# A methodology for audio ingestion, restoration and analysis in the sound archiving field

Application to mechanical recordings (Berliner 2110A, HMV AA172, HMV T6917/T6918)

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# Abstract

The goal of this master thesis is to propose a practical methodology for audio ingestion, restoration and analysis, focusing on the reproduction, signal extraction and restoration of obsolete mechanical formats (discs of the pre-vinyl era) and reproduction artefacts, from the point of view of patrimonial institutions and sound archives. It also aims at evaluating some current tools available for the analysis and restoration of degraded audio signals. Reviewed knowledge has been applied to a specific patrimonial collection, allowing thorough documentation, mechanical restoration and preservation, signal extraction and digital processing for relevant recordings of the first half of the XX century.

## Images

## Tables

## Preface

Sound recordings constitute, from their appearance at the end of the nineteenth century, broad containers of a significant part of the intangible cultural heritage of any society. From the first Lomax[1] ethno musicological field recordings to the current digital massive production, concern to record sound events for posterity stands alongside with any other historical or artistic manifestation. Access and consultation of sound repositories allows us to unveil essential aspects of our social, historical or cultural collectives.

The IASA, International Association of Sound and Audiovisual Archives, watches since 1969 for the preservation of audiovisual materials from an essentially "librarian" point of view (mainly intended for institutional sound archives). Other remarkable initiatives in a European framework include PrestoSpace[2], PrestoPrime[3], Europeana[4], etc.

The need for signal extraction of original analogue or digital sources into digital repositories is today, and will continue to be, and ongoing necessity. At the same time, whatever the approaching domain -institutional, academic or commercial- digital audio processing stands at the core of this activity, with implications that go far beyond technological aspects. Even though traditional digital archiving would end up with a proper transcodification (an everlasting change of format: from disc to tape, from tape to CD, from CD to a server, etc.), digital audio restoration -its evaluation, implementation, use (or abuse) and documentation- will play an important for the future of sound heritage preservation. As pointed out by Nadja Wallaszkovits[5], we need to establish clear boundaries among methodological aesthetics and ethics in the preservation, handling and dissemination of sound heritage: we are confronting commercial, artistic and aesthetic concerns that may threaten the integrity and veracity of a sound object. The role and responsibility of the audiovisual industry in the process of sound heritage preservation and handling (corporate broadcast, recording studios and producers - driven by economic revenue) should not be thus underestimated, and recent standards proposed by the Audio Engineering Society, AES60 and AES57 (AES standard for audio metadata - Audio object structures for preservation and restoration[6]), seem to look at the right direction.

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[1] nord-american etnomusicogists John (1867-1948) and Alan (1915-2002) Lomax

[2] http://prestospace.org/

[3] http://www.prestoprime.org/

[4] http://www.europeana.eu/portal/

[5] http://www.bl.uk/reshelp/bldept/soundarch/unlockaudio/papers09/nadiawallaszkovits.pdf

[6] http://www.aes.org/standards/comments/cfc-draft-aes57-xxxx.cfm

Despite more than twenty years since the first mass digitization processes of sound material began, and a similar amount of time since the first attempts to digitally restore degraded audio signals, it is believed that much can still be done in the field of preservation and accessibility to audio content. It could be argued that we are yet at the beginning of an exponential generation of new audiovisual media that will need renewed attention to preservation, restoration and accessibility.

This master thesis proposal aims at shading some light into this specific domain in order to review and document signal extraction and digital audio restoration of patrimonial audio items, be them unique (i.e. field recordings, instantaneous recordings) or from a commercial origin, and thus gain deeper knowledge for the development of local audiovisual archiving procedures in accordance with reference standards. It also aims to provide or enrich new methodological proposals about core technological, technical and procedural aspects regarding digital processing for the restoration of degraded audio signals. The ultimate goal is the evaluation and comparison of these proposals in the real-case context of the digitization process of a local patrimonial collection, thus establishing parameters that would eventually allow evaluation of its performance in key areas defined by both the OAIS model and the best practices recommended in the IASA-TC04 Guidelines.

We would like to emphasize the following aspects:

- documentation of the state-of-the-art of signal extraction, and digitization technologies, preservation methodologies and physical (artefact) and content (sound) restoration, be it unintentional or intentional, both during analogue (signal extraction and ingestion) or digital (post-production) procedures

- focus on reproduction, signal extraction and source-to-noise separation from historical disc recordings in the analogue domain

- documentation of the state-of-the-art generation, embedding and discovery of metadata for the previous processes, paying special attention to the guidelines proposed in the IASA-TC04 document[7]

- technological review, analysis and proposals in the field of digital audio processing tools for audio restoration of degraded signals, primarily focusing on model-based algorithms

[7] http://www.iasa-web.org/tc04/audio-preservation

- technological review of current commercially available tools for digital audio restoration

- documentation and review of the processes associated with the OAIS[8] functional model (Open Archival Information System) for audiovisual repositories

- review and proposal of specific methodologies in accordance with the OAIS functional model. Qualitative assessment[9] of its practical implementation on a given repository domain considerations on the sociological implications, ethics and aesthetics in post-production and dissemination of sound objects.

[8] http://public.ccsds.org/sites/cwe/rids/Lists/CCSDS%206500P11/Attachments/650x0p11.pdf

[9] see *Trustworthy Repositories Audit & Certification* (TRAC), http://www.crl.edu/sites/default/files/attachments/pages/trac_0.pdf

## 1. Introduction

Audio restoration is, per se, a conservative discipline. It implies knowledge, perspective, judgment and a sense of sobriety when deciding on the overwhelming amount of tools available. It is not about subjectivity and awesome sound improvement over the original rendition, but about transparency and fidelity to it. The latter is harder to achieve than the former.

This master thesis is oriented from a rather practical point of view, keeping in mind that audio restoration is both a research field and a profession in the sound industry. The gap between this two worlds, often seen as antagonistic, makes it difficult for restoration engineers to master all processes (to know *what's in the black box*, both in the analogue and digital domains), as well as for developing software engineers to design the tools and interfaces needed.
But this is not just a quest for professionals. As in any real business, clients (mostly public institutions, but also particular holders) need also to understand the foundations of the discipline, the ethical and technological frameworks and other nuances of an activity that, as it often happens, is both and art and a science.
There is, thus, the intention to give out and informative and approachable review of the main aspects of audio restoration, keeping an eye on pedagogy by trying to explain what audio restoration is –or should be- to the many actors involved.

The following document has been conceived upside-down in a sense, as the actual need for the preservation of specific contents has brought to wider reflections on how do we approach audio preservation, digitization (in the case of analogue carriers) or transcodification (migration within digital formats), restoration and notation of all procedures (metadata information). State-of-the-art revision and therefore proposals for good practices derive from study cases where, prior to action – and often encompassing it-, such theoretical frameworks have been reviewed. The practical aspects of this master thesis focus in gramophone mechanical recordings, both from the acoustic and electronic era previous to the LP (basically pre-1953), letting aside for the moment other very widespread containers as magnetic recordings (be them analogue such, as open-reel and cassette tape, or digital, such as DAT) and optical/digital formats (mostly CD).

## 2. A short review at the history of disc technology

From the first patents of Edouard-Léon Scott de Martinville -dating back to 1857 in France- to the theoretical approaches of Charles Cros[10] that preceded Berliner's Gramophone, and from Edison's Phonograph (1877) to today's digital systems, the timeline of sound recording extends for more than 150 years. Our interest is broadly focused on the time span of 1888 – 1958, from the first gramophone public presentation at the Franklin Institute of Philadelphia to the adoption of early Blumlein's 45º/45º stereo recording approach on microgroove vinyl. These first 70 years were mostly dominated, in terms of commercial success, by coarse-groove shellac discs, with the remarkable exception of lacquer records for home and professional recording (radio) use. These years also witnessed the ill fate of the phonograph (declining already in 1910), the quick change from the acoustic to the electric era (from 1925, encompassing the widespread of commercial radio), as well as the introduction of the first stereo recording techniques on disc[11].
It should also be noted, of course, the advent of magnetic recording, which was called on to master music production technologies from the 1950s well over the 1990s as also for home consumption, especially with the Philips cassette (1963). Letting aside these magnetic and other –i.e. optical- analogue technologies, discs remained a foremost source for music and sound heritage.

It is fair to remember that Edison himself considered discs as recording medium back in the 1870s, as did Charles S. Tainter –the inventor of the graphophone, and improved version of the phonograph- and other researchers at the Volta Laboratory (Morton 2004:31) . Although disc players were patented, this option was then considered second only to wax cylinders and thus remained in oblivion until Berliner's commercial success.

### 2.1. First discs: the Berliner approach

The website of the U.S. Library of Congress (LoC) provides, in one of its web pages[12], valuable information about the figure of Emile Berliner and especially on the technical aspects of disc manufacturing and composition.
First attempts on celluloid (1888) were followed by discs made from vulcanized rubber (1892-1895), also known as Vulcanite or Ebonite[13]. It was from 1895 on when Berliner, concerned from

[10] Cook et al. 2009:153

[11] Alan D. Blumlein, Harvey Fletcher

[12] http://memory.loc.gov/ammem/berlhtml/berlgramo.html

the very beginning with the mass production of pre-recorded music copies and therefore interested in their durability, chose the proposal made by the Durinoid Company of New Jersey Ltd[14]. Durinoid[15] was actually engaged in the production of buttons for the textile industry (Morton 2004:36). The actual material was a mixture of powdered shellac (around 20%) and a type of clay called byritis (around 80%), bound with cotton flock and coloured with lamp black (Cook et al. 2009:155, Calas 1996:61). Later on, lacquer (derived from insect excretions) was introduced, altogether with lampblack (powdered carbon), byritis and flakes of cotton fibre.

First discs were actually recorded on a master zinc-based disc covered with a layer of a mixture of beeswax and cold gasoline. Sound pressure waves would make a mica diaphragm vibrate. Such diaphragm was connected to a chisel (stylus) which would eventually carve zigzagged grooves on the soft wax layer. After varnishing the non-recorded back side (recording was initially at one side only) the disc was immersed in a bath of chromic acid which, after a while (around 20 minutes, according to Copeland 2008:293) would etch the zinc through the fine lines discovered on the wax, thus creating U-shaped lateral grooves on the zinc. The rest of the disc, protected by wax, remained uncarved. One could then play this master disc with a soft steel needle.

**Image 1. Berliner disc player manual model, marketed from 1889. Source http://www.emil-berliner-studios.com/en/chronik1.html**

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[13] see St-Laurent, Gilles (1996): *The care and handling of recorded sound materials* - http://cool.conservation-us.org/byauth/st-laurent/care.html also available in Spanish as PDF at http://www.bib.ub.edu/fileadmin/fdocs/conser8.pdf

[14] interesting reports of the first trials with this new material and Berliner's concern about the quality of the delivered copies - http://soundofthehound.com/2011/06/08/setting-up-a-record-company-4-making-better-records/

[15] also refered as *Duranoid* - see http://memory.loc.gov/ammem/berlhtml/berlgramo.html, http://www.aes.org/aeshc/docs/recording.technology.history/berliner.html

Unlike the process of recording and reproducing a wax cylinder, the machines for recording and playing back Berliner discs were different.

Following master recording on zinc, mass replication techniques for subsequent commercial marketing were needed. A metal reverse master metal with the grooves facing outward instead inward was first generated by the negative method known as electroplating, which allowed printing final copies of "positive" marketable disc copies on different thermoplastic materials over the years: celluloid at first, then vulcanite (1888) and finally shellac, as early as 1895.

## 2.2. The inception of radio and need for improvement: the electrical era

Technologically speaking, no relevant novelties are found until radio broadcasting became a serious competitor (mid-end 1920s). This and other reasons (i.e. the Great Depression in the USA) provoked a very significant sales decrease, and technological improvements proved anyhow insufficient to compensate for it.

The electrical transmission of sound finally made its way to disc recordings when the Western Electric Company –through its subsidiary Bell Telephone Laboratories- devised a commercially optimal solution: an electronically amplified disc recording system, along with an initially matched-impedance mechanical (thus acoustical) reproducing system. The Maxfield/Harrison electric recording system (1924-25)[16], developed under the leadership of Harvey Fletcher[17], eventually allowed for an overall increase in the frequency response –from the acoustic era bandwidth of 200Hz-2400Hz up to 50Hz-6000Hz, often at the expense of increased high frequency surface noise- and the flourishment of related technologies: carbon and condenser microphones (E.C. Wente), vacuum tube amplification (Lee de Forest), tone controllers, loudspeakers (Rice-Kellogg). From 1925 on, Columbia, Victor Talking Machine, RCA and most of the companies adopted the new system which, at the consumer's side, meant the introduction of new reproduction

[16] see http://charm.cchcdn.net/redist/pdf/maxfield_harrison.pdf (accessed 19 April 2013)

[17] the Philadelphia Orchestra conductor Leopold Stokowski was among the first enthusiasts of sound recording. Both he and physicist Harvey Fletcher were behind many pioneering efforts in music recording. See http://www.stokowski.org/Development_of_Electrical_Recording.htm and http://www.stokowski.org/Harvey%20Fletcher%20Bell%20Labs%20Recordings.htm for extended detail

equipments, first acoustically improved (such as Victor Ortophonic Victrola), later on also electrical.

## 2.3. Easy recording: transcription discs

At the beginning of the 1930s instantaneous recording was possible thanks to different technologies. The term "instantaneous" emphasized that playback was possible immediately after recording, without further processing (Morton 2004:96). Radio stations began using annealed aluminium for transcription discs, were a groove was painfully and shallowly embossed (not cut) using a powerful amplifier, an electromagnetic transducer and a heavy special stylus, and had to be played back with a bamboo stylus as it would be destroyed by traditional steel needles.
Shellac discs had the monopole mass production market. These were some laminated discs, though, as with the *Columbia CPS (Coated Paper Sheet)* method, introduced in 1922, where three layers were cemented together: the outer –engraved- layer was shellac, the intermediate kraft-paper with traces of cotton, and the inner a coarse compound for the powder core[18].
On the other hand, 1934 saw the introduction of the lacquer laminated transcription disc, usually based on a cellulose nitrate recording surface layer –although ethyl cellulose and cellulose acetate were reportedly used too[19]-. These recording materials were bounded onto a core layer, usually aluminium and most rarely glass or zinc, even cheap cardboard. Such transcription discs were up to 16-inch wide, vertically recorded (hill-and–dale) and already turning at 33 1/3 rpm[20], offering a maximum of 15 min per side in standard coarse groove.
Lacquer discs, wrongly known also as acetates, offered a smooth response with lower background surface noise than its shellac counterpart, but at the expense of rather limited playability before notorious degradation occurs.

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[18] fro extended detail see the following sources

- Mari-France Calas, Jean-Marc Fontaine, Philippe Aigrain. *La conservation des documents sonores*. CNRS Editions, Paris 1996:60
- Peter Copeland. *Manual of Analogue Sound Restoration Techniques* (*http://www.bl.uk/reshelp/findhelprestype/sound/anaudio/analoguesoundrestoration.pdf* - page 319) 2008:39
- Pickett, A. G. and M. M. Lemcoe.. *Preservation and Storage of Sound Recordings*. Washington: Library of Congress, 1959
- Gilles St-Laurent. *The care and jandling of recorded sound materials* (*http://cool.conservation-us.org/byauth/st-laurent/care.html*)

[19] see https://www.ischool.utexas.edu/~hollyr/portfolio/projects/instadiscs/patent.html as well as Copeland 2008:51

[20] such speed would not be finally considered as the de-facto standard until 1948, with the introduction of the lateral-recorded microgroove LP

## 2.4. Vinylite discs

Already from 1929, RCA had been experimenting with plastic vinyl (vinilyte, polyvinyl chloride or PVC) for the transcription of optical soundtracks onto discs. Western Electric introduced vinylite as the final material for pressed copies of transcription discs. RCA joined one year later and offered vinilyte 33 1/3 rpm coarse groove discs under the trademark Vitrolac[21]. Nevertheless, it was not until 1948 with the 12-inch microgroove LP that vinyl gained momentum and eventually replaced shellac as the prevalent material for commercial disc mass production.

Disc production techniques didn't witness any major changes until *Direct Metal Mastering* technology[22] (DDM), introduced by Neumann and Teldec (Telefunken/Decca) by 1980 and still in used today for vinyl re-issues.

[21] see *AES Recording Technology History* at http://www.aes.org/aeshc/docs/recording.technology.history/notes.html (accessed 19 April 2013)

[22] see http://www.resolutionmag.com/pdfs/KNOWHOW/VINYLA~1.PDF (accessed 19 April 2013)

# STATE OF THE ART

The following lines compile standard approaches and best practices, along with personal experiences, for the ingestion and preservation of audio content and its original carriers (i.e. discs) in the context of audio archiving.

## 3. Inspecting, dating and cataloguing records

Dating and cataloguing a record to be digitized and restored is a primary step towards retrieving the best possible sound. Regarding physical characteristics intrinsic to the carrier itself, we can consider the following major sources of evidence

- inner composition of the carrier
- surface markings: matrix numbers and other symbols
- labels and catalogue numbers
- main discographies

### 3.1.1. Inner composition of the carrier

Narrowing the scope to discs recorded or produced before 1950, we can trace a chronological list of possible implementations depending on materials and technologies used, and propose a generic priority advice for preservation and digitization:

| composition (main material) | intended for | introduction year | technology / inventor | notes |
|---|---|---|---|---|
| celluloid | mass production | 1888 | Berliner | |
| ebonite/vulcanized rubber | mass production | 1892 | Berliner | |
| zinc | mass production | 1895 | Berliner | |
| shellac | mass production | 1895 | Berliner | |
| wax | master | 1900 | Berliner | |
| phenol laminated | mass production | 1912-1929 | Edison Diamond Disc | |
| shellac laminated | mass production | 1922 | Columbia CPS (Coated Sheet Paper) | medium layer potentially hygroscopic |
| aluminium, copper | master (instantaneous disc) | 1931 | | |
| vinylite | mass production | 1931 | | |
| gelatine lacquer | master (instantaneous disc) | 1934 | | highly hygroscopic |
| acetate (cellulose acetate) | master (instantaneous disc) | 1934 | | highly hygroscopic |
| lacquer (cellulose nitrate) | master (instantaneous disc) | 1934 | | |

**Table 1. Disc materials and implementations**

An example of such research can be here included.

3.1.1.1. Study case: laminated disc review from Arxiu Nacional d'Andorra

A fragment of a disc was received from Arxiu Nacional d'Andorra[23] to be inspected in order to retrieve information on its origin. The disc fragment appeared be of similar characteristics to other well-preserved discs.

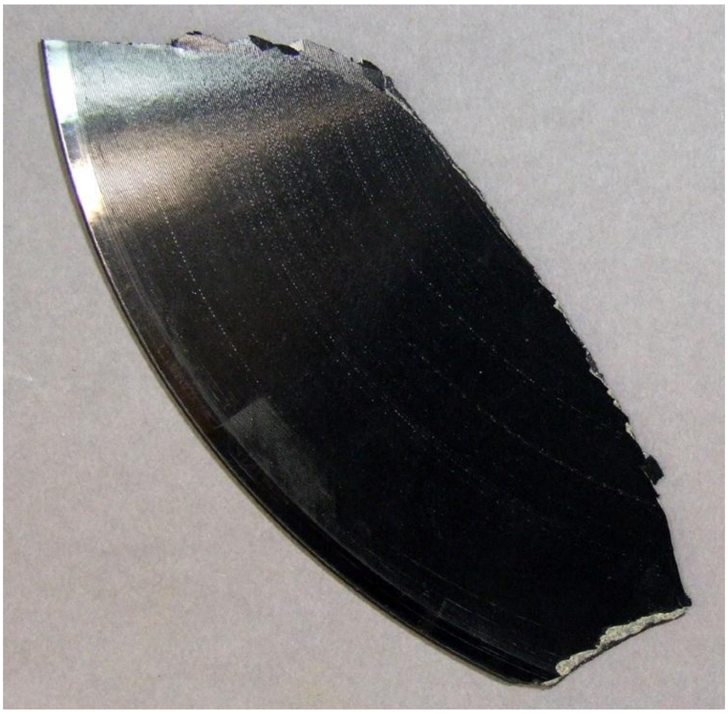

**Image 2. Laminated disc fragment. Arxiu Nacional d'Andorra**

Exclusively from its physical appearance, and according to the documentation provided by Gilles Saint-Laurent[24], it could be stated that the carrier was a laminated disc type Columbia CPS (Coated Sheet Paper), a technology introduced in 1922. Pending confirmation by chemical analysis, it could be concluded the probable existence of some of the following materials

- lacquer (material furrowed)
- silicon (crystalline structure)
- barite (barium sulphate, BaSo4)

[23] http://www.arxius.ad/

[24] Gilles St-Laurent. *The care and jandling of recorded sound materials* (*http://cool.conservation-us.org/byauth/st-laurent/care.html*)

- binder (Congo gum?)
- carbon black
- cotton, paper, cardboard

Visual inspection with stereoscopic microscope Nikon SMZ-2B (8-50x) allowed a closer look to inner materials of the laminated disc

**Image 3. Nikon SMZ-2B stereo microscope of 50x with which the observations were made**

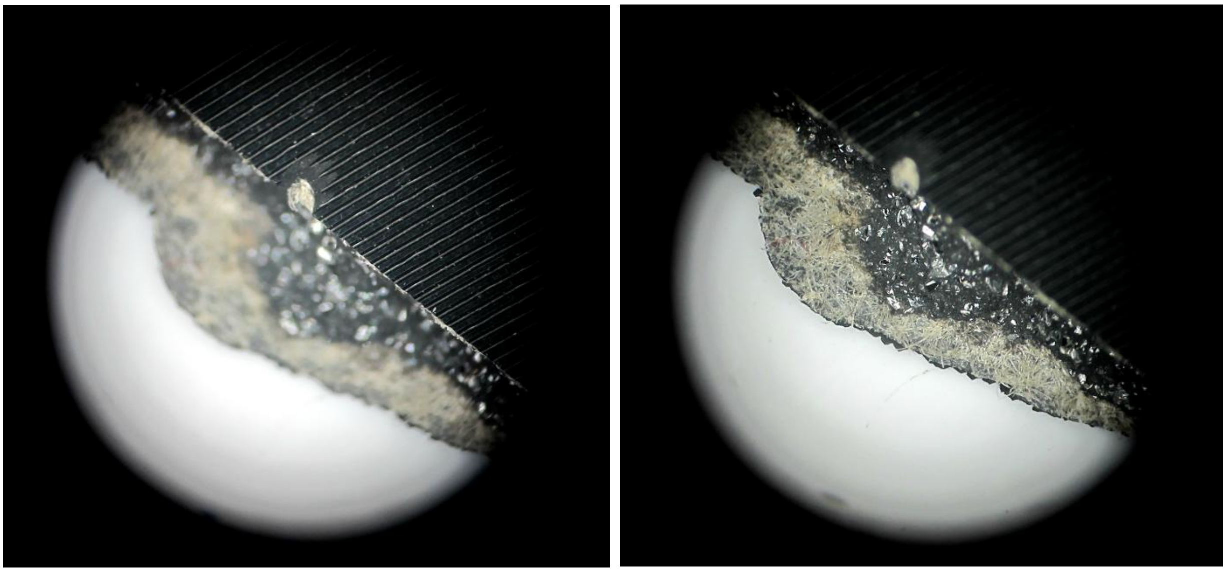

**Image 4. Details of the grooves on the surface recorded and the laminated disc structure**

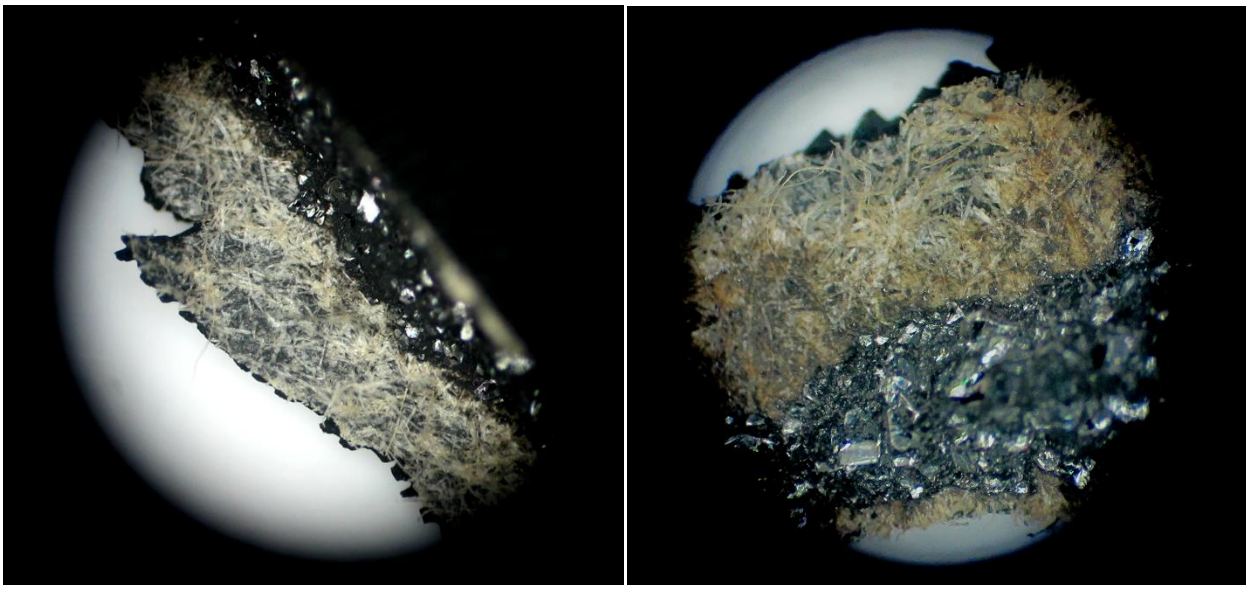

**Image 1. Laminated structure and inner pars: paper fibre and conglomerate with crystalline structure**

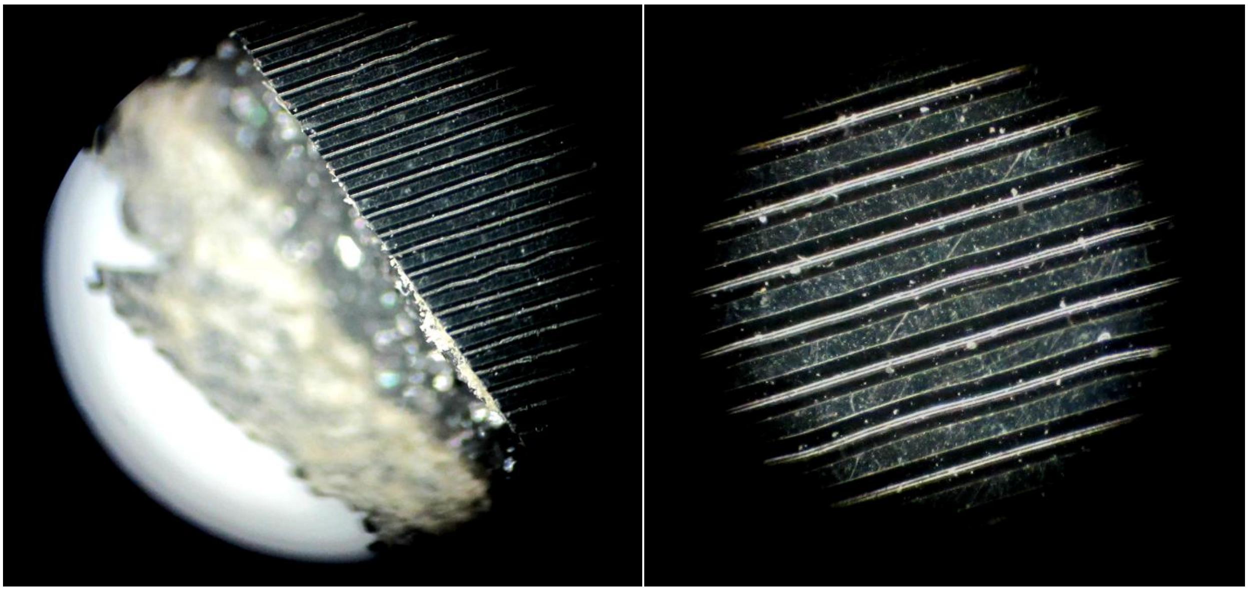

**Image 5. Recorded grooves (monophonic recording)**

A proposal of chemical assay was made and a sample was delivered to the Department of Chemistry from Applus + LGAI (Bellaterra, UAB Campus) in order to determine the composition of the laminated components, by

- X-ray diffraction
- ray infrared spectrophotometry (IR)

Consumo

Campus UAB
Crta. de Acceso a la Universidad de Medicina s/n
08193 Bellaterra (Barcelona)
Tlf.: 93 5672000 Fax: 93 5672001

Applus

**PRESUPUESTO Nº: 00/01469/11-CE**

**PROTOCOLO DE ACTUACIONES**

El presente presupuesto engloba la realización de los siguientes análisis:

**57709 - ANALISIS PIEDRA** **Precio Total: 641,00€**

| Concepto | Técnica | Precio | Notas |
|---|---|---|---|
| Difracción de Rayos X | Difracción de RX | | |
| Espectro Infrarrojo | Espectrofotometría IR | | |

**Image 5. Estimation for an X-Ray diffraction and spectrophotometry analysis (Applus)**

Finally, main gathered data was collected in the following chart:

| characteristics | result |
|---|---|
| **types of materials** | shellac type<br>intermediate layer of paper or cardboard (cotton traces?)<br>conglomerate core: coarse shellac, rock dust (i.e. slate - crystalline structure?) |
| **chemical composition** | pending - most likely inorganic |
| **hygroscopic test** | negative over recording layer (gelatine material discarded in the recording layer. Intermediate layer (paper-type or cardboard) may be damaged |
| **delamination** | minimal |
| **exudation** | negative |
| **disc type** | laminate disc (Columbia CBS) |
| | double-side pressing |
| **groove width** | coarse |
| **recording modulation** | lateral |
| **recording technology** | electroacoustic |
| | probably hybrid amplitude / constant velocity upon frequency region |
| **number of channels** | 1 (monophonic) |
| **pre-emphasis curve** | no determinable (potentially 1925 Columbia or Columbia 1938[25]) |
| **playback speed** | no determinable (probably 78rpm) |
| **dating and possible origin** | Post 1925, probably after 1932<br>From Marie-France Calas[26], Peter Copeland[27], A.G. Pickett[28] and Gilles St-Laurent could be the case of a hard laminate disc pressed according to the Columbia CPS (*Coated Paper Sheet)* method, or similar. Such discs were produced in France from 1932 on |
| **possible companies** | Columbia |

**Table 2: Laminated disc characteristics chart**

[25] see IASA-TC 04. http://www.iasa-web.org/tc04/mechanical-carriers-replay-equalisation

[26] Mari-France Calas, Jean-Marc Fontaine, Philippe Aigrain. *La conservation des documents sonores*. CNRS Ed.s, Paris 1996

[27] Peter Copeland. *Manual of Analogue Sound Restoration Techniques* (*http://www.bl.uk/reshelp/findhelprestype/sound/anaudio/analoguesoundrestoration.pdf* - page 319)

[28] Pickett, A. G. and M. M. Lemcoe. 1959. *Preservation and Storage of Sound Recordings*. Washington: Library of Congress

### 3.1.2. Surface markings: matrix numbers and other symbols

Already from the first Berliner commercial recordings, surface markings (in some cases hand-engraved) can let us know a great a deal about who, when and where a disc was recorded.
Matrix numbers are the most important piece of information. Usually engraved in the inner edge of the disc around the label, sometimes also printed in the label itself –perhaps to properly match labels with discs-, they also known as "master numbers" and constitute a unique identifier (Cook et. al 2009: 190). For a double-sided disc, each side will show its own matrix number as well as possibly other symbols, which may well be located *below* the label (as an inheritance from the wax master). Different formats and readings of matrix numbers are bound to different record companies and also vary substantially with years and countries.

Symbols, prefixes and suffixes accompanying the matrix ordinal number may indicate various information

- recoding location (usually city)
- type of recording (studio, on location, etc.)
- name of the recording engineer
- take number
- transcription lathe number (see Tresize in Cook et. al 2009: 186-192)
- mother letter/order, stamper letter/order (see http://www.normanfield.com/markings.htm for HMV and Decca codes)
- type of electrical recording licensing (Columbia, Westrex, Parlophone, HMV; American Victor, etc.)
- development of negative and positive metal parts from the wax (until the end of 1940s) or acetate (until the advent of DDM around the 1980s) session disc and to the sequence of transfers (Cook et. al 2009: 191)

A tentative list of symbols –which were very often inscribed in a circle- specifically referred to the various recording systems mainly used from 1925 to 1945, would be the following:

| symbol type | introduction year | company | recording system |
|---|---|---|---|
| W | 1925 | Columbia, Lindström | Westrex |
| C | 1932 | Columbia | Blumlein |
| £ , £W, L, P | 1928 | Parlophone, Odeon | Lindström/Westrex |
| Δ | 1924-25 | American Victor, HMV | Westrex |
| ◊ | 1924-25 | American Victor | Westrex |
| □ | 1931-1944 | HMV/EMI | Blumlein |
| V.E. | 1926-1937 | American Victor | Westrex/Victor Ortophonic |

**Table 3. Incomplete list of main symbols referring to electrical recordings, 1925-1945**

The above list is by all means incomplete, as research is still being made in this domain (see Copeland 2009: 116-136). As it will be seen in, different symbols refer to different playback EQ curves, which should be applied in order to retrieve the intended original frequency response.

Suffices here to list the most important clues that can be retrieved from a matrix number, taking advantage, for the sake of the argument, of a particular matrix number from an EMI/HMV disc record from 1929

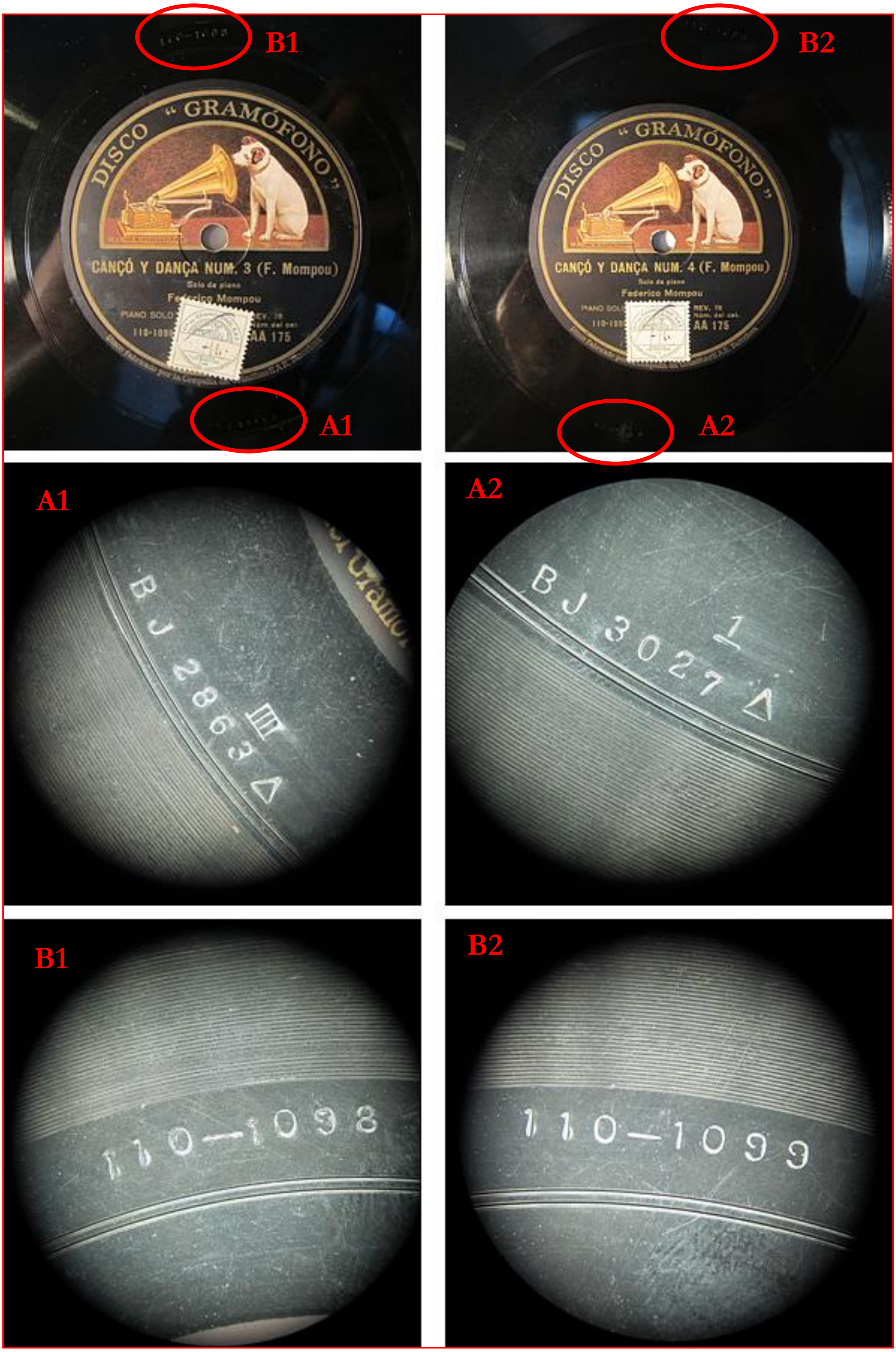


**Image 6. HMV AA175 (catalogue number). Matrix numbers & symbols**

| | | |
|---|---|---|
| **HMV AA175 matrix numbers and other symbols** | | |
| **matrix number system introduced by HMV from 1921 on (main source: Alan Kelly – *The Spanish Catalogue*)** | | |
| **SIDE A engravings** | **SIDE B engravings** | **retrieved information** |
| **matrix numbers** | | |
| BJ 2863$^{IIII}$ Δ / 110-1098 | BJ 3027$^{I}$ Δ / 110-1099 | B = 10inch disc / BJ = Barcelona / 2863, 3027 = cardinal numbers (non-contiguous) / IIII = 4th take, I = first take |
| **catalogue numbers** | | |
| 110-1098 | 110-1099 | 110- = indicates recordings made in Barcelona between 1929 and 1934 / 1098, 1999 = Barcelona local registers |
| recorded 20-12-1929 | recorded 29-01-1930 | probable recording location: Compañía del Gramófono-Odeon S.A.E / c/Urgell 234 Barcelona |
| BJ/CJ series also give clues to the recording engineer: H. E. Davidson, 1925-1930 | | |
| **order number** | | |
| AA 175 | | |
| **other symbols** | | |
| Δ | Westrex (English Western Electric) EQ curve symbol | see EQ details at http://www.vadlyd.dk/English/RIAA_and_78_RPM_preamp.html |

**Table 4. Matrix numbers and other symbols referred to HMV AA175 disc**

Many documents explain the insights of this almost-archaeological activity[29] and some particular examples will be review in the case studies.

[29] see for instance, relevant information in

- Field, Norman (2009): *Markings and letters on & "in" 78 rpm records*. http://www.normanfield.com/markings.htm
- Tresize, Simon. *The recorded document: interpretacion and discography*. Cook et. al 2009: 186-192
- Friedman, Howard S. (2009). *Matrix and Catalogue Numbers in G&S Discography.* http://gasdisc.oakapplepress.com/matrix1.htm
- *Development and Licensing og the Western Electric Electrical Recording System* - http://www.stokowski.org/1925%20First%20Electrical%20Recording%20Stokowski%20-%20Philadelphia.htm (last accessed 25 May 2013)
- Pasquini, Elisabetta (2005). *Problemi di catalogaziones dei dischi a 78 giri.*
- Canazza, Sergio (2005). *Conservazione attiva e restauro audio dei 78 giri. Un caso di studio: Eternamente*

### 3.1.3. Labels, order numbers and catalogue numbers

Order numbers represent the stock number for the reseller, and refer to one physical item. The catalogue number will usually, but not always, be the same for a two-sided one disc (in the previous AA175 record there were two catalogue numbers). As expected, the label will included the catalogue number(s) and order number if present) and should retrieved the most usual metadata

- record label
- record collection
- recorded content (musical works, movements, etc.)
- performer
- …

Catalogue numbers, as well as matrix numbers, allow for immediate access to complete discographies (by label, performer or subject) if existent (i.e. Alan Kelly's HMV/EMI, Michael Gray's Decca, WERM – *The World's Encyclopaedia of Recorded Music*, CHARM discographical references, etc.[30]) or annual catalogues issued by each record company.

[30] see references at http://www.charm.rhul.ac.uk/discography/search/disco_intro.html

## 4. Signal extraction from mechanical carriers

What should be understood by a proper signal extraction?

In his essay *The ethics of preservation, restoration and re-issues of historical sound recordings*, Dietrich Schüller defines an *historically faithful copy* as *"the recording as it has been produced, precisely equalized for intentional recording equalizations, compensated for eventual errors caused by misaligned recording equipment and replayed on modern equipment to minimize replay distortions"* (Schüller 1991, 1016).

The IASA TC-04 document (Guidelines on the Production and Preservation of Digital Audio Objects)[31] establishes the current state-of the-art procedures for signal extraction from original carriers, and we'll refer to them for a general reference. Very valuable information can also be found from the CHARM (Centre for the History and Analysis of Recorded Music) web page, as for example in *The Changing Sound of Music: Approaches to Studying Recorded Musical Performances*[32]. Other important references are found in the bibliography.

### 4.1. Selection of best copy

Thanks to the galvanotypic negative matrices for mass production, multiples copies are often available for published records. This would not be the case for instantaneous discs or master discs in any form, where each item should be treated as unique. Even though such discs could be copied, before the existence of electrotyping, via pantographic methods for real-time engraving or even acoustically –one playing back to the other recording-, master and instantaneous samples should be all digitized with utter priority.

As for replicated mechanical media, quoting IASA best practices (TC-04 2009:33),

> 5.2.2.8 Selection of the best copy of replicated mechanical media draws on knowledge of the production of the recording, and the ability to visually recognise wear and damage which would have an audible effect on the signal. The recording industry uses numbers and codes, generally located in the space between the run-out groove and the label in a disc recording, to identify the nature of the recording. This will help the technician determine which recordings are in fact identical, or alternate recordings of the same material. Visual signs of wear or damage are best seen in the way a recording reflects light. To best show the effect an incandescent light is a necessity, generally aimed at the recording from behind the technician's shoulder, so that they are looking down the beam of light. Fluorescent tubes or energy saving compact fluorescent lights

[31] http://www.iasa-web.org/tc04/audio-preservation

[32] see http://www.charm.kcl.ac.uk/studies/chapters/chap3.html

> do not provide the necessary coherent light source to reveal wear and should not be used. A stereoscopic microscope is helpful in assessing groove shape and size, and in examining wear caused by previous replay, which helps selection of the correct replay stylus. A more objective approach involves using a stereo-microscope with a built-in reticule which enables more accurate selection of styli (Casey and Gordon 2007).

## 4.2. Cleaning and carrier restoration

Before actual cleaning, close inspection of the disc condition is needed. This includes taking notice of the natural decomposition of the constituent materials, accumulated debris within the grooves, mould on the surface -whether active or greasy-like or rather latent or feathery, thread-like-, etc. Especial care regarding mould has to be considered, as there can be cross-contamination among discs. Last but absolutely not least, moulds and spores can cause health problems if breath.
Some specific problems arise with laminated lacquer discs, mainly exudation of the plasticizers (mainly castor oil or camphor) from the lacquer. In such cases a greasy texture is to be observed, similar to active mould, and the consequence of the lack of plasticizer is the cracking and peeling of the coated lacquer from the core, which may render the disc unplayable.

Very illustrative examples of damaged lacquer discs are found in the FACET Format Characteristics and Preservation Problems[33]

The possibility of wet cleaning must be first assessed. Gelatine lacquer discs and laminated discs with paper or cardboard in inner layers are hygroscopic, so wet cleaning must be discarded and only dry options are feasible. Whenever in doubt, a slightly intrusive test can be carried on. A water drop is left on the inner lacquer surface, between the disc label and the run-out grooves. If the water drop is sucked in within a few seconds, the recording surface is hygroscopic. Of course, this is an invasive method and caution is needed. It may not render clear results with laminated hybrid discs such as Columbia CPS (see chart).

Once wet cleaning is accepted, we should focus our attention on the type of cleaning solutions and solvents used. Shellac discs should be basically cleaned with demineralised water, sometimes with a proper proportion of previously known alcohol-free solutions. Vinyl discs accept, solvents including isopropyl alcohol (propan-2-ol).
Here there are some notes on methods and recommendation from the British Library Sound Archive[34], collected by the author during an internship in June-September 2009:

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[33] http://www.dlib.indiana.edu/projects/sounddirections/facet/facet_formats.pdf

[34] from conversations with Will Prentice, Head of the Techical Services (june 2009)

**Method 1: electrostatic charge (ultrasonic bath)**

**Suited for:** any disc *but* gelatine lacquers

**Not suited for:** gelatine lacquers

A way of cleaning any kind of disc which is known not to be damaged by water (and that includes nitrocellulose lacquer discs) is by electrostatic charge of demineralised water. That provokes mechanical ultrasonic perturbations in the water, so by inserting a disc in a pool having this electrostatically charged special water we can actually help come off the incrusted debris.

- **How would you know that a disc won't be damaged by water?**[35]
  If you apply a drop a water in the *inner surface* of the disc (not grooved – no audio content) and you see that the water is rapidly -around 10secs after- beginning to suck inside the disc, water will definitely damage the disc (so it cannot be used to clean it). You're then probably dealing with a gelatine-type lacquer disc.
  Actual damage is the following: as water penetrates the disc, it dilates the gelatine and so grooves dilate as well. Although water may eventually evaporate, the affected surface will in months' time crackle and peel.

- **How to clean a gelatine lacquer disc?**
  By gently hand-applying a soft cloth humidified with *Photoflo* to the surface of the disc and immediately drying it with the Keith Monks device (groove vacuuming).

Method 1 is usually followed by Method 2a in order to rinse and vacuum-dry the disc.

**Method 2: Keith Monks cleaning machine**

It is actually a combination of three possible approaches

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[35] This test will determine whether a lacquer surface contains gelatine or is otherwise hydroscopic. A disc may be damaged by water in other ways however, or by cleaning techniques through vibration, contact with the vacuum head etc. Some argue that any contact with water will accelerate the decay of any lacquer disc (Eric Jacobs' site). See also the Sound Directions report for alternative lacquer cleaning solutions.

