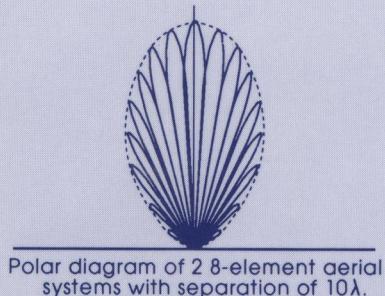
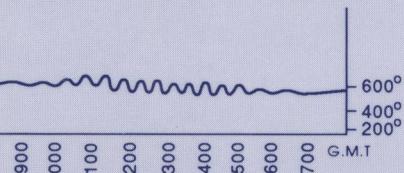




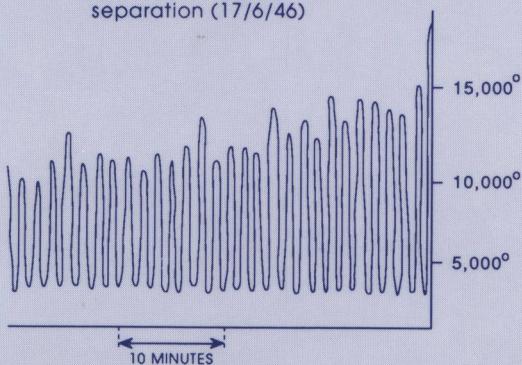
RADIO INTERFEROMETRY: THEORY, TECHNIQUES, AND APPLICATIONS



Polar diagram of 2 8-element aerial systems with separation of 10λ .



Record obtained with 10λ separation (17/6/46)



Record obtained with 140λ separation. (26/7/46)

Edited by
T. J. Cornwell and R. A. Perley

**RADIO INTERFEROMETRY:
THEORY, TECHNIQUES, AND APPLICATIONS**

A SERIES OF BOOKS ON RECENT DEVELOPMENTS IN ASTRONOMY AND ASTROPHYSICS

© Copyright 1991 Astronomical Society of the Pacific
390 Ashton Avenue, San Francisco, California 94112

All rights reserved

Printed by BookCrafters, Inc.

First published 1991

Library of Congress Catalog Card Number: 91-73701
ISBN 0-937707-38-4

D. Harold McNamara, Managing Editor of Conference Series
408 ESC Brigham Young University
Provo, UT 84602

ASTRONOMICAL SOCIETY OF THE PACIFIC
CONFERENCE SERIES



Volume 19

**RADIO INTERFEROMETRY:
THEORY, TECHNIQUES, AND APPLICATIONS**

Edited by
T. J. Cornwell and R. A. Perley

A SERIES OF BOOKS ON RECENT DEVELOPMENTS IN ASTRONOMY AND ASTROPHYSICS

- Vol. 1-*Progress and Opportunities in Southern Hemisphere Optical Astronomy: The CTIO 25th Anniversary Symposium*
ed. V. M. Blanco and M. M. Phillips ISBN 0-937707-18-X
- Vol. 2-*Proceedings of a Workshop on Optical Surveys for Quasars*
ed. P. S. Osmer, A. C. Porter, R. F. Green, and C. B. Foltz ISBN 0-937707-19-8
- Vol. 3-*Fiber Optics in Astronomy*
ed. S. C. Barden ISBN 0-937707-20-1
- Vol. 4-*The Extragalactic Distance Scale: Proceedings of the ASP 100th Anniversary Symposium*
ed. S. van den Bergh and C. J. Pritchett ISBN 0-937707-21-X
- Vol. 5-*The Minnesota Lectures on Clusters of Galaxies and Large-Scale Structure*
ed. J. M. Dickey ISBN 0-937707-22-8
- Vol. 6-*Synthesis Imaging in Radio Astronomy: A Collection of Lectures from the Third NTAO Synthesis Imaging Summer School*
ed. R. A. Perley, F. R. Schwab, and A. H. Bridle ISBN 0-937707-23-6
- Vol. 7-*Properties of Hot Luminous Stars: Boulder-Munich Workshop*
ed. C. D. Garmany ISBN 0-937707-24-4
- Vol. 8-*CCDs in Astronomy*
ed. George H. Jacoby ISBN 0-937707-25-2
- Vol. 9-*Cool Stars, Stellar Systems, and the Sun*
ed. G. Wallerstein ISBN 0-937707-27-9
- Vol. 10-*The Evolution of the Universe of Galaxies. The Edwin Hubble Centennial Symposium*
ed. Richard G. Kron ISBN 0-937707-28-7
- Vol. 11-*Confrontation Between Stellar Pulsation and Evolution*
ed. C. Cacciari and G. Clementini ISBN 0-937707-30-9
- Vol. 12-*The Evolution of the Interstellar Medium*
ed. L. Blitz ISBN 0-937707-31-7
- Vol. 13-*The Formation and Evolution of Star Clusters*
ed. K. Janes ISBN 0-937707-32-5
- Vol. 14-*Astrophysics with Infrared Arrays*
ed. R. Elston ISBN 0-937707-33-3

