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INSTITUT
FÜR NACHRICHTENTECHNIK
UND HOCHFREQUENZTECHNIK
TECHNISCHE UNIVERSITÄT WIEN

DOKUMENTATION

STAND:
1. OKTOBER 1999

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Diese Dokumentation ist auch am **World Wide Web** einsehbar:/
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Auflage November 1999

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Mag. Dr. Bernhard Mayr
Dr. Peter Proksch
Dr. Alexander Renner
Dipl.-Ing. Paul Skritek

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Dipl.-Ing. Markus Danner
Dipl.-Ing. Torbjörn Ekman
Dipl.-Ing. Martin Gotschlich
Dipl.-Ing. Martin Hagenauer
Dr. Andras Kalmar
Dipl.-Ing. Udo Krebelder
Dipl.-Ing. Alexander Kuchar
Dr. Mathias Lang
Dipl.-Ing. Heinz Novak
Dr. Michael Rasztovits-Wiech
Dr. Alexander Schneider
Katalin Stibli

Gastmitarbeiter:
Keattisak Sripimanwat Oktober 1998 – September 1999 Asian Institute of Technology, Thailand

Sponsoren und Projektpartner
Sponsors and Cooperation partners

Alcatel Corporate Research, Stuttgart
AMS - Austria Micro Systems
CA Creditanstalt Rilkeplatz
COST 258, 259 (EU)
Deutsche Telekom AG
Dornier Satellitensysteme GmbH
ENSEEIHT Toulouse
ENST Paris
Ericsson Austria
Ericsson Hellas
ESA - European Space Agency
ESPRIT Div. for Basic Research
EU Marie Curie Fellowship
EU Socrates programme
European Commission
France Telecom
FWF - Fonds zu Förderung der Wissenschaftlichen Forschung
Infineon Villach
Infineon München
KTH Stockholm
Mobilkom AG
Nokia Austria
Nokia Research Center Helsinki
Norwegian Telecom
OeNB - Österreichische Nationalbank
Siemens AG Österreich
Signal and Systems Group, Uppsala University
Stadt Wien / Wiener Städtische Allgemeine Versicherung AG
Stanford University, Information Systems Laboratory
Telekom Austria AG

AKTUELLE FORSCHUNGSGEBIETE: ÜBERSICHT
CURRENT RESEARCH AREAS: SYNOPSIS

Im Bereich der *digitalen Signalverarbeitung* bearbeiten wir derzeit die folgenden Schwerpunkte: *Zeit-Frequenz-Signalverarbeitung, Nichtlineare Signal- und Sprachverarbeitung, Digitale Filter und adaptive Systeme zur Sprachentstörung*, sowie die *Automatische Generierung optimierter Programme für Signalprozessoren*.

Zur Analyse und Verarbeitung instationärer Signale wenden wir *Zeit-Frequenz-Signaldarstellungen* an. Im Rahmen zweier vom FWF finanzierter Forschungsprojekte entwickeln wir neue Zeit-Frequenz-Verfahren zur Analyse, Filterung, Codierung und Detektion von Signalen. Einerseits arbeiten wir an statistischen Zeit-Frequenz-Verfahren zur optimalen Filterung und Detektion, andererseits an der Anwendung von Zeit-Frequenz-Konzepten auf Problemkreise der Mobilkommunikation.

Zunehmende Bedeutung erlangt die *nichtlineare Signal- und Sprachverarbeitung* sowohl für die Modellierung als auch für die Signalprädiktion bei unterschiedlichen Anwendungsgebieten. Dabei werden neue Algorithmen aus der Chaostheorie und der Informationstheorie ebenso eingesetzt wie neurale Netze und nichtlineare adaptive Filter. Anwendungen realisieren wir in der Sprachsynthese und Sprachcodierung, der Fehlerverdeckung für Bild- und Sprachsignale, der digitalen Übertragungstechnik und der Analyse und Prädiktion von Lastkurven in der Energieversorgung. Ein Teil dieser Projekte wird mit Unterstützung des FWF, in Kooperation mit der Industrie oder mit internationalen Partnern (KTH Stockholm, Cornell University, University Uppsala) durchgeführt. An der COST Aktion 258 "The Naturalness of Synthetic Speech" nehmen wir aktiv teil.

Die Leistungsfähigkeit moderner Signalprozessoren kann nur durch effiziente Programme wirklich ausgenutzt werden. Dazu entwickeln wir Algorithmen für die automatische Umsetzung von Datenflußgraphen in optimierte Programme für Signalprozessoren. Auf diesem Gebiet werden wir durch den FWF und die OeNB unterstützt, es bestehen aber auch enge Kooperationen mit Industriefirmen.

Ein weiteres Forschungsgebiet umfaßt die *Entstörung massiv verrauschter Sprachsignale* mit Hilfe adaptiver Filter und Filterbänken. Neben dem Entwurf von Multiratenfilterbänken werden auch adaptive Algorithmen zur Modifikation der einzelnen Teilbandsignale entwickelt.

