Helsinki University of Technology
Communications Laboratory

2.10.2007/sgh

S-72.3210 Channel Modeling for Radio Communication Systems (3 credits)

Course presentation,

Period II, 2007 – 2008

Course status:

Compulsory course in

↓ **Degree program of Communications Engineering**
↓ **Master's major subject Radio Communications**
- **the option Radio Communication Systems**

Compulsory course in

↓ **Degree program of Electronics and Electrical Engineering**
↓ **Master's major subject Communications Applications**
- **Option Radio Communication Systems**

Compulsory course in

↓ **International Master's Program in Communications Engineering**
- **Radio Communications option.**

Replacement:

S-72.135 Fixed Radio Networks
S-72.232 Radio Communication Systems Networks

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S-72.3210 Channel Modeling for Radio Communication Systems
S-72.3220 Radio Communication Systems

Course motivation:

- **The radio channel has a crucial impact on the transmission of information through it.**
- **In almost all radio communication applications *multipath propagation* will occur during a significant part of the time.**
- **This *time dispersivity* causes a frequency selective behavior of the channel transfer function, and without countermeasures harmful *intersymbol interference* is generated.**
- **Movements in the transmission medium and especially the movement of the transmitting or receiving station cause *Doppler-shifts*.**
- **This *frequency dispersivity* causes a time selective behavior of the received signal level, *signal fading*. This fading requires that the operation of multipath countermeasures must adapt to the actual channel situation.**
- **Frequency and time selectivity can also be utilized for better performance and higher capacity**
- **In order to design proper radio link budgets or to rollout radio network nodes in a cost effective way the radio communication engineer must know which propagation mechanisms are important in different applications, and how they build up the received signals.**

- **As the phenomena are random channel models for the linear time-variant radio channel are required to estimate the performance of radio links and radio networks.**
- **For effective fading countermeasures channel estimation is necessary**

Prerequisites: The course S-72.1140 Transmission Methods in Communication Systems and S-72.1110 Signals and Systems or their equivalents are assumed to be acquired before this course.
Lectures and exercises: These are held weekly at the following times in Period II in the academic year 2007 – 2008 starting at November 1.

Tuesdays 12 – 14, I346;
Wednesdays 12 – 14, I346;
Thursdays 12 – 14, I346

The lecture plan is attached. Possible changes are announced on the course homepage (http://www.comlab.hut.fi/opetus/3210/) and on the information board on floor E3.
In the exercises demonstrative problems and solving methods are presented. In each exercise a home work is given, which should be returned for checking and grading. The scores will have an impact on the final course grade.

Teacher: The course is lectured by professor emeritus Sven-Gustav Häggman, who is the responsible teacher of this course. The exercises are also held by him.

Contents:

- Outdoor propagation environments
  - Base station antenna above roof tops/vegetation
  - Base station antenna below roof tops/in vegetation
- Outdoor to indoor propagation
- Indoor propagation environments
  - Buildings
  - Tunnels, street canyons

Shadow fading

Channel parameter statistics

- Narrow-band systems
- Wide-band systems

Broadcasting

- LF/MF
- HF
- VHF/UHF

Terrestrial l.o.s.radio relay systems

- Standard propagation
  - Free space loss
  - Diffraction losses over single and multiple obstacles
- Propagation during sub-refractive situations
  - k-fading

- **Tropospheric multipath propagation**
  - **Signal enhancement**
  - **Flat and frequency selective fading**
- **Rain attenuation**
- **Attenuation from tropospheric gases**

- **Transhorizontal radio links**
- **Satellite links**

Channel parameter statistics

- **Narrow-band systems**
- **Wide-band systems**

The lecture plan is given below. All the above topics will not be deeply treated in the lectures. If needed, the plan may be changed

Requirements: The course is carried out by an exam. The exam requirements consist of the material distributed to the students. There will be two exams, the first exam is on December 17, 2007.

This is an open-book exam, where the use of arbitrary source material is allowed except for team work between the students or other persons. Use of scientific calculators is usually required.

Final grade: The final course grade is calculated from the formula:

$$\text{Final grade} = T_{exam} + 0.2T_{exercises}$$

The student must pass the exam.

Literature:

[1] Lecture and exercise material.

Corresponding material can partly be found from the following books and publications (which also contain a lot of topics not included in this course):

[2] J.D. Parsons: The Mobile Radio Propagation Channel, 2nd edition, Wiley 2000, 418p.

