In This Issue – Technically

Articles

- Implementation of Hand Geometry
  
  *E. Kukula & S. Elliott*
  
  **3**

- Human Being Detection by Radar
  
  *A.G. Yarovoy, L.P. Lightart, J. Matuzas & B. Levitas*
  
  **10**

- GMTI Along-Track Interferometry Experiment
  
  *E. Chapin & C.W. Chen*
  
  **15**

- Low Cost X-Band Power Amplifier MMIC
  
  *W. Bosch, J.G.E. Mayock, M.F. O’Keefe & J. McMonagle*
  
  **21**

- Improved CFAR Performance in the Littoral
  
  *A. Butrym & S. Pivenenko*
  
  **26**

- Challenges of Education in Engineering
  
  *V.A. Skormin*
  
  **Centerfold**

Book Review

- Radar Systems Analysis and Design Using MATLAB
  
  *B.R. Mahafza*
  
  **31**

Columns

- Systems and Systems-of-Systems — R.C. Rassa
  
  **33**

- New Member Grades Available — Evelyn H. Hirt
  
  **35**

News & Information

- Distinguished Lecturers
  
  **34**

- Call for 2006 Education Award Nominations
  
  **35**

- Position Vacancy
  
  **35**

- IEEE AESS Society Organization
  
  **36**

- Newbie Engineers
  
  **37**

- Verona, NY, Hosts Radar 2006
  
  **38**

- St. Petersburg & Australia / New Zealand
  
  **39**

- PLAN 2006: Joint by IEEE & ION
  
  **40**

- Kershner Award to Bar-Itzhack in 2004
  
  **42**

- PLAN 2006 Tutorial & Sessions
  
  **43**

- Florence, Italy, Hosts Fusion 2006
  
  **44**

- Student Project Contest Open to All
  
  **45**

- Student Membership Application
  
  **46**

- “The Place Where It All Began” Boston in 2007
  
  **47**

- Membership Application
  
  **48**

- Directory
  
  **Inside Back Cover**

- Meetings
  
  **Back Cover**
In This Issue - Technically

Implementation of Hand Geometry
An Analysis of User Perspectives and
System Performance
This discusses the implementation issues of installing a
commercially available hand geometry system in the current
infrastructure of Purdue University's Recreational Sports
Center. In addition to a performance analysis of the system, a
pre- and post-data collection survey was distributed to the 129
test subjects gathering information on perceptions of
biometrics, in particular hand geometry, as well as
participants' thoughts and feelings during their interaction
with the hand geometry device. The results of the survey
suggest that participants were accepting of hand geometry.
Additionally, analyses of the participants' survey responses
revealed that 93% liked using hand geometry, 98% thought it
was easy to use, and 87% preferred it to the existing
card-based system, while nobody thought the device invaded
their personal privacy. System performance achieved a 3-try
match rate of 99.92% (FRR 0.08%) when "gaming"/potential
impostor attempts were removed from analysis. The failure to
enroll rate was zero. Statistical analyses exposed a significant
difference in the scores of attempts made by users with prior
hand geometry usage, and subjects that could not straighten
out their hand on the device. However, there were no
statistical difference in the effects of rings/no rings, improper
hand placements/proper hand placements, or gender on hand
game score.

UWB Radar for Human Being Detection
UWB radar for detection and positioning of human beings
in complex environments has been developed and
manufactured. Novelty of the radar lies in its large operational
bandwidth (11.7GHz at -10dB level) combined with high
time stability. Detection of respiratory movement of a person
in laboratory conditions has been demonstrated. Based on
experimental results human being radar return has been
analysed in the frequency band from 1 GHz to 2 GHz. Novel
principle of human being detection is considered and verified
experimentally.

GMTI Along-Track Interferometry Experiment
Synthetic aperture radar (SAR) along track interferometry
(ATI) has been used extensively to measure ocean surface
currents. Given its ability to measure small velocities (~10
cm/s) of relatively radar-dark water surfaces, there is great
potential that this technique can be adapted for ground
moving target indication (GMTI) applications, particularly as
a method for detecting very slow targets with small radar
cross-sections. In this paper we describe preliminary results
from an ATI GMTI experiment.
The SAR data described herein were collected by the
dual-frequency NASA/JPL airborne radar in its standard
dual-baseline ATI mode. The radar system imaged a
variety of control targets including a pickup truck, sport
utility vehicles, passenger cars, a bicycle, and pedestrians
over multiple flight passes. The control targets had horizontal
velocities of less than 5 m/s. The cross-sections of the targets
were not purposely enhanced, although the targets' reflectivities
may have been affected by the existence of the
gps equipment used to record the targets' positions.
Single-look and multiple-look interferograms processed to
the full azimuth resolution were analyzed. In the data
processed to date, all of the targets were observed by visual
inspection in at least one of the four combinations of
dual-frequency, dual-baseline interferometric data. This
extremely promising result demonstrates the potential of ATI
for GMTI applications.

CPW to CPS Transition for Feeding UWB Antennas
The paper considers a transition (balun) from Coplanar
Waveguide (CPW) to Coplanar Stripline (CPS) which is
currently non-resonant and suitable for feeding UWB antennas
such as Tapered Slot Antennas (Vivaldi antennas, in particular),
bow-tie antennas, and other. Some numerical and
experimental results are presented that show performance of
the transition alone and as a feeder for a Vivaldi antenna.

Low Cost X-Band Power Amplifier MMIC
A family of X-Band MMIC power amplifiers using a low
cost GaAs pHEMT process is reported. The stepper-based
volume 0.5 micron and 0.25 micron GaAs pHEMT processes
utilize 4 inter-level metallisation and four dielectric layers for
high frequency performance whilst maintaining the
economies of scale of 150 mm (6') diameter substrates.
The fabricated GaAs X-Band PA MMICs exhibit 5W to 10W RF
output power under pulsed conditions; 16dB of power gain
and power added efficiencies approaching 40%. Excellent
repeatability and high yields over a number of wafers have
been demonstrated. The design and GaAs process approach
taken here with DUV stepper and 150 mm wafer diameter
will lead to a significant cost reduction for high performance
power amplifier MMICs up to 30GHz.

Improved CFAR Performance in the Littoral
Littoral operation of radars poses severe signal processing
difficulties due to the highly stressing, inhomogeneous
clutter. This report describes an initial investigation into the
feasibility of utilising site-specific radar modelling to provide
a localised estimate of the clutter statistics which can then be
used to predict the required threshold to maintain a given false
alarm rate. The technique has been applied to littoral clutter
recordings obtained from the experimental S-band phased
array radar, MESAR2. Results are presented for the technique
in comparison with a conventional, non-adaptive, cell
averaging CFAR. This paper concludes that significant
performance enhancements are possible through the use of
this new technique.
Implementation of Hand Geometry
An Analysis of User Perspectives and System Performance

Eric Kukula & Stephen Elliott
Purdue University

ABSTRACT
This discusses the implementation issues of installing a commercially available hand geometry system in the current infrastructure of Purdue University’s Recreational Sports Center. In addition to a performance analysis of the system, a pre- and post- data collection survey was distributed to the 129 test subjects gathering information on perceptions of biometrics, in particular hand geometry, as well as participants’ thoughts and feelings during their interaction with the hand geometry device. The results of the survey suggest that participants were accepting of hand geometry. Additionally, analyses of the participants’ survey responses revealed that 93% liked using hand geometry, 98% thought it was easy to use, and 87% preferred it to the existing card-based system, while nobody thought the device invaded their personal privacy. System performance achieved a 3-try match rate of 99.02% (FRR 0.98%) when “gaming”/potential impostor attempts were removed from analysis. The failure to enroll rate was zero. Statistical analyses exposed a significant difference in the scores of attempts made by users with prior hand geometry usage, and subjects that could not straighten out their hand on the device. However, there were no statistical difference in the effects of rings/no rings, improper hand placements/proper hand placements, or gender on hand geometry score.

INTRODUCTION
This paper explores the feasibility and performance related to implementing a hand geometry system for access and audit control at Purdue University’s Recreational Sports Center (RSC). The current access control system requires a user to swipe a student identification card through a magnetic strip reader to gain access to the recreational center. Since the decision is based solely on a token, which can be stolen, lost, handed to others, or copied; accurate auditing is not possible, causing a two fold problem: (1) an insurance risk – as accurate records of members in the facility are not available, and (2) a loss of revenue for the recreational center – as multiple people could use the same identification card. The use of biometrics, particularly hand geometry, removes the token (something members “have”) and replaces or adds to it a physical or behavioral trait (something members “are”), which removes the possibility for lost or stolen tokens to be used for fraudulent access.

This paper describes a modified operational evaluation of Recognition Systems Handkey II hand geometry system at Purdue University’s Recreational Sports Center (RSC) during the Spring semester of 2005. The project began in Fall 2003 as a class project for IT 545, a graduate level biometrics course in the College of Technology, with the purpose of assessing the facility’s environment and infrastructure, as well as the management team and potential users [1]. Initially, a survey of 453 participants was distributed and analyzed during the Fall of 2003 to determine RSC usage patterns, perceptions of biometrics, and thoughts about the current access control.
system. The results revealed that 55% of the participants felt fingerprint recognition was least intrusive, followed by hand geometry (30%), eye – iris and retinal imaging (7%), and face (6%), which is shown in. [1] also conducted an environmental assessment of the Purdue RSC, which investigated four biometric applications based on assumed user familiarity, ease of use, and climate conditions at the two entrance locations – the front gate located indoors, and the back gate located outdoors.

The recommendations by the IT545 class to RSC Management were to install hand geometry due to its track record for access control applications (AC) and use in outdoor environments. It was determined by RSC Management that Purdue University Facilities Services would install the hand geometry device separate from the current access control system, so testing and evaluation would not interfere with students and faculty attempting to gain access to the facility. Further discussion on the environment and system setup occurs later in this paper.

Motivation

The motivation behind the research was four-fold: 1) To collect prior biometric use information, as well as participants perceptions of biometrics before using the hand geometry system, to establish implementation feasibility and user acceptance of the technology; 2) To monitor participants initial perceptions and interactions during training and enrollment; 3) To collect user perception and interaction data after the evaluation concluded, and 4) To measure the performance of the hand geometry system, including: the failure to enroll rate (FTE), failure to acquire rate (FTA), and the false reject rate (FRR).

Environment Overview

The hand geometry system was installed in the front entrance of Purdue University’s RSC. The implementation was isolated from the current access control system (magnetic ID cards), so it would not interfere with members trying to enter the RSC. In addition, the current design of the access control area was not suitable to accommodate the commercially off the shelf (COTS) hand geometry device without significantly affecting performance, which will be discussed in section 3.2. The environment, which the hand geometry system was installed, is shown in Figure 2.

Characteristics of Current System

The current access control system at the Purdue University RSC uses magnetic strip readers mounted on top of a turnstile. To gain access to the facility, a member swipes their identification card through the magnetic strip reader. If the card is active, the turnstile will unlock and the member can gain access. The current system involving the magnetic card readers has two lanes or stations. One of the stations is depicted on the left side of Figure 3.

Characteristics of Operational System Evaluated

Figure 3 depicts the hand geometry unit placement in the front entranceway. It was noted by the authors that by separating the hand geometry device from the turnstile, participant interaction with the hand geometry device would not be identical to that of a real-world deployment. There are two significant explanations for this. First, the COTS hand geometry unit was a right-handed model and the base of the turnstile was located on the left. Therefore if a user were to use the hand geometry device, they would have to reach across their body to use the device, influencing users’ interaction with the device. The results of this incorrect setup could possibly cause inconsistent hand placements on the device ultimately affecting the performance of the algorithm, which in turn could influence users’ perceptions of hand geometry. Installation was performed by Purdue’s Facility Services, which closely followed the protocol developed in the Fall 2003 feasibility study.
Scenario Testing in an Operational Environment

The primary goal of the hand geometry implementation was to examine the performance of the hand geometry system at the Purdue RSC on a population of students and faculty. This goal is harmonious with the ISO/IEC Biometric Performance Testing and Reporting definition that states operational testing is an "evaluation in which the performance of a complete biometric system is determined in a specific application environment with a specific target population [2]. However the end result of a user interacting with the hand geometry system did not affect them entering the facility, thus was not a true operational test; and was classified as a modified scenario test.

Operational Environment during Testing

The operational environment shown in Figure 2 had a mean temperature in the evaluation area of roughly 74°F. Since Purdue is located in Indiana and the test was conducted between February and May, outdoor temperatures were variable throughout the evaluation with a mean high of 65°F and low of 43°F [3], however quantitative measures on the effects of temperature changes on hand geometry scores were not recorded as the evaluation type was unattended. Illumination levels were not monitored during the evaluation, but were consistent with a building entrance with glass doors. Quantitative measures on the effects of illumination on the performance of the hand geometry system were also outside the scope of this evaluation.

Future State

The RSC has plans to remodel the front entrance within the next two years. Regardless of whether or not hand geometry is adopted and implemented system wide, the re-design should include a reversal of the turnstiles to accommodate COTS hand geometry readers allowing members to walk up to the turnstile, stop in front of the barrier, type their ID number or swipe their ID card, place their hand on the platen, and proceed. Figure 4 depicts an entranceway modeled in this fashion at another university recreational sport facility in the United States.

TECHNOLOGY OVERVIEW

Hand geometry is one of the oldest commercialized biometric modalities, with foundation patent applications dating from the late 1960s [4]. The technology came of age in the 1980s when it was selected for deployment in several US nuclear power plants. Since then, over 100,000 devices have been installed for physical access control (AC), identity management (IM), and time & attendance (TA) applications. Typical AC and IM sites include airports, prisons, hospitals, military bases, commercial buildings, dining applications, and health clubs. In TA applications, hand geometry units replace traditional time clocks to eliminate “buddy punching” (in which one employee signs in/out for another employee so they are paid for more hours than they actually worked) and to control/authorize overtime expenses.

Hand geometry devices measure the size and shape of human hands. They do not measure palm prints, fingerprints, vein patterns, or other traits. The type of hand reader used at the RSC is shown in . This device uses a CMOS sensor and near infrared illumination to image the hand from above and from the side (the side-view is captured via a mirror adjoining the hand surface). These views are converted to binary silhouettes that are traversed to calculate over 90 length, width, thickness, and area measurements. These measurements are “compressed” into a proprietary 9-byte template in such a way that only the unique characteristics of each hand are stored; a hand image cannot be uniquely reconstructed from its 9-byte template.
The Handkey II is generally considered a verification device (where the user proves a claim of identity), not an identification device (where the user is selected from a list of possible identities). Due to the small 9-byte template, the Handkey II can store up to 32,516 users in its internal database (without an external PC). Hand geometry can also be used in smartcard applications, where memory and processing power are at a premium. For a more detailed discussion on hand geometry, see [5, 6].

Hand Geometry Modifications for Data Collection

In this evaluation, a COTS hand geometry device was modified for testing purposes by adding a data logging card containing a flash memory card similar to those used in digital cameras. After each hand placement, the hand reader's main processor spent approximately two seconds writing to flash. During this time, the processor did not respond to network requests, including enrollment or verification requests. For this reason some users were enrolled at the hand reader, but the PC auditing software occasionally timed out waiting for the enrollment notification. Subsequently, these users were considered invalid by the auditing software and were summarily rejected during the verification attempts following enrollment. Re-enrolling these users solved the problem.

Because re-enrollment was triggered by a software timeout caused by using a non-standard hand reader, not by image acquisition or algorithm problems, these cases were not considered failures to enroll (FTE). Moreover, enrollment trials without the auditing software were conducted offline in a laboratory environment and no enrollment problems were apparent. See section 7.1 for further enrollment analysis.

EXPERIMENTAL SETUP

Before the experimental setup is discussed, the application under which this evaluation occurred must be defined. The taxonomy for an application falls under six categories: cooperative/non-cooperative, covert/overt, habituated/ non-habituated, attended/unattended, public/private, and open/closed. For further information on application taxonomies, refer to [7, 8]. For this access control evaluation, the taxonomy was cooperative, overt, habituated and non-habituated, unattended – except for training and enrollment, private, and closed.

As discussed previously, all aspects of this evaluation took place in the front entrance of the Purdue University RSC (Figure 2), including training, enrollment, and unattended verification. In addition, two surveys were distributed before and after the evaluation to collect demographic information, RSC usage patterns, prior knowledge, and/or use of biometrics, feelings toward hand geometry, and feelings towards the current access control system of the test subjects. The first survey was given after the participant enrolled using the hand geometry device. At the conclusion of the test period, each test subject was asked to complete a follow-up survey to assess if their interaction with the device over a two-month period changed their thoughts or perceptions of hand geometry. As the surveys were voluntary and electronic, response rates varied, which is discussed in the next section.

Training

Before training, each subject was presented an IRB human subjects consent form to read and sign. Once this was signed training began. Training consisted of a 5-10 minute briefing including: the purpose of the project, a technology overview, a hand placement tutorial, instruction on specific enrollment and verification procedures to follow, and a question and answer period. For repeatability purposes a manual was created, ensuring that each individual received the same orientation and training.

Enrollment

Enrollment was attended by one of the authors to ensure each test subject followed the test protocol for enrollment. Each subject was asked to provide a four digit number that they could remember for subsequent verification attempts. Enrollment consisted of three hand placements, to create a unique template for that test subject; however the device may have required additional hand placements if the first three did not satisfy the enrollment criteria. It was observed by the authors that enrollment generally took thirty seconds or less, although this data was not collected or documented.

Unattended Verification

The COTS hand geometry unit functions as a one-to-one (verification) system. During each verification attempt, the test subject entered the four digit number provided during enrollment, and when prompted by the system – placed their hand on the platen around the guide pins. Since the hand geometry system was separated from the functioning access control system, as discussed earlier in the paper, a failed verification attempt did not result in a user not entering the facility. To enter, a test subject still had to provide her/his Purdue ID card and follow the access control procedure. Furthermore, as one of the purposes of the evaluation was to examine participants’ interactions and perceptions of the device, they were allowed to use the device repeatedly at their discretion. This resulted in some participants never using the device after the first visit, while others used the device once a week, once per day, and even multiple times per day.

Survey Distribution

Two electronic surveys were distributed during the evaluation to gather demographic information, RSC usage patterns, prior knowledge and/or use of biometrics, feelings toward hand geometry, and feelings towards the current access control system of the test subjects. The first survey was given after the participant enrolled using the hand geometry device. At the conclusion of the test period, each test subject was asked to complete a follow-up survey to assess if their interaction with the device over a two-month period changed their thoughts or perceptions of hand geometry. As the surveys were voluntary and electronic, response rates varied, which is discussed in the next section.

