AESS MEETINGS & CONFERENCES

Barry C. Breen, Vice President-Conferences
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DATE          MEETING                                PLACE                  CONTACT


September 20-23, 2004  AESSCON 2004 San Antonio, TX  W. Nottke, (212) 359-2863  (212) 452-3604 F  w.nottke@worldwide.net  www.aesscon.org

September 21-3, 2004  Board of Governors San Antonio, TX  Society Secretary  P. Konar, (202) 413-6645  (202) 534-6890 F  pkonar@ieee.org  http://www.ieee.org

October 3-6, 2004  Intelligent Transportation Systems Washington, DC  E. Janssen, (459) 225-9646  (409) 332-2523 F  banasen@iti.cleveland.org  www.itl.gov


October 19-21, 2004  Rafe ‘04 - International Radar Conference Toulouse, France  ICS, (301) 714-1114  (301) 424-1247 F  conference@ieee.org  www.ieee.org/conferences

October 24-28, 2004  25th Digital Avionics Systems Salt Lake City, UT  J. Randell, (503) 528-1354  (503) 528-1354 F  randell@missouri.edu  www.aess.org

November 8-10, 2004  IEEE Waveform Diversity & Design 2004 Edinburgh, UK  NEET, (44) (1) 448-763-64  (44) (1) 448-763-64 F  neet@ieee.org  www.aess.org

May 9-12, 2005  2005 IEEE Radar Conference Arlington, VA  IEEE, (703) 417-7631  (703) 417-7631 F  radcon@ieee.org  www.aess.org


September 18-21, 2006  AESSCON 2006 Anaheim, CA  R. Barsa, (617) 560-6222  (617) 560-6222 F  r.barasa@ieee.org  www.aesscon.org

OTHER SOCIETY MEETINGS OF AESS INTEREST

September 19-22, 2004  The 23rd International Workshop on Ultrawideband & Ultrashort Impulse Signals Sevastopol, Ukraine  N. Kobrigin, UWWRSISTM Theoretical Radiophysics Department Kharkiv National University, 4 Federation Sq, Kharkiv, 61057, Ukraine, +38 057 357-256, +38 057 357-256 F  w.w.kinh.uwwrsistm.com  or www.www.uwwrsistm.com


Send all corrections and omissions to Barry C. Breen at his address on the inside back cover.
This Month’s Cover...

photograph was taken in the exhibit area of the PLANS Conference, held earlier this month in Monterey, California. From left: Ron Schaffer, Former Editor-in-Chief, and Dave Dobson, Administrative Editor, of this publication with Evi Gaugl, Chairman of the AESS Awards Committee, following the totally unexpected and surprise presentation of plaques. They read: Exceptional Service Award to... for Editing and Publishing Special Issues of the Aerospace and Electronic Systems Magazine, JUINer – October 2000: A Century of Powered Flight – July, 2001. Presented by the Institute of Electrical and Electronic Engineers, Inc., Aerospace and Electronic Systems Society. Board of Governors, 24 April 2004.

A related article by Chris McManus will be found on page 43 of this issue.

Correspondence

Editor:
Every since I started working in the ultra-wideband radar area, I have been concerned with our original definition of fractional bandwidth (or relative bandwidth).
Backgrounds: Believe about 1994 or 1995, as we used impulse and monostatic radar. These terms came to mean, to us, but the rest of the community possibly. As I recall, Colonel Barry Cruise coined the term ultra-wideband and defined it as the terms of the 25% or center frequency.
Absolute: The main concern centered on the nano-second pulse video type signals which had a usable wideband about from 0 to 1 GHz. Research centered on this region and all systems including the more advanced systems such as CAREAS stayed in those regions.
Using that spectrum kept the advances of fine range resolution (15 to 30 cm), and provided foliage and materials penetration. The community produced some spectacular results in Burnett mine detection, foliage penetration, detection of vehicles and structures hidden in trees, etc.
In the future, we can achieve similar high resolution effects at higher frequencies, but without some of the advantages of operating below 1 GHz. There might be good reasons for wanting to achieve fine range resolution in the 100 to 1000 wavelengths.
I propose alternative definitions of UWB radar: 1) Radar with a range resolution less than 30 cm, and 2) Radar using a bandwidth exceeding 1 GHz. The alternative meets the numerical definition as frequencies below 1 GHz, but also include high resolution systems operating at higher frequencies.
Practically, they define UWB radar in terms of what it does and makes the concept more understandable by the rest of the technical community.

Jim Taylor (Jim@UWBcom)

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IEEE AEROSPACE & ELECTRONIC SYSTEMS MAGAZINE

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Back Cover
Role of BIT in Support System Maintenance and Availability

The role of built in test (BIT) in electronic systems has grown in prominence with the advances in system complexity and concern over maintenance lifecycle costs of large systems. In an environment where standards drive system designs (and provide an avenue for focused advancement in technology), standards for BIT are very much in an evolutionary state. The reasons for advancing the effectiveness of BIT include reduced support overhead, greater confidence in operation, and increased system availability. The cost of supporting military electronic systems (avionics, communications, and weapons systems) has driven much of the development in BIT technology. But what about the systems that support these end items that contain test and measurement instrumentation – such as Automatic Test Equipment (ATE), simulators and avionics development suites? There has also been a beneficial effect on the maintenance and availability of these systems due to the infusion of BIT into their component assemblies. But the effect has been much more sporadic and fragmented. This paper looks at the state of BIT in test and measurement instruments, explain its affect on system readiness, and present ideas on how to improve BIT technologies and standards. This will not provide definitive answers to BIT development questions, since the factors that affect it are specific to the instrument itself.

AI Techniques in Uninhabited Aerial Vehicle Flight

This describes the development of an application of Artificial Intelligence (AI) for Unmanned Aerial Vehicle (UAV) control. The project was part of the requirements for a class in AI at NOVA Southeastern University and a beginning project at NASA Wallops Flight Facility for a resilient, robust, and intelligent UAV flight control system. A method is outlined which allows a base level application for applying an Artificial Intelligence method, Fuzzy Logic, to aspects of Control Logic for UAV flight. One element of UAV flight, automated altitude hold, has been implemented and preliminary results displayed.

The Use of Laser Scanning Technology for Perimeter Protection

The Police Scientific Branch (PSDB) is part of the Crime Reduction and Community Safety Group (CRCSC) of the Home Office. Part of PSDB’s work includes evaluating and assessing new technologies for perimeter intrusion detection.

Laser scanning technology has been used for some time in a range of industrial and commercial applications. This spans from detecting hands when they are close to dangerous machinery to preventing collisions at container ports and monitoring manufacturing processes. Laser scanners are non-contact measurement systems and scan their surroundings two-dimensionally.

This describes the application of laser scanning to physical security, including modifications to such systems for their use as perimeter intrusion detection systems (PIDS). In these systems, motion detection is provided by a pulsed laser beam by measuring the propagation time for the reflected beam to return to its source. Using this information, a contour plot of the surrounding area is built up. Once this contour information has been obtained, the detector can recognize the addition of an object to its field of view through a change in the programmed surroundings. Consequently, the size, shape, and direction of targets moving in the frame can be assessed and an alarm output given, if required.

This explains the main operating principles of the systems, including mechanisms for detection of a potential intruder and the handling of false alarms. Detection capabilities and the potential for low false alarm rates will be described, along with configurations for operational deployment.

Time-Domain Measurements of Radiated and Conducted UWB Emissions

This summarizes results obtained from time-domain full-bandwidth emissions measurements of selected ultrawideband (UWB) transmitting devices. Brief descriptions of two NIST-developed measurement systems are provided. High-fidelity time-domain waveforms are shown, along with associated amplitude spectra for several devices. Results are shown for both conducted and radiated emissions from UWB devices.

A Door-Opening System Using A Low-Cost Fingerprint Scanner and a PC

Biometrics can offer improved security for access control. Several biometric devices can be adapted to our special requirements and some criterion is needed to choose the best solution for us. On the one hand, it is possible to use a standalone embedded system. On the other hand, a low-cost PC-based system can be better fitted to our special requirements, by means of special purpose software. With the actual reduction on the price of informatic components, it can be a good alternative. This describes one of these systems for door-opening with the user’s fingerprint. Special emphasis is given on the design, advantages, and inconveniences with respect to embedded systems.

Radar Technology in the Czech Republic

A contemporary status of Radar technology in the Czech Republic is reviewed. We may find activity in many different directions in this field now. Those are: new primary radar development both for military and civil application, primary and secondary radar upgrades, new passive radar development for civil application, ELINT and ESM equipment, intruding alarm radar sensors for commercial application / high mass production, radar warning and seeking receivers and military targets RCS minimization.
Role of BIT in Support System Maintenance and Availability

Ron Drees & Neal Young
BAE Systems

ABSTRACT

The role of built in test (BIT) in electronic systems has grown in prominence with the advances in system complexity and concern over maintenance lifecycle costs of large systems. In an environment where standards drive system designs (and provide an avenue for focused advancement in technology), standards for BIT are very much in an evolutionary state. The reasons for advancing the effectiveness of BIT include reduced support overhead, greater confidence in operation, and increased system availability. The cost of supporting military electronic systems (avionics, communications, and weapons systems) has driven much of the development in BIT technology. But what about the systems that support these end items that contain test and measurement instrumentation - such as Automatic Test Equipment (ATE), simulators and avionics development suites? There also has been a beneficial effect on the maintenance and availability of these systems due to the infusion of BIT into their component assemblies. But the effect has been much more sporadic and fragmented.

This paper looks at the state of BIT in test and measurement instruments, and its impact on system readiness, and presents ideas on how to improve BIT technologies and standards. This will not provide definitive answers to BIT development questions, since the factors that affect it are specific to the instrument itself.

The topics covered in this paper are:

- Definitions of Built-In Test
- Instrument BIT history
- Importance of BIT fault coverage and isolation in support systems
- Overview of BIT development process
- Issues that limit the effectiveness of BIT
- Standards related to instrument BIT
- Making BIT more effective in support system maintenance and availability
- Conclusions

DEFINITIONS OF BUILT IN TEST

One area that adds confusion to the role of BIT are its various definitions. This is the result of a past lack of professional/academic association attention and standards. Built in test can generally be described as a set of evaluation and diagnostic tests that use resources that are an integral part of the system under test. Within that broad description, specific levels of BIT can be defined based upon the size of the system.

Circuit Level (Built In Self Test)

Built in testing techniques applied to circuit cards using digital and analog methods. For convenience, this paper will refer to this level as Built in Self Test (BIST), a term that is sometimes used interchangeably with BIT. This level of testing is characterized by well-developed standards and technologies (IEEE 1149, boundary scan, signature analysis, etc.) and tools.

Module/Assembly Level (Instrument, LRU/WRA)

Unique electronic assemblies comprised of one or more circuit card assemblies. With support systems, this level refers to programmable instrumentation. Within military platforms, this refers to intermediate or line replaceable units.

System Level Self Contained Testing
(Self Test/Diagnostics/Operational Assurance Testing)

System level self test can be considered built in test based upon the similarity of high level requirements and concerns: test coverage, fault detection, execution time, development and manufacturing costs. A key requirement for this level of test that is not usually levied on the other BIT levels is fault...
Table 1. Timeline for Bit-Related Events

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>IEEE-488 Bus comes into wide use, spurring programmable instrumentation</td>
</tr>
<tr>
<td>1978</td>
<td>Instruments with BIT become available</td>
</tr>
<tr>
<td>1984</td>
<td>USAF MATE program starts</td>
</tr>
<tr>
<td>1987</td>
<td>IEEE-488.2 published, VXI standard published</td>
</tr>
<tr>
<td>1990</td>
<td>SCPI standard published</td>
</tr>
<tr>
<td>1994</td>
<td>VXIplug&amp;play consortium founded</td>
</tr>
<tr>
<td>1998</td>
<td>IVI Foundation started</td>
</tr>
</tbody>
</table>

Fig. 1. Built In test has specific meanings for specific assembly levels

isolation (the ability for a test to diagnose the failing lower level module/assembly).

The focus of this paper is on instrumentation Built-in Test, so all succeeding references to BIT implies a test instrument BIT.

INSTRUMENTATION BIT HISTORY

Operational monitoring has been part of high end instrumentation for a number of years. (See Table 1.) But it was not until the emergence of computer controlled instrumentation in the late 1970s (spurred by the development of the IEEE-488 Bus) that instrument BIT became prevalent. One of the earliest instruments to provide a remote commanded BIT test was the Hewlett Packard (now the Agilent Technologies) 3325A Function Generator, whose BIT included a simple confidence test and RAM tests. Instrumentation vendors began to provide BIT capability as a feature in their instruments, to provide a better diagnostic indication for service returns. In the early 1980s, the USAF developed the Modular Automatic Test Equipment (MATE) program which, among other things, mandated a common instrument control language (CIEL – Common Instrument/Control Intermediate Interface Language). This was an important step in the use of BIT in instrumentation because MATE compatible instruments responded to the same commands for BIT and responded with status or error messages in a consistent manner. Though the MATE program did not have the desired lasting effect of universal instrument commonality in USAF ATE, it was an important step in that direction. The technologies and industry standards that grew out of that effort are a basis for the ATE industry today. A primary example of this is the VXI standard, which grew out of the MATE Instrument-on-a-Card effort. The VXI form factor spurred the growth of modular instruments that installed offerings from different vendors on a common chassis. The advances in instrumentation technology, specifically the growth of digital synthesis and analysis of analog signals also fueled this growth. The level of BIT circuitry sophistication also grew in proportion. With the emergence of the standardized hardware elements of VXI came an effort to standardize the programming elements. The first efforts in this area were based (like CIEL) on common ASCII instrument programming commands. Both IEEE-488.2 (released in 1987) and The Standard Commands for Programmable Instrumentation (SCPI) defined commands for initiating instrument BIT, as well as formats for error and status responses. Standardized control languages did not bring the desired level of interoperability and multi-vendor compatibility, however. Addressing compatibility at a software interface drove the creation of the VXIplug&play Systems Alliance, supporting the VXIplug&play Instrument driver standards, and the Interchangeable Virtual Instruments Foundation. The goal of these organizations is to provide a means of defining an Applications Programming Interface (API) that will allow different instruments from different vendors to be controlled by relatively common and supportable access routines. Though a common means of calling and reporting errors is supported, publishing of instrument BIT fault coverage and isolation is not addressed by any of these efforts.

IMPORTANCE OF BIT FAULT COVERAGE AND ISOLATION IN SUPPORT SYSTEM MAINTENANCE

A primary function of support systems (and, in particular, automatic test equipment) is to certify that electronic military hardware (i.e., avionics elements) is mission ready. In order to accomplish this, the support system must have its operational performance verified. This is likely to be accomplished through a suite of self test software programs. Self test programs are normally specified to provide a certain level of fault detection (or fault coverage) and isolate failures to the least amount of replaceable units as much as possible. The level of fault coverage directly affects the size, complexity, and development cost of the self test programs. The increased use of BIT-equipped COTS instrumentation in support equipment naturally spurred the use of instrument BIT as part of the self test solution. The advantages include additional self test coverage with little development cost and decreased fault isolation ambiguity (because the BIT failure could be attributed to only one replaceable unit). Unfortunately, the test coverage provided by an instrument's BIT is not (in most cases) specified by the vendor. This means that in order to meet
a system specification for fault coverage, a system integrator must develop additional self test routines to provide the needed coverage. If the fault coverage was specified and the functions tested were well defined, the system integrator could rely on the BIT test and not have to incur the cost of the extra self test development.

