# Using Electromagnetic Properties to Detect Hydration Levels in the Human Body

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***Abstract*—Our group looked at a non-invasive method to detect hydration levels in the human body. This paper will present the motivations, the pre-existing literature with our analysis and insights.**

## I. Introduction

### A. Motivation

The human body is made up of 60% water [9]. As such, drinking enough water is important for personal health. A study by the US Center for Disease Control has found that nearly half of America's population is not drinking enough water [7]. Dehydration, that is, the lack of water in the human body due to not drinking enough water could cause muscle fatigue, dizziness etc [10].

Plasma osmolality is the ratio of blood solutes to water in blood plasma. When a person is dehydrated, the osmoreceptors in the body's hypothalamus detect an increase in plasma osmolality and the hypothalamus signals a release of antidiuretic hormone (ADH) into the body. ADH signals the kidneys to retain water, and that is why the color intensity of urine in blood increases when one is dehydrated. Besides this, the person will also feel thirsty as a result [8].

However, researchers caution the use of urine indices as an indication of one's hydration level [2]. The coloration of urine occurs at the late stages of the thirst reaction and as such, is not very reliable. The same goes for the feeling of thirst as well - research has also shown that old people are less sensitive to feelings of thirst [5].

Before undergoing physically demanding activities, it is important that one is sufficiently hydrated. Currently, the only reliable way to test one's hydration level is by the means of blood tests. Blood tests damage body tissue and takes a significant amount of time, so it is not a method that could be used on a regular basis. We aim to use electromagnetics to reliably test one's hydration level quickly, and the procedure should be non-invasive to the human body.

### B. Classification of hydration levels

According to [2], the hydration level of an individual could be reliably detected with the concentration of sodium chloride in one's blood, [NaCl]. Table I lists how [NaCl] and one's hydration level are related.

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TABLE I
Classification of Hydration Levels

| [NaCl] | Less than 135 mmol/L | Between 135 mmol/L and 145 mmol/L | More than 145 mmol/L |
|---|---|---|---|
| Hydration level | Overhydrated (hyponatremia) | Hydrated (normonatremia) | Dehydrated (hypernatremia) |

### C. [NaCl] and its relation to electromagnetic properties

*1) Relative permittivity of sodium chloride solution:* According to [3], the relative permittivity of sodium chloride solution, $\varepsilon_r$ is related to [NaCl] by

$$\varepsilon_r = \varepsilon_w - \alpha\,[\text{NaCl}] \tag{1}$$

given that [NaCl] $<$ 1.5 mol/L (this model fits our study). Experiments in [4] suggest that $\alpha = 11.7\,(\text{mol/L})^{-1}$, $\varepsilon_w = 78.3$.

*2) Conductivity of sodium chloride solution:* Linear regression in [1] suggests that the conductivity of sodium chloride, $\sigma$ in mS/cm is given by

$$\sigma = 0.1673\,[\text{NaCl}] + 2.3381 \tag{2}$$

The model in (2) was developed for 0 mmol/L $<$ [NaCl] $<$ 500 mmol/L (appropriate for our study) and has an R-squared value of $R^2 = 0.9926$ which implies a very strong linear correlation.

*3) Relative permeability of sodium chloride solution::* The relative permeability of sodium chloride solution is independent on [NaCl]. According to CST Material Library, the relative permeability of distilled water and sea water (highly concentrated with sodium chloride) both equal to $\mu_r = 0.999991$.

## II. The Proposed Solution

### A. Device description

Figure 1 shows a simple illustration of our proposed solution. Our proposed solution consists of two rectangular microstrip patch antennas on two sides of the user's wrist. The red block shown on Figure 1 is the blood inside the user's wrist. One microstrip patch antenna will be the transmitting (Tx) antenna whereas the other microstrip patch antenna will be the receiving (Rx) antenna.

### B. Design considerations

We have chosen to allow the test to be performed on the user's wrist, for the following reasons:

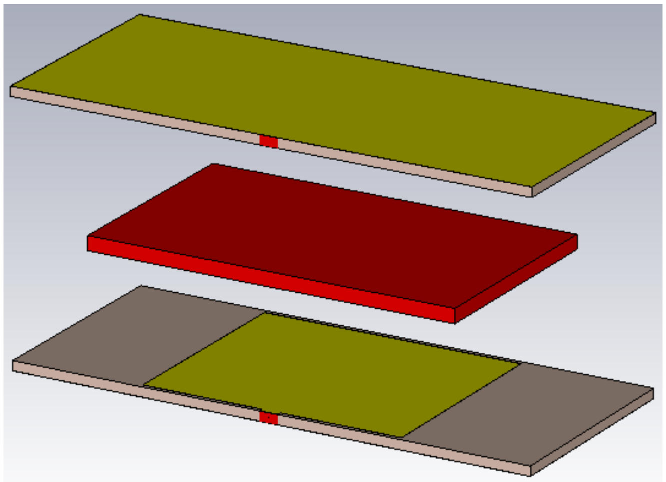
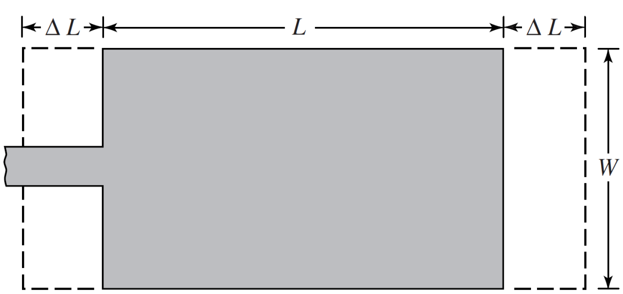


Fig. 1. Simple illustration of prototype showing a patch of blood (red) being sandwiched between two rectangular microstrip patch antennas.

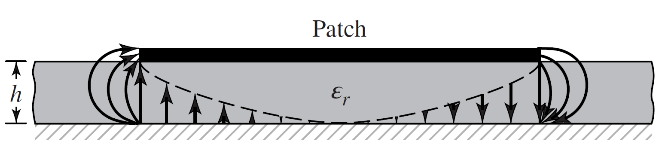
1) Safety: we avoided the placement of the test to be on body parts close to vital organs sensitive to electromagnetic interference (e.g. the user's heart and brain) to avoid electromagnetic interference with the functioning of these organs
2) Amount of blood: our simulations suggest that test results can be more conclusive when we test on places of the body with a good amount of blood
3) Ease of placement of device: we avoided the placement of the device on the lower body so that it would be easier for the user to use our device on upper body parts

### *C. Rectangular Microstrip Patch Antennas*

The rectangular microstrip patch antennas are made up of the 500 Series Copper Clad Boards milled using a PCB milling machine.




(a) Top view




(b) Side view

Fig. 2. Physical and effective lengths of rectangular microstrip patch. Image obtained from [6].

### *D. Block of Blood in Simulations*

## III. Validation

## IV. Analysis and Discussion

## V. Conclusion

## Acknowledgements

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