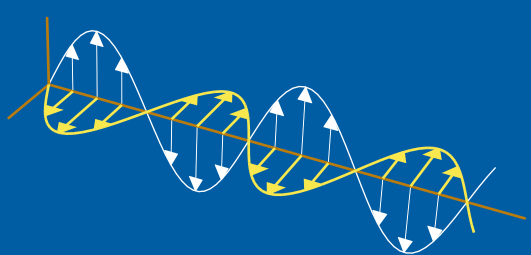
CODEN:LUTEDX/(TEAT-3021)/1-41/(2010)

Annual Report 2009

Electromagnetic Theory

Electromagnetic Theory
Department of Electrical and Information Technology
Lund University
Sweden



Editors: Gerhard Kristensson & Daniel Sjöberg

Lund, May 7, 2010

Preface

We are pleased to welcome another new graduate student, Marius Cismasu, to the group this year. Marius is engaged in the project entitled: "Physical bounds on the information capacity for MIMO and UWB antenna systems," supported by the Swedish Research Council (VR). We all wish him good luck in his graduate studies.

Figure 1: Marius Cismasu.

Vanja Plicanic, who is one of our external graduate student (industridoktorand from Sony Ericsson Mobile Communications AB), presented her Licentiate thesis in November under the supervision of Assistant professor Buon Kiong Lau, see Figure 8 on Page 11. We wish her all the success in her pursuit for the PhD exam. A short presentation of the contents of her thesis is given on Page 10.

Sven Nordebo has been a regular guest in the group during many years. He has contributed with his expertise in numerous projects and papers. Therefore, it is with great pleasure that we, this year, employed him part time in one of our EU projects. We are hoping for a continuing productive and fruitful collaboration.

Figure 2: Sven Nordebo.

Our research depends very much on financial support from external sources. In Section 1.6 on Page 4 a list our external funding during 2009 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, Försvarets materielverk (FMV). We are very grateful to these organizations for their generous supports.

A large portion of our research on antennas and communications is supported by the Center for High Speed Wireless Communication (HSWC), which is a center funded by the Swedish Foundation for Strategic Research (SSF). In particular, these projects encompass our efforts at higher frequencies, *i.e.*, at 60 GHz.

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 2. 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, Försvarets materielverk (FMV), we have completed a very interesting project on micromodeling. This project was quite multidisciplinary and enroled researchers from FOI and industry. We value these projects highly, since they give us insight into the problems that our leading industry in the country are facing.

Many conferences have been attended during 2009. A list of our efforts is presented on Page 23.

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 — analytic, numerical, and measurements — are relevant to us.

The main research activities are concentrated to the area of electromagnetic scattering theory and its 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 2009 is given in the following table:

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

[a] CI Master of Engineering; MSc Master of Science; Doc Docent; TeknD PhD in Engineering; FD Doctor of Philosophy, PhD

[b] D Graduate Student; P Professor; FA Postdoctoral Fellow; UL Senior Lecturer

[c]Started his employment 2009-10-01.

[d]Ended his employment 2009-03-31.

[e]Employed by the Communications group.

[f]Employed by the Communications group.

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
Vanja Plicanic	TeknL	Sony Ericsson Mobile Communications, Lund

[a] TeknL Licentiate in Engineering

1.4 Adjunct professors and Visiting scientists

Several Adjunct professors and Visiting scientists take active part in the scientific activities of the group of Electromagnetic Theory.

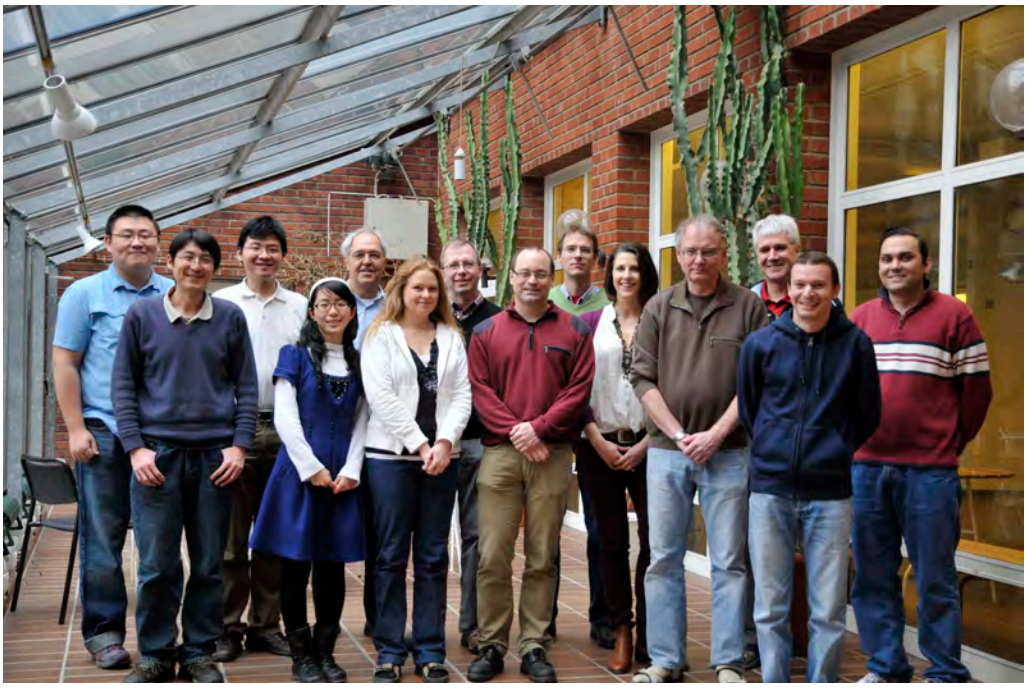


Figure 3: The Electromagnetic Theory group. From the left: Ruiyuan Tian, Yi Tan, Buon Kiong (Vincent) Lau, Hui Li, Gerhard Kristensson, Kristin Persson, Christer Larsson, Daniel Sjöberg, Niklas Wellander, Vanja Plicanic, Richard Lundin, Anders Karlsson, Marius Cismasu, and Alireza Kazemzadeh. The photo was taken March 12, 2010. Missing on the photo are Anders Bernland and Mats Gustafsson.

Name	**Degree** [a]	**Company**
Anders Höök[b]	TeknD	Saab Microwave Systems AB
Anders Derneryd	TeknD	Ericsson AB
Christer Larsson	FD	Saab Bofors Dynamics AB
Sven Nordebo[c]	P	Växjö University
Anders Sunesson	TeknD	Perlos
Niklas Wellander	TeknD	Swedish Defence Research Agency, FOI

[a] FD Doctor of Philosophy, PhD
P Professor
TeknD PhD in Engineering
[b] Ended his engagement 2009-04-01.
[c] Started his employment 2009-08-01.

A photo of the group is given in Figure 3.

1.5 URL-address

The home page of the Department of Electrical and Information Technology is: **www.eit.lth.se**. From this home page it is easy to find the home page of the group of Electromagnetic Theory.

1.6 External funding

The external research support during 2009 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)”.
- 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 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). *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”.
- Sony Ericsson Mobile Communications AB. Sponsoring the consulting professorship of Anders Derneryd.

- Sony Ericsson Mobile Communications AB. Financing of an external graduate student.
- Ericssons forskningsstiftelse (Ericsson Research Foundation). Partial financing of Michael A. Jensen as guest professor in "Advanced Antenna Systems".
- The Swedish Defence Materiel Administration, Försvarets materielverk (FMV). *Principal investigator:* Gerhard Kristensson. *Title of the project:* "Teknikstudier signaturanpassade radomer (Stealth radomes)".
- NFFP4, Nationellt flygforskningsprogram (National Aviation Research Program), 2006–2009. *Principal investigator:* Daniel Sjöberg.

