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SURFACTANT-ENHANCED ALKALINE FLOODING FOR LIGHT OIL RECOVERY

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OBJECTIVE

The overall objective of this project is to develop a very cost-effective method for formulating a successful surfactant-enhanced alkaline flood by appropriately choosing mixed alkalis which form inexpensive buffers to obtain the desired pH (between 8.5 and 12.0) for ultimate spontaneous emulsification and ultra-low tension. In addition, the novel concept of pH gradient design to optimize flood water conditions will be tested.

SUMMARY OF TECHNICAL PROGRESS

The problem of characterizing emulsions in porous media is very important in enhanced oil recovery applications. This is usually accomplished by externally added or insitu generated surfactants that sweep the oil out of the reservoir. Emulsification of the trapped oil is one of the mechanisms of recovery. The ability to detect emulsions in the porous medium is therefore crucial to designing profitable flood systems. The capability of microwave dielectric techniques to detect emulsions in porous medium is demonstrated by mathematical modelling and by experiments.

This quarter the dielectric properties of porous media are shown to be predicted adequately by treating it as an O/W type dispersion of sand grains in water. Serious discrepancies between Beer-Lambert's rule and the effective medium model predictions are noted. The frequency invariant dielectric modulus at 20% rock porosity suggests viability of lower frequency measurements. Porous rock characteristics at much greater depth of field can, therefore, be obtained since there is much less attenuation at lower frequencies. The lower limit of usable frequency will be governed by salinity considerations.

Coreflood Experiments

A computer controlled absorption instrument was developed in our laboratory for the automated measurement of oil/water saturation in laboratory models of porous media. It consists of a PDP-11/10 mini computer, two constant rate pumps, a differential pressure transducer, an automated fraction collector, and a microwave adsorption analyzer. The components of the measuring device are the microwave focused lens horns, one of them transmitting and the other receiving. The attenuation data has been interpreted to date under the assumption that when microwave radiation travels through a homogeneous medium, the power intensity of the beam is reduced according to Beer-Lambert's rule. Microwave energy is considered to be absorbed exclusively by the water molecules. Other model components such as oil, gas, consolidated rock, and epoxy paint are considered nearly transparent compared with water. Thus, the total absorption is a direct function of the number of water molecules in the beam path and is described by Beer Lambert's rule:

$$\frac{I_t}{I_i}=A=\exp(-K_a Ch)$$

where I_t is the radiation emerging from the sample, I_i is the radiation intensity incident on the sample, K_a is the molar absorption coefficient, C is the concentration of the absorber, h is the thickness of the sample, and A is the absorbance. Water saturation is obtained from the logarithmic ratio of the microwave signal.

The serious limitation in this approach is that it treats the porous medium, which is a dispersion of sand grains in brine, as a simple mixture. The porous medium is better modelled as a dispersion of sand grains. For a spherical dispersion of sand grains, the dielectric behavior of the porous medium can be described by Hanai's model as

$$\frac{(\varepsilon_1-\varepsilon_2)^3}{(\varepsilon_1-\varepsilon_m)^3}\left(\frac{\varepsilon_m}{\varepsilon_2}\right)=\frac{1}{(1-\phi)^3}$$

This formula is applicable to non-spherical dispersions that possess self similarity. The experimental measurements, obtained from reference 1, for a model porous media of fused glass beads in various solvents, is shown in Figure 1.

As can be seen from the figure, the comparison between the measured values of the dielectric constant and the theoretical predictions of the effective medium theory is very good. Experimental measurements of the dielectric properties of dry Berea sandstone core were made at 23.45 GHz during the course of this study. The measured value of the permittivity compared with the effective medium theory to within 8%. The deviation from Beer-Lambert's mixing rule was substantially much higher at 26%. Thus the effective medium theory which treats the porous medium as an O/W type dispersion appears to be valid in predicting porous medium dielectric characteristics.

The practical consequences of using Beer-Lambert's rule instead of effective medium models is illustrated in Figure 3 for an O/W type dispersion. As can be seen from the figure, theoretical calculation using Beer's law will tend to overpredict the amount of water present, especially at high water saturations. The loss factor plotted in Figure 3 is directly proportional to the measured attenuation for a constant size core. Earlier core flooding experiments gave good results as they were calibrated to the porosity by material balance.

