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THE SADAF SYSTEM FOR IMAGE PROCESSING

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Abstract

A system for A/D conversion and processing of images (SADAF) has been developed and realized at the "Istituto di Elaborazione dell'Informazione del C.N.R. - Pisa".

The characteristics of the system are such that SADAF well covers the gap existing between the performances of the CRT scanners used in the field of the nuclear physics (high speed and high spatial resolution) and those of the electromechanical scanners used in spectroscopy and astrophysics (low speed and very high photometric and spatial resolution).

The main characteristics of SADAF and some typical examples of application are given in the paper.

Introduction.

About 6 years ago at the Istituto di Elaborazione della Informazione (I.E.I.) we started with a project concerning the construction of a flying spot digitizer. The system, called S.A.D.A.F., was initially developed for applications in the biomedical field (analysis of chromosomes, fingerprints, X-ray images, cestoda etc.). For this purposes the SADAF was developed with a spatial and photometric resolution and an operating speed that well fit the gap between the performances of the CRT scanner for bubble chamber photograms analysis, and those of the microdensitometers used in spectrometry.

The S.A.D.A.F. became operating in early 1970 and since then it was used not only in the biomedical field, but also in astronomy, astrophysics and geophysics. The use of the machine in these fields has been more and more increased so that now it represents its main activity.

The S.A.D.A.F. structure.

The S.A.D.A.F. digitizes a transparent image by a flying spot technique (fig. 1): a spot is generated on the surface of a CRT and focused, by a high quality optical system, on the surface of the transparency to be analysed. The position of the spot on the CRT and its intensity are controlled by a minicomputer (PDP 8/I), hence the scanning procedure is not constrained to a particular one but a random access to each point of the image is allowed.

The image of the diaphragm of the optical system is focused on a pair of photomultipliers through two different paths: the transparency is interposed in one of the paths, so that it acts as a second diaphragm, while the other path is used as a reference. By this way it is possible to compensate changes of the efficiency of the phosphorus of the CRT and of the optical system from point to point.

The measure of the transparency of the image in each point is thus assumed as the ratio of the intensity of the light through the image (I_M) to the intensity of the light in the reference path (I_R). What usually interests to measure is the optical density (D) of an image. The signals I_M and I_R , respectively generated by the measure and by the reference photomultiplier, are thus amplified by two logarithmic amplifiers and subtracted one from the other. The analog signal so obtained, that corresponds to the optical density

$$\text{Log } I_M - \text{Log } I_R = \text{Log } \frac{I_M}{I_R} = D,$$

is converted in digital form by a 7 bits A/D converter.

Before to convert the signal in digital form, some of the processing, as changes of threshold and amplification, are performed on the analog signal. This allows to match a prefixed range of the optical density to the dynamics of the A/D converter so that, over an established range, an improve of the optical resolution is achieved (fig. 2a, 2b).

The digital data so obtained can be stored in a mass memory (magnetic tape or disc) or preprocessed by the PDP8 in real time with the scanning procedure.

Usually the analysis of the image is performed off-line by a larger general purpose computer. The main characteristics of the S.A.D.A.F. are given in Table 1. A conversational software allows a continuous interaction between the operator and the system: the scanning procedure and the A/D conversion modes are easily defined.

Table 1 : Characteristics of the S.A.D.A.F.

Optics

Accepted Area	24 x 36 mm
Scanned Area	24 x 24 mm
Spot Generator	30 N DEC
Spatial Resolution	1024 x 1024 points (-23.5 at 50% intensity overlap)

Access time to any point	40	μ s
Photometric resolution	64	Levels
Optical density accepted	0,05 \pm	2
Automatic film advance; positioning accuracy	\pm 0,2	mm

Computer

PDP 8/I with DMA and wired aritmetics

word	12	b
Core memory	8	k w
Core memory cicle	1.5	μ s

Mass Memories

Disc	32k	word
Mean access Time	20	ms
Magnetic Tape	800	b/inch
Speed	36k	b/s

I/O units

Memory display KV8/I	1024 x 1024	points
Tape puncher	120	b/s
Tape reader	300	b/s
Teletype	10	chr/s
Line printer	300 \pm 1200	Lines/min

Experimental results.

The scanning apparatus and the optics of the S.A.D.A.F. are very simple and do not make use of sofisticated components; for instance the spot generator has been realized by a 30N precision display. In this way something has been missed both in spatial and optical resolution, but a very high reliability has been achieved: the system can run months and months without any special tuning up. Figure 3 shows the stability of the measure of the optical density of a clear photogram and the effect of an artificial aging of the CRT. Figure 4 show the experimental results obtained by scanning a reference image.

The problems, that have been treated by the S.A.D.A.F., can be divided in two classes. A first class concerns the recognition and the reconstruction of images: the problem of chromosomes anal-

ysis is an example of this class. A second class concerns the analysis of the evolution of an image. In this class we have to distinguish between two points of view: for instance it may be interesting to follow the change in brilliance of a point fixed on the image of the sun disc or, alternatively, to follow the change in brilliance of a point fixed in latitude and longitude on the sun surface, and therefore moving with respect to the image as a consequence of the rotation of the sun.

In the following two examples of image analysis by S.A.D.A.F. are presented. More details on each problem are given in other reports at this conference.

