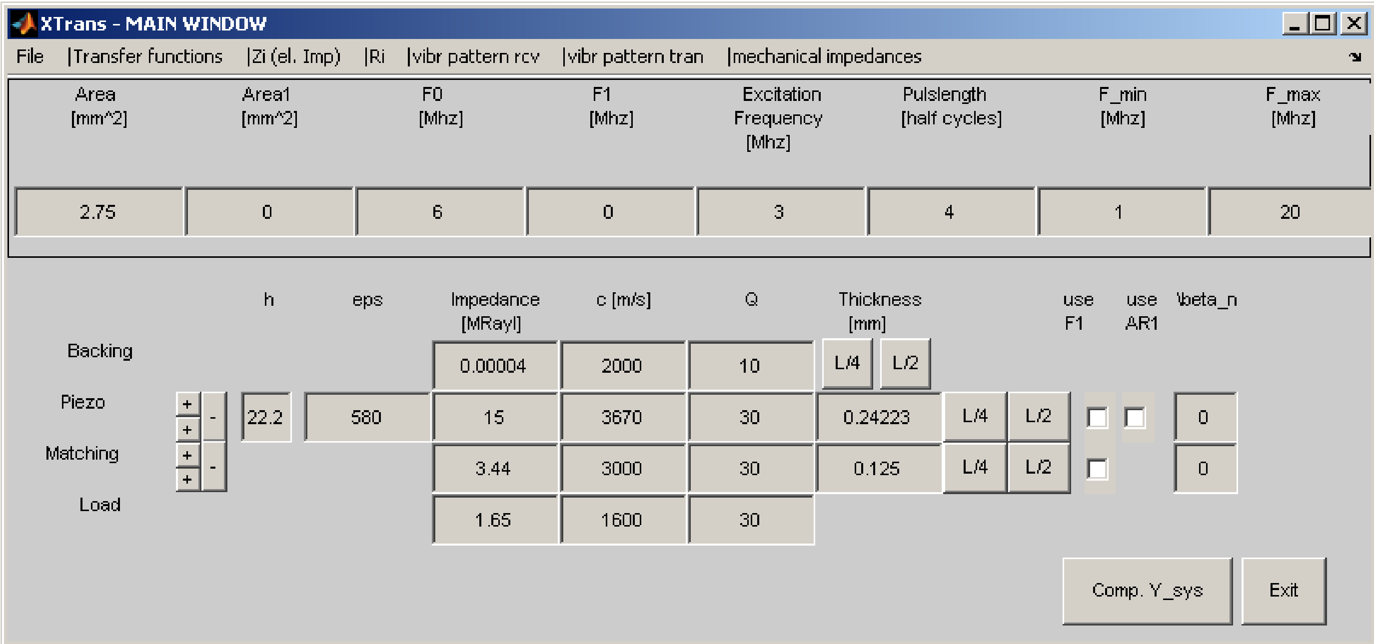
MEDT8007 Simulation methods in Medical Imaging

Solution Exercise 4

Transducer simulations using xTrans

xTrans model 1, layer backing by air.:

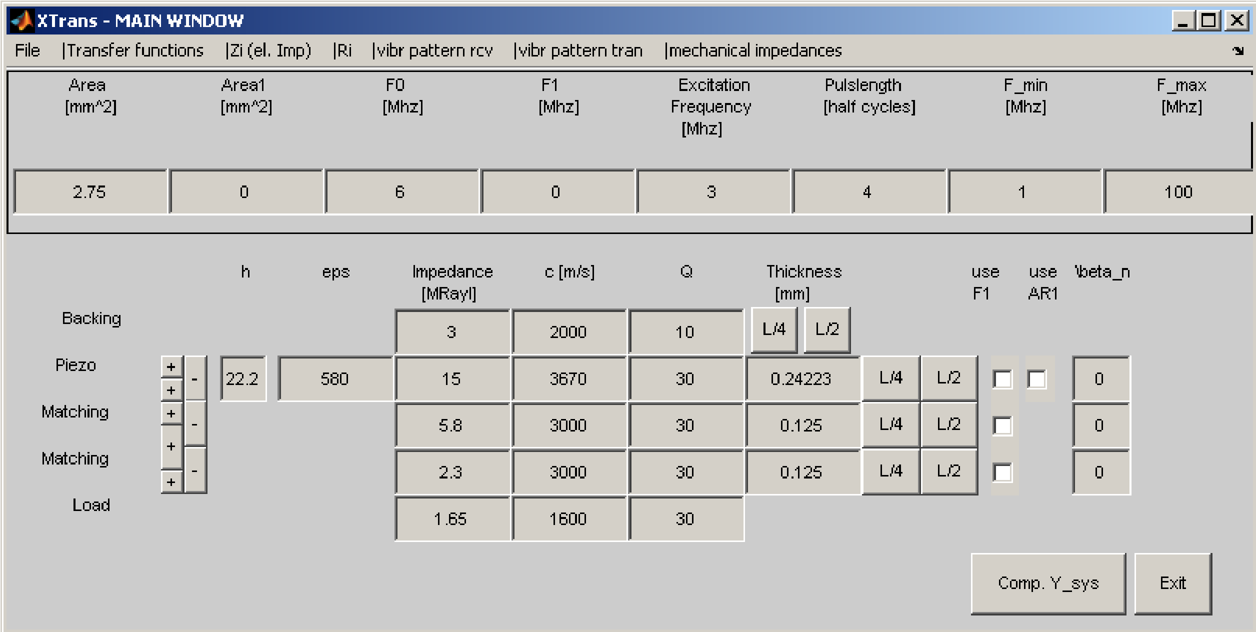
$Z_m = Z_L^{1/3} Z_0^{1/3} = 1.65^{2/3} 15^{1/3} = 3.44$ MRayl

