Contents

Acknowledgements **ix**

Resumen **xi**

Resum **xiii**

Abstract **xv**

I Preamble **1**

1 Introduction **3**
1.1 Motivation and objectives 3
1.2 State of the art 6
1.3 Organization of this research 8
1.3.1 Structure 8
1.3.2 Main contributions 9

2 Energy detector **13**
2.1 Detectors design 13
2.1.1 Bayes detector 14
2.1.2 Neyman Pearson detector 14
2.2 Signal detection in presence of Gaussian noise 15
2.2.1 Deterministic signal 15
2.2.2 Random signal 16
2.2.3 Detection in correlated Gaussian noise 18
2.2.4 Signal in subspace 19
2.3 Performance of the ED and the PED 20
2.3.1 Detector evaluation: ROC performance factor 20
2.3.2 Comparison of the ED and the PED in Gaussian noise 23
2.4 Conclusions 24

II Theoretical framework **27**

3 Extensions of the energy detector in non-Gaussian and non-independent noise **29**
3.1 Detection in presence of non-Gaussian noise 29
3.1.1 Study of Gaussianity 30
3.1.2 Detection of random signals: Rao test 31
3.2 Extended energy detector (EED) 35
3.2.1 Alternative estimates of the non-linear function 35
3.2.2 The parametric power transformation 36
3.2.3 Transformation based on the data PDF 37
3.2.4 Optimality study of the EED 40
3.3 Detection with statistical dependence between noise samples . 43
3.3.1 Introduction 43
3.3.2 Review of ICA model 44
3.3.3 Estimating the transformation matrix **U** 45
3.4 Generalized matched subspace filter: GMSF 48
3.4.1 Introduction 48
3.4.2 Rao test generalization 49
3.4.3 Extension of the MSF 50
3.5 Evaluation results of the EED in non-Gaussian independent noise 51
3.5.1 Estimation of the power transformation parameter . . 52
3.5.2 Comparison of the EED using the non-parametric and parametric Box-Cox transformation 54
3.6 Performance evaluation of the PEED 56
3.6.1 Non-independent noise samples 56
3.6.2 Independent noise samples 58
3.7 Experimental results of the GMSF 60
3.7.1 Signal model 60
3.7.2 Experimental setup 61
3.7.3 Comparing GMSF and MSF 61
3.8 Conclusions 65

4 Structure of multiple energy detectors (MED) **67**
4.1 Detection of signals with unknown duration 67
4.1.1 Revision of the ED 68
4.1.2 Description of the multiple energy detector structure . 68
4.2 Theoretical performance of the MED 70
4.2.1 Derivation of the PFA_{MED} 70
4.2.2 Derivation of the PD_{MED} 72

4.3 MED theoretical evaluation 78
4.3.1 The signal duration is comparable to the observation vector length at the top layer 78
4.3.2 The signal duration is comparable to the observation vector length at the bottom layer 80
4.3.3 The signal duration is comparable to the observation vector length at intermediate layers 81
4.4 General comments on the MED 82
4.4.1 Segmentation techniques 83
4.4.2 Signal and noise models 84
4.4.3 Real-time applications 85
4.5 Performance of the MED in the time and frequency domains . 85
4.5.1 Frequency MED structure 85
4.5.2 Time ROC curves 86
4.5.3 Frequency ROC curves 88
4.6 Conclusions 90

III Acoustic applications 93

5 Acoustic event detection 95
5.1 Detection in real acoustic applications 95
5.1.1 Surveillance applications 96
5.1.2 Equipment and scenarios 97
5.1.3 Detection system 99
5.2 Acoustic database 104
5.2.1 Analysis of real background noises 104
5.2.2 Description of the acoustic events 107
5.3 Practical background noise considerations 109
5.3.1 Experimental parameter setting 110
5.3.2 Generalization of the energy detector 111
5.4 Performance of the ED and its generalization with acoustic signals 112
5.4.1 Acoustic event detection in Gaussian noise using the ED and the EDe 113
5.4.2 Comparison of EDe, EEDe and PEEDe with real background noises 113
5.5 Performance of the MED in acoustic event detection 116
5.5.1 Experimental setup and analysis of acoustic events . . 116
5.5.2 Acoustic detection results 117
5.6 Conclusions 121

6 Application of the ED and the MED to the acoustic scene analysis 123
6.1 Improvement of localization algorithms by means of an adaptive energy detector approach . . . 123
6.1.1 Introduction . . . 123
6.1.2 Current techniques . . . 124
6.1.3 Modified localization algorithms by means of an ED . 127
6.2 Acoustic classification using time and frequency MED features 133
6.2.1 Introduction . . . 133
6.2.2 Classification method . . . 134
6.2.3 Evaluation results . . . 139
6.3 Application in surveillance scenarios . . . 142
6.3.1 General system structure . . . 142
6.3.2 Graphical user interface . . . 146
6.4 Conclusions . . . 152

IV Conclusions 155

7 Conclusions and future work 157
7.1 Conclusions . . . 157
7.2 Future lines of research . . . 160

V Appendix 163

A Probability density functions 165
A.1 Gaussian distribution . . . 165
A.2 Non-central chi-squared distribution . . . 166

B Derivation of P_{lm} 169

List of Acronyms 173

Bibliography 175

Publications 183