

## TCCR BASED ISI CANCELLATION IMPROVEMENT BY CHANNEL ESTIMATION IN DTMB MC-MODE

Chisato IRAMINA and Tomohisa WADA

Graduate School of Engineering and Science, University of the Ryukyus  
Senbaru 1, Nishihara, Okinawa, 903-0213, Japan  
chisato@lsi.ie.u-ryukyu.ac.jp, wada@ie.u-ryukyu.ac.jp

### ABSTRACT

In Digital Terrestrial/Television Multimedia Broadcasting (DTMB) Multicarrier (MC) mode system, Tail Cancellation and Cyclic Restoration (TCCR) is needed for Inter Symbol Interference (ISI) cancelling. In this paper, Threshold method combined with averaging method and Power profile width detection method are proposed as new channel estimation in order to improve the performance of TCCR.

**Index Terms**— Channel estimation, Correlation, Digital Terrestrial/Television Multimedia Broadcasting (DTMB), Equalization, Multicarrier (MC) mode, TCCR.

### 1. INTRODUCTION

In recent years, Digital TV broadcasting is being spread around the world. In China, DTMB has been utilized as a digital terrestrial television broadcasting standard in August 2006. In the Chinese digital TV DTMB system, there are two types of broadcasting modes such as Single Carrier (SC) and Multi Carrier (MC). This paper focuses on DTMB MC mode, which was proposed by Tsinghua University [1].

Because of replacing conventional cyclic prefix with pseudo noise (PN) sequence in Frame Head between OFDM symbols, demodulation performance will be degraded by Inter Symbol Interference (ISI) in multipath channel. In order to solve this ISI problem, Tail Cancellation and Cyclic Restoration (TCCR) was proposed in [2]. However, the performance of TCCR strongly depends on the accuracy of channel estimation. This paper investigated the TCCR based ISI cancellation performance with proposing two channel estimation improvement methods.

Rest parts of this paper are organized as follows. Section 2 describes the main features of DTMB MC mode system. TCCR process is explained in Section 3. Section 4 shows two types of proposal channel estimation method. Simulation results for both proposal methods are presented in Section 5. Conclusions are drawn in Section 6.

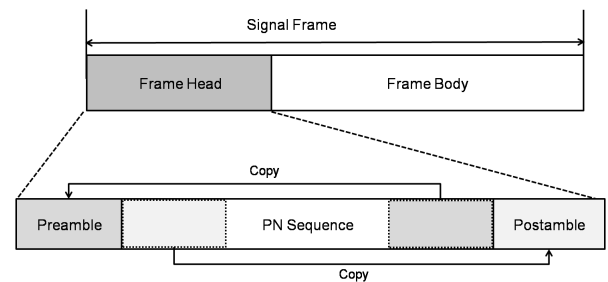


Fig. 1. Frame structure of DTMB MC mode

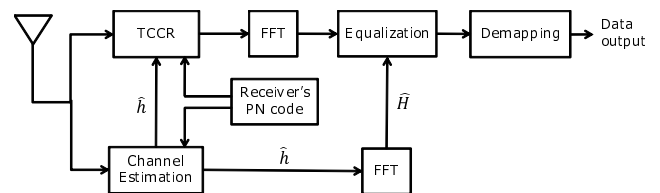


Fig. 2. Block diagram of DTMB MC-Mode receiver

### 2. SYSTEM DESCRIPTION OF DTMB MC MODE

Fig.1 shows a frame structure in DTMB MC mode. OFDM frame has two parts: Frame Head and Frame Body. The Frame Head is padded between frame bodies as guard interval (GI). The Frame Body carries information data and the Frame Head. The number of subcarriers are 3780 within each Frame Body. Frame Head consists of preamble, a PN sequence and postamble. PN sequence is defined by m-sequence and is able to be generated with a linear feedback shift register (LFSR). MC mode uses different value of PN sequence in each Frame Head. Preamble and postamble are the cyclic extension of the PN sequence. By extending PN sequence, Frame Head can have quasi-cyclic property. Frame Body has 3780 symbols length ( $500\mu s$ ). Frame Head length of 420 symbols ( $55,556\mu s$ ) and 945 symbols ( $125\mu s$ ) are used in MC mode. When Frame Head length is 420, it is called PN420 and length of 945 is PN945.