THE BIT DEVELOPMENT PROCESS

When developing a BIT for an assembly (i.e., a VXI card) the developer is given a set of requirements and a schedule for completion. These requirements stem from several sources. If the card is being designed specifically to be in a large system (support equipment, in this case) then some of the system requirements would flow down at this time. The developer must now incorporate these requirements in the BIT.

Will there be:

- A power on BIT?
- A background BIT?
- A stand-alone BIT (a BIT that can be run autonomously with no external connections)?
- A BIT that requires a wraparound?
- Some kind of combination?
- A requirement on the time it takes for a BIT to run?

All these have to be taken into account with respect to the system into which the unit will be installed. During the initial design process these questions lead to even more questions:

- If there is a power-on BIT, how will the system check the status once it is finished?
- If a background BIT will be running, how will it provide status for the system to check (which will create more overhead for the system software)?

If a BIT that requires a wraparound is chosen, then care must be taken during the design of the system to take the wraparound into account when designing the System BIT.

In our experience we’ve found that a combination of the above (power-on BIT, stand-alone BIT, and BIT with a wrap-around) provides for the best solution. This gives the flexibility needed to perform different levels of testing. The power-on BIT is used as a sanity check to insure communications are up and running. (This is used at all levels of test.) The BIT with a wrap-around is used during manufacturing. (This insures that not only the internal circuitry is good, but also that the signals are good to the interface.) The stand-alone BIT is used during system level test to check the functionality and then more testing at the system level is done to insure that all signals are good at the interface.

THINGS THAT LIMIT THEIR EFFECTIVENESS

Fault Isolation and Detection (Coverage)

Now that the type(s) of BIT has been chosen, the actual development process can start. The goal of every BIT test should be to have a Non-Detection Percentage (NDP) of zero. This means that the particular assembly could detect all faults through BIT and could be pulled out of the system to be diagnosed at a later time, thereby decreasing the downtime of the entire system. 100% coverage, however, is not an economically achievable goal. If this goal were achieved for every system assembly then the System level test could more easily diagnose failures in the system and diagnose them with more confidence down to a single assembly. However there are several things that limit the effectiveness and development of assembly level BIT.

Time

When designing support equipment, maintainability and availability should be a high priority. As requirements for the system flow down to the assemblies we can see that one factor would be time. This refers both to the time it takes to develop a BIT and the time it takes to run it.

Fault coverage takes on a logarithmic curve with respect to time, as can be seen in Figure 2. This figure also shows that that the productivity of the developer (slope of the curve) starts out extremely high and then tapers off toward the end of development. This is true for a number of reasons. For example, at the beginning of development, for the most part, there are a number of tools that can be used to provide for all types of tests (e.g., automatic pattern generation, vector generation, etc.). These tools will allow the BIT developer to quickly ramp up the percentage of detected faults. (There is a difference between detected and isolated faults. At the system level, detecting faults is the main concern, while at the manufacturing or repair level, isolating the faults also becomes
important.) As the development continues the developer finds it harder to detect the fewer faults that remain. The decision is made to add more circuitry to the initial design. (This circuitry is purely for testing other functional circuits on the assembly.) This poses a conundrum: What about the circuitry just added? Should it be tested too? If only this circuitry fails, is the assembly considered not functioning? All the while time keeps ticking; pretty soon, the established schedule and budget has been exceeded by 10%. It is not in the engineer’s nature to quit before 100% coverage is achieved. Economics, however, prevent this from happening which emphasizes the point that one of the limiting factors of BIT is time. Not only development time, but also the time placed on the running of BIT. For example, if the developer is given a time limit of 30 seconds for this particular BIT to run, but only 93% of the faults can be detected in that amount of time, then the other 7% will go undetected in this particular BIT test.

REAL LIFE TESTING

As good as BIT is, in our experience, it should only be used as a building block when used in a system level test. Too many times we have found an assembly that passes BIT but fails a system level real life functional test. This could be due to many reasons. One of which could be (as in the previous example) the 7% that went undetected during BIT development. But also, it could be that real life does not always mimic theory. Perhaps the BIT developed was done so at a clock frequency of 1 kHz, but the assembly is specified to operate in a range from 500 Hz to 10 kHz. When the card was tested in the system at 10 kHz, a race condition was found that was not accounted for during the development of BIT. Though this is an oversimplification of the problem, it does make the point. Also in some instances, a module could be used in the system in a way not intended by the original manufacturer. In this case, real life testing would be the best solution because the BIT, as supplied by the manufacturer, would only test the card to the extent that it was intended to be used.

FALSE ALARMS

When performing a system level test, another drawback of BIT is false alarms. Many of the assemblies that are installed in a system have their own BIT that tests a certain percentage of the assembly. The usage within the system, however, may be limited to a small subset of the device’s full potential. Take, as an example a 1 GHz oscilloscope. If the system requirements only specified that the scope work up to 500 MHz and the scope failed BIT only in the 750 MHz and higher frequencies, this would be a false alarm. The scope will still provide all functionality with respect to the system even though a portion of the device was not functioning properly. To keep the system availability high, these types of failures should be discarded. Once a failure is detected in the device that causes the system to fail, then the unit should be pulled from the system and sent back to the Original Equipment Manufacturer (OEM) for a complete repair.

COMMERCIAL OFF THE SHELF (COTS) AND STANDARDS

When choosing a COTS assembly for a system, it is quite difficult to find information concerning BIT and its fault coverage. Many companies do not participate in industry standards concerning testability and BIT, on top of that, if you do find information, it may not be what you think. One manufacturer may speak of his BIT as only power-on BIT while another (assuming that all assemblies have power-on BIT) only speaks of I-BIT (initiated BIT). One manufacturer may specify isolatable faults with respect to only detectable faults while another specifies his with respect to all possible faults. As can be seen by these examples, choosing an assembly with respect to its BIT capabilities is difficult when comparing different manufacturers.

MAKING BIT MORE EFFECTIVE IN SUPPORT SYSTEM MAINTENANCE AND AVAILABILITY

Publishing BIT Test Fault Coverage

The knowledge of the fault detection capability is a powerful advantage for support systems developers. It allows them to plan and budget development costs accordingly for self test development and to ensure that redundant testing is not performed. Instrument vendors, unfortunately, do not have enough incentive to do this. The reasons for not doing this are many:

- no standardized way of determining fault coverage percentage;
- no standardized way of reporting the coverage capability; and
- additional development costs associated with characterizing the test coverage.

The possible solutions to these issues lie within organizational and standardization efforts already under way. The IEEE Instrumentation and Measurement Society formed Technical Committee 21 in 2000 to improve effectiveness of self test and built-in test methodologies. In particular, one of the stated goals of the committee is to "promote the use of Systems Engineering techniques and methodologies in the overall design process where BIT and self-test are required." A priority issue within the systems engineering domain is requirement management and validation. A logical extension of this thought would be to come up with the means for vendors to specify an instrument’s BIT fault coverage percentage and voids – in a way that is not so onerous that it discourages the vendor from doing so. But that, however, is beyond the scope of this article.

Another approach leverages the work going on within the IVI Foundation with regard to instrument driver development. One growing trend within that organization is the idea that the
instrument driver and the instrument itself are inseparable components of a complete system. Most of this discussion seems to be centered on ideas that are not germane to this issue (such as source code availability and intellectual property concerns). Though one important issue is advanced, which is the vendor is responsible for the operation and performance of the hardware device and the software driver – the whole system. And within this framework, we can also apply the IVI driver concept that instrument parameters are made available to the higher level users via attributes to BIT capabilities. Through a combination of applied, standardized requirement analysis and specification practices, and the support of an industry consortium, vendor supplied and supported instrument BIT fault coverage information may become readily available to system integrators.

Adding BIT Capabilities into Register Based Devices via Instrument Driver Standards

The lack of BIT circuitry and capability for register based instruments seems to be a foregone conclusion in today’s COTS offerings. Without a means to control BIT functions (due to the lack of an on board processor and firmware), vendors simply choose to omit BIT capabilities from register based devices. But it doesn’t have to be that way.

BAE SYSTEMS Mission Solutions has been building circuit card assemblies to implement test and measurement instrumentation functions since the 1970s. A key feature of these cards is on-board self test connections that connect key signals within a circuit to a systemwide analog self test bus and/or a system trigger bus system. These connections allow the measurement of voltage and timing parameters of these signals without tying up UUT interface signals. This concept was used in BAE SYSTEMS’ recent development of VXI based instruments to support unique functionality in the F-16 Improved Avionics Intermediate Shop (IAIS) Technology Insertion program. Though the analog self test bus does not exist in the new system (because its operation is not supported by the open standard VXI bus), self test circuitry (in the form of on-board A-D converters and switching circuitry) still exists. These modules are register based VXI modules, so all on-board self test circuitry must be under the control of the external system controller. As part of the development of IVI drivers for these instruments, BAE SYSTEMS developers incorporated code to implement on-board built in tests within the IVI self test function. This approach was applied to other COTS register based modules as well, verifying register and memory operation via data writes and reads. This capability afforded us additional and documented fault coverage that will be available to other systems where we may use these instruments.

CONCLUSION

The capabilities of instrumentation built in test have increased with the sophistication of the technology in the instrumentation. The quality of the BIT for a given instrument is determined through a series of design trade-offs that balance the fault coverage of the BIT with the time and cost restraints of its development. The usefulness of BIT to system integrators is improved when the system integrator is aware of the fault coverage of an instrument BIT both from a functional and quantitative viewpoint. Positive steps toward industry acceptance of an instrument BIT quality specification can be made via organizations that are already in the business of improving instrument software interoperability and self test effectiveness.

REFERENCES


AI Techniques in Uninhabited Aerial Vehicle Flight

Warren R. Dufrene, Jr.
Nova Southeastern University

ABSTRACT

This describes the development of an application of Artificial Intelligence (AI) for Unmanned Aerial Vehicle (UAV) control. The project was part of the requirements for a class in AI at NOVA Southeastern University and a beginning project at NASA Wallops Flight Facility for a resilient, robust, and intelligent UAV flight control system. A method is outlined which allows a base level application for applying an Artificial Intelligence method, Fuzzy Logic, to aspects of Control Logic for UAV flight. One element of UAV flight, automated altitude hold, has been implemented and preliminary results displayed.

INTRODUCTION

Man's attempt to fly UAVs has been on-going for a long time. Use of UAVs can be traced back to World War I. Current research continues at institutions such as Berkeley, MIT, Georgia Tech, and many government groups such as NASA, NOAA, the Navy, Air Force, and the Army. Universities in countries all over the world continue to research unmanned aerial flight and push the envelope for applications of Artificial Intelligence and conventional control methods, which guide aircraft.

Current research attempts to advance full autonomous flight of these craft. While there seems to be many definitions of what the autonomy encompasses, each discipline has highlighted its meaning and benefits.

Liu discusses a good outline of the problems involved in achieving control of complex systems today [1]. He outlines the heterogeneous modeling and design of an advanced control system approach. One of the key problems faced is the fact that systems and sensors involved are heterogeneous in nature. These systems must be integrated and resolved into a working system. For the most part, this will be true for most complex UAV systems which attempt full autonomy.

BACKGROUND

New applications of AI, which include Intelligent Agents, are providing new areas of research [2]. Research has expanded during the past five years within the applications of Artificial Intelligence (AI) methods applied to the concepts of flight for the UAV. The UAV can be described as any platform operated without on board human occupation. Systems, which exist today, include helicopters, airplanes, balloons, blimps, and even satellites. Their autonomy varies from human interaction from a remote console to full autonomous takeoff and landing. Earlier research, conducted by Handelman and Stengel, applied AI methods such as expert systems and schedulers, which applied rule-based systems [3]. These systems attempted to formulate the art of flying an aircraft into logical tasks that step through a series of events to maintain control of specific functions of the aircraft. This concept will still be a key component with systems designed for future use.

The initial concept of using an Expert System to control an aircraft seems simple at first, but proves difficult to apply. Some of the problems that still exist today include the fact that an expert pilot's decision-making process is difficult to imitate with computers. The dynamic environment and conditions affecting aircraft are areas that have to be adapted to such an Expert System.

Later research efforts began to divide the many tasks involved in the control of UAV flight into manageable steps. Concentrated efforts of applying logic schemes, similar to Fuzzy Logic and Neural Networks, are being applied to improve the mathematical solutions for flight control. In an article on flight control systems, Robinson commented that Dr. Anthony J. Calise, professor of aerospace engineering at Georgia Tech, stated that, "... several areas of control for UAV's can be adapted to the use of Neural Networks" [4]. The author gives several accounts of the advantages of applying Neural Networks in addition to the normal control methods of a UAV through an integration of these systems.

Current research efforts are evolving the application of AI approaches into Hybrid Systems. He gave accounts of researchers who were thinking about the expected advances in aerial vehicle control. Page quoted an associate professor of mechanical engineering at the University of Florida, Norman
Fitz-Coy, who stated: “Ultimately, it is expected that an ideal flight control system for an adaptive wing Miniature Aerial Vehicle (MAV) will use soft computing techniques, such as fuzzy logic, neural networks, genetic algorithms, pattern recognitions, or knowledge-based systems” [5].

Past research efforts are being modified to include an integration of more AI methods. These current research efforts are the interesting advancements taking place: How does a machine fly an aircraft like a human can? What does a human think about in the process of reacting to the environment? Can a machine really “think” enough to fly a UAV fully autonomously? These are the questions pushing UAV research.

THE PROBLEM OUTLINED

Research of the applications of AI soon reach a point where the approaches, algorithms, and models need to be applied for further understanding of their usefulness and applicability toward any given project for a UAV [6, 7]. Most of the research papers reviewed gave excellent theory but not give enough information on the mechanics or steps for applying the methods outlined for beginning a research effort.

The focus of this research has been to outline some of the AI techniques used for UAV flight control and discuss some of the tools used to apply AI techniques. The intent is to succeed with the implementation of applying AI techniques toward actually controlling different aspects of UAV flight. These tools and techniques serve as the project’s basic start.

THE APPROACH

There is an endless increase in the content of research and papers existing on accomplishments and proposed research within the subject matter of unmanned flight. The field was narrowed to include AI methods that could be applied easily in a laboratory environment.

During the completion of the steps in Figure 1, the following work was accomplished. The decision to use JAVA was due to a requirement for the AI class; although the use of a new language was slow at first, this programming language environment proved very beneficial for this type of project. The following summary is given for the general approach:

A. The first approach to the problem was to research past and current efforts of UAV flight control at universities. This research was done on the web through sites and journal articles.

B. Research was done after isolating the choice for elevator control to maintain altitude. An attempt was made to find a fuzzy logic program or applet written in the JAVA language.

C. While doing the research, several books were purchased for learning JAVA. The Sun JAVA site was also used, as recommended, for

![Fig. 1. Design Approach](image)

initial understanding of the format and structure of JAVA.

