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INSTITUT
FÜR NACHRICHTENTECHNIK
UND HOCHFREQUENZTECHNIK
TECHNISCHE UNIVERSITÄT WIEN

DOKUMENTATION

STAND:
1. OKTOBER 1997

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MITARBEITER DES INSTITUTS (STAND: 1.10.1997)
STAFF MEMBERS

Professoren:

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AO.Univ.Prof. Dr. Walter Leeb
AO.Univ.Prof. Dr. Gottfried Magerl
AO.Univ.Prof. Dr. Johann Weinrichter

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Dipl.-Ing. Christian Seyringer

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Dipl.-Ing. Peter Winzer

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AO.Univ.Prof. Dr. Johannes Riegl
O.Prof. Dr. Gerhard Schiffner
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Dr. Peter Kreuzgruber
Dr. Wolfgang Lothaller
Mag. Dr. Bernhard Mayr
Dipl.-Ing. Bernhard Oehry
Dr. Peter Proksch
Dr. Alexander Renner
Dipl.-Ing. Paul Skritek

Im letzten Jahr sind folgende Mitarbeiter ausgeschieden:

Mag. Dipl.-Ing. Josef Fuhl
Dipl.-Ing. Werner Kreuzer
Dr. Wolfgang Pusch
Dr. Martin Schreiblehner
Dr. Ralph Sucher

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Torbjörn Ekman	09.97 -	University of Uppsala, Uppsala, Schweden
Pauliina Erätuuli	01.96 -	Technische Universität, Helsinki, Finnland
Robert Finan	09.97 -	University of Abertay, Dundee, Schottland
Ralph Kattenbach	08.97 - 09.97	Universität Gesamthochschule, Kassel, Deutschland
Khanh P. Nguyen	03.94 -	HCMC University of Technology, Vietnam
Henrik Nord	07.97 -	Royal Institute of Technology, Stockholm, Schweden
Albert Silvestre	07.97 - 08.97	Ramon Llull University, Barcelona, Spanien

SPONSOREN UND PROJEKTPARTNER
SPONSORS AND COOPERATION PARTNERS

AMS - Austria Micro Systems

CA Creditanstalt Rilkeplatz

Cochlear AG, Basel

COST 258, 259 (EU)

Deutsche Telekom AG

Ericsson Austria

Ericsson Hellas

ESA - European Space Agency

ESPRIT Div. for Basic Research

EU Socrates programme

European Commission

France Telecom

FWF - Fonds zu Förderung der Wissenschaftlichen Forschung

Hischmann Electronic GmbH

Norwegian Telecom

OeNB - Österreichische Nationalbank

PTA - Post und Telekom Austria

Siemens AG Österreich

The Swedish Institute and Signal and Systems Group, Uppsala University

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 Z-F-Verfahren zur Analyse, Filterung, Codierung und Detektion von Signalen. Einerseits arbeiten wir an statistischen Z-F-Verfahren zur optimalen Filterung und Detektion, andererseits an der Analyse und dem Entwurf überabgetasteter ein- und mehrdimensionaler Filterbänke sowie deren Anwendungen auf die Kompression von Audio- und Videosignalen.

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 (Bell Laboratorien, Cornell University) durchgeführt.

Mit der stark gestiegenen Leistungsfähigkeit integrierter digitaler Signalprozessoren eröffnen sich immer mehr Anwendungen für den Einsatz *digitaler Systeme*. In einem unserer Forschungsprojekte beschäftigen wir uns mit speziellen Entwurfsalgorithmen für digitale Filter. Dafür wurden effiziente und flexible Optimierungsverfahren entwickelt, die auch auf andere Probleme, wie Strahlformung mit Antennen- oder Mikrophongruppen, anwendbar sind. Dieses Projekt wird vom FWF und der OeNB unterstützt. 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. Besides performing research on statistical time-frequency methods for optimal filtering and detection, we investigate the analysis and design of oversampled one- and multi-dimensional filterbanks, as well as their application to the compression of audio and video signals.

