

A Time-Domain Channel Equalizer using Sample Matrix Inversion for T-DMB E-DOCR Systems

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Abstract—The main problem of a conventional digital on channel repeater (DOCR) is that its performance is significantly degraded by the inverse operation when the channel has a deep null. Moreover, for the stable operation, conventional DOCR requires additional parts such as the minimum phase filter and the all pass filter, which increase the hardware complexity. To overcome these undesirable effects, we propose a novel DOCR structure which is simple yet robust to frequency nulls based on sample matrix inversion (SMI) method. Simulation results show that the proposed DOCR has a similar performance with the conventional DOCR in favorable channel conditions while it has a better performance than that of the conventional one when the channel has a deep null [6].

Index Terms—T-DMB, SMI, E-DOCR, Equalization, Interference cancellation

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) systems including terrestrial digital multimedia broadcasting (T-DMB) system have been widely deployed due to the possibility of realizing single frequency network (SFN) and its robustness against the multipath fading [1]. However, One of the most serious problems for OFDM systems is that the quality of reception are deteriorated by the shadowing phenomenon. One possible solution to resolve this problem is the installation of digital on-channel repeater (DOCR) which is a cost effective solution compared to the microwave links and optical fiber lines [2].

In the previous works, the equalized DOCR (E-DOCR) systems was independently proposed by [3][4] for T-DMB system. The equalization procedure in [3][4] is based on the inverse operation in the frequency domain and inverse fast Fourier transform (IFFT). Furthermore, to guarantee the stability and causality, the minimum-phase and all-pass filtering processes are inevitably required. To resolve these problems, we propose a simple yet improved E-DOCR with the time domain channel equalization using SMI algorithm. By applying the time domain approach, the redundant procedures such as FFT/IFFT operation, inverse operation and additional filters can be omitted.

The rest of this paper is organized as follows. In section II we introduce the conventional DOCR. After that, Section

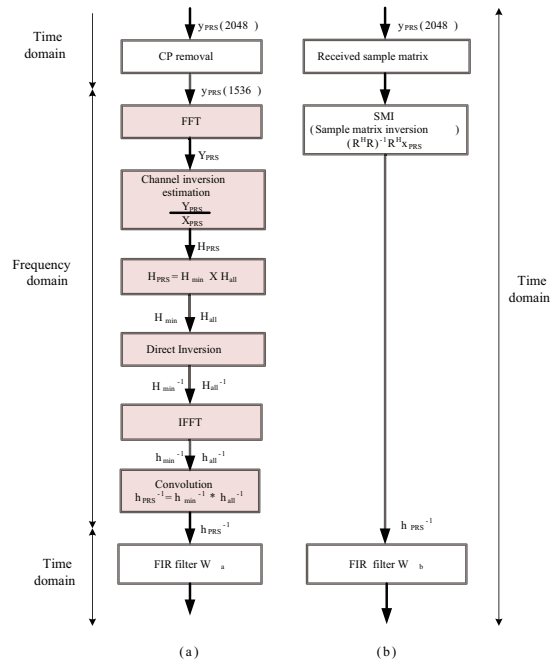


Fig. 1. The overall procedure of DOCR channel estimation; (a) conventional structure of EDOCR (b) proposed EDOCR structure with SMI equalization

III presents the new structure using SMI algorithm. Next, Simulation results are followed by Section IV and the paper is concluded in Section V.

II. PROBLEM STATEMENT OF E-DOCR AND MOTIVATION

For T-DMB to achieve effective solution for filling gap among the network and extending the service coverage, DOCR have been proposed. Several conventional DOCRs have been proposed for this purpose. In this section, we introduce two different well-known structures of the conventional DOCRs and overview their inherent problems.

A. ICS-OCR

We consider first the OCR which effectively detects and removes both echoes at the repeaters input, providing a clear signal at the repeaters output. In general, the transmit signals

