High-resolution Acoustic Imaging at Low Frequencies using 3D-printed Metamaterials

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Metamaterials are engineered structures, typically consisting of well-organized arrays of basic cells, which exhibit exotic properties that cannot be found usually in nature [1]. Metamaterials can show super-lensing effects, thus helping in beating the so-called “diffraction limit” and recovering finer image details [2]. Although the efforts made so far on the development of these devices [3], there are many aspects that needs to be investigated further to allow the acoustic metamaterials to be used for acoustic imaging applications (e.g. in Non-Destructive Testing (NDT)). In particular, there is a need to increase the working frequency of these devices in order to reach ultrasonic frequencies and to make them work into a broad frequency range. Here, a PMMA 3D-printed acoustic metamaterial containing 100 channels was used to image an L-shaped aperture, which was machined into a 1.5 mm thick aluminium slab, as shown in Figure 1(a). A planar acoustic field was incident onto this aperture, and the signal transmitted through the structure in air was imaged on the far side over an 8-10 kHz frequency range. The dimensions of the specimen and metamaterial are shown in Figure 1. Note that the dimensions of the “L”, in particular its width, are sub-wavelength when compared to the acoustic wavelength in air over the imaging frequency range used in this experiment.

An acoustic tweeter was used as the source for the acoustic pressure field, positioned within a waveguide to help in obtaining a planar incident wave. The tweeter could be driven using a chirp signal within the frequency range of 7500-14000 Hz. The experimental results are shown in Figure 2, where the amplitude is plotted as a function of position at various frequencies in the 9.9 – 10.4 kHz range. This is done for two distances (0.5 mm and 1 mm) from the metamaterial surface. It can be seen that the L-shaped aperture has been recovered well over a range of frequencies in both cases.
Conclusions
It has been demonstrated that 3D-printed metamaterials can be used for sub-wavelength acoustic imaging in air.

References