D. The approach for the project was to learn basic JAVA programming techniques for reading simulated UAV flight files, converting these files, if needed, and running or modifying a Fuzzy Logic application.

E. Three strong candidates for usable Fuzzy Logic JAVA programs were found:

1). The first package was a complete JAVA class developed for use within a JAVA program. This program is called Fuzzy Engine by Professor Edward Sazonov and can be found on: (http://www.csee.wvu.edu/~esazonov/FuzzyEngine.htm). This package was reviewed and set aside as a future application for more advanced work.

2). The primary candidate was a program called FIT written for Fuzzy control by Gerald A. De Jong (gerald@beautifulcode.nl) retrieved from: (http://www.beautifulcode.nl). This package included a program already designed for a fan controller. The code was a good candidate for modification to a simple elevator controller for the UAV.

3). The second candidate was a commercial package with free demo download called
Fuzzy Logic System

Inputs

Acceleration

Fuzzy Engine

Altitude

Outputs

Throttle

Elevator

Fig. 2. Fuzzy Controller

FuzzyTech 5 which can be retrieved from: (http://www.fuzzytech.com/index.htm). The FuzzyTech package allowed input of a data file into a Fuzzy Controller that can be designed within the program's own Graphical User Interface. Work was done with this package (and some results will be presented). The licensed package will also convert the design to code into JAVA or C.

The description of the contents of Figure 1 are discussed in greater detail.

REVIEW UNIVERSITY UAV RESEARCH

The key concepts reviewed included work done by Berkeley, the University of Florida, and several other universities. The research papers provided key ideas for the application of actual concepts to use Fuzzy Logic as a base AI approach. While success was not guaranteed, an educated evaluation was done to review the applicability.

The main attempt was to duplicate linear control methods by using a fuzzy controller.

Narrow AI Techniques for Application

The approaches seen in most of the research included Expert Systems, Neural Networks, Fuzzy Logic, and Hybrid combinations of these and PID control schemes. The AI approaches selected to use were Fuzzy Logic, Expert System, and, later, a combination of Neural/Fuzzy for adaptive capability.

Obtain Applicable Expertise in AI Methods

The first AI approach attempted during the project was Fuzzy Logic. This technique was used to control the altitude hold of a simulated UAV. Several approaches were attempted; the first application involved writing JAVA code to simulate a flight using calibrated steps of altitude climbs. The second application involved learning a demo copy of a commercial program for designing a Fuzzy Control System (FuzzyTech 5.x). The output data from the first application was used for input into the demo program. The output data file from FuzzyTech was imported into an Excel spreadsheet for comparison against the input data.

Fig. 3. Autonomy Objective

Load Mission

Flight Computer

Mission

Control UAV

Review

Fig. 4. Project Goals

Design a Model for AI Application

A model was needed to allow a confined implementation of a simple Fuzzy control scheme. The chosen altitude hold was used with an added input for acceleration control. The acceleration control was for future work involving degrees of power needed during different scenarios of flight (take-off, level flight, disturbed flight, and approach).

The design for the fuzzy controller is outlined in Figure 2. The first system only included altitude as an input and elevator as the output and proved to be a simple and stable control scheme. Acceleration was added to give future degrees of control for a throttle output to compensate for levels of dynamic change in conditions of the flight envelope.

Design Autonomy Definition

The definition for autonomy for this project has been defined as the creation of a craft (which includes the smallest breakdown of agents) which can perform its pre-determined function without additional human interaction. This definition
will follow the same criteria. The mission plan will be the desired altitude to hold. The mission objective will become the desired altitude. The fuzzy controller will control the UAV craft and a review is still done inherently by the change in input to the fuzzy controller.

**Design Project Goals**

The project goals in Figure 4 outlines the required steps attempted to complete the project. The choice was made to work within existing JAVA code and implement an off-the-shelf application. This was decided so the control output effects could be compared against each other for verification of correct response behavior.

**Apply AI Techniques and Evaluate**

The chosen technique for this project was to apply a specific Artificial Intelligence technique (Fuzzy Logic) to the problem of flight control for a UAV. The chosen control problem was to maintain a desired altitude as shown in Figure 5. Although the main desired output for the aircraft was "Elevator Control," the application was studied further to gain knowledge of the effects of aircraft speed also. This type of application will allow Intelligent Agent approach to be implemented at a later date.

The desired project was outlined (Figure 6) but the application chosen for the simulator graphical user interface (GUI) FlightGear proved too complex for the allotted development time. This will be a key application for any research because it provides a visual representation of the UAV control effects. The software is a free distribution and very well supported.

**RESULTS**

The work performed is described in the following sections.

**Results from Tests of the System with Appropriate Data**

The results from the first program (modified beautifulcode fuzzy logic demo) were somewhat stable but required tweaking of the Degrees of Membership in the program to provide smoother transitions. The program output was in the form of graphs as depicted in Figure 7. Although the desired output for altitude and elevator was achieved, some experimentation was done with speed. The obvious effects of elevator angle will be different depending on the speeds at which the aircraft is moving. This is similar to holding your hand out the window of a moving car. At slow speeds you can turn your flattened hand at different angles and keep your arm still, but when speed increases to approximately 50 mph your arm becomes unstable and moves wildly about when you increase the angle of attack of your hand.

The off-the-shelf program (FuzzyTech demo) was used on a data input file created with a Java program written to give simulated calibrated UAV flight data (not real data). FuzzyTech 5.5 was used to design a simple fuzzy controller. The designed fuzzy controller was used to successfully read the data and output a data file. The output file was then read...
using another Java program written for it. Microsoft Excel was used to graph the data file. The desired altitude was 5000 feet, and the graph in Figure 8 displays the expected elevator outputs for the generated altitude calibration steps.

CONCLUSION AND FUTURE WORK

The AI techniques can be greatly expanded with further work in this development. Attempts can be made to expand the use of AI techniques so a comparison can be done against more conventional flight controllers. While this paper describes the accomplished work only, much time was spent installing and learning to compile the flight simulator FlightGear. This flight simulator program would provide an excellent interface option for the tools used so far. The completed JAVA code would have to be expanded to use one of the communication protocols that FlightGear provides. The setup and protocol for the communications was the primary blockade during this project assignment.

Once these tools are farther developed, the combination of code plus the capability to visually view the performance and analyze the results real-time will provide a strong, practical, and low cost platform for experimentation with AI techniques which are applied to flight control. The summary of some of these conclusions and future work are outlined in Figure 9.

The variety of research being conducted today is vast. Figure 10 illustrates a small part of the variety in UAV systems and parallel bionic types of systems. These types of systems are combining knowledge from our natural environment with software and advancements in technology to produce adaptable systems.

REFERENCES


Use of Laser Scanning Technology for Perimeter Protection

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Police Scientific Development Branch

ABSTRACT

The Police Scientific Branch (PSDB) is part of the Crime Reduction and Community Safety Group (CRC SG) of the Home Office. Part of PSDB’s work includes evaluating and assessing new technologies for perimeter intrusion detection.

Laser scanning technology has been used for some time in a range of industrial and commercial applications. These span from detecting hands when they are close to dangerous machinery to preventing collisions at container ports and monitoring manufacturing processes. Laser scanners are non-contact measurement systems and scan their surroundings two-dimensionally.

This describes the application of laser scanning to physical security, including modifications to such systems for their use as perimeter intrusion detection systems (PIDS). In these systems, motion detection is provided by a pulsed laser beam by measuring the propagation time for the reflected beam to return to its source. Using this information, a contour plot of the surrounding area is built up. Once this contour information has been obtained, the detector can recognise the addition of an object to its field of view through a change in the programmed surroundings. Consequently, the size, shape, and direction of targets moving in the frame can be assessed and an alarm output given, if required.

This explains the main operating principles of the systems, including mechanisms for the detection of a potential intruder and the handling of false alarms. Detection capabilities and the potential for low false alarm rates will be described, along with configurations for operational deployment.

OPERATING PRINCIPLES

Laser scanning systems typically produce a detection field by reflecting a pulsed laser beam from a rotating mirror. For example, using appropriate optics, a detection field can be produced which forms a plane, approximately 50 mm deep, over a scanning angle of up to 190°. The maximum scanning radius achievable is approximately 80 metres and the angular resolution of the pulses can be set between 0.25° and 1°. If the angular resolution is set to 0.25°, 760 measured values will be taken over the 190° range of the detector.

The time taken for each complete scan is directly related to the angular resolution and, depending on the value chosen, will vary between 10 and 50 milliseconds.

The time for the laser pulse to be reflected back to the detector is measured at each point, allowing the distance to the reflecting object to be calculated via the equation, Distance = Speed of light x time of flight. In this case, the propagation time is for the laser light to reach the target and return to the source. Therefore, the distance calculation is:

\[ D = c(t/2) \]  

where D is the distance to the target, c is the speed of light and t is the total propagation time. For example, if a propagation time of 200 nanoseconds is recorded, the distance to the target will be:

\[ D = 3 \times 10^8 \text{ms}^{-1} (200 \times 10^{-9}/2) = 30 \text{metres} \]  

subsequently, a contour plot of the surrounding area can be built-up. Real-time monitoring of this information allows the associated software to determine whether there are any changes within the scene.

An example of a real-time user interface is shown in Figure 1.

DETECTION CAPABILITIES

Multiple detection zones can be programmed into a typical detector. The shape, depth, and distance of each detection zone are defined with the user software. Communication with the
detector for real-time monitoring and changing parameters is established via an RS232/422 interface.

Alarms are generated when an object enters the detection zone and meets a set of pre-defined criteria. These criteria can describe the size, location, and time of the target within the field, allowing the user to specify which targets are of relevance.

The radial nature of the detection field determines the range at which targets of a given size can be detected. In order for the scanner to recognise an object in the detection field, at least two neighbouring laser pulses must be intersected consecutively (see Figure 2).

Thus, if the angular resolution of the unit is known, simple trigonometric calculations can be used to determine the maximum range at which a certain size of object can be detected.

Using this principle, parameters can be programmed into the software that determine the minimum size of object that will generate an alarm. This programmability allows the user to specify the minimum size of object needed to generate an alarm at the required range, as in the following examples.

* At 20 metres from a unit, with an angular resolution of 1°, the object width required to break two consecutive pulses is 0.70 metres.

* If it was desirable to detect objects with a width no smaller than 1.4 metres at this distance (to reduce the false alarm rate), the unit may be programmed only to alarm after four consecutive pulses are intersected.

**DETECTION ZONES**

Areas of unwanted detection can be blanked out to prevent unnecessary alarm activation. By programming in a number of "detection zones" (maximum number determined by model of scanner and software), the user can specify which parts of the scene he/she wants to protect. The use of multiple zones (with their associated outputs) allows the user, via the alarm interface, to determine precisely the area in which the unwanted intrusion has occurred and respond accordingly.

Reference points can be programmed that can be beyond the range of a desired detection zone. The scanner will "look" for these reference points at all times and alarm if they are not detected. This can be useful in alerting system administrators of a fall in detection range (possibly due to the presence of fog) and attempts to mask detection zones or move the scanner from its mounting configuration.

**FALSE ALARM HANDLING**

False alarms often occur during periods of bad weather or when wildlife is present.

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1. PSDB uses the term "false alarm" to describe alarms that have not been caused by a human or vehicle in the detection zone.

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**Fig. 1. Real-time field monitoring [1]**

**Fig. 2. Target intersecting two pulses**

* Alarms caused by birds flying through the detection field can be filtered out using the same principle that defines the minimum size of target, i.e., by setting the number of scan lines that need to be intersected to cause an alarm. Birds flying in the detection field are unlikely to break, say, four consecutive pulses, except when in close proximity to the source and, thus, the false alarm potential created by wildlife can be greatly reduced.

* Alarms that would be caused by birds and wind-swept debris can also be filtered out by stipulating a time period that the object must
remain in the detection zone. By selecting the number of scan cycles (not scan lines) that need to be intersected for an alarm to be generated, the user can determine how long an object must be in the field before an alarm activation. Therefore, the detector can be programmed so that fast moving objects, such as birds, are unlikely to be in the field long enough to be a source of false alarms.

- Rain is often the cause of many false alarms in PIDS. Laser scanning PIDS filter false alarms from rain and snow by monitoring the data received from every pulse within a single scan. By repeatedly examining each pulse, the software can “recognise” data conditions that correspond to rain (random, small interval detections on each scan line) and give an output only when a significant number of close-proximity scan lines are intersected for the pre-determined interval.

- Fog can have a varying effect on laser detectors, depending on its density. Multiple reflections of the laser beam from water particles within the fog cause the transmitted (and reflected) signal to be attenuated. This has the effect of making the target object appear less reflective, thus reducing the detection range. This effect may, to some extent, be corrected for by increasing the sensitivity of the detector.

**FALSE ALARM RATES (FAR)**

Tests conducted by PSDB on laser scanning PIDS suggest that they are capable of low false alarm rates in varying weather conditions. An evaluation of one system showed a false alarm rate of 0.75 per kilometre per day over a one-month evaluation period.¹

**DETECTION RATES**

Data collected in the above evaluation showed that it is possible to detect a human target over a range of 40 metres with 100% confidence. With suitable scanner configuration, attacks carried out using a cylindrical test target of 200 mm diameter also resulted in high detection rates.

**APPLICATIONS**

Laser scanners can be mounted in a number of different configurations, depending on the application for which they are required. They are suitable for attaching to walls, roofs, lighting poles, fences, and any other (relatively stable) object. When mounted on lighting poles, and in similar positions subject to movement in high winds, the detection zones can be programmed with a tolerance at their extremities. This is done by terminating the zone before it hits the surface and leaving a “gap” that is equal to the maximum expected movement.

The orientation of the unit can be adjusted to suit the user’s needs. This ability is a direct result of the programmability of the field and the fact that the detector does not need a surface on which to terminate the detection zone.

The tests carried out by PSDB using a 200 mm diameter target recorded good detection results over a 45-50 metre range. Further testing using human targets produced similarly encouraging results and showed the potential of laser scanners for protecting open areas, perimeters, and flat roofs against intrusion.

HM Prison Services are currently conducting a trial of laser scanning technology, applied to the detection of inmates attempting to exit buildings via their cell windows.

Laser scanning is suitable for identifying the unauthorised presence of vehicles, as well as detection of personnel. Because of the much larger scale and higher reflectivity of vehicles, the detection range should be greatly increased from that of approximately 25 metres for people. Ranges up to 80 or 100 metres may be possible for this application.

![Fig. 3. Scanner configuration for evaluation at PSDB](image)

For perimeter applications, longer zone lengths can be covered using multiple detectors. A detection field overlap of five metres is recommended for multiple detectors to provide full area coverage. Detectors may need to be synchronised for multiple usage to prevent false readings being obtained via multiple reflections from targets. Advice on the maximum number of units that one system can operate (if applicable) should be sought from the manufacturer.

Large areas can also be covered with laser scanning PIDS. The radial nature of the unit produces a semi-circular detection zone, whose effective size depends on the target object. For personnel detection, a radius of 30 metres is achievable; this results in a semi-circular detection area of approximately 1400m².