In the area of *digital signal processing* we focus on the following topics*: Time-frequency signal processing, nonlinear signal and speech processing, digital filters and adaptive systems for speech enhancement,* and *automatic program generation for signal processors*.

We apply *time-frequency signal representations* to the analysis and processing of nonstationary signals. Two FWF supported research projects deal with the development of new time-frequency methods for the analysis, filtering, coding, and detection of signals. Our current work emphasizes research on statistical time-frequency methods for optimal filtering and detection and the application of time-frequency concepts to advanced techniques for mobile communications.

Nonlinear signal and speech processing receives growing interest for modeling purposes and signal prediction in various application scenarios. New algorithms from chaos theory and information theory are instrumental tools as are neural networks and nonlinear adaptive filters. We solve application problems in speech synthesis, speech coding, error concealment for image and speech signals, digital communications, and the analysis and prediction of load profiles in energy management systems. Some of these projects are carried out with support from FWF, in cooperation with industry, or with international partners (KTH Stockholm, Cornell University, Uppsala University). We actively contribute to COST 258 "The Naturalness of Synthetic Speech".

The exploitation of the full performance of modern signal processors requires efficient programs. To meet this challenge, we develop algorithms for the automatic conversion of data flow graphs into highly optimized programs for signal processors. In this area, we receive support from FWF and OeNB, and there exist close cooperations with industrial companies.

Another research area comprises the *enhancement of massively noise-corrupted speech* using adaptive filters and filterbanks. Besides the design of multi-rate filterbanks, a number of adaptive algorithms is developed for the modification of the subband signals.

Im Bereich der *Kanal-Kodierung* untersuchen wir Trellis-codierte Modulation für unterschiedliche Kanäle (z.B. Fading-Kanäle). Von besonderem Interesse sind hier Codes für Übertragungsysteme bei denen mehrere Sendeantennen zur Verfügung stehen (space-time-codes). Fortgesetzt wird die Analyse von Übertragungsverfahren, bei denen die Codeworte an die Impulsantwort des Kanals angepaßt werden. Wir versuchen auch, vereinfachte Algorithmen für die Decodierung von Turbo-Codes zu implementieren.

Im Bereich der *Datenübertragung* bearbeiten wir spezielle Probleme des VDSL (very high speed digital subscriber loop)-Übertragungsverfahrens, hauptsächlich im Hinblick auf die elektromagnetische Verträglichkeit mit anderen Diensten.

In der *Mobilkommunikation* arbeiten wir mit der Telekom Austria AG und der Mobilkom AG zusammen auf den Gebieten Optimierung von Mobilfunknetzen, künftiges UMTS (Universal Mobile Telecommunications System), Konvergenz von Fest- und Mobilnetz und Funkzugang zum Internet. Wir untersuchen die grundlegenden Fehlermechanismen in Mobilfunkkanälen und spezifizieren im Rahmen eines EU-Projekts, was an Mobilfunkkanälen mit welcher Genauigkeit gemessen werden soll. Für intelligente Antennen entwickeln wir Algorithmen für Auf- und Abwärtsstrecke, die auf Signalprozessoren in Echtzeit implementiert sind. Mit "blinden" Algorithmen nutzen wir strukturelle Eigenschaften der Mobilfunksignale um gewünschte Teilnehmer von unerwünschten zu trennen, selbst wenn sie räumlich nicht trennbar sind. An der COST Aktion 259 "Wireless Flexible Personalized Communications" nehmen wir aktiv und mit einem Arbeitsgruppenleiter (Antennen und Wellenausbreitung) teil. Die Einbindung in das ITG-Fokusprojekt "Mobile Kommunikation" führt zu einem intensiven Wissensaustausch mit deutschen Hochschulen und Firmen. Die Spezialausbildung in der Mobilkommunikation, zu der verschiedene Bereiche des Instituts beitragen, zieht Studenten aus ganz Europa an.

Auf dem Gebiet der *Hochfrequenztechnik* beschäftigen wir uns mit Sendeempfängern einerseits für Frequenzbänder bis zu mehreren GHz und andererseits für Kurzwelle. In allen Fällen steht der Einsatz digitaler Verfahren im Vordergrund. Selbstverständlich streben wir an, die entwickelten Baugruppen hochintegrierbar zu gestalten.

In the area of *channel coding* we investigate Trellis Coded Modulation for specific channels (e.g. fading-channels). Most interesting are space-time codes for systems using antenna arrays. We continue to analyze data transmission methods using codewords which are matched to the impulse response of the channel transfer characteristic. Additionally, we try to implement reduced complexity algorithms for decoding parallel or serially concatenated turbo codes.

In the field of high speed *data transmission* over short twisted pairs as used in local loops we work on specific problems of VDSL systems especially concerning electromagnetic compatibility with existing services.

