

Ultrasonic Radiation Force Apparatus and Application to Porcine Tissue

Amber Love and Christian Paul

Freeport High School, Freeport NY USA

Abstract Can focused ultrasound induce movement of biological tissue at the cellular level? Such ability might engender novel methods of biomedical diagnosis and therapy. Varying motion is induced by ultrasound in different substances; one key factor is the stiffness of the substance. Because the stiffness of malignant and benign tumors differs, determining the amount of movement induced in tissue can yield evidence of cancer. Furthermore, cellular motion, leading to the triggering of mechanoreceptors, can promote healing of some diseases. Thus, a detailed study of acoustic radiation forces at the cellular level can elucidate important biomedical processes. In this pilot study, the motion of porcine tissue was induced by focused ultrasound and observed optically with an inverted microscope. Images were recorded before and during insonification; difference images were calculated, displayed as contour graphs, and used to determine tissue motion.

Keywords - High Intensity Focused Ultrasound (HIFU), Low Dosage Bio-effective Focused Ultrasound

INTRODUCTION

Observing the effects of ultrasound on tissue can be substantial to many current day processes in the medical world [1-10]. In particular, if a biological tissue is targeted with focused ultrasound, the accompanying acoustic radiation force will induce movement on a cellular level; such motion can be used diagnostically and therapeutically [11].

Optical observation of tissue motion under radiation force can provide a measure of the motion independent of the acoustic beam. The goal of this pilot study was to setup and calibrate such a system with a biological tissue sample.

METHODS

This project was implemented with a chain of devices to produce, calibrate, and transform power in order to produce a radiation force incident on a slice of porcine tissue (Figure 3). A function generator (model 4011A, B&K Precision Corp., Yorba Linda CA USA) was calibrated using an oscilloscope (model COS5020TM, Kikusui International Corp., Torrance CA USA); the result of this calibration is shown in Figure 4. The function generator is directly linked to an RF power amplifier (model 403LA, Electronics & Innovation Ltd., Rochester NY USA) in order to increase the amount of power output by approximately tenfold; the amplification is displayed graphically in Figure 5. The power amplifier was directly attached to a single-element, focused therapeutic ultrasound transducer (model SU-107, Sonic Concepts, Inc., Bothell WA USA, 35 mm focal-length 33 mm diameter, operated at 3.5 MHz) which changes the electrical input that comes from the power amplifier into acoustic energy that is directed towards the porcine tissue. The transducer was submerged in normal saline solution in order to prevent the acoustic energy from causing its overheating, and to avoid tissue swelling. Care was needed in setting up the transducer and target, because the focal region of the transducer is 0.5 mm in diameter and about a centimeter in length. Transducer output was verified by using paraffin wax as a test target and observing a small dimple at the ultrasound focus. Movement of the tissue was measured by recording microscopic images (model 3032, Accu-Scope Inc.,

Sea Cliff NY USA) before and during exposure to ultrasound, and taking difference images. Visibility of tissue motion was enhanced by overlaying the tissue with carbon-particle-toner impregnated gelatin.

RESULTS

Figure 2 shows images of porcine tissue overlaid with the toner-impregnated gelatin, before and during insonification. Difference images were displayed as contour graphs (Figure 1); the size of the contours indicates displacement. Small, scattered contour peaks were considered to be noise. Large, continuous contour peaks were considered to be motion. There was movement observed that was the length of about one pixel, or about 2 microns.

DISCUSSION

In further studies thicker porcine tissue could be used, in order to simulate a more realistic situation. Alternatively, cell cultures could be used to study cellular-level effects.

CONCLUSIONS

The acoustic energy absorbed by the porcine tissue led to cellular movement. Movement as small as 2 microns induced in the tissue was measured quantitatively and expressed on a contour line graph.

