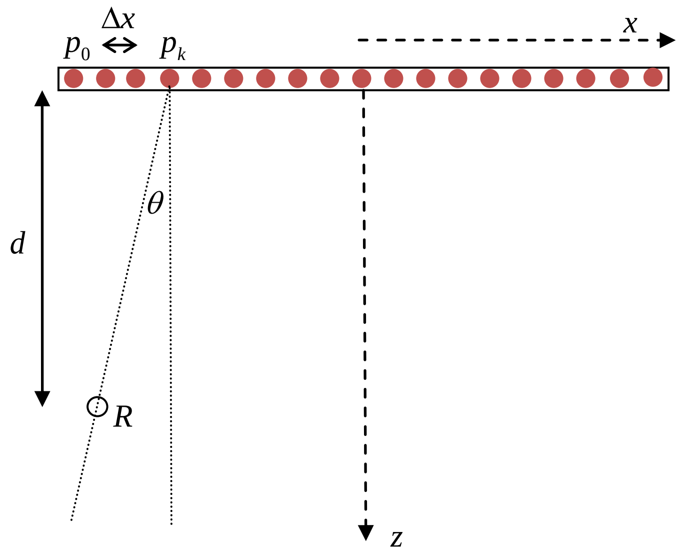
Medical Image Analysis (EE61008)

Assignment 10

Due: 30 Mar 2015, 2:30 - 4:30 PM, N232 Dept. of Electrical Engineering
Type: Solve in class.
Spring 2014-15

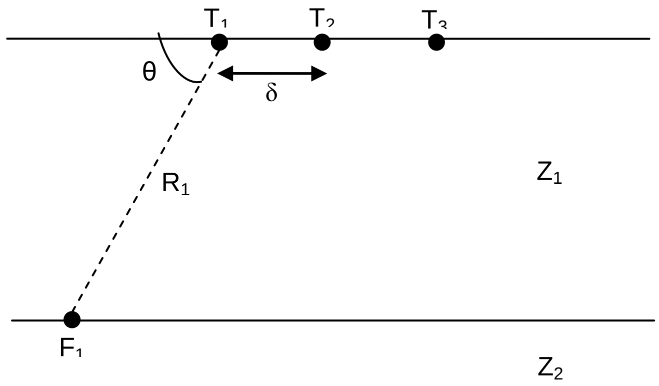
1. Consider the beamforming arrangement of an ultrasound scanner and solve for the following assuming c to be the velocity of sound in the media, the transducer to have a frequency of f and elucidating any further assumptions / notations used in the solution.



   a. Find the transmit beamformer triggering sequence for each of the transducer elements p_j where $j \in [0, N-1]$ such that the pulses from all of the elements arrive at the focus point R on the scanline corresponding to element p_k and oriented at an angle θ to the normal from the plane of transducer elements?
   (Hint: Sec 4.1, SPRAB12)
   b. Find the transmitter apodization factor such that the pulses arriving from all elements are of same amplitude on the focus point?
   (Hint: Sec 4.1 and Sec 2.4.2, SPRAB12)
   c. Find the receiver apodization factor for all the receiver elements when a pulse is received from the focus point?

2. An ultrasonic imaging transducer T operating at a frequency of 10MHz is used to image an internal organ comprising of soft tissues with different acoustic indices. The transducer is placed on a tissue with an acoustic index of Z_1. T_1, T_2 and T_3 are location of three piezoelectric elements on the transducer T. Consider that the transducer is focused on the junction between the two tissues characterized by acoustic indices Z_1 and Z_2. F_1 is a point on this junction as indicated in the figure. Consider a compounded excitation and image acquisition strategy whereby T_1, T_2 and T_3 are excited with appropriate time delay to constructively focus energy at F_1 and the reflected energy is sensed with appropriate time delay and amplification prior to beam formation. The inter-element spacing between the transducer elements is δ

and the point F_1 being imaged is at a distance of R_1 from T_1. The velocity of sound in the tissue with acoustic index Z_1 is c_1. θ is the angle formed by the line R_1 to the horizontal line connecting T_1, T_2 and T_3.



a. If P_0 is the acoustic pressure of the ultrasonic wave originating at T_1 and no compounded excitation system is switched on, what would be the magnitude of pressure ($P_{T1,F1}$) of the wave reflected from F_1 and sensed at T_1? Specify any assumptions if made or any variables if introduced.
b. If we switch on a compounded excitation arrangement, where $\tau_{1,2}$ is the time difference between switching on T_2 and T_1, and $\tau_{2,3}$ is the time difference between switching on T_3 and T_2, then find the analytical expressions of $\tau_{1,2}$ and $\tau_{2,3}$ in terms of the information provided herein?
c. In a compounded image acquisition arrangement, signal acquisitions at T_1, T_2 and T_3 are appropriately amplified to match their signal strength using the time gain control circuitry. If A_1 is the amplification factor of the signal sensed by T_1, then what are the amplification factors A_2 and A_3 for the transducer T_2 and T_3 respectively in terms of A_1?
d. Does a change in the operating frequency of the transducer to 63MHz induce any change in $\tau_{1,2}$ and $\tau_{2,3}$ and the ratio A_2/A_1 and A_3/A_1?

3. Find the following parameters for an OCT system which operates using a 1,325 nm laser source with BW of 100 nm
   a. Axial resolution (air equivalent) along a scan line? (Hint: Pg. 24, Fujimoto)
   b. What should be the spot size of beam incident on objective lens of focal length 20 cm such that the transverse resolution is 6 μm?
   c. What would be the change in axial and transverse resolution when imaging in a media with refractive index of 1.53?
   d. If the BW of the system is increased to 200 nm, what would be the changes in the air equivalent axial and transverse resolution of the OCT imaging system?
   e. If the OCT now operates using a 800 nm laser source with BW of 100 nm, what would be the air equivalent axial and transverse resolution keeping the other arrangement of optics constant?

4. Consider a 1.5 T MRI scanner with a slice encoding gradient of 10 mT/m. What should be the step size in scanning frequency to achieve a slice resolution of 10 mm? (Hint: Sec 5.4.1) What would be the maximum scanning time at this resolution when max T1 relaxation is 2400 ms and T2 relaxation is 160 ms for CSF?