## **Contents**

Contents	1
Table List	iii
Figure List	iv
Chapter 1 Introduction	1
Chapter 2 Time-Frequency Mapping Tools in MP3 and MPEG 2/4	4
2.1 Polyphase Filter bank in MP3	5
2.1.1 Fast Filtering Algorithm of Analysis Filter Bank by Polyph	hase
Decomposition	7
2.1.2 Fast Filtering Algorithm of Synthesis Filter Bank by Polyph	hase
Decomposition	8
2.2 Modified Discrete Cosine Transform	11
Chapter 3 Zero Band Dithering Method	21
3.1 Quantization Model in MP3 and AAC	21
3.2 Zero Bands Occurring Condition	22
3.3 Dithering Model	22
3.4 Dithering Algorithm	23
3.4.1 Patch Gain Determining Module	24
3.4.2 Zero Band Searching Module	27
3.4.3 Zero Band Dithering Module	28
3.4.3.1 Null Quantization Band Protection	29
3.4.3.2 Pseudo Quantization Step Size in AAC Decoder	29
3.5 Summary	30
Chapter 4 High Frequency Reconstruction Method by Linear Exploration	33
4.1 Least Squares Method by Linear Model	34
4.2 Fast Computing method for $a_{opt}$ and $b_{opt}$	35
4.3 Reconstruction Algorithm	37
4.3.1 Envelope Extractor Module	38
4.3.2 Spectrum Duplication Module	41
4.3.3 Envelope Adjustment Module	42
4.4 Reconstruction Algorithm	43
Chapter 5 Experiments	47
5.1 Verification of Quality Enhancement by Audio Patch Method based	
MPEG Test Tracks	47

5.2 Verification of Quality Enhancement by Audio P	atch Method based on Music
Database	58
Chapter 6 Conclusion	68
References	69



## **Chapter 1Table List**

Table 1: The twelve test tracks recommended by MPEG.	48
Table 2: The PSPLAB audio database.	60



## Figure List

Figure 1: Audio spectrum containing a zero band	I
Figure 2: Block diagram of zero band dithering.	1
Figure 3: Spectrum of a band-limited audio signal	2
Figure 4: Block diagram of high frequency reconstruction.	2
Figure 5: Block diagram of audio patch method incorporated into frequence	y-based
audio decoder	4
Figure 6: Block diagram of the hybrid filter bank consisting of an analysis po	olyphase
filter bank and MDCT in MP3 encoder.	5
Figure 7: Uniform M-band maximally decimated analysis-synthesis filter bank	<b></b> 6
Figure 8: Magnitude response of oddly stacked uniform M-band filter bank	6
Figure 9: Polyphase implementation of the analysis filter bank	8
Figure 10: Polyphase implementation of the synthesis filter bank	11
Figure 11: MDCT: (a) Lapped forward transform (analysis). (b) Inverse tr	ansform
(synthesis).	12
Figure 12: The artificial aliasing of MDCT.	13
Figure 13: The MDCT-based transform system and the relative eq	
SDFT-based transform system.	20
Figure 14: A block diagram of zero band dithering algorithm	24
Figure 15: The spectrum of the original audio signal.	25
Figure 16: The spectrum of the compression audio signal.	25
Figure 17: The spectrum of the compression audio signal with zero band d	_
that sets patch gain as $\left(\frac{1}{2}\right)^{\frac{4}{3}}$	25
Figure 18: The spectrum of the compression audio signal with zero band d	ithering
that sets patch gain as 1/32	25
Figure 19: The block diagram of patch gain determining module	26
Figure 20: The block diagram of zero band searching module	27
Figure 21: The relative relation between the last zero band and the current zero.	
Figure 22: The block diagram of zero band dithering module.	
Figure 23: The flow chart of zero band dithering.	
Figure 24: Linear extrapolation on the magnitude with logarithm scale	
Figure 25: Signal flow diagram of the fast computing method.	
Figure 26: The block diagram of high frequency reconstruction method	
Figure 27: An automatic determining mechanism of cut-off frequency	40

