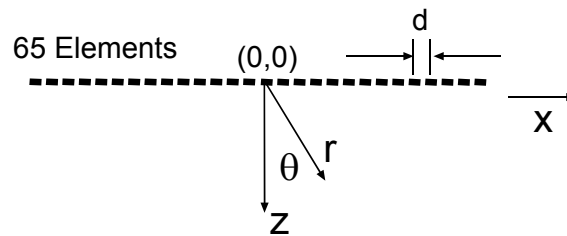# Ultrasound Project
Due Date: Nov. 7, 2004

In this project, you will implement the beamforming and scan conversion algorithms for a simulated ultrasound system (above). This system is a little different than most discussed in class in that this system uses only a single transmit element (the (0,0) element at the center of the array) which illuminates all reflectors in the object and the receive array focusing and beam steering is used to provide all lateral localization – that is, we will use one data set to create the entire image of the object. System description:

> Number of elements = 65
> Operating frequency (f_0) = 5 MHz
> Element spacing (d) = $\lambda/2$

The simulated data was generated according to the following assumptions:

> Speed of sound (c) = 1.54 mm/µs
> No attenuation (no gain compensation needed)
> Point receivers (w infinitely small)

The simulated echoes are sampled at f_s = 20 Mhz yielding a 1600 point waveform for each of the 65 array elements. I will provide you with this 1600x65 matrix. Your task is to take this data and generate a 90° sector scan image using by following the steps described below.

Administrative items (read this!):
- You may choose a partner for this project or choose not to work with a partner. There will be three projects assigned in this class – you must have a different partner for each project. If you have a partner, I require that you place his/her name on your solutions.
- I expect you to do your own work, but when you get stuck, you may ask your partner or the instructor for help. Think of this as an exam, but one in which on may ask for help from one other person (and the instructor).
- Getting help from anyone other than the instructor or your partner or copying solutions (even from your partner) will be considered a violation of the engineering honor code. (see http://www.engin.umich.edu/org/ehc/hcode.html)
- Each person must hand in his/her own solution.
- Title and label the axes on all plots and images (do this by hand if you like).
- Files to get you started can be found in ftp://ftp.eecs.umich.edu/people/dnoll/bme516/usproj/ or by using anonymous ftp to ftp.eecs.umich.edu and then cd to people/dnoll/bme516/usproj.
- If you are having problems, please come and see me (or send e-mail).
- Grading: 60% correct Matlab code, 30% report content, 10% plots, labeling axes, etc.

Questions/Tasks:
Prepare a report describing the tasks below. Hand in answers to questions below, all requested plots/graphs/images and copies of your final ".m" files. For each question/task please write 2 or 3 sentences about what you did, what equation you implemented, and about the appearance of the resultant images, etc. Say something interesting!

A. Make a "wavefield" plot of the data. We will provide software to image the wavefield. The wavefield is the 1600 x 65 image of the raw ultrasonic data. The gray scale is setup so that zero pressure is midgray, positive pressure is white and negative pressure is black. The "showimage" script sets up the 1600 x 65 image into 4-panel format. Your response to this may be combined with that of part K.

B. Define the number of total beams and the beam spacing to properly sample a 90° sector.

C. Define time delays (i.e., sampling delays) as a function of range (r) for each channel and beam direction. What formulae were implemented?

D. 1. I have placed 2 solitary reflectors along $\theta = 0$ at range locations r = 8 and 15 mm. Create the $\theta = 0$ beam by computing the coherent sum across the array using the delays derived in part C. Before combining data from the detector elements, make plots of the delayed raw data from several of the receive elements (e.g. 1, 33, and 65) to insure that pulses and waves will add constructively for those two reflectors.
2. Create data for the r-sinθ buffer for all beams. Use showimage function to display results using a 40 dB log scale.

E. Baseband convert the data to provide complex representations of the signal on every channel. Use baseband.m to perform this operation (no modifications are necessary). Plot the signals for one element before and after baseband conversion. Is this what you expect?

F. In addition to the time delays (part C.), calculate the phase rotations as a function of range for each channel and beam direction. Again, what formulae were implemented?

G. Create data for the r-sinθ buffer for all beams using the baseband converted data. You can again look at $\theta = 0$ beam to make sure that wavefronts add constructively. Display results on 40 dB scale. Is this image better than the result from part D and why?

H. In this part, we will look at the effect of introducing an amplitude apodization (windowing) function across the aperture? Specifically, we now apply a hanning window to the data as a function of element number (e.g., beams 1 and 65 are weighted to nearly 0 and beam 33 is weighted 1). Display results on 40 dB scale. Describe at least two ways that this has altered the point spread function (impulse response) and why?

I. Scan convert the r-sinθ buffer to produce a sector scan image for a 512 by 512 pixel grid. You should display two images over a log scale, one of 40 dB and the other of 20 dB. The sector scan should be to a range of 60 mm. This means that the dimension of each pixel in the final image should be $\Delta x = \Delta y = (60/512)$mm, which represents about 117 μm per pixel. Again, we will provide software to display the images on a log scale. Do this both for your answers to E and F.

J. What is the object? Use the 20 dB image from part G to answer this question. What artifacts are present? Use the 40 dB display to answer this. What does the point spread function look like? Also discuss differences in the artifacts between the images created by the processing of parts D, G and H.

K. Based on your new knowledge of what the object is, go back to the wavefield plot of part A and discuss why it looks the way it does. Discuss the angle and curvature of reflections off of the point objects and what that says about their location.