DVB-S3 시스템의 64-APSK 방식에 대한 연판정 비트 검출 기법

이국문[*], 장매향[*], 김수영[*] 종신회원

A Soft Demapping Method for 64-APSK in the DVB-S3 System

Guowen Li[*], Meixiang Zhang[*], Sooyoung Kim[*] *Lifelong Member*

요 약

본 논문에서는 DVB-S3 시스템에 정의되어 있는 64-APSK 변조 방식에 대한 연판정 비트 검출 기법을 제안한다. 본 논문에서 제안한 방식은 심볼을 구성하고 있는 각 비트에 대하여 경판정 경계(hard decision threshold; HDT) 선을 이용한 방법으로써, 수신단에서 검출된 심볼과 HDT 선과의 거리를 연판정 값으로 계산하는 것이다. HDT가 간단하게 결정될 경우 복잡도는 기존의 지수적 복잡도를 요구하는 최우(maximum likelihood; ML) 검출 기법에 비하여 매우 급격히 감소될 수 있다. 이러한 점을 고려하여, 본 논문에서는 먼저 64-APSK에 대한 각 구성 비트별 HDT 선을 유도하고, 이를 이용하여 연판정 비트 값을 계산할 수 있는 방법을 제안한다. 연판정 입출력을 필요로 하는 터보부호를 이용하여 ML 기법과 성능을 비교한 결과, 본 논문에서 제시한 방법은 ML 기법보다 적은 복잡도를 가지고 거의 유사한 성능을 도출할 수 있음을 보였다.

Key Words : satellite communication, soft demapping, 64-APSK, DVB-S3, satellite broadcasting.

ABSTRACT

In this paper, we propose a soft demapping method for 64-ary APSK in the DVB-S3 system. The proposed method in this paper uses the hard decision threshold (HDT) line for each constituent bit in a symbol, and calculates the soft bit information with the distance between the HDT line and the detected symbol. If the HDT lines are defined in a simple manner, the complexity to estimate soft information can be largely reduced compared with the maximum likelihood detection (MLD) which has an exponential complexity. By considering this, we first derive HDT lines for each constituent bit for a 64-APSK symbol, and propose a method to calculate soft bit information. We simulate the BER performance of the proposed scheme by using a turbo codes which requires soft-input-soft-output information, and compare it that of the MLD. The result show that the proposed scheme produces approximating performance to MLD with largely reduced complexity.

I. Introduction

Digital Video Broadcasting via Satellite-Second Generation (DVB-S2), was standardized by the European Telecommunications Standards in 2005 [1]. It specifies several advanced techniques to enhance the service quality, which enable two-way interactive service. For example, an adaptive coding and modulation techniques was adopted in combination with M-ary amplitude and phase shift keying (APSK) schemes up to 32-APSK and low density parity check (LDPC) codes. As an extension of DVB-S2 standard, DVB-S3 defines 64-APSK modulation scheme [2]. The FEC scheme with LDPC codes produce excellent performance, approximating to the Shannon limit, mainly because of iterative decoding with soft-input-soft-output. For this reason, accurate soft bit information (SBI) should be provided to the decoder input.

A soft demapping scheme, more generally known as a soft decision demodulation (SDD) scheme, refers to the process of extracting soft bit information from a detected symbol at the receiver. A maximum-likelihood (ML) SDD scheme, can achieve the maximum performance. However,

※ 본 연구는 미래창조과학부 및 정보통신산업진흥원의 IT/SW 창의연구과정의 연구결과로 수행되었음 (NIPA-2013-H0502-13-1090)
[*]전북대학교 전자공학부 IT융합연구센터 (liguowen0703@gmail.com, mei1986xiang@live.cn, sookim@jbnu.ac.kr), 교신저자 : 김수영
접수일자 : 2014년 4월 30일, 수정완료일자 : 2014년 5월 21일, 최종게재확정일자 : 2014년 5월 23일

the complexity of ML SDD scheme increases in exponential order by the modulation order, and thus it is infeasible to implement for a high order modulation scheme.

An efficient soft demapping scheme with a linear order was proposed in order to solve the complexity problem [3]. In this schemes, the SBI is calculated by a liner metric, which is the distance between the hard decision threshold (HDT) line and the detected symbol, and thus computational complexity is largely reduced. In order to use this idea, we first propose the HDT lines for each constituent bit in a 64-APSK symbol, and subsequently derive equations to estimate SBI.

