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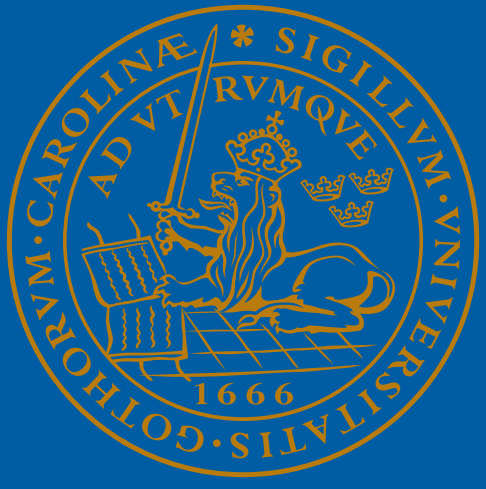
Annual Report 2008

Electromagnetic Theory

Electromagnetic Theory
Department of Electrical and Information Technology
Lund University
Sweden



Editors: Gerhard Kristensson & Daniel Sjöberg

Lund, June 25, 2009

Preface

This is the second year with the newly created Department of Electrical and Information Technology. We believe that this new organization has created several interesting interdisciplinary opportunities for our group of Electromagnetic Theory, and we look forward to the new scientific challenges, which is a product of this interdisciplinary collaboration.

Our industrial contacts have been intense during 2008. In particular, we wish Anders Höök from Saab Microwave Systems AB in Mölndal welcome to the group as a visiting scientist, and to a successful collaboration and interaction in the future. Anders' visits are supported by a mobility grant from the Swedish Foundation for Strategic Research (SSF). Our adjunct professors and visiting scientists are listed in Section 1.4 on Page 3.

Figure 1: Anders Höök.

Elzbieta Szybicka has been the secretary of the group of Electromagnetic Theory for several decades. In July she retired after a long and highly appreciated service. We wish her now a very relaxing and enjoyable retirement.

Christian Sohl presented his doctoral thesis in September this year. Professor Craig F. Bohren was the official faculty opponent of the thesis and for details we refer to Section 3.1 below. Christian has now joined the Saab Microwave Systems company in Järfälla, Stockholm. We wish him good luck with his new position.

Two larger awards were appointed to members of the group in 2008. Anders Karlsson, together with G. Kiani, K. Esselle, and L. G. Olsson, received the Best paper award at the Workshop on Applications of Radio Science, Queensland, Australia. Christian Sohl received the URSI Commission B "Best Student Paper Prize" at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA, August 9–16, 2008, see Figure 12 on Page 32. We, of course, congratulate them for these extraordinary accomplishments.

The successful scientific achievements this year could not have been accomplished without the generous support by several external funding. We are very grateful for the essential financial support given by *e.g.*, the Swedish Defence Materiel Administration (FMV), The Swedish Research Council (VR), The Swedish Foundation for Strategic Research (SSF) and VINNOVA.

The members of the group have been very active in conferences during 2008. In particular, the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA, see Figure 14 on Page 34. Other conferences that we participated in are found in Section 5.4 on Page 31.

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 2008 is given in the following table:

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

[a] CI Master of Engineering FD Doctor of Philosophy, PhD
Doc Docent TeknD PhD in Engineering
[b] D Graduate Student P Professor UL Senior Lecturer
FA Postdoctoral Fellow S Secretary
[c] Employed by the Communications group.
[d] Employed by the Communications group.
[e] Ended his employment 2008-11-30.
[f] Ended her employment 2008-06-30.

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
Sören Poulsen	TeknL	Applied Composites AB, Linköping
Vanja Plicanic	CI	Sony Ericsson Mobile Communications, Lund

[a] CI Master of Engineering
TeknL Licentiate in Engineering

Figure 2: The Electromagnetic Theory group on an excursion to Falsterbo. Standing from the left: Andreas Ioannidis, Anders Bernland, Vanja Plicanic, Christian Sohl, Christer Larsson, Mats Gustafsson, Gerhard Kristensson, Daniel Sjöberg, Kristin Persson, Buon Kiong (Vincent) Lau, and Richard Lundin. The photo was taken May 30, 2008 by Elzbieta Szybicka.

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.

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

[a] TeknD PhD in Engineering
[b] Started as Visiting scientist 2008-05-01.

A photo of the group is given in Figure 2.

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 2008 is given by:

- The Swedish Research Council (VR). *Principal investigator:* Mats Gustafsson. *Title of the project:* "Känslighetsanalys och optimala mätningar för inverssprídning (Sensitivity analysis and optimal measurements for imaging and inverse scattering)".
- The Swedish Research Council (VR). *Principal investigator:* Anders Karlsson. *Title of the project:* "Konstruktion av trådlösa kommunikationskanaler för ökad kapacitet och minskad exponering (Architecture of indoor wireless communication channels for increased capacity and reduced exposure)".
- The Swedish Research Council (VR). *Principal investigator:* Gerhard Kristensson. *Title of the project:* "Utveckling av analys och mätmetoder för komplexa materials elektriska egenskaper (Development of analysis and measurement techniques for electric properties of complex materials)".
- 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 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".
- Ericssons forskningsstiftelse (Ericsson Research Foundation). *Principal investigator:* Buon Kiong Lau. *Title of the project:* "Advanced Antenna Systems" (Grant for a Guest Professor).
- Sony Ericsson Mobile Communications AB. Sponsoring the consulting professorship of Anders Derneryd.
- Sony Ericsson Mobile Communications AB. Financing of an external graduate student.
- The Swedish Defence Materiel Administration, Försvarets materielverk (FMV). *Principal investigator:* Gerhard Kristensson. *Title of the project:* "Teknikstudier signaturanpassade radomer (Stealth radomes)".
- Traveling funds from Royal Physiographic Society and Ericsson AB. *Contract holder:* Christian Sohl.
- NFFP4, Nationellt flygforskningsprogram (National Aviation Research Program), 2006–2008. *Principal investigator:* Daniel Sjöberg.

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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 3.6 and 3.9.

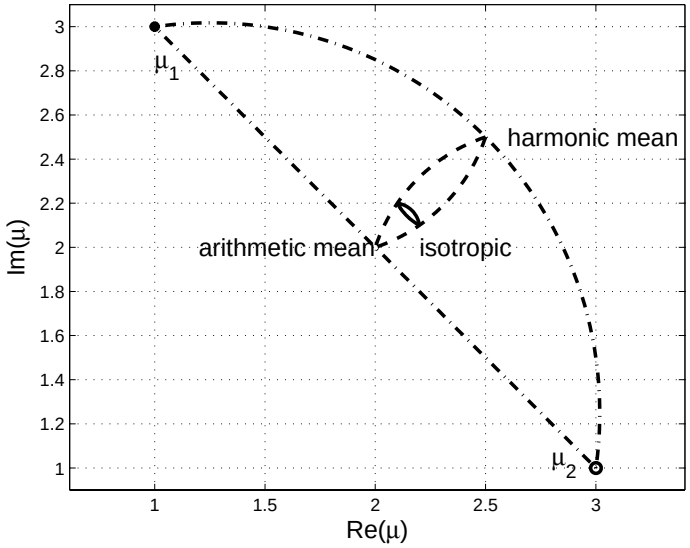

Figure 3: Example of a project under Section 2.1. Example of bounds in the complex plane for a diagonal element of the effective permeability.

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. J. Ramprecht, M. Norgren, and D. Sjöberg. Scattering from a thin magnetic layer with a periodic lateral magnetization: application to electromagnetic absorbers. *Progress in Electromagnetics Research*, **83**, 199–224, 2008.

2. J. Ramprecht and D. Sjöberg. Magnetic losses in composite materials. *J. Phys. D: Applied Phys.*, **41**, 135005, 2008.
3. D. Sjöberg. Analysis of wave propagation in stratified structures using circuit analogs, with application to electromagnetic absorbers. *European Journal of Physics*, **29**(4), 721–734, 2008.
4. D. Sjöberg. A modified Drude-Born-Fedorov model for isotropic chiral media, obtained by finite scale homogenization. *J. Phys. D: Applied Phys.*, **41**(15), 155412, 2008.

Conferences: C9–10, C18–21.

Technical reports: TEAT-7167, TEAT-7169, TEAT-7172, TEAT-7175, TEAT-7176.

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. C. Sohl, C. Larsson, M. Gustafsson, and G. Kristensson. A scattering and absorption identity for metamaterials: experimental results and comparison with theory. *J. Appl. Phys.*, **103**(5), 054906:1–5, 2008.

Conferences: C6, C8–14, C24–26.

Technical reports: TEAT-7163, TEAT-7166, TEAT-7168, TEAT-7170, TEAT-7171, TEAT-7174.

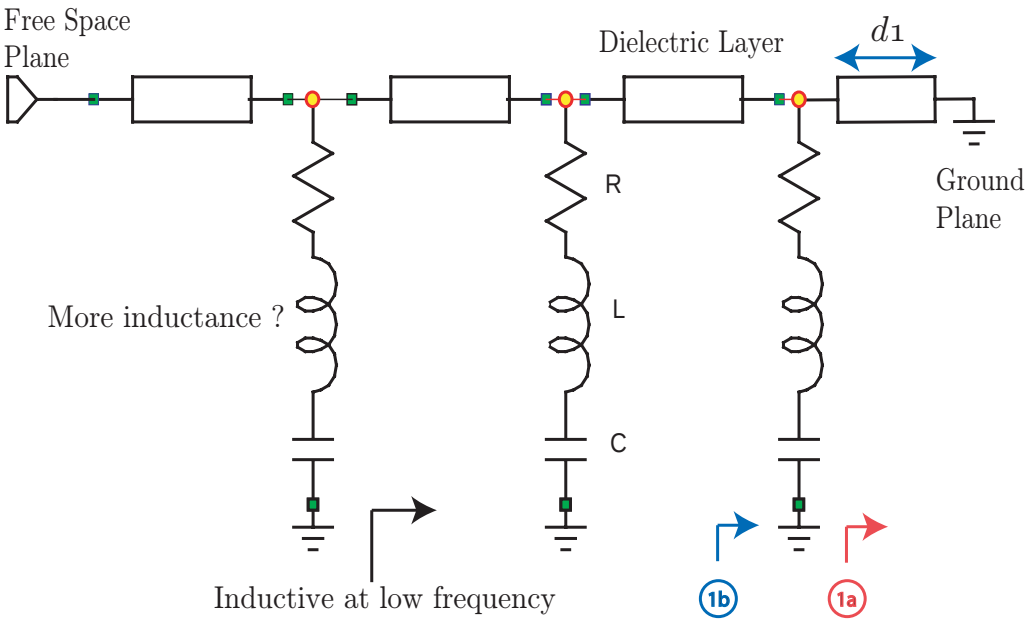

Figure 4: Example of a project under Section 2.2. The circuit model of a generic three layered circuit analog absorber.

