電子情報通信学会技術研究報告 = IEICE technical report : 信学技報
(2016.2) 115(464):47-50.

Feasibility Study of Lensed CW-Doppler Orthography for Clinical Device Design : Single Pixel 1:1 Focused Reception Experiment (超音波)

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THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
IEICE Technical Report
US2015-116 (2016-02)

Feasibility Study of Lensed CW-Doppler Orthography for Clinical Device Design

Single Pixel 1:1 Focused Reception Experiment

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Abstract: In order to have technical feasibility proof for lens-focused orthographic focal plane Doppler imager having per-pixel Doppler receiver array, trial single pixel reception was successfully performed with 1:1 focused projection using phase continuous Fresnel lens which we developed in prior research.

Keywords: Doppler; Orthography; Fresnel Lens; Focal Plane Array

レンズ結像式 CW ドプラオルソグラフィーの臨床実用化に向けた基礎実験

単一ピクセル１対１結像での受信実験

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あらまし：レンズ結像式の焦点面アレイドプラオルソグラフィー映像装置の臨床実用化へ向けて、レンズの焦点同志の間で１：１結像させて 1 ピクセル分のレンズ結像受信を行った結果を報告する。先に開発した位相連続フレネルレンズを用いている。

キーワード：ドプラ、オルソグラフィー、フレネルレンズ、焦点面アレイ

I. BACKGROUND AND OBJECTIVE OF STUDY

For Doppler examination, intra-corporeal major vascular flows are relatively easy object for duplex or CFM scanner, shallow small flows are also easy for single beam CWD system because their locations are relatively well known. Motivation and object of this study is to provide a skill-free volumetric method and means for Doppler imaging and measurement for deep intra-corporeal small flows, for example, in pelvic zone where urologist, obstsrician and gynecologist have greeat concern.

II. STATEMENT OF CONTRIBUTION

Here we use lens-focused orthographic focal plane Doppler imager having per-pixel Doppler receiver array. The subsystem level studies are completed years of ago (1,2), the study here presented is in-water vessel feasibility verification by 1:1 focused projection to single pixel receiver using double strength full (convex-convex) version of our previously developed half version (plano-convex) phase continuous Fresnel lens (2,3). Sample target (2mm dia. flow phantom and human palm artery) is illuminated by 3MHz 2mW/cm2 CW plane wave while Doppler echo is 1:1 lens-focused to 2x2mm small single element transducer representing unit pixel of focal plane array, followed by unit CW Doppler receiver. Focal length of the lens is 10cm. f-number is 2. Fig.1 shows front view of the lens, figs.2a,b show its designated and measured focusing pattern (given in (1)).

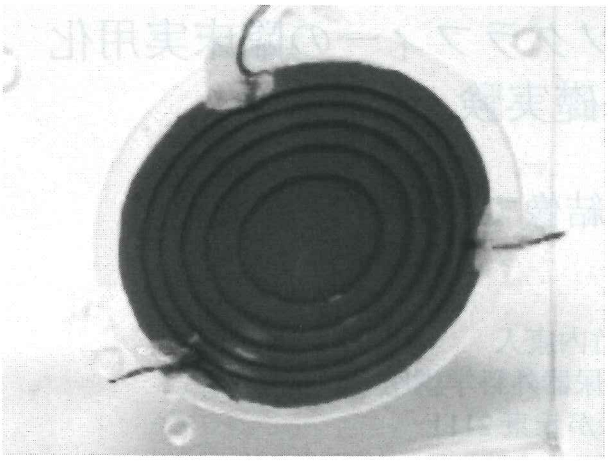

Fig.1: Front view of our phase-continuous Fresnel lens. Diameter 50mm, "suttered" to acrylic plate having 50mm dia, hole.