**2a) Photoflo+purified water**

**Suited for:** any disc *but* gelatine lacquers
**Not suited for:** gelatine lacquers

To nitrocellulose lacquers and/or shellacs, you can squirt and uniformly spread around the disc surface a dilution of 0,5% (1 part) of Kodak's "*Photoflo*" liquid into 100% purified water[36] (200 parts) using the *Keith Monks* specifically-designed artefact. Once done, the disc must be dried by groove vacuuming.

**2b) Kodak Lens Cleaner**

**Suited for:** any disc *but* gelatine lacquers
**Not suited for:** gelatine lacquers

A *previous optional step* to the latter [2a] would be squirting and uniformly spreading Kodak Lens Cleaner liquid (no dilution needed) on the disc surface using the same *Keith Monks* specifically-designed artefact. Once done, the disc must be dried by groove vacuuming. Then, in order to rinse the disc from Kodak Lens Cleaner liquid, you must proceed to [2a].

Kodak Lens Cleaner liquid would be a good option to remove, for instance, plasticizers (such as camphor or castor oil) which come off from cellulose nitrate lacquer discs in the shape of white "butter-like" stains.

**2c) IMS+water**

**Suited for:** vinyl discs
**Not suited for:** lacquer (any sort), shellac discs

A dilution of 50% Water and 50% IMS (Industrial Methylated Spirits = ethanol) can be used also with the *Keith Monks* specifically-designed artefact.
Bear in mind that IMS contains alcohol. No ethanol, methanol or any alcohol should be used to clean any kind of lacquer discs, as camphor (the plasticizer from lacquer discs) reacts immediately with it.

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[36] purified, demineralised or deionised water (not tap water)

In-depth information on these topics is found in the TC-04 document, Chapter 5.

### 4.3. Contact (physical) and non-contact (optical) reproduction approaches

There still many reasons to stick to physical contact when reproducing grooved recordings. That means properly setting an especially-modified archivist turntable and choosing the right stylus and pickup. Among them, the fact that taking into account gravity and the inner resonant modes of coupled systems (spring-mass systems) is an inherent part of playback (as well as recording) disc behaviour. In terms of cost, "laser" turntables such as the ones from ELP (Japan) are still at very high prices, 6000 to 12000€, and offer far less versatility than the standard approach for non-vinyl records (that is, coarse groove discs of different types).

The author had the chance to see and hear in action optical playback alternatives for analogue discs, and the general opinion was that results were not fully convincing[37].

On the other hand, the ability to reproduce and therefore digitise sound sources from high resolution scanning of disc images[38] is not new, and there are many projects, even very recent based on the recovery of sound from old photographs[39] – a discipline called paleospectrophony[40]. This technology can be applied to essentially two-dimensional objects (such as a laterally recorded disc) and three-dimensional (such as cylinders[41]). This possibility is especially valuable when the object is broken or corrupt and its mechanical reproduction becomes difficult or even dangerous to its integrity.

Promising research is ongoing and, in the area of cylinder reproduction, we can refer for instance to the task of the University of Southampton in collaboration with the BL Sound Archive[42] as well as most recently,to a new digital reformatting service for early audio recordings on mechanical sound carriers that will be offered at

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[37] ELP Laser Turntable (http://www.elpj.com/) tested at ERESBIL (www.eresbil.com), March 2012

[38] see the following projects

- IRENE/3D - http://irene.lbl.gov/, Lawrence Berkeley National Laboratory (Berkeley Lab) - . 'IRENE' is the acronym for Image, Reconstruct, Erase Noise, Etc.
- VISUAL AUDIO, *Fonoteca Nazionale Svizzera,* Stefano Cavaglieri - http://www.fonoteca.ch/visualAudio/index.htm
- University of Southampton - http://www.sesnet.soton.ac.uk/archivesound/media/

[39] Patrick Feaster - http://mediapreservation.wordpress.com/2012/06/20/extracting-audio-from-pictures/

[40] Patrick Feaster - http://www.phonozoic.net/paleospectrophony.html

[41] *Three Dimensional Non Contact Optical Surface Metrology* http://www.escholarship.org/uc/item/6qk9j5sx#page-1

[42] see http://eprints.soton.ac.uk/63830/1/63830.pdf

the NEDCC (NorthEast Document Conservation Center) from Spring 2014[43], using the IRENE/3D technology.

## 4.4. Considerations on historical equipment for sound reproduction

The practice of reproducing the original sound through historical equipment, techniques, and/or supposedly historical rooms is not endorsed by the IASA Technical Committee, and should at most be considered an intentional re-creation of the original sound.

## 4.5. Main components of the replay chain

### 4.5.1. Turntables

Many options are possible, from top Simon Yorke designs[44] in use at the LoC or the Finnish National Sound Archive, to the workhorse models derived from the standard Technics SL-1200[45], as used in the British Library Sound Archive and most other institutions and facilities.

### 4.5.2. Electrical Pickups

Set aside the far less prized piezoelectric pickups, two main technologies are available: moving magnet (MM) and moving coil (MC)[46]. Both rely on Faraday's law of induction and, as the name implies, refer to the moving part of the electromagnetic couple. MC pickups are lighter, with a lower moment of inertia which allows for better tracking of the HF groove nuances. Many audiophiles prefer moving coil setups as they tend to display better tonality, transparency, imaging, and also tend to create less distortion than their MM counterparts[47]. MC output voltage is nonetheless very low, around 0,2mV, with coil's output impedance at around 10-20Ohms. On the contrary, MM designs are heavier and sturdier, but also flatter in frequency response and capable of delivering higher voltages (i.e. a Shure M44-7 cartridge with a typical elliptical stylus

[43] see http://www.nedcc.org/audio-preservation

[44] see http://www.recordplayer.com/

[45] see, for instance, Rek-o-Kut models CVS-14 and CVS-16 at http://www.esotericsound.com/turntable.htm

[46] a colorful history of electrical pickups is available at http://www.normanfield.com/pickups.htm (last retrieved 15 May 2013)

[47] see "*Who needs an MM cartridge when we have MC?*" http://forum.audiogon.com/cgi-bin/fr.pl?eanlg&1200430667 (last retrieved 15 May 2013)

will give out 9,5mV with a tracking force around 1.5 - 4grams, depending on disc type). Even though MC pickups are considered to be the most sensitive, they lack the robustness needed for intensive use within archival facilities, as well as its pricing, has pushed forward MM pickups as the most used among archivists. IASA T04 recommends *that "A good, high compliance, low tracking force (less than 15 mN, commonly quoted as 1.5 grams) variable reluctance (moving magnet) cartridge with a bi-radial ("elliptical") stylus will be the most practical choice"*[48]. Some MM popular cartridges, able to cope with a very wide range of replaceable styli, are Shure M44-7, Shure M44G and Stanton 500.V3 series.

On the other hand, stereo pickups are recommended (and has been our practice) as they allow for the separate capture of each groove wall, as well as for M-S matrixing and post-production.

### 4.5.3. Styli

Being physical contact reproduction the preferred option, the selection of the proper stylus is one of the most delicate issues. The AES-16id-2010[49] (*AES information document for transfer technologies – Stylus dimensions and selection*) is a valuable reference to begin with, as it summarises styles shapes and recommendations, and we'll quote here relevant aspects.

#### 4.5.3.1. Stylus shape

To begin with, it's worth recalling the impossibility to match the original recording stylus type, shape and size with the actual diamond-cut playback stylus. The goals of both styli are basically different – one has to cut through, the other to track the cut surface-, and thus they have inherently different shapes[50]. As with many other parts in the audio chain, sound retrieval will once again be a matter of compromise and decisions are based on previous experience and aural judgement.

From the times of Berliner to modern production -both on acetate or direct cutting to vinyl- **cutting stylus** have steadily shown a triangular, "chisel-shaped" or "V-shaped" pattern. The cross-sectional shape of such stylus is a 90- degree- triangle, and its radius varies from 38,1µm typical for coarse groove (shellac) to 6,3µm

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[48] see http://www.iasa-web.org/tc04/microgroove-replay-equipment, 5.3.4.2

[49] see http://www.aes.org/tmpFiles/aessc/20130514/aes-16id-2010-i.pdf for a preview

[50] such inequalities were nonetheless evaluated, and an actual (and quite ill-fated) process of pre-distortion during the recording stage to compensate for tracking errors for a spherical stylus playback was devised by RCA around 1963 and called *Dynagroove*. See http://en.wikipedia.org/wiki/Dynagroove

for microgroove discs (vinyl). It is nowadays made of diamond or sapphire. Some older recordings may come from other non-standard cutting stylus though, so generalisation is not always possible.

**Image 7. Modern cutting stylus available at http://www.diamond-cutting-stylus.com/**

As for **playback stylus**, most common shapes are

- spherical or conical styli

The simplest and cheapest to produce, it represents the straight evolution from legacy steel styli. As the contact area to lateral groove walls is broader, that can help blur out high frequency noise content from coarse-groove recordings (digs, holes and other irregularities). The downside of course is a reduced high-frequency response, also for the background noise. Spherical styli can be recommended in all cases where robustness and economy are taken into consideration in the purchase of a cartridge, but are not usually a first approach.

- elliptical or bi-radial styli

Such styli were devised to reduce the *pinch effect*, which happens at grooves with large-amplitude high-frequency recorded content and refers to a differential groove width provoked by the recording stylus. In such cases spherical styli will pump up-and-down with the groove walls, causing harmonic distortion.

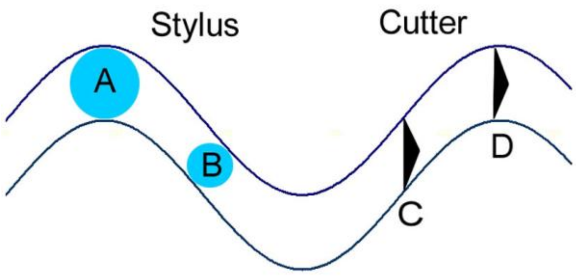


**Image 8. Comparison between the varying-width groove carved by the cutter, and the corresponding vertical modulation caused on a playback stylus. From** [**http://www.vinylengine.com/turntable_forum/viewtopic.php?t=31865**](http://www.vinylengine.com/turntable_forum/viewtopic.php?t=31865)

, It is worth here quoting the description the manufacturer Ortofon offers from this kind of stylus:
*"The elliptical shaped stylus bears greater resemblance to the triangular shaped cutting stylus that is used when cutting master records. The elliptical stylus is able to follow the groove oscillations more accurately than the spherical type, and its distortion and phase error will, therefore, be less. In the outer turns of the record groove where the diameter is the greatest, it may be difficult to hear the difference between a spherical and an elliptical diamond, as there is relatively good space in the groove for the highest frequencies. However, in the innermost turns of record groove, the wider radius of the spherical diamond makes it difficult for this shape to track the finer groove undulations. This can muffle the treble, and lead to audible distortion in difficult passages. There was a time when the experts disagreed about the choice between spherical and elliptical cartridge styli. However, this debate can now be considered resolved and today, very few, if any, elite cartridges are supplied with spherical styli."*[51]

As the AES document points out, such styli should only be used for new or very well preserver records, as mistracking is possible.

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[51] *Everything you need to know about cartridges: Stylus types*. Ortofon. http://www.ortofon.com/images/stories/stylus/Everything%20you%20need%20to%20know%20about%20cartridges_Stylus%20type.pdf (last accessed 15 May 2013)

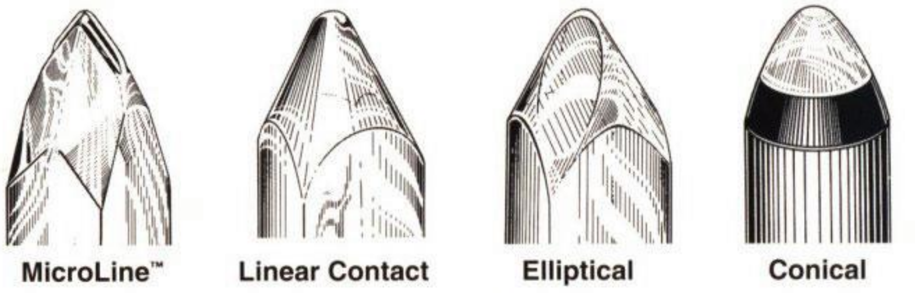


**Image 9. From [http://www.co-bw.com/Audio_Turntables_And_Cartridges.htm#tc](http://www.co-bw.com/Audio_Turntables_And_Cartridges.htm#tc)**

- line-contact stylus (*MicroLine*, Linear Contact, Fine Line, etc.)

Intended only for microgroove recordings, this stylus sets a compromise between conical and elliptical shapes. Its main particularity is the ability to reduce the stylus/groove back pressure by broadening the contact area, without losing the HF content that can be retrieved with an elliptical stylus. Some prominent manufacturers are Shibata, Van den Hul, etc.

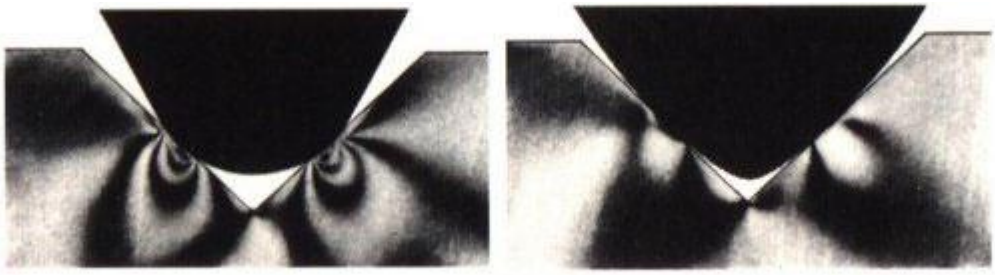

**Image 10. Comparison between an elliptical (left) and a line-contact stylus (right). Note the enlarged contact area. From [http://www.co-bw.com/Audio_Turntables_And_Cartridges.htm#tc](http://www.co-bw.com/Audio_Turntables_And_Cartridges.htm#tc)**

- truncation (conical-truncated and elliptical-truncated styli)

Truncation is a general improvement an all types of styli, devised to reduce contact with the bottom of the groove. Such contact is unnecessary for lateral modulated recordings, and actually retrieves increases background noise (from deposited dirt). Thus, the tip is somehow flattened to avoid touching the bottom of the groove.

Such styli are not appropriate for vertical recordings, as in this case contact with the bottom of the groove is needed for actual modulation

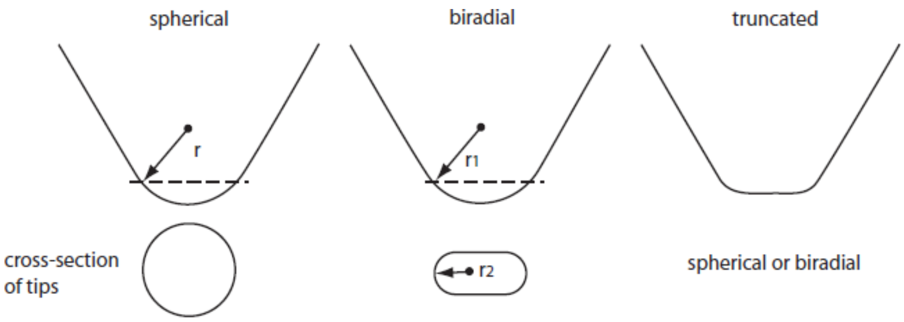


**Figure 1 - Stylus shapes**

**Image 11. Stylus shapes. From AES-16-id-2010 document**

4.5.3.2. Stylus recommendations

Based on personal experience, AES-16id-2010 and IASA TC-04 recommendations, the following table gathers best approaches for stylus selection depending on the historical period:

| Period | Sub-period | Stylus size | Notes |
|---|---|---|---|
| **Early acoustic (1890-1910)** | Acid-etched Berliners (pre 1900) | 1,5mil[52] to 2,3mil, conical truncated (CT) or elliptical truncated (ET) | |
| | All-wax Berliners (post 1900) | 2,3 to 4mil, CT or ET | |
| **Late acoustic (1910-1926)** | coarse groove | 3 to 4mil, CT or ET | |
| **Early electric (1926-1955)** | coarse groove | 2,5mil to 3mil, CT or ET | |
| **Late electric (1955-1960)** | coarse groove | 2,5mil, CT or ET | standardised groove profile |
| **First microgroove (1950-1955)** | | 1,1mil, CT or ET | pre-RIAA standardisation |
| **Instantaneous laminated (1934-)** | cellulose nitrate | 2-2,5mil, CT or ET | |
| | gelatine | smaller than 2mil | |
| **instantaneous metal (1934-)** | aluminium | should not be played with conventional stylus. Microscopic investigation needed prior to transfer | |
| **Standard microgroove (1955-)** | vinyl | 0,7mil x 0,3mil ET, 0,7 spherical or CT | RCA *Dynagroove* recordings (1963-1970) should be played with an spherical stylus |

[52] 1 mil = 25,4μm

**Image 12. Different CT and ET examples from Expert Stylus. Radius 1mil - 4mil. Tasso Laboratori de so**

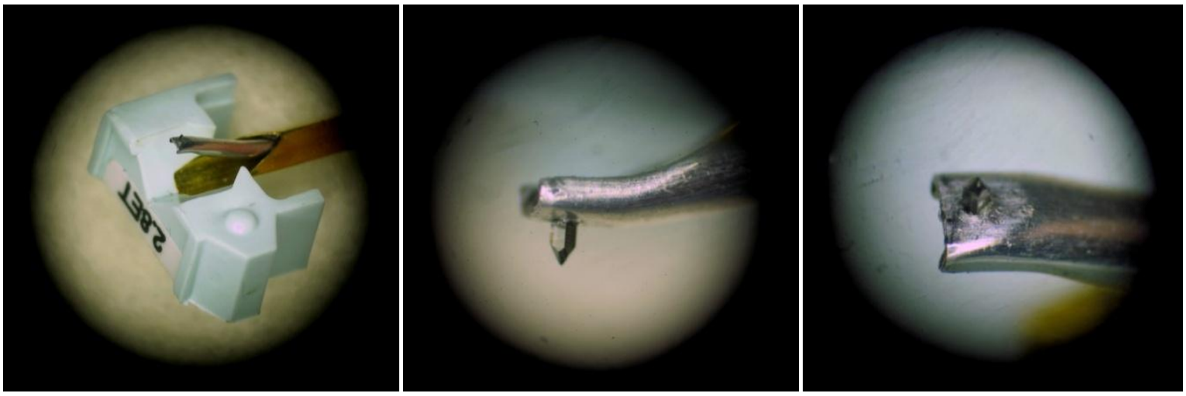

**Image 13. Microscopic views (x50) of a ET 2,8mil stylus. Tasso Laboratori de so**

### 4.6. Reproduction speed

It was no until the final years of the acoustic era (around 1925) that most of disc recordings were recorded at a consistent speed of 78 rpm[53]. Before that many recording speeds were in use, and this lack of standardisation settles interesting challenges for the restoration engineer.

It is worth reading Peter Copeland's chapter on the matter (Copeland 2008, 81:98), as well as the very informative article from Warren R. Isom "*Before the Fine Groove and Stereo Record and Other Innovations...*", available from the AES Library[54], where one can learn, for instance, the exact reasons for choosing 78 and 33 1/3rpm nominal speeds.

For our purposes suffices to say that early Berliners (1885-1900) had a speed scope of 70 to 90rpm or even 100rpm, which means that quite often side information is needed (technological, musical, historical) to properly establish the reproduction speed, as it will be shown in the following chapters.

### 4.7. Replay equalization

Replay equalization becomes a crucial step for electrical recordings proper reproduction and digitisation in order to compensate for the original recording equalization applied.

This operation should be at its best, the inverse operation of the recording step, this being obviously both a historical and a technological challenge.

For the technical understanding and its relevance, mastering key concepts such as "constant velocity" (for acoustic recordings) and "constant amplitude" (for electric recordings) is needed, and the reader is encouraged to consult approachable[55] and in-depth[56] sources.

---

[53] in 1925, 78.26 rpm was chosen as a standard for motorized phonographs, because it was suitable for most existing records, and was easily achieved using a standard 3600-rpm motor and 46-tooth gear (78.26 = 3600/46)

[54] Isom, (1977). "*Before the Fine Groove and Stereo Record and Other Innovations...*" http://www.aes.org/e-lib/browse.cfm?elib=3319

[55] see Galo (1996), "*Disc recording equalization demystified*" http://www.smartdevicesinc.com/chpt14.pdf (last accessed 20 May 2013)

[56] see Copeland (2008: 99) http://www.bl.uk/reshelp/findhelprestype/sound/anaudio/analoguesoundrestoration.pdf

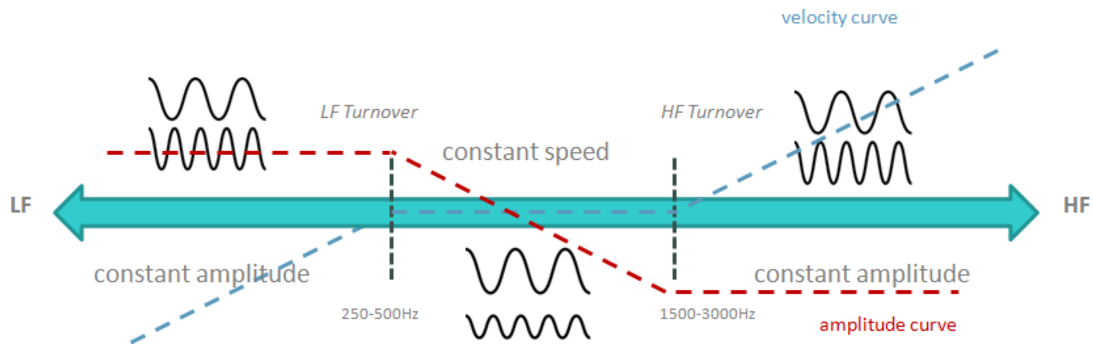


**Image 14. Constant speed and constant amplitude EQ characteristics**

Once again, as it often happens for recordings prior to the RIAA 1955 standardisation, many playback EQ curves were in use, and the question is always to know (or sometimes propose) which is the right one to be applied for the particular case.

More or less comprehensive lists are available from authoritative sources, being the IASA one of the most referred to[57], among others[58].

As was described in chapter 3.1.2 (see Table 3), information on the proper EQ curve can sometimes be gathered from symbology accompanying the matrix number, especially in the early years of electric recording. We will be reviewing specific examples in the following chapters.

It must be remembered that, in case of doubt, the judgement of a trained ear should prevail. And of course, parallel digitisation (with and without applied EQ curve - that is, a flat transfer) is always possible.

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[57] see http://www.iasa-web.org/tc04/mechanical-carriers-replay-equalisation

[58] see James R. Powell Jr. *The audiophile's guide to phonorecord playback equalizer settings* - http://arsc-audio.org/journals/v20/v20n1p14-23.pdf

# 5. Digitisation

## 5.1. The resolution window

To begin with, let us remember for lovers -or neophytes- of analogue sound an irrefutable aphorism, credited to American pianist Ivan Davis, which we quote from Milner 2009: 194: *"analogue sound is about approximating perfection, while digital is about perfecting approximation"*.
What are the criteria for the selection of the two basic parameters of analogue to digital conversion, i.e. the number of bits (dynamics) and the sampling frequency (frequency response)?
To answer this question it is worth remembering the following illustration, which qualitatively locates the range of some of the most common degradations in the resolution (dynamic/spectrum) framework.

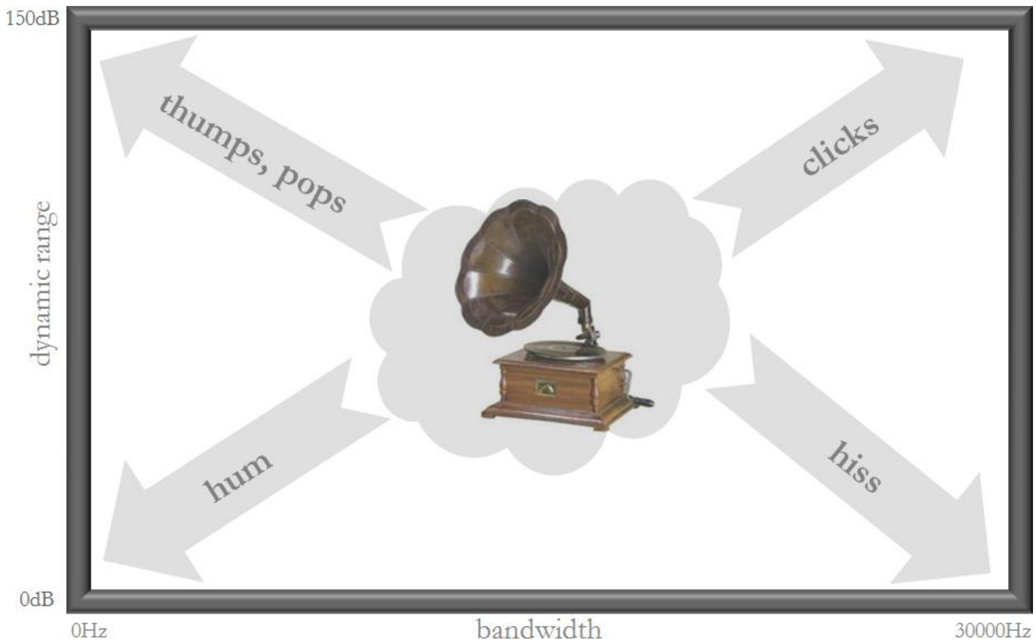


**Image 15. Scope and dynamic range of sound degradation in the resolution window**

It should be stated well in advance that the supposedly original resolution analogue audio carrier can be much smaller than the actual once obtained through the reproducing device. In fact, even if paradoxical, it is often said that the lower the theoretical resolution of the original item, the greater should be that of the A/D converter.  This implies considering the degradations associated with the physical carrier (the surface noise, clicks or thumps in a disc) as information with historical significance and, in response to the original question regarding technical criteria, as sound material that requires, at least in the digitized master file, specific preservation (instead of removal).

If we look at the figure above we can deduce that if the "clicks" have historical significance in the whole record, we must have a converter with enough dynamic range for preservation, which implies a sufficient number of bits per sample (24 bits allows for a theoretical SNR of approximately 6 x 24 = 144 dB). In the same sense, to ensure the preservation of the clicks high frequency content we a high sampling frequency is required, capable of a response no lower than the human auditory margin (20-2000Hz ideally), ideally larger is we bypass anthropocentric criteria. Hence the well-known advisable sampling frequencies of 88200, 96000 or 192000Hz (192 kHz) for archival purposes.
We could generalize the requirements for other types of degradation (thumps, pops, hum and hiss) to realize that in every case a generous resolution window is required to convert from analogue to digital.
It will be seen later our adherence to 24bits/96Khz or 24bits/192Khz standard resolutions.

## 5.2. Standard parameters of the digitization equipment

As the IASA-TC04 document describes in the introduction of its Chapter 2 – *Key Digital Principles*, "*it is integral to the preservation of audio that the formats, resolutions, carrier and technology systems selected adhere to internationally agreed standards appropriate to the intended archival purposes. Non-standard formats, resolutions and versions may not in the future be included in the preservation pathways that will enable long term access and future format migration*." (IASA-TC04 2009:8).

The main parameters of these agreed technological standards (sample rate, bit depth, THD+N, Dynamic Range, etc.) for professional digitization are highlighted here

| A/D Parameter | Values | Notes |
|---|---|---|
| **Dynamic range** | ≥ 115dB, 117dBA | THD+N relative to $0dB_{FS}$, f = 997Hz at $-60dB_{FS}$ |
| **Frequency response** | ±0,1dB at 20Hz-20Khz | |
| **Intermodulation distortion IMD** | ≤ -90dB | SMPTE/DIN/AES17 twin-tone test sequences, combined equivalent to full-scale amplitude sine |
| **Amplitude linearity** | ±0,5dB | within $-120dB_{FS}$ to $0dB_{FS}$, f = 997Hz |
| **Spurious non-harmonic signals** | ≤ $-130dB_{FS}$ | f = 997Hz at $-1dB_{FS}$ |
| **Internal sample clock accuracy** | ± 25ppm | digital output stream measured clock |
| **Jitter** | < 5ns | |
| **External synchronization** | ± 0,2% from nominal value | PPL jitter removal capabilities |
| **Digitization bit depth** | 24 bits | |
| **Sample rate** | 96Khz/192Khz | 88.2Khz/176.4Khz also possible |
| **Audio File formats** | BWF wave files | EBU Tech 3285 |

**Table 5. Main standard parameters for A/D conversion**

# 6. Restoration

## 6.1. A framework to audio restoration

One of the issues that should be well defined before attempting any restoration is its scope and reach. Based on the reasonable similarities between the terms "to restore" and "to move back" in time and space, we can speculate about several “retuning points” to several more or less "original" states of the sound object, both for the carrier itself and its sound content.

Thus, from a conceptual point of view, we may locate three returning points of particular relevance

1. the state after production and distribution processes
2. the state after original transduction, prior to the recording/distribution medium (master media)
3. the original state prior to the any electroacoustical transduction due to the recording chain

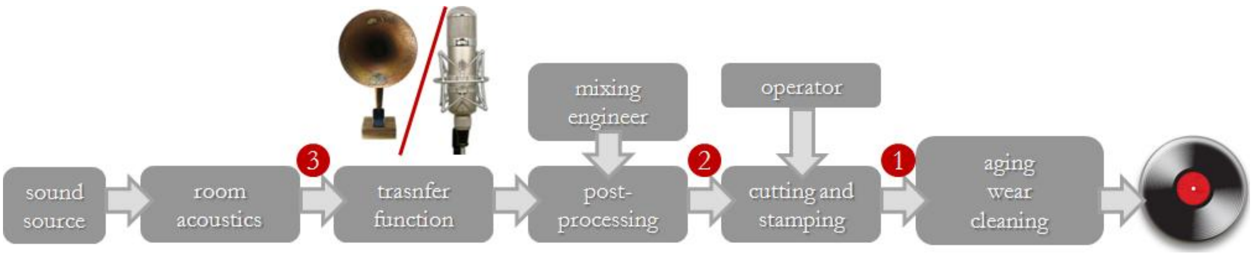


**Image 16. A schematic view of the recording chain**

Why are these three states relevant?

- **The state after production and distribution processes** (dot 1), refers to the duplicated content bound to the limitations of the mass distribution recording media (replications on shellac, vinyl, cassette, CD, etc.). In either case the audio content is limited in quality (frequency range and dynamics), duration, preservation state, reliability and ultimately sound fidelity to the characteristics of the physical/logical container, mainly due to technological limitations. Restoring sound objects at this point is probably the most common and feasible option for the potential ease of access to several copies.

- **The state after original transduction, prior to the recording/distribution media** (red dot 2) actually implies access to recording original material, prior to the generation of bulk copies. It applies to instantaneous/unique recordings (acetates, field recordings, etc.) as well as original master recordings (matrixes, two-inch tapes, etc) of usually higher quality than mass-distributed consumer copies. A well known and also controversial example of a restoration at this stage is the re-mastering of the entire catalogue of The Beatles, carried on at Abbey Road Studios from the original two-inch tapes.

- **The original state prior to any electroacoustical transduction** (red dot 3) dissociates the content of the carrier. The content would be exclusively conditioned by the original rendition and the room acoustics, but freed from the disturbances of the original electroacoustic transduction chain, that is, the overall transfer function imposed from the on-location sound capture to the preserved media. As summarized in Figure 1, we are talking about room acoustics (with its unique reverberation time, room modes, diffusion, etc.) as well as the recording chain. The latter can be broadly acoustic or electric, the first common until 1925, with the introduction of the method patented by Western Electric in response to the invention of radio. In the case of acoustic recordings it is worth pointing out the strong resonance and colouring effect introduced by the recording pavilion (horn) of acoustic phonographs and gramophones. In the case of electrical recordings we should include the microphone in its various inceptions, tube and transistorized amplifiers and speakers, not to mention the possible devices intended for the electronic modification of tonal response (equalizers) and dynamics (compressors)

It seems clear in any case the difficulty to dissociate content and its continent, as the latter continuously conditions and feeds back the former (see Katz 2004, Milner 2009, Ashby 2010).

An example of the effort to achieve sound restoration before the transduction chain is found in the early experiments conducted by one of the fathers of digital audio, Thomas Stockham (1933-2004). Researcher at MIT (*Massachusetts Institute of Technology*) and founder of Soundstream Inc., Stockham developed the technique of blind deconvolution for sound restoration processes and applied it to recordings made by Enrico Caruso during 1902-20. Stockham published a groundbreaking article on restoration techniques in the digital domain and edited a number of results obtained in commercial LPs (The Complete Caruso - Stockham / Soundstream Computer Process – RCA Red Seal). Such techniques based on blind deconvolution have been lately retaken by Zynaptiq's Unveil and Unfilter software applications[59].

[59] see http://www.zynaptiq.com/products/

The reader can infer the ambitious implications associated with this intended stage of "original" restoration and its historical, aesthetic and technological connotations. The concept of "original" sound will always remain open to speculation and to some extent, to utopia: or is it not the case to dream of hearing Caruso (for the sake of the argument) "as it was" back in time and space, without the blur of old recording devices and degraded media?

## 6.2. Types of restoration

An initial, conceptual distinction should be made between restoring the carrier format (medium or continent) and the carried information (sound content). In the first case we should talk of a physical restoration and in the second, of a logic one. Both domains are yet closely related, and even though not as intuitive, this is especially true in the digital domain.

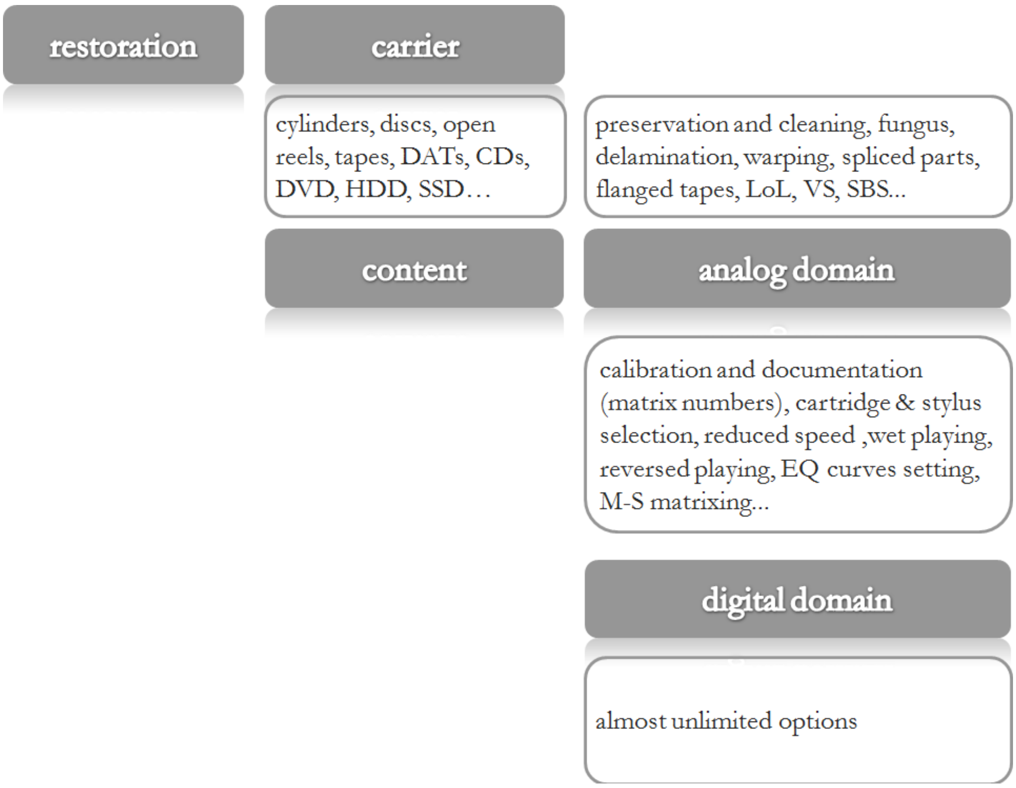


**Image 17. Main types and domains restoration**

The illustration above describes only some of the many restoration actions associated with some of the many types of sound carriers, as well as some restoration actions applicable to sound data in the analogue and digital domains. Each of these restoration actions will require prior in-depth knowledge in many different fields (chemistry, bacteriology, physics, mechanics, engineering, musicology and many others).

Beyond the natural quest for preservation and the technologies involved, what might be the reasons for restoration? As indicated in Cannaza and Orcalli 2007 and 2006, we could pursue different goals, including those aimed at the real-time recovery of the word intelligibility in noisy environments at the expense of the tonal voice quality (such as in mobile telephony, audiovisual broadcasting, etc.) or conversely, in the techniques applied to the forensic field.

Focusing on audio archival, where real time results are not -and should not- be the issue, different approaches apply, and we'd like to quote here literal excerpts of the proposal made by Angelo Orcalli (Orcalli 2006)[60]:

### 6.2.1. Preservative approach

*"the* ***preservative approach*** *takes account of the set of information presented by the document seen as an artefact. It centres on the physiognomy of the document and its goal is to conserve the unity of the document (…). Restoration work must be well documented and is only permitted if the aim is to restore the functionality of the support medium and this includes splicing breaks, drying out to combat hydrolysis phenomena and lubrication. Identification of the format and the choice of reproduction/listening equipment are crucial. Any intentional alterations in the signal occurring in the recording phase (equalisation, noise reduction systems) must be compensated for. The remediation process with the new digital medium must represent, directly and with the maximum transparency, the informational and material characteristics of the original document as it is now. This approach aims to answer the question: what is the document like?"*

### 6.2.2. Documentary approach

*"the* ***documentary approach*** *focuses on the form of each document, on the relationships within the sound fabric and, in the case of multiple examples of the same work, the relationships between these documents. The focus is also on the production equipment and techniques, the compositional procedure and the writing basics (...). The aim of this approach is to create accurate editions accompanied by information about any variations introduced to reconstruct the sound fabric of each recording. Operations to reduce alterations in the signal produced over time or by micro-imperfections on the original support media are permitted, provided that the restoration work never transcends the technological level at the time the work was produced and always making a distinction between the noise resulting from the historic system, from defects in the support medium and intentional noise. If unintentional alterations are found, due to poor alignment of the equipment in the production phase, and if the precise entity of these is known, they may be compensated for only in order to improve the capture of the original signal. From the methodological point of view, this means guaranteeing the transparency of the medium in relation to the sound fabric. The documentary approach therefore, answers the question: where is the sound fabric of the document?"*

[60] quotation comes from a re-edited English version of the original document (in Italian) available at http://audiolab.uniud.it/pdf/pubblicazioni/Orcalli_Orientations.pdf

6.2.3. Sociological approach

*"the **sociological approach** is based on a study of the properties of historic systems of memorising and disseminating sound. Its aims is to make a historical reconstruction of the recording as it was heard at the time of production, in the hope of writing a history of listening habits. It answers the question: how was the published document perceived?"*[61]

6.2.4. Reconstructive approach

*"the **reconstructive approach** examines the production of the document from the point of view of intellectual and material responsibility. The objective is to recreate the sound fabric in a way that corresponds, to the highest possible degree, to the composer's intention. (…) This route, although difficult to put into practice from the operating point of view, now seems feasible thanks to the numerical sound processing, making it possible to compare examples in quantitative, visible terms, and to perform accurate syntheses based on models. Within the limits of the reconstructive operation, the remediation must maintain the transparency of the new medium in relation to the alterations introduced unintentionally by the technician-composer during the production phase. In the field of electronic music, the reconstructive approach must provide a synthesis between two inseparable lines of research: a) knowledge of the compositional model and its implementation; b) defining the work's tradition by collating examples of the audio sources. The reconstructive approach answers the question: what should the sound texture have been like?"*

6.2.5. Aesthetical approach

*"in the **aesthetical approach** the potential of the work is examined in relation to the possibilities for its use on the recorded music market and in performance. Its objective is the commercial edition or the presentation of the audio material in formats destined for performance. This is an interpretive approach that focuses on listening methods and conditions, on the event and on the performance of the moment. Within the remediation process, the medium is able to act on sensorial relationships and forms of perception. It is appropriate to emphasize that, because each aesthetic operation performed directly on the recorded signal introduces subjective choices made by the restorer, this reduces the sound director's freedom and her/his own interpretative choices. The invisibility of the sound fabric, the decisive role played by the aural dimension and the unbreakable link with the medium make it impossible to draw a clear distinction between the performance and the text, as can be done when musical notation is involved. Within the interpretative act, the de-crystallised document becomes the work, the source of originality and of new information. The aesthetic approach answers the question: how could this document be transformed?"*

As Orcalli states and the reader can also deduct, the preservative and the aesthetic approaches are "polar opposites", in the sense that the former aspires to create a facsimile copy in order to obtain a "quasi-

[61] that would be the case, to a certain extent, of the Stockham/Soundstream blind deconvolution approach for the retrieval of original Caruso recordings

reversible process", while latter aims to take the maximum advantage of the potential of new media. On the other hand, the sociological approach would tend to use vintage equipment in a way nor endorsed by the IASA, but respected by well-known specialists (see Copeland 2008: 6-8).
Finally, the reconstructive approach seems to point at minimizing or removing the toll of original technological limitations in favour of the implementation of the composer's/musician's ideal, an approach that might find examples in today's bandwidth extension and spectral band replication (SBR) technologies.

## 6.3. Restoration limits

From what it has already been said, and echoing the guidelines of the engineer from the Phonogrammarchiv Wien Nadja Wallaszkovits (Wallaszkovits 2009), we can make some statements for debate:

- one of the weaknesses of restoration procedures is the lack of documentation on the applied methodology, especially in commercial restorations
- audio restoration in the digital domain should follow, because of its capacity for "inaudible" manipulations, the saying "less is more"
- sales revenues should not compromise the rigor of a restoration. If the final purpose is commercial, then we should talk about a remix (aesthetical postproduction: EQ, compression, reverb)
- the quality of the restoration in the digital domain will depend on the processing power of the available tools (state-of-the-art) and the technical skills and taste of the producer (temporality)
- commercial versions of historical recordings as a result of aesthetic restorations are not a reliable sources for research

## 6.4. Types of disturbances

Once revised the scope, type and limits of the restoration processes we should now define the trigger for restorative action. Most authors (as for instance Canazza 2007) tend to classify the different disturbances suffered by a sound object into two main types

- local disturbances
- global disturbances

As evidenced by the terminology, local disturbances affect only a portion of the total audio content and can be identified as discontinuities in the waveform. The effects may vary upon the physical conditions of the medium and the frequency domain of the degradation, its dynamics, duration and location. Among the various types of degradation we should include the local *ticks* in discs caused by the inherent granularity of the material, dust, etc.., as well as other more severe alterations of the physical environment (*pops*, breakage, etc.)., tape demagnetizing (*drop-outs*) or degradation of the digital medium (digital saturation or *clipping*, instability in the sampling time base or *jitter*, etc.).

In contrast, global disturbances affect the entire sound signal -not only in time domain but often also in the frequency domain too- and include among others background noise tape (*hiss*), *wow & flutter* due to the instability in the mechanical transport, and some types of nonlinear distortion.

The following illustration includes a good number of degradations grouped by type and nomenclature:

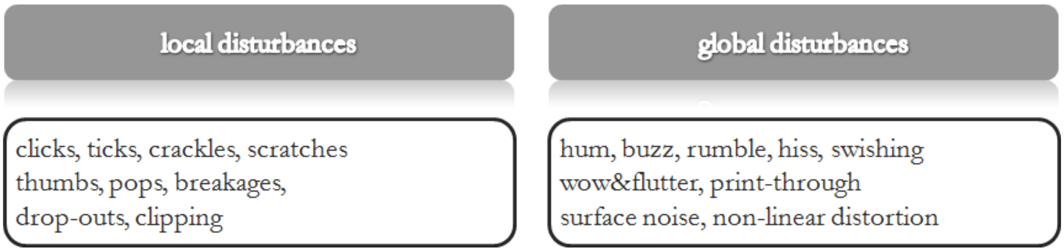


**Image 18. Main types of sound degradation**

There are several alternatives for the classification of disturbances in terms of other parameters. A complementary alternative to the above ranks disturbances between deterministic and stochastic depending on the quality of noise, being predictable those deterministic (e.g. hum harmonic distortion) and stochastic those unpredictable (e.g. noise *hiss*).

## 6.5. Dimension historical degradation

Once listed the different types of sound disturbances and before undertaking any restoration that could eliminate or minimize their effects, we should consider this main question:

To what extent a disturbance acquires historical significance and should be preserved?

Other questions arise from this, such as:

- where do these disturbances or alterations come from?
- are they a result of the history, origin, purpose or use of the recording?
- can they assist in uniquely identifying information?
- is it acceptable to modify the original dynamics and/or spectral content of the recording?

- is it correct to "fill" drop-outs (sound discontinuities) by interpolation processes? (e.g. using Izotope's *Spectral Repair*)

And since many disturbances are a product of its time, to what extent have technical limitations shaped and constrained musical performances?
Prior knowledge and documentation is therefore strongly advised, based on the correct classification of different levels of audio restoration.

## 6.6. Levels of sound restoration

Any restoration process begins in the analogue domain (when applicable)

- with knowledge of the recording technology of the time home
- with knowledge of the process of sound reproduction and digital conversion, related equipment and possible disturbances

to proceed in the digital domain with knowledge of available digital tools and the collateral sound artefacts (a.k.a as disturbances) introduced.

According to Nadja Wallaszkovits (Wallaszkovits 2009) 7 levels of restoration should be considered:

- 5 levels which are common in the analogue domain and should be unintentionally compensated, including calibration procedures and playback

- 2 further levels which are commonly treated in the digital domain, grouped into

    - compensation for unintentional alterations
    - compensation for intentional alterations

Restoration in the analogue domain involves the following 5 main levels, which coincide with the preservative approach proposed by Orcalli (Orcalli, 2006)

1. selection of the best preserved original carrier t to create a copy for further restoration

2. physical and chemical improvements on the state if the audio carrier to optimize the process of reproduction (repair of splices, cleaning discs or tapes, gluing broken cylinders, thermal treatment of tapes suffering from hydrolysis, cameras for the extraction of oxygen[62], freezing, etc.)
3. selection of replay machines
4. calibration of the machines to match historical parameters (speed, equalization, track formats, etc.)
5. compensation for possible misalignment of recording devices (azimuth and cutting angle deviations, etc.)