RESULTS AND DISCUSSION

An accurate way to interpret microwave dielectric data to determine porous media saturation characteristics is to use an effective medium theory, with ε' and ε'' computed by phase and attenuation measurements. The dielectric modulus for a water saturated Berea sandstone core with 20% porosity is shown in Figure 4.

It is important to note from Figure 4 that the modulus of the system is frequency invariant over a wide range of frequencies. This result has the important implication that low frequency data is adequate for determining the saturation characteristics and is especially significant for insitu monitoring of porous medium in oil fields. The porous medium is akin to an oil-in-water emulsion system and low frequency microwave techniques are preferable since there is considerably less attenuation at low microwave frequencies. Porous rock characteristics at much greater depths can, therefore, be obtained by a single frequency measurement of the dielectric constant. The lower limit of the usable frequency will be governed by salinity considerations. The dielectric data of O/W type systems, including porous media, from several sources at various frequencies in the microwave region is represented as a dielectric modulus in Figure 5. The data spans virtually the entire range of dispersed phase volume fractions and compares favorably with the dielectric modulus of O/W emulsion systems obtained from our model computations.

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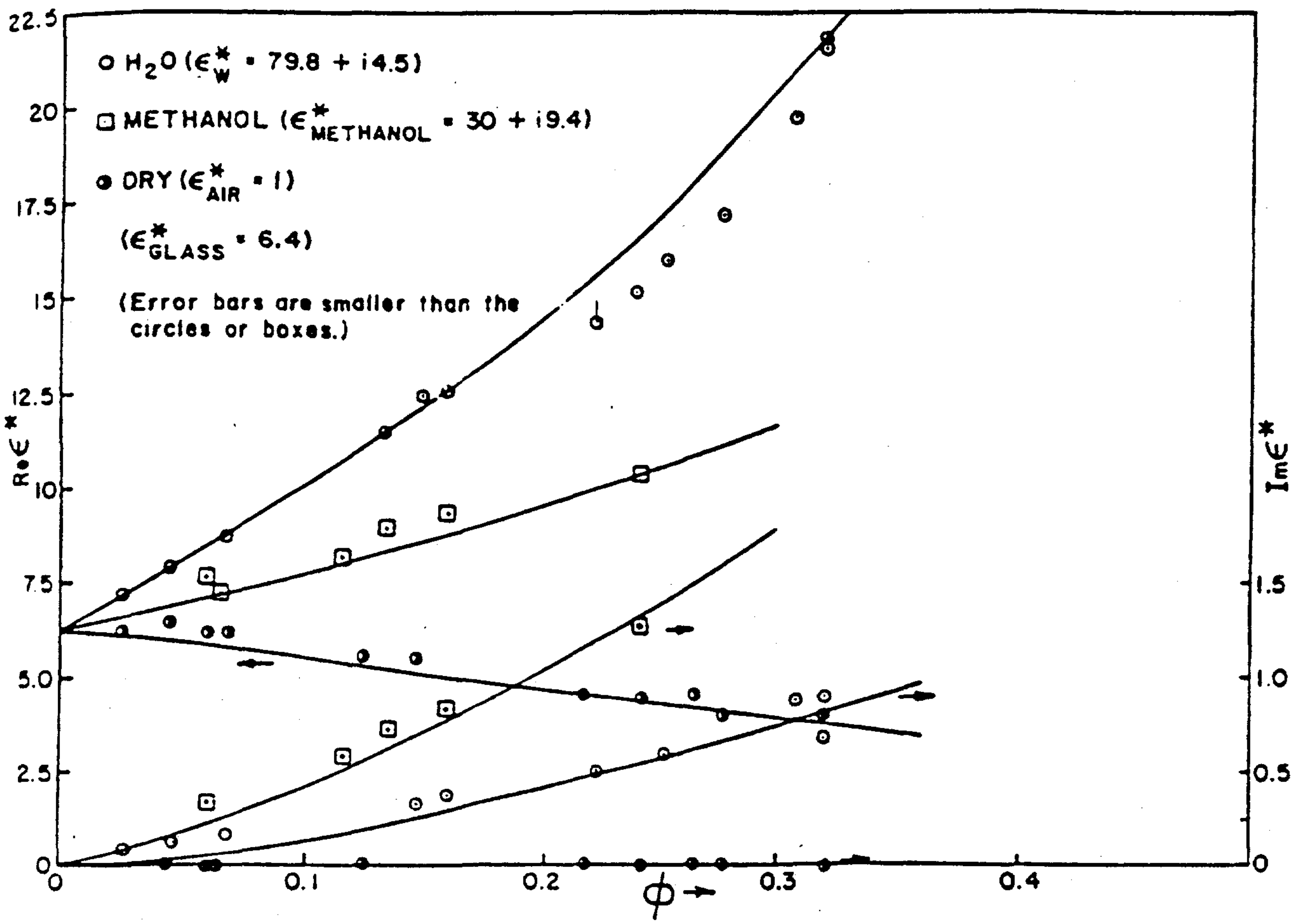

