Diagnostic Ultrasound Imaging: Inside Out by T. L. Szabo
Prerequisites: Read Chapter 4
List of Problems

1. Given a tissue that has a power law absorption with $\alpha_1 = 0.07$ nepers/MHz^y –cm, c=1.7mm/us, and y=1.3, (a) Write an expression for the complex wavenumber gamma as a function of frequency using all known constants. (b) Plot $\alpha(f)$ and $\beta_E(f)$ and $c(f)$ (phase velocity) from 0.1 to 10 MHz.
2. A broadband pulse is propagating in a lossy medium with $\alpha_1 = 0.2$ nepers/MHz–cm, c=1.5mm/us, and y=1.0. The one way pulse is measured at a distance of 1 cm and it has a pressure amplitude of 1 MegaPascal and a pulse length of 2.5 microseconds. (a) Find the amplitude and pulse length at a distance of 20 cm. (b) Approximately where will the pulse be centered in time for these two distances? (c) Repeat (a) but with $\alpha_1 = 0.2$ nepers/MHz^y –cm and y=1.4.
3. A new imaging system is being tested in a pulse-echo imaging mode on a tissue mimicking phantom with a linear with frequency loss characteristic with $\alpha_1 = 0.1151$ nepers/MHz –cm and c=1.5 mm/us. If the system has a dynamic range of 120 dB, and assume f_c = 5 MHz,
   (a) What is the allowable round trip penetration for this system, assuming perfect 100% reflecting targets in the phantom?
   (b) This system has six Time Gain Control (TGC) amplifiers that have a stepped logarithmic gain characteristic with scan depth $\left(G = 20\log_{10}\left[A(z)\right]\right)$ like that shown in Fig. 4.15a where A is amplitude. For a scan depth of 12 cm, at what gain levels would you set the TGC amplifiers and explain why. Draw or sketch your solution.
4. Given a lossy propagation medium with an absorption characteristic that has an exponent y=2,

(a) Derive an expression for the material impulse response function (mirf)
(b) What happens to the mirf as z approaches zero?
(c) The time causal loss theory predicts a true Gaussian for y=2, but Gaussians have infinite time extent. Find out how good this approximate theory is by finding the value of the mirf at t=0 relative to its peak value in dB for the following conditions: for z=1.0 mm, c=1.5mm/us and $\alpha_1 = 0.1$ nepers/MHz^2 –cm.