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Experimental Study of Brain Activity on ECVT-Based Motor Movements

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ABSTRACT

This study investigates the characterization of brain signals in response to motor stimulation using the principle of Electrical Capacitance Volume Tomography (ECVT). The experiment was conducted on a 21-year-old male subject, who was exposed to motor tasks (hand gripping and imagined movement) and audiovisual stimulation (watching a film), alongside control conditions with water and air. Data acquisition was performed using an ECVT helmet sensor at frequencies of 500 kHz, 1 MHz, and 5 MHz. The results revealed variations in vpp values across different conditions, with the highest sensitivity observed at 500 kHz during imagined movement. These findings indicate that internal motor imagery elicits stronger brain activity compared to resting or external stimulation. Overall, the study demonstrates that ECVT is capable of distinguishing brain signal characteristics under different types of stimulation, with 500 kHz identified as the optimal frequency for sensitivity.

Keywords:
ECVT; Brain Signals;Motor Stimulation;Characterization;Frequency.

Introduction

PT. Ctech Lab Edwar Teknologi is a technology-based company that has positioned itself at the forefront of innovation in medical and industrial imaging systems. In the era of rapid technological advancement, the development of software and tomographic imaging techniques has become increasingly crucial, particularly through global collaborations such as its partnership with The Ohio State University, United States. The company has pioneered the development of Electrical Capacitance Volume Tomography (ECVT) and Electro-Capacitive Cancer Therapy (ECCT), two breakthrough technologies that have significant implications both in industrial applications and in the medical field. ECVT, as a tomographic imaging system, is designed to electronically manage the transmission and reconstruction of three-dimensional permittivity distributions within a scanned medium. Its applications range from monitoring industrial processes to providing non-invasive diagnostic and therapeutic tools in healthcare. In parallel, ECCT represents a novel therapeutic modality for cancer treatment, offering a safer and more energy-efficient alternative to conventional therapies (Purwo, 2015).

The development of ECVT reflects the company's strong commitment to sustainability, efficiency, and precision control. Within the medical domain, the integration of this technology represents a smart adaptation of industrial tomography principles to enhance the performance and reliability of medical devices. By emphasizing cancer treatment, PT. Ctech Lab Edwar Teknologi has established itself as a key innovator in the healthcare sector, dedicated to improving diagnostic accuracy, therapeutic effectiveness, and overall patient care through advanced technological solutions (Goktas & Grzybowski, 2025).

From a safety perspective, ECVT demonstrates considerable advantages over traditional imaging methods such as CT-Scan, MRI, or ultrasound. Whereas CT utilizes ionizing X-rays, ultrasound relies on high-frequency sound waves, and MRI employs strong magnetic fields, ECVT operates by generating low-intensity electric fields. The power supply required for ECVT is approximately 220 V, yet the electric field intensity delivered to the human body is only around 87

V/m—well below the World Health Organization (WHO) safety threshold of 5000 V/m. This feature highlights not only the innovative character of ECVT but also its safety and suitability for continuous use in medical imaging (Aminatun et al., 2023).

Complementing this imaging technology, ECCT emerges as an alternative cancer therapy that applies alternating current (AC) electric fields within the frequency range of 100–300 kHz at remarkably low intensities. Unlike radiotherapy, which requires high-voltage X-ray sources (10–300 kV), or chemotherapy, which relies on chemical agents with systemic side effects, ECCT is powered by as little as two AA batteries (1.5 V each). This low-frequency, low-intensity approach opens new opportunities for targeted, efficient, and minimally invasive cancer therapy. By reducing potential adverse effects while maintaining therapeutic efficacy, ECCT embodies a significant advancement in cancer management strategies (Handayani, 2012).

Taken together, the integration of ECVT and ECCT illustrates a paradigm shift in medical technology development. ECVT provides non-invasive, safe, and accurate imaging for characterizing biological tissues, while ECCT offers a groundbreaking therapeutic option that reduces reliance on high-risk conventional treatments. These innovations not only position PT. Ctech Lab Edwar Teknologi as a strategic contributor to both industrial and medical sectors but also demonstrate how technological breakthroughs can bridge diverse domains to create sustainable, patient-centered healthcare solutions (Lee et al., 2025).

