Document:
Ultrasound Needle Design and Specifications
Project:
Ultrasound Needle Guidance for Hydrogel Injection During Cervical Cancer Brachytherapy
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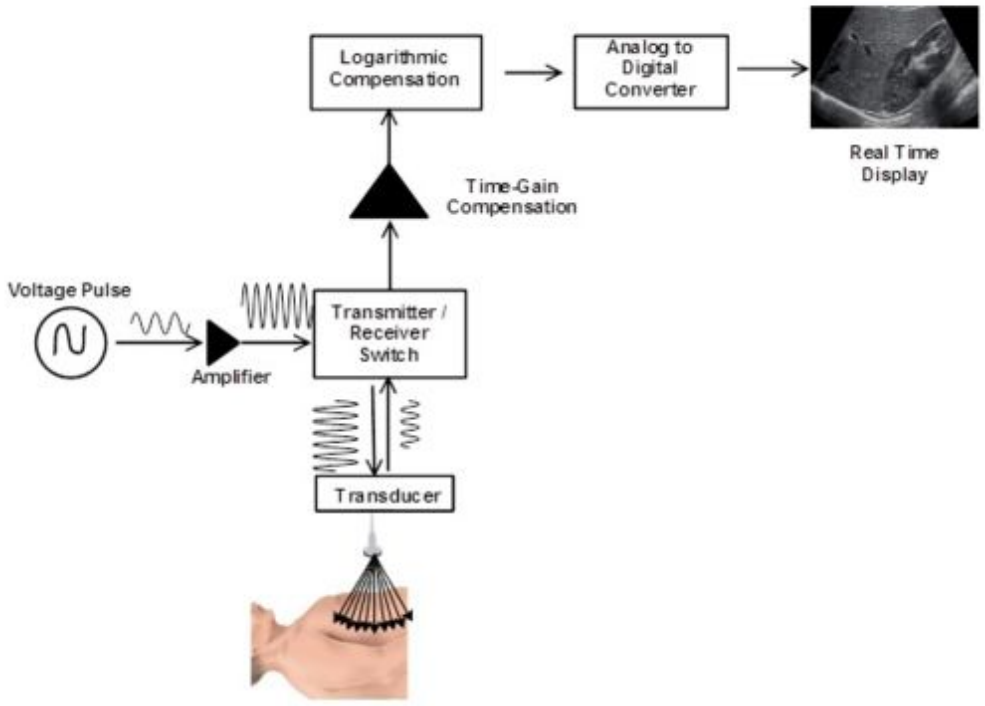
The kind of needle that is used for hydrogel spacer injection is a typical spinal needle, as shown in this figure:

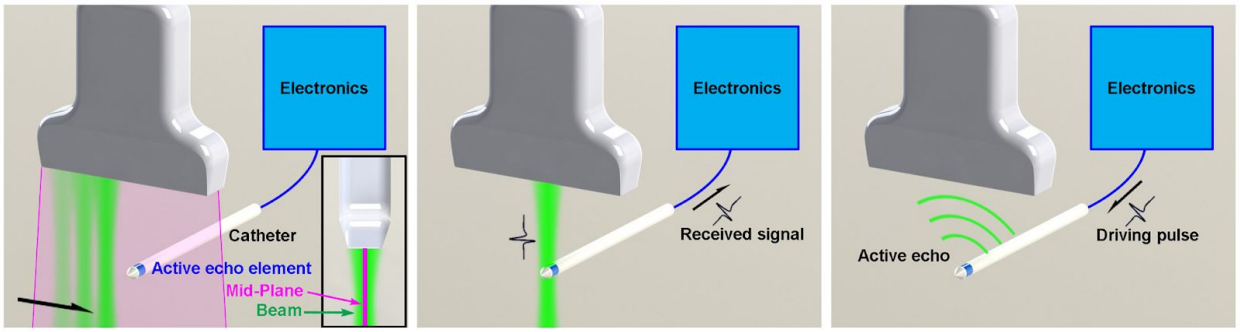
The needle includes two parts, the outer tube for positioning, then a detachable inner tube that can be removed for injection purposes. The length of the needle allows for access to deeper structures in the vaginal wall that guide the placement of the hydrogel. The size and specification of the needle will be based on what is given.

