

Aspects of HF Communications: HF Noise and Signal Features

by

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Contents

Contents	iii
Abstract	ix
Thesis Declaration	xi
Acknowledgments	xiii
Conventions	xv
Publications	xvii
List of Figures	xix
List of Tables	xxv
I Background	1
Chapter 1. Introduction	3
1.1 Research Motivation	4
1.2 Summary	6
Chapter 2. Background	9
2.1 The Ionosphere	10
2.2 Software Radio	14
2.3 Single Site Location	17
2.4 Signal Separation	25
2.5 Summary	31

Contents

Chapter 3. Thesis Statement	33
3.1 Organization and Content	34
3.2 Thesis Objectives	35
3.3 Original Contributions	35
3.4 Summary	37
II Probability Density Function of HF Noise	39
Chapter 4. Introduction to HF Noise	41
4.1 A Definition of HF Noise	42
4.2 Literature Review	43
4.3 Summary	46
Chapter 5. Methods for Measuring the PDF of HF Noise	49
5.1 Introduction to Methods	50
5.2 Swept-Narrowband Method	50
5.3 Broadband Method	53
5.4 The Electric Field at each Sampling Instant	54
5.5 Summary	56
Chapter 6. Experimental Setup for Noise Measurements	59
6.1 Receiver Chronology	60
6.2 Swept-Narrowband Receiver	62
6.3 Broadband Receiver	65
6.4 Summary	79
Chapter 7. HF Noise	81
7.1 Introduction to Results	82
7.2 Results of the Swept-Narrowband Method	82
7.3 Results of the Broadband Method	84

7.4	The Effect of the Noise Threshold on the PDF	101
7.5	Bi-Kappa Fit to Data Sets	104
7.6	Noise versus Frequency	109
7.7	Other Supporting Evidence	111
7.8	Summary	115
Chapter 8. Conclusions & Further Work for Part II		119
III Signal Features for Modulation Recognition		125
Chapter 9. Introduction to Modulation Recognition		127
9.1	A Context for Modulation Recognition	128
9.2	Literature Review	129
9.3	Summary	136
Chapter 10. Signal Features for Modulation Recognition		139
10.1	Introduction to Methods	140
10.2	Coherence as a Signal Feature	143
10.3	Entropy as a Signal Feature	152
10.4	Signal-to-Noise Ratio as a Signal Feature	161
10.5	Summary	165
Chapter 11. Experimental Setup		167
11.1	Receiver Chronology	168
11.2	Narrowband Receiver	170
11.3	Matlab Test Platform	173
11.4	Summary	177
Chapter 12. Feature Parameters of the Signal Set		179
12.1	Introduction to Results	180

Contents

12.2 Coherence Results	180
12.3 Entropy Results	207
12.4 Signal-to-Noise Ratio	233
12.5 Summary	240
Chapter 13. Conclusions & Further Work for Part III	241
IV Additional Information	251
Symbols	253
Glossary	255
Bibliography	261
Appendix A. Mathematical Derivations and Examples	269
A.1 Derivation of the Modified Bi-Kappa Distribution	270
A.2 Mathematics of Overlapping Segments	275
A.3 Coherence Calculation Examples	277
Appendix B. Data Collection	287
B.1 Data Set for Part II	288
B.2 Data Set for Part III	306
Appendix C. Cascade Analysis of Gain Control System	311
Appendix D. ITU Predicted versus Measured Noise Levels	315
Appendix E. Data Sheets	321
Appendix F. Australian HF Spectrum Allocations	323
Appendix G. Signs Toolbox Guide	327

G.1	Introduction to Signs	328
G.2	Description of the Analysis Process	332
G.3	Signs Toolbox Reference	340
Appendix H. Signs Toolbox Code		343
H.1	Signs Configuration Modules	344
H.2	Signs Initiate Script	356
H.3	Signs Analysis Modules	358
H.4	Signs Data Generation	379
H.5	Signs Feature Extraction Tools	382
H.6	Signs Reporting Tools	403
H.7	Signs Miscellaneous Functions	447
H.8	Signs C Routines	561
Index		587
Biography		591
Scientific Genealogy		593

