Solid State Science and Technology, Vol. 19, No 1 (2011) 1-5
ISSN 0128-7389

SIMULTANEOUS ANALYSIS OF CONDUCTIVITY AND CONCENTRATION OF SALINE SOLUTIONS AND SEA WATER AT MICROWAVE FREQUENCIES FROM DIELECTRIC INVESTIGATION

Mohd Amiruddin Abd Rahman*, Kaida Khalid and Jumiah Hassan

Department of Physics, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

**Corresponding Author: amiruddin@science.upm.edu.my*

ABSTRACT

Prediction of conductivity and concentration of saline solutions and sea water are calculated from dielectric spectra at microwave frequencies of 2 GHz and 5 GHz respectively. The calculation is based on two different previously published empirical models relating to conductivity and concentration. An empirical relationship is established and is used to find corrected calculated conductivity and concentration. The expected results are verified with standard measurement where correlation coefficient of given is 0.98 and above. The data is useful as tools for quality indication of liquid samples.

Keywords: Dielectric; microwave; seawater;

INTRODUCTION

Conductivity is an indicator of salinity in water. Salinity or concentration of liquids could be notified from variation of dielectric properties of the water. For saline solutions, conductivity is a linear proportional function of salt content or concentration of the solution [1]. However the linear relationship changes as other constituents introduced into the solutions where conductivity is not anymore a linear function of concentration. Therefore it is useful to know at once both conductivity and concentration information of saline solutions and sea water as a qualitative indicator.

Conductivity and concentration of liquids could be obtained from measurement of dielectric properties where it is frequency dependence. Information of dielectric measurement of both saline solutions and sea water and their analytical models at microwave frequencies were found in literature [1-3]. Previous investigation was done in terms of conductivity relationship with dielectric models such as Debye and Cole-Cole models. The dielectric models does not relate directly concentration data with permittivity as dielectric mixture model does. Additionally, the models require dispersive frequencies data thus needing extensive analysis. For that reason, the main objective of this work is to investigate the relationship of both conductivity and concentration of saline and sea water samples from microwave dielectric spectra at two specified frequencies respectively and later using two different previously published empirical models notably for conductivity and concentration and later is verified against commercial and standard method, respectively.

THEORY AND MODELS

There are two dominant effects that occur at microwave frequency ranges namely ionic conductivity and dipole polarization. These phenomena are frequency and material-type dependence where the prior dominates at usually very low megahertz microwave frequencies and the latter governs high gigahertz region. The ionic conductivity which is proportionally related to the total dielectric loss factor of materials is a function of DC conductivity is assumed as obtained from Kaatze [4, 5]:

$$\varepsilon''_{total} = \varepsilon'' + \frac{\sigma_0}{\varepsilon_0 \omega} \qquad (1)$$

where ε'' is the dielectric loss due to non-ionic effect and σ_0 is the DC conductivity. The model is an approximation of the Debye model.

On the other hand, relationship of concentration and permittivity which are due to dipole polarization effect are described by numerous mixture models. Among the simplest is Kraszewski model [6] which only requires information of permittivity of both water and the liquid in solid form. The relationship is described as:

$$\sqrt{\varepsilon_m^*} = v_w \sqrt{\varepsilon_w} + (1 - v_w)\sqrt{\varepsilon_s} \qquad (2)$$

where ε_m^* is the complex permittivity of the bulk liquid, ε_w and ε_s are the permittivity of water and material (in dry form) respectively, and v_w is the volume fraction of water. Concentration of materials is found from v_w by [7]:

$$v_w = \frac{\rho_s - C\rho_s}{C(\rho_w - \rho_s) + \rho_s} \qquad (3)$$

where C is the concentration of materials and ρ_s and ρ_s are the density of solid material and water respectively. The main reason the simple models was chosen is to test whether simultaneous measurement of conductivity and moisture content could be carried out.

MATERIALS AND METHOD

Sea water samples are obtained from South China Sea at Terengganu coast. The samples are diluted with deionised water as preparation for different concentration. Samples of saline solutions are prepared using salt purchased from HmbG Chemicals (Code number: C0753-21416592) with purity of 99.5%. The concentration of prepared sea water and saline solutions are within the range of 1 to 4% of total solid content (TSC) and 1 to 17 wt% respectively. Permittivity measurements at microwave frequencies are done using HP85070B open-ended coaxial probe attached to Agilent N5203C Personal Network Analyser (PNA). The dielectric data are obtained from Agilent 85070 software within the PNA. The data are investigated at 2GHz for conductivity measurement and 5GHz for concentration or moisture relation. Conductivity of the samples is demined by a Hanna HI8733 commercial portable conductivity meter. Concentration of sea water is determined using standard oven drying method.

