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Direct Measurement of the Envelope Generated by Temporal Interference and Phase Modulation Interference during Electrical Stimulation: Measurements using a Tissue Phantom

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***Abstract*— Interferential stimulation is attracting attention as a method of noninvasive brain stimulation. In this study, the envelope waveform generated by the interference was visualized, and their dependence on spatial location was discussed.**

***Clinical Relevance*— This study facilitates a deeper understanding of noninvasive therapeutics with interferential stimulation from the spatiotemporal perspective.**

I. Introduction

In recent years temporal interference (TI) has been proposed as a technique to enable noninvasive brain stimulation [1]. In TI, two sinusoidal waves with slightly different frequencies of electric fields are applied to two pairs of stimulating electrodes. The resulting envelope generated by the interference of two waves evokes neural excitation in the area distant from the stimulating electrodes. More recently our group proposed another interferential stimulation called phase modulation interference (PMI, [2]) which enables precise temporal control of interferential stimulation. The spatial distribution of the envelope modulation amplitude $\boldsymbol{E_{AM}}$, which corresponds to the intensity of interferential stimulation, has already been reported in the literature [1][2]. However, not only the $\boldsymbol{E_{AM}}$ but the waveforms of the envelopes and their dependence on the spatial location are essential to facilitate further understanding of interferential stimulation. In this study, we directly observed the envelope waveforms of PMI and discussed their dependence on spatial locations.

II. Methods

A 24 mm diameter counterbore filled with saline was used as the tissue phantom (Fig. 1). Two pairs of electrodes placed on the sidewall of the counterbore were connected to the external current sources. Sinusoidal current waves with frequency of 2000 Hz were applied to the two electrodes (electrode 1 and 2 in Fig. 1). The phase difference between the two sinusoidal waves applied to electrode 1 and 2 was zero or π to induce PMI [2]. The electric field strength was recorded via a recording electrode using an oscilloscope. Experimental details are described in [2].

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III. Results

The largest amplitude of the carrier wave in the Y direction was observed at the location which was closest to the stimulating electrode (P_2 in Fig. 1), however, the $\boldsymbol{E_{AM}}$ in the Y direction was smaller compared to the amplitude measured on the centerline between electrode 1 and 2 (P_3). The $\boldsymbol{E_{AM}}$ in the Y direction was almost zero at the location distant from stimulating electrodes (P_3). At P_3, the phases of the envelope between X and Y direction were opposite.

IV. Discussion & Conclusion

We successfully visualized the envelope waveforms at different spatial locations. The difference of $\boldsymbol{E_{AM}}$ in the Y direction between P_1 and P_3 suggests that the interference was evident only at the location where the current amplitude from electrode 1 was close to that from the electrode 2. There were locations where the amplitude of carrier wave was relatively large, and the $\boldsymbol{E_{AM}}$ was small (such as P_2). Further investigation is necessary whether such a large-amplitude carrier wave leads to unintentional neural excitation ,as discussed in [3].

References

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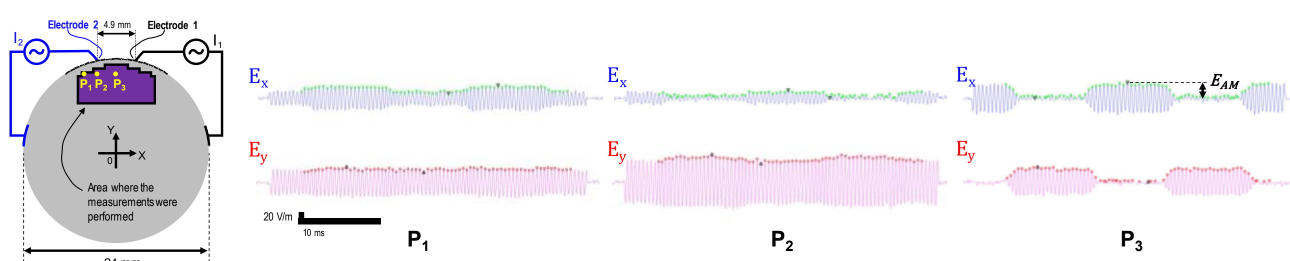

Figure 1. (Left) Top view of the tissue phantom. (Right) The electric field strength of PMI measured at points P_1, P_2, and P_3. The blue lines and red lines represent the electric field strength of horizontal direction and vertical direction respectively.

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