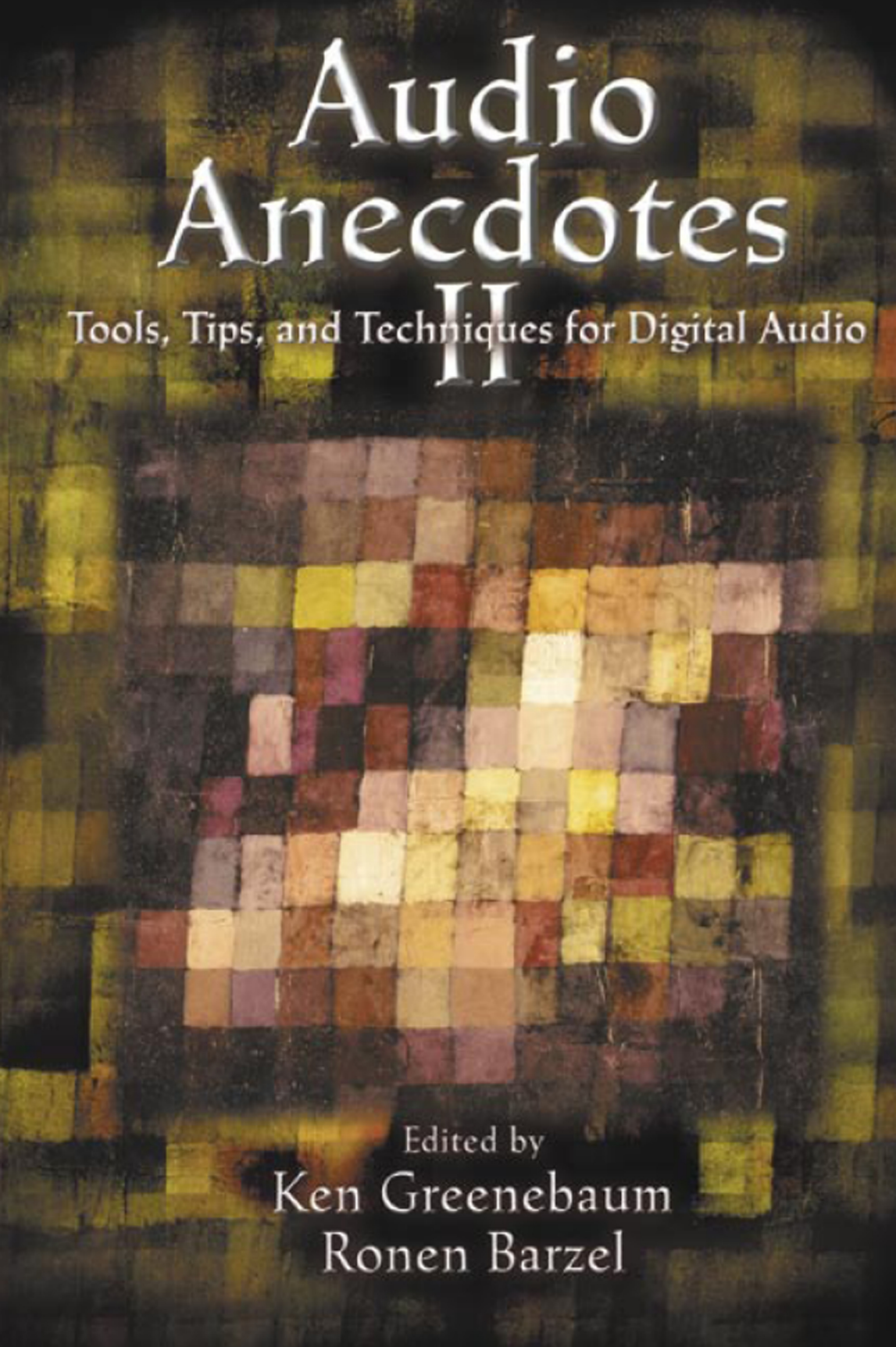
Audio Anecdotes II
Tools, Tips, and Techniques for Digital Audio
Edited by
Ken Greenebaum
Ronen Barzel

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Preface

The publication of *Audio Anecdotes II* follows closely behind that of Audio *Anecdotes I*, for which the editors have received positive feedback as well as some constructive criticism. We appreciate all comments and have tried to incorporate as many suggestions as possible into the second volume. Most significantly, we have incorporated an index and provide superior support for Apple's OS X based computers.

Audio Anecdotes I introduces fundamental digital audio concepts. This second volume continues to explore these topics at a deeper level and introduces new topics such as music theory.

My early explorations of digital media, the application of digital computer techniques to previously analog media, were enabled by the inexpensive and increasingly powerful microprocessor while at the same time frustrated by the lack of appropriate resources in the literature or in the form of accessible programs and implementations. The research literature was abstract, making it difficult to approach or apply; free implementations for experimentation were almost nonexistent. More surprisingly there was a lack of communication among the practitioners of the many diverse fields that relate to digital media: sound design, music composition, recording engineering, signal processing, cognitive psychology, software design, etc. As I entered the field as a professional, the dramatic gap between the state of digital media research and practice became even more apparent to me.

Audio Anecdotes is an attempt to address these concerns by providing a collection of articles written by experts, bridging many fields, and describing practical tools and techniques. Wherever possible, articles provide motivation, working examples (programs, source code, and media

files), and a list of annotated references to allow the reader to dig deeper into the subject and ultimately to enhance their own applications and products.

Recalling my own experiences, I decided to share this material with those just starting out, students. I created and taught the class, "Introduction to Dynamic Sound Synthesis," at the DigiPen Institute of Technology (perhaps the first school to offer a computer science degree dedicated to game design and simulation), using *Audio Anecdotes* as the textbook. I was pleasantly surprised and encouraged by the large enrollment and the enthusiasm for the class.

It takes many people to produce a book such as this, and thanks are due to all whose participation has helped make it successful. It was wonderful for me to work with our contributors, all esteemed professionals in their respective fields, and with the ideas represented in this volume. I hope you, the reader, share my excitement.

Many people have helped create this second volume by allowing me to bounce ideas off them, by reading and re-reading drafts of articles, and by contributing code, editorial, and technical expertise. Unfortunately, there are too many to list them all here; however, some deserve special mention:

Technical help: Mike Gonzalez and Greg Silber. Special thanks to Howard Good for his tremendous help with all aspects of the CD-ROM.

Editorial help: Jeffrey Greenebaum, John Nordlinger, and David Thiel.

I also want to thank those not otherwise mentioned. Thanks to Alice, Klaus, and the rest of the wonderful A K Peters publishing family.

For my own articles in this book, I must thank all the people who have shared their ideas, inspired me with their enthusiasm, and sharpened my understanding with their questions. I am especially grateful to my colleagues at Microsoft and Silicon Graphics and my students at DigiPen.

Finally, thank you to all my dear friends and loved ones who have supported me during this project.

Ken Greenebaum
Redmond, Washington
May 2004

Introduction

Introduction

Welcome to the second volume of *Audio Anecdotes*! Those of you already familiar with the first volume will find a host of new content in a familiar format. Those of you new to *Audio Anecdotes* should be able to dive right in, but for the full experience please use *Audio Anecdotes II* in conjunction with *Audio Anecdotes I*. Articles in this volume expand on the introductory material found in *Audio Anecdotes I* and, whenever possible, reference related material from the first volume.

