LINKÖPINGS TEKNISKA HÖGSKOLA
Tekniska fakultetskansliet

FÖRSLAG TILL PROGRAMNÄMND INFÖR ÅR 2017

NÄMND/NÄMNDER: EF

Förslagsställare (Namn, funktion, Inst/Enhet)

Emil Björnsson. Klas Nordberg, studierektor, ISY

FÖRSLAGET GÄLLER:

a) EXISTERANDE KURS (Ange kurskod och kursnamn)

TSKS03 Trådlösa system

b) NY KURS (Ange kursnamn, årskurs, önskad läsperiod, schemablocksplacering. Bifoga utkast till kursplan.)

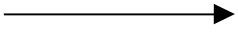
TSKSzz Multiple Antenna Communications / Flerantenn-kommunikation

c) ÄNDRING I EXISTERANDE PROFIL/INRIKTNING (Ange Program och Profil/Inriktning. Bifoga beskrivning över vad förslaget går ut på.)

d) NY PROFIL/INRIKTNING (Ange Program och Profilnamn. Bifoga utkast till Profilbeskrivning.)

e) ÖVRIGT (Bifoga beskrivning över vad förslaget går ut på.)

PROGRAMNÄMNDENS BESKED:



FÖRSLAGET I DETALJ:

Vi föreslår inrättandet av en ny kurs på avancerad nivå i ”Flerantenn-kommunikation” (eng: Multiple Antenna Communications), valbar i högre årskurs för D, ELE, I, Ii, IT, SY och Y.
Förslaget har diskuterats med EF-nämndens vice ordförande Martin Enqvist.

Kursen ska vara valbar på Kommunikationsprofilen för Y, Yi, D & IT. Föreslagen schemaplacering: VT2, block 2. (Kursen kan med fördel läggas i det block som kursen TSKS03 Trådlösa system använder idag).

Kursen ger en ingående introduktion till flerantenn-teknik för trådlös kommunikation. Dessa tekniker används i de flesta kommunikationssystem som utvecklats de senaste fem åren, för att uppnå hög överföringskapacitet och för att hantera situationer där flera användare vill kommunicera samtidigt. Flerantenn-tekniker antas få en än mer framträdande roll i framtida trådlösa system. Inrättandet av denna kurs är därför en central del i moderniseringen av kurspaketet på avancerad nivå inom kommunikationssystem.

Som en del av moderniseringen av kurspaketet på avancerad nivå inom kommunikationssystem ersätter den föreslagna kursen TSKS03 Trådlösa system.

Förslag till text i studiehandboken samt preliminär föreläsningsplanering bifogas.

Föreslagen text till studiehandboken

TSKS?? Multiple Antenna Communications 6 ECTS credits. / Flerantenn-kommunikation /

Area of Education: Technology

Main field of studies: Electrical Engineering

Advancement level: A

Prel. scheduled hours: 56
Rec. self-study hours: 104

Aim
After passing the course, the student should

- be able to describe and discuss the fundamental limitations when using the wireless medium for communications; in particular, the relations between channel capacity, channel coherence, spatial degrees of freedom, transmission power, pilot contamination, and bandwidth.
- be able to identify and describe how multiple antenna techniques are used to achieve high capacity in point-to-point as well as multi-user communications.
- with some precision be able to solve engineering oriented problems regarding the achievable performance and limits of multiple antenna communications.
- be able to utilize power control and other parameters to design communication systems that meet given service quality requirements.
- experimentally validate the main theoretic multiple antenna concepts.

Prerequisites
From Linear algebra: Computations with matrices and vectors, determinant, eigenvalues.
From Signals, information and communication (or equivalent): Channel models, channel capacity, the entropy concept.
From Digital communications: Multi-carrier systems, link adaptation.
From Detection and Estimation of Signals: Estimation with linear signal models.

The course “Wireless communications” is also recommended for students that want to put the course content into context (e.g., link budget analysis and the cellular network concept), but is not necessary.

Organization
Teaching is given as lectures, tutorials and laboratory exercises.

Course contents

Fundamental limits: Capacity behavior as power or bandwidth increases. Examples of practical systems that are power and bandwidth limited. Orthogonal versus non-orthogonal transmission in scenarios with multiple users.
Basic multiple antenna channels: Array gain, capacity of channels with multiple antennas at one side. Modeling of multi-antenna channel responses.
Fading channels: Rayleigh fading channels, outage capacity, diversity, channel coherence, ergodic capacity.
Point-to-point MIMO: Capacity of channels with multiple antennas at both sides, multiplexing gain, spatial degrees of freedom.
Uplink multi-user MIMO: Uplink capacity, non-linear and linear detection, channel estimation, capacity bounds in systems with many antennas.
Downlink multi-user MIMO: Linear precoding, capacity bounds in systems with many antennas, differences and similarities between uplink and downlink.
Power control: Rate region, typical operating points, basic power allocation formulations.
Cellular networks: Engineering aspects of applying multiple antenna techniques in cellular networks, including reuse strategies, pilot contamination, and interference management.

The purpose of the laboratory work is to become familiar with the zero-forcing processing concept, to implement such a technique, and to evaluate its behaviors experimentally.

Course literature

T. L. Marzetta, E. G. Larsson, H. Yang, H. Q. Ngo, “Fundamentals of Massive MIMO,” 2016.
Additional material will be distributed during the course.

Examination

TEN1	Written examination	5 ECTS
LAB1	Laboratory work	1 ECTS

The exam (TEN1) examines the first four course aims, while the laboratory work (LAB1) examines the last course aim. The final grade is determined by the exam result. The exam is normally written, but the course director can decide to use oral examination, as complement to or as replacement for a written exam, in case there are few students taking the exam, or in other special cases.

Preliminär föreläsningsplanering:

1. **Fundamental capacity limits**
   Parameters that affect capacity: bandwidth and transmit power
   Capacity scaling when power or bandwidth increases
   Examples of communication scenarios: which are power/bandwidth limited?
   Multiple users – orthogonal or non-orthogonal sharing?

2. **Basic multi-antenna channels**
   Antenna array concept and geometry
   Capacity of time-invariant MISO channels: Maximum ratio processing
   Example: Multi-antenna line-of-sight channel modeling

3. **Fading channels**
   Rayleigh fading for one and multiple antennas
   Outage probability, outage capacity, diversity with multiple antennas
   Ergodic capacity for fading channels

4. **Point-to-point MIMO channel**
   Computing the MIMO capacity
   Multiplexing gain (spatial degrees of freedom)

5. **Uplink multi-user MIMO** (1)
   Basic motivation of multi-user MIMO
   Detection with successive interference cancelation and obtaining the capacity
   Capacity region concept and different operating points

6. **Channel estimation in uplink multi-user MIMO**
   Channel coherence concept
   Channel estimation from pilot sequences

7. **Uplink multi-user MIMO** (2)
   Capacity bound with a linear detector and estimated channels
   Maximum ratio processing for detection
   Optimal linear detection

8. **Massive MIMO and favorable propagation**
   Concept of favorable propagation
   Uplink capacity bound with Rayleigh fading
   Engineering insights from the bound

9. **Downlink massive MIMO communications**
   Downlink capacity bound with linear precoding
   Maximum ratio processing for precoding
   Similarities and differences between uplink and downlink

10. **Power control in massive MIMO**
    Different operating points and problem formulations
    Solve one power allocation problem

11. **Massive MIMO in cellular networks**
    Universal and non-universal reuse strategies
    Pilot contamination
    Power control and interference management

12. Summary
    What are the techniques to achieve high capacity?
    What are their respective merits and demerits?