CONTENTS

Abstract (Arabic) *v*

Abstract (English) *vi*

List of Tables *xi*

List of Figures *xii*

List of Symbols *xv*

CHAPTER 1 INTRODUCTION

1.1 Overview 1

1.2 Half and Full-Duplex Data Transmission Over the Telephone Network 2

1.3 Problem Identification and Motivation of the Research 3

1.4 Scope of the Thesis 5

1.5 Thesis Organization 6

CHAPTER 2 ECHO PHENOMENA

2.1 Typical Telephone Network 8

2.2 Echo : Causes and Types 12

2.3 Conventional Methods of Echo Control in Voice Communication 13

2.4 Full-Duplex Data Transmission over Telephone Networks 15
2.5 Echo Signal Modelling in Data Transmission 21
2.6 Summary 21

CHAPTER 3 ECHO CANCELLERS

3.1 Basic Structure 23
3.2 Adaptation Mechanisms 28
3.2.1 The Gradient Approach 29
3.2.2 The Method of Steepest Descent 32
3.2.3 The Least-Mean-Square (LMS) Algorithm 36
3.3 Classifications of Echo Cancellers 37
3.3.1 Voice-Type Cancellers 38
3.3.2 Data-Type Cancellers 38
3.3.3 Baseband and Passband Cancellers 54
3.3.4 Digital and Analog Cancellers 55
3.4 Problems Encountered in Echo Cancellation 55
3.4.1 Effect of Frequency Offset 56
3.4.2 Frequency Offset Compensation 60
3.5 Summary 61

CHAPTER 4 THE SYSTEM DESIGN

4.1 The PN Generator and the Signal Space Encoder 62
4.2 The Modulator 67

4.3 Transmitting and Receiving Sections 68
4.4 The Echo Canceller 71
4.5 Frequency Offset Measurement 77
4.5.1 The Phase Estimater and the Hilbert Transformer 78
4.5.2 The Second Order Phase Locked Loop 80
4.6 Summary 84

CHAPTER 5 SIMULATION RESULTS

5.1 Echo Channel Characteristics 85
5.2 Adaptation Process and the Optimum Step Size 87
5.3 Effect of Noise 90
5.3.1 Power of the Noise. 90
5.3.2 Performance of the Canceller in the Presence of noise 91
5.4 Effect of Frequency Offset (Phase Roll) 96
5.5 Compensation for Frequency Offset 105
5.6 Summary 109

CHAPTER 6 NEW TECHNIQUES FOR FREQUENCY OFFSET COMPENSATION AND FOR PHASE ROLL ESTIMATION DURING DATA MODE

6.1 Sequential Adaptation (New Proposed Technique) 111
6.2 Evaluation and Comparison between Sequential Adaptation and Joint Adaptation 115

6.2.1 Computation Complexity (Cost) 115

6.2.2 Performance 117

6.2.3 Recommendations for Practical Applications 119

6.3 A New Approach to Phase Roll Estimation during Data Mode 120

6.4 Summary 128

CHAPTER 7 CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 Conclusions 129

7.2 Suggestions for Further Research 132

APPENDIX *133*

REFERENCES *156*