The first example belongs to the first class and deals with a sample of sand in which some grains has been marked with a phluorescent colour. The tecnique has been developed at the Laboratorio Grandi Masse of CNR to study some problems of the Lagoon of Venice. The sample appears as shon in Figure 5 and it is requested to count the number of coloured grains. Scanning sequentially the transparency, signals as the ones shown in Figure 6 are obtained; to solve the problem we have to count the number of the maxima, both in x and y, exceeding a threshold. The threshold can be defined by a visual inspection of the signals or by an inspection of the histogram of the amplitudes of the relative maxima. After the photogram has been digitized processing has been performed on a HP 2116 computer with a HP 5451/A Fourier analyser.

The second example is still connected to the research activities carried on at the "Laboratorio grandi masse" of Venice and belongs to the second class of problems. An ammount of colouring dye is injected at regular intervals into the sea; the analysis of an air photograph of the area gives some informations about the current : velocity, direction and turbulence. The photograph appears as in Figure 7a, where it is possible to see the drift of the colouring patches and three reference marks. The three marks, which have a well known position, are used for the geometric reconstruc-

tion of the photograph.

Starting from the digitized image (Fig. 7b) it is possible to characterize the current by calculating the position of the optical barycenter of the subsequent patches (Fig. 7c). Information about the diffusion of the colouring dye in a prefixed direction can be obtained by normalizing and superimposing the barycentral scanning of the patches along a prefixed direction (Fig. 8).

Conclusions

The S.A.D.A.F. has been successfully applied in different fields. The experience collected has demonstrated that a system with a moderate resolution both spatial and densitometric has a wide range of application.

The main restriction encountered in using the S.A.D.A.F. concern the size of the images. For this reason we are developing a flexible optical system for analyzing images of different sizes.

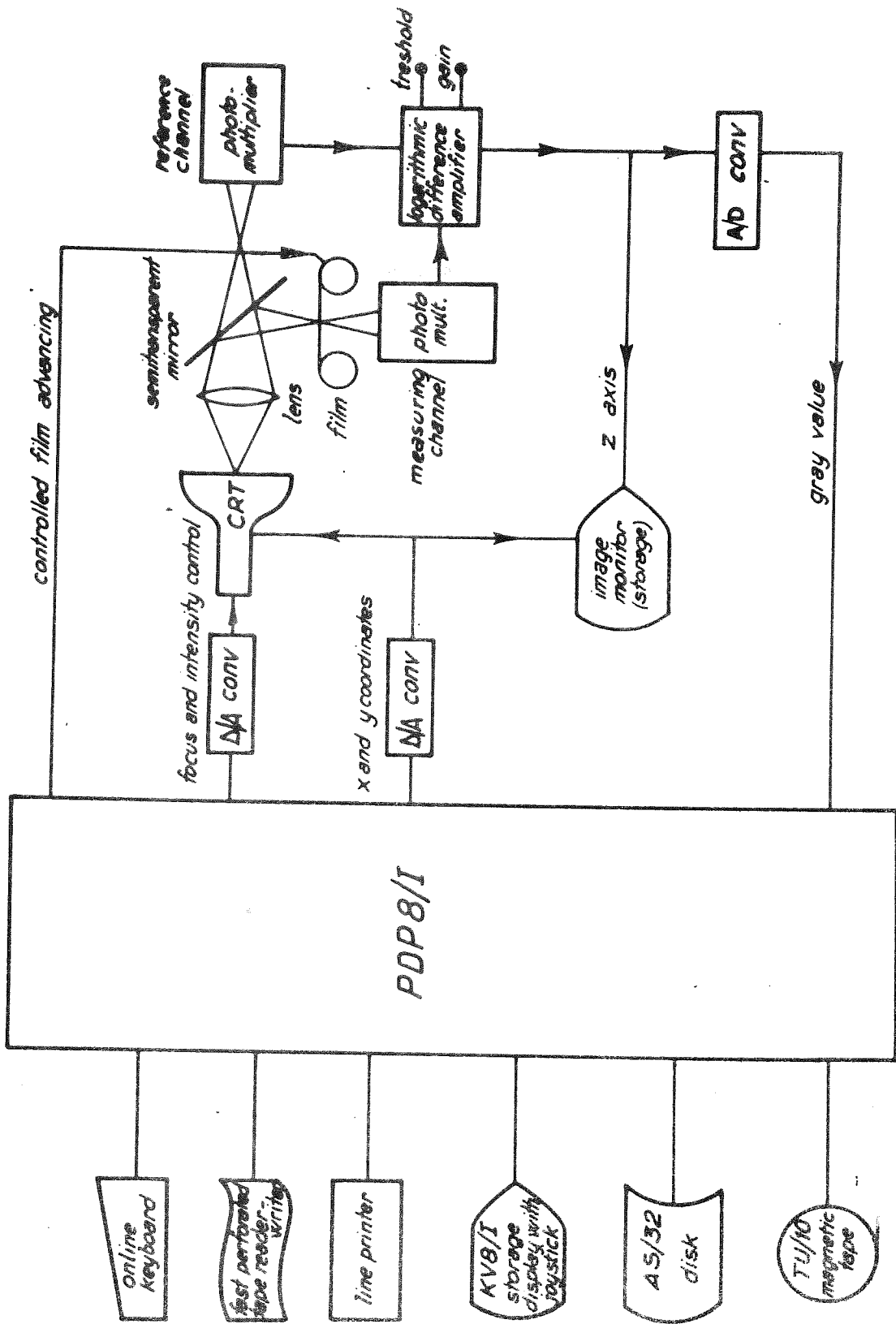


FIG. 1 - BLOCK DIAGRAM OF THE S.A.D.A.F. .

