Design and realisation of a simple, rapid Beam Plotting System for medical ultrasound fields

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40th Annual Symposium of the Ultrasonic Industry Association
Wolfson Medical School, University of Glasgow, UK, 23 May 2011
Presentation plan

- The Problem
- Requirements of a Solution
- Our Design & Implementation
- Measurement Procedure
- Testing
- Future Improvements
The Problem (1/3)

- Number of ultrasound scans carried out each year is increasing, systems becoming more complex
- Safety committees recommend QA procedures
- QA of medical ultrasound devices is time consuming and expensive
- Many hospitals find it difficult to undertake QA measurements
The Problem (2/3)

BMUS Safety Guidelines Recommend periodic checking of acoustic output:

- ‘There should be independent checks that the displayed TI and MI values are accurate’
The Problem (3/3)

Thermal Index:

‘the relative potential for a tissue temperature rise.’

Mechanical Index:

‘relative potential for ... an adverse bio effect by a non-thermal mechanism including cavitation.’
System Requirements (1/5)

- Rapid
- Easy to use
- Portable
- Cost effective
- No need to submerge device under test
System Requirements (2/5):
Scanned and Non-Scanned Modes
System Requirements (3/5): Mechanical Index

\[ MI = \frac{p_{r.3}(at \ z_{sp})}{\sqrt{f}} \]
System Requirements (4/5): Thermal Index (Soft Tissue)

- **Scanned / At Surface Non-Scanned**

\[ TIS_{as,ns} = \frac{P_{1x1} f_{awf}}{210 \text{ mW MHz}} \]

- **Below Surface Non-Scanned**

\[ TIS_{bs,ns} = \min \left[ \frac{P_\alpha(Z_{s,ns}) f_{awf}}{210 \text{ mW MHz}}, \frac{I_{spta,\alpha}(Z_{s,ns}) f_{awf}}{210 \text{ mW cm}^{-2} \text{ MHz}} \right] \]
System Requirements (5/5):
Required Measurements

- Axial scan \( (p_r, l_{ta}) \)
- Pulse repetition rate / frame rate & pulses per frame
- Acoustic working frequency
- Output power and bounded square power
Design & Implementation (1/5):
Pressure Measurement Sensor

- Onda HGL-0200 Hydrophone & AG-2020 Preamp
- PicoTech PicoScope 4224 PC Oscilloscope
- LabVIEW Software on a Laptop PC

Frequency Response

80 MS/s
20 MHz Bandwidth
Design & Implementation (2/5): Power Measurement

- Thermal method
- Pyroelectric effect of thin (52 µm) pvdf layer
- Backed by a thick, highly absorbent layer (75 dB cm⁻¹ at 1MHz)
- Output proportional to rate of change of temperature of pvdf

Design & Implementation (3/5): Power Measurement

- Transducer
- Thin Mylar membrane
- Bounded Square Aperture
- Pyroelectric pvdf layer
- Perspex tank wall
- Absorbing backing

ON

OFF
Design & Implementation (4/5): Diagram
Design & Implementation (5/5): Photos
Design & Implementation (5/5): Photos
Design & Implementation (5/5): Photos
Measurement Procedure (1/10): 1) Alignment

Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations
Measurement Procedure (2/10): 1) Alignment
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Measurement Procedure (2/10): 1) Alignment

Diagram showing the alignment process with steps:

1. Alignment
2. PRR/FRR
3. Axial Scan
4. Frequency
5. Power
6. Calculations
Measurement Procedure (3/10):
2) Pulse / Frame Rate Measurement

- Non-Scanned Mode
Measurement Procedure (4/10):
2) Pulse / Frame Rate Measurement

- Scanned Mode with Constant Pulse Rate

Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations
Measurement Procedure (5/10):
2) Pulse / Frame Rate Measurement

- Scanned Mode with Varying Pulse Rate

Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations
Measurement Procedure (6/10):
2) Pulse / Frame Rate Measurement

Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations
Measurement Procedure (7/10): 3) Axial Scan
Measurement Procedure (8/10):
4) Frequency Measurement

Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations
Measurement Procedure (9/10):
5) Power Measurements
Measurement Procedure (10/10): 6) De-rating and MI TI Calculation
Summary

- Portable system
- Simple alignment of hydrophone to beam axis
- Automatic beam plotting
- Simple power measurement as part of same system
- Automatic calculation of MI and TI
Future Work

- Easier alignment
- Reduce effect of vibration on power sensor
- More portable
- Comparison with existing systems

Acknowledgments

Thanks to Bajram Zeqiri, Mark Hodnett, Adam Shaw, Jill Barrie, Andrzej Jastrzebski, Michael Lynn, Hazel Starritt and the National Measurement Office.

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National Measurement System

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