Dr. –Ing. Robert Yu Wang

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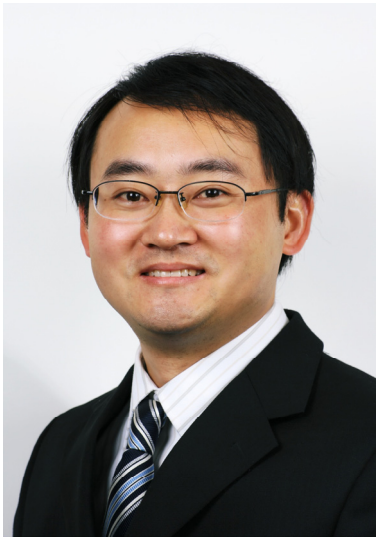

EDUCATION

Dr.-Ing. (Ph. D.)	Feb., 2007	Communication and Information Systems Graduate University of Chinese, Academy of Sciences Beijing, China Supervisors: Prof. Yunkai Deng, and Prof. Zhimin Zhang Institute of Electronics, Chinese Academy of Sciences Beijing, China
B. S.	Jul., 2002	Control engineering University of Henan, Kaifeng, China

PROFESSIONAL EXPERIENCES

Feb. 2007 - present	Research scientist (Postdoc) Center for Sensor systems (ZESS), University of Siegen Siegen, Germany
Nov. 2005 - Dec. 2006	Research assistant Leader of the group of the full-polarimetric real-time SAR processor Institute of Electronics, Chinese Academy of Sciences (IECAS) Beijing, China
Jul. 2002 – Oct. 2005	Research assistant Institute of Electronics, Chinese Academy of Sciences Beijing, China

RESEARCH INTERESTS

Signal processing for advanced SAR modes (squint, spotlight, and circular)

Multimode radar system design and data processing

Bi- /multi-static SAR system design and data processing

Mono- /bi-static 3D SAR imaging technology

CW SAR system design and data processing

THz radar technology and data processing

Image fusion

Adaptive signal processing, optimization theory and method

MEMBERSHIP

IEEE Geoscience and Remote Sensing Society

REVIEWER FOR THE JOURNALS

IEEE Transactions on Aerospace and Electronics Systems

IEEE Transactions on Geoscience and Remote Sensing

IEEE Transactions on Industrial Electronics

IEEE Geoscience and Remote Sensing Letters

IET Radar, Sonar and Navigation

International Journal of Aerospace Engineering

EURASIP Journal on Advances in Signal Processing

Acta Electronica Sinca

Journal of Electronics & Information Technology

SUPERVISED STUDENTS

Lingyan Yang, Bachelor, Xidian University Subject: Evaluation Software of SAR Image Quality Joint supervision with Prof. Yunkai Deng
Xiaoxue Jia, Bachelor, Beijing University of Posts and Telecommunications Subject: Analysis of Quantization Errors for Spaceborne SAR Joint supervision with Prof. Yunkai Deng
Bin Wang, Master, Graduate University of Chinese, Academy of Sciences Subject: Airborne SAR Real-Time Processing Joint supervision with Prof. Zhimin Zhang
Xiao Hu, Master, Graduate University of Chinese, Academy of Sciences Subject: On-Chip Airborne SAR Real-Time Processing Joint supervision with Prof. Zhimin Zhang
Jinfang Wan, Master, Graduate University of Chinese, Academy of Sciences Subject: Control Software for Real-Time Processor Joint supervision with Prof. Zhimin Zhang

RESEARCH EXPERIENCES

Project 1	**Spaceborne/airborne hybrid bistatic SAR experiment** (DFG: Lo 455/7-1 BiFocus)
Duration	Mar. 2007 - present
Status	Research scientist (Principle member who completes the project)
Description	TerraSAR-X serves as the illuminator in the spotlight or sliding spotlight modes, and FGAN's PAMIR system mounted on a Transall airplane is used as a bistatic receiver in the spotlight or inverse sliding spotlight modes.
Contributions	• Analyze and validate the hybrid bistatic experiment. • Propose the weighting idea to extend Prof. Loffeld's Bistatic Formula to work in extreme bistatic configurations (e.g. spaceborne/airborne and high-squint configurations). • Propose a quadratic signal model to derive the bistatic point target reference spectrum based on the special characteristics of the spaceborne/airborne hybrid configuration. • Develop two independent frequency-domain processing algorithms for this hybrid experiment: one is developed based on the extended version of Prof. Loffeld's method, and another is based on the quadratic signal model. • Derive an accurate quasi-monostatic bistatic point target spectrum by using the two-dimensional principle of stationary phase which is firstly applied in the open literature in SAR community. • Responsible for the calibration of the hybrid experiment. • Analyze and validate the signal mode of the orthogonal trajectory for this hybrid experiment.