From this point on we can approach the digitization process that will allow us, if needed, to apply restoration processes in the digital domain.

## 6.7. Restoration in the digital domain

Once in the digital domain we are enabled a large number of restoration processes, grouped in

- digital compensation of unintentional alterations, with the goal of objectivity and transparency
- digital compensation of intentional alterations, with the goal of subjectivity and alteration (re-master)

### 6.7.1. Unintentional processes

Should be able to tackle to the following common disturbances

- HVAC[63] noise
- high frequency harmonic noise due to, among others,
  - errors in the power supply grounding (hum noise)
  - noise sources in the power supply system, such as light dimmers (buzz)
  - transformers, external magnetic fields (EMIs)
- EQ (or blind deconvolution, and in the process Stockham/Soundstream) to compensate for the lack of linearity in frequency response
- broadband noise from tape transport (hiss)

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[62] see VELOXY® (VEry Low OXYgen) - http://www.insituconservation.com/en/products/nitrogen_disinfestation_systems/veloxy_system/

[63] ***H**eating, **V**entilation & **A**ir **C**onditioning*

- tonal noise (hum, buzz, thumps)
- noise caused by the granularity of the material
- damaged grooves (clicks, crackles, scratches, glitches, clips), etc.
- compensation of the influence of the recording device, position and dynamics of the acoustic source
- audible degradations due to the very same recording process
  - switch-on / switch-off noise,
  - cutting defects of the groove (Azimuth adjustment)
- degradations caused by the storage and conservation state of the sound carrier
  - fungal species or mould (especially in cylinders and shellac discs) that consumes organic compounds and leaves millions of small marks on the carrier surface that result in "crackles" during replay. Such damage cannot be removed by physical and chemical cleaning or restoration processes
  - wear by replay /use of the sound carrier, damage of the sound quality by duplication processes ((loss of high frequency response, etc.)
  - wow in a domed, uneven or non-centered discs
  - non-uniform magnetic density in tape carriers (drop-outs)
- degradation caused by the process of modern reproduction
  - nonlinear distortions caused by the geometry of the needle, pickup and tonearm
  - wow&flutter from reproducing devices, digital jitter, etc.

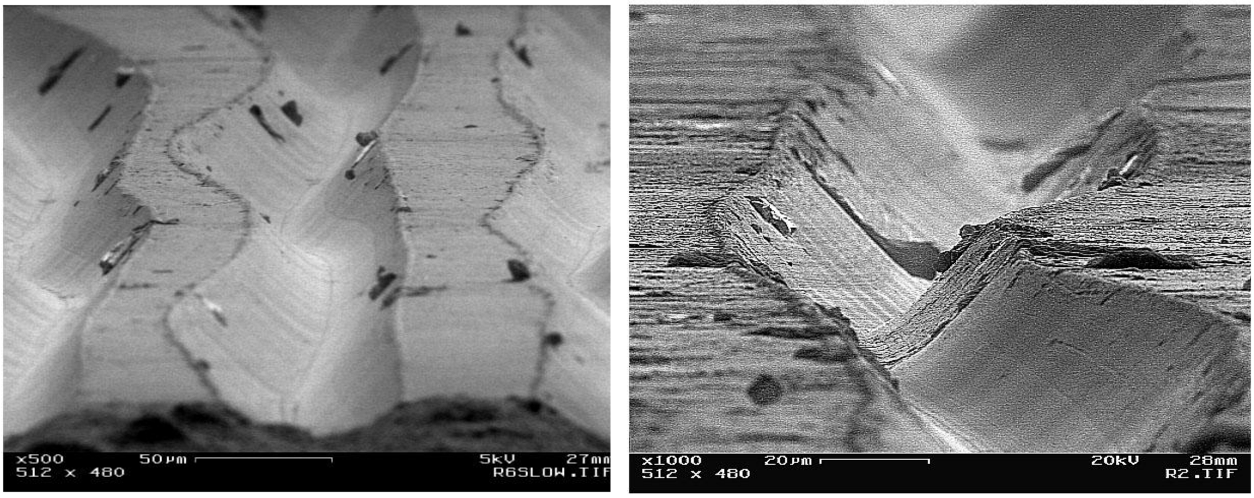


**Image 19. Detail of a groove stereo vinyl disc viewed through an electron microscope. Chris Supranowitz. Institute of Optics, University of Rochester.**
**http://www.optics.rochester.edu/workgroups/cml/opt307/spr05/chris/**

To particularize the case for discs, we're quoting the following chart made available by Mike

Casey, (Indiana University) and Bruce Gordon (Harvard University) at *Sound Directions: Best Practices for Audio Preservation*[64]

| # | Problem | Identification and Definition |
|---|---|---|
| 1 | Broken | The disc has broken into distinct parts. This applies to shellac discs or glass-based lacquer discs. |
| 2 | Bubbles | Bubbles in the disc, usually caused by faulty pressing. |
| 3 | Chips | Small missing pieces from the edge or rim of a recording. |
| 4 | Cracks | A break without physical separation of the disc into distinct, separate parts. |
| 5 | Crayon Markings | The grooved surface of the disc has marks on it that were created by a crayon. Sometimes called chinagraph markings. |
| 6 | Crazing | Thin fracture lines on the surface of a lacquer disc caused by shrinkage of the lacquer coating. |
| 7 | Cutover Grooves | The breaking through the wall of one groove into the wall of the next groove, usually caused by overmodulation |
| 8 | Delamination | The cracking and then separating of the coating of a disc from its base. Enter "0" if there are no signs of delamination, "1" if there are a few cracks starting to appear on the surface of the disc, "2" if there are a significant number of cracks and some separating of the coating, "3" if the coating is clearly coming off in a number of places. |
| 9 | Dirt/Dust | The presence of dirt or other foreign matter on the disc. A significant amount of foreign matter may cause drop-outs or lead to spacing loss from poor tape-to-head contact. |
| 10 | Foreign Matter | Usually describes material (cardboard, etc.) which has adhered to, or become embedded in, the surface of vinyl or shellac discs following manufacture. |
| 11 | Fungus | Look for patterned, fuzzy, thread-like, or hairy-looking growths on the surface of the disc. Typically, these growths are white in color although they may also be black, brown, or mustard-colored. Try to distinguish mold from other types of visible contamination such as dirt, which may look similar but usually does not appear as fuzzy or patterned. |
| 12 | Locked Groove | Usually a spiral groove at the end of a recording that provides a groove for the stylus to ride in until an automatic record changer mechanism is tripped. Here, the term is used for any groove that is closed, that is, there is no path to the next groove |
| 13 | Marks | Any type of a mark such as a fingerprint or a scuff on the grooved surface. |
| 14 | Pitting | A visible pit or break in the surface of the recording. |
| 15 | Plasticizer Exudation | In lacquer discs, the movement of the plasticizer (usually castor oil turning into palmitic acid) to the surface of the disc. This is the first step towards delamination. It manifests as a white, oily sheen on the surface of the recording. It is not fungal growth, and there are no fuzzy parts as there often are with fungi. |
| 16 | Scratches | Using the categories outlined above, document the number and severity of scratches on the disc. |
| 17 | Stains | Water or other stains on the surface of the disc. |
| 18 | Surface Imprint | The transfer of material from the recording sleeve to the surface of the recording itself due to high contact stress caused by high temperatures, wrinkled or uneven surfaces of the packaging material, or uneven storage pressure. The transferred material may interfere with stylus tracking. |
| 19 | Tracking Problems | Scratches, chips, cracks, damaged grooves, etc. that impede playback on a disc may cause the stylus to lift out of the groove and/or skip grooves or otherwise mis-track. Use "0" if the disc contains scratches but plays with no problems. Use "1" if the disc contains a problem or two that impedes playback but is able to be played by adjusting the tracking force, anti-skate, adding weight, etc. Use "2" if most of the disc is playable but one or several problems cause mis-tracking regardless of attempts to get the disc to play. Use "3" if the disc is worse than above and seems beyond repair. |
| 20 | Warped | Alteration in disc surface shape (usually along several planes), causing the stylus to jump when the disc is played |

**Table 6. *Sound Directions: Best Practices for Audio Preservation*, Appendix1 Version1.0. The Audio Technical Metadata Collector (ATMC). Indiana University Archives of Traditional Music.**
**http://www.dlib.indiana.edu/projects/sounddirections/papersPresent/sd_app1_v1.pdf**

[64] see http://www.dlib.indiana.edu/projects/sounddirections/papersPresent/sd_app1_v1.pdf

### 6.7.2. Intentional processes

Among the main intentional processes are those based on the subjective reinterpretation of the aesthetic taste of current listeners

- aesthetic equalization
- compression, limiting
- background noise / room noise reduction
- frequency enhancement (aural excitation, spectral band replication, bandwidth extension techniques)
- reverberation, auralization, spatialization
- restoration based on historical (a.k.a non modern) equipment

In relation to commercial products available in the market, let us remind certain terminological aspects (Wallaszkovits 2009)

- when modifying the sound of an historical record to "modern" sound aesthetics (contemporary taste), we should be talking of a reissue or remastering
- following the same approach as in the previous case, when applying processes from the very same mix and adding anything deemed necessary (new tools, parts, effects, etc.) we should be talking of a reinterpretation or remix

## 6.8. Methods for audio restoration in the digital domain

Technical research literature on the issue is rather extensive, although only a few papers or Ph.D. thesis have made its way into published books or book-chapters (Godsill and Rayner 1998, Canazza 2007 and Esquef 2008 being the most well-known). Nevertheless, no major breakthroughs seem to have happened in recent years.

Most of the state-of-the-art methods used for audio restoration are model-based (mathematical-statistical models). Such models can be

- sound source models, when aimed at describing the *source* that has generated the waveform under consideration.
- signal models, when aimed at describing the actual signal waveform with the different types of disturbances under consideration included

Regarding the implementation domain, Canazza proposes a classification in three main groups

- time-domain algorithms
- frequency-domain algorithms
- algorithms based on psychoacoustic models

6.8.1. Time-domain algorithms

They can be divided in

- signal modelling approach (Bari, Canazza, De Poli, and Mian, 2001)
    - autoregressive (AR) models (Vaseghi and Rayner, 1988)
        - Extended Kalman Filter (EKM) methods (Paliwal and Basu, 1987)
    - autoregressive moving-average (ARMA) models (Biscainho, Diniz, Esquef, 2002)[65]
    - sinusoidal models (McAulay and Quartieri, 1986)
        - sinusoidal + residual (Serra 1997)
        - HILN (Harmonic and Individual Lines + Noise)
    - audio inpainting / sparse atomic modelling (2011)[66]
- sound source modelling (SSM) approach (Esquef, Valimaki, and Karjalainen, 2001)[67]
    - analysis by synthesis
    - restoration enhancement

6.8.2. Frequency-domain algorithms

This approach is based on the use of "acoustic fingerprints" or estimations and is broadly used in commercial restoration tools for broadband noise reduction.

- STSA, Short-Time Spectral Attenuation (Lagadec and Pellon 1983, Moorer and Berger, 1986; Vaseghi, 1988, etc.).

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[65] see http://www.acoustics.hut.fi/~esquef/mypapers/ISCAS01.pdf

[66] see http://hal.inria.fr/docs/00/57/70/79/PDF/RR-7571.pdf and http://recherche.ircam.fr/pub/dafx11/Papers/79_e.pdf

[67] see http://www.acoustics.hut.fi/~mak/PUB/AES_Esquef9933.pdf

### 6.8.3. Algorithms based on psychoacoustic models

They can be implemented both in the time domain or frequency domain, being the latter the most powerful approach. The audio signal is here considered not from an ("outer") perspective, but bounded to how the human ear, statistically speaking, would perceive it ("inner" perspective). Some common approaches are those used in perceptual coding (MPEG-4 Audio, Dolby Digital, DTS, etc.) which benefit from techniques such as bandwidth extension or spectral band replication (SBR).

The suitability of using one or the other models depends largely on the type of degradation to be addressed (global or local).

### 6.8.4. An approach to most common signal models

Among the models based on time domain algorithms we must mention the **autoregressive (AR) model**. Simply put, the AR model determines the current value of a signal as a weighted sum of P previous samples plus a white noise term (linear predictive analysis):

$$s[n]=\sum_{i=1}^{P_n} s[n-i]a_i + e[n]$$

$e[n]$ = white noise term
$s[n]$ = original digital signal (unwnown)
$a_i$ = model coeffcients

**Expression 1. AR model (Godsill 1998)**

The main goal of this method is to model a perfect original signal which is unknown (s[n]).

This is a valid model for stationary signals with defined characteristics between noise and harmonicity. We need to adapt the model periodically (e.g. every 20 milliseconds) with a windowing between 500 and 2000 samples, which calls for adaptive coding blocks (Time-Varying Autoregressive Modelling, TVAR).

Another approach is **sinusoidal modelling** (and the more restrictive harmonic modelling). It is a synthetic model particularly suitable for music signals (highly harmonic content) where the signal is represented by amplitude-modulated sinusoidal synthesis ($a_i$ [n]) and frequency (sin $w_i(t)$).

$$s[n]=\sum\left(a_i[n]\sin\left(\int w_i(t) + \Phi_i\right)\right)$$

**Expression 2. Sinusoidal model (Godsill 1998)**

This model is not suitable to represent signals with high stochastic content (noise).

Sound source modelling is a specific area of knowledge which is out of the scope of this master thesis. Relevant insight applied to audio restoration can be obtained from Esquef et al. 2001[68].

## 6.9. Unintentional restoration techniques in the digital domain

Following the guidelines set by Simon Peter Rayner and Godsill (Godsill, PS, Rayner, PJW 1998), the restoration process should follow the order proposed in the following table:

| order | disturbance type | frequency range | temporal range | possible modulation |
|---|---|---|---|---|
| **1** | *clicks, crackles* | high frequency content | discrete [µs] /local | - |
| **2** | *pops, thumps* | low and high frequency | discrete [ms] /local | low frequency |
| **3** | *hiss* | full spectrum | continuous /global | cyclical, temporal and frequential |
| **4** | *clipping* | full spectrum | discrete [ms] /local | non-linear distortion, intermodulation |

**Table 7. Possible action order in the process of digital restoration**

1. detection and reduction of high-frequency transients (clicks)
2. detection and reduction of low-frequency resonant pulses (thumps)
3. detection and reduction of tonal noise (hum, buzz) and background noise (hiss)
4. detection and reduction of nonlinear distortion (clipping)

A rule of application is starting by the more noticeable disturbances: this will unveil the rest of disturbances and well ease treatment.

A final disturbance type (5) to be tackled would be the instability of pitch, commonly known as wow & flutter, which often appears mainly due to the instabilities in the transport section of reproducing devices.

[68] see http://signal.hut.fi/publications/finsig01/audio_restoration_using.pdf

We will briefly expose the cornerstones of each of the possible improvements on the prototypical disturbances listed. Information will be mostly based in the work from Godsill and Rayner 1998, Esquef 2004 and Canazza 2007, to which the reader is referred for a wider insight.

### 6.9.1. Detection and reduction of clicks and crackles

Impulsive-like disturbances, often heard as *clicks*, cover a wide range of local degradations of short duration (between µs and ms). They are due to several factors

- granularity of the recording medium (surface noise)
- adhered dirt, dust
- defective preservation state of the carrier
- inherited disturbances from erroneous AD transfer: digital wordclock errors, etc..

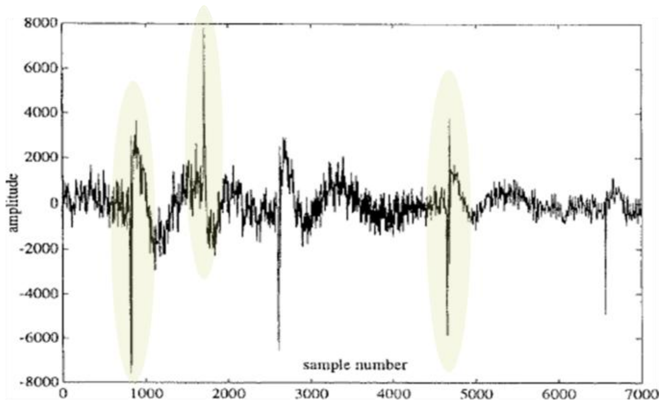



**Image 20. Examples highlighted in yellow-clicks in an audio signal (Godsill 1998)**

Local disturbances dues to saturation (clipping) are not included in this category. On the other hand, it will be assumed that clicks will interfere o modify the timing content of the original signal x[n] to restore

Typical characteristics of clicks are

- a random onset: they appear in bursts of random duration
- temporal interdependence among affected samples
- huge dynamic range, well above and below that of the original signal, with consequent difficulties in determining detection thresholds

We should distinguish between click modelling, detection and removal.

Regarding modelling, two approaches are possible

- an additive model, where the click is considered added to the original audio signal
- a replacement model, where the disturbance is too large (scratches, breakages) and the timing content of the original signal may have been modified

Just the additive model will be considered.

Regarding detection, a model-based AR memory-less additive detection procedure is often applied which will give rise to a detection signal $e_d[n]$

- memory-less **additive autoregressive model for click detection**

$$x[n]=s[n] + i[n]e[n]$$

i[n] = error switch 0/1
e[n] = click error
s[n] = original signal
x[n] = corrupted signal

$$e_d[n]=x[n]-\sum x[n-i]a_i$$

how to control the i[n] switch?

approaches

- high pass filtering (HPF) for detection and LPF for removal
- AR model ➡ threshold settled by non typical deviations (*outliers*)
- by statistics ➡ analyzing s[n] and determining the probability of i[n]=1
- psychoacoustic approach ➡ limiting statistic criteria to perceptual audibility

- a detection threshold signal $e_d[n]$ signal is obtained with an error-prediction filter
- the value of samples marked as corrupted by the threshold signal will be either
  - recalculated by estimation of minimal variance
  - interpolated using an AR model (as done in CD errors)
    - up to 100 consecutively interpolated samples for $f_s$=44,1KHz

**Image 21. Detection and reduction of clicks**

Regarding correction, replacement of corrupted samples is made by interpolation from surrounding uncorrupted values. Most effective and flexible methods are model-based, such as the Least Squares AutoRegressive (LSAR) method, originally devised for the concealment of uncorrectable CU errors in the CD. In such methods, no attempt is made to recover original data from the disturbed data and it is thus completely interpolated.

### 6.9.2. Detection and reduction of noise pulses

Noise pulses (pops, thumps) are typical disturbances from mechanical carrier's reproduction (cylinders, discs) as a result from groove discontinuities (cracks, notches, etc) on the relief of carrier surface, resonances in the transduction system, etc.

Pulses can be decomposed into two effects concatenated in time but with different power spectral density (see **Image 22**):

A. a high-frequency transient (pop)
B. a low frequency resonance due to the pickup spring-mass system characteristics

Different approaches have been proposed to minimize pulses, among them

- template-based methods (Vaseghi and Rayner 1988)
- model-based methods
  - signal modelling
    - AR modelling (Godsill 1993)
    - TPSW-based algorithm (Esquef 2004)
  - sound source modelling

One of the first approaches to treat this disturbance is a **template-base method** or template-matching method (Vaseghi and Rayner 1988). The idea behind is to use a template for the noise pulse waveform, assuming that long pulses are basically identical in shape and vary only in amplitude. Thus, noise pulses would be the step response of a liner time-invariant (LTI) mechanical system. The template would be obtained by long-term averaging of many pulses through the corrupted signal, or from detached excerpt of a pulse – i.e., in the run-out groove of a disc. Once the template is obtained, locating pulses would be based on the cross-correlation between the template and the corrupted signal.
Noise suppression is finally achieved by subtracting the amplitude-scaled template from the corrupted signal at synchronized locations.

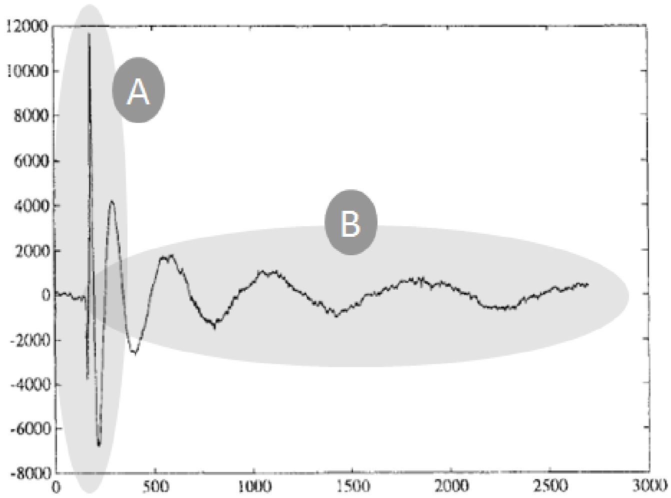


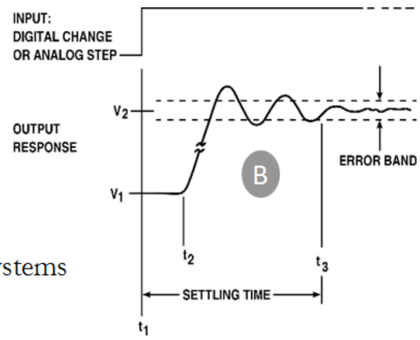

**Image 22. Thump disturbance (Godsill 1998)**

The following illustration summarises the procedure:

- typical approaches are **template-based methods**
- a template of B, t[n] is obtained by averaging of a "clean" signal including the resonance (learning pattern)
- cross-correlation between t[n] and the corrupted signal x[n] is established
- t[n] is subtracted from x[n] properly scaled in time M and amplitude G to get s[n]

$$s[n]=x[n] - G[n-M]$$

t[n] = template
G,M = scalefactors
s[n] = original signal
x[n] = corrupted signal




- disturbances in the transient A can be reconstructed by interpolation once minimized B
- limitations due to time-varying nature of mechanical systems as the stylus moves inwards, non-linearities, etc.
- other methods exist based in the physical modelling of the actual impulse response of the playback device

**Image 23. Pulse detection and reduction**

Although quite successful, this method has in its simplicity one of its limitations: noise pulses do vary in time -and not only in amplitude-, especially by the fact that the transfer function of disc reproduction is time-varying. As the stylus moves towards the disc, the groove density, linear velocity and overall tracking changes, affecting also potential thumps. That would not be much the case of a cylinder, where linear velocity is kept constant[69]

Godsill proposed an alternative linear **signal modelling approach** (Godsill 1993) based on the combination of two autoregressive processes. It is assumed that the overall response x[n] can be written as a linear superposition of individual responses of the playback system (electromechanical transduction, EQ, etc.) to the original audio signal and the original thump disturbance (returning point 1, chapter 6.1).

$$x[n]=s[n] + v[n]$$

v[n] = transduced thump noise
s[n] = transduced original signal
x[n] = transduced corrupted signal

**Image 24. Double AR model approach for thump reduction (Godsill 1993)**

The restoration task is based on separating the two superimposed responses, s[n] and v[n], to be treated separately and modelled with different AR processes: a high-order AR model for the signal, and a low-order AR model for the noise pulse.

As stated at Godsill and Rayner 2008, noise pulse's response v[n] is modelled by a low order (i.e. order 2) autoregressive process which is driven by a low level white noise excitation with variance $\sigma^2_{v0}$ (LF, low level resonance) most of the time, and bursts of high level impulsive excitation with variance $\sigma^2_{v1}$ (impulsive HF pop) at the initial discontinuity of the noise transient, where $\sigma^2_{v1} >> \sigma^2_{v0}$. We can define a binary noise switching process i[n] to switch between low and high variance components (pulse characteristics) in a similar way to the previously explained click generation model. The switching process can be estimated much as clicks are detected, that is, with an AR model (Godsill and Rayner 2008: 142-143). On the other hand, the audio signal's response s[n] can also modelled as high-order AR process (i.e. orders around 80).

This modelling approach is quite flexible in that it allows for variations in the shape of individual noise pulses as well as for the presence of many superimposed pulses within a short period. Nevertheless, it is also computationally intensive (Esquef 2004).

Other approaches have been proposed, as for instance **a TPSW[70]-based algorithm** for long pulse removal based upon non-linear and polynomial smoothing filters. It is stated that the performance of such algorithm is comparable to the AR-based pulse removal methods, being considerable less computationally intensive (Esquef 2004).

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[69] and would somehow give credit to Edison, who always argued the superiority of cylinders over discs for this very same reason of uniform-speed (ergo uniform-quality) reproduction

[70] TPSW corresponds to a filtering technique called two-pass split-window

A third approach would rely on sound **source modelling (SSM**) applicable for specific playback systems, modelling the possibly non-linear response of the physical tonearm + pickup + stylus equipment. This option has been theorized but remains academic and still to be fostered.

Finally, we should consider alternative playback methods such as **non-contact reproduction** via laser or photographic scanning -already introduced- as means for minimizing the effect of the spring-mass resonance coupling from the electromechanical pickup, although other side-drawbacks may appear.

### 6.9.3. Detection and reduction of background noise (hiss)

Background noise is here defined in the context of any unwanted additive random noise due to the transduction chain. A prototypical example of such disturbance is produced by magnetic tape transport on the playback/recording head (hence the onomatopoeic hiss, Gaussian noise).
We should not mistake such electromechanically transduced noise by ambient noise or room noise. Such "noise" allows the original sound to be contextualized within an actual space, and confers not only "atmosphere" to the recording (reverberation cues included), but also very meaningful side information. Indeed, ambient noise should be considered sound of historical significance and thus be preserved (see Wallaszkovits 2009). In case of doubt, master copies should always be as conservative and transparent as possible and background noise removal should only be left for dissemination copies.

Other examples are found in the playback of phonograph cylinders and gramophone discs, in the shape of cycle-stationary background noise modulated by the revolutions of the groove (*swishing* noise). Tape background noise can be considered largely constant over time and spectrally uniform (white noise).

Detection and reduction is based on non-parametric methods suitable for all types of signals. The classic approach is based on STSA (*Short-Time Spectral Attenuation*).

- STSA (Short-Time Spectral Attenuation)
  - does not require the definition of a model for the audio signal
  - the corrupted signal [X] is analyzed and segmented in frequency via a filter bank or transformate coefficients (STFT, 50-66% overlapping hop size)
  - selective attenuation [G] in each filter bank (or bin) according to noise suprpresion rules
  - a SNR is stablished between the power of the original signal signal [X] and the PSD estimation of noise [P], per sub-band ➡ relative signal level [Q ≈ X/P]

the bigger the relative level [Q], the smaller the suppresion level [G]

  - STSA does **not** reduce noise within sub-bands that contain large signal components

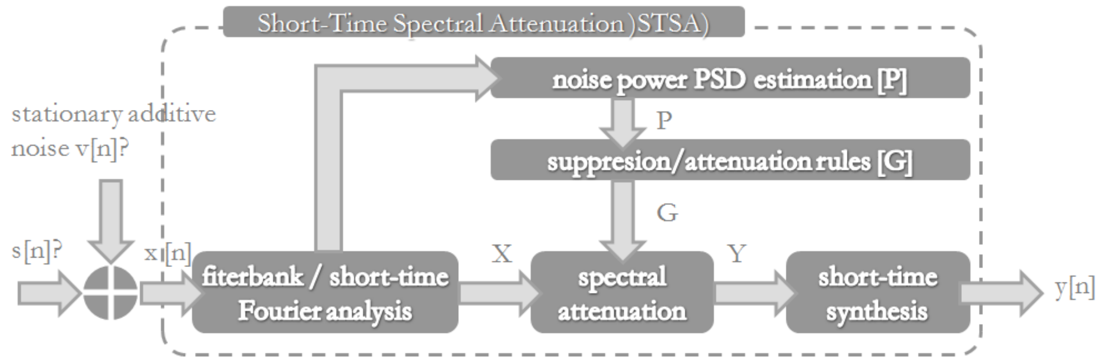


**Image 25. Detection and reduction of background noise (Godsill 1998)**

To put it simply, the classic concept of the noise gate is extended to a large number of sub-bands, with attack and release time settings independent of each sub-band.

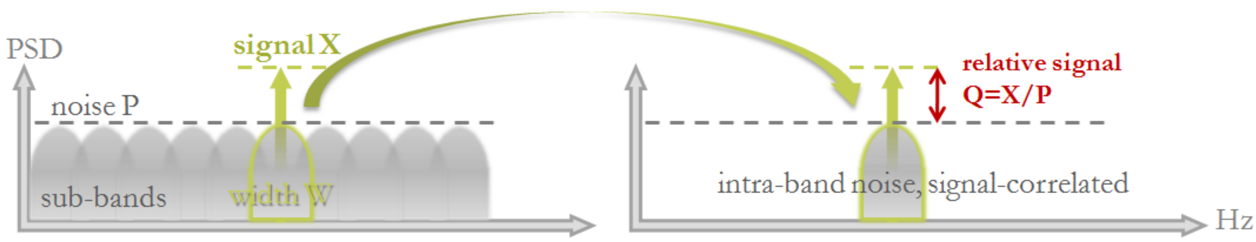


**Image 26. Details of the concept of sub-band noise**

The larger the sub-band width W, the higher the power spectral density (PSD) of intra-band noise (higher Q), the lower the relative signal Q and the more likely the erroneous removal of entropic audio signal.

One of the drawbacks of this method is the transformation of the original broadband noise into a band-pass noise, a residual noise called "musical noise" (Godsill 1998, Ephraim and Malahat, 1984) sonically unnatural and unpleasant. Currently, state-of-the-art commercial software tries to overcome it using Non-Local Means (NLM) algorithms (Lukin, A, Todd, J. AES 2007)[71].

On the other hand, the expected interdependent processing capabilities between time and frequency resolutions appear. Thus, the larger time window in the STFT processing (≈ 20-40 ms)

- the lower the sub-band width and the less the intra-band noise
- the worst the handling of transient noise, with possible sound smearing and the appearance of residual or "musical" noise

### 6.9.4. Detection and reduction of nonlinear distortion

These types of disturbances generate mainly amplitude-modulated overtones caused by the factors listed below (Roys 1978)[72]. It is important to remember, though, that many sources of distortion are possible and they are often undocumented or unknown

- waveform squaring by clipping
- intermodulation distortion due forcing devices (i.e. amplifiers) to work beyond the linear range magnetic tape saturation due to over recording or biasing beyond the linear range of the hysteresis cycle
- tracing distortion due to incorrect matching of the reproducing stylus with the original (usually known) recording/cutting stylus (unmatched diameter, shape, etc.)
- elastic deformation (by temporary reproduction) and plastic or wear-out deformation (by gradual use) of the disc groove

A "blind" modelling of the non-linear transfer function is attempted:

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[71] NLM, *Non-Local Means Algorithm at* http://imaging.cmc.msu.ru/pub/MusicalNoise07.pdf and http://www.izotope.com/tech/aes_suppr/LukinTodd_AES123.pps and its practical implemntation at *Smoothing and Musical Noise Reduction,*a http://izotope.fileburst.com/guides/iZotope_RX_Restoration_Guide_v_1.pdf

[72] see H. E. Roys, editor. *Disc Recording and Reproduction.* Dowden, Hutchinsonand Ross, Inc., Stroudsberg, Pennsylvania, 1978.

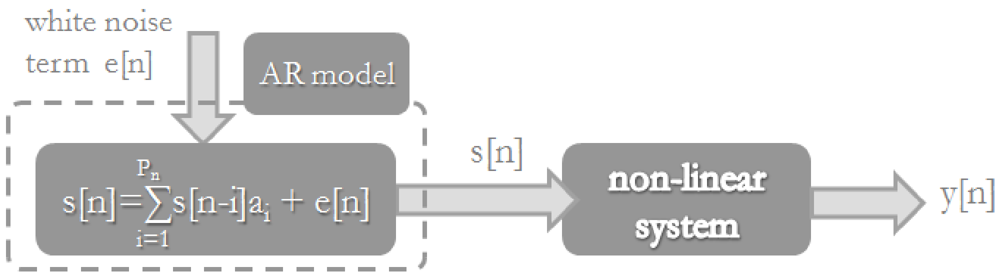



**Image 27. Detection and reduction of nonlinear distortion (Godsill 1998)**

There are basically two types of models

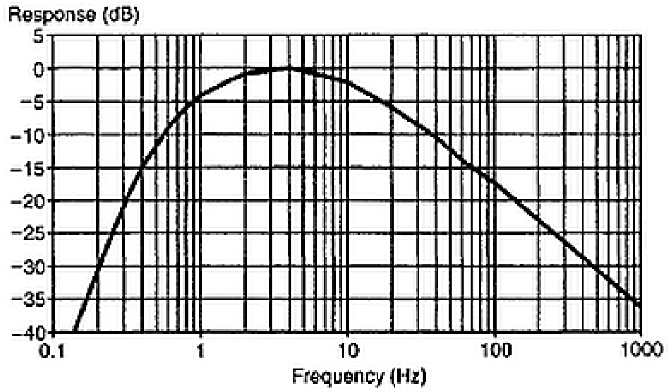
- non-linear AR models without memory (AR-NML)
  - only take into account instantaneous distortion of the original signal s [n]
  - based on Volterra series without memory (parameters h, k)

- non-linear AR models with memory (AR-NAR)
  - needed to memorize feedback distortion disturbances
  - distorted output x [n] depends on original s[n] and the weighted previous outputs, $a_i$x[n-i]
  - suitable to detect and reduce feedback effect of distorted sound effects from a guitar amplifier, or the hysteresis curve effect on a saturated tape, for instance

In both models, the correct estimation of the weighting parameters for s[n] and x[n-i] is a key factor for the final outcome.

6.9.5. Detection and reduction of pitch variation

Commonly referred to "wow" and "flutter" disturbances, pitch instabilities are often encountered when playing back carriers based on rotational transport motors (as it is the case for all analogue playback artefacts). 'Wow" broadly refers to any low-frequency pitch modulation which becomes psychoacoustically most disturbing at modulation frequencies around 4Hz. 'Flutter' will commonly refer to higher-frequency pitch modulation, being similar to a "tremolo" effect. Such HF disturbances would actually be most disturbing at around 100-200Hz.




Wow & Flutter Weighting Curves (IEC 386)

IEC386 Wow & Flutter Weighting

| Hz | dB | Tolerance |
|---|---|---|
| 0.2 | −30.6 | +10-4 |
| 0.315 | −19.7 | ±4 |
| 0.4 | −15.0 | ±4 |
| 0.63 | −8.4 | ±2 |
| 0.8 | −6.0 | ±2 |
| 1 | −4.2 | ±2 |
| 2 | −0.9 | ±2 |
| 4 | 0 | 0 |
| 6.3 | −0.9 | ±0.2 |
| 10 | −2.1 | ±2 |
| 20 | −5.9 | ±2 |
| 40 | −10.4 | ±2 |
| 63 | −14.2 | ±4 |
| 100 | −17.3 | ±4 |
| 200 | −23.0 | ±4 |

**Image 28. IEC 386 wow and flutter weighting curves (Talbot-Smith 1999: 3-104)**

Specific causes of wow and flutter are various:

- variation of the rotational speed superimposed at the recording stage (thus recorded in the carried waveform) or generated during playback
- eccentricity in the carrier's shape, i.e. non-centred holes in the case of discs, or uneven inner diameter in the case of cylinders
- unevenly stretched magnetic tape carriers, especially for PVC and polyester tape bases (mostly excluding cellulose acetate bases) due to excessive tape tension

Even though disc centring will minimize wow at the analogue playback stage, for the rest of cases digital processing is needed.

Godsill (Godsill 1993) establishes the basic approach to pitch correction which has been followed, with improvements, by state-of-the-art commercial applications[73].

The idea behind Godsill's approach is to consider the physical mechanism behind *wow* a non-uniform warping of time axis, were an original undistorted signal s(t) is being warped in time by a warping function $f_w(t)$. This results in a "wobbled" signal x(t). If this warping function could be retrieved, so would the original signal s(t)

[73] see the following sources

- Celemony Capstan Wow&Flutter Removal - http://www.celemony.com/cms/index.php?id=capstan&L=2
- Plangent Processes - http://www.plangentprocesses.com/faq.htm
- *DSP Techniques for Determining "Wow" Distortion (Abril 2007) J. Audio Eng. Soc., Vol. 55, No. 4* - http://www.prestospace.org/training/images/GUT_070401_JAES.pdf

$$\boxed{x(t) = s(f_w(t)) \rightarrow s(t)\ )\ x(f_w^{-1}(t))}$$

A wow restoration system would be thus concerned with estimation of $f_w(t)$ in order to retrieve a pitch variation function $p_w(t)$, where $p_w(t)=f'_w(t)$ represented as $p_w[n] = p_w(nT)$ in the digital domain. As pitch change can be achieved modulating the sampling frequency value accordingly, digital resampling operations will be involved.

As pitch variations actually imply variations in the harmonic content of the signal, the problem can be approached using sinusoidal modelling, to model as sinusoids the tonal components of both the distorted -x(t)- and undistorted -s(t)- signals. Then, wow will be affecting the whole signal to the same ratio, frequency-modulating *all spectral components with frequency $w_i(t)$ by the same amount $p_w(t)$ at the same time.*

Three stages are needed

- estimation of tonal components (spectral peaks detection) to get time-frequency patterns or "tracks"
- extraction of smooth pitch variation information from the time-frequency tracks
- re-sampling (sample-rate conversion)

The first stage could be implemented in many ways, but the goal is to establish the onset and end of individual tones, which will be considered stable within the STFT temporal window (time-frequency resolution).

The second stage allows for discrimination among non-original frequency modulation (wow and treble), original frequency modulation -which could be for instance musical vibrato, tremolo or combinations of both- and finally, tracking errors due to limited resolution. Thus, the tracked ith tonal component within a frame will have a $f_i[n]$ frequency value, as combination of the following terms

$$\boxed{\left.\begin{array}{l} f_i[n] = f0_i + p_w[n] + v_i[n] \text{ for } b_i \leq n \leq d_i \\ \\ \qquad = 0 \text{ otherwise} \end{array}\right\} 1 \leq i \leq P_{max}}$$

where

- $f_i[n]$ – detected frequency
- $f0_i$ – nominal centre frequency, assumed fixed over the period of interest $b_i \leq n \leq d_i$
- **$p_w[n]$ – pitch variation value, due to wow & flutter**
- $v_i[n]$ – noise component, due to

  - inaccuracies in frequency tracking
  - genuine/particular pitch deviations due to vibrato, etc.
- $b_i$, $d_i$ – 'birth' and 'death' of the tracked frequency, where $b_i$ and $d_i$ indicate the first and last frame window where the tone is present. Ith track length $N_i = (d_i - b_i) + 1$
- $P_{max}$ – total number of tonal components tracked in the interval of N data blocks (window frames)

Once known the pitch variation function $p_w[n]$, the corrected pitch will follow a new playback sample rate conversion (third stage) where $f_s' = f_s'^* p_w[n]$.

As previously stated, sinusoidal modelling will have it more difficult handling highly stochastic signals such as voice, or even music with frequent sliding tones, and this constitutes not only a theoretical but also a practical limitation for commercial implementations of pitch correction (see Celemony *Capstan*).

## 6.10. Other related state-of-the-art technologies applicable to audio restoration

Which is the place for new technologies such as blind deconvolution, bandwidth extension, spectral band replication (SBR)[74], audio inpainting[75], (blind) source separation, audio enhancement and similar approaches in the world of audio archiving?

A detailed technical description of the state-of-the art is beyond the scope of this work and the reader is referred to the bibliography, the discussion being actually centred more into

- methodological and ethical questions

  Which of these techniques fail into unintentional or intentional restoration domains? Once into real applications, are such limits clear enough? (see 10. Conclusions and future work for more reflections)

- its applicability in the proposed case studies

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[74] see Novak, C. *"Spectral Band Replication and AAC+ Coding . An overiew"*. http://telos-systems.com/techtalk/aacplus/aacPlus_overview.pdf

[75] see Adler, Emiya, Jarafi, Elad, Gribonval, Plumbley (March 2011): *Audio* Inpainting. INRIA. http://www.eecs.qmul.ac.uk/~markp/2012/AdlerEmiyaJafariEGP12-audio-inpainting_accepted.pdf

We have tried blind source separation and bandwidth extension and retrieved revealing information from the original audio content, often hidden under the constraints of the recording media and artefact's limitations of the time (see 8.7.3 for more detail).

## 6.11. List of most used commercial tools for audio archiving and restoration

Here it is a non-comprehensive list of the most popular commercial utilities that implement the above mentioned approaches for audio restoration. As in the previous chapter, the reader is referred to the manufacturer documentation, patents and white papers for further information.

- CEDAR Audio. http://www.cedar-audio.com/
- iZotope. http://www.izotope.com/products/audio/rx/
- Celemony Capstan. http://www.celemony.com/cms/index.php?id=capstan
- Zynaptiq Unfilter. http://www.zynaptiq.com/unfilter/faq/
- Waves Restoration. http://www.waves.com/content.aspx?id=197&l=4
- Wave Arts. http://wavearts.com/
- Sonnox. http://www.sonnoxplugins.com/pub/plugins/products/restore.htm
- BIAS. http://www.bias-inc.com/
- Diamond Cut. http://www.diamondcut.com/store/index.php
- Dart Pro. http://www.dartpro.com/index.html
- Sonic Studio. http://www.sonicstudio.com/sonic/products/sonic_nnproductoverview.html

On the other side, some utilities help to the analysis and (music) information and metadata retrieval

- Fraunhofer IDMT's A/V Analyzing Toolbox. www.idmt.fraunhofer.de/en/Service_Offerings/technologies/a_d/av_analyzing_toolbox.html
- Cube-Tec Quadriga Audiofile-Inspector. http://www.cube-tec.com/en/products/media-inspector/audiofile-inspector
- Noa Audio Solutions. http://www.cube-tec.com/en/products/media-inspector/audiofile-inspector
- Audio Inspector. https://www.audioinspector.com/

# 7. Administrative/Technical Metadata

## 7.1. BeXT field (BWF) and ID3 tags (MP3)

One of the main advantages of the BWF[76] format (extension *. wav) for sound files in the field of preservation is the ability to introduce metadata in the BeXT chunk of the file itself[77], particularly descriptive metadata and administrative/technical metadata. This metadata should refer to detailed information about the inspection, cleaning, reproduction, scanning and post-production processes carried out. Some of these metadata fields can be eventually be inherited in ID3 tag files (or similar) for perceptual coders like MP3, MPEG, AAC or Ogg Vorbis, among others, as well as lossless FLAC or Monkey's Audio (APE).

| **main parameters from the BeXT (Broadcast audio eXTension) chunk (BWF files)** | |
|---|---|
| **field** | **description** |
| Description | ASCII string (maximum 256 characters) for a free description of the sequence |
| Originator | ASCII string (maximum 32 characters) containing the name of the originator/ producer of the audio file |
| OriginatorReference | ASCII string (maximum 32 characters) containing an unambiguous reference allocated by the originating organisation (UID - unique identifier) |
| OriginatorDate | 10 ASCII characters containing the date of creation of the audio sequence. The format shall be « ‘,year’,-,’month,’-‘,day,’» |
| LoudnessValue | 16-bit signed integer. $LU_{FS}$ |
| LoudnessRange | 16-bit signed integer. LU |
| CodingHistory | Unrestricted ASCII . Description of a coding process applied to the audio data |

**Table 8. Main parameters of the field BeXT (Broadcast Extension Chunk) BWF file types**

It is worth repeating here paragraph 7.4 of the IASA TC-04 which refers to the basic metadata that should be included with an audio file:

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[76] see https://tech.ebu.ch/docs/tech/tech3285.pdf

[77] one useful tool to be cited for metadata integration into a BWF files is *BWF Meta Edit*, a public domain software downloadable at http://sourceforge.net/projects/bwfmetaedit/. For guidelines on metadata imbrication within BWF files, see http://www.studiodaily.com/2009/07/guide-to-broadcast-wave-file-software-utilities/ and http://www.digitizationguidelines.gov/guidelines/digitize-embedding.html

## 7.2. List of basic metadata

*"… A detailed metadata record of all technical, process, provenance and descriptive aspects is a vital part of the preservation process (…)"*

- ***Unique Identifier****: Should be structured, meaningful and human readable as well as unique. A meaningful identifier can also be used to relate objects like: master or preservation files and distribution copies, metadata records, series, etc where a sophisticated system will manage that in the metadata.*
- ***Description****: Description of the sound sequence. A small amount of text to simply identify the content of the audio file.*
- ***Technical Data****: Format, sampling rate, bit rate, file size. Though this information can be acquired later, making it an explicit part of the record allows management and preservation planning of the collection.*
- ***Coding History****: In BWF a number of discrete lines of information describing the original item and the process and technology of creating the digital file that is being archived. (See also 3.1.4 Metadata).*
- ***Process errors****: Any error data which the transfer system can collect which describes failings in the transfer process (e.g. uncorrectable errors in CD or DAT transfers).*

*The information described in Unique Identifier, Description, and Technical Data can be recorded in Dublin Core records or the BWF headers. Coding History and Process errors can be recorded in the BeXT chunk of the BWF headers or in related XML encoded documents (…)"*

Although metadata imbrication within audio file formats such as BWF is highly recommended, it should be reinforced according to the recommendations held by the IASA guidelines. Thus, information included in the chunk BeXT BWF should be complemented, broadened or redounded in an external database according to the METS standard (XML file format).

## 7.3. OAIS Model

Under the OAIS model (Open Archival Information System), the generation of master files (master copies), reproduction copies (playback copies) and lower resolution broadcast copies (dissemination copies) with possible perceptual coding relies on specific ontologies. Thus, the container object (disc) would generate a first *Submission Information Package* or SIP that, once ingested into the digital broadcasting, would become an *Archival Information Package* or AIP, containing the digital master with associated metadata. In addition, reproduction and/or dissemination copies for potential end users will be handled a *Dissemination Information Package* or DIP.