2 Research Activities

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

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 3.5 and 3.8, 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

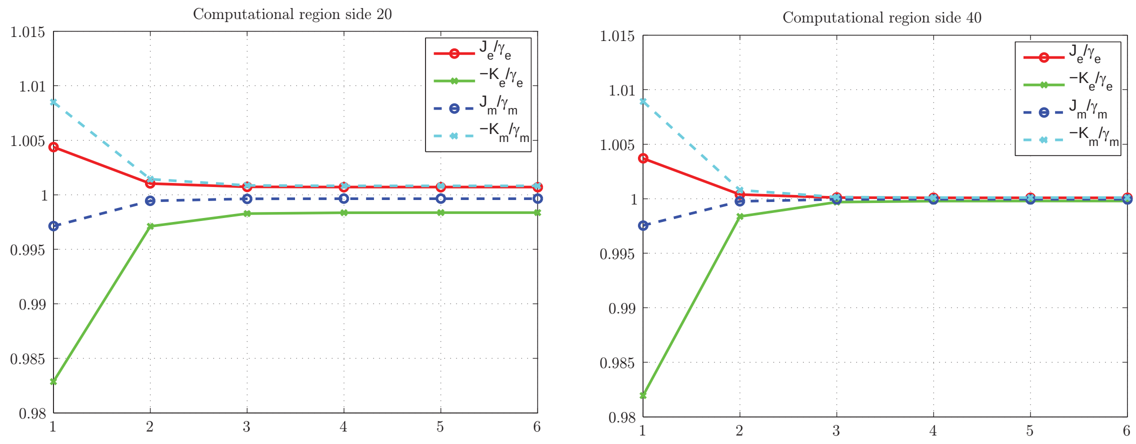


Figure 4: Example of a project under Section 2.1. The static electric and magnetic polarizability of a structure can be bounded by minimizing direct and dual energy functionals as shown in [3]. In the graphs to the left, the bounds are computed using scalar or vector potentials for solving the static field equations, and become sharper as the number of degrees of freedom increases (along the x-axis). The bounds in the right figure are sharper, since a larger computational volume is used, and hence the situation is more similar to the free space case it is supposed to model.

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. D. Sjöberg. Determination of propagation constants and material data from waveguide measurements. *Progress In Electromagnetics Research B*, **12**, 163–182, 2009.
2. D. Sjöberg. Low-frequency scattering by passive periodic structures for oblique incidence: low-pass case. *Journal of Physics A: Mathematical and Theoretical*, **42**, 2009.
3. D. Sjöberg. Variational principles for the static electric and magnetic polarizabilities of anisotropic media with perfect electric conductor inclusions. *Journal of Physics A: Mathematical and Theoretical*, **42**, 335403, 2009.

Conferences: C14

Technical reports: TEAT-7178

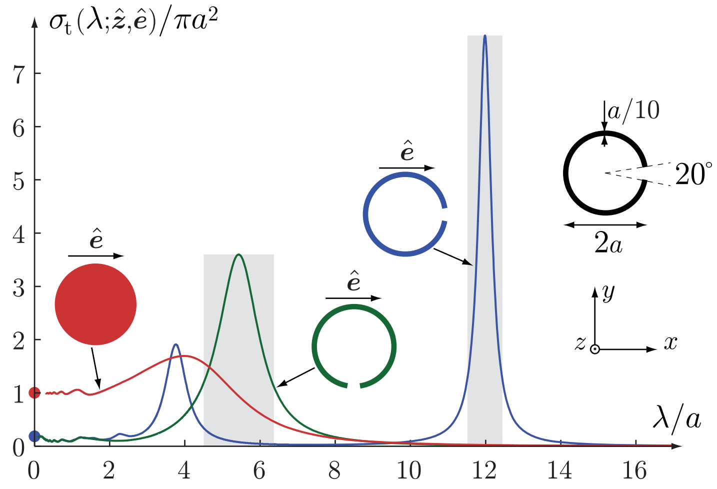


Figure 5: Example of a project under Section 2.2. Transmission cross sections for circular and split ring apertures in an opaque screen for an incident plane wave propagating in the normal direction of the screen.

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. Sum rule for the transmission cross section of apertures in thin opaque screens. *Optics letters*, **34**(13), 2003–2005, 2009.
2. M. Gustafsson, C. Sohl, C. Larsson, and D. Sjöberg. Physical bounds on the all-spectrum transmission through periodic arrays. *EPL (Europhysics Letters)*, **87**, 2009.

Conferences: C1–C2, C4, C7

Technical reports: TEAT-7181, TEAT-7182

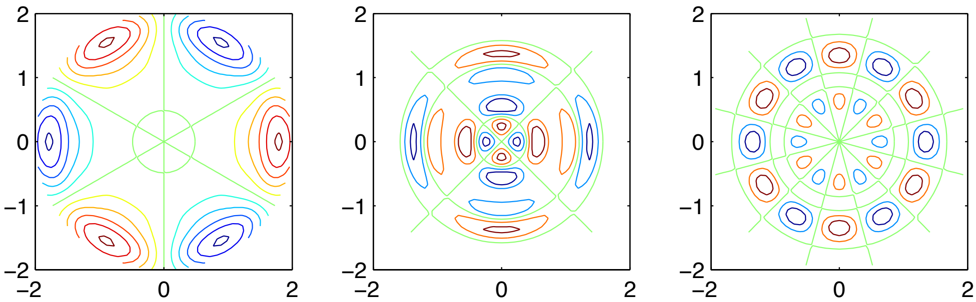


Figure 6: Example of a project under Section 2.3. A selection of useful eigenfunctions corresponding to the Fisher information operator for a two-dimensional circular domain. The cartesian x and y axes shown are normalized to the wavelength and the radius of the circular domain is $a = 2\lambda_0$.

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 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 and M. Gustafsson. A priori modeling for gradient based inverse scattering algorithms. *Progress In Electromagnetics Research B*, **16**, 407–432, 2009.

Conferences: C9–C10

Technical reports: TEAT-7179, TEAT-7180

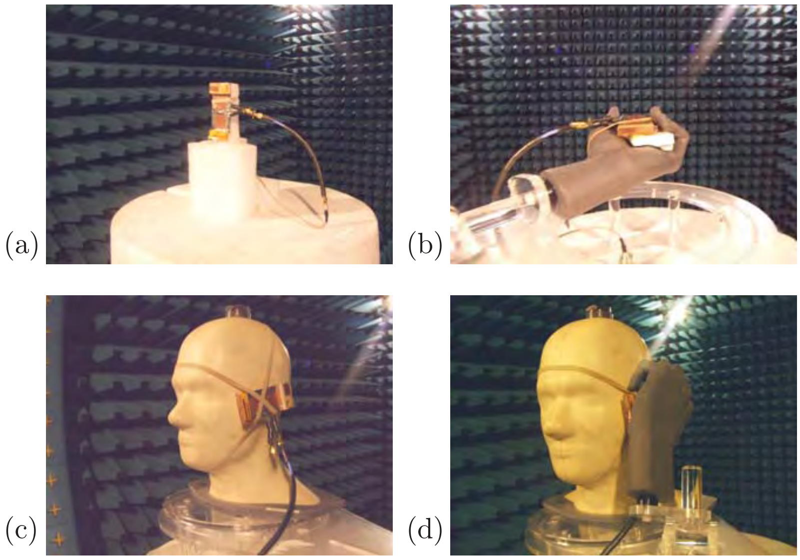


Figure 7: Example of a project under Section 2.4. Four different scenarios for diversity performance evaluation with user interaction.

