INSTITUT FÜR NACHRICHTENTECHNIK UND HOCHFREQUENZTECHNIK

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AKTUELLE FORSCHUNGSGEBIETE: ÜBERSICHT / CURRENT RESEARCH AREAS: SYNOPSIS

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

Die Arbeitsgruppe *Zeit-Frequenz-Signalverarbeitung* entwickelt Methoden zur Analyse, Verarbeitung, Modellierung und Simulation von hochgradig instationären Signalen und schnell zeitvarianten Systemen bzw. Kanälen. Unsere derzeitigen Arbeiten konzentrieren sich auf den Einsatz neuartiger Zeit-Frequenz-Verfahren und anderer Methoden in der Mobilkommunikation. Wir entwickeln Algorithmen zur Kanalschätzung und -prädiktion, zur Zeit-Frequenz-Synchronisierung und zur Impulsoptimierung für OFDM-Systeme. Neuartige Detektionsalgorithmen für Mehrfachantennen-Funksysteme (MIMO-Funksysteme) kommen der Leistungsfähigkeit optimaler Detektoren nahe, obwohl sie nur einen Bruchteil der Komplexität optimaler Detektoren beanspruchen. Wir entwickeln weiters Zeit-Frequenz-Methoden zur Modellierung und Simulation von instationären Zufallsprozessen, zeitvarianten Systemen und Mobilfunkkanälen. Zeit-Frequenz-Filter erlauben eine einfache Spezifikation zeitvarianter Filtercharakteristiken. Zeit-Frequenz-Leistungsdichtespektren ergeben eine hochauflösende Spektralanalyse instationärer Zufallssignale. Neuartige Zeit-Frequenz-Methoden zum Entwurf und zur Implementierung instationärer Signalschätzer und -detektoren zeichnen sich durch hohe statistische Robustheit und numerische Effizienz aus.

Die Leistungsfähigkeit moderner Signalprozessoren kann nur durch effiziente Programme wirklich ausgenutzt werden. Dazu entwickeln wir *Algorithmen für die automatische Umsetzung von Datenflußgraphen* in für Signalprozessoren optimierte Programme. Auf diesem Gebiet bestehen enge Kooperationen mit Industriefirmen.

Ein weiteres Forschungsgebiet umfasst die Entstörung verrauschter Audiosignale mit Hilfe *adaptiver Filter und Filterbänke*. Neben dem Entwurf von Multiratenfilterbänken werden auch adaptive Algorithmen zur Modifikation der einzelnen Teilbandsignale entwickelt. In Kooperation mit einem Industriepartner werden derzeit Anwendungen im Bereich adaptiver, ein- und zweidimensionaler Mikrofon- und Lautsprecherarrays untersucht.

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

The *time-frequency signal processing group* is developing techniques for the analysis, processing, modeling, and simulation of highly nonstationary signals and fast time-varying systems/channels. Our current work focuses on the application of time-frequency and other techniques to mobile radio communications. We develop algorithms for channel estimation/prediction, time-frequency synchronization, and pulse shape optimization in OFDM systems. New detection algorithms for multi-antenna wireless systems (MIMO wireless systems) almost achieve the performance of optimum detectors at just a fraction of the computational complexity of optimum detectors. We are also developing and studying time-frequency techniques for the modeling and simulation of time-varying systems, nonstationary random processes, and mobile radio channels. Time-frequency filters allow an easy specification of time-varying filter characteristics. Novel time-frequency power spectra perform a high-resolution spectral analysis of nonstationary random signals. Our methods for the time-frequency design and implementation of nonstationary signal detectors and estimators are statistically robust and numerically efficient.

The exploitation of the full potential 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 there exist close cooperations with industrial companies.

Another research area concerns the enhancement of noise-corrupted audio signals by means of *adaptive filters and filterbanks*. Besides the design of multirate filterbanks, a number of adaptive algorithms are developed for the modification of the subband signals. In cooperation with an industrial partner, we currently investigate the design and application of two-dimensional adaptive microphone arrays.

Die Arbeitsgruppe *Codierung und Datenübertragungsverfahren* beschäftigt sich mit der Optimierung von Übertragungssystemen. Codes, die so gestaltet sind, dass sie fast die Shannon-Grenze erreichen, wie Turbo- und LDPC-Codes sind weiterhin von großem Interesse. Insbesondere haben wir uns im vergangenen Jahr gemeinsam mit dem ftw sehr intensiv mit deren Implementierung befasst und hohe Datenraten sowohl auf kommerziellen DSP-Strukturen als auch auf speziellen Vektorprozessoren erreicht.

Ein brandaktuelles neues Forschungsgebiet ist die Raum-Zeit-Codierung, bei der Sender und Empfänger in Form von Antennengruppen realisiert sind. Mehr-

In the area of *coding and data transmission* we try to optimize data transmission over difficult channels. Codes, like Turbo- and LDPC Codes that reach the Shannon limit are still of interest. In particular, we focused in the past year in cooperation with ftw on implementation issues. We obtained very high data throughputs on commercial DSPs as well as on special vector processors.

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. Several quasi-orthogonal space-time codes for various multiple antenna element systems are under investigation.

fach-Antennensysteme versprechen hohe Diversität und hohen Codegewinn sowie eine Steigerung der Kanalkapazität um eine Größenordnung. Dafür effiziente Raum-Zeit-Codes zu finden, ist eine faszinierende Aufgabe. Wir untersuchen sowohl Raum-Zeit Block-Codes als auch Raum-Zeit Trellis-Codes und ihre Gewinne in Bezug auf eine größere Diversität bzw. die Reduktion der benötigten Sendeleistung (Code-Gewinne). Insbesondere wurden bisher einfache Codes gefunden, die einfach realisierbar sind und mit Hilfe von sehr geringer Rückkopplungsinformation (typisch ein bis zwei bit) sich so gut wie optimale Codes verhalten. Erste Echtzeitexperimente im Zusammenarbeit mit der Rapid Prototyping-Gruppe haben diese Systemeigenschaften bestätigt. Von großem Interesse sind die Gewinneinbußen bei zunehmender Korrelation der Teilübertragungsfunktionen zwischen den einzelnen Antennenelementen. Mit zunehmender Korrelation gewinnen die adaptiven Antennen (smart antennas) mit einstellbarer Richtcharakteristik an Bedeutung. Diese Thematik wird in der Mobilfunkgruppe an unserem Institut seit längerer Zeit sehr erfolgreich bearbeitet.

We investigated space-time block as well as space time trellis codes for their diversity and coding gain. In particular, codes very suitable for implementation were found that allow optimal behaviour if small feedback information (typically one or two bit) is available. First real-time implementations with the rapid prototyping group have corroborated these results. Of high interest are the transmission losses resulting from the correlation of the transmission paths between the antenna elements. With increasing correlation smart antennas gain interest, a research topic followed up upon in our mobile communication group for a longer period.

In der *Mobilkommunikation* arbeiten wir mit der Mobilkom Austria AG zusammen auf den Gebieten Optimierung von Mobilfunknetzen, UMTS (Universal Mobile Telecommunications System), Lokalisierungsalgorithmen, Scheduling für paketvermittelte Dienste über mehrere Übertragungsschichten (Cross Layer Optimization), Video-Evaluation, künftige neue Systeme sowie Funkzugang zum Internet. In Zusammenarbeit mit Partnern am ftw., in Helsinki und in Paris verfeinern wir Modelle des Funkkanals, die seine letzte noch ungenützte Ressource, nämlich die räumliche Komponente, in bisher nicht erreichter Präzision beschreiben. Diese genaue Charakterisierung wird erforderlich, wenn man die ungeheure Übertragungskapazität der neuen MIMO-Systeme nutzen will. MIMO steht dabei für multiple-input multiple-output und beschreibt Funkstrecken/systeme, die bei Sender und Empfänger Antennengruppen einsetzen.

In einer neuen Forschungskooperation mit dem japanischen Netzbetreiber NTTDoCoMo untersuchen wir die Eignung von MIMO-Kanälen für ultraschnelle Funkübertragung für die 4. Generation von Mobilfunksystemen ("Beyond 3G"), die ab 2010 eingesetzt werden soll. In COST 273 führen wir die Aktivitäten von COST 259 weiter; die Unterarbeitsgruppe für MIMO-Kanäle wird dort von einem unserer Absolventen betreut.

Die Spezialausbildung in der Mobilkommunikation, zu der verschiedene Bereiche des Instituts beitragen, zieht Studenten aus ganz Europa an. Mit der ETH Zürich und der TU München bieten wir ein gemeinsames Mobilfunkseminar an.

In the field of *mobile communications*, we cooperate with Mobilkom Austria AG on mobile network optimization, UMTS (Universal Mobile Telecommunications System), localisation algorithms, scheduling for packet-switched services, cross-layer optimisation, video evaluation, future systems, and radio access to the internet. In cooperation with groups at ftw, in Helsinki and in Paris we refine models of the mobile radio channel that exploit the last frontier of this channel, the spatial component. We can determine directions of arrival and of departure (DOAs, DODs) with unprecedented precision at the same time. Such characterization of the mobile radio channel becomes crucial to put to use the enormous transmission capacity offered theoretically by MIMO systems. MIMO stands for multiple-input multiple-output and describes radio links with antenna arrays at the receiver and at the transmitter.

In a research collaboration with NTTDoCoMo of Japan we will investigate MIMO channels´ usefulness for high-speed wireless access of the 4th generation of mobile radio systems ("Beyond 3G"), to be deployed from about 2010 onwards.

We continue our past efforts in COST259 now in COST 273 "Towards Mobile Broadband Multimedia Networks". The newly founded sub-working group on MIMO is led by an alumnus of our group.

The dedicated course plan in mobile communications draws students from all over Europe. Together with ETH Zurich and TU Munich we offer an International Seminar on Mobile Communications.

