Optical Transfer Technologies for Radio Transcription Discs

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This is an Accepted Manuscript of an article published by Taylor & Francis in the **Journal of Archival Organization** ***on 07 July 2020, available online: https://www.tandfonline.com/doi/10.1080/15332748.2020.1788313.***

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Abstract

The bulk of recorded radio content prior to the introduction of magnetic tape in the late 1940s was made on lacquer transcription discs. These discs have proven highly unstable and are considered a top preservation priority in radio archives. While preservation reformatting via mechanical playback is ideal, when it comes to damaged or deteriorating discs, the risk of losing content and the amount of labor needed to perform one-to-one transfers is high. As an alternative, several optical scanning technologies have been developed. This paper offers a comparative study of four existing optical transfer systems for discs: IRENE, Saphir, VisualAudio, and Endpoint Audio.

Keywords: radio; lacquer discs; transcription discs; mechanical playback; optical transfer

Introduction

From the time of its introduction in the 1920s until the rise of magnetic tape in the late 1940s, the most commonly used recording medium within the broadcast industries was the lacquer type of instantaneous transcription disc. These discs contain the bulk of this era's recorded radio content and, in many instances, are the only extant recordings of early radio broadcasts. Unfortunately, these discs, which typically consist of a thin lacquer coating over an aluminum, paper, or glass base, were never meant for long-term storage and must be digitally reformatted if we are to preserve their content. The combination of unique historical content and inherent instability makes these discs a high priority for preservation among other recorded sound materials. However, the need for digital reformatting is complicated by the sheer abundance of these materials, the complexity and fragility of the media itself, and the amount of resources required for their digitization. While traditional strategies for digitizing and preserving these materials have focused on mechanical playback using a stylus (needle) placed in physical contact with the disc, in recent years, several competing systems have emerged that use contactless optical scanning methods that may be preferable for discs that are especially fragile or too damaged to permit traditional mechanical playback.

These optical scanning technologies are typically given only passing mention in recognized professional audio preservation guides such as the *ARSC Guide to Audio Preservation* and the International Association of Sound and Audiovisual Archives' (IASA) well-known series of "TC" manuals.[1] Creators of these systems have presented on their developments at conferences and provide technical information on their respective websites, but little published work on these systems as a whole has been recently produced.[2] Ottar Johnsen et al described the system they were then developing, VisualAudio, in the *IASA Journal*, while Vitaliy Fadeyev and Carl Haber detailed their own system IRENE, in the *Journal of the Audio Engineering Society*.[3] To date, the most comprehensive discussion of available optical scanning technologies comes from Jean-Hugues Chenot, Louis Laborelli, and Jean-Étienne Noiré's 2018 report in the *Association for Computing Machinery Journal on Computing and Cultural Heritage*.[4] In this report, the authors provide an overview of the optical approach and touch on some techniques that have developed to read different types of discs — from the Finial/Edison Laser Player process (patented in 1989 but only successful with vinyl LPs) and the use of flatbed scanners for low-resolution imaging to more advanced, high-resolution systems like VisualAudio and IRENE. While their report includes brief overviews of available technologies, its primary focus is their own system, Saphir, and does not cover newer systems such as Endpoint Audio Lab's Disc

Transfer Machine, which was publicly unveiled at the 2019 ARSC Conference, seven months after the Saphir report had been submitted.[5]

This paper seeks to enhance existing literature on optical scanning technologies by reviewing four of the more prominent and promising systems in the United States and European markets that were developed with the intent of retrieving recorded sound from obsolete carriers. Although most of these systems are currently available for use by custodians of such recorded sound collections, some are only available as a vendor-provided service while others can be purchased as an entire system. The majority have already been used successfully in audio preservation projects. IRENE, created by Haber and Fadeyev of the Lawrence Berkeley National Laboratory, is currently in use in the United States by the Berkeley Lab, Library of Congress, and the Northeast Document Conservation Center (NEDCC). Saphir, developed by Institut National de l'Audiovisuel's (INA) Chenot, Laborelli, and Noiré, is currently being used to preserve INA discs in France. VisualAudio, created by the Swiss National Sound Archives' (SNSA) Stefano Cavaglieri and Pio Pellizzari with Pierre Hemmer in partnership with the School for Engineering and Architecture Fribourg (HEIA-FR), is in use at the SNSA and HEIA-FR in Switzerland. The Endpoint Disc Transfer Machine is still in development by Nicholas Bergh of Endpoint Audio Labs in Burbank, but in the future, institutions will be able to either outsource their lacquer digitization projects to Endpoint or purchase the entire disc transfer system.