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. Alayon Glazunov, M. Gustafsson, A. Molisch, F. Tufvesson, and G. Kristensson. Spherical Vector Wave Expansion of Gaussian Electromagnetic Fields for Antenna-Channel Interaction Analysis. *IEEE Transactions on Antennas and Propagation*, **57**(7), 2055–2067, 2009.
2. A. Derneryd, M. Gustafsson, G. Kristensson, and C. Sohl. Application of gain-bandwidth bounds on loaded dipoles. *IET Microwaves, Antennas & Propagation*, **3**(6), 959–966, 2009.

3. M. Gustafsson, C. Sohl, and G. Kristensson. Illustrations of new physical bounds on linearly polarized antennas. *IEEE Trans. Antennas Propagat.*, **57**(5), 1319–1327, 2009.
4. V. Plicanic and B. K. Lau. Impact of spacing and gain imbalance between two dipoles on HSPA throughput performance. *Electronics Letters*, **45**(21), 1063–1065, 2009.
5. V. Plicanic, B. K. Lau, A. Derneryd, and Z. Ying. Actual diversity performance of a multiband diversity antenna with hand and head effects. *IEEE Transactions on Antennas and Propagation*, **57**(5), 1547–1556, 2009.

Conferences: C8, C11–13, C15–16

Technical reports: TEAT-7177

3 Dissertations, Published papers and Reports

3.1 Doctoral dissertations

No doctoral dissertations were presented this year.

3.2 Licentiate dissertations

Vanja Plicanic, "Performance characterization of multiple antenna terminals." November 18, 2009.

Reviewer: Dr Jon Wallace, Jacobs University Bremen, Germany.

3.2.1 Short presentation of Vanja Plicanic's thesis

Co-band multi-antenna implementation in realistic compact user terminals is of great interest to the wireless telecom industry for achieving high data rates. This licentiate thesis focuses on the mechanisms behind the implementation of multiple antennas for diversity and MIMO gains in everyday user terminals. Specifically, the effects of compactness, user interaction and propagation channel on the implementation are investigated through extensive simulation and measurement studies. In Paper I, the diversity performance of internal multiple antennas with multiband coverage in a mock-up with the size of a typical mobile handset is investigated in different user interaction scenarios and compared to single multiband antenna prototype for the

Figure 8: Vanja Plicanic (left), Buon Kiong (Vincent) Lau (right), and the reviewer Dr Jon Wallace (far right) at Plicanic's Licentiate seminar, November 18, 2009.

same user cases. The performance at frequency bands below and above 1 GHz are presented and discussed. Paper II is an extension of the study in Paper I to single input multiple output (SIMO) and multiple input multiple output (MIMO) ergodic capacity evaluation of the antenna prototypes in the proximity of a user. In Paper III, the gain imbalance and antenna separation in a dual dipole configuration are explored at frequencies below and above 1 GHz in a multipath environment in a live HSPA network. Since compactness of a user terminal affects the antenna separation and gain imbalance of the multiple antennas, the focus is to gain knowledge on how the gain imbalance and antenna separation affect the end user experience in practice. Lastly, Paper IV comprises the evaluation of a compact antenna array designed to exploit spatial, angle and polarization diversities. The evaluation is performed using extensive channel measurements of line of sight (LOS) and non line of sight (NLOS) scenarios in an indoor office environment and simulation of the throughput performance using the measured channels. The research contributions in this thesis highlight the necessity of design techniques to exploit all available degrees of freedom in the communication channels for optimum implementation of compact multiple antenna user terminals. For the perspective of the user terminals, the communication channel comprises the allocated volume in a terminal, the near field interaction with the user and the propagation environment.

3.3 Journal publications

J1. A. Alayon Glazunov, M. Gustafsson, A. Molisch, F. Tufvesson, and G. Kristensson. Spherical Vector Wave Expansion of Gaussian Electromagnetic Fields for Antenna-Channel Interaction Analysis. *IEEE Transactions on Antennas and Propagation*, **57**(7), 2055–2067, 2009.

J2. A. Derneryd, M. Gustafsson, G. Kristensson, and C. Sohl. Application of gain-bandwidth bounds on loaded dipoles. *IET Microwaves, Antennas & Propagation*, **3**(6), 959–966, 2009.

J3. M. Gustafsson. Sum rule for the transmission cross section of apertures in thin opaque screens. *Optics letters*, **34**(13), 2003–2005, 2009.

J4. M. Gustafsson, C. Sohl, and G. Kristensson. Illustrations of new physical bounds on linearly polarized antennas. *IEEE Trans. Antennas Propagat.*, **57**(5), 1319–1327, 2009.

J5. M. Gustafsson, C. Sohl, C. Larsson, and D. Sjöberg. Physical bounds on the all-spectrum transmission through periodic arrays. *EPL (Europhysics Letters)*, **87**, 2009.

J6. A. Ioannidis, G. Kristensson, and D. Sjöberg. On the dispersion equation for a homogeneous, bi-isotropic waveguide of arbitrary cross-section. *Microwave and Optical Technology Letters*, **51**(11), 2701–2705, 2009.

J7. A. Karlsson. Approximate boundary conditions for thin structures. *IEEE Transactions on antennas and propagation*, **57**(1), 144–148, 2009.

J8. A. Karlsson, H. Bladh, and P.-E. Bengtsson. Accurate method for predicting light scattering from soot aggregates with subparticles of arbitrary shape and structure. *Journal of the the Optical Society of America, JOSA A: Optics Image Science and Vision*, **26**(7), 1704–1713, 2009.

J9. A. Kazemzadeh and A. Karlsson. Capacitive circuit method for fast and efficient design of wideband radar absorber. *IEEE Transactions on Antenna and Propagation*, **57**(8), 2307–2314, 2009.

J10. S. Nordebo and M. Gustafsson. A priori modeling for gradient based inverse scattering algorithms. *Progress In Electromagnetics Research B*, **16**, 407–432, 2009.

J11. V. Plicanic and B. K. Lau. Impact of spacing and gain imbalance between two dipoles on HSPA throughput performance. *Electronics Letters*, **45**(21), 1063–1065, 2009.

J12. V. Plicanic, B. K. Lau, A. Derneryd, and Z. Ying. Actual diversity performance of a multiband diversity antenna with hand and head effects. *IEEE Transactions on Antennas and Propagation*, **57**(5), 1547–1556, 2009.

J13. D. Sjöberg. Determination of propagation constants and material data from waveguide measurements. *Progress In Electromagnetics Research B*, **12**, 163–182, 2009.

J14. D. Sjöberg. Low-frequency scattering by passive periodic structures for oblique incidence: low-pass case. *Journal of Physics A: Mathematical and Theoretical*, **42**, 2009.

J15. D. Sjöberg. Variational principles for the static electric and magnetic polarizabilities of anisotropic media with perfect electric conductor inclusions. *Journal of Physics A: Mathematical and Theoretical*, **42**, 2009.

3.4 Books

B1. A. Karlsson and G. Kristensson. *Microwave Theory*. E-husets tryckeri, 2009.

B2. G. Kristensson, editor. *SNRV 75 år*. Swedish National Committee of URSI (SNRV), 2009.

3.5 Conference publications

C1. A. Bernland, M. Gustafsson, and S. Nordebo. Summation rules and physical bounds for partial wave scattering in electromagnetics. In *The 9th International Conference on Mathematical and Numerical Aspects of Waves Propagation (WAVES 2009)*, pages 206–207, Pau, France, June 15–19 2009.