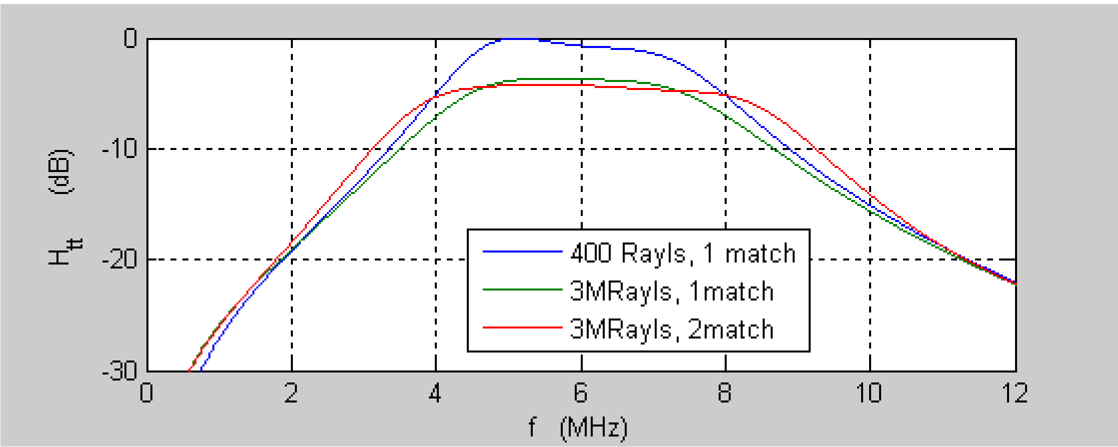


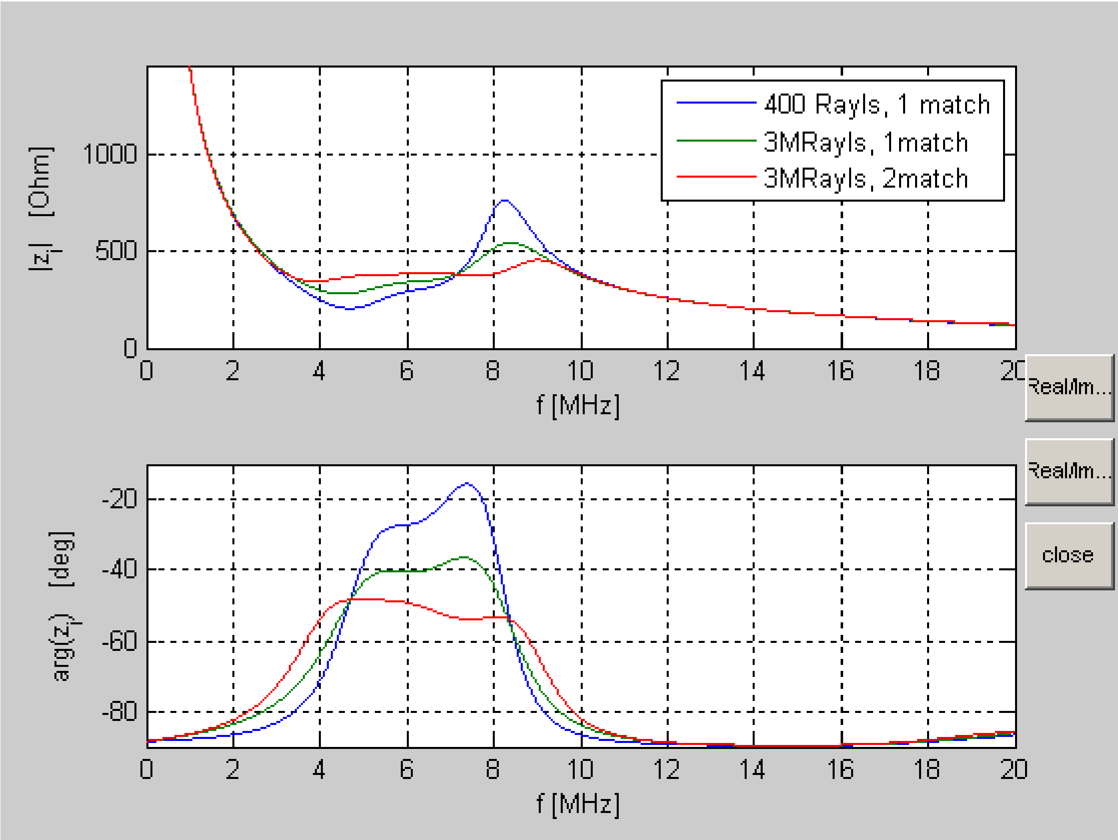
xTrans model, 2 matching layers model

$$Z_{m1} = Z_L^{3/7} Z_0^{4/7} = 1.65^{3/7} 15^{4/7} = 5.82\,\text{MRayl}$$

$$Z_{m2} = Z_L^{6/7} Z_0^{1/7} = 1.65^{6/7} 15^{1/7} = 2.26\,\text{MRayl}$$







Comments: lower sensitivity with higher impedance backing, but smoother transfer function and less resonant impedance.

Tuning

Using xTrans/ Transfer / El.impedance window one find a serial inductance 13.3 μH. Running a script similar to plot_Vrx.m (see exer4_solu.m), one get receive transfer function as shown below. The top at around 5 MHz is not satisfactory so by trial and error I found better results with 7 μH.

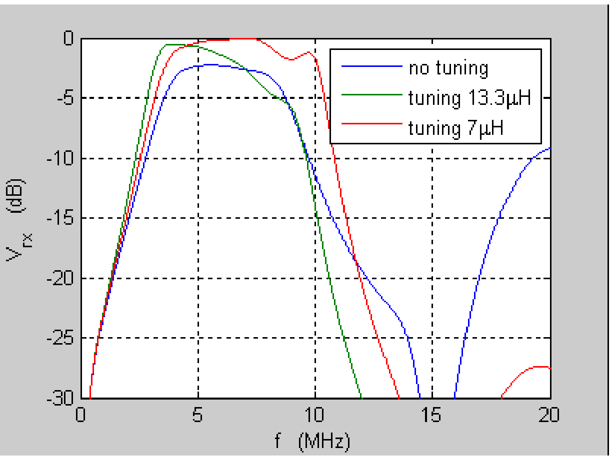


Fig. Receive transfer functions normalised to max value.

With 7 μH one get a wider passband, elevated sensitivity (around 2.5 dB compared to no tuning), but more ripple in the passband. Note that the transfer function without any tuning is the smoothest.