TEST POPULATION & SURVEY RESULTS

The evaluation involved 129 test subjects from Purdue University, including students, faculty, and full-time RSC employees. The pre- evaluation survey resulted in a 92% response rate, while the survey distributed after the evaluation
ended was 42%. The latter survey was available for a month after data collection ended, but reduced response rates were expected by the authors due to the end of the academic semester, although multiple email messages were sent prior to the survey distribution, as well as three reminder messages after distribution.

Demographics
From the 119 out of 129 respondents, 88% were 18-25 years of age, with 71% male and 29% female. 88% were students, 8% were Purdue University faculty, and the remaining 3% were RSC employees. 104 test subjects, or 87%, classified themselves as right-handed. 87% of the respondents were Caucasian, 9% Asian, 2% African American, and 1% Native American. Moreover, none of the participants had missing digits. Refer to [9] for a complete listing of the demographic survey results.

Results for Subjects’ Prior Use & Perceptions of Biometrics
Test subjects were asked seven questions regarding prior usage and perceptions of biometrics after training and enrollment. From the 119 survey respondents 37% stated they have never used biometrics, while 42% stated they had used fingerprint recognition, followed by dynamic signature verification (28%), voice recognition (21%), and hand geometry (18%). From the test subjects that have previous biometric experience, 34% used multiple biometric technologies. A complete analysis of the responses can be found in [9]. It should be noted that there are fingerprint ATMs on campus, and near the vicinity of students, which might account for prior usage.

With regards to hand geometry, 94 of the 119 responses from test subjects never used hand geometry prior to this study (79%), 98% stated that the hand geometry device did not look hard to use, and 92% stated the device did not look invasive to them. However, there were conversations with some subjects during the training and enrollment sessions that revealed many common misconceptions such as: hand geometry collected fingerprints, the platen scanned their fingerprints, “people or government could steal their fingerprints from the hand reader”, and “that government agencies were collecting their data from the hand reader”.

User Experiences
After the data collection concluded, a post data collection survey was released to all participants. Of the 129 participants, 55 responded (42% response rate). The results from the survey dealing with participant experiences can be found in Table 1.

Analysis of the user experiences survey results revealed that 85% remembered how to use the hand geometry device each time they used it, while 15% forgot the correct procedure or how to place their hand on the device correctly. From the respondents, 71% used the hand geometry device up to 20 times in a two-month period. When participants did use the device, 19 of the 55 respondents performed multiple verification attempts in the same day; either in succession or

<table>
<thead>
<tr>
<th>Table 1. User experiences survey results post data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How many times did you use the hand geometry device?</strong></td>
</tr>
<tr>
<td>Less than 10</td>
</tr>
<tr>
<td>11-20 times</td>
</tr>
<tr>
<td>21-30 times</td>
</tr>
<tr>
<td>31-40 times</td>
</tr>
<tr>
<td>41-50 times</td>
</tr>
<tr>
<td>More than 50 times</td>
</tr>
<tr>
<td><strong>How many times did you forget how to use the hand geometry device?</strong></td>
</tr>
<tr>
<td>Never</td>
</tr>
<tr>
<td>1-3</td>
</tr>
<tr>
<td>4-6</td>
</tr>
<tr>
<td>More than 6 times</td>
</tr>
<tr>
<td><strong>Did you perform multiple attempts on the hand reader during the same visit, either in succession, or once entering and once leaving?</strong></td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td><strong>Did you like using the hand geometry device?</strong></td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No Response</td>
</tr>
<tr>
<td><strong>Was the hand geometry device hard to use?</strong></td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No Response</td>
</tr>
<tr>
<td><strong>Did the hand geometry device feel like it involved your privacy or personal space?</strong></td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td><strong>Did you show any of your friends or co-workers how the device worked?</strong></td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
</tbody>
</table>

over a period of time. More generally, 93% of the survey respondents liked using the device, and 98% stated the hand geometry device was easy to use. Furthermore, all 55 survey responses stated they felt the hand geometry device did not invade their privacy or personal space.

Another interesting point is that 64% of the responding participants showed either their friends or co-workers how the hand geometry device worked. It is hypothesized that during these explanations to friends and co-workers that imposter attempts and experimental or “game” hand placements took place. While this cannot be proven due to the unattended nature.
of this test, analysis of the raw images stored with each hand placement strongly supports this theory. Lastly, when asked whether participants preferred to use hand geometry or magnetic strip cards to access the RSC, 87% responded with hand geometry, 5% responded with the magnetic strip cards, 7% were undecided, and 1% did not respond.

SYSTEM PERFORMANCE

Enrollment Analysis

As stated in section 4, a conflict arose between the auditing software and the flash card inside the hand geometry device, which collected the raw images. The result of this conflict caused 16 test subjects' unique user identification numbers not to be recognized, causing additional enrollment sessions for these participants. Moreover, an analysis of the enrollment images of these 16 subjects revealed that there were no problems in the acquired images, as the samples were of sufficient quality that these 16 subjects who enrolled more than once were deemed not to be classified as failure to enroll (FTE) attempts. For further explanation, please refer back to sections 4 and 5.2.

The analysis of the enrollment data confirmed 156 enrollment sequences were completed during the evaluation. The flash card and auditing software error required one subject to perform 3 additional enrollment sequences, 8 subjects requiring 2 additional enrollment sequences, and 7 subjects requiring 1 additional enrollment sequence. Four test subjects were required to provide 4 hand placements, as the device deemed the standard 3 enrollment images as not sufficient. In summary, the hand geometry device had a 0% FTE, when the additional enrollments due to the external software data communication error were removed.

Failure to Acquire Analysis

The failure to acquire (FTA) rate is the percentage of attempts where the system fails to capture a biometric sample of sufficient quality; including attempts where extracted features are substandard [5]. As such, the ground truth of the FTA cannot be ascertained, as this was an unattended evaluation.

Verification System Analysis

Since this was a simulated scenario evaluation, it is essential to report the false reject rate (FRR) and the false accept rate (FAR). However, since the evaluation was unattended, the ground truth FAR could not be ascertained since it was untenable to differentiate impostor attempts from subjects "gaming" the device. Thus, the analysis below represents the authors' best efforts to remove impostor and gaming attempts from the data to predict biometric performance. For all analyses the system threshold was set at 100.

Performance analysis of the hand geometry system

After analyzing the data for specific hand placements constituting impostor attempts or "gaming" of the system, the authors removed 37 placements from the dataset. Seventeen other placements were removed for reasons including: multiple hands present at the same time, jacket sleeves occluding the hand, and grossly incorrect hand placements.

The remaining 1788 hand placements were analyzed for 1-try, 2-try, and 3-try rejection rates. For users placing the hand more than 3 times in close succession (within 15 minutes and no other users utilizing the system in-between), only the first 3 placements from that session were analyzed. Figure 6 shows the resulting rejection rates versus hand reader threshold. The Handkey II deployed at Purdue's RSC was set at a global threshold of 100, therefore the 1-try false reject rate was 2.26%, the 2-try rate was 1.18%, and the 3-try rate was 0.98%. Extremely low 3-try false rejection rates of 0.1% were possible, but only at a false acceptance rate approaching 2%.

The false acceptance rate was estimated by comparing the same 1788 verification attempts against the enrollment database. This is only an estimate, as impostor attempts may be present in the data since the installation was unattended. At the default threshold of 100, the predicted false accept rate was 0.87%.

The large number of gaming attempts, as well as the survey result that 65% of users were excited about hand geometry technology to show their friends how it worked, questions the validity of the unattended dataset. This may account for the discrepancy in performance reported here and claims made by the device manufacturer. The authors made a best-effort attempt to identify all gaming of the system, but if 17 placements went undetected, the FRR would be overstated by more than 1%.

Unique characteristic performance analysis

During image analysis, it was noticed that there were problematic attempts. These attempts were classified into 3 categories, including: shirt/coat sleeves covering the hand, ring(s) present, improper thumb placement, and little fingers that would not straighten. One-way analysis of variance (ANOVA) tests were conducted on each of the categories to determine if the group had an effect on the score. Results were compared based at alpha = .05.
The first ANOVA tested attempts with rings versus attempts with no rings. The results stated that there was not a significant difference between scores for attempts with rings and without rings, $F(1, 1686)=.11$ (p=.743), however larger rings were problematic as they fused multiple fingers together changing the silhouette of the hand. Moreover, there was a significant difference between correct and incorrect thumb placement on the score, however only 6 verification attempts were recorded. The mean scores for correct thumb placement attempts was 39.9 (standard deviation of 173.7) and 1125.2 (1145.6) for incorrect thumb placement attempts.

Slight variations in the angle and a slight angle of the fingers were easily determined by examining multiple images of a user. There was a significant difference between the 40 attempts with shirt/coat sleeves covering the hand and those attempts without a sleeve present, $F(1, 1665)=173.27$ (p=.0000). Mean scores for shirt/coat sleeves were 767.6 (760.8) and 39.8 (173.7) without a shirt/coat sleeve covering the hand. The last analysis looked at one particular user who had difficulty straightening out their little finger. The mean (and standard deviation) for these attempts was 133.1 (101.8), causing false rejections at a threshold of 100. In a real world deployment, this user would obtain a special threshold setting to accommodate their variable hand placement.

**Demographics and performance**

A statistical analysis was also conducted on gender versus the score and prior hand geometry use versus the score. The results revealed that there was no significant difference between gender and score, $F(1, 1840)=.73$ (p=.48). Moreover, the mean and median for gender were approximately the same – 50.6 and 49.6 for females and males respectively. However, there was a significant difference between the scores of subjects who used hand geometry prior to this study and those who had not $F(1, 1840)=5.90$ (p=.003). In particular, the mean score for subjects who had used hand geometry before was 25, compared to 62.1 for those who had never used hand geometry prior to this study. This is expected as users who had used hand geometry prior to this evaluation have been habituated with the device for a period of time, whereas the rest of the test subjects had never used the device and had a longer acclimation period.

**CONCLUSION & FUTURE WORK**

The data presented here suggest that participants were accepting of hand geometry at Purdue University’s Recreational Center. Analyses of the participants’ survey responses revealed that 93% liked using hand geometry, 89% thought the technology was easy to use, and 87% preferred hand geometry to the existing card-based system, while nobody thought the device invaded their personal privacy.

System performance in this study of 129 subjects suggest that hand geometry would be an appropriate fit for this AC application. The FTE was 0% as all users were able to enroll. However, it will be interesting to continue data collection to see the reactions of users and system performance in a longitudinal evaluation. Furthermore, the individual analyses reveal that either more training or stricter policies for subjects interacting with the device need to be implemented for some users, as roughly 100 attempts deviated from the training that was given.

The complexity of analyzing an unattended system was noted throughout this paper, specifically the difficulty of differentiating a genuine attempt, a genuine “game” attempt, and an impostor attempt. These difficulties call into question the validity of the performance data in Section 7.1. In addition, the authors will provide these questions to groups such as ISO/IEC JTC1 SC37 to seek guidance for future operational tests, including treatment of impostor and “gaming” attempts that may have corrupted the data. Such guidance is critical to generating meaningful performance curves for operational tests in the future. Recommendations for future research would be to include a monitoring device in the evaluation area to assess who is actually using the device, differentiating genuine users from those “gaming” the device and impostors. This would assist in quantifying the number of attempts attacking the system, so the FAR and FRR could be calculated with higher confidence.

**REFERENCES**


UWB Radar for Human Being Detection

A.G. Yarovoy & L.P. Ligthart
Delft University of Technology
&
J. Matuzas & B. Levitas
GeoZondas, Ltd.

ABSTRACT

UWB radar for detection and positioning of human beings in complex environment has been developed and manufactured. Novelty of the radar lies in its large operational bandwidth (11.7GHz at −10dB level) combined with high time stability. Detection of respiratory movement of a person in laboratory conditions has been demonstrated. Based on experimental results human being radar return has been analysed in the frequency band from 1 GHz to 2 GHz. Novel principle of human being detection is considered and verified experimentally.

INTRODUCTION

Ultra-wideband radars are used nowadays for different applications such as subsurface sensing, classification of aircrafts, collision avoidance, etc. In all of these applications the ultra-high resolution of UWB radars is essentially used. One of these applications is detection of humans trapped in buildings on fire, in collapsed buildings or avalanche victims. Despite of relatively small scope of this application, it has large social importance. Very similar to the human detection application is another UWB radar application, namely remote cardiography (measurements of heart beatings). Both applications are based on similar principles.

Detection of human beings with radars is based on movement detection. Heart beating and respiratory motions cause changes in frequency, phase, amplitude and arrival time of reflected from a human being electromagnetic wave. Generally speaking, the changes of amplitude are negligible. Therefore only frequency, phase and arrival time changes can be used for human being detection. Based on these three features different radar systems have been developed: Doppler radars [1], interferometric radars [2, 3] and video impulse radars [4, 5]. While the Doppler and interferometric radars are narrow band systems, the video impulse radars are ultra wideband (UWB) systems. UWB radar has several key advantages over continuous wave radars:

1) The pulse has a wide frequency spectrum that can easily pass through obstacles.
2) The pulse duration is very small that it has a very high resolution.
3) The short pulse leads to the low energy consumption.
4) It possesses good immunity against multipath interference.
5) It allows not only detect presence of a human being, but also position it.

Two last advantages of UWB radars have not yet been proven experimentally.

In this paper we present development of UWB radar for human being detection and localization in complex environment (building on a fire or collapsed building). Novelty of the radar lies in its large operational bandwidth combined with excellent time stability. Together with a novel principle for motion/breathing detection based on UWB radar return, the above-mentioned hardware features result in reliable instrument for human being detection in complex environment.

DESCRIPTION OF THE RADAR

The radar consists of a pulse generator, a pulse shaper, a sampler unit, a sampling oscilloscope and a control PC. The sampling oscilloscope synchronizes the sampling unit and the pulse generator using trigger pulses. Using a GPIB (General Purpose Information Bus), the measured time signal is
transferred to a PC where the data is stored for later processing and analysis.

The system bandwidth (as it has been determined by external calibration on metal) equals 11.7 GHz (at -10 dB level) (Figure 1). From formal point of view, such a bandwidth results in a resolution of about 1.3 cm in free space, which should be just sufficient for detecting small motions of human chest due to breathing. Furthermore, the operational bandwidth (as determined at -10 dB level) of the radar starts from 0.9 GHz. This leads to increase of the magnitude of a signal reflected from a human being (see [5]) and improves penetration through walls and/or rubble (which is of importance for e.g., earthquake victim detection).

For the radar for human being detection the second (after the bandwidth) important design issue is choice of the pulse repetition frequency. It affects unambiguous range of the radar (which should be of about 30 m at least) and single signal measurement time (which should be of about 5 times shorter than the average breathing period). The time needed for measurement a single reflected signal depends on the pulse repetition frequency, number of samples in the recorded signal and the averaging (stacking) number. For keeping the power budget of the system sufficiently high, high averaging number is desirable. Optimization of these parameters led to a selection of 10 MHz as optimal pulse repetition frequency.

Time stability is third important parameter of the system. The detection can be done based on a series of signals recorded within a short period of time. Within this period of time the system drift should be considerably smaller than a sampling time (which is of about hundreds of femoseconds). Due to use of internal calibration circuits the radar instability is characterized by a time drift of about 5 ps per hour.

Power budget of the radar is determined by the generator output and noise level of the sampling scope. By averaging 256 the power budget equals 100 dB.

**Fig. 1. Spectrum of the probing signal**

**Fig. 2. Example of a UWB pulse reflection from a breathing person. Vertical polarization**

**Fig. 3. Example of a UWB pulse reflection from a non-breathing person. Vertical polarization**

Linear dynamic range of the radar is determined by the maximum peak-to-peak voltage (it reaches 2 V), and the maximum RMS noise (i.e., quantization noise) of the oscilloscope is about 4 mV (without averaging). So without averaging the dynamic range equals 54 dB and with averaging 256 the dynamic range increases up to 78 dB.

**SCATTERING FROM A HUMAN BODY**

In the initial measurements a person has been positioned vertically at the distance of about 2.6 m in front of the antenna systems. Such distance allows isolate in time signals due to transmit-receive antenna coupling, reflections from this person and reflections from environment (clutter). The radar worked
in the continuous mode (each new signal has been acquired immediately after previous one). Averaging 16 has been used in all measurements.

Several sets of 256 signals have been acquired. Some sets correspond to a normally breathing person (Figure 2), while during acquisition of other ones the person kept his breathing (Figure 3).

It can be seen that the radar is capable to detect range variations due to respiratory movements. During one breathing cycle of about 22 signals have been recorded by the radar, which seems to be sufficient in order to observe respiratory movements.

Typical reflected from a person signals for inflated and deflated lungs are shown in Figure 4. Due to high dielectric permittivity and high ohmic losses of a human body [5], the reflected signal is mainly determined by the front reflection. Spatial variations of the chest position due to breathing are clearly observed and have a magnitude of about 0.6 cm. Despite of the fact that these variations are two times smaller in amplitude than the formal downrange resolution of the radar, these spatial variations are clearly resolved by the radar.

The reflected from a human body signal consists not only from the front reflection but also from signals scattered by other parts of the body and a signal due to a creeping wave, which circumferences around human trunk. The latter is delayed by approximately 1 ns from the front reflection.

Both magnitude and waveform of the reflected signal depends on probing wave polarization. As it can be expected, the front reflection of vertically polarized waves is larger than that of horizontally polarized waves.

as it can be seen from Figure 5 the reflectivity has been recovered for the frequency range much wider than the radar bandwidth as determined at -10 dB level. This is demonstrates that -10 dB level is very much arbitrary chosen and does not determine the full bandwidth, which is actually used by the radar. Practical experience shows that reconstruction of spectral parameters from the radar data can be done up to 26 GHz.
In general it seems that the human body reflectivity and the waveform of the human body response does not contain very specific features, may considerably vary from person to person and depends on position of the body and its aspect angle.

**MOVEMENT DETECTION ALGORITHM**

From the study above it becomes evident that detection of a signal, which is reflected from a human being and arrives within a strong clutter due to multiple reflections from indoor environment, is a difficult issue due to unknown waveform of the signal and unknown time of arrival. Published so far results are based on cyclic variations of the time of arrival of some part of measured signal (Figure 2). Such a detector requires long observation time (at least a few seconds), very dense sampling of the radar return and, probably, human operator supervision. So development of a reliable human being detector is important.

