Analysis of Pilot Study Data for Microwave Hydration Assessment

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***Abstract*—Previous work showed a relationship between changes in weight in athletes undergoing acute water loss and changes in bulk tissue permittivity. This paper focuses on a pilot study involving volunteers abstaining from food and drink from sunrise to sunset as they participated in Ramadan. While the data was rigorously analyzed, there are systematic errors in the data collection that preclude definitive conclusions on the efficacy of the microwave hydration assessment in this study.**

***Index Terms*—microwave sensors, microwave imaging**

I. Introduction

HYDRATION is important to human physiology as water is a critical component to many biological process in the body. Even mild changes in total body water can lead to measurable decreases in mental and physical performance [1]. While there exist many different methods of assessing hydration there is no single method established as the gold standard [2]. This has led to increased interest in novel methods of hydration assessment such as chemical biomarkers or bioimpedance analysis [3]. However, these novel methods present new complexities and often do not measure physiologically meaningful parameters [3]. The bulk permittivity of tissues has been shown to be closely related to the water content of those tissues [4] and thus, potentially, a person's state of hydration [5].

An initial study carried out on a group of athletes undergoing acute water loss showed a strong correlation between weight changes (assumed to come solely from water loss) and changes in permittivity [6]. To further validate the microwave hydration assessment system a study was carried out with volunteers fasting during Ramadan 2018. Ramadan is the ninth month of the Islamic calendar during which Muslims abstain from food and drink from sunrise to sunset. Previous studies have shown states of dehydration during Ramadan fasting days [7] and subsequent loss in weight throughout the day [8]. The object of this work is to provide initial analysis of the data collected during Ramadan 2018.

II. Methods

A brief overview of the microwave hydration assessment system will be provided here. A complete description is provided in [6]. The system consists of two ultrawideband antennas placed in contact with either side of the subject's forearm. The antennas are connected to a standard VNA. Signals are transmitted through the arm and recorded in the frequency domain. The same measurement is taken without the arm in place. The signals are then converted into the time domain where arrival time of the pulse peak is found. From the difference in arrival times Δt the bulk permittivity ϵ_r of the arm is estimated as

$$\varepsilon_r = \left[1 + \frac{\Delta t \cdot c}{z}\right]^2 \quad (1)$$

where z is the antenna separation distance and c is the speed of light. Signals were collected from 10 MHz to 10 GHz in 10 MHz steps.

Volunteers were measured three times a day on three days while fasting during Ramadan and three times after Ramadan as a baseline. Each measurement session consisted of five microwave measurements with the volunteer removing and replacing their arm into the measurement setup between each measurement. In addition to the microwave measurements subjects' weight was measured each measurement session.

Volunteers were recruited through the University of Calgary Muslim Students' Association. The study was approved by the University of Calgary Conjoint Health Research Ethics Board (ID: REB18-0700). Eight volunteers were recruited.

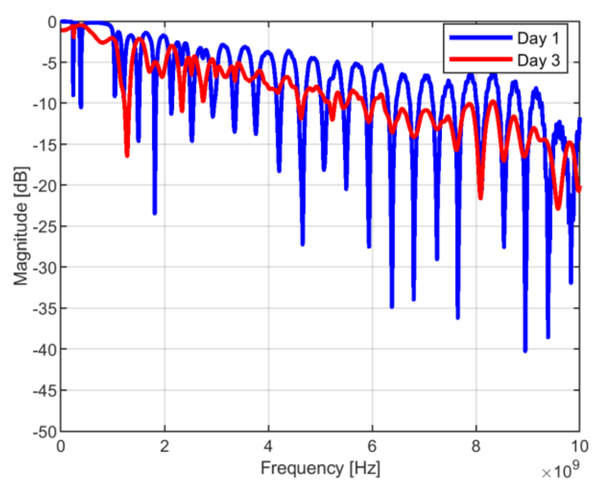

Fig. 1. Antenna only S11 signals showing a good measurement (red) and bad measurement (blue) for Volunteer I while fasting.