C2. M. Gustafsson, G. Kristensson, S. Nordebo, C. Larsson, A. Bernland, and D. Sjöberg. Physical bounds and sum rules in scattering and antenna theory. In *International Conference on Electromagnetics in Advanced Applications (ICEAA)*, pages 600–603, Turin, Italy, September 14–18 2009.

C3. M. Gustafsson and C. Sohl. New physical bounds on elliptically polarized antennas. In *European Conference on Antennas and Propagation (EuCAP)*, pages 400–402, Berlin, Germany, March 23–27 2009.

C4. M. Gustafsson, C. Sohl, G. Kristensson, S. Nordebo, C. Larsson, A. Bernland, and D. Sjöberg. An overview of some recent physical bounds in scattering and antenna theory. In *European Conference on Antennas and Propagation (EuCAP)*, pages 1795–1798, Berlin, Germany, March 23–27 2009.

C5. A. Ioannidis. On the cavity problem for the general linear medium in electromagnetic theory. In *International Conference on Modern Mathematical Methods in Sience and Technology*, pages 77–78, Poros, Greece, September 3–5 2009.

C6. C. Larsson, M. Gustafsson, and G. Kristensson. Polarimetric Measurements of the Extinction Cross Section. In *International Conference on Electromagnetics in Advanced Applications (ICEAA)*, pages 311–314, Turin, Italy, September 14–18 2009.

C7. C. Larsson, C. Sohl, M. Gustafsson, and G. Kristensson. Measuring the extinction cross section. In *European Conference on Antennas and Propagation (EuCAP)*, pages 3633–3636, Berlin, Germany, March 23–27 2009.

C8. B. K. Lau and J. Bach Andersen. Unleashing multiple antenna systems in compact terminal devices. In *2009 IEEE International Workshop on Antenna Technology: Small Antennas and Novel Metamaterials (IWAT)*, Santa Monica, CA, USA, March 2–4 2009.

C9. S. Nordebo, A. Fhager, M. Gustafsson, and B. Nilsson. Applications of the Fisher information integral operator for inverse problems. In *The 9th International Conference on Mathematical and Numerical Aspects of Waves Propagation (WAVES 2009)*, pages 302–303, Pau, France, June 15–19 2009.

C10. S. Nordebo, A. Fhager, M. Gustafsson, and B. Nilsson. Fisher information analysis in microwave tomography. In *The Third International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP 2009)*, Aruba, Dutch Antilles, December 15 2009.

C11. V. Plicanic, B. K. Lau, A. Derneryd, and Z. Ying. Channel capacity performance of multi-band dual antenna in proximity of a user. In *2009 IEEE International Workshop on Antenna Technology: Small Antennas and Novel Metamaterials (IWAT)*, pages 5–8, Santa Monica, CA, USA, March 2–4 2009.

C12. V. Plicanic, M. Zhu, and B. K. Lau. Diversity mechanisms of a compact dielectric resonator antenna array for high MIMO throughput performance. In *9th COST2100 Management Committee Meeting*, volume TD(09) 969, Vienna, Austria, September 28–30 2009.

C13. D. Sjöberg, M. Egard, M. Ärlelid, G. P. Vescovi, and L.-E. Wernersson. Design and manufacturing of a dielectric resonator antenna for impulse radio at 60 GHz. In *European Conference on Antennas and Propagation (EuCAP)*, pages 3549–3553, Berlin, Germany, March 23–27 2009.

C14. J. C.-E. Sten and D. Sjöberg. Analytical approach to low-frequency scattering and homogenisation of split-ring elements. In *European Conference on Antennas and Propagation (EuCAP)*, pages 147–149, Berlin, Germany, March 23–27 2009.

C15. R. Tian and B. K. Lau. Correlation-based phase synthesis approach for MIMO capacity prediction using antenna magnitude patterns. In *7th COST2100 Management Committee Meeting*, volume TD(09) 727, Braunschweig, Germany, February 16–18 2009.

C16. R. Tian and B. K. Lau. Simple and improved approach of estimating MIMO capacity from antenna magnitude patterns. In *European Conference on Antennas and Propagation (EuCAP)*, Berlin, Germany, March 23–27 2009.

C17. R. Tian, V. Plicanic, B. K. Lau, J. Långbacka, and Z. Ying. MIMO performance of diversity-rich compact six-port dielectric resonator antenna arrays in measured Indoor environments at 2.65 GHz. In *2nd COST2100 Workshop - Multiple Antenna Systems on Small Terminals (Small and Smart)*, Valencia, Spain, May 20 2009.

3.6 Thesis publications

T1. V. Plicanic. Performance characterization of compact multiple antenna terminals, 2009. Licentiate Thesis.

3.7 Diploma works

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

D1. Christina Cullin, "Characterization of GPS Antenna Performance in the Mobile Phone".
Advisor: Mats Gustafsson and SonyEricsson Mobile Communications AB

D2. Meifang Zhu, "On optimal IEEE802.11n Schemes for Maximum Throughput Performance of Four 6×6 MIMO Antenna Configurations in Measured Indoor Office Environments".
Advisors: Buon Kiong Lau, Vanja Plicanic, and Sony Ericsson Mobile Communications AB

D3. Filip Danielsson, "Development of NFC Antennas".
Advisor: Anders Sunesson and Perlos AB

D4. Muhammad Ali Khan and Salman Hussain Changazi, "Robust On-Body MIMO Communications".
Advisor: Buon Kiong Lau and Sony Ericsson Mobile Communications AB

D5. David Olsson, "Impedance Matching in Mobile MIMO Terminals".
Advisor: Anders Sunesson and Perlos AB

D6. Said A. Abusamleh "Verification of Impedance Relations for Antenna Using Experiment and Theory".
Advisors: Mats Gustafsson and Anders Sunesson

D7. Pau Latorre, "Real time visualisation of antenna pattern".
Advisor: Daniel Sjöberg

3.8 Technical reports

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

TR1. Andrés Alayón Glazunov, Mats Gustafsson, Andreas F. Molisch, and Fredrik Tufvesson. Physical modeling of mimo antennas and channels by means of

the spherical vector wave expansion. *LUTEDX/(TEAT-7177)/1-31/(2009).*
Abstract: In this paper we propose a new physically motivated model that allows to study the interaction between the antennas and the propagation channel for Multiple-Input Multiple-Output (MIMO) systems. The key tools employed in the model are the expansion coefficients of the electromagnetic field in spherical vector waves and the scattering matrix representation of the properties of the antenna. We derive the expansion of the MIMO channel matrix, $\mathbf{H}$, in spherical vector wave modes of the electromagnetic field of the antennas as well as the propagation channel. We also introduce the channel scattering dyad, $\mathcal{C}$, with a corresponding correlation model for co- and cross-polarized elements and introduce the concept of mode-to-mode channel mapping, the $\mathbf{M}$-matrix, between the receive and transmit antenna modes. The $\mathbf{M}$-matrix maps the modes excited by the transmitting antenna to the modes exciting the receive antennas and vice versa. The covariance statistics of this M-matrix are expressed as a function of the double-directional power-angular spectrum (PAS) of co- and cross-polarized components of the electromagnetic field. Our approach aims at gaining insights into the physics governing the interaction between antennas and channels and it is useful for studying the performance of different antenna designs in a specified propagation channel as well as for modeling the propagation channel. It can furthermore be used to quantify the optimal properties of antennas in a given propagation channel. We illustrate the developed methodology by analyzing the interaction of a 2×2 system of slant polarized half-wavelength dipole antennas with some basic propagation channel models.