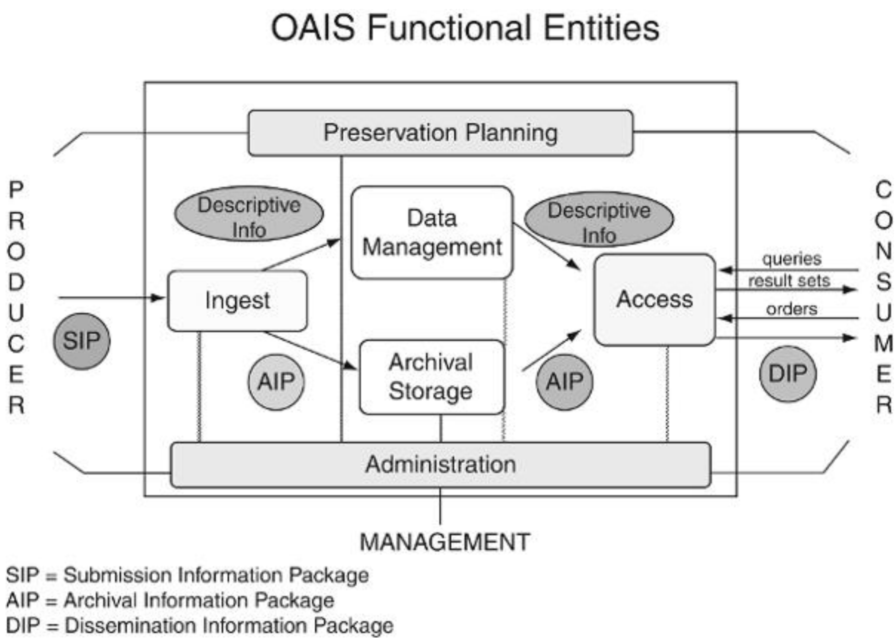


**Image 29. OAIS functional model of the system**

Monitoring the implementation of the OAIS model is also important. Theoretical concepts and best practices in the design, implementation and maintenance of digital repositories are included in the concept Trusted Digital Repositories (TDR), proposed by the OCLC (Online Computer Library Center - USA)

- theoretical framework - Trusted Digital Repositories: attributes and responsibilities (TDR)
- implementation - *Trustworthy Repositories Audit & Certification (TRAC)*

# CASE STUDIES

## 8. Berliner disc 64508/2110A "*Els Segadors*"

### 8.1. Historical context and finding

The Music Museum of Barcelona (www.museudelamusica.bcn.es), holder of a valuable legacy of historical sound recordings, decided in late 2011 to undertake the digitization of the disc collection from Catalan violinist Joan Manén i Planas (Barcelona, 1883-1971), one of the greatest world virtuosi of his time, as well as conductor and composer.

During a comprehensive review of these holdings, conducted together with the librarian Sara Guasteví, a total of twenty five 78s, mostly shellacs but also lacquer and radio transcription gelatine discs, were set aside for digitisation. The collection featured interesting items, but one of them stood out: a Berliner 7 inch (17.8 cm) disc, about 2mm thick, recorded on one side, the only record of its kind. The record was found in a case for standard 12-inch discs, inside a 10-inch plain paper sleeve, located in one of the tabs of the case along with other 10 and 12-inch discs. Carved in the inner disc area it could be read:

**Spanish Coro y Orquesta**

**Los Segadors – Himno Catalan**

**Cantado por el Coro Catalunya Nova**

**Barcelona**

What is its intrinsic value as a historical document? Who recorded where and when? What is the audio content? What criteria should be followed to reproduce, digitize and eventually restore it?

The following pages seek to answer these and other questions detailing the research conducted to date, from the discovery and historical research to its reproduction, digitization and restoration.

### 8.2. Dating and cataloguing the disc

A close inspection of the disc retrieves valuable information.

The surface shows the well-known "recording angel"[78], an anagram that from 1902 would distinguish Berliner discs manufactured by the UK branch of The Gramophone Company from those made in the U.S. or Canada[79].

Apart from the recording angel, the following information can be read:

| | |
|---|---|
| **recording company** | *E. Berliner's Gramophone. Covered by English & Continental Patents.* |
| **catalogue number** | *64508* |
| **matrix number** | *2110A*[80] |

**Table 9. Catalogue and matrix numbers of the Berliner disc**

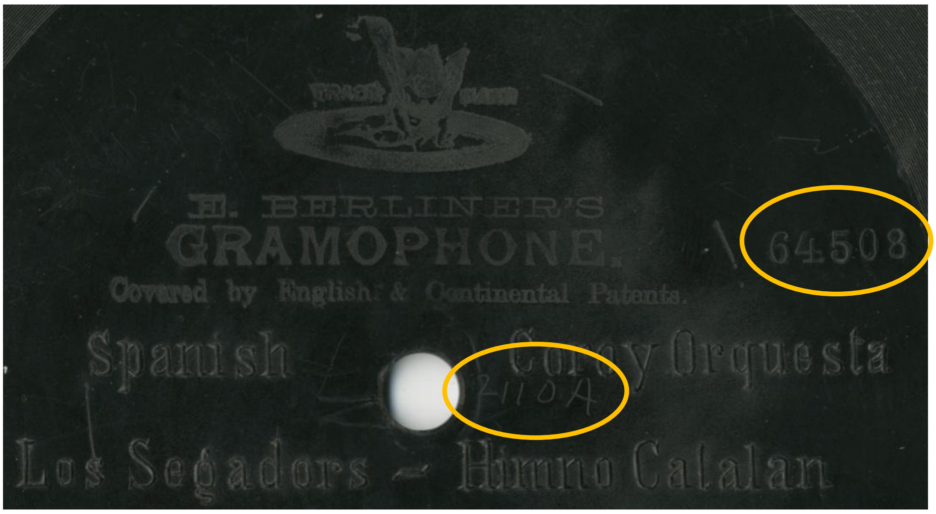


**Image 30. Details of the Berliner catalogue number -64508 - and below, originally engraved in the zinc matrix and consequently pressed in the shellac copies, the matrix number 2110A**

The rear side shows an inscription, in uppercase letters, which refers to the pressing plant were the disc was duplicated: *REPRODUCED IN HANOVER* (traditional English spelling).

As it is known, the first discs records were produced by Emile Berliner (1850-1929), a German immigrant, initially through the *United States Berliner Gramophone Company*, established in 1892 with headquarters in

[78] Theodore Birnbaum, the Gramophone Company managing director in Berlin, had the original idea to represent an angel carving the sound grooves with a feather. From 1898 on, this "recording angel" became a registered trademark for gramophone recordings and reproducing devices (see http://www.flickriver.com/photos/w77t/5925138685/)

[79] valuable information can be found in Torrent, Antoni (2009): *Girant al voltant dels Berliner's*. – http://www.aspe.cat/Butlleti3/But3-1.htm (in Catalan)

[80] hand-engraved, as all Berliners up to 1903 (source: Franz Lechleitner, Phonogrammarchiv Wien)

Washington DC[81]. Even though initially supplying foreign markets with discs recorded in the United States, it was soon seen the opportunity to produce recordings abroad, and with this goal travelled to London the North American musician, sound engineer and producer Frederick William Gaisberg (1873-1951), who was soon joined by fellow American William Sinkler Darby (1878-1950) as an assistant. In 1897 the Gramophone Company Ltd. was founded in London and first European disc recordings were made, all but pressed at the same factory in Hanover, Germany.[82]

The whole of those first recordings carried out in Europe by the Gaisberg/Sinkler Darby team, together or separately, fall generally into two periods: the so-called first (1899) and second continental tours (1900).

**Image 31. Fred Gaisberg (right) and William Sinkler Darby (smoking a pipe) writing letters from his hotel room in Vienna, which also served as recording studio (June 1899). In the background on the right hand-side the recording equipment is seen. Source http://soundofthehound.com/tag/william-sinkler-darby/**

It was precisely during the second continental tourthat will take place in Barcelona, among others, the recording of "*Els Segadors*."

[81] see http://memory.loc.gov/ammem/berlhtml/berlgramo.html

[82] see Hugo Strötbaum's documents at http://www.recordingpioneers.com/docs/GAISBERG_DIARIES_1.pdf

8.2.1. The catalogue number: 64508

Researcher Alan Kelly gives account, in his monumental revision of the Gramophone Company/HMV archives from 1898 to 1930 (since 1931, part of EMI), of the catalogue number 64508 as part of the production recorded in the Iberian Peninsula[83], which covers the numerical range from 60,000 to 69,999.

| Gramophone catalogue | Numbers |
|---|---|
| English (London headquarters) | 00001 to 09999 |
| Orient | 10000 to 19999 |
| Russia (Poland, etc.) | 20000 to 29999 |
| France | 30000 to 39999 |
| Germany | 40000 to 49999 |
| Italy | 50000 to 59999 |
| **Iberian (Spain and Portugal)** | **60000 to 69999** |
| Czech-Hungarian | 70000 to 79999 |
| Scandinavia | 80000 to 89999 |
| Dutch-Belgian | 90000 to 99999 |

**Table 10. General Catalogue of the Gramophone Company. Structure of the Gramophone Company and Its output (2000). Alan Kelly**

As detailed in Kelly 2000:5, almost from the beginning the company was organized into ten branches, even though the terminology used with some freedom. The company shared the Victorian tendency to classify everything.

| Catalogue numbers (after geographical prefix) | Type of record |
|---|---|
| 0001 - 0499 | Band |
| 0500 - 0999 | Orchestra |
| 1000 - 1999 | Talking |
| 2000 - 2999 | Male solo voice |
| 3000 - 3999 | Female solo voice |
| 4000 - 4499 | Duets, Trios, etc. |
| **4500 - 4749** | **Chorus** |
| 4750 - 4999 | Choir (sacred) |
| 5000 - 5499 | Cornet |

[83] see Kelly, Alan a(2000). *Structure of the Gramopohone Company and its outp – HMV and Zonophone* - http://charm.cchcdn.net/redist/pdf/general_introduction.pdf

| | |
|---|---|
| 5500 - 5999 | Piano |
| 6000 - 6249 | Clarinet |
| 6250 - 6499 | Banjo |
| 6500 - 6699 | Bagpipes with drums |
| 6700 - 6749 | Bugle calls |
| 6750 - 6999 | Xylophone |
| 7000 - 7249 | Trombone |
| 7250 - 7549 | Mandoline |
| 7550 - 7699 | Bassoon |
| 7700 - 7849 | Bagpipes |
| 7850 - 7899 | Cello |
| 7900 - 7999 | Violin |
| 8000 - 8499 | Concerted instruments |
| 8500 - 8999 | Balalaika |
| 9000 - 9099 | Piccolo |
| 9100 - 9149 | Harmonica/Concertina |
| 9150 - 9249 | Flute |
| 9250 - 9799 | Diverse & Sundries |
| 9800 - 9999 | Viola |

**Table 11. Types of records ("branches") of the Gramophone Company. Structure of the Gramophone Company and Its output (2000). Alan Kelly**

The catalogue number 64508 of the Berliner disc *Els Segadors* matches the style of choral music classification determined by the Gramophone Company. It can be thus presumed that number '08 ' refers to the 9th Berliner disc classified as choral music (not sacred) ever recorded in the Iberian Peninsula.

Specifically with regard to the production of non-sacred choral music in the 7" disc format, Alan Kelly refers to the following numbering in his Spanish Catalogue:

| **Type of record** | **Gramophone Company 7" discs - catalogue numbers** |
|---|---|
| Choral (non-sacred) | 64500 to 64549 |

**Table 12. Special numbering for choral 7" records production from the Gramophone Company. The English Catalogue (2006). Alan Kelly**

We can thus deduce the existence of some 50 original discs with choir recordings over 7-inch Berliners.

8.2.2. The matrix number: 2110A

In the same way that the catalogue number gives us clues about the "official" story of the recording, the matrix number can shed light over more subtle evidences. Unlike the catalogue number, printed in relief with every disc copy produced, the matrix number was originally chiselled by the same recording technician onto the master disc (be it zinc, as was the case until mid/late 1900s, or wax). The cataloguing policy and guidelines that guided the matrix numbering vary over the years.

Table 1 Indicating Letters and the Experts Who Used Them (All Countries):

A. General System in Use, 1898 to 1921

| Expert | 7" size | 10" size | 12" size | Notes |
|---|---|---|---|---|
| F W Gaisberg | -; a | b | c | - = zinc ; a/b/c = wax |
| W C Gaisberg | Con 1/d<br>Rad0100 | Con100/e<br>Rad 0500 | Con500/f | Con (1903)<br>Zono issues (1903) became d/e/f |
| W S Darby | A; B/g | x/h | y/i(j) | A zinc ; B/x/y became g/h/i |
| F Hampe | C/k | z/l(L) | Hp/m | C/z/HP became k/l/m |
| C Wallcutt | F/n | F/o | F/p | F became n/o/p<br>(Comp. Française du Gram.) |
| M Hampe | g | r | s | |
| C Scheuplein | 7001F/t | 7001F/u | 7001F/v | F became t/u/v<br>(Comp. Française du Gram.) |
| A S Clarke | x | y | z | |
| A Hancox | aa | ab | ac | |
| E J Pearse | ad | ae | af | |
| H Murtagh | ag | ah | ai (aj) | |
| G Dillnutt | | ak | al | |
| W J Beckwith | | am | ar | |
| B G Royal | R | R | R | used within other series |

a. The e/f series were used by W C Gaisberg until the end of 1910, after which the letters were used to indicate London recordings by whichever expert was working there; the expert in residence at the time then put his own indicating letters as a prefix to the matrix number, as with z5283f.

b. Short series suffixed g/h/i were used in Berlin in 1905; these are not part of the regular x/h series.

c. When a second studio was opened in London, its products were prefixed HO (Head Office). Two separate matrix series were used, one for 10" and the other for 12" recordings. Each carried the indicating letters of the expert then in charge as a suffix - thus HO 116 ae and HO 199 af.

**Table 13. General matrix code system used by the Gramophone Company, 1898-1921. Framed in red suffixes used by Sinkler Darby. Alan Kelly, The French Catalogue. Greenwood Publishing Group**

As shown highlighted in red in the table above, the suffix "A" refers to the sound technician, in this case William Sinkler Darby, as well as to the disc diameter (7 inches) and the recording process, still carried out on a zinc matrix (as opposed to the prefix "B", to distinguish it from later recordings Sinkler Darby made on wax masters[84]).

[84] see Kelly, Alan (2000): *Structure of the Gramophone Company and its Output* - http://charm.cchcdn.net/redist/pdf/general_introduction.pdf

William Sinkler Darby, at the time a young man just turned 22 in Barcelona, carried out recordings in this city from September 27 to October 30 1900[85], recording a whole set of 175 matrices, according to data provided by Antonio Massísimo and collected at Jones 1995: 32-36. These recordings began with the matrix numbers 2063 and 2064 (with corresponding catalogue numbers 62500 and 62501[86]) and concluded, according to researcher Susana Belchior[87] and also corroborated by Kelly, with the matrix number 2230. Both Jones 1995: 34-36 and Torrent 2009 refer to a total production of 104 discs, so that would rule out 71 faulty matrixes. It is worth recalling that there is not faithfully sequential correlation between catalogue numbers and matrix numbers, so we cannot infer general relationships.

It is worth transcribing some of the information previously collected by Daniel E. Jones and Jaume Queralt (Jones 1995, 34-36):
*"A year later, in September and October of 1900, another technician sent from London by the Gramophone Company, the young American William Sinkler Darby, probably made in the* Casa Provincial de la Caritat*, the* Teatro Gran Vía*, the* Palau de les Belles Arts *and some hotels in Barcelona, what can be considered as the first commercial musical recordings made in* Catalunya. *Darby hired seventeen different performers in the country, recording 175 arrays of all types of genres -sardana, mazurkas, operettas, xotis, Catalan songs, flamenco-71 of which were considered faulty, to obtain a final number of 104 discs[88] (...) "* .
It continues stating out that *"all disks were Berliners, 12.5 cm in diameter[89], 75-85 rpm, single-sided recorded, without paper labels -the recording info directly engraved on the shellac, surrounding the central hole-,*
*pressed in Hannover, with an initial edition of about five hundred copies to be sold in Catalunya from April 1901. "*

The recorded works are also mentioned, among which we will refer just to those by the *Societat Coral Catalunya Nova*[90]: "Catalunya Nova *would record the* Benedictus *of the* Missa de Glòria *as well as nine catalan tradicional songs,*

[85] as stated by Susana Belchior and Franz Lechleitner, the matrix number 2231A has not been found, and the next one (2232A) appears recorded in Lisbon the same year 1900. Information obtained during the *78 rpm Shellac Digitisation and Restoration.*course held in ERESBIL. Errenteria, 14-16/3/2012 -
http://www.aedom.org/_web/images/pdf/cursos/franz_lechleitner_curso.pdf

[86] it is worth noting that the original text refers to catalogue numbers '6250' and '6251, where Kelly's documentation refers to 625**00** and 625**01,** following the *Gramophone Company* cataloguing system at the time

[87] researcher at the Instituto de Etnomusicologia. Centro de estudos de música e dança, Lisboa

[88] even though other sourcer refer to 94 recordings instead – see Hita Maldonado 2002:31, as also the article *Arte Regional* by Pau Vernon, at the *Folkroots* magazine*,* number 157 - http://bolingo.org/audio/texts/fr157flamenco.html

[89] that would correspond to 5-inch discs, although all discs recorded by Sinkler Darby in Barcelona were, according to Kelly, 7-inch – that is, 17,8cm

[90] it should be noted that by the same days of 1900, Sinkler Darby also recorded the rival ensemble, *l'Orfeó Català*, although not *Els Segadors* neither any other patriotic song of the time (see Kelly, A. (2006): *The Spanish Catalogue*)

*including Els Segadors (subtitled as* Himne Català*),* L'Hereu Riera*,* Crit de Pàtria*,* La mort de la Núria *and -divided in five discs-* Los nets dels Almogavers *with the ominous subtitle* Rigodón bélico*)*."

Jones 1995: 34, according to data from Massíssimo, refers to a total of 24 matrixes recorded by *Catalunya Nova*, from which only 14 discs would become published. Of these 14 discs, *Els Segadors* would be first registered with the lowest catalogue and matrix numbers. However, Antoni Torrent -in his article "*Anem pel bon camí*"[91]- attributes to *Catalunya Nova* one recording that both Jones and specially Kelly (MAT101 matrix numbers and CAT6 catalogue numbers) include to the output of l'*Orfeó Català* (Berliner 64521/2189A, a recording of the popular catalan song *La Filadora*). If it were so, we should be talking of fifteen discs instead of fourteen. According to Torrent 2009 and up to now, with the rediscovered disc of *Els Segadors*, unfortunately only four of *Catalunya Nova* Berliners have been located (apart from *Els Segadors,* the other three are *Els tres tambors* 64512/2115A, and the first -64514/2206A- and second discs -64515/2208A- of *Los nets dels Almogavers*).

It is worth noting Jones statement (Jones 1995, 34-36) according to which Sinkler Darby himself hired the different performers, which in turn would give him and the Gramophone Company the initiative –the executive production, at least- of the recordings. They are pending to clarify the local intermediaries –their names and their modus operandi -between the sound technician and the recorded ensembles.

In the quoted text, Jones refers to a playback speed of 75-85rpm. It is appropriate to emphasize the difficulty of specifying in advance the playback speed of such Berliners, as there was no formal standard. This matter will be further developed in 8.5.7.

Finally, we should also include the following excerpt from Torrent's article "*Els primers enregistraments a casa nostra*" (Barcelona 2009) as it gives insight of the recording activity of those times, as well as an historical context:

*"The only existing disc record producer in the market, the "Berliner's", began its production in our land during the last year of the nineteenth century, in 1900. It recorded 175 matrices, of which 71 were rejected as defective and, therefore, pressed 104 records. Such discs are single-sided. In the pressed side one sees the Recording Angel, the* Berliner's Gramophone *brand with specific information recorded by hand using a needle. On the back side it can read "Reproduced in Hanover."*

*In this set of recordings were involved, among others:*

[91] Torrent, A (2009): "*Anem pel bon camí*". http://www.fonovilassar78.com/articles/som21.pdf and http://www.fonovilassar78.com/articles/som21.pdf

- L'Orfeó Català *which, aside religious music, will record the zarzuela* El Maestro de obras, *the dance* Marina *and* La celadora, La pastoreta, Los Xiquets de Val's *and* El cant dels cells
- *The* Cur Catalunya Nova *records the* Benedictus de la Missa de Glòria *and nine Catalan songs among which Els Segadors (subtitled as* Himne catalpa*)* – L'hereu Riera – Crit de Pàtria – La mort de la Núria - Los nets dels Almogavers *with the ominous subtitle* Rigodón bélico

*Fortunately I own a record of this coral. It's the song "*Els tres tambors", *which sounds great. It is a very didactical disc that makes you think over.*

- La Banda de la Casa de la Caritat de Barcelona *recorded six "sardanes": two versions of* La platja de Riells, Montserrat, Mercedes, Maria Cristina *and* Garin. *Also recorded three havaneras, two chotis, two malagueñas one mazurka and one "American" piece entitled "*Despedida*"*

*It is quite surprising that six out of these last 15 recordings were sardanes, at a time when there dance was not as popular in Barcelona. Rather, it was a popular dance for low-class peasants –i.e. with few financial resources.*

*Back in those times, a small disc recorded on one side and containing a maximum of 2 minutes of music would cost 4 pesetas. A normal disc of 25 cm in diameter -also recorded on one side with a maximum of 3'30" of music- would cost 8 pesetas. I think that an average wage of the time would not make 5 pesetas per day, so owning a gramophone player was a luxury only available to wealthy people not interested in sardanes, as it was for them a peasant and pastoral music. (...)*
*It would really be great to find some of these discs. I do not lose hope. With the collaboration of people, patience and perseverance, anything is possible."*

## 8.3. Significance of the recording

There are many and recent studies related to the origin of the popular song *Els Segadors* (see full citation of Ayats 2011, Anguera 2010 and Massot 1983, among others). So are the references in relation to the blooming choral movement of the turn of the century, as also to *catalanism* as a cultural and political movement in a broader sense (especially Marfany: 1987 and 1995: 307-321). We should also mention the work focused on the history and significance of the *Societat Coral Catalunya Nova* (Alier 1973, 1975) and the leading figure of conductor and composer Enric Morera (1865-1942).

These studies emphasize the significance of *Catalunya Nova,* the choir founded and directed by Enric Morera between 1895 and the end of 1900[92], and the musical and sociological contrast it offered to both the *Orfeó Català* (leaded by Lluís Millet) and the *Cors Clavé*. *"[Morera] sought to deeply renew the interpretative ways towards an style that would immediately be his own: a colourful aesthetic of voices that would remain 'in an eternal scream' and that 'vigour'*[93] *of the 'male' temperament of Morera, that never did a piano, in contrast to the Orfeó Català (Esteve Suñol referred for La veu de Catalunya, January 14, 1899*"(Ayats 2011: 69). Morera himself criticized in the second number of the magazine "*Catalunya Nova*" (March 1900) the "pretentious and sugary" interpretations of the Orfeó Català (Alier 1973: 64). Years later (January 1912) he would still insist in the review *L'Aurora* from the Cors Clavé, censoring the style of the *orfeons*, a manner "too soft and flourished". Like Ayats states, "albeit from afar, this allows us to imagine the sound effect of the striking voices Morera advocated, in contrast to the contended and elaborated vocal lyricism of the *orfeons*. These first recordings from those *orfeons* now cause us great aesthetical perplexity, as can be stated from the wax cylinder reproduced in the CD attached "(Ayats 2011: 146).

[92] from 1900 the one, already without Morera and with many ups and downs, its existence is documented up to the end of 1935 (Alier 1973: 69)

[93] original "*brahó*" in a catalan review from January 1900

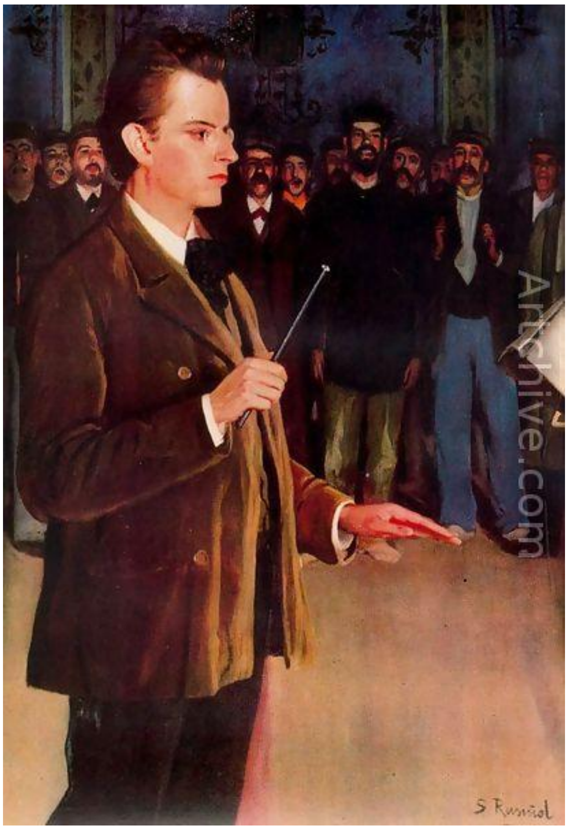


**Image 32. Enric Morera at the age of 31, conducting the choir Catalunya Nova. Painting by Santiago Rusiñol (January-February 1897)[94]. Source www.artchive.com**

The reference to the 1900 recording now recovered is quoted in some of these works. "*It was made at that time the first reported sound recording of* Els Segadors*, which we haven't yet found:* Catalunya Nova *directed by Enric Morera recorded it for the Berliner Company (Torrent 2009). Because the first half of 1900, with the final episodes of the closure of banks and the visit of Minister Dato to Catalunya, it was the annus mirabilis of Els Segadors* "(Ayats 2011: 121)[95].

Now we may compare the newfound version of *Catalunya Nova* with a cylinder recorded by the *Orfeó Català* at an unknown date but in any case slightly later, between the first and second decade of the twentieth century. It is the arrangement by Lluís Millet – performed for the first time in September 28, 1897- with the traditional

[94] see the analysis undertaking by Josep de C Laplana at *Santiago Rusiñol: El Pintor, l'home*. Biblioteca Abat Oliba, Publicacions de l'Abadia de Montserrat (1995), pages 264-265

[95] it should be recalled a recording made from *Els Segadors* made by *Catalunya Nova* significatively later, in 1915, a 78 shellac from Odeon, with the verses sung by tenor Vicenç Estrada the and refrains, at unison, by a male's choir. It can be heard in a digitised version at http://orio43musica.blogspot.com.es/2011/05/cor-catalunya-nova-no-passareu-78-rpm.html, and the key is G minor

lyrics used by the original composer Francesc Alió (Ayats 2011: 88) which can be heard on the CD mastered by the sound engineer Jordi Roquer that accompanies the latest work of Ayats[96].

Indeed, the version of *Els Segadors* contained in the Berliner disc is precisely the harmonized version for four male voices[97] arranged by Enric Morera and first performed by *Catalunya Nova* on 18 July 1897. The lyrics are none but the "new text", also from 1897 and clearly supported by Morera, as opposed to "traditional" performed by the *Orfeó Català* well until the 1930s (Ayats 2011: 85-88). This new text for *Els Segadors* is the work of Emili Guanyavents i Jane (1860-1941). In particular one can hear two rounds of the first verse, with the already traditional refrain "*Bon cop de falç, defensors de la terra!*" proposed by Ernest Moliné i Brasés and repeated at the end of each verse. The contrast between the versions is notorious, and the rivalry between the two choirs at the time is well confirmed if we look at the first performances for both versions, spaced just over two months.
Another look to the press of the time gives us more insight (Alier 1973: 51, quoting a review at the newspaper *La Protección Nacional* from concert given by *Catalunya Nova* at the Teatre Líric, Barcelona 10 February 1898): "*'Els pescadors'* [a work by Josep Anselm Clavé] *conducted by the genius of Morera, excludes all eclecticism, boasting a genuine hallmark never seen in any of other Catalan choirs, resulting more vigorous, more popular, full of life and, overall, more real (...)* "

Comparisons were beyond strictly musical aspects: "if we believe these statements (referring to Morera 1936: 45) we will understand the position of the *Societat Coral Catalunya Nova*: modernist, independentist, popular and republican, with a social penchant towards the working people, however paternalistic this attitude may seem. This was an in-between position: on one side there was, as we have emphasized, the *Orfeó Català*, clearly more a conservative model, traditionalist and prejudiced, and on the other side the movement of the *Cors Clavé*, burdened by historical inertia" (Ayats 2011: 92-93).

Historian Pere Anguera (Anguera 2010: 28:56) documents in great detail the public performances of *Els Segadors*, especially by the emblematic *Orfeó Català* -with the arrangements of Amadeu Vives and especially Lluís Millet, with the traditional lyrics from Alió and Milà i Fontanals- and *Catalunya Nova* -with the arrangement made by Enric Morera and the new lyrics of Emili Guanyavents-, but later on from other choirs too all over the country (Ayats 2011: 96). Such performances were in crescendo, reaching its peak precisely by the middle of 1900, just before the recording of this recently newfound version. Morera's resignation in late 1900 from *Catalunya Nova* to engage himself in the Teatre Líric Català announces also this inflection. The

[96] "Orfeó Català, probably conducted by Lluís Millet, around 1900-1905. Wac cylinder –unique item- preserved at the Biblioteca de Catalunya, Fons Regordosa-Turull (Ayats 2011: 253)

[97] although at a first listening it may recall rather a mixed choir, Cor Catalunya Nova was originally –until 1919, at least- an exclusively male choir, which led us to consider the presence of children or boy's "white" voices in the recording

ever-growing official ban for the public interpretation of *Els Segadors* –a product of its rapid and undeniable position as a National Anthem, as well as for a certain exhaustion due to its very same success- in parallel with the expansion of the Sardana among catalanist circles (Ayats 2011), seem to close this first expansive cycle of *Els Segadors* and adds in turn significant value to the finding of this historical recording.

## 8.4. The unknown date and location of the recording

When, where and how was made the recording of *Els Segadors*?

Regarding its location, it would be sensible to assume two possible scenarios

- any of the sites where Sinkler Darby moved his recording equipment and cited in Jones 1995: 34
- the actual rehearsal room of the cor *Catalunya Nova*

Although we've been unable up to now to determine the location of the headquarters of the *Societat Coral Catalunya Nova* at the time of the recording, we know they were having there a concert on October 13 1900. This information is collected in an anonymous manuscript of 61 pages with the title "La societat coral '*Catalunya Nova*" which includes the vicissitudes of choir from 1895 to 1919 and especially from 1895 to the end of 1900, during Morera's leadership. This document, preserved in the Arxiu Històric de Barcelona (AHB)[98] is the starting point for the rigorous work of the historian and critic Roger Alier (Alier 1973), which reproduces and comments the whole manuscript and from which we've quoted the following passage: "*The 15 August [of 1900] back in this city* [Olot] *and in the Teatre Principal for the inauguration of the "Exposició Regional Olotina" ... and I've found no other celebration or concert until October 13 and this time in their headquarters* [a reference we understand as the choir headquarters]. *And enough for 1900, even though I believe something else was done, though for lack of details I'm finishing this review in this month, but I also have to say that the maestro Morera resigned from the post of conductor of Catalunya Nova for particular reasons*."(Alier 1973: 56).

Unfortunately, the manuscript – written in fact much later to the facts- does not contain any explicit reference to the episode of the recording of 1900 and thus we lose the opportunity to calibrate the real significance that this event had for the choir.

However, if we remember that Sinkler Darby stayed in Barcelona from 27 September to 30 October 1900 and the recording of Berliners 2063 to 2230 is well documented, the event of the recording of *Els Segadors* would

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[98] AHB, Ms. A-289

match appropriately. Would this concert October 13, 1900 in Barcelona a possible occasion for the recording of *Els Segadors*?

Considering the way the recording sessions were held at the turn of the century, with musicians literally dumped on the gramophone horn –something even more difficult in the case of a mass choir of the dimensions of *Catalunya Nova,* around 100 people as we shall read in 8.6.1- a live recording within a public concert is hard to believe As an example we can see the following historical photography, again with Fred Gaisberg (playing the piano) and William Sinkler Darby (on the right-hand side of the image). The soprano is Marcella Lindh (1867-1966), talking with the managing director of the Gramophone Company in Berlin Theodore[99] Birnbaum (see footnote #70).

**Image 33. Recordings of the couple Gaisberg / Sinkler Darby Budapest, 30 May to 15 June 1899. Source http://soundofthehound.com/tag/william-sinkler-darby**
**and http://www.flickriver.com/photos/w77t/5925138685/**

Needless to say, to get a recording of acceptable quality proximity to the recording horn recording was a key factor. This can be demonstrated not only by the horn facing the soundboard of the piano (which is raised, and so the pianist, to reinforce the projection and capture of sound) but also by a second gramophone horn facing towards singer. Is it this second horn part of a second independent recording equipment, or we most likely talking about two horns connected to the same gramophone, for an early and significant example of a "passive multi-microphone" technique?

[99]and not Thomas, as stated in http://soundofthehound.com/tag/marcella-lindh/

Another contemporary example of a Berliner recording equipment of the time is found in the following picture, although it is a fixed equipment installed in the sound studios that the Gramophone Company established in London (1898) and therefore comparatively bulkier to those used in Barcelona.

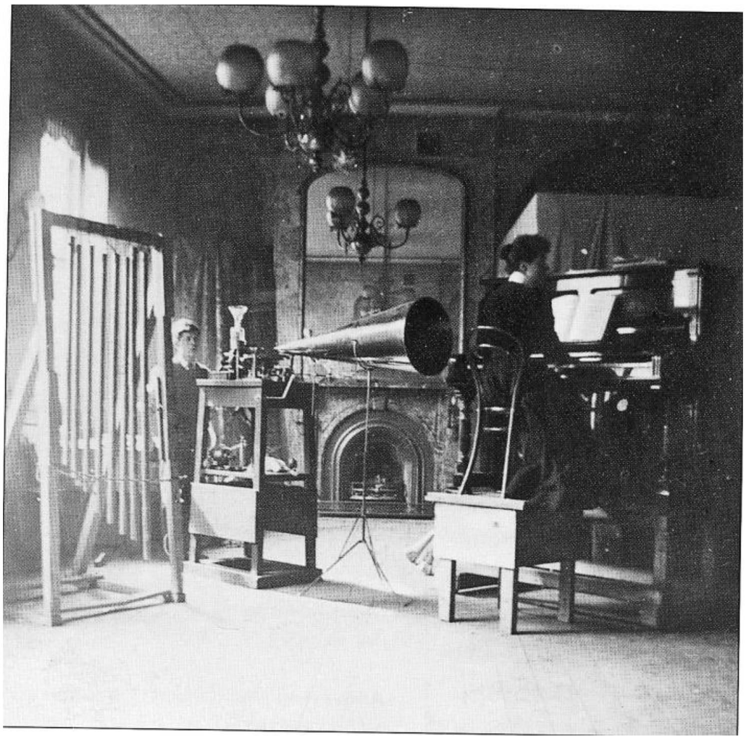

**Image 34. A pianist (sitting on a pedestal to face fit gramophone bell) the first studio recording of Emil Berliner in London, the Cockburn Hotel, Maiden Lane, 1898. Source [http://www.emil-berliner-studios.com/en/chronik1.html](http://www.emil-berliner-studios.com/en/chronik1.html)**

Returning to *Els Segadors*, it should be noted that the limitations as to recording duration (less than 2 minutes) did not allow a complete interpretation of the anthem, which with Emili Guanyavents lyrics already had the three verses we know today. The Berliner recording was thus limited to the repetition of the first verse, and we may interpret this decision as a significant effort aimed at "reinforcing the message", overcoming to some extent the high level of the recording noise over a matrix zinc: psicoacoustically speaking, re-listening to the same verse allows for easier understanding.
These factors actually reinforce the idea that the recording was not taken during a live concert. In contrast, the wax cylinder recorded by the *Orfeó Català* some years after (around 1905 - Ayats 2011: 157) may indeed have been recorded live, or at least not within the controlled conditions of a recording studio of the time.

Despite all the reasons against a live recording, it seems reasonable to assume that the excuse of a concert in Barcelona at the headquarters of the Choral Society in October 13 1900 -the only concert documented in those days- may have served as a catalyst for the actual recordings (not only *Els Segadors*) around this date.

## 8.5. Playing back of a disc of 1900

### 8.5.1. The pressing copy: inspection and duplication methods

The inspected Berliner pressing did not show serious cracks nor longitudinal or transverse scratches that would prevent groove tracking to the settled speed for reproduction, once selected the appropriate needle and cartridge and adjusted the tracking weight and anti-skating parameters.

Taking as a starting point the development of the first Berliners (as already seen in chapter 2.1), we should gain more insight about the characteristics of the electrotyping methods used for duplication at that time, which allegedly allows for 500 shellac pressings of *Els Segadors*. The understanding of such processes helps determine the diameter of the suitable needle for reproduction[100] (see chapter 4.5.3).

The interpretation of the 'A' suffix from matrix code allows us to state that the master of *Els Segadors* by Sinkler Darby was indeed recorded on zinc-based disc type -prior to the adoption of wax as the homogeneous material for master matrixes- coated with a layer composed of a mixture of beeswax and cold gasoline[101], as already explained. From Beardsley[102] we know that "(... ) *after the zinc master was plated with copper in an alkaline bath, the zinc would be removed by sulphuric acid, which does not attack the copper, leaving the copper negative ready for pressing records. Of course, this was a one-trip process, and is the reason why when a recording was deemed likely to be popular beyond the pressing capacity of a single stamper, multiple takes were made of the same selection. It also appears that a process involving lead and graphite as a separating film was tried. This was already in use in the photographic industry, but full details are being researched".* This *one-trip process* would mean that no second stamper could be made from the original zinc master, and thus potential mass-production was limited to the endurance of this unique metal shell. Even though, from 1900 on, with the consolidation of full-wax masters, "*frequently it was possible to re-plate the wax to produce a 'second shell', but it was not always successful, and of course for a very popular record, there was a need for mass replication of shells for use as stampers*". This would finally lead, for as soon as 1903, to introduce the five-step process, perfected around 1918. The key novelty was the possibility of making repeated positive metal duplicates ("mothers") of the original negative ("father") shell that would allow the making of several negative "stampers" and thus real mass-duplication. The advantages of this five-step process were clear, at the expense of "*greater surface noise and a lack of definition if not carefully made*".

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[100] in short, Berliner's disc duplication is a three-step method (master → matrix shell or "father" stamper → pressing), a precursor to the standard five-step method (master → matrix → mother → stamper → pressing) for 78s and vinyls.

[101] although Fred Gaisberg was already using, by May 1900, the "Johnson method" of direct cutting into a 100% wax master (Eldridge R. Johnson, initially Berliner's partner and eventually founder of the Victor Talking Machine Company) – see [http://www.recordingpioneers.com/docs/GAISBERG_DIARIES_1.pdf](http://www.recordingpioneers.com/docs/GAISBERG_DIARIES_1.pdf) and [http://www.thetalkingmachine.com/](http://www.thetalkingmachine.com/)

[102] Beardsley, R (2009): *Waxes, shells and stampers* at CHARM - [http://www.charm.rhul.ac.uk/history/p20_4_7.html](http://www.charm.rhul.ac.uk/history/p20_4_7.html)

As our Berliner was based on a three-step technology process previous to 1900, any further discussion gets outside the scope of this work. We refer to Beardsley and also Field[103] for detailed information.

### 8.5.2. Groove modulation

The recording is monophonic, with lateral (side-to-side) groove modulation, and corresponds to the technology used by Berliner for his gramophone recordings.

This can be confirmed by visual inspection with a stereoscopic microscope. In the pictures below, the upper margins of the two side walls of the groove shape ("V" or rather "U" shape) can be seen, depending on the recording stylus and the cumulative wear and sediment (debris). The bottom edge of the groove will have the highest reflectivity to light. In a lateral groove modulation, the margins of the two walls of the groove are progressing in parallel (mono recording), with a light reflectivity basically constant throughout recorded spiral. In the case of vertical (hill-and-dale) modulation, as it is for Edison cylinders, the incident light is modulated in its width, following the groove width modulation.

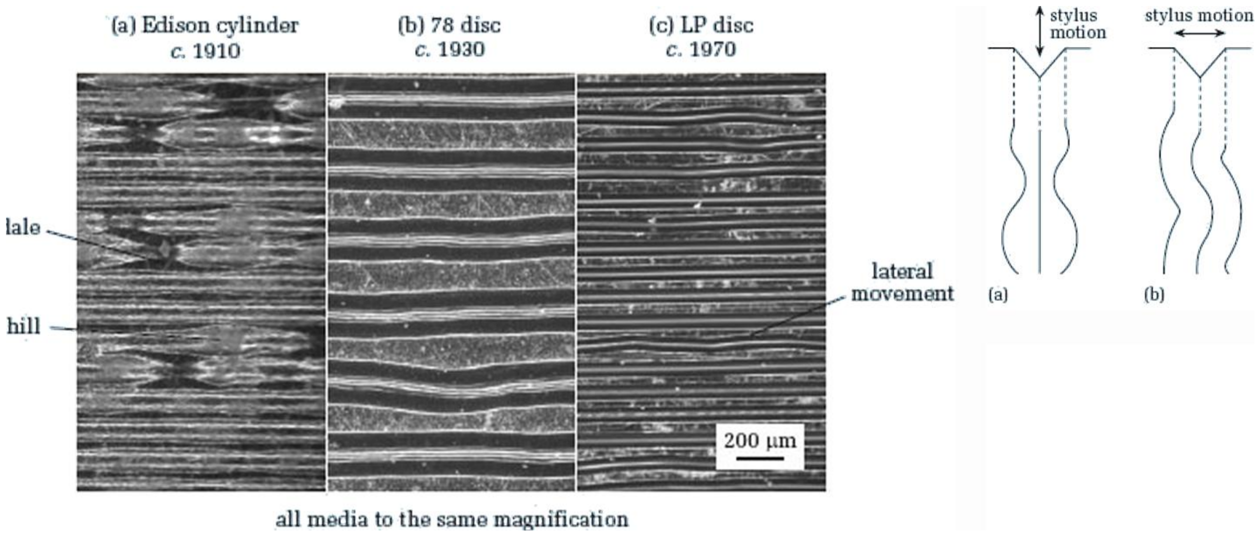


**Image 35. Comparison between vertical modulations (Edison cylinder) and lateral (78s and vinyl records). We can see the different groove density per unit of area. The Open University Learning Space. Source [http://openlearn.open.ac.uk/mod/oucontent](http://openlearn.open.ac.uk/mod/oucontent)**

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[103] Field, Norman (2009): *How were 78rpm records made?* - [http://www.normanfield.com/78manufacture.htm](http://www.normanfield.com/78manufacture.htm)

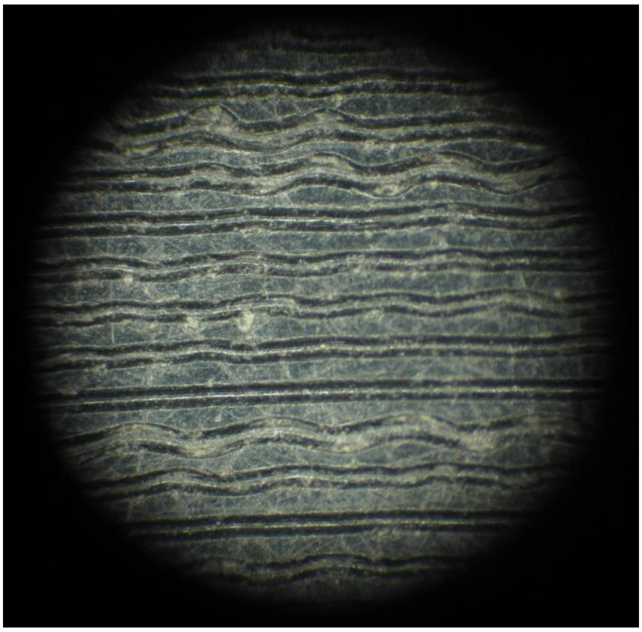 

**Image 36. Detail of the lateral modulation of the monophonic groove of Berliner disc 64508/2110A. Microscopic vision with x50. Tasso Laboratori de so**

### 8.5.3. Recording length

The usual duration of a Berliner disc is between 1,5 min and 2min per side, depending on the playback speed. The Berliner 64508, recorded on one side, lasts 1'47 "played at 70 rpm (chosen speed, as detailed in point) or of 1'37" 78 rpm reproduced (theoretical nominal speed).

| Reproduction speed | Recording length |
|---|---|
| 70 rpm (right speed) | 1’47” |
| 78 rpm (theoretical nominal speed) | 1’37” |

**Table 14. Duration of recording depending on the speed of rotation**

One of the technical factors that most obviously affect the final result is the angular velocity of the disc reproduction: the relationship between speed and pitch height is straightforward.

On the other hand, the inner groves are reproduced at an increasingly low linear speed, and this has direct consequences to sound quality too, as stated in the next paragraphs.

### 8.5.4. Relationship between disc diameter, speed, medium consumption, IR and SNR

Given a fixed disc diameter, a not so obvious consequence of the increase in speed is the relationship between information ratio (IR) and medium consumption, which can be considered as a medium density value: the faster the speed, the higher the recording medium consumption – the lower its density- and consequently, the best preserved the transient response (high frequency information) and the lower the distortion. Of course, the recording capacity will also be less.

Unlike the cylinder, which maintains constant both angular and linear velocities, the disc technology implies a decreasing linear speed. Both Berliner and Eldridge Johnson were well aware of this disadvantage from the very beginning: indeed, despite the constant angular (or rotational) speed, the spaced travelled for each revolution decreases gradually (linear or instantaneous speed, measured in meters per second) as the needle approaches the centre of the disc. This explains the relative medium waste in terms of the relationship between recorded area versus total diameter of the disc: a too-small spiral diameter would imply an excessive level of distortion (or what is the same, the medium density would become excessive to preserve required SNR - see Figure 2 4). Improvements on these constraints implied an increasing disc diameter (from 5" to 7", 10" and finally 12" as standard)[104] and of course, once vinyl was introduced (Columbia LP, 1948) and microgroove made possible, the speed was reduced too (33 rpm 1/3) to preserve recording medium capacity.

### 8.5.5. The pitch

Knowing the standard reference pitch at the time of the recording is a previous step to gain evidence for the setting of the reproduction speed.

One of the more reasonable options for the 'A' concert pitch around 1900 in Barcelona is, a priori, 435Hz. We would suppose here Morera's adscription to the French tradition, were such "normal pitch", was established in 1859 and ratified by the Congress of Vienna in 1885 as an "international reference. It was widespread in many European countries before the standardization of "A" to 440Hz, which is preferred from 1939 on the initiative of Germany[105].