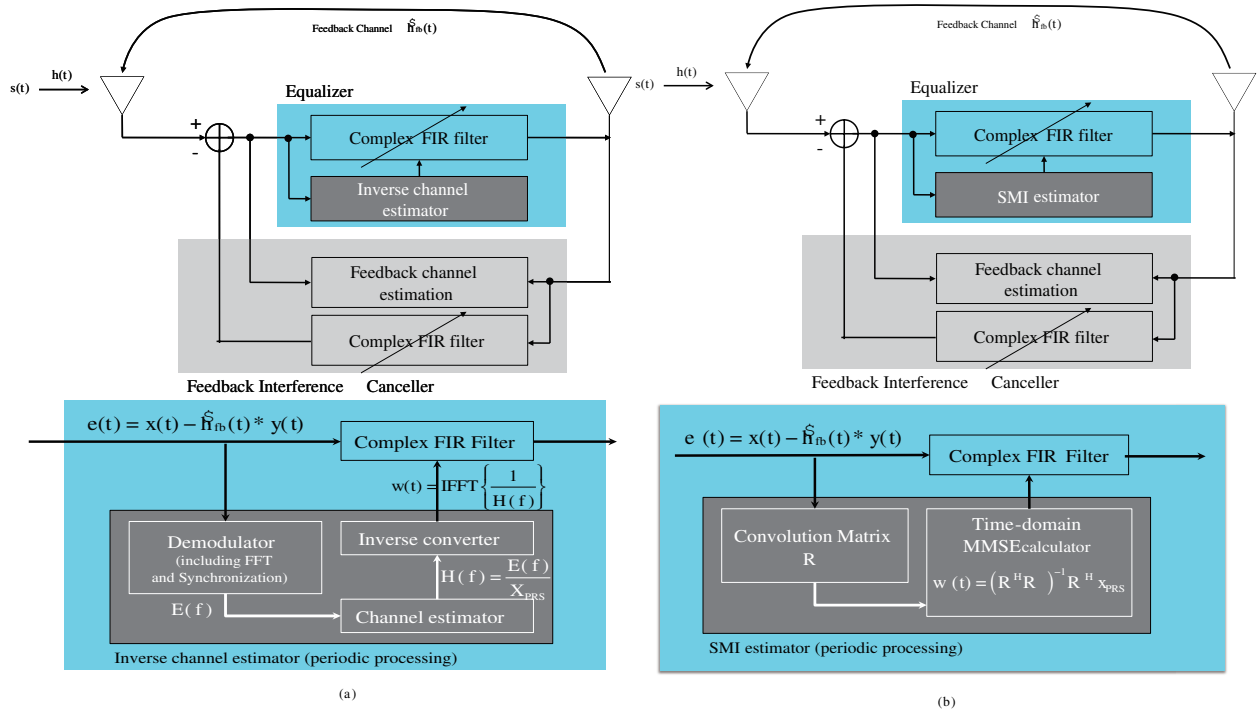


Fig. 2. Procedure of DOCR channel estimation in (a) Conventional structure of EDOCR (b) Proposed structure of EDOCR with SMI equalization

of the DOCR are fed back into its receive antenna due to the imperfect isolation between transmit and receive antennas. consequently, these unwanted signals lead to some problems on the performance issue such as frequency oscillation and system instability. To resolve these problems, the interference cancellation system (ICS) was proposed by [2]. However, ICS is not able to compensate the channel distortion resulting from the paths between main transmitter and ICS even if it can remove the feedback signals. Due to insufficient antenna isolation, the transmission power is limited by feedback signals, and the quality of a transmitted signal does not guarantee a satisfying performance at the repeater and the receiver. For the purpose of resolving this problem, E-OCR which can effectively mitigate the inter-symbol interference (ISI) was proposed by [3].

B. E-OCR

By using E-DOCR, we can improve the quality of receive signals since it can compensate the signal distortion caused by multipath transmission. In conventional E-OCR, in order to estimate channel coefficient, the received phase reference symbol (PRS) without CP in time domain is converted to the frequency domain. The time domain channel equalizer (TDCE) coefficients can be obtained by an IFFT operation of the inverse of the channel coefficient over frequency domain as

$$\mathbf{w}_a = \text{IFFT}\left\{\frac{1}{\mathbf{H}_{PRS}}\right\}. \quad (1)$$

This inversion operation, however, tends to make the system unstable due to the deep fading, the case that some poles

and zeros of the estimated channel are outside the unit circle over Z-plane. To overcome this problem, E-OCR employs the minimum phase and all-pass component so that redundancy procedures should be added as shown in Fig. 1(a). If the long echoes exist over SFN, more frequent deep nulls over frequency domain occur so that the stability of E-OCR does not be guaranteed, even using additional filtering [3].

$$\mathbf{H}_{PRS} = \mathbf{H}_{min} \cdot \mathbf{H}_{all}. \quad (2)$$

To solve this problem inherited by E-OCR, a novel channel estimation technique using SMI is proposed where all operation is performed over time domain as depicted in Fig. 1(b). In the proposed technique, taking the inverse of the convolution matrix $\mathbf{R}$ replaces the blocks from cyclic prefix (CP) removal to convolution for minimum phase filtering as well as the FFT/IFFT operation in E-OCR so that the procedures are simplified without any redundancy.

