터보부호화된 시공간부호를 이용한 위성-지상 분산 다이버시티 기법

박운희*, 김영민*, 김수영*, 김희욱**, 안도섭**

Distributed satellite-terrestrial diversity schemes using turbo coded STC

Unhee Park*, Youngmin Kim*, Sooyoung Kim*'
Hee Wook Kim**, and Doseob Ahn**

요 약

본 논문에서는 위성-지상 통합(hybrid/integrated)망에서 멀티미디어 방송 서비스를 효율적으로 제공하도록 기여할 수 있는 여러 가지 다이버시티 방식에 대한 성능을 비교 분석한다. 시공간 부호는 부가적인 대역폭 요구 사항 없이도 다중경로 환경에서 다이버시티 이득을 얻을 수 있는 효율적인 방식이다. 위성시스템에서 시공간 부호와 오류정정부호를 적절히 결합하여 지상 중계 장치와의 협동 다이버시티 이득 구현이 가능함이 제안되어 왔다. 본 논문에서는 이러한 선행 연구 결과를 바탕으로 하여, 다양한 시공간부호 및 오류정정 부호의 결합 방식에 따른 성능 분석 결과와 장단점등을 제시하여, 향후 시스템 구현에 도움이 될 수 있도록 한다.

Key Words : Cooperative diversity, transmit diversity, satellite communications, space-time block coding, turbo codes

ABSTRACT

In this paper, we evaluate the performance of various diversity techniques which can contribute to provide efficient multimedia broadcasting services via hybrid/integrated satellite and terrestrial network. Space-time coding can achieve the diversity gain in a multi-path environment without additional bandwidth requirement. Recent study results reported that satellite systems can achieve high diversity gains by appropriate utilization of STC and/or forward error correction. Based on these previous study results, we present various cooperative diversity techniques by combing STC and rate compatible turbo codes in order to realize the transmit diversity for the mobile satellite system. The satellite and several terrestrial repeaters operate in unison to send the encoded signals, so that receiver may realize diversity gain. The results demonstrated in this paper can be utilized in future system implementation.

I. Introduction

Multimedia broadcast and multicast services (MBMS) will play important roles in future mobile syst^^/ems, and a satellite system is a very effective means to provide these services, due to its inherent broadcasting capability. Recently, the International Telecommunica-tion Union (ITU) defined the concept of integrated mobile satellite services (MSS) system and hybrid satellite/ terrestrial system [1].

In order to improve the performance of these hybrid/integrated systems for providing MBMS, efficient diversity techniques using space-time coding (STC) were proposed [5-8]. Because this is a transmit diversity technique, it does not require any channel quality information (CQI) from the return link. In the proposed scheme in [5], the terrestrial repeaters and satellite transmit the STC encoded signal via cooperation, and the Alamouti code was used [9]. In this case the terrestrial repeater must have encoding capability, instead of

* 전북대학교 전자공학부 디지털통신 시스템 연구실(sookim@jbnu.ac.kr),
** 한국전자통신연구원 위성휴대전송연구팀
논문번호 : 논0902-05, 접수일자 : 2009년 9월 16일, 최종게재논문통보일자 : 2009년 12월 28일

being a simple amplifier. The satellite and the terrestrial equipment must cooperate when transmitting signals to achieve STC gain.

Later, in order to achieve more diversity gain, cooperative diversity scheme using STC schemes for more than two transmit antennas were proposed in [7][8]. In addition, in reference [6], cooperative diversity technique by combining STC and turbo codes were proposed.

The performance of these cooperative techniques can be varied how we combine all available paths. Therefore, the purpose of this paper is to evaluate the performance of cooperative diversity techniques by various combinations of STC and forward error correction (FEC) schemes.

The rest of the paper is organized as follows. In section 2, we first introduce the system configuration of the cooperative satellite-terrestrial network along with the concept of the transmit diversity. In section 3, we describe various application examples to achieve diversity gains. Section 4 presents the simulation results of the application examples described in Section 3. Finally, the conclusion is drawn in section 5.

Ⅱ. System model

Figure 1 shows the system model of the integrated satellite-terrestrial network which can utilize the cooperative diversity techniques using STC and/or FEC coding schemes. In this network, a satellite in the geostationary orbit and an ensemble of terrestrial repeaters are deployed. The satellite transmits data in the form of “signal format 1” to all repeaters in the ground. Then, each of the repeaters transforms the received signal from the satellite to a given encoded signal format, and retransmits it to the user terminal. At the same time, the same signal is transmitted directly to user terminal from the satellite.

