CHANNEL ESTIMATION OF DMB-T

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Abstract: This paper investigates the channel estimation technique of DMB-T. The channel impulse response is obtained by measuring the correlation between the received PN sequence and the locally generated PN sequence. Channel compensation is done in the frequency domain afterwards.
Keywords: DMB-T, channel estimation, PN sequence, correlation

1. INTRODUCTION

After a decade of intense research and development, there exist three digital TV terrestrial broadcasting standards. The first is the trellis-coded 8-level vestigial side-band (8-VSB) modulation system developed by Advanced Television Systems Committee (ATSC) [1]. The second is the Coded Orthogonal Frequency Division Multiplexing (COFDM) modulation adopted in the Digital Video Terrestrial Broadcasting (DVB-T) standard[2]. The third is the bandwidth segmented transmission (BST)-OFDM system for Terrestrial Integrated Service Digital Broadcasting (ISDB-T) from Japan [3]. Generally speaking, each system has its own unique advantages and disadvantages. The 8-VSB system is more robust in an additive white Gaussian noise (AWGN) channel, has a higher spectrum efficiency, a lower peak-to-average power ratio, and is more robust to impulse noise and phase noise. The DVB-T COFDM system has performance advantages with respect to high level (up to 0dB), long delay static and dynamic multipath distortion.

Recently, Tsinghua University and Legend Silicon Corp. jointly proposed a new standard for the Chinese DTV. This proposal is called Digital Terrestrial Multimedia Broadcasting (DMB-T). Compared with the COFDM and ISDB-T, which insert known pilots in the subcarriers, DMB-T makes use of time domain training sequence for time/frequency synchronization and OFDM modulation for information transmission. Besides broadcasting, it is also targeted at combined services of broadcasting, voice, and data.

Digital television broadcasting over the terrestrial VHF and UHF radio channels requires to adopt to serve both fixed and mobile receivers in a multi-path propagation environment, affected by frequency selective fading and Doppler effects. Accurate channel estimation can be used to improve performance by allowing for coherent demodulation. Conventional channel estimators are based on pilot tones, the pilot spacing has to be selected jointly according the Doppler spread and the delay spread of the channel according to sample theorem. Systems use different pilots lead to different channel estimations:

ATSC is a Single Carrier (SC) system, the optimal Data-aided (DA) channel estimator is the 1-D wiener filter in time direction. In this system adaptive equalization using a DFE is designed to eliminate multi-path, with LMS algorithm using the field sync and/or the 8-VSB data itself. To obtain good performance, the implemented filter circuit consists of all the feed-forward (64 taps) and the feedback taps (192 taps), to cope with the delays and reflections caused by indoor environments. This implementation however is very expensive to design, because the VLSI circuit needs huge multipliers and adders and accumulators. For the more, the DFE obtains worse performance for long reflections and is sensitive to the variation of the reflections.

COFDM is a Multiple Carrier (MC) system, the optimal Data-aided (DA) channel estimator is a 2-D wiener filter in time direction and frequency direction. Many schemes have been proposed in order to offer a good trade-off between performance and complexity. In[7],[8],[9],[10], channel estimators have been proposed based on the singular-value-decomposition or frequency-domain processing, and time-domain filtering to further improve estimator performance. But in the channel estimators for COFDM, the additive noise becomes multiplicative after channel equalization, which generates more noise enhancement compared with ATSC DFE, and greatly affects the performance of the channel estimator.

This paper describes how to obtained the channel impulse response by measuring the correlation between the received PN sequence and the locally generated PN sequence, channel equalization is done in the frequency domain afterwards. This scheme averages the noises of all samples in time grid, and improves performance of the channel estimator obviously.

In the following, we first give a brief introduction of the DMB-T frame structure and the basic receiver structure. Section 3 discusses the channel estimation in more detail. Finally, simulation results are presented.

2. DMB-T FRAME STRUCTURE

A simplified block diagram of the DMB-T transmitter and receiver is shown in Figure 1.Signal Frame in DMB-T is the basic elements of the downlink physical channel. It consists of two parts as shown in Figure 1. Frame Sync uses PN

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sequence and BPSK modulation for robust synchronization. OFDM modulation scheme is used for Frame Body. A Signal Frame has 4584 symbols: 384 for PN, 420+3780 (420 is for Guard Interval which corresponds to 1/9 DFT block) for OFDM.

In order to limit the transmitted to 8MHz bandwidth, a Square Root Raised Cosine (SRRC) filter is used for pulse shaping. The baseband Signal Frame is then up-converted to IF/RF signal.

