Study on the Link Analysis for Satellite Broadcasting Service Using Ka Band Transponders in the Korean Area

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ABSTRACT

The study discussed the link analysis for the Ka band satellite broadcasting service in Korea with respect to the transmission schemes based on the DVB-S2 standard. To analyze the effect of the rain fading to the link budget, we estimated the rain attenuation from the measured rainfall intensity in Korea. We analyzed the link budget for the Ka band transponders of Koreasat-3, and DirecTV BSS-99W, and showed the possible link availability with the DVB-S2 transmission schemes for each transponder. Based on the link analysis of the available satellites with the Ka band transponders, we suggested the required EIRP for the satellite which will be employed for the Ka band satellite broadcasting service in Korea.

Key Words : Ka band, satellite broadcasting, link analysis, DVB-S2, rain fading

I. Introduction

As the portion of the HDTV programs in the satellite broadcasting service is increasing, the shortage of the spectrum resource becomes critical. It is indispensable to exploit the Ka band resource for the service to resolve the spectrum problem, but the Ka band usage has an issue of a rain fading and many researchers have been studying to resolve the problem.

The DVB-S2 standard [1] has transmission modes to mitigate the rain fading problem, and they are a VCM (Variable Coding and Modulation) mode and an ACM (Adaptive Coding and Modulation) mode. It is important to set up a link budget to employ the transmission mode properly for the satellite broadcasting or communication services. We studied a link budget for the DVB-S2 transmission system using some existing Ka band transponders [2, 3] for the satellite HDTV service in Korea, and suggested the values of the important parameters of a Ka band transponder and the transmission system for the service. The rain attenuation is a critical parameter for the link budget, is different depending on the service area, and changing year by year. We estimated the rain attenuation from the rainfall intensity statistics measured recently in Korea [4] to obtain more precise estimations.

The paper is organized as follows: Chapter II discusses about the estimation of rain attenuation, chapter III discusses about the link design, and chapter IV analyzed the link budget.

II. The Estimation of Rain Attenuation

The rain attenuation value is estimated from a rain rate statistics by Rec. ITU-R P.618-9 [8], and the recommendation requires the knowledge of the local 1-minute rain rate statistics to estimate the rain attenuation.

1. Rainfall Rate

The rainfall rate data in Rec. ITU-R P.837-5 [5] can be used when the measured data is not available in the location of the earth station. ETRI proposed the rainfall rates which were estimated from the measured data in Korea from 1990 to 1999 [6]. To obtain the latest rainfall rate statistics, we used the data which were measured in Seoul

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논문번호 : K3-2-2 , 접수일자 : 2008년 11 월 27일, 최종게재논문통보일자 : 2008 년 12 월 26일

from 2003 to 2007 by the Seoul National University [4]. Since they are measured in the 10 minutes integration time, we applied the cumulative distribution model to convert the rainfall rate to a 1 minute rainfall rate statistics. The 1 minute rain rate statistics can be obtained by (1).

$$R_1(p) = a\left[R_\tau(p)\right]^b \ \text{(mm/h)} \qquad (1)$$

where $R_1(p)$ and $R_\tau(p)$ are rainfall rates with 1-min and τ-min integration times separately exceeded with equal probability, p%, and a and b are regression coefficients. Table 1 shows the regression coefficients suggested by ITU-R, Emiliani [7] and ETRI [6].

Table 1. Regression coefficients.

T	ITU-R		Emiliani		ETRI	
	a	b	a	b	a	b
5 min.	0.986	1.038	0.924	1.044	0.934	1.032
10 min.	0.919	1.088	0.829	1.097	0.864	1.069
20 min.	0.680	1.189	0.736	1.169	0.774	1.124
30 min.	0.564	1.288	0.583	1.265	0.723	1.162
60 min.	-	-	0.509	1.394	-	-

Table 2 shows the estimated rain rate for 0.01 % of time in the Seoul area. We will apply the results by ETRI to the estimation of the rain attenuation because the regression coefficients are obtained by the Korean rainfall data.

Table 2. Estimation of rainfall rate for 0.01 % of time in Seoul (2003~2007).

