Electromagnetics and Apps
2D Project First Presentation

Group 5

Problem Statement

People currently check their urine colour to gauge their hydration level, or conduct clinical blood tests.

However, these methods are either late indicators or are invasive.

Our group is interested in coming up with a pre-emptive and non-invasive way to detect one’s hydration level.

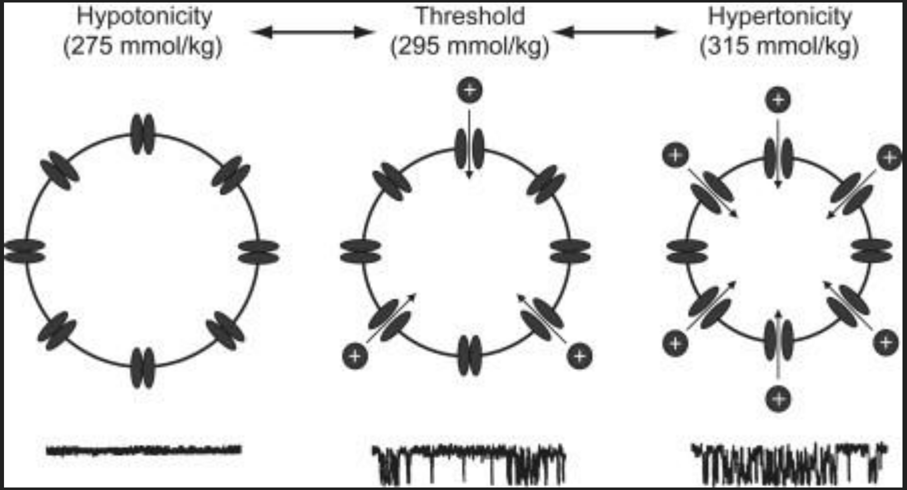
The Thirst Reaction

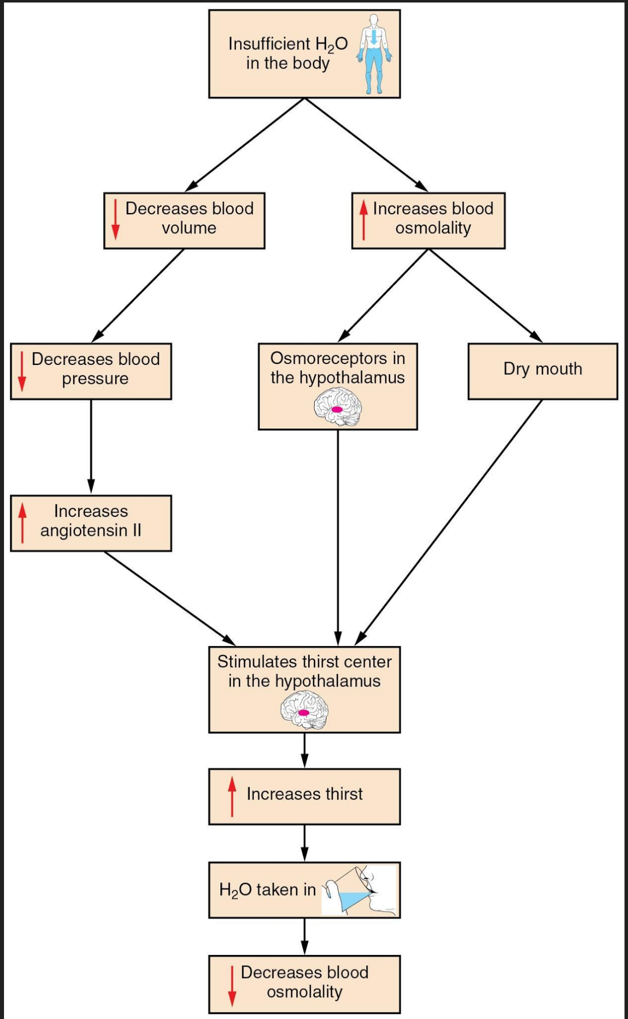
When one is dehydrated, the plasma osmolality of the person's blood increases. The plasma osmolality is the ratio of solutes to water in blood plasma.

Osmoreceptors in the pituitary gland detect the increase in plasma osmolality and triggers a series of response reactions.

One way osmoreceptors detect changes in osmolality:

When the plasma osmolality increases, there will be more ions present to enter non-selective cation channels.