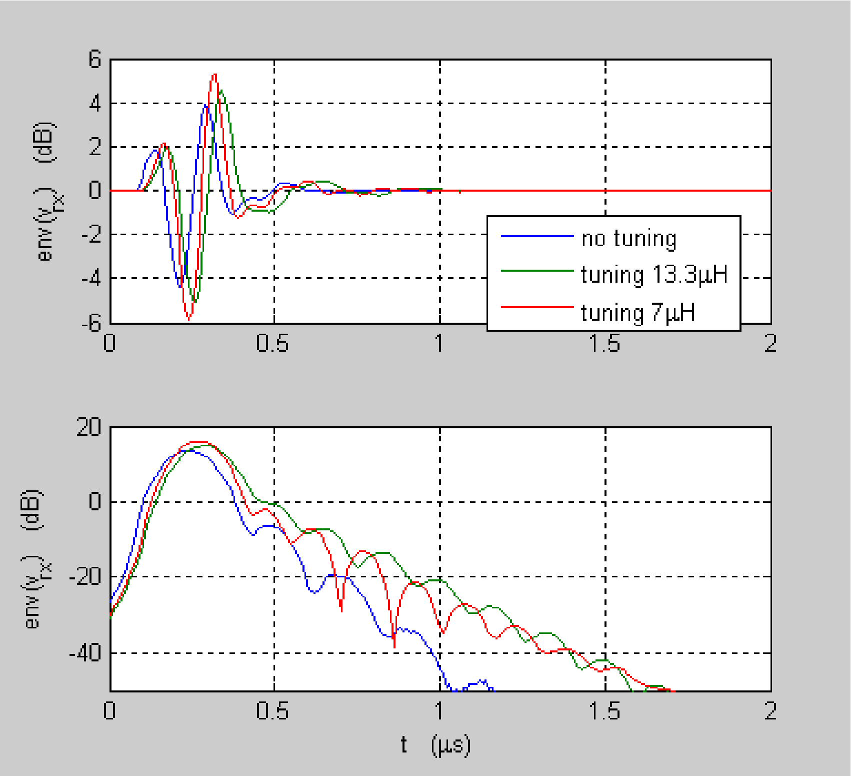


Figure receive pulse responses as function of tuning Upper panel, pulse response, lower panel pulse envelope in dB.

The pulse responses are shown in the figure above. Note that the tuned responses are longest. When evaluating a transducer the -20dB pulse length is an important measure, together with sensitivity and bandwidth.

Pulse echo

Here pulse echo is evaluated with cable, with and without tuning.
A stiff voltage source, 1V, is assumed.
The roundtrip voltage transfer function from generator to receive preamp is

$$H_{roundtrip} = \frac{V_{rx}}{V_g} = H_{t,el} H_{tt} Z_{L,tissue} 2 A_r H_{tt} H_r$$

To find the pulse echo response, the pulse spectre is multiplied with the transfer function and inverse Fourier transform is done. The results are shown below.

