MEDT 8007 Exercise 3: Comparing measured and simulated phantom images

The purpose of this exercise is to learn how to simulate an ultrasound image in Field II, and to evaluate the similarity with measured images from the V7 scanner.

The probe that we will use in the measurements, is the 3S probe. The parameters of this probe are the same as the ones in exercise 2. The exercise will be split in two parts. First lab experiments, then simulations.

1. Lab experiment. Using the GE/Vingmed Vivid 7 scanner and the 3S probe, record an image of the CIRS 40 phantom.
    a. Select the right probe and application using the *probe*-button. Select the 3S probe (left click) and the *Cardiac* application.
    b. Take the 3S probe (the names of the probes are also on the connectors) and put a little bit of echo gel on it.
    c. The phantom is divided in two parts with different attenuation (look on the side of the phantom). Use the low attenuation part (0.5dB/MHz/cm) and try to find the cross-section of figure 1. Make sure the image is not flipped in the left-right direction.
    d. Set the frequency to 2.5MHz using the dial that says *FREQ* and checking its value on the display. Change depth of the image to 13cm by using the *Depth*-dial and set the focus to 9.5cm using the dial that says *FOCUS POS*.
    e. Try to optimize the image by tilting the probe in the left-right and forward-backward direction and twisting the probe clock- and anti-clockwise. Adjust the gain, by using the *Active Mode*-dial to get an appropriate image where both background speckle and point-scatterers are visible.
    f. If you are satisfied with the image press the *Freeze*-button and save the image to a memory stick. Place your memory stick in the USB port next to the probe connectors. Press the *Menu*-button and select *Save As*. Select the *USB Flash Card* location from the *Save in archive* menu and select the JPG format from the *Save as type* menu. Select *Save*.
    g. Clean the probe and phantom (with some care) and put the probe back on the scanner.

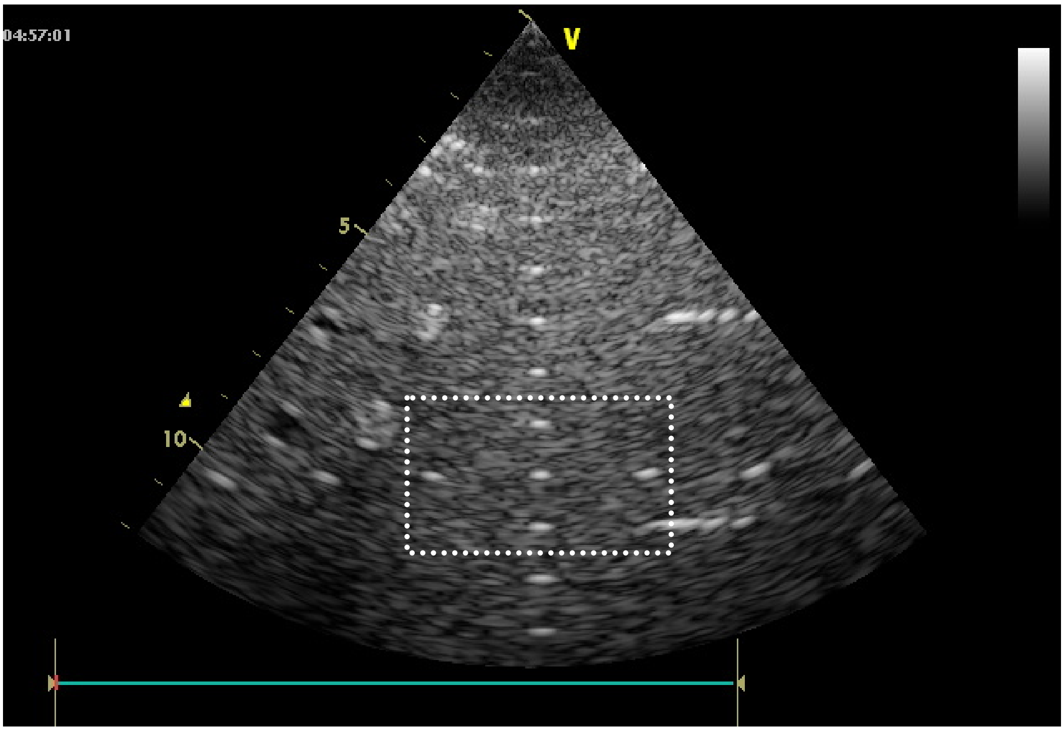

Figure 1. Vivid 7 image of the CIRS 40 phantom.