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 (Bell Laboratories, Cornell University).

The dramatic performance increase witnessed by integrated digital signal processors opens ever more application possibilities for digital systems. One of our research projects focuses on special design algorithms for digital filters. For this purpose, we developed several efficient and flexible optimization algorithms which can also be applied to other related problems, such as beamforming with antenna or microphone arrays. This project is supported by the FWF and OeNB. 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.

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.

Im Bereich der *Kanalcodierung* untersuchen wir Trellis-codierte Modulation für unterschiedliche Kanäle (z.B. Fading-Kanäle) sowie fehlerkorrigierende Übertragungsverfahren, die an den Frequenzgang des Kanals angepaßt sind. Wir versuchen, das Prinzip der Turbo-Codes bzw. der iterativen Decodierung auf Kanal angepaßte Übertragungsverfahren anzuwenden. Im Bereich der Quellencodierung testen wir verschiedene Varianten der Datenkompression bei der Bildcodierung und arbeiten an einer optimalen Kombination von Quellen- und Kanal-Codierung.

In der *Mobilkommunikation* arbeiten wir mit der Post und Telekom Austria AG zusammen auf den Gebieten Intelligente Antennen, Wellenausbreitung, Funknetzplanung und digitale Mobilfunksysteme (GSM, DECT, HiperLAN, künftiges UMTS). Wir untersuchen die grundlegenden Fehlermechanismen in Mobilfunkkanälen und spezifizieren im Rahmen eines EU-Projekts, was an Mobilfunkkanälen mit welcher Genauigkeit gemessen werden soll. 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.

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.

In the area of *channel coding* we investigate Trellis Coded Modulation for specific channels (e.g. fading-channels) as well as error correction methods combined with spectral shaping. We try to adapt the principle of Turbo-Decoding to channel matched data transmission methods. We are furthermore testing several data compression methods in connection with image coding and try to combine source coding and channel coding in an optimal way.

In the field of *mobile communications*, we cooperate with the Austrian PTT on smart antennas, wave propagation, on network planning, and on digital mobile radio (GSM, DECT, HiperLAN, future UMTS). 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.

Im Bereich der *Mikrowellentechnik* stehen Industrieaufträge zur Entwicklung von Mikrowellen-Anlagen im Vordergrund. Derzeit wird ein 5-Watt Leistungsverstärker für 1,5GHz entworfen und aufgebaut, der nach dem Prinzip der Beeinflussung der Harmonischen arbeitet. Mit einem halbsinusförmig angesteuerten Verstärker wurde ein Wirkungsgrad von besser als 75% erreicht. Der Verstärker wird zunächst als Hybrid realisiert, das Ziel ist jedoch ein monolithisch integrierter Schaltkreis in GaAs-Technologie.

Auf dem Gebiet der *Optischen Nachrichtentechnik* setzen wir zur Zeit zwei Forschungsschwerpunkte. Zum einen entwickeln wir im Auftrag der Europäischen Weltraumbehörde ESA eine optische, phasengesteuerte Antennengruppe für Datenübertragungssyteme mittels Laserlicht und untersuchen Wind-Lidar-Empfänger. Zum anderen beteiligen wir uns an den ACTS-Projekten "PHOTON" und "MOON" der Europäischen Kommission, in denen Wellenlängenmultiplexsysteme mit Datenraten von 10Gbit/s aufgebaut werden.

Our *microwave group* thrives on industrial contracts for the development of microwave systems. At present we design and build a 5-Watt power amplifier for the 1.5GHz frequency range. We use the concept of harmonic control amplifiers with different input waveforms. With a half-sinusoidally driven harmonic control amplifier we obtained a power-added efficiency of better than 75%. The amplifier is designed as a hybrid, our final goal, however, is a GaAs monolithic microwave intergrated circuit.

In the area of *optical communications* we currently work in two main research areas. First, we develop an optical phased array antenna to be used in the European Space Agency's (ESA) intersatellite communication links and investigate wind lidar receivers. Second, we participate in the European Commission's ACTS projects "PHOTON" and "MOON", where wavelength-multiplexed systems with data rates of 10Gbit/s are implemented.