Beginning with a short history and overview of each system, I evaluate each along five axes most relevant to those considering embarking on lacquer disc preservation projects in the near future: (1) availability, (2) affordability, (3) ease of use, (4) quality of resulting transfers, and (5) the potential for each technology to transform current archival workflows through automated and parallel transfer capabilities. As elaborated below, each of these systems shows considerable promise in the realm of radio preservation, but none scores consistently high across all five axes. One preferred system for the audio preservation field as a whole might be impossible to determine at this time, due to the varying needs of each institution's recorded sound collections, existing infrastructure, and available resources; but, the available systems offer important alternatives to mechanical transfer, and this analysis aims to provide necessary information for helping archivists create viable work plans as they seek ways to preserve the broken, deteriorating, or extremely fragile lacquer radio transcription discs in their collections.

Background

The popularity of lacquer transcription discs has resulted in an abundance of these materials in archives across the world, including those that do not specialize in audiovisual collections. In 2010 the National Recording Preservation Board estimated that "tens of thousands of lacquer discs in archives in the United States remain unpreserved" and "if the proper care or preservation of sound recordings is postponed until their significance is realized, it may well be too late."[6] Personal interviews I conducted in late 2018 and early 2019 with representatives from the Library of Congress' National Audio-Visual Conservation Center (NAVCC), the New York Public Library (NYPL), British Library, and Indiana University's Media Digitization and Preservation Initiative (MDPI) revealed that each institution held large numbers of lacquer discs ranging from 8,100 to 370,000-plus items per institution, many of which had yet to be digitized due to cracks, delamination, and warpage, which prevented proper mechanical playback.[7]

Because of the evolution and the lack of standards in national and international manufacturing of instantaneous discs, it can be difficult for many archivists to properly identify a disc and take appropriate preservation action. The most widespread type of instantaneous disc was the lacquer transcription disc, ranging in size from seven to sixteen inches in diameter. The soft lacquer coating of these discs consists mainly of cellulose nitrate that is plasticized with castor oil or camphor on a metal (usually aluminum), glass, cardboard, or paper base.[8] During World War II, aluminum was rationed, so disc manufacturers could only produce lacquers with glass substrates, with recent research revealing significant variation in chemical composition of the glass layer used by different manufacturers that directly impacts the ability of the thinner lacquer coating to successfully adhere to the disc over time.[9] While working on a FONSART (Fondation pour la sauvegarde du patrimoine audiovisuel de la Radio Télévision Suisse) mass digitization project, conservator and preventative preservation expert Rebecca Rochat began a research project on lacquer discs from this period that originated from a range of international manufacturers. The challenges associated with the wide variety of lacquers in the collection led to Rochat's desire to have chemical analyses performed on the different disc types. Rochat's years of historical research on the various discs and their manufacturers resulted in the creation of a typology guide that is currently available as an open resource.[10]

Regardless of their chemical makeup, lacquer discs as a whole are extremely unstable and vulnerable to many problems ranging from the fairly minor (scratches, groove wear, surface contamination) to the more serious (cracks, breaking, delamination, and exudation) that can greatly limit their ability to be played back and digitally reformatted. In delamination or laminate separation, the cellulose nitrate reacts with oxygen and water vapor and produces acids, which cause the lacquer coating of a disc to begin to shrink. Since its metal or glass substrate is unable to shrink, the lacquer begins to crack and come apart from the base.[11] While most lacquer discs should be stored vertically, delaminating, cracked, or broken discs must be stored horizontally to alleviate stress from gravity and to prevent further damage.[12] Although institutions such as the Library of Congress, the Hoover Institution at Stanford University, and Indiana University (IU) Libraries Preservation Department have created customized housing to protect these deteriorating discs, the chemical process cannot be reversed, and delamination will eventually spread across a disc's surface.[13] Exudation occurs when the plasticizer in a disc begins to break down, and its acid components start to appear on the surface of the lacquer in the form of powder. Acid exudation can be mistaken for mold since it manifests in the form of a white powder, but is distinguished by its greasy texture. While external signs of exudation can be removed through cleaning a lacquer's surface with castor oil, mineral oil, or solutions like Disc Doctor, this does not stop the process and is only a temporary fix to enable a cleaner digital transfer.[14]

