Coded Cooperative MIMO Transmission Schemes for DVB-T2 Digital Terrestrial Television: Postprint

Authors: Zhang Yiyang

Date: 2023-10-08T00:00:00+00:00

Abstract

Digital terrestrial television is a modern broadcasting technology used by broadcasters to provide television services with high-quality video and audio. This paper discusses the application of a coded cooperative multiple-input multiple-output (MIMO) transmission scheme in modern digital broadcasting systems to achieve additional transmit diversity and coding gain. The main idea is to implement a coded cooperative MIMO scheme based on Low-Density Parity-Check (LDPC) codes. Coded cooperative transmission can achieve robust forward error correction capability. Through this approach, more stable system performance can be realized and enhanced mobility for next-generation handheld systems can be achieved. To demonstrate its potential practical applications, the performance of the proposed method was evaluated based on the Second Generation Digital Terrestrial Television Broadcasting (DVB-T2) system. Simulation results demonstrate that this method can be utilized to support the development of DVB broadcasting systems for highly mobile handheld devices, such as the Next-Generation Handheld Digital Television Broadcasting (DVB-NGH) system.

Full Text

Coded Cooperative MIMO Transmission Schemes in DVB-T2 Digital Terrestrial Television

Abstract: Digital terrestrial television represents a modern broadcasting technology that enables broadcasters to provide television services with high-quality video and audio. This paper discusses the application of coded cooperative multiple-input multiple-output (MIMO) transmission schemes in modern digital broadcasting systems to achieve additional transmit diversity and coding gains. The core concept involves implementing a coded cooperative MIMO scheme based on low-density parity-check (LDPC) codes. Coded cooperative transmission can obtain robust forward error correction capabilities, thereby enabling more stable system performance and improving mobility for next-generation handheld systems. To demonstrate potential practical applications, the performance of this method was evaluated based on the second-generation terrestrial digital video broadcasting (DVB-T2) system. Simulation results indicate that this approach can be used to support the development of DVB broadcasting systems for highly mobile handheld devices, such as the next-generation handheld digital video broadcasting (DVB-NGH) system.

Keywords: Digital television broadcasting; Cooperative transmission; MIMO; DVB-T2
Classification Number: TN919.3+1
Document Code: A
Article ID: 1671-0134(2017)07-082-04
DOI: 10.19483/j.cnki.11-4653/n.2017.07.026

Author: Zhang Yiyang

Countries worldwide (including the United States, Europe, and Japan) are conducting research on high-definition advanced television systems. Due to various technical, organizational, and political reasons, multiple digital television (DTV) standards have been adopted across different regions. Currently, the industrial demand for analog-to-digital conversion is increasing, and broadcasting systems are no exception—many nations are actively promoting the digitization of their broadcasting infrastructure. The transition from analog to digital technology in terrestrial television platforms has stimulated economic growth in the television market. To achieve spatial diversity, researchers have employed MIMO systems. Furthermore, a 3D MIMO scheme has been proposed for DTV broadcasting systems in single frequency networks (SFNs), demonstrating efficient handling of equal and unequal reception rights within SFN configurations.

1. Research Status

In the context of developing next-generation terrestrial digital video broadcasting (DVB-T) systems, scholars have investigated DTT broadcasting systems incorporating MIMO and orthogonal frequency division multiplexing (OFDM) technologies. Developed software has been applied to mobile reception, with analysis and verification of its impact on DVB-T networks. The single frequency network (SFN) transmission scheme offers significant advantages in DTV systems, as it allows broadcasters to use the same frequency for identical data transmission across arbitrarily large areas. Numerous studies on DVB-T2 have been ongoing since 2006, examining parameters such as guard intervals and FFT sizes, as well as evaluating mobile performance and conducting research using rotated constellations. However, MIMO technology has not yet been applied to the DVB-T2 standard. According to DVB-NGH recommendations, MIMO technology will be a key research area for next-generation broadcasting standards, helping to improve channel capacity.

MIMO technology is considered essential for next-generation terrestrial broadcast television systems, leading to increased research activity in this domain. Scholars have proposed a near-capacity MIMO coordinate interleaved coded modulation scheme using independent or iterative mapping, which will see broader application when higher transmission rates and spectral efficiency are required. Significant progress has been made in applying MIMO technology to enhance SFN system advantages in DTV systems. Researchers have studied fundamental channel parameters, cross-polarization discrimination, spatial correlation, and 4$×$4 MIMO antenna configurations to characterize MIMO wireless channels in the UHF band. A novel SFN model for diversity gain in DTV systems has been proposed, and spatial diversity techniques have been implemented using MIMO systems.