The remainder of this paper is organized as follows. Section Ⅱ presents 64-APSK constellation in the DVB-S3 system, and presents conventional soft demapping methods based on exhaustive search. The ML soft demapping method using log-likelihood ratio (LLR) will be introduced first, and a Max LLR method for eliminating computations of exponential and log operations will be introduced. In section Ⅲ, we define HDT lines for six constituent bits for a 64-APSK symbol, and derive the corresponding equation to calculate SBI In section Ⅳ, we present simulation results. Finally, we draw conclusions in section Ⅴ.

Ⅱ. Soft demmaping for 64-APSK in DVB-S3

1. Constellation of 64-APSK

A constellation diagram of the 64-APSK defined in the DVB-S3 system is shown in Fig. 1, where there are four circles [2]. A complex 64-APSK symbol, $s_{(\iota,i)}$ locked at the ith point on the ιth ring, can be represented as follows:

$$s_{(\iota,i)} = r_\iota e^{j(\frac{2\pi}{n_\iota})i+\theta_\iota}, i = n_\iota - 1, \quad (1)$$

where n_ι, r_ι and θ_ι are the number of symbols in the points ιth ring, the radius and relative phase shift for the ιth ring, respectively.

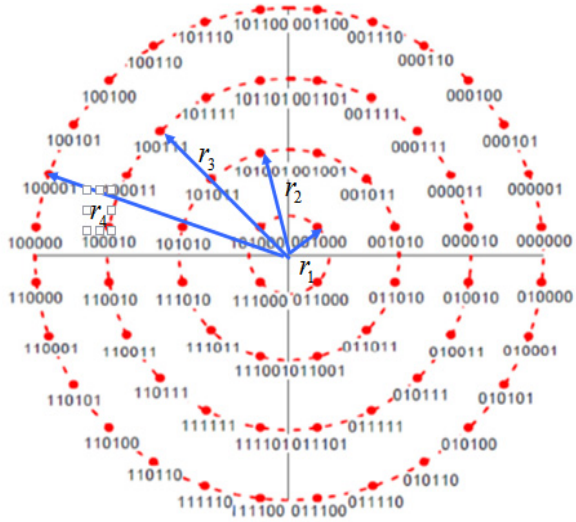


Fig. 1. 64-APSK Constellation

2. ML Detection with LLR Estimation

The objective of ML demodulator is to compute maximum a posteriori LLRs for all the information bits of the received symbol. We consider that $P(b_i = 1) = P(b_i = 0) = 1/2$, where b_i is the ith transmitted bit, then the LLR can be represented as follows:

$$L(b_i|r) = \log\left(\frac{\sum_{s:b_i=1}\exp(-\frac{1}{2\sigma^2}\parallel r - hs \parallel^2)}{\sum_{s:b_i=0}\exp(-\frac{1}{2\sigma^2}\parallel r - hs \parallel^2)}\right), \quad (2)$$

where s denotes an M-ary modulation symbol, and each element of s is composed of $m = \log_2(M)$, which is 6 for 64-APSK, information bits of b_i, h is a channel gain, σ^2 is the variance of additive white Gaussian noise (AWGN), and r is the received symbol.

In order to reduce the computational complexity, the idea is to approximate each of the sums in (1) by its largest term, which gives Max LLR values as follows:

$$L(b_i|r) \approx \frac{1}{2\sigma^2}\left[\min_{s:b_i=0} \parallel r - hs \parallel^2 - \min_{s:b_i=1} \parallel r - hs \parallel^2\right]. \quad (3)$$

Without losing generality, we assume a complex modulation scheme with in-phase (I) and quadrature-phase (Q) channels. Let us consider a BPSK scheme where a single bit is contained in a symbol and thus a real part of s, $R(s)$ is transmitted via the

I-channel. Assuming a detected symbol with perfect channel estimation, the detected sumbol $\hat{s}$ can be represented as follows[3][4]:

$$\hat{s}=\frac{h^{*}}{\|h\|^{2}}r. \tag{4}$$

Therefore, LLR value from ML detection in (2) for b_1 can be derived:

$$\begin{aligned} L(b_1|r) &= \log\left(\frac{\exp(-\frac{1}{2\sigma^2}\|r-h\|^2)}{\exp(-\frac{1}{2\sigma^2}\|r+h\|^2)}\right) \\ &= \frac{1}{2\sigma^2}(\|r+h\|^2-\|r-h\|^2) \\ &= \frac{1}{2\sigma^2}(\|h\hat{s}+h\|^2-\|h\hat{s}-h\|^2) \\ &= \frac{4\|h\|^2}{2\sigma^2}R(\hat{s}) \\ &= \omega R(\hat{s}), \end{aligned} \tag{5}$$

where $\omega=2\|h\|^2/\sigma^2$.