[Insert Fig. 1 and Fig. 2 about here]

Until recently, the only option for digitizing lacquer discs was via mechanical playback, using a turntable and stylus (needle), to listen to and reformat a disc. However, mechanical playback can be time-consuming and resource intensive for even the best-preserved lacquer discs. The amount of labor needed to perform a custom, one-to-one mechanical transfer workflow for deteriorating discs is significantly higher. In a 2001 article "Stating the Obvious: Lessons Learned Attempting Access to Archival Audio Collections," Harvard University's

Virginia Danielson writes, "Getting the 'last, best play' from a fragile recording may require four hours of skilled labor for one hour of sound."[15] Mechanical playback may also result in irreparable loss of content when an existing break is worsened or a flake of delaminated lacquer is lost during the transfer process. In addition, mechanical replay causes deterioration to the shape of the disc's grooves and, as stated in *IASA-TC 05*, "because of their susceptibility to deterioration by replay, strategies have to be in place to restrict the replay of mechanical carriers to the absolute minimum."[16] Finally, mechanical transfer of 16-inch lacquer discs requires increasingly difficult to locate equipment such as special styli and a turntable designed to accommodate a large disc and a wide range of playback speeds.

Optical scanning systems offer an alternative that overcomes some of the challenges associated with mechanical playback workflows and can be particularly useful for more severely deteriorated discs. As noted in *IASA-TC 04*, "A typical application for optical retrieval technology is for records in very bad condition, where mechanical replay devices would fail, or where the recordings are so fragile that the replay process would cause unacceptable damage."[17] The four systems selected for review below were developed at different times and use different scanning technologies. Stemming from projects begun in 1999 and 2003, SNSA's VisualAudio system and Berkeley Lab's IRENE are the two oldest systems and create photographic images of the record. VisualAudio takes an analog photograph of the entire disc surface at once, and IRENE uses a laser tracking system to take a series of digital images of individual grooves that are then stitched together using proprietary software. First introduced in 2007, INA's Saphir Optical Scanner measures variable refraction levels of multicolored light shined onto groove walls to create a visual color map of a disc's surface.[18] Endpoint Audio Labs unveiled the most recently introduced system in 2019. Their Disc Transfer Machine uses lasers added onto a standard turntable to scan a disc's tracks into custom software for real-time playback. IRENE, VisualAudio, and Saphir are currently available and in-use in the United States in Europe, and official rollout of Endpoint's system is expected shortly.

Methodology

Information used to evaluate these four systems was culled from developer's public websites, conference presentations, and personal interviews conducted between 2018 and 2020. Using this available information, I evaluate each system for its availability, affordability, ease of use, quality of resulting digital transfers, and its potential to transform current archival workflows through automated and parallel transfer capabilities.

A system's level of availability describes how archivists are able to access these technologies, either commercially or noncommercially. For example, archivists who wish to outsource their disc digitization projects can work with either Endpoint Audio Labs or the NEDCC. Those who specifically wish to use the IRENE system must pursue this path through the NEDCC. Archivists who instead wish to pursue in-house digitization projects can purchase the entire Endpoint or Saphir desktop system for their institutions. When the above are not desirable options, archivists can also pursue partnerships with INA or SNSA/HEIA-FR to have small quantities of discs scanned with Saphir or with VisualAudio for projects that involve specific instances such as cultural grant projects.

