Acoustic transparency and opacity using Fano Interferences in Metamaterials

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Abstract: We investigate both experimentally and theoretically how to generate the acoustical analogue of the Electromagnetically Induced Transparency. This phenomenon arises from Fano resonances originating from constructive and destructive interferences of a narrow discrete resonance with a broad spectral line or continuum. Measurements were realized on a double-cavity structure by using a Kundt’s Tube. Transmission properties reveal an asymmetric lineshape of the transmission that leads to acoustic transparency.

Resonances are phenomena that cut across a plenty of physical fields, and researches around them have not ceased to reveal effects with promising applications. With the advent of metamaterials, the field of acoustics is taking a new twist, improving our ability to develop acoustic devices having a higher sound flow control. Recently, various studies involving resonators have shown how to create acoustic opacity 1,2, or even acoustic transparency 3, with resonators taking different shapes depending on the context. For relatively simple systems, these resonances remain classical, in the sense that they exhibit symmetric Lorentzian lineshapes. However, since this past century, resonances with asymmetrical lineshapes have been highlighted: they are referred to as Fano resonances. Ugo Fano explained them as originating from the constructive and destructive interference of a narrow discrete resonance with a broad spectral line or continuum 4. Since then, numerous studies have allowed a better understanding of Fano resonances in others fields of physics such as electromagnetism, plasmonics 5, and more recently acoustics 6, through the acoustical analogue of the Electromagnetically Induced Transparency 7.

The aim of this work is to study how the coupling between two resonators, with different quality factors, can lead to Acoustically Induced Transparency (AIT). For this purpose, we present experimental results obtained using a Kundt’s Tube. The transmission measurements of a wave impinging our structure along its axis of symmetry are compared to transmission calculations realized using the Finite Elements Method FEM. In this work, the structure we propose is constituted of two endcapped cylinders, one centrally embedded inside the other. The inner cavity acts as an acoustic quarter wave, as well as the second cavity which is characterized by the inter-wall space of both cylinders. Indeed, taken separately, the inner and the outer cavity are slightly detuned resonators. They both exhibit a total reflection (when considering hard boundaries) at their resonance frequencies, respectively with a low and a high quality factor. The quality factor of each resonator can be tuned through geometrical parameters, and particularly inter-wall spaces.
By combining these two resonators, a coupling is created when excited by an incident wave, which leads to an asymmetric Fano lineshape in the transmission spectra. Geometrical parameters can then be chosen to find the good configuration for AIT. Figure 1 shows such an asymmetric lineshape leading to AIT. We clearly observe that the structure is acoustically transparent at the normalized frequency of 0.25, result of the coupling of two resonant modes slightly detuned. At this frequency, we reached quasi-total transparency by using a structure 4 times smaller than the relevant wavelength.

REFERENCES
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