Time availability (%)	ITU-R	Emiliani	ETRI
0.01	69.33	64.82	60.44

2. Rain Attenuation

The rain attenuation is estimated by Rec. ITU-R P.618-9, and the required parameters are as follows:

- rainfall rate for 0.01% of an average year
- frequency: 21 GHz
- latitude of the earth station: 33.5°N~37.5°N
- elevation angle: 44° ~ 49°

Figure 1 shows the rain attenuation data from 1990 to 1999 based on the rainfall rate obtained by ETRI. The Seoul area has the highest rain attenuation, and the averaged rain attenuation is similar to the one obtained by using Rec. ITU-R P.837-5 rainfall rate.

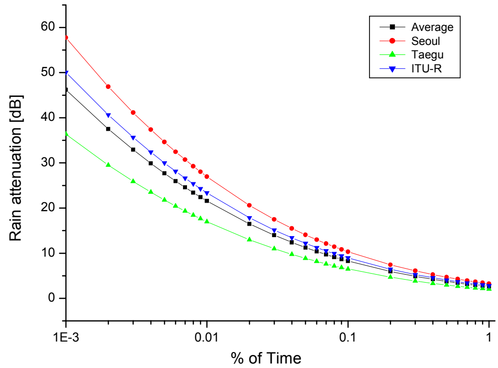

Figure 1. Rain attenuation with respect to the percent of time from 1990 to 1999.

Figure 2 shows the rain attenuation data in the Seoul area from 2003 to 2007, and each one is obtained by the regression coefficients of ITU-R P.837-5, Emiliani and ETRI. The one using the regression coefficients suggested by ETRI has similar result to the 1990 ~ 1999 data.

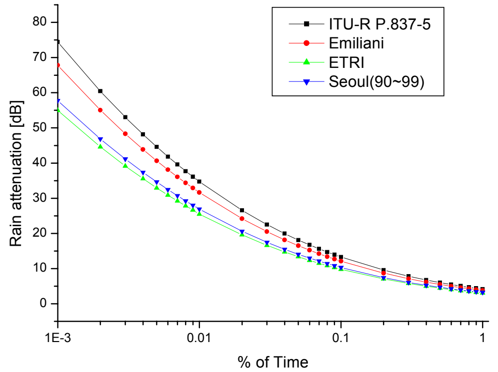

Figure 2. Rain attenuation with respect to the percent of the time from 2003 to 2007 in Seoul.

III. Link Design

Based on the rain attenuation data in Figure 2, we made a link design for the Ka band transponders of Koreasat-3, and DIRECTV BSS-99W. We considered only the downlink for the total receiving performance since the uplink can be designed much better than the downlink. The satellite transmission system is assumed to exploit the DVB-S2 standard. The following parameters are used through the link design.

- Receiving site: Seoul
- Link availability for Rain: 99.7%
- Distance between the receiving earth station and the satellite: 35,786 km
- Frequency: 21 GHz
- The receiving antenna: diameter = 45 cm, efficiency = 0.65
- Roll-off factor = 0.2

1. Koreasat-3

Koreasat-3 loads three Ka band transponders whose bandwidth is 200 MHz separately. The centerpiece of the beam is located at 128^{o}E, 37.75^{o}N.

The downlink frequency is 20.335~21.155GHz whose bandwidth is about 800 MHz, and its guard band is nearly 50MHz. The measured characteristics is shown in Table 3.

Table 3. The measured characteristics of the Ka band transponder of Koreasat-3.

Bandwidth[MHz]	EIRP [dBW]	Noise BW [dB/Hz]	IBO [dB]	OBO [dB]
50	49.0	76.20	11.0	5.0
100	54.5	79.21	7.0	2.5
200	60.0	82.22	0.0	0.0

Table 4 shows the link budget for the Ka band transponder of Koreasat-3. As the bandwidth is increasing, the EIRP is increasing as shown in Table 3 but the noise bandwidth is also increasing. We applied the bandwidth of 200 MHz to get the best receiving performance. To get the 99.7 % link availability, the QPSK modulation with the coding rate of 2/5 in the LDPC encoder is possible as shown in Table 4.