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[104] Edison too progressively increased the cylinder dimensions and speed with the introduction of the *Concert Cylinders* (1898- 1902) - see http://cylinders.library.ucsb.edu/history-concerts.php. While the first cylinders were reproduced at 100 rpm (1888), this rate increased gradually to 125rpm (1892), 144rpm (1900) and 160rpm (1902 onwards. see Copeland 2008: 87). This increase was in parallel to the diameter of the cylinder, to maintain effective duration of the recording. Sound quality improved and as a consequence, cost (Morton 2004: 40). Over time, however, the undeniable superiority of the cylinders in terms of quality compared to disc did not mean its prevalence

[105] source: Ted Kendall. 128th AES Convention. London, May 21-25 2010. *W2 Audio Archiving, preservation, restoration*. For more information on the 1939 Congress, see Rosenfeld, L.: *How the Nazis ruined musical tuning* -

Nevertheless, at the end of the nineteenth century there was a clear tendency across Europe to raise the pitch, and around 1858 the *Teatro Real* in Madrid seemed to have the tuning fork at 444.5 Hz. At a date much closer to our recording, in 1896, the UK to standardized A4 to 439Hz. In short, the pitch of the late nineteenth century was far from standardized across Europe[106], although it seemed to swing in the range of 432Hz (Brussels[107], 1876/Milano, 1881) to 452Hz ( England, 1890).

### 8.5.6. The key

It is also important to bear in mind the key used by Enric Morera to harmonise his version of *Els Segadors* in 1897. The arrangement was published in the collection of *Cançons populars harmonitzades* released by *L'Avenç* between 1897 and 1901, and even 1910 (see Image 38). It should be also noted his work for orchestra and choir *Catalunya: epigrama symfònic*, released on May 10, 1898, ending triumphantly with his arrangement of *Els Segadors* (see Image 39 ). In both cases the key of B minor was chosen[108].

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https://larouchepub.com/eiw/public/1988/eirv15n35-19880902/eirv15n35-19880902_054-how_the_nazis_ruined_musical_tun.pdf

[106] see Ellis, J. (1880): *On the history of musical pitch* - http://www.dolmetsch.com/musictheory27.htm and a Cavanagh, L: *A brief history of the establishment of international standard pitch A=440 hertz* - http://www.wam.hr/sadrzaj/us/Cavanagh_440Hz.pdf

[107] it should be remember that in the late 1880s Enric Morera was formed musically in the Belgian capital, until he settled permanently in Barcelona in 1890

[108] although in the current "official" version, approved by commission in July 1980, the piece is in E minor (Ayats 2011: 201-203,211-212).

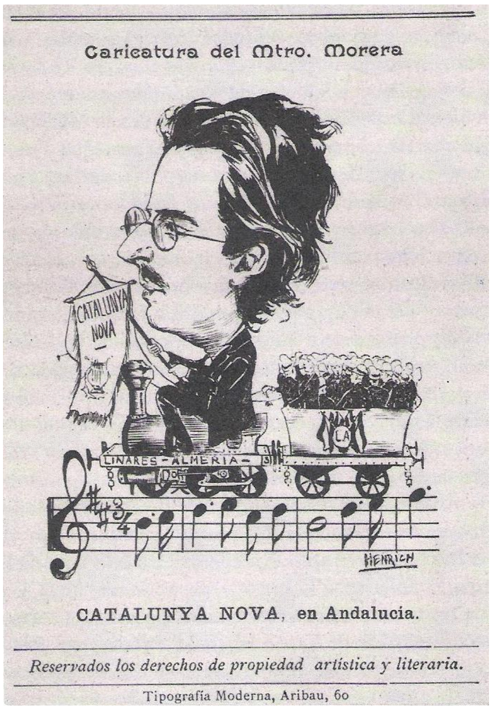
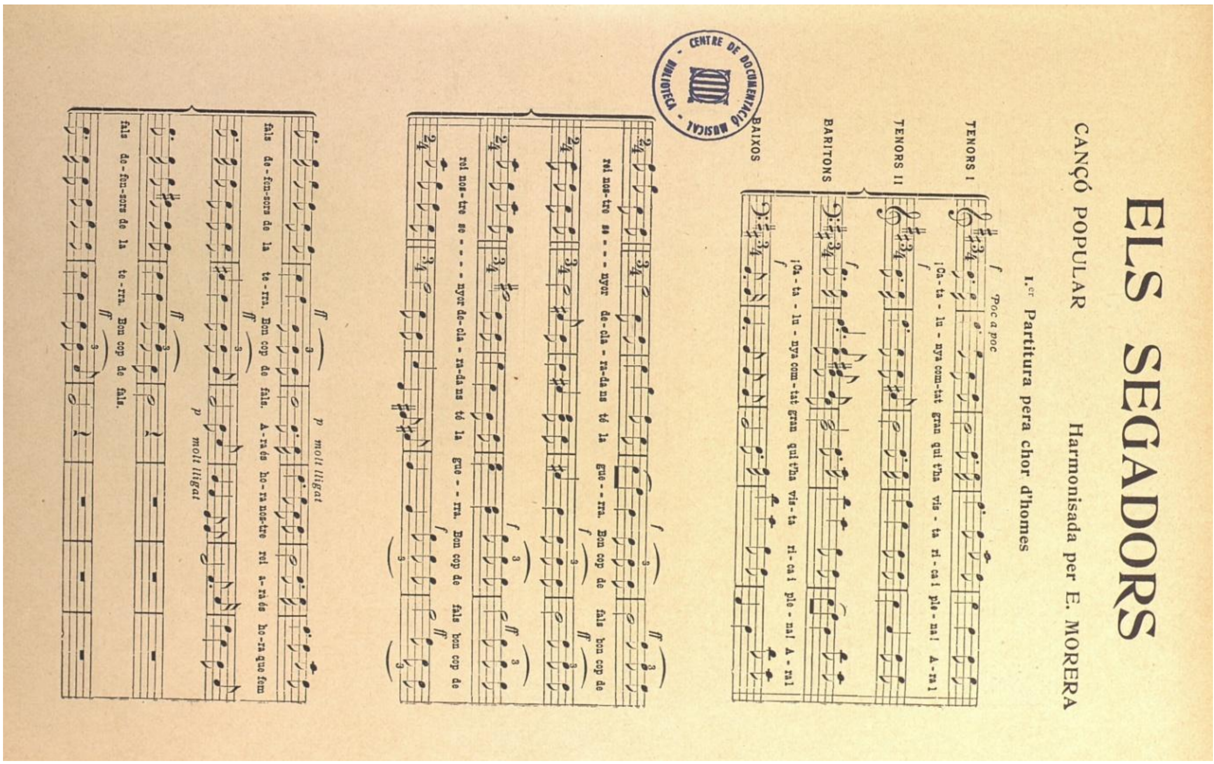
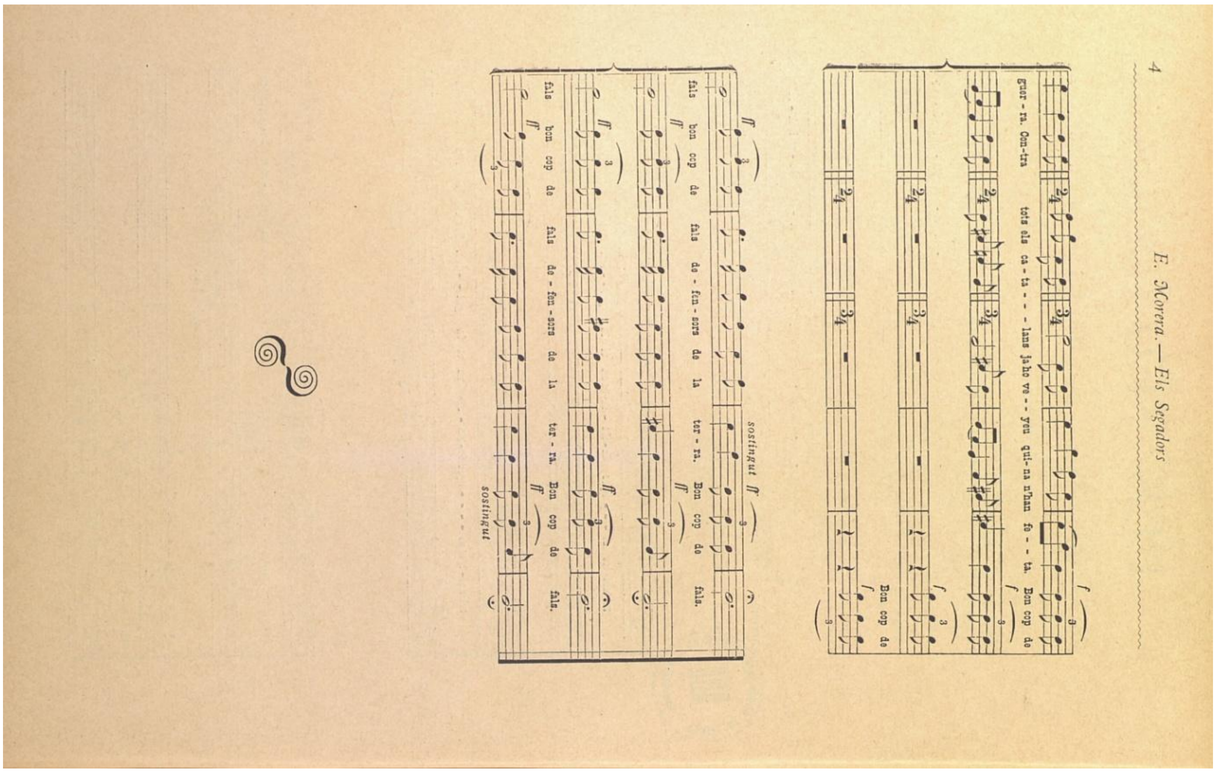
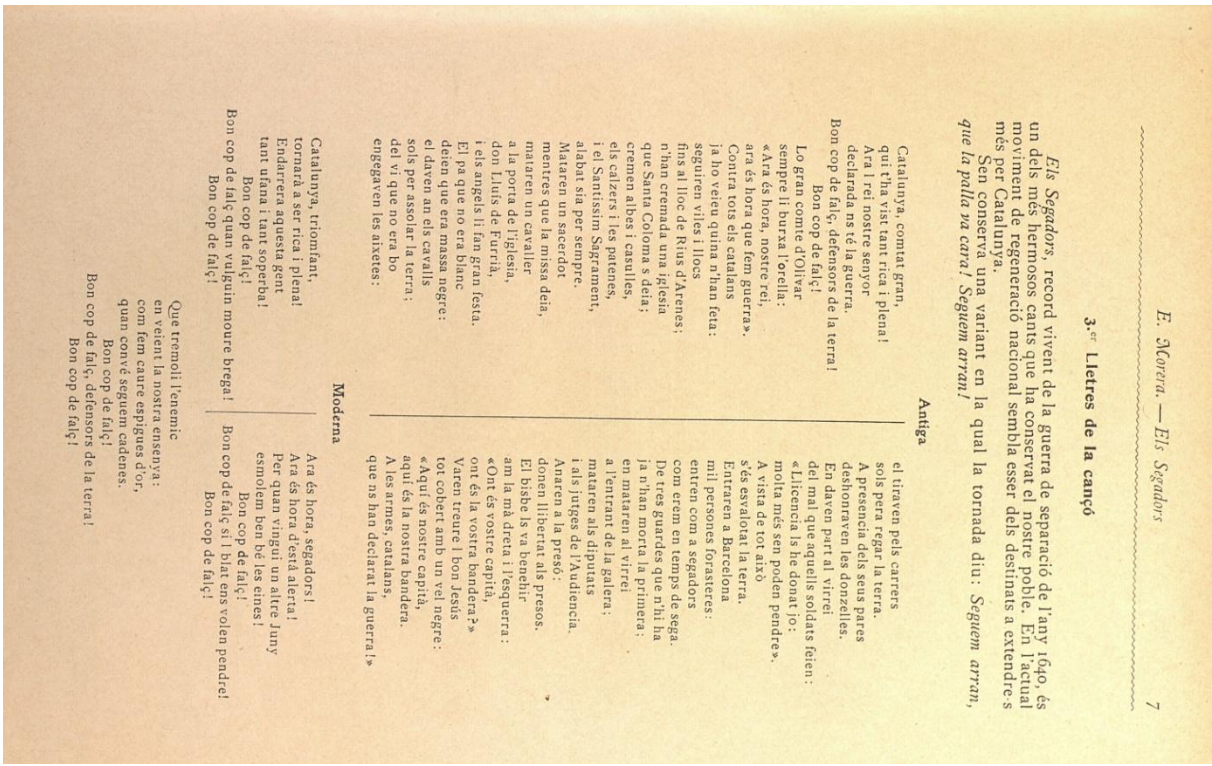



**Image 37. 1899 cartoon. First notes of *Els Segadors* in the key of B minor (Ayats 2011)**


CANÇONS CATALANES
Harmonisades per ENRIC MORERA
Els
Segadors
(CANÇÓ POPULAR)
1er Partitura pera chor d'homes.
2on Reducció pera cant i piano.
3er Lletres de la cançó (antiga i moderna).
Preu: 2 rals
Barcelona: Tipografia «L'Avenç», Ronda de l'Universitat, 20. — Telefon 115
3.000
SEGONA EDICIÓ


ELS SEGADORS
CANÇÓ POPULAR
Harmonisada per E. MORERA
1.er Partitura pera chor d'homes
TENORS I
TENORS II
BARITONS
BAIXOS
Poc a poc
molt lligat



E. Morera. — Els Segadors 7

**3.er Lletres de la cançó**

*Els Segadors,* record vivent de la guerra de separació de l'any 1640, és un dels més hermosos cants que ha conservat el nostre poble. En l'actual moviment de regeneració nacional sembla esser dels destinats a extendre·s més per Catalunya.

Sen conserva una variant en la qual la tornada diu: *Seguem arran, que la palla va cara! Seguem arran!*

**Antiga**

Catalunya, comtat gran,
qui t'ha vist tant rica i plena!
Ara l rei nostre senyor
declarada ns té la guerra.
Bon cop de falç, defensors de la terra!
Bon cop de falç!
Lo gran comte d'Olivar
sempre li burxa l'orella:
«Ara és hora, nostre rei,
ara és hora que fem guerra».
Contra tots els catalans
ja ho veieu quina n'han feta:
seguiren viles i llocs
fins al lloc de Rius d'Arenes;
n'han cremada una iglesia
que Santa Coloma s deia;
cremen albes i casulles,
els calzers i les patenes,
i el Santíssim Sagrament,
alabat sia per sempre.
Mataren un sacerdot
mentres que la missa deia,
mataren un cavaller
a la porta de l'iglesia,
don Lluís de Furrià,
i els angels li fan gran festa.
El pa que no era blanc
deien que era massa negre:
el daven an els cavalls
sols per assolar la terra;
del vi que no era bo
engegaven les aixetes:
el tiraven pels carrers
sols pera regar la terra.
A presencia dels seus pares
deshonraven les donzelles.
En daven part al virrei
del mal que aquells soldats feien:
«Llicencia ls he donat jo:
molta més sen poden pendre».
A vista de tot això
s'és esvalotat la terra.
Entraren a Barcelona
mil persones forasteres:
entren com a segadors
com erem en temps de sega.
De tres guardes que n'hi ha
ja n'han morta la primera;
en mataren al virrei
a l'entrant de la galera;
mataren als diputats
i als jutges de l'Audiencia.
Anaren a la presó:
donen llibertat als presos.
El bisbe ls va benehir
am la mà dreta i l'esquerra:
«Ont és vostre capità,
ont és la vostra bandera?»
Varen treure l bon Jesús
tot cobert amb un vel negre:
«Aquí és nostre capità,
aquí és la nostra bandera.
A les armes, catalans,
que ns han declarat la guerra!»

**Moderna**

Catalunya, triomfant,
tornarà a ser rica i plena!
Endarrera aquesta gent
tant ufana i tant soperba!
Bon cop de falç!
Bon cop de falç quan vulguin moure brega!
Bon cop de falç!
Ara és hora, segadors!
Ara és hora d'està alerta!
Per quan vingui un altre Juny
esmolem ben bé les eines!
Bon cop de falç!
Bon cop de falç si l blat ens volen pendre!
Bon cop de falç!

Que tremoli l'enemic
en veient la nostra ensenya:
com fem caure espigues d'or,
quan convé seguem cadenes.
Bon cop de falç!
Bon cop de falç, defensors de la terra!
Bon cop de falç!

**Image 38. Cover and full score of *Els Segadors* as arranged by Enric Morera for male voices (1897), and published in *L'Avenç*, 1901. Source: Biblioteca Nacional de Catalunya**

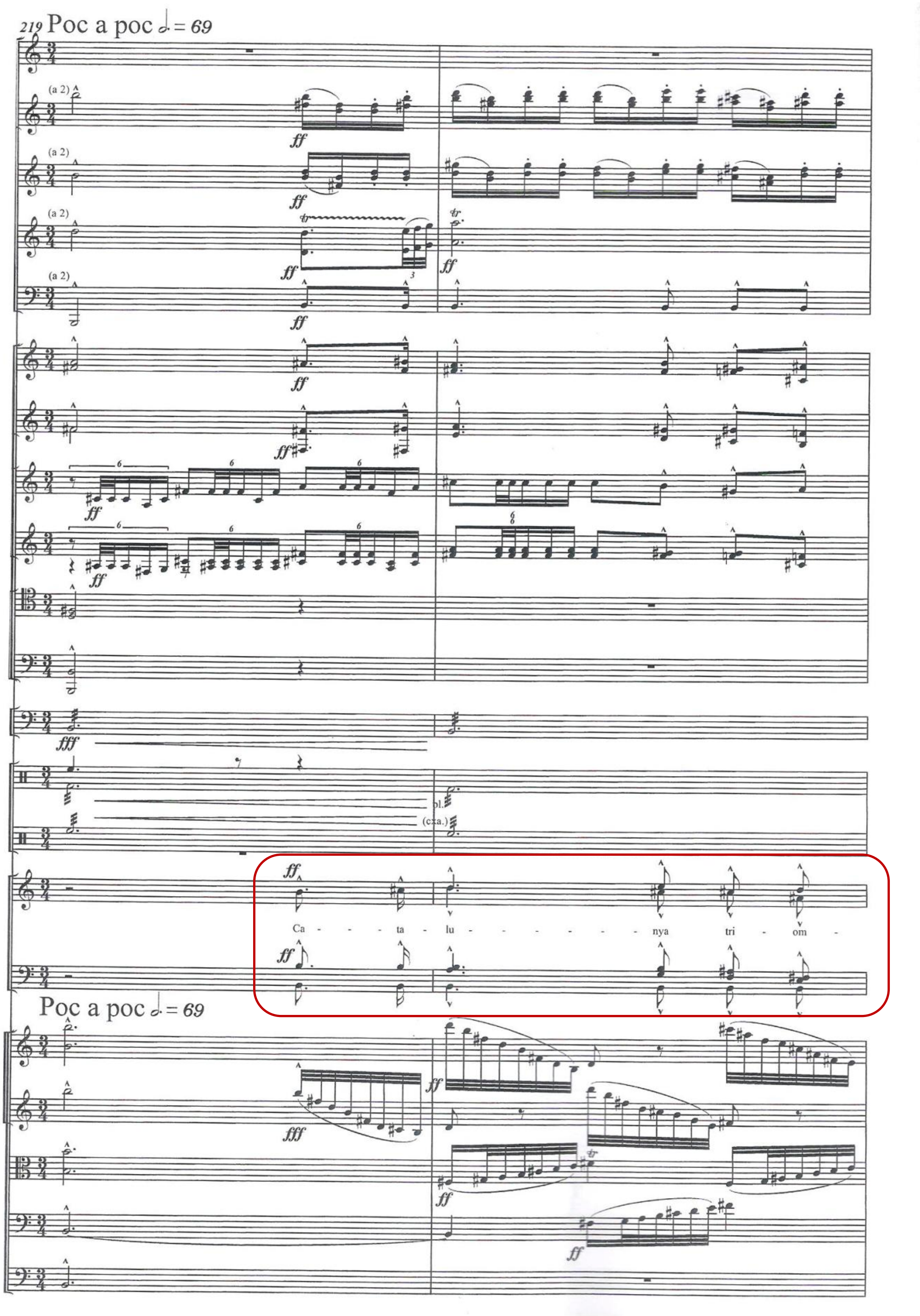



**Image 39. Last bars of *Catalunya: epigrama symfònic*, were *Els Segadors* appearing already with the new letter from Emili Guanyavents. The male choir sing the anthem in B minor. Edicions Brotons & Mercadal, 2007**

### 8.5.7. Reference to 70.0 rpm

These two facts, the concert pitch of the time of the recording and especially the original key of Morera's arrangement, have guided the determination of the rotational playback speed. It should also be justified in terms of the margin rate historically considered feasible for 7-inch Berliners. In this respect we should quote once again the work of the BL Sound Archive engineer Peter Copeland (Copeland 2008: 86-89): "*Berliner Gramophone Company. Instructions for the first hand-cranked gramophones recommended a playing-speed of about 100rpm for the five-inch records dating from 1890-1894, and 70rpm for the seven-inch ones dating from about 1894-1900. But these are only "ballpark" figures.* "

Copeland proposes 70 rpm as a first playback approach for Berliners after 1894 (recording and playback equipment were provided, the latter from 1896 on, with motors by Eldridge Johnson). Other sources also indicate that the same *Emile Berliner's United States Gramophone Company* propaganda from 1894 included the recommendation to play discs 7 "at the speed of 70rpm[109]. Just this speed –and not 78 rpm or any other in the range of 75-85 rpm- allows us to hear *Els Segadors* in the key of Bminor for an A4 reference very close to our current standard of 440Hz. The decision is thus technically and historically justified.

### 8.5.8. Cleaning the disc for playback

Already from 1895, with the introduction of shellac as the base material for mass-production, Berliner pressings may be considered and treated with the care related to standard 78rpm shellac records . Unlike gelatine disks or nitrocellulose or other hygroscopic materials, shellac discs accept liquid solutions for cleaning. However, we must avoid any solution that contains alcohol (unlike the case of vinyl, were the use of ethanol is possible, *if* diluted appropriately).

Prior to digitization, the Berliner of *Els Segadors* has been cleaned using a special alcohol-free solution of 1 part (20ml) dissolved in 50 parts (1 litre) of distilled deionised water, sprayed and evenly disseminated over the entire surface of the disk, followed by suction and dried with a suction pump, groove by groove, thanks to a professional record cleaner.

[109] upon Ober, Norman (1973-12). "*You Can Thank Emil Berliner for the Shape Your Record Collection Is In*". *Music Educators Journal*, Vol. 60, No. 4 (Dec., 1973), pp. 38-40


**Image 40. Cleaning process with a *Loricraft Audio PRC4N*[110] professional record cleaner**

8.5.9. Analogue reproduction

We've been using a special direct-drive turntable mounted on an inertial mass to reduce the resonance frequencies that might be inducted by solid transmission during playback. The 70rpm angular velocity has been calibrated with a digital tachometer.

There has been no use of playback equalization, since we are dealing with an acoustic recording prior to the introduction of electrical means (by 1925), and thus it is approximately a constant speed recording[111].

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110 see http://ouir.ch/generated/datenblaetter/produkte/495_3_Loricraft_PRC4.pdf for an explanation of the procedures

111 for more insight on the concepts of constant speed vs. constant amplitude recording, see the article by Gary A. Galo, *Disc Recording Equalization Demystified* - http://www.novotone.be/_site/projets/Projet06/Doc01.pdf

**Image 41. Analogue chain inspection, cleaning and playing. Tasso Laboratori de so**

8.5.9.1. Cartridge and stylus matching

The recording of the first Berliner masters on zinc gave rise to grooves considerably narrow and shallow. While for most later 78 rpm discs needles with diameters from 2mil on are recommended -depending on the disc type, company and time of recording- some Berliners may constitute an exception and we should be considering, a priori, needles with diameters between 1mil (25.4 microns) and 2mil (50.8 microns).
Indeed, the document AES-16id-2010 differs just among Berliners recorded over zinc masters (acid-etched technique) before mid/late 1900s, and later ones over wax masters[112].

We've been using a collection of conical and elliptical needles, both truncated and not truncated, between 1.1mil and 4mil, coupled to their corresponding stereo light weight MM cartridges. Total weight of the cartridge+stylus set was settled to 3.2 gram, confirmed with a professional digital scale.

It should be noted again, in spite of the monophonic record, the value of independently capturing the modulations of both walls that conform the grooves: the erosion due to repeated handling, playback on poorly calibrated equipment and overall time wear will have probably affected randomly the surface of the disc and surely produced noticeable differences in the theoretically identical modulations of parallel grooves. Thus, at least with regard to the digital master copy, it is good practice to retrieve and keep both signals into a stereo file for later processing, choosing one track or the other (L or R, depending on the preservation state ) or the sum of both (MONO = L+R) if there's enough phase consistency. When the latter is feasible, signal may be increased to 6dB whilst noise, being uncorrelated, would increase just by 3dB, yielding a total SNR improvement of +3dB.

[112] let us recall that the suffix "A" from the 2110A matrix number of *Els Segadors* refers precisely to a zinc master

After experimenting with selected needles, best results in terms of frequency response and SNR were achieved with elliptical truncated elliptical needles in both cases with diameters between 2mil and 3mil, slightly higher than the initial assumptions. This latter extent may be the result of a groove erosion and width broadening due to repeated playback over the years.

## 8.6. Analysis of the audio content

### 8.6.1. The performing ensemble and the performance

Even though Morera's harmonization from 1897 as published by *L'Avenç* is written for four male voices, a careful listen to the 1900 recording presents some interesting features and allows some hypotheses:

a. listening suggests an interpretation by a mixed choir, with the participation of female voices –which, for historical reasons, should be ruled out- or more likely, a boy's choir, singing the part of the first and second tenors
b. the rendition is *a cappella* (no instrumental parts, despite the reference to "*coro y orquesta"* found in the inner part of the disc) and follows the harmony of the original version of 1897, pending to confirm part of the middle voices (tenors and baritones II) and the perception of octaves in the bass part
c. as mentioned earlier, the lyrics correspond to the version of Emili Guanyavents, repeating the first verse and ending with the famous exhortation "*Bon cop de falç!*" from Ernest Moliné

Regarding the first hypothesis, once discarded women's participation in the choral groups of the time -with the significant exception of the *Orfeó Català* (Ayats 2011: 71)- research from Roger Alier allows us to assume the involvement of men and boys in recording, the last doubling the part of the first tenors and probably also the seconds. In a review in the *Diari de Barcelona* from March 9, 1896, the first concert given out by *Catalunya Nova* in the *Ateneu Barcelonès*, it is detailed that "*currently,* [the choir] *consists of about eighty-something singers, among men and children*". In later concerts from the same 1896, a number of 80 singers, 50 men and 30 boys are reported (Alier 1973: 47-48), as well as 70 men and 30 boys in June 1899 (Alier 1973: 54), as well as on the occasion of the frustrated action at the International Exhibition held in Paris from April 15 to November 12 1900 (Alier 1973: 68).
We can thus assume that this mixed ensemble of 100 singers was the one recording *Els Segadors* by September-October 1900.

### 8.6.2. Temporal and spectral analysis with Sonic Visualiser

Once digitised, the software Sonic Visualiser[113] allows for a closer analysis in the time and frequency domains of the sound recording from *Els Segadors* contained in the Berliner disc.

We'll be analysing the original audio content once in a digitized file BWF (Broadcast Wave File) without any subsequent changes (EQ, compression or noise reduction) except for peak normalization to -1dBFS. The characteristics of the analyzed sound file are:

- format: BWF (. wav)
- duration: 01'50'
- size: 27.9 MB
- sampling rate: 192kHz
- wordlength: 24 bit
- channels: 2
- Ref. A4 = 440Hz
- Blackmann-Harris 8192 samples. Overlap 87.5%

Focusing exclusively on the recorded harmonic content (music) and discarding retrieved stochastic energy due to inherent disturbances, we can estimate the following margin:

| ***A4 (International Pitch)[114] = 440Hz*** | | | |
|---|---|---|---|
| **Low frequency limit** | | **High frequency limit** | |
| 250Hz | around B3 | 1500Hz | around F#6 |

**Image 42. Estimated spectral and musical range**

This working frequency range (250-1500Hz) is insufficient to reproduce the lower frequency notes – such as the low fundamental F#2 from the score, around 92Hz -. This doesn't come as a surprise, regarding the limited features of the recording technology of the time.

[113] *Sonic Visualiser*. Queen Mary University (London). GNU Public License. http://www.sonicvisualiser.org

[114] curiously enough, Sonic Visualiser uses the franco-belgian notation reference to index musical notes, so the A4 reference (440Hz) from the international system is written in Sonic Visualiser as A3 (for the same 440Hz)

On the other hand, and regarding the potential existence of children voices, it is especially revealing the ending passage "*Bon cop de falç...*" where the octave interval [B3 - B4] is heard (Image 43). The B4 register (488Hz= is indeed too high for a chest male's voices and that supports the hypothesis that children voices would be doubling the lines written for tenors and II.

This possibility is also consistent with the way the 1897 arrangement was written, in G-clef for the Tenor I and II voices (see Image 38).

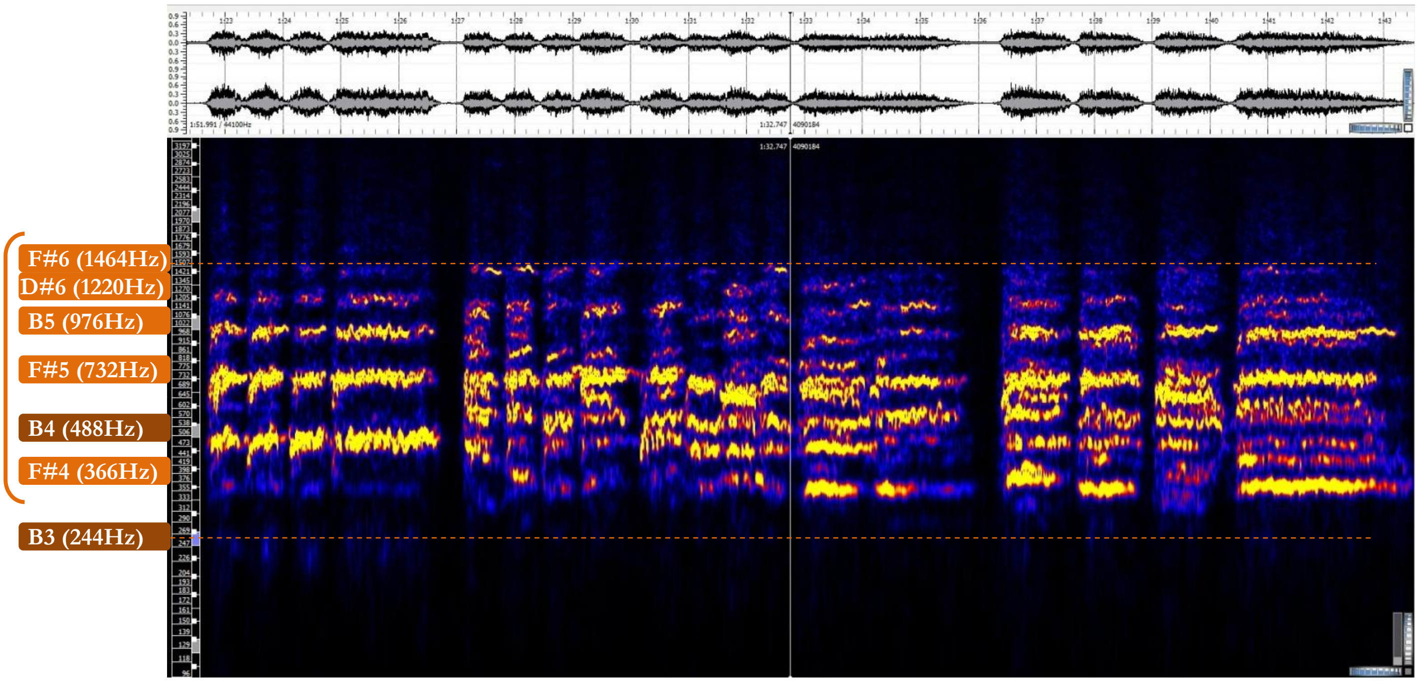


**Image 43. Spectrogram from the final words "*Bon cop de falç...*" Restored audio file. We can observe the parallel harmony in the first sentence and the descending movement of the bass line in the second. Blackmann-Harris 8192 samples. Overlap 87,5%. Ref La4 = 440Hz[115]**



The spectral analysis of this fragment (Image 43) should reveal, either by its harmonic content or by the two fundamental notes being sung, localized energy in the first two main frequencies corresponding to B3 (bass and baritones) and B4 (tenors) notes, followed by a perfect fifth (F # 5) corresponding to the third harmonic formant from the fundamental sung by the baritone and bass voices. Nevertheless, the energy located in B3 very little, although if we consider the harmonic progression retrieved from the spectrogram [B4 – F#5 – B5 – D#6 – F#6] it would correspond to the fundamental B3 (244Hz). Again, this low PSD at B3 can be due to the reduced recording bandwidth of the time, though it can certainly be psicoacoustically perceived.

[115] tempered and rounded frequential values taking A4 = 440Hz as reference, where $f=440*2^{n/12}$ and, for n = -10, B3 = 244Hz

This would be an example of psychoacoustic perception based on the *missing fundamental* phenomenon[116] that could effectively explain the perception of fundamental notes -especially the low bass register which goes from F#2 (approx. 92Hz) to B2 (approx. 122Hz)" despite a very weak or almost inexistent record on the gramophone grooves.

Going further in the missing fundamental theory, we can also suggest an octave *divisi* for the bass voice at the beginning of the sentences "*Bon cop de falç...*" a priori not written in Morera's arrangement: we would be talking of B2 (122Hz) and B3 (244Hz), both audible, something which would explain the presence of harmonic F#4 (366Hz) in the spectrogram and the 122Hz difference between these consecutive harmonics (fundamental frequency $f_0 = f_{k+1} - f_k$). It can actually be heard, at "*...bon cop de falç, defensors de la terra!*" the beginning of the diatonic descendant progression from B2 to to E2.

It is also interesting to note the clearly visible *vibrato* on sustained notes (i.e. the sustained octave in the "*Bon cop de falç"* excerpt), with a fairly common modulation frequency for male voice, between 5Hz (0.20 s) and 6.6 Hz (0.15 s)[117]. This modulation may be influenced by many causes and not by only musical performance: the non-uniformity in the disc transport mechanism during recording (inconstant angular velocity, eccentric rotation, etc.) may introduce wow and flutter distortion[118].

It should not be forgotten that the recording system at the time could introduce many distortions, among which –set aside the scratch, crackle, swishing and other surface noises- stands out the harmonic distortion (THD) introduced by the horn, acting as a resonator filter. Already at the dawn of digital audio processing, Thomas Stockham tackled this characteristic distortion (Stockham et al. 1975) in his attempts to restore the first recordings made by Enrico Caruso (from 1902 on)[119]. Indeed in our recording a significant resonant

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116 (Justus 2002), as well as Auditory *Conflicts and Illusions in* http://www.usaarl.army.mil/publications/HMD_Book09/files/Section%2021%20-%20Chapter13%20Auditory%20Conflicts%20and%20Illusions.pdf

117 see Maher 1990:229

118 even though off-topic, it's worth here pointing out Mark Katz's discussion on the influence of early recording technology over the violin vibrato technique. See Katz, M (2004: 94-108): *4. Aesthetics out of exigency: violin vibrato and the phonograph*. A *Capturing sound forever. How technology has changed music*. University of California Press Ltd

119 as Stockham stated in his seminal paper (Sotckham et. al. 1975), "*contrary to the popular concept concerning old recordings, whether they be acoustic or electric, the problem of surface scratch is not the most important. (...). For acoustic recordings the major problem seems to be the resonant or reverberant characteristic given to musical instruments or vocal sound by the primitive recordings horns which were used to focus the sound energy onto the original wax discs. While it is well known that these acoustic mechanisms were incapable of transcribing frequencies much below 200Hz or above 4000Hz, these frequency limitations alone do not account for the degree of the degradation produced. (...) Indeed measurements made on old recording equipment indicate that from 10 to 20dB or more re commonly encountered in the frequency range between 100 and 1000Hz on such recordings. This effect not only produces a megaphone quality (which the*

*coloratura* in the frequency range of 350-400Hz, which corresponds to the first harmonics of fundamentals F#3 - G3 in the area of the baritones and minimize, on the contrary, the perception of D3 (147Hz) and its harmonics. The effect is especially noticeable in the final articulation of the final sentences "*Bon cop de falç*".

To confirm or dismiss these deviations between the performance and the score of the arrangement taken as a reference, we should apply further analysis tools.

## 8.7. Comparative analysis between the performance and the source

The aim of the this chapter is to be able to localize and separate the different sources (harmonic voices) in order to confirm or discard the following hypothesis

- HYPOTHESIS I

  The recorded version of *Els Segadors* basically corresponds to the first verse of the core shown in Image 38. Cover and full score of *Els Segadors* as arranged by Enric Morera for male voices (1897), and published in *L'Avenç*, 1901. Source: Biblioteca Nacional de Catalunya
- HYPOTHESIS II

  The recorded version presents fundamental frequencies out of the male tenor *tessitura*, which would confirm the presence of children or boy's voices
- HYPOTHESIS III

  There are *divisi* in the performance of some of voices of the harmony not written in the referenced score

Four approaches were devised

a. sinusoidal and sinusoidal + residual model (DAFX/MTG Spectral Processing Algorithms[120])
b. sinusoidal + residual model using commercial tools (iZotope RX2 De-Construct[121])
c. supervised blind source separation (BSS) by signal decomposition using BHAD Algorithm[122]

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*reader might simulated by cupping his hands in front of his mouth and speaking) but also produces a very unpleasant effect in the form of loud bursts of sound when certain frequencies are played or sung."*

[120] the algorithms for the implementation of this model can be found in *DAFX: Digital Audio Effects* (Zölzer, Udo 2011:393-473)

[121] see http://www.izotope.com/products/audio/rx/

[122] Fuentes B., Badeau R., Richard, G. (2012). *Blind Harmonic Adaptive Decomposition Applied to Supervised Source Separation* 20th European Signal Processing Conference (EUSIPCO), Bucharest, Romania, August 27-31, 2012, pp. 2654-2658.

d. source separation using commercial tools (Celemony Melodyne Editor[123])

Source informed or more explicitly score-informed source separation methods have not been tested, something which is pending and should help reveal differences between the score and the actual recording.

The sound source has been excerpts of the restored version of *Els Segadors* (as explained in chapter 8.9), peak-normalized to 0.0dBFS.

### 8.7.1. Sinusoidal modelling and sinusoidal + residual modelling

As it is known, musical sounds can be modelled as a sum of deterministic and stochastic parts or, for our matters, as a sum of a set of sinusoids plus noise residual [Serra 1989, 1997]. We are choosing this approach due the polyphonic nature of the sound source, where the deterministic content will not be inter-harmonically related (different harmonics from different polyphonic sources). This decomposition approach into sinusoidal content and residual (original – sinusoids) offers the greatest fidelity to the original content, where no suppositions are being made regarding the harmonicity of the deterministic content and the nature of the left residual (non-sinusoidal) and thus we can talk of a conservative identity matrix.

The original code was modified (see codes *sinemodel_GINE_Segadors.m* and *sprsmodel_GINE_Segadors.m* in the Annex 1.7) in order to get

- yh → sinusoidal component
- yr → residual component
- y = [yh+yr] → identity matrix

#### 8.7.1.1. Regarding the **sinusoidal model** parameters,

```
function [y,Xhalf,plocHalf,halfpmag,halfpphase] = sinemodel_GINE(x, w, N, t)
% Analysis/synthesis of a sound using the sinusoidal model
% x: input sound, w: analysis window (odd size), N: FFT size,
% t: threshold in negative dB, y: output sound
```

a. **analysis window w type and size**

The analysis window **w** type and size (M) is greatly responsible for the trade off time/frequency resolution. As we are dealing with sustained male chords and we are mainly interested in the

[123] see http://www.celemony.com/cms/index.php?id=383&L=2

harmonic content, we should be thinking a priori of a fairly large window size for better frequency resolution. Regarding the window type, we should discard rectangular windowing (non-averaging window) and choose among Hann (Hanning), Hamming, Blackman-Harris or Kaiser-Bessel windows.

According to hypothesis III we should first consider the fundamental frequencies ($f_0$) we are expecting to retrieve. The lowest $f_0$ should correspond to note E2 at 83Hz. Thus, we would need a window size of around

$$w \geq n\frac{fs}{f0}$$

where

- M = window w size
- $f_s$= sampling frequency (Hz)
- $f_0$ = fundamental frequency = $|f_{k+1}- f_k|$ (distance in Hz between consecutive harmonics)
- n = main lobe bandwidth in number of bins for the considered window (i.e. Hamming, n=4)

We'll consider a Hamming window, as it offers us a good trade-off between peak detection and side-lobe effects. Then, M ≥ (44100Hz/83Hz)*4= 2125, where finally a size of w = Hamming(2249) has been chosen.

**b. FFT size N**

The FFT (from the STFT) size N does not affect much in the analysis part, but for more accurate $f_0$ detections. Zero padding will not increase frequency resolution, just improve frequency plotting. In any case, N must be kept larger than w (N>M), and for the case of a Hamming window (whose main lobe is defined by a number of bins n=4), it is advised N ≥ n*M in order to assure that the FFT window includes at least one whole period of the lowest frequency signal.

