A Review Of Various Frame Structure For Channel Estimation In Digital Terrestrial Television Broadcasting Systems

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***Abstract*—OFDM (orthogonal frequency division multiplexing) is a multi-carrier modulation technology with great spectral efficiency that may be employed in multipath propagation. Because of its enticing characteristics, OFDM has been proposed as a modulation technology for a variety of global digital television terrestrial broadcasting (DTTB) systems. There are several frame structures proposed for efficient communication with numerous factor optimisations; however, there are always tradeoffs among the parameters. This research analysis is applied to discussed algorithms to determine the best outcome among them.**

***Index Terms*—Digital terrestrial television broadcasting (DTTB), time domain synchronous orthogonal frequency division multiplexing (TDS-OFDM), fast fading channel, channel estimation, least mean square (LMS) algorithm, Quadrature Phase Shift Keying (QPSK).**

I. Introduction

TDS-OFDM (Time-Domain Synchronous Orthogonal Frequency Division Multiplexing) has emerged as a favored alternative in modern communication systems due to its effective frame coordination and spectrum utilization [1]. TDS-OFDM, on the other hand, has a severe hurdle in the form of inter-block interference (IBI) [2] induced by the interaction of the training sequence (TS) with the data block and pseudorandom noise (PN) sequence [3]. This interference reduces the accuracy of channel estimation and equalization, resulting in poor system performance.

Researchers have offered different strategies in the literature to handle the IBI issue. Iterative Padding Subtraction (IPS) [3] is one such approach that combines channel estimation and equalisation to efficiently reduce interference. Despite its usefulness in reducing IBI, IPS reduces TDS-OFDM efficiency regardless of the multipath channel's characteristics.

The Dual PN Stuffing (DPNS) [4] frame structure has emerged as a possible solution to the interference problem in TDS-OFDM in recent research endeavours. DPNS integrates two identical PN sequences within the frame structure and provides a low computational cost, simplicity, and reliability channel estimation approach. As a result, TDS-OFDM based on DPNS is gaining traction as a possible contender for the future digital terrestrial broadcasting (DTTB) standard [5].

It is crucial to note, however, that DPNS-based TDS-OFDM has lower spectrum efficiency than IPS-based TDS-OFDM [6] since the existence of two PN sequences affects total efficiency. Furthermore, DPNS-based TDS-OFDM has a substantial disadvantage in that it assumes a time-invariant channel at each symbol interval. This constraint degrades performance, particularly in rapid fading channels, and has an impact on the system's bit-error-rate (BER) performance.

Given these factors, continuing research efforts seek to investigate novel strategies for improving TDS-OFDM [7], [8] performance by finding a balance between interference mitigation, spectral efficiency, and adaptation to changing channel circumstances. Appropriate channel estimation and equalization algorithms must be developed to address the obstacles given by IBI and achieve reliable and efficient communication in TDS-OFDM systems.

II. LMS algorithm

The LMS algorithm [9], [10] then fine-tunes the channel estimate after it has been computed using the TS of the guard interval.

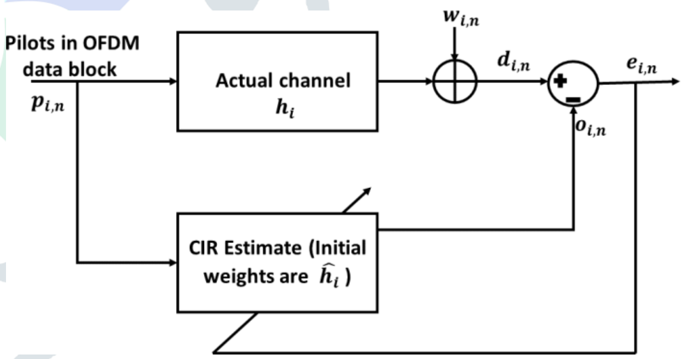

Fig. 1. **Block diagram of LMS algorithm for tuning channel coefficients**

For modifying CIR coefficients using the LMS approach, default values are chosen. In the OFDM data block, pilots are inserted as follows: $p_{i,n} = \{p_{i,0}, p_{i,1}, \cdot, p_{\alpha p-1}\}$ where α_p is the total number of pilots put in the OFDM block. α_p should be greater than maximum channel delay n_L, *i.e.* $\alpha_p \geq n_L$. As shown in Fig. 1, $d_{i,n}$ is the desired output given by,

