

Contents

Chapter 1 Introduction	1
Chapter 2 Fundamentals of OFDM	3
2.1 OFDM Basics	3
2.1.1 Continuous-time OFDM Model	4
2.1.2 Discrete-time OFDM Model	5
2.2 Effect of the Synchronization Errors for OFDM	6
2.2.1 Effect of the Carrier Frequency Offset	6
2.2.2 Effect of the Timing Offset	8
Chapter 3 Introduction to OFDM-Based Systems	9
3.1 Eureka 147 DAB System	9
3.1.1 System Overview	9
3.1.2 Transmission System	11
3.2 DVB-T	13
3.2.1 System Overview	13
3.2.2 The Frame Structure	15
3.2.3 Reference Signals	16
3.2.4 Transmission Parameter Signaling (TPS)	18
3.3 IEEE 802.16a	20
3.3.1 Operation and Considerations of OFDMA	20
3.3.1.1 Time Domain Description	21
3.3.1.2 Frequency Domain Description	21
3.3.2 OFDMA Carrier Allocation	22

3.3.2.1 Downlink Pilot Allocation	22
3.3.2.2 Uplink Pilot Allocation	24
3.3.3 OFDMA Frame Structure	25
3.3.4 Modulation	26
3.3.4.1 Data modulation	26
3.3.4.2 Pilot modulation	27
3.3.4.3 Preamble Pilot Modulation	27
Chapter 4 Investigation of OFDM Synchronization Techniques	29
4.1 Eureka 147 DAB System	29
4.1.1 Frame Detection	30
4.1.2 Detection of Symbol Timing and Fractional Frequency Offset	31
4.1.3 Integral Frequency Offset Estimation	33
4.1.4 Tracking Mode	34
4.2 DVB-T	34
4.2.1 Detection of the Symbol Timing and Fractional Frequency Offset	35
4.2.2 Integral Frequency Offset Estimation	35
4.2.3 Frame Detection	36
4.3 IEEE 802.16a	37
4.3.1 Synchronization Requirements	37
4.3.2 DL Synchronization Scheme	38
4.3.3 Symbol Timing and Fractional Frequency Offset Synchronization	39
4.3.4 Integral Frequency Offset and Frame Synchronization	39
4.3.5 Tracking Mode	40
Chapter 5 Simulation Results	41
5.1 Eureka 147 DAB System	41

5.1.1 Simulation Parameters and Channel Conditions	42
5.1.2 Performance of Frame Detection	43
5.1.3 Performance of Symbol Timing and Fractional Frequency Synchronization	43
5.1.4 Performance of the Integral Frequency Synchronization	46
5.1.5 Overall Performance	49
5.2 DVB-T51	51
5.2.1 Simulation and Parameters and Channel Environments	51
5.2.2 Performance of Symbol Timing and Fractional Frequency Synchronization	52
5.2.3 Performance of the Integral Frequency Synchronization	55
5.2.4 Performance of the Frame Detection	57
5.3 IEEE 802.16a	57
5.3.1 Simulation Parameters and Channel Environments	57
5.3.2 Detection of the Symbol Time	58
5.3.3 Integer Frequency Offset and Frame Synchronization	61
5.3.4 System Performance	66
Chapter 6 Conclusion and Future Work	68

List of Figures

Figure 2.1	Guard interval and cyclic structure of an OFDM symbol	4
Figure 2.2	Continuous-time OFDM system mode	4
Figure 2.3	Spectrum of an OFDM symbol	5
Figure 2.4	Discrete-time OFDM system mode	6
Figure 3.1	Block diagram of Eureka 147 DAB system	10
Figure 3.2	Transmission frame structure of DAB system	11
Figure 3.3	Functional block diagram of the system	14
Figure 3.4	Scattered pilot locations of DVB-T system	17
Figure 3.5	Continual pilot locations of DVB-T system	18
Figure 3.6	802.16a OFDMA symbol structure	21
Figure 3.7	OFDMA frequency description	22
Figure 3.8	Carrier allocation in the OFDMA DL	23
Figure 3.9	Carrier allocation in the OFDMA UL	24
Figure 3.10	Illustration of TDD time frame of IEEE 802.16a	25
Figure 3.11	QPSK, 16-QAM and 64-QAM constellations	26
Figure 3.12	PRBS for Pilot Modulation	27
Figure 4.1	Block diagram of our adopted Eureka 147 DAB synchronization scheme	30
Figure 4.2	The response of the double-sliding-window frame detection algorithm	31
Figure 4.3	The structure of the symbol time and the fractional frequency offset	32