In our technique, we will mount an active ultrasound element: a piezo ceramic cylinder, onto the needle. A sample one is shown in the figure below. Additional manufacturing will ensure solid connections between the piezo tube, the needle (conductive), and accompanying electronics for pulse control. The plan is to mount this at the very tip of the needle, in order to maximize the point source localization of the needle tp, and minimize error in placement. It is especially important to work with these small, sensitive elements, as the anatomical area we are dealing with is delicate and difficult to work with.

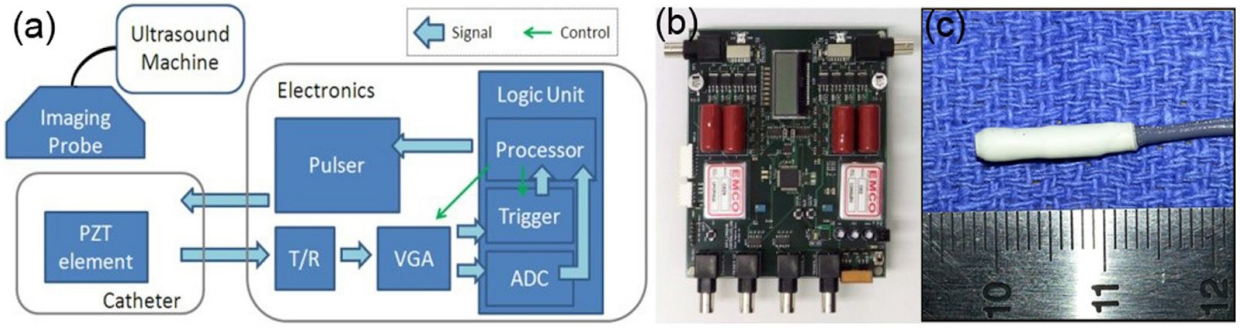
Here is a diagram showing the key principles of ultrasound imaging, and processing involved in order to generate the image. For this project, we are already innovating at the level of the transducer; the subsequent processing can be done using available devices and systems.



In order to design a fitting hydrogel injection for the ultrasound context, this project will adapt the electronic layout and algorithmic technology developed in the Adapt Active Ultrasound Pattern Injection System (AUSPIS). Under this ultrasound-based tool tracking paradigm, bi-directional ultrasound communication is enabled between the interventional tool and ultrasound imaging machine within the tissue. The secondary, interventional tool generates an active ultrasound field counter the original imaging signals. Control of timing and amplitude allows a virtual pattern to be displayed on the ultrasound image.



The electronics that make it possible, as utilized in the AUSPIS system and published in their corresponding paper, are shown below. Attachment of a piezoelectric element onto the needle tip allows for the needle to generate the secondary field in active response to the primary transducer. Our needle acts as the “catheter” shown in image (a) below. The rest of the components in the figure are the proposed interfacing electronics.



Additionally, in order to maximize the resolution of the ultrasound in the rectal region, a Endo-Rectal Ultrasound System (ERUS) [also known as Trans-Rectal Ultrasound System (TRUS)] will be used. Currently, it’s often used in conjunction with brachytherapy for prostate cancer. A T-shaped ultrasound element array will allow us to image precisely in 3D, allowing us to place the hydrogel needle accurately.

For further reading on adapting needles for ultrasound guidance, please refer to the following papers:

Zhang, Haichong K., et al. "Toward dynamic lumbar punctures guidance based on single element synthetic tracked aperture ultrasound imaging." *Medical Imaging 2017: Image-Guided Procedures, Robotic Interventions, and Modeling*. Vol. 10135. International Society for Optics and Photonics, 2017.

Guo, Xiaoyu, et al. "Active ultrasound pattern injection system (AUSPIS) for interventional tool guidance." *PloS one* 9.10 (2014): e104262.