ITG INFORMATION TECHNOLOGY SOCIETY WITHIN VDE

CHEMNITZ UNIVERSITY OF TECHNOLOGY

WFMN 2007

Wave Propagation in Communication, Microwave Systems and Navigation

A conference of ITG commission 7.5 “Wave Propagation”

Conference Programme & Abstracts

Venue	Günnewig Hotel Chemnitzer Hof Theaterplatz 4 D-09111 Chemnitz Germany phone: +49 (0)371 – 684-0 fax: +49 (0)371 – 676 2587 e-mail: chemnitzer.hof@guennewig.de
Dates	4th and 5th of July 2007
Conference Contacts	Prof. Dr. rer. nat. Madhukar Chandra Jana Viessmann Professur HF und Photonik Fak. für ET/IT TU Chemnitz Reichenhainer Str. 70 09126 Chemnitz e-mail: WFMN07@infotech.tu-chemnitz.de phone: +49 (0)371 531 24340 fax: +49 (0)371 531 24349

Preface

The subject of ITG commission 7.5 is electromagnetic wave propagation. This phenomenon plays a crucial role in several different areas, such as: communication systems, microwave remote sensing systems, navigation, surveillance and security, transport safety, and more recently, in the area of biological effects, to name a few. The commission, therefore, has a daunting responsibility of relating to the science and technology in all these diverse areas and uniting them under the common banner of electromagnetic wave propagation.

The aim of this conference is to seek scientific representation from all these areas and to motivate the participants to mutually strengthen their knowledge of electromagnetic wave propagation by sharing with each other and their own specific brand of propagation application. To promote this synergy amongst the heterogeneous group of scientists, this meeting will be fielding a total of 33 contributions out of which nine are invited tutorial papers. This feature promises to make the meeting appeal not only to the experts but also to the young scientists entering the field. The ITG commission on wave propagation will continue to serve in this capacity by developing this spirit even further.

The city of Chemnitz has an established record in fostering scientific and technological innovation. This medium sized city is surrounded by landscape of rich natural beauty. The ITG commission 7.5 and the faculty of electrical engineering of the Chemnitz University of Technology are delighted to be hosting this conference.

We look forward to welcoming you in Chemnitz at this meeting.

Madhu Chandra,	Chairman of ITG commission 7.5, on behalf of
Wolfgang Keydel,	Former Director of Microwaves and Radar Institute, DLR,
Gerd Wanielik,	Professor of Communications Engineering, TU Chemnitz,
Volker Schanz,	Managing Director VDE/ITG, and
Thomas Geßner,	Dean of Faculty of Electrical Engineering, TU Chemnitz.

Conference Board

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Prof. Dr. rer. nat. Madhukar Chandra (TU Chemnitz)

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Dipl.-Ing. Jörg Steinert (TU Chemnitz)

Dipl.-Ing. Patrick Tracksdorf (TU Chemnitz)

Jana Viessmann (TU Chemnitz)

Programme Overview

Day 1: Wednesday, 4th July 2007	
08:45 – 09:25	Opening of the conference
09:25 – 10:30	Inaugural Session
10:30 – 10:50	Coffee Break
10:50 – 12:30	Mobile and Indoor Propagation
12:30 – 13:45	Lunch Break
13:45 – 15:00	Polarimetric and Multi-Parameter Scattering
15:00 – 15:30	Multi-parameter Radar Systems and Applications
15:30 – 16:00	Coffee Break
16:00 – 17:40	Multi-parameter Radar Systems and Applications, continued
17:40 – 18:00	Panel discussion
19:00 – 23:00	Conference Dinner

Day 2: Thursday, 5th July 2007	
09:00 – 10:05	Propagation in Systems and Navigation
10:05 – 10:30	Coffee Break
10:30 – 11:10	Rain Attenuation and Scattering
11:10 – 12:20	Terrestrial Propagation and Signatures
12:20 – 13:30	Lunch Break
13:30 – 15:20	Calibration, Antennas, Signal Processing and System Aspects of Propagation
15:20 – 15:45	Coffee Break
15:45 – 16:05	Calibration, Antennas, Signal Processing and System Aspects of Propagation, continued
16:05 – 17:45	Polarisation in Propagation and Remote Sensing
17:45 – 18:00	Closing of the Conference

Day 1: Wednesday, 4th July 2007

08:30 – 08:45	Get-together and Registration (Hotel Foyer)
08:45 – 09:25	Opening of the conference
	Inaugural Session
	Session Chair: **W. Keydel** (DLR, Oberpfaffenhofen) **M. Chandra** (TU Chemnitz)
09:25 – 09:55	Antenna diversity for the improvement of satellite radio reception in fading scenario (Inaugural Lecture) **Lindenmeier, S.**, Reiter, L., Hopf, J., Barié, D. Institute of High Frequency Technology and Mobile Communication, University of the Bundeswehr Munich, Neubiberg, Germany
09:55 – 10:30	The TerraSAR-X/TanDEM-X Program (Inaugural Lecture) **Zink, M.**, Buckreuß, S. Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany
10:30 – 10:50	Coffee Break
	Session 1: Mobile and Indoor Propagation
	Session Chair: **R. Großkopf** (Institut für Rundfunktechnik)
10:50 – 11:10	Propagation measurements and modelling for future indoor communication systems at THz frequencies **Piesiewicz, R.**[1,3], Schoebel, J.[2,3], Koch, M.[2,3], Kürner, T.[1,3] (1) Institut für Nachrichtentechnik, Technical University of Braunschweig, Braunschweig, Germany (2) Institut für Hochfrequenztechnik, Technical University of Braunschweig, Braunschweig, Germany (3) Terahertz Communications Lab, Braunschweig, Germany
11:10 – 11:30	Einsatz von Mikrozellen als Optimierungsmaßnahme von UMTS Netzen Pouhè, D.[1], **Emini, D.**[2], Salbaum, M.[3] (1) Technische Universität Berlin, Berlin, Germany (2) Teleca Systems GmbH, Nürnberg, Germany (3) T-Mobile Deutschland GmbH, Nürnberg, Germany
11:30 – 11:50	Ray-Tracing for Mobile Communications **Knörzer, S.**, Fügen, T., Wiesbeck, W. Institut für Höchstfrequenztechnik und Elektronik, Universität Karlsruhe (TH), Karlsruhe, Germany
11:50 – 12:10	Hardware Acceleration Techniques for 3D Urban Field Strength Prediction Reyer, M., **Rick, T.**, Mathar, R. Institute for Theoretical Information Technology, RWTH Aachen University, Aachen, Germany

12:10 – 12:30	Investigation and suppression of multipath influence on indoor radio location in the millimetre wave range **Meier C.**[1], Terzis, A.[2], Lindenmeier, S.[1] (1) Institute of High Frequency Technology and Mobile Communication, University of the Bundeswehr Munich, Neubiberg, Germany (2) DaimlerChrysler Group Research, Ulm, Germany
12:30 – 13:45	Lunch Break
	Session 2: Polarimetric and Multi-Parameter Scattering Session Chair: **A. Hornbostel** (DLR, Oberpfaffenhofen)
13:45 – 14:30	Polarisation in nature, science and technology in the visible and near infrared spectral range (Review Lecture) **Böttger, U.** Institut für Planetenforschung, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Berlin, Germany
14:30 – 15:00	Use of multispectral information in safety relevant applications (Review Lecture) **Wanielik, G.** Professorship of Communications Engineering, TU Chemnitz, Chemnitz, Germany
	Session 3: Multi-parameter Radar Systems and Applications Session Chair: **C. Simmer** (Universität Bonn) **O. Fišer** (ASCR, Prague)
15:00 – 15:30	Perspectives for future SAR Antenna Development (Review Lecture) **Keydel, W.**[1], Chandra, M.[2] (1) Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany (2) Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
15:30 – 16:00	Coffee Break
	Session 3 continued
16:00 – 16:20	State-of-the-Art of Weather Radar Technology illustrated by the Selex Product Portfolio **Gekat, F.** SELEX Sistemi Integrati GmbH, Gematronik Weather Radar Systems, Neuss-Rosellen, Germany
16:20 – 16:40	Degree of Polarization for Weather Radar **Galletti, M.**[1], Bebbington, D. H. O.[2], Chandra, M.[3], Börner, T.[1] (1) Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany (2) Department of Electronic Systems Engineering, University of Essex, Colchester, UK (3) Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany

16:40 – 17:00	Reflectivity relationships of polarimetric C-band measurements of rain signatures **Steinert, J.**, Chandra, M. Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
17:00 – 17:20	Study of mixed-phase clouds using multipeak analysis of cloud radar data **Melchionna, S.**, Peters, G. Land im Erdsystem, Max-Planck-Institut für Meteorologie, Hamburg, Germany
17:20 – 17:40	Simulations and observations of multiple scattering effects in space-borne radars when observing precipitation systems (Review Lecture) **Simmer, C.**, Battaglia A. Meteorological Institute, University of Bonn, Bonn, Germany
17:40 – 18:00	Panel discussion
19:00 – 23:00	Conference Dinner