The repeaters and satellite may cooperate to transmit space-time and/or rate compatible FEC coded signals. The repeaters have the ability to encode signals rather than being simple amplifiers. A user terminal has the ability to receive the STC encoded signals. If the user terminal receives multiple signals from repeaters and also from the satellite, then it can achieve diversity gains.

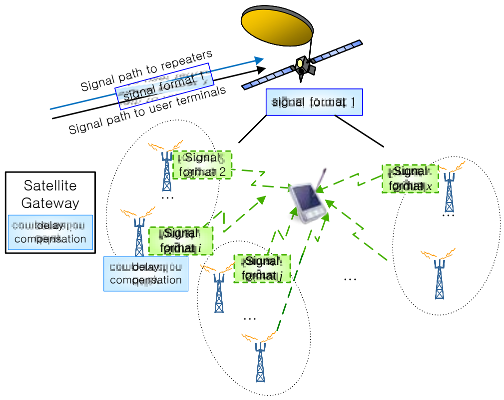

그림 1. 협동 다이버시티 이득을 얻을 수 있는 위성-지상간 통합망 구성도

Figure 1. Hybrid/integrated satellite-terrestrial network incorporating cooperative diversity schemes

In addition, a delay compensation algorithm is required, which can make the signal from the satellite and the repeaters are arrived at the user terminal at the same time. Since we can estimate processing delay to transform to a given STC encoded format at the repeaters as well as time difference of propagation delay between the links from the satellite and repeaters, the delay compensation for the signal paths of the repeaters can achieve successful synchronization at the user terminal. For example, as shown in Fig. 1 a coarse and fine compensation can be made at the satellite gateway and each repeater, respectively.

Ⅲ. Application model

1. Comparison of diversity gains by STC versus FEC coding schemes

In this section, we compare cooperative diversity gain by STC scheme versus by FEC coding schemes. As shown in Fig. 2 (a), we assume a rate compatible FEC code with its mother code rate of 1/3. The code is composed of systematic part of S, and parity parts of P1 and P2. If S, P1 and P2 are the same length, a code can be consisted of [S P1] with a code rate of 1/2, and another code can be consisted of [S P2] with the same code rate of 1/2.

In order to compare the diversity gains by STC and FEC schemes, we first consist 2×1 STC using rate 1/2 FEC codes as shown in Fig. 2 (b). We use as the Alamouti code as an STC scheme [9].

In this scheme, two transmit antennas send [S P1] using the Alamouti code, and thus the code rate is 1/2.

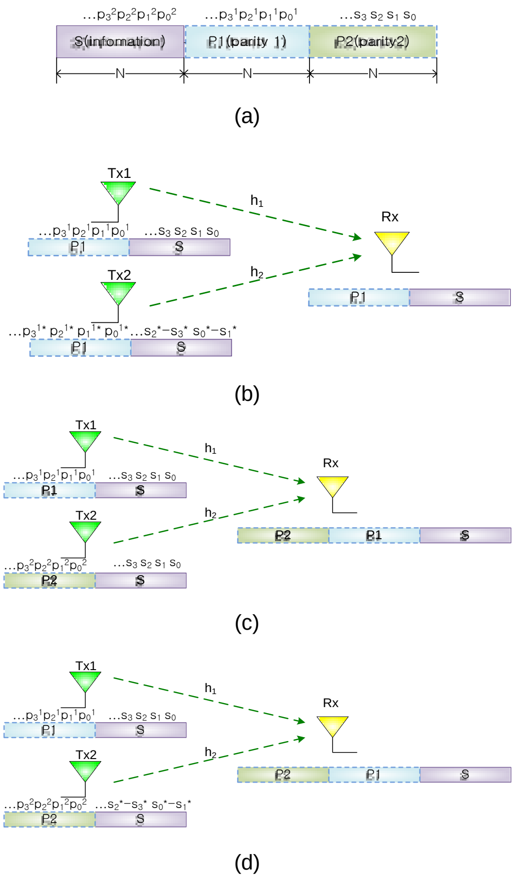

그림 2. STC 부호 또는 오류정정 부호를 사용한 2×1 시스템에 대한 다이버시티 방식

Figure 2. 2×1 diversity schemes using STC and FEC coding schemes

On the other hand, in order to utilize coded cooperation technique using two transmit antenna, the first antenna sends [S P1], and the second antenna sends [S P2]. In Fig. 2 (c), a coded cooperation scheme is shown without any STC schemes. By this way, each transmitter sends with code rate of 1/2, while at the receiver we can detect the information by using the decoder for rate 1/3 code by virtue of combination of two signals. However, in order to utilize this scheme, we need a means to identify P1 and P2 at the user terminal. In the previous study of coded cooperation scheme for a terrestrial application, time division multiplexing (TDM) operation is assumed [10]. In our previous study on this coded cooperation to satellite application, frequency division multiplexing (FDM) was assumed [6].