Thus, N≥ 4*2125 → N = 9000

**c. threshold t [$dB_{FS}$]**

Threshold should be kept low if we want to detect low-level peaks, evebn though the recording dynamics (or SNR) is also very low. The threshold level determines also the amount of room noise or reverberation kept in the modelled output signal

As a consequence, results were obtained with the following parameters:

- w=hamming (2249) / w=blackmanharris(2249)
- H = 512 (hop size for analysis and synthesis)
- N=9000 (STFT size)

- t= -50dBFS (dynamics resolution threshold)

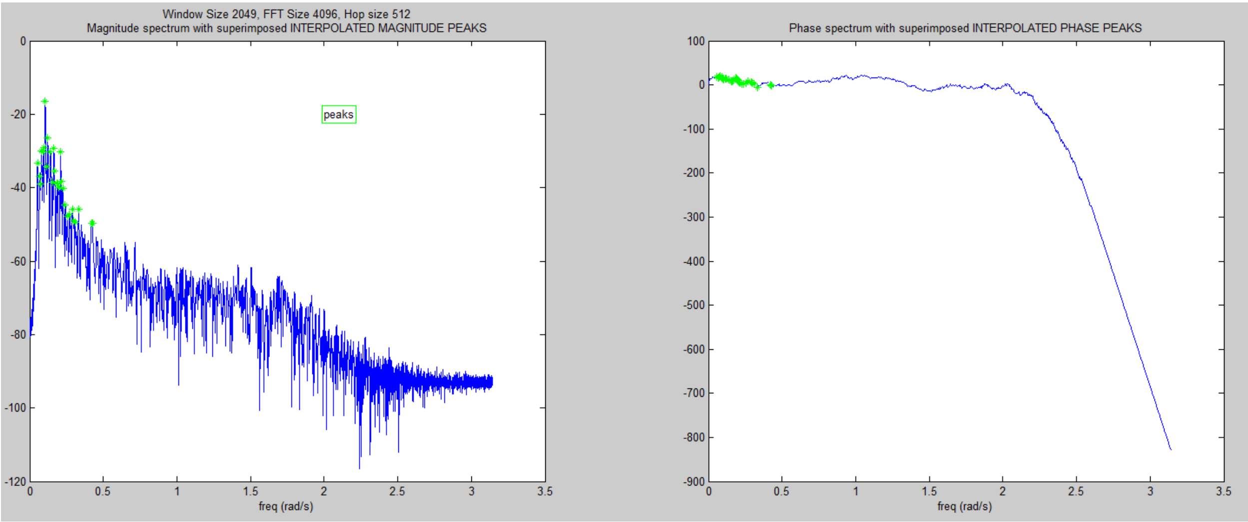


**Image 44. *Els Segadors* sinusoidal modelling. Magnitude and phase response**

We have loaded a monophonic version of the restored audio (SegaMONO.wav), 16bits/44.1KHz. Windowing is large, as we are mainly interested in the frequency resolution. The output file is SINUSOIDAL MODEL Segadors -50 512 2249.wav

Here it is the whole is SINUSOIDAL MODEL Segadors -50 512 2249.wav, as seen with Sonic Visualiser:

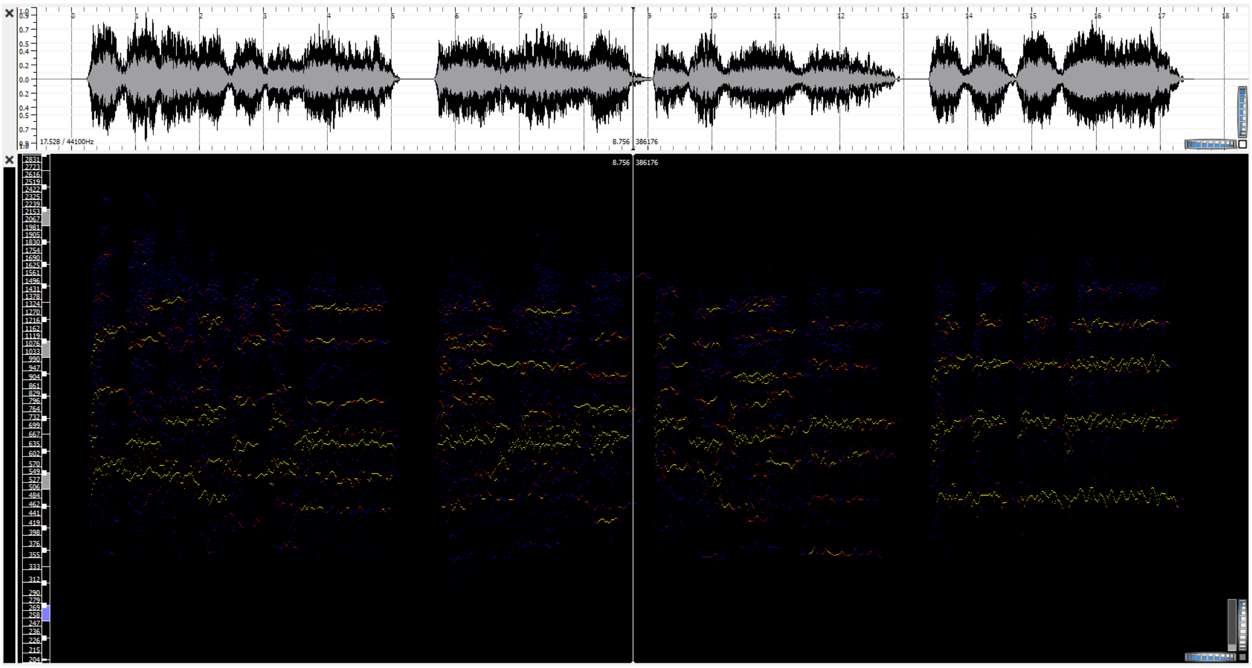

**Image 45. Melodic range spectrogram of SINUSOIDAL MODEL Segadors -50 512 2249.wav**

Once the model has shown itself capable of retrieving sinusoids down to 83Hz even at window size M=1025, we can confirm that the recording does not contain relevant recoverable energy below 244Hz (B4 note). Therefore, any perceived low frequencies –originally intended and sung- will have to be interpolated from the upper harmonic content

8.7.1.2. As for the **sinusoidal + residual model** parameters, we kept the previous most relevant ones.

```
function [y,yh,yr] = spsr_GINE_Segadors(x,fs,w,N,t,maxnS,stocf)
%=> analysis/synthesis of a sound using the sinusoidal plus residual or stochastic
model
% x: input sound, fs: sampling rate, w: analysis window (odd size),
% N: FFT size (minimum 512), t: threshold in negative dB,
% maxnS: maximum number of sinusoids,
% stocf: decimation factor of mag spectrum for stochastic analysis
% y: output sound, yh: harmonic component, ys: stochastic component
```

- **stocf: decimation factor of mag spectrum for stochastic analysis**

A decimation factor is available to smoothen a background noise, simplify spectrum output, facilitate manipulation and thus transformation. As we are focused on preservation and identity decomposition, no decimation factor should be applied (stocf = 1)

[y,yh,yr] = sprsmodel_GINE_Segadors(x,fs,hamming(2249),4096,-50,20,1)

- w=hamming(2249) / w=blackmanharris(2249)
- H = 512
- N=9000
- t= -50dBFS

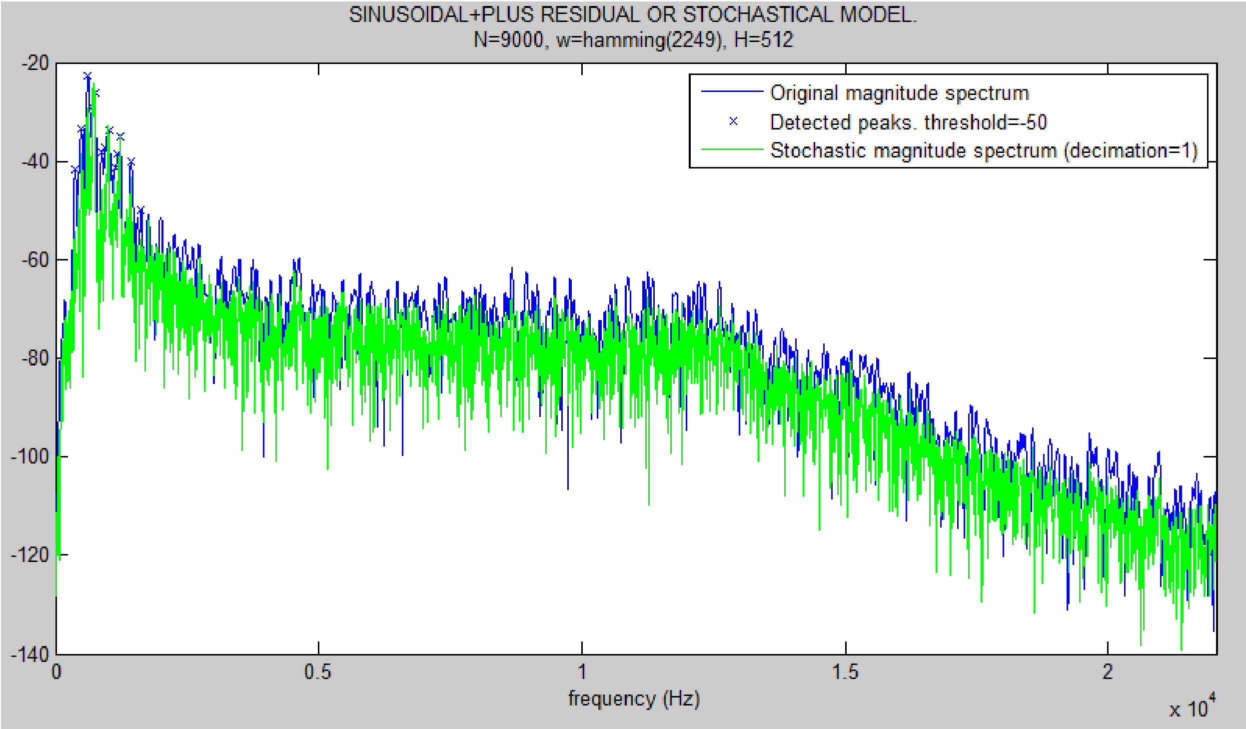


**Image 46. *Els Segadors* sinusoidal + residual modelling magnitude response. Too large N & M window sizes deliver "musical" residuals**

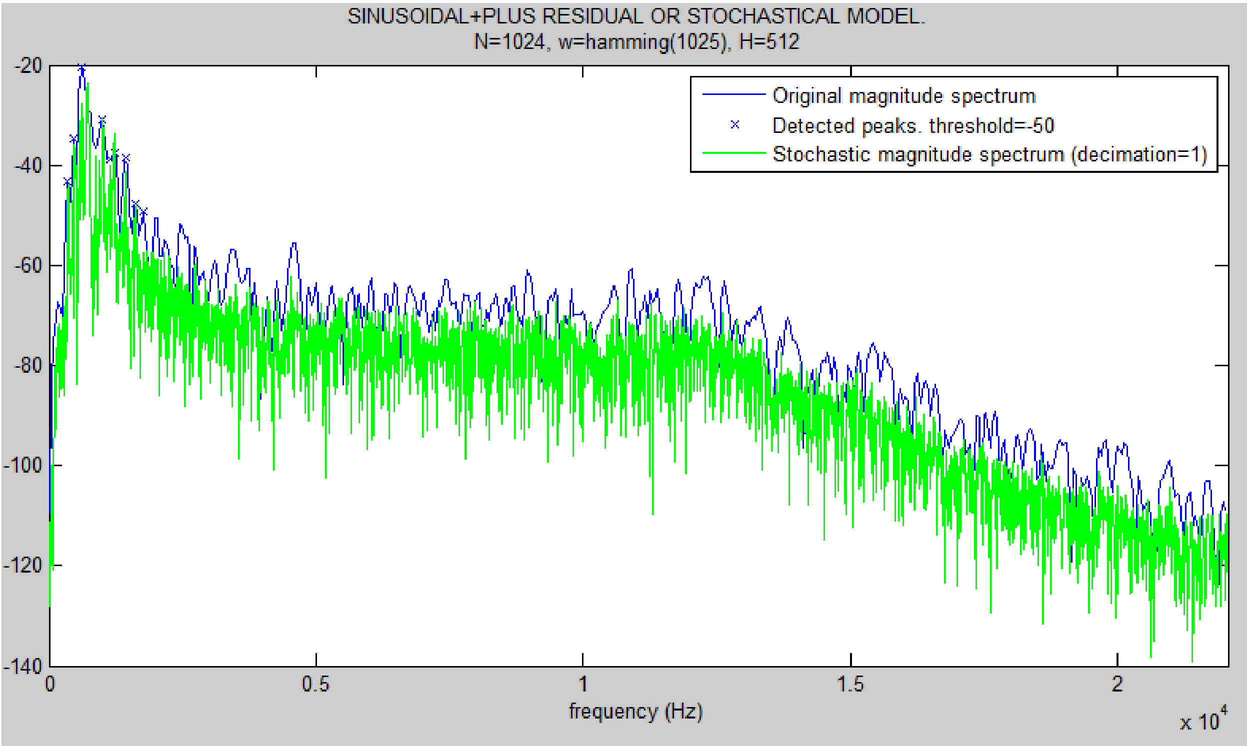


**Image 47. *Els Segadors* sinusoidal + residual modelling magnitude response. Reduced w & M windows sizes delivers a more stochastic residual**

It should be noted that, the larger the window sizes N and M, the worse the residual modelling (i.e. the more harmonic – compare Image 46 and Image 47), as a peaky filter will be superimposed over the noise spectra, resulting in the inclusion of modulated "noisy partials" (Serra 1997: 4). Tests have been made with smaller window sizes (M=1025) and results for the residual part were actually better, keeping the modulated noise within the deterministic part.

Once the signal has been modelled and recorded deterministic content below 244Hz (as a rule of a thumb) has been discarded, our next goal is to be able to better distinguish the different parts/voices. We have got now a signal that should theoretically give better clues about the actual recorded harmonies. Nevertheless, it also depends on the ability of the model to detect peaks and on the bandwidth limits of the recordings.

Our next step has been, based on this modelled version and also the original (restored) one, as well as the original score, to use a source separation tool in order to detect and track the harmonic lines suggested in 8.6.2.

### 8.7.2. Sinusoidal + residual model using commercial tools (iZotope RX2 *De-Construct*[124])

iZotope RX2 offers a tool which, although not stated in the reference manual, seems rooted in the sinusoidal + residual model (here defined as tonal vs. noisy content), and would be an alternative to the above implementation[125].

No options for windows type and sizes, hop-size, etc. are provided.

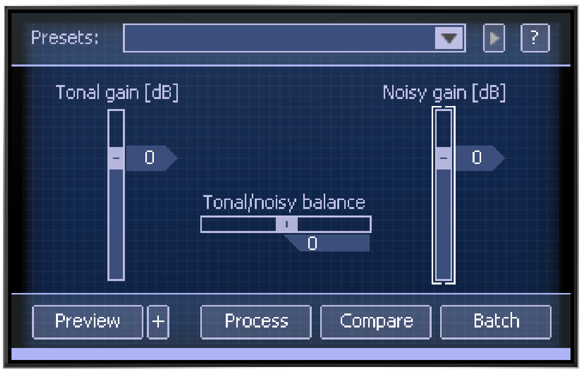


**Image 48. Main menu of iZotope *De-Construct* tool**

[124] see http://www.izotope.com/products/audio/rx/

[125] further use of sinusoidal modelling by iZotope RX are found in *Spectral Repair* and *Noise Reduction* modules (*Harmonic Enhancement*, *HF Synthesis*).

As done previously, we have loaded a monophonic version of the restored audio (SegaMONO.wav), 16bits/44.1KHz and tested to fully remove noisy components.

- Tonal gain = 0dB
- Noisy gain = -∞ dB
- Tonal/noisy balance[126] = 0

Results can be heard at SegaMONO_DeConstruct.wav. Artefacts in the form of musical noise (see chapter 6.9.3 ) are audible.

### 8.7.3. Supervised blind source separation (BSS) by signal decomposition using BHAD Algorithm[127]

We have been using the BHAD algorithm included in a MATLAB tool proposed by Fuentes B., Badeau R., Richard, G. (2012) at *Blind Harmonic Adaptive Decomposition Applied to Supervised Source Separation* (20th European Signal Processing Conference (EUSIPCO), Bucharest, Romania, August 27-31, 2012, pp. 2654-2658). This algorithm is based in the Constant-Q Transform (CQT), a wavelet-based approach.

The algorithm is capable, from the detected PSD envelope of the harmonic content, to propose missing f0 fundamentals and assign them a correspondent energy. Thus, we should be able to retrieve and view originally located energy below the 250Hz limit (especially between B2, 122Hz, and E2, 83Hz) even though missing from the recording[128].

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[126] *"controls balance between tones and noise in the separation algorithm"* (iZotope manual)

[127] Fuentes B., Badeau R., Richard, G. (2012). *Blind Harmonic Adaptive Decomposition Applied to Supervised Source Separation* 20th European Signal Processing Conference (EUSIPCO), Bucharest, Romania, August 27-31, 2012, pp. 2654-2658.

[128] a reverse approach -that is, audio enhancement by the generation of upper harmonics related to original fundamental frequencies- is used by Waves in their plug-ins MaxBass and Renaissance Bass – see *MaxxBass® psycho-acoustic technology* at http://www.maxx.com/objects/PDF/MaxxBassAESPaper.pdf

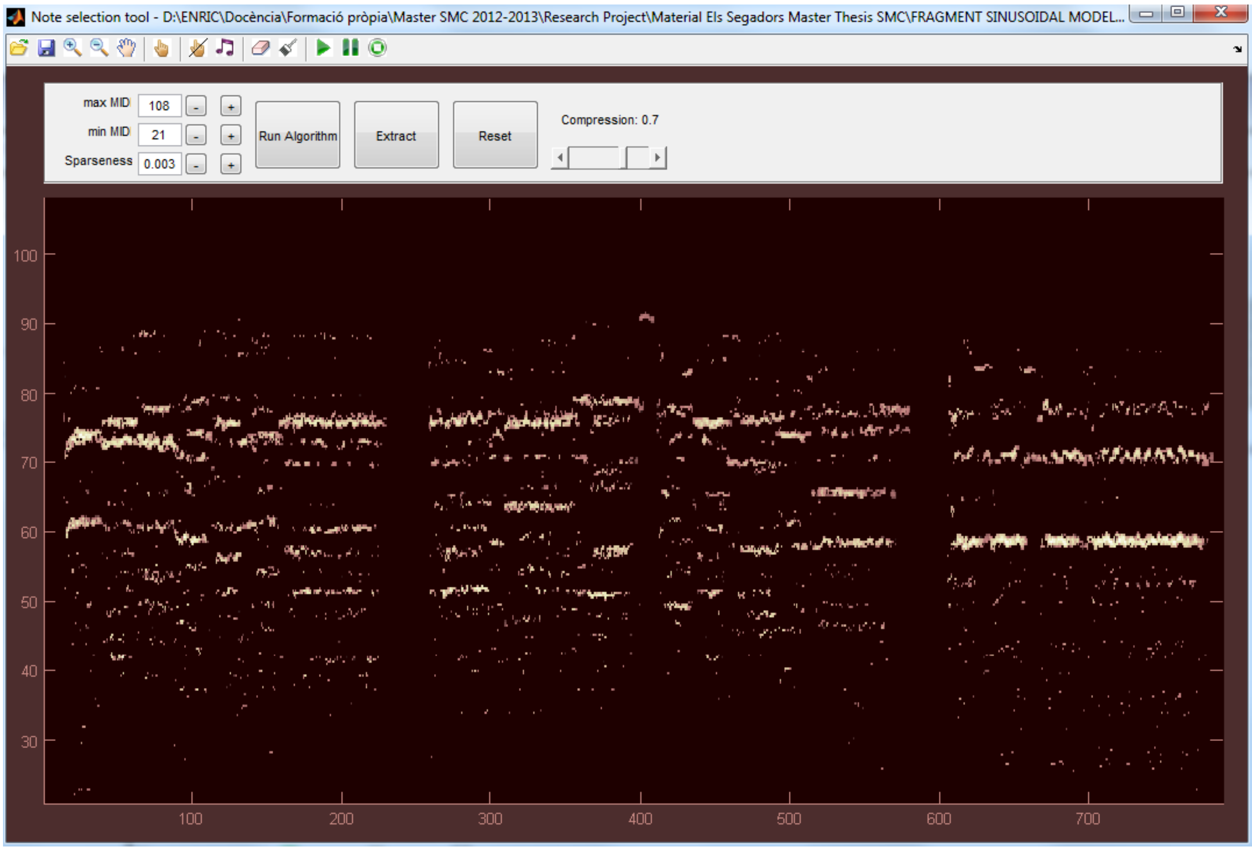


**Image 49. BHAD algorithm implementation with SINUSOIDAL MODEL Segadors -40 512 1025.wav**

- HYPOTHESIS I

  The recorded version of *Els Segadors* basically corresponds to the first verse of the score shown in Image 38. Cover and full score of *Els Segadors* as arranged by Enric Morera for male voices (1897), and published in *L'Avenç*, 1901. Source: Biblioteca Nacional de Catalunya

This seems clear just by aural analysis. The pitch and the basic harmonic lines of the recording correspond to the arrangement for the first verse (repeated), as has been already states in previous chapters

- HYPOTHESIS II

  The recorded version presents fundamental frequencies out of the male tenor *tessitura*, which would confirm the presence of children or boy's voices

We have tried to isolate the upper voices, Tenors I & II and render separated files for both. We have used the score as a departing point, but taking into account PSD for each frame. The software allows relative large files for analysis (the recording of Els Segadors lasts 1'47") but not for source separation rendering, so we chose the second verse and split it in 4parts.

We show here a fragment of the *original* –i.e. non-modelled- digitised file (SegaMONO4-3.wav) corresponding to the Tenor I, actually Soprano for children, as it has been tracked and, once separated, analysed in Sonic Visualiser.

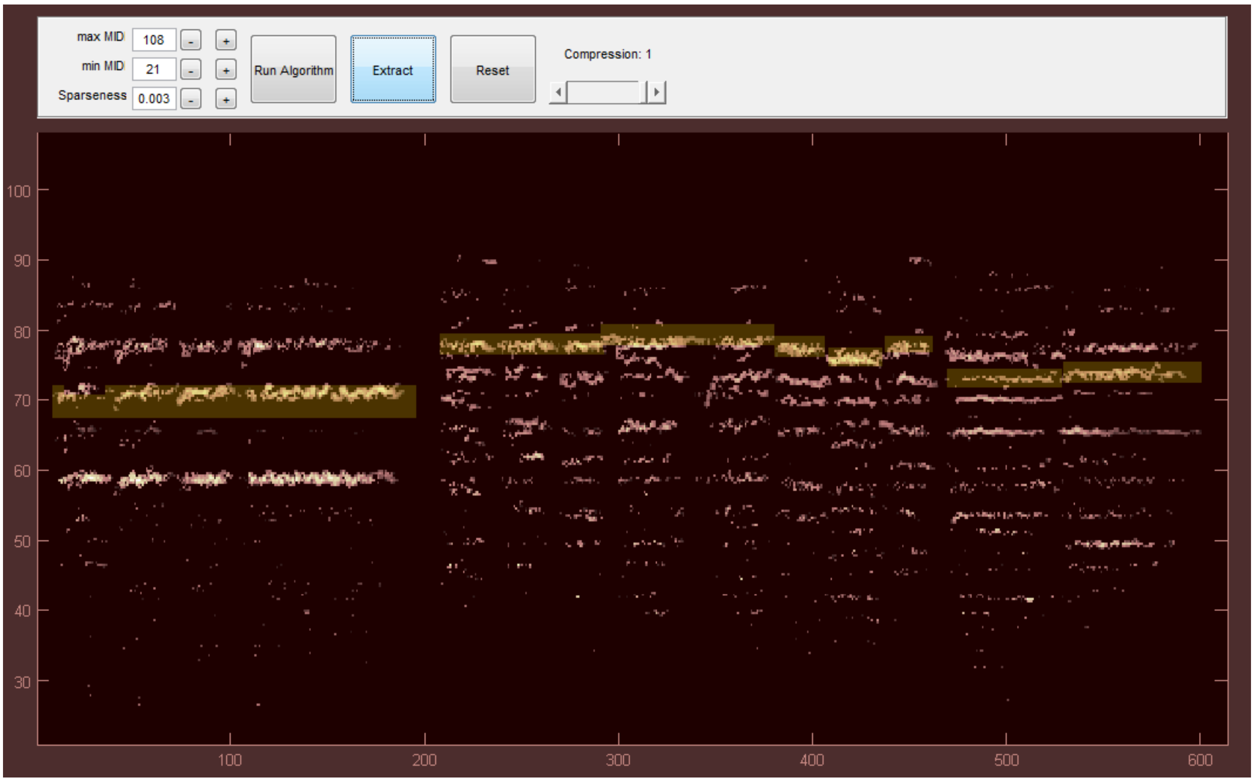


**Image 50. Tenor I part for "*Bon cop de falç, defensors de la terra*" (SegaMOM4-3.wav)**

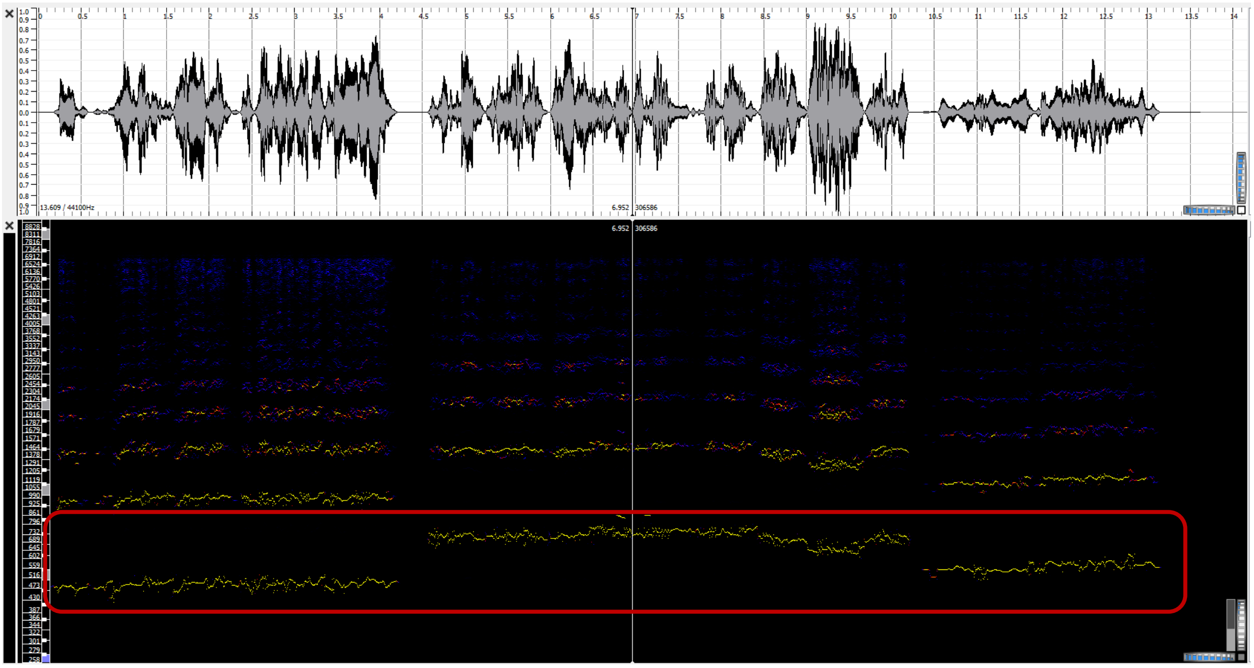

**Image 51. Tenor I (actually soprano children) as retrieved from SegaMONO4-3.wav**

The excerpt can be heard in the file SegaMONO4-3 – TenorID.wav.

- HYPOTHESIS III

  There are *divisi* in the performance of some of voices of the harmony not written in the referenced score

As commented in 8.6, aural inspection of fragment #3 seems to confirm a bass line being sung an octave below the written part. We tried to detect and track this voice using the same MATLAB tool.

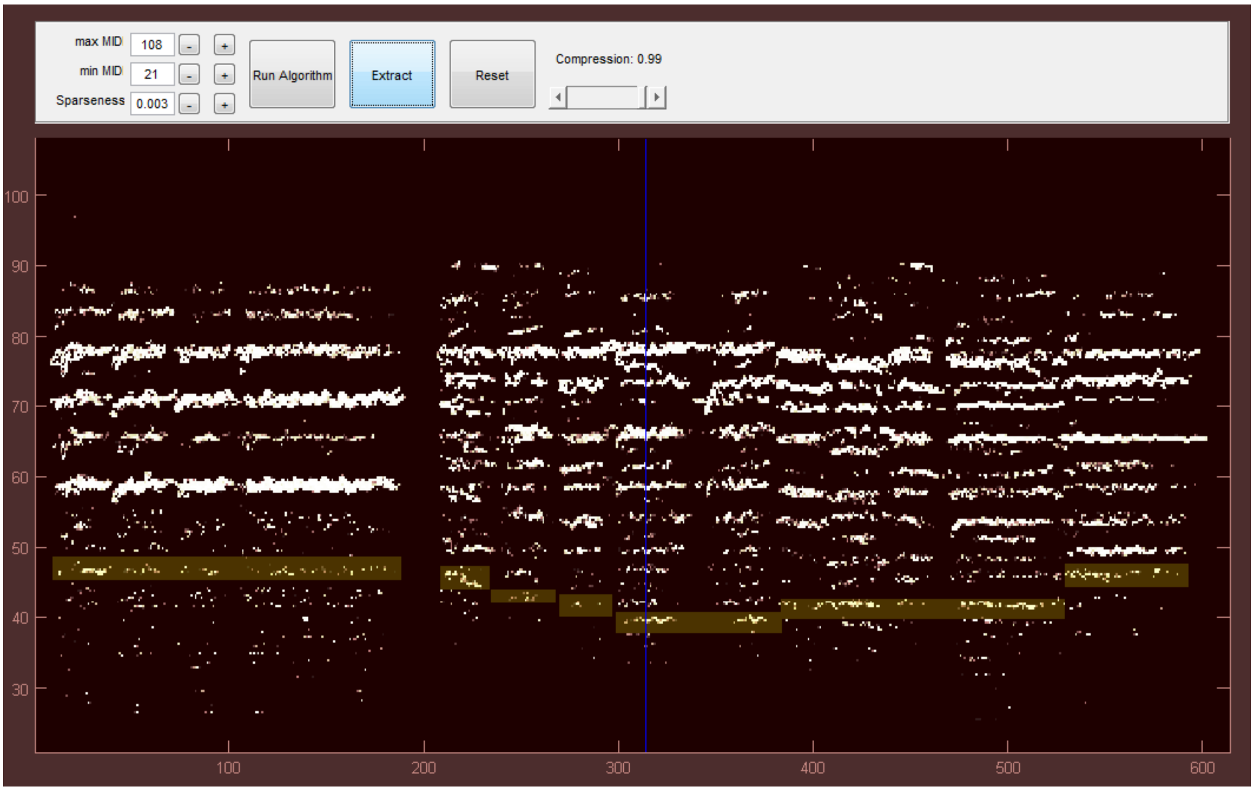


**Image 52. Contra-bass voice proposal - fragment #3**

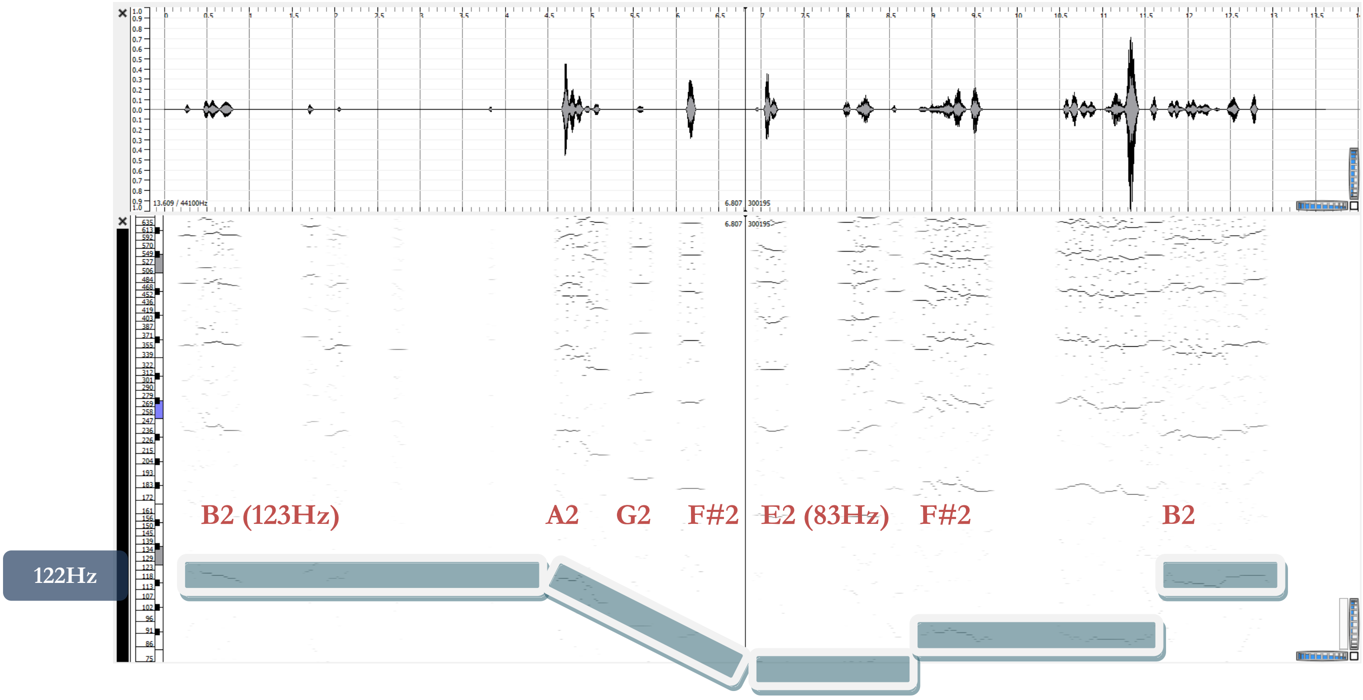


**Image 53. Contra-bass voice proposal with its musical notation**

The resulting file, SegaMONO4-3 – Octavat.wav, has very low PSD and thus has been normalized to peak, respecting original dynamics.

Nonetheless, the extended low fundamentals are audible and the harmonic progression fully corresponds to the psychoacoustic perception.

The sudden increment of energy at the end of fundamental note F#3 (183Hz) is due to the inherent resonances of the recording horn at the first harmonic, F#4 (366Hz), which is also being sung by the baritones at that point.

8.7.4. Source separation using commercial tools (Celemony Melodyne Editor[129])

Even though *Melodyne Editor* and *Melodyne Studio* are well known commercial tools focused to commercial audio production, they offer similar some source separation capabilities. Nevertheless, its interface seems more intended to edit existing separated sources than to render them in separate files and doesn't infer related energy from the harmonic content.

[129] see http://www.celemony.com/cms/index.php?id=383&L=2

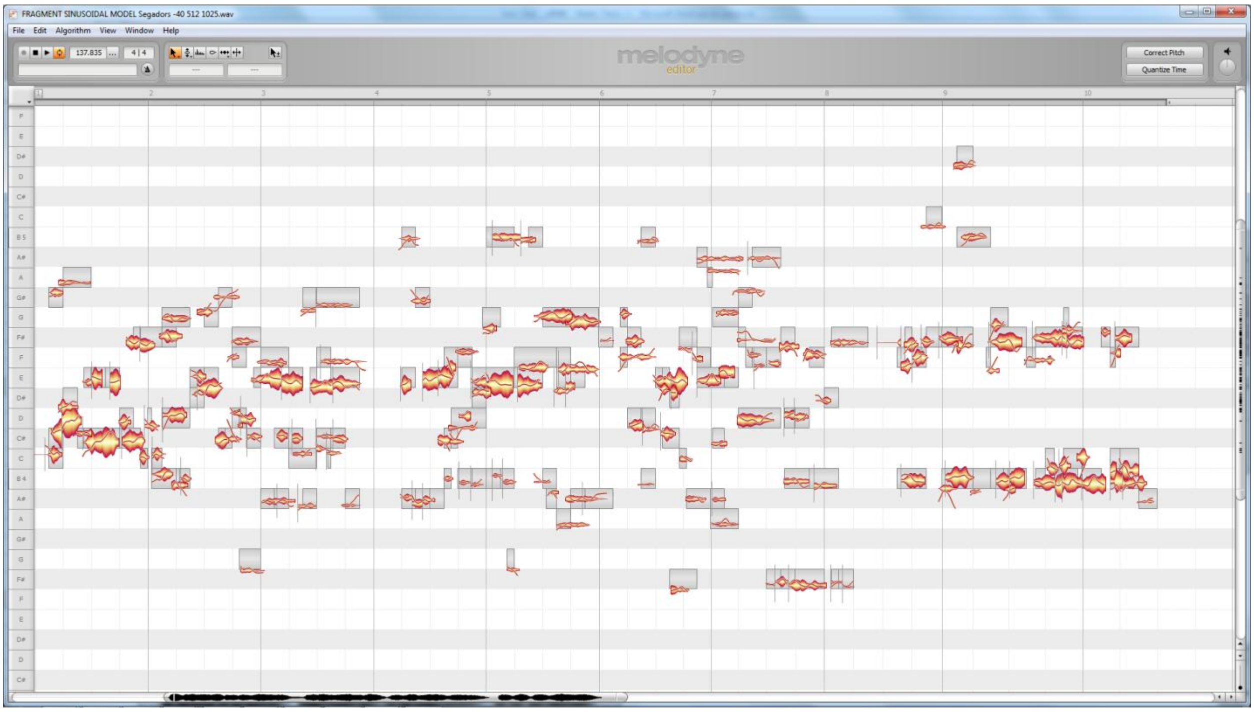

**Image 54. Melodyne Editor with SINUSOIDAL MODEL Segadors -40 512 1025.wav**

## 8.8. Practical aspects of the restoration

The restoration of the *Els Segadors* in the digital domain follows the guidelines outlined in Chapter 6.

### 8.8.1. Scope and type of restoration

This process begins with the speculation about the conditions of the available disc after the processes of cutting and pressing (see Image 16), as limited in both quality (frequency range and dynamic), and preservation state, reliability and loyalty to the potential characteristics of the original recording on a zinc master.

Based on Orcalli 2006, we will be discussing restoration upon the following approaches

- a *preservative approach* to the functional support – see 6.2.1
- a *documentary approach* to minimize unintentional disturbances – see 6.2.2
- an *aesthetical approach* for intentional restoration in response to contemporary taste – see 6.2.5

For reasons endorsed in chapter 4.4, any approach to a historical reconstruction (i.e. using vintage equipment from the time of the actual recording) has been discarded, even though experts do not categorically rule this out (see the description of the experience from the Nimbus Records label in their collection "Prima Voce" in Copeland, 2008: 53).

### 8.8.2. Main types of disturbances

| type | detail | possible causes |
|---|---|---|
| **local** | periodic and random clicks and crackles (T = 0,85s - 1,17Hz) of length 20µs to 4ms | breakages, indents, notches, adhered debris, inherent granularity of the recording material from the pressing (shellac) |
| **global** | surface friction noise, *swishing* noise | friction, irregular surface erosion, granularity of the recording material from the pressing (shellac) |
| | wow (modulation between 0,5 and 6Hz) | non-constant rotational speed, uneven speed between recording and playback processes |
| | harmonic distortion (THD) | resonances from the recording horn, from the cartridge and stylus coupling, etc. |

**Table 15. Major disturbances found in the Berliner pressing**

Once commented and applied reproduction and restoration processes in the analogue domain, the digital domain allows for the following changes

- digital compensation of *unintentional alterations*, with the goal of objectivity and transparency
- digital compensation of *intentional alterations*, with the goal of subjectivity and alteration (re-mastering)

| type | detail | possible procedures |
|---|---|---|
| **unintentional disturbances** | periodic and random clicks and crackles | reduction of click and crackle |
| | wow | not treated |
| | surface *swishing* noise | slight noise reduction applied. Noiseprint (NLM method[130]) |
| **intentional disturbances** | harmonic distortion compensation (THD) | subjective EQuing (LPF, HPF, *Notch*, BPF) |
| | low signal | peak normalizing to -1dB$_{FS}$ (no compression applied) |
| | | re-mastering |

**Table 16. Digital compensation for intentional and unintentional alterations**

[130] see http://www.izotope.com/tech/aes_suppr/, http://imaging.cmc.msu.ru/pub/MusicalNoise07.pdf

## 8.9. Implementation and results

Even though there is a myriad of available tools in the market, we've used one of the most recognized and state-of-the art solutions, *iZotope RX2 Advanced*[131], to treat the whole of the above mentioned disturbances in accordance with the order proposed by Godsill and Rayner 1998

- local-type disturbances
- global-type disturbances

As already mentioned, intentional restoration is bond to the aesthetic tastes of the sound engineer or the artistic producer, to the time and the intended public. Therefore it should be noted, again, the following points

- set aside the original analogue (if existent), the original digital source should always be kept, as only this source has documentary value
- all processes carried out at any time should be documented. In this case, by generating an XML document (see Appendix)


**Image 55. Izotope RX2 Advanced. Main Screen**

The following graphs illustrate the results step by step. Superimposed are the waveform (in light blue) and its spectrogram (in light orange).

[131] see http://www.izotope.com/products/audio/rx/

### 8.9.1. Unintentional processes

#### 8.8.8.1. Reduction of local disturbances (clicks and crackles)

The transient clicks and crackles are caused by both random and periodic causes, in the latter case especially at the beginning of the disc, with a periodicity of 0,85 seconds (1,18 Hz) probably due to transversal scratches. Such disturbances are up to 25dB above the background noise. This reinforces the need to use 24bits or more in order to preserve the dynamics of disturbances without digital clipping.

We made use of multiband algorithm for clicks of analogue origin and wider spectral content wider than that of digital clips.

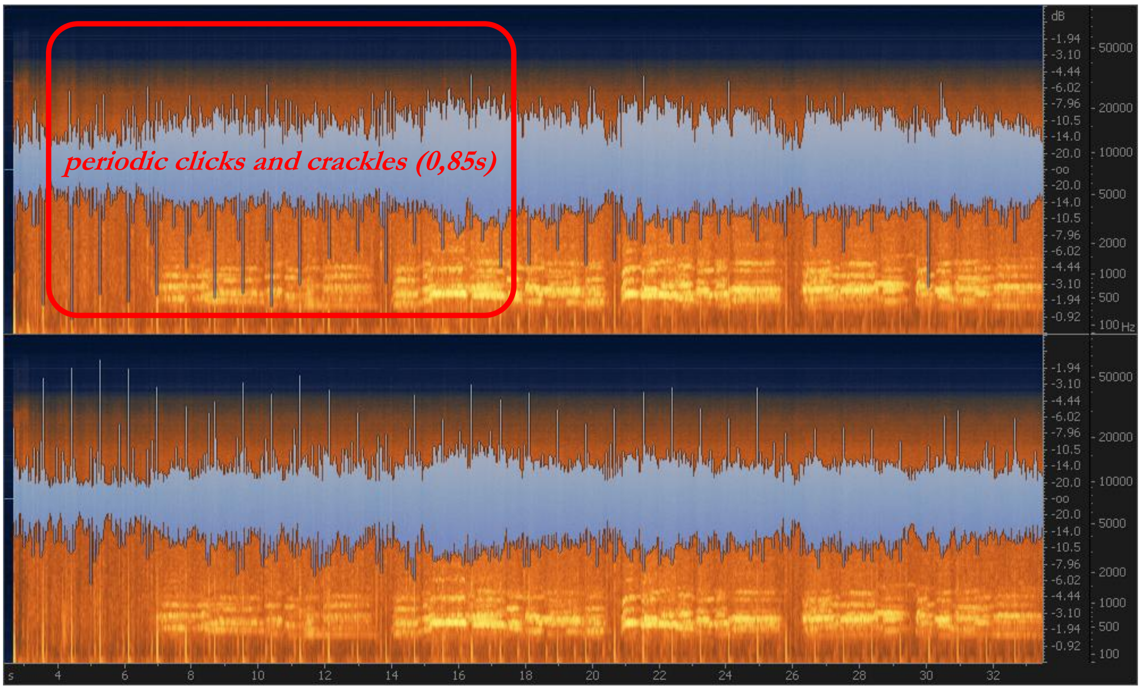


**Image 56. Excerpt from the beginning of the Berliner disc. Original file**

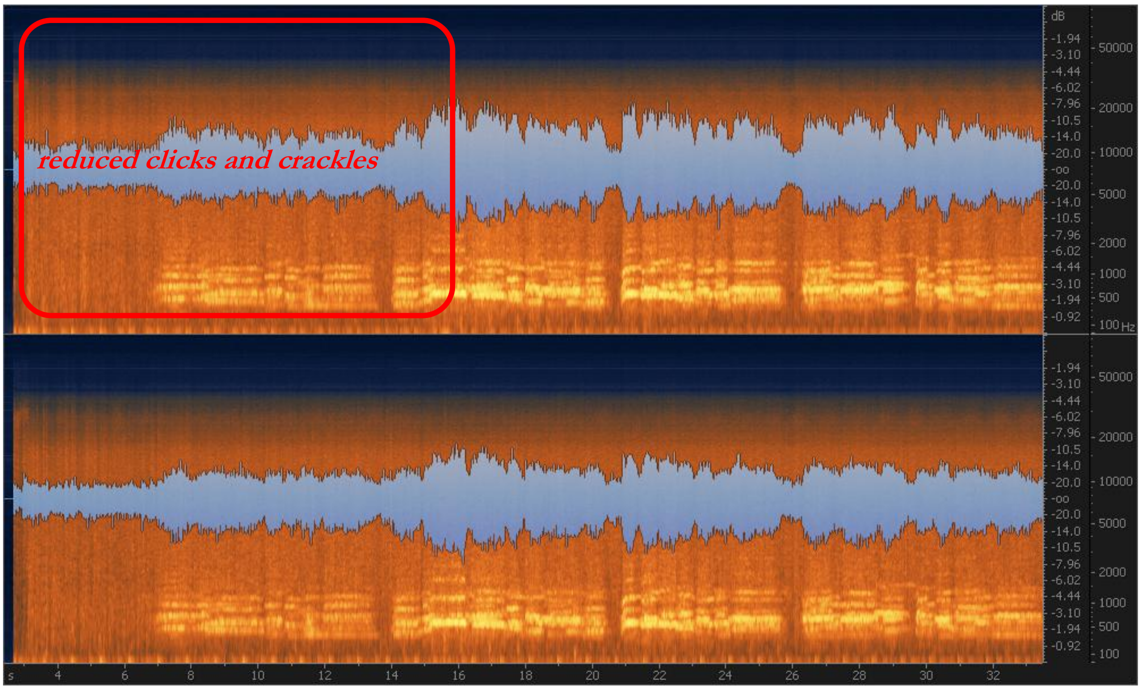


**Image 57. Excerpt from the beginning of the Berliner disc. Click and Crackle reduction. There is a noticeable reduction in periodic transient impulses present in the original waveform**

8.8.1.2. Reduction of global degradation (swishing)

The background noise level, as indeed any disturbance, depends largely on the type of stylus selected and the weight exerted by the cartridge set on the disc during playback. The calibration of the playback equipment, detailed in 8.5.9.1, responds to minimize this effect.

However, roughness and hardness of the disc material itself (*Durinoid*) as well as the methods and materials used to record of the original master, are important factors.

We should recall that, at least in Europe in late 1900, Sinkler Darby was still using zinc-based masters evenly coated with wax. The needle would remove the wax, leaving a modulated trail of exposed zinc. The following bath with chromic acid would attack zinc, where the groove would be engraved. However, the acid did not eat out the zinc in a uniform manner (Morton 2004: 38), which generated random irregularities in the surface that were subsequently transferred to the Durinoid pressings as background noise. Such noise would not be minimized until Eldrige Johnson1896-98 proposal of a master disc entirely made of wax that significantly improved signal to noise ratio (Copeland 2008: 293).

Yet in 1900, the recording of *Els Segadors* on a zinc matrix would partly justify the high background noise level (swishing noise).

Noise reduction process has had the foremost goal of preserving as much as possible the harmonic content of the recording. The fact that the musical signal level is so low and actually similar to the noise we want to minimize made us choose a very low threshold separation between signal and noise levels. In contrast, a low threshold (and therefore less aggressive) allows us to apply higher levels of reduction.

Moreover, the practical lack of transient signals (a cappella choir, sustained notes) allowed the use of a priori relatively longer time windows (FFT around the 50ms) that prioritize frequency resolution. At the end, we opted for a dynamic windowing procedure adjusted according to the incident signal, to preserve potential musical transients and minimize echoes (smearing).

One of the usual downsides in noise reduction processes, especially if being too aggressive, is the emergence of sound artefacts included under the name of "musical noise" or residual noise (Godsill 1998: 141). We tried to minimize this defect by smoothing the algorithm noise reduction estimates (global/fine smoothing).

Remember that the end goal is not the elimination of disturbances, as they can also have a historical dimension and may help contextualize the signal. So, in spite of any proposal of aesthetic restoration, we opted to preserve such disturbances to a certain degree (preservative approach). Moreover, a complete elimination of the noise component without damaging the tonal component of the signal (singing voice) becomes virtually impossible without the development of collateral "musical noise" and compromise is thus needed.