A simplified DTMB MC mode system is shown in Fig.2. PN sequence is already known at the receiver side. From this reason, it is possible to make a Frame Head in the receiver. In Chinese digital TV system, this pre-determined PN sequence can be utilized for synchronization and channel estimation.

### 3. TAIL CANCELLATION AND CYCLIC RESTORATION (TCCR)

Since PN sequence value is different for each frame in MC mode, ISI has caused by Frame Head in FFT window when the delay path comes. Fig.3 shows ISI from Frame Head. In order to solve the problem, TCCR is needed.

The process of TCCR is implemented as follow:

1. Make a linear convolution between Receiver's PN sequence and estimated channel impulse response (CIR)  $\hat{h}$ .
2. Remove Frame Head in each signal frame.
3. Add delayed Frame Body part into Frame body.

Fig.4 shows the image of TCCR process. G1 is the current OFDM symbol's Frame Head, G2 is the next OFDM symbol Frame Head. L is defined as multipath delay time,  $len_{SF}$  is the length of signal frame and  $len_{FH}$  is the length of Frame Head. Convolution result outputs G which is a estimated state of Frame Head in received signal. After calculating linear convolution, data symbol can be reconstructed by using (1).

$$\begin{aligned} X_1(m) &= \text{Frame Body}(m) - G(m + len_{FH}) \\ X_2(m) &= G_2(m) - G(m), \quad m = 0, \dots, L - 2 \quad (1) \\ X(n) &= \begin{cases} X_1(n) + X_2(n), & 0 \leq n < L - 1 \\ \text{Frame Body}(n), & L - 1 \leq n < len_{SF} \end{cases} \end{aligned}$$

X(n) is the Frame Body after applying TCCR. If estimated CIR is correct, FFT and equalization can be done, and only Frame Bodies without the ISI will be left after applied this TCCR algorithm.

### 4. CHANNEL ESTIMATION METHOD

#### 4.1. Threshold Method

Channel estimation can be implemented by using PN sequence. Channel impulse response (CIR) can be calculated by correlation. Received signal and receiver's PN sequence are used in correlation calculation. When Frame Head is PN420, correlation is defined such as:

$$\begin{aligned} correlation(n) &= \sum_{i=0}^{255-1} y(n+i+165)p(i+165) \quad (2) \\ n &= 0, 1, \dots, 420 - 1 \end{aligned}$$

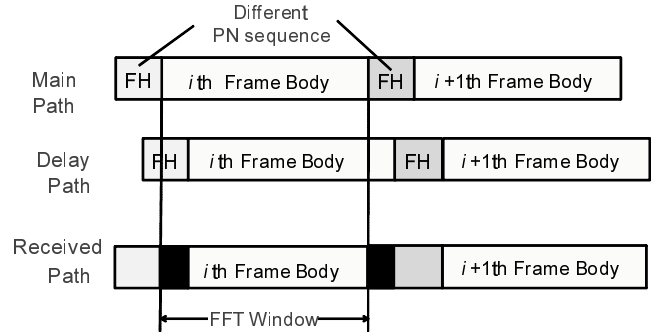


Fig. 3. Interference from PN sequence

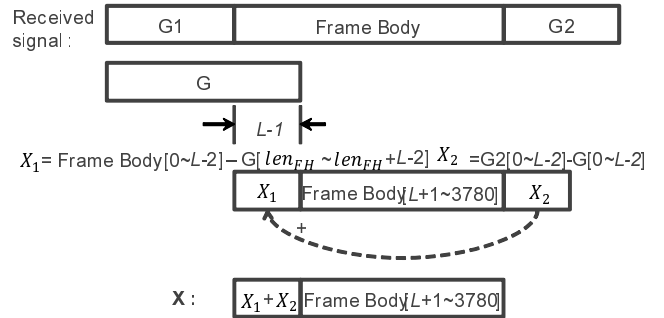


Fig. 4. The process of the TCCR

And correlation of PN945 is also defined as:

