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Firming ultrasonic beam using Fresnel zone plate
フレネルゾーンプレートを用いた超音波ビームフォーミング

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1. Introduction

As one of the ultrasonic medical technology, there is a High-Intensity Focused Ultrasound (HIFU).

HIFU can be increased to the temperature of over 90 ℃ by concentrating ultrasonic energy in the focus. Also, this is a technique to kill out the cancer cells of the vicinity. This technology has been put to practical use as a method of treatment of the prostatic cancer. [1]

In the HIFU technology, it is important to control the focus area of the ultrasound spatially. In a conventional method, which controls the focal area by manipulating a HIFU device mechanically. However, in this method is sizable burden of doctors, and take a long time. There, if doctors can manipulate the HIFU device electronically, they can greatly reduce the effort.

It proposes the method of patterning the Fresnel zone plate to 2D array transducer as a focusing method of the ultrasound. In this paper, the ultrasound beam profile formed by this method is evaluated.

2. Fresnel zone plate

The Fresnel zone plate(FZP) is a flat plate with varying permeable and impermeable the concentric circles. When a concentric circles pattern is changed, the distance between plate and focal point is adjusted by Fresnel pattern.

In case of FZP(Fig.1), given that the distance of sound source and plate is r_1, distance of plate and focus is r_2, the Fresnel zone are given by [3]

$$\sqrt{R_n^2 + r_1^2} + \sqrt{R_n^2 + r_2^2} = n\frac{\lambda}{2} + r_1 + r_2 \quad (1)$$

where λ is the wavelength, n=1,2,… is a consecutive number and R_n are the zone boundaries of the Fresnel rings.

$r_1 \rightarrow \infty$ are given by

$$R_n = \sqrt{n\lambda(r_2 + \frac{n\lambda}{4})} \quad (2)$$

In this case, the element in the range of n=2m+1 (m=0,1,2…) from n=2m is driven.

3. Simulation

The focusing acoustic field formation simulation of ultrasound in water was created by using the Visual Studio 2008.

A set value of the simulation environment is indicated in Table1.

2D array has 24×50 elements, and size of 2D array is 16.8mm×35mm. Three kinds of focusing coordinates were set and simulated. The FZP pattern was constructed respectively and each Fresnel patterns were shown in Fig.2.

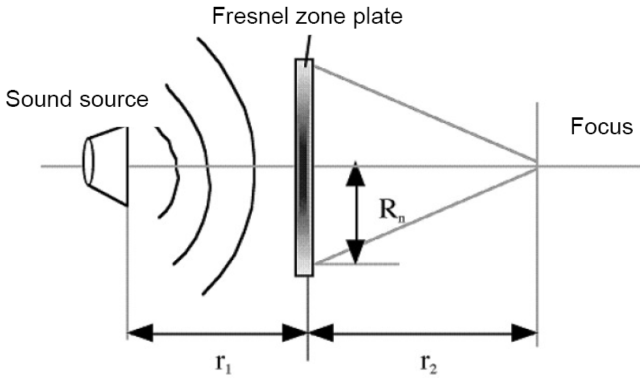

Fig.1 Fresnel zone plate

Table.1 Simulation setting value

Width of x coordinates	0.7[mm]
Width of y coordinates	0.7[mm]
Width of z coordinates	0.7[mm]
Range of x	-8.4≦x≦7.7
Range of y	-17.5≦y≦16.8
Range of z	0≦z≦70
Number of elements	1200
Sound velocity	$1.5*10^6$[mm/s]
Frequency	1.0[MHz]
Wavelength	1.5[mm]
Coordinates of focus	(0,0,30)(0,0,40)(0,10,30)