Similar to the original book, *Audio Anecdotes II* discusses creating, recording, processing, and analyzing many forms of sound and music. Opportunities presented by digital media are emphasized, as are the powerful techniques made possible by inexpensive and nearly ubiquitous digital computing.

Perhaps because hearing is a subtle sense, sound and hearing are often misunderstood or undervalued in our society. While the sound of a twig snapping causes us to quickly localize the sound and orient our head in the direction from which the snap came, we often find ourselves looking in a direction without consciously being aware of the events that caused us to do so. Similarly, we might not realize that it was a sound that awoke us suddenly from a deep sleep. Equally powerful but less easy to explain is the dramatic influence sound and music have on our emotions.

In this book we explore sound and our sense of hearing, the one sense which never sleeps and works omnidirectionally from a distance. *Audio Anecdotes* attempts to present opportunities to improve the audio experience where sound already exists, or to encourage the integration of sound

into presently mute applications, leading to richer, more expressive, and more valuable applications.

Since most interactions in the real world involve sound, we feel that there are many opportunities!

Structure

Each volume of *Audio Anecdotes* is comprised of articles that cover a wide range of audio-related topics. The articles take a variety of forms: introductions, essays, in-depth technical explorations, presentation of tools and techniques, and postmortem analyses.

Many articles contain the authors' personal anecdotes and hard-earned experience from the trenches. We, therefore, encourage our readers to learn about the authors' backgrounds before diving into each article by consulting the biography section at the end of the book.

The subjects covered in our articles are deep and often could fill their own book. Consequently, the articles are designed to act as a jumping-off point for readers who wish to further explore the topic. Each article contains an annotated list of references that serves not so much to document the sources of the article, but to direct readers to significant texts and further sources of information on the topic area. Where possible, articles reference other articles in this or other *Audio Anecdotes* volumes.

Articles are grouped into chapters by topics organized to form an arc spanning:

- The fundamentals: the physics, measurement, and perception of sound
- Recording and playback of sound: whether of music, voice, or nature
- Synthesis: rendering sounds which never existed including the synthesis of musical instruments, voice, or noise (Foley Sound)
- Signal processing: the mathematical analysis and manipulation of sound
- Signal processing applications: from compression techniques to signal detection and recognition
- Computer techniques: efficiently implementing low latency high performance audio systems on digital computers

- Music theory: the mathematics of both western and non-western music
- Creative topics: composition and sound design
- Nature, mind, and body: how sound exists in nature and affects the mind and body

This arc is rooted in the belief that to understand any topic or to be able to make informed trade-offs in design, an understanding of the physics and human perception of the phenomena is required. Great engineering efforts such as the design of the telephone system, color television, and computer graphics all demonstrate a mastery of the interplay between physics and human perception. From the fundamentals, the arc extends to the abstract through the applied and the creative, to again revisit human perception from a different perspective.

While each *Audio Anecdotes* volume can't include articles covering every topic area, the articles are organized according to this arc. *Audio Anecdotes II* contains the chapters described in the following sections:

Chapter 1. Field Recording

This chapter expands on the recording fundamentals chapter in *Audio Anecdotes I*. This time we explore trading the controlled environment of the recording studio for recording in the great outdoors, complete with the resulting wind, ambient noise, and other challenges.

The first two articles provide colorful descriptions of the author's experiences with field recording. The last article describes use of binaural recording techniques in nature to capture and recreate the three-dimensional sonic experience of actually being there.

Chapter 2. Synthesis

In this volume we expand on the synthesis articles from the first volume by presenting three unconventional approaches to solving common synthesis challenges.

We begin with an article describing an inexpensive technique for creating rich, nonrepeating synthetic ambiences. The next two articles are complimentary and describe ways to translate analog synthesis techniques to digital computers while avoiding the pitfalls that more straightforward digital implementations encounter.

The first article of the pair describes a methodology for very efficiently generating band-limited oscillators. The other article presents an intriguing algorithm for performing subtractive synthesis without the use of the filters most of us naively think are required.

Chapter 3. Signal Processing

This chapter presents detailed descriptions and implementations for some of the most fundamental signal processing techniques: spectral filters and time/frequency transformations.

The first two articles demonstrate finite and infinite impulse response filters. The next article describes a method for converting analog filters to the digital domain. The final two articles begin by explaining the venerable Fourier transform and then describe implementations of the Fast Fourier Transform in both floating point and fixed point implementations.

Chapter 4. Spatialization

Spatialization refers to the ability to determine the location in space from which a sound emanates or to artificially make a sound appear to emanate from a specific location. This chapter describes two techniques for creating spatialized sound using loudspeakers.

The first article examines techniques commonly applied to spatialize sound in the common stereo loudspeaker configuration: balance, panning, and distance attenuation. The second article expands on the first by providing a mathematical framework for spatializing sound using arrays of loudspeakers of various geometries.

Chapter 5. Computer Techniques

While most of our articles explore algorithms and briefly describe the engineering techniques needed to implement them, this chapter focuses on the implementations themselves and the resulting implications. These articles continue where the computer techniques chapter from *Audio Anecdotes I* leaves off.

The first article describes how the role of the humble volume control has been changed by the digital convergence and how PC audio's migration away from the analog mixer has left us with applications that tend to shout. The second article suggests that uniformly measuring digital audio in units of frames can help eliminate a common source of frustration and

bugs when developing digital audio applications. The final two articles explore the opportunities for applying advanced buffering and audio I/O techniques. One introduces the ring buffer FIFO and related algebra; the other wraps the buffer in a library interface to provide uniform access and advanced functionality like blocking or variable latency I/O.

Chapter 6. Computer Tools

This chapter introduces three sets of tools that we distribute on the CD-ROM accompanying this book.

The first article describes the SoX sound exchange library, which provides tools for converting and manipulating many audio file formats. This article compliments "Audio File Formats: A formal description based approach" from *Audio Anecdotes I*. Next an author from the first volume returns to describe the Synthesis Toolkit (STK), a diverse collection of synthesis and signal processing algorithms written in C++. The final article describes the QEDesign filter design package. This package helps design the IIR and FIR filters described in the spectral filtering articles found in Chapter 2.

Chapter 7. Music Theory

Music theory is a highly evolved, and somewhat baroque, system for useful for composing, classifying, and analyzing music. For nonmusicians, and even many musicians, all but the most basic music theory concepts can be a confusing mystery. Simple exercises like equating notes to frequencies or converting note duration to seconds require an understanding of deeper concepts like scales and time signatures.

This chapter provides an introduction to music theory in two comprehensive articles. The first article covers topics related to pitch and the second to rhythm and meter.

Chapter 8. Sound Design

Visualization is a well-understood concept. Charts and graphs are commonly used for compact and clear communication. Visual attributes such as color or size are often used to convey additional information. Photographs, paintings, or advertisements are generally carefully composed for specific effect. This chapter explores sonification and sound design, the audio analogues to visualization and visual design.

