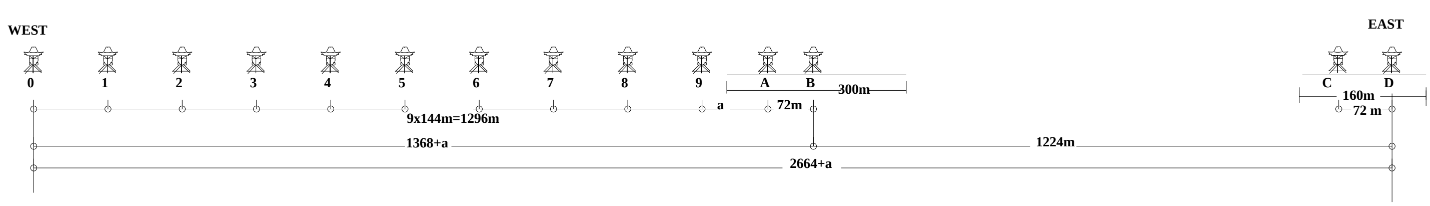
THE WESTERBORK SYNTHESIS RADIO TELESCOPE USER DOCUMENTATION

EDITED BY
OLAF M. KOLKMAN

JULY 16, 1993

VERSION
1.0.0

Netherlands Foundation for Research in Astronomy
Stichting Astronomisch Onderzoek in Nederland
Postbus 2, 7990 AA Dwingeloo, the Netherlands
Oude Hoogeveensedijk 4, Dwingeloo
tel: 05219-7244, telefax:05219-7332



WSRT USER DOCUMENTATION PREFACE

INTRODUCTION TO THE WSRT USER DOCUMENTATION

INTRODUCTION

This is the user documentation for the Westerbork Synthesis Radio Telescope. It replaces the old manual and the WSRT information packet.
The old manual was released in 1980. It contained several useful articles but it had not been updated since its release and much of the information presented was out of date. In 1987 a WSRT information packet was released for users of the WSRT. This information packet contained a brief description of the instrument and all the information needed to write a proposal.
The user documentation replaces the documents mentioned above. It contains new material and updated parts from the old manual and the information packet.

THE STRUCTURE AND CONTENTS OF THE DOCUMENTATION

The user documentation consists of six parts which can be used and distributed separately. Each part is relevant for a separate stage of of using the WSRT. The advantage of this modular approach is that the sizes of the individual parts do not become too large and that the individual parts are easy to maintain. To provide easy access to the information each individual part has it's own table of contents in addition to a table of contents and subject index for the complete user documentation.
Below a general description of the contents of the user documentation is given.

The documentation begins with a short description of the user documentation documentation (which is what you are reading now), a table of contents, a subject index, and a list of references.

Part 1: Proposing for WSRT observing time.

This part contains all the information necessary to write a proposal. Here we present a summary of the capabilities of the WSRT, explain how time is awarded, supply the necessary addresses and present a list of persons whom to contact with specific questions.

This part can be used individually and will be sent to people who are interested in observing with the WSRT. There is some redundancy with information in other parts of the documentation.

Part 2: Introduction to the theory of aperture synthesis

This part contains an introduction to the theory of aperture synthesis with some emphasis on the WSRT. It is probably not needed by experienced radio astronomers but may be of use to those who are new to the field. This part contains some chapters with introductory theory with references to the standard literature. In the last chapter we included a bibliography and a 'dictionary' for quick reference to standard literature.

Part 3: Specific aspects of the WSRT

In this part we describe the different modes of operation of the WSRT, provide some technical information and explain how a setup must be specified when proposing for an observation. There is some redundancy with the first part of the documentation. While writing a proposal the less experienced WSRT user may find it useful to consult this part for more details about the differences between the several instrumental setups.

Part 4: Calibration and reduction of WSRT data

In this part we describe the corrections and calibrations that are and/or need to be performed on WSRT data. We present some tips and hints for further data reduction and present pictures with errors that may be encountered in WSRT maps.

Part 5: Various

In this part we present equations, graphs and tables that may be useful for the specification of a proposal or during the reduction phase. We also included a brief guide to ARCQUERY, the archive query software.