PREISTRÄGER DES INSTITUTS / AWARDS (1.10.1996 - 30.9.1997)

Dipl.-Ing. Peter Winzer	Würdigungspreis des BMWV	1996
Dipl.-Ing. Peter Winzer	ÖVE/GIT-Preis	1996
Dipl.-Ing. Alexander Kuchar	ÖVE/GIT-Preis	1996

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 (Sommer 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 (summer 1999).

1. PFLICHTLEHRVERANSTALTUNGEN / MANDATORY COURSES

			WS	SS
Bonek:	Wellenausbreitung 1	VO	2,0	—
Bonek mit Hagenauer:	Wellenausbreitung 1	UE	1,0	—
Magerl:	Wellenausbreitung 2	VO	—	2,0
Magerl mit Kuchar:	Wellenausbreitung 2	UE	—	1,0
Bonek, Mecklenbräuker, Seifert:	Nachrichtentechnik Labor B	LU	9,0	—
Bonek:	Nachrichtentechnik Labor für TPH	LU	—	4,0
Leeb:	Optische Nachrichtentechnik	VO	2,0	—
Leeb mit Kudielka:	Optische Nachrichtentechnik	UE	1,0	—
Bonek:	Hochfrequenztechnik 1	VO	—	2,0
Bonek mit Novak:	Hochfrequenztechnik 1	UE	—	1,0
Mecklenbräuker:	Signal- und Systemtheorie 1	VO	1,5	—
Mecklenbräuker mit Kubin:	Signal- und Systemtheorie 1	UE	1,0	—
Mecklenbräuker:	Signal- und Systemtheorie 2	VO	—	1,5
Mecklenbräuker mit Doblinger:	Signal- und Systemtheorie 2	UE	—	1,0
Mecklenbräuker:	Übertragungsverfahren 1	VO	2,0	—
Mecklenbräuker mit Bernhard:	Übertragungsverfahren 1	UE	1,0	—
Mecklenbräuker:	Übertragungsverfahren 2	VO	—	2,0
Mecklenbräuker mit Hlawatsch:	Übertragungsverfahren 2	UE	—	1,0
Mecklenbräuker, Bonek:	Nachrichtentechnik Labor B für Computertechnik	LU	3,5	—
Mecklenbräuker, Bonek, Seifert:	Nachrichtentechnik Labor A	LU	—	5,0
Ehrlich-Schupita:	Hochfrequenztechnik 2	VO	2,0	—
Ehrlich-Schupita:	Hochfrequenztechnik 2	UE	1,0	—
Weinrichter:	Einführung in die Nachrichtentechnik	VO	—	3,0
Weinrichter mit Sucher:	Einführung in die Nachrichtentechnik	UE	—	1,5
Weinrichter:	Grundlagen nachrichtentechn. Signale	VO	—	2,0
Weinrichter mit Sommer:	Grundlagen nachrichtentechn. Signale	UE	—	1,0

