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INSTITUT
FÜR NACHRICHTENTECHNIK
UND HOCHFREQUENZTECHNIK
TECHNISCHE UNIVERSITÄT WIEN

DOKUMENTATION

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KONTAKTPERSONEN UND -ADRESSEN
CONTACTS AND ADDRESSES

Institut für Nachrichtentechnik und Hochfrequenztechnik
Technische Universität Wien
Gußhausstraße 25/389
A-1040 Wien, Austria

Tel.: (+43 1) 588 01-ext.
Fax: (+43 1) 588 01-38999
E-mail: sekretariat@nt.tuwien.ac.at

	Nebenstelle/ Extension
Sekretariat / Secretariat (Fr. Jarosch, Fr. Hueber-Heigl)	38901
❑ Automatische Codeerzeugung / Automatic Code Generation Prof. Mecklenbräuker / Dr. Wess	38929, 38919
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MITARBEITER DES INSTITUTS (STAND: 1.10.2000)
STAFF MEMBERS

Professoren:
O.Univ.Prof. Dr. Ernst Bonek
O.Univ.Prof. Dr. Wolfgang Mecklenbräuker
Univ.Prof. Dr. Walter Leeb
Univ.Prof. Dr. Johann Weinrichter

Dozenten:
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Ao.Univ.Prof. Dr. Arpad Scholtz

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Dr. Markus Kommenda
Dr. Reinhard Kuch
Prof.Dr. Peter Leuthold
Prof.Dr. Josef Nossek
Dr. Peter Proksch
Dr. Alexander Renner

Im letzten Jahr sind folgende Mitarbeiter ausgeschieden:
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Dr. Plamen Bratanov
Dipl.-Ing. Andreas Gehring
Dr. Anton Helm
Dipl.-Ing. Helmut Hofstetter
Dipl.-Ing. Herbert Jäger
Dr. Gernot Kubin
Dr. Klaus Kudielka
Dr. Juha Laurila
Dipl.-Ing. Manfred Taferner

Gastmitarbeiter:
Pabuwal Nitin, Nuñcz, Indian Institute of Technology, New Dehli, 1. Juni 2000 bis 31. Juli 2000
Samer El Housseini, American University of Beirut, Beirut, Libanon, 27. Juni 2000 bis 24. August 2000.
Luiz Fernando de Oliveira Nunes, UNESP - Universidade Estadual Paulista, Sao Paulo, Brasilien, seit 25. August 2000
Tavoletti Francesco, Facoltá di Ingegneria, Universitá degli Studi di Bologna, Diplomarbeit zum Thema: "Traffic Modelling for UMTS Services", 1 März 2000 bis 31 August 2000.

SPONSOREN UND PROJEKTPARTNER
SPONSORS AND COOPERATION PARTNERS

Alcatel Corporate Research, Stuttgart
CA Creditanstalt Rilkeplatz
COST 258 "The Naturalness of Synthetic Speech"
COST 259 "Wireless Flexible Personalised Communications
COST 260 "Smart Antennas: Computer Aided Design & Technology"
Deutsche Telekom AG
e-plus, Düsseldorf
Ericsson Austria
Ericsson Hellas
ESA - European Space Agency
EU Socrates programme
France Telecom
FWF - Fonds zu Förderung der Wissenschaftlichen Forschung
Infineon, Villach
Infineon, München
Mobilkom Austria AG
Nokia Austria
Nokia Research Center, Helsinki
Telenor, Oslo
OeNB - Österreichische Nationalbank
Österreichisches Forschungszentrum, Seibersdorf
Stanford University, Information Systems Laboratory
Telekom Austria AG

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.

Im Bereich *nichtlineare Signal- und Sprachverarbeitung* werden Algorithmen der Chaostheorie und Informationstheorie sowie neuronale Netze angewendet. Wir beschäftigen uns im besonderen mit Sprachsignalanalyse und -synthese. Projekte werden mit Unterstützung des FWF, und im Rahmen der europäischen COST Aktion 258 "The Naturalness of Synthetic Speech" durchgeführt.

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.

In the field of *nonlinear signal and speech processing* algorithms from chaos theory and information theory as well as neural networks are applied. Our specific interest lies in speech signal analysis and synthesis. Current projects are supported by FWF, and we actively contribute to the European COST 258 action "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.

Die Abteilung *Datenübertragung* und *Codierung* beschäftigt sich mit der Optimierung von Übertragungssystemen. Von aktuellem Interesse sind zwei Typen von Kanälen:

zeitinvariante Kanäle mit relativ langer Impulsantwort (Leitungen bei schneller Datenübertragung), und

zeitvariante Mobilfunkkanäle (stochastisch auftretender Schwund).

