NBE-E4310 D - Biomedical Ultrasonics 2023

Independent/group work 12.10.2023 at 12-14h; Submission: Please submit your responses via MyCourses as one zip file containing your responses in pdf and Matlab/Python format. The deadline for submitting your Exercise 2 responses is at 1:00 PM on October 23, 2023.

Please, note that not all details needed for the exercises have been necessarily presented during the lectures. If missing information, please refer to open sources or course book. Students are expected to have basic knowledge of signal processing and Matlab/Python skills.

TASK 1 (12 points)

Observe a rectangular region on xy plane with coordinates of the corners (-10,0), (+10,0), (-10,-10) and (+10,-10), the units being mm. Consider an array of 11 monopole sources oscillating radially, the sources positioned linearly at 0.5 mm spacing from (-5,0) to (+5,0). Since in the exercise you are calculating is a 2D simplification, assume that any sources are line sources unless else is assumed. Neglect any attenuation mechanisms, geometric or dissipation. The speed of sound is that in soft tissue. Use complex pressure in your studies leading to your solution. Assume continuous wave. Explain and justify in your own words each step of your calculation.

a. What needs to be the frequency to have destructive interference of the wave along the x axis? (2p)

b. For this frequency you calculated in *a)*, present the momentary pressure generated by the sound sources at t = 0 s. (4p)

c. For the field of task *b)*, present the pressure field, *i.e.* the envelope. (2 p)

d. Recalculate the maps of *b)* and *c)* by considering geometric attenuation for your source (2 p)

e. Recalculate the maps of *d)* by now considering the sources being point sources. (2p)

TASK 2 (10 points)

Generate a *'dense'* array of monopole sources, where the source spacing must be of, at least, $< \lambda/8$. The sources are placed at a distance 20 mm from origin of your xy-coordinates, positioned symmetrically to x = 0, where y > 0, forming a circularly symmetric transducer with a 90 degrees opening angle. Consider a 2D simplification and a rectangular region on the xy plane with coordinates of the corners (-25,25), (25,25), (-25,-10) and (+25,-10). The frequency is 1 MHz and the medium is water. Neglect any attenuation mechanisms, geometric or dissipation. Assume continuous wave. Explain and justify in your own words each step of your calucaltion.

a. For the frequency given, present the momentary real pressure generated by the sound sources at t = 0 s. (4p)

b. For the field of task *a)*, present the pressure field, i.e. the envelope. (2 p)

c. Recalculate the maps of *a)* and *b)* by considering geometric attenuation for your source, *i.e.* now your sound source being a line source (2 p)

d. Recalculate the maps of *c)* by now considering the sources being point sources. (2p)

TASK 3 (10 points)

On the lecture slides you were presented an animation (please, see the *.gif* file attached) of particles being within a space and oscillating back-and-forth parallel to the direction of the sound propagation in a linear harmonic fashion, forming a planar longitudinal wave traveling from left to right along the x-axis. Give the molecules within that space random rest positions, the space in the 2D simplification being an area rather than a volume. The

corners of the space on the xy-plane are at coordinates (-10,5), (10,5), (-10,-5) and (10,-5). Assume the wavelength to be 2 mm and the medium to be water.

Recreate the animation of the black spots according to the instructions above. Your animation does not need to be exactly the same as the animation above (text, arrows or red objects are not expected), but still it needs to be physically correct. You may want to tune the amplitude and molecule density to see a visible compression and rarefaction and clear wave propagation of a continuous wave (10p)