The first article compliments "Designing a Movie for Sound" from *Audio Anecdotes I* by exploring sound design and the role of sound in telling a story. The second introduces the field of audio display, using sound to communicate information. The final article describes an actual research study evaluating the effectiveness of various sonification techniques.

Chapter 9. Nature

In this last chapter we reach the end of our topic arc by exploring sound in nature.

The first article describes the intriguing phenomena of brainwave entrainment and presents potential applications. We conclude the book with an article introducing bioacoustics, the study of interactions between sound and living organisms. This article suggests that we still have much to learn by studying the diverse sonic adaptations in living creatures and reminds us that Leonardo da Vinci also looked to nature for inspiration.

Glossary, Contributor Biographies, and Index

Following the main chapters are an extensive glossary, defining many of the audio terms used throughout the book, contributor biographies, and an index.

CD-ROM

Audio Anecdotes II is accompanied by a CD-ROM containing supplemental materials to the articles including audio and video files and executable demos. The demos support the Windows, Mac, and Linux platforms. Wherever possible, articles reference these materials so that readers can immediately listen to examples or experiment with the concepts introduced in the articles. Please be sure to explore the CD-ROM's contents via the HTML based tour as well, since additional materials have been included. Programs are also distributed as source code that may be modified and incorporated into the reader's own projects.

This material is distributed on the CD-ROM as tar balls (tar'd compressed archives). A wizard-based installer is provided for automatic installation on our supported platforms. README files provide installation information if the installation wizard doesn't automatically start upon

CD-ROM insertion. Once installed on your computer, the demo material is organized by chapter and author.

Unless otherwise specified, the contents of the CD-ROM are protected by the BSD license, and the reader may use the source code provided on the CD-ROM for any purpose as long as the following statement is prominently displayed: This product includes code from *Audio Anecdotes II*, edited by Ken Greenebaum and Ronen Barzel, published by A K Peters, 2004. The code is to be used at your own risk: Ken Greenebaum, Ronen Barzel, and A K Peters make no claim regarding the suitability of this material for any use.

A Note on Patents and Trade Secrets

All of our authors have certified that their articles do not contain trade secrets. In some articles, authors have explicitly stated that the algorithms that they describe are patented. However, even algorithms that lack such statements may be under some form of patent protection. For many reasons, including the long gestation of patent applications (so-called submarine patents), we can not vouch for the suitability of using these algorithms for any use other than educational purposes.

Please Participate

Visit us at the *Audio Anecdotes* website (http://www.audioanecdotes.com) to find errata, download code updates, or find out what's new.

Audio Anecdotes was created as a forum to share tools and techniques with the greater audio community. The subjects covered in this volume only scratch the surface of topics that we would like to cover. If you have been inspired by *Audio Anecdotes*, we encourage you to share your own tools, techniques, or experiences. If you would like to contribute to a future volume, please send your name, email address, postal address, and brief concept to submission@audioanecdotes.com. If you find an error in the text or code, or have a code improvement, please send it to errata@audioanecdotes.com.

A Final Thought

We wanted to create a book that would be fun to leaf through or read cover-to-cover; a book that would be useful both as a reference and a source of creative inspiration. We hope that we have succeeded.

Field Recording

A Quick Field Recording Primer for the Adventurous Sound Effects Recordist

Mike Caviezel

1 Introduction

As an end user of sound effects, I know that having the right effect is very important to convey realism to a listener, or conversely, can aid in a listener's sense of imagination when viewing or hearing a scene. In short, sound effects are a very powerful creative tool; just ask any radio producer or film director. Unfortunately, as great as most sound effect CDs are, sometimes they just don't have the effect you're looking for. That's when it's time to get creative and make your own. As a recordist/editor of a few sound effects CDs myself, I've learned a few techniques, which we will be exploring in this article. These techniques can help you make field recordings that suit your production perfectly.

2 Field Gear

The first thing to determine is what kind of machine you want to record to, and what format you want to end up with. If you're going to be later editing these recordings using a computer-based Digital Audio Workstation (DAW), I strongly recommend using a digital recorder out in the field. Use of a DAT (Digital Audio Tape), Deva (portable hard disk recorder), or other digital device makes for good, clean recordings, and

eases transfers later on. I recommend the HHB PortaDat; it's loaded with I/O features, isn't too heavy, has a timecode option, and has proven to be pretty bulletproof in my experience. Any recordist will appreciate the headroom that its two built-in mic preamps have, as well as the built-in limiter that you can switch in or out. The limiter has proven to be useful for those situations where you're not sure how loud something will be, but you know you're only going to get one take of it (such as the Kingdome in Seattle imploding). Most portable DAT recorders have some kind of mic preamp on them, but be sure to check whether or not they can supply phantom power for your condenser microphones.

Be sure that your DAT recorder can record at the sampling rate at which you'll be editing later! Sample rate conversion issues are not fun. If portability isn't an issue to you (i.e., you're not going to be physically running around recording stuff), a DA-88, ADAT or other digital multitrack can be kind of cool out in the field. These recorders give you the ability to capture up to eight different perspectives at once, which is something to think about for the not-too-distant 5.1 surround-sound future. Of course, supplying power to these AC powered devices then becomes an issue. In lieu of a reeeeaaallly long extension cord, a company called Galaxy Audio makes something called the Far Outlet, which is a relatively heavy rechargeable black battery and inverters that can supply 120V AC power to two devices at once. I personally have used a DA-88 along with a Mackie 1402 mixer plugged into a Far Outlet, and it worked great. For your portable DAT recorders, most ship with rechargeable batteries included, but a few companies make external portable batteries that can run for much longer than the stock recorder batteries.

Once you've decided on a recorder, it's time to pick your microphone(s). I generally choose to use stereo condensers for, in my experience, they capture more high-end detail than dynamic mics, and the stereo perspective can always be collapsed to mono later. For general, all-purpose stereo recording, I can recommend a few things. The Audio Technica 825 stereo microphone has two capsules configured in an X-Y cardioid pattern, and has been a good all-around workhorse for me. As a more expensive option, the Neumann RSM 191 stereo microphone has also given me outstanding results. This is a dual capsule MS (midside) mic, which gives you options like being able to vary the stereo width of the mic, and can also record a split MS signal with the ability to decode it later. For recording ambiences, I have yet to use anything that works as well as the RSM 191. Sennheiser also makes a cardioid stereo mic that I've gotten good results with, the MKE 44-P, which is also an X-Y setup. All of the above mics are condensers with high SPL ratings, and have

some sort of attenuation switch (or pad). All of these microphones can be powered with AA or 9V batteries, and they can all be either mounted on a mic stand for studio use, or function as handheld mics, which we'll discuss next.

3 Don't Let that Mic Go Outside Naked

The best physical set-up for me when I've made field recordings is to wear my DAT recorder hanging at my side, slung over my shoulder, wearing my headphones normally, and carrying the microphone in my hand. To carry the mic noiselessly, you're going to need some kind of pistol grip mount with a shock-absorbing mic clip. This will then allow you to simply point the mic like a gun at your sound source, and also allows you to quickly move the mic around without any handling noise. You could simply hold the mic in your hand without a shock-mount, but I think you'll find that unless you keep your hand absolutely still, you're going to get low frequency bumps from moving the mic around, from the mic cable hitting the mic, and other unexpected handling noises. Having a pistol mount also opens up all kinds of options for wind protection, which is absolutely necessary for recording outside (especially here in the Pacific Northwest).