Project 2	**Millimeter-wave FMCW SAR data processing** (Joint project between ZESS and FHR)
Duration	Sep. 2008 - present
Status	Research scientist (Principle member who completes the project)
Description	FGAN's airborne millimeter-wave SAR system (i.e. MEMPHIS) is a unique experimental millimeter-wave SAR system which contains two front-ends: one operates at 35GHz (Ka-band) and another at 94 GHz (W-band).
Contributions	• Propose an analytical signal model for FMCW SAR where an additional range azimuth coupling term is firstly mentioned in the FMCW SAR community. • Develop the wavenumber domain algorithm based on the analytical signal model. It shows better focusing performance compared to the present processing algorithms.

Project 3	**Airborne/stationary bistatic SAR experiment with non-synchronized oscillators** (Joint project between ZESS and FHR)
Duration	July 2008 – June 2009
Status	Research scientist (Principle member who complete the project)
Description	Transmitter is stationary, whereas FGAN's PAMIR system mounted on a Transall airplane is used as a moving receiver in the spotlight mode.
Contributions	• Develop the signal model and approaches to estimate and compensate clock drifts. • Propose an analytical signal mode for the airborne/stationary bistatic configuration. • Propose a frequency-domain processing algorithm based on the corresponding signal model.

Project 4	**Airborne real-time SAR raw data simulator** (Knowledge Innovation Program of the Chinese Academy of Sciences)
Duration	Aug. 2005 – Jan. 2007
Status	Research assistant, Co-PI
Description	The simulator can work in stripmap and spotlight modes. It has the flexible interfaces and can be used as the signal generator for the real-time processor. It can test the real-time processor in the real-time case.
Contributions	• Propose the idea of designing the simulator. • Analyze and design the frame of the simulator. • Develop the frequency-domain algorithm for the real-time raw data simulation.

Project 5	**Airborne real-time full-polarimetric SAR processor** (Joint project between IECAS and industrial institute of 207)
Duration	Nov. 2005 – Dec. 2006
Status	Research assistant, group leader + PI
Description	This is a high-throughput X-band full-polarimetric processor for a dual receive antenna mode SAR system. It contains real-time azimuth pre-processor and real-time motion compensation system. It is able to process four images in a full-polarimetric mode in the complex flight conditions.
Contributions	• Analyze and design the frame of the processor. • Responsible for the processing algorithm and software. • Utilize parallel techniques with multiple DSPs for maximum processing performance. • Use single DSP to implement pre-processing and Doppler estimation to save the cost and volume of the processor.

Project 6	**High-resolution small-size spaceborne SAR/GMTI system** (National High Technology Research and Development Program of China:863 Program, No. 2003AA782042)
Duration	July 2002 – May 2005
Status	Research assistant
Description	This SAR system works at X-band with a bandwidth of 840 MHz in different modes (i.e. stripmap, spotlight, and scan). I work in the following three subprojects: • Real-time processor and real-time azimuth pre-processor (Principle member); • Real-time motion compensation system (Co-PI); • Stripmap/spotlight SAR data processing (Principle member).
Contributions	• Responsible for the processing algorithm and software. • Complete the assemble coding of all the DSPs independently (***more than 100000 lines***). • Utilize parallel techniques of multiple DSPs for maximum processing performance. • Utilize the real-time motion compensation. • Develop the Range-Variant Phase Gradient Autofocus (RVPGA) algorithm which is quite suitable for X-band SAR, by which the fine images with resolution of 0.2m×0.2m are obtained. • Improve the performance of Contrast Optimization Autofocus (COA) using linear optimization principles (i.e., Golden section method and Fibonacci series method).