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. T. Lenart, M. Gustafsson, and V. Öwall. A hardware acceleration platform for digital holographic imaging. *Journal of VLSI Signal Processing Systems*, **52**(3), 297–311, 2008.
2. A. Mölder, M. Sebesta, M. Gustafsson, L. Gisselson, A. G. Wingren, and K. Alm. Non-invasive, label-free cell counting and quantitative analysis of adherent cells

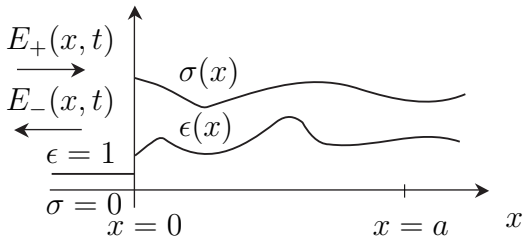

Figure 5: Example of a project under Section 2.3. One-dimensional inverse problem for an isotropic half space with relative permittivity $\epsilon(x)$ and conductivity $\sigma(x)$.

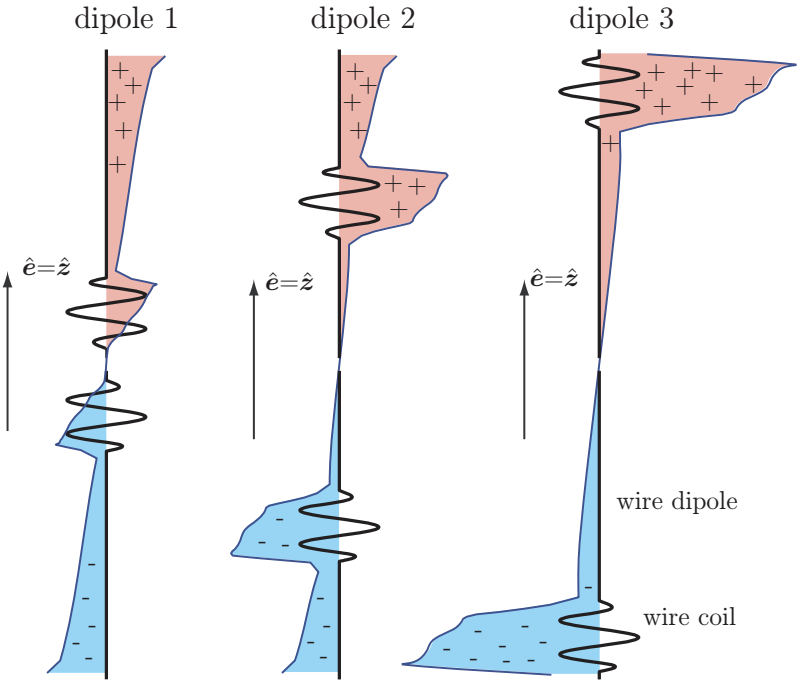

Figure 6: Example of a project under Section 2.4. Illustration of the charge density on a dipole induced by an applied static field with vertical polarization.

using digital holography. *Journal of Microscopy*, **232**(2), 240–247, 2008.

3. S. Nordebo, A. Fhager, M. Gustafsson, and M. Persson. A systematic approach to robust preconditioning for gradient-based inverse scattering algorithms. *Inverse Problems*, **24**(2), 025027, 2008.

Technical reports: TEAT-7164, TEAT-7165.

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. Y. Fei, Y. Fan, B. K. Lau, and J. S. Thompson. Optimal single-port matching impedance for capacity maximization in compact MIMO arrays. *IEEE Trans. Antennas Propagat.*, **56**(11), 3566–3575, 2008.
2. C. Sohl and M. Gustafsson. A priori estimates on the partial realized gain of ultra-wideband (UWB) antennas. *Quart. J. Mech. Appl. Math.*, **61**(3), 415–430, 2008.

Conferences: C1–C5, C7, C14–17, C22–23, C27–29.

Technical reports: TEAT-7161, TEAT-7162, TEAT-7173.

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3 Dissertations, Published papers and Reports

3.1 Doctoral dissertations

Christian Sohl, "Dispersion Relations in Scattering and Antenna Problems," September 23, 2008, see Figure 7.

Faculty opponent: Professor Craig F. Bohren, Pennsylvania State University, USA.

Examining committee:

Figure 7: Professor Craig F. Bohren and Christian Sohl at the dissertation.

1) Lecturer Svend Berntsen, Department of Mathematics and Computer Science, Aalborg University, Aalborg, Denmark
2) Professor Olav Breinbjerg, Electrical Engineering Department of Electrical Engineering, Technical University of Denmark, Lyngby, Denmark
3) Professor Carl-Gustaf Ribbing, Department of Engineering Sciences, Solid State Physics, Uppsala University, Uppsala, Sweden

3.1.1 Short presentation of Christian Sohl's thesis

The dissertation of Christian Sohl deals with physical bounds on scattering and absorption of acoustic and electromagnetic waves. A general dispersion relation or sum rule for the extinction cross section of such waves is derived from the holomorphic properties of the scattering amplitude in the forward direction. The derivation is based on the forward scattering theorem via certain Herglotz functions and their asymptotic expansions in the low-frequency and high-frequency regimes. The result states that, for a given interacting target, there is only a limited amount of scattering and absorption available in the entire frequency range. The forward dispersion

relation is shown to be valuable for a broad range of frequency domain problems involving acoustic and electromagnetic interaction with matter on a macroscopic scale. In the modeling of a metamaterial, *i.e.*, an engineered composite material that gains its properties by its structure rather than its composition, it is demonstrated that for a narrow frequency band, such a material may possess extraordinary characteristics, but that tradeoffs are necessary to increase its usefulness over a larger bandwidth.

The dispersion relation for electromagnetic waves is also applied to a large class of causal and reciprocal antennas to establish a priori estimates on the input impedance, partial realized gain, and bandwidth of electrically small and wideband antennas. The results are compared to the classical antenna bounds based on eigenfunction expansions, and it is demonstrated that the estimates presented in this dissertation offer sharper inequalities, and, more importantly, a new understanding of antenna dynamics in terms of low-frequency considerations.

The dissertation consists of 11 scientific papers of which several have been published in peer-reviewed international journals. Both experimental results and numerical illustrations are included. The General Introduction addresses closely related subjects in theoretical physics and classical dispersion theory, *e.g.*, the origin of the Kramers-Kronig relations, the mathematical foundations of Herglotz functions, the extinction paradox for scattering of waves and particles, and non-forward dispersion relations with application to the prediction of bistatic radar cross sections.

3.2 Licentiate dissertations

No licentiate dissertations were presented this year.

3.3 Journal publications

1. Y. Fei, Y. Fan, B. K. Lau, and J. S. Thompson. Optimal single-port matching impedance for capacity maximization in compact MIMO arrays. *IEEE Trans. Antennas Propagat.*, **56**(11), 3566–3575, 2008.
2. T. Lenart, M. Gustafsson, and V. Öwall. A hardware acceleration platform for digital holographic imaging. *Journal of VLSI Signal Processing Systems*, **52**(3), 297–311, 2008.
3. A. Mölder, M. Sebesta, M. Gustafsson, L. Gisselson, A. G. Wingren, and K. Alm. Non-invasive, label-free cell counting and quantitative analysis of adherent cells using digital holography. *Journal of Microscopy*, **232**(2), 240–247, 2008.
4. S. Nordebo, A. Fhager, M. Gustafsson, and M. Persson. A systematic approach to robust preconditioning for gradient-based inverse scattering algorithms. *Inverse Problems*, **24**(2), 025027, 2008.

5. J. Ramprecht, M. Norgren, and D. Sjöberg. Scattering from a thin magnetic layer with a periodic lateral magnetization: application to electromagnetic absorbers. *Progress in Electromagnetics Research*, **83**, 199–224, 2008.
6. J. Ramprecht and D. Sjöberg. Magnetic losses in composite materials. *J. Phys. D: Applied Phys.*, **41**, 135005, 2008.
7. D. Sjöberg. Analysis of wave propagation in stratified structures using circuit analogs, with application to electromagnetic absorbers. *European Journal of Physics*, **29**(4), 721–734, 2008.
8. D. Sjöberg. A modified Drude-Born-Fedorov model for isotropic chiral media, obtained by finite scale homogenization. *J. Phys. D: Applied Phys.*, **41**(15), 155412, 2008.
9. C. Sohl and M. Gustafsson. A priori estimates on the partial realized gain of ultra-wideband (UWB) antennas. *Quart. J. Mech. Appl. Math.*, **61**(3), 415–430, 2008.
10. C. Sohl, C. Larsson, M. Gustafsson, and G. Kristensson. A scattering and absorption identity for metamaterials: experimental results and comparison with theory. *J. Appl. Phys.*, **103**(5), 054906:1–5, 2008.

3.4 Books

1. Gerhard Kristensson, Second order differential equations — special functions and their classification, 2008.

3.5 Contributions in books

1. G. Kristensson, C. Larsson, C. Sohl, and M. Gustafsson. Bounds on metamaterials: Theoretical and experimental results. In *Metamaterials and Plasmonics: Fundamentals, Modelling, Applications*, ISSN 1874-6500, pages 21–33. Springer-Verlag, Netherlands, 2008.

3.6 Conference publications

1. A. A. Glasunov, A. Molisch, M. Gustafsson, F. Tufvesson, and G. Kristensson. On the mean effective gain expressed in terms of the spherical vector wave expansion of the electromagnetic field. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
2. A. A. Glasunov, F. Tufvesson, M. Gustafsson, A. Molisch, and G. Kristensson. Branch cross-correlation in presence of spatially selective interference expressed in terms of the spherical vector wave expansion of the electromagnetic field. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.

