|  |
| --- |
|  |
| JOURNAL ARTICLE REVIEW |
| NUCL 597W Rev 0 |
| Ergün, a S. (2011). Analytical and numerical calculations of optimum design frequency for focused ultrasound therapy and acoustic radiation force. Ultrasonics, 51(7), 786–94. doi:10.1016/j.ultras.2011.03.006 |
|  |
| **Alex Hagen** |
| **11/19/2012** |

# Abstract

Ergun sets forth a proposed optimization for ultrasound power delivery with applications in ultrasound therapy.

Table of Contents

[I. Abstract i](#_Toc337024824)

[III. List of Figures and Tables iv](#_Toc337024825)

[A. List of Figures iv](#_Toc337024826)

[B. List of Tables iv](#_Toc337024827)

[IV. Nomenclature and Abbreviations v](#_Toc337024828)

[V. Summary of Article 1](#_Toc337024829)

[A. Introduction 1](#_Toc337024830)

[1. Motivation 1](#_Toc337024831)

[2. Background 1](#_Toc337024832)

[B. Calculations 1](#_Toc337024833)

[1. Plane Wave 1](#_Toc337024834)

[2. 1D and 2D Focused Wave 1](#_Toc337024835)

[3. Inhomogeneous Tissue 1](#_Toc337024836)

[C. Materials and Methods 1](#_Toc337024837)

[D. Acoustic Field Simulation and Results 1](#_Toc337024838)

[E. Discussion 2](#_Toc337024839)

[1. Validation 2](#_Toc337024840)

[2. Harmonics and Other Inaccuracies 2](#_Toc337024841)

[F. Conclusion 2](#_Toc337024842)

[VI. Critique of Article 2](#_Toc337024843)

[A. Motivation 2](#_Toc337024844)

[B. Methodology 2](#_Toc337024845)

[C. Verification and Validation 2](#_Toc337024846)

[D. Impact 3](#_Toc337024847)

[VII. Extension of Article 3](#_Toc337024848)

[A. Existing Modeling Platform Simulation 3](#_Toc337024849)

[VIII. Conclusions 3](#_Toc337024850)

[IX. Works Cited 3](#_Toc337024851)

[A. This Paper 3](#_Toc337024852)

[B. Paper for Invention of Ultrasound/Big Paper in Ultrasound Imaging 3](#_Toc337024853)

[C. Paper for Invention of Ultrasound Therapy 3](#_Toc337024854)

[D. FEM/COMSOL Paper 3](#_Toc337024855)

[E. Paper for acoustic energy harvesting from PZT elements (COMSOL Journal) 3](#_Toc337024856)

[F. Current frequency optimization work paper 3](#_Toc337024857)

[G. 4+ More 3](#_Toc337024858)

# List of Figures and Tables

## List of Figures

## List of Tables

# Nomenclature and Abbreviations

# Summary of Article

## Introduction

### Motivation

Ultrasound therapy allows for focusing of vibrational energy on to small volumes of tissue, which is then converted to thermal energy. This energy can be used to destroy cancerous tissue or even deliver pharmaceuticals.

### Background

Existing “Rule of Thumb” equations are often used for frequency optimization, which optimizes the power delivered while minimizing the power delivered to unwanted volumes.

Wave theory accurately models these phenomena with several stipulations: a several-dimensional representation of the transducer is used, harmonics are neglected, and far field radiation assumptions are used.

## Calculations

### Plane Wave

The optimization of frequency for a plane wave is done based on the general intensity attenuation law and the acoustic power equation provided in the introduction.

### 1D and 2D Focused Wave

A plane wave approximation is oversimplified for this case, and a more involved derivation was conducted to include the source as a one or two dimensional array of beam sources with differing weighting.

### Inhomogeneous Tissue

As tissue within the body is almost always inhomogeneous, a correction to the above equations, using summation of tissue elements and Pi summation of attenuation, was performed.

## Materials and Methods

A method of approximating the above calculations was developed for analysis in the discussion section. This method is provided as an iterative process, with the frequency iterating and element pitch and far-field radiation pattern calculated using Matlab.

## Acoustic Field Simulation and Results

As shown, side by side 1D and 2D results are provided for optimization of two different parameters, for maximum spatial peak, and for maximum power applied to given spot.

## Discussion

### Validation

Values for Simulation Results were compared against the “Rule of Thumb” values used in modern ultrasound therapy, showing only modest correlation.

### Harmonics and Other Inaccuracies

Inaccuracies in the given analytical models stem from several sources, two of which are the fact that harmonics are not included in the given model, and that the geometric location of the transducer is not defined homogenously in all models.

## Conclusion

The research group successfully created analytical models to optimize frequencies for homogenous and nonhomogeneous tissue. However, the models are clearly incomplete and must include increased complexity to correctly model this complex phenomenon.

# Critique of Article

## Motivation

The field of ultrasound therapy (and its direct correlation to ultrasound imaging) is an interesting and growing field. Unfortunately, the field is often overshadowed by nuclear medicine for the ability to deliver more power to a more precise volume element.

## Methodology

The methodology of the research group must be called into question, as the models developed are hardly more than a small step past currently existing “Rule of Thumb” laws. The proposed method uses a computer to only slightly improve on hand calculated techniques, and a full simulation would be better served.

## Verification and Validation

Validation of the above models is done thoroughly, and the assumptions given have a physical basis. The comparison to other models allows inaccuracies to be identified and “ballpark” figures examined.

No verification work was done for the models developed, a great oversight for any theoretical work. A simple experiment with attenuation through water or other tissue like substances could be used for verification. Infrared thermometers would have allowed for non-invasive benchmarking of temperatures and heat fluxes.

## Impact

For the above mentioned reasons, this work has little impact on the field of ultrasound therapy. The idea of optimizing the power delivered is well conceived, but the study presented is over simplified and has not been proven to be experimentally sound.

# Extension of Article

## Existing Modeling Platform Simulation

Using COMSOL Multiphysics software, an Acoustic-Structure Interaction cum Heat-Transfer in Fluids model will be created to simulate an ultrasound therapy type experiment. A methodology will be scripted (using FORTRAN and COMSOL Batch capabilities) to sweep frequencies and obtain the separate optimum frequencies.

# Conclusions

The paper reviewed has exciting applications within cancer treatment fields and also direct connection to existing ultrasound imaging applications. Despite the paper’s promise, it fails to deliver because of an over-simplistic and unneeded approach. Existing Multiphysics platforms can easily model the physical situation explained, and experimental work must be done to verify the theoretical results.

# Works Cited

## This Paper

## Paper for Invention of Ultrasound/Big Paper in Ultrasound Imaging

## Paper for Invention of Ultrasound Therapy

## FEM/COMSOL Paper

## Paper for acoustic energy harvesting from PZT elements (COMSOL Journal)

## Current frequency optimization work paper

## 4+ More