We decided to use a new approach for movement (e.g., breathing) detection, firstly suggested in [6]. The basic idea is based on the fact that the radar return is a sum of the signals, which are reflected from different objects. The interference of these signals results in dips in the spectrum of the radar return at some frequencies. While all reflectors are still, the interferometric picture in frequency domain does not change in time. However if one of the reflectors moves, interferometric minima in the radar return spectrum are not stable in time. Variations of the spectra around interferometric minima are very large and can be easily detected.

The basic idea is demonstrated by measurement results. Spectral variations of 256 recorded radar returns from a metal sheet (normalized to a radar return itself) are shown in Figure 6. In the frequency band from 1 GHz till 12GHz these variations are of about a few percents. At the high frequencies the amplitude of variations increases inversely with frequency due to radar jitter. Spectral variations of 256 recorded radar returns from a breathing person (staying in the same place where the metal sheet was situated) are shown in Figure 7. Large variations are seen at 8 frequencies within the frequency band from 1 GHz till 10.6 GHz. In the contrary to jitter-caused variations, the magnitudes of variations due to movements of the reflector are large then 1. This is can be explained by to increase of the spectral minima of the radar return due to time variations of a signal reflected from a breathing person.

In order to evaluate impact of breathing, spectral variations of 256 recorded radar returns from a non-breathing person (staying in the same place where the metal sheet was situated) are shown in Figure 8. Considerable spectral variations can be seen in the figure. They can be explained by minor movement of a person, who keeps breathing. Magnitude of the variations is decreased in comparison with a breathing case, but is much higher than that one for a "frozen" scenario. So for the suggested human being detector breathing is not of prime importance: the detector can detect a person just due to minor movements.

As the suggested human being detector does not use any range information, it can be potentially used also outside the unambiguous range of the radar. However, if the radar is used not only for detection but also for the positioning of a human being, then the latter can be done properly only within the unambiguous range.

**CONCLUSIONS**

In this paper UWB radar for detection and positioning of human beings in complex environment is presented. Novelty of the radar lies in its large operational bandwidth combined with excellent time stability. Based on experimental results the radar return from a human body has been analysed. It has been shown that due to breathing the range to a person varies within 0.6 cm. The breathing influences the front reflection from
human chest, which is just a part of the radar return from a human body. The reflectivity of a body in the frequency band from 0.5 GHz till 10 GHz decreases with frequency. And for electromagnetic waves polarized along human body the reflectivity is higher than for the waves with orthogonal polarization.

A novel motion/breathing detector has been used in the radar. The detector is based on measurements of radar return spatial variations. The detector does not require separation of a body reflection signal from the background and works reliably in multi-path indoor environment.

Next step in research will be development of an antenna array to be used together with multi-channel receiver. As soon as reflected form a human being signal is detected, direction of its arrival will be determined by simultaneous processing of signals coming from different receive antennas within the antenna array. Finally, the positioning of a human being will be done based on the direction of arrival and time of arrival.

ACKNOWLEDGEMENT

This research work has been partly supported by European Commission within the FP6 STREP project European (project number 004154).

REFERENCES

[1] M. Bimpas, K. Nikellis, N. Parasekevopoulos, D. Economou and N. Uzunoglu,
Development and Testing of a Detector System for Trapped Humans in Building Ruins,
33rd European Microwave Conference,

[2] I. Arai,
Survivor Search Radar System for Persons Trapped under Earthquake Rubble,
Proceeding of the IEEE Microwave Conference,

[3] H. Chuang, Y. Chen and K.-M. Chen,
Microprocessor Controlled Automatic Clutter-Cancellation Circuits for Microwave Systems to Sense Physiological

Fig. 8. Spectral variations of a radar return from a non-breathing person

Movements Remotely through the Rubble,
Proceedings of the IEEE International Conference on Instrumentation and Measurement Technology,
pp. 177-181, February 1999.

[4] G. Ossberger, T. Buchegger, E. Schimbach, A. Stelzer and R. Weigel,
Non-Invasive Respiratory Movement Detection and Monitoring of Hidden Humans Using Ultra Wideband Pulse Radar,
Proceedings of the International Workshop on Ultrawideband Systems and Technologies,

[5] C. Gabriel,
Compilation of the Dielectric Properties of Body Tissues at RF and Microwave Frequencies,

[6] S. Efremov and B. Levins,
On application of a Pulse Method in Detecting the Living Objects,
GMTI Along-Track Interferometry Experiment

Elaine Chapin & Curtis W. Chen  
California Institute of Technology

ABSTRACT

Synthetic aperture radar (SAR) along track interferometry (ATI) has been used extensively to measure ocean surface currents. Given its ability to measure small velocities (~10 cm/s) of relatively radar-dark water surfaces, there is great potential that this technique can be adapted for ground moving target indication (GMTI) applications, particularly as a method for detecting very slow targets with small radar cross-sections. In this paper we describe preliminary results from an ATI GMTI experiment.

The SAR data described herein were collected by the dual-frequency NASA/JPL airborne radar in its standard dual-baseline ATI mode. The radar system imaged a variety of control targets including a pickup truck, sport utility vehicles, passenger cars, a bicycle, and pedestrians over multiple flight passes. The control targets had horizontal velocities of less than 5 m/s. The cross-sections of the targets were not purposely enhanced, although the targets' reflectivities may have been affected by the existence of the GPS equipment used to record the targets' positions. Single-look and multiple-look interferograms processed to the full azimuth resolution were analyzed. In the data processed to date, all of the targets were observed by visual inspection at least one of the four combinations of dual-frequency, dual-baseline interferometric data. This extremely promising result demonstrates the potential of ATI for GMTI applications.

INTRODUCTION

Along-track interferometry (ATI) is an interferometric synthetic aperture radar (SAR) technique for mapping the line-of-sight velocities of surface targets [1]. Because velocity-measurement accuracies of a few centimeters per second have been achieved in oceanographic contexts with this technique, ATI holds great promise for ground moving target indication (GMTI). The processing algorithms and performance models used for oceanographic applications do not necessarily apply to the case of detecting moving targets amidst clutter, however. In the oceanographic case, the entire ocean surface acts as a single large target moving at a nearly uniform velocity, whereas in the GMTI case, the objective is the detection of dim, discrete targets against a stationary background.

Unlike the widely-used cross-track interferometric SAR techniques that are able to map surface topography by utilizing data acquired from phase centers separated in the elevation or across-track direction on a moving platform, ATI techniques involve the acquisition of data from phase centers that are separated in the direction of the SAR flight path. SAR images formed from these two phase centers are therefore characterized by a temporal baseline equal to the time required for the platform(s) to travel the distance of the along-track offset (i.e., the physical baseline) between the two phase centers. Thus, while stationary elements of the imaged scene contribute identically to the two images, moving targets in the scene exhibit phase shifts between the two images. An interferogram formed from the two complex SAR images consequently depicts surface movements in the imaged scene, and the system can be made very sensitive to small velocities with the use of a long interferometric baseline.

In addition to their sensitivity to low target velocities, ATI systems can also be made very sensitive to targets with low radar reflectivities. This is because the SAR ATI technique makes use of long coherent integration times that reduce the amount of clutter competing with any given target. An unresolved target of interest competes only with the clutter in a single image pixel, so with appropriate SAR resolution, high signal-to-clutter ratios can be achieved. ATI thus offers the capability of detecting targets too dim to detect by other means. Such long coherent integration times are often not possible with space-time adaptive processing (STAP) techniques in which the coherent processing intervals are limited by sample-support restrictions.

Moreover, ATI techniques are less sensitive to channel mismatch than other GMTI techniques. ATI techniques do not cancel clutter through the complex subtraction of two signals.
as STAP and displaced phase center antenna (DPCA) techniques do. ATI techniques rely on a conjugate-product operation and involve only two channels, so algorithms for correcting channel bias, topographic effects, etc. are simpler, more efficient computationally, and less demanding of sample support.

While previous ATI experiments relying on oceanographic models have reported anecdotal observations of targets of opportunity or detections of radar-bright targets whose reflectivities were artificially enhanced by retroreflectors [2], little experimental work has addressed the problem of detecting slow, dim, discrete ground targets. To evaluate the suitability of the ATI technique for detecting such objects, we performed a proof-of-concept demonstration utilizing airborne SAR data. In this paper we describe the experimental set-up for the demonstration and the encouraging preliminary analysis and results.

**EXPERIMENTAL SET-UP**

The radar data discussed in this paper were acquired opportunistically as "piggy-back" collections during four routine calibration flights of the NASA/JPL AIRSAR system [3,4] on 26 February 2004, 15 April 2004, 17 September 2004, and 6 December 2004. A total of thirteen passes of data were acquired. During each pass, 40 MHz range-bandwidth stripmap SAR data were collected simultaneously at both C-band and L-band from multiple phase centers separated along the fuselage of the NASA DC-8 platform. Figure 1 shows a photograph of the plane and the locations of the C-band and L-band antennas used for along-track interferometry. The fully processed SAR image data have a range resolution of 3.75 m and an azimuth resolution of 85 cm. The C-band and L-band along-track physical baselines are 1.9 m and 19.8 m, respectively. Typical platform velocities are 200 to 215 m/s and typical pulse repetition frequencies are 1 kHz. The plane normally flies 8 km above the imaged surface. For twelve of the thirteen passes, the pulse transmissions from the fore antenna were interleaved with the pulse transmission from the aft antenna on a pulse by pulse basis while the pulse echoes were received by both antennas for every pulse. This is done simultaneously for both frequencies. The resulting data allow for full-baseline and half-baseline (as well as zero-baseline) interferometric combinations of the phase centers to be synthesized for both frequency bands.

The collections imaged control targets and targets of opportunity moving amidst a relatively radar-dark scene. The experiment was performed in the Mojave Desert south of the NASA/JPL AIRSAR calibration test site at Rosamond Dry Lake and north of Lancaster, California—a rural area with very little vegetation. Ten of the thirteen passes view the background scene from the west with very similar imaging geometries. The remaining passes view the same scene from the east with very similar imaging geometries. The passes were repeated and oriented this way to facilitate signal-to-clutter and signal-to-noise calculations for the control targets which will be done as follow-on work.

**DATA ANALYSIS**

A variety of control targets including ordinary passenger cars, sport utility vehicles, a pickup truck, a bicycle, and pedestrians were deployed as control targets. During each pass of radar data, between one and five control targets were imaged. Each control target was equipped with a precision global positioning system (GPS) unit and operated slower than 5 m/s. Figure 2 shows one of the control targets and the character of the scene's terrain and vegetation. Although the cross-sections of the control targets were not deliberately enhanced, the GPS equipment used to record the control targets' positions may have increased the targets' backscatter. All of the control targets operated on paved rural roads. The grid of roads at the test site is approximately aligned along track and across track, and some control targets were imaged traveling in both directions.

We have performed a preliminary analysis of four of the passes of radar data, and the initial analysis is very encouraging. The passes' data were processed using JurassicProk, JPL's advanced interferometric SAR processor for airborne data [5]. We have examined the SAR imagery and both single-look and multiple-look interferograms for both the full- and the half-interferometric baselines at both frequencies.
Fig. 3. Sample four-look C-Band full-baseline along-track interferogram showing a control target. Increasing range is to the left of the image. The aircraft's flight direction is down the page. The area represented covers 1630 m in range and 1060 m in azimuth.

We have processed data to the full available azimuth resolution at the Doppler centroid of the stationary background, although future work may involve evaluating the impact of different azimuth integration times on target detectability. For the slow velocities of the control targets, however, the Doppler spectra of the targets are expected to match the Doppler spectrum of the stationary background fairly well.

Before attempting to develop a target detection algorithm, we have attempted to answer the more basic question of whether a human observer is able to detect the signatures of the moving targets upon visual inspection of the interferometric data. Consequently, our data analysis thus far has consisted primarily of visual inspection of the single-look and multiple-look interferograms. We have used the GPS data of the control targets’ positions and velocities at the imaging times to compute the expected positions of the targets in the interferograms, accounting for the apparent shift of the moving targets in the SAR imagery [6].

The motor vehicle targets moving predominantly perpendicular to the flight direction were easily visible in both the C-band and the L-band interferograms. These targets had radial velocities of 2 to 3 m/s, corresponding to multiple cycles of the interferometric phase for the longer along-track baselines. The targets appear at the expected positions in the slant plane data products displaced in azimuth from their nominal GPS positions in proportion to their radial velocities.

Figure 3 shows a sample four-look interferogram containing the control target shown in Figure 2 while it was moving roughly perpendicular to the flight direction. The brightness of the image represents magnitude, which is approximately proportional to the amount of signal energy backscattered to the radar. Agricultural fields and roads are visible in the magnitude imagery. The color superimposed on the brightness image represents the interferometric phase. The blue-green color indicates a constant background phase value for the stationary background scatterers in the scene. Objects with suitable line-of-sight velocities appear as different colored dots. The dots should appear shifted in the along-track direction (vertically in the images here) relative to the stationary background. The expected shift can be calculated if the range to the target, the velocity of the radar, and the velocity of the target are known [6]. In Figure 3, the purple dot displaced in azimuth above the road near the center of the image in range is the control target.

Figure 4 shows C-band and L-band single-look interferograms for both of the non-zero interferometric baselines that can be synthesized because the antenna used for transmit was alternated. Each interferogram is centered at the expected location of the control target shown in Figures 2 and 3. As with Figure 3, the brightness indicates the magnitude, and the color indicates the interferometric phase. The phase offset of the target is different in each of the four cases because of differences in the effective interferometric baseline. The target appears more smeared in the L-band interferograms than in the C-band interferograms. This is likely due to deviations of the target motion from linear, which cause misfocusing of the target in azimuth, and the longer L-band integration period.
Fig. 5. Full-baseline L-band interferogram centered at position of a target moving predominantly in azimuth. The area imaged covers 1524 m in range and 1025 m in azimuth. The pickup truck shown in Figures 2, 3, and 4 appears as the orange dot in the upper right corner of the image.

Fig. 6. Example of interferograms of a control target moving predominantly in azimuth. The figure is in the same format as Figure 4.

The coherent integration times for the C-band and L-band data are approximately 2 s and 8 s.

The cars and trucks moving predominantly parallel to the flight direction have much lower radial velocities (e.g., 10 cm/s). They were detectable only in the shortest baseline L-band interferogram, the interferometric pair with the highest sensitivity to velocity. These targets appear at the expected positions in the slant plane imagery although they are visibly smeared. Such smearing is expected because the along-track component of the target motion gives rise to a mismatch between the target phase history and the reference phase history used for azimuth compression.

Fig. 7. Photograph of bicycle control target operating during 15 April 2004 experiment. The target’s GPS equipment is mounted on and in the child carrier.

Fig. 8. Interferogram chips showing the bicycle. The figure format is the same as Figure 4.

Figures 5 and 6 show an example of a control target, in this case a Subaru Legacy station wagon, moving approximately parallel to the flight direction. For this case the radial velocity of the target was 11 cm/s although the horizontal velocity of the target was 2 m/s. The target is visible as the purple dot near the center of the four-look interferogram in Figure 5. Figure 6 shows portions of the single-look interferograms for all four interferometric pairs. The target is not detectable in the C-band interferograms where the ambiguous velocities are 5.9 m/s and 3.0 m/s, respectively, for the half-baseline and full-baseline interferometric pairs. Because the ambiguous velocities for the
L-band cases are 2.4 m/s and 1.2 m/s, the target's phase is more significantly offset from the stationary background making the target visible in the full-baseline L-band data. Comparing Figures 4 and 6, it is clear that the target moving predominantly parallel to the flight track is more smeared than the target moving predominantly perpendicular to the flight track as expected.

In order to examine the limits to which the ATI technique can afford the detection of slow, dim targets; we also deployed a bicycle and pedestrians as control targets. Figure 7 shows a photograph of the bicycle control target. The bicycle was towing a trailer which carried the GPS equipment. Note that parts of the bicycle that were not moving in a nearly linear fashion (e.g., the wheels and pedals) would not be expected to focus well in the SAR data, so the target signature of Figure 7 is likely due to scattering from the aluminum frames of the bicycle and the trailer, from the GPS equipment, and perhaps, from the rider's body. The bicycle had a horizontal velocity of approximately 3 m/s and a radial velocity of 1.5 m/s at the imaging time corresponding to the single-look interferograms shown in Figure 8. Because of the target's low reflectivity and the relatively coarse range resolution of the radar data, the bicycle does not have a signal-to-clutter ratio sufficient for it to be visible in the multiple-look interferograms. The bicycle target is visible in the single-look interferograms at both C-band and L-band. (Note that spatial averaging does not enhance the detectability of the target because the target occupies only one resolution cell.) The bicycle target is most clearly visible in the C-band full-baseline interferogram because the bicycle's radial velocity corresponds to an approximately 180° phase offset from the stationary background for this baseline. For this baseline, the bicycle appears as a red dot at the center of the image.

To test the detectability of even slower targets, we also used pedestrians as control targets. Figure 9 shows a photograph of a pedestrian pushing a cart instrumented with high precision GPS equipment. The horizontal velocity of the pedestrian was 1 m/s. The cart consists of a steel frame with upper and lower decks made of wood. The cart may have a strong radar reflection, especially at the L-band wavelength, because of double-bounce phenomena of the VV-polarized signal associated with the vertical members of the cart frame and the flat horizontal surface of the paved road.

Fig. 10. L-Band interferograms imaging the pedestrian pushing the electronics cart. The image on the left corresponds to the interferometric pair with the shorter baseline while the image on the right corresponds to the longer baseline. Each interferogram displays 216.5 m in range and 40.625 m in azimuth. For each chip, range increases across the page while platform flight direction is down the page.

Preliminary results for the pedestrian targets are very encouraging. Figure 10 shows the L-band interferograms imaging the pedestrian pushing the electronics cart. Given the low radial velocities, we only expect to see the pedestrian targets in the L-band interferograms since they have smaller ambiguous velocities. Comparing Figures 7 and 9, the pedestrian target is more smeared in azimuth than the bicycle. The smearing may be caused by nonlinear movements of the target or by a greater degree of internal motion for the human pushing the cart compared with the bicycle. As expected given its small radial velocity, the target is more easily detected in the full-baseline interferogram.

CONCLUSIONS AND FUTURE WORK

ATI has potential as a technique to detect ground moving targets with velocities that are too low and cross-sections that are too small for other methods. We have conducted an airborne flight test to evaluate this potential. Preliminary analysis of the test data is promising. For this analysis, we formed full resolution interferograms for both available interferometric baselines at both the C-band and L-band frequencies. All of our control targets (cars, sport utility vehicles, a pickup truck, a bicycle, and pedestrians) are detectable upon visual inspection of the interferograms. This result is very encouraging, implying that automated detection may be possible.