3. M. Gustafsson and C. Sohl. Physical bounds and summation rules in antenna theory. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
4. M. Gustafsson and C. Sohl. A priori estimates on the partial realized gain of UWB-antennas. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
5. M. Gustafsson and C. Sohl. Summation rules for the antenna input impedance. In *IEEE AP-S International Symposium on Antennas and Propagation*, San Diego, U.S., July 5, 2008.
6. M. Gustafsson, C. Sohl, A. Karlsson, and G. Kristensson. A time-domain approach to the extinction paradox for scattering of electromagnetic waves. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
7. M. Gustafsson, C. Sohl, and S. Nordebo. Physical bounds on the antenna scattering matrix. In *IEEE AP-S International Symposium on Antennas and Propagation*, San Diego, U.S., July 5, 2008.
8. G. Kiani, K. Esselle, A. Karlsson, and L. G. Olsson. Transmission improvement of useful signals through energy saving glass windows using frequency selective surfaces. In *Workshop on Applications of Radio Science*, Queensland, Australia, February 10, 2008.
9. G. Kristensson, C. Sohl, and M. Gustafsson. Physical bounds on scattering by metamaterials. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
10. G. Kristensson, C. Sohl, C. Larsson, and M. Gustafsson. Bounds on metamaterials: theoretical results. In *NATO Advanced Research Workshop: Metamaterials for Secure Information and Communication Technologies*, Marrakesh, Morocco, May 7, 2008.
11. C. Larsson, C. Sohl, M. Gustafsson, and G. Kristensson. Extinction cross section measurements. In *Nordic Conference on Radio Science and Communications*, Växjö, Sweden, June 9, 2008.
12. C. Larsson, C. Sohl, M. Gustafsson, and G. Kristensson. Wideband extinction measurements for thin and planar samples. In *IEEE AP-S International Symposium on Antennas and Propagation*, San Diego, U.S., July 5, 2008.
13. C. Larsson, C. Sohl, G. Kristensson, and M. Gustafsson. Bounds on metamaterials: experimental results. In *NATO Advanced Research Workshop: Metamaterials for Secure Information and Communication Technologies*, Marrakesh, Morocco, May 7, 2008.
14. S. Nordebo, M. Gustafsson, C. Sohl, and G. Kristensson. On the optimal limitations for scattering of spherical modes. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
15. V. Plicanic, B. K. Lau, A. Derneryd, and Z. Ying. On MIMO capacity of a dual multiband antenna prototype with user interactions. In *6th COST2100 Management Committee Meeting*, Lille, France, October 6–8, 2008.

16. V. Plicanic, B. K. Lau, and Z. Ying. Influence of user hand on the performance of a multiband diversity antenna. In *4th COST2100 Management Committee Meeting*, Wroclaw, Poland, February 6–8, 2008.
17. V. Plicanic, B. K. Lau, and Z. Ying. Performance of a multiband diversity antenna with hand effects. In *Proceedings of iWAT2008, 2008 IEEE International Workshop on Antenna Technology*, pages 534–537, Chiba, Japan, March 4, 2008.
18. J. Ramprecht and D. Sjöberg. On the amount of magnetic material necessary in broadband magnetic absorbers. In *IEEE AP-S International Symposium on Antennas and Propagation*, San Diego, U.S., July 5, 2008.
19. D. Sjöberg. Finite scale homogenization of chiral media. In *XXIXth General Assembly, URSI*, Chicago, U.S., August 7, 2008.
20. D. Sjöberg and J. Ramprecht. Waves in ferromagnetic media. In *Radio Science and Communications & Mathematical Modeling of Wave Phenomena (RVK08/MMWP08)*, pages 114–117, Växjö, Sweden, June 9 , 2008.
21. D. Sjöberg, J. Ramprecht, and N. Wellander. Stability and causality of effective material parameters for biased ferromagnetic materials. In *XXIXth General Assembly, URSI*, Chicago, U.S., August 7, 2008.
22. C. Sohl and M. Gustafsson. A priori bounds on the onset frequency of wideband antennas. In *Nordic Conference on Radio Science and Communications*, Växjö, Sweden, June 9, 2008.
23. C. Sohl and M. Gustafsson. Theoretical bounds on the directivity and bandwidth of electrically small and wideband antennas. In *IEEE AP-S International Symposium on Antennas and Propagation*, San Diego, U.S., July 5, 2008.
24. C. Sohl, M. Gustafsson, and A. Bernland. Some paradoxes associated with a recent sum rule in scattering theory. In *URSI General Assembly*, Chicago, U.S, August 7, 2008.
25. C. Sohl, M. Gustafsson, and G. Kristensson. Bounds on the direct scattering problem of acoustic and electromagnetic waves. In *International Conference on Mathematical Modelling of Wave Phenomena*, Växjö, Sweden, June 9, 2008.
26. C. Sohl, M. Gustafsson, G. Kristensson, and S. Nordebo. A general approach for deriving bounds in electromagnetic theory. In *URSI General Assembly*, Chicago, U.S., August 7, 2008.
27. R. Tian and B. K. Lau. On compact MIMO antenna systems with optimized uncoupled impedance matching. In *4th COST2100 Management Committee Meeting*, Wroclaw, Poland, February 6–8, 2008.
28. R. Tian and B. K. Lau. On prediction of MIMO capacity performance with antenna magnitude patterns. In *6th COST2100 Management Committee Meeting*, Lille, France, October 6–8, 2008.
29. R. Tian and B. K. Lau. Uncoupled antenna matching for performance optimization in compact MIMO systems using unbalanced load impedance. In *IEEE Ve-*

hicular Technology Conference (VTC Spring 2008), pages 299–303, Singapore, May 11–14, 2008.

3.7 Thesis publications

1. C. Sohl. *Dispersion Relations in Scattering and Antenna Problems*. PhD thesis, Lund University, Department of Electrical and Information Technology, P.O. Box 118, S-221 00 Lund, Sweden, 2008.

3.8 Diploma works

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

Henrik Ramberg, "Investigation of the High Dielectric Feed (HDF) Antenna"
Advisor: Mats Gustafsson

Jesper Petersson, "Investigation of Head and Hand Influence on Clamshell Mobile Phone Antenna Matching"
Advisor: Anders Karlsson.

David Olsson, "Impedance Matching In Moblie MIMO Terminals"
Advisor: Anders Karlsson.

3.9 Technical reports

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

1. Andrés Alayón Glazunov, Andreas F. Molisch, and Fredrik Tufvesson. On the mean effective gain of antennas. *LUTEDX/(TEAT-7161)/1-25/(2008)*.
   Abstract: The mean effective gain (MEG) is one of the most important parameters for the characterization of antennas in wireless channels. This paper provides an analysis of some fundamental properties of the MEG and gives corresponding physical interpretations. Three points are analyzed in detail: (i) we provide closed-form expressions for MEG in a mixed environment with both stochastic and deterministic components, showing that the MEG can be written as a sum of gains for the deterministic and stochastic components, (ii) we show that under some assumptions the propagation channel and the antenna are equivalent in the sense that the impact of the channel cross-polarization ratio (XPR) and the antenna effective-XPD on the MEG are symmetrical, (iii) based

on the fact that MEG depends on random variables, such as the XPR and antenna rotations due to user's movements, we define the average, the minimum and maximum MEG of antennas, respectively. Finally, we derive the maximum effective gain of antennas and show that it is bounded by $4\pi\eta_{\text{rad}}$, where η_{rad} is the radiation efficiency of the antenna.

2. Andrés Alayón Glazunov, Mats Gustafsson, Andreas F. Molisch, Fredrik Tufvesson, and Gerhard Kristensson. Spherical vector wave expansion of gaussian electromagnetic fields for antenna-channel interaction analysis. *LUTEDX/(TEAT-7162)/1-28/(2008).*
   Abstract: In this paper we introduce an approach to analyze the interaction between antennas and the propagation channel. We study both the antennas and the propagation channel by means of the spherical vector wave mode expansion of the electromagnetic field. Then we use the expansion coefficients to study some properties of general antennas in those fields by means of the antenna scattering matrix. The focus is on the spatio-polar characterization of antennas, channels and their interactions. We provide closed form expressions for the covariance of the field multi-modes as function of the Power Angle Spectrum (PAS) and the channel cross-polarization ratio (XPR). A new interpretation of the Mean Effective Gains (MEG) of antennas is also provided. The maximum MEG is obtained by conjugate mode matching between the antennas and the channel; we also prove the (intuitive) results that the optimum decorrelation of the antenna signals is obtained by the excitation of orthogonal spherical vector modes.

3. Christian Sohl, Mats Gustafsson, and Anders Bernland. Some paradoxes associated with a recent sum rule in scattering theory. *LUTEDX/(TEAT-7163)/1-6/(2008).*
   Abstract: This paper reports on some peculiarities associated with a recently published summation rule for scattering of electromagnetic waves. The summation rule states that the extinction cross section integrated over all frequencies is equal to the low-frequency response of the target. Although the summation rule is intriguing by itself, it becomes even more paradoxical when a static conductivity model or the PEC boundary condition is introduced. The paradoxical character lies in the fact that the extinction cross section integrated over all frequencies is independent of the static conductivity as long as it is non-zero. This puzzling result is explained by rejecting the static conductivity model at zero frequency as suggested by numerical simulations of a homogeneous and isotropic sphere. In addition, the low-frequency behavior of diamagnetic materials is investigated using Herglotz functions and arguments from the theory of special relativity.

4. Sven Nordebo, Andreas Fhager, Mats Gustafsson, and Mikael Persson. A systematic approach to robust preconditioning for gradient based inverse scattering algorithms. *LUTEDX/(TEAT-7164)/1-23/(2008).*
   Abstract: This paper presents a systematic approach to robust preconditioning for gradient based non-linear inverse scattering algorithms. In particular,

one- and two-dimensional inverse problems are considered where the permittivity and conductivity profiles are unknown and the input data consists of the scattered field over a certain bandwidth. A time-domain least-squares formulation is employed and the inversion algorithm is based on a conjugate gradient, or quasi-Newton algorithm together with an FDTD-electromagnetic solver. A Fisher information analysis is used to estimate the Hessian of the error functional. A robust preconditioner is then obtained by incorporating a parameter scaling such that the scaled Fisher information has a unit diagonal. By improving the conditioning of the Hessian, the convergence rate of the conjugate gradient or quasi-Newton methods are improved. The preconditioner is robust in the sense that the scaling, *i.e.*, the diagonal Fisher information is virtually invariant to the numerical resolution and the discretization model that is employed. Numerical examples of image reconstruction are included to illustrate the efficiency of the proposed technique.

