Ultrasound Bioinstrumentation

Problem Assignment #1

Max Grade: 10 Points – Assigned: November 21, 2009 – Due Date: December 12, 2009

Q1: Compute and plot the 2D ultrasound field at z=5,10,15 cm for the following shapes for an ultrasound frequency of 5 MHz:

a)
0.4 mm
0.5 mm

b)
0.6 mm
0.8 mm

c)
0.2 mm
0.4 mm 0.6 mm
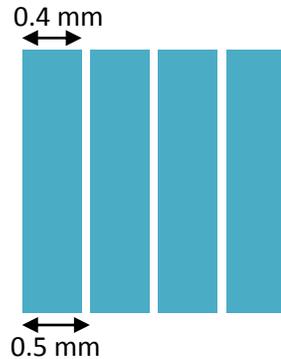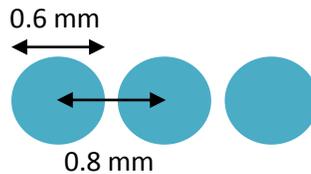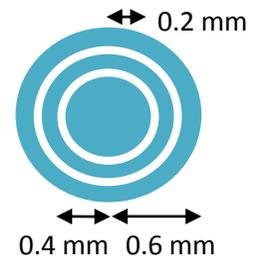
Q2: Compare the field at z=1, 5, and 10 cm estimated for a square aperture of size 0.5 mm using the exact, Fresnel and Fraunhofer calculation methods using analytical derivation and numerically using Matlab. Compare the analytical and numerical results and report your comments. Assume an ultrasound frequency of 5 MHz.

Q3: Download and examine the Field II ultrasound field calculation Matlab software package. You are required to run and report about one of the examples included with this package.

Q4: Write a Matlab code that enables the delay between two signals to be estimated for use in phase aberration correction. Comment on the delay resolution attainable with your technique.

Q5: Consider an ultrasound imaging linear array probe with 32 elements, element width=0.5 mm, kerf=0.05 mm, and elevation width=0.8 mm. Evaluate the main lobe width vs. side lobe magnitude for the following apodization functions (at a frequency of 5 MHz):

a. Rectangular window
b. Hamming window
c. Gaussian window

Q6: Write a Matlab program that allows the computation of focusing/steering delays for a linear array with an arbitrary size N with element width W and kerf K for a focal point defined relative to the array center (0,0) by (Xf , Zf) (in cm). Use this program to compute the delays for focal points at (0,10) and (1,10) with N=32, W=0.8mm, and K=0.1mm.

Q7: Repeat problem Q6 for a convex array probe with a radium of curvature of 6 cm.

Q8: Use Matlab to show experimentally that the Hadamard coding scheme improves SNR the same way averaging does.

Q9: Expanding aperture is a technique in ultrasound beamforming where the objects very close to the aperture are imaged by a lower number of aperture elements. That is, as the depth gets higher, the number of active aperture elements becomes higher or the aperture is "expanded". To show that, write a Matlab code that simulates the field of an ultrasound linear array of 32 elements with element width of 0.5 mm and kerf of 0.1 at a frequency of 5 MHz. Compare the field at 1 cm, 2 cm, 3 cm, and 4 cm with different number of array elements to show this. Is there a rule that you can derive from your observation to tell us when to turn on array elements?

Q10: Assume that a human with a fat layer of 3 cm, muscle layer of 3 cm and liver depth of 10 cm is being imaged. Using the ultrasound speed in those tissues, compare the focusing delays at the depth of 16 cm assuming the standard ultrasound speed and using the correct ones for different layers.

Q11: Second harmonic imaging offers an improved ultrasound beam than imaging at the fundamental frequency. Write a Matlab code that simulates the azimuthal field of an ultrasound linear array of 32 elements with element width of 0.5 mm and kerf of 0.1 at a frequency of 3.5 MHz compared to that at 7 MHz. Provide your comments about the differences in main lobe and side lobes between the two beams.

Important Notes:

1. Problems are 1 point each.
2. Assume any missing information. Do not assume information that can be inferred from the problem statement.
3. Solutions are to be submitted by individual students not groups.
4. You are encouraged to discuss the problems with other students but not to copy other students' solutions. You should acknowledge any help received in writing in your answer sheet in specific terms. Make sure to cite any references used in the solutions.
5. On your submitted answers, please write a statement that the solutions submitted were your own and that you fully acknowledged the help you received from others. You should also acknowledge that you are aware of the consequences of plagiarism should your statement prove to be incorrect and sign this statement.