Last, in Fig. 2 (d), we jointly apply the STC and FEC schemes to achieve diversity gains. In this case, the Alamouti code is utilized only in the systematic part. Therefore, the first antenna sends [S′ P1], and the second antenna sends [S′ P2], and S′ is the STC encoded version of the systematic part. As in the case of Fig. 2 (c), each transmitter sends with code rate of 1/2, while at the receiver we can detect the information by using the decoder for rate 1/3 code by virtue of combination of two signals.

2. Various cooperative diversity applications

In this section, we investigate cooperative diversity schemes, applied to hybrid/integrated satellite and terrestrial systems. Fig. 3 shows a cooperative diversity scheme applied to the hybrid/integrated satellite network using the Alamouti code. In the situation where a user terminal can receive both signals from two different repeaters, the user terminal may be able to achieve a diversity gain from the application of the STC coding scheme to the repeaters.

In the cooperative diversity scheme in Fig. 3, each transmit antenna including the satellite sends the same FEC code. In other words, they can either send [S P1] with a rate of 1/2 or [S P1 P2] with a rate of 1/3. We can assume that the signal from the satellite to a repeater is almost error-free. After receiving the error-free coded sequence [S P1 (P2)] from the satellite, each repeater applies Alamouti encoding, and retransmit to the user terminal. Then, the user terminal can detect the transmitted signal by using a linear decoding method for the Alamouti code. This method can be applied to a single frequency network (SFN).

If we deploy two antennas at a user terminal, we may achieve additional receiver diversity gain via maximal-ratio receiver combining (MRRC) [9]. The application model for this case is depicted in Fig. 4. This case is applicable to the case when the satellite and repeaters sends signal by using different frequency bands. In this scheme, after detecting STC encoded signals from the repeaters, we can effectively combine the satellite signals in order to achieve additional gain.

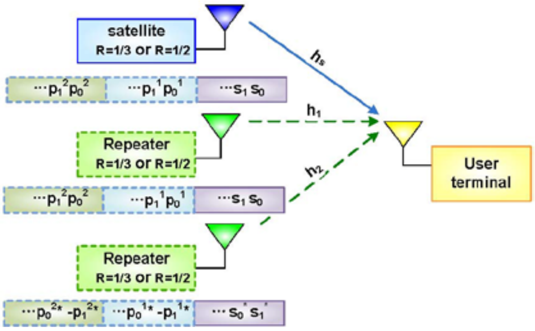

그림 3. 위성-지상 통합망에서 하나의 수신 안테나를 갖는 단말기에 대해 STC 부호를 적용한 협동방식
Figure 3. Cooperation with the satellite and two repeaters using STC for a single antenna at the terminal

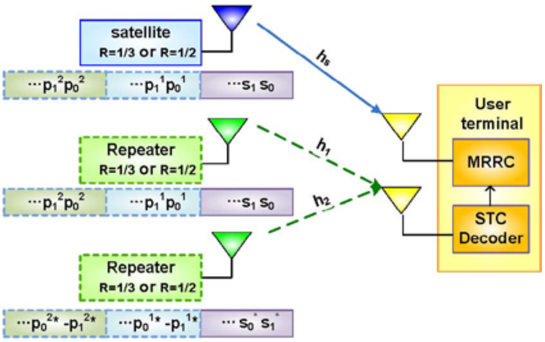

그림 4. 위성-지상 통합망에서 두개의 수신 안테나를 갖는 단말기에 대해 STC 부호를 적용한 협동방식
Figure 4. Cooperation with the satellite and two repeaters using STC for two antennas at the terminal

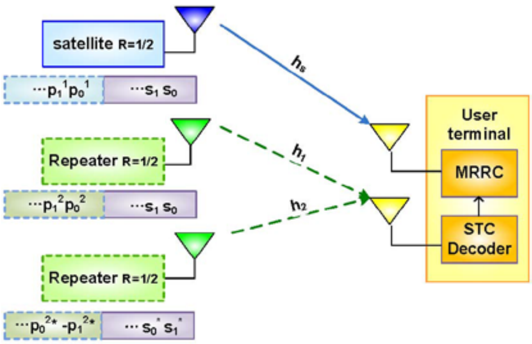

그림 5. 위성과 두 개의 지상 중계기가 존재하는 위성-지상 통합망을 위한 부호화된 협동방식
Figure 5. Coded cooperation with the satellite and two repeaters for two antennas at the terminal