$$\begin{aligned} correlation(n) &= \sum_{i=0}^{511-1} y(n+i+434)p(i+434) \quad (3) \\ n &= 0, 1, \dots, 945 - 1 \end{aligned}$$

$y(n)$  is a received signal and  $p(n)$  is a quasi-FrameHead in the receiver. Fig.5 shows a calculated correlation between PN sequence in received signal and receiver PN sequence. When whole PN sequence matches, correlation will have peaks. As a result of correlation, we can find the result as CIR. However, the output includes noise component. In order to distinguish noise and CIR, common method is to use threshold value to cut noise component such as:

$$\hat{h}(n) = \begin{cases} correlation(n), & |correlation(n)| \geq threshold \\ 0, & |correlation(n)| < threshold \end{cases} \quad (4)$$

$$n = 0, 1, \dots, len_{FH} - 1$$

Although setting a threshold value, one OFDM symbol correlation result shows bigger noise. Because of this factor, larger threshold value is needed to cut them. However, this larger threshold setting might cut correlation results of weak

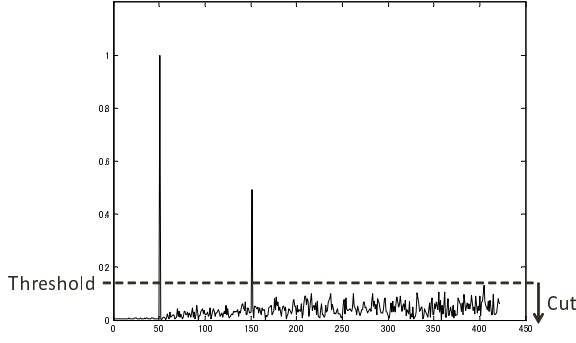


Fig. 5. Threshold Method

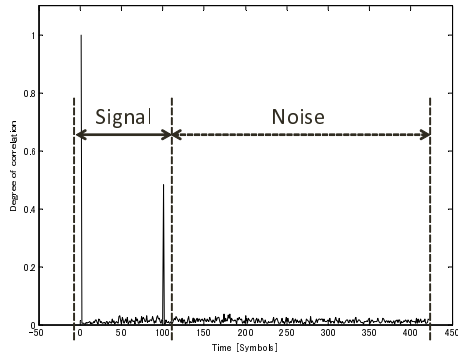


Fig. 6. Power profile

delay path. This causes performance degradation very much. In order to reduce the noise and get clearer CIR, averaging several correlation results method is used. Since the noise component has random property, averaging process can effectively reduce the noise component and enhance CIR component. Averaging can be expressed as:

$$correlation(n) = \frac{1}{N} \sum_{i=0}^{N-1} correlation_{(i)}(n) \quad (5)$$

$$n = 0, 1, \dots, len_{FH} - 1$$

$i$  means  $i$ th OFDM symbol's correlation and  $N$  means the number of averaging OFDM symbols' correlation. After applying the averaging method, smaller threshold value can be used.