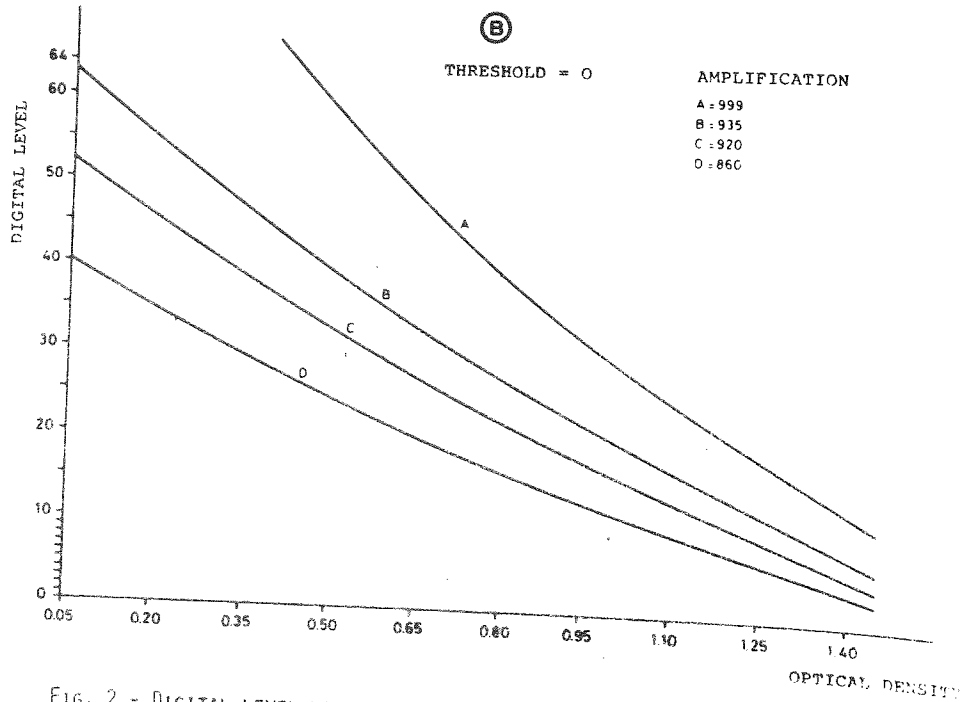
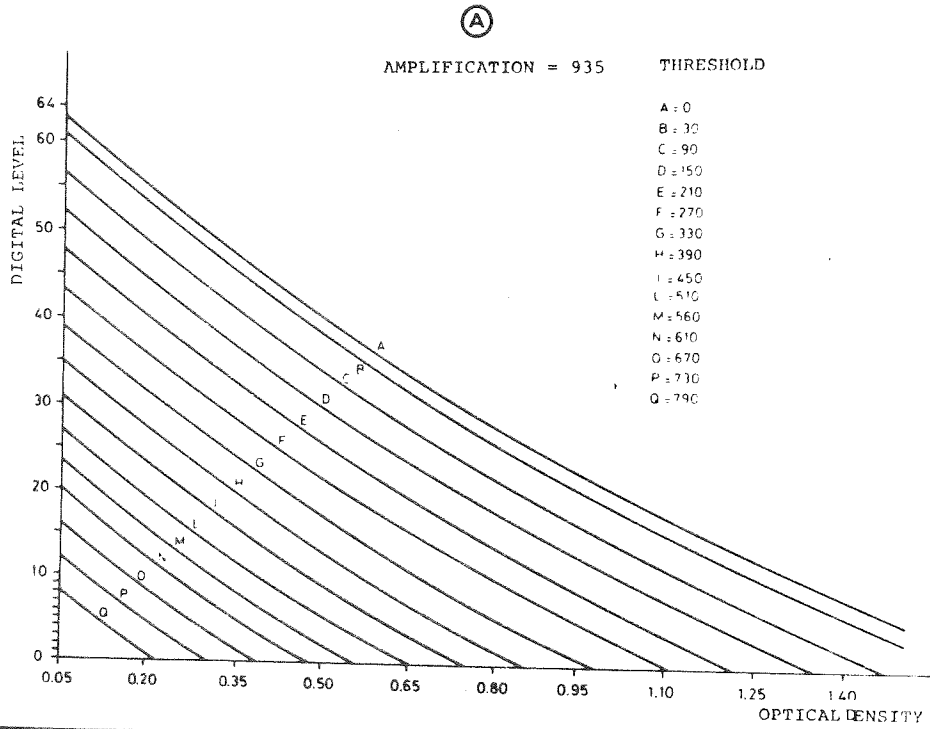


FIG. 2 - DIGITAL LEVEL VERSUS OPTICAL DENSITY: A) EFFECT OF A CHANGE OF THE THRESHOLD, B) EFFECT OF A CHANGE OF THE AMPLIFICATION.