The work done thus far is preliminary and does not fully exploit the rich data set or the full capabilities of ATI processing. Only four of the data takes have been evaluated. The processing done on the data thus far has produced the standard oceanographic products. Future algorithmic work includes optimizing the processing to enhance the detection probability and developing detection algorithms. Target and clutter phenomenology will be addressed after the full set of flight lines have been processed and both the control targets and the faster moving targets of opportunity have been
evaluated. The processed data will also be used to refine and verify performance models.

Our experiment has revealed the suitability of ATI GMTI for slow, dark targets. This rich data set has given us a peek at what possible future ATI systems, more suitably designed for detecting ground moving targets, may be capable of.

ACKNOWLEDGEMENTS

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The authors thank Michael Fitzsimmons, Scott Hensley, Michael Jourdan, Charles Le, Thierry Michel, Charles Morris, Ron Muellerschoen, Paul Rosen, Scott Shaffer, and the JPL AIRSAR group for their help in conducting the airborne experiment and processing the data.

REFERENCES

[1] R.M. Goldstein and H.A. Zebker,
Interferometric Radar Measurement of Ocean Surface Currents,

Traffic Monitoring Using SRTM Along-Track Interferometry,

Y. Leu, G. Alberti, S. Vetrella and A. Cucci,
The TOPSAR Interferometric Topographic Mapping Instrument,

[4] D.A. Imel,
AIRSAR Along-Track Interferometry Data,

Improved Processing of AIRSAR Data Based on the GeoSAR Processor,

[6] C.W. Chen,
Performance Assessment of Along-Track Interferometry for Detecting Ground Moving Targets,
Low Cost X-Band Power Amplifier MMIC

Wolfgang Bösch, James G.E. Mayock, Matthew F. O'Keefe & Jason McMonagle
Filtronic plc

ABSTRACT

A family of X-Band MMIC power amplifiers using a low cost GaAs pHEMT process is reported. The stepper-based volume 0.5 micron and 0.25 micron GaAs pHEMT processes utilize 4 inter-level metallisation and four dielectric layers for high frequency performance whilst maintaining the economies of scale of 150 mm (6") diameter substrates. The fabricated GaAs X-Band PA MMICs exhibit 5W to 10W RF output power under pulsed conditions; 16dB of power gain and power added efficiencies approaching 40%. Excellent repeatability and high yields over a number of wafers have been demonstrated. The design and GaAs process approach taken here with DUV stepper and 150 mm wafer diameter will lead to a significant cost reduction for high performance power amplifier MMICs up to 30GHz.

INTRODUCTION

There is a continuous drive to reduce the cost and weight and improve the performance of T/R modules for airborne radars. One of the key components in the modules is the high power amplifier, which may need to deliver power output in excess of 10W. A Microwave Monolithic Integrated Circuit (MMIC) approach is particularly well suited to this application because of the small size and weight and the ability to manufacture with a repeatable performance in high volumes.

There are a number of key design issues for power amplifiers in radar applications. The major drivers are to improve the efficiency in order to reduce the DC power requirements and also ease the thermal management, and to obtain a rugged repeatable design, which will result in good electrical yields and lower fabrication costs [1].

The Filtronic proprietary FD05 and FD25 GaAs pHEMT processes offers a good solution to meet these demands. The pHEMT process exhibits adequate gain, good power densities, excellent ruggedness and repeatability, high yields, and low manufacturing cost. In particular the stepper-based technology offers good reproducibility and the large wafer size (150 mm) a low cost base even at moderate volumes for high performing applications.

Fig. 1. Image of circuit fabricated using FD25

FD05 - 0.5µm pHEMT PROCESS

The Filtronic 6" (150 mm) pHEMT technology, based on an AlGaAs/InGaAs/GaAs structure, is grown by MBE. The active portion of the device consists of an undoped InGaAs channel sandwiched between two silicon planar doping layers, separated from the channel by unintentionally doped AlGaAs spacer layers. The structure has doped cap layers optimized to simultaneously achieve low resistance ohmic contacts whilst maintaining high breakdown voltage. The device fabrication uses a selective Inductively Coupled Plasma (ICP) dry etch chemistry to achieve high uniformity of pinch-off voltage over the full area of the 150 mm wafer. ICP etch technology has the advantage over conventional RIE technology in that ICP enables the user to control ion energy and ion density independently. This is very important for applications requiring minimal critical dimension (CD) growth coupled with minimal plasma damage.

NiAuGe ohmic contacts and TiPtAu gate, local interconnects, and interlevel metallizations provide external
Table 1. Typical Transistor Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>FD05</th>
<th>FD25</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{\text{MAX}}$</td>
<td>Maximum current</td>
<td>500</td>
<td>550</td>
<td>mA/mm</td>
</tr>
<tr>
<td>$I_{\text{DSS}}$</td>
<td>Drain Current</td>
<td>250</td>
<td>280</td>
<td>mA/mm</td>
</tr>
<tr>
<td>$V_{\text{BVD}}$</td>
<td>Breakdown Voltage</td>
<td>20</td>
<td>16</td>
<td>Volts</td>
</tr>
<tr>
<td>$f_{T}$</td>
<td>Transition Frequency</td>
<td>20</td>
<td>50</td>
<td>GHz</td>
</tr>
<tr>
<td>$G_{\text{MAX}}$</td>
<td>Max Available Gain @ 10GHz</td>
<td>15</td>
<td>18</td>
<td>dB</td>
</tr>
<tr>
<td>$V_{\text{P0}}$</td>
<td>Pinch-off Voltage</td>
<td>-1.0</td>
<td>-1.0</td>
<td>Volts</td>
</tr>
<tr>
<td>$I_{\text{OSS}}$</td>
<td>Gate-source leakage</td>
<td>-1</td>
<td>-1</td>
<td>$\mu$A/mm</td>
</tr>
<tr>
<td>$g_{m0}$</td>
<td>Intrinsic transconductance</td>
<td>400</td>
<td>500</td>
<td>mS/mm</td>
</tr>
<tr>
<td>$R_{on}$</td>
<td>On Resistance</td>
<td>2</td>
<td>2</td>
<td>Ohm/mm</td>
</tr>
</tbody>
</table>

connects. A “T” gate metal technology ensures a very low gate resistance.

Silicon nitride layers provide encapsulation and capacitor dielectric. Several dielectric films are used facilitating the formation of different capacitances per unit area. These films of silicon nitride (SiN)x are deposited by means of plasma enhanced chemical vapor deposition. During the process each of the films has an important role to play and only the combination of all layers provide best performance. All deposition processes were developed to minimize stress that is directly related to dispersion and RF performance and hydrogen content that influences life time. Particular attention has been paid to these processes to achieve high reliability and environmental protection. An optional protective overcoat layer provides handling robustness.

Dry etch processing is also used for the through-substrate via process module. Optimization of this process required excellent across wafer uniformity and accurate end-point detection. Wafer throughput is high and over 50 wafers a day may be processed in a single chamber. Maintaining a high selectivity to resist also ensures a high via yield and small feature size.

Resistors are provided using both epitaxial layers and TaN thin films. All fabrication processes provide a zero handling environment [2, 3] to achieve high yields and uniform characteristics.

**FD25 – 0.25μm pHEMT PROCESS**

In addition to these characteristics the 0.25 μm mm-wave pHEMT (FD25) process combines high-power and low-noise operation up to 50 GHz through the epitaxial and cross-section design. Table 1 provides typical transistor characteristics. An extra metal interconnect layer provides three MIM capacitance densities. The “cap-on-via” and “cap-on-source” process assists size compactness and offers low inductance grounds for higher frequency performance. Fine line air bridges produce minimal interconnect capacitance and improved performance. Wafers are thinned to 50 μm for improved thermal and RF performance. Figure 1 shows an image of a power cell fabricated in FD25.

**DESIGN PHILOSOPHY**

The MMIC X-Band power amplifiers were initially designed on FD05 (0.5 micron process) with two stages of gain to meet the required specification of 16 dB. Previous experience with FD05 and load-pull data, which is shown in Figure 2, confirm that CW power densities of greater than 0.6W/mm gate periphery can be achieved at X-band frequencies.

Efficiencies of greater than 50% were achieved by tuning the load further, at the slight expense of output power. Further improvements in efficiency could have been achieved by harmonic tuning at both the gate and drain of the pHEMT, and drain pulsing the device to minimize heating effects, and to operate the pHEMT as per the application. It was decided that the output stage should “see” approximately 35 Ω/mm, in order to obtain a good trade-off between output power and efficiency. This was further validated with large-signal simulations.

![6x100 Power](image)

*Figure 2: Output Power as a Function of Load for a 6 x 100 μm pHEMT (Tuned for Output Power)*

Optimum Conditions

Pin = 16.96 dBm  
Pout = 25.7 dBm  
Efficiency = 41.59%  
R = 57.48+11.65 W

A total gate periphery of 19.2 mm was chosen for the 10 W designs, and a periphery of 9.6 mm for the 5W versions. The output device can be considered as sixteen smaller cells in the 10W design, and eight cells in the 5W design. Each of the cells
consists of a $10 \times 120 \, \mu m$ pHEMT transistor. Shorter unit gate width devices would offer higher gains, but in order to meet the total required gate periphery, more fingers would have been needed which would result in an excessively large MMIC size in the y-dimension of the chip. The gate-to-gate spacing can be reduced to pack the required periphery in a smaller chip size at the expense of thermal performance.

Each individual cell is stabilized at the input of the device by a lossy matching circuit. It is critical to stabilize the cell at the out of band frequencies without losing gain in band [2]. This is of particular importance when using the FD05 process at X-band frequencies and above, where gain is of a premium. The output-matching network provides the optimum impedance transformation and the combining of the individual cells.

The input gain stage consists of four $14 \times 100 \, \mu m$ cells in the 10 W design and two in the 5 W design. Each cell is stabilized with a similar lossy structure to the output cells. The total periphery of the first stage was chosen such that it was sufficiently large to drive the output device into saturation, without being excessively sized such that it's DC power requirement degraded the total efficiency. It was decided to split the input device into distinct cells so that the electrical requirements of the interstage-matching network could be physically implemented. The interstage-matching network was designed such that each of the input cells should see the optimum load to extract maximum output power, and also to provide the signal splitting to feed the individual cells in the output device.

The input-matching network provides the combining of the input driver cells and also provides a good input match to the amplifier. In both the input and output matching networks the effects of the bond-wires were included in the design. Figure 3 and 4 show photographs of the fabricated 5W and 10 W MMICs on the FD05 process.

A very similar design of a 5W X-Band PA was fabricated on the advanced FD25 pHEMT process, capable of providing higher gain and improved bandwidths while maintaining output power and efficiency capabilities. The design procedure was the same for the FD25 designs as described previously for the input, interstage, and output matching networks of the FD05 circuits. The same gate periphery was used for the output stage but a much smaller one was employed for the driver stage. This was because the gain of the FD25 process is much higher resulting in a much lower RF power capability for the driver. A reduced driver size results in the potential for a much
higher efficiency part due to the reduced DC power consumption, with the same level of output power. The load impedances required to extract maximum power for the driver and output devices is similar in both the FD25 and FD05 designs, this is due to the same levels of $I_{md}$ on both processes. The FD25 designs employ the enhanced circuit features such as the cap-on-vias.

**MEASURED RESULTS**

The MMICs were initially measured on-wafer with $V_{ds}$ set at 3V. This is a much lower voltage than the circuit was designed to operate from but gives a good indication of the variation of the MMIC performance on a wafer-to-wafer basis without experiencing any thermal problems. Figure 5 shows the typical performance of the 5W MMIC on the FD05 process with 15-16 dB of small-signal gain and an input return loss better than 10 dB between 9-10 GHz. The input return loss rolls off at the top end, but this is evident in the simulations at 3V, but not at 9V. The output return loss is also better than 10 dB, even with the output circuit matched for power. In Figure 5, the effect of the bond-wires has been added to the measured S-parameters of the MMIC amplifier.

Small-signal measurements have been taken on MMIC power amplifiers across a range of wafers from different lots. Figure 6 shows the variation in gain across 38 devices measured across a single wafer and indicates the excellent repeatability of the process. In this case, none of the devices failed and tight gain variation of less than 1 dB was achieved.

The MMICs have been tested under large-signal conditions at BAE SYSTEMS in both single-ended and balanced configurations. The devices were mounted in radar T/R modules, and tested under pulsed conditions (10% duty cycle). Figure 7 shows the performance of a balanced pair of 5W MMICs on the FD05 process. An output power of 10 W was achieved between 9-10 GHz, with an efficiency of approximately 35% including the package and combining losses. The bare MMIC was performing at a peak power added efficiency of 44%.

Figure 8 shows the measured performance of a single-ended 10 W design (FCSXPAv20) on the FD05 process. An output power of approximately 10 W was achieved, with a peak efficiency of 40% at the lower edge of the band.

Initial on-wafer small-signal measurements have been carried out on the MMIC amplifiers on the FD25 process. Approximately 17 dB of gain was achieved between 7-11 GHz, with excellent input return losses between 8-11 GHz. The small-signal results measured with a low $V_{ds}$ are shown in Figure 8 (effect of bond-wire included). The measured results
Fig. 9. Small-Signal Results from the X-Band PA realized on 0.25 μm stepper-based pHEMT process show good agreement to the simulated results at the design stage.

The X-band power amplifiers (FD25 process) have been evaluated under both pulsed power and CW conditions. The CW saturated power was measured across a range of frequencies and a best performance of 37% PAE and 5.3W of output power off 9V was achieved at 8.5 GHz. Higher PAEs of 42% were obtained off 7V at the expense of output power. The MMICs were measured under a range of pulsed conditions ranging from 1 to 10% duty cycle. Figure 9 shows the measured performance in terms of PAE and output power for a range of supply voltages for the FD25 designs. A best efficiency of greater than 50% was achieved off a 7V supply and the highest output power of 7W off 9V was obtained. In both cases the measurement frequency was 8.5 GHz.

CONCLUSIONS

High performance X-band MMIC power amplifiers have been developed. Excellent performance has been accomplished with greater than 10 W of output power, and peak efficiency in excess of 40% for designs on Filtronic's 0.5 micron process (FD05). Improved performance has been achieved using Filtronic’s 0.25 micron process (FD25). The PA MMICs were fabricated on a low-cost power pHEMT process, based on 6 inch (150 mm) wafer substrates using a DUV stepper for gate formation. Excellent repeatability and yield has been achieved. The low cost base in combination with the excellent performance has a significant impact on the employment of future phased array radar T/R modules.

Fig. 10. Pulsed Power measurements for the FD25 X-Band MMIC Amplifier

ACKNOWLEDGMENTS

The authors thank the staff of Filtronic Compound Semiconductors for their contribution to the development of this technology; the MMIC design group for their contribution to the design; and BAE SYSTEMS for their design and test support.

REFERENCES


Improved CFAR Performance in the Littoral

Bill Dawber & James Branson
QinetiQ, Ltd.

ABSTRACT

Littoral operation of radars poses severe signal processing difficulties due to the highly stressing, inhomogeneous clutter. This report describes an initial investigation into the feasibility of utilising site-specific radar modelling to provide a localised estimate of the clutter statistics which can then be used to predict the required threshold to maintain a given false alarm rate. The technique has been applied to littoral clutter recordings obtained from the experimental S-band phased array radar, MESAR2. Results are presented for the technique in comparison with a conventional, non-adaptive, cell averaging CFAR. This paper concludes that significant performance enhancements are possible through the use of this new technique.

INTRODUCTION

This paper describes the results of initial experiments to determine the feasibility of applying locally estimated statistics produced using radar modelling to determine a spatially varying threshold in radar signal processing to obtain a constant false alarm rate (CFAR) in inhomogeneous, littoral clutter.

Radar clutter returns from different clutter types are known to have substantially different statistics [1-4], and yet conventional range cell averaging CFARs apply only a constant threshold multiplier (relative to the local mean).

Figure 1 shows an example of plots recorded from an in-service surveillance radar, collected over a period of about 10 minutes. The varying plot densities are clearly visible with high plot density due to sea clutter returns over the first ~ 20 km and further high densities over the land at beyond ~ 40 km. The regions of high density plots can cause considerable degradation of tracking performance, with poor plot-to-track association, track seduction on to clutter, and a high false track rate.

These problems may be exacerbated in advanced multifunction radars (MFRs), such as MESAR2 [5], where initial surveillance detections are followed by a "look-back" dwell for plot confirmation and then a rapid train of several dwells for track initiation. If clutter produces false plots then these may cause the radar to spend resources attempting to confirm the detections and (if these are correlated on the look-back) then initiating tracks. In regions of high clutter, this may contribute to the radar becoming overloaded and unable to carry out all of its functions in a timely manner. Use of track-while-scan to maintain clutter tracks can mitigate some of these issues, but tracking performance in the regions of high plot densities is still severely degraded.

In order to maintain an approximately constant false alarm rate, a commonly implemented solution is to provide a slow-time feedback loop to adjust the threshold multiplier to maintain a constant overall false alarm rate. This process is typically carried out over large areas and over many consecutive scans to obtain sufficient statistics that wanted targets are not discounted. This "clutter mapping" process is problematic from moving platforms where the clutter may change on a rapid timescale preventing the false alarm statistics from being accurately measured. Regions of strong clutter tend to show spiky intensity characteristics in contrast
to regions of benign clutter. These regions of intense spiky clutter therefore tend to drive the thresholds up, such that where a measurement cell in the clutter map contains a mixture of regions of strong clutter and benign clutter, the strong clutter region will dominate the resultant threshold. In practice, in local areas of high clutter density the thresholds will be too low and in regions of low clutter, the threshold will be too high. The net result is there is reduced sensitivity in the regions of low clutter and a locally high plot density in the regions of high clutter.

This research has investigated the potential to make local estimates of the higher order clutter statistics (the “spikiness”) using site-specific radar modelling so that the threshold can be adjusted from range cell to range cell in an effort to provide a constant false alarm rate over inhomogeneous clutter. The potential benefits of this approach are to provide improved track initiation and maintenance in regions of strong clutter, combined with greater sensitivity in regions of low clutter. In addition, the response time of the radar after turn-on or resuming transmission in regions where sector-blanking has been applied should be much faster, without the need to wait for the clutter map to be established. A further advantage for MFRS will be the avoidance of overload caused by excessive false alarm rates.

Unlike previous research [6-8], which concentrated on using the radar data to form a local estimate of clutter statistics, the modelling approach will limit the impact of targets or noise spikes, which can otherwise lead to high CFAR loss.

