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The Microwave Properties of Jovian Clouds: Laboratory Measurement of Aqueous Ammonia (NH4OH) Between 2-8.5GHz

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Abstract

Laboratory measurements of the complex dielectric properties of aqueous ammonia, under conditions characteristic of Jovian clouds, have been made in the 2-8.5GHz range at temperatures ranging from 4-40^{o}C and concentrations of 0-8.5% NH_3 by volume. A model has been developed to characterize the effects of NH_3 on the complex dielectric properties relative to water.

1. Introduction

No previous laboratory measurements have been made to characterize the microwave complex dielectric properties of aqueous ammonia. Previous models of Jovian microwave emission [1,2] have assumed that for low concentrations of ammonia in solution, the dielectric properties of aqueous ammonia are approximately equal to those of water; however, these measurements suggest that even at concentrations as low as 0.5% NH3 by volume, there is a marked difference in the complex dielectric properties of aqueous ammonia. Assuming Raleigh scattering, these measurements are applied to a cloud attenuation model to calculate the opacity of the Jovian aqueous ammonia clouds. These measurements will improve our understanding of the data collected by the Juno microwave radiometer (MWR) by characterizing the absorption properties of the aqueous ammonia present in the Jovian atmosphere.

2. Measurement Systems

Three separate measurement systems were developed to take measurements near 4^{o}C, 24^{o}C, and 40^{o}C denoted as cold, room, and high temperature measurements, respectively. Measurements of the complex dielectric properties of aqueous ammonia were taken using an Agilent E5071C vector network analyzer (VNC) and an Agilent 87050E dielectric probe kit. Deionized water measurements were taken for calibration. Custom software was written in MATLAB^{TM} to automate data retrieval.

Due to the volatile nature of aqueous ammonia, different experimental set-ups were used for each temperature. For example, during the high temperature experiments, a sealed jar system replaced the open beaker used in room temperature experiments. The pH and temperature readings were used to confirm the solutions' NH_3 concentration. The final schematics of the room temperature, high temperature, and cold temperature measurement systems are shown in figures 1-3.

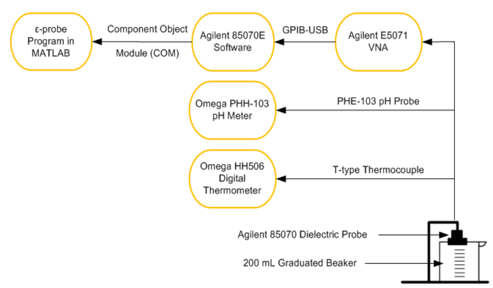

Figure 1: Schematic of the room temperature system.

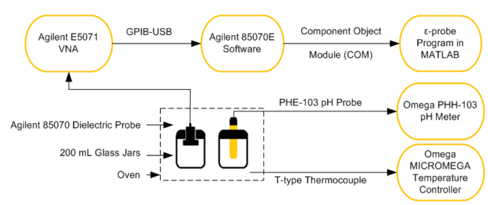

Figure 2: Schematic of the high temperature system.

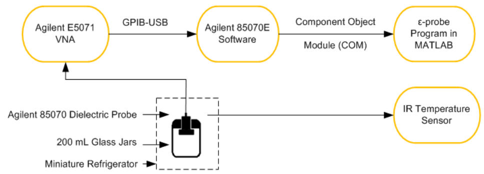

Figure 3: Schematic of the cold temperature system.

3. Uncertainties

There are three sources of uncertainty that were considered when evaluating the accuracy of the measurements of complex dielectric properties of aqueous ammonia: instrumentation errors, including those from noise, and errors resulting from uncertainty in the dissolved ammonia concentration and temperature of the liquid mixtures under test. The instrumentation error comes from the Agilent E5071C VNA and Agilent 87050E dielectric probe kit. This error is determined by evaluating the statistical repeatability of the measurements of pure water (whose properties are well known [3]) over multiple measurement sweeps and then applying those uncertainties to the data collected using mixtures.

Errors due to temperature uncertainties were determined by evaluating uncertainties in temperature measurement from the thermometers, probes, and thermocouples used and then applying the deviations to the Meissner and Wentz model for the complex dielectric properties of pure water [3] so as to estimate the resulting effects on the complex dielectric properties. Errors in mixture concentration are determined from the precision provided by the manufacturer, and on measured effects of the environment on mixture pH.

4. Model Theory

An example of the measured data is given in Figure 4. The new model for the effects of dissolved ammonia is based on a modifying term (dependent on temperature and concentration) to the Meissner and Wentz model for the complex dielectric properties of pure water [3].

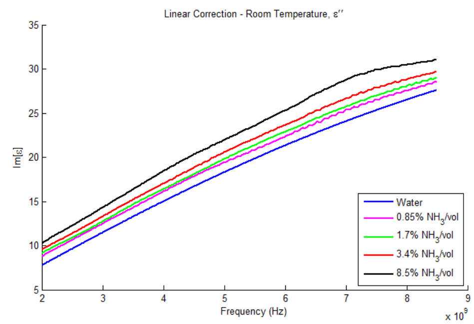

Figure 4: ε'' of NH_4OH solutions measured at room temperature with initial linear corrections based on Meissner and Wentz's model for pure water.

5. Summary and Conclusions

A new model has been developed that can calculate the complex dielectric properties of aqueous ammonia between frequencies of 2-8.5GHz, temperatures of 4-40^{o}C, and concentrations of 0-8.5% NH_3/volume. This model can be directly applicable to determining the microwave opacity of Jovian clouds; any addition of any concentration of ammonia increases the microwave opacity of Jovian clouds.

6. Acknowledgments

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7. References

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