Das Gedächtnis des Kanals wird dabei als innerer Code interprediert und Modulation und äußere Codierung darauf abgestimmt.

Bearbeitet werden derzeit rekursive Detektionsverfahren (Turbo-Decoder), bei denen sich Decodierung und Demodulation gegenseitig unterstützen. In letzter Zeit wurden verschiedene Codierverfahren (Turbo-Codes, Low density parity check codes, Mehrdimensionale Produkt-Codes) bekannt, mit denen man praktisch die Shannon´sche Kanal-Kapazität erreicht.

Ein brandaktuelles neues Forschungsgebiet ist die Raum-Zeit-Codierung, bei der Sender und Empfänger in Form von Antennengruppen realisiert sind. Die Theorie zu diesem Verfahren verspricht hohe Diversität und hohen Codegewinn sowie eine Steigerung der Kanalkapazität um eine Größenordnung. Dafür effiziente Raum-Zeit-Codes zu finden, ist eine faszinierende Aufgabe.

Im Bereich der schnellen Datenübertragung über kurze Zweidraht Leitungen (VDSL) wurden Zeitbereichsentzerrer und Algorithmen zur Unterdrückung des Sendespektrums in schmalen Frequenzbändern entwickelt.

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. In Zusammenarbeit mit Partnern in Helsinki, Paris und Illmenau verfeinern wir Modelle des Funkkanals, die seine letzte noch ungenützte Komponente, nämlich die räumliche, beschreiben.

In the area of *data transmission* and *channel coding* we try to optimize data transmission over difficult channels by combining modulation, equalization and channel coding. We focus on two types of channels:

Time invariant channels with long impulse response time (e.g. xDSL over twisted pairs)

Time variant mobile radio channels with deep fades.

Methods to cope with the resulting intersymbol interference like Turbo-equalization are investigated. In some cases the channel memory can be considered as inner code. Then the outer code can be matched to the inner code and recursive detection methods can be applied.

Alternatively trellis codes using line codes matched to the ISI-channel are studied and compared to more popular systems like precoded data transmission.

In the field of data transmission over twisted pairs (VDSL) time domain equalizers and digital notching of transmit spectrum have been implemented.

Examples of most effective codes like Turbo-codes, low density parity check codes, and product codes, which have been become popular in the very last time are under investigation.

A newly attacked field of investigation are space-time codes applied to antenna arrays. With this approach diversity and channel capacity can be increased by an order of magnitude.

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 Convergence, and radio access to the internet. 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. In cooperation with groups in Helsinki, Paris and Illmenau we refine models of the mobile radio channel that exploit the last frontier of this channel, the spatial component. We can establish directions of arrival and of departure (DOAs, DODs) with unprecedented precision in several domains at the same time.

AKTUELLE FORSCHUNGSGEBIETE: ÜBERSICHT (Forts.)
CURRENT RESEARCH AREAS: SYNOPSIS (cont´d)

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. Die Ergebnisse der COST Aktion 259 "Wireless Flexible Personalized Communications" werden demnächst als Buch veröffentlicht, in dem unsere Mitarbeit an führender Stelle (Arbeitsgruppenleiter Antennen und Wellenausbreitung, Autoren mehrerer Kapitel) dokumentiert ist. Die Einbindung in das ITG-Fokusprojekt "Mobile Kommunikation" führt zu einem intensiven Wissensaustausch mit deutschen Hochschulen und Netzbetreibern. Die Spezialausbildung in der Mobilkommunikation, zu der verschiedene Bereiche des Instituts beitragen, zieht Studenten aus ganz Europa an.

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. Our leading involvement in COST 259 "Wireless Flexible Personalized Communications" will be documented in the forthcoming book about this action (chapter authors, chairman of the working group on antennas and propagation.) Our involvement in the ITG project "Mobile Kommunikation" lead to intensive mutual knowledge exchange with German universities and network operators. The dedicated course plan in mobile communications draws students from all over Europe.

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 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* entwickelten wir für die Europäische Weltraumbehörde ESA Komponenten in integrierter Technik für phasengesteuerte optische Antennengruppen zur Laser-Datenübertragung zwischen Satelliten. Auf dem Konzept eines Glasfaser-Interferometers beruht auch das von uns für die ESA untersuchte Vielfach-Raumteleskop zur Vermessung extrasolarer Planeten. Andererseits erforschen wir Laser-Freiraumverbindungen, die bei Datenraten zwischen 2,5 und 10 Gbit/s entweder NRZ- oder RZ-codiert sind und bei einer Wellenlänge von 1,5µm unter Verwendung von Erbium-dotierten Faserverstärkern arbeiten.