So this paper proposed E-OCR with SMI can provide reduction of demodulation block in conventional E-OCR in order to just simply like ICS-OCR. In addition, proposed time domain channel equalizer also has the advantage of conventional E-OCR.

III. E-DOCR WITH SAMPLE MATRIX INVERSION

A. Sample Matrix Inversion

The SMI algorithm employs direct inversion of the covariance matrix $\mathbf{R}$. Received signals are not known and the channels between a main transmitter and repeater is Frequency-selective fading channel. Consequently, optimal weights can be calculated by taking the estimates of the covariance matrix $\mathbf{R}$ and

the correlation matrix $\mathbf{r}$, by the time averaging from the block of received signal.

$$\mathbf{R} = \frac{1}{K} \sum_{k=1}^K \mathbf{x}(t) \mathbf{x}^H(t). \quad (3)$$

$$\mathbf{r} = \frac{1}{K} \sum_{k=1}^K \mathbf{d}(t) \mathbf{x}^H(t). \quad (4)$$

where K is number of data samples in a block.

If a priori information such as PRS symbol is known, then the optimum weights will be updated for first block of the each frame using wiener solution as

$$\mathbf{w}_{opt} = \mathbf{R}^{-1} \mathbf{r}. \quad (5)$$

By using block-adaptive approach, we proposed time domain channel estimation method in DOCR.

B. E-DOCR using SMI

In this paper, the proposed time domain channel estimation method is based on least square (LS) solution. We calculate convolution matrix $\mathbf{R}$ using the received PRS symbol $\mathbf{r}_{PRS}$. In T-DMB system, the PRS symbol is delivered in the first symbol of every frame. In conventional SMI algorithm, it can utilize a part of the next symbol in generating the convolution matrix R [5]. The proposed time domain channel estimation technique is modified to use the samples within the PRS symbol. Thus, the length of FIR filter M is limited up to the length of CP. $M \leq 512$.

The CP should be removed in order to estimate the channel estimation based on zero-forcing (ZF) manners in conventional E-DOCR, while the proposed SMI technique can use the all received samples including CP samples so that more higher stability in estimations can be achieved. Therefore, the convolution matrix $\mathbf{R}$ is composed of the first PRS samples without CP removal as

$$\mathbf{R} = \begin{bmatrix} r_{PRS}(0) & r_{PRS}(1) & \cdots & r_{PRS}(M-1) \\ r_{PRS}(1) & r_{PRS}(2) & \cdots & r_{PRS}(M) \\ \vdots & \vdots & \ddots & \vdots \\ r_{PRS}(N_{pr}-1) & r_{PRS}(N_{pr}) & \cdots & r_{PRS}(N_{pr}-M+1) \end{bmatrix} \quad (6)$$

where

$$\mathbf{r}_{PRS} = [r_{PRS}(1) \ r_{PRS}(2) \ \cdots \ r_{PRS}(2048)]. \quad (7)$$

From (3), the SMI filter $\mathbf{w}_b$ in the time domain minimizes the minimum square error (MSE) between the filtered time samples and the transmitted symbols in the time domain, i.e.,

$$\mathbf{w}_b = \arg \min \|\mathbf{R} \mathbf{w} - s_{PRS}\|^2. \quad (8)$$

where s_{PRS} contains transmitted PRS symbols in time domain with a CP. we can compute the optimal weight vector based on LS approach as

$$\mathbf{w}_b = (\mathbf{R}^H \mathbf{R})^{-1} \mathbf{R}^H s_{PRS}. \quad (9)$$

TABLE I
SPECIFICATION OF SIMULATION

Parameters	Value
IFFT/FFT point	2048
Sampling frequency	2.048MHz
Useful bandwidth	1.536MHz
Number of CP subcarrier	512
Number of Useful carrier	1536
GI duration	246 us
GI duration	76
T-DMB frame duration	96ms

IV. SIMULATION RESULTS

Computer simulations were performed to evaluate the performance of the proposed DOCR, the BER performance of the receiver must be considered.

A. Simulation Parameters

Specification of T-DMB are shown in table I. In order to clarify the performance of the DOCR, we consider the BER performance both the receiver and the OCR output. We will denote the channel between the main transmitter and the DOCR channel 1, and the channel between the DOCR and receiver channel 2. The simulation in OCR part, it is only consider the between the main transmitter and the DOCR. In OCR part, we are using Brail-A and Okma channels on the channel 1. According to [6], named the Okma channel measured in SFN environments, long echo is contained so that the frequent deep nulls are observed in the frequency domain compared to the Brazil-A channel.