**CONSIDERATIONS**

Since the detector relies on information received from a reflected laser beam, the reflective properties of the target object have an influence on the effective range of the system. Materials with high reflective properties, such as light

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¹ As detailed in PSDB Publication No. 30/02 "Laser Scanning Evaluation for Perimeter Protection."
coloured or shiny objects, will display higher detection ranges than those with higher levels of optical absorbency, such as dark coloured, matte finished objects.

Consideration should therefore be given to the type of clothing the potential attacker may be wearing. Intruders are likely to be dressed in dark coloured clothing, such as denim, with a reflectivity value ranging between approximately 10-20%, making them harder to detect. Users should account for the worst case, which is matte black clothing, when installing a system and can then be confident that objects with higher reflectivity values will be detected at their desired range.

Changes to the sensitivity of the detector can help meet the user's needs. Increases in sensitivity will improve the detection of dark objects but may increase susceptibility to effects from ambient light. Inversely, the effects of ambient light can be reduced by reducing the sensitivity, although this will have the effect of reducing the ability to detect dark objects.

The presence of ambient lighting is not stated as an essential requirement for the operation of laser scanners. Trials conducted by PSDB on currently available commercial scanners, however, have shown reduced detection ranges with low ambient lighting levels. This has highlighted the need for a comprehensive site survey and, depending on detection profile and reflectivity values, adequate detection zone illumination for effective night-time operation.

LIMITATIONS

For perimeter applications, where multiple detectors may be required to cover large zone lengths, cost may be a limiting factor in using laser scanning PIDS.

Laser scanners are relatively large units and, thus, cannot be deployed covertly. Including weather shielding, the detector is likely to protrude 400-500 mm from the surface on which it is mounted.

For outdoor applications, an internal heater element is required to prevent condensation build-up on the lens and mirror. This should be provided on all outdoor scanners.

SAFETY

Laser scanners operate using class 1, eye-safe, laser diodes.

SUMMARY

System Benefits

- Non-contact detection system.
- Monostatic (laser transmission and detection hardware located in a single unit).
- Difficult to defeat.

Table 1. Reflectivity of some well-known materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Reflectivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black rubber tyre wall</td>
<td>2</td>
</tr>
<tr>
<td>Cardboard, matte black</td>
<td>10</td>
</tr>
<tr>
<td>Cardboard, grey</td>
<td>20</td>
</tr>
<tr>
<td>Wood (raw pine, dirty)</td>
<td>40</td>
</tr>
<tr>
<td>PVC, grey</td>
<td>50</td>
</tr>
<tr>
<td>Tissue paper, two ply</td>
<td>60</td>
</tr>
<tr>
<td>Paper, matte white</td>
<td>80</td>
</tr>
</tbody>
</table>

- Large area coverage (~1400 m² for human detection).
- Can define target size and other parameters for alarm activation.
- Definition of multiple zones.
- Good detection rate.
- Low False Alarm Rate.
- Visual monitoring of changes in the programmed contour.
- Low maintenance (although reliability of the rotating mirror remains to be established).

**System Drawbacks**

- Relatively high cost of detectors (~£3000 – £5000).
- For linear perimeter detection of personnel, this figure represents approximately £100 per metre (excluding installation costs).
- Detectors are not covert.
- High power requirement (with use of internal heater).

Perimeter intrusion detection systems need to be carefully selected for operational deployment. Each system has unique strengths and weaknesses that can strongly influence their effectiveness if chosen for an unsuitable application. Such attributes need to be considered with particular reference to detection requirements and false alarm susceptibility.

**Advantages of Laser Scanning Technology over other Monostatic, Volumetric PIDS:**

- Passive Infra Red
- Laser scanners are much less sensitive to effects from ambient lighting and environmental conditions than passive infra red detectors.
- Larger detection area.
- Laser scanners cannot be defeated by slow movement.
- Detection zones cannot be programmed into PIRs, nor can complex contour plots. Laser scanning PIDS provide this programmability and visual monitoring of any changes to the programmed contour.

**Doppler Microwave**

- The size of the detection envelope can be changed in Doppler microwave detectors; however, this provides little selectivity of detection area compared with the contour programmability of laser scanning PIDS.
- Doppler microwave detectors can be defeated by slow movement. Because of the contour information used by laser scanners, even the slowest moving objects can be detected.

**Microwave Radar**

- Microwave radar systems cannot pinpoint the location of a target in the detection zone, only that something has entered. Laser scanners, however, can produce a real-time user interface that allows the user to identify where the intrusion has occurred.
- Range gating used in microwave radar systems allows the user to define a radial area in which he/she wants to detect intrusion. This is determined by the transmit/receive time of the radar. Laser scanners provide a more complex system for determining contour information and programming in multiple detection zones. The shape and size of these zones are independent of the radial nature of the scanner and are set with programmable user software.

Laser scanning detectors offer an alternative to traditional detection systems. The radial nature of the scanners allows large areas to be monitored, as well as the option of linear detection zones. Outputs from the scanner could be used to raise intruder alarms and trigger recording of CCTV footage.

Scanners can be mounted in orientations specific to the application and detection rates can be good with correct configuration. This, combined with low false alarm rates and system programmability, make laser scanning detectors a possibility for a range of intruder detection applications.

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Time-Domain Measurements of Radiated and Conducted UWB Emissions

Robert T. Johnk, David R. Novotny, Chriss A. Grosvenor, Nino Canales & Jason G. Veneman
NIST

ABSTRACT

This summarizes results obtained from time-domain full-bandwidth emissions measurements of selected ultrawideband (UWB) transmitting devices. Brief descriptions of two NIST-developed measurement systems are provided. High-fidelity time-domain waveforms are shown, along with associated amplitude spectra for several devices. Results are shown for both conducted and radiated emissions from UWB devices.

INTRODUCTION

Ultrawideband (UWB) systems that employ nanosecond duration baseband pulses have been in use since the 1960’s [1]. Early systems were used primarily for metrology-grade time-domain network analysis, precision calibrations of sensors and antennas, precision scattering measurements, and electromagnetic pulse (EMP) field generation. During the past decade, UWB technology has been adopted by the private sector for a wide range of innovative applications such as digital radio, local area networks, ground-penetrating radar systems, and intrusion detection. There is currently much concern on the part of US government regulatory agencies, such as the Federal Communications Commission (FCC) and the National Telecommunications and Information Agency (NTIA), about potential interference effects that UWB systems might have on conventional communications, safety, and navigation systems. A unique time-domain measurement system has been developed by NIST researchers [2-4] to provide fast, accurate, and full-bandwidth measurements of UWB emissions.

The NIST-radiated UWB system is based on a combination of a single-event waveform measurement system and ultrawideband horn antennas. This system possesses a unique, full-bandwidth measurement capability that is unmatched by the conventional CW scalar spectrum analysis systems. This system has characterized both time- and frequency-domain emissions from a number of commercial UWB devices, with excellent measurement fidelity obtained. Results are presented here for a wireless communications system, and a radar system. In addition, results from a more recent evaluation of a reference radiator are also shown.

NIST MEASUREMENT SYSTEMS

Two measurement systems have been developed for the characterization of UWB devices. The first, depicted in Figure 1, is configured to measure conducted emissions directly from

![Fig. 1. Measurement system for conducted UWB emissions](image-url)
Fig. 2. Measurement system for radiated UWB emissions

Fig. 3. Conducted time-domain pulse from a wireless UWB communications device

The output port of a UWB device. The output signal is attenuated to a suitable level and applied to a 3 dB power splitter, which provides equal signal and trigger voltages. The heart of this system is a transient digitizer with a 4.5 GHz bandwidth. A transient digitizer is a real-time oscilloscope that rapidly sweeps an electron beam across an array of diodes, located inside a cathode-ray tube. The trigger signal initiates a single sweep of the electron beam, with the deflection proportional to the applied signal level. The electron beam illuminates an array of diodes, which, in turn, provides the

Fig. 4. Conducted amplitude spectrum from a wireless UWB communications device

Fig. 5. Radiated time-domain pulse obtained from a UWB wireless communications device
mechanism for digitizing the applied signal. In essence, the electron beam "writes" the waveform directly to the diode array. The deflection plates have a traveling-wave structure with very high bandwidth and high deflection speed. Internal software provides correction and interpolation of the diode array output, resulting in an effective resolution of 1024 points horizontal and 2048 points vertical. This instrument currently has the highest bandwidth available for real-time oscilloscopes, with a realizable bandwidth of 15 GHz, achievable through the combination of a reference sampling oscilloscope and deconvolution [5]. The single-event measurement capability of this instrument enables capture and high-fidelity resolution of single pulses within asynchronous pulse trains.

The second system, designed for measurements of radiated UWB pulses is shown in Figure 2. A UWB emitter is placed at a specified distance (typically 1-3 m) from the receiving antenna of the measurement system. The receiving antenna used is a NIST-developed 30 cm TEM horn antenna, with a frequency range of 150-3800 MHz. The TEM horn provides less distortion and reduced impulse response duration due to linear phase characteristics of its receiving transfer function [6]. The system also incorporates an amplifier to boost the received signal and to provide a stable trigger.

RESULTS

Results are given for two representative UWB transmitting devices: a wireless communications system and a UWB radar.
Fig. 10. Conducted generator output of the precision reference radiator

Fig. 11. Conducted generator amplitude spectrum of the precision reference radiator

In addition, a set of results is presented for a reference UWB radiator used for intercomparisons of EMC emissions measurement facilities. The measurement system was deployed in the NIST (8 m × 5 m × 5 m) anechoic chamber in order to suppress environmental ambients and scattering.

One device investigated was designed for general data and voice communications. The conducted time-domain waveform is shown in Figure 3. The acquired waveform contains a high-fidelity replica of a transmitted UWB pulse, from which useful information can be extracted, i.e., pulse duration and peak voltage can be readily evaluated. The pulse has an extended temporal response, due to a fast pulse applied to a band pass filter with rapid cut-off characteristics. The frequency-domain spectrum of Figure 4 was obtained from a Fast Fourier Transform (FFT) of the acquired waveform. The bandpass characteristics of the transmitted impulse are readily visible. Equi-ripple characteristics are noted in the pass band of the filter.

Radiated emission results were obtained by installing an antenna on the device and placing it at a distance of 1 m from the receiving antenna. A 30 cm TEM horn antenna was employed for this measurement sequence. Radiated characteristics are shown in Figures 5 and 6. The peak signal amplitude is significantly reduced from that of the conducted case – from 9V to approximately 0.15V, due to a combination of antenna efficiency and path loss. Some change occurs in the emitted amplitude spectrum and the temporal response is longer, caused primarily by resonant behavior of the transmitting antenna.

Another device evaluated in this effort was a UWB radar. Radiated pulse characteristics are depicted in the time- and frequency-domains in Figures 7 and 8, respectively. The time-domain characteristics are dramatically different in this case, with a much shorter duration that permits high range resolution. The main pulse duration is approximately 1.5 ns,
and the associated amplitude spectrum is extended over a much broader bandwidth of 400-4000 MHz. There is a great deal of variability in emissions spectra of UWB signals, depending on the design of the transmitted waveform.

The system was next used to characterize the precision reference radiator depicted in Figure 9. This device consists of a short-pulse generator and a detachable antenna/balun network. The pulse generator is battery operated and emits a very stable train of short unipolar pulses at a fixed repetition rate. The conducted generator output is shown in Figure 10 with a pulse duration of approximately 2 ns. The reference radiator is designed for intercomparisons of radiated EMI measurement facilities in the 30-1000 MHz frequency range. The associated single-pulse amplitude spectrum, shown in Figure 11, indicates true ultrawideband behavior. In addition to the conducted measurements of the pulse generator, a series of radiated measurements were performed using a 40 cm biconical antenna supplied by the manufacturer and a 30 cm TEM horn antenna. Time-domain results, obtained at a distance of 2 m, are shown in Figure 12, and the associated frequency-domain amplitude spectra are shown in Figure 13. The tests highlight the influence of the antenna on both the emitted pulse characteristics and the emissions levels.

**CONCLUSIONS**

Single-event measurement systems at NIST have the ability to capture single pulses from asynchronous UWB transmissions. The use of a fast single-event transient digitizer in conjunction with broadband, linear-phase TEM horns enables high-fidelity time-domain measurements of transmitted UWB pulses. Signal processing is subsequently used to compute spectral amplitude characteristics of transmitted pulses. In addition, the captured pulses can be used in systems simulators to predict impact on conventional communications, navigation, and other electronic systems.

Results are shown for three UWB emitters: a wireless communications device, radar, and a precision reference radiator. The results demonstrate the utility of NIST-developed measurement systems, and the different characteristics of transmitted UWB signals.

**ACKNOWLEDGEMENTS**

The authors thank Drs. Perry Wilson and Dennis Friday of the NIST RF Technology Division for their support of this on-going research.

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A Door-Opening System Using A Low-Cost Fingerprint Scanner and a PC

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ABSTRACT

Biometrics can offer improved security for access control. Several biometric devices can be adapted to our special requirements and some criterion is needed to choose the best solution for us. On the one hand, it is possible to use a standalone embedded system. On the other hand, a low-cost PC-based system can be better fitted to our special requirements, by means of special purpose software. With the actual reduction on the price of informatic components, it can be a good alternative. This describes one of these systems for door-opening with the user’s fingerprint. Special emphasis is given on the design, advantages, and inconveniences with respect to embedded systems.

INTRODUCTION

Concerning security matters, biometrics can play a key role. The strengths and weaknesses of biometrics compared to classical security methods is beyond the scope of this paper and can be found in [1]. In this paper, a design for a door-opening system is presented. Once a decision has been taken to adopt a biometric solution instead of (or in combination with) a hand-held token or a knowledge-based system, the next step is to adopt a standalone embedded system or a PC-based system. So far, the former has seemed to be more professional, compact, and low-cost. However, nowadays, the cost of personal computers is considerably low, and there are small low-cost cards available (PC-on-chip module). All together is an alternative to be taken into account before making a decision. Table 1 summarizes the main advantages and drawbacks of both solutions.

Figure 1 shows an example of a standalone device suitable for a door-opening system, and Figure 2 shows the PC-based door-opening system with a low-cost fingerprint sensor, and special software developed for our purposes.