[3] S.R. Saunders: Antennas and Propagation for Wireless Communication systems, Wiley 2001, 409p.

[4] R. Vaughan, J. Bach Andersen: Channels, Propagation and Antennas for Mobile Communications, IEEE Books 2003, 784p.

[5] Recommendation ITU-R P.368-8, Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz. 2005, 54p.

[6] Recommendation ITU-R P.676-5, Attenuation by atmospheric gases, 2001, 21p.

[7] Recommendation ITU-R P.834-4, Effects of tropospheric refraction on radiowave propagation, 2003, 11p.

[8] Recommendation ITU-R P.1411-2, Propagation data and prediction methods for the planning of short-range outdoor radiocommunication

systems and radio local area networks in the frequency range 300 MHz to 100 GHz, 2003, 17p.

[9] Recommendation ITU-R P.1546, Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz. 2001, 51p.

S-72.3210 Channel Modeling for Radio Communication Systems, 3 credits, Lecture plan 2007

Thu.	1.11.	12 – 14 I346	Lecture 1 Lecture 2	Introduction Radio wave propagation: ground wave prop.
Tue.	6.11.	12 – 14 I346	Lecture 3 Lecture 4	Radio wave propagation: free space prop. Radio wave propagation: tropospheric refraction
Wed.	7.11	12 – 14 I346	Exercise 1 Exercise 2	
Thu.	8.11.	12 – 14 I346	Lecture 5 Lecture 6	Radio wave propagation: tropospheric refraction Radio wave propagation: diffraction
Tue.	13.11.	12 – 14 I346	Lecture 7 Lecture 8	Radio wave propagation: diffraction Radio wave propagation: absorption
Wed.	14.11.	12 – 14 I346	Exercise 3 Exercise 4	
Thu.	15.11.	12 – 14 I346	Lecture 9 Lecture 10	LTV-channel characterization: LTV concept LTV-channel characterization: determ. LTV-ch.
Tue.	20.11.	12 – 14 I346	Lecture 11 Lecture 12	LTV-channel characterization: determ. LTV-ch. LTV-channel characterization: stoch. LTV-ch.
Wed.	21.11.	12 – 14 I346		Exercise 5 Exercise 6
Thu.	22.11.	12 – 14 I346	Lecture 13 Lecture 14	LTV-channel characterization: stoch. LTV-ch. LTV-channel characterization: parametric repr.

Tue.	**27.11.**	**12 – 14 I346**	**Lecture 15 Lecture 16**	**LTV-channel characterization: example LTV-channel characterization: NB condition**
Wed.	**28.11.**	**12 – 14 I346**	**Exercise 7 Exercise 8**	
Thu.	**29.11.**	**12 – 14 I346**	**Lecture 17 Lecture 18**	**Radio channel modeling: mobile channel Radio channel modeling: mobile channel**
Tue.	**4.12.**	**12 – 14 I346**	**Lecture 19 Lecture 20**	**Radio channel modeling: broadcast channel Radio channel modeling: broadcast channel**
Wed.	**5.12.**	**12 – 14 I346**	**Exercise 9 Exercise 10**	
Tue.	**11.12.**	**12 – 14 I346**	**Lecture 21 Lecture 22**	**Radio channel modeling: fixed terr. channel Radio channel modeling: fixed terr. channel**
Wed.	**12.12.**	**12 – 14 I346**	**Lecture 23 Lecture 24**	**Radio channel modeling: satellite channel Radio channel modeling: other radio channels**
Thu.	**13.12.**	**12 – 14 I346**	**Exercise 11 Exercise 12**	

Core topic analysis

	Always actual topics	Sometimes needed topics	Sometimes useful topics
Knowledge	• Most usual propagation mechanisms in VHF – EHF • Deterministic and random LTV channel analysis • Channel models for mobile and fixed radio in VHF – EHF	• Most usual propagation mechanisms in LF – HF • Channel models for mobile and fixed radio in LF – HF	• Most usual propagation mechanism in lowest bands • Channel models for mobile and fixed radio in lowest bands
Understanding	• Importance of different propagation mechanisms in different frequency bands • Nature and effects of multipath propagation and Doppler shifts		
Application	• Path loss estimation in the radio link budget • Creation and verification of ray tracing tools • Channel description and synthesizing • System performance analysis and simulation		

	• Range estimation		