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A simple method for measuring ultrasound slice thickness with depth

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Introduction

The B- mode performance of an ultrasound scanner is determined by its ability to discriminate contrast details within the patient. One parameter which can have a significant impact on this is the slice resolution. Lens shape changes with wear can be seen when performing reverberation measurements. More recently the trend is to replace lenses rather than entire probes. This may produce changes which are clinically relevant but which are not routinely checked. In many QA programs the only parameter measured which would be affected is the low echo penetration depth (the depth to which speckle structures can be seen). A direct measure of the beam slice thickness would allow detection of either changes in lens shape of a probe due to wear or differences following a lens replacement.

Axial and lateral resolution parameters are already established measurements carried out as part of routine QA checks, however they provide only the in-plane 2D (length and width) information of the image beam. The slice thickness is a measure of the out-of-plane beam and is not routinely measured. There are established techniques such as the Skolnick method [1] using 45° scanning orientation but this method is limited in that it measures only one point at a time and at different positions on the slice. Other methods require special test objects [2].

The aim of this study was to demonstrate a simple, reproducible method that can be carried out routinely to measure slice thickness with depth across the whole of the probe using a standard 2D imaging phantom. The technique aims to allow quantification of acoustic lens wear via changes in measured slice thickness at different stages of a transducer's working life. The intention is to produce a beam profile that shows the changes in slice thickness with time due to wear changing the lens shape and to evaluate the quality of lens replacements.

Method

Equipment required: The Gammex -RMI (Model 403) test object, customised jig, spirit level, scanner with linear array probe attached. Post processing PC running MATLAB (MathWorks Inc).

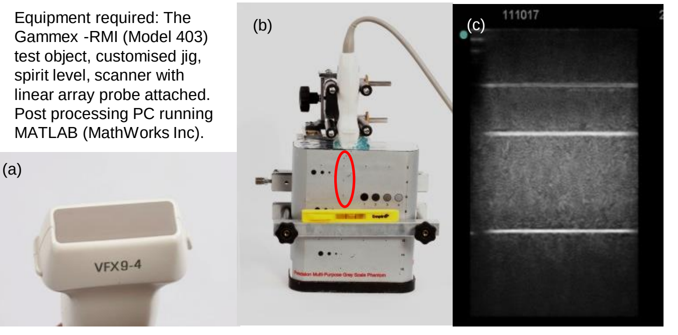


Figure 1 (a) example probe used for the tests (b) probe mounted on the jig. The position of the pins used in the test is highlighted. (c) example image obtained at one probe position during an experiment.

Set-up: The scanner and monitor are set to established QA settings. Gain and TGC are adjusted to give uniform response from background noise where possible.

Slice measurement: The probe is drawn across the Gammex phantom. It is orientated such that the wires of known depths are either present or absent in the field of view depending on the slice thickness of the beam at that depth. The probe is manipulated using a customised jig with a screw thread mechanism that allowed a 0.5mm positional resolution. Obtaining and exporting the images required around twenty minutes per session.

Analysis procedure: A MATLAB script was written to plot the signal intensity versus the probe position for each wire. A beam profile curve was produced for each plot using an average of 3 passes across the phantom. The FWHM of each fitted curve was assumed to be a robust estimate of the slice thickness at each wire depth.

Results

All plots in this section were generated using the bespoke MATLAB script. A detailed description of the analysis is provided in an accompanying presentation. The appearance of the slice thickness profile is determined by the angle at which the probe is joined to the phantom. Using the prototype jig it proved tricky to ensure that the probe was always vertical, hence the different angulations of the represented profiles. After taking this into consideration the results obtained demonstrated good reproducibility of the method at all available wire depths.

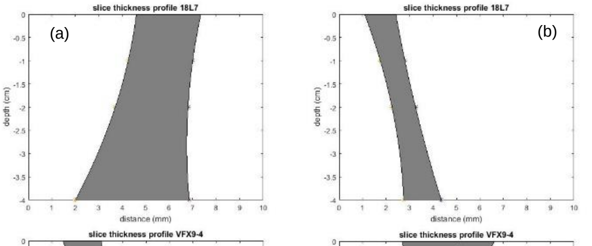
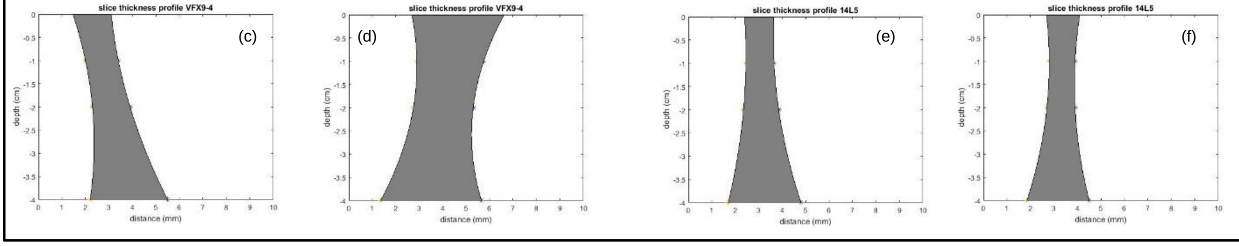


Figure 2
Comparison between two 18L7 probes on a Toshiba A500 machine: (a) recently refurbished and (b) lightly used, non-refurbished probe. A thicker slice profile is clearly obtained in the refurbished case.
Comparison between two VFX9-4 probes on a Siemens Antares machine: (c) lightly used and (d) very heavily used probe. A thicker slice profile is clearly visible in the probe that can be expected to have experienced more wear during its lifetime.
Assessment of the effect of post processing applied using one 14L5 probes on a Siemens S1000 machine: (e) post processing has been minimised (f) clinical post processing applied. The slice profiles are sufficiently similar to demonstrate reproducibility of the technique.



Discussion/Conclusion/Further Work

The study demonstrated proof of principle that ultrasound beam slice thickness profile with depth can be reproducibly measured using the method described above. Further, a significant change in slice thickness profile has been established between probes with different frequencies of clinical use and wear. The test duration and simplicity is suitable to be incorporated into acceptance testing of ultrasound probes as it involves a standard phantom and simply engineered jig. As part of subsequent annual QA it is anticipated that the method would allow the possibility of a pass/fail criteria to be created regarding an acceptable level of slice thickness expansion due to probe wear. The clinical implications of this finding are unknown but likely to be non-negligible.

Convex array probe or other types of probes could not be investigated due to the design and structure restrictions of the jig. A separate customised jig is recommended for such probe design. The measurements were performed on a Gammex phantom with a removable dam, a feature is not available on newer models. A customised urethane or open water phantom may be more suitable for future measurements. An assessment of the clinical impact of the anecdotal slice profile widening demonstrated here would be welcome, specifically regarding the partial volume effect.

References

[1] Skolnick, M. L. (1991). Estimation of ultrasound beam width in the elevation (slice thickness) plane. *Radiology, 180*, 286-288. [2] Goldstein, A. (1988). Slice Thickness Measurements. *Jouranl of Ultrasound in Medicine*, 487-498. [3] Goodsitt, M. et. Al. (1998). Real-time B-mode ultrasound quality control test procedures. Report of AAPM Ultrasound Task Group 1. *Medical Physics*, 1385-1406.

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