Methods

Tools and materials

The tools and materials used in this research consist of several components designed to support data acquisition and analysis. A laptop was employed as the central control unit as well as the storage medium for measurement results. Microsoft Excel software was utilized for data processing and analysis. The core instrument, ECCT, was integrated with an Arbitrary Function Generator to provide test signals required for the experiment. A Hantex device was also used as a supporting measurement instrument. The connections between devices were established using T-connectors, BNC connectors, and cables to ensure system stability. In addition, an oscilloscope was employed to visualize and analyze signal waveforms in real time.

The data acquisition process in this study was conducted on a single male subject aged 21 years. The experimental design consisted of three stimulations applied directly to the subject and two stimulations applied to the helmet, with each stimulation administered for a duration of three minutes. To minimize potential artifacts and ensure measurement reliability, the subject was seated in a controlled position, wearing footwear to prevent unintended grounding, and instructed not to hold any objects throughout the experiment.

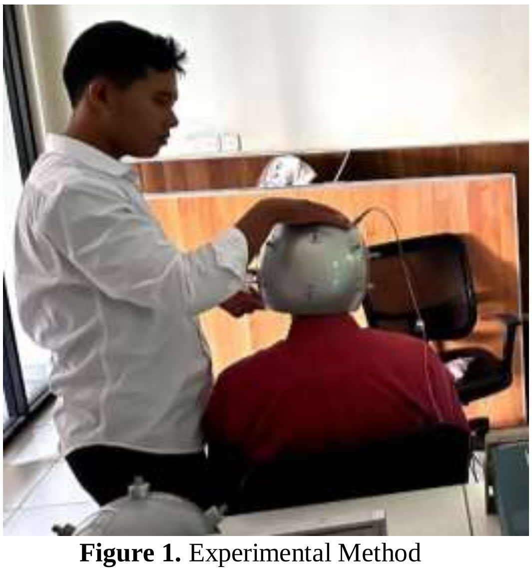
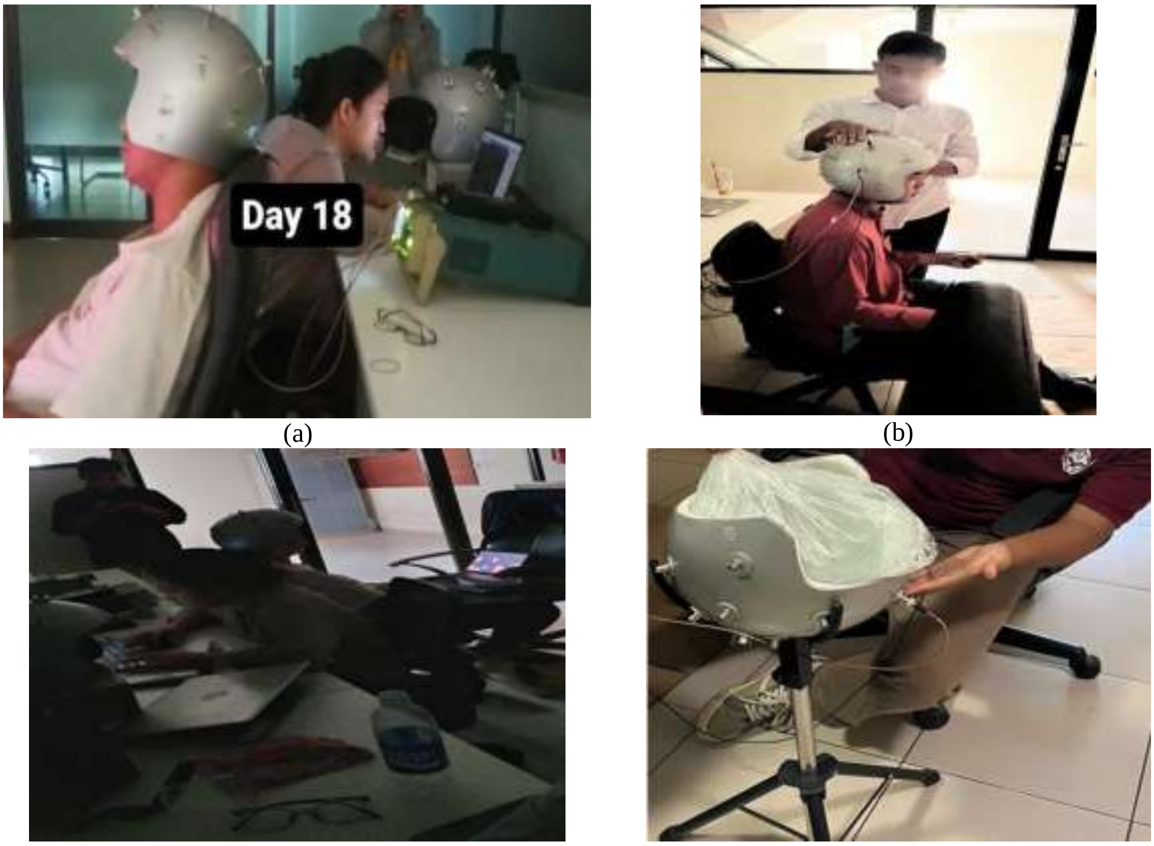