Figure 1 Comparison of Experimental Data with Effective Medium Theory for Model Porous Medium of Fused Glass Beads with various Solvents [74]

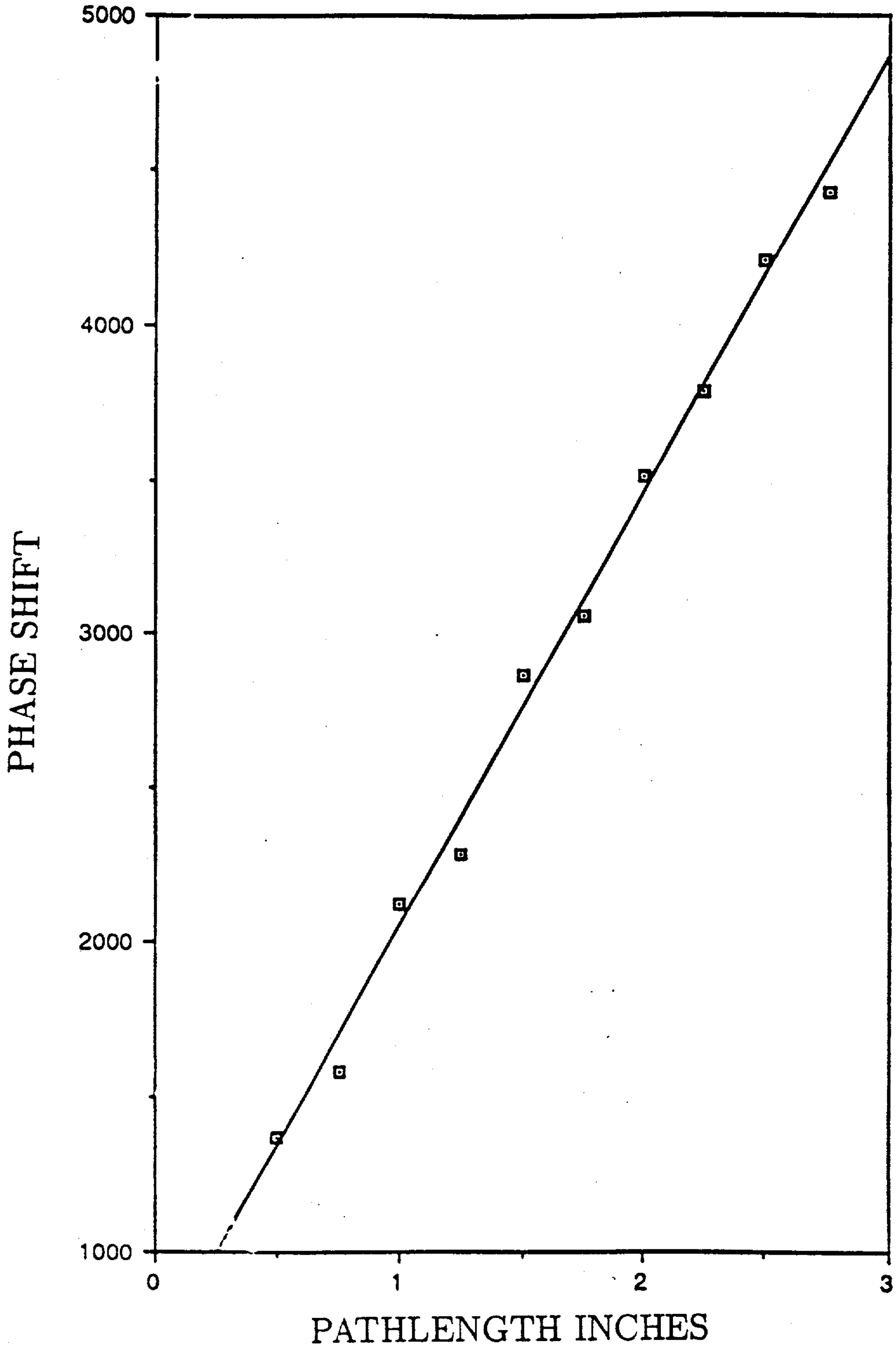

Figure 2 Dry Core Variable Pathlength Phase Shift Data at 23.45 GHz.

