AN APERTURE IMAGING SYSTEM WITH INSTANT DECODING AND TOMOGRAPHIC CAPABILITIES

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A system for electronically decoding images from a coded aperture device is presented. The aperture is a single annulus in a thin lead (1/16-in.) plate and the coded images are stored in a commercial scan converter. Decoding is performed instantly (¼ sec) by reading the image with an electron beam which scans in a helical fashion. Changing the diameter of the helix allows tomographic reconstruction.

The development of stationary imaging devices (cameras) is at a stage where further improvements in resolution can only be obtained by an unacceptable sacrifice in sensitivity. This is due to the limitations of the conventional-type collimators and is unavoidable.

Recently much interest has been shown in the zone-plate imaging systems (*1–4*) in which the conventional collimator is replaced by a thin masking plate. This plate is in the form of a Fresnel zone plate which produces a coded shadow image that is subsequently decoded by a laser and optical system. These systems offer an increase in sensitivity of two or three orders of magnitude and also produce tomographic images. One disadvantage of these techniques is the time taken in the optical decoding process.

The system described below uses a single annular aperture and decodes the images electronically in approximately ¼ sec after the study is completed.

SYSTEM

A block diagram is shown in Fig. 1 where it can be seen that the annular aperture (diameter 2 in., annular width ⅛ in., thickness $\frac{1}{16}$ in. lead) is placed at about 17 cm (S_2) in front of a gamma camera (Nuclear-Chicago HP). A point source placed in front of this, as shown, then produces a coded annular image in the camera. This coded image is stored on an image storage tube which is an integral part of a commercial scan converter unit. If we wish to view this coded image, we switch the scan converter to the read mode whereupon its internal scanner deflects the read beam across the stored image in a TV-type raster and transfers the image to the monitor oscilloscope screen.

If we wish to decode the images from the annular aperture, we superimpose, from an external generator, a sine wave and a cosine wave onto the horizontal and vertical sawtooth generators in the scanner circuits. This causes the reading electron beam to scan in a helical fashion as shown at the bottom of Fig. 1. If the helix is closely packed, then the net effect is as if we were reading our stored image with a circle. When the scanning circle coincides with a stored circle, we get a sharp increase in the output from the storage tube. This output feeds the z axis of the monitor oscilloscope which gets its x and y deflection signals from the linear sawtooth waveforms available from the scan converter.

Some z signal is present when the circles partially overlap, but this may be removed by the brightness control on the monitor or, in the future, by a threshold amplifier as shown in Fig. 1. These unwanted z signals correspond closely to the so-called "DC component" that is a problem in the zone plate imaging systems.

In the system used to date, the reading raster is

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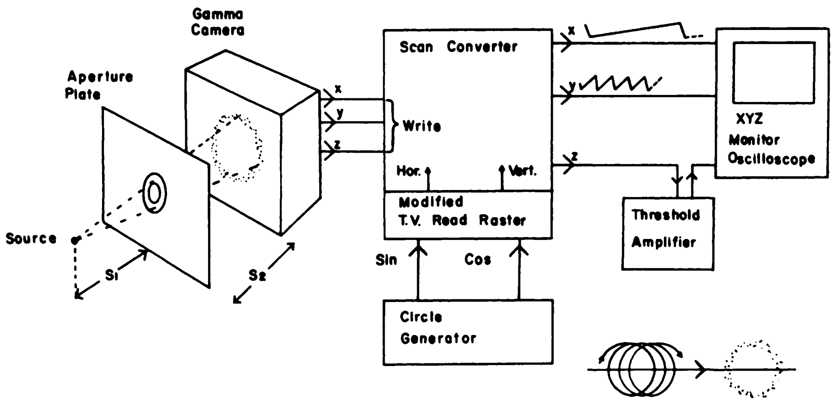

FIG. 1. System for decoding images produced by annular aperture.

a normal 525-line (interlaced) TV system which has been slowed down by a factor of about 16 so that each scan line now takes approximately 1 msec. The sin/cos generator is set at approximately 100 kHz so that the helix consists of about 100 loops per scan line. (It was necessary to slow down the scan rate since increasing the helix frequency above 100 kHz resulted in severe pickup in the storage tube output preamplifier.)

A point source at a different distance from the aperture produces a different size circle of dots on the camera. By changing the size of the reading circle, it is therefore possible to pick out different depths within the patient and so produce tomographic images.

With most scan converters it is possible to read the stored image continuously for a period of approximately 20 min with little degradation.

