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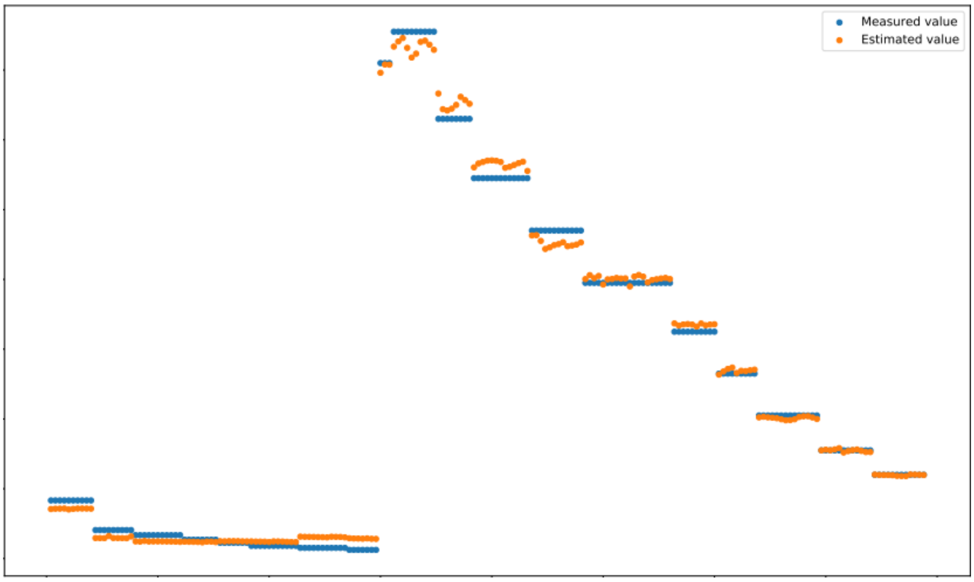
FMH606 Master's Thesis 2018
Industrial IT and Automation

Characterization of Rheological Properties of Drilling Fluids Using Ultrasonic Waves



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Summary:
Drilling fluid rheology is important for drilling safety and has to be constantly monitored and adjusted during drilling operations. The goal of this thesis is to attempt to create a model with neural networks that can estimate rheological properties of drilling fluids based on dampening and travel time of ultrasonic waves. The current way of measuring rheology consists of sampling and use of offline rheological measurements using lab equipment, and an online measurement system would allow for faster corrections.

Experiments have been planned and carried out accordingly to create data for training and testing the neural network models, and this data has been used for training the models along with previously gathered data.

The neural network models have been created with TensorFlow in Python, with Adam Optimiser, relu6 and sigmoid activation functions, and square error loss function. Models have been created for Density, Yield Point, Gel Strength and Plastic Viscosity. The best models for each output, in the same order, have an RMSE of 2.7%, 2.2%, 1.7% and 3.0% with all available data based on two different drilling fluids gradually diluted, and 5.1%, 3.6%, 3.7% and 3.8% with data gathered in this thesis based on one type of drilling fluid gradually diluted, where the best models were selected based on mean square error. These models were the best out of more than 250 models each that were trained with the same datasets for the same output variable.

Preface

This thesis was worked on and written from January to May in 2018 at University of South-Eastern Norway, as part of a masters degree in Industrial IT and Automation. The thesis is part of the Semi-kidd project. Through this thesis, models were made through machine learning in order to estimate rheological properties of drilling fluids. Experiments for gathering data for training and evaluating the models was also planned and carried out as part of the thesis. The data from the experiments were used along with data previously gathered with the same setup on a different drilling fluid.

The primary goal of estimating rheological properties is to make drilling operations safer through online measurements of drilling fluid rheology. It can be advantageous to have some basic prior knowledge of ultrasound and ultrasonic transducers for reading this report. It can also be helpful to have some basic understanding of neural networks and machine learning.

I would like to thank Håkon Viumdal for supervising the thesis work and helping guide my work. I would also like to thank Morten Hansen Jondahl, Geir Elseth, Kenneth Mozie and Saba Mylvaganam for assisting with the thesis. I would also like to thank Morten Tande and Statoil for running the rheological tests on the drilling fluids.

The text editing tool used for writing this report is ShareLaTeX. The neural network and data analysis was done using Python, including Anaconda for virtual environment, Spyder as IDE, and the libraries TensorFlow and Pandas. Organisational tool used is Microsoft Project.

The task description for the thesis can be found in appendix A. The Gantt chart used to organise the thesis work can be found in appendix B.

Porsgrunn, 15th May 2018

Morten Hafredal

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Nomenclature

Symbol	**Explanation**
ANN	Artificial Neural Network
API	Application Programming Interface
CPU	Central Processing Unit
GPU	Graphics Processing Unit
IDE	Integrated Development Environment
KCl	Potassium Chloride
MSE	Mean Square Error
NDT	Non-Destructive Testing
NTNU	Norwegian University of Science and Technology
RMSE	Root Mean Square Error
TLS	Transport Layer Security
USN	University of South-Eastern Norway

1 Introduction

Drilling fluids are an essential part of drilling operations, both for the effectiveness of the drilling and more importantly for the safety and integrity of the borewell. To avoid kick or loss situations and to allow the drilling fluid to fulfil its other purposes, control of the rheological properties of the drilling fluid such as density and viscosity is important. [1]

1.1 Objectives

A brief literature study on drilling with focus on drilling fluids, rheological properties and ultrasonic waves will be carried out and documented in this report. The objective of this thesis is to generate and compare models that estimates rheological properties of drilling fluids based on ultrasonic signal dampening and time of flight using artificial neural networks. Experiments will be planned and carried out to gather data for training and evaluating the neural networks, and this data will be used both by itself and together with existing data gathered previously on a different drilling fluid. Dense neural networks with varying number of hidden layers and neurons in each layer will be generated and evaluated, and compared according to their mean square error and other error performance variables, with the best models for each dataset and output combination selected by having the lowest mean square error.

1.2 Earlier and current work with drilling fluids at USN

There is ongoing work at USN concerning measurement principles on drilling fluids for flow and rheology in particular. The work has been going on for a few years, resulting in multiple projects, theses and publications.

Some experiments were done towards characterising drilling fluids with ultrasonic waves in 2017 at USN. This was done as a Masters thesis by Kenneth Mozie. The work showed a promising correlation between the attenuation and time of flight of ultrasonic waves through drilling fluids and their rheological properties. The analysis was done with multivariate tools.[2]

The results and ideas from this thesis was further worked on, refined and published as an article by Morten Hansen Johndal. [3]

Two bachelor projects were conducted in designing, building and programming a testing rig for of measurement principles on drilling fluids.[4][5] A significant focus of this rig was to test an open channel Venturi flow meter that was designed in another master thesis.[6] This work has been in cooperation with Statoil.

Other current work and publications on drilling fluids, using the testing rig for measurement principles, is being done by Khim Chhantyal on mass and volume flow of non-Newtonian fluids, most recently mass flow in open channel. [7]

1.3 Project Semi-kidd

The Semi-kidd project is a research initiative with the primary objective to ”enable cost-effective and automatic kick/loss detection by developing new knowledge on model-based estimation and utilisation of new sensor technology for drilling operations.”. This is both because kick and loss detection is essential for security and integrity of drilling operations, and because cost-effective operations are essential to continue production on the Norwegian continental shelf. The Semi-kidd project is ran by USN, partnered with NTNU, Kelda Drilling Controls, Cybernetic Drilling Technologies, MHWirth, S-Tec and Statoil. This thesis primarily falls under Research Task 4, named ”Estimation of flow rate and fluid properties using multi sensor data fusion”. [8]

1.4 Other work with ultrasonic rheological measurements

Most use of ultrasonic transducers in rheometers are in the form of ultrasonic transit time or Doppler flowmeters combined with Venturi type pressure drop measurements to estimate viscosity.[9] There are also existing patents and papers for ultrasonic viscometers based on reflection from as far back as 1994.[10][11] These viscometers measure the phase shift of reflections from particles in the liquid in order to estimate velocity. The velocity profile is used together with a differential pressure sensor to estimate viscosity. There is continuous work being done on improving this type of viscometer using ultrasonic Doppler.

Specific work being done on ultrasonic viscometers include work with rheology of non-Newtonian fluids like ketchup[12] and cement grouts[13] with ultrasound Doppler velocity profile and differential pressure by Johan Wiklund at SP Technical Research Institute of Sweden along with other researchers. For the cement grouts the ultrasonic transducers were strong enough to determine a velocity profile throughout half the pipe diameter.

There has also been successful tests on sludge water[14] and mineral suspension[15] with the ultrasound velocity profile and differential pressure method by Rainer Haldenwang along with other researchers.

1.5 Report structure

The report is structured in the following way:
Chapter 1 covers the introduction and some background of the thesis.
Chapter 2 covers some theory about drilling fluid.
Chapter 3 covers some ultrasound theory
Chapter 4 covers some rheology theory with focus on the Bingham plastic model
Chapter 5 covers theory for neural networks with focus on dense networks.
Chapter 6 details the planning, execution and results of the experiments for gathering ultrasonic data.
Chapter 7 contains the analysis of the raw experimental data from the ultrasonic experiments.
Chapter 8 covers the design and parameters of the neural network models for estimation of rheological properties
Chapter 9 covers the results of the training of the neural network models and the performance of the most successful models.
Chapter 10 contains the discussion of the work and results, including limitations and suggestions for further work.
Chapter 11 concludes the report contents and thesis results.

2 Drilling Fluid Theory

This chapter details some information about drilling fluid and its role in drilling operations. Drilling fluid, or mud, is the medium that experiments and measurements in this thesis will be done on.

The purposes of the drilling fluid in drilling operations are:

- Transporting cuttings from the drilling to the surface.
- Equalising the pressure from the formation to avoid kick or loss.
- Support and stabilising against the walls of the wellbore during drilling.
- Cooling and lubricating the bit and drillstring
- Carries power to the bit through hydraulic pressure.
- Allows for information about the formation through the content of the returned drilling fluid, as well as signalling through pressure pulses.

As a kick scenario, a scenario where the drilling fluid is not heavy enough to counteract the pressure from the well, is potentially very dangerous as it can lead to a blowout. A slight amount of loss of drilling fluids to the formation is preferable, but a loss can also lead to influx of hydrocarbons into the drilling fluids or loss of production later on, as well as the cost of the drilling fluid. A small amount of influx of drilling fluids into the reservoir is inevitable. The design and control of drilling fluid to maintain a density and viscosity that allows it to perform the tasks listed above is necessary for safe drilling operations. Drilling fluids can deteriorate because of shear, pressure and temperature, and it is as a result necessary to keep analysing the rheological properties of the drilling fluid. Online measuring of the rheology of drilling fluids would allow for faster correction if the drilling fluid is deteriorating compared to the current method of sampling and offline measurements. Figure 2.1 shows a simplified sketch of the flow loop that drilling fluid is circulated through during drilling operation[16]. [1]

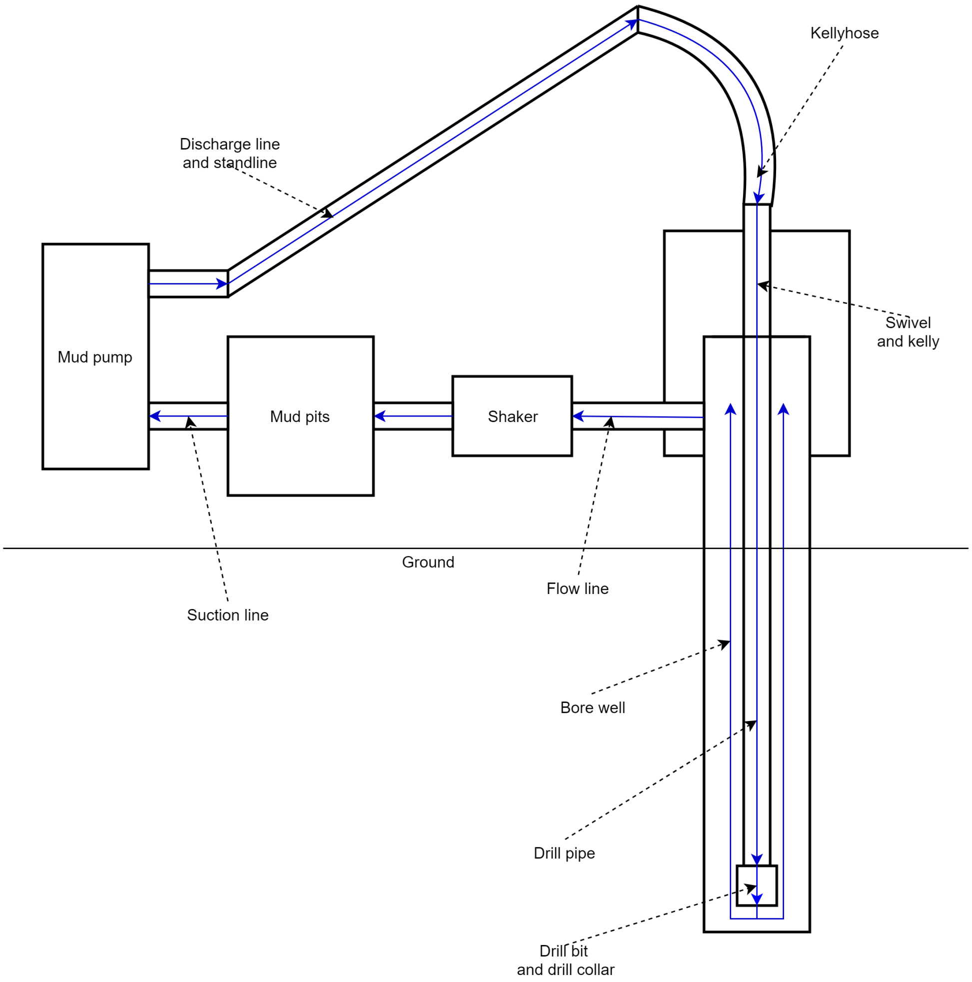

Figure 2.1: Simplified circulation loop of drilling fluids

2.1 Water based drilling fluids

Water based drilling fluids are mixtures of chemicals and minerals that are dissolved into water in order to create the desired rheological properties of the system. Water based fluids are easier to mix on site as sea water or production water can be used. Water based fluids are used for about 80% of drilling operations, with oil based and synthetics based fluids being used primarily when the required properties cannot be achieved with water based drilling fluid systems. [1]

2.2 Oil based drilling fluids

Oil based drilling fluids were developed to tackle challenges not possible or difficult with water based systems, such as high temperature, contaminants or clays in the formation that react with water based systems. Oil based fluids also tend to offer a higher degree of lubrication than water based drilling fluid. One issue with oil based drilling fluids compared to water based fluids is that they are significantly more harmful with the environment, and has as a result has stricter regulations for containment of the fluid and cuttings carried out by the fluid separated in the shaker. [1]

2.3 Synthetic based fluids

Synthetic based fluids were developed as a more environmentally sound alternative to oil-based system. Oil-based systems are in places regulated such that discharging cuttings removed with oil based fluids are prohibited. Synthetic based drilling fluids can be expensive. [1]

3 Ultrasound Theory

Ultrasound is high frequency sound waves. As sound waves travel through a medium, depending on what the medium is, the speed of sound and the dampening of sound waves in the medium will vary. The goal of this thesis is to explore the possibility of determining rheological properties of drilling fluids with non-intrusive ultrasonic transducers. [17]

3.1 Types of ultrasonic waves

There are multiples ways ultrasonic waves propagate through a medium, but for liquids this is primarily limited to longitudinal waves which compress the medium in waves. Any other types of waves, such as traverse waves, will rapidly dissipate in a liquid and will be contributing to the reduction of signal strength. [18]

3.2 Acoustic impedance and attenuation

Acoustic impedance is the rate at which sound waves deteriorate in amplitude when propagating through a medium. In the case of this thesis, the medium in question will always be a liquid. Figure 3.1 shows a sketch of how signal amplitude changes between the transmitter and the receiver.

Attenuation is the decay of energy in the ultrasonic waves as they propagate through a medium. The decay is caused by a mixture of Scattering and absorption of the wave energy. In addition there is the reflection when the sound waves goes from one medium to another. The attenuation in a medium is expressed in Nepers per meter [Np/m]. Scattering and absorption is dependant on the rheological properties of the liquid, but will also be effected by solids and gas bubbles in the medium. Attenuation constitutes only a small part of the loss of signal strength with distance, with the more substantial part being a result of spreading of the wave. [19] [20]

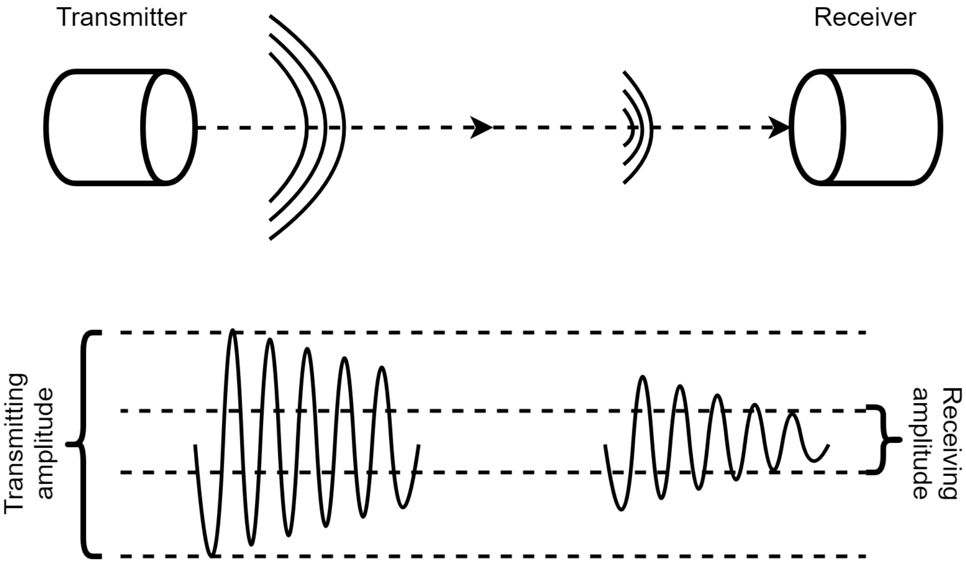

Figure 3.1: Acoustic impedance reducing signal amplitude

3.3 Time of flight

Figure 3.2 shows a transmitter and receiver pair of ultrasonic transducers. The time of flight is the time it takes for a sound wave to travel from the transmitter to the receiver. The speed of sound through a medium is decided by two factors. The first of these are the elasticity of the medium, which is related to the viscosity for liquids, but is more noticeable when comparing speed of sound in solids, liquids and gases. The second factor that decides the speed of sound through a medium is the density. [21]

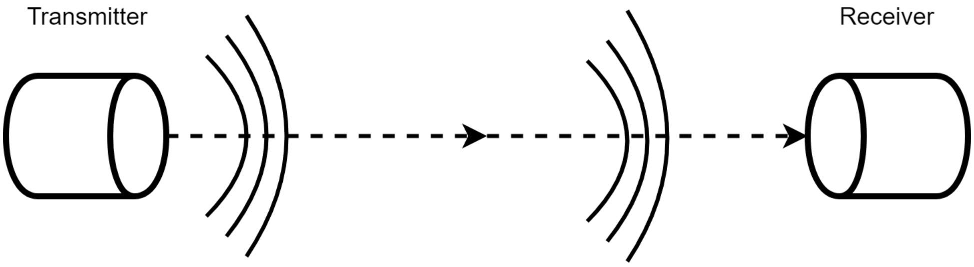

Figure 3.2: Ultrasonic wave travelling from transmitter to receiver

4 Rheology Theory

Drilling fluids are non-Newtonian fluids, meaning that their viscosity changes depending on shear stress. The rheological properties that will be attempted to estimate through neural networks are density, yield point, gel strength and plastic viscosity. Yield point and plastic viscosity is calculated according to the Bingham plastic model. [22]

4.1 Density

The density is the mass per unit of volume of the drilling fluid. The base unit for density is [kg/m], but for the purpose of this report the unit used will be [g/cm]. The density of a drilling fluid effects how the drilling fluid offsets the reservoir pressure to avoid blowout or loss.

4.2 Yield point

Yield point is the shear stress required for a liquid to start flowing. The unit used for shear stress is Pa, Pascals. For Newtonian fluids this is 0, but non-Newtonian fluids have a yield point higher than 0, requiring a certain amount of shear stress before they start flowing. In the Bingham plastic model. Figure 4.1 shows the yield point according to the Bingham plastic model. The yield point is calculated from the 300- and 600-rpm viscometer readings by calculating the slope and subtracting that from the 300-rpm value to find the zero intercept. [23]

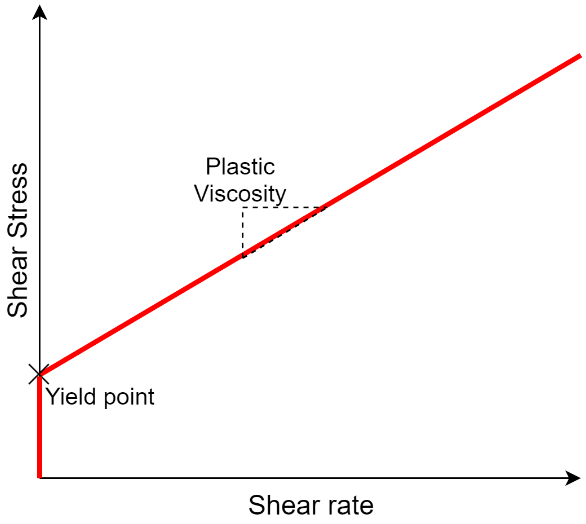

Figure 4.1: Plastic model showing yield point and plastic viscosity

4.3 Gel strength

The gel strength of a drilling fluid is the shear stress measured at low shear rates after the fluid has been given time to set. [24]

4.4 Plastic viscosity

Plastic viscosity is the slope or first order derivative of the shear stress against shear rate in the Bingham plastic model. The base unit used for plastic viscosity is Pas, Pascal seconds. For this report, the unit used will be mPas, milli-Pascal seconds. Higher plastic viscosity comes from a more viscous fluid or higher number of colloids in the fluid. Figure 4.1 shows the plastic viscosity according to the Bingham plastic model. [25]

5 Neural Networks Theory

Neural networks are a type of machine learning that is based on the human brain, simulating neurons with vast numbers of connections. A neural network is made up of multiple neurons which each has a set of weighted inputs and a function, and gives an output from this function. This output can be to another neuron or out of the network. For dense neural networks, every neuron has inputs from every neuron on the previous layer and outputs to every neuron on the next layer. Figure 5.1 shows an example of a simple neural network, with one neuron detailed with inputs, weights, biases, activation function and output. Equations 5.1-5.2 shows the calculation of the output of the neuron where i_n are the inputs, w_n are the weights and b_n are the biases. Weights and biases are specific to each input from the previous layer and neuron combination. [26][27][28]

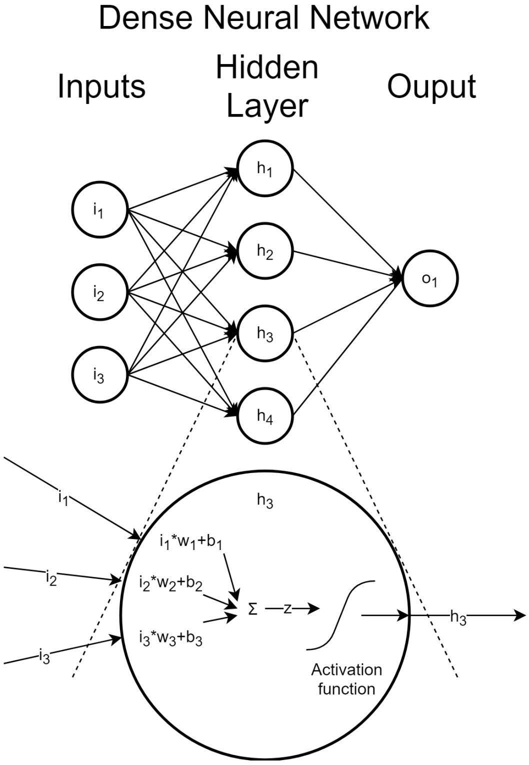

Figure 5.1: Neural network with one neuron (h_3) detailed

$$z = \sum_{n=1}^{3} (i_n \cdot w_n + b_n) \tag{5.1}$$

$$h_3 = f_{\text{activation}}(z) \tag{5.2}$$

Neural networks will be used to create models that will attempt to predict the density, and viscosity parameters like yield point, gel strength and plastic viscosity of the fluid. The neural network needs input data with known output data for training, which will be achieved through experiments to create the input data and lab measurements of the experiment fluid to create the output data. The lab measurements will be carried out by the external partner, Statoil.

5.1 Activation function

The weighted function in the neurons of a neural network is called an activation function. There are various common activation functions. In this report the focus will be on the sigmoid and relu activation functions. The activation functions has as input the sum of the inputs to the neuron adjusted with weights and biases.

5.2 Training neural networks

Neural networks are trained by a loss function and an optimiser. The loss function can be any function that increases as the error of the output increases, commonly this means squared or absolute error values. The optimiser reduces the loss function towards a minimum by changing weights and biases, which in turn modifies how an input effects the activation function.

5.3 TensorFlow

TensorFlow is the second generation machine learning and neural networks framework developed by Google Research. It allows for running of training and other algorithms on GPUs for faster calculations. The TensorFlow API is also created to operate across multiple devices, allowing for complex deep learning neural networks to be trained by large supercomputers. The distributed execution is orchestrated by a master process, and calculations are done on multiple worker processes. Each worker process contains one CPU, but can contain multiple GPUs. Selection of worker process to assign a task to is decided by their ability to complete the task, i.e. whether they contain the appropriate kernel. Further selection if several worker processes are viable, the one that will complete the task in the shortest amount of time is selected. The assignment of tasks to the worker processes is the task of the master process. TensorFlow also has built in functions for gradient calculation, which is widely used in training neural networks. This allows for easier and more effective manual implementation of gradient based training algorithms. [29]

6 Experiments

In order to train a neural network that estimates rheological properties based on signal dampening and time of flight, experimental data is needed. This data needs to consist of both input and output data. To this end, the input data is gathered through experiments at USN, measuring the time of flight and attenuation at different distances through different concentrations of drilling fluid. The different concentrations will be achieved through step-wise dilution where water will be added equal in volume to 5% of the current total volume. The output data is gathered by rheological analysis of each concentration of the drilling fluid at Statoil's research centre at Herøya, Porsgrunn.

6.1 Health, Safety and Environment

The drilling fluid used in previous experiments, which data will be used to supplement the new data gathered in these experiments to train models, is an irritant and is prone to vaporising. Because of this, safety precautions are necessary when handling the drilling fluid left in the tank from these previous experiments. Because the exposure is limited in time, the vaporisation is not a significant concern and can be ignored, but any continuous exposure would require precautions against breathing the vapour. For the irritant, gloves should be used to avoid directly touching the liquid and protective glasses should be used too, in case of droplets splashing from the liquid as a result of agitation. [2]

The drilling fluid used in this experiment is a KCl Polymer system, and it is not classified as a health or environmental hazard. As a result, protective clothing is not required to ensure the safety of personnel. However, protective glasses should be used to avoid irritation to the eyes due to particles in the fluid. It will also be beneficial for the personnel to use protective gloves as a hygienic precaution and to help keep the working area clean. The safety data sheet for the drilling fluid can be found in appendix C.

The drilling fluids can be harmful to the environment, and as a result the drilling fluids should not be disposed of by washing it down a drain or equivalent. Instead, drilling fluid tapped out to make room for dilution and the remaining fluid at the end of the experiments are complete, needs to be returned to containers for transport so the fluid can be disposed of safely. This safety precaution is also necessary for the drilling fluid used for previous experiments that has to be removed from the tank before experiments can start.

6.1.1 Data integrity and security

This report is confidential for a period of time, though no requirements are set for non-disclosure or confidentiality agreement on part of the people involved with work on the thesis. The primary reason for the period of confidentiality is that the ongoing research material and data will not be made public until after some planned publications that will be using the data have been published. The measurement data will be saved on Microsoft OneDrive. OneDrive uses 2048 bit encryption keys and TLS 1.0, 1.1 and 1.2 during file transfer, and stronger local encryption locally in Microsoft's datacenters. This ensures that the data files are backed up and available in the case of disc failure. [30]

6.2 Earlier experiments

The results from experiments made for a master's thesis in 2017 at USN will be used along with new experimental data to create the models. To allow the data to be as consistent as possible, the same setup and parts of the same method will be used.

6.3 Experimental setup

The frame that holds the transducers allow for change both in distance and in alignment of the sensors. Due to very limited results and low signal strengths for attenuation with linear offset by adjusting the alignment between the transmitter and receiver in previous work[2], the experiments will be limited to changes in linear distances in addition to the change of the rheological properties.

The experimental setup consists of a square tank that holds fluid. The tank dimensions are $80[\mathrm{cm}] \times 40[\mathrm{cm}] \times 40[\mathrm{cm}]$ and the tank is made of stainless steel. The frame that holds the two transducers is made of aluminium, and has rails that allow for the sensors to be moved apart linearly and offset the linearity. Figure 6.1 shows the experimental setup.

The instrument used to transmit and receive the ultrasonic signal is an Olympus Epoch 1000i.[31]. Settings used on the instrument during the experiments are described in table 6.1. Signal strength, gain and time of flight is read manually and input into an excel sheet. The transducers used in cooperation with the instrument are immersion transducers produced by Olympus of the type V301-SU, V302-SU and V304-SU.[32] The base excel sheet used for storing data from the experiments can be found in appendix D.

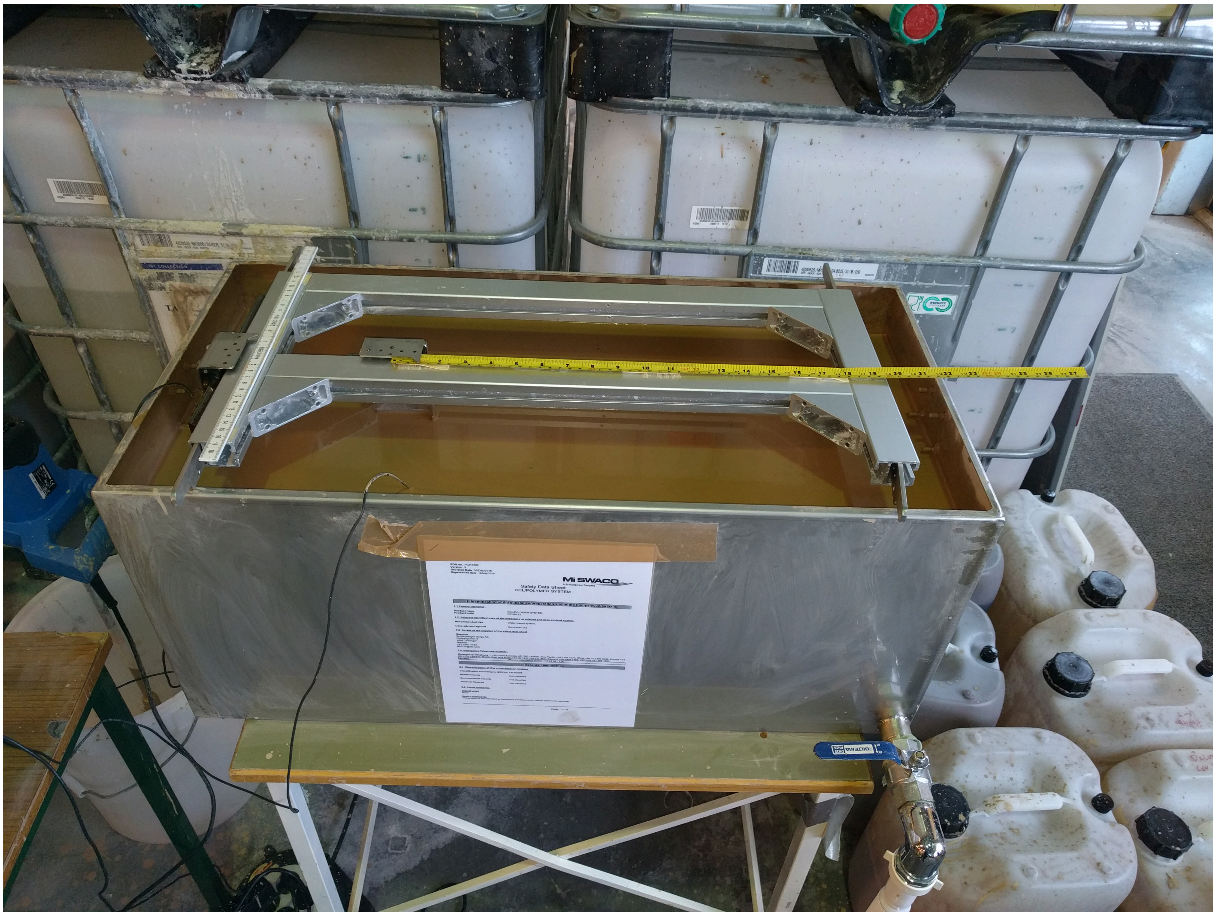

Figure 6.1: Experimental setup

Table 6.1: Epoch 1000i settings during experiments

Setting	**Value**
PRF Mode	Auto High
Energy	300[V]
Damp	400[Ω]
Mode	Thru
Pulser	Square
Filter	0.2-10.0[MHz]
Freq(0.5[MHz])	0.5[MHz]
Freq(1.0[MHz])	1.0[MHz]
Freq(2.25[MHz])	2.27[MHz]

6.4 Drilling fluid dilution

To create data with various rheological properties for training the neural network, drilling fluids with different rheological properties are required. To produce this with minimal cost, the drilling fluid was diluted by steps. For each step of dilution, experiments were done and samples taken for the lab analysis. For each new dilution, the level varies, the levels can be found in the experimental notes in appendix E.

6.4.1 Drilling fluid sampling

In order to pick up on settling of the drilling fluid throughout the experiments, each concentration is sampled twice; once before the first set of the first sensor pair and once after the last set of the last sensor pair. The samples are taken as close to the experiments as possible. Both samples are sent to the lab for testing the rheological properties, and the value that will be used to train the neural networks will be an average of the two samples.

6.5 Experimental procedure

Below is the experimental procedure for a single drilling fluid concentration. Sampling of the drilling fluid is done on either side, before the first measurement and after the last measurement, of the experiment to offset any changes to the rheological properties throughout the experiment. Three transducers are used with the signal frequencies 0.5MHz, 1MHz and 2.25MHz. Two sets are recorded for each concentration with each transducer, with mixing between each full set to give each series the same conditions. The drilling fluid is diluted with tap water.

The following is the step by step procedure for carrying out the experiments:

1. Put on safety equipment (Gloves, Glasses)
2. Mix fluid and wait for at least 5 minutes for it to settle
3. If first run: take first drilling fluid sample for laboratory
4. Set distance to 3cm
5. Take measurements
6. Adjust distance +2 cm
7. If signal strength is below 7%, adjust Gain up, to 100% if that allows for good signal
8. Go to 5 until 43cm or no good signal available
9. Go to 4 until 2 sets of samples
10. Switch transducer frequency
11. Go to 2 until all transducers have been used
12. Take second drilling fluid sample for laboratory

6.5.1 Experimental matrix

Table 6.2 shows the experiments that are planned to be carried out and the total number of experiments that has been planned. The experimental matrix does not account for experiments stopping at lower distances than 43cm due to no good signal being available.

Table 6.2: Experimental Matrix

Drilling Fluid	Distance [cm]	Transducers [MHz]	Repetitions	Total experiments
#1	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#2	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#3	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#4	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#5	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#6	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#7	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#8	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#9	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#10	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
#11	{3, 5, ..., 43}	{0.5, 1.0, 2.25}	2	129
Total				1419

6.5.2 Measurement uncertainty

Any experiment has some sources of uncertainty as a result of equipment, setup or human error. The ultrasonic transducers used[32] and the Epoch 1000 instrument[31] for measuring the signal strength and travel time are assumed to be a low sources of error compared to the human error and the error due to displayed resolution on the instrument.

Because of limitations in the instrument and the procedure used, the error for some of the samples will be as much as 7% due to the signal strength and resolution alone (0.5% error from resolution at 7% signal) for signal strength data. This is without considering noisy signals, which cause the measurement values on the instrument to fluctuate at long distances and low signal strengths. While it would reduce the uncertainty, increasing the signal strength to 100% for every measurement would both decrease the distance at which measurements can be taken and as such reducing the width of the dataset, and increase the time per sample in creating the data, effectively reducing the number of data points for training the neural networks.

Figure 6.2 shows the interface of the instrument in the experimental setup, and shows that the signal strength output has a resolution of 1%. To minimise the error, it is important that the experimental procedure is followed and that the distance adjustments are done exactly. It is also important to confirm that the values recorded are as expected with increasing time of flight and decreasing signal strength with increasing distances for all data before diluting the drilling fluid.

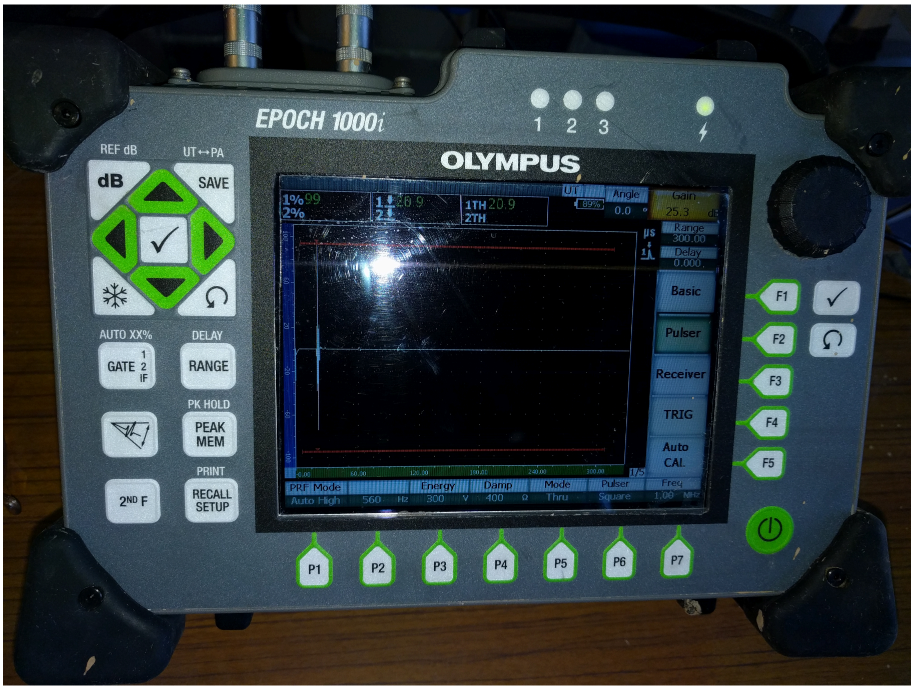

Figure 6.2: Epoch 1000 instrument in the experimental setup

6.5.3 Normalisation of signal strength

The signal strength parameter measured by the instrument in the experiments has two parts; signal gain in dB and signal strength in percentage. In order to reconcile this into one parameter describing the gain required to propagate a 100% signal strength signal through the liquid, the gain has been normalised into a Normalised Gain parameter according to equation 6.1. This allows the signal strengths to be more easily compared. The calculation is done as part of the data gathering in the experimental data sheet during experiments.

$$\mathrm{NormalisedGain[dB]} = \mathrm{Gain[dB]} - 20 \cdot \mathrm{Log}_{10}\left(\frac{\mathrm{SignalStrength}[\%]}{100[\%]}\right) \tag{6.1}$$

6.6 Experimental results

With the exception of the data on concentration 2, 3 and 4, the data from the experiments are consistent with expected trends. The dampening seen in concentrations 2, 3 and 4 is consistent throughout a whole day of measurements, while not reproduce-able in any other day. It is likely that the additional dampening stems from one or both of the connectors on the instrument side as the transducers are connected and removed multiple times during each concentration. One other slightly unexpected part of the data is that Concentration 7 and 8 intersect across all three sensors. It is difficult to say why this is as the procedure for all the sets are the same, and there is no obvious error in the sets. The data marked as Concentration 12 is the same drilling fluid Concentration as Concentration 11, but with the experiment done by the same person as the old data from a previous master thesis[2] in order to attempt to pick up on any difference in the human element. Larger versions of the plots can be found in appendix F. The actual number of usable data points from the experiments are 808, rather than the 1419 data points projected by the experimental matrix in table 6.2. One of the reasons for the reduced number of data points is because of the maximum distance for each measurement series is limited by signal strength too and noise too, rather than just by the upper limit of 43cm. The other reason for a lower number of data points than projected is that the three concentrations that had an additional source of dampening during the experiments are unsuited for use in training or testing the models. Figures 6.3-6.8 shows the plots of the data from the experiments along with fitter polynomials, second order for gain and first order for time of flight according to observed progression. It is also as expected that the time of flight is proportional to distance.

The normalised gain plots shown in figures 6.3, 6.5 and 6.7 shows that the maximum normalised gain for the experiments appear to be around 105dB for all three transducers and all concentrations, at which point an adequate signal is not available according to the experimental procedure. The normalised signal gain required to propagate the signal over the same distance increases with increasing signal frequency.

The time of flight plots shown in figures 6.4, 6.6 and 6.8 shows that the time of flight changes primarily based on the distance, with only small changes due to the dilution of the liquid, barely perceptible in the plots.

The notes from the experiments can be found in appendix E, and the full resulting data from the experiments can be found in appendix G. The code used to generate the analysis plots can be found in appendix H.

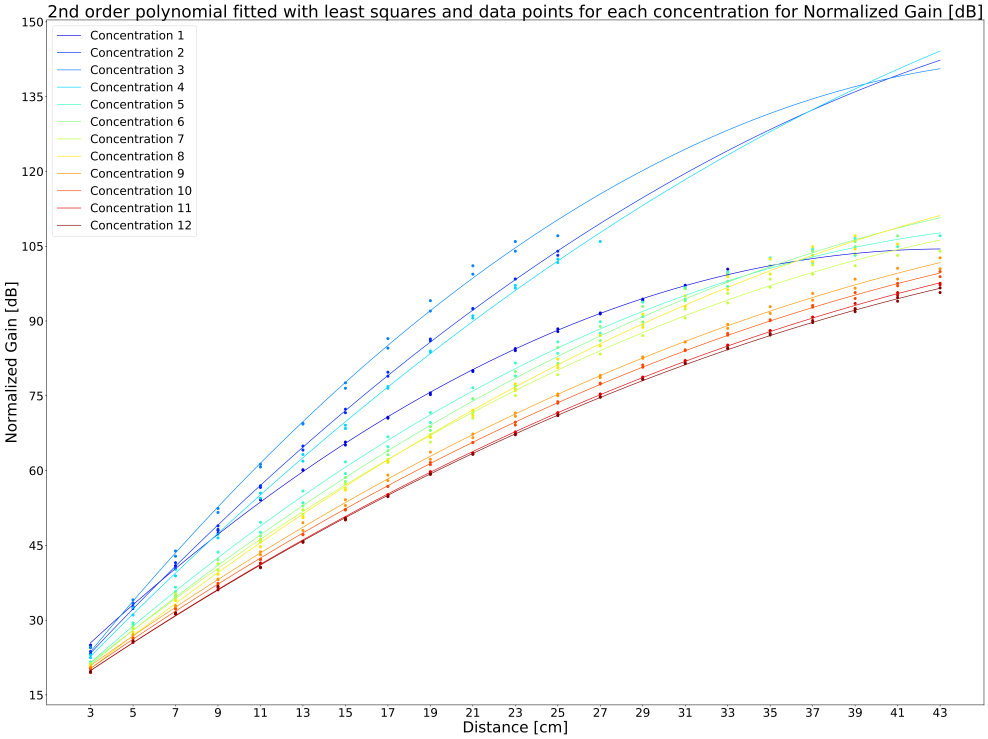

Figure 6.3: Normalised Gain data points for 0.5MHz transducer, including fitted polynomial for the data

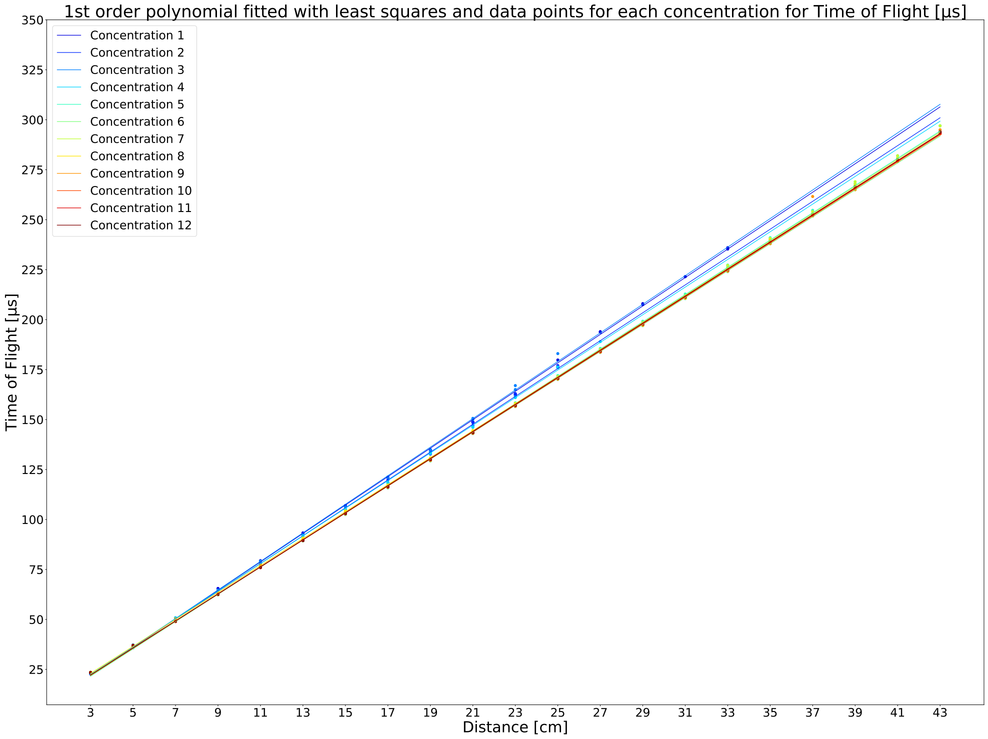

Figure 6.4: Time of Flight data points for 0.5MHz transducer, including fitted polynomial for the data

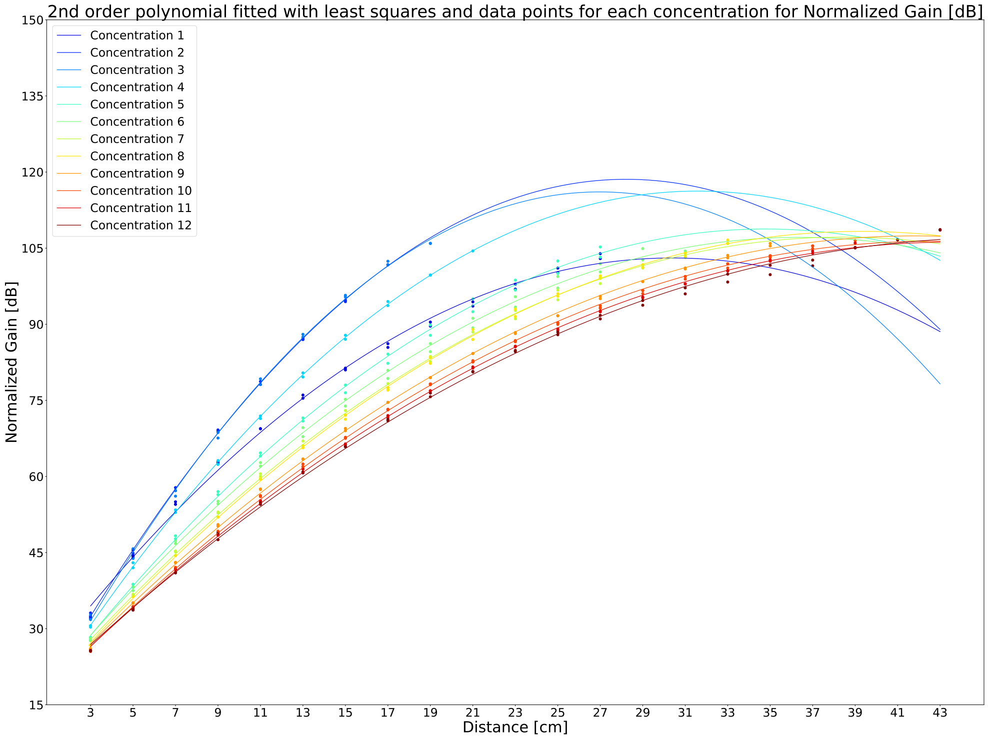

Figure 6.5: Normalised Gain data points for 1.0MHz transducer, including fitted polynomial for the data

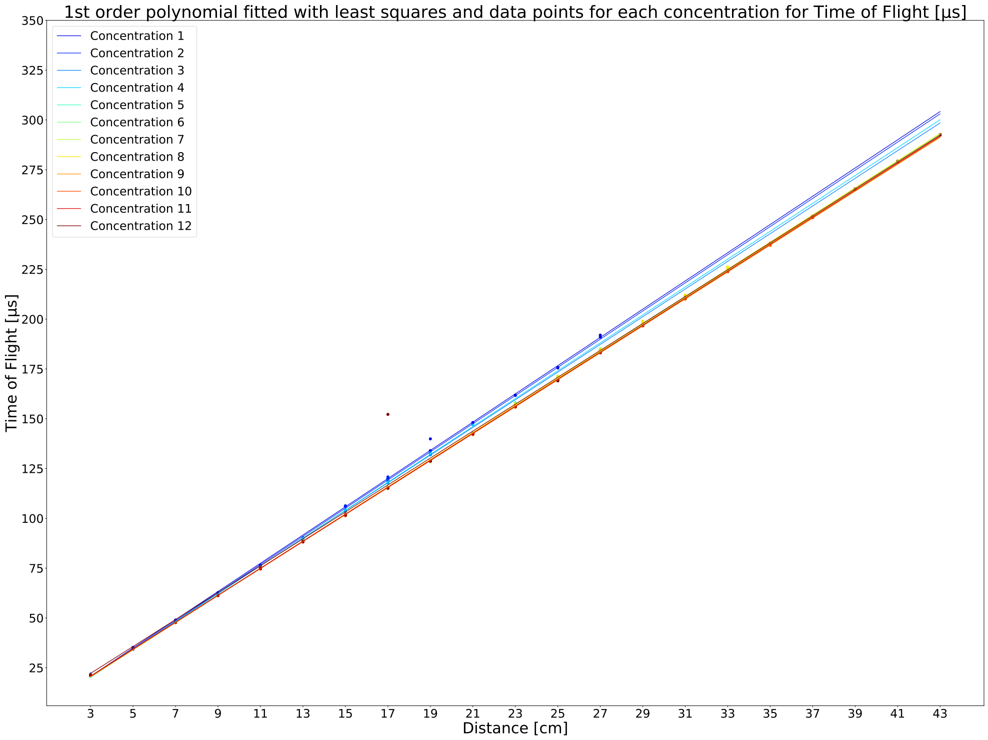

Figure 6.6: Time of Flight data points for 1.0MHz transducer, including fitted polynomial for the data

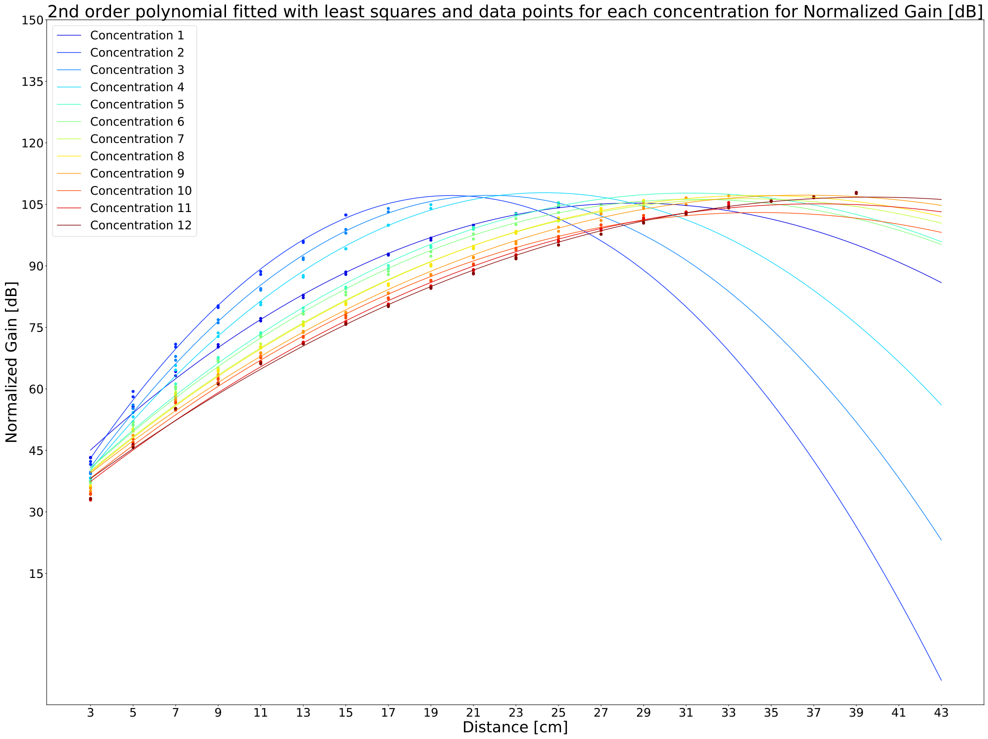

Figure 6.7: Normalised Gain data points for 2.25MHz transducer, including fitted polynomial for the data

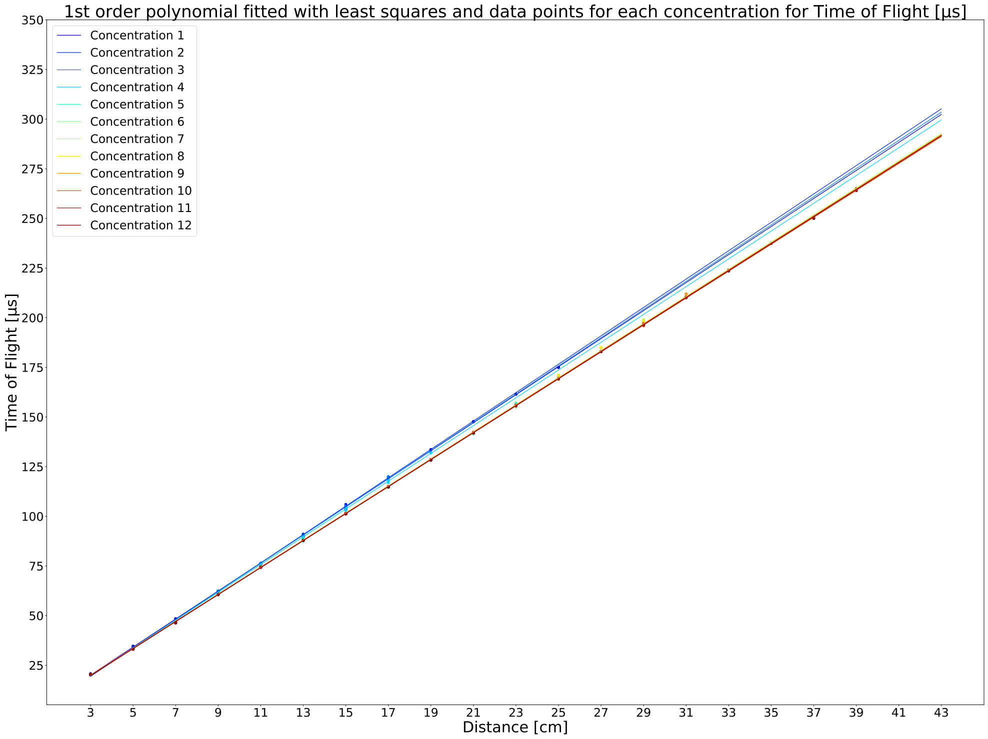

Figure 6.8: Time of Flight data points for 2.25MHz transducer, including fitted polynomial for the data

6.7 Lab Rheology Results

The rheology lab data was gathered at Statoil's research centre in Porsgrunn. The instrument used was an Anton Paar Modular Compact Rheometer MCR 502[33]. The rheological data from these lab experiments that are used in this thesis can be found in appendix I. The rheological data is separated in post and pre sample data, the average of these two values will be used as the target for the neural network models.

7 Experimental Raw Data Analysis

Figures 7.1-7.6 shows the average error for each set of data against it's fitted curve as presented in figures 6.3-6.8 in chapter 6.6. The average error plots shows that there does not seem to be a significantly higher error on any of the datasets, which would mean a higher variance and/or divergence from a second order development for normalised gain and first order for time of flight with increasing distance. The most significant error is in concentration 12 time of flight data with the 1.0MHz transducer, but this error seems to stem primarily from an outlier in the measurements at one of the 17cm measurements which can be seen in figure 6.4. The concentration 12 being a duplicate of the concentration 11 experiment and not having independent rheology data means that it will not be used in the model creation, and as such will not effect the results.