ADAPTIVE CFAR TECHNIQUES

Conventional Cell Averaging CFAR

In a “conventional” cell averaging CFAR, the threshold in each range cell is defined by the local estimate of the mean multiplied by an additional constant. The local estimate is calculated using the surrounding range cells as shown in Figure 2, where the guard cells are used to avoid an extended target in the range cell under test affecting the background mean estimation.

The threshold might be a pre-set value, manually adjusted or automatically set by using a feedback loop where the number of false alarms in the sector is counted over many scans (a “clutter map”) and the threshold incrementally adjusted to obtain the required false alarm rate. In this paper, we use values for the window and guard cell lengths of 16 and 2, respectively, either side of the test cell. There are many variations of this basic approach, in particular the mean is typically taken to be the geometric mean (a “log CFAR”). Where a geometric mean is used false alarms can be created at boundaries where the mean level changes. To avoid this problem a “Greatest Of” (GO) rule is usually applied [9] to the geometric means, individually calculated using the data from the in-range and out-range windows around the range cell under test.

Radar Model (NEMESIS) Based CFAR

The Naval Electro-Magnetic Environmental Simulation Suite, NEMESIS [10], is a site-specific radar model which utilises Digital Terrain Elevation Data (DTED) data to predict radar propagation and clutter levels. The model provides a Parabolic Equation solution to Maxwell’s equations to predict propagation factors and incidence angles together with the Naval Environment Clutter and Propagation Specification (NECAPS) [11] model to predict the clutter statistics. NECAPS assumes a Weibull distribution for land clutter and K distribution for sea clutter [12]. The resulting NEMESIS radar return predictions consist of a compound of exponential (from noise) and Weibull (from land clutter) or K (from sea clutter) distributions. In order for accurate modelling predictions to be made, various environmental parameters are required including the wind-speed and direction and refractivity profile, though the latter can be inferred from the real radar returns, as described in [10].

The resulting modelled clutter statistics are then used to produce a spatially varying additional CFAR threshold multiplier to be applied to a conventional cell averaging CFAR. The threshold multipliers are computed using a lookup table, generated by Monte-Carlo modelling of synthetic compound noise-plus-K and noise-plus-Weibull distributions, to produce the required false alarm rate (in this case 1 in 10⁶).

STATISTICAL ANALYSIS OF MESAR2 CLUTTER DATA

This paper is primarily aimed at developing improved detection techniques for future Multi-Function Radars (MFR).
MFRs such as SAMPSON (the MFR being fitted onto the Royal Navy's Type 45 destroyer) will have a higher power aperture product and dynamic range than has previously been available to surface radars, and as such may produce clutter returns with different statistics than have previously been observed with existing radar systems. MESAR2 is an Applied Research Technology Demonstrator developed in collaboration between BAE Systems (now AMS), Roke Manor Research and DERa (now QinetiQ and DSTL). MESAR2 is a multi-function, high power, active phased array radar demonstrator operating at S-band. The data sets used for this analysis were collected as part of a series of trials conducted at the MoD Hebrides Range between January 2000 and November 2001. The radar was located on South Uist approximately 22 m above sea level.

A great benefit of the data sets was that there were very few man-made moving targets in this remote part of the outer Hebrides, which allows an estimate of the false alarm rate to be made without the need for clutter mapping. The data used for this analysis were collected with the radar aligned to the South. Figure 3 shows the general trials site geometry. Radar beams to the left of centre (with respect to the radar field of view, or FOV), corresponded to beams 1-12 at short range are predominantly over land, whilst beams 20-30 were over the sea.

The medium range beams contained a mixture of both land and sea clutter with a group of islands from around 40 to 60 km. The bottom beam radar surveillance data analysed here were from the medium range sector. This consisted of 9 pulse coherent dwells at a variable Pulse Repetition Frequency (PRF) of approximately 3 kHz each with 1024, 60m, range cells, corresponding to a range from 18 to 80 km.

For this analysis, the radar returns have been Doppler processed using a Dolph-Chebychev windowed Fourier transform, with the side-lobe level set to -70 dB. Figure 4 illustrates typical clutter power returns produced in the slow Doppler channel for each of the bottom radar beams.
Table 1. Number of false alarms in MESAR2 data

<table>
<thead>
<tr>
<th>CFAR Type</th>
<th>Number of false alarms (Threshold multiplier set for noise FAR $10^{-4}$)</th>
<th>Additional threshold (dB) to maintain FAR $10^{-4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GO Log</td>
<td>135</td>
<td>12.9</td>
</tr>
<tr>
<td>NEMESIS</td>
<td>37</td>
<td>7.8</td>
</tr>
</tbody>
</table>

The returns from the islands are clearly visible in beams 12 to 18 with some response from the close-in clutter visible in beams 1 to 11. Some variation in the noise level from beam to beam is observable. Figure 5 shows a Weibull paper plot for data from all of the beams. The characteristic dogleg curve indicates a two component Weibull distribution due to noise and clutter.

Using the Graph estimation technique [7] for all of the data, the clutter Weibull $\alpha$ value was 8. For comparison, using data collected just over the islands from beams 16 to 18, $\alpha$ was 9. Taking the data over the sea, beams 19 to 31, $\alpha$ was 2.7. This analysis clearly illustrates the need for spatially varying CFAR processing, as the data is highly inhomogeneous and exceedingly non-Gaussian.

**CFAR PERFORMANCE IN MESAR2 DATA**

SAR2 was modelled at the Hebrides range using NEMESiS. The simulated power returns are shown in Figure 6, normalized to the noise power in the real data. These can be compared with the real returns shown in Figure 4.

In general the model has captured the principal areas of high clutter and is accurate to within about 5 dB, but there are some differences. In particular the range and azimuth sidelobes are too high in the modelled data – it is expected that these will be improved in future modelling. Also there are some small clutter features that do not appear in the modelled data, which are possibly due to sea spikes. Overall the coarse resolution DTED data (level 1, 90m) used in the modelling has also limited the accuracy of the position of the clutter returns. Because the DTED data doesn’t capture all of the details of the radar clutter returns, we have used the real radar data to estimate the local mean level (using a conventional cell averaging CFAR), and only use the modelled statistics to estimate the spatially varying threshold multipliers.

Figure 7 illustrates the NEMESiS predicted threshold multipliers required to obtain a false alarm rate of $10^{-4}$. It can be seen that, as expected, higher threshold multipliers are required in the regions of strong clutter over land, with lower thresholds over the sea.

The NEMESiS threshold multipliers were applied to the MESAR2 data and compared with a conventional GO log cell averaging CFAR. Table 1 illustrates the number of false alarms for the two CFARs when set up to produce a desired FAR of $10^{-4}$ in noise. The table also shows the additional threshold, which would be required to obtain a FAR of $10^{-4}$ in the data.

Table 1 shows that the NEMESiS CFAR has maintained a lower false alarm rate than the conventional GO log CFAR, although it hasn’t managed to fully compensate for all of the clutter induced false alarms.

If we assume a radar system which utilises a clutter map to (slowly) adapt the threshold multipliers over sectors in order to maintain an approximately constant false alarm rate, then the resultant “corrected” threshold levels will be indicative of the detection performance. Figures 8 and 9 show the corrected NEMESiS and GO log CFAR levels, respectively. It can be seen that the corrected NEMESiS levels are generally lower than those of the conventional GO log CFAR over the majority of the data. However, locally over the regions of strong clutter, the NEMESiS CFAR levels are slightly higher than the
conventional CFAR levels. This indicates that detection performance for the same false alarm rate will be better over the regions of low clutter using the NEMESIS CFAR, but locally in regions of strong clutter the GO log CFAR will have slightly better detection capability.

Table 2 lists the mean corrected threshold levels, relative to the GO log CFAR, measured over the entire data set and also measured just over the sea in beams 19-31. It can be seen that the mean threshold levels over the sea are 7.9 dB lower for the NEMESIS CFAR and when measured over all of the data, are 6.7 dB lower.

The impact of these lower thresholds can be seen in Figure 10, which shows the probability of detection as a function of received target power, for Swerling 0 targets.

The figure clearly shows the significant improvement in detection performance brought about by the NEMESIS adaptive CFAR.

CONCLUSIONS

The use of site-specific radar modelling to support adaptive CFARs offers potential for significant improvements in the detection performance of Naval radars operating in littoral environments. Because this approach uses a-priori knowledge of the clutter environment and is not solely reliant on radar returns to deduce the statistical nature of the data, it is far less susceptible to occasional noise spikes and thus does not suffer from the high CFAR losses typically associated with adaptive CFARs. It is also relatively unaffected by the presence of targets within the CFAR window.

These results are preliminary and more research is needed to determine the further benefits of higher resolution DTED and DFAD (texture) databases to improve the modelled threshold levels.

REFERENCES

[1] Billingsley, J.B.,
Low-angle radar land clutter,

Statistical analysis of measured radar ground clutter,

[3] Davidson, G.,
Doppler filtering and detection strategies for multi function radar,
PhD dissertation,

[4] Oliver, C., Blacknell, D. and White, R.,
Optimum edge detection in SAR,

MESAR Multi-function, Electronically Scanned, Adaptive Radar,
Radar 97 IEE Conf. pub. No. 449, pp. 55-60.

[6] Davidson, G., Griffiths, H.D. and Ablett, S.,
Analysis of high resolution land clutter,

[7] Dawber, W. and Branson, J.,
Comparison of CFAR Algorithms in Littoral Radar Clutter Data,
DASP 2004, Conf. pub (to be published).

[8] Blacknell, D.,
Comparison of parameter estimation for K-distribution,

Analysis of CFAR detectors in non-homogeneous background,

Modelling assessment of the Littoral Environment for real-time radar performance assessment,

Naval Environment, Clutter, Attenuation and Propagation Specification,
March 2003, unpublished QinetiQ report.

[12] Watts, S.,
Radar detection prediction in K-distributed sea clutter and thermal noise,

Fig. 10. Probability of detection for Swerling 0 targets

Table 2. Mean Corrected threshold levels

<table>
<thead>
<tr>
<th>CFAR Type</th>
<th>Mean Corrected threshold level</th>
<th>Mean Corrected threshold level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All beams (dB)</td>
<td>Over sea only (beams 19-31) (dB)</td>
</tr>
<tr>
<td>GO Log</td>
<td>51.6</td>
<td>48.7</td>
</tr>
<tr>
<td>NEMESIS</td>
<td>44.9</td>
<td>40.8</td>
</tr>
</tbody>
</table>
Radar Systems Analysis and Design
Using MATLAB – Second Edition

Bassem R. Mahafza
Chapman & Hall/CRC
Taylor & Francis Group
Boca Raton, FL, USA
2005, 639 pages, Hard Cover
ISBN 1-58488-532-7

In Radar Systems Analysis and Design Using MATLAB, Mahafza attempts to create a general purpose radar analysis reference, with the added benefit of provided source code. Mahafza succinctly summarizes the goal of the book in the preface with the following statement:

"There is a need for a comprehensive reference book that can provide the reader with a hands-on-like experience."

His fulfillment of this proclaimed need is this volume, which serves as a generic radar analysis handbook filled with numerous software examples in MATLAB. Whether the concept of such a handbook will be met with open arms depends in part on the execution of this concept by Mahafza.

Bassem Mahafza is currently President of deciBel Research, Inc., in Huntsville, Alabama. While the book lacks a biography of the author, the fact that the author is not employed by a university is of interest. One would expect that his range of experience be quite different from a full-time lecturer. A radar book authored by someone in the private sector might be expected to be concerned merely with "practical" issues, which for hopeful students is lay-speak for "less math." As one flips through the book, however, such expectations are woefully and abruptly annihilated. The book boasts no less than 1190 equations in its 638 pages. In fact, the value of the book rests principally on its emphasis of math and physics, despite the code-centric novelty implied by the title.

However, the key distinguishing feature of this book is clearly the implied emphasis on MATLAB source code, which is provided to illustrate the mechanics of radar analysis from the perspective of simulation. Code samples are scattered throughout the text, such that the full printout of each example appears right in the text. Each code sample takes the form of a MATLAB function, thereby fully encapsulating the algorithm or calculation in a self-contained unit of input-output. In my experience, the practice of quoting source code in pulp texts is limited to computer science publications, in which code listings provide illustrations of language form, syntax, misuse, or standardized practices. Other books, such as the well-known Numerical Recipes series, provide source code implementations to very difficult but common mathematical problems. In this book, however, the extensive code listings probably serve various user needs. The book sans code stands well on its own, as a comprehensive resource on a variety of topics of interest to a radar systems analyst. On the other hand, another user may see the code as the primary product, having the text as a glorified user manual. Taken on its own, the code library can be seen as a multi-purpose MATLAB radar analysis "Toolbox."

According to a statement in Chapter 14, the code itself is available by download from the publisher’s website. However, attempts on my part to locate the code on the website were unsuccessful. Assuming that the code is in fax available online, all the utility of the code is arguably provided without having to refer to listings printed inside the actual text. On the other hand, I have personally known people who visualize numerical flow more easily by reading code. Fortunately, highly dense MATLAB code facilitates this kind of interpretation. Such readers would invariably find the code listings a welcome supplement to the usual mathematical developments.

From the perspective of instruction, an apparent danger with the book's approach is that the math-to-code hand-holding is taken a step too far. A student or junior analyst using the provided tools to design or analyze a radar system need not necessarily develop the requisite skills to translate equations and abstract mathematical ideas into code. This is an absolutely necessary skill to develop if the learner is to be...
expected to implement and understand ideas outside the scope of the book. But to this reviewer, Mahafz's book smells more like a reference book. While the ingredients are there for instructional use (e.g., problem sets at the end of each chapter); on balance the volume is biased toward providing depth and breadth of coverage, at the cost of emphasizing lucidity of instruction for newcomers to the field.

Topical coverage is quite good in this book. Radars are classified as either pulsed or continuous wave, with adequate discussions of waveform characteristics, waveform/target interaction, ambiguity functions, antennas, clutter, and synthetic aperture radar (SAR). Early on, the radar range equation is developed in multiple forms and the fundamentals of signal processing are covered in broad strokes. The signal processing chapter is stylistically dictionary-like, consisting of endless mathematical term-definition pairs (such as Fourier transform, Z-transform, etc.). Such items are treated as mere tools of the trade, so to speak, and are covered in a brutally functional means-to-an-end reference style.

In addition to adequate coverage throughout, appropriate emphasis has been placed on areas not covered by many other texts. For example, the chapter on radar detection is especially well done. It starts out immediately with an I and Q signal model of an envelope detector and proceeds to derive the Rician pdf of the target return in Gaussian noise. The limiting cases of Rayleigh and Gaussian distribution, for weak and strong returns (respectively) immediately follow, providing a concise derivation of one of the most important results for a radar analyst. It then goes on to provide a purely mathematical development of false alarm and detection probability (Pf and Pd), the effects of pulse integration, fluctuating targets, threshold selection, then the classic Swerling and Marcum closed form expressions for detection probability for various fluctuating targets (along with approximations). The concepts of fluctuation loss, cumulative Pd (for search), CFAR, and cell-averaged CFAR complete the chapter. All throughout the chapter, numerous illustrations, figures, and code listings help to convey to the student or practitioner the fundamentals of radar detection.

Anyone familiar with the subject of detection can see that this is an awful lot of coverage in one chapter, especially in the provided mathematical detail. It must be emphasized that a basic education in classical detection theory would be mandatory to fully appreciate (and understand) this chapter. After all, the chapter opens with the statement:

"A simplified block diagram of a radar receiver that employs an envelope detector followed by a threshold decision is shown in Figure 4.1."

Absent is any discussion of the concept of hypothesis testing, Bayesian risk, decision spaces, sufficient statistics, etc. Therefore, without a background in detection theory fundamentals, the reader will not be able to apply the covered topics to real world problems that differ materially from those in the text. Given the breadth of signal processing background covered in Chapter 2, I fail to see how a similar chapter on detection theory could have been omitted. Nonetheless, numerous other examples of conspicuously missing discussions are apparent. For example, the domain of the optimality of matched filtering is not discussed even though Chapters 5-7 focus on waveforms, matched filtering, and pulse compression. For educators, I strongly recommend other texts which focus purely on detection, estimation, and signal processing as a separate course(s) to serve as prerequisites for this material.

The chapter on target tracking is somewhat disappointing, especially considering that tracking is the principal function of most modern radars. The section titles themselves are misleading to anyone with casual familiarity with target tracking terminology. The section entitled "Single Target Tracking" in this book actually refers to tracking a single target with fixed gain filters. The Kalman filter (the workhorse of state estimator) is treated only very tersely. The Extended Kalman filter receives no mention at all. Unfortunately, there is no coverage of important and relevant multitarget tracking topics such as measurement-to-track association, probabilistic assignment algorithms, multiple hypothesis tracking, and other topics worth mentioning in this growing field. Instead, the coverage heavily emphasizes fixed gain filtering, which is mostly limited in usefulness to analysis of a few legacy systems.

On the other hand, the book boasts some strengths. As I mentioned previously, the breadth of coverage in this book is impressive. Chapter 8 (Radar Wave Propagation) is well done, featuring very comprehensive coverage of atmospheric refraction. Chapter 10 contains much welcomed detailed discussions of planar arrays with various geometrical features. Chapter 13 (Radar Cross Section) provides a wonderful presentation of RCS for a multitude of primitive shapes, and also includes a nice overview of methods of computational electromagnetics. This alone is a tremendous contribution, raising awareness and providing much needed depth in a very important area for radar analysis. Finally, access to a complete, basic radar analysis code library can itself have substantial value.

In closing, I recommend this book to any experienced practitioner due to its comprehensive coverage and plentiful code samples. The book contains rich detail in some areas not typically covered in other radar engineering texts (such as Chapter 13). However, my recommendation would not extend to classroom use due to its "cookbook" stylistic tendency. The provided discussions fail to give context, which is typically needed in a successful teaching instrument.

- Paul Burns
  Senior Research Engineer
  Georgia Tech Research Institute
FROM THE EXECUTIVE VICE PRESIDENT

Systems and System-of-Systems

Throughout the defense-oriented part of the industrial sector, there has been a heavy focus on systems, systems engineering, and systems integration, primarily because we have been generally not successful in developing major defense systems over the past decade. Software systems have grown dramatically in size and complexity as software absorbs more functionality for the target system. Systems of all types are expected to work seamlessly with other systems in what we call the system-of-systems environment. Major subsystems initially developed for one application are being rapidly adapted for use on another. Lastly, the complexity of major integrated systems such as destroyers, fighter aircraft, ground combat vehicles and similar is far greater than just a decade ago. And commercial systems such as passenger aircraft are exhibiting similar increases in complexity and functionality.

