Shear Wave Spectroscopy from a complex wave field

Steve Beuve[1], Samuel Callé[2], Léopold Kritly[1], Jean-Pierre Remenieras[1], [1]UMR 1253, iBrain, Université de Tours, Inserm, Tours, France [2]GREMAN UMR 7347, Université de Tours, CNRS, INSA Centre Val de Loire, Tours, France

Background, Motivation and Objective

In the context of tissue biomechanical characterization, this work proposes an elegant method to measure the shear wave phase velocity dispersion in function of the frequency without knowing the position of the shear sources. With conventional methods, this lack of knowledge induces bias in the measurement of the phase velocity because the analysis direction can be different from the propagation direction of the wave field.

Statement of Contribution/Methods

Two in vitro experiments, numerically pre-validated, were designed. The first one is the simple case of a continuous progressive monochromatic plane wave source situated frontally and transversely to the US L11-4v probe, allowing the measurement of axial V_z and lateral V_x component of the shear wave field. The second one is a more complex field generated by 7 vibrators situated all around a cylindrical phantom(E=3.6kPa) supposed spatially homogeneous. Each vibrator is driven with its own electronic and is excited with a different white noise in the [80-300] Hz bandwidth. The ultrafast cine loop of tissue particle velocity, obtained with a Verasonics system, shows the spatio-temporal complexity of the wave field V(x,z,t). V(x,z,ω) is obtained after temporal Fourier transform and the 2D spatial spectrum $V(f_x,f_z,\omega_0)$ can be computed for each frequencies of the wave bandwidth. A Dirac function appears in the wave propagation direction $(\overrightarrow{f_x},\overrightarrow{f_z})$ located at a distance $1/\lambda$ of the origin.

Results/Discussion

Experimental in vitro results with the complex wave field is presented on Fig.1 which plots the 2D spatial spectrum magnitude for frequencies [83, 101, 116,138,153,178] Hz. Positions of the bright spots are not the same for the different frequencies. We then propose a strategy using a reference growing circular Gaussian ring to estimate the position of these circles situate at $1/\lambda_0$of the origin for each temporal frequencies $f_0$to thereby deduce the phase velocity $v_\varphi(f_0)$. The shear wave phase velocity dispersion curve, obtained for 10 different realizations, varies from 1.15m/s to 1.25m/s between 80Hz to 200Hz. Viscoelastic analysis through a Voigt model gives μmedian=1.23±0.05 kPa(Emedian=3.7±0.15 kPa) and ηmedian=0.51±0.09 kPa which are consistent with the phantom elasticity. Future in vivo experiments will focus on liver viscoelastic analysis using vibrators situated all around the volunteer rib cage.

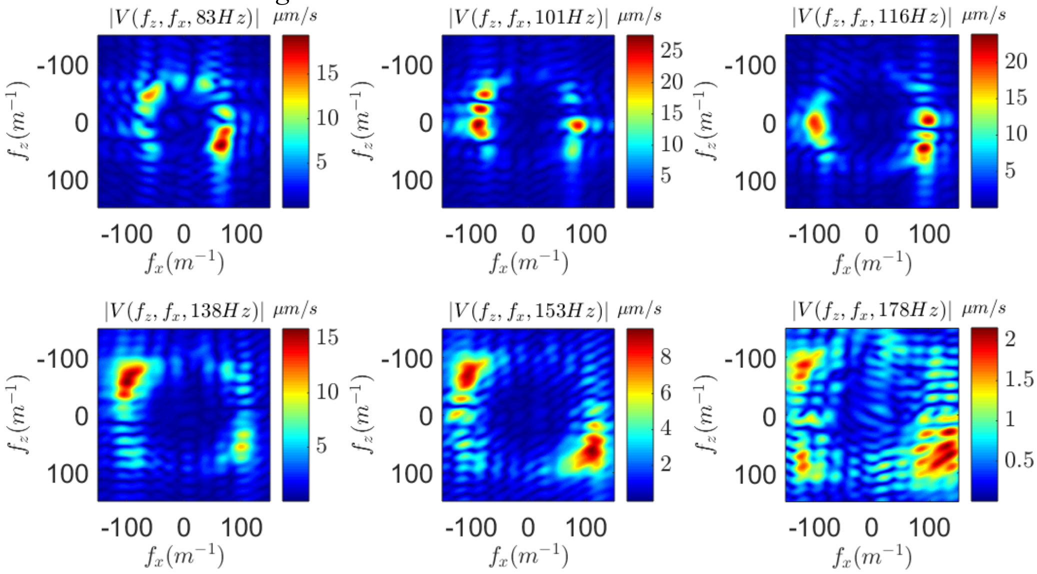

Fig. 1. Particle velocity Spectrum magnitude $|V_z(f_z,f_x,f)|$ for several frequencies: f = [83, 101, 116, 138, 153, 178]Hz