

An Advanced Hierarchical Modulation with Rotated Constellation

Soonki Jo*, Jinyong Choi*, Jongsoo Seo*

**Department of Electronic and Electornical Engineering, Yonsei University, Seoul,, Korea*

Joangel21@yonsei.ac.kr, jeeney@yonsei.ac.kr, jsseo@yonsei.ac.kr

Abstract— Hierarchical modulation has advantage that has Improved efficiency. And advanced hierarchical modulation was proposed that enhanced layer symbols are rotated to improve system efficiency. But this conventional hierarchical modulation scheme has some problems such as reduction of minimum distance of inner symbols in constellation that have 2bit error. And only constellation rotation can not optimize hierarchical modulation system. In this paper, we propose a novel hierarchical modulation scheme that includes constellation rotation and symbol's image value interleaving. System can get SSD(signal space diversity) gain with constellation rotation and interleaving that brings efficiency improvement. Comparing with existing system by simulation, we can confirm excellence of proposed system

Keywords— Advanced hierarchical modulation, constellation rotation, DVB, DMB, Digital broadcasting

I. INTRODUCTION

Digital Broadcast systems have increasingly been deployed for services. But there is tradeoff between maximizing capacity and required coverage. Since there is problem like this, some digital broadcast systems are designed with a flexibility of transmitting with different bit rates by allowing different modulating constellations, and error correction codes of different coding rates. However, almost of existing systems do not have such flexibility and error correction codes of fixed rate. They are designed with a fixed modulation scheme. Therefore, it is interesting to provide different quality of service to users based on not only the content they requested but also the receiver capability as well as their reception conditions.

There are rising interests in upgrading existing digital broadcast systems with more services for new users while be able to keep existing users unchanged, and providing unequal protection on digital contents with high spectral efficiency.

Hierarchical modulation is one of the promising technologies for upgrading existing systems. It is technique for multiplexing and modulating multiple data streams into one single symbol stream, where the base-layer subsymbols and enhancement-layer subsymbols are added before transmission. Users with good reception and advanced receiver can obtain more that one data streams. Then They

can enjoy ultra definition service. Conventional or poor reception receiver only the data streams embedded in base layer can obtain. Base-layer offers standard definition service but they can get same contents with ultra definition service. Fig. 1 represents this concept. Existing hierarchical modulation, however, suffers from interference which is caused by enhanced-layer so that the achievable rates by base-layer data streams are dented by the interference from high-layer signals. In order to solve this interference problem, enhancement-layer signal constellation rotation was applied[1]-[3]. Constellation rotation brings diversity between I value and Q value of symbol and this diversity makes capacity improvement. But because of constellation rotation, symbols, have 2 bit error each other have shorter minimum distance that cause additional bit error.

In this paper, we propose the advanced hierarchical modulation system. We use constellation rotation in hierarchical modulation and its constellation is symmetrically rotated so its low priority symbol has 1bit error with other symbol of course, but also with the nearest side quadrant symbol. And by component interleaving, real component and image component of a symbol have different channel constant and the system can get SSD gain[4].

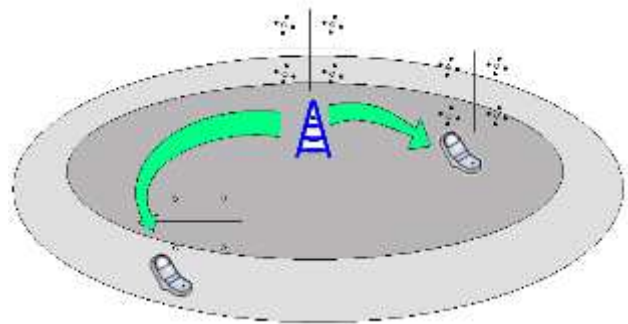


Fig. 1 Different broadcast channel models with two coverage

II. SYSTEM MODEL

A. Hierarchical Modulation

Fig.2 is non-uniform 16QAM constellation. Hierarchical modulated symbols are composed of four bits. First two bits are determined by first data stream, base-layer, also called high priority, and other bits are determined by second data stream, enhanced-layer, also called low priority. ○ is base-layer symbol and ● is enhanced-layer symbol. Each symbol represent two bits and has QPSK symbol values. In constellation, α is defined by minimum distance of base-layer symbol and enhanced-layer symbol.

$$\alpha = \frac{d_2}{d_1} \quad (1)$$

Fig. 3 is a block diagram that show a process of hierarchical modulation. Base-layer data has standard definition information and if good or advanced receiver demodulate and decode enhanced-layer also, receiver obtains additional bitstream that has ultra definition information. Gained additional information can be used to multi channel service or high quality service.