In the field of *mobile communications*, we cooperate with Telekom Austria AG and Mobilkom AG on mobile network optimization, the future UMTS (Universal Mobile Telecommunications System), Fixed-Mobile correspondence, and radio access to the internet. We develop smart antennas algorithms for up- and downlink, which are implemented on a DSP in real time. With so-called "blind" algorithms we utilize structural signal properties to separate and detect desired/interfering user signal, which are not separated in the spatial domain. We actively contribute to COST 259 "Wireless Flexible Personalized Communications" where we head the working group on antennas and propagation. We investigate fundamental error mechanisms in the mobile radio channel and specify, within the framework of the EU-funded project METAMORP, what can and should be measured in such a channel. Our involvement in the ITG project "Mobile Kommunikation" lead to intensive mutual knowledge exchange with German universities and companies. The dedicated course plan in mobile communications draws students from all over Europe.

In the domain of *radio frequency technology* we deal with the exploitation of bands up to several GHz on one hand and with shortwave radio on the other. In both cases we employ digital technology wherever possible. Our main goal is to develop systems which are highly integratable.

Auf dem Gebiet der *Optischen Nachrichtentechnik* beteiligten wir uns an den ACTS-Projekten PHOTON und MOON der Europäischen Kommission, in denen Glasfasersysteme mit Wellenlängen-Multiplex aufgebaut wurden. Für die Europäische Weltraumbehörde ESA entwickeln wir optische Antennengruppen, die als Empfangsteleskope in der Laser-Datenübertragung zwischen Satelliten eingesetzt werden sollen. Andererseits untersuchen wir Laser-Freiraumverbindungen, die bei Datenraten von 10 Gbit/s RZ-codiert sind und bei einer Wellenlänge von 1,5µm unter Verwendung von Erbium-dotierten Faserverstärkern arbeiten. Schließlich erarbeiteten wir Beiträge auf dem Gebiet der satellitengestützten Windmessung mittels Laserradar.

In the area of *optical communications* we participated in the European Commission's ACTS projects PHOTON and MOON where wavelength-multiplexed fiber systems were implemented. For the European Space Agency ESA we develop, on one hand, optical phased array antennas to be used as receive telescopes in intersatellite laser links. On the other hand, we investigate RZ coded free space laser links for data rates of 10 Gbit/s which will operate at a wavelength of 1.5µm and use Erbium-doped fiber amplifiers as booster and as preamplifier. In addition, we contributed to the field of satellite-borne Doppler wind lidar to determine wind velocity.

PREISTRÄGER DES INSTITUTS / AWARDS (1.10.1998 - 30.9.1999)

Dipl.-Ing. Klaus Hugl: ÖVE/GIT-Preis	1998
Dipl.-Ing. Martin Michael Strasser: ÖVE/GIT-Preis	1998
Dr. Mathias Lang: ÖVE/GIT-Preis	1999
Dipl.-Ing. Alexander Kuchar: "Best Paper Award" bei "EPMCC'99, European Personal Mobile Communications Conference", Paris	1999
Dipl.-Ing. Manfred Taferner: "Student Paper Award" bei "PIMRC'99, The 10th Symposium for Personal, Indoor and Mobile Radio Communications", Osaka, Japan	1999

INSTITUT FÜR KOMMUNIKATIONSNETZE / INSTITUTE OF COMMUNICATION NETWORKS

In den Räumen des Instituts ist seit 01.03.1996 auch das neu eingerichtete Institut für Kommunikationsnetze (Inst. Vorstand: O.Univ.Prof. Dr. Harmen R. van As) untergebracht. Diese Interimslösung soll die Zeit bis zur Adaptierung der für dieses Institut zugesagten Räume in der Favoritenstraße 9-11 überbrücken (Herbst 1999).

Since 01.03.1996 the recently established Institute of Communication Networks (Head: Prof. Dr. Harmen R. van As) is accommodated within the premises of the Institut für Nachrichtentechnik und Hochfrequenztechik. This interim solution is planned to bridge the time period needed for adaptation of premises at Favoritenstrasse 9-11 designated to this new Institute (fall 1999).

Nach umfangreichen Vorarbeiten wurde heuer das Forschungszentrum Telekommunikation Wien (FTW) als Kplus Kompetenzzentrum gegründet, das von Bund und Land Wien unterstützt wird.

Am FTW sind 13 Telekommunikationsfirmen aus dem Wiener Raum und die TU-Wien Institute für Nachrichtentechnik und Hochfrequenztechnik, für Kommunikationsnetze und für Elektrische Meß- und Schaltungstechnik beteiligt.

Kooperative Forschungsprojekte werden in den folgenden drei Themenbereichen durchgeführt:

- Telekommunikationsnetze und -dienste
- Signalverarbeitung zur Datenübertragung
- Mobilkommunikation

In jedem der drei Themenbereiche bildet ein Grundlagenprojekt die Basis für spezifische anwendungsorientierte Projekte, an denen jeweils zumindest 3 Unternehmen beteiligt sind.