Part 6: NewStar

The second version of the user documentation will contain the NewStar program descriptions and recipes. We expect that this part will become available before the end of 1993. NewStar is the special software for *u*,*v*-data processing, developed at the NFRA.

THE FORMAT OF THE MANUAL

The documentation was produced using the LaTeX type setting program. The output format of the manual is PostScript. The advantages of this are that the User Document can be distributed electronically and can be reproduced locally by the user without loss of quality of pictures and text. (WISIWYG,what I see is what You get.)
Another format we considered for the reproduction of the documentation was TeX-Info. TeX-Info is a system with which information can be reproduced on paper and online on a computer terminal. We did not choose for this system because it is not able to display information like mathematical formulae and figures. We also think that the information in the documentation will be read elsewhere than behind a computer terminal.

THE PRODUCTION, DISTRIBUTION AND MAINTENANCE OF THE MANUAL

The user documentation was produced in a 16 month period. The work was done on a computer account in Groningen. All texts were typeset in LaTeX and all figures were redrawn using SM, Xfig and IslandDraw. All the files were shipped to an account (referred to as the documentation account) at NFRA Dwingeloo and will be maintained at NFRA. Observers who showed interest in the use of the WSRT are always supplied with the most recent version of part 1 of the documentation. A complete copy of the user documentation can be obtained in two ways.

1. A copy of the user documentation can be requested at NFRA. This can be done by sending an e-mail request to the documentation account or by contacting the NFRA secretary by surface mail or telephone.

2. An alternative way to obtain a copy of the documentation is to make use of anonymous ftp to obtain the necessary PostScript files.

The user documentation is maintained on the documentation account at NFRA. Whenever parameters of the instrument change, new information becomes available, or errors in the documentation are corrected a new version of the user documentation will be released. The structure of the user documentation is such that changes in the text do not need to affect more than a few pages. So to update the user documentation to a new version only a few pages need to be replaced or added in a recent version. Users of the documentation can register them selves so that they are informed about the change to a new version so they can update their private copy. Updates can be obtained in a similar way as a complete version of the documentation i.e. PostScript format on the anonymous ftp-node and paper copies by surface mail. Information about recent updates can be found in the NFRA-Newsletter and on the anonymous ftp-node.

OBTAINING OR UPDATING A PRIVATE COPY OF THE USER DOCUMENTATION

OBTAINING THE USER DOCUMENTATION

The documentation is stored in postscript format on an anonymous ftp node. It can be printed out on every regular postscript device. To obtain a copy of the documentation use the following procedure.

– Find a suitable computer and type `ftp rzmws10.nfra.nl` or if the route cannot be found `ftp 192.87.1.160`

– At the prompt `username` type: `anonymous`. Type your e-mail address as password.

– type `get README` to get the README file and read it

– Change directory to `wsrt.userdoc/total.copy/`

– type `binary` to set the file transport to binary

– type `mget part*.ps.Z` and `y` at the prompt

– type `get registration.form`

– Leave ftp by typing `quit`

– Uncompress the files and print files on a postscript printer e.g.
`zcat part*.ps.Z |lpr -s -P⟨ printername ⟩`

  should work in a 'standard' UNIX environment.

– Fill in the `registration.form` and send it to `wsrt@nfra.nl`. You will then be informed when new versions of the documentation appear.

In the case you are not able to get, uncompress or print out the User Documentation, you are requested contact NFRA at the user documentation account.
Remember that obtaining a complete version of the user documentation is a somewhat time consuming job. First you have to transfer a few mega bytes of data at a rate typically of the order of 5kb per second. Then you have to print the documentation, which takes in the order of 1 to 2 hours.
It is in most cases more practical to Xerox a library copy and ftp the updates or to obtain a paper copy from NFRA.

