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DIGITALIZATION OF TECHNICALLY OBSOLETE FORMATS OF ANALOG SOUND RECORDINGS

Abstract: Digitalization of obsolete analog formats makes it possible that historically important material recorded on them can be again presented to contemporary listeners. During the history of recorded sound, there were several sound recording formats of which the phonograph record was one of the most common. The phonograph record has been used during almost the whole era of sound recording and reproduction. It has been produced of different materials and had various physical dimensions. Also, the nature of the recording varied. Learning about these details makes it possible to choose the digitalization strategy on optimal, the most rational way. Through several examples of digitalization and sound restoration of a particular 78rpm phonograph record, we demonstrate influence of various factors on the final result—restored audio recording.
Key words: digitalization, National Library of Serbia, analog sound recordings, sound restauration

1. Introduction

Historically speaking, at the time of analogue technique recording and reproduction, until digital sound formats as well as tools for their creation came into wide application, only a few eminent foreign record companies attempted to reissue old sound material and turn into commercial records that sound pleasant. Such companies generally limited their reissues to most popular performers or composers. At present times of digital sound supremacy, possibility arises the first time to publish old sound recordings in acceptable quality, using contemporary standardized digital formats. In addition, digitalization and subsequent sound restoration can dramatically improve accessibility of vintage sound materials to scholars, archivists, musicologists, theatrologists, language experts, media history researchers and culture sociologists.

Categorization of phonograph record types regarding historic development, applied materials, and dimensional peculiarities media itself.

2. Material

Pre-microgroove (coarse-groove) disks are among the oldest media used for commercial, archival and private audio recordings. They can be categorized based on:

- Recording media
- Running time/rotation speed
- Shape of cut
- Technology used for recording acoustic signal
- Disk keeping and storage

Pre-microgroove disks are now colloquially known as "shellacs", "standard groove" or "78rpm records". In fact, using any of these terms to refer to a variety of disk recordings before the era of microgroove disks is inadequate precisely due to various categories a specific

record may belong according to the aforementioned taxonomies; e.g., shellac was a prevalent but not sole material for pressing and cutting records, while the speed of 78rpm was de facto standardized, other recording speeds existed concurrently; finally, the "standards" of pre-microgroove era specified lateral cut, but, as discussed in other parts of this study, other ways of mechanically engraving sound information into disk media also existed. Nevertheless, for the sake of simplicity, when there is no danger of ambiguity, we will in the rest of this study refer to all pre-microgroove disks as "78rpm records".

Recording Media. Pre-microgroove disk records were prevalent from beginning of development of audio industry to the middle of the 20th century: i.e., from 1895 to 1960s. The records were produced by pressing complex composite polymer material consisting of shellac, slate, soot, various kinds of fillers, etc. Due to technological properties of the polymer, these phonograph records are extremely breakable and fragile. During 1930s there were successful experiments with celluloid flexible records. At the same time the use of polyvinyl-chloride material (a.k.a. vinyl) began [9]. Also, there were attempts with other material: e.g., "Columbia Record Company" experimented with producing laminated records, consisting of cardboard core covered with thin layers of the finest shellac available.

78rpm records appeared with the following diameters: 20cm (7'') (similar to a size of microgroove 45 rpm single records), 25cm (10'') and 30cm (12'') (the size of microgroove 33rpm long-play records). 25cm format is the most common, 30cm records were predominantly used for recordings of classic music, while 20cm records were often opted for cheaper issues of popular music [6].

Besides commercially pressed standard phonograph records, there were a series of most diversified products with shapes and functionality similar to records. These products were used at remote recording sessions or location recordings; for home recording; for sound recording for production of matrices and stampers ("lacquers"); for the recording of unique program transcription records, etc.. These records are usually referred to as "acetate discs", but in reality their surface could be made of nitrocellulose, acetate, gelatin and wax layer, de-celith foil (covered in zinc, aluminum, cardboard and glass core). Such discs rapidly decline physically and chemically and their prompt digitalization is essential [4].

Running time and speed variations. Nominal rotational speed of "shellac" records was 78rpm, but due to lack of industrial standards and enforcement, practical speeds ranged from 60 to 90 rpm. The 33 rpm speed was first introduced in 1928, for the sound one-reel films (the Vitaphone system). These records were 16" in diameter and were made initially of celluloid; which was later replaced by vinyl. Vitaphone turntables and cutting lathes were released in wide use in 1930, in order to record musical groups, speaking programs and similar materials for radio broadcast.

