2}$$

where Q_1 and β values can be selected as various propagation effects and locations. In this paper, Global rain effect values Q_1=0.13 and β=2.85 are adopted. As a result, annual rainfall rate exceeded at 0.01 % was 63.5 mm/h.

Two typical theoretical rain attenuation models, ITU-R method and Global Crane model, are commonly used. ITU-R rain attenuation calculation method includes the polarization, frequency and distance characteristics and can calculate attenuation as follows:

$$r_R = kR^a \tag{3}$$

Specific attenuation r_R(dB/km) is obtained from the rain rate R(mm/h) using the power-law relationship and the frequency-dependent coefficients k and α are given in ITU-R Recommendation P.838 Table 1 for linear polarizations(horizontal: H, vertical: V) and can be calculated as follows:

$$k = [k_H + k_V + (k_H - k_V)\cos^2\theta\cos 2\tau]/2 \tag{4}$$

$$a = [k_H a_H + k_V a_V + (k_H a_H - k_V a_V)\cos^2\theta\cos 2\tau]/2k \tag{5}$$

where θ is the path elevation angle and τ is the polarization tilt angle relative to the horizontal. The Global Crane calculation method can calculate rain attenuation using its experimental formula and climate characteristics like rainfall rate at specific region[8].

Ⅲ. Experimental Results

The usual climate of South Korea can be characterized that the three month period from July to September has much rain due to Typhoons which are originated from the Pacific Ocean. Therefore, wireless communication systems at higher frequency have to consider the rainfall phenomenon and rain attenuation for the suitable link distance or cell radius selection, specially, for normal system operation under the worst rainy seasons. Fig. 3 shows that the annual precipitation in 1998 was scored 1,507 mm which is 37 % higher than that of 42-years(1961～2002) average. The worst three month rainfall in 1998 was scored 633 mm and is about 26 % higher[2]. It can be explained that so much rain at the southern area of Korea might be affected from the increased El Nino signal due to tele-connection with Nino 3 region located in the equatorial eastern

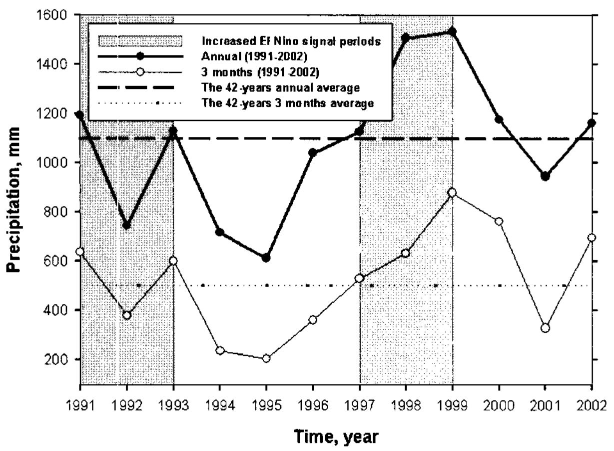

Fig. 3. Precipitation on annual and the worst three months(July-September).

Pacific[3]. The measured rainfall characteristics and rain attenuation at 38 GHz on that period can be used not only for normal maintenance and operation of wireless system but for designing the protective link margin against the abnormal change of weather due to El Nino effects.

Fig. 4 shows the rainfall rate against percentage of time for comparing measured rainfall rate with those of various ITU-R rain climate zones. Measured rainfall rate was drawn by using the Rec. ITU-R P.530's percentages of time formula on the basis of annual rainfall rate exceeded at 0.01 %. Most of South Korean peninsula except far south island region is classified as ITU-R rain climate zone K which has below 42 mm/h on annual rainfall rate exceeded at 0.01 %[6]. However, measured results show 97.4 mm/h on the basis of a worst month and 63.5 mm/h on the annual basis. This characteristic is close to that of rain climate zone N. Rain attenuation had recorded on strip line chart in the form of varying AGC DC voltage simultaneously. The received signal in volts was converted into received power in dBm using conversion curve which is obtained from the laboratory test and calibration procedure. The approximated conversion formula from system AGC DC voltage to RSL(Received Signal Level) is given by:

$$RSL(dBm) = 7.95(V_{AGC} - 1) - 80 \tag{6}$$

where threshold RSL is −80 dBm and AGC DC voltage was measured from 1 to 6.1 volts bounds on the transmission system.