<b>Figure 28</b> : A fault envelope due to a modified model that only adjusts $a_{opt}$ 41
Figure 29: A suitable envelope reconstructed by a modified model that adjusts both
$a_{opt}$ and $b_{opt}$ 41
Figure 30: A spectrum with an unsuitable envelope on high frequency after spectrum
duplication module42
Figure 31: The unsuitable spectrum in Figure 30 is adjusted after envelope adjustment module
<b>Figure 32</b> : The flow chart of high frequency reconstruction
Figure 33: The diagram of Audio Patch Method incorporated into MP3 decoder49
Figure 34: The diagram of Audio Patch Method incorporated into AAC decoder49
Figure 35: The spectrum of the original audio signal
<b>Figure 36</b> : The spectrum of the compression audio signal with two zero bands50
<b>Figure 37</b> : The spectrum of the audio signal with zero band dithering50
<b>Figure 38</b> : The spectrum of the original audio signal
<b>Figure 39</b> : The spectrum of the compression audio signal with narrow bandwidth50
<b>Figure 40</b> : The spectrum of the audio signal with high frequency reconstruction50
Figure 41: The ODG of the QT 6.3 tracks, ZBD audio, HFR audio and APM audio
under 128k bit rate
Figure 42: The gain of Zero Band Dithering, High Frequency Reconstruction and
Audio Patch Method corresponding to Figure 4152
Figure 43: The ODG of the QT 6.3 tracks, ZBD audio, HFR audio and APM audio
under 96k bit rate53
Figure 44: The gain of Zero Band Dithering, High Frequency Reconstruction and
Audio Patch Method corresponding to Figure 4353
Figure 45: The range of the gain of ZBD, HFR and APM corresponding to
QuickTime 6.3 at 128k and 96k bit rate54
Figure 46: The ODG of the LAME 3.88 tracks, ZBD audio, HFR audio and APM
audio under 128k bit rate54
Figure 47: The gain of Zero Band Dithering, High Frequency Reconstruction and
Audio Patch Method corresponding to Figure 4655
Figure 48: The ODG of the MP3 tracks, ZBD audio, HFR audio and APM audio
under 96k bit rate55
Figure 49: The gain of Zero Band Dithering, High Frequency Reconstruction and
Audio Patch Method corresponding to Figure 4856
<b>Figure 50</b> : The range of the gain of ZBD, HFR and APM corresponding to Lame 3.88
at 128k and 96k bit rate56

Figure 51: The ODG range comparison of the QT 6.3 tracks, the LAME 3.88 tracks,
ZBD audio, HFR audio and ASP audio under 128k and 96k bit rate57
Figure 52: The average ODG of the LAME 3.88 tracks and APM audio under 128k
bit rate for the sixteen track sets of the PSPLab database61
Figure 53: The gain of Audio Patch Method for the sixteen track sets corresponding
to Figure 5261
Figure 54: The average ODG of the LAME 3.88 tracks and APM audio under 96k bit
rate for the sixteen track sets of the PSPLab database62
Figure 55: The gain of Audio Patch Method for the sixteen track sets corresponding
to Figure 5462
Figure 56: The enhancement track distribution among the 322 tracks contained in the
sixteen track sets of the PSPLab database under 128k bps
Figure 57: The enhancement track distribution among the 322 tracks contained in the
sixteen track sets of the PSPLab database under 128k bps
Figure 58: The degradation track distribution among the 322 tracks contained in the
sixteen track sets of the PSPLab database. The source music band-limited
originally is not counted under 128k bps64
Figure 59: The enhancement track distribution among the 322 tracks contained in the
sixteen track sets of the PSPLab database under 96k bps64
Figure 60: The enhancement track distribution among the 322 tracks contained in the
sixteen track sets of the PSPLab database under 96k bps65
Figure 61: The degradation track distribution among the 322 tracks contained in the
sixteen track sets of the PSPLab database. The source music band-limited
originally is not counted under 96k bps65
Figure 62: The spectrum of horn track. The high frequency content is not rich66
Figure 63: The spectrum of the original audio that is an artificial signal containing a
wide gap between the tone component and noise-like component66
Figure 64: The spectrum of decoded audio corresponding to Figure 63
Figure 65: The spectrum of decoded audio with audio patch method corresponding to
Figure 64. The zero band dithering generates the unsuitable noise floor with
an excessive energy66
Figure 66: The spectrum of the original audio that contains exquisite harmonic
structures67
Figure 67: The spectrum of decoded audio corresponding to Figure 66
Figure 68: The spectrum of decoded audio with audio patch method corresponding to
Figure 6767