But base-layer symbol and enhanced-layer symbol divide only QPSK symbol's power. It means that if QPSK symbol's power is 1, hierarchical modulated symbol's power is $(d_2 + d_1) * \sqrt{2}$ so there should be capacity degrading by power division.

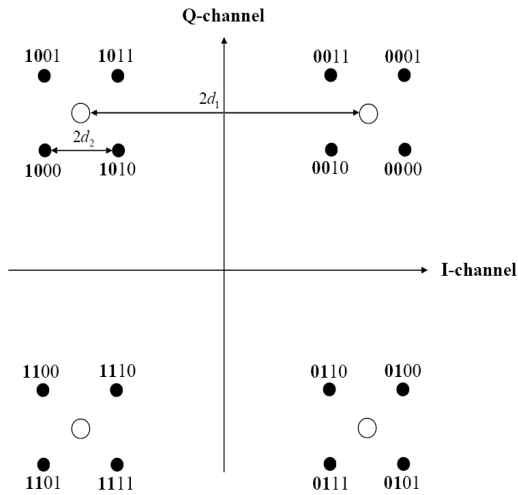


Fig. 2 Constellation of Hierarchical Modulation

B. Hierarchical Modulation

To compensate this degrading, the enhanced hierarchical modulation was proposed. Data symbols usually pass through fading environment. In constellation, all symbols have real value, or I, image value, or Q. Because of fading channel, symbols each values are damaged and changed.

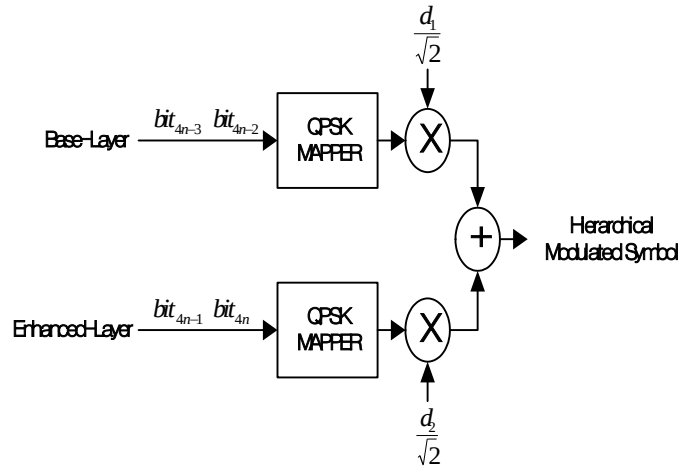


Fig. 3 Hierarchical Modulation Block Diagram

Fig.4 shows that symbols experience deep fading channel that fades symbol's image value but real value remain same. In this case, each symbols minimum distance becomes shorter and then it cause decoding symbol efficiency reduction. Constellation rotation helps to solve this problem. Maintaining symbol's power, rotated symbols in constellation have diverse values each. In the same fading environment, these symbols are also damaged image values but each symbols has more diversity then before, it makes decoding work brilliant. It called signal space diversity(SSD) gain. Symbols are rotated by following symbol. S is original symbol and SR is rotated symbol.

$$S = (a_i b_i) \quad S^R = (x_i y_i) \quad (2)$$

$$x_i = a_i \cos \theta + b_i \sin \theta \quad (3)$$

$$y_i = -a_i \sin \theta + b_i \cos \theta \quad (4)$$

$$[S_i^R S_q^R] = [S_i S_q] \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} \quad (5)$$

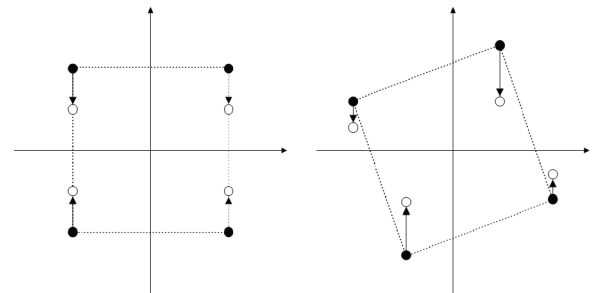


Fig. 4 Rotated Constellation of QPSK in fading channel

Fig.5 is constellation of hierarchical modulated symbols which constellation rotation is applied to. Due to rotation, hierarchical modulated symbol becomes powerful in fading channel. This is the enhanced hierarchical modulation.