Der Schwerpunkt der Forschung auf dem Gebiet der *Digitalen Signalverarbeitung in der Mobilkommunikation* liegt in den Methoden des Rapid Prototyping. Dabei werden Ideen und Algorithmen der digitalen Signalverarbeitung sehr schnell in Echtzeitexperimente umgesetzt. Aussagen über die technische Realisierbarkeit sind schon in einem sehr frühen Entwicklungsstadium möglich. Konkret befassen wir uns mit Verfahren zur Kanalschätzung für sehr schnell veränderliche Ka-

Signal Processing in Mobile Communications focuses on methods for rapid prototyping. Here, system concepts and algorithms are mapped rapidly into real-time experiments, hence allowing an assessment of technical feasibility at an early stage of the development process. We are investigating rapid channel movements in which channel estimation based on long periods of observation are not available. In cooperation with ftw we developed new methods based on sophisticated

näle, wo lange Beobachtungszeiten für die Schätzung von Kanalparametern nicht möglich sind. Gemeinsam mit dem ftw wurden Verfahren entwickelt, die aufgrund geschickt gewählter Basisfunktionen wesentlich besser funktionieren als herkömmliche Algorithmen. Wir untersuchen ebenso adaptive Entzerrerstrukturen, um den schnellen Datenmodus (HSDPA), der demnächst in UMTS angeboten wird, nutzbar zu machen und zu verbessern. Erste Echtzeitexperimente hierzu wurden bereits erfolgreich im Rapid Prototyping-Bereich umgesetzt. Weiters entwickeln wir eine adaptive, nichtlineare Vorverzerrung für UMTS-Endverstärker, um nichtlineare Verzerrungen des Sendesignals und störendes Übersprechen in Nachbarbändern zu verringern. Im Zuge dieser Entwicklung sind wir Mitglied bei TARGET (Top Amplifier Research Group in a European Team), einem Network of Excellence der EU. Wir entwickeln Empfänger für Mehrfachantennensysteme (MIMO-Systeme) und bauen dazu echtzeitfähige Prototypen. In Zukunft werden auch Funksysteme der 4. Generation untersucht werden. Die größten Verbesserungen gegenüber Systemen der 3. Generation (UMTS) werden momentan in der Verbindung von Kanal- und Quellkodierung gesehen; auch neuartige Kodierungsmethoden und Methoden zur Fehlerverdeckung zielen auf weitere Verbesserungen ab. Ein Systementwurf unter Einschluss solcher Methoden ist eine sehr lohnende Herausforderung für zukünftige Forschungen.

base functions that are performing better by magnitudes when compared to conventional methods. We also investigate adaptive equalizer techniques to allow for the new rapid data mode (HSDPA) of UMTS and to further improve data rates and transmission quality. First real-time experiments were already conducted successfully as a rapid prototype. Furthermore, we develop adaptive, nonlinear predistortion techniques for UMTS power amplifiers, in order to reduce nonlinear distortion in neighbouring bands. In the process of these investigations we became a member of TARGET (Top Amplifier Research Group in a European Team), a Network of Excellence of the European Union. Furthermore, we develop a receiver for multiple transmit and receive antenna systems (MIMO) for which we also build real-time prototypes. In future, also wireless systems of the fourth generation will be a focus. The most important improvements when compared with 3rd generation wireless systems (UMTS) are expected in the combination of channel and source coding. Also new methods for error concealment are of interest. A complete system design based on such new techniques is a very interesting challenge for the future.

Das im Juli 2002 gegründete *Christian Doppler Pilotlabor für Designmethodik für Signalverarbeitungsalgorithmen* hat mittlerweile seine erste Evaluierung positiv überstanden und ist damit zu einem vollwertigen Christian Doppler Labor geworden. Gleichzeitig wurde zum 1. Juli 2004 mit ARC Seibersdorf ein neuer Vertragspartner gefunden, so dass nun sechs Mitarbeiter (davon ein Stipendiat) im Bereich der Designmethodik arbeiten. Die Arbeitsgebiete umfassen sowohl digitalen Chipentwurf auf der Algorithmik- und Architekturebene als auch Rapid Prototyping im Analog- und Digitalbereich zur schnellen experimentellen Umsetzung neuer Ideen. Durch selbst erzeugte sogenannte translatorische Werkzeuge sind wir in der Lage, zunächst nichtkompatible Designwerkzeuge in konsistenter Weise zu verknüpfen. Dies erlaubt uns, hochkomplexe Schaltungsentwürfe, wie sie für einen UMTS Handy-Chip oder einen ADSL Modem-Chip von Infineon erforderlich sind, innerhalb von Sekunden automatisch von einer Beschreibungsebene in die andere zu transferieren, eine Aufgabe, mit der früher viele Mitarbeiter mehrere Monate beschäftigt waren.

The *Christian Doppler Pilot Laboratory for Design Methodology of Signal Processing Algorithms*, founded in July 2002, has had its first successful evaluation and as a result became a full Christian Doppler Laboratory. Also with July 2004, ARC Seibersdorf became a new industrial partner, so that altogether six researchers (including one scholarship) are now working in the field of design methodology. Our research covers the design on the algorithmic and architectural levels as well as rapid prototyping in analog and digital domains. By our so-called translatorial tools we are able to integrate consistently prior non-compatible tools. This allows us to transfer automatically designs of highest complexity as required for a UMTS cellular phone chip or an ADSL modem chip from Infineon, in a few seconds from one description level to another, a task which previously occupied several persons for a couple of months.

Auf dem Gebiet der *Hochfrequenztechnik* beschäftigen wir uns mit integrierten Schaltungen in Si- und SiGe-Technologien. Das Ziel dieser in Zusammenarbeit mit Infineon Technologies AG durchgeführten Untersuchungen ist es, die physikalischen Grenzen der Herstellungsverfahren auszuloten.

Einige Arbeiten befassen sich mit Sonderformen von Funkantennen und der Erfassung der Leistungsfähigkeit von Bluetooth-Verbindungen in industrieller Umgebung.

Gemeinsam mit dem Institut für Astronomie der Universität Wien sind wir dabei, eine Erdefunkstelle

In the domain of *radio frequency technology* we deal with the design of integrated circuits in Si and SiGe technologies. The goal is to find out the physical limits of chip performance for existing fabrication methods. Our industrial partner here is Infineon Technologies AG.

Furthermore, we are involved in the custom design of antennas and in the testing of Bluetooth links in industrial scenarios.

Together with the University of Vienna we are just setting up a ground station in the urban area for communication with low earth orbiting satellites.

in städtischer Umgebung für die Kommunikation mit LEO-Satelliten aufzubauen.

Auf dem Gebiet der *Optischen Nachrichtentechnik* untersuchen wir weiterhin gemeinsam mit der Abteilung Quantenexperimente von Prof. Zeilinger (Universität Wien) und der Fa. Contraves Space/CH optische Datenübertragungssysteme, die auf der Quanteninformation beruhen. Auftraggeber ist die Europäische Weltraumbehörde ESA. Unter Zuhilfenahme einer Quelle von verschränkten Photonen an Bord der Internationale Raumstation ISS soll für krytographische Zwecke ein Schlüssel an zwei Bodenstationen verteilt werden. Unsere Aufgabe besteht vor allem darin, notwendige Adaptierungen von bereits entwickelten klassischen optischen Sendeempfängern für den Einsatz in der Quantenkommunikation aufzuzeigen. Dies umfasst Fragestellungen wie die automatische Nachführung der optischen Antennen unter Benutzung eines Laserleitstrahls, die Sicherstellung einer stabilen Referenzrichtung für die Polarisationsmessung in den Quantendetektoren, die Abschätzung der Streckendämpfung unter Bedachtnahme des Einflusses der Atmosphäre und die Erstellung eines Ablaufplans während der nur wenige Minuten dauernden Sichtverbindung zwischen ISS und Bodenstationen auf Teneriffa und in Mittelitalien.

Auf dem Konzept eines Interferometers beruht das Vielfach-Raumteleskop, mit dem im Rahmen der ESA-Mission DARWIN extrasolare Planeten vermessen werden sollen. Die dafür notwendigen extrem schmalen Antennenkeulen lassen sich nur mit großen Basislängen erzielen, wofür man selbst im Weltraum auf das Prinzip einer Teleskopgruppe angewiesen ist. Eine weitere Herausforderung stellt die erforderliche extrem starke Unterdrückung des Lichtes des fremden Sternes dar. Sie verlangt eine in hohem Maß idente Feldverteilung der zur Interferenz zu bringenden Signale der Einzelteleskope. Dies lässt sich nur durch den Einsatz von Wellenfrontfiltern in der Form von Monomode-Fasern erreichen. Dafür entwickeln und testen wir gemeinsam mit EADS Astrium/D und ART-Photonics/D Silber-Halid-Fasern im Wellenlängenbereich von 4μm bis 20μm. Zur Bestimmung der Modenreinheit des am Ausgang dieser Fasern bestehenden Feldes setzen wir ein Mach-Zehnder Interferometer ein und bestimmen so die Eignung dieser Infrarotfasern zur räumlichen Modenfilterung. In einem verwandten ESA-Projekt wird die Erprobung des Konzepts der Vielfach-Antenne unter Verwendung von astronomischen Teleskopen geplant. Dabei optimieren wir die Regelschleifen, die eine möglichst kleine Phasenverschiebung der zu überlagernden optischen Einzelsignale gewährleisten sollen und berechnen das zu erwartende Signal-zu-Rausch-Verhältnis im hier angepeilten Wellenlängenbereich um 3,7 μm.

Gemeinsam mit Contraves Space/CH untersuchen wir Methoden zur effizienten Einkopplung von optischen Freiraum-Wellen in Glasfasern. Die adaptiven Konzepte, die auf sich ändernde Umwelteinflüsse reagieren können und dadurch einen besonders hohen, zeitlich stabilen Einkoppelgrad ermöglichen, werden sowohl für den Einsatz in der astronomischen Interferometrie als auch für die optische Freiraumkommunikation benötigt.

In the area of *optical communications* we still cooperate with Prof. Zeilinger's group at Vienna University and with Contraves Space/CH to investigate optical data transmission systems based on quantum information for the European Space Agency (ESA). Using a source of entangled photons onboard the international space station (ISS), quantum key distribution to two ground stations for cryptographic purposes shall be demonstrated. Our task is basically to point out the adaptations necessary if already developed "classical" optical transceivers were to be used in quantum communications. This includes questions like automatic tracking of the optical antennas using a beacon laser, provisioning of a stable polarization reference for quantum detection, calculation of link attenuation taking into account the influence of the atmosphere, and planning the time sequence during the short period of line-of-sight between the ISS and ground stations at Tenerife and in Italy.

The multiple space telescope to be developed for probing extra-solar planets within ESA's DARWIN mission is based on the principle of interferometry. The extremely narrow beam widths required can only be achieved by employing large baselines which even in space asks for an array of telescopes. A further challenge is the required strong suppression of star light. It asks for highly identical field distributions of the signals to be superimposed. This can only be achieved by employing wavefront filters in the form of single-mode fibers. Together with EADS Astrium/D and ART-Photonics/D we develop and test silver-halide fibers in the wavelength range of 4μm to 20μm. To determine the uniqueness of the optical field at the fiber output we employ a Mach-Zehnder interferometer and in this way we test the usefulness of these infrared fibers as spatial mode filters. The feasibility of the multi-telescope concept is investigated in a related ESA project, using terrestrial astronomical telescopes. Here we design the control loops which have to ensure the smallest possible optical path differences between the individual optical signals, and we calculate the signal-to-noise ratio around the wavelength of 3.7 μm.

Together with Contraves Space/CH we investigate methods to efficiently couple optical free-space radiation into glass fibers. The adaptive concepts in mind can respond to a changing environment and thus allow a stable, high coupling efficiency. These concepts are necessary for applications in both free-space laser communications and in astronomic interferometry.