Für die Startphase wurden 10 Projekte definiert:

Grundlagenprojekte:

- Network Technologies and Services
- Signal Processing: Coding and Modulation
- UMTS and Supporting Technologies

Anwendungsorientierte Projekte:

- Advanced Service Control Architecture
- Network Management
- Interactive Multimedia Services
- Broadband Access over Wire
- Speech Database and Related Algorithms
- UMTS Applications Development
- Smart Antennas

Vizepräsident des FTW ist Prof. Ernst Bonek.

The Telecommunications Research Center Vienna (FTW) was founded this year as a cooperative research and development institution for telecommunications technology. The FTW is co-financed by the Austrian Federal Government and the City of Vienna.

FTW participants are 13 Vienna-based telecommunications companies and three departments of the Vienna University of Technology (Institute of Communications and Radio-Frequency Engineering; Institute of Communication Networks; Institute of Electrical Measurement and Circuit Technology).

Cooperative research projects are being conducted in the following three areas:

- Communication Networks and Services
- Signal Processing for Data Transmission
- Mobile Communications

In each of these research areas, a basic research project lays the foundations for specific applied research projects in which at least three companies participate.

For the initial phase, the following 10 projects were formulated:

Basic Research Projects:

- Network Technologies and Services
- Signal Processing: Coding and Modulation
- UMTS and Supporting Technologies

Applied Research Projects:

- Advanced Service Control Architecture
- Network Management
- Interactive Multimedia Services
- Broadband Access over Wire
- Speech Database and Related Algorithms
- UMTS Applications Development
- Smart Antennas

The FTW's vice president is Prof. Ernst Bonek.

1. PFLICHTLEHRVERANSTALTUNGEN / MANDATORY COURSES

			WS	SS
Weinrichter:	Einführung in die Nachrichtentechnik	VO	—	3,0
Fröhlich:	Einführung in die Nachrichtentechnik	UE	—	1,5
Weinrichter:	Grundlagen nachrichtentechn. Signale	VO	—	2,0
Matz:	Grundlagen nachrichtentechn. Signale	UE	—	1,0
Magerl:	Hochfrequenztechnik 1	VO	—	2,0
Ingruber:	Hochfrequenztechnik 1	UE	—	1,0
Ehrlich-Schupita:	Hochfrequenztechnik 2	VO	2,0	—
Ehrlich-Schupita:	Hochfrequenztechnik 2	UE	1,0	—
Mecklenbräuker, Bonek, Seifert:	Nachrichtentechnik Labor A	LU	—	5,0
Bonek, Mecklenbräuker, Seifert:	Nachrichtentechnik Labor B	LU	9,0	—
Mecklenbräuker, Bonek:	Nachrichtentechnik Labor B für Computertechnik	LU	3,5	—
Leeb:	Optische Nachrichtentechnik	VO	2,0	—
Winzer:	Optische Nachrichtentechnik	UE	1,0	—
Mecklenbräuker:	Signal- und Systemtheorie 1	VO	1,5	—
Bölcskei:	Signal- und Systemtheorie 1	UE	1,0	—
Mecklenbräuker:	Signal- und Systemtheorie 2	VO	—	1,5
Doblinger:	Signal- und Systemtheorie 2	UE	—	1,0
Hlawatsch:	Übertragungsverfahren 1	VO	2,0	—
Kubin:	Übertragungsverfahren 1	UE	1,0	—
Hlawatsch:	Übertragungsverfahren 2	VO	—	2,0
Artés /Seyringer	Übertragungsverfahren 2	UE	—	1,0
Bonek:	Wellenausbreitung 1	VO	2,0	—
Pospischil:	Wellenausbreitung 1	UE	1,0	—
Bonek:	Wellenausbreitung 2	VO	—	2,0
Winzer:	Wellenausbreitung 2	UE	—	1,0

