SOUND RECORDING EVOLUTION THROUGH ITS HISTORY - SOME STAGES

43.38.-p / 43.38.Md

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ABSTRACT - For 125 years, audio recording has been carried out thanks to different kinds of processes making it possible to pick-up and write information on carriers. A significant improvement in the different recording processes, but essentially a technological “mutation” eased the evolution of sound quality. Digital sound recording was a decisive stage, and more particularly in terms of quality. Moreover, it became possible to adapt the recording process in order to optimize structure signal (sampling, code, format,…) corresponding to objectives that were planned (Phonographic publication, Broadcast and Web diffusion, digitizing old analog recording…), but it was generally done with compromises of quality.

As sound recording quality stands out at a culminant level but seems anyway to "mark time"…, it is interesting to point out the significant stages of technical evolution related with writing sound information on a physical carrier.

Recording associates a specific carrier with a technological sector. It is possible to outline 4 processes : engraving a record, fixing a magnetic state along a tape or on a disc area covered with a ferromagnetic layer, photographic track on a film border (this process will not be dealt with here), and finally thermally modified material by laser writing.

Analog recording quality on records and magnetic tapes is often a bit weak, but the obstinate progress that was made on every recording / player elements made it possible to approach the highest limitations of information recording by means of engraving and magnetization.

Digital recording still concerns carriers (magnetic tapes,magnetic discs and optical discs), but contrary to the preceeding cases, such medias will not have a prominent responsability in reproduction quality. Usage, reliability, and information protection performances as well as costs will be considered so as to choose the kind of carrier in a global framework of a system of services. Digitizing conditions (format), signal processing (compression) will determine the acoustical perception quality for any kind of carrier.

About twenty years ago, vinyl record replacement by the compact disc represented a decisive mutation in sound recording listening practice. Thus the CD not only destroyed LPs, but it also made the appreciation of sound specificities and of quality sound coming from mechanical recording *disappear* of collective remainder within some years. Re-editions issued from ancient records are often accompanied by background noise cleaning treatments which can remove substantial information elements in a more or less subtle way.

SOUND RESTITUTION QUALITY EVOLUTION THROUGH THE EXAMPLE OF THE RECORD

The names of Charles Cros and Thomas A.Edison are still indissociable from the invention of sound recording dated 1877. Recording on engraved discs went on for many years. For more than a century, a lot of progress have been achieved and studies are continuing far beyond the commercial withdrawal of this technology (beggining 1980'), which makes possible the exploitation of the sound archives in the best conditions we can have nowadays.

Sound restitution coming from records dating of an old and past age can subsequently be realized later with unsuspected conditions.

Among the innumerable innovations, we can briefly recall some significant stages :

- 1888 : beginning of the industrial production of records by means of moulding process. The recording apparatus requires mechanical principles only which induce strong limitations and product distorsions : stylus, diaphragm, horn, speed irregularity,…

- 1925 : sound pick-up, engraving, playing and diffusion processes are run with electromagnetic transducers, from the microphone to loudspeakers. Sound fixing and reproduction improvements are remarkable in such context in synthesizing numerous inventions.

- 1948 : LP (Vinyl) gradually replaces the lacquer disc (78 rpm). For more than 40 years, all the improvements that had been achieved for manufacturing and reading LPs, do not question the initial design of groove format, and playing speed, ...

- 1948 : tape recorders are installed in recording studios. Magnetic tape allows sound corrections and editing tasks. Several sound takes make "musical note editing" possible for instance.

- 1958: the general public discovers stereophony effects thanks to 2 groove-side-wall decoupling.

- 1981: beginning of the “scheduled end” of LPs mass production; the LP will be replaced by the CD in few years.

It would be a big mistake to underestimate all the richness of the information written on a record, and even today. Specific and high quality equipment are required.

Conducted in the 60s and the 70s, theoretical studies allowed to understand better the mechanical distorsion produced during engraving and especially playing phases. Manufacturing of very high quality main pieces have been carried out : turntable, arm, cartridge, stylus in order to comply with stereophonic groove players. Numerous moving magnet and moving coil cartridges were available. The size and style of diamonds were designed to get groove contact which improved the sound restitution.

However, research will continue and offer some proposals, original sometimes, to extract information. At the end of the 1980s, two player devices were presented.

- A glass fiber sensor follows the irregularities of the groove in a delicate manner, moving a light spot (Ecole Polytechnique Fédérale de Lausanne).

- The difficult problem of detecting lateral deformations corresponding to 2 groove walls by means of laser beam found a solution. On such principle, a player system (commercialized under ELP label : http://www.elpj.com) makes it possible to play also fragile and fissured records. It can reproduce non

accessible informations with traditionnal mechanical processes but may produce a signicative "material noise". Signal processing post treatment is sometimes necessary to attenuate such a noise.