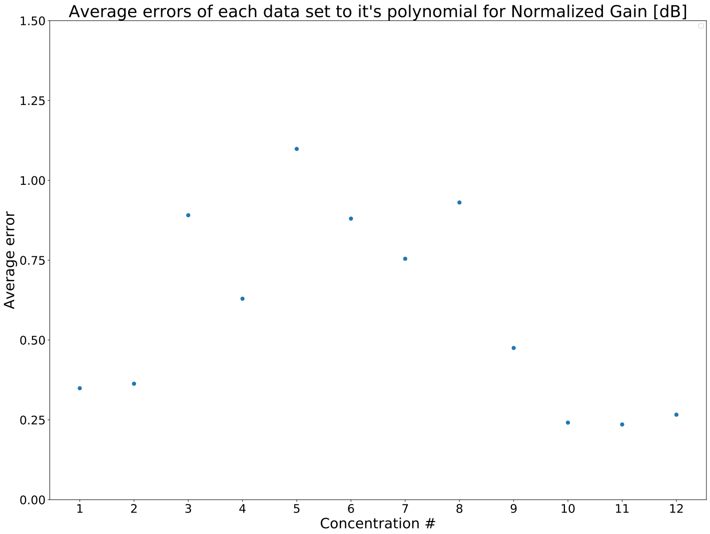

Figure 7.1: Average error of the Normalised Gain samples against the 2nd order polynomial for the 0.5MHz transducer

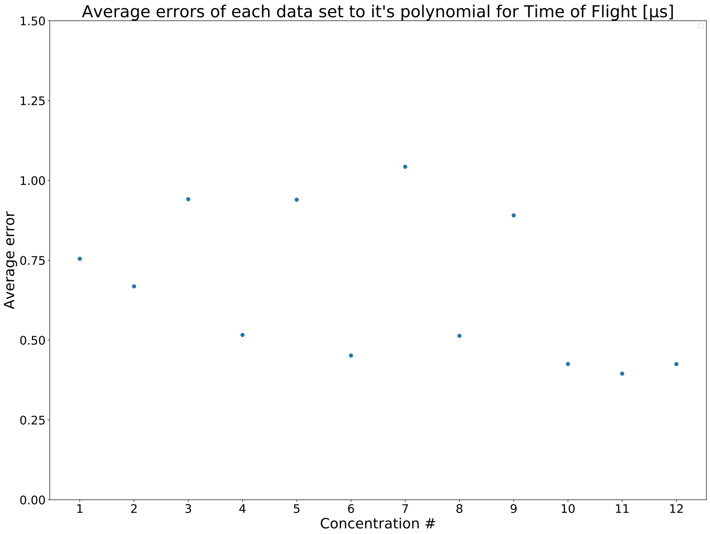

Figure 7.2: Average error of the Time of Flight samples against the 1st order polynomial for the 0.5MHz transducer

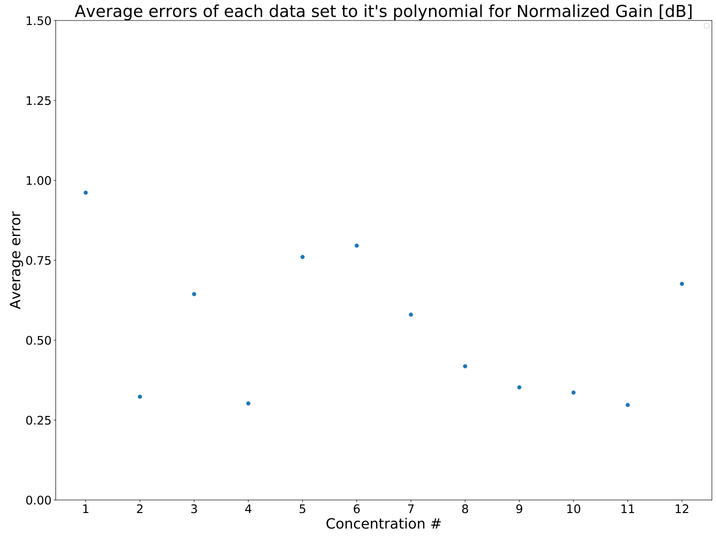

Figure 7.3: Average error of the Normalised Gain samples against the 2nd order polynomial for the 1.0MHz transducer

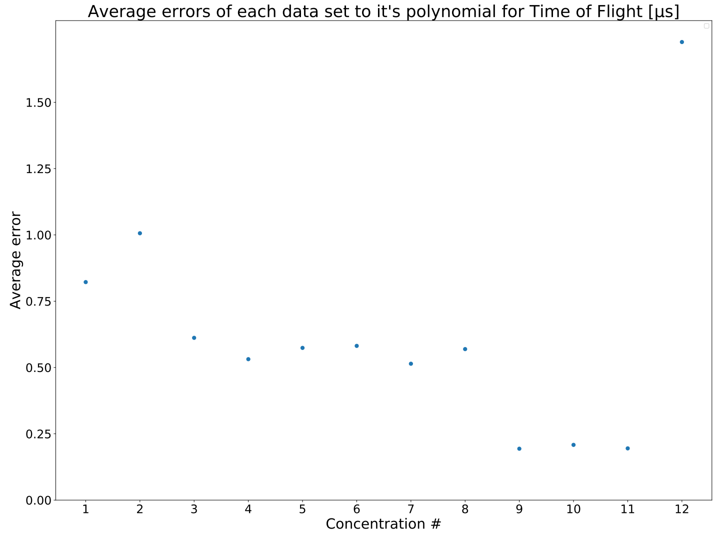

Figure 7.4: Average error of the Time of Flight samples against the 1st order polynomial for the 1.0MHz transducer

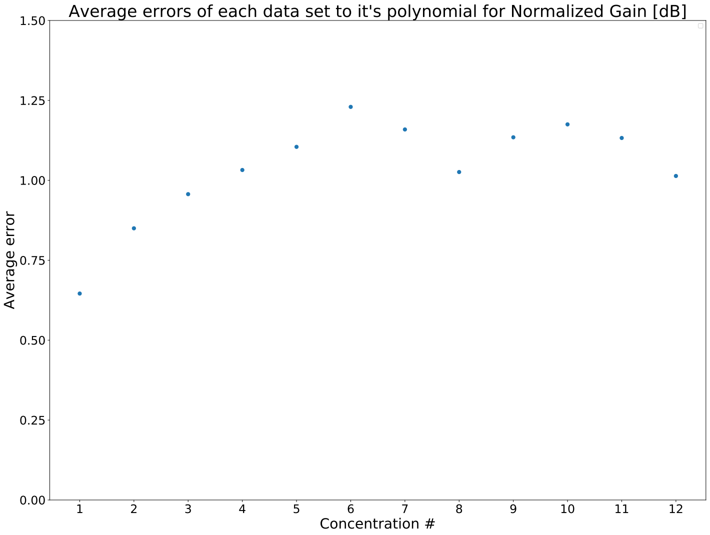

Figure 7.5: Average error of the Normalised Gain samples against the 2nd order polynomial for the 2.25MHz transducer

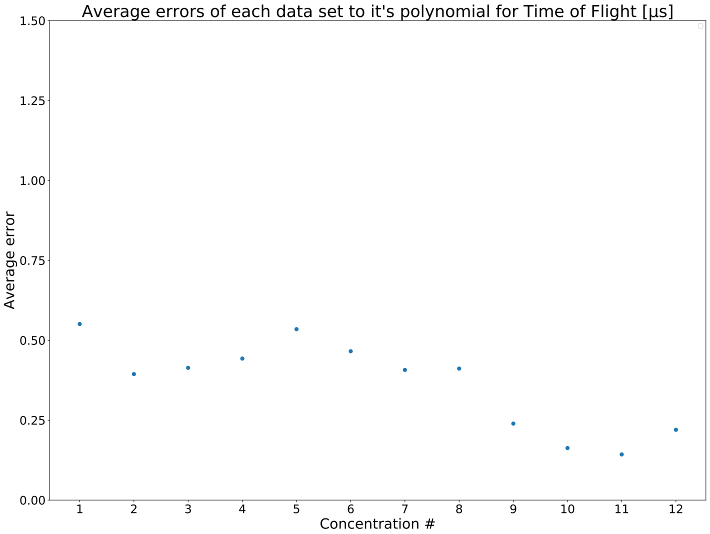

Figure 7.6: Average error of the Time of Flight samples against the 1st order polynomial for the 2.25MHz transducer

7.1 Concentration 12

The test labelled concentration 12 is an extra test done on concentration 11. This test was executed by Kenneth Mozie who did the previous experiments on the other drilling fluid and wrote a master thesis on a similar subject last year.[2] This was to establish if the current and previous measurements were comparable, and to help detect any human error during the rest of the experiments. Figures 7.7-7.12 shows the normalised gain and time of flight data for concentration 11 and 12 for each of the three transducers along with the fitted polynomials for each. It can be seen from these plots that the values are consistent for concentration 11 and 12 with the only points of concern being an outlier in the time of flight data for concentration 12 with the 1.0MHz transducer which is likely to be a human error, the outlier can be seen at 17cm in figure 7.10. Another difference is slightly lower normalised gain on four points near the end of one of the series for 1.0MHz for concentration 12, which can be seen at 31 to 37cm in figure 7.9. One more difference between the two datasets is that measurements have been taken further out for concentration 12 with the 1.0MHz and 2.25MHz transducers, the data furthest out were considered too noisy or with too low signal strength in measurements for concentration 11. The final values with concentration 12 were taken all the way down to 4% and signal strength up to 86dB Gain on the Epoch 1000 instrument, while concentration 11 stops at 84dB and 8% according to the experimental procedure detailed in chapter 6.5.

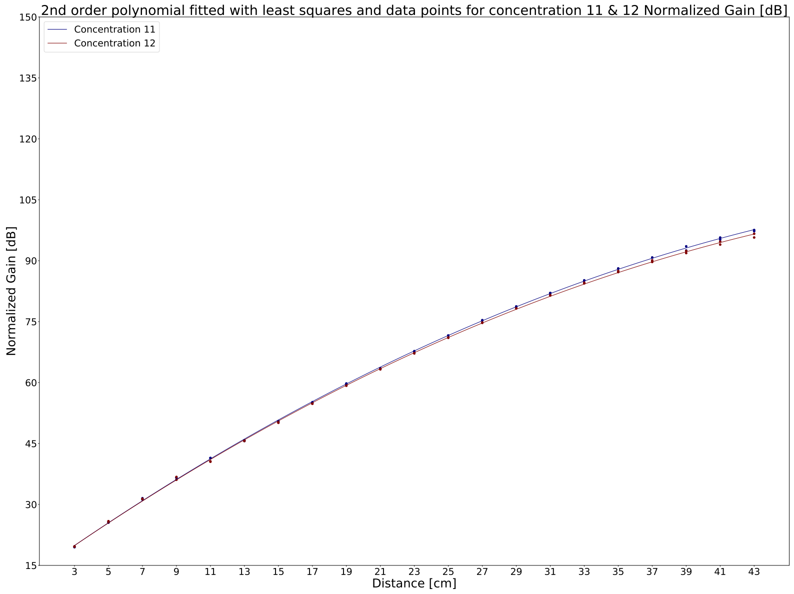

Figure 7.7: Concentration 11 vs Concentration 12 plot Normalised Gain for the 0.5MHz transducer

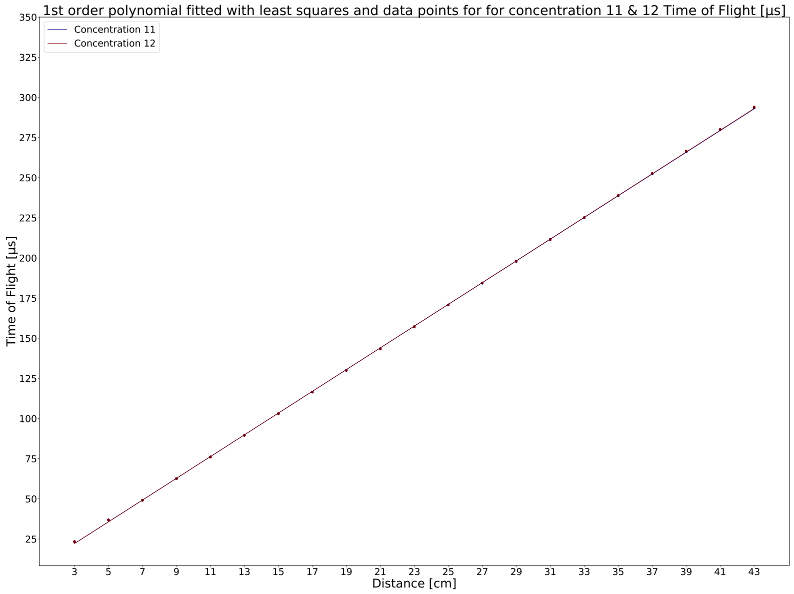

Figure 7.8: Concentration 11 vs Concentration 12 plot Time of Flight for the 0.5MHz transducer

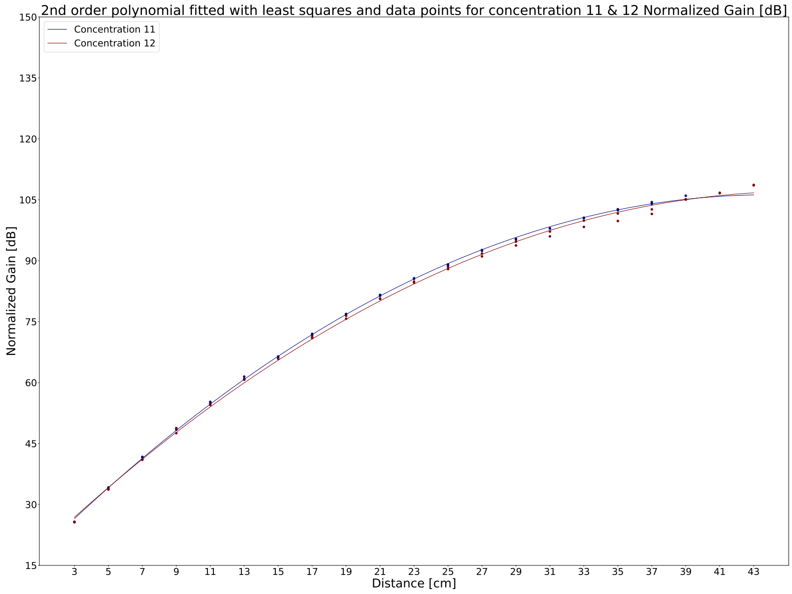

Figure 7.9: Concentration 11 vs Concentration 12 plot Normalised Gain for the 1.0MHz transducer

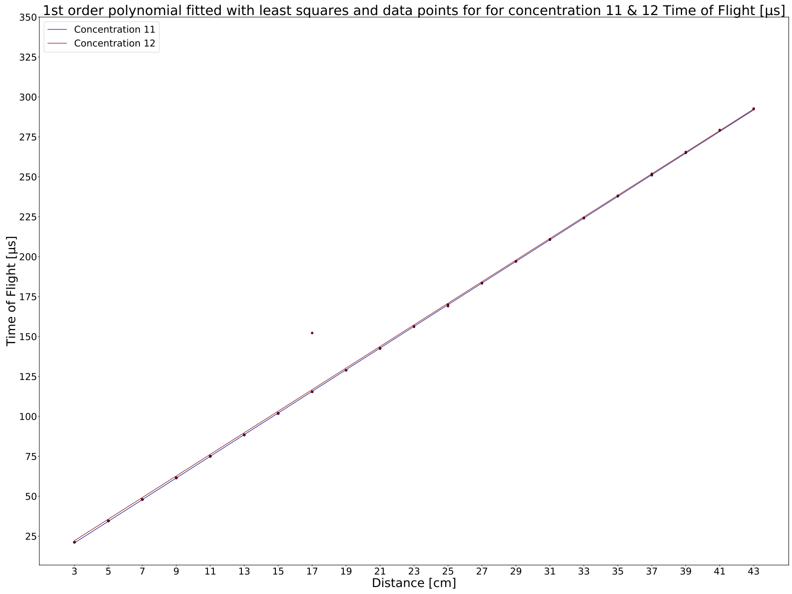

Figure 7.10: Concentration 11 vs Concentration 12 plot Time of Flight for the 1.0MHz transducer

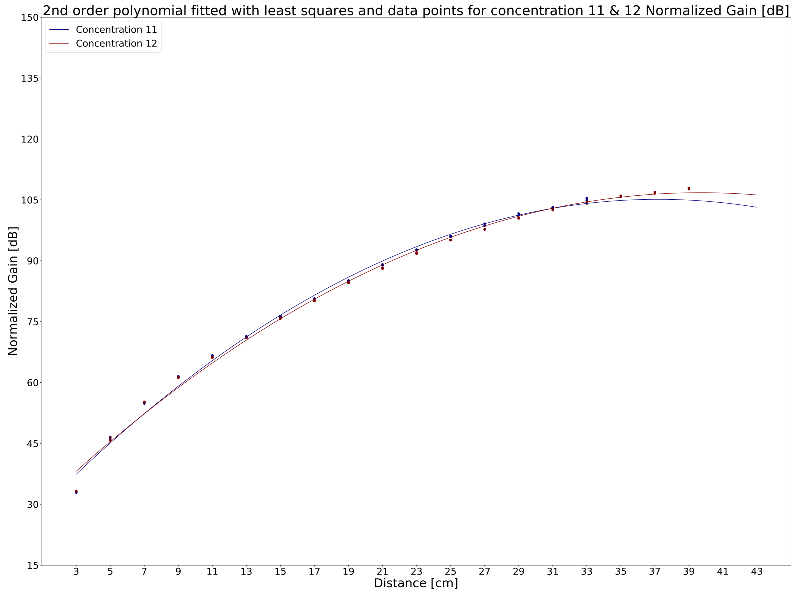

Figure 7.11: Concentration 11 vs Concentration 12 plot Normalised Gain for the 2.25MHz transducer

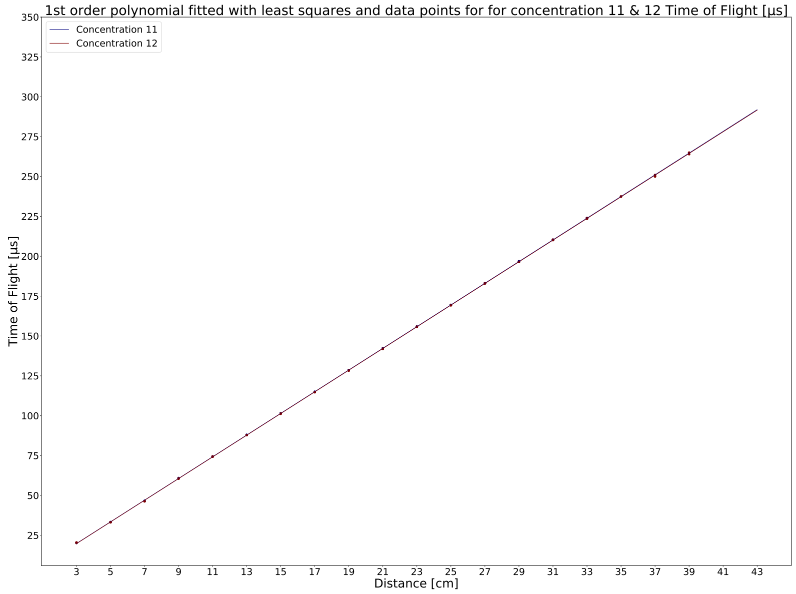

Figure 7.12: Concentration 11 vs Concentration 12 plot Time of Flight for the 2.25MHz transducer

8 Neural Network Models for Estimation of Rheological Properties

The platform used to create and train the neural networks for estimation of rheological properties is the TensorFlow software library for Python 3.5. The IDE used is Spyder, and a Python environment was created using Anaconda. Pandas library for python was used for organising the data.

The specific method used to create the regression networks is tf.DNNRegressor. This method is made to create dense neural networks for regression. The DNNRegressor method, other than being limited to fully connected regression networks, is also limited to using mean square error as the loss function. [34]

The code used to create, train, evaluate and plot the results of the neural networks can be found in appendix J

8.1 Training optimiser

The Adam optimiser in TensorFlow was chosen as the optimiser. One reason for selecting the Adam optimiser was that it, unlike the gradient descent optimiser in TensorFlow, allows for a continuous decay of learning rate without having to reload the training methods with a new learning rate in steps. The gradient descent optimiser was tried initially but because of this limitation it did not compete efficiently, showing more of a tendency to getting stuck in local minima. Another reason was that the Adam optimiser also has a stated function of training well with noisy gradients, which could be a factor given the sources of error described in chapter 6.5.2. [35]

8.2 Activation functions

The two activation functions that will be used for the models are relu6 and sigmoid.

8.2.1 Relu6

Relu6 is a variant of the relu activation function, Relu is short for rectified linear unit. Relu is a linear function that will not go below 0, and is defined as shown in equation 8.1.The relu6 activation function also has the additional upper constraint of 6. This means that the weighting difference of neurons is somewhat limited, which should limit over training to an extent. It also makes the part of the output that is before the decimal point limited to 3 bits, which makes large models use less memory. The memory concern is not really relevant for the size of models worked with here. Initial testing showed a better performance in loss from the relu6 function over regular relu. This could be because the limited output from the function keeps any one neuron from having too high an output and dominating the network. One of the drawbacks of the relu activation function is that it's not differentiable at every point and for values at or below 0 has a gradient of 0. Figure 8.1 shows the relu activation function, for relu6 this would be capped at 6, which is out of the plot range. [36]

$$y = \max(x, 0) \tag{8.1}$$

$$y = \min(\max(x, 0), 6) \tag{8.2}$$

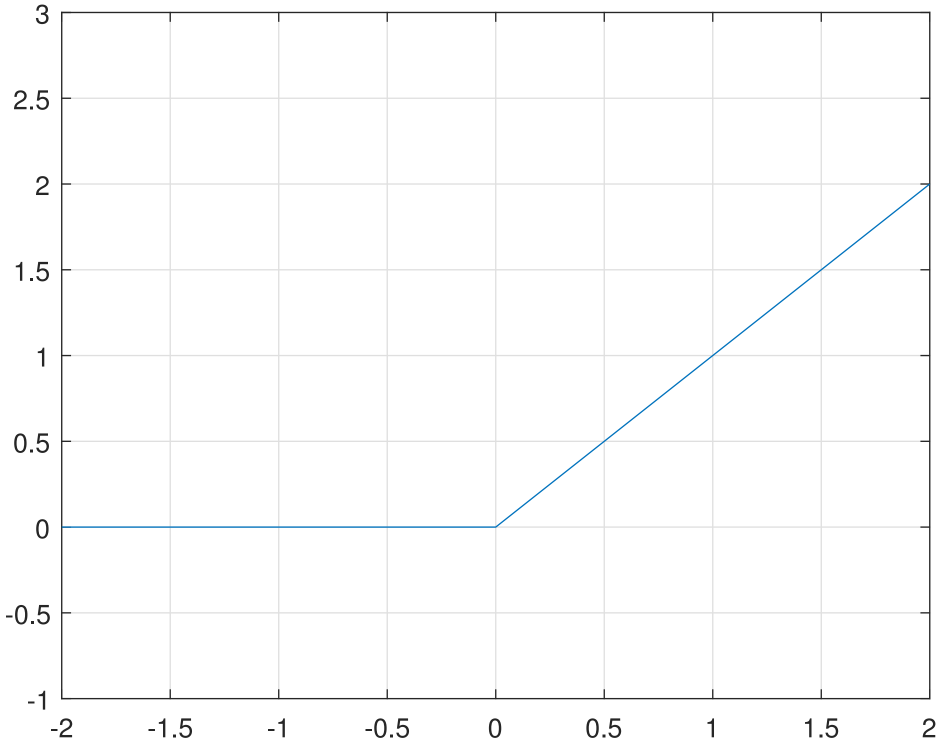

Figure 8.1: Relu activation function

8.2.2 Sigmoid

The sigmoid function is a commonly used activation function for neural networks, being a continuous function that is differentiable at all points and always has a gradient that is not zero. These properties makes the sigmoid function work well with simple gradient based solvers. The definition of the sigmoid function in TensorFlow is shown in equation 8.3. Figure 8.2 shows the sigmoid activation function. [37]

$$y = \frac{1}{1+e^{-x}} \tag{8.3}$$

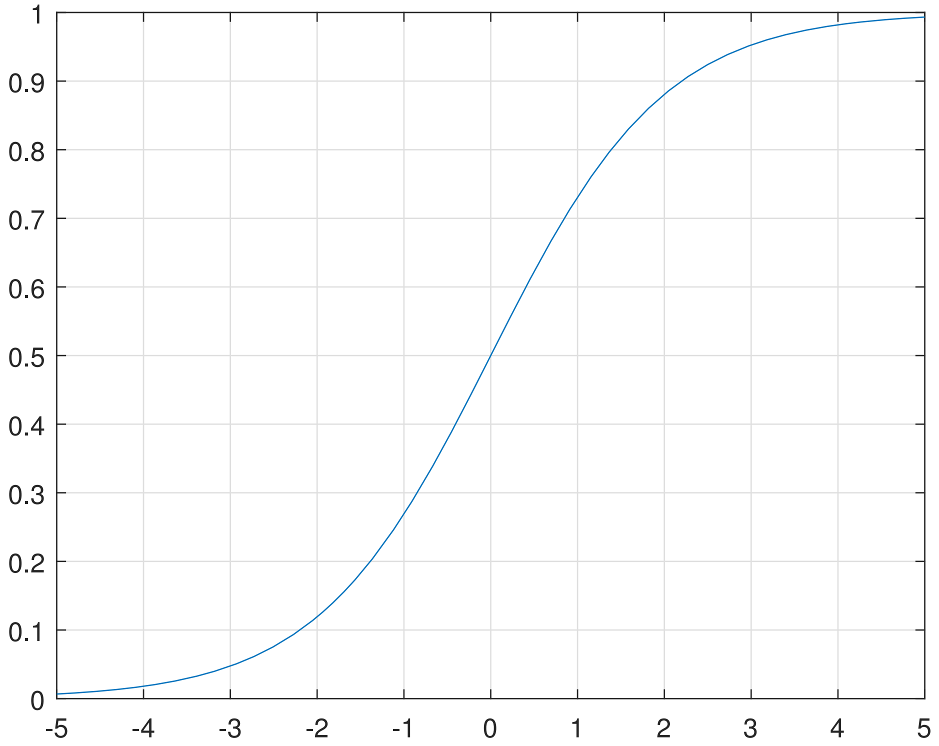

Figure 8.2: Sigmoid activation function

8.3 Regularisation with dropout

Dropout is a method of regularisation of neural networks, preventing over fitting to the training data by dropping out a portion of the neurons for any given training epoch. When a neuron is dropped out, all the input and output weights from that neuron is also not used or adjusted for that epoch. The dropout variable is a variable between 0 and 1 which indicates the chance that any given neuron is dropped out during a training epoch. Dropout has been showed to decrease over fitting of neural networks. Figure 8.3 shows a diagram of a neural network without dropout and one where the third neuron in the hidden layer is dropped out for the current training epoch. [38]

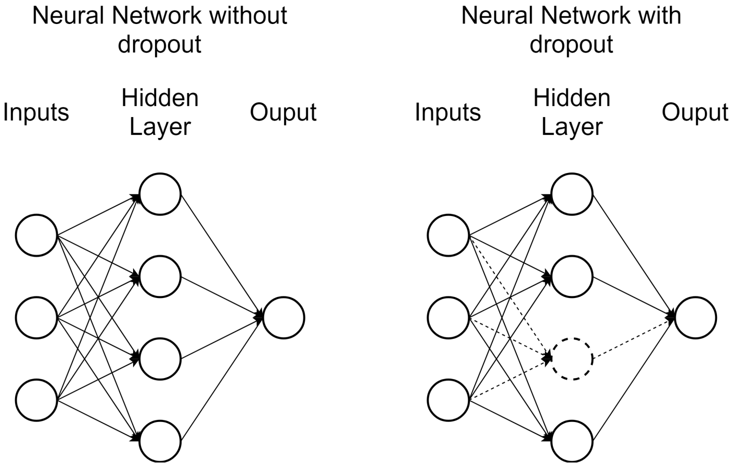

Figure 8.3: Neural network with and without dropout

8.4 Normalisation of data

Normalisation of data for neural networks is very important, especially when working with relu activation functions that outputs 0 for all input values under 0. It is also important when working with inputs with different metrics and units of measurement in order to give the inputs equal chance to effect the neurons weights during training. For the neural networks in this report, a linear 0 to 1 normalisation will be used with the formula shown in equation 8.4.

$$x_{normalised} = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{8.4}$$

8.5 Modified time of flight input

In an attempt to make the neural networks easier to train, two alternative inputs were created to the time of flight input variable. The alternative inputs were used in separate models. The first modified input was to use the time of flight and distance inputs to create a speed of sound input for each data point. Because the normalised gain input is still dependant on distance, the speed of sound input can only replace the time of flight input. The second modified input was to further modify the speed of sound input by taking an average for the drilling fluid concentration. As the rheological data for each drilling fluid is only one point, this will work as a filtering of the speed of sound data. This does however mean that the datasets, while having the same number of data points, has the same value for all the average speed of sound inputs for each fluid.

8.6 Randomisation of training data order and initial weights

Training data is input into the neural network in a random order for each epoch to avoid over training towards specific data points. In addition, the weights and biases that each neuron starts with is randomised in initialisation of the neural network. This means that there is an element of randomness in how the networks are trained, and subsequent training with the same network set-up will not get the exact same result.

8.7 Neural network configurations

Table 8.1 shows the primary neural network configurations that were tested. Some additional configurations were also tested for certain input and output combinations. Each number in the layer configuration is the number of neurons in that hidden layer, so that [9,18,9] signifies a neural network with 3 hidden layers, with 9 neurons in the first hidden layer, 18 in the second hidden layer and 9 in the third and final hidden layer. Other configuration parameters for the training of neural networks that were set based on initial trial and error is shown in table 8.2.

Table 8.1: Neural network configurations to test

Layer configuartion	Activation Function
[9]	relu6
[9,9]	relu6
[9,9,9]	relu6
[9,18,9]	relu6
[9,18,36,18,9]	relu6
[9,18,36,36,18,9]	relu6
[9,18,18,9]	relu6
[9,27,27,9]	relu6
[9,27,54,27,9]	relu6
[9,27,81,27,9]	relu6
[18]	relu6
[21]	relu6
[24]	relu6
[27]	relu6
[30]	relu6
[36]	relu6
[42]	relu6
[54]	relu6
[18]	sigmoid
[21]	sigmoid
[24]	sigmoid
[27]	sigmoid
[30]	sigmoid
[36]	sigmoid
[42]	sigmoid
[54]	sigmoid

Table 8.2: Neural network training parameters

Parameter	Value
Learning Rate	0.005
Dropout	0.2
Epochs	3000
Adam beta1	0.95
Adam beta2	0.999
Adam epsilon	1×10^{-8}

9 Results

This chapter details the results of training the neural networks and the resulting models. The neural networks are in two different categories, models trained with only data gathered as part of this thesis with the updated experimental procedure, and models trained with the full datasets that additionally includes the old data from previous work[2] and the new data. The raw data from the new experiments can be found in appendix G. The old data reorganised into spreadsheets that match the new data can be found in appendix K.

Tests were done on deeper neural networks with up to six layers, but they were consistently outperformed by the wider and shallower neural networks with single layer configuration. Because of limited time, deeper neural networks were only tested with time of flight and average speed of sound input variations, not with the calculated speed of sound for each individual data point as input. The reason the deep neural networks were the ones to be down prioritised due to lack of time is that these network configurations performed worst in all other input and output combinations.

The total number of neural networks trained for each dataset and output combination is over 250, taking the total number of neural networks trained for these results, with documented loss to over 2000. Appendix L and appendix M contains between them all the network configurations and their mean square error losses.

Mean square error, or MSE, is calculated directly by the TensorFlow as part of the evaluation process, the formula for calculating MSE from output and target values is shown in equation 9.1. The formula for calculating Root Mean Square Error from MSE is shown in equation 9.2. The lowest MSE also gives the lowest RMSE value. The MSE and RMSE values in this chapter will all be of data normalised to 0-1, which is in some cases converted to percentage of span.

$$\mathrm{MSE} = \frac{\sum(\mathrm{output} - \mathrm{target})^2}{n_{\mathrm{outputs}}} \tag{9.1}$$

$$\mathrm{RMSE} = \sqrt{\mathrm{MSE}} \tag{9.2}$$

9.1 New data neural networks

This section covers the neural network models that uses only the new data gathered during this thesis, and the stated best models have the lowest MSE of the networks trained with only new data for that output. The full list of neural networks trained with only the new data and their error as available can be found in appendix L. The data has been ordered by concentration number, with progressively more diluted drilling fluids from left to right in the plots in this section.

9.1.1 Density

Table 9.1 shows the best neural networks for each transducer and speed input combination for predicting density. The best model, as determined by mean square error, for density is the 2.25MHz, average speed of sound. This model has an RMSE of 0.051 or 5.1%, and a mean error of 4.3% of full span. The mean error equivalates to 0.0075g/cm^3. The evaluation of the best model is shown in figure 9.1. With one exception the relu6 activation function outperforms the sigmoid activation function for this model. All the best models for density with the new data are single hidden layer networks with between 42 and 60 neurons in the hidden layer.

Table 9.1: Best neural networks for density estimation with only new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[g/cm^3]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0043	5.1	0.0091	relu6	[54]
0.5MHz	Speed of Sound	0.0039	5.0	0.0089	relu6	[42]
0.5MHz	Average Speed of Sound	0.0028	4.2	0.0074	relu6	[54]
1.0MHz	Time of Flight	0.0047	5.4	0.0096	relu6	[42]
1.0MHz	Speed of Sound	0.0043	5.2	0.0091	sigmoid	[54]
1.0MHz	Average Speed of Sound	0.0030	4.2	0.0074	relu6	[60]
2.25MHz	Time of Flight	0.0038	5.1	0.0091	relu6	[42]
2.25MHz	Speed of Sound	0.0039	5.2	0.0091	relu6	[42]
2.25MHz	Average Speed of Sound	0.0026	4.3	0.0075	relu6	[42]

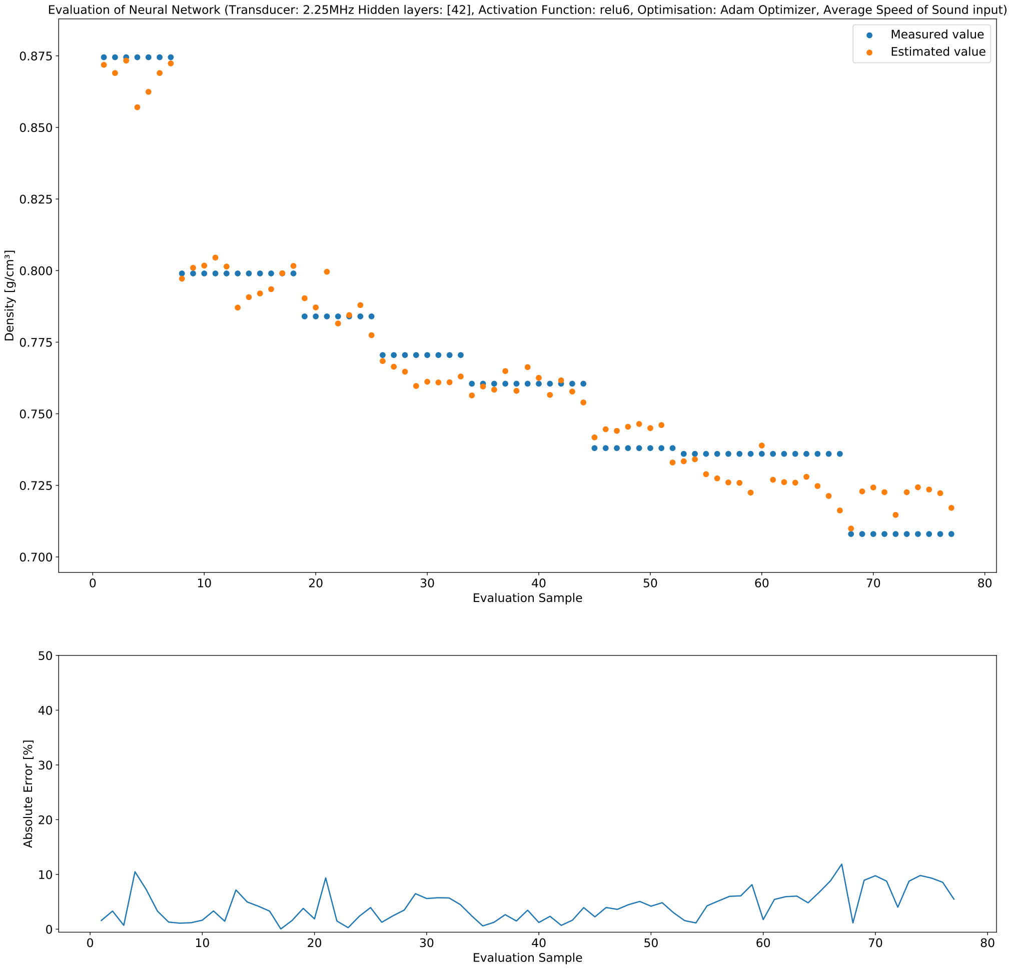

Figure 9.1: Lowest MSE neural network for density with new data

9.1.2 Yield point

Table 9.2 shows the best neural networks for each transducer and speed input combination for predicting yield point. The best model, as determined by mean square error, for yield point is the 2.25MHz, average speed of sound. This model has an RMSE of 0.036 or 3.6%, and a mean error of 3.1% of full span. The mean error equivalents to 0.062Pa. The evaluation of the best model is shown in figure 9.2. For this yield point model, the relu6 activation function performed best for time of flight and average speed of sound inputs, while sigmoid performed better for the speed of sound input. All the best models of this type were single hidden layer networks with between 27 and 54 neurons in the hidden layer.

Table 9.2: Best neural networks for yield point estimation with only new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[Pa]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0034	4.1	0.084	relu6	[42]
0.5MHz	Speed of Sound	0.0029	4.2	0.085	sigmoid	[54]
0.5MHz	Average Speed of Sound	0.0020	3.2	0.066	relu6	[42]
1.0MHz	Time of Flight	0.0022	3.4	0.069	relu6	[30]
1.0MHz	Speed of Sound	0.0026	4.0	0.082	sigmoid	[27]
1.0MHz	Average Speed of Sound	0.0016	3.0	0.061	relu6	[42]
2.25MHz	Time of Flight	0.0027	4.3	0.086	relu6	[27]
2.25MHz	Speed of Sound	0.0033	4.6	0.094	sigmoid	[54]
2.25MHz	Average Speed of Sound	0.0013	3.1	0.062	relu6	[42]

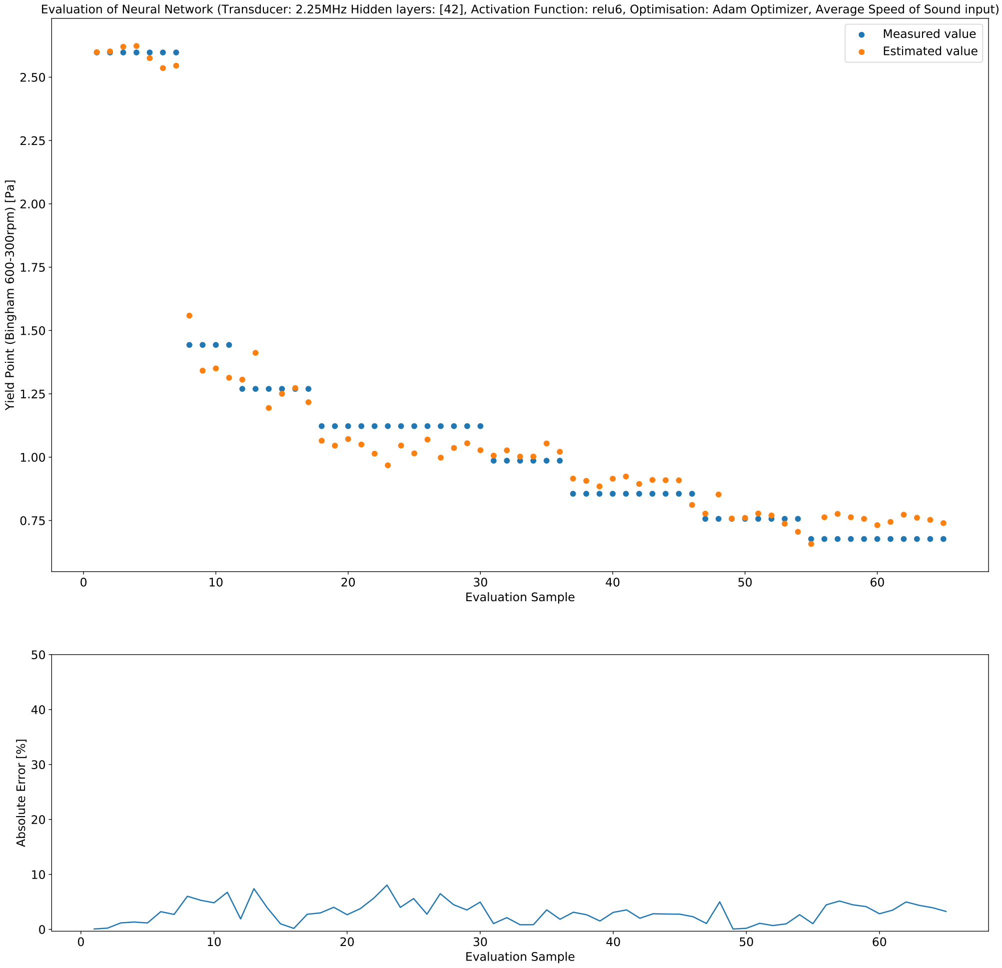

Figure 9.2: Lowest MSE neural network for yield point with new data

9.1.3 Gel strength

Table 9.3 shows the best neural networks for each transducer and speed input combination for predicting gel strength. The best model, as determined by mean square error, for gel strength is the 2.25MHz, average speed of sound. This model has an RMSE of 0.037 or 3.7%, and a mean error of 2.9% of full span. The mean error equivalents to 0.044Pa. The evaluation of the best model is shown in figure 9.3. Similarly to the yield point models, the gel strength models for new data had relu6 performing best for time of flight and average speed of sound input while sigmoid performed best for the speed of sound input models. The best models were all single hidden layer models with between 21 and 54 neurons in the hidden layer.

Table 9.3: Best neural networks for gel strength estimation with only new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[Pa]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0036	4.4	0.067	relu6	[30]
0.5MHz	Speed of Sound	0.0038	4.4	0.068	sigmoid	[36]
0.5MHz	Average Speed of Sound	0.0025	3.5	0.054	relu6	[42]
1.0MHz	Time of Flight	0.0019	3.4	0.052	relu6	[27]
1.0MHz	Speed of Sound	0.0032	4.4	0.067	sigmoid	[21]
1.0MHz	Average Speed of Sound	0.0016	3.1	0.048	relu6	[54]
2.25MHz	Time of Flight	0.0021	3.7	0.058	relu6	[30]
2.25MHz	Speed of Sound	0.0019	3.6	0.056	sigmoid	[54]
2.25MHz	Average Speed of Sound	0.0014	2.9	0.044	relu6	[54]

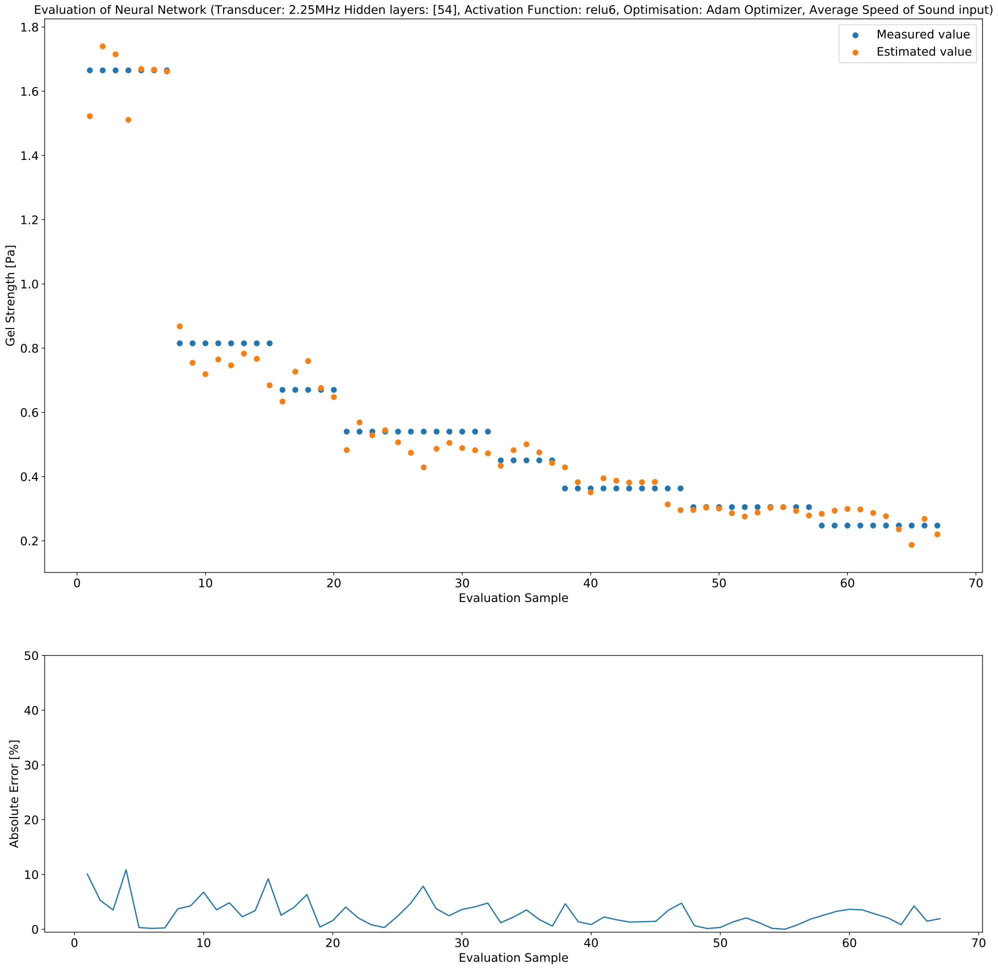

Figure 9.3: Lowest MSE neural network for gel strength with new data

9.1.4 Plastic viscosity

Table 9.4 shows the best neural networks for each transducer and speed input combination for predicting plastic viscosity. The best model, as determined by mean square error, for plastic viscosity is the 2.25MHz, average speed of sound. This model has an RMSE of 0.037 or 3.7%, and a mean error of 3.0% of full span. The mean error equivalents to 0.11mPas. The evaluation of the best model is shown in figure 9.4. Most of the model variations performed best with relu6 activation function for the plastic viscosity models. All the best models for predicting plastic viscosity with only the new data were single hidden layer networks with either 42 or 54 neurons in the hidden layer.

Table 9.4: Best neural networks for plastic viscosity estimation with only new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[mPas]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0035	4.7	0.17	relu6	[54]
0.5MHz	Speed of Sound	0.0034	4.3	0.15	relu6	[54]
0.5MHz	Average Speed of Sound	0.0027	3.8	0.14	sigmoid	[54]
1.0MHz	Time of Flight	0.0022	3.7	0.13	relu6	[42]
1.0MHz	Speed of Sound	0.0028	4.3	0.15	sigmoid	[42]
1.0MHz	Average Speed of Sound	0.0020	3.5	0.12	relu6	[42]
2.25MHz	Time of Flight	0.0033	4.7	0.17	relu6	[54]
2.25MHz	Speed of Sound	0.0022	3.8	0.13	relu6	[54]
2.25MHz	Average Speed of Sound	0.0014	3.0	0.11	relu6	[42]

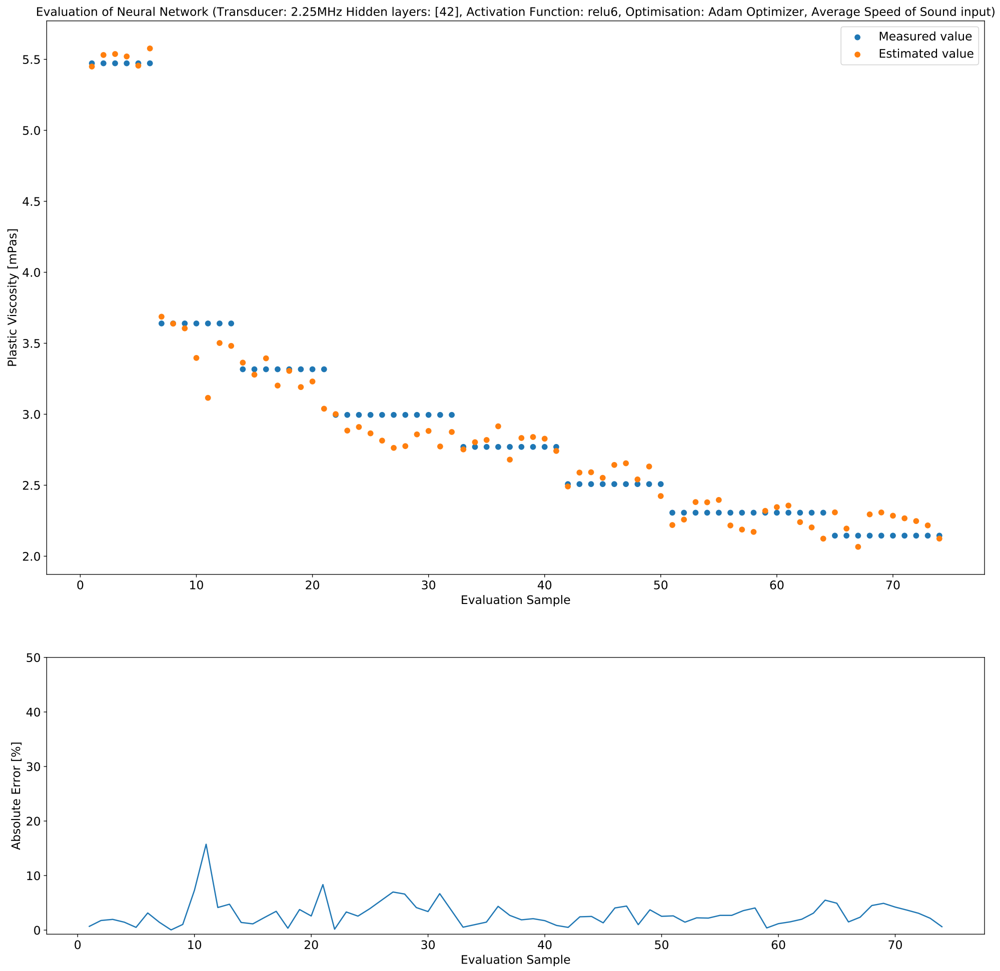

Figure 9.4: Lowest MSE neural network for plastic viscosity with new data

9.2 Full data neural networks

This section covers the neural network models that uses all the new data gathered during this thesis and the old data gathered previously[2], and the stated best models have the lowest MSE of the networks trained with full data for that output. The full list of neural networks trained with the full datasets and their error as available can be found in appendix M. The data has been ordered with the new datasets produced in this thesis first and old data from previous work, then by concentration number, with progressively more diluted drilling fluids in the plots in this section.

9.2.1 Density

Table 9.5 shows the best neural networks for each transducer and speed input combination for predicting density. The best model, as determined by mean square error, for density is the 2.25MHz, average speed of sound. This model has an RMSE of 0.027 or 2.7%, and a mean error of 2.1% of full span. The mean error equivalates to 0.014g/cm^3. The evaluation of the best model is shown in figure 9.5. All of the model variations performed best with sigmoid activation functions and with single hidden layer networks. The number of neurons in the hidden layers vary between 27 and 54.

Table 9.5: Best neural networks for density estimation with old and new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[g/cm^3]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0037	4.5	0.030	sigmoid	[54]
0.5MHz	Speed of Sound	0.0034	4.2	0.027	sigmoid	[54]
0.5MHz	Average Speed of Sound	0.00089	2.2	0.014	sigmoid	[36]
1.0MHz	Time of Flight	0.0019	3.2	0.021	sigmoid	[54]
1.0MHz	Speed of Sound	0.0016	2.9	0.019	sigmoid	[30]
1.0MHz	Average Speed of Sound	0.00080	2.3	0.015	sigmoid	[54]
2.25MHz	Time of Flight	0.0015	3.0	0.020	sigmoid	[30]
2.25MHz	Speed of Sound	0.0010	2.2	0.015	sigmoid	[27]
2.25MHz	Average Speed of Sound	0.00074	2.1	0.014	sigmoid	[42]

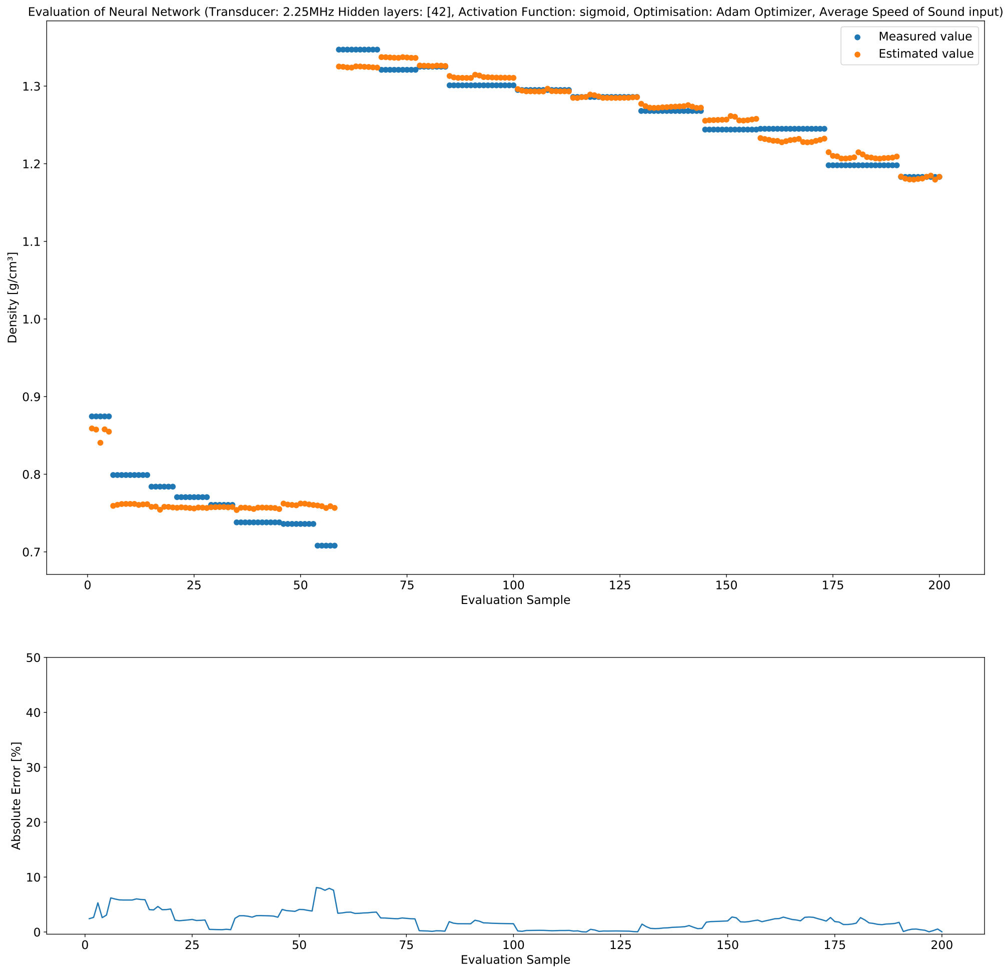

Figure 9.5: Lowest MSE neural network for density with full data

9.2.2 Yield point

Table 9.6 shows the best neural networks for each transducer and speed input combination for predicting yield point. The best model, as determined by mean square error, for yield point is the 2.25MHz, average speed of sound. This model has an RMSE of 0.022 or 2.2%, and a mean error of 1.6% of full span. The mean error equivalents to 0.27Pa. The evaluation of the best model is shown in figure 9.6. Most of the model variations performed best with relu6 activation function. All of the best performing models are single hidden layer networks with somewhere between 24 and 54 neurons in the hidden layer.

Table 9.6: Best neural networks for yield point estimation with old and new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[Pa]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0073	6.1	1.0	relu6	[36]
0.5MHz	Speed of Sound	0.0047	5.1	0.84	sigmoid	[42]
0.5MHz	Average Speed of Sound	0.00084	2.1	0.35	sigmoid	[24]
1.0MHz	Time of Flight	0.0056	5.3	0.88	relu6	[30]
1.0MHz	Speed of Sound	0.0030	3.9	0.65	relu6	[42]
1.0MHz	Average Speed of Sound	0.0012	2.7	0.45	relu6	[54]
2.25MHz	Time of Flight	0.0039	4.5	0.75	relu6	[42]
2.25MHz	Speed of Sound	0.0016	2.7	0.45	relu6	[54]
2.25MHz	Average Speed of Sound	0.00047	1.6	0.27	relu6	[54]

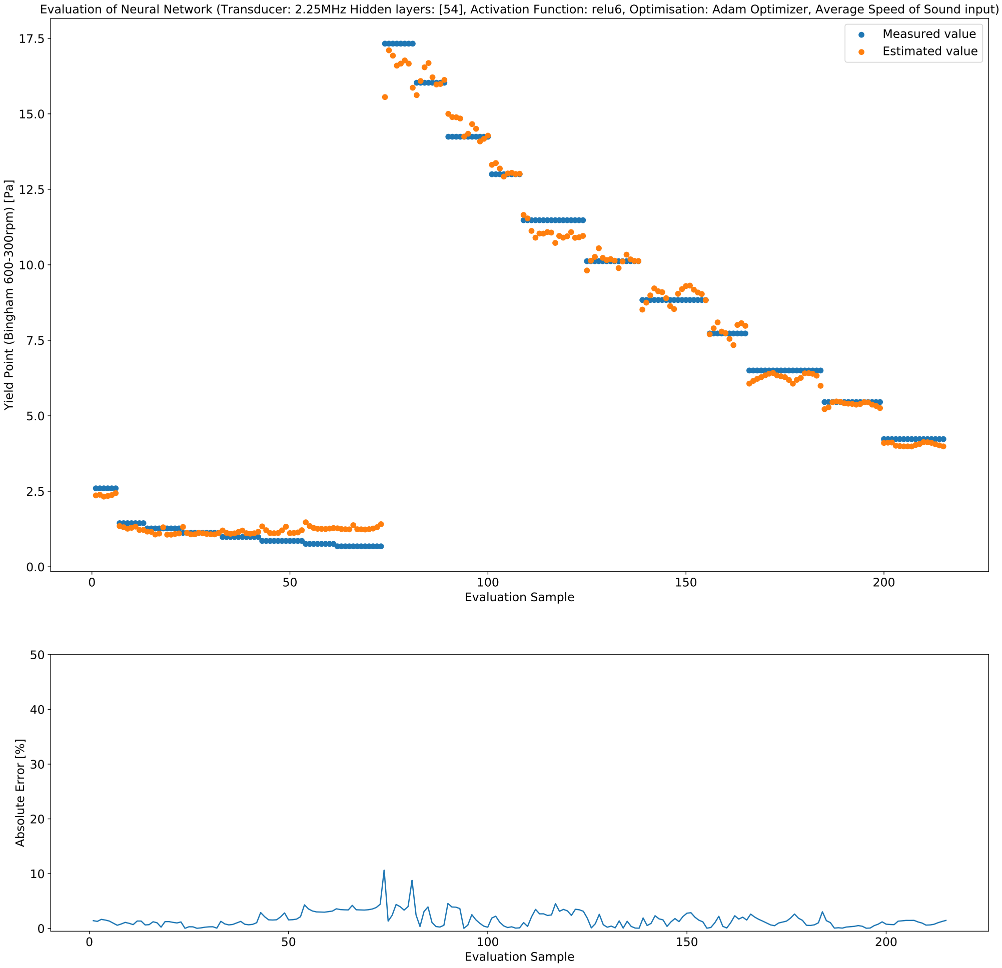

Figure 9.6: Lowest MSE neural network for yield point with full data

9.2.3 Gel strength

Table 9.7 shows the best neural networks for each transducer and speed input combination for predicting gel strength. The best model, as determined by mean square error, for gel strength is the 2.25MHz, average speed of sound. This model has an RMSE of 0.017 or 1.7%, and a mean error of 1.3% of full span. The mean error equivalents to 0.20Pa. The evaluation of the best model is shown in figure 9.7. The best models are all except two using the relu6 activation function, the two exceptions both using the average speed of sound input. All the best models are single hidden layer networks with between 30 and 54 neurons in the hidden layer.

Table 9.7: Best neural networks for gel strength estimation with old and new data

Transducer	Sound Input	Mean Square Error	Mean Error [%]	Mean Error ±[Pa]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0056	5.5	0.82	relu6	[42]
0.5MHz	Speed of Sound	0.0036	4.4	0.65	relu6	[36]
0.5MHz	Average Speed of Sound	0.0011	2.4	0.36	sigmoid	[54]
1.0MHz	Time of Flight	0.0059	5.8	0.86	relu6	[30]
1.0MHz	Speed of Sound	0.0034	3.4	0.51	relu6	[36]
1.0MHz	Average Speed of Sound	0.0017	2.8	0.41	sigmoid	[36]
2.25MHz	Time of Flight	0.0048	5.2	0.78	relu6	[42]
2.25MHz	Speed of Sound	0.0016	2.9	0.43	relu6	[42]
2.25MHz	Average Speed of Sound	0.00028	1.3	0.20	relu6	[54]

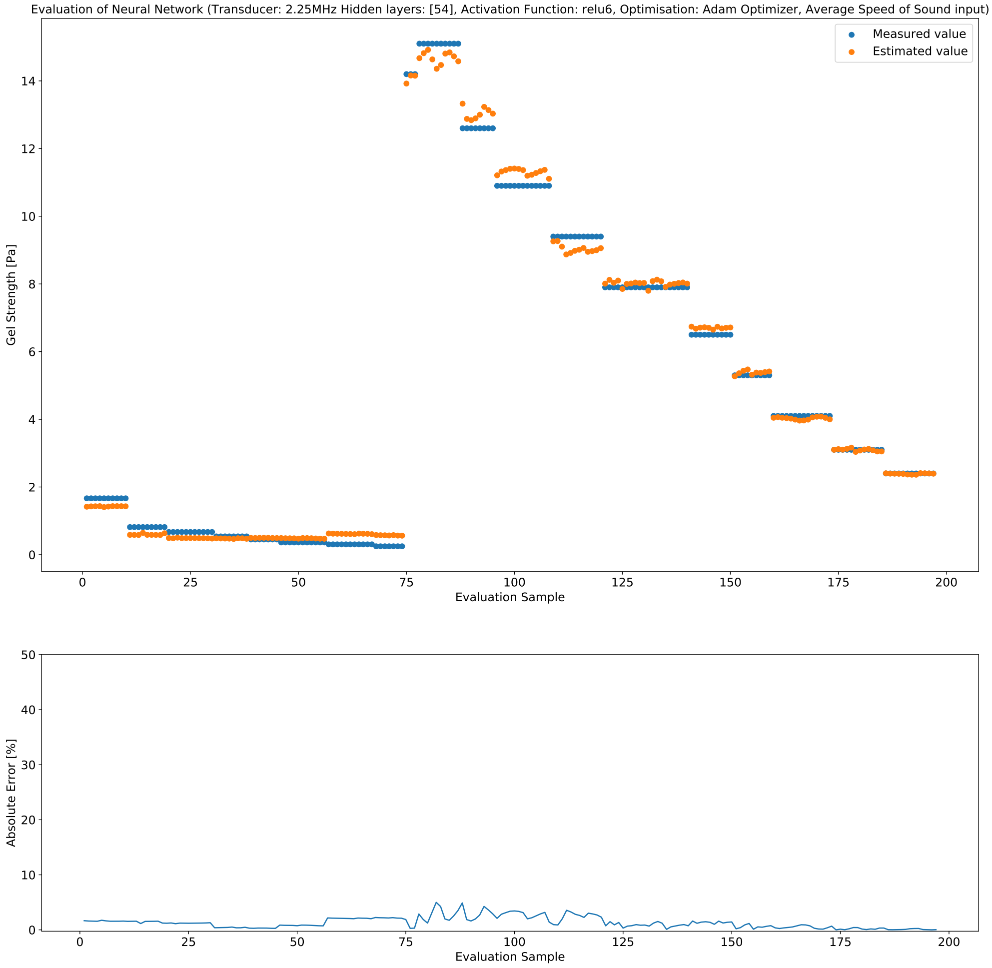

Figure 9.7: Lowest MSE neural network for gel strength with full data

9.2.4 Plastic viscosity

Table 9.8 shows the best neural networks for each transducer and speed input combination for predicting plastic viscosity. The best model, as determined by mean square error, for plastic viscosity is the 1.0MHz, average speed of sound. This model has an RMSE of 0.030 or 3.0%, and a mean error of 2.4% of full span. The mean error equivalents to 0.89mPas. The evaluation of the best model is shown in figure 9.8. The best models are all except one using the relu6 activation function, the exception however is one of the best performing networks, with the lowest mean error. All the best models are single hidden layer networks with between 36 and 54 neurons in the hidden layer.

