Characterization of Temperature Effect on the Dielectric of Aqueous Solutions

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Recent study has indicated the advantage and potentials of the microwave way in the characterization of the dielectric of glucose aqueous solutions with concentration variation, specially for its noninvasive nature and continuous sensing capability (M. Hofmann, G. Fischer, R. Weigel and D. Kissinger, *IEEE Trans. Microw. Theory Techn.,* 61, No. 5, 2013]. These studies indicated that glucose variation does produce a definite change in dielectric properties, however, the variation of the glucose level within the human physiological range (typically 60-700 mg/dL) is small, and the dielectrics will also be affected by the temperature. For the applications of microwave non-invasive biomedical detection, it is still a challenge in order to accurately determine the minor variation of the glucose concentration-dependent dielectric and its temperature effect within this most interested range.

In this study, we utilize an effective and concise transmission line measuring system and the integrated modified Debye dielectric dispersion model in (1) to characterize the temperature effect on the dielectric parameters (ε_{r0}, $\Delta\varepsilon_r$, τ, and σ) through the frequency range 10M-18GHz for various aqueous solutions. Our study indicates that the dielectric parameters of glucose solutions non-linearly vary with the concentrations of glucose or the other infusions, and the temperature. Whereas the dielectric spectra in glucose aqueous solution reveals a single relaxation process, the other mixtures like ethanol aqueous solutions indicate multiple relaxation processes. The temperature effect on the relaxation time of these aqueous solutions can be approximately described by the dispersion model in (1) by considering the temperature effect on the viscosity variation based on Stokes-Einstein-Debye equation. Comparison in the frequency domain between the measurement and model-based prediction indicates the effectiveness of the described concise measuring system in the characterization of temperature effect on the dielectrics for various aqueous solutions.

$$\varepsilon_r(\omega) = \varepsilon_{r\infty} + \frac{\Delta\varepsilon_{r1}}{1 + j\omega\tau_1} + \frac{\Delta\varepsilon_{r2}}{1 + j\omega\tau_2} + \frac{\sigma}{j\omega\varepsilon_0} \quad (1)$$

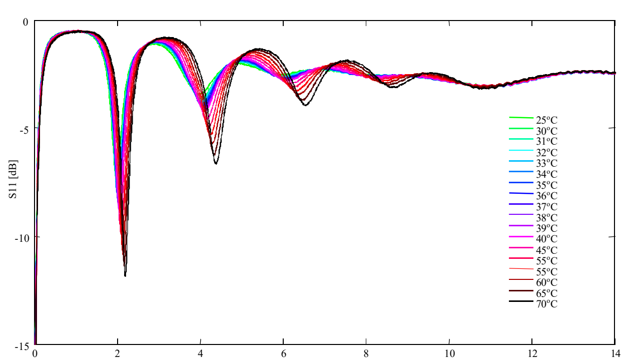

Fig. 1 Measured S_{11} for 200 dg/dL glucose solution with various temperature

TABLE I Retrieved dielectric parameters for 200 dg/dL glucose solutions at various temperature

T [°C]	$\varepsilon_{r\infty}$	$\Delta\varepsilon_r$	τ [ps]	σ [mS/m]
25	5.25	66.97	11.5	42.3
30	5.22	65.29	10.2	45.5
32	5.13	64.63	9.7	46.7
34	5.09	63.99	9.2	47.5
36	5.01	63.28	8.7	49.0
38	5.04	62.58	8.3	50.1
40	5.05	61.82	7.8	51.3
45	4.93	60.21	6.8	55.2
50	4.58	59.00	6.0	58.1
55	4.33	57.76	5.3	61.3
60	4.01	56.66	4.7	64.6
65	3.61	55.50	4.0	67.7
70	3.38	54.41	3.6	68.7