From (5), we can clearly see that $L(b_1|r)$ is equivalent to the distance between the HDT line and the detected symbol $\hat{s}$ multiplied with a weighting factor, ω. By extending this idea, SBI is the distance between HDT line multiplied with the factor ω, i.e.,

$$L(b_i|r)=\omega\hat{b}_i(\hat{s}), \tag{6}$$

where $\hat{b}_i(r)$ is the distance between $\hat{s}$ and the ith HDT line.

Ⅲ. HDT based Soft demmaping for 64-APSK

1. HDT method for 64-APSK

We extend the concept of soft demapping using HDT to 64-APSK, so that SBI for the ith bit, $L(b_i|r)=\omega\hat{b}_i(\hat{s})$. In Fig. 2, the HDT lines for the first and second soft bits are represented, where H_i is the HDT line for the ith bit, and $\hat{b}_i(\hat{s})$ can be written as:

$$\hat{b}_1=-R(\hat{s}), \quad \hat{b}_2=-I(\hat{s}), \tag{7}$$

where $I(\hat{s})$ is the imaginary part of the detected symbol.

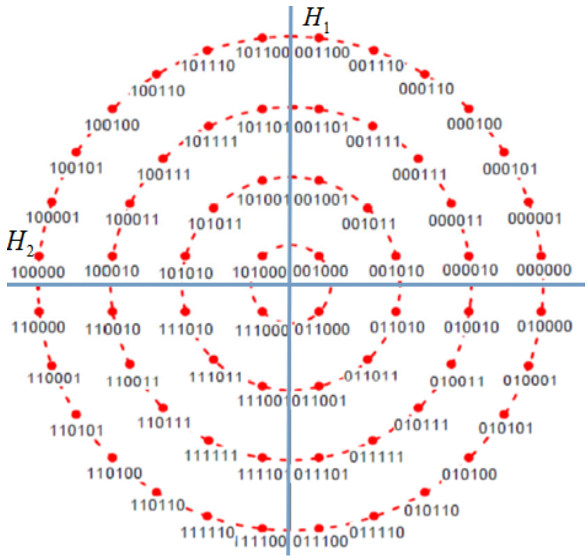


Fig. 2. HDT for the first and second bit of a 64-APSK symbol

In Fig. 3 and Fig. 4, the HDT lines for the third and fourth bits are represented. Because H_4 is the rotated version of H_3, calculation of SBI for the third bit automatically provides the value for SBI for the fourth bit as expressed in (8) and (9), respectively.