Figure 1. Experimental Method

Figures 1 through 5 illustrate the different experimental conditions. Specifically, Figure 1 depicts the baseline experimental setup, while Figure 2 represents the condition in which the subject was instructed to mentally simulate a hand movement. Figure 3 shows the state when the subject physically clenched his hand, whereas Figure 4 demonstrates the condition when the subject was provided with water. Finally, Figure 5 corresponds to the resting or neutral condition without any applied stimulation or task.

The selection of these conditions was intended to capture distinct neural responses associated with both motor imagery and motor execution, as well as to evaluate potential physiological changes under external stimuli (such as water intake). These variations provide a comparative framework for analyzing brain activity patterns recorded by the ECVT system, thereby offering insights into the system's sensitivity in detecting subtle cognitive and physiological changes in the subject.



(a) (b)

(c) (d)

Figure .2 (a) Thinking about Hand Movements (b) Holding (c) Watching Movies with Music (d) Water Stimulation

The latest ECVT sensor (Figure 3) demonstrates the capability to detect brain activity in the upper region of the head as well as in some surrounding areas; however, certain other regions remain difficult to capture in the reconstructed images. This limitation arises from variations in sensor sensitivity across different parts of the system, with the upper region exhibiting higher sensitivity and therefore being more effectively covered by the sensor array. During the experimental procedure, the helmet-shaped sensor was positioned directly on the top of the subject's head, whereas on the lateral sides it did not maintain direct contact. Consequently, the distance between the sensor and the head was smaller in the upper region and larger in other areas.

The shorter distance between the sensor and the upper part of the head allows for more accurate detection of brain activity, which in turn produces higher permittivity values in the reconstructed data. By contrast, the increased distance in other regions remains a significant constraint, leading to incomplete detection of changes in those areas within the images. This highlights the importance of sensor positioning and sensitivity distribution in ensuring the accuracy and reliability of brain activity monitoring using the ECVT system.

Figure 3. Brain Scanning System Based on 16-Electrode ECVT

Results and Discussions

Frequency Data Results 500 kHz, 5 MHz, 1 MHz Various ECVT Channels

Based The sensitivity matrix of the ECVT Helmet Sensor, consisting of 16 electrodes, demonstrates robust performance, as evidenced by the variations in electric field distributions across different electrode pairs. These distributions, presented in the corresponding tables, represent the effective sensing regions of the system within a 16×16×16 voxel framework. The variations indicate that the ECVT system is capable of capturing distinct electrical responses under different experimental conditions, which is a critical factor in validating its effectiveness for brain activity monitoring.

Specifically, Tables 1, 6, and 11 illustrate sensitivity during hand-grasping tasks, reflecting localized field responses associated with motor execution. Tables 2, 7, and 12 show sensitivity during motor imagery, demonstrating the ability of the sensor to detect subtle cortical activations related to cognitive motor planning. Tables 3, 8, and 13 display sensitivity when the subject was exposed to audiovisual stimulation (a strawberry-themed video accompanied by music), which corresponds to broader cortical engagement triggered by multimodal stimuli. In contrast, Tables 4, 9, and 14 highlight sensitivity to water, which acts as a conductive medium and enhances the field interaction patterns. Finally, Tables 5, 10, and 15 depict sensitivity under empty or air conditions, providing a baseline response for comparison.

Table 1. Frequency 500 kHz Gripping

14_6	14_12	14_13	14_15	16_8	16_9	16_10	16_15
10.028	10.039	10.027	10.024	10.027	10.028	10.031	10.016
10.031	10.036	10.035	10.02	10.033	10.027	10.036	10.011
10.024	10.036	10.036	10.024	10.027	10.031	10.031	10.016
10.028	10.035	10.036	10.02	10.027	10.027	10.035	10.016
10.024	10.036	10.035	10.017	10.033	10.027	10.031	10.016
10.024	10.039	10.036	10.017	10.027	10.024	10.035	10.019

Taken together, these findings confirm that the 16-electrode ECVT helmet sensor can effectively discriminate between diverse mental and environmental conditions. This robustness underscores its potential as a non-invasive tool for analyzing brain activity, supporting further applications in neuroscience and biomedical engineering research.