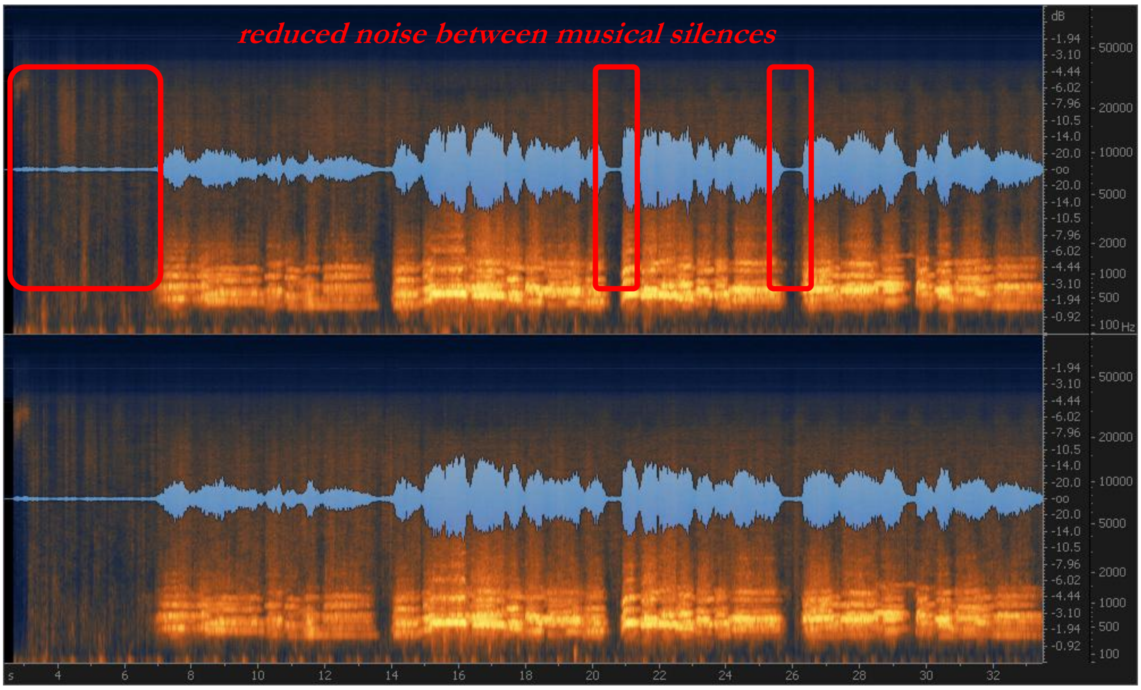


**Image 58. Excerpt from the beginning of the Berliner disc. Click & crackle + noise reduction. There is a better definition of the high-frequency content, especially in the absence of signal**

8.9.2. Intentional processes

Linear phase equalization has been applied, with the basic proposal to reinforce the edges of the recorded bandwidth (loudness).

| EQ | HPF | BPF1 | BPF2 | BPF3 | LPF |
|---|---|---|---|---|---|
| frequency (Hz) | 100 | 150 | 375 | 1450 | 13000 |
| gain (dB) | -30dB/oct | 3.0 | -3.0 | 3.0 | -30dB/oct |
| Q factor | - | 1.5 | 12 | 4.0 | - |
| goal | reduction of non-recorded energy (noise introduced by transduction system) | slight enhancement of low frequency content (around B2) | punctual decrease of resonant energy (harmonic distortion) | slight enhancement of high frequency content for increase intelligibility (around F#6) | reduction of noise located above the recorded bandwidth. A certain amount of it will be preserved (subjective value) |

**Image 59. Intentional equalization parameters and values**

Note the slight intervention in the resonant region mentioned in chapter **¡Error! No se encuentra el origen de la referencia.**, centred around 375Hz. We've used a rejection-band filter with a very narrow Q-factor ("surgical" EQ). We should speak in this case of an intervention aimed to retrieve the sound quality back to a state prior to the transduction chain (see Image 16. *A schematic view of the recording chain*) in order to attenuate the resonances probably introduced by gramophone's recording horn.

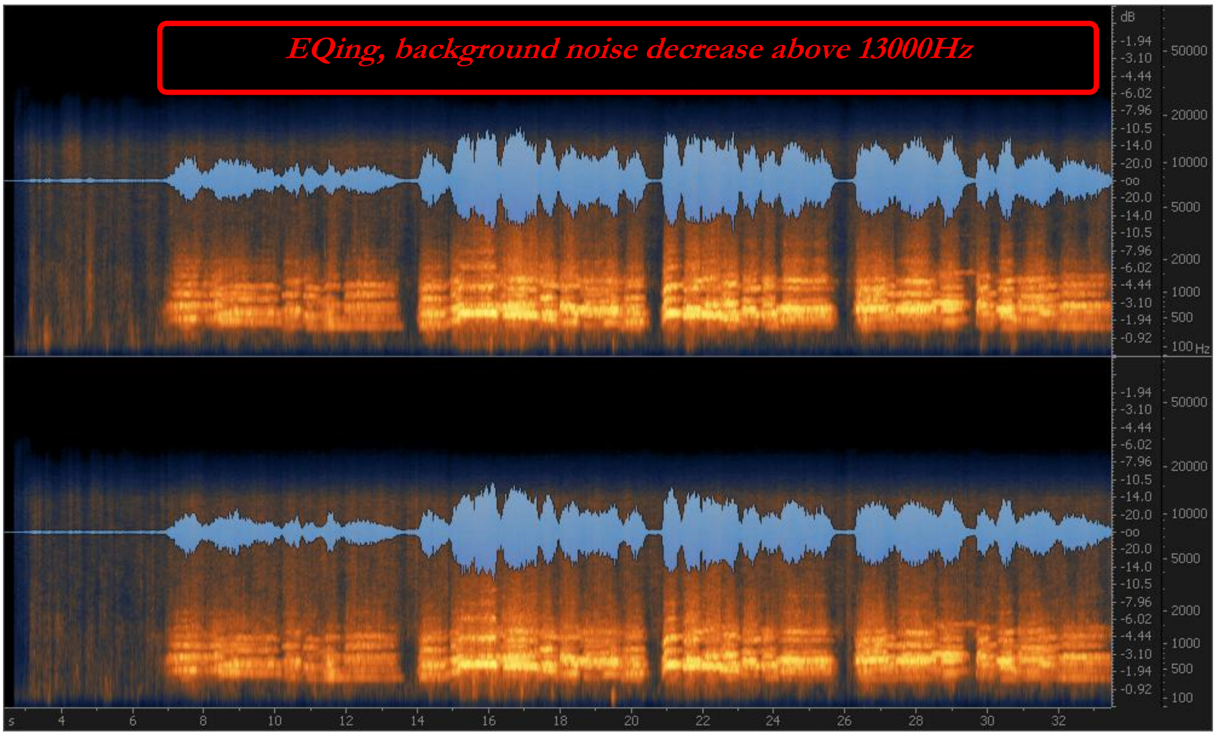


**Image 60. Excerpt from the beginning of the Berliner disc. Intentional equalization. There is a significant reduction on the signal energy around 12000Hz and an increase around 250Hz and 1450Hz**

Finally, we applied peak normalization to -1dB$_{FS}$ without altering the dynamics of the recording. We kept in any case the monophonic version by summing up both groove tracks (channels L + R) and discarded in any case the addition of artificial reverberation.

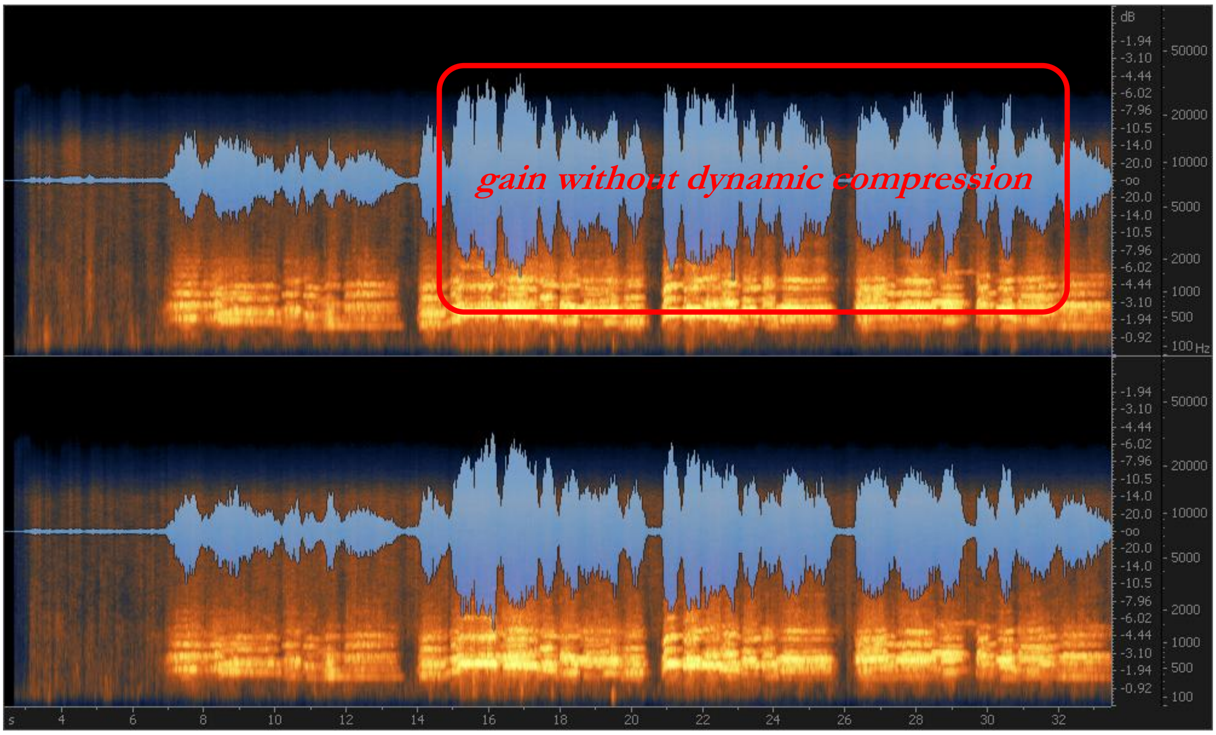


**Image 61. Excerpt from the beginning of the Berliner disc. +6 dB gain. -1dBFS-peak value**

The final results can be heard on the audio files

- M01Segadors.wav (master copy) - original 192KHz/24bits without post
- P01Segadors.wav (playback copy) - with intentional application of restoration
- D01Segadors.flac (dissemination copy) - with intentional application of restoration

Moreover, an example of every restoration step can be seen in the following video

- V01Segadors.avi

| | | | |
|---|---|---|---|
| **Tasca** | Transcodificació i postproducció de discs del Fons Sonor Joan Manén | | |
| **Client** | Museu de la Música Barcelona | www.museumusica.bcn.es | |
| | | Sara Guatevi [sguastevi@bcn.cat] | |
| **Ítem** | 26 | | |
| **Data de transcodificació** | 20/4/2012, 5/8/2012 | | |
| **Data de post-producció** | 09/06/2012 | | |
| **Metadades descriptives** | | | |
| **Museu de la Música** | **Nº registre** | MDMB 6833 | |
| | **Altres números** | FSD 487 | |
| | **Nom de l'objecte** | Disc | |
| | **Títol/nom propi** | Los Segadors [Enregistrament sonor] : himno catalán / Coro Catalunya Nova.— [S.l.] : E. Berliner Gramophone, 1895?.—2110A.— | |
| | **Precisions al nombre** | 1 disc sonor : analògic, velocitat 70 rpm ; 17'8 cm (7") | una sola cara enregistrada |
| **Companyia discogràfica** | E. Berliner's Gramphone | | |
| **Números de matriu [C1/C2]** | 2110A | A = William Sinkler Darby, segon viatge continental / màster de zenc / 47ena matriu enregistrada de 94 o 104, segons les fonts | His Master's Voice: The French Catalogue : a Complete Numerical Catalogue of ... - Alan Kelly,Gramophone Company,EMI Music Archive |
| **Número de catàleg [C1/C2]** | 64508 | 60000-69999 = catàleg d'Espanya i Portugal / 6 = Spanish, 45 = Chorus / 08 = 8è enregistrament de cor | http://books.google.es/books?id=EgCJlp0sw6gC&pg=PA31&lpg=PA31&dq=William+Sinkler+Darby+barcelona&source=bl&ots=ZrL0ck-iBv&sig=CESKC2YQzzJzWxIqJ5B-G7aYIrA&hl=es&sa=X&ei=oUUhUJKgKBPR0QXbqIHYAQ&ved=0CFYQ6AEwAA#v=onepage&q=William%20Sinkler%20Darby%20barcelona&f=false |
| **Revers** | Reproduced in Hannover | | JONES, Daniel E.; BARÓ I QUERALT, Jaume. La indústria musical a Catalunya. Barcelona: Llibres de l'Índex, 1995. (Quaderns de Comunicació, 4). pàgs. 32-36. referències d'Antonio Massísimo (Mataró, T 08-03-2012) |
| **Signe d'enregistrament elèctric** | No | | |
| **Altres signes** | | | |
| **Data d'enregistrament** | Barcelona, 27/9 - 30/10/1900 | Segon viatge continental (1900) | Casa Provincial de la Caritat / Teatro Gran Vía / Palau de Belles Arts |
| **Altres observacions** | **Tècnic** | William Sinkler Darby (1878 - 1950) | http://www.recordingpioneers.com/RP_DARBY1.html |
| | | | http://soundofthehound.com/tag/william-sinkler-darby/ |
| | **Versió musical** | Francesc Alió (1892, música), Emili Guanyabens (1897, lletra). Harmonització d'Enric Morera | enregistrada només la 1era estrofa, repetida |
| | | Cor Catalunya Nova (Fundat per Enric Morera l'any 1895, dirigit fins a finals (o fins a la fi?) de 1900) | http://www.raco.cat/index.php/Dart/article/viewFile/99743/150782 |
| | **Possible origen de l'harmonització/versió** | Harmonització per a quatre veus masculines, 1897. Catalònia (maig 1898). Epigrama simfònic per a orquestra i cor d'homes. Estrenat el 19 de maig del 1899 | http://cbueg-mt.iii.com/iii/encore/record/C__Rb2611462__Scatalonia+enric+morera__Orightresult__X2?lang=cat&suite=def |
| | | Associació per a la Salvaguarda del Patrimoni Enregistrat | http://www.aspe.cat/Butlleti1/But1-1.html |
| | | AYATS, Jaume. Els Segadors. L'avenç, 2012 | veure capítol "L'ocasió fa l'himne" (pàgs 65-116) - pàg 116: referència a Joan Manén |
| | **Referències a l'enregistrament** | JONES, Daniel E.; BARÓ I QUERALT, Jaume. La indústria musical a Catalunya. Barcelona: Llibres de l'Índex, 1995. (Quaderns de Comunicació, 4) | pàgs. 32-36. referències d'Antonio Massísimo (Mataró, T 08-03-2012) |
| **Metades tècniques i de preservació** | | | |
| **Composició** | goma laca (*shellac* provinent de The Durinoid Company) | Introduït per Berliner l'any 1897 | master gravat en relleu sobre làmina de zenc |
| **Velocitat teòrica reproducció** | Entre 60 i 80 rpm. Preferentment 70 rpm (veure referència adjunta) | http://www.bl.uk/reshelp/findhelprestype/sound/anaudio/analoguesoundrestoration.pdf | 5.4 (pàgs 86-89) |
| **Velocitat escollida reproducció** | 70.0 rpm | velocitat calibrada amb tacòmetre digital Standard ST-6236B | http://www.standardinst.com/frames/tacho_2.html |
| | | a aquesta velocitat de reproducció, el to de la peça musical és si menor | d'acord amb la versió inclosa al final de l'obra "Catalònia" d'Enric Morera (1898), tot i que en aquest cas es tracta d'un cor d'homes i no pas mixte com en l'enregistrament sonor |
| | | AYATS, Jaume. Els Segadors. L'avenç, 2012 | veure pàg. 211 - " A quin to cal cantar Els Segadors?" |
| **Corbes d'equalització** | cap | http://www.iasa-web.org/tc04/mechanical-carriers-replay-equalisation | enregistrament acústic |
| | transcodificació plana | | |
| **Procediments de neteja** | Loricraft Audio | PRC4- DL | |
| | L'Art du Son | Record Cleaning Liquid | |
| | | 1 part (20ml) de la solució dissolta en 50 parts (1 litre) d'aigua destilada desionitzada | |
| **Equipament analògic** | **Tocadiscs** | Rek-o-Kut Direct Drive Restoration Deck CVS 16" | |
| | **Càpsula** | MM Stanton 500.V - Tracking Force 2-5g | amb agulles Rek-o-Cut |
| | | Shure M44/7 | amb agulles Expert Stylus |
| | **Calibració** | AES-S0001-064 | |
| | **Agulles reproducció** | Rek-o-Kut Archival Elliptical Stylus Kit | D5125EJ 2.5mil x 0.5mil |
| | | Expert Stylus - Elliptical Truncated | ET 2,8mil (.0028 x .0009"), ET 2,3mil (.0023 x .0007") |
| | **Pre-amplificador / Equip d'equalització** | Vadlyd MD12 Mk3 | flat mode |
| **Equipament digital** | **A/D/A** | ProTools HD2 9.0.5 | |
| | **Rellotge extern** | Antelope Isochone OCX-V | |
| **Resolució master [M]** | **format** | BWF (wav) | |
| | **bits/mostra** | 24 | |
| | **freqüència mostreig [Hz]** | 192 | |
| **Resolució reproducció [R]** | **format** | BWF (wav) | |
| | **bits/mostra** | 16 | |
| | **freqüència mostreig [Hz]** | 44.1 | |
| **Resolució difusió [D]** | **format** | FLAC | Lossless Audio Coder. http://flac.sourceforge.net/format.html |
| | **bitrate** | variable | |
| | **freqüència mostreig [Hz]** | 44.1 | |
| **Post-producció** | **Procediments no intencionals** | clicks, crackles periòdics i aleatoris reducció de click i crackle | reducció de clicks i crackles |
| | | compensació de sorolls de supercifície, *swishing* | lleugera reducció de soroll (-8dB) a partir d'una petja de referència (mètode NLM) amb increment de la relació S/N |
| | **Procediments intencionals** | compensació e distorsions harmòniques (THD) | equalització subjetiva (LPF, HPF, Notch, BPF) |
| | | senyal feble | normalització a nivell de pic -1dBFS (dinàmica original mantinguda) |
| | **Software de restauració** | iZotope RX2 Adavanced | RX2 Advanced. Fitxer XML adjunt amb el detall de metadades associades a la restauració intencional |
| **Metades estructurals** | | | |
| **Fitxers associats** | **Master** | wav | |
| | **Reproducció** | wav | |
| | **Difusió** | flac | |



**Image 62. Excerpt of technical and descriptive metadata. Berliner 64508/2110A. Tasso Laboratori de so**

# 9. Frederic Mompou recordings, 1929-1950

## 9.1. Historical context: the composer and his recordings

Frederic Mompou i Dencausse (Barcelona 1893-1987), a prominent composer and pianist, devoted most of his creativity to the piano. His compositional style is initially embedded with the French Impressionism (Satie, Faure) and later on Poulenc -to cite a contemporary musician often compared to- resulting in a style in which musical development is minimized, and expression is concentrated into very small forms. His music has been considered as delicate and intimate, sometimes meditative.

Mompou was fond of recording, as shown by the series of discs were he plays his own compositions. Such recordings began in 1929/1930 in Barcelona (even though he was actually established in Paris from 1921 to 1931), later in 1944, also in Barcelona, and by 1950 in London, were he recorded for EMI at Hayes an important number of compositions. Finally, by 1974, at the age of 80, he recorded his complete work for the Spanish label Ensayo. These late recordings have been issued on four CDs by both Ensayo and Brilliant Classics.

It can be very valuable for performers, record engineers, historians of recording technology and historians of performance to be able to listen to and compare the different renditions of a very same piece that Mompou gave in the span of 45 years.

## 9.2. The set of recordings and its significance

Up to now, a number of commercial matrixes have been listed from Mompou himself playing his own compositions and some arrangements. The list, compiled by the author and pianist and researcher Marisa Gupta, is referred in the Table 21 of the Annex.

It must be pointed out that only those recordings with catalogue/order number were actually issued, and the whereabouts of other pressing (faulty or alternative matrixes) is known by the author. From this list, recordings 16 & 17 (highlighted in green), both from 1944, weren't reportedly commercially issued and thus constitute quite a novelty and rarity.

## 9.3. Two particular recordings: HMV AA172 and HMV T 6917$^{II}$/T 6918

Recording number 2 and 16 from the previous list will be indistinctly used to illustrate the proposed restoration methodology above stated, step by step:

- dating and cataloguing
- signal extraction
- digitisation
- restoration

They have been chosen for different reasons

- HMV AA172, for the paradigmatic disturbances retrieved during playback, which involve intensive digital restoration
- HMV T-6917/6918, for the cleaning challenges involved in the container (disc – see Table 6) and its value, as it is a sample of a 100 unit private issue. Also the important amount of *wow* detected

9.3.1. Information retrieval from order, catalogue and matrix numbers

9.3.1.2. HMV AA172

We can retrieve very similar information as the one obtained with disc AA175, seen in Table 4. Matrix numbers and other symbols referred to HMV AA175 disc.

| **HMV AA172 matrix numbers and other symbols** | | |
|---|---|---|
| **matrix number system introduced by HMV from 1921 on (main source: Alan Kelly – *The Spanish Catalogue*)** | | |
| **SIDE A engravings** | **SIDE B engravings** | **retrieved information** |
| **matrix numbers** | | |
| BJ 2830II Δ / 110-886 | BJ 2831II Δ / 110-887 | B = 10inch disc / BJ = Barcelona / 2830, 2831 = cardinal numbers (non-contiguous) / II = 2nd take |
| **catalogue numbers** | | |
| 110-886 | 110-887 | 110- = indicates recordings made in Barcelona between 1929 and 1934 / 886, 887 = Barcelona local registers |
| recorded 13-12-1929 | recorded 13-12-1929 | probable recording location: Compañía del Gramófono-Odeon S.A.E / c/Urgell 234 Barcelona |
| BJ/CJ series also give clues to the recording engineer: H. E. Davidson, 1925-1930 | | |
| **order number** | | |
| AA 175 | | |
| **other symbols** | | |
| Δ | Westrex (English Western Electric) EQ curve symbol | see EQ details at http://www.vadlyd.dk/English/RIAA_and_78_RPM_preamp.html |

**Table 17. Matrix numbers and other symbols referred to HMV AA172**

### 9.3.1.3. HMV T $6917^{II}$/T 6918

Less information can be obtained, as the record was not issued.

| **HMV T $6917^{II}$/T 6918 matrix numbers and other symbols** | | |
|---|---|---|
| **recordings are not catalogued** | | |
| **SIDE A engravings** | **SIDE B engravings** | **retrieved information** |
| **matrix numbers** | | |
| **T-$6917^{II}$** | T-6918 | II = second recorded matrix used for pressing |
| **catalogue numbers** | | |
| | | |
| Recorded 1944, upon preserve discographic agreement document | Recorded 1944, upon preserve discographic agreement document | probable recording location: Compañía del Gramófono-Odeon S.A.E / c/Urgell 234 Barcelona |
| | | |
| **order number** | | |
| | | |
| **other symbols** | | |
| **G, 1** | http://www.normanfield.com/markings.htm | **G** R A M O P H L T D<br>**1** 2 3 4 5 6 7 8 9 10 |
| **R, 1** | http://www.normanfield.com/markings.htm | G **R** A M O P H L T D<br>1 **2** 3 4 5 6 7 8 9 10 |

**Table 18. Matrix numbers and other symbols referred to HMV T $6917^{II}$/T 6918**

### 9.3.2. Cleaning, centring, playback and digitisation

Only the case of HMV T $6917^{II}$/T 6918 will be commented, as it is the most relevant.

Visual inspection gave clues of the possibility of inactive fungus. Being a standard shellac pressing, ultrasonic bath was considered and applied, prior to vacuum cleaning


**Image 63. Tierratech LT-150 PRO ultrasonic bath cleaning solution**

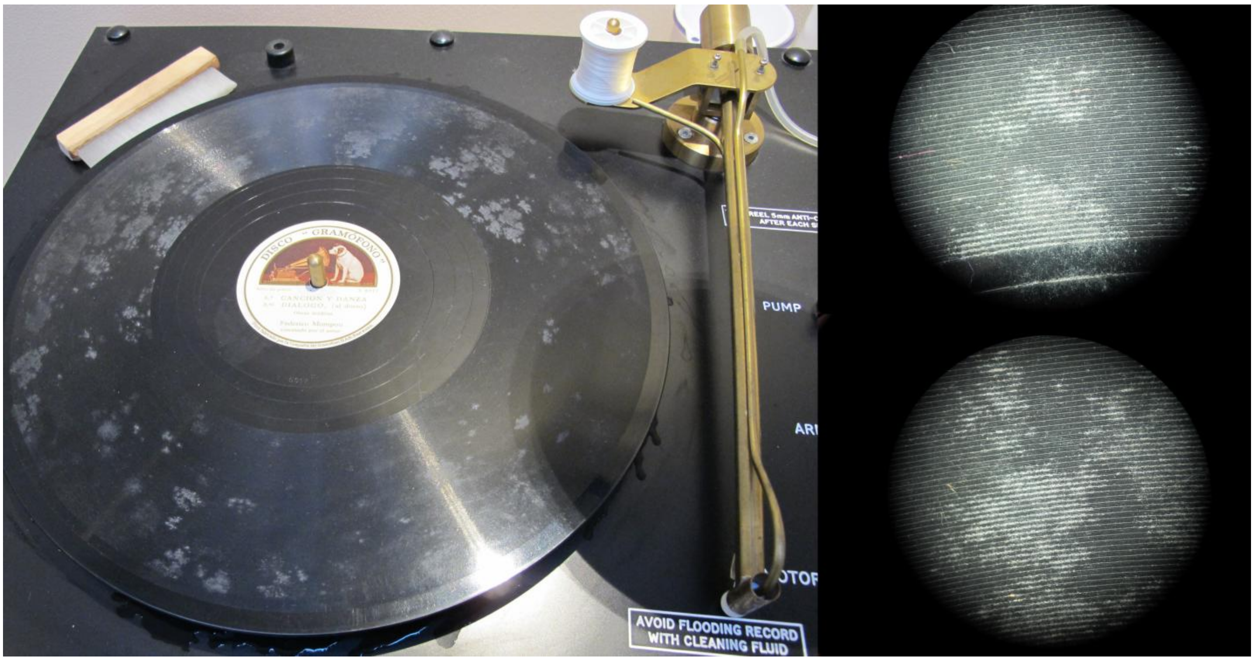


**Image 64. Possible fungus on the disc surface, HMV T $6917^{II}$/T 6918**

As for playback, two styli were considered:

| | | |
|---|---|---|
| **Turntable** | Rek-o-Kut Direct Drive Restoration Deck CVS 16" | |
| **Cartridge** | Shure M44-7 | |
| **Calibration** | Centring | |

| | | |
|---|---|---|
| **Playback styli** | Expert Stylus | Rek-o-Kut Archival Elliptical Stylus Kit |
| | 3,2ET | D5130EJ |
| | truncated elliptical 3,2milx1,2mil | elliptical 3,0milx0,5mil |
| | | |
| **Tracking force** | 3,1 grams | 3 grams |
| **Playback EQ** | WESTREX Vadlyd MD12 Mk3 | WESTREX Vadlyd MD12 Mk3 |

**Table 19. Analogue playback equipment for disc HMV T $6917^{II}$/T 6918**

Regarding HMV T 6917II/T 6918, Expert Stylus 3,2ET (elliptical truncated) stylus was finally chosen as it retrieved better perceptual SNR ratio[132] and a slightly more extended HF response. This decision was based on

- visual inspection of the grooves with a stereoscopic microscope (preservation state, signs of wear)
- documentation about the recommended styli by IASA TC-04, AES-16id-2010 and others
- critical listening in order to retrieve the best possible SNR

Physical centring was tried out for both discs, although HMV T-6917/6918 still had a very important remnant wow, possibly from the recording itself, which was later minimized in the digital restoration stage (unintentional processes) using a commercial tool.

As for the HMV AA172, chosen stylus was an Expert Stylus 2,8ET (truncated elliptical), with an applied tracking force of 3,1g with the ShureM44-7 cartridge.

Digitization followed in all cases the standard 24bits/192KHz, recommended by IASA with the equipment listed in Table 20 (annexes).

### 9.3.3. Temporal and spectral analysis with Sonic Visualiser

From here on, the following musical pieces will be analyzed to illustrate practical cases of the disturbances listed in chapter. 6.4

- *Cançó i Dansa num1* (1921) from the disc HMV AA172
- *La fuente y la campana* (1942) from *Paisajes* (1942-1960) as recorded in the disc HMV T 6918

For the analysis we have been using the Melodic Range Spectrogram feature found in Sonic Visualiser.

[132] choice is based on experience and subjective critical listening

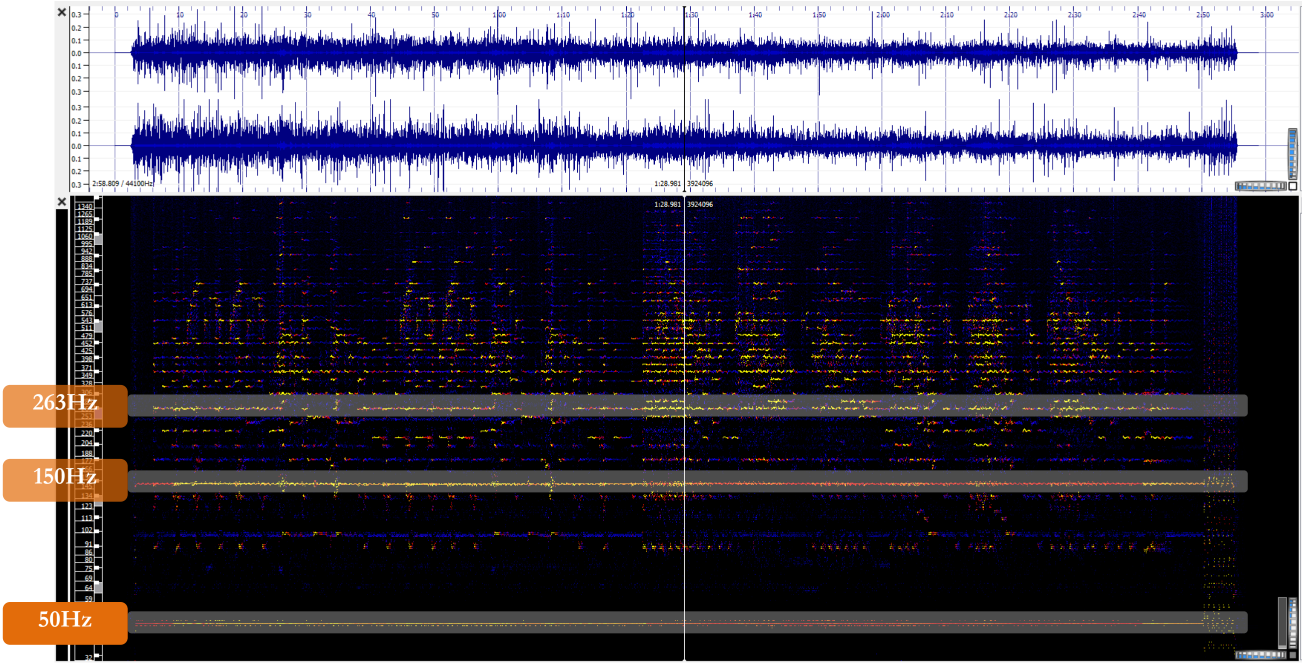


**Image 65. Temporal and spectral analysis. HMV AA172**

It can be seen –and clearly heard- an imporant amount of *hum* located in frequencies around 50Hz and multiples, especially odd ones (50Hz, 150Hz, 250Hz, etc.) as well as a marked resonance around 263Hz. Also important is the amount of impulsive noise (click, crackle). *Wow* is not as noticeable as in disc HMV T 6918.

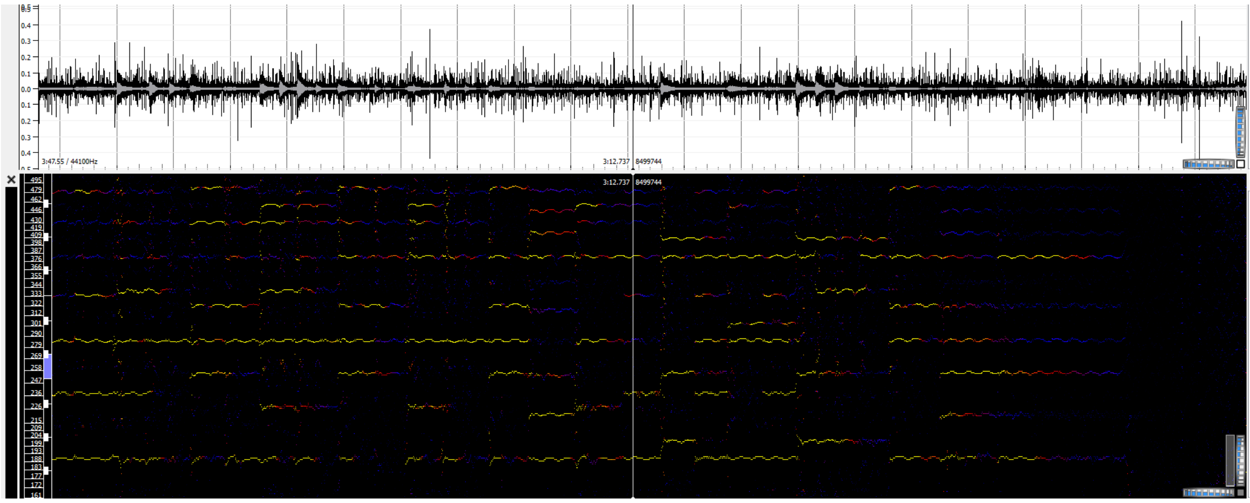

**Image 66. Temporal and spectral analysis. HMV T6918. Wow detail**

The *wow* disturbance from the HMV T 6918 is especially noticeable, as it can be seen from the last sustained piano chords in the recording. Wow frequency is around 1,4Hz (0,7s period), consistent with habitual wow figures encountered in disc recordings.[133]

[133] see data apported by Ted Kendall in Cook, et al. 2009:211

### 9.3.4. Restoration in the digital domain

Details of the restoration processes for both disc examples are attached in the Annex (see 1.5and 1.6), so they will be just highlighted here.

#### 9.3.4.1. Unintentional processes

- hum reduction (AA 172) → odd harmonics 50 and 150Hz, resonances at 263Hz
- decliping, interpolation, noise reduction
- wow&flutter reduction (T 6918) with CAPSTAN software

We've tested the ability of Celemony CAPSTAN software to reduce detected wow (1,4Hz), with good results (compare Image 66 and Image 68).

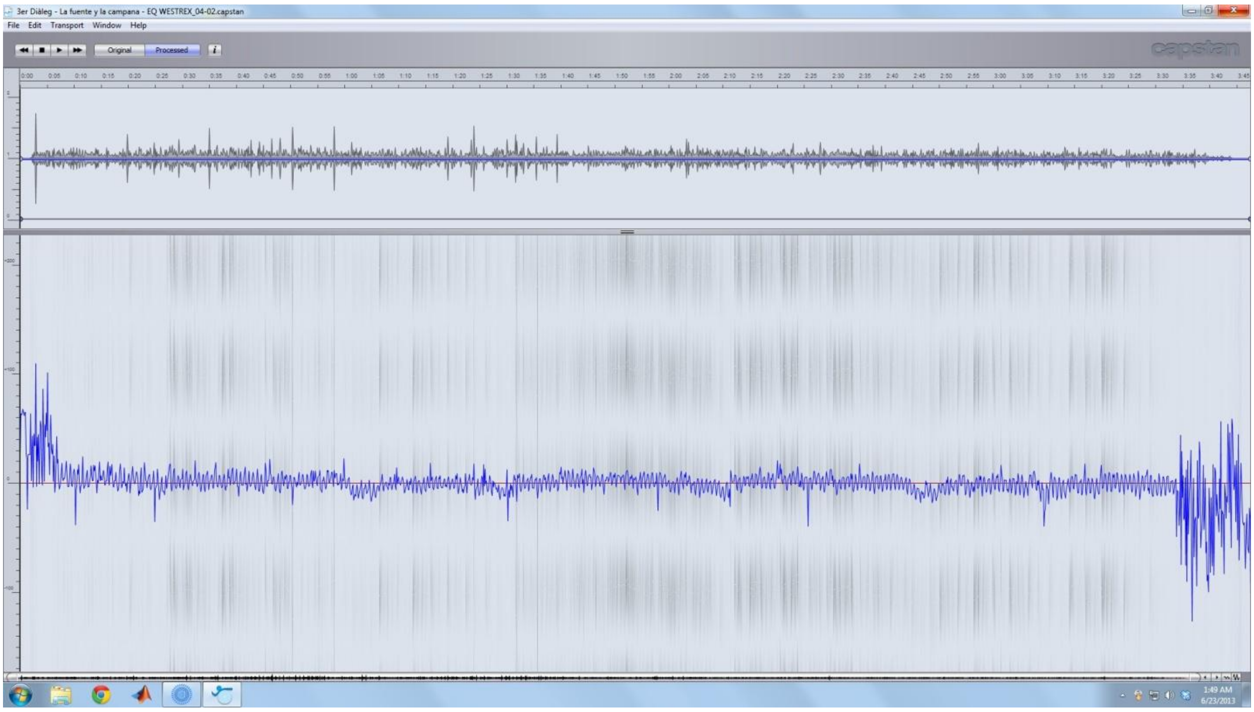


**Image 67. Celemony CAPSTAN software for wow correction on dics HMV T6918. In/out noise is due to in/out disc grooves**

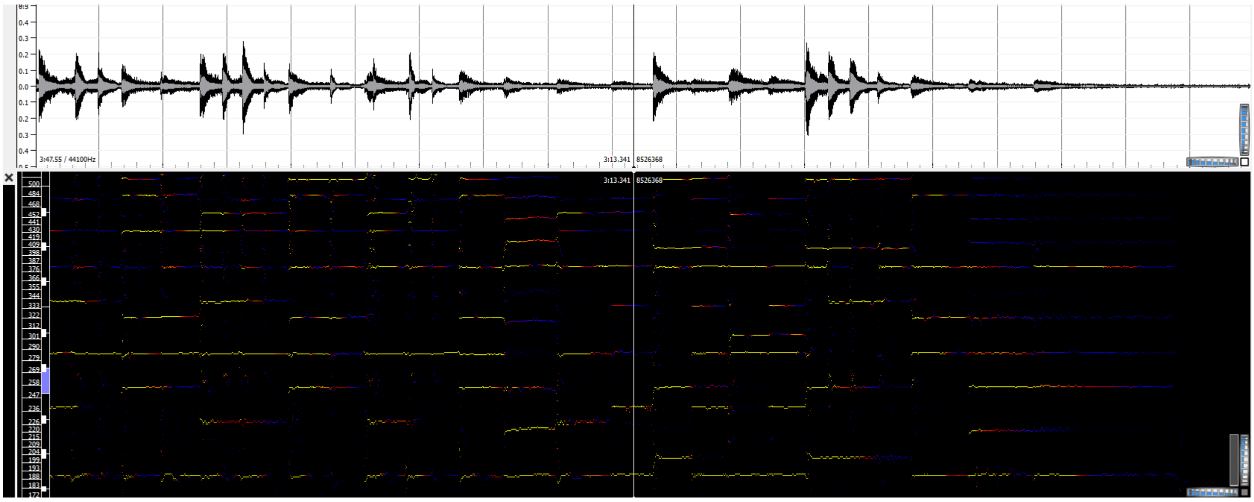

**Image 68. Temporal and spectral analysis. HMV T6918. Reduced wow detail (Celemony CAPSTAN)**

9.3.4.2. Intentional processes

- Intentional EQ → gentle phase-linear LPF at 11000Hz to cope with standard BW of the original recording
- Gain +6dB (no compression applied)

## 10. Conclusions and future work

From a traditional point of view, "*an archive aims to preserve history, not rewrite it, so any subjective alterations to the sound captured by the original recordist, deliberate or otherwise, must be minimised and documented.*"[134]

Such claim should seem to reduce archiving, from the perspective of audio content, to "transparent" playback and digitisation, set aside the necessary descriptive, structural and administrative metadata harvesting and cataloguing, retrieved automatically or by manual means (by musicologists, historians and other specialists). Both case studies presented in this work are somehow an example of these combining efforts, as they offer a compendium of many applied areas of knowledge.

Sticking to sound carriers and contents –with the proper know-how and metadata retrieval- remediation may often imply a certain degree of unintentional restoration, both in the analogue and digital domains.
Standard frameworks and methodologies should be ensued, as well as objective monitoring and evaluation in order to reinforce the aim for transparency. Furthermore, objective and subjective comparison methods for audio restoration systems (i.e. in the form of perceptual tests) should be carried on focused in signal preservation and transparency[135].
Overall, ongoing proposals are on the table, mostly driven by the IASA framework – at least in the European scene. One of the most recent and promising comes from the University of Verona, Italy[136], and seems to combine acknowledged best practices with open source software tools to help assist the ingestion, preservation and accessibility of valuable audio materials within the scope of sound archives.

At the far end of the OAIS model, access copies may ask for intentional restoration. Ted Kendall, a prominent audio engineer, states that "*the aim of remastering is to make these performances accessible to a modern audience, in terms of both physical availability and the most informative sonic presentation possible*" (Cook, et al. 2009:210).
Taking that to the letter, is there a place for techniques such as bandwidth extension, spectral band replication (SBR), audio enhancement, source separation and others? Is there a way to balance aesthetics (i.e. good sounding) and ethics (i.e. the commitment to fidelity, perhaps meaning *worse* sounding)?
From the perspective of the potential listener, what would "*a modern audience*" mean? And what should be understood as "*a most informative sonic presentation*"? On the long run, is there a broadly acknowledged methodology for intentional restoration - that is, re-mastering or re-issuing? Should we overcome the fidelity vs. aesthetics the dilemma? Should we ever care about that?

---

[134] Prentice, Will. September 2012 - http://thewire.co.uk/in-writing/essays/collateral-damage_archivist-will-prentice

[135] see Canazza S., De Poli G., Mian G.A., Scarpa A. 2001

[136] see Bressan F., Canazza S. 2013

Despite latest efforts from AES[137], the musical industry -responsible for the everlasting number of "black box" re-masters and re-issuings of all-time classics- may have it tough to respond to such questions. Yet there's a need for objective metadata rapports and evaluation of such (un)intentional restoration too.

Back to traditional archives, the actual demand for online accessibility in nowadays a key factor to its success (controversially enough, one that often justifies *per se* the mere existence of such public institutions and services). If everything is readily available online, what are the role and future of such devoted archives? As Prentice recalls, it all comes to trustable metadata. "*As to the purpose of sound archives in an era where everything is becoming available online, I think the answer will increasingly be authentication and intelligent navigation – necessary components of research. Instant accessibility still seems miraculous to me, but much online material typically carries very little context or reliable provenance, making it easy to misinform, or to disinform. Archival documents carry their provenance with them in the form of metadata, whether on a sleeve or virtually, with the intention of making clear to the listener exactly what they're listening to. Historical research demands reliable provenance, and our provision of explicit and impartial metadata will increasingly be where our value lies*". Even though barely referred to in this work, adherence and custom development of an OAIS model based workflow becomes crucial for responsible archiving.

Massive projects such as Europeana[138] are expected to reduce the gap between traditional libraries and audiovisual archives with potential users worldwide, and do offer online access to audio materials[139]. But, sometimes due to insufficient research capabilities or because of the inherent poor quality of original audio materials (mere down-rated preservation copies), such services are still underused. Here, properly defined restoration procedures (also intentional) may help increase their appeal. We believe that any future work aimed at combining accessibility, fidelity and enhanced audio quality, with a respectful eye to signal preservation and transparency, might go in the right direction. For instance, automatically cross-correlating and combining several preserved physical renditions of the very same commercial audio content (for instance, several copies of a shellac disc), in order to retrieve the best sounding *original* preservation copy in the digital domain. These should be made possible automatically in a batch mode, establishing objective quality parameters (i.e. SNR, click/crackle density, etc.). Or even, as shown in the first case study at 8.7.3, retrieving lost *originally existent* information through bandwidth extension processes or others, with the correspondent metadata information.