You can first start by fitting the mic capsule with the windscreen it came with, and putting it in the pistol grip. You can then cover the entire pistol-grip assembly with a zeppelin windshield. A zeppelin windshield looks just like it sounds—a big gray plastic tube shaped like a zeppelin, which has been specially made to allow wind protection without killing frequency response to the mic. For even more wind protection, you can then cover the zeppelin with a WindJammer. A WindJammer is basically a fur coat for your zeppelin, and that's exactly what it looks like, except it's been specially made to diffuse wind noise while still allowing good frequency response to your mic. You slide this thing over your zeppelin, zip it up, and you're ready to go. All of these wind protection measures applied at once may seem a bit extreme, but believe me, it's worth it. After having entire tapes ruined by wind noise, you'll know what I'm talking about. I never do outdoor recording anymore without my pistol grip, zeppelin, and WindJammer. The company that makes all of these products is Rycote, and they are your one-stop source for microphone wind protection. Their products have certainly saved my recordings more than a few times.

4 It's Noisy Outside—Use the Right Mic for Noise Rejection!

OK, so you've got your microphone assembly plugged into the preamps on your DAT player, you're hearing sound though your headphones (which should be completely closed-ear headphones to keep outside noises out of your ears), and everything's groovy. You load up a DAT, and you're ready to record. You walk outside of your suburban home, and let's say you want to record that woodpecker that's been banging away on your siding for the last three days. You walk up to him and start rolling tape. Once you turn the gain up to get a good recording level, you notice something. You're picking up not only the woodpecker, but you're also picking up cars driving by on the street, planes flying far overhead, other birds screeching and making noise, insects chirping... in short, it's not exactly an isolation booth with just you and the woodpecker. Welcome to the plague of every field recordist—extraneous noises from the outside environment.

Unless you're specifically trying to capture the overall ambience of where you're standing, unwanted noises from the environment around you will give you fits when you're trying to edit your effects later. Unfortunately, easy solutions are few and far between.

Using a mic with the right polar pattern for the job is crucial. With cardioid (front-facing pick-up pattern) mics, you can angle them so that your sound source is on-axis, with sounds to the rear (and sides, to a lesser degree) of the mic being rejected. With omni mics, nothing gets rejected. If you're using an omnidirectional mic to try and record isolated effects, be prepared for lots of extraneous noise in your recordings, which also means be prepared to do a lot of editing later. If, however, you are recording overall ambiences, then an omni mic might be exactly what you want. A good rule of thumb is: cardioid (or other highly directional) patterns for individual effects, omni patterns for ambiences.

The first thing to try is to get as close to the sound source as you can. Then, if you're using a cardiod mic, try angling your mic differently. You can easily lower your noise floor by pointing your mic so it still faces your sound source, but also so that it doesn't face the street, or the airport, or the elementary school down the street, or whatever happens to also be making noise.

Rejection can be pretty good with most stereo cardioid microphones. But if you really care about rejection, a shotgun microphone can offer a highly directional pick-up pattern, with amazing rejection of sounds to either side and to the rear of the microphone. Basically, these mics are designed to pick up whatever's directly in front of it, and that's it. There

is a potential downside, though. Some people feel that certain shotgun mics don't have quite the fidelity that a standard hand-held mics have, so be sure and try before you buy. Also, a lot of shotgun mics are mono only, but if you care more about isolation and rejection than you do about mono versus stereo, then a shotgun mic may be your best bet.

If you can't get very close to your sound source, you also may want to consider a parabolic mic. A parabolic microphone is one of those mics that you see guys on TV carrying around the sidelines of football games, with what looks like a small satellite dish attached to it. They are highly directional mics, and the attached reflector dish allows them to pinpoint sound sources up to 200 feet away. Again, these are mono mics, but for isolating faraway sound sources, they're hard to beat.

John Klepko's article, "Understanding Microphones," (see *Audio Anecdotes I*), provides much more technical information about microphones that should help you understand and select an appropriate mic.

5 If It is Still Noisy, Find a Quieter Place ...

If you're recording a very loud sound source, your job just got a lot easier, as you can get away with setting your mic gain very low, while still getting a good recording level. If your source isn't very loud, then that is a much bigger can of worms. The more you increase the gain to get a good signal on tape, the more background elements you'll find buried in your sound. If your sound source is VERY quiet, you'll even hear the self-noise of the equipment you're using. You'll probably hear your own self-noise, too, such as your own breathing and your clothing. Always remember to wear clothes that don't make a lot of noise. Nothing is worse than having the perfect effect ruined by your coat rustling at the wrong moment, or your keys jingling in your pocket. Leave the loose change back in the car.

Clothing issues aside, for fighting background noise, many times the easiest solution is to find a quiet environment (where there's no wind, bugs, birds, planes, cars, etc.), and record your effects there. Places like that still exist, you know. It may mean sometimes driving out to the middle of nowhere, but many times it's the only way to record clean sound effects. Not having to edit background noises out of your effects can save you weeks, even months of editing time. You can also try recording at night, when traffic and other activity has died down. Obviously, you can also try recording your effects indoors whenever possible, but some things you just have to do in cooperation with Mother Nature.

6 Social Engineering

Cooperation with Mother Nature is one thing, but cooperation with other people is something else. An important thing to remember while walking around loaded up with your DAT rig is that most people who see you working won't know a cardioid microphone from a carotid artery, and will want to know what you're doing. The actual intent of this question is entirely dependent on the manner in which it is asked.

For instance, it could be, "Hey, what are you doing?" as in, "Wow, I'm curious about all that cool stuff you've got there," or it could be, "Hey, what are you doing!" as in, "Get off of my property!" or "You can't do that here!" At this moment, you'll need to break out your diplomatic people-handling skills (if you have any), or be prepared to leave your location immediately. Or possibly both.

You should definitely have some kind of statement ready, such as, "Oh, we're just recording some sound effects for a documentary" (or movie studio, or video game, or whatever you think will impress people, if your actual project doesn't seem glamorous enough). Then you can ask, "Is that OK? We'll stay totally out of the way." You can even offer them a copy of the finished product to help grease the wheels. Most of the time, once people hear the words "TV" or "movie" or "documentary," they'll be receptive. They may even go out of their way to accommodate you. People can be very friendly when they think they're going to be part of something famous. If you're making it up though, just be ready for the follow-up question, "Really? What movie?" or, "Wow! What TV show?"—just try and be believable.

However, if people don't want you recording there, there isn't much you can do. Even if you're on public property, some people will put up a stink about you being there. If you don't want them to get the police involved, the best solution is to quickly apologize and then leave the immediate area. Just go someplace where Mr. Party Pooper won't be offended. It could be around the block, or it could be a few miles away. As with most cases, just use your best judgement and a little common sense, and you should be fine.

But the best way to handle a confrontation is not to have one at all by getting permission from the relevant parties BEFOREHAND to do some recording there. Obviously, if you're out on a 20-mile stretch of country road, out in the middle of nowhere with nobody else around, you could probably get away with just showing up and recording; providing, of course, that you're not going to be recording explosions, car chases, starting forest fires, or anything else that could get you arrested. However,

if you want to go wandering around a construction site recording the construction crew, you should probably warn the foreman beforehand so you don't get hurt by falling beams, etc.; again, the common sense rule should prevail.