Table 2. Frequency 500 kHz Thinking Movement

14_6	14_12	14_13	14_15	16_8	16_9	16_10	16_15
10.027	10.035	10.035	10.024	10.027	10.035	10.039	10.03
10.036	10.035	10.035	10.024	10.031	10.035	10.035	10.028
10.030	10.035	10.035	10.02	10.031	10.035	10.044	10.031
10.033	10.039	10.036	10.024	10.028	10.039	10.036	10.024
10.033	10.039	10.031	10.024	10.024	10.031	10.039	10.031
10.039	10.039	10.044	10.030	10.027	10.035	10.036	10.028

Table 3. Frequency 500 kHz Watching the Movie Strawberry

3_2	3_4	3_11	7_6	7_8	7_15	3_2	3_4
9.951	9.939	9.914	9.995	10.014	10.014	9.951	9.939
9.958	9.933	9.933	10.002	10.014	10.014	9.958	9.933
9.951	9.932	9.901	9.995	10.014	10.033	9.951	9.932
9.958	9.927	9.914	9.998	10.008	10.014	9.958	9.927
9.958	9.939	9.914	10.005	10.008	10.02	9.958	9.939
9.958	9.782	9.914	10.002	10.008	10.008	9.958	9.782

Table 4. Frequency 500 kHz Water

3_2	3_4	3_11	7_6	7_8	7_15	3_2	3_4
9.672	9.727	9.638	9.722	9.719	9.711	9.672	9.727
9.672	9.719	9.683	9.719	9.719	9.716	9.672	9.719
9.667	9.727	9.680	9.722	9.719	9.715	9.667	9.727
9.854	9.704	9.854	9.726	9.879	9.867	9.854	9.704
9.857	9.704	9.848	9.726	9.886	9.726	9.857	9.704
9.857	9.700	9.704	9.722	9.732	9.876	9.857	9.700

Table 5. 500 kHz Empty Frequency

3_2	3_4	3_11	7_6	7_8	7_15	3_2	3_4
9.859	9.862	9.862	9.862	9.862	9.870	9.859	9.862
9.862	9.859	9.862	9.862	9.862	10.023	9.862	9.859
9.859	9.862	9.862	9.862	9.862	9.870	9.859	9.862
10.014	10.011	10.019	10.011	10.014	10.024	10.014	10.011
10.014	10.016	10.014	10.011	10.014	10.027	10.014	10.016
10.011	10.014	10.019	10.019	10.014	10.024	10.011	10.014

Tables 1 to 5 present the experimental results obtained from Subject A after undergoing five different treatments, measured using the ECVT sensor with Vpp values as the primary parameter. Observations across these tables reveal noticeable variations, particularly in channel 16 for motor stimulation and channel 3 for audiovisual stimulation, when compared against the control condition with water. These findings indicate that significant differences in Vpp values emerge under the various treatments applied to Subject A.

Table 6. 1 MHz Frequency Handling

14_6	14_12	14_13	14_15	16_8	16_9	16_10	16_15
9.876	9.882	9.882	9.87	9.857	9.875	9.882	9.876
9.87	9.882	9.878	9.863	9.870	9.874	9.886	9.864
9.873	9.882	9.878	9.863	9.857	9.874	9.882	9.870
9.873	9.878	9.879	9.876	9.870	9.875	9.882	9.870
9.873	9.882	9.879	9.876	9.863	9.878	9.882	9.857
9.873	9.879	9.882	9.87	9.870	9.875	9.879	9.864

Table 7. Frequency 1 MHz Thinking Movement

14_6	14_12	14_13	14_15	16_8	16_9	16_10	16_15
9.879	9.882	9.882	9.882	9.87	9.882	9.882	9.871
9.882	9.882	9.887	9.882	9.871	9.887	9.886	9.875
9.882	9.882	9.882	9.882	9.875	9.882	9.882	9.878
9.873	9.882	9.882	9.870	9.873	9.879	9.882	9.875
9.879	9.882	9.882	9.882	9.87	9.882	9.882	9.875
9.879	9.882	9.882	9.882	9.875	9.882	9.885	9.875

