Music *and* Hearing Aids

A CLINICAL APPROACH

Marshall Chasin, AuD, MSc

PLURAL
PUBLISHING
INC.

PLURAL PUBLISHING
INC.

5521 Ruffin Road
San Diego, CA 92123

e-mail: information@pluralpublishing.com
Website: https://www.pluralpublishing.com

Typeset in 11/13 Garamond by Flanagan's Publishing Services, Inc.
Printed in the United States of America by Integrated Books International

For permission to use material from this text, contact us by
Telephone: (866) 758-7251
Fax: (888) 758-7255
e-mail: permissions@pluralpublishing.com

Library of Congress Cataloging-in-Publication Data

Names: Chasin, Marshall, author.
Title: Music and hearing aids : a clinical approach / Marshall Chasin.
Description: San Diego, CA : Plural Publishing, Inc., [2022] | Includes bibliographical references and index.
Identifiers: LCCN 2021054266 (print) | LCCN 2021054267 (ebook) | ISBN 9781635503951 (paperback) | ISBN 1635503957 (paperback) | ISBN 9781635503968 (ebook)
Subjects: MESH: Hearing Aids | Music | Correction of Hearing Impairment | Persons With Hearing Impairments | Acoustics
Classification: LCC RF300 (print) | LCC RF300 (ebook) | NLM WV 274 | DDC
617.8/9--dc23/eng/20211124
LC record available at https://lccn.loc.gov/2021054266
LC ebook record available at https://lccn.loc.gov/2021054267

Contents

Foreword

Marshall Chasin is not only highly regarded as an audiologist, but has extensive experience in music and musical instrument acoustics, hearing-aid-fitting methods for musicians, and an extensive knowledge of the literature in those fields, not to mention his having made significant contributions to those areas. Perhaps most important, he himself is a musician. Not surprisingly, Chasin is considered ***the*** go-to audiologist by numerous practicing musicians.

In an unusual approach, the first chapter of this book provides a good explanation of the wavelength associated acoustics of musical instruments. A clear explanation of the reasons for this as applied to musical instruments is a delightful beginning for this treatise.

Bringing it closer to home, Marshall's second chapter summarizes the differences and similarities between music and speech in understandable terms, providing the basic understanding that can stand in good stead when the client is a musician. For this purpose, the mp3 audio files accompanying this and other chapters help bring understanding to the words.

A major feature of this book is the extensive review of the literature in the third chapter. In each case, the relevance of the research findings to their implications for hearing aid design and fitting is emphasized. Frequency-response shaping, and the effect of defects in the frequency response, wide-dynamic-range compression characteristics—good and bad, and the danger of using Standards measurements that provide for quality control but often do not provide the information required for intelligent hearing aid adjustments. An extensive discussion follows on the advantages and challenges of digital signal processing, frequency lowering for those with cochlear dead regions and when it may be expected to fail, peaks in the frequency response, and possibly excessive delay times in digital hearing aid circuits. A wealth of research is summarized with an eye to the clinical approach and fitting of hearing aids.

The fourth chapter concentrates on the application of the previous information as applied to the clinical environment for the avoidance and/or solving of several challenging problems with some current approaches to hearing aid design. Starting with input overload and avoidance, this chapter discusses how to find cochlear dead regions simply by using a piano keyboard. The chapter ends with a discussion of MEMS microphones and digital delay.

The final chapter contains an interesting summary of some "lost" earlier circuits, and an eleven-item ***Wish List*** compiled from well-known musicians, two of whom are audiologists.

Marshall Chasin is a musician, a clinician, and a good teacher. He brings that background to this book, intended to provide additional solutions to difficult fitting challenges with musicians and nonmusicians.

—Mead Killion, PhD, DSc

Preface

I do play several instruments, but I am not a musician. I read the music and try to convey the music in an artistic manner, but my art is a learned and practiced one. I use memorized and technical knowledge to generate what may appear to be acceptable.

But I am an audiologist. I do feel that any audiologist, regardless of their musical abilities or talents, can work with musicians or those people for whom music is important in their lives. You don't need to know that the note A on the second space of the treble clef has its fundamental frequency at 440 Hz, but it can be useful to learn this when communicating with musicians. Even when communicating with nonmusicians, this knowledge is important so that at least one can understand why frequency lowering, for example, is not a useful idea, despite its success for amplified speech. One does not need to be a musician in order to work with professional musicians or just someone who wants to appreciate the music that they hear. One needs to be an audiologist.

An audiologist is an ideal person to work with amplified music and this is true whether a client requires hearing aids or cochlear implants. Audiologists know about earmold acoustics, room acoustics, speech acoustics, and psychoacoustics. Audiologists know about digital processing and technologies that can assist a hard-of-hearing person to play, or listen to amplified music. In addition, audiologists know about the verification, counseling, and follow-up required for the fine tuning of a "music program" in a hearing aid and when the use of additional accessories are warranted. Throughout this book, each of these fundamental areas of audiology will be touched upon en route to establishing the most optimal series of settings and technologies that will constitute a "music program" in a hearing aid.