2. WAHLLEHRVERANSTALTUNGEN / OPTIONAL COURSES

			WS	SS
Bonek:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Bonek mit Molisch:	Mobilkommunikation	SV	2,0	—
Bonek, Weinrichter, Molisch:	Mobilfunk	KO	—	3,0
Bonek, Weinrichter, Molisch:	Mobile Radio Communications	KO	—	3,0
Braunbeck:	Geschichte der Nachrichtentechnik	VO	1,5	—
Doblinger:	Signalprozessoren	VO	1,5	—
Doblinger, Bernhard:	Programmieren von Signalverarbeitungsalgorithmen in C	SE	—	1,5
Ehrlich-Schupita, Oehry:	Meßgeräte der Hochfrequenztechnik A	KO	—	1,5
Fröhling, Renner:	Numerische Methoden in der HF- und Mikrowellentechnik	VO	1,5	—
Garn:	Elektromagnetische Verträglichkeit elektronischer Geräte	VO	—	1,5
Garn:	Elektromagnetische Verträglichkeit elektronischer Geräte	UE	—	1,5
Hlawatsch:	Time-Frequency Methods for Signal Processing	VO	1,5	—
Horak:	Einführung in die Kryptologie	VO	1,5	—
Kommenda:	Ein- und Ausgabe von Sprache	VO	—	2,0
Kreuzgruber:	Meßgeräte der Hochfrequenztechnik B	KO	1,5	—
Kubin:	Chaotic Signal Processing	VO	—	1,5
Kubin:	Adaptive Signal Processing	VO	1,5	—
Leeb:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Leeb:	Kohärente optische Systeme	VO	—	1,5
Lothaller:	Satellitennachrichtentechnik	VO	—	1,5
Magerl:	Mikrowellenmeßtechnik	SE	1,5	—
Magerl:	Integrierte Mikrowellenschaltungen	VO	—	1,5
Magerl mit Ingruber:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Mayr:	Modulationsangepaßte Codierung	VO	—	1,5
Mecklenbräuker:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0

			WS	SS
Mecklenbräuker:	Ausgewählte Kapitel der digitalen Signalverarbeitung	VO	1,5	—
Mecklenbräuker, Birgmeier, Doblinger:	Digitale Signalverarbeitung A	SE	3,0	—
Mecklenbräuker, Birgmeier, Doblinger:	Digitale Signalverarbeitung B	SE	—	3,0
Mecklenbräuker:	Signalverarbeitung mit MatLab	LU	3,0	—
Proksch:	Phasenregelschleifen in der Nachrichtentechnik	VO	—	1,5
Riegl:	Radartechnik	VO	—	1,5
Scholtz:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Scholtz:	Hochfrequenz-Schaltungstechnik	VO	—	1,5
Skritek:	Computerunterstützter Schaltungs-entwurf	VO	—	1,5
Weinrichter:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Weinrichter:	Einführung in die Codierung	VO	2,0	—
Weinrichter:	Filter	VO	1,5	—
Wess:	Dimensionierung und Simulation analoger Filter	SE	—	1,5
Zemanek:	Computerentwicklungen in Nordamerika, Europa, Japan	VO	1,0	—
Zemanek:	Abstrakte Computer-Architekturen	VO	1,5	—

Automatische Codeerzeugung / Automatic Code Generation

Code generation for digital signal processors.
Contact: A. Helm, M. Gotschlich
Partner: Siemens Duration: 01.02.1993 -

Digital signal processing for Cochlear implants.
Contact: S. Fröhlich *Partner:* Cochlear AG, Basel Duration: 01.04.1996 - 31.03.1997

Generation of optimized DSP assembly programs.
Contact: B. Wess *Partner:* FWF (Project P10701-ÖTE) Duration: 01.08.1995 -

Codierung und Datenübertragung / Coding and Data Communications

Coding techniques for fading channels.
Contact: J. Weinrichter *Partner:* FWF (Project P10294-ÖPY) Duration: 01.10.1994 - 28.02.1997

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 - 30.04.1998

Digitale Signalverarbeitung / Digital Signal Processing

Digital signal processing in data transmission facilities.
Contact: U. Krebelder *Partner:* Ericsson Austria Duration: 01.10.1993 -

Mikrowellentechnik / Microwave Engineering

High efficiency harmonic control amplifier.
Contact: G. Magerl *Partner:* FWF (Project P11422-ÖPY) Duration: 01.06.1996 - 31.12.1997

High efficiency solid state power amplifier for L-band.
Contact: G. Magerl *Partner:* Hirschmann Electronic GmbH and ESA
Duration: 01.04.1996 - 30.06.1999

Mobilkommunikation / Mobile Communications

Smart antennas for mobile communications systems.
Contact: E. Bonek Partner: FWF (Project P12147-MAT) Duration: 06.1997 - 05.1999

Telecommunications.
Contact: E. Bonek *Partner:* PTA Duration: 1990 -

Wireless flexible personalized communications.
Contact: E. Bonek *Partner:* COST 259 Duration: 04.1996 -