RESULTS AND DISCUSSION

The results of dielectric properties in terms of conductivity (Figure 1) and TSC (Figure 2) of sea water and saline solutions show that the measured conductivity is almost similar to the calculated conductivity from equation (1). However, the calculated TSC (equation 2) of both samples is about two times higher than concentration of standard measurement. The empirical relationships for conductivity and TSC obtained are given as:

For sea water samples

$$wt\%_{measured} = 0.4944(wt\%_{calculated}) - 0.0490 \quad (4)$$

$$\sigma_{measured} = 0.9964(\sigma_{calculated}) - 0.0083 \quad (5)$$

For saline water samples

$$wt\%_{measured} = 0.4799(wt\%_{calculated}) - 0.0682 \quad (6)$$

$$\sigma_{measured} = 0.9916(\sigma_{calculated}) - 0.0047 \quad (7)$$

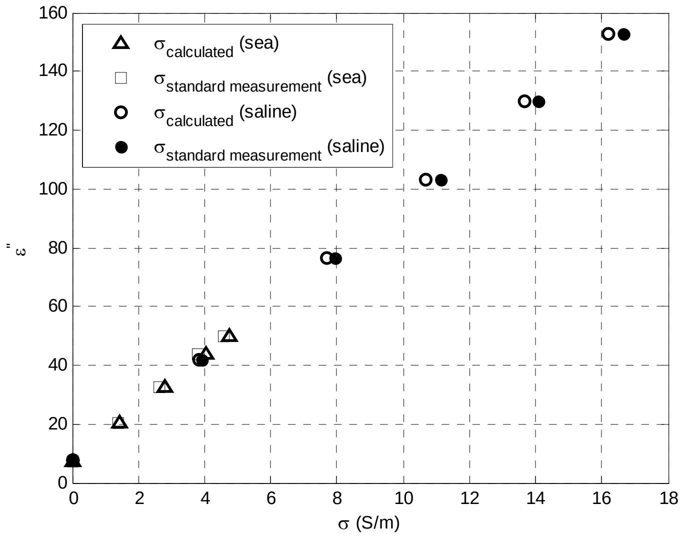

Figure 1: Relationship of dielectric loss factor ε'' with conductivity σ of tested samples

Solid State Science and Technology, Vol. 19, No 1 (2011) 1-5
ISSN 0128-7389

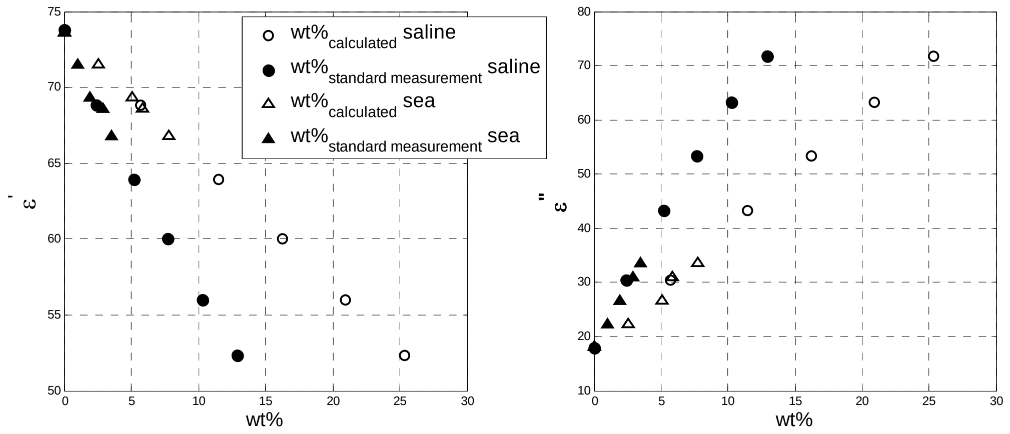

Figure 2: Relationship of dielectric constant and dielectric loss factor with TSC of tested samples