#### 4.2. Power Profile Width Detection

Even though using averaging method, low level delay path might not be able to be detected when the peak is lower than

Table 1. Simulation Parameters

Carrier modulation	64QAM
Frame Head Length	420 (55.556 $\mu$ s)
Frame Body Length	3780 (500 $\mu$ s)
Channel model	2-wave multipath, AWGN
FFT size	3780
Delay time	13 $\mu$ s
DUR	0 ~ 30 dB
CNR	30 dB
Number of OFDM symbol	1, 16, 32, 64

the threshold. Then Power profile width detection method is proposed. Instead of using threshold, this method calculates signal power profile to measure CIR length as shown in Fig.3. The power profile is divided into 2 ranges such as Signal-range and Noise-range. The power of Signal-range  $P_S$  and Noise-range  $P_N$  is defined as follow:

$$P = \sum_{n=0}^{len_{FH}-1} |correlation(n)|^2$$

$$P_S = \sum_{m=0}^a |correlation(m)|^2 \quad (6)$$

$$P_N = P - P_S$$

$P$  is the power of all CIR power profile range and  $a$  is a assumed value which divides CIR into Signal-range and Noise-range. The longest delay multipath is defined by  $a$ .  $a$  is finally determined such as:

$$SNR = 20 \log_{10} \frac{P_S}{P_N} \quad (7)$$

By defining S/N value properly, the border value  $a$  between those can be calculated. Once Signal-range is determined, CIR length is known as follow:

$$\hat{h}(n) = \begin{cases} correlation(n), & 0 \leq n < a \\ 0, & a \leq n < len_{FH} \end{cases} \quad (8)$$

## 5. SIMULATION RESULT

In order to evaluate the performance of MC mode, TCCR ISI cancellation is used in the simulation. Table.1 shows simulation parameters. By changing DU ratio (DUR), BER performance was measured. Simulation results are shown by Fig.7 and Fig.8. Fig.7 is threshold method and Fig.8 is power profile width detection. According to Fig.7, although averaging is effective, BER performance is degraded when has lower level than threshold. According to Fig.8, 64 correlation averaging is effective in the power profile width detection method. However, 16 averaging and 32 averaging results is still existing a little degradation when DUR is high.

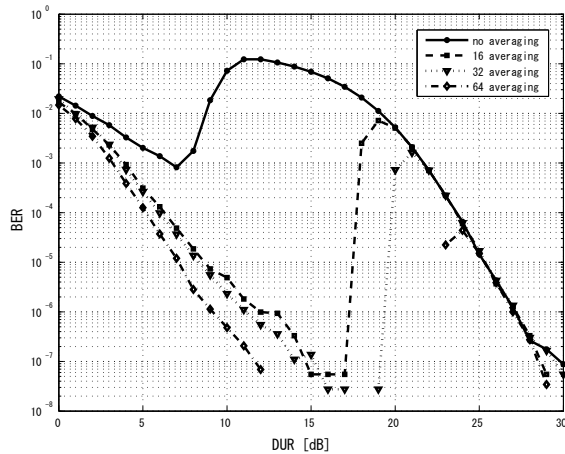


Fig. 7. Simulation result of Threshold method

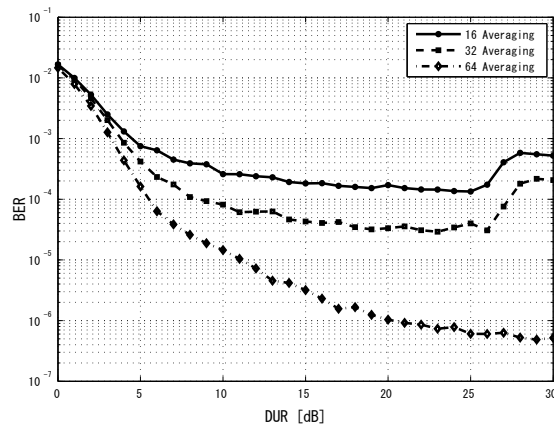


Fig. 8. Simulation results of averaging and Width Detection

## 6. CONCLUSION

In this paper, we proposed Threshold method and Power profile width detection method in order to improve channel estimation algorithm. The threshold method is that correlation averaging method is added for noise reduction. The power profile width detection method determines multipath delay by S/N calculation. In order to evaluate their performances, BER was simulated. As a result of this simulation, Threshold method needs special care for high DUR condition. Another method is needed large number of correlation in averaging.

## 7. REFERENCES

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