Measuring Transmembrane Potential of Myelomas Hypridoma cell culture in Radio Frequency Spectrum

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***Abstract*—This article explores using dielectric spectroscopy in an attempt to measure the trans-membrane potential of synthetic cells in radio frequency spectrum. The purpose of this test is to "mimic" a capacitor with the cell suspension acting as a dielectric. This is a non-invasive way to measure the average membrane potential across your cell suspension and has been proven in [1] for frequencies up to $10^5 Hz$.**

I. Implications of Membrane Potential

Although there may be many implications of transmembrane potential at radio frequencies, the focus of this example is in disease models. In the late 1930's it was suggested that a relationship lie between cancer and the bioelectric properties of host tissue. Interestingly, membrane voltage (V_{mem}) analysis in many different mammalian cell types reveals that proliferative potential is correlated with unique ranges of V_{mem} : quiescent cells tend to be hyperpolarized, whereas highly plastic cells such as embryonic cells,adult stem cells and tumors cells are depolarized. [4]. During the early stages of tumor formation, V_{mem} is a key regulator of the cell cycle and determines the proliferative state of many different kinds of cells. These statements excite the possibility of non-invasive techniques being used to track bioelectric cell states and detection of tumors, or even mitigation of tumor formation by canonical oncogene.

II. Hypothesis

III. Calculating Membrane Potential

We model the impedance of the cell suspension as a resitor $R = d/\sigma A$ in parallel with a capacitor $C = \epsilon A/d$, where σ and ϵ are the conductivity and dielectric permittivity of the cell suspension and A and d are the surface area of the two disk electrodes and the distance between them.

$$\sigma(\omega) = Re\frac{d_1 - d_2}{A(Z_1^O - Z_2^O)} \tag{1}$$

$$\epsilon(\omega) = Im\frac{d_1 - d_2}{\omega A(Z_1^O - Z_2^O)} \tag{2}$$

Electrode distance variation technique:

$$\begin{aligned} \mathcal{Z}_1^S - Z^P &= Z_1^O \\ \mathcal{Z}_2^S - Z^P &= Z_2^O \end{aligned} \tag{3}$$

$$Z_1^S - Z_2^S = Z_1^O - Z_2^O \tag{4}$$

Where Z^S is the sample impedance, Z^P is the unknown polarization impedance, and Z^O is the measured impedance.

I have been assured by Dr.Dharmakeerthi Nawarathna that equation (1) and equation (2) are sufficient in finding the potential of the solution.

IV. Distance Between Plates:

With regards to near and far field transmission. The most agreed upon definition of near field transmission is less than one wavelength(λ) away [3]. If we consider a sinusoidal wave traveling at a constant speed, we can calculate wavelength with the following formula ...

$$\lambda = \frac{v}{f} \tag{5}$$

Where v is the magnitude of the phase velocity and f is the frequency of the sinusoid. It is difficult to determine the phase velocity of our electromagnetic wave while propagating through our cell suspension, but if we consider water, we can make a prediction of the wavelength. The velocity of EM waves is more than 4 orders faster than acoustic waves according to [2]. Knowing that the speed of sound is $343.2 m/s$ we can say ...

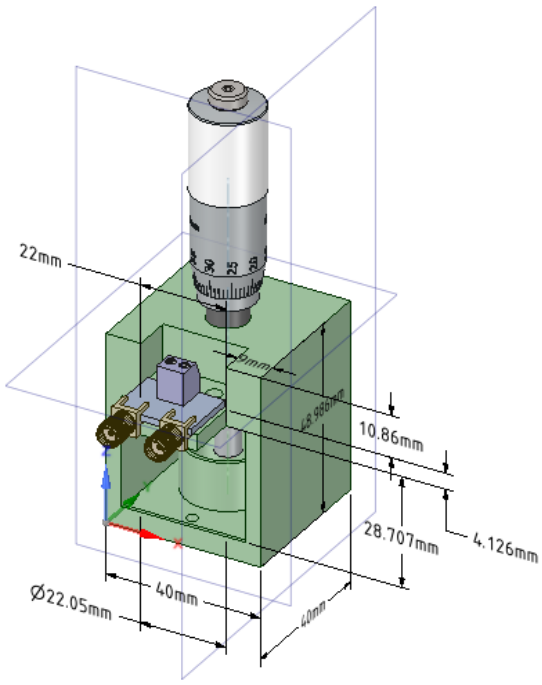
$$\lambda = \frac{343.2 \cdot 4}{10^9} = 1.3728 \times 10^{-6} m \tag{6}$$

Water is a good basis for the phase velocity as the cell suspension is made from deonized water and synthetic cells. I used $10^9 Hz$ as our frequency, which is in the radio spectrum. Our micrometer is sensitive to $10 \mu m$, thus our test fixture will be capable of measuring only waves 10 times greater than the fundamental wavelength, meaning far field transmissions will be measured. This is a satisfactory result, as the far field is the "real" radio waves, that propagate through space at just about the speed of light [3].