A system's affordability takes into consideration the cost to digitize an item or small number of items, as well as the cost to purchase an entire system. According to a 2014 survey conducted by AVPreserve and the NEDCC, the cost to mechanically transfer a single standard lacquer disc with no damage is approximately $75, while the "Specialized Cost per Item" for a damaged disc is estimated to be $150.[19] Taking these amounts into consideration, this paper considers an 'affordable' optical transfer for a single disc to be between $150 and $200. Amounts exceeding $200 are considered 'expensive.' However, if an archive holds hundreds of damaged lacquer discs, it might be more affordable to purchase a system as a whole, so prices for the two available systems are presented below as 'affordable' or 'expensive' in relation to one another. In this analysis, ease of use is defined by the amount of additional resources required to transform an optical scan of a disc into a usable audio file, using a scale of 'easy,' 'moderate,' or 'difficult.' This includes whether the required software is proprietary or open source and whether an archivist will require specialized training to use the software.

The quality of a digital transfer is measured as 'fair' or 'good' according to how closely resulting audio files align with established standards for the digitization of lacquer discs. In this analysis I compare resulting files to ARSC and IASA recommendations for a sampling rate of 96 kHz and a bit depth of 24 bits for a preservation master file.[20] Finally, a system's ability to transform current workflows considers the amount of time required to scan a typical 16-inch lacquer disc containing approximately 15 minutes of recorded material per side, the time to interpret the created digital image, as well as the level of automation the system affords an archivist. I asked of each system, once a disc is put into place, is the scanning process fully automated, or does an archivist need to continually make adjustments to system components from beginning to end? Can different steps in the system's process be conducted on multiple discs in parallel? Additionally, will the amount of time and effort an archivist must dedicate to conducting optical transfers in-house be so great that it negatively impacts the other activities of the archive (e.g. adding to the archive's backlog of yet-to-be-digitized recordings)? This potential is ranked as either 'low,' 'moderate,' or 'high.'

IRENE

The IRENE system uses no-contact digital imaging to optically recover sound recordings from cracked, broken, and delaminating discs.[21] Carl Haber and Vitaliy Fadeyev, scientists at the Lawrence Berkeley National Laboratory, came up with the idea for their system in 2003 after hearing the drummer for the Grateful Dead discuss on a radio show the loss of cultural heritage due to the breakdown of audio recordings.[22] Haber and Fadeyev's subsequent experiments resulted in the system they named "IRENE," for the song "Goodnight, Irene" by the Weavers because it was the first record, a 78 rpm shellac disc, from which they were able to extract sound.[23] IRENE became an acronym for Image, Reconstruct, Erase Noise, Etc., because the system creates a high-resolution digital map of a disc by using light, a digital camera, and a laser to drive the motorized arm that allows the camera to focus properly and scan images of the disc's groove floor. Their proprietary software – RENE for 2D data and PRISM for 3D data – then analyzes the motion occurring within the grooves and converts the data into WAV sound files.[24] The modulation of the grooves cut into discs is generally lateral (2D data), as opposed to cylinders, which all demonstrate vertically cut grooves (3D data). While only a few disc formats (Pathé, Edison Diamond Discs) are vertically cut, grooves on lacquer discs can be either lateral- or vertical-cut (3D data).[25]

It was around 2003 when Peter Alyea, a digital conversion specialist at the Library of Congress, first learned of IRENE and realized its potential for reading damaged discs. This marked the beginning of a collaborative relationship between the Library of Congress, Haber, and the Berkeley Lab to continue to develop the system. The first 2D IRENE for reading lateral-cut discs was installed at the Library in 2006 and eventually found its permanent home at the NAVCC when a new 2D/3D system was delivered for reading vertical-cut discs and cylinders.[26] In 2013, the Northeast Document Conservation Center (NEDCC) received a National Leadership Grant from the Institute of Museum and Library Services to "move this technology out of the lab environment and to create a sustainable digital reformatting service for archives, libraries, and museums across the U.S."[27] An IRENE system was installed in the NEDCC's Andover, Massachusetts facility in 2013. Since that time it has been used to successfully digitize numerous audio recordings, including glass-based, delaminating lacquer discs that contained a previously lost Native Alaskan dialect held by the Alaska and Polar Regions Archives at the University of Alaska Fairbanks and WNYC radio broadcast recordings on broken glass-based lacquer discs held at the New York Public Radio Archives.[28]