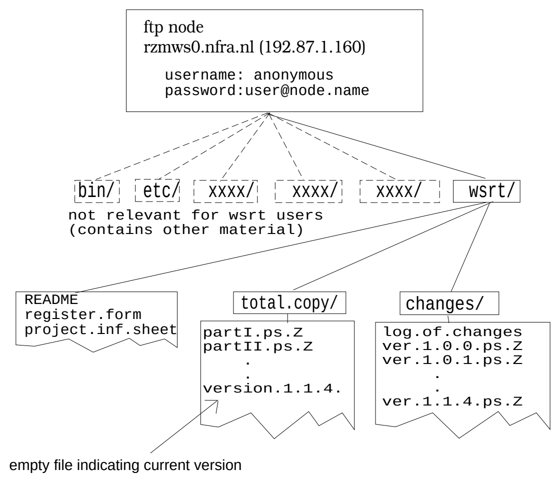


Figure 1.1: Directory structure of the anonymous ftp node on which a user can find the complete WSRT User Documentation

UPDATING THE USER DOCUMENTATION

Whenever information is added to the documentation or information has been changed in the documentation a new version appears. The User Document as obtained from the `wsrt.userdoc/total.copy/` directory on the anonymous ftp node is always the most recent one.

Once you have sent in the registration form you will be informed by e-mail when the documentation is changed. You may then obtain a new version of the User Documentation. However, because ftp-ing and printing completely new parts is not only cumbersome but also bad for the environment (paper, toner, energy) the most recent changes are placed in files on a separate directory on the anonymous ftp-node. In this directory (`wsrt.userdoc/changes/`) there is a file called `log.of.changes` which contains information about the changes since appearance of the manual referring to the corresponding version numbers. By comparing the version number on the front cover of your manual you will be able to see which files you have to ftp to obtain a updated version of the manual. The reader is strongly advised to read this `log.of.changes`- file before ftp-ing new files. Of course you may always decide to obtain a new full copy of the Documentation in which all cross referencing and page numbering is correct.

NB: To get notification about new versions you should be registered. To register send the registration form from the anonymous ftp-node to the documentation account. If you do not have e-mail available please send a message by surface mail to the NFRA secretary.

ADDRESSES

The person responsible for the maintenance of the user documentation and its distribution can be contacted by: sending an e-mail message to the documentation account or via the NFRA secretary. Complaints about, suggestions on, requests for, and contributions to the user documentation should also be sent tot he documentation account or the NFRA secretary.

documentation account : WSRT@NFRA.NL

NFRA Secretary : NFRA
P.O. Box 2
NL-7990 AA Dwingeloo
The Netherlands
tel:+31-(0)5219-7244
fax:+31-(0)5219-7332

CONCLUDING REMARKS

The WSRT user documentation will provide all scientists interested in using the WSRT with useful and up-to-date information. Regular maintenance will ensure that one is always provided with information about the latest developments in the hardware of the WSRT or in the software used to reduce its data. If you are interested in a copy please obtain one at the anonymous ftp-node (rzmws10.nfra.nl (192.87.1.160)), send a request for a paper copy to the documentation account (wsrt@nfra.nl), or contact the NFRA secretary (Postbus 2, NL-7990 AA Dwingeloo, The Netherlands). This is also the address to send your registration form to. A copy of the registration form can be found below or on the anonymous ftp-node.
If you have any comments or suggestions about improving this documentation please contact us at the documentation account (wsrt@nfra.nl), or contact the NFRA secretary (Postbus 2,NL-7990 AA Dwingeloo, The Netherlands). We specially welcome

- Additions of anything you feel is missing from this documentation.
- Any remarks and/or suggestions which may improve the intelligibility of parts of the user documentation.
- Detections of typos, etc.

COPYRIGHT

ACKNOWLEDGMENTS

The editing and production of this documentation was done as a civil service project financially supported by NFRA.
The Netherlands Foundation for Research in Astronomy is financially supported by the Netherlands Organization for Scientific Research.

```
--- Registration Form ------------------------   WSRT User Documentation ----

(..)    I obtained a copy of (a part of) the WSRT User Documentation and
        I want to be informed by e-mail when updates appear.

(..)    I would like to receive a paper copy of the WSRT proposal packet
        (Part 1 of the User Documentation).

(..)    I would like to receive a paper copy of part ... of the WSRT
        User Documentation.

(..)    I would like to receive a copy of the complete
        WSRT User Documentation.

My name is: ............................................................

   address: ............................................................

         ............................................................

         ............................................................

         ............................................................

         ............................................................

   country: ............................................................

telephone: (...).................... E-mail: ..........................


Please send this form to:
     NFRA
     Postbus 2
     NL-7990 AA Dwingeloo
     The Netherlands
or a similar message by e-mail to WSRT@NFRA.NL

----------------------------------------------------------------------------
```

WSRT USER DOCUMENTATION

CONTENTS

Part II Introduction to the Theory of Aperture Synthesis

Part III Specific Aspects of the WSRT

Part IV Calibration and Reduction of WSRT Data

Part V Various

WSRT USER DOCUMENTATION INDEX

The Roman numbers in the page numbers indicate in which part the item can be found. The titles of the parts are summarized below. In the preface we give a short description of the contents of the parts.