In the area of *optical communications* we developed for the European Space Agency ESA integrated-optics devices for optical phased array antennas, to be used in intersatellite laser links. The concept of a glass-fiber interferometer is, too, the underlying principle of a multiple-arm space-borne telescope which we investigated for ESA. It is designed for the exploration of extra-solar planets. On the other hand, we research free-space laser links for data rates between 2.5 and 10 Gbit/s which are either NRZ- or RZ-coded. They operate at a wavelength of 1.5µm and use Erbium-doped fiber amplifiers as booster and as preamplifier.

ERNENNUNGEN VON UND PREISE AN MITARBEITER / NOMINATION AND AWARDS (1.10.1999 - 30.9.2000)

Ao.Univ.Prof. Dr. Franz Hlawatsch: Senior Member IEEE
Dipl.-Ing. Alexander Kuchar: "Best Paper Award" bei "European Wireless 99", München, 1999
Univ.Doz. Andreas Molisch: Senior Member IEEE
Univ.Doz. Andreas Molisch: "Kardinal Innitzer Förderungspreis", 1999

Herr Dr. Kubin hat am 30. August 2000 seine Tätigkeit am Institut beendet. Er ist einem Ruf an die TU Graz als Universitätsprofessor für Nichtlineare Signalverarbeitung gefolgt und hat diese Stelle am 1. September 2000 am dortigen Institut für Nachrichtentechnik und Wellenausbreitung in der Fakultät für Elektrotechnik angetreten.

FORSCHUNGSZENTRUM TELEKOMMUNIKATION WIEN / TELECOMMUNICATIONS RESEARCH CENTER VIENNA

Das Forschungszentrum Telekommunikation Wien (FTW) ist eine kooperative Forschungs- und Entwicklungseinrichtung, an der derzeit drei Institute der TU Wien (darunter auch das Institut für Nachrichtentechnik und Hochfrequenztechnik) und vierzehn Unternehmen beteiligt sind. Die Initiative wird im Rahmen des Kompetenzzentrenprogramms Kplus von Bund und Land Wien gefördert.

Die Forschungsprojekte des FTW erstrecken sich auf die drei Kerngebiete

- Telekommunikationsnetze und -dienste
- Signalverarbeitung zur Datenübertragung und Codierung
- Mobilkommunikation.

Die zwei letzten Projekte wurden wesentlich von den Professoren des Instituts für Nachrichtentechnik vorbereitet und konzipiert. Die Themenschwerpunkte liegen dabei auf den Gebieten der schnellen Datenübertragung über Kabel (xDSL), der modernen Codierverfahren, wie z.B. Turbo-Codes und dem Aufbau einer Sprachdatenbank, die auch lokale und regionale Dialekte beinhaltet. Für diese Projekte konnten sehr rasch international anerkannte Forscher gewonnen werden. Durch wissenschaftliche Publikationen dokumentierte Forschungsergebnisse gibt es bereits auf den Gebieten der Kanal-Kapazität von Mehrträger-Übertragungssystemen, der Modellierung von Impulsstörungen auf Leitungen, der Interoperabilität verschiedener xDSL Systeme, der Entbündelungsproblematik bei Teilnehmerleitungen, der Reduktion des Verhältnisses von Signalspitzenwerten zum Signaleffektivwert, usw.

Im September 2000 wurde zusammen mit dem FTW an der TU-Wien ein internationaler xDSL-Workshop organisiert an dem etwa 80 Experten teilgenommen haben.

Sehr fruchtbar gestaltet sich auch die regelmäßige Abhaltung des "Telekommunikationsforums", einer vom FTW unterstützten Lehrveranstaltung, die Gelegenheit zu internationalem Wissenstransfer bietet.

Insgesamt stellt sich das FTW als ein vielversprechendes Bindeglied zwischen Industrie und Universität dar.

Vizepräsident des FTW ist Prof. Ernst Bonek.

The Telecommunications Research Center Vienna (FTW) is a cooperative research and development institution presently supported by three departments of the Vienna University of Technology (including our Institute of Communications and Radio-Frequency Engineering) and 14 telecom companies. The FTW is supported by the Austrian government and the government of the City of Vienna.

Cooperative research projects within the FTW cover the three main topics

- Communication Networks and Services
- Signal Processing for Data Transmission and Coding

and

- Mobile Communications.

