GAMMA MEETING

BOLOGNA SEMINAR OF JULY 1996

STEPS,TECHNIQUES, AND ETHICS
OF SOUND RESTORATION

FROM OPTICAL SOUND TRACK TO DIGITAL RESTORATION

Right from the very beginning of cinema there was always the idea of adding sound to the pictures in movement.
Many attempts were made to synchronize a cinematographic projector and a gramophone, but they never tackled the problem of synchronization between sound and image.
The solution was to find a way to attach the sound to the film. The introduction of the Selenium photoelectric cell whose electrical resistance was varying with the light allowed to record sound under the shape of more or less luminous areas according to the intensity of the sound and to its frequency.
A sound is an analogical signal that may undergo a lot of alterations during the process of making the sound track of a film and that suffers the damages of time.
Thanks to digital treatments some of these alterations and damages can be removed. But these digital systems are no magic : they will not make a sound good if at the start it is not. A good sound is a sound that has been properly recorded on the set, then correctly transferred on an optical negative film and suitably processed by the laboratory.

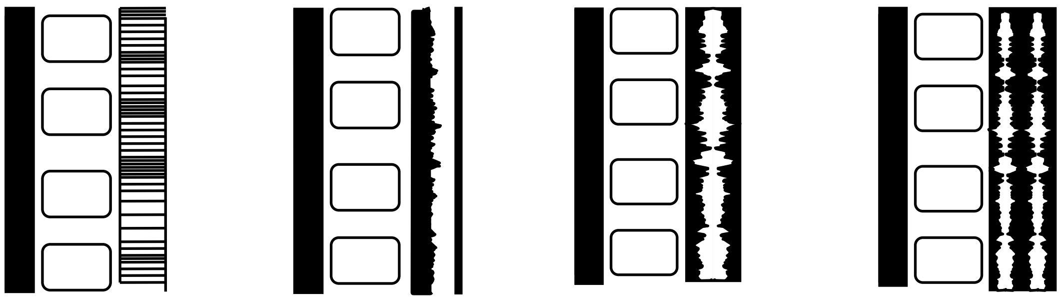
I - OPTICAL SOUND : a short reminder

Sound is composed of vibrations, as we all well know, and these vibrations can be transformed into electric variations through the use of a microphone. In optical recording these electric variations are used to modulate the light that hits the film.

An optical sound track is the part of the film on which is printed the light that goes through a very narrow slot. The sound is transmitted to a modulator that turns the electrical variations of the sound into light variations. The system carries the picture of the narrow luminous slot onto the film that is moved with a regular motion and perpendicular to it.
A latent image is thus formed on the optical negative film that will be developed and printed.

The shape of the tracks has deeply changed as time went on.
At the beginning, the **variable density** optical sound track was mostly used.

Then in 1955 the variable density disappeared with the introduction of the colour film, and was completely replaced by the **variable area** optical sound track



Variable density track | Variable area unilateral track | Bilateral variable area track | Dual bilateral variable track

II - ANALOGICAL AND DIGITAL SOUND

Sound is represented by a signal whose value varies according to time in a continuous way.

An example is that of a sinusoidal signal (whistle or tuned note).

We use to call it an **analogical** signal. Its shape is rather simple. This signal may be altered in many ways during :

- the process of producing and recording sound (microphones)
- the transfer of the recorded sound onto another tape (35 mm magnetic stock for example)
- the exhibition in cinemas (amplifiers and loud speakers).

The analogical signal is sensitive to interferences. It can be altered by the transmitting devices both in amplitude and in phase, and therefore acquire distortions.
Each time we process a sound (to rerecord it for example) we most often reduce the quality of it in comparison to that of the original.

The basis of Pulsion Coded Modulations (PCM), i.e. the digitalisation of a signal, has been first described more than 40 years ago. The **digital** signal is represented by sequences of binary symbols : 0 and 1, corresponding to : 0 = nothing, 1 = electric impulse. That signal is much less sensitive to defects induced by transmission systems.