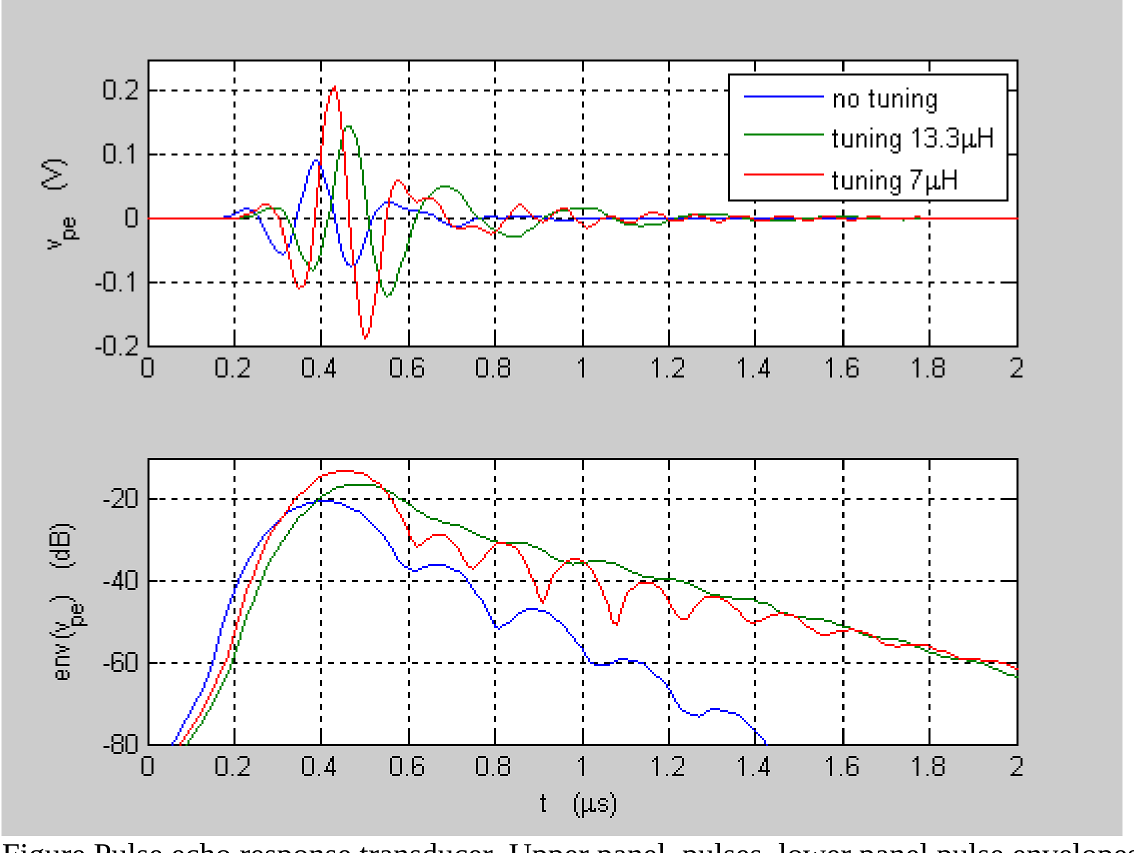


Figure Pulse echo response transducer. Upper panel, pulses, lower panel pulse envelopes in dB.

Comments: The case with 7 µH has much higher sensitivity than the others. Part of the elevated sensitivity is due to higher transmit level $H_{t,el}$, which can be compensated for with higher output voltage.
Note that the case without tuning has shortest pulse, t_{-20dB}≈0.53µs, while the 7 µH case have t_{-20dB}≈0.65µs and a slower ring down slope.

Reflection coefficient

Use the xTrans/ Ri / El.impedance window

Disregard the cable here to be able to use the Reflection coefficient option directly. Matched impedance is believed to be the one with maximum electrical power transfer from the transducer to its load (tuning inductance + pre amp resistance), and thus lowest reflection coefficient. Several cases are shown below.

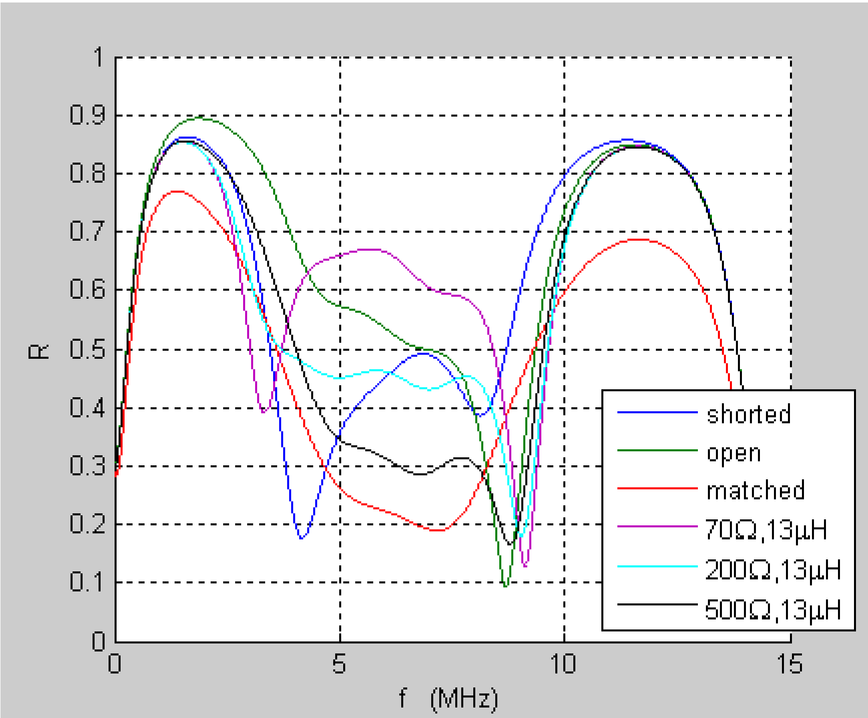


Figure Reflection coefficient for 2 matching layer transducer.

The matched impedance case has the lowest reflection coefficient in the transducer passband. Introducing the matching inductance is destructive if the load resistance is kept (70Ω), higher pre amp input resistance give lower reflection coefficient.
The reflection from the transducer surface is an important source of acoustic noise in the ultrasound images (reverberation noise), so a low reflection coefficient is important.