Abstract

To many, high-frequency (HF) radio communications is obsolete in this age of long-distance satellite communications and undersea optical fiber. Yet despite this, the HF band is used by defence agencies for backup communications and spectrum surveillance, and is monitored by spectrum management organizations to enforce licensing. Such activity usually requires systems capable of locating distant transmitters, separating valid signals from interference and noise, and recognizing signal modulation. Research presented here targets the latter issue. The ultimate aim is to develop robust algorithms for automatic modulation recognition of *real* HF signals, where *real* means signals propagating by multiple ionospheric modes with co-channel signals and non-Gaussian noise. However, many researchers adopt Gaussian noise models for signals for the sake of convenience at the cost of accuracy. Furthermore, literature describing the probability density function (PDF) of HF noise does not abound. So an additional aim of this research is measurement of the PDF of HF noise. A simple empirical technique, not found in the literature, is described that supports the hypothesis that HF noise is generally not Gaussian. In fact, the probability density function varies with the time of day, electromagnetic environment, and state of the ionosphere.

Key contributions of this work relate to the statistics of HF noise and the discrimination of real HF signals via three signal features. Through two unique experiments, the density function of natural HF noise is found to closely follow a Bi-Kappa distribution. This distribution can model natural and man-made HF noise through a single control parameter. Regarding signal features, the coherence function is found to be a brute-force technique suitable only for hard (not soft) decisions. A novel application of an entropic distance measure proves able to separate four real HF signals based on their modulation types. And, an estimator for signal-to-noise (SNR) ratio is shown to provide reasonable measures of SNR for the same real HF signals.

Thesis Declaration

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Signature

2 May 2008

Date

Acknowledgments

“Hast thou not known? Hast thou not heard, that the everlasting God, the Lord, the Creator of the ends of the earth, fainteth not, neither is weary? There is no searching of his understanding.”

—(Isaiah 40:28)

“Mine hand also hath laid the foundation of the earth, and my right hand hath spanned the heavens: when I call unto them, they stand up together.”

—(Isaiah 48:13)

The Creator has created a wonderful universe for us to discover. If not for Him, man’s insatiable quest for knowledge would cease. To Him, the author offers grateful thanks.

For their support and advice the following organizations and individuals also deserve recognition: The University of Adelaide and Ebor Computing for providing financial assistance for this work; Ebor Computing for providing access to and data from its advanced HF receiver; my supervisors Derek Abbott and Russell Clarke for their guidance; Nigel Brine for providing data for part of the noise analysis from his swept-narrowband receiver; Mathias Baumert for useful discussions; Mark McDonnell for some editorial comments; Withawat Withayachumnankul for help in troubleshooting L^AT_EX₂e issues; and most importantly my wife and family for supporting me in this work.

Conventions

The format of this thesis is based on a template created by Greg Harmer and modified by Bradley Ferguson. It is typeset using the $\text{\LaTeX}2\text{e}$ software. TeXnicCenter 1 Beta 7.01 was used as the interface to $\text{\LaTeX}2\text{e}$. Harvard style is used for referencing and citation in this thesis. Canadian English spelling is adopted.

MATLAB[®] 6.1 is used for analysis of data and production of plots. Microsoft Excel 2002 is used for some charts and calculations. Microsoft Visio 2002, Microsoft Paint, Picture Publisher, and GSView 4.3 are used for most figures other than those prepared by **MATLAB**[®].

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List of Figures

1.1	Overview of the advanced HF receiver	5
<hr/>		
2.1	Density profile of Earth's electron plasma	11
2.2	Groundwave and skywave propagation	13
2.3	A conventional superheterodyne receiver	15
2.4	A typical software radio with digital and analog domains	17
2.5	A typical modulation recognition structure	18
2.6	A typical SSL system	19
2.7	A simple model for range calculation in SSL	19
2.8	A typical vertical incidence ionogram	24
2.9	A typical oblique incidence ionogram	24
2.10	Concept of the signal separation technique	26
<hr/>		
<hr/>		
<hr/>		
5.1	Time-based measurement of HF noise PDF	52
5.2	Resulting sequence after excision of environmental noise	56
<hr/>		
6.1	Chronology of receiver development	61
6.2	Model of the swept-narrowband receiver	63
6.3	Attenuation of LMR400 coaxial cable	64
6.4	Architecture of the advanced HF receiver (repeated)	65
6.5	Schematic of wideband gain control system	67