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[137] see AES57-2011: *AES standard for audio metadata - Audio object structures for preservation and restoration*

[138] see http://www.europeana.eu/

[139] see DISMARC, Audio Aggregation Platform for Europeana, at http://www.dismarc.org/

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  - *Una recerca interessant.* http://www.fonovilassar78.com/articles/aspe04.pdf
  - *Les primeres gravacions de masses corals* http://www.fonovilassar78.com/articles/som25.pdf http://www.fonovilassar78.com/articles/som24.pdf
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  - *Visió Europea del naixement de l'enregistrament sonor* http://www.fonovilassar78.com/articles/aspe01.pdf


[140]the webpage www.fonovilassar78.com could not be accessed on June 10th 2013

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[141] it should be here recognised the excellent work of the *Associació per la Salvaguarda del Patrimoni Enregistrat, ASPE, sadly inactive since August 2012* . Its bulletin http://www.aspe.cat/ASPE.htm may still be available via *The Wayback Machine* at www.archive.org

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# 1. Annexes

## 1.1. Equipment (*Tasso Laboratori de so*)

| Equipment | Model | Function |
|---|---|---|
| **Stereoscopic microscope** | Nikon SMZ-2B | Preservation analysis. Observation and measurement of groove condition. Determination of proper stylus for playback |
| **Cleaning machine** | Loricraft Audio PRC4 | Mechanized cleaning by vacuum. Waste liquid removal from within the grooves |
| **Cleansing fluids** | L'Art du son | Cleansing fluids |
| **Styli** | Expert Stylus / Rek-o-Cut | Elliptical, spherical and conical styli of different shapes and sizes |
| **Disc turntable** | Rek-o-cut CVS16 | Disc turntable with fine adjustments for speed, bidirectional reproducing sense and stroboscope |
| **Tacometer** | Tanita 1479Z | For cartridge and stylus applied weigth calibration |
| **Reference** | AES-S001-064 coarse- groove calibration disc | Calibration reference disc for coarse groove, side-to-side modulation. AES (Audio Engineering Society) standard |
| **Analogue EQ** | Vadlyd MD12 Mk3 | Analogue domain emphasis EQ upon disc type characteristics |
| **DAW** | Digidesign HD2 + 192 I/O | A/D ,24bits/192kHz conversion and post-production |
| | Carillon AC1-Core4 | Digital audio processing PC |
| **Digital master clock** | Antelope OCX-V | Wordclock master for analogue to digital conversion |
| **Monitoring** | Genelec 8050A | Near field speakers |
| **Monitor matrix** | Presonus Central Station | Sound matrix for audio source selection. M-S/L-R monitoring |
| **RTA** | DK Audio MSD100T | Goniometer, phase meter, spectral analysis, VUmeter |
| **Metadata software** | Audio Inspector | Metadata administration software BWF and XML/METS files |
| **Analysis software** | Sonic Visualiser | Time/frequency and waveform analysis |
| **Restoring software** | iZotope RX2 | Digital audio restoration suite |

| Stylus type | Expert Stylus |
|---|---|
| Conical Truncated | Elliptical Truncated |
| .0015" | .0015 x .0004" |
| .0018" | .0018 x .0006" |
| .0023" | .0023 x .0007" |
| .0028" | .0028 x .0009" |
| .0032" | .0032 x .0012" |
| .0035" | .0035 x .0012" |
| .0040" | |

**Table 20. Tasso Laboratori de so ingestion equipment**

1.2. Berliner 64508 / 2110A. Frontal image


**Image 69. Frontal side of Berliner 64508. Resolution: 1200ppp (taken by Sara Guasteví. Museu de la Música)**

1.3. Berliner 64508 / 2110A. Back image

**Image 70. Back side of Berliner 64508. Resolution: 1200ppp (taken by Sara Guasteví. Museu de la Música)**

## 1.4. Restoration metadata XML document[142] for Berliner 2110A


```
<?xml version="1.0" encoding="UTF-8"?>
<RXHistory format="1" product="iZotope RX 2 v2.10.656" generated-on="2012-08-26 20:00:30Z">
  <ClipStorageSingleFile>
    <File>D:\Museu de la MÃºsica\Projecte Joan Manen\Processat\Processat Els Segadors\Processat Izotope RX2\Nou\v6 Berliner14\IZOTOPED DECLICK-DENOISE-EQ-GAIN+6dB-v6- Berliner 14 - 70.0 rpm - Expert Stylus 2,8mil ET.wav</File>
  </ClipStorageSingleFile>
  <OriginalClipInfo>
    <ChannelCount>2</ChannelCount>
    <BitsPerSample>24</BitsPerSample>
    <IntegerSamples/>
    <SamplingRate>192000.000000</SamplingRate>
    <SampleFrameCount>22317247</SampleFrameCount>
  </OriginalClipInfo>
  <History>
    <Process>
      <Description>Declick [0 22317246]</Description>
      <OperationName>Declick &amp; Decrackle</OperationName>
      <UndoStyle>0</UndoStyle>
      <TimeStamp>2012-08-26 18:48:14Z</TimeStamp>
      <Key>Declicker Algorithm</Key>
      <Enum>M-band (periodic clicks)</Enum>
      <Key>Decrackler Quality</Key>
      <Enum>High</Enum>
      <Key>Declicker Sensitivity</Key>
      <Number>7.9882354736328125</Number>
      <Key>Decrackler Skew</Key>
      <Number>7</Number>
      <Key>Decrackler Strength</Key>
      <Number>7.0352940559387207</Number>
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        <Feathering>0</Feathering>
        <Poly>0</Poly>
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      </PolyRegion>
    </Process>
    <Process>
      <Description>Denoise [0 22317246]</Description>
      <OperationName>Denoise</OperationName>
      <UndoStyle>0</UndoStyle>
      <TimeStamp>2012-08-26 19:54:58Z</TimeStamp>
      <Key>TrainingBounds</Key>
      <Str>Sample range [960000-1445142], Frequency range [0.000000-96000.000000]</Str>
      <Key>TrainingClip</Key>
      <Str>D:\Museu de la MÃºsica\Projecte Joan Manen\Processat\Processat Els Segadors\Digitalitzades bones\Berliner 14 - 70.0 rpm - Expert Stylus 2,8mil ET.wav</Str>
      <Key>Algorithm</Key>
      <Enum>D (best, slowest)</Enum>
      <Key>MNS Algorithm</Key>
      <Enum>Adv.+Extr.</Enum>
      <Key>Mode</Key>
      <Enum>Advanced</Enum>
      <Key>Multi-resolution</Key>
      <Bool>1</Bool>
```


[142] there are numerous open license applications for tracking and editing XML documents. One is *EditiX XML Editor Free*, available at http://free.editix.com/

```
    <Key>HF synthesis</Key>
    <Number>7</Number>
    <Key>Harmonic enhancement</Key>
    <Number>9</Number>
    <Key>Musical noise suppression</Key>
    <Number>7</Number>
    <Key>Noise reduction dB</Key>
    <Number>20</Number>
    <Key>Noise threshold dB</Key>
    <Number>-5.0117645263671875</Number>
    <Key>Psycho-constrained suppression</Key>
    <Number>3</Number>
    <Key>Residual whitening</Key>
    <Number>8</Number>
    <Key>Simple noise reduction dB</Key>
    <Number>0</Number>
    <Key>Smoothing</Key>
    <Number>7.6999998092651367</Number>
    <Key>Tonal reduction dB</Key>
    <Number>0</Number>
    <Key>Tonal threshold dB</Key>
    <Number>-6</Number>
    <Key>Wide-band gating</Key>
    <Number>7</Number>
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      <Poly>0</Poly>
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    </PolyRegion>
  </Process>
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    <Enum></Enum>
    <Key>FFT size</Key>
    <Enum></Enum>
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    <Bool>0</Bool>
    <Key>Band Enable 3</Key>
    <Bool>0</Bool>
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    <Number>250</Number>
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    <Key>Q 2</Key>
    <Number>1.5</Number>
```

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<Poly>0</Poly>
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</PolyRegion>
</Process>
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</Process>
</History>
</RXHistory>

## 1.5. Restoration metadata XML document for HMV AAA172

<?xml version="1.0" encoding="UTF-8"?>
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reduction dB</Key><Number>0</Number><Key>Tonal threshold dB</Key><Number>6</Number><Key>Wide-band gating</Key><Number>7</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0, 22050) (7885485, 22050) (7885485, 0) (0, 0)</Loop></PolyRegion></Process><Process><Description>EQ [0 7885485]</Description><OperationName>EQ</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-17 23:34:47Z</TimeStamp><Key>EQ type</Key><Enum/><Key>Band Enable 2</Key><Bool>0</Bool><Key>Band Enable 3</Key><Bool>0</Bool><Key>Band Enable 4</Key><Bool>0</Bool><Key>Band Enable 5</Key><Bool>0</Bool><Key>Band Enable 6</Key><Bool>1</Bool><Key>Frequency 2</Key><Number>160</Number><Key>Frequency 3</Key><Number>255</Number><Key>Frequency 5</Key><Number>1873.45166015625</Number><Key>Frequency 6</Key><Number>11000</Number><Key>Gain 2</Key><Number>-1</Number><Key>Gain 3</Key><Number>-30</Number><Key>Gain 5</Key><Number>2</Number><Key>Gain 6</Key><Number>-0.12499237805604935</Number><Key>Q 2</Key><Number>1</Number><Key>Q 3</Key><Number>12</Number><Key>Q 5</Key><Number>3</Number><Key>Q 6</Key><Number>3</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0, 22050) (7885485, 22050) (7885485, 0) (0, 0)</Loop></PolyRegion></Process><Process><Description>Gain [0 7885485]</Description><OperationName>Gain</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-17 23:34:56Z</TimeStamp><Key>Gain, dB</Key><Number>6</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0, 22050) (7885485, 22050) (7885485, 0) (0, 0)</Loop></PolyRegion></Process></History></RXHistory>

## 1.6. Restoration metadata XML document for HMV T6918


```
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2013\MASTER FILES\IZOTOPED\3er Diàleg - La fuente y la campana - EQ WESTREX_04-02-IZOTOPED
v2.wav</File></ClipStorageSingleFile><OriginalClipInfo><ChannelCount>2</ChannelCount><BitsPerSample>24</Bi
tsPerSample><IntegerSamples/><SamplingRate>44100.000000</SamplingRate><SampleFrameCount>10034992</
SampleFrameCount></OriginalClipInfo><History><Process><Description>Declick [0
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Decrackle</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24
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22050) (10034991, 22050) (10034991, 0) (0, 0)</Loop></PolyRegion></Process><Process><Description>Decrackle
[0 10034991]</Description><OperationName>Declick &
Decrackle</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24
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Quality</Key><Enum>High</Enum><Key>Mode</Key><Enum>Decrackle</Enum><Key>Declicker
Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><Key>Interpolator
Order</Key><Number>400</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0,
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Decrackle</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24
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Quality</Key><Enum>High</Enum><Key>Mode</Key><Enum>Interpolate</Enum><Key>Declicker
Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
y><Loop>(1881595, 0) (1881595, 22050) (1882932, 22050) (1882932, 0) (1881595,
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12:17:49Z</TimeStamp><Key>Declicker Algorithm</Key><Enum>M-band (random clicks)</Enum><Key>Decrackler
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Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Quality</Key><Enum>High</Enum><Key>Mode</Key><Enum>Interpolate</Enum><Key>Declicker
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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y><Loop>(2424669, 0) (2424669, 22050) (2425785, 22050) (2425785, 0) (2424669,
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
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Sensitivity</Key><Number>6.5058822631835937</Number><Key>Decrackler
Strength</Key><Number>5.9764704704284668</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Pol
y><Loop>(2627693, 0) (2627693, 22050) (2629215, 22050) (2629215, 0) (2627693,
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bands</Key><Enum>1024</Enum><Key>Replace Mode Number of
bands</Key><Enum>2048</Enum><Key>Partials Mode Multi-resolution</Key><Bool>1</Bool><Key>Replace Mode
Multi-resolution</Key><Bool>1</Bool><Key>Attenuate Mode Repair
Strength</Key><Number>1.5</Number><Key>Partials Mode Harmonics
threshold</Key><Number>0.82352942228317261</Number><Key>Partials Mode Left/right tilt</Key><Number>-
1</Number><Key>Partials Mode Surround length</Key><Number>86.76470947265625</Number><Key>Pattern
Mode Surround length</Key><Number>200</Number><Key>Replace Mode Left/right
tilt</Key><Number>0.011764706112444401</Number><Key>Replace Mode Surround

length</Key><Number>200</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Poly><Loop>(5431448, 0) (5431448, 22050) (5436822, 22050) (5436822, 0) (5431448, 0)</Loop></PolyRegion></Process><Process><Description>Gain [5431448 5436822]</Description><OperationName>Gain</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24 12:22:37Z</TimeStamp><Key>Gain, dB</Key><Number>3</Number><PolyRegion><Feathering>20</Feathering><Poly>0</Poly><Loop>(5431448, 0) (5431448, 22050) (5436822, 22050) (5436822, 0) (5431448, 0)</Loop></PolyRegion></Process><Process><Description>Denoise [0 10034991]</Description><OperationName>Denoise</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24 12:30:57Z</TimeStamp><Key>TrainingBounds</Key><Str>Unknown</Str><Key>TrainingClip</Key><Str>Unknown</Str><Key>Algorithm</Key><Enum>D (best, slowest)</Enum><Key>MNS Algorithm</Key><Enum>Extreme</Enum><Key>Mode</Key><Enum>Advanced</Enum><Key>Multi-resolution</Key><Bool>1</Bool><Key>HF synthesis</Key><Number>10</Number><Key>Harmonic enhancement</Key><Number>9</Number><Key>Knee sharpness</Key><Number>6.0235295295715332</Number><Key>Musical noise suppression</Key><Number>8</Number><Key>Noise reduction dB</Key><Number>15</Number><Key>Noise threshold dB</Key><Number>3</Number><Key>Psycho-constrained suppression</Key><Number>0</Number><Key>Residual whitening</Key><Number>4</Number><Key>Simple noise reduction dB</Key><Number>0</Number><Key>Smoothing</Key><Number>7.6999998092651367</Number><Key>Tonal reduction dB</Key><Number>0</Number><Key>Tonal threshold dB</Key><Number>6</Number><Key>Wide-band gating</Key><Number>7</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0, 22050) (10034991, 22050) (10034991, 0) (0, 0)</Loop></PolyRegion></Process><Process><Description>EQ [0 10034991]</Description><OperationName>EQ</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24 12:35:12Z</TimeStamp><Key>EQ type</Key><Enum/><Key>Band Enable 3</Key><Bool>0</Bool><Key>Band Enable 4</Key><Bool>0</Bool><Key>Band Enable 6</Key><Bool>1</Bool><Key>Frequency 2</Key><Number>190</Number><Key>Frequency 5</Key><Number>2000</Number><Key>Frequency 6</Key><Number>11000</Number><Key>Gain 2</Key><Number>-2</Number><Key>Gain 5</Key><Number>3</Number><Key>Gain 6</Key><Number>-0.12499237805604935</Number><Key>Q 2</Key><Number>2</Number><Key>Q 5</Key><Number>3</Number><Key>Q 6</Key><Number>3</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0, 22050) (10034991, 22050) (10034991, 0) (0, 0)</Loop></PolyRegion></Process><Process><Description>Gain [0 10034991]</Description><OperationName>Gain</OperationName><UndoStyle>0</UndoStyle><TimeStamp>2013-06-24 12:35:21Z</TimeStamp><Key>Gain, dB</Key><Number>6</Number><PolyRegion><Feathering>0</Feathering><Poly>0</Poly><Loop>(0, 0) (0, 22050) (10034991, 22050) (10034991, 0) (0, 0)</Loop></PolyRegion></Process></History></RXHistory>

## 1.7. Adaptaded MATLAB code for sinusoidal and sinusoidal + residual modelling

```
function y = Lab5

% Analysis/synthesis of a sound using the short-time Fourier transform with
```

```
% peak interpolation and sinusoidal modelling

close all

%load the waveform
[x,fs]=wavread('SegaMONO.wav');
[m,n] = size(x);
if(n>1) % stereo
    x=x(:,1);
end

ws=[1025]; % different window sizes
wslength= length(ws);
Hs=[512]; % different hop sizes
Hslength= length(Hs);
ts=[-40]; % different thresholds/
tslength= length(ts);
N=1024; % size of the stft
N2=N/2+1;
%numFig = 1;
cstring='grmcykb'; % color string, using green and red (index k)

col=2; %number of columns in subplot (rows, columns, pane number)
nbits=16;

% loop for all window sizes
for i = 1:wslength;
    w = hamming(ws(i));

    % loop for all hop sizes
    for j = 1:Hslength
        H = Hs(j);
        % loop for all thresholds (ts)
        for k = 1:tslength
            t = ts(k);

            %calculation of the stpt
            [y,Xhalf,plocHalf,Pmag,Pphase]=sinemodel_GINE(x,w,N,t);
            mXhalf = 20*log10(abs(Xhalf(1:N2)));    % magnitude spectrum of positive frequencies
            pXhalf = unwrap(angle(Xhalf(1:N2)));    % unwrapped phase spect. of positive freq.

            figure(1);
            % ***magnitude spectrum*** %
            subplot(wslength*Hslength, col, (i-1)*Hslength*col+(j-1)*col +1);
            if(k==1)
                plot((0:N/2) / (N/2)*pi,mXhalf);
                title({sprintf('Window Size %d, FFT Size %d, Hop size %d', ws(i), N,H),'Magnitude
spectrum with superimposed INTERPOLATED MAGNITUDE PEAKS'});
                xlabel('freq (rad/s)');
                hold on;
            end
            plot((plocHalf-1)/(N/2)*pi,Pmag,'*','MarkerEdgeColor',cstring(k));
            text(2,(-20-((k-1)*10)),'peaks','EdgeColor',cstring(k))
            hold on;

            % ***phase spectrum*** %
            subplot(wslength*Hslength, col, (i-1)*Hslength*col+(j-1)*col +2);
            if(k==1)
                plot((0:N/2) / (N/2)*pi,pXhalf);
                title(sprintf('Phase spectrum with superimposed INTERPOLATED PHASE PEAKS'));
                xlabel('freq (rad/s)');
                hold on;
            end
            plot((plocHalf-1)/(N/2)*pi,Pphase,'*','MarkerEdgeColor',cstring(k));
            hold on;

            % ***difference between y and x*** %
            %figure(2);
            %subplot(wslength*Hslength*tslength+1, 1, (i-1)*Hslength*tslength + (j-1)*tslength +
k +1);
            %plot(y(:)-x(:));
            %title(sprintf('Difference between y and x. Window Size %d, FFT Size %d,Hop size
%d,threshold %d', ws(i), N,H,t));

            outfile=sprintf('SINUSOIDAL MODEL Segadors %d %d %d', t,H,ws(i));
            wavwrite(y,fs,outfile);
        end
```

```
    end
end

    %subplot(wslength*Hslength*tslength+1, 1, 1);
    %plot(x);
    %title('Original signal');

end
```

---

```
function [y,Xhalf,plocHalf,halfpmag,halfpphase] = sinemodel_GINE(x, w, N, t)
% Analysis/synthesis of a sound using the sinusoidal model
% x: input sound, w: analysis window (odd size), N: FFT size,
% t: threshold in negative dB, y: output sound
%
%-------------------------------------------------------------------------
% This source code is provided without any warranties as published in
% DAFX book 2nd edition, copyright Wiley & Sons 2011, available at
% http://www.dafx.de. It may be used for educational purposes and not
% for commercial applications without further permission.
%-------------------------------------------------------------------------

M = length(w);                              % analysis window size
Ns= 1024;                                   % FFT size for synthesis (even)
H = 256;                                    % analysis/synthesishop size
N2= N/2+1;                                  % size of positive spectrum
soundlength = length(x);                    % length of input sound array
hNs = Ns/2;                                 % half synthesis window size
hM = (M-1)/2;                               % half analysis window size
pin = max(H+1,1+hNs); % initialize sound pointer to middle of analysis window
pend = soundlength-max(H,hNs);               % last sample to start a frame
fftbuffer = zeros(N,1);                     % initialize buffer for FFT
y = zeros(soundlength,1);                     % initialize output array
w = w/sum(w);                               % normalize analysis window
sw = zeros(Ns,1);
ow = triang(2*H-1);                         % overlapping window
ovidx = Ns/2+1-H+1:Ns/2+H;                  % overlap indexes
sw(ovidx) = ow(1:2*H-1);
bh = blackmanharris(Ns);                    % synthesis window
bh = bh ./ sum(bh);                         % normalize synthesis window
sw(ovidx) = sw(ovidx) ./ bh(ovidx);

%freq = [0:fs/N:fs/2];
% auxiliar variable used for the assingment of plot
assigned=0;

%number of peaks acumulator init
npeaks=0;

while pin<pend
  %-----analysis-----%
  xw = x(pin-hM:pin+hM).*w(1:M);             % window the input sound
  fftbuffer(:) = 0;                          % reset buffer
  fftbuffer(1:(M+1)/2) = xw((M+1)/2:M);      % zero-phase window in fftbuffer
  fftbuffer(N-(M-1)/2+1:N) = xw(1:(M-1)/2);
  X = fft(fftbuffer);                        % compute FFT
  mX = 20*log10(abs(X(1:N2)));     % magnitude spectrum of positive frequencies
  pX = unwrap(angle(X(1:N2)));     % unwrapped phase spect. of positive freq.
  ploc = 1+find((mX(2:N2-1)>t).*(mX(2:N2-1)>mX(3:N2)).*(mX(2:N2-1)>mX(1:N2-2)));

   %-----peak interpolations-----%

  [ploc,pmag,pphase] = peakinterp(mX,pX,ploc);      % refine peak values

    if(pin > soundlength/2 && assigned==0)
      Xhalf = X;
      plocHalf = ploc;
      halfpmag=pmag;
      halfpphase=pphase;
      assigned = 1;
    end

  %-----transformations-----%
```

```
  %transcoef=1;    %when transcoef=1 we have no transformation. transcoef != 1 means
transposition
  %ploc2 = round(transcoef*ploc);


  %-----synthesis-----%

  plocs = (ploc-1)*Ns/N;              % adapt peak locations to synthesis FFT
  Y = genspecsines(plocs,pmag,pphase,Ns);          % generate spec sines
  yw = fftshift(real(ifft(Y)));                    % time domain of sinusoids
  y(pin-hNs:pin+hNs-1) = y(pin-hNs:pin+hNs-1) + sw.*yw(1:Ns);    % overlap-add

  pin  = pin+H;                                    % advance the sound pointer

end
```

---

```
function [y,yh,yr] = spsr_GINE_Segadors(x,fs,w,N,t,maxnS,stocf)
%=> analysis/synthesis of a sound using the sinusoidal plus residual or stochastic model
% x: input sound, fs: sampling rate, w: analysis window (odd size),
% N: FFT size (minimum 512), t: threshold in negative dB,
% maxnS: maximum number of sinusoids,
% stocf: decimation factor of mag spectrum for stochastic analysis
% y: output sound, yh: harmonic component, ys: stochastic component
M = length(w);                          % analysis window size
Ns = 1024;                              % FFT size for synthesis
H = 256;                                % hop size for analysis and synthesis
N2 = N/2+1;                             % half-size of spectrum
soundlength = length(x);                % length of input sound array
hNs = Ns/2;                             % half synthesis window size
hM = (M-1)/2;                           % half analysis window size
pin = max(hNs+1,1+hM);   % initialize sound pointer to middle of analysis window
pend = soundlength-max(hM,hNs);           % last sample to start a frame
fftbuffer = zeros(N,1);                 % initialize buffer for FFT
yh = zeros(soundlength+Ns/2,1);         % output sine component
yr = zeros(soundlength+Ns/2,1);         % output residual component
ys = zeros(soundlength+Ns/2,1);         % output stochastic component
w = w/sum(w);                           % normalize analysis window
sw = zeros(Ns,1);
ow = triang(2*H-1);                     % overlapping window
ovidx = Ns/2+1-H+1:Ns/2+H;              % overlap indexes
sw(ovidx) = ow(1:2*H-1);
bh = blackmanharris(Ns);                % synthesis window
bh = bh ./ sum(bh);                     % normalize synthesis window
wr = bh;                                % window for residual
sw(ovidx) = sw(ovidx) ./ bh(ovidx);
sws = H*hanning(Ns)/2;                % synthesis window for stochastic
lastysloc = zeros(maxnS,1);           % initialize synthesis harmonic locations
ysphase = 2*pi*rand(maxnS,1);         % initialize synthesis harmonic phases
fridx = 0;                            % frame pointer
isInitFrame=1;                        % =1 for frames equivalent to initial frame (for synth part)
lastnS=0;                             % it doesnot harm to initialize this variable with 0.

f = (0:N/2-1)*(fs/N);
fsyn = (0:Ns/2-1)*(fs/Ns);
plotting = true;
lastplot = soundlength/8;
plotperiod =0.2*fs;
fig = figure;

while pin<pend

   if((fridx==0)||(lastnS==0))       %whenever lastnS is zero implies frame is equivalent to
initial frame
       isInitFrame=1;
   end

  %-----analysis-----%
  xw = x(pin-hM:pin+hM).*w(1:M);          % window the input sound
  fftbuffer(:) = 0;                       % reset buffer
  fftbuffer(1:(M+1)/2) = xw((M+1)/2:M);   % zero-phase window in fftbuffer
  fftbuffer(N-(M-1)/2+1:N) = xw(1:(M-1)/2);
```

```
  X = fft(fftbuffer);                    % compute the FFT
  mX = 20*log10(abs(X(1:N2)));           % magnitude spectrum
  pX = unwrap(angle(X(1:N/2+1)));        % unwrapped phase spectrum
  ploc = 1 + find((mX(2:N2-1)>t) .* (mX(2:N2-1)>mX(3:N2)) ...
                .* (mX(2:N2-1)>mX(1:N2-2)));     % find peaks
  [ploc,pmag,pphase] = peakinterp(mX,pX,ploc);     % refine peak values
  [smag,I] = sort(pmag(:),1,'descend');  % sort peaks by magnitude
  nS = min(maxnS,length(find(smag>t)));  % get peaks above threshold
  sloc = ploc(I(1:nS));
  sphase = pphase(I(1:nS));
  if (isInitFrame)                 % update last frame data
      lastnS = nS;
      lastsloc = sloc;
      lastsmag = smag;
      lastsphase = sphase;
  end
  sloc(1:nS) = (sloc(1:nS)~=0).*((sloc(1:nS)-1)*Ns/N);  % peak locations for synthesis
  lastidx = zeros(1,nS);
  for i=1:nS  % find closest peak to create trajectories
    [dev,idx] = min(abs(sloc(i) - lastsloc(1:lastnS)));
    lastidx(i) = idx;
  end
  ri= pin-hNs;                     % input sound pointer for residual analysis
  xr = x(ri:ri+Ns-1).*wr(1:Ns);    % window the input sound
  Xr = fft(fftshift(xr));          % compute FFT for residual analysis
  Yh = genspecsines(sloc,smag,sphase,Ns);  % generate sines
  Yr = Xr-Yh;                              % get the residual complex spectrum
  mYr = abs(Yr(1:Ns/2+1));                % magnitude spectrum of residual
  mYsenv = decimate(mYr,stocf);           % decimate the magnitude spectrum
  ysloc = sloc;                            % synthesis locations
  ysmag = smag(1:nS);                      % synthesis magnitudes

  %-----synthesis-----%
  if (isInitFrame==1)
      % Variables need to be initialized like for the first frame
      lastysloc = zeros(maxnS,1);          % initialize synthesis harmonic locations
      ysphase = 2*pi*rand(maxnS,1);        % initialize synthesis harmonic phases

      lastysphase = ysphase;       % phase for first frame
  end
  if (nS>lastnS)                   % initialize peaks that start
      lastysphase = [ lastysphase ; zeros(nS-lastnS,1) ];
      lastysloc = [ lastysloc ; zeros(nS-lastnS,1) ];
  end
  if (size(lastysloc(1:nS)) ~= size(ysloc))
    ysloc = ysloc'; % sometimes matrixs are transposed
  end
  ysphase = lastysphase(lastidx(1:nS)) + 2*pi*( ...
            lastysloc(lastidx(1:nS))+ysloc)/2/Ns*H; % propagate phases
  lastysloc = ysloc;
  lastysphase = ysphase;
  lastnS = nS;                               % update last frame data
  lastsloc = sloc;                           % update last frame data
  lastsmag = smag;                           % update last frame data
  lastsphase = sphase;                       % update last frame data
  Yh = genspecsines(ysloc,ysmag,ysphase,Ns); % generate sines
  mYs = interp(mYsenv,stocf);                % interpolate to original size
  roffset = ceil(stocf/2)-1;                 % interpolated array offset
  mYs = [mYs(1)*ones(roffset,1); mYs(1:Ns/2+1-roffset)];
  pYs = 2*pi*rand(Ns/2+1,1);      % generate phase spectrum with random values
  mYs1 = [mYs(1:Ns/2+1); mYs(Ns/2:-1:2)]; % create complete magnitude spectrum

     %-----plot-----%
  %if pin > lastplot + plotperiod && plotting ==true
  if pin > soundlength/8 && plotting==true
      plotting = false;
     % original magnitude spectrum
     p1 = plot(f,mX(1:N/2));
     hold;
     % detected peaks
     p2 = plot((ploc-1)*fs/N, pmag,'x');
%       % detected harmonics
%       p3 = plot(sloc*fs/Ns, hmag,'o','Color','r');
     % stochastic
     p3 = plot(fsyn,20*log10(abs(mYs1(1:Ns/2))),'Color','g');
     title({'SINUSOIDAL+PLUS RESIDUAL OR STOCHASTICAL MODEL.',sprintf('N=%d, w=hanning(%d),
H=%d',N,M,H)});
```

```
     xlabel('frequency (Hz)');
   legend([p1,p2,p3],'Original magnitude spectrum',...
        sprintf('Detected peaks. threshold=%d',t),...
        sprintf('Stochastic magnitude spectrum (decimation=%d)',stocf));
     hold;
     v = axis;
     axis([0 fs/2 v(3:4)]);
     figure(fig);
     lastplot = pin;
  end


  pYs1 = [pYs(1:Ns/2+1); -1*pYs(Ns/2:-1:2)]; % create complete phase spectrum
  Ys = mYs1.*cos(pYs1)+1i*mYs1.*sin(pYs1);   % compute complex spectrum
  yhw = fftshift(real(ifft(Yh)));     % sines in time domain using inverse FFT
  yrw = fftshift(real(ifft(Yr)));     % sines in time domain using inverse FFT
  ysw = fftshift(real(ifft(Ys)));     % stochastic in time domain using IFFT
  yh(ri:ri+Ns-1) = yh(ri:ri+Ns-1)+yhw(1:Ns).*sw;  % overlap-add for sines
  yr(ri:ri+Ns-1) = yr(ri:ri+Ns-1)+ysw(1:Ns).*sw; % overlap-add for stochastic
  ys(ri:ri+Ns-1) = ys(ri:ri+Ns-1)+ysw(1:Ns).*sws; % overlap-add for stochastic
  pin = pin+H;                                    % advance the sound pointer
  fridx = fridx+1;                          % advance frame pointer
  isInitFrame=0;                            % variable meaningful for only current frame,
therefore zero at each frame
end
%y= yh+ys; % sum sines and stochastic
y= yh+yr;   % sum sines and residual
outfile=sprintf('S+R MODEL y %d %d %d', t,H,M);
wavwrite(y,fs,outfile);
outfile=sprintf('S+R MODEL yh %d %d %d', t,H,M);
wavwrite(yh,fs,outfile);
outfile=sprintf('S+R MODEL yr %d %d %d', t,H,M);
wavwrite(yr,fs,outfile);
```

## 1.8. Contacts with *Expert Stylus & Co.* (UK)

**On 25/04/2012 8:06 PM, Enric wrote:**

Dear Mr. Hodgson,

Thank you for the catalogue sent us over mail in previous days.

We'd like to best retrieve the sound of a Berliner disc recorded on Sept-Oct. 1900, produced in Hannover (matrix number 2110A, recorded by William Sinkler Darby during his second continental journey).

I've been acquainted that a good option would be using a fairly small stylus, around 1,5mil (instead for instance a more usual 3,0mil), as such discs were seemingly scratched or etched rather than actually cutted.

My doubts arise mostly when choosing between conical or elliptical truncated profiles.

We're actually thinking of adquiring one or two among these sets of yours:

- 1 Shure M44/7 complete catridge with Stylus .0015 x .0004" Conical Truncated Diamond
- 1 Shure M44/7 complete catridge with Stylus .0018 x .0006" Conical Truncated Diamond
- 1 Shure M44/7 complete catridge with Stylus .0015 x .0004" Elliptical Truncated Diamond
- 1 Shure M44/7 complete catridge with Stylus .0018 x .0006" Elliptical Truncated Diamond

I'd appreciate your advice and, upon this, would like to set a firm order asap, as the disc should be soon digitised.

Thanks in advance for your attention,

Enric Giné

www.tasso.cat

---

**----- Original Message -----**

**From: info@expertstylus.co.uk**

**To: enric@tasso.cat**

**Sent: Tue, 15 May 2012 11:56:47 +0100**

**Subject: Re: Berliner disc - Stylus option and order**

Dear Mr Gine,

I am responding on behalf of Paul Hodgson, as I have more experience with Berliner discs. The world authority on Berliner discs is a man by the name of Peter Adamson who at one time was a lecturer at St Andrews University in Scotland. Peter and I developed diamond sizes to get the best results from the groove modulations and we found a .0035" elliptical truncated diamond produced the best results. One must understand however, not all of the discs were etched identically and therefore some experimentation is necessary if one is to get the best results.

Having considered the styli you have ordered, although I feel the .0015" and .0018" are a little small you may get a good result.

Should you find the larger radius is better, then the smaller diamonds can be used for laterally cut shellac discs that are in

good condition. Those records produced from 1939 onwards you will find the best.

Please let us know if you wish to amend your order in any way.

We look forward to hearing from you.

Yours sincerely,

Expert Stylus & Cartridge Co.,

Wyndham Hodgson

---

**On 15/05/2012 14:16, Enric wrote:**

Dear Mr. Wyndham Hodgson,

Thank you very much for you email and the valuable information!

The fact is that I recently had the chance to attend a course on coarse groove disc recordings given in Spain by Franz Lechtleitner, former chief sound engineer of the Wien Phonogrammarchiv and also costumer of yours.

We inspected and digitized with his supervision early Berliners (1899-1900) and were using, to his advice, fair small stylii (also from Expert Stylus if I well remember) of around 1.5-1.8 mil which, compared to the more usual 3.5-4.0mil, retrieved a slightly better result. I was also accuainted wuth this approach by the AES16id-210 documentation on stylus dimensions and selection.

The digitisation of our Berliner (1900) has already been tried with a 3.5 mil stylus from another well-known branch with fair results, but would like to have the opportunity to test a smaller diameter which, us you suggest, may perhaps give us interesting results...

We'd to proceed with the whole order if possible, being able to adquire a broad set of your stylii.

Looking forward to hearing from yours,

Thanks again,

Enric.

---

## 1.9. List of known studio recordings by Frederic Mompou

Catalogued Recordings by Frederic Mompou, 1919-1950

17-6-2013

| # | Record | Available? | Digitised? |
|---|---|---|---|
| 1 | Composer: Mompou, Work: Canço y Dansa No 1Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 13-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ 2830-1<br>Date: 13-12-29<br>Title: Canço y Dansa No 1<br>Composer: Mompou | NO | |
| 2 | Composer: Mompou, Work: Canço y Dansa No 1Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 13-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ 2830-2<br>Date: 13-12-29<br>Title: Canço y Dansa No 1<br>Composer: Mompou<br>Note: 110-886 AA172 | YES | YES |
| 3 | Composer: Mompou, Work: Canço y Dansa No 2Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 13-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ 2831-1<br>Date: 13-12-29<br>Title: Canço y Dansa No 2<br>Composer: Mompou | NO | |
| 4 | Composer: Mompou, Work: Canço y Dansa No 2Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 13-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ 2831-2<br>Date: 13-12-29<br>Title: Canço y Dansa No 2<br>Composer: Mompou<br>Note: 110-887 AA172 | YES | YES |
| 5 | Composer: Mompou, Work: Canço y Dansa No 4Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 13-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ 2832-1<br>Date: 13-12-29<br>Title: Canço y Dansa No 4<br>Composer: Mompou | NO | |
| 6 | Composer: Mompou, Work: Canço y Dansa No 4Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 13-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ 2832-2<br>Date: 13-12-29<br>Title: Canço y Dansa No 4<br>Composer: Mompou<br>Note: [repeated on 3027] | NO | |
| 7 | Composer: Mompou, Work: Canço y Dansa No 3Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 20-12-29<br>Catalogue: Kelly<br>Performer: FEDERICO MOMPOU (piano solo)<br>Num: BJ2863-1<br>Date: 20-12-29 | NO | |

| | | | |
|---|---|---|---|
| | Title: Canço y Dansa No 3 | | |
| | Composer: Mompou | | |
| 8 | | | |
| | Composer: Mompou, Work: Canço y Dansa No 3Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 20-12-29 | NO | |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ2863-2 | | |
| | Date: 20-12-29 | | |
| | Title: Canço y Dansa No 3 | | |
| | Composer: Mompou | | |
| 9 | | | |
| | Composer: Mompou, Work: Canço y Dansa No 3Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 29-1-30 | NO | |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ2863-3 | | |
| | Date: 29-1-30 | | |
| | Title: Canço y Dansa No 3 | | |
| | Composer: Mompou | | |
| 10 | | | |
| | Composer: Mompou, Work: Canço y Dansa No 3Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 29-1-30 | YES | YES |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ2863-4 | | |
| | Date: 29-1-30 | | |
| | Title: Canço y Dansa No 3 | | |
| | Composer: Mompou | | |
| | Note: 110-1098 AA175 | | |
| 11 | | | |
| | Composer: Chopin Arr Mompou, Work: Vals en la menor Op 34 No 2Chopin arr Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 20-12-29 | NO | |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ 2864-1 | | |
| | Date: 20-12-29 | | |
| | Title: Vals en la menor Op 34 No 2 | | |
| | Composer: Chopin arr Mompou | | |
| | Note: 110-1204 AA177 | | |
| 12 | | | |
| | Composer: Chopin Arr Mompou, Work: Vals en la menor Op 34 No 2Chopin arr Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 20-12-29 | NO | |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ 2864-2 | | |
| | Date: 20-12-29 | | |
| | Title: Vals en la menor Op 34 No 2 | | |
| | Composer: Chopin arr Mompou | | |
| 13 | | | |
| | Composer: Mompou, Work: SecretMompou, Performer: FEDERICO MOMPOU (piano solo), Date: 20-12-29 | NO | |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ 2865-1 | | |
| | Date: 20-12-29 | | |
| | Title: Secret | | |
| | Composer: Mompou | | |
| 14 | | | |
| | Composer: Mompou, Work: SecretMompou, Performer: FEDERICO MOMPOU (piano solo), Date: 20-12-29 | NO | |
| | Catalogue: Kelly | | |
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ 2865-2 | | |
| | Date: 20-12-29 | | |
| | Title: Secret | | |
| | Composer: Mompou | | |
| | Note: 110-1205 AA177 | | |
| 15 | | | |
| | Composer: Mompou, Work: Cançó y Dança No 4Mompou, Performer: FEDERICO MOMPOU (piano solo), Date: 29-1-30 | YES | YES |
| | Catalogue: Kelly | | |

| | | | |
|---|---|---|---|
| | Performer: FEDERICO MOMPOU (piano solo) | | |
| | Num: BJ 3027-1 | | |
| | Date: 29-1-30 | | |
| | Title: Cançó y Dança No 4 | | |
| | Composer: Mompou | | |
| | Note: 110-1099 AA175 [repeat of 2832] | | |
| 16 | _ | | |
| | Composer: MOMPOU, Work: 6ª Canción y Danza, Performer: Frederico Mompou, piano, Date: 6-1944? | | |
| | Catalogue: Fundació Mompou | | |
| | CatNum: UNISSUED | | |
| | Date: 6-1944 (?) | | |
| | Label: Compañía del Gramófono-Odeon S.A.E | | |
| | Composer: MOMPOU | YES | YES |
| | Title: 6ª Canción y Danza | | |
| | Num: T-6917[ii] | | |
| | Performer: Frederico Mompou, piano | | |
| | Addtional notes: 19-6-1944 was the date of the recording agreement signature. Private presssing, 100 units | | |
| 17 | _ | | |
| | Composer: MOMPOU, Work: 3er DIÁLOGO (al dorso), Performer: Frederico Mompou, piano, Date: 6-1944? | | |
| | Catalogue: Fundació Mompou | | |
| | CatNum: UNISSUED | | |
| | Date: 6-1944 (?) | | |
| | Label: Compañía del Gramófono-Odeon S.A.E | YES | YES |
| | Composer: MOMPOU | | |
| | Title: 3er DIÁLOGO (al dorso) | | |
| | Num: T-6918[i] | | |
| | Performer: Frederico Mompou, piano | | |
| | Addtional notes: 19-6-1944 was the date of the recording agreement signature. Private presssing, 100 units | | |
| 18 | _ | | |
| | Composer: MOMPOU, Work: Scenes d'enfants No. 5, Performer: Frederico Mompou, piano, Date: 1950-02-06 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | YES | YES |
| | Composer: MOMPOU | | |
| | Title: Scenes d'enfants No. 5 | | |
| | Num: CAX 11916 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 19 | _ | | |
| | Composer: MOMPOU, Work: Cancion y danza No. 9, Performer: Frederico Mompou, piano, Date: 1950-02-06 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | NO | |
| | Composer: MOMPOU | | |
| | Title: Cancion y danza No. 9 | | |
| | Num: CAX 11917 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 20 | _ | | |
| | Composer: MOMPOU, Work: Preludes No. 9 + 10, Performer: Frederico Mompou, piano, Date: 1950-02-06 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | YES | YES |
| | Composer: MOMPOU | | |
| | Title: Preludes No. 9 + 10 | | |
| | Num: CAX 11918 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 21 | _ | | |
| | Composer: MOMPOU, Work: Cancion y danza No. 7, Performer: Frederico Mompou, piano, Date: 1950-02-06 | | |
| | Catalogue: Gray | YES | YES |
| | CatNum: UNISSUED | | |

| | | | |
|---|---|---|---|
| | Date: 1950-02-06 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | | |
| | Title: Cancion y danza No. 7 | | |
| | Num: CAX 11919 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 22 | _ | | |
| | Composer: MOMPOU, Work: Suburbs No. 1, Performer: Frederico Mompou, piano, Date: 1950-02-06 | YES | YES |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | | |
| | Title: Suburbs No. 1 | | |
| | Num: CAX 11920 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 23 | | | |
| | Composer: MOMPOU, Work: Cancion y danza No. 5, Performer: Frederico Mompou, piano, Date: 1950-02-06 | YES | YES |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | | |
| | Title: Cancion y danza No. 5 | | |
| | Num: CAX 11921 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 24 | _ | | |
| | Composer: MOMPOU, Work: La fuente y la campana, Performer: Frederico Mompou, piano, Date: 1950-02-06 | YES | YES |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | | |
| | Title: La fuente y la campana | | |
| | Num: CAX 11922 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 25 | _ | | |
| | Composer: MOMPOU, Work: Cancion y danza No. 1, Performer: Frederico Mompou, piano, Date: 1950-02-06 | YES | YES |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | | |
| | Title: Cancion y danza No. 1 | | |
| | Num: CAX 11923 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 26 | _ | | |
| | Composer: MOMPOU, Work: El lago, Performer: Frederico Mompou, piano, Date: 1950-02-06 | YES | YES |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-06 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | | |
| | Title: El lago | | |
| | Num: CAX 11925 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 27 | _ | | |
| | Composer: MOMPOU, Work: Impresiones intimas, No. 9, Performer: Frederico Mompou, piano, Date: 1950-02-10 | YES | YES |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-10 | | |
| | Label: Columbia | | |

| | | | |
|---|---|---|---|
| | Composer: MOMPOU | | |
| | Title: Impresiones intimas, No. 9 | | |
| | Num: CAX 11926 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 28 | _ | | |
| | Composer: MOMPOU, Work: Cancion y danza No. 4, Performer: Frederico Mompou, piano, Date: 1950-02-09 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-09 | | |
| | Label: Columbia | NO | |
| | Composer: MOMPOU | | |
| | Title: Cancion y danza No. 4 | | |
| | Num: CAX 11927 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 29 | _ | | |
| | Composer: MOMPOU, Work: Impresiones intimas, No. 5 + 8, Performer: Frederico Mompou, piano, Date: 1950-02-10 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-10 | | |
| | Label: Columbia | YES | YES |
| | Composer: MOMPOU | | |
| | Title: Impresiones intimas, No. 5 + 8 | | |
| | Num: CAX 11928 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 30 | _ | | |
| | Composer: MOMPOU, Work: Cancion y danza No. 6, Performer: Frederico Mompou, piano, Date: 1950-02-09 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-09 | | |
| | Label: Columbia | YES | YES |
| | Composer: MOMPOU | | |
| | Title: Cancion y danza No. 6 | | |
| | Num: CAX 11929 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |
| 21 | _ | | |
| | Composer: MOMPOU, Work: Trois variations, Performer: Frederico Mompou, piano, Date: 1950-02-10 | | |
| | Catalogue: Gray | | |
| | CatNum: UNISSUED | | |
| | Date: 1950-02-10 | | |
| | Label: Columbia | | |
| | Composer: MOMPOU | NO | |
| | Title: Trois variations | | |
| | Num: CAX 11930 | | |
| | Performer: Frederico Mompou, piano | | |
| | Additional_x0020_Dates_x0020__x002F__x0020_Notes: 12 | | |

**Table 21. Mompou recordings 1929-1950**

## 1.10. SMC Master Thesis *Prezi* Presentation

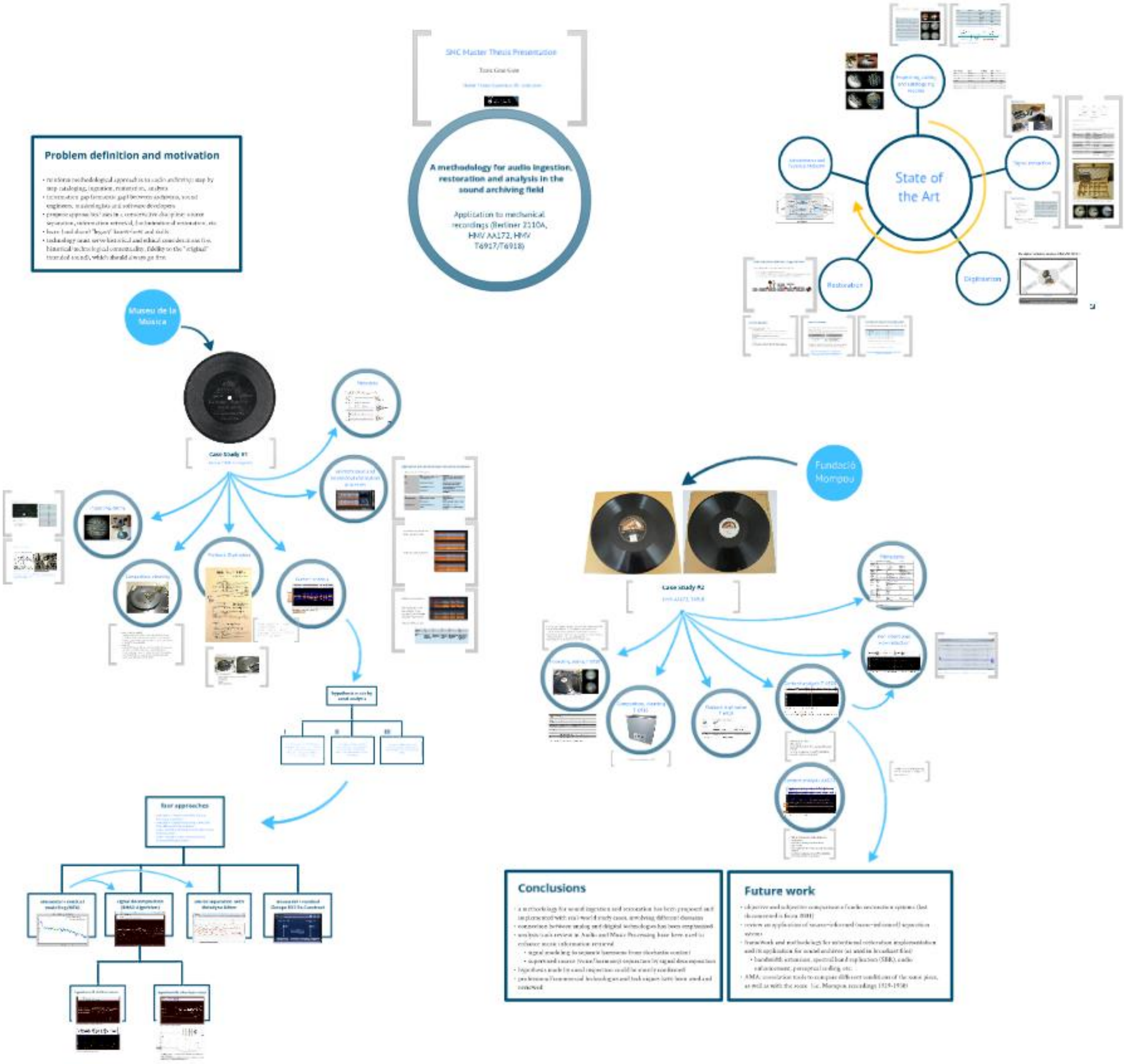


**Image 71. SMC *Prezi* Master Thesis Presentation**