Table 9.8: Best neural networks for plastic viscosity estimation with old and new data

Transducer	Speed Input	Mean Square Error	Mean Error [%]	Mean Error ±[mPas]	Activation Function	ANN Setup
0.5MHz	Time of Flight	0.0065	5.8	2.2	relu6	[42]
0.5MHz	Speed of Sound	0.0041	4.8	1.8	relu6	[36]
0.5MHz	Average Speed of Sound	0.00096	2.3	0.87	relu6	[54]
1.0MHz	Time of Flight	0.0064	5.4	2.0	relu6	[54]
1.0MHz	Speed of Sound	0.0019	3.4	1.3	relu6	[54]
1.0MHz	Average Speed of Sound	0.00088	2.4	0.89	relu6	[42]
2.25MHz	Time of Flight	0.0038	4.8	1.8	relu6	[54]
2.25MHz	Speed of Sound	0.0013	2.7	1.0	relu6	[54]
2.25MHz	Average Speed of Sound	0.00089	2.1	0.78	sigmoid	[36]

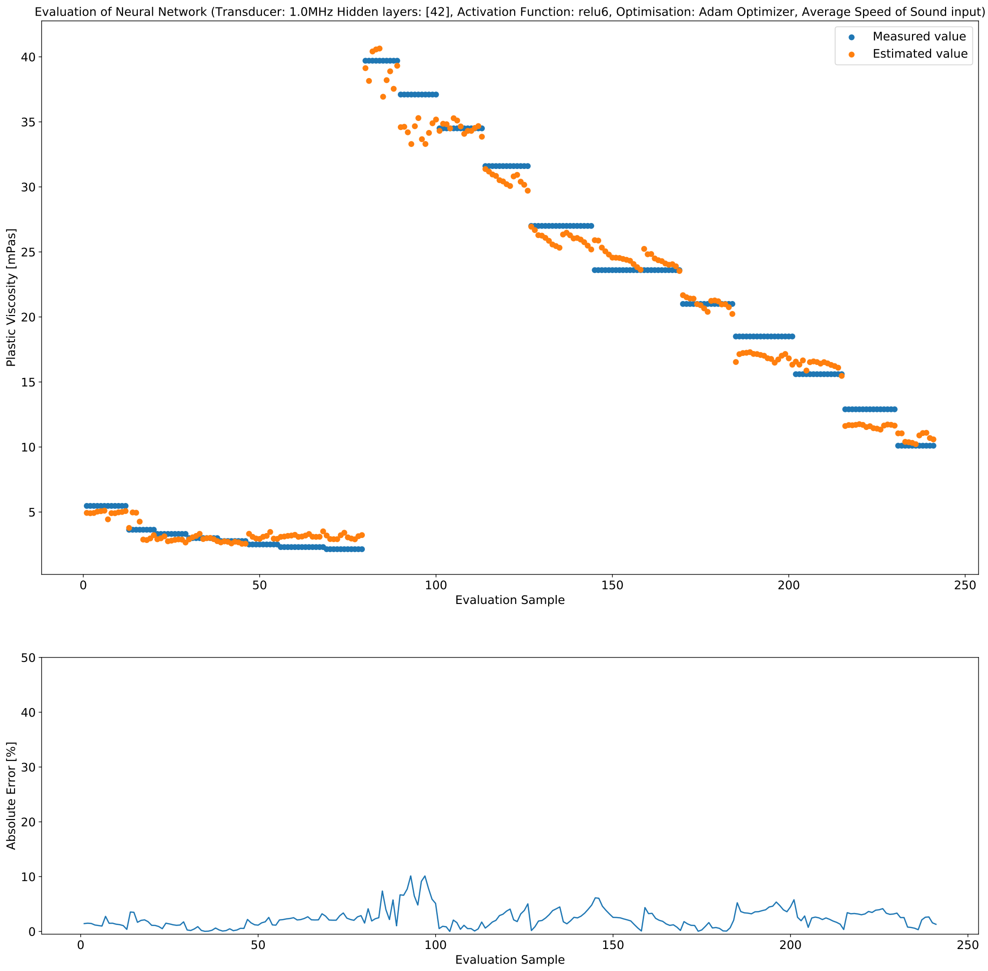

Figure 9.8: Lowest MSE neural network for plastic viscosity with full data

9.3 Comparing results

For all but one of the outputs, the best performing neural network model is the 2.25MHz transducer with average speed of sound replacing the time of flight input. The one exception is the plastic viscosity with the full dataset, but as can be seen in table 9.8, the mean square error of the best model with the 1.0MHz transducer with average speed of sound input is very close to the mean square error of the 2.25MHz model, and the 2.25MHz model has a significantly lower mean error, which probably makes it a better model overall. The averaging of the speed of sound input is however a bit over simplified, as in a real world system the inputs will vary slightly with imperfect mixing and noise even with filtering. One trend going through all of the neural network models that use all the data is that the neural networks with speed of sound replacing time of flight perform better, both the averaged and not averaged input.

It can be seen in all of the full data neural network models that the new data has a significantly lower amount of data and for all but the density also has a significantly lower variation within the normalised span. The result of this is that the full data models estimate the larger part of the new data significantly worse than for the old data, and in some cases as an average, or close to an average, of the new data. The reason the data amount is lower for the new data is some issues with three of the concentrations as well as higher dampening and a slightly more stringent requirement for data quality with the higher signal strength lower limit.

The lowest percentage of span absolute error and lowest RMSE model is the 2.25MHz and average speed of sound input model for Gel Strength on the full dataset at 1.3% absolute error and 1.7% RMSE. This model has a 0.20Pa mean error, while the new data equivalent has an equivalent error of 0.044Pa with 2.9% mean error and 3.7% RMSE.

10 Discussion

This chapter contains points of improvement and discussion around the methods and results found in this report.

10.1 Signal strength and cuttings

With the clean drilling fluid without cuttings, significant gas bubbles or anything else that might further scatter or absorb the signal from the transducers, the signal only penetrates 25-33cm for the original concentration of the drilling fluid. This could cause problem in an implemented system as it will mean the sensors need to be mounted close together to get a good signal, especially as the best models use the 2.25MHz sensor which has the lower end of the penetration length at 25cm in the clean fluid.

10.2 Implementation of rheometer

The experiments and analysis done in this report has been on a stationary drilling fluid. Because drilling fluids are non-Newtonian fluids, they change properties based on flow rates, this might effect both signal strength and travel time in the fluids. Given these limitations, the results found in this report cannot be directly applied to a flowing drilling fluid. This means that for this method of estimating rheological properties to be implemented, the drilling fluids needs to be stationary. One way of doing the measurements at rest in a drilling operation is to do the measurements in the shaker tank, which is the tank after the returned drilling fluid has been filtered of larger pieces of shale by the shaker, or the mud pits where drilling fluid is stored before being pumped back into circulation. This will also mean that large pieces of shale are not available in the fluid to block or scatter the signal further. [39] One limitation of this is the delay in any detection of change in the rheological properties of the drilling fluid caused by the time taken for the fluid to get to and through the shaker. Another method of implementation would be to create an instrument that separates a sample from the return flow and takes the measurements before releasing it back into the return flow. This would require mechanical parts and filtering in order to take a representative sample from the flow, and will require extensive design where the corrosive nature of the environment and potential for clogging of the sample chamber is considered.

10.3 Continuous data for increasing accuracy

Neural networks to a point gets better when they are trained with more, more varied, and better data. If the method can be further tested, it is possible to continue to train the neural networks with more data. It is also possible if the system is implemented to continue doing rheological analysis and storing the raw ultrasound data during operation, and then use this data to improve the soft sensor over time.

10.4 Deterioration detection

If the sensor technology laid out and tested in this report is found to not have high enough accuracy to be used as a continuous estimation of rheological properties in drilling fluids, there is one other option that can be explored. The experiments show that the rheological properties of a fluid has an effect on the ultrasonic signal, if a reliable baseline for the drilling fluid being used can be established, it might be possible to create a neural network that gives an alarm when the rheology of the drilling fluid changes too much. In order to train a neural network for such an alarm system, the baseline needs to be set for the fluid being used as well as deteriorated fluid for training the alarm condition. This type of system would not be able to replace offline measurements of rheology, but might provide additional safety by giving an early warning of change in rheology of the drilling fluid.

10.5 Experimental data quality and quantity

The experimental data used in analysis and training the neural network is unfiltered and manually read data from an analytics instrument. For further work on this type of system, it is highly recommended to set up an automated setup that will allow for larger amounts of measurements at the same distances within less time, so that the data can be filtered to reduce error, and better networks can be trained with the increased amount of data. An automated setup will also lower the impact of human error or slight differences in methodology between people running the experiments, and thus might make the samples more reproducible.

10.6 Co-variance, limitations of diluting the fluid

Diluting the fluids, as have been done for the experiments in this thesis, changes all the rheological properties at once. Because of this, it is impossible to say for certain which of the rheological properties the sensors are picking up on, and which just varies along because of the dilution of fluids. In order to fully evaluate neural networks for estimation of rheological properties, the networks should be tested with more varied drilling fluids and with better control over rheological properties. For testing and implementing the discussed concept in chapter 10.4 of an alarm system for detecting deterioration of drilling fluids rather than estimating the rheological properties, drilling fluid should be shear deteriorated or otherwise deteriorated in other ways rather than just dilution for testing and calibration to ensure that the alarm system can pick up on other types of deterioration than just influx of water.

10.7 Sophisticated learning rates and regularisation

There are more sophisticated methods of adjusting learning rates and more complex regularisation methods that might provide better results for the neural networks, it is however not trivial to implement in TensorFlow with the DNNRegressor class, and implementation would increase run-time of training, as training would have to be cancelled and restarted with every outside adjustment of learning rate and with every check of the evaluation or testing data.

11 Conclusion

The experiments were carried out according to the experimental procedure, there was however an issue in three of the concentrations, causing the data to be unsuitable for the training of the neural network models.

The neural network models trained and tested with only new data showed the ability to detect changes in the rheological properties as the drilling fluid was diluted, as did the neural network models trained with the combined new and old data, though with the lower amount of data and span in the new data, the full data models were over trained towards the old data to a degree. The best performing models were wide networks, with a single hidden layer of between 24 and 54 neurons, and with the time of flight input converted to an average speed of sound input for that concentration. For the most part, relu6 activation function performed better than sigmoid for the models, with the primary exception of sigmoid activation function performing better on all the full dataset density models. There were also exceptions where the sigmoid function performed better for specific pairings of inputs and outputs, in particular performing better on Yield Point and Gel Strength models with speed of sound input replacing time of flight.

The best model based on error of full span was the gel strength model for the full dataset with 1.3% absolute error and 1.7% RMSE. Table 11.1 shows the best model results found for each output with new data and with full data.

Table 11.1: Overview of the best model results for new and full datasets, for each output

Output	Dataset	MSE	RMSE	Mean Error	Mean Error
Density	New only	0.26 [%]	5.1 [%]	4.3 [%]	0.0075 [g/cm^3]
Yield Point	New only	0.13 [%]	3.6 [%]	3.1 [%]	0.062 [Pa]
Gel Strength	New only	0.14 [%]	3.7 [%]	2.9 [%]	0.044 [Pa]
Plastic Viscosity	New only	0.14 [%]	3.8 [%]	3.0 [%]	0.11 [mPas]
Density	Full set	0.074 [%]	2.7 [%]	2.1 [%]	0.014 [g/cm^3]
Yield Point	Full set	0.046 [%]	2.2 [%]	1.6 [%]	0.27 [Pa]
Gel Strength	Full set	0.028 [%]	1.7 [%]	1.3 [%]	0.20 [Pa]
Plastic Viscosity	Full set	0.088 [%]	3.0 [%]	2.4 [%]	0.89 [mPas]

As the fluids have been diluted by stages with no other way of changing the rheological properties of the drilling fluids, it is hard to conclude what changes in the drilling fluids that the models are picking up on, as they are all co-varying with the step-wise dilution.

It can be observed in table 11.1 that the neural networks have better percentage error on the larger span from using both datasets, but the absolute error in the output units are higher. This shows the importance of calibrating the model to the expected span of output values for implementation.

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[39] D. Williamson, "Drilling fluid basics", *Oilfield Review Spring*, vol. 25, no. 1, 2013. [Online]. Available: `https://www.slb.com/resources/oilfield_review/~/media/Files/resources/oilfield_review/ors13/spr13/defining_fluids.ashx`.

Appendix A

Task Description

This appendix contains the final version of the task description that outlines the work of this thesis.

FMH606 Master's Thesis

Title: Characterization of rheological properties of drilling fluids using ultrasonic waves

HSN supervisor: Håkon Viumdal (main supervisor), Morten Hansen Jondahl (co-supervisor) and Saba Mylvaganam (co-supervisor)

External partner: Geir Elseth, Statoil

Task background:
There is a need of enhanced drilling operation for oil and gas, to increase the cost-efficiency, and simultaneously maintain or improve the safety of these operations. Thus, there is currently an increased research activity on improving the drilling operation by enhancement of sensor and control systems. As a part of the sensor research, ultrasonic measurements are evaluated for flow rate estimation and for estimation of rheological properties of the drilling fluids.
As a basis for this research, this master thesis emphasize on how ultrasonic waves, in drilling fluids, are influenced by variations of rheological properties. In summer 2017, a series of experiments were performed at USN and Statoil on drilling fluids with different concentrations under static conditions. Both ultrasonic and rheological properties were measured. Initial analysis of the collected dataset was performed, and published at IEEE IUS, Autumn 2017. To generate an improved model that covers a larger range of densities, some new experiments are to be made. Hence, the student will have both practical and theoretical work in this project,

Task description:

1. Brief literature study of oil/gas drilling, emphasizing the flow loop of the drilling fluid.
2. Brief literature review of rheological properties of drilling fluids
3. Brief literature review of ultrasonic wave propagation in fluids
4. Generating neural network models to estimate rheological properties (viscosity and density) based on ultrasonic measurements
    a. Planning of ultrasonic and rheological measurements
    b. Running the ultrasonic experiments at USN. Statoil will run the rheological experiments
    c. Analysing the experimental results and building model(s)
5. Write a report according to the USN standards, and have an oral presentation of the results

Student category: IIA students (this will involve system identification, neural network and/or multivariate data analysis)

Practical arrangements:
A test rig for ultrasonic measurements is available at USN, campus Porsgrunn. Statoil will deliver required drilling liquid. Rheological analysis will be performed at Statoil, Herøya.

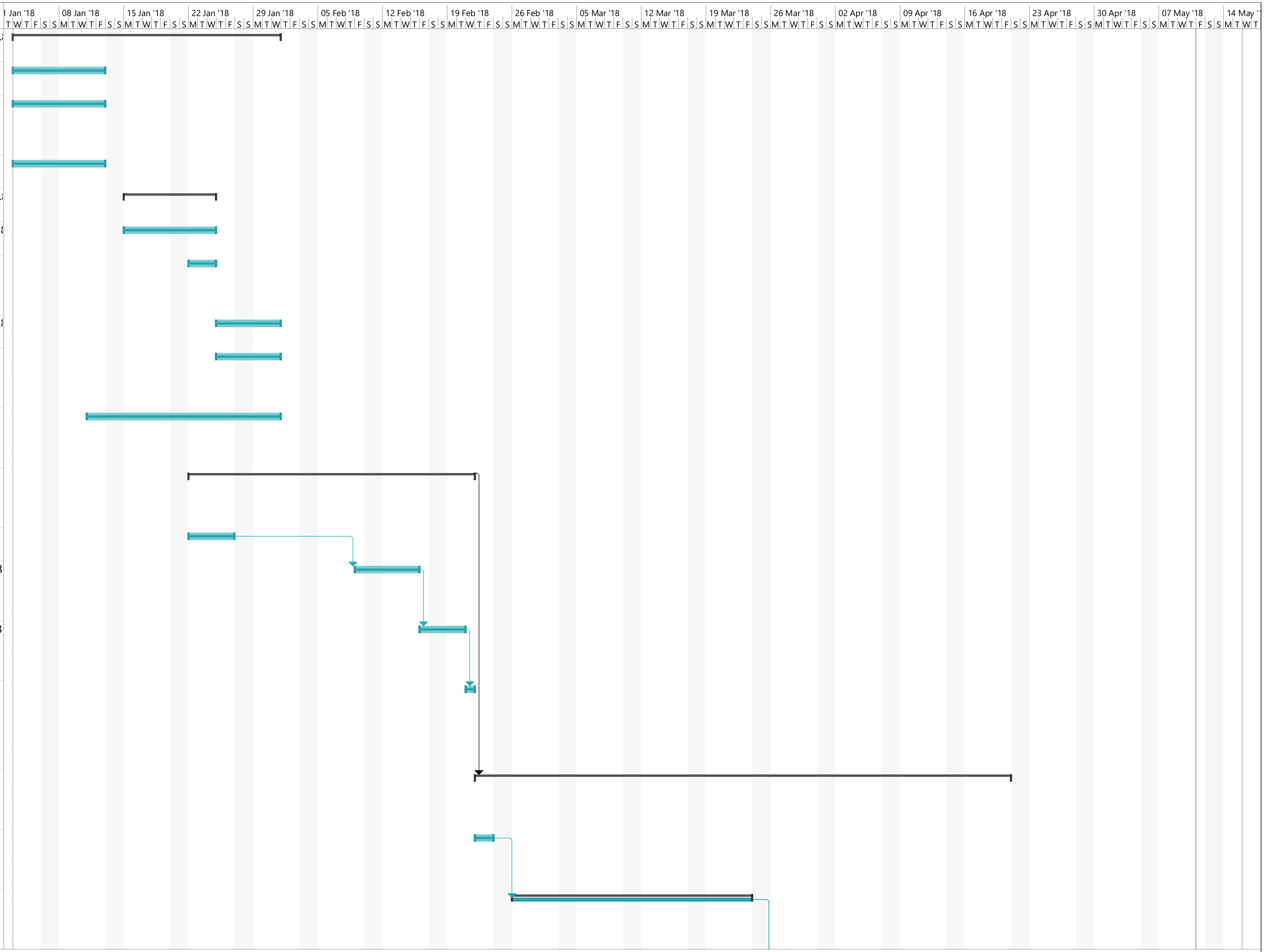
Signatures:
Student (date and signature):
Supervisor (date and signature):

Appendix B

Gantt Chart

This appendix contains the completed progress Gantt chart for the thesis work.

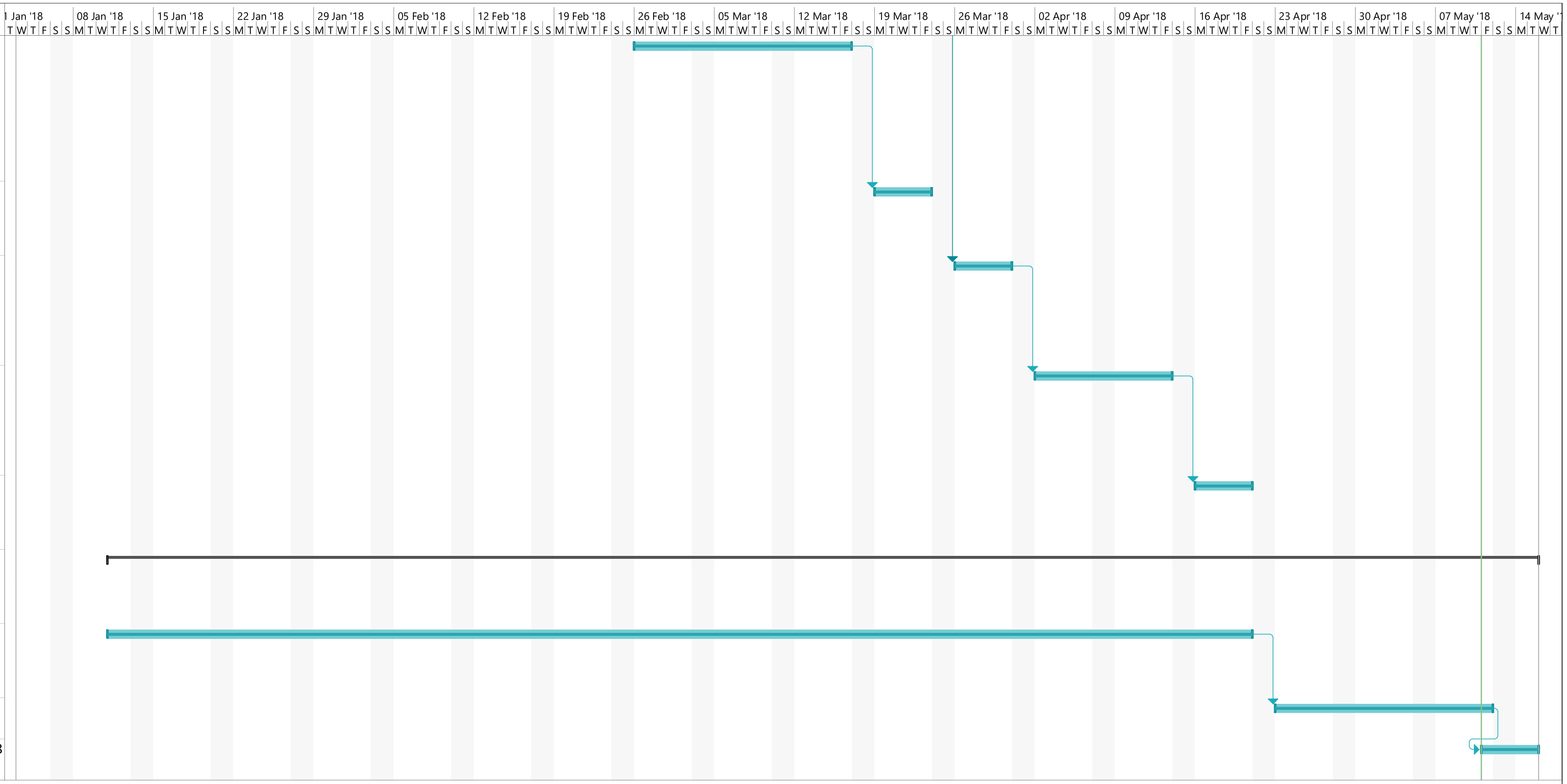
ID		Task Mode	Task Name	Duration	Start	Finish
1	✓		**Literature study**	**21 days**	**Wed 03.01.1**	**Wed 31.01.1**
2	✓		Ultrasound	8 days	Wed 03.01.1	Fri 12.01.18
3	✓		Drilling operations	8 days	Wed 03.01.18	Fri 12.01.18
4	✓		Drilling mud	8 days	Wed 03.01.1	Fri 12.01.18
5	✓		**Neural Networks**	**8 days**	**Mon 15.01.1**	**Wed 24.01.1**
6	✓		Tensor Flow	8 days	Mon 15.01.1	Wed 24.01.1
7	✓		Few input networks	3 days	Mon 22.01.18	Wed 24.01.18
8	✓		Similar systems	5 days	Thu 25.01.18	Wed 31.01.1
9	✓		Existing Rheometers	5 days	Thu 25.01.18	Wed 31.01.18
10	✓		Report: Theory chapter draft	15 days	Thu 11.01.18	Wed 31.01.18
11	✓		**Experiments**	**23 days**	**Mon 22.01.18**	**Wed 21.02.18**
12	✓		Planning	5 days	Mon 22.01.1	Fri 26.01.18
13	✓		Running experiments	5 days	Fri 09.02.18	Thu 15.02.18
14	✓		Analysing results	3 days	Fri 16.02.18	Tue 20.02.18
15	✓		Combining and comparing with old sets	1 day	Wed 21.02.18	Wed 21.02.18
16	✓		**Model**	**42 days**	**Thu 22.02.18**	**Fri 20.04.18**
17	✓		Preparing datasets	2 days	Thu 22.02.18	Fri 23.02.18
18	✓		**Developing networks**	**20 days**	**Mon 26.02.18**	**Fri 23.03.18**



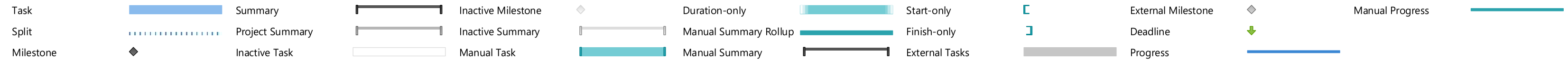
Project: Gantt
Date: Fri 11.05.18

Task	Summary		Inactive Milestone	◇	Duration-only		Start-only	[	External Milestone	◆	Manual Progress	
Split	Project Summary		Inactive Summary		Manual Summary Rollup		Finish-only	]	Deadline	⇩		
Milestone ◆	Inactive Task		Manual Task		Manual Summary		External Tasks		Progress			

ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
19	✓	📌	Generating tools for network configurations	15 days	Mon 26.02.18	Fri 16.03.18
20	✓	📌	Generating networks	5 days	Mon 19.03.18	Fri 23.03.18
21	✓	📌	Comparing network configurations	5 days	Mon 26.03.18	Fri 30.03.18
22	✓	📌	Further work on most promising network	10 days	Mon 02.04.18	Fri 13.04.18
23	✓	📌	Comparing to previous results	5 days	Mon 16.04.18	Fri 20.04.18
24	✓		**Report**	**89 days**	**Thu 11.01.18**	**Tue 15.05.18**
25	✓	📌	Continuous writing	72 days	Thu 11.01.18	Fri 20.04.18
26	✓	📌	Finalizing report	15 days	Mon 23.04.1	Fri 11.05.18
27	✓	📌	Proof reading	3 days	Fri 11.05.18	Tue 15.05.18



Project: Gantt
Date: Fri 11.05.18



Appendix C

Safety Data Sheet KCL/POLYMER System, MiSwaco

This appendix contains the safety data sheet that follows the KCl/polymer drilling fluid system used in the experiments in this thesis.

SDS no. PID16782
Version 3
Revision Date 08/Dec/2015
Supersedes date 19/May/2010

MI SWACO
A Schlumberger Company

Safety Data Sheet
KCL/POLYMER SYSTEM

1. Identification of the substance/preparation and of the Company/undertaking

1.1 Product identifier

Product name	KCL/POLYMER SYSTEM
Product code	PID16782

1.2 Relevant identified uses of the substance or mixture and uses advised against

Recommended Use	Water based system.
Uses advised against	Consumer use

1.3 Details of the supplier of the safety data sheet

Supplier
Schlumberger Norge AS
Risabergveien 3
4056 Tananger
Norway
+47 5157 7424
MISDS@slb.com

1.4 Emergency Telephone Number

Emergency telephone - (24 Hour) Australia +61 2801 44558, Asia Pacific +65 3158 1074, China +86 10 5100 3039, Europe +44 (0) 1235 239 670, Middle East and Africa +44 (0) 1235 239 671, New Zealand +64 9929 1483, USA 001 281 561 1600

Norway	Poison information centre: +47 22 59 13 00

2. Hazards identification

2.1 Classification of the substance or mixture

Classification according to (EC) No. 1272/2008

Health hazards	Not classified
Environmental hazards	Not classified
Physical Hazards	Not classified

2.2 Label elements

Signal word
None

Hazard statements
This product is not classified as hazardous therefore no (H) hazard statements assigned.

Appendix D

Data sheet for storing experimental data

This appendix contains the blank version of the data sheet used for storing experimental data in the context of this thesis.

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3				1	#NUM!	
5				1	#NUM!	
7				1	#NUM!	
9				1	#NUM!	
11				1	#NUM!	
13				1	#NUM!	
15				1	#NUM!	
17				1	#NUM!	
19				1	#NUM!	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3				2	#NUM!	
5				2	#NUM!	
7				2	#NUM!	
9				2	#NUM!	
11				2	#NUM!	
13				2	#NUM!	
15				2	#NUM!	
17				2	#NUM!	
19				2	#NUM!	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3				1	#NUM!	
5				1	#NUM!	
7				1	#NUM!	
9				1	#NUM!	
11				1	#NUM!	
13				1	#NUM!	
15				1	#NUM!	
17				1	#NUM!	
19				1	#NUM!	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3				2	#NUM!	
5				2	#NUM!	
7				2	#NUM!	
9				2	#NUM!	
11				2	#NUM!	
13				2	#NUM!	
15				2	#NUM!	
17				2	#NUM!	
19				2	#NUM!	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3				1	#NUM!	
5				1	#NUM!	
7				1	#NUM!	
9				1	#NUM!	
11				1	#NUM!	
13				1	#NUM!	
15				1	#NUM!	
17				1	#NUM!	
19				1	#NUM!	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3				2	#NUM!	
5				2	#NUM!	
7				2	#NUM!	
9				2	#NUM!	
11				2	#NUM!	
13				2	#NUM!	
15				2	#NUM!	
17				2	#NUM!	
19				2	#NUM!	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

Appendix E

Experiment Notes

When diluting the drilling fluid for each new concentration, 5% of the current volume of drilling fluid of water is added. When the level got too high for mixing to be done without spilling, the volume needed to be reduced by tapping some of the drilling fluid into a container for disposal. Table E.1 shows the volume and level for each concentration, as well as the amount of water to add to dilute it further. When tapping was not required, the volume was checked against the expected volume, this was done to confirm level and to document it if vaporising of the fluid was a significant factor.

There is a phenomenon that appears to be the fluid settling noticeably during the experiment. To give the sensors as equal conditions as possible, the fluid is mixed between each sensor pair, but not between each set of the same pair. The further out the sensors are moved, the stronger the phenomenon of slowly dropping attenuation gets. It is also more noticeable on high signal ratios, but this is likely because of the higher resolution. To avoid allowing this to affect the measurements overly much, the measurements are taken at a steady pace. This should show up when analysing the data as there is no mixing between sets on the same sensor pair.

One extra set was done at Concentration 10 with the 1.0MHz transducer as at the first set the frame was slightly out of place, this set will not be used in training the neural network initially, but could potentially be used as part of the testing separate from other data.

There was an issue with data gathered on the second day of experiments. The experiments done on that day for Concentration 2, 3 and 4 has some added source of attenuation, possibly bad connection though the signal was clean and consistent. And as such can not be used for training or testing the neural network. The difference was not noticed until the third day of experiments when there was a better point of reference to see the difference. All subsequent data gathering was checked, but the problem did not reoccur.

The signal at low signal strengths and high gain settings on the instrument caused the signals to be noisy, fluctuating in a range of up to 3% for signal strength and up to 6-7µs

Table E.1: Volume in tank during experiments

Concentration [#]	Volume [l]	Level [cm]	5% volume [l]	Matches last +5%
1	81	25.4	4.1	NA, no prior
2	85	26.6	4.3	Yes
3	89	27.9	4.5	Yes
4	87	27.1	4.4	NA, level reduced
5	86	27.0	4.3	NA, level reduced
6	90	28.2	4.5	Yes
7	84	26.3	4.2	NA, level reduced
8	88	27.6	4.4	Yes
9	84	26.3	4.2	NA, level reduced
10	88	27.4	4.4	Yes
11	84	26.1	NA	NA, level reduced

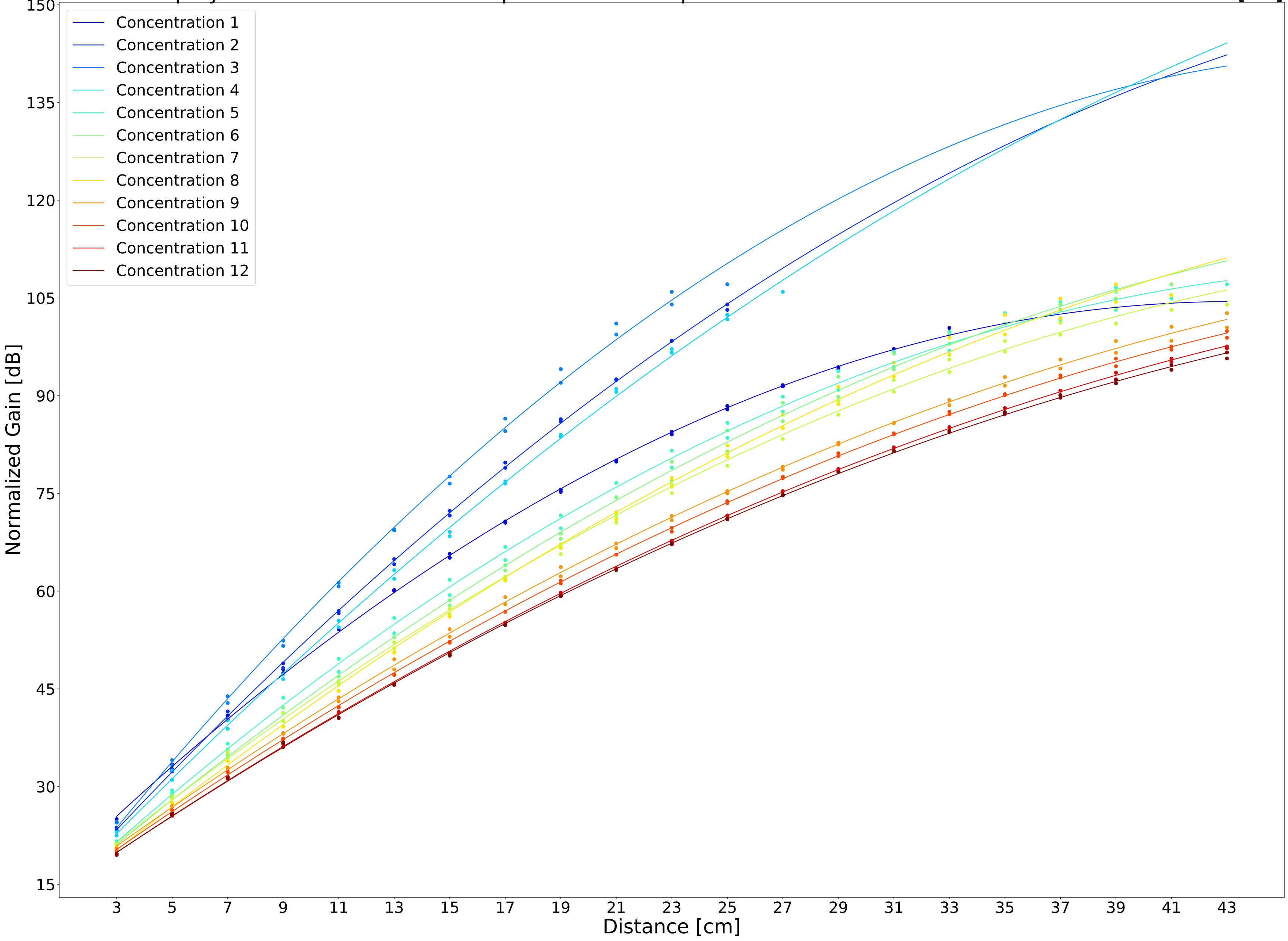
for travel time. If no number was significantly more prevalent than the rest, an average was attempted based on the numbers seen.

Appendix F

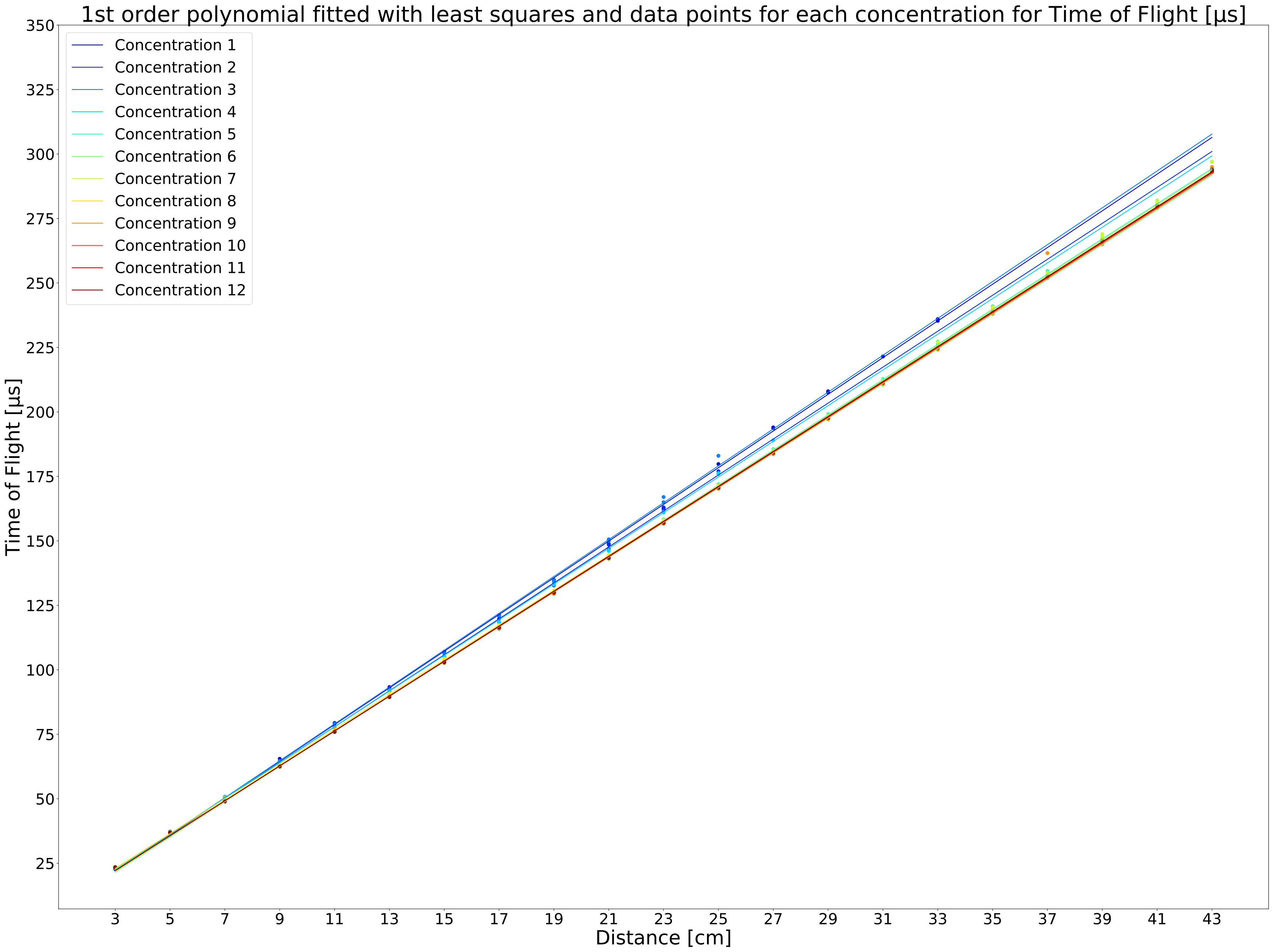
Analysis plots of experimental data, including fitted polynomials

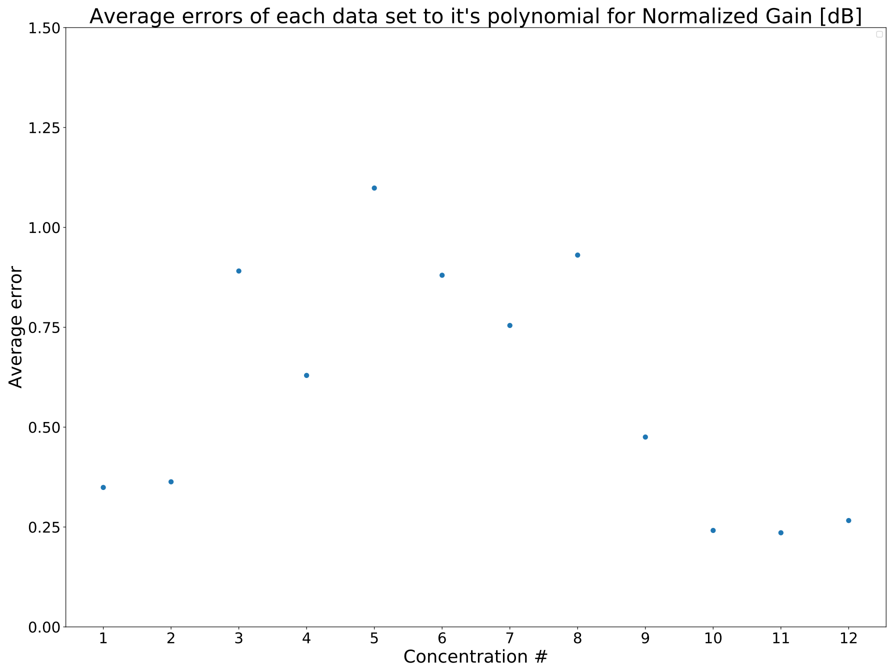
This appendix includes the full size plots used for analysis.

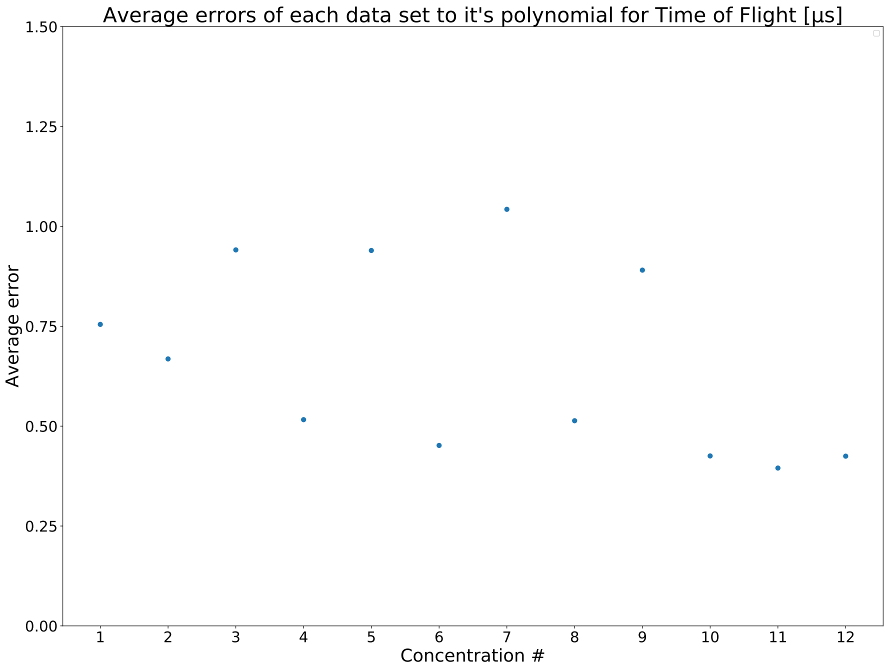
F.1 Analysis plots 0.5MHz transducer



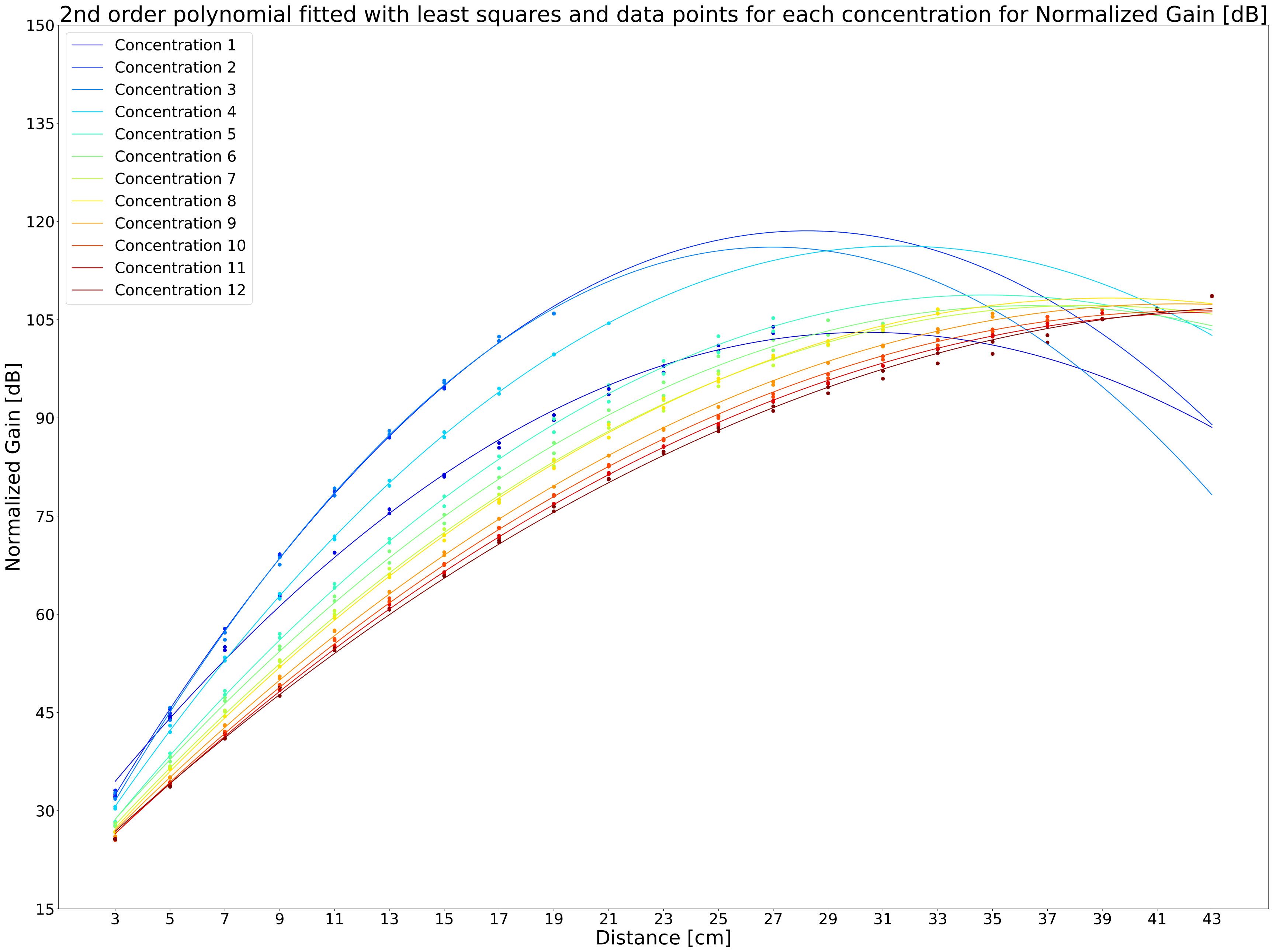
2nd order polynomial fitted with least squares and data points for each concentration for Normalized Gain [dB]

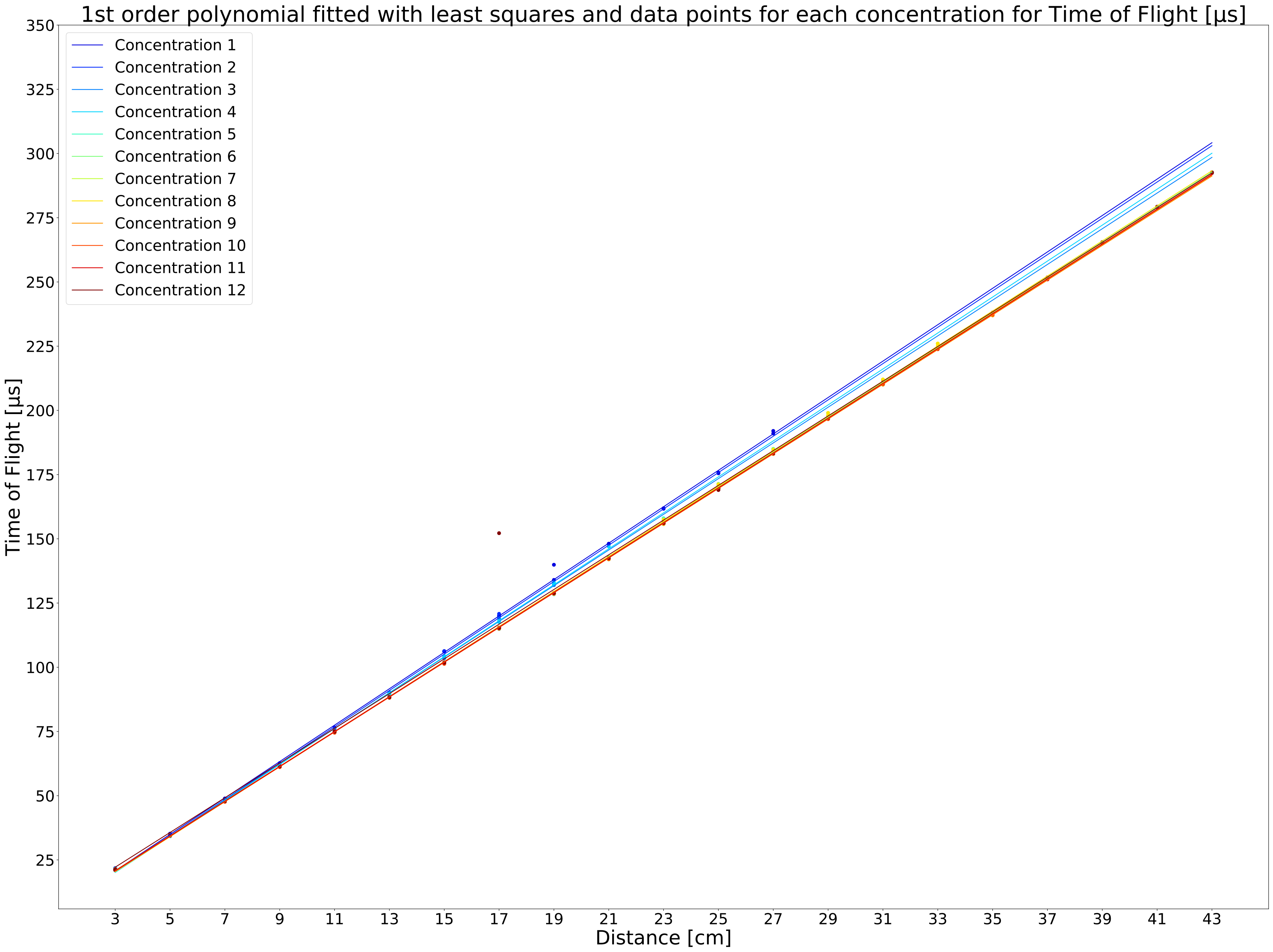

1st order polynomial fitted with least squares and data points for each concentration for Time of Flight [µs]
Concentration 1
Concentration 2
Concentration 3
Concentration 4
Concentration 5
Concentration 6
Concentration 7
Concentration 8
Concentration 9
Concentration 10
Concentration 11
Concentration 12
Time of Flight [µs]
350
325
300
275
250
225
200
175
150
125
100
75
50
25
Distance [cm]
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43

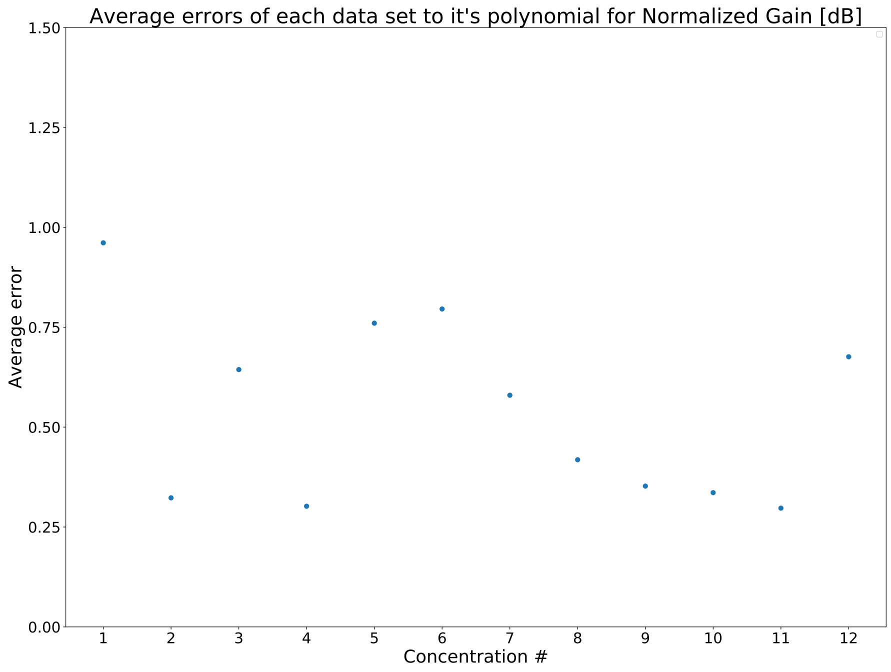

Average errors of each data set to it's polynomial for Normalized Gain [dB]
Average error
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Concentration #

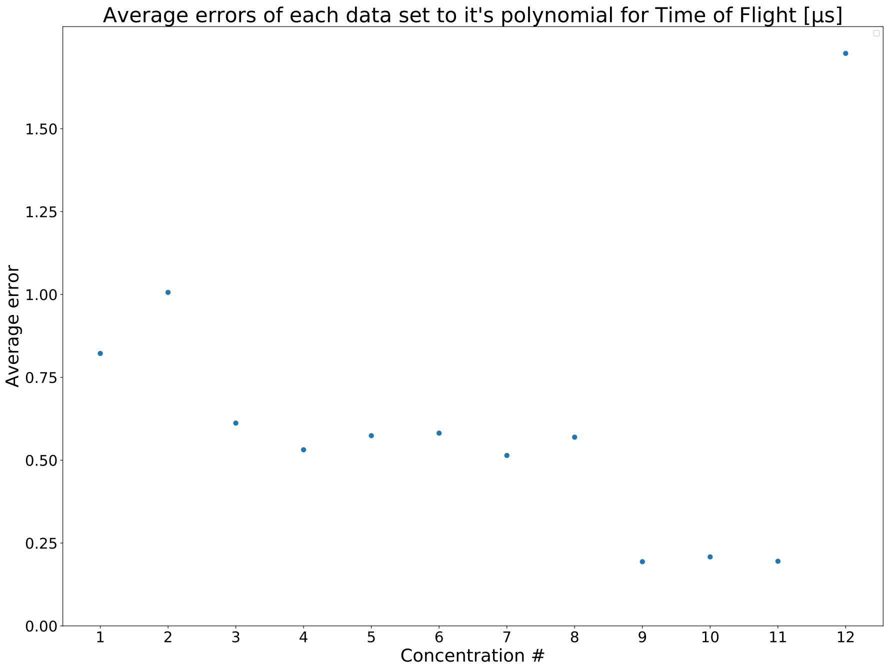

Average errors of each data set to it's polynomial for Time of Flight [µs]
Average error
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Concentration #

F.2 Analysis plots 1.0MHz transducer

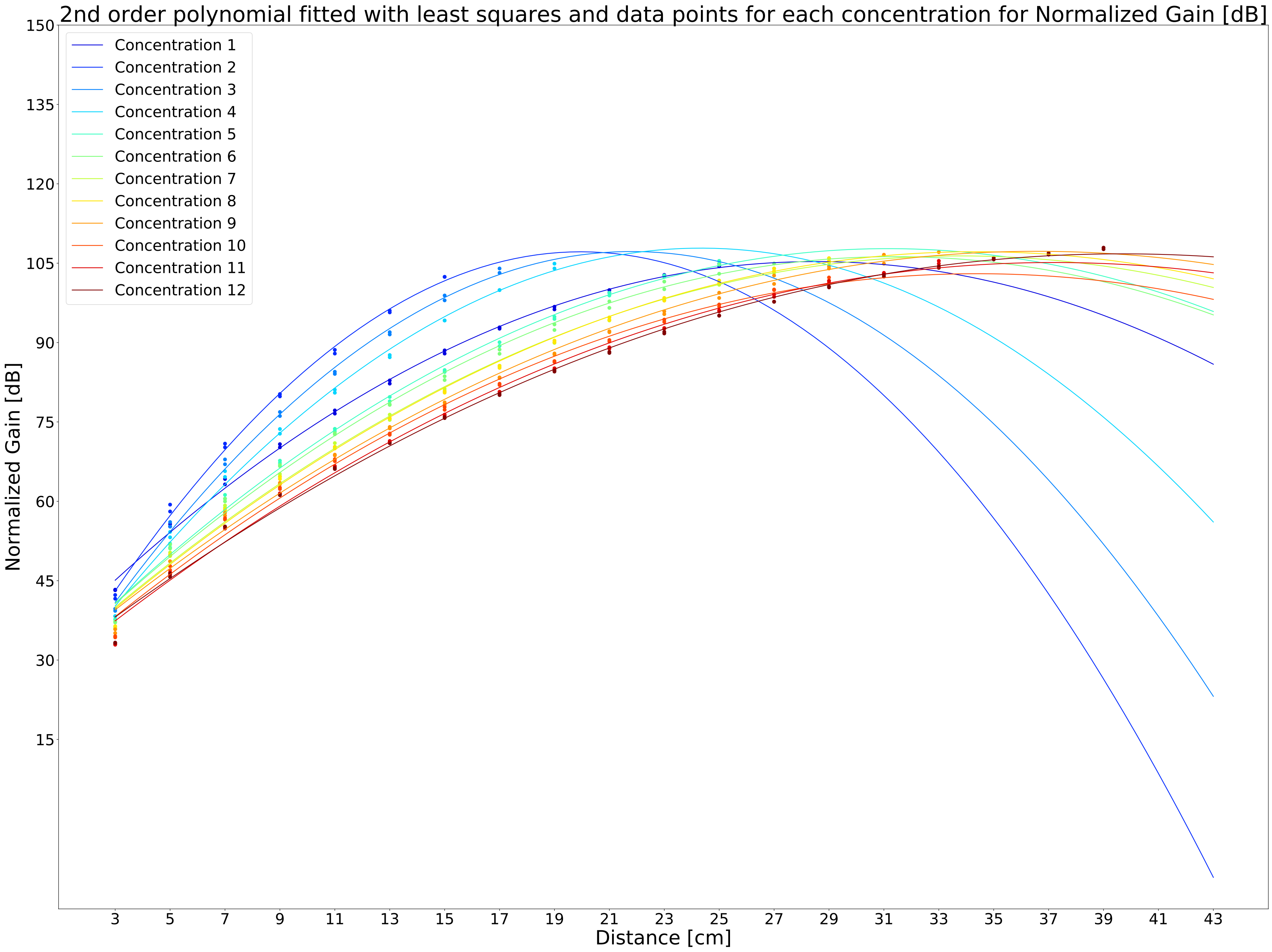

2nd order polynomial fitted with least squares and data points for each concentration for Normalized Gain [dB]
Concentration 1
Concentration 2
Concentration 3
Concentration 4
Concentration 5
Concentration 6
Concentration 7
Concentration 8
Concentration 9
Concentration 10
Concentration 11
Concentration 12
Normalized Gain [dB]
150
135
120
105
90
75
60
45
30
15
Distance [cm]
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43


1st order polynomial fitted with least squares and data points for each concentration for Time of Flight [µs]
Concentration 1
Concentration 2
Concentration 3
Concentration 4
Concentration 5
Concentration 6
Concentration 7
Concentration 8
Concentration 9
Concentration 10
Concentration 11
Concentration 12
Time of Flight [µs]
350
325
300
275
250
225
200
175
150
125
100
75
50
25
Distance [cm]
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43

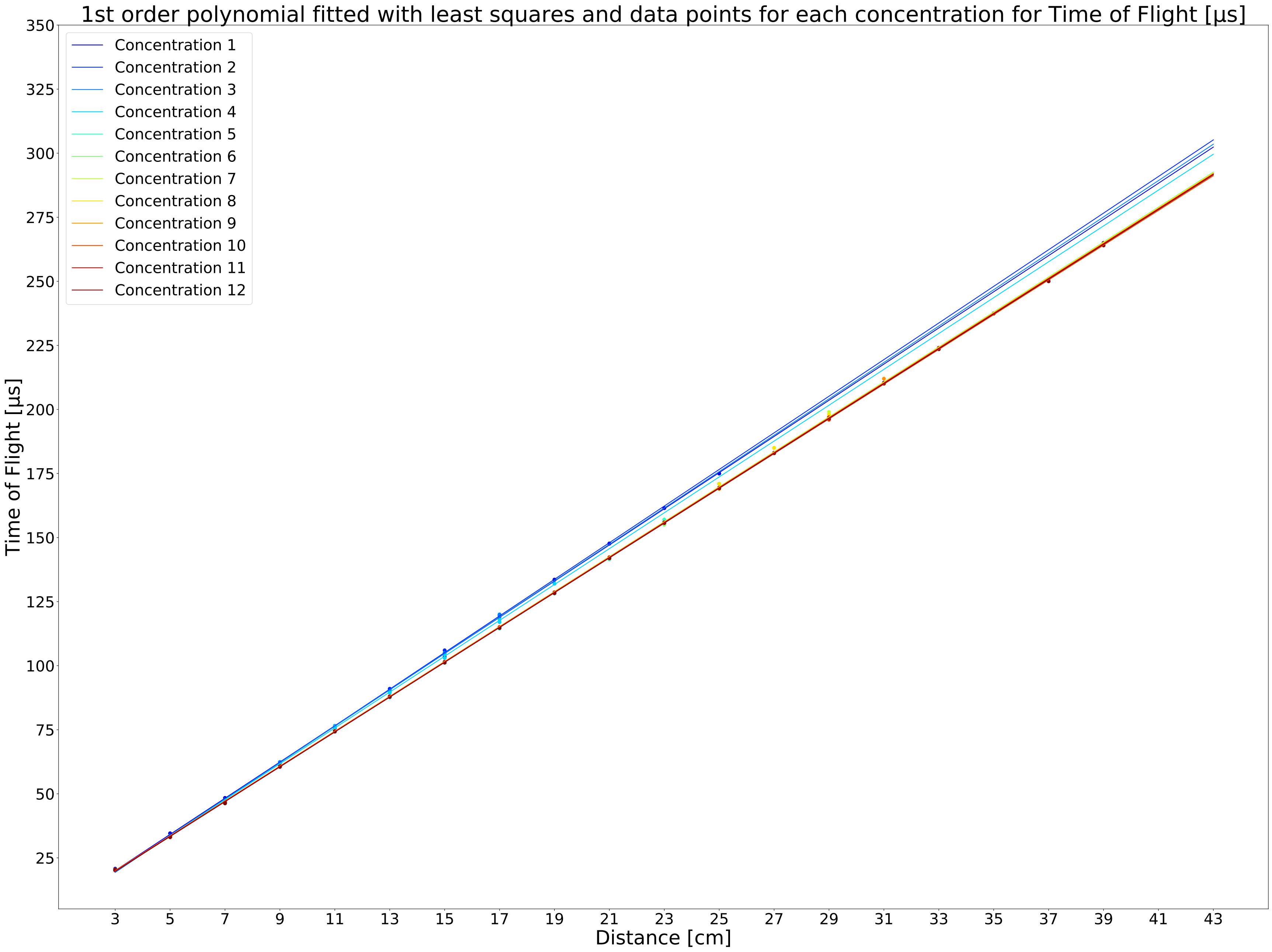

Average errors of each data set to it's polynomial for Normalized Gain [dB]
Average error
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Concentration #


Average errors of each data set to it's polynomial for Time of Flight [µs]
Average error
0.00
0.25
0.50
0.75
1.00
1.25
1.50
Concentration #
1
2
3
4
5
6
7
8
9
10
11
12

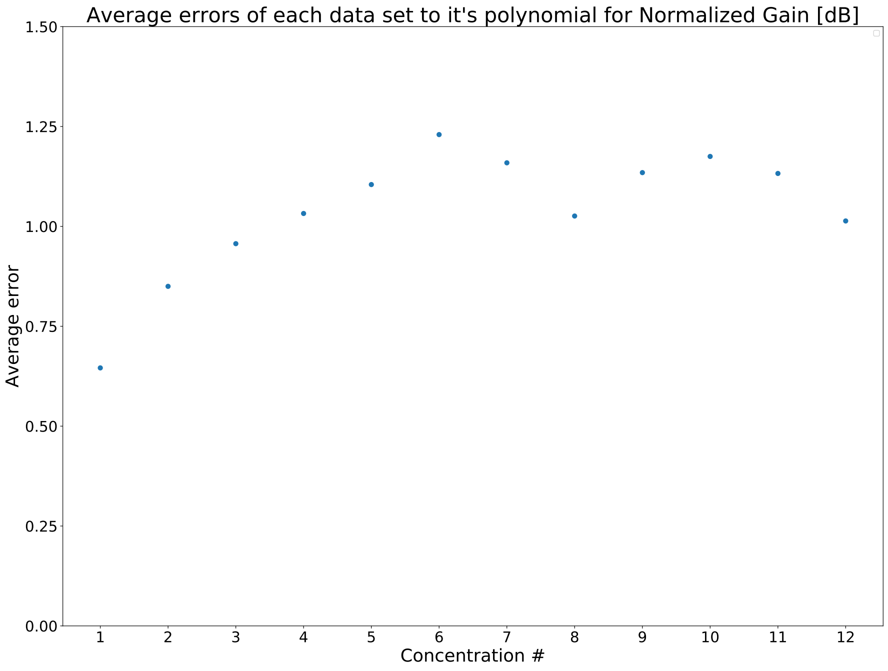
F.3 Analysis plots 2.25MHz transducer

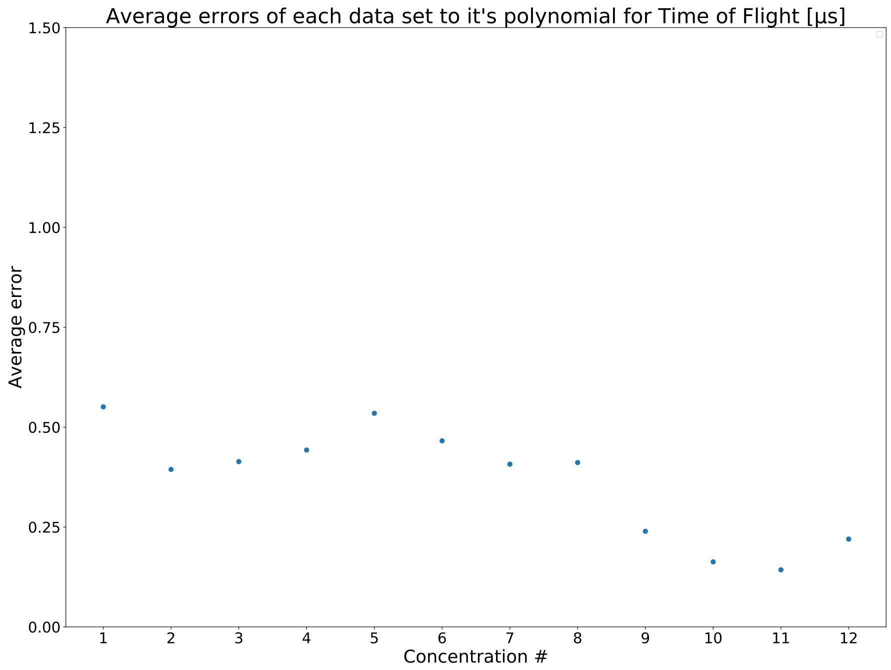


2nd order polynomial fitted with least squares and data points for each concentration for Normalized Gain [dB]



1st order polynomial fitted with least squares and data points for each concentration for Time of Flight [µs]


Average errors of each data set to it's polynomial for Normalized Gain [dB]
Average error
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Concentration #


Average errors of each data set to it's polynomial for Time of Flight [µs]
Average error
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1
2
3
4
5
6
7
8
9
10
11
12
Concentration #

Appendix G

New experimental data according to experimental procedure

This appendix includes all the measurement data gathered on the KCl/polymer drilling fluid during this thesis.

