Preface to the Matched Filter Issue

This issue of the PGIT TRANSACTIONS is the first in what is intended to be a series devoted to special topics. Such Special Issues will be organized from time to time whenever the Editors feel that they have identified a sizeable body of new and previously unavailable results having a common unity.

This Special Issue takes as its point of departure a disarmingly humble and specific notion: that the correlation of one waveform with another can be carried out by 1) passing the first waveform through a linear system whose impulse response is the time reverse of the second waveform, and 2) observing the output at a certain instant of time. If the two waveforms are made the same, we say that the filter is "matched" to the input waveform. The filter output as a function of real time is then the autocorrelation function of the waveform.

The subject was introduced in 1943 in North's study of maximization signal-to-noise ratio out of the IF of a pulse radar. Correlation detection was studied at first as a separate subject, but the equivalence of the two operations was soon appreciated. By now they have long since fused and the only meaningful distinction lies in the matter of actual hardware—whether the correlation operations take place using multipliers and integrators, or alternatively by observing the sampled outputs of matched filters. Often, but not always, there are compelling engineering reasons for preferring the latter approach.

No matter what formalism is used to view a given communication or detection situation, Gaussian noise statistics lead usually to some form of correlation or matched filtering as a part of the set of operations that will perform the desired function most efficiently. This appears to be true even when in addition to the noise there are other perturbing factors present, such as randomly varying multipath, uncertainties in signal delay or Doppler shift, Doppler or delay smearing, or unwanted clutter.

The present issue contains a sampling of some important aspects of the by now large subject of "matched filter communication and detection." A central feature of this volume is the tutorial survey by Turin prepared by special invitation. This paper will serve as a valuable introduction and guide to the literature for those who may be reading about matched filter theory for the first time, and should help to unify the various notions for those already familiar with separate aspects of the field.

The next paper, by Bello, treats the question of uncertainties in the simultaneous estimation of range, velocity, and acceleration of targets observed by pulse radar. Westerfield, Prager, and Stewart, analyze the use of a matched filter radar or sonar in discriminating targets from clutter by exploiting the fact that the clutter may have a characteristic distribution of returned power as a function of range and Doppler that is different from that of the signal. Middleton's paper deals with a formulation of the statistical detection problem in such a way that over a wide class of conditions, some sort of filter specification appears as the result. In general these filters may be time-variant, but in the simple white noise case they are the same as the more familiar fixed filters matched in the sense indicated above.

Kailath's paper discusses a point of view in which earlier work on optimum receivers for channels with certain multiplicative disturbances (*e.g.* varying multipath) is shown to make use of a maximum-likelihood estimate of the transmitted waveform as modified by the multiplicative disturbance. Sussman describes an operating antimultipath communication system built around the matched filter notion. A large time-bandwidth product is required in such applications, and in this case the filter is made up of a large number of narrow-band elements spaced uniformly in frequency.

The design of matched filter equipment is also discussed by Lerner, Cutrona, *et al.*, and Craig. Lerner is interested in matched filters having a high degree of time delay discrimination and an ability to accommodate and measure Doppler shifts. The basic matched filter he uses is made up of a number of wideband elements spaced uniformly in delay, *i.e.*, a tapped delay line.

Cutrona, Porcello, Palermo, and Leith, discuss the treatment of signals by optical processors. An interesting feature of this class of techniques is the ease with which large numbers of hypotheses can be tested simultaneously, a capability that appears to be increasingly necessary as communication and detection systems become more complex. Craig analyzes what can be done in designing a linear filter for best performance as a matched filter when only a limited number of design parameters may be varied.

Two specific approaches to the important problem of choosing the waveforms so as to have desirable auto- and cross-correlation properties are presented by Welti and Titsworth. This problem is touched on in Lerner's paper as well, and by implication at least, by Sussman.

The Abstracts Section, a new regular feature of the TRANSACTIONS, appears for the first time. The Editors of this section have prepared a number of abstracts summarizing various important papers relating to matched filters.

The reader will recognize at once that the collection of papers in this issue is more indicative than it is exhaustive. More is being added to the story daily. It is hoped that this Special Issue will stimulate a wider discussion and suggest profitable directions for further work.

PAUL E. GREEN, JR.,
Editor of Matched Filter Issue