$$d_{i,n} = h^H_{i,n}\ p_{i,n} + w_{i,n} \tag{1}$$

The symbol for actual channel coefficients is $h_{i,n}$. Similar to this, when the pilots $p_{i,n}$ are sent through the filter $\hat{h}_{i,n}$, the resulting $o_{i,n}$ is given by,

$$o_{i,n} = \hat{h}_{i,n}^{H}\, p_{i,n} \tag{2}$$

Consequently, the description of the estimated error or error signal $e_{i,n}$ is

$$e_{i,n} = d_{i,n} - o_{i,n} \tag{3}$$

The LMS algorithm's tap-weight adaptation is provided by,

$$\hat{h}_{i,n+1} = \hat{h}_{i,n} + \mu\, p_{i,n}\, e_{i,n} \tag{4}$$

When the range of the step-size parameter μ is provided by,

$$0 < \mu < \frac{2}{\alpha_p\, S_{max}},$$

where α_p stands for the filter length and S_{max} is the greatest power spectrum density of the input $d_{i,n}$.

III. gOMP Algorithm Based

Channel estimation in MIMO-OFDM systems is divided into two approaches based on signal type: time domain estimation and frequency domain estimate. Mutually orthogonal pilots are introduced to the training sequences in the frequency domain channel estimation approach. The channel responsiveness is estimated using these pilots. Each antenna inserts pilots at equal intervals at distinct frequencies. The frequency domain channel response may be determined by examining the received pilots and their known sent values. However, when the number of antennas rises, this strategy introduces pilot overhead and lowers spectral efficiency.

Time-domain channel estimation, on the other hand, provides superior spectral efficiency. It gathers extensive channel information by using all sub-carriers of a given sequence, especially in slow-fading channels. Instead of employing unique pilot symbols, this technique estimates the channel response using the full broadcast signal.

Both time domain and frequency domain channel estimate approaches have benefits and drawbacks. The frequency domain technique allows for greater flexibility in pilot pattern selection and can be useful in fast-fading channels. It does, however, increase pilot overhead and diminish spectrum efficiency. Time-domain channel estimation, on the other hand, improves spectral efficiency by using the full sent signal. It is especially useful in slow-fading channels when detailed channel information is required.

TDS-OFDM, also known as time-domain synchronous OFDM, is a different variant of OFDM systems. For synchronisation and channel estimation, it employs a widely known pseudorandom noise (PN) sequence as both a guard interval and a training sequence. TDS-OFDM is a common choice in digital television terrestrial broadcasting (DTTB) applications due to its greater spectrum efficiency and quicker synchronisation.

TDS-OFDM, on the other hand, has several drawbacks. TDS-OFDM channel estimation error can become rather severe in circumstances with fast-fading channels and higher-order modulation techniques. In these difficult conditions, the accuracy of the anticipated channel response may be impaired. It is crucial to note that the limitations of TDS-OFDM in fast-fading channels and higher-order modulation are unique to this technology. Other OFDM variants or channel estimation algorithms may perform better in such settings.

Researchers introduced the priori-aided compressive sampling matching pursuit (PACoSaMP) and adaptive simultaneous orthogonal matching pursuit (A-SOMP) algorithms to circumvent the constraints of TDS-OFDM in fast-fading channels and higher-order modulation circumstances. In a single-input, single-output (SISO) system, these methods take advantage of the features of pseudorandom noise (PN) sequences as well as the intrinsic sparsity of the channel.

Both the PACoSaMP and A-SOMP algorithms leverage PN sequence features to extract partial channel prior information at first. This helps to improve channel estimate accuracy. There is, however, a distinction between the two techniques. While both algorithms use the PN sequence, A-SOMP also takes use of the common sparsity in the time domain to find the remaining support sets. These techniques to improve the accuracy of channel estimation in TDS-OFDM systems by considering the features of PN sequences and utilising channel sparsity. They aid in reducing channel estimation error, especially in difficult settings including fast-fading channels and higher-order modulation schemes.

introduce an adaptive structured-generalized orthogonal matching pursuit (AS-gOMP) technique based on PN sequence characteristics and shared sparsity in space and temporal domains. The partial channel prior information is acquired in the same way, and the gOMP approach is then arranged by the common sparsity of the MIMO system. The gOMP technique is an OMP algorithm modification that reduces iterations and computation by selecting T indexes at a time. The updated ASgOMP approach outperformed the other methods in the MATLAB simulation trial.