DOOR-OPENING SYSTEM BASED ON A PERSONAL COMPUTER

Although our actual version is based on a standard PC, the application can be easily transferred to a low-cost ARM CORE PC, and some of the advantages of the embedded system can be achieved. An example of these systems is the PC-on-chip module. Table 2 summarizes the main features of one of these hardware systems [3]. Anyway, the proposed PC-based system seems to be more suitable for testing the device, and a further step would be to transfer the application to this module.
Table 1. Comparison Between Embedded and Personal Computer Based Systems for Fingerprint Access Control

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Embedded system</th>
<th>Personal computer + software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>• It usually is a solid-state sensor [2, chap 2] in order to reduce the device’s size. Thus, it should be fixed by a specialized repairing service.</td>
<td>• It can be freely chosen and easily replaced if it goes old or is destroyed due to vandalism.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• It is connected by a standard USB, parallel etc. port, so no soldering process is needed.</td>
</tr>
<tr>
<td>Cost</td>
<td>• It requires a special hardware, so its cost depends on the number of products sold by the manufacturer.</td>
<td>• PCs are massively sold, so their price can be quite competitive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low-cost cards that implement the main functionalities of a computer are available. [3]</td>
</tr>
<tr>
<td>Size</td>
<td>• It is quite compact, and devices about 20cm×15cm×10cm exist.</td>
<td>• Its size is bigger, but low-cost and small-size cards exist [3] that have the required PC functionalities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>• They just have the strictly necessary electronics, so their power consumption is usually low.</td>
<td>• Unless a PC-on-chip module is used, their power consumption is higher than an embedded system because a PC is a general purpose device with more electronic components than needed to open a door.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The PC should be inside the door. Thus, the unique vulnerability point is the sensor.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The PC should be disconnected from internet, if remote attacks want to be avoided.</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>• Main vulnerability points according to [1] are the sensor and decision levels (the whole system can be pulled out from the wall and the control wires for opening the door manipulated).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptability to special requirements</td>
<td>• The companies offer a general product that cannot normally be adapted to special requirements.</td>
<td>• It is just needed to modify the software, which can be a C program. Thus, it is easy to include or eliminate some functionality.</td>
</tr>
<tr>
<td>Computational power</td>
<td>• In order to reduce the cost, size and consumption, these systems have a microprocessor.</td>
<td>• State of the art computers include a powerful microprocessor that lets to operate on an identification mode and make hundreds of comparisons per second.</td>
</tr>
<tr>
<td></td>
<td>• Due to the processor limitations it is restricted to verification mode.</td>
<td></td>
</tr>
<tr>
<td>Malfunctioning solving</td>
<td>• It is a closed system, so it is quite difficult to arrange, so a special repairing service must be called.</td>
<td>• It is quite easy to debug the problems and replace the damaged portions, which are quite standard (the hardware consists of a personal computer).</td>
</tr>
</tbody>
</table>

Low-cost fingerprint scanners designed for a PC environment are mainly thought to lock the computer screen and avoid passwords. Thus, one interesting experiment is to see whether they are suitable for 24-hour, 7-day-per-week working. In our experiments there were no problems due to the sensor. The problems that appeared were because of the low-cost computer, which crashes when operating in continuous mode for several days. Taking into account that the door-opening system must be operative around 12 hours per day, the adopted solution, which also reduces the power consumption, was to install a program, like ICPU shutdown [4]. This program turns on and off the computer at predefined hours (turn on at 8:00 AM, turn off at 9:00 PM in our case).

Table 2. Features of a PC-on-chip module (ARMCORE)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Below 50 USD (basic configuration)</td>
</tr>
<tr>
<td>CPU</td>
<td>Up to 400 MHz, 32+32KB cache</td>
</tr>
<tr>
<td>RAM</td>
<td>Up to 64MBYTE</td>
</tr>
<tr>
<td>Disk</td>
<td>1-128 Mbyte flash disk</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Below 1W</td>
</tr>
<tr>
<td>Weight</td>
<td>25 grams</td>
</tr>
<tr>
<td>Size</td>
<td>66×44×7 mm</td>
</tr>
<tr>
<td>Operating systems</td>
<td>Linux, VxWorks and Windows CE</td>
</tr>
</tbody>
</table>
Fig. 2. PC-based door-opening system

Fig. 3. Block diagram of the implemented system

Fig. 4. Snapshot of the application screen

Figure 3 presents the main constitutive blocks of a PC-based door-opening system. Mainly they are:

1. Low-cost inkless fingerprint sensor: An optical sensor has been chosen. In our implementation, this is the unique part outside the door. The other parts are inside, although they are visible through a big glass.

2. Personal computer: The core of the system is a standard Pentium III at 800MHz. Thus, it is a several-year-old computer, not state-of-the-art.

3. Screen: It displays the result of the identification (if the user is recognized) and the entrance time. For future versions it can be replaced by a simpler display (for instance, a red and green light).

4. Keyboard: Our system works on identification mode. The user does not need to provide any information except for his/her fingerprint. Thus, the keyboard is just used to typewrite the usernames for registering new users, and is not used during normal operation mode.

Fig. 5. A fragment of the access list
5. **Relay card**: Although it is quite easy to output a control signal through the serial or parallel port, we have included a relay card Ariston CT-188 [5] able to manage up to 16 signals. This will be used for future versions with one computer controlling several doors at a time.

6. **Actuator (Door-opening device)**: The computer just takes the decision to open or not open the door. A standard device is needed, similar to the manual remote door-opening systems in our houses (entry phone).

7. **Software**: A special application in visual C++ has been programmed using the System Developer Kit (SDK) of digital persona [6]. Figure 4 shows a snapshot of the application’s screen. This program controls the door, but it also produces a Microsoft Access file with the registers of the user accesses (name and access time). Figure 5 shows a fragment of this file. Interestingly, it is worth observing that we also record the attempts to access of unauthorized people.

**CONCLUSIONS**

The door-opening system allows us to control students' access to the laboratory, such that they do not need to have a key nor do they have to wait for someone to open the door. It lets us rationalize the entry, update the authorized persons inside the database without collecting or distributing physical keys, etc.

The door-opening system has also let us check that, with a proper configuration, it is able to work during the entire working day, and it also enables us to study the number of accesses and users that it supports. So far, the database consists of 30 people.

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Radar Technology in the Czech Republic

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University of Pardubice

ABSTRACT

A contemporary status of Radar technology in the Czech Republic is reviewed in this paper. We may find activity in many different directions in this field now. Those are: new primary radar development both for military and civil application, primary and secondary radar upgrades, new passive radar development for civil application, ELINT and ESM equipment, intruding alarm radar sensors for commercial application / high mass production, radar warning and seeking receivers and military targets RCS minimization.

INTRODUCTION

In the 80's there were two or three big enterprises in the former Czechoslovakia delivering most of the radar and microwave communication products with their own or closely coupled research plants all under a tight government control and support. In the field of radar these were Tesla Pardubice with its Radio Research Institute Opocinek, supported by antenna system producer LET Kutnovec. Microwave semiconductor devices were designed and produced by VUST Prague both for radar and for communication equipment. The Czech Technical University in Prague, Faculty of electrical engineering, supported the research and development in radar and communication also. In those years mainly airport systems consisting of mid range S-band Primary Surveillance Radar and X-band Precision Approach Radar were developed and produced in relatively large volumes (800 PAR devices) (see [1]). In lesser extent also further radar products and measurement techniques were designed and produced. For instance the riverboat radar RR-3, firing radar, battlefield radar could be mentioned. A significant activity was also in the field of passive military systems, mainly wideband TDOA reconnaissance systems Ramona and Tamara ([2]). A part of production was designed for Czechoslovakia customer, i.e. for airports and army but a huge volume was sold also to foreign countries mainly to the former USSR.

After 1990 the situation completely changed. An abrupt loss of the eastern market and of the government support destroyed the big enterprises. They were converted into many small companies, rivaling with each other for the remaining clients. The research and development was damped completely and production was limited to the minimum. Starting new subjects was a very hard deal in this situation, with limited access to modern technology, limited human resources and in difficult non-transparent economy environment. Most of these companies offered only a maintenance and repair of the existing equipment or its slow upgrades to achieve compatibility with new standards and component bases.

Now after more than ten years all radar sector in the Czech Republic is in private hands achieving no support from the government. Several well-established companies mastering modern technology and getting relatively stable crews operate at the market. New devices and modernization of their products are developed mainly in their own facilities and research projects are solved in cooperation with Universities and other academic organizations which are only slightly supported by grant agencies.

Due to a very limited amount of investment into the military systems in the Czech Republic in nineties an upgrading program was accepted in this field. Nevertheless new primary radars both for military and civil application were also developed in those years. Following a long tradition in passive military systems, completely new civil applications of passive radar in the Air Traffic Control was introduced. Also a new ELINT/ESM system was developed recently.

In the following sections we will describe the most interesting results in the respective area in the Czech Republic achieved in the last years.

NEW PRIMARY AND SECONDARY RADARS

Mobile Surveillance / Approach Radar KOMAR-2

A highly mobile and completely autonomous military radar system was designed at the T.E.S.I.A. CZ (formerly Tesla Pardubice). It comprises functions of a Primary Surveillance Radar (PSR), a Precision Approach Radar (PAR) and a Secondary Surveillance Radar (SSR) and it was designed for air traffic control and navigation to meet both military and civil
Table 1. KOMAR-2 Basic Technical Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PSR mode</th>
<th>PAR mode</th>
<th>SSR mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>1</td>
<td>1</td>
<td>D</td>
</tr>
<tr>
<td>Target data update</td>
<td>4 s</td>
<td>2 s</td>
<td>4 s or 2 s</td>
</tr>
<tr>
<td>Range</td>
<td>60 km</td>
<td>25 km</td>
<td>120 km</td>
</tr>
<tr>
<td>Azimuth</td>
<td>360°</td>
<td>±15°</td>
<td>360°</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.5 - 45°</td>
<td>-1 - +19°</td>
<td>0.5 - 45°</td>
</tr>
<tr>
<td>Ceiling</td>
<td>4000 m</td>
<td>2000 m</td>
<td>10000 m</td>
</tr>
<tr>
<td>Accuracy in range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in azimuth</td>
<td>1°</td>
<td>0.6% of range or 9 m</td>
<td>2°</td>
</tr>
<tr>
<td>in elevation</td>
<td></td>
<td>0.4% of range or 6 m</td>
<td>-</td>
</tr>
<tr>
<td>Tracking capacity</td>
<td>150 targets</td>
<td>30 targets</td>
<td>150 targets</td>
</tr>
<tr>
<td>Deployment</td>
<td>To operation 30 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>On the road, by the railway, by plane (C-130, C-160, IL-76)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTBF</td>
<td>450 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTTR</td>
<td>30 min.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The main parameters of the system are shown in the Table 1. The system consists of two parts: the Antenna Unit and the Operation Center. The AU is designed on towed four-wheel chassis. It contains an antenna subsystem, the PSR Transmitter - Receiver Subsystem, the SSR interrogator, a Signal Processor Subsystem and a Power Station (see Figure. 1).

The PSR antenna and PAR azimuth antenna are identical and its reflector serves also for SSR main antenna. The PAR/PSR antenna offset feeder array was synthesized such as to achieve excellent side-lobe level (-40 dB) even in this case of a low profile reflector. Polarization is circular. The monopulse SSR antenna feeder is integrated with that of the primary radar. Due to the reflector is narrow for easy transport the secondary antenna has got a relatively wide beam in azimuth (11°). Then the application of monopulse processing in SSR is a logical arrangement. The high level sidelobes of the narrow reflector are partially suppressed by the optimal feeder array design (-20 dB). On the other hand the relatively large vertical aperture of the SSR reflector (1,7 m) enables to design the vertical diagram of the SSR antenna such as to avoid reflections from ground comparably to advanced LVA SSR antennas. The antenna subsystem contains further a SSR SLS antenna, the monitoring (anti-jamming) antenna (1 band) and the elevation PAR antenna, permanently rotating around the horizontal axis. The reflector of this elevation antenna is very narrow in the azimuth and the feeder was also peculiarly designed to achieve low sidelobes (-38 dB).

The coherent transmitter consists of a high power klystron and of a solid state amplifier driven by a 16-channel pulse to pulse or burst to burst frequency agile synthesizer. In the PSR mode the 5.2 ms transmitted pulse is BPSK modulated by the Barker13 code. In the PAR mode only an unmodulated pulse 0.4 ms is generated. The dual frequency conversion receiver is equipped by a multi PIN-diode STC with 45 dB dynamics. The signal processor is controlled by a clutter map divided into 64 (azimuth) x 16 (range) pixels. The AMTI doppler filter processes 3 pulses in the case of a single static or moving target or 5 pulses in the case of a combined interference. The switchable linear/logarithmic CA-CFAR detector and a special anti jamming processor enable to achieve high sensitivity and a low PFA = 10-6 also in situation of simultaneous and multiple threat condition e.g. ground and weather clutter and active jamming.

River Radar RR3000
This river radar was designed at the ERA Inc., Pardubice. It is a short range radar for river and coastal navigation. It meets the rigorous standards of the central Commission for Navigation on the river Rhine. The main features are:

- color display with a high resolution CRT (1024x1280 dpi) or with flat screen TFT technology display
- the DAY, NIGHT and several color/monochromatic display selection
- sophisticated BITE fault self diagnostics
- Enhanced First Edge display of echoes
- synthetic and data information in combination with the analog display of echoes
- connection to navigational equipment conforming to NMEA standard (RTI, Rudder, GPS, gyro, pilot, echo sounder, speed meter, wind meter) and respective data display

The slotted waveguide single-end-fed antenna with parabolic cylinder reflector has optionally 1,2° / 0,9° beamwidth in azimuth and about 30° in elevation.

Mode A/C/S Interrogator / Transponder
ERA Inc. finished development of a unique equipment a SSR interrogator / transponder. It is used as a complementary device for their passive surveillance VERA system (see below). In the Interrogator mode it initiates on-board SSR
transponders to transmit SSR replies in areas of insufficient or even none interrogation density and thus allows a full operation of the VERA system. The implementation of the device to the VERA Surface Control System on the airport enables selective interrogation in order to get the aircraft identification.

Beside this the equipment can periodically transmit replies at 1090 MHz. This ensures monitoring and integrity checking of the VERA system operation. Located at the known position it could be used as a test equipment for passive system accuracy measurement.