2. DVB-T2 System

The input to a DVB-T2 system may consist of one or more MPEG-2 transport streams and/or generic streams. Services to be transmitted must first pass through an input pre-processor, which includes a service splitter or demultiplexer that divides services into T2 system inputs—comprising one or more logical data streams. The pre-processed input is then forwarded to individual physical layer pipes (PLPs). DVB-T2 employs an innovative technique called "rotated constellation," which provides significant improvements in system robustness, particularly effective in terrestrial channels. The system output is typically a single-antenna signal transmitted on an RF path, though the system can also generate another set of output signals transmitted on a separate antenna, known as "MISO transmission mode."

The DVB-T2 standard includes additional 16k and 32k carrier modes, which can expand SFNs without increasing expected overhead. DVB-T2' s maximum guard interval exceeds 500, sufficient for implementing a large national SFN. The standard defines eight modes that can be selected based on FFT size and specific transmission guard intervals, reducing pilot overhead while ensuring adequate channel estimation. Interleaving is a common concept in digital signal transmission technology, designed to separate digital content in time or frequency domains to prevent impulse noise and frequency-selective fading from destroying long sequences of the original data stream. DVB-T2 implements four types of interleaving stages. If data symbols are interleaved by the frequency interleaver block before SFBC, they combine with space-frequency mapping and thus experience identical attenuation coefficients. However, if data symbols are interleaved after the SFBC block, they have different attenuation coefficients, which can improve transmission diversity techniques.

3. Proposed Scheme

Cooperative diversity is a well-known scheme where multiple nodes collaborate to form a virtual multi-antenna array. In fading environments, multiple antennas can utilize space-time coding to improve wireless communication link capacity and reliability. Recent scientific interest in ad-hoc networks has focused on exploiting antennas from different users in the network to develop spatial and transmission diversity, with studies utilizing repetition and space-time algorithms to improve spatial diversity. Coded cooperation provides another approach for cooperative diversity in SFN systems.

3.1 Coded Cooperative Transmission Scheme

The coded cooperative transmission scheme proposed here for DVB-T2 systems focuses primarily on coding gain. This scheme adds FEC coding combination methods for cooperative transmission, which can reduce code rates and improve coding gain for mobile nodes. Figure 1 [Figure 1: see original paper] illustrates the coded cooperative transmission scheme between two base stations. The main objective of this work is to identify a method that achieves effective new coding gains while maintaining the same transmission efficiency as DVB-T2 systems. The proposed cooperative transmission mechanism employs 1/3 or 1/4 LDPC code rates, which are not implemented in DVB-T2 systems. Since the LDPC encoder used in the DVB-S2 system provides the core for DVB-T2' s LDPC encoder, a DVB-S2 LDPC encoding block is utilized for implementation.

3.2 1/3 Code Rate

3.2.1 Coding Cooperation Scheme Figure 2 [Figure 2: see original paper] presents an example of a 1/3 code rate coded cooperative transmission scheme. Each base station generates a predefined 1/3 inner code where S represents symmetric data bits, and 1P and 2P are parity bits 1 and 2, respectively. Each base station punctures one parity bit based on the proposed FEC type to produce a new 1/2 rate inner code after the internal FEC process. For instance, as shown in Figure 2 [Figure 2: see original paper], Base Station A generates the original inner code C and punctures one parity bit according to the proposed FEC type, resulting in a new code that is transmitted. Base Station B follows a similar process. Finally, each base station can process MIMO block codes (SFBC or STBC) to transmit the modified code rate data.

3.2.2 Cooperative Transmission Scheme In wireless communication systems, signals from other base stations typically cause small-interval interference, which degrades system performance and necessitates a frame transmission scheme to prevent such interference. Frames should be separated when transmitting completely different information. Each base station has different frame start offsets and frame hopping pointers. Assuming all base stations achieve perfect time synchronization using GPS and transmission frame sizes are identical, Base Station A has a frame start offset of 0 and a frame hopping pointer of 2.

During the frame period (TFRAME), Base Station A transmits the first frame and then waits for TFRAME time. A frame hopping pointer is also designated for one T2 frame. When transmission begins, Base Station B waits for the given frame start offset time, with the specified value for Base Station B' s frame start offset being "1." After waiting for TFRAME time, Base Station B can transmit its first frame. The specific transmission scheme is shown in Figure 3 [Figure 3: see original paper], with these frame mapping schemes derived from the time interleaver mapping method in the DVB-T2 standard.