The research plans for the last two fields are essentially based on proposals conceived by the staff of the Institute of Communications and Radio-Frequency Engineering. One of the core research topics concentrates on high speed data transmission over digital subscriber lines (xDSL) including modern concepts on channel coding, like Turbo-Codes. Another project, compiling a speech data base including local and regional dialects; is successfully realized. For these projects a number of distinguished international experts could be engaged at the FTW. The competence of the FTW is already documented in scientific publications on channel capacity of multicarrier transmission systems, the modelling of impulse noise on digital subscriber lines, the interoperability of different xDSL systems, the unbundling of digital subscriber lines, the reduction of peak-to-average ratio in multicarrier transmission, etc.

In September 2000 an international xDSL-workshop with some 80 participants has been organized by FTW and our Institute at the Vienna University of Technology.

A special course, called Telecommunication-Forum, is organized at our University together with FTW. This course provides an excellent platform for an international exchange of up-to-date research results.

In summary, the FTW has established itself as a mutually benefical link between industry an university.

Prof. Ernst Bonek serves as a Vice-President of FTW.

1. PFLICHTLEHRVERANSTALTUNGEN / MANDATORY COURSES

			WS	SS
Weinrichter:	Einführung in die Nachrichtentechnik	VO	—	3,0
Dortschy:	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
Neubauer:	Hochfrequenztechnik 1	UE	—	1,0
Ehrlich-Schupita:	Hochfrequenztechnik 2	VO	2,0	—
Ehrlich-Schupita:	Hochfrequenztechnik 2	UE	1,0	—
Mecklenbräuker, Bonek, Leeb, Weinrichter:	Nachrichtentechnik Labor A	LU	—	5,0
Bonek, Mecklenbräuker, Leeb, Weinrichter:	Nachrichtentechnik Labor B	LU	9,0	—
Mecklenbräuker, Bonek:	Nachrichtentechnik Labor B für Computertechnik	LU	3,5	—
Leeb:	Optische Nachrichtentechnik	VO	2,0	—
Kudielka:	Optische Nachrichtentechnik	UE	1,0	—
Mecklenbräuker:	Signal- und Systemtheorie 1	VO	1,5	—
Rank:	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	—
Seyringer:	Übertragungsverfahren 1	UE	1,0	—
Hlawatsch:	Übertragungsverfahren 2	VO	—	2,0
Artés	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
Scholtz:	Antennentechnik	LU	—	2,0
Mecklenbräuker:	Ausgewählte Kapitel der Digitalen Signalverarbeitung	VO	1,5	—
Mecklenbräuker:	Ausgewählte Kapitel der Netzwerktheorie	VO	1,5	—
Kubin:	Chaotic Signal Processing	VO	—	1,5
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	—
Professoren und Assistenten:	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Bonek, Leeb:	English for electrical engineering students	KO	2,0	—
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	—
Scholtz:	Funkweitverkehrstechnik	VO	1,5	—
Braunbeck:	Geschichte der Nachrichtentechnik	VO	1,5	—
Leeb:	Glasfaser-Nachrichtensysteme	VO	—	1,5
Scholtz:	Hochfrequenz-Schaltungstechnik	VO	—	1,5
Magerl:	Integrierte Mikrowellenschaltungen	VO	—	1,5
Kuch:	Internet-Telefonie und Echtzeit-IP-Dienste	VO	—	2,0
Bonek, Leuthold Nossek:	Internationales Seminar Mobile Kommunikation	SE	—	3,0
Leeb:	Kohärente optische Empfänger	VO	—	1,5
Kreuzgruber:	Meßgeräte der Hochfrequenztechnik B	KO	1,5	—
Wess:	Methoden der automatischen Codegenerierung	VO	—	1,5

Magerl:	Mikrowellenmeßtechnik	SE	1,5	—
Bonek, Weinrichter, Molisch:	Mobilfunk	KO	—	3,0
Molisch:	Mobilkommunikation	SV	—	2,0
Neubauer:	Mobilkommunikation	UE	—	1,0
Bonek, Weinrichter, Molisch:	Mobile Radio Communications	KO	—	3,0
Mayr:	Modulationsangepaßte Codierung	VO	—	1,5
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
Riegl:	Radartechnik	VO	—	1,5
Doblinger, Hlawatsch:	Research Projects in Advanced Signal Processing	SE	3,0	3,0
Weinrichter:	Schnelle Datenübertragung über Kabel (xDSL)	VO	3,0	—
Doblinger:	Signalprozessoren	VO	1,5	—
Mecklenbräuker, Doblinger:	Signalverarbeitung mit MATLAB	LU	3,0	—
Molisch:	Smart Antennas for Mobile Communications	VO	2,0	—
Hlawatsch:	Statistical Signal Processing	VO	—	2,0
Henkel:	Theorie und Verfahren der Kanalcodierung	VO	3,0	—
Mecklenbräuker, van As, Magerl:	Telekommunikationsforum	KO	2,0	2,0
Hlawatsch:	Time-Frequency Methods for Signal Processing	VO	1,5	—