**Main Characteristics:**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azimuth sector</td>
<td>360°</td>
</tr>
<tr>
<td>Repetition frequency rate</td>
<td>100 – 450 Hz</td>
</tr>
<tr>
<td>Interrogator mode:</td>
<td>SSR interrogation in the A / C / S mode</td>
</tr>
<tr>
<td>Transmitting:</td>
<td>SSR replies in the A / C / S mode</td>
</tr>
<tr>
<td>Output power:</td>
<td>200 W</td>
</tr>
</tbody>
</table>

**Transponder mode:**

** SSR replies in the A / C / S mode **

**Output power:**

200 W

**MODERNIZATION PROGRAMS AND UPGRADE OF MILITARY RADARS**

This program is performed at least in two of the Czech companies i.e., in the RETIA Inc. Pardubice, which is concentrated mainly on radars from the former USSR and ELDIS Ltd. Pardubice, dealing with the Czech radars from Tesla Pardubice. In lesser extent also another companies take part in this business. The main reason of this effort is not only to increase performance of the old devices for a reasonable price but also to bring compatibility and interoperability with NATO. According to the leading company RETIA Inc. the whole modernization program is quite general for all the radars and other electronic systems and could be divided into the following steps, which could be eventually performed independently step by step:
• IFF reconstruction in compliance with NATO standards

• Radar data and voice interface – data and voice recording, radio, wire or fibreoptic link transmission

• Signal and data processing modernization – application of signal processors

• Display system modernization including color high resolution rasterscan display

• Increase of reliability introducing up to date technology and BITE

• Increase of ECCM capability and reduction of the ARM vulnerability

• Including of a hybrid INS/GPS navigation system

The modular approach enables construction of highly versatile blocs of wide range of applications:

Signal and data processor system RSP-03

A modular RETIA system for 2D and 3D radars is based on 32-bit floating point DSP’s (ADSP21062-SHARC) and on programmable logic arrays FPGA. CPU works with a real-time multitask OS QNX. From 2 to 32 DSP’s could work together in the modular system depending on the particular requirements. The FPGA are used for preprocessing of input signal and for generation and simulation of signal for BITE operation. The system technical characteristics are as follows:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>600x200 mm</th>
<th>800x400 mm</th>
<th>1600x400 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>10.5 dB</td>
<td>14 dB</td>
<td>17 dB</td>
</tr>
<tr>
<td>Beam-width in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>azimuth in elevation</td>
<td>27°</td>
<td>23°</td>
<td>12°</td>
</tr>
<tr>
<td>elevation</td>
<td>80°</td>
<td>80°</td>
<td>80°</td>
</tr>
<tr>
<td>Interrogation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sector</td>
<td>14°</td>
<td>11.5°</td>
<td>6.5°</td>
</tr>
<tr>
<td>SLL</td>
<td>-17 dB</td>
<td>-22 dB</td>
<td>-22 dB</td>
</tr>
</tbody>
</table>

IFF System Interrogator

The confidential friend or foe identification (IFF) interrogator system designed by RETIA increases combat effectiveness against enemy forces and reduces the risk of fire on the friendly objects. It could be integrated into any radar. It is based on a modified AN/TPX-56 (200W/500W) and on a flat plate antenna system of own design. The arrays of patches form two beams (see [5]): the sum beam S (the main antenna) and the SLS beam W. They are produced in three versions and their characteristics are as follows:

The above mentioned and other modules has been successfully applied in the modernization of the following radar and firing systems, performed by the RETIA itself or in cooperation with other suppliers:
Fig. 2. Signal Processor RSP 03 and its SP Card

Fig. 3A.  
Fig. 3B.  
Fig. 3. The mobile airport radar system RPL-5M

- P-18, P-19, long range surveillance radars (signal and data processing, communication, display, IFF).
- P-35, P37, S-band long range surveillance radars (receiver, signal and data processing, communication, display, IFF).
- 2K12 KUB, anti-aircraft rocket firing system (signal and data processing, communication, display, IFF).
- OSA - AKM anti-aircraft firing control system (IFF, signal processing, communication)
- SAM SA-13 rocket firing system against low altitude targets (IFF, signal processing, C3I terminal)

**RPL-5M Upgraded ATC Radar System**

The ELDIS Ltd company offers large scale modernization of the mobile airport radar system RPL-4 of the former Tesla Pardubice production. Originally it consisted of an S-band

Fig. 4. The SDD Station
PASSIVE MULTILATERATION SYSTEMS FOR CIVIL APPLICATION

Following a long tradition in the passive ELINT systems Ramona and Tamara, developed and produced in several variants from sixties through eighties by Tesla Pardubice new civil application primarily for the Air Traffic Control (ATC) has been introduced by ERA Inc. in nineties. The whole family of these devices is called VERA. Each system consists of several receiving stations, displaced on terrain and of a central processing station. The VERA systems are used for aircraft position location from the land. The receiving stations receive the replies of the on-board SSR transponder and retransmit it to the central processing station by microwave links. There the Time Differences of Arrival (TDOA) at the individual stations are measured. Moreover at the central station the replies are analyzed and the messages are evaluated. Typically three receiving stations are needed for 2D location of the aircraft and four stations are needed for 3D location. (See for inst. [3]). The system achieves a very high position accuracy, independent altitude measurement (with high accuracy) and is more cost effective than the Secondary Surveillance Radar system. ERA Inc. offers several options of this system namely 2D long range ATC aid, 3D mid-range Height Measuring Equipment (HME) and Airport surveillance equipment for surface movement control. Further research is going on possibilities of the system parameter enhancement by combining TDOA and DOA (direction of arrival) and on a semiactive system (4). A brief review of the offered passive systems with main characteristics follows.

VERA AP

Passive system VERA AP is a long range surveillance system dedicated for ATC. It consists of three receiving stations and of a central processing station. The side stations are deployed about 10 km off the central station. It is capable to process SSR replies (1090 MHz) in 3/A, C, S modes and TACAN/DME interrogation signals. The system evaluates horizontal position independently on the board from TDOA measurement, the altitude is taken from the C-mode reply.

Technical Characteristics:

- Range: 240 nm (limited by radio horizon)
- Azimuth sector: min 120°
- Accuracy – horizontal: 10 – 100 m depending on the aircraft position and geometry
- – altitude: 100 feet (from C mode)
- Tracking capacity: 300 aircraft

VERA P3D

System consists of three receiving stations and of a SSR interrogator and is dedicated for 3D independent surveillance at airports or at high traffic areas particularly at the TMA. The system is used as a replacement of SSR and MSSR systems and
features excellent price/performance ratio. It received certification issued by the Czech Aviation Authority.

VERA HME

System is used as a Height Measurement Equipment (HME) for monitoring of aircraft altitude in the areas of a very high density traffic. It consists of four or more receiving stations and of a central processing station.

Technical Characteristics:

- Monitoring region: cylinder of up to 45 nm in diameter, lower base FL290, upper base FL410
- Accuracy: horizontal: 50 feet
  - altitude: 25 feet at altitude 20 nm
- Track capacity: 200 aircrafts
- Update rate: 1 s
- Output data: 3D position in WGS-84

System is used for instance within the EUROCONTROL RVSM (Reduced Vertical Separation Minimum) program.

VERA ASCS

The VERA ASCS (Airport Surface Control System) is a sensor designed to provide position and identification data of aircraft on the airport surface and in the airport vicinity. It consists typically of four or five receiving stations and of a processing station and produces 2D position information and identification. The higher number of stations is used due to screening of airport areas by terrestrial objects as buildings also. Communication is provided by microwave links or by fibreoptic cables. Hard technical problems due to multipath propagation was solved using correlation analysis based signal processing methods.

Technical Characteristics:

- Range: airport area + 16 nm in CTR
- Azimuth sector: 360°
- Accuracy:
  - horizontal: 3 – 10 m RMS at airport surface
  - altitude: 60 feet
- Tracking capacity: 200 aircrafts
- Update rate: 1 s
- Output data: x, y, geometric altitude, barometric altitude, velocity, heading, mode A/S address, flight plan processing, ADS-B data, . . .

BORAP

The system is based on advanced wideband interferometric Direction Finding (DF) technique complemented with high performance ELINT analysis subsystem. It is able to handle all types of radar signals, SSR replies, TACAN / DME interrogations and other navigation and communication means. One station consists of the antenna unit and of the operator unit, both on their own mobile chassis (see Fig. 5). The antenna located on the errectable mast of maximum height 12 m is laid in a horizontal position during transport. One station may find direction of the particular target along with a complete analysis of the received signals and their identification according to the target library. A system of two stations located apart is able to evaluate a horizontal position of each target with accuracy depending on the geometry.

Characteristics of the Antenna Unit:

- Antennas for 0,5 – 1 GHz band, 1 – 18 GHz band, 18 – 40 GHz in selected ranges
- Linear interferometric (3 element) antenna system in standard bandwidths for circular polarization.
- Receivers (-84 dBm), local oscillators, if amplifiers, phase detectors.
- Field of view 120°, range up to 400 km SRS- 4M a Small Radar Searcher and WARNS – I a radar indicator.
The both portable devices were developed in the Military Research Inst. Brno (VTUO) and now are produced by RAMET C.H.M. The SRS-4M Radar Searcher is designed for detection and direction finding of ground radars operating in a frequency band of 1 GHz to 18 GHz as well as for determination of their basic parameters. This portable device, which can also be used as a warning receiver, contains two antenna systems in the frequency bands from 1 to 8 GHz and 8 to 18 GHz, microwave detectors, log-video amplifiers and digital circuits for received signal analysis. Both audio and light signalization of parameters of received signals is performed. The equipment can be connected to a recording device or to a signal analyser. Direction finding accuracy is \( \pm 10^4 \), minimum sensitivity – 25 dBm.

The WARNS-1 is a miniature passive wideband receiver designed for the Czech Army. Its main application is detection of battlefield radars operating in a frequency band from 8 to 18 GHz. It is suitable for use in field operations under any weather conditions.

MISCELLANEOUS

Several new radar sensors for intruder alarm service, activation of public lights and automation of various processes have been designed at the Steinel Elektronik Ltd., Pardubice in the last years. The sensors are designed for mass production. All variations are based on two families of sensors:

SRIM

An UWB sensor in frequency band 0.5 – 1.8 GHz is used for target detection and selection on the basis of its movement characterization in a strictly defined area. A short 1 ns pulse is used to achieve very sharp range resolution. The reflected pulse after reception is mixed with a delayed replica of the transmitted one and a correlation of both is analyzed. The range period could be adjusted from 30 mm to 1.5 m by setting delay and pulse length. Selecting filter response we may choose the desired target characteristics. Technology: microstrip on a plastic substrate, printed antenna, metal screening. The device is in mass production as a part of various hygienic equipment.

RK XX

Microwave Doppler sensor at 5.8 GHz in CW or pulse mode is used for automation of various processes on the basis of the doppler signal analysis. Range is roughly adjustable from 0.5 m up to 8 m by setting pulse parameters. Microstrip on a ceramic substrate, thick film technology, DRO, dielectric resonator antenna, digital signal filtering and analysis. It is in a mass production as part of various automation equipment.

Further upgrading and family extension of well known police radars RAMER for vehicle speed measurement was held by its producer the RAMET C.H.M. Kunovice in the last years.

RAMER 7M AND ITS VARIATIONS

Used for speed of vehicles on the road measurement. Range of speed: 5 km per hour, accuracy 1 km/hour, Frequency: 34, 3 GHz, RF power: 0.5 mW, EIRP: 40 mW, max. range: 60 m, beamwidth: 5 – 6°

RAMER 8

An informative radar speed equipment permitting to set speed limits ranging from 20 to 130 km/h, in 12 bands. The system identifies speeding, displaying it on a large-space signal panel. The measuring equipment is activated automatically, when a vehicle is passing. The system fits for danger spots with limited speed (such as those in front of schools, where road-works are under way, motorway exit points, etc.).

REFERENCES


Book Review

Fundamentals of Short-Range FM Radar

Igor V. Komarov & Sergey M. Smolskiy
Artech House, Norwood, MA, USA
2003, 289 pages, Hard cover

The early days of radar (back in the 1930s) were partly devoted to extending the target detection range of experimental systems at hand. All relevant physical phenomena were not yet processed deeply enough and unexpected losses of signal frequently occurred regardless of selected operating principle. Available electronic components for radar transmitters and receivers did not allow large physical surveillance volumes to be covered. Many of those initial—enthusiastic, but sometimes furious—experimental arrangements were de facto short-range radars, but contrary to their designers' view. Later, when commercial pulse Doppler radar systems having megawatt-class output stages, and sometimes even parametric amplifier front-ends, started giving ranges above 500 kilometers, the interest in handy equipment for close-by detection tasks rose again. Here, due to fundamental principles, frequency modulated continuous wave (FMCW) radars were particularly studied. Authorities started observing vehicle speeds on the highways with tiny radars and modern cars come with built-in anti-collision radars, no larger than a box of candies. Industrial use of radar includes monitoring of fluid levels in containers and detection of very small physical displacements; e.g., of rotating shafts and searching buried metal objects during construction work (Ground Penetrating Radar or GPR, for example). Medical doctors have found radars suitable for accurate definition of muscle trembling in Parkinson's disease. Defense has also initiated projects utilizing physically small FMCW concepts. The new book Fundamentals of Short-Range FM Radar by Igor Komarov and Sergey Smolskiy leads us into this particularly interesting field of radar.

This book contains two main parts: Part I, written by Dr. Komarov; and Part II, by Dr. Smolskiy. There are 11 main chapters, an alphabetical index of 360 search items, and a List of Symbols. The book is mathematical in nature with over 750 equations, but don't be frightened, most can be mastered through normal university-level calculus skills, although occasional "monsters" require some patience. Each chapter has its own references, but this time, there are not very many, only 41. Illustrations, 132 in total, are used throughout the text to clarify the concepts at hand. They are either block diagrams, circuit drawings, or line art showing waveforms or spectra of signals in use. Chapter 1 is an introduction to FMCE radar technology and relevant applications and gives an easy start even for a novice. Then in Chapter 2, the authors give a comprehensive treatment of FMCW radar signals and various realizations and define the phase-related processing of received target echoes. Various FMCW radar modulation waveforms and their mathematical treatment are the topic of Chapter 3. Particular attention is given to the commonly used sawtooth derivatives. Chapter 4 contains an in-depth analysis of a combined processing scheme for FMCW signals in the receiver. The intention is to highlight means of simultaneously taking into account the amplitude, phase, and frequency characteristics of target returns. The last chapter in Part I, Chapter 5 discusses converted signal processing based on its spectrum properties.

In Part II of the book, the focus is on circuit-level things, and especially autodynes, which are devices containing the transmitter and receiver conversion functions inside one simple circuit structure. Chapter 6, named Analysis of Constant Frequency Oscillators, develops a symbolic method for autodyne computation in pure CW applications. This process is extended in Chapter 7 to cover modulated FM systems and, according to the authors, this material is expected to be completely new in open literature. Challenges caused by unavoidable unwanted modulations, in this case AM, are mathematically analyzed in Chapter 8 as a further extension of the preliminary outlook of Part I. Chapter 9 contains equations and explanations related to nonlinearities in FM modulation hardware. A very thorough and detailed discussion of autodyne fundamentals and theory is compressed into Chapter 10, where the FMCW radar's performance limitations, due to various input signal conditions and autodyne sensitivity issues, are further developed. Finally, in Chapter 11, the authors show what happens in such typical cases where the FMCW radar front-end meets not only the theoretically-generated and trouble-free signal but also to handle near-by hostile emissions.

The authors of Fundamentals of Short-Range FM Radar are experienced scientists in the field and began their professional careers when this reviewer was still hugging his teddy bear. Dr. Komarov graduated from the Radio
Engineering Faculty of the Moscow Power Engineering Institute (MPEI, in brief) in 1954. He started working with radio receivers and continued until 2000. During his career, Komarov was involved in academic education and scientific research which was heavily connected to local industry. Much of his work in the 1990s was focused on conversion directions of short-range radar systems development. Interesting applications vary from navigation, level measurement, maritime navigation, to workshop-floor equipment for motion and vibration measuring systems. Komarov has published more than 100 scientific papers, two books, and ten patents for the former USSR. He has received the nomination of Honorary Radio Specialist of the USSR. When not working with radar, he might be found listening to classical music or fixing his house.

Dr. Smolskiy graduated from MPEI in 1970, also in radio engineering. After that, he started working with radio transmitters and made his Ph.D. thesis in 1974. Since then, Smolskiy has been involved in short range radar equipment design, particularly their transmitter stages and oscillators. He became a professor of these topics in 1993 and was appointed the chairman of the Radio Receivers Department of MPEI in 1995. His projects deal with various instrumentation tasks of the fuel and energy industries, the usage of wireless systems in process control, and certain medical electronics applications. Smolskiy has authored more than 110 scientific papers, and four books, and holds three patents for the former USSR. He is a member of the International Academy of Electrical Engineering Sciences and a member of the IEEE. He has been awarded an honorary degree from several foreign universities. His leisure time consists of reading and philately. He, too, listens to classical music. According to our sources, Smolskiy also likes repairing electronic gadgets and preparing food.