G.1 New fluid Concentration 1

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	25	100	22.70	1	25.0	
5	25	38	36.40	1	33.4	
7	25	16	50.10	1	40.9	
9	48	100	65.50	1	48.0	
11	48	48	79.40	1	54.4	
13	48	25	93.10	1	60.0	
15	48	13	107.00	1	65.7	
17	70.7	100	120.90	1	70.7	
19	70.7	57	134.90	1	75.6	
21	70.7	34	148.80	1	80.1	
23	70.7	20.5	162.70	1	84.5	
25	70.7	13	179.80	1	88.4	
27	70.7	9	193.70	1	91.6	
29	80.4	20	207.50	1	94.4	
31	80.4	14.5	221.50	1	97.2	
33	80.4	10	235.30	1	100.4	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	24.4	99	22.90	2	24.5	
5	24.4	38.5	36.50	2	32.7	
7	24.4	16	50.30	2	40.3	
9	47.4	100	64.10	2	47.4	
11	47.4	46	77.80	2	54.1	
13	47.4	23	93.30	2	60.2	
15	47.4	13	106.90	2	65.1	
17	70.5	100	121.00	2	70.5	
19	70.5	58	134.70	2	75.2	
21	70.5	34	148.80	2	79.9	
23	70.5	21	162.60	2	84.1	
25	70.5	13.5	176.40	2	87.9	
27	70.5	9	194.00	2	91.4	
29	84	31.5	208.00	2	94.0	
31	84	23.5	221.50	2	96.6	
33	84	17	236.00	2	99.4	ToF unclear
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	32.4	100	21.7	1	32.4	
5	32.4	25	35.2	1	44.4	
7	55	100	48.9	1	55.0	
9	55	40	62.6	1	63.0	
11	55	19	76.5	1	69.4	
13	76	99.5	90.2	1	76.0	
15	76	54	106.2	1	81.4	
17	76	31	120.1	1	86.2	
19	76	19	139.9	1	90.4	
21	76	12	147.9	1	94.4	
23	83	18	161.7	1	97.9	
25	83	12.5	175.5	1	101.1	
27	83	9	192	1	103.9	ToF unclear
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	32.1	100	21.8	2	32.1	
5	32.1	25	35.2	2	44.1	
7	54.5	100	48.9	2	54.5	
9	54.5	39	62.7	2	62.7	
11	54.5	18	76.5	2	69.4	
13	54.5	9	90.2	2	75.4	
15	81	100	106.3	2	81.0	
17	81	60	120.1	2	85.4	
19	81	37	134	2	89.6	
21	81	23.5	148.1	2	93.6	
23	81	16	161.9	2	96.9	
25	81	11	175.8	2	100.2	
27	81	8	191	2	102.9	ToF unclear
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	43.3	100.0	20.8	1	43.3	
5	43.3	24.0	34.5	1	55.7	
7	43.3	9.0	48.3	1	64.2	
9	70.8	100.0	62.1	1	70.8	
11	70.8	48.0	76.0	1	77.2	
13	70.8	25.0	89.7	1	82.8	
15	70.8	13.0	103.4	1	88.5	
17	84.0	36.0	119.7	1	92.9	
19	84.0	23.0	133.5	1	96.8	
21	84.0	16.0	147.6	1	99.9	
23	84.0	11.5	161.5	1	102.8	
25	84.0	9.0	175.0	1	104.9	ToF unclear
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	43.2	100.0	20.5	2	43.2	
5	43.2	25.0	34.6	2	55.2	
7	43.2	10.0	48.4	2	63.2	
9	70.2	100.0	62.2	2	70.2	
11	70.2	48.0	76.0	2	76.6	
13	70.2	25.0	89.8	2	82.2	
15	70.2	13.0	103.5	2	87.9	
17	83.5	35.0	119.8	2	92.6	
19	83.5	23.0	133.6	2	96.3	
21	83.5	16.0	147.7	2	99.4	
23	83.5	11.0	161.5	2	102.7	
25	83.5	9.0	175.0	2	104.4	ToF unclear
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.2 New fluid Concentration 2

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	23.8	101	23.00	1	23.7	
5	23.8	36	36.30	1	32.7	
7	23.8	13	50.80	1	41.5	
9	49	101	64.10	1	48.9	
11	49	40	77.30	1	57.0	
13	49	16	90.40	1	64.9	
15	72.4	101	105.20	1	72.3	
17	72.4	43	118.40	1	79.7	
19	72.4	20	133.20	1	86.4	
21	72.4	10	147.00	1	92.4	
23	84	19	162.00	1	98.4	
25	84	10	176.00	1	104.0	ToF unclear
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	23.2	99	23.10	2	23.3	
5	23.2	35	36.30	2	32.3	
7	23.2	14	50.60	2	40.3	
9	48.2	100	64.00	2	48.2	
11	48.2	38	77.30	2	56.6	
13	48.2	16	91.80	2	64.1	
15	71.6	100	104.90	2	71.6	
17	71.6	43	119.80	2	78.9	
19	71.6	19	132.70	2	86.0	
21	71.6	9	148.50	2	92.5	
23	84	19	163.00	2	98.4	
25	84	11	177.00	2	103.2	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	33.1	100	21.7	1	33.1	
5	33.1	24	34.8	1	45.5	
7	57.8	100	48.1	1	57.8	
9	57.8	27	61.3	1	69.2	
11	57.8	9	75.6	1	78.7	
13	84	69	90	1	87.2	
15	84	29	106.2	1	94.8	
17	84	13	120	1	101.7	
19				1	#NUM!	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	32.1	100	21.7	2	32.1	
5	32.1	23	34.8	2	44.9	
7	57.2	100	48.1	2	57.2	
9	57.2	26	61.3	2	68.9	
11	57.2	9	75.6	2	78.1	
13	84	71	90	2	87.0	
15	84	30	106.1	2	94.5	
17	84	13	120.8	2	101.7	
19				2	#NUM!	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	42.3	100	20.1	1	42.3	
5	42.3	14	33.3	1	59.4	
7	70.9	100	47.5	1	70.9	
9	70.9	34	61.9	1	80.3	
11	70.9	13	76.4	1	88.6	
13	84	25	91	1	96.0	
15	84	12	105	1	102.4	
17				1	#NUM!	
19				1	#NUM!	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	41.6	100	20.3	2	41.6	
5	41.6	15	33.3	2	58.1	
7	70.2	100	47.5	2	70.2	
9	70.2	33	61.8	2	79.8	
11	70.2	13	76.5	2	87.9	
13	84	26	90.9	2	95.7	
15	84	12	106	2	102.4	
17				2	#NUM!	
19				2	#NUM!	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.3 New fluid Concentration 3

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	24.7	101	22.90	1	24.6	
5	24.7	34	37.10	1	34.1	
7	24.7	11	50.20	1	43.9	
9	52.4	100	64.60	1	52.4	
11	52.4	36	79.10	1	61.3	
13	52.4	14	92.00	1	69.5	
15	77.6	100	106.30	1	77.6	
17	77.6	36	121.00	1	86.5	
19	77.6	15	134.00	1	94.1	
21	84	14	150.00	1	101.1	
23	84	8	165.00	1	105.9	ToF unclear
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	24.4	99	23.00	2	24.5	
5	24.4	36	37.30	2	33.3	
7	24.4	12	50.40	2	42.8	
9	51.6	100	64.70	2	51.6	
11	51.6	35	79.10	2	60.7	
13	51.6	13	92.10	2	69.3	
15	76.6	101	106.60	2	76.5	
17	76.6	40	121.30	2	84.6	
19	76.6	17	135.00	2	92.0	
21	84	17	150.60	2	99.4	
23	84	10	167.00	2	104.0	
25	84	7	183.00	2	107.1	ToF unclear
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	32.6	99	21.5	1	32.7	
5	32.6	22	34.8	1	45.8	
7	57.3	101	48.1	1	57.2	
9	57.3	27	61.3	1	68.7	
11	57.3	8	75.5	1	79.2	
13	84	63	88.8	1	88.0	
15	84	26	103.5	1	95.7	
17	84	12	119	1	102.4	
19	84	8	132	1	105.9	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	31.8	100	21.7	2	31.8	
5	31.8	25	34.7	2	43.8	
7	56.2	101	48	2	56.1	
9	56.2	27	61.4	2	67.6	
11	56.2	8	75.5	2	78.1	
13	84	67	90	2	87.5	
15	84	27	104	2	95.4	
17	84	13	119	2	101.7	
19	84	8	132	2	105.9	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	39.6	99	20.3	1	39.7	
5	39.6	15	33.4	1	56.1	
7	68	101	47.8	1	67.9	
9	68	36	62.4	1	76.9	
11	68	15	75.6	1	84.5	
13	84	40	90.2	1	92.0	
15	84	18	104.9	1	98.9	
17	84	10	120	1	104.0	
19				1	#NUM!	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	39.3	100	20.2	2	39.3	
5	39.3	16	33.5	2	55.2	
7	67	100	47.8	2	67.0	
9	67	35	62.4	2	76.1	
11	67	14	75.5	2	84.1	
13	84	42	90.2	2	91.5	
15	84	20	105	2	98.0	
17	84	11	119	2	103.2	ToF unclear
19				2	#NUM!	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.4 New fluid Concentration 4

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	23.1	101	23.10	1	23.0	
5	23.1	34	36.30	1	32.5	
7	23.1	14	50.70	1	40.2	
9	47.3	101	64.00	1	47.2	
11	47.3	39	77.30	1	55.5	
13	47.3	16	91.90	1	63.2	
15	69.1	100	105.00	1	69.1	
17	69.1	41	118.30	1	76.8	
19	69.1	18	133.00	1	84.0	
21	69.1	8	146.10	1	91.0	
23	84	22	161.00	1	97.2	
25	84	12	176.00	1	102.4	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	22.4	99	23.30	2	22.5	
5	22.4	37	36.50	2	31.0	
7	22.4	15	50.80	2	38.9	
9	46.5	100	64.20	2	46.5	
11	46.5	40	77.60	2	54.5	
13	46.5	17	92.20	2	61.9	
15	46.5	8	105.20	2	68.4	
17	76.6	101	118.50	2	76.5	
19	76.6	44	133.20	2	83.7	
21	76.6	20	146.30	2	90.6	
23	76.6	10	161.30	2	96.6	
25	84	13	176.30	2	101.7	
27	84	8	189.00	2	105.9	ToF unclear
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	30.6	100	20.9	1	30.6	
5	30.6	24	34.2	1	43.0	
7	53.5	101	48.2	1	53.4	
9	53.5	33	61.6	1	63.1	
11	53.5	12	74.9	1	71.9	
13	80.5	101	89.5	1	80.4	
15	80.5	43	104.3	1	87.8	
17	80.5	20	118	1	94.5	
19	80.5	11	133	1	99.7	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	30.3	100	21.1	2	30.3	
5	30.3	26	34.4	2	42.0	
7	53	101	48.4	2	52.9	
9	53	34	61.7	2	62.4	
11	53	12	75	2	71.4	
13	79.7	101	89.7	2	79.6	
15	79.7	43	104.4	2	87.0	
17	79.7	20	117.6	2	93.7	
19	79.7	10	132.6	2	99.7	
21	84	9.5	147	2	104.4	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	38.3	100	20.3	1	38.3	
5	38.3	16	33.6	1	54.2	
7	65.7	100	47	1	65.7	
9	65.7	40	61.4	1	73.7	
11	65.7	17	76.1	1	81.1	
13	65.7	8	89.4	1	87.6	
15	84	31	104.4	1	94.2	
17	84	16	118	1	99.9	
19	84	9	132	1	104.9	
21				1	#NUM!	
23				1	#NUM!	
25				1	#NUM!	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	38.3	100	20.4	2	38.3	
5	38.3	18	33.7	2	53.2	
7	64.6	100	47	2	64.6	
9	64.6	39	61.4	2	72.8	
11	64.6	16	76.4	2	80.5	
13	84	69	89.6	2	87.2	
15	84	31	103	2	94.2	
17	84	16	117	2	99.9	
19	84	10	132	2	104.0	
21				2	#NUM!	
23				2	#NUM!	
25				2	#NUM!	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.5 New fluid Concentration 5

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21.7	101	23.50	1	21.6	
5	21.7	41	36.70	1	29.4	
7	21.7	18	50.30	1	36.6	
9	21.7	8	62.30	1	43.6	
11	49.7	101	77.30	1	49.6	
13	49.7	49	89.30	1	55.9	
15	49.7	25	102.50	1	61.7	
17	49.7	14	115.80	1	66.8	
19	49.7	8	129.30	1	71.6	
21	76.7	101	143.00	1	76.6	
23	76.7	57	158.40	1	81.6	
25	76.7	35	172.00	1	85.8	
27	76.7	22	185.60	1	89.9	
29	76.7	14	199.20	1	93.8	
31	76.7	10	212.80	1	96.7	
33	76.7	7	226.30	1	99.8	
35	83.5	11	240.00	1	102.7	
37	83.5	9	253.00	1	104.4	
39	83.5	7	267.00	1	106.6	
41	83.5			1	#NUM!	
43	83.5			1	#NUM!	
45	83.5			1	#NUM!	
3	21.3	99	23.60	2	21.4	
5	21.3	41	35.70	2	29.0	
7	21.3	19	49.10	2	35.7	
9	21.3	10	62.50	2	41.3	
11	47.7	101	76.10	2	47.6	
13	47.7	51	89.40	2	53.5	
15	47.7	26	102.80	2	59.4	
17	47.7	14	116.00	2	64.8	
19	47.7	8	129.60	2	69.6	
21	74.4	100	143.20	2	74.4	
23	74.4	59	156.60	2	79.0	
25	74.4	35	170.20	2	83.5	
27	74.4	22	183.70	2	87.6	
29	74.4	15	197.10	2	90.9	
31	74.4	10	210.70	2	94.4	
33	74.4	7.5	227.30	2	96.9	
35	84	17	241.00	2	99.4	
37	84	13	254.70	2	101.7	
39	84	11	268.00	2	103.2	
41	84	9	282.00	2	104.9	
43	84	7	297.00	2	107.1	
45	84			2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	28.3	100	21.4	1	28.3	
5	28.3	30	34.5	1	38.8	
7	28.3	10	47.8	1	48.3	
9	57.1	101	61.3	1	57.0	
11	57.1	42	74.8	1	64.6	
13	57.1	19	88.2	1	71.5	
15	57.1	9	101.4	1	78.0	
17	83.3	91	114.9	1	84.1	
19	83.3	47	128.4	1	89.9	
21	83.3	26	142	1	95.0	
23	83.3	17	157	1	98.7	
25	83.3	11	171	1	102.5	
27	83.3	8	185	1	105.2	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	27.7	99	21.3	2	27.8	
5	27.7	30	34.6	2	38.2	
7	27.7	10	47.8	2	47.7	
9	56.5	101	61.2	2	56.4	
11	56.5	42	74.6	2	64.0	
13	56.5	19	88.1	2	70.9	
15	56.5	10	101.4	2	76.5	
17	82.3	100	115	2	82.3	
19	82.3	53	128.5	2	87.8	
21	82.3	31	143	2	92.5	
23	82.3	19	158	2	96.7	
25	82.3	13	171	2	100.0	
27	82.3	9	184	2	103.2	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	37.6	99	20.3	1	37.7	
5	37.6	19	33.1	1	52.0	
7	61.3	101	47.3	1	61.2	
9	61.3	48	60.8	1	67.7	
11	61.3	24	74.2	1	73.7	
13	61.3	12	87.6	1	79.7	
15	83.5	86	101.1	1	84.8	
17	83.5	47	114.6	1	90.1	
19	83.5	27	128.2	1	94.9	
21	83.5	16	141.5	1	99.4	
23	83.5	11	157	1	102.7	
25	83.5	8	171	1	105.4	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	37.7	100	20.5	2	37.7	
5	37.7	21	33.2	2	51.3	
7	60.5	100	47.3	2	60.5	
9	60.5	46	60.9	2	67.2	
11	60.5	23	74.3	2	73.3	
13	60.5	12	87.7	2	78.9	
15	84	95	101.3	2	84.4	
17	84	54	114.5	2	89.4	
19	84	30	128.2	2	94.5	
21	84	18	141.7	2	98.9	
23	84	12	157	2	102.4	
25	84	9	171	2	104.9	
27				2	#NUM!	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.6 New fluid Concentration 6

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21.2	100	23.50	1	21.2	
5	21.2	42	36.80	1	28.7	
7	21.2	19	49.00	1	35.6	
9	21.2	9	62.40	1	42.1	
11	46.9	100	76.00	1	46.9	
13	46.9	50	89.40	1	52.9	
15	46.9	26	102.90	1	58.6	
17	46.9	14	116.00	1	64.0	
19	46.9	8	129.40	1	68.8	
21	74.5	101	143.00	1	74.4	
23	74.5	54	156.50	1	79.9	
25	74.5	31	170.10	1	84.7	
27	74.5	19	183.60	1	88.9	
29	74.5	12	197.00	1	92.9	
31	74.5	8	210.50	1	96.4	
33	84	17	224.00	1	99.4	
35	84	12	238.00	1	102.4	
37	84	10	252.00	1	104.0	
39	84	8	267.00	1	105.9	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	20.9	99	23.60	2	21.0	
5	20.9	42	36.90	2	28.4	
7	20.9	20	49.10	2	34.9	
9	20.9	11	62.60	2	40.1	
11	46.1	101	76.20	2	46.0	
13	46.1	50	89.60	2	52.1	
15	46.1	26	102.90	2	57.8	
17	46.1	14	116.20	2	63.2	
19	46.1	8	129.80	2	68.0	
21	72.1	101	143.30	2	72.0	
23	72.1	57	157.10	2	77.0	
25	72.1	34	170.40	2	81.5	
27	72.1	20	183.90	2	86.1	
29	72.1	13	197.20	2	89.8	
31	72.1	8	210.90	2	94.0	
33	84	20	224.40	2	98.0	
35	84	14	238.00	2	101.1	
37	84	11	252.00	2	103.2	
39	84	9	265.00	2	104.9	
41	84	7	279.00	2	107.1	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	28.1	100	21.4	1	28.1	
5	28.1	31	34.5	1	38.3	
7	28.1	11	47.8	1	47.3	
9	55.2	101	61.3	1	55.1	
11	55.2	42	74.7	1	62.7	
13	55.2	19	88.3	1	69.6	
15	55.2	10	101.5	1	75.2	
17	81	101	115.1	1	80.9	
19	81	55	128.6	1	86.2	
21	81	31	142.1	1	91.2	
23	81	19	156	1	95.4	
25	81	12	171.4	1	99.4	
27	81	9	185	1	101.9	
29	84	9	198	1	104.9	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	27.6	100	21.3	2	27.6	
5	27.6	32	34.6	2	37.5	
7	27.6	11	47.9	2	46.8	
9	54.7	101	61.3	2	54.6	
11	54.7	43	75	2	62.0	
13	54.7	22	88.4	2	67.9	
15	54.7	11	101.7	2	73.9	
17	79.4	101	115.3	2	79.3	
19	79.4	55	128.8	2	84.6	
21	79.4	32	142.3	2	89.3	
23	79.4	20	156	2	93.4	
25	79.4	13	169.6	2	97.1	
27	79.4	9	183	2	100.3	
29	83.5	11	199	2	102.7	
31	83.5	9	212	2	104.4	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	37.4	101	20.4	1	37.3	
5	37.4	19	33.3	1	51.8	
7	60.5	100	47.5	1	60.5	
9	60.5	48	60.9	1	66.9	
11	60.5	24	74.4	1	72.9	
13	60.5	13	88	1	78.2	
15	83.8	102	101.5	1	83.6	
17	83.8	57	114.9	1	88.7	
19	83.8	33	128.4	1	93.4	
21	83.8	20	141.8	1	97.8	
23	83.8	13	155	1	101.5	
25	83.8	9	171	1	104.7	
27				1	#NUM!	
29				1	#NUM!	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	37.1	100	20.5	2	37.1	
5	37.1	20	33.3	2	51.1	
7	59.9	99	47.4	2	60.0	
9	59.9	46	61.1	2	66.6	
11	59.9	23	74.5	2	72.7	
13	59.9	12	88	2	78.3	
15	83	101	101.5	2	82.9	
17	83	57	115.1	2	87.9	
19	83	34	128.7	2	92.4	
21	83	21	142	2	96.6	
23	83	14	155.6	2	100.1	
25	83	10	171	2	103.0	
27	83	8	185	2	104.9	
29				2	#NUM!	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.7 New fluid Concentration 7

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21.3	100	23.50	1	21.3	
5	21.3	43	36.80	1	28.6	
7	21.3	20	50.20	1	35.3	
9	21.3	10	62.40	1	41.3	
11	46.3	101	77.30	1	46.2	
13	46.3	51	89.50	1	52.1	
15	46.3	28	102.80	1	57.4	
17	46.3	16	116.20	1	62.2	
19	46.3	9	129.70	1	67.2	
21	71.5	100	143.30	1	71.5	
23	71.5	57	156.90	1	76.4	
25	71.5	33	170.30	1	81.1	
27	71.5	21	183.80	1	85.1	
29	71.5	13	197.30	1	89.2	
31	71.5	9	210.80	1	92.4	
33	83.5	25	227.10	1	95.5	
35	83.5	18	240.60	1	98.4	
37	83.5	13	254.00	1	101.2	
39	83.5	10	268.00	1	103.5	
41	83.5	8	281.00	1	105.4	
43				1	#NUM!	
45				1	#NUM!	
3	20.9	99	23.50	2	21.0	
5	20.9	43	36.90	2	28.2	
7	20.9	21	49.10	2	34.5	
9	20.9	11	62.60	2	40.1	
11	45.7	101	76.20	2	45.6	
13	45.7	53	89.60	2	51.2	
15	45.7	29	102.90	2	56.5	
17	45.7	16	116.20	2	61.6	
19	45.7	10	129.80	2	65.7	
21	70.6	101	143.40	2	70.5	
23	70.6	60	157.00	2	75.0	
25	70.6	37	170.50	2	79.2	
27	70.6	23	184.00	2	83.4	
29	70.6	15	197.50	2	87.1	
31	70.6	10	211.10	2	90.6	
33	84	33	224.70	2	93.6	
35	84	23	238.40	2	96.8	
37	84	17	252.00	2	99.4	
39	84	14	269.00	2	101.1	
41	84	11	282.00	2	103.2	
43	84	10	297.00	2	104.0	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	26.9	101	21.2	1	26.8	
5	26.9	32	34.5	1	36.8	
7	26.9	12	47.8	1	45.3	
9	53	100	61.3	1	53.0	
11	53	42	74.8	1	60.5	
13	53	20	88.3	1	67.0	
15	53	10	101.6	1	73.0	
17	78.3	100	115.1	1	78.3	
19	78.3	54	128.6	1	83.7	
21	78.3	31	142.2	1	88.5	
23	78.3	19	155.7	1	92.7	
25	78.3	12	169.3	1	96.7	
27	78.3	9	184	1	99.2	
29	84	13	198	1	101.7	
31	84	10	212	1	104.0	
33	84	8	226	1	105.9	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	26.7	99	21.2	2	26.8	
5	26.7	32	34.5	2	36.6	
7	26.7	12	47.8	2	45.1	
9	52.9	101	61.4	2	52.8	
11	52.9	44	74.9	2	60.0	
13	52.9	22	88.4	2	66.1	
15	52.9	11	101.7	2	72.1	
17	77.1	99	115.3	2	77.2	
19	77.1	53	128.9	2	82.6	
21	77.1	32	142.3	2	87.0	
23	77.1	20	156	2	91.1	
25	77.1	13	169.6	2	94.8	
27	77.1	9	183.2	2	98.0	
29	84	14	197	2	101.1	
31	84	11	210	2	103.2	
33	84	8	226	2	105.9	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	35.9	100	20.4	1	35.9	
5	35.9	19	33.3	1	50.3	
7	59.3	101	47.4	1	59.2	
9	59.3	51	60.9	1	65.1	
11	59.3	26	74.6	1	71.0	
13	59.3	14	88	1	76.4	
15	59.3	8	101.5	1	81.2	
17	83.2	77	115	1	85.5	
19	83.2	46	128.5	1	89.9	
21	83.2	28	142	1	94.3	
23	83.2	18	155.6	1	98.1	
25	83.2	13	169	1	100.9	
27	83.2	10	183	1	103.2	
29	83.2	8	199	1	105.1	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	36.1	99	20.5	2	36.2	
5	36.1	21	33.3	2	49.7	
7	58.9	101	47.5	2	58.8	
9	58.9	51	61	2	64.7	
11	58.9	27	74.5	2	70.3	
13	58.9	15	87.9	2	75.4	
15	58.9	8	101.4	2	80.8	
17	84	83	115.2	2	85.6	
19	84	50	128.6	2	90.0	
21	84	31	142.1	2	94.2	
23	84	20	155.8	2	98.0	
25	84	14	169.3	2	101.1	
27	84	10	185	2	104.0	
29	84	8	197	2	105.9	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.8 New fluid Concentration 8

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	20.8	99	23.50	1	20.9	
5	20.8	46	36.70	1	27.5	
7	20.8	22	50.20	1	34.0	
9	20.8	12	63.90	1	39.2	
11	44.8	101	77.20	1	44.7	
13	44.8	51	90.60	1	50.6	
15	44.8	27	104.00	1	56.2	
17	44.8	14	117.30	1	61.9	
19	44.8	8	130.80	1	66.7	
21	72.2	101	144.50	1	72.1	
23	72.2	55	158.10	1	77.4	
25	72.2	31	171.50	1	82.4	
27	72.2	18	185.10	1	87.1	
29	72.2	11	198.60	1	91.4	
31	84	28	212.10	1	95.1	
33	84	18	225.70	1	98.9	
35	84	12	239.30	1	102.4	
37	84	9	253.00	1	104.9	
39	84	7	266.00	1	107.1	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	20.8	100	23.50	2	20.8	
5	20.8	46	36.80	2	27.5	
7	20.8	22	50.30	2	34.0	
9	20.8	12	63.70	2	39.2	
11	44.7	100	77.40	2	44.7	
13	44.7	51	90.80	2	50.5	
15	44.7	27	104.30	2	56.1	
17	44.7	14	116.30	2	61.8	
19	44.7	8	129.60	2	66.6	
21	71	100	143.20	2	71.0	
23	71	56	156.90	2	76.0	
25	71	33	170.30	2	80.6	
27	71	20	183.80	2	85.0	
29	71	13	197.20	2	88.7	
31	71	8	210.80	2	92.9	
33	83.5	23	225.00	2	96.3	
35	83.5	16	240.00	2	99.4	
37	83.5	12	253.00	2	101.9	
39	83.5	9	267.00	2	104.4	
41	83.5	8	280.00	2	105.4	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	26.7	100	21.4	1	26.7	
5	26.7	33	34.5	1	36.3	
7	26.7	13	47.9	1	44.4	
9	52.1	101	61.4	1	52.0	
11	52.1	42	74.8	1	59.6	
13	52.1	20	88.2	1	66.1	
15	52.1	10	101.6	1	72.1	
17	77.6	101	115.2	1	77.5	
19	77.6	51	128.6	1	83.4	
21	77.6	27	142	1	89.0	
23	77.6	17	157.5	1	93.0	
25	77.6	12	171.2	1	96.0	
27	77.6	8	184.7	1	99.5	
29	84	13	198	1	101.7	
31	84	10	212	1	104.0	
33	84	8	225	1	105.9	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	26.7	99	21.3	2	26.8	
5	26.7	33	34.5	2	36.3	
7	26.7	13	47.9	2	44.4	
9	52.1	101	61.4	2	52.0	
11	52.1	43	75	2	59.4	
13	52.1	21	88.3	2	65.7	
15	52.1	11	101.7	2	71.3	
17	77.1	101	115.2	2	77.0	
19	77.1	55	128.9	2	82.3	
21	77.1	32	142.3	2	87.0	
23	77.1	19	155.9	2	91.5	
25	77.1	12	169.6	2	95.5	
27	77.1	8	184	2	99.0	
29	83.5	13	199	2	101.2	
31	83.5	10	212	2	103.5	
33	83.5	7	226	2	106.6	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	35.8	99	20.4	1	35.9	
5	35.8	20	33.3	1	49.8	
7	58.6	101	47.3	1	58.5	
9	58.6	50	60.8	1	64.6	
11	58.6	26	74.4	1	70.3	
13	58.6	14	87.8	1	75.7	
15	58.6	8	101.3	1	80.5	
17	84	83	114.9	1	85.6	
19	84	48	128.5	1	90.4	
21	84	29	141.9	1	94.8	
23	84	19	156	1	98.4	
25	84	13	171	1	101.7	
27	84	10	185	1	104.0	
29	84	8	197	1	105.9	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	36.4	100	20.5	2	36.4	
5	36.4	21	33.3	2	50.0	
7	36.4	8	47.3	2	58.3	
9	64.3	101	61	2	64.2	
11	64.3	52	74.6	2	70.0	
13	64.3	27	88.1	2	75.7	
15	64.3	15	101.4	2	80.8	
17	64.3	9	115	2	85.2	
19	83.5	47	128.5	2	90.1	
21	83.5	29	142.1	2	94.3	
23	83.5	19	155.6	2	97.9	
25	83.5	13	169	2	101.2	
27	83.5	10	183	2	103.5	
29	83.5	8	198	2	105.4	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.9 New fluid Concentration 9

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	20.5	100	23.50	1	20.5	
5	20.5	47	37.10	1	27.1	
7	20.5	24	50.20	1	32.9	
9	20.5	13	62.80	1	38.2	
11	43.7	100	77.40	1	43.7	
13	43.7	51	89.60	1	49.5	
15	43.7	30	102.70	1	54.2	
17	43.7	17	116.20	1	59.1	
19	43.7	10	129.60	1	63.7	
21	67.4	101	143.40	1	67.3	
23	67.4	62	156.70	1	71.6	
25	67.4	40	170.40	1	75.4	
27	67.4	26	183.90	1	79.1	
29	67.4	17	197.30	1	82.8	
31	67.4	12	210.90	1	85.8	
33	67.4	8	224.30	1	89.3	
35	83.5	34	238.00	1	92.9	
37	83.5	25	261.60	1	95.5	
39	83.5	18	265.00	1	98.4	
41	83.5	14	280.00	1	100.6	
43	83.5	11	295.00	1	102.7	
45				1	#NUM!	
3	20.4	99	23.50	2	20.5	
5	20.4	47	36.90	2	27.0	
7	20.4	24	49.00	2	32.8	
9	20.4	13	62.60	2	38.1	
11	43.1	100	76.20	2	43.1	
13	43.1	57	89.70	2	48.0	
15	43.1	32	103.10	2	53.0	
17	43.1	18	116.45	2	58.0	
19	43.1	11	129.80	2	62.3	
21	66.6	100	143.50	2	66.6	
23	66.6	61	157.10	2	70.9	
25	66.6	38	170.65	2	75.0	
27	66.6	25	184.15	2	78.6	
29	66.6	16	197.65	2	82.5	
31	66.6	11	211.40	2	85.8	
33	66.6	8	224.70	2	88.5	
35	84	42	238.60	2	91.5	
37	84	31	252.10	2	94.2	
39	84	23.5	266.00	2	96.6	
41	84	19	279.70	2	98.4	
43	84	15	293.00	2	100.5	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	25.9	99	21.4	1	26.0	
5	25.9	35	34.5	1	35.0	
7	25.9	14	48	1	43.0	
9	50.6	101	61.7	1	50.5	
11	50.6	45	75	1	57.5	
13	50.6	23	88.4	1	63.4	
15	50.6	12	101.8	1	69.0	
17	74.6	100	115.5	1	74.6	
19	74.6	57	128.7	1	79.5	
21	74.6	33	142.4	1	84.2	
23	74.6	20.5	156	1	88.4	
25	74.6	14	169.4	1	91.7	
27	74.6	9.5	183.1	1	95.0	
29	84	19	196.8	1	98.4	
31	84	14	210.4	1	101.1	
33	84	10.5	224	1	103.6	
35	84	8	237	1	105.9	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	26	99	21.2	2	26.1	
5	26	35	34.5	2	35.1	
7	26	14	47.8	2	43.1	
9	50.3	101	61.3	2	50.2	
11	50.3	44	74.8	2	57.4	
13	50.3	22	88.2	2	63.5	
15	50.3	11	101.6	2	69.5	
17	74.6	100	115.3	2	74.6	
19	74.6	57	128.6	2	79.5	
21	74.6	33	142.3	2	84.2	
23	74.6	21	155.9	2	88.2	
25	74.6	14	169.4	2	91.7	
27	74.6	9	183.1	2	95.5	
29	83.5	18	196.9	2	98.4	
31	83.5	13.5	210.3	2	100.9	
33	83.5	10.5	224	2	103.1	
35	83.5	8	237	2	105.4	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	35.1	100	20.4	1	35.1	
5	35.1	21	33.3	1	48.7	
7	57.3	100	47.5	1	57.3	
9	57.3	49	61	1	63.5	
11	57.3	27	74.5	1	68.7	
13	57.3	15	88	1	73.8	
15	57.3	9	101.4	1	78.2	
17	83.5	101	115.1	1	83.4	
19	83.5	60	128.6	1	87.9	
21	83.5	37	142.2	1	92.1	
23	83.5	24	155.8	1	95.9	
25	83.5	16	169.3	1	99.4	
27	83.5	11	183	1	102.7	
29	83.5	9	197	1	104.4	
31	83.5	7	212	1	106.6	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	35.9	101	20.4	2	35.8	
5	35.9	23	33.3	2	48.7	
7	35.9	8	47.4	2	57.8	
9	63.3	101	61	2	63.2	
11	63.3	53	74.5	2	68.8	
13	63.3	29	88	2	74.1	
15	63.3	17	101.5	2	78.7	
17	63.3	10	115	2	83.3	
19	84	65	128.6	2	87.7	
21	84	40	142.3	2	92.0	
23	84	27	155.9	2	95.4	
25	84	19	169.4	2	98.4	
27	84	14	183	2	101.1	
29	84	10	197	2	104.0	
31	84	9	210	2	104.9	
33	84	7	224	2	107.1	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.10 New fluid Concentration 10

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	20.3	101	23.50	1	20.2	
5	20.3	50	36.90	1	26.3	
7	20.3	25	49.20	1	32.3	
9	20.3	14	62.80	1	37.4	
11	20.3	8	76.00	1	42.2	
13	47.2	100	89.40	1	47.2	
15	47.2	57	102.90	1	52.1	
17	47.2	33	116.10	1	56.8	
19	47.2	19	129.80	1	61.6	
21	47.2	12	143.30	1	65.6	
23	69.8	101	156.80	1	69.7	
25	69.8	63	170.40	1	73.8	
27	69.8	41	183.80	1	77.5	
29	69.8	27	197.50	1	81.2	
31	69.8	19	211.20	1	84.2	
33	69.8	13	224.60	1	87.5	
35	69.8	9.5	238.50	1	90.2	
37	84	35	251.90	1	93.1	
39	84	26	265.60	1	95.7	
41	84	21	279.30	1	97.6	
43	84	16	293.00	1	99.9	
45				1	#NUM!	
3	20.2	100	23.30	2	20.2	
5	20.2	49	36.60	2	26.4	
7	20.2	25	48.90	2	32.2	
9	20.2	14	62.50	2	37.3	
11	20.2	8	75.90	2	42.1	
13	47.2	101	89.50	2	47.1	
15	47.2	56	103.30	2	52.2	
17	47.2	33	116.20	2	56.8	
19	47.2	20	129.70	2	61.2	
21	47.2	12	143.20	2	65.6	
23	47.2	8	156.80	2	69.1	
25	73.6	101	170.40	2	73.5	
27	73.6	65	183.90	1	77.3	
29	73.6	44	197.50	2	80.7	
31	73.6	30	211.10	2	84.1	
33	73.6	21	224.60	2	87.2	
35	73.6	15	238.60	2	90.1	
37	73.6	11	252.10	2	92.8	
39	73.6	9	265.80	2	94.5	
41	83.5	21	279.80	2	97.1	
43	83.5	17	293.00	2	98.9	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	25.5	100	21	0	25.5	frame not fully in
5	25.5	36	34.4	0	34.4	
7	25.5	15	47.6	0	42.0	
9	49.2	101	61.1	0	49.1	
11	49.2	45	74.5	0	56.1	
13	49.2	23	88.1	0	62.0	
15	49.2	12	101.3	0	67.6	
17	73.2	100	115	0	73.2	
19	73.2	56	128.6	0	78.2	
21	73.2	34	142.1	0	82.6	
23	73.2	21	155.9	0	86.8	
25	73.2	14	169.7	0	90.3	
27	73.2	10	183.1	0	93.2	
29	83.5	22	196.6	0	96.7	
31	83.5	16	210.3	0	99.4	
33	83.5	12	223.8	0	101.9	
35	83.5	10	237.3	0	103.5	
37	83.5	8	251.3	0	105.4	
39				0	#NUM!	
41				0	#NUM!	
43				0	#NUM!	
45				0	#NUM!	
3	25.6	99	21.2	1	25.7	
5	25.6	37	34.4	1	34.2	
7	25.6	15	47.9	1	42.1	
9	49.1	101	61.3	1	49.0	
11	49.1	45	74.9	1	56.0	
13	49.1	23	88.2	1	61.9	
15	49.1	12	101.7	1	67.5	
17	73.2	99.5	115.4	1	73.2	
19	73.2	56	128.8	1	78.2	
21	73.2	33	142.2	1	82.8	
23	73.2	21	156.1	1	86.8	
25	73.2	14	169.6	1	90.3	
27	73.2	9.5	183.2	1	93.6	
29	83.5	22	196.7	1	96.7	
31	83.5	16	210.1	1	99.4	
33	83.5	12	224	1	101.9	
35	83.5	10	237.6	1	103.5	
37	83.5	8	251	1	105.4	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	25.6	99	21.2	2	25.7	
5	25.6	37	34.4	2	34.2	
7	25.6	15	47.8	2	42.1	
9	49.3	101	61.3	2	49.2	
11	49.3	45	75	2	56.2	
13	49.3	22	88.3	2	62.5	
15	49.3	12	101.6	2	67.7	
17	73.2	101	115.3	2	73.1	
19	73.2	57	128.7	2	78.1	
21	73.2	34	142.3	2	82.6	
23	73.2	21.5	156.1	2	86.6	
25	73.2	14.5	169.6	2	90.0	
27	73.2	10	183.1	2	93.2	
29	84	25	196.9	2	96.0	
31	84	18	210.5	2	98.9	
33	84	14	224	2	101.1	
35	84	11	237.9	2	103.2	
37	84	9	251.3	2	104.9	
39	84	7.5	265	2	106.5	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	34.2	99	20.3	1	34.3	Venturi riggen kjører
5	34.2	21	33	1	47.8	Mindre klare signaler
7	56.9	101	47.1	1	56.8	Stopper sett tidligere
9	56.9	52	60.7	1	62.6	
11	56.9	28	74.4	1	68.0	
13	56.9	16	88	1	72.8	
15	56.9	9	101.2	1	77.8	
17	82.3	101	114.9	1	82.2	
19	82.3	63	128.4	1	86.3	
21	82.3	39	142	1	90.5	
23	82.3	25	155.9	1	94.3	
25	82.3	18	169.1	1	97.2	
27	82.3	13	183	1	100.0	
29	82.3	10	196	1	102.3	
31				1	#NUM!	
33				1	#NUM!	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	34.6	101	20.2	2	34.5	
5	34.6	24	33.2	2	47.0	
7	34.6	8	47.3	2	56.5	
9	62.4	101	60.8	2	62.3	
11	62.4	55	74.4	2	67.6	
13	62.4	31	88	2	72.6	
15	62.4	18	101.4	2	77.3	
17	62.4	10.5	114.8	2	82.0	
19	84	75	128.6	2	86.5	
21	84	49	142	2	90.2	
23	84	32	155.6	2	93.9	
25	84	23	169.2	2	96.8	
27	84	16	183	2	99.9	
29	84	13	196	2	101.7	
31				2	#NUM!	
33				2	#NUM!	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.11 New fluid Concentration 11

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.5	100	23.40	1	19.5	
5	19.5	50	36.80	1	25.5	
7	19.5	25	49.10	1	31.5	
9	19.5	14	62.60	1	36.6	
11	19.5	8	76.00	1	41.4	
13	45.8	100	89.70	1	45.8	
15	45.8	58	103.00	1	50.5	
17	45.8	34	116.50	1	55.2	
19	45.8	20	130.00	1	59.8	
21	45.8	13	143.50	1	63.5	
23	45.8	8	157.10	1	67.7	
25	71.6	100	170.80	1	71.6	
27	71.6	65	184.30	1	75.3	
29	71.6	44	197.90	1	78.7	
31	71.6	30	211.60	1	82.1	
33	71.6	21	225.00	1	85.2	
35	71.6	15	238.70	1	88.1	
37	71.6	11	252.40	1	90.8	
39	71.6	8	266.20	1	93.5	
41	84	26	280.00	1	95.7	
43	84	21	293.50	1	97.6	
45				1	#NUM!	
3	19.5	100	23.40	2	19.5	
5	19.5	49	36.90	2	25.7	
7	19.5	26	49.10	2	31.2	
9	19.5	14	62.50	2	36.6	
11	19.5	8	75.90	2	41.4	
13	45.7	101	89.60	2	45.6	
15	45.7	58	103.00	2	50.4	
17	45.7	34	116.40	2	55.1	
19	45.7	20	130.00	2	59.7	
21	45.7	13	143.40	2	63.4	
23	45.7	8	157.10	2	67.6	
25	71.6	100	170.70	2	71.6	
27	71.6	65	184.30	2	75.3	
29	71.6	44	197.80	2	78.7	
31	71.6	30	211.40	2	82.1	
33	71.6	21	225.00	2	85.2	
35	71.6	15	238.70	2	88.1	
37	71.6	11	252.30	2	90.8	
39	71.6	9	266.10	2	92.5	
41	83.5	26	279.90	2	95.2	
43	83.5	20.5	293.40	2	97.3	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	25.8	101	21.1	1	25.7	
5	25.8	38	34.6	1	34.2	
7	25.8	16	48	1	41.7	
9	48.7	99	61.6	1	48.8	
11	48.7	47	75.1	1	55.3	
13	48.7	23	88.4	1	61.5	
15	48.7	13	101.9	1	66.4	
17	72	100	115.4	1	72.0	
19	72	57	128.9	1	76.9	
21	72	34	142.5	1	81.4	
23	72	21	156.2	1	85.6	
25	72	14	169.8	1	89.1	
27	72	9.5	183.3	1	92.4	
29	83.5	26	197	1	95.2	
31	83.5	19	210.7	1	97.9	
33	83.5	14	224.2	1	100.6	
35	83.5	11	237.9	1	102.7	
37	83.5	9	251.8	1	104.4	
39	83.5	7.5	265	1	106.0	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	25.7	100	21.2	2	25.7	
5	25.7	39	34.5	2	33.9	
7	25.7	16	47.9	2	41.6	
9	48.5	101	61.6	2	48.4	
11	48.5	47	74.9	2	55.1	
13	48.5	24	88.4	2	60.9	
15	48.5	13	101.7	2	66.2	
17	71.7	100	115.4	2	71.7	
19	71.7	55	128.9	2	76.9	
21	71.7	32	142.5	2	81.6	
23	71.7	20	156.2	2	85.7	
25	71.7	14	169.8	2	88.8	
27	71.7	9	183.4	2	92.6	
29	84	27	197.1	2	95.4	
31	84	20	210.7	2	98.0	
33	84	15	224.1	2	100.5	Venturi started
35	84	12	238	2	102.4	
37	84	10	251	2	104.0	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	33	100	20.2	1	33.0	
5	33	21	33.3	1	46.6	
7	55.3	101	46.6	1	55.2	
9	55.3	49	60.9	1	61.5	
11	55.3	27	74.4	1	66.7	
13	55.3	16	88	1	71.2	
15	55.3	9	101.5	1	76.2	
17	80.7	100	115	1	80.7	
19	80.7	60	128.6	1	85.1	
21	80.7	38	142.1	1	89.1	
23	80.7	25	155.9	1	92.7	
25	80.7	17	169.4	1	96.1	
27	80.7	12	183	1	99.1	
29	80.7	9	196.8	1	101.6	
31	84	11	210.2	1	103.2	
33	84	9	224	1	104.9	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	32.9	100	20.3	2	32.9	
5	32.9	22	33.2	2	46.1	
7	32.9	8	46.5	2	54.8	
9	61.5	100	60.8	2	61.5	
11	61.5	56	74.4	2	66.5	
13	61.5	32	87.9	2	71.4	
15	61.5	18	101.4	2	76.4	
17	61.5	11	114.9	2	80.7	
19	83.5	85	128.6	2	84.9	
21	83.5	54	142.3	2	88.9	
23	83.5	35	155.9	2	92.6	
25	83.5	24	169.5	2	95.9	
27	83.5	17.5	183.1	2	98.6	
29	83.5	13	196.8	2	101.2	
31	83.5	10.5	210.4	2	103.1	
33	83.5	8	224	2	105.4	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

G.12 New fluid Concentration 12

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.6	100	23.30	1	19.6	
5	19.6	50	36.80	1	25.6	
7	19.6	26	49.10	1	31.3	
9	19.6	15	62.60	1	36.1	
11	19.6	9	76.20	1	40.5	
13	19.6	5	89.50	1	45.6	
15	50.1	100	103.10	1	50.1	
17	50.1	58	116.50	1	54.8	
19	50.1	35	130.10	1	59.2	
21	50.1	22	143.50	1	63.3	
23	50.1	14	157.20	1	67.2	
25	50.1	9	170.80	1	71.0	
27	74.8	100	184.50	1	74.8	
29	74.8	67	197.90	1	78.3	
31	74.8	46	211.40	1	81.5	
33	74.8	33	225.20	1	84.4	
35	74.80	24	238.90	1	87.2	
37	74.80	18	252.60	1	89.7	
39	74.80	14	266.50	1	91.9	
41	74.80	11	280.00	1	94.0	
43	74.80	9	293.80	1	95.7	
45				1	#NUM!	
3	19.70	100	23.40	2	19.7	
5	19.7	49	36.90	2	25.9	
7	19.7	26	49.10	2	31.4	
9	19.7	14	62.60	2	36.8	
11	19.7	9	76.00	2	40.6	
13	19.7	5	89.50	2	45.7	
15	50.2	100	103.00	2	50.2	
17	50.2	59	116.50	2	54.8	
19	50.2	35	130.00	2	59.3	
21	50.2	22	143.50	2	63.4	
23	50.2	14	157.20	2	67.3	
25	50.2	9	170.70	2	71.1	
27	74.7	100	184.40	2	74.7	
29	74.7	66	198.00	2	78.3	
31	74.7	46	211.60	2	81.4	
33	74.70	32	225.10	2	84.6	
35	74.70	23	238.90	2	87.5	
37	74.70	17	252.70	2	90.1	
39	74.70	13	266.50	2	92.4	
41	74.70	10	280.10	2	94.7	
43	74.70	8	294.00	2	96.6	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	25.6	100	21.3	1	25.6	
5	25.6	39	34.5	1	33.8	
7	25.6	17	48	1	41.0	
9	25.6	8	61.4	1	47.5	
11	54.8	100	75	1	54.8	
13	54.8	50	88.4	1	60.8	
15	54.8	28	101.9	1	65.9	
17	54.8	15	115.3	1	71.3	
19	54.8	9	128.9	1	75.7	
21	80.6	100	142.6	1	80.6	
23	80.6	63	156.3	1	84.6	
25	80.6	43	169	1	87.9	
27	80.6	30	183.4	1	91.1	
29	80.6	22	197	1	93.8	
31	80.6	17	210.9	1	96.0	
33	80.6	13	224.2	1	98.3	
35	80.6	11	238	1	99.8	
37	80.6	9	251.5	1	101.5	
39	80.6	6	265.4	1	105.0	
41	80.6	5	279.3	1	106.6	
43	80.6	4	292.7	1	108.6	
45				1	#NUM!	
3	25.7	100	21.2	2	25.7	
5	25.7	40	34.5	2	33.7	
7	25.7	17	47.9	2	41.1	
9	25.7	7	61.4	2	48.8	
11	54.5	100	74.9	2	54.5	
13	54.5	49	88.3	2	60.7	
15	54.5	27	101.8	2	65.9	
17	54.5	15	152.2	2	71.0	
19	54.5	8	128.9	2	76.4	
21	80.7	100	142.5	2	80.7	
23	80.7	62	156.2	2	84.9	
25	80.7	41	169.8	2	88.4	
27	80.7	28	183.5	2	91.8	
29	80.7	20	197.1	2	94.7	
31	80.7	15	210.7	2	97.2	
33	80.7	11	224.3	2	99.9	
35	80.7	9	238.1	2	101.6	
37	80.7	8	251.4	2	102.6	
39	80.7	6	265.5	2	105.1	
41	80.7	5	279	2	106.7	
43	80.7	4	292.4	2	108.7	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	33.2	100	20.5	1	33.2	
5	33.2	22	33.1	1	46.4	
7	33.2	8	46.3	1	55.1	
9	33.2	4	60.5	1	61.2	
11	66.1	100	74.3	1	66.1	
13	66.1	57	87.8	1	71.0	
15	66.1	33	101.2	1	75.7	
17	66.1	20	114.8	1	80.1	
19	66.1	12	128.3	1	84.5	
21	66.1	8	142	1	88.0	
23	85.7	50	155.7	1	91.7	
25	85.7	34	169.3	1	95.1	
27	85.7	25	183	1	97.7	
29	85.7	18	196.4	1	100.6	
31	85.7	14	210.1	1	102.8	
33	85.7	12	223.5	1	104.1	
35	85.7	10	237.4	1	105.7	
37	85.7	9	251	1	106.6	
39	85.7	8	264	1	107.6	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	33.3	100	20.2	2	33.3	
5	33.3	24	33.2	2	45.7	
7	33.3	8	46.3	2	55.2	
9	33.3	4	60.6	2	61.3	
11	66.3	100	74.4	2	66.3	
13	66.3	58	87.8	2	71.0	
15	66.3	33	101.3	2	75.9	
17	66.3	20	114.7	2	80.3	
19	66.3	12	128.3	2	84.7	
21	66.3	8	141.9	2	88.2	
23	86	50	155.8	2	92.0	
25	86	35	169.2	2	95.1	
27	86	26	182.9	2	97.7	
29	86	19	196.5	2	100.4	
31	86	15	210.4	2	102.5	
33	86	12	223.9	2	104.4	
35	86	10	237.5	2	106.0	
37	86	9	250	2	106.9	
39	86	8	265	2	107.9	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

Appendix H

Code for generating analysis plots

This appendix contains the code used for generating the analysis plots used in this report.

```python
#Resets console
from IPython import get_ipython
get_ipython().magic('reset -sf')

import pandas as pd
import numpy as np

from matplotlib.backends.backend_pdf import PdfPages
import matplotlib.pyplot as plt
import matplotlib.cm as cm


"""
Methods
"""
def multi_page_pdf(filename, figs=None, dpi=200):
    pp = PdfPages(filename)
    if figs is None:
        figs = [plt.figure(n) for n in plt.get_fignums()]
    for fig in figs:
        plot = fig
        plot.savefig(pp, format='pdf')
    pp.close()


"""
Main code
"""

#Loading 0.5MHz data
for i in range(1,13):
    if not ('dataset05' in locals()):
        dataset05 = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 0, header = 0)
        #dataset05[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "0.5MHz Consentration " + str(i))
        #figs = [dataset05[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "0.5MHz Consentration " + str(i))]
        dataset05['Consentration'] = i

    else:
        dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 0, header = 0)
        dataset_temp['Consentration'] = i
        dataset05 = dataset05.append(dataset_temp, ignore_index=True)
        #dataset_temp[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "0.5MHz Consentration " + str(i))
        #figs.append(dataset_temp[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "0.5MHz Consentration " + str(i




#Loading 1.0MHz data
for i in range(1,13):
    if not ('dataset10' in locals()):
        dataset10 = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 1, header = 0)
        dataset10['Consentration'] = i
        #dataset10[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "1.0MHz Consentration " + str(i))
        #figs.append(dataset10[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "1.0MHz Consentration " + str(i)))

    else:
        dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 1, header = 0)
        dataset_temp['Consentration'] = i
        dataset10 = dataset10.append(dataset_temp, ignore_index=True)
        #dataset_temp[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "1.0MHz Consentration " + str(i))
        #figs.append(dataset_temp[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "1.0MHz Consentration " + str(i

#Loading 2.25MHz data
for i in range(1,13):
    if not ('dataset225' in locals()):
        dataset225 = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 2, header = 0)
        dataset225['Consentration'] = i
        #dataset225[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "2.25MHz Consentration " + str(i))
        #figs.append(dataset225[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "2.25MHz Consentration " + str(i)

    else:
        dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 2, header = 0)
        dataset_temp['Consentration'] = i
        dataset225 = dataset225.append(dataset_temp, ignore_index=True)
        #dataset_temp[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "2.25MHz Consentration " + str(i))
        #figs.append(dataset_temp[['Distance [cm]', 'Gain [dB]', 'Signal Strength [%]']].plot(title = "2.25MHz Consentration " + str(

#Dropping notes column
dataset05 = dataset05.loc[:, ~dataset05.columns.str.contains('^Unnamed')]
dataset10 = dataset10.loc[:, ~dataset10.columns.str.contains('^Unnamed')]
dataset225 = dataset225.loc[:, ~dataset225.columns.str.contains('^Unnamed')]

#Dropping any rows with missing data
dataset05 = dataset05.dropna(axis=0, how='any')
dataset10 = dataset10.dropna(axis=0, how='any')
dataset225 = dataset225.dropna(axis=0, how='any')

#Compounding datasets
datasetfull = dataset05
datasetfull = datasetfull.append(dataset10, ignore_index=True)
datasetfull = datasetfull.append(dataset225, ignore_index=True)
```

```python
#Plotting
n0 = 1
n = 13
colours = cm.jet(np.linspace(0, 1, n))

#Select data set and file name
dataset = dataset225
filename = "225AnalysisPlots.pdf"

for i in range(n0, n):
    #Generating least square polynom fits
    data = dataset.loc[(dataset["Consentration"] == i)]
    gain_poly = np.polyfit(data["Distance [cm]"], data["Normalized Gain [dB]"], 2)
    tof_poly = np.polyfit(data["Distance [cm]"], data["ToF [µs]"], 1)

    #Getting average absolute errors
    gpoly = np.poly1d(gain_poly)
    tpoly = np.poly1d(tof_poly)
    k = 0
    gain_errorsum = 0
    tof_errorsum = 0
    for index, row in data.iterrows():
        gain_errorsum = gain_errorsum + np.absolute(row["Normalized Gain [dB]"] - gpoly(row["Distance [cm]"]))
        tof_errorsum = tof_errorsum + np.absolute(row["ToF [µs]"] - tpoly(row["Distance [cm]"]))
        k = k + 1
    gain_averageerror = gain_errorsum / k
    tof_averageerror = tof_errorsum / k

    #Generating lists
    if (i == 1):
        gain_polynoms = gain_poly
        tof_polynoms = tof_poly
        gain_avgerrors = [gain_averageerror]
        tof_avgerrors = [tof_averageerror]
    else:
        gain_polynoms = np.vstack((gain_polynoms, gain_poly))
        tof_polynoms = np.vstack((tof_polynoms, tof_poly))
        gain_avgerrors.append(gain_averageerror)
        tof_avgerrors.append(tof_averageerror)

#Generate plots for polyfitted normalized gain
fig = plt.figure(figsize = [40, 30])
distance = np.linspace(3, 43, 100)
for i in range(n0, n):
    poly = np.poly1d(gain_polynoms[i-1])
    plt.plot(distance, poly(distance), '-', color = colours[i])
    plt.scatter(dataset["Distance [cm]"].loc[dataset["Consentration"] == i],
                dataset["Normalized Gain [dB]"].loc[dataset["Consentration"] == i],
                c = colours[i])

plt.legend(labels=["Concentration " + str(x) for x in range(n0,n)], loc=2, fontsize = 28)
plt.title("2nd order polynomial fitted with least squares and data points for each concentration for Normalized Gain [dB]", fontsize =
plt.xlabel("Distance [cm]", fontsize = 36)
plt.ylabel("Normalized Gain [dB]", fontsize = 36)
plt.xticks(np.linspace(3, 43, 21), fontsize = 28)
plt.yticks(np.linspace(15, 150, 10), fontsize = 28)
fig = plt.gcf()
plt.show()

#Generate plots for polyfitted time of flight
fig2 = plt.figure(figsize = [40, 30])
for i in range(n0, n):
    poly = np.poly1d(tof_polynoms[i-1])
    plt.plot(distance, poly(distance), '-', color = colours[i])
    plt.scatter(dataset["Distance [cm]"].loc[dataset["Consentration"] == i],
                dataset["ToF [µs]"].loc[dataset["Consentration"] == i],
                c = colours[i])

plt.legend(labels=["Concentration " + str(x) for x in range(n0,n)], loc=2, fontsize = 28)
plt.title("1st order polynomial fitted with least squares and data points for each concentration for Time of Flight [µs]", fontsize =
plt.xlabel("Distance [cm]", fontsize = 36)
plt.ylabel("Time of Flight [µs]", fontsize = 36)
plt.xticks(np.linspace(3, 43, 21), fontsize = 28)
plt.yticks(np.linspace(25, 350, 14), fontsize = 28)
fig2 = plt.gcf()
plt.show()

#legend vector for error plots
error_labels = ["0.5MHz", "1.0MHz", "2.25MHz"]

#Generate plot for avg error normalized gain
fig3 = plt.figure(figsize = [20, 15])
plt.legend(labels = error_labels)
plt.scatter(range(n0, n), gain_avgerrors)
plt.title("Average errors of each data set to it's polynomial for Normalized Gain [dB]", fontsize = 28)
plt.xlabel("Concentration #", fontsize = 24)
plt.ylabel("Average error", fontsize = 24)
plt.xticks(np.linspace(1, 12, 12), fontsize = 20)
plt.yticks(np.linspace(0, 1.5, 7), fontsize = 20)
fig3 = plt.gcf()
plt.show()


#Generate plot for avg error time of flight
fig4 = plt.figure(figsize = [20, 15])
plt.legend(labels = error_labels)
plt.scatter(range(n0, n), tof avgerrors)
```

```
plt.title("Average errors of each data set to it's polynomial for Time of Flight [μs]", fontsize = 28)
plt.xlabel("Concentration #", fontsize = 24)
plt.ylabel("Average error", fontsize = 24)
plt.xticks(np.linspace(1, 12, 12), fontsize = 20)
plt.yticks(np.linspace(0, 1.5, 7), fontsize = 20)
fig4 = plt.gcf()
plt.show()

#print([fig, fig2, fig3, fig4])
multi_page_pdf(filename, [fig, fig2, fig3, fig4])
```

Appendix I

Rheological data

This appendix includes the data sheets containing rheological lab data the models are trained towards and evaluated against.