I Proposing for WSRT Observing Time
II Introduction to the Theoryu of Aperture Synthesis
III Specific Aspects of the WSRT
IV Calibration and Reduction of WSRT Data
V Various
VI The NewStar Software

WSRT USER DOCUMENTATION GLOSSARY

A : azimuth
a : altitude
$A(\sigma), A(l,m)$: antenna reception pattern
A_e : effective aperture of antenna
A_T : geometrical cross-sectional area of antenna aperture
$A_N(\sigma), A_N(l,m)$: normalized antenna reception pattern (= $A(\sigma)/\mathbf{A}(\mathbf{0})$ or $A(\sigma)/\mathbf{A}_{\text{max}}$
B : total bandwidth
$B(\sigma)$: brightness distribution in direction σ
$B'(\sigma)$: modified brightness distribution indirection σ
b : channel separation $b = B/N_F$
b : new galactic latitude
D : degradation factor, increase in noise when using a digital instead of an analogue correlator
$\mathbf{D}$: baseline vector
$\mathbf{D}_\lambda$: baseline vector in units of wavelength
D_λ : length of baseline vector in units of wavelength
$D_{\lambda,max}$: maximum baseline length in units of wavelength
$D_{\lambda,min}$: minimum baseline length in units of wavelength
$D_{\lambda,inc}$: baseline length increment in units of wavelength
$\mathbf{E}$: complex electric field column vector
E_x : x component of complex electric field column vector
E_y : y component complex electric field column vector
D_{proj} : projected baseline length
D_x, D_y, D_z : components of baselinevector in equatorial coordinates
$\hat{\mathbf{e}}_\mathbf{u}$: unit vector of the astrometric coordinate system, points to $\delta = 0°$, $h = 0^h$
$\hat{\mathbf{e}}_\mathbf{v}$: unit vector of the astrometric coordinate system, points to $\delta = 0°$, $h = 6^h$
$\hat{\mathbf{e}}_\mathbf{w}$: unit vector of the astrometric coordinate system, points to $\delta = 90°$
$\hat{\mathbf{e}}_\mathbf{x}$: unit vector of the equatorial coordinate system, points to $\delta = 0°$, $h = 0^h$
$\hat{\mathbf{e}}_\mathbf{y}$: unit vector of the equatorial coordinate system, points to $\delta = 0°$, $h = 6^h$
$\hat{\mathbf{e}}_\mathbf{z}$: unit vector of the equatorial coordinate system, points to $\delta = 90°$
$\mathbf{F}$: response matrix
$F(\mathbf{D}_\lambda, \mathbf{s}_0)$: fringe function
$F(\mathbf{s}_0)$: fringe function
$F(\mathbf{s})$: fringe function
G : grading function
G : (complex) gain factor
$g(u,v)$: grading function