Day 2: Thursday, 5th July 2007

	Session 4: Propagation in Systems and Navigation
	Session Chair: **G. Wanielik** (TU Chemnitz)
09:00 – 09:25	Propagation Problems in Satellite Navigation (Review Lecture) **Hornbostel, A.** Institut für Kommunikation und Navigation, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany
09:25 – 09:45	Maximum Likelihood Parameter Estimation in a GNSS Receiver **Antreich, F.**[1], Nossek, J. A.[2] (1) German Aerospace Center (DLR), Oberpfaffenhofen, Germany (2) Munich University of Technology, Munich, Germany
09:45 – 10:05	On the impairment of SAR images caused by propagation through clouds **Danklmayer, A.**[1], Chandra, M.[2] (1) Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany (2) Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
10:05 – 10:30	Coffee Break and Poster Display
	Session 5: Rain Attenuation and Scattering
	Session Chair: **H.-R. Verworn** (Universität Hannover) **G. Peters** (Universität Hamburg)
10:30 – 10:50	Selected DSD properties for meteo radar applications and microwave link attenuation in rain **Fišer, O.** Institute of Atmospheric Physics, Prague, Czech Republic
10:50 – 11:10	Estimation of attenuation coefficients of an X-band weather radar using a dual frequency microwave link **Krämer, S.**, Verworn, H.-R. Institute of Water Resources Management, Leibniz University of Hanover, Hanover, Germany
	Session 6: Terrestrial Propagation and Signatures
	Session Chair: **D. Pouhè** (TU Berlin) **T. Kürner** (TU Braunschweig)
11:10 – 11:40	ITU Field-strength prediction methods for terrestrial point-to-area services (Review Lecture) **Großkopf, R.** Institut für Rundfunktechnik, München, Germany
11:40 – 12:00	Microwave Radar Signature Acquisition of Urban Structures **Kempf, T.**, Peichl, M., Dill, S., Süß, H. Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany

12:00 – 12:20	Soil Parameter Estimation and Analysis of Bistatic Scattering X-Band Controlled Measurements **Khadhra, K.-B.**[1,2], Börner, T.[1], Chandra, M.[2], Zink, M.[1], Hounam, D.[1] (1) Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany (2) Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
12:20 – 13:30	Lunch Break
	Session 7: Calibration, Antennas, Signal Processing and System Aspects of Propagation Session Chair: **W. Keydel** (DLR, Oberpfaffenhofen) **F. Gekat** (Gematronik Weather Radar Systems)
13:30 – 14:00	Microwave Radiometery – Imaging Technologies and Applications (Review Lecture) **Dill, S.**, Peichl, M., Jirousek, M., Süß, H. Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany
14:00 – 14:20	Weights Estimation of Phased Arrays moving in a Test Field **Molkenthin, T.** Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
14:20 – 14:40	Design of an Airborne SLAR Antenna in X-band **Limbach, M.** Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany
14:40 – 15:00	TerraSAR-X Calibration Ground Equipment **Döring, B.**, Schwerdt, M., Bauer, R. Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany
15:00 – 15:20	A Direct Comparison of SAR Processing as Non-Orthogonal Transform to both Fourier and Wavelet Transform **Fischer, J.**[1], Molkenthin, T.[2], Chandra, M.[2] (1) Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany (2) Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
15:20 – 15:45	Coffee Break
	Session 7 continued
15:45 – 16:05	Statistical aspects of polarimetric weather radar echoes **Tracksdorf, P.**[1], Chandra, M.[1], Danklmayer, A.[2] (1) Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany (2) Microwaves and Radar Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany

	Session 8: Polarisation in Propagation and Remote Sensing
	Session Chair: **U. Böttger** (DLR, Berlin) **G. Wanielik** (TU Chemnitz)
16:05 – 16:25	Electromagnetic and Computational Approach to Detect Depth of the Buried Object Using Radar Remote Sensing Data at X – band **Singh, D.** Department of Electronics & Computer Engineering, Roorkee, India
16:25 – 16:45	Investigations on the Polarimetric Behavior of a Target near the Soil **Marquart, N.** German Aerospace Center (DLR), Oberpfaffenhofen, Germany
16:45 – 17:15	On the differential propagation phase in weather radar measurements (Review Lecture) **Otto, T.** Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
17:15 – 17:45	Whither Polarimetry Today (Review Lecture) **Chandra, M.** Professur für Hochfrequenztechnik und Photonik, TU Chemnitz, Chemnitz, Germany
17:45 – 18:00	Discussion and Closing of the Conference: Panel

Abstracts

Inaugural Session

Session Char: W. Keydel
M. Chandra

WFMN07_I_A1

Antenna diversity for the improvement of satellite radio reception in fading scenario (Inaugural Lecture)

S. Lindenmeier, L. Reiter, J. Hopf, D. Barié

Institute of High Frequency Technology and Mobile Communication, University of the Bundeswehr Munich, Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany

In the last years digital satellite radio reception in cars has won increasing interest in the united states and is to be expected in Europe too. However the satellite radio services enable the reception of more than 100 channels in good quality, the reception quality is harmed a lot in urban multipath scenario where no supporting terrestrial repeaters are available as well as in rural multipath scenario where trees with dense foliage cause Rayleigh fading.
In this contribution the different fading scenarios are discussed with respect to the satellite reception quality. Concepts for antenna diversity are compared for the solution of this problem and a fast and efficient antenna diversity is introduced. The diversity concept is raising the reception performance in critical situations by up to two orders in magnitude and is easy to realize since no additional antenna cable and no additional tuner are required for the diversity function. By way of bit error rate measurements the performance of the antenna diversity concept is evaluated in a hardware demonstrator.

WFMN07_I_A2

The TerraSAR-X/TanDEM-X Program
(Inaugural Lecture)

M. Zink, S. Buckreuß

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After the successful participation in the Shuttle missions SIR-C/X-SAR and SRTM, the first national SAR mission TerraSAR-X opened a new era in the German Space Programme and provided a major push for our R&D activities on high resolution X-band SAR. TerraSAR-X will be launched in June 2007 will supply high-quality radar data for purposes of scientific observation of the Earth for a period of at least five years. At the same time it is designed to satisfy the steadily growing demand of the private sector for remote sensing data in the commercial market. In this spirit, the proposal to add a second, almost identical spacecraft (TDX), to TerraSAR-X (TSX) and to fly the two satellites in a closely controlled tandem formation building a single-pass SAR-interferometer with adjustable baselines in across- and in along-track directions was born. With typical across-track baselines of 200-400m DEMs according to the High Resolution Terrain Information (HRTI)-3 standard will be generated. TerraSAR-X and TanDEM-X are being implemented in a public-private partnership between the German Aerospace Centre (DLR) and EADS Astrium GmbH.

TSX features an advanced high-resolution X-Band Synthetic Aperture Radar based on the active phased array technology which allows the operation in Spotlight-, Stripmap- and ScanSAR Mode with various polarizations. It combines the ability to acquire high resolution images for detailed analysis as well as wide swath images for overview applications. In addition, experimental modes like the Dual Receive Antenna Mode allow for full-polarimetric imaging as well as along-track interferometry, i.e. moving target identification. TDX has SAR system parameters which are fully compatible with TSX, allowing not only independent operation from TSX in a mono-static mode, but also synchronized operation (e.g. in a bi-static mode). The HELIX concept provides a save solution for the close formation flight with vertical separation of the two satellites over the poles and adjustable horizontal baselines at the ascending/descending node crossings. Beyond the generation of a global HRTI-3 DEM as the primary mission goal, local DEMs of even higher accuracy level (HRTI-4) and applications based

on Along-Track Interferometry (ATI) like measurements of ocean currents, sea ice drift and glacier flow are important secondary mission objectives. Along-track interferometry will also allow for innovative applications to be explored and can be performed by the so-called dual-receive antenna mode on each of the two satellites and/or by adjusting the along-track distance between TSX and TDX to the desired value. Combining both modes will provide a highly capable along-track interferometer with four phase centers. The different ATI modes will e.g. be used for improved detection, localisation and ambiguity resolution in ground moving target indication and traffic monitoring applications. Furthermore, TanDEM-X supports new SAR techniques, with focus on multi-static SAR, polarimetric SAR interferometry, digital beam forming and super resolution.

Session 1: Mobile and Indoor Propagation

Session Chair: R. Großkopf

WFMN07_I_B1

Propagation measurements and modelling for future indoor communication systems at THz frequencies

R. Piesiewicz[1,3], J. Schoebel[2,3], M. Koch[2,3], T. Kürner[1,3]

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[2] Institut für Hochfrequenztechnik, Schleinitzstr. 22, Technical University of Braunschweig, Germany,
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[3] Terahertz Communications Lab, Braunschweig, Germany

The demand for higher data rates in indoor wireless communications is steadily growing. Current communication systems operate at few tens Mbps speeds in the ISM band at 2.4 GHz. Higher data rates require however larger bandwidths and consequently higher carrier frequencies. The unlicensed 60 GHz band, where data rates of the upcoming radio systems will reach up to 3 Gbps is an option. In order to have even greater data rates, higher carrier frequencies must be tapped. In the future, systems operating with data rates of 10 Gbps and beyond at the carrier frequencies above 100 GHz will be envisaged [1].
For the modelling of propagation behaviour of indoor radio systems, it is necessary to know the reflection and transmission characteristics of common building materials. Reflection and transmission losses of interior structures have been thoroughly characterised and modelled up to the frequencies of 60 GHz [2]. The lower part of the THz-band, extending from 300 GHz to 1000 GHz, which might be interesting to accommodate ultra-broadband high speed communication systems in the future, is still an almost unexplored land in this respect.
In the recent past, propagation studies at the Terahertz Communications Lab (TCL) at Braunschweig Technical University focused on modelling reflection and scattering processes in indoor environments based on measurements beyond 100 GHz [3,4,5,6]. This paper provides an overview of these activities and the results achieved so far. In particular, rough surface reflections are investigated. For exam-

ple, for concrete plaster or ingrain wallpaper (raufaser), which appear as flat surfaces at microwave bands, the surface roughness gains in importance at mm or sub-mm wavelengths. Also the effect of multiple reflections cannot be neglected any more for layered media. Typical examples for multi-layer surfaces are wall paper or wall paint on plaster.