This book is a clinically based resource that covers the "recent" post-1988 history of research concerning how music can, and should, be processed through modern hearing aids. The book will include a series of clinically based strategies to optimize the sound of amplified music for hard-of hearing people; a "wish list" of technologies either yet to be invented, or that have already been invented, but are no longer used, to optimize a "music program" in a hearing aid.

After a short primer of wavelength acoustics, this book features an overview entitled, "Music (and Speech) for the Audiologist" that provides the reader with some basic knowledge about music. Then, one will quickly realize that one's own audiology training has already provided them with this information, perhaps using differing terminologies.

Comparable with the many other areas of audiology study, audiologists need to make clinical decisions where the knowledge is not yet completely known, or where the research data appears to be contradictory, or perhaps absent. Music as an input to hearing aids is one such area. In cases such as these, one needs to fall back on general principles, and where appropriate, these guiding principles are discussed to at least "get us going in the right direction."

Throughout this book, a series of audio files are available, either by being embedded in the e-book version or in the print version. (There is a dedicated portion of a server on the Plural Publishing site that will house these files.) These audio files are used to bolster the information in the text and provide the interested reader with the opportunity to perform their own spectral analyses. These will be marked with the "audio icon" in the margin as shown here. Along with being adjacent to the discussion at hand, a listing of all of the 15 audio files will also appear in Appendix C. And similar to the many areas of audiology where studies are waiting to be done, many of these can be addressed within the scope of a student research project, such as an AuD Capstone study. Twelve of these are noted throughout the text and are marked with the "study icon" in the margin as shown here, referencing the associated description in Appendix B of this book.

Dr. Mead Killion has graciously agreed to write the Foreword for this book. He is a mathematician, an audiologist, a researcher, an inventor, founder of Etymotic Research (https://www.Etymotic.com), and most recently founder of MCK Audio—and one of the great thinkers in the field of music and hearing aids. He is the "father" of the K-AMP, which is a 1988 analog technology hearing aid that was, and still is, one of the best hearing aids for amplified music. As an industry, we have been trying to play catch-up to the 1988 K-AMP, and only in the last several years do I think we are now back to where we were, and should be.

A big thank you goes to Shaun Chasin (http://www.Chasin.ca), a composer who has kept me on the "straight and narrow" when discussing music issues. Shaun also supplied all of the audio files and many of the spectra used in this book.

I would also like to acknowledge, and thank, the many hard-of-hearing musicians, and other hard-of-hearing clients over the years for their honestly and perseverance in not just putting up with the sound of their amplified music, but articulating how perhaps it can be improved. We wouldn't be where we are without their feedback. Specifically, I would like to thank and acknowledge the insights of Charles Mokotoff, Larry Revit, Richard Einhorn, Stu Nunnery, Phil Nimmons, Wendy Cheng, and Rick Ledbetter.

I would also like to acknowledge some people whose work provided the foundation for some of the technologies used today that allow our hard-of-hearing clients to have the best fidelity for music listening and playing. Of the many people I would like to single out are: Ed Villchur, who is the father of multichannel compression; Harry Teder, who is the inventor of adaptive compression in hearing aids; and Elmer Carlson, who was instrumental in the development of many of the miniature microphones we use today.

And, finally, I have had the chance to work with some delightful and knowledgeable colleagues in this field and would like to thank Mead Killion, John Chong, Wm. A. Cole, Steve Armstrong, Neil Hockley, Frank Russo, Mark Schmidt, Francis Kuk, Jim Kates, and Brian Moore for the many discussions over the years about music and hearing aids, as well as the peer reviewers who provided constructive comments in the writing of this book.

Marshall Chasin, AuD,
Musicians' Clinics of Canada
http://www.MusiciansClinics.com

All royalties from the sale of this book go to support educational activities of the Musicians' Clinics of Canada.

Reviewers

Plural Publishing and the author would like to thank the following reviewers for taking the time to provide their valuable feedback during the manuscript development process.

Shelly Boelter, AuD, F-AAA
Assistant Professor
Pacific University School of Audiology
Forest Grove, Oregon

Margaret Brac, BSc, (Hon), MCISc, Reg. CASLPO, AuD(C)
Audiologist
London Audiology Consultants
London, Ontario, Canada

Gail B Brenner, AuD
Doctor of Audiology
Hearing Technology Associates, LLC
The Tinnitus and Sound Sensitivity Treatment Center of Philadelphia, PC
Bala Cynwyd, Pennsylvania

Kathy Landau Goodman, AuD
Founder and President
Main Line Audiology
Narberth, Pennsylvania

Neil S. Hockley, MSc, Aud(C)
Head of Audiology
Bernafon AG
Bern, Switzerland

Robert L B Stevenson, AuD
Owner and President
Bridgerland Audiology and Hearing Aids LLC
Logan, Utah

To all the hard-of-hearing musicians
who have been my best teachers.