Lists of publications

■ Peer-reviewed publications (published or accepted):

❖ Journals:

[1] R. Wang, O. Loffeld, Y. L. Neo, H. Nies, and Z. Dai, “Extending Loffeld’s Bistatic Formula for general bistatic SAR configurations,” ***IET Radar Sonar and Navig.***, accepted for publication, Aug. 05, 2009.

[2] R. Wang, O. Loffeld, Y. L. Neo, H. Nies, I. Walterscheid, T. Espeter, J. Klare, and J. H. G. Ender, “Focusing bistatic SAR data in airborne/stationary configuration,” ***IEEE Trans. on Geosci. Remote Sens.***, accepted for publication, June 17, 2009.

[3] R. Wang, O. Loffeld, H. Nies, S. Knedlik, Q. Ul-Ann, A. Medrano-Ortiz, and J. H. G. Ender, “Frequency-domain Bistatic SAR processing for spaceborne/airborne configuration,” ***IEEE Trans. on Aero. Elec. Syst.***, accepted for publication, Mar. 03, 2009.

[4] R. Wang, O. Loffeld, H. Nies, and J. H. G. Ender, “Focusing hybrid spaceborne/airborne bistatic SAR data using wavenumber domain algorithm,” ***IEEE Trans. on Geosci. Remote Sens***., vol. 47, no. 7, pp. 2275-2283, July 2009.

[5] R. Wang, O. Loffeld, H. Nies, A. Medrano-Ortiz, and S. Knedlik, “Bistatic Point Target Reference Spectrum (BPTRS) in the presence of trajectories deviation,” ***IET Radar Sonar and Navig.*** , vol. 3, no. 2, pp. 177-185, April 2009.

[6] R. Wang, O. Loffeld, H. Nies, S. Knedlik, and J. H. G. Ender, “Chirp scaling algorithm for the bistatic SAR data in the constant-offset configuration,” ***IEEE Trans. on Geosci. Remote Sens***., vol. 47, no.3, pp. 952-964, Mar. 2009.

[7] R. Y. Wang, Z. Zhang, and Y. Deng, “Squint spotlight SAR raw signal simulation in the Frequency Domain Using Optical Principles,” ***IEEE Trans. on Geosci. Remote Sens****.,* vol. 46, no.8, pp. 2208-2215, Aug. 2008.

[8] R. Wang, O. Loffeld, Q. Ul-Ann, H. Nies, A. Medrano-Ortiz, and A. Samarah, “A bistatic point target reference spectrum for general bistatic SAR processing,” ***IEEE Geosci. Remote Sens. Letters***, vol. 5, no. 3, pp.517-521, July 2008.

[9] R. Wang, B. Wang. Z. Zhang, and Y. Deng, “The research and application of Modified Wavenumber Domain Algorithm (MWDA) to real-time processing,” ***Journal of Electronics & Information Technology***, vol.30, no.6, pp. 1-5, June 2008.

[10] O. Loffeld, H. Nies, S. Knedlik and R. Y. Wang, “Phase unwrapping for SAR interferometry—a data fusion approach by Kalman Filtering”, ***IEEE Trans. on Geosci. Remote Sens.,*** vol. 46, no.1, pp. 47-58, Jan. 2008.

[11] Y. Deng, R. Wang, X. Yang, and Z. Zhang, “The research of auto-focus optimization algorithms based on Contrast Optimization Criterion,” ***Acta Electronica Sinca***, vol. 34, no.9, pp1742-1744, Sep. 2006.

[12] R. Wang, Z. Zhang, and Y. Deng, “The analysis of the quantization errors in the real-time SAR azimuth preprocessing,” ***Modern Radar***, vol.28, no.2, pp. 36-39, Feb. 2006.

[13] X. Yang, R. Wang, and D, Shen, “Channel Blind Equalization Algorithm for Airborne Bi-channel SAR/GMTI System,” ***Electronic Warfare***, NO.3, pp1-6, Mar. 2005.

❖ Conferences:

[14] R. Wang, O. Loffeld, H. Nies, Q. Ul-Ann, and A. Medrano-Ortiz “A two-step method to process bistatic SAR Data in the general configuration,” in *Proc.* ***IEEE Radar Conference***, Rome, Italy, June 2008.

[15] R. Wang, Z. Zhang, and Y. Deng, “Spotlight SAR raw Data simulation using frequency scaling algorithm,” in *Proc.* ***IEEE Radar Conference***, Boston, USA, May 2007.

