EL582/BE620 Medical Imaging I, Fall 2006, Professor Yao Wang

Final Exam, 12/18/06, 2:00-5:00PM
(closed book, 2 sheets of notes allowed)

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1. (15 pt) (a) In nuclear imaging, a patient is usually imaged twice, one before and one after being injected a radio tracer. Explain why this is necessary. (b) What determines how long the patient must wait before being imaged again? (c) What type of radiotracer is needed for SPECT? What type is needed for PET? (d) Do we need to use a collimator in SPECT camera? What about for PET? Why? (e) List one thing that is similar between SPECT/PET/X-ray CT, and one thing that is different between SPECT/PET and X-ray CT.

2. (15 pt) (a) What are the main functions of an ultrasound transducer? what does the transducer measure? (b) How do we relate the signal detected at time t with the distance z from the transducer? (c) Describe briefly the scanner data and display format with the following three imaging modes: A-mode, M-mode, B-mode.

3. (15 pt) (a) Describe the main functions of the following components in a MRI scanner: the magnet, the gradient coil, and the RF coil. (b) what is the purpose of the $\pi/2$ pulse in a pulse sequence used for MRI? How does the bulk magnetization vector change immediately after the $\pi/2$ pulse is applied? How does it change afterwards? (c) What is the purpose of the π pulse? Can we get T2-weighted image without using a π pulse? Suppose the time between $\pi/2$ pulse and π pulse is T1, when do we measure the signal?

4. (20 pt) A 2-D slice to be imaged is shown in Fig. P-4, which consists of two sections R1 and R2. The linear attenuation coefficients in the regions are $\mu_1 = 1cm^{-1}$, $\mu_2 = 2cm^{-1}$.

   a. Suppose a solution containing a gamma ray emitting radionuclide with concentration of 0.5 mCi/cm^2 fills section R1. We image the radioactivity distribution in this slice using a rotating SPECT camera. Compute the measured signal by the camera at positions A, B, C, D, respectively. Assume the signal is measured signal at time *t* after the injection of the radionuclide solution. Assuming the half life for this radionuclide is 6h.
   b. Now suppose a radionuclide in (a) is replaced by a positron emitting radionuclide with the same concentration. This time the slice is imaged using a PET scanner with a pair of cameras. Compute the measured signal by the cameras positioned at A and B, and the signal when the cameras are positioned at C and D.

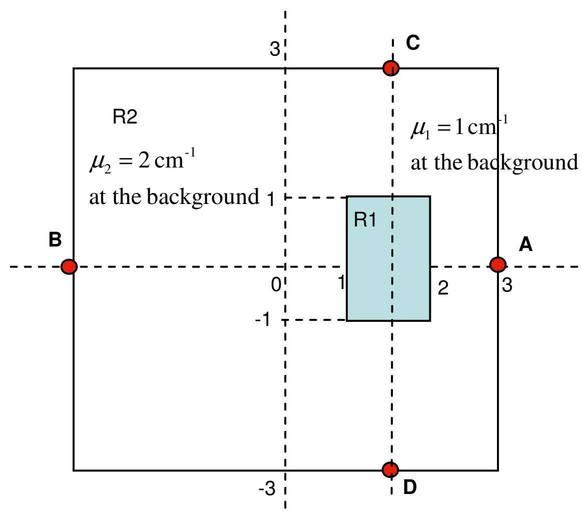


Figure P4

5. (10 pt) Consider an ultrasound imaging scenario illustrated in Fig. P5. Assume the media has three layers, with their depths indicated in the figure, with d1=2cm, d2=0.5cm. The acoustic impedance, speed of sound, and attenuation coefficients of different media are denoted by $Z_i; c_i; \mu_i, i = 1,2,3$, respectively. The values are given in Table P5. Assume the transducer generates an acoustic wave with envelop being a rectangular pulse of duration T=10 μs at frequency of 3 MHz and an amplitude of 1. Assume that there is no reflection between the transducer and the medium it resides in (medium 1). (a) write down an expression for the signal received by the transducer. (b) sketch the A-mode signal (envelope of the received signal) received by the transducer. Note that you only need to consider waves that enter a surface in the normal directions. You should take into account of signal attenuation in distance.

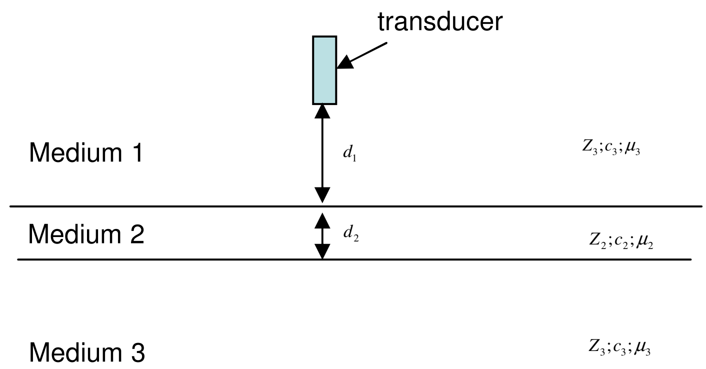
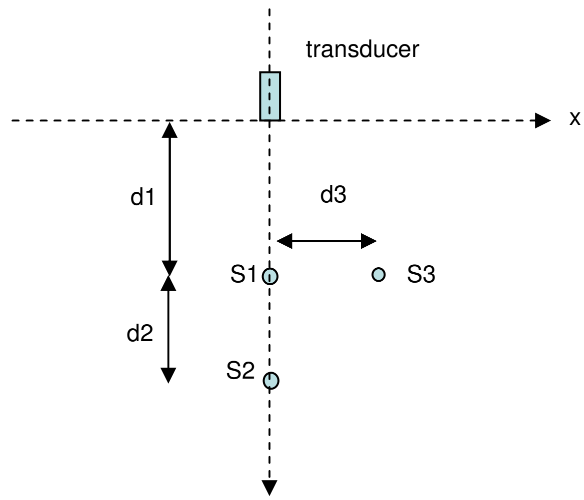