2. WAHLLEHRVERANSTALTUNGEN / OPTIONAL COURSES

			WS	SS
Zemanek:	Menschliche Aspekte des Computers	VO	1,5	—
Kubin:	Adaptive Signal Processing	VO	1,5	—
Mecklenbräuker:	Ausgewählte Kapitel der Netzwerktheorie	VO	1,5	—
Mecklenbräuker:	Ausgewählte Kapitel der Digitalen Signalverarbeitung	VO	1,5	—
Skritek:	Computerunterstützter Schaltungs-entwurf	VO	—	1,5
Kubin:	Chaotic Signal Processing	VO	—	1,5
Zemanek:	Geschichte der Informatik	VO	1,0	—
Mecklenbräuker, Doblinger, Fröhlich:	Digitale Signalverarbeitung A	SE	3,0	—
Mecklenbräuker, Fröhlich, Doblinger:	Digitale Signalverarbeitung B	SE	—	3,0
Wess:	Dimensionierung und Simulation analoger Filter	SE	1,5	—
Bonek:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Assistenten:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Hlawatsch:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Leeb:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Mecklenbräuker:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Scholtz:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Weinrichter:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Weinrichter:	Einführung in die Codierung	VO	2,0	—
Kommenda:	Ein- und Ausgabe von Sprache	VO	2,0	—
Garn:	Elektromagnetische Verträglichkeit elektronischer Geräte	VO	—	1,5
Garn:	Elektromagnetische Verträglichkeit elektronischer Geräte	UE	—	1,5
Weinrichter:	Filter	VO	1,5	—
Braunbeck:	Geschichte der Nachrichtentechnik	VO	1,5	—
Leeb	Glasfaser-Nachrichtensysteme	VO	—	1,5

			WS	SS
Scholtz:	Hochfrequenz-Schaltungstechnik	VO	—	1,5
Magerl:	Integrierte Mikrowellenschaltungen	VO	—	1,5
Bonek, Leeb	English for electrical engineering students	KO	2,0	—
Leeb:	Kohärente optische Empfänger	VO	—	1,5
Ehrlich-Schupita:	Meßgeräte der Hochfrequenztechnik A	KO	—	1,5
Kreuzgruber:	Meßgeräte der Hochfrequenztechnik B	KO	1,5	—
Wess:	Methoden der automatischen Codegenerierung	VO	—	1,5
Magerl:	Mikrowellenmeßtechnik	SE	1,5	—
Mayr:	Modulationsangepaßte Codierung	VO	—	1,5
Bonek, Weinrichter, Molisch:	Mobilfunk	KO	—	3,0
Molisch:	Mobilkommunikation	SV	2,0	—
Bonek, Weinrichter, Molisch:	Mobile Radio Communications	KO	—	3,0
Fröhling, Renner:	Numerische Methoden in der HF- und Mikrowellentechnik	VO	1,5	—
Proksch:	Phasenregelschleifen in der Nachrichtentechnik	VO	—	1,5
Doblinger:	Programmieren von Signalverarbeitungsalgorithmen in C	SE	—	1,5
Bölcskei, Doblinger, Hlawatsch, Kubin:	Research Projects in Advanced Signal Processing	SE	3,0	3,0
Doblinger:	Signalprozessoren	VO	1,5	—
Mecklenbräuker, Doblinger:	Signalverarbeitung mit MatLab	LU	3,0	—
Hlawatsch	Statistical Signal Processing	VO	—	2,0
Hlawatsch:	Time-Frequency Methods for Signal Processing	VO	1,5	—

GASTVORLESUNGEN / GUEST LECTURES

			WS	SS
Prof. Thomas J. Brazil University College Dublin	Nonlinear Device Modelling and Simulation Techniques for Microwave Circuits	VO	—	2,0
Prof. Allister G. Burr University of York	Advanced Modulation and Coding for Radio Systems	VO	—	2,0
Prof. Dr. John Dunlop University of Strathclyde, Glasgow, U.K.	Private Mobile Radio: TETRA	VO	—	2,0

Automatische Codeerzeugung / Automatic Code Generation

Code-Generation for Digital Signal Processors.
Contact: A. Helm, B. Wess
Partner: Infineon Villach Duration: 01.02.1993 -

Code Optimization for the Carmel DSP Core.
Contact: T. Zeitlhofer, B. Wess
Partner: Infineon München Duration: 01.04.1998 -

Optimization of DSP Schedules by Evolutionary Algorithms.
Contact: B. Wess Partner: OeNB (Project 8083) Duration: 01.08.1999 - 31.03.2000

Codierung und Datenübertragung / Coding and Data Transmission

Local Loops.
Contact: J. Weinrichter *Partner:* Ericsson Austria Duration: 01.11.1996 -

Digitale Filter und Signalprozessoren / Digital Filters and Signal Processors

FIR filter design by complex function approximation.
Contact: G. Doblinger *Partner:* FWF (Project P11133-ÖMA) Duration: 01.05.1996 - 30.04.1999

Digitale Signalverarbeitung / Digital Signal Processing

Redundant Signal Expansions in Wireless Communications.
Contact: H. Bölcskei *Partner:* FWF (Project J1629-TEC), University of Stanford Duration: 01.02.1999 - 31.01.2001

Mobilkommunikation / Mobile Communications

Telecommunications.
Contact: E. Bonek *Partner:* Telekom Austria Duration: 1990 -

Wireless Flexible Personalized Communications.
Contact: E. Bonek *Partner:* COST 259 Duration: 04.1996 - 04.2000

METAMORP Measurement and testing of mobile radio channel sounders and simulators.
Contact: A. Molisch *Partner:* Ericsson Hellas, Deutsche Telekom AG, France Telecom, Norwegian Telecom Duration: 09.1996 - 12.1999