III. METHODS

As shown in figures 3a,b, proximity reception and 1:1 lens- focused reception are compared. For lens-focused reception, the projection transducer is 10mm diameter flat (unfocused) transducer originally used for fetal heart auscultation having two semilunar air-backed transducer, however, here these two elements are electrically paralleled to make one flat circular disc transducer. It is driven by fetal heart beat detector transmitter electronics to make 2mW/cm2 illumination intensity at its surface. The flat beam is introduced about 45 degree oblique, 2 to 3 cm distant to imaging field where target vessel in soft tissue is ultrasonically visible. Thumb artery at the root of thumb finger located about 1cm depth is selected for this experiment. The thumb artery is placed at original focal point of the lens, about 10cm distant fromlens location. The lens is two sided bersion of our prior research reported in reference (2) and (3). Briefly introducing, it is 50mm diameter 6-zone double-sided phase continuous Fresnel lens to perform 1:1 focused image for 10cm distant focal planes for both side.

In this aspect its thepretical F-number is 2, viewing solid angle makes about 30 degree. The receiver transducer is 2x2mm air-backed square flat disc, located at another focal point, however, mounted on slidable platform to find and locate exact at a position for maximum receiving level of the Doppler signal. The Doppler receiver used for this investigation is balanced demodulator type non-directional receiver having 3KHz designed bandwidth and 2dB measured noise figure.

For controll proximity reception the above mentioned reception transducer was placed on the thumb root skin surface for opposite oblique view position to the incidence projection flat beam, where the viewing solid angles are kept similar, about 30 deg.

The reception signal Doppler components are analyzed by Matlab-5 running in G3 Macintosh via its own audio imput A/D converter. Signal level (or power) was also measured within Matlab for comparison.

IV. Results

It was found that the reception signal intensity of our lens-focused system is generally about 3dB to 6dB less than proximity reception, in addition to insertion loss of the lens (measured as 2dB to 4dB(1,2)). This makes supposed practical throughout system loss being 6 to 10dB. Additional divergence loss may be encountered. Spatial resolution of this lens focused 1:1 projection system seemed reasonable respective to our prior studies (1,2), however, since Doppler signal source for this investigation is natural peripheral artery in soft tissue, exact measurement is yet to be done.

These results suggests that, when the single element test probe is replaced by per-pixel focal plane CW-Doppler array, it is expected to make intra-corporeal observation focal plane CW-Doppler imaging system having reasonable sensitivity and angular resolution. However, since this study presented here actually remains only with on-axis lens performance test, following aspect of view should be for further studies to be done.

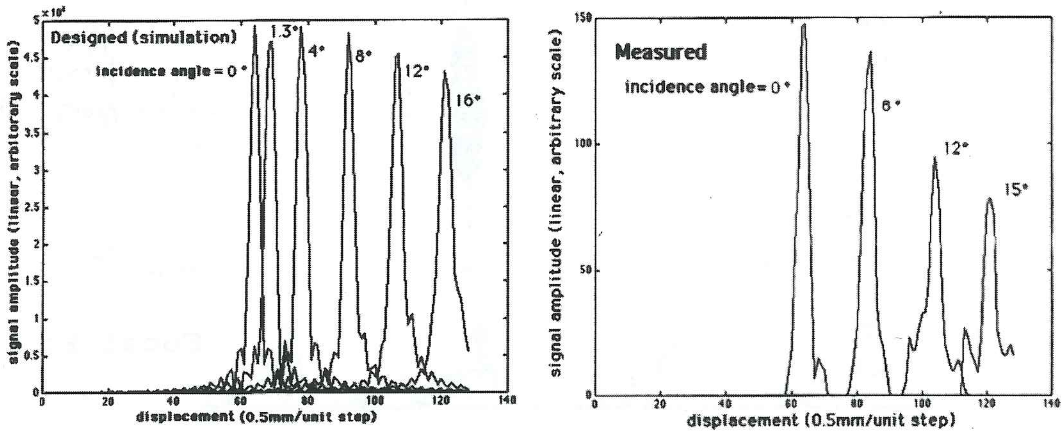

Fig.2a,b: Focusing patterns of our lens, designated (left) and meeasured (right) (1). The data suggests that usable imaging field is like a big postage stamp size, across the center axis.

(1) paraxial measurement for actually usable imaging field (steradian).

(2) construction of 2D FPA and water chamber type lnsed transducer assembly.

(3) construction of Doppler receiver array to support the 2D FPA.

(4) more intense, but imaging field selective illumination system.