Figure P5

	Acoustic Impedance Z (kg/m^2 sec)	Speed of sound c (m/sec)	Attenuation factor (cm^-1)
Medium 1	1.4 E6	1500	0.02
Medium 2	1.5 E6	1550	0.03
Medium 3	10.0 E6	2000	0.04

Table P5

6. (5 pt) A flat face transducer with square shape and size DxD (D=1cm) is used to image a medium with three point scatters S1, S2, S3, with reflectivity R1, R2, R3, respectively, with positions indicated in Fig. P6. The distances d1=25cm, d2=1cm, d3=1.1cm. The medium has a speed of sound c=1540 m/s. The resonance frequency of the transducer is 3 MHz. The narrowband signal generated by the transducer has a rectangular envelop of width T=10 μs.
    a. Do you think one can separate the two scatters S1 and S2 based on the received signal by the transducer? Why?
    b. Do you think one can separate the two scatters S1 and S3 ? Why?



7. (10 pt) A pulse sequence for MRI imaging is given in Fig. P6. Draw the corresponding Fourier trajectory. Clearly mark the time interval corresponding to each period indicated in the pulse sequence. Also clearly mark the frequency values for u,v at each key point in your trajectory.

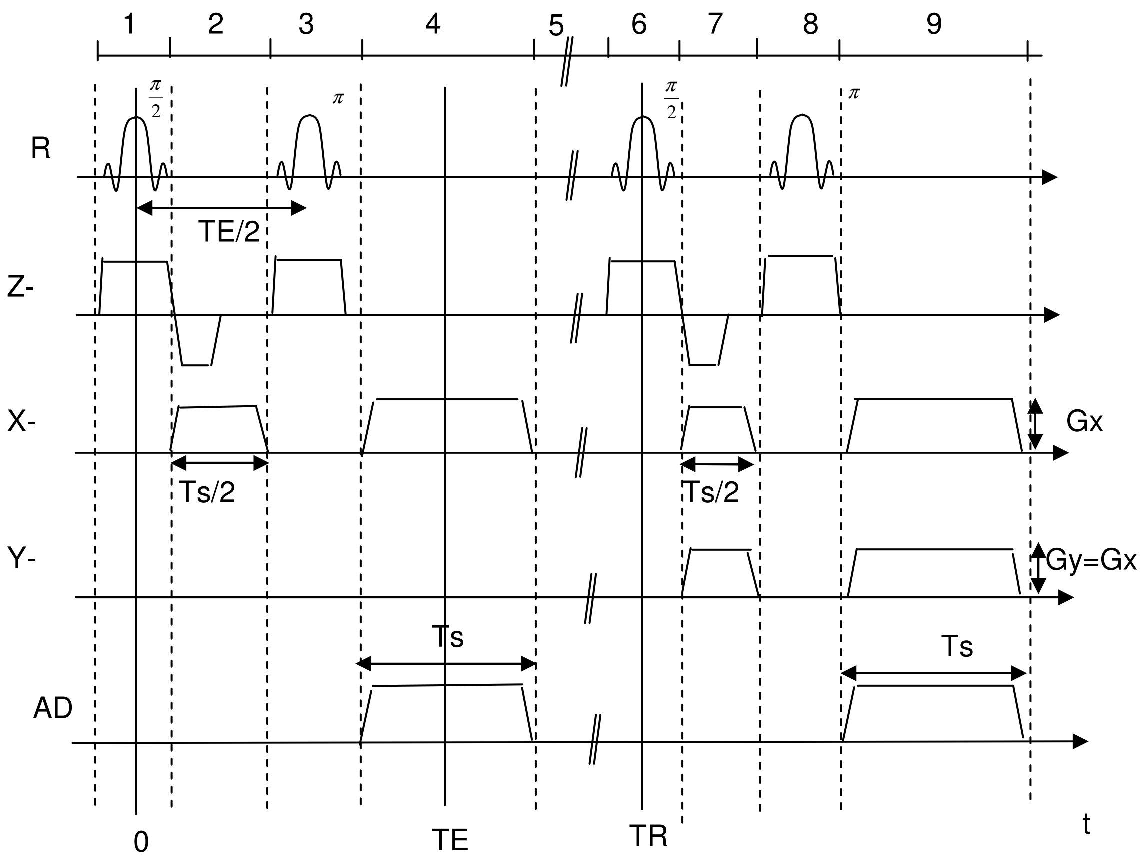


Figure P6

8. (10 pt) Consider a MRI session. Assume the static field strength is B_0=1.5Tesla, the z-gradient is Gz=2 gauss/mm, and the gyromagnetic ratio is γ=4.258 KHz/gauss. We would like to image a slice with center position $\bar{z}$ =10cm, thickness Δz =1mm. (a) Find the frequency range of the RF waveform required to excite this slice and sketch the desired spectrum of the RF waveform. (b) Write down the mathematical expression for the "ideal" waveform that will yield the desired spectrum. (c) determine the amplitude A of this RF waveform required to induce a flip angle of $\pi/2$.

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