■ Submitted manuscripts (peer reviewing):

[16] R. Wang, O. Loffeld, H. Nies, Z. Dai, Y. L. Neo, I. Walterscheid, T. Espeter, J. Klare, and J. H. G. Ender, “Focusing spaceborne/airborne bistatic SAR data by using range stacking based on 2D principle of stationary phase,” Submitted to ***IEEE Trans. on Geosci. Remote Sens.***, Aug. 08, 2009, under reviewing.

[17] R. Wang, O. Loffeld, H. Nies, S. Knedlik, M. Hägelen, and H. Essen, “Focus FMCW SAR data using Wavenumber Domain Algorithm (WDA),” Submitted to ***IEEE Trans. on Geosci. Remote Sens.,*** May 12, 2009, and accepted with minor revision.

[18] K. Natroshvili, O. Loffeld, H. Nies, R. Wang, Q. Ul-Ann, and J. Ender, “Bistatic SAR Doppler centroid and bandwidth,” Submitted to ***IET Radar Sonar and Navig.,*** Mar. 19, 2009, and accepted with major revision, June 24, 2009.

[19] R. Wang, O. Loffeld, Y. L. Neo, H. Nies, “Focusing the bistatic SAR data of the azimuth-variant configurations in the frequency domain,”, Submitted to ***IEEE Trans. on Geosci. Remote Sens****.,* Mar. 29, 2009, and accepted with major revision.

[20] I. Walterscheid, T. Espeter, A. R. Brenner, J. Klare, J. H. G. Ender, H. Nies, R. Wang, and O. Loffeld, “Bistatic SAR experiment with PAMIR and TerraSAR-X – setup, processing, and image results,” Submitted to ***IEEE Trans. on Geosci. Remote Sens.***, Jan. 30, 2009, accepted with major revision.

■ Invited presentations:

[21] R. Wang, O. Loffeld, Q. Ul-Ann, H. Nies, A. Medrano-Ortiz, and S. Knedlik, “A special point target reference spectrum for spaceborne/Airborne bistatic SAR processing,” in *Proc.* ***EUSAR***, Friedrichshafen, Germany, June 2008.

[22] R. Wang, O. Loffeld, Q. Ul-Ann, H. Nies, A. Medrano-Ortiz, and S. Knedlik, “ Analysis and extension of Loffeld’s Bistatic Formula in spaceborne/airborne configuration,” in *Proc.* ***EUSAR***, Friedrichshafen, Germany, June 2008.

■ Invited tutorials:

[23] R. Wang, O. Loffeld, H. Nies, D. Zhen, S. Knedlik, I. Walterscheid, T. Espeter, A. R. Brenner, J. Klare, and J. H. G. Ender, “Results and progresses of advanced bistatic SAR experiments,” European Radar Conference, Rome, Italy, Sep. 2009.

[24] O. Loffeld, H. Nies, and R. Wang, “Progress in bistatic SAR concepts and algorithms,” in ***EUSAR***, Friedrichshafen, Germany, June 2008.

■ Non-peer-reviewed publications:

[25] R. Wang, O. Loffeld, H. Nies, Z. Dai, Y. L. Neo, I. Walterscheid, T. Espeter, J. Klare, and J. H. G. Ender, “Focusing and analysis of hybrid bistatic experiments in the spaceborne/airborne configurations,” in *Proc.* ***IRS***, Hamburg, Germany, Sep. 2009.

[26] Q. Ul-Ann, O. Loffeld, H. Nies, and R. Wang, **“**Determining the weighting factor for the unequal azimuth contribution of transmitter and receiver phase terms based on the balidity constraints for bistatic SAR processing,” in *Proc.* ***IRS***, Hamburg, Germany, Sep. 2009.

[27] R. Wang, O. Loffeld, H. Nies, Z. Dai, A. R. Brenner, I. Walterscheid, and J. H. G. Ender, “Focusing and analysis of hybrid bistatic experiments,” in *Proc.* ***CEOS SAR 2008,*** Oberpfaffenhofen Germany, Nov. 2008.