About the treatment which follows signal extraction, designing and carrying out of the preamplifier widely contributed to restitute quality. The preamp has to practice a desaccentuation in response to the spectral preaccentuation that occurred during the engraving process ; in such way, it palliates problems linked with analog signal engraving on all audio passband, it attenuates background noise and amplifies the signal before introducing it into the main amplification stages. Contrary to vinyl records whose correction curve has been normalized (RIAA) at the beginning of the 1950s (and later reajusted), older records need specific adjustements according to the characteritics of the record, and wear conditions...

This operation, depending on the choice of player means (in particular pick-up cartridge and stylus size and shape), can't be conducted without the all subjectivity of the operator…

MAGNETIC RECORDING

The first research on sound recording on magnetic media have been justified by phone i.e. voice applications. The word “Telegraphon" chosen by V. Poulsen (1898) for his first wire recorder illustrates in a right way the association of 2 technologies : the telephone which permits to free oneself of the distances, and the recording which permits to control the time. The objectif is, for the first time, to send a message to a distant and absent correspondant.

Another application concerns the possibility to dictate mail and more generally to do transcriptions. These applications can be qualified as professionnal applications while replicated record using was effectively becoming predominant in leisure applications.

In spite of principle limitations (magnetization on a generator line of a wire which rotates between the recording and playing configuration, irregular running, and vibrations,...) Military applications during second World War have motivated a great development in the United States but sound quality improvement is still limited.

While wire recording was developping in the United States, tape recording processes were invented and ameliorated in Europe. Broadcast services cannot be satisfied with emission carrier such as records (direct groove or "acetate") and wire. A steel tape is put up in Germany at the beginning of the 1930s. Heavy reels make 20-minute-long programmes possible ; the passband lies between 70 Hz and 5500 Hz and autorizes to record and broadcast musical programs in very modest conditions, without any possible editing though.

Acetate or PVC tapes coated with ferromagnetic powder and binder compound (1935) was also conceived for broadcast and military applications. For more than a decade, tape recording will be used and developped in Germany exclusively. Since 1948, thanks to its extraordinary sound quality and efficiency for editing, Magnetophon has been an indispensable apparatus in broadcast stations, in sound recording studios for phonographic production and cinema set.

The sound quality that is reached comes from a lot of improvements brought by tape and recorder. Magnetic coating composition is of first importance. The binder and the substrate will have a decisive part in the preservation or the non preservation of recorded information. Substrate material concerns only a few families of polymeres, essentially cellulose acetate and polyester (PET). At the beginning of the 1960s, polyester substrate will be generalized in sound application.

With regards to tape recorder improvements, the elements involved with sound quality cannot be totally named ; recorder and player heads, track width, speed value and speed regularity, electronic circuits to obtain egalisation and amplification will be remembered...). Finally, an essential invention must be mentioned : bias processing with high frequency current. Discovered on several occasions with empirical circumstances, the addition of a high frequency current with a modulate signal will find later its physical justification. Such procedure has been systematically applied since 1940.

The spectrum reaches the audible band in its fullness. The signal / noise ratio exceeds 60 dB, but it is not possible to describe in such a simplistic way performances of an analog recording system. It is neccessary to take many phenomena into account and introduce all the characteristics related to distorsion phenomenon as modulation noise, harmonic distorsion, crosstalk, print-through effect, drop-out, etc.

DIGITAL AUDIO RECORDING

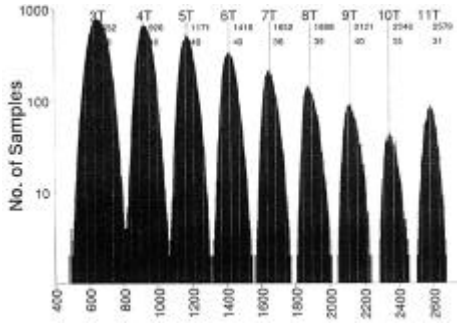
The development of digital technologies synthesizes a great number of contributions starting with signal processing in the telecommunication domain. The mutation realized by the CD arrival is one of the most important stages which mark sound recording evolution. We have to underline the extraordinary perspicacity of CD designers who implemented and launched a product in 1981 that is still a reference today. After 20 years' life, the success of this disc is so great that the possible replacement by some media (DVD-Audio and SACD for instance) is still quite laborious, or even uncertain in spite of high definition and multitrack diffusion offered by such formats. DVD-Video success attests the fact that, in the development of digital audiovisual products, sound essentially stays at the service of moving images

Thanks to CDs, the public discovers an easy using, a direct access to tracks, and the safe playing mechanism. Restitution quality jumps up in comparison with LPs (in the early 1980s) : the bandwidth reaches 20 kHz easily, dynamic moves up from 60 dB to 90 dB, and the crosstalk is totally out, to list a piece of progress among others.

However some listeners are not satisfied during the monitoring of CD programs. Distinction between voluntary noise cleaning processing and particular digital technology weaknesses must be mentioned here.