1

A Primer on Wavelength Acoustics for Musical Instruments

SOURCE-FILTER-RADIATION MODEL

Most musical instruments are made up of a type of tube or a hollow body that acts as an acoustic amplifier or resonator. This is not the case of some percussion instruments where a trapped (or semi-trapped) volume of air is caused to resonate as a result of a strike to a drum head or solid structure that is hit like a glockenspiel. This chapter deals with the wavelength-associated resonances only. There are a number of references about percussive acoustics for the interested reader, such as Morrison and Rossing (2018). Although this is a chapter on the relevant acoustics of musical instruments, it solidifies the bases for many of the acoustic properties observed in related fields of audiology, including speech acoustics, earmold acoustics, and even the acoustic behavior of cerumen occlusion of the outer ear canal.

Gunnar Fant was among the first to apply the model of "source-filter-radiation" to acoustical systems (Fant, 1960). His work focused on the vocal tract and speech acoustics, but it can be used in a wide range of applications including hearing aid acoustics, car muffler systems, and the study of musical instruments. What has colloquially become known as "Fant's model of the vocal tract" is shown in Figure 1–1.

The Source

This block schematic shows that sound begins with a "source," which can be one's vocal cords during speech phonation, or the vibration of a reed, or the use of a bow in musical instruments. The exact rigidity of the reed for reeded woodwind instruments and the stiffness and material makeup of the bow for stringed instruments will act as an input (or source) to some type of resonator. Although the block schematic in Figure 1–1 shows a progression of sound energy from the source, through a filter, and finally the radiation properties into a room, it is simplistic, especially for musical instruments. In reality, in order to fully understand the acoustics of some musical instruments, a feedback loop needs to be considered between the "filter" stage and the initial "source." More on this is discussed in Chapter 2, and the interested reader is referred to the *Springer Handbook of Systematic Musicology* edited by Rolf Bader (2018) for more information.

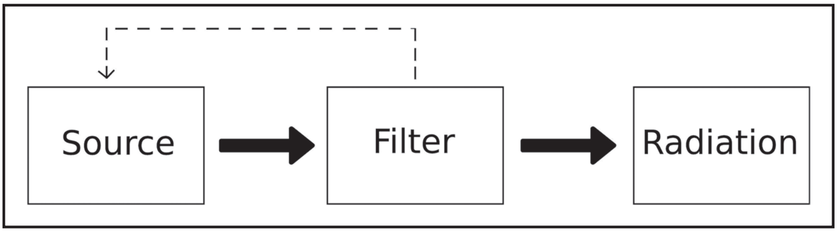

Figure 1–1. This is a box diagram showing the three components of Gunnar Fant's 1960 description of a "source-filter-radiation" model. Although this was conceived to study the vocal tract, this approach has been quite useful in the study of all resonator systems, including musical instruments. In reality, there is a feedback loop (*dotted line*) from the filter to the source, which generates some nonlinear behavior as the playing level increases.

The Filter

The "filter" (or "filter response") refers to any resonant chamber or tube (or series of chambers and tubes). In the realm of speech acoustics, the filter refers to the oral and nasal cavities with their own unique resonating properties as the tongue, soft palate, and other structures move, creating differing resonances and turbulent action. In the creation of music, the filter is the hollow body of stringed instruments or the variable lengths and diameters in woodwind and brass instruments. For example, a clarinet playing the note C [262 Hz] just below the treble clef has a well-defined length of the resonating tube, as shown in Figure 1–2 (Chasin, 2009). In this case, most of the sound emanates or radiates out of the first non-covered hole, and the lower part of the clarinet does not contribute significantly to the sound generation.

Radiation

The "radiation" portion refers to the output conditions of the resonant system, such as the size and shape of the output apertures (e.g., bell). This can be thought of as a change in the amplitudes of (typically higher frequency) energy as the mouth is opened wider in speech acoustics, or a musical instrument having an acoustic flare or bell. In hearing aid and earmold acoustics, this would refer to any changes in the frequency response due to changes of the inner diameter of hearing aid tubing, such as the use of a flared bore or Libby horn. The size of the bell or flare of the musical instrument will define the increase or decrease of the higher frequency acoustic output depending on whether the bell of the instrument was left unobstructed or whether a mute (or hand) was situated in the bell portion of the instrument. The amplitude enhancement related to an acoustic bell (whether it's in a hearing aid with a Libby horn, a vocal tract with the mouth wide open, or a musical instrument with a bell as part of its design) is that the boost of higher frequency sound energy is length-dependent and begins its enhancement for all frequencies above $F = v/2L$. In the hearing aid example, this is typically for sound energy above 2500 Hz, for the adult vocal tract with