2. DIRECTV BSS-99W

DIRECTV has been providing the Ka-band satellite broadcasting service using DIRECTV 8S, DIRECTV 9S, DIRECTV BSS-99W, DIRECTV-10 and DIRECTV-11 since June of 2006. We investigate the link budget of DIRECTV BSS-99W under the environment of Korea and U.S.A.

Table 5 shows link parameters for DIRECTV BSS-99W with the downlink site located in Miami, FL. The Miami city is a typical heavy rain region in the U.S

Table 4. The link budget for the Ka band transponder of Koreasat-3.

Parameters	Clear Sky	Rain	Units
Satellite EIRP (Saturated)	59.50	59.50	dBW
Free Space Loss	-209.96	-209.96	dB
Downlink Rain Loss	0.00	-5.79	dB
Noise temp. due to Rain	0.00	-3.44	dB
Rx. Antenna Gain	38.04	38.04	dB
System Noise temp. (290K).	-24.62	-24.62	dB/K
Noise Bandwidth	-82.22	-82.22	dB/Hz
Boltzmann's constant	228.60	228.60	dBW/K/Hz
C/N	9.34	0.11	dB
Required C/N for QPSK 2/5	-1.27	-1.27	dB
Link Margin	10.61	1.38	dB

Table 6 shows the link design for the DIRECTV BSS-99W satellite whose receiving earth station is located in Miami, U.S.A. To get the 99.7 % link availability, the 8PSK modulation with the coding rate of 2/3 in the LDPC encoder is possible as shown in Table 6.

Table 5. Link parameters for DIRECTV BSS-99

Uplink Earth Station	Los Angeles		
Downlink Earth Station	Miami		
Satellite Name	DIRECTV BSS-99W		
Service Coverage	U.S.A. & International		
Link Parameters	**Uplink**	**Downlink**	**Units**
Frequency	24.75~25.25	17.3~17.8	GHz
ITU-R Rain-Climatic Zone	Region K		
Surface Temperature	20		C
Satellite Parameters			
Satellite Longitude	99W.L		Degrees
Distance from Earth Station	36021		km
Transmit EIRP at Saturation	60		dBW
Transponder Bandwidth	24, 36		MHz

Table 6. The link design for the Ka band transponder of DIRECTV BSS-99 operating with the specification in Table 5.

DIRECTV BSS-99W(Miami)	Clear Sky	Rain	Units
Satellite EIRP(24MHz)	60.00	60.00	dBW
Free Space Loss	-208.48	-208.48	dB
Atmospheric Loss/Absorption	-1.00	-1.00	dB
Rain Loss	0.00	-7.20	dB
Rain TEMP increase	0.00	-3.70	dB
Rx antenna pointing loss	-1.00	-1.00	dB
Antenna wetting+noise increase	0.00	-1.00	dB
Rx Antenna Gain	38.04	38.04	dB
System Noise TEMP(290K)	-24.62	-24.62	dB/K
Bandwidth	-73.01	-73.01	dB/Hz
Boltzmann's constant	228.60	228.60	dBW/K/Hz
C/N	18.52	6.62	dB
Required C/N for 8PSK 2/3	5.82	5.82	dB
Link Margin	12.70	0.80	dB

Table 7 shows the link design of the DIRECTV BSS-99W satellite whose receiving earth station is located in Seoul. We applied the same specifications of the Koreasat-3 satellite except EIRP and the noise bandwidth.

Table 7. The link design for the Ka band transponder of DIRECTV BSS-99W operating in Seoul.

DIRECTV BSS-99W (SEOUL)	Clear Sky	Rain	Units
Satellite EIRP(24MHz)	60.00	60.00	dBW
Free Space Loss	-209.96	-209.96	dB
Atmospheric Loss/Absorption	-1.00	-1.00	dB
Downlink Rain Loss	0.00	-5.79	dB
Rain TEMP increase	0.00	-3.44	dB
Rx antenna pointing loss	-1.00	-1.00	dB
Antenna wetting+noise increase	0.00	-1.00	dB
Rx Antenna Gain	38.04	38.04	dB
System Noise TEMP(290K)	-24.62	-24.62	dB/K
Bandwidth	-73.01	-73.01	dB/Hz
Boltzmann's constant	228.60	228.60	dBW/K/Hz
C/N	17.04	6.81	dB
Required C/N for 8PSK 2/3	5.82	5.82	dB
Link Margin	11.22	0.99	dB

To get the 99.7 % link availability, the 8PSK modulation with the coding rate of 2/3 in the LDPC encoder is possible as shown in Table 7.