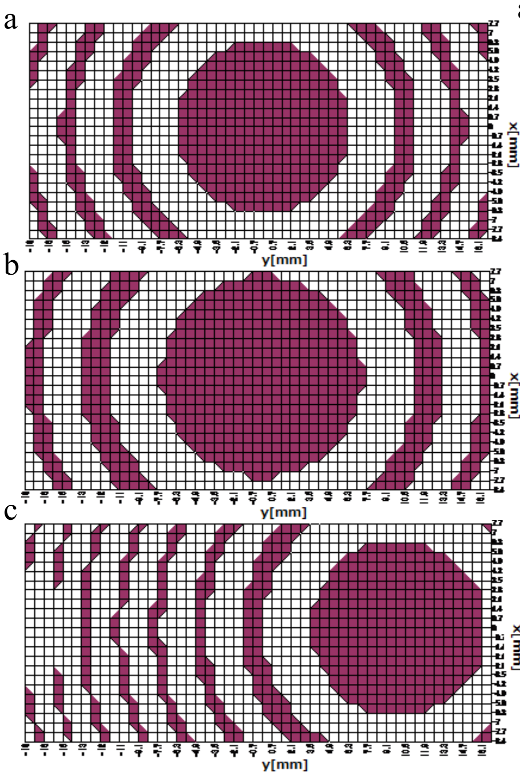

Fig.2 Arrangement of drive element

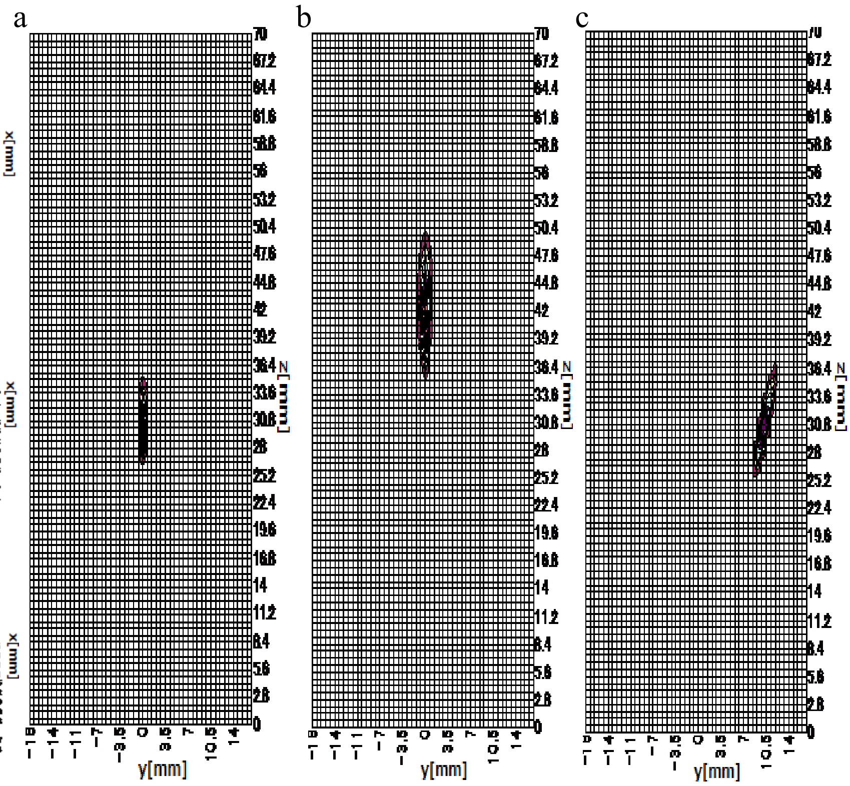

Fig.3 Shape of focus of y-z plane

4. Result and Discussion

Fig.2 shows the arrangement of the drive element. (a), (b), (c) sets the focus to (0, 0, 30), (0, 0, 40), (0, 10, 30) respectively. In case of (c) set, the drive elements were not enough at the y>0 area.

Fig.3 shows distribution of sound pressure of yz plane. The focal points were formed by every case. The set (c) gives the skew shape of focus. If the plate has enough size, the shape of focus should be same size and shape of it of set (a). However, in the simulations, the small plate was used. Therefore, (c) have become focus there is an angle for the plate.

For the evaluation of beam shape, theory value of the beam length and beam diameter is calculated by

$$L = \frac{2\alpha}{\alpha^2 - 1} F \quad (\alpha = \frac{D^2}{4\lambda F}) \tag{3}$$

$$d = 1.02 \frac{Fc}{fD} \tag{4}$$

where L is beam length, d is beam diameter. F is the focal length, c is sound velocity, f is the frequency, λ is the wavelength, D is aperture of 2D array. Value of beam diameter by reason of the rectangle whose shape of the 2D array calculates two types of d_x and d_y.

Table.2 Comparison of beam length L and beam diameter d_x, d_y

Focus		Measured value[mm]	Theoretical value[mm]	difference [mm]
(0,0,30)	d_x	2.8	3.9	-1.1
	d_y	1.4	1.3	+0.1
	L	9.1	9.0	+0.1
(0,0,40)	d_x	4.2	5.2	-1.0
	d_y	1.4	1.7	-0.3
	L	15.4	16.3	-0.9
(0,10,30)	d_x	3.5	3.9	-0.4
	d_y	1.4	1.3	+0.1
	L	11.7	9.0	+2.7

Table.2 shows comparison of simulated beam length and beam diameter.

The ultrasound focus was formed by patterning the Fresnel zone plate pattern to 2D array transducer. The beam profile became near the theory value.

References

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