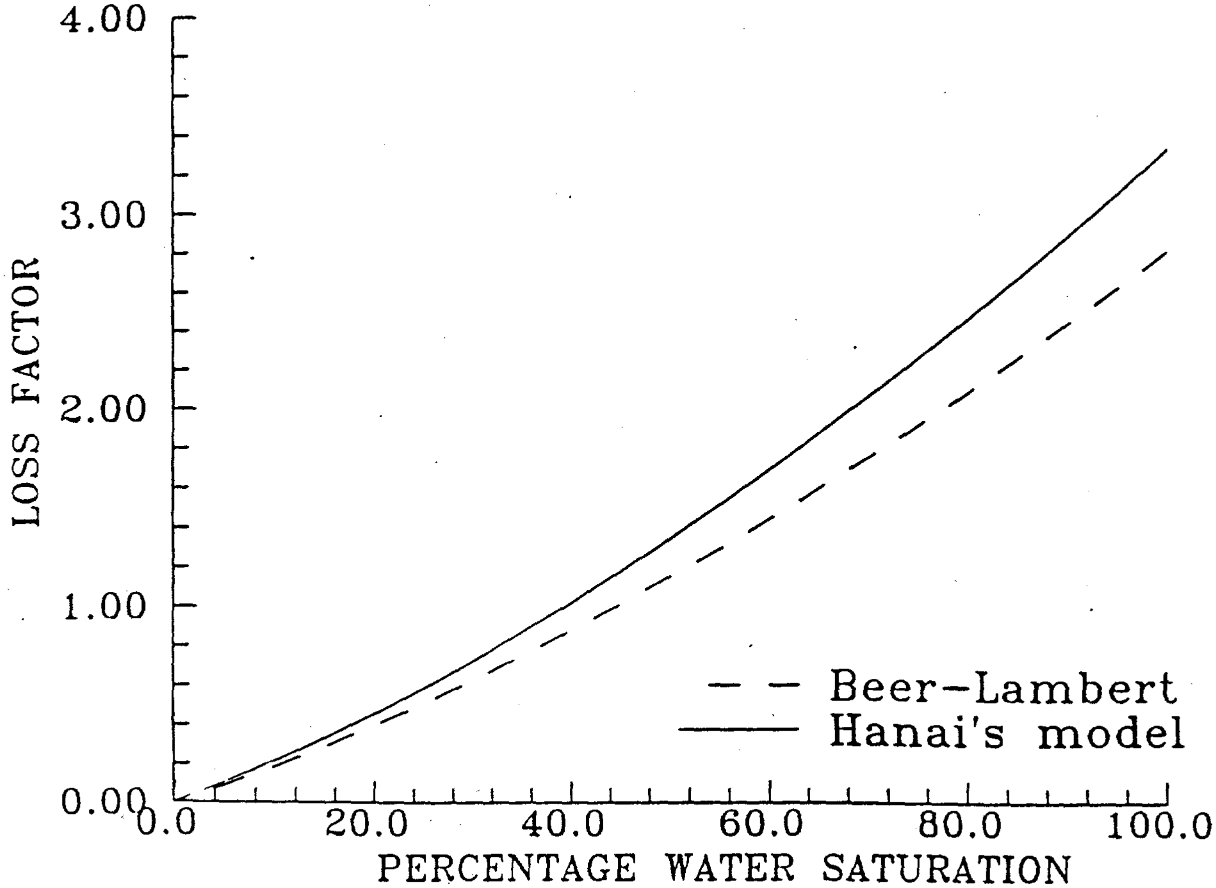

Figure 3 Comparison of Beer Lambert Law with Effective Medium Models for an O/W type Dispersion at 23.45 GHz.