[28] R. Wang, O. Loffeld, H. Nies, Q. Ul-Ann, A. Medrano-Ortiz, S. Knedlik, and A. Samarah, “Analysis and processing of spaceborne/airborne bistatic SAR data”, in *Proc.* ***IGARSS***, Boston, USA, July

2008.

[29] A. Medrano-Ortiz, O. Loffeld, H. Nies, and R. Wang, “Second-order motion compensation in bistatic airborne SAR based on the windowed Fourier-transformation,” in *Proc.* ***IGARSS***, Boston, USA, July 2008.

[30] H. Nies, O. Loffeld, and R. Wang, “Phase unwrapping using 2D-Kalman filter - potential and limitations,” in *Proc.* ***IGARSS***, Boston, USA, July 2008.

[31] H. Nies, O. Loffeld, and R. Wang, “Two dimensional Kalman filter approach for phase unwrapping of TerraSAR-X data,” in *Proc.* ***EUSAR***, Friedrichshafen, Germany, June 2008.

[32] Q. Ul-Ann, O. Loffeld, H. Nies, R. Wang, K. Natroshvili, and S. Knedlik, “Performance analysis of the validity constraints of the bistatic SAR processing,” in *Proc.* ***EUSAR***, Friedrichshafen, Germany, June 2008.

[33] A. Medrano-Ortiz, R. Wang, O. Loffeld, and H. Nies, “Motion compensation in bistatic SAR for the hybrid experiment,” in *Proc.* ***EUSAR***, Friedrichshafen, Germany, June 2008.

[34] R. Wang, O. Loffeld, H. Nies, S. Knedlik, and A. Medrano-Ortiz “Chirp scaling algorithm for the bistatic SAR Data in the constant offset configuration,” in *Proc.* ***IRS***, Cologne, Germany, Sep. 2007.

[35] R. Wang, O. Loffeld, A. Medrano-Ortiz, S. Knedlik, and Holger Nies, “Spotlight-mode SAR data focusing using Modified Wavenumber Domain Algorithm (MWDA),” in *Proc.* ***IGARSS,*** Barcelona, Spain July 2007.

Planned Research Project

Conventional monostatic and recent bistatic Synthetic Aperture Radar (SAR) systems all work in pulsed mode, ensuring a good isolation between transmit and receive signal, where transmitter and receiver use the same antenna. Continuous-Wave (CW) technology, however, requires less peak transmit power, and is conceptually simpler, especially in bistatic operation modes. Thus, the combination of Frequency-Modulated Continuous-Wave (FMCW) technology and SAR techniques offers all the benefits of a high resolution imaging sensor, additionally compact size, lightweight, etc. Since FMCW components are more and more becoming components “of the shelf” due to their wide application in automotive radar based driver assistance systems, this will enable a significant cost reduction in remote sensing applications. Hence FMCW SAR systems, especially in bistatic imaging configurations, can play an important role in remote sensing, reconnaissance and surveillance applications, especially for the application of small-size unmanned aerial vehicles (UAVs).

The conceptual and hardware simplifications are, however, at the expense of having more complex processing approaches. The comparably long signal duration time in the CW mode introduces an additional range walk term, compared to the conventional pulsed SAR, which means that the conventional processing algorithms cannot be directly applied to focus FMCW SAR data. This especially holds for bistatic SAR systems, where up to day, no FMCW focussing approaches are known. Additionally the issues of “in pulse” motion compensation, must be considered. The main objectives of this research project are to develop the complete processing chain, starting with accurate signal models to formulate the effect of the continuous motion during pulse on the signal characteristics of FMCW SAR, and further develop effective and efficient motion compensation approaches to deal with motion errors during pulse for FMCW SAR systems. Although some preliminary approaches to monostatic FMCW SAR imaging have been published in the scientific community, no scientific work has been devoted to bistatic configurations. Hence bistatic FMCW SAR systems form an implicit focus of this work.

In addition, FMCW can also be related to the Research Training Group intended THz technology. The combination of FMCW and THz technology requires new sensor technology, new signal model, and processing approach which will be emphasized in the planned research.

