

CD COPIES OF TAPED AUDIO RECORDINGS: *A Poor Forensic Alternative for Attorneys*



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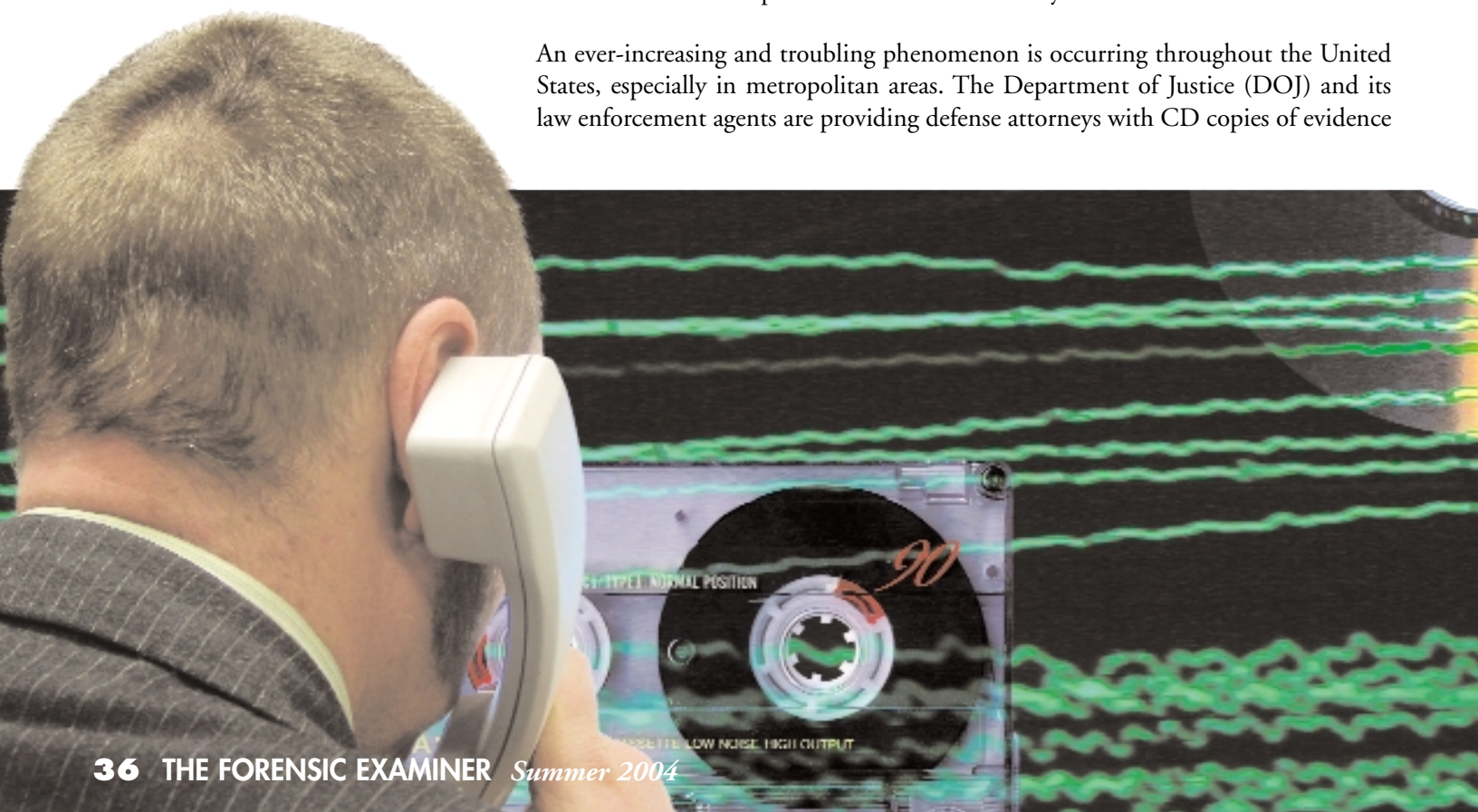
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Abstract

The law enforcement community has traditionally provided analog copies of original tape recordings for forensic testing. With the advent of the computer and its digitizing sound card, there are increasing numbers of compact discs (CDs) being provided to defense attorneys as evidence. This article examines the potential pitfalls of relying too heavily on CD copies of evidence recordings. Many recently examined CD copies were corrupted in that they contained heavily compressed and missing audio data that was not suitable for tape authentication, tape enhancement, or voice identification examinations. The best way to truly confirm the integrity of a CD copy is to obtain the original analog tape from which it was made; this process should be a common practice for defense discovery.