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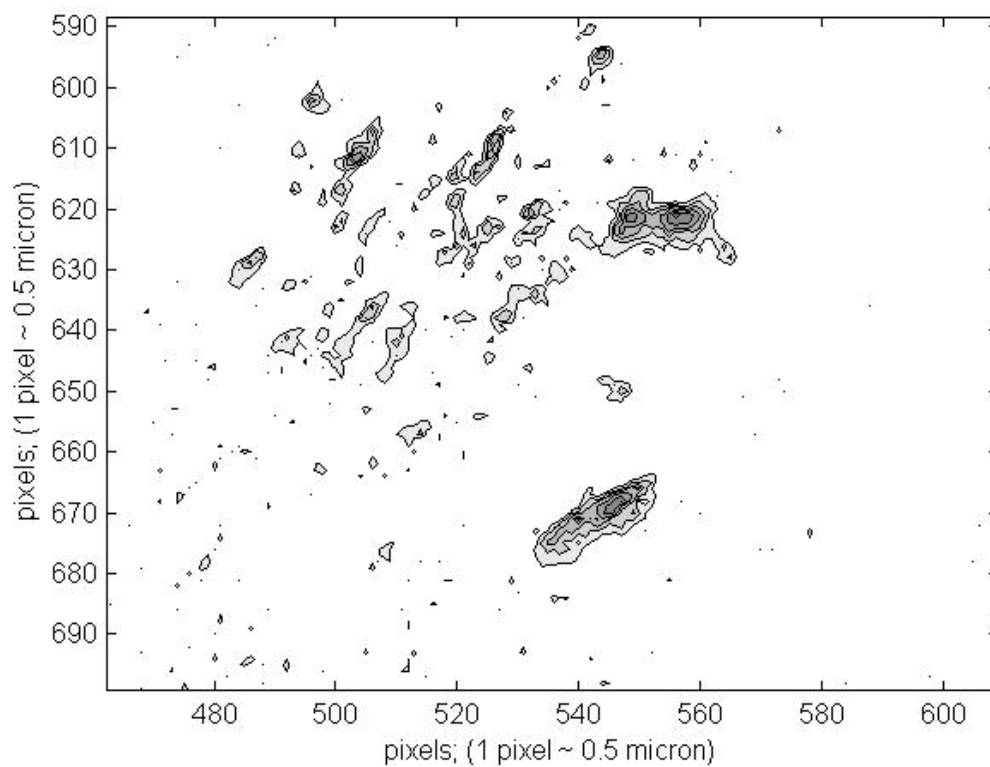


Figure 1: This contour graph displays the movement that was observed between the pictures taken before and during insonification (Figure 2).

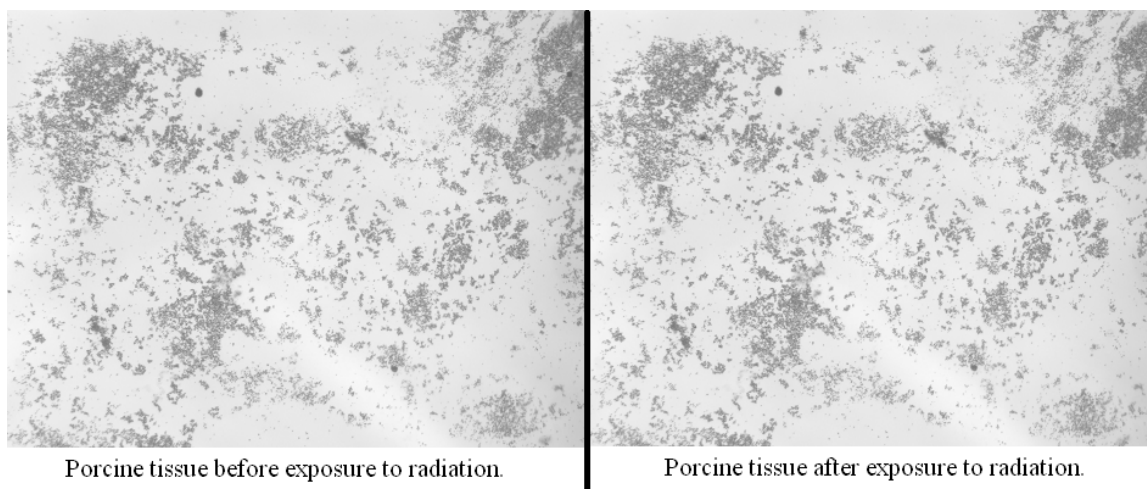


Figure 2: Images of porcine tissue and carbon-toner impregnated gelatin before and during exposure to ultrasonic radiation. The difference image is shown in Figure 1.

