ELG7177: MIMO Communications

Instructor: Dr. Sergey Loyka, CBY A608
Lectures: Wed. 16:00-18:50, CBY C206
Office hours: Thursdays, 5-6pm. Outside office hours - by appointment only. No exceptions! You are encouraged to ask questions immediately after lectures (but not before). No questions by email (will not be answered).
Course web page: http://www.site.uottawa.ca/~sloyka/

Pre-(Co) requisites: solid knowledge of digital communication theory; wireless communications and information theory are a plus. Mathematics: basic probability theory, calculus and linear algebra. Matrix theory is a plus.
- ELG4179, or ELG5133, or ELG5132, or Instructor permission.

Marking scheme:
Course project + presentation  50%
Final exam 50%
Lots of bonus points to everybody who takes active part in the course.
Final exam: will be scheduled by the university; 3h, open book.

Week-by-week Description (approximate):


2. MIMO (multi-antenna) systems: information-theoretic limits (channel capacity), optimal signaling strategies and system architectures. Channel models.

3. V-BLAST and successive interference cancellation; application to cognitive radio. Alamouti scheme and space-time codes. Diversity and multiplexing gains.

4. Impact of channel state information (CSI). Full CSI and no CSI at the transmitter. Transmission on channel eigenmodes and water-filling algorithm. Optimality of beamforming and isotropic signaling.

5. Fading channels and ergodic capacity. Statistical CSI.

7. Multi-user MIMO: multiple access channel (MAC), broadcast channel (BS), interference channel (IC). Performance gains due to MIMO. Capacity region, symmetric and sum capacities (total throughput). Optimal signaling.

8. Massive MIMO and 5G.

9. Physical-layer security via MIMO: wiretap channel, secrecy capacity, wiretap codes and optimal secure signaling.

**Rationale: Why?**

Since its discovery around 1995, MIMO (multiple-input multiple-output or multi-antenna) wireless systems have gained wide-spread popularity and acceptance in both academia and industry due to its unprecedentedly high spectral efficiency. This is clearly illustrated by the reference list above with a large number of books and even larger number of papers published every year (including special issues of almost all relevant journals in the field, and special sessions in almost every related conference), in addition to being included in key industrial standards, e.g. IEEE 802.11 (WiFi), LTE and 5G (cellular). A few years ago, a significant new spike of interest in this area was observed in a form of massive MIMO, which is considered now a key technology to meet the demands of 5G systems, which are currently under extensive R&D by all leading telecommunications companies and standardization bodies.
Textbook: there is no single textbook to cover all topics. The following books will be used on a need-to-know basis:

1. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005. *(this is a comprehensive well-written textbook on a wider topic, but approx. 50% of it deal with MIMO systems or closely-related subjects while giving a good introduction of basic digital communications and information theory as it relates to wireless communications. You are strongly encouraged to read this book not only to learn the technical subject but also to learn how to write well in technical English. Solving end-of-chapter problems is essential for deep understanding of the material.)*


Additionally, the following special issues of leading journals provide comprehensive review articles as well as many original research papers on the topic:


7. Special Issue on Massive MIMO, Journal of Communications and Networks (JCN), vol. 15, no. 4, Aug. 2013.


10. Special Issue on MIMO Systems, IEEE Journal Selected Areas Comm, v. 21, N. 3 and 5, April and June 2003

To review basic communication theory or/and probability:


This is an exceptionally good book on information theory:

How to Study: Learning Efficiency Pyramid


“Tell me and I’ll forget; show me and I may remember; involve me and I’ll understand.” – old Chinese proverb.

“No pain, no gain” – common wisdom.
How to Study

Learning efficiency pyramid is a good guideline

- **Reading** is necessary, but taken alone is not efficient
- **Solving problems** (“practice by doing”) is much more efficient
  - examples, assignments, end-of-chapter problems
- **Group discussions**
  - help provided you contribute something
- **Systematic study** during the semester
  - is a key to a success.
  - do not leave everything to the last day/night before exams!
- **Lectures**
  - should be supplemented by the items above
- **There is no substitute for active learning!** “Seat and watch” approach does not work!