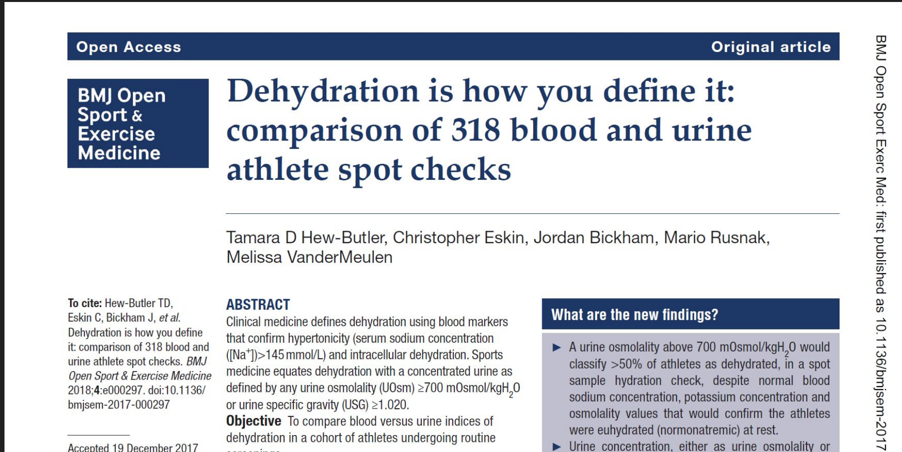
Insufficient H_2O in the body
Decreases blood volume
Increases blood osmolality
Decreases blood pressure
Osmoreceptors in the hypothalamus
Dry mouth
Increases angiotensin II
Stimulates thirst center in the hypothalamus
Increases thirst
H_2O taken in
Decreases blood osmolality

Methodology

Sodium chloride, NaCl (commonly referred to as table salt) contributes part of the ions in our blood.

The concentration of NaCl, [NaCl] in blood is used clinically and is better than urine color in measuring levels of hydration. Urine color is an effect of dehydration, which happens in the later stages of the thirst response.

[NaCl] is between 135 to 145 mmol dm^{-3} for a hydrated person. If one has [NaCl] of above 145 mmol dm^{-3}, he/she is considered to be dehydrated.



Open Access Original article

BMJ Open Sport & Exercise Medicine

Dehydration is how you define it: comparison of 318 blood and urine athlete spot checks

Tamara D Hew-Butler, Christopher Eskin, Jordan Bickham, Mario Rusnak, Melissa VanderMeulen

To cite: Hew-Butler TD, Eskin C, Bickham J, *et al*. Dehydration is how you define it: comparison of 318 blood and urine athlete spot checks. *BMJ Open Sport & Exercise Medicine* 2018;**4**:e000297. doi:10.1136/bmjsem-2017-000297

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ABSTRACT

Clinical medicine defines dehydration using blood markers that confirm hypertonicity (serum sodium concentration ($[Na^+]$)>145 mmol/L) and intracellular dehydration. Sports medicine equates dehydration with a concentrated urine as defined by any urine osmolality (UOsm) ≥700 mOsmol/kgH_2O or urine specific gravity (USG) ≥1.020.

Objective To compare blood versus urine indices of dehydration in a cohort of athletes undergoing routine

What are the new findings?

- A urine osmolality above 700 mOsmol/kgH_2O would classify >50% of athletes as dehydrated, in a spot sample hydration check, despite normal blood sodium concentration, potassium concentration and osmolality values that would confirm the athletes were euhydrated (normonatremic) at rest.
- Urine concentration, either as urine osmolality or