List of Figures

6.6	Internal structure of the ICS554 digital receiver	68
6.7	Format of samples generated by the ICS554 digital receiver	70
6.8	A satellite view of Swan Reach, South Australia	72
6.9	Array configuration and antenna construction at Swan Reach	73
6.10	Connections for broadband receivers at Swan Reach	74
6.11	Model of RF chain used for data collection at Swan Reach	75
6.12	Mismatch loss for antennas at Swan Reach	76
<hr/>		
7.1	PDF of HF noise measured by the swept-narrowband method	83
7.2	The PDF of HF noise—06 April 2006, 17:00 hr to 18:30 hr local time . . .	86
7.3	The PDF of HF noise—06 April 2006, 18:30 hr to 20:30 hr local time . . .	89
7.4	The PDF of HF noise—06 April 2006, 20:30 hr to 23:00 hr local time . . .	90
7.5	The PDF of HF noise—07 April 2006, 04:30 hr to 06:30 hr local time . . .	91
7.6	The PDF of HF noise—07 April 2006, 06:30 hr to 07:30 hr local time . . .	92
7.7	The PDF of HF noise—07 April 2006, 07:30 hr to 09:30 hr local time . . .	93
7.8	The PDF of HF noise—07 April 2006, 09:30 hr to 11:00 hr local time . . .	94
7.9	The PDF of HF noise—26 May 2006, 04:50 hr to 07:20 hr local time	97
7.10	The PDF of HF noise—26 May 2006, 07:20 hr to 08:45 hr local time	98
7.11	The PDF of HF noise—26 May 2006, 08:45 hr to 10:20 hr local time	99
7.12	The PDF of HF noise—26 May 2006, 10:20 hr to 10:30 hr local time	100
7.13	The effect of the threshold on the shape of the noise PDF	103
7.14	A lognormal model for the PDF of atmospheric HF noise in Japan	104
7.15	The effect of κ on the modified Bi-Kappa distribution	107
7.16	The PDF of HF noise from Johnson	108
7.17	Bi-Kappa fit to the HF noise PDF	109
7.18	Fit of Bi-Kappa Distribution to Swan Reach data	110
7.19	Measured noise levels throughout the day	112
7.20	Measured noise levels versus frequency	113

9.1	A parallel FM/PM recognizer	134
-----	---------------------------------------	-----

10.1	Common model for analysis of signal features	140
10.2	Power spectra of various real HF signals	141
10.3	Pictorial representation of the CMD for m -ary FSK	146
10.4	Theoretical coherence of two arbitrary sinusoids	148
10.5	Coherence versus SNR at a single frequency	150
10.6	Benedetto's entropy calculation method	155
10.7	Arbitrary spectra for entropic distance calculations	160

11.1	Chronology of receiver development (repeated)	169
11.2	L shaped array for the narrowband receivers	171
11.3	External components for the narrowband receiver	172
11.4	Transmit section of the Signs toolbox	174
11.5	Receive section of the Signs toolbox	175
11.6	Modulation recognition section of the Signs toolbox	175

12.1	Coherence estimate at 20% overlap ($m = \frac{2}{3}$)	183
12.2	Mean & variance of coherence estimate at 20%, 50%, & 70% overlap ($m = \frac{2}{3}$)	185
12.3	Mean & variance of coherence estimate at 20%, 50%, & 70% overlap ($m = \frac{5}{4}$)	185
12.4	Mean & variance of coherence estimate at 20%, 50%, & 70% overlap ($m = 2$)	186
12.5	Mean & variance of coherence estimate at 20%, 50%, & 70% overlap ($m = \frac{5}{2}$)	186