Vol. 15-Large-Scale Structures and Peculiar Motions in the Universe

ed. D. W. Latham and L. A. N. da Costa

ISBN 0-937707-34-1

Vol. 16-Atoms, Ions and Molecules: New Results in Spectral Line Astrophysics

ed. A. D. Haschick and P. T. P. Ho

ISBN 0-937707-35-X

Vol. 17-Light Pollution, Radio Interference, and Space Debris

ed. D. L. Crawford

ISBN 0-937707-36-8

Vol. 18-The Interpretation of Modern Synthesis Observations of Spiral Galaxies.

ed. M. Duric and P. C. Crane

ISBN 0-937707-37-6

Inquiries concerning these volumes should be directed to the:

Astronomical Society of the Pacific

CONFERENCE SERIES

390 Ashton Avenue

San Francisco, CA 94112-1722

CONTENTS

Foreword	i
List of Attendees	iii
 <u>Theory of Interferometry</u>	
Self noise in interferometers	1
M. Vivekanand (USRA), S. K. Kulkarni (Caltech)	
Source-noise in radio synthesis images	6
K. R. Anantharamaiah, A. A. Deshpande, V. Radhakrishnan (RRI), R.D. Ekers (ATNF), T. J. Cornwell, W. M. Goss (NRAO)	
The effect of spatial coherence of sources on synthetic aperture mapping	10
D. F. V. James (institute of Optics)	
 <u>Hardware for Interferometry</u>	
The design of high frequency antennas (Invited)	15
J. Delannoy (IRAM)	
Correlators for interferometry – Today and Tomorrow (Invited)	26
Y. Chikada (NRO)	
The use of optical fibers in radio interferometry (Invited)	33
A. Young (ATNF)	
The multi-frequency front end: a new type front end for the Westerbork Synthesis Radio Telescope	42
G. H. Tan (NFRA)	
Hardware considerations for high-dynamic-range imaging (Invited)	47
D. Bagri, A. R. Thompson (NRAO)	
A pulse calibration system for the VLBA	55
A. R. Thompson, D. Bagri (NRAO)	
Cryogenically cooled, HEMT amplifiers and receivers in 1-50 GHz range: state-of-the-art	60
M. Pospieszalski (NRAO)	
Tape recorders for VLBI (Invited)	65
A. E. E. Rogers (Haystack)	
Burst Mode VLBI and Pulsar Applications	76
R. D. Wietfeldt (ISTS), D. A. Frail (NRAO)	
Using sub-aperture illumination to solve the short-spacing problem	81
D. P. Woody, N. Z. Scoville (OVRO), L. G. Mundy (U. Maryland)	
Direct Imaging Digital Lens for Transient Radio Source Survey	86
T. Daishido, K. Asuma, K. Nishibori, J. Nakajima, M. Yano, E. Otobe, N. Watanabe, A. Tsuchiya (Waseda University, Tokyo) S. Iwase (Sony Corporation)	
Phase Control in the Digital Lens	90