$G(l, m)$: Synthesized beam (Fourier transform of the grading)
$H(\nu)$: bandpass shape function
H_i : signal in Hanning tapered frequency channel
H_{AV} : average signal signal in added Hanning tapered channels
$H(\beta)$: normalized voltage main beam response
h : hour angle
h_0 : hour angle of pointing center
$h(t)$: time cross correlation function
I : Stokes parameter, total intensity (complex)
$I_b(R)$: integral of synthesized beam of circular area with radius R
J_0 : zero order Bessel function
j : imaginary unit ($j = \sqrt{-1}$)
K_λ : Constant involved in noise calculation
$K(\beta)$: normalized voltage crosstalk term
k : Boltzmann's constant
L : left hand circular $= I - V$
L_s : linear shadowing
l : new galactic longitude
M : factor depending on type of receiver and dipole combination
N_B : Bitmode (equals 1 or 2)
N_{BL} : number of spacings
N_F : number of frequency channels
N_I : number of interferometers
N_P : Number of polarizations
n : an integer vallue
M : scaling factor depending on type of receiver and dipole combination used
m : fraction of polarization
P : percentage polarization
P_s : polarization summation factor
P_A : polarization position angle
$P(R)$: normalized synthesized beam intensity at radius R
p : position angle of the baseline
Q : Stokes parameter, linear polarization component (complex)
q : parallactic angle
R : right hand circular $= I + V$
$\mathbf{R}(\rho)$: Rotation matrix
R_{EW} : complex response of a polarization interferometer
RT : shorthand for radio telescope
R_{tel} : Telescope response
$r(\mathbf{D}_\lambda, \mathbf{s}_0)$: response of a correlating array as a function of baseline seperation and pointing direction
S : coherence matrix
$S_{xx}, S_{xy}, \ldots$: components of the coherence matrix
S : observed flux
S_0 : source flux density
S_m : matched flux density
s : direction vector pointing to arbitrary center
$\mathbf{s}_0$: direction vector pointing to field center
s_x, s_y, s_z : components of pointingvector in equatorial coordinates
T_A : antenna temperature

T_F	:	system temperature of fixed telescope
T_M	:	system temperature of movable telescope
T_b	:	brightness temperature
T_n	:	noise temperature
T_r	:	temperature of a resistor
T_s	:	system temperature
t	:	integration time
U_i	:	signal in frequency channel i
U	:	Stokes parameter, linear polarization component (complex)
V	:	output voltage column vector
V_x	:	x component of output voltage column vector
V_y	:	y component output voltage column vector
V	:	Stokes parameter, circular polarization component (complex)
W	:	power
W_A	:	power measured by radio antenna
W_r	:	power at resistor terminal (Nyquist)
w	:	spectral power (power per unith bandwidth)
w_A	:	spectral power (power per unith bandwidth) measured by antenna
XX	:	(complex signal in) correlation channel made from dipole X and dipole X in telescope 'p' and 'q' respectively
XY	:	(complex signal in) correlation channel made from dipole X and dipole Y in telescope 'p' and 'q' respectively
YY	:	(complex signal in) correlation channel made from dipole Y and dipole Y in telescope 'p' and 'q' respectively
YX	:	(complex signal in) correlation channel made from dipole Y and dipole X in telescope 'p' and 'q' respectively
α	:	right accension
β	:	boresight angle
β_f	:	full width at half maximum of the power beam
β_m	:	distance from the center to the point at which the voltage polarization has its maximum
β_0	:	the distance in degrees of the beam center to the first null of the voltage pattern
$\Gamma(u, v, t)$	:	coherence function
$\Delta\Phi$	:	phase shift
$\delta\nu$	:	noise equivalent bandwidth
δ	:	declination
δ_0	:	declination of pointing center
$\sigma_a v$	:	r.m.s. noise in added frequency channels after (Hanning) tapering
$\delta\nu$	:	frequency separation, bandwidth
Δ^-	:	(scalar) dipole setting error difference (=$\Delta_{RTWEST} - \Delta_{RTEAST}$)
Δ^+	:	(scalar) dipole setting error sum (=$\Delta_{RTWEST} + \Delta_{RTEAST}$)
ΔS	:	error associated with total flux density S
ΔS_{rms}	:	thermal noise fluctuations in total flux density
ϵ	:	(complex small instrumental term (=$\Delta^- - j\Theta^+$)
η_a	:	aperture efficiency
η_g	:	grading efficiency factor
η	:	(complex small instrumental term (=$\Delta^+ - j\Theta^-$)
Θ^-	:	(scalar) dipole elipticity difference(=$\Theta_{RTWEST} - \Theta_{RTEAST}$)
Θ^+	:	(scalar) dipole elipticity sum (=$\Theta_{RTWEST} + \Theta_{RTEAST}$)
ν	:	frequency

Ω_A : beam area (integral over the beam)
ρ : rotation angle
σ : vector in image plain ($\sigma = \mathbf{s} - \mathbf{s_0}$)
σ : error associated with matched flux density S_m
σ_{XX},σ_{XY}, etc: error associated with matched flux density for different polarizations
τ_g : geometrical delay
τ_i : inserted delay
Φ : latitude
Φ_z : phase of complex number z
$\Phi_{\mathcal{V}}$: visibility phase
χ : nominal position angle of dipole
χ^+ : sum of nominal position angle of dipoles = $\chi_W + \chi_E$
χ^- : nominal position angle of dipole = $\chi_W - \chi_E$
$\mathcal{V}$: complex visibility
$|\mathcal{V}|$: visibility amplitude
III : Shah function
$\Re(z)$: real part of complex number z
$\Im(z)$: imaginary part of complex number z
$++$: paralel dipoles
$+\times$: crossed dipoles

WSRT USER DOCUMENTATION

REFERENCES

In the User Documentation we refer to several articles and books. For convenience we included a list of all those references.