What results is an extreme demand for systems integrators, systems designers, and systems engineers above and beyond anything we have ever experienced. Defense companies and major commercial companies just cannot hire enough experienced systems engineers, and there simply are not enough to go around. Further, it takes a good 10 to 15 years to grow candidates into solid, multi-disciplined systems engineers, and many electrical/electronics engineers simply aren’t cut out for the true systems work. Couple this with the fact that only graduate programs in the academic environment teach systems engineering, and there are only about 35 or so of those in the US, and the complexion of the problem starts to grow more clear.

What is driving the complexity issue?

Simply stated, it is the fact that the advanced technology now available to us allows us to do more and more, and the user community demands it. As each new airplane, automobile, or ship is developed, we want more out of it. Looking at just the automobile, we find dozens of microprocessors controlling everything from the engine to the transmission to the brakes to the suspension, and then we add the entertainment system, environmental (climate) system, safety system, security system, and controls & display system. The average automobile is so complex that there basically aren’t any more back yard mechanics who can fix the typical car failure.

Did you know that between 50% and 60% of the typical fault (failure) in automobiles today is electronic in nature? And requires costly specialized equipment to troubleshoot? And replacements parts are only available from the dealer as opposed to the neighborhood auto parts store?

Major commercial and defense systems are becoming highly interactive as well, not with just the human operator or user but with other major systems. This aspect of interoperability implies some loss of autonomy of individual systems that are designated to be critically interoperable with other systems. In the defense world, that is now called “Net Centricity” and the implications are enormous. Imagine dozens of separately-developed major systems, some mature and some just being fielded, under the control of different agencies or military services, all of which are now expected to perform an expected function to an external set of commands and provide the specifically requested functionality on demand, reliably and consistently.

Using a definition: System-of-Systems is a federation of semi-independent, semi- or fully-autonomous devices or elements whose integrated collective behavior is loosely connected and usually under different control authority. To implant this system-of-systems environment requires a level of systems engineering and systems integration talent that we have precious few in today’s world.

What are the implications?

Encourage every engineer you know to try systems engineering as the chosen specialty field. Encourage every college engineering student you know to go on to a Masters’ Program in Systems Engineering. Maybe, just maybe, we’ll start to get the talent we need.

— Robert C. Rassa
Executive Vice President,
AESS, 2006
## March 2006
### Distinguished Lecturers Program

**James R. Huddle, Chair**

All AESS Chapters and IEEE Sections are encouraged to take advantage of the AESS Distinguished Lecturers Program for their regular or special meetings. We have selected an outstanding list of speakers who are experts in their fields. The AES Society will cover up to $500 of the speaker’s expenses for travel in North America, with any remaining amount normally covered by the AES Chapter or Section or by the speaker’s organization. For travel outside North America, the AES Society will cover half of the speaker’s expenses per trip, up to a maximum of $1500. The procedure for obtaining a speaker is as follows: If a Chapter or Section has an interest in inviting one of the speakers, it should first contact the speaker directly in order to obtain his agreement to give the lecture on a particular date. After this is accomplished, and if the Chapter or Section wishes to request financial support from the AESS, it should contact James R. Huddle on (818) 715-3264, F (818) 715-3976, j-huddle@ieee.org at least 30 days before the planned meeting, in order to obtain approval for the financial support. The list of distinguished speakers who have expressed their willingness to speak to Chapters or Sections, along with their organization, topics, and telephone numbers, is given below.

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Contact Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Control Technology Applied to Aircraft &amp; Automobiles</td>
<td>Dr. Kinio Kanji, National Defense Academy of Japan</td>
<td>814-45-812-1244 (V&amp;F) <a href="mailto:k.kanji@nrl.nps.navy.mil">k.kanji@nrl.nps.navy.mil</a></td>
</tr>
<tr>
<td>Avionics for Manned Spacecraft</td>
<td>Dr. Myron Kayton, Raytheon Engineering Co.</td>
<td>(310) 392-1819</td>
</tr>
<tr>
<td>Evolution of Aircraft Avionics</td>
<td></td>
<td>(310) 392-1819</td>
</tr>
<tr>
<td>Navigation: Land, Sea, Air and Space</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Hundred Years of Inertial Navigation: Practitioner’s View of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bistatic &amp; Multistatic Radar</td>
<td>Dr. Hugh D. Griffiths, University College, London</td>
<td></td>
</tr>
<tr>
<td>Synthetic Aperture Radar</td>
<td></td>
<td>+44-20-7679-7301</td>
</tr>
<tr>
<td>Current Advances in Radar Technology</td>
<td>Robert T. Hill, Consultant and Lecturer</td>
<td>(301) 262-8792 (V&amp;F)</td>
</tr>
<tr>
<td>Evolution of Inertial Navigation</td>
<td>Dr. Itzhack Bar-Itzhack</td>
<td>+972-4-829-3106</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+972-4-829-2030</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:is@technion.ac.il">is@technion.ac.il</a></td>
</tr>
<tr>
<td>Formal Methods in System Design</td>
<td>Dr. James F. Peters, III, Univ. of Manitoba</td>
<td>(204) 474-7419</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(204) 261-4639</td>
</tr>
<tr>
<td>Future of Electronic Warfare and Modern Radar Signals</td>
<td>Dr. Richard G. Wiley, Research Associates of Syracuse</td>
<td>(315) 463-2266</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(315) 463-8261</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:Dick.Wiley@acr.com">Dick.Wiley@acr.com</a></td>
</tr>
<tr>
<td>Multisensor Data Fusion</td>
<td>Dr. Pranod Varshney, Syracuse University</td>
<td>(315) 443-4013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(315) 443-2583</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:varshney@syr.edu">varshney@syr.edu</a></td>
</tr>
<tr>
<td>National Missile Defense and Early Warning Radars</td>
<td>Larry Chasteen, University of Texas at Dallas</td>
<td>(972) 234-3170</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(972) 883-2799</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:chasteen@udallas.edu">chasteen@udallas.edu</a></td>
</tr>
<tr>
<td>Novel Orbits &amp; Satellite Constellations</td>
<td>Dr. Daniele Mortari, Texas A&amp;M University</td>
<td>(979) 845-0734</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(979) 845-6051 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:mortari@acm.tamu.edu">mortari@acm.tamu.edu</a></td>
</tr>
<tr>
<td>Radar — Past, Present and Future</td>
<td>Dr. Eli Brookner, Raytheon</td>
<td>(978) 440-4007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(978) 440-4040 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:Eli_Brookner@res.raytheon.com">Eli_Brookner@res.raytheon.com</a></td>
</tr>
<tr>
<td>Satellite Communication Systems</td>
<td>Dr. S.H. Durrani, Consulting Engineer</td>
<td>(301) 774-4607 (V&amp;F)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Engineering for International Development</td>
<td>Paul Gartz, Boeing Co.</td>
<td>(206) 954-9616</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:p.gartz@ieee.org">p.gartz@ieee.org</a></td>
</tr>
<tr>
<td>Target Tracking and Data Fusion: How to Get the Most Out of Your</td>
<td>Dr. Yaskov Bar-Shalom, Univ. of Connecticut</td>
<td>(860) 480-4823</td>
</tr>
<tr>
<td>Sensors</td>
<td></td>
<td>(860) 480-2265 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:ybar@engr.uconn.edu">ybar@engr.uconn.edu</a></td>
</tr>
</tbody>
</table>

All data on this page is under the purview of James Howard, VP-Member Affairs.

Please send all corrections and omissions to him at the address on the inside back cover.
FROM THE EDITOR-IN-CHIEF

New Member Grade Available

I'd like to call your attention to the new IEEE Graduate Student Member (GSM) grade and the important role it can play in the long-term successes and contributions to the fields of interest of the IEEE Aerospace and Electronic Systems Society (AESS).

IEEE Regional Activities and the Board of Directors recognized that both the needs and contributions of graduate students who are members of IEEE are different than those of student members working toward their first professional degree. In response, IEEE instituted the GSM grade of membership that will receive more visibility in 2006. In an effort to assist this I'd like to review important aspects of the new GSM grade and related areas of IEEE membership.

First, the Graduate Student Member is defined in IEEE Bylaw I-104.6 thusly: A Graduate Student Member must qualify for Member grade and carry at least 50% of a normal full-time academic program as a registered graduate student in a regular course of study in IEEE-designated fields. The total cumulative period for a member to hold the Student Member grade and/or the Graduate Student Member grade shall be limited to 8 years. Graduate Student Members, upon graduation or upon reaching the total cumulative 8-year limit as a Student Member and/or the Graduate Student Member (whichever occurs first), shall be transferred to Member grade.

There are three important points to take away from IEEE Bylaw I-104.6:

1) GSMs qualify for IEEE Member grade with the rights and privileges of Members: Vote in elections and hold office on committees, Chapters, Sections, and other organizational units (OUs) as highlighted in IEEE Bylaw I-105.

2) The IEEE-designated fields do not restrict student (or other) members to the traditional electrical engineering or computer science department/fields. One critical test used in judging whether education or work is relevant to the six areas outlined: Does it apply? or: Is it related to the application of mathematics, science, or technology for the betterment of humankind?

3) There are no restrictions placed on the employment status of a GSM. (A GSM could be a full-time employee and a part-time student.)

Reinforcing the point made above about IEEE members existing outside the traditional electrical engineering or computer science areas, IEEE Bylaw I-402 defines an IEEE Student Branch and its subunit the Student Branch Chapter as being at a particular college, university, technical institute, or in unusual cases, attached to a Section. This includes the entire campus and is particularly important to note for the AESS fields of interest are frequently taught outside the traditional electrical engineering or computer science departments.

As members of AESS and IEEE, let us embrace this change and look for opportunities to encourage students, professors, or other individuals interested in the IEEE's designated fields to join us in advancing AESS fields of interest and take advantage of the new GSM grade to strengthen existing AESS Chapters and to establish new ones. (Our fields of interest are listed on the inside front cover.)

— Evelyn Hirt

P.S. More details can be found on the IEEE website.

Call For 2006 Education Award Nominations

The IEEE Educational Activities Board seeks nominations for seven awards that recognize IEEE members, pre-university educators, and employers of members who have made noteworthy contributions to education.

The deadline for nominations is 30 April.

For award descriptions, honorarium details, and nomination packets, visit: <http://www.ieee.org/portal/cms_docs/education/EABAwards/index.htm>.

For more information on these awards, contact: "MailTo:eab-awards@ieee.org".

Future Position Vacancy

This IEEE Society is seeking an individual to become the Administrative Editor for our publications, enjoying the work while gathering the knowledge, recognition, and reputation that accrues to the individual filling this position.

Remuneration is provided.

Please contact: Ed Reedy, Vice President-Publications, 2776 Dellinger Drive, Marietta, GA 30062, USA; (678) 557-3044 or (770) 971-2383; ed.reedy@gtri.gatech.edu
IEEE AEROSPACE & ELECTRONIC SYSTEMS SOCIETY ORGANIZATION

OFFICERS

President – James V. Leonard
Executive Vice President – Robert C. Rassa
Secretary – Theodora S. Saunders
Treasurer – Charles H. Gager
Vice President – Administration – Robert N. Trebits
Vice President – Conferences – Barry C. Breen
Vice President – Education – Sajjad H. Durrani
Vice President – Member Affairs – James Howard
Vice President – Publications – Edward K. Reed
Vice President – Technical Operations – James R. Huddle

IEEE ASSOCIATE OFFICERS

Associate Treasurer – Jose R. Bolaños
Associate VP – Administration – Open
Associate VP – Conferences – Inman J. Weinstein
Associate VP – Education – Open
Associate VP – Member Affairs – S. Zafrir Taqvi
Associate VP – Publications – Joel F. Walker

BOARD OF GOVERNORS

Senior Past President — Russell J. Lefevre  Junior Past President — Paul E. Gartz

Members-at-Large

1/1/04 To 12/31/06
Walter D. Downing
Paul E. Gartz
J. Scott Goldstein
Hugh D. Griffiths
Philip Holmer
James V. Leonoud
Tsunee Takahashi
Peter K. Willett

1/1/05 To 12/31/07
W. Dale Blair
Jose R. Bolaños
Barry C. Breen
Robert P. Lyons, Jr.
Robert C. Rassa
Cary R. Spitzer
S. Zafrir Taqvi
Joel F. Walker

1/1/06 To 12/31/08
Ram Gopal Gupta
Evelyn H. Hirt
William Lyons
Ron T. Ogden
Robert N. Trebits
Irmak J. Weinstein
John R. Weynauh
Shanjun Wu

STANDING COMMITTEES

Accomplishments Search – W. Cooper
Awards – Erwin C. Gangl
• M. Barry Carlton Award – W. Dale Blair
• Harry Rowe Minnow Award – Ron Schroer
• Warren D. White Award – Mark Davis
• Pioneer Award – Erwin C. Gangl
• Judith Rosenk IEEE Field Award – Erwin C. Gangl
Chapters – Ron T. Ogden
Constitution, Organization & Bylaws – Charles C. Gager
Distinguished Lectures – James R. Huddle
Education – Sajjad H. Durrani
Strategic Planning – Paul E. Gartz
Fellow Evaluation – Fritz Steudel
Fellow Search – Elliot L. Axelband
History – Henry Omar
International Activities – Hugh D. Griffiths
Nominations – Paul E. Gartz
Professional Activities – M. Cardinale
Public Relations – James R. Huddle
Publications – Edward K. Reed
• Systems – Evelyn H. Hirt
• Transactions – Peter K. Willett
• Administrative Editor – David B. Dobson
Social Implications – Technical – Open
Standards – Arnold M. Greenapan
Student Activities – Jose R. Bolaños
Transnational Activities – Hugh D. Griffiths, Chair

TECHNICAL PANELS

Gyro and Accelerometer – R.K. Curey, Chair
Integrated Avionics Systems – G.T. Logan, Chair
Radar Systems – J. Day, Chair
Space Systems – M. Ruggieri, Chair
Large Scale Systems Engineering – P.E. Gartz, Chair
Target Tracking Systems – W.D. Blair, Chair

IEEE/ASSOCIATE OFFICERS

IEEE PUBLICATIONS

IEEE Press – Russ J. Lefevre
Journal of Lightwave Technology – D. Chamin & M. Cardinale
Transactions on Pattern Analysis & Machine Intelligence – J. Harris
IEEE Organizational Units
• H. Griffiths (2006-2007)
• Sensors Council – M. Wicks
• IEEE-SA, IEEE SCC-20 Hardware Interfaces Sub-Committee
(RFI and SATS Standards) – A. Greenapan
• IEEE-USA, Communication & Information Technical Policy – Open
• USA, PACE – M. Cardinale
• IEEE-USA, Research & Development Technical Policy – P. Holmer
• IEEE-USA, Transportation & Aerospace Technical Policy – P. Holmer
• PSPE Magazine Committee – Systems Editor-in-Chief – E.H. Hirt
• PSPE Transactions Committee – Transactions Editor-in-Chief – P.K. Willett
• Society on Social Implications of Technology – M. Cardinale

CONFERENCE LIAISONS

• IEEE Aerospace – M. Ruggieri & R.C. Rassa
• IEEE International Carmanah Conference on Security Technology – R.B. Trebits
• IEEE/ASES Digital Avionics Systems Conf. – C.R. Spitzer & B.C. Breen
• All Radar Conferences – M.E. Davis
• IEEE Position, Location & Navigation Symposium – J.R. Huddle
• International Energy Conversion Engineering – G. Lukemich

LIAISONS TO NON-IEEE TECHNICAL SOCIETIES

• American Institute of Aeronautics & Astronautics (AIAA) – C.R. Spitzer
• Association of Old Crows (AOC) – E.C. Gangl
• French Institute of Navigation (SIN) – J.R. Huddle
• German Institute of Navigation (DGON) – J.R. Huddle
• Institution of Electrical Engineers (IEE) Radar, Sonar & Navigation (RSN)
• Professional Networks (PN) – R.T. Hull
• Institute of Navigation (ION) – J.R. Huddle
• International Council on Systems Engineering (INCOSE) – G. Friedman

IEEE/AESS Website: http://www.cwh.ieee.org/ases
Please send corrections or omissions for this page to the Secretary
Newbie Engineers

The pager goes off and you call the extension to talk with your IPT SE Lead to schedule a TIM with the JPO to discuss the latest change in the project's TPM such as why the predicted MTBF has decreased from the ADR to the PDR.

But first . . .

Let's start at the beginning. I'm now a Principal Systems Engineer with almost eight years of experience for a major aerospace company. In my first few weeks, I did not know what any of the above acronyms stood for. (Would it be embarrassing to say months for some of those?) In fact, my current responsibilities in RMSS (sorry: Reliability, Maintainability, Supportability, and Safety) were foreign to me as well.

For your first engineering job right out of college, sometimes you are just thrown into a situation with very little knowledge as to what is going on.

Thus, it is very important to take a proactive role in your career. Not only is the job market more competitive within companies; those on projects are both very busy and usually working on more than one project at a time. So, although every effort is made to make sure you are assigned a dedicated mentor, you could easily get lost and frustrated in your new job.

It usually takes a few days before your management will find a project for you to work on. Getting paid to do nothing is only fun for a day or two and you'll soon be extremely bored. If you are waiting for security clearance, sometimes days will turn into weeks. So take the time to walk around the office and visit different buildings within your company to familiarize yourself with your surroundings. If there's an organization chart, study it and see who the managers and senior employees are (not just your own direct line manager). And then talk to them. Engineers sometimes get a bad rap of being anti-social), but sometimes it will surprise you how enthusiastic and how long engineers will talk about their jobs.

In addition to seeking words of wisdom from senior employees, seek out the newer employees (not necessarily young, but new to the company) to find out what problems they have encountered in their first few weeks on the job, how they adjusted to the project once they were assigned, and the most important (especially if you've moved for your job), where the best places to eat and drink are. Some companies have support groups for young engineers (similar to IEEE GOLD) while others may have periodic new engineer meetings or training.

Training is another avenue of which to take advantage. Companies are likely to offer technical, career-oriented, and company-specific training courses. Not only will taking these courses get you more familiar with how your company works, what processes they follow, and what products they make; you'll meet like-minded employees with which to network. And don't just take the technical courses; look for lunch-time seminars on topics such as how to manage your 401k or similar retirement investments, and lab safety courses.

