Jens Havskov
Gerardo Alguacil

Instrumentation in Earthquake Seismology

Second Edition

Springer

Instrumentation in Earthquake Seismology

Jens Havskov • Gerardo Alguacil

Instrumentation in Earthquake Seismology

Springer

Jens Havskov
University of Bergen
Department of Earth Science
Bergen, Norway

Gerardo Alguacil
Andalusian Institute of Geophysics
and Earthquake Disaster Prevention
University of Granada
Granada, Spain

This is a revised and updated edition of the book "Instrumentation in Earthquake Seismology" by Jens Havskov and Gerardo Alguacil, 2004, Springer Dordrecht.

Every effort has been made to contact the copyright holders of the figures and tables which have been reproduced from other sources. Anyone who has not been properly credited is requested to contact the publishers, so that due acknowledgment may be made in subsequent editions.

The facts and opinions expressed in this work are those of the authors and not necessarily of the publisher.

ISBN 978-3-319-21313-2 ISBN 978-3-319-21314-9 (eBook)
DOI 10.1007/978-3-319-21314-9

Library of Congress Control Number: 2015953012

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface to the 2016 Edition

This book first came out in 2004. Since then there has been a lot of changes in the technology used for detecting and recording earthquakes. Some recording media like tape and optical disk have completely disappeared. Seismic recorders have become smaller, using less power, and the trend is for much more standardization with Linux operating system, Ethernet communication, MiniSeed recording, and SeedLink or EarthWorm real-time transmission. Real-time transmission and continuous recording are now the norm, partly due to better communication and cheap large capacity storage. The new open standards for seismic data transmission and data storage have forced the manufacturers to offer more standardized products to the benefit of the users. Compared to 2004, there are now a lot more open seismic stations which provide free real-time access to seismic data, so it is now possible to make a seismic network without owning a single station using free data collection software. The sensor development has been significant with new very compact and easy to deploy broadband sensors, and for new networks broadband sensors are now used almost exclusively. The MEMS accelerometers are now everywhere, even in mobile phones and actually used in community seismic networks. Despite the instrument development, there are several sensors and recorders that are nearly identical to the models sold 10 years ago, so quality lasts! While no new analog stations are installed, there are still hundreds of analog stations in operation, even in very sophisticated networks, since they provide cheap reliable backup when the digital technology fails, are cheap to operate, and require little maintenance. So analog technology is still described in this book. Several equipment manufacturers have disappeared, and some new ones have come on the market. The many changes over the last 10 years have therefore required a significant revision of this book, both in terms of the technology used and new equipment available.

The book's first edition included a copy of SEISAN software, which has been used to generate several examples in the book. This is no longer needed, since this set of programs is freely available from its University of Bergen web site www.seisan.info. This is the standard seismic data processing for many institutions around world.

Individuals from various companies helping us with information include Jean-Charles Boigues (Sercel), Mauro Mariotti (SARA), Adam Pascale (ESANDS), Dieter Stoll (Lennartz), Robert Leugoud (Eentec), Tony Russell (Earth Data), Tim Allmendinger (GeoSpace), Albert Riera (Worldsensing), Leonid Zimakov (REFTEK), Liu Minghui (Geodevice), Oleg Razinkov (GeoSIG), Ogie Kuraica (Kinemetrics), Nathan Pearce (Güralp Systems), and Nick Ackerley (Nanometrics). Terje Utheim and Mauro Mariotti read the whole book and made valuable suggestions and corrections.

Bergen, Norway — Jens Havskov
Granada, Spain — Gerardo Alguacil

Preface to the 2004 Edition

This book is primarily intended for seismologists and technicians working with seismological instruments. Seismologists tend to take their data for granted, hoping that the black boxes of seismographs and processing software will take care of all the nasty problems, much like driving a car and not worrying too much of how it works. But cars stop or malfunction and so do seismographs. Thus a basic understanding of seismic instrumentation is essential, even for the seismologist who is never going to turn a knob on an instrument.

Instrumentation is not just a topic for seismologists, since most equipment is in fact installed and maintained by non-seismologists, so this group of professionals has just as much a need for information on instrumentation.

