NBE-E4310 D - Biomedical Ultrasonics 2023

Independent/group work 30.11.2023 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 3 responses is at 1:00 PM on December 11, 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 (17 points)

Consider a circular ultrasound transducer of radius $a = 8$ mm and operating frequency of $f_0 = 1.5$ MHz in water.

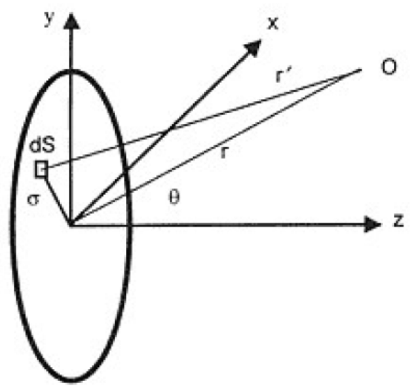

Figure 1: The geometry for the calculation of the pressure field $p(r', t)$ at an observer point O, due to a plane circular piston source (Duck et al.)

a. What is the Rayleigh distance for this planar transducer (2p)

b. Calculate the pressure p_z along the center axis Z from $z = 0$ to 1.5 × Rayleigh distance as a complex presentation. Then plot the real part of the pressure. Use Equation 1 (5p))

$$p_Z(Z, r) = i\frac{\hat{p}k}{2\pi}\int_S \frac{e^{-ikr'}}{r'}dS \tag{1}$$

Consider that the pressure amplitude is $\hat{p} = 3$ kPa.

c. Using Equation 1, calculate and plot the envelope of the pressure (hint: absolute of the complex pressure). You can neglect attenuation. (5p)

d. Plot the numerical expression from Task 1a and 1b and the pressure based on the analytical expression at the center axis in the same graph. The analytical expression is given in Equation 2. (5p)

$$p_z(z) = 2\hat{p}\left|sin\left\{\frac{kz}{2}\left[\sqrt{1+\left(\frac{a}{b}\right)^2}-1\right]\right\}\right| \tag{2}$$

TASK 2 (7 points)

A focused continuous wave is travelling along the z-axis. The file ($I_{TA}.txt$) contains a z-slice of intensity data in the x-y plane near the focus of the beam. Each element of the matrix corresponds to the time-averaged intensity (in W/cm^2) in a 140 μm by 140 μm area. Apply the field to a perfect absorber. The entire power defined by $I_{TA}.txt$ is absorbed.

a. What is the radiation force exerted on the absorber? (3p)

b. What is the maximum Langevin pressure applied to the interface, given that the interface is at the focus of the beam (2p)

c. Consider that in the previous case you are applying pulses with a duty cycle of 70%. What is the radiation force exerted on the absorber when the sound is on? (hint: think about the spatial peak pulse average) (2 p)

TASK 3 (10 points)

Ultrasound can be used to heat the tissue to thermally damage it for therapeutic purposes, e.g. thermal ablation of cancer tissue. Pathologically, you can consider 30 and 240 equivalent minutes to represent edema and thermal necrosis, respectively. Please, study the review in the slides about the equations of the paper by Sapareto & Dewey (click here to access it) and calculate the time to reach thermal dose of 30 and 240 equivalent minutes at temperatures:

a. 45 ^{o}C (6p)

a. 56 ^{o}C (2p)

a. 80 ^{o}C (2p)