Effectiveness of a Dielectric Probe Calibration using Deionized, Distilled and Tap Water

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***Abstract*—A dielectric materials measurement can provide important parameter information for wireless applications that require an antenna design in complex environments and for such measurements, an accurate calibration technique is critical to achieve consistency, accuracy and reliability. In this paper, a study on the calibration method of a dielectric probe is performed. Specifically, a Keysight's N1500 coaxial probe was used and experiments were performed using samples of deionized, distilled, and tap water to study the calibration effectiveness. Following each calibration method, the dielectric properties of SPEAG tissue simulating liquid were measured over a broad-band frequency range and results were compared with the datasheet. The results showed that despite the differences in the calibration methods, the measurements obtained from these experiments were in good agreement.**

***Index Terms*—Dielectric probe, dielectric properties, calibration.**

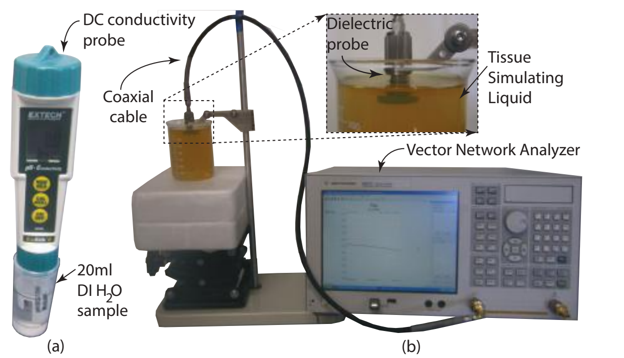

Fig. 1. (a). Extech's EC500 DC conductivity probe with a sample of DI water, and (b) Measurement setup showing Keysight's N1500 dielectric probe connected with a vector network analyzer measuring the properties of a sample of tissue simulating liquid.

I. INTRODUCTION

Researchers have studied the dielectric characteristics of tissues for many years for multiple applications [1], [2]. Among many of these properties, relative permittivity, conductivity and loss tangent are of particular interest especially for the design and development of implantable medical devices with radio frequency capabilities. For example, in [3], these properties are given important consideration in the overall design of an implantable antenna for a wireless pacemaker system.

A range of commercially available techniques and hardware are available to measure the dielectric properties, mainly permittivity, permeability, conductivity, and loss tangent, of various materials. These instruments often have a broad frequency range and are very high-precision, which is often required for good measurements. The accurate measurements of the dielectric properties can be achieved if the dielectric probe is properly used and the calibration technique is correctly followed. For the Keysight's dielectric probe, N1500, the application notes are a good resource for the use and calibration [4]. It is however reported in [4] that for the calibration of this dielectric probe, the use of both distilled or deionized water is recommended. The use of tap water for calibration purposes is unknown and is hence investigated in this work.

In this work, we have investigated the use of distilled, deionized, as well as tap water for the calibration of Keysight's dielectric probe, N1500. The DC conductivity of each of these calibration liquids was separately measured to validate the difference, and then the dielectric probe was calibrated each time using separate liquids and results were measured. To investigate further, following each calibration, the dielectric properties of the SPEAG tissue simulating liquid was measured and compared the results with the data sheet.

II. CALIBRATION OF THE PROBE USING DEIONIZED, DISTILLED AND TAP WATER

A. DC conductivity of Deionized, Distilled and Tap Water

To validate the differences, the DC conductivity of these samples was first measured using a EXTECH Instrument (ExStick II), EC500, as shown in Fig. 1. A reference calibration liquid with a conductivity of 84 μS was used before measuring the conductivity of a 20ml sample of deionized water, which turned out to be well below the range that can be measured using this instrument. From the Milli-Q Advantage A10 system however, a resistivity of 18.2 MΩ.cm @ 25°C resulted in a conductivity of 54.94 nS. The conductivity of the distilled water was measured to be 12.7 μS @ 24.1°C. Finally, for the tap water, the calibration was performed using a reference liquid with a conductivity of 1413 μS and

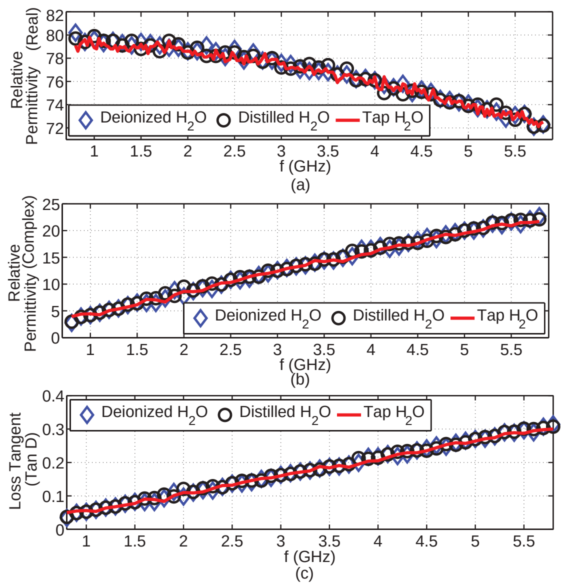

Fig. 2. Measured properties of deionized, distilled and tap water over a wide frequency range. A comparison of (a) real relative permittivity, (b) complex relative permittivity, and (c) loss tangent.