An ever-increasing and troubling phenomenon is occurring throughout the United States, especially in metropolitan areas. The Department of Justice (DOJ) and its law enforcement agents are providing defense attorneys with CD copies of evidence



in Title III, RICO (Racketeer Influenced and Corrupt Organizations Act), and other types of serious felony cases involving consensual telephone intercepts or face-to-face undercover encounters. What may have started as a cost-effective means for the DOJ to provide digital tape copies to defense attorneys is turning into a growing number of corrupted CDs that contain compressed and missing audio data that is not suitable for voice identification, tape enhancement, or tape authenticity examinations. In addition, there is a loss of fidelity between the original tape and the CD copy. For these reasons it is essential that defense attorneys request all original recording equipment and tapes rather than rely on CD copies alone for evidentiary purposes.

A recent Chicago case illustrates the problems surrounding CD copies of taped recordings. In the case, the FBI provided the defense with supposedly uncompressed WAV (a standard audio file format) audio files that should have been easily readable. When these files were opened, however, the different files were found to contain over 5,000 truncated telephone conversations. They had not been labeled, nor were they continuous (linear) recordings of the original telephone calls. It was further noted

that even the speech content itself had been corrupted, and that many of the conversations were discontinuous and had not been recorded in their entirety. The defense attorney in this case requested additional relevant technical data, such as the make and model of the recorder, analog or digital "original" formats, any information concerning special encoding algorithms or compression information, and any other information that the FBI may have included as proprietary methodology in constructing their digital WAV files from the original analog cassette tapes. The U.S. prosecuting attorney declined to provide any of the requested data. The presiding federal judge voiced concern regarding this missing data and the reluctance of the DOJ to provide it to the defense. Eventually the U.S. prosecuting attorney declined to provide any of the requested CD manufacturing data, and the tape issue was later made moot because the original recorded tapes were never introduced into evidence.

Even though the case described here resolved itself, the problems regarding CD copies of taped audio recordings remain. It is important that forensic specialists understand how CDs work, the problems surrounding the use of CD recordings, and how these problems impact the forensic examination of CD copies of taped recordings.

Critical Quality Control Issues Regarding CD Integrity

There are numerous ways in which problems and defects in a CD can negatively impact the forensic specialist's ability to utilize a CD recording in his or her investigation. Listed below are several ways in which CDs can become corrupted or otherwise damaged.

Fragile CDs: Some discs develop cracks near their centers when they are read or recorded at high speeds. The protective layers in others delaminate over time. High quality polycarbonate substrates should not exhibit these characteristics.

CD Contamination: Improper handling and storage techniques by manufacturers, distributors, and users are producing an increasing number of discs with scratches, dirt, smears, and other surface contamination. During readout, this



material will partially block the laser beam in the playback process and could result in a permanent defect in the dye layer. One should carefully examine any CD-R discs under low power magnification and reject any with contaminated surfaces.

Defective CD ROM Discs: Many discs fail low radial tracking or contain high "jitter" characteristics. Poor quality control in the mastering or molding is normally the cause. Such discs will read on some drives but fail in others.

CD Radial Acceleration: Sudden radial jumps in track location can cause unpredictable field failures. This is normally caused by either mastering or molding flaws.

Brand of CDs: Both interchange and longevity can be compromised by poor media selection.

Jewel Case Damage: In many cases, forensic specialists have received CD-R discs that have been damaged in their jewel cases and have also been scratched or otherwise physically damaged during shipment. Other discs contain uncorrectable errors.

CD-R Interchange: Severe defects are often caused by recording systems themselves. Absent or short post gaps, high jitter, and severe error correction algorithms can result from flaws in the recording software or in the CD-R drives themselves.

Observations and Recommendations From Forensic Audio Experts Regarding Corrupted CDs

One Philadelphia-based sound engineer commented that most of the mass production of CDs is accomplished through third-party mastering or duplication houses that may or may not protect the integrity or do other quality control inspections to ensure that the produced CD

copies consist of a continuous stream of recorded data with no distortion, clipping, or other degrading factors. He agreed that the only real way of ensuring that the original tape-recorded content had been accurately transferred to the CD copy was to compare the contents of the original tape to the CD recording. He further indicated that most duplication houses add equalization, an act that will affect the original tonal quality of the taped conversation but will also compress some of the data, depending upon the needs of the client and the length of information to be placed on the CD.

Some federal law enforcement personnel have indicated that many of the present-day undercover recorders used by federal law enforcement agencies utilize a digital format rather than an analog one. Though they did not identify the exact make and model of the digital integrated-circuit recorders now being used in the field, they indicated that most of them compressed the audio data by as much as 8 to 1 during the recording process. In essence, this means that as much as 80% of the original analog information is being discarded because of the compression process, thus potentially leaving out important acoustic and forensic information that may be beneficial in tape authentication cases. The law enforcement personnel warned that many of the recorders do not permit a linear or continuous uncompressed recording of the evidential conversation; instead they digitize the information into compressed files.