Next Figure 5 shows the application model for the coded cooperation technique applied to the hybrid/integrated satellite and terrestrial system [6], and this can be regarded as an application of the coded cooperation in Fig. 2 (d). In this scheme, a satellite transmits the coded sequence [S P1], and after receiving this, the repeaters generate another parity part P2 and apply the Alamouti code to [S P2] and retransmit to the user terminal. By this way, each transmitter sends with a code rate of 1/2, while at the receiver we can detect the information by using the decoder for rate 1/3 code by virtue of combination of multiple signals.

Ⅳ. Simulation Results

This section presents the simulation results of the BER performance of the various cooperative diversity schemes presented in the previous section. The signal is modulated by using QPSK, and the total transmit signal power was equally divided by the number of transmit antennas. We also assume that the amplitude of fading from the satellite to the receiver is Rician distributed, with factor K of 10 dB, and those from the repeaters to the receiver are uncorrelated Rayleigh distributed. In each case, we assume that fading is constant across two consecutive symbols, and the average signal powers at the receiver, from each transmitter, are the same. The receiver has perfect knowledge of the channel.

For the channel coding scheme, we use a duo-binary turbo code, with an information block size of N symbols. The encoder generates 3N symbols with the code rate of the mother code, 1/3. In our simulation, we use the information block size N of 212 bits. The Max-log-MAP algorithm was used as an iterative decoding algorithm. Figure 6 shows performance comparison of various schemes in Fig. 2 over a Rayleigh fading channel. The two transmit antennas in Fig. 2 (b)-(d) transmit 2N symbols with the code rate of 1/2, by puncturing the mother code. A pure coded cooperation scheme in (c) shows about 0.3 dB performance gain compared to the transmit diversity scheme using the Alamouti code in (b). If we apply the Alamouti code to the systematic part in (c), then we can obtain the coded cooperation scheme in (d) and we can get another 0.2-0.3 dB gain. Therefore, the coded cooperation scheme in (d) results in about 0.5 dB gain compared to the transmit diversity scheme using the Alamouti code in (b).

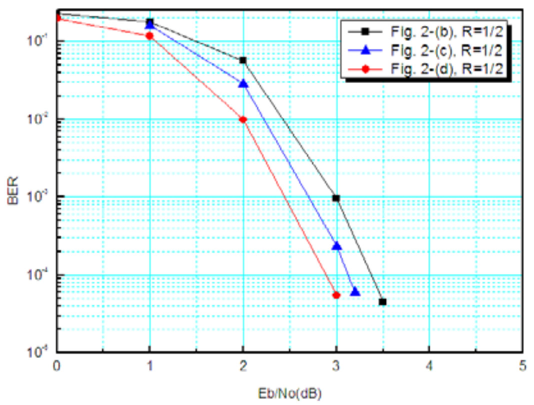

그림 6. 레일레이 채널에서 시공간, 오류정정 부호를 사용한 2× 1 다이버시티 방식에 대한 성능 비교
Figure 6. Performance comparison of 2×1 diversity schemes using STC and FEC coding schemes over a Rayleigh fading channel

In order to compare the BER performances of the various cooperative application models for the hybrid/integrated satellite-terrestrial system, we present Fig. 7. We can see the performance of the coded cooperation technique in Fig. 5 superior to that of the cooperative technique using only STC in Fig. 3. If a terminal uses two receiving antennas, we can expect a performance gain about 2.2 dB compared to the scheme in Fig. 5.

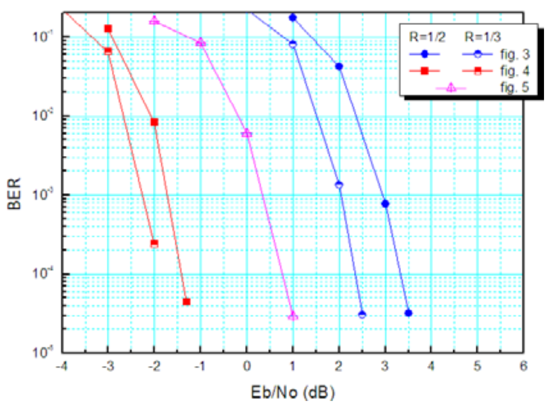

그림 7. 위성-지상 통합망에서의 다양한 다이버시티 방식의 BER 성능
Figure 7. BER performances of various cooperative diversity schemes for the hybrid/integrated satellite systems

Ⅴ. Conclusion

This paper, we presented the performance of various cooperative diversity schemes combining STC and turbo codes for the hybrid/integrated satellite-terrestrial network. From the simulation results investigated in this paper, diversity gains from FEC coding shows superior to that from STC scheme. However, in order to utilize diversity gain from FEC code, we need a means to identify different parity parts, i.e. frequency bands or time slots. In order to implement the proposed diversity scheme, more practical simulation condition should be considered in future.