5. Sven Nordebo and Mats Gustafsson. A priori modelling for gradient based inverse scattering algorithms. *LUTEDX/(TEAT-7165)/1-21/(2008)*.
   Abstract: This paper presents a Fisher information based Bayesian approach to analysis and design of the regularization and preconditioning parameters used with gradient based inverse scattering algorithms. In particular, a one-dimensional inverse problem is considered where the permittivity and conductivity profiles are unknown and the input data consist of the scattered field over a certain bandwidth. A priori parameter modelling is considered by nonlinear exponential and arctangential parameter scalings and robust preconditioners are obtained by choosing the related scaling parameters based on a Fisher information analysis of the known background. The Bayesian approach and a principal parameter (singular value) analysis of the stochastic Cramér-Rao bound provide a natural interpretation of the regularization that is necessary to achieve stable inversion, as well as an indicator to predict the feasibility of achieving successful reconstruction in a given problem set-up. In particular, the Tikhonov regularization scheme is put into a Bayesian estimation framework. A time-domain least-squares inversion algorithm is employed which is based on a quasi-Newton algorithm together with an FDTD-electromagnetic solver. Numerical examples are included to illustrate and verify the analysis.

6. Christer Larsson, Chistian Sohl, Mats Gustafsson, and Gerhard Kristensson. Wideband extinction measurements for thin and planar samples. *LUTEDX/(TEAT-7166)/1-10/(2008)*.
   Abstract: A method to determine the extinction cross section for a thin and planar object for a large bandwidth in the microwave region is developed. The method is based on a regular measurement of the monostatic radar cross section. It is compared to and validated with a more general measurement method based on a measurement of the radar cross section in the forward direction. The result shows that monostatic RCS measurements can be used with good accuracy to determine the extinction cross section for this type of thin samples.

7. Daniel Sjöberg. A modified Drude-Born-Fedorov model for isotropic chiral media, obtained by finite scale homogenization. *LUTEDX/(TEAT-7167)/1-10/(2008)*.
   Abstract: Isotropic chiral media can be modeled in several ways. We show that when realizing such a medium from spiral inclusions with real permittivities and permeabilities in a periodic structure, a modified Drude-Born-Fedorov model is obtained. This model equals the original Born model for small wave vectors, but the strength of the chirality depends on the propagation direction. The effective parameters are calculated by an unbiased finite scale homogenization method, which in principle could generate any model.

8. Anders Karlsson. Approximate boundary conditions for thin structures. *LUTEDX/(TEAT-7168)/1-9/(2008)*.
   Abstract: In wave propagation problems thin structures are often replaced by boundaries of zero thickness, in order to reduce the numerical mesh. In this simplification of the geometry it is crucial that the approximate boundary condition compensates for the reduction of thickness of the structure. In this paper a boundary condition originally introduced by Mitzner is compensated for this reduction. The new compensated Mitzner condition is more general and accurate than the common impedance boundary condition. For frequency domain solvers it is as easy to implement as the impedance boundary condition. The condition is tested and compared with the impedance boundary condition for planar and cylindrical structures. The new condition is exact at normal incidence on a planar structure.

9. Jörgen Ramprecht and Daniel Sjöberg. Magnetic losses in composite materials. *LUTEDX/(TEAT-7169)/1-28/(2008)*.
   Abstract: We discuss some of the problems involved in homogenization of a composite material built from ferromagnetic inclusions in a nonmagnetic background material. The small signal permeability for a ferromagnetic spherical particle is combined with a homogenization formula to give an effective permeability for the composite material. The composite material inherits the gyrotropic structure and resonant behavior of the single particle. The resonance frequency of the composite material is found to be independent of the volume fraction, unlike dielectric composite materials. The magnetic losses are described by a magnetic conductivity which can be made independent of frequency and proportional to the volume fraction by choosing a certain bias. Finally, some concerns regarding particles of small size, *i.e.*, nanoparticles, are treated and the possibility of exciting exchange modes are discussed. These exchange modes may be an interesting way to increase losses in composite materials.

10. Ghaffer I. Kiani, Anders Karlsson, and Lars Olsson. Glass characterization for designing frequency selective surfaces to improve transmission through energy saving glass windows. *LUTEDX/(TEAT-7170)/1-7/(2008)*.
    Abstract: This paper reports initial work on creating frequency selective surfaces (FSS) on modern day glass windows to improve the transmission of wireless

communication signals through the glass. The manufacturers of these glass windows apply very thin layers of metallic oxides on one side of glass to provide extra thermal insulation. These coatings block the infrared and ultraviolet waves to provide thermal insulation, but they also attenuate communication signlas such as GSM 900, GSM 1800/1900, UMTS and 3G mobile signals. This creates a major communication problem when buildings are constructed using mostly such type of glass. A bandpass FSS can provide a solution to increase the transmission of useful bands through the coated glass. In order to design an appropriate FSS, the relative permittivity and conductivity of glass should be measured accurately. Moreover, electrical properties of the coated layer must also be known in order to obtain a resonance in the desired band. In this work, we used two different methods of measuring the permittivity and conductivity of glass. Electrical properties of one of the common glass windows (Optitherm^{TM} SN) are presented. Simulations of Optitherm glass shows about 35 dB transmission loss over 900 - 2200 MHz frequency band.

11. Alireza Kazem zadeh and Anders Karlsson. New aspects of ultra thin absorbers. *LUTEDX/(TEAT-7171)/1-12/(2008).*
Abstract: Ultra thin absorbers are studied in detail to provide a comprehensive model for their absorption mechanism. It is shown that the transmission line (TML) approach is not able to model the absorber frequency response correctly. It results in large errors when the thickness to wavelength (d/λ) ratio is below a certain level. It is explained that large amplitudes of high order Floquet modes and excitation of non-transverse component of the scattered field at the absorption frequency are the reasons for the TML model inaccuracy. It is illustrated that at small d/λ ratios, the structure becomes a localized lossy resonator which exhibits absorption even in a finite size array configuration. For a resistive squared patch periodic array, the resonance frequency can be estimated fairly accurately by the cavity model of a single perfect conductor patch antenna.

12. Jörgen Ramprecht, Martin Norgren, and Daniel Sjöberg. Scattering from a thin magnetic layer with a periodic lateral magnetization: application to electromagnetic absorbers. *LUTEDX/(TEAT-7172)/1-21/(2008).*
Abstract: A magnetized thin layer mounted on a PEC surface is considered as an alternative for an absorbing layer. The magnetic material is modeled with the Landau-Lifshitz-Gilbert equation, with a lateral static magnetization having a periodic variation along one lateral direction. The scattering problem is solved by means of an expansion into Floquet-modes, a propagator formalism and wave-splitting. Numerical results are presented, and for parameter values close to the typical values for ferro- or ferrimagnetic media, reflection coefficients below -20 dB can be achieved for the fundamental mode over the frequency range 1-4 GHz, for both polarizations. It is found that the periodicity of the medium makes the reflection properties for the fundamental mode almost independent of the azimuthal direction of incidence, for both normally and obliquely incident waves.

13. Anders Derneryd, Mats Gustafsson, Gerhard Kristensson, and Christian Sohl. Application of gain-bandwidth bounds on loaded dipole antennas. *LUTEDX/(TEAT-7173)/1-14/(2008)*.
Abstract: The concept of physical limitations based only on antenna volume, form factor, and material parameters is applied to electrically small antennas in the form of single dipoles. The upper bound on the gain-bandwidth product is solely determined by the polarizability matrix that characterizes the antenna when it is immersed in a uniform applied static field. The polarizability, and hence the bandwidth, is increased by inductively loading the dipole arms close to their ends. The half-power impedance bandwidth is increased from 5% to 13% by moving the inductors from the center to the ends of the dipole arms. The introduction of a stub-matching further improves the bandwidth but the physical limit is not reached. Finally, a dual-resonance dipole antenna is analyzed. It is observed that a second resonance hardly reduces the bandwidth of the first resonance if the resonances are separated more than 1.7 times in frequency.

14. Alireza Kazem Zadeh and Anders Karlsson. Capacitive circuit method for fast and efficient design of wideband radar absorbers. *LUTEDX/(TEAT-7174)/1-20/(2008)*.
Abstract: A simple, fast and efficient method for designing wideband radar absorbers is proposed. The idea is to modify the circuit analog absorber method without perturbing the bandwidth. This is done by utilizing the asymptotic behavior of such an absorber at low frequency and replacing the band-stop resonating frequency selective surfaces with low-pass capacitive ones, which can be synthesized by square patches. It is shown that higher frequencies are not influenced by these modifications. A thin wideband capacitive circuit absorber (CCA) is presented with 28% reduction of thickness and 57% increase of bandwidth in comparison to the Salisbury screen. It is also explained why some optimized metamaterial designs fail to compete with the CCA method. For high permittivity layers, it is shown that the CCA is a better solution than the Jaumann absorber and improvements both in thickness and bandwidth are possible. A three layered ultra wideband (4–24 GHz) CCA is presented with total thickness of 15.1 mm. Finally, a design capable of handling oblique angles of incidence for both polarizations and fulfilling different mechanical, thermal and fabrication constraints is given. The absorption band covers the entire C, X and Ku radar bands (4–18 GHz), showing significant improvement compared to the published circuit analog absorbers.

15. Daniel Sjöberg. Variational principles for the static electric and magnetic polarizability of anisotropic media with PEC inclusions. *LUTEDX/(TEAT-7175)/1-21/(2008)*.
Abstract: We derive four variational principles for the electric and magnetic polarizabilities for a structure consisting of anisotropic media with perfect electric conductor inclusions. From these principles we derive monotonicity results and upper and lower bounds on the electric and magnetic polarizabilities. When computing the polarizabilities numerically, the bounds can be used as error bounds.

The variational principles demonstrate important differences between electrostatics and magnetostatics when PEC bodies are present.

16. Daniel Sjöberg. Low frequency scattering by passive periodic structures for oblique incidence: low pass case. *LUTEDX/(TEAT-7176)/1-13/(2008)*.
Abstract: We derive the low frequency behavior of the scattering coefficients from a low pass structure which periodic in a plane, and finite in the normal direction. The analysis is for oblique incidence of arbitrary polarization on a structure which can be anisotropic in both electric and magnetic material properties, and may contain metal inclusions. The metal inclusions can be modeled both as perfect electric conductors (PEC), and with a finite conductivity. It is found that the low frequency reflection and transmission coefficients are proportional to the sum and difference of the electric and magnetic polarizability per unit area of the periodic structure. If the metal inclusions are modeled as PEC instead of as a finite conductivity, the first order low frequency reflection is larger whereas the first order transmission is smaller.

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4 Guests and Seminars

4.1 Visitors at the group of Electromagnetic Theory

Jørgen Bach Andersen, Department of Electronic Systems, Aalborg University, Aalborg, Denmark, February 14–15, 2008.

Mats Andersson, Bluetest AB, Sweden, September 8, 2008.

Svend Berntsen, Department of Mathematics and Computer Science, Aalborg University, Aalborg, Denmark, September 22–23, 2008.