BMJ Open Sport Exerc Med: first published as 10.1136/bmjsem-2017

Scientific Background

- This allows Na^+ and K^+ ions to enter the cell

- This leads to Ca^{2+} influx

$$[NaCl] = 135 - 145\, mmol/dm^3$$

$$[K^+] = 3.5 - 5\, mmol/dm^3$$

$$[Ca^{2+}] = 2.2 - 2.6\, mmol/dm^3$$

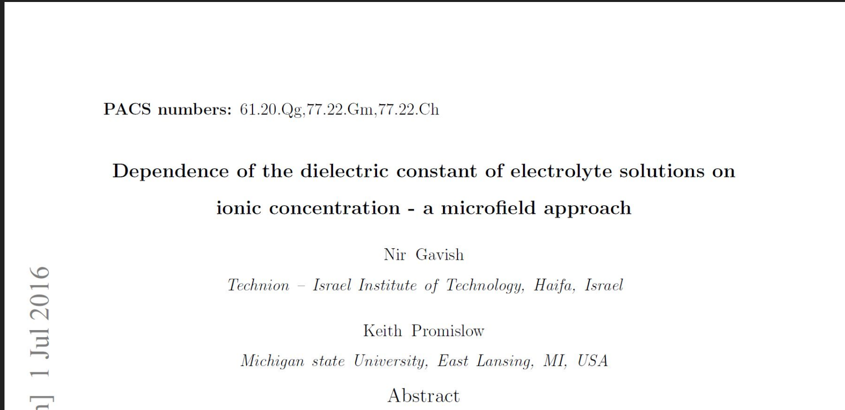
Modelling the system

Here, the independent variable is [NaCl] in blood. As such, we investigate the effects of a change in [NaCl] to electrical properties of blood that is detectable.

The permittivity (or dielectric constant) of aqueous NaCl solution is given by

$$\varepsilon_r = \varepsilon_\omega - \alpha[\mathrm{NaCl}]$$

on the condition that [NaCl] < 1.5 M, where α is the total excess polarization of the ionic species. The permeability, μ of water is approximately 1 and is independent on [NaCl] (in CST's material library the permeability for pure water and sea water is the same).



PACS numbers: 61.20.Qg,77.22.Gm,77.22.Ch

Dependence of the dielectric constant of electrolyte solutions on ionic concentration - a microfield approach

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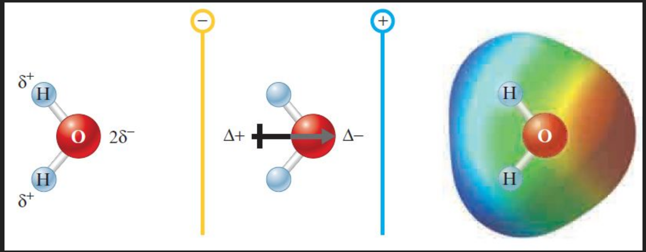
n] 1 Jul 2016

Abstract

Permittivity of NaCl solution



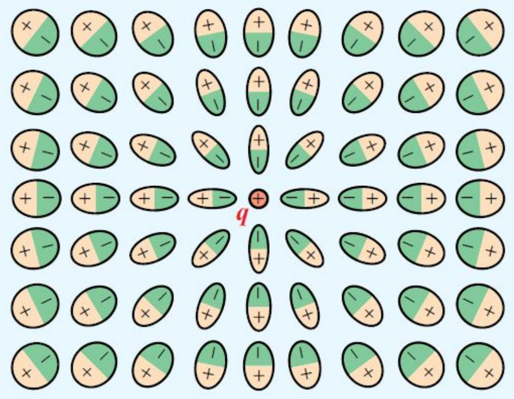


Figure 1-7 Polarization of the atoms of a dielectric material by a positive charge *q*.

Due to the difference in electronegativity and the positioning of atoms, water is a polar compound.

On the other hand, NaCl is an ionic compound that dissociates into Na^+ and Cl^- ions in water.

The presence of Na^+ and Cl^- ions in water will cause the polarization and repositioning of water molecules, with a net dipole moment.

Permittivity of NaCl solution

Due to the presence of Na^+ and Cl^- ions, the electric field in the water due to a charged particle in water is greater. Considering the relationship we have derived from Coulomb's Law,

$$\vec{E} = \hat{R}\frac{q}{4\pi\varepsilon R^2}$$

permittivity $\mathcal{E}$ decreases.

Using experimental data obtained for α, the value is:

$\alpha = 11.7\ M^{-1}$ and $\mathcal{E}_w = 78.3$.

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Article

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pubs.acs.org/JPCB

Dielectric Decrement for Aqueous NaCl Solutions: Effect of Ionic Charge Scaling in Nonpolarizable Water Force Fields

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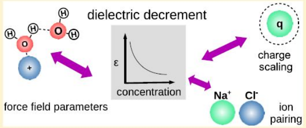
Supporting Information

ABSTRACT: We investigate the dielectric constant and the dielectric decrement of aqueous NaCl solutions by means of molecular dynamic simulations. We thereby compare the performance of four different force fields and focus on disentangling the origin of the dielectric decrement and the influence of scaled ionic charges, as often used in nonpolarizable force fields to account for the missing dynamic polarizability in the shielding of electrostatic ion interactions. Three of the force fields showed excessive