References

[1] R. Piesiewicz, et al., "Short-Range Ultra Broadband Terahertz Communications: Concept and Perspectives", accepted for publication in *IEEE Antennas & Propagation Magazine.*

[2] K. Sato, et al., "Measurements of reflection and transmission characteristics of interior structures of office building in the 60 GHz band", *IEEE Trans. on Antennas and Propagation,* **45**, (12), 1997, pp.1783-1792.

[3] Piesiewicz, R., Kleine-Ostmann, T., Krumbholz, N., Mittleman, D., Koch, M., Kürner, T., "Terahertz characterisation of building materials", *Electronics Letters*, Vol. 41, No. 18, pp. 1002-1004, September 2005.

[4] Piesiewicz, R., Jansen, C., Wietzke, S., Mittleman, D., Koch, M., Kürner, T., "Properties of building and plastic materials in the THz range", *Interntl. Journal of Infrared and Millimeter Waves,* Vol. 28, No. 5, pp. 363-371, May 2007.

[5] Piesiewicz, R., Jansen, C., Mittleman, D., Kleine-Ostmann, T., Koch, M., Kürner, T., "Scattering analysis for the modeling of THz communication systems", accepted for publication in *IEEE Transactions on Antennas and Propagation.*

[6] Jansen, C., Piesiewicz, R., Mittleman, D., Kürner, T., T., Koch, M., "The impact of reflections from stratified building materials on the wave propagation in future indoor terahertz communication systems", submitted for publication in *IEEE Transactions on Antennas and Propagation.*

WFMN07_I_B2

Einsatz von Mikrozellen als Optimierungsmaßnahme von UMTS Netzen

D. Pouhè[1], **D. Emini**[2], M. Salbaum[3]

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UMTS Netze fordern eine exakte Planung und im Betrieb eine ständige Überwachung aller für die Qualität der Dienste relevanten Parameter. Die Leistungsfähigkeit des UMTS Netzes (Network Performance) wurde bislang unter dem Einsatz von sektorisierenden Makrozellen untersucht. Da für viele Dienste (Multimedianwendungen, Mobile-TV, Videotelefonie etc.) die erforderliche Kapazität schnell ausgeschöpft sein kann, müssen Netzbetreiber in Hotspot-Bereiche für Kapazitätserweiterungen sorgen. Eine weitere interessante Alternative zur Kapazitäts- und Qualitätserweiterung neben HSDPA und HSPUA könnte der Einsatz von Mikrozellen bieten. In GSM-Netzen wurden bereits sehr gute Erfahrungen mit deren Einsatz gemacht.
Die vorliegende Arbeit prüft, ob bei der Übertragung mit gleichem Träger (Gleichkanal zwischen Mikro- und Makrozellen) der Einsatz von Mikrozellen die Leistungsfähigkeit des UMTS Netzes steigern kann. Kernpunkt der Optimierungsstrategie ist dabei die Platzierung der Mikrozelle innerhalb des Referenzsektors, um ein möglichst großes Nutzen zu erzielen.
Haupterkenntnis bei der Variation des Abstandes zwischen Mikrozelle[1] und Referenz-Makrozelle ist, dass mit zunehmendem Abstand zwischen beiden Zellen das System wenig beeinträchtigt wird. Beim Einsatz der Mikrozelle im Nahfeldbereich der Makrozelle liegt der Durchsatz unter dem Wert, als würde sich keine Mikrozelle im System befindet (Abbildung 1). Die geringfügige Verbesserung der Empfangsleistung geht auf Kosten der örtlichen Interferenzsituation.

[1] Die eingesetzte Mikrozelle hat bei der praktischen als auch bei der numerischen Untersuchung eine Rundstrahlcharakteristik. Ferner setzt sie sich aus drei Outdoor-Abstrahlpunkten und einem Indoor-Abstrahlpunkt zusammen, die jeweils mit ¼ der Gesamtausgansleistung (20 Watt) senden.

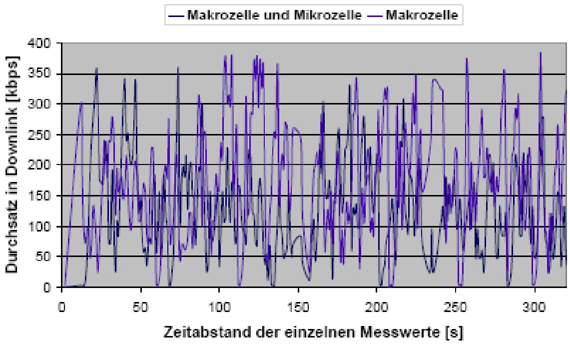

Abbildung 1: Durchsatz mit und ohne Mikrozelle, Mikrozelle im Nahbereich der Referenz-Makrozelle.

Aufgrund der gewonnenen Erkenntnis stellt sich die Frage: Wie verhält sich das System, wenn die Mikrozelle am Versorgungsrandgebiet einer Referenz-Makrozelle eingesetzt wird?
Versorgungsrandgebiete sind in d. R. schwach versorgt und es herrscht Unstabilität hinsichtlich des Best-Servers im System (d.h., kein „dominierender" Sender, so dass mehrere Sender zur Interferenzsituation beitragen). Es könnten auch Versorgungslücken in Folge der Zellatmung entstehen. Durch den Einsatz von Mikrozellen kann in einem solchen Bereich die Leistungsfähigkeit des UMTS-Netzes stark gesteigert werden. Neben der Verbesserung der Empfangsleistung (Abbildung 2) wird auch die Interferenzsituation enorm verbessert, da nun die Mikrozelle im System als „dominierender" Sender existiert, so dass der Signal-Rausch-Abstand wesentlich größer wird und das Nutzsignal gegenüber dem Rauschsignal dominiert. Im Durchschnitt ergibt sich eine Verbesserung des SNR zwischen 3 und 4 dB.

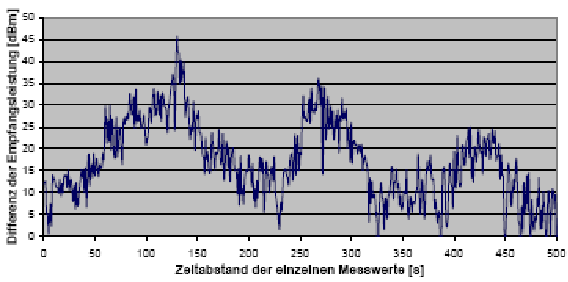

Abbildung 2: Differenzpegel[2] bei Einsatz einer Mikrozelle im System.

Anhand des „Optimierungsdreieckes für Mobilfunknetze" wird das erreichbare Optimum des untersuchten UMTS-Netzes unter Einsatz von Mikrozellen aufgezeigt.

[2] Die Messwerte ergeben sich beim Durchlaufen der drei Outdoor-Versorgungsbereiche.

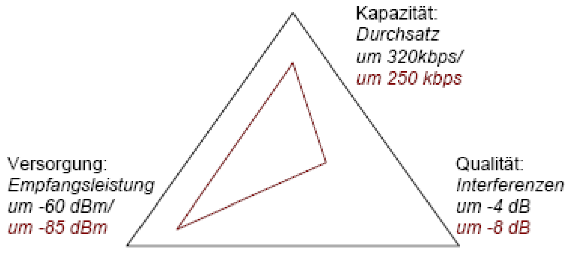

Abbildung 3: „Optimierungsdreieck", Rotes[3] Dreieck: Das Netz ist nicht optimiert, Schwarzes[4] Dreieck: Erreichbares Optimum durch Mikrozellen.

Im Untersuchungsgebiet (Altstadt von Nürnberg) können mehrere Bereiche identifiziert werden, die die Randbedingungen[5] für den Einsatz von Mikrozellen erfüllen.

[1] Harri Holma , Anti Toskala, "WCDMA for UMTS", John Wiley & Sons, Chichester 2000.

[2] Joseph Shapira, "Microcell Engineering in CDMA Cellular Networks", IEEE Transactions on Vehicular Technologie, Vol.43, No.7, November 1994.

WFMN07_I_B3

Ray-Tracing for Mobile Communications

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For the parameterization and standardization of future mobile communications systems realistic values of the characteristic channel parameters are needed.
Due to its ability to analyze the frequency-selective, time-variant as well as spatial behavior of the channel, ray-tracing is a popular channel characterization method. Moreover, it is capable to calculate very large structures (i.e. site-specific scenarios) with reasonable computation resources.
Ray-tracing is based on a detailed simulation of the actual physical wave propagation proc-

[3] Die rot markierten Werte zeigen die Mittelwerte der gemessenen Parameter in den jeweils identifizierten Bereichen.
[4] Die schwarz markierten Werte zeigen die Mittelwerte der gemessenen Parameter unter Einsatz von Mikrozellen.
[5] Randbedingungen: Hotspot (Hohes Verkehrsaufkommen) sowie Blackspot (Schwach versorgte Gebiete).

ess. In order to produce a deterministic description of the wave propagation, suitable formulations of the physical propagation phenomena are applied to a deterministically described scenario. The modeling of the propagation phenomena is usually based on geometrical optics (GO) and the uniform geometrical theory of diffraction (UTD).
In the presentation and paper a basic description of the characteristic channel parameters like delay spread, Doppler shift, Doppler spread, angular shift, angular spread is given. Further, an actual implementation of ray-tracing for mobile communications developed at the IHE is presented. The propagation phenomena taken into account in the channel model are combinations of multiple reflections, multiple diffractions and scattering.
Three application examples are given using the ray-tracing model to characterize the channel parameters. First, the ray-tracing approach is applied for a car-2-car communications system. The model is verified by comparing measurements with simulation results in a realistic urban scenario and in statistically generated highway scenarios. Second, the same tool is used to calculate the propagation channel in urban outdoor environments. Third, the characteristic channel parameters for a high-speed train communications system are presented. The fast moving trains that cause high Doppler spread in the channel are a special challenge for the design of the communications system.

