Blind Signal Modulation Recognition through Clustering Analysis of Constellation Signature

A Thesis submitted by
Gaurav Jajoo

in partial fulfillment of the requirements for the award of the degree of
Doctor of Philosophy



॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥

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Department of Electrical Engineering
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Declaration

I hereby declare that the work presented in this thesis titled *Blind Signal Modulation Recognition through Clustering Analysis of Constellation Signature* submitted to Indian Institute of Technology Jodhpur in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work carried out under the supervision of Dr. Sandeep Kumar Yadav. The contents of this thesis in full or in parts, have not been submitted to, and will not be submitted by me to any other Institute or University in India or abroad for the award of any degree or diploma.

Gaurav Jajoo
P16EE002

Certificate

This is to certify that the thesis titled *Blind Signal Modulation Recognition through Clustering Analysis of Constellation Signature*, submitted by *Gaurav Jajoo (P16EE002)* to Indian Institute of Technology Jodhpur for the award of the degree of *Doctor of Philosophy*, is a bonafide record of the research work done by him under my supervision. To the best of my knowledge, the contents of this report, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Sandeep Kumar Yadav
Ph.D.Thesis Supervisor

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List of Symbols

Symbol	*Description*
f_c	Carrier frequency
$\mathbb{M}$	Modulation scheme
γ_{max}	Maximum value of the spectral power density of the normalized and centered instantaneous amplitude
σ_{ap}	Standard deviation of the absolute value of the non-linear component of the instantaneous phase
σ_{dp}	Standard deviation of the non-linear component of the direct instantaneous phase
P	Evaluation of the spectrum symmetry around the carrier frequency
σ_{aa}	Standard deviation of the absolute value of the normalized and centerd instantaneous amplitude of the signal samples
σ_{af}	Instantaneous frequency
σ_a	Instantaneous amplitude
μ_{42}^a	Kurtosis of the normalized and centered instantaneous amplitude
y	Received complex baseband signal
x	Transmitted complex baseband signal
d	Extracted complex symbol at receiver
s	Transmitted symbol
θ_0	Phase offset
Z	Number of sample or signal length
M	Modulation order
N	Number of symbols
f_0	Carrier frequency offset
$p < . >$	Pulse shaping filter
f_c'	Estimated carrier frequency
$\mathscr{F} < . >$	Fourier transform of $< . >$
f_s	Sampling frequency
q	Oversampling factor
ϕ	Instantaneous phase
r	Passband received signal
T_s	Symbol time
x_p	Passband transmitted signal
y'	Carrier frequency offset corrected baseband signal
SR_{est}	Estimated symbol rate
a	Standard deviation of the contiguous amplitude difference
e	Linear regression error
Δf_c	Carrier frequency offset
ζ	Timing error

List of Abbreviations

Abbreviation	*Full form*
ALRT	Average Likelihood Ratio Test
AMC	Automatic Modulation Classification
ANN	Artificial Neural networks
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
BSMR	Blind Signal Modulation Recognition
CD	Core Distance
CFO	Carrier Frequency Offset
COMINT	Communications Intelligence
CR	Cognitive Radio
CWT	Continuous Wavelet Transform
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
DC	Direct Current
DFT	Discrete Fourier Transform
DMA	Direct Memory Access
DNN	Deep Neural Network
EM	Expectation Maximization
FB	Feature Based
FEC	Forward Error Coding
FFT	Fast Fourier Transform
FIFO	First In First Out
FPGA	Field-Programmable Gate Array
FSK	Frequency Shift Keying
GBRT	Gradient Boosted Regression Tree
GLRT	Generalized Likelihood Ratio Test
GMM	Gaussian Mixture Model
GP-KNN	Genetic Programming- k Nearest Neibour
HLD	Hierarchical and Local Density
HLRT	Hybrid Likelihood Ratio Test
ITU	International Telecommunications Union
K-S	Kolmogorov-Smirnov
LB	Likelihood Based

Abbreviation	*Full form*
MF	Match Filtering
MFCC	Mel-frequency Cepstral Coefficients
ML	Machine Learning
MSK	Minimum Shift Keying
NI	National Instrument
OPTICS	Ordering Points To Investigate the Clustering Structure
OQPSK	Offset Phase Shift Keying
OSP	Onboard Signal Processing
PDF	Probability Density Function
PSK	Phase Shift Keying
PXI	PCI eXtensions for Instrumentation
QAM	Quadrature Amplitude Modulation
RD	Reachability Distance
RF	Radio Frequency
RRC	Root Raised Cosine
SCTL	Single Cycled Timed Loop
SD	Standard Deviation
SDR	Software Defined Radio
SMA	SubMiniature Version A
SNR	Signal to Noise Ratio
SR	Symbol Rate
SVM	Support Vector Machine
UN	United Nations
VI	Virtual Instrument