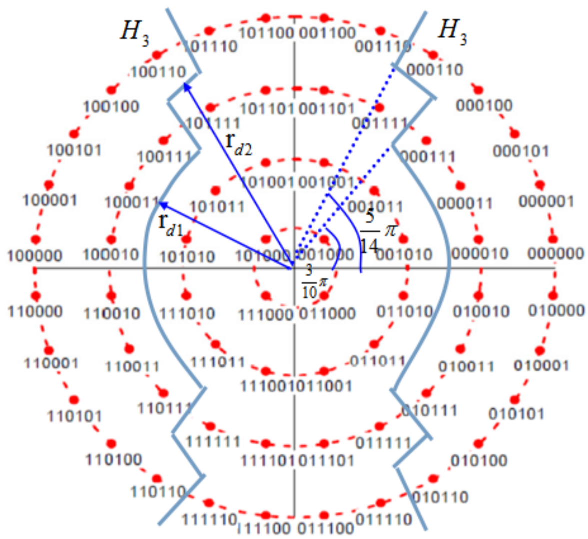


Fig. 3. HDT for the third bit of a 64-APSK symbol

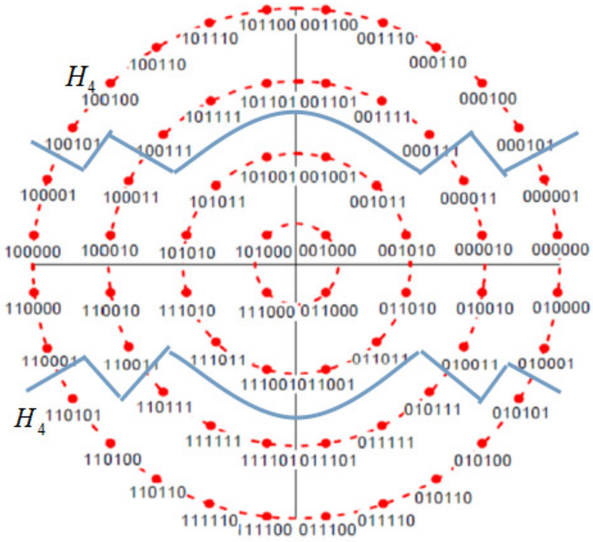


Fig. 4. l HDT for the fourth bit of a 64-APSK symbol

$$\hat{b}_3(r)=\begin{cases} r_{d1}-\|r\|, & \text{if } \theta_r \le \frac{3}{10}\pi, \|r\| \le r_{d2}, \\ \left\| r - r_{d1}e^{j\frac{3}{10}\pi} \right\|, & \text{if } \theta_r > \frac{3}{10}\pi, \|r\| \le r_{d2}, \\ -\min\{\|r\|-r_{d1}, \|r\|\sin(\frac{3}{10}\pi-\theta_r)\}, & \text{if } \theta_r \le \frac{3}{10}\pi, r_{d2} < \|r\| \le r_{d3}, \\ \min\{r_{d2}-\|r\|, \|r\|\sin(\theta_r-\frac{3}{10}\pi)\}, & \text{if } \frac{3}{10}\pi < \theta_r \le \frac{5}{14}\pi, r_{d2} < \|r\| \le r_{d3}, \\ \left\| r - r_{d2}e^{j\frac{5}{14}\pi} \right\|, & \text{if } \frac{5}{14}\pi < \theta_r, r_{d2} < \|r\| \le r_{d3}, \\ -\min\{\|r\|-r_{d1}, \left\| r - r_{d2}e^{j\frac{3}{10}\pi} \right\|\}, & \text{if } \theta_r < \frac{3}{10}\pi, \|r\| > r_{d3}, \\ -\min\{\|r\|-r_{d2}, \|r\|\sin(\frac{5}{14}\pi-\theta_r)\}, & \text{if } \frac{3}{10}\pi < \theta_r \le \frac{5}{14}\pi, \|r\| > r_{d3}, \\ \|r\|\sin(\theta_r-\frac{5}{14}\pi), & \text{if } \theta_r > \frac{5}{14}\pi, \|r\| > r_{d3}. \end{cases} \tag{8}$$

$$\hat{b_4}(\hat{s}) = -\hat{b_3}(\|\hat{s}\| e^{(\frac{\pi}{2}-\theta_r)}). \tag{9}$$

where $\theta_r = \tan^{-1}(|I(\hat{s})|/|R(\hat{s})|)$, $r_{d_1}=(r_1+r_2)/2$, $r_{d_2}=(r_2+r_3)/2$, and $r_{d_3}=(r_3+r_4)/2$. When we estimate $\hat{b_4}(\hat{s})$, we can use the symmetry characteristics of H_3 and H_4. Therefore, we rotate $\|r\|e^{\theta}$ by $\pi/2-2\theta_r$ anticlockwise, resulting in a simplified estimation using $\hat{b_3}$ which is in (9).

In Fig. 5 and Fig. 6, there are HDT lines for the fifth and sixth bits, H_5 and H_6. The discontinuities of H_5 and H_6 incur comparatively complex comparison operations for estimation of $\hat{b_5}$ and $\hat{b_6}$. Thus, the SBI for the fifth and sixth bit can be represented as (10) and (11), respectively. In here, we also can use the symmetry characteristics of H_5 and H_6.