The digital treatment of a sound consists of quantifying this sound in binary impulses then deciding and determining the new shapes to give to the sound. We can therefore use the wide range of possible applications provided by sophisticated processing algorithms to give nearly every desired shape to the sound impulse we wish to process.
Therefore it is easier than with analogical treatments (where only filters and limiters-compressors can be used) to recognize a voice and isolate it from the treatment we will apply to the other signal data. Thanks to processing algorithms it becomes possible to treat a noise modulation or an induction, and to remove it from the sound signal while taking into account the other sounds that exist at the same place (masking effect). We can also process and take away automatically the transient phenomenon that are the interferences. Digital processing is able to replace the suppressed interference by a sample of the sound before and after it.
With analogue correcting processes sound is treated as a whole, not by samples. All the sounds receive the same amount of treatment as the entire process. This is why a noise modulation or an analogue processed induction will also alter part of good quality sound that we would prefer to leave unaffected. Nowadays there exist many specially developed softwares that are adapted to digital sound treatments.

III - STEPS AND TECHNIQUE OF DIGITAL SOUND RESTORATION

Most of the digital sound restoration work is done .... before and after the digital treatment itself.
Happily enough, Man has kept the lead over the magic black box

The **1st critical step** is to look for the element (an original negative or a print) that will allow us to get the best result in the restoration work.

A. ORIGINAL NEGATIVE :

An original negative can be used except when fungi or decay does not permit the sound track to be read. The original negative may require some repairs in order to allow it to go through printing machines (shrinkage, etc.). But blooping is prohibited if digital sound restoration is used : punching a hole in the sound will never be as precise as will be the digital analysis of the signal and may increase the defect when detected digitally.
The printing of this negative shall be determined by the results of comparative tests. There is no other way to avoid adding distortion in printing an original sound negative. For high quality recording and reproduction, it is essential that the print has the highest possible density to give a high ratio signal to noise, a high level (difference between opacity and transparency), and a low distortion.

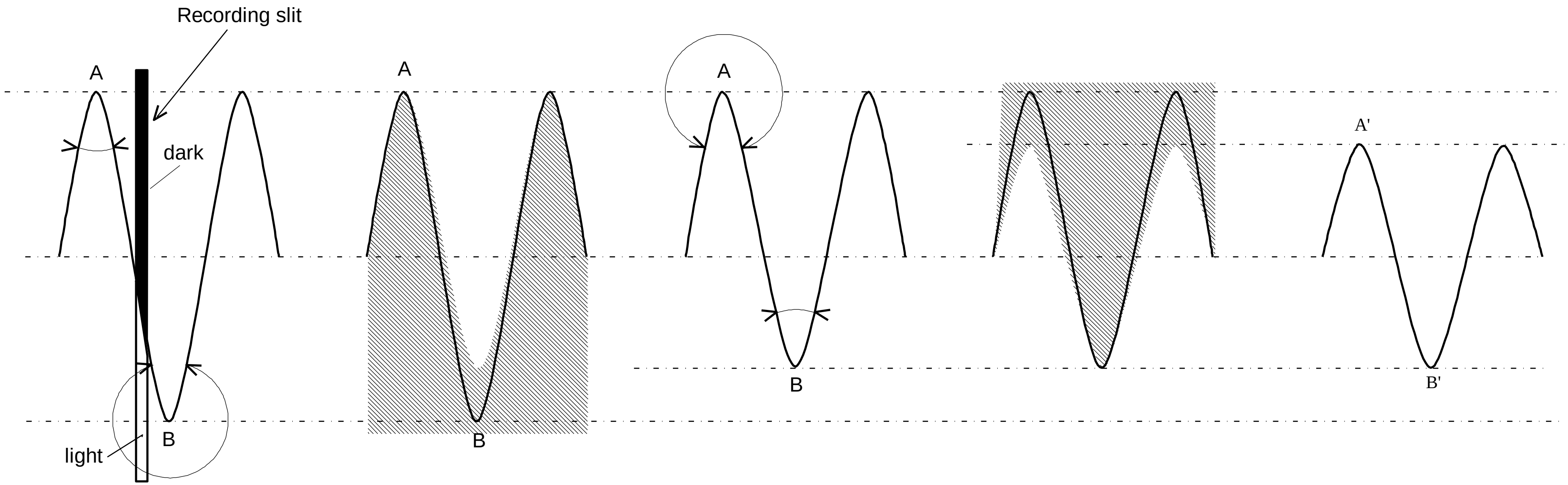
The comparative tests procedure is as follows.