If you're going to a paid event to try and record, it is definitely wise to get permission beforehand. If you don't get permission, you can always go sneaking around, but be ready for all sorts of possible unpleasant consequences, from being merely kicked out of the event to having your equipment confiscated! Besides, getting permission often will allow you access to areas and sounds that you could never get to just by sneaking around. If you're trying to stage complicated, dangerous effects where you know you'll need government permission (such as blowing things up, throwing cars off of cliffs, etc), you'll need to obtain a permit from the local county or city office. Many cities have media relations offices that deal specifically with issuing permits for filming and recording. They'll tell you everything you need to do in order to get your effects recorded legally. Plus, police officers are downright friendly when they know you've got a legal permit to be there.

7 Use Indexing and Timecode So You Can Find Your Sounds

OK, back to the technical stuff. So now you're out in the field, you've got all-access clearance, you're ready to go. Just before you press "Record," you should check your DAT player to see if it's set on Auto ID, or Manual ID. For those of you not familiar with these terms, having Auto ID engaged will mean the DAT player will drop an index point on the DAT whenever audio passes above a preset threshold, which your DAT manufacturer sets at the factory, and you usually can't adjust. Auto ID is fine for studio recordings, but horribly annoying for field recording. With Manual ID, the DAT will be indexed every time you start the DAT machine recording. For example: When you first start recording, it drops a ID. When you're done recording, you can then pause the tape or stop recording. When you take the machine out of pause, or resume recording, the machine will drop another ID. I wholeheartedly recommend using Manual ID, as your tape can be very frustrating to sort through later if your machine has dropped an ID number after every loud noise while using Auto ID. With Manual ID, it's much easier to skip around logically on your tape. In any case, Start IDs can be revised and edited after your content is recorded.

You should also make sure to start your tape recording from the very beginning to establish an Absolute Time Code (or ABS) on your tape. Once you stop recording, you should ALWAYS resume recording right where you stopped, if not a little bit before, in order to preserve your tape's ABS. Trust me, this is pretty important. It's much easier to find an effect later if you know what ABS time it happened versus just knowing your effect is somewhere in the 25 minutes of tape between index points 4 and 5 on your DAT. Once you start editing your effects, you'll be glad you had ABS all the way through your tape.

8 Be Creative, Climb a Tree

Now that you're up and recording, with all the technical elements in place, you can get creative with recording techniques. Don't be afraid to climb trees, fences, fire escapes, etc. if you think it'll give you a unique sound. Also, don't be afraid to put the mic in places that you physically can't get to, such as hanging a mic by its cable down a small hole, or strapping a mic to the exhaust pipe of a car, and then recording from inside the car (see article, "Holding on for Dear Life: Recording the Automobile," (page 13), for all the gory details). Be prepared to improvise. A little duct tape and some cable ties will go a long way towards helping you put your mic in places where you can't hold it yourself.

Sometimes it can be advantageous to bring a friend along to help you out. It's very tricky to try to stage effects by yourself, especially if you're holding the DAT rig and trying to be as quiet as possible. Just do whatever it takes to get the effect you want. It's easier to record it right the first time than to have to fix it later.

9 Before Going Home

Once you're finished recording and it's time to go home, take the tape out of the DAT player, set the write-protect tab on it, and label it right there. Don't lose it! Also, please make sure you leave with everything you came with.

When you're back home and unpacking the gear, take the time to clean everything up and start all the batteries recharging. That way, you know everything will be ready to go and working when you have to dash out the door to go record that marching band that's coming down the street (true story).

10 Have Fun!

To sum up my feelings about field recording, I think it's a lot of fun. When done properly, it can yield fantastic results, and can get you into cool places you never thought you'd be. Hopefully, my little tidbits of information can start you out on the right foot, and send you on your way to making great sound effects. Good luck!

Holding on for Dear Life: Recording the Automobile

Mike Caviezel

What's the craziest thing you can think of doing with a car? 360s, jumps, crashes, ridiculous high speeds?

Well, I've done just about everything you can do with an automobile, all while holding my breath and clutching my bulletproof Mackie mixer and Tascam D-98 multitrack. Challenging? Yes. Fun? Mostly yes. Motion-sickness-inducing? DEFINITELY. Ugh. I get green just thinking about it. But the end result was one of the most comprehensive set of car sounds on the planet (Wheels II, from Sound Ideas), and we (our small company team) accumulated some great car stories with which we can out-macho our gearhead friends.

1 Multitrack Multiperspective

When we first started planning our car projects, we knew we wanted to approach the recording from a unique perspective, literally. Most sound effect sets at the time contained a good deal of exterior car sounds, such as drive-bys, skids, etc., but what we wanted to capture (along with the exterior perspective) was what doing these stunts sounded like from a bunch of different perspectives all over the car. We also wanted to record and edit these tracks simultaneously, so that users of these effects could either use our mixes, or make their own mixes of each perspective. This meant finding a suitable multitrack unit that we wouldn't be afraid to

strap in a car going 150+ mph. We thought the DA98 from Tascam looked pretty bulletproof, so we got one. We also bought a small Mackie mixer, and some microphones that we thought could take the abuse. Little did we know.

From there, we played around with our own cars a bit, holding microphones out of windows and such, and decided on four positions which sounded best:

- Driver's perspective. Stereo cardioid condenser mic mounted between the driver and passenger seats.
- Tire perspective. Stereo, with two small lavalier condenser mics strapped to the wheel well, on either side of the car, facing the road.
- Engine perspective. Mono, omnidirectional dynamic mic basically strapped to the engine block!
- Exhaust perspective. Mono, omnidirectional dynamic mic hanging under the rear bumper facing the exhaust pipe.

We also took into account the external perspectives to be recorded by people walking around with portable DAT rigs and stereo microphones.

2 Wind Noise

In our test recordings, we found that wind noise was definitely an issue to be reckoned with, especially with our tire mics. The only workable place to put them was in the wheel well facing towards the rear of the car, so any wind from driving would be deflected by the wheel well. This works great as long as there are no side winds, which of course there always are. At one point, we thought about abandoning our tire perspective altogether, but it made for such a cool stereo effect that we just had to have it.

This may seem severe as far as wind protection goes, but here's what it took to make it work: First, we ended up putting a small windscreen on each lavalier tire mic. Then, we punched a mic cable-sized hole in the bottom of a couple of empty Kodak film canisters. We put each mic in its own canister, facing the open end, with the cable trailing through our punched holes in the bottom. We then stuffed small pieces of acoustic foam into the canister, filling in around the mic. With the top of the mic flush with the open end of the film can, we shoved the whole assembly

into a WindJammer (sort of a fuzzy acoustic windsock) and mounted it in the wheel well. When we first did this, we thought for sure that our fidelity, especially our high treble end, was going to be so reduced that it would be make for muffly, lifeless audio tracks. But surprisingly, we didn't compromise that much in the way of fidelity. Some of the high end definitely went away because of the canister and the foam, but it wasn't nearly as bad as we thought it was going to be. We were even able to add a little high end in the editing process, which helped out further.