WFMN07_I_B4

Hardware Acceleration Techniques for 3D Urban Field Strength Prediction

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Accurate radio wave propagation predictions are a prerequisite for effective dimensioning of cellular radio networks. Automatic cell planning algorithms have to explore a vast amount of network configurations to find an optimal solution. Hence, on one hand the reliability of cell planning solutions is strongly influenced by the prediction quality of the propagation algorithms. On the other hand, planning time is directly dominated by the run-time of the underlying field strength prediction algorithms. Therefore, low computation times of accurate field strength predictions are essential for automatic cell planning algorithms to find appropriate solutions in acceptable time.
In spite of their very poor prediction quality, statistical propagation models are frequently used, due to short run-times. This may be sufficient for simple rural environments. However, complex urban scenarios demand for a great emphasis on sitespecific details in the propagation environment which are not covered by such statistical approaches. Ray tracing algorithms compute paths through a scene due to wave guiding effects like reflection and diffraction and are well-known to achieve extremely accurate prediction results at the cost of very large run-times. To cope with high run-times, usually all necessary propagation predictions are precomputed and stored in large databases, to be accessed later by planning algorithms.
In previous work a discrete ray launching approach has been proposed to counteract the high run-times of classical ray tracing algorithms while maintaining high prediction accuracy. This has successfully reduced run-times down to roughly 10 seconds for a 7 km^2 urban area. The key idea of this ray launching algorithm is to represent urban environments by a grid of discrete blocks which are either filled or empty, depending on whether a building is present in the location of the block or not. Costly ray-object intersections are then replaced by traversing those blocks via an algorithm which samples a continuous line into discrete components.
Graphics cards for personal computers offer a hardware implementation of such a line rasterization algorithm. In this paper we therefore propose to exploit such hardware. Our current results indicate that run-times are significantly reduced by this approach.
The advantages of the enormous run-time reduction is twofold. First, field strength predictions can be delivered to cell planning algorithms on demand, i.e., there is no longer a need for precomputations. Second, statistical propagation models can be replaced by accurate ray launching algorithms improving overall results, without increasing planning time.

WFMN07_I_B5

Investigation and suppression of multipath influence on indoor radio location in the millimetre wave range

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In an increasing range of indoor applications a precise localization of objects is required. This

can be done by mounting one or multiple transponders onto the objects and to track these transponders by help of receivers which are installed at fixed positions inside the room. The accurate radio location and tracking of transponders in indoor environment is usually harmed very much by multipath propagation effects.
In this presentation an ultra wideband radio location system concept is investigated which is able to suppress spurious solutions of reflection paths. The concept is based on the transmission of fast ultra wideband pseudo-noise codes and a time of arrival and phase measurement together with a tailored signal processing. By example of a hardware demonstrator, measurement results show the precision of the system in the mm-range and its ability to suppress spurious influence of reflections inside a complex indoor environment.

Session 2: Polarimetric and Multi-Parameter Scattering

Session Chair: A. Hornbostel

WFMN07_I_C1

Polarisation in nature, science and technology in the visible and near infrared spectral range (Review Lecture)

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An overview is given about the polarization of visible and near infrared light in nature. An historical abstract of the discovery of polarized light is presented. The processes producing polarized light as well as its 'usage' in nature is shown. A short introduction will provide an inside, how polarization is treated in science by solving the radiative transfer equation. The focus is put here on remote sensing. The problems which arise due to polarization for remote sensing optical technology are pointed out. At the end an application of polarization measurements with POLDER/ADEOS from space to derive aerosol Characteristics is presented.

WFMN07_I_C2

Use of multispectral information in safety relevant applications (Review Lecture)

G. Wanielik

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Scattering of electromagnetic waves depends strongly on the frequency of the wave. Each frequency delivers another "look" onto the same object and generates different information. Sensors for advanced driver assistance systems (ADAS) make use of this different information provided from different spectral bands of the electromagnetic spectrum. The combination of this multispectral information is the task of multisensor data fusion which is the emphasis of his paper.

Due to safety relevant applications the scenario interpretation around the car has to deliver a high systems performance. Most applications need a very low false alarm rate and a good detection rate which can not be guaranteed by one sensor. This is the reason why different sensors are combined.

ADAS –sensors are 77 Ghz long range radar, 24 GHz short range radar, multilayer Lidar, Far- and Near- Infrared cameras as well as cameras within the visible spectral region and a 3D-camera. A number of combinations of different sensors is discussed in several ADAS-applications.

Session 3: Multi-Parameter Radar Systems and Applications

Session Chair: C. Simmer
O. Fišer

WFMN07_I_C3

Perspectives for future SAR Antenna Development (Review Lecture)

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A Synthetic Aperture Radar, principally, produces a long linear array antenna by means of computer technique moving a small antenna along a straight line and collecting and storing all signals with respect to amplitude, phase, frequency, polarization, and running time for gaining desired information with special processing algorithms. Therefore, a SAR is an antenna. The most essential SAR system component, however, is the real SAR antenna itself; it is, for example, the greatest weight driver for space borne SAR, and there is no SAR system design equation which does not content SAR antenna parameters.
Goal of the paper is to present the expected development of future antennas for space borne SAR based on the state of the art and to point out under that aspect some perspectives and visions for future space borne SAR systems.
Future space borne SAR systems will consist mainly of the antenna with a small number of peripheral elements only, like solar cells, GPS, power supply, downlink equipment etc.. The present space borne SAR Antenna will mutate to a complete Antenna SAR that means a SAR which is primary an antenna where all radar components inclusive the AD-Converter and the image processing computer are integrated. A substantial step to an Antenna-SAR is the expected progress in miniaturization shown in a respective roadmap. The miniaturization will drastically reduce the mass and volume of the antenna including the RF system down to 10 % of the today's value. Ultra-light-weight antennas with large structural components, such as deployable ore inflatable booms, and membranes with very low power consumption will be available during the next decade.
For a senor fleet in space consisting of many satellites in a well known and controlled formation flight each satellite receiver (and transmit-

ter respectively) may be considered as a single element of a very large DBF-Array.
For airborne SAR the antenna dimensions are limited due to the size and shape of the platform. Here digital beam forming allows to form small sub arrays to a conformal array, a so called smart skin. For the next two decades broadband arrays are expected which are able to share between SAR, other radars, forward looking radar for example, electronic support as well as electronic countermeasures, and communication purposes. This will increase the effectiveness and the applicability of future SAR systems by reducing the overall mass, volume, and cost which are indispensable requirements for the future.
Based on both the states of the art and the expected developments of antennas, RF micro electronics, and SAR techniques and technologies an outlook in the future of SAR antenna development shows that the SAR Antenna will mutate to an Antenna SAR.

WFMN07_I_D1

State-of-the-Art of Weather Radar Technology illustrated by the Selex Product Portfolio

F. Gekat

SELEX Sistemi Integrati GmbH, Gematronik Weather Radar Systems, Neuss-Rosellen, Germany

A brief overview over the state-of-the-art of weather radar technology will be provided. Aspects of Doppler and polarimetric operation will be addressed. Technical data will be given for small and mobile X-Band weather radars as well as for long-range fixed installation S- and C-Band systems based on the product portfolio of Selex Sistemi Integrati GmbH.

WFMN07_I_D2

Degree of Polarization for Weather Radars

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Weather Radars are a fundamental tool for National Weather Services. Planned operational systems are likely to include Doppler and dual polarization, whose usefulness has been widely demonstrated in the last twenty years. Such radars will probably implement hybrid polarization, a mode that involves transmitting slant 45° and receiving the horizontal and vertical components of the backscattered signal. The reasons for such a choice are both theoretical and practical. The theoretical assumption is that weather targets most often appear to satisfy mirror reflection symmetry about the vertical axis. Practical considerations that make this choice operationally attractive is that, besides being more expensive, switched systems are characterized by increased feed complexity and more difficult calibration procedures. Further, hybrid polarization was conceived to effectively measure Z_{DR}, KDP and ρ_{HV}, which have been perceived operationally to be useful qualitative and quantitative parameters.
A variable available to dual polarization coherent radar systems is the degree of polarization, obtainable from Wolf's coherency matrix. However, for a given incoherent target, the degree of polarization of the backscattered wave is dependent on the transmit polarization state. To investigate this dependence, we resorted to process fully polarimetric weather radar signatures and compute, from the same dataset, the degree of polarization for different transmit states. A way to measure the degree of polarization capability to capture information from an incoherent target is a confrontation with entropy, a scalar quantity relating to the heterogeneity of statistically independent degrees of freedom existing in the scattering population. As Entropy is designed to capture the whole polarimetric heterogeneity of the scattering population, the minimal degree of polarization (the degree of polarization obtained from the transmit states that minimize its value) is expected to mirror entropy behavior rather faithfully.
A fully polarimetric radar is able to transmit pulses whose polarization state is switched every pulse repetition period (polarization agility) and is set to simultaneously receive the co- and cross- polar components of the backscattered signal (dual receiver). Such a set up allows quasi-simultaneous measurements of the complete scattering matrix. The first meteorological radar designed to measure complete scattering matrices of weather targets was developed at DLR about twenty years ago and is known to the weather radar community as POLDIRAD, acronym for polarization diversity radar. The term polarization diversity refers to its capability of being able to fast-switch on transmit between any pair of orthogonal polarization states. To collect the data presented in this work, POLDIRAD was operated to switch between horizontal and vertical polarization states on transmit, and was set to receive the copolar and cross-polar components of the

backscattered signal. This operation mode is called VHVH, but, as pointed out above, other modes are also possible like RLRL using right and left circularly polarized transmissions, as well as hybrid polarization. Ideally, all elements of a scattering matrix should be measured simultaneously. However, since (unless some coding scheme can be used) the transmit polarizations must be emitted sequentially, the scattering matrix measured by a fully polarimetric weather radar is affected by both mean motion of the target and decorrelation due to random displacements of the single scatterers. Mean motion results in a phase offset between the first and second column of the scattering matrix while random motion manifests itself in amplitude and phase fluctuations of the backscattered signal as well as some depolarization. If the second effect cannot be corrected, special signal processing procedures must be applied to correct for the Doppler phase shift.