List of Figures

12.6	Mean, minimum, & maximum as estimators of true coherence	187
12.7	Coherence estimate at 20% overlap ($m = \frac{5}{4}$)	188
12.8	Coherence versus SNR	190
12.9	Coherence & CMD of 2-FSK/S signals versus Hamming distance	191
12.10	Coherence versus SNR at various Hamming distances	194
12.11	A synthetic 2-FSK signal	195
12.12	Power spectrum of an FSK Alt. Wide/R signal	196
12.13	Coherence of 2-FSK/S & FSK Alt. Wide/R signals	197
12.14	Coherence of 2-FSK/S & FSK Alt. Wide/R signals for various trials	198
12.15	Power spectrum of another FSK Alt. Wide/R signal	199
12.16	Coherence of two FSK Alt. Wide/R signals received at different times (same antenna)	200
12.17	Power spectrum of another FSK Alt. Wide/R signal (different antenna)	201
12.18	Coherence of two FSK Alt. Wide/R signals received at the same time (different antennas)	202
12.19	Reference and received Stanag 4285 signals (same antenna)	203
12.20	Coherence of two Stanag 4285 signals (same antenna)	204
12.21	Reference and received Stanag 4285 signals (different antennas)	205
12.22	Coherence of two Stanag 4285 signals (different antennas)	206
12.23	Shannon's entropy vs. Benedetto's entropy (12-bit LZW)	208
12.24	The effect of message length on Benedetto's self-entropy	209
12.25	Effect of probability and message length on Benedetto's self-entropy	210
12.26	A comparison of 12-bit LZW and Zip 2.3 compression algorithms	211
12.27	Benedetto's entropy with Zip 2.3 at various message lengths	211
12.28	Shannon's entropy vs. Benedetto's entropy (Zip 2.3)	212
12.29	Effect of message structure on self-entropy	213
12.30	Effects of quantizer resolution on relative entropy	215
12.31	Effects of quantizer resolution on entropic distance	216
12.32	Self-entropies for 2-FSK/S with LZW compression	217

12.33	Entropic distance between the real signals of Table 10.1	220
12.34	Entropic distance of real HF signals (16-bit quantizer)	221
12.35	Entropic distance of real HF signals (9-bit quantizer)	222
12.36	The MSD measures for various quantizer resolutions	225
12.37	IEEE 754 double-precision floating-point representation	226
12.38	Entropic distances for synthetic HF signals (again)	227
12.39	Histogram of time series data	228
12.40	Entropic distances for synthetic HF signals with Gaussian noise	229
12.41	Entropic distances between real HF signals (repeated)	230
12.42	Entropic distances between real HF signals—13-bit LZW compression	231
12.43	Estimates of SNR for various synthetic digital signals	234
12.44	Estimates of signal power of various digital signals	236
12.45	Theoretical average power for various digital signals	237
12.46	SNR estimation from power spectra of real digital signals	239
—————		
A.1	The effect of range and κ on normalization	274
A.2	A vector of overlapping segments	275
A.3	Theoretical coherence of two arbitrary sinusoids (repeated)	283
—————		
—————		
—————		
—————		
—————		
—————		
F.1	Australian HF spectrum allocations	325
—————		
G.1	Transmit section of the Signs toolbox (repeated)	329

List of Figures

G.2	Receive section of the Signs toolbox (repeated)	330
G.3	Modulation recognition section of the Signs toolbox (repeated)	330
G.4	Directory structure of the Signs Toolbox	332

List of Tables

6.1	Configuration parameters for the GC4016	78
7.1	Comparison of ITU predicted noise levels and measured noise levels . .	114
10.1	HF signals used for modulation recognition experiments	142
12.1	Theoretical coherence values of two arbitrary sinusoids	182
12.2	Estimating the bias of the signal power estimator	237
12.3	Comparison of the SNR estimator & SNR from the power spectrum . . .	238
A.1	Normalizing coefficient for the modified Bi-Kappa distribution	273
B.1	Skywave recordings made at Swan Reach SA 6-7 April 2006	302
B.2	Skywave recordings made at Swan Reach SA 25-26 May 2006	304
B.3	Files of real HF signals	307
C.1	Overall noise figure for the wideband gain control system	312
C.2	Gains & noise figures for the wideband gain control system	313
D.1	Predicted & measured HF noise levels at Swan Reach, South Australia— 06 April 2006	317
D.2	Predicted & measured HF noise levels at Swan Reach, South Australia— 07 April 2006	318
D.3	Predicted & measured HF noise levels at Swan Reach, South Australia— 26 May 2006	319

List of Tables