The first impression of Fundamentals of Short-Range FM Radar is a certain compactness. This has been partly achieved by leaving out material, which is more general in radar engineering; such as target fluctuations, wave propagation, and clutter. Chapters have been kept manageable in size and lengthy back-and-forth style discussions have been avoided. If more in-depth treatment is needed, the authors have split the process into two or more sections. It was also a good idea to first give the readers a system-level view of FM CW radar and discuss various technological topics and difficulties on the block diagram level, and only after that, in Part II, tackle the circuits and components suitable for the electronic implementation of such radar front-ends. The apparent strengths of this book is in its numerous algorithmic examples and derivations. Signal generation and processing in the FM CW environment are treated comprehensively. An interesting feature of Fundamentals of Short-Range FM Radar is the way in which spectrograms and waveform plots have been created. Where Western authors might be seduced to take smudged screenshots from Matlab or MatCad, Drs. Komarov and Smolskiy have done all the computational graphics carefully “by hand” – and the clarity of the plots is much better. The authors’ backgrounds as long-time university educators is clearly visible. They put much effort in trying to explain things in an understandable manner and, as far as I can figure, they succeed. Here is one of the eternal dilemmas in scientific writing: if one is making a book just to show colleagues how talented the author is, there is possibly great merit to come, but if you want to educate the next generations, you have to take into account their initial level and include considerable amounts of explanatory text. In this respect, Komarov and Smolskiy have taken the student-friendly attitude, which I found very positive and encouraging. The clear and meaningful illustrations further help an inexperienced reader get into this field. For example, waveform plots have been adequately labeled in such a way that even a hasty reviewer can easily find their meaning. It is also very important that the authors have carefully limited the amount of data in each figure. In this way, the reader will not be confused and less text is necessary as an explanation.

As the authors state in Preface, there is a certain difference between the two parts of this book. For me, Part I was easy to follow and although new ideas came up, there was enough background connection in my head to those related texts and books that I have recently seen in the Western market. Part II is clearly more complicated, but not in a negative sense; especially the fact that the authors intentionally put the original Russian autodyne results to the reader’s desk can confuse some. The authors did not want to collect Russian original references to their book as such papers (apparently) would be of limited help to Western readers. I think this decision is justified; however, as many of us not familiar with the Russian autodyne research would like to try and connect the book’s presentation to our existing technical and educational background, it might have been still better to include more examples of similar Western work, despite the fact that might not be so straightforward in Moscow.

Some small details might be adjusted in possible coming editions of the book. It is customary to show radio frequency circuits without DC biasing networks and this is mostly the case here, too. It might add to the books practical value, if occasionally, full circuit examples were shown as well, perhaps including true component values. Maybe a short section about using new DSP, A/D, and D/A building blocks for VCO linearization could be considered. Examples of well-analyzed diode-resistor-diode configurations for improving varactor response are convincing and make, at least, me respect the author’s engineering skills, but thoughtless youngsters could regard such circuits as obsolete. I was delighted to find a List of Symbols in an Arte House book. The mathematical approach of the authors surely deserves it. However, this time there is no List of Acronyms and Abbreviations. Fortunately, the tradition of technical writing is slightly different in the US as compared to Russia, and, perhaps, due to the fact that there are not so many abbreviations in Fundamentals of Short-Range FM Radar. According to my observations, many US authors prefer abbreviating whenever, and wherever, possible, but this sometimes leads to complications, too. Although there are very many fine
drawings in this book, figure captions are often short and do not necessarily tell the reader what he/she is supposed to look at, or why. At least those illustrations containing subsections with own labels (a, b, c and so on) should have in their caption a brief list telling which is what. This problem might be partly caused by the publisher’s design outlines—they generally want to keep captions short, if I remember correctly.

In the Preface, Komarov and Smolskiy, jointly, express that it is not possible to construct a frequency modulated continuous wave radar just by the guidance given in their book. In principle, they are right, because the design of any functioning piece of electronic equipment usually relies on theory and years of practical knowledge and skills. Unfortunately, books seldom, if ever, can pass hands-on experience to newcomers. But, the authors are too diffident about their fine work. After reading through *Fundamentals of Short-Range FM Radar*, most engineers, already in the radar business, can create outlines of FMCW units and autodynes without too much difficulty even if they have previously not worked with such CW systems. The book’s strong educational spirit encourages using it for university courses, as well. Due to the book’s mathematical formulations and necessary background in electronics and radio circuitry, I recommend special “topical” courses that typically come around fourth or fifth year in European technical universities.

Alternatively, selected sections of *Fundamentals of Short-Range FM Radar* could be used in a more classical radar systems course. If you are interested in not-so-common FMCW radar techniques, *Fundamentals of Short-Range FM Radar* is worth reading indeed!

—Reviewed by Pekka Eskelinen
Possible Ultra-Wideband Radar Terminology

A Supplement to the terms proposed by Malek G.M. Hussain and James D. Taylor

Dr. Hongbo Sun
School of Electrical & Electronic Engineering
Nanyang Technological University
Singapore

About the evaluation of UWB signal bandwidth

- fractional bandwidth
- relative bandwidth
- spreading ratio
- Johnston factor

Other old terms about UWB waveform/radar

- baseband waveform/radar
- nonsinusoidal waveform/radar
- carrier-free waveform/radar
- impulse waveform/radar

Conventional modulated UWB waveform/radar

- ultra-wideband frequency modulated waveform/radar
- ultra-wideband frequency coded waveform/radar
- ultra-wideband frequency hopping waveform/radar
- ultra-wideband phase modulated waveform/radar
- ultra-wideband phase coded waveform/radar

Random noise modulated in UWB waveform/radar

- ultra-wideband random noise waveform/radar
- ultra-wideband pseudo-random noise waveform/radar
- ultra-wideband random noise frequency modulated waveform/radar
- ultra-wideband random noise frequency coded waveform/radar
- ultra-wideband pseudo-random noise frequency modulated waveform/radar
- ultra-wideband pseudo-random noise frequency coded waveform/radar
- ultra-wideband pseudo-random noise frequency hopping waveform/radar
- ultra-wideband pseudo-random noise frequency phase modulated waveform/radar
- ultra-wideband pseudo-random noise phase coded waveform/radar
- ultra-wideband pseudo-random noise phase modulated waveform/radar
- ultra-wideband pseudo-random noise phase coded waveform/radar

Correspondence (continued from cover 2)

Mr. Key gave no definition of LPI radar. The term is not presently defined by IEEE Std 686, but will be added in the upcoming revision. One possible definition is that LPI radar transmits a waveform intending that the signal will be difficult for an intercept (ESM) receiver to detect/identify. Note that “low probability” means a finite number greater than zero.

Regarding LPI altimeters: What about the circa-1957 EGYPTIAN noise modulated altimeter, the US/AN/APQ-181 multimode radar for the B-2 bomber, and the multitude of LPI altimeters listed in the literature?

Stephen L. Johnston
Huntsville, Alabama

A recent literature search evinced LPI radars – as defined by their manufacturers – for: battlefield surveillance, naval surface search, terrain following/avoidance, altimeters, fire control, and automobile collision. J.C. Wise Associates: (http://www.radios.org.uk) recently issued a listing of 55 FM/CW LPI radars with 16 functions: altimeters (16); battlefield surveillance (11); and navigation (6).
Dawn of the Second Century:
Racing to Transform the Legacy
22nd Digital Avionics Systems Conference

Ron Schroer
Editor-in-Chief Emeritus

The 22nd Digital Avionics Systems Conference (DASC), co-sponsored by the IEEE Aerospace and Electronic Systems Society (AESS) and the Digital Avionics Technical Committee of the American Institute of Aeronautics and Astronautics (AIAA), was held at the Crown Plaza Hotel, Indianapolis, Indiana, October 12-16, 2003. The Crown Plaza Hotel is located within the restored “Union Station” (railroad) featured on the cover of our January 2004 Systems Magazine. The theme was “Dawn of the Second Century: Racing to Transform the Legacy,” appropriate for 2003 because the nation celebrated the “Centennial of the Wright Brothers Flight.” Copies of our July Centennial issue of Systems Magazine were made available to all DASC participants.

DASC is the premiere aviation/space electronics and air traffic systems conference that supports private/commercial aviation and aerospace R&D, as well as military. It offers a broad spectrum of new technical information for aerospace and electronics professionals. DASC traditionally covers a broad range of air traffic systems and equipment. Air traffic management is one of the largest engineering challenges we face today, especially with the congestion, security mandates, and budget constraints.

Jim Rankin, (Ohio University) was the Conference Technical Chair and will be General Chair for the 23rd DASC in 2004. The technical program of over 180 papers was divided into 13 tracks with 38 sessions covering avionics hardware, software, and systems. In addition to its usual offerings, the technical program continued the new tracks from last year in Air Traffic Management (ATM) and Communication, Navigation & Surveillance (CNS), plus added new tracks for Electronic Flight Bags (EFB) and Required Navigation Performance (RNP). There were three joint sessions combining various topics in ATM, CNS, Synthetic Vision and UAVs. As usual, days one and two were set aside for tutorials.

George Andrews, Professional Education Chair, organized 33 technical sessions that covered a broad spectrum of hardware, software, systems engineering, and operations advances, including 13 new tutorials not previously offered.

The next DASC will be held at the Hilton Salt Lake City Center, Salt Lake City, Utah, October 24-28, 2004, with the theme: Avionics Systems: Transitioning to the Next Generation. For more information go to: www.dasconline.org.

PLENARY SESSION HIGHLIGHTS

DASC General Chair Jon Paris, (Figure 1) (Strategic Aeronautics) opened the plenary session by introducing Joe Avella, Raytheon. Joe extended a formal "Welcome to Indianapolis" to the attendees, and pointed out that, in addition to car racing, Indy was home to a Norden Bombsite Manufacturing Facility during World War II.

Ensuring the Future of the National Airspace System
Jon then introduced the first plenary speaker, Herm Rediess, (Figure 2) (FAA Washington) who discussed ongoing research and planning. A Joint Planning Office was recently formed that will identify long-term needs based on what has previously been developed as part of the Operational Evolution Plan (OEP) and Capital Investment Plan (CIP). Six US government agencies are working together in order to transform the National Airspace System (NAS) in order to chart the “Next Century of Flight” and ensure the future of air transport. The team goal is a national vision for 2025 that includes flexible and accessible
airports and provides a rapid, efficient, and reliable air traffic system that is safe and secure.

Avionics Evolution/Revolution

Next, Gary Van Oss, (Figure 3) (US Air Force), projected the evolution of avionics from today into the future. Considering that the service life of tankers and bombers can be 80 years, and fighters 30; it becomes clear that avionics savings must be, at least, part of the answer to lower costs. Avionics provides the opportunity to attempt a performance revolution instead of evolution since we can expect gigabit processing and much higher speed databases in the near future.

Overall capability is driven by system architecture including communications, network-centric connectivity, system integration, processor performance, global ATM, and countermeasures. Global Hawk and Predator UAVs provide remote surveillance and attack capability 24/7 with much lower cost and risk. Significant challenges remain in remote control, weather, and communications.

General Aviation Avionics

Ron Swanda, (Figure 4) (General Aircraft Manufacturing Association (GAMA)) the US representative to ICAO for avionics, described near-term advances on the horizon for small aircraft. Cessna and Eclipse have begun putting flat panel displays in their aircraft, which improves IFR operation and may help relieve congestion at large hub airports. Swanda pointed out several challenges that must be overcome. Software cost is the largest single stumbling block to avionics integration, reliability, and cost. Safety, noise, and certification are also concerns. A question in the Q&A session that followed also addressed the need to simplify certification. Establishing a Joint Planning Office was thought to be a step in the right direction.

AWARDS LUNCHEON

Paul Gartz, incoming IEEE AES President, presented the leadership award to Jon Paris, (Figure 5) 22nd DASC Conference Chair. Vanessa Fong presented the Mitre Corporation Best Paper Award from the 2002 DASC to a team from the U of Washington for their UAV path planning algorithm paper. Ms. Fong’s presentation entitled

"Revolutionizing Aviation - Through Integration and Evolution" cited work done with the Operational Evolution Plan and related road mapping and conceptual vision documents. Establishing the Joint Planning Office was a positive step toward defining a new air traffic management system. Improvements in computers, decision support software, communications, and GPS operations are still needed. The restructuring of airspace due to increasing numbers of regional jets and GA aircraft along with UAVs is expected to have an impact. In addition, the expected presence of UAVs in civil airspace will present new and substantial challenges in security, surveillance, and environmental management.

CONFERENCE PAPER HIGHLIGHTS

Certification Concerns

Papers on certifying databases [1] and Integrated Modular Avionics (IMA) [2] by two FAA authors provided insight into
Fig. 7. System Characteristics of Glass Fibers and their Consequences

<table>
<thead>
<tr>
<th>Glass Fiber System Characteristic</th>
<th>Glass Fiber System Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Transmission Loss</td>
<td>Long Repeater Spacings, Reduced Outside Plant Expense</td>
</tr>
<tr>
<td>Large Bandwidth</td>
<td>High Data Rates, Large Message Capacity</td>
</tr>
<tr>
<td>Small Cable Size &amp; Weight</td>
<td>Space Efficiency, Ease of Handling</td>
</tr>
<tr>
<td>Immune to Electromagnetic Interference</td>
<td>Low Signal Noise, Can be Used in Noisy Environments</td>
</tr>
<tr>
<td>Non-Inductive</td>
<td>No Crosstalk, No Hazard, Secure Communications</td>
</tr>
</tbody>
</table>

Fig. 8. Characteristics of Potential EV-Sensors Under Adverse Weather

<table>
<thead>
<tr>
<th>Imaging Principle</th>
<th>Image Rate [Hz]</th>
<th>Resolution</th>
<th>Visual Range [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR</td>
<td>2-D</td>
<td>&gt; 25</td>
<td>0.05°</td>
</tr>
<tr>
<td>Lidar, Ladar</td>
<td>2.5-D</td>
<td>2</td>
<td>0.35° x 0.20°</td>
</tr>
<tr>
<td>MMW Radar angle / range</td>
<td>15</td>
<td>0.25°</td>
<td>&gt; 3000</td>
</tr>
<tr>
<td>MMW Radar 2.5-D</td>
<td>&lt;1</td>
<td>6m</td>
<td>2.5°</td>
</tr>
</tbody>
</table>

"Pencil Beam"

developing, selecting, and/or approving systems for civil aircraft. A number of alternatives have been proposed to replace the proven ARINC 429 and 629 databases. Ethernet, SAFEbus, firewire, etc., are prime candidates for large transport aircraft. Integrated Modular Avionics (IMA) is proposed for implementation on a number of new transport aircraft. Managing the multiple levels of systems and software requirements is expected to be a challenge. Both papers present the background for these new developments and highlight functional concerns regarding certification.

