Synthetic Aperture Acoustic Microscope for Evaluation of Finger Tip Peripheral Skin Structure.

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ABSTRACT

Setup for reconstruction of 2D quasi periodical structures from measurements of it's ultrasonic diffractive field is presented. Construction of the ultrasonic head is based on prototype of our ultrasonic sensor for fingerprint pattern recognition. Example of measured and reconstructed acoustic image of a fingerprint is compared with an optical picture.

1. INTRODUCTION

Basic area of author's interest are the methods of ultrasonic measurements and identification of 2D structures, especially fingerprint lines. In case of quasi periodical objects their Fourier transform structure looks simpler than the object itself. Fourier transform of an reflecting or transmitting object can be found in its far diffraction field[1,2]. It means that one can get full representation of the quasi-periodic object using smaller number of samples by scanning diffraction spectrum, instead of the object itself. For example sinusoidal diffraction grating is fully represented, by the position and amplitude of three points of -1, 0 , +1 diffractive order.

Due to the achievements of dactyloscopy[3] , criminologists are able to identify a person basing on the fingerprints left on the place of crime. Restricted area or data access and credit cards market create the need for identification of the user. Authors develop a method of identification, basing on analysis of far ultrasonic field diffracted on fingerprint lines[4]. Due to uniqueness of skin structure and its specific physical features it may be expected that preparation of an artificial finger or other way of cheating that system would be very complicated and expensive. Constructions of ultrasonic heads for this purpose were presented previously [5]. The same ultrasonic heads can be also used as a synthetic aperture microscope, for observation of acoustic image of biological and technical objects.

For identification purpose it is sufficient to measure the amplitude and phase of the diffracted acoustic wave. To obtain tomographical reconstruction of the object we have to measure full pulse response of the object. Measurements are made by sending a pulse and sampling the echo by a scope board at different positions .

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2. DESCRIPTION OF THE PROBLEM

Let us consider 2D structure with reflectivity distribution f(x,y) (Fig.1a.). Projection p(r,φ) of this distribution on direction φ is defined by integral of f(x,y) along lines perpendicular to φ direction:

$$p(r,\varphi)=\int f(r\cos(\varphi)-s\sin(\varphi),r\sin(\varphi)+s\cos(\varphi))ds \qquad (1)$$

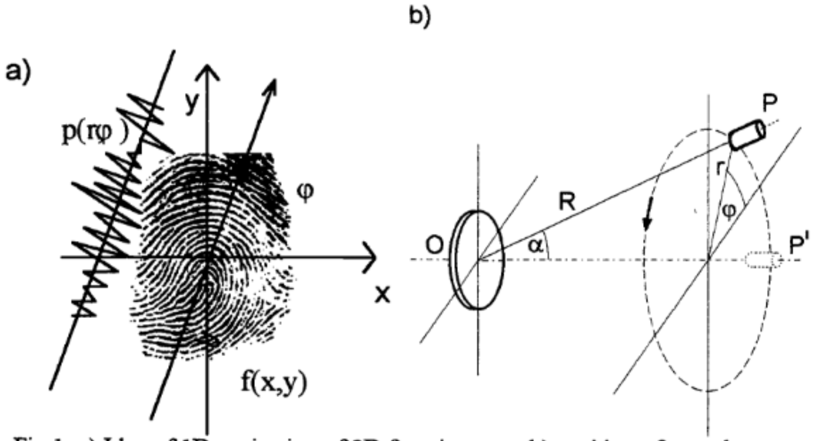

Fig.1. a) Idea of 1D projection of 2D function , b) position of transducer .

Two dimensional function p(r,φ) containing projections of f(x,y) on all directions φ is called the Radon transform of f(x,y)

$$p(r,\varphi) = R(f(x,y)) \qquad (2)$$

Ultrasonic transducer (Fig.1b), positioned at the point α,φ,R, generates short acoustic pulse propagating in medium as a wave of velocity c. In successive moments wave front of the pulse intersects the object O along lines perpendicular to direction φ, and comes back to the transducer. In ideal case pulse response (or echo) may be considered as scaled projection of structure reflection coefficient f(x,y). Sampling of pulse responses is made for a number of angles φ. That way we collect whole Radon transform p(r,φ) of function f(x,y).
Reconstruction of f(x,y) from the set of projections is made on the force of the Projection Theorem

$$F^{2D}(u,v)=F^{2D}(f(x,y))(q\cos(\varphi),q\sin(\phi))=F^{1D}(p(r,\varphi))(q) \qquad (3)$$

where:

F^{1D} ,F^{2D} are one and two dimensional Fourier transforms respectively,
u,v - space frequencies .