ADANT Demonstrator for adaptive antennas.
Contact: W. Konrad *Partner:* PTA Duration: 06.1995 - 12.1997

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

Testbed for mobile radio RF chip sets.
Contact: H. Novak *Partner:* Austria Micro Systems (AMS) Duration: 01.02.1997 - 31.01.1998

Optische Nachrichtentechnik / Optical Communications

Coherent detection at low photon numbers (DELPHI).
Contact: W. Leeb *Partner:* ESA-ESTEC Duration: 01.03.1996 - 30.04.1997

Direct detection Doppler lidar receivers.
Contact: W. Leeb *Partner:* ESA-ESTEC Duration: 01.06.1997 - 01.10.1997

Management of optical networks (MOON).
Contact: W. Leeb *Partner:* European Commission Duration: 01.09.1996 - 31.12.1998

Optical phased arrays.
Contact: W. Leeb *Partner:* ESA-ESTEC Duration: 01.08.1994 - 01.03.1998

Paneuropean photonic network (PHOTON).
Contact: W. Leeb *Partner:* European Commission Duration: 01.10.1995 - 30.09.1998

Sprachverarbeitung und Nichtlineare Signalverarbeitung / Speech Processing and Nonlinear Signal Processing

Information- and chaos-theoretic analysis for control and automation engineering.
Contact: H.-P. Bernhard *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 - 1997

European network of excellence in language and speech (ELSNET).
Contact: G. Kubin *Partner:* ESPRIT Div. for Basic Research
Duration: 1992 -

Nonlinear models for the time-evolution of mobile radio channels.
Contact: G. Kubin *Partner:* The Swedish Institute and Signals and Systems Group, Uppsala University Duration: 01.09.1997 - 31.12.1998

The naturalness of synthetic speech.
Contact: G. Kubin *Partner:* COST 258 Duration: 10.12.1996 - 09.12.2000

Thematic network in speech communication sciences.
Contact: G. Kubin *Partner:* EU Socrates programme, grant 25409-CP-2-97-1-NL-ERASMUS-ETN Duration: 01.10.1996 - 30.09.1998

Zeit-Frequenz-Signalverarbeitung / Time-Frequency Signal Processing

Matched time-frequency signal representations.
Contact: F. Hlawatsch *Partner:* FWF (Project P10531-ÖPY) Duration: 01.06.1995 - 31.08.1997

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

Time-frequency methods for statistical signal processing.
Contact: F. Hlawatsch *Partner:* FWF (Project P10012-ÖPH) Duration: 01.05.1994 - 30.11.1996

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

Birgmeier Martin **Kalman-Trained Neural Networks for Signal Processing Applications**

This thesis deals with the application of neural networks to signal processing tasks. We show how the Kalman filtering algorithm, as known from communication and control engineering, can be used for the optimization of the parameters of neural networks. In analogy to known algorithms for multi-layer perceptions, we develop an efficient set of extended Kalman filter equations for radial basis function (RBF) networks. We highlight the connection to the standard method of steepest descent: In the steepest descent algorithms, we have „error backpropagation", whereas in the extended Kalman filter, we find a similar quantity which we interpret as „backpropagated gradient".

Following are applications of the algorithms described to two problems in communication engineering. The first deals with optimum receivers for arbitrary communication channels using Kalman-trained neural networks. We show that this type of training results both in greatly reduced training time as well as in a better approximation to the ideal decision boundary, when compared to standard backpropagation. Also in this chapter, we include a small excursion into the topic of evolutionary programming. This is an optimization method which we use to find the parameters of a trellis coded modulation scheme. Decoding of such a scheme may then again be performed using neural networks. The second application deals with prediction and synthesis of speech signals by Kalman-trained RBF networks. We demonstrate the superior performance of this training algorithm when compared to the standard training algorithm as found in the literature. We compare various forms of both direct RBF predictors, and ones used in cascade with a linear predictor. From the improved prediction gain of nonlinear RBF predictors when using an embedding of lower dimension, we see that signals representing voiced speech themselves have low dimensionality. From the theory of dynamical systems, one can develop algorithms which, for a given signal, compute an estimate of the upper bound of its predictability into the future. It is thus interesting to see if it is possible to build predictors which get close to this bound. We show that this is indeed the case using an extended form of RBF network. Finally, we show that RBF networks trained as predictors subsequently can be used as nonlinear oscillators. This oscillator model is capable of reproducing chaotic phenomena which are similar to those found in natural speech signals.

