DETECTION WITH UNCERTAINTY:
NONPARAMETRIC, ROBUST OR ADAPTIVE APPROACHES

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1. INTRODUCTION

In many practical applications, and particularly in underwater acoustics, the signal detection problem cannot be reduced to a test between two simple hypotheses. Of course this reduction gives a lot of simplifications and particularly introduces the optimal receiver as a system which makes the decision by comparing the likelihood ratio to a threshold. In practice the hypotheses are not simple because we do not know exactly the probability densities of the observation of the noise or of the signal plus noise.

This lack of knowledge is due to various factors. The uncertainty on the signal is mainly due to the propagation and reflexion phenomena which very often cannot be described correctly, even statistically. But the noise also can present very strong variations in its statistical properties and the classical assumptions of a stationary Gaussian noise are often far from the reality.

In spite of this approximative knowledge it is necessary to make a decision on the presence or absence of signal in an observation and then to specify the signal processing procedure leading to this decision. For this purpose various approaches are possible.

The nonparametric approach is used when our knowledge is very elementary. In some sense this approach can be considered as

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very conservative. The idea is to construct a receiver which has some constant properties for a very broad class of possible noises. For example we can impose a constant false alarm probability for any noise which has a symmetric distribution.

The robust approach can be used when the class of possible signals and noise is well defined and the idea is to search a procedure which guarantees some minimum performances for all the possible situations.

The adaptive approach is in some sense more sophisticated. Assuming that our lack of knowledge can be reduced to some dominant parameters the idea is to make an estimation of these parameters and to adapt the receiver to this estimation. In this adaptation some conditions on the performances can be imposed.

It is not always possible to compare these approaches because they are working in different contexts, and any increase in our knowledge can in principle give a gain in performance. Moreover the concept of optimality which is perfectly clear in the case of simple hypotheses becomes more obscure in the other cases.

The purpose of this lecture is to give an overview of the principal ideas used in these various approaches. Of course as the literature on the subject is considerable it is an almost impossible task. Then the presentation is restricted to the principal ideas and is more tutorial in nature. In the same way only the principal references are given and by successive approximations on these references any reader can obtain a fairly good idea on the subject.

2. BASIC IDEAS IN SIGNAL DETECTION

2.1. Detection of two simples hypotheses

The purpose of this section is to give a simple presentation of the fundamentals concepts in signal detection which are used in the other parts of the paper. Of course we restrict ourselves in the presentation to basic ideas. Details and extensions can be easily found in classical text books on this subject [1] [2] [3] [4].

The simplest detection problem for which most of the concepts can be applied is the binary hypothesis testing problem. It consists to make a decision (or a choice, or a test) between two hypotheses $H_0$ and $H_1$ from an observation $x$. In detection problems $H_0$ means that the observation is a noise vector and $H_1$ means that