3 Our Set-Up

Our technical set-up was as follows: All mics went into six channels of our Mackie 1402. Phantom power was provided by the mixer. To get our mic signals to tape, we went out of the channel inserts on the 1402 into the tape ins of our DA-98. This signal was pre-fader and pre-eq, so our level to tape was controlled by the mic gain knob at the top of the Mackie channel strip. Any eq we did was limited to high-pass (low cut) filtering via the bass rolloff switch on the mixer channel strip or on the mic itself. We would then take the tape outs from the DA-98 and plug them into channels 7-14 of the 1402, so the recordist could monitor either the input signal from the mics, or the signal coming back from tape. Both the 1402 and DA-98 were powered by a Galaxy Audio "Far Outlet," a large portable battery with integrated inverter that could supply AC to our two devices simultaneously for up to four hours.

We determined that the recordist should be in the back seat whenever possible, giving instructions to our driver, and holding onto the gear to make sure it wasn't rattling around. The recordist would sit down, put the Mackie on his lap, belt himself in, arm the DA-98, and watch levels as he went around the track, making adjustments when necessary. We tried never to change levels in the middle of an effect, as we knew it would give us headaches when we tried to edit them later. If something was distorted or was too low in level, we'd just do the effect again right then and there.

We found that absolutely everything in the interior of the car had to be shut off to make the interior as quiet as possible. This meant shutting up any humans inside the car as well, which definitely proved to be harder than it sounds (try not breathing hard or gasping/panicking when you're going into a hairpin turn at 90 mph). Anyway, once we got our recording method down, we were ready to try it for real.

4 Stunt Driving

While it would have been fun to try some stunt driving ourselves, we decided it would be in the company's best interest if we all actually LIVED through the experience, so we hired a stunt driver. He happened to be the son of the owner of the company where we were renting the cars. I don't think he ever told his dad just what we were going to be doing with those horribly expensive sportscars. I know I wouldn't have. Once we had our driver and cars lined up, we rented a local racetrack for a week or so, and got everything ready to roll.

5 The Plan

At 7:00 am on the first day of recording, we all showed up at the racetrack to start wiring our first car, a BMW four-door sedan. Once we attached all the mics to the car and safety-belted the multitrack in, it was time to decide who was going to get to ride inside, and who was going to put on a DAT rig and be outside. Well, we all kind of wanted to be the first guy to go riding, but the first guy to actually say so was Bob, a freelance recordist we had hired for the project. So we strapped Bob in, had the driver rev it hard a few times to make sure the levels were cool, and sent Bob down to the track with our driver in his dad's shiny green BMW. Sean (another company recordist) and I elected to camp out on the track with DAT rigs to get some drive-bys and any other external effects. The sequence of events was going to be: two laps around the tracks at a slow speed (10–20 mph); two laps at a medium speed (35–45 mph); and two laps as fast as our driver could safely go. Needless to say, we were all curious as to just how fast that would be. Then, we'd do some skids, peel-outs, S-curve effects, parking simulations, and anything else we could think of.

6 First Impressions

So the first two laps go by, no problem. At the end of the second lap, the car pulled over and shuts off. Bob rolls his window down and hands us his headphones so we can listen to the tapes. Everything sounds great, but upon sticking our heads into the car, we immediately notice that it's pretty hot and foggy in there. I guess driving around on a muggy early summer morning with all the windows rolled up and no fan going will do that. But other than looking a little sticky, Bob seemed OK. After we adjusted a few settings, we sent our boys out again for the medium

and high speed laps. As the car came around the track and went roaring between Sean and me in the straightaway, we're both thinking, "Man, how cool is that?" This sentiment immediately changed when we saw Bob's face after the car pulled over, tires smoking from the fast laps. Bob didn't bother with the window, he just opened the door and leaned out, definitely a little green around the gills. We asked him how he felt, and he said that the straightaways are OK, but that the S-curves feel like a horrible G-force-laden ride at the fair that you can't stop. At that point, we reminded Bob that we still had the forward and reverse 180s to record. He said he'd be all right, he just needed a minute to get his composure. We did a few slow speed parking maneuvers, and when Bob was ready, he and the driver buckled up and went down the track 75 yards or so to do some 180s, with the car spinning out in front of Sean and me.

The effects were impressive. Our driver was pretty aggressive, so a few of the 180s ended up being almost 360s, which put the car about four feet away from where both Sean and I were standing, which was a little nerve-racking. Controlling the urge to run for your life while a car is seemingly spinning out of control towards you takes considerable willpower. Anyway, after a few vicious spins and burnouts, we were done. Bob opened the door, and he is Kermit-the Frog-style green this time. He staggers out of the car, a sweaty, nauseous mess. We ask him how he's doing, and he just waves his hand and shakes his head, not able to speak. After five minutes of laying down on the pavement outside the car, he finally rights himself and tells us all, "Never again." The driver thinks this is hilarious, and is laughing his head off, wanting to know who his next victim will be. As bad as Bob looks, my curiosity gets the better of me, and I volunteer to be the backseater for the next car. Bob asks me if I'm sure that's what I want to do. "Yep. I just gotta know," I foolishly reply.

7 My Turn

So we drive back to our staging area and wire up the next car, a two-door BMW with a higher horsepower engine than Bob's four-door BMW sedan. Cooool. We check levels, everything's OK, and I get strapped down into the backseat. I tell everyone not to worry, and we go out to the track to do our slow laps. Sure enough, the interior fogs up immediately, and both the driver and I start to break a sweat from the heat inside the car. But I'm OK so far. After the slow laps, we pull over to air the

car out a bit, and the driver asks me if I'm alright. I say yes. He says, "That'll change." So we go out for the medium laps, and I begin to see what Bob is talking about. Going around a tight curve at 15 mph is one thing; going around it at 45 mph is something else entirely. You start to get pressed up against the side of the car, and all the recording gear starts to rattle a bit, so you have to hold the equipment in place with one half of your body while holding yourself in place with the other half, and you have to do it all noiselessly, as to not ruin your recording. Not to mention the increasing effect of G-forces on your stomach as you wind around turn after turn ... After the medium laps, we pull over to air the car out again, and my head is definitely swimming a bit. Sean and Bob walk over to see how I am, and I tell them I think I can make it. Bob merely laughs, as does the driver. Sean says, "You sure about this, man? You look kind of bad ..." "Just gimme a minute," I reply. Five minutes go by, and I'm feeling a little less queasy, so I give our driver the thumbs up, and off we go for our hot laps.

We peel out, and head down the straightaway. We accelerate up to about 110 mph quicker than I thought possible. During the straightaway, I'm thinking "Hey, this is fun! I've never been this fast in a car before!" Then all inklings of potentially having a good time disappeared as the driver launched us into Turn 1, a nearly 180-degree turn with a very short radius. The thing about riding with a stunt driver/race car driver is that they brake and accelerate in almost the opposite places that you, a normal human being, would choose. As we head into Turn 1, we're not slowing down. The wall is getting closer, and we're still not slowing down. The wall is right in our FACE, and we're not slowing down. The only thing I can think of is, "Well, at least I'm going to die in a nice car ..."