Störungstolerante Kommunikationssysteme

Die Globalisierung der Wirtschaft bringt einen rapiden Anstieg an Kommunikationsbedarf mit sich und favorisiert robuste Kommunikationssysteme. Robuste Kommunikationssysteme sind Übertragungssysteme, welche Informationen mit akzeptabler Qualität auch in stark gestörten elektromagnetischen Umgebungen übertragen können. Ein wichtiger Vertreter für zukünftige robuste Funkübertragungssysteme ist die Spread-Spectrum Technik. Das Systemverhalten eines Spread-Spectrum Systems ist sehr verschieden von konventionellen Übertragungssystemen. Dies beinhaltet potentielle Möglichkeiten, mit den geänderten Anforderungen zurechtzukommen. Aussichtsreiche Kandidaten für künftige terrestrische Funkübertragungssysteme müssen in einer Mehrwegeumgebung ausgezeichnete Ergebnisse liefern. Das Spread-Spectrum Konzept offeriert, speziell für Mehrwegekanäle, die RAKE-Empfängerstruktur. Der RAKE-Empfänger sammelt die Signalenergie in den Mehrwegen auf und erreicht so einen wesentlich höheren Signal/Störabstand als konkurrierende Systeme.

Unsere Forschungsaktivitäten konzentrieren sich auf störungsreduzierene Verfahren mit adaptiven Nichtlinearitäten. Statistische Kenngrößen formen die Nichtlinearität, um möglichst viel Störenergie zu unterdrücken. Diese Verfahren werden in Spread-Spectrum Systemen eingesetzt. Andere Forschungsaktivitäten befassen sich mit dem Entwurf von CDMA-Netzen und der Synchronisation von RAKE-Empfängern. In allen Aktivitäten wird auf minimalen Ressourceneinsatz geachtet.

Robust Communications

The globalization tendency increases the need for more active communication systems and favours the robust communication philosophy. This philosophy has no abrupt loss of the link if the signal quality degrades due to channel disturbances. It is able to hold the link by gradually reducing one or more link parameters (data rate) to some degree. This property of a robust communication system in termed flexibility. The most promising candidate for future mobile communication technology is the spread-spectrum technology. The reason for that is its excellent behaviour in a multipath environment using the RAKE-receiver.

The focus of our research activities is interference reduction in any kind of interference using adaptive nonlinearities. The structure of the nonlinearity is formed by statistical parameters of the received signal. We implement the proposed interference reduction schemes in spread-spectrum systems. Other research activities are centered around CDMA network design and RAKE receiver synchronization. In all our research we take care of minimum resource allocation and minimum power consumption.

ERNENNUNGEN UND PREISE / NOMINATIONS AND AWARDS

30.9.2003 – 1.10.2004

Am 1. März 2004 wurde W. Mecklenbräuker als Corresponding Fellow in die Royal Society of Edinburgh gewählt. Am 9. September 2004 wurde ihm von EURASIP (European Association for Signal, Speech, and Image Processing) der “European Individual Technical Achievement Award 2004” verliehen.

1. Pflichtlehrveranstaltungen / Mandatory Courses

			WS	SS
Goiser	Einführung in die Telekommunikation	VO	—	2,0
Rupp	Deterministische Signalverarbeitung	VU	—	3,0
Scholtz	Hochfrequenztechnik, Vertiefung	VU	4,0	—
Magerl, Ehrlich-Schupita, Mayer	Hochfrequenztechnische Systeme	VU	4,0	—
Arthaber, Aschbacher, Ehrlich-Schupita	Labor Hochfrequenztechnik	UE	—	2,0
Goiser, Scholtz, Keim	Labor Mobilfunk	UE	—	2,0
Mecklenbräuker	Methoden der digitalen Signalverarbeitung	VU	—	3,5
Rupp, Trojer	Mobile Kommunikation	VU	4,0	—
Goiser	Mobilkommunikation, Vertiefung	VU	4,0	—
Hlawatsch, Seethaler	Modulations- und Detektionsverfahren	VU	—	3,0
Rupp, Mecklenbräuker, Leeb, Doblinger	Nachrichtentechnik Labor B	LU	9,0	—
Leeb, Pfennigbauer	Optische Nachrichtentechnik	VU	2,5	—
Scholtz	Seminar Hochfrequenztechnik	SE	3,0	—
Leeb, Pfennigbauer	Seminar Photonik und optische Nachrichtentechnik	SE	3,0	—
Mecklenbräuker, Doblinger	Signale und Systeme 2	VU	—	3,0
Doblinger	Signalprozessoren	VU	2,5	—
Goiser	Telekommunikation	VU	—	5,0
Rupp	Verarbeitung stochastischer Signale	VU	3,0	—
Scholtz, Jachan	Wellenausbreitung	VU	3,0	—

2. Wahllehrveranstaltungen / Optional Courses

			WS	SS
Nilsson, Nordström	Broadband Access over Wires	VO	—	2,0
Scholtz	Computer Aided RF Circuit Design	PR	3,0	3,0
Weidmann	Data Compression	VO	—	2,0
Doblinger, Zeitlhofer	Digitale Signalverarbeitung A	SE	3,0	—
Doblinger	Digitale Signalverarbeitung, Vertiefung	VU	—	4,0
Doblinger, Zeitlhofer	Digitale Signalverarbeitung	SE	—	3,0
Rupp	DSP Seminar	SE	1,0	1,0
Professoren und Assistenten	EDV-orientierte Projektarbeit für ET	AG	4,0	4,0
Kommenda	Ein- und Ausgabe von Sprache	VO	2,0	—
Goiser	Einführung in die Telekommunikation	VO	—	2,0
Garn, Ehrlich-Schupita, Lamedschwandner, Neubauer	Elektromagnetische Felder und Wellen, Bakk.-Vertiefung	VU	—	6,0

			WS	SS
Garn	Elektromagnetische Verträglichkeit elektronischer Geräte	VO	—	1,5
Garn, Lamedschwandner	Elektromagnetische Verträglichkeit elektronischer Geräte	UE	—	1,5
Magerl, Scholtz	Hochfrequenztechnik, Vertiefung	VU	4,0	—
Hlawatsch	Information Theory for Communications Engineers	VO	2,0	—
Rupp	Internationales Seminar Mobile Kommunikation	SE	—	3,0
Ehrlich-Schupita	Messgeräte der Hochfrequenztechnik A	KO	—	1,5
C. Mecklenbräuker, Zemen	MIMO Communications	VO	—	2,0
C. Mecklenbräuker	Mobilfunknetze der dritten Generation	VO	2,0	—
Goiser	Mobilkommunikation, Vertiefung	VU	4,0	—
Leeb, Pfenningbauer, Fiedler	Photonik und optische Nachrichtentechnik, Vertiefung	VU	—	4,0
Toumpis	Point Processes for Communications Networks	VO	—	2,0
Ullrich	Radartechnik	VO	—	1,5
Hlawatsch, Doblinger, Matz, Rupp	Research Projects in Advanced Signal Processing	SE	3,0	3,0
Doblinger, Zeitlhofer	Seminar Digitale Signalverarbeitung	SE	—	3,0
Magerl, Scholtz	Seminar Hochfrequenztechnik	SE	3,0	—
Rupp, Scholtz	Seminar Mobilkommunikation	SE	—	3,0
Leeb, Pfennigbauer	Seminar Photonik und optische Nachrichtentechnik	SE	3,0	—
Doblinger	Seminar Signalverarbeitung	SE	—	3,0
Wess	Signale und Systeme, Bakk.-Vertiefung	VU	6,0	—
Doblinger	Signalprozessoren	VO	1,5	—
Doblinger	Signalverarbeitung mit MATLAB	LU	3,0	—
Matz	Signalverarbeitung, Vertiefung	VU	—	4,0
Kommenda, Mayr	Telekommunikation, Bakk.-Vertiefung	VU	—	6,0
Mecklenbräuker, van As, Magerl	Telekommunikationsforum	KO	2,0	2,0
Sayir, Lechner	Theory and Design of Turbo and Related Codes	VO	—	2,0
Toumpis	Wireless Ad Hoc Networks	VO	2,0	—

3. Gastvorträge von Institutsmitgliedern / Guest Talks by Members of the Institute

E. Bonek, “Channel model for smart antennas and MIMO,” Short Course at the Centre for Wireless Commmunications (CWC), Oulu University, Finland, June 3, 2004

E. Bonek, K. Hugl, W. Weichselberger, A. F. Molisch,” Smart Antennas and MIMO Systems,” Tutorial at ICC Paris, June 20, 2004

E. Bonek, “ MIMO and Its Radio Channel Modeling,” Competence Centre for Circuit Design (CCCD), Lund University, Sweden, Sept. 27, 2004

F. Hlawatsch, “Wavelets and affine distributions: A time-frequency perspective,” lecture presented at the summer school “Wavelets and Multifractal Analysis,” Institut d’Etudes Scientifiques de Cargèse, Corsica (France), July 21, 2004

F. Hlawatsch, “Efficient detection algorithms for MIMO channels: A geometrical approach to approximate ML detection,” Lehrstuhl für Netzwerktheorie und Signalverarbeitung, Technische Universität München (Germany), July 7, 2004

M. Hartmann, F. Hlawatsch, D. Schafhuber, “Two-day tutorial on OFDM communication systems,” Siemens AG, Vienna, June 21-22, 2004

G. Matz, “System capacity of wideband OFDM communications over fading channels without channel knowledge,” Nokia Research Center, Helsinki (Finland), Feb. 2004.

G. Matz, “Adaptive tracking of fading channels for wireless MIMO-OFDM systems,” Nokia Research Center, Helsinki (Finland), Feb. 2004

G. Matz, “Multipulse multicarrier systems for wireless communications,” Nokia Research Center, Helsinki (Finland), Feb. 2004

G. Matz, “Characterization of non-WSSUS fading dispersive channels,” Nokia Research Center, Helsinki (Finland), Feb. 2004

W. Mecklenbräuker, “Data Register Assignment Based on Optimizing Algorithms,” University of Edinburgh, Nov. 8, 2004

M. Rupp, “Improving MIMO Transmission by Channel Structuring,” UCLA, Los Angeles, Nov. 2003

H. Weinrichter, “Space-Time Coding for Wireless MIMO Channels,” Lehrstuhl für Netzwerktheorie und Signalverarbeitung, TU München, May 19, 2004

B. Wess, “Register Assignment Based on Optimum Algorithms – Address Pointer Assignment,” Department of Electrical & Computer Engineering, University of Maryland, May 28, 2004

T. Zeitlhofer, “Register Assignment Based on Optimum Algorithms – Data Register Assignment,” Department of Electrical & Computer Engineering, University of Maryland, May 28, 2004

4. Forum Telekommunikation / Telecommunications Forum

Vortragsreihe gemeinsam mit ftw (http://www.ftw.at) mit Themen aus den drei Arbeitsbereichen Telekommunikationsnetze und -dienste, Signalverarbeitung für die Datenübertragung und Mobilfunk.