WFMN07_I_D3

Reflectivity relationships of polarimetric C-Band measurements of rain signatures

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With dual polarimetric radar it is possible to distinguish between several types of precipitation. In this study the view was focused on liquid hydrometeors which appear in stratiform and convective clouds with different polarimetric signatures. The basis for the analysis are datasets from the dual polarimetric C-Band weather radar POLDIRAD (DLR, Oberpfaffenhofen).

The aim of this study was to find out relations for raindrops between the reflectivity at horizontal polarisation Z_H and the differential reflectivity Z_{DR}. These empirical Z_H - Z_{DR} relationships will be introduced and the differences of raindrops in stratiform and convective clouds will be discussed.

A future task can be the comparison of the empirical equations with the microphysical properties and theoretical models of raindrops.

WFMN07_I_D4

Study of the mixed-phase clouds using multipeak analysis of cloud radar data

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In this contribution the use of a vertically pointing 8.3 mm wavelength radar for studying mixed-phase in clouds will be described. The Ka-band radars are particularly suited for cloud droplets and small rain drop regime measurements, by their capability to penetrate through rain- and snow-falls and to detect small hydrometeors. Traditionally three moments of Doppler spectra are used as basis to retrieve microphysical cloud parameters, e. g. characteristic particle size, liquid water content and turbulence parameters. Here additional features of the Doppler vertical velocity spectra will be described, which permit to extract more detailed information on the microphysical structure of clouds and on the kinetics in clouds, particularly in cases of mixed-phase coexisting cloud- and drizzle-droplets.

A peak detection algorithm has been developed, by which the Dopplerspectra are decomposed into multiple peaks. When possible, also the peak-specific linear depolarization ratio is estimated for every mode of the spectra, to derive information on phase and type of the hydrometeor associated to it. Examples of Doppler spectra profiles will be shown to illustrate the retrieval technique.

This peak detection algorithm appears to be an advantageous tool to extract information on mixed-phase clouds by the evaluation of multimode moments and LDR of hydrometeors. A prospective to a better cloud kinetics understanding is outlined by the assessment of the vertical mean velocity gradient in clouds. Also the observation of parallel structures present in the spectra profiles can be useful to this purpose.

Further steps towards unambiguous interpretation is to integrate this enhanced analysis in a multi-sensor system, including lidar and microwave radiometer measurements and a cloud resolving model.

In order to assess the feasibility of this hydrometeor classification to inferring mixed-phase ratios, measurements are now being collected together with other remote sensing systems as well as in-situ aircraft measurements of cloud microphysics within the COPS experiment (Convective and Orographically-induced Precipitation Study) taking place presently in southern Germany (http://www.uni-hohenheim.de/spp-iop).

WFMN07_I_D5

Simulations and observations of multiple scattering effects in space-borne radars when observing precipitation systems (Review Lecture)

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Recent work has highlighted the importance of multiple scattering effects when dealing with high frequency space-borne radars in configurations like those planned or employed for the GPM, the CloudSat, and the EarthCare missions. The first images delivered by the 94 GHz Cloud Profiling Radar on board of CloudSat when passing precipitating systems provide distinctive signatures of multiple scattering effects (e.g. no 'discontinuity' peak in the reflectivity signal at the surface range, long tails in the reflectivity profiles at apparent ranges below the surface).

A numerical model based on the Monte Carlo solution of the vector radiative transfer equation has been developed to simulate radar signals. Except for contributions due to the backscattering enhancement, the model is particularly suited for evaluating multiple scattering effects. The model accounts for general radar configurations such as airborne/space-borne/ground-based, monostatic/bistatic, and includes the polarization, the antenna pattern and the interaction with a Kirchoff surface as particularly relevant features. Multiple scattering effects in co- and cross-polar radar returns are evaluated for realistic vertically inhomogeneous scenarios involving rainfall, snow, graupel, and ice crystals extracted from cloud resolving model simulations forspace-borne and air-borne configurations.

Results show that the multiple scattering enhancements become a real issue for space-borne Ka band radars for medium to heavy precipitation and for W band radars already in the presence of light precipitation. Multiple scattering effects can reach several tens of dB when heavy cold rain systems are considered, i.e. when the profiles include rain layers with a high density of ice particles aloft. Multiple scattering effects are, however, highly dependent on the ice layer of the cloud and on its microphysical assumptions (e.g. large ice particles strongly enhance multiple scattering). For some of the simulated profiles, reflectivities display no discontinuity at the surface range and long signal tails at ranges below the surface range in accordance with Cloudsat observations.

When the cross-polar returns are analyzed, high LDR values appear both in space-borne and air-borne configurations. The LDR signatures are indicators of multiple scattering effects since they cannot be explained by single scattering computations even including non-spherical particles.

Session 4: Propagation in Systems and Navigation

Session Chair: G. Wanielik

WFMN07_II_A1

Propagation Problems in Satellite Navigation (Review Lecture)

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The presentation will provide an overview about the mechanisms of the main propagation phenomena which are relevant for satellite navigation, their magnitude, temporal and regional variation and standard methods to correct and mitigate them.
Since satellite navigation is based on measuring the signal delay between transmission at the satellite and reception by the user, the modelling and correction of the additional delay due to the propagation through the atmosphere plays an important role for the accuracy of the derived position solution. The largest signal delay occurs within the ionosphere. Because the ionospheric delay depends on frequency, it can be precisely determined and nearly completed eliminated by dual frequency measurements. However, for single frequency receivers, like most commercially available GPS receivers for the mass market, it must be corrected by modelling, and a significant error can remain.
The troposphere delay can be separated in a wet component due to water vapour and a dry component due to other atmospheric gases. While the dry delay can be modelled with high accuracy, the wet delay is a crucial component if accuracies in the decimetre or centimetre range are required, although it contributes normally only with 10%-20% to the total delay, because of the high temporal and spatial variability of the water vapour content in the troposphere.
Since current global navigation satellite systems like GPS, GLONASS and coming Galileo operate in L-band, attenuation by the atmosphere is negligible. This may change for next generation systems in the future, if additionally higher frequency bands are utilized, e.g. C-Band, which is already allocated for Galileo. However, also in L-band, occasionally, fast amplitude and phase scintillations can occur due to fast variations of the total electron content in the ionosphere or atmospheric turbulences. Strong scintillations occur only rarely, but then they are critical and can even lead to complete loss of the navigation signals by the receiver.
Due to the extreme low signal power of the satellite navigation signals when arriving at the Earth, the signals can be easily attenuated and shadowed by buildings or vegetation, e.g. in urban or rural environments or for indoor applications. In these environments additionally multipath propagation by reflexions of the signals by buildings and other obstacles before they arrive at the user antenna can significantly degrade the ranging and positioning accuracy. Multipath propagation is difficult to correct by models, because it depends strongly on the local user environment. Different techniques exist to mitigate the effect of multipath signals partly in the signal processing of the receiver, but multipath mitigation is still a hot topic of research.

WFMN07_II_A2

Maximum Likelihood Parameter Estimation in a GNSS Receiver

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The potential of the SAGE (Space Alternating Generalized Expectation Maximization) algorithm for global navigation satellite systems (GNSS) in order to distinguish the line-of-sight signal (LOSS) is to be considered. The SAGE algorithm is a low-complexity generalization of the EM (Expectation-Maximization) algorithm, which iteratively approximates the maximum likelihood estimator (MLE) and has been successfully applied for parameter estimation (relative delay, incident azimuth, incident elevation, Doppler frequency, and complex amplitude of impinging waves) in mobile radio environments. This study discusses receivers using an uniform rectangular array (URA) of isotropic sensor elements. We estimate the complex amplitudes, relative delays, and Doppler frequencies, and the spatial signature of the impinging waves (incident azimuth and elevation). The results of the performed computer simulations and discussion indicate that the SAGE algorithm has the potential to be a very powerful high resolution method to successfully estimate parameters of impinging waves for navigation systems. SAGE has proven to be a promising method to combat multipath for safety-of-life navigation applications due to its good performance, fast convergence, and low complexity.

WFMN07_II_A3

On the impairment of SAR images caused by propagation through clouds

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Imaging of the earth surface using space- and airborne SAR systems is generally considered to be independent of weather conditions. However, cloud systems are "active" media when it comes to microwaves propagating through them.
The "activity" is capable of generating attenuation, phase-shifts and depolarisation. These features are, in turn, capable of distorting the SAR images generated from radar signal propagating through such cloud media. In this paper, we shall quantify the magnitude of these propagation effects that can typically arise from precipitating cloud systems. The proposed analysis will exploit weather radar observations for this purpose. The changes in the SAR images resulting from such propagation impairments will be highlighted.