Fuhl Josef **Smart Antennas for Second and Third Generation Mobile Communications Systems**

In this work I analyze a promising scheme for capacity enhancement of mobile communication systems - *smart antennas.* Smart antennas make use of the directional nature of radiowave propagation. They receive (transmit) signals only from (into) angular sections, where the desired waves come from. Therefore smart antennas reduce interference, reduce time dispersion, increase coverage, and combat fading. I discuss two different ways of employing this technology:

- SFIR (Spatial Filtering for Interference Reduction): One user is served per traffic channel.
- SDMA (Space Division multiple Access): Multiple users are served simultaneously in the same traffic channel.

I investigate the crucial steps necessary to implement smart antennas, i.e. DOA estimation beamforming, signal separation, and synchronization for SR (Spatial Reference) algorithms; I propose a system concept for upgrading a 2^{nd}-generation TDMA system with smart antennas.

The design of smart antenna systems requires directional-dependent channel models, therefore I extend existing channel models to include DOAs (Direction of Arrival) and determine space and frequency correlation coefficients of the incident waves. The frequency correlation between uplink and downlink in FDD (Frequency Division Duplex) systems, like GSM and DCS1800, is very low. For instance, in NLOS situations with a radius of the scatterer circle $R = 100\lambda$, the frequency separation for a frequency correlation coefficient $\rho_{\Delta\omega} = 0.5$ is about 0.3% of the center frequency for the investigated systems. The fading on the uplink and on the downlink is therefore uncorrelated in NLOS situations.

SR algorithms perform better than TR algorithms, if nominal DOAs exist. The expression nominal DOA indicates that the DOA is non-discrete but rather consists of a mean DOA associated with a small angular spread. This scenario exists for rural and urban macrocells with BS (Base Station)-antennas well above the rooftops. In contrast, e.g. in indoor NLOS (Non Line-Of-Sight)-picocells, where waves are incident from nearly all directions, TR algorithms have to be employed. SR algorithms have the additional advantage over TR algorithms that system synchronization can be done after beamforming and signal separation. Consequently the antenna pattern (nulls on interfering signals) can be made use of. For pure Rayleigh fading environments: SR algorithms with correlation- based synchronization give a BER of 3.10^{-5}, whereas a TR algorithm with correlation-based synchronization gives BER = 2.10^{-2}.

For uplink processing I develop two new TR algorithms for space-time array structures, named Space Time Decomposition (STD) and STD Single Matrix Inversion (STD-SIMI). These algorithms show lower computational complexity ($O\{M^3 R_t\}$ for STD and $O\{M^3\}$ for STD-SIMI) than conventional algorithms ($O\{(MR_t)^3\}$), where M is the number of antenna elements and R_t is the number of temporal stages. In addition, for given array size, M, they require a training sequence of length l_{conv}/R_t only, where l_{conv} is the length of the training sequence necessary for accurate performance of conventional algorithms.

The capacity of a cellular network achievable by this technology for the traffic channels increases by about a factor of 3 for SFIR and a factor of 5.4 for SDMA as compared to a system employing today's 120°-sector antennas. For SFIR a cluster size of $N_{cl} = 1$ for the traffic channels becomes feasible, i.e. the same frequency group could be used in every (even neighboring) cells.

SDMA increases the spectral efficiency beyond that of SFIR and provides the system with more flexibility, since temporally occurring hot spots in specific locations can be dealt with. In contrast to the uplink, where sophisticated power control algorithms should be applied, the downlink of an SDMA-system should not use power control at all to achieve high CIR's at the mobile stations. The SDMA component needs only to be introduced in such cells where capacity increase is required, whereas SFIR has to be implemented in larger areas to achieve the wanted capacity increase.