Craig F. Bohren, Pennsylvania State University, USA, September 22-25, 2008.

Roy Booth, Hartebeesthoek Radio Astronomy Observatory, Hartebeesthoek, South Africa, and Onsala Space Observatory, Sweden, February 7, 2008.

Anders Boström, Department of Applied Mechanics, Chalmers University of Technology, Göteborg, Sweden, April 25, 2008.

Olav Breinbjerg, Electrical Engineering Department of Electrical Engineering, Technical University of Denmark, Lyngby, Denmark, September 23, 2008.

Christian Bergljung, Ericsson Mobile Platform, Sweden, September 8, 2008.

Nicholas Buris, Motorola Labs, Schaumburg, USA, September 8–9, 2008.

Zhi Ning Chen, Institute for Infocomm Research, Singapore, September 8–9, 2008.

Margaret Cheney, Mathematics Department, Rensselaer Polytechnic Institute, Troy, USA, June 13, 2008.

Fredrik Edelvik, Computational Engineering and Design, Fraunhofer-Chalmers Research Centre for Industrial Mathematics (FCC), Göteborg, Sweden, August 27, 2008.

Anders Ekman, SONDERO Technologies AB, Halmstad, Sweden, October 10, 2008.

Andreas Fhager, Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden, November 19, 2008.

Hans Giertz, Bromma, Sweden, January 22, 2008.

Johan Helsing, Department of Mathematics, Lund University, Sweden, February 1, 2008.

Stefan Jacobsson, Computational Engineering and Design, Fraunhofer-Chalmers Research Centre for Industrial Mathematics (FCC), Göteborg, Sweden, August 27, 2008.

Lars Jonsson, School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, September 8, 2008.

Stefan Kröll, Division of Atomic Physics, Department of Physics, LTH, Lund, December 19, 2008.

Jonas Medbo, Ericsson Research AB, Sweden, September 8–9, 2008.

Lars Montelius, Division of Solid State Physics, Department of Physics, LTH, Lund, October 30, 2008.

Ben Munk, Department of Electrical Engineering, Ohio State University, USA, February 4–6, 2008.

Börje Nilsson, The School of Mathematics and Systems Engineering, Växjö University, Växjö, Sweden, September 30 2008.

Sven Nordebo, The School of Mathematics and Systems Engineering, Växjö University, Växjö, Sweden, numerous visits during 2008.

Risto Pirjola, Finnish Meteorological Institute, Helsinki, Finland, February 12, 2008.

Carl-Gustaf Ribbing, Department of Engineering Sciences, Solid State Physics, Uppsala University, Uppsala, Sweden, September 23, 2008.

Sara Rydström, The School of Mathematics and Systems Engineering, Växjö University, Växjö, Sweden, September 30 2008.

Staffan Ström, School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, May 13, 2008.

Tomas Svensson, Atomic Physics, Physics Department, Lund, Sweden, June 17, 2008.

Carl Tylén, SONDERO Technologies AB, Halmstad, October 10, 2008.

Carl-Henrik Walde, Näsbypark, Sweden, September 25, November 13, 2008.

Jon Wallace, Jacobs University, Bremen, Germany, September 8–9, 2008.

Zhinong Ying, Sony Ericsson Mobile Communications AB, Sweden, September 8–9, 2008.

4.2 Seminars

Henrik Ramberg, Presentation of Diploma thesis, "Investigation of the High Dielectric Feed (HDF) Antenna," January 31, 2008.

Johan Helsing, "Boundary integral equations on difficult geometries," February 1, 2008.

Nicholas Buris, "Antenna: END-to-END Approach for MIMO Antenna Design," , September 8, 2008.

Jesper Petersson, Presentation of Diploma Thesis, "Investigation of head and Hand Influence on Clamshell Mobile Phone Antenna Matching," September 18, 2008.

Craig F. Bohren, "Who Nose? The Chemistry, Physiology, Psychology, Physics, Meteorology, and Fluid Mechanics of Canine Olfactory Tracking," September 24, 2008.

Sara Rydström, "Localization of cracks in wooden logs with inverse acoustic scattering," September 30, 2008.

Carl Tylén, October 10, 2008.

David Olsson, Presentation of Diploma Thesis, "Matching Mobile MIMO Terminals," December 15, 2008.

4.3 Courses and Workshops

1. **Professor Ben Munk** gave on February 4–6, 2008 a very well received course on metamaterials, circuit analog absorbers, and radome shutters at LTH. The course was a joint arrangement with Defence Materiel Administration (FMV), see Figure 9.

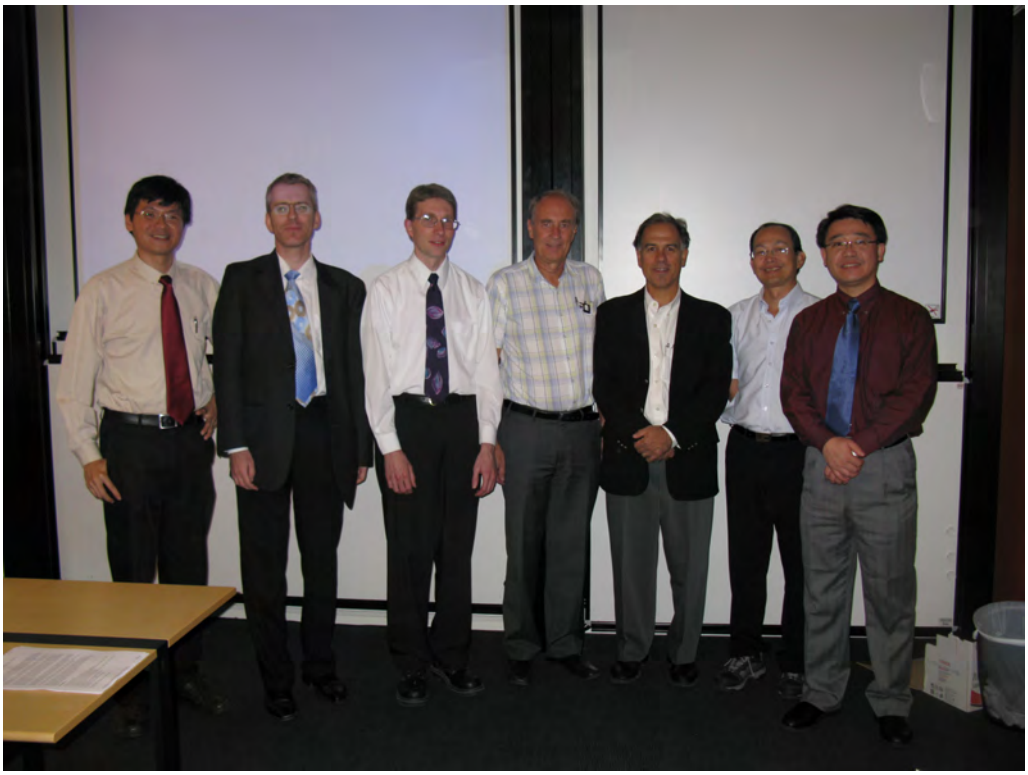

Figure 8: Some of the main speakers at the combined IEEE AP Chapter and the Workshop on MIMO Antenna Systems research held at LTH on September 8–9, 2008. From left to right: Buon Kiong Lau, Andreas F. Molisch, Jon Wallace, Anders Derneryd, Nicholas E. Buris, Zhinong Ying, and Zhi Ning Chen.

2. **High Speed Wireless Center Workshop** (HSWC), Arild, Sweden, April 21–22, 2008.

3. An **IEEE AP Chapter** at LTH was held on September 8, 2008 in combination with a **workshop on MIMO Antenna Systems research** on September 8–9, 2008, see Figure 8. The workshop was organized by Buon Kiong Lau, Anders Derneryd, Ruiyuan Tian, and Vanja Plicanic, and it was attended by more than 50 people, and it could have been more, if we did not limit the number of participants, see Figure 10.

   Program September 8:

   (a) IEEE Distinguished Lecturer: Dr Nicholas E. Buris, Motorola Labs, USA. *Title:* Antenna: END-to-END Approach for MIMO Antenna Design.

   (b) Christian Bergljung, Ericsson Mobile Platform, Sweden *Title:* MIMO Antenna Systems from the Standardization Perspective.

   (c) Mats Andersson, Bluetest AB, Sweden *Title:* Very Fast Measurements of Diversity and MIMO Gain of Both Passive and Active Multiport Antenna

Figure 9: The participants at the course of Ben Munk on February 4–6, 2008.

Figure 10: Some of the participants at the Workshop on MIMO Antenna Systems research held at LTH on September 9, 2008.

Systems with Reverberation Chambers.

Program September 9:

(a) Jon Wallace, Jacobs University Bremen, Germany. *Title:* Antenna Design Considerations for MIMO and Diversity Systems.

(b) Zhi Ning Chen, Institute for Infocomm Research, Singapore. *Title:* Notes on Antenna Design in MIMO Systems.

(c) Andreas F. Molisch, Lund University, Sweden and MERL USA. *Title:* Super-Antennas.

(d) Anders Derneryd, Ericsson Research AB, Sweden. *Title:* Performance of Closely Spaced Multiple Antennas for Terminal Applications.

(e) Zhinong Ying, Sony Ericsson Mobile Communications AB, Sweden. *Title:* Characterization of a Compact MIMO DRA Antenna and Its Application in WLAN.

(f) Jonas Medbo, Ericsson Research AB, Sweden. *Title:* MIMO Channel Measurement and Modeling Experiences.

4. **Workshop at Lidingö, Stockholm** together with colleagues from the Department of Electromagnetic Theory, Royal Institute of Technology, and Växjö University, October 23–24, 2008.
Participants from the department were:

Anders Derneryd
Mats Gustafsson
Andreas Ioannidis
Anders Karlsson
Gerhard Kristensson
Alireza Kazemzadeh
Richard Lindin
Daniel Sjöberg
Christian Sohl

5. A **workshop on micro modeling** was held at the Swedish Defence Research Agency, FOI, Linköping, Sweden, December 5, 2008. The workshop was organized by Niklas Wellander and Daniel Sjöberg and 14 persons attended the workshop.

   (a) Micro modeling - Homogenization of Maxwell's equations, classical homogenization and finite scale

   (b) Numerical modeling in Comsol Multiphysics

   (c) Mixing formulas

   (d) Modeling real materials

   (e) On the measurement of bianisotropic material parameters in metallic waveguides

6. A **workshop on material measurements** for microwave frequencies was organized by Daniel Sjöberg and Christer Larsson at Saab Bofors Dynamics, Linköping, Sweden, December 10, 2008.