Session 5: Attenuation and Scattering

Session Chair: H.-R. Verworn
G. Peters

WFMN07_II_B1

Selected DSD properties for meteo radar applications and microwave link attenuation in rain

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The radar reflectivity factor as well as the specific rain attenuation (of the radar signal, or of the microwave and mm wave link or MWS signal) does depend on the rain rate only roughly. They both depend on the drop size distribution (DSD) primarily; this fact is frequently neglected. As we have an one year DSD measurement, we used the DSD data to derive the radar reflectivity factor as well as the rain rate from it on one hand and the rain attenuation in the cm and mm frequency bands on the other hand. Interesting properties were selected. The particular contribution of rain drops of certain diameters to the rain attenuation is varying considering varying frequency. More concretely, the role of small rain drops is increasing with the frequency. The prevailing contribution is caused by drops of the equivolumetric sphere diameter close to 0.7–1.5 mm.
A big dispersion of rain rate values R corresponding to the observed values of the radar reflectivity factor Z is known through scatterplots. It is due to the DSD variability. Similar scatterplots "attenuation versus rain rate" were done considering frequencies in the 10 - 100 GHz region. A big dispersion is observed, too, but the dispersion depends on the frequency. It was found that the rain attenuation at frequencies close to 40 GHz depends on rain rate quite uniquely. These phenomena are discussed in this contribution.
All results in this contribution were derived from the actual drop size distributions measurement by the videodistrometer of ESA, which was lent to the Institute of Atmospheric Physics Prague in the period July 1998–July 1999.

WFMN07_II_B2

Estimation of attenuation coefficients of an X-band weather radar using a dual frequency microwave link

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Weather radar systems for monitoring rainfall suffer from the problem of attenuation due to intervening rainfall. This holds especially for radars operating at X-band frequencies but also C-band frequencies are seriously attenuated in case of severe rainfall. The problem of attenuation was addressed by Hitschfeld and Bordan (1954). They proposed an algorithm to correct the radar signal for attenuation. Even though mathematically exact, their solution shows an inherent instability due to radar calibration errors, clutter echoes and inappropriate estimation of the attenuation coefficients (a,b) which are used to express the relation between specific attenuation k and reflectivity Z ($k = a \times Z^b$). When applying the Hitschfeld-Bordan algorithm generally a preselected combination of attenuation coefficients is used. In many cases the attenuation correction becomes instable due to overestimation of the signal correction. When a reference is available the signal overestimation can be avoided.
In order to provide an attenuation reference for an X-band weather radar (9.47 GHz horizontal polarisation) a dual frequency microwave link was installed operating at 17.5 GHz and 10.5 GHz vertical polarisation. With the receivers on the radar tower the link with a length of 29.6 km is parallel to one of the radar beams. When appropriate algorithms are used to define periods of rainfall within the link, time series of signal attenuation may be derived for the 10.5 GHz frequency as reference ($a_{reference}$). These reference time series have been used for the optimal estimation of the attenuation coefficients a and b of the radar correction algorithm
($a_{reference} \equiv a_{radar\ correction}$ (a,b))
The results show that a large number of (a,b) combinations exists for each minutely measurement which satisfy the optimization criterion. The location of the optimized (a,b) combinations within the (a,b) parameter space reveals a systematic behaviour depending on rainfall type and intensity. The use of attenuation variable coefficients to correct the radar signal is highly efficient and allows signal corrections of up to 30 dB.

Session 6: Terrestrial Propagation and Signatures

Session Chair: D. Pouhè
T. Kürner

WFMN07_II_B3

ITU Field-strength prediction methods for terrestrial point-to-area services (Review Lecture)

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Introduction

The International Telecommunication Union (ITU) is the leading United Nations agency for information and communication technologies. As the global focal point for governments and the private sector, ITU's role in helping the world communicate spans 3 core sectors: radiocommunication, standardization and development. ITU is based in Geneva, Switzerland, and its membership includes 191 Member States and more than 700 Sector Members and Associates.

Propagation prediction methods

ITU Study Group 3 "Radiowave Propagation" and its Working Parties developed a number of field-strength prediction methods for various applications. Since 2001 the author of this paper is the Chairman of ITU Working Party 3K dealing with propagation for terrestrial point-toarea services and, hence the emphasis of this paper is on prediction methods for these services. This paper gives an overview of the propagation methods developed under the responsibility of WP 3K, covering applications such as terrestrial broadcasting, land mobile services, aeronautical services, broadband radio access systems, radio local area networks, short-range indoor and outdoor radiocommunication systems and ultra-wideband devices.

The respective ITU-R Recommendations dealing with propagation aspects for terrestrial services will be presented. These are:

P.528 Propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands

P.1238 Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 900 MHz to 100 GHz

P.1406 Propagation effects relating to terrestrial land mobile service in the VHF and UHF bands

P.1410 Propagation data and prediction methods required for the design of terrestrial broadband radio access systems operating in the frequency range 3 to 60 GHz

P.1411 Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz

P.1546 Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz

P.1791 Propagation prediction methods for assessment of the impact of ultra-wideband devices

New A path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands

New The prediction of the time and the spatial profile for broadband land mobile services using UHF and SHF bands

WFMN07_II_B4

Microwave Radar Signature Acquisition of Urban Structures

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Global and reliable reconnaissance using remote sensing techniques requires a weather and time independent detection, recognition, and identification capability for objects of interest. A space-borne high resolution SAR system in a spotlight mode can be an appropriate instrument. In the design phase of such a mission the availability of representative radar data from ground measurements is important for the analysis, the understanding simulation of complex target signatures, and for reference signatures used in automatic target recognition (ATR).
Inverse SAR (ISAR) imaging allows the collection of very precise two-dimensional high-resolution radar signatures from objects. For a space-borne radar system, the imaging geometry is similar and differs only by a geometrical transformation. With ISAR high resolution images in the decimetre range are accomplished by rotating an object on a turntable with respect to a spatially fixed broadband radar system, and by recording a sequence of corresponding radar range returns within a specific azimuth angle area.
Especially target recognition by radar in urban environment is challenging due to several image confusing effects like multi-path reflections, overlay, and shadowing. In order to support SAR simulation tools with measured data of urban elements, tower-turntable ISAR experiments have been performed on walls of miscellaneous building materials. Following an introduction of the measurement setup and the image processing, this paper shows some first results.

WFMN07_II_B5

Soil Parameter Estimation and Analysis of Bistatic Scattering X-Band Controlled Measurements

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To date only very few bistatic measurements (airborne or in controlled laboratories) have been reported. Therefore most of the current remote sensing methods are still focused on monostatic (backscatter) measurements. These methods, based on theoretical, empirical or semi-empirical models, enable the estimation of soil roughness and the soil humidity (dielectric constant). For the bistatic case only theoretical methods have been developed and tested with monostatic data. Hence, there still remains a vital need to gain of experience and knowledge about bistatic methods and data. The main purpose of this paper is to estimate the soil moisture and the soil roughness by using full polarimetric bistatic measurements. In the experimental part, bistatic X-band measurements, which have been recorded in the Bistatic Measurement Facility (BMF) at the DLR Oberpfaffenhofen, Microwaves and Radar Institute, will be presented. The bistatic measurement sets are composed of soils with different statistical roughness and different moistures controlled by a TDR (Time Domain Reflectivity) system. The BMF has been calibrated using the Isolated Antenna Calibration Technique (IACT). The validation of the calibration was achieved by measuring the reflectivity of fresh water. In the second part, the sensitivities of the bistatic surface scattering to soil moisture and surface roughness will be dis-

cussed. Then, the validation of the specular algorithm by estimating the soil moisture of two surfaces with different roughness scales will be reported. Additionally, a new technique using the coherent term of the Integral Equation Method (IEM) to estimate the soil roughness will be presented, as well as evaluation of the sensitivity of phase and reflectivity with regard to moisture variation in the specular direction.

Session 7: Calibration, Antennas, Signal Processing and System Aspects of Propagation

Session Chair: W. Keydel
F. Gekat

WFMN07_II_C1

Microwave Radiometery – Imaging Technologies and Applications (Review Lecture)

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Microwave radiometry deals with the measurement of the natural thermally caused electromagnetic radiation of matter at a physical temperature above 0K. In the case of Earth observation significant contrasts can be observed between reflective and absorbing materials due to the impact of reflected sky radiation of cosmic origin. The main MMW windows for sufficient atmospheric penetration and low sky brightness temperatures are at frequencies around 35, 94, 140 and 220GHz. For Earth observation, an approximate brightness temperature range from 3K to more than 300K can be observed. In the microwave region the spatial two-dimensional brightness temperature distribution can be used as a daytime and almost weather independent indicator for many different physical phenomena. Hence, interesting application areas incorporate geo science, climatology, agriculture, pollution and disaster control, detection, reconnaissance, surveillance, and status registration in general. Since a few years security applications like personnel screening and the monitoring of critical infrastructures are also of major interest. Many of those applications require high spatial and radiometric resolution, high precision, large fields of view, and high frame rates.
Today three radiometric imaging methods are mainly considered. The first more classical one is based on a linescanner approach and is relatively easy to implement, but it has strong limitations concerning the spatial resolution and the field of view (FOV). The second more innovative method called aperture synthesis uses interferometric techniques and offers higher resolution, real-time imaging, and a larger field of view at the cost of much more expense. It is a subject of actual research. The third principle uses a focal plane array and a focusing aperture as in many optical systems. Thus real-time imaging is possible, but for

present technologies high resolution systems with larger FOVs are associated with a high expense. Coherent signal processing for a very high and almost distance independent spatial resolution as in the case of synthetic aperture radar is not applicable to radiometric imaging.
The paper gives a brief introduction to the physical background of microwave radiometry and illustrates the mostly considered imaging principles. Typical examples from current practice and basic experimental measurements for future applications are shown.

