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Technical Workshop 2

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Dissemination Level		
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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1 Introduction

This Networking Activity – Technical dissemination - concentrates mainly on the organization of a series of technical workshops. A special focus will be on the technical achievements and progress of the JRAs in this project in order to disseminate these results in the community. The main objective is to exchange ideas and new directions, and to attract the interest of researchers and industrial engineers in related fields to collaborate in the development of Radio Astronomy as well as industry applications with the aim to transfer knowledge in both directions.

2 Technical Workshop 2

2.1 Rationale

Phased Array Feed systems are considered as a future receiver option for the single dish telescopes, providing additional functionalities compared with currently used single dish receivers. Effelsberg as well as Jodrell Bank telescopes have implemented a phased array for first evaluation, while Westerbork array is operating the APERTIF PAF for science, and significant RadioNet partners are involved in the development of the Pharos II Phased array.

The Workshop on Phased Array Feeds for radio-astronomical observations 2019 took place 16-18 September 2019 in Bonn/DE and it was organised by the Max Planck Institute for Radio Astronomy: <https://events.mpifr-bonn.mpg.de/indico/event/108/overview>

The scope of the workshop was to exchange ideas and solutions among the developers of radio-astronomical instrumentation in the frequency range below 100GHz, specially under the aspect of phased array feed systems. After single pixel systems and discrete array receivers have been developed to sensitivities close to the physical limits, phased array feed systems are now the next logical step to further increase the science output of the observing facilities. These receiving systems with up to several hundred receiving channels introduce new technological challenges in all areas.

The workshop fostered the exchange and interaction between communities on the Phased Array Feed technologies. Especially a cryogenic PAF system has shown a high complexity, requiring technological interaction in-between the RadioNet community. Several technological cooperations have been discussed during the workshop and are going to be initiated.

The workshop presentations approved for publication are available at the event webpage: <https://events.mpifr-bonn.mpg.de/indico/event/108/timetable/#20190916>

2.2 Agenda

Monday, 16.09.2019		
Time	Title	Speaker
8.00	Workshop: Registration desk (<i>Hotel Collegium Leoninum</i>)	
9.00	Workshop: Introduction and organization	
	Session 1: PAF Science Applications	Chair: G. Wieching
9.10	Scientific Use Cases for a Phased Array Feed	Laura Spitler
	Session 2: PAF Theory and Simulations	Chair: K. Warnick
9.40	Beamforming Basics	Douglas Hayman
10.10	Poster Introduction – 3 min. Each	
10.35	Poster Session and Coffee Break	
	Wide Scan Range PAF Telescope for Massive MIMO 5G Base Stations (<i>poster presentation</i>)	A. Elsakka, U. Johannsen, O. Iupikov, M. N. Johansson, M. Ivashina and A. B. Smolders
	A room temperature Phased Array Feed for Arecibo telescope (<i>poster presentation</i>)	Anish Roshi
11.10	Prediction of PAF Performance Through a Simplified Model	Chengjin Jin, Bo Peng, Bin Liu, Shenghua Yu, Xiaoming Chai, Yang Cao, Yan Zhu and Jun Wang
11.30	Attempts to Simulate the Mutual Coupling Matrices of a Small PAF	Titus Oyedokun and Stefan Heyminck
11.50	Beam-forming and RFI Mitigation	Stefan Heyminck
	Session 3: PAF systems	Chair: S. Barker
12.10	The Operational Challenges of APERTIF, a 40 Beam Phased Array Feed Interferometer	Van Cappellen, Wim
12.40	Deploying ASKAP's Phased Array Feeds: Lessons from the Field	Aaron Chippendale
13.00	Workshop: Lunch Break	
14.00	Update on ALPACA and FLAG	Karl F. Warnick on behalf of the ALPACA and FLAG Teams
14.30	Digital Beamforming with PHAROS2 PAF: Updates on Warm Receiver Section, Digital Backend and Beampattern Characterization Results	A. Navarrini, A. Scalambra, A. Melis, S. Rusticelli, R. Concu, P. Ortu, G. Naldi, G. Pupillo, A. Maccaferri, A. Cattani, A. Ladu, L. Schirru, F. Perini, M. Morsiani, J. Monari, J. Roda, P. Marongiu, A. Saba, M. Poloni, M. Schiaffino, A. Mattana, G. Bianchi, G. Comoretto, R. Nesti, E. Urru, T. Pisanu, F. Schillirò, K. Zarb Adami, A. Magro, R. Chiello
14.50	Calibrating ASKAP's Phased Array Feeds with External Noise Sources	Aaron Chippendale
15.10	Coffee Break	
15.40	Pharos 2 – Upgraded C-band PAF	Simon Melhuish, Mike D'Cruze, Keith Grainge, Michael Keith and Mark McCulloch
16.00	Phased Array Developments for Purposes Other Than Radio Astronomy	D. Heberling
16.50	Workshop: Closing Remarks	
18.15	Social Event (Bonn City Centre)	