UMTS
Contact: T. Neubauer *Partner:* mobilkom Austria Duration: 1.04.1997 -

Smart antennas for mobile communications systems
Contact: E. Bonek Partner: FWF (Project P12147-MAT) Duration: 06.1997 - 06.2000

Real-time signal processing for smart antennas
Contact: A. Kuchar Partner: Alcatel Corporate Research, Stuttgart Duration: 06.1997 - 06.1999

Directional channel models
Contact: M. Steinbauer Partner: COST 259 Duration: 02.1999 - 04.2000

Adaptive antennas for UMTS
Contact: K. Kopsa Partner: Alcatel Corporate Research, Stuttgart Duration: 04.1999 - 12.1999

Noise floor in UMTS band.
Contact: T. Neubauer Partner: Nokia Austria Duration: 09.1999 -

Smart antennas in cellular networks
Contact: K. Hugl Partner: Nokia Research Center, Helsinki Duration: 08.1999 -

Optische Nachrichtentechnik / Optical Communications

Management of optical networks (MOON).
Contact: W. Leeb *Partner:* European Commission Duration: 01.09.1996 - 29.02.1999

Paneuropean photonic network (PHOTON).
Contact: W. Leeb *Partner:* European Commission Duration: 01.10.1995 - 30.11.1998

Optical phased arrays.
Contact: W. Leeb *Partner:* ESA-ESTEC Duration: 01.08.1994 - 01.02.2000

Coherent Systems within ESA's Atmospheric Dynamics Mission.
Contact: W. Leeb *Partner:* Dornier Satellitensysteme / ESA-ESTEC
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Doppler Wind Lidar Receiver Technology.
Contact: W. Leeb *Partner:* Dornier Satellitensysteme / ESA-ESTEC
Duration: 01.12.1998 - 01.12.1998

Sprachverarbeitung und Nichtlineare Signalverarbeitung / Speech Processing and Nonlinear Signal Processing

Information- and chaos-theoretic analysis for control and automation engineering.
Contact: G. Kubin *Parnter:* Siemens PSE Duration: 12.1994 -

Conversion of phonological representations into acoustical parameters for a concept-to-speech system.
Contact: G. Kubin *Partner:* FWF (Project P10822) and OeFAI
Duration: 1995 - 1998

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Duration: 1992 -

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Speech and audio coding in a perceptual domain.
Contact: G. Kubin *Partner:* KTH Stockholm Duration: 07.1998 -

Zeit-Frequenz-Signalverarbeitung / Time-Frequency Signal Processing

Oversampled filter banks and redundant signal expansions.
Contact: F. Hlawatsch *Partner:* FWF (Project P11228-TEC) Duration: 01.09.1997 -

Time-frequency processing and modeling of nonstationary random processes.
Contact: F. Hlawatsch *Partner:* FWF (Project P11904-ÖPY) Duration: 01.01.1997 -

MOLISCH Andreas

Bit error probability of cordless telephones in time-dispersive environment

The work presented in this thesis deals with various aspects of the error probability of cordless communications systems in time-dispersive fading channels. Cordless stands here as an abbreviation for unequalized, uncoded, TDMA and/or FDMA systems. Evaluations of results concentrate on MSK as modulation format, since it is used in DECT, the European standard for cordless telephones.

The first chapter is an introduction that reviews the various methods for BER computations in time-dispersive environments. The second chapter deals with differential detection with fixed sampling. We first introduce a new method for computing the error floor in a two-delay channel. We show that errors occur if the normalized phasors of the instantaneous impulse response fall into certain regions of the complex plane; then we average over the statistics of the phasors to arrive at the mean BER; we call this method the error region method. With this method, we derive analytical expressions for the BER for arbitrary amplitude statistics of the paths. For the inclusion of noise and arbitrary power delay profiles, we introduce the two-path equivalent-matrix (TPEM) method. In this method, we reduce the general channel (including noise) exactly to a two-path fading channel without noise. With this method, we can find analytically the BER for both filtered and unfiltered (G)MSK if the BER is small; for large BER a single well-behaved integral must be solved numerically. In a first approximation, the error floor varies as K◊(S/T)^2, where S is the rms delay spread and T the bit length, and K is on the order of unity. We show that K exhibits a weak dependence on the shape of the power delay profile. The BER is increased by less than 50% for Gaussian filtering of the data sequence and receiver filtering with a time-bandwidth product larger than 0.3. For diversity, we find that the error floor is proportional to (S/T)^4. The proportionality constant depends also on whether we use RSSI (received signal strength indication)-driven diversity and BER (bit error rate)-driven diversity. The error floor can be reduced by fractional-bit detection. However, increasing the sampling-time shift in that scheme trades off error floor against noise susceptibility. We furthermore demonstrate that receiver filtering and filtering of the input data sequence reduces the ability of the fractional-bit detection to combat the error floor. Finally, we propose and verify that a nonlinear frequency discriminator can achieve zero error floor for pure binary FSK and drastically reduced error floor for filtered FSK by clipping off the ISI-induced FM clicks. The stronger the receiver filtering, the more the beneficial effect of the nonlinearity is reduced.