For a variable-area recording, the print density should be approximately 1.5 for satisfactory reproduction (this number is given by stock manufacturers). At this density, after development of the positive, an image spread appears that fills the valleys of modulation and keeps sharp the peaks of modulation. This nonsymmetry is caused by the high density needed. It produces an incorrect distorted signal.
It is necessary to have image spread in the negative to compensate for the image spread in the print (which is in the opposite direction). The Cross-modulation test is used with variable-area recording to determine the correct negative by measuring the fill-in of the valleys in modulations. A similar test was used with variable-density recording for determining negative density, but it was named « Intermodulation test ».

On the illustration on the following page you can see the recording slit. Around A there is less light received than around the point B. This quantity of light produces a latent image in the grains outside the exposure area. When developed at low density the filling is reduced, and it is increased under higher densities.
On the developed negative a distorted signal is produced.
Fortunately, when this negative is printed on positive film, around the point A there is a greater transmission of amount of light while a lot less in B. This gives a compensation, after positive development, which can be exactly managed by the Cross-modulation test. Finally a good symmetrical signal is obtained.

When restoring the sound track of an archive film we usually start with a negative sound, and obviously it is impossible to change this negative density. It is only possible to change the print density. This is the only way to determine the good positive density that will give the best result. The optimum positive density is determined by making a range of exposures print tests starting at a low-exposure lamp current setting and increasing the exposure current in fractions of ampere. We do that for five to eight samples of sound (preferably dialogue), then we play-back these prints on a reproducer and pay particular attention to high-frequency distortion and sibilance, signal to noise ratio and output level. Thus we can select the good exposure for the future print. The same procedure can be successfully used both for variable-area and variable density sound tracks.
All wet printing processes may also effectively reduce scratch noises.

IMAGE SPREAD and CANCELLATION ON VARIABLE-AREA SOUND TRACKS



Theoretical sinusoïdal signal.

B receives more light than A

Image Spread in B after negative development

Dissymmetrical signal with distortion for printing.

Now A receives more light than B

Compensation on the Print obtained after positive development

Possible obtainment of a symmetrical signal without distortion (level loss < 1 dB)

In Labs this phenomenon must be daily managed by Cross-Modulation tests

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B. PRINT :

In the case of a print the sound must be thoroughly analysed in order to distinguish its intrinsic quality among crackles and other damages that time has produced. A hardly audible and distorted sound will be useless. In that case we will have to look for another existing print in the archives of other countries.
Intermediates made from prints for preservation purposes are generally not suitable if they have been printed with an exposure that corresponds to the image and not to the sound track. The quality of the sound track is therefore most often very poor and unsuitable for restoration work.
Here also blooping must be prohibited: this treatment consists in applying special ink with a pencil to fill in a gap in the sound. It can never be as precise as the digital analysis of the signal and therefore the ink may increase the defect when detected digitally.

The **next step** of restoration is to check the correspondence between image and sound. Synchronism and gaps in the sound track must be analysed in order to detect if they existed in the original. Sometimes the sound track has to be reconstructed to recover the missing sounds. This study of the sound track will allow the legal right owners to decide the extent of the restoration.