The one nice thing about intense fear is that it masks any underlying nausea you may have at the time. You're simply too frightened to get sick. Coming out of Turn 1, I tried to steady myself for the upcoming set of S-curves. Something you may not know about S-Curves: At 15 mph, they feel like a normal road; at 45 mph they feel like a bad carnival ride (Bob was right!); but at 75 mph, they feel like you've been jammed into a washing machine set on "maximum agitate." The bad thing about knowing you're not going to die is that your body then can release any pent-up queasiness. And we'd decided not to have a break between the two fast laps, lucky me. So as I was praying the driver would notice me turning colors and cut me a break on Lap 2, I think he must have smelled my fear, because we instead tore into the straightaway at 165 mph (I know, because I looked) to start our second lap. To be honest, I don't remember much about Lap 2. I was just trying not to throw up most

of the time. I remember being vaguely scared going into Turn 1 again, which was kind of nice, but then the S-curves brought it all back again.

I somehow managed to make it through Lap 2 without losing my lunch in the car, and we finally ground to a halt next to Sean and Bob. I undid my seatbelt and basically fell out of the car onto the pavement. Sean came up to me and asked if I was OK. I've never wanted to vomit so much in my entire life, but I ended up holding back. After ten minutes of lying down, I was ready to talk, but there was no way I was going to make it through the upcoming spins and skids that we needed to do. I switched places with Sean, who, despite having seen both Bob and me go through the wringer, was still itching to go. Sean climbed in, we did the skids, no problem. He's ready to go again in the next car, a Dodge Viper. Turns out, Sean was the only one of us who was smart enough to take some Dramamine before coming out to the track today. Duh. He had a great time in the Viper, and even wanted the driver to take him on an extra hot lap, and he happily obliged. Hey, it wasn't his car ...

8 The Smoking Mic

As a side note, that turned out to be an expensive extra lap. As Sean pulled up from it with the tires smoking, he rolled down the window and asked if somebody could check our exhaust mic. He said it was making a funny noise, then it quit working altogether. We looked in the back of the car, and the apparent reason the exhaust mic wasn't working was that it had been burnt to a crisp, or at least the zeppelin windscreen that held the mic was. Once we took the zeppelin off, we saw that our $750 condenser mic had been reduced to a molten pile of metal by the heat from the exhaust pipe. Whoops! Guess we won't put our exhaust mic so close next time. As it turned out, we ran that particular car so hard that we had to get a new set of tires for it as well. From showroom tires to junkyard in under an hour. Expensive. But I think it was worth it to see that thing spin around in a 360, and then peel out as if its tail was on fire (which of course, it was).

9 Mostly Uneventful

After learning our lessons early, we were able to successfully record most of our cars that week fairly uneventfully. Some highlights: Getting up to 185 mph in a souped-up Porsche, which turned out to be our overall

top speed of any car we recorded; recording two police cars simulating a high speed chase with a forced spinout finish, where one car bumped the other one from behind to stop it; dropping a VW Rabbit from 150 feet up onto concrete pavement; dropping the same car off of a cliff, and then into 15 feet of water suspended from a crane; nearly getting hit from outside the car while recording a stretch limo doing spins and 180s; and nearly flipping over an Isuzu Rodeo when our driver got a little too aggressive. But our scariest moment came while recording a 1963 Pontiac GTO muscle car.

Terry (another company member) had elected to ride in the GTO backseat, while Sean and I stood outside with the DAT rigs. All of our lap routines went smoothly, as did our spins and skids. Then we decided we wanted some high-speed, smoking-tire burnouts, along with some hard, tire-squealing braking stops.

The sequence of events was supposed to go like this: The GTO would start out in front of Sean and me, and peel out. It would then go down the track about 150 yards or so, and skid to a stop. Then it would turn around, peel out again, and then skid to a stop directly in front of Sean and me.

So Terry climbed in the back of our two-door GTO, braced himself appropriately, as there are no seatbelts in the back of most 1960 muscle cars, and gave the driver the OK. Sean and I started rolling tape, and the car peeled out, no problem. It went down the track about 150 yards, skided to a stop, and turned around. Sean and I got ready for our upcoming skid-stop, and gave Terry and our driver the "OK" wave. The car peels out, and IMMEDIATELY skided to a stop, a good 100 yards short of Sean and me. We kind of looked at each other a little confused, and began walking towards the GTO to see what went wrong. Before we could get there, the car came racing back to meet us. The driver hurriedly got out and said, "We need to check your buddy Terry out—I just put his head through the windshield." Yeah, sure. Ha-ha. Then we look at the windshield. The passenger side looks like somebody hit it with a large rock, with glass all over and a large hole in the center. Then Terry steped out of the car, looking a little dazed, and muttered "I gotta take a little breather, fellas..." His head wasn't bleeding, but the top of it was definitely bruised, and he was acting goofy enough to make us think he had a concussion. He claimed he was all right, but we watched him very closely. Once it was established that Terry was OK, we asked him and the driver what in the world had happened.

As it turned out, Terry didn't explain the sequence of events very clearly to the driver, who was not our usual stunt-driver, and didn't really

know what to expect from us. Before we started our sequence, Terry told the driver to peel out, go down the track, skid to a stop, and turn around. The driver did exactly what Terry told him to, and Terry braced himself appropriately. Once they were turned around ready to come back to Sean and me, Terry told the driver to peel out, which he did. He then was going to tell the driver, "Now I want you to skid to a stop in front of Sean and Mike," but his sentence came out only as far as "Now I want you to skid to a stop. . . ," and then the driver jammed on his brakes. Not ready for the sudden stop, Terry came flying over the passenger seat, which simply folded over, and smashed his head into the windshield. Thank God he was wearing headphones. The padded band of the Sony headphones he was wearing probably saved him from severe injury.

10 On the Tape . . .

He was rolling tape from inside the car the whole time, though. When we took the car back to the garage, we were all pretty curious as to what the whole thing sounded like. Sean put on the headphones and had the first listen. He made this awful face, took off his headphones, and said, "I don't really need to listen to that again." Then I took a turn. You could hear the whole thing. The actual impact sounded like someone throwing a hard melon against a glass window. Pretty rough. The next thing you hear is the driver saying, "Oh my God, man, are you OK? I'm so sorry! You told me to skid to a stop, so I did. . . " And then Terry mutters, "I meant DOWN THERE. . . Ahhh, my head. . . " And then more apologizing by the driver as he speeds back to Sean and me. Later, whenever we'd watch somebody listening to the tape, you could always tell that the impact had just happened, because the person listening to it always says something like "Oh my God!!!" and then made the same kind of awful face that Sean and I did when we first heard it. We didn't include the effect in the final product because it seemed a little too graphic, but the thought of thousands of listeners making that face still amuses me.

11 The Results

When we got the tapes back to our studio, we loaded them into our computer workstations (using Digidesign's Pro Tools as our audio editor), and started sifting through the material. To our slight surprise, and more than a few "whews," everything turned out pretty much as we expected.