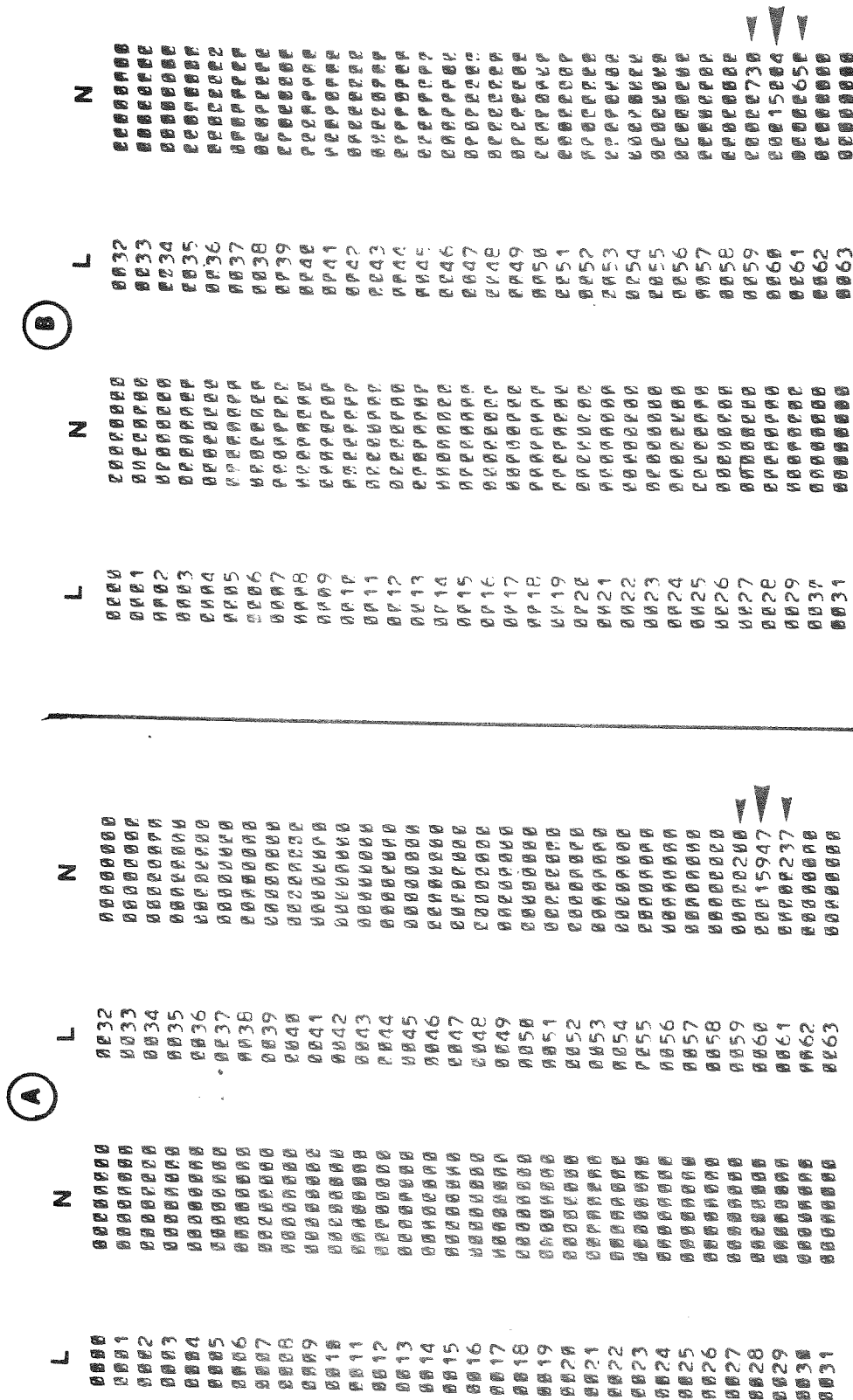
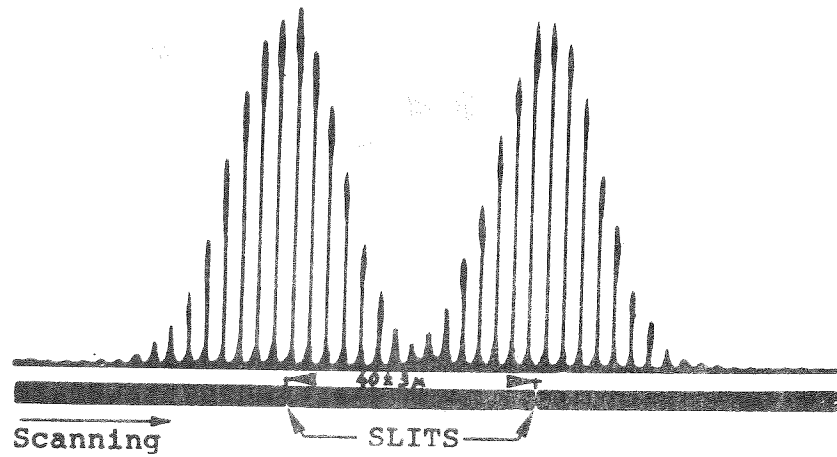
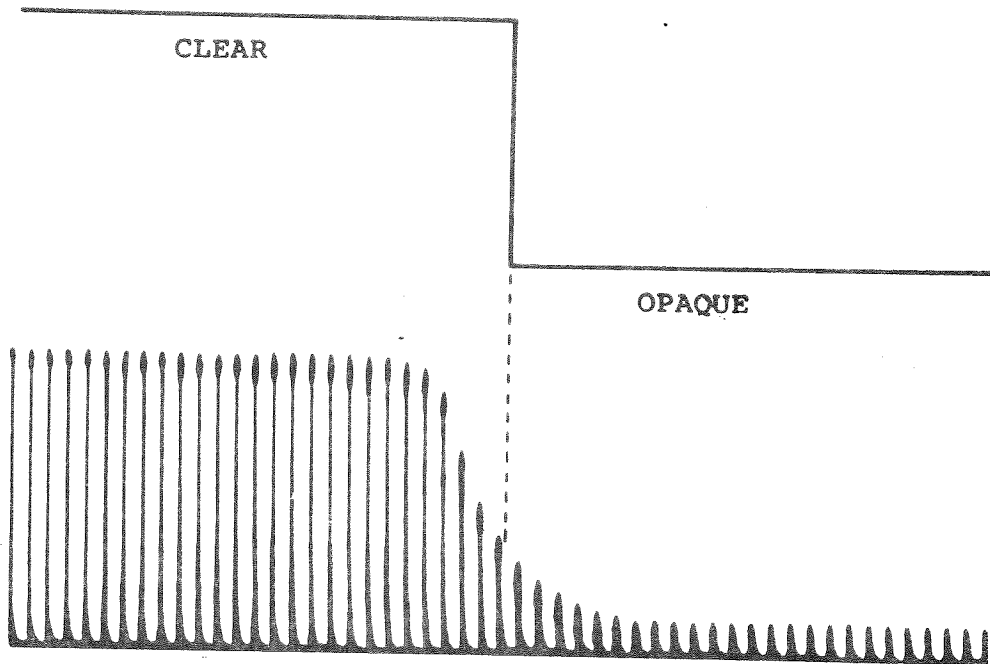