5 Visits and Lectures by the Staff

5.1 Visits to other institutes and departments

Anders Derneryd:

SNRV årsmöte, Göteborg, Sweden, April 15–16, 2008.

Mats Gustafsson:

Measurement campaign at Saab Bofors Dynamics, Linköping, Sweden, February 14, 2008.

Ericsson Research AB, Göteborg, Sweden, February 27, 2008.

FMV, Linköping, March 18, 2008.

NFFP, Göteborg, March 19, 2008.

Charmant workshop, Chalmers, May 12, 2008.

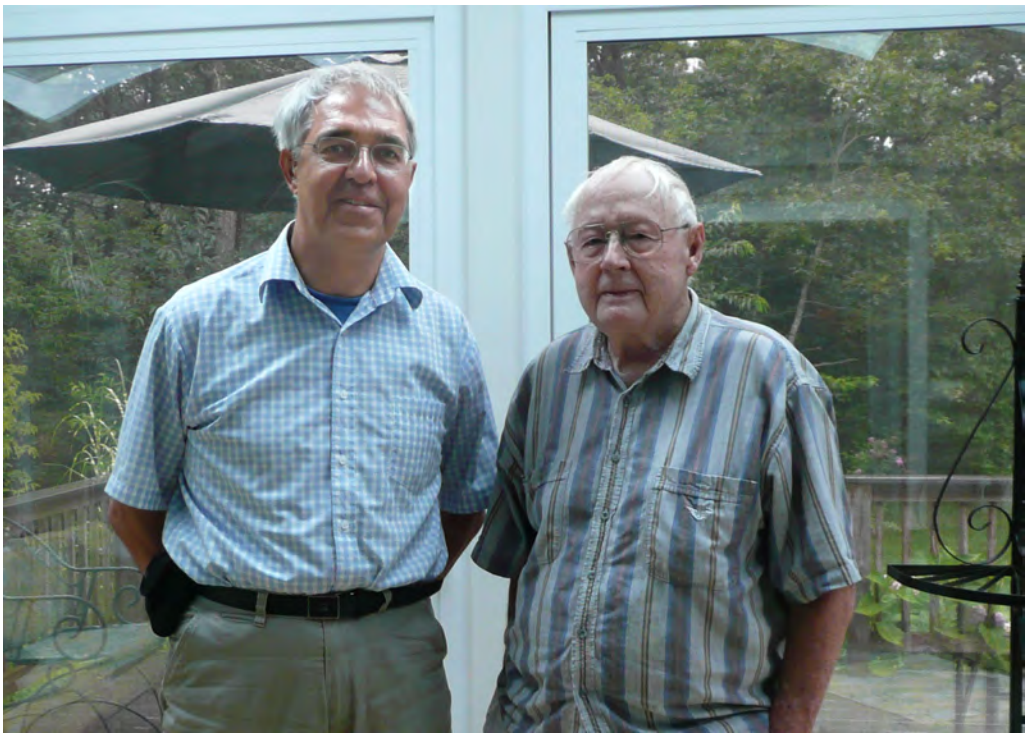

Figure 11: Gerhard Kristensson together with Peter Waterman in Peter's home.

NFFP, Mölndal, June 25, 2008.

Motorola Labs, Schaumburg, IL, USA, August 11, 2008.

SNRV B/F meeting at MaxLab, Lund, Sweden, August 18, 2008.

VINNOVA Sino-Swedish Project Kicko, KTH, Stockholm, Sweden, September 18, 2008.

NFFP, Linköping, October 1, 2008.

Andreas Ioannidis:

The School of Mathematics and Systems Engineering, Växjö University, Växjö, Sweden, November 30, 2008.

Alireza Kazemzadeh:

FoT25 CAA, ACAB, Linköping, Sweden, November 20, 2008.

Anders Karlsson:

SNRV B/F meeting at MaxLab, Lund, Sweden, August 18, 2008.

Gerhard Kristensson:

Sigma Flyg 33, Saab Microwave Systems AB, Mölndal, Sweden, March 11, 2008.

FoT25 CAA, ACAB, Linköping, Sweden, March 27, 2008.

Planning of RVK08, Växjö University, Växjö, Sweden, April 2, 2008.

IPT meeting, Saab Aerosystems AB, Linköping, Sweden, April 10, 2008.

SNRV årsmöte, Göteborg, Sweden, April 15–16, 2008.

IPT meeting, Saab Aerosystems AB, Linköping, Sweden, April 18, 2008.

Teknikutveckling SAT, Saab, Stockholm, Sweden, April 29, 2008.

IPT meeting, FMV, Stockholm, Sweden, May 16, 2008.

Visiting Peter Waterman, USA, August 19, 2008, see Figure 11.

Teknikutveckling SAT, Saab, Stockholm, Sweden, October 7, 2008.

SNRV höstmöte, KVA, Sweden, October 22, 2008.

FoT25 CAA, ACAB, Linköping, Sweden, November 20, 2008.

Swedish Defence Research Agency, FOI, Linköping, Sweden, December 5, 2008.

Buon Kiong Lau:

Antenna Group, Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden, April 11, 2008.

Motorola Labs, Schaumburg, IL, USA, August 11, 2008.

VINNOVA Sino-Swedish Project Kickoff, KTH, Stockholm, Sweden, September 18, 2008.

Daniel Sjöberg:

SIGNOS och SIGANT (NFFP), Saab Communication, Linköping, Sweden, March 18, 2008.

FoT25 CAA, ACAB, Linköping, Sweden, March 27, 2008.

NFFP seminarium, Saab Linköping, Sweden, April 2, 2008.

IPT discussion, Saab, Linköping, Sweden, April 18, 2008.

IPT3 FMV, Stockholm, Sweden, May 16, 2008.

SBD, Linköping, Sweden, May 22, 2008.

School of Electrical Engineering, Electromagnetic Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, June 5, 2008.

The Department of Materials and Manufacturing Technology, Chalmers University of Technology, Göteborg, Sweden, June 12, 2008.

CP-DGR, Ticra, Copenhagen, Denmark, June 18, 2008.

FoT25-möte SMW Mölndal, Sweden, June 25, 2008.

SIGANT NFFP ACAB Linköping, Sweden, November 4, 2008.

Swedish Defence Research Agency, FOI, Linköping, Sweden, December 5, 2008.

Saab Bofors Dynamics, SBD, Linköping, Sweden, December 10, 2008.

Christian Sohl:

Measurement campaign at Saab Bofors Dynamics, Linköping, Sweden, February 14, 2008.

Ericsson Research AB, Göteborg, Sweden, February 27, 2008.

Guest researcher, Royal Institute of Technology, Stockholm, Sweden, September 5–November 30, 2008.

5.2 Guest Lectures by the department's staff

Mats Gustafsson:

HSWC seminar. *Title of the talk:* "Antennas and Channels for MIMO Systems," February 19, 2008.

Invited talk at Ericsson Research AB, Göteborg, Sweden. *Title of the talk:* "Partial waves and summation rules in antenna theory," February 27, 2008.

Participated with a talk at the EM-workshop, KTH, Sweden. *Title of the talk:* "Physical bounds on antennas," April 25, 2008.

Andreas Ioannidis:

Invited talk at the School of Mathematics and Systems Engineering, Växjö University, Växjö, Sweden. *Title of the talk:* "Direct and inverse problems for Maxwell equations in waveguide geometry," November 28, 2008.

Buon Kiong Lau:

Invited talk at Motorola Labs, Schaumburg, IL, USA. *Title of the talk:* "On MIMO Systems for Compact Mobile Terminals," August 11, 2008.

Daniel Sjöberg:

Moodle LTHs inspirationskurs, Lund, Sweden, November 5, 2008.

Participated with a talk at the EM-workshop, KTH, Sweden. *Title of the talk:* "Edge matching," April 25, 2008.

Workshop micro modeling, Swedish Defence Research Agency, FOI, Linköping, Sweden. *Title of the talks:* "Mixing formulas and bounds," "Modeling real materials," and "On the measurement of bianisotropic material parameters in metallic waveguides," December 5, 2008.

Workshop material measurements SBD, Linköping, Sweden. *Title of the talk:* "Material measurements in waveguides," December 10, 2008.

Christian Sohl:

Invited talk at Ericsson Research AB, Göteborg, Sweden. *Title of the talk:* "Theoretical bounds on the directivity and bandwidth of electrically small and wideband antennas," February 27, 2008.

Invited talk at Royal Institute of Technology, Stockholm, Sweden. *Title of the talk:* "Sum rules and fundamental bounds in scattering theory," October 22, 2008.

5.3 Awards

Anders Karlsson

Best paper award at the Workshop on Applications of Radio Science (together with G. Kiani, K. Esselle, and L. G. Olsson), Queensland, Australia, February 10, 2008.

Christian Sohl:

Young Scientist Award at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA, August 11, 2008.

URSI Commission B "Best Student Paper Prize" at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA, August 9–16, 2008, see Figure 12.

5.4 Participation in conferences

Anders Bernland:

Participated at the Swedish National Conference on Radio Science (RVK08), Växjö, Sweden. June 9–11, 2008.

Figure 12: Christian (left) receives his URSI Commission B "Best Student Paper Prize" at XXIXth URSI General Assembly, Chicago, USA, August 11, 2008.

Anders Derneryd:

Participated in the 4th Management Committee Meeting of COST Action 2100 on "Pervasive Mobile & Ambient Wireless Communications," Wroclaw, Poland, February 6–8, 2008.

Mats Gustafsson:

Participated in the workshop on metamaterials, circuit analog absorbers, and radome shutters at LTH, Sweden. February 4–6, 2008.

Participated in the workshop High Speed Wireless Center Workshop (HSWC), Arild, Sweden. April 21–22, 2008.

Participated at the Swedish National Conference on Radio Science (RVK08), Växjö, Sweden. June 9–11, 2008.

Participated with a paper at the IEEE Antennas and Propagation Symposium, San Diego, USA. *Title of the Paper:* "Summation rules for the antenna input impedance," July 5–12, 2008.