17. Oktober 2003: Helmut Boelcskei, ETH Zürich, Schweiz, “Capacity scaling laws in MIMO wireless networks”
17. Oktober 2003: Oliver Jung, Universität Siegen, Deutschland, “Suitability of Cryptographics Modes of Operation for Encryption in High-Speed Networks”
31. Oktober 2003: Tadashi Matsumoto, Universität Oulu, Finnland, “Iterative (Turbo) MIMO Equalization Techniques”
7. November 2003: Michael Tüchler, TU München, Deutschland, “Design of serially concatenated systems depending on the block length (irregular constructions, capacity achieving codes)”
14. November 2003: Ingmar Land, Arbeitsgruppe für Informations- und Codierungstheorie, Universität Kiel, Deutschland, “Bounds on Information Combining”
28. November 2003: Thomas Wiegand, Gruppe für Bildübertragung, Heinrich Hertz Institut, Berlin, Deutschland, “Video Coding Using the Emerging H.264/AVC Standard and Beyond”
28. November 2003: Sonja Koppensteiner, InterGlobe Consulting, Santa Clara, Kalifornien, USA, “Agile Development”
5. Dezember 2003: Sriram Vishwanath, Universität Stanford, USA, “Duality, Achievable Rates, Outer Bounds and Sum Capacity of Gaussian Vector Broadcast Channels”
12. Dezember 2003: Amos Lapidoth, ETH Zürich, Schweiz, “The Asymptotic Capacity of Fading Channels: Facts and Artifacts”
16. Jänner 2004: Jérôme Lebrun, I3S Labor, CNRS/UNSA, Sophia-Antipolis, Frankreich, “Algebraic Methods in Digital Communications”
23. Jänner 2004: Alexander Raake, Institut für Kommunikationsakustik, Ruhr-Universität Bochum, Deutschland, “Assessment and Prediction of Speech Quality under Packet Loss”
23. Jänner 2004: Josef A. Nossek, Lehrstuhl für Netzwerktheorie und Signalverarbeitung, TU München, Deutschland, “Cross-Layer Optimization in Multi-Antenna Communication Systems”
28. Jänner 2004: Johann F. Böhme, Lehrstuhl für Signaltheorie, Ruhr-Universität Bochum, Deutschland, “Topics in Automotive Signal Processing”
29. Jänner 2004: Eberhard Hänsler, Gruppe für Signaltheorie, Universität Darmstadt, Deutschland, “Single-Channel Noise Reduction in Hands-free Telephone Systems”

30. Jänner 2004: Peter Hoeher, Arbeitsgruppe für Informations- und Codierungstheorie, Universität Kiel, Deutschland, "Single-Antenna Co-Channel Interference Cancellation for TDMA Cellular Radio Systems"
6. Februar 2004: Jörg Kliewer, Institut für Netzwerk- und Systemtheorie, Universität Kiel, Deutschland, "Joint Source-Channel Decoding for Reliable Transmission of Multimedia Signals"
20. Februar 2004: Saida Goudrar, Universität Bordeaux 1, Frankreich, "Smart cards security"
5. März 2004: Martin Heusse, Laboratoire LSR, Institut d'Informatique et Mathématiques Appliquées de Grenoble, Frankreich, "Adaptive Routing and Resource Preservation for Traffic Engineering in Communication Networks"
8. März 2004: Jan Mampuys, Alacatel, Belgien, "A new approach for xDSL interoperability"
12. März 2004: Renato Lo Cigno, Dipartimento di Informatica e Telecomunicazioni (DIT), Universität Trento, Italien, "QoS Routing: Enforcing Robustness Through Adaptive Graph Reduction"
19. März 2004: Klaus Huber, T-Systems, ITC-Security, Darmstadt, Deutschland, "Applications of Elliptic Functions in Communications"
26. März 2004: Gunnar Karlsson, Royal Institute of Technology (KTH), Schweden, "Quality of Service and the End-to-End Principle"
2. April 2004: George Ginis, Texas Instruments, Broadband Communications Group, San Jose, Kalifornien, USA, "Power Control in Digital Subscriber Line Systems"
22. April 2004: Martin Petraschek, TU Wien, "Public Key Infrastructure for Wireless Devices"
23. April 2004: Bálint Laczay, Abteilung für Informatik und Informationstheorie, Technische Universität Budapest, Ungarn, "Signature Coding and Information Transfer" and Sándor Györi, Abteilung für Informatik und Informationstheorie, Technische Universität Budapest, Ungarn, "Bounds for multiple-access collision channel"
30. April 2004: Sarah Kate Wilson, Gastprofessor, Gruppe für Signale, Sensoren und Systeme, KTH, Stockholm, Schweden, "Multi-user diversity and OFDM"
30. April 2004: Mérouane Debbah, Institut Eurecom, Sophia-Antipolis, Frankreich, "A new look at CDMA cellular coverage"
3. Mai 2004: Leandros Tassiulas, Universität Maryland, USA / Universität Thessaly, Griechenland, "Cross-layer design issues for quality of service provisioning in wireless networks"
7. Mai 2004: David Hasler, GretagMacbeth/LOGO, Steinfurt, Deutschland, "Some aspects of the evaluation of colour and image quality"
7. Mai 2004: Vassilis Vassalos, Abteilung für Informatik, Wirtschaftsuniversität Athen, Griechenland, "Data Integration: Current state and challenges"
14. Mai 2004: Andreas Polydoros, Institut für Elektronik, Universität Athen, Griechenland, "Phase Impairment Effects and Compensation Algorithms for OFDM Systems"
24. Mai 2004: Stefano Salsano, Universität Rom "Tor Vergata," Italien, "The Simplicity Project: easing the burden of using complex and heterogeneous ICT devices and services"
26. Mai 2004: Rainer Wohlgenannt, Center for Wireless Communications, Universität Oulu, Finnland, "Design of LDPC Codes for SIMO Systems with Frequency Selective and Slow Fading Channels"
28. Mai 2004: Daniela Tuninetti, Ecole Polytechnique Fédérale de Lausanne (EPFL), Schweiz, "An information theoretic look at wireless networks"
28. Mai 2004: Saverio Mascolo, Politecnico di Bari, Italien, "A description and performance evaluation of Westwood+ TCP congestion control"
18. Juni 2004: João Barros, Lehrstuhl für Nachrichtentechnik, TU München, Deutschland, "Reachback Communication in Wireless Sensor Networks"
25. Juni 2004: Klaus Umschaden, TU Wien, "Session Initiation Protocol (SIP) Security"
21. Juli 2004: Mark Reed, National ICT Australien und Australische Nationale Universität, Canberra, Australien, "Return Link Code Acq. for 1-D and 2-D with DS-CDMA for High Capacity Multiuser Systems"
13. September 2004: Mats Viberg, Technische Universität Chalmers, Göteborg, Schweden, "Regularization Strategies With Signal Processing Applications"
16. September 2004: Michele Casà, Forschungszentrum für Elektronik (CRES), Sizilien, Italien, "Routing on the MANET & Implementation of the TBRPF Protocol"

5. Veranstaltungen / Events

EUSIPCO 2004

The 12th European Signal Processing Conference (EUSIPCO) 2004 was held at Vienna University of Technology from 6 to 10 September 2004. This flagship conference of EURASIP (European Association for Signal, Speech, and Image Processing) has been organized by the Institute of Communications and Radio-Frequency Engineering in close cooperation with the Research Center for Telecommunications (ftw) and the conference organizer Mondial. Strong support was also provided by the Signal Processing and Speech Communication Laboratory of Graz University of Technology and the Institute of Computer Aided Automation of Vienna University of Technology.

EUSIPCO 2004 attracted nearly 700 participants from 55 countries. 920 papers were submitted from which 580 were accepted for oral or poster presentation. The peer review process was based on full paper (4 pages) submission and was organized by 52 internationally well known experts.

On Monday, September 6, six tutorials were presented. The regular conference started on Tuesday, September 7 by an opening session where the rector of the university, the president of EURASIP and the co-chairs of the Technical Program Committee welcomed the participants. The conference offered four invited Plenary Talks and twenty Special Sessions (of which nine were invited). These were organized on topics of great current interest in Signal Processing and its Applications. Ten of the Special Sessions included an Extended Talk providing a broad and detailed view of the session's topic. Together, these Plenary Talks, Special Sessions, and Extended Talks offered an almost complete coverage of Signal, Speech, and Image Processing and a sound perspective of future developments. All accepted papers were published in the Proceedings EUSIPCO 2004. On CD-ROM they were distributed to all participants, in printed form they were also offered.

The social programme consisted of an Icebreaker Party as welcome on Monday evening, a cocktail reception at Vienna's City Hall on Tuesday evening, where three Young Authors Awards were presented, and a conference banquet on the MS Admiral Tegetthoff with an entertaining cruise on the Danube's waves on Thursday evening. At this event, in which also the Ceremony of the Prizes and Awards of EURASIP was held, 300 conference delegates participated. On Friday evening a special and entertaining event was offered at a Heurigen location in Neustift am Walde, it was attended by 150 participants.

During the conference a well attended exhibition of industries, research institutes and publishing houses was organized. Ten Sponsors could be attracted which supported several activities of the conference by different contributions.

6. Sonstiges / Miscellaneous

Internationales Seminar mit ETH Zürich und TU München über Mobilkommunikation

FORSCHUNGSPROJEKTE / RESEARCH PROJECTS

1.10.2003 – 30.9.2004

Digitale Signalverarbeitung / Digital Signal Processing

Advanced Multicarrier Systems for Wireless Communications
Contact: G. Matz, F. Hlawatsch *Partner:* FWF (Project P15156) Duration: 01.2002 – 12.2004

Nonlinear Speech Processing
Contact: W. Mecklenbräuker *Partner:* COST 277 Duration: 06.2002 – 12.2003

Christian Doppler Pilot-Laboratory for Design Methodology of Signal Processing Algorithms
Contact: M. Rupp *Partner:* Christan Doppler Society, Infineon Technologies
Duration: 06.2002 – 06.2004

Christian Doppler Laboratory for Design Methodology of Signal Processing Algorithms
Contact: M. Rupp *Partner:* Christan Doppler Society, Infineon Technologies, ARCS
Duration: 07.2004 – present

Information Geometric Analysis and Design of Iterative Algorithms in Wireless Communication Systems
Contact: G. Matz *Partner:* FWF (J2302), Ecole Supérieure d'Electricité (F)
Duration: 03.2004 – 02.2005

Mobilkommunikation / Mobile Communications

Advanced Network Radio Identification Equipment for Universal Mobile Communications (ANTIUM)
Contact: F. Hlawatsch *Partner*: EU (Project IST-2000-26222) Duration: 01.2001 – 12.2003

Mobilkommunikation
Contact: M. Rupp, A. L. Scholtz *Partner*: mobilkom Austria Duration: 12.2003 – 12.2006

Toward Mobile Broadband Multimedia Networks
Contact: E. Bonek *Partner:* COST 273 Duration: 04.2001 – 04.2005

MIMO
Contact: M. Rupp *Partner*: ARCS Duration: 04.2004 – 07.2004

MIMO for 4G Broadband Wireless Access
Contact: E. Bonek *Partner*: NTT DoCoMo Duration: 10.2003 – 08.2004

Optische Nachrichtentechnik / Optical Communications

Advanced Fibre Coupling Technology (AFCT)
Contact: W. Leeb *Partner*: Contraves Space AG/CH, ESA-ESTEC/NL,
Observatorium Leiden /NL, Max-Planck-Institut für Astronomie /D
Duration: 02.2003 – 10.2003

Single-Mode Fibres for DARWIN
Contact: F. Fidler *Partner*: EADS Astrium GmbH, ART Photonics GmbH/D, ESA-ESTEC
Duration: 08.2002 – 12.2004

Darwin-GENIE: Instrument Definition Study
Contact: W. Leeb *Partner*: EADS Astrium GmbH, TNO-TPD/NL, ESA-ESTEC/NL
Duration: 12.2003 – 12.2004

Accommodation of a Quantum Transceiver in an Optical Terminal (ACCOM)
Contact: M. Pfennigbauer *Partner*: Inst. f. Experimentalphysik, Univ. Wien,
Contraves Space AG/CH, ESA-ESTEC/NL
Duration: 12.2003 – 12.2004

HABILITATIONEN / HABILITATION THESES

1.10.2003 – 30.9.2004

G. Matz **"Time-Varying Linear Systems in Wireless Communications"**
Habilitation Thesis, Vienna University of Technology, Feb. 2004.

