CHAPTER 8

CONCLUSION AND FUTURE WORK

In this thesis, a concentrated effort was made to solve the nonlinear index problem. The goal of this problem is to find an indicator that could be used as a guide for linear extrapolation in transducer characterizations. Under ideal linear conditions, the pressure at the focus of a transducer would scale linearly with the voltage applied to the transducer. However, nonlinear effects, namely, asymmetric distortion and nonlinear absorption, alter the focal waveform so that the pressure values are not the same as those predicted by linear extrapolation. The purpose of the indicator would be to quantify these nonlinear effects so that the manufacturer would know over which applied voltages linear extrapolation could be performed, reducing the characterization time of each transducer.

The first step in finding a suitable indicator is to obtain an understanding of the nonlinear effects that corrupt the ideal linear extrapolation. To this end, a detailed theoretical analysis was performed of asymmetric distortion and nonlinear absorption. Unfortunately, currently no theory has been developed that captures both effects.

After discussing the different effects, a series of possible indicators of nonlinearity were introduced. In each case, there was a discussion of the indicators theoretical basis, method of determination, and an evaluation of their respective advantages and disadvantages. The advantages and disadvantages were of course only based on a theoretical evaluation of the indicator.

Once the indicators to be evaluated had been introduced, the next step was to find an appropriate extrapolation factor so that the ability of each of the indicators to govern linear extrapolation could be assessed. After a series of experiments where a hydrophone was placed near a series of transducers, the voltage corresponding to the maximum frequency across the virtual resistor in the RLC circuit model for the transducer was selected. In this thesis, this voltage is denoted as V_{2sn}.

Once the extrapolation factor had been selected, each of the indicators were evaluated in terms of their consistency and overall behavior within each data set. Unfortunately, none of the indicators of nonlinearity evaluated in this thesis proved to be consistent, with the possible exception of the relative focal pressure. However, the relative focal pressure would only work as an indicator for extrapolating p_r values since its overall behavior was not strictly monotonic for the other pressure measures of the waveform. This lack of consistency stemmed from the fact that none of the indicators proposed attempted to include both asymmetric distortion and nonlinear absorption.

Based on our results, there are some definite steps that could be taken in the future. First of all, it would be beneficial to develop approximate analytical expressions that included both nonlinear absorption and asymmetric distortion. If such a theory could be developed, it may be possible to find a consistent indicator to govern linear extrapolation.

Another option that could be pursued is the development of other extrapolation schemes. In this thesis, only linear extrapolation was considered, but other extrapolation schemes could potentially yield better results. However, the development of such schemes might require a more complete theory as well.