At the receiving side, RF signal needs first to be down-converted and transformed (by Hilbert transform) to baseband signal. Secondly, SRRC filtering process follows. Then frame synchronization, symbol timing recovery, and frequency synchronization is conducted. Now the OFDM symbol maybe is distorted by channel (such as multipath), by residual carrier frequency resulting from the automatic frequency control (AFC), or by timing offset. The proposed algorithm uses the PN sequence part of the signal frame to estimate the channel impulse response. The PN sequence is known to have an impulse like autocorrelation function, thus being excellent candidates for channel estimation. In the following, we will discuss this method in more detail.

3. PROPOSED CHANNEL ESTIMATION

Suppose the subcarriers are X_k, transmitter SRRC is $SRRC_{tx}$, receiver SRRC is $SRRC_{rx}$, the combined channel response is $h(t)$. The received OFDM symbols after FFT can be represented as

$$\begin{aligned} R_k &= FFT[IFFT(X_k) * SRRC_{tx} * h(t) * SRRC_{rx}] \\ &= X_k FFT(SRRC_{tx}) FFT(h(t)) FFT(SRRC_{rx}) \end{aligned} \quad (1)$$

This representation means that subcarriers are distorted by channel, by possible imperfection of SRRC. Notice that SRRC imperfection is fixed for a fixed implementation. On the other hand, PN sequence passes through the same SRRC filters and the channel,

$$\begin{aligned} P_k &= FFT[(PN * SRRC_{tx} * h(t) * SRRC_{rx}) \otimes PN] \\ &= FFT(PN \otimes PN) FFT(SRRC_{tx}) FFT(h(t)) FFT(SRRC_{rx}) \end{aligned} \quad (2)$$

where $\otimes$ denotes correlation. If R_k is compensated by P_k, channel and filtering effect will be removed. The only term left besides the required subcarriers is the FFT of the PN correlation, which is nearly constant. From the implementation point of view, there may exist truncation for PN correlation, however, the corresponding effect is fixed for fixed truncation (or windowing).

In our implementation, PN correlation is done in 4 over sampling rate. The correlation is then truncated (large enough to cover the possible maximum delay profile), and padded with 0's to form a block of size 3780 to do FFT. The output is interpolated to obtain the symbol FFT. Finally, minor correction is done to the channel FFT in order to alleviate the effect of truncation, interpolation and limited SRRC filter length. The channel equalization is performed by multiplying the OFDM subcarriers with the inverse of the frequency response of the channel.

In addition, small values in the rough estimate of the impulse response are discarded since they are unreliable when additive noise and carrier frequency offset are present. A removal threshold of 5% of the peak is used.

4. PERFORMANCE ANALYSIS

Simulations are done under different conditions. The major simulation parameters are shown in Table.1.

Table.1 Major simulation parameters

Carrier frequency	634MHz
Sample frequency	7.56MHz
Over-sampling rate	4
Sub-carrier modulation	256QAM
Number of carriers	3780
Guard Interval	1/9
PN length	255

The first is to compare the performance of the achievable SNR for different SRRC filter length but with no timing recovery and frequency error. Thus sampling clock of the receiver is exactly the same as the transmitter. Figure 3 shows that the receiver achieves SNR 38.83 dB for SRRC tap length 128. Notice that there are constellation points around (6,6) and (-6,-6) which is due to the insertion of these points in the frame. Disregarding these points, SNR will be higher. Figure 4 shows the same results for tap length 256. Therefore, SRRC filter tap length can be compensated.

Figure 5 shows the constellation when receiver has higher sampling rate (thus symbol timing is in action) but without frequency error. SRRC tap length is 128. The correction parameter is from Figure 3 (thus when timing is perfect). One notices that there exists some mismatch. On the contrary, Figure 6 demonstrates the constellation when parameter is tuned so that the input and the output constellation have the minimum distance. In Figure 7, correction parameter is from tap length 128, but the actual SRRC length is 256, it is apparent that the tap length mismatch causes the phenomenon.

Overall BER performance with the proposed channel estimation technique is shown in Figure.8, for channels with AWGN and multi-path distortion. As seen from Figure.8, it is obvious that the proposed technique with AWGN significantly has better BER performance compared to multi-path. It should be noted that, with stronger error-correcting capability, the proposed technique achieves larger BER performance improvement.

5. CONCLUSION

The most contribution of this paper is to propose a method employs correlation to obtain the channel impulse response. The method is simulated in the context of the DMB-T system. Nowadays ASIC chips based on the proposed channel estimation have been designed and the prototype system has been demonstrated successfully. In addition, field trials will be done in this year.

