Dielectric Brine-Ice Mixtures on Europa, and the Need for New Experiments. K. Chan[1], C. Grima[1], D. D. Blankenship[1], K. M. Soderlund[1], D. A. Young[1], [1]Institute for Geophysics, University of Texas at Austin, J.J. Pickle Research Campus, Bldg. 196; 10100 Burnet Road (R2200), Austin TX 78758-4445 (kristian.chan@utexas.edu).

Introduction: The recent hypothesis of brine mobilization in Europa's ice regolith, ranging from hundreds of meters to kilometers thick [1-2], makes this region an intriguing target for understanding habitability on the icy moon. In addition, the Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) instrument on the Europa Clipper mission is capable of detecting near-surface brines within depths of tens of meters, while brines may be potentially located in range of in-situ sampling from a future lander mission [3]. Successful radar detection of brine-soaked firn in the McMurdo Ice Shelf of Antarctica [4] is attributed to the radar being sensitive to the dielectric constant of mixtures containing ice, brine and pore space. However, the electromagnetic properties of near-surface brines on Europa remain poorly constrained but are important for investigating physical surface properties derived from reflectometry measurements by REASON [5].

Dielectric Model: To understand REASON's sensitivity to such mixtures, we develop a three-component Debye-mixing model based on classical mixing approaches and assess its ability for constraining the permittivity of icy brine mixtures under near-surface conditions on Europa. These mixtures include a combination of ice, vacuum pores, liquid brine and/or salt hydrates. The single Debye model was used to obtain the frequency dependence of the complex permittivity for liquid and frozen brines. Experiments previously conducted with salt hydrates and liquid brine at low temperatures [6-8] provide the necessary input parameters for the Debye model. The results were then used in several dielectric homogenization mixing rules (Fig. 1) aimed to characterize a heterogeneous mixture with a bulk effective macroscopic permittivity [9, 10].

We demonstrate for mixtures containing ice, pores and modeled salt hydrates on Europa [11], the different mixing rules agree quite well with each other, predicting a mixture permittivity with a value somewhere in between the permittivities of its constituents. However, for cases containing liquid brine, the model fails to provide adequate permittivity predictions. Although suitable for modeling brine pockets in ice on Earth, the different mixing rules yield dissimilar results at relatively high liquid brine volume fractions (Fig 1.), which would be representative of a brine saturated ice regolith on Europa. The real part of the effective complex permittivity can achieve values much higher than any of its constituents, often attributed to polarization enhancement phenomena for high-loss mixtures [12].

Experiments: Additional laboratory experiments are crucial for determining the electromagnetic characteristics of icy brine mixtures under near-surface Europan conditions, given the limited data available in recent literature. Factors such as composition, salinity, temperature gradients and porosity can affect the dynamics and evolution of near-surface brines. New experiments should test the effects of these parameters in order to provide better estimates of Debye model parameters, determine whether current homogenization mixing approaches are appropriate, and/or develop new empirical models needed to model mixtures of near-surface brines on Europa.

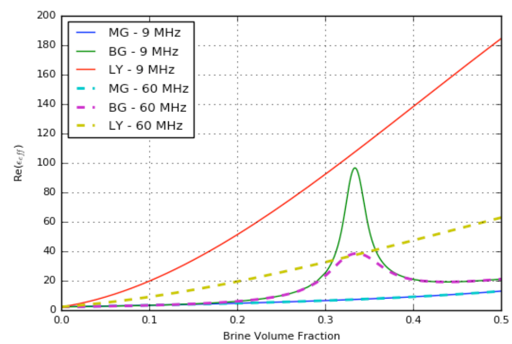

Fig 1. Real part of the complex permittivity for a mixture containing 50% ice with varying volume fractions of liquid brine and vacuum pores, using the Maxwell Garnett (MG), Polder-van Santen or Bruggeman (BG), and Looyenga (LY) mixing approaches.

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