Improvements in Air Traffic Management

The FAA has been conducting a Global Communications, Navigation, and Surveillance System (GCNSS) program to evaluate approaches for managing air traffic while satisfying new security constraints. This government/industry program makes extensive use of today's satellite networks to greatly improve communications, navigation, and surveillance (CNS) performance. The paper [3] reports the results on two of three flight demonstrations. Segment A focused on using both wireless and satellite technologies that would enhance
communications connectivity with the ground for aviation security. Segment B added automatic dependent surveillance (ADS) capability to enable precision (radar-like) control to the basic satellite communications. Figure 6 illustrates the architecture of this segment. Aircraft navigation is expected to rely on traditional inertial navigation systems and flight management integrated with GPS satellites. Simulation results thus far have been positive.

Optical Communications State-of-the-Art

Optical systems have enormous information handling capability and can provide services such as voice and video conferencing plus electronic messaging, shopping, and financial data. Fiber optics has the inherent advantage of being immune to electrical interference and crosstalk. The challenge of lightwave systems is to make them easy to install, operate, and maintain by telecom technicians. An additional challenge has been to keep up with the rapid evolution of these systems. This paper [4] provides an overview and discusses and analyzes these problems along with their economic feasibility as well as versatility when used in future open systems architecture applications. Figure 7 highlights some of the performance characteristics of glass fiber.

Landing Aids for Enhanced Vision Systems (EVS)

As traffic becomes more congested, especially in Europe, there is a need to improve visibility in extreme weather conditions. Enhanced vision systems (EVS), using weather penetrating forward looking sensors definitely help the pilot close this gap. The performance of these sensors depends upon operating wavelength, with increasing wavelength improving atmospheric penetration (Figure 8). Radar displays are often difficult to interpret so that passive radar reflectors [5] installed along the runway edge can provide visual cues similar to runway and approach lights. This addition can be especially valuable on grass runways where there is little contrast between the runway and the area immediately surrounding it.

Designed In Obsolescence

Because the lifetime of government, and especially military, electronics systems has become so much longer than that of the commercial computer and electronic components they now contain, obsolescence has become an important concern for systems engineers. As the commercial component lifecycle decreases, this problem becomes increasingly severe. Implementation and independent testing offers potential savings of up to 75% to offset the effects of this replacement phenomenon. Figure 9 illustrates the tendency toward increasing verification with system upgrade. This paper [6] describes appropriate systems design methodologies and tools that lead toward an implementation independent design which can result in substantial savings in both cost and time.

REFERENCES

The following references will be found in the 22nd Digital Avionics Systems Conference Proceedings, Indianapolis, Indiana, October 12-16, 2003. It carries IEEE Catalog Number 03CH37449, ISBN 0-7803-7844-X, and is available from IEEE Publishing Services, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, USA. These Proceedings are available in either book-form (2 volumes) or as a CD-ROM.

[1] Criteria for Certifying Databases on Civil Aircraft; Volume 1, I.A.2, Leanna Rieper and John Lewis; Federal Aviation Administration (FAA), Washington.


IEEE-USA/AESS Cooperation at PLANS

Chris McManes

When Jim Leonard served as IEEE-USA president in 2003, one of his main goals was to improve relationships between IEEE-USA and other IEEE organizational units. This cooperative spirit was reflected in the 100-year avionics timeline exhibit, which premiered at the 100th Anniversary of Powered Flight Celebration in Dayton, Ohio, in July 2003.

The 100-year timeline features key developments in avionics, or the electronic equipment that supports aerospace systems. It begins with the Wright Brothers famous 1903 flight in Kitty Hawk, NC, and runs through the SENSOR CRAFT, an unmanned US Air Force advanced design concept. The Boeing 7E7 Dreamliner jet will be one of the timeline’s newest additions.

The avionics display was the brainchild of IEEE Senior Member Erwin (Erv) Gangl, director of Dayton Operations for CACI Technologies, Inc. Gangl, who lives in Washington Township, Ohio, worked with four IEEE entities to build the timeline: the Aerospace and Electronic Systems Society (AESS); the Dayton Section; the Student Branch at Wright State University; the Institute of Technology; and IEEE-USA.

“ar was very pleased with how well everybody supported the project,” Gangl said. “Every time I asked for some help, I got it. Nobody said, ‘I’m not in this organization or that organization.’ It was great teamwork on the part of so many people. Not only did volunteers support any request I had, but also they helped fund the development and production of the exhibit.”

Past IEEE-USA President Leonard, who is also AESS’ Executive Vice-President, was so impressed with Gangl’s effort that he honored him with an IEEE-USA Special Citation at April’s IEEE PLANS (Position Location and Navigation Symposium) Conference in Monterey, California.

“I was delighted,” Gangl said. “Being the AESS Awards Chairman, I usually arrange for other people to be recognized. So it was very satisfying to get recognition for a little side effort. It wasn’t really my job, but I felt strongly that it was important to do something for the 100th anniversary.”


Leonard was instrumental in gaining IEEE-USA’s financial support of the timeline exhibit, and in ensuring that the IEEE-USA display appeared with it. Even though the centennial of flight celebration has passed, the timeline and the IEEE-USA display have been so well received that they will continue to be used together around the country.

The avionics display is just one example of IEEE-USA working with other IEEE organizations. In February, IEEE-USA and the IEEE Power Engineering Society (PES) cosponsored a North American electric power system briefing on Capitol Hill for congressional staffers. In April, IEEE-USA worked with the Industry Applications Society, the Power Electronics Society, the Society on Social Implications of Technology, and PES in producing a hydrogen economy conference (http://www.ieee.org/power/hydrogen) in Washington.

Last fall, IEEE-USA and IEEE Spectrum magazine teamed to conduct a survey (http://eww.eweek.org/site/news/eweek/2004_specturm.shtml) of IEEE members to find out what they like most about their profession.

IEEE-USA’s mission is to promote the careers and public policy interests of the more than 225,000 technology professionals who are US members of IEEE. Leonard thinks the IEEE benefits greatly when its organizational units (OUs) work in harmony.

“It’s like synergism,” Leonard said. “When two or more things work together, they can produce an effect greater than their individual effects. The avionics timeline is a perfect example. Four IEEE OUs collaborated, resulting in an outstanding display that made the global IEEE look like positive contributors to the first century of flight.”

Gangl earned his bachelor’s degree in electrical engineering from the University of Akron (Ohio) in 1964, and added a master’s in electrical engineering from the University of Michigan in 1967. As a civilian employee for the US Air Force at Wright-Patterson Air Force Base in Dayton, Ohio, from 1965 to 1988, Gangl was an early pioneer in integrating digital computers into military aircraft.

In the late 1960s, Gangl was assigned to handle the digital computer requirements in the F-15 program office. His work resulted in the data bus standard (Mil-Std-1553) that led to plug-and-play digital avionics. The standard, still in use, is featured on the avionics timeline.

Before retiring from his Air Force position as chief avionics engineer, Gangl was appointed US representative to the NATO Military Agency for Standardization’s (MAS) Digital Avionics Systems
Committee in the early 1980s. He introduced Mil-Std-1553 as a NATO STANAG (Standardization Agreement), and it was adopted as STANAG 3838. Gangl was also made US representative to the Air Standardization Coordinating Committee (ASC) Working Party 50, which approved 1553 as an ASC standard.

Just as Leonard’s vision is to have IEEE-USA work closer with other IEEE entities, 1553 resulted from the work of many people. “The standard evolved due to dedicated teamwork between the military, government, and the aerospace industry, including international support,” said Gangl in the September 2002 issue of Avionics Magazine (http://www.aviationtoday.com/cgi/avshow_mag.cgi?pub=av&mon=0902&file=0902interview.htm). “That was the key to 1553’s success. I may have lighted the match, but the team made the fire roar.”

After appearing at the 100th Anniversary of Powered Flight Celebration in July 2003, the IEEE avionics exhibit went to the October 2003 IEEE/American Institute of Aeronautics and Astronautics’ Digital Avionics Systems Conference in Indianapolis, Indiana.

In late April, the timeline was displayed at the IEEE PLANS conference in central California. The biannual event was well-attended from around the world. While organizers prepared for 240 attendees, 340 took part in the four-day symposium at the Hyatt Regency Monterey. Honeywell, Raytheon, Northrop Grumman, CAST Navigation, and BAE Systems were included among the 23 exhibitors. More than 100 papers and 800 pages of Proceedings – both PLANS records – were submitted.

Chris McManes is IEEE-USA’s senior public relations coordinator.
FROM THE PRESIDENT

Your Board at Monterey ...

The AESS Board of Governors met at the PLANS Conference in Monterey, California. I defined AESS activities for 2004, which are:
1) Goals and Objectives;
2) Implementation Actions; and
3) Improving Best Practices.

Goals & Objectives: Continue current activities and commitments effectively and efficiently, add new products and services that are strategic and/or opportunistic, and improve AESS' operation as a society.

Implementation Actions: Improve daily management. Bring on new AESS products and services with emphasis on education, large-scale systems technology (to facilitate this, we have added four new panels associated with large-scale technology; systems engineering process, transportation system of systems (SoS), Earth observation SoS, and security SoS) and improving internal AESS communications. Each panel is led by a member of the BoG. We solicit volunteers to serve on these panels; contact Jim Leonard, AESS Executive Vice-President at: j.leonard@ieee.org

Improving Best Practices: Focus on people, communications, distinguished lecturers, and chapters.

The Board was briefed by John Reagan, Division IX-Signals & Applications Director, who reported on division structure and activities. He will liaison with AESS for a number of IEEE Activities, including TAB, Meetings and Services, Publications, New Technology, Education Activities Board, IEL, and other Societies. He suggested five high interest discussion topics: Membership, Publications, Conferences, Industry Relationships, and Partnerships, and offered to provide support for the upcoming AESS Society Review in November.

The Board elected 8 members for the 2005 to 2007 term: Dale Blair, Jose Bolanos, Barry Breen, Bob Lyons, Bob Rassa, Cary Spitzer, Zafar Taqvi, and Joel Walker. Their contact information will be in the next issue. Congratulations!

Erwin Gangl, a long-time AESS volunteer who has served in many capacities (currently Awards Chair), was presented the IEEE-USA President's Award.

AESS is very strong financially. The 2003 surplus was $639K, our reserve is $1440K. This follows several years of IEEE financial woes and should enable the Board to fund strategic initiatives that have been on hold pending improvement in finances.

The next meeting of the Board will be in conjunction with Auto. testscon in San Antonio, Texas, September 21 - 22.

Paul Gartz

FROM THE EDITOR-IN-CHIEF

Grants & Chapters

Technical Symposia Grant Program 2004

IEEE Regional Activities provides grants of $500 each to Sections or Chapters sponsoring a one-day technical symposium. The 2004 program is underway, and two events have already been funded. The guidelines have changed slightly for 2004: units funded in the past may apply again for funds provided at least one year has passed. Units are advised to apply at least three months in advance of their event. For more information and the grant request form, visit: http://www.ieee.org/scs and click on “FORMS.” Please direct questions to Tracy Hawkins at: t.hawkins@ieee.org, or call (732) 562-5512.

Forming New Chapters

AESS Chapters are ideal vehicles for informative technical meetings and for networking. If you have 12 or more members, above Student grade, of AESS within your Section, a Chapter for AESS may be formed. The link to the Society Chapter petition can be found on the web at: http://www.ieee.org/scs/forms_petitions.

Please review your completed form carefully before submitting. Incorrect or incomplete information can delay the formation of your Chapter. For more information, contact Lauren Leaston at: l.leaston@ieee.org.

Evelyn H. Hirt
August 2004

Distinguished Lecturers Program

James R. Hundle, Chairman

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 AESS 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. Hundle on (818) 715-3264, F (818) 715-3976, j.hudle@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.

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<tr>
<th>Title</th>
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<td>Applications of Formal Methods in System Design</td>
<td>James F. Peters, III, Univ. of Manitoba</td>
<td>(204) 474-7419</td>
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<td>(204) 261-4639 F</td>
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<td><a href="mailto:jfpeters@ee.umanitoba.ca">jfpeters@ee.umanitoba.ca</a></td>
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<td>+44-20-7388-7325 F</td>
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<tr>
<td>Bistatic &amp; Multistatic Radar</td>
<td>Dr. Hugh D. Griffiths, University College, London</td>
<td><a href="mailto:h.griffiths@ee.ucl.ac.uk">h.griffiths@ee.ucl.ac.uk</a></td>
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<td></td>
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<td>(301) 262-8792 (V&amp;F)</td>
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<td>Current Advances in Radar Technology</td>
<td>Robert T. Hill, Consultant and Lecturer</td>
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<td>The Future of Electronic Warfare and Modern Radar Signals</td>
<td>Dr. Richard G. Wiley, Research Associates of Syracuse</td>
<td>(315) 463-2266 F</td>
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<td>(315) 463-8261 F</td>
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<td>(315) 443-4013:</td>
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<td>Multisensor Data Fusion</td>
<td>Dr. Pramod Varshney, Syracuse University</td>
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<td>(315) 443-2585 F</td>
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<td><a href="mailto:varshney@sy.edu">varshney@sy.edu</a></td>
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<td>National Missile Defense and Early Warning Radars</td>
<td>Larry Chasteen, University of Texas at Dallas</td>
<td>(972) 234-3170;</td>
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<td>(972) 883-2799</td>
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<td>Navigation — Land, Sea, Air and Space</td>
<td>Dr. Myron Kayton, Kayton Engineering Co.</td>
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<td>Planetary Exploration with Spacecraft — to Jupiter, Saturn, Uranus, Neptune and Beyond</td>
<td>Dr. William W. Ward, Consultant &amp; Lecturer</td>
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<td>Practitioner's View of System Engineering</td>
<td>Dr. Myron Kayton, Kayton Engineering Co.</td>
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<td>Radar — Past, Present and Future</td>
<td>Dr. Eli Brookner, Raytheon</td>
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<td>Satellite Communication Systems</td>
<td>Dr. S.H. Durrani, Consulting Engineer</td>
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<td>System Engineering for International Development</td>
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<td>Target Tracking and Data Fusion: How to Get the Most Out of Your Sensors</td>
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<td>The Evolution of Inertial Navigation</td>
<td>Dr. Itzhack Bar-Itzhack</td>
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IEEE AEROSPACE & ELECTRONIC SYSTEMS SOCIETY ORGANIZATION

IEEE/AESS Website: http://www.ewh.ieee.org/aess

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FOR INFORMATION CALL (732) 981-0060 OR 1 (800) 676-IEEE
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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.

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MEMBERSHIP NUMBER |

Grade |

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Date of Birth:  ☐ Male ☐ Female

Day |

Month |

Year

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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

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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 |

Program/Course of Study

College/University |

Campus

State/Province |

Country

Mo./Yr. Degree Received

Highest Technical Degree Received |

Program/Course of Study

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Country

Mo./Yr. Degree Received

### 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 |

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Office Fax |

Home Fax

Office E-mail |

Home E-mail

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*IEEE Canadian Business No. 125364159

**Application is to be received by IEEE after 16 August full year.

Subscription to Spectrum ($) (16.00) and IEEE/OSA Journal of Lightwave Technology.

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- **Canadian residents pay 7% GST or 15% HST on Society fees only. Reg. No. 125364158**

**TAX:** $ |

**AMOUNT PAID WITH APPLICATION TOTAL $**

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Full signature of applicant using credit card |

Date