Tuesday, 17.09.2019		
Time	Title	Speaker
9.00	Workshop: Registration desk (<i>Hotel Collegium Leoninum</i>)	
9.30	Workshop: Organization	
	Session 4: PAF frontend technology	Chair: W. Van Cappellen
9.40	A Cryogenic Phased Array Receiver for the Parkes Radio Telescope	Alex Dunning, Douglas Hayman, Les Reilly, Peter Roush, Sean Severs, Nick Carter, Steve Barker, Paul Doherty, Paul Roberts, Jeganathan Kanapathippillai, Yoon Chung, Robert Shaw and Santiago Castillo
10.00	Cryogenic PAF Receiver Design for the Parkes Telescope Australia	K. Jeganathan, A. Dunning, Y. S. Chung, M. Bourne, S. Castillo, N. Carter, P. Doherty, D. B. Hayman, S. Mackay, L. Reilly, P. Roberts, P. Roush, S. Severs, K. Smart, R. D. Shaw, S. Barker, J. Tuthill and J. Bunton
10.20	A Digitization and Data Transmission Module for a Full Size Cryo-PAF on the Parkes Telescope	Paul Roberts
10.40	Coffee Break	
	Low Noise Amplifiers technology at the MPIfR	A Sener Türk and Frank Schäfer
11.10	PAF Developments at MPIfR	Stefan Heyminck, Gundolf Wieching, Christoph Kasemann, Frank Schäfer and Ewan Barr
11.40	Frontend Technologies for an S-Band Phased Array Feed	Mark McCulloch, Keith Grainge, Michael Keith and Simon Melhuish
12.00	Advanced Low Noise Ambient-Temperature Amplifiers	Sander Weinreb and Jun Shi
12.20	Low Noise Amplifier Development at the University of Manchester	William McGenn, Claudio Jarufe, Daniel White, Danielle George, Gary Fuller
12.40	LNAs Developments for Cryo-PAFs	Frank Schäfer and Sener Türk
13.00	Workshop: Lunch Break	
	Session 5: Digital Data Processing and Backend Technology	Chair: J. Chengjin
14.00	Real Time GPU-Based Digital Back-end for PAFs	Hariharan Krishnan
14.20	MPIfR Backend Developments	Jason WU
	SNAP2 & GPU Design for wideband and multichannel Backend (<i>poster presentation</i>)	Dongliang Liu, Shenghua Yu, Xiaoming Chai, Bin Liu, Lei Yu, Yezhao Yu, Hongwei Xi
	Session 6: PAF Related	Chair: S. Heyminck
14.40	Prospects for the SKA Observatory Development Program	Tim Stevenson and Joseph McMullin
15.00	Coffee Break	
15.30	Solar Power Mirror Arrays for Radio Astronomy	Olaf Wucknitz and Alan Roy
15.50	Studies Towards a Cryo-Cooled Phased Array Radar System for Space Surveillance	Andreas Froehlich, Hicham Barbri, Nadya Ben Bekhti, Oliver Grenz, Felix König, Lukas Naumann, Michael Pricher, Sergiy Putselyk, Florian Rahlf, Moritz Schneider and Marco Tiesing