Kozek Werner — **Matched Weyl-Heisenberg Expansions of Nonstationary Environments**

This thesis is about various aspects of linear time-varying systems and nonstationary processes (together nonstationary environments). Such nonstationary environments play an important role in modern communication engineering, particularly as models for natural signals or time-varying communication channels.

Emphasis is on time-frequency-parametrized representations of nonstationary environments, i.e., time-varying power spectra and time-varying transfer functions. Introduction of the generalized Weyl correspondence enables a unified formulation of classical, so far seemingly disparate definitions like Priestley's evolutionary spectrum, the Wigner-Ville spectrum, Zadeh's time-varying transfer function (Kohn-Nirenberg symbol) and the Weyl symbol. Nonstationary Wiener filtering provides an illustrative example for the limited applicability of these time-frequency concepts to a straightforward generalization of frequency domain solutions. We introduce a fundamental classification into underspread/overspread environments based on characterizing the underlying linear operator by the essential support of its spreading function. For underspread environments it is shown that the time-frequency-parametrized representations get essentially definition-independent and can be used in the same manner as the frequency-parametrized representations of stationary environments. Combining the practical efficiency of time-frequency-parametrized representations with the theoretical optimality of a diagonalizing transform leads to window matching criteria for the short-time Fourier transform/Gabor expansion (discrete/continuous Weyl-Heisenberg expansion) of signals and linear systems.

Kudielka Klaus — **Adaptive Telescope Array for Laser Communication in Space**

This thesis investigates phased telescope arrays to be employed in receive terminals of coherent free-space laser communication links. Potential advantages over single, monolithic telescopes consist in non-mechanical, adaptive fine pointing of the mainlobe and a reduction of terminal volume, mass, and cost.

First, the basic function, the interfaces, and the performance parameters of such telescope arrays are identified. Next, three fundamentally different methods of coherently combining the radiation collected by several subtelescopes are discussed. A quantitative assessment reveals that arrays using coaxial beam superposition are best suited for optical data communications. Based on this finding, the main characteristics of superimposing telescope arrays are calculated. A statistical analysis concerning the performance deterioration due to various alignment errors shows moderate tolerance requirements and thus confirms the feasibility of the superimposing telescope array concept. Further calculations prove that, in practical applications, the influence of incoherent background radiation is negligible.

Coaxial beam superposition and subtelescope phasing can be accomplished either in the optical or in the electrical regime. A system best suited for optical communications performs both operations in the optical regime. It consists of N fiber-coupled, refractive subtelescopes (N should be a power of two), N piston actuators, a binary tree of N-1 symmetric directional couplers, N-1 power sensors, and a control unit. Subtelescope phasing is performed in an adaptive manner, i.e. the array automatically compensates for the varying direction of the incident wave. A dither algorithm is used to find the correct piston actuator settings. A single dither frequency is sufficient for simultaneous control of all subtelescope paths.

A proof-of-principle experiment has been conducted to demonstrate the feasibility of the preferred telescope array concept. The laboratory demonstrator consisted of four refractive subtelescopes coupling the incident radiation (wavelength: 1.06µm) into four polarization-maintaining single-mode fibers. Piezo-electric fiber stretchers were used to control the subtelescope path lengths. Three symmetric polarization-maintaining fiber-optic directional couplers superimposed the optical subfields. Sensitive photo detectors made up of InGaAs photodiodes and transimpedance amplifiers fed a control unit calculating the required piston actuator settings. The system was able to adapt the subfield phases with respect to the incident wavefront and to direct the available optical power into a single output mode with an efficiency of 99.7%, even for communication signal power levels as low as 1nW per subtelescope. The response time after a step-shaped change of the direction of arrival amounted to 0.8ms.