GASTVORLESUNGEN / GUEST LECTURES

			WS	SS
Prof. Klaus Dostert Universität Karlsruhe	Telekommuniktion über Energieverteilnetze	VO	—	3,0

Automatische Codeerzeugung / Automatic Code Generation

Code-Generation for Digital Signal Processors.
Contact: 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)
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EGGER Hubert — **Investigations on Drop Foot Correction by Personal Nerve Stimulation with Surface Electrodes**

This thesis is concerned with drop foot correction of hemiplegic individuals. The conventional approach to address the inadequate limb function, specifically insufficient ankle dorsiflexion (drop foot correction) is the prescription of an ankle foot orthosis. The goal of such an orthosis is to prevent the foot from dropping towards the floor during the swing. An alternative approach is to electrically stimulate the ankle dorsiflexors during the swing phase to reproduce motion which can no longer be performed volitionally. An electrically stimulated muscle contraction incorporated into purposeful movement is classified as functional electrostimulation (FES). Generally, FES for swing phase correction is applied on the peroneal nerve by surface electrodes and triggering is performed with a heel switch placed in the patient's shoe. Devices are attached at the waist or directly to the leg below the knee. In spite of all attempts, progress towards restoration of locomotion has been slow so far. Control difficulties arise from the neur-musculo skeletal's high non-linearity and time variance.

Within the scope of a case study the gait improvement of a 50-year old man suffering from spastic hemiplegia was investigated. Trials were performed with a manually controlled single-channel stimulator on the treadmill three times a week over a period of six months. The main goals of the case-study were to investigate suitable stimulation and control parameters for a more normal gait pattern at various walking speeds, additional range of motion, enhancement of walking distance and finally to measure muscle fatigue. A secondary aim was to investigate the time-dependency of the empirically optimized parameters with regard to an intelligent control system of a fully implanted peroneal stimulator. Besides the more normal gait pattern, there was a considerable increase of walking distance from the initial 100 meters to about 600 meters at the end of the training after six months. This result was a consequence of muscle re-education, prevention of tissue atrophy and an increase in range of motion.

For further investigations the need for an improved research environment becomes apparent. Thus, a computer aided system was designed primarily to investigate different control strategies for swing phase restoration. It consists of four stimulation/sensor channels controlled from a PC's user interface via the parallel port. The device simultaneously supports modulation of stimulation pulses, such as pulse width, pulse frequency, and pulse amplitude, as well as acquisition, displaying and on-line processing of sensor data. The operating system Linux with real-time extension was used which provided a simple and easily extendible hardware structure without using a microcontroller.

The final part of this thesis is concerned with the discussion of results gathered. Possibilities how to handle the research environment and, finally, the feasibility of a fully integrated implant are discussed, which would be an interesting alternative to present surface stimulators.

HELM Anton — **Codegenerierung für Mehrraten-Signalverarbeitung in Echtzeitsystemen mit strikten Zeitbedingungen**

This thesis presents a code generation method for multirate DSP systems under hard real-time conditions. Meeting both release times and deadlines is mandatory for all input and output signals.

Only the case where timing constraints are met exclusively by appropriate positioning of the input and output commands is considered. No buffers and/or IRQs are used.

Digital signal processing algorithms are usually specified by data flow graphs. These data flow graphs describe all valid schedules for a given problem but do not imply timing constraints. On the other hand, timing constraints for input and output signals represent the surrounding hardware. Therefore, these constraints cannot be changed by the programmer. Unfortunately, data flow and timing constraints are often inconsistent. In this case the data flow graph must be modified to comply with the timing constraints. Only such modifications are valid that leave the purpose of the underlying signal processing algorithm unchanged.

To resolve the inconsistencies between data flow and timing constraints, unit time delay elements are inserted at certain places in the data flow graph. These unit time delay elements can be implemented extremely efficiently into DSP programs.

If the data flow graph is decomposed into functional blocks (e.g. filters), for which optimum DSP code can be generated by well-known algorithms, unit time delay elements that are inserted into the data flow *between* such blocks can easily be implemented by changing the order of the blocks in the execution sequence. The blocks themselves remain *unchanged.*

The modified execution sequences can easily be enforced by simple manipulations of the arcs in the dependency graph that is derived from the data flow graph.