I.1 New data pre-experiment rheological data

Con 1 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	20	35.846	772	27.669	599.94	1.62E+06	1468.9
2	20	43.333	386	16.725	299.98	2.27E+06	887.9
1	20	50.521	257	12.997	199.95	2.66E+06	689.99
2	20	52.933	232	12.257	179.97	3.00E+06	650.7
1	20	68.336	129	8.7902	99.976	3.21E+06	466.66
2	20	72.039	116	8.3405	89.985	3.37E+06	442.78
1	20	87.673	77.2	6.7666	59.986	3.49E+06	359.23
2	20	125.66	38.6	4.8494	29.995	3.56E+06	257.45
1	20	317.32	7.72	2.449	5.9984	3.58E+06	130.01
2	20	485.47	3.86	1.8735	2.9995	3.59E+06	99.463
1	19.86	667.21	2.32	1.545	1.7997	3.59E+06	82.021
2	18.95	1016.3	1.16	1.1769	0.89998	3.59E+06	62.478

Yield point (CSS)	Shear stress [Pa]	
Yield point	1.27	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	5.195	
Slope Pa/ 1/min	0.036	
Plastic Viscosity	10.944	mPas
Density	[g/cm^3]	
	1.749	
Gel strength	G' [Pa]	
	3.33	
Crossover G'=G"	[Pa]	
flow point	1.932	

Con 2 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	20	32.525	772	25.106	599.94	1.37E+06	1332.8
2	20	38.957	386	15.036	299.98	2.01E+06	798.23
1	20	45.136	257	11.612	199.95	2.41E+06	616.46
2	20	47.136	232	10.914	179.97	2.74E+06	579.43
1	20	60.605	129	7.7957	99.976	2.95E+06	413.86
2	20	63.792	116	7.3856	89.985	3.12E+06	392.09
1	20	77.517	77.2	5.9827	59.986	3.24E+06	317.61
2	20	111.04	38.6	4.2855	29.995	3.30E+06	227.51
1	20	278.15	7.72	2.1467	5.9984	3.32E+06	113.97
2	20	424.54	3.86	1.6383	2.9994	3.33E+06	86.977
1	19.84	581.66	2.32	1.3468	1.7997	3.33E+06	71.502
2	18.92	880.65	1.16	1.0198	0.9	3.33E+06	54.137

Yield point (CSS)	Shear stress [Pa]	
Yield point	1.16	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	4.542	
Slope Pa/ 1/min	0.034	
Plastic Viscosity	10.07	mPas
Density	[g/cm^3]	
	1.702	
Gel strength	G' [Pa]	
	2.87	
Crossover G'=G"	[Pa]	
flow point	1.787	

Con 3 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	20	28.688	772	22.144	599.94	1.35E+06	1175.6
2	20	34.149	386	13.18	299.97	2.00E+06	699.7
1	20	39.471	257	10.155	199.95	2.39E+06	539.09
2	20	41.257	232	9.5532	179.97	2.73E+06	507.17
1	20	53.115	129	6.8322	99.976	2.93E+06	362.71
2	20	55.974	116	6.4805	89.985	3.10E+06	344.04
1	20	68	77.2	5.2482	59.986	3.22E+06	278.62
2	20	97.261	38.6	3.7536	29.995	3.28E+06	199.27
1	20	241.33	7.72	1.8626	5.9987	3.31E+06	98.883
2	20	363.75	3.86	1.404	2.9999	3.31E+06	74.535
1	19.77	493.24	2.32	1.1422	1.7997	3.32E+06	60.635
2	18.82	733.94	1.16	0.84985	0.89998	3.32E+06	45.117

Yield point (CSS)	Shear stress [Pa]	
Yield point	1.05	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	3.935	
Slope Pa/ 1/min	0.029	
Plastic Viscosity	8.964	mPas
Density	[g/cm^3]	
	1.689	
Gel strength	G' [Pa]	
	2.35	
Crossover G'=G"	[Pa]	
flow point	1.559	

Con 4 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	25.608	772	19.767	599.94	1.10E+06	1049.4
2	19.99	30.27	386	11.682	299.97	1.74E+06	620.21
1	19.99	34.91	257	8.981	199.95	2.14E+06	476.79
2	19.99	36.378	232	8.4235	179.97	2.47E+06	447.19
1	19.99	46.717	129	6.0093	99.976	2.68E+06	319.03
2	19.99	49.165	116	5.6922	89.985	2.85E+06	302.19
1	19.99	59.725	77.2	4.6095	59.986	2.97E+06	244.71
2	19.99	85.24	38.6	3.2896	29.995	3.03E+06	174.64
1	19.99	209.22	7.72	1.6147	5.9984	3.05E+06	85.722
2	19.99	312.47	3.86	1.2059	2.9995	3.06E+06	64.02
1	19.84	419.65	2.32	0.9717	1.7997	3.06E+06	51.586
2	18.93	616.13	1.16	0.71343	0.89997	3.07E+06	37.875

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.964	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	3.352	
Slope Pa/ 1/min	0.026	
Plastic Viscosity	8.085	mPas
Density	[g/cm^3]	
	1.628	
Gel strength	G' [Pa]	
	1.96	
Crossover G'=G"	[Pa]	
flow point	1.4	

Con 5 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	22.739	772	17.552	599.93	1.13E+06	931.83
2	19.99	26.619	386	10.273	299.96	1.78E+06	545.39
1	19.99	30.535	257	7.8554	199.95	2.17E+06	417.03
2	19.99	31.767	232	7.3558	179.97	2.51E+06	390.51
1	19.99	40.722	129	5.2382	99.976	2.72E+06	278.09
2	19.99	42.868	116	4.963	89.985	2.88E+06	263.48
1	19.99	52.04	77.2	4.0164	59.986	3.00E+06	213.23
2	19.99	74.161	38.6	2.8621	29.995	3.07E+06	151.94
1	19.99	179.04	7.72	1.3818	5.9984	3.09E+06	73.358
2	19.99	265.63	3.86	1.0251	2.9994	3.09E+06	54.421
1	19.86	354.07	2.32	0.8198	1.7996	3.10E+06	43.522
2	18.95	513.7	1.16	0.59481	0.89994	3.10E+06	31.578

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.895	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	2.886	
Slope Pa/ 1/min	0.024	
Plastic Viscosity	7.279	mPas
Density	[g/cm^3]	
	1.598	
Gel strength	G' [Pa]	
	1.63	
Crossover G'=G"	[Pa]	
flow point	1.257	

Con 6 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	20.531	772	15.848	599.94	1.20E+06	841.34
2	19.99	23.875	386	9.2144	299.97	1.85E+06	489.18
1	19.99	27.266	257	7.0145	199.95	2.24E+06	372.39
2	19.99	28.419	232	6.5804	179.97	2.58E+06	349.34
1	19.99	36.451	129	4.6887	99.976	2.79E+06	248.92
2	19.99	38.367	116	4.442	89.985	2.95E+06	235.82
1	19.99	46.525	77.2	3.5908	59.986	3.07E+06	190.63
2	19.99	66.083	38.6	2.5503	29.995	3.14E+06	135.39
1	19.99	157.51	7.72	1.2156	5.9983	3.16E+06	64.536
2	19.99	230.89	3.86	0.89103	2.9994	3.16E+06	47.304
1	19.86	304.28	2.32	0.70451	1.7995	3.17E+06	37.401
2	18.96	434.48	1.16	0.50308	0.89995	3.17E+06	26.708

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.838	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	2.539	
Slope Pa/ 1/min	0.022	
Plastic Viscosity	6.6336	mPas
Density	[g/cm^3]	
	1.568	
Gel strength	G' [Pa]	
	1.340	
Crossover G'=G"	[Pa]	
flow point	1.144	

Con 7 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	18.503	772	14.282	599.94	8.94E+05	758.24
2	19.99	21.483	386	8.291	299.96	1.54E+06	440.16
1	19.99	24.465	257	6.2939	199.95	1.93E+06	334.14
2	19.99	25.405	232	5.8826	179.97	2.27E+06	312.3
1	19.98	32.453	129	4.1745	99.976	2.48E+06	221.62
2	19.98	34.097	116	3.9476	89.985	2.65E+06	209.57
1	19.99	41.289	77.2	3.1867	59.986	2.76E+06	169.18
2	19.99	58.452	38.6	2.2558	29.995	2.83E+06	119.76
1	19.99	137.03	7.72	1.0575	5.9984	2.85E+06	56.143
2	19.99	198.84	3.86	0.76732	2.9993	2.85E+06	40.736
1	19.85	259.54	2.32	0.6009	1.7995	2.86E+06	31.901
2	18.96	365.25	1.16	0.42292	0.89995	2.86E+06	22.452

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.804	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	2.245	
Slope Pa/ 1/min	0.019	
Plastic Viscosity	5.991	mPas
Density	[g/cm^3]	
	1.541	
Gel strength	G'	
	[Pa]	
	1.08	
Crossover G'=G"	[Pa]	
flow point	1.032	

Con 8 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	16.947	772	13.081	599.94	8.94E+05	694.46
2	19.99	19.54	386	7.541	299.96	1.54E+06	400.34
1	19.99	22.149	257	5.6982	199.95	1.93E+06	302.51
2	19.99	22.971	232	5.3189	179.97	2.27E+06	282.38
1	19.99	29.227	129	3.7595	99.976	2.48E+06	199.59
2	19.99	30.753	116	3.5605	89.984	2.65E+06	189.02
1	19.99	37.14	77.2	2.8664	59.986	2.76E+06	152.17
2	19.99	52.408	38.6	2.0226	29.995	2.83E+06	107.38
1	19.99	120.82	7.72	0.93244	5.9984	2.85E+06	49.502
2	19.99	173.41	3.86	0.66918	2.9993	2.85E+06	35.526
1	19.83	224.66	2.32	0.52016	1.7995	2.86E+06	27.614
2	18.91	311.6	1.16	0.36079	0.89993	2.86E+06	19.154

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.772	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	1.972	
Slope Pa/ 1/min	0.018	
Plastic Viscosity	5.54	mPas
Density	[g/cm^3]	
	1.521	
Gel strength	G'	
	[Pa]	
	0.901	
Crossover G'=G"	[Pa]	
flow point	0.944	

Con 9 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	15.213	772	11.743	599.94	8.94E+05	623.41
2	19.99	17.431	386	6.7272	299.96	1.54E+06	357.14
1	19.99	19.638	257	5.0523	199.96	2.14E+06	268.22
2	20	20.338	232	4.7097	179.98	2.48E+06	250.03
1	20	25.791	129	3.3175	99.976	2.69E+06	176.12
2	20	27.118	116	3.1397	89.984	2.85E+06	166.68
1	20	32.662	77.2	2.5208	59.986	2.97E+06	133.83
2	20	45.885	38.6	1.7708	29.995	3.04E+06	94.01
1	20	104.26	7.72	0.80469	5.9985	3.06E+06	42.72
2	20	148.07	3.86	0.57143	2.9995	3.06E+06	30.337
1	19.85	190.02	2.32	0.44	1.7997	3.07E+06	23.359
2	18.93	259.66	1.16	0.30064	0.8999	3.07E+06	15.961

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.743	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	1.711	
Slope Pa/ 1/min	0.018	
Plastic Viscosity	5.0158	mPas
Density	[g/cm^3]	
	1.476	
Gel strength	G'	
	[Pa]	
	0.726	
Crossover G'=G"	[Pa]	
flow point	no	

Con 10 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	13.942	772	10.762	599.94	8.94E+05	571.32
2	19.98	15.933	386	6.1491	299.96	1.54E+06	326.45
1	19.98	17.93	257	4.6126	199.95	1.94E+06	244.88
2	19.98	18.575	232	4.3011	179.97	2.27E+06	228.34
1	19.98	23.484	129	3.0207	99.976	2.48E+06	160.37
2	19.98	24.618	116	2.8502	89.985	2.65E+06	151.31
1	19.99	29.648	77.2	2.2882	59.986	2.77E+06	121.48
2	19.99	41.434	38.6	1.599	29.995	2.83E+06	84.89
1	19.99	92.428	7.72	0.71334	5.9985	2.85E+06	37.87
2	19.99	129.84	3.86	0.5011	2.9996	2.86E+06	26.603
1	19.85	164.67	2.32	0.38125	1.7995	2.86E+06	20.24
2	18.95	222.07	1.16	0.25712	0.8999	2.86E+06	13.65

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.731	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	1.513	
Slope Pa/ 1/min	0.015	
Plastic Viscosity	4.6129	mPas
Density	[g/cm^3]	
	1.472	
Gel strength	G'	
	[Pa]	
	0.61	
Crossover G'=G"	[Pa]	
flow point	no	

Con 11 PRE

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	12.9	772	9.9576	599.94	8.94E+05	528.64
2	19.98	14.687	386	5.668	299.96	1.54E+06	300.91
1	19.99	16.426	257	4.2257	199.95	1.97E+06	224.34
2	19.99	17.011	232	3.9389	179.97	2.30E+06	209.11
1	19.99	21.409	129	2.7538	99.976	2.51E+06	146.2
2	19.99	22.446	116	2.5987	89.984	2.68E+06	137.96
1	19.99	26.909	77.2	2.0768	59.986	2.80E+06	110.25
2	19.99	37.457	38.6	1.4456	29.996	2.88E+06	76.744
1	19.99	82.283	7.72	0.63504	5.9984	2.89E+06	33.713
2	19.99	114.33	3.86	0.44121	2.9994	2.90E+06	23.423
1	19.86	143.56	2.32	0.33237	1.7995	2.91E+06	17.645
2	18.96	190.96	1.16	0.2211	0.8999	2.91E+06	11.738

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.724	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	1.354	
Slope Pa/ 1/min	0.014	
Plastic Viscosity	4.2896	mPas
Density	[g/cm^3]	
	1.416	
Gel strength	G'	
	[Pa]	
	0.495	
Crossover G'=G"	[Pa]	
flow point	no	

I.2 New data post-experiment rheological data

Con 1 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	20	37.022	772	28.577	599.94	1.63E+06	1517.1
2	20	44.7	386	17.253	299.98	2.27E+06	915.92
1	20	52.033	257	13.386	199.95	2.67E+06	710.65
2	20	54.491	232	12.618	179.97	3.00E+06	669.85
1	20	70.239	129	9.0349	99.976	3.21E+06	479.65
2	20	74.018	116	8.5696	89.985	3.38E+06	454.95
1	20	89.981	77.2	6.9447	59.986	3.50E+06	368.69
2	20	128.81	38.6	4.9711	29.995	3.56E+06	263.91
1	20	324.33	7.72	2.5032	5.9986	3.58E+06	132.89
2	20	498	3.86	1.922	2.9996	3.59E+06	102.03
1	19.88	685.63	2.32	1.5877	1.7998	3.59E+06	84.288
2	18.99	1049.2	1.16	1.2149	0.89998	3.59E+06	64.496

Yield point (CSS)	Shear stress [Pa]	
Yield point	1.29	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	5.383	
Slope Pa/ 1/min	0.037	
Plastic Viscosity	11.324	mPas
Density	[g/cm^3]	
	1.746	
Gel strength	G' [Pa]	
	3.57	
Crossover G'=G"	[Pa]	
flow point	1.985	

Con 2 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	20	32.431	772	25.033	599.94	1.63E+06	1329
2	20	38.973	386	15.042	299.98	2.28E+06	798.56
1	20	45.254	257	11.642	199.95	2.67E+06	618.07
2	20	47.362	232	10.967	179.97	3.01E+06	582.22
1	20	61.056	129	7.8537	99.976	3.21E+06	416.94
2	20	64.325	116	7.4474	89.985	3.38E+06	395.37
1	20	78.19	77.2	6.0347	59.986	3.50E+06	320.37
2	20	112	38.6	4.3222	29.995	3.56E+06	229.46
1	20	280.72	7.72	2.1665	5.9984	3.59E+06	115.01
2	20	427.37	3.86	1.6493	2.9995	3.59E+06	87.559
1	19.87	583.96	2.32	1.3521	1.7997	3.60E+06	71.784
2	18.98	881.77	1.16	1.0211	0.90001	3.60E+06	54.207

Yield point (CSS)	Shear stress [Pa]	
Yield point	1.16	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	4.576	
Slope Pa/ 1/min	0.033	
Plastic Viscosity	9.991	mPas
Density	[g/cm^3]	
	1.654	
Gel strength	G' [Pa]	
	2.87	
Crossover G'=G"	[Pa]	
flow point	1.761	

Con 3 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	28.547	772	22.035	599.94	1.36E+06	1169.8
2	20	34.026	386	13.132	299.97	2.00E+06	697.18
1	20	39.384	257	10.132	199.95	2.40E+06	537.89
2	19.99	41.129	232	9.5236	179.97	2.73E+06	505.59
1	19.99	52.929	129	6.8084	99.976	2.94E+06	361.45
2	19.99	55.774	116	6.4573	89.985	3.11E+06	342.81
1	19.99	67.814	77.2	5.2339	59.986	3.23E+06	277.86
2	19.99	97.014	38.6	3.744	29.995	3.29E+06	198.77
1	19.99	239.64	7.72	1.8495	5.9984	3.31E+06	98.186
2	19.99	362.01	3.86	1.397	2.9994	3.32E+06	74.167
1	19.84	490.94	2.32	1.1368	1.7997	3.32E+06	60.349
2	18.93	731.1	1.16	0.84657	0.89999	3.32E+06	44.944

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	1.05	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	3.873	
Slope Pa/ 1/min	0.029	
Plastic Viscosity	8.903	mPas
Density	[g/cm^3]	
	1.665	
Gel strength	G'	
	[Pa]	
	2.27	
Crossover G'=G"	[Pa]	
flow point	1.569	

Con 4 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	25.759	772	19.883	599.94	1.08E+06	1055.6
2	19.99	30.405	386	11.735	299.97	1.73E+06	622.97
1	19.99	34.98	257	8.999	199.95	2.12E+06	477.75
2	19.99	36.491	232	8.4496	179.97	2.46E+06	448.58
1	19.99	46.894	129	6.0321	99.976	2.67E+06	320.23
2	19.99	49.368	116	5.7156	89.985	2.83E+06	303.44
1	19.99	59.93	77.2	4.6253	59.986	2.95E+06	245.55
2	19.99	85.513	38.6	3.3002	29.995	3.02E+06	175.2
1	19.99	209.12	7.72	1.614	5.9985	3.04E+06	85.685
2	19.99	312.65	3.86	1.2066	2.9996	3.04E+06	64.059
1	19.85	419.66	2.32	0.97174	1.7997	3.05E+06	51.589
2	18.94	616.36	1.16	0.7137	0.89997	3.05E+06	37.889

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.964	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	3.795	
Slope Pa/ 1/min	0.027	
Plastic Viscosity	8.148	mPas
Density	[g/cm^3]	
	1.634	
Gel strength	G'	
	[Pa]	
	1.762	
Crossover G'=G"	[Pa]	
flow point	1.406	

Con 5 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	22.921	772	17.692	599.94	1.20E+06	939.27
2	19.99	27	386	10.421	299.97	1.85E+06	553.22
1	19.99	31.018	257	7.9798	199.95	2.24E+06	423.64
2	19.98	32.34	232	7.4883	179.97	2.58E+06	397.54
1	19.98	41.537	129	5.343	99.976	2.79E+06	283.65
2	19.98	43.714	116	5.061	89.985	2.96E+06	268.68
1	19.98	53.094	77.2	4.0978	59.986	3.07E+06	217.54
2	19.98	75.675	38.6	2.9205	29.995	3.14E+06	155.05
1	19.98	182.97	7.72	1.4121	5.9984	3.16E+06	74.968
2	19.99	271.07	3.86	1.0461	2.9995	3.16E+06	55.537
1	19.84	361	2.32	0.83585	1.7996	3.17E+06	44.374
2	18.95	523.13	1.16	0.60572	0.89994	3.17E+06	32.157

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.906	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	2.942	
Slope Pa/ 1/min	0.024	
Plastic Viscosity	7.271	mPas
Density	[g/cm^3]	
	1.595	
Gel strength	G' [Pa]	
	1.538	
Crossover G'=G"	[Pa]	
flow point	1.265	

Con 6 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.99	20.584	772	15.888	599.94	1.20E+06	843.5
2	20	24.067	386	9.2884	299.97	1.85E+06	493.11
1	20	27.572	257	7.0932	199.95	2.24E+06	376.57
2	19.99	28.673	232	6.6393	179.97	2.58E+06	352.47
1	19.99	36.714	129	4.7226	99.976	2.79E+06	250.72
2	19.99	38.655	116	4.4753	89.984	2.95E+06	237.59
1	19.99	46.855	77.2	3.6162	59.986	3.07E+06	191.98
2	19.99	66.58	38.6	2.5695	29.995	3.14E+06	136.41
1	19.99	158.26	7.72	1.2214	5.9984	3.16E+06	64.84
2	19.99	232.1	3.86	0.89567	2.9994	3.16E+06	47.55
1	19.8	306.45	2.32	0.70953	1.7995	3.17E+06	37.668
2	18.85	437.85	1.16	0.50699	0.89995	3.17E+06	26.916

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.846	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	2.593	
Slope Pa/ 1/min	0.022	
Plastic Viscosity	6.5996	mPas
Density	[g/cm^3]	
	1.533	
Gel strength	G' [Pa]	
	1.190	
Crossover G'=G"	[Pa]	
flow point	1.113	

Con 7 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	18.57	772	14.334	599.94	8.94E+05	760.97
2	19.98	21.586	386	8.3307	299.96	1.54E+06	442.27
1	19.99	24.556	257	6.3175	199.95	1.94E+06	335.39
2	19.98	25.538	232	5.9133	179.97	2.27E+06	313.93
1	19.98	32.659	129	4.2009	99.976	2.48E+06	223.02
2	19.98	34.323	116	3.9738	89.985	2.65E+06	210.96
1	19.98	41.539	77.2	3.2059	59.986	2.77E+06	170.2
2	19.98	58.815	38.6	2.2698	29.995	2.83E+06	120.5
1	19.99	138.38	7.72	1.068	5.9984	2.85E+06	56.696
2	19.99	200.71	3.86	0.77456	2.9994	2.86E+06	41.121
1	19.84	261.93	2.32	0.60644	1.7995	2.86E+06	32.195
2	18.94	369.01	1.16	0.42727	0.89995	2.86E+06	22.683

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.806	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	2.219	
Slope Pa/ 1/min	0.02	
Plastic Viscosity	6.0033	mPas
Density	[g/cm^3]	
	1.526	
Gel strength	G' [Pa]	
	1.09	
Crossover G'=G"	[Pa]	
flow point	1.036	

Con 8 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	16.725	772	12.91	599.94	8.94E+05	685.36
2	19.99	19.307	386	7.4511	299.96	1.54E+06	395.57
1	19.99	21.879	257	5.6287	199.95	1.94E+06	298.82
2	19.99	22.695	232	5.2551	179.97	2.27E+06	278.99
1	19.99	28.917	129	3.7196	99.976	2.48E+06	197.47
2	19.99	30.353	116	3.5141	89.985	2.65E+06	186.56
1	19.99	36.743	77.2	2.8358	59.986	2.77E+06	150.55
2	19.99	51.886	38.6	2.0024	29.995	2.83E+06	106.3
1	19.99	119.97	7.72	0.92591	5.9984	2.85E+06	49.155
2	19.99	172.45	3.86	0.6655	2.9994	2.86E+06	35.331
1	19.87	223.24	2.32	0.51686	1.7995	2.86E+06	27.439
2	18.97	310.24	1.16	0.35922	0.89993	2.86E+06	19.071

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.771	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	1.942	
Slope Pa/ 1/min	0.018	
Plastic Viscosity	5.4589	mPas
Density	[g/cm^3]	
	1.49	
Gel strength	G' [Pa]	
	0.877	
Crossover G'=G"	[Pa]	
flow point	0.944	

Con 9 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	20	15.346	772	11.846	599.94	8.94E+05	628.88
2	19.99	17.643	386	6.8092	299.96	1.54E+06	361.49
1	20	19.903	257	5.1203	199.95	2.04E+06	271.83
2	20	20.648	232	4.7812	179.98	2.38E+06	253.83
1	20	26.189	129	3.3687	99.976	2.58E+06	178.84
2	20	27.467	116	3.18	89.985	2.75E+06	168.82
1	20	33.16	77.2	2.5593	59.986	2.87E+06	135.87
2	20	46.614	38.6	1.7989	29.995	2.94E+06	95.503
1	20	106.14	7.72	0.81915	5.9986	2.95E+06	43.488
2	20	151.01	3.86	0.58281	2.9997	2.96E+06	30.941
1	19.87	193.63	2.32	0.44835	1.7997	2.96E+06	23.802
2	18.95	265.56	1.16	0.30747	0.89989	2.97E+06	16.323

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.745	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	1.767	
Slope Pa/ 1/min	0.016	
Plastic Viscosity	5.0368	mPas
Density	[g/cm^3]	
	1.49	
Gel strength	G' [Pa]	
	0.783	
Crossover G'=G"	[Pa]	
flow point	0.833	

Con 10 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.98	13.85	772	10.69	599.94	8.94E+05	567.54
2	19.98	15.851	386	6.1175	299.96	1.54E+06	324.77
1	19.98	17.851	257	4.5924	199.95	2.04E+06	243.8
2	19.98	18.489	232	4.2813	179.98	2.38E+06	227.29
1	19.98	23.391	129	3.0088	99.976	2.58E+06	159.73
2	19.98	24.523	116	2.8392	89.984	2.75E+06	150.73
1	19.98	29.573	77.2	2.2824	59.986	2.87E+06	121.17
2	19.99	41.418	38.6	1.5984	29.995	2.93E+06	84.858
1	19.99	92.716	7.72	0.71557	5.9985	2.95E+06	37.988
2	19.99	130.43	3.86	0.5034	2.9997	2.96E+06	26.725
1	19.86	165.64	2.32	0.38351	1.7996	2.96E+06	20.36
2	18.97	223.88	1.16	0.25921	0.8999	2.97E+06	13.761

Yield point (CSS)	Shear stress [Pa]	
Yield point	0.728	
Bingham (600-300rpm)	Shear stress [Pa]	
Yield point	1.529	
Slope Pa/ 1/min	0.015	
Plastic Viscosity	4.5725	mPas
Density	[g/cm^3]	
	1.445	
Gel strength	G' [Pa]	
	0.622	
Crossover G'=G"	[Pa]	
flow point	0.676	

Con 11 Post

Point No.	Temperature [°C]	Viscosity [mPa·s]	Shear Rate [1/s]	Shear Stress [Pa]	Rotational Speed [1/min]	Shear Strain [%]	Torque [µN·m]
1	19.97	12.556	772	9.692	599.94	8.94E+05	514.53
2	19.98	14.287	386	5.514	299.96	1.55E+06	292.73
1	19.98	16.035	257	4.1252	199.95	1.95E+06	219
2	19.98	16.634	232	3.8517	179.97	2.29E+06	204.48
1	19.98	21	129	2.7012	99.976	2.50E+06	143.4
2	19.98	22.032	116	2.5507	89.984	2.67E+06	135.41
1	19.98	26.49	77.2	2.0445	59.986	2.79E+06	108.54
2	19.98	37.004	38.6	1.4281	29.996	2.86E+06	75.816
1	19.98	81.697	7.72	0.63052	5.9985	2.88E+06	33.473
2	19.98	113.74	3.86	0.43892	2.9994	2.89E+06	23.302
1	19.83	143.28	2.32	0.33176	1.7996	2.89E+06	17.613
2	18.9	190.87	1.16	0.22099	0.8999	2.89E+06	11.732

Yield point (CSS)	Shear stress	
	[Pa]	
Yield point	0.718	
Bingham	Shear stress	
(600-300rpm)	[Pa]	
Yield point	1.335	
Slope Pa/ 1/min	0.013	
Plastic Viscosity	4.178	mPas
Density	[g/cm^3]	
	1.396	
Gel strength	G'	
	[Pa]	
	0.645	
Crossover G'=G"	[Pa]	
flow point	0.671	

I.3 Old data experiment rheological data

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
		Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress
Yield point (CSS)	YP	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		2.15	3.05	3.04	2.82	2.47	2.1	1.69	1.29	1.06	0.83	0.641
(600-300rpm)	YP	17.6	16.64	14.22	12.98	11.62	10.19	8.905	7.725	6.6	5.505	4.227
Slope Pa/ 1/min		0.06263	0.05823	0.05486	0.0499	0.0455	0.03941	0.03473	0.03018	0.02556	0.02102	0.01606
Density		[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]
		1.321	1.358	1.325	1.303	1.298	1.276	1.271	1.232	1.252	1.197	1.186
Gel strength		G'	G'	G'	G'	G'	G'	G'	G'	G'	G'	G'
		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		12.15	14.18	12.76	11.06	9.47	7.8	6.4	5.2	4.09	3.05	2.65
Crossover G'=G" (flow)		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		5.54	6.88	6.56	6.0	5.24	4.45	3.77	2.98	2.39	1.77	1.08
PV (600-300rpm)		39.3	36.5	34.3	31.3	28.4	24.6	21.7	18.8	15.9	13.2	10.2
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
		Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress
Yield point	YP	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		3.72	3.42	3.26	2.72	2.33	2.01	1.61	1.36	1.04	0.8	0.619
(600-300rpm)	YP	17.05	15.57	14.49	13.18	11.23	9.912	8.827	7.662	6.443	5.436	4.236
Slope Pa/ 1/min		0.06416	0.05986	0.0552	0.05103	0.04119	0.03603	0.03232	0.02905	0.02449	0.02045	0.01595
Density		[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]
		1.321	1.346	1.326	1.291	1.289	1.293	1.269	1.278	1.244	1.202	1.155
Gel strength		G'	G'	G'	G'	G'	G'	G'	G'	G'	G'	G'
		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		16.2	16.64	12.85	10.8	9.3	7.7	6.4	5.2	4.1	3.2	2.0
Crossover G'=G" (flow)		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		8.1	7.4	6.9	5.9	5.1	4.3	3.7	3.1	2.3	1.7	1.1
		[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]
PV (600-300rpm)		40.1	37.6	34.7	32.0	25.7	22.6	20.3	18.2	15.2	12.7	10.0

		C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
		Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress
Yield point	YP	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		4.55	2.9	2.57	2.34	1.99	1.6	1.29	1.06	0.833	0.616
(600-300rpm)	YP	15.7	13.96	12.55	11.44	10.12	8.794	7.624	6.442	5.425	4.137
Slope Pa/ 1/min		0.05736	0.05012	0.04651	0.04238	0.03677	0.03337	0.02928	0.02444	0.02009	0.01594
Density		[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]
		1.356	1.329	1.305	1.289	1.275	1.266	1.232	1.251	1.199	1.219
Gel strength		G'	G'	G'	G'	G'	G'	G'	G'	G'	G'
		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		14.6	12.4	10.8	9.4	8.1	6.5	5.4	4.1	3.1	2.4
Crossover G'=G'' (flow)		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		7.5	6.3	5.7	5.1	4.3	3.6	3.0	2.4	1.8	1.1
		[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]
PV (600-300rpm)		35.9	31.3	29.2	26.5	23.0	20.9	18.4	15.2	12.5	10.0

		D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
		Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress
Yield point	YP	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		3.61	2.98	2.63	1.63	1.98	1.59	1.35	1.03	0.829	0.647
(600-300rpm)	YP	16.21	14.3	13.29	11.62	10.26	8.813	7.894	6.516	5.454	4.314
Slope Pa/ 1/min		0.06459	0.05479	0.05084	0.04497	0.03954	0.03467	0.03036	0.02478	0.02153	0.01615
Density		[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]
		1.327	1.319	1.304	1.305	1.298	1.264	1.235	1.234	1.193	1.171
Gel strength		G'	G'	G'	G'	G'	G'	G'	G'	G'	G'
		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		14.8	12.5	11.0	9.3	7.9	6.6	5.2	4.0	2.9	2.5
Crossover G'=G'' (flow)		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		7.6	6.5	5.9	4.9	4.3	3.6	3.1	2.3	1.8	1.2
		[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]
PV (600-300rpm)		40.5	34.5	32.0	28.2	24.9	21.7	19.0	15.7	13.6	10.1

		1	2	3	4	5	6	7	8	9	10	11
		Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress	Shear stress
Yield point	YP	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		2.94	3.66	3.05	2.69	2.19	2.02	1.62	1.32	1.05	0.82	0.63
	S		0.55	0.13	0.09	0.33	0.05	0.04	0.03	0.01	0.01	0.01
	95% student-t		0.88	0.21	0.15	0.52	0.08	0.06	0.05	0.02	0.02	0.02
(600-300rpm)	YP	17.325	16.03	14.2425	13	11.4775	10.1205	8.83475	7.72625	6.50025	5.455	4.2285
	S		0.43	0.19	0.28	0.16	0.13	0.04	0.10	0.06	0.03	0.06
	95% student-t		0.68	0.30	0.45	0.26	0.21	0.07	0.16	0.10	0.05	0.10
Slope Pa/ 1/min		0.06340	0.06001	0.05374	0.04957	0.04351	0.03794	0.03377	0.02972	0.02482	0.02077	0.01603
	S		0.00279	0.00210	0.00182	0.00179	0.00156	0.00100	0.00056	0.00045	0.00055	0.00009
	95% student-t		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Density		[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]	[g/cm^3]
		1.347	1.321	1.325	1.301	1.295	1.286	1.268	1.244	1.245	1.198	1.183
	S		0.012	0.004	0.006	0.007	0.010	0.003	0.020	0.007	0.003	0.024
	95% student-t		0.02	0.01	0.01	0.01	0.02	0.00	0.03	0.01	0.01	0.04
Gel strength		G'	G'	G'	G'	G'	G'	G'	G'	G'	G'	G'
		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		14.2	15.1	12.6	10.9	9.4	7.9	6.5	5.3	4.1	3.1	2.4
	S		0.94	0.18	0.12	0.07	0.15	0.08	0.09	0.04	0.11	0.24
	95% student-t		1.50	0.29	0.19	0.11	0.24	0.13	0.14	0.07	0.17	0.38
Crossover G'=G" (flow)		[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa]
		6.8	7.3	6.7	5.9	5.1	4.4	3.7	3.1	2.3	1.8	1.1
	S		0.30	0.18	0.05	0.14	0.07	0.07	0.06	0.04	0.04	0.05
	95% student-t		0.48	0.28	0.08	0.22	0.11	0.11	0.09	0.07	0.07	0.08
PV (600-300rpm)		[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]	[mPas]
		39.7	37.1	34.5	31.6	27.0	23.6	21.0	18.5	15.6	12.9	10.1
	S		1.76	1.36	1.11	1.14	1.01	0.62	0.33	0.27	0.40	0.07
	95% student-t		2.80	2.17	1.77	1.81	1.60	0.98	0.53	0.43	0.64	0.12
						Acoustic data						
0.5 MHz	K1	1.93	1.70	1.67	1.59	1.42	1.44	1.47	1.46	1.47	1.43	1.38
	K2	0.26	0.21	0.20	0.18	0.16	0.15	0.15	0.14	0.13	0.13	0.12
	K1/K2	7.45	8.27	8.29	8.97	9.11	9.57	10.11	10.51	11.09	10.67	11.98
	V	1528	1540	1537	1534	1526	1526	1521	1513	1506	1496	1497
1.0 MHz	K1	1.86	1.69	1.42	1.29	1.26	1.29	1.28	1.32	1.32	1.40	1.31
	K2	0.29	0.25	0.23	0.21	0.19	0.18	0.18	0.17	0.16	0.16	0.14
	K1/K2	6.32	6.66	6.11	6.14	6.53	7.01	7.26	7.70	8.05	8.55	9.05
	V	1567	1568	1571	1567	1562	1561	1555	1541	1540	1524	1525
2.25 MHz	K1	1.03	0.96	0.80	0.73	0.65	0.58	0.57	0.65	0.73	0.88	0.96

K2	0.31	0.28	0.25	0.23	0.20	0.19	0.19	0.18	0.18	0.19	0.17
K1/K2	3.34	3.40	3.21	3.13	3.18	3.00	3.04	3.51	3.97	4.70	5.63
V	1585	1589	1586	1581	1575	1572	1568	1563	1556	1550	1542

Appendix J

Code for generating, testing, plotting and evaluating neural network models

This appendix contains the code used for generating, testing, plotting and evaluating the neural network models.

```python
#Resets console
from IPython import get_ipython
get_ipython().magic('reset -sf')


import tensorflow as tf
import pandas as pd
import numpy as np
import os

from matplotlib.backends.backend_pdf import PdfPages
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec


"""
Methods used in code below
"""
def multi_page_pdf(filename, figs=None, dpi=200):
    pp = PdfPages(filename)
    if figs is None:
        figs = [plt.figure(n) for n in plt.get_fignums()]
    for fig in figs:
        plot = fig
        plot.savefig(pp, format='pdf')
    pp.close()

#Gives the normalisation coefficients for each column for a 0-1 normalisation
#All columns must contain only numbers for the method to work.
def calc_norm_coeff(data_frame):
    norm_coeffs = pd.DataFrame(np.zeros((data_frame.shape[1], 3)), columns = ["Column", "Min", "Span"])
    for i in range(0, data_frame.shape[1]):
        norm_coeffs.iloc[i] = [data_frame.columns[i], data_frame.iloc[:,i].min(), data_frame.iloc[:,i].max() - data_frame.iloc[:,i].mi

    return norm_coeffs


def regression_dnn(data_frame_train, data_frame_eval, mode, model_name, layers, epochs, learning_rate, activfn, optimiser, drop_out):
    #Checking of model directory exists, if not creates it.
    model_directory = os.path.realpath("D:/OneDrive/MasterOppgave/PythonCode/ANNs/" + model_name + "/")
    if not os.path.exists(model_directory):
        os.makedirs(model_directory)
    model_directory = os.path.realpath("D:/OneDrive/MasterOppgave/PythonCode/ANNs/" + model_name + "/")

    #Mode creation (Will load if model exists in directory)
    input_columns = [tf.feature_column.numeric_column(key="NGain"), tf.feature_column.numeric_column(key=SpeedColumn),
                     tf.feature_column.numeric_column(key="Distance")]
    if (optimiser == "Adam"):
        model = tf.estimator.DNNRegressor(hidden_units = layers, feature_columns = input_columns,
                                optimizer = tf.train.AdamOptimizer(learning_rate = learning_rate,
                                                                   beta1 = 0.95, beta2 = 0.999, epsilon=1e-08),
                                activation_fn = activfn, model_dir = model_directory, dropout = drop_out)
    elif (optimiser == "GradDesc"):
        model = tf.estimator.DNNRegressor(hidden_units = layers, feature_columns = input_columns,
                                optimizer = tf.train.GradientDescentOptimizer(learning_rate = learning_rate),
                                activation_fn = tf.nn.relu6, model_dir = model_directory, dropout = drop_out)
    else:
        raise ValueError("Choose optimiser to be Adam or GradDesc")

    #Training
    if (mode == tf.estimator.ModeKeys.TRAIN):
        model = model.train(input_fn = get_input_fn(data_frame_train, num_epochs = epochs), steps = epochs)
        eval_result = model.evaluate(input_fn = get_input_fn(data_frame_eval, num_epochs = epochs))
        return model

    #Evaluation, not currently working
    if (mode == tf.estimator.ModeKeys.EVAL):
        eval_result = model.evaluate(input_fn = get_input_fn(data_frame_eval, num_epochs = epochs))
        return eval_result

def train_input_fn05():
    return {'NGain': normalised05["NGain"], 'ToF': normalised05["ToF"], 'Distance': normalised05["Distance"]}

#INPUTS = ["NGain","ToF","Distance"]
#OUTPUTS = "YieldPoint"

def get_input_fn(data_set, num_epochs=None, shuffle=True):
    print(data_set[k].values for k in INPUTS)
    return tf.estimator.inputs.pandas_input_fn(
      x=pd.DataFrame({k: data_set[k].values for k in INPUTS}),
      y = pd.Series(data_set[OUTPUTS].values),
      num_epochs=num_epochs,
      shuffle=shuffle)

def normalisation(a, b, x):
    norm = (x - b) / a
    return norm

def denormalisation(a, b, x):
    norm = a * x + b
    return norm

def normaliseframe(data_frame, coeff_frame):
    norm_ngain = coeff_frame.loc[coeff_frame["Column"] == "Normalized Gain [dB]"]
    norm_tof = coeff_frame.loc[coeff_frame["Column"] == "ToF [µs]"]
    norm_dens = coeff_frame.loc[coeff_frame["Column"] == "Density"]
    norm_visc = coeff_frame.loc[coeff_frame["Column"] == "PlasticViscosity"]
```

```python
    norm_dist = coeff_frame.loc[coeff_frame["Column"] == "Distance [cm]"]
    norm_yp = coeff_frame.loc[coeff_frame["Column"] == "YieldPoint"]
    norm_gelstr = coeff_frame.loc[coeff_frame["Column"] == "GelStrength"]
    norm_crossg = coeff_frame.loc[coeff_frame["Column"] == "CrossoverG"]
    norm_sof = coeff_frame.loc[coeff_frame["Column"] == "SpeedOfSound"]
    norm_asof = coeff_frame.loc[coeff_frame["Column"] == "AvgSpeedOfSound"]

    normal_frame = data_frame["Normalized Gain [dB]"].apply(lambda x: normalisation(norm_ngain["Span"], norm_ngain["Min"], x))
    normal_frame.columns = ["NGain"]
    normal_frame["ToF"] = data_frame["ToF [µs]"].apply(lambda x: normalisation(norm_tof["Span"], norm_tof["Min"], x))
    normal_frame["Density"] = data_frame["Density"].apply(lambda x: normalisation(norm_dens["Span"], norm_dens["Min"], x))
    normal_frame["PlasticViscosity"] = data_frame["PlasticViscosity"].apply(lambda x: normalisation(norm_visc["Span"], norm_visc["Min"
    normal_frame["Distance"] = data_frame["Distance [cm]"].apply(lambda x: normalisation(norm_dist["Span"], norm_dist["Min"], x))
    normal_frame["YieldPoint"] = data_frame["YieldPoint"].apply(lambda x: normalisation(norm_yp["Span"], norm_yp["Min"], x))
    normal_frame["GelStrength"] = data_frame["GelStrength"].apply(lambda x: normalisation(norm_gelstr["Span"], norm_gelstr["Min"], x))
    normal_frame["CrossoverG"] = data_frame["CrossoverG"].apply(lambda x: normalisation(norm_crossg["Span"], norm_crossg["Min"], x))
    normal_frame["SpeedOfSound"] = data_frame["SpeedOfSound"].apply(lambda x: normalisation(norm_sof["Span"], norm_sof["Min"], x))
    normal_frame["AvgSpeedOfSound"] = data_frame["AvgSpeedOfSound"].apply(lambda x: normalisation(norm_asof["Span"], norm_asof["Min"],
    return normal_frame

def denormaliseoutput(norm_output, coeff_frame, col_name):
    norm_output_pd = pd.DataFrame(np.array(norm_output).reshape(-1, 1))
    norm_output_pd.columns = ["Output"]
    coeff = coeff_frame.loc[coeff_frame["Column"] == col_name]
    denorm_output = norm_output_pd["Output"].apply(lambda x: denormalisation(coeff["Span"], coeff["Min"], x))
    return denorm_output

"""
Loading and preparing data
"""

#Rheological data for new data (New_Con)
#Pre data
Density_Pre = [1.749,1.702,1.689,1.628,1.598,1.568,1.541,1.521,1.476,1.472,1.416]
YieldPoint_Pre = [5.195,4.542,3.935,3.352,2.886,2.539,2.245,1.972,1.711,1.513,1.354]
GelStrength_Pre = [3.33,2.87,2.35,1.96,1.63,1.340,1.08,0.901,0.726,0.61,0.495]
PlasticVisc_Pre = [10.944,10.07,8.964,8.085,7.279,6.6336,5.991,5.54,5.0158,4.6129,4.2896]
CrossoverG_Pre = [1.932,1.787,1.559,1.4,1.257,1.144,1.032,0.944,0.833,0.676,0.671] #none flowpoint values taken from post
ShearStress_Pre = [1.27,1.16,1.05,0.964,0.895,0.838,0.804,0.772,0.743,0.731,0.724]

#Post data
Density_Post = [1.746,1.654,1.665,1.634,1.595,1.533,1.526,1.49,1.49,1.445,1.396]
YieldPoint_Post = [5.383,4.576,3.873,3.795,2.942,2.593,2.219,1.942,1.767,1.529,1.335]
GelStrength_Post = [3.57,2.87,2.27,1.762,1.538,1.190,1.09,0.877,0.783,0.622,0.645]
PlasticVisc_Post = [11.324,9.991,8.903,8.148,7.271,6.5996,6.0033,5.4589,5.0368,4.5725,4.178]
CrossoverG_Post = [1.985,1.761,1.569,1.406,1.265,1.113,1.036,0.944,0.833,0.676,0.671]
ShearStress_Post = [1.29,1.16,1.05,0.964,0.906,0.846,0.806,0.771,0.745,0.728,0.718]

#Calculating averages for the pre and post data
Density_Sum = (Density_Pre + Density_Post)
YieldPoint_Sum = (YieldPoint_Pre + YieldPoint_Post)
GelStrength_Sum = (GelStrength_Pre + GelStrength_Post)
PlasticVisc_Sum = (PlasticVisc_Pre + PlasticVisc_Post)
CrossoverG_Sum = (CrossoverG_Pre + CrossoverG_Post)
ShearStress_Sum = (ShearStress_Pre + ShearStress_Post)

Density = [x / 2 for x in Density_Sum]
YieldPoint = [x / 2 for x in YieldPoint_Sum]
GelStrength = [x / 2 for x in GelStrength_Sum]
PlasticVisc = [x / 2 for x in PlasticVisc_Sum]
CrossoverG = [x / 2 for x in CrossoverG_Sum]
ShearStress = [x / 2 for x in ShearStress_Sum]

#Rheological data for old data (Old_Con)
YieldPoint_Old = [17.325,16.03,14.2425,13,11.4775,10.1205,8.83475,7.72625,6.50025,5.455,4.2285]
Density_Old = [1.347,1.321,1.325,1.301,1.295,1.286,1.268,1.244,1.245,1.198,1.183]
ShearStress_Old = [2.94,3.66,3.05,2.69,2.19,2.02,1.62,1.32,1.05,0.82,0.63]
GelStrength_Old = [14.2,15.1,12.6,10.9,9.4,7.9,6.5,5.3,4.1,3.1,2.4]
CrossoverG_Old = [6.8,7.3,6.7,5.9,5.1,4.4,3.7,3.1,2.3,1.8,1.1]
PlasticVisc_Old = [39.7,37.1,34.5,31.6,27.0,23.6,21.0,18.5,15.6,12.9,10.1]

##Retrieving parameters for denormalising results
#print("Density Max:" + str(max(Density_Old)))
#print("Density Min:" + str(min(Density_Old)))
#print("YP Max:" + str(max(YieldPoint_Old)))
#print("YP Min:" + str(min(YieldPoint_Old)))
#print("GS Max:" + str(max(GelStrength_Old)))
#print("GS Min:" + str(min(GelStrength_Old)))
#print("PV Max:" + str(max(PlasticVisc_Old)))
#print("PV Min:" + str(min(PlasticVisc_Old)))
#raise ValueError("Stop")

#Loading 0.5MHz data
#for i in range(1,12):
for i in [1,5,6,7,8,9,10,11]:
    if not ('dataset05' in locals()):
        dataset05 = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 0, header = 0)
        dataset05['Density'] = Density[i-1]
        dataset05['PlasticViscosity'] = PlasticVisc[i-1]
        dataset05['ShearStress'] = ShearStress[i-1]
        dataset05['YieldPoint'] = YieldPoint[i-1]
        dataset05['GelStrength'] = GelStrength[i-1]
        dataset05['CrossoverG'] = CrossoverG[i-1]
        dataset05["SpeedOfSound"] = (dataset05["Distance [cm]"] / 100) / dataset05["ToF [µs]"] #[m/µs]
        dataset05["AvgSpeedOfSound"] = dataset05["SpeedOfSound"].mean()

    else:
```

```
        dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 0, header = 0)
        dataset_temp['Density'] = Density[i-1]
        dataset_temp['PlasticViscosity'] = PlasticVisc[i-1]
        dataset_temp['ShearStress'] = ShearStress[i-1]
        dataset_temp['YieldPoint'] = YieldPoint[i-1]
        dataset_temp['GelStrength'] = GelStrength[i-1]
        dataset_temp['CrossoverG'] = CrossoverG[i-1]
        dataset_temp["SpeedOfSound"] = (dataset_temp["Distance [cm]"] / 100) / dataset_temp["ToF [µs]"] #[m/µs]
        dataset_temp["AvgSpeedOfSound"] = dataset_temp["SpeedOfSound"].mean()
        dataset05 = dataset05.append(dataset_temp, ignore_index=True)

#Loading 1.0MHz data
for i in [1,5,6,7,8,9,10,11]:
    if not ('dataset10' in locals()):
        dataset10 = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 1, header = 0)
        dataset10['Density'] = Density[i-1]
        dataset10['PlasticViscosity'] = PlasticVisc[i-1]
        dataset10['ShearStress'] = ShearStress[i-1]
        dataset10['YieldPoint'] = YieldPoint[i-1]
        dataset10['GelStrength'] = GelStrength[i-1]
        dataset10['CrossoverG'] = CrossoverG[i-1]
        dataset10["SpeedOfSound"] = (dataset10["Distance [cm]"] / 100) / dataset10["ToF [µs]"] #[m/µs]
        dataset10["AvgSpeedOfSound"] = dataset10["SpeedOfSound"].mean()

    else:
        dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 1, header = 0)
        dataset_temp['Density'] = Density[i-1]
        dataset_temp['PlasticViscosity'] = PlasticVisc[i-1]
        dataset_temp['ShearStress'] = ShearStress[i-1]
        dataset_temp['YieldPoint'] = YieldPoint[i-1]
        dataset_temp['GelStrength'] = GelStrength[i-1]
        dataset_temp['CrossoverG'] = CrossoverG[i-1]
        dataset_temp["SpeedOfSound"] = (dataset_temp["Distance [cm]"] / 100) / dataset_temp["ToF [µs]"] #[m/µs]
        dataset_temp["AvgSpeedOfSound"] = dataset_temp["SpeedOfSound"].mean()
        dataset10 = dataset10.append(dataset_temp, ignore_index=True)

#Loading 2.25MHz data
for i in [1,5,6,7,8,9,10,11]:
    if not ('dataset225' in locals()):
        dataset225 = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 2, header = 0)
        dataset225['Density'] = Density[i-1]
        dataset225['PlasticViscosity'] = PlasticVisc[i-1]
        dataset225['ShearStress'] = ShearStress[i-1]
        dataset225['YieldPoint'] = YieldPoint[i-1]
        dataset225['GelStrength'] = GelStrength[i-1]
        dataset225['CrossoverG'] = CrossoverG[i-1]
        dataset225["SpeedOfSound"] = (dataset225["Distance [cm]"] / 100) / dataset225["ToF [µs]"] #[m/µs]
        dataset225["AvgSpeedOfSound"] = dataset225["SpeedOfSound"].mean()

    else:
        dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/New_Con" + str(i) + ".xlsx",
                                sheet_name = 2, header = 0)
        dataset_temp['Density'] = Density[i-1]
        dataset_temp['PlasticViscosity'] = PlasticVisc[i-1]
        dataset_temp['ShearStress'] = ShearStress[i-1]
        dataset_temp['YieldPoint'] = YieldPoint[i-1]
        dataset_temp['GelStrength'] = GelStrength[i-1]
        dataset_temp['CrossoverG'] = CrossoverG[i-1]
        dataset_temp["SpeedOfSound"] = (dataset_temp["Distance [cm]"] / 100) / dataset_temp["ToF [µs]"] #[m/µs]
        dataset_temp["AvgSpeedOfSound"] = dataset_temp["SpeedOfSound"].mean()
        dataset225 = dataset225.append(dataset_temp, ignore_index=True)

#Loading Old Data
#Loading 0.5MHz data
for i in range(1,12):
    dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/Old_Con" + str(i) + ".xlsx",
                                sheet_name = 0, header = 0)
    dataset_temp['Density'] = Density_Old[i-1]
    dataset_temp['PlasticViscosity'] = PlasticVisc_Old[i-1]
    dataset_temp['ShearStress'] = ShearStress_Old[i-1]
    dataset_temp['YieldPoint'] = YieldPoint_Old[i-1]
    dataset_temp['GelStrength'] = GelStrength_Old[i-1]
    dataset_temp['CrossoverG'] = CrossoverG_Old[i-1]
    dataset_temp["SpeedOfSound"] = (dataset_temp["Distance [cm]"] / 100) / dataset_temp["ToF [µs]"] #[m/µs]
    dataset_temp["AvgSpeedOfSound"] = dataset_temp["SpeedOfSound"].mean()
    dataset05 = dataset05.append(dataset_temp, ignore_index=True)

#Loading 1.0MHz data
for i in range(1,12):
    dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/Old_Con" + str(i) + ".xlsx",
                                sheet_name = 1, header = 0)
    dataset_temp['Density'] = Density_Old[i-1]
    dataset_temp['PlasticViscosity'] = PlasticVisc_Old[i-1]
    dataset_temp['ShearStress'] = ShearStress_Old[i-1]
    dataset_temp['YieldPoint'] = YieldPoint_Old[i-1]
    dataset_temp['GelStrength'] = GelStrength_Old[i-1]
    dataset_temp['CrossoverG'] = CrossoverG_Old[i-1]
    dataset_temp["SpeedOfSound"] = (dataset_temp["Distance [cm]"] / 100) / dataset_temp["ToF [µs]"] #[m/µs]
    dataset_temp["AvgSpeedOfSound"] = dataset_temp["SpeedOfSound"].mean()
    dataset10 = dataset10.append(dataset_temp, ignore_index=True)

#Loading 2.25MHz data
for i in range(1,12):
    dataset_temp = pd.read_excel("file://localhost/D:/OneDrive/MasterOppgave/Eksperimenter/Old_Con" + str(i) + ".xlsx",
```

```
                                sheet_name = 2, header = 0)
    dataset_temp['Density'] = Density_Old[i-1]
    dataset_temp['PlasticViscosity'] = PlasticVisc_Old[i-1]
    dataset_temp['ShearStress'] = ShearStress_Old[i-1]
    dataset_temp['YieldPoint'] = YieldPoint_Old[i-1]
    dataset_temp['GelStrength'] = GelStrength_Old[i-1]
    dataset_temp['CrossoverG'] = CrossoverG_Old[i-1]
    dataset_temp["SpeedOfSound"] = (dataset_temp["Distance [cm]"] / 100) / dataset_temp["ToF [μs]"] #[m/μs]
    dataset_temp["AvgSpeedOfSound"] = dataset_temp["SpeedOfSound"].mean()
    dataset225 = dataset225.append(dataset_temp, ignore_index=True)


#Dropping notes column
dataset05 = dataset05.loc[:, ~dataset05.columns.str.contains('^Unnamed')]
dataset10 = dataset10.loc[:, ~dataset10.columns.str.contains('^Unnamed')]
dataset225 = dataset225.loc[:, ~dataset225.columns.str.contains('^Unnamed')]

#Dropping any rows with missing data
dataset05 = dataset05.dropna(axis=0, how='any')
dataset10 = dataset10.dropna(axis=0, how='any')
dataset225 = dataset225.dropna(axis=0, how='any')

#Compounding datasets
datasetfull = dataset05
datasetfull = datasetfull.append(dataset10, ignore_index=True)
datasetfull = datasetfull.append(dataset225, ignore_index=True)

#Normalisation coefficients
normco05 = calc_norm_coeff(dataset05)
normco10 = calc_norm_coeff(dataset10)
normco225 = calc_norm_coeff(dataset225)

#Normlisation of datasets, transducer pairs independent
normalised05 = normaliseframe(dataset05, normco05)
normalised10 = normaliseframe(dataset10, normco10)
normalised225 = normaliseframe(dataset225, normco225)


#Separating into training and evaluation sets
training_index_vector = np.random.rand(len(normalised05)) <= 0.7
training_norm05 = normalised05[training_index_vector].sample(frac=1)
evaluation_norm05 = normalised05[~training_index_vector].sort_index()
evaluation_denorm05 = dataset05[~training_index_vector].sort_index()
training_index_vector = np.random.rand(len(normalised10)) <= 0.7
training_norm10 = normalised10[training_index_vector].sample(frac=1)
evaluation_norm10 = normalised10[~training_index_vector].sort_index()
evaluation_denorm10 = dataset10[~training_index_vector].sort_index()
training_index_vector = np.random.rand(len(normalised225)) <= 0.7
training_norm225 = normalised225[training_index_vector].sample(frac=1)
evaluation_norm225 = normalised225[~training_index_vector].sort_index()
evaluation_denorm225 = dataset225[~training_index_vector].sort_index()

"""
Parameters for the current networks and plotting of results
"""

#Sets the current output variable
#model_description = "_New" #NB! Change model_description below to +=
SpeedColumn = "AvgSpeedOfSound" #NB! Change in title and description!!
SpeedTitle = "Average Speed of Sound"

#Inputs vector
INPUTS = ["NGain",SpeedColumn,"Distance"]


##Uncomment the appropriate set of variabels for the output.
#OUTPUTS = "Density" #NB! Change description
#OutputText = "Density [g/cm³]"
#model_description = "_"

OUTPUTS = "YieldPoint" #NB! Change description
OutputText = "Yield Point (Bingham 600-300rpm) [Pa]"
model_description = "_YP_"

#OUTPUTS = "GelStrength" #NB! Change description
#OutputText = "Gel Strength [Pa]"
#model_description = "_GS_"

#OUTPUTS = "PlasticViscosity" #NB! Change description
#OutputText = "Plastic Viscosity [mPas]"
#model_description = "_PV_"


#Learning Rates
#For gradient descent use a manually decaying vector of rates, for Adam use just one rate
rates = [0.005]
#rates = [0.0005, 0.00005, 0.000005, 0.0000005, 0.00000005, 0.000000005]
#rates = [0.000005, 0.0000005, 0.00000005, 0.000000005, 0.0000000005, 0.00000000005]

#Layers
dnn_layers = [54]
layers_str = "["
for dnn_layer in dnn_layers:
    layers_str += (str(dnn_layer)+ ",")
    model_description += (str(dnn_layer)+ "_")

layers_str = layers_str[:-1]
layers_str += "]"
```

```
      _

#Activation Function
activfn = tf.nn.relu6
activfn_str = "relu6"
#activfn = tf.nn.relu
#activfn_str = "relu"
#activfn = tf.nn.sigmoid
#activfn_str = "sigmoid"
model_description += (activfn_str+"_")

#Optimiser
optim = "Adam"
optim_str = "Adam Optimizer"
#optim = "GradDesc"
#optim_str = "Gradient Descent"
model_description += optim
model_description += "_ASoS_New"
#model_description += "_5"
epochs = 30000 #Total number of epochs for Adam, epochs per learning rate for gradient descent
drop_out = 0.2

#Creating a gridspec for the plots
gs = gridspec.GridSpec(2,1,height_ratios=[2,1])

"""
Running code
"""
#0.5MHz
#Loading the 0.5MHz data
transducer = "0.5MHz"
training_norm = training_norm05
evaluation_norm = evaluation_norm05
evaluation_denorm = evaluation_denorm05
coeffs_norm = normco05

#Training network
for rate in rates:
    dnn_model = regression_dnn(training_norm, evaluation_norm, mode = tf.estimator.ModeKeys.TRAIN,
                               model_name = ("050"+model_description), layers = dnn_layers,
                               epochs = epochs, learning_rate = rate, activfn = activfn, optimiser = optim,
                               drop_out = drop_out)


#Creating predictions and comparing to evaluation dataset
predictions = dnn_model.predict(input_fn = get_input_fn(evaluation_norm, num_epochs = 1, shuffle = False))
pred_list = list(predictions)
pred_flist = np.zeros((len(pred_list), 1))
pred_flist = [[float(x) for a, x in b.items()] for b in pred_list]
pred_flist = [x[0] for x in pred_flist]
pref_flist_denorm = denormaliseoutput(pred_flist, coeffs_norm, OUTPUTS)
n_pred = len(pred_flist)
x_axis = np.linspace(1, n_pred, n_pred)
abs_error = abs(evaluation_norm[OUTPUTS].values - pred_flist)
percentage_error = [z * 100 for z in abs_error]

#Plotting and generating figure for the evaluation
fig1 = plt.figure(figsize = [20, 20])
plt.subplot(gs[0])
plt.scatter(x_axis, evaluation_denorm[OUTPUTS])
plt.scatter(x_axis, pref_flist_denorm)
plt.legend(labels = ["Measured value", "Estimated value"], loc = 1, fontsize = 14)
plt.title("Evaluation of Neural Network (Transducer: " + transducer + " Hidden layers: " + layers_str + ", Activation Function: " +
                                         activfn_str + ", Optimisation: " + optim_str + ", " + SpeedTitle + " input)", fontsize = 14)
plt.xlabel("Evaluation Sample", fontsize = 14)
plt.ylabel(OutputText, fontsize = 14)
plt.xticks(fontsize = 14)
plt.yticks(fontsize = 14)

plt.subplot(gs[1])
plt.plot(x_axis, percentage_error)
plt.xlabel("Evaluation Sample", fontsize = 14)
plt.ylabel("Absolute Error [%]", fontsize = 14)
plt.xticks(fontsize = 14)
plt.yticks(np.linspace(0, 50, 6), fontsize = 14)
fig1 = plt.gcf()
plt.show()

#Calculating average error
avgError05 = sum((abs(evaluation_norm[OUTPUTS].values - pred_flist)))/len(pred_flist)

#1.0MHz
#Loading the 1.0MHz data
transducer = "1.0MHz"
training_norm = training_norm10
evaluation_norm = evaluation_norm10
evaluation_norm = evaluation_norm10
evaluation_denorm = evaluation_denorm10

#Training network
for rate in rates:
    dnn_model = regression_dnn(training_norm, evaluation_norm, mode = tf.estimator.ModeKeys.TRAIN,
                               model_name = ("100"+model_description), layers = dnn_layers,
                               epochs = epochs, learning_rate = rate, activfn = activfn, optimiser = optim,
                               drop_out = drop_out)

#Creating predictions and comparing to evaluation dataset
predictions = dnn_model.predict(input_fn = get_input_fn(evaluation_norm, num_epochs = 1, shuffle = False))
pred list = list(predictions)
```

```
pred_flist = np.zeros((len(pred_list), 1))
pred_flist = [[float(x) for a, x in b.items()] for b in pred_list]
pred_flist = [x[0] for x in pred_flist]
pref_flist_denorm = denormaliseoutput(pred_flist, coeffs_norm, OUTPUTS)
n_pred = len(pred_flist)
x_axis = np.linspace(1, n_pred, n_pred)
abs_error = abs(evaluation_norm[OUTPUTS].values - pred_flist)
percentage_error = [z * 100 for z in abs_error]

#Plotting and generating figure for the evaluation
fig2 = plt.figure(figsize = [20, 20])
plt.subplot(gs[0])
plt.scatter(x_axis, evaluation_denorm[OUTPUTS])
plt.scatter(x_axis, pref_flist_denorm)
plt.legend(labels = ["Measured value", "Estimated value"], loc = 1, fontsize = 14)
plt.title("Evaluation of Neural Network (Transducer: " + transducer + " Hidden layers: " + layers_str + ", Activation Function: " +
                                         activfn_str + ", Optimisation: " + optim_str + ", " + SpeedTitle + " input)", fontsize = 14)
plt.xlabel("Evaluation Sample", fontsize = 14)
plt.ylabel(OutputText, fontsize = 14)
plt.xticks(fontsize = 14)
plt.yticks(fontsize = 14)

plt.subplot(gs[1])
plt.plot(x_axis, percentage_error)
plt.xlabel("Evaluation Sample", fontsize = 14)
plt.ylabel("Absolute Error [%]", fontsize = 14)
plt.xticks(fontsize = 14)
plt.yticks(np.linspace(0, 50, 6), fontsize = 14)
fig2 = plt.gcf()
plt.show()

#Calculating average error
avgError10 = sum((abs(evaluation_norm[OUTPUTS].values - pred_flist)))/len(pred_flist)

#2.25MHz
#Loading the 2.25MHz data
transducer = "2.25MHz"
training_norm = training_norm225
evaluation_norm = evaluation_norm225
evaluation_norm = evaluation_norm225
evaluation_denorm = evaluation_denorm225

#Training network
for rate in rates:
    dnn_model = regression_dnn(training_norm, evaluation_norm, mode = tf.estimator.ModeKeys.TRAIN,
                               model_name = ("225"+model_description), layers = dnn_layers,
                               epochs = epochs, learning_rate = rate, activfn = activfn, optimiser = optim,
                               drop_out = drop_out)

#Creating predictions and comparing to evaluation dataset
predictions = dnn_model.predict(input_fn = get_input_fn(evaluation_norm, num_epochs = 1, shuffle = False))
pred_list = list(predictions)
pred_flist = np.zeros((len(pred_list), 1))
pred_flist = [[float(x) for a, x in b.items()] for b in pred_list]
pred_flist = [x[0] for x in pred_flist]
pref_flist_denorm = denormaliseoutput(pred_flist, coeffs_norm, OUTPUTS)
n_pred = len(pred_flist)
x_axis = np.linspace(1, n_pred, n_pred)
abs_error = abs(evaluation_norm[OUTPUTS].values - pred_flist)
percentage_error = [z * 100 for z in abs_error]

#Plotting and generating figure for the evaluation
fig3 = plt.figure(figsize = [20, 20])
plt.subplot(gs[0])
plt.scatter(x_axis, evaluation_denorm[OUTPUTS])
plt.scatter(x_axis, pref_flist_denorm)
plt.legend(labels = ["Measured value", "Estimated value"], loc = 1, fontsize = 14)
plt.title("Evaluation of Neural Network (Transducer: " + transducer + " Hidden layers: " + layers_str + ", Activation Function: " +
                                         activfn_str + ", Optimisation: " + optim_str + ", " + SpeedTitle + " input)", fontsize = 14)
plt.xlabel("Evaluation Sample", fontsize = 14)
plt.ylabel(OutputText, fontsize = 14)
plt.xticks(fontsize = 14)
plt.yticks(fontsize = 14)

plt.subplot(gs[1])
plt.plot(x_axis, percentage_error)
plt.xlabel("Evaluation Sample", fontsize = 14)
plt.ylabel("Absolute Error [%]", fontsize = 14)
plt.xticks(fontsize = 14)
plt.yticks(np.linspace(0, 50, 6), fontsize = 14)
fig3 = plt.gcf()
plt.show()

#Calculating average error
avgError225 = sum((abs(evaluation_norm[OUTPUTS].values - pred_flist)))/len(pred_flist)

#Generating pdf with all 3 plot figures.
multi_page_pdf("Plots" + model_description + ".pdf", [fig1, fig2, fig3])

#Reloading and evaluating with same evaluation data to get console write out of Loss and Error.
print("Evaluation epoch with 0 learning rate:")
print("0.5MHz")
dnn_model = regression_dnn(evaluation_norm05, evaluation_norm05, mode = tf.estimator.ModeKeys.TRAIN,
                               model_name = ("050"+model_description), layers = dnn_layers,
                               epochs = 1, learning_rate = 0.0, activfn = activfn, optimiser = optim,
                               drop_out = 0.0)
print("Avg error: " + str(avgError05))
```

```
#Reloading and evaluating with same evaluation data to get console write out of Loss and Error.
print("1.0MHz")
dnn_model = regression_dnn(evaluation_norm10, evaluation_norm10, mode = tf.estimator.ModeKeys.TRAIN,
                               model_name = ("100"+model_description), layers = dnn_layers,
                               epochs = 1, learning_rate = 0.0, activfn = activfn, optimiser = optim,
                               drop_out = 0.0)
print("Avg error: " + str(avgError10))

#Reloading and evaluating with same evaluation data to get console write out of Loss and Error.
print("2.25MHz")
dnn_model = regression_dnn(evaluation_norm225, evaluation_norm225, mode = tf.estimator.ModeKeys.TRAIN,
                               model_name = ("225"+model_description), layers = dnn_layers,
                               epochs = 1, learning_rate = 0.0, activfn = activfn, optimiser = optim,
                               drop_out = 0.0)
print("Avg error: " + str(avgError225))
```