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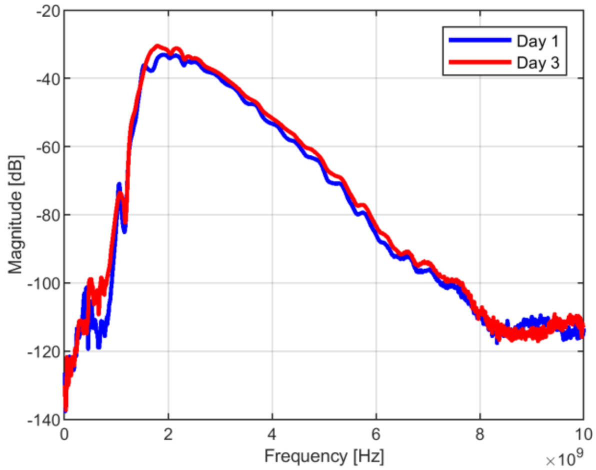

Fig. 2. Average transmission signals showing a good measurement (red) and bad measurement (blue) for Volunteer I while fasting.

III. Results

The raw frequency domain signals were inspected to ensure good signal quality. Looking first at the signals recorded with only air between the antennas ("antenna only"), there were large inconsistencies with some measured S11 signals. Fig. 1 shows representative examples two measurements. One measurement includes strong resonant features that were not present in the typical data from previous studies with the microwave assessment system. The S22 signals were consistent across volunteers indicating an issue with the antenna 1 signal path. After investigating the measurement setup, the issue was found to be a loose SMA connection on the antenna that is moved in contact with the subject's arm.

While antenna 1 had a connection issue, further analyses was done to examine the impact of the issue. Looking at the transmission signals with and without the connection issue there is not a drastic difference as seen in Fig. 2.

The permittivity estimation algorithm [6] was applied to the Volunteer I fasting and non-fasting data. The change in permittivity from each day was fit to change in weight as seen in Fig. 3. While the trend is as expected the adjusted-R^2 was 0.17 indicating a poor correlation.

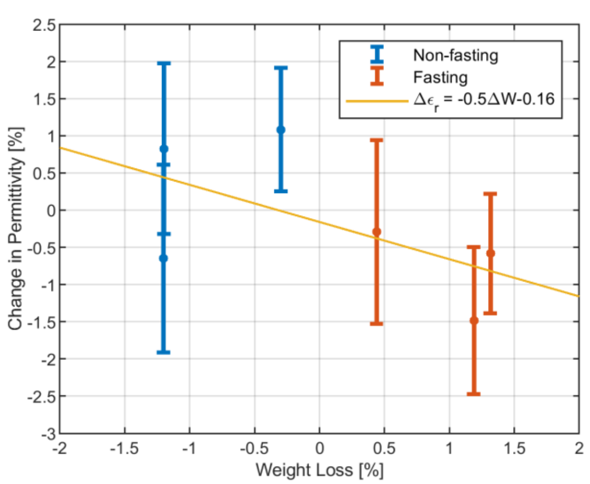

Fig. 3. Change in permittivity vs weight loss each day for Volunteer I. Bars are estimates of standard deviation.

IV. Conclusion

There were fundamental issues with the data collected that prevented meaningful conclusions from being made. In most measurements, antenna 1 experienced a connection issue that subtly changed the measured data. Due to the relatively small changes in hydration (< 2% total body water) this small error in the measurements could obfuscate any changes in permittivity. In the current data there is no correlation between weight and permittivity change where previously an R^2 of 0.6 was reported [6].

An alternative approach to obtaining permittivity estimates may be identifying narrow frequency ranges, then removing the antenna effect through a gate-reflect-through (GRT) calibration that has been previously developed with this system [9]. A method of real-time feedback for quality control when taking measurements will be implemented to prevent measurement errors in the future.

V. Award Impact

The MTT-S Undergraduate Scholarship has provided me with many great experiences that have taught me a lot in the field of microwave engineering and reaffirmed my interest in the field. Attending IMS 2019 in Boston was a tremendous introduction to the depth and breadth of the microwave field and the exciting work being done in industry and academia. While the results of this study were disappointing this has provided an invaluable lesson in the need to be careful with microwave measurements. It has given me many ideas for future work while I complete my Master's work. I am hoping to pursue further academic studies in the field.

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