It will be shown that this method will not only resolve the inconsistencies between data flow and timing constraints, but will also implement the modified data flow graphs in such an efficient way that signal processors which were too slow for the original problem can be used.

KNAPP Herbert **Realisierung optimierter monolithisch integrierter Oszillatoren und Frequenzteiler für Mikrowellen in Si- und SiGe-Technologie**

Die vorliegende Arbeit befaßt sich mit der optimalen Auslegung monolithisch integrierter Hochfrequenzschaltungen. Durch den stark wachsenden Mobilfunkmarkt besteht große Nachfrage nach integrierten Hochfrequenzschaltungen, bei denen Optimierung auf geringen Leistungsverbrauch entscheidendes Kriterium ist. Zusätzlich werden mit LMDS (Local Multipoint Distribution System) neue Massenmärkte für integrierte Hochfrequenzschaltungen erschlossen. Für diesen Standard zur drahtlosen Verteilung von Internet- und Multimedia-Diensten sind weltweit mehrere Frequenzbänder zwischen 20 GHz und 42 GHz vorgesehen. Um integrierte Schaltungen für diesen Frequenzbereich in kostengünstigen silizium-basierten Technologien realisieren zu können, ist konsequente Optimierung auf höchste Arbeitsgeschwindigkeit erforderlich.

Am Beginn der vorliegenden Arbeit wird ein Überblick über Transistormodelle und Modellparameter gegeben. Die Auswirkungen der Wahl verschiedener Transistorgeometrien auf die Transistorparameter werden diskutiert. Darauf folgt ein Überblick über ECL- und CML-Schaltungskonzepte und Strategien zur Optimierung dieser Schaltungen. Anschließend wird anhand ausgewählter Beispiele die Optimierung monolithisch integrierter Hochfrequenzschaltungen gezeigt.

Als erstes Beispiel wird die Entwicklung einer digitalen Schaltung anhand eines Frequenzteilers (Dual-Modulus Prescaler) für Mobilfunkanwendungen demonstriert. Neben einer geringen Stromaufnahme ist ein weiter Versorgungsspannungsbereich von 2,3V bis 7V ein wichtiges Entwurfsziel. Unter Verwendung einer konventionellen Silizium-Bipolar-Produktionstechnologie mit 0,8 µm-Lithographie wird eine maximale Betriebsfrequenz von 2,5 GHz bei einer Leistungsaufnahme von nur 3,8 mW erzielt. Dieser Wert ist wesentlich geringer als der Leistungsverbrauch derzeit auf dem Markt befindlicher Prescaler. Neben der sorgfältigen Auslegung aller Teilschaltungen tragen auch neue Schaltungskonzepte für die Ausgangsstufe und das Referenznetzwerk des Prescalers zu diesem Ergebnis bei.

Ein monolithisch integrierter Oszillator für die Frequenzbereich von 19,5 bis 23 GHz dient als Beispiel, um die Optimierung einer Analogschaltung auf hohe Arbeitsfrequenzen zu zeigen. Die Schaltung verwendet monolithisch integrierte Spiralinduktivitäten im frequenzbestimmenden Resonator und ist in einer 0,5 µm Silizium-Bipolar-Technologie gefertigt. Damit konnte erstmals ein monolithisch integrierter Oszillator für diesen Frequenzbereich in Silizium-Bipolar-Technologie realisiert werden. Bisher waren derartige Oszillatoren für Frequenzen höher als etwa 5 GHz ausschließlich Silizium-Germanium- oder III-V-Technologien vorbehalten.

Schließlich wird ein dynamischer Frequenzteiler beschrieben. Diese Schaltung ist in Silizium-Germanium-Technologie hergestellt und ist bis zu einer maximalen Frequenz von 79,2 GHz funktionsfähig. Damit ist die Maximalfrequenz höher als bei allen bisher veröffentlichten dynamischen Frequenzteilern, nicht nur in Silizium- sondern auch in GaAs- und InP-Technologien. Darüber hinaus ist der Betriebsfrequenzbereich der Schaltung mit einem Verhältnis von 3:1 zwischen maximaler und minimaler Betriebsfrequenz sehr groß, was einen vielfältigen Einsatz der Schaltung ermöglicht.

KUCHAR Alexander **Real-Time Smart Antenna Processing for GSM1800**

This work describes a DOA-based smart antenna system for GSM1800. The focus lies on the developed antenna array processor that performs real-time adaptive beamforming in every GSM frame. The smart antenna consists of an eight-element uniform linear array, eight transceiver trains and the Adaptive Antenna Array Processor (AAAP). The system allows digital beamforming in uplink and in downlink. The run-time of AAAP is in the order of 1ms, thus suitable for real-time operation. AAAP is optimized for Spatial Filtering for Interference Reduction, but can be easily extended for Space Division Multiple Access operation.