Appendix K

Experimental data from previous work, reorganised

This appendix includes all the measurement data gathered on the water based drilling fluid previously gathered by Kenneth Mozie[2], reorganised into the data sheet for experimental data used in this thesis for easier import into other programs.

K.1 Old fluid Concentration 1

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	17.5	101	21.3	1	17.4	
5	17.5	55	34.8	1	22.7	
7	17.5	33	47.2	1	27.1	
9	17.5	19	59.6	1	31.9	
11	17.5	10	72.2	1	37.5	
13	41.6	100	85.7	1	41.6	
15	41.6	60	97.9	1	46.0	
17	41.6	33	110.3	1	51.2	
19	41.6	19	123.9	1	56.0	
21	41.6	11	136.4	1	60.8	
23	59.3	50	148.9	1	65.3	
25	59.3	30	161.3	1	69.8	
27	59.3	18	173.8	1	74.2	
29	59.3	12	187.5	1	77.7	
31	77.1	50	199.9	1	83.1	
33	77.1	31	213	1	87.3	
35	77.1	19	225.8	1	91.5	
37	77.1	13	238.4	1	94.8	
39	77.1	8	251.3	1	99.0	
41	77.1	6	264	1	101.5	
43				1	#NUM!	
45				1	#NUM!	
3	16.5	100	21.2	2	16.5	
5	16.5	56	33.8	2	21.5	
7	16.5	34	47.3	2	25.9	
9	16.5	21	59.9	2	30.1	
11	16.5	12	72.2	2	34.9	
13	39.7	101	85.7	2	39.6	
15	39.7	62	98.1	2	43.9	
17	39.7	36	110.5	2	48.6	
19	39.7	21	122.9	2	53.3	
21	39.7	13	136.5	2	57.4	
23	62	100	149.1	2	62.0	
25	62	61	161.4	2	66.3	
27	62	37	173.9	2	70.6	
29	62	21	187.3	2	75.6	
31	74	50	199.8	2	80.0	
33	74	30	212.1	2	84.5	
35	74	17	225.9	2	89.4	
37	74	11	238.2	2	93.2	
39	74	7	250.9	2	97.1	
41	74	4	263.1	2	102.0	
43				2	#NUM!	
45				2	#NUM!	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	20.5	100	20	1	20.5	
5	20.5	50	32.6	1	26.5	
7	20.5	25	45	1	32.5	
9	20.5	13	57.5	1	38.2	
11	43.9	100	70.2	1	43.9	
13	43.9	52	82.7	1	49.6	
15	43.9	28	95.2	1	55.0	
17	43.9	15	108.3	1	60.4	
19	64.9	100	120.8	1	64.9	
21	64.9	55	133.4	1	70.1	
23	64.9	29	145.8	1	75.7	
25	64.9	16	158.3	1	80.8	
27	80.5	50	171.9	1	86.5	
29	80.5	30	184.2	1	91.0	
31	80.5	18	196.7	1	95.4	
33	80.5	11	209.5	1	99.7	
35	80.5	7	222.5	1	103.6	
37	80.5	5	235.2	1	106.5	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	20.3	100	20.1	2	20.3	
5	20.3	53	32.7	2	25.8	
7	20.3	28	45.1	2	31.4	
9	20.3	14	57.7	2	37.4	
11	42.7	100	70.2	2	42.7	
13	42.7	52	82.8	2	48.4	
15	42.7	27	92.5	2	54.1	
17	42.7	14	107.6	2	59.8	
19	64.4	100	120.9	2	64.4	
21	64.4	59	133.3	2	69.0	
23	64.4	33	146	2	74.0	
25	64.4	18	158.5	2	79.3	
27	78.7	50	170.9	2	84.7	
29	78.7	28	184.2	2	89.8	
31	78.7	17	196.8	2	94.1	
33	78.7	10	209.2	2	98.7	
35	78.7	7	222.4	2	101.8	
37	78.7	5	235	2	104.7	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	24.1	100	18.8	1	24.1	
5	24.1	34	31.5	1	33.5	
7	24.1	14	43.9	1	41.2	
9	49	100	56.4	1	49.0	
11	49	45	69	1	55.9	
13	49	21	81.5	1	62.6	
15	49	11	93.9	1	68.2	
17	72.7	100	107.1	1	72.7	
19	72.7	56	119.6	1	77.7	
21	72.7	33	133.1	1	82.3	
23	72.7	19	145.6	1	87.1	
25	72.7	11	158.1	1	91.9	
27	84	25	171.6	1	96.0	
29	84	17	184.1	1	99.4	
31	84	11	196.5	1	103.2	
33	84	8	210	1	105.9	
35				1	#NUM!	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	22.8	100	18.9	2	22.8	
5	22.8	37	31.4	2	31.4	
7	22.8	15	43.9	2	39.3	
9	47.2	100	56.6	2	47.2	
11	47.2	42	69.2	2	54.7	
13	47.2	20	81.5	2	61.2	
15	47.2	10	93.9	2	67.2	
17	72	101	107.2	2	71.9	
19	72	56	119.7	2	77.0	
21	72	32	133.1	2	81.9	
23	72	19	145.7	2	86.4	
25	72	12	158.1	2	90.4	
27	82.8	25	171.7	2	94.8	
29	82.8	17	184.2	2	98.2	
31	82.8	11	196	2	102.0	
33	82.8	8	210.1	2	104.7	
35				2	#NUM!	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

K.2 Old fluid Concentration 2

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	16.8	100	21.4	1	16.8	
5	16.8	64	34	1	20.7	
7	16.8	42	46.5	1	24.3	
9	16.8	27	59.1	1	28.2	
11	16.8	17	71.6	1	32.2	
13	16.8	11	85.3	1	36.0	
15	39.1	100	97.8	1	39.1	
17	39.1	67	110.2	1	42.6	
19	39.1	43	122.7	1	46.4	
21	39.1	28	135.3	1	50.2	
23	39.1	18	147.9	1	54.0	
25	39.1	12	160.4	1	57.5	
27	61.6	100	173	1	61.6	
29	61.6	65	185.4	1	65.3	
31	61.6	43	198.1	1	68.9	
33	61.6	28	210.5	1	72.7	
35	61.6	19	224.3	1	76.0	
37	61.6	13	237	1	79.3	
39	61.6	9	249.5	1	82.5	
41	61.6	6	262.1	1	86.0	
43	61.6	5	274.6	1	87.6	
45	61.6	3	286.9	1	92.1	
3	16.3	100	21.5	2	16.3	
5	16.3	67	34	2	19.8	
7	16.3	43	46.8	2	23.6	
9	16.3	28	59.1	2	27.4	
11	16.3	18	71.7	2	31.2	
13	16.3	12	85.4	2	34.7	
15	38.6	100	97.9	2	38.6	
17	38.6	68	110.3	2	41.9	
19	38.6	45	122.8	2	45.5	
21	38.6	30	135.5	2	49.1	
23	38.6	20	148.1	2	52.6	
25	38.6	13	160.4	2	56.3	
27	60.2	101	173.1	2	60.1	
29	60.2	66	185.6	2	63.8	
31	60.2	45	198.1	2	67.1	
33	60.2	29	210.5	2	71.0	
35	60.2	19	223.1	2	74.6	
37	60.2	14	236.9	2	77.3	
39	60.2	10	249.4	2	80.2	
41	60.2	7	262	2	83.3	
43	60.2	5	274.4	2	86.2	
45	60.2	3	286.8	2	90.7	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.7	100	20	1	19.7	
5	19.7	54	32.7	1	25.1	
7	19.7	30	45.2	1	30.2	
9	19.7	16	57.8	1	35.6	
11	40.1	100	70.4	1	40.1	
13	40.1	58	83.1	1	44.8	
15	40.1	35	95.5	1	49.2	
17	40.1	21	108	1	53.7	
19	40.1	13	120.6	1	57.8	
21	62.7	100	133.2	1	62.7	
23	62.7	61	145.7	1	67.0	
25	62.7	37	158.2	1	71.3	
27	62.7	22	170.8	1	75.9	
29	62.7	13	183.4	1	80.4	
31	78.8	50	195.8	1	84.8	
33	78.8	32	209.4	1	88.7	
35	78.8	22	221.9	1	92.0	
37	78.8	15	234.4	1	95.3	
39	78.8	10	247	1	98.8	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	19.5	100	20	2	19.5	
5	19.5	56	32.6	2	24.5	
7	19.5	31	45.3	2	29.7	
9	19.5	18	57.8	2	34.4	
11	39.3	100	70.5	2	39.3	
13	39.3	60	82.9	2	43.7	
15	39.3	35	95.4	2	48.4	
17	39.3	22	107.9	2	52.5	
19	39.3	13	120.4	2	57.0	
21	61.8	101	133	2	61.7	
23	61.8	61	145.6	2	66.1	
25	61.8	37	158.1	2	70.4	
27	61.8	22	170.6	2	75.0	
29	61.8	14	183	2	78.9	
31	77.7	50	195.7	2	83.7	
33	77.7	31	208.1	2	87.9	
35	77.7	20	221.8	2	91.7	
37	77.7	14	234.4	2	94.8	
39	77.7	10	247.1	2	97.7	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21.5	100	18.7	1	21.5	
5	21.5	39	31.3	1	29.7	
7	21.5	16	43.7	1	37.4	
9	45	100	56.4	1	45.0	
11	45	46	69	1	51.7	
13	45	23	81.5	1	57.8	
15	45	12	94	1	63.4	
17	68.5	100	106.6	1	68.5	
19	68.5	63	120.1	1	72.5	
21	68.5	40	132.5	1	76.5	
23	68.5	25	145.1	1	80.5	
25	68.5	15	157.7	1	85.0	
27	82.7	50	171.4	1	88.7	
29	82.7	34	183.9	1	92.1	
31	82.7	23	196.5	1	95.5	
33	82.7	16	208.8	1	98.6	
35	82.7	11	222	1	101.9	
37				1	#NUM!	
39				1	#NUM!	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	21.5	100	18.6	2	21.5	
5	21.5	42	31.3	2	29.0	
7	21.5	18	43.8	2	36.4	
9	43.7	100	56.5	2	43.7	
11	43.7	46	69	2	50.4	
13	43.7	22	81.6	2	56.9	
15	43.7	12	94	2	62.1	
17	67.4	100	106.5	2	67.4	
19	67.4	58	119.9	2	72.1	
21	67.4	37	132.5	2	76.0	
23	67.4	24	145.1	2	79.8	
25	67.4	15	157.7	2	83.9	
27	82.2	50	170.2	2	88.2	
29	82.2	33	183.9	2	91.8	
31	82.2	22	196.3	2	95.4	
33	82.2	15	208.7	2	98.7	
35	82.2	10	221.9	2	102.2	
37				2	#NUM!	
39				2	#NUM!	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

K.3 Old fluid Concentration 3

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	16.3	100	21.5	1	16.3	
5	16.3	67	34	1	19.8	
7	16.3	44	46.6	1	23.4	
9	16.3	29	59.3	1	27.1	
11	16.3	18	71.9	1	31.2	
13	16.3	12	85.3	1	34.7	
15	38.4	100	98.1	1	38.4	
17	38.4	67	110.5	1	41.9	
19	38.4	43	123.2	1	45.7	
21	38.4	28	135.8	1	49.5	
23	38.4	18	148.6	1	53.3	
25	38.4	12	161	1	56.8	
27	60.2	101	173.7	1	60.1	
29	60.2	68	186.1	1	63.5	
31	60.2	46	198.7	1	66.9	
33	60.2	32	211.2	1	70.1	
35	60.2	21	223.9	1	73.8	
37	60.2	14	236.4	1	77.3	
39	60.2	10	249.1	1	80.2	
41	60.2	6	261.6	1	84.6	
43	60.2	5	275.6	1	86.2	
45	60.2	3	286.5	1	90.7	
3	16.3	100	21.5	2	16.3	
5	16.3	67	34.2	2	19.8	
7	16.3	45	46.8	2	23.2	
9	16.3	29	59.3	2	27.1	
11	16.3	19	72	2	30.7	
13	16.3	12	84.5	2	34.7	
15	38.5	101	98.2	2	38.4	
17	38.5	69	110.6	2	41.7	
19	38.5	46	123.3	2	45.2	
21	38.5	30	135.9	2	49.0	
23	38.5	21	148.5	2	52.1	
25	38.5	14	161.1	2	55.6	
27	59.6	101	173.6	2	59.5	
29	59.6	68	186.2	2	62.9	
31	59.6	47	198.7	2	66.2	
33	59.6	33	211.3	2	69.2	
35	59.6	23	224	2	72.4	
37	59.6	16	236.4	2	75.5	
39	59.6	11	249.2	2	78.8	
41	59.6	8	261.8	2	81.5	
43	59.6	5	274.1	2	85.6	
45	59.6	4	286.5	2	87.6	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.4	100	19.5	1	19.4	
5	19.4	53	32	1	24.9	
7	19.4	29	44.6	1	30.2	
9	19.4	17	57.8	1	34.8	
11	19.4	11	70.5	1	38.6	
13	43.4	101	83.1	1	43.3	
15	43.4	61	95.6	1	47.7	
17	43.4	38	108.3	1	51.8	
19	43.4	24	120.9	1	55.8	
21	43.4	15	133.3	1	59.9	
23	43.4	10	146	1	63.4	
25	68	100	158.7	1	68.0	
27	68	63	171.3	1	72.0	
29	68	38	183.8	1	76.4	
31	68	23	196.4	1	80.8	
33	68	15	209.1	1	84.5	
35	82.6	50	221.7	1	88.6	
37	82.6	32	234.2	1	92.5	
39	82.6	23	247.8	1	95.4	
41	82.6	16	260.7	1	98.5	
43	82.6	12	273.1	1	101.0	
45	82.6	9	285.6	1	103.5	
3	19	100	19.5	2	19.0	
5	19	57	32.1	2	23.9	
7	19	31	44.7	2	29.2	
9	19	18	57.4	2	33.9	
11	19	11	70.6	2	38.2	
13	42.5	100	83.2	2	42.5	
15	42.5	62	95.7	2	46.7	
17	42.5	38	108.1	2	50.9	
19	42.5	24	121	2	54.9	
21	42.5	15	133.7	2	59.0	
23	42.5	10	146.1	2	62.5	
25	67	100	158.8	2	67.0	
27	67	64	171.2	2	70.9	
29	67	40	183.9	2	75.0	
31	67	25	196.5	2	79.0	
33	67	16	209	2	82.9	
35	80.8	50	221.6	2	86.8	
37	80.8	33	234.2	2	90.4	
39	80.8	21	246.9	2	94.4	
41	80.8	15	260.6	2	97.3	
43	80.8	11	273	2	100.0	
45	80.8	8	285.4	2	102.7	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21.5	100	18.7	1	21.5	
5	21.5	40	31.2	1	29.5	
7	21.5	17	43.9	1	36.9	
9	21.5	8	56.6	1	43.4	
11	49.4	100	69.2	1	49.4	
13	49.4	53	81.8	1	54.9	
15	49.4	30	94.4	1	59.9	
17	49.4	18	106.9	1	64.3	
19	49.4	11	119.5	1	68.6	
21	72.8	101	132.2	1	72.7	
23	72.8	67	145.7	1	76.3	
25	72.8	45	158.3	1	79.7	
27	72.8	30	170.9	1	83.3	
29	72.8	20	183.4	1	86.8	
31	72.8	13	196.1	1	90.5	
33	82	25	208.5	1	94.0	
35	82	18	222.2	1	96.9	
37	82	14	235.3	1	99.1	
39	82	10	247.8	1	102.0	
41				1	#NUM!	
43				1	#NUM!	
45				1	#NUM!	
3	20.8	100	18.7	2	20.8	
5	20.8	45	31.3	2	27.7	
7	20.8	20	43.9	2	34.8	
9	20.8	9	56.6	2	41.7	
11	47.9	100	69.3	2	47.9	
13	47.9	51	81.9	2	53.7	
15	47.9	29	94.3	2	58.7	
17	47.9	17	106.8	2	63.3	
19	47.9	11	119.5	2	67.1	
21	71.8	100	132.2	2	71.8	
23	71.8	63	145.8	2	75.8	
25	71.8	43	158.3	2	79.1	
27	71.8	30	170.9	2	82.3	
29	71.8	20	183.5	2	85.8	
31	71.8	14	196.1	2	88.9	
33	80.6	25	208.6	2	92.6	
35	80.6	18	222	2	95.5	
37	80.6	13	235.4	2	98.3	
39	80.6	10	248	2	100.6	
41				2	#NUM!	
43				2	#NUM!	
45				2	#NUM!	

K.4 Old fluid Concentration 4

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	15.7	100	21.8	1	15.7	
5	15.7	69	34.2	1	18.9	
7	15.7	48	47	1	22.1	
9	15.7	33	59.8	1	25.3	
11	15.7	23	72.4	1	28.5	
13	15.7	16	85	1	31.6	
15	35.2	100	97.7	1	35.2	
17	35.2	70	110.2	1	38.3	
19	35.2	49	122.7	1	41.4	
21	35.2	35	135.6	1	44.3	
23	35.2	24	148.4	1	47.6	
25	35.2	17	160.8	1	50.6	
27	54.1	100	173.6	1	54.1	
29	54.1	68	186.1	1	57.4	
31	54.1	47	198.8	1	60.7	
33	54.1	34	211.2	1	63.5	
35	54.1	24	224.1	1	66.5	
37	54.1	17	238	1	69.5	
39	54.1	13	250.7	1	71.8	
41	54.1	9	263.5	1	75.0	
43	54.1	7	276	1	77.2	
45	54.1	6	288.5	1	78.5	
3	15.5	100	21.8	2	15.5	
5	15.5	69	34.5	2	18.7	
7	15.5	48	47.1	2	21.9	
9	15.5	33	59.9	2	25.1	
11	15.5	23	72.6	2	28.3	
13	15.4	16	85.1	2	31.3	
15	34.6	101	97.5	2	34.5	
17	34.6	71	110.2	2	37.6	
19	34.6	50	122.8	2	40.6	
21	34.6	35	135.6	2	43.7	
23	34.6	24	148.2	2	47.0	
25	34.6	17	160.8	2	50.0	
27	53.4	100	173.5	2	53.4	
29	53.4	69	186.1	2	56.6	
31	53.4	47	198.6	2	60.0	
33	53.4	33	211.2	2	63.0	
35	53.4	24	224	2	65.8	
37	53.4	17	236.5	2	68.8	
39	53.4	12	250.6	2	71.8	
41	53.4	9	263.3	2	74.3	
43	53.4	7	276	2	76.5	
45	53.4	5	288.2	2	79.4	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19	100	19.6	1	19.0	
5	19	58	32.3	1	23.7	
7	19	34	44.9	1	28.4	
9	19	20	57.6	1	33.0	
11	19	12	70.2	1	37.4	
13	41.5	100	82.9	1	41.5	
15	41.5	63	95.3	1	45.5	
17	41.5	40	108.1	1	49.5	
19	41.5	26	120.6	1	53.2	
21	41.5	17	134.1	1	56.9	
23	41.5	11	146.7	1	60.7	
25	64	100	159.2	1	64.0	
27	64	66	172.1	1	67.6	
29	64	44	184.8	1	71.1	
31	64	31	197.4	1	74.2	
33	64	21	210	1	77.6	
35	64	14	222.6	1	81.1	
37	78.1	50	235.1	1	84.1	
39	78.1	34	248.1	1	87.5	
41	78.1	24	260.7	1	90.5	
43	78.1	17	273.3	1	93.5	
45	78.1	12	285.6	1	96.5	
3	18.5	100	19.7	2	18.5	
5	18.5	60	32.3	2	22.9	
7	18.5	36	44.9	2	27.4	
9	18.5	21	57.6	2	32.1	
11	18.5	13	70.3	2	36.2	
13	40.6	101	83	2	40.5	
15	40.6	64	95.5	2	44.5	
17	40.6	41	108.1	2	48.3	
19	40.6	26	120.8	2	52.3	
21	40.6	17	133.5	2	56.0	
23	40.6	11	145.9	2	59.8	
25	63.4	101	159.6	2	63.3	
27	63.4	67	172.2	2	66.9	
29	63.4	45	184.7	2	70.3	
31	63.4	31	197.4	2	73.6	
33	63.4	21	209.9	2	77.0	
35	63.4	14	222.6	2	80.5	
37	77.7	50	235.2	2	83.7	
39	77.7	35	247.9	2	86.8	
41	77.7	25	260.8	2	89.7	
43	77.7	18	272.3	2	92.6	
45	77.7	13	285.5	2	95.4	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21	100	18.7	1	21.0	
5	21	41	31.4	1	28.7	
7	21	18	44	1	35.9	
9	21	9	56.7	1	41.9	
11	47.7	100	69.4	1	47.7	
13	47.7	54	82	1	53.1	
15	47.7	31	94.6	1	57.9	
17	47.7	19	107.2	1	62.1	
19	47.7	12	119.9	1	66.1	
21	69.9	100	132.7	1	69.9	
23	69.9	63	145.3	1	73.9	
25	69.9	41	158.9	1	77.6	
27	69.9	28	171.7	1	81.0	
29	69.9	20	184.3	1	83.9	
31	69.9	13	196.9	1	87.6	
33	84.6	50	209.5	1	90.6	
35	84.6	37	222.2	1	93.2	
37	84.6	27	234.8	1	96.0	
39	84.6	20	247.3	1	98.6	
41	84.6	16	261	1	100.5	
43				1	#NUM!	
45				1	#NUM!	
3	20.5	100	18.9	2	20.5	
5	20.5	45	31.5	2	27.4	
7	20.5	20	44.1	2	34.5	
9	20.5	10	56.7	2	40.5	
11	46.7	100	69.5	2	46.7	
13	46.7	53	82.1	2	52.2	
15	46.7	30	94.7	2	57.2	
17	46.7	18	107.2	2	61.6	
19	46.7	11	120	2	65.9	
21	69.6	100	132.7	2	69.6	
23	69.6	65	145.4	2	73.3	
25	69.6	42	158	2	77.1	
27	69.6	28	171.7	2	80.7	
29	69.6	20	184.2	2	83.6	
31	69.6	14	197.1	2	86.7	
33	83.6	50	209.5	2	89.6	
35	83.6	36	222.3	2	92.5	
37	83.6	26	235	2	95.3	
39	83.6	19	247.7	2	98.0	
41	83.6	15	261.5	2	100.1	
43				2	#NUM!	
45				2	#NUM!	

K.5 Old fluid Concentration 5

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	15.2	100	22	1	15.2	
5	15.7	70	34.7	1	18.8	
7	15.7	51	47.4	1	21.5	
9	15.7	37	60.2	1	24.3	
11	15.7	27	72.9	1	27.1	
13	15.7	19	85.6	1	30.1	
15	32.5	100	98.2	1	32.5	
17	32.5	71	110.8	1	35.5	
19	32.5	51	123.5	1	38.3	
21	32.5	37	136.2	1	41.1	
23	32.5	27	149.1	1	43.9	
25	32.5	19	161.6	1	46.9	
27	49.7	100	174.5	1	49.7	
29	49.7	73	187.2	1	52.4	
31	49.7	54	199.9	1	55.1	
33	49.7	40	212.5	1	57.7	
35	49.7	30	225.2	1	60.2	
37	49.7	23	237.9	1	62.5	
39	49.7	17	250.8	1	65.1	
41	49.7	13	263.4	1	67.4	
43	49.7	10	276.1	1	69.7	
45	49.7	8	288.6	1	71.6	
3	15	100	22	2	15.0	
5	15	72	34.8	2	17.9	
7	15	52	47.5	2	20.7	
9	15	38	60.2	2	23.4	
11	15	27	72.8	2	26.4	
13	15	20	85.7	2	29.0	
15	32.1	100	98.2	2	32.1	
17	32.1	71	110.8	2	35.1	
19	32.1	51	123.6	2	37.9	
21	32.1	37	136.3	2	40.7	
23	32.1	27	149.1	2	43.5	
25	32.1	19	161.8	2	46.5	
27	49.3	100	174.5	2	49.3	
29	49.3	73	187.1	2	52.0	
31	49.3	54	200	2	54.7	
33	49.3	41	212.5	2	57.0	
35	49.3	30	225.4	2	59.8	
37	49.3	23	238	2	62.1	
39	49.3	18	250.7	2	64.2	
41	49.3	14	263.5	2	66.4	
43	49.3	11	276.1	2	68.5	
45	49.3	8	288.8	2	71.2	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	18.5	100	19.8	1	18.5	
5	18.5	59	32.6	1	23.1	
7	18.5	36	45.2	1	27.4	
9	18.5	22	57.9	1	31.7	
11	18.5	14	70.7	1	35.6	
13	39.2	100	83.4	1	39.2	
15	39.2	68	96	1	42.5	
17	39.2	45	108.6	1	46.1	
19	39.2	30	121.3	1	49.7	
21	39.2	20	133.9	1	53.2	
23	39.2	14	146.8	1	56.3	
25	60	101	159.4	1	59.9	
27	60	69	172.1	1	63.2	
29	60	49	184.7	1	66.2	
31	60	35	197.4	1	69.1	
33	60	24	210.1	1	72.4	
35	60	17	222.7	1	75.4	
37	72.2	50	235.5	1	78.2	
39	72.2	36	248.4	1	81.1	
41	72.2	26	261	1	83.9	
43	72.2	19	273.6	1	86.6	
45	72.2	14	286.1	1	89.3	
3	18.2	100	19.9	2	18.2	
5	18.2	62	32.6	2	22.4	
7	18.2	38	45.3	2	26.6	
9	18.2	24	58.2	2	30.6	
11	18.2	15	70.7	2	34.7	
13	38.5	100	83.4	2	38.5	
15	38.5	67	96	2	42.0	
17	38.5	44	108.7	2	45.6	
19	38.5	30	121.3	2	49.0	
21	38.5	20	134	2	52.5	
23	38.5	13	146.7	2	56.2	
25	59.5	100	159.5	2	59.5	
27	59.5	68	172.1	2	62.8	
29	59.5	48	184.7	2	65.9	
31	59.5	33	197.3	2	69.1	
33	59.5	23	210.1	2	72.3	
35	59.5	16	222.8	2	75.4	
37	72.3	50	235.5	2	78.3	
39	72.3	36	248.2	2	81.2	
41	72.3	26	260.9	2	84.0	
43	72.3	19	273.4	2	86.7	
45	72.3	14	286	2	89.4	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	21.4	100	18.9	1	21.4	
5	21.4	42	31.6	1	28.9	
7	21.4	20	44.5	1	35.4	
9	21.4	10	57.1	1	41.4	
11	46.4	100	69.9	1	46.4	
13	46.4	57	82.6	1	51.3	
15	46.4	35	95.1	1	55.5	
17	46.4	23	107.9	1	59.2	
19	46.4	16	120.5	1	62.3	
21	65.4	100	133.4	1	65.4	
23	65.4	70	146.2	1	68.5	
25	65.4	48	158.9	1	71.8	
27	65.4	33	171.7	1	75.0	
29	65.4	24	184.2	1	77.8	
31	65.4	17	196.9	1	80.8	
33	65.4	12	209.6	1	83.8	
35	80.6	50	222.3	1	86.6	
37	80.6	37	235.1	1	89.2	
39	80.6	39	247.8	1	88.8	
41	80.6	22	260.6	1	93.8	
43	80.6	17	273.3	1	96.0	
45				1	#NUM!	
3	20.7	101	19	2	20.6	
5	20.7	48	31.7	2	27.1	
7	20.7	23	44.5	2	33.5	
9	20.7	12	57.1	2	39.1	
11	45.2	100	69.8	2	45.2	
13	45.2	54	82.5	2	50.6	
15	45.2	32	95.2	2	55.1	
17	45.2	21	107.8	2	58.8	
19	45.2	14	120.7	2	62.3	
21	65.2	101	133.5	2	65.1	
23	65.2	70	146.2	2	68.3	
25	65.2	48	159	2	71.6	
27	65.2	34	171.5	2	74.6	
29	65.2	24	184.2	2	77.6	
31	65.2	17	197	2	80.6	
33	65.2	13	209.5	2	82.9	
35	80.2	50	222.4	2	86.2	
37	80.2	37	235	2	88.8	
39	80.2	28	247.7	2	91.3	
41	80.2	21	260.4	2	93.8	
43	80.2	17	273.1	2	95.6	
45				2	#NUM!	

K.6 Old fluid Concentration 6

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	14.4	100	22.1	1	14.4	
5	14.4	71	34.7	1	17.4	
7	14.4	52	47.4	1	20.1	
9	14.4	39	60.1	1	22.6	
11	14.4	29	72.9	1	25.2	
13	14.4	21	85.8	1	28.0	
15	30.6	100	98.4	1	30.6	
17	30.6	73	111	1	33.3	
19	30.6	54	123.8	1	36.0	
21	30.6	40	136.5	1	38.6	
23	30.6	29	149.3	1	41.4	
25	30.6	21	162	1	44.2	
27	46.8	100	174.7	1	46.8	
29	46.8	74	187.3	1	49.4	
31	46.8	54	200.3	1	52.2	
33	46.8	40	212.8	1	54.8	
35	46.8	30	224.4	1	57.3	
37	46.8	23	237	1	59.6	
39	46.8	18	249.8	1	61.7	
41	46.8	14	262.4	1	63.9	
43	46.8	11	275	1	66.0	
45	46.8	9	287.6	1	67.7	
3	14.2	100	21.9	2	14.2	
5	14.2	71	34.8	2	17.2	
7	14.2	52	47.6	2	19.9	
9	14.2	38	60.3	2	22.6	
11	14.2	28	72.9	2	25.3	
13	14.2	21	85.6	2	27.8	
15	30.8	100	98.3	2	30.8	
17	30.8	72	110.9	2	33.7	
19	30.8	53	123.6	2	36.3	
21	30.8	39	136.6	2	39.0	
23	30.8	28	149.3	2	41.9	
25	30.8	21	161.9	2	44.4	
27	47.2	100	174.7	2	47.2	
29	47.2	74	187.4	2	49.8	
31	47.2	55	200.1	2	52.4	
33	47.2	40	212.8	2	55.2	
35	47.2	30	224.2	2	57.7	
37	47.2	23	236.8	2	60.0	
39	47.2	18	249.6	2	62.1	
41	47.2	14	262.3	2	64.3	
43	47.2	11	274.8	2	66.4	
45	47.2	9	287.3	2	68.1	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	18.7	101	20.4	1	18.6	
5	18.7	62	32.5	1	22.9	
7	18.7	39	45.2	1	26.9	
9	18.7	25	58.1	1	30.7	
11	18.7	17	70.9	1	34.1	
13	37.8	100	83.4	1	37.8	
15	37.8	68	96	1	41.1	
17	37.8	47	108.6	1	44.4	
19	37.8	32	121.2	1	47.7	
21	37.8	22	134	1	51.0	
23	37.8	15	146.7	1	54.3	
25	57.6	100	159.4	1	57.6	
27	57.6	69	172.1	1	60.8	
29	57.6	48	184.8	1	64.0	
31	57.6	34	197.4	1	67.0	
33	57.6	24	210.1	1	70.0	
35	57.6	17	222.7	1	73.0	
37	69.8	50	235.5	1	75.8	
39	69.8	36	248.5	1	78.7	
41	69.8	27	261.1	1	81.2	
43	69.8	20	273.8	1	83.8	
45	69.8	15	286.6	1	86.3	
3	17.8	100	19.8	2	17.8	
5	17.8	63	32.6	2	21.8	
7	17.8	40	45.3	2	25.8	
9	17.8	25	58	2	29.8	
11	17.8	17	70.7	2	33.2	
13	37.1	100	83.4	2	37.1	
15	37.1	68	95.9	2	40.4	
17	37.1	47	108.7	2	43.7	
19	37.1	32	121.3	2	47.0	
21	37.1	22	133.9	2	50.3	
23	37.1	15	146.7	2	53.6	
25	56.8	100	159.4	2	56.8	
27	56.8	69	172.2	2	60.0	
29	56.8	49	184.7	2	63.0	
31	56.8	35	197.6	2	65.9	
33	56.8	25	210.2	2	68.8	
35	56.8	17	223	2	72.2	
37	68.9	50	235.6	2	74.9	
39	68.9	36	248.5	2	77.8	
41	68.9	27	261.2	2	80.3	
43	68.9	20	273.7	2	82.9	
45	68.9	15	286.4	2	85.4	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.2	100	19.2	1	19.2	
5	19.2	45	31.8	1	26.1	
7	19.2	21	44.6	1	32.8	
9	19.2	11	57.2	1	38.4	
11	44.8	100	69.9	1	44.8	
13	44.8	59	82.5	1	49.4	
15	44.8	36	95.2	1	53.7	
17	44.8	23	108	1	57.6	
19	44.8	12	120.8	1	63.2	
21	44.8	16	133.5	1	60.7	
23	66.7	100	146.3	1	66.7	
25	66.7	71	159.1	1	69.7	
27	66.7	50	171.7	1	72.7	
29	66.7	37	184.5	1	75.3	
31	66.7	27	197.2	1	78.1	
33	66.7	20	209.9	1	80.7	
35	66.7	15	222.8	1	83.2	
37	66.7	12	235.6	1	85.1	
39	81.8	50	248.3	1	87.8	
41	81.8	39	261.1	1	90.0	
43	81.8	31	273.6	1	92.0	
45	81.8	25	286.4	1	93.8	
3	20.1	100	19.1	2	20.1	
5	20.1	48	31.8	2	26.5	
7	20.1	23	44.3	2	32.9	
9	20.1	12	57.2	2	38.5	
11	43.8	101	69.9	2	43.7	
13	43.8	56	82.7	2	48.8	
15	43.8	34	95.2	2	53.2	
17	43.8	22	108	2	57.0	
19	43.8	15	120.6	2	60.3	
21	43.8	11	133.4	2	63.0	
23	66.3	100	146.2	2	66.3	
25	66.3	70	159.1	2	69.4	
27	66.3	50	171.8	2	72.3	
29	66.3	36	184.4	2	75.2	
31	66.3	26	197.1	2	78.0	
33	66.3	19	210.1	2	80.7	
35	66.3	15	222.7	2	82.8	
37	66.3	11	235.6	2	85.5	
39	81.8	50	248.1	2	87.8	
41	81.8	39	261	2	90.0	
43	81.8	31	273.6	2	92.0	
45	81.8	25	286.2	2	93.8	

K.7 Old fluid Concentration 7

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	14.2	100	22	1	14.2	
5	14.2	73	34.8	1	16.9	
7	14.2	54	47.5	1	19.6	
9	14.2	40	60.4	1	22.2	
11	14.2	30	73	1	24.7	
13	14.2	22	85.8	1	27.4	
15	30	100	98.5	1	30.0	
17	30	74	111.4	1	32.6	
19	30	55	123.9	1	35.2	
21	30	41	136.6	1	37.7	
23	30	31	149.6	1	40.2	
25	30	23	162.3	1	42.8	
27	45.5	100	175	1	45.5	
29	45.5	75	187.7	1	48.0	
31	45.5	56	200.5	1	50.5	
33	45.5	42	213.2	1	53.0	
35	45.5	31	226.1	1	55.7	
37	45.5	23	238.7	1	58.3	
39	45.5	18	251.8	1	60.4	
41	45.5	14	264.5	1	62.6	
43	45.5	11	277.4	1	64.7	
45	45.5	8	290	1	67.4	
3	14.1	100	22	2	14.1	
5	14.1	73	34.8	2	16.8	
7	14.1	54	47.6	2	19.5	
9	14.1	41	60.3	2	21.8	
11	14.1	31	73	2	24.3	
13	14.1	23	85.8	2	26.9	
15	29.5	100	98.5	2	29.5	
17	29.5	73	111.2	2	32.2	
19	29.5	54	123.9	2	34.9	
21	29.5	40	136.7	2	37.5	
23	29.5	30	149.6	2	40.0	
25	29.5	22	162.3	2	42.7	
27	45.2	100	175.1	2	45.2	
29	45.2	75	187.8	2	47.7	
31	45.2	56	200.8	2	50.2	
33	45.2	42	213.4	2	52.7	
35	45.2	32	226.2	2	55.1	
37	45.2	24	239	2	57.6	
39	45.2	19	251.8	2	59.6	
41	45.2	14	263.2	2	62.3	
43	45.2	11	275.9	2	64.4	
45	45.2	9	288.6	2	66.1	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	17.8	100	19.8	1	17.8	
5	17.8	62	32.7	1	22.0	
7	17.8	40	45.5	1	25.8	
9	17.8	26	58.3	1	29.5	
11	17.8	18	71.1	1	32.7	
13	36.3	101	83.9	1	36.2	
15	36.3	70	96.4	1	39.4	
17	36.3	49	109.1	1	42.5	
19	36.3	35	121.8	1	45.4	
21	36.3	24	134.6	1	48.7	
23	36.3	17	147.5	1	51.7	
25	54.6	100	160.2	1	54.6	
27	54.6	70	173.1	1	57.7	
29	54.6	49	185.6	1	60.8	
31	54.6	36	198.5	1	63.5	
33	54.6	26	211.1	1	66.3	
35	54.6	19	224	1	69.0	
37	66	50	236.7	1	72.0	
39	66	37	249.6	1	74.6	
41	66	27	262.4	1	77.4	
43	66	20	275	1	80.0	
45	66	15	287.7	1	82.5	
3	17.4	100	19.9	2	17.4	
5	17.4	65	32.5	2	21.1	
7	17.4	42	45.3	2	24.9	
9	17.4	27	58.1	2	28.8	
11	17.4	18	70.9	2	32.3	
13	35.8	101	83.7	2	35.7	
15	35.8	69	96.4	2	39.0	
17	35.8	48	109.2	2	42.2	
19	35.8	33	121.9	2	45.4	
21	35.8	23	134.7	2	48.6	
23	35.8	16	147.4	2	51.7	
25	54.9	101	160.1	2	54.8	
27	54.9	70	173	2	58.0	
29	54.9	49	185.8	2	61.1	
31	54.9	35	198.4	2	64.0	
33	54.9	26	211.2	2	66.6	
35	54.9	18	223.9	2	69.8	
37	66.4	50	236.7	2	72.4	
39	66.4	37	249.6	2	75.0	
41	66.4	27	262.5	2	77.8	
43	66.4	21	275.3	2	80.0	
45	66.4	16	287.9	2	82.3	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.1	101	19	1	19.0	
5	19.1	47	31.7	1	25.7	
7	19.1	23	44.7	1	31.9	
9	19.1	12	57.3	1	37.5	
11	43.1	100	70.2	1	43.1	
13	43.1	57	83	1	48.0	
15	43.1	35	95.5	1	52.2	
17	43.1	22	108.3	1	56.3	
19	43.1	15	121.3	1	59.6	
21	43.1	11	134	1	62.3	
23	43.1	8	146.8	1	65.0	
25	67.7	101	159.5	1	67.6	
27	67.7	72	172.4	1	70.6	
29	67.7	53	185.1	1	73.2	
31	67.7	39	197.8	1	75.9	
33	67.7	29	210.6	1	78.5	
35	67.7	22	223.5	1	80.9	
37	67.7	17	236.2	1	83.1	
39	67.7	13	249.2	1	85.4	
41	67.7	10	261.8	1	87.7	
43	67.7	8	274.6	1	89.6	
45	67.7	7	287.3	1	90.8	
3	18.7	100	19	2	18.7	
5	18.7	52	31.8	2	24.4	
7	18.7	25	44.4	2	30.7	
9	18.7	12	57.2	2	37.1	
11	42.5	101	70.1	2	42.4	
13	42.5	54	82.8	2	47.9	
15	42.5	32	95.5	2	52.4	
17	42.5	21	108.3	2	56.1	
19	42.5	14	121.1	2	59.6	
21	42.5	10	133.9	2	62.5	
23	42.5	8	146.8	2	64.4	
25	67.9	100	159.6	2	67.9	
27	67.9	72	172.3	2	70.8	
29	67.9	53	185.1	2	73.4	
31	67.9	40	197.9	2	75.9	
33	67.9	30	210.6	2	78.4	
35	67.9	23	223.5	2	80.7	
37	67.9	18	236.3	2	82.8	
39	67.9	14	249.1	2	85.0	
41	67.9	11	261.9	2	87.1	
43	67.9	9	274.6	2	88.8	
45	67.9	7	287.4	2	91.0	

K.8 Old fluid Concentration 8

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	14.2	100	22.3	1	14.2	
5	14.2	74	35.1	1	16.8	
7	14.2	56	47.8	1	19.2	
9	14.2	43	60.6	1	21.5	
11	14.2	33	73.7	1	23.8	
13	14.2	25	86.4	1	26.2	
15	14.2	19	99.1	1	28.6	
17	14.2	14	112	1	31.3	
19	14.2	11	124.8	1	33.4	
21	14.2	8	137.8	1	36.1	
23	38.9	100	150.7	1	38.9	
25	38.9	75	163.5	1	41.4	
27	38.9	56	176.2	1	43.9	
29	38.9	42	189.1	1	46.4	
31	38.9	32	201.8	1	48.8	
33	38.9	24	214.6	1	51.3	
35	38.9	18	226.2	1	53.8	
37	38.9	14	239.1	1	56.0	
39	38.9	11	252.1	1	58.1	
41	38.9	9	264.9	1	59.8	
43	38.9	7	277.5	1	62.0	
45	38.9	6	290.1	1	63.3	
3	14.1	100	22.3	2	14.1	
5	14.1	74	35.1	2	16.7	
7	14.1	55	47.8	2	19.3	
9	14.1	42	60.7	2	21.6	
11	14.1	32	73.7	2	24.0	
13	14.1	25	86.6	2	26.1	
15	14.1	19	99.2	2	28.5	
17	14.1	14	111.9	2	31.2	
19	14.1	10	124.7	2	34.1	
21	14.1	8	137.6	2	36.0	
23	38.8	100	150.4	2	38.8	
25	38.8	75	163.5	2	41.3	
27	38.8	56	176.4	2	43.8	
29	38.8	42	188.8	2	46.3	
31	38.8	32	201.9	2	48.7	
33	38.8	24	214.6	2	51.2	
35	38.8	18	226.4	2	53.7	
37	38.8	14	239.1	2	55.9	
39	38.8	11	251.9	2	58.0	
41	38.8	9	264.7	2	59.7	
43	38.8	7	277.4	2	61.9	
45	38.8	6	289.9	2	63.2	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	17.4	100	20.4	1	17.4	
5	17.4	64	33.3	1	21.3	
7	17.4	42	46	1	24.9	
9	17.4	28	58.9	1	28.5	
11	17.4	19	71.6	1	31.8	
13	17.4	13	84.4	1	35.1	
15	17.4	9	97.2	1	38.3	
17	41.1	100	109.9	1	41.1	
19	41.1	70	122.9	1	44.2	
21	41.1	49	135.6	1	47.3	
23	41.1	34	148.6	1	50.5	
25	41.1	24	161.3	1	53.5	
27	41.1	17	174	1	56.5	
29	41.1	12	187	1	59.5	
31	41.1	9	199.6	1	62.0	
33	65	100	212.4	1	65.0	
35	65	73	225.3	1	67.7	
37	65	53	238.2	1	70.5	
39	65	38	251.2	1	73.4	
41	65	29	263.9	1	75.8	
43	65	21	276.6	1	78.6	
45	65	16	289.4	1	80.9	
3	17.3	100	20.5	2	17.3	
5	17.3	66	33.2	2	20.9	
7	17.3	44	45.9	2	24.4	
9	17.3	29	58.8	2	28.1	
11	17.3	20	71.7	2	31.3	
13	17.3	14	84.4	2	34.4	
15	17.3	10	97.3	2	37.3	
17	40.8	101	110	2	40.7	
19	40.8	72	122.9	2	43.7	
21	40.8	50	135.6	2	46.8	
23	40.8	35	148.5	2	49.9	
25	40.8	25	161.4	2	52.8	
27	40.8	18	174.2	2	55.7	
29	40.8	13	186.9	2	58.5	
31	40.8	9	199.8	2	61.7	
33	64.3	101	212.4	2	64.2	
35	64.3	74	225.5	2	66.9	
37	64.3	54	238.4	2	69.7	
39	64.3	40	251.1	2	72.3	
41	64.3	29	263.9	2	75.1	
43	64.3	22	276.7	2	77.5	
45	64.3	17	289.3	2	79.7	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	19.2	100	19	1	19.2	
5	19.2	49	31.7	1	25.4	
7	19.2	25	44.7	1	31.2	
9	19.2	13	57.3	1	36.9	
11	41.6	100	70.3	1	41.6	
13	41.6	58	83.1	1	46.3	
15	41.6	37	95.8	1	50.2	
17	41.6	24	108.5	1	54.0	
19	41.6	16	121.5	1	57.5	
21	41.6	11	134.4	1	60.8	
23	41.6	8	147.2	1	63.5	
25	65.8	100	160.1	1	65.8	
27	65.8	72	172.9	1	68.7	
29	65.8	53	185.8	1	71.3	
31	65.8	39	198.6	1	74.0	
33	65.8	29	211.5	1	76.6	
35	65.8	22	224.3	1	79.0	
37	65.8	17	237.2	1	81.2	
39	65.8	13	250.2	1	83.5	
41	65.8	10	262.9	1	85.8	
43	65.8	8	275.6	1	87.7	
45	65.8	6	288.4	1	90.2	
3	18.6	100	19.1	2	18.6	
5	18.6	52	31.8	2	24.3	
7	18.6	27	44.6	2	30.0	
9	18.6	14	57.6	2	35.7	
11	40.4	100	70.1	2	40.4	
13	40.4	57	83.3	2	45.3	
15	40.4	34	95.9	2	49.8	
17	40.4	22	108.7	2	53.6	
19	40.4	15	121.6	2	56.9	
21	40.4	10	134.5	2	60.4	
23	40.4	8	147.4	2	62.3	
25	65.7	100	160.1	2	65.7	
27	65.7	73	173	2	68.4	
29	65.7	54	185.8	2	71.1	
31	65.7	40	198.6	2	73.7	
33	65.7	30	211.3	2	76.2	
35	65.7	23	224.3	2	78.5	
37	65.7	18	237.1	2	80.6	
39	65.7	14	250	2	82.8	
41	65.7	11	262.8	2	84.9	
43	65.7	9	275.5	2	86.6	
45	65.7	7	288.4	2	88.8	

K.9 Old fluid Concentration 9

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	14.2	99	22.3	1	14.3	
5	14.2	74	35.1	1	16.8	
7	14.2	57	48.1	1	19.1	
9	14.2	45	61	1	21.1	
11	14.2	35	73.9	1	23.3	
13	14.2	27	86.7	1	25.6	
15	14.2	21	99.6	1	27.8	
17	14.2	16	112.5	1	30.1	
19	14.2	12	125.4	1	32.6	
21	14.2	9	138.3	1	35.1	
23	37.5	100	151.2	1	37.5	
25	37.5	77	164.2	1	39.8	
27	37.5	59	177	1	42.1	
29	37.5	46	189.8	1	44.2	
31	37.5	35	202.8	1	46.6	
33	37.5	27	215.6	1	48.9	
35	37.5	21	228.5	1	51.1	
37	37.5	16	241.5	1	53.4	
39	37.5	12	253.1	1	55.9	
41	37.5	9	266	1	58.4	
43	37.5	8	278.8	1	59.4	
45	37.5	6	291.5	1	61.9	
3	13.9	100	22.3	2	13.9	
5	13.9	75	35.1	2	16.4	
7	13.9	58	47.9	2	18.6	
9	13.9	45	60.9	2	20.8	
11	13.9	35	73.9	2	23.0	
13	13.9	27	86.8	2	25.3	
15	13.9	20	99.5	2	27.9	
17	13.9	15	112.4	2	30.4	
19	13.9	12	125.3	2	32.3	
21	13.9	9	138.2	2	34.8	
23	37.6	100	151.3	2	37.6	
25	37.6	77	164.2	2	39.9	
27	37.6	59	177	2	42.2	
29	37.6	46	189.8	2	44.3	
31	37.6	35	202.8	2	46.7	
33	37.6	27	215.6	2	49.0	
35	37.6	21	228.5	2	51.2	
37	37.6	16	241.4	2	53.5	
39	37.6	12	253	2	56.0	
41	37.6	10	266	2	57.6	
43	37.6	8	278.6	2	59.5	
45	37.6	6	291.3	2	62.0	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	16.8	100	20.9	1	16.8	
5	16.8	65	32.9	1	20.5	
7	16.8	44	45.7	1	23.9	
9	16.8	30	58.8	1	27.3	
11	16.8	21	71.6	1	30.4	
13	16.8	15	84.3	1	33.3	
15	16.8	10	97.2	1	36.8	
17	16.8	7	110	1	39.9	
19	16.8	5	122.9	1	42.8	
21	16.8	4	135.8	1	44.8	
23	16.8	3	148.6	1	47.3	
25	51.7	100	161.6	1	51.7	
27	51.7	72	174.4	1	54.6	
29	51.7	52	187.3	1	57.4	
31	51.7	38	200.1	1	60.1	
33	51.7	28	212.8	1	62.8	
35	51.7	21	225.6	1	65.3	
37	51.7	16	238.5	1	67.6	
39	51.7	12	251.5	1	70.1	
41	51.7	9	264.5	1	72.6	
43	51.7	7	277.3	1	74.8	
45	51.7	5	290	1	77.7	
3	17.1	100	20.2	2	17.1	
5	17.1	68	32.9	2	20.4	
7	17.1	46	45.8	2	23.8	
9	17.1	31	58.7	2	27.3	
11	17.1	22	71.8	2	30.3	
13	17.1	15	84.5	2	33.6	
15	17.1	11	97.3	2	36.3	
17	17.1	8	110.1	2	39.0	
19	17.1	6	123	2	41.5	
21	17.1	4	135.9	2	45.1	
23	17.1	3	148.9	2	47.6	
25	50.9	100	161.6	2	50.9	
27	50.9	72	174.4	2	53.8	
29	50.9	52	187.3	2	56.6	
31	50.9	38	200.1	2	59.3	
33	50.9	28	212.9	2	62.0	
35	50.9	21	225.8	2	64.5	
37	50.9	16	238.6	2	66.8	
39	50.9	12	251.7	2	69.3	
41	50.9	9	264.4	2	71.8	
43	50.9	7	277	2	74.0	
45	50.9	5	290	2	76.9	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	18.8	100	19.3	1	18.8	
5	18.8	51	32.1	1	24.6	
7	18.8	28	44.9	1	29.9	
9	18.8	16	57.8	1	34.7	
11	18.8	9	70.7	1	39.7	
13	18.8	6	83.6	1	43.2	
15	48	100	96.3	1	48.0	
17	48	63	109.3	1	52.0	
19	48	41	122	1	55.7	
21	48	29	134.9	1	58.8	
23	48	21	148	1	61.6	
25	48	15	160.9	1	64.5	
27	48	11	173.6	1	67.2	
29	48	8	186.5	1	69.9	
31	72.5	100	199.3	1	72.5	
33	72.5	74	212.3	1	75.1	
35	72.5	56	225.1	1	77.5	
37	72.5	42	238	1	80.0	
39	72.5	33	251.2	1	82.1	
41	72.5	26	263.9	1	84.2	
43	72.5	20	276.7	1	86.5	
45	72.5	16	289.5	1	88.4	
3	18.2	100	19.3	2	18.2	
5	18.2	54	32	2	23.6	
7	18.2	29	44.9	2	29.0	
9	18.2	16	57.8	2	34.1	
11	18.2	9	70.8	2	39.1	
13	18.2	5	83.7	2	44.2	
15	47.8	100	96.3	2	47.8	
17	47.8	64	109.1	2	51.7	
19	47.8	42	122	2	55.3	
21	47.8	29	135	2	58.6	
23	47.8	21	147.8	2	61.4	
25	47.8	15	160.7	2	64.3	
27	47.8	11	173.6	2	67.0	
29	47.8	8	186.4	2	69.7	
31	72	100	199.5	2	72.0	
33	72	75	212.2	2	74.5	
35	72	57	225.1	2	76.9	
37	72	43	238.1	2	79.3	
39	72	33	251.2	2	81.6	
41	72	26	264.1	2	83.7	
43	72	21	276.7	2	85.6	
45	72	16	289.5	2	87.9	

