Application

2015-03-31

2015-04850	Bengtsson, Mats	NT-14

Information about applicant

Name: Mats Bengtsson

Doctorial degree: 2000-02-03

Birthdate: 19671128

Academic title: Docent

Gender: Male

Employer: Kungliga Tekniska högskolan

Administrating organisation: Kungliga Tekniska högskolan

Project site: Avdelningen för Signalbehandling

Information about application

Call name: Forskningsbidrag Stora utlysningen 2015 (Naturvetenskap och teknikvetenskap)

Type of grant: Projektbidrag

Focus: Fri

Subject area:

Project title (english): Optimization Based Information Processing and Design under Uncertainty

Project start: 2016-01-01

Project end: 2019-12-31

Review panel applied for: NT-14

Classification code: 20205. Signalbehandling, 10105. Beräkningsmatematik

Keywords: Optimization, Robustness, Statistical modeling and analysis

Funds applied for

Year:	2016	2017	2018	2019
Amount:	897,700	1,334,000	1,382,500	1,026,400

Descriptive data

Project info

Project title (Swedish)*

Informationsbehandling och design under osäkerhet, baserat på optimering

Project title (English)*

Optimization Based Information Processing and Design under Uncertainty

Abstract (English)*

Numerical optimization techniques are getting increasingly important in many application areas. Using statistical signal and information processing and resource management in wireless communication as a starting point, we will investigate distributed optimization techniques with the purpose to design algorithms that are robust to uncertainties. The uncertainties may stem from errors in the prior assumptions but may also appear within the distributed implementation, because of limited computational power at the different processing units and in sharing intermediate results between the units.

In estimating and detecting information from data, it is common to optimize cost functions related to least squares or to likelihood functions, which is well motivated from statistical theory when considering the estimation/detection problem in isolation. However, in most practical applications, the resulting estimate is used as input for some further processing, where the statistically "best" estimate is not necessarily the value providing the best end performance. Therefore, we will investigate different utility functions that can better represent the end performance. In other words, the goal is rather to use the optimization based strategy to do system design, i.e. to optimize a number of system parameters, given the available data and (imprecise) prior knowledge.

Popular scientific description (Swedish)*

Matematiska metoder för optimering används i fler och fler sammanhang. T ex skrivs det i dagspressen om "big data", dvs att Google, Facebook, Netflix, men även företag som inte primärt är internetrelaterade, såsom ICA, analyserar och extraherar information ur all data de har tillgängligt om oss konsumenter, för att kunna erbjuda individanpassad information och marknadsföring. Denna analys baseras till stor del på algoritmer for optimering. Optimering, både över korta och långa tidsskalor, används även t ex i mobiltelefonisystem för att se till att så många användare som möjligt får en bra förbindelse, i transportbranchen där man vill leverera varor snabbt men minimera bränsleförbrukningen, eller i cancerbehandling, där man med en minimal stråldos vill slå ut cancerceller utan att förstöra frisk vävnad.

I många av dessa tillämpningar måste beräkningarna spridas ut på flera enheter, bl a för att det skulle bli alltför krävande att samla all information på en plats. Det finns ofta även osäkerhet och fel, både i data, i de matematiska samband man utnyttjar och i de beräkningsresultat som delas mellan enheterna. För att fungera väl, krävs därför beräkningsrutiner (algoritmer) som är robusta nog att hantera denna osäkerhet.

I detta projekt kommer vi att vidareutveckla och analysera distribuerade algoritmer för robust optimering. Vi försöker även hitta nya tillämpningsområden där denna typ av algoritmer är användbara och hämta inspiration från dessa tillämpningar till att identifiera och lösa mer generella problemformuleringar.

Project period

Number of project years*

4

Calculated project time*

2016-01-01 - 2019-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*

2. Teknik > 202. Elektroteknik och elektronik > 20205. Signalbehandling

1. Naturvetenskap > 101. Matematik > 10105. Beräkningsmatematik

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Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

Optimization

Keyword 2*

Robustness

Keyword 3*

Statistical modeling and analysis

Keyword 4

Keyword 5

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

Inga specifika etiska överväganden är relevanta för denna ansökan. I de fall det blir aktuellt att applicera metoder från projektet på medicinska data eller persondata, kommer datainsamling och analys av resultaten att ske utanför detta projekt.

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

1 Purpose and Aims

It is getting more and more popular to solve problems in signal processing, data analytics, and many other applications by (approximately) formulating them as optimization problems with quadratic or convex utility functions and constraints. The end goal is often formulated as an estimator, detector or classifier. However, in most applications, the output of this estimator/detector is used as input for some further processing. Here, we intend to go beyond the standard linear regression models, often employed, and try to approach the goal of optimizing the end performance (customer satisfaction, reduced CO^2 emissions, revenue, ...) of the full system. In other words, the goal is to **optimize** a number of system parameters—**design** the system—in terms of a suitable utility function.

Another main driver for the proposed project is the need to provide solutions that are robust to **uncertainties** and errors, both in data, in system models, and in intermediate results (due to limits in computational power or storage, or due to quantized inter-node communication in a distributed algorithm implementation). Finally, many of these algorithms will be applied in non-stationary scenarios, where the system parameters have to be continuously updated to track the variations in the environment.

To summarize, we will consider problems and scenarios that require

- distributed implementation,
- robustness to uncertainties in data, in system models and to non-exact solutions of subproblems,
- utility functions and problem formulations that are non-convex
- adaptability in non-stationary scenarios,

and the goals of this project will be to

- Develop and analyze new and improved algorithms for utility based designs, in distributed and uncertain scenarios.
- Develop relevant and mathematically tractable utility functions that reflect the end performance rather than the accuracy of some intermediate value.
- Develop relevant and mathematically tractable models for stochastic and deterministic uncertainties.
- Identify classes of utility functions and problem structures that allow for more efficient algorithmic solutions, and develop and analyze specific algorithms for these.

Most of the results are expected to be applicable not only in signal processing, but in general optimization theory and system design.

2 Survey of the Field

A caricature view of the field of signal processing research, is that it mainly deals with various applications of least squares. It is indeed true, that many estimation problems in statistical signal processing, boil down to solving a least squares problem. Similarly, other problems in signal processing and systems theory such as filter design, beamforming design, signal design and optimal control, are often formulated and solved as optimization problems with quadratic cost functions. During the last two decades, more general convex optimization formulations have become increasingly popular in research areas such as signal processing and data analytics [BV04, CM13]. Unfortunately, many real-world problems are not well approximated by convex formulations and may even be NP-hard to solve [LZ08].