REFERENCE

[1] ATSC, "ATSC Digital Television Standard", ATSC Standard A/53, September 16, 1995.

[2] ETS 300 744, "Digital broadcasting systems for television, sound and data services; framing structure, channel coding and modulation for digital terrestrial television", ETSI Draft EN 300 744 V1.2.1, (1999-1).

[3] ITU-R WP 11A/59, "Channel coding, frame structure and modulation scheme for terrestrial integrated service digital broadcasting (ISDB-T) ", ITU-R WP 11A/59-E, May 17, 1999.

[4] Yiyan Wu, Bernard Caron, Pierre Bouchard and Gerald Chouinard, "Comparison of Terrestrial DTV Transmission Systems: The ATSC 8-VSB, the DVB-T COFDM and the ISDB-T BST-OFDM".

[5] Y. Wu, M. Guillet, B. Ledoux, and B. Caron, "Results of laboratory and field tests of a COFDM modem for ATV transmission over 6 MHz Channels", *SMPTE Journal,* vol. 107, Feb. 1998.

[6] H. Meyr, M. Moeneclaey, and S. A. Fechtel, Digital Communication Receivers: Synchronization, Channel Estimation and Signal Processing, John Wiley & Sons, 1997.

[7] O. Edfors, M. Sandell, J.-J. van de Beek, S. K. Wilson, and P. O. Börjesson, "On channel estimation in OFDM systems," Proc. Of 45th IEEE Vehcular Technology Conference, pp.815-819, Jyly 1995.

[8]O. Edfors, M. Sandell, J.-J. van de Beek, S. K. Wilson, and P. O. Börjesson, "OFDM channel estimation by singular value decomposition," in Proceedings IEEE Vehicular Technology Conference, pp. 923-927. 71, Atlanta, USA, April 28-May 1, 1996.

[9]V.Mignone and A.Morello, "CD3-OFDM: a novel demodulation scheme for fixed and mobile receivers," IEEE Trans. On Comm., COM-44: pp,1144-1151,Sept.1996.

[10]Y. Li, L. J. Cimini, Jr, and N. R. Sollenberger, "Robust channel estimation for OFDM systems with rapid dispersive fading channels," IEEE Trans. Commun., vol. 46, pp. 902-915,July1998.