K.10 Old fluid Concentration 10

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	14.1	100	22.5	1	14.1	
5	14.1	76	35.2	1	16.5	
7	14.1	58	48	1	18.8	
9	14.1	45	61	1	21.0	
11	14.1	34	74.1	1	23.5	
13	14.1	26	87	1	25.8	
15	14.1	20	99.6	1	28.1	
17	14.1	15	112.4	1	30.6	
19	14.1	11	125.5	1	33.3	
21	14.1	8	139.4	1	36.0	
23	38.2	100	152.5	1	38.2	
25	38.2	78	165.4	1	40.4	
27	38.2	60	178.3	1	42.6	
29	38.2	46	191.1	1	44.9	
31	38.2	35	204.1	1	47.3	
33	38.2	27	216.8	1	49.6	
35	38.2	21	229.7	1	51.8	
37	38.2	16	242.6	1	54.1	
39	38.2	13	255.6	1	55.9	
41	38.2	10	268.6	1	58.2	
43	38.2	7	281.2	1	61.3	
45	38.2	6	294	1	62.6	
3	14.1	100	22.3	2	14.1	
5	14.1	74	35.2	2	16.7	
7	14.1	57	48	2	19.0	
9	14.1	44	61	2	21.2	
11	14.1	34	74	2	23.5	
13	14.1	26	86.9	2	25.8	
15	14.1	19	99.6	2	28.5	
17	14.1	14	122.5	2	31.2	
19	14.1	11	125.4	2	33.3	
21	14.1	8	139.5	2	36.0	
23	38.6	100	152.5	2	38.6	
25	38.6	78	165.4	2	40.8	
27	38.6	60	178	2	43.0	
29	38.6	46	191.1	2	45.3	
31	38.6	36	204	2	47.5	
33	38.6	28	216.9	2	49.7	
35	38.6	22	229.7	2	51.8	
37	38.6	17	242.7	2	54.0	
39	38.6	13	255.6	2	56.3	
41	38.6	11	268.5	2	57.8	
43	38.6	8	281.2	2	60.5	
45	38.6	7	293.9	2	61.7	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	17.1	100	20.9	1	17.1	
5	17.1	67	33.7	1	20.6	
7	17.1	45	46.7	1	24.0	
9	17.1	31	59.6	1	27.3	
11	17.1	22	72.5	1	30.3	
13	17.1	15	85.4	1	33.6	
15	17.1	11	98.3	1	36.3	
17	17.1	8	111.2	1	39.0	
19	17.1	6	124.1	1	41.5	
21	17.1	5	137.1	1	43.1	
23	17.1	3	149.4	1	47.6	
25	50.3	100	162.8	1	50.3	
27	50.3	71	175.8	1	53.3	
29	50.3	50	188.6	1	56.3	
31	50.3	36	201.5	1	59.2	
33	50.3	26	214.6	1	62.0	
35	50.3	19	227.3	1	64.7	
37	50.3	14	240.3	1	67.4	
39	50.3	10	253.3	1	70.3	
41	50.3	8	266.1	1	72.2	
43	50.3	6	278.9	1	74.7	
45	50.3	4	291.4	1	78.3	
3	17.3	100	20.8	2	17.3	
5	17.3	67	33.7	2	20.8	
7	17.3	46	46.6	2	24.0	
9	17.3	32	59.6	2	27.2	
11	17.3	22	72.6	2	30.5	
13	17.3	16	85.5	2	33.2	
15	17.3	12	98.3	2	35.7	
17	17.3	9	111.2	2	38.2	
19	17.3	6	124	2	41.7	
21	17.3	5	136.9	2	43.3	
23	17.3	3	149.3	2	47.8	
25	50.3	100	162.9	2	50.3	
27	50.3	71	175.8	2	53.3	
29	50.3	50	188.7	2	56.3	
31	50.3	37	210.6	2	58.9	
33	50.3	27	214.3	2	61.7	
35	50.3	20	227.3	2	64.3	
37	50.3	14	240.2	2	67.4	
39	50.3	11	253.1	2	69.5	
41	50.3	8	266.1	2	72.2	
43	50.3	6	278.7	2	74.7	
45	50.3	5	291.6	2	76.3	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	18.2	100	19.4	1	18.2	
5	18.2	55	32.1	1	23.4	
7	18.2	31	45.1	1	28.4	
9	18.2	18	58	1	33.1	
11	18.2	11	71.1	1	37.4	
13	18.2	7	83.9	1	41.3	
15	45.9	100	96.8	1	45.9	
17	45.9	64	109.6	1	49.8	
19	45.9	41	122.4	1	53.6	
21	45.9	27	135.3	1	57.3	
23	45.9	19	148.4	1	60.3	
25	45.9	13	161.4	1	63.6	
27	45.9	9	174.1	1	66.8	
29	45.9	7	187.1	1	69.0	
31	72.8	100	199.9	1	72.8	
33	72.8	71	212.8	1	75.8	
35	72.8	50	225.7	1	78.8	
37	72.8	35	238.9	1	81.9	
39	72.8	25	251.6	1	84.8	
41	72.8	19	265.5	1	87.2	
43	72.8	14	278.2	1	89.9	
45	72.8	11	290.8	1	92.0	
3	18.4	100	19.3	2	18.4	
5	18.4	55	32.2	2	23.6	
7	18.4	31	45.1	2	28.6	
9	18.4	19	57.9	2	32.8	
11	18.4	11	70.9	2	37.6	
13	18.4	7	83.9	2	41.5	
15	45.6	100	96.7	2	45.6	
17	45.6	64	109.6	2	49.5	
19	45.6	41	122.6	2	53.3	
21	45.6	27	135.5	2	57.0	
23	45.6	18	148.6	2	60.5	
25	45.6	13	161.4	2	63.3	
27	45.6	9	174.3	2	66.5	
29	45.6	7	187	2	68.7	
31	72.1	100	200	2	72.1	
33	72.1	72	212.8	2	75.0	
35	72.1	51	225.9	2	77.9	
37	72.1	37	238.7	2	80.7	
39	72.1	27	251.6	2	83.5	
41	72.1	23	265.6	2	84.9	
43	72.1	18	278.7	2	87.0	
45	72.1	14	291.3	2	89.2	

K.11 Old fluid Concentration 11

0.5MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	13.5	100	22.4	1	13.5	
5	13.5	78	35.2	1	15.7	
7	13.5	62	48.2	1	17.7	
9	13.5	49	61.1	1	19.7	
11	13.5	40	74.2	1	21.5	
13	13.5	32	87.1	1	23.4	
15	13.5	25	99.9	1	25.5	
17	13.5	20	112.9	1	27.5	
19	13.5	15	125.9	1	30.0	
21	13.5	12	138.9	1	31.9	
23	34.1	100	152	1	34.1	
25	34.1	78	164.9	1	36.3	
27	34.1	63	177.8	1	38.1	
29	34.1	50	190.8	1	40.1	
31	34.1	40	203.7	1	42.1	
33	34.1	32	216.6	1	44.0	
35	34.1	25	229.7	1	46.1	
37	34.1	20	242.6	1	48.1	
39	34.1	16	255.8	1	50.0	
41	34.1	13	268.8	1	51.8	
43	34.1	11	281.5	1	53.3	
45	34.1	9	294	1	55.0	
3	13.6	100	22.4	2	13.6	
5	13.6	78	35.3	2	15.8	
7	13.6	62	48.3	2	17.8	
9	13.6	50	61.3	2	19.6	
11	13.6	40	74.4	2	21.6	
13	13.6	32	87.3	2	23.5	
15	13.6	25	100.1	2	25.6	
17	13.6	20	113.1	2	27.6	
19	13.6	15	126.1	2	30.1	
21	13.6	12	139	2	32.0	
23	34.2	100	152	2	34.2	
25	34.2	79	165	2	36.2	
27	34.2	63	177.9	2	38.2	
29	34.2	51	190.8	2	40.0	
31	34.2	41	203.9	2	41.9	
33	34.2	32	216.6	2	44.1	
35	34.2	26	230	2	45.9	
37	34.2	21	242.7	2	47.8	
39	34.2	17	255.9	2	49.6	
41	34.2	13	268.9	2	51.9	
43	34.2	11	281.7	2	53.4	
45	34.2	9	294.3	2	55.1	

1.0MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	16.5	100	20.8	1	16.5	
5	16.5	70	33.8	1	19.6	
7	16.5	50	46.7	1	22.5	
9	16.5	35	59.2	1	25.6	
11	16.5	26	72.3	1	28.2	
13	16.5	19	85.1	1	30.9	
15	16.5	14	98.1	1	33.6	
17	16.5	10	111	1	36.5	
19	16.5	8	124	1	38.4	
21	16.5	6	136.8	1	40.9	
23	16.5	5	149.9	1	42.5	
25	45.4	100	163.6	1	45.4	
27	45.4	73	176.5	1	48.1	
29	45.4	54	188.7	1	50.8	
31	45.4	40	201.8	1	53.4	
33	45.4	30	214.6	1	55.9	
35	45.4	22	227.6	1	58.6	
37	45.4	17	240.5	1	60.8	
39	45.4	13	253.6	1	63.1	
41	45.4	10	266.6	1	65.4	
43	45.4	8	279.3	1	67.3	
45	45.4	6	291.9	1	69.8	
3	16.5	99	20.8	2	16.6	
5	16.5	69	33.9	2	19.7	
7	16.5	48	46.1	2	22.9	
9	16.5	35	59.1	2	25.6	
11	16.5	25	72.3	2	28.5	
13	16.5	19	85.2	2	30.9	
15	16.5	14	98	2	33.6	
17	16.5	10	111	2	36.5	
19	16.5	8	123.9	2	38.4	
21	16.5	6	136.9	2	40.9	
23	16.5	5	150.1	2	42.5	
25	46.1	100	163.6	2	46.1	
27	46.1	73	175.8	2	48.8	
29	46.1	55	188.8	2	51.3	
31	46.1	42	201.7	2	53.6	
33	46.1	31	214.6	2	56.3	
35	46.1	24	227.7	2	58.5	
37	46.1	18	240.6	2	61.0	
39	46.1	14	253.9	2	63.2	
41	46.1	11	266.8	2	65.3	
43	46.1	8	279.8	2	68.0	
45	46.1	7	292.1	2	69.2	

2.25MHz

Distance [cm]	Gain [dB]	Signal Strength [%]	ToF [µs]	Experiment nr.	Normalized Gain [dB]	
3	18.2	100	19.5	1	18.2	
5	18.2	59	32.4	1	22.8	
7	18.2	35	45.3	1	27.3	
9	18.2	21	58.3	1	31.8	
11	18.2	13	71.4	1	35.9	
13	18.2	9	84.4	1	39.1	
15	42	100	97.2	1	42.0	
17	42	66	110.2	1	45.6	
19	42	46	123.1	1	48.7	
21	42	32	136.2	1	51.9	
23	42	22	149.2	1	55.2	
25	42	16	162.1	1	57.9	
27	42	12	175.3	1	60.4	
29	42	9	188.1	1	62.9	
31	65.8	100	201	1	65.8	
33	65.8	74	213.8	1	68.4	
35	65.8	55	227	1	71.0	
37	65.8	41	239.9	1	73.5	
39	65.8	32	252.9	1	75.7	
41	65.8	24	266	1	78.2	
43	65.8	19	278.9	1	80.2	
45	65.8	15	291.6	1	82.3	
3	18.4	100	19.4	2	18.4	
5	18.4	60	32.4	2	22.8	
7	18.4	36	45.4	2	27.3	
9	18.4	22	58.5	2	31.6	
11	18.4	14	71.5	2	35.5	
13	18.4	9	84.4	2	39.3	
15	42.4	100	97.3	2	42.4	
17	42.4	68	110.3	2	45.7	
19	42.4	46	123.3	2	49.1	
21	42.4	32	136.2	2	52.3	
23	42.4	23	149.3	2	55.2	
25	42.4	16	162.1	2	58.3	
27	42.4	12	175	2	60.8	
29	42.4	9	188	2	63.3	
31	65.8	100	201.1	2	65.8	
33	65.8	75	214	2	68.3	
35	65.8	56	227.1	2	70.8	
37	65.8	42	240	2	73.3	
39	65.8	32	253	2	75.7	
41	65.8	24	266	2	78.2	
43	65.8	19	278.8	2	80.2	
45	65.8	15	291.7	2	82.3	

Appendix L

Spreadsheet of neural network results using only new data

This appendix includes all the loss and error numbers available for the neural networks trained with the measurement data gathered during this thesis. This data is available in appendix G.

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.016338099	0.008349144	0.010603201	9.5%	6.2%	8.1%
[9, 9]	relu6	Adam	0.016012266	0.008956157	0.026981357	9.5%	6.4%	13.3%
[9, 9, 9]	relu6	Adam	0.023685489	0.015453219	0.015314147	11.7%	9.0%	7.7%
[9, 18, 9]	relu6	Adam	0.013027073	0.016374346	0.022370977	9.0%	7.8%	11.0%
[9, 18, 36, 18, 9]	relu6	Adam	0.016153876	0.03052238	0.037187316	9.3%	11.9%	13.8%
[9,18,36,36,18,9]	relu6	Adam	0.015939387	0.02580672	0.031062324	9.6%	10.9%	12.6%
[9,18,18,9]	relu6	Adam	0.018086357	0.015103631	0.028757757	10.8%	8.5%	12.6%
[9,27,27,9]	relu6	Adam	0.015860772	0.013103578	0.032647878	9.6%	7.4%	12.4%
[9,27,54,27,9]	relu6	Adam	0.012138689	0.07485212	0.023294652	8.6%	19.4%	11.7%
[9,27,81,27,9]	relu6	Adam	0.018351737	0.009331527	0.026832398	9.5%	6.3%	11.4%
[18]	relu6	Adam	0.010200308	0.029494964	0.006723801	8.1%	12.0%	6.2%
[21]	relu6	Adam	0.00680406	0.011802821	0.011233767	6.3%	8.3%	8.3%
[24]	relu6	Adam	0.005111611	0.009394983	0.005494851	5.6%	6.5%	5.7%
[27]	relu6	Adam	0.006644655	0.005482966	0.007235747	6.3%	5.4%	6.8%
[30]	relu6	Adam	0.004941694	0.008268122	0.005776636	5.3%	6.6%	5.6%
[36]	relu6	Adam	0.005758795	0.007621766	0.005550179	6.0%	6.7%	5.9%
[42]	relu6	Adam	0.004702263	0.007018442	0.004938782	5.3%	6.1%	5.3%
[54]	relu6	Adam	0.004270662	0.007331332	0.004002327	5.1%	5.5%	4.7%
[18]	sigmoid	Adam	0.014185209	0.01117206	0.011445753	8.2%	7.9%	7.7%
[21]	sigmoid	Adam	0.009900742	0.009466927	0.008556089	7.1%	6.6%	7.1%
[24]	sigmoid	Adam	0.010509158	0.011004308	0.009481848	7.5%	7.4%	7.1%
[27]	sigmoid	Adam	0.009587755	0.010198157	0.006669159	7.3%	7.7%	6.5%
[30]	sigmoid	Adam	0.007735759	0.00744456	0.011925903	6.9%	6.5%	7.1%
[36]	sigmoid	Adam	0.009958396	0.010079905	0.007896456	7.5%	7.0%	6.3%
[42]	sigmoid	Adam	0.007817167	0.013256997	0.008441772	6.4%	7.6%	6.5%
[54]	sigmoid	Adam	0.011922251	0.014839668	0.007527273	7.8%	8.3%	6.3%
[27] (2)	relu6	Adam	0.007608151	0.006867847	0.005973676	6.9%	5.5%	6.0%
[30] (2)	relu6	Adam	0.006595373	0.012986764	0.006904	6.3%	8.0%	6.5%
[36] (2)	relu6	Adam	0.009079082	0.005058368	0.00627388	8.0%	5.2%	5.9%
[42] (2)	relu6	Adam	0.005996294	0.004651785	0.003843612	6.2%	5.4%	5.1%
[54] (2)	relu6	Adam	0.004707615	0.006055167	0.005693106	5.2%	5.6%	5.9%
[42] (2)	sigmoid	Adam	0.008511604	0.008319231	0.005426414	6.7%	6.5%	5.4%
[54] (2)	sigmoid	Adam	0.006329872	0.009384376	0.009140971	6.0%	6.6%	6.8%

Avg Error [±g/cm^3] 0.5[MHz]	Avg Error [±g/cm^3] 1.0[MHz]	Avg Error [±g/cm^3] 2.25[MHz]	Notes
0.0168454	0.010962983	0.014343023	
0.016726696	0.011349652	0.023509069	
0.020660952	0.015944046	0.013611264	
0.01579892	0.013782641	0.019385765	
0.01634908	0.02105168	0.024422148	
0.016922417	0.01918745	0.022210678	
0.019120499	0.014919332	0.022233183	
0.016920257	0.012997824	0.021952746	
0.015108179	0.034220405	0.020576226	
0.016804781	0.011154073	0.020191255	
0.014211739	0.021260601	0.010927487	
0.011095917	0.014609512	0.014717238	
0.009967289	0.011426939	0.010000242	
0.011121477	0.009480088	0.011986619	
0.009325876	0.01162094	0.009923007	
0.010605552	0.011770834	0.010491141	
0.00934977	0.010745732	0.009283396	
0.009087541	0.009671271	0.008304786	
0.014387182	0.013913073	0.013538604	
0.012585988	0.011648418	0.012596409	
0.013203642	0.013002139	0.01245097	
0.01293539	0.013620736	0.011461236	
0.012253482	0.0115421	0.012475151	
0.013232973	0.012308597	0.011165921	
0.011293255	0.013479073	0.011529954	
0.013695186	0.014722758	0.011174566	
0.012123494	0.009748462	0.010504716	
0.011141474	0.014160828	0.011484029	
0.014089273	0.009155049	0.010447454	
0.011021352	0.009618829	0.009058392	
0.009145108	0.009822704	0.010446573	
0.011843766	0.011514908	0.009505515	
0.01058681	0.011586841	0.011995768	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.004473174	0.008280106	0.0373002	5.4%	7.0%	15.0%
[9, 9]	relu6	Adam	0.019507464	0.07241853	0.012087302	10.5%	19.4%	8.1%
[9, 9, 9]	relu6	Adam	0.019605955	0.011862435	0.014089702	8.7%	8.6%	8.2%
[9, 18, 9]	relu6	Adam	0.027235635	0.012162572	0.12102731	8.9%	7.2%	30.6%
[9, 18, 36, 18, 9]	relu6	Adam	0.040613625	0.06455658	0.06543722	13.3%	15.6%	18.2%
[9,18,36,36,18,9]	relu6	Adam	0.061806653	0.032129325	0.057378426	15.4%	12.8%	15.7%
[9,18,18,9]	relu6	Adam	0.024091853	0.012902169	0.05583422	10.1%	9.6%	16.5%
[9,27,27,9]	relu6	Adam	0.02073488	0.03941243	0.048817266	9.0%	12.9%	13.5%
[9,27,54,27,9]	relu6	Adam	0.02821729	0.053360917	0.062307954	11.8%	13.2%	15.3%
[9,27,81,27,9]	relu6	Adam	0.019914823	0.014738077	0.035731446	8.6%	9.4%	12.4%
[18]	relu6	Adam	0.004495167	0.008408167	0.005224448	5.4%	6.7%	5.5%
[21]	relu6	Adam	0.00420168	0.006949264	0.00562509	4.7%	5.3%	5.3%
[24]	relu6	Adam	0.004876005	0.007111099	0.005493688	5.4%	4.5%	5.7%
[27]	relu6	Adam	0.004375676	0.005225294	0.003044491	4.9%	5.6%	4.4%
[30]	relu6	Adam	0.005944595	0.002592784	0.002860907	5.7%	3.7%	4.2%
[36]	relu6	Adam	0.005546696	0.008087238	0.003241274	5.7%	4.7%	4.5%
[42]	relu6	Adam	0.004191242	0.004231999	0.002914874	4.8%	4.5%	4.4%
[54]	relu6	Adam	0.004428308	0.002999021	0.005989201	4.8%	4.3%	5.0%
[18]	sigmoid	Adam	0.013356685	0.017385157	0.007014409	8.1%	7.2%	5.3%
[21]	sigmoid	Adam	0.014003914	0.011665658	0.006880959	7.1%	6.9%	6.5%
[24]	sigmoid	Adam	0.009683691	0.009603351	0.009044563	6.3%	7.0%	7.1%
[27]	sigmoid	Adam	0.009989301	0.012709574	0.006658624	6.7%	7.4%	5.2%
[30]	sigmoid	Adam	0.00854452	0.008174489	0.022743544	6.6%	5.6%	8.9%
[36]	sigmoid	Adam	0.01739515	0.009498165	0.01349644	7.0%	5.6%	6.0%
[42]	sigmoid	Adam	0.006584192	0.010659634	0.012673066	4.9%	6.5%	7.4%
[54]	sigmoid	Adam	0.009531377	0.013399477	0.004034572	6.0%	6.0%	5.0%
[27] (2)	sigmoid	Adam	0.019764682	0.008044709	0.007279787	8.0%	4.9%	5.3%
[30] (2)	sigmoid	Adam	0.016852414	0.012166323	0.010988279	7.8%	6.7%	6.2%
[36] (2)	sigmoid	Adam	0.016557775	0.01309213	0.009453211	6.3%	7.2%	5.7%
[42] (2)	sigmoid	Adam	0.00724247	0.012074318	0.004954901	5.7%	6.8%	5.2%
[54] (2)	sigmoid	Adam	0.013775188	0.015536899	0.008235079	6.6%	6.0%	5.4%
[27] (2)	relu6	Adam	0.005896951	0.006852718	0.002698961	5.8%	5.1%	4.3%
[30] (2)	relu6	Adam	0.004406243	0.002191358	0.004080805	5.2%	3.4%	5.3%
[36] (2)	relu6	Adam	0.004474234	0.00319276	0.002809785	5.0%	3.9%	4.1%
[42] (2)	relu6	Adam	0.003350244	0.005251626	0.003180757	4.1%	4.4%	4.6%
[54] (2)	relu6	Adam	0.003809437	0.004240005	0.002956078	4.8%	4.8%	4.7%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0.108916691	0.142030801	0.304610582	
0.212563076	0.393602996	0.16373907	
0.175368491	0.173398985	0.165842451	
0.180290031	0.145442686	0.619740101	
0.26908501	0.316078983	0.368231721	
0.312223372	0.259123487	0.316764795	
0.204879348	0.194471695	0.333964395	
0.181321733	0.260357112	0.272839499	
0.23821234	0.267820201	0.309056428	
0.173578856	0.189795003	0.251188804	
0.10900715	0.135679831	0.11108333	
0.09535079	0.106406887	0.108223631	
0.10996513	0.090804549	0.114614533	
0.099507524	0.113143496	0.089156322	
0.115345419	0.075747161	0.084230802	
0.116195079	0.095491018	0.090275251	
0.097757392	0.091900942	0.089719231	
0.096523197	0.087363688	0.102114542	
0.164746513	0.146301601	0.106856254	
0.14413659	0.140130668	0.132417563	
0.126575961	0.141474878	0.142821889	
0.135266012	0.150380718	0.106142313	
0.133416809	0.113021826	0.18047711	
0.141431934	0.112496321	0.122176945	
0.099930959	0.130666516	0.149358203	
0.120765675	0.121088943	0.101587956	
0.162809171	0.09906243	0.108174692	
0.158479356	0.13521154	0.124927551	
0.127838602	0.145991741	0.114762692	
0.115315017	0.138489083	0.105643047	
0.132650635	0.121504839	0.108285877	
0.117804152	0.103692046	0.086476476	
0.105833459	0.069149979	0.107517443	
0.101840034	0.078408953	0.083726484	
0.083775444	0.089743802	0.092930211	
0.096501481	0.096758037	0.09416348	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]	Avg Error [±Pa] 0.5[MHz]
[9]	relu6	Adam	0.011888523	0.04656345	0.00687875	8.84%	15.63%	6.35%	0.135843082
[9, 9]	relu6	Adam	0.011834146	0.011927305	0.018158743	8.99%	7.17%	8.84%	0.138296818
[9, 9, 9]	relu6	Adam	0.014511947	0.013993514	0.022601731	9.69%	9.08%	10.06%	0.149034153
[9, 18, 9]	relu6	Adam	0.0306034	0.006822486	0.028822754	12.34%	6.76%	9.43%	0.189728941
[9, 18, 36, 18, 9]	relu6	Adam	0.0450623	0.025834717	0.03343296	12.06%	11.59%	11.33%	0.185412389
[9,18,36,36,18,9]	relu6	Adam	0.035723068	0.050709013	0.058267143	16.67%	16.26%	16.22%	0.256334741
[9,18,18,9]	relu6	Adam	0.011416708	0.003926715	0.033866584	9.19%	4.42%	9.16%	0.141297322
[9,27,27,9]	relu6	Adam	0.106747456	0.028655874	0.014311858	24.17%	10.97%	8.58%	0.371583245
[9,27,54,27,9]	relu6	Adam	0.045016408	0.031251024	0.03875605	13.06%	10.50%	13.13%	0.200806288
[9,27,81,27,9]	relu6	Adam	0.021888567	0.036216676	0.06333931	10.79%	12.39%	14.95%	0.16585802
[18]	relu6	Adam	0.005295128	0.006702025	0.004157519	6.13%	5.41%	4.98%	0.094208749
[21]	relu6	Adam	0.006997567	0.005684671	0.004959523	6.69%	4.72%	5.21%	0.102917659
[24]	relu6	Adam	0.005771563	0.005632008	0.003339791	5.79%	5.18%	4.41%	0.088948687
[27]	relu6	Adam	0.008423499	0.001896328	0.005150968	6.39%	3.41%	5.34%	0.098187317
[30]	relu6	Adam	0.003632703	0.008453927	0.002051992	4.37%	4.71%	3.74%	0.067182767
[36]	relu6	Adam	0.004471181	0.005775009	0.00949049	4.69%	4.07%	4.92%	0.072043096
[42]	relu6	Adam	0.00476573	0.007486145	0.003462932	5.17%	4.57%	4.54%	0.079528147
[54]	relu6	Adam	0.0052346	0.008744407	0.004552833	5.43%	5.01%	4.55%	0.083425838
[18]	sigmoid	Adam	0.011962083	0.021106703	0.023126394	7.15%	8.25%	9.23%	0.110001149
[21]	sigmoid	Adam	0.021441307	0.017976332	0.012399506	9.34%	6.51%	6.80%	0.143618698
[24]	sigmoid	Adam	0.007062871	0.021153286	0.006169147	5.31%	8.07%	4.84%	0.081613502
[27]	sigmoid	Adam	0.022737624	0.011401548	0.006139904	8.21%	6.69%	5.20%	0.126210542
[30]	sigmoid	Adam	0.01506031	0.017907055	0.009622366	7.09%	7.94%	5.82%	0.108933396
[36]	sigmoid	Adam	0.006402569	0.016567161	0.010113983	4.80%	6.57%	6.52%	0.073765826
[42]	sigmoid	Adam	0.013738196	0.009045455	0.016018113	6.72%	5.64%	7.23%	0.103327453
[54]	sigmoid	Adam	0.008637141	0.007247525	0.011551234	5.57%	5.62%	7.00%	0.085601964
[27] (2)	relu6	Adam	0.005267546	0.008141024	0.00358337	5.24%	5.95%	4.92%	0.080512699
[30] (2)	relu6	Adam	0.005438252	0.003701702	0.003964423	5.35%	3.88%	5.52%	0.082195888
[36] (2)	relu6	Adam	0.005413197	0.008197425	0.002178662	5.51%	5.44%	3.93%	0.08469353
[42] (2)	relu6	Adam	0.005570445	0.009298672	0.003281559	5.84%	4.60%	4.17%	0.089796117
[54] (2)	relu6	Adam	0.004915786	0.003639341	0.003223839	5.07%	4.13%	4.47%	0.077917185
[27] (2)	sigmoid	Adam	0.017181361	0.01670836	0.010063732	7.14%	8.57%	6.05%	0.109718073
[30] (2)	sigmoid	Adam	0.011550874	0.014626646	0.007325266	7.00%	6.82%	5.46%	0.107597833
[36] (2)	sigmoid	Adam	0.011889867	0.014647986	0.015075314	7.00%	6.75%	7.03%	0.107599613
[42] (2)	sigmoid	Adam	0.010675796	0.023176609	0.005405337	5.72%	8.19%	4.47%	0.087923576
[54] (2)	sigmoid	Adam	0.012422392	0.008109092	0.015130059	6.60%	4.72%	7.59%	0.101528382

Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0.240321732	0.0975632	
0.110193281	0.135930269	
0.139548552	0.154692753	
0.103960065	0.144967238	
0.178140715	0.174264144	
0.249993397	0.249442087	
0.067898901	0.140880596	
0.168724236	0.131887942	
0.161498824	0.201843557	
0.190470073	0.22981172	
0.083127277	0.076576617	
0.072619965	0.080029259	
0.079650997	0.067856161	
0.052393753	0.082103862	
0.072464701	0.057558308	
0.062505924	0.075612105	
0.070253412	0.069816379	
0.077088159	0.069939705	
0.126842781	0.141890593	
0.100082308	0.104545579	
0.124033256	0.074461921	
0.102843153	0.080009707	
0.122144301	0.089477308	
0.101080511	0.100298952	
0.086722724	0.111204958	
0.086423612	0.107631011	
0.09147431	0.075595767	
0.059722635	0.084889056	
0.083657338	0.060360325	
0.070726347	0.064090985	
0.063442487	0.068741199	
0.131833925	0.093064184	
0.104863799	0.084017492	
0.103820256	0.108145897	
0.125877967	0.068797722	
0.072602174	0.116743462	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.01857735	0.047970563	0.017431742	10.12%	16.32%	9.29%
[9, 9]	relu6	Adam	0.009217702	0.010196679	0.017314803	7.36%	7.57%	9.41%
[9, 9, 9]	relu6	Adam	0.030674962	0.023908908	0.10515924	15.21%	10.99%	21.09%
[9, 18, 9]	relu6	Adam	0.013758794	0.012604017	0.011275173	10.54%	8.72%	8.78%
[9, 18, 36, 18, 9]	relu6	Adam	0.01925108	0.018909853	0.07082336	9.87%	8.67%	17.70%
[9,18,36,36,18,9]	relu6	Adam	0.052641362	0.21616313	0.011861571	15.03%	39.78%	8.90%
[9,18,18,9]	relu6	Adam	0.014971283	0.026678942	0.02251428	9.35%	13.08%	9.59%
[9,27,27,9]	relu6	Adam	0.017467726	0.03024463	0.012237922	9.34%	9.56%	9.62%
[9,27,54,27,9]	relu6	Adam	0.022893645	0.05529331	0.045654476	10.59%	13.17%	14.81%
[9,27,81,27,9]	relu6	Adam	0.016054666	0.07674847	0.023414211	9.36%	24.69%	9.61%
[18]	relu6	Adam	0.005188989	0.005774928	0.003831267	5.75%	5.57%	4.82%
[21]	relu6	Adam	0.006403034	0.0081113	0.006877748	5.79%	6.40%	5.90%
[24]	relu6	Adam	0.005591164	0.003602677	0.004365474	5.98%	4.32%	5.42%
[27]	relu6	Adam	0.005455461	0.008606561	0.007280672	5.50%	5.33%	5.81%
[30]	relu6	Adam	0.007252283	0.005119034	0.003481865	6.69%	4.87%	4.86%
[36]	relu6	Adam	0.008071317	0.003533493	0.004494409	6.60%	4.52%	5.80%
[42]	relu6	Adam	0.004440957	0.006771089	0.005999139	5.54%	4.96%	5.85%
[54]	relu6	Adam	0.003532247	0.002934149	0.005348724	4.70%	4.49%	5.93%
[18]	sigmoid	Adam	0.008268435	0.011315523	0.009543289	6.59%	6.98%	5.58%
[21]	sigmoid	Adam	0.013685687	0.009804764	0.01568226	6.92%	6.11%	7.70%
[24]	sigmoid	Adam	0.018141143	0.008124345	0.008363426	8.15%	5.65%	6.83%
[27]	sigmoid	Adam	0.014942489	0.011722984	0.013391761	7.59%	6.31%	7.55%
[30]	sigmoid	Adam	0.009565355	0.011824873	0.014645694	6.82%	6.98%	8.10%
[36]	sigmoid	Adam	0.010992978	0.009424266	0.005083728	6.72%	5.99%	4.72%
[42]	sigmoid	Adam	0.006904614	0.005356523	0.009304732	5.24%	4.88%	6.55%
[54]	sigmoid	Adam	0.006592457	0.010688905	0.010689145	5.75%	6.14%	6.10%
[27] (2)	relu6	Adam	0.006321038	0.009996934	0.005481953	6.30%	7.11%	5.88%
[30] (2)	relu6	Adam	0.006321661	0.0057981	0.004372119	6.04%	5.27%	5.53%
[36] (2)	relu6	Adam	0.005320053	0.002997874	0.003763098	5.66%	3.82%	4.77%
[42] (2)	relu6	Adam	0.004764542	0.002240199	0.005977037	5.20%	3.67%	5.86%
[54] (2)	relu6	Adam	0.004455124	0.006177818	0.003301483	5.03%	4.84%	4.66%
[27] (2)	sigmoid	Adam	0.011286009	0.013376271	0.012676509	6.95%	7.61%	7.10%
[30] (2)	sigmoid	Adam	0.009233099	0.0103933	0.01706056	6.41%	6.45%	7.88%
[36] (2)	sigmoid	Adam	0.012469597	0.009620972	0.010122216	7.33%	6.18%	6.31%
[42] (2)	sigmoid	Adam	0.009034358	0.020063952	0.010041177	5.92%	8.59%	6.29%
[54] (2)	sigmoid	Adam	0.0089615	0.013063871	0.006655049	6.05%	6.37%	4.53%

Avg Error [±mPas] 0.5[MHz]	Avg Error [±mPas] 1.0[MHz]	Avg Error [±mPas] 2.25[MHz]	Notes
0.361452774	0.583081236	0.33205477	
0.262839537	0.270521973	0.336163493	
0.543593067	0.39282436	0.753394126	
0.376751102	0.311408042	0.313704394	
0.352696212	0.309714477	0.632447749	
0.537137108	1.421299629	0.318165749	
0.334114652	0.467502111	0.342479035	
0.333595449	0.341730837	0.343706796	
0.378393023	0.470610972	0.529248614	
0.334402087	0.882084282	0.343476255	
0.205542835	0.199109862	0.172358554	
0.206870447	0.228563515	0.210637796	
0.21354723	0.154412265	0.193720978	
0.196470323	0.190592022	0.207591295	
0.2388578	0.174055536	0.173605145	
0.235863395	0.161448406	0.207352347	
0.19791787	0.177098644	0.208928726	
0.16783513	0.160569875	0.211879801	
0.235436401	0.24954271	0.199541085	
0.247209193	0.218430148	0.275075981	
0.29136913	0.202021249	0.244055011	
0.271140728	0.225310558	0.26964353	
0.243657749	0.249297895	0.289516938	
0.240187521	0.214061545	0.168811305	
0.187248525	0.174463169	0.234026156	
0.205592284	0.219496747	0.217979839	
0.224999469	0.254080076	0.21001355	
0.21581413	0.188177153	0.197646334	
0.202084419	0.136312852	0.170578908	
0.185632431	0.130953793	0.209449212	
0.179802572	0.172844244	0.166433517	
0.248205262	0.271992675	0.253710119	
0.228887359	0.230462523	0.281712027	
0.261772765	0.220654287	0.225441342	
0.211473736	0.30700299	0.224709995	
0.216211285	0.227575858	0.161903998	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 9, 9] (2)	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 9] (2)	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.006583049	0.006587979	0.006911898	6.56%	6.19%	6.31%
[21]	relu6	Adam	0.007185551	0.011449234	0.005297273	6.58%	8.39%	5.68%
[24]	relu6	Adam	0.007834323	0.008798054	0.006154758	6.83%	5.47%	6.44%
[27]	relu6	Adam	0.00658768	0.006859792	0.004789087	6.07%	6.41%	5.19%
[30]	relu6	Adam	0.005234378	0.006356645	0.004562756	5.75%	6.27%	5.44%
[36]	relu6	Adam	0.005586517	0.007896935	0.006765829	5.73%	5.05%	6.66%
[42]	relu6	Adam	0.003905176	0.00551101	0.003851474	5.03%	5.97%	5.17%
[54]	relu6	Adam	0.004524209	0.009171137	0.00414428	5.56%	6.11%	5.13%
[18]	sigmoid	Adam	0.007293813	0.006436453	0.008217755	6.73%	6.49%	7.45%
[21]	sigmoid	Adam	0.005200874	0.005983599	0.005747814	5.86%	5.74%	5.96%
[24]	sigmoid	Adam	0.005186164	0.006469812	0.005578504	5.64%	6.13%	6.14%
[27]	sigmoid	Adam	0.005372388	0.005285297	0.006368052	5.89%	5.29%	6.35%
[30]	sigmoid	Adam	0.004256435	0.012315862	0.006312908	5.29%	6.55%	6.69%
[36]	sigmoid	Adam	0.006117536	0.011451795	0.005766196	6.29%	6.80%	6.23%
[42]	sigmoid	Adam	0.005360127	0.0133263	0.005997472	5.63%	7.06%	5.99%
[54]	sigmoid	Adam	0.004443284	0.004272361	0.005493512	5.24%	5.18%	5.82%

Avg Error [±g/cm³] 0.5[MHz]	Avg Error [±g/cm³] 1.0[MHz]	Avg Error [±g/cm³] 2.25[MHz]	Notes
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0.011582047	0.010925664	0.011133386	
0.011608175	0.014802966	0.010022742	
0.012056362	0.009654665	0.011363736	
0.010706433	0.01131528	0.009166552	
0.010140843	0.011064911	0.009601288	
0.010109345	0.00890461	0.011760354	
0.008870901	0.010533862	0.009127621	
0.009812418	0.010777846	0.009056446	
0.011883557	0.011456312	0.013147044	
0.010348467	0.010131893	0.010525761	
0.009961672	0.010818811	0.010831813	
0.01039236	0.009333552	0.011199544	
0.009333223	0.011556901	0.011813608	
0.011109911	0.011999486	0.010997781	
0.009930361	0.012461278	0.010566726	
0.009254354	0.009148931	0.010271766	
0	0	0	
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0	0	0	
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Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9] (2)	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.005551389	0.005247188	0.008010095	6.1%	5.6%	7.0%
[21]	relu6	Adam	0.004444333	0.008893151	0.004967728	5.0%	5.7%	5.6%
[24]	relu6	Adam	0.007649801	0.004335188	0.014184484	5.2%	4.6%	7.6%
[27]	relu6	Adam	0.005528462	0.004351841	0.008326991	5.7%	4.9%	6.4%
[30]	relu6	Adam	0.006696545	0.006276605	0.003655223	5.5%	5.2%	4.7%
[36]	relu6	Adam	0.003082993	0.005586117	0.004038516	4.3%	5.4%	4.3%
[42]	relu6	Adam	0.004467339	0.003990354	0.003695938	5.0%	4.7%	4.5%
[54]	relu6	Adam	0.004501605	0.004220307	0.00446683	4.7%	4.9%	5.2%
[18]	sigmoid	Adam	0.008624845	0.006621738	0.003813301	6.5%	5.3%	4.8%
[21]	sigmoid	Adam	0.004638227	0.002794337	0.006307792	4.7%	4.3%	6.1%
[24]	sigmoid	Adam	0.00448974	0.005712626	0.003814007	5.3%	5.2%	5.3%
[27]	sigmoid	Adam	0.004735676	0.002643713	0.007891865	5.5%	4.0%	6.5%
[30]	sigmoid	Adam	0.007244302	0.008397116	0.004198888	5.6%	5.6%	5.2%
[36]	sigmoid	Adam	0.004437722	0.016236315	0.003419058	4.7%	6.3%	4.9%
[42]	sigmoid	Adam	0.0051257	0.003564449	0.003359629	5.3%	4.9%	4.5%
[54]	sigmoid	Adam	0.002943791	0.00339173	0.003310099	4.2%	4.6%	4.6%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0	0	0	
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0	0	0	
0	0	0	
0	0	0	
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0	0	0	
0.123324191	0.11427299	0.142421014	
0.100322469	0.115039004	0.114043659	
0.105484188	0.093516409	0.153676306	
0.115090506	0.09916977	0.129242807	
0.110613093	0.105903618	0.095459953	
0.088039109	0.109929791	0.086925734	
0.101849211	0.094381434	0.090790975	
0.094778257	0.098558765	0.105279943	
0.131820244	0.107918419	0.097325238	
0.096128164	0.087368308	0.124020143	
0.106303912	0.105308819	0.106505363	
0.111879608	0.081954549	0.131948957	
0.112817098	0.114139673	0.104388028	
0.095725862	0.126610161	0.09862298	
0.106969866	0.099671771	0.090072927	
0.084656993	0.092581041	0.093966467	
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Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.005799993	0.006488438	0.004739786	5.36%	5.85%	5.18%
[21]	relu6	Adam	0.007029768	0.007454502	0.007803297	5.73%	5.14%	5.80%
[24]	relu6	Adam	0.005881331	0.006544851	0.010393349	5.61%	5.79%	6.31%
[27]	relu6	Adam	0.004437141	0.003706588	0.003605146	5.03%	4.38%	4.65%
[30]	relu6	Adam	0.005566557	0.034685414	0.003211477	5.73%	5.61%	4.53%
[36]	relu6	Adam	0.004791418	0.016614381	0.00236104	4.76%	5.46%	3.61%
[42]	relu6	Adam	0.005703138	0.003829432	0.002589914	5.54%	4.24%	4.20%
[54]	relu6	Adam	0.005137274	0.009825117	0.002058703	5.27%	4.10%	3.38%
[18]	sigmoid	Adam	0.006925619	0.004131106	0.008231351	5.91%	4.66%	6.07%
[21]	sigmoid	Adam	0.00753971	0.003167087	0.008095091	5.85%	4.36%	7.20%
[24]	sigmoid	Adam	0.006705027	0.005208409	0.00741587	6.32%	4.64%	6.33%
[27]	sigmoid	Adam	0.004476787	0.003198965	0.006211649	4.99%	4.44%	5.78%
[30]	sigmoid	Adam	0.004369085	0.017355034	0.004944116	4.78%	5.97%	5.45%
[36]	sigmoid	Adam	0.003763908	0.014477941	0.005234744	4.41%	6.03%	5.98%
[42]	sigmoid	Adam	0.005773471	0.10300691	0.005547311	5.54%	10.05%	5.17%
[54]	sigmoid	Adam	0.004132324	0.009808639	0.00188214	4.49%	5.07%	3.62%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0	0	0	
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0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0.082431393	0.089867106	0.079612174	
0.088050039	0.078966372	0.089175389	
0.086183086	0.08904884	0.097021885	
0.077395064	0.067390357	0.071553618	
0.088102395	0.086221123	0.069640671	
0.073224339	0.083922634	0.055504063	
0.085196836	0.065136825	0.064630963	
0.081068981	0.063104715	0.05191882	
0.090809563	0.071654623	0.093382138	
0.089922549	0.066965596	0.110647612	
0.097146402	0.071268868	0.097287834	
0.076656547	0.068202475	0.088800891	
0.073559422	0.091852401	0.083795737	
0.067782721	0.092672217	0.091917368	
0.085217864	0.154586103	0.079486583	
0.068982399	0.077915763	0.055692934	
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Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.005743894	0.007347505	0.00274412	5.83%	6.04%	4.15%
[21]	relu6	Adam	0.011898546	0.010220879	0.007829725	7.23%	7.05%	7.13%
[24]	relu6	Adam	0.004654909	0.004750262	0.004060306	5.39%	5.09%	5.10%
[27]	relu6	Adam	0.017755132	0.004849661	0.006072767	8.61%	5.18%	6.53%
[30]	relu6	Adam	0.003720839	0.003577363	0.004312788	4.54%	4.79%	5.01%
[36]	relu6	Adam	0.00508692	0.005757362	0.004110709	5.56%	5.16%	4.56%
[42]	relu6	Adam	0.005868205	0.004274706	0.003032154	5.47%	4.78%	4.46%
[54]	relu6	Adam	0.003369108	0.003449137	0.002232072	4.27%	4.25%	3.76%
[18]	sigmoid	Adam	0.005540016	0.004481496	0.008985222	5.69%	5.39%	6.82%
[21]	sigmoid	Adam	0.006411402	0.004339237	0.006406744	6.33%	4.81%	6.73%
[24]	sigmoid	Adam	0.009463773	0.003056627	0.007560525	6.61%	4.23%	6.88%
[27]	sigmoid	Adam	0.00596767	0.007225134	0.002928624	5.72%	5.99%	4.34%
[30]	sigmoid	Adam	0.009707577	0.003150011	0.005417187	6.72%	4.40%	5.69%
[36]	sigmoid	Adam	0.00519219	0.003582708	0.004490096	5.06%	5.04%	5.23%
[42]	sigmoid	Adam	0.006094335	0.00283665	0.004304925	5.41%	4.31%	5.06%
[54]	sigmoid	Adam	0.00567442	0.003192067	0.004787881	5.49%	4.54%	5.54%

Avg Error [±mPas] 0.5[MHz]	Avg Error [±mPas] 1.0[MHz]	Avg Error [±mPas] 2.25[MHz]	Notes
0	0	0	
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0	0	0	
0.208278721	0.215741678	0.148238588	
0.258398768	0.251722002	0.254791603	
0.19261156	0.181735805	0.182137565	
0.307782003	0.18499504	0.233264729	
0.162215935	0.171124446	0.17918349	
0.19860135	0.184259577	0.163081404	
0.195462367	0.170783358	0.159357942	
0.15267664	0.151973808	0.134378024	
0.203242242	0.192692046	0.243692891	
0.22609746	0.171796927	0.240526987	
0.236345646	0.151042224	0.245788911	
0.204245734	0.213883251	0.155051728	
0.240165283	0.157053173	0.203454208	
0.180928749	0.180177602	0.186991668	
0.193162902	0.15384717	0.18086985	
0.196215704	0.162351339	0.198014828	
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Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.009412854	0.00992169	0.014521944			
[9, 9]	relu6	Adam	0.015940951	0.008786171	0.012892835			
[9, 9, 9]	relu6	Adam	0.019530067	0.02429575	0.031702865			
[9, 9, 9] (2)	relu6	Adam						
[9, 18, 9]	relu6	Adam	0.010793506	0.020345734	0.005727412			
[9, 18, 36, 18, 9]	relu6	Adam	0.013701151	0.0277915	0.031920794			
[9,18,36,36,18,9]	relu6	Adam	0.028695732	0.01609684	0.031470798			
[9,18,18,9]	relu6	Adam	0.019011818	0.013353566	0.011650999			
[9,27,27,9]	relu6	Adam	0.019505976	0.011690907	0.024447272			
[9,27,54,27,9]	relu6	Adam	0.03101173	0.026157977	0.024448168			
[9,27,81,27,9]	relu6	Adam						
[27]	relu6	Adam	0.006088969	0.005441475	0.004278604			
[18]	relu6	Adam	0.011838168	0.006661672	0.009306335			
[21]	relu6	Adam	0.005291452	0.005272683	0.003831809			
[24]	relu6	Adam	0.006787725	0.004979517	0.005059769			
[18]	sigmoid	Adam	0.00579831	0.006685769	0.005007782			
[21]	sigmoid	Adam	0.005188115	0.005125159	0.003123872			
[24]	sigmoid	Adam	0.007272534	0.004856747	0.005237749			
[9,9]	sigmoid	Adam	0.009983921	0.008007514	0.010864457			
[18,18]	sigmoid	Adam	0.006987863	0.004905279	0.006778115			
[18,9]	sigmoid	Adam	0.007538024	0.005950121	0.0075113			
[30]	sigmoid	Adam	0.005948569	0.007207838	0.005771773			
[27]	sigmoid	Adam	0.004915215	0.004305886	0.003166442			
[42]	sigmoid	Adam	0.004800507	0.004754296	0.004327542			
[30]	relu6	Adam	0.00562796	0.006149226	0.005037366			
[42]	relu6	Adam	0.00338557	0.004229819	0.004835476			
[54]	relu6	Adam	0.00517127	0.004623161	0.002864497			
[9]	sigmoid	Adam	0.022786729	0.013257362	0.02558402			
[18]	sigmoid	Adam	0.009431842	0.009966672	0.015416862			
[24]	sigmoid	Adam	0.013245738	0.0083342	0.012087448			
[27]	sigmoid	Adam	0.010426221	0.008219758	0.009825388			
[30]	sigmoid	Adam	0.005295794	0.007018962	0.008377146			
[42]	sigmoid	Adam	0.007289418	0.00546905	0.008950616			
[54]	sigmoid	Adam	0.007841041	0.007753319	0.008137153			
[9]	relu6	Adam	0.012317519	0.012171041	0.0205209			
[18]	relu6	Adam	0.015367985	0.012889258	0.011590214			
[24]	relu6	Adam	0.007849623	0.011107618	0.021982782			
[27]	relu6	Adam	0.011786538	0.008078287	0.010015552			
[30]	relu6	Adam	0.007351097	0.009943717	0.007529942			
[42]	relu6	Adam	0.004269793	0.007262735	0.004692523			
[54]	relu6	Adam	0.007056417	0.005300486	0.004363385			
[42] (2)	sigmoid	Adam	0.004696606	0.004911612	0.005272229	5.31%	4.92%	5.64%
[42] (2)	relu6	Adam	0.005566885	0.00506115	0.004235003	5.78%	5.52%	5.36%
[54] (2)	relu6	Adam	0.003740927	0.004224048	0.003303772	4.76%	5.05%	4.78%
[42] (3)	relu6	Adam	0.005600849	0.004929632	0.002623805	5.64%	5.47%	4.26%
[54] (3)	relu6	Adam	0.004203467	0.003706302	0.003374274	4.96%	4.93%	4.73%
[60]	sigmoid	Adam	0.004847274	0.003535087	0.003814665	5.39%	4.51%	5.12%
[60]	relu6	Adam	0.004547541	0.002960441	0.003436823	5.47%	4.19%	4.94%
[60] (2)	sigmoid	Adam	0.004506168	0.004649545	0.003042461	5.14%	4.95%	4.45%

[60] (2)	relu6	Adam	0.00501786	0.004290014	0.003450565	5.67%	5.34%	4.80%
[42] (4)	relu6	Adam	0.003965606	0.004138364	0.003079413	5.09%	4.99%	4.62%
[54] (4)	relu6	Adam	0.00496667	0.004181859	0.004318932	5.73%	5.06%	5.51%
[42] (5)	relu6	Adam	0.004859264	0.003886488	0.003208687	5.39%	4.83%	4.47%
[54] (5)	relu6	Adam	0.004224682	0.00471616	0.003334719	5.20%	5.35%	4.72%
[42] (6)	relu6	Adam	0.004367917	0.004911245	0.004955865	4.91%	5.51%	5.74%
[54] (6)	relu6	Adam	0.004651451	0.003503576	0.003707528	5.34%	4.59%	5.24%
[42] (4) (retrain)	relu6	Adam	0.002899972	0.003191603	0.003351744	4.32%	4.25%	4.82%
[54] (4) (retrain)	relu6	Adam	0.003445407	0.00601074	0.005041919	4.81%	5.82%	5.71%
[54] (7)	relu6	Adam	0.003727746	0.004679968	0.003748156	5.07%	5.49%	4.86%
[54] (8)	relu6	Adam	0.004378809	0.003832144	0.003250323	5.26%	4.89%	4.65%
[54] (9)	relu6	Adam	0.002782275	0.005412886	0.002973964	4.19%	5.95%	4.57%
[42] (3)	sigmoid	Adam	0.003838728	0.004972284	0.005031767	4.80%	5.25%	5.60%
[54] (3)	sigmoid	Adam	0.004090222	0.005626661	0.005078375	4.84%	5.42%	5.53%
[42] (7)	relu6	Adam	0.004528522	0.004547544	0.003746386	5.38%	5.29%	5.23%
[42] (8)	relu6	Adam	0.006008645	0.005487233	0.002955967	6.11%	5.30%	4.47%
[54] (10)	relu6	Adam	0.00421601	0.003738884	0.003592298	5.11%	4.68%	5.07%
[54] (11)	relu6	Adam	0.003560749	0.004808804	0.003965277	4.58%	5.49%	5.14%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
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0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
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0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0.009364803	0.008688815	0.009955012	
0.010201805	0.009749162	0.009461553	
0.0084024	0.008908628	0.008434922	
0.0099629	0.00966082	0.00751394	
0.008758753	0.008705783	0.00834227	
0.009520627	0.007963699	0.009044922	
0.009663301	0.007395728	0.008716238	
0.009078682	0.008744091	0.007858887	

0.010013394	0.00941741	0.00847041
0.008976874	0.008808709	0.008155256
0.010112721	0.008928114	0.009721659
0.009506258	0.008521179	0.007893439
0.009181125	0.009441112	0.008335739
0.00866301	0.009730361	0.010127404
0.009416947	0.00809969	0.009250008
0.007631973	0.00749483	0.008507658
0.008495182	0.010269539	0.01007537
0.008956458	0.009683294	0.008572583
0.00928741	0.008632241	0.00820138
0.007394441	0.010506395	0.008069807
0.008470761	0.009265131	0.009882116
0.008538162	0.009558072	0.009758944
0.009491317	0.009338853	0.009238982
0.010782951	0.009355578	0.007898224
0.009017265	0.008252068	0.008954376
0.008090852	0.009697898	0.00906822

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	sigmoid	Adam	0.0080441	0.004438942	0.00776682			
[9, 9]	sigmoid	Adam	0.007138448	0.004424245	0.007520638			
[9, 9, 9]	relu6	Adam	0.022221742	0.005977642	0.00770268			
[9, 18, 9]	relu6	Adam	0.013861215	0.012161436	0.017556593			
[9, 18, 36, 18, 9]	relu6	Adam	0.013786471	0.005472331	0.014066529			
[9,18,36,36,18,9]	relu6	Adam	0.016131043	0.008726913	0.010949147			
[9,18,18,9]	relu6	Adam	0.016749727	0.016912855	0.009244397			
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam	0.009874546	0.013511981	0.009957684			
[9,27,81,27,9]	relu6	Adam						
[18]	sigmoid	Adam	0.004787944	0.003745462	0.004431664			
[21]	sigmoid	Adam	0.004328702	0.003234095	0.004184744			
[24]	sigmoid	Adam	0.004289124	0.003279108	0.002090284			
[9,9]	sigmoid	Adam	0.010251052	0.002226267	0.007726189			
[18,18]	sigmoid	Adam	0.003665376	0.003234946	0.00484557			
[18,9]	sigmoid	Adam	0.004747965	0.003434801	0.006696481			
[30]	sigmoid	Adam	0.004939923	0.002573382	0.00190986			
[27]	sigmoid	Adam	0.004782475	0.002660832	0.001914036			
[42]	sigmoid	Adam	0.004095636	0.001958277	0.002961179			
[24]	relu6	Adam	0.003668577	0.004828545	0.002223522			
[30]	relu6	Adam	0.003038936	0.003959282	0.002720721			
[27]	relu6	Adam	0.005499365	0.002586528	0.002649062			
[42]	relu6	Adam	0.003081176	0.001734415	0.002360485			
[54]	relu6	Adam	0.003169359	0.001861964	0.001868734			
[9]	sigmoid	Adam	0.011819259	0.006144525	0.012233815			
[18]	sigmoid	Adam	0.010489082	0.005624717	0.010004356			
[24]	sigmoid	Adam	0.010614394	0.004130517	0.009818504			
[27]	sigmoid	Adam	0.006281004	0.004153361	0.007741805			
[30]	sigmoid	Adam	0.009461296	0.005222876	0.0081467			
[42]	sigmoid	Adam	0.005523561	0.003462009	0.007450804			
[54]	sigmoid	Adam	0.006740851	0.003117662	0.00572864			
[9]	relu6	Adam	0.011958026	0.008082819	0.007371911			
[18]	relu6	Adam	0.016583513	0.004808562	0.008405915			
[24]	relu6	Adam	0.009365344	0.006290204	0.009437093			
[27]	relu6	Adam	0.006081128	0.006093023	0.003212457			
[30]	relu6	Adam	0.003621964	0.004616267	0.005828666			
[42]	relu6	Adam	0.003254823	0.002459682	0.004697482			
[54]	relu6	Adam	0.003075152	0.002293882	0.004741686			
[30] (3)	sigmoid	Adam	0.003287355	0.002150687	0.003404048	4.4%	3.5%	5.1%
[27] (3)	sigmoid	Adam	0.004429048	0.002498354	0.002618437	5.2%	4.1%	4.1%
[42] (3)	relu6	Adam	0.002683821	0.001563598	0.001297663	4.1%	3.0%	3.1%
[54] (3)	relu6	Adam	0.003095582	0.002874738	0.001397247	4.2%	3.2%	2.9%
[42] (2)	relu6	Adam	0.002015292	0.002097701	0.003049536	3.2%	3.7%	4.3%
[54] (2)	relu6	Adam	0.002863431	0.002150186	0.001835732	3.8%	3.5%	3.5%
[36] (3)	relu6	Adam	0.002935415	0.00194903	0.002299825	4.5%	3.4%	4.2%
[42] (4)	relu6	Adam	0.003148585	0.002421741	0.001714836	4.0%	4.1%	3.3%
[54] (4)	relu6	Adam	0.002900038	0.003087416	0.001436401	4.1%	3.5%	3.2%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0	0	0	
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0	0	0	
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0.088253497	0.069943671	0.102340327	
0.105968927	0.083801142	0.082150039	
0.082534783	0.061201659	0.06218436	
0.085716301	0.064523237	0.058511931	
0.065699285	0.074726132	0.087463147	
0.076160185	0.070225589	0.070825409	
0.090903318	0.069139772	0.084723984	
0.081757668	0.083363271	0.06737959	
0.082360281	0.071281273	0.06420096	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	sigmoid	Adam	0.011983026	0.003722655	0.0118073			
[9, 9]	sigmoid	Adam						
[9, 9, 9]	sigmoid	Adam	0.017389981	0.005011552	0.004033336			
[9, 18, 9]	relu6	Adam	0.019127853	0.004540155	0.013190473			
[9, 18, 36, 18, 9]	relu6	Adam	0.013387186	0.003902781	0.016172979			
[9,18,36,36,18,9]	relu6	Adam	0.014373331	0.018289331	0.005762977			
[9,18,18,9]	relu6	Adam	0.014502198	0.006459679	0.015044636			
[9,27,27,9] (2)	relu6	Adam	0.00850739	0.013866545	0.012390561			
[9,27,54,27,9] (2)	relu6	Adam	0.02074138	0.008505242	0.011233058			
[9,27,81,27,9]	relu6	Adam	0.016840687	0.015488875	0.012714812			
[18]	sigmoid	Adam	0.004643175	0.002816165	0.005512775			
[21]	sigmoid	Adam	0.005311965	0.002489036	0.004733592			
[24]	sigmoid	Adam	0.004198854	0.003824009	0.005067416			
[9,9]	sigmoid	Adam						
[18,18]	sigmoid	Adam	0.005555369	0.002447258	0.002780963			
[18,9]	sigmoid	Adam	0.006725127	0.003587293	0.004764675			
[30]	sigmoid	Adam	0.004354306	0.002185087	0.004385848			
[27]	sigmoid	Adam	0.005164495	0.002989842	0.005601989			
[42]	sigmoid	Adam	0.004622297	0.001643654	0.001928179			
[24]	relu6	Adam	0.004984032	0.004074227	0.002428507			
[30]	relu6	Adam	0.004598724	0.002350804	0.002041681			
[27]	relu6	Adam	0.006259802	0.001979431	0.002647256			
[42]	relu6	Adam	0.002933066	0.002965912	0.00219742			
[9]	sigmoid	Adam	0.00930261	0.006946231	0.012871415			
[18]	sigmoid	Adam	0.011162181	0.005813706	0.009078219			
[24]	sigmoid	Adam	0.008024395	0.003970988	0.007657025			
[27]	sigmoid	Adam	0.007740124	0.003461318	0.008593199			
[30]	sigmoid	Adam	0.010024547	0.005903167	0.008782834			
[42]	sigmoid	Adam	0.00525584	0.003602611	0.008736018			
[54]	sigmoid	Adam	0.005257104	0.003985836	0.005267043			
[9]	relu6	Adam	0.012380749	0.01198858	0.011183357			
[18]	relu6	Adam	0.006083435	0.007509854	0.006703981			
[24]	relu6	Adam	0.009174195	0.004701132	0.00554173			
[27]	relu6	Adam	0.00793587	0.006608153	0.008203371			
[30]	relu6	Adam	0.007145756	0.00207116	0.004262633			
[42]	relu6	Adam	0.004724022	0.003133246	0.003443817			
[54]	relu6	Adam	0.004831141	0.00336312	0.002302318			
[42] (2)	relu6	Adam	0.002865412	0.001751562	0.002140795	4.07%	3.18%	3.92%
[42] (2)	sigmoid	Adam	0.004087842	0.002580559	0.002861417	4.80%	3.98%	4.55%
[54] (2)	sigmoid	Adam	0.003665624	0.001867602	0.002936544	4.32%	3.44%	4.35%
[54] (2)	relu6	Adam	0.003079046	0.001630774	0.001358805	4.11%	3.13%	2.86%
[54] (3)	sigmoid	Adam	0.003960553	0.001726934	0.002612148	4.58%	3.10%	4.07%
[54] (3)	relu6	Adam	0.003368138	0.001702703	0.001730261	4.06%	3.26%	3.45%
[42] (3)	relu6	Adam	0.002539283	0.002328036	0.001763993	3.49%	3.93%	3.42%
[42] (3)	sigmoid	Adam	0.002544126	0.001939465	0.00238817	3.52%	3.61%	4.00%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0.062651701	0.048863775	0.060292557	
0.073768317	0.061256441	0.070003468	
0.066400147	0.05282152	0.066811546	
0.063212195	0.048052383	0.043938713	
0.070418763	0.047628132	0.062589647	
0.062416522	0.050047211	0.053106959	
0.053701676	0.060357476	0.052543418	
0.054091393	0.055516544	0.061462898	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.007758606	0.007445073	0.010033994			
[9, 9]	relu6	Adam	0.017770814	0.009226775	0.009333161			
[9, 9, 9]	relu6	Adam	0.025531016	0.005193825	0.015094332			
[9, 18, 9]	relu6	Adam	0.011099017	0.017907545	0.013535707			
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam	0.020459104	0.00543438	0.01351411			
[9,27,27,9]	relu6	Adam	0.010611911	0.01261197	0.016904492			
[9,27,54,27,9]	relu6	Adam						
[30]	relu6	Adam	0.003591733	0.003917522	0.002349088			
[42]	relu6	Adam	0.003047172	0.002430062	0.001446112			
[18]	relu6	Adam	0.00571292	0.003129592	0.002671741			
[27]	relu6	Adam	0.00657682	0.006227553	0.00665007			
[9,9]	sigmoid	Adam	0.008468336	0.003287042	0.00367646			
[9]	sigmoid	Adam	0.008279854	0.004568947	0.007437503			
[18]	sigmoid	Adam	0.005864866	0.003227898	0.005117878			
[21]	sigmoid	Adam	0.005413353	0.004435974	0.005247373			
[24]	sigmoid	Adam	0.004354964	0.002146571	0.002978432			
[9,9]	sigmoid	Adam	0.007289266	0.004216479	0.007459661			
[18,18]	sigmoid	Adam	0.006486342	0.003932572	0.006032893			
[18,9]	sigmoid	Adam	0.005891064	0.004269301	0.006752573			
[30]	sigmoid	Adam	0.004046611	0.002099014	0.002999971			
[27]	sigmoid	Adam	0.00429923	0.002779577	0.003706969			
[42]	sigmoid	Adam	0.003992596	0.002163902	0.002489467			
[9]	sigmoid	Adam	0.014639475	0.006605407	0.01366402			
[18]	sigmoid	Adam	0.008897027	0.005083232	0.01098428			
[24]	sigmoid	Adam	0.009269448	0.004485265	0.008161294			
[27]	sigmoid	Adam	0.00733841	0.005476355	0.010835473			
[30]	sigmoid	Adam	0.008761549	0.005568914	0.016718136			
[42]	sigmoid	Adam	0.006777606	0.004669567	0.005780132			
[54]	sigmoid	Adam	0.007093798	0.002530439	0.005801299			
[9]	relu6	Adam	0.01507198	0.012278948	0.026146285			
[18]	relu6	Adam	0.014686357	0.008206872	0.013010776			
[24]	relu6	Adam	0.011495653	0.008728593	0.010889184			
[27]	relu6	Adam	0.01030957	0.008503007	0.005395267			
[30]	relu6	Adam	0.006888378	0.005586717	0.005344694			
[42]	relu6	Adam	0.004061121	0.005070675	0.003622062			
[54]	relu6	Adam	0.00548747	0.003056494	0.002821477			
[42]	relu6	Adam	0.005173035	0.002001134	0.002183405	5.31%	3.50%	3.40%
[54]	relu6	Adam	0.004594402	0.002231209	0.002106794	4.87%	3.66%	3.95%
[42] (2)	relu6	Adam	0.003952345	0.002073102	0.001435809	5.26%	3.61%	2.98%
[54] (2)	relu6	Adam	0.004275236	0.002535277	0.001598294	5.18%	3.94%	3.34%
[42] (2)	sigmoid	Adam	0.005253796	0.002154646	0.002756356	5.43%	3.49%	4.03%
[54] (2)	sigmoid	Adam	0.00270929	0.002118426	0.003018815	3.82%	3.66%	4.52%

Avg Error [±mPas] 0.5[MHz]	Avg Error [±mPas] 1.0[MHz]	Avg Error [±mPas] 2.25[MHz]	Notes
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	2.25MHz is average of all
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	Dropout = 0.4
0	0	0	
0.189673337	0.124996125	0.121548255	(file names missing Adam_ASoS_New_2)
0.173993495	0.13070882	0.141159441	(file names missing Adam_ASoS_New_2)
0.187813087	0.129108012	0.106476782	
0.185159695	0.140792564	0.11935982	
0.194120586	0.124585702	0.144047868	
0.136365339	0.130689495	0.161404749	

Attribute	Density [g/cm³]	Yield Point [Pa]	Gel Strength [Pa]	Plastic Viscosity [mPas]
min	0.698	0.6675	0.2475	2.089
max	0.8745	2.6915	1.785	5.662
span	0.1765	2.024	1.5375	3.573

Appendix M

Spreadsheet of neural network results using both old and new data

This appendix includes all the loss and error numbers available for the neural networks trained with both the measurement data gathered during this thesis and the data gathered previously. This data is available in appendix G for the new data gathered in this thesis and appendix K from the old data gathere previously.

