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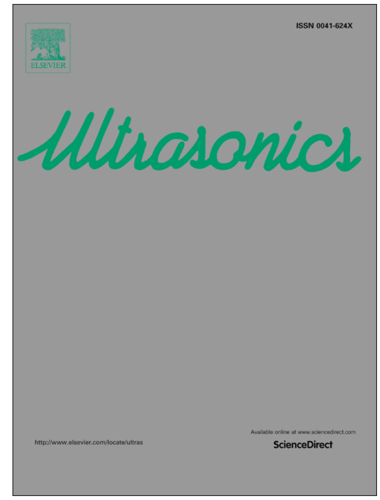

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Manipulation of focal patterns in acoustic Soret type zone plate lens by using reference radius/phase effect

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Abstract

The manipulation of focal patterns of acoustic underwater Soret Zone Plate lens in far fields, such as manipulation (optimization) of Sidelobe Level and the design of long depth of focus by selecting the simple free parameter called reference radius (phase) has been demonstrated.Two effects have been studied by means of numerical simulations. Regarding the first effect, simulations demonstrate diffraction limited focal spot (0.47 wavelength) and 3 dB reduction of the first Side Lobe Level using Soret ZP with an optimal reference radius and without causing neither main lobe broadening or gain reduction. In the second effect, by using numerical simulations an increasing of depth of focus, more than 2 times, in comparison with classical Soret ZP with high numerical aperture (F/D=2.5), was observed.

Keywords: Ultrasonic lenses, Soret Zone Plate, Side Lobel Level, Reference Radius
PACS: 43.20.f, 43.35.Bf, 43.58.Ls,

1. Introduction

A lens is a device that can manipulate waves by taking advantage of both their refractive and diffractive properties to produce wave focalization. Acoustic lenses have attracted the attention of scientists around the world for their application in multiple areas of industry, engineering, acoustic tweezers, biomedicine and for other applications requiring low-cost acoustic focusing lenses [1–11], to mention a few. This explains why their design is subject of much research nowadays. One of the effects of these lenses is their capability of focalization, which it can be obtained by means of different types of methods and techniques.

Acoustic lenses based on phononic crystals have been designed and fabricated [12]. Other types of acoustic lenses are those designed with a refractive index that varies throughout the medium continuously. These are the so-called Gradient-Index (GRIN) lens, and the variation of the refractive index is achieved by forming labyrinthine structures [13–15]. Acoustic metamaterials [16] and acoustic resonators [17] have also been used in the design of acoustic lenses.

There are also acoustic devices that focus sound through the phenomenon of diffraction. Acoustic lenses based on constructive interferences of diffracted fields, such as Fractal Lenses or Fresnel Zone Plates (FZP), are a good alternative to refractive lenses. FZP lenses have advantages in situations where size, weight, system complexity and fabrication are important [18, 19]. The classic FZPs that are implemented alternating transparent to opaque Fresnel zones are called Soret Zone Plates (SZP) [20]. This work is focused on this type of Fresnel's lenses.

In Ref. [21] the authors study a lens formed by slits of different thickness located at r_n, while in the present work rigid scattered located at r_n (r_n is a radius of n-th Fresnel zone) has been used. Following Babinet's principle considerations, both approaches can be considered equivalent. Recently Calvo et al. [22] fabricated and characterized an underwater acoustic SZP lens with alternating transparent and opaque zones made of soft silicone rubber. Calculations shown some reduction of the first Side Lobe Level (SLL), but with a main lobe broadening.

Although the diffraction of the acoustic field produce a maximum pressure field in the axis, the focal point shows some miss-definition due to the existence of secondary lobes [23–25]. In such a way, the relationship between the main and secondary lobe, known as SLL, is one of the main problems that SZPs can exhibit [26].

Even though the maximum energy is obtained at the Focal Length (F_L), the SLL are not high enough with SZP lenses for applications where high precision is required. In this regard, a new technique used in biomedicine such as High Intensity Focused Ultrasound [27, 28], both in acoustical printer [8] or in acoustical particle manipulations [10] requires very precise targeting area so it is desirable to be able to control the lobes of the transmitted signal.

In other fields of physics, such as electromagnetism, this problem has already been raised. Minin et al [29] studied the possibility of altering the energy distribution function in a predetermined focus area. Recently, the authors themselves have shown that by choosing a radius of the first zone or a reference phase, non-standard values of the SZP radii can be obtained