Pusch Wolfgang — **Kanalangepaßte Trelliscodes mit Runlength-Beschränkung**

The traditional approach to providing spectral shaping and error protection for data transmission is to separate both parts and to employ a line code or a nonlinear precoder in concatenation with an outer forward error correcting (FEC) code. E.g., for data transmission over channels with spectral nulls or other spectral constraints shaping is achieved by means of specific line codes; for transmitting data over ISI channels nonlinear precoding in the transmitter can be applied. In both cases, an outer FEC code provides the necessary level of error protection.

Our new concept is as follows: Instead of a code concatenation we use a single combined code which provides error protection, restricts the symbol-runlength, and matches the transmission signal to the frequency response of the channel.

This theses deals with the construction of efficient runlength limited codes which have a power density spectrum (pds) matched to a prescribed channel transfer function. Most of our codes have a spectral null at DC and are well matched to the AWGN channel as well as the (normalized) 1-D partial response channel.

Further, we also present some codes for other types of ISI channels. As an example, codes whose pds is matched to an ISI channel with filter coefficients {0.8, 0.5, 0.33} are constructed. Due to their high coding gain these codes are attractive alternatives to FEC-coded transmission systems using decision feedback equalization or Tomlinson precoding.

In order to introduce runlength limitations, time variant codes and trellis shaped codes have been constructed.

The information rate of the new codes is in between $1/3 \leq R_b \leq 1$bits/symbol. Compared to uncoded information transmission over the AWGN channel with rate R_b=1bits/symbol, the asymptotic coding gains of the new codes are in the range of 1.5 to 4.77dB and 1.1dB to 5.9dB for the AWGN channel and the normalized 1-D channel, respectively.

For the ISI channel with filter coefficients {0.8, 0.5. 0.33} an asymptotic coding gain of 5.5dB and 3.7dB is observed for codes with information rate R_b=1/3 and R_b=1/2, respectively. The corresponding baseline system is hereby an uncoded binary transmission over this ISI channel results in a SNR loss of 0.61dB compared to uncoded binary transmission over an AWGN channel.

Compared to known methods in the literature, all new codes are superior in terms of bit error rate and decoder complexity.

Rasztovits-Wiech M. — **565 Mbit/s Optical Heterodyne Reception of Nd:YAG Laser Radiation**

I designed, realized and tested a coherent optical 565Mbit/s PSK heterodyne receiver demonstrator for space communications which employs a diode-pumped Nd:YAG ring laser at λ=1.064µm as local oscillator (LO). The entire system was built as a robust and compact unit, with a fiber connector input for the received signal. The required optical input power is 22 photons/bit for a bit error probability of 10^{-6}, corresponding to a sensitivity degradation of 3dB compared to an ideal, shot noise limited PSK heterodyne system.

Reliable, fully automatic frequency acquisition is achieved employing a microcomputer controlled multi-step algorithm. For initial frequency differences of up to 30GHz the average acquisition time is 140s. A frequency tracking subunit controls the LO laser frequency to keep the intermediate frequency constant, even in the presence of Doppler shift. Doppler shift rates of up to 11.5MHz/s can be compensated.

Sucher Ralph — **Adaptive nichtlineare Filter zur Unterdrückung von Impulsrauschen in Bildern**

This thesis is concerned with methods for suppression of impulse noise in images. For this purpose, we use systems which consist of an impulse detector and a nonlinear filter. The impulse detector yields fuzzy decisions about the impulsivity of the input samples and the nonlinear filter provides robust estimates of the original samples for reconstruction. It has been shown that a special combination of both parts leads to an efficient structure with only a small number of parameters. Conventional algorithms for optimization of these parameters require the original, uncorrupted signal as training data. Since this reference signal is usually not available, we propose a new method for unsupervised learning and adaption. The approach is based on a new type of cost function and is related to blind equalizers. Thereby, we dramatically reduce the necessary a-priori information as well as the total computational complexity. We discuss several applications of the new algorithm and present simulation results which show that the performance of the self-organizing systems is equivalent to that of methods with supervised training, which is superior over many other existing techniques for impulse noise removal.

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