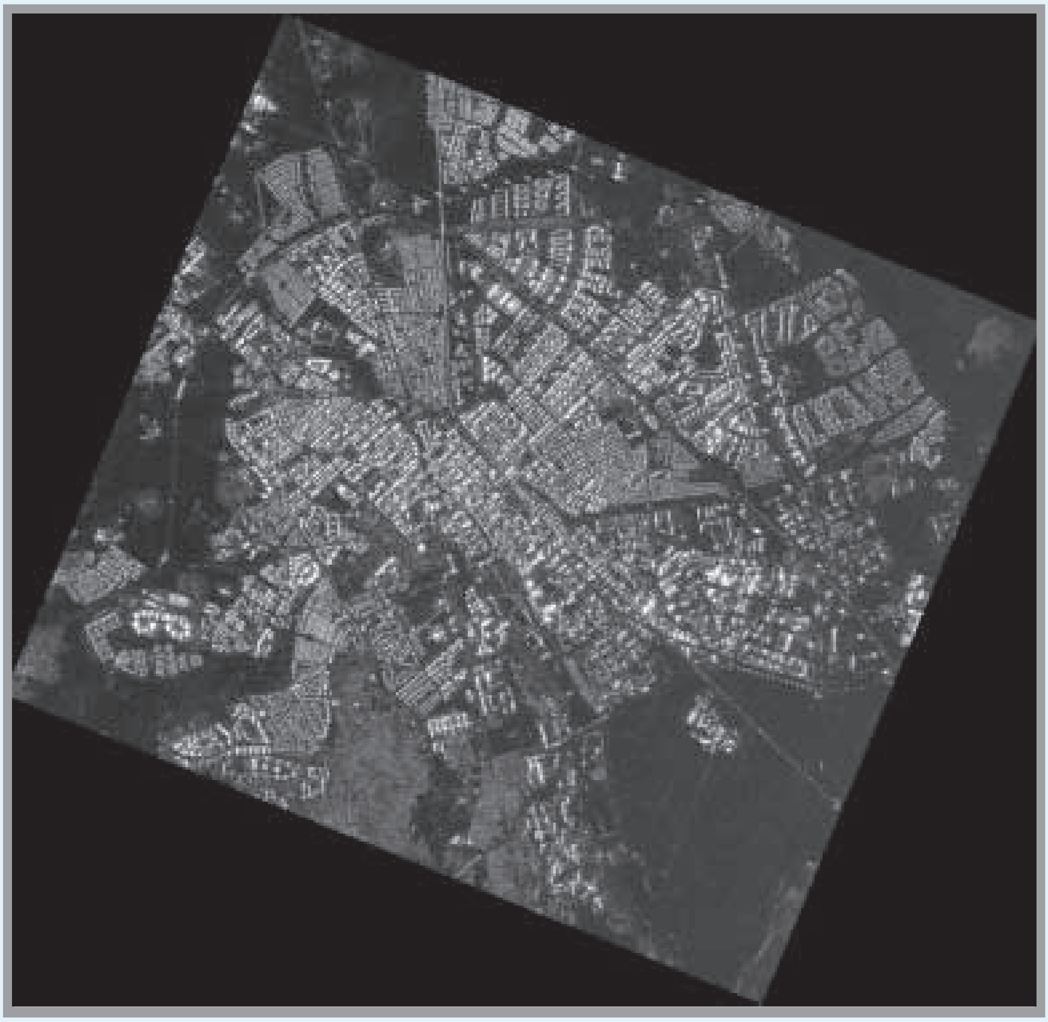
FOI
SWEDISH DEFENCE
RESEARCH AGENCY

Division of SENSOR TECHNOLOGY



Annual Report 2000

The Defence Research Establishment (FOA) merged 1 january 2001 with Aeronautical Defence Research Establishment, FFA, the new agency Swedish Defence Research Agency, FOI is organised in eight research divisions located in Umeå, Stockholm, and Linköping. FOI has about 1200 employees and an annual turnover of about 800 million SEK (MSEK). The Division of Sensor Technology is situated in Linköping.

CONTENTS

- Division of Sensor Technology 1
- Department of Electromagnetic and Optic Materials 5
- Department of Laser Systems 8
- Department of IR Systems 11
- Department of Microwave Technology 14
- Department of Surveillance Radar 17
- Department of Radar Sensors 21
- Publications 24
- Tables

FOA and FFA became FOI

When this report is published FOA has ceased to exist. A new agency is formed as a result of a merger with Aeronautical Defence Research Establishment jan, 1st, 2001. More than half a century of research experience, system and defence knowledge, will in the future be developed into new combinations, in new networks, for coming challenges.

For more information please contact us or visit our website www.foi.se. We especially welcome you if you wish to work or co-operate with us.

Best regards
Svante Ödman
Division of Sensor Technology

Division of Sensor Technology

P.O. Box 1165
SE-581 11 Linköping
Sweden

Phone: + 46 13 378000
Fax: + 46 13 378100
http://www.foi.se/eng/sensor.html

About the cover:
A radar image of Uppsala city acquired with the airborne VHF SAR CARABAS-II. The radar scene is 8.5 km by 8.5 km and has been generated by processing the frequency band 22-82 MHz. The radiometrically calibrated and geolocated image has an original, non-resampled, spatial resolution of about 3m by 3m.

Division of Sensor Technology

Dr Svante Ödman
Head of Division of Sensor Technology

Introduction

Year 2000 could be pronounced "the Year of quality" at the Division of Sensor Technology. Successful efforts to reach the goals set for the Swedish Quality, as well as the Measurement Quality awards, and an international evaluation of the scientific quality of the research at the Division, have been continuously ongoing throughout the year.

In an ever-changing world in which we are supposed to be able to foresee the technical developments in sensor technology, many factors, aside from the main scientific, influence the future. The Division management has therefore written a "Foresight" based on political, cultural, ethnical and demological mainstreams in society.

This annual report offers a sample of the research and other activities carried out at the Division of Sensor Technology during year 2000. Research is performed in projects using competence from the following Departments:

Functional Materials
Laser Systems
IR Systems
Microwave Technology
Surveillance Radar
Radar Sensors

A list of articles, conference papers and non-classified FOA reports issued during the year, can be found at the end of this report. Readers interested in references, or in more information, are welcome to contact the Division at the addresses listed on the inside of the cover.

International evaluation

In year 2000 it was the Division's turn to be evaluated by an international committee. The group was chaired by Olle Nilsson, Prof. em. Chalmers, Sweden. Other members of the committee were Dieter Clement, Dr., Forschungsinstitut für Optronik und Mustererkennung (FGAN-FOM), (Research Institute for Optronics and Pattern Recognition), Germany; Tapio Halkola, Lt.Col (Eng), ERC/ Finnish Defence Forces, Riihimäki, Finland; Dominique J. Serafin, Dr, Centre d´etudes de Gramat, F-4600 Gramat, France; Laurent Malier, Dr, DGA, DSP/STTC, F-00460 Armées, France and Bo Wahlberg, Prof, Inst. f. Reglerteknik, Royal Institute of Technology, Stockholm, Sweden.

Figur 1. International evaluation committee

Figur 2. Lennart Holm was responsible for the visit of the international evaluation committee.

The following is quoted from the executive summary: "FOA Division of Sensor Technology has a good vision on the mid-term needs of the research for the digitised battlefield. The vision reflects the Swedish military needs stated in the Dominant Battlespace Awareness (DBA) documents. However, FOA3 in the report the Division is refered to as FOA3 should take stronger initiative regarding the strategic planning of defence from a technology and scientific point of view. It should play a major role in identifying the long-term needs, opportunities and threats. This issue should be addressed at FOA level and become a major objective."

"The scientific level of FOA3 is good and at some departments excellent. There is a noticeable impact of the Quality activities as well as the Educational programs."

"The management of the division is conducted excellently. There is an extreme concern to match the demands, current and future, of a scientific organisation with the interests of the national Defence within the boundary conditions of available funds."

"FOA3 personnel is very dedicated to their work. This may be one reason why the Division is trying to cover too much with limited resources."

"The mutual transfer of knowledge between FOA3 and their customers is generally good and in some cases excellent."

"Research areas that should be strengthened or taken up by FOA3 are:

- Modelling and simulation of sensors and subsystems for complex systems
- Autonomous sensor-based systems and sensor fusion
- Signal processing and perception
- Countermeasures (including signature management)
- Futuristic microwave systems; active, multifunction and adaptive antennas
- High power microwave"

Competence

MS Ulla Backlund
Assistent Head of the Division of Sensor Technology

The Division arranged several courses for its own personnel during the year as a complement to the scientific knowledge deriving from working in research projects. Some courses given this year were:

- Presentation technique
- Purchasing in theory and practice
- Project management (science, work environment, etc)
- Environment

A seminar "leadership for the future" was given during last autumn. This seminar will help the participants in formulating their personal career-plans. The participants were given the opportunity of taking three different tests: Gordon's, Myers-Brigg's and an entrepreneurs test, after which a psychologist presented the test results to the participants. This investment will help the participants in formulating their personal career-plans. The Division aims to offer relevant courses in the future, thereby facilitating individual and divisional competence maintenance.

Courses are continuously evaluated to ensure their quality (Table 6).

International cooperation

The Division has international co-operation in about many projects. Special efforts were made during the year to find new possibilities for co-operation within the Common European Priority Areas, CEPAs: radar, microtechnology and optronics (CEPA 1, 2 and 8). We succeeded with the assistance of the Defence Material Administration, FMV, Mr Gunnar Ericsson, to start a project in CEPA 2, Mimosa with France and United Kingdom.

Finances

Revenues reached MSEK 153 in 2000, which is the same level as 1999. We had expected an increase in revenues but, due to a shortage of personnel at the start of the year, this could not be achieved (see Figure 4). Our two most prominent customers are the Swedish Armed Forces and the Defence Material Administration, which both increased their number of orders. The most significant increase, however, comes from Swedish industry.

To stimulate creativity and secure immaterial property-rights for the Swedish Defence, several patents have been applied for and granted. The interest from industry for patents has increased, and the sale of one such patent to Saab Avionics was a break-through for our patent-policy granted (Table 1).

Table 1

Number of Patents	Applied	Accepted
1996	-	9
1997	9	2
1998	8	8
1999	4	9
2000	4	5

Personnel

To ensure that FOA will be able to operate in the fast developing information research sector, FOA must engage in the keen competition for attractive and competent personnel. Personnel turnover during the year exceeded 10%, and we were forced to take strong measures. Much time and energy were used on recruiting, with a great deal of advertising.

The Division would like to direct thanks to Mr Bertil Brusmark for his long-time (1996) engagement, and Leif Carlsson for assuming the main responsibility at the end of the year as head of the Department of Radar Sensors,

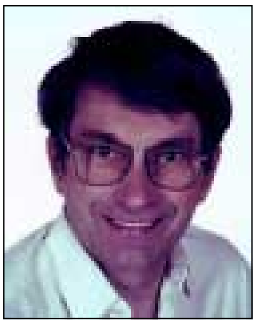


Figure 3.
Nils Gustavsson was awarded by the Swedish Royal Academy of War

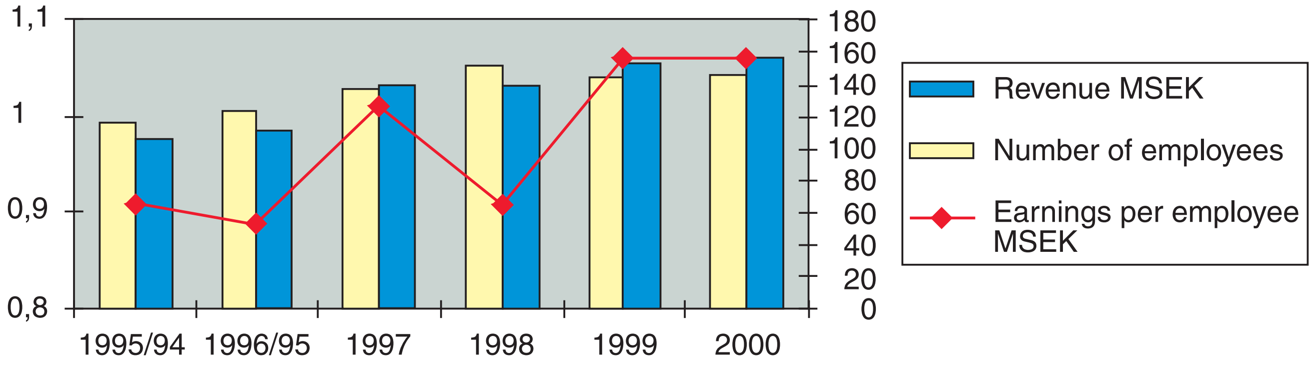


Figure 4 Revenue, employees and earnings per employee

also to Dr Magnus Danestig for managing the Department of Microwave Technology. Mr Brusmark is now program manager at the FOA Program office and Dr Danestig has now left FOA for a research position at the Swedish company ACREO.

Once again the Sensor Division has gained the honour of ”Ahlbergerska priset”. Nils Gustavsson was awarded SEK 50 000 and a silver medal by the Swedish Royal Academy of War. Mr Gustavsson has developed a new and economical material for stealth in the microwave area (Figure 3).

FOA Education in Linköping

Education activities in Linköping have again increased during the past year. The purpose of the education project “FOA Education in Linköping” is to strengthen the ongoing process in which FOA aims to increase it´s support for the National Defence College (FHS) in the area of Postgraduate Education for the Swedish Armed Forces. This is primarily achieved by transferring knowledge achieved from the results of the research at FOA, into education.

FOA Education in Linköping has, in 2000, carried out more than fifteen courses with a duration of more than one week each. FOA scientists at the research divisions in Linköping and Stockholm are engaged in teaching. Some courses of special interest at FOA Linköping were:

- Electronic Warfare (EW)
- Robust Optronic Systems
- Robust Communications Systems
- Robust Radar Systems
- Robust Information Systems (new course)
- Electronic Counter-Measurements (ECM) for helicopter systems (new course)

The main courses are Academic Courses and the students are awarded points in the grading-system for a Ph.D. degree, or a diploma. An examiner from the University of Linköping is involved to assure that academic quality is maintained.

Foresight

International development in security policy influences the directions and demands made on the Swedish armed forces and the demand on future sensor technology. An increased interest in Revolution in Military Affairs as well as in international operations from the Swedish Government indicate new challenges in the field of research.

The management of the Division has begun a study of international trends, risks and development for the coming 20 year period, including financial, technological, security, political, cultural, and military sectors. Scientists in the Division of Defence Analyses are offering support in the area concerning methodology which involves definition of focus, development factors, scenarios and strategies for possible new future directions for the Division.

Military conflicts

Two contradictory trends concerning future conflicts can be perceived: small-scale regional conflicts and high-tech conflicts. These differ from earlier perceived threats in the Swedish scenario. In regional conflicts with distributed forces, sometimes mixed with civilians, localisation and identification is mandatory. A failing mission could possibly deepen a conflict, or even damage peace-keeping forces. The high-tech scenario demands new concepts in sensor technology with a total situation awareness. The major threat might come from modern information attacks, but a war-scenario of swarms of cruising missiles co-ordinated with ECMs has recently been discussed and are possible in a military attack.

System development

Therefore, future sensor systems must be characterised by significantly enhanced precision and capacity. To accurately detect a large amount of targets, we foresee the need for antenna arrays in frequencies from UHF/VHF to the high GHz domain in radar systems. This situation calls for signal processing to detect, classify and select targets with low radar cross-section areas. Increasing ECM threat will force the use of multi-function systems. The high information collection-rate asks for

- multipurpose and re-configurable antenna arrays
- conformal and smart-skin antennas

Increased integration of RF- and digital circuits with the antenna structure, provides multiple functions such as radar, ECM, and communication in the same antenna. This also reduces the number of apertures and the signature of a platform. In microwave technology we foresee an increased focus on HPM and EMI causing a threat to civilian infrastructure.

In photonics a number of military applications are being developed. Laser systems or combined laser/EO systems include reconnaissance, target recognition, weapon guidance and rapid terrain visualisation, where the high resolution (cm) of optical systems in 3-D is utilised. High resolution laser radar and passive sensors include guidance of autonomous vehicles. Lasers can sense gases, aerosols and wind for BC detection. Laser light penetrates water for target-track detection and depth-sounding.

The use of lasers in directed infrared countermeasure systems (DIRCM) is becoming increasingly accepted, and in the long-run diode-pumped solid-state laser will enable compact laser weapons to be used for tactical purposes.

Free space optical communication systems for both air to air, air to ground and air to underwater situations is possible as a complement to conventional radio and microwave systems in situations where extremely low probability of interception and or high bandwidth (Gb/s) is needed. The potential for complete interception free communication using quantum cryptography is noted.

Photonics, used in combination with conventional electronics, will increase sensor performance by allowing extremely fast and parallel data transmission within sensors (optical interconnects, smart pixels) allowing distributed sensor-information to be transmitted by radar/radio signals onto an optical carrier. Photonics might lead to ultrafast AD converters and efficient tuneable radiation generation from GHz to THz. Optical memories, an optical signal processing will also increase sensor performance.

Overall developments are leading to a better fundamental understanding of material properties and improved production methods. This will result in new low signature materials and stealth design. The improved understanding of which factors control the properties of a material can be used in two ways:

- Optimisation of a particular property
- Multifunctional materials

Optimisation of one particular material property can be driven to extreme lengths. We can therefore expect a continued rapid development of e.g. ballistic protection, batteries, electronics and sensors. Another trend is “tuneable” materials with properties which can be varied by e.g. an electrical signal. These allow continuous signature control depending on the local situation and tactical system requirements.

Department of Functional Materials

Mr. Sören Svensson
Head of the Department of Functional Materials

The Department of Functional Materials' primary mission is to research materials with applications in military sensors, and in sensor countermeasures across the electromagnetic spectrum, from the visible spectrum, through infra-red and including radar wavelengths. Research activities include synthesis, measurement and modelling of the electromagnetic and acoustic properties of materials.

Our present research activities are divided into two main areas - materials for:

- protection against lasers
- signature reduction

A new research effort in the area of nanostructured materials was started during the year.

The Department has an extensive network of national and international co-operation with universities and other defence research organisations.

At the beginning of the year 2000 the Department moved into a new, purpose-built 400 m^2 laboratory block, adjacent to the Department's offices. The laboratories contain facilities for materials synthesis and measurement, laser laboratories, a powder technology laboratory, x-ray diffraction, and a controlled climate laboratory.

The Department continues to expand, and during the year three new scientists have joined us. We are now 15 researchers, approximately half with higher academic degrees, plus administrative support staff.

Protection against lasers

Various approaches to counter the threat of lasers for jamming or destroying electro-optical sensors or the human eye are being studied. Many activities are partly performed within the Photonics program described in the Department of Laser Systems section within this report. The results below were obtained in close cooperation with Linköping University, the Royal Institute of Technology and Chalmers Institute of Tecnology.

Our results include:

- Identification of limitations in the applicability of liquid crystal components
- Installation of a standardised test-bed for the measurement of 3rd order non-linear optical (NLO) materials
- Success in modelling the NLO properties of organo-metallic compounds.

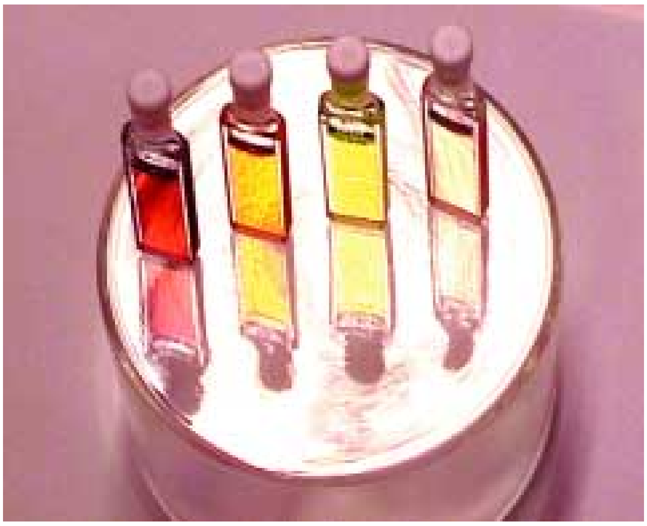


Figure 5. Shows some examples of optical power limiting materials studied in our laboratory.

Signature reduction

Our activities in this area are aimed at optimising (i.e. minimising) the electromagnetic signatures of military platforms, in two main spectral regions: optical (including infra-red) and microwave wavelengths.

Optical wavelengths

- The emissivity of multilayer pigments from stacked dielectric films has been modelled and measured
- Non-uniform polarisation of surface emission has been investigated

Microwave region

- Various materials have been studied and their microwave properties (reflectance and transmission) were measured
- A study has been initiated (into approaches) to substitute impedance boundary conditions for radar absorbing materials in radar cross-section calculations of complex shaped objects.
- Vapour-grown carbon nanofibre/polymer composites have been synthesised are beeing studied as microwave absorbers.

Nanostructured materials

This is a new research area for the Department, initiated and funded by the Swedish Armed Forces, with supplementary funding from FMV. The initial objective is to identify and prioritise defence applications of nanostructured materials, with special emphasis on aerospace and sensors/sensor countermeasures. This special class of materials is currently the centre of much research interest throughout Europe, North America, and Asia. Several national programmes already exist, and many more are being planned, including a national programme for Sweden which is expected to start during 2001. Most recently the USA, which has long seen nanotechnology as being essential to the development of new technologies in all spheres of society, including defence, has announced massive new funding for fiscal year 2001.

What are nanostructured materials?

A simple, but adequate definition of a nanostructured material is one that contains at least one characteristic dimension of about 100 nanometres (nm) or less. By characteristic dimension is meant for example; the grain size in a bulk material; the particle size in a powder; the thickness of a layer, interface or surface coating; or the diameter of a fibre or wire.

Nanostructured materials are by no means new! Many biological materials, including wood, bone, seashells, and feathers fit the above definition. Many such materials (e.g. spider's thread) are well known to have excellent mechanical properties, which combined with their low density gives exceptional specific properties. More recently, it has been realised that even natural applications of signature control, for example the iridescent colouring of butterfly wings, are created by a nanostructured material.

Why the military interest?

There are few, if any defence *materiel* systems which are not limited in performance by the *materials* used in their construction or operation. Both national and international defence operations will in the future demand increased performance in terms of mobility, endurance and situation awareness. The latter is of central importance for the doctrine of Dominant Battlefield Awareness (DBA).

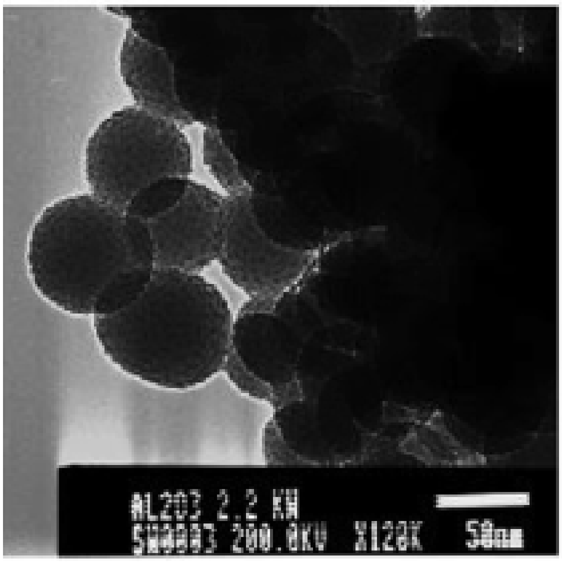
There are several factors which contribute to the rapidly growing defence interest in nanostructured materials. A major reason is the realisation that new materials with new functions can be produced. These include extreme physical (electrical, optical and thermal) properties (conductivities much better than e.g. copper, non-linear optical effects, etc), enhanced mechanical strength (many times stronger than the best steel available today), and greatly enhanced chemical reactivity. Secondly, during the past two decades it has been realised that the microstructures of metals, alloys, semiconductors and ceramics contain many features on the nanometre scale, and that these features (dislocations, precipitates, grain boundaries, etc) play a crucial role in determining the material's physical and mechanical properties. A third factor is the scientific advances in instrumentation, which now allow us to examine the internal structure of materials at magnifications great enough to "see" and measure nm scale features. Such instruments include the electron microscope, the scanning tunnelling microscope, atom probes, etc. The sum of these developments is leading us to a much better understanding of how to produce materials with properties tailored for a specific application. In the near future it will also be possible to synthesis materials with new combinations of properties, that is *multifunctional materials* which combine for example signature control with ballistic protection. Other examples are multispectral signature control, energy storage and novel electronics.

Experimental research activities

An international defence co-operation has been started, to investigate the optical properties of nanostructured materials.

Using civilian technology, polymer nanocomposites have been produced at KTH using melt intercalation processing. The objective of this is to develop techniques to synthesise multifunctional polymer nanocomposites. Various properties of the nanocomposite materials produced have been measured, including tensile strength, polymer degradation, permeability and degree of intercalation. This work is continuing, and will be complemented with measurements of toxic gas permeability and optical transmission.

Experiments at the Ångström Laboratory have produced noble metal (gold, silver) and reactive metal nanoparticles on glass and polymer substrates. Preliminary results show the particle size to be in the range <10 nm, where non-linear optical transmission effects are observed. Results of electrical conductivity measurements on aluminium nanoparticle films show a temperature coefficient of resistivity which is sample dependent. These results are analysed using a percolation model.



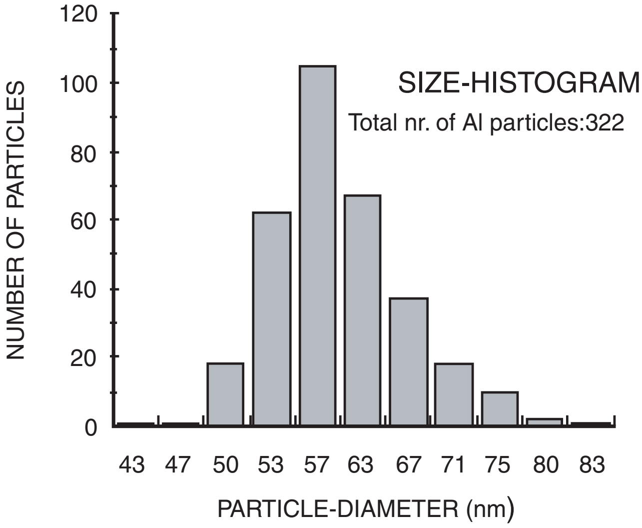


Figure 6. A transmission electron microscope image of aluminium nanoparticles, and associated size analysis histogram.

Applications of nanostructured materials

Some potential applications of novel nanostructured materials in defence materiel are listed below.

- Signature control
- Electrical energy generation and storage
- Chemical sensors with increased selectivity and sensitivity
- Ultra-high strength structural materials
- Improved polymer composites with multifunctionality
- Improved warhead materials
- Improved explosives
- Improved missile propellants
- Low observable armour materials (ceramics and metal alloys)
- Improved protection against chemical and biological weapons
- Non-linear optical materials for protection against lasers

Department of Laser Systems

Dr. Ove Steinvall
Head of the Department of Laser Systems

Department of laser systems

The Department of Laser Systems consists of about 30 researchers with master degree or higher in electronics, physics or information technology. The activities within the Department are organised in four research areas: Lasers for remote sensing, Distributed laser sensor networks, Photonics and optical components, and Modelling and simulation. The Department hosts a great variety of laser equipment and test facilities, most notable a 100-m indoor test-range for optical measurements and a large roof-top laboratory. The research focuses mainly on application oriented projects where laser based sensor systems and photonic components are developed in close collaboration with national universities and the defence industry. There is a long tradition of exchange with foreign defence research organisations. Currently we are actively studying laser radar applications with DERA (UK). Researchers from the Department participate regularly in education, seminars and studies involving other branches of the Swedish Armed Forces. During 2000 we have published or submitted more than half a dozen papers to scientific journals, several scientific reports, many contributions to national and international conferences and a great number of user reports and test protocols, many of which are classified.

The high-lights during 2000 included a successful field study of fibre hydrophones, test of an electronic nose in Kosovo, field tests of range gated viewing for target recognition, development of a compact coherent laser radar, demonstration of an antisensor laser system (LYSA), development of a computer based laser radar model, field trial and data analysis of airborne and ground based laser scanning for synthetic environments, and finally, results of a variety of laser radar cross-section measurements. The department of laser systems also participated in a number of studies for precision engagement, DBA and under-water mine warfare using new laser technology. An important new research area within photonic components is spatial light modulators for laser beam-steering, optical signal processing and adaptive optics. This is one area of research where we expect user needs in the near and long term perspective. The rest of this annual report we devote to a more specific description of the photonics program.

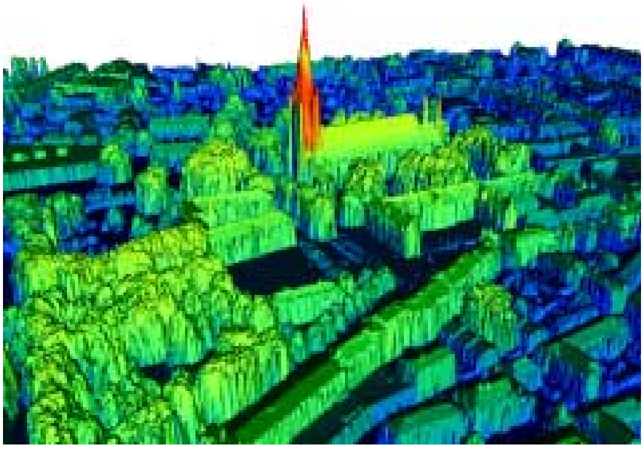


Figure 7. Example of a laser scan of Linköping used in the work on synthetic environments.

Photonics

In studies carried out at Swedish defence agencies during 1995 - 97 it was concluded that photonic materials and components will be critical ingredients and become more important in certain defence system applications. Examples: Collection, evaluation, transfer and storage of large quantities of information in command systems. Providing novel technological means of detection, identification and tracking of targets and unidentified objects in sensor systems. Enabling new means for controlling and steering electromagnetic fields and light in electronic warfare systems.

A new research and technology program in photonics, supported by the Swedish head quarters and administrated by FMV, was initiated during 1998. This effort also includes the participation of Swedish industry, universities and foreign research organisations. The whole program and several subprojects are co-ordinated and managed by members of the Department of laser systems.

The aim is to initiate research and/or support research within the field of photonics. Since related projects are also conducted within the civilian society by research foundations, governmental research councils, or on commercial basis, the emphasis in this program is on defence related applications. The 5 year program is divided in two phases. The program is comprised of six projects, based upon proposals submitted and discussed at a workshop in October 1997 attracting approximately 40 participants from Swedish defence agencies, commercial and academic research institutions, and industry. The project goals for the initial phase (1998 - 2000) were:

- To demonstrate various aspects of photonics technology

relevant to certain strategic defence needs.
- To establish a photonics infrastructure among Swedish defence agencies and the international research community.

The second phase of the program was defined after a new call for proposals during the spring 2000, and a major revision of running projects. New and renewed project were launched during the fall 2000.

The photonics program is also supported by strategic competence projects within the Division of Sensor Systems at FOA. The goal is to establish competence and technological know-how for optical signal processing, primarily in free-space propagation applications, but in longer terms also optical interconnection technology using optics integrated with electronic and mechanical microstructures. During 2000 a "Fourier optics laboratory" was equipped and initiated. Here spatial light modulators and other equipment for optical phase front modulation will be characterised for beam steering applications and adaptive optics. This research is supported by and carried out in close collaboration with the Advanced Instrumentation and Measurements (AIM) graduate school of Uppsala University.

Short summaries of the projects within the program are given below.

Non-mechanical beam steering

The traditional way of steering light is by using turnable mirrors, prismas or other optical components by mechanical actuators. These are usually large and/or heavy and consume relatively high powers. Moreover, the speed at which light can be modulated is slow compared with today's demand on switching speeds and modulation frequencies. There is considerable value for both military and civilian applications of adding non-mechanical (here electrical) steering of laser beams. Precisely this function is enabled by phase steering using transmission or reflection spatial light modulators (SLM), both in one and two dimensions. A main aim of the project is to develop a one-dimensional laser beam steerer based on liquid crystal technology. The project is carried out mainly at the Optics group and Liquid crystal group at the Chalmers University of Technology. FOA Laser System is responsible for system specifications and final evaluation.

During the first two years of the project suitable LC materials were evaluated and a 1-dimensional test component and driving electronics developed. This project will continue in a modified form during photonics phase 2. The aim will be to combine beam-steering capability of liquid crystal SLMs with fast multi-quantum well modulators to realise a high capacity data transfer system for free-space laser communication.

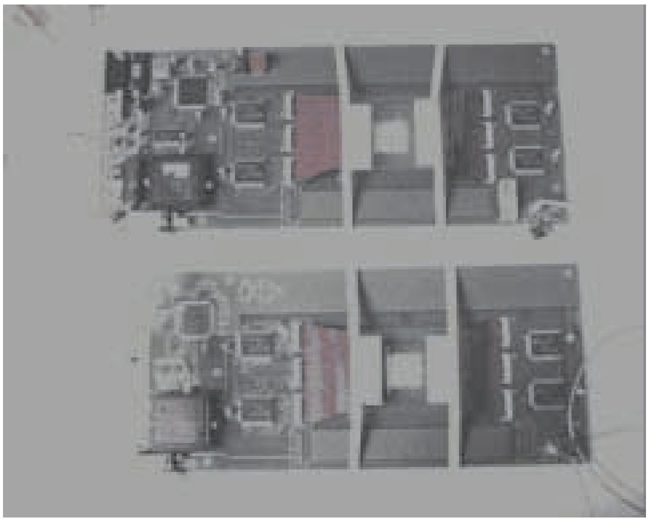


Figure 8. Two binary SLMs each with 1 x 256 pixels. The SLMs are designed for different phase shifts and in combination they can be used to deflect laser light using only electric signals.

High power fiber laser

The project was limited to phase one of the program as a joint effort primarily conducted by FOA and ACREO AB. The aim was to investigate if a fiber laser is a suitable light source, particularly for laser radars and fiber sensor networks but also for microwave photonic links. The targeted laser has high output power at 1.5 µm, is single mode both longitudinally and transversally, has a narrow linewidth and is polarised or polarisation controlled. Rather than a survey of how to use a fiber laser and how it behaves the project became a study of how to make such a device.

A multi-mode laser with 250 mW of output power was demonstrated. Characteristics of this lasing fiber revealed important limitations in the fiber which were traced to processing problems. Therefore the goal of the projects (1 Watt single mode output power) was not reached. A low output power, single mode, narrow linewidth, fiber laser intended for a master oscillator power amplifier (MOPA) configuration was demonstrated. The work at FOA was focused on the development of a simulation tool for Er/Yb fiber lasers used to find how to configure the laser as regard to pump, cavity, gratings, ion concentrations, fiber dimensions etc. in order to achieve desired characteristics. Furthermore fiber laser sensors as tools for hydro-acoustic applications were surveyed at FOA. A semiconductor MOPA was shown to be an optional solution able to satisfy most of the desired characteristics although the narrow linewidth in reach with fiber lasers would not be possible with a semiconductor master oscillator.

Passive and active polymer materials for optical communication

The future battlefield will urge high demands on real-time command and communication, that is, collection, evaluation, transfer and storage of large quantities of information. The applications will require optical interconnect technology and the design of compact sensor systems with integrated electronic and/or optical processing capabilities near the sensor. There are a vast number of photonic materials, components and systems that are necessary to develop to explore the DBA scenario, and many of these, primarily based on semiconductor and inorganic materials, are studied in related civilian applications. The primary targets in this project were to develop new unique polymers with very low optical losses and an optical amplification function that can be processed into waveguide structures. The synthetic work was carried out by the Department of Polymer Technology at the Royal Institute of Technology. Material characterisation was carried out at the Department of Laser Systems in collaboration with external partners: AFRL, Acreo-Kista, IBM-Zürich and Linköping University.

In the project, development of novel dendritic fluorinated polymer materials, including process technology, for low-loss optical waveguides was carried out (the goal 0.1 dB/cm @ 1.55 µm was reached). Promising optical amplification materials were achieved by doping fluorinated dendrons with Erbium and other lanthanide cations (see figure 9).

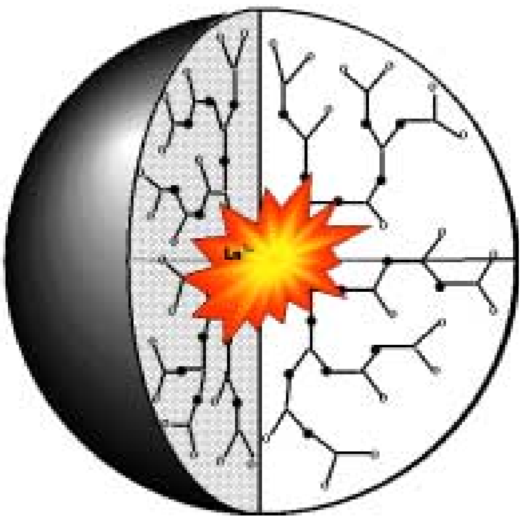


Figure 9. Principle for site-isolation for optical amplification. (Material developed within the photonics program.)

For the second phase of the photonics program the same dendritic materials will be modified and developed for laser protection applications.

Microwave photonics

Future radar systems will include radar, electronic warfare and communication functions integrated in the same system (multi-function radar). To achieve this a large bandwidth for transferring data is required. In order to achieve non-distorted lobe forming using broad band antennas one must use true-time delay schemes in antenna beam steering. The purpose of the microwave photonics project was to study optically controlled beam steering, optical and electro-optical components for sensor and microwave systems. VCSELs and related technologies were studied at Chalmers University of Technology and Ericsson Microwave Components, Mölndal. The subproject related to VCSEL devices will continue in photonics phase 2. The goal will be to establish a broad band optical microwave link demonstrator (2 - 18 GHz) and develop relevant VCSEL technology. The Department of Microwave technology FOA (bå 2000) will participate in the continuation of the project into phase 2 of the photonics program.

Information technology for target recognition

A comparative study between electronic and optical processors led to the conclusion that optics may offer substantial advantages for certain demanding pattern recognition applications, when weight, volume and/or power consumption are critical parameters to minimise. The objective of the current project, as part of the defence photonics program, is to further develop the knowledge in this field, and more specifically to identify the performance and potentialities of hybrid opto-electronic processors for automatic target recognition and tracking. FOI:s contribution within this field is coordinated by the image processing group at the Department of IR systems.

Materials and components for laser protection

By laser protection we mean the protection of optical sensors and eyes against hostile laser radiation. Research and development of different aspects in this field has been going on for years in a number of defence organisations in Sweden. The project within the photonics program emphasised on initiating joint efforts between a number of universities and external research organisations with the related projects within the Division of Sensor Technology. The activities are coordinated at the Department of Functional Materials.

Department of IR Systems

Mr Lars Bohman
Head of the Department of IR Systems

The research activities at the Department altogether aim at edifying the knowledge of the whole chain from the sensor itself to what the sensor can apprehend, i.e. from target and background signatures, atmospheric phenomena, sensor performance including image/signal processing to the display technique. The main focus is on thermal IR but we are working within the whole optical spectrum, i.e. UV, visual, near IR and thermal IR regions.

The results of the research are presented in FOA reports and at international conferences. Other important channels for conveying the experience and knowledge of the Department are education, participation in studies and investigations for the Defence Material Administration, the Armed Forces and the National Defence College. During the year there has been an increase in terms of lecturing hours, which have engaged almost everybody at the Department. A number of essays for masters degree in engineering were based on works at the Department.

Signatures

A substantial part of the research at the Department concerns signatures including atmospheric physics. This work is fundamental for work in the research area of signature management and low observables. We have for this purpose a unique measuring resource, which is continuously developed and used for characterization of target and background properties such as spectral, spatial, and polarising effects. During this year the emphasis has been on natural backgrounds. Land backgrounds have been studied with respect to clutter, particularly texture variations and their dependence on weather and radiation conditions. Different targets have been studied upon request such as helicopters and IR countermeasures. Verification of a model for synthetic IR scenery has been started. Preparations for the modelling of exhaust flame signature were initiated.

The detection of chemical warfare agents by spectral methods were studied in co-operation with NBC Defence Division.

Concerning optical mine detection, extensive experiments and modelling were carried out. Genuine data was used in order to verify different physical based models. This activity has been accomplished in close connection with university research. Efforts during the year were spent on the preparation of an EU project called ARC with the intended to start in year 2001.

Also in atmospheric physics there are international connections. This year on the evaluation of a recent field trial, “Baltic 99”, together with TNO, the Netherlands, concerning atmospheric effects in naval environment. An EU research program called Earlinet, on aerosol content in the atmosphere, has started.

E/O and IR sensors

The research on sensors is focused on performance analysis and optimization on novel sensors.

Research on uncooled IR digital focal plane arrays has reached completion. A demonstrator producing 320x240 pixel images is the result of several years of research in co-operation with DSTO, Australia. An evaluation of performance characteristics has concluded the project.

Studies on electro-optical missile approach warning sensors for aircraft have been carried out trying to state the potential of different solutions in UV and in thermal infrared.

Concerning signal and image processing close to the sensor the Department has expanded substantially during the year. A new strategic project on Signal processing for moving EO/IR sensors, SIREOS, has started. There is also a related competence project in this area. The competence group will serve several application projects with their expertise. The stake will be beneficial for several projects, namely Optical mine detection, Optical information processing, Information systems for target recognition, Electro-optical missile approach warning sensors and Optronic sensor systems.

Finally, we are proud to announce some promising results on gaze control and smart display techniques.

Gaze control with approximately 1 ° accuracy has been demonstrated as well as dynamic resolution in order to facilitate real time augmented scenery vision.

Figure 10. Test-set of a smart display system.

Optical Signatures activities

Signatures is one of the key areas of the Department. The need for knowledge in this field is increasing as new and improved techniques for signature suppression are developed. These techniques will adapt the signature to the background in several aspects: temperature, surface structure, and spectral reflectivity. Polarisation control will be important in some applications. At the same time there is a parallel improvement in the ability of optical sensor systems. Hyperspectral sensor systems with advanced signal processing might be a serious threat in the future.

Several projects at the Department deal with signatures. They have somewhat different focus but they all interact and complement each other. The project called Optical signatures serves as a scientific basis and includes background research, signature assessment methods, atmospheric studies and radiometric methods and equipment. Other projects deal more with target signatures, e.g. improvements of aircraft signature and methods for specifying signature requirements of vehicles. Modelling and simulation of signatures, especially IR signatures are becoming more important. There are many applications ranging from evaluation of stealth designs to real-time simulators for pilot training. Hence, there is a need to implement signature research results into computer models of different complexity. The validation of a commercial, synthetic IR scene simulation program started during 2000.

Below are three activities within the Optical signatures project described.

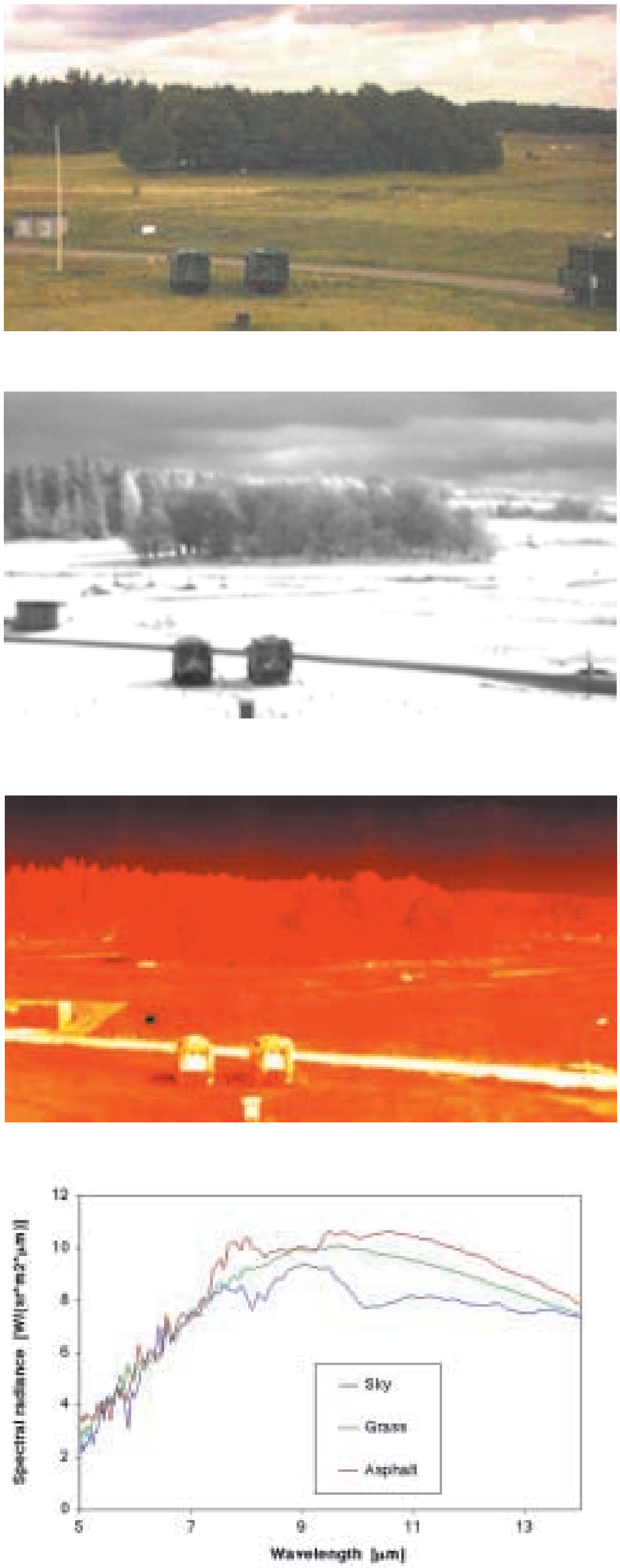


Figure 11. The background scene recorded in different wavelength bands. From top to bottom: visual, near IR, thermal IR and finally spectra of different scene components.

An IR Background Database

In 1999, systematic measurements started in order to establish a background data base. The measurements will be finished in spring 2001. The obtained data will be used for a wide range of applications and provide a basis for the modelling of optical background properties and variations of Swedish terrain. Experimental data is also necessary for the validation of methods and programs for synthetic IR scene simulation. The data was collected from the surroundings next to the FOA site in Linköping. The sensors were placed in the FOA building. The chosen scene has been well characterised concerning topography and tree species.

The measurements were performed with several sensor systems. The main system is based on a Thermovision®900 with image sensors for the 3-5 µm and the 8-12 µm band. This system used an automatic mosaic scanner and produced combined images of 23° x 12° every third minute. Measurements were performed periodically, 24 hour every month during a year. Four other complementary sensors were used for shorter periods:

- ScanSpec (imaging spectrometer designed at the department) collected hyperspectral images
- A colour CCD camera was used in the visual
- A filtered CCD camera was used in the near IR
- Thermovision®900 with polarising filters

During all measurements a weather station collected data including sky and earth radiation levels.

Assessing Camouflage Using Textural Features

Signature suppression makes target recognition more difficult. In order to keep the false alarm rate low it is necessary to observe spatial and spectral properties. Hence, there is a genuine need to take into account the spatial properties when analysing the difference between a target and the surrounding background.

The approach is to apply texture descriptors to characterize both the background and the camouflaged targets. Other descriptors are also used to characterize man-made objects. It is necessary to focus on these features that discriminate the targets from the background. A more precise description of background and targets is then required. The underlying assumption is that an area containing low observable targets has changed statistical properties if the signature reduction is poor. Statistical properties along with detected target specific features (straight lines, edges, corners, reflections from windows etc.) have to be combined with methods used in data fusion. A PC program for the computing of the statistical differences is under development, see below. The next step is to be able to combine spatial features and multi-spectral features. In the future motion may be an important feature.

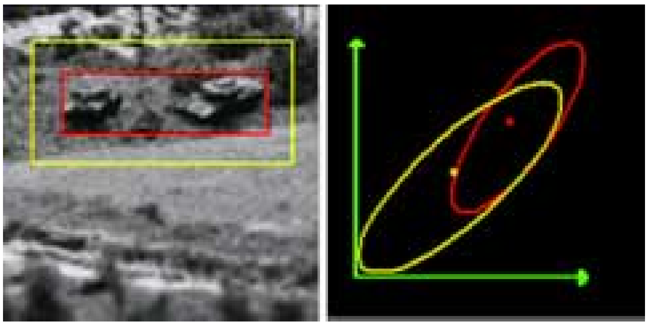


Figure 12 . The selected target area is marked in red and the background area in yellow. In the diagram the statistics for the two regions are shown. The amount of overlap indicates how well the target is adapted to the background.

Radiometric Quality

A variety of instrumentation and other equipment are available for signature measurements at the Department. This equipment is necessary for efficient and qualified studies, both for basic research and for assessments of signature reduction measures. The radiometric equipment is calibrated routinely.

All instruments are described in a document: *Measurement Equipment at the Department of IR System* (FOA-R--99-01111-615--SE) that provides description of measurement methods and routines for uncertainty estimations. The document serves as a base for radiometric measurements at the Department.

Department of Microwave Technology

Mr Hans Frennberg
Head of the Department of Microwave Technology

The research activities of the Microwave Department are focused on the evaluation of new technical possibilities within the microwave frequency range (including RF and millimetre waves) and how they can be developed for future advanced defense applications. Our competence profile includes antennas and antenna arrays, packaging and design of microwave monolithic integrated circuits (MMIC), microwave photonics, high power microwaves (HPM) and EMC, numerical electromagnetics and antenna related signal processing.

By cooperation with universities and Swedish industry and through an established and expanding international contact network we take part in the R&D development of microwave technology. Organized cooperation programs exist with TNO-FEL/NLR in the Netherlands concerning ”Smart Skin Array Technologies” and ”SiC and GaN transistors for microwave power amplifiers” and with several countries in the HPM field.

Planar active antenna arrays

Our efforts in this field are concentrated on the development of an electronically steerable Smart Skin array concept demonstrator (SIGA Beta) with 16 receiver channels, digital beamforming, aperture fed patch elements and single-chip MMIC receivers (Figure 13).

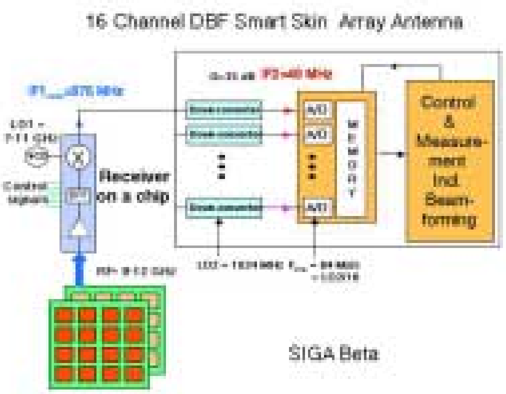


Figure 13. Block diagram of Smart Skin array antenna module with aperture coupled antenna array (16 elements), MMIC receivers and digital beam forming.

As the module will be realised with multilayer circuit technology, it can be integrated in the structure of flying platforms. The bandwidth goal is to cover 8-12 GHz. One possible application is as a subarray in a planar or conformal radar antenna. During 2000 we have focused on critical building stones such us on-chip receivers, planar antenna arrays and multilayer technologies.

Wideband antenna arrays

Circuit and antenna technology for arrays with bandwidths larger than one octave is another important activity. Primary applications in mind are two-dimensional arrays for electronic warfare (EW) applications and, in the future, general broadband multipurpose systems. A block diagram of a transmitter application is shown in (Figure 14).

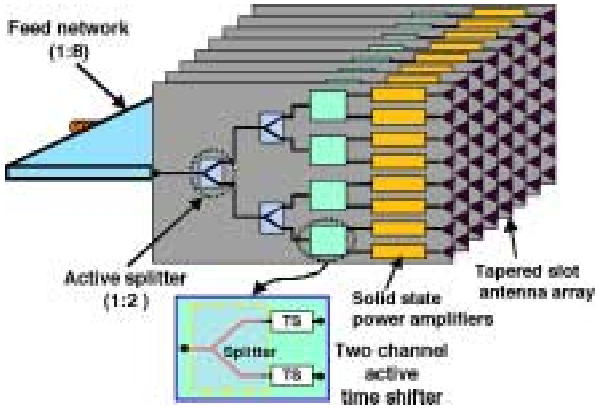


Figure 14. Wideband active antenna array electrically steerable in two dimensions using time delay circuits.

Radar on a chip (ROAC)

Radar On a Chip is part of the Smart Sensors project, financed by the Swedish Foundation for Strategic Research (SSF) and carried out by LiU and FOA. The main objective is to find efficient and low cost receiver implementation strategies, well adopted for digital beam forming antennas used in adaptive radar systems. FOA is responsible for the analog (MMIC) receiver parts. Recently we have designed a two chip front end with an active tunable bandpass filter and an image rejection mixer.

Millimetre wave technology

The millimetre wave research activities have been concentrated on the development of an imaging 94 GHz radar for the IR/mm-wave project. A novel active gate mixer with an integrated patch antenna has been presented. The MMIC and the antenna circuits were manufactured by Philips and ACREO. Using the Philips MMIC process we have designed a reflective SPDT switch for use in a chipset for the 60 GHz WLAN SSF project.

A linearly tapered slot antenna element suitable for use in a sector antenna for a mobile 60 GHz WLAN system has been designed and manufactued on a quartz substrate.

Contributions to several theoretical studies ordered by the Defence Material Administration have also been given.

High power microwave transistors

Silicon Carbide (SiC) and Gallium Nitride (GaN) are promising materials for high power microwave MESFET and HEMT amplifiers. Theoretical calculations indicate that such transistors can have output power densities a factor 5-10 higher than today´s standard.

We are studying SiC MESFETs on semiinsulating substrates in collaboration with CTH, KTH and LiU. During 2000 SiC MESFETs, fabricated on a structure with non-constant doping-profiles in the channel and buffer layers, have been studied in detail. A very good correspondence between experimental DC-characteristics and physical simulations was obtained, when using the doping profiles from SIMS measurements. Work on non-linear transistor modelling as support for transistor and amplifier design has been started.

Microwave photonics

An initial study of the possibility to use optical beamforming methods to control a microwave antenna array has been made. This technology can be of special interest for arrays at lower frequencies and for large arrays. The realization of an optical feed network for an electrically steerable array for EW applications, preferably at lower microwave frequencies, has been proposed.

High Power Microwaves (HPM)

The focus of the HPM project has to some extent been shifted towards protection methods for front-door coupling, in particular for phased array antennas. This work comprises initial investigations of using intentional electric discharges to reduce the coupling as well as the application of transient suppressors. Further work on the significance of directivity effects in susceptibility testing, especially concerning the relation between anechoic and reverberation chamber testing, has been carried out. In the field of numerical modelling further development has been made on the semi-empirical model of apertures and on modelling of microwave discharges in apertures.

Antennas

The design of the antenna system for the Swedish low frequency airborne synthetic aperture radar system LORA has been finalised. The LORA system is an experimental ultra wide band radar operating in the 200 to 800 MHz band, and is partly based on the experience gained from the earlier CARABAS project. The work carried out recently also includes simulations, design and measurements of a balanced and matched antenna feed.

Possible antenna concepts for man-held or vehicle mounted mine detecting radar systems have been studied in a project supported by the Swedish Rescue Services Agency (SRV). In this work focus has been on exploring fundamental properties and possible design of wide band Ground Penetrating Radar (GPR) antennas in the vicinity of a lossy ground. Theoretical properties of dielectric rod antennas have been investigated. An experimental TEM horn antenna (MPAX) designed earlier has also been evaluated by measurements.

Several activities with focus on Computational Electromagnetics have been pursued. A three-year project under the National Aeronautical Research Program (NFFP), in which we participated, has been successfully completed. The objective of this project was to develop numerical electromagnetic codes for Swedish industry.

In focus: Multipurpose Antenna Arrays

The active antenna arrray technology, earlier regarded as an exclusive and expensive solution for large scale applications, is currently being considered for use in many future systems, military as well as civilian. The main driving forces behind this are advances in MMIC design, microwave multilayer packaging technology, digital beam-forming and EM simulation of antenna arrays.

As circuits and antennas now tend to be more and more integrated, the realisation of platform integrated front end systems with internal signal processing will be possible. Furthermore, wideband phased arrays can be used not only for electronic warfare purposes but also for truly multi-purpose systems, where a number of functions within radar, warfare, communication, navigation, positioning, etc, can be performed in the same hardware – but with different software. Thus active antenna arrays do not have to be designed for each separate purpose but may become general reconfigurable ”tools”, programmed to function over a wide frequency band or with special properties within smaller bands.

With this vision in mind our research activities concerning active antenna arrays are focused on circuits and apertures, which are miniaturized in size, cover a large frequency band and include possibilities for electronic tuning and/or reconfiguration.

MMIC circuits

One circuit example is a fully integrated X-band receiver front end based on a singular downconverting stage. Here image rejection mixers and tunable filters are key components. We have realised MMIC mixers with a measured image rejection of 45-50 dB and a conversion loss of 9-11 dB over the full X-band. The IF frequncy is about 1 GHz as indicated in Figure 13. Furthermore, a frequency tunable recursive active MMIC filter has been designed using a balanced topology with two identical second order filters placed between two Lange couplers.

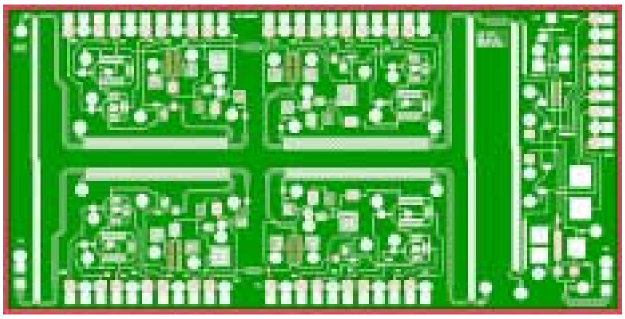


Figure 15. MMIC on-chip receiver for X-band with a balanced tunable active filter (left) and an image rejection mixer (right). The size of the chip is about 3x6 mm^2.

The tunability is accomplished by using time shifters and the relative tuning range is about 20 %. By combination of these circuits a one-chip receiver has been designed (Figure 15). The circuit simulations indicate that the performance of this chip may be adequate for multichannel receivers of future adaptive array antennas.

Circuits with very wideband properties such as power splitters and time shifters, developed for EW applications (Figure 14), are of considerable interest for multipurpose systems. A power splitter divides the incoming signal in two equal parts for the two output ports. By cascading a number of these circuits a power distribution network can be realised. Traditional passive power splitters like Wilkinson couplers are lossy, which limits the possible size of the network. We have developed in MMIC technology an active power splitter, where the signal from input to each output is amplified. The isolation between the outputs is also much improved, which together with the elimination of the loss problem, makes it possible to realise very large distribution networks. As an example (Figure 16) an active beam forming network for 2-18 GHz using three 1:2 power splitters and four 5-bit time shifters has been developed as a building stone for phased arrays.

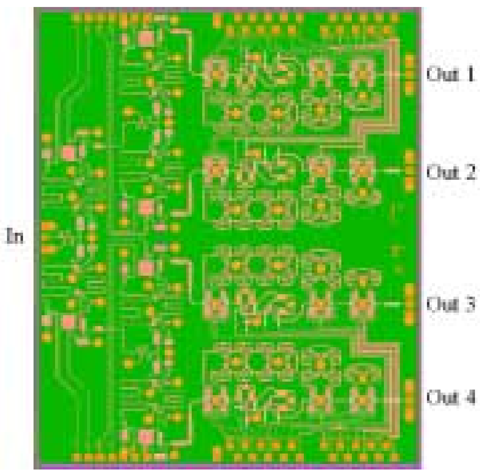


Figure 16. Active beamformer consisting of an active power splitter 1:4 and time delay elements. Frequency range 2-18 GHz. The MMIC chip size is about 5x6 mm^2.

Antenna apertures

Designing antenna arrays for wide frequency bands is a difficult task. For the planar configuration in Figure 13 it is of large importance to minimize the thickness of the structure, which limits the widebanding possibilities. For this case we have chosen an aperture coupled patch array and various means to increase its originally rather modest bandwidth have been investigated. With a two-layer patch structure a relative bandwidth of 20-30 % can be obtained.

Arrays consisting of tapered slot antenna (TSA) elements are usually the most appropriate choice for wideband applications. The frequency range of 2-18 GHz can be covered by two units. However, these elements have a considerable extension in the broadside direction, usually several wavelengths, and cannot be easily integrated with the beamforming network.

We have studied the properties of phased array apertures with TSA elements using electromagnetic simulation software and laboratory experiments. Our recent activities include the design and evaluation of a dual polarised antenna array for 2-6 GHz, consisting of two displaced co-located linear polarised arrays. In each array there are 7x8 elements. Focus has been on experimental evaluation of the array to verify the design and obtain a starting point for the development of a corresponding array for the 6-18 GHz band.

An example of the electromagnetic field simulation results for the 2-6 GHz array is shown in Figure 17. The elements have been excited with an internal phase difference to produce radiation in the 30° direction off broadside.

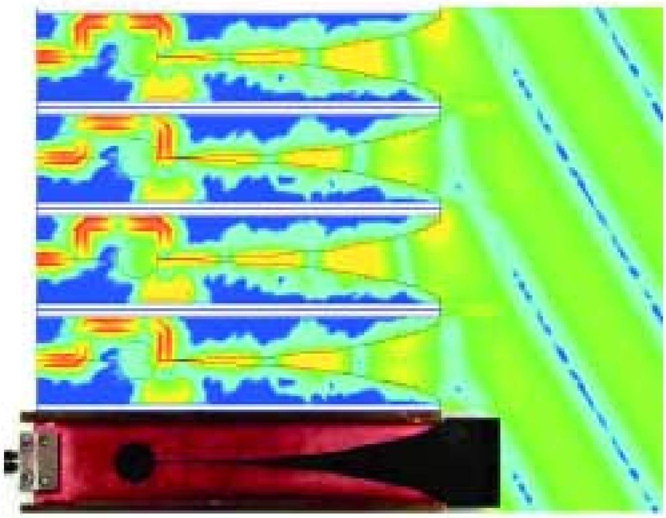


Figure 17. The simulated electromagnetic field in an infinite array of stripline fed tapered slot antenna elements. The elements are excited to produce a wave front in a direction of 30° off broadside. A photo of the antenna element is shown at the bottom of the figure.

Department of Surveillance Radar

Dr. Hans Hellsten
Head of the Department of Surveillance Radar

The focus of the Department is on long-range radar reconnaissance and surveillance. There is an increasing need for flexible systems with wide coverage both in time and space, having the capability to detect all types of ground and air targets. Decision-makers at various levels within the Armed Forces should have access in near real-time to images of targets, including information of their type and position. The images may show the position of own and enemy resources, communication networks, status of infrastructure etc. The next generation of radar configurations and systems should be embedded in such an envisioned dynamic command and control structure to attain dominant battlespace awareness, an advantage provided through information superiority.

The main research efforts at the Department concern basic principles and technical realisations of system concepts, both at VHF, UHF and at microwave bands. Knowledge of target signatures at low frequencies demands development of scattering models, simulations and verifying radar measurements. For microwave radars the activities primarily address problems in multifunction radar, where the use of active digital array antennas combined with powerful signal processing is an emerging field of interest. This gives flexibility and new possibilities regarding beam steering, radar energy utilization and jammer and clutter suppression.

The major radar equipment available at the Department for use in field experiments consist of the airborne VHF synthetic aperture radar (CARABAS-II) and an S-band radar with a receiving digital antenna. The airborne UHF (200-800 MHz) SAR system LORA (Low frequency Radar) is scheduled for the first imaging measurements in 2001.

The Department has participated in different studies for the Swedish Armed Forces under the concept of Revolution in Military Affairs (RMA). One of the important cornerstones of RMA is superior situation awareness. This gives you the ability to act faster and more precisely than your opponent. The requirements for long range, large volume and wide area surveillance will predominently be performed by different types of radar systems, especially in high altitude surveillance platforms. Different radar concepts have been presented which can enable us information superiority in the operational area.

High performance UHF air surveillance

For several years a concept for distributed radar known as AASR, or "Associative Aperture Synthesis Radar", has been under development at the department. The basic idea is to adopt a grid of radar stations relying on range and doppler measurements only, but without angular information, for air surveillance. Targets are positioned by trilateration. The idea was contrived originally in 1992 as a technique in which VHF frequencies could be combined with reasonably small antennas for air surveillance radar. The motivation for VHF was the need to counter stealth and detecting concealed targets.

The main challenge in developing the idea is to find robust ways of associating detections at different stations to one and the same target. The use of correlations of higher order time derivatives of radar range for a target between different stations was the originally suggested method. Several improved suggestions came into light. In 1998 the association problem was attacked in an entirely different fashion leading to a different system concept, provisionally called AASR-II. Experimentation was initiated in 1998 to obtain true radar data for verification of the AASR-II concept. Experimentation has continued throughout 1999 and 2000.

With AASR-II important advantages of the trilateration technique for high performance radar were recognized. The suggested frequency was UHF. The main drawback of AASR-II was the necessity to have several stations in a cluster at each site. Further development revealed the possibility of having just a single station at each facility, while keeping the high performance of AASR-II. Significant efforts to develop this new concept have been spent during the year and a patent process for this new concept is now initiated.

Furthermore, a study has been initiated during 2000 for UHF aerostat radar. The concept exploits the large volume available inside an aerostat to occupy a large lightweight UHF array antenna.

CARABAS-II operations

The airborne VHF SAR system CARABAS-II has been operated extensively during the year. A number of field campaigns for both military and civilian customers have been carried out, requiring more than 50 hours of flying time in total. The largest effort was the participation in the military exercise ”Focus 2000”, held within and in the vicinity of the test range Vidsel in northern Sweden. The CARABAS-II sensor suite was not a full partner of the exercise but was used on a test basis in the events focusing on international peace support operations. Sweden has offered to have a reconnaissance squadron of up to 10 aircraft able to deploy overseas within 30 days. The objective of including a VHF SAR in the training program was to investigate how this new sensor type can be integrated with fielded reconnaissance systems to improve the overall capability. The concept of operations is to use the VHF SAR to screen large areas and detect potential targets with a high probability based on the proven change detection approach. The sorties for the squadron units are then to verify and identify the detected candidates by means of aerial photography, a task limited to small areas pinpointed by the radar. CARABAS-II covered the full area twice each day and in between and during the nights various surface-to-air defence units relocated on the ground, violating the regulations in a stated treaty. A crucial part in the preparations was the development of a streamlined processing chain, including the implementation of a new fast SAR algorithm as well as software for geocoding and change detection applied on the time series of generated radar images.

CARABAS-II has also been tested against an upgraded jammer device with some new jamming principles available. Radar signatures of a number of different army vehicles have been collected, including fielded units, prototypes under development and various decoy targets. With economical support from a timber company an area of about 600 km^2 has been imaged to investigate the performance of stem volume retrieval over forested terrain exhibiting a variability of the topographic conditions.

SAR image formation algorithms

SAR image formation involves processing (inversion) of pulse echo data to form high-resolution radar images of ground objects. When the radar pulse echoes are collected along a linear aperture, the exact inversion problem may be solved in the frequency domain using fast transform techniques. Alternatively, the inversion may also be solved in the time domain by so-called back-projection integration. The main advantage of back-projection compared to frequency-domain methods is that the former can handle any aperture geometry and is therefore the preferred choice when the flight track deviates from being linear. However, a significant drawback with earlier back-projection algorithms has been the heavy computational burden. For example, an image with $N \times N$ pixels and an aperture with N positions requires about N^3 number of operations.

We have shown that the back-projection integral can be partitioned (factorized) using a recursive method. Each recursion stage then consists of integrating along sub-apertures of increasing length and forming images with successively finer spatial resolution. The algorithm represents the images in local polar co-ordinates which drastically reduces the number of necessary operations. A full resolution image in a Cartesian grid is formed during the final processing stage. The total number of operations for the factorized back-projection algorithm is $nN^2 \log_n N$ where n is an integer which amounts to the degree of factorization. Hence, the factorized back-projection has a computation effort similar to frequency-domain algorithms when n is small. In this manner, we have achieved a significant breakthrough in SAR processing. The algorithm has the advantages of time-domain methods, i.e. accurate wide-beam compensation for non-linear apertures and small computer memory requirement, while at the same time a small computational effort in parity with frequency domain methods.

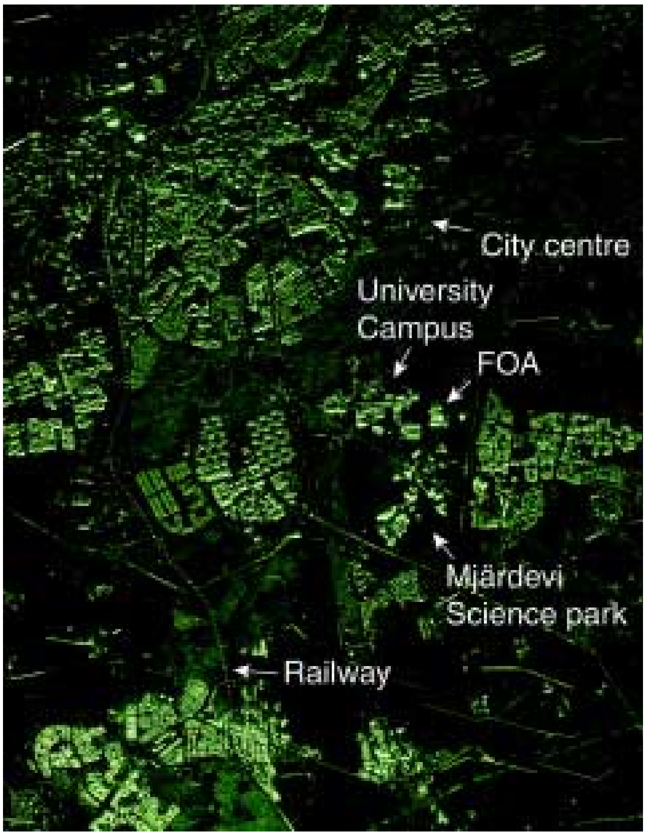


Figure 18. Image over Linköping processed with the factorized back-projection algorithm.

The factorized back-projection has been implemented and verified in the operational CARABAS SAR processor. Practical experiments on Sun Ultra-30 workstations show that the computation time for SAR image formation is reduced by more than two orders of magnitude. Several days of processing time now takes a fraction of an hour. The algorithm will also be important for microwave SAR in the future when wider beamwidths are used to increase spatial resolution in strip-map mode. An example of an image over Linköping is shown in figure 18 which has been processed with the factorized back-projection algorithm.

The LORA system

LORA is a generic multimode radar operating from 200 to 800 MHz in the UHF-band. The system is designed for a wide range of applications and experiments, both airborne and on the ground. The prime usage will be high resolution SAR and GMTI (Ground Moving Target Indication). The system design is based on the successful CARABAS program.

One of the applications for the LORA system is to detect moving ground targets. This requires that the antenna system contains a number of antenna elements in the line of flight in order to suppress the background terrain clutter. In principle, consecutive images with a small time gap can be made during the flight and succesively subtracted from each other. The stationary background will then be cancelled out while signals from moving objects will remain. Signal processing techniques for GMTI are being developed and the hardware system has been specified and designed. During the year several subsystems have been manufactured and delivered from subcontractors. System integration and testing are in progress at FOI.

Figure 19. The Data Control Unit (DCU) of the LORA system

The RF, digital control, and data collection systems (figure 19) have been built very flexible to meet all possible needs in the upcoming testing. The data flow in the system is completely data driven, allowing new features to be incorporated at a later stage of development.

The LORA array antenna system, consisting of two transmitting and three receiving elements, is contained in two push booms. One of them operates over 200–400 MHz and the other over 400–800 MHz. The electrical design of the antennas has been finalized and the mechanical design is in its final stage. A number of antenna elements have been built and measurements have validated the simulated performances. Flight testing will commence the year 2001.

Microwave multifunction radar

Many future radar systems for various applications will be designed as multifunction radars with array antennas and powerful signal and data processing. Several simultaneous functions for target search, track and recognition will be possible. Adaptive and flexible control of for example beam steering and energy utilization give optimized performance with increased jamming and clutter resistance and robustness. Signal and data processing for active digital array antennas combined with advanced waveforms and measurement geometries offer new possibilities for suppression of jamming and clutter. Also increased range and accuracy of the radar system is obtained. Wideband coherent waveforms, advanced signal processing and accurate electromagnetic target models give possibilities for automatic target recognition of different targets.

Multifunction radar design and ideas of improved radar system concepts have been investigated for command and control systems and weapon platforms. Increased modularity, flexible control, decreased vulnerability and increased jamming resistance allow new concepts for command and control systems and weapon platforms with limited space and shared apertures with other command and control and electronic warfare systems. The threat environment and requirements on cost-effectiveness make multifunction radar more important for future army, navy and air force radar applications.

Digital array antenna

The experimental digital active array antenna has been used for radar measurements and scattered jamming measurements. The receiving antenna consists of a twelve element linear array at S-band with individual receiver modules with down-conversion and 12-bit analogue to digital converters with buffer memories. The receiver signal bandwidth is 5 MHz and one Mword of twelve-channel data can be recorded at 25.8 MHz sampling frequency. The measurements were performed both in an anechoic chamber and outside from a roof-top site overlooking nearby terrain. Accurate calibration of the frequency and direction dependencies for the antenna channels is important. A thorough overall system calibration procedure is carried out in the anechoic chamber and it is to some extent updated at the time of each new measurement using an internal calibration network.

Scattered jamming measurements

Terrain scattered jamming is a problem for many airborne radar systems. Jammer signals entering into the receiver antenna sidelobes can be suppressed by adaptive sidelobe cancellation methods. However, jamming signals can also enter via terrain scattering into the antenna mainbeam and these signals are not easily suppressed without also suppressing the target signals as shown in figure 20. Terrain scattered jamming has been simulated in anechoic chamber measurements by a rough surface reflector. These short range measurements were performed to characterize the rough surface scattering environment as shown in figure 21. Terrain scattered jamming in the mainbeam is more evident for low sidelobe antennas with a high suppression of direct path jamming signals.

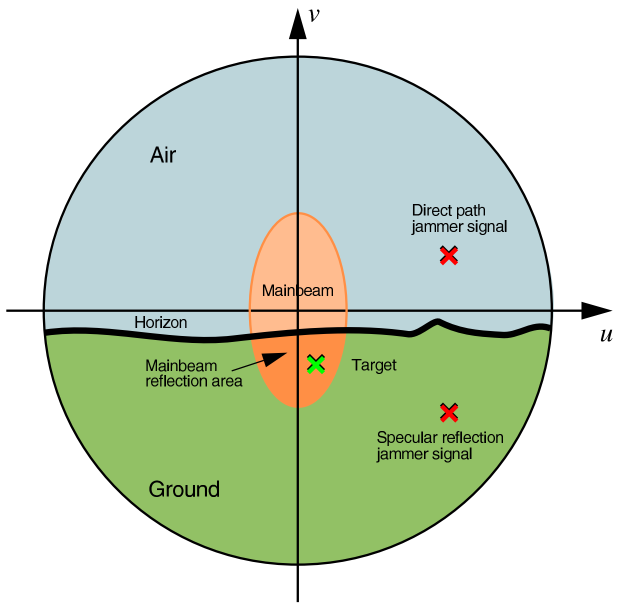


Figure 20. Terrain scattered jamming scenario into uv-coordinates (sinθ space). The jamming signal enters the radar antenna sidelobes through the direct path and into radar antenna mainbeam and sidelobes via terrain scattering. The target signal has to compete with the terrain scattered jamming signals from approximately the same direction in the mainbeam.

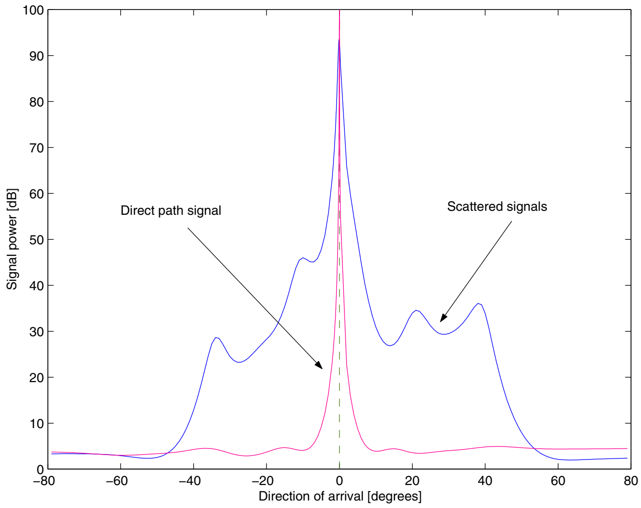


Figure 21. Rough surface scattering in an anechoic chamber. The received signals are analyzed by the Capon directional spectrum to characterize the scattering surface. The scattered signals (blue) are about 60 dB lower than the direct path signal. This can be compared with the Capon spectrum without the rough surface reflector (red).

Department of Radar Sensors

Mr. Johan Söderström
Head of the Department of Radar Sensors

The Department of Radar Sensors has about 30 employees, most of whom have master degrees in electronics, physics or information technology. Higher academic degrees are held by seven. The department conducts applied research in the following main areas:

- Missile seekers
- Land mine detection
- Radar signatures

Within these research areas a great number of unique experimental equipment and facilities have been developed:

- Imaging mm-wave radar and an IR-camera as a multisensor seeker.
- Mobile coherent radar measurement system (8-18 GHz)
- Airborne experimental system for anti-radiation missile seeker evaluation (2-18 GHz).
- Man-carried mine detector (radar, radar and metal-detector).
- Outdoor testrange for ISAR and mono-/bistatic radar measurements (1-110 GHz).

Missile seekers

Within this area we study and evaluate different problems in the duel between the seeker and the targets including the ECM aspects.

For ground targets the problem is to accurately identify and classify the targets and to handle ECM. The solution under study is to utilise dual sensors and an advanced signal processing technique including datafusion. The sensors must have high resolution, and we use IR and imaging mm-wave systems in our research projects. For sea targets there is less demand on resolution and we evaluate IR and K_u-band radar for this application in another project. In our view the multisensor seeker will be the future solution to the problem to obtain sufficient robustness and to be able to handle the threat environment.

One of the used methods for studies in duels between radar seekers and different kinds of electronic attack (EA), is to measure and record target and decoy signatures, and use the extracted data in computer simulators, running many variable combinations to get a statistically reliable result. The main research area is to develop accurate measurement systems and advanced methods for analysing the data. As a spin-off, accurate and relevant data could be gathered from advanced jammers in development and in production phase. During this year a couple of such evaluations have been made.

In the field of ARM-missiles many measurements and evaluations have been carried out. Data from the helicopter borne measurement system could also be used for other purposes such as ESM predictions and jamming power attenuation/reflection studies.

Experience from measurements on real platforms in real situations is a valuable human investment. Several scientists benefit from this by participating in different military studies as experts.

Land mine detection

Presently, the most important tool for mine detection is the metal detector. With its help a vast majority of presently existing mines may be detected. Modern metal detectors are sensitive enough to detect even a small amount of metal, but the high sensitivity also gives drastically increased sensitivity for all other metal objects in the ground. This results in a large amount of false alarms, all of which must be treated with the same amount of caution and carefulness. It's in the light of this that FOA since 1991 has done research in the field of mine detection using ground penetrating radar, and presently FOA has a leading position within the field of radar signal processing. The radar detects mines by recognizing dielectric properties different from those of the surrounding soil. These differences produce a reflection of radar energy from the mine, which reveals its position and depth. Together, the form and material of the mine give it unique properties, a fingerprint for the radar, and a possibility of identifying an anti-personnel mine or an anti-tank mine, but above all the possibility of making a discrimination between a mine and a false alarm. During the last year robust algorithms for classification of anti-tank mines in real time have been developed. The results are promising. The method may be used for a system carried by a person as well as for one carried by a vehicle.

The merge of the metal detector and the ground penetrating radar into a multi-sensor system, is made to combine the best properties of each sensor. Information from both sensors brings increased confidence in mine detection, an ability to discriminate from false alarms, and in the long run a considerably higher speed and an increased safety for the operator.

The research has been reported as papers. There is co-operation primarily with STE and DTU in Denmark.

Radar signatures

The main research effort within the area of radar signatures is to develop models and methods for evaluation of target and background signatures, on the basis of theoretical and experimental results. This gives conditions to achieve good signature management.

Columbus, an in-house development, is a software tool for analysis of radar cross section of ISAR-data, which has been further improved during the year. The 'millennium' edition, contains a new module for statistical analysis. Great effort has been put into optimising the algorithms, and the program now runs 2-5 times faster than before.

In order to simplify for users of Columbus, a new data converter has been developed. The software converts data from four Swedish RCS measurement facilities to Columbus format.

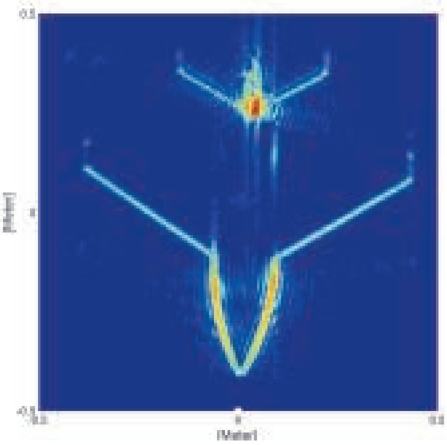


Figure 22. ISAR-image of an aircraft model.

Polarimetric, 6-16 GHz, ISAR-measurements have been carried out of a handful of objects in FOA's anechoic chamber "Stora Mäthallen" (see Figure 22). The results have been analysed and compared with theoretical data.

An RCS optimisation of an UAV has been performed. The modifications of the original shape have resulted in a substantial RCS reduction.

We have also developed a program for calculation of radar cross section based on physical optics and where the shape of an object is described by NURBS-surfaces.

A study of plasma as a radar wave absorber has been carried out in collaboration with CTH. It turned out that plasma under certain conditions could substantially reduce the radar cross section. A deeper study is desirable.

In Focus: Modern radar and ground targets

The ability to map terrain and to identify ground targets in real time with radar is gaining importance in applications like UAV-systems (Unmanned Arial Vehicles) and missile seekers. Earlier it has not been possible to use conventional radar in these applications due to the low contrast between targets and background. The advances in technology have made it possible to introduce coherent radar techniques in these applications. The cost for the necessary radar and computer components has decreased and their performance has made it possible to implement the algorithms in real time systems.

There are mainly two different approaches for increasing the target to background contrast. One is to increase the radar spatial resolution and the other is to process the doppler generated by moving objects . The mostly used methods are SAR (Synthetic Aperture Radar), spotlight-SAR, high resolution range profiling, GMTI (Ground Moving Target Indication) or doppler filtering.

The department of radar sensors operates a number of different systems that can be used for experiments with these methods, except SAR.

During the past year we have used the ARKEN-system to perform measurements of ground vehicles in terrain. ARKEN is a mobile coherent radar system with high range resolution and doppler capability.

Conventional radar

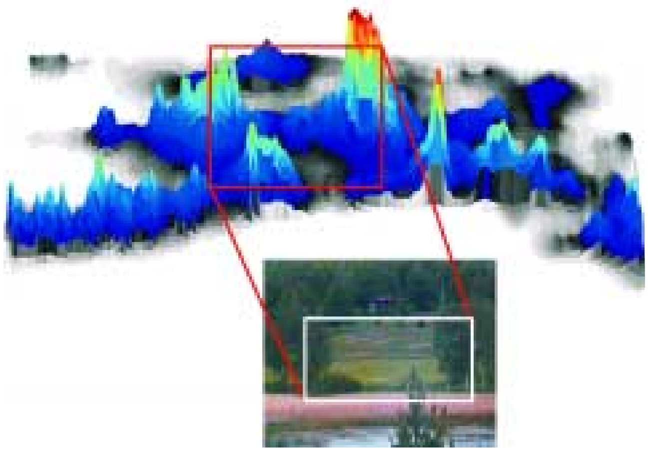


Figure 23. Radar scan over the terrain which is partially shown in the video image at the bottom. The lines indicate corresponding sections in radar and video.

Figure 23 shows a 3D representation of the radar signal from a conventional radar scan over the terrain. The peaks at the edges of the red rectangle, indicate strong radar returns from the trees and boulders that can be seen in the video image.

Conventional radar systems are limited in resolution by the length and width of the transmitted radar pulse. Hence the resolution in Figure 23 is fairly low, but this limitation can be overcome by using advanced signal processing, as is described below.

High resolution range profiling

One way to increase the range resolution is to collect radar returns at a number of different frequencies and then use the inverse Fourier transform to calculate a range profile. By using this technique a resolution better than the pulse length can be achieved.

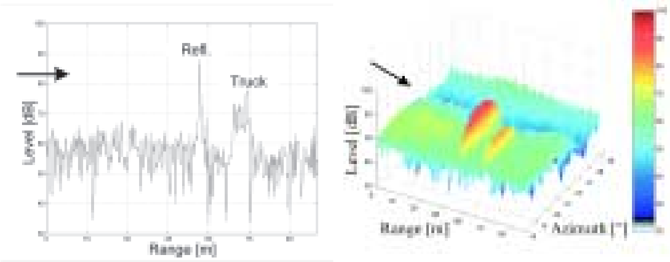


Figure 24. High range resolution, achieved by stepped frequency measurement. Left: Single direction range profile. Right: Scanned range profile. The arrows indicate viewing direction of the radar.

The images in Figure 24, show a truck and a radar reflector in the centre of the field indicated by the rectangles in Figure 1. The objects are one third of a pulse length apart (10 m).

In the single direction profile, the truck and the reflector are well separated. The range resolution is approximately 0.3 m, so the truck is also partially resolved in range.

The right image in Figure 24 shows the same objects with the radar scanned in small angular increments. The lobe width of the antenna, gives a low angular resolution. The angular profiles of the objects cover one antenna beamwidth.

High angular resolution

By moving the radar and looking at the objects from different locations, while keeping track of the phase of the radar signal, the lobe width can be reduced using SAR and spotlight-SAR-processing. By doing this, a more precise location of the objects can be obtained and the ground clutter reduced.

Doppler processing

By using doppler a moving target can be separated from the background, even if the target itself has a very weak return. In Figure 25 the band in the middle of the doppler spectra is the ground clutter. The signal from the vehicle is the broadened spectra, starting from the lower right and moving up and to the left.

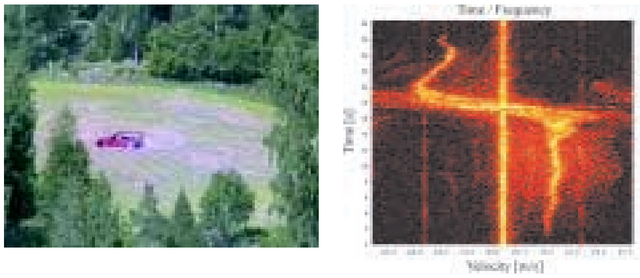


Figure 25. A Volvo making a U-turn in a field (not the same field as shown in Figure 23 and Figure 24). The image at right shows the doppler spectra as a function of time (time is increasing upwards).

The doppler is positive (right half of spectra in Figure 25) when the vehicle is moving towards the radar and negative when moving away from it. As the driver is turning, the back end of the car is skidding. This results in the peak in the doppler signal just before the car is moving perpendicularly to the radar and crosses the zero doppler line.

The weaker parts of the target spectra (red) are caused by vibrations and moving parts in the vehicle. These properties can be characteristic for particular objects and can therefore be used for target identification.

Knowledge and experience gained from the performed measurements will be used in development and performance evaluation of future systems.

FOI Division of Sensor Technology

Publications 2000

Journal articles:

S. Abrahamson, A. Ericsson, A. Gustafsson, H.C. Strifors, G.C. Gaunaurd, "Comparison of Fuzzy-Cluster Based Time-Frequency Signatures for Automatic Classification of Underground Mine-Like Targets," *Automatic Target Recognition IX - Proc. SPIE,* F A Sadjadi, ed., vol. 3718, pp. 128-139, 1999.

M. Brogren, G L. Harding, R. Karmhag, C-G. Ribbing, G A. Niklasson, L. Stenmark, "Titanium-aluminium-nitride coatings for satellite temperature control," *Thin Solid Films 370*, pp 268-277, 2000.

H. Brunzell, J. Eriksson, "Feature Reduction for Classification of Multidimensional Data," *Pattern Recognition*, no. 33, pp. 1741-1748, 2000.

I.A. Buyanova, T. Hallberg, L.I. Murin, V.P. Markevich, "Effect of High-Temperature Electron Irradiation on the Formation of Radiative Defects in Silicon," *Physica B: condensed Matter*, 273-274, (1-4), pp. 528-531.

A. Eriksson, C. Lopes, M. Lindgren, S. Svensson, T. Mckay, J. Davy, "Modeling and Characterisation of Nonlinear Materials for Optical Limiting. Mononuclear and Binuclear Platinum Ethynyls," *Nonlinear Optics*, vol. 25, pp. 297-302, 2000.

J. Fransson, F. Walter, L. Ulander, "Estimation of Forest Parameters Using CARABAS-II VHF SAR Data, *" IEEE Trans. Geosci. and Remote Sensing*, vol. 38, no. 2, pp. 720-727, Mar. 2000.

G.C. Gaunaurd, H.C.Strifors, "Applications of Time-Frequency Signature Analysis to Target Identification," *Wavelet Applications VI - Proc. SPIE, H H Szu, ed.*, vol. 3723, pp. 78-90, 1999.

G.C. Gaunaurd, H.C. Strifors, "Further Applications of Time-Frequency Methods in Acoustics," *J. Acoust. Soc. Am.*, vol. 106, no. 4, pt. 2, p. 2184, Oct 1999.

G. Hansson, "Solid State Multiple-Beam Laser with Tunable Wavelength Difference Between Beams," *Opt. Eng.* 39 (10), pp. 2700, Oct. 2000.

G. Hansson, H. Karlsson, S. Wang, F. Laurell, "Transmission Measurements in KTP and Isomorphic Compounds," *Applied Optics,* vol. 39, no. 27, pp. 5058-5069 2000.

G. Hansson, D.D. Smith, "Optical Parametric Generation in 2 um Wavelength Pumped Periodically Poles LiNbO3," *Optics Letters*, vol. 25, no. 24, Dec. 15, 2000.

H. Israelsson, L. Ulander, T. Martin, J. Askne,. "A Coherent Scattering Model to Determine Forest Backscattering in the VHF-Band," *IEEE Trans. Geosci. and Remote Sensing*, vol. 38, no. 1, pp. 238-248, Jan. 2000.

R. Jonsson, Q. Wahab, S. Rudner, "Physical Simulations on the Operation of 4H-SiC Microwave Power Transistors," *Materials Science Forum*, vol. 338-342, pp. 1263-1266, 2000.

P. Kadhoda, C. Amra, J. M. Bennett, C. Deumie, A. Duparré, S. Gliech, C. Jolie, H. Kessler, H. Lauth, T. Lindström, A. Müller, N. Reng, C-G. Ribbing, D. Ristau, R. Schuhmann, U. Schuhmann, M. Tilsch, " International Round-Robin Experiment on Optical Total Scattering at 633 nm According to ISO/DIS 13696," *Proceedings of the Conference on Optical Fabrication and Testing SPIE* vol.3739, pp. 548-556, 1999.

P. Kadhoda, A. Müller, D. Ristau, A. Duparré, S. Gliech, H. Lauth, U. Schuhmann, N. Reng, M. Tilsch, R. Schuhmann, C. Amra, C. Deumie, C. Jolie, H. Kessler, T. Lindström, C-G. Ribbing, J M. Bennett, "International Round-robin Experiment to Test the International Organization for Standardization Total-scattering Draft Standard, *Applied Optics,* vol. 39, pp. 3321-3332, 2000.

J. Karlholm, "Generalizations of the Maximum Average Correlation Height Filter," *J. of the Optical Society of America A.*, vol. 17, no. 8, pp. 1399-1406, 2000.

A. Karlsson, N. Karlsson, P. Wide, "A Dynamic Safety System Based on Sensor Fusion," *J. of Intelligent Manufacturing*, no. 11, pp. 475-483, 2000.

C. Karlsson, F. Olsson, D. Letalick, M. Harris, "All-Fiber Multifunction Continuous-Wave Coherent Laser Radar at 1.55 mm for Range, Speed, Vibration and Wind Measurements," *Applied Optics*, vol. 39, no. 21, pp. 3716-3726, 2000.

N. Karlsson, "A Study of a High-Resolution Linear Circuit for Capacitive Sensors," *IEEE Trans. on Instrumentation and Measurement.*, vol. 48, no. 6, pp. 1122-1124, 2000.

R. Karmhag, C-G. Ribbing, "TiN-alloy Coatings for Temperature Control of Space Vessels," *Applied Optics*, vol. 38, pp. 674-678, 1999.

M. Lindgren, J. A. Hermann, T. Bubner, T. J. McKay, P. J. Wilson, J. Staromlynska, A. Eriksson, S. Svensson, "Optical Limiting Capability of Thick Nonlinear Absorbers," *J. of Nonlinear Optical Physics* & *Materials,* vol. 8(2), pp. 179-195, 1999.

M. Lindgren, R. Owenius, M. Österlund, M. Svensson, O. H. Olsen, E. Persson, P-O. Freskgård, U. Carlsson, "Properties of Spin- and Fluorescent Labels at a Receptor-Ligand Interface," *Biophysical Journal,* vol. 77, pp. 2237-2250, 1999.

K. Madsén, D. Anderson, A. Kim, M. Lisak, "Self-Induced Erosion and Spectral Breaking of High-Power Microwave Pulses." *J. of Plasma Physics*, vol. 63, part 4, pp. 329-341, 2000.

T. Martin, L. Pettersson, "Dispersion Compensation for Huygens' Sources and Far-Zone Transformation in FDTD," *IEEE Trans. Antennas and Propag*, vol. 48, no. 4, pp. 494-501, Apr. 2000.

A. Ouacha, M. Mamor, H. Ouacha, M. Willander, F.D. Auret, S.A. Goodman, E. Sveinbjörnsson, "High-Energy He-ion Irradiation-Induced Defects and their Influence on the Noise Behaviour of Pd/nSi1-xGex Schottky Junctions," *Appl. Phys. Lett.* vol. 76 (25), p. 3750, 2000.

A. Ouacha, H. Ouacha, M. Mamor, M. Willander, F.D. Auret, "The Impact of Plasma Etching on the Noise Performance of Ti/p-Si and Ti/p-SI1-XGex Schottky Contact," *J. Appl. Phys.* vol. 87 (8), p. 3858, 2000.

G. Smith, L. Ulander, "A Model Relating VHF-Band Backscatter to Stem Volume of Coniferous Boreal Forest," *IEEE Trans. Geosci. and Remote Sensing*, vol. 38, no. 2, pp. 728-740, Mar. 2000.

O. Steinvall, "Effects of Target Shape and Reflection on Laser Radar Cross Sections," *Applied Optics*, vol. 39, no. 24, Aug. 2000.

H.C. Strifors, S. Friedmann, S. Abrahamson, G.C. Gaunaurd, "Comparison of the Relative Merits for Target Recognition by Ultra-Wideband Radar Based on Emitted Impulse or Step-Frequency Wave," *Automatic Target Recognition X - Proc. SPIE, F A Sadjadi*, ed., vol. 4050, pp. 2-11, 2000.

Contribution to conferences:

S. Abrahamson, A. Ericsson, A. Gustafsson, H.C. Strifors, G.C. Gaunaurd, "Comparison of Fuzzy-Cluster Based Time-Frequency Signatures for Automatic Classification of Underground Mine-like Targets," *SPIE's 14th Annual International Symposium on Aerospace/Defense Sensing, Simulation and Controls, Automatic Target Recognition IX*, 5-9 Apr. 1999.

M. Alfredson, A. Gustafsson, A. Ouacha, "Design Considerations for an Image Rejection Mixer in a Broadband Digital Beamforming Phased Array System," *Proc. of GigaHertz 2000 Symposium*, Göteborg, 13-14 Mar. 2000, pp. 153-156.

M. Alfredson, A. Gustafsson, A. Ouacha, "Design Considerations for an Image Rejection Mixer in a Broadband Digital Beamforming Antenna Array System," *Proc. of Asia Pacific Microwave Conference*, Sydney, Australia, 3-6 Dec. 2000, pp. 245-248.

S. R. J. Axelsson, "Synthetic Generation of SAR Raw Data for Complex Scene, " *EUSAR 2000 Proc. of the European Conference on Synthetic Aperture Radar*, Münich, 23-25 May 2000, pp. 479-482.

H-O. Berlin, J. Rahm, C. Larsson, "Columbus - An ISAR navigator," *AMTA Antenna Measurement Techniques Association*, Philadelphia, USA, Oct. 16-20 2000, pp. 75-80.

M. Björkqvist, P.-O. Olsson, H.C. Strifors, L.-Ö. Olsson, N. Gustavsson, J.-O.Ousbäck, "The Electromagnetic Wave Absorbing Properties of a Single Layer of Ferrite-Rubber Composite on a Simple-Shaped Conducting Surface," *Proc. 9th Cimtech-World Ceramics Congress, Ceramics: Getting into the 2000's - Part E, P Vincenzini, Ed.* Florence, Italy, June 1998, Faenza: Techna Srl, 1999, pp. 413-417.

S. Björklund, P. Grahn, A. Nelander, "Analysis of Array Antenna Measurements with a Rough Surface Reflector," *Thirty-fourth Asilomar Conference on Signals, Systems and Computers IEEE*, Pacific Grove, CA, USA, 29 Oct. – 1 Nov. 2000, pp. 1135-1139.

S. Björklund, A. Heydarkhan, "High Resolution Direction of Arrival Estimation Methods Applied to Measurements from a Digital Array Antenna," *SAM 2000 Workshop, First IEEE Sensor Array and Multichannel Signal Processing Workshop*, Cambridge, MA, USA, 16-17 Mar. 2000, pp. 464-468.

S. Björklund, J. Rantakokko, "An Interactive Software Demonstrator of Radar Array Processing," *NORSIG 2000, IEEE Nordic Signal Processing Symposium*, Norrköping, Sweden, 13-15 June 2000, pp. 61-64.

M. Brogren, G L. Harding, R. Karmhag, C-G. Ribbing, G A. Niklasson, L. Stenmark, "TixAlyN Coatings for Temperature Control of Spacecraft," *EUROPTO Proceedings Vol. 3738 Advances in Optical Interference Coatings, Ed C Amra, A Mac Leod,* Berlin, May 25-28, 1999, pp. 493-501.

M. Bäckström, G.J. Freyer, "Comparison of Anechoic & Reverberation Chamber Coupling Data as a Function of Directivity Pattern," *Proc. of IEEE2000 Int. Symp. on EMC*, Washington, USA, 21-25 Aug. 2000, pp. 615-620.

M. Bäckström, G.J. Freyer, "Some Implications of a Single Aspect Angle Electromagnetic Compatibility Test," *Proc. of 19th Digital Avionics Systems Conference*, Philadelphia, USA, 7-13 Oct. 2000, pp. 3.B.1-1—1-7.

M. Bäckström, L. Jansson, T.S. Seow, P.C. Yeo, "Microwave Testing of a Computer: A Representative Example of the Susceptibility of Commercial System," *Proc. of EUROEM2000*, Edinburgh, Scotland, 30 May - 2 June 2000, p. 14.

M. Bäckström, O. Lundén, M. Höijer, A.M. Andersson, "Numerical Simulations as a Tool for Optimizing the Geometrical Design of Reverberation Chambers," *Proc. of IEEE2000 Int. Symp. on EMC*, Washington, USA, 21-25 Aug. 2000, pp. 1-6.

M. Bäckström, O. Lundén, M. Höijer, A-M. Andersson, "Three-Dimensional Finite Difference Time Domain Analysis of Reverberation Chambers," *Proc. of 4th European Symposium on Electromagnetic Compatibility*, Brugge, Belgium, 11-15 Sep. 2000, pp. 263-268.

G. Carlsson, "Uncooled IR Array Readout Electronics", *Microelectronics 2000,* Stockholm, Sweden, 13-14 Nov. 2000.

C. Desroches, S. Parola, P. Miele, J. Bonix, A. Eriksson, C. Lopes, M. Lindgren, S. Svensson, V. Vocarson, R. Lemartine, "New Thiacalixavenes and Related Metal Complexes for Optical Limiting," *ISOPL 2000, International Symposium on Optical Power Limiting,* Venice, Italy, 2-5 July 2000.

J. Ericsson, N. Rorsman, H. Zirath, R. Jonsson, Q. Wahab, S. Rudner, "A Comparison Between Physical Simulations and Experimental Results in 4H-SiC MESFETs with Non-constant Doping in the Channel and Buffer Layers," *Proc. of The Third European Conference on Silicon Carbide and Related Materials*, Kloster Banz, Germany, 3-7 Sep. 2000, pp. 699-702.

J. Fransson, A. Gustavsson, L. Ulander, F. Walter, "Mapping of Forest Stand Parameters Using VHF SAR Data," *EUSAR 2000, 3rd European Conference on Synthetic Aperture Radar,* Munich, Germany, 23-25 May 2000, pp. 157-160.

J. Fransson, A. Gustavsson, L. Ulander, F. Walter, "Towards an operational use of VHF SAR data for forest mapping and forest management, *IGARSS 2000, IEEE 2000 International Geoscience and Remote Sensing Symposium*, Hawaii, USA, 24-28 July 2000, pp. 399-401.

H. Frennberg, R. Erickson, J. Lorén, M. Alfredson, "Design and Platform Integration of an Airborne Wideband Low Frequency SAR Antenna," *Proc. of AP 2000*, Davos, Switzerland, 9-14 Apr. 2000, p. 189.

P.-O. Frölind, A. Gustavsson, L. Ulander, "Verification of Ultra-Wideband VHF-SAR Data DEM," *IGARSS 2000, IEEE 2000 International Geoscience and Remote Sensing Symposium*, Hawaii, USA, 24-28 July 2000, pp. 3196-3198.

P.-O. Frölind, L. Ulander, A. Gustavsson, "Repeat-pass VHF interferometry over forest covered terrain," *EUSAR 2000, 3rd European Conference on Synthetic Aperture Radar*, Munich, Germany, 23-25 May 2000, pp. 119-122.

G.C. Gaunaurd, H.C. Strifors, "Applications of Time-Frequency Signature Analysis to Target Identification," *SPIE's 14th Annual International Symposium on Aerospace/Defense Sensing, Simulation and Controls, Wavelet Applications VI*, Orlando, Florida, 5-9 Apr. 1999.

P. Grahn, S. Björklund, "Short Range Radar Measurements with an Experimental Digital Array Antenna," *RADAR 2000, IEEE International Radar Conference*, Alexandria, VA, USA, 7-12 May 2000, pp. 178-182.

A. Gustafsson, M. Alfredson, M. Danestig, R. Malmqvist, A. Ouacha, "A Fully Integrated Radar Receiver Front End Including an Active Tunable Band Pass Filter and an Image Rejection Mixer," *Proc. of Asia Pacific Microwave Conference*, Sydney, Australia, 3-6 Dec. 2000, pp. 99-102.

L-G. Huss, M. Alfredson, A. Ouacha, S. Hagelin, "Electronically Steered X-band Smart Skin Antenna," *Proc. of AP 2000*, Davos, Schweiz, 9-14 Apr. 2000, p. 442.

R. Jonsson, Q. Wahab, S. Rudner, "Physical Simulations of Wide Bandgap Semiconductor Microwave Power Transistors," *Proc. of GigaHertz 2000 Symposium*, Göteborg, 13-14 Mar. 2000, pp. 387-390.

E. Jungert, C. Jönsson, P. Klöör, S. Zyra, "Decision Making and Data Fusion in an Interactive Adaptive UGS Network," *Command and Control Research and Technology Symposium.*, Cambera, Australia, 24-26 Oct. 2000.

J. Karlholm, "Composite Filter Design for Minimal Correlation Peak Shape Variation in Cluttered Images," *Optical Pattern Recognition XI, SPIE 4043*, Orlando, Florida, 24-28 Apr. 2000.

B. Karlsen, J. Larsen, K.B. Jakobsen, H. Sörensen (all 4 from Technical University of Denmark), S. Abrahamson, "Antenna Characteristics and Air-Ground Interface Deembedding Methods for Stepped-Frequency Ground Penetrating Radar Measurements," *Proc. of SPIE, AeroSense 2000*, Orlando, Florida, 24-28 Apr. 2000.

F. Kullander, "A Novel Algorithm for Passive Demodulation of Optical Fiber Interferometric Signals Using a 3x3 Coupler," *14th International Conference on Optical Fiber Sensors, of s2000 SPIE,* Venice, Italy, Oct. 2000, vol. 4185, pp. 480-483.

M. Lindgren, J. Örtegren, P. Busson, A. Eriksson, A. Hult, U. W. Gedde, G. Andersson, "Linear to Nonlinear Optical Characterization of FLC Dendrimers," *The 18th International Liquid Crystal Conference (ILCC 2000),* Sendai, Japan, 24-28 July, 2000.

M. Lindgren, C. Pitois, A. Hult, Å. Claesson, "Fluorinated Dendrimeric Complexes Functionalized with Light Amplification Lanthanide Cations," *The European Material Conference (EMRS 2000)*, Strasbourg, France, 30 May -2 June, 2000.

M. Lindgren C. Pitois, A. Hult, D. Wisman, Å. Claeson, "Functionalized Polymers for Photonic Applications," *International Conference for Organic Nonlinear Optics (ICONO5)*, Davos, Switzerland, 12-16 Mar., 2000.

M. Lindgren, R. Owenius, P. Hammarström, U. Carlsson, "Aggregation of molten globular human carbonic anhydrase II monitored by spin and fluorescent cysteine probes", *Rocky Mountain Conference,* Denver, USA, 30 July - 3 Aug., 2000.

M. Lindgren, S. Mahapatro, M. Woltkamp, C. Nguyen, S.S. Eaton, G.R. Eaton, "Paramagnetic phase relaxation due to surrounding methyls and magnetic nuclei in diluted spin spin systems", *Rocky Muntain Conference,* Denver, USA, 30July - 3 Aug, 2000.

M. Lindgren, C. Pitois, P. Busson, J. Örtegren, A. Hult, U. W. Gedde, "Functionalized Polymers for Photonic Applications" *ECME99 (European Conference on Molecular Electronics),* Linköping, 8-11 Sept, 1999.

M. Lindgren, J. Örtegren,P. Busson, A. Hult, U. W. Gedde, A. Eriksson, P. P. Arntzen, D. S. Hermann, P. Rudquist, S. T. Lagerwall, "Time-dependent nonlinear optical properties of pyroelectric liquid crystalline polymers." *Macromolecular Symposia,* 1999, vo1.48 pp. 179-195.

T. Lindström, R. Lööw, C-G. Ribbing, "Candidate materials for semi-transmitting DVD mirror coatings," *SPIE vol. 3779 Current Developments in Optical Design and Optical Engineering VIII,* Denver, 19-20 July, 1999, pp. 250-259.

O. Lundén, M. Bäckström, "Stirrer Efficiency in FOA Reverberation Chambers. Evaluation of Correlation Coefficients and Chi-Squared Tests," *IEEE2000 Int. Symp. on EMC*, Washington, USA, 21-25 Aug. 2000, pp. 11-16.

R. Malmqvist, M. Danestig, S. Rudner, C. Svensson, "Analysis of Narrow-band High Performance Recursive Active MMIC Filters for Future Adaptive On-ship Radar Receivers," *GigaHertz 2000 Symposium*, Göteborg, 13-14 Mar. 2000, pp. 137-140.

R. Malmqvist, A. Gustafsson, M. Danestig, A. Ouacha, S. Hagelin, S. Rudner, "Noise and Intermodulation Properties of Tunable Recursive Active MMIC Filters for Future Adaptive On-chip Radar Receivers," *Proc. of European Microwave Conference*, Paris, France, 2-6 Oct. 2000, vol. 1, pp. 1-4.

R. Malmqvist, A. Gustafsson, M. Danestig, A. Ouacha, S. Hagelin, S. Rudner, "Analysis of Tunable Narrow-band Recursive Active MMIC Filters for Future Adaptive On-chip Radar Receivers," *Proc. of Asia Pacific Microwave Conference*, Sydney, Australia, 3-6 Dec. 2000, pp. 1073-1076.

A. Nelander "Model-Based Adaptive Detection of Fluctuating Targets," *RADAR 2000, IEEE International Radar Conference,* Alexandria, VA, USA*,* 8-12 May 2000, pp. 381-386.

C. Nelsson, "Passive Detection of Ammonia with an Imaging FTIR Spectrometer", *The* 3^{rd} *International Workshop on BC-detection,* Stenungsund, Sweden, 24-27 Sep. 2000.

C. Nelsson, F. Lundberg, P. Nilsson, M. Lundberg, "ScanSpec: an Imaging FTIR Spectrometer Targets and Background", *VI: Characterization, Visualization, and Detection Process SPIE,* Orlando, USA, 24-26 Apr. 2000, vol. 4029, pp. 324-336.

S. Nyberg, K. Schutte, "Assessing camouflage methods using textural features", *NATO SCI-12 Workshop on Search and Target Acquisition*, Utrecht, The Netherlands, 21-23 June 1999.

F. Olsson, C. Karlsson, "1.55-um Multifunction Laser Radar Using Fibre Optic Components," *CLEO/Europe - IQEC 2000*, Nice, France, Oct. 2000.

F. Olsson, C. Karlsson, "Multifunction Laser Radar," *Northern Optics 2000,* Uppsala, Sweden, Sep. 2000.

A. Ouacha, H. Ouacha, M. Mamor, M. Willander, F.D. Auret, S.A. Goodman, "Two Abnormal Peaks Induced by Plasma Process in the Noise Spectra of Etched Si and Si_{1-Gex}." *5th International Symposium on Plasma Process-induced Damage*, Santa Clara, California, USA, 22-24 May 2000, pp. 101-104.

A. Ouacha, H. Ouacha, M. Willander, "Noise Properties in Some Si-based Diodes." *Proc. of GigaHertz 2000 Symposium*, Göteborg, 13-14 Mar. 2000, pp 375-378.

L. Pettersson, T. Boman, "Performance of Internal Calibrations of a Digital Beamforming Antenna." *Antenn 00, Nordic Antenna Symposium SNRV*, Lund, 12-14 Sep. 2000, pp. 237-242.

M. Pettersson, "Focusing of moving targets in an ultra-wide band SAR GMTI system," *EUSAR 2000, 3rd European Conference on Synthetic Aperture Radar*, Munich, Germany, 23-25 May 2000, pp. 837-840.

I. Renhorn, "Optical Missile Warning Systems and Countermeasures." *Electronic Defence* & *Weapon systems Technology Conference,* 4 Sep. 2000.

C-G. Ribbing, Ö. Staaf, "Ceramic surface polariton sensor, "*Proceedings SPIE vol. 4103, Optical Diagnostic Methods for Inorganic Materials II,* San Diego, 3-4 August, 2000, pp. 116-125.

C-G. Ribbing, "Getting the sunshine right, "*Proceedings SPIE vol.3789, Solar Optical Materials XVI,* Denver, 1999, pp. 84-90.

G. Scalia, D. S. Hermann, C. Pitois, F. De Marco, G. Abbate, M. Lindgren, A. Hult, "Novel Polymer/ Ferroelectric Liquid Crystal Waveguides," *The 18th International Liquid Cruystal Conference (ILCC 2000)*, Sendai, Japan, 24-28 July 2000.

G. Smith, L. Ulander, "Forest Stem Volume Measurement with VHF SAR on Sloping Terrain," *EUSAR 2000, 3rd European Conference on Synthetic Aperture Radar*, Munich, Germany, 23-25 May 2000, pp. 153-156.

G. Smith, L. Ulander, X. Luo, T. Martin, "VHF SAR Models and Measurements of Targets under Coniferous Forest Canopies," *IGARSS 2000, IEEE 2000 International Geoscience and Remote Sensing Symposium*, Hawaii, USA, 24-28 July 2000, pp. 990-992.

O. Steinvall, "3-D Imaging Laser Radars: Modelling and Experimental Results," *CLEO Europe 2000*, Nice, France, Sep. 2000.

O. Steinvall, "Laser Sensing at FOA," *Northern Optics 2000*, Uppsala, Sweden, June, 2000.

O. Steinvall, "Laser Countermeasure Capabilities," *The 3rd International Association of Old Crows (AOC) Electronic Warfare Conference*, Zurich, Switzerland, May 2000.

H.C. Strifors, A. Friedmann, S, Abrahamson, G.C. Gaunaurd, "Comparison of the Relative Merits for Target Recognition by Ultra-Wideband Radar Based on Emitted Impulse or Step-Frequency Wave." *SPIE's 15th Annual International Symposium on Aerospace/Defense Sensing, Simulation and Controls, Automatic Target Recognition X,* 24-28 Apr. 2000.

M. Tulldahl, M. Andersson, O. Steinvall , "Airborne Laser Depth Sounding: Improvements in Positions- and Depth Estimates by Local Corrections for Sea Surface Slope," *OCEANS 2000*, Providence, USA, Sep., 2000.

M. Tulldahl, M. Andersson, O. Steinvall, "Experimental results of small target detection in airborne laser depth sounding," *OCEAN OPTICS XV 2000*, Monaco, Oct. 2000.

L. Ulander, J. Askne, J. Fransson, A. Gustavsson, T. Le Toan, T. Manninen, J.-M. Martinez, P. Melon, G. Smith, F. Walter, "Retrieval of Stem Volume in Coniferous Forest from Low VHF-band SAR," *IGARSS 2000, IEEE 2000 International Geoscience and Remote Sensing Symposium*, Hawaii, USA, 24-28 July 2000, pp. 441-443.

L. Ulander, P.-O. Frölind, A. Gustavsson, H. Hellsten, M. Herberthson, T. Jonsson, B. Larsson, G. Stenström, "Trans-Ionospheric Distorsion in Satellite VHF-Band SAR Systems,*" IGARSS 2000, IEEE 2000 International Geoscience and Remote Sensing Symposium*, Hawaii, USA, 24-28 July 2000, pp. 1177-1179.

L. Ulander, H. Hellsten, G. Stenström, "Synthetic-aperture radar processing using fast factorised backprojection," *EUSAR 2000, 3rd European Conference on Synthetic Aperture Radar*, Munich, Germany, 23-25 May 2000, pp. 753-756.

L. Ulander, "Development of Wavelength-Resolution Synthetic Aperture Radar in the Metric Radio-Band: A New Tool for Remote Sensing," *EUROEM 2000, Euro Electromagnetics*, Edinburgh, Scotland, 30 May-2 June 2000, p. 126.

M. Uppsäll, L.M. Pettersson, M. Georgson, S. Sjökvist, "Temporal IR Contrast Variation of Buried Land Mines" *SPIE's 14th International symposium on Aerospace/Defense Sensing, Simulation and Controls.* Orlando, USA, 24-28 April, 2000, pp. 146-155.

Reports:

M. Ahlberg, U. Backlund, B. Eriksson, I. Fängmark, S. Hultberg, T. Lodehed, J. Norlin, C. Sahlin, A. Sundström, I. Söderquist, J. Thorpsten, R. Tryman
"Implementation of an Environmental Security System: Final Report."
(Text in Swedish. Abstract in English.)
FOA- R--00-01483-991--SE

S. Ahlberg
"Creation of High-Resolution Laser Radar based Digital Terrain Maps for Applied Sensor Simulation."
FOA-R--01207-408--SE

R. Bergman
"A Study of Some Spatial and Spatiotemporal Methods for Enhancement of Image Sequences."
(Text in Swedish. Abstract in English.)
FOA-R--00-01671-408--SE

H.-O. Berlin, J. Löthegård, A. Sume
"Determination of Surface Curvature with Radar Polarimetry. Study of Spheroids."
(Text in Swedish. Abstract in English.)
FOA-R--00-01602-408--SE

K. Bertilsson
"Simulation of Erbium-Ytterbium. Co-Doped Fiber Lasers."
FOA-R--00-01493-408--SE

S. Björklund, D. Axelsson
"Experimental Research Facilities at FOA for Finding Land Mines with Radar in 2000."
FOA-R--00-01810-310--SE

S. Björklund
"DBT release 2.14. A MATLAB Toolbox for Radar Array Processing. Extension Guide."
FOA-R--00-01592-408--SE

S. Björklund
"Estimation of the Number of Targets in a Radar Application Using an Array Antenna."
FOA-R--0-01805-408--SE

S. Björklund
"A MATLAB simulator for wideband radar and radio signals received by digital array antennas."
FOA-R--00-01809-408--SE.

S. Björklund
"Analysis of hot clutter in radar using spatial data."
FOA-R--00-01807-408--SE

S. Björklund, D. Rejdemyhr
"DBT Release 2.14 A MATLAB Toolbox for Radar Array Processing. Reference Guide."
FOA-R--99-01376-408--SE

S. Björklund, P. Grahn, A. Nelander, A. Alm
"Hot clutter reduction in radar. Measurement report for anechoic chamber measurements in Spring 2000."
FOA-R--00-01806-408--SE.

S. Björklund, A. Nelander, D. Rejdemyhr, P. Grahn
”Signal processing in directinal-of-arrival in multifunction radar.”
(Text in Swedish. Abstract in English.)
FOA-R--00-001808-408--SE.

T. Boman
“A circular Antenna Array with Vivaldi-element.”
FOA-R--00-01789-504--SE.

T. Boman, L. Pettersson
“Direction Finding Error due to Scattering from Wind Mills, Analysis and Computations.”
FOA-R--00-01522-616--SE.

M. Bäckström, S. Silfverskiöld, J. Lorén
“Microwave Field-to-Wire Coupling Measurements in Anechoic and Reverberation Chambers.”
FOA-R--00-01538-612--SE.

B. Carlegrim, R. Gunnarsson, L. Pettersson, R. Erickson
“Properties of a 2-6 GHz Tapered Slot Antenna Array.”
FOA-R--00-01742-616--SE.

C. Carlsson, L. Carlsson, P. Grahn, P. Hörling , E. Jungert, P. Klöör, F. Lantz, A. Lauberts, D. Letalick, A. Lindahl, J. Schubert, D. Strömberg , J. Svensson, C.-L. Westerlund
“Multisensor Technology and Data Fusion - Aspects on Sensor Selection, Data Administration and Development.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01577-408--SE

H. Eliasson, D. Evekull, H. Kariis
“Laser Protection Using Liquid Crystal Devices.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01537-612--SE

R. Erickson, T. Holmgren
“Antennas for Pulsed HPM-Sources. A Survey of the Literature.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01668-612--SE

J. Fagerström, S. Leijon, N. Gustafsson, T. Martin
“A Study of a Three-Dimensional Photonic Band-Gap Material in the Microwave Region.”
FOA-R--00-01566-408--SE

G. Forssell
“Model Calculations of Rough Surfaces - Adjusted to Reflection Measurements on Colour Samples.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01478-615--SE

G. Forssell, T. Hallberg
“Polarization Properties in the IR Region of Painted Surfaces and Rough Al Surfaces.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01646-615--SE

Å. Fällman, C. Nelsson, G. Olofsson, M. Strömqvist
“Passive Remote Detection of Toxic Chemicals and CWA: a Report on Trials, Calculations and Assessments.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01638-862--SE

T. Gundmark, W. Asp, C. Johansson, N. Karlsson, U. Oreborn, U. Rääf, M. Wilow
“Development of Signal Measurement Equipment.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01449-616--SE

T. Gustafsson
“Smart focal plane arrays.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01694-408--SE

T. Gustafsson, P. Carleberg
“The gaze-Direction-Sensor - a Key Component in a Smart Display System.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01486-706--SE

O. Gustavsson, L. Sjöqvist, S. Karlsson, O. Steinvall, J. Pettersson
“Study of explosively pumped lasers.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01695-310, 612--SE

E. Jungert, D. Letalick
“An information System for Target Recognition — Analysis of Needs and Problems.”
(Text in Swedish. Abstract in English.)
FOA-R--00-01607-408--SE

T. Kaijser
”The Primal-Dual Algorithm for the Assignment Problem.”
FOA-R--00-01496-408--SE

J. Karlholm, M. Ulvklo, J. Nygårds, M. Karlsson, S. Nyberg, M. Bengtsson, L. Klasén, A. Linderhed, M. Elmqvist
“The Target Detection and Tracking Chain: A Survey of Methods with Special Reference to EO/IR Sequences.”
FOA-R--00-01767-408,616--SE

M. Karlsson, A. Lauberts
"Usage of Datafusion for Classification of Ground Targets, a Preliminary Study."
(Text in Swedish. Abstract in English.)
FOA-R--00-01655-314--SE

M. Karlsson, A. Lauberts, D. Letalick, S. Nilsson, J. Nygårds
"Laser Radar/IR/millimetre-wave Radar in Seeker Application. A Preliminary Study of Different Combinations."
(Text in Swedish. Abstract in English.)
FOA-R--00-01552-314--SE

N. Karlsson, C. Johansson, M. Wilow
"Characterisation of Signal Measurement Unit, SMU, in an Operation-like Environment."
(Text in Swedish. Abstract in English.)
FOA-R--00-01465-616--SE

A. Kjellström, L. Sarholm, M. Gustavsson, S. Abrahamsson
"Study Tour to Cambodia. Studies of Mine Clearance Activity, Mine Detection Dogs and Activities at Cambodian Mine Action Center. "
(Text in Swedish. Abstract in English.)
FOA-R--00-01688-310--SE

P. Klum, J. Rahm, K. Rixon, L. Bergström, C. Larsson
"Mfactor 1.0 User Manual."
(Text in Swedish. Abstract in English.)
FOA-R--00-01546-616--SE

B. Knuthammar, F. Kullander, M. Andersson, P.-O. Arntzen, S. Gruffman
"Initial Trials with a 4 Channel Fiberoptic Hydrophone Array."
FOA-R--00-01468-409--SE

F. Kullander, B. Knuthammar, M. Andersson
"Fiber Optic Hydrophone Technology, a Review."
(Text in Swedish. Abstract in English.)
FOA-R--00-01467-409--SE

F. Kullander, M. Andersson, A. Olsson
"Demonstration of a Four Element Fiber Optic Hydrophone Cable."
FOA-R--00-01778-409--SE

F. Kullander, B. Knuthammar
"Fiber Laser Hydrophones, an Introductory Survey."
FOA-R--00-01779-409--SE

H.-S. Lee, Ö. Staaf, H. Ghaemi
"IR-Properties of Some Binders for the Coatings Industry."
FOA-R--00-01576-615--SE

P.-E. Martinsson, F. Kullander, B. Knuthammar
"Construction and Evaluation of a Planar Fiber-Optic Hydrophone for Military Applications."
FOA-R--00-01481-409--SE

L. Morhagen, C. Karlsson, C. Carlsson
"Performance and Characteristics of Frequency Estimators for Coherent Laser Radar Systems."
FOA-R--00-01520-408--SE

C. Nelsson
"Project Optical Signatures - Fiscal Year 2000."
(Text in Swedish. Abstract in English.)
FOA-R--00-01732-615--SE

C. Nelsson , L. Bohman, R. Lindell, G. Forssell, S. Nyberg, L. Pettersson
"A Study of the IR Background - Strategy for Data Acquisition."
(Text in Swedish. Abstract in English.)
FOA-R--00-01473-615--SE
33

C. Nelsson, R. Persson, P. Nilsson, A. Hågård
"Results from Baltic 99 Maritime Measurements - Optical Wave Propagation and IR-Background."
FOA-R--00-01771-615--SE

C. Nelsson
"Remote Detection of NH_3 and SO_2 - a Study of the Influence of the Atmosphere by use of Modtran and Hitran-PC."
(Text in Swedish. Abstract in English.)
FOA-R--00-01443-862--SE

C. Nilsson, C. Lopes, A. Eriksson
"Optical Power Limiting - Investigation of New Materials."
FOA-R--00-01680-612--SE

H. Olsson
"2-D Automatic Image Analysis and Image Enhancement for Gated Viewing Imagery."
FOA-R--00-01554-408--SE

H. Olsson
"An Implemented 2-D Local Feature Extraction Framework."
FOA-R--00-01553-408--SE

J.-O. Ousbäck
"Radar Absorbing Materials, an overview"
(Text in Swedish. Abstract in English.)
FOA-R--00-01543-615--SE

L. Pettersson
"Concept and Relations for the Analysis of Plane Periodic Antenna Arrays."
FOA-R--00-01666-616--SE

J. Rahm, H-O.Berlin, C.Larsson
"Development and Implementation of Columbus, a Tool for ISAR-analysis. VU-SAT Report."
(Text in Swedish. Abstract in English.)
FOA-R--00-01491-615--SE

I. Renhorn, G. Carlsson, I. Engquist, T. Hallberg, L. Holm, R. Lindell, C. Nelsson, R. Persson
"IRST:Airborne Sensor for Tactical Applications."
(Text in Swedish. Abstract in English.)
FOA-R--00-01437-408--SE

C-G. Ribbing
"Photonbandgaps - a research survey"
(Text in Swedish. Abstract in English.)
FOA -R--00-01432-318--SE

U. Ringh, G. Carlsson
"FOA/DSTO Uncooled IR-Sensors. Summary of Activities 1994-2000."
FOA-R--00-01715-408--SE

S. J. Savage
"Defence Applications of Nanostructural Materials."
FOA-R--00-01772-318--SE

S.J. Savage
"ISMANAM 2000. International Symposium on Mechanically Alloyed, Metastable and Nanocrystalline Materials."
FOA-R--00-01625-318--SE

S. J. Savage, L.-G.Olsson, L. Lood
"Study Visit to Japan"
FOA-R--00-01580-318--SE

S. Sjökvist, M. Georgsson
"Thermal transport analysis of construction materials."
(Text in Swedish. Absract in English)
FOA-R--00-01761-615--SE

L. Sjöqvist
"Adaptive Optics in Laser Countermeasures. An Introduction."
FOA-R--00-01736-612--SE

L. Sjöqvist, K. D'have, S. Hård, T. Matuszczyk, P. Rudquist, S. Walles
"Laser Beam Steering - Final Report."
FOA-R--00-01684-408--SE

Ö. Staaf
"Multilayered pigments for low camouflage paints."
(Text in Swedish. Abstract in English)
FOA-R--00-01598-615--SE

Ö. Staaf, G. Forssell
"Polarization Properties of Camouflage Painted Surfaces."
(Text in Swedish. Abstract in English.)
FOA-R--00-01484-615--SE

O. Steinvall
"Waveform Simulation for 3-D Sensing Laser Radar."
FOA-R--001530-612-408--SE

O. Steinvall, D. Letalick
"The potential of combined active and passive electro-optical sensors."
FOA-R--00-01605-408--SE

S. Svensson, S. Ödman
"Optical R&D in Finland."
(Text in Swedish. Abstract in English.)
FOA-R--00-01574-612--SE

M. Tulldahl, M. Andersson, B. Knuthammar
"Detection of Sea Mines with Airborne Lidar."
FOA-R--00-01444-409--SE

M. Ulvklo, M. Karlsson, J. Karlholm, J. Nygårds
"Signal Processing System Architecture for EO/IR Aerial ATR: Specification of a Scalable Computing System."
FOA-R--00-01768-408, 517--SE

H. Åkermark
"Signal Processing in Radar Imaging Applications."
(Text in Swedish. Abstract in English.)
FOA-R--00-01564-408--SE

H. Åkermark
"Analysis of the Coupling of Target Motion to Radar Imaging."
(Text in Swedish. Abstract in English.)
FOA-R--01579-408--SE

Classified reports: 15

Table 2

Number of employees at Educational levels	*00*	*99*	*98*	*97*	*96*	*95*	94
Undergraduate	33	25	28	28	29	27	27
B.A.	13	13	23	19	9	11	11
M.Sc.Eng.	56	55	57	55	59	55	53
Licentiate	6	6	6	5	4	4	3
Ph.D.	39	43	36	28	28	24	21
Officer	1		1	1	2	1	1
Total	148	143	151	136	131	122	116

Table 3

Commissioners [%]	*00*	*99*	*98*	*97*	*95/96**	94/95
Swedish Armed Forces	72	71	71	70	78	75
Defence Material Administration	20	19	19	17	17	21
Swedish Agency for Civil Emergency Planning	2	0,2		2	2	2
Swedish industry	5	2	4	9		2
Others	1	8	6	2	3	

* 95/96 was a period of one and a half year 165 MSEK corresponds to 110 MSEK on a yearly basis

Table 4

Turnover, total employment	*00*	*99*	*98*	*97*	*95/96**	94/95
MSEK total	153	153	138	138	110*	106
Total	148	143	151	136	123	116
Earnings per employee [%]	1.03	1.06	0.91	1.01	0.89	0.91

Table 5

Research and Development areas	*Revenue [%]*	*[%] of total FOA*
Swedish Armed Forces, specification see below	70,9	25,5
Sensors for Ground Surveillance and Reconnaissance	22,8	85
Underwater Sensors	2,4	11
Weapons, Effects and Protection	7,5	16
Electromagnetic Weapons and Protection	10,9	75
Guided Weapons	3,7	42
Low Observables	9,9	91
Electronic warfare	13,7	25

Table 6

Courses	Participants from division	Courseevaluation
Presentationtechniques	2	4.5 out of 5 points
Purchasing in theory and practice	19	3,9 out of 10 points
Projectmanagement	12	8,5 out of 10 points
Seminar ”leadership for the Future”	19	3,2 out of 5 points
A course about Environment for the leaders etc	10	4,4 out of 5 points
A course about Environment for all the empoyees	46	3.7 out of 5 points

Swedish Defence Research Agency
Division of Sensor Technology, P.O. Box 1165, SE-581 11 Linköping Sweden. Phone: +46 13 378000, Fax: +46 13 378100,
http://www.foi.se/eng/sensor.html