FIG. 3 - EFFECT OF A SIMULATED AGING OF THE CRT ON THE A/D CONVERSION: A) A/D CONVERSION OF A CLEAR PHOTOGRAM (MATRIX 128 X 128 PTS), PICK CURRENT OF THE MEASURING PHOTOMULTIPLIER = 1 MA; B) AS IN A) WITH THE EFFICIENCY OF THE CRT REDUCED 5 TIMES, PICK CURRENT OF THE MEASURING PHOTOMULTIPLIER = 0.2 MA. L = DIGITAL LEVEL, N = NUMBER OF POINTS.



A



B

FIG. 4 - SIGNALS OBTAINED BY SCANNING REFERENCE IMAGES: A) OPAQUE PHOTOGRAM WITH TWO TRANSPARENT SLITS SPACED 40 u; B) PHOTOGRAM WITH AN ABRUPT CHANGE FROM CLEAR TO OPAQUE.

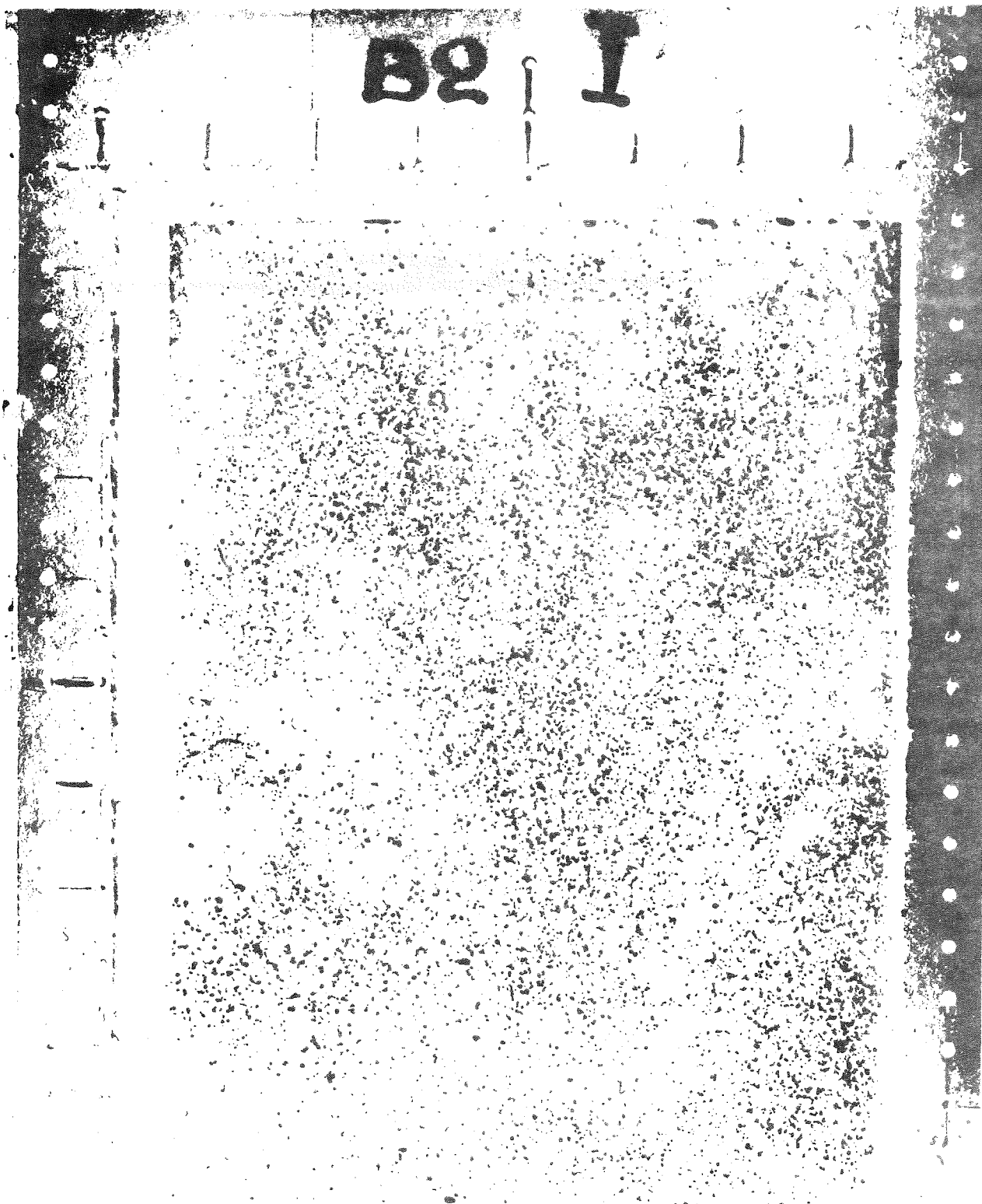


FIG. 5 - SAMPLE OF SAND AS IT APPEARS AT THE WOOD'S LIGHT.