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.024152273	0.012555996	0.01963478			
[9, 9]	relu6	Adam	0.005716796	0.005940338	0.015135192			
[9, 9] (2)	relu6	Adam	0.005094755	0.019490847	0.006235211			
[9, 9, 9]	relu6	Adam	0.005245768	0.004526517	0.008820937			
[9, 18, 9] (2)	relu6	Adam	0.030584317	0.0076857	0.016936304			
[9, 18, 9]	relu6	Adam	0.015424694	0.005582176	0.006406008			
[9, 18, 36, 18, 9]	relu6	Adam	0.026001964	0.01041771	0.021077678			
[9,18,36,36,18,9]	relu6	Adam	0.015817638	0.04388176	0.014760369			
[9,18,18,9]	relu6	Adam	0.01832526	0.041443	0.008093338			
[9,27,27,9]	relu6	Adam	0.005608222	0.005868764	0.01724739			
[9,27,54,27,9]	relu6	Adam	0.007515992	0.00976906	0.005864741			
[9,27,81,27,9]	relu6	Adam	0.06399763	0.00567206	0.009202655			
[9]	relu6	Adam	0.022760624	0.015853897	0.012435144	12.3%	9.6%	8.6%
[18]	relu6	Adam	0.012452275	0.016147431	0.014251353	8.7%	9.1%	8.7%
[21]	relu6	Adam	0.013918561	0.012215395	0.012453365	8.4%	8.7%	7.8%
[24]	relu6	Adam	0.013032263	0.010227037	0.011914926	8.6%	7.2%	7.7%
[27]	relu6	Adam	0.012407083	0.013130513	0.012136326	9.1%	8.0%	8.1%
[30]	relu6	Adam	0.011369652	0.010340571	0.011696138	8.0%	7.8%	8.4%
[36]	relu6	Adam	0.008602339	0.012520744	0.009956248	6.7%	8.0%	7.6%
[42]	relu6	Adam	0.014679413	0.013762577	0.009009285	9.2%	8.9%	6.8%
[54]	relu6	Adam	0.010110162	0.009849007	0.010214616	7.3%	7.1%	6.8%
[18]	sigmoid	Adam	0.039271746	0.024370445	0.025327163	13.8%	11.0%	11.3%
[21]	sigmoid	Adam	0.039620508	0.023012355	0.02476512	14.5%	10.8%	11.6%
[24]	sigmoid	Adam	0.030568069	0.02009207	0.024631351	12.3%	10.1%	11.2%
[27]	sigmoid	Adam	0.03381544	0.02671715	0.032203287	13.1%	11.1%	12.5%
[30]	sigmoid	Adam	0.02733009	0.019286973	0.025371168	11.7%	9.7%	11.3%
[36]	sigmoid	Adam	0.02592933	0.024397833	0.020695673	11.5%	11.3%	10.6%
[42]	sigmoid	Adam	0.032273695	0.021334006	0.019437484	12.0%	10.9%	10.3%
[54]	sigmoid	Adam	0.028559783	0.023104316	0.021723727	12.0%	10.4%	10.3%
[27] (2)	relu6	Adam	0.005970245	0.010365567	0.004935834	5.6%	7.1%	4.8%
[30] (2)	relu6	Adam	0.006377176	0.009290115	0.006052754	6.0%	6.8%	5.5%
[36] (2)	relu6	Adam	0.004608463	0.008714326	0.002360232	5.0%	6.5%	3.7%
[42] (2)	relu6	Adam	0.008309573	0.007932808	0.004283079	6.6%	5.9%	5.1%
[54] (2)	relu6	Adam	0.005978712	0.002330341	0.002185976	5.7%	3.7%	3.3%
[27] (2)	sigmoid	Adam	0.009659168	0.002901246	0.002533057	6.6%	3.8%	3.1%
[30] (2)	sigmoid	Adam	0.004291005	0.002070213	0.001487382	4.7%	3.2%	3.0%
[36] (2)	sigmoid	Adam	0.00597575	0.002361218	0.001590457	5.6%	3.2%	3.0%
[42] (2)	sigmoid	Adam	0.006664922	0.002376435	0.002137517	4.6%	3.3%	3.2%
[54] (2)	sigmoid	Adam	0.003713799	0.001915415	0.002282649	4.5%	3.2%	3.4%

Avg Error [±g/cm^3] 0.5[MHz]	Avg Error [±g/cm^3] 1.0[MHz]	Avg Error [±g/cm^3] 2.25[MHz]	Notes
0	0	0	
0	0	0	Parts of 2.25 estimates averages from the new data sets
0	0	0	
0	0	0	Named as (2)
0	0	0	
0	0	0	
0	0	0	0.5 and 2.25 stuck in averages from each dataset and not reliably the right one
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0.07966824	0.062367909	0.055886295	
0.056735248	0.059212388	0.05647404	
0.054205796	0.056774842	0.050350019	
0.055902489	0.046682224	0.049728909	
0.058849846	0.051944341	0.052429044	
0.052126357	0.050407665	0.054655833	
0.043609075	0.052036097	0.049194874	
0.059533181	0.057749175	0.043978367	
0.047624385	0.04577898	0.044064878	
0.08961815	0.071253024	0.073464106	
0.093920797	0.069922772	0.075232381	
0.080143923	0.065383303	0.072671123	
0.085023592	0.072251087	0.08124226	
0.07581114	0.062689372	0.073398052	
0.074340719	0.073178346	0.068661372	
0.077994091	0.070615736	0.066568544	
0.077571527	0.067668825	0.067091539	
0.03651399	0.045938581	0.031462137	
0.038766427	0.044252364	0.035590229	
0.032149229	0.042109582	0.023886223	
0.042618801	0.038492181	0.032843845	
0.036865842	0.023763159	0.021439508	
0.04267345	0.024850346	0.020137366	
0.030376228	0.020557481	0.019504068	
0.036206254	0.02109143	0.019455543	
0.029714839	0.021545281	0.021067778	
0.029516836	0.020600676	0.022241324	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.03008547	0.018869918	0.030991342	13.32%	10.89%	15.03%
[9, 9]	relu6	Adam	0.008428223	0.01774082	0.04329053	7.08%	11.19%	18.43%
[9, 9, 9]	relu6	Adam	0.011772292	0.02904127	0.05001269	7.51%	13.59%	17.85%
[9, 18, 9]	relu6	Adam	0.016366646	0.020111911	0.024294447	7.74%	10.11%	11.73%
[9, 18, 36, 18, 9]	relu6	Adam	0.07809616	0.021909142	0.022503452	20.20%	9.47%	12.60%
[9,18,36,36,18,9]	relu6	Adam	0.116396315	0.028096544	0.0583334	24.84%	13.12%	17.94%
[9,18,18,9]	relu6	Adam	0.010890387	0.03429195	0.010023525	8.07%	14.25%	7.59%
[9,27,27,9]	relu6	Adam	0.09416617	0.021328216	0.017494833	24.21%	9.31%	10.02%
[9,27,54,27,9]	relu6	Adam	0.01289418	0.008226549	0.031516228	7.03%	6.80%	13.43%
[9,27,81,27,9]	relu6	Adam	0.035128	0.016703956	0.03744595	12.24%	7.97%	13.65%
[18]	relu6	Adam	0.010353763	0.011249298	0.009206564	7.84%	7.62%	7.15%
[21]	relu6	Adam	0.011542358	0.008732763	0.007925314	8.33%	6.89%	6.95%
[24]	relu6	Adam	0.009277079	0.010226268	0.004477355	7.36%	6.64%	5.11%
[27]	relu6	Adam	0.010915751	0.011510548	0.00606918	7.31%	8.09%	5.84%
[30]	relu6	Adam	0.010058661	0.006676544	0.005466063	7.76%	5.77%	5.94%
[36]	relu6	Adam	0.007309983	0.008020861	0.006386216	6.13%	6.25%	5.93%
[42]	relu6	Adam	0.008841396	0.006109779	0.00464297	6.91%	5.38%	5.28%
[54]	relu6	Adam	0.008028605	0.007112136	0.006005269	6.46%	5.48%	6.06%
[18]	sigmoid	Adam	0.031093374	0.03031767	0.033410482	13.08%	12.96%	13.74%
[21]	sigmoid	Adam	0.032932434	0.03295291	0.033012733	13.11%	14.23%	13.97%
[24]	sigmoid	Adam	0.030881068	0.026435107	0.03467306	11.90%	11.78%	14.10%
[27]	sigmoid	Adam	0.040923886	0.028162098	0.032458134	14.24%	12.44%	13.61%
[30]	sigmoid	Adam	0.03723708	0.024829835	0.025104668	14.35%	11.42%	12.13%
[36]	sigmoid	Adam	0.041201867	0.024871374	0.034536347	15.46%	11.57%	12.94%
[42]	sigmoid	Adam	0.029132787	0.023051359	0.03144567	12.40%	11.04%	13.45%
[54]	sigmoid	Adam	0.033620834	0.027468588	0.030946244	14.58%	12.50%	12.94%
[27] (2)	relu6	Adam	0.010455211	0.011709147	0.010814289	8.10%	7.78%	7.22%
[30] (2)	relu6	Adam	0.008842472	0.00564963	0.007130867	7.20%	5.29%	5.57%
[36] (2)	relu6	Adam	0.008639544	0.007825026	0.005555031	7.13%	6.26%	5.74%
[42] (2)	relu6	Adam	0.0091345	0.008859535	0.003917961	7.22%	6.63%	4.48%
[54] (2)	relu6	Adam	0.00889996	0.00768321	0.005158373	7.30%	6.41%	4.92%
[27] (2)	sigmoid	Adam	0.034919694	0.03041489	0.028851006	13.68%	12.68%	13.05%
[30] (2)	sigmoid	Adam	0.03368622	0.027537795	0.020704681	13.02%	11.59%	11.19%
[36] (2)	sigmoid	Adam	0.032885	0.02944526	0.02183537	13.68%	12.28%	11.52%
[42] (2)	sigmoid	Adam	0.032648895	0.022185018	0.02912685	13.44%	10.58%	12.85%
[54] (2)	sigmoid	Adam	0.031112371	0.020152405	0.027994476	13.34%	10.63%	12.82%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
2.21831757	1.814558665	2.503126224	
1.179951165	1.864209238	3.069619893	
1.250215259	2.264115832	2.973602385	
1.289652741	1.683945652	1.954717527	
3.365210996	1.577639329	2.099456911	
4.138501746	2.185757607	2.987869081	
1.344178532	2.374174268	1.264689769	
4.032158445	1.551610396	1.668297418	
1.171533635	1.132813362	2.236486648	
2.038257346	1.326855944	2.274414755	
1.305369924	1.26915125	1.190357822	
1.386924782	1.147973883	1.158357207	
1.225946457	1.1059658	0.851968827	
1.217083455	1.348047046	0.972037114	
1.292820077	0.96034501	0.989304356	
1.020796511	1.041370315	0.987550167	
1.151398665	0.895403495	0.880238004	
1.075307581	0.912080979	1.00885057	
2.178257791	2.158115853	2.288012309	
2.184011937	2.371014973	2.327416548	
1.981919538	1.961425754	2.348916921	
2.372409169	2.07225872	2.266912321	
2.390214697	1.901762717	2.020927328	
2.575198558	1.927877702	2.15568493	
2.065470886	1.838460983	2.240500077	
2.429268952	2.083017108	2.156124496	
1.350061605	1.296667267	1.201882488	
1.198553675	0.880438062	0.927418579	
1.187107241	1.04357078	0.955627024	
1.202528579	1.104407996	0.746142027	
1.216458707	1.067372776	0.819197862	
2.279210738	2.112830363	2.174330704	
2.168293608	1.931428431	1.864598666	
2.279041458	2.045732737	1.919771004	
2.239503804	1.763023643	2.141167955	
2.221954936	1.771237975	2.135679192	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.013063232	0.011275766	0.011491423	8.81%	8.21%	7.98%
[9, 9]	relu6	Adam	0.010736809	0.012527445	0.021536991	7.83%	8.83%	11.79%
[9, 9, 9]	relu6	Adam	0.036615476	0.022892611	0.014186262	14.92%	10.96%	7.61%
[9, 18, 9]	relu6	Adam	0.006531667	0.04843551	0.014095948	6.16%	15.77%	8.27%
[9, 18, 36, 18, 9]	relu6	Adam	0.03478579	0.02318091	0.038670566	12.65%	9.97%	14.52%
[9,18,36,36,18,9]	relu6	Adam	0.039008226	0.029938998	0.105889834	14.27%	12.37%	27.72%
[9,18,18,9]	relu6	Adam	0.0185315	0.03555467	0.05050658	9.56%	13.97%	17.69%
[9,27,27,9]	relu6	Adam	0.079929136	0.023630468	0.06526385	18.71%	9.49%	17.73%
[9,27,54,27,9]	relu6	Adam	0.07228054	0.13264641	0.027576508	19.88%	23.79%	11.70%
[9,27,81,27,9]	relu6	Adam	0.050587114	0.04155684	0.022340802	14.39%	13.15%	9.82%
[18]	relu6	Adam	0.01253201	0.00967499	0.006659094	9.07%	6.89%	6.55%
[21]	relu6	Adam	0.009228731	0.006989415	0.005787956	6.90%	6.11%	6.41%
[24]	relu6	Adam	0.01018336	0.008677653	0.007932919	7.96%	6.99%	6.31%
[27]	relu6	Adam	0.015393486	0.012973003	0.005233966	9.48%	8.56%	5.56%
[30]	relu6	Adam	0.01277341	0.011356719	0.007302449	8.21%	7.81%	6.76%
[36]	relu6	Adam	0.008376494	0.006518117	0.006692026	6.94%	5.60%	6.49%
[42]	relu6	Adam	0.007254904	0.008232523	0.004842289	6.38%	6.01%	5.23%
[54]	relu6	Adam	0.005678706	0.011507118	0.005145703	5.50%	6.64%	5.04%
[18]	sigmoid	Adam	0.040397495	0.023292884	0.0358959	13.74%	11.01%	14.82%
[21]	sigmoid	Adam	0.047807157	0.032828975	0.03756236	16.02%	13.35%	14.83%
[24]	sigmoid	Adam	0.038557973	0.029423036	0.03313525	14.62%	12.65%	14.08%
[27]	sigmoid	Adam	0.033179466	0.031091891	0.03281546	13.00%	12.92%	14.14%
[30]	sigmoid	Adam	0.033138745	0.035013244	0.026377762	13.41%	13.49%	12.46%
[36]	sigmoid	Adam	0.04251772	0.028012762	0.03679765	13.74%	12.54%	14.24%
[42]	sigmoid	Adam	0.03369964	0.025774255	0.032503452	13.94%	11.86%	13.77%
[54]	sigmoid	Adam	0.04255472	0.027077718	0.024237834	14.62%	12.32%	11.55%
[27] (2)	relu6	Adam	0.010862497	0.007812445	0.010991171	7.45%	6.35%	8.08%
[30] (2)	relu6	Adam	0.006127406	0.005855972	0.006276136	5.83%	5.82%	6.10%
[36] (2)	relu6	Adam	0.008357461	0.009675507	0.007625154	7.04%	6.31%	6.30%
[42] (2)	relu6	Adam	0.005568689	0.010419212	0.013950825	5.49%	7.87%	9.23%
[54] (2)	relu6	Adam	0.00914119	0.008788209	0.004992649	7.09%	6.96%	5.17%
[27] (2)	sigmoid	Adam	0.036269184	0.030899493	0.03028951	14.28%	13.19%	13.91%
[30] (2)	sigmoid	Adam	0.035432972	0.027578013	0.03415983	14.17%	11.80%	14.64%
[36] (2)	sigmoid	Adam	0.03532977	0.031430744	0.034954194	13.57%	13.21%	14.24%
[42] (2)	sigmoid	Adam	0.033667173	0.02874634	0.02504628	13.03%	12.85%	12.41%
[54] (2)	sigmoid	Adam	0.026780693	0.028417163	0.02667259	12.23%	13.18%	13.02%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
1.308811168	1.219991636	1.185280042	
1.163084837	1.311658328	1.751284073	
2.21593825	1.62839804	1.129542658	
0.914968727	2.342642751	1.228963766	
1.879294361	1.48121237	2.156834855	
2.119936146	1.836892398	4.117639468	
1.420514326	2.075017373	2.62693875	
2.778593599	1.409404346	2.633729017	
2.952867534	3.53300572	1.738300563	
2.13752937	1.952408896	1.459165415	
1.346415134	1.022763377	0.973026012	
1.025199529	0.907256177	0.952435262	
1.182092637	1.038357646	0.936548046	
1.40871208	1.271034855	0.826412349	
1.219984257	1.160496165	1.004011904	
1.030786524	0.831054033	0.964292396	
0.948278135	0.892413819	0.776815086	
0.816232423	0.985553876	0.748112147	
2.040465275	1.634909377	2.201470217	
2.379084994	1.983080164	2.202808355	
2.170881934	1.879355391	2.091513528	
1.930530757	1.918688794	2.100108678	
1.99205734	2.00368664	1.851361164	
2.041368835	1.86235304	2.115194299	
2.071045159	1.761933078	2.044568441	
2.171432129	1.829266814	1.715329167	
1.106213033	0.943062299	1.199727122	
0.86519272	0.864957815	0.906145492	
1.045246157	0.937240212	0.935796029	
0.815234466	1.168654014	1.371064854	
1.052856577	1.034375648	0.768378766	
2.12134325	1.958589437	2.065673857	
2.10460306	1.752252831	2.175096145	
2.014764864	1.96274066	2.115396338	
1.935075504	1.908091374	1.842500214	
1.81684883	1.957980917	1.933621904	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.015944581	0.010358041	0.010131966	9.89%	8.02%	7.77%
[9, 9]	relu6	Adam	0.008582495	0.008213998	0.01692764	6.68%	6.91%	9.69%
[9, 9, 9]	relu6	Adam	0.05281085	0.07139397	0.019192908	18.46%	23.71%	10.49%
[9, 18, 9]	relu6	Adam	0.026847646	0.12408866	0.014416736	11.04%	31.22%	8.61%
[9, 18, 36, 18, 9]	relu6	Adam	0.048169255	0.03196456	0.039724175	15.84%	13.45%	15.29%
[9,18,36,36,18,9]	relu6	Adam	0.064936824	0.059850555	0.06873007	19.35%	17.69%	18.32%
[9,18,18,9]	relu6	Adam	0.039645996	0.008978093	0.03304893	13.60%	6.97%	14.40%
[9,27,27,9]	relu6	Adam	0.027699426	0.11029243	0.051843796	9.03%	28.72%	14.78%
[9,27,54,27,9]	relu6	Adam	0.11306842	0.025183091	0.026520815	23.01%	10.22%	8.75%
[9,27,81,27,9]	relu6	Adam	0.039386574	0.032986283	0.03604918	11.13%	13.04%	11.35%
[18]	relu6	Adam	0.014174965	0.0116067	0.006508474	8.80%	7.76%	5.88%
[21]	relu6	Adam	0.00977048	0.011556103	0.006871606	7.51%	7.92%	5.96%
[24]	relu6	Adam	0.008827673	0.00884013	0.00606664	6.93%	6.47%	6.13%
[27]	relu6	Adam	0.011944355	0.01321855	0.006016914	8.20%	8.72%	6.07%
[30]	relu6	Adam	0.008998017	0.008016883	0.006653207	6.79%	6.01%	6.79%
[36]	relu6	Adam	0.007385077	0.008494477	0.00591752	6.60%	6.39%	5.63%
[42]	relu6	Adam	0.009596087	0.006947021	0.005867314	7.79%	6.24%	6.06%
[54]	relu6	Adam	0.007470455	0.006371819	0.003819146	6.36%	5.41%	4.81%
[18]	sigmoid	Adam	0.04019006	0.02509894	0.03180536	14.67%	11.28%	13.70%
[21]	sigmoid	Adam	0.039138265	0.03081626	0.02953566	14.73%	12.72%	13.62%
[24]	sigmoid	Adam	0.038405016	0.029548535	0.030123804	16.35%	12.52%	13.38%
[27]	sigmoid	Adam	0.0423207	0.029436938	0.033835288	14.39%	13.10%	14.73%
[30]	sigmoid	Adam	0.03935102	0.022551222	0.032775737	14.35%	11.40%	13.96%
[36]	sigmoid	Adam	0.035582826	0.024415974	0.031128975	14.15%	11.54%	13.16%
[42]	sigmoid	Adam	0.030383194	0.030445186	0.028786963	12.86%	12.30%	13.51%
[54]	sigmoid	Adam	0.030943306	0.022377197	0.025326967	13.04%	11.50%	12.35%
[27] (2)	relu6	Adam	0.012160177	0.008937561	0.006291636	7.89%	6.72%	5.84%
[30] (2)	relu6	Adam	0.009038261	0.009664862	0.005990643	6.78%	6.23%	6.04%
[36] (2)	relu6	Adam	0.010531046	0.007131231	0.005343126	8.07%	6.14%	5.38%
[42] (2)	relu6	Adam	0.00654811	0.006510612	0.004447389	5.84%	6.03%	5.07%
[54] (2)	relu6	Adam	0.007938357	0.006702414	0.007627961	6.75%	5.90%	7.18%
[27] (2)	sigmoid	Adam	0.039453533	0.026338307	0.027935205	14.67%	12.33%	13.20%
[30] (2)	sigmoid	Adam	0.03247178	0.031134922	0.03474842	13.25%	13.93%	14.20%
[36] (2)	sigmoid	Adam	0.037703462	0.030496698	0.023885507	14.95%	13.12%	11.61%
[42] (2)	sigmoid	Adam	0.031073207	0.027670117	0.023759903	13.33%	12.08%	12.21%
[54] (2)	sigmoid	Adam	0.021963555	0.016686276	0.015088068	10.51%	9.14%	9.36%

Avg Error [±mPas] 0.5[MHz]	Avg Error [±mPas] 1.0[MHz]	Avg Error [±mPas] 2.25[MHz]	Notes
3.719545997	3.016900149	2.922576964	
2.513354405	2.597249212	3.646348939	
6.944139308	8.917202008	3.946813678	
4.152621309	11.74183551	3.237441476	
5.957495837	5.057939545	5.751381935	
7.27948405	6.651605261	6.891935229	
5.116303071	2.623337799	5.414980148	
3.394533923	10.80079305	5.560111178	
8.654678411	3.844804272	3.28913207	
4.186908118	4.903575721	4.268445979	
3.308277532	2.91852261	2.210701613	
2.823488698	2.978490761	2.241559414	
2.607909345	2.432201106	2.30677024	
3.08440154	3.280986224	2.281989953	
2.555201918	2.262136449	2.55335539	
2.484051304	2.404063259	2.117895813	
2.931244378	2.347348294	2.278251706	
2.391586163	2.03592695	1.810662655	
5.51587866	4.241740609	5.151299314	
5.538396997	4.784453253	5.121661408	
6.149780667	4.710171517	5.03337151	
5.410838193	4.928700949	5.539208843	
5.398407175	4.288571582	5.249720963	
5.321489735	4.340160735	4.949635618	
4.836446269	4.626046015	5.07979649	
4.905750262	4.326930756	4.646175139	
2.966572216	2.527629947	2.196554635	
2.551320709	2.341773805	2.272018109	
3.034882371	2.308214449	2.024495447	
2.196524786	2.26634818	1.908659048	
2.537907757	2.220886809	2.699666015	
5.517348203	4.638157289	4.962956894	
4.983687639	5.24063188	5.341259732	
5.621750545	4.936245456	4.365737943	
5.014436367	4.543680007	4.593495709	
3.952323306	3.437979153	3.520596785	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 9, 9] (2)	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 9] (2)	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.011995876	0.01187041	0.004830459	8.15%	7.71%	4.61%
[21]	relu6	Adam	0.010124944	0.008743369	0.006821472	7.37%	6.81%	6.50%
[24]	relu6	Adam	0.010663608	0.0076252	0.004943445	7.32%	6.32%	5.48%
[27]	relu6	Adam	0.00997893	0.009495391	0.003576774	7.41%	6.51%	4.15%
[30]	relu6	Adam	0.014218144	0.0053545	0.002172	8.85%	5.27%	3.40%
[36]	relu6	Adam	0.007155056	0.008601218	0.005195808	5.99%	5.58%	4.86%
[42]	relu6	Adam	0.004980789	0.003958779	0.002682147	4.92%	4.28%	3.59%
[54]	relu6	Adam	0.006426992	0.00381788	0.003026014	6.10%	3.79%	3.97%
[18]	sigmoid	Adam	0.006053391	0.002307258	0.001984508	5.39%	3.40%	2.95%
[21]	sigmoid	Adam	0.007485729	0.003042942	0.001729879	6.03%	3.39%	2.82%
[24]	sigmoid	Adam	0.006811172	0.002388371	0.00215713	5.75%	3.37%	3.20%
[27]	sigmoid	Adam	0.006879099	0.002110616	0.001008671	5.23%	3.18%	2.24%
[30]	sigmoid	Adam	0.006742307	0.001574755	0.001125401	5.16%	2.94%	2.52%
[36]	sigmoid	Adam	0.003628111	0.002722187	0.001403163	4.43%	3.51%	2.72%
[42]	sigmoid	Adam	0.007524079	0.002878669	0.001059516	5.23%	3.72%	2.48%
[54]	sigmoid	Adam	0.003358326	0.001591032	0.001479415	4.16%	2.85%	2.72%

Avg Error [±g/cm^3] 0.5[MHz]	Avg Error [±g/cm^3] 1.0[MHz]	Avg Error [±g/cm^3] 2.25[MHz]	Notes
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0.05286212	0.050038909	0.029903975	
0.047833503	0.044194141	0.042185237	
0.047513299	0.041003564	0.035560665	
0.048067816	0.042268264	0.026907826	
0.057457543	0.034230902	0.022049675	
0.038857695	0.036209031	0.031547415	
0.031924122	0.027763092	0.023288903	
0.039580917	0.024571679	0.02574361	
0.034979084	0.022046801	0.019123939	
0.039103216	0.021978481	0.018281585	
0.037302604	0.021884465	0.02078108	
0.033920708	0.020626732	0.014533409	
0.033460409	0.019106576	0.016380092	
0.028756772	0.022798266	0.01764635	
0.033924197	0.024125996	0.016091624	
0.026998877	0.018497663	0.017662054	
0	0	0	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9] (2)	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	sigmoid	Adam	0.007204677	0.009765203	0.002533548	6.43%	5.38%	3.69%
[21]	sigmoid	Adam	0.005710784	0.006147192	0.00193408	5.67%	4.82%	3.00%
[24]	sigmoid	Adam	0.00670399	0.008245288	0.0021688	5.91%	4.89%	3.15%
[27]	sigmoid	Adam	0.005681251	0.004389447	0.00351687	5.61%	4.45%	3.76%
[30]	sigmoid	Adam	0.004821013	0.003325789	0.00293439	5.09%	3.90%	3.67%
[36]	sigmoid	Adam	0.005801119	0.011366962	0.002228644	5.68%	5.45%	3.20%
[42]	sigmoid	Adam	0.004684932	0.006072713	0.001718118	5.06%	4.62%	2.96%
[54]	sigmoid	Adam	0.00655451	0.004695157	0.00225885	5.34%	4.18%	3.34%
[18]	relu6	Adam	0.006462571	0.007720476	0.003393576	6.20%	5.64%	4.34%
[21]	relu6	Adam	0.005501004	0.006001885	0.003387119	6.06%	5.89%	4.17%
[24]	relu6	Adam	0.004893359	0.007031495	0.00228143	5.26%	5.61%	3.35%
[27]	relu6	Adam	0.005901379	0.004738937	0.002993516	5.85%	4.56%	3.65%
[30]	relu6	Adam	0.006558238	0.007773907	0.002816503	5.66%	5.53%	3.67%
[36]	relu6	Adam	0.005213699	0.00656205	0.002105172	5.44%	4.99%	3.58%
[42]	relu6	Adam	0.004751802	0.002995782	0.002950283	5.18%	3.90%	3.70%
[54]	relu6	Adam	0.005039747	0.004830086	0.001571454	5.55%	4.15%	2.69%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
1.070676775	0.895946688	0.613891356	
0.944231023	0.802714764	0.499833059	
0.985251132	0.814603819	0.524797401	
0.934786462	0.7409568	0.626791616	
0.847716388	0.649497562	0.611133081	
0.945345934	0.907491608	0.533321295	
0.842659733	0.769661274	0.493218075	
0.889966959	0.695779968	0.555931122	
1.032485355	0.939912555	0.723601759	
1.0102626	0.980955305	0.69502774	
0.876347256	0.933870145	0.557387513	
0.974683848	0.760065109	0.607708628	
0.942728177	0.921789176	0.610862068	
0.906257981	0.830407834	0.595903468	
0.863169434	0.64937577	0.616864179	
0.923703005	0.690606579	0.447508352	
0	0	0	
0	0	0	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.006865146	0.006584405	0.003955126	5.87%	5.90%	4.74%
[21]	relu6	Adam	0.004902955	0.010106519	0.004758443	5.32%	6.86%	5.17%
[24]	relu6	Adam	0.005109617	0.005983723	0.002942148	4.87%	5.38%	3.85%
[27]	relu6	Adam	0.005695549	0.009722941	0.003110075	5.62%	6.59%	3.93%
[30]	relu6	Adam	0.005412271	0.004624337	0.003035	5.29%	4.61%	4.03%
[36]	relu6	Adam	0.003634356	0.003377139	0.002474892	4.40%	3.40%	3.56%
[42]	relu6	Adam	0.005226153	0.004765245	0.001618351	4.94%	5.29%	2.92%
[54]	relu6	Adam	0.004043525	0.00648148	0.00239597	4.93%	5.37%	3.49%
[18]	sigmoid	Adam	0.007806221	0.005682756	0.00294489	5.76%	5.43%	3.73%
[21]	sigmoid	Adam	0.006913779	0.006241072	0.002704586	5.80%	5.31%	3.90%
[24]	sigmoid	Adam	0.005950948	0.00692023	0.002576329	5.67%	5.39%	3.91%
[27]	sigmoid	Adam	0.005507559	0.006473733	0.002417011	5.86%	4.89%	3.94%
[30]	sigmoid	Adam	0.004835778	0.010428293	0.003164985	5.10%	5.91%	3.93%
[36]	sigmoid	Adam	0.006099352	0.009089631	0.002925065	5.91%	5.19%	3.70%
[42]	sigmoid	Adam	0.006892297	0.006223537	0.002485124	5.77%	4.74%	3.56%
[54]	sigmoid	Adam	0.004764945	0.012332401	0.001995697	5.19%	4.94%	3.29%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
0	0	0	
0	0	0	
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0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0.871292549	0.876678046	0.704336424	
0.790675515	1.018234048	0.768583438	
0.724023771	0.799496425	0.572247919	
0.835423835	0.978336238	0.583082101	
0.785133472	0.685375938	0.598727135	
0.652924278	0.505230882	0.528323161	
0.734092436	0.785530692	0.433546033	
0.732605652	0.797358474	0.517783788	
0.854888086	0.806468148	0.553677598	
0.861990787	0.788760136	0.579848744	
0.842337342	0.800928684	0.580367958	
0.870986561	0.726230737	0.585066844	
0.757623761	0.877569492	0.584031074	
0.877072724	0.770422326	0.548870171	
0.856790463	0.704472933	0.529189417	
0.770141966	0.733779863	0.48932506	
0	0	0	
0	0	0	
0	0	0	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam						
[9, 9]	relu6	Adam						
[9, 9, 9]	relu6	Adam						
[9, 18, 9]	relu6	Adam						
[9, 18, 36, 18, 9]	relu6	Adam						
[9,18,36,36,18,9]	relu6	Adam						
[9,18,18,9]	relu6	Adam						
[9,27,27,9]	relu6	Adam						
[9,27,54,27,9]	relu6	Adam						
[9,27,81,27,9]	relu6	Adam						
[18]	relu6	Adam	0.009098019	0.006864401	0.003121211	7.31%	6.02%	4.20%
[21]	relu6	Adam	0.005905136	0.005157935	0.003074659	5.98%	5.51%	4.33%
[24]	relu6	Adam	0.007018508	0.004321085	0.002336597	6.47%	5.22%	3.95%
[27]	relu6	Adam	0.007711574	0.007706065	0.002204385	6.37%	5.22%	3.30%
[30]	relu6	Adam	0.006929013	0.004118762	0.002441186	6.12%	4.79%	3.63%
[36]	relu6	Adam	0.004057472	0.005487602	0.003132895	4.83%	5.14%	4.07%
[42]	relu6	Adam	0.007405894	0.004816539	0.001938146	6.07%	3.89%	3.22%
[54]	relu6	Adam	0.004281083	0.001926562	0.001344223	4.52%	3.41%	2.72%
[18]	sigmoid	Adam	0.00510995	0.003081777	0.002169596	5.33%	4.02%	3.02%
[21]	sigmoid	Adam	0.007659693	0.004882079	0.001530705	5.77%	5.03%	2.91%
[24]	sigmoid	Adam	0.006286257	0.003386824	0.001864702	5.74%	4.34%	3.09%
[27]	sigmoid	Adam	0.005817876	0.003936702	0.00192438	5.08%	4.35%	3.79%
[30]	sigmoid	Adam	0.005824345	0.003149157	0.002159408	4.99%	3.88%	3.66%
[36]	sigmoid	Adam	0.007050392	0.004746832	0.002203357	5.82%	4.40%	3.36%
[42]	sigmoid	Adam	0.00658366	0.008342198	0.002383634	5.36%	4.57%	3.43%
[54]	sigmoid	Adam	0.006475722	0.005412156	0.002435717	5.23%	4.82%	3.24%

Avg Error [±mPas] 0.5[MHz]	Avg Error [±mPas] 1.0[MHz]	Avg Error [±mPas] 2.25[MHz]	Notes
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
2.75089694	2.263217222	1.581289121	
2.249525381	2.070916639	1.629302062	
2.435051565	1.964444186	1.486468438	
2.396894816	1.964296833	1.24070952	
2.303477363	1.800964426	1.367018735	
1.817194339	1.933096268	1.530286661	
2.281640072	1.462702542	1.212571475	
1.699238367	1.282213366	1.024722535	
2.006415756	1.512147243	1.137043798	
2.170242052	1.890885588	1.093893282	
2.159819744	1.633962844	1.162815999	
1.909385239	1.636184988	1.423955272	
1.875281936	1.458345905	1.375355487	
2.190204383	1.656436383	1.265398947	
2.016940373	1.717939658	1.289146089	
1.96739915	1.81438407	1.219503189	
0	0	0	
0	0	0	
0	0	0	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.006714582	0.008156584	0.013446786			
[9, 9]	relu6	Adam	0.004086285	0.003399482	0.006124512			
[9, 9, 9]	relu6	Adam	0.002075631	0.056329403	0.044581123			
[9, 9, 9] (2)	relu6	Adam	0.010632455	0.041803766	0.003964974			
[9, 18, 9]	relu6	Adam	0.007781419	0.005504964	0.001876052			
[9, 18, 36, 18, 9]	relu6	Adam	0.005211434	0.01670787	0.009046343			
[9,18,36,36,18,9]	relu6	Adam	0.028038358	0.007911437	0.006774447			
[9,18,18,9]	relu6	Adam	0.027550992	0.050922908	0.003360206			
[9,27,27,9]	relu6	Adam	0.006935122	0.007837392	0.002786276			
[9,27,54,27,9]	relu6	Adam	0.005102002	0.006244084	0.015882306			
[9,27,81,27,9]	relu6	Adam	0.005574097	0.006785712	0.004314918			
[18]	relu6	Adam	0.002370355	0.003130498	0.013886284			
[21]	relu6	Adam	0.007061187	0.004851334	0.008591874			
[24]	relu6	Adam	0.006465501	0.00197009	0.008440908			
[27]	relu6	Adam	0.00310361	0.002092948	0.006749385			
[30]	relu6	Adam	0.002429027	0.004866557	0.008874466			
[36]	relu6	Adam	0.006171362	0.001565452	0.007180569			
[42]	relu6	Adam	0.002414156	0.004638228	0.008462717			
[54]	relu6	Adam	0.002323144	0.001429127	0.008920387			
[18]	sigmoid	Adam	0.001335932	0.00207198	0.002541488			
[21]	sigmoid	Adam	0.001148467	0.003099221	0.002440773			
[24]	sigmoid	Adam	0.001155199	0.000915988	0.001753213			
[27]	sigmoid	Adam	0.0012905	0.00275645	0.003088674			
[30]	sigmoid	Adam	0.001453418	0.001537838	0.001623791			
[36]	sigmoid	Adam	0.000985204	0.001015463	0.002736028			
[42]	sigmoid	Adam	0.001031012	0.001153957	0.001899155			
[54]	sigmoid	Adam	0.001023979	0.000815697	0.00240501			
[30] (2)	sigmoid	Adam	0.00119767	0.001335137	0.001790875			
[36] (2)	sigmoid	Adam	0.001310654	0.001452133	0.001806033			
[54] (2)	sigmoid	Adam	0.001347841	0.000866056	0.002099968			
[27] (3)	sigmoid	Adam	0.001391637	0.001025286	0.001022008	2.76%	2.45%	2.57%
[30] (3)	sigmoid	Adam	0.001297742	0.001134228	0.000870439	2.62%	2.66%	2.13%
[36] (3)	sigmoid	Adam	0.000887216	0.000962414	0.000888075	2.20%	2.33%	2.20%
[42] (3)	sigmoid	Adam	0.00126471	0.000860591	0.001006746	2.72%	2.33%	2.35%
[54] (3)	sigmoid	Adam	0.001422634	0.001221643	0.001265958	2.88%	2.84%	2.45%
[27] (2)	relu6	Adam	0.005954615	0.004449713	0.003766302	5.22%	5.19%	4.25%
[30] (2)	relu6	Adam	0.006419361	0.002314618	0.004930233	5.79%	3.84%	5.36%
[36] (2)	relu6	Adam	0.001595625	0.003982184	0.005041483	2.85%	4.28%	4.66%
[42] (2)	relu6	Adam	0.001823968	0.003890243	0.001773717	3.18%	4.55%	3.05%
[54] (2)	relu6	Adam	0.002534127	0.001489009	0.00116703	3.71%	3.24%	2.48%
[27] (4)	sigmoid	Adam	0.000975243	0.001329792	0.00211058	2.54%	2.52%	2.80%
[30] (4)	sigmoid	Adam	0.000914152	0.001338144	0.001153563	2.44%	2.67%	2.69%
[36] (4)	sigmoid	Adam	0.0010545	0.00110257	0.001063738	2.41%	2.57%	2.35%
[42] (4)	sigmoid	Adam	0.001248706	0.00122901	0.000735877	2.54%	2.75%	2.08%
[54] (4)	sigmoid	Adam	0.001016024	0.000804014	0.000898526	2.38%	2.29%	2.05%

Avg Error [±g/cm^3] 0.5[MHz]	Avg Error [±g/cm^3] 1.0[MHz]	Avg Error [±g/cm^3] 2.25[MHz]	Notes
0	0	0	
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0	0	0	
0	0	0	
0	0	0	
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0	0	0	
0.017931305	0.015877641	0.016692675	
0.017005783	0.017282047	0.013853471	
0.014289132	0.015104822	0.014303051	
0.017635974	0.015093549	0.01524151	
0.018692835	0.018437481	0.015876899	
0.033859	0.033691306	0.027612206	
0.037578564	0.024893951	0.034759044	
0.018500368	0.027749159	0.030252805	
0.020645491	0.029514319	0.019780752	
0.024061154	0.021047568	0.016126647	
0.016459898	0.01636637	0.018203337	
0.01586457	0.017323931	0.017478794	
0.015637731	0.016703698	0.015276066	
0.016516904	0.017870352	0.013503185	
0.015446966	0.014864333	0.0133129	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.008649653	0.006590255	0.023215575			
[9, 9]	relu6	Adam	0.009244266	0.00559462	0.004672634			
[9, 9, 9]	relu6	Adam	0.03796834	0.042960934	0.003942723			
[9, 18, 9]	relu6	Adam	0.0048062	0.008481124	0.003706365			
[9, 18, 36, 18, 9]	relu6	Adam	0.028072111	0.022962304	0.012305371			
[9,18,36,36,18,9]	relu6	Adam	0.027419847	0.05140992	0.007808351			
[9,18,18,9]	relu6	Adam	0.009550396	0.033092078	0.004577978			
[9,27,27,9]	relu6	Adam	0.009289838	0.011921438	0.008016008			
[9,27,54,27,9]	relu6	Adam	0.015390951	0.037516408	0.009803924			
[9,27,81,27,9]	relu6	Adam	0.054416873	0.01450152	0.016104065			
[18]	relu6	Adam	0.002888981	0.003412754	0.011118216			
[21]	relu6	Adam	0.002179948	0.002661628	0.01052593			
[24]	relu6	Adam	0.002338926	0.003320161	0.008336065			
[27]	relu6	Adam	0.002856664	0.002170102	0.010367029			
[30]	relu6	Adam	0.002479045	0.0019694	0.008230265			
[36]	relu6	Adam	0.001016382	0.001626646	0.009137645			
[42]	relu6	Adam	0.001499468	0.001648044	0.006997007			
[54]	relu6	Adam	0.001071742	0.002410296	0.003327578			
[18]	sigmoid	Adam	0.002831737	0.002093886	0.00309149			
[21]	sigmoid	Adam	0.001694795	0.001890407	0.002396604			
[24]	sigmoid	Adam	0.002161269	0.001275782	0.002420179			
[27]	sigmoid	Adam	0.001219881	0.001586587	0.001932786			
[30]	sigmoid	Adam	0.00214473	0.001610675	0.002126342			
[36]	sigmoid	Adam	0.001372432	0.001415124	0.002300479			
[42]	sigmoid	Adam	0.001349707	0.001233581	0.002041831			
[54]	sigmoid	Adam	0.001430673	0.001438627	0.002598189			
[21] (2)	sigmoid	Adam	0.001030406	0.002272292	0.000965025	2.54%	3.27%	2.12%
[24] (2)	sigmoid	Adam	0.000844787	0.002133064	0.000949465	2.09%	3.50%	1.95%
[27] (2)	sigmoid	Adam	0.001071993	0.001864703	0.001034169	2.35%	3.51%	2.14%
[30] (2)	sigmoid	Adam	0.001274126	0.00176345	0.001015741	2.25%	3.15%	2.20%
[36] (2)	sigmoid	Adam	0.001764372	0.001699866	0.001429959	2.69%	3.06%	2.53%
[42] (2)	sigmoid	Adam	0.001583319	0.001654743	0.001303442	2.52%	3.03%	2.25%
[54] (2)	sigmoid	Adam	0.001974077	0.001694542	0.000833469	2.47%	3.05%	2.00%
[27] (2)	relu6	Adam	0.001730735	0.003736095	0.001871725	3.08%	4.17%	3.27%
[30] (2)	relu6	Adam	0.002086606	0.001921024	0.001473771	3.19%	3.53%	2.85%
[36] (2)	relu6	Adam	0.002290278	0.001384204	0.00076509	2.99%	3.09%	2.06%
[42] (2)	relu6	Adam	0.001400235	0.002319058	0.00063193	2.55%	3.65%	1.93%
[54] (2)	relu6	Adam	0.001617455	0.001230579	0.00046543	2.78%	2.70%	1.62%
[21] (3)	sigmoid	Adam	0.001621709	0.001647252	0.001178873	2.59%	3.29%	2.34%
[24] (3)	sigmoid	Adam	0.001414785	0.001845599	0.001170265	2.46%	3.10%	2.23%
[27] (3)	sigmoid	Adam	0.001940677	0.002011183	0.001264542	3.00%	3.33%	2.36%
[30] (3)	sigmoid	Adam	0.002207446	0.001261012	0.001462208	2.65%	2.73%	2.67%
[36] (3)	sigmoid	Adam	0.0013096	0.001546327	0.001300558	2.35%	2.90%	2.36%
[42] (3)	sigmoid	Adam	0.001600644	0.001561295	0.001070297	2.39%	3.01%	2.03%
[54] (3)	sigmoid	Adam	0.001432129	0.001261906	0.000696758	2.28%	2.73%	1.87%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
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0.42373225	0.544357723	0.352382159	
0.348261876	0.58278444	0.325052885	
0.390689097	0.584490254	0.356027646	
0.374977571	0.524080687	0.365815607	
0.448475554	0.509834005	0.420963367	
0.420502958	0.504231608	0.374814606	
0.410964664	0.50854427	0.332353435	
0.512536198	0.694689407	0.543974462	
0.531820311	0.587626795	0.474938295	
0.497844598	0.513953207	0.343813294	
0.424987081	0.607612907	0.321961193	
0.463901294	0.449260873	0.27023458	
0.432152146	0.548194268	0.390422881	
0.41032024	0.51558486	0.370999262	
0.499064055	0.554385099	0.393647922	
0.441782263	0.454355663	0.445158152	
0.391606528	0.482595753	0.393622625	
0.398272492	0.50199966	0.338817039	
0.380261673	0.454847239	0.31080699	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.003329545	0.006001551	0.04270118			
[9, 9]	relu6	Adam	0.004887927	0.009839872	0.003345905			
[9, 9, 9]	relu6	Adam	0.016072435	0.058795124	0.009468364			
[9, 18, 9]	relu6	Adam	0.01048812	0.019448526	0.011022661			
[9, 18, 36, 18, 9]	relu6	Adam	0.018570345	0.054575216	0.006861177			
[9,18,36,36,18,9]	relu6	Adam	0.07972843	0.06718816	0.026012003			
[9,18,18,9]	relu6	Adam	0.004365229	0.050060265	0.009718028			
[9,27,27,9]	relu6	Adam	0.02400139	0.009261339	0.008643373			
[9,27,54,27,9]	relu6	Adam	0.010309349	0.018389625	0.019041685			
[9,27,54,27,9] (2)	relu6	Adam	0.027928019	0.0230867	0.017526463			
[18]	relu6	Adam	0.002505807	0.002243585	0.017587474			
[21]	relu6	Adam	0.002626295	0.00292797	0.013964847			
[24]	relu6	Adam	0.002292778	0.00313197	0.01618499			
[27]	relu6	Adam	0.002967131	0.003810408	0.018074706			
[30]	relu6	Adam	0.003131372	0.002584005	0.009341817			
[36]	relu6	Adam	0.00133215	0.003014731	0.010855297			
[42]	relu6	Adam	0.001853785	0.002958491	0.013034897			
[54]	relu6	Adam	0.001708969	0.002033573	0.000282387	2.71%	2.96%	1.33%
[18]	sigmoid	Adam	0.002629567	0.00369218	0.003976392			
[21]	sigmoid	Adam	0.001897673	0.002688712	0.002643612			
[24]	sigmoid	Adam	0.002978912	0.002640452	0.002935859			
[27]	sigmoid	Adam	0.002641219	0.003178584	0.003080349			
[30]	sigmoid	Adam	0.001248239	0.003756113	0.003417969	2.75%	3.65%	4.40%
[36]	sigmoid	Adam	0.001960628	0.001731801	0.002225071	2.82%	2.79%	3.85%
[42]	sigmoid	Adam	0.001255212	0.002176079	0.003143329	2.18%	3.22%	3.73%
[54]	sigmoid	Adam	0.001376891	0.002886271	0.002741195	2.72%	3.06%	4.07%
[30] (2)	relu6	Adam	0.002981972	0.001820995	0.002096738	3.81%	2.98%	3.75%
[36] (2)	relu6	Adam	0.001627769	0.003040611	0.00063336	2.90%	3.64%	1.94%
[42] (2)	relu6	Adam	0.001859447	0.002367497	0.000410982	2.74%	3.25%	1.48%
[54] (2)	relu6	Adam	0.002215362	0.001844234	0.000642104	3.37%	2.67%	1.89%
[54] (3)	relu6	Adam	0.001718956	0.002276567	0.000489711	2.92%	3.29%	1.49%
[54] (4)	relu6	Adam	0.001681721	0.001826259	0.000327557	2.74%	3.09%	1.45%
[42] (3)	relu6	Adam	0.002729876	0.001981005	0.000350266	3.78%	3.03%	1.50%
[42] (4)	relu6	Adam	0.0018593	0.002450293	0.000680448	3.09%	3.56%	1.87%
[36] (3)	sigmoid	Adam	0.002043722	0.002328405	0.000825882	3.09%	3.21%	2.24%
[42] (3)	sigmoid	Adam	0.001892112	0.002323765	0.00071137	2.89%	3.12%	1.89%
[54] (3)	sigmoid	Adam	0.001147849	0.002195893	0.000509704	2.41%	3.43%	1.85%
[54] (5)	relu6	Adam	0.001243168	0.002498343	0.001201771	2.53%	3.24%	2.76%

Avg Error [±Pa] 0.5[MHz]	Avg Error [±Pa] 1.0[MHz]	Avg Error [±Pa] 2.25[MHz]	Notes
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0	0	0	
0	0	0	
0	0	0	
0.402150478	0.4400555	0.196946534	
0	0	0	
0	0	0	
0	0	0	
0	0	0	
0.408218257	0.541409082	0.653668119	Marked as (2)
0.418685781	0.414973277	0.571343409	Marked as (2)
0.324312809	0.478817982	0.553830215	Marked as (2)
0.403614591	0.454976628	0.605017688	Marked as (2)
0.565702999	0.442251494	0.557386296	
0.430636911	0.539979083	0.287711033	
0.406884929	0.483158159	0.219743153	
0.499976305	0.396918692	0.281234384	
0.434075394	0.488425123	0.221467275	
0.407456414	0.458649333	0.215795386	
0.561711543	0.450369945	0.222362111	
0.459116218	0.52936345	0.277861041	
0.458301345	0.477044799	0.332367189	
0.429073997	0.46336167	0.281300853	
0.357830959	0.509260495	0.274425174	
0.375808882	0.481808577	0.40941847	

Layer configuartion	Activation Function	Optimiser	Avg Loss 0.5[MHz]	Avg Loss 1.0[MHz]	Avg Loss 2.25[MHz]	Avg Error 0.5[MHz]	Avg Error 1.0[MHz]	Avg Error 2.25[MHz]
[9]	relu6	Adam	0.010552003	0.00567511	0.026995098			
[9, 9]	relu6	Adam	0.015101804	0.006091688	0.003234588			
[9, 9, 9]	relu6	Adam	0.002551112	0.03434454	0.003542288			
[9, 18, 9]	relu6	Adam	0.004059771	0.029371079	0.009540827			
[9, 18, 36, 18, 9]	relu6	Adam	0.015521893	0.014213005	0.012243754			
[9,18,36,36,18,9]	relu6	Adam	0.01250735	0.027827585	0.009991441			
[9,18,18,9]	relu6	Adam	0.034431066	0.032975823	0.004377556			
[9,27,27,9]	relu6	Adam	0.017096175	0.019212326	0.017524032			
[9,27,54,27,9]	relu6	Adam	0.00990828	0.039535876	0.025181383			
[9,27,81,27,9]	relu6	Adam						
[9, 18, 36, 18, 9] (2)	relu6	Adam						
[18]	relu6	Adam	0.002879402	0.003048956	0.011070389			
[27]	relu6	Adam	0.001433953	0.003021647	0.008228898			
[21]	relu6	Adam	0.002535414	0.001456667	0.01233054	3.87%	2.98%	9.26%
[24]	relu6	Adam	0.001495015	0.001628396	0.008007853	2.88%	3.27%	7.36%
[30]	relu6	Adam	0.001171561	0.001293381	0.015176802	2.53%	2.96%	10.45%
[36]	relu6	Adam	0.002185088	0.000994347	0.006527664	3.74%	2.51%	6.86%
[42]	relu6	Adam	0.002152434	0.000875988	0.005714219	3.41%	2.36%	6.10%
[54]	relu6	Adam	0.000957832	0.001416346	0.007013231	2.31%	3.11%	6.82%
[18]	sigmoid	Adam	0.00254332	0.0018492	0.001794653	3.44%	3.39%	3.13%
[21]	sigmoid	Adam	0.002274261	0.001602852	0.002581803	2.97%	3.35%	3.99%
[24]	sigmoid	Adam	0.001384347	0.00157598	0.001876981	2.49%	3.13%	3.42%
[27]	sigmoid	Adam	0.00137692	0.00133782	0.002793031	2.40%	2.91%	4.38%
[30]	sigmoid	Adam	0.001356642	0.001773787	0.002240075	2.20%	3.10%	3.75%
[36]	sigmoid	Adam	0.001210973	0.001449022	0.002065048	2.46%	3.29%	3.56%
[42]	sigmoid	Adam	0.001540028	0.001697398	0.002246378	2.37%	2.81%	3.30%
[54]	sigmoid	Adam	0.000967989	0.001599351	0.001626535	1.99%	2.69%	3.11%
[30] (3)	sigmoid	Adam	0.001103899	0.001471274	0.001325826	2.31%	2.85%	2.28%
[36] (3)	sigmoid	Adam	0.001925311	0.001331631	0.000885557	2.72%	2.95%	2.09%
[42] (3)	sigmoid	Adam	0.001107552	0.000963675	0.001086737	2.56%	2.46%	2.29%
[54] (3)	sigmoid	Adam	0.001488536	0.000985656	0.001023282	2.46%	2.31%	2.21%
[30] (3)	relu6	Adam	0.002112411	0.001044833	0.00110673	3.38%	2.70%	2.51%
[36] (3)	relu6	Adam	0.001807059	0.001180763	0.001446995	3.14%	2.87%	2.64%
[42] (3)	relu6	Adam	0.001344211	0.00184297	0.001326381	2.76%	3.36%	2.37%
[54] (3)	relu6	Adam	0.001047086	0.001197905	0.001436929	2.38%	2.69%	2.67%

Avg Error [±mPas] 0.5[MHz]	Avg Error [±mPas] 1.0[MHz]	Avg Error [±mPas] 2.25[MHz]	Notes
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0	0	0	
0	0	0	
1.455905942	1.12098317	3.484561963	Marked as (2)
1.08391067	1.229352435	2.769427931	Marked as (2)
0.951081735	1.114649067	3.929198566	Marked as (2)
1.40735946	0.944772229	2.58158753	Marked as (2)
1.281974535	0.889302285	2.293319182	Marked as (2)
0.869774473	1.168530911	2.563913106	Marked as (2)
1.295096922	1.276229745	1.178732095	Marked as (2)
1.116094868	1.261358312	1.500435285	Marked as (2)
0.935821684	1.1783719	1.285497674	Marked as (2)
0.902975081	1.095167365	1.64553294	Marked as (2)
0.826077979	1.164812043	1.409216813	Marked as (2)
0.924428947	1.239266332	1.339575197	Marked as (2)
0.890170187	1.05559514	1.239821468	Marked as (2)
0.747740034	1.013248208	1.170100152	Marked as (2)
0.869216045	1.070328044	0.859268001	
1.02474135	1.109268587	0.784990423	
0.963616629	0.924348451	0.863037326	
0.925782311	0.869826979	0.831103329	
1.272875691	1.01730573	0.945782607	
1.179471656	1.078528091	0.992295736	
1.036330647	1.26363691	0.891343835	
0.893279314	1.011043008	1.00455297	

Attribute	Density [g/cm³]	Yield Point [Pa]	Gel Strength [Pa]	Plastic Viscosity [mPas]
min	0.698	0.6675	0.2475	2.089
max	1.347	17.325	15.1	39.7
span	0.649	16.6575	14.8525	37.611