Fig. 5 shows the cumulative probability distribution functions of rain attenuation on a vertical polarization transmission. Two kinds of measured attenuation values are derived from measured rainfall rate and system AGC voltage and results are compared with the two existing prediction model: the ITU-R model and Global Crane model on the basis of D2 rain-rate distributions. The measured maximum rain attenuation by system AGC voltage is limited to 40.5 dB due to the system threshold RSL. The comparison indicated that measured attenuation by rainfall rate is similar to Global Crane model but that by AGC voltage has much higher attenuation than the existing prediction models. Specially, measured attenuation by system AGC voltage is much different from that by rainfall rate. From the measurement, one can conclude that new rainfall criterion, which reflects the abnormal climate phenomenon like El Nino, is necessary for adequate prediction for the new system planning in this region. Modified attenuation model which includes system AGC attenuation characteristic is also required to estimate the effect of realistic rain attenuation on the system.

Ⅳ. Conclusion

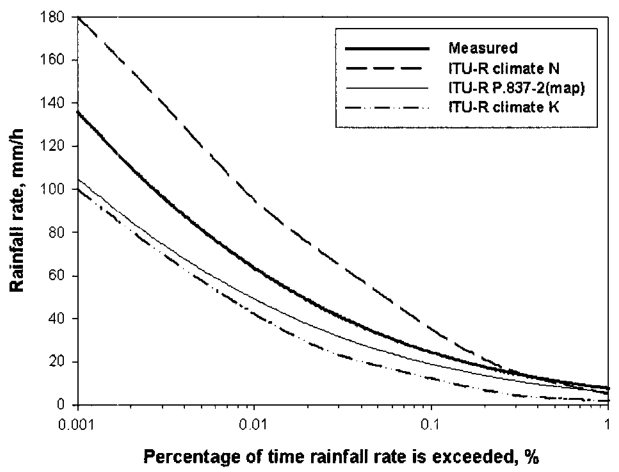

Fig. 4. Rainfall rate distributions.

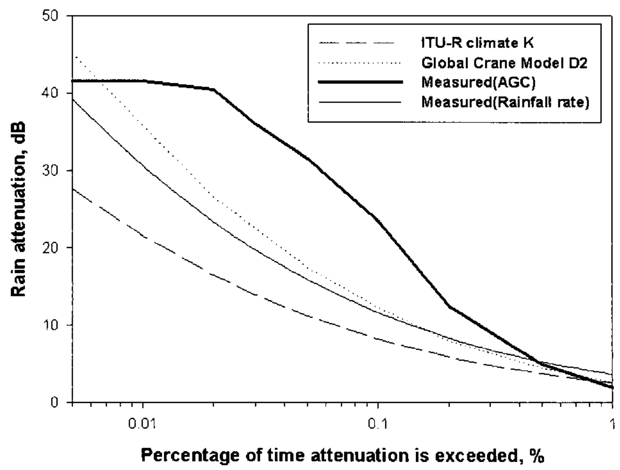

Fig. 5. Measured and predicted attenuation distributions.

The 38 GHz experimental terrestrial links at South Korea in 1998 was affected by severe rainfall due to increased El Nino signal. A rainfall rate exceeded at 0.01 % was 97.4 mm/h during a worst month and annual rate was 63.5 mm/h. The rain attenuation was much higher than those of existing prediction models. Therefore, new rain attenuation model after further measurement is necessary for the proper design of link margin and stable system operation in measured region at all times.

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