TR2. Andreas Ioannidis, Daniel Sjöberg, and Gerhard Kristensson. On the propagation problem in a metallic homogeneous bi-isotropic waveguide. *LUTEDX/(TEAT-7178)/1-27/(2009).*
Abstract: We investigate the problem of defining propagating constants and modes in metallic waveguides of an arbitrary cross section, filled with a homogeneous biisotropic material. The approach follows the guidelines of the classical theory for the isotropic, homogeneous, lossless waveguide: starting with the Maxwell system, we formulate a spectral problem where the (square of the) propagation constant shows up as the eigenvalue and (the building bricks of) the corresponding mode as the eigenvector. The difficulty that arises, and this is a feature of chirality, is that the eigenvalue is involved in the boundary conditions. The main result is that the problem is solvable whenever the Dirichlet problem for the Helmholtz equation in the cross section is solvable. The analysis also confirms the splitting in left and circularly polarized waves.

TR3. Anders Karlsson, Henrik Bladh, and Per-Erik Bengtsson. An accurate method for predicting light scattering from soot aggregates with sub-particles of arbitrary shape and structure. *LUTEDX/(TEAT-7179)/1-22/(2009).*
Abstract: Soot particles can be formed in hydrocarbon flames as a result of an inefficient combustion process. The particles are near-spherical, and normally a few tens of nanometers in diameter. At later stages in the soot growth

process, they form chain-like sparse aggregates. When applying optical diagnostic methods such as combined scattering and extinction measurements in sooting flames, this aggregation influences the evaluation of soot properties based on assumptions of isolated particles. In this paper an efficient and accurate method for calculating scattering of light from these structures is presented. The method can handle aggregates with several hundred sub-particles with no restrictions on shape, internal structure, or conglutination of the sub-particles. The basic idea is that the induced dipole moments of the sub-particles are determined from the solution of a quasi-static problem that can be solved with high accuracy by *e.g.*, the finite element method.

TR4. Sven Nordebo, Andreas Fhager, Mats Gustafsson, and Börje Nilsson. Fisher information integral operator and spectral decomposition for inverse scattering problems. *LUTEDX/(TEAT-7180)/1-21/(2009).*
Abstract: The purpose of this paper is to introduce the Fisher information integral operator and related spectral decomposition for inverse scattering problems. The Fisher information integral kernel is derived using a variational formulation and Fréchet derivatives leading naturally to a first order perturbation analysis of the partial differential equation at hand, and an application of corresponding Green's function techniques. The integral operator and its spectrum can be efficiently approximated by using suitable quadrature methods for numerical integration. The eigenfunctions of this integral operator, corresponding to the identifiable parameters via the significant eigenvalues and the corresponding Cramér-Rao bounds, constitute a suitable global basis for sensitivity and resolution analysis as well as for optimization. In depth analysis and numerical examples for one- and two-dimensional inverse electromagnetic scattering problems are given that illustrate the spectral decomposition and the related resolution analysis.

TR5. Mats Gustafsson. Sum rule for the transmission cross section of apertures in thin opaque screens. *LUTEDX/(TEAT-7181)/1-8/(2009).*
Abstract: Extraordinary transmission through sub-wavelength apertures is usually observed in a narrow bandwidth range and the transmission outside this range is low in agreement with classical results. The analysis presented here is based on the Babinet's principle and hence scattering by the complementary structure, where the apertures are replaced by finite scatterers. It is shown that the transmission cross section of a set of apertures in an opaque screen satisfies a sum rule that relates the transmission cross section integrated over all wavelengths with the polarizability of the complementary structure as defined by Babinet's principle. The theoretical results are illustrated with numerical examples.

TR6. Christer Larsson, Mats Gustafsson, and Gerhard Kristensson. Wideband microwave measurements of the extinction cross section—Experimental techniques. *LUTEDX/(TEAT-7182)/1-22/(2009).*
Abstract: This paper describes the development of a method to determine

the extinction cross section for a very large bandwidth in the microwave region. The method is based on measurements of the radar cross section in the forward direction to calculate the extinction cross section for the frequency range $[2.5, 38]$ GHz. The method is applicable to samples of arbitrary shape and composition and can also be used for polarimetric measurements. Coherent background subtraction is used to remove the contribution from antenna to antenna coupling. Time domain gating is employed to increase the sensitivity. Different calibration methods are discussed. The efficiency of the background subtraction and the accuracy of the measurements are estimated.

4 Guests and Seminars

4.1 Visitors at the group of Electromagnetic Theory

Jørgen Bach Andersen, Department of Electronic Systems, Aalborg University, Aalborg, Denmark, March 16–20, 2009.

Ola Dickman, The Swedish Defence Materiel Administration, Försvarets materielverk (FMV), Stockholm, Sweden, December 8, 2009.

Stefan Gabrielsson, The Swedish Defence Materiel Administration, Försvarets materielverk (FMV), Stockholm, Sweden, December 8, 2009.

Anders Grop, The Swedish Defence Materiel Administration, Försvarets materielverk (FMV), Stockholm, Sweden, December 8, 2009.

Anders Höök, Saab Microwave Systems AB, January 30, 2009.

Michael A. Jensen, Brigham Young University, USA, April, June-July 2009.

Lars Jonsson, School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, September 10, 2009.

Stefan Kröll, Division of Atomic Physics, Department of Physics, LTH, Lund, August 27, 2009.

Lars Malmgren, Maxlab, Lund, December 15, 2009.

Torleif Martin, Saab Aerosystems AB, Linköping, May 5, 2009.

Margaret Newman-Nowicka, LTH, Lund, Sweden, May 6, 2009.

Ana Perez Neira, UPC, Spain, February 23, 2009.

Sören Poulsen, ACAB, Linköping, October 14, 2009.

Harmen Schippers, National Aerospace Laboratory (NLR), The Netherlands, May 15, 2009.

Torbjörn Solér, Vattenfall, Malmö, Sweden, January 22, 2009.

Carl-Henrik Walde, Näsbypark, Sweden, February 24, June 30, October 17, 2009.

David Wall, Department of Mathematics and Statistics, University of Canterbury, Christchurch, New Zealand, July 17–26, 2009.

Jon Wallace, Jacobs University, Bremen, Germany, November 17–18, 2009.

4.2 Seminars

Ana Perez Neira, "What does duality mean in Multiuser MIMO systems?" February 23, 2009.

Christina Cullin, Presentation of Diploma thesis, "Characterization of GPS Antenna Performance in the Mobile Phone," February 26, 2009.

Meifang Zhu, Presentation of Diploma thesis, "On optimal IEEE802.11n Schemes for Maximum Throughput Performance of Four 6×6 MIMO Antenna Configurations in Measured Indoor Office Environments," April 28, 2009.

Torleif Martin, "Presentation of current research at Saab Aerosystems", May 5, 2009.

Filip Danielsson, Presentation of Diploma thesis, "Development of NFC antennas," May 6, 2009.

Muhammad Ali Khan and Salman Hussain Changazi, Presentation of Diploma thesis, "Robust On-Body MIMO Communications," May 15, 2009.

Harmen Schippers, "Multi-scale topics of electromagnetic research at NLR," May 15, 2009.

Matthew Eifler, Presentation of Bachelor project, "The theory and design of a resistive screen for radiation visualization," May 28, 2009.

Said Abushamleh, Presentation of Diploma thesis, "Verification of Impedance Relations for Antennas Using Experiment and Theory," June 12, 2009.

Marius Cismasu, "Leaky Waves structures based on metamaterials," September 7, 2009.

Lars Jonsson, "Asymptotic wave splitting in anisotropic media for linear acoustics", September 10, 2009.

Pau Latorre, Presentation of Diploma thesis, "Real time visualisation of antenna patterns," October 30, 2009.

Vanja Plicanic, Presentation of Licentiate thesis, "Performance characterization of compact multiple antenna terminals," November 18, 2009.