Abramowitz, M. and Stengun, I.A., (1965): *"Handbook of Mathematical functions"* Dover Publications Inc., New York. ISBN 0-486-61272-4.

Baars, J.W.M., Brugge, J.F. van der, Casse, J.L., Hamaker, J.P., Sondaar, L.H., Visser, J.J. and Wellington, K.J. (1973): *Proc IEEE* **61**, p. 158.

Baars, J.W.M. and Hooghoudt, B.G. (1974): *Astron.& Astrophys.* **31**, p. 323.

Blackman, R.B and Tukey, J.W., (1959): *"The measurement of power spectra : from the point of view of communications engineering"*. Dover publications, New York. ISBN 0-486-60507-8 first appeared in: Bell system technical journal **37** (1958).

de Blok and Woudt, (1992): 'WSRT polarization at 21 cm' students radio practicum report.

Bos, A. (1985): 'On instrumental effects in spectral line observations' Ph.D. Thesis, University of Leiden

Bos, A. (1993): *NFRA internal tech. report*, **200** (available at NFRA).

Bos, A., Raimond, E., and Someren Greve, H.W. van (1981): *Astron.& Astrophys.* **98**, p. 251.

Bracewell, R.N. (1978): *" The Fourier Transform and Its Applications (2nd edition)"* McGraw-Hill International Book Company. ISBN 0-07-007013-X.

Braun, R. and Walterbos, R.A.M. (1985): *Astron.& Astrophys.* , **143**, p. 307.

Bregman, J.D. *et al.*(1982): '6 cm bundel van een 25 m SRT spiegel', *NFRA NOTE*, **Draft** (available at NFRA).

Bregman, J.D. (1983): 'WSRT antenna pattern reference data', *NFRA NOTE*, **417** (available at NFRA).

Brouw, W.N. (1971): Ph.D. Thesis, University of Leiden.

Brouw, W.N. (1974): *NFRA internal tech. report*, **78** (available at NFRA).

Brouw, W.N. and van Someren Gréve, H.W.(1973): *NFRA internal tech. report*, **112** (available at NFRA).

Brigham, E.O. (1974): *"The Fast Fourier Transform"* Prentice-Hall.

Burns, W.R (1972): *Astron.& Astrophys.* , **19**, pp. 41.

Casse, J.L., Woestenburg, E.E.M. and Visser, J.J. (1981): *I.E.E.E. Trans. Micr. Teory and Techn.*, **30**, 2, pp. 201-209

Christiansen, W.N. and Högbom, J.A. (1985): *"Radio Telescopes"*. Cambridge University Press 1969, 1985(2nd ed.). ISBN 0-521-26209-7 (2nd ed.) / 0-521-07054-6 (1st ed.)(see also review in part II Chapter 9.1, book 4).

Ekers, R.D. and Rots, A.H. (1979): " Short spacing synthesis from a primary beam scanned interferometer" in Proc. IAU Coll. 49 *"Image Formation from Coherence Functions in Astronomy"*, Ed. C. van Schooneveld. D. Reidel (Dordrecht, Holland), pp. 61-66

Gonzales, C. and Wintz, P. (1987): *"Digital Image Processing"* Addison-Wesley Publishing Company 1987 ISBN 0-201-11026-1.

Hamaker, J.P. (1979): in '*Image Formation from Coherence Functions in Astronomy*' Ed. Schooneveld, C. D Reidel Publishing Company

Harris, F. (1978): 'On the use of windows for Harmonic analysis with the discrete Fourier Transform' *Proc IEEE*, **66** no.1, pp. 51-83.

Henneken and Robijn, (1989: ‘WSRT polarization at 327 MHz’ students radio practicum report.