In several of these applications, decentralized solutions are desirable, for example since the origin or storage of the data is spatially distributed or since the amount of data is so large that the analysis och processing has to be split [CZ14]. Popular methods to obtain decentralized and parallelized solutions include primal and dual decompositions [PC06], block-wise coordinate descent [RHL13, MB30], and Alternating Direction Method of Multipliers (ADMM) [BPC+11, PB14]. In these scenarios, it is common to have to deal with uncertainties in data (due to noise, incomplete data or data reduction), and in prior assumptions on parameters, models and utility functions. This calls for solutions that are robust to such uncertainties. In a distributed implementation, the smaller subproblems computed at each processing unit are solved only up to a certain accuracy, due to limited time and computational power. Approximations will typically also appear in the aggregation step of the distributed algorithms, where local variables are shared between the processing units. These uncertainties introduced within the distributed algorithm need also be taken into account to guarantee convergence to a near-optimal solution [TLR12].

Many practical scenarios are non-stationary, in which case the optimization algorithm should not converge, but rather attempt to track the time variations, see for example [SKL14] for a recent example of such algorithms and analysis.

From our previous research, we have significant experience of the design and analysis of distributed algorithms for radio resource management in wireless communication systems [MB24, MB21, MB15, MB30]. We also have significant experience of different models and approaches for robustness, among others from our currently ongoing VR funded project Robust Algorithms for Wireless Communications, see the scientific report. Many of the problem formulations we have studied earlier are non-convex, and we have used different strategies like approximations [MB19], relaxation techniques [MB32, LMS+10] and block-wise coordinate descent [RHL13, MB30] to handle the non-convexity. We have also studied global optimization methods like branch-reduce-and-bound (BRB), to find the guaranteed global optimum [MB18]. The computational complexity if the BRB algorithm is clearly too high to be used in any real-time application, but it is still useful as a benchmark in system level simulations.

One main option to obtain robustness, is to model the uncertain parameters as belonging to a deterministic uncertainty region, and optimize the worst case performance, see for example [MB13]. The other main option, is to view the uncertain parameters as stochastic variables. Given a stochastic uncertainty model, we could either optimize the average performance, the performance of the $x\%$ worst case [MB6], or take a Bayesian view point, finding maximum a posteriori estimates [MB3]. Finding the best suited robustness approach is problem dependent and it is a goal of this project to develop guidelines and design principles in selecting a suitable uncertainty model and robustness strategy.

3 Project Description

The application is for a period of four years, starting January 1, 2016. The research within the project will be done by myself and by two PhD students, Ehsan Olfat, who is expected to graduate during 2018, and a second PhD student to be recruited during 2017. The one year overlap is important for the continuation of the project and to provide a good start for the second PhD student. I am/will be the main supervisor of both students. Assoc. Professor Joakim Jaldén will be involved as co-supervisor as he has a very suitable background in statistical signal processing and optimization. We have chosen not to divide the work plan into work packages, since all three of us would be involved in all the work packages and those would run more or less in parallel throughout the project.

All of us involved in the project are part of the Signal Processing department at the School of Electrical Engineering, KTH and also of the Linneaus centre ACCESS, `www.access.kth.se`. Within the Signal Processing department, we organize weekly internal seminars, where each PhD student gives a presentation once a semester, both to train presentation skills but also to get feedback on the research, from the full group. The ACCESS center also provides seminar series, both internally with presentations by the ACCESS faculty, and externally with presentations by invited world-leading experts. Within the ACCESS center, there are also ample opportunities for informal collaboration and information exchange.

The project will be driven by a combination of bottom-up and top-down approaches. In other words, some of the work will start with a specific problem formulation and seek to generalize and abstract the resulting solutions and approaches to a more general setting. Other work will start with very generic problem formulations, narrowing down to find theoretically interesting aspects and later seek practical applications.

As described earlier, the main focus of the project will be on the intersection between distributed optimization, statistical signal processing and information processing, and robustness to uncertainties. Thus, the theoretic background comes from optimization theory, mathematical statistics, numerical linear algebra, and computer science.

As a generic time plan, we will during each year work in parallel with a couple of already identified problem formulations, perform a literature review to identify both generic and specific interesting and challenging scenarios, applications and algorithms, to study further, and attempt to generalize already obtained results and problem formulations. In the search for relevant applications, we will also continuously search for relevant industrial collaboration, and also seek funding from funding agencies like Vinnova and Horizon2020, related to applications of the results in the current project. Any larger scale data collection or application specific analysis will be performed outside this particular project, for example by master thesis students under our supervision, or in the case we obtain separate funding, by another PhD student.

This is a free continuation of the previously granted project “Robust Algorithms for Wireless Communications” (funded by VR 2012–2015). Therefore, application examples will primarily be found in distributed radio resource management for wireless communication systems, during the initial year of the project. In particular, we will investigate mixed discrete/continuous problems related to joint optimization of clustering of users and access points, association of users to relays and access points and MIMO precoding, given uncertainties due to estimation errors and delays, but also due to changes in the interference situation, from uncoordinated uncoordinated scheduling decisions by transmitters in the surroundings. The literature studies during the first year of the project will focus on data analytics.

Since we deal with a hot, rapidly evolving, research topic with many active researchers around the world, it is currently hard to predict exactly what problem formulations we will focus on during the final years of the project. However, we list below a number of issues that will be tackled during the project.

Non-convex utilities If the cost functions and/or constraints are non-convex, we can in general not hope to obtain as strong results as for the convex case, and the best we can hope for is often to find at least a local optimum, possibly combined with a bound on the difference from the global optimum. Still, many practically useful problems are inherently non-convex, so finding good decentralized algorithms that can handle non-convex problems is an important issue.

Bounds on outage probabilities Finding algorithmically tractable bounds on outage events, is one of the main challenges in outage based robustness strategies.

Tracking Most algorithms in the literature are designed for static scenarios. Developing and analyzing tracking optimization algorithms is important for many applications.

Choice of robustness models and strategies To the best of our knowledge, there is no well established theory available to guide the choice of uncertainty modeling and robustness strategy. It is often hard to relate the assumptions between the different models, so performing a fair comparison is difficult. Nevertheless, an important goal of this project is to provide more structured guidelines in the choice of robustness strategy for a given problem.