Figure 4.4	Synchronization structure of DVB-T	34
Figure 4.5	Block diagram of the integral frequency offset synchronization algorithm	36
Figure 4.6	Frame synchronization structure for DVB-T	37
Figure 4.7	Synchronization structure of IEEE 802.16a DL TDD system	39
Figure 5.1	Performances of the mode-III frame synchronization	43
Figure 5.2	Standard deviations of symbol timing synchronization vs. SNR (a) in AWGN channel (b) in the ETSI "Vehicular B" multipath channel, of DAB system	44
Figure 5.3	Standard deviations of FFO synchronization versus different initial FFO with SNR 9dB in AWGN channel	45
Figure 5.4	Standard deviations of fractional frequency offset synchronization versus SNR in ETSI "Vehicular B" multipath channel, of DAB system, FFO=0.2	45
Figure 5.5	Performances of integral frequency synchronization of the conventional method and proposed method in AWGN channel, assuming perfect symbol timing synchronization, mode-III DVB, IFO=2 carrier spacing	46
Figure 5.6	Performances of integral frequency synchronization of the conventional method and proposed Method1 in AWGN channel, assuming perfect symbol timing synchronization, mode-III DVB, IFO=2 carrier spacings.	47
Figure 5.7	Performances of the conventional and proposed Method1 for IFO synchronization in AWGN channel, with 5-sample of symbol timing synchronization error, DAB mode-III, IFO=2 carrier spacings.	48

Figure 5.8	Performances of the conventional and proposed Method1 for IFO synchronization in the assumed multipath channel, with 5-sample of symbol timing synchronization error, DAB mode-III, IFO=2 carrier spacings.	48
Figure 5.9	BER performances of the proposed combined synchronization scheme in AWGN channel, mode-III DAB system.	49
Figure 5.10	BER performances of the proposed combined synchronization scheme in ETSI “Vehicular B” Channel	50
Figure 5.11	BER performances of the proposed combined synchronization scheme in ETSI “Vehicular B” Channel with $f_d T_s = 0.00624$.	51
Figure 5.12	Standard deviations of the time offset estimation errors (a) in AWGN Channel (b) in the assumed multipath channel, 2K-mode DVB-T system.	54
Figure 5.13	Standard deviations of the frequency offset estimation errors in the assumed multipath channel, 2K-mode DVB-T system.	54
Figure 5.14	Performances of the two proposed integral frequency synchronization algorithms in the assumed multipath channel, 2K-mode DVB-T system.	55
Figure 5.15	Performance of the proposed integral frequency synchronization Algorithm 1 in the assumed multipath channel, 2K-mode DVB-T system.	56
Figure 5.16	Performances of the proposed integral frequency synchronization Algorithm 1 in the assumed multipath channel, $f_d=90\text{Hz}$, 2K-mode and 8K-mode DVB-T system.	56
Figure 5.17	Performances of the time offset estimation methods (a) in AWGN	

channel; (b) in the assumed multipath channel, IEEE 802.16a DL system.	59
Figure 5.18 Symbol time synchronization error distribution in the assumed multipath channel, IEEE 802.16a DL system.	60
Figure 5.19 Error distribution of the fractional frequency synchronization in the assumed multipath channel, IEEE 802.16a DL system.	61
Figure 5.20 The matched filter output of the first symbol in a frame (a) in noiseless case; (b) in AWGN channel, IEEE 802.16a DL system.	62
Figure 5.21 Frame synchronization probability versus threshold in multipath channel.	63
Figure 5.22 Values of IFO and frame synchronization metric vs. pilot number.	63
Figure 5.23 Frame and IFO synchronization probabilities under Channel A, IEEE 802.16a DL system.	64
Figure 5.24 Frame and IFO synchronization probabilities of long and short cp lengths under Channel A, IEEE 802.16a DL system.	65
Figure 5.25 BER of the proposed synchronization system in AWGN channel, IEEE 802.16a DL system.	66

Lists of Tables

Table 3.1	DAB OFDM parameters in different modes	12
Table 3.2	Specifications of the 8K and 2K modes for 8MHz DVB-T channel	16
Table 3.3	Carrier indices for continual pilot carriers of DVB-T system	18
Table 3.4	TPS signaling information of DVB-T system	19
Table 3.5	OFDMA 802.16a DL Carrier allocations	23
Table 3.6	OFDMA 802.16a UL Carrier allocations	25
Table 5.1	System parameter of mode-III in Eureka 147 DAB	42
Table 5.2	ETSI “Vehicular B” channel model	42
Table 5.3	System parameters of DVB-T 2K and 8K mode	51
Table 5.4	Relative power, phase and delay values of DVB-T system	52
Table 5.5	The assumed system parameters of IEEE 802.16a	58
Table 5.6	Characteristics of ETSI ‘Vehicular A’ channel environment	58