IV. Joint Estimation Technique

Blind channel estimate is another approach for channel estimation that does not rely on the transmission of pilot symbols. Instead, it estimates the channel using higher-order statistics from the received signals. However, one big disadvantage of blind channel estimation is that it requires a lengthy data sequence to get good findings. This is often impracticable, especially in fast-changing channels. Semi-blind channel estimation approaches, on the other hand, combine the broadcast of pilot symbols with the statistical features of the received signal. This method minimises the amount of pilot symbols necessary, resulting in higher spectral efficiency.

ASpace-time (ST) based channel estimation is an appealing channel estimation approach in which a known ST sequence is algebraically added to the data symbols for channel estimation. While this approach enhances spectrum efficiency, it is limited by mutual interference between data symbols and the ST sequence. To solve this issue, iterative strategies for reducing interference and improving performance have been devised. However, these iterative approaches come at the expense of increasing receiver complexity.

A novel ST-based channel estimate approach for single carrier transmission is proposed, in which a ST sequence is created as the sum of a known sequence and an unknown to the receiver data-dependent sequence. This approach attempts to neutralise the interference created by data symbols on the known sequence, resulting in more precise channel estimates and better performance than previous ST-based algorithms.

A Data-Dependent Superimposed Training (DDST) based channel estimation approach is used in the context of the CP-OFDM system. Data symbols are distributed throughout all subcarriers in this manner, and a nulling matrix is utilised to insert nulls at specified subcarriers corresponding to the ST sequence subcarriers. In terms of channel estimate accuracy and bit error rate (BER), the DDST technique offers potential improvements.

In terms of complexity, spectral efficiency, and performance, each channel estimate approach has its own set of pros and disadvantages. The approach chosen is determined by the communication system's unique requirements and restrictions.

V. A Compressive Sensing-Based Channel Estimation

A guard interval (GI) is generally employed between OFDM data blocks to decrease inter-block interference (IBI) and inter-carrier interference (ICI) in OFDM-based systems. The GI isolates neighbouring symbols while keeping the subcarriers orthogonal. In addition, the GI can be used for synchronisation and channel estimation (CE).

The most prevalent OFDM scheme is cyclic prefix OFDM (CP-OFDM), which maintains the circular convolution feature between the transmitted OFDM data block and the channel impulse response (CIR). Zero padding OFDM (ZP-OFDM) is another technique that substitutes the CP with zero samples to alleviate the null problem in the channel and enhance equalisation performance. However, in order to accomplish synchronisation and CE, both CP-OFDM and ZP-OFDM require specialised frequency domain pilots, leading in a considerable reduction in spectral efficiency (about 5%-15%).

TDS-OFDM outperforms CP-OFDM and ZP-OFDM in terms of spectrum efficiency by use a previously known pseudo-noise (PN) sequence for synchronisation and CE instead of CP or ZP. There is no longer a requirement for frequency domain pilots. However, in multipath channels, the PN sequence and the OFDM data block introduce mutual IBI. To address this issue, the system implementation must use iterative interference cancellation methods, which are computationally demanding. Unfortunately, in strong frequency selective channels, the CE performance of these algorithms decreases, resulting in considerable performance deterioration for TDS-OFDM, particularly in multipath channels with large path delay spread.

The dual-PN padded OFDM (DPN-OFDM) technique was developed to overcome the CE problem in TDS-OFDM. DPN-OFDM doubles the PN sequence, which aids in the resolution of the TDS-OFDM interference problem. Although the doubled PN sequence reduces spectral efficiency, DPN-OFDM provides a simple and practical solution to TDS-OFDM interference concerns.