WFMN07_II_C2

Weights Estimation of Phased Arrays moving in a Test Field

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Due to the high performance and degree of flexibility of microwave instruments using phased array antennas, a comprehensive characterization of the antenna is essential and a major challenge. New concepts are needed to keep the costs and effort acceptable. A new characterization technique is proposed, the so-called Weight-Estimation Method (WEM), which permits the excitation coefficients, or weights of the array elements to be estimated from a limited number of far-field measurements. With these weights, i.e. the gains and phase settings applied to the elements of the phased array, the complete antenna pattern in the range of +/- 90 degree about the boresight can be derived. The concept is applicable for any phased array system sensing electromagnetic signals. The paper describes the measurement concept, the estimation method and presents simulated results for measurements in a compact range and with the antenna in motion. The method was developed to characterize phased array antennas of synthetic aperture radars (SAR) and promises to simplify the on-board calibration circuitry of future instruments.

WFMN07_II_C3

Design of an Airborne SLAR Antenna in X-band

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Considerable interest has been developed recently in pollution surveillance in ocean regions with microwave radar systems. SLAR- systems appears to be extremely useful for the wide range detection of oil pollution on sea surface.
The paper describes first steps and results in the development of an airborne x-band antenna for a real aperture side looking radar systems. A slotted waveguide design is suitable to meet the requests of high power and high gain capability.
For proper resolution the antenna azimuth beamwidth should be less than 0.6 degree because the maximum operational distance is 40km. Therefore the length of the real aperture has to be about 120 to 150 wavelengths long. Changes in mechanical structure due to temperature drift, wind load and vibrations could lead to distortions of the antenna's directivity function. To prevent for these degradations the slotted waveguide antenna is designed as an array of small radiating elements with a standing wave configuration, feed by a waveguide, guiding a travelling wave.
General design parameters are presented and the concept of the SLAR antenna is shown.

WFMN07_II_C4

TerraSAR-X Calibration Ground Equipment

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The Microwaves and Radar Institute regularly performs calibration campaigns for spaceborne SAR systems, among which have been X-SAR, SRTM, and ASAR. In 2007, the German SAR satellite TerraSAR-X will be launched. Before it is ready for scientific and commercial use, the instrument has to be calibrated to ensure highly accurate data products. An absolute radiometric accuracy of better than 1 dB is required.
The relative and absolute radiometric calibration of SAR systems depends on reference

point targets (i.e. passive corner reflectors and active transponders) with precisely known RCS. For the TerraSAR-X mission, the reference targets will be deployed on ground in the South of Germany during a 6 month lasting field campaign. This paper describes these reference targets (i.e. ground receivers, passive corner reflectors, and active transponders) and their characterization.

WFMN07_II_C5

A Direct Comparison of SAR Processing as Non-Orthogonal Transform to both Fourier and Wavelet Transform

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The term *SAR processing* is commonly used to denote the process of producing fully focused SAR images from SAR raw data. Beside its main task of applying a two-dimensional range-dependent convolution it simultaneously performs many other incorporated processing steps such as motion compensation, interference filtering, calibration, coregistration, geometry conversions, apodization techniques or speckle filtering.

Above all, SAR processing can roughly be described as applying a two-dimensional convolution designed in order to reverse a two-dimensional convolution performed during the imaging process. This forward-backward process can be modelled as nonorthogonal transform and there are great similarities to both Fourier and Wavelet transform.

Most modern fast SAR processing techniques rely on the Fourier transform as it is known to be the state-of-the-art technique for performing fast convolutions. However, in recent years, Wavelet transforms outperform the Fourier transform in terms of computational burden. It only requires O(n) or even O(log n) operations instead of O(n * log n) operations.
In a previous work, we derived the matrix form of SAR raw and image data from the continuous case and defined the SAR transform which maps the two matrices onto each other. We concluded that the SAR transform is a Wavelet transform.

In this paper, we would like to do a direct comparison of Fourier, Wavelet and SAR transform. We analyse the way Fourier and Wavelet transform gain computational speed and show a perspective how this can be done for SAR processing.

WFMN07_II_D1

Statistical aspects of polarimetric weather radar echoes

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Polarimetric weather radar echoes resulting from an observed resolution volume are commonly defined to be the composite of echoes from a large number of individual randomly distributed hydrometeors and refractive index irregularities of the atmosphere. In this contribution we shall examine some important statistical aspects of polarimetric weather radar echoes. The statistical properties of polarimetric weather radar echoes are readily obtained from basic principles, most of them are well known and their properties, from the point of view of interpretation of weather radar observables, are important features. Using time series weather radar data recorded with the coherent polarimetric C-band weather radar "POLDIRAD" (DLR, Wessling, Germany) allows us to examine the statistical properties of polarimetric weather radar echoes and also enables us to examine the dependence of the statistical properties of measured polarimetric weather radar signals on instrumental features. The proposed analysis can be used to detect possible radar-hardware malfunctions and can also serve as a diagnostic tool for validating or trouble-shooting radar hardware modifications.

Session 8: Polarisation in Propagation and Remote Sensing

Session Chair: U. Böttger
G. Wanielik

WFMN07_II_D2

Electromagnetic and Computational Approach to Detect Depth of the Buried Object Using Radar Remote Sensing Data at X – band

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Extended Summary:

Present paper deals with the potential application of Radar Remote Sensing to detect the depth of the buried object using electromagnetic and computational techniques. Estimating the depth of the buried object with satellite/airborne data is not an easy task due to the complexity of the returned signal. So, in this paper, it is tried to solve the complexity of the returned signal and estimate the depth of the buried objects.
The detection of buried objects has so long been a challenging problem to researchers in a variety of fields including archaeology, criminology, geophysical exploration and submarine detection. It can be extraordinarily difficult to find objects covered by a few centimeters of earth, unless one knows in advance about where to look for. The soil is opaque, and discourages extensive digging by its weight and bulk. Moreover, mechanical probing of the soil is often an impractical or undesirable method in many problems of locating buried archaeological or paleontological remains, military explosives and buried treasures. Suitable methods of detection are therefore needed which can search large areas in a reasonable time frame, preferably without disturbing the soil or things existing on it. This ideally means a subsurface search without touching the ground surface and preferably operating from a stand off distance. The subject therefore would come under the heading of remote sensing. Presently, a variety of remote sensing techniques are in use, which are classified according to their principle of operation and the spectral band, used. Such methods should be capable of finding objects no larger than a few hundred cubic centimeters in volume, be it

metallic or non metallic and buried upto several meters in depth.

Subsurface target identification is a problem far more severe than the identification of aerospace targets by conventional radars where the target can literally be seen and the class of false targets is limited in scope. On the other hand, in case of underground targets, there are a variety of unknown, false or undesired targets to complicate the task. Furthermore, the medium involved (i. e. the ground is usually lossy, inhomogeneous and most of all, weather dependent. These together with the presence of air-ground interface, make the task of subsurface target identification truly formidable.

There are several useful techniques, which are used for the detection and identification of buried (metallic and non – metallic) objects. Some of these techniques are Magnetometers, Electromagnetic Induction Technique, Electromagnetic Radar, Acoustic Techniques, imaging, Nuclear Detection and Trace Gas Analysis technique. The Electromagnetic Radar technique is used here which is very commonly used for satellite/air-borne remote sensing.

The electromagnetic waves are attenuated in soil/sand and the loss in signal strength increases with frequency. This conflicts with the requirement of using relatively high frequency to resolve small objects with portable antennas. This signal loss depends on soil type and the moisture content, which limit the effective penetration depth to a few centimeters in certain cases. Keeping in view these difficulties, a radar system was developed which used a relatively low frequency band (250-1000 MHz) so as to ease the attenuation problem. The basic principle of this radar is same as conventional radars. But since the soil is non-uniform, dispersive and weather dependent medium, its electrical parameters vary considerably and hence the velocity of electromagnetic waves in it is not known accurately. In order to determine depths of buried objects it is required to measure this velocity in situ. This is done by measuring the return time or the pulse corresponding to two horizontally separated positions of radars. Further complications arise due to dispersion in soil, natural stratification of soil and isolated discontinuities such as rocks, soils, tree roots etc if any. Considerable efforts have been made to overcome these difficulties and some successes too have been achieved.

The microwave reflection/scattering phenomenon from buried objects basically depends upon its conductivity, dielectric constant, permittivity and the target characteristics (viz. size, shape, thickness, depth as well as medium of the burying object). The objects/materials having higher conductivity and larger dielectric constant give higher reflection/scattering and those having lower conductivity and smaller dielectric constant give lesser reflection/scattering when microwaves are directed on to it reflected microwave signatures are studied. This phenomenon is mainly dependent upon the frequency of operation, look angle and the sensitivity of the system, which governs the depth of penetration of microwaves. The dielectric constant, conductivity and the permittivity for aluminum sheet and sand are different and hence the received power is expected to be different for both. Thus the buried object can be detected easily by the electromagnetic radar technique in which all the above mentioned three factors are affected greatly and the signal reflected/back-scattered from the object give nearly true extent of the target.

Electromagnetic radars are used to detect the depths of buried utility pipes and cables. Some radar is also designed to detect and resolve reliably small objects buried in soils. The role of radar is much more promising as a mine detection tool than as a range clearance tool. Any radar that measures the scattering or reflective properties of surfaces and/or volumes is called a scatterometer. Thus a scatterometer may be radar specifically designed for backscattering measurement; or it may be radar designed for other purposes such as imaging or altimetry, but calibrated accurately enough so that scattering measurement with it are possible.