Jon Wallace, "Experimental Investigation of MIMO Reciprocal Channel Key Generation," November 18, 2009.

4.3 Courses and Workshops

1. **High Speed Wireless Center Workshop** (HSWC), Örenäs Slott, Glumslöv, Sweden, April 20–21, 2009. Anders Bernland made a presentation of his research.

2. A workshop with an audience from the Swedish Defence Materiel Administration, Försvarets materielverk (FMV), Stockholm, Sweden, December 8, 2009.

   Program December 8:

   a) Mats Gustafsson, *Title:* Physical bounds and sum rules in antenna and electromagnetic theory
   b) Daniel Sjöberg, *Title:* Magnetiska material, mätteknik, homogenisering
   c) Anders Karlsson, *Title:* Signaturer u-båtar
   d) Alireza Kazemzadeh, *Title:* CAA-tekniker
   e) Kristin Persson, *Title:* Backning av fält
   f) Anders Bernland, *Title:* Fysikaliska begränsningar för multipelantennsystem
   g) Christer Larsson, *Title:* Samarbete med LTH
   h) Niklas Wellander, *Title:* Cloaking & mikromodellering
   i) Michael Andersson, *Title:* Knowledge transfer

5 Visits and Lectures by the Staff

5.1 Visits to other institutes and departments

Anders Derneryd:

SNRV (Swedish National Committee of URSI) B/E/F meeting at SP, Borås, Sweden, April 15, 2009.

Mats Gustafsson:

SNRV (Swedish National Committee of URSI) B/E/F meeting at SP, Borås, Sweden, April 15, 2009.

Växjö University, April 17, 2009.

EU-ISTIMES meeting, Paris, France, September 28, 2009.

Zhejiang University, Hangzhou, China, October 7–9, 2009.

Tsinghua University, China, October 15, 2009.

Beihang University, China, October 15, 2009.

Anders Karlsson:

SNRV (Swedish National Committee of URSI) B/E/F meeting at SP, Borås, Sweden, April 15, 2009.

Gerhard Kristensson:

SNRV (Swedish National Committee of URSI) B/E/F meeting at SP, Borås, Sweden, April 15, 2009.

SNRV (Swedish National Committee of URSI) årsmöte, Helsinki University of Technology, Finland, May 12–14, 2009.

Marconi 100 år, KVA, Sweden, May 28, 2009.

IPT meeting, Saab Aerosystems AB, Linköping, Sweden, June 2, 2009.

The Swedish Defence Materiel Administration, Försvarets materielverk (FMV), Stockholm, Sweden, August 25, 2009.

Mikromodellering, FOI, Linköping, Sweden, September 23, 2009.

SNRV (Swedish National Committee of URSI) höstmöte, KVA, Sweden, October 20, 2009.

IPT meeting, Saab Aerosystems AB, Linköping, Sweden, October 16, 2009.

Marconi 100 år, KVA, Sweden, November 9, 2009.

Nationalkommittémöte, KVA, Sweden, November 26, 2009.

Buon Kiong Lau:

Tsinghua University, China, January 15–16, 2009 and October 14–15, 2009

Beihang University, China, January 12–14, 2009 and October 16, 2009.

Daniel Sjöberg:

Saab Bofors Dynamics, Linköping, Sweden, almost every week througout 2009 as part of an SSF Strategic Mobility Grant.

Slutredovisning SAT Swedish Defence Materiel Administration, World Trade Center, Stockholm, Sweden, October 8, 2009.

FOI, Linköping, Sweden, December 16, 2009.

5.2 Guest Lectures by the department's staff

Mats Gustafsson:

Linnaeus Coffee, automatic control, Lund University, Sweden. *Title of the talk:* "Physical bounds, sum rules, inverse scattering, and digital holography," March 13, 2009.

SNRV (Swedish National Committee of URSI) B/E/F meeting at SP, Borås, Sweden. *Title of the talk:* "Lundensiska erfarenheter av simuleringsprogram för elektromagnetiska Problem," April 15, 2009.

Zhejiang University, Hangzhou, China. *Title of the talk:* "Physical bounds and sum rules in scattering and antenna theory," October 9, 2009.

Chase seminar, Chalmers, Göteborg, Sweden. *Title of the talk:* "Physical bounds and sum rules in antenna and electromagnetic theory," November 20, 2009.

Invited talk at Ericsson Research AB, Göteborg, Sweden. *Title of the talk:* "Physical bounds and sum rules in antenna and electromagnetic theory," November 20, 2009.

Andreas Ioannidis:

ETK Seminarier, School of Electrical Engineering, Royal Institute of Technology, Stockholm, Sweden. *Title of the talk:* "Eigenproblems for General Waveguides in Electromagnetic Theory," January 30, 2009.

Seminar in Differential Equations, Department of Mathematics, University of Athens, Greece. *Title of the talk:* “Spectral Problems for Waveguides in Electromagnetic Theory,” February 20, 2009.

Buon Kiong Lau:

Gave a talk at the School of Information Science and Technology, Tsinghua University, China. *Title of the talk:* “Neutralizing a MIMO Killer — a story of compact MIMO antenna systems.” January 16, 2009.

Daniel Sjöberg:

Gave two talks at the Summer School of Electromagnetic Computations, Göteborg, Sweden. *Titles of the talks:* “Method moments solutions for periodic problems,” and “Efficient and accurate numerical evaluation of modal Green’s functions,” June 11, 2009.

Gave a talk at the Division of Mathematical Statistics, Department of Mathematics, Lund University, Sweden. *Title of the talk:* “Elektroniska frågeformulär som tempohållare och återkopplingsinstrument,” September 4, 2009.

5.3 Participation in conferences and workshops

Anders Bernland:

Presented a paper at the 9$^{\text{th}}$ International Conference on Mathematical and Numerical Aspects of Waves Propagation, Pau, France. *Title of the Paper:* “Summation Rules and Physical Bounds for Partial Wave Scattering in Electromagnetics,” June 15–19, 2009, see Figure 9.

Anders Derneryd:

Presented a paper at the 3$^{\text{rd}}$ European Conference on Antennas and Propagation (EuCAP), Berlin, Germany. *Title of the Paper:* “Performance of closely spaced multiple antennas for terminal applications,” March 23–27, 2009.

Participated in the IWPC workshop on “Managing coexistence of 15 modes & 40 bands for MIMO handsets and data devices” with a contribution entitled “Impact of terminal antennas on MIMO signal processing and performance,” Kastrup, Denmark, October 13–16, 2009.

Mats Gustafsson:

Presented a paper at the 3rd European Conference on Antennas and Propagation (EuCAP), Berlin, Germany. *Title of the Talk:* “An overview of some recent physical bounds in scattering and antenna theory,” March 23–27, 2009.

Figure 9: Mats Gustafsson and Anders Bernland at Pau, France outside the birth place of the Swedish king Karl XIV Johan, born Jean Bernadotte.

Presented a poster at the 3rd European Conference on Antennas and Propagation (EuCAP), Berlin, Germany. *Title of the Poster:* "New physical bounds on elliptically polarized antennas," March 23–27, 2009.

Participated in the 9$^{\text{th}}$ International Conference on Mathematical and Numerical Aspects of Waves Propagation, Pau, France. June 15–19, 2009, see Figure 9.

Presented a paper at the International Conference on Electromagnetics in Advanced Applications (ICEAA), Turin, Italy. *Title of the Talk:* "Physical bounds and sum rules in scattering and antenna theory," September 14–18, 2009.

Andreas Ioannidis:

International Conference on Modern Mathematical Methods in Science and Technology, Poros Image Hotel, Greece. *Title of the Talk:* "On the Cavity Problem for the General Linear Medium in Electromagnetic Theory," September 3–5, 2009.