Layered-division multiplexing (LDM) is used in the Advanced Television Systems Committee (ATSC) 3.0, the next-generation digital terrestrial broadcasting standard, to increase spectrum efficiency. LDM allows numerous services with varying robustness and throughputs to be delivered in a single 6 MHz channel. A unique layer-modulated TDS-OFDM (LM-TDS-OFDM) technique was recently suggested. LM-TDS-OFDM, as opposed to LDM, is a frequency-division multiplexing (FDM) technique that permits multi-service transmissions with varying throughputs. OFDM subcarriers in LM-TDS-OFDM are separated into many independent physical layers with various low-order or high-order modulation modes.

In this research, a new compressive sensing-based CE algorithm based on the LM-TDS-OFDM structure is suggested. Data transferred in the low-order modulated layers can be reliably retrieved by using the error-correcting capacity of forward error correction (FEC) decoding. This recovered data can then be used in a feedback loop to achieve accurate CE. The suggested technique, known as the priori-information hold (PH) subspace pursuit (SP) algorithm, provides great accuracy in CE while reducing the needed computing cost considerably

VI. Conclusions

TDS-OFDM has gained popularity in modern communication systems due to its effective frame coordination and spectrum utilization. However, it faces challenges such as inter-block interference (IBI), which degrades system performance. Different strategies have been proposed in the literature to mitigate IBI, including Iterative Padding Subtraction (IPS) and Dual PN Stuffing (DPNS). While DPNS shows promise in reducing interference and providing low computational cost, it has limitations in terms of spectrum efficiency and assumes a time-invariant channel. Further research efforts are needed to find a balance between interference mitigation, spectral efficiency, and adaptation to changing channel conditions. Techniques such as the LMS algorithm, gOMP algorithm, joint estimation techniques, and compressive sensing-based channel estimation offer potential solutions to improve TDS-OFDM performance. The development of accurate channel estimation and equalization algorithms is crucial to overcome the challenges posed by IBI and achieve reliable and efficient communication in TDS-OFDM systems.

Regenerate response

References

[1] Y. S. Cho, J. Kim, W. Y. Yang, and C. G. Kang, *MIMO-OFDM Wireless Communications with MATLAB*. Wiley Publishing, 2010.

[2] L. Dai, Z. Wang, and Z. Yang, "Next-generation digital television terrestrial broadcasting systems: Key technologies and research trends," *IEEE Communications Magazine*, vol. 50, no. 6, pp. 150–158, June 2012.

[3] J. Wang, Z.-X. Yang, C.-Y. Pan, J. Song, and L. Yang, "Iterative padding subtraction of the PN sequence for the TDS-OFDM over broadcast channels," *IEEE Transactions on Consumer Electronics*, vol. 51, no. 4, pp. 1148–1152, Nov. 2005.

[4] J. Fu, J. Wang, J. Song, C. Y. Pan, and Z. X. Yang, "A simplified equalization method for dual PN-sequence padding TDS-OFDM systems," *IEEE Transactions on Broadcasting*, vol. 54, no. 4, pp. 825–830, Dec. 2008.

[5] L. Dai, Z. Wang, and Z. Yang, "Next-generation digital television terrestrial broadcasting systems: Key technologies and research trends," *IEEE Communications Magazine*, vol. 50, no. 6, pp. 150–158, Jun. 2012.

[6] L. Dai, Z. Wang, and S. Chen, "A novel uplink multiple access scheme based on TDS-FDMA," *IEEE Transactions on Wireless Communications*, vol. 10, no. 3, pp. 757–761, Mar. 2011.

[7] H. Wu, X. Huang, and D. Xu, "Novel semi-blind ICI equalization algorithm for wireless OFDM systems," *IEEE Transactions on Broadcasting*, vol. 52, no. 2, pp. 211–218, Jun. 2006.

[8] H. Wu, X. Huang, Y. Wu, and X. Wang, "Theoretical studies and efficient algorithm of semi-blind ICI equalization for OFDM," *IEEE Transactions on Wireless Communications*, vol. 7, no. 10, pp. 3791–3798, Oct. 2008.

[9] D. G. Manolakis, "Statistical and adaptive signal processing, vinay k. ingle, stephen m. kogon," 2000.

[10] R. D. Hippenstiel, *Detection theory: applications and digital signal processing*. CRC Press, 2017.