You don't have to be social or outgoing on the job, but you do need to take your new job very seriously and take charge of your career regardless if you're employed at a small or large company. The enthusiasm you show for your job will build confidence in the eyes of your management. Don't be afraid of not knowing things; just go and seek the answers.

Oh, and what about those acronyms? Here's the full text:

The pager goes off and you call the extension to talk with your Integrated Product Team Systems Engineer Lead to schedule a Technical Information Meeting with the Joint Performance Office to discuss the latest change in the project's Technical Performance Measure such as why the predicted Mean Time Between Failure has decreased from the Advanced Design Review to the Preliminary Design Review.

Cheers!

Scott M. Tamashiro,
IEEE GOLD Member
Raytheon,
Principal Systems Engineer;
Certified Reliability Engineer
“Radar...Our Sight Into a Spectrum of Information,” Highlights the Connection Between Radar and Information. This Theme Provides an Interesting Perspective to Consider the Increasingly Wider Spectrum of Target and Environmental Information that has Evolved, Far Beyond the Original Capability to Detect the Target and Determine its Range, from Innovative Radar Research, Technology, and Component Development, for both Military and Civilian Applications.

For more information visit www.radar06.org

Sponsored by: Aerospace & Electronic Systems Society
Mohawk Valley IEEE Section
Syracuse IEEE Section
St. Petersburg Joint Chapter

The joint SPS/AESS/UFFCS (Signal Processing Society, Aerospace and Electronic Systems Society, Ultrasonics Ferroelectrics and Frequency Control Society) Russian North-West Chapter met at LETI, St. Petersburg, Russia, on 4 November 2005.

The chapter meeting took place in conjunction with the visit of Zafar Taqvi, Member IEEE/AESS Board of Governors. Taqvi visited Russia and Ukraine as the new AESS Director At-Large International Development. The objective of his trip was to meet chapter members and key executives of local aerospace companies. He wanted to open a dialogue on behalf of IEEE/AESS to explore the possibility of how AESS resources can help the local Russian and Ukrainian professionals in organizing new and innovative activities that will benefit them.

The joint chapter chair Yuri Filatov presented the chapter history and main directions of its activity. He paid special attention to chapter activity in 2005 which included such important events as taking part in the 12th St. Petersburg International Conference of Integrated Navigation Systems and St. Petersburg International Conference “Radio — That Connects Time and the Anniversary of Radio Invention” (see September issue of “Region & News”).

Taqvi followed with a talk on the ways of global technology progress and appearance of new concept — system-of-systems, as the result of this process. He spoke about IEEE and the Aerospace Society development in conjunction with the globalization process. This theme produced active discussion in which section vice chair Mikerev spoke about special conditions of IEEE development in Russia.

Luikianov then lectured on the history of the ring laser gyro development in the states of the former Soviet Union; first, in Russia and Ukraine. He compared results obtained in East and West and showed some very close concepts used by Russian and American scientists.

Yuri V. Filatov
SPS/AESS/UFFCS Joint Chapter Chair of IEEE Russia (Northwest) Section
Head of Laser Measurement & Navigation Department
St. Petersburg Electrotechnical University

Australia / New Zealand Visit

On 30 November and 01 December an international AESS event was conducted in Australia led by Bill Lyons. He set up a UAV Workshop as a lightning rod to attract the Queensland government, the Queensland University (QUT), and many industries. It was a huge winner.

Bill also leveraged his own time by delegating to Dr. Rod Walker, QUT Head of the Airborne Avionics Research Group, who did a lot of the organizing and thereby became an in-country believer and supporter of AESS. This is similar to what Marina did for her event on Space and Systems-of-Systems in Rome and is a great model for all to gain leverage of their time and others.

— Paul Gartz
PLANS 2006
POSITION LOCATION AND NAVIGATION SYMPOSIUM

Technical Meeting: April 25–27, 2006
Tutorials: April 24

The IEEE and the ION® are hosting PLANS together in 2006!

Loews Coronado Bay Resort, San Diego

Coronado (San Diego), California

Register by March 23 at www.plans2006.org andSAVE!

Registration Information

Attendees
- Member/Corporate Member Rate (received and paid by March 23): $700;
  after March 23: $800
- Non-member Rate (received and paid by March 23): $750; after March 23: $850
- Student Rate (sessions only, does not include meals functions, events or proceedings; must be full-time student): $200

Primary Authors
- Primary Author/Presenter Member Rate (received and paid by March 23): $650;
  after March 23: $800
- Primary Author/Presenter Non-member Rate (received and paid by March 23):
  $700; after March 23: $850

Advance Hotel Reservation Information
The get the special conference rate of $195 single/double per night, make your hotel reservations at the Loews Coronado Bay Resort by March 23. Call 800-615-6397 or 619-424-4000, or send a fax to 619-424-4470. Be sure to identify yourself as an IEEE/ION® PLANS meeting participant.

Limited government rates available to those U.S. government employees paying for the room with a U.S. government credit card and traveling with government travel orders.

*In March 2005, the IEEE and the ION® entered into an agreement whereby both organizations would equally sponsor and support the technical program and conference management of the PLANS 2006 conference. As part of the agreement, the PLANS 2006 conference will replace the ION’s annual summer meeting. The ION’s annual awards and Fellow awards, which are typically awarded during the ION’s summer meeting, will be awarded during the course of PLANS 2006.

We invite you to participate in the joint IEEE/ION® meeting with exciting new opportunities for technical exchange and networking.
April 2006 PLANS Joint Meeting with
Institute of Navigation (ION)

AESS and the Institute of Navigation (ION) have entered into an agreement to equally sponsor the Position, Location and Navigation Symposium (PLANS) 2006 meeting at the Loews Coronado Bay Resort, San Diego, California, April 24-27. As part of the agreement, this event will replace the normal ION summer meeting. Combining the resources and membership of both groups will provide an outstanding event. The ION partnership should add substantially to meeting attendance plus the previous PLANS attendance was already up by more than one-third. The partnership objective is to maximize networking and present a comprehensive overview of existing and new GNSS programs and their applications as well as highlight recent research and development. The General Chair for this combined meeting is Charles Bye, Program Chair will be Wayne Soehren. Both societies will present awards at this meeting.

The PLANS technical program includes papers covering the spectrum of sensors, electronics, interfaces, subsystems and entire navigation systems. Integrating GPS/GNSS into existing navigation systems to improve performance and reduce costs (e.g., use of MEMS) will be the major focus. Technical sessions will be preceded by a day of tutorials to update new attendees in navigation basics and highlight future GPS (now more often referred to as the Global Navigation Satellite System – GNSS) directions, plus highlight related technologies and interfaces. Further details and registration information can be found on the PLANS website: www.plans2006.org or www.ion.org/meetings/plans.

The following is a brief summary of the 2004 PLANS conference held in Monterey, California. This conference presented 100 papers in 4 tracks and a poster session. A total of 275 attended and everyone had the opportunity to visit 34 exhibit booths at the sponsor-provided evening buffets. General Chair Bahar Uttam was ably assisted by Program Lead Charles Bye and 2002 General Chair John Weyrauch, IEEE Liaison, and a regular PLANS participant.

Luncheon Keynote Speaker Michael May, a legally blind engineer, discussed his earlier career and efforts to initiate development of a talking GPS with associated information systems. The Kershner Award was presented at the Awards Luncheon (see next page, 42). A number of awards were also presented at the AESS Board of Governors (BoG) meeting which was held in parallel with PLANS. The photos on the cover of this issue capture some of these activities both at PLANS and the AESS BoG.

— Ron Schroer
Kershner Award

The Executive Committee of PLANS 1986 established an award for outstanding achievement to recognize individuals who have made a substantial contribution to the technology of navigation and position equipment, systems, or practices. The committee established this as a PLANS tradition, thus permitting the IEEE to recognize those who have contributed most significantly to this modern era of electronic navigation.

It is appropriate that the award was named for Dr. Richard B. Kershner (1913 - 1982). Dr. Kershner participated in the initial conception and then led the development of Transit, the world's first navigation satellite system. His technical contributions and his leadership of the program at the Johns Hopkins Applied Physics Laboratory are examples of the highest standards of personal and professional performance which this award is intended to recognize. The Transit program was first funded in 1959, and the system became operational in 1964. During this short interval Dr. Kershner directed the development and launch of some of the World's first satellites, developed user equipment for both submarines and surface ships, and founded the science of satellite Doppler geodesy to improve knowledge of the Earth's gravity field. The result was a navigation satellite system which serves the US Navy and tens of thousands of civil users worldwide.

The PLANS 2004 Kershner Award was presented to Professor Itzhack Y. Bar-Itzhack

Prof. Itzhack Y. Bar-Itzhack is the Sophie and William Shamban Professor of Aeronautical Engineering at the Technion-Israel Institute of Technology and previously served as the Dean of Aerospace Engineering at the Technion.

Professor Bar-Itzhack has made valuable contributions to the field of navigation throughout his career and continues to do so at present. He has been involved in a wide range of topics from the Apollo Program to the Trident Missile Program. His most significant contributions have been to the art of Inertial and Aided Navigation Systems. He was one of the pioneers who developed the theory of Strapdown Inertial Navigation Systems (INS). His 1968 Ph.D. dissertation was titled "Strapdown Inertial Navigation Systems," and his first paper on the subject was published in 1970. He continued to make significant contributions to the field for the next three decades. He is credited with the formulation of INS error models in terms of modern control theory.

PAST RECIPIENTS OF THE KERSHNER AWARD

<table>
<thead>
<tr>
<th>Year</th>
<th>Recipient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>Bradford Parkinson</td>
</tr>
<tr>
<td>1988</td>
<td>Fred Aronowitz</td>
</tr>
<tr>
<td>1990</td>
<td>Bahar Uttam</td>
</tr>
<tr>
<td>1992</td>
<td>Alvin Pierce &amp; Eric Swanson</td>
</tr>
<tr>
<td>1994</td>
<td>Joseph Killpatrick</td>
</tr>
<tr>
<td>1996</td>
<td>Charles Trimble</td>
</tr>
<tr>
<td>1998</td>
<td>Charles C. 'Chuck' Counselman III</td>
</tr>
<tr>
<td>2000</td>
<td>Tom Stansell</td>
</tr>
<tr>
<td>2002</td>
<td>H. Grover Brown</td>
</tr>
</tbody>
</table>
## Tutorials April 24

<table>
<thead>
<tr>
<th>Mon. Morning</th>
<th>Mon. Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m.—noon</td>
<td>1:30 p.m.—5 p.m.</td>
</tr>
</tbody>
</table>

- **Dr. Chris Barton**  
  Fundamentals & Details of Satellite Navigation Using GPS

- **Dr. Dorota A. Grieger-Brzezinska**  
  Network-Based RTK GPS & Precise Point Positioning

- **Ralph E. Hopkins**  
  MEMS Inertial Technology: A Short Course

- **Dr. Ira M. Weiss**  
  Allen M. Morrison  
  GPS Protection  
  Toolbox: Picking the Right Technology for Interference Suppression

- **Dr. James J. Farrell**  
  Low-Cost INS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 a.m.—noon</td>
<td>2 p.m.—5:30 p.m.</td>
<td>8:30 a.m.—noon</td>
<td>2 p.m.—5:30 p.m.</td>
<td>8:30 a.m.—noon</td>
<td>1 p.m.—4 p.m.</td>
</tr>
</tbody>
</table>

- **Constellation A**  
  **A1:** Advanced Inertial Sensing Technology  
  **A2:** Sensor Software and Signal Processing  
  **A3:** Inertial Measurement Unit Technology

- **G. Jeffrey Geier**  
  Fundamental Issues Affecting GPS/INS Integrations

- **Dr. Chris Hegarty**  
  Aviation Augmentations to GPS

- **Marvin B. May**  
  Navigation Software

- **Dr. Dorota A. Grieger-Brzezinska**  
  Network-Based RTK GPS & Precise Point Positioning

- **Constellation B**  
  **B1:** Advanced Integrated Navigation Technology  
  **B2:** Integration of Inertial Systems with Satellite Navigation Systems 1  
  **B3:** Integrated Navigation for Precision & Non-Precision Landing Approaches

- **Benjamin H. Hopkins**  
  MEMS Inertial Technology: A Short Course

- **Dr. Ira M. Weiss**  
  Allen M. Morrison  
  GPS Protection  
  Toolbox: Picking the Right Technology for Interference Suppression

- **Constellation B**  
  **B4:** Integration of Inertial Systems with Satellite Navigation Systems 2

- **Constellation B**  
  **B5:** Inertial Navigation Appl. for Space, Commercial, & Military Systems

- **Constellation B**  
  **B6:** Part 1: Underwater Navigation  
  **B6:** Part 2: Precision Agriculture

- **Constellation A**  
  **C1:** Atmospheric Effects & Modeling  
  **C2:** Receiver and Antenna Technology 1

- **Constellation B**  
  **C3:** Ground & Space-Based Augmentation Systems

- **Constellation A**  
  **C4:** Infrastructure Applications of Positioning, Navigation, and Timing Technology

- **Constellation B**  
  **C5:** GPS & Galileo

- **Constellation A**  
  **C6:** Receiver & Antenna Technology 2

- **Commodore Balloon Room**  
  Noon—1 p.m.  
  Informal Luncheon With Exhibitors

- **Commodore Balloon Room**  
  6 p.m.—8 p.m.  
  Exhibitor Hosted Meet and Greet Social

- **Commodore Balloon Room**  
  Noon—2 p.m.  
  Awards Luncheon

- **Commodore Balloon Room**  
  Noon—1 p.m.  
  Informal Luncheon With Exhibitors
The 9th International Conference on Information Fusion
Florence, 10 – 13 July 2006

CALL FOR PAPERS

Overview. The 9th International Conference on Information Fusion will be held in Florence, Italy, at the Convento della Calza Convention Centre. Authors are invited to submit papers describing advances and applications in information fusion, with submissions of non-traditional topics encouraged.

Conference Site. Lying in the heart of Tuscany, surrounded by gentle green hills, Florence is a unique treasure chest of works of art. Florence is the home of Dante, Giotto and Botticelli. Leonardo da Vinci, Michelangelo, and Raphael all came to Florence to learn about art and to teach it. Renaissance buildings, churches and museums like the Uffizi gallery provide an extraordinary voyage through the history of art. The coastline is approximately an hour’s distance, as are the notable Italian centers of Pisa and Siena. Florence is served by a modern international airport. The conference venue is the Convento della Calza, a former monastery built in the 14th century. It is strategically located in the heart of the historical center, surrounded by remarkable works of the Renaissance, and close to the Boboli Gardens and Palazzo Pitti.

Topics of interest include (but are not limited to) the following:

1. Foundational tools
   - Probability theory; non-Bayesian approaches to uncertainty representation; random sets; fuzzy logic; risk-sensitive approaches; fusion modeling; agents; genetic optimization.

2. Technological advances
   - Sensor modeling (radar, active and passive sonar, acoustic, seismic, magnetic, optical, visual, infrared); fusion-related hardware, software and communications technology.

3. Algorithmic developments
   - Classification; data mining; nonlinear filtering and smoothing; contact-based tracking algorithms; combined detection/tracking; resource management; distributed fusion; active and passive data fusion; data registration; image fusion; database fusion.

4. Application areas
   - Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR); network centric warfare; decision support; situation assessment; computer vision; economics and finance; condition monitoring; medical diagnostics and biological systems; robotics; intelligent transportation systems; security.

Paper Submissions. Prospective authors are invited to submit 4-8 page papers through the conference website (wwwfusion2006.org), where paper templates and submission instructions are available, by 15 January 2006.

Special Session Proposals. Proposers are invited to submit by email (coraluppi@nurc.nato.int, willett@engr.uconn.edu) the theme of the special session, as well as the list of committed papers, by 1 December 2005.

Tutorial Proposals. The first day of the conference will be devoted to tutorials on information fusion. Organizers for proposed tutorials are invited to submit by email (marano@unisa.it) a title and description for their tutorial, by 15 January 2006.

Student Paper Program. Fusion 2006 is featuring a student paper program to encourage the involvement of young engineers and scientists in information fusion research. Conference fees will be waived for the leading author of the best paper. Further details are available at the Conference website.

Invited Speakers. Fusion 2006 will include the following invited talks:

- Dr. Nils Sandell (BAE Systems Advanced Information Technologies). Fusion Technology and Applications; A Retrospective and Some Thoughts about the Future.
- Dr. Marcel Hernandez (QinetiQ). Performance Measures for Sensor Management: Computationally Efficient Formulations and Associated Applications.

Important deadlines

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special session proposal</td>
<td>1 December 2005</td>
</tr>
<tr>
<td>Tutorial proposal</td>
<td>15 January 2006</td>
</tr>
<tr>
<td>Regular paper submission</td>
<td>15 January 2006</td>
</tr>
<tr>
<td>Acceptance of papers</td>
<td>1 April 2006</td>
</tr>
<tr>
<td>Final papers</td>
<td>15 May 2006</td>
</tr>
</tbody>
</table>
All India Student Project Contest

IEEE-India AES / Com / LEO Societies Chapter

Chapter Chair: Dr. Ram Gopal Gupta
Student Project Contest Program Chair: Dr. V. Prasad Kudali

ELIGIBILITY

This contest is open to all IEEE Student Members in India. Participating Student Member need not be a member of the IEEE Aerospace and Electronic Systems Society (AESS).

SCOPE

Technical area of the project must be within the AESS fields of interest. Within the framework of IEEE, AESS fields of interest cover the organization, design, development, integration, and operation of complex systems for space, air, ocean, or ground environments. These systems include, but are not limited to: navigation, avionics, spacecraft, aerospace power, radar, sonar, telemetry, defense, transportation, automated testing, and command and control. The student project may typically be an under-graduate project, or a post-graduate thesis or project in any one or more of the above areas. For purposes of the present contest, the project must result in a product, either hardware or software, such as a simulation package / tool. The work must be that of a single student or a group of students – not to exceed four students. Contest entries will be separately judged in the under-graduate and post-graduate categories.

Students intending on participating in this contest are encouraged to peruse recent issues of the IEEE Aerospace and Electronic Systems Magazine and the IEEE Transactions on Aerospace and Electronic Systems for several examples of technical areas and topics of current interest.

After completion of the project, a technical paper containing a description of the project product and the results obtained along with photographs, if any, should be submitted to the Project Contest Coordinator on or before May 1, 2006.

EVALUATION CRITERIA

A panel of judges will evaluate the entries on the basis of concept, creativity, technical content, and presentation. Authors of the best four entries in each of the two categories (viz. under-graduate and post-graduate) will be invited to demonstrate their product and make a technical presentation or a special function to be arranged by the IEEE in Hyderabad during June 2006. Following this presentation, the First and Second Best Projects in each of the two categories will be selected.