The AAAP performs four main tasks: (1) Direction-of-arrival (DOA) estimation from the received input data in the uplink with a high-resolution estimator. (2) A DOA identification classifies the DOAs and decides whether a wavefront (DOA) belongs to a user or to an interferer. (3) A tracker follows each nominal DOA (multipath component) of the user. The tracker does not only include averaging of the DOAs, but also measures the reliability of each multipath. (4) Signal reconstruction and

beamforming, where a beamforming algorithm forms an antenna pattern with a main beam steered into the direction of the strongest reliable user multipath, while simultaneously minimizing the influence of the interfering wavefronts.

Experiments bear out the viability of DOA-based processing. The gain in carrier-to-interference ratio (C/I) is 25dB, if the interferer signal is incident with a small angular spread (on the order of one degree). Even if the user and interferer signals are partly overlapping, AAAP achieves an interferer suppression of 18dB. Placing broad nulls instead of conventional sharp nulls does not improve C/I gain, but it does increase the robustness against a reduced angular resolution of the DOA estimates and against a large angular spread.

From the measurement evaluation I concluded that the C/I gain does not degrade as long as the angular resolution is larger than five degrees. DOA estimation with angular resolution in the sub-degree range is not required.

LAURILA Juha **Semi-blind Detection of Co-Channel Signals in Mobile Communications**

This work analyses semi-blind detection schemes for mobile communications systems which employ adaptive antennas at the base stations. The proposed methods estimate and detect signals using their structural properties. Known bit fields (training sequences) are used for initialisation of the estimation.

I introduce the DILFAST (Decoupled Iterative Least squares Finite Alphabet Space-Time) algorithm, which combines array signals jointly in space and time. The algorithm performs separation, space-time equilisation and detection of multiple incoming signals. The received signal samples are mapped directly to the known finite alphabet (FA) constellation without any kind of subspace estimation. In addition to an underlying finite alphabet constellation of the modulation format, DILFAST utilises, optionally, also the Toeplitz structure of the symbol matrix. The algorithm is computationally very efficient leading to significant savings compared to subspace-based techniques. The computational load of DILFAST is in the same range as conventional adaptive antenna techniques. Thus, the algorithm can be implemented in real-time with current base station technology.

I also introduce a subspace-based approach for semi-blind signal estimation. An additional step of joint space-time equalisation of all incoming signals is carried out before separation and detection. This is done by estimating the row space of the specially structured input data matrix by two sequential subspace filtering processes. Depending on the length of these filters, either the DILSF (Decoupled Iterative Least Squares with Subspace Fitting) algorithm or DILFAST (as an add-on for subspace estimation) separates and detects the desired signals. The additional space-time equilisation leads to improved performance, but the required matrix decompositions increase the computational load by a factor of 10 to 30. I also show how the computational complexity can be reduced by employing adaptive subspace tracking methods instead of singular value decomposition (SVD).

I carry out my investigations from the application point of view assuming a GSM radio interface using GMSK (Gaussian Minimum Shift Keying) modulation. However, the algorithms are not restriced to any specific standard. The performance of the algorithms is analysed both with SDMA (Space Division Multiple Access) and with SFIR (Spatial Filtering for Interference Reduction). In the latter case both synchronous and asynchronous network operation is studied. For propagation modelling I use two different spatial channel models. I also include the imperfections of real hardware in my simulations and demonstrate their negligible effect on algorithm performance.

My simulations show that a small number of antenna elements (M = 3-4) can provide a good performance. This reduces the complexity of the receiver hardware and can improve the commercial viability of adaptive antenna systems. Semi-blind techniques do not carry out a direction of arrival (DOA) estimation based on the phase differences between the individual elements of the array. This means that the algorithms are very robust to the imperfections of real hardware, which alleviates the requirements for the array calibration. Additionally, signals with the same DOA can be detected if their channel responses are different.

I compare conventional adaptive antenna techniques based on spatial and temporal reference algorithms with DILFAST. My simulation results demonstrate that DILFAST outperforms these techniques by at least 4.5 dB at the BET 10^{-3} level. The gain provided by joint space-time processing (DILFAST) compared to separate processing in space and in time (DILSF-RAKE receiver) was on the order of 2 dB. The performance of the subspace methods is far better than the other investigated techniques, but at the cost of additional computational load.