Gerhard Kristensson:

Participated in the workshop on the future NFFP5, Nationellt flygforskningsprogram (National Aviation Research Program), Stockholm, Sweden, February 3, 2009.

Participated with an oral presentation at the workshop in Mathematics, Chalmers, Göteborg, Sweden. *Title of the Talk:* "Physical bounds in electromagnetic scattering problems," March 25, 2009.

Participated with an oral presentation at the workshop on SAT, FHS/Livgardet, Stockholm, Sweden. *Title of the Talk:* "Cloaking — (o)möjligt," April 20–21, 2009.

Participated with an oral presentation at the workshop on Flygteknik, FHS, Stockholm, Sweden. *Title of the Talk:* "Kretsanalogiabsorbenter, CAA," December 9, 2009.

Christer Larsson:

Presented a paper at the European Conference on Antennas and Propagation (EUCaP), Berlin, Germany. *Title of the Paper:* "Measuring the extinction cross section", April 23–27, 2009.

Presented a paper at the International Conference on Electromagnetics in Advanced Applications (ICEAA), Turin, Italy. *Title of the Paper:* "Polarimetric Measurements of the Extinction Cross Section", September 14–18, 2009.

Buon Kiong Lau:

Participated with a paper at the 7th COST2100 Management Committee Meeting in Braunschweig, Germany. *Title of the Paper:* "Correlation-based phase synthesis approach for MIMO capacity prediction using antenna magnitude patterns," February 16–18, 2009.

Participated with an oral presentation in the High Speed Wireless Center (HSWC) Workshop, Örenäs Slott, Sweden. *Title of the Talk:* "On Compact MIMO Systems," April 20–21, 2009.

Participated with two papers at the International Workshop on Antenna Technology (IWAT), Santa Monica, USA. *Title of the Papers:* "Unleashing multiple antenna systems in compact terminal devices" and "Channel capacity performance of multi-band dual antenna in proximity of a user," March 2–4, 2009

Participated in the 8th COST2100 Management Committee Meeting in Valencia, Spain, May 18–19, 2009.

Participated with a paper in the 2nd COST2100 Workshop on "Small Terminal Antennas", Valencia, Spain. *Title of the Paper:* "MIMO performance of diversity-rich compact six-port dielectric resonator antenna arrays in measured Indoor environments at 2.65 GHz," May 20, 2009.

Participated with a paper in the 9th COST2100 Management Committee Meeting, Vienna, Austria. *Title of the Paper:* "Diversity mechanisms of a compact dielectric resonator antenna array for high MIMO throughput performance," September 28–30, 2009.

Richard Lundin:

Participated with a poster at Utvecklingskonferens 09, Lund, Sweden. *Title of the Poster:* "Miljöföreläsningar med simulerad klimatkonferens i elektronikundervisning, " September 15, 2009.

Vanja Plicanic:

Participated with a poster at the International Workshop on Antenna Technology (IWAT), Santa Monica, USA. *Title of the Poster:* "Channel Capacity performance of milt-band dual antenna in proximity of a user," March 2–4, 2009.

Presented a paper at the IWPC workshop on "Managing coexistence of 15 modes & 40 bands for MIMO handsets and data devices" Kastrup, Denmark. *Title of the Paper:* ´´Challenges in terminal MIMO antenna design for performance in real channels," October 13–16, 2009.

Daniel Sjöberg:

Participated in the High Speed Wireless Center (HSWC) Workshop, Örenäs Slott, April 20–21, 2009.

Presented a paper at the European Conference on Antennas and Propagation (EUCaP), Berlin, Germany. *Title of the paper:* "Design and manufacturing of a dielectric resonator antenna for impulse radio at 60 GHz," March 23–27, 2009.

Presented a poster at the 3$^{\text{rd}}$ European Conference on Antennas and Propagation (EUCaP), Berlin, Germany. *Title of the Poster:* "Analytical approach to low-frequency scattering and homogenisation of split-ring elements," March 23–27, 2009.

Ruiyuan Tian:

Presented a paper at the European Conference on Antennas and Propagation (EuCAP), Berlin, Germany. *Title of the paper:* “Simple and improved approach of estimating MIMO capacity from antenna magnitude patterns,” March 23–27, 2009.

Presented a paper at the 2nd COST2100 Workshop — Multiple Antenna Systems on Small Terminals (Small and Smart), Valencia, Spain. *Title of the paper:* “MIMO performance of diversity-rich compact six-port dielectric resonator antenna arrays in measured Indoor environments at 2.65 GHz,” May 20, 2009.

5.4 Examination committees

Anders Karlsson:

Member of the examination committee for Xin Hu, KTH, Stockholm, Sweden. *Title of the thesis:* “Some studies on metamaterial transmission lines and their applications”, April 2, 2009.

Member of the examination committee for Anders Andersson, Växjö University, Växjö, Sweden. *Title of the thesis:* “Numerical Conformal mappings for regions Bounded by Smooth Curves”, September 25, 2009.

Gerhard Kristensson:

Member of the examination committee for Per Jacobsson, Chalmers, Göteborg, Sweden. *Title of thesis:* “Shape and material optimization for antenna applications,” June 3, 2009.

Buon Kiong Lau:

Member of the examination committee for Kristian Karlsson, Chalmers University of Technology, Sweden. *Title of the thesis:* “Embedded element patterns in combination with circuit simulations for multi-port antenna analysis,” October 2, 2009.

5.5 Referee for international journals and conferences

Anders Derneryd:

IET Electronics Letters

IET Proc. Microwaves, Antennas and Propagation

IEEE Transactions on Antenna and Propagation

39$^{\text{th}}$ *European Microwave Conference, EuMC 2009*

71$^{\text{th}}$ *IEEE Vehicular Technology Conference, VTC 2009 Spring*

Mats Gustafsson:

Optics letters

Physica Scripta

Inverse Problems

IEEE Transactions on Antenna and Propagation

Wave Motion

Anders Karlsson:

Journal of the Optical Society of America A

Wave Motion

Physical Review Letters (twice)

Gerhard Kristensson:

Wave Motion (as editor)

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 Communications

IEEE Transactions on Wireless Communications

IET Microwaves, Antennas & Propagation

IEEE Global Communications Conference 2009

IEEE 69$^{\text{th}}$ *Vehicular Technology Conference 2009 (VTC2009-Fall)*

IEEE 70$^{\text{th}}$ *Vehicular Technology Conference 2009 (VTC2009-Spring)*

Vanja Plicanic:

IEEE Antennas and Wireless Propagation Letters

Daniel Sjöberg:

IEEE Trans. Antennas Propagation (three times)

European Journal of Physics

Physical Review B

5.6 Other activities

Mats Gustafsson:

Utbildningsdag LTH, Lund, Sweden, January 16, 2009.

Participated in the leadership program AKKA, Lund University, Sweden. Several meetings throughout 2009.

Participated in the Strategy Event of the Board of Education, April 2, 2009.

Internat AKKA, Höör, Sweden, November 17-18, 2009.

Daniel Sjöberg:

Utbildningsdag LTH, Lund, Sweden, January 16, 2009.

Participated in the leadership program AKKA, Lund University, Sweden. Several meetings throughout 2009.

Popular lecture for high school students on invisibility, March 9, 10, 12, 2009.

Gave a talk on the Strategy Event of the Board of Education, April 2, 2009. *Title of the talk:* Nätbaserade frågor som tempohållare och återkopplingsinstrument.

Internat AKKA, Höör, Sweden, November 17–18, 2009.

---

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 10.