Institutions cannot currently purchase an IRENE system for in-house digitization, and IRENE scans are available only as a vendor service through the NEDCC. The NEDCC's audio preservation department offers digitization via IRENE as a paid service.[29] Since the cost to have a lacquer disc scanned by IRENE fluctuates depending on the disc's physical condition, it is understandable that the NEDCC has not published a price sheet for IRENE services. However, when George Blood of George Blood Audio/Video/Film presented his analysis of the IRENE System, "IRENE: Messiah or False Prophet," at the 2016 ARSC Conference, he estimated the price for the transfer of a single lacquer disc in good condition to be $250.[30] In 2017, Indiana University's Media Digitization and Preservation Initiative (MDPI) sent three broken, glass-based discs from Orson Welles' "The War of the Worlds" broadcast to be scanned by the NEDCC. While recounting details from the project at the 2019 ARSC Conference, MDPI Media Preservation Specialist Patrick Feaster referred to the use of the IRENE system for damaged discs as "an expensive proposition, often prohibitively expensive."[31] Using my previously stated metrics for affordability, specifically that an 'affordable' optical transfer for a single disc is below $200, George Blood's estimate of $250 for scanning a disc in good condition would fall in line with Feaster's classification of this system as 'expensive.' If a disc is broken into several pieces or delaminating, which is common to most use cases for such materials (including the aforementioned Alaska and Polar Regions Archives, WNYC, and IU projects) then the potential cost would be even higher.

Based on the above criteria, the IRENE system is relatively easy to use for most typical projects. Although the system is expensive, the NEDCC provides clients with master files (TIFF image files of the disc) and access files (the images converted to uncompressed Broadcast WAV audio files), making the process for an archivist rather easy since they have outsourced the entire reformatting process to the NEDCC. However, if a client wished to work with the master file in the future – perhaps performing additional restoration on a track– they would have to use the system's proprietary software (RENE for 2D data or PRISM for 3D data) to access these files. However, this software is currently not available for purchase. With respect to the quality of resulting digital files, Fadeyev and Haber report that when images were taken every 8 microns along the groove path of a 78-rpm disc using IRENE 2D for laterally inscribed grooves, "This corresponded to a sampling frequency of 61.3 kHz at a groove radius of 60 millimeters."[32] This clearly falls short of my criterion for a 'good' transfer quality, which requires a sampling frequency of 96 kHz and a bit depth of 24 bits, and would only be considered 'fair.' However, it is possible for IRENE 3D data, used for discs with vertically inscribed grooves, to be captured at 96 kHz and a bit depth similar to mechanical transfer.[33] Quality of digital files resulting from IRENE 3D transfers would therefore qualify as 'good.' In analyzing IRENE's ability to transform current archival workflows, we must also consider the labor and time involved in the process. According to Feaster, "Extracting audio from one disc side takes about an hour, most of which can be unattended."[34] However, because the NEDCC currently performs all IRENE transfers one at a time, its potential to transform current archival workflows through automated and parallel transfer capabilities is low.

VisualAudio

The idea for VisualAudio came to Stefano Cavaglieri, current chief technology officer at the Swiss National Sound Archives (SNSA), in 1999.[35] He began developing the system with former SNSA director Pio Pellizzari and entrepreneur Pierre Hemmer, before forming a partnership with School for Engineering and Architecture Fribourg (HEIA-FR). Partially funded by the Swiss National Science Foundation, the three co-creators worked with HEIA-FR professors and students to conduct feasibility tests and construct prototypes in 2000. The group began presenting their results the following year, describing the system quite simply: "We take a picture of each side of the disk using a dedicated analog camera, we store the film as our working copy and when needed, we scan the film and process the image in order to extract the sound."[36]

VisualAudio uses Agfa Alliance CE film purchased in sheets large enough to capture the entire surface of a disc. This inexpensive film is stable as an archival medium, so the grooves are preserved even as the original disc continues to deteriorate. The turntable scanner used to capture the images consists of a glass plate mounted on a motor, which rotates the film at a constant speed, and a light source under the plate. “That way we get, after one rotation, the scanning of a ring of a record that becomes a matrix. Notice that the ring contains several rotations of the groove. A motor moves the disk radially. Thus by making several scans we get the picture of the whole film.”[37] Once the film is digitized at a high resolution (using a linear scanner element with 2,048 pixels, each being 10 microns-square in size), the resulting TIFF image is analyzed to correct any imperfections caused by the film grain, dust on the scanner, or cracks and scratches on the disc, and to determine the radial displacement of the groove, which contains the sound. The sound is then extracted by digitally processing the groove signal, using undisclosed software.