In the third chapter, we discuss differential detection with adaptive sampling, i.e. determination of the sampling instant that changes with the channel. We prove that for pure MSK and low time dispersion, training-sequence based adaptive sampling can completely avoid errors caused by intersymbol interference. The actual errors are caused by "secondary" effects (filtering and finite-resolution sampling) in conjunction with the channel time dispersion. The error floor again goes like K◊(S/T)^2; the proportionality constant K depends strongly on the Gaussian filtering in the transmitter, the receiver filtering, and depends also on the amount of oversampling. The BER can be orders of magnitude lower than for the fixed sampling case. Similar results are obtained for BPSK; however, pi/4-DQPSK does not allow a strong reduction of the error floor by this method. When noise is included in the computations, we find that the total BER is approximately the sum of the flat-fading BER plus the error floor. The choice of the optimum sampling instant can be obtained under these circumstances either by optimum or suboptimum methods; we propose an approach that gives a simplification of the sampling-time determination while increasing the BER by less than a factor of two. For diversity, we find that again, the error floor is proportional to (S/T)4. RSSI-driven diversity gives little improvements in the admissible S for BER=10^-3, while BER-driven diversity increases it by some 50%. In the last chapter, we analyze the applications of our analyses to cordless system design. We find that both for DECT and the Japanese PHS system, delay spreads of up to 300-500ns are admissible; if the delay spreads are larger, equalizers have to be used.

BRATANOV Plamen **User mobility modeling in cellular communications networks**

Mobility management is the cornerstone of cellular philosophy. Mobility analysis gives a deep insight on the impact of the terminal mobility on the cellular system performance. In third-generation mobile communication systems, the influence of mobility on the network performance will be strengthened, mainly due to the huge number of mobile users in conjunction with the small cell size. In particular, the accuracy of mobility modeling becomes essential for the evaluation of system design alternatives and network implementation cost issues. Currently available mobility models tend to be either too simplifying or too sophisticated. For mobility modeling under realistic traffic and environmental conditions, this thesis introduces a novel representation technique which uses the distribution functions of street length, direction changes at crossroads, and terminal velocity. The parameter required, e.g. mean and variance of street length, user velocity, and direction changes distributions, can be easily derived by observation and measurement. Other important factors influenced by user mobility concern the mobile user calling behavior expressed by the incoming/outgoing call arrival rate and average call duration. This work thus brings together teletraffic theory and vehicular traffic theory.

This is capable its to describe the user behavior in detail, and is applied for the characterization of the traffic in individual single cells of the mobile network. The effect of mobility has been analyzed in terms of the local performance measures like probability of handover and call blocking probability (for new and handover calls). Additionally, this model has been used to calculate the distribution of channel holding times. The performance of new call handling algorithms are evaluated.

The global performance criteria of interest are *call dropping probability for all calls*, call processing time dependent *forced termination of handovers*, and *channel utilization*. Thus the average number of functions per call for information handling systems with different hierarchical structures can be computed, too.

All these parameters are expressed as a function of the user calling and mobility behavior. To assess the accuracy of the proposed mobility model a simulation tool has been constructed. The tool takes into account the unser traffic and mobility behavior over different environments (high density city center, outskirts, etc.). Theoretical results, simulation trials, and measurement data coincide, indicating the excellent accuracy the analytically described mobility model provides.

Additionally, an approach for Space Division Multiple Access (SDMA) system modeling is presented. The influence of the different users mobility behavior on key SDMA parameters as the time-dependent angle and distance variation between terminal and supported base station, respectively, are explored.

KALMAR Andras **Self-phasing multiple-aperture receive telescope for free-space laser communication**

This thesis describes the design, realization, and testing of a phased telescope array for optical space communications. Due to their non-mechanical pointing capability, inherent modularity, and redundancy, phased telescope arrays are an interesting alternative to conventional single-telescope designs. They further allow for lightweight and compact telescope setups and are therefore well suited as receive terminals in coherent intersatellite links.

The thesis evolved from a research project supported by the European Space Agency (ESA). The main objective of the work was to realize a laboratory demonstrator, which is a representative model of a phased receive telescope array for intersatellite communications in terms of aperture size, optical performance, and pointing capabilities.

The laboratory demonstrator, designed to operate at a wavelength of λ = 1064nm, is completely independent of any subsequent receiver and of the data modulation format employed. The telescope array is self-phasing, i.e. the main lobe of the antenna pattern automatically follows the direction of the incident wave. It thus performs non-mechanical fine tracking.