But this technique also has problem. after rotation, grey coding scheme is broken. All inner symbols of four quadrant has 2bit error with side symbols and this cannot achieve the least bit error constellation.

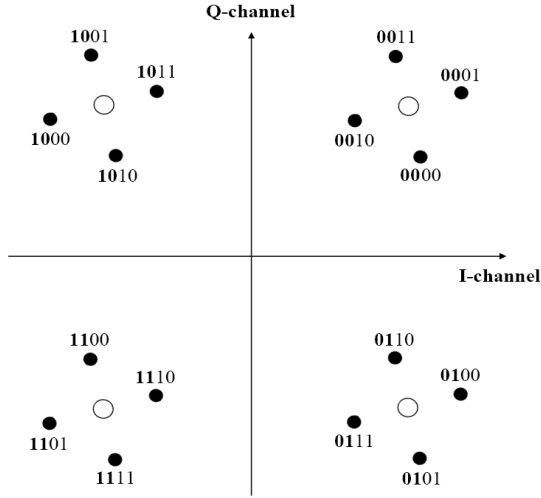


Fig. 5 Constellation of
Enhanced Hierarchical Modulation

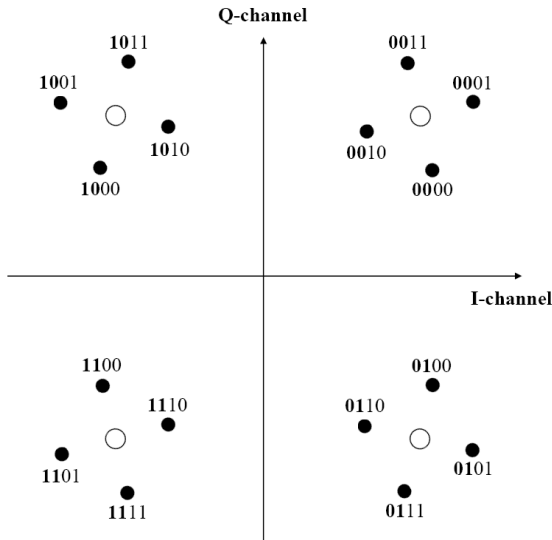


Fig. 6 Symmetrically Rotated Constellation
of Hierarchical Modulation

III. THE PROPOSED HIERARCHICAL MODULATION

A. Hierarchical Modulation with Symmetrically rotated constellation

As aforementioned, constellation rotation has still not optimized for reducing BER. To complete optimized constellation that each symbols has 1 bit error with side symbols, symmetrically rotated constellation is proposed. This rotating method creates symbols like Fig.6 that each symbols in each quadrant has different rotating angle and constellation appears like butterfly's wing. In this scheme, nearest symbols from the origin in each quadrant have 1 bit error with side symbols. Because of this, BER can be reduced.

B. Hierarchical Modulation with Component Interleaving

In SISO system, one symbol can have one channel constant. It means that symbol's real value and image value have same channel constant. If they have different channel constant, this symbol also has signal space diversity gain. This is similar with constellation rotation effect, but this technique gives symbols more SSD Gain. Component interleaving is represented following equation.