Time	Title	Speaker
16.10	Development of a Next Generation Digital Front-end for ALMA and Outlook for Submm PAFs	Andrei Baryshev
	Introduction of Korea Radio Astronomy Facilities (<i>poster presentation</i>)	Hyunwoo Kang
	PAF Systems: An Application for 3D Printing (<i>poster presentation</i>)	Majid Norooziarab
	Superconducting Filters, Not Only for Cryogenic Phased Array Feeds (<i>poster presentation</i>)	Przemyslaw Michal Bryndza and Sener Türk
16.40	Summary Karl Warnick	

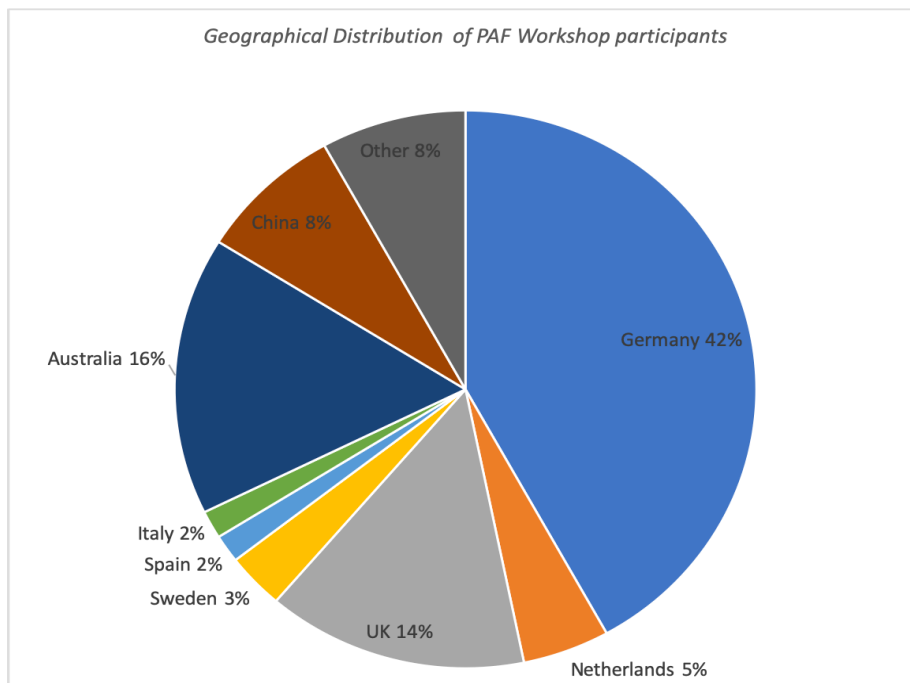
Wednesday, 18.09.2019		
Time	Title	Speaker
8.30	Visit to 100m Effelsberg: Bus transfer from Bonn (City-centre) to MPIfR	
9.00	Bus transfer from MPIfR to Effelsberg	
10.00	Visit to 100m Effelsberg	
12.00	Lunch	
12.30	Bus transfer from Effelsberg to MPIfR	
13.30	Bus transfer from MPIfR to Bonn (centre)	
14.00	SKA-PAF Consortium: Consortium Meeting (by invitation)	<i>Organized by S. Barker</i>

2.3 Participants



Fig. 2-1 Participants of the workshop © M. Schmitz

A total of 63 participants attended the workshop. Only 4 were female (2 speakers). The participations came from various institutes, 68% from EU and 32% from outside EU. See in the following graph the detailed geographical distribution:



PAF Workshop 2019

- Participants list -

	Name	Last name	Institution	Country
Mr.	Hicham	Barbri	Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik FHR	Germany
Mr.	Steve	Barker	CSIRO	Australia
Prof.	Andrey	Baryshev	Kapteyn Astronomical Institute/ MPIFR Bonn	Netherlands
	Mieke	Bouwuis	CSIRO	Australia
	Przemyslaw Michal	Bryndza	Max-Planck Institute for Radio-astronomy	Germany
Dr.	XIAOMING	CHAI	NATIONAL ASTRONOMICAL OBSERVATORITES CHINESE ACADEMY OF SCIENCES	China
Dr.	Aaron	Chippendale	CSIRO Astronomy	
Dr.	Michael	D'Cruze	The University of Manchester	United Kingdom
Mr.	Alex	Dunning	CSIRO	Australia
Mr.	Amr	Elsakka	Eindhoven University of Technology	Netherlands
Dr.	Ilana	Feain	CSIRO	Australia
Mr.	Jonas	Flygare	Onsala Space Observatory, Chalmers University of Technology	Sweden
Mr.	Andreas	Froehlich	Fraunhofer FHR	Germany
Dr.	Lars	Fuhrmann	Fraunhofer FHR	Germany
Dr.	Jose Francisco	Gomez	Instituto de Astrofisica de Andalucia, CSIC	Spain
Prof.	Keith	Grainge	University of Manchester	United Kingdom
Mr.	Oliver	Grenz	Fraunhofer Institut FHR	Germany
Dr.	Douglas	Hayman	CSIRO	Australia
Dr.	Stefan	Heyminck	MPIfR	Germany
Mr.	Gary	Hovey	Onsala Space Observatory/ Chalmers University	Sweden
Mr.	Claudio	Jarufe	University of Manchester	United Kingdom
Mr.	Kanapathippillai	Jeganathan	CSIRO	Australia
Dr.	Chengjin	Jin	NAOC	China
Dr.	Hyunwoo	Kang	Korea Astronomy and Space Science Institute	Korea, Republic of
Dr.	Vassilis	Karamanavis	Fraunhofer FHR	Germany
Dr.	Michael	Keith	University of Manchester	United Kingdom
Dr.	Reinhard	Keller	MPI für Radioastronomie	Germany
Dr.	Alex	Kraus	MPIfR	Germany

PAF Workshop 2019

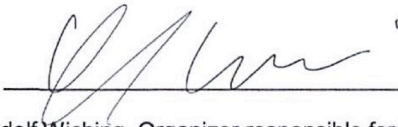
- Participants list -

	Name	Last name	Institution	Country
Dr.	Hariharan	Krishnan	National Centre for Radio Astrophysics (NCRA-TIFR)	India
Mr.	Felix	König	Technical Development	Germany
Mr.	Christian	Leinz	MPIfR	Germany
Dr.	Bin	Liu	NAOC	China
Dr.	Dongliang	LIU	NAOC	China
Mr.	Michael J.	Luddy	Lockheed Martin	United States
Dr.	Mark	McCulloch	The University of Manchester	United Kingdom
Dr.	William	McGenn	University of Manchester	United Kingdom
Dr.	Simon	Melhuish	University of Manchester	United Kingdom
Mr.	Lukas	Naumann	Fraunhofer FHR	Germany
Dr.	Alessandro	Navarrini	INAF-Astronomical Observatory of Cagliari	Italy
Dr.	Majid	Norooziarab	Max Planck Institute for radio astronomy	Germany
Dr.	Titus	Oyedokun	MPIfR	Germany
	Robert	Perkuhn	Fraunhofer FHR	Germany
Dr.	Sergiy	Putselyk	FHR	Germany
Dr.	Paul	Roberts	CSIRO	Australia
Dr.	Anish	Roshi	Arecibo Observatory	United States
Dr.	Alan	Roy	MPIfR	Germany
Mr.	Moritz	Schneider	Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik	Germany
Mr.	Frank	Schäfer	MPIfR	Germany
Dr.	Johnston	Simon	CSIRO	Australia
Dr.	Laura	Spitler	MPIfR	Germany
Mr.	Tim	Stevenson	SKAO	United Kingdom
Mr.	Marco	Tiesing	Fraunhofer FHR	Germany
Dr.	Tasso	Tzioumis	CSIRO	Australia
Mr.	Sener	Türk	Max-Planck-Institute for Radio Astronomy	Germany
Mr.	Wim	van Cappellen	ASTRON	Netherlands
Prof.	Karl	Warnick	Brigham Young University	United States
Dr.	Robert	Watson	University of Manchester	United Kingdom
	Gundolf	Wieching	MPIfR	Germany
Mr.	Thomas	Wirths	Fraunhofer Institute for High Frequency Physics	Germany