My experimental setup comprises 16 subtelescopes with an equivalent total diameter of 10cm and a digital control unit employing digital signal processors. Besides inertia-free tracking, the control unit also checks and, if necessary, restores parallel alignment of the subtelescope axes at regular intervals. Space-worthy concepts have been applied wherever possible, although experiments have been performed only in the laboratory. Automatic fine-tracking is achieved within a single subtelescope's field of view (30µrad) in the frequency range up to 730Hz.

LANG Mathias **Algorithms for the constrained design of digital filters with arbitrary magnitude and phase response**

This thesis presents several new algorithms for designing digital filters subject to specifications in the frequency domain. Finite impulse response (FIR) as well as infinite impulse response (IIR) filter design problems are considered.

Unlike many standard filter design algorithms, all methods proposed here solve the problem of simultaneously approximating specified magnitude and phase response. Filters of this type can be used to optimally equalize magnitude and phase distortions. Such problems occur e.g. in data transmission systems or in oversampled analog-to-digital conversion. Another application of the proposed algorithms is the design of filters with low group delay in the passbands. In the FIR case, the exactly linear phase property is given up in order to reduce the delay while maintaining a good approximation to phase linearity in the passbands. IIR filters can also be designed to have an approximately linear passband phase response. Their passband group delay is usually considerably smaller than the delay of linear phase FIR filters with equivalent magnitude responses.

An important feature of the algorithms presented in this thesis is that they allow for design constraints which often arise in practical filter design problems. Meeting a required minimum stopband attenuation or a maximum deviation from the desired magnitude and phase responses in the passbands are common design constraints that can be handled by the methods proposed here. For the design of IIR filters, an important constraint is the prescription of a maximum pole radius. This not only allows to guarantee stability but also helps to avoid undesirable effects when implementing the designed filter with fixed-point arithmetic. An algorithm solving this constrained IIR design problem is presented.

During the development of the proposed design techniques special emphasis has been placed on their computational efficiency. This and the fact that this thesis includes Matlab programs implementing all proposed algorithms makes all results of this dissertation directly applicable to many practical design problems.

WINZER Peter **Analysis and modeling of noise with applications to Doppler wind lidar**

This thesis investigates the fundamental nature of noise in optoelectronic systems, placing emphasis on lidar instruments.

The first part is generally concerned with the phenomenon 'noise', discussing problems associated with uncertainty analyses on a fairly abstract level. We critically review frequently used quantitative uncertainty measures (such as the signal-to-noise ratio) and reveal some of their limits of validity. We further tackle the question under which circumstances a closed-form noise analysis should be made and when noise simulations seem more appropriate. These considerations are followed by a detailed analysis of shot noise, excess noise, and optical amplification noise, which brings to light some novel aspects: We discourse about the assumptions under which the non-additive, non-stationary, and non-Gaussian shot noise becomes stationary and Gaussian, discuss important aspects of speckle (in particular the coupling of random optical fields to optical single-mode structures), present a semiclassical derivation of optical amplification noise that fully takes account of the photodetector's impulse response, and contrast our approach with a fully quantum electrodynamical treatment. Throughout our analyses, we provide examples related to lidar systems and optical communications.

The second part of this work is devoted to noise analyses and simulations in spaceborne Doppler wind lidar systems. Depending on how the Doppler frequency shift imposed on the backscattered laser pulse is made accessible to electronic measurement, we differentiate between coherent and incoherent Doppler wind lidar systems, sketching both concepts' principle of functionality. We present a patent-pending, incoherent Doppler wind lidar system, whose novelty with respect to state-of-the-art systems is threefold: First, by using a receive telescope array, one heavy and expensive telescope is replaced by a number of smaller subtelescopes; second, the use of fiber-optic components makes the setup flexible, robust, and cheap; third, we efficiently use all received power to retrieve the Doppler frequency shift information.

We then focus on methods for simulating coherent Doppler wind lidar systems. We critically review a simulation model for atmospheric backscattering and show how to properly incorporate laser amplitude and phase noise in a computer simulation tool. We further present three different approaches for the computer simulation of shot noise, developed in the frame of this work. The fields of applicability of the models are thoroughly analyzed and shown to range from low-photon direct detection encountered in optical communications to optical heterodyne receivers employing high local oscillator power levels. A discussion of the results obtained by our simulation tool for coherent Doppler wind lidar systems shows good agreement with the ones reported in literature.

Using the novel incoherent Doppler wind lidar system described above as an example, we demonstrate how a closed-form noise analysis can be accomplished; we express variance and offset of the wind velocity estimates as a function of the relevant system parameters. The noise analysis includes all major features found in a typical incoherent Doppler wind lidar scenario: speckle, atmospheric backscatter properties (aerosol and molecular backscattering), background radiation, hardware tolerances, and temporal drifts of the system components. An assessment shows the competitiveness of our approach with respect to other incoherent Doppler wind lidar instruments.

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