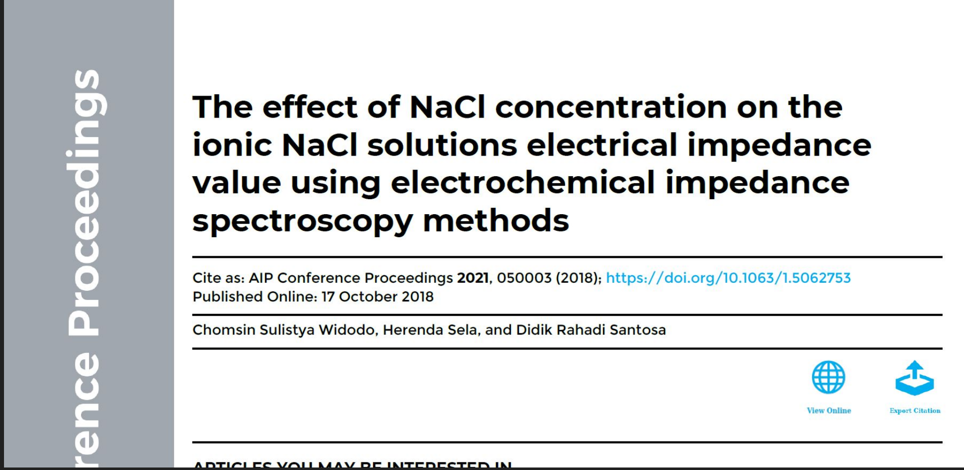


Modelling the system

Researchers have conducted experiments and found out that the conductivity of NaCl solution can be well approximated using

$$\sigma = 0.1673\,[\mathrm{NaCl}] + 2.3381$$

The regression coefficient of $R^2 = 0.9926$ shows that a strong linear correlation between conductivity and [NaCl] exists. This is especially true for [NaCl] from 0 mM to 200 mM.



rence Proceedings

The effect of NaCl concentration on the ionic NaCl solutions electrical impedance value using electrochemical impedance spectroscopy methods

Cite as: AIP Conference Proceedings **2021**, 050003 (2018); https://doi.org/10.1063/1.5062753
Published Online: 17 October 2018

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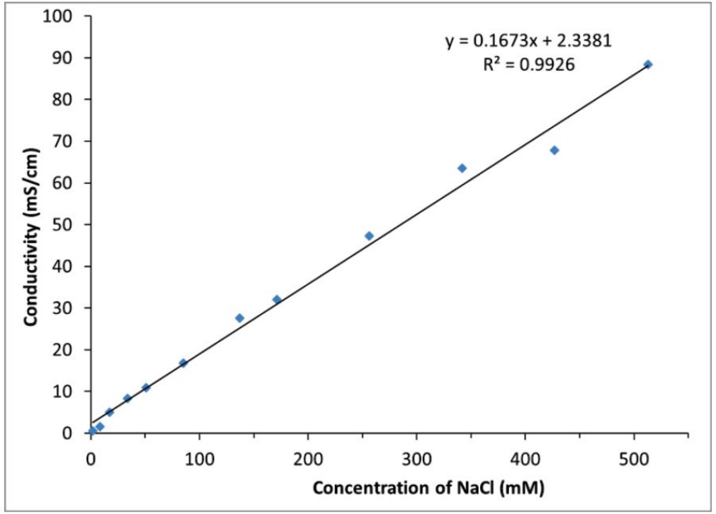
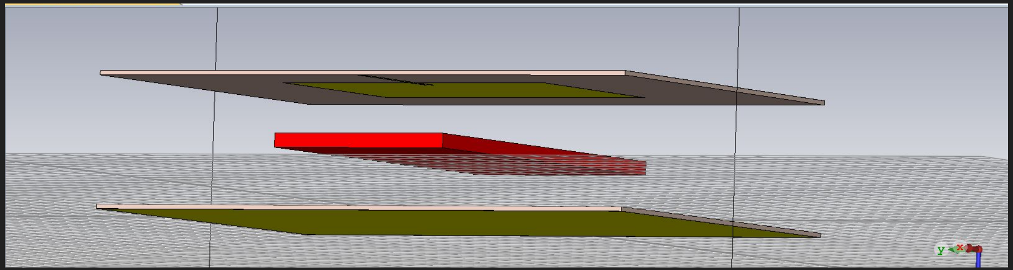


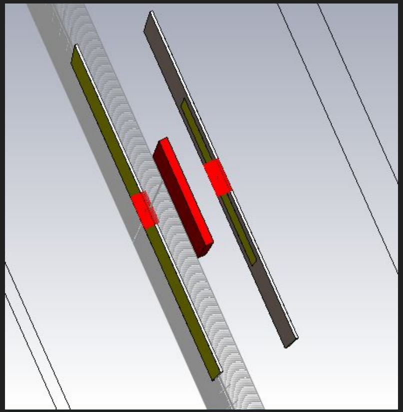
FIGURE 4. The plot of the Conductivity of NaCl aqueous at various percentage NaCl mass.