K. Asuma (Soka High School), S. Iwase, K. Nishibori (Sony Corporation), J. Nakajima, E. Otobe, A. Tuchiya, N. Watanabe, T. Daishido (Waseda University, Tokyo),	
The portable Holographic Antenna Measurement System	94
D. B. Shaffer, J. M. Gipson (Interferometrics)	
Compatibility issues in VLBI	98
R. D. Wietfeldt (ISTS), L. D'Addario (NRAO)	
 <u>Space-based VLBI</u>	
IVS-a second generation space VLBI mission	102
G. Pilbratt (ESA)	
Simulations of space VLBI	107
D. W. Murphy (JPL)	
Space Ground Interferometer	112
A. I. Savin, M. B. Zaxon (Corporation Kometa), L. I. Matveyenko (IKI)	
The requirement on baseline knowledge for Space VLBI	115
L. R. Kogan, N. A. Eysmont (IKI)	
 <u>Seeing</u>	
Opacity at the Owens Valley Millimeter Array	119
S. L. Scott and D. P. Woody (OVRO)	
The NRAO Millimeter Array Site survey	124
F. N. Owen (NRAO)	
 <u>Computing</u>	
Software systems for the Ryle Telescope	128
D. J. Titterington (MRAO)	
 <u>History</u>	
Some highlights of Interferometry in early Radio Astronomy (Invited)	132
W. T. Sullivan, III (U. Washington)	
Reminiscences of the early days of the VLA (Invited)	150
D. Heeschen (NRAO)	
The early technical development of the VLA (Invited)	160
G. Swenson (U. Ill.)	
The Design and Construction of the VLA: The project Manager's view (Invited)	165
J. Lancaster	
 <u>Imaging</u>	
Multi-Frequency Synthesis (Invited)	171
J. E. Conway (Caltech)	
The use of beam-sets in the analysis of wide-field maps from the CLFST	180
E. M. Waldram (MRAO)	
Imaging with non-coplanar baselines	184
R. A. Perley, T. J. Cornwell (NRAO)	
Adding short spacings to synthesis maps in the "sky"- domain	188
U. J. Schwarz (Kapteyn Laboratory), B. P. Wakker (U. Ill.)	

The use of redundancy in interferometry: a comparison between redundancy and self-calibration	192
M. Wieringa (Leiden Observatory)	
The Bi-spectrum analysis technique in millimeter interferometry	197
K.-I. Morita (NRO)	
Self-calibration of M.O.S.T. data	202
A. D. Gray (U. Sydney)	
High accuracy ($\ll 1\%$) polarization measurements with WSRT	206
J. Noordam (NFRA)	
GMRT Mapping Strategies	212
A. P. Rao (TIFR)	
Low Frequency imaging and the non-isoplanatic atmosphere	218
C. R. Subrahmanya (TIFR)	
333 MHz observations at the VLA: A search for pancakes	223
J. M. Uson, D. Bagri, T. J. Cornwell (NRAO)	
The three dimensional structure of astronomical sources through optimal inversion	228
E. R. Keto (U. Ill.), W. Jeffrey (IDA)	
Imaging for the Australia Telescope: Present needs and future strategies	233
R. P. Norris (AT)	
Speckles in Interstellar Radio-Wave Scattering	238
K. M. Desai, C. R. Gwinn (UCSB), J. Reynolds, E. A. King (ATNF), D. Jauncey (CSIRO), G. Nicholson, C. Flanagan (HRAO), R. A. Preston, D. L. Jones (JPL)	
A modified CLEAN algorithm for wide field images with extended structures	242
K. S. Dwarakanath, A. A. Deshpande, N. Udaya Shankar (RRI)	
Application of an estimator-free information criterion (WIC) to aperture synthesis imaging	243
M. Ishiguro (ISM), K. Morita and M. Ishiguro (NRO)	
The first VLA observations of radio soures at 73.8 MHz	249
N. Kassim (NRL), R. Perley (NRAO), W. Erickson (Tasmania)	
Wide field mapping of 5C12	253
J. E. Okopi, L. B. Baath (OSO)	
Phase calibrators for MERLIN	257
A. R. Patnaik, I. W. A. Brown, P. N. Wilkinson (NRAL), J. Wrobel (NRAO)	
Observational test of the homogeneous array concept: An X-band image of the Crab Nebula	260
J. M. Uson, T. J. Cornwell (NRAO)	
Visibility based continuum subtraction	264
H. J. van Langevelde (Leiden), W. D. Cotton (NRAO)	
The Multi-resolution CLEAN	268
B. P. Wakker (U. Illinois), U. J. Schwarz (Kapteyn Observatory)	
Numerical Experiments with low SNR data in Radio Interferometry	272
P. N. Wilkinson, P. Woodall (NRAL)	
Hot spots in Cygnus A: A mosaiced map at 86 GHz	276
M. C. H. Wright (UCB), R. J. Sault (NCSA)	

