ON THE DETECTION OF SIGNALS WITH UNKNOWN PARAMETERS IN NOISE AND REVERBERATION

by

ANOOP LAL VYAS

A thesis submitted
in fulfilment of the requirments
for the degree of
DOCTOR OF PHILOSOPHY

DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
HAUZ KHAS, NEW DELHI
1988

CERTIFICATE

This is to certify that the thesis entitled "ON THE DETECTION OF SIGNALS WITH UNKNOWN PARAMETERS IN NOISE AND REVERBERATION" being submitted by ANOOP LAL VYAS for the award of the degree of Doctor of Philosophy to the Indian Institute of Technology, Delhi, is a record of the bonafide research work done by him under my guidance. The results obtained in this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

Surendra Prasad
Professor
Department of Electrical Engineering
Indian Institute of Technology
Hauz Khas, New Delhi-110016

ACKNOWLEDGEMENTS

No amount of words would suffice to express my deep sense of gratitude to my guide and supervisor, Prof. Surendra Prasad for his advice, encouragement and invaluable guidance during the course of this work. It is entirely due to his abiding interest and guidance that this work has been accomplished.

I also express my gratitude to Prof. P.V.Indiresan for his interest and suggestions from time to time. It is he who first introduced me to the field of Sonars and Signal Processing.

I would also like to thank Prof. Bharathi Bhat, Head, Centre for Applied Research in Electronics for her interest and support provided to me in this endeavour.

It is pleasure to acknowledge the fruitful association I have had with my colleagues in the Signal Processing Group at CARE. The very helpful companionship of Dr. R.Bahl is gratefully acknowledged.

And lastly, it is with the deep sense of gratitude that I acknowledge the care, understanding and constant encouragement I have received from my wife Anju throughout the course of this work.

I.I.T.,DELHI

JULY, 1988.

ANOOP LAL VYAS

ABSTRACT

This thesis deals mainly with some aspects of problems arising in the detection of signals with unknown parameters specifically as they arise in sonar processors. The specific problems taken up for study here pertain to the derivation and analysis of some optimum and/or suboptimum receiver structures for detecting signals with an unknown doppler shift in noise and reverberation, with the aim of developing a hierarchy of optimum and/or suboptimum detectors on the one hand and a better understanding of their performance via their ROC's on the other.

The class of broadband (energy detectors) are the first taken up for the study here, mainly to serve as an introduction to the basic methodology, both for the derivation of the receiver structures as well as for their approximate performance analysis. This is followed up by a reformulation of the broadband detection problem so as to make the detection statistic sensitive to the sense of direction of motion (viz., whether approaching or receding) of the target. This reformulation is based on a psuedo-Bayesian argument and is shown to lead to a new receiver structure called by us the "direction sensitive detector" which produces an output whose sign indicates the sense of target's motion. The properties and performance of the new structure are also a subject of investigation here. It is shown that the performance of this class of detectors is marginally better than that of energy detector.

The second related class of problems studied here, are concerned with the detection of doppler shifted signals (again in the sonar context) in the presence of reverberation. The problem has been mainly treated here as that of detection of known or partially known signals in coloured noise, which is motivated by the fact that the reverberation power spectrum is closely related to the power spectrum of the transmitted signal.

The object here is to study this problem using the modern time series models for reverberation and to generalize the theories developed for the white noise case to include the case of reverberation interference. Once again, the hierarchical approach is used to design the equivalents of the square law (energy) detector and the direction sensitive detector. The use of modern parametric spectral detectors is also shown here to be naturally suited to the case of detection in the presence of reverberation.

More specifically, we take up the following problems for investigation in this regard. We first consider the detection of narrowband signals of unknown amplitude and phase in AR modeled reverberation. This is then generalized to include an unknown doppler shift in the signal, which following the broadband formulation, is assumed to be a uniformly distributed random variable. Finally, we obtain a direction sensitive version of the broadband detector in a reverberation limited situation. Attempts are also made to obtain approximate ROC's for these receivers, a task which is too complex in its complete generality, but shown to be manageable at least for the simple case of a first order AR model for reverberation. It is shown that the direction sensitive detector, in this case, performs significantly better than that of energy detector.

Finally we also look at the problem from the point of view of regarding the doppler shifted waveform as a narrowband process. Using this model, it is shown that an estimator correlator philosophy can be usefully employed to derive a new, closed form expression for the detection statistic for the narrowband detection of doppler shifted signals. A detailed investigation of this structure shows that it is closely related to other spectral detectors, including the AR spectral peak detector. The performance of the new detection statistic is also explored vis-a-vis other narrowband detection statistics.

CONTENTS