V. Materials

A. Copper Plates

Two copper plates $3/4\, inch$ in diameter will be used. One plate will be fixed to the bottom of the beaker and the other is attached to a micrometer. To create the copper plates a hole puncher will be used.



B. Copper Wire Leads

Two wires will be attached to the copper plates. The wire attached to the fixed bottom plate will be attached to the center and run through the bottom of the test fixture to later be attached to a network analyzer.The second wire will be attached to top plate on one of the edges and run up the side of the beaker to be attached to a network analyzer. These two wires will provide the radio frequency signal and the probes to be attached to a network analyzer.

C. 3-D printed Beaker

A 3-D printed beaker will be made to perfectly fit the test fixture. The beaker will be made of ABS plastic and is used to hold the cell suspension and two copper plates. It will be placed in the center of the Test fixture stand.

D. Micrometer

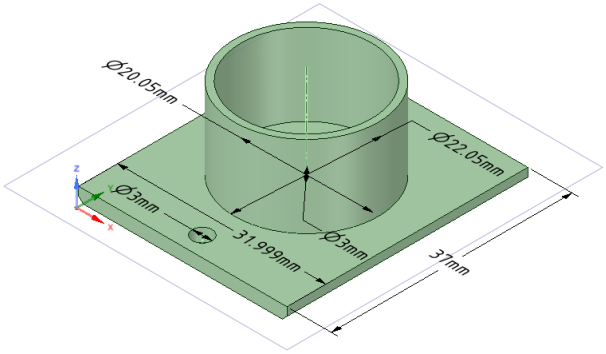
A micrometer will be used to adjust the height of one of the copper plates. The micrometer will be attached to the test fixture stand, and the drive of the micrometer will be attached to one of the copper plates. A micrometer cap will be 3-D printed in ABS plastic to perfectly fit the micrometer and later be adhered to the copper plate.

E. Test Fixture Stand

Provide a base for the beaker as well as an accurate and stable micrometer mount.This item will be 3D printed with ABS plastic.

F. Cells

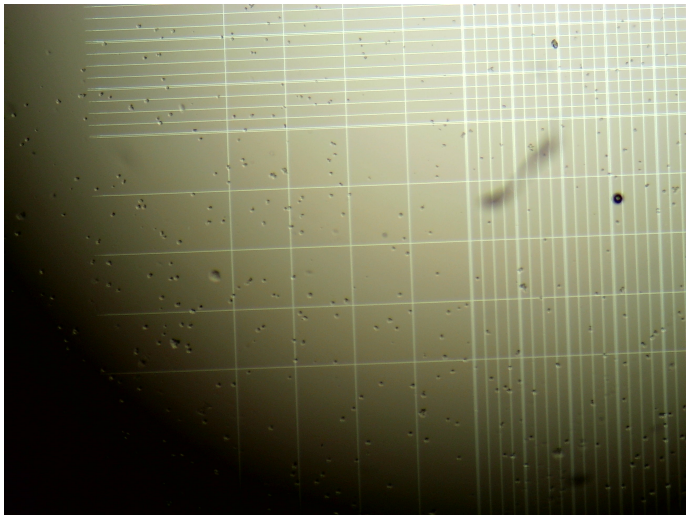
SP 2/0 myelomas hypridoma cell line. These are nonadherent cells, and are essentially cancer cells from mice.[6] They are rated at biosafety level 1. This level is suitable for work involving well-characterized agents not known to consistently cause disease in healthy adult humans, and of minimal potential hazard to laboratory peronnel and the environment. Reasearch with these agents may be performed on standard open laboratory benches without the use of special containment equipment and it is not necessary for Biosafety level 1 labs to be isolated from the general building.[5]



VI. Methods

A. Cell Concentration

The cell concentration will be measured using a hemocytometer. An example of the process of counting the cells can be seen in figure



VII. Conclusion

The reason for the test fixture is to hold a beaker dish and adjust the height between the two parallel copper plates. In order to be as accurate as possible a micrometer will be attached to the top copper plate and then attached to the top of the test fixture. This will allow us to accurately set the parallel plate distance and also change the height as needed.

VIII. Acknowledgement

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References

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