Using this theorem, 2D Fourier transform of the object can be obtained from the set of projections . After inverse, two dimensional Fourier transformation we get reconstructed image of the object . Numerical realization of reconstruction is speeded up by fast Fourier transform algorithm (FFT). Also the reconstruction of the object by the back projections algorithm is used.

3. EXPERIMENTAL SETUP AND RESULTS

Laboratory setup is composed of three main functional blocks (Fig.2.):

- mechano-acoustical head with a composite 6 MHz transducer, water filled vessel with measurement window, mechanical system with step motor, step motor controller, position sensor;

- sending-receiving block with a pulse generator, directional switch and preamplifier;

- microcomputer 486/60 MHz with 100 MHz scope board and digital processing (DSP) card.

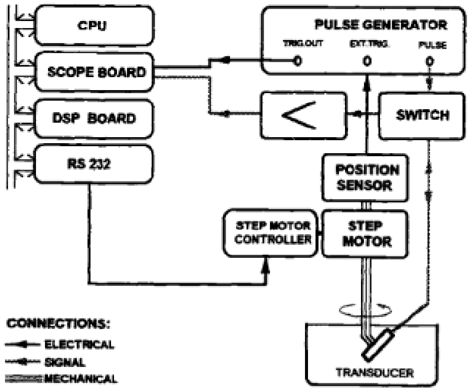

Fig.2. Schematic diagram of the setup

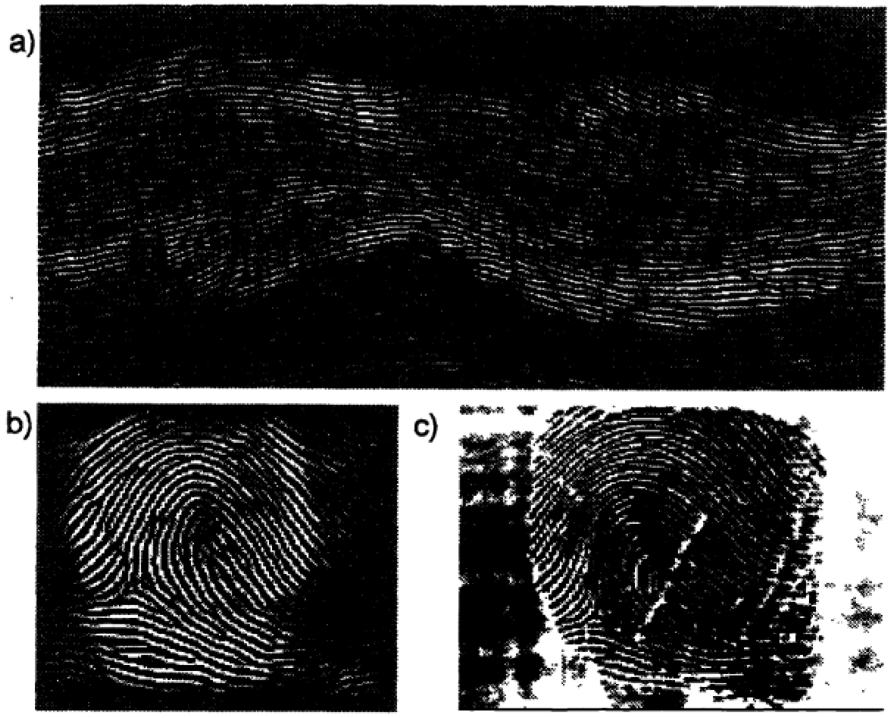

Fig.3. Example of measurement and reconstruction: (a) matrix of pulse responses, (b) acoustical image reconstructed from a , (c) optical picture of the same finger.

During the measurements, ultrasonic transducer positioned at $\alpha=15°$, sends short pulses and receives echo of waves diffracted on a finger attached to the window of ultrasonic head. Those pulse responses are sampled by scope board and stored in a matrix of 256x256 elements - one column for each angular position (Fig.3a). Reconstruction algorithm is done by the computer and DSP board performing FFT. Whole measurement and object reconstruction takes about 8 seconds.

As a reconstruction result we get a complex function. In our laboratory , measurements and fingerprint reconstructions are carried out to obtain some information about acoustical properties of finger subsurface structure. Phase distribution of reconstructed function gives information about thickness of measured object. Also aberrations appear as phase disturbances of reconstruction .

4. CONCLUSION

Measurement and reconstructions of finger tip shows, that acoustic field diffraction occurs on structures identical to fingerprint lines. Reconstruction of other structures were also obtained, e.g. rubber stamps, standard diffraction gratings. Quality of the pictures strongly depends on precise adjustment of the head , bandwidth of transducer, and on precision of focusing system . Analysis of reconstruction errors allows us to state the apparatus function. By applying instead of the moving transducer a circular matrix of point transducers, switched by a multiplexer we will transform described system in to a fast ultrasonic Fourier microscope.

5. REFERENCES

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