The maximal recording time per record side depends on the rotational speed, record diameter and the width of the recorded grooves. The geometrically characteristics of recorded grooves were not standardized, until 1939 when the first attempts of standardization took place. Running time of music that could be recorded on one side of 78 rpm records is approximately equivalent to content that can be recorded on later microgroove single records (45 rpm records)—3.5 and 4.5minutes respectively for the most ubiquitous 25cm and 30cm formats. The Victor record company modified in 1931. recording process and narrowed empty space between grooves, extending the running time from 4.5 to 6 minutes [3].

The commercial use of microgroove discs came to practice in 1948, when Columbia inaugurated microgroove long-play records which have remained a standard till present time. Running time per each side of this format is typically 22.5 minutes. Circa 1950, RCA launched the single format on 45 rpm [1].

Vertically/horizontally cut records. This classification is based on the direction the recording needle moves during the recording process. Horizontally cut records, where the recording needle makes radial movements, were more popular and mass produced. Vertically cut records, where the needle moves in direction orthogonal to the record surface, were commercially produced from the beginnings of record industry till cca 1930, when they were abandoned. Vertically cut records have comparatively longer recording times. The best known labels were Edison Diamond Disc and French Pathe.

Acoustical/electrical recordings. Acoustic recordings started from the very beginning of the recorded sound industry, and was performed using a large horn attached to membrane at the head of the cutter. This way, acoustic energy was directly converted into mechanical and preserved in grooves. Electrical recording uses conversion of acoustic energy into electrical signals, as intermediary before mechanical recording of grooves. "Electrical discs" were cut by means of electromagnetic cutting heads, driven by electrical signals generated by microphones and amplified in tube amplifiers. After series of experiments that began 1923, electrical recording practically started 1925. when Victor and other recording companies launched the new technologically improved discs [2].

The basic difference between acoustical and electrical recordings is in sonic characteristics. Acoustical records had smaller acoustic bandwidth, with bass and high register ranges cut off. When the electrical process came into wide use, various record companies started to use equalization curves in order to better cover the wider frequency range. As in the past there were many (around 100 types) different equalization curves in use, and standardization was performed in 1955. by RIAA. The standardized equalization curve has been used since then [7].

3. Disk keeping and storage

a) Deterioration. This problem started at the time of 78 rpm records, when there were not adequate technical solutions regarding friction of iron needle upon hard record grooves. Old discs quickly have been worn and expensive needles that were able to reproduce records frequently were not in use. Vinyl is somewhat different case, as it is elastic deformation material in case. Diamond needle getting through grooves heats its edges up to temperature between 40–45°C. At the end of reproduction grooves gets into the starting position
b) Deterioration in time. Certain discs used for unique studio recordings (often called acetates), due to characteristics of recordable surface (instability of lamination) inclined to show the signs of deterioration (such as peeling the surface and those discs should be first in the digitalization hierarchy [4]**.**
c) Surface senility. The record material is very unstable toward moisture which very easily infused causing its erosion. Material erosion is in direct correlation in final noise percentage registered at sound image.

Digitalization of old records requires blend of technical and artistic skills. Strategy and decision making are tightly connected with final result. The overall fashion how the restored musical material should sound changes: e.g., in recent past, the results of restoration that sounded laboratory clean, without any noise, and with artificial reverbs and echoes added, were considered optimal. Nowadays, restored recordings are required to sound as neutral as possible, so that all characteristics of recording studio regarding equipment possibilities, as well as desired interactions between musicians and are preserved. Shortly, restoration engineer must feel the limits in editing and filtering, to be modest and to develop feeling and

common sense how far he or she can go intervening during digitalization. The main objective should be not to ruin overall impression or annihilate subtle hues that each recording consists of.

Fig. 1. 16" acetate master disc ("lacquer"), 1944.

4. Digitalization and sound restoration

Some technical preconditions and requirements for digitalization of old records include:

1) Solid, acoustically correct and rightfully tuned gramophone (turntable), with a possibility for fine tuning of tonearm and cartridge. Speed regulator must support large ranges of rotation speeds, due to great speed differences regarding individual discs (discussed in previous section).
2) Series of different needle types for various groove types. Minimum 3 types of needles are necessary (one of the best experts on remastering field, Brit JRT Davies owned 40 types!). Needles should have peculiar geometric characteristics—with truncated tips—suitable for reproduction of 78rpm record. Such needles are currently (as of May 2008) manufactured only by a small family manufacture in England, Hodgeson father and son – Expert Stilys Company. Note that LP needles cannot be recommended for reproduction of coarse groove records. For pickup, magnet type cartridges should be used. For special cases stereo cartridge can be rewired to produce adequate signals.
3) Special pre-amplifier, equipped with different switches for all types of turnover frequencies and equalization curves [6]**.**
4) Special fluid for cleaning and removal of dust particles, grease, smoke residue, tar and debris from iron needles damaging of the record surface. Old records cannot be cleaned by any known means that can be found commercially – i.e. alcohol, acetone, benzene, petrol and similar dissolvers are strictly forbidden [8].

