Digitizing High-rate Signals With Affordable Hardware

Digital signal representations offer several advantages over analog: precision, ease of handling by computers, and storage and transmission with low error probability. Putting a signal in digital form entails measuring its amplitude several thousand times per second for audio or several million for video. Important applications, notably digital radar, could use analog-to-digital converters (ADCs) with yet higher rates— billions of samples per second. Unfortunately, such devices are still quite expensive.

A salient factor is the *Nyquist theorem*: a signal confined to a limited frequency band can be reconstructed from uniform samples if the sampling rate is at least twice the bandwidth. Otherwise *aliasing* can occur: the samples may fail to distinguish a higher-frequency signal from a lower, and energy may appear at the wrong places in a power-spectrum estimate.

Under ONR sponsorship, Meyer Institute faculty Michael Melich and Rodney Johnson are investigating signal digitization by multiple ADCs with sampling rates lower than the Nyquist rate. Earlier NPS work on phased-array antennas by these investigators and others may have a bearing on the sampling of signals in time.

Random spacing of antenna elements has been observed to greatly reduce or eliminate the *grating lobes* that appear in sparse, regular arrays; these are regions of high gain at directions away from the main beam and may cause spurious estimates of target direction. Grating lobes are the spatial analog of aliasing in time-domain signal processing. Thus the investigators are led to study the benefits of *non-uniform* sampling by multiple sub-Nyquist ADCs. If spreading the "aliasing energy" across the power spectrum introduces small enough error, it may be feasible to replace expensive high-rate ADCs with a system using cheaper ADCs in parallel.

Quantitative analysis is needed to tell whether this is economically preferable to the "classical" alternative: banks of bandpass filters. Several modeling and physical questions must be kept in mind. The usual mathematical model of sampling assumes values of the signal at sharply defined sample times. But no real device works instantaneously; charge proportional to signal strength is collected over a non-zero time and then "counted" with an accuracy that determines the accuracy of the measured signal value. These limitations are generally reflected in the bandwidth of the device.

The antenna-array work exploited the search capabilities of genetic algorithms. These may also be used in exploring the design space of multi-ADC systems. The ADCs can be characterized by parameters that include sampling rate, bandwidth, resolution, and cost. Among the measures available for characterizing the deviation of the "undersampled" signal representation from the original are a simple least-squares computation and various weighted spectral-distortion metrics.

Maritime Domain Protection Task Force Hosts Symposium in August

The Maritime Domain Protection Task Force (MDP-TF) is sponsoring a symposium from 18-19 August 2004 at the Naval Postgraduate School in Monterey, California. Created in January 2004, the MDP Task Force is coordinated by the Meyer Institute, under the leadership of CAPT Jeff Kline, USN.

The purpose of the 18-19 August MDP Symposium is to bring together various commands, agencies, and departments involved in maritime security to exchange information on all aspects of maritime domain protection and specifically review NPS MDP-TF research projects. Briefs presented at the Symposium will include:

- Overview of Maritime Domain Protection Task Force
- Systems Engineering and Integration
- Threat and Vulnerability Assessment
- Multi Source Data Fusion for Maritime Domain Awareness
- Attack-Defender Modeling with a Focus on Critical Infrastructure
- Maritime Domain Protection Wargaming
- An Integrated Approach for MDP Estimation of Atmosphere and Surface Influences on Rf/IR Sensors
- Maritime Domain Awareness Data Effort
- PACOM's Joint Interagency Coordination Group for Combating Terrorism
- Modeling in the Cognitive Dimension with Software Agents
- CNO Strategic Studies Group/Homeland Protection Concept Generation Team

Participants have been invited to present agency briefs relevant to MDP during a "Forum" on the second day of the Symposium. For registration information on the MDP Symposium, please contact Ms. Ann Wells at abwells@nps.edu.

Chair of Undersea Warfare, VADM Roger Bacon, USN (ret.) Reports…...
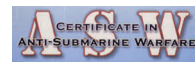
The first Anti-Submarine Warfare Certificate distance learning program commenced in July. It consists of four fully accredited courses delivered over a one-year period. The courses are: Introduction to Sonar Equations, Search Theory and Detection, Introduction to Oceanography for Undersea Warfare, and Review of Signals and Systems. These courses develop critical skills and understanding of fundamental principles applied in Anti-Submarine Warfare (ASW).

A great deal of interest in the ASW Certificate program has been generated with initial student enrollment requests filling the courses. With the stand up of the Fleet ASW Command and renewed interest in Anti-Submarine Warfare in the Navy, Naval Postgraduate School is forging ahead in this key element of Sea Power 21 and Sea Shield.

Naval officers (active or reserve), government laboratory engineers, Navy civilians, and Navy enlisted are all eligible for the ASW certificate program.

ASW Certificate information is available at http://online.nps.navy.mil/vu_programs/asw_info.htm   In addition, Professor Kevin Smith reports that 17 new students are enrolled in the two year Undersea Warfare curriculum distance learning program.