Reference

[1] Annex 12 to Working Party 4B Chairman's Report on the twenty sixth meeting, Document 4B/85, 27 May 2009

[2] Snyder J, Patsiokas S., “XM satellite radio-satellite technology meets a real market", Proceedings of the 22nd AIAA International Communications Satellite Systems Conference & Exhibit, Monterey, CA, U.S.A., May 2004.

[3] Akturan R. “An overview of the Sirius satellite radio system", International Journal of Satellite Communications and Networking, vol. 26, no. 5, pp. 349-358, Sep. 2008.

[4] Sang-Jin Lee, SangWoon Lee, Kyung-Won Kim, and JongSoo Seo, “Personal and Mobile Satellite DMB Services in Korea," IEEE Transactions on Broadcasting, vol. 53, no. 1,pp. 179-187, Mar. 2007.

[5] Sooyoung Kim, Hee Wook Kim, Kunseok Kang, and Do Seob Ahn, “Performance enhancement in future mobile satellite broadcasting services," IEEE Communication, Magazine, vol. 46, no. 7, July 2008, pp. 118-124.

[6] Sooyoung Kim, Heewook Kim, Do Seob Ahn, "A Cooperative Transmit Diversity Scheme for Mobile Satellite Broadcasting Systems," 4th Advanced Satellite Mobile Systems, 2008. 26-28 Aug. 2008, pp. 72 - 75

[7] Sooyoung Kim, Unhee Park, Heewook Kim, Do Seob Ahn, “Evaluation of cooperative diversity techniques using STC for future S-

DMB services", to be published in IEICE Transactions on Communications on Nov. 2009

[8] Unhee Park, Jing Li, and Sooyoung Kim, "An efficient STBC for a cooperative satellite-terrestrial system," Korea Information and Communication Society, Vol. 33. No. 10. October. 2008.

[9] S. M. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," IEEE Journal on Selected Areas in Communications, vol. 16, no. 8, Oct. 1998, pp. 1451-1458.

[10] T. E. Hunter, and A. Nosratinia, "Diversity though coded cooperation," IEEE Transactions on Wireless Communications, vol. 5, no. 2, Feb. 2006, pp. 283 – 289.

저 자

박 운 희(Un-Hee Park)

2008년 2월: 전북대학교 전자정보공학부 학사
2008년 3월~현재: 전북대학교 전자공학 석사 과정

<관심분야> 시공간블록부호, 이동/위성통신

김 영 민(Young-Min Kim)

2009년 2월: 전북대학교 전자정보공학부 학사
2009년 3월~현재: 전북대학교 전자공학 석사 과정

<관심분야> 시공간블록부호, 이동/위성통신

김 수 영(Soo-Young Kim)

1990년 2월: 한국과학기술원 전기 및 전자공학과 학사
1990년 2월~1991년 9월: ETRI 연구원
1992년 10월: Univ. of Surrey, U.K 공학석사
1995년 2월: Univ. of Surrey, U.K 공학박사
1994년 11월~1996년 6월: Research Fellow, Univ. of Surrey, U.K
1996년 8월~2004년 2월: ETRI 광대역무선정송연구 팀장
2004년 3월~현재: 전북대학교 전자정보공학부 부교수

<관심분야> 오류정정부호화방식, 이동/위성통신

김 희 욱(Hee Wook Kim)

2001년 8월: 고려대학교 전기전자전파공학부 학사
2004년 2월: 한국과학기술원 전자공학과 석사
2004년 3월～현재: ETRI 광역무선연구그룹 광대역무선전송연구팀

<관심분야> 위성통신, OFDM, 동기, MIMO

안 도 섭(Doseob Ahn)

1988년 2월: 경북대학교 전자공학과 석사
1990년 2월: 경북대학교 공학석사
1990년 2월~현재: 한국전자통신연구원 위성휴대전송연구팀장

<관심분야> 위성통신, 성층권통신(HAPS) 시스템