Table 8. Frequency 1 MHz Watching Strawberry Movie

3_2	3_4	3_11	7_6	7_8	7_15
9.813	9.788	9.757	9.845	9.87	9.863
9.82	9.776	9.769	9.848	9.87	9.864
9.807	9.788	9.763	9.845	9.87	9.87
9.813	9.788	9.763	9.848	9.87	9.846
9.807	9.776	9.763	9.848	9.857	9.846
9.801	9.782	9.757	9.842	9.876	9.864

Table 9. 1 MHz Air Frequency

3_2	3_4	3_11	7_6	7_8	7_15
9.691	9.700	9.694	9.707	9.707	9.696
9.696	9.700	9.700	9.707	9.707	9.696
9.688	9.700	9.694	9.707	9.713	9.696
9.697	9.700	9.700	9.726	9.726	9.719
9.697	9.700	9.697	9.719	9.732	9.722
9.704	9.697	9.700	9.716	9.729	9.729

Table 4. 10 Free 1 MHz Frequencies

3_2	3_4	3_11	7_6	7_8	7_15
9.859	9.859	9.866	9.862	9.862	9.870
9.859	9.859	9.862	9.862	9.862	9.870
9.862	9.862	9.862	9.859	9.862	9.870
9.859	9.862	9.862	9.862	9.862	10.027
9.863	9.859	9.862	9.862	9.862	10.027
9.863	9.862	9.866	9.862	9.862	10.024

Tables 6 through 10 present the experimental results obtained from Object A after being subjected to five different treatments, measured using the ECVT sensor with peak-to-peak voltage (Vpp) serving as the primary parameter. Careful examination of the data across these tables demonstrates that the values recorded for each channel remain essentially unchanged, indicating an absence of measurable differences among the channels. This consistency strongly suggests that the treatments applied to Object A did not introduce any significant variation in Vpp values, thereby implying that the electrical response of the object, as captured by the ECVT system, remained stable under the given experimental conditions.

Table 11. 5 MHz Frequency Handheld

14_6	14_12	14_13	14_15	16_8	16_9	16_10	16_15
8.464	8.477	8.466	8.464	8.452	8.617	8.475	8.464
8.468	8.618	8.471	8.468	8.446	8.624	8.474	8.458
8.471	8.474	8.471	8.458	8.452	8.620	8.475	8.452
8.468	8.471	8.471	8.766	8.455	8.463	8.628	8.458
8.467	8.477	8.466	8.621	8.609	8.466	8.474	8.753
8.467	8.471	8.471	8.452	8.452	8.463	8.623	8.458

Table 12. 5 MHz Frequency Thinking Movement

14_6	14_12	14_13	14_15	16_8	16_9	16_10	16_15
8.468	8.475	8.474	8.464	8.463	8.468	8.475	8.471
8.468	8.475	8.474	8.483	8.458	8.471	8.628	8.463
8.468	8.624	8.628	8.483	8.463	8.474	8.777	8.777
8.624	8.471	8.628	8.471	8.458	8.468	8.474	8.617
8.471	8.475	8.474	8.458	8.463	8.624	8.747	8.62
8.471	8.471	8.475	8.477	8.463	8.474	8.624	8.466

Table 13. 5 MHz Frequency Watching Strawberries

3_2	3_4	3_11	7_6	7_8	7_15
8.408	8.533	8.358	8.455	8.464	8.452
8.383	8.383	8.358	8.446	8.458	8.596
8.245	8.383	8.213	8.439	8.471	8.471
8.383	8.383	8.364	8.446	8.464	8.458
8.402	8.383	8.358	8.439	8.471	8.464
8.389	8.383	8.37	8.439	8.471	8.446

Table 14. 5 MHz Air Frequency

3_2	3_4	3_11	7_6	7_8	7_15
8.179	8.301	8.326	8.326	8.32	8.329
8.182	8.314	8.320	8.320	8.32	8.336
8.195	8.301	8.320	8.182	8.32	8.333
8.176	8.314	8.195	8.336	8.455	8.213
8.317	8.301	8.191	8.194	8.455	8.359
8.176	8.323	8.330	8.334	8.459	8.355