AWARDS

First Prize in each category is a cash award of Rs.20,000 and a certificate. The Second Prize in each category is a cash award of Rs.10,000 and a certificate. The Faculty Supervisor / Advisor of each of the four Award winning projects will be presented a Certificate of Recognition and his/her IEEE membership dues, including membership in the AESS, paid for 2007.

PROJECT CONTEST COORDINATORS

Dr. M.R. Srinivas, Associate Professor
Center for VLSI and Embedded Systems
BIT, Gachi Bowling, Hyderabad – 500-619
E-mail: srinivas@in.ac.in

Dr. Kudati Srinivas, Manager (DBS)
National Remote Sensing Agency
Holangar, Hyderabad 500-037
E-mail: srinivas.k@nrsa.gov.in
STUDENT MEMBERSHIP APPLICATION

2006 IEEE AEROSPACE AND ELECTRONIC SYSTEMS SOCIETY

CURRENT IEEE MEMBERS: DO NOT USE THIS FORM TO RENEW YOUR MEMBERSHIP; YOU WILL RECEIVE A RENEWAL NOTICE.

Mail to: IEEE, Admission & Advancement Dept., 445 Hoes Lane, P.O. Box 133104, Piscataway, New Jersey 08855-1331 USA
or Fax to: (732) 981-0225 (credit card payments only)

For info call (732) 981-0060 or 1 (800) 678-IEEE. E-mail: new-membership@ieee.org or www.ieee.org/join

NAME AS IT SHOULD APPEAR ON IEEE MAILINGS: SEND MAIL TO: Address During Academic Year OR Family/Home Address

If not indicated, mail will be sent to academic address. Enter your name as you wish it to appear on membership card and all correspondence. PLEASE PRINT. Do not exceed 40 characters or spaces per line. Abbreviate as needed. Please circle your last name as a key identifier for the IEEE database.

TITLE: ________________________________ FIRST OR GIVEN NAME: ________________________________ MIDDLE NAME: ________________________________

SURNAME/LAST NAME: ________________________________ CITY: ________________________________ STATE/PROVINCE: ________________________________

ADDRESS DURING ACADEMIC YEAR: ________________________________ COUNTRY: ________________________________

POSTAL CODE: ________________________________

1. Are you now or were you ever a member of IEEE? Yes ☐ No ☐

If yes, please provide, if known:

MEMBERSHIP NUMBER: ________________________________

Grade: ________________________________ Year Membership Expired: ________________________________

2. HOME / FAMILY ADDRESS

Street Address: ________________________________

City: ________________________________ State / Province: ________________________________

Postal Code: ________________________________

4. EDUCATION

University: ________________________________ Campus: ________________________________

School or College: ________________________________ Program / Course of Study: ________________________________

Address: ________________________________

State / Province: ________________________________ Country: ________________________________

Postal Code: ________________________________

Degree(s): ________________________________

Program: ________________________________

Course of Study: ________________________________

Other (Please describe) ________________________________

Highest Technical Degree Held: ________________________________

Degree Program (check one) ________________________________

Degree completed: 2 or 3 year ☐ 4 or 5 year ☐ Master's ☐ Ph.D. ☐

3. HOME / FAMILY ADDRESS

If you hold other degrees? Yes ☐ (complete below) ☐ No ☐

School or College: ________________________________ Program / Course of Study: ________________________________

Address: ________________________________

City / State / Province / Country: ________________________________

Other Degrees Held: ________________________________

School or College: ________________________________ Program / Course of Study: ________________________________

Address: ________________________________

City / State / Province / Country: ________________________________

5. SIGNATURE OF APPLICANT

I hereby make application for IEEE membership and agree to be governed by IEEE's Constitution, Bylaws, Statements of Policies and Procedures and Code of Ethics.

Full signature of applicant: ________________________________ Date: ________________________________

METHODS OF PAYMENT: Prices stated are in US dollars

- Credit Card – American Express, VISA, MasterCard, Diners Club
- Check + Bank Drafts + Money Orders: Payable on a US bank

6. DEMOGRAPHIC INFORMATION – ALL APPLICANTS –

Date of Birth: ________________________________ Day: ______ Month: ______ Year: ______

Gender: Male ☐ Female ☐

7. CONTACT INFORMATION

School Phone: ________________________________ Home Phone: ________________________________

School Fax: ________________________________ Home Fax: ________________________________

School E-mail: ________________________________ Home E-mail: ________________________________

2006 IEEE MEMBER RATES

Check (✓) a box: 16 Aug 2005 ☐ 1 Mar 2006 ☐

IEEE DUES: ________________________________

28 Feb 2006 ☐ 15 Aug 2006 ☐

Residence: Pay Full Year ☐ Pay Half Year ☐

United States: $30.00 ☐ $15.00 ☐

Canada (includes GST)*: $32.10 ☐ $16.05 ☐

Canada (includes HST)*: $34.15 ☐ $17.08 ☐

Other Countries: $25.00 ☐ $12.50 ☐

Options for IEEE Members:

Potentials Magazine (Outside US and Canada)*: $5.00 ☐ $3.00 ☐

Proceedings Print ☐ $20.00 ☐ N/A ☐

Online ☐ $20.00 ☐ N/A ☐

Print & Online ☐ $37.00 ☐ N/A ☐

Standards Association (IEEE-SA): $36.00 ☐ Full Year Only ☐

IEEE Women in Engineering (WIE): $FREE ☐ Full Year Only ☐

IEEE Canadian Business No. 125634188

*Application is to be received by IEEE after 16 August pay/roll year. Subscription to Spectrum (316.50/year) and The Institute are included in dues.

2006 AESS MEMBER RATES

AES SYSTEMS Membership Fee*: $13.00 ☐

Includes AES Magazine and online access to IEEE/OSA Journal of Lightwave Technology (print & electronic included in membership).

Publications available only with AESS membership:

Transactions on:

Aerospace and Electronic Systems: Print ☐ $13.00 ☐

Electronic ☐ $13.00 ☐

Print & Electronic ☐ $18.00 ☐

Pattern Analysis and Machine Intelligence: Print ☐ $24.00 ☐

Electronic ☐ $24.00 ☐

Print & Electronic ☐ $35.00 ☐

IEEE/OSA [ ]

IEEE membership required if joining the AES Society.

Amount Paid: ________________________________

IEEE Membership Dues

Aerospace and Electronic Systems Society Fees Total: $_________

Canadian residents pay 7% GST or 15% HST on Society fees only, Reg. No. 125634188

TAX $_________

AMOUNT PAID WITH APPLICATION TOTAL: ____________

Prices stated are in US dollars, subject to change without notice.

☐ Check or money order enclosed (Payable to IEEE)

☐ American Express ☐ VISA ☐ MasterCard ☐

☐ Diners Club

Charge Card Number: ________________________________

Expiry Date: ______/______

Cordholder's 5 Digit Zip Code: ________________________________

Billing Statement Address: ________________________________

Full signature of applicant using credit card: ________________________________ Date: ________________________________
Announcement

Radar Conference 2007
17–20 April 2007
Boston, Massachusetts
- "The place where it all began"

Revolutionary Time
April is the ideal time to be in Boston. The conference follows the world's oldest annual marathon, the Boston Marathon and the locally famous Patriots' Day holiday. Join the locals in a reenactment of Paul Revere's ride and the Revolutionary War battles at Lexington and Concord.

Field Trips
From "where it all began" to where "the future is being created" take a half-day guided tour inside MIT Lincoln Laboratory's 100-GHz upgrade to the Haystack radar, or go behind the scenes at Raytheon's MMIC R&D Center in Andover.

International Coordination
Technical survey talks will be encouraged highlighting recent radar developments in these and other countries:

- Canada
- Sweden
- Italy
- Britain
- Australia
- Israel
- France
- Japan
- China
- Germany
- Russia
- India

Poster Sessions
Discuss details and meet with the authors...

Tutorials
Let the experts update you on the latest topics.

Exhibits
Contact exhibits@radar2007.org

For more information visit the symposium web site:
www.radar2007.org or email: info@radar2007.org

Sponsor: IEEE, IEEE Aerospace & Electronic Systems Society Boston Section
1. NAME AS IT SHOULD APPEAR ON IEEE MAILINGS: SEND MAIL TO: [Home Address] OR [Business/School Address]
   If not indicated, mail will be sent to home address. NOTE: Enter your name as you wish it to appear on membership card and all correspondence.
   PLEASE PRINT. Do not exceed 40 characters or spaces per line. Abbreviate as needed. Please circle your last name as a key identifier for the IEEE database.

   TITLE: [First or Given Name]  SURNAME/LAST NAME

   HOME ADDRESS

   CITY

   POSTAL CODE

   STATE / PROVINCE

   COUNTRY

2. Are you now or were you ever a member of IEEE? [Yes] [No]
   If yes, please provide, if known:

   MEMBERSHIP NUMBER

   Grade

   Year Membership Expired

3. BUSINESS / PROFESSIONAL INFORMATION

   Company Name

   Department / Division

   Title / Position

   Years in Current Position

   Years in the Profession Since Graduation [PE] State / Province

   Street Address

   City

   State / Province

   Postal Code

   Country

4. EDUCATION

   A baccalaureate degree from an IEEE reference list of programs assures assignment of "Member" grade. For others, additional information and references may be necessary for grade assignment.

   Baccalaureate Degree Received

   College / University

   State / Province

   Highest Technical Degree Received

   College / University

   State / Province

5. SIGNATURE OF APPLICANT

   I hereby make application for IEEE membership and agree to be governed by IEEE's Constitution, Bylaws, Statements of Policies and Procedures and Code of Ethics.

   Full signature of applicant

   Date

6. CONTACT INFORMATION

   Office Phone

   Home Phone

   Office Fax

   Home Fax

   Office E-mail

   Home E-mail

7. 2005 IEEE MEMBER RATES

   Check (v) a box

   16 Aug. 2004

   1 Mar. 2005

   Check (v) a box

   28 Feb. 2005

   15 Aug. 2005

   Residence

   Pay Full Year

   Pay for Year

   United States

   $151.00 $96.50

   Canada (includes GST)*

   $139.12 $69.56

   Canada (includes HST)*

   $214.40 $74.20

   Africa, Europe, Middle East

   $127.00 $63.50

   Latin America

   $120.00 $60.00

   Asia, Pacific

   $121.00 $60.50

8. METHODS OF PAYMENT: Prices stated are in US dollars
- Credit Card - American Express, VISA, MasterCard, Diners Club
- Check • Bank Drafts • Money Orders Payable on a US bank

9. 2005 AESS MEMBER RATES

   Aerospace and Electronic Systems Society Membership Fee* $25.00

   AESS Magazine (print & electronic included in membership fee)

   Online access to IEEE Trans on Aerospace & Electronic Systems and IEEEO/OSA Journal of Lightwave Technology

   Subscriptions available only with AESS membership:

   Transactions on:

   Aerospace and Electronic Systems

   Print $25.00

   Electronic $25.00

   Pattern Analysis and Machine

   Print $25.00

   Intelligence

   Print $25.00

   Journal of Lightwave Technology, IEEE/OSA

   $35.00

*IEEE membership required or request
Affiliate application to join AESS Society only.

Amount Paid

METHODS OF PAYMENT: Prices stated are in US dollars
- Credit Card - American Express, VISA, MasterCard, Diners Club
- Check • Bank Drafts • Money Orders Payable on a US bank

IEEE Membership Dues

Aerospace and Electronic Systems Society Fees Total

Canadian residents pay 7% GST or 15% HST
on Society fees only. Reg. No. 125834188

TAX $ TED

AMOUNT PAID WITH APPLICATION TOTAL $ 

Prices stated are in US dollars; subject to change without notice.

☐ Check or money order enclosed (Payable to IEEE)

☐ American Express  ☐ VISA  ☐ MasterCard

☐ Dinera Club

Charge Card Number

Exp. Date

Mo/Yr.USA Only

Cardholder's Signature

Billing Statement Address

Full signature of applicant using credit card

Date

IEEE A&E SYSTEMS MAGAZINE, MARCH 2006
Challenges of Education in Engineering

Victor A. Skormin

IEEE Aerospace and Electronic Systems Magazine
Volume 21 Number 3
March 2006
Challenges of Education in Engineering

Victor A. Skormin

Some time ago, I received an e-mail from my former graduate student, Joe Watkins (name changed), who after 18 years since his graduation, became one of the pillars of the local BAE System Division. He told me that his son is interested in becoming an engineer and asked if I had any previous experience in teaching two generations of the same family. I easily recalled Joe who used to come to my home and we both, young and not-so-young perfectionists, worked on polishing his MS thesis. His first child had just been born and he was sharing sleepless nights of parenting with his wife. I was touched by Joe's question. I replied that I am proud and willing to deal with the father, son and Holy Spirit (hopefully not too soon with the latter). I look forward to introducing Watkins Junior to the wonderful world of engineering. As a matter of fact, I would like to make such an introduction to most graduates of American high schools. Herein lies a problem I wish to address and discuss possible solutions.

We are aware of the ever-increasing societal role of engineering in providing the ways and means for the creation of a comfortable habitat for modern humanity. Unlike "natural sciences" that discover laws of nature, engineering deals with the man-made world utilizing mathematics to address the properties of matter in quantitative terms and "bending" these properties for the benefit of mankind. As a species, we are departing further from the natural world of forests, caves, and bonfires, and moving deeper into the man-made world of skyscrapers, automobiles, computers, and air-conditioned areas. Consequently, the role of engineers becomes increasingly important, and engineering education becomes an increasingly assured way to obtain guaranteed employment and the means to provide for your family – in spite of inherent ups and downs of the globalized economy.

Unfortunately, in our society, the role of engineers is taken for granted, and, in competition for the hearts and souls of the brightest American youth, the engineering profession does not offer much glamour and income potential. Engineering is not a popular choice of American high school graduates and "Watkins Junior" is just an exception. America has increasingly become the "profession of immigrants" who not necessarily will continue, and formally are not obligated to continue, pioneering traditions of American engineers set forth by Edison and the Wright brothers. The undermining effect of this tendency on our society should not be underestimated.

Let us examine some factors responsible for this reality. In addition to income and glamour issues, engineering programs are notorious for scaring potential students by the rigors of math. Many high school math teachers, who often had chosen teaching careers because of the same "math scare," perpetuate this phobia among their students. "Math scare" does not end in the university either. Calculus, as a necessary part of the engineering curriculum, is often presented not as a general-purpose tool that enables us to understand laws of nature and get access to engineering methodologies, but as a combination of formulas, derivations, and theorems that are difficult to memorize. Indeed, instead of a screwdriver that belongs to a professional toolbox, pragmatic American engineering students are often offered a kind of "soap bubble" that they have to carry intact until the day of the final exam. And only those who manage to prevent this bubble from bursting before taking circuits, signal processing and controls realize, to their amazement, that it is not a bubble after all but a very useful instrument.
Is there a way to address the “Math scare?”

I cannot offer any constructive suggestions at the level of public high schools that would survive the steamroller of the omni-powerful teacher’s union. Sorry. But what we can – and ought – do at the university level is quite doable. Mathematics for undergraduate engineering students must be taught not by mathematicians, but by engineers. Only engineers can address the pragmatism of an American engineering student by starting from the problem that must be solved and then offering necessary mathematical and computer tools for its solution. It is time to realize that for many reasons, including but not limited to industry, industry does not and would not rely on derivations made by an engineer; consulting mathematicians exist for this purpose. A practicing engineer is expected to use computer tools implementing the most advanced mathematical techniques and providing scrupulous documentation of the initial and final results for possible legal complications. I have no intention to offend bright, witty, theoretical, and highly intellectual members of the mathematical priesthood. Yes, you are still indispensable in any scientific environment and graduate school, but your involvement in the undergraduate engineering education should be limited by the development of the most advanced software tools with symbolic computations and phenomenal graphic interfaces for the young and pragmatic users. Give our students a chance to mature. Some will still come to you for the wisdom and power of real math!

How Does A Graduate of An American High School Decide To Apply To An Engineering Program?

In our experience, it happens primarily because of the personal influence of an engineer, relative, mentor, friends – seldom a teacher. Too often American high schools are not capable of familiarizing their students with modern engineering concepts. Popular TV shows glorify doctors, lawyers, cops, and firefighters; much less often: scientists; but virtually never engineers. A high school graduate, especially from a rural area and/or a minority group, has very little chance to get the motivation to become an engineering student. Is there a way out of this unhealthy trend for our nation, other than funding Hollywood to produce a soap opera about engineers and/or doubling engineering salaries (which, on second thought, is not such a bad idea, after all)!

The Internet era presents an interesting solution to the above-mentioned problem. The Internet successfully competes against TV for the time of our youth. It facilitates many novel ways to shape the new generation of Americans. I believe that it is time to explore the power of the Internet to offer a new approach enabling both teachers and students of high schools to get valuable insight into the world of engineering. The most intelligent and pragmatic part of high school students could be attracted to engineering by presenting, in popular form, modern engineering concepts and technologies. The effect would be multiplied by the free access to modern high-tech equipment that could not only be viewed from a distance, but also operated by the students. Unfortunately, modern technical systems are too expensive and could be easily damaged by future Edisons and Fords. Installation and maintenance of such equipment is often well beyond the reach of high schools and even universities.

This is exactly the situation where Internet-accessible engineering laboratories could be very effective. The realization of this concept, developed at Binghamton University, has been funded by the NSF at the proof-of-concept stage, and later was funded under the Major Research Instrumentation (MRI) program. It includes the development of several remotely operated laboratory setups featuring one of the state-of-the-art technologies, satellite-based laser communication. The choice of this technology is quite purposeful; it allows for the demonstration of various concepts in communication, lasers, satellites, robotics and systems. During the experimental implementation of the system prototype approximately 1000 users worldwide were able to access this, otherwise inaccessible, equipment through the Internet, conduct specially designed experiments, and download experimental data for further analysis.

Yes, we would love to continue getting funding for the further development of the Internet-accessible laboratories, but this is not why I write. For the sake of preserving the endangered specie – the indigenous American Engineer – we propose a massive effort, jointly funded by government and industry, aimed at the development of Internet technologies demonstrating advanced engineering concepts thus promoting early interest in engineering careers among American youth. The social and societal impact of this effort could be quite dramatic. Offered in high schools nationwide, it would reach all social groups of population, teachers, students, and parents, stimulating interest in science and engineering. Ultimately, it will help to increase the involvement of talented American youth in engineering university programs.