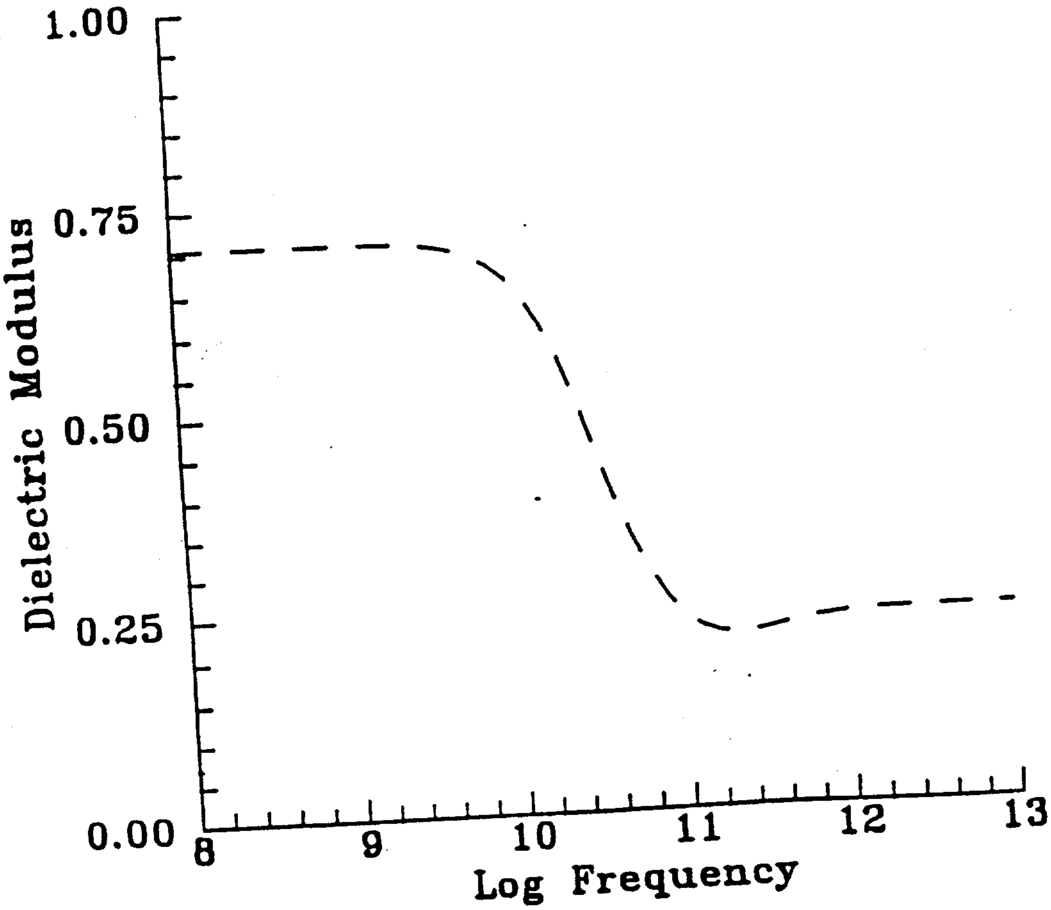

Figure 4 Frequency Invariant Modulus Plot of the Dielectric Modulus of Berea Sandstone Porous Medium at 20% Porosity