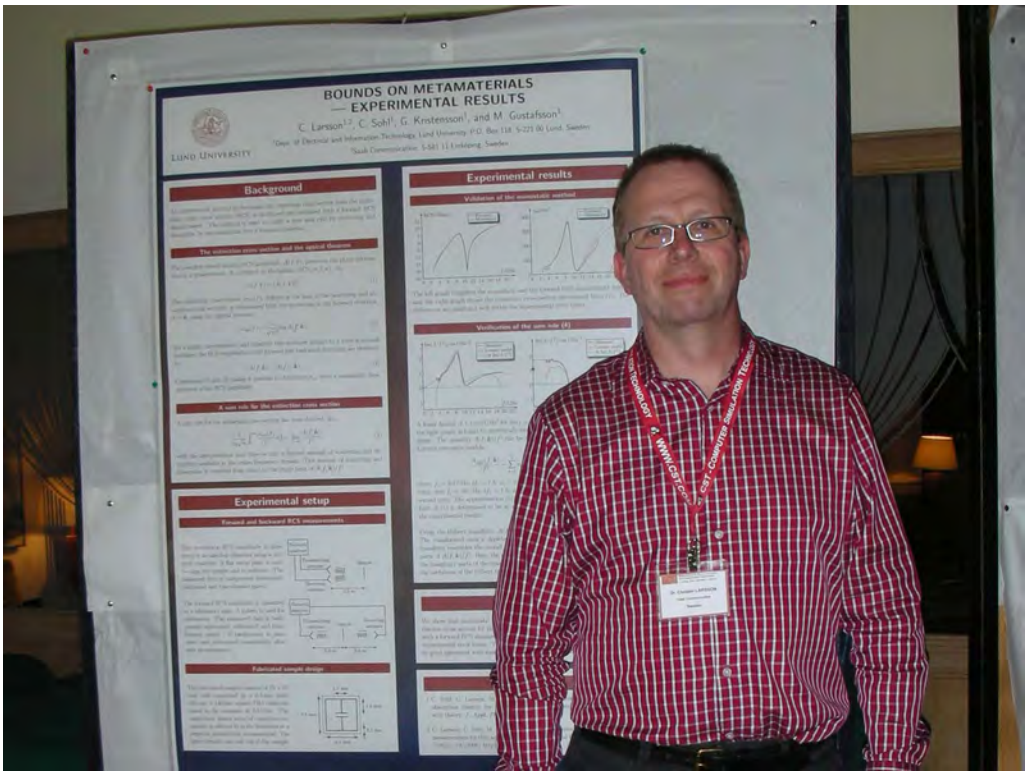

Figure 13: Christer Larsson in front of his poster at the NATO Advanced Research Workshop (Meta'08), Marrakesh, Morocco.

Participated with a paper at the IEEE Antennas and Propagation Symposium, San Diego, USA. *Title of the Paper:* "Physical bounds on the antenna scattering matrix," July 5–12, 2008.

Participated with an invited paper paper at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA, see Figure 14. *Title of the Paper:* "Physical bounds and summation rules in antenna theory," August 9–16, 2008.

Participated with a paper at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA. *Title of the Paper:* "A time-domain approach to the extinction paradox for scattering of electromagnetic waves," August 9–16, 2008.

Andreas Ioannidis:

Participated with an oral talk at the National Workshop on Metamaterials and Special Materials for Electromagnetic Applications and TLC, Naples, Italy. *Titles of the paper:* "On the direct and inverse problem of the homogeneous bi-isotropic waveguide with an arbitrary cross-section," December 18–19, 2008.

Figure 14: Some of participants at the XXIXth URSI General Assembly, Chicago, USA.

Anders Karlsson:

> Participated in the workshop on metamaterials, circuit analog absorbers, and radome shutters at LTH, Sweden. February 4–6, 2008.
>
> Participated at the Swedish National Conference on Radio Science (RVK08), Växjö, Sweden. June 9–11, 2008.

Alireza Kazemzadeh:

> Participated in the workshop on metamaterials, circuit analog absorbers, and radome shutters at LTH, Sweden. February 4–6, 2008.

Gerhard Kristensson:

> Participated in the workshop on metamaterials, circuit analog absorbers, and radome shutters at LTH, Sweden. February 4–6, 2008.
>
> Participated in the workshop High Speed Wireless Center Workshop (HSWC), Arild, Sweden. April 21–22, 2008.
>
> Participated with a oral paper at the International NATO Advanced Research Workshop (Meta'08), Marrakesh, Morocco. May 7–10, 2008. *Title of the Paper:* "Bounds on metamaterials: theoretical results," May 7–10, 2008.

Participated at the Swedish National Conference on Radio Science (RVK08), Växjö, Sweden. June 9–11, 2008.

Participated at the LOIS conference, Växjö, Sweden. June 16, 2008.

Participated with a invited paper at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA. *Title of the Paper:* "Physical bounds on scattering by metamaterials," August 9–16, 2008.

Christer Larsson:

Participated with a poster at the International NATO Advanced Research Workshop (Meta'08), Marrakesh, Morocco. *Title of the Poster:* "Bounds on metamaterials: experimental results," May 7–10, 2008, see Figure 13.

Participated at the Swedish National Conference on Radio Science (RVK08), Växjö, Sweden. June 9–11, 2008.

Participated with a paper at the IEEE AP-S International Symposium on Antennas and Propagation, San Diego, USA. *Title of the paper:* "Wideband extinction measurements for thin and planar samples," July 5–9, 2008.

Buon Kiong Lau:

Participated with an oral paper (and co-authored another oral paper) at the COST2100 4th Management Committee Meeting (MCM) in Wroclaw, Poland, February 6–8, 2008.

Participated with a poster paper at the IEEE Vehicular Technology Conference Spring in Singapore, May 11–14, 2008.

Co-convened and chaired the Commission C oral session at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, IL, USA. *Title of the Paper:* "Multiple Antenna Systems," August 9–16, 2008.

Participated with two oral papers at the COST2100 4th Management Committee Meeting (MCM) in Lille, France, October 6–8, 2008.

Vanja Plicanic:

Participated with a poster at 2008 IEEE International Workshop on Antenna Technology (iWAT 2008), Chiba, Japan. *Title of the Poster:* "Performance of a multiband diversity antenna with hand effects," March 4–6, 2008.

Participated at the IEEE AP-S International Symposium on Antennas and Propagation, San Diego, USA. July 5–9, 2008.

Participated at the IEEE AP Chapter at LTH, Sweden. September 8, 2008.

Participated at the workshop on MIMO antenna systems research at LTH, Sweden. September 9, 2008.

Daniel Sjöberg:

Participated in the workshop on metamaterials, circuit analog absorbers, and radome shutters at LTH, Sweden. February 4–6, 2008.

Participated with a talk at the workshop High Speed Wireless Center Workshop (HSWC), Arild, Sweden. *Title of the Talk:* "Integrated antennas," April 21–22, 2008.

Presented an invited paper at the Swedish National Conference on Radio Science (RVK08), Växjö, Sweden. *Title of the Paper:* "Waves in ferromagnetic media," June 9–11, 2008.

Participated at the National Workshop on Metamaterials and Special Materials for Electromagnetic Applications and TLC, Naples, Italy, December 18–19, 2008.

Participated with a paper at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA. *Title of the Paper:* "Finite scale homogenization of chiral media," August 9–16, 2008.

Participated with an invited paper at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA. *Title of the Paper:* "Stability and causality of effective material parameters for biased ferromagnetic materials," August 9–16, 2008.

Christian Sohl:

Participated with an oral presentation at the IEEE AP-S International Symposium on Antennas and Propagation, San Diego, USA. *Title of the paper:* "Theoretical Bounds on the Directivity and Bandwidth of Electrically Small and Wideband Antennas," July 7–11, 2008.

Participated with three oral presentations at the XXIX$^{\text{th}}$ URSI General Assembly, Chicago, USA *Title of the papers:* "Some paradoxes associated with a recent sum rule in scattering theory," "A priori estimates on the partial realized gain of UWB-antennas," and "A general approach for deriving bounds in electromagnetic theory," August 9–16, 2008.

Participated with an oral presentation at the International Conference on Mathematical Modelling of Wave Phenomena, Växjö, Sweden. *Title of the paper:* "Bounds on the direct scattering problem of acoustic and electromagnetic waves," June 9–13, 2008.

Participated with an oral presentation at the Nordic Conference on Radio Science and Communications, Växjö, Sweden. *Title of the paper:* "A priori bounds on the onset frequency of wideband antennas," June 9–13, 2008.

5.5 Examination committees

Buon Kiong Lau:

Ph.D. Thesis Committee Member for doctoral candidate Tommy Hult of Department of Signal Processing, School of Engineering, Blekinge Institute of Technology, Sweden. *Title of the thesis:* "Space-Time Processing Applications for Wireless Communications," September 19, 2008.

Daniel Sjöberg:

External reviewer of the Licentiate thesis for Anna Jänis, The Department of Materials and Manufacturing Technology, Chalmers University of Technology, Göteborg, Sweden. *Title of the thesis:* "Investigation of electrical and magnetic properties of nanoparticles and nanofibers with the aim to tailor material properties of nanocomposites," June 12, 2008.

5.6 Referee for international journals and conferences

Anders Derneryd:

IET Electronics Letters

IET Proc. Microwaves, Antennas and Propagation

IEEE Trans. Antennas Propagat.

38$^{\text{th}}$ European Microwave Conference, EuMC 2008

67$^{\text{th}}$ IEEE Vehicular Technology Conference, VTC2008 Spring

IEEE International Conference on Ultra-Wideband, ICUWB 2008

Mats Gustafsson:

Inverse Problems

IEEE Trans. Antennas Propagat. (twice)

URSI GA

Trees - Structure and Function

IEEE Transactions on Wireless Communications

Anders Karlsson:

IEEE Trans. Antennas Propagat.

Optics Express

Wave Motion

Physical Review

Editor of the book *Mathematical Modeling of Wave Phenomena* (MMWP) (and 7 reviews)

Gerhard Kristensson:

Wave Motion (as editor)

XXIX$^{\text{th}}$ URSI General Assembly.

Christer Larsson:

IEEE Transactions on Antenna and Propagation (twice)

Buon Kiong Lau:

IEEE Transactions on Antenna and Propagation

IEEE Antennas and Wireless Propagation Letters

IEEE Transactions on Signal Processing

IEEE Transactions on Communications

IEEE Transactions on Wireless Communications

IET Microwaves, Antennas & Propagation

IEEE COMSOC/SBrT Joint Issue of the Journal of Communication and Information Systems (JCIS)

International Symposium on Information Theory and its Applications (ISITA).

IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC).

XXIX$^{\text{th}}$ URSI General Assembly.

Daniel Sjöberg:

IEEE Trans. Antennas Propagation (twice)

Physical Review E

Journal of Physics and Chemistry of Solids

Progress in Electromagnetics Research

5.7 Other activities

Mats Gustafsson:

Participated in the course "Examination — utveckling av examinationspraxis genom aktionsforskning," during the fall, 2008.