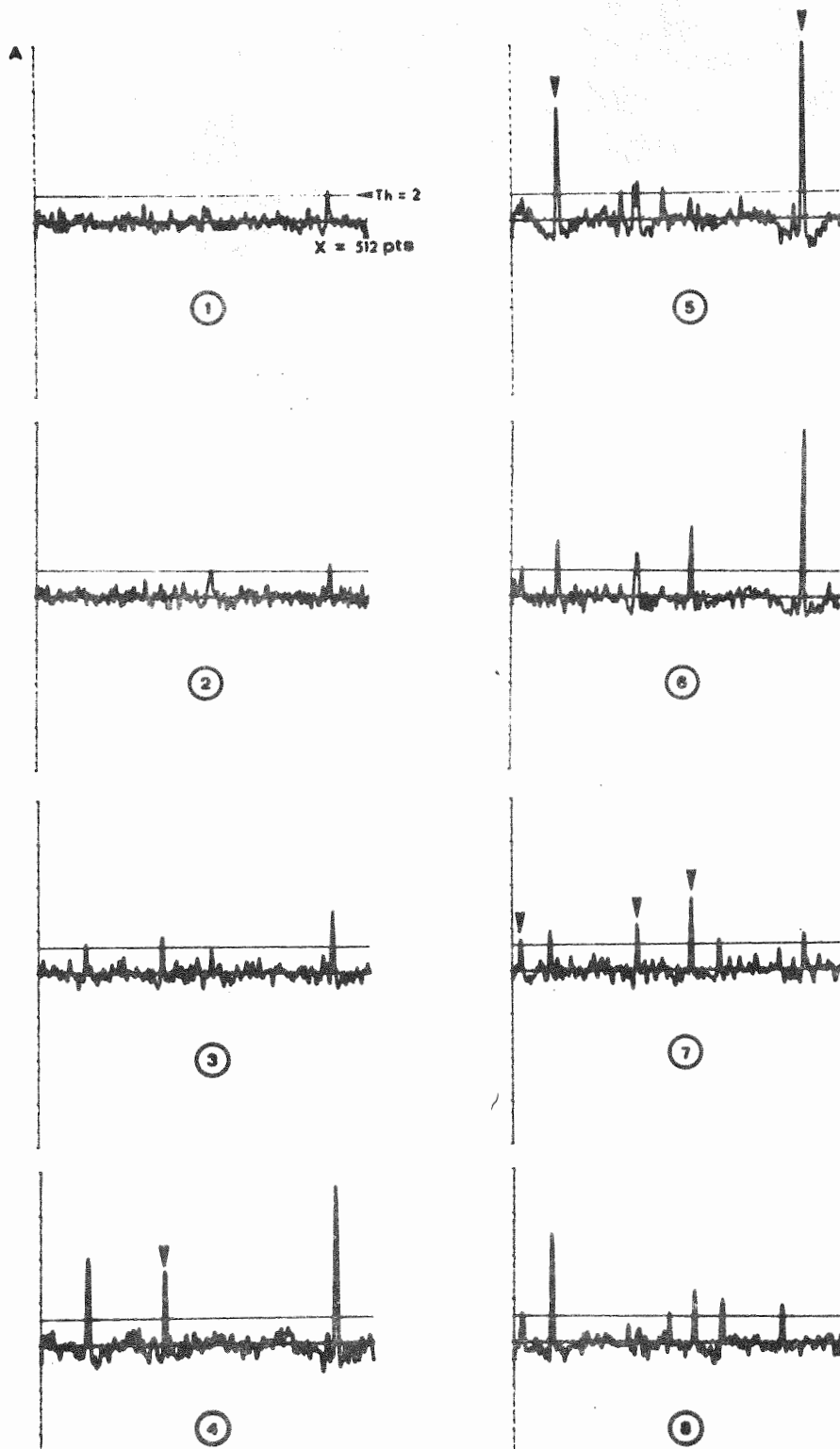
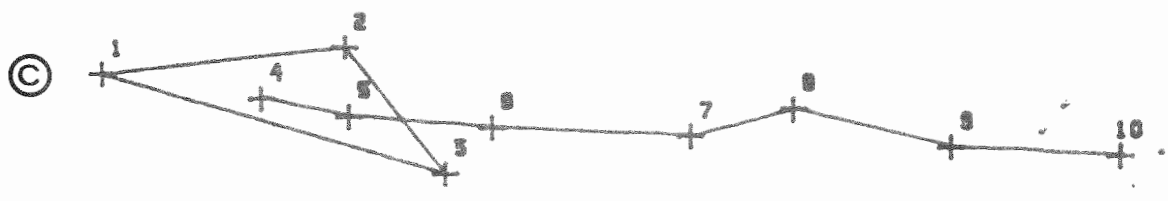
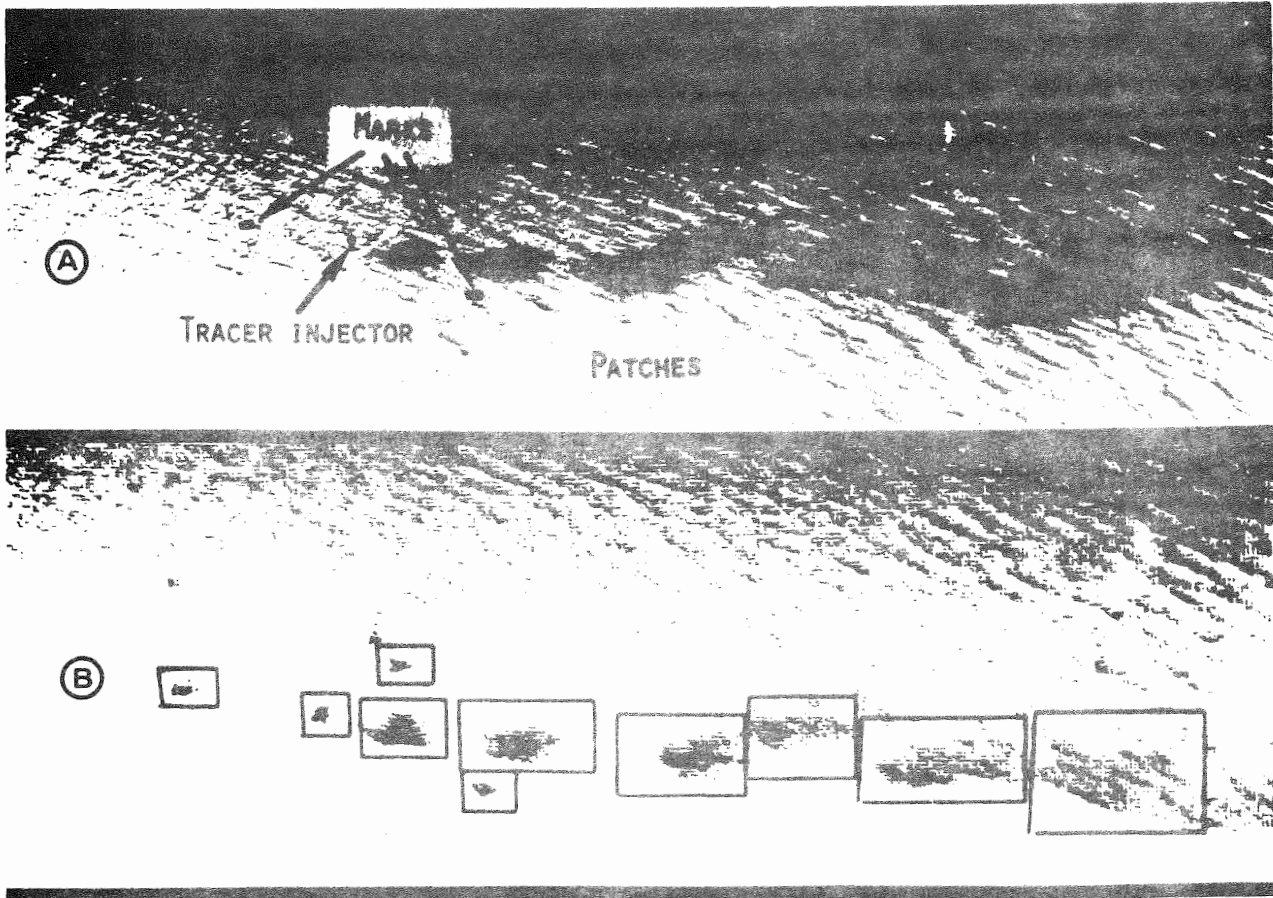


FIG. 6 - SIGNALS OBTAINED FROM A SEQUENTIAL SCANNING OF A SAMPLE OF SAND; LARGE ARROWS SHOW THE MAXIMA DETECTED BY AUTOMATIC ANALYSIS.