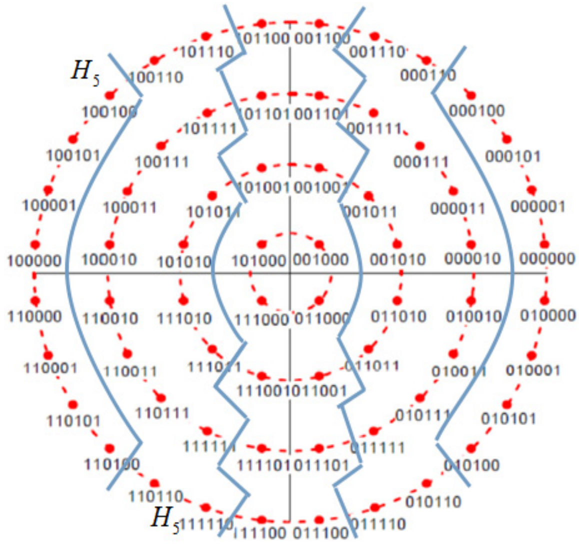


Fig. 5. HDT for the fifth bit of a 64-APSK symbol

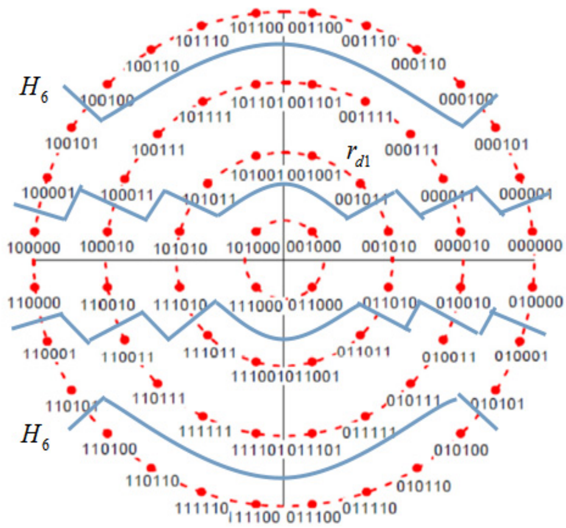


Fig. 6. HDT for the sixth bit of a 64-APSK symbol

$$\hat{b}_5(r)=\begin{cases} -(r_{d1}-\|r\|), & \text{if } \theta_r < \frac{1}{3}\pi, \|r\| < r_{d1}, \\ -\left\| r - r_{d1}e^{j\frac{1}{3}\pi} \right\|, & \text{if } \theta_r > \frac{1}{3}\pi, \|r\| \le r_{d1}, \\ \min\{\|r\|-r_{d1}, \|r\|\sin(\frac{1}{3}\pi-\theta_r)\}, & \text{if } \theta_r \le \frac{1}{3}\pi, r_{d1} < \|r\| \le r_{d2}, \\ -\min\{r_{d2}-\|r\|, \|r\|\sin(\theta_r-\frac{1}{3}\pi)\}, & \text{if } \frac{1}{3}\pi < \theta_r \le \frac{4}{10}\pi, r_{d1} < \|r\| \le r_{d2}, \\ -\left\| r - r_{d2}e^{j\frac{4}{10}\pi} \right\|, & \text{if } \theta_r > \frac{4}{10}\pi, r_{d1} < \|r\| \le r_{d2}, \\ r_{d3}-\|r\|, & \text{if } \theta_r \le \frac{4}{14}\pi, r_{d2} < \|r\| \le r_{d3}, \\ \min\{\left\| r - r_{d2}e^{j\frac{4}{14}\pi} \right\|, \left\| r - r_{d2}e^{j\frac{1}{3}\pi} \right\|\}, & \text{if } \frac{4}{14} < \theta_r \le \frac{1}{3}\pi, r_{d2} < \|r\| \le r_{d3}, \\ \min\{\|r\|-r_{d2}, \|r\|\sin(\frac{4}{10}\pi-\theta_r), \left\| r - r_{d2}e^{j\frac{4}{14}\pi} \right\|\}, & \text{if } \frac{1}{3}\pi < \theta_r \le \frac{4}{10}\pi, r_{d2} < \|r\| \le r_{d3}, \\ -\min\{r_{d3}-\|r\|, \|r\|\sin(\theta_r-\frac{4}{10}\pi)\}, & \text{if } \frac{4}{10}\pi < \theta_r \le \frac{6}{14}\pi, r_{d2} < \|r\| \le r_{d3}, \\ -\left\| r - r_{d3}e^{j\frac{6}{14}\pi} \right\|, & \text{if } \theta_r > \frac{6}{14}\pi, r_{d2} < \|r\| \le r_{d3}, \\ -\min\{r_{d3}-\|r\|, \|r\|\sin(\frac{4}{14}\pi-\theta_r)\}, & \text{if } \theta_r \le \frac{4}{14}\pi, \|r\| > r_{d3}, \\ \min\{\|r\|\sin(\frac{6}{14}\pi-\theta_r), \left\| r - r_{d2}e^{j\frac{4}{10}\pi} \right\|, \|r\|\sin(\theta_r-\frac{4}{14}\pi)\}, & \text{if } \frac{4}{14}\pi < \theta_r \le \frac{4}{10}\pi, \|r\| > r_{d3}, \\ \min\{\|r\|-r_{d3}, \|r\|\sin(\theta_r-\frac{4}{14}), \|r\|\sin(\frac{6}{14}\pi-\theta_r)\}, & \text{if } \frac{4}{10}\pi < \theta_r \le \frac{6}{14}\pi, \|r\| > r_{d3}, \\ -\|r\|\sin(\theta_r-\frac{6}{14}\pi), & \text{if } \theta_r > \frac{6}{14}\pi, \|r\| > r_{d3}. \end{cases} \tag{10}$$

$$\hat{b}_6(\hat{s}) = -\hat{b}_5(\|\hat{s}\| e^{(\frac{\pi}{2}-\theta_r)}). \quad (11)$$

