Potential for Decomposition of the Human Gut using Optimisation of Model Fitting to Resonant Ultrasound Spectroscopy Data

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Resonant ultrasound spectroscopy (RUS) is a technique widely used to measure material properties. Subsequently, the combination of RUS with acoustic models reproducing the behaviour of complex materials and material structures such as multiple layers has proven to be a powerful tool in the field of materials characterization.

Extensive work has been done to apply this procedure in different applications, including testing aeronautical carbon-fibre reinforced polymer (CRFP) for the aerospace industry and determining the properties of plant leaves in botanical characterization for agriculture. The naturally-layered structure of leaves, as well as their heterogeneity, are particularly challenging and thus provide an excellent test of the power of RUS combined with multilayered acoustic models and the optimisation routines that have been developed. In both cases, RUS has been applied using air-coupled ultrasound in the frequency range 0.1 – 2.5 MHz to avoid altering the behaviour of the samples under study.

In this paper, we first present measurements of magnitude and phase spectra of the transmission coefficient of plant leaves of different dicot species at normal incidence using through-transmission air-coupled ultrasound where at least two orders of thickness resonances are observed, Figure 1. These spectra are processed with a stochastic gradient descent fitting routine to obtain the acoustic properties, first considering the whole sample as a homogeneous layer, then considering two different acoustic layers.

(a) (b)

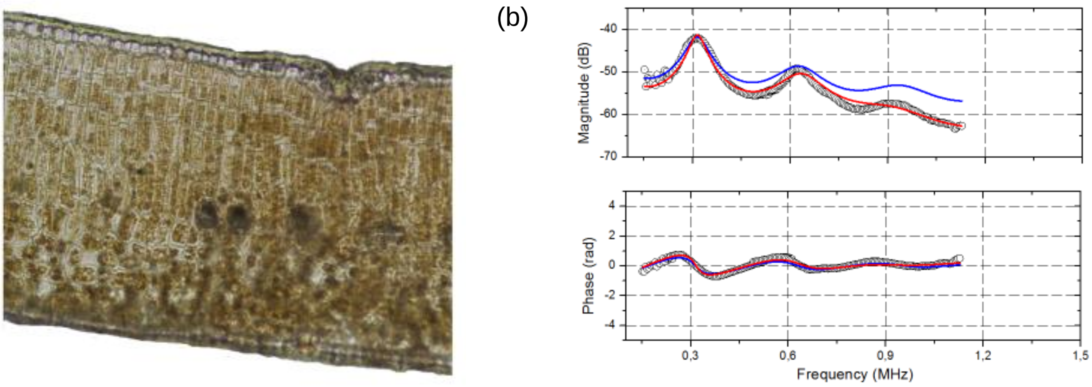

Figure 1- (a) Optical cross-section image of a Ligustrum dicot leaf. (b) Measurements on this leaf: broken lines - experimental transmission coefficient; blue lines - one-layer model fitting; red lines - two-layer model fitting.

Following the success of layer decomposition with RUS in industrial and botanical applications, we have begun to explore the application of this technique in the human body. Specifically, ultrasound capsule endoscopy (USCE) offers a new approach to the gastrointestinal tract, opening up previously impossible avenues for diagnosis. In the context of RUS, it is significant that the gut wall is intrinsically a multilayer structure formed by up to four histologically different layers, though these may initially be simplified to two layers, mucosa and muscle.

In this paper, we consider the similarities and differences between application in human tissue in the gut compared with industrial and botanical samples. These include the need for liquid coupling and the ability to access the sample only from within the lumen of the gut, i.e. from one side. We report results of early experiments using conventional immersion transducers and instrumentation with phantoms based on *ex vivo* tissue and consider additional problems raised by the application of the technique using USCE within the human body.