The transmission process can also utilize Future Extension Frames (FEF), which are parts of the superframe between two T2 frames. The FEF portion process is similar to the frame mapping scheme, where each base station has its own offset and hopping pointer for the FEF part. The mapping scheme is not discussed further here. The most significant difference between DVB-T2 and DVB-T during the interleaving stage is that DVB-T2 introduces time interleaving, which better protects against impulse noise and time-selective fading.

3.2.3 Signal Transmission Calculation Assuming two antennas are applied at Base Stations A and B and at the destination node, Base Station A transmits its punctured codeword while Base Station B transmits its punctured codeword. For the MIMO process after FEC, base stations use SFBC mapping schemes on transmission antennas when T2 frames are transmitted according to the transmission scheme. The transmitted bit stream is encoded into blocks of size N by the space-frequency encoder. The mapping scheme for data symbol iS with two antennas is: for subcarrier i, antenna 1 corresponds to iS and antenna 2 corresponds to *iS; for subcarrier 1+i, antenna 1 corresponds to 1+iS and antenna 2 corresponds to* 1+iS, where l is the l-th subcarrier pointer. Conjugate complex values are denoted by (.*). The SFBC mapping scheme is selected so that original data can be transmitted on the first antenna without any modification. Noise is added at the receiver end.

After channel estimation processing, the received signals are combined and sent to a maximum likelihood detector. Following the MIMO decoding process and combining processing, the received signals are as follows: the data symbols detected in the signal transmitted by Base Station A are , while the data symbols detected in the signal transmitted by Base Station B are .

3.3 1/4 Code Rate

A brief description of examples implementing 1/4 code rate coded cooperative transmission schemes with two and three base stations is provided here. Each base station generates a 1/4 inner codeword where S is a symmetric data bit and P1, P2, and P3 represent parity bits 1, 2, and 3. After the FEC process, each base station divides one FEC block into two parts according to its own FEC type. Base Station A generates an original 1/4 inner codeword C' and divides the FEC block into two parts. Finally, Base Station A can select one from the divided FEC part C1 or C' 2 and will transmit the selected FEC part.

Base Station B follows a process similar to Base Station A. If Base Station A selects FEC part C1, Base Station B will select C' 2, and vice versa.

For three-base-station cooperative transmission schemes, other coding types can be considered. Each base station generates a default 1/4 inner codeword C' , then splits and reorganizes the default codeword. Each base station selects a new codeword different from other base stations and processes SFBC MIMO block coding. Finally, each base station follows the cooperative transmission scheme to transmit data. The above describes 1/3 and 1/4 code rate coding schemes for two-base-station and three-base-station coded cooperation scenarios. In the previous examples, two and three cooperative base stations should transmit different information, and transmission frames should be separated when transmitting completely different information.

In two-base-station 1/3 coding cooperation or three-base-station 1/4 coding cooperation, each cooperative base station contains shared information S. If each cooperative base station shares some information, another transmission method can be used. One new FEC block Cn can be divided into two parts: the symmetric part S and the parity bit part Pi. Since all base stations contain the symmetric part, S can be transmitted simultaneously to obtain diversity gain after the combining process at the receiving end. However, because Pi differs in each base station, Pi should be transmitted at different times.

4. Simulation Results

This section presents simulation parameters and results for the 1/3 code rate scheme. The simulation assumes a quasi-static Rayleigh fading channel and ideal channel estimation. Most simulation parameters are set according to the DVB-T2 standard. Since the pilot model for MIMO transmission schemes is not applicable, MISO transmission parameters are used during the MIMO process. The simulation employs an 8K FFT size and 8 MHz channel bandwidth. The number of carriers per symbol, number of P2 symbols, and number of other carriers are 6817, 2, and 48, respectively. The transmission frame size is 250 ms, which is the maximum frame size in DVB-T2. Short LDPC blocks are selected as the inner coding type, with an FEC block length of 16200. Since 1/3 and 1/4 LDPC code rates are not applied in the DVB-T2 standard, the DVB-S2 standard' s 1/3 and 1/4 LDPC matrices are used for generation in the simulation. The inner decoder iteration count is 50. Specific parameters are shown in Table 1 .