12880 μS, which resulted in a conductivity of the tap water to be 566 μS (approx.).

B. Calibration of Dielectric Probe

As shown in Fig. 1(b), Keysight's N1500A coaxial high temperature probe was used in this work. A standard shorting block is provided (in the hardware kit) by the manufacturer for the calibration of the probe, but it also uses air and water. The water samples mentioned in the previous section were used to perform the calibration as advised in the application notes [4]. The calibration of the probe was first performed using the deionized water, then distilled water, and finally using the tap water (filtered water from the faucet).

Following each calibration method, the real and complex relative permittivity, as well as the loss tangent of each water sample (deionized, distilled and tap) over a broad frequency range was measured.

III. Measurement and Results

SPEAG Human body tissue simulating liquid (TSL) is a broad-band solution, which has dielectric properties similar to that of a human body and is good for the frequency range of 800 MHz to 5800 MHz. The specific product used in this study had 10% tolerance and is called MBBL600-6000V6 [5]. The given dielectric probe was used to measure the dielectric properties of the TSL but each time the calibration of the probe was separately performed using the deionized, distilled or tap water. To illustrate the comparison of the dielectric properties of the samples of the calibration liquids, the measured results are presented in Fig. 2 (a-c). A very good agreement is observed between all the results. For further investigation, the measured dielectric properties of the TSL are compared with the datasheet as shown in Fig. 3 (a-c). It is

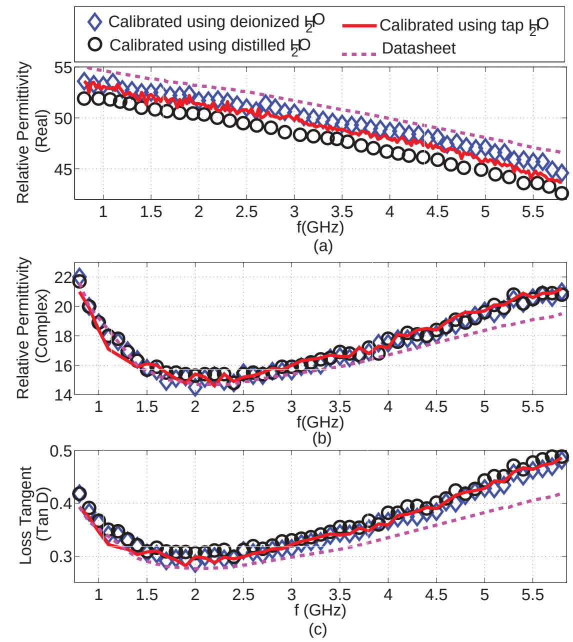

Fig. 3. Data sheet and measured properties of the tissue simulating liquid, when calibration was performed using deionized, distilled and tap water. A comparison of (a) real relative permittivity, (b) complex relative permittivity, and (c) loss tangent.

evident that the measured results of the TSL have also showed good agreement with the results from each case, i.e., when the probe is calibrated using (a) deionized water, (b) distilled water, or (c) tap water.

IV. Conclusion

In this paper, a study on the calibration methods of a dielectric probe (Keysight N1500A) was performed. The use of deionized water, distilled water and tap water for the calibration process demonstrated similar results and it is hence shown that tap water may be used for calibration purposes of such dielectric probes. Note, the quality of the tap water may be different at other locations and hence may require a separate study.

Acknowledgment

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References

[1] H. P. Schwan, "Electrical properties of tissue and cell suspensions", *Adv. Biol. Med. Phys.*, vol. 5, pp. 147-209, 1957.

[2] R. Cooke and I. D. Kuntz, "The properties of water in biological systems", *Annu. Rev. Biophys. Bioeng.*, vol. 3, pp. 95-126, 1974.

[3] S. M. Asif et al., "Design and in vivo test of a batteryless and fully wireless implantable asynchronous pacing system," *IEEE Tran. Biomed. Eng.*, vol. 63, no. 5, pp. 1070-1081, May 2016.

[4] Keysight Tech.,(2017, Jan., 09) N1500A Materials Measurement Suite, [Online]. Available: www.keysight.com.

[5] Schmid & Partner Engineering AG (SPEAG) (2017, Jan., 09), Body Tissue Simulating Liquids, [Online]. Available:www.speag.com.