The **digital process of restoration** will then start. It is imperative to process each kind of damage and defect separately and to adjust progressively the level of treatment in order to avoid taking off safe parts of the signal. Spending time in doing so will give a more accurate restoration and the nature of the original sound will be preserved. Generally the existing systems allow to the removal of the clicks automatically. The crackles must be analysed before cleaning. Broad band noise has to be analysed and treated sequence by sequence.
It must be understood that attempts to lessen the cost of sound restoration in filtering the sound before digital restoration are useless. The software can only work properly on continuous defects stacked over the original sound. Different filtering actions on different parts of the sound track modify the defects and break the continuity that is necessary for digital repair.

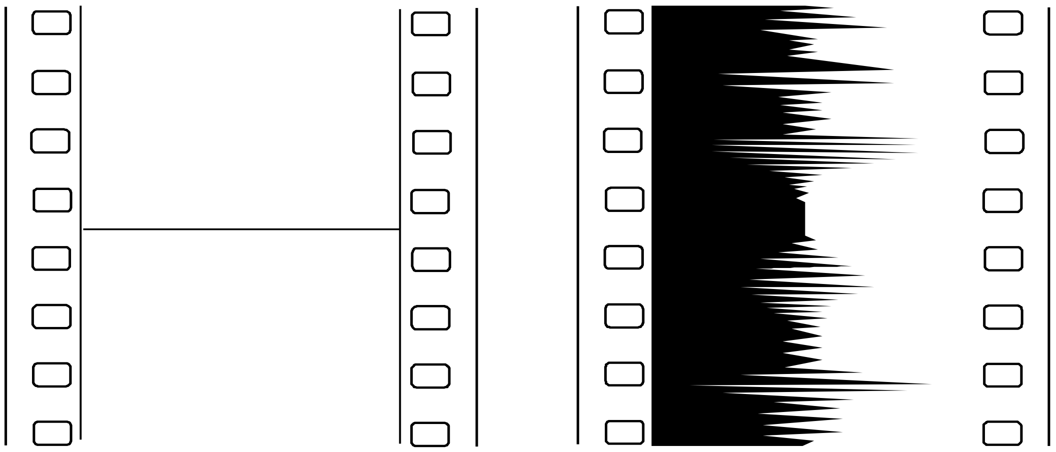
The **last step** before optical transfer is to check that the level and the tonality of the restored sound is compatible with modern playback equipment. If the film is to be exhibited in cinemas the sound will have to be processed in a mixing studio to make the necessary adjustments for optical transfer. A sound track equalised in film mixing studios is correct for cinema and video exhibition, but a sound track equalised in a video mixing studio will only be correct for video exhibition.

IV - SPECIAL FORMATS RECOVERING :

We have had to restore a film called « L'eau du Nil ». It was recorded in 1928 with the Petersen and Poulsen Process. It was really an odd system. It used two separate films and a variable-area sound track occupying the whole area between the perforations.. The picture ran, at the beginning, at 16 frames per second, and later at 24 frames per second. The sound ran in at 32 frames per second. Gaumont bought the French rights and called it « G.P.P. System ». The film was shown in Paris during October 1928. The process was never commercially successful compared to the single-film method from America.

PETERSEN AND POULSEN SOUND SYSTEM

(GAUMONT PETERSEN AND POULSEN : G.P.P. in France)