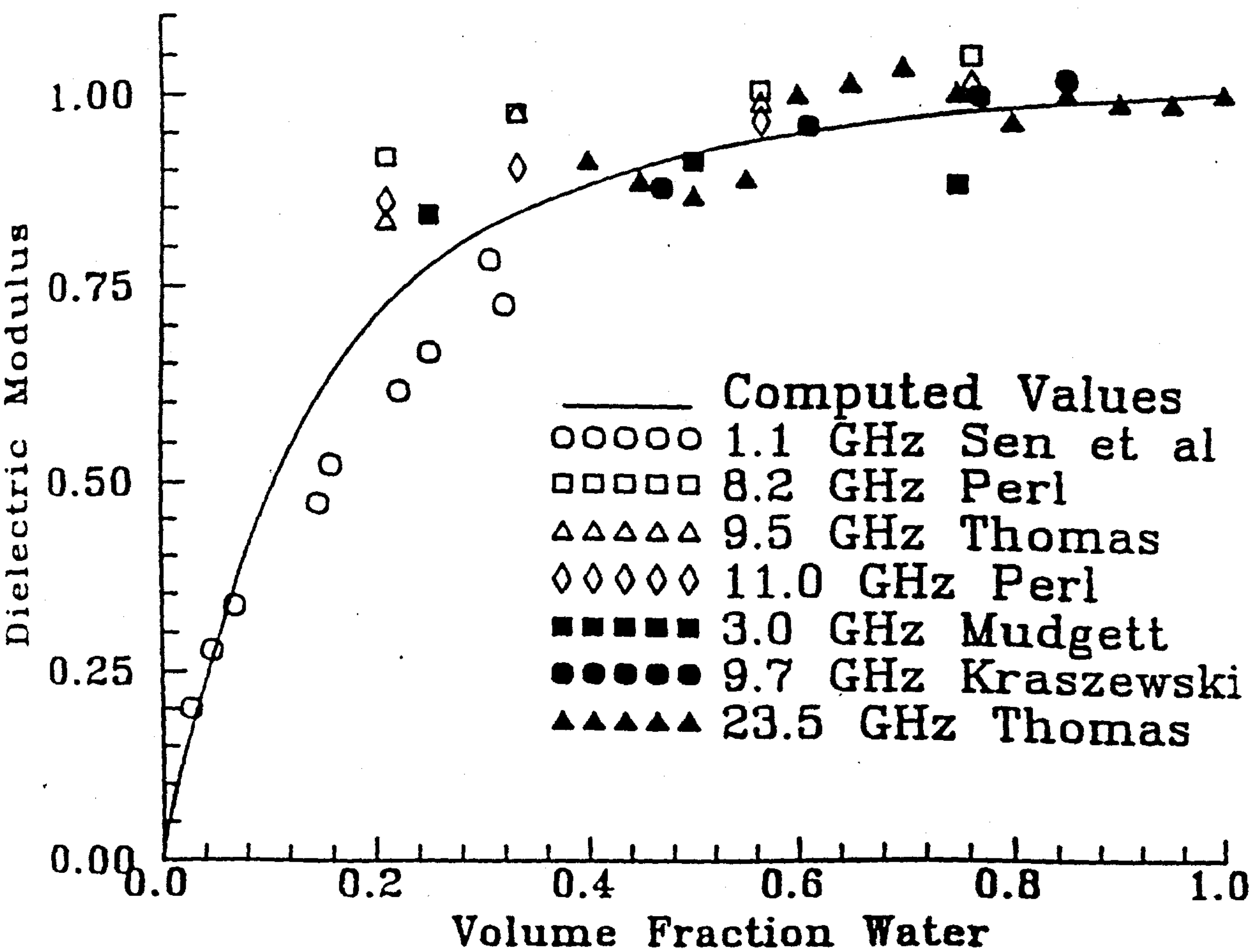

Figure 5 Frequency Invariant Modulus Plot of the Dielectric Modulus of O/W Type Dispersions using Effective Medium Theory