RESULTS

The sensitivity of the aperture described is about 30 times that of the standard Nuclear-Chicago pinhole collimator. This factor is just the ratio of the aperture areas and has been confirmed by measurements using ^{99m}Tc.

The imaging results obtained so far have used groups of point sources, and it is realized that problems will probably arise when clinical situations are encountered. The contrast will probably be poor and, when the threshold amplifier is used to improve this, large objects will be poorly reproduced.

Figure 2 A(1) shows the coded camera image obtained from a ^{57}Co point source placed sequentially, in the same plane, at the corners of a 4.2 cm sided square ($S_1 = S_2 = 17$ cm). The decoded image which is a Polaroid print from the monitor oscilloscope is shown in Fig. 2 A(2). The point sources

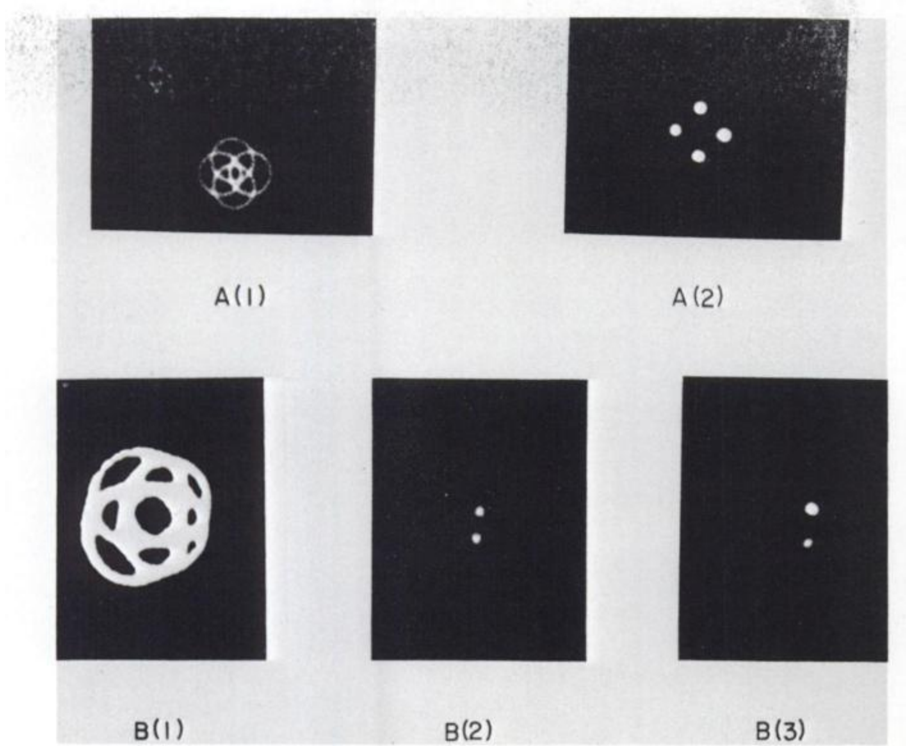

FIG. 2. A(1), Coded image (obtained from Anger camera's three-lens Polaroid camera) of four point sources. A(2), Decoded image of same four point sources. B(1), Coded image, stored in scan converter, of two point sources at distance $S_1 = 17$ cm and two sources at $S_1 = 13$ cm. B(2), Tomographic reading of plane with $S_1 = 17$ cm. B(3), Tomographic reading of plane with $S_1 = 13$ cm.

are clearly separated and the resolution looks quite good.

Figure 2B shows the tomographic effect. Two point sources (^{57}Co) were placed 3 cm apart at 17 cm ($S_1 = S_2 = 17$ cm) from the annulus, and the two were then displaced laterally by 3 cm and moved 4 cm closer to the aperture so that $S_1 = 13$ cm. The total coded picture stored in the scan converter is shown in Fig. 2 B(1) and the decoded images of the two planes, picked out by changing the read circle diameter, are clearly shown in Fig. 2 B(2) and B(3). With this simple system, each plane is seen with the complete obliteration of the other—unfortunately this is a very artificial situation. The stored coded image is rather poor and will have to be improved considerably. It has not yet been possible to store an adequate gray scale with the result that stored images are too contrasty and valuable information necessary for the decoding of more complex images is missing.

Preliminary experiments which have been underway for about 6 months are very encouraging. Further work is taking place to improve the resolution and gray scale of the scan converter which is capable of better results. A threshold amplifier will be incorporated; the effects of different aperture dimensions will be examined, and the resolution will be measured.

It is suspected that, as Barrett (*3*) has found with the zone plate systems, a camera with better intrinsic resolution than the Anger camera will be required.

ACKNOWLEDGMENTS

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