Picture Film

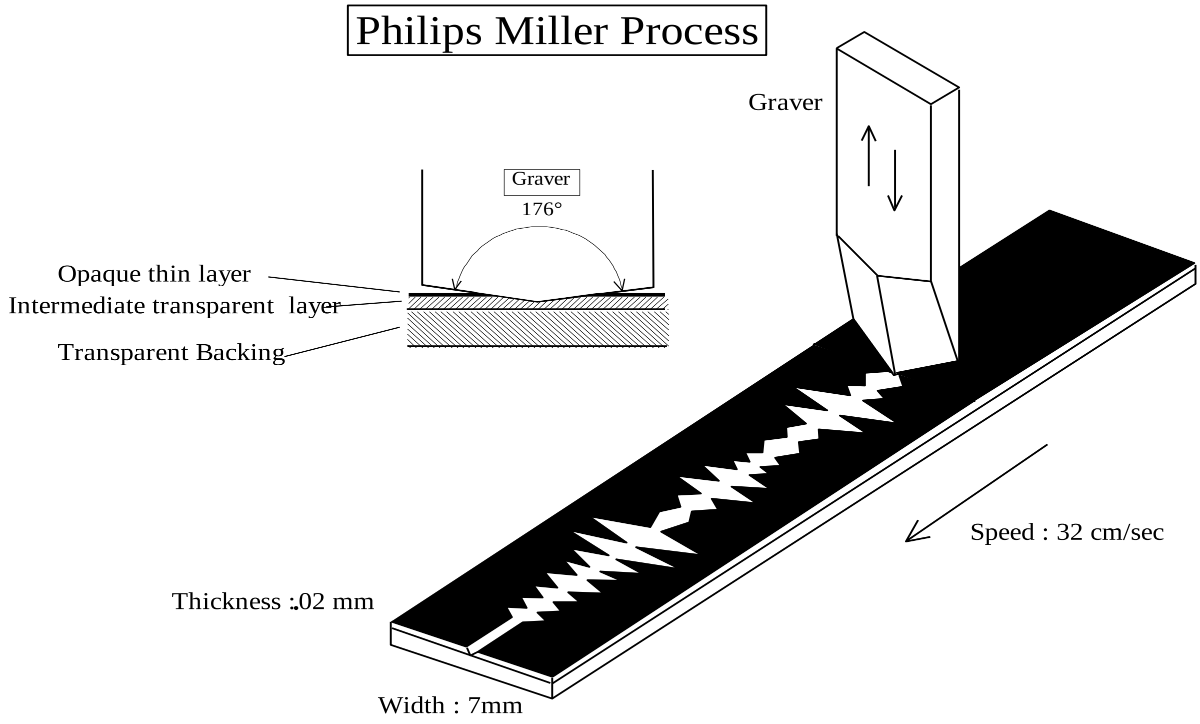
Speed : 16 fps
later 24 fps

Sound Film

Speed : 32 fps

The Philips-Miller Process was derived from the disc recording and the optical recording. It was, certainly, the sound recorder that gave, before the coming of magnetic recording, the best mechanic and electroacoustic performances.

Philips Miller Process



It must be pointed out that we have had to develop a special playback machine for these 2 kinds of sound restoration. The transport system had to be adapted for each process and the reading was done by a solar cell through laser scanning.
If we had not proceeded that way we should have had to look for an original machine to play the sound. And if we had been lucky to find one that could be put in working order we would have undergone all the problems deriving from old original equipment such as :

- hazardous projection speed
- mechanical and electrical defects of machines that had the state-of-the-art quality of the time

Therefore we had near to perfect quality of reading and we could strictly dedicate ourselves to repairing mishaps in recording and damages of time.

V - ETHICS OF SOUND RESTORATION

As you have noticed, digital sound restoration offers a wide range of processes from simple cleaning of clicks and crackles to the reconstruction of missing sounds.

For our part we have decided to follow one single rule : tell the client what could be the extent of the operations on the film sound track and leave the decision to him.

It seems that the ethical attitude differs between archives that are dedicated to preservation of the cinematographic heritage and other institutions whose activity is based on commercial exhibition of old time films to general audiences.

Beside these considerations digital sound restoration raises another type of problem.
During some early periods of technological evolution of sound films the sound tracks were just spliced together leaving huge parts of blank spaces. As long as the film is not restored we get used to the bad quality of sound reproduction. Sound restoration makes it obvious that blank spaces in the sound track are not silences and this is very disturbing to our ears. There again the decision is left with the client.