In presentations on the system, Cavaglieri acknowledges that while it is not quicker to produce a digital copy with optical photography versus more traditional mechanical means, VisualAudio has the capability of digitally reformatting broken and delaminated discs. He states of this capability, “We can take a picture and work on the picture in order to reconstruct the audio. This is the real strength of optical technology. There’s room for improvement on the image capture, image processing, and signal processing, [but] imaging is still a good thing.”[38] To illustrate a promising use case of VisualAudio, the SNSA system was utilized in 2019 to recover a 1949 audio recording held by the Aldo Spallicci Archive about Italian doctor, politician, and poet Aldo Spallicci from a 78 rpm disc “in precarious conservation conditions.”[39] In addition, it was reported on Public Radio International's *The World* that HEIA-FR Professor Ottar Johnsen and his student Sylvain Stotzer had successfully used the VisualAudio system to image fragile 70-year old lacquer discs containing recordings of the Nuremberg trials.[40] Although the discs were ultimately sent to France's audio digitization company Gecko for mechanical transfer, the VisualAudio test scans were a useful tool in determining that the disc surfaces were in good enough shape to be played mechanically using a stylus.

VisualAudio is not commercially available, and SNSA has not disclosed the estimated cost of scanning a single disc with the system or how much it would cost to put together an entire system for an archive. If an archive has a recording that is deemed culturally significant, such as the Nuremberg trial discs, collaborative efforts with SNSA or HEIA-FR are possible. In such collaborations, a partner archive would receive the already processed audio access files from SNSA or HEIA-FR, making VisualAudio an easy option, in terms of use. When it comes to quality of resulting transfers, though, the system ranks as fair. SNSA disclosed that when the sound signal is obtained by extracting radial position of the groove, "often, the sound is oversampled (the sampling frequency depends on the tangential distance between pixels). In an example, the sound was sampled at 197 kHz."[41] However, when it comes to reaching ideal bit depth, Visual Audio's system currently falls short. To achieve 24-bit resolution, the pixels captured by the system would need to be 56,000 times smaller than what it currently images for a coarse-groove disc and even smaller for a microgroove disc. This is extremely small, and a scenario that Cavaglieri refers to as a "utopic."[42]

It is estimated that the entire VisualAudio process can take approximately three hours.[43] This estimate includes the ten minutes required to take the photo, thirty minutes to scan the film, and about two and a half hours to process the image to sound, depending on the shape of the surface of the grooves. This is a lengthy process, considering that a standard lacquer disc contains only about fifteen minutes material per side. However, these steps can be separated and performed by different staff members at different times, so if multiple lacquers needed to be transferred, the potential for a parallel transfer workflow is increased. Therefore, I consider VisualAudio's potential to transfer current archival workflows through automated and parallel transfer to be moderate.

Saphir

In designing the Saphir process, Institut National de l'Audiovisual's (INA) research and development project manager Jean-Hugues Chenot and inventor Louis Laborelli used principles concerned with reflecting light onto a disc surface, such as the Buchmann-Meyer method that measured the width of the resulting pattern from reflecting light at a 45-degree angle onto a disc.[44] They received a patent in 2004 and began presenting on Saphir in 2007.[45] Saphir takes advantage of the highly reflective properties of a disc and uses a colored light process to read delaminating and broken lacquer discs. The system consists of a translation bench, acquisition head, optical scanning head, and a user interface. The translation bench has a turntable where the disc is placed and held flat with a pane of glass, while the acquisition head contains a light that delivers six flashes per second across the disc surface. The acquisition head can be adjusted in height and angle. A 45-degree angle is used for most discs, but a top view is used for discs exhibiting a high level of exudation. The acquisition head casts rays of light onto the groove wall. The optical scanning head physically follows the light path cast onto the disc by the acquisition head with lenses and mirrors built from a standard color camera and 3D-printed parts. A color mask is used so that color is reflected back to the camera, which collects rings of pictures from the disc – about sixty rings of 1,125 overlapping 640 x 480, 8-bit images from one side of an average 78 rpm disc in three hours. Audio is then extracted from the collected pictures by automatically translating the color into an audio signal track using proprietary software. An operator uses the custom graphic interface to engage the software in the decoding of the image and re-connecting groove fragments.[46]

