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Fall 2004 REU Semester Report

Sea Ice is a heterogeneous material that consists of ice, brine, and air pockets. This material is arranged in a random, complex, geometric scheme, where the microstructure changes dramatically depending on the temperature. As a result, it is very difficult to determine the relative volume fractions of the different materials when a comparatively long electromagnetic wave is sent into the Sea Ice. Much research has been done modeling the forward problem, where the brine volume fraction is known and the electromagnetic wave response is predicted. The inverse problem, where the electromagnetic wave response is given and the brine volume fraction is estimated, still needs significant work. However, to understand the inverse problem, I needed to understand the forward problem first.

The forward problem assumes certain things about the geometry of the Sea Ice and predicts what the electromagnetic response (E*) will be at given frequencies. In order to accomplish this, the concept of continually eliminating possible responses is used until accurate predictions can be made. In other words, new "boundaries" are continually introduced and the electromagnetic wave response must lie within them. These bounds are found by exploiting effective analytic properties of the geometry and gradually increasing the assumptions made about the geometry until an accurate prediction can be made.

During the course of Fall Semester 2004, several tasks were accomplished. The primary goal was to recreate the formulas already used for getting bounds on the forward problem and to recreate the graphical displays of the boundaries using a software program called Maple. Both tasks were done successfully.

The graph below shows my reproductions of the boundaries that the electromagnetic wave response must lie within on the complex plane. This graph is based on the assumption that the frequency is 4.75 GHz, salinity of the brine is S=3.8 ppt, brine volume is P1=0.015 and the ice volume is P2=0.985, where P1+P2=1. The red boundaries are created assuming only the volume fractions of the different materials. The blue boundaries are created further assuming isometry and they are called the Hashin-Shtrikman bounds. Theoretically, this process of creating more and more precise bounds can be accomplished using sophisticated algebra.