V. References

[1] Y. Takeuchi, "Ultrasonic low-loss phase contiounou Fresnel lens for focal plane array imaging", 2002 IEEE IUS proceedings pp1139-1142

[2] Y. Takeuchi, "Focal plane array Doppler imaging with per-pixel CW-Doppler receiver array", 2000 IEEE IUS proceedings pp1501-1504

[3] K. Mori. et al., "Basic study of FDTD analysis for phase continuous Fresnel lens " IEICE Technical Report US2006-34 (2006-08) pp21-26.

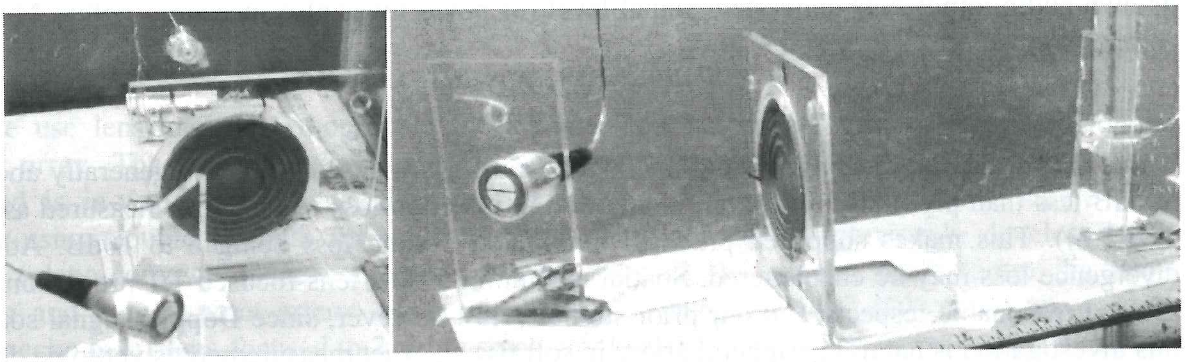

Fig.3: Experimental water vessel setup view. Flat PZT rojection transducer (left, oblique) is in origin half disc pair Doppler transducer, the 2 elements are used in parallel to make one flat disc projector.

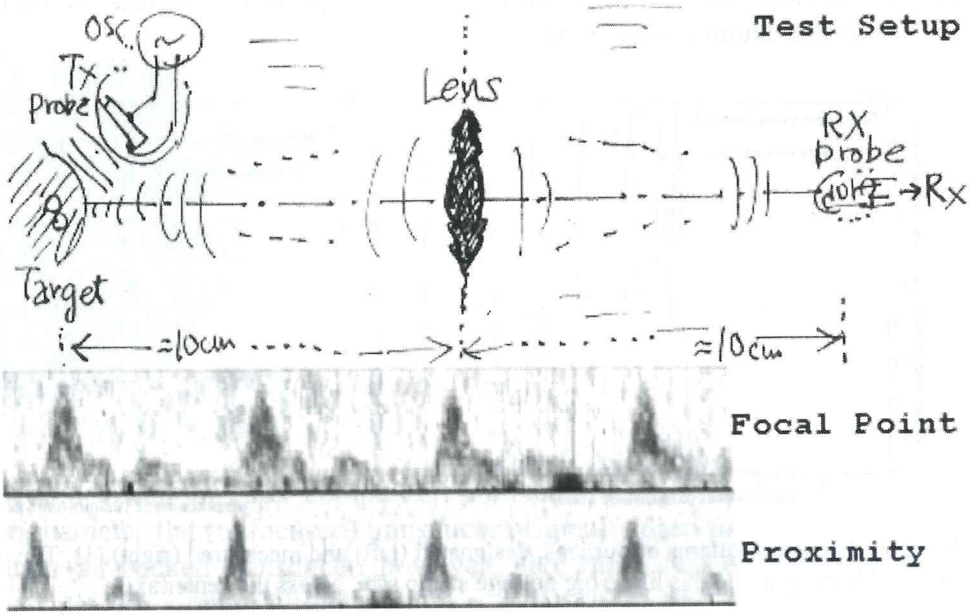

Fig.4a,b: (a, upper) Schematic drawing of test water vessel setup. Target is thumb artery at root of thumb finger. (b, lower) Focal point receprion Doppler spctrum and proxomoty receprion Doppler spectrumare not synchronously taken, the physiological status of target vessel (root of thumb artery) and heart rate are not same.