In December 2018, INA unveiled a new desktop Saphir scanner that still captures about sixty rings of around 1,000 pictures per ring, but in a much shorter period of time: thirty minutes per each disc side.[47] It must be noted, however, that neither Saphir system can be used to read lacquer discs that are vertically cut or those with a transparent coating (Metallophon or discolored Thorens brands). Beginning in 2016, the INA team was able to recover audio from broken glass-based lacquers and 1951 cabaret audio recordings from delaminating lacquers in their collections. From 2018 to 2019, INA used Saphir in two significant recovery projects, including post-WWII French radio broadcasts of the Spanish Diaspora community and the first-ever recording of fado singer Maria Teresa de Noronha, dated 1939, all on delaminating lacquer discs.[48]

Saphir is not available for archivists who wish to outsource disc digitization projects. However, collaboration may be a possibility, as the institute is currently looking for institutional partners willing to scan their collection materials with Saphir in order to continue to assess the range of discs that can be read with their process. INA has not yet published the potential cost to scan a single disc using their system, but the price for their desktop system is approximately

$5,600.[49] In comparison to the only other system commercially available for institutional purchase (Endpoint's, which is expected upon its commercial rollout to cost $20,000-$30,000), the Saphir system is relatively affordable.[50] INA began training staff internally to use Saphir at the end of 2019 and the foundation for a training module for those who purchase a desktop system has been laid. Because reviews of these training sessions have not been published, the ease with which an archivist may use the desktop system is undetermined. Chenot stated in his 2019 ARSC Conference presentation that the software to decode the disc images would be made open source.[51] The availability of open source software will likely positively impact the system's overall ease of use.

As to the quality of resulting digital audio files, Saphir can extract audio up to 22 kHz for 78 rpm discs and up to 12-15 kHz for 33 rpm discs.[52] When considering that the standard for the sampling rate of a preservation master audio file is 96 kHz, the quality of Saphir's transfers can be ranked as fair. From start to finish, the Saphir system remains a lengthy process. While scanning time has been reduced to about thirty minutes per side of a disc using the desktop system, throughput is still far from real time. The entire process could take from an hour and a half to several hours, depending on the condition of the disc. This includes five minutes to set up the system, thirty minutes to scan, one hour for initial decoding, and from a few seconds to several hours for reconnecting the grooves of broken or delaminating discs. The potential of the system to transform current archival workflows through automated and parallel transfer capabilities, however, is high because the most time consuming steps – the initial decoding and reconnections – can be done for several disc sides in parallel.

Endpoint Audio

In 2001, Nicholas Bergh, founder of Endpoint Audio Labs in Burbank, California, began developing the predecessor of the Disc Transfer Machine, the Endpoint Cylinder Transfer Machine, which he unveiled at the 2015 ARSC Conference.[53] Both machines fall in line with Endpoint's philosophy of delving into the history of a format's original playback system to inform the creation of new, custom-built or heavily modified stock equipment.[54] Indiana University's MDPI was the first institution to purchase an Endpoint Cylinder Machine, and four additional systems have been installed in the U.S. and Europe.[55] Bergh is currently developing the Endpoint Disc Transfer System, an optical playback machine for discs with the goal of being able to identify and examine any potential problem areas by switching from stylus to optical playback on the same machine. The system employs two lasers to create a high-resolution digital surrogate of a stereo recording, using proprietary software. The system is built as an add-on to a standard Technics SP-10 turntable. Since the system is still in development, no use cases are currently available.[56]

The price to scan a single lacquer disc is estimated to be around $250, depending on the condition of the disc; a cost that is close to the estimate for an IRENE scan performed by the NEDCC. The entire Endpoint Disc Transfer Machine will cost between $20,000-$30,000 for an archive to purchase, which is expensive in relation to the price of Saphir's desktop model ($5,600). If an archive were to purchase the Endpoint system, they would need training. Bergh delivers Endpoint machines in person, so that he can train personnel on site, and the cost is included in the overall price of the system. Since training reviews have not been published, ease of use cannot be determined at this time. Similarly, Bergh has not disclosed figures on the quality of the optical transfers. If an archivist is interested in purchasing a system or having lacquers transferred on the Endpoint machine, they can schedule a consultation and demonstration with Bergh.