The compression, by digital extraction methods, from the original analog cassette tape presents the greatest threat to tape integrity for the defense attorney. It is essential that the defense attorney request all of the original recording equipment and tapes rather than rely on



CD copies alone for evidentiary purposes. In addition, there is a loss of fidelity between the original tape and the CD copy. One CD manufacturer, Philips, reported that even a personal copy made from an original CD disc will contain decreased amplitude linearity, increased signal-to-noise ratios, and an increase in total harmonic distortion and overall noise levels.

DOJ personnel are normally reluctant to provide any specific data on the digital encoding of analog cassette tapes onto CD-ROMs. The best evidence for now will continue to be an analog tape recording, which is the only format that should preserve all of the originally available speech information. The list at the end of this article describes some of the more recent and informative Internet



poly-carbonate. During manufacturing, this plastic is impressed with microscopic bumps arranged as a single, continuous, long spiral track of data. Subsequently, a reflective aluminum layer is "sputtered" onto the disc, covering the bumps, followed by a thin acrylic layer that is sprayed over the aluminum for protection. The incredibly small size of the bumps (known as bits) makes the spiral track of a CD extremely long. A very precise reading mechanism is required to read something this small.

How is audio data stored on a CD? All data on an audio disc is organized into frames to ensure a constant read rate. In addition, each frame consists of 24 bytes of user data, plus synchronization, error correction, and control and display bits. The CD audio contains data that is not arranged in distinct physical units; instead one frame is interleaved with many other frames so that a scratch or defect in the disc will not damage a single frame beyond correction.

Two preliminary methods for creating files on a CD-ROM include using an audio CD track or a WAV file. Only the former will play in a CD player, although CD-R software can convert an audio file into the necessary format to read the audio file from a CD onto your hard disc (hard drive) as a WAV file.

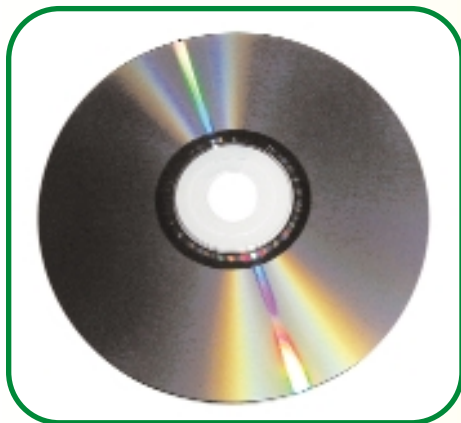
Can an audio CD correct for errors on the disc? Unlike ordinary data files, a sound file does not contain error-correcting codes within it to handle data lost in transfer. One way in which CD players can vary in quality is that they are more or less effective in using error-correcting codes to repair errors in reading the audio

What exactly is a WAV file? A WAV file consists of three elements: a header, audio data, and a footer. The mandatory

header contains specifications for the file, including information on interpreting the audio data. Unfortunately, not all CD players or software programs follow all of the same rules. Consequently, the file format data may not be quite what it should be to make a valid WAV file. When that difference occurs, the CD player may not be able to open the WAV file, or at a minimum, it will need be told the format of the audio data for playback purposes.

What problems surround digital-to-audio conversion? As all recorded data on a CD is stored in digital format, to listen to it one must convert it back to analog information. The quality of the signal going into your sound card depends on the quality of the CD reader or player you are using. Within the sound card, an analog signal is then converted into digital data, which produces its own set of problems. Analog-to-digital conversion presents a more difficult engineering problem than converting from digital to analog. In essence, most sound cards are not that effective in converting all of the analog and digital data in a continuous fashion without signal losses and potential corruption of originally recorded data on the CD.

What is the impact of reading errors? Another key factor in determining the quality of encoded audio data on a CD is the quality of the reading. Some errors derive from the way the track is formed on the disc; these are related to the term jitter. In addition, the faster the data flies past the laser pickup, the greater the chance that a bit will be misinterpreted. If the attorney's CD player does not support digital audio extraction, the CD may not play back at accelerated rates and a greater number of ticks and pops (i.e. bit errors) will be encountered.



sites that address many of the issues discussed regarding the problems involved in properly mastering a CD and later making reliable copies for dissemination to attorneys.