Internat AKKA, Båstad, Sweden, December 16–17, 2008.

Andreas Ioannidis:

Gave a series of internal lectures on "Mathematics in Electromagnetism" during the spring, 2008.

Richard Lundin:

Participated in the course "Teaching and Learning through English" during the fall, 2008.

Daniel Sjöberg:

Kick-off Photonics program, Atomic Physics, Lund, Sweden, June 19, 2008.

Nätverksträff E & F-utbildningar, Linköpings universitet, Sweden, May 28–29, 2008.

Nätverket ingenjörsutbildarna, KTH, Stockholm, Sweden, November 26–27, 2008.

Gymnasieföredrag osynlighet, March 10, 12, 13, 2008.

Teknikens dag, October 5, 2008.

Workshop pedagogisk portfölj, November 7, 2008.

Internat AKKA, Båstad, Sweden, December 16–17, 2008.

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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). The group also teaches courses in the international master program Wireless Communication (MWIR). In order to complete one of these programs the student must accomplish 270 ECTS credits, where one academic year corresponds to 60 ECTS credits. This makes the nominal time to complete one of these programs to be four and a half years.

Sweden is in the process of adapting to a European system of higher education, the so called Bologna process. As a part of this, the programs will expand to 300 ECTS credits, corresponding to five years of study. In 2007, the first students were accepted to the new programs.

6.1.1 Undergraduate courses given during 2008

Program[a]	**Name of the Course**	**Lecturer**[b]
E1	Electronics	**Anders Karlsson**
		Anders Bernland
		Alireza Kazem Zadeh
D1	Electronics	**Anders J Johansson**
F2	Electronics	**Mats Gustafsson**
		Anders Bernland
E3	Electromagnetic Fields	**Richard Lundin**
E3	Engineering Aspects of an Application	**Richard Lundin**
F3	Modelling and Simulation in Field Theory	**Anders Karlsson**
		Kristin Persson
Pi3	Electromagnetic Fields	**Gerhard Kristensson**
N3	Electromagnetics and Electronics	**Daniel Sjöberg**
E3	Electromagnetic Fields, Advanced Course	**Richard Lundin**
E3, F3, Pi4,	Antenna Technology	**Richard Lundin**
MWIR		Anders J Johansson
		Alireza Kazem Zadeh
		Ruiyuan Tian
E4, F4, Pi4	Electromagnetic Wave Propagation	**Gerhard Kristensson**
		Anders Bernland
E4, F4, Pi4	Computational Electromagnetics	**Mats Gustafsson**
D4, E4, C5,	Multiple Antenna Systems	**Buon Kiong Lau**
MWIR2		Ruiyuan Tian

[a] F1=Engineering Physics, first year; E1=Electrical Engineering, first year; D2=Computer Science, second year *etc.*, MWIR=International master programme on Wireless Communication.

[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. Ap-

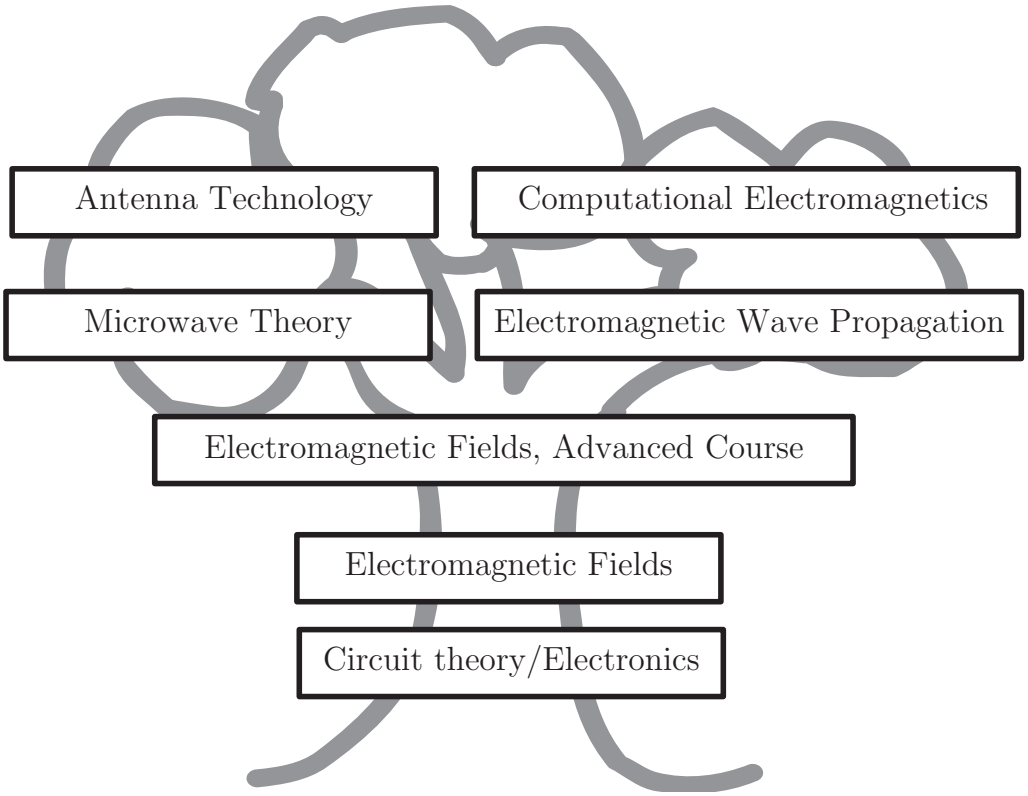

Figure 15: The undergraduate courses given by the Electromagnetic Theory group.

proximately 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, A. Karlsson, and R. Lundin, "Kretsteori, exempelsamling, KF Sigma 2008"; Franco, "Design with operational amplifier," McGraw-Hill, 2002.

ETI190 Electronics: (12 ECTS credits, 118 hours):
Given for the first year students of the Computer Science, or D-, program. Approximately 70 students.
The group gives the circuit theory part of this course, corresponding to approximately 4 credit points.
Course literature: Alexander and Sadiku, "Electric circuits," McGraw Hill, 1999; M. Gustafsson, A. Karlsson, and R. Lundin, "Kretsteori, exempelsamling, KF Sigma 2008"; Franco, "Design with operational amplifier," McGraw-Hill, 2002.

ETE022 Electronics (6 ECTS credits, 56 hours):
Given for the second year students of the Engineering Physics, or F-, program. Approximately 70 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.
Course literature: D. Sjöberg and M. Gustafsson, Kretsteori, ellära och elektronik, Dept. Electrical and Information Technology, Lund University, 2008; problem collection; M. Gustafsson, A. Karlsson, and R. Lundin, "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.

ETE110 Modelling and Simulation in Field Theory (16.5 ECTS credits, 60 hours):
Given for the third year students of the Engineering Physics program. Approximately 60 students.
It is a multicultural course that involves teachers at the departments of Physics, Solid Mechanics and Electroscience. The course covers basic vector analysis, electromagnetic field theory, and the finite element method.
Course literature: D. J. Griffiths, "Introduction to Electrodynamics," Prentice-Hall, 1999; problem collection, KF Sigma 2004.

ETE055 Electromagnetic Fields (6 ECTS credits, 56 hours):
Given for the third year students of the Engineering Mathematics program. Approximately 20 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.

ETE115 Electromagnetics and Electronics (7.5 credits, 56 hours):
Given for the third year students of the Engineering Nanoscience program. Approximately 35 students.
The course has three basic components: circuit theory, quasistatic electromagnetic field theory, and applications in electronics. The course emphasizes understanding of the modeling chain 1) extract circuit models from the physical processes in the individual components (resistors, capacitors, diodes, transistors etc), 2) mathematical analysis of the circuit model, and 3) interpretation of the results in terms of system properties such as amplification and bandwidth.
Course literature: D. Sjöberg and M. Gustafsson, "Kretsteori, ellära och elektronik," Dept. Electrical and Information Technology, Lund University, 2008; problem collection.

ETI015 Electromagnetic Fields, Advanced Course (6 ECTS credits, 56 hours):
Given for the third year students of the Electrical Engineering, or E-, program. Approximately 35 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.

ETE071 Electromagnetic Wave Propagation (6 ECTS credits, 42 hours):
Given for the fourth year students of the Engineering Physics, Electrical Engineering, and Engineering Mathematics, or F-, E-, and Pi-programs. 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: G. Kristensson, "Elektromagnetisk Vågutbredning," Studentlitteratur, Lund 1999.

ETE091 Microwave Theory (6 ECTS credits, 42 hours):
This course is given every other year for the fourth year students of the Engineering Physics and the Electrical Engineering, or F- 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, "Mikrovågsteori," Lund, 2004.

ETI260 Computational Electromagnetics (6 ECTS credits, 42 hours):
This course is given every other year for the fourth year students of the Engineering Physics, Electrical Engineering, and Engineering Mathematics, or F-, E-, and Pi-programs. Approximately 15 students.
This course covers the most important numerical methods in electromagnetics, such as FDTD (Finite Difference Time Domain), MoM (Method of Moments), and high frequency methods (GO, GTD, raytracing).
Course literature: A. Bondeson, T. Rylander, P. Ingelström, "Computational Electromagnetics," Chalmers tekniska högskola.

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

Buon Kiong Lau:

Presented an Invited Lecture entitled "Channel Measurement and Characterization with MIMO Sounder" for the CHASE MIMO Reverberation Chamber PhD Course, Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden, April 11, 2008.

6.3 Diploma Works

See **3.8 Diploma Works**.

6.4 Development and revisions of teaching materials

1. D. Sjöberg and M. Gustafsson. *Kretsteori, ellära och elektronik*. Department of Electrical and Information Technology, Lund University, Sweden, 2008.

6.5 Graduate courses

Mats Gustafsson:

ETI 260 Computational Electromagnetics (extended version), 5 credit units, 42 hours.

Anders Karlsson:

Light Scattering by Systems of Particles, 3 credit points, spring, 2008.

Gerhard Kristensson:

ETE071 Electromagnetic Wave Propagation (extended version), 5 credit units, 42 hours.

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), Cannes, France.

TPC member 1st COST2100 Workshop on "MIMO and Cooperative Communications," Trondheim, Norway.

Chair of Organizing Committee for 2008 Workshop on MIMO Antenna Systems, Lund, Sweden.

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

Anders Karlsson:

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

Gerhard Kristensson:

Member of Senate of Science, Faculty of Engineering, Lund University.

Daniel Sjöberg:

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).

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