Proposed prototype

Two microstrip patch antennas will be placed in parallel to each other.

One of the microstrip patch antenna will be the receiving (Rx) antenna. The other microstrip patch antenna will be the transmitting (Tx) antenna. The Rx antenna will emit a electromagnetic wave of frequency 916 MHz. The S1,2 (or S2,1) parameters will be observed and used to make a conclusion on the user's hydration level.





Parameter List

Name		Expression	Value	Description	Type
alpha	=	11.7	11.7		Undefined
c	=	140/1000	0.14	NaCl concentration	Undefined
d	=	12.7	12.7	Microstrip feed	Undefined
di	=	5	5	Vein diameter	Undefined
epsilon	=	epsilonwater - alpha * c	76.662	Solution permittivity	Undefined
epsilonwater	=	78.3	78.3	Pure water permittivity	Undefined
f	=	916	916	Frequency	Undefined
g	=	0.5	0.5	Microstrip feed	Undefined
h	=	1.55	1.55	Dielectric height	Undefined
L	=	79.65	79.65	Patch height	Undefined
Lf	=	32	32	Microstrip feed	Undefined
midpoint	=	th/2	22.5		Undefined
mu	=	0.999991	0.999991	Solution permeability	Undefined
sigma	=	(0.1673*c*1000+2.3381)/10	2.57601	Solution conductivity	Undefined
t	=	18/1000	0.018	Patch antenna thickness	Undefined
th	=	45	45	Wrist thickness	Undefined
W	=	101.5	101.5	Patch width	Undefined
Wf	=	2.3	2.3	Microstrip feed	Undefined
wi	=	65	65	Wrist width	Undefined
<new parameter>					

$S_{1,1}$ $S_{2,1}$ parameters

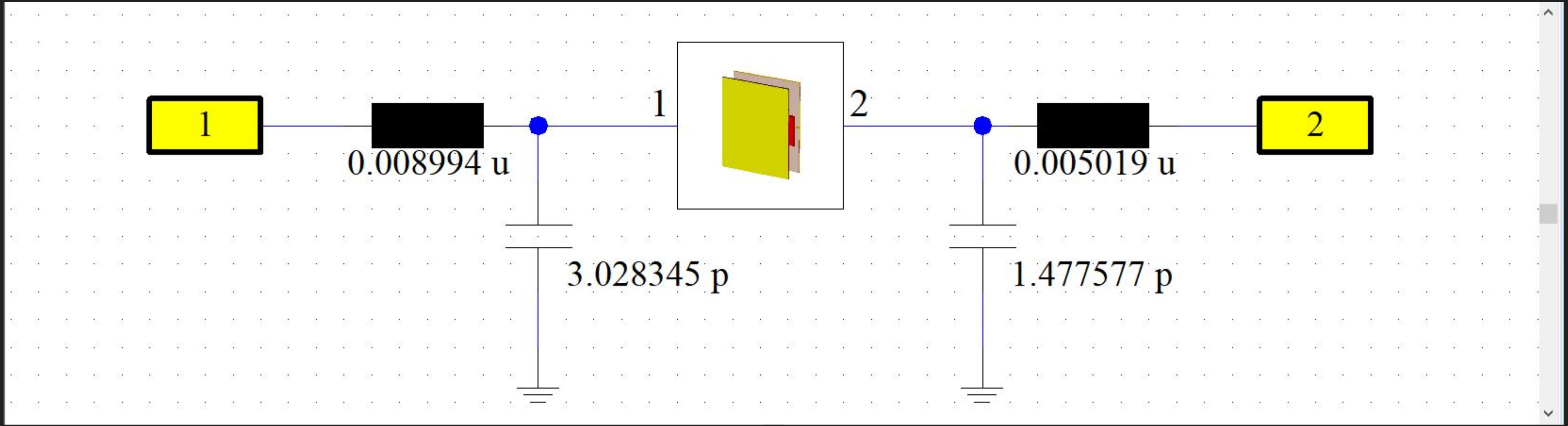
S-parameters describe the input-output relationship between between the ports