6.1.1 Undergraduate courses given during 2009

Program[a]	**Name of the Course**	**Lecturer**[b]
E1	Electronics	**Anders Karlsson**
D1	Electronics	**Anders J Johansson**
F2, N2	Electronics	**Mats Gustafsson**
		Anders Karlsson
		Anders Bernland
		Richard Lundin
E3	Electromagnetic Fields	**Richard Lundin**
E3	Engineering Aspects of an Application	**Richard Lundin**
F3	Electromagnetic Field Theory	**Gerhard Kristensson**
		Anders Bernland
		Richard Lundin
Pi3	Electromagnetic Field Theory	**Gerhard Kristensson**
		Anders Bernland
		Richard Lundin
E3	Electromagnetic Fields, Advanced Course	**Richard Lundin**
E3, F3, Pi4, MWIR1	Antenna Technology[c]	**Richard Lundin**
		Mats Gustafsson
		Anders J Johansson
		Alireza Kazemzadeh
		Ruiyuan Tian
E4, F4, Pi4	Electromagnetic Wave Propagation	**Daniel Sjöberg**
		Alireza Kazemzadeh
E4, F4, Pi4	Microwave Theory	**Anders Karlsson**
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.

[c] The course in Antenna Technology was given twice during 2009.

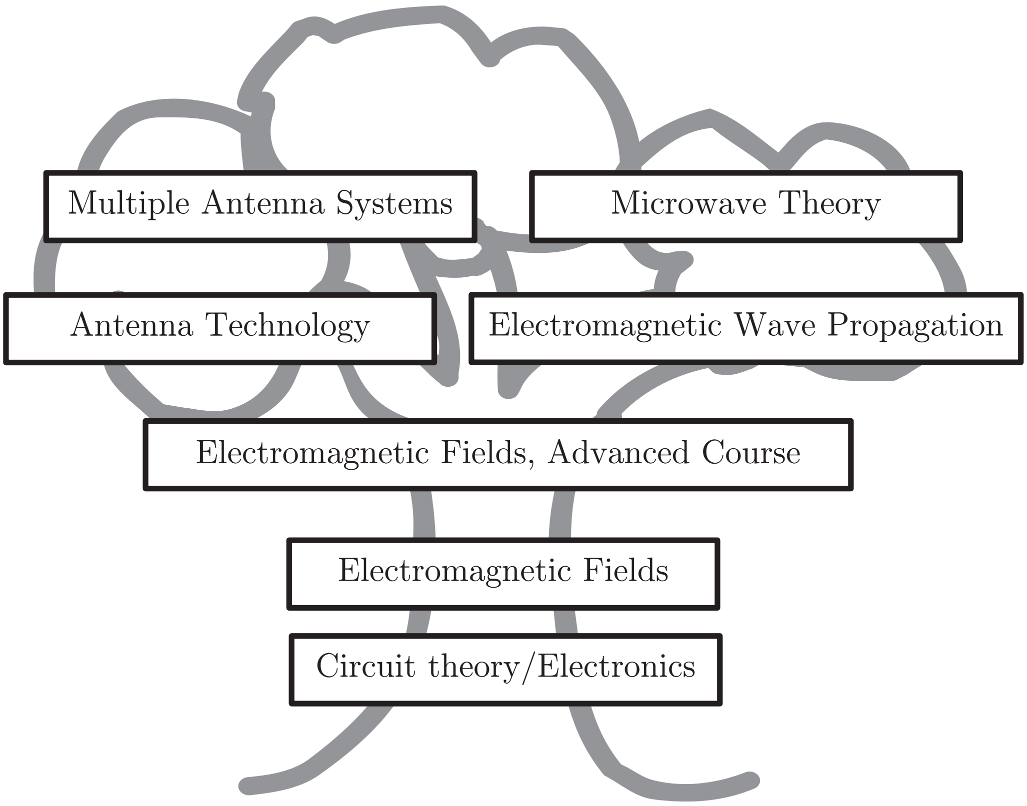


Figure 10: The undergraduate courses given by the Electromagnetic Theory group.

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 80 students.
The group gives the circuit theory part of this course, corresponding to approximately 6 ECTS credits.
Course literature: Alexander and Sadiku, “Electric circuits,” McGraw Hill, 1999; M. Gustafsson and A. Karlsson, “Kretsteori, exempelsamling, KF Sigma 2008”; Franco, “Design with operational amplifier,” McGraw-Hill, 2002.

ETIA01 Electronics: (8 ECTS credits, 116 hours):
Given for the first year students of the Computer Science, or D-, program. Approximately 70 students.
Course literature: Alexander and Sadiku, “Electric circuits,” McGraw Hill, 1999; M. Gustafsson and A. Karlsson, “Kretsteori, exempelsamling, KF Sigma 2008”; Franco, “Design with operational amplifier,” McGraw-Hill, 2002.

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; M. Gustafsson and A. Karlsson, "Kretsteori, exempelsamling, KF Sigma 2008";

ESS050 Electromagnetic Fields (9 ECTS credits, 84 hours):
Given for the third year students of the Electrical Engineering, or E-, program. Approximately 40 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. A role play in the form of a simulated climate conference is included in the course.

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 20 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.

ETE100 Antenna technology (6 ECTS credits, 50 hours):
Given for the third 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 20 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/`. G. Kristensson, "Elektromagnetisk Vågutbredning," Studentlitteratur, Lund 1999.

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 Eningeering Mathematics, and the Electrical Engineering, or F-, Pi-, and E-, programs. Approximately 30 students.
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, 2009.

EITN10 Multiple Antenna Systems (7.5 ECTS credits, 28 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

Mats Gustafsson:

Rundabordssession: Nätbaserade frågeformulär som del av examination, Den 2:a Utvecklingskonferensen för Sveriges ingenjörsutbildningar, Lund, Sweden. December 2, 2009.

Participated in Examination — utveckling av examinationspraxis genom aktionsforskning (3v)

Richard Lundin:

Publication: Lärande i Lund, Genombrottet, Lund University, Lund, Sweden. "Miljöföreläsningar med simulerad klimatkonferens i elektronikundervisning", Number 8, page 5, 2009.

Daniel Sjöberg

Rundabordssession: Nätbaserade frågeformulär som del av examination, Den 2:a Utvecklingskonferensen för Sveriges ingenjörsutbildningar, Lund, Sweden. December 2, 2009.

6.3 Diploma Works

See **3.7 Diploma Works**.

6.4 Development and revisions of teaching materials

1. A. Karlsson and G. Kristensson. *Microwave Theory*. E-husets tryckeri, 2009.

6.5 Graduate courses

Gerhard Kristensson:

PHD002 Electromagnetic Theory, 12 credit units.

6.6 External teaching

Buon Kiong Lau:

Lectured at the EU COST Action 2100 Training School on "MIMO: From Theory to Implementation" in Paris, France. *Title of the lecture:* "Multiple antenna Terminals", March 9–11, 2009

7 Official Commissions

7.1 Official scientific committees

Anders Derneryd:

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

Expert at COST 2100 on “Pervasive Mobile & Ambient Wireless Communications”.

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 Steering group of Academy Southeast (Styrgruppen för Akademi Sydost)

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:

Co-chair of Subworking Group 2.2 on “Compact Antenna Systems for Terminals (CAST)” within EU COST Action 2100.

Technical Program Committee (TPC) member for IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Tokyo, Japan.

TPC member for IEEE 69th Vehicular Technology Conference (VTC) -Spring, Barcelona, Spain, 26–29 Apr. 2009.

TPC Chair of 2nd COST2100 Workshop on “Small Terminal Antennas”, Valencia, Spain, 20 May 2009.

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).

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.

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).