This habilitation thesis is a collection of several articles that deal with the application of time-varying linear systems in wireless communications. These articles are preceded by an introduction, where we discuss the role of of communications engineering in nowadays information society, describe recent research trends in wireless communications, consider the application of time-varying systems in communications engineering, and provide an overview of related work. The topics of the individual articles in the subsequent chapters are within the following main areas:

Analysis/Synthesis of Time-Varying Systems. We first provide a mathematically coherent framework for a time-frequency transfer function calculus of time-varying systems. Based on that, we cover some aspects of the (statistical) characterization of random time-varying channels satisfying the common assumption of wide-sense stationary uncorrelated scattering (WSSUS). Then, we discuss an efficient and flexible WSSUS channel simulation scheme and introduce a novel framework for the statistical description of non-WSSUS channels.

Measurement and Estimation of Channel Properties. Channel measurements and suitable evaluation and estimation procedures are indispensable for any communication system design. We present a quantitative assessment of the systematic errors of correlative sounding techniques used to measure the impulse response or transfer function of time-varying channels. In addition, efficient training-based and data-driven algorithms for the reliable estimation of WSSUS channel statistics are introduced.

Design of Wireless Communication Schemes. We also discuss some design aspects for wireless multicarrier communication schemes. Our focus is on the estimation and prediction of time-varying channels in a multicarrier context (both training-based and decision-directed). We finally introduce a new modulation format that allows to increase the robustness of multicarrier transmissions against time and frequency dispersion introduced in wireless links.

DISSERATIONEN / DOCTORAL DISSERTATIONS

1.10.2003 – 30.9.2004

S. Aleksic **"Design of Packet-Switched Access Nodes for Time-Multiplexed Photonic Networks"**
Advisor: H.R. van As, Co-advisor: W. Leeb

Photonic networks are probably the most appropriate solution to meet growing bandwidth requirements in the future Internet. The very high bandwidth of optical fibers can be exploited in some extent by multiplexing the data either in the wavelength, in the time or in the code domain. However, new telecommunications applications require a dynamical, high-capacity optical network with capability to carry heterogeneous network traffic. This cannot be obtained by employing a channel-based or a circuit-switched technique.

This thesis concentrates on the design of access nodes for all-optical networks that provide a dynamical high-speed access to the optical fiber. This can be achieved by transmitting data packets in a dynamical manner at a very high bit-rate. In order to achieve very high bit-rates, the data-rate of the packet to be transmitted is up-converted in an optical rate-conversion unit located at the node. The packets are then transmitted through the all-optical packet-switched network, while fast optical header processing at the transit nodes allows fast switching, data-rate/format transparency, and a low network latency.

High-speed subsystems that are required in the network nodes to attain ultra fast bit-rates and fast switching on the packet-by-packet basis are investigated in this work. First, a survey on technologies for implementing the high-speed functions and an implementational strategy for ultra fast network nodes are given. The fast optical subsystems including short pulse sources, fast optical switches, header processing and clock recovery units are reviewed.

Further, novel techniques for optical rate-conversion (i.e., compression and expansion of large optical packets), processing of packet's header, improvement of transmission efficiency and component/node cascadibility as well as architectures supporting multicast in the optical domain are proposed. Appropriate models based on analytical and numerical methods can be very useful during the design process. Different methods for modeling the components and the main building blocks of an all-optical packet-switched network node are described and used to predict the behavior, interactions, and limitations of the system. It has been shown that network nodes, when equipped with the proposed high-speed optical subsystems, can provide transmission, reception, and switching of optical packets at high bit-rates beyond 100 Gbit/s in an effective manner, and thus, can build a dynamical high-capacity packet-switched network capable of dealing with heterogeneous network traffic.

H. Artés **"Algorithms for Time-Varying Channels: Scattering Function Estimation and Blind Equalization"**
Advisor: F. Hlawatsch, Co-adviser: P. Loubaton

This thesis is concerned with communications over linear time-varying (LTV) channels. After a general introduction to LTV channels, we show how to discretize a continuous LTV channel with respect to all variables, namely time, time shift (delay), frequency, and frequency-shift (Doppler). We discuss the difficulties arising through discretization and the differences from linear time-invariant channels.

Next, we introduce two estimators of the scattering function of a random discrete LTV channel. Both estimators are based on the interpretation of the scattering function as a 2-D power spectral density and are thus spectral estimators in spirit. However, a striking difference from conventional spectral estimation is the fact that the 2-D channel realizations cannot be observed directly but must be measured via a channel sounding procedure. One of the estimators is designed for the case in which the user is able to choose the sounding signal. The other estimator is designed for use during an ongoing data transmission where the transmitted data signal must be used as the sounding signal. A bias/variance analysis for both estimators is presented, and their performance is assessed through simulations.

Finally, we consider blind equalization of discrete LTV channels, that is, calculation of the input signal only from the received signal and some basic structural properties of the channel. No pilot symbols or \emph{a priori} channel knowledge is used. We show how the structure inherent to the LTV channel can be utilized for blind equalization and we present some identifiability results. Furthermore, we present computationally efficient algorithms for blind equalization which are based on the so-called "projections onto convex sets" algorithm. We also extend our identifiability results and equalization algorithms to the multi-user case.

W. Bakalski **"Integrated Microwave Power Amplifiers"**
Advisor: A.L. Scholtz, Co-adviser: G. Magerl

New wireless communication systems like wireless local area networks (wireless LAN, WLAN), satellite communications, wireless point to multipoint radio links, etc. lead to increasing efforts in the development of high-speed semiconductor technologies and RF circuits for these applications. Due to the demand for low-cost solutions and miniaturization, technologies enabling the complete monolithic integration of major RF building blocks on single semiconductor chips are strongly preferred. One of the key RF building blocks is the power amplifier (PA). Due to its position in front of the antenna, is has to fulfill several needs standing in contrary to each other: Low power consumption but high output power levels, or high transistor robustness and high speed efforts or high linearity and high efficiency. Another important task comes from the economic side: Expensive housing or matching networks are not wanted, but a high efficiency is required to face the market. A major limiting factor is the limited quality factor of on-chip passives. So some design techniques have to be considered to relax the limitations. All this, and accurate models for the transistors as well, are required to optimize the design.

The main results are:

- A highly integrated 2.4 GHz ISM PA with a minimum of external components is presented. It shows outstanding efficiency performance of over 50% at 2V of supply voltage.
- The first fully-integrated wireless 5.3 GHz LAN PA in SiGe-bipolar technology is developed. It fulfills the needs on linearity and is free of any external matching components including DC-block capacitors. Further it shows almost perfect input and output matching. It features efficiency levels comparable with solutions requiring expensive external networks or ceramics.
- The first fully integrated SiGe-bipolar PA working up to 18 GHz is reported.

It features as well all matching components integrated on-chip.

It is an example for the technological limits as it rises up to an fT /fop of only about 4.2. It is further an example for the limits in the usage of on-chip transformers.

F. Bektas **"Investigation of Antenna Diversity Techniques for Bluetooth Communication"**
Advisor: A.L. Scholtz, Co-adviser: A. Goiser

This thesis aims to improve performance of Bluetooth communication in industrial and office environments by using antenna diversity techniques. The motivation for this work is the fact that Bluetooth communication in factories can reduce the use of cables and is in some cases a good alternative to wired connections. When transmitting or receiving information from rotating and moving machine parts, it is of great advantage to use wireless communication. Another type of application is an autonomous guided vehicle, which is dependent on some sort of wireless communication for communicating with surrounding machines. In the future, machines assembling products might be able to communicate with the product without physical connection during the assembly sequence, performing tests and downloading software to the products. Presently, Bluetooth is the fastest growing short range wireless communication technology. It operates in the 2.4 GHz ISM-band and is based on a frequency hopping physical layer. The signal transmission via a radio channel is affected by path loss, narrow and wideband fading, and co-channel-interference. With Bluetooth, the packets transferred consecutive in time do not use the same frequency, thus avoiding the drawbacks of narrowband transmission. The link performance depends on the fading of the individual channels occupied. Therefore all methods of improving the physical layer have to be frequency agile. As such an approach, in course of my thesis the first Bluetooth antenna diversity demonstrator was developed. In order to investigate the performance of Bluetooth antenna diversity, extensive experimental

investigations have been done. It was shown that the effects of multipath and fading can be combated to a large extent by antenna diversity. Therefore, antenna diversity was confirmed to be a powerful technique for improving the quality of Bluetooth links so that Bluetooth communication can be used in industrial applications.

A. Gerdenitsch "System Capacity Optimization of UMTS FDD Networks"
Advisor: E. Bonek, Co-adviser: G. Raidl

In this thesis I investigate the problem of capacity optimization in UMTS FDD networks. The goal is to improve the capacity of the network, measured as served users, only by changing the base station parameters. The focus is on the optimization of antenna tilt and common pilot channel (CPICH) power of the base stations. These parameter adjustments improve the UMTS radio network capacity by means of reducing inter-cell interference, achieve cell load sharing, and optimize base station power resources.

Altogether five different algorithms for finding the best settings of antenna tilt and CPICH power are presented. The first three optimization algorithms, Rule Based Approach, Simulated Annealing and Adaptive Rule Based Approach, are local techniques. Furthermore, a global technique, the Genetic Algorithm, will be presented. Also, an Analytic Optimization Algorithm will be discussed.

The fitness function used for the algorithms considers the number of served users as the main optimization goal. For the Genetic Algorithm I use a fitness function that additionally also considers coverage and soft handover.