IV. Analysis of Link Budget

We analyzed the link budget for the Ka band transponders of the Koreasat-3 satellite and the DIRECTV BSS-99W. The Koreasat-3 case showed us a limited performance (QPSK 2/5 for the 99.7 % link availability) in operating for the Ka band satellite broadcasting service, but the DIRECTV BSS case showed us a reasonable performance (8PSK 2/3 for the 99.7 % link availability). The difference for the result comes from a performance of the transponder. The Koreasat-3 transponder can be operated on the narrower bandwidth, but its EIRP value becomes lower than the improvement of the noise bandwidth. The DIRECTV BSS transponder has an EIRP of 60 dBW and a noise bandwidth of 24 MHz, and they showed the better performance than the Koreasat-3.

To further analyze the satellite broadcasting transmission system using the DVB-S2 standard, we assumed a virtual Ka band transponder and transmission parameters as follows.

- EIRP = 60 dBW
- Bandwidth = 24 MHz
- Rx Antenna Diameter = 65 cm
- Roll-off factor = 0.2

Figure 3 shows the required C/N values with respect to the percentage of time for the virtual transponder, and the possible transmission configurations for the percentage of time. For the link availability of 99.9%, the configuration of 8PSK with 3/4 is found to be possible with some link margin from Figure 3. When the bandwidth is increased to 36 MHz (1.76 dB down) and the receiving antenna diameter is decreased to 45 cm (3.19 dB down), the C/N value is lowered by 4.95 dB, and the configuration of QPSK with 3/4 is found to be possible for the link availability of 99.9%.

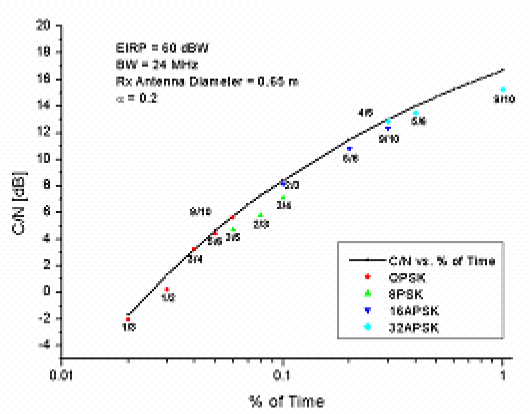

Figure 3. C/N versus % of time and possible transmission schemes.

V. Conclusions

The new service needs to show the better quality as well as the stronger robustness than the current service. For the better performance, the available Ka band bandwidth provides enough bit rates for the HDTV service. For the robustness, the link availability of 99.9 % is possible with the suggested specification of the virtual transponder.

The recommended values for the important parameters for the Ka band HDTV service in Korea becomes as follows:

- Satellite EIRP ≥ 60 dBW
- Bandwidth of transponder: 24 MHz or 36 MHz
- Diameter of the receiving antenna ≥ 45 cm

Reference

[1] ETSI EN 302 307, “Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications”, 2004.

[2] KT, “The characteristics of the Ka band transponder for Koreasat 3”, personal conversation, 2008.

[3] DIRECTV Enterprise, LLC, “Link Budget Analysis for DIRECTV BSS-99W”, File No. SAT-LOA-2006, Sep. 2006.

[4] Seoul National University, “Rainfall rate of Seoul from 2003 to 2007”, Automatic Weather System in Seoul National University, 2008.

[5] ITU-R, Recommendation 837-5, “Characteristics of precipitation for propagation modeling,”Geneva, 2007.

[6] ETRI, “The common fundamental technology development for Radio/Broadcast”, 2001.

[7] L.D. Emiliani, L. Luini and C. Capsoni, “Extension of ITU-R Method for conversion of rain rate statistics from various integration times to one minute”, Electronics Letters, vol. 44, No. 8, April 2008.

[8] ITU-R, Recommendation 618-9, “Propagation data and prediction methods required for the design of Earth-Space Telecommunication systems”, Geneva, 2007.

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