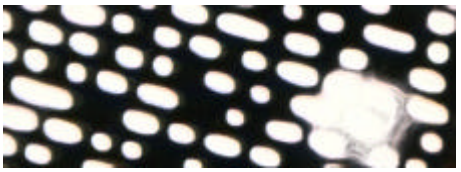
- In the case of **analog recording reeditions**, treatments are sometimes done to eliminate background noises in order to make programs "digitally correct". Nevertheless, such practises may severally impoverish the original document.
  Here, all the interrogations can be formulated relatively to the preservation of the essential constituants of the work, and the vigilance of actors (artistic director, sound engineer,...) is required. Information restoration can be in total contradiction with sound preservation in its integrity : sound processing in vue of improve sound quality - based on debatable criteria - involves operations which always lead to the loss of elements of primary information.

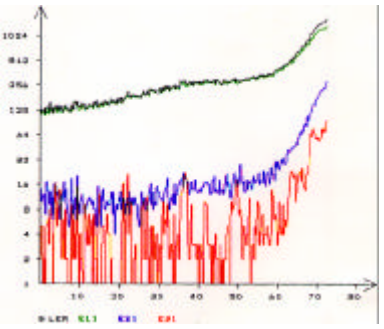
- **Insufficient restitution of digital information** may come from making and degradation of carriers, player performances : mecanical servo control, time irregularities, digital errors conversion D/A, and post-conversion signal processing,... We can mention 4 stages among one of the most sensitive with regards to audible distorsions.
  - Jitter treatment. Transition pulse variations come from the difficulties to recognise information fixed on the substrate : pit irregularities, unbalanced disc, eccentricity, and deformation,etc. Delay can also be produced by wavelenght deformation all along the digital circuits and link cables. Always present, Jitter effects depend on the aptitude of the system to correct these delays. The phenomena can generate quantification and modulation noise and cause digital errors.



Exemple of Jitter histogram corresponding to each pit lenghts of a CD-R. Some confusion are possibles in recognising 3T/4T to 5T/6T.

  - Digital errors correction. Every perturbation coming from media or data transmission introduces errors. In spite of the high efficiency of detection codes and error correction processing (enterleaving and algorithm process), uncorrectable errors may subsist.





Every obstacle (on optical disc here) will improve error rate. On the right example, error correction processing can't compensate such an increasing level at the end of the disc.

For event sound recordings of which temporal evolution is relatively predictive it is possible to replace lost or corrupted samples by estimated samples according with the context. Moreover, a procedure is activated in order to replace residual defective samples (clics production) by micro-silent instants (up to 4 ms).

- D/A conversion : the heart of the player device can alterate the process : non linearity at 0 level passing, response time dispersion, commutation artefact (glich) as triggered from one code to another one,... Different solutions round up conversion difficulties : 1 bit conversion, intermediate or hybrid conversion,... Using 2 converters, a de-multiplexage serie / parallel may solve delay problems coming from successive left and right channel reading (time smear) affecting in particular high frequencies stereo effects.

- Post-conversion filtering. Filtring quality for waveshape reconstitution and elimination of quantization residuals is of substantial importance for sound quality. Important progress have been realized since first age not only in designing, but also in implementing circuits (that stays anayway the weakness stage). Analog filtering which introduces transient dephasing and distorsion has been modified (oversampling) or replaced by digital filtering.

Data inscription on substrate reacting to magnetic or optical phenomenon will show aptitude in adaptation in an evolutive context more and more demanding.

Digital transmission development, audio data processing evolution to be massively transfered, such objectives originated a new situation over the past few years.

As recording development was systematicaly oriented towards an improvement of recorded sound quality, one begins to accept quality degradation to satisfy constraints like density increasing, higher access speed and stream data rate reduction.

For the first time, technical recording evolution has not followed an obstinated improvement quality direction with lossy compression processes. Numerous studies are conducted based on perception tests to determine and validate the compression algorithmic tools. For instance, a wide set of quality is offered with DVD-Audio format. A lot of choice are available from highest to lowest quality conversion (and channel number) corresponding to stream rate from 6144 kbps to 32 kbps.

When one is interested in the future of recordings in the context of cultural and scientific heritage, several preoccupations spring up to manage long term preservation of sound archives. Digital sound recording solutions had never been so numerous before, nor so complex considering signal processing, and, in most cases, they had been perfectly incompatible among themselves. A situation which concern in the same way mass storage systems (magnetic tapes, hard discs) and unitary media (optical discs, magnetic tapes in cassettes).

It is necessary to face several kinds of difficulties, among them : technological obsolescence, carrier degradation (and it is well-known that it can appear rapidly), increasing incompatibility by encryption to protect document against illegal copy. A great challenge is launched for the benefit of future generations. Thus, the implication of the Ministère de la Culture et de la Communication in France in safeguarding sound heritage.