4 Significance

Mathematical optimization is used in a large number of applications, in addition to those mentioned above. We believe that the aspects of robust, decentralized optimization that we will focus on in this project, will be highly relevant in many of these applications. We expect to contribute with both algorithmic development and analytic results that are of interest not only in the signal processing community but be useful in many different application areas and also contribute to the development of optimization theory, in general.

A second important outcome of the project will be educated PhD students.

The scientific results will mainly be presented in peer-reviewed high impact international journals and conferences.

5 Preliminary Results

Several related results are described in the scientific report for the currently ongoing project "Robust Algorithms for Wireless Communications".

One specific problem that was mentioned earlier is the calculation of outage events, which often boils down to calculating the PDF of a quadratic form of a Gaussian vector variable. Several approaches have been proposed in the literature, but finding a bound that is both tight and algorithmically tractable is still a challenge. We provided some preliminary insights on different options in [MB59].

6 International and National Collaboration

As mentioned in the project description, the researchers in the project will be affiliated with the Signal Processing department at KTH and the ACCESS Linneaus centre at KTH.

We have extensive connections with both national and international collaborators in academia and (telecom) industry, among others from previous and currently ongoing FP6 and FP7 projects such as METIS, WINNER I+II+III and HIATUS. We do not currently have any EU funding that overlaps the planned project period.

References

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[TLR12] K. I. Tsianos, S. Lawlor, and M. G. Rabbat. Consensus-based distributed optimization: Practical issues and applications in large-scale machine learning. In *50th Annual Allerton Conference on Communication, Control, and Computing (Allerton), 2012*, pages 1543–1550, 2012.

Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

This is a status report of the project "Robusta algoritmer för trådlös kommunikation" ("Robust Algorithms for Wireless Communications"), dnr 2012-4134, 2 700 000SEK, for the period 2013-2015. Within the project, we have, studied a number of different forms of uncertainties that can appear in the optimization of wireless communication systems. We have also investigated different strategies to obtain robustness to these uncertainties.

Deterministic Uncertainty

One form of uncertainty is deterministically bounded uncertainties, where the true parameters are assumed to be confined to bounded set around a given estimate. In order to obtain maximal robustness, the solution that maximizes the worst case performance is used. For the case of a single MIMO link with uncertainties in the channel state information (CSI), [MB13, MB39] finds the worst case optimal precoder for a number of different characterizations of the uncertainty region. For general convex uncertainty regions, the optimally robust solution can be found solving a single convex optimization problem. For unitarily invariant uncertainty regions, channel diagonalization is proven to be optimal, which reduces the original matrix valued problem to a vector valued problem, where a convex formulation is provided. Finally, for the uncertainty regions described by the class of Schatten norms, a closed form solution is provided.

Related results for a different problem formulation have been presented in [MB5], which analyzes optimal design of training sequences for MIMO channel estimation, given an uncertain estimate of the channel long term statistics. For arbitrary convex uncertainty sets, the optimally robust training signal design problem is shown to have a unique optimum and it can be found numerically. With additional assumptions on Kronecker structured covariance matrix, either for the estimated or for the true channel, and assuming the uncertainty set to be unitarily invariant, the problem can be diagonalized, which significantly reduces the problem dimension. Finally, for the special case of MISO channels (single receive antenna), closed form solutions are provided for cases where the uncertainty region is defined by a norm, for several different choices of norms. For MIMO radar applications, we have studied robust beampattern design, given a bounded uncertainty in the array response vectors. Exploiting the, so-called, S-lemma we showed how the optimal worst case design problem can be solved using a convex semidefinite formulation. A related problem formulation and solution for applications in hyperthermia based cancer treatment, was included in the PhD thesis of Nafiseh Shariati "Robust Transmit Signal Design and Channel Estimation for Multiantenna Systems", ISBN 978-7595-331-1, 2014.

Stochastic Uncertainty

The other main alternative is to assume the true parameter to be a stochastic variable with a known distribution (or at least known first and second moments). Given such a characterization, we could either try to optimize the average performance or consider the performance at a certain outage level. As a third main option, we could view the uncertainty as nuisance parameters with a given prior distribution and apply a Bayesian framework.

An outage based formulation has been considered in [MB32] for MISO precoder design in satellite communications, where it is reasonable to assume that only the phase shifts but not the magnitudes of the channel coefficients are uncertain. Using some approximations of the outage probability, a robust solution can be found using semidefinite optimization. Formulations related to outage based robust design have also been considered in [MB6], where we consider training signal design for MIMO channel estimation, but where we do not directly consider the uncertainty in some parameters or estimates, but rather the stochastic variability in the end performance of an equalizer or precoder, when the estimated channel coefficients are used as input to the equalizer or precoder design. Two different strategies are proposed to handle the outage probability, one where we convert the problem to a deterministic uncertainty by defining an ellipsoidal uncertainty region with an easily calculated probability and using a worst case design over this uncertainty ellipsoid. In the second strategy, we use a Markov bound to express the outage probability in terms of the expected value. For practically useful outage levels, the Markov bound,i.e. optimizing the average performance, turns out to provide better solutions.

Another example where robustness techniques are used to improve the end performance is treated in [MB30]. Here, we investigate how channel estimation and precoder design should be combined in a distributed implementation of MIMO multi-user multi-cell systems, aiming to optimize the system sum-rate. As a starting point, we used a well-known WMMSE precoder optimization algorithm [SRLH11], which often is claimed to be fully distributed. However, it is non-trivial to determine a useful combination of signaling and distributed estimation for a practical distributed implementation of the algorithm. Among others, we show that robustifications are needed in the sub-problems solved at the different nodes, to handle the channel estimation errors and we derive suitable techniques for these robustifications.

A Bayesian approach to robustness is described in [MB3], where we consider a classical linear data model, but with uncertain covariances of both the noise and the signal of interest, here modeled as stochastic with an inverse Wishart prior distribution for both covariance matrices. The resulting maximum a posteriori estimator is shown to outperform standard non-robust estimators from the literature. It is also shown that there is a negligible difference between estimating the nuisance parameters (the covariance matrices) or marginalizing the cost function with respect to the nuisance parameters and using MAP only for the signal.

Uncertainty/non-ideality in RF hardware
Finally, we have considered uncertainties caused by non-ideal hardware. In particular, we have used a model for radio frequency power amplifiers, where the residual errors, after using standard techniques to compensate for non-linearities and phase noise, is modeled as additive Gaussian noise whose power depends on the power of the signal of interest. In [MB14], the capacity of a single MIMO channel is analyzed, for the proposed “dirty RF” model. In [MB35], the previously mentioned WMMSE algorithm for precoder optimization is extended to incorporate the dirty RF model and the resulting performance is clearly improved compared to the non-robust version of the algorithm.

Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	Mats Bengtsson	

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	2019	Total
1	Applicant	Mats Bengtsson	10	102,400	105,500	108,700	111,900	428,500
2	Other personnel without doctoral degree	Ehsan Olfat	80	423,300	472,400	262,300	0	1,158,000
3	Other personnel without doctoral degree	NN	80	0	212,100	449,500	493,500	1,155,100
	Total			525,700	790,000	820,500	605,400	2,741,600

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

	Type of premises	2016	2017	2018	2019	Total
1	Office space	54,000	81,000	85,000	62,000	282,000
	Total	54,000	81,000	85,000	62,000	282,000

Running Costs

	Running Cost	Description	2016	2017	2018	2019	Total
1	Travels		55,000	80,000	80,000	60,000	275,000
2	Publications		25,000	25,000	25,000	25,000	100,000
3	IT/infrastructure		42,000	63,000	66,000	48,000	219,000
	Total		122,000	168,000	171,000	133,000	594,000

Depreciation costs

Depreciation cost	Description	2016	2017	2018	2019

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	2019	Total, applied	Other costs	Total cost
Salaries including social fees	525,700	790,000	820,500	605,400	2,741,600		2,741,600
Running costs	122,000	168,000	171,000	133,000	594,000		594,000
Depreciation costs					0		0
Premises	54,000	81,000	85,000	62,000	282,000		282,000
Subtotal	701,700	1,039,000	1,076,500	800,400	3,617,600	0	3,617,600
Indirect costs	196,000	295,000	306,000	226,000	1,023,000		1,023,000
Total project cost	897,700	1,334,000	1,382,500	1,026,400	4,640,600	0	4,640,600

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

The VR budget covers 50% of the salary cost for the PI, for his involvement in the project. KTH does not provide direct funding for professors' research, that is no, so called, "ämnespott" exists, intended for both supervision but also advancements in the area.

The VR budget covers the salary cost for one PhD-student (Ehsan Olfat) working with 80% activity during the first 2.5 years of the project and a new PhD student, to be recruited, working 80% activity within the project during the last 2.5 years of the project. The overlap of one year is important too keep the continuation of the project. The two PhD students are/will be employed (doktorandtjänst) and follow the doctoral salary ladder at KTH.

Travel cost are calculated as one travel per participant per year, based on the Department's budget key. A similar budget has been prepared for the rent.

Indirect costs are specified below.
Summa högskolegemensamma: 23,76%
Summa skolgemensamma: 6,33%
Summa avdelningsgemensamma: 7,26%
Summa indirekta kostnader: 37,4%

The budget above is according to the guidelines. Funding for related activities of relevance (including procurement of equipment) will be provided by the accumulated faculty funding (positivt myndigheteskapital) according to Dnr:E-2010-0088) available at the Department of Signal Processing. If a reduced funding is granted (up to a reasonable amount), faculty funding will be secured so that a project can be adapted to the new funding level (omställningskostnader). The research outlined in this application is not covered by other funded or applied for external project grants.

We have participated in an application for a Marie Curie ITN, see below. During the project, we will obviously apply for different other funding in projects that may involve applications of the techniques developed in the project.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

	Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018	2019	Total
1	European Commission (appl. submitted)	Ana Peréz, CTTC, Barcelona, Spain	Marie Curie ITN	675 084	815,708	815,708	815,708		2,447,124
	Total				815,708	815,708	815,708	0	2,447,124

CV and publications

CV

Curriculum Vitae – Mats Bengtsson (born: 1967)

Address:		
Signal Processing	**Phone:**	08–790 8463
School of Electrical Engineering	**Fax:**	08–790 7260
Kungl Tekniska Högskolan	**E-mail:**	`mats.bengtsson@ee.kth.se`
SE–100 44 Stockholm, Sweden	**www:**	`http://www.ee.kth.se/~mabe`

1. Higher education qualification: Computer Science and Technology (D), Linköping Institute of Technology, 1991.

2. Doctoral degree: Electrical Engineering/Signal Processing, KTH, 2000.

3. Postdoctoral position: —

4. Qualification required for the appointments as a docent: Docent in Signal Processing, KTH, Jan. 2007 –

5. Current position: University lecturer (universitetslektor, tillsvidareanställning), 50% research, Jun. 2007 –

6. Previous positions and periods of appointment:

2006-2007 Researcher (forskare) in Signal Processing, Royal Institute of Technology, 60% Research, 40% teaching and department duties.

2000-2005 Research associate (forskarassistent) in Signal Processing, Royal Institute of Technology, 65% Research, 35% teaching and department duties.

1995-2000 PhD student (doktorand) in Signal Processing, Royal Institute of Technology.

1991-2000 Software engineer, Ericsson Telecom AB, Karlstad. On leave from February 1995.

7. Paternal Leaves:

Jan 2006 – June 2006, 80%
Aug 2008 – Dec 2008, 60%
Nov 2011 – May 2012, 10%

8a. Supervision, doctoral students: **Nafiseh Shariati Eshkavari** PhD degree December 2014.

Rasmus Brandt Licentiate degree June 2014, continuing towards PhD degree.

Ehsan Olfat Admitted Oct. 2013.

Ahti Ainomäe Admitted March 2013, pursuing joint degree with Technical Univ. of Tallin.

Ahmad Gharanjik Admitted April 2013, pursuing joint degree with Univ. of Luxembourg.

Jinghong Yang Admitted Nov. 2008.

In addition, co-supervisor of 4 current and 8 graduated doctoral students.

8b. Supervision, postdocs: **May. 2014 –** Rami Mochaourab

Nov. 2012 – Oct. 2014 Su Min Kim

Sept. 2010 – June 2011 Le-Nam Tran

Sept. 2010 – Sept 2011 Jiaheng Wang

9. Other information of relevance to the application

- Member of the IEEE Signal Processing for Communications (SPCOM) technical committee 2007–2012.
- Associate editor for IEEE Trans. Signal Processing 2007–2009.
- Technical co-chair for IEEE SPAWC 2015. Special Sessions chair at EUSIPCO 2011, Area chair for "Signal processing for communications" at EUSIPCO 2010, Publication chair for IEEE CAMSAP 2007.
- Co-author of best student paper award at CAMSAP 2011.
- Program director for the master program in Wireless Systems at KTH, 2007–. Local academic coordinator for the Erasmus Mundus program MERIT, 2009–2016.