First, the Rule Based Approach is adressed. The optimization process is characterized by reducing the CPICH power and increasing the antenna downtilt in the individual cells according to a configurable rule set. Subsequently, this algorithm is extended by incorporating Simulated Annealing. Here, the decision whether to take a worse result is, in contrast to the first method, independent of the rule set. The third local algorithm is also a further development of the Rule Based Approach. The main difference between the Adaptive Rule Based Approach and the other two local approaches is that CPICH power and antenna tilt are changed together, and that also an increase of CPICH power and antenna up tilting is possible during the optimization process.

Further, a Genetic Algorithm is introduced which I improved by taking operators that are adapted for the UMTS capacity optimization problem by taking into account the quality of the network. In addition, a local optimization is included to improve the performance.

Finally, I address an Analytical Optimization Algorithm. Beside antenna tilt and CPICH power settings, this algorithm optimizes also the antenna azimuth.

The performance of the algorithms is evaluated using a static UMTS FDD network simulator on two virtuals-cenarios of a typical European city. In the first scenario the network covers the whole area of the city. The second scenario only spans across downtown.

With the different algorithms, I show improvements in capacity of up to 105% compared to the initial settings. The Genetic Algorithm performs best, but with the drawback of a high computation time. If we compare the three local optimization techniques, Rule Based Approach, Simulated Annealing and Adaptive Rule Based Approach, we see that the Adaptive Rule Based Approach achieves the highest improvement. The computation effort for all three algorithms is approximately the same. The Analytic Optimization Algorithm shows, with only five network evaluations, almost the same optimization result as the local algorithms.

G. Gritsch "Error Performance of Multiple Antenna Systems"
Advisor: H. Weinrichter, Co-adviser: E. Bonek

In this thesis the error performance of multiple antenna systems has been investigated. Our focus lies on the analytical calculation of performance measures. Unfortunately, due to the difficult framework and the rather unpredictable behavior of the signal distances in randomly varying channels a closed form solution of the exact error performance could not be derived. However, tight performance bounds have been found that can be used to get important performance parameters.

This thesis consists of two main parts concerning the uncoded and the space-time block coded data transmission over spatially correlated, frequency flat Multiple Input / Multiple Output (MIMO) channels using Maximum Likelihood receivers. The spatial correlation is modelled by the so-called W-model, where measured data are used to determine the model parameters.

Uncoded MIMO-systems: Even for uncoded systems, the only simple to calculate performance measure is a union bound, which is simply the sum over all pairwise error probabilities. In this thesis it is shown that the error performance can be described by a few so called Error Types (ETs). The results of the corresponding union bound are compared with simulation results for different system parameters, i.e., number of transmit antennas, number of receive antennas, modulation formats, and for spatially uncorrelated and correlated MIMO-channels. The derived union bound is tight for Bit Error Ratio (BER) values below 10-3 for all systems investigated.

By means of this bound a high Signal to Noise Ratio (SNR) approximation for the BER vs. SNR performance is calculated. With this approximation the diversity order of the system and a so-called performance loss due to fading correlation can be figured out. Especially, the loss due to spatial correlation can be quantified. Using two parameters, the slope and the horizontal position of the BER vs. SNR curves, the error performance can be fully described in the high SNR range.

An optimal precoder, which minimizes the correlation induced power loss, is presented. For the example discussed in this thesis the error performance applying the optimal precoder in correlated fading is even better than the performance of the standard system in the low SNR range in uncorrelated fading channels.

Space-time block coded MIMO-systems: The second main part of this thesis is devoted to the calculation of

performance measures for space-time block coded data transmission. In principle, we follow the same analysis as for uncoded systems. First, it is shown that for some channel types multiple instead of single errors dominate the error performance in MIMO systems (MIMO paradoxon). In deriving the union bound the ET concept is applied also. The calculated union bounds are compared with simulation results for several codes and several channel correlation types. It turns out that the union bound is tight for BER values of 10-3 and below.

Once again, a high SNR approximation of the union bound is calculated, to determine the diversity order and the power loss in case of correlated channels.

An optimal precoder for correlated fading is derived. Simulation results show that the precoder effectively mitigates the loss induced by correlated fading.

In addition, an extraordinarily tight lower bound of the BER is derived that allows for a two-sided bounding of the BER vs. SNR performance from below and from above. Several code examples assess the tightness of the lower bound, where, for uncorrelated channels, an almost exact performance approximation is achieved.

M. Herdin **"Non-Stationary Indoor MIMO Radio Channels"**
Advisor: E. Bonek, Co-adviser: A. Burr

Stationarity is an often used assumption for the mobile radio channel. For a single-input single-output (SISO) channel this means that the channel statistics does not change with time or frequency. Unfortunately, real channels never fulfil this exactly. They can only be assumed to be quasi-stationary, i.e. the channel statistics stays approximately constant within a specific timefrequency stationarity region. If this stationarity region is large enough, a transmission scheme can take advantage of the channel statistics by estimating it and adapting the transmission accordingly. For such systems, the performance depends essentially on the extent of this stationarity region. In case of multiple-input multiple-output (MIMO) systems, the spatial structure has to be taken into account, additionally. Because of the great importance of the spatial domain for MIMO systems, especially the time and frequency intervals within which the spatial statistics stay approximately constant, become essential.

The main goal of this thesis is to investigate to what degree indoor MIMO channels can become non-stationary. As a first step, I consider different metrics to measure the non-stationarity of the MIMO channel. It turns out that a space-only stochastic description of the MIMO channel is a good basis for a stationarity definition for MIMO channels. On the one hand, it covers the main aspect of MIMO channels, i.e. the spatial structure, on the other hand, it can easily be applied to measured channels. Based on this approach, I introduce the correlation matrix distance (CMD) to measure to what extent the channel statistics changes over time or frequency. Although, it is a simplified viewpoint, I treat correlation, i.e. the spatial structure of the channel, at transmit and receive side separately. This allows for comparison to MIMO transmission schemes that make use of the channel statistics, since they often adapt the transmission to the spatial structure at transmit side only. Before investigating measurements, I analyse theCMDusing synthetic data. It turns out that in case of a CMD below 0.2, the spatial structure of the channel did not change largely, whereas a value of 0.4 or more means that there were significant changes.

In the main part of the thesis, measured channels are investigated. I analyse measurements that were taken in an indoor office environment, and on the Vienna International Airport, at 2.45GHz and 5.2GHz centre frequency. I analyse the non-stationarity of the MIMO channel regarding different aspects including mutual information, variation of the spatial structure, and the influence of the non-stationarity on the performance of a MIMO transmission scheme. I will show that the indoor MIMO channel cannot be assumed to be stationary, a priori.

Movements of the mobile tend to signicantly inuence the spatial structure of the channel, which shows up as changed mutual information and also as performance degradation of MIMO transmission schemes. It will turn out that it becomes necessary to distinguish between downlink and uplink for indoor environments where a fixed base station and a moving mobile is considered. The spatial structure at the base station, i.e. the fixed transmitter in the measurements, is found to be relatively constant if movements of the mobile (the receiver) within one office room are considered. As soon as the mobile moves to another office room, the spatial structure at the base station side changes significantly. The spatial structure at the mobile, however, varies strongly, also for small movements within one office room. The consequence for MIMO transmission schemes is that knowledge of the spatial structure of the channel may be assumed at a fixed base station, but at a moving receiver, this assumption is problematic. People that are moving around, act mainly as blockers, hence they do not signifficantly contribute to the spatial structure of the channel. They only shadow multipath components dependent on their movements.

W. Konrad **"Design of an Adaptive Antenna Demonstrator for Digital Beamforming"**
Advisor: E. Bonek, Co-adviser: A.L. Scholtz

The application of adaptive antennas to mobile communications has attracted considerable interest in the last decade. Adaptive antennas, in a broad sense, implement spatial filtering by means of beamforming, using an antenna array with a small number of antenna elements at the base station. In uplink, the received signals of all antenna elements are complexly, and adaptively weighted according to some prescribed performance criterion, to either enhance the carrier-to-interference-ratio for the reception of a single mobile ´s signal, or, ultimately, serve many mobiles, transmitting at the same time, and at the same frequency, but spatially separated, by utilizing the spatial filter to separate the mobile ´s signals, thus implementing spatial-domain-multiple-access, SDMA. To establish the performance criterion, adaption algorithms need a known reference for operation, either a training sequence embedded in the received signals (temporal reference), or the direction-of-arrival of the impinging signals (spatial reference), no explicit reference, except some knowledge of the impinging signal ´s properties (blind algorithms), or combinations thereof.

Algorithm research for adaptive antennas is a vivid and ongoing discipline, as new mobile communication applications, and requirements emerge. While performance evaluation of these algorithms is possible by computer simulation to a certain extent, an experimental assessment by means of a dedicated adaptive antenna testbed, or demonstrator, reveals the real-world performance, and allows the examination and the demonstration of new ideas.

In this thesis, I present the design of an adaptive antenna demonstrator for digital beamforming, that is especially targeted at algorithm evaluation and demonstration. The system works in the 2.45 GHz ISM - band according to a modified DECT- air interface. A nine- channel transceiver unit allows the real-time reception of the signals of several mobiles via a 9 - element antenna array, and is interfaced to an embedded personal computer, where off-line digital beamforming or direction-of-arrival estimation is performed. The demonstrator system implements a digital quadrature demodulation / modulation concept, i.e. passband sampling of the received signals at the second intermediate frequency of the double heterodyne receivers allows further signal processing in the digital domain. For transmitting downlink information to the mobiles, necessary for synchronization to the demonstrator, the system is capable of cyclic transmission of data packets, with fixed, non-adaptive beamforming.

I explain adaptive antennas in general, their application to mobile communications, recent examples, and the benefits that are gained for cellular systems. Then, I discuss adaptive digital beamforming, and explain some important concepts and algorithms that are representative to set the scene for the design of the demonstrator system. I give a detailed reasoning and the design procedure that I used. Based on the requirements due to the algorithms under consideration, and the needs of the algorithm research team of the mobile communications group at the department of communications and RF technoloy at the Technical University of Vienna that I had the privilege to join for some time, I derive firstly a system concept, and basic design parameters. Because digital quadrature conversion is required for this system, I explain the solution I have chosen. Secondly, with respect to these parameters, I perform the system design of the digital transceivers. The results are figures of merit to be implemented for the analog, and the digital part of the system. This finally leads to the detailed presentation of the resulting demonstrator structure, and the circuit designs that have been designed according to the requirements and the figures of merit derived previously. This includes the whole transceiver chain from antenna ports, to the embedded personal computers, the required synthesized signal sources, and interfacing and control units. Additionally, I briefly describe the mobiles that accompany the core demonstrator, and a simplified demonstrator that was derived from the designs described previously.