The next part is to simulate a small section of the CIRS40 phantom in Field II (indicated in the figure above). The simulation script that we will start out with, is a slightly modified version of Exercise 2.11, where we have added a scan grid and a loop iterating over all your transmit and receive directions. We will only simulate a small part of the CIRS40 phantom, since it otherwise would take to much time to simulate. More specifically the rectangular area from x=-2.2cm to x=2.2cm, z=7.5cm to z=10.5cm.

<u>Transducer parameters</u>:

no_elements=64, pitch=0.29mm, elementHeight=13mm, kerf=0.020mm, Rfocus=60mm, no_sub_x=5, no_sub_y=15, focus = [0,0,95]

2. Start out with the script *Ex3_startingpoint.m*.
3. Specify the position of a single point scatter located at x=0, y=0, z=95mm. Do this in the GENERATE COMPUTER PHANTOM section. Use a vector 3x1 called *phantom_positions* containing the x,y and z coordinate of the point. Set the amplitude to 1 in the *phantom_amplitudes* vector. Much like you specified the measurement points in exercise 2, only that you also have to specify the amplitude of the points. These are input to the function *calc_scat(yourTransmitAperture, yourReceiveApertire, phantom_positions, phantom_amplitudes)*. See Field II manual for further information.
4. Run simulation. The image you will get is not suitable for display. Your image data will now be stored in the *rf_data* matrix (or *rf_d*, which has been decimated). This is your raw data, which needs to be processed to get an regular ultrasound image. The steps are:
    a. Hilbert transform (remove negative frequency spectrum *hilbert()*)
    b. Demodulation (move frequency content to baseband). Multiply with a complex exponential *exp(-j*2*pi*tDemod*f0)*, where tDemod is a time vector of same length as number of rows in your Hilbert transformed data, time increment *1/fn*. This vector will have to be repeated one time for each column in the *rf_data* matrix. Use *repmat(yourComplexExponential, 1, size(rf_data,2))*.
    c. Detection (*iqData.*conj(iqData)*) . That way

   d. Log compression (*10*log(yourDetectedData)*)

5. Image your Log compressed data in the same way the rf_data was displayed in the initial plot. This should now resemble something lik this:

Figure 2. Simulated image of a single point scatterer at 95mm range.

6. Lateral sampling. Change number of scan lines using the oversamplingfactor in the start of the script.
   a. Try to change it to 4, 8, 2, 1, in that order and compare the resulting images. Check the *N_lines* variable for each value. *N_lines* is the number of scanlines used to image your single point scatterer. What happens to the image at 2 and 1 compared to 4 and 8? Is this related to the beams being spaced too widely at 2 and 1?
   b. Set show2dFourier to 1. This will plot the 2D Fourier transform of your RF raw data.
   c. Copy and paste the code for showing the Fourier transform image after each of the steps in 4. This will display the frequency content of your image at the different stages of processing. Compare the frequency spectrum of using oversamplingfactor 4,8,2 and 1. What happens at each step? Especially what is happening after detection? Which oversampling ratio is the minimum we should use?
7. Create square of randomly distributed point scatterers using the *ph_rect_gauss()*. The size of the rectangle should be x=-2.2cm to x=2.2cm, z=7.5cm to z=10.5cm.
   a. Start out with 200 scatterers inside the rectangle. Use oversamplingfactor 4. Simulate an image. (you can disable the Fourier plots if you like…).
   b. Your goal is that the scatter density should be large enough so that the amplitude distribution of your decimated raw data *rf_d* should be gaussian. At that point your speckle pattern is fully developed. Increase the number of scatterers until this is the case. Use *histfit(rf_d(:), 100)* to check the distribution vs a gaussian. Alternatively use *hist()* if you do not have *histfit()* in your Matlab installation.
8. Simulate the section of the CIRS40 phantom in the position indicated in Figure 1.
   a. Specify the five point scatterer positions in addition to the rectangle of randomly distributed scatterers in exercise 3.7 with fully developed speckle.
   b. Set the power of these scatterers to 25 dB. The amplitude then becomes *10^(25/20)*.
9. Compare to the measured image.