Aspects of HF Communications:

HF Noise and Signal Features

by

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Contents

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To many, high-frequency (HF) radio communications is obsolete in this age of long-distance satellite communications and undersea optical fiber.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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	2 May 2008
Signature	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 LaTeX2e 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 LaTeX2e software. TeXnicCenter 1 Beta 7.01 was used as the interface to LaTeX2e. 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**®.

At various points in the thesis, the reader is interrupted by a symbol conveying information. These symbols are used for highlighting important and ancillary information, warnings for the reader on specific issues, and messages for the reader to perform or not perform an action. Important and ancillary information is indicated by an *Information Box* pictured here.

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A *Stop Box* is almost exclusively used to tell the reader critical information regarding the operation of **MATLAB**® scripts or other software.

Publications

1. **Giesbrecht, James E.**; (2006). "A monitoring tool for HF frequency management and license enforcement," *10th IET International Conference on Ionospheric Radio Systems & Techniques (IRST2006)*; London, U.K.; (CP517) pp. 263-267; 18–21 July 2006.

2. **Giesbrecht, James E.**; Clarke, Russell; & Abbott, Derek; (2006). "Parameters for automatic modulation recognition of HF signals," *10th IET International Conference on Ionospheric Radio Systems & Techniques (IRST2006)*; London, U.K.; (CP517) pp. 281-285; 18–21 July 2006.

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4. **Giesbrecht, James E.**; Clarke, Russell; & Abbott, Derek; (2005). "Modulation recognition for real HF signals", *Proc. SPIE Microelectronics: Design, Technology, and Packaging II*. Edited by Alex J. Hariz; Vol. 6035; Art. No. 60351S (12 pages); 5 January 2006.

5. **Giesbrecht, James E.**; Clarke, Russell; & Abbott, Derek; (2005). "Coherence as a feature of real HF signals," *Proc. SPIE Noise in Communication Systems*. Edited by Costas N. Georghiades and Langford B. White; Vol. 5847; pp. 188-198; 23 May 2005.

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7. **Giesbrecht, James E.**; Clarke, Russell; & Abbott, Derek; (2004). "Monitoring the HF spectrum in the presence of noise," *Proc. SPIE Noise in Communication*. Edited by Langford B. White; Vol. 5473; pp. 76-84; 25 May 2004.

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