Publication list

Mats Bengtsson — Publications

Database for citation count: Scopus, per March 26, 2015. A few of the entries have been updated with citations listed under the Scopus "View Secondary documents".

1. Peer-reviewed original articles

[MB1] H. Ghauch, T. Kim, M. Bengtsson, and M. Skoglund. Distributed low-overhead schemes for multi-stream MIMO interference channels. *IEEE Trans. SP*, 63(7):1737–1749, 2015. Accepted for publication.
Number of citations: 0.

[MB2] E. Björnson, M. Bengtsson, and B. Ottersten. Optimal multiuser transmit beamforming: A difficult problem with a simple solution structure. *IEEE SP Magazine*, 2014.
Number of citations: 1.

* [MB3] D. Zachariah, N. Shariati, M. Bengtsson, M. Jansson, and S. Chatterjee. Estimation for the linear model with uncertain covariance matrices. *IEEE Trans. SP*, 62(6):1525–1535, Mar. 2014.
Number of citations: 0.

[MB4] N. Shariati, E. Björnson, M. Bengtsson, and M. Debbah. Low-complexity polynomial channel estimation in large-scale MIMO with arbitrary statistics. *IEEE J. Sel. Topics Signal Process.*, 8(5):815–830, Oct. 2014.
Number of citations: 1.

* [MB5] N. Shariati, J. Wang, and M. Bengtsson. Robust training sequence design for correlated MIMO channel estimation. *IEEE Trans. SP*, 62(1):107–120, 2014.
Number of citations: 2.

* [MB6] D. Katselis, C. R. Rojas, M. Bengtsson, E. Björnson, X. Bombois, N. Shariati, M. Jansson, and H. Hjalmarsson. Training sequence design for MIMO channels: An application-oriented approach. *EURASIP Journal on Wireless Communications and Networking*, 2013(245), 2013.
Number of citations: 2.

[MB7] D. Katselis, C. R. Rojas, M. Bengtsson, and H. Hjalmarsson. Frequency smoothing gains in preamble-based channel estimation for multicarrier systems. *Sig. Proc.*, 93(9):2777–2782, 2013.
Number of citations: 2.

[MB8] D. Zachariah, M. Jansson, and M. Bengtsson. Utilization of noise-only samples in array processing with prior knowledge. *IEEE SP Letters*, 20(9):865–868, 2013.
Number of citations: 1.

[MB9] E. Björnson, M. Kountouris, M. Bengtsson, and B. Ottersten. Receive combining vs. multi-stream multiplexing in downlink systems with multi-antenna users. *IEEE Trans. SP*, 61(13):3431–3446, 2013.
Number of citations: 1.

[MB10] S. Han, C. Yang, and M. Bengtsson. User scheduling for cooperative base station transmission exploiting channel asymmetry. *IEEE Trans. Commun.*, 61(4):1426–1435, 2013.
Number of citations: 1.

[MB11] L.-N. Tran, M. Juntti, M. Bengtsson, and B. Ottersten. Weighted sum rate maximization for MIMO broadcast channels using dirty paper coding and zero-forcing methods. *IEEE Transactions on Communications*, 61(6):2362–2373, 2013.
Number of citations: 4.

[MB12] L.-N. Tran, M. Juntti, M. Bengtsson, and B. Ottersten. Beamformer designs for MISO broadcast channels with zero-forcing dirty paper coding. *IEEE Trans. Wireless Comm.*, 12(3):1173–1185, 2013.
Number of citations: 4.

* [MB13] J. Wang, M. Bengtsson, B. Ottersten, and D. P. Palomar. Robust MIMO precoding for several classes of channel uncertainties. *IEEE Trans. SP*, 61(12):3056–3070, 2013.
Number of citations: 8.

[MB14] E. Björnson, P. Zetterberg, M. Bengtsson, and B. Ottersten. Capacity limits and multiplexing gains of MIMO channels with transceiver impairments. *IEEE Commun. Letters*, 17(1):91–94, 2013.
Number of citations: 10.

[MB15] Y. Huang, G. Zheng, M. Bengtsson, K.-K. Wong, L. Yang, and B. Ottersten. Distributed multicell beamforming design approaching Pareto boundary with max-min fairness. *IEEE Trans. Wireless Comm.*, 11(8):2921–2933, 2012.
Number of citations: 17.

[MB16] L.-N. Tran, M. Bengtsson, and B. Ottersten. Iterative precoder design and user scheduling for block-diagonalized systems. *IEEE Trans. SP*, 60(7):3726–3739, 2012.
Number of citations: 10.

[MB17] E. Björnson, M. Bengtsson, and B. Ottersten. Pareto characterization of the multicell MIMO performance region with simple receivers. *IEEE Trans. SP*, 60(8):4464–4469, 2012.
Number of citations: 6.

[MB18] E. Björnson, G. Zheng, M. Bengtsson, and B. Ottersten. Robust monotonic optimization framework for multicell MISO systems. *IEEE Trans. SP*, 60:2508–2523, 2012.
Number of citations: 30.

[MB19] E. Björnson, N. Jaldén, M. Bengtsson, and B. Ottersten. Optimality properties, distributed strategies, and measurement-based evaluation of coordinated multicell OFDMA transmission. *IEEE Trans. SP*, 59(12):6086–6101, Dec. 2011.
Number of citations: 23.

[MB20] Y. Huang, L. Yang, M. Bengtsson, and B. Ottersten. Exploiting long-term channel correlation in limited feedback SDMA through channel phase codebook. *IEEE Trans. SP*, 59:1217 – 1228, Mar. 2011.
Number of citations: 7.

[MB21] Y. Huang, G. Zheng, M. Bengtsson, K.-K. Wong, L. Yang, and B. Ottersten. Distributed multicell beamforming with limited intercell coordination. *IEEE Trans. SP*, 59:728 – 738, Feb. 2011.
Number of citations: 30.

[MB22] J. Wang and M. Bengtsson. Joint optimization of the worst-case robust MMSE MIMO transceiver. *IEEE SP Letters*, 18:295–298, May 2011.
Number of citations: 7.

[MB23] Y. Huang, L. Yang, M. Bengtsson, and B. Ottersten. A limited feedback joint precoding for amplify-and-forward relaying. *IEEE Transactions on Signal Processing*, 58:1347 – 1357, Mar. 2010.
Number of citations: 26.