$S_{1,1}$ (and $S_{2,2}$) is the amount of power reflected to the port, therefore it represents the reflection coefficient

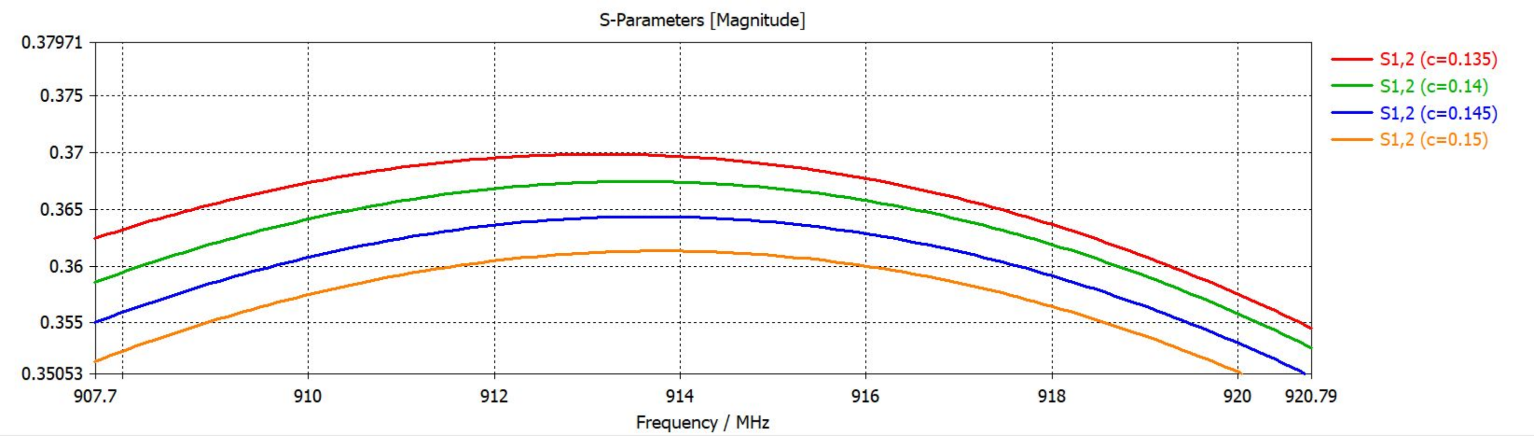
$S_{1,2}$ is the power transferred from port 2 to port 1

$S_{2,1}$ is the power transferred from port 1 to port 2

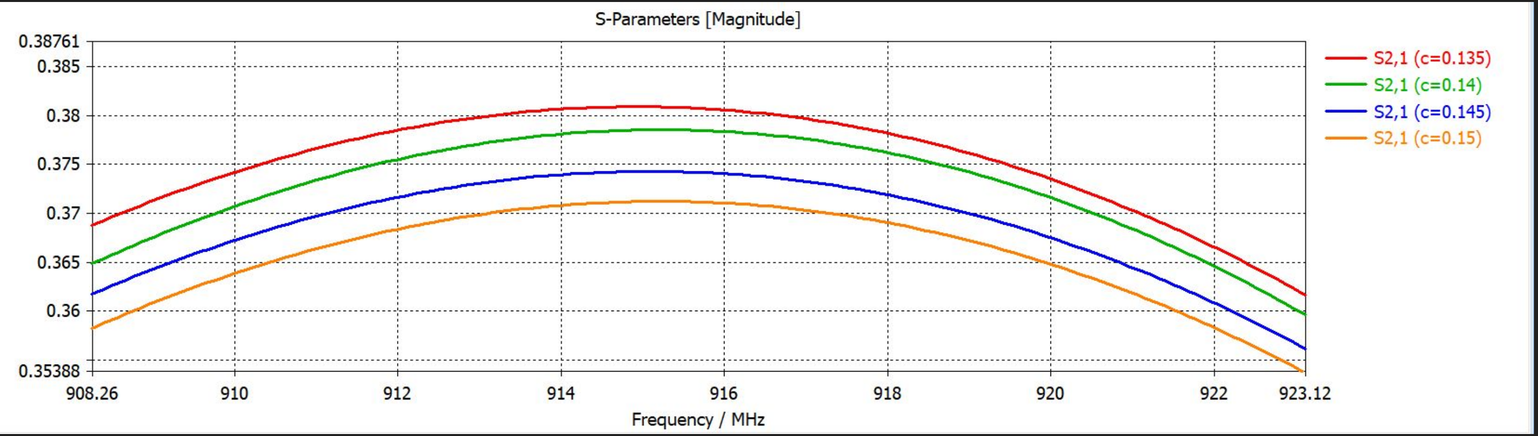
We will get one of the antennas to resonate at a frequency of 916 MHz using impedance matching. It was designed to resonate at 916 MHz when $[NaCl] = 140\ mmol\ dm^{-3}$.