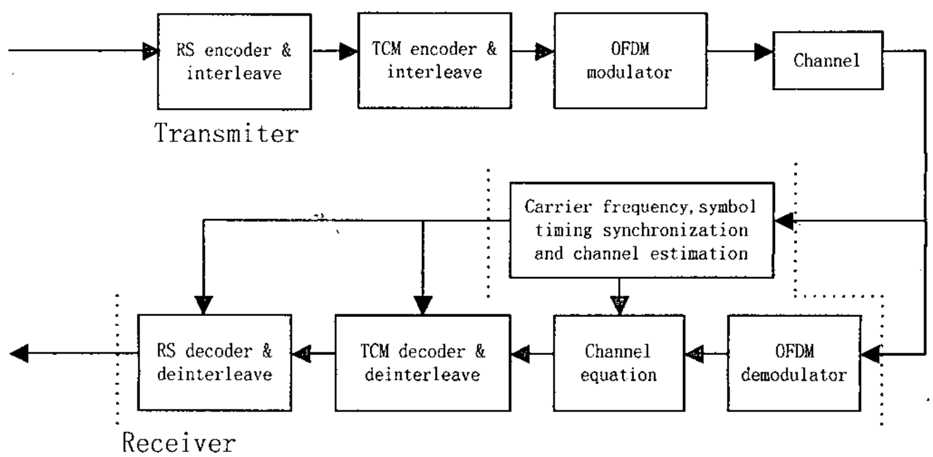

Figure 1. Block diagram of DMB-T transmitter and receiver

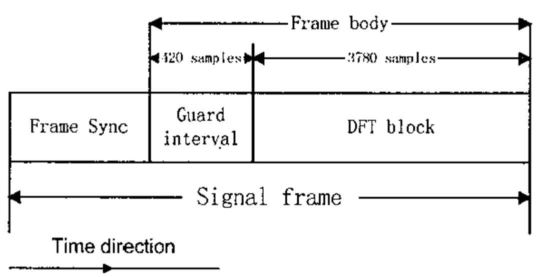

Figure.2 Signal frame structure in DMB-T

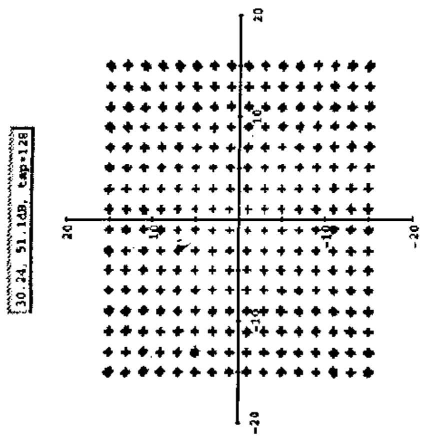

Figure 3. No timing/frequency error, SRRC tap=128

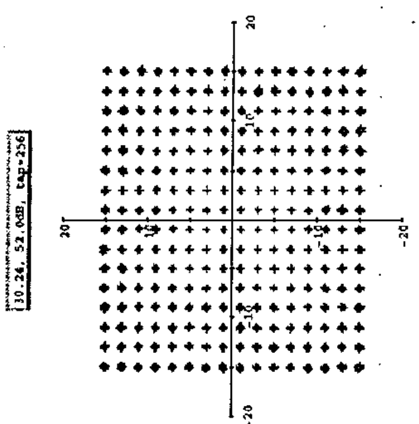

Figure 4. No timing/frequency error, SRRC tap=256

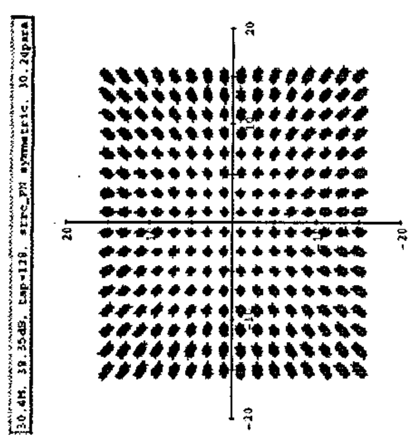

Figure 5. No frequency error, with symbol timing recovery, SRRC tap=128, correction parameter is from Figure 3.

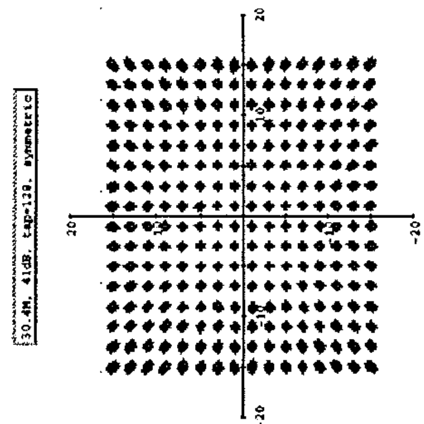

Figure 6. No frequency error, with symbol timing recovery, SRRC tap=128, correction parameter is self-generated.

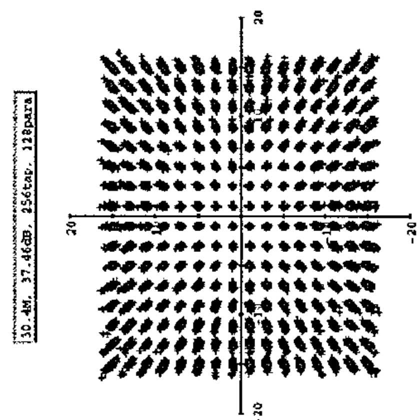

Figure 7. No frequency error, with symbol timing recovery, SRRC tap=256, correction parameter is from Figure 6.

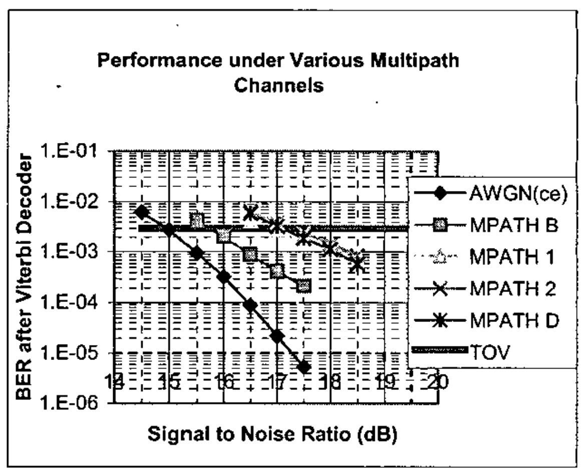

Figure.8 Performance of BER vs. Eb/No for 64QAM in AWGN and multi-path channels