- 1 - MARK 1
- 2 - MARK 2
- 3 - MARK 3
- 4 - TRACER INJECTOR
- 5. 6. 7. 8. 9. 10 - POSITION OF THE OPTICAL BARYCENTRE OF THE TRACER PATCHES

FIG. 7 - ANALYSIS OF AN AIR PHOTOGRAPH (SEE TEXT): A) ORIGINAL; B) DIGITALIZED IMAGE; C) RECONSTRUCTION OF THE POSITION OF THE REFERENCE MARKS AND OF THE OPTICAL BARYCENTER OF THE TRACER PATCHES.

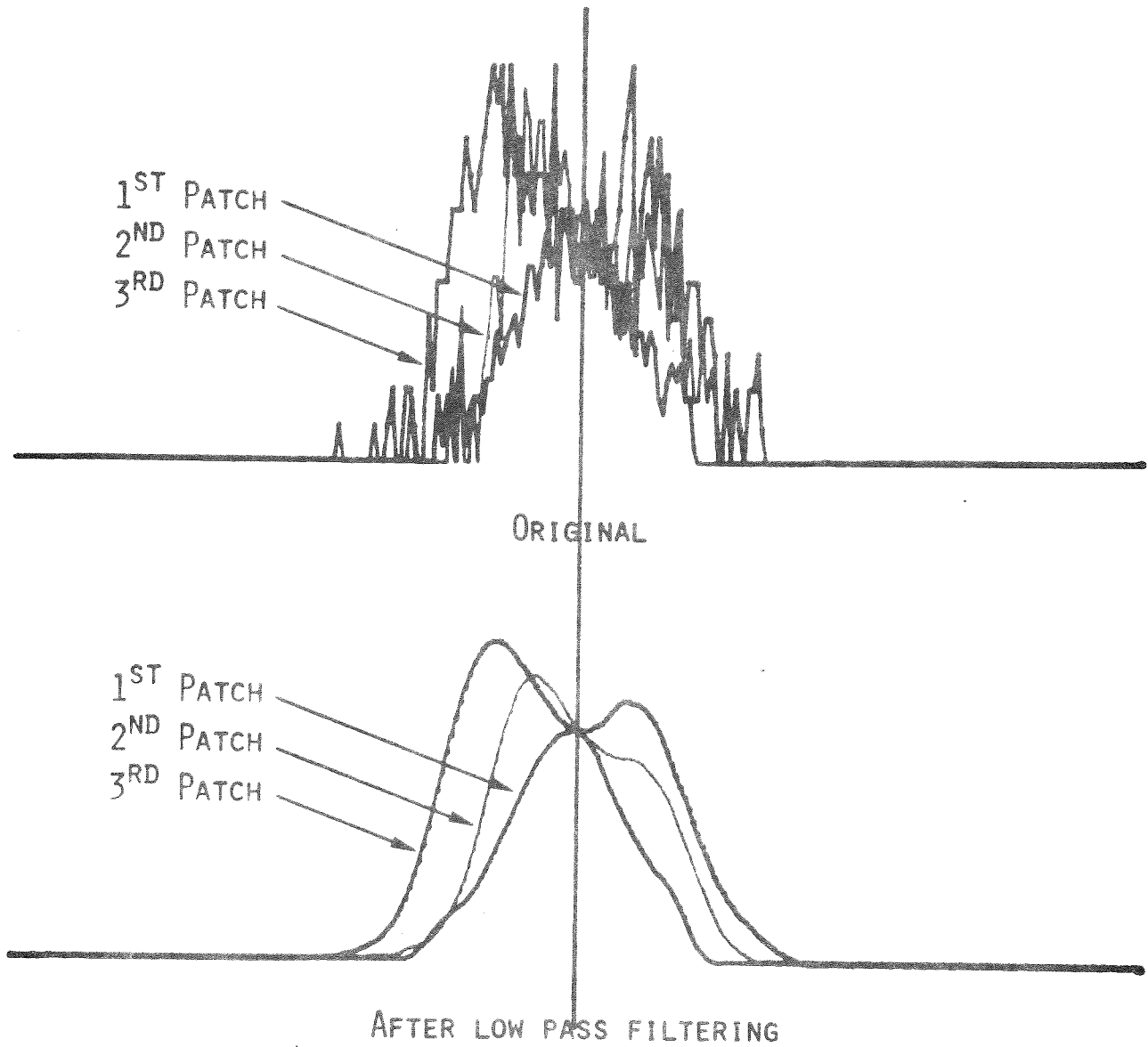


FIG. 8 - SUPERIMPOSITION OF A NORMALIZED BARYCENTRAL SCANNING OF THE FIRST THREE PATCHES. NORMALIZATION AND SUPERIMPOSITION ARE REFERED TO THE OPTICAL BARYCENTER.