Symbols

$$x_n = x_{n1} + x_{n2}i \quad (6)$$

$$x_m = x_{m1} + x_{m2}i \quad (7)$$

Interleaving

$$x_n = x_{n1} + x_{m2}i \quad (8)$$

$$x_m = x_{m1} + x_{n2}i \quad (9)$$

Transmitting

$$y_n = h_n * (x_{n1} + x_{m2}i) + h_n * n \quad (10)$$

$$y_m = h_m * (x_{m1} + x_{n2}i) + h_m * n \quad (11)$$

Channel Equation & Processing

$$\frac{h'_n}{|h_n|} y_n = \frac{h'_n}{|h_n|} h_n * (x_{n1} + x_{m2}i) + \frac{h'_n}{|h_n|} h_n * n \quad (12)$$

$$= |h_n| x_{n1} + |h_n| x_{m2}i + |h_n| n$$

$$\frac{h'_m}{|h_m|} y_m = \frac{h'_m}{|h_m|} h_m * (x_{m1} + x_{n2}i) + \frac{h'_m}{|h_m|} h_m * n \quad (13)$$

$$= |h_m| x_{m1} + |h_m| x_{n2}i + |h_m| n$$

De-Interleaving

$$y'_n = |h_n| x_{n1} + |h_m| x_{n2}i + n' \quad (14)$$

$$y'_m = |h_m| x_{m1} + |h_n| x_{m2}i + n' \quad (15)$$

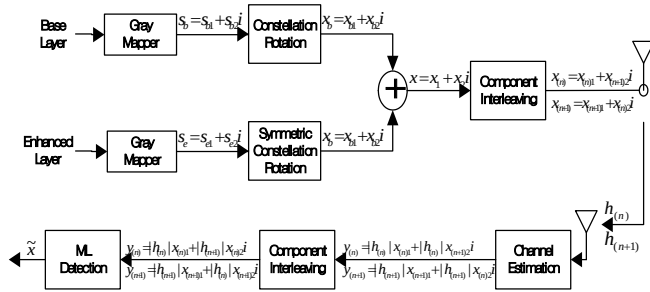


Fig. 7 Proposed system Block diagram

Fig.7 shows block diagram of proposed hierarchical modulation system with constellation rotation and component interleaving for SSD gain. Base-layer data, normally modulated in QPSK and enhanced-layer, symmetrically modulated in QPSK are added to make transmission symbols. These symbols image values are interleaved and transmitted. While transmitting, channel constant h would be timed with symbols and receiver estimates h for multiply symbols by to make channel constant to real number. After that, multiplied symbols are interleaved again to get back to original symbols. At last, symbols are decoded by ML detection.

IV. SIMULATION RESULT

Fig. 7 represents BER performance of only constellation rotated hierarchical modulation, symmetric rotated hierarchical modulation and symmetric rotated hierarchical modulation with component interleaving. As shown in this figure, only constellation rotated system has BER= at SNR 38dB. On the other hand, symmetric rotated system has capacity improvement about 1dB; BER= at SNR 37dB, and proposed system has advantage about 5dB; BER= at SNR 33dB. From these result, proposed system with SSD can provide additional gain.

V. SIMULATION RESULT

In this paper, we designed a novel system with new hierarchical modulation scheme and SSD algorithm. These chosen techniques are bring improved efficiency and extra gain obviously. A novel hierarchical modulation indicates BER reduction and SSD provides extra diversity gain. Simulation result show that the novel hierarchical modulation has gain about 1dB than conventional hierarchical modulation and about 5dB gain in BER= can be achieved in proposed system. These result confirms excellence of this proposed system.

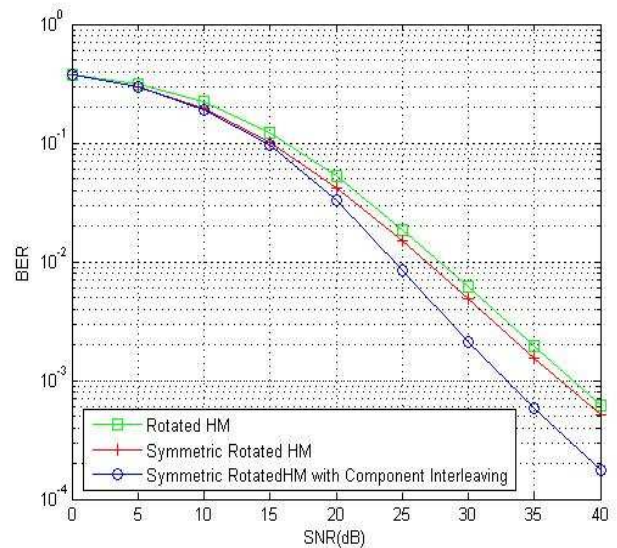


Fig. 8 BER performance of Each Hierarchical Modulation

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