Högbom, J.A. (1974): *Astron.& Astrophys. Suppl.* , **15**, p. 417.

Högbom, J.A. and Brouw, W.N. (1974): *Astron.& Astrophys.* , **33**, p. 289.

Kraus, J.D. (1986): *“Radio Astronomy” (2nd edition)* Cygnus-Quasar Books, Ohio. ISBN:- (see also review in part II Chapter 9.1, book 6).

Lilley and Palmer (1967): *Astrophys. J. Suppl.* **16**, p. 143.

Lovas, Snyder and Johnson (1979): *Astrophys. J. Suppl.* **41**, p. 451.

Morris et al (1964): *Astrophys. J.* **139**, p. 551.

Napier, P.J., Thompson, A.R. and Ekers, R.D. (1983): ‘The Very Large Array; Design and Performance of a Modern Synthesis Radio Telescope’, *Proc IEEE*, **71**, pp. 1295-1320.

Noordam, J.E. and de Bruyn, A.G. (1982): *Nature*, **299**, pp. 597-600.

Perley T.J. and Readhead, A.C.S. (1984): *ARA&A*, **22**, pp. 97.

Perley, R.A., Schwab, F. and Bridle, A.H. (Editors) (1989): *“Synthesis Imaging in Radio Astronomy”*. Astronomical Society of the Pacific.. ISBN:0-937707-23-6. (see also review in part II Chapter 9.1, Book 2).

Q.M.C, (1978): ’Quality Monitoring Committee report on 6 cm beam properties’.

Resch, G.M. (1984): ‘Water vapour radiometry in geodetic applications’, in *“Geodetic refraction, effects of electromagnetic wave propagation through the atmosphere”*, ed. F.K. Brunner, Springer Verlag, Berlin, pp.53.

Rohlfs, K. (1986): *“Tools of Radio Astronomy”*. Springer Verlag, Berlin.. ISBN:3-540-16188-0/0-387-16188-0. (see also review in part II Chapter 9.1, book 1).

Rots, A.H. (1975): Ph.D. Thesis, University of Groningen.

Someren Greve, H.W. van (1974): *Astron.& Astrophys. Suppl.* , **15**, p. 343.

Spoelstra, T.A.Th. (1983): *Astron.& Astrophys.* , **120**, pp. 313-321.

Spoelstra, T.A.Th. (1984): Radio Science, **19-no3.**, pp. 779-788.

Spoelstra, T.A.Th. (1992): ‘Ionosphere and Troposphere seen through a Radio Interferometer’ in *“Remote Sensing of the Propagation Environment”*, AGARD Conference Proceedings 502, Advisory Group for Aerospace Research & Development, Neuilly sur Seine, France.

Tan, G.H. (1990): *NFRA NOTE*, **555** (available at NFRA).

Thompson, A.R., Clark, B.G. and Napier, P.J (1980): *Astrophys. J. Suppl.* , **44**, pp. 151-167.

Thompson, A.R., Moran, J.M. and Swenson Jr., G.W. (1986): *“Interferometry and Synthesis in Radio Astronomy”*. John Wiley & Sons, New York.. ISBN 0-471-80614-5. (see also review in part II Chapter 9.1, book 3).

Verschuur, G.L. and Kellerman, K.l. (Editors) (1988): *“Galactic and Extragalactic Radio Astronomy (2nd edition)”* Springer Verlag, Berlin.. ISBN 0-387-96575-0 / 3-540-96575-0 (see also review in part II Chapter 9.1, book 5).

Weiler, K.W. (1973): *Astron.& Astrophys.* **403**, p. 403.

Weiler, K.W., v. Someren Gréve, H.W. and Piersma (1973): ’21 cm primary beam properties of the WSRT’ *NFRA internal tech. report*, **117** (available at NFRA).

Weiler, K.W. and Wilson, A.S.(1977): *Astron.& Astrophys.* **58**, pp. 17-26.

Weiler, K.W. and Raimond E. (1977): *Astron.& Astrophys.* **54**, pp. 965-975.

Weiler, K.W. and de Pater, I (1980): *Astron.& Astrophys.* **91** p. 41.

Wieringa, M.H. (1992): Experimental Astronomy, **2**, pp.203-225.