NOVAK Heinz **Switched-beam adaptive antenna system**

In this thesis a complete switched-beam adaptive antenna system at a frequency of 2.45 GHz was designed and implemented. The system consists of a base station receiver with an 8-element patch antenna and beamforming network and two mobile station transmitters with omnidirectional antennas.

The beamforming network of the base station is completely microstrip based and strictly linear. Thus the beamforming network does not limit input signal range as compared to fully adaptive antenna systems, where beamforming is done in baseband and where highly linear receivers are needed. As beamforming is done at RF, only one receiver is needed for the system, whereas a receiver for each antenna element is needed in systems using baseband beamforming. Thus the implemented system offers considerably reduced costs as compared to fully adaptive antenna systems with multiple, highly linear receivers.

The 8-element base station antenna array is equipped with an additional dummy element on each side to equalize mutual coupling. An 8x8 Butler matrix, which was implemented in a fully single layer structure for easy manufacturing, is used as a beamforming network. In the standard configuration of the beamforming network eight Woodward Lawson beams with a relatively high sidelobe level of 8 dB and a gain of 7.1dBi are generated. To reduce sidelobes it is possible to illuminate two neighboring beams at the same time, which results in tapered amplitudes of the antenna element feed currents and an excellent sidelobe level of 17 dB at a gain of 9.1 dBi.

The base station receiver uses a hetereodyne RF frontend with quadratur downconversion from IF to base band, which makes it universally adaptable to different modulation formats. In combination with a powerful bit error meter (BER), the receiver offers excessive diagnostics features. The BER allows to measure on-line bit erro ratio values and to record received data bits with the bit clock or with an 8-times oversampling clock. The quadratur baseband signals can be recorded at a resolution of 8 bits with the 8-times oversampling clock to perform post processing.

The whole system is controlled from a PC via an easy-to-use graphical user interface. From there it is possible to start measurements and to set all parameters of the base station receiver. For reception and on-line bit error rate measurement it is possible to select bewteen two algorithms for beam selection. A RSSI (received signal strength indicator) based algorithm selects the beam with the strongest receive signal, while a bit error rate based algorithm chooses the beam with the smallest bit error rate.

The transmitters generate a DECT like (Digital enhanced Cordless Telecommunications) protocol with a pseudo noise sequence used as data. The output level of the transmitter is 14 dBm.

A powerful diagnostics tool has beeen designed to evaluate the benefits that can be gained by applying a switched beam antenna to a mobile communication system.

TWAROCH Teresa **Signal Representations and Group Theory**

The *covariance method* and the *characteristic function method* are the two main existing methods for a systematic construction of quadratic signal representations depending on two variables (such as, in particular, quadratic time-frequency signal representations). This thesis provides an in-depth discussion of the covariance method and characteristic function method, with special emphasis placed on their group-theoretical fundamentals. Of particular importance in this context are locally compact abelian (LCA) groups and two specific Lie groups (the group (R^2,+) and the affine group), as well as their unitary or projective representations.

The first part of this thesis is a brief introduction into the theory of topological groups, specifically LCA groups and their unitary representations, transformation groups, and Lie groups.

The second part discusses unitary representations of LCA groups with a viewpoint towards the covariance method and the characteristic function method. Two specific unitary representations of LCA groups with particular importance in time-frequency analysis -- called *modulation operators* and *warping operators* -- are developed. Furthermore, two fundamental types of pairs of unitary representations are considered: *dual operators* and *affine operators*. Dual operators generalize the time-shift and frequency-shift operators, while affine operators generalize the time-shift and time-frequency scaling operators. It is shown that pairs of modulation operators and warping operators may be dual or affine. It is furthermore shown that compositions of dual or affine operators are closely related to projective or unitary representations of the group (R^2,+) or the affine group, respectively.

The third part of this thesis provides a detailed group-theoretical discussion of the covariance method and the characteristic function method. The concept of *displacement operators* is introduced, and the general class of quadratic time-frequency representations covariant to a given displacement

operator is explicitly characterized. A key element in the development of covariant time-frequency representations is the so-called *displacement function* that characterizes the action of a displacement operator in the time-frequency domain. General properties of the displacement function are discussed, and a method for constructing the displacement function is presented. The displacement function is explicitly calculated for dual and affine modulation and warping operators.

The characteristic function method is considered next. Among other results, it is shown that this method works for dual and affine operators but may fail to produce reasonable results for other pairs of operators (such as, for example, commuting operators). An extension of the characteristic function method is also presented. Finally, it is shown that for dual operators, the characteristic function method produces the same class of signal representations as the covariance method.

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