Frequently Asked Questions Regarding Corrupted or Contaminated CD Copies

What is a CD? The evidence CD is normally an audio CD produced in WAV format, which is sampled at 44.1 kilohertz (KHz) with 16-bits depth. The typical CD can normally store up to 74 minutes of audio, which involves over 783 million bytes of encoded digital information. The CD disc is plastic, about 1.2 millimeters thick, and consists of an injection-molded piece of clear

What problems do buffer underruns create? Buffer underrun means that the buffer supplying data to the writer has emptied before the data was completely written. Consequently, the CD reader often does not perform at the expected speed. One reason for this is consistently high error rates typical of a scratched CD-R or a dirty pressed disc. A second factor that can slow the CD-ROM reader is a severe scratch or similar type of localized damage, causing it to read most of the time but to have trouble in one area. The buffer will be seen to fall rapidly as the reader rereads to try to get valid data. You often can see a light flash as you watch the buffer drain.

Can I make a copy of an audio CD at high speed? Some CD-ROM and CD-R drives have problems extracting digital audio at high speed, so if you are experiencing many clicks and pops, try extracting the data at a slower speed. You can also encounter problems if you attempt to extract data faster than your hard drive can write, especially if the hard drive requires defragmentation.

Why might the CD copy have a poor sound quality? All CD writers need a continuous supply of data, and if anything interrupts that flow, the buffers can empty and underrun. Oftentimes it is better to copy a CD not on the fly (i.e. with another CD burner) but to extract the files to your hard drive as WAVs and check them during playback for signal discontinuities or other corrupted sound information.

Can data be compressed or encrypted on a CD-ROM? There are many encryption and compression algorithms that are employed in the original duplication and mastering process. Unfortunately, the end user, such as an attorney, may not be able to read the data unless that information is supplied by the government. Some of these encryption programs are proprietary, while others remain open to the general public.

What are the most common CD player problems? A short list of com-

mon causes for difficulties tracking an audio readout include the following: dirty optics; drawer loading belts that malfunction; sticky mechanisms; broken parts within the CD player; a need for electronic servo adjustments; bad connections, such as solder joints or cracked flex cable traces; defective motors; laser-dead or weak laser diode or drive problems; a photo diode array that produces weak or shortened segments and loss of power; bad or heat-sensitive electronic components; and a bad or missing optical pickup shield ground.

What are jitter and jitter correction? Jitter usually refers to a time-based error when digital samples are converted back to an analog signal. Jitter correction is a process of compensating for jitter and restoring the audio to its intended form. Most modern digital audio extraction programs will perform jitter correction.

What is Firmware? Firmware is a type of software that lives within the computer. It is a firmware of your CD recorder that controls the operation of the device and handles everything from decoding the CD-ROM sectors to writing the disc table of contents. Sometimes there are bugs or missing features that are upgradeable. Firmware upgrades have been used to add features like disc-at-once recording and to fix bugs like reversed left and right audio channels. Sometimes, however, the upgrade will inadvertently add bugs, causing the recorder to work improperly.

Information Resources

www.cdrfaq.org. Andy McFadden's FAQ: Listed below are sites from McFadden's Section 8: Net Resources.

www.mrichter.com. Mike Richter's collection of files and URLs related to CD-R.

www.cdpage.com. Lots of valuable information, including a library of technical articles.

www.cd-info.com. Information about CDs and CD-Rs, especially technology and industry.

www.osta.org. Optical Storage Technology Association (OSTA); see the CD-R Q&A doc.

www.sigcat.org. SIGCAT (Special Interest Group on CD Applications and Technology).

www.roxio.com. A lot of useful information on CD-R.

www.howstuffworks.com. Provides a clear explanation of how CDs work.

www.repairfaq.org. Science Electronics Repair FAQ.

About the Author

Steve Cain, M.F.S., is a Fellow of ACFEI and a Diplomate of the American Board of Recorded Evidence, the American Board Forensic Examiners, and the American Board of Law Enforcement Experts. He has over 20 years of experience examining audio and video tapes for the U.S. Department of Justice (cases included the White House Senate Select Judiciary Committee's Clarence Thomas and Anita Hill investigation and the Senate Investigation Subcommittee's "China Gate" investigation); the U.S. Attorney's office, over 100 public defender offices; the Federal Bureau of Investigation; the U.S. Securities and Exchange Commission; the Drug Enforcement Administration; U.S. Customs and Border Patrol; the Internal Revenue Service; the U.S. Secret Service; the Bureau of Alcohol, Tobacco, Firearms and Explosives; and over 1,000 law firms in both criminal and civil cases in the United States and abroad. He has testified in criminal and civil cases in more than 40 U.S. states, as well as in Hong Kong, Puerto Rico, and Canada. He has examined over 20,000 cases during his 35 years of forensic experience.

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