Table 15. 5 MHz Free Frequency

3_2	3_4	3_11	7_6	7_8	7_15
8.453	8.453	8.610	8.603	9.862	8.466
8.45	8.458	8.458	8.458	9.862	8.458
8.45	8.455	8.458	8.458	9.862	8.458
8.607	8.459	8.459	8.455	9.862	8.459
8.612	8.454	8.454	8.455	9.862	8.619
8.455	8.459	8.459	8.463	9.862	8.462

Tables 11 through 15 present the experimental data obtained from Object A after being subjected to five different treatments, measured using the ECVT sensor with peak-to-peak voltage (Vpp) as the primary measurement parameter. A careful examination of these tables reveals that the recorded results show no observable differences, thereby indicating that the treatments applied to Object A did not cause any significant variation in the Vpp values. This finding suggests a consistent electrical response of the object under different treatment conditions, as captured by the ECVT system.

Discussion

Based on the operational data obtained during the experimental sessions, signal frequencies of 500 kHz, 1 MHz, and 5 MHz were applied across multiple electrode channel variations. Motor stimulation was evaluated using channel pairs 15-16, 9-16, 8-16, and 10-16 in comparison to 6-14, 15-14, 12-14, and 13-14, while audiovisual stimulation was examined through channel pairs 2-3, 4-3, and 11-3 compared with 6-7, 8-7, and 15-7. The stimulation protocols included physical motor execution (hand gripping), motor imagery (imagined movement), audiovisual stimulation (film viewing), and control conditions (water and air inside the ECVT helmet).

The analysis of peak-to-peak voltage (Vpp) values revealed significant variations depending on frequency and channel configuration. Notably, the most pronounced sensitivity was observed at a frequency of 500 kHz during motor imagery stimulation, suggesting that low-frequency signals provide enhanced detection capability for subtle brain activity.

The each experimental condition yields distinct Vpp values, reflecting variations in brain activation patterns. Notably, the lowest Vpp values were recorded during the hand-gripping condition, whereas the highest Vpp response was observed during the motor imagery task. This finding aligns with the theoretical framework that suggests when the body is in a relaxed state, the brain also exhibits reduced neural activity, resulting in a lower degree of cortical excitation. Consequently, the ECVT sensors detect fewer electrical charges, leading to minimal Vpp values. Thus, during physical gripping, where motor activity is relatively stable and the brain is partially relaxed, the recorded Vpp values remain comparatively low (Blazhenets et al., 2021).

In contrast, the motor imagery condition elicited significantly higher Vpp values compared to both the gripping and audiovisual stimulation tasks. This outcome indicates that imagining movement generates greater cortical activation than passive rest or external stimulation. During the hand-gripping task, the absence of novel external input allows the brain to remain in a quasi-resting state. Conversely, during audiovisual stimulation (e.g., watching a movie with music), the brain responds to external sensory input, which elevates activity but remains limited to the processing of external stimuli (Dodakian et al., 2021). However, in the motor imagery condition, the stimulus originates intrinsically from the subject, activating motor-related cortical regions without corresponding physical execution. Such internally driven activity appears to demand greater neural resources, thereby producing a stronger Vpp response (Borràs et al., 2025).

Overall, these results suggest that motor imagery engages the brain more intensively than both passive motor execution and audiovisual stimulation, which is consistent with previous neurophysiological findings on motor-cognitive coupling (Mustile et al., 2024). The elevated Vpp values recorded under motor imagery demonstrate the sensitivity of the ECVT system in capturing subtle variations in brain activity and highlight its potential as a non-invasive tool for studying cortical responses under diverse stimulation conditions (Tedeschi, 2024) .

Conclusion

The study on the application of Electrical Capacitance Volume Tomography (ECVT) demonstrates its significant potential as a non-invasive imaging modality for both industrial and medical purposes. ECVT utilizes the fundamental principles of capacitance and electric fields to reconstruct three-dimensional volumetric images with advantages in data acquisition speed, sensitivity, and versatility. ECVT is a capacitance-based tomography system designed to integrate hardware and software for reconstructing three-dimensional permittivity distributions. This technology has been widely applied, including in the medical field, particularly for supporting cancer diagnosis and therapy. The operation of ECVT relies on measuring capacitance between multiple electrodes arranged to cover a three-dimensional sensing domain. The measured capacitance values are then processed through specialized mathematical reconstruction algorithms to map the volumetric permittivity distribution of the observed object. The study indicates that a frequency of 500 kHz provides the optimal sensitivity for detecting brain signal fluctuations, making it a recