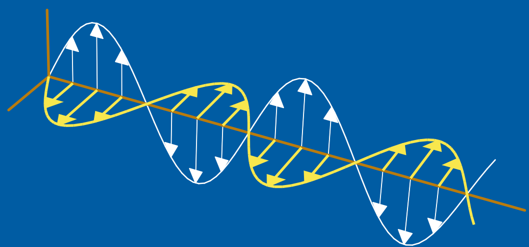
CODEN:LUTEDX/(TEAT-3022)/1-53/(2011)

Annual Report 2010

Electromagnetic Theory

Electromagnetic Theory
Department of Electrical and Information Technology
Lund University
Sweden



Editors: Gerhard Kristensson & Christian Sohl

Lund, May 31, 2010

Preface

During 2010, we have rejoiced in several very pleasant events — new members of the group, several PhD and Licentiate examinations, prestigious awards *etc.*. Here is a short summary of the major events during 2010.

To start with, Alireza Kazemzadeh successfully defended his PhD thesis in May with Lecturer Lee Ford from the University of Sheffield, England, as faculty opponent. A short summary of Alireza's thesis is found in Section 3.1 on page 11. Moreover, both Kristin Persson and Anders Bernland presented their Licentiate theses in February and May, respectively. Short summaries of their theses and pictures from the events are found in Section 3.2 on page 13. Another important event this year was the appointment of our Adjunct professor Christer Larsson as Docent.

The personnel of the group has expanded in 2010. First of all, two new PhD students, Alexander Bondarik and Magnus Gustafsson, have been employed. Alexander is working on array antennas in a project entitled: "60 GHz Wireless Systems" supported by the Swedish Foundation for Strategic Research (SSF), and Magnus, who is an externally funded graduate student, is working on wave propagation problems in random media. Christian Sohl, who successfully defended his PhD thesis in 2008 has returned to the group with a PostDoc position sponsored by the faculty. A final addition to the group is Sena Esen Bayer Keskin, who is a PhD student in the Department of Electronics Engineering at Gebze Institute of Technology (GIT) and research assistant in Mechatronics Engineering Department at Kocaeli University in Turkey. Sena is staying with us as a Guest Researcher for some longer time. We wish all these new colleagues good luck in their studies and endeavors.

Our research efforts during the past years have paid off well. During 2010, two major awards were given to members of the group. The IEEE Antennas and Propagation

Figure 1: New members of the group. From left: Alexander Bondarik, Magnus Gustafsson, and Sena Esen Bayer Keskin.

Figure 2: Christian Sohl receives the IEEE Sergei A. Schelkunoff Transactions Prize Paper Award.

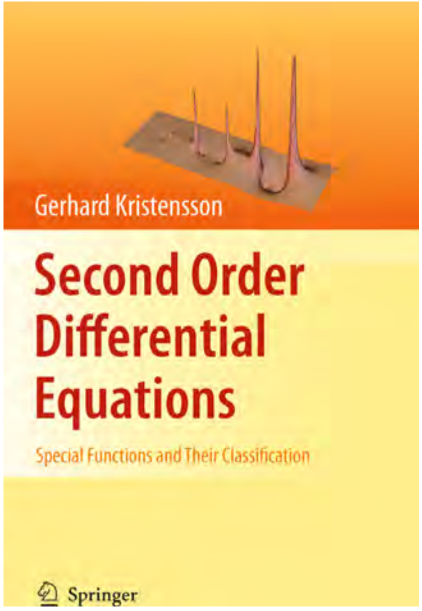


Figure 3: Springer publication.

2010 Sergei A. Schelkunoff Prize Paper Award was awarded Mats Gustafsson, Christian Sohl, and Gerhard Kristensson, see Figure 2. The winning paper is entitled: "Illustrations of new physical bounds on linearly polarized antennas," vol. 57, no. 5, pp. 1319–1327, May 2009. Moreover, Alireza Kazemzadeh was awarded 2^{nd} prize in the Young Scientist Best Paper Award at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany, August 16–19, 2010, see Figure 12 on page 32.

Our research depends very much on financial support from external sources. In Section 1.7 on Page 4 a complete list of external funding during 2010 is presented. We are fortunate to have support from a number of sources including The Swedish Research Council (VR), the FP7 Programme (EU), VINNOVA, The Swedish Foundation for Strategic Research (SSF), Sony Ericsson Mobile Communications AB, and The Swedish Defence Materiel Administration (FMV). We are very grateful to these organizations for their generous supports.

A great deal of work is done in collaboration with researchers from leading Swedish industry. This is borne out by the many Adjunct professors that we have in the group, see Section 1.4 on Page 3. We see strong mutual benefits from both parts in this interaction, and we are looking forward to continuing and deepening this collaboration.

Under the auspices of the Swedish Defence Materiel Administration (FMV), we have completed a very interesting project on micromodeling of absorbing structures. This project was multidisciplinary and enroled researchers from FOI and industry. We value these projects highly, since they give us insight into the problems that the leading Swedish industry are facing.

After three years of preparation, Gerhard Kristensson's book on classifying solutions to second order differential equations has finally been published, see Figure 3.

Many conferences have been attended during 2010. A list of our efforts is presented on Page 33.

Contents

1 The group of Electromagnetic Theory

1.1 General

The Faculty of Engineering (Lunds Tekniska Högskola, LTH) is Sweden's third largest higher educational institute for the engineering sciences, and it is part of Lund University — one of the oldest and largest universities in Scandinavia. The Faculty of Engineering consists of 19 departments, some of which are divided into divisions.

The basis for the research and teaching activities in the group of Electromagnetic Theory at the Department of Electrical and Information Technology is the fundamental macroscopic electromagnetic laws as they apply to the generation and propagation of electromagnetic waves in vacuum or in material media. Special emphasis is also given to the theoretical study of the various devices that can be constructed to amplify and regulate these effects. In our ambition to meet these goals all methods — analytical, numerical, and experimental — are relevant to us.

The main research activities are concentrated to the area of electromagnetic scattering theory and related topics, *e.g.*, antenna and radome applications. Progress in this area is fundamental for the development of devices and tools that use electromagnetic waves for information exchange. The last few decades have very clearly showed an increasing need and demand for this kind of sensors and carriers of information.

During the last decade, wave propagation phenomena in periodic structures have been a prosperous research field in the group of Electromagnetic Theory. For larger structures, where the wavelength is comparable to the periodicity of the material, the frequency selective structures (FSS) are a striking example of this effort. On the other end of the scale, with a vanishingly small periodicity, we address the field of homogenization. This application makes it possible to find the effective electromagnetic parameters of a material exactly in terms of the microscopic constituents (microstructure) of the material.

Multiple antenna systems have received much interest due to the ability to increase the spectral efficiency in wireless communication. In many cases it is desired to have both high capacity and small physical size. Research has been directed towards establishing physical limitations on information capacity based on antenna size, keyhole effects, and the wave propagation environment. A related area is the study of antenna signal correlation among closely spaced elements.

1.2 Personnel

The personnel employed in the group during 2010 is given in the following table:

Name	Degree[a]	Position[b]
Anders Bernland	TeknL	D
Alexander Bondarik[c]	MSc	D
Marius Cismasu	MSc	D
Mats Gustafsson	TeknD, Doc	UL
Anders Karlsson	TeknD, Doc	P
Alireza Kazemzadeh	TeknD	FA
Buon Kiong (Vincent) Lau[d]	TeknD, Doc	UL
Gerhard Kristensson	FD, Doc	P
Richard Lundin	TeknD	UL
Sven Nordebo[e]	TeknD	P
Kristin Persson	TeknL	D
Christian Sohl[f]	TeknD	FA
Daniel Sjöberg	TeknD, Doc	UL
Ruiyuan Tian[g]	MSc	D

[a] Doc Docent; TeknD PhD in Engineering; FD Doctor of Philosophy, PhD; TeknL Licentiate in Engineering; MSc Master of Science
[b] D Graduate Student; P Professor; FA Postdoctoral Research Fellow; UL Senior Lecturer
[c]Started his employment 2010-05-03.
[d]Employed by the Communications group.
[e]From Linnæus University. Part time employed during 2010.
[f]Started his employment 2010-09-01.
[g]Employed by the Communications group.

A photo of the group is given in Figure 4.

1.3 External graduate students (industridoktorander)

Under this heading we list those graduate students of the group that are fully employed at a company and at the same time are graduate students in the group of Electromagnetic Theory.

Name	Degree[a]	Company
Michael Andersson	TeknL	Applied Composites AB, Linköping
Magnus Gustafsson[b]	CI	Swedish Defence Research Agency, FOI
Vanja Plicanic	TeknL	Sony Ericsson Mobile Communications, Lund

[a] CI Master of Engineering; TeknL Licentiate in Engineering
[b]Started his employment 2010-11-10.

Figure 4: The Electromagnetic Theory group with guests. From the left: Yi Tan, Daniel Sjöberg, Anders Karlsson, Elsbieta Szybicka, Richard Lundin, Anders Melin, Marius Cismasu, Alexander Bondarik, Anders Bernland, Sena Esen Bayer Keskin, Erdinç Keskin, Ioannis Stratis, Ivaylo Vasilev, Vanja Plicanic, Alireza Kazemzadeh, Mats Gustafsson, Niklas Wellander, Buon Kiong (Vincent) Lau, and Ruiyuan Tian. The photo was taken August 27, 2010 by Gerhard Kristensson. Missing on the photo are Christian Sohl, Kristin Persson and Christer Larsson.

1.4 Adjunct professors

Four adjunct professors are associated with the group of Electromagnetic Theory:

Name	Degree[a]	Company
Anders Derneryd	TeknD	Ericsson AB
Christer Larsson	FD, Doc[b]	Saab Dynamics AB
Anders Sunesson	TeknD	Perlos
Niklas Wellander	TeknD	Swedish Defence Research Agency, FOI

[a] Doc Docent
FD Doctor of Philosophy, PhD
TeknD PhD in Engineering
[b] Appointed Docent 2010-02-09.

1.5 Visiting scientists

Several Visiting scientists take part in the scientific activities and participate in joint projects with researchers in the group. These are:

Name	University
Sena Esen Bayer Keskin[a]	Kocaeli University, Turkey
Jørgen Bach Andersson	Aalborg University, Denmark
Anders Melin	Department of Mathematics, Lund University, Sweden
Andreas Ioannidis	Hausdorff Center for Mathematics, Bonn, Germany
Iman Vakili[b]	Lund University, Sweden

[a]Arrived June 2, 2010.
[b]Carried out the design work in one of microwave projects.

1.6 URL-address

The home page of the Department of Electrical and Information Technology is: **www.eit.lth.se/research/emtheory**. From this home page it is easy to find more, and up to date, information of the group of Electromagnetic Theory.

1.7 External funding

The external research support during 2010 is given by:

- The Swedish Research Council (VR). *Principal investigator:* Mats Gustafsson. *Title of the project:* "Physical bounds on the information capacity for MIMO and UWB antenna systems".
- The Swedish Research Council (VR). *Principal investigator:* Buon Kiong Lau. *Title of the project:* "Fundamentala begränsningar för små bredbandiga MIMO-System (Fundamental Limits of Wideband Information Capacity for Compact MIMO Systems)".
- The Swedish Research Council (VR). *Principal investigator:* Börje Nilsson. *Title of the project:* "Grundläggande vågmodellering för signalestimering på transmissionsledningar med förluster (Fundamental wave modelling for signal estimation on lossy transmission lines)".
- VINNOVA. *Principal investigators:* Gerhard Kristensson and Buon Kiong Lau. *Title of the project:* "MIMO teknik i kompakta flerbandsantennsystem (Compact Multiband, Multiple Antenna Systems)".
- VINNOVA. *Principal investigator:* Buon Kiong Lau. *Title of the project:* "Harmonisering av Antenn och Kanal för Ökad Överföringshastighet i Avancerade Mobila Terminaler (Antenna-Channel Harmonization for Throughput Enhancement in Advanced Mobile Terminals)".
- VINNOVA. *Principal investigator:* Buon Kiong Lau. *Title of the project:* "Innovativ Multipelantenn Design för Kompakta Terminaler (Innovative Multiple Antenna Structures for Compact Mobile Terminals)".

- VINNOVA. *Principal investigators:* Mats Gustafsson and Buon Kiong Lau. *Title of the project:* "Access technologies: multiple access, multiple users, multiple distributed antenna systems".
- SSF Center for High Speed Wireless Communication (HSWC). *Principal investigator:* Mats Gustafsson. *Title of the project:* "MIMO Antennas and Channels".
- SSF Center for High Speed Wireless Communication (HSWC). *Principal investigator:* Daniel Sjöberg. *Title of the project:* "Nano Devices, RF Transceivers and CMOS GHz Electronics".
- SSF Charmant (Strategic Research Center on Microwave Antenna Systems). *Principal investigator:* Mats Gustafsson. *Title of the project:* "Microwave tomography".
- SSF Strategic Mobility Grant. *Principal investigator:* Anders Karlsson.
- SSF Strategic Mobility Grant. *Principal investigator:* Daniel Sjöberg.
- FP7 Programme, EU. *Principal investigator:* Mats Gustafsson. *Title of the project:* "Integrated System for Transport Infrastructures surveillance and Monitoring by Electromagnetic Sensing".
- Swedish Defence Materiel Administration (FMV), sponsoring several projects in collaboration with Swedish industry.
- Sony Ericsson Mobile Communications AB. Sponsoring the Adjunct professorship of Anders Derneryd.
- Saab Dynamics AB. Sponsoring the Adjunct professorship of Christer Larsson.
- Swedish Defence Research Agency, FOI. Sponsoring the Adjunct professorship of Niklas Wellander.
- Perlos. Sponsoring the Adjunct professorship of Anders Sunesson.
- Sony Ericsson Mobile Communications AB. Financing of an external graduate student.

2 Research Activities

The current research projects of the group of Electromagnetic Theory are organized in four major categories:

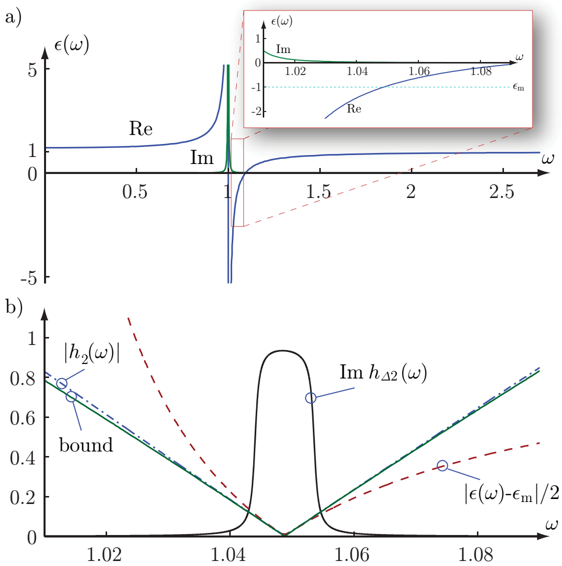


Figure 5: Example of a project under Section 2.1. Illustrations of a low-loss model with $n_{\rm m} = -1$. a) the refractive index $n(\omega)$. b) integrand (solid curved) of the sum rule, $|h_1(\omega)|$, $|n(\omega) - n_{\rm m}|$, and bandwidth bound.

2.1 Material modeling and electromagnetic interaction

2.2 Electromagnetic scattering and design

2.3 Inverse scattering and imaging

2.4 Antennas and communication

For each category, we give a short general description followed by a list of recent literature produced within the group. Only journal papers are cited explicitly, which serves the double purpose of documenting the researchers involved, and providing key words describing the activities. Full references for conference contributions and technical reports can be found in Sections 3.6 and 3.9, respectively.

2.1 Material modeling and electromagnetic interaction

In these projects, the focus is on the interaction between the electromagnetic field and material structures. This includes wave propagation in complex materials and structures (inhomogeneous, nonlinear, anisotropic, chiral, frequency selective etc), as well as mathematical modeling of physical mechanisms behind the interaction (representations of dispersive effects, homogenization).

Primary questions in these projects regard the possibilities to reduce the amount of information needed to describe the interaction. For instance, wave propagation in strongly inhomogeneous media (many parameters) can be modeled with propagation in homogeneous materials (very few parameters) if the wavelength is sufficiently long. This reduction is called homogenization. The properties of the fictitious homogeneous material must be carefully calculated, usually from a static or quasi-static field problem. In another class of problems, interaction on an electronic scale can be modeled with voltages and currents in classical circuit models, where the major challenges lie in constructing accurate models, including the calculation of circuit parameters from static or quasi-static field problems.

Key publications:

1. M. Gustafsson and D. Sjöberg. Sum rules and physical bounds on passive metamaterials. *New Journal of Physics*, **12**, 043046–, 2010.

Conferences: C16, C26

Technical reports: TEAT-7196

2.2 Electromagnetic scattering and design

Under this heading, the scattering problem is of central importance, that is, when a prescribed electromagnetic field interacts with a particular object (the scatterer), the task is to determine the scattered field. There is often a particular design goal associated with the scattering, for instance to minimize the scattering for all frequencies, maximize the transmission through a panel for a certain frequency band, or maximize the scattering in order to obtain the most information on the object.

The design of complex structures and systems to obtain the design goals relies on the combination of relatively simple physical models to assert the overall function, as well as general or highly devoted numerical codes to compute the specific details of the different constituents. Much of our work in this category is performed in collaboration with industry, who often supply the broader systems perspective.

Key publications:

1. M. Gustafsson. Time-domain approach to the forward scattering sum rule. *Proceedings of the Royal Society A Mathematical Physical and Engineering Sciences*, **466**(2124), 3579–3592, 2010.
2. A. Ioannidis, G. Kristensson, and D. Sjöberg. The propagation problem in a bi-isotropic waveguide. *Progress In Electromagnetics Research B*, **19**, 21–40, 2010.
3. A. Kazemzadeh and A. Karlsson. Multilayered wideband absorbers for oblique angle of incidence. *IEEE Transactions on Antennas and Propagation*, **58**(11), 3637–3646, 2010.

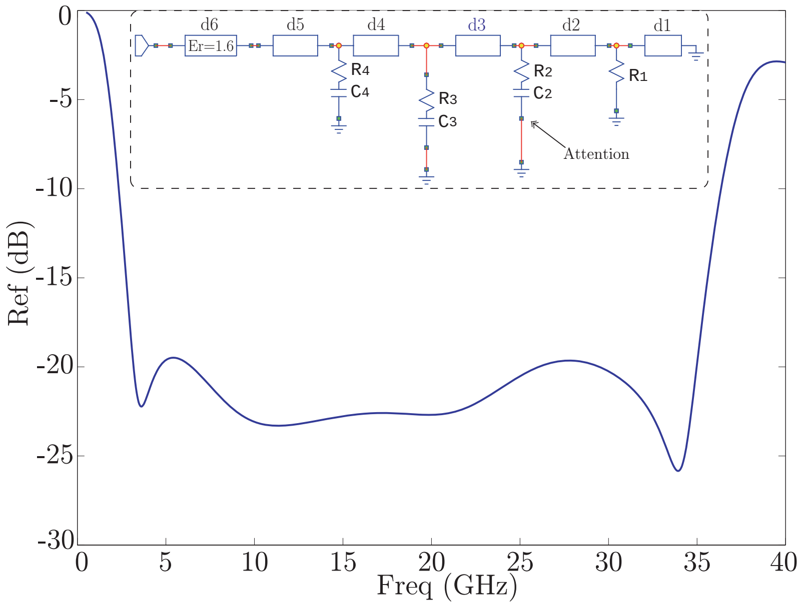


Figure 6: Example of a project under Section 2.2. The frequency response of the capacitive circuit absorber with single spatial periodicity and its equivalent circuit model. The second layer shown by the arrow (Attention) is embedded in the middle of a dielectric cover not shown in the figure ($T_c = 0.2$mm and $\epsilon_r = 2$). The 20 dB absorption bandwidth 3.16–34.96 GHz ($f_H/f_L \simeq 11.03$).

4. A. Kazemzadeh and A. Karlsson. On the absorption mechanism of ultra thin absorbers. *IEEE Transactions on Antennas and Propagation*, **58**(10), 3310–3315, 2010.

5. D. Sjöberg, M. Gustafsson, and C. Larsson. Physical bounds on the all-spectrum transmission through periodic arrays: oblique incidence. *EPL (Europhysics Letters)*, **92**, 34009–p1–34009–p6, 2010.

Conferences: C8, C13, C29

Technical reports: TEAT-7189, TEAT-7194

2.3 Inverse scattering and imaging

In this category, the goal is to infer information on some object or structure using electromagnetic waves, including light. Depending on what is *a priori* known about the object and scattering situation, different strategies may be employed. One alternative is to back propagate the measured field through a region which is known (usually air), as close as possible to the scatterer, and then see what equivalent currents this corresponds to. Another alternative is to set up several theoretical models

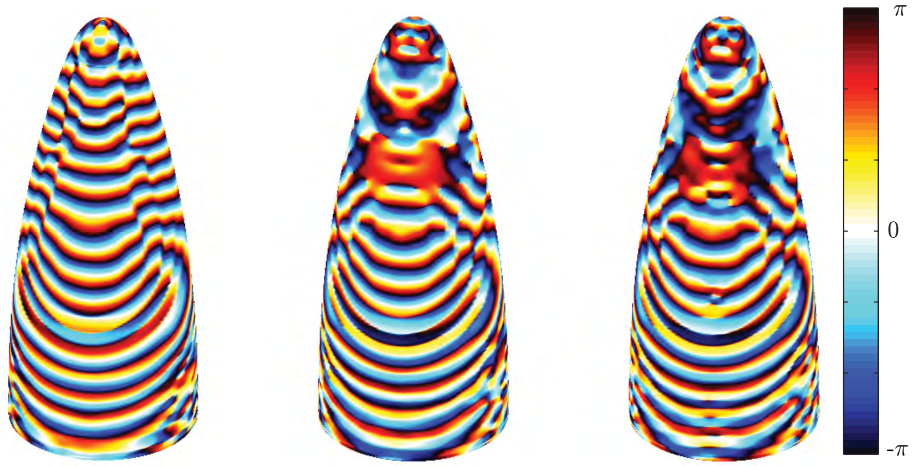


Figure 7: Example of a project under Section 2.3. The recreated phase of the E^{v}-component on the front side of the radome in a linear scale. a) No radome present. b) Radome present. c) Defect radome present.

of the scatterer, and see which one fits the measured data best. This usually results in computationally demanding algorithms.

A more specific set of problems is termed imaging. Here, the aim is to obtain an overall image of the scatterer, for instance its shape or location. This can sometimes be obtained in a relatively straightforward way from the scattering data, especially in the high frequency limit (ray optics).

Key publications:

1. S. Nordebo, R. Bayford, B. Bengtsson, A. Fhager, M. Gustafsson, P. Hashemzadehk, B. Nilsson, T. Rylander, and T. Sjöden. An adjoint field approach to Fisher information based sensitivity analysis in electrical impedance tomography. *Inverse Problems*, **26**, 125008–, 2010.

2. S. Nordebo, A. Fhager, M. Gustafsson, and B. Nilsson. A Green's function approach to Fisher information analysis and preconditioning in microwave tomography. *Inverse Problems in Science and Engineering*, **18**(8), 1043–1063, 2010.

3. K. Persson, M. Gustafsson, and G. Kristensson. Reconstruction and visualization of equivalent currents on a radome using an integral representation formulation. *Progress in Electromagnetics Research B*, **20**, 65–90, 2010.

Conferences: C6

Technical reports: TEAT-7184

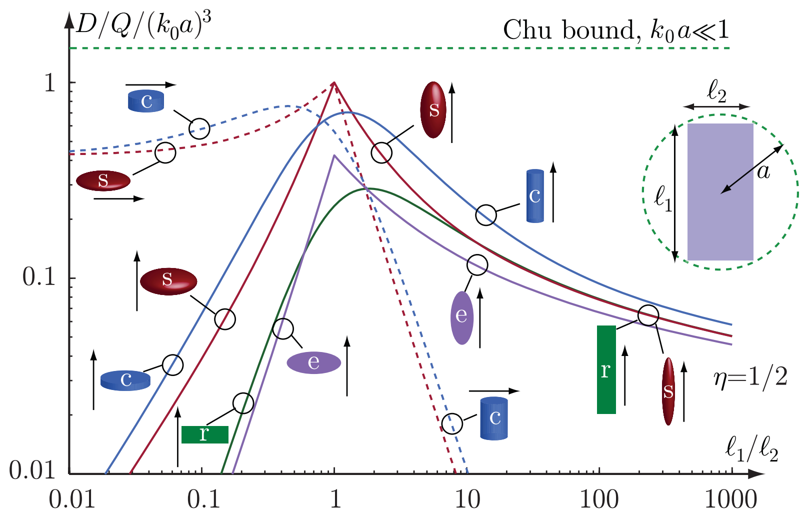


Figure 8: Example of a project under Section 2.4. Physical bounds on D/Q for non-magnetic linearly polarized antennas circumscribed by spheroids (s), elliptic disks (e), cylinders (c), and planar rectangles (r).

2.4 Antennas and communication

In a wireless system, the antenna is the interface between the electric circuit and waves propagating in the surrounding medium. From a system point of view, the antenna suffers from several fundamental limitations in terms of available bandwidth, gain *etc.* versus, for instance, the available volume or complexity in the matching network. New antenna concepts such as MIMO (Multiple Input, Multiple Output) provide new opportunities for increased performance.

Our investigations of antennas and wireless systems concern sharpening of fundamental limitations of antennas in various circumstances. We also deal with higher levels of integration, for instance of the antenna with the amplifier or the matching network, or the antenna and the surrounding structure, including the interaction of the user. Computational means of simulating the antenna and related structures are also developed.

Key publications:

1. A. A. Glazunov, M. Gustafsson, A. Molisch, and F. Tufvesson. Physical modelling of multiple-input multiple-output antennas and channels by means of the spherical vector wave expansion. *IET Microwaves, Antennas and Propagation*, **4**(6), 778–791, 2010.

2. M. Gustafsson, M. Cismasu, and S. Nordebo. Absorption Efficiency and Physical Bounds on Antennas. *International Journal of Antennas and Propagation*, **2010**(Article ID 946746), 1–7, 2010.

Figure 9: Left figure: Lee Ford (left) and Alireza Kazemzadeh (right) at Alireza's dissertation. Right figure: The examination committee, faculty opponent and supervisor. From the left: Martin Norgren, Thomas Rylander, Torleif Martin, Lee Ford, and Anders Karlsson.

3. M. A. Jensen and B. K. Lau. Uncoupled matching for active and passive impedances of coupled arrays in MIMO systems. *IEEE Transactions on Antennas and Propagation*, **58**(10), 3336–3343, 2010.
4. R. Tian, V. Plicanic, B. K. Lau, and Z. Ying. A compact six-port dielectric resonator antenna array: MIMO channel measurements and performance analysis. *IEEE Transactions on Antennas and Propagation*, **58**(4), 1369–1379, 2010.

Conferences: C3, C5

Technical reports: TEAT-7195

---

3 Dissertations, Published papers and Reports

3.1 Doctoral dissertations

Alireza Kazemzadeh, "Design and Analysis of Nonmagnetic Specular Radar Absorbing Materials," May 27, 2010, see Figure 9.

Faculty opponent: Lecturer Lee Ford, Department of Electronic and Electrical Engineering, The University of Sheffield, England.

Examining committee:

1) Associate Professor Thomas Rylander, Signals and Systems, Chalmers University, Göteborg, Sweden
2) Dr Torleif Martin, Saab Aerosystems, Linköping, Sweden
3) Associate Professor Martin Norgren, School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden

3.1.1 Short presentation of Alireza Kazemzadeh's thesis

The design and analysis of specular radar absorbing materials are investigated throughout the dissertation. Although the topic has been investigated for more than 60 years by many researchers and numerous designs have been proposed, still many technical challenges are remained unanswered. The basic questions are, e.g., the optimal thickness of a design, the possibility of utilization of unconventional materials in an absorber to meet more design requirements, e.g. thermal or mechanical, than solely the electrical properties, the maximum possible bandwidth achievable with a low profile nonmagnetic coating and the feasibility of designing wideband multilayered absorbers for large scan angles. The thesis proposes systematic solutions for these challenging problems.

The dissertation is composed of six peer-reviewed papers. A new versatile design method is proposed in the first paper with outstanding capabilities and remarkable applications. The method is named ”capacitive circuit absorber” (CCA) and is demonstrated with different design examples to verify its superiority in comparison to the other design approaches. For example, the possibility of utilizing high permittivity dielectric spacers in conjunction with frequency selective surfaces (FSS) in wideband designs is illustrated. The second paper deals with ultra thin absorbers. Recently different proposals based on meta-materials or electromagnetic band-gap structures were suggested for low profile absorbers. The thesis shows that the absorption mechanisms in ultra thin structures are due to excitation of longitude electric field component and no meta-material effect is involved in the absorption process. It is demonstrated that TM cavity modes of patch antennas can approximate fairly accurately the absorption frequency in both periodic and finite extent absorbers. The design of multilayered Jaumann and FSS based absorbers for large scan angles are presented in the third paper. The possibility of extension of the scan and frequency compensation techniques, formerly formulated for single resistive layer designs, to multilayered absorbers is illustrated. It is shown that in contrast to single resistive layer designs, there are some degrees of freedom in the selection of the dielectric layers. Design of ultra wideband absorbers, bandwidth ratios in order of 10:1, with optimal thickness is studied in the fourth paper. It is shown that for achieving an ultra wideband design with optimal thickness, utilization of different spatial periodicities for the periodic layers is essential. By the aid of the physical

Figure 10: Kristin Persson (left) and Ari Sihvola (right) at Kristin's Licentiate seminar, February 5, 2010.

bound for absorbers it is verified that our design approach leads to optimal total thicknesses. Design of thin wideband absorbers is the topic of the fifth paper, where the challenging problem of reasonable tradeoff between bandwidth and thickness is addressed. The effect of mutual coupling between periodic layers and the ground plane on the frequency response of a thin design is investigated and practical methods for minimizing the couplings are introduced. A thin design is proposed for the X-band which has a total thickness very close to the theoretical limit. Finally in the last paper the physical bound on the absorbers, originally published for normal angle of incidence, is extended to arbitrary angle of incidence for different polarizations. Applicability of the new bounds is examined with different design examples.

3.2 Licentiate dissertations

Kristin Persson, "Retrieval of equivalent currents by the use of an integral representation and the extinction theorem — radome applications." February 5, 2010, see Figure 10.

Reviewer: Professor Ari Sihvola, Aalto University, Finland.

Anders Bernland, "Sum rules and constraints on passive systems — a general approach and applications to electromagnetic scattering." May 5, 2010, see Figure 11.

Reviewer: Associate Professor Lars Jonsson, Royal Institute of Technology, Sweden.

3.2.1 Short presentation of Kristin Persson's thesis

The aim of Kristin Persson's thesis is to solve an inverse source problem. The approach is based on an integral representation together with the extinction theorem. Both a scalar and a full-wave integral representation are implemented and solved by a Method of Moment procedure. The body of revolution enables usage of a Fourier

Figure 11: Anders Bernland (left) and Lars Jonsson (right) at Anders' Licentiate seminar, May 5, 2010.

transform to reduce the dimensions of the problem. A singular value decomposition is utilized to suppress singular values in the inversion process. A nose-cone radome is diagnosed by recreating the equivalent surface currents on its surface from measured near fields. It is shown how the radome interacts with the field, creating beam deflection, pattern distortion, *etc.*. The phase shift of the field due to the transmission through the radome, *i.e.*, the insertion phase delay, is visualized. Disturbances due to defects, not detectable in the measured near field, are correctly localized by the equivalent surface currents. The alteration of side and flash lobes, together with the introduction of scattering due to the defects, are also visualized. Verification is made by comparison between the calculated and measured far field.

3.2.2 Short presentation of Anders Bernland's thesis

Physical processes are often modeled as input-output systems. Many such systems obey passivity, which means that power is dissipated in the process. This thesis deals with the inevitable constraints imposed on physical systems due to passivity. A general approach to derive sum rules and physical limitations on passive systems is presented. The sum rules relate the dynamical behavior of a system to its static and/or high-frequency properties. This is beneficial, since static properties are in general easier to determine. The physical limitations indicate what can, and what can not, be expected from certain passive systems. At the core of the general approach is a set of integral identities for Herglotz functions, a function class intimately related to the transfer functions of passive systems.

In this thesis, the general approach is also applied to a specific problem: the scattering and absorption of electromagnetic vector spherical waves by various objects. Physical limitations are derived, which limit the absorption of power from each individual spherical wave. They are particularly useful for electrically small scatterers. The results can be used in many fields where an understanding of the interaction between electromagnetic waves and matter is vital. One interesting application is within antenna theory, where the limitations are helpful from a designer's viewpoint; they can give an understanding as to what factors limit performance, and also indicate if there is room for improvement or not.

3.3 Journal publications

J1. A. A. Glazunov, M. Gustafsson, A. Molisch, and F. Tufvesson. Physical modelling of multiple-input multiple-output antennas and channels by means of the spherical vector wave expansion. *IET Microwaves, Antennas and Propagation*, **4**(6), 778–791, 2010.

J2. M. Gustafsson. Accurate and efficient evaluation of modal Green's functions. *Journal of Electromagnetic Waves and Applications*, **24**(10), 1291–1301, 2010.

J3. M. Gustafsson. Sum rules for lossless antennas. *IET Microwaves, Antennas and Propagation*, **4**(4), 501–511, 2010.

J4. M. Gustafsson. Time-domain approach to the forward scattering sum rule. *Proceedings of the Royal Society A Mathematical Physical and Engineering Sciences*, **466**(2124), 3579–3592, 2010.

J5. M. Gustafsson, M. Cismasu, and S. Nordebo. Absorption Efficiency and Physical Bounds on Antennas. *International Journal of Antennas and Propagation*, **2010**(Article ID 946746), 1–7, 2010.

J6. M. Gustafsson and D. Sjöberg. Sum rules and physical bounds on passive metamaterials. *New Journal of Physics*, **12**, 043046–, 2010.

J7. A. Ioannidis, G. Kristensson, and D. Sjöberg. The propagation problem in a bi-isotropic waveguide. *Progress In Electromagnetics Research B*, **19**, 21–40, 2010.

J8. M. A. Jensen and B. K. Lau. Uncoupled matching for active and passive impedances of coupled arrays in MIMO systems. *IEEE Transactions on Antennas and Propagation*, **58**(10), 3336–3343, 2010.

J9. A. Kazemzadeh and A. Karlsson. Multilayered wideband absorbers for oblique angle of incidence. *IEEE Transactions on Antennas and Propagation*, **58**(11), 3637–3646, 2010.

J10. A. Kazemzadeh and A. Karlsson. On the absorption mechanism of ultra thin absorbers. *IEEE Transactions on Antennas and Propagation*, **58**(10), 3310–3315, 2010.

J11. G. I. Kiani, L. G. Olsson, A. Karlsson, and K. P. Esselle. Transmission of infrared and visible wavelengths through energy-saving glass due to etching of frequency-selective surfaces. *IET Microwaves Antennas & Propagation*, **4**(7), 955–961, 2010.

J12. S. Nordebo, R. Bayford, B. Bengtsson, A. Fhager, M. Gustafsson, P. Hashemzadehk, B. Nilsson, T. Rylander, and T. Sjöden. An adjoint field approach to Fisher information based sensitivity analysis in electrical impedance tomography. *Inverse Problems*, **26**, 125008–, 2010.

J13. S. Nordebo, A. Fhager, M. Gustafsson, and B. Nilsson. A Green's function approach to Fisher information analysis and preconditioning in microwave tomography. *Inverse Problems in Science and Engineering*, **18**(8), 1043–1063, 2010.

J14. K. Persson, M. Gustafsson, and G. Kristensson. Reconstruction and visualization of equivalent currents on a radome using an integral representation formulation. *Progress in Electromagnetics Research B*, **20**, 65–90, 2010.

J15. M. Proto, M. Bavusi, R. Bernini, L. Bigagli, M. Bost, F. Bourquin, L.-M. Cottineau, V. Cuomo, P. D. Vecchia, M. Dolce, J. Dumoulin, L. Eppelbaum, G. Fornaro, M. Gustafsson, J. Hugenschimdt, P. Kaspersen, H. Kim, V. Lapenna, M. Leggio, A. Loperte, P. Mazzetti, C. Moroni, S. Nativi, S. Nordebo, F. Pacini, A. Palombo, S. Pascucci, A. Perrone, S. Pignatti, F. C. Ponzo, E. Rizzo, F. Soldovieri, and F. Taillade. Transport infrastructure surveillance and monitoring by electromagnetic sensing: the ISTIMES project. *Sensors*, **10**(12), 10620–10639, 2010.

J16. D. Sjöberg and M. Gustafsson. Realization of a matching region between a radome and a ground plane. *Progress in Electromagnetics Research Letters*, **17**, 1–10, 2010.

J17. D. Sjöberg, M. Gustafsson, and C. Larsson. Physical bounds on the all-spectrum transmission through periodic arrays: oblique incidence. *EPL (Europhysics Letters)*, **92**, 34009–p1–34009–p6, 2010.

J18. R. Tian, V. Plicanic, B. K. Lau, and Z. Ying. A compact six-port dielectric resonator antenna array: MIMO channel measurements and performance analysis. *IEEE Transactions on Antennas and Propagation*, **58**(4), 1369–1379, 2010.

3.4 Books

B1. G. Kristensson. *Second order differential equations - special functions and their classification.* Springer, New York, 2010.

3.5 Contributions in books

CB1. D. Sjöberg. Circuit analogs for wave propagation in stratified structures. In *Wave Propagation in Materials for Modern Applications*, pages 489–508. Intech, 2010. ISBN 978-953-7619-65-7.

CB2. D. Sjöberg. Finite scale homogenization of periodic bianisotropic structures. In *Modern theory of gratings*, pages 335–366. Springer, 2010. ISBN 978-1-4419-1199-5.

3.6 Conference publications

C1. M. Albani, P. Balling, L. Datashvili, G. Gerini, P. Ingvarson, K. Pontoppidan, M. Sabbadini, D. Sjöberg, S. Skokic, and G. Vecchi. Concepts for polarising sheets & "dual-gridded" reflectors for circular polarisation. In *20th International Conference on Applied Electromagnetics and Communications (ICECOM 2010)*, pages 1–4, Dubrovnik, Croatia, 2010-09-20.

C2. A. Bernland, A. Luger, and M. Gustafsson. Sum rules and constraints on passive systems with applications in electromagnetics. In *International Symposium on Electromagnetic Theory*, 2010-08-15–19.

C3. M. Cismasu and M. Gustafsson. Illustrations of Physical Bounds on Directive Antennas. In *20th International Conference on Applied Electromagnetics and Communications - ICECom*, 2010-09-20.

C4. X. Gao, X. Wang, B. K. Lau, and B. Thomas. On RF implementation of WINNER II channel model for MIMO OTA performance evaluations. In *11th COST2100 Management Committee Meeting*, 2010-06-02–04.

C5. M. Gustafsson, G. Kristensson, A. Bernland, D. Sjöberg, and B. Jonsson. Physical bounds on the partial realized gain. In *The 26th International Review of Progress in Applied Computational Electromagnetics*. ACES, 2010-04-25–29.

C6. M. Gustafsson and S. Nordebo. Information fusion in electromagnetic sensing. In *TAMSEC*, 2010-10-27.

C7. M. Gustafsson and D. Sjöberg. Constraints on the temporal dispersion of metamaterials. In *The 4th European Conference on Antennas and Propagation (EuCAP)*, 2010-04-12–16.

C8. M. Gustafsson, D. Sjöberg, A. Bernland, G. Kristensson, and C. Sohl. Sum rules and physical bounds in electromagnetic theory. In *International Symposium on Electromagnetic Theory*, 2010-08-16–19.

C9. F. Harrysson, A. Derneryd, and F. Tufvesson. Evaluation of user hand and body impact on multiple antenna handset. In *IEEE Antennas and Propagation Society International Symposium*. IEEE, 2010-07-11–17.

C10. A. Ioannidis. On a linear neutral integro-differential equation. In *IWOTA 2010: International Workshop on Operator Theory and Applications*, 2010-07-12.

C11. M. A. Jensen and B. K. Lau. Uncoupled impedance matching for coupled multi-antenna systems. In *European Conference on Antennas and Propagation (EuCAP)*, 2010-04-12–16.

C12. B. L. G. Jonsson and M. Gustafsson. Limitations on the effective area and bandwidth product for Array Antennas. In *International Symposium on Electromagnetic Theory*, 2010-08-16.

C13. A. Karlsson and A. Kazemzadeh. On the physical limit of radar absorbers. In *Electromagnetic Theory Symposium*, 2010-08-16.

C14. A. Kazemzadeh. Thin wideband absorber with optimal thickness (Invited). In *Electromagnetic Theory Symposium*, 2010-08-16.

C15. C. Larsson, M. Gustafsson, and G. Kristensson. Calibration methods for wideband forward RCS measurements. In *The 4th European Conference on Antennas and Propagation (EuCAP)*, 2010-04-12.

C16. C. Larsson and D. Sjöberg. High temperature waveguide measurements of the permittivity and permeability. In *20th International Conference on Applied Electromagnetics and Communications (ICECOM 2010)*, 2010-09-20.

C17. B. K. Lau, J. Medbo, and J. Furuskog. Single-user capacity performance of downlink cooperative MIMO in urban macrocell vehicular routes. In *10th COST2100 Management Committee Meeting*, 2010-02-03–05.

C18. B. K. Lau, J. Medbo, and J. Furuskog. Downlink cooperative MIMO in urban macrocell environments. In *IEEE International Symposium on Antennas and Propagation*, 2010-07-11–17.

C19. H. Li, B. K. Lau, Z. Ying, and Y. Tan. Antenna design tradeoff of multiple antenna terminals with ground plane excitation. In *11th COST2100 Management Committee Meeting*, 2010-06-02–04.

C20. S. Nordebo, R. Bayford, B. Bengtsson, A. Fhager, M. Gustafsson, P. Hashemzadeh, B. Nilsson, T. Rylander, and T. Sjöden. Fisher information analysis and preconditioning in electrical impedance tomography. In *XIV International Conference on Electrical Bioimpedance and 11th Conference on Biomedical Applications of Electrical Impedance Tomography*. Institute of Physics, 2010-04-04.

C21. S. Nordebo, B. Bengtsson, M. Gustafsson, B. Nilsson, and T. Sjödén. Fisher information analysis and gradient based optimization for electrical impedance tomography. In *5th International Conference on Inverse Problems, Modeling and Simulation*, pages 65–66, 2010-05-24–29.

C22. S. Nordebo, M. Gustafsson, and F. Soldovieri. Data fusion for reconstruction algorithms via different sensors in geophysical sensing. In *EGU General Assembly 2010*. Copernicus GmbH, 2010-05-05.

C23. L. Ohlsson, D. Sjöberg, M. Ärlelid, M. Egard, E. Lind, and L.-E. Wernersson. Admittance Matching of 60 GHz Rectangular Dielectric Resonator Antennas for Integrated Impulse Radio. In *2010 Loughborough Antennas & Propagation Conference*. IEEE, 2010-11-08–09.

C24. V. Plicanic, M. Zhu, and B. K. Lau. Diversity mechanisms and MIMO throughput performance of a compact six-port dielectric resonator antenna array. In *International Workshop on Antenna Technology (IWAT)*, 2010-03-01–03.

C25. D. Sjöberg and M. Gustafsson. A physical bound on high impedance surfaces. In *2010 Loughborough Antennas & Propagation Conference*. IEEE, 2010-11-08–09.

C26. D. Sjöberg, M. Gustafsson, and C. Larsson. All-spectrum oblique transmission through a periodic screen. In *Electromagnetic Theory Symposium*. URSI, 2010-08-16.

C27. D. Sjöberg and C. Larsson. Characterization of composite materials in waveguides. In *Electromagnetic Theory Symposium*. URSI, 2010-08-16.

C28. C. Sohl and M. Gustafsson. The T-Matrix Method for Solving Two-Dimensional Scattering Problems. In *International Symposium on Electromagnetic Theory*. URSI, 2010-08-16.

C29. R. Tian and B. K. Lau. Six-port antennas for experimental verification of six degrees-of-freedom in wireless channels. In *COST2100 12th MCM, TD(10)12054*, 2010-11-23.

C30. N. Wellander and G. Kristensson. Electromagnetic cloaking by change of variables. In *International Symposium on Electromagnetic Theory*, 2010-08-16–19.

3.7 Thesis publications

T1. A. Bernland. *Sum rules and constraints on passive systems - a general approach and applications to electromagnetic scattering*. Licentiate thesis, Lund University, 2010.

T2. A. Kazemzadeh. *Design and Analysis of Nonmagnetic Specular Radar Absorbing Materials*. PhD thesis, Lund University, 2010.

T3. K. Persson. *Retrieval of equivalent currents by the use of an integral representation and the extinction theorem — radome applications*. Licentiate thesis, Lund University, 2010.

3.8 Diploma works

The diploma works listed below can be downloaded from our web-page with address: **www.eit.lth.se**

D1. Xiaoguang Wang and Xiang Gao, “Performance Evaluation of MIMO Terminals with Multipath Simulator”.
Advisor: Thomas Bolin, Sony Ericsson Mobile Communications AB
Examiner: Buon Kiong Lau

D2. Peng Li, “Antenna-Channel Interactions in On-Body Communications”.
Advisor: Buon Kiong Lau
Examiner: Anders Karlsson

D3. Joel Cramsky, “FEM-computations for electrostatic precipitators”.
Advisor: Anders Karlsson
Examiner: Richard Lundin

D4. Mladen Milutinovic and Ubaid Mahmood Khan, “Dual polarized dielectric resonator antennas”.
Advisor: Anders Derneryd, Ericsson Research
Examiner: Mats Gustafsson

D5. Mikael Håkansson, “Decoupling techniques for a multi-band MIMO antenna system”.
Advisors: Thomas Bolin and Zhinong Ying, Sony Ericsson Mobile Communications AB
Examiner: Buon Kiong Lau

3.9 Technical reports

The technical reports listed below can be downloaded from our web-page with address: **www.eit.lth.se**

TR1. Daniel Sjöberg and Mats Gustafsson, ”Realization of a matching region between a radome and a ground plane,”
LUTEDX/(TEAT-7183)/1-6/(2010).
Abstract: In order to reduce the monostatic signature of the junction between a radome and the metallic structure to which it is attached, a tapered resistive sheet can be used. In this paper, we describe an easy method to realize this tapering using geometric variations on a subwavelength scale, with a significant reduction of the number of processing steps as a result.

TR2. Kristin Persson, Mats Gustafsson, and Gerhard Kristensson, ”Reconstruction and visualization of equivalent currents on a radome using an integral representation formulation,”
LUTEDX/(TEAT-7184)/1-45/(2010).
Abstract: In this paper an inverse source problem is investigated. The measurement set-up is a reflector antenna covered by a radome. Equivalent currents are reconstructed on a surface shaped as the radome in order to diagnose the radome’s

interaction with the radiated field. To tackle this inverse source problem an analysis of a full-wave integral representation, with the equivalent currents as unknowns, is used. The extinction theorem and its associated integral equation ensure that the reconstructed currents represent sources within the radome. The axially symmetric experimental set-up reduces the computational complexity of the problem. The resulting linear system is inverted by using a singular value decomposition. We visualize how the presence of the radome alters the components of the equivalent currents. The method enables us to determine the phase shift of the field due to the transmission of the radome, i.e. the IPD (insertion phase delay). Also, disturbances due to defects, not observable in the measured near field, are localized in the equivalent currents. The results are also compared with earlier results where a scalar integral representation was employed.

TR3. Mats Gustafsson, ”Time-domain approach to the forward scattering sum rule,” *LUTEDX/(TEAT-7185)/1-14/(2010)*.
Abstract: The forward scattering sum rule relates the extinction cross integrated over all wavelengths with the polarizability dyadics. It useful for deriving bounds on the interaction between scatterers and electromagnetic fields, antenna bandwidth and directivity, and energy transmission through sub-wavelengths apertures. The sum rule is valid for linearly polarized plane waves impinging on linear, passive, and time translational invariant scattering objects. Here, a time-domain approach is used to clarify the derivation and the used assumptions. The time-domain co-polarized forward scattered field defines an impulse response. Energy conservation shows that this impulse response is the kernel of a passive convolution operator that imply that the Fourier transform of the impulse response is a Herglotz function. The forward scattering sum rule is finally constructed from integral identities for Herglotz functions.

TR4. Mats Gustafsson and Daniel Sjöberg, ”Sum rules and physical bounds on passive metamaterials,”
LUTEDX/(TEAT-7186)/1-19/(2010).
Abstract: Frequency dependence of the permittivity and permeability is inevitable in metamaterial applications such as cloaking and perfect lenses. In this paper, Herglotz functions are used as a tool to construct sum rules from which we derive physical bounds suited for metamaterial applications, where the material parameters are often designed to be negative or near zero in the frequency band of interest. Several sum rules are presented that relate the temporal dispersion of the material parameters with the difference between the static and instantaneous parameter values, which are used to give upper bounds on the bandwidth of the application. This substantially advances the understanding of the behavior of metamaterials with extraordinary material parameters, and reveals a beautiful connection between properties in the design band (finite frequencies) and the low- and high-frequency limit.

TR5. Mats Gustafsson, ”Accurate and efficient evaluation of modal Green's functions,”
LUTEDX/(TEAT-7187)/1-10/(2010).

Abstract: Accurate and efficient numerical evaluations of the modal Green's functions are essential in radar cross section, scattering, and antenna problems involving bodies of revolution. It is shown that a combination between the trapezoidal rule and Gauss-Hermite quadrature along the steepest-decent contours produce 10 digits of accuracy for a low computational cost in non-singular cases. The near singular cases are of similar accuracy for a slightly higher computational cost.

TR6. Alireza Kazemzadeh and Anders Karlsson, "Multilayered Wideband Absorbers for Oblique Angle of Incidence,"
LUTEDX/(TEAT-7188)/1-18/(2010).
Abstract: Design procedures of Jaumann and circuit analog absorbers are mostly formulated for normal angle of incidence. Only a few design methods considering oblique angle of incidence are published. The published methods are restricted to single resistive layer circuit analog absorbers or multilayered Jaumann absorbers with low permittivity spacers. General design procedures are developed in this paper for multilayered Jaumann and capacitive circuit absorbers. By expanding the scan and frequency compensation techniques to multilayered structures, Jaumann absorbers with outstanding performances are designed. A capacitive circuit absorber is presented with a stable frequency response up to 45° for both polarizations, having an ultra wide bandwidth of 26 GHz.

TR7. Alireza Kazemzadeh and Anders Karlsson, "Nonmagnetic Ultra Wideband Absorber with Optimal Thickness,"
LUTEDX/(TEAT-7189)/1-14/(2010).
Abstract: Design of ultra wideband absorbers with bandwidth ratios larger than 10:1 is investigated. It is explained that if there is no constraint on the total thickness of the absorber, achieving large bandwidths is straightforward. The problem becomes challenging when the minimization of the total thickness is considered. It is shown that for a given frequency response, the total thickness of a nonmagnetic absorber cannot be less than a theoretical limit. If a design method can reduce the total thickness to the theoretical limit level, its superiority over other design methods is doubtless. It is demonstrated that the capacitive circuit absorber approach has this unique feature. In order to clarify the design ideas and techniques, the optimal absorber is developed in different stages. It is shown that unequal periods for the low-pass frequency selective surfaces are essential for attaining the optimal performance.

TR8. Daniel Sjöberg and Christer Larsson, "Cramér-Rao bounds for determination of permittivity and permeability in slabs,"
LUTEDX/(TEAT-7190)/1-13/(2010).
Abstract: We compute the Cramér-Rao lower bounds for determination of isotropic permittivity and permeability in slabs using scattering data such as reflection and transmission coefficients. Assuming only the fundamental mode is propagating in the slab, the results are formally the same regardless if the slab is in free space, or inside a rectangular or coaxial waveguide. The bounds depend only on signal quality and not the actual inversion method used, making them suitable to evaluate a par-

ticular measurement setup. The results are illustrated with several measurements in a rectangular waveguide setting.

TR9. Anders Karlsson and Alireza Kazemzadeh, "On the Physical Limit of Radar Absorbers,"
LUTEDX/(TEAT-7191)/1-10/(2010).
Abstract: A previous investigation has shown that at normal angle of incidence, the integral of the reflectance over wavelength is bounded for a flat metal backed absorber. The bound is applicable to any absorber made of linear, time-invariant, causal and passive materials. We generalize the physical bound to arbitrary angle of incidence and polarization. Different design examples and numerical calculations are provided to investigate the inequalities. It is shown that the theoretical limit for TE polarization results in fair approximations of the integral of the reflectance over wavelength but the TM polarization overestimates the integral value. A simple relation for estimating the optimal thickness of a nonmagnetic absorber is suggested for arbitrary angle of incidence.

TR10. Alireza Kazemzadeh, "Thin Wideband Absorber with Optimal Thickness,"
LUTEDX/(TEAT-7192)/1-9/(2010).
Abstract: The known methods for designing nonmagnetic absorbers usually aim for either the reduction of total thickness or increase of absorption bandwidth by sacrificing the other parameter. The conventional circuit analog absorbers aim for large bandwidths whereas the newly proposed meta-material or optimized geometry designs try to reduce the thickness of the absorber. By the aid of the capacitive circuit absorber approach, an optimal method for designing thin absorbers with practical bandwidths is proposed. An absorber is designed for the whole radar X-band with total thickness about $\lambda/10$. It is shown that the absorber thickness is satisfactorily close to the theoretical limit. The effect of mutual coupling on the performance of thin absorbers are investigated and some techniques for reducing the mutual couplings are suggested.

TR11. Anders Bernland, Annemarie Luger and Mats Gustafsson, "Sum Rules and Constraints on Passive Systems,"
LUTEDX/(TEAT-7193)/1-28/(2010).
Abstract: A passive system is one that cannot produce energy, a property that naturally poses constraints on the system. A system on convolution form is fully described by its transfer function, and the class of Herglotz functions, holomorphic functions mapping the open upper half plane to the closed upper half plane, is closely related to the transfer functions of passive systems. Following a well-known representation theorem, Herglotz functions can be represented by means of positive measures on the real line. This fact is exploited in this paper in order to rigorously prove a set of integral identities for Herglotz functions that relate weighted integrals of the function to its asymptotic expansions at the origin and infinity.

The integral identities are the core of a general approach introduced here to derive sum rules and physical limitations on various passive physical systems. Although similar approaches have previously been applied to a wide range of specific applications, this paper is the first to deliver a general procedure together with the necessary proofs. This procedure is described thoroughly, and exemplified with examples from electromagnetic theory; one revisits Fano's matching equations, while another makes a link to the Kramers-Kronig dispersion relations and discusses physical limitations on metamaterials.

TR12. Anders Bernland, Mats Gustafsson, and Sven Nordebo, "Physical Limitations on the Scattering of Electromagnetic Vector Spherical Waves,"
LUTEDX/(TEAT-7194)/1-23/(2010).
Abstract: Understanding the interaction between electromagnetic waves and matter is vital in applications ranging from classical optics to antenna theory. This paper derives physical limitations on the scattering of electromagnetic vector spherical waves. The assumptions made are that the heterogeneous scatterer is passive, and has constitutive relations which are on convolution form in the time domain and anisotropic in the static limit. The resulting bounds limit the reflection coefficient of the modes over a frequency interval, and can thus be interpreted as limitations on the absorption of power from a single mode. They can be used within a wide range of applications, and are particularly useful for electrically small scatterers. The derivation follows a general approach to derive sum rules and physical limitations on passive systems on convolution form. The time domain versions of the vector spherical waves are used to describe the passivity of the scatterer, and a set of integral identities for Herglotz functions are applied to derive sum rules from which the physical limitations follow.

TR13. Mats Gustafsson, "Polarizability and physical bounds on antennas in cylindrical and rectangular geometries,"
LUTEDX/(TEAT-7195)/1-11/(2010).
Abstract: Recently developed physical bounds on antennas relate the directivity bandwidth product to the polarizability of the antenna structure. Although, the polarizability can be determined numerically for arbitrary objects, it is advantageous to have simple closed form expressions for canonical geometries. Here, rational approximations are presented for the polarizability of cylinders and planar rectangles.

TR14. Christer Larsson, Daniel Sjöberg, and Lisa Elmkvist, "Waveguide measurements of the permittivity and permeability at temperatures up to 1000 °C,"
LUTEDX/(TEAT-7196)/1-22/(2010).
Abstract: This paper describes a method to measure the permittivity and the permeability at temperatures from room temperature up to 1000 °C using a single rectangular waveguide. The hardware design of the setup that can handle these temperatures and the procedure that is required to correct for the thermal expansion is developed. This includes the sample displacement, the displacement of the calibration reference planes, the thermal expansion of the waveguide and the gap between the sample and the waveguide wall. Measurements on Macor® and NiZn Ferrite samples are performed in order to evaluate the performance of the setup and the procedure that is used to determine the permittivity and permeability from the measured S-parameters.

TR15. Andreas Ioannidis, ”On the cavity problem for the general linear medium in Electromagnetic Theory,”
LUTEDX/(TEAT-7197)/1-13/(2010).
Abstract: In this paper we study the propagation problem of a time harmonic electromagnetic field inside a cavity filled with a generic bianisotropic medium. We define the concepts of eigenfrequencies and modes of the cavity and we propose a method to prove their existence and countability. We extend, in this respect, the theory for the isotropic, homogeneous, lossless cavity.

TR16. Mats Gustafsson and Daniel Sjöberg, ”Physical bounds and sum rules for high-impedance surfaces,”
LUTEDX/(TEAT-7198)/1-17/(2010).
Abstract: High-impedance surfaces are artificial surfaces synthesized from periodic structures. The high impedance is useful as it does not short circuit electric currents and reflects electric fields without phase shift. Here, a sum rule is presented that relates frequency intervals having high impedance with the thickness of the structure. The sum rule is used to derive physical bounds on the bandwidth for high-impedance surfaces. Numerical examples are used to illustrate the result, and show that the physical bounds are tight.

TR17. Daniel Sjöberg, Mats Gustafsson, and Christer Larsson, ”Physical bounds on the all-spectrum transmission through periodic arrays: oblique incidence,”
LUTEDX/(TEAT-7199)/1-13/(2010).
Abstract: The performance of a low-pass screen designed to block electromagnetic waves in a stop-band is shown to have an upper bound defined by the static electric and magnetic polarizability per unit area of the screen. The bound is easy to calculate for all angles of incidence and polarizations, and applies regardless of how complicated the screen's microstructure is. For a homogeneous dielectric sheet the bound for TM polarization is more restrictive than the bound for TE, but this is not generally true for a screen with microstructure. The results are verified by measurements and simulations of oblique transmission through an array of split ring resonators, printed on a dielectric substrate.

TR18. Mats Gustafsson, Marius Cismasu, and Sven Nordebo, ”Absorption Efficiency and Physical Bounds on Antennas,”
LUTEDX/(TEAT-7200)/1-20/(2010).
Abstract: The all spectrum absorption efficiency appears in the physical bounds on antennas expressed in the polarizability dyadics. Here, it is shown that this generalized absorption efficiency is close to 1/2 for small idealized dipole antennas and for antennas with a dominant resonance in their absorption. Also, the usefulness of this parameter is analyzed for estimation of antenna performance. The results are illustrated with numerical data for several antennas.

TR19. Ruiyuan Tian, Buon Kiong Lau, and Zhinong Ying, ”Characterization of MIMO Antennas with Multiplexing Efficiency,”
LUTEDX/(TEAT-7201)/1-6/(2010).

Abstract: A simple and intuitive metric of multiplexing efficiency is proposed for evaluating the performance of MIMO antennas in the spatial multiplexing mode of operation. The metric is particularly useful for antenna engineers whose goal is to achieve the optimum antenna system design. Experimental results involving prototype mobile terminals highlight the effectiveness of our proposal.

TR20. Andreas D. Ioannidis, Gerhard Kristensson, and Ioannis G. Stratis, "On the well-posedness of the Maxwell system for linear bianisotropic media," *LUTEDX/(TEAT-7202)/1-25/(2010)*.

Abstract: The time dependent Maxwell system is supplemented with the constitutive relations of linear bianisotropc media and is treated as a neutral integro-differential equation in a Hilbert space. By using the theory of abstract Volterra equations and strongly continuous semigroups we obtain general well-posedness results for the corresponding mathematical problem.

TR21. Gerhard Kristensson, "The polarizability and the capacity change of a bounded object in a parallel plate capacitor," *LUTEDX/(TEAT-7203)/1-39/(2010)*.

Abstract: A method to solve the change in capacitance of an object in a parallel plate capacitor is developed. The integral representation of the potential is exploited in a systematic way to solve the potential everywhere inside the capacitor. In particular, the change in capacitance is extracted. The method shows similarities with the null field approach to solve dynamical problems.

---

4 Guests and Seminars

4.1 Visitors at the group of Electromagnetic Theory

Jørgen Bach Andersen, Department of Electronic Systems, Aalborg University, Aalborg, Denmark, September 27–October 9, 2010.

Curt Eidefeldt, The Swedish Defence Materiel Administration, FMV, Stockholm, Sweden, November 26, 2010.

Andreas Fhager, Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden, January 27, 2010.

Andreas Ioannidis, Hausdorff Center for Mathematics, Bonn, Germany, August 23–25, 2010.

Lars Jonsson, School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden, May 5–6, 2010.

Daniel Kipowski, Invest in Skåne, September 2, 2010.

Ahmed A. Kishk, Department of Electrical Engineering, University of Mississippi, USA, February 11, 2010.

Annemarie Luger, Centre for Mathematical Sciences, Lund, Sweden, several occasions during 2010.

Lars Malmgren, Maxlab, Lund, Sweden, January 18, 2010.

Peter Olsson, Chalmers, Göteborg, Sweden, November 1, 2010.

Ari Sihvola, Aalto University, Finland, February 4–5, 2010.

Håkan Strandberg, ECTECO Nordic AB, Lund, Sweden, March 31, 2010.

Ioannis Stratis, Department of Mathematics, University of Athens, Greece, August 22–28, 2010.

Björn Widenberg, Applied Composites AB, Linköping, Sweden, September 7, October 14, and December 2, 2010.

4.2 Seminars

Ari Sihvola, "Varieties of boundary conditions in electromagnetics," February 5, 2010.

Ahmed Kishk, "Design of Dielectric Resonator for Multi-Functions for Microwave Circuits and Antennas," February 11, 2010.

Håkan Strandberg, "Demonstration of modeFRONTIER," March 31, 2010.

Xiaoguang Wang and Xiang Gao, Presentation of Diploma thesis, "Performance Evaluation of MIMO Terminals with Multipath Simulator," May 7, 2010.

Peng Li, Presentation of Diploma thesis, "Antenna-Channel Interactions in On-Body Communications," May 21, 2010.

Lee Ford, "An overview of some research activities at the department of Electronic and Electrical Engineering at the University of Sheffield," May 27, 2010.

Joel Cramsky, Presentation of Diploma thesis, "FEM-computations for electrostatic precipitators," June 14, 2010.

Buon Kiong Lau, Career Preparation in Doctoral Education at the Department of Electrical and Information Technology, June 15, 2010.

Alexander Bondarik. Antenna course seminar, "60GHz High Speed Wireless Communication System," June 22, 2010.

Ioannis Stratis, “Some ideas from the theory of linear ODE and PDE control systems,” August 24, 2010.

Ioannis Stratis, “Controllability of Maxwell’s equations for complex media,” August 26, 2010.

Jørgen Bach Andersen, “MIMO Richness and Propagation” and ”Room Electromagnetics Applied to an Aircraft with Passengers,” September 29, 2010.

Mladen Milutinovic, Presentation of Diploma thesis, “Dual polarized dielectric resonator antennas,” October 12, 2010.

Mikael Håkansson, Presentation of Diploma thesis, “Decoupling techniques for a multi-band MIMO antenna system,” October 28, 2010.

Peter Olsson, “Can you hide from ultrasound? — Elastodynamic cloaking by means of fiber-reinforced materials,” November 1, 2010.

4.2.1 Internal seminar series

Gerhard Kristensson, “3D vision and polarization effects,” January 22, 2010.

Mats Gustafsson, “Physical bounds on High-impedance surfaces and cloaking,” October 22, 2010.

Alireza Kazemzadeh, “Nonmagnetic Specular RAM with Optimal Performance,” October 29, 2010.

Marius Cismasu, “Illustrations of Physical Bounds on Directive Antennas,” November 5, 2010.

Sena Esen Bayer Keskin, “A Reflection/Transmission Measurement System For Planar Materials and Verification By Thin Wire Grids,” November 12, 2010.

Alexander Bondarik, “60GHz Microstrip Antenna Examples,” November 26, 2010.

Anders Karlsson, “High frequency hydro acoustics,” December 3, 2010.

Daniel Sjöberg, “High temperature waveguide measurements of the permittivity and permeability,” December 10, 2010.

5 Visits and Lectures by the Staff

5.1 Visits to other institutes and departments

Anders Bernland:

School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden, October 13–14, 2010.

Marius Cismasu:

School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden, March 11, 2010.

Efield AB, Kista, Sweden, March 10, 2010.

Mats Gustafsson:

School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden, March 11, July 2, and September 3, 2010.

Montagnole, France, 3rd WP4 meeting in ISTIMES, September 9–10, 2010.

Department of Natural Sciences, Middlesex University, London, October 11, 2010.

Department of Signals and Systems, Chalmers, Göteborg, Sweden, May 19 and November 2, 2010.

Alireza Kazemzadeh:

Kickoff FoT25 Saab Electronic Defense Systems, Mölndal, Sweden, May 31, 2010.

Kickoff FMV-projekt, Saab, Linköping, Sweden, September 22, 2010.

Sigma Flyg, Saab Aerosystems AB, Linköping, Sweden, October 25, 2010.

Anders Karlsson:

SNRV (Swedish National Committee of URSI), , autumn meeting, The Royal Swedish Academy of Sciences, Stockholm, Sweden, October 19, 2010.

SNRV (Swedish National Committee of URSI) B/F meeting at Saab Communications, Växjö, Sweden, December 9, 2010.

Gerhard Kristensson:

Department of Mathematics, University of Athens, Greece, February 28–March 7, November 14–21, 2010.

RVK meeting at RUAG, Göteborg, Sweden, March 22, 2010.

SNRV (Swedish National Committee of URSI), annual meeting, Ludvika, Sweden, March 12–13, 2010.

Kickoff Teknikutveckling SAT, Saab, Järfälla, Sweden, May 25, 2010.

Kickoff FoT25, Saab Electronic Defence Systems, Mölndal, Sweden, May 31, 2010.

SNRV (Swedish National Committee of URSI), autumn meeting, The Royal Swedish Academy of Sciences, Stockholm, Sweden, October 19, 2010.

Sigma Flyg, Saab Aerosystems AB, Linköping, Sweden, October 25, 2010.

SNRV (Swedish National Committee of URSI) B/F meeting at Saab Communications, Växjö, Sweden, December 9, 2010.

Buon Kiong Lau:

Department of Signals and Systems, Chalmers University of Technology, Sweden, October 1 and 27, 2010.

School of Engineering & Science, Jacobs University Bremen, Germany, November 12, 2010.

Daniel Sjöberg:

Efield AB, Kista, Sweden, March 10, 2010.

Meeting NFFP5 EMSS, Efield AB, April 13, 2010.

Meeting NFFP5 EMSS, Fraunhofer Chalmers Centre, Göteborg, Sweden, June 21, 2010.

Startup meeting Teknikinnovativa studier, Saab Aeronautics, Linköping, Sweden, September 22, 2010.

Meeting SAT 10–12, Saab, Stockholm, Sweden, October 26, 2010.

Meeting Multifunctional perimeter, Electronic Defence Systems, Mölndal, Sweden, November 19, 2010.

Meeting Micro Modelling, FOI, Linköping, Sweden, October 27, December 20, 2010.

Meeting Multifunctional perimeter, Saab, Linköping, Sweden, December 21, 2010.

Christian Sohl:

Saab Electronic Defence Systems, Järfälla, Sweden, August 25, 2010.

5.2 Guest Lectures by the department's staff

Anders Bernland:

School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden. *Title of the talk:* "Sum Rules for Passive Systems and Limitations on the Scattering of Spherical Modes," October 13, 2010.

Mats Gustafsson:

SonyEricsson, Lund Sweden. *Title of the talk:* "Physical bounds and sum rules in antenna and electromagnetic theory," February 23, 2010.

School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden. *Title of the talk:* "Physical bounds and sum rules in antenna and electromagnetic theory," March 11, 2010.

Lunds Matematiska Sällskap, Lund, Sweden. *Title of the talk:* "Herglotz functions, physical bounds, and sum rules in antenna and electromagnetic theory," November 9, 2010.

Gerhard Kristensson:

Department of Mathematics, University of Athens, Greece. *Title of the talk:* "Cloaking of electromagnetic waves," March 4, 2010.

Department of Mathematics, University of Athens, Greece. *Title of the talk:* "Physical bounds in electromagnetic scattering problems," March 5, 2010.

Department of Mathematics, University of Athens, Greece. *Title of the talk:* "Implications on passive systems by the use of analytic function theory," November 19, 2010.

Buon Kiong Lau:

Department of Signals and Systems, Chalmers University of Technology. *Title of the talk:* "Efficient MIMO Antennas for Compact Terminals," October 1, 2010.

5.3 Awards

Mats Gustafsson, Christian Sohl, and Gerhard Kristensson:

2010 Sergei A. Schelkunoff Prize Paper Award. *Title of the paper:* "Illustrations of new physical bounds on linearly polarized antennas," IEEE Transactions on Antennas and Propagation, vol. 57, no. 5, pp. 1319–1327, May 2009.

Figure 12: Alireza (left) receives his Young Scientist Best Paper Award, 2nd prize, at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany, from the hands of the CST representative (right), August 18, 2010.

Alireza Kazemzadeh:

> Young Scientist Award at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany, August 16–19, 2010.
>
> Young Scientist Best Paper Award, 2nd prize, at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany, August 16–19, 2010, see Figure 12. The prize was € 750.- sponsored by CST AG, Germany.

Vanja Plicanic, Buon Kiong Lau, Zhinong Ying and Anders Derneryd:

> 2010 CST University Publication Award. *Title of the paper*: "Actual diversity performance of a multiband diversity antenna with hand and head effects," IEEE Transactions on Antennas and Propagation, vol. 57, no. 5, pp. 1547–1556, 2009. The prize was two additional seats of CST Microwave Studio Educational License.

5.4 Organization of Courses and Workshops

1. Mikromodellering workshop, FOI, Linköping, February 16, 2010.

Figure 13: Some of the participants at the Banquet at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany, August 18, 2010. Left: Harmen Schippers (NLR, The Netherlands), Gerhard Kristensson, Daniel Sjöberg, and Anders Stjernman (Ericsson). Right: Magnus Gustafsson (FOI), Niklas Wellander, and Mats Gustafsson.

5.5 Participation in conferences and workshops

Anders Bernland:

Presented an invited paper at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the paper:* "Sum Rules and Constraints on Passive Systems with Applications in Electromagnetics," August 16–19, 2010, see Figure 14.

Marius Cismasu:

Presented a paper at 20th International Conference on Applied Electromagnetics and Communications (ICECOM 2010), Dubrovnik, Croatia. *Title of the Paper:* "Illustrations of Physical Bounds on Directive Antennas," September 2010.

Anders Derneryd:

Participated in the International Workshop on Antenna Technology: Small Antennas, Innovative Structures and Materials, iWAT 2010, Lisbon, Portugal, March 1–3, 2010.

Mats Gustafsson:

Presented a paper at the 4th European Conference on Antennas and Propagation, EuCAP 2010, in Barcelona, Spain. *Title of the paper:* "Constraints on the temporal dispersion of metamaterials," April 12–16 2010.

Participated in UN1 strategidag, Trolleholm, Sweden, April 23, 2010.

Figure 14: Some of the participants at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany, August 16–19, 2010. From left standing: Elena Cherkaev (University of Utah), Christian Sohl, Lars Jonsson (KTH), Mats Gustafsson, Martin Norgren (KTH), Niklas Wellander, Anders Stjernman (Ericsson), Anders Karlsson, Tomas Lundin (Saab), and Alireza Kazemzadeh. From the left kneeling: Magnus Gustafsson (FOI), Staffan Ström (KTH), Christian Engström (ETH, Zürich), Anders Bernland, and Daniel Sjöberg. Behind the camera: Gerhard Kristensson.

Presented an invited paper at the 27th International Review of Progress in Applied Computational Electromagnetics (ACES 2010) in Tampere, Finland. *Title of the paper:* "Physical bounds on the partial realized gain," April 26–29, 2010.

Participated with an oral presentation at the Charmant workshop, Chalmers, Sweden. *Title of the talk:* "Biomedical Applications of EM Microwave Tomography," May 19, 2010.

Participated in the 3rd Workshop of the Sino-Swedish Cooperative Program: IMT-Advanced and Beyond Uppsala University, Uppsala, Sweden, June 21–22, 2010.

Chairman at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the session:* "Analytic identities and limitations in electromagnetic theory," August 16–19, 2010.

Presented an invited paper at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the paper:* "Sum rules and physical bounds in electromagnetic theory," August 16–19, 2010.

Participated with an invited oral presentation at the 3rd Gap Wave Workshop at Chalmers, Sweden. *Title of the talk:* "Physical bounds on artificial structures," October 14-15 2010.

Presented a poster at the First National Symposium on Technology and Methodology for Security and Crisis Management (TAMSEC 2010) in Linköping, Sweden. *Title of the paper:* "Information fusion in electromagnetic sensing," October 27–28, 2010.

Anders Karlsson:

Presented a paper at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the paper:* "On the Physical Limit of Radar Absorbers," August 16–19, 2010.

Alireza Kazemzadeh:

Presented an invited paper at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the paper:* "Thin Wideband Absorber with Optimal Thickness," August 16–19, 2010.

Gerhard Kristensson:

Participated in the workshop on Micromodeling, FOI, Linköping, Sweden. February 16, 2010.

Chairman at the conference GigaHertz, Lund, Sweden. March 9, 2010.

Participated in the Commission B Technical Advisory Board (B-TAB) of URSI Commission B, Berlin, Germany. April 24–25, 2010.

Chairman at two sessions at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Titles of the sessions:* "Analytic identities and limitations in electromagnetic theory," and "Complex Media," August 16–19, 2010.

Participated with an oral presentation at the workshop on SAT, FHS/Livgardet, Stockholm, Sweden. *Title of the Talk:* "Cloaking — (o)möjligt," April 20–21, 2010.

Christer Larsson:

Presented a paper at the 4th European Conference on Antennas and Propagation, EuCAP 2010, in Barcelona, Spain. *Title of the paper:* "Calibration methods for wideband forward RCS measurements," April 12–16 2010.

Presented a paper at 20th International Conference on Applied Electromagnetics and Communications (ICECOM 2010), Dubrovnik, Croatia. *Title of the Paper:* "High temperature waveguide measurements of the permittivity and permeability," September 2010.

Buon Kiong Lau:

Special Session Convener and Chairman (with Zhinong Ying, Sony Ericsson Mobile Communications AB) at the 2010 IEEE International Symposium on Antennas and Propagation and CNC/USNC/URSI National Radio Science Meeting, Toronto, Canada. *Title of the session:* "Antenna-channel interactions in practical MIMO implementations," July 11–17, 2010.

Presented a special session paper at the 2010 IEEE International Symposium on Antennas and Propagation and CNC/USNC/URSI National Radio Science Meeting, Toronto, Canada. *Title of the paper:* "Downlink cooperative MIMO in urban macrocell environments", July 11–17, 2010.

Special Session Convener and Chairman (with Prof. Reiner Thomä, Ilmenau Technical University, Germany) and Chairman of a regular oral session in 2010 European Conference on Antennas and Propagation (EuCAP), Barcelona, Spain. *Titles of the sessions:* "MIMO Performance Evaluation" and "MIMO Antenna 1", April 12–16, 2010.

Participated at the 2010 International Workshop on Antenna Technology, Portugal, Lisbon, March 1–3, 2010.

Co-Chairman of Subworking Group 2.2 at the COST Action 2100 Management Committee Meetings in Athens, Greece (February 3–5, 2010), Aalborg, Denmark (June 2–4, 2010), Bologna, Italy (November 23–25, 2010).

Presented a temporary document (TD) at the COST Action 2100 Management Committee Meetings in Aalborg, Denmark. *Title of the TD:* "On RF implementation of WINNER II channel models for MIMO OTA performance evaluations," June 2–4, 2010.

Presented two temporary documents (TDs) at the COST Action 2100 Management Committee Meetings in Bologna, Italy. *Title of the TDs:* "On bandwidth enhancement of compact multiple antennas with parasitic decoupling" and "Six-port antennas for experimental verification of six degrees-of-freedom in wireless channels," November 23–25, 2010.

Daniel Sjöberg:

Participated in the HSWC workshop on Self Organizing Wireless Networks, Mölle, Sweden, April 19-20, 2010.

Participated in UN1 strategidag, Trolleholm, Sweden, April 23, 2010.

Chairman at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the session:* "Micromodeling and Characterization of Composite Materials," August 16–19, 2010.

Presented two invited papers at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Titles of the papers:* "All-spectrum oblique transmission through a periodic screen," and "Characterization of composite materials in waveguides," August 16–19, 2010.

Presented two posters at the Loughborough Antennas and Propagation Conference (LAPC 2010), Loughborough, UK. *Titles of the papers:* "A physical bound on high impedance surfaces", and "Admittance Matching of 60 GHz Rectangular Dielectric Resonator Antennas for Integrated Impulse Radio". November 8–9, 2010.

Christian Sohl:

Presented a paper at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Titles of the paper:* "The T-Matrix Method for Solving Two-Dimensional Scattering Problems," August 16–19, 2010.

Niklas Wellander:

Chairman at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the session:* "Micromodeling and Characterization of Composite Materials," August 16–19, 2010.

Presented an invited paper at the URSI International Symposium on Electromagnetic Theory (EMTS 2010), Berlin, Germany. *Title of the paper:* "Electromagnetic Cloaking by Change of Variables," August 16–19, 2010.

5.6 Examination committees

Anders Karlsson:

Member of examination for Xuan Li, Division of Electromagnetic Engineering, KTH, Stockholm, Sweden. *Title of thesis:* "Imaging subwavelength information with layered metamaterials," April 30, 2010.

Gerhard Kristensson:

Member of the examination committee for Gvidas Astromskas, Department of Physics, Lund University, Sweden. *Title of thesis:* "Electrical characterization of integrated InAs nano-structures," December 14, 2010.

Buon Kiong Lau:

A pre-examiner for the doctoral thesis of Juha Toivanen, Department of Radio Science and Engineering, Aalto University, Finland. *Title of the thesis:* "Measurement Methods for Mobile Terminal Antenna Performance," July 2010.

Reviewer of the licentiate thesis defense of Xiaoming Chen, Department of Signals and Systems, Chalmers University of Technology, Sweden. *Title of the thesis:* "Reverberation Chamber Characterization for Passive and Active OTA Measurements," October 1, 2010.

Daniel Sjöberg:

External reviewer of the Licentiate thesis for Alireza Motevasselian, Department of Electromagnetic Engineering, School of Electrical Engineering, Royal Institute of Technology, Stockholm, Sweden. *Title of thesis:* "On the Scattering Reduction of an Aircraft Wing Profile Enclosing an Antenna", May 25, 2010.

5.7 Referee for international journals and conferences

Anders Derneryd:

IET Electronics Letters

IET Proc. Microwaves, Antennas and Propagation

IEEE Transactions on Antenna and Propagation

40th European Microwave Conference (EuMC 2010)

Mats Gustafsson:

IEEE Antennas and Wireless Propagation Letters

IEEE Transactions on Antenna and Propagation

IEEE Geoscience and Remote Sensing Letters

URSI International Symposium on Electromagnetic Theory (EMTS 2010)

Gerhard Kristensson:

Wave Motion (as editor)

URSI International Symposium on Electromagnetic Theory (EMTS 2010)

Christer Larsson:

IEEE Transactions on Antenna and Propagation

Buon Kiong Lau:

IEEE Transactions on Antenna and Propagation

IEEE Antennas and Wireless Propagation Letters

IEEE Transactions on Wireless Communications

IET Microwaves, Antennas & Propagation

Daniel Sjöberg:

European Journal of Physics

Physical Review E

URSI International Symposium on Electromagnetic Theory (EMTS 2010)

Christian Sohl:

IEEE Transactions on Antennas and Propagation

URSI International Symposium on Electromagnetic Theory (EMTS 2010)

Ruiyuan Tian:

IEEE Transactions on Antennas and Propagation

Progress in Electromagnetics Research

IEEE 71st Vehicular Technology Conference (VTC2010-Spring)

IEEE 72nd Vehicular Technology Conference(VTC2010-Fall)

Niklas Wellander:

SIAM Multiscale Modeling and Simulation

SIAM Journal on Scientific Computing

URSI International Symposium on Electromagnetic Theory (EMTS 2010)

5.8 Other activities

Mats Gustafsson:

Participated in the course: "Teaching and Learning Through English" during the fall 2010.

Invited to a reception with the Vice-Chancellor Per Eriksson, Lund University, Lund, Sweden, November 11, 2010.

Gerhard Kristensson:

> Invited to a reception with the Vice-Chancellor Per Eriksson, Lund University, Lund, Sweden, November 11, 2010.

Christian Sohl:

> Participated in the course "Akademisk hederlighet — studenter bortom plagiat" during the fall, 2010.
>
> Participated in the course "Den goda föreläsningen" during the fall, 2010.
>
> Invited to a reception with the Vice-Chancellor Per Eriksson, Lund University, Lund, Sweden, November 11, 2010.

Daniel Sjöberg:

> Participated as a mentor in the Lund University Mentorship programme for Engineering PhD students (PLUME).

---

6 Teaching Activities

6.1 Undergraduate teaching

The Electromagnetic Theory group gives courses in Circuit Theory and in Electromagnetic Field Theory. The students come from five educational programs: Engineering Physics (F), Electrical Engineering (E), Computer Science (D), Engineering Mathematics (Pi), and Engineering Nanoscience (N). In order to complete one of these programs the student must accomplish 300 ECTS credits, where one academic year corresponds to 60 ECTS credits. The nominal time to complete one of these programs is thus five years. The group also teaches courses in the international master program Wireless Communication (MWIR), corresponding to the final two years. An overview of the courses is presented in Figure 15.

6.1.1 Undergraduate courses given during 2010

Program[a]	Name of the Course	Lecturer[b]
E1	Electronics	**Anders Karlsson**
		Alexander Bondarik
D1	Electronics	**Anders J Johansson**
F2, N2	Electromagnetics and Electronics	**Richard Lundin**
		Kristin Persson
E3	Electromagnetic Fields	**Richard Lundin**
		Christian Sohl
E3	Engineering Aspects of an Application	Richard Lundin
F3	Electromagnetic Field Theory	**Gerhard Kristensson**
		Anders Bernland
Pi3	Electromagnetic Field Theory	**Gerhard Kristensson**
		Anders Bernland
E3	Electromagnetic Fields, Advanced Course	**Richard Lundin**
E3, F3, Pi4, MWIR1	Antenna Technology	**Mats Gustafsson**
		Rohit Chandra
		Anders J Johansson
		Ruiyuan Tian
E4, F4, Pi4	Electromagnetic Wave Propagation	**Daniel Sjöberg**
D4, E4, C5, MWIR2	Multiple Antenna Systems	**Buon Kiong Lau**
		Ruiyuan Tian

[a] F1=Engineering Physics, first year; E1=Electrical Engineering, first year; D2=Computer Science, second year *etc.*, MWIR = Master program in Wireless Communications.

[b] The examiner/lecturer is given in bold face.

6.1.2 A brief presentation of the courses

ESS010 Electronics (15 ECTS credits, 110 hours):
Given for the first year students of the Electrical Engineering, or E-, program. Approximately 100 students.
Course literature: Hambley, "Electric Engineering," Pearson, 2008; "Kretsteori, ellära och elektronik, exempelsamling," 2010.

ETIA01 Electronics: (8 ECTS credits, 116 hours):
Given for the first year students of the Computer Science, or D-, program. Approximately 150 students.
Course literature: Hambley, "Electric Engineering," Pearson, 2008; "Kretsteori, ellära och elektronik, exempelsamling," 2010.

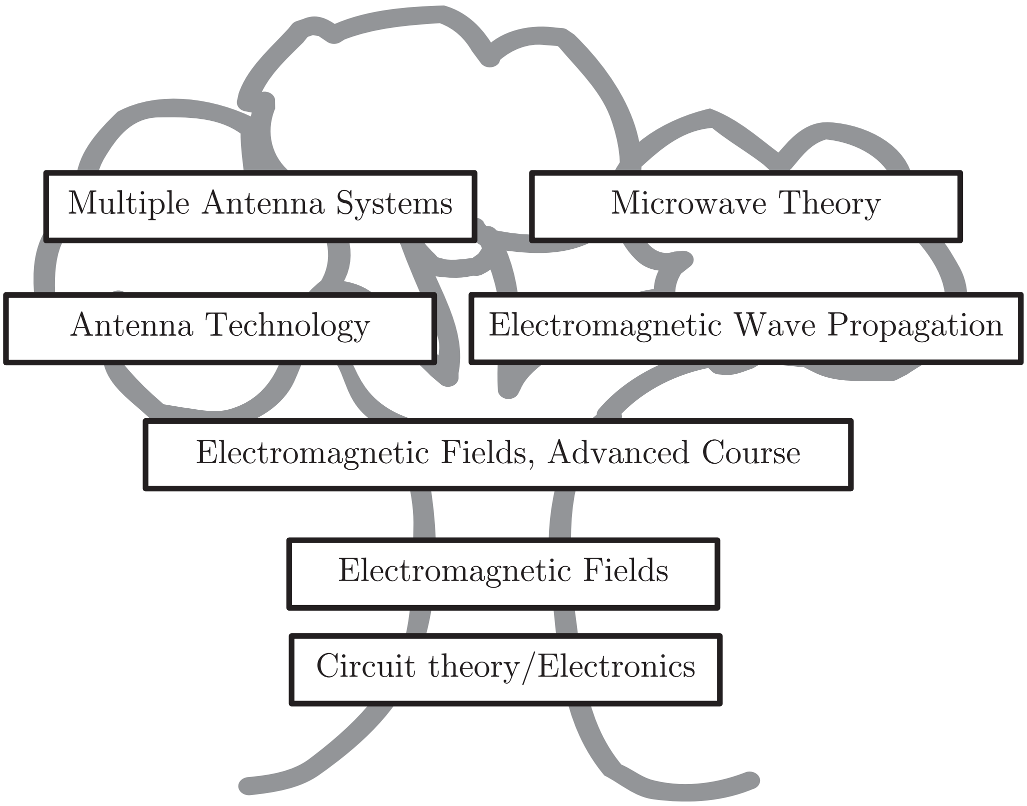


Figure 15: The undergraduate courses given by the Electromagnetic Theory group.

ETE115 Electromagnetics and Electronics (7.5 ECTS credits, 62 hours):
Given for the second year students of the Engineering Physics and Engineering Nanoscience, or F- and N-, programs. Approximately 120 students.
The course includes: Potential, voltage, current, voltage source, current source, resistor, Ohm´s law, Kirchhoff´s laws. Capacitors, inductors, differential equations, phasors, impedance, admittance, power. Node-voltage method, Thevenin and Norton equivalents. Transfer function, Bode diagram, filters. Diodes, field-effect transistors and operational amplifiers. Transmission line theory. Electrostatics. Magnetostatics. Maxwell's equations. Properties of materials.
Course literature: D. Sjöberg and M. Gustafsson, "Kretsteori, ellära och elektronik," Dept. Electrical and Information Technology, Lund University, 2008; problem collection; "Kretsteori, ellära och elektronik, exempelsamling," 2010.

ESS050 Electromagnetic Fields (9 ECTS credits, 84 hours):
Given for the third year students of the Electrical Engineering, or E-, program. Approximately 50 students.
Vector analysis: Scalar fields and vector fields. Gradient, divergence and curl in Cartesian coordinates. Gauss's theorem and Stokes's theorem. Cylindrical coordinates. Spherical coordinates.
Quasi-stationary fields: Coulomb's law. Electrostatic fields in vacuum. Fields in

the presence of dielectrics. Electric images. Current fields. Biot-Savart's law. Magnetostatic fields in vacuum. Magnetic fields in material media. Magnetic circuits.
General electromagnetic fields: The Maxwell equations. Plane waves. Retarded potentials. Radiation fields from known sources and simple antennas. The Poynting vector.
Course literature: Popovic and Popovic, "Introductory Electromagnetics," Prentice-Hall, 2000; lecture notes; problem collection, KF Sigma 2002.

ESS081 Engineering Aspects of an Application (6 ECTS credits, 50 hours):
Given for the third year students of the Electrical Engineering, or E-, program. Approximately 50 students.
The course comprises an electrotechnical project and a series of lectures dealing with environmental problems and sustainable development. The project work is done in groups of four students. The students write technical reports and make oral presentations.

ETE055 Electromagnetic Field Theory (6 ECTS credits, 56 hours):
Given for the third year students of the Engineering Physics program. Approximately 90 students.
The course is an introductory course in the basic electro-static and magneto-static problems. It covers the basic laws such as the Coulomb's and Biot-Savart's laws. The latter part of the course covers the electromagnetic problems, the Poynting vector, and the Maxwell equations. Basic wave propagation problems, *i.e.*, plane waves, retarded potentials, and radiation fields from known sources and simple antennas are also part of this course.
Course literature: D. J. Griffiths, "Introduction to Electrodynamics," Prentice-Hall, 1999; problem collection, KF Sigma 2004.

ETEF01 Electromagnetic Field Theory (7 ECTS credits, 66 hours):
Given for the third year students of the Engineering Mathematics program. Approximately 40 students.
The course is an introductory course in the basic electro-static and magneto-static problems. It covers the basic laws such as the Coulomb's and Biot-Savart's laws. The latter part of the course covers the electromagnetic problems, the Poynting vector, and the Maxwell equations. Basic wave propagation problems, *i.e.*, plane waves, retarded potentials, and radiation fields from known sources and simple antennas are also part of this course.
Course literature: D. J. Griffiths, "Introduction to Electrodynamics," Prentice-Hall, 1999; problem collection, KF Sigma 2004.

ETI015 Electromagnetic Fields, Advanced Course (6 ECTS credits, 56 hours):
Given for the third year students of the Electrical Engineering, or E-, program. Approximately 15 students.
The course focuses on: transmission line theory, wave propagation in free space and conductive medium, rectangular metallic waveguides and antenna theory.

Course literature: Popovic and Popovic, "Introductory Electromagnetics," Prentice-Hall, 2000; lecture notes; problem collection, KF Sigma 2002.

ETEN10 Antenna technology (7.5 ECTS credits, 50 hours):
Given for the fourth year students of the Engineering Physics, Electrical Engineering, and Engineering Mathematics, or F-, E-, and Pi-programs, and the international master program: Wireless Communication. Approximately 50 students.
Basic electromagnetic principles with applications to antenna design and analysis are treated in this course. A broad range of antenna types from single antenna elements to arrays of radiating elements and continuous sources are covered. Synthesis of radiation patterns is included as an integral part. The course gives a good understanding and knowledge of various types of antennas, their characteristics and various applications. Three laboratory exercises have to be carried out. These involve computer simulation and measurements of antenna parameters.
Course literature: Kraus, J. D. and Marhefka, R., "Antennas". 3 ed., McGraw-Hill, 2002.

ETEN05 Electromagnetic Wave Propagation (7.5 ECTS credits, 46 hours):
Given for the fourth year students of the Engineering Physics, Electrical Engineering, and Engineering Mathematics, or F-, E-, and Pi-programs, and the international master program: Photonics. Approximately 15 students.
Basic electromagnetic wave propagation is described in this course. The emphasis is laid on the propagation properties of plane harmonic waves in homogeneous media. Other topics treated in some detail are: dispersion, reflection, transmission, and scattering in homogeneous and inhomogeneous (stratified) media.
Course literature: Sophocles J. Orfanidis: Electromagnetic Waves and Antennas, `http://www.ece.rutgers.edu/~orfanidi/ewa/`.

ETEN01 Microwave Theory (7.5 ECTS credits, 60 hours):
This course is given every other year for the fourth year students of the Engineering Physics, the Engineering Mathematics, and the Electrical Engineering, or F-, Pi-, and E-, programs. Approximately 30 students. This course was not given 2010.
A theoretical treatment, based upon the Maxwell equations, of wave propagation in guided structures is the basis for this project course. Three projects are performed, one of which is presented orally. The projects involve mathematical modeling and analysis as well as numerical treatment.
Course literature: A. Karlsson and G. Kristensson, "Microwave theory ," Lund, 2010.

EITN10 Multiple Antenna Systems (7.5 ECTS credits, 42 hours):
This course is given annually during the fall for second year students enrolled in the Wireless Communications Master Program. It is also open for students enrolled in other programs (D4, E4, C5, MWIR2). Approximately 20 students.
The aim of this course is to provide a comprehensive treatment of the area of multiple antenna systems for wireless communications. It begins with the theoretical aspects of multiple antenna or multiple-input-multiple-output (MIMO) systems, which predicts huge performance gains in comparison to conventional single antenna systems.

The critical role of overall channel gain and correlation (e.g. influence of line-of-sight (LOS) component in a scenario) in MIMO system performance will be emphasized. The theoretical results provided the momentum for practical implementations, several aspects of which will be covered in the course.
Course literature: Paulraj A, Nabar R, and Gore D: Introduction to Space-Time Wireless Communications, Cambridge University Press, UK, 1996. ISBN 0-521-82615-2.

6.2 Other teaching activities

Buon Kiong Lau:

> Career preparation in doctoral education at the departmental level Lund Institute of Technology's 6th Pedagogical Inspiration Conference (LTHs 6:e Pedagogiska Inspirationskonferens), Lund, Sweden. December 12, 2010.

Daniel Sjöberg

> Career preparation in doctoral education at the departmental level Lund Institute of Technology's 6th Pedagogical Inspiration Conference (LTHs 6:e Pedagogiska Inspirationskonferens), Lund, Sweden. December 12, 2010.

6.3 Diploma Works

See **3.8 Diploma Works**.

6.4 Development and revisions of teaching materials

Anders Karlsson and Gerhard Kristensson:

> *Exempelsamling i Elektromagnetisk fältteori för F3 och Pi3.* 2010.

Gerhard Kristensson:

> *Solution manual to Second order differential equations - special functions and their classification.* 2010.

Daniel Sjöberg:

> Developed several python GUI demonstration programs for the course ETEN05 Electromagnetic Wave Propagation.

6.5 Graduate courses

Buon Kiong Lau:

EITN10 Multiple Antenna Systems, 7.5 credits points, fall 2010.

Mats Gustafsson:

ETEN10 Antenna technology, 7.5 credits points, fall 2010.

Anders Karlsson:

Accelerator technique, 7.5 credit points, spring, 2010.

Daniel Sjöberg:

ETEN05 Electromagnetic Wave Propagation, 7.5 credits points, fall 2010.

6.6 External teaching

Buon Kiong Lau:

One of several lecturers in the course "Characterization of MIMO and diversity antenna systems in reverberation chamber", Department of Signals and Systems, Chalmers University of Technology. *Title of the lecture:* "Practical MIMO Antenna Design & OTA Standardization Overview — in relation to COST2100 SWG2.2 activities," October 25–29, 2010.

Daniel Sjöberg:

Commissioned teaching at FOI, Linköping, Sweden. Corresponding to the advanced course ETEN05 "Electromagnetic Wave Propagation," 36h lectures, March 18–June 17, 2010.

---

7 Official Commissions

7.1 Official scientific committees

Anders Derneryd:

Co-opted member of Section B of SNRV (Swedish National Committee of URSI).

Mats Gustafsson:

Co-opted member of Section B of SNRV (Swedish National Committee of URSI).

Anders Karlsson:

Member of SNRV (Swedish National Committee of URSI).

Chairman of Commission B of SNRV (Swedish National Committee of URSI).

Official delegate of SNRV (Swedish National Committee of URSI) for Commission B.

Gerhard Kristensson:

Member of SNRV (Swedish National Committee of URSI).

Chairman of SNRV (Swedish National Committee of URSI).

Official Swedish delegate of URSI (Swedish National Committee of URSI).

Member of the Commission B Technical Advisory Board (B-TAB) of URSI Commission B.

Member of the Board of Editors of the international journal *Wave Motion*.

Member of the Editorial and Review Board of the international journal *Journal of Electromagnetic Waves and Applications* and the publication series *Progress in Electromagnetic Research*.

Fellow of the Institute of Physics, UK.

Member of "Kungl. Fysiografiska Sällskapet i Lund".

Buon Kiong Lau:

Associate Editor of the *IEEE Transactions on Antennas and Propagation*.

Co-chairman of Subworking Group 2.2 on "Compact Antenna Systems for Terminals (CAST)" of COST Action 2100.

Technical Program Committee (TPC) Member of the 5th International Conference on Cognitive Radio Oriented Wireless Networks and Communications (Crowncom), Cannes, France, May 2010.

TPC Member of the IEEE 71th Vehicular Technology Conference (VTC) - Spring, Taipei, Taiwan, 15–19 May 2010.

Co-convener for oral session "Intelligent antennas" in 2010 Asia-Pacific Radio Science Conference (AP-RASC'2010), Toyama, Japan, 21–25 Sep. 2010.

Richard Lundin:

Co-opted member of Section B of SNRV (Swedish National Committee of URSI).

Daniel Sjöberg:

Co-opted member of Section B of SNRV (Swedish National Committee of URSI).

Niklas Wellander:

Co-opted member of Section B of SNRV (Swedish National Committee of URSI).

7.2 Other official committees

Mats Gustafsson:

Member of the Educational Board I at the Faculty of Engineering, Lund University (Utbildningsnämnd I, UN1).

Anders Karlsson:

Member of the Appointment Board II at the Faculty of Engineering, Lund University (Lärarförslagsnämnd II).

Gerhard Kristensson:

Member of the Board of the Faculty of Engineering (LTH), Lund University.

Member of the Board of the Department of Electrical and Information Technology, Lund University.

Buon Kiong Lau:

Director of Postgraduate Studies for the Department of Electrical and Information Technology, Lund University.

Daniel Sjöberg:

Director of Studies for the Department of Electrical and Information Technology.

Assistant Director of Studies for the Master of Science Educational Program in Engineering Physics at Lund University, Faculty of Engineering (biträdande programledare för civilingenjörsprogrammet i teknisk fysik vid LTH).

Inspector for the PhD Student Chapter of the Student Union at Lund Institute of Technology (Inspektor för doktorandsektionen vid Lunds tekniska högskola), May 18, 2010.