Before impedance matching,

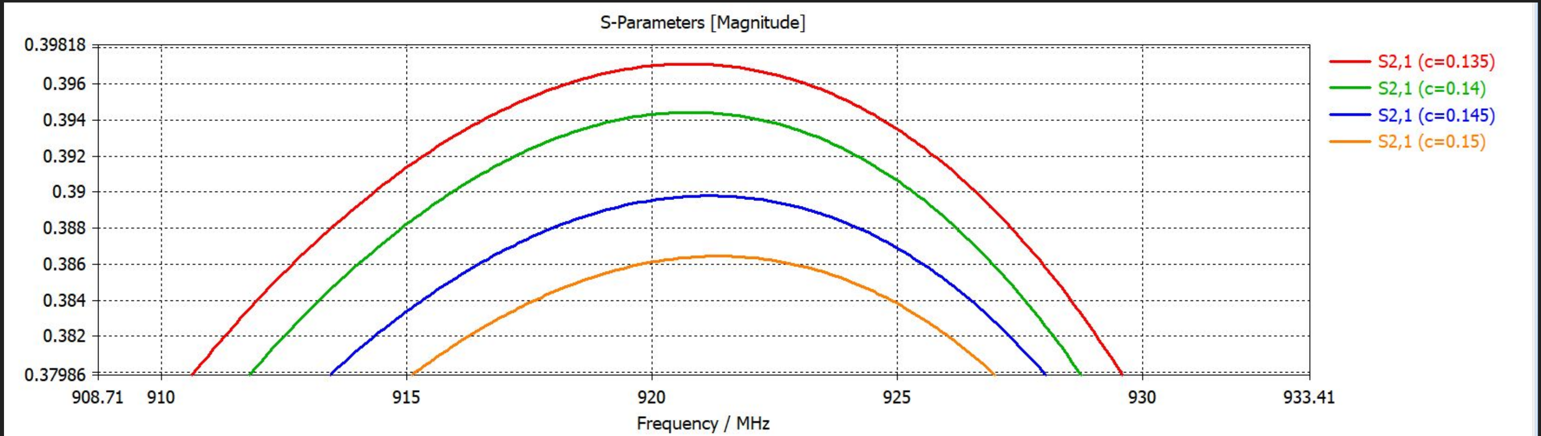


S2,1 parameters

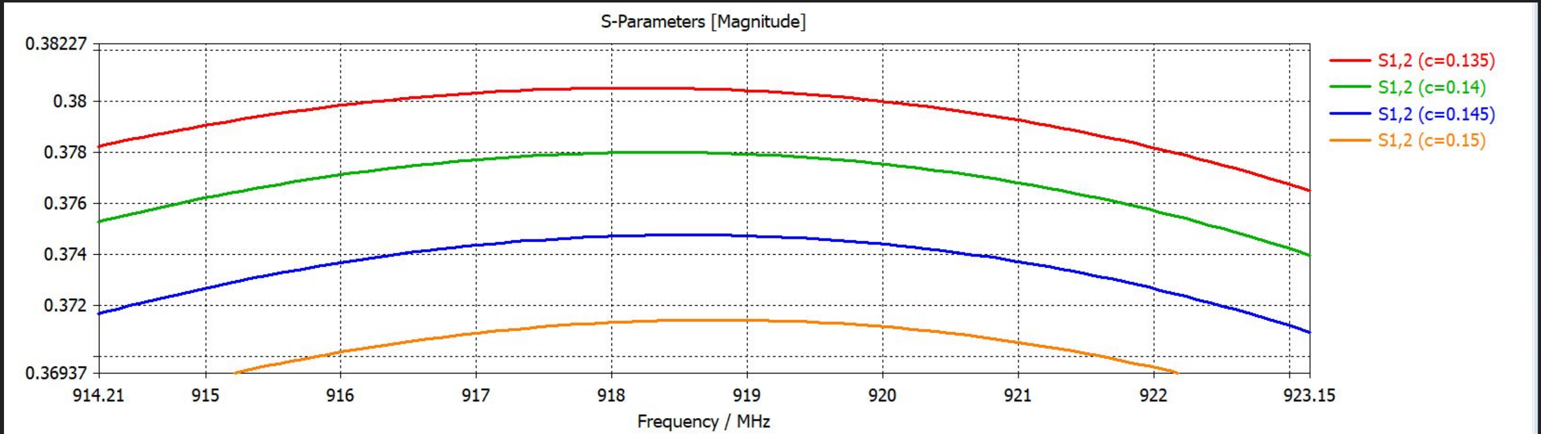


S1,2 parameters

After impedance matching,



S2,1 parameters



S1,2 parameters

Future improvement

- End product is to be wearable technology
- Include the material surrounding the device (the containment unit)
- Band to allow wearer to wear product on the wrist
- This allows active feedback during activity

