A Comparative Study of the Physical Properties of Five Commonly used Ultrasound Test Phantoms

J.E. Browne¹, K.V. Kammarine², P.R. Hoskins² and A.J. Watson¹.

1: MDA, Ultrasound Equipment Evaluation Project, Glasgow Western Infirmary.

2: Dept. of Medical Physics, Edinburgh University

3: Dept. of Medical Physics, University Hospitals of Leicester

Medical Devices Agency (MDA) and Ultrasound Equipment Evaluation Project (UEEP)

- UEEP - based in the Western Infirmary, Glasgow and has been evaluating ultrasound equipment since 1985.

- Funded by the MDA, which is an executive agency of the Dept. of Health in the UK.

- UEEP - has recently begun a development program with the aim of extending the technical evaluations - Automated B-mode Image Analysis and Doppler Ultrasound Performance Evaluation.
Outline of Talk

- Background
- Methodology
- Results - Frequency & Temperature
- Discussion
- Future Work

Tissue Mimicking Materials - (1)

- Tissue Mimicking Phantoms are used for Quality Assurance Testing and Performance Testing.

- TMM should exhibit similar acoustic properties to the tissue which they are representing.

- The speed of sound, attenuation, backscatter, non-linearity properties of these TMM should be known for the frequency range of 2MHz - 15MHz.
Tissue Mimicking Materials - (2)

- Standards for design of TMM
  - IEC 1390
  - ICRU Report 61
    Speed of sound in TMM 1540 m/s
    Attenuation of TMM 0.5 dB/cm/MHz
    Response of attenuation to frequency
    $\alpha = a f^n$
    $a = 0.5 \quad n = 1$
    Non-linearity parameter has not been specified but tissue has a non-linearity parameter between B/A values of 5-11.

Known Acoustic Properties of Commonly used TMMs
Methodology (1) - Acoustic Properties of the TMM Samples

- The effect of frequency on the acoustic measurements of the samples was measured using the Scanning Acoustic Microscope (SAM) with four broadband transducers centered at 2.25MHz, 3.5MHz, 7MHz and 15MHz @ 20°C.

- The effect of temperature on the acoustic measurements of the samples was measured using the SAM with a 7MHz broadband transducer between 10°C - 35°C ± 1°C.
Methodology (2) - Acoustic Properties of the TMM Samples

- Attenuation
  \[ \alpha(x,y,f) = -(20/2d) \log_{10} A(x,y,f)/A_0(x,y,f) \text{ [dB/cm]} \]

- Speed of sound
  \[ \Delta T = t_R - t_S = 2d/c_w - 2d/c_s \text{ [m/s]} \]

- Backscatter
  \[ \eta(x,y,f) = -20 \log_{10} \frac{A(x,y,f)}{A_0(x,y,f)} \text{ [dB]} \]

Results (1) - Effect of Frequency on the Acoustic Properties of the TMM Samples

- The speed of sound of all the TMMs tested remained relatively constant with increasing frequency.
Results (2) - Effect of Frequency on the Acoustic Properties of the TMM Samples

- The attenuation coefficient of all the TMMs increased with increasing frequency. However, the largest increase in attenuation coefficient was observed for ATS TMM and Zeredine TMM.

Results (3) - Effect of Frequency on the Acoustic Properties of the TMM Samples

- The attenuation coefficient of all the TMMs increased with increasing frequency. However, the largest increase in attenuation coefficient was observed for ATS TMM and Zeredine TMM.
Results (4) - Effect of Temperature on the Acoustic Properties of the TMM Samples

- The speed of sound of the EEC, Zeredine, Gammex(0.5) and Gammex(0.7) TMMs all increased with increasing temperature by a rate of approx. 1.2 m/s/°C. While the ATS TMM decreased with increasing temperature by a rate of approx. 1.5 m/s/°C.

Results (5) - Effect of Temperature on the Acoustic Properties of the TMM Samples

- The attenuation coefficient of all the TMMs decreased with increasing temperature by a rate of <0.015 dB/cm/MHz/°C apart from the EEC TMM which remained constant. The ATS TMM had the largest variations with temperature.
**Results (6) - Effect of Temperature on the Acoustic Properties of the TMM Samples**

- The relative backscatter value of all of the TMMs remained relatively constant with increasing temperature.

---

**Discussion (1) - Speed of Sound**

- Differences in speed of sound \( c \) between the TMM samples and the calibrated scanner \( c \), which occur due to changes in frequency or temperature may cause inaccuracies in distance measurements and defocusing of the beam which may result in deterioration of the lateral resolution results of the scanner.
- This effect may be more prominent in the ATS TMM as it has a different speed of sound (1460m/s) to the calibrated speed of sound in ultrasound scanners (1540m/s).
- However the changes in speed of sound with temperature observed in the other TMM samples tested would have a negligible effect.
Discussion (2) - Attenuation Coefficient

- Large changes in attenuation coefficient with temperature may effect the penetration results for the ultrasound scanners and cause variations not related to the performance of the scanner.

- However, the changes observed in attenuation coefficient with temperature for the TMM samples tested would have a negligible effect.

Conclusions & Future Work

- It is important to have knowledge of the variations of the acoustic properties of TMMs with both frequency and environmental changes such as temperature, so that reliable QC and Performance Test results can be obtained.

- Perform nonlinearity (B/A) measurements for the ATS, EEC, Gammex(0.5 & 0.7) and Zeredine TMMs.
Acknowledgements

The authors wish to acknowledge the assistance from colleagues in the Dept. of Clinical Physics, Glasgow and the support of the Medical Devices Agency, London.