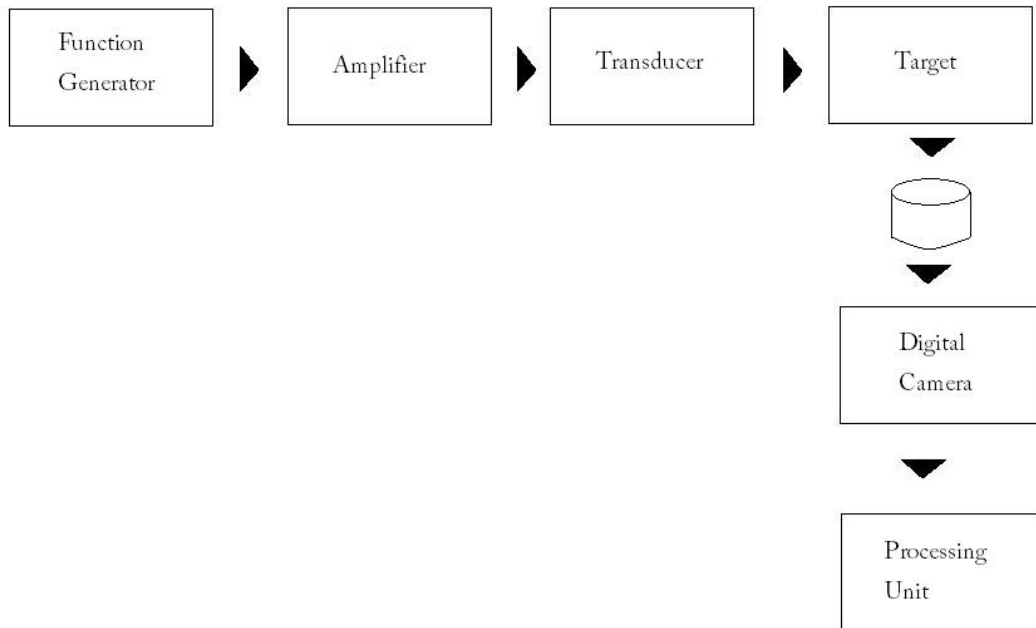


Figure 3: Flowchart of apparatus used in acoustic radiation force experiments.