Bistatic Synthetic Aperture Radar (BiSAR) is characterized by spatially separated transmitter and receiver, and hence offers considerable capability, reliability and flexibility in designing SAR missions. Such a spatial separation brings the additional benefits in comparison with its monostatic counterpart: reduced vulnerability for military applications, flexible illuminators of opportunity with several receive-only systems and also the possibility of downward-, forward- or backward-looking SAR imaging. The research in the area of 2D imaging will be concentrated on the bistatic forward-looking configuration, which is highly desirable, e.g. for helicopter night vision systems and aircraft landing systems. For the research in the area of the bistatic forward-looking case, my intended objective is to develop the accurate bistatic point target reference spectrum, and further develop the corresponding processing algorithms. Furthermore, the fusion technology of

the 2D radar image in the forward- and downward-looking cases (especially the downward-looking case) and optical image will be emphasized. The characteristic of radar image in the down-looking geometry is very similar to the optical image due to the analogous imaging geometry.

A further and newly upcoming area is the field of 3D (non interferometric) SAR imaging techniques. While one sensor flying along a single trajectory and thus creating a one dimensional synthetic aperture can acquire a 2D image, a collection of SAR sensors, flying along spatially separated tracks and therefore creating a two dimensional synthetic aperture could acquire a true 3D image. Although several monostatic experiments, providing a proof of concept, have been performed, bistatic extensions are not known so far. For this kind of bistatic 3D (tomographic) imaging, we will concentrate on the bistatic spaceborne/stationary configuration. TerraSAR-X[1] works as the illuminator, whereas ZESS' passive receiver is used as the separate receiver. The 3D image is achieved by combining 2D spacborne/stationary bistatic images. For every 2D imaging collection, we realize different heights (Positions) for the passive receiver. The translational movement of the height of the passive receiver can form a second synthetic aperture in the elevation direction. By focusing in the second aperture, we can obtain image volumetric objects such as forests or cities. The intended objective is to firstly develop effective and accurate 2D imaging algorithms for the bistatic spaceborne/stationary configuration, and then develop the accurate algorithm for 3D imaging.

In summary, the planned research in the Research Training Group is as follows:

- Mono-/bi-static FMCW technology and THz imaging technology (Sensor development, signal model and data processing algorithm)
- Image fusion (radar image and optical image)
- 2D/3D radar imaging technology (Sensor development , signal model and data processing algorithm)

Finally, it needs to be emphasized that this planned research project is only a part of my DFG-proposal, entitled "Frequency-Modulated Continuous-Wave (FMCW) Synthetic Aperture Radar (SAR) Imaging, Bistatic 2D/3D SAR Imaging", which will be submitted to DFG in Sep. 2009 to apply for the Emmy Noether Programme. The corresponding funding period is Mar. 2010 – Feb. 2015.

[1] TerraSAR-X is a German radar Earth-observation satellite.

2D/3D imaging technology

Synthetic Aperture Radar (SAR) image processing is a sophisticated field of higher dimensional signal or image processing and shows lots of interesting relationships to other fields of mathematic imaging theory. The image formation process of monostatic SAR can be interpreted, e.g. as a circular Radon transform, which consequently can be inverted by a Hankel Transformation in conjunction with a Stolt interpolation, where the Stolt mapping is rather well known in the inversion of seismic data surveys. SAR imaging can also be interpreted from the standpoint of tomographic imaging again giving rise to Radon transform techniques known from general imaging physics. I will address these issues in a specific lecture, which I am going with the tentative title “Scientific 2D/3D imaging”. The intended course also includes a full range of the basic signal processing techniques on which all radar systems rely, including topics such as target and interference models, matched filtering, waveform design, Doppler processing, and real-time processing technology for imaging system.

The Degree Awarding Committee, in accordance with "The Regulations Concerning Academic Degrees in the People's Republic of China", has conferred upon

Wang Yu

the degree of

DOCTOR OF **Engineering**

Communication and Information Systems

with all its rights, privileges and honors

given at **Beijing**, China, on the **31st** day of **March**,

in the year of **2007**

President, **Graduate University of Chinese Academy of Sciences**

Chairman, Degree Awarding Committee

No. **8000122007000290**

普通高等学校

毕业证书

学生　王宇　性别 男 ，

一九八零 年十二 月五 日生，于一九九九 年

九 月至 二零零三 年 七 月在本校

自动化 专业

四 年制本科学习，修完教学计划规定的全部课程，成绩合格，准予毕业。

校(院)长：

校　名：河南大学

二零零三 年 七 月 一 日

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