Further research - Multipath propagation

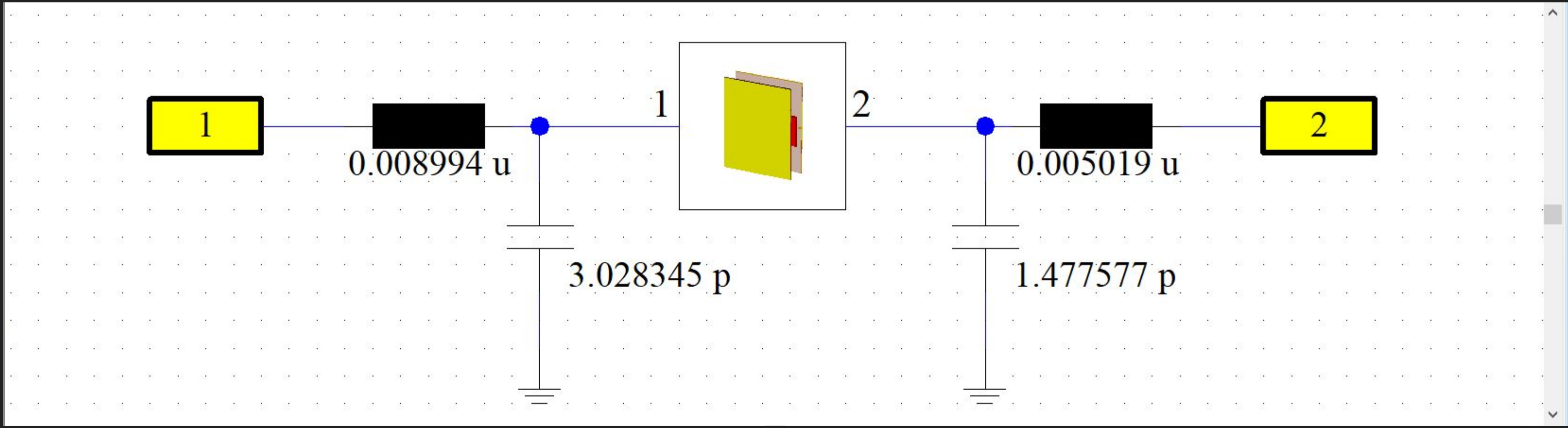
Multiple of the same signal will reach the receiver at slightly different time

Fading of the transmitted signal

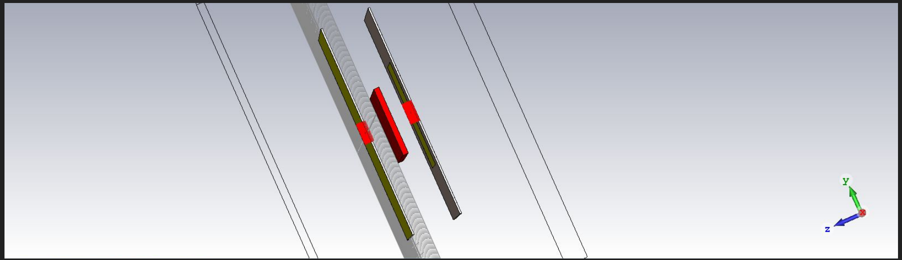
- Reflection
- Diffraction
- Scattering
- Refraction

Reduce reflectors in the environment

MIMO - multiple output, multiple input



1
0.008994 u
1
2
0.005019 u
2
3.028345 p
1.477577 p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