M. Pfennigbauer **"Design of Optical Space-to-Ground Links for the International Space Station"**
Advisor: W. Leeb, Co-adviser: P. Winzer

Innovative technologies will have to be developed in the near future to satisfy the ever increasing demand on bandwidth associated with new communication services. Free-space laser communication is a promising candidate in this field. The outstanding advantage of systems employing optical carrier frequencies in comparison to widely used radio-frequency technology is the low beam divergence. However, small beam diameters lead to high technological demands concerning mutual pointing, acquisition, and tracking (PAT) of the communicating terminals.

Within this thesis, the major concepts and technological requirements of an optical link operating in the Gb/s-regime between the International Space Station (ISS) and a ground station are being investigated. Such a link could serve as broadband communication channel for the scientific experiments aboard the station and would, additionally, extend the operational experience with optical space-to-ground links. I am deriving numerical benchmarks for the parameters concerning the link loss, the pointing accuracy, and the effects of atmospheric propagation. I am calculating the power spectral density originating from celestial bodies and the atmosphere of the Earth accepted by a telescope aboard the ISS or on ground and assess its impact on the performance of the system.

The distances to be bridged between the ISS and a ground station are up to 2200 km. This fact, together with the limited transmit power, the high cost of large telescopes, and the impossibility of in-line amplification lead to the need for highly sensitive receivers to fully exploit the low signal power available. After comparing different receiver technologies, I am focussing on optically preamplified direct detection receivers. The system parameters affecting the receiver's performance are investigated by a self-developed simulation program and by experiments. Two forms of on-off keying modulation formats, namely non return-to-zero (NRZ) and return-to-zero (RZ), are implemented and the effect on the receiver sensitivity is being assessed. By using an RZ coded transmit signal and by optimizing optical and electrical filter bandwidths in the receiver, I experimentally approached – at a data rate of 10 Gb/s – the theoretical limit of receiver sensitivity, the quantum limit, as close as 1.1 dB.

I set up a laboratory breadboard of an optical transceiver implementing devices commercially available off-the-shelf to assess the potential of utilizing fiber communication technology for free space laser communication. I show that Erbium-doped fiber amplifiers are suitable to serve as high-power booster amplifier in the transmitter and as preamplifier in the receiver.

Many aspects of classical optical free-space communication systems, e.g., PAT, link loss, and background radiation are also relevant for quantum communication in space. I am investigating the implementation of quantum cryptography for distributing a secret key to two ground stations by employing a source of entangled photons aboard the ISS. In an assessment of the technological requirements of this scenario I identify the data rate, the accuracy of synchronization, and the link availability as critical issues.

D. Schafhuber **"Wireless OFDM Systems: Channel Prediction and System Capacity"**
Advisor: F. Hlawatsch, Co-adviser: H. Bölcskei

The general theme of this thesis is orthogonal frequency division multiplexing (OFDM) communications over time and frequency selective fading channels. We propose and study linear prediction techniques for acquiring channel state information (CSI) in OFDM receivers, and we perform an information-theoretic analysis of the performance of OFDM systems.

After a review of the generic discrete-time pulse-shaping OFDM system (which comprises conventional cyclic-pre x OFDM systems as a special case), we consider the transmission over a time and frequency selective fading channel. We arrive at an approximate multiplicative system input-output relation in which intersymbol and interchannel interference is neglected.

Based on this approximate input-output relation, we propose decision-directed channel predictors that are capable of yielding up-to-date CSI without regular transmission of pilot symbols. We derive the minimum mean-square error (MMSE) predictor and a reducedcomplexity version that allows for an e cient DFT implementation. We also develop adaptive predictors that do not need statistical prior knowledge and can track nonstationary channels. Several applications of channel prediction are discussed, and the excellent performance of the proposed techniques is demonstrated by computer simulations. The second major contribution of this thesis is an information-theoretic analysis of the performance of OFDM systems transmitting over time and frequency selective channels. We study the system capacity of wideband OFDM communications in the absence of CSI at the transmitter and the receiver. Using a codebook that is \peaky" in time and frequency, we show that OFDM can approach the in nite-bandwidth channel capacity. On the other hand, using a \nonpeaky" constant-modulus signaling scheme, we show that the information rate is reduced by a penalty term that is related to the predictability of the fading channel. We quantify the impact of the spread and shape of the scattering function on this penalty term. Finally, we formulate an upper and a lower bound on system capacity and demonstrate by simulations that both bounds are close to the AWGN channel capacity for large ranges of bandwidth and for practically relevant system parameters.

E. Trojer **"Security Functions in Mobile Communication Systems"**
Advisor: E. Bonek, Co-adviser: T. Johansson

The security features provided to a user by a communication network represent a key parameter for the success of the system. Data confidentiality, entity authentication and bindingness are thus main design principles of new generation mobile communication systems. To obtain this goal, new security related protocols and algorithms for data encryption and authentication are used in these systems. Most information on the security architectures can be found in standards and researchers can analyze the security system for weaknesses by trying to mount efficient attacks. If such holes in a standard are found, protocol and cipher designers can react by changing the design principle or by exchanging broken algorithms. The aim of the present work is to evaluate the security functions of almost all mobile systems in terms of protocol and crypto security by advanced mathematical tools. For weaknesses found, countermeasurements are investigated and researched. The main attention is thereby focused on the access part of the mobile network, i.e. the radio interface, which is vulnerable to eavesdropping by an adversary. The following list gives a more detailed outline of the systems and algorithms discussed.

The authentication algorithms (Algorithm: COMP128/1, COMP128/2-R) and the data encryption functions (Algorithms: A5/1, A5/2) of the second generation cell phone system GSM (Global System for Mobile Communications) are cryptanalysed and several attacks and improvements are summarized. Together with some exploits on the protocol layer, the GSM system can be viewed as insecure. Two new algorithms COMP128/2 and A5/3 have been standardized recently. Since the details of these cipher designs are not publicly available, cryptanalysis has not been possible. It is assumed that these two algorithms are improved, but they will not be in use soon.

Also the security of the encryption algorithm used for the packet switched GPRS service (General Packet Radio Service) is discussed on the basis of a reference algorithm (Algorithm: GEA-R) which is inherited from the secret original version (Algorithm: GEA). It turns out, that the reference algorithm, as well as the original, exhibit weaknesses that allow for practical key recovery by eavesdropping.

The third generation mobile network UMTS (Universal Mobile Telecommunications System) uses an improved security architecture derivated from the one used in GSM. Stronger cipher primitives for data encryption (Algorithm: Kasumi) and authentication (Algorithm: MILENAGE) have been chosen. This result is obtained by analyzing the resistancy of the cryptobox against the two most powerful attacks (linear and differential cryptanalysis).

The short range mobile communications standard Bluetooth represents a challenging task in terms of security because of its ad-hoc character. The data encryption over the radio interface (Algorithm: E0) is presented and cryptanalysed. Although several efficient attacks are found, the complexities are to high for gaining practical relevancy.

P. Veith **"Thermographische Untersuchung elektrischer Nahfelder kompakter und integrierter Antennen"**
Advisor: G. Magerl, Co-adviser: E. Bonek

The thesis describes the investigation of a new measurement method fulfilling the actual needs of the industrial and mobile communication engineering and having impact to the design of especially integrated antennas. Here, the electrical fieldstrength's near-field components of resonant and radiating structures are of major importance, determining e.g. efficiency and background noise. The new method developed utilizes dielectric power dissipation due to orientational polarizability in detector materials. Inserted into the near-field region close to the antenna structure, the detector material causes losses and is warmed up. This temperatur is detected by thermophotography showing the local field-strength as temperature. In order to get more than qualitative results the detector materials have been investigated and a calibration method was found and verified, the impact of measurement to the measurand was evaluated. To employ the method for actual demands, a demonstrator setup was built and tested. As an example for usage the design of antennas for mobile communication devices was shown by means of this new measurement technology. These and further results give evidence to the impact of the new method to the actual needs of the engineers designing communication devices.

O. Wallner **"Modal Filtering of Optical Waves"**
Advisor: W. Leeb, Co-adviser: P. Winzer

This thesis investigates theoretical and practical aspects of modal wavefront filtering. It also introduces an interferometric method for measuring the performance of a modal wavefront filter based on a single-mode waveguide and describes practical testing of prototype fibers in the mid-infrared.

Modal filtering of optical waves is a type of wavefront filtering which relies on the unique properties of single-mode waveguides. As, by definition, single-mode waveguides only propagate the fundamental mode, they provide -- at their output -- a field with predefined transverse distribution which is independent of the input field. The input field only determines the output field‘s complex amplitude. Modal wavefront filtering therefore allows for equalizing optical fields with respect to the transverse profile which, e.g., is of particular importance in astronomical interferometry.

The first part of this thesis is concerned with theoretical aspects of wavefront filtering in general and modal wavefront filtering in particular. We elaborate the fundamental difference between spatial wavefront filtering and modal wavefront filtering. The first is blocking of spatial frequency components of a field by, e.g. focussing the field onto a pinhole, the latter is projecting the field onto a field with predefined transverse amplitude and phase distribution, e.g. by coupling the field into a single-mode waveguide. We discuss the essential requirements on modal wavefront filters which are uniqueness and spatial stationarity of the transverse outputfield distribution. In view of practical application of modal wavefront filters, we investigate broadband performance and the significance of the coupling phase. We compare the waveguiding properties of single-mode waveguides, such as step-index fibers, integrated optical waveguides, and photonic crystal fibers, and of lossy multi-mode waveguides, like hollow dielectric and hollow metallic fibers, which -- at least in theory -- can serve as modal wavefront filters. Today modal wavefront filters are only available at telecommunications wavelengths, i.e. for wavelengths between 0.6μm and 1.55μm. However, astronomical applications ask for an operation between 4μm and 20μm, hence we review materials and fabrication technologies for mid-infrared fibers. We conclude the theoretical part with the analysis of a multi-axial single-mode beam recombination scheme, a setup incorporating the functionality of beam recombination into the modal wavefront filter.

The second part is devoted to wavefront filter performance evaluation and describes measurements with prototype silver-halide fibers in the mid-infrared. We review several conventional methods which allow to determine whether a waveguide is single-mode or not and propose an interferometric measurement to determine the waveguides‘ filter action, i.e. the increase in interferometer output power contrast by applying a modal wavefront filter. An increase in output power contrast by orders of magnitudes can only be achieved with single-mode waveguides. The setup allows to quantify the waveguide‘s modal wavefront filter performance. We describe a corresponding measurement setup which incorporates a Mach-Zehnder interferometer operating at a wavelength of 10.6μm and discuss the results obtained for prototype silver-halide fibers, developed within an ESA-funded project and to be used as wavefront filter for the DARWIN mission.

W. Weichselberger **"Spatial Structure of Multiple Antenna Radio Channels"**
Adviser: E. Bonek, Co-adviser: A. Molisch

The employment of multiple antennas at one side of a communications radio link (multiple-input single-output=MISO) allows for the utilization of the spatial domain by means of signal processing. Beamforming focuses the antenna array pattern into a specific direction and thereby enhances the signal strength. Multiple spatial replicas of the radio signal give rise to spatial diversity, which increases the reliability of the fading radio link. By applying an additional antenna array at the other link end (multiple-input multiple-output=MIMO), the radio channel supports multiple parallel signal streams in the spatial domain, i.e. the spatial multiplexing of data.