<u>VLBI Imaging</u>	
VLBI polarization observations (Invited)	281
D. H. Roberts, L. F. Brown, J. F. C. Wardle (Brandeis)	
VLBI phase referencing for observations of weak radio sources (Invited)	289
J.-F Lestrade (Bureau des Longitudes)	
EVN as a phase stable instrument	298
L. Baath (OSO), F. Mantovani (Instituto di Radioastronomia)	
Are the bandwidth synthesis delay and delay rate observables useful for VLBI imaging?	302
P. Charlot (JPL)	
Errors in high precision source position determination	307
P. Elosegui, J.-M.Marcaide (IAA), I. I. Shapiro (CfA)	
MERLIN observations of superluminal motion in the jet of 3C120	312
T. W. B. Muxlow, P. N. Wilkinson (NRAL)	
A new method of analysis and reduction of VLBI observations	317
E. F. Arias, M. S. de Biasi (FCAG)	
Global Fringe Fitting on MkIII VLBI data	321
L. Baath (OSO)	
mmVLBI - High resolution imaging	326
L. Baath, R. S. Booth (OSO)	
The link to extragalactic sources: observations of radio stars	330
A. Baudry, Y. Requieme (Obs. de l'Université de Bordeaux)	
Dual Frequency Synthesis VLBI Observations of 3C84 at 18cm wavelength	334
J. A. Biretta (NRAO), N. Bartel (CFA), J. Deng (U. Iowa)	
Astrometry of SiO Masers	338
F. Colomer (OSO), D. Graham, T. Krichbaum, (MPIfR), B. O. Rönnäng (OSO), P. de Vicente, A. Barcia (CAY), R. S. Booth (OSO), A. Witzel (MPIfR), J. Gomez-Gonzalez (CAY), A. Baudry (Obs. de Bordeaux)	
High accuracy equation of equinox and VLBI astrometric modelling	342
A. M. Gontier, N. Capitaine (Obs. de Paris)	
Mk-III VLBI astrometry of pulsars	346
D. L. Jones, R. J. Dewey (JPL), C. R. Gwinn (UCSD), M. M. Davis (NAIC)	
Exploring the limits of Phase Referenced VLBI; a progress report	350
R. C. Vermeulen, J. E. Conway (Caltech)	
State of the art VLBI imaging: 3C345	354
A. Wehrle (UCLA), S. C. Unwin (OVRO)	
 <u>Other fields</u>	
Imaging Optical interferometry (Invited)	358
R. S. Simon (Interferometrics), K. J. Johnston, D. Mozurkewich, K. W. Weiler, D. J. Hutter (USNO), J. T. Armstrong (USRA), T. S. Brackett (Interferometrics)	
Quantitative assessment of the science return from an Orbiting, Imaging, Optical Interferometer	368
D. L. Meier, S. P. Synnott, P. J. Dumont, D. L. Jones (JPL)	
VHF Radio Interferometry of Lightning	372

P. R. Krehbiel, X. M. Shao, R. J. Thomas (NMIMT), C. T. Rhodes (LANL), C. O. Hayenga (Array Tech. Corp)

Interferometric Telescopes

Giant Meterwavelength Radio Telescope (GMRT)	376
G. Swarup (TFIR)	
The MERLIN - phase 2	381
P. N. Wilkinson (NRAL)	
Progress on Chinese VLBI network project	386
Ye Shuhua, Wan Tongshan, Qian Zhihan (Shanghai Observatory)	
The Very Long Baseline Array	390
P. Napier (NRAO)	
Microwave Background interferometry at Cambridge	395
M. E. Jones (MRAO)	
The Owens Valley Millimeter Array	400
S. Padin, S. L. Scott, D. P. Woody (OVRO)	
The Smithsonian Astrophysical Observatory Submillimeter Wavelength Array	405
C. R. Masson (SAO)	
The Millimeter Array	410
R. L. Brown (NRAO)	
The Proposed Radio Schmidt Telescope: technical challenges	415
P. E. Dewdney, T. E. Landecker (DRAO)	
Aperture Synthesis imaging from the Moon (Invited)	420
J. O. Burns (NMSU)	
The Hydrogen Array	428
P.N. Wilkinson (NRAL)	
A test of Radio Interferometry by Lunar reflection	433
L. Belkora, T. Hagfors, T. Phillips (Arecibo)	
Imaging Characteristics of a Homogeneous Millimeter Array	437
M. Holdaway (NRAO)	
Imaging Characteristics of the proposed NRAO MMA, with and without a single large element, and a pointing correction algorithm	441
D. T. Emerson (NRAO)	
Monitoring source variability with the Fast All Sky Telescope	445
K. J. Johnston, R. Fiedler (NRL), R. Simon (Interferometrics)	
The IRAM Plateau de Bure Interferometer	449
R. Lucas (IRAM)	
The Canadian Geophysical LBI System: Status and Future Plans	453
W. T. Petrachenko, P. Mathieu, J. Popelar, M. Daniels (GSC)	
Optimal antenna configurations for the BIMA Array	457
N. Thatte, Wm. J. Welch (UCB)	