PAF Workshop 2019

- Participants list -

	Name	Last name	Institution	Country
Dr.	Olaf	Wucknitz	MPIfR	Germany
Dr.	Jason	Wu	MPIfR	Germany
Dr.	Shenghua	YU	National Astronomical Observatories, Chinese Academy of Sciences	China
Prof.	Dirk	Heberling	FHR	Germany

Signed: 
 Dr. Gundolf Wiching, Organizer responsible for the Workshop

3 Summary and Impact

The scope of the workshop was to exchange ideas and solutions among the developers of radio-astronomical instrumentation in the frequency range below 100GHz, especially under the aspect of phased array feed systems. After single pixel systems and discrete array receivers have been developed to sensitivities close to the physical limits, phased array feed systems are now the next logical step to further increase the science output of the observing facilities. These receiving systems with up to several hundred receiving channels introduce new technological challenges in all areas.

Contributions covered the following technological topics:

- PAF systems - Contributions targeting mainly the PAF system as a whole, e.g. system layout, commission strategy, performance
- PAF theory and simulations - Contributions, e.g. on the PAF theoretical background, beam-forming algorithms, RFI-mitigation schemes, system simulations, system optimization
- PAF frontend technology - Contributions targeting technologies of the receiver frontend, e.g. Antenna-array, analog signal processing, ADC
- Digital data processing and backend technology - Contributions targeting technologies of the digital part, e.g. beam-former, network-topology, computer cluster, data processing, backend software
- PAF science applications - Contributions related to possible (new?) science cases of PAFs, new observing strategies, data calibration
- Misc (but PAF related) - Misc topics which do not directly fit into the other topics, e.g. cryogenic cooling, large diameter vacuum windows

The workshop stimulated an intensive discussion and exchange on PAF developments. This covers the following areas including open questions:

- First generation of PAF's are now in science operations.

- Wide field of view provides ground-breaking advances for imaging surveys and transient detections
- System complexity (monitoring, control, amount of data) is a challenge
- Providing an important reference point in terms of performance and costs of PAF technology
- Currently, PAF's are envisaged to be very effective on (existing) large reflectors
 - Increased field of view
 - RFI mitigation, beam optimization
 - Requirement: Little compromise on single-beam sensitivity, leading to cryo-cooled systems
- Next generations of PAFs
 - Most new developments aim to reduce the system temperature, mostly by cryo-cooling, improved antenna and RF electronics design
 - Reduce backend costs, but limited control over key component costs
 - Cryo PAFs may reduce spillover to ~1 K
- Open Questions
 - Are different beamformers used other than max-SNR?
 - Beam stability, characterization, and maintenance is generally more important than controlled beam shape (Aaron Chippendale)
 - What is the optimal reflector shape for a given PAF?

4 RadioNet contribution

The RadioNet project supported the workshop with a total amount of 3500 EURO. The RadioNet financial contribution has been used to co-fund the venue and technical equipment to hold the workshop.

5 Publications

The workshop presentations agreed for publication are available at the event webpage: <https://events.mpifr-bonn.mpg.de/indico/event/108/timetable/#20190916>

6 Acronyms

PAF	Phased Array Feed
MPG	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.
MPIfR	Max-Planck-Institut für Radioastronomie
SKA	Square Kilometre Array
APERTIF	APERture Tile In Focus

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