The first part of this thesis deals with MISO channels, which show a fundamental trade-off between beamforming and diversity. To which extent spatial diversity or beamforming can and should be utilized depends on the spatial properties of the radio channel, the knowledge about the channel state, and the requirements of the communications system. On one hand, I discuss the notions of array gain and diversity gain for the case of (i) no channel knowledge, (ii) knowledge of second-order statistics only, and (iii) full channel knowledge. On the other

hand, I focus on the case of an antenna array at the transmit side, where only the second-order statistics of the channel are known. By allocating different fractions of transmit power on the diversity branches, a smooth trade-off between diversity and beamforming can be established. I investigate the optimum power allocation scheme, for the case of Rayleigh fading, and derive an approximate solution in closed form.

In the second part of this work, I extend the concept of spatial eigenmodes, which has been well understood for MISO systems, to the MIMO case. Due to the inherent matrix nature of MIMO channels, the second-order statistics of MIMO channels emerge naturally as fourth-order tensors. In contrast to the MISO case, the MIMO correlation tensor offers three different possiblities of decomposition: The MIMO eigendecomposition makes use of the Hermitian symmetry of the correlation tensor and is analogous to the eigendecomposition of Hermitian matrices. It yields matrix-valued eigenmodes which have the same physical interpretation as a MIMO channel matrix. The Kronecker mode decomposition decomposes the correlation tensor into separate receive and transmit components. It corresponds to the singular value decomposition of asymmetric matrices. The Kronecker modes are also matrix-valued but can be interpreted as spatial correlation matrices of the receive or transmit side, respectively. The vector mode decomposition is based on the tensor-valued nature of the second-order statistics of MIMO channels, and has no equivalent in matrix notation. It generalizes the concept of eigendecompositions and singular value decompositions to tensors, and decomposes the correlation tensor in vector-valued components. These components can be interpreted as link-end related excitation vectors of the MIMO channel.

After establishing the MIMO eigenstructure, I apply the corresponding mathematical tools to the spatial modeling of MIMO channels. I develop a nested hierarchy of channel models that are solely based on the eigenstructure of MIMO channels. Starting from an exact description of the MIMO correlation tensor, I gradually decrease the model complexity which, in turn, also decreases its accuracy. Furthermore, I present similar nested hierarchies for models based on steering vectors or random vectors. By combining the presented model hierarches and additional modeling approaches from literature, I establish a general framework for analytical MIMO channel models. The benefit of this framework is two-fold. On one hand it facilitates the understanding and classification of existing models. On the other hand, it allows for choosing the right model for a specific application by identifying the appropriate trade-off between accuracy and simplicity. The MIMO part of the thesis is wrapped up by comparing the performance of various analytical channel models. The ability of the models to reproduce the spatial power distribution and the mutual information of measured MIMO channels is evaluated and discussed.

T. Zemen **"OFDM Multi-User Communication Over Time-Variant Channels"**
Advisor: E. Bonek, Co-adviser: M. Rupp

Wireless broadband communications for users moving at vehicular speed is a cornerstone of future fourth generation (4G) mobile communication systems. We investigate a multi-carrier (MC) code division multiple access (CDMA) system which is based on orthogonal frequency division multiplexing (OFDM). A spreading sequence is used in the frequency domain in order to distinguish individual users and to take advantage of the multipath diversity of the wireless channel. The transmission is block oriented. A block consists of OFDM pilot and OFDM data symbols.

At pedestrian velocities the channel can be modelled as block fading. We apply iterative multi-user detection and channel estimation. In iterative receivers soft symbols are derived from the output of a soft-input soft-output decoder. These soft symbols are used in order to reduce the interference from other users and to enhance the channel estimates. We develop an iterative channel estimation scheme for MC-CDMA. The iterative MC-CDMA receiver achieves a performance close to the single-user bound in moderately overloaded systems. The single-user bound is defined as the performance for one user and perfect channel knowledge.

In order to obtain enhanced iterative channel estimates we take advantage of additional information like the estimated mean and variance of the soft symbols, which can be obtained from the decoder output since the used symbol alphabet has constant modulus. Using these information a linear minimum mean square error (MMSE) channel estimator is derived. The iterative receiver achieves enhanced convergence towards the single-user bound with the linear MMSE channel estimator.

At vehicular velocities, the channel can not be treated as block fading for the duration of a data block. Instead, its temporal variation must be modelled adequately. We investigate channel estimation algorithms that do not need the knowledge of complete second order statistics. We assume an upper bound for the Doppler bandwidth only, which is determined by the carrier frequency and the maximum supported velocity. This approach is motivated by the fact that existent wireless channels do not adhere to Jakes‘ model. First, we deal with time-variant frequency-flat channels. We analyze the Fourier basis expansion, i.e. a truncated discrete Fourier transform (DFT), for time-variant channel estimation. The analysis shows that the windowing due to the block-based transmission leads to spectral leakage and the truncation of the DFT gives rise to an effect similar to the Gibbs phenomenon. Both mechanisms together lead to biased channel estimates.

Slepian‘s theory of time-concentrated and bandlimited sequences allows a new approach for time-variant channel estimation. It enables the design of doubly orthogonal discrete prolate spheroidal (DPS) sequences with just two parameters; the block length and the maximum Doppler bandwidth. The DPS sequences are used to define a Slepian basis expansion. We give analytic results showing that the bias of the Slepian basis expansion is at least one magnitude smaller compared to the Fourier basis expansion.

The Slepian basis expansion performance degrades for pilot based channel estimation because the orthogonality of the basis functions is lost due to the pilot grid. We tackle this problem by designing a new set of finite

sequences that are orthogonal over the pilot index positions but keep their bandlimited and time-concentrated properties. The resulting generalized finite Slepian basis expansion achieves best performance for pilot based time-variant channel estimation which is proven by analytical results and shown in numerical simulations.

We apply the generalized finite Slepian basis expansion for time-variant frequency-selective channel estimation in an MC-CDMA downlink and discuss simulation results. The time-variant frequency-selective channel offers Doppler diversity in addition to multipath diversity. An MC-CDMA system can take advantage of the Doppler diversity through interleaving and coding over a data block. We derive an analytic measure for the Doppler diversity of a time-variant channel and support it by simulation results.

In this thesis, we design an iterative receiver-architecture for an MC-CDMA uplink with multi-user decoding for time-variant mobile radio channels. It is shown that this receiver type reaches the single-user bound up to 2.5dB under full load with N=64 users, at an Eb/N0=14dB, and for mobile users moving with velocities in the range from 0 to 100km/h.

DIPLOMARBEITEN / DIPLOMA THESES

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A. Bolzer	"Denoising of Audio Signals Using Wavelet Packets" Supervisor: G. Doblinger
N. Czink	"Optimum training for MIMO wireless channels" Supervisor: D. Seethaler
B. Dehlink	"Atmospheric Impact on Laser Beam Propagation" Supervisor: M. Pfennigbauer
F. Fidler	"Performance enhancement in WDM systems" Supervisors: M. Pfennigbauer, P. Winzer, W. Leeb
P. Fuxjäger	"Antenna Selection for MIMO Systems with Space-Time Coding" Supervisors: H. Weinrichter, B. Badic
M. Georgiev	"Speech Coding based on Auditory Model" Supervisor: E. Rank
A. Hofer	"ATRIS – a concept for a location based Automatic TRaffic Information Service" Supervisor: G. Pospischil
B.M. Hofer	"Adaptive Robuston Filters" Supervisors: M. Jachan, G. Matz
G. Karner	"Implementierung eines Prototypen zur verteilten Spracherkennung" Supervisor: E. Rank
W. Karner	"Optimum Default Base Station Parameter Settings for UMTS Networks" Supervisor: A. Gerdenitsch
G. Kolar	"Performance of Combined Beamforming and Space-Time Coding for Multiple Antenna Systems" Supervisor: G. Gritsch
R. Langwieser	"Entwicklung von HF-Baugruppen für ein MIMO Echtzeit-Übertragungssystem" Supervisor: W. Keim
H. Lauffer	"Intermodulationsfestes Empfangsmodul für Basisstationen im 900 MHz Band" Supervisor: W. Simbürger
A. Linduska	"Super-Orthogonale Space-Time Trellis-Codierung für eine Funk-Übertragung mit mehreren Sende-Antennen" Supervisors: H. Weinrichter, B. Badic
H.-P. Lintner	"Störungstolerantes Modem für den VHF-Funkkanal" Supervisor: A. Goiser
G. Maier	Prototypen-Entwicklungsumgebung zur schnellen Simulation Supervisors: M. Rupp, M. Huemer
C. Mehlführer	"Implementation and Real-Time Testing of Space-Time Block Codes" Supervisors: M. Rupp, B. Badic
M. Moura	"Mapping MIMO Channel Models into Multi-DSP Architectures" Supervisor: K. Siamitros
H. Perko	"Robust Nonstationary Detection with Application to Seismic Data" Supervisor: G. Matz
R. Prestos	"Auswertung von 5,2 GHz MIMO-Messungen am Institut für Nachrichten- und Hochfrequenztechnik" Supervisor: H. Özcelik
A.E. Raidl	"Robust Time-Frequency Methods for Nonstationary Detection and Estimation" Supervisor: G. Matz

J. Schreiner	"Entwurf optimierter Lautsprecherarrays" Supervisor: G. Doblinger
A. Selhofer	"Evaluation of Turbo Code in ADSL" Supervisors: H. Weinrichter, B. Dortschy
E. Stanka	"Non stationarity of MIMO radio channels" Supervisor: M. Herdin
M. Steinmair	"Identifikation und Linearisierung nichtlinearer Leistungsverstärker mit Volterrareihen" Supervisor: E. Aschbacher
P. Stipek	"On the Channel Influence when Utilizing Multiple Antenna Transmission" Supervisor: M. Rupp
P. Svoboda	"A Traffic Generator for Modelling Mobile Services" Supervisor: P. Dintchev
W. Tertnig	"Netzparameter-basierte Lokalisierung in GSM" Supervisor: P. Dintchev
A. Tomik	"Several Methods for the Optimization of GSM 900/1800 Networks" Supervisor: P. Bratanov
R. Wohlgenannt	"Design of Low-Density Parity-Check Codes Using Extrinsic Information Transfer Charts" Supervisor: H. Weinrichter, B. Dortschy
A. Wörndl-Aichriedler	"Code Optimization of VLIW DSPS with Genetic Algorithms" Supervisor: T. Zeitlhofer
G. Zach	"Zweidimensionale Richtungsschätzung mit Mikrofonarrays" Supervisor: G. Doblinger
S. Zauner	"Oscillators with Film Bulk Acoustic Wave Resonators at 2 GHz" Supervisor: W. Keim

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