Acoustic gap solitons in layered media

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Wave propagation is common to many fields of physics such as mechanics, optics or acoustics. In the case of acoustics, high intensity waves present specific features such as distortion, shock formation or harmonic generation. These phenomena have been studied since the second half of 18th century [**1**]. Common acoustic media are characterized by a quadratic nonlinearity and very weak dispersion. During last decades a class of artificial materials, the so-called sonic crystals, have received increasing interest, owing to their ability of manipulating sound wave propagation. They consist of a periodic arrangement of scatterers embedded in a host medium. Due to periodicity, sonic crystals present *band gaps*, that is, ranges of frequency where waves are not allowed to propagate. At the edges of the bands near the band gaps, waves propagate but experience high dispersion. There is a recent interest in studying the propagation of intense waves through periodic acoustic media [**2**]. The interplay between nonlinearity and dispersion leads to several phenomena including selective harmonic generation and propagation of solitary waves. In fact, in the band gap, waves are not allowed to propagate in linear regime, but under certain conditions, solitary waves can propagate without changing its shape. These waves have been called *gap solitons*. In the case of quadratic media, such solutions take the name of simultons, since localization affects both to the fundamental wave and its second harmonic. In this work, we study a 1D periodic system, formed by the periodic repetition of a set of two layers of different fluid materials, producing a 1D periodic modulation of the physical properties.

The propagation of acoustic waves in the multilayered media is described by a second-order nonlinear wave equation, also known as the lossless-Westervelt equation [**1**],

$$\frac{\partial^2 p}{\partial z^2} - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = -\frac{\beta}{\rho c^4}\frac{\partial^2 p^2}{\partial t^2}, \tag{19}$$

where p is the acoustic pressure field, c is the space-dependent sound velocity, ρ is the fluid density and β the nonlinearity parameter. From (19), we have derived a set of coupled-mode equations for the envelopes of the acoustic pressure profiles, analogous to the ones that appear in the optical case [**3**].

In this work, we demonstrate numerically the existence of acoustic gap solitons (simultons) in a 1D layered acoustic media in the frame of the coupled-mode theory, and discuss the physical parameters corresponding to a realistic acoustic medium where such solitary waves could be observed experimentally.

Keywords: acoustics, phononics, harmonic generation, gap solitons.

Acknowledgments

This research was partially supported by Ministerio de Economía y Competitividad under grant FIS2015-65998-C2-2. LJSC and AM acknowledge UPV for predoctoral contract FPI-Subprograma 1.

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