The combination of the stereo "cockpit" mic with the engine, exhaust, and tire mics really made it sound like you were sitting in the driver's seat of that particular car, barreling around the track. We did have to doctor a few of the tracks that had problems, such as removing clicks and pops that would occur when rocks would hit the tire mics, and a few other anomalies, but nothing too problematic. We also had to try and remove bird chirps, airplanes, train whistles, clothing rustle, and other "extraneous" noises from our external perspective tracks, the ones that were recorded by the guys walking around with portable DAT rigs. However, we had shot so many different effects, that we could usually just find a decent take where there wasn't too much noise going on around us, and use that one with a minimum of editing.

After all the editing, listening, documenting, and mastering were completed, I listened to each CD (20 CDs in all, one car per disc) as a final quality check, and though I could still hear little things I might change about it, I was (and still am) pretty proud of that sound effects set. It's a shame about that exhaust mic, though. Should have kept it as a souvenir...

12 What We Learned

If there is one catchphrase to describe what we learned from our car experiences, it would have to be "Expect the unexpected." Obviously, we could've avoided a few problems if we'd have thought some things through a little more thoroughly, but the fundamental problem was that none of us really knew what to expect when we were recording. Nobody had ever really tried this before, not to this extent. Sure, we were somewhat prepared, but we had to fly by the seat of our pants on at least a few things every day. And some things you always have to learn the hard way. I guess that's true in most areas of audio, though. So for all you guerilla recordists out there, just remember: Always wear your seatbelt, and don't forget the Dramamine.

Audio examples are available on the accompanying CD-ROM.

A Brief Introduction to Binaural Recording

Gordon Hempton and Ken Greenebaum

This article provides a brief discussion of the equipment I use for binaural recording, my technique-of-choice for recording ambiences both wild and civil around the world for the past two decades.

1 What is Binaural Recording?

Binaural recording seeks only one objective—to replicate human hearing. In this sense, the field journals of naturalist John Muir—which include detailed descriptions of natural sounds as he heard them—might very well be considered one of the earliest binaural "recordings" of nature. His work is collected in the *Eight Wilderness Discovery Books* [1]. Had Muir been alive today he most certainly would be interested in binaural recording as a means to not only record the world in vivid detail, but also explore the sonic world.

A binaural microphone looks like a human head. It is made out of a well-engineered blob of flesh density rubber to separate two ears (each with a molded outer ear), and short auditory canals that lead to sensitive, low-noise transducers.

Sound must pass around the head, then reflect off the outer ears and finally enter the auditory canal before it is recorded. Each side of the head, left and right channels, records different arrival times and spectral content, thereby preserving all of the information that the brain uses to form a three-dimensional image or soundscape.

There's no doubt about it, binaural recordings offer convincing realities and first-time listeners to recordings of passing locomotives, wolf attacks, and make-out sessions are often unprepared.

Binaural is always my first choice when I want to record what it *feels* like to be in the real world, places like the Hoh Valley Rain Forest at Olympic National Park or Koln Cathedral in Germany. Binaural microphones produce great sound, capture incredible depth, and preserve the *maximum amount of information* that you can obtain on location over a two-channel system. In the studio, this information can be processed to create excellent mono or even 5.1 surround sound (reportedly better than any other two-channel source with transaural processors). It can also be made speaker-compatible. The information also provides you with the perfect reference for the recorded area's acoustics and can be used to create additional sound files that conform to those acoustics. Yet despite this versatility and excellent quality, binaural recording remains largely undiscovered.

Binaural technology was first developed in the 1960s, but was relegated to a curiosity. At that time, only stereo headphone users would receive the impression accurately, and speaker playback was less than satisfactory because phase cancellations removed much of the detail, making the recording sound *far-away.* These restrictions have largely been overcome by further refinements in design. (Please refer to Haferkorn's article "Head-Related Transfer Functions and the Physics of Spatial Hearing," (see *Audio Anecdotes III*), and Gehring's articles "Why 3D Sound through Headphones," (see *Audio Anecdotes III*), and "Interactive Entertainment with 3D Sound," (see *Audio Anecdotes III*), describing the mathematics, reproduction, and application of binaural hearing.)

2 Recommended Equipment

The Dimensional Stereo Microphone (DSM) systems manufactured by Sonic Studios offer binaural type recording with outstanding results using your head instead of a separate dummy head. It is about the price of a popular SLR 35mm camera, and the sound images are so hallucinogenic the picture pops right out in the listener's imagination. This "covert" system (they fit on glasses and dangle in front of your ears) is popular for recording in social environments where the recordist would like to get the natural activity of people rather than record a lot of questions about what he or she is doing. I use DSMs myself for almost all social settings to avoid drawing attention to myself. The drawback is size, which impacts the noise floor of the system significantly (quiet places will sound hissy.)

For quieter acoustic environments with delicate sounds such as individual leaf rustles or the flight of an insect, the noise floor of the system is crucial. To this end, there is Neumann's KU81i system (which is no longer manufactured, unfortunately).

But even this might not be enough when the dBs drop very low, and for that there is a make-shift design by Lang Elliot that uses Crown's SASS system retrofitted with a pair of Sennheiser MKH-20s. But I hesitate to mention it, since true binaural has excellent front-center detail (meaning that if an event is moving across the sound stage, say from left to right, through the stereo image it sounds natural and does not change frequency content based on movement, while if a system is flawed, it will have a dip in the center) and the SASS system does not. However, if the subject, such as a songbird, is at a distance of 200 feet or more (not too unreasonable with this system), the atmospheric attenuation will take out the highest frequencies, which most influence our perception of "front-center"—in other words, the SASS system has a weak center stage, but at a distance of 200 feet or more, that won't really matter.

The DSM system is under $1,000, the SASS-Sennheiser hybrid is around $3,500 (and requires tooling and assembly), and the Neumann KU81 system is around $4,000 used (if you are lucky enough to find one). There are other binaural systems, some good and some bad, but these three are the only ones that I have tried and liked. If you go out shopping for a "binaural" system, ask to test it first (expect to leave a healthy deposit) and then use it under real conditions. If you plan to use it outdoors, you absolutely need to judge the unit's sensitivity to temperature, humidity changes, and wind.

For a simple and less expensive start-up system, you can always go with *poor man's binaural*, which is a pair of cardioid microphones in an ORTF configuration (named for the Organisation de Radio et Television Francaise who pioneered this technique). Play with the spacing and the angles for what sounds best to you. Start with a spacing of 7.5 inches and an angle of 65 degrees and then, while wearing headphones, focus the image. You will notice that your preference may change as your brain learns how to process this new information.

3 In Conclusion

Binaural recording is a sensational means for recording the real world. It reproduces the full soundscape and teaches the sound recordist about acoustic environments.

My article, "Listening to Nature: Hearing is More than Meets the Eye" (see *Audio Anecdotes I*), describes my own recording work and philosophy.

Please be sure to listen to the environmental binaural recordings included on the CD-ROM accompanying this book.

Annotated Bibliography

[1] John Muir. *The Eight Wilderness Discovery Books* Seattle, WA: The Mountaineers Books, 1992.

John Muir (1838–1914) was a naturalist and a promoter for what has become our national parks system. This collection contains his beautifully detailed observations of nature.

[2] http://www.sonicstudios.com/. Sonic Studios web site.

Sonic Studios is a great source for portable binaural recording gear.

Synthesis