A monostatic scatterometer system has been developed for the prediction of depth of buried objects at 10.0 GHz. Experimental setup is assembled for detecting an aluminum sheet and wooden block size of 59.2 X 59.2 cm^2 at different depths in the sand pit of 146 X 128 cm^2 and the top surface was leveled completely. The surface is assumed smooth at 10.0 GHz frequencies and sand was dry with dielectric constant 3 during whole experiment. The system uses only one pyramidal horn antenna for transmitting and receiving microwave power at 0^0 incident angle at the frequency of 10.0 GHz. The whole system was mounted on a movable platform where the antenna is moved in the direction of X – axis and Y – axis. The antenna angle was said to be 0^0 when it was looking down vertically. The scanning of the buried objects was done in the XY – plane horizontal to the surface of the earth along X – axis and Y – axis to find out the extent of the objects by noting the returned reflected / back – scattered signals. Experiments were carried out with Aluminum and dummy mines separately, both buried under sands at depths varying from 1 cm to 10 cm.

Numerical results of scattered signal power were obtained using Electromagnetic wave interaction with multiple media principle. The total electrical field E_R due to incident electrical field E_1 received at the scatterometer was measured in each case and noted for analysis. Only the effect of specular reflection from the air (medium1)- sand (medium 2) interface and reflection from the aluminum/dummy mines reflector (medium 3) at depth H under the surface was measured. Diffuse and diffractional components of the electrical field scattered by the aluminum reflector and dummy mines too has been neglected, as it is smooth with respect to the radar wavelength of approximately 3 cm. As compared to the thickness of the skin layer which is of the order 10^{-6} m, the thickness of the aluminum reflector and dummy mines (1 cm) is much greater and its surface can be considered a flat boundary through which there is no further penetration of the electrical field into further sand. The Electromagnetic model used here for measuring $E_{R,}$ consists of a homogeneous layer of sand that is located between medium 1 and 3 with a flat specularly reflecting boundary and a boundary between medium 1 and medium 2. The electrical field E_R thus resulting is a superposition of the three electrical fields viz. the electrical field returned from the air-sand interface, E_S; the electrical field returned after one reflection at the aluminum/dummy mines reflector, E_{C1}; and the electrical field returned after two reflections at the aluminum/dummy mines reflector and one at the sand-air interface, E_{C2}; and so on upto $E_{CN.}$ The final expression used for the total returned electrical field at the scatterometer receiver, $E_{R,}$ for the aluminum reflector and dummy mines buried at depth H under a sand layer with a smooth surface is

$$E_R = \sqrt{1-4K^2\sigma^2\cos\theta_1.\exp(-\sin\theta_1/2)} \times \frac{R_{1-2} + R_{2-3}\exp(-2\gamma_2 H)}{1 + R_{1-2}.R_{2-3}\exp(-2\gamma_2 H)} \qquad (1)$$

R_{1-2}(= $-R_{2-1}$) and R_{2-3} are the Fresnel reflection coefficients of the medium boundaries 1-2 and 2-3 respectively. K is wave number, σ is conductivity of buried object, and γ_2 is the propagation constant in sand. The E_R gives the value of calculated electrical backscatter coefficient and it is clearly seen that it is a function of dielectric constant of the mediums and depth (H).

$$E_R(\theta) = f(\varepsilon,\theta) \,.\, f(H,\theta) \qquad (2)$$

The dielectric constant of the medium is assumed constant during whole measurement, so it can be written as

$$E_R = \xi .\, f(H,\theta) \qquad (3)$$

Where ξ is a dielectric constant dependent parameter and in our case it is constant. This calculated electrical backscatter coefficient is used for the Non Linear Least Square Optimization computational technique for estimating the depth of buried object with the measured electrical backscattering coefficient by the scatterometer as represented in equation (4),

$$\text{Minimize} = \sum[\ \{(1/\lambda_1^2).(E_{R\_obs} - E_{R\_cal})^2\} + \{(1/\lambda_2^2).(H_{obs} - H_{est})^2\}\ ] \qquad (4)$$

Where λ_1^2 standard deviation of measured E_{R_obs} at 0° incidence angles.

E_{R_obs} = electrical backscattering coefficient observed during experiment at 0^0 incidence angle.
E_{R_cal} = electrical backscattering coefficient calculated by equation (1)
λ_2^2 = Standard deviation of the observed (*a priori*) depth (H_{obs})
H_{obs} = Depth of buried object (*a priori* information or guess value) observed during experiment.
H_{est} = Depth to be retrieved (i.e., estimated).

For estimation of $H_{est,}$ known values of other parameter i.e. λ_1^2, E_{R_obs}, E_{R_cal}, λ_2^2, and H_{obs}, were inserted into a computer program using software and it gives the values of H_{est}.
A good agreement between observed and estimated depth is obtained for aluminum and dummy mines, but for aluminum target better results than dummy mines is observed, it may be due to the reason that aluminum conductivity is very high in comparison to dummy mines and also aluminum gives more reflection than dummy mines. This shows that the Radar remote sensing technique with including computational and EM principles has great potential to estimate the depth of buried object in large areas with reasonable cost.

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Some References:

[1] A. Sullivan, R. Damarla, N. Geng, Y. Dong, and L. Carin, "Ultrawide- band synthetic aperture radar for detection of unexploded ordinance: Modeling and measurement," *IEEE Trans. Antennas Propagat.*, vol. 48, pp. 1306–1315, Sept. 2000.

[2] C. Balanis, *Advanced Engineering Electromagnetics*. New York: Wiley, 1989.

[3] F. T. Ulaby, R. K. Moore, and A. K. Fung, *Microwave Remote Sensing Active and Passive*. Reading, MA: Addison-Wesley, 1981, vol. 1, Microwave Remote Sensing Fundamentals and Radiometry.

[4] H. S. Chang and K. K. Mei, "Scattering of electromagnetic waves by buried and partly buried objects of revolution," *IEEE Trans. Geosci. Remote Sensing*, vol. GE-23, pp. 596–605, 1985.

[5] I. L. Morrow, and Gendern, P., "Effective Imaging of Buried Dielectric Object," IEEE Trans. Geosci. and Rem. Sens., vol. 40, pp. 943-949, 2002.

[6] L. Carin, N. Geng, M. McClure, and J. S. L. Nguyen, "Ultra-wide-band synthetic-aperture radar for mine-field detection," *IEEE Antennas Propagat. Mag.*, vol. 41, pp. 18–33, Feb. 1999.

[7] M. Skolnik, *Radar Handbook*, 2nd ed. NewYork: McGraw-Hill, 1990.

[8] M. E. Shenawaee, "Polarimetric scattering from two layered two dimensional random rough Surface with and Without Buried objects," *IEEE Trans. Geosci. Remote Sensing*, vol. 42, pp. 67-75, 2004.

WFMN07_II_D3

Investigations on the Polarimetric Behavior of a Target near the Soil

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The diffraction of a plane wave by an object situated close to an interface of a two-layer medium has been investigated by many authors and an extensive literature exists on this topic. However, only a few publications have been devoted to the analysis of the polarimetric behaviour of the diffracted field. In general, very simple ray models based on the Geometrical Optic (GO) are considered involving single and double bounced waves for explaining some experimental results. Here, this problem is again investigated by using a more refined ray model based on the Geometrical Theory of Diffraction (GTD). As a result a ray system composed of 13 different rays was implemented for the monostatic case by applying the principle of Fermat. The different spatial and creeping waves give a physical insight in the mechanisms involved in the entire scattering process. Depending on the geometrical properties of the target, lit and shadow regions arise in the backscattered GTD field for a variation from perpendicular to grazing incidence for a monostatic alignment of the transmitting and receiving antenna. The separating line of such a lit and shadow region is called a Surface Shadow Boundary (SSB). A special emphasis is attributed to the transition regions near the shadow boundaries where the reflected spatial waves disappear and transform into creeping waves leading to a strong attenuation. The diffracted field for look angles related to the transition zones has a characteristic polarimetric behaviour which is represented on the Poincaré sphere. The typical locations on the sphere can be exploited in order to get information about the geometrical parameters of the target and its height above the ground.

WFMN07_II_D4

On the differential propagation phase in weather radar measurements (Review Lecture)

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Besides differential attenuation the differential phase due to propagation in anisotropic media like precipitation is one of the mechanisms that is responsible for depolarisation of polarised electromagnetic waves in the microwave region.
Modern coherent polarimetric weather radars are able to measure the differential propagation phase and use it as additional parameter for weather remote sensing.
A review on the historical development of the use of differential propagation phase in weather radar technology will be given, including a critical assessment and overview of up-to-date applications.

WFMN07_II_D5

Whither Polarimetry Today (Review Lecture)

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The advent of polarimetry in modern engineering probably started with the development of radar and its applications. The engineering approach in its initial form was based on the **scattering matrix** concept. This approach is generally described as **coherent polarimetry**. Well before the days of radar, however, polarimetry developed from the study of partially polarised natural light. This approach, commonly described as **incoherent polarimetry**, was based on the **Stokes matrix** concept. Both methods today have a place in modern polarimetry. In this contribution, the evolution of the current manifestations of these two methods and their derivatives will be presented. The strength and weaknesses of the two methods, with reference to applications, will be highlighted with the help of results published in the recent past. Examples from weather radar and synthetic aperture radar applications will be used for this purpose. Finally the paper will dwell on the most recent developments in the field and the emerging new applications in remote sensing and propagation.

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