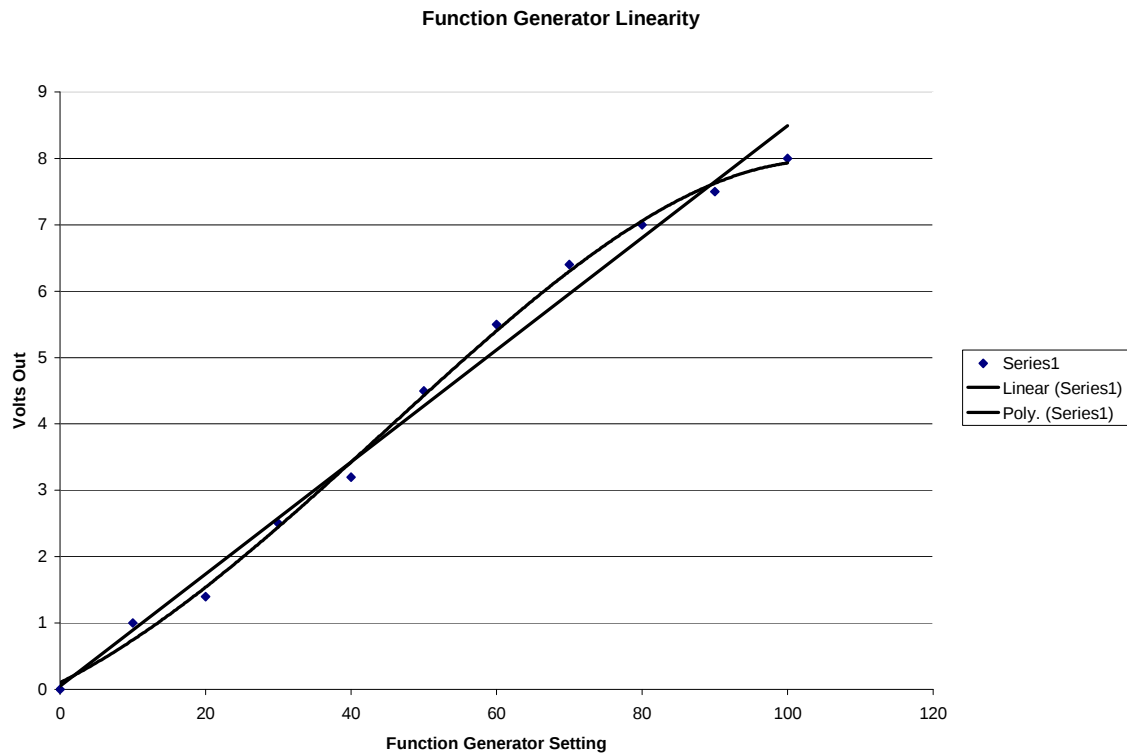


Figure 4: Calibration curve of B&K Precision model 4011A function generator, demonstrating a direct relationship between the amplitude setting and the unloaded output.

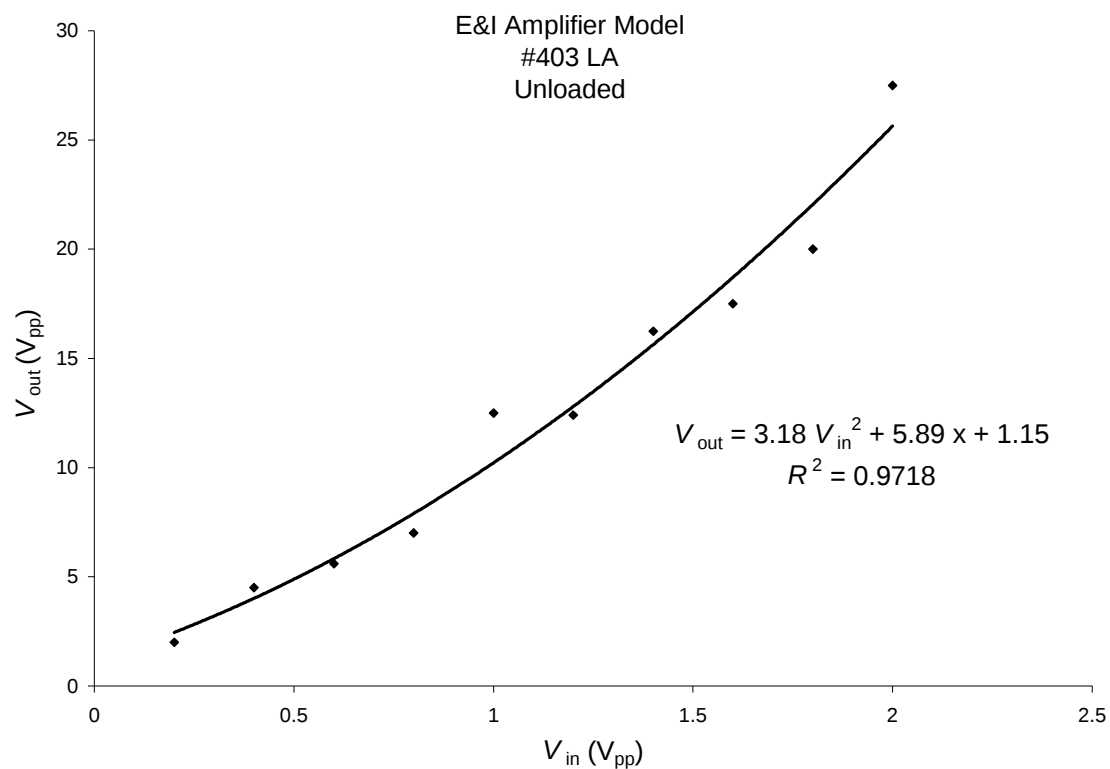


Figure 5: Calibration curve of Electronics & Innovation Ltd. model 403LA power amplifier, demonstrating a quadratic relationship between the driving input amplitude from the function generator and the unloaded output.