5) Quality sound card for A/D conversion with line in level attenuation
6) Specialized software for audio restoration for noise reduction, click and crackle reduction, parasite signals elimination, as well as stereo channel positioning, re-equalization and dynamic range modification (compression) [7].
7) Microscope, special polymer glues and tools for reassembling preserved pieces of broken records.
8) Mechanical devices for reproducing discs with eccentrically positioned hole (such disks are abound in wow and flutter).

Fig. 2. Vintage Technics SP15 directly driven (drive unit only) used in digitization process

Fig. 3. 78rpm record reproduction needle type ("Ortofon")

To illustrate different phases of the digitalization process, we use a commercial recording of romance "Kad mi pišeš mila mati" sung by Milan Timotic (a singer from Belgrade) and accompanied by Paja Todorović Roma Orchestra, matrix mx z2192, record z2174. This record is produced by Croatian/Yugoslav recording company "Edison Bell Penkala" at beginning of 1930s (the exact determination of recording date is difficult due to absence of ledgers). Audio files from different steps of the digitalization are available at http://tesla.cis.desu.edu/Sound/

Fig. 4. Various needle types for 78rpm record reproduction

Fig. 5. Discussed record label scan

The first file, Timotic01.wav, contains the results of raw digital transfer, where a wrongly selected needle is used to reproduce the analog record. Intense audible wow and flutter are results of the disc eccentricity (the matrix was eccentrically positioned inside the printing machine at the processing plant).
To remove the effects of the eccentric disk position, we used a specially designed mechanical device. As we can hear from Timotic02.wav, this helps removing unpleasant speed fluctuations, but the noise level still stays high.

Noise level and other unpleasant artifacts can be reduced by expert selection of the needle, as we can hear from Timotic03.wav. The selection of the optimal needle is record dependent and requires hours and hours of listening transfers made by various types of needles. Note that for this reason, the digitalization process of 78 rpm discs cannot be reduced to narrow and short time frames. Instead, each case should be approached with full attention regarding equipment and means of reproduction

Further improvement is done by mechanical disc cleaning with special fluid which provides minimum of noise disturbance and removes mechanical distortions caused by layers of dirt. The most optimal result can be obtained through extensive process of digital filtering in specialized software, resulting in canceling series of very unpleasant disturbances and artifact. Software for this type of sound restoration is extremely expensive and sophisticated – e.g., CEDAR, and its plugins for sound editors can cost $5,000-10,000 per license or more. File Timotic04.wav illustrates application of Algorithmix Sound Laundry 2.5 software **[7]** on our example.

Recall that 78rpm records (as well as early microgroove records) are recorded mono. The optimally filtered mono recording hence can be enriched by digital postprocessing which enables pseudo-stereo effects and various reverb and other sound ambient improvements. An example of such an intervention is provided in Timotic05.wav.

Forced by unrealistic end user requirements (and sometimes governed by ignorance and underestimating limitations of digital filtering), a sound engineer may attempt to minimize noise and disturbance in the final product to the minimal level. As can be observed from Timotic06.wav, this can introduce high levels of digital artifacts and, as unpleasant, cannot be recommended.

5. Conclusion

Adding all above mentioned disc specifications it could be definitely stated that their digitalization, in case of rather professional quality, is not an easy task, and that it requires effort, series investment in equipment and technical knowledge, musical literature knowledge and music sense and patient work on sound editing.

It is known that human ear get tired by constant listening of the same material and after a while it is difficult to differ a quality result from "acquired sound".

Knowing that 78 rpm are very often technically imperfect medium, full of incredible mechanical imperfections based on noises, rumble in lowest registry spectrum, clicks and crackles in shellac, and taking into consideration the fact that the piling of material has very dubious musical and dramatic character, the great love, understanding of period when recordings were originated are required in order to achieve quality transfer and to accomplish the best possible results.

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