The simulation design is based on a two-base-station, 1/3 code rate coded cooperation model (as shown in Figure 2). According to the proposed scheme, the simulation measures bit error rate (BER) performance as a function of energy per symbol to noise power spectral density ratio (Es/N0) and compares it with traditional non-cooperative SFBC schemes. The SFBC cooperation scheme corresponds to the coded cooperation scheme shown in Figure 3. In Figure 4 [Figure 4: see original paper], the 1BS SFBC scheme means using a 1/2 rate LDPC code for Alamouti SFBC transmission based on a single base station. The 2BS cooperation repetition scheme means Alamouti SFBC transmission based on two base stations without the proposed coded cooperation scheme, where each base station transmits identical data and the destination node repeatedly receives the same data. The 2BS conventional scheme means the proposed scheme with the same data transmission rate as the 2BS cooperation repetition scheme. In the 2BS conventional scheme, each base station shares the same symmetric data but has different parity data, enabling the proposed scheme to achieve combining coding gains at the destination node.

As shown in Figure 4, the proposed scheme improves performance compared to both traditional schemes. The 2BS coded cooperative transmission scheme achieves gains of 0.6 dB over 1BS SFBC and 0.3 dB over the 2BS conventional scheme.

5. Conclusion

This paper summarized the development of MIMO and related technologies in digital television broadcasting, described relevant content of the DVB-T2 standard, investigated coded cooperative transmission schemes for DVB-T2, and proposed coded cooperative transmission schemes based on two and three base stations in DVB-T2 systems. Finally, corresponding performance simulations were conducted under slow Rayleigh fading channels.

Simulation results demonstrate that the coded cooperation scheme offers advantages in system performance and cooperative diversity compared to traditional transmission schemes based on one and two base stations. Additionally, the coded cooperation scheme shows significant results in improving channel performance for DVB systems. System performance can be further enhanced through optimized design of the cooperation scheme. Moreover, effective power allocation and rate adaptation transmission schemes for coded cooperation require further research.

References: [1] El-Hajjar M, Hanzo L. A Survey of Digital Television Broadcast Transmission Techniques[J]. IEEE Communications Surveys & Tutorials, 2013, 15(4):1-26. [2] Hu Liujun, Lu Zhaohua, Chen Yijian, et al. Analysis of Multi-Antenna Technology Development Trends[J]. Modern Telecommunication Technology, 2014, (12):5-9. [3] Cheng T, Peng K, Yang F, et al. A Near-Capacity MIMO Coded Modulation Scheme for Digital Terrestrial Television Broadcasting[J]. IEEE Transactions on Broadcasting, 2015, 61(3):367-375. [4] Radmard M, Majd M N, Chitgarha M M, et al. Spatial diversity gain of MIMO single frequency network in passive coherent location[J]. Scientia Iranica, 2014, 21(6):2186-2199. [5] Wei Zehua. Research on Downlink Multi-Cell Joint Transmission in 3D MIMO Systems[D]. Beijing University of Posts and Telecommunications, 2015. [6] Nasser Y, Helard J, Crussiere M, et al. Efficient MIMO-OFDM Schemes for Future Terrestrial Digital TV with Unequal Received Powers[C]// in Proc. of IEEE International Conference on

Communications, 2008. ICC ' 08. 2008:2021. [7] Bahgat N M, Khalil D E S, El-Ramly S H. Energy efficient design of DVB-T2 constellation demapper[C]// Quality Electronic Design (ISQED), 2015 16th International Symposium on. IEEE, 2015. [8] Sugaris A, Reljin I. DVB-T2 technology improvements challenge current strategic planning of ubiquitous media networks[J]. Eurasip Journal on Wireless Communications & Networking, 2012, 2012(8):701-710. [9] Kulkarni A N, Sharma S K. Frequency Reconfigurable Microstrip Loop Antenna Covering LTE Bands With MIMO Implementation and Wideband Microstrip Slot Antenna all for Portable Wireless DTV Media Player[J]. IEEE Transactions on Antennas & Propagation, 2013, 61(2):964-968. [10] European Telecommunications Standards Institute. ETSI EN 302 755 V1.4.1[DB/OL]. http://www.etsi.org/deliver/etsi_{en}/302700_{302799}/302755/01.04.01_{60}/en_{302755v010401p}.pdf, 2015(7).

(Author' s Affiliation: Technical Support Department, State Administration of Press, Publication, Radio, Film and Television)

Note: Figure translations are in progress. See original paper for figures.