B. BER Performance

In Fig. 3, the channel between the main transmitter and the DOCR channel is the Brazil-A channel or the Okma channel [6]. Simulation result shown that the proposed DOCR has gain compared with conventional DOCR.

In Fig. 4, the simulation in receiver side shown that the proposed algorithm has gain both side of the receiver and OCR. It is the channel between the main transmitter and the DOCR channel is the Brazil-A channel or the Okma channel. The channel between the DOCR and receiver is assumed as COST207 TU-6 channel.

In Fig. 3 and Fig. 4, The performance of E-DOCR with SMI is almost identical to that of the conventional E-DOCR in Brazil-A channel. In Brazil-A channel show that almost same performance in low SNR, but in high SNR the performance gap can be shown between the two technique. However, the performance gap between the two techniques is increased in Okma channel, the larger echo channel compared to the Brazil-A channel. This is due to the fact that deep nulls is increased so that the frequency domain algorithms degrade significantly their performance. However, the SMI approach in the time domain only worsens slightly by avoiding almost all the effect of the deep fading after the FFT.

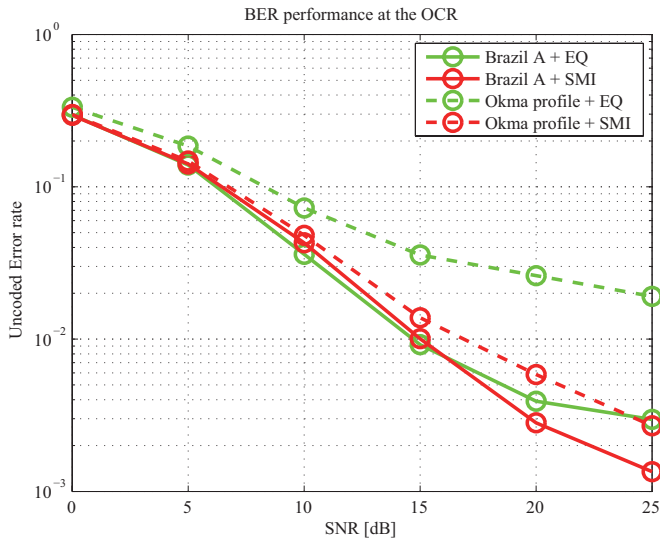


Fig. 3. Uncoded BER Performance According to SNR at the Output of an OCR

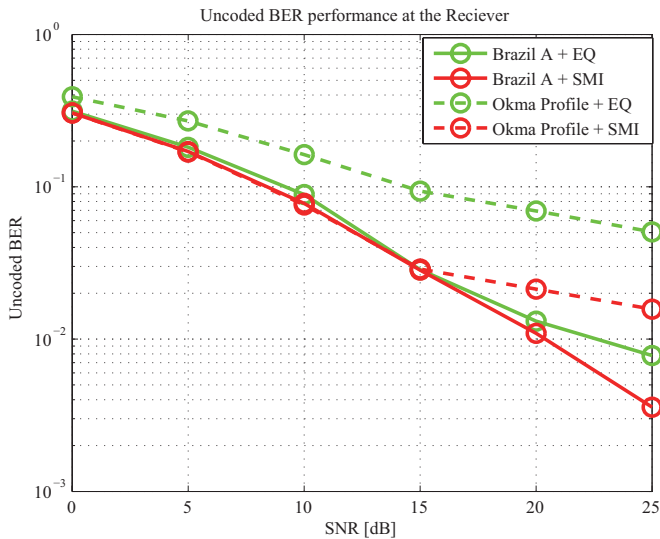


Fig. 4. Uncoded BER Performance According to SNR at the Output of an Receiver

V. CONCLUSION

In this paper, the DOCR with time domain channel estimation was presented for T-DMB system is proposed in order to reduction of hardware complexity. Conventional E-DOCR needed to FFT/IFFT block such as demodulation block due to the channel estimation performs in frequency domain. However, proposed technique performs channel estimation in time domain which can able to low cost and simple DOCR by removing demodulation block. During the channel estimation in frequency domain, system instability caused by calculating coefficient directly inversion operation in frequency domain.

This paper proposed time domain channel equalizer shows the reduction of hardware complexity. And simulation re-

sult show that the proposed time domain channel estimation method provides higher quality of OCR output and better BER performance in both OCR and receiver.

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