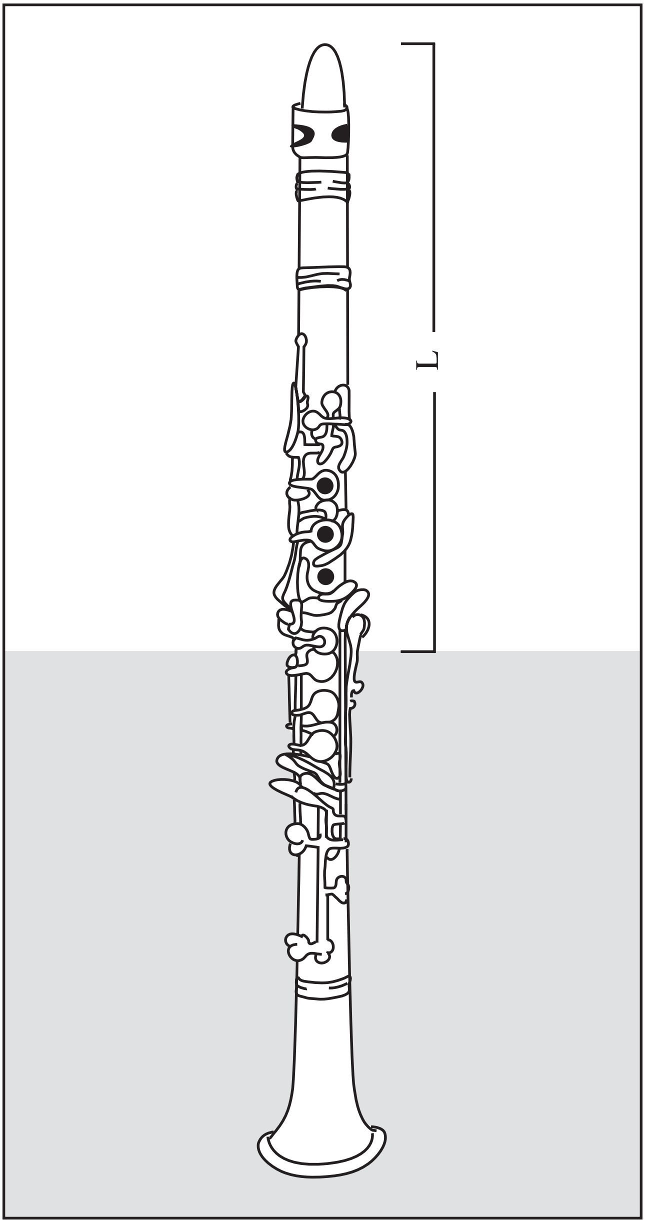

Figure 1–2. Stylized clarinet showing that the "acoustic length" is governed primarily by the length to the first noncovered air hole. The longer the length L, the lower its resonant frequency(ies) will be. From *Hearing Loss in Musicians: Prevention and Management* (p. 130) by Marshall Chasin. Copyright © 2009 Plural Publishing. All rights reserved.

an open mouth, for example, it is for all energy above 1000 Hz, and for the longer lengths found with many brass instruments, the enhancement can be for all energy above 100 Hz—all being inversely related to the resonator length (L).

WAVELENGTH RESONATORS OF THE FILTER

In speech acoustics there can be both wavelength-associated and "Helmholtz" (volume/constriction)-associated resonances. Mid and high vowels have primarily Helmholtz-related formant structures, at least for their first two formants. However, in music, there are very few situations with constrictions (and adjacent volumes) that would generate Helmholtz resonances. Most of the acoustic behavior can be described by wavelength properties and are primarily related to the length (L) of the resonating filter and its "boundary conditions." In all acoustic formulae, the length factor (L) is always found in the denominator; longer length instruments will always have a lower frequency resonant behavior than their shorter length cousins. Boundary conditions are related to several issues in acoustics, but we can restrict our discussions to (i) whether the two ends of the resonating tube have similar impedances or different ones (i.e., are they both "closed" or is one end "open" and the other end "closed"?), and (ii) the shape of the tube (e.g., cylindrical like a clarinet, or conical like a saxophone).

Quarter-Wavelength Resonators

In speech acoustics, the unconstricted vowel [ə], also known as the reduced vowel "schwa" as in the final vowel in 'feeder'([fidər]) is a quarter-wavelength resonator because the vocal tract is "closed," or has a high impedance at the vocal cords or source, and "open" or has a low impedance, at the open mouth. The vocal tract is relaxed and is almost a straight cylindrical tube during the articulation of this vowel. The [ə] vowel is characterized by a series of resonances (or formants) that have odd numbered multiples of the first resonance.