Ⅳ. Simulation results

We simulated the BER performance of the proposed soft demapping scheme for 64-APSK and compared to that of the MLD scheme. We used duo-binary turbo code with an information block size N of 192 symbols (384bits), and a code rate, R of 1/2 to verify the performance of the soft demapping schemes.

The BER performance comparison shown in Fig. 7 demonstrated that the performance of the proposed HDT method scheme can achieve an approximating performance of the MLD scheme.

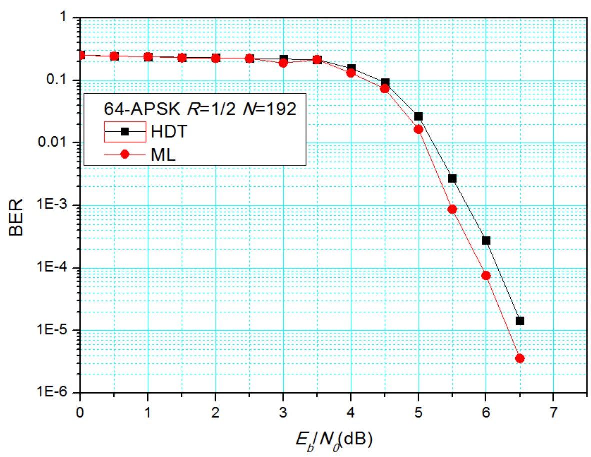


Fig. 7. BER performance of the soft demapping schemes for 64-APSK

Ⅵ. Conclusion

In this paper, we proposed an efficient soft demapping method for 64-APSK in the DVB-S3 system. Based on the HDT lines, SBI can be estimated in a linear complexity. Simulation results showed that the performance of our proposed method can approximate to that of the ML method.

References

[1] ESTI EN 302 307 V1.2.1: Second Generation Framing Structure, Channel Coding and Modulation System for Broadcasting, Interactive Services, News Gathering and Other Broadband Satellite Applications (DVB-S2),2009.
[2] K. P. Liolis and N.S. Alagha, "On 64-APSK constellation design optimization" Proc. of 10th International Workshop on Signal Processing for Space Communication, 6-8 Oct. 2008.
[3] M. Zhang, and S. Kim, "Efficient soft demapping for M-ary APSK", Proc. IEEE ICTC 2011, Seoul, Korea, September 2011, pp. 641-644.
[4] M. Zhang, and S. Kim, "Efficient soft demodulation scheme for Digital Video Broadcasting via Satellite – Second Generation system", IET Communications, vol.18, no.1, pp. 124-132, Jan 2014

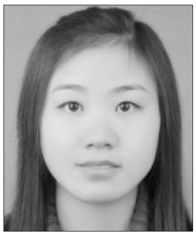
저자

이 국 문 (Guowen Li)

- 2012년 7월 : 내몽고과학기술대학 통신공학 학사졸업
- 2013년 3월~현재 : 전북대학교 전자공학부 석사과정

<관심분야> : 위성통신, 연판정 검출

장 매 향 (Meixiang Zhang)



- 2009년 7월 : 중남민족대학교 컴퓨터공학 학사졸업
- 2012년 8월 : 전북대학교 전자공학부 석사졸업
- 2012년 9월~현재 : 전북대학교 전자공학부 박사과정

<관심분야> : 위성통신, 디지털 통신, 오류정정부호방식, 연판정 검출, 무율부호

김 수 영 (Sooyoung Kim) 종신회원

- 1990년 2월 : 한국과학기술원 전기 및 전자공학과 학사졸업
- 1990년~1991년 : ETRI 연구원
- 1992년 : Univ. of Surrey, U.K 공학석사
- 1995년 : Univ. of Surrey, U.K 공학박사
- 1994년~1996년 : Research Fellow, Univ. of Surrey, U.K
- 1996년~2004년 : ETRI 광대역무선전송연구팀장
- 2004년~현재 : 전북대학교 전자공학부 교수