Early versions of the book have been used for a lab course in seismic instrumentation given at the University of Bergen since 1999 and also in a few other countries. The experience from these courses has helped to improve the book, and we think that it is suitable for students in seismology.

There have been numerous publications on instrumental topics in seismology, with very special emphasis on particular subjects, but few – if any – general textbooks. Some overview was made by Lee and Stewart (1981), which, on the instrumental side, mainly dealt with microearthquake networks. The old *Manual of Seismological Observatory Practice* (*MSOP*) (Willmore 1979) dealt with all the classical analog seismographs, but is mostly outdated now. The *New Manual of Seismological Observatory Practice* (*NMSOP*, Bormann 2002, www.gfz-potsdam.de/bib/nmsop_formular.html) is the most up-to-date book on seismic instruments, and one of the authors of this book (JH) has also participated in making *NMSOP*. So, why another book? The *NMSOP* deals with a lot of issues in addition to seismic instruments, and we felt there would be a need for a book which further expands on the instrumental topics, much more than was possible within *NMSOP*, and put it all together in one volume. The intention with this book is that it should be a practical tool with only the amount of theory needed to understand the basic principles and that answers to most practical problems should be found here.

The book particularly deals with seismic sensors, their response functions, and how to make calibration and correct for the instrument. More details of the signal processing are the matter of Scherbaum's book *Of Poles and Zeros* (Scherbaum 2001), published in the same series as this one. We consider Scherbaum's a companion book to ours and have taken care to have a minimum of overlap.

The book tries to make an overview of some of the current equipment on the market as well as references to where it can be obtained. We are well aware that this can only be a snapshot in time due to the fast changes currently taking place, and by the time the book is published, new equipment will be available and not mentioned. On the other hand, there is equipment mentioned that has been sold for more than 20 years, so even outdated equipment will serve to illustrate how the technology is used. And the basic principles behind nearly all equipment sold today have been known for some time and are less likely to change rapidly.

Mentioning particular equipment does not mean we endorse that equipment, and we have not tried to include all equipment available.

Most of the signal processing examples are made with the earthquake processing software SEISAN (Havskov and Ottemöller 1999) (seisan.info), and there are also examples using the data acquisition software SEISLOG (Utheim et al. 2001) (ftp.geo.uib.no/pub/seismo/SOFTWARE/SEISLOG/).

Many people have given corrections and comments, in particular students who had to read the book. We are grateful to all of them. Einar Mæland has revised Sects. 6.2 and 6.3 in detail, and Ole Meyer has checked the appendix. Several companies have provided technical details for their equipment and reviewed relevant text: Tony Russell (Earth Data), Nathan Pierce (Güralp Systems), Ogie Kuraica (Kinemetrics), Dieter Stoll (Lennartz), Paul Passmore (REFTEK), Christoph Kundig (GeoSIG), and Robert Leugoud (PMD Eentec). Christoph Kundig has in addition reviewed the whole book. Peter Bormann has done a great job of finding a lot of inconsistencies. Miguel Abril revised the appendix and some chapters. Mathilde Bøtter Sørensen did a very complete final review. The bulk of the book was written during one of the authors' (JH) sabbatical stay at the University of Granada with support from the University of Bergen.

Bergen, Norway — Jens Havskov
Granada, Spain — Gerardo Alguacil

References

Bormann P (ed) (2002) IASPEI New manual of seismological observatory practice (NMSOP). Geo Forchungs Zentrum, Potsdam

Havskov J, Ottemöller L (1999) SEISAN earthquake analysis software. Seismol Res Lett 70:532–534

Lee WHK, Stewart SW (1981) Principles and applications of microearthquake networks. Academic Press, New York

Scherbaum F (2001) Of poles and zeros, fundamentals of digital seismology, second edn. Kluwer Academic Publishers, Dordrecht

Utheim T, Havskov J, Natvik Y (2001) Seislog data acquisition systems. Seismol Res Lett 72:77–79

Willmore PL (ed) (1979) Manual of seismological observatory practice, Report SE-20, World Data Center A for Solid Earth Geophysics, US Dep. of Commerce, NOAA. Boulder, Colorado

Contents