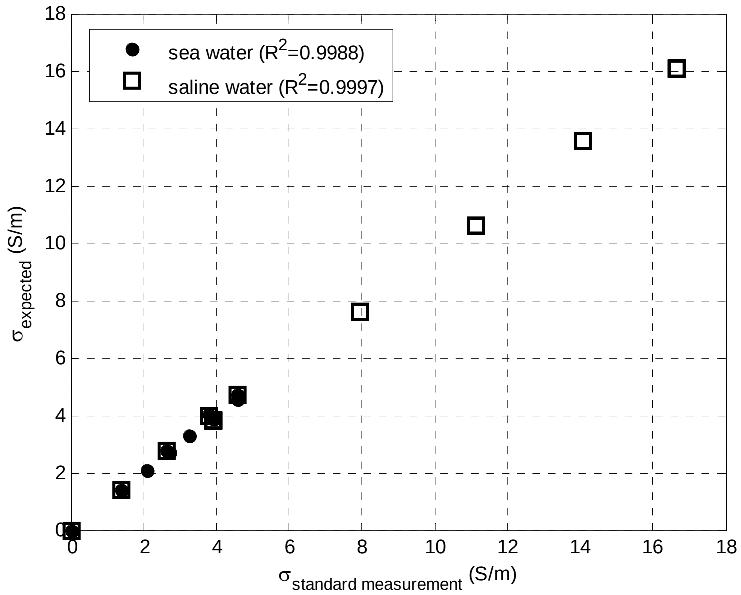

Figure 3: Relationship of conductivity of expected results with standard measurement

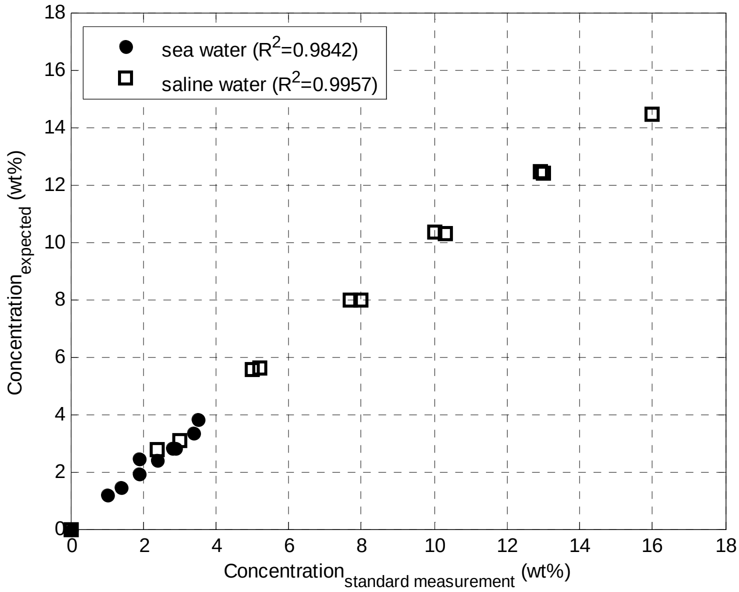

Figure 4: Relationship of TSC of expected results with standard measurement

As previously discussed where the proposed model to calculate the TSC is about two times higher, the relationship of measured and calculated data is corrected using the empirical relationship in equation 4 to 7 to calculate expected conductivity and TSC. The expected data is verified against commercial and standard method as shown in Figure 3 and 4. The expected results show good agreement with standard measurements with correlation coefficient of all data is above 0.98 as shown in the respective figures.

CONCLUSION

It has been shown that *in-situ* dual information of conductivity and concentration of samples could be obtained from measurement of dielectric properties at two different microwave frequencies. The information is important especially in designing devices for quality assessment of solutions.

REFERENCES

[1] J. H illand, *Measurement Science and Technology*, **8** (1997) 901
[2] A. Stogryn, *IEEE Transactions on Microwave Theory and Techniques,* **19** (8) (1971) 733-736
[3] L. Klein, and C. Swift, *IEEE Transactions on Antennas and Propagation,* **25** (1) (1977) 104-111
[4] U. Kaatze, *Metrologia*, **47** (2) (2010) S91
[5] U. Kaatze, *Journal of solution chemistry,* **26** (11) (1997) 1049-1112
[6] A. Kraszewski, *J. Microwave Power,* **12** (3) (1977) 215-222
[7] A. Kraszewski, S. Kulinski, and M. Matuszewski, *Journal of Applied physics,* **47** (4) (1976) 1275-1277