The Endpoint system's ability to perform optical transfers in real time is unique among the four evaluated systems. Recalling that a standard lacquer disc contains about fifteen minutes of content per side, the fact that optical takes the same amount of time as mechanical playback makes its potential to transform current archival workflows high. As Bergh states, "The main benefit of my optical system is that it is real-time. It takes just as long to play a disc optically as it would to play it with a stylus."[57]

Conclusion

Optical technologies not only provide institutions with a no-contact method of retrieving sound recordings from broken or deteriorating lacquer discs without the risk of causing more damage to the items. They can also provide a means of capturing a disc frozen in time. By obtaining a high-resolution image of a disc's surface now, before further degradation has taken place, there is potential for archivists to use the high-resolution surrogates in new ways in the future, as new technological innovations emerge and become available. One example of this can be seen in the continuing work of IU MDPI's Feaster. Over a decade ago, a group of audio historians, working under the moniker of First Sounds (David Giovannoni, Richard Martin, Meagan Hennessey, and Feaster), enlisted the aid of the Berkeley Lab to use IRENE to convert a phonoautogram of "Au Clair de la Lune," recorded in 1860 on Édouard-Léon Scott de Martinville's phonoautograph machine, into sixteen separate tracks. These tracks were "meticulously stitched back together" by

First Sounds, “making adjustments for variations in the speed of Scott’s hand-cranked recording.”[58] At that time, Feaster began work on Picture Kymophone, a software to process the TIFF files produced by the IRENE system with the hopes that users would be able to access the visual preservation masters.[59] “My hope is to demonstrate that IRENE images aren’t in a ‘proprietary’ format that only PRISM [the proprietary software attached to IRENE] can use for anything, but are instead something that could be productively parsed by any number of programs – so that broader public input into their specifications might be appropriate,” shares Feaster.[60] Studies such as his should be followed closely by those interested with preserving damaged discs in their collections in order to continue to push the potential of optical technologies forward.

The need to recognize highly at-risk materials like lacquer discs, identify their unique preservation needs, and take appropriate actions, are essential skills for all archivists because it is inevitable that they will encounter discs or other analog audio carriers in collections, despite their area of specialization and training. The purpose of this article is to bring increased awareness of optical scanning technologies to archivists who are the custodians of broken and deteriorating lacquer discs that contain highly unique radio broadcasts and other historical recordings. It is my hope that this article can be a resource for archivists embarking on radio preservation projects by providing an overview of preservation priorities and risks inherent in many recorded sound collections and by offering the information necessary to evaluate emerging digital reformatting systems. By understanding the promises and limitations of each system, archivists will be able to create workflows, write grant applications, and determine the budget needs for future preservation projects. In addition, this paper aims to encourage collaborations between institutions and the creators of the four systems, and provoke discussion amongst librarian-archivists, engineers, and conservationists, so further developments into optical playback technologies for damaged and deteriorating media carriers can be made.

Acknowledgements

The author wishes to thank the archivists, librarians, audio experts, historians, and engineers, who took time to share their systems, data, and experiences: Jean-Hugues Chenot, Nicholas Bergh, Bryan Hoffa, Caitlin Hunter, David Giovannoni, Mike Casey, Patrick Feaster, Melissa Widzinski, Adam Tovell, and Jeff Willens. I would like to acknowledge this journal's editors and reviewers for their assistance with revisions on this piece. I thank my partner and son for their endless patience and support in all of my endeavors.

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Figure 1

Caption: A broken glass-based lacquer disc suffering from extreme delamination. Yuri Shimoda, "Delaminated Disc," digital image, July, 2018.

Figure 2

Caption: A lacquer disc exhibiting exudation. Yuri Shimoda, "Disc Exudation," digital image, June, 2018.

Notes

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