[MB24] P. von Wrycza, M. R. B. Shankar, M. Bengtsson, and B. Ottersten. Spectrum allocation for decentralized transmission strategies: Properties of Nash equilibria. *EURASIP Journal on Advances in Signal Processing*, Apr. 2009.
Number of citations: 2.

[MB25] Y. Zeng, Y. Fu, M. Bengtsson, X. Chen, W. Lu, and H. Ågren. Finite-difference time-domain simulations of exciton-polariton resonances in quantum-dot arrays. *Optics Express*, 16(7):4507–4519, Mar. 2008.
Number of citations: 6.

[MB26] D. Hammarwall, M. Bengtsson, and B. Ottersten. Acquiring partial CSI for spatially selective transmission by instantaneous channel norm feedback. *IEEE Transactions on Signal Processing*, 56(3):1188–1204, Mar. 2008.
Number of citations: 35.

[MB27] D. Hammarwall, M. Bengtsson, and B. Ottersten. Utilizing the spatial information provided by channel norm feedback in SDMA systems. *IEEE Transactions on Signal Processing*, 56:3278–3293, Jul. 2008.
Number of citations: 12.

[MB28] T. T. Kim, M. Bengtsson, E. G. Larsson, and M. Skoglund. Combining long-term and low-rate short-term channel state information over correlated MIMO channels. *IEEE Transactions on Wireless Communications*, 7:2409–2414, Jul. 2008.
Number of citations: 5.

1. Journal articles in review

[MB29] S. M. Kim and M. Bengtsson. Virtual full-duplex buffer-aided relaying in the presence of inter-relay interference. *IEEE Trans. Wireless Comm.*, 2015. Under review
Number of citations: 0.

[MB30] R. Brandt and M. Bengtsson. Distributed CSI acquisition and coordinated precoding for TDD multicell MIMO systems. *IEEE Trans. VT*, 2015. Under review
Number of citations: 0.

[MB31] L. Fu, M. Johansson, and M. Bengtsson. Energy efficient transmissions in cognitive MIMO systems with multiple data streams. *IEEE Trans. Wireless Comm.*, 2014. Under review
Number of citations: 0.

2. Peer Reviewed Conference Papers

[MB32] A. Gharanjik, B. S. M. R., P. D. Arapoglou, M. Bengtsson, and B. Ottersten. Robust precoding design for multibeam downlink satellite channel with phase uncertainty. In *Proc. IEEE ICASSP*, 2015. Accepted
Number of citations: 0.

[MB33] A. Ainomäe, T. Trump, and M. Bengtsson. Distributed diffusion LMS based energy detection. In *Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2014 6th International Congress on*, pp. 176–183, Oct 2014.
Number of citations: 0.

[MB34] A. Ainomäe, T. Trump, and M. Bengtsson. Distributed recursive energy detection. In *Proc. IEEE WCNC*, 2014.
Number of citations: 0.

[MB35] R. Brandt, E. Björnson, and M. Bengtsson. Weighted sum rate optimization for multicell MIMO systems with hardware-impaired transceivers. In *Proc. IEEE ICASSP*, 2014.
Number of citations: 0.

[MB36] M. Bengtsson. Algorithmic solutions for pilot design optimization in arbitrarily correlated scenarios. In *Proc. IEEE ICASSP*, 2014.
Number of citations: 0.

[MB37] N. Shariati, D. Zachariah, and M. Bengtsson. Minimum sidelobe beampattern design for MIMO RADAR systems: A robust approach. In *Proc. IEEE ICASSP*, May 2014.
Number of citations: 0.

[MB38] H. Ghauch, T. Kim, M. Bengtsson, and M. Skoglund. Interference alignment via controlled perturbations. In *Proc. GLOBECOM*. IEEE, 2013.
Number of citations: 0.

[MB39] J. Wang, M. Bengtsson, B. Ottersten, and D. P. Palomar. Robust MIMO precoding for the Schatten norm based channel uncertainty sets. In *Proc. GLOBECOM*, 2013.
Number of citations: 0.

[MB40] S. M. Kim and M. Bengtsson. Virtual full-duplex buffer-aided relaying - relay selection and beamforming. In *Proc. PIMRC*, 2013.
Number of citations: 0.

[MB41] O. Aldayel, M. Bengtsson, and S. A. Alshebeili. Evaluation of MIMO channel non-stationarity. In *Proc. EUSIPCO*, 2013.
Number of citations: 0.

[MB42] N. Shariati, E. Björnson, M. Bengtsson, and M. Debbah. Low-complexity channel estimation in large-scale MIMO using polynomial expansion. In *Proc. PIMRC*, 2013.
Number of citations: 1.

[MB43] N. Shariati, J. Wang, and M. Bengtsson. A robust MISO training sequence design. In *Proc. IEEE ICASSP*, 2013.
Number of citations: 0.

[MB44] R. Brandt, P. Zetterberg, and M. Bengtsson. Interference alignment over a combination of space and frequency. In *IEEE International Conference on Communications 2013: IEEE ICC'13 - Workshop Beyond LTE-A*, pp. 149–153. Budapest, Hungary, Jun. 2013.
Number of citations: 1.

[MB45] J. Yang and M. Bengtsson. Robust receive beamforming with interference and channel uncertainty. In *Proc. PIMRC*, pp. 2231–2236, 2012.
Number of citations: 1.

[MB46] M. Bengtsson, J. Lilliesköld, M. Norgren, and H. Sohlström. Developing and implementing a program interfacing project course in electrical engineering. In *Proc. 8th International CDIO Conference 2012*. Brisbane Australia, Jul. 2012.
Number of citations: 0.

[MB47] D. Katselis, C. R. Rojas, H. Hjalmarsson, and M. Bengtsson. Application-oriented finite sample experiment design: A semidefinite relaxation approach. In *SYSID 2012*. Brussels, Belgium, July 2012.
Number of citations: 0.

[MB48] D. Katselis, C. Rojas, H. Hjalmarsson, and M. Bengtsson. A Chernoff convexification for chance constrained MIMO training sequence design. In *Proceedings of IEEE SPAWC'12, Signal Processing Advances in Wireless Communications*, 2012. Invited paper
Number of citations: 0.

[MB49] D. Katselis, C. R. Rojas, H. Hjalmarsson, and M. Bengtsson. A chernoff relaxation on the problem of application-oriented finite sample experiment design. In *IEEE Decision and Control (CDC)*, Proceedings of the IEEE Conference on Decision and Control, pp. 202–207. IEEE, 2012.
Number of citations: 0.

[MB50] E. Björnson, P. Zetterberg, and M. Bengtsson. Optimal coordinated beamforming in the multicell downlink with transceiver impairments. In *Proc. GLOBECOM*, IEEE Global Telecommunications Conference (Globecom), pp. 4775–4780. IEEE, 2012.
Number of citations: 0.

[MB51] N. Shariati, J. Wang, and M. Bengtsson. On robust training sequence design for correlated MIMO channel estimation. In *Proc.* 46^{th} *Asilomar Conf. Sig., Syst., Comput.*, pp. 504–507, 2012.
Number of citations: 0.

[MB52] R. Brandt, H. Asplund, and M. Bengtsson. Interference alignment in frequency — a measurement based performance analysis. In *2012 19th International Conference on Systems, Signals and Image Processing (IWSSIP)*, pp. 237–240. Vienna, Austria, Apr. 2012.
Number of citations: 3.

[MB53] L.-N. Tran, M. Juntti, M. Bengtsson, and B. Ottersten. Successive zero-forcing DPC with sum power constraint: Low-complexity optimal designs. In *IEEE ICC 2012 - Wireless Communications Symposium (ICC'12 WCS)*. Ottawa, Ontario, Canada, Jun. 2012.
Number of citations: 0.

[MB54] L.-N. Tran, M. Juntti, M. Bengtsson, and B. Ottersten. On the optimality of beamformer design for zero-forcing DPC with QR decomposition. In *IEEE ICC 2012 - Communications Theory (ICC'12 CT)*. Ottawa, Ontario, Canada, Jun. 2012.
Number of citations: 1.

[MB55] L.-N. Tran, M. Juntti, M. Bengtsson, and B. Ottersten. Successive zero-forcing DPC with Per-Antenna power constraint: Optimal and suboptimal designs. In *IEEE ICC 2012 - Signal Processing for Communications Symposium (ICC'12 SPC)*. Ottawa, Ontario, Canada, Jun. 2012.
Number of citations: 0.

[MB56] J. Wang, M. Bengtsson, B. Ottersten, and D. P. Palomar. Robust maximin MIMO precoding for arbitrary convex uncertainty sets. In *Proc. IEEE ICASSP*, pp. 3045–3048, 2012.
Number of citations: 2.

[MB57] E. Björnson, M. Bengtsson, G. Zheng, and B. Ottersten. Computational framework for optimal robust beamforming in coordinated multicell systems. In *Proc. IEEE CAMSAP*, pp. 245–248, 2011.
Number of citations: 0.

[MB58] D. Katselis, M. Bengtsson, C. R. Rojas, H. Hjalmarsson, and E. Kofidis. On preamble-based channel estimation in OFDM/OQAM systems. In *Proc. EUSIPCO*, 2011.
Number of citations: 3.

[MB59] C. R. Rojas, D. Katselis, H. Hjalmarsson, R. Hildebrand, and M. Bengtsson. Chance constrained input design. In *Proc. IEEE CDC-ECC*, pp. 2957–2962, 2011. ISSN 0743-1546.
Number of citations: 0.

[MB60] X. Hou, C. Yang, and M. Bengtsson. Impact of channel asymmetry on base station cooperative transmission with limited feedback. In *Proc. VTC Fall*, 2011.
Number of citations: 0.

[MB61] M. R. R. Bhavani Shankar, P. von Wrycza, B. Mats, and B. Ottersten. Convergence of the iterative water-filling algorithm in multiple user spectrum sharing scenarios. In *2011 IEEE Swedish Communication Technologies Workshop, Swe-CTW 2011*, pp. 80–85, 2011.
Number of citations: 0.

[MB62] E. Björnson, M. Bengtsson, and B. Ottersten. Receive combining vs. multistream multiplexing in multiuser MIMO systems. In *2011 IEEE Swedish Communication Technologies Workshop, Swe-CTW 2011*, pp. 103–108, 2011.
Number of citations: 0.

[MB63] L.-N. Tran, M. Juntti, M. Bengtsson, and B. Ottersten. Beamformer designs for zero-forcing dirty paper coding. In *2011 International Conference on Wireless Communications and Signal Processing, WCSP 2011*, 2011.
Number of citations: 0.

[MB64] N. Shariati and M. Bengtsson. How far from Kronecker can a MIMO channel be? Does it matter? In *European Wireless 2011*, 2011.
Number of citations: 1.

[MB65] J. Wang and M. Bengtsson. Simplified alternating optimization for robust MMSE MIMO transceiver. In *2011 International Conference on Wireless Communications and Signal Processing, WCSP 2011*, 2011.
Number of citations: 0.

[MB66] J. Yang, E. Björnson, and M. Bengtsson. Receive beamforming design based on a multiple-state interference model. In *Proc. ICC*, 2011.
Number of citations: 2.

[MB67] M. Bhavani Shankar, P. von Wrycza, M. Bengtsson, and B. Ottersten. Convergence of the iterative water-filling algorithm with sequential updates in spectrum sharing scenarios. In *Proc. IEEE ICASSP*, pp. 3216–3219, 2011.
Number of citations: 0.

[MB68] N. Shariati and M. Bengtsson. Robust training sequence design for spatially correlated MIMO channels and arbitrary colored disturbance. In *Proc. PIMRC*, pp. 1939–1943, 2011.
Number of citations: 0.

[MB69] R. Brandt and M. Bengtsson. Wideband MIMO channel diagonalization in the time domain. In *Proc. PIMRC*, pp. 1958–1962, 2011.
Number of citations: 2.

[MB70] E. Björnson, M. Bengtsson, and B. Ottersten. Optimality properties and low-complexity solutions to coordinated multicell transmission. In *Proceedings IEEE Global Communications Conference (GLOBECOM)*, Dec. 2010.
Number of citations: 6.

[MB71] A. F. Hanif and M. Bengtsson. Evaluation of low rate channel feedback schemes for MIMO systems. In *Proc. Future Network & Mobile Summit 2010*, Jun. 2010.
Number of citations: 0.

[MB72] P. Komulainen, A. Tölli, B. Song, F. Roemer, E. Björnson, and M. Bengtsson. CSI acquisition concepts for advanced antenna schemes in the WINNER+ project. In *Future Network and Mobile-Summit 2010 Conference Proceedings*, Jun. 2010.
Number of citations: 0.

[MB73] Y. Huang, L. Yang, M. Bengtsson, and B. Ottersten. A multiuser downlink system combining limited feedback and channel correlation information. In *Proceedings IEEE International Conference on Communications*, May 2010.
Number of citations: 0.

[MB74] S. Han, C. Yang, M. Bengtsson, and A. I. Pérez-Neira. Channel norm-based user scheduler in coordinated multi-point systems. In *Proceedings IEEE Global Telecommunications Conference*, Dec. 2009.
Number of citations: 0.

[MB75] P. von Wrycza, M. R. B. Shankar, M. Bengtsson, and B. Ottersten. A game theoretic approach to multi-user spectrum allocation. In *Proceedings IEEE Global Telecommunications Conference*, Nov. 2009.
Number of citations: 0.

[MB76] Y. Huang, L. Yang, M. Bengtsson, and B. Ottersten. A limited feedback SDMA scheme with dynamic multiplexing order. In *IEEE Internatonal Workshop on Signal Processing Advances in Wireless Communications*, pp. 211–215, Jun. 2009.
Number of citations: 0.

[MB77] Y. Huang, L. Yang, M. Bengtsson, and B. Ottersten. A codebook-based precoding for dual-hop downlink with MIMO amplify-and-forward relaying. In *IEEE International Workshop on Signal Processing Advances in Wireless Communications*, pp. 245–249, Jun. 2009.
Number of citations: 3.

[MB78] M. Bengtsson. Spatial interference suppression for shared spectrum. In *Proceedings ICT Mobile and Wireless Communications Summit*, Jun. 2008.
Number of citations: 0.

[MB79] E. Björnson, D. Hammarwall, R. Zakhour, M. Bengtsson, D. Gesbert, and B. Ottersten. Feedback design in multiuser MIMO systems using quantization splitting and hybrid instantaneous/statistical channel information. In *Proceedings ICT Mobile and Wireless Communications Summit*, Jun. 2008.
Number of citations: 0.

[MB80] P. von Wrycza, M. R. B. Shankar, M. Bengtsson, and B. Ottersten. Game theoretic approach to spectrum allocation for weak interference systems. In *Proceedings IEEE Global Communications Conference*, pp. 1–5, Nov. 2008.
Number of citations: 0.

[MB81] P. von Wrycza, M. R. B. Shankar, M. Bengtsson, and B. Ottersten. Spectrum allocation from a game theoretic perspective: Properties of Nash equilibria. In *Proceedings Asilomar Conference on Signals, Systems & Computers*, Oct. 2008.
Number of citations: 0.

[MB82] P. von Wrycza, M. Bengtsson, and B. Ottersten. Decentralized dynamic channel allocation for MIMO systems. In *Proceedings Asilomar Conference on Signals, Systems & Computers*, pp. 1689 – 1693, Nov. 2007.
Number of citations: 0.

[MB83] D. Hammarwall, M. Bengtsson, and B. Ottersten. Beamforming and user selection in SDMA systems utilizing channel statistics and instantaneous SNR feedback. In *Proceedings IEEE International Conference on Acoustics, Speech, and Signal Processing*, Apr. 2007.
Number of citations: 1.

[MB84] T. T. Kim, M. Bengtsson, and M. Skoglund. Quantized feedback design for MIMO broadcast channels. In *Proceedings IEEE International Conference on Acoustics, Speech, and Signal Processing*, Apr. 2007.
Number of citations: 2.

3. Monographs

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4. Research review articles

* [MB85] A. B. Gershman, N. D. Sidiropoulos, S. Shahbazpanahi, M. Bengtsson, and B. Ottersten. Convex optimization-based beamforming: From receive to transmit and network designs. *IEEE Signal Processing Magazine*, 27:62–75, Mar. 2010.
Number of citations: 120.

5. Books and book chapters

[MB86] A. Tölli, P. Komulainen, F. Boccardi, M. Bengtsson, and A. Osseiran. Multiuser MIMO systems. In A. Osseiran, J. Montserrat, and W. Mohr, eds., *Mobile and Wireless Communications for IMT-Advanced and Beyond*, pp. 89–120. John Wiley & Sons, 2011.
Number of citations: 0.

6. Patents

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7. Open access computer programs

Reference implementations ("reproducible research") of examples from the publications [MB2, MB35, MB9, MB14] are published at the web page of our school, `http://www.ee.kth.se/reproducible`.

8. Popular science articles/presentations

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Five most cited publications

[MB87] M. Bengtsson and B. Ottersten. Optimal and suboptimal transmit beamforming. In L. C. Godara, ed., *Handbook of Antennas in Wireless Communications*, chap. 18, pp. 18–1 — 18–33. CRC Press, Aug. 2001.
Number of citations: 270.

[MB88] M. Bengtsson and B. Ottersten. Optimal downlink beamforming using semidefinite optimization. In *Proc. 37th Annual Allerton Conference on Communication, Control, and Computing*, pp. 987–996, Sep. 1999.
Number of citations: 170.

[MB89] A. B. Gershman, N. D. Sidiropoulos, S. Shahbazpanahi, M. Bengtsson, and B. Ottersten. Convex optimization-based beamforming: From receive to transmit and network designs. *IEEE Signal Processing Magazine*, 27:62–75, Mar. 2010.
Number of citations: 120.

[MB90] K. Yu, M. Bengtsson, B. Ottersten, D. McNamara, P. Karlsson, and M. Beach. Modeling of wideband MIMO radio channels based on NLOS indoor measurements. *IEEE Trans. VT*, 53(3):655–665, May 2004.
Number of citations: 127.

[MB91] M. Bengtsson and B. Ottersten. Low-complexity estimators for distributed sources. *IEEE Trans. SP*, 48(8):2185–2194, Aug. 2000.
Number of citations: 82.

CV

Name: Mats Bengtsson	**Doctorial degree:** 2000-02-03
Birthdate: 19671128	**Academic title:** Docent
Gender: Male	**Employer:** Kungliga Tekniska högskolan

Research education

Dissertation title (swe)
Gruppantennsignalbehandling för högrangsdatamodeller

Dissertation title (en)
Antenna Array Signal Processing for High Rank Data Models

Organisation	Unit	Supervisor
Kungliga Tekniska Högskolan, Sweden Sweden - Higher education Institutes	Avdelningen för Signalbehandling	Björn Ottersten

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20205. Signalbehandling	1103-8039	2000-02-03

Publications

Name: Mats Bengtsson	**Doctorial degree:** 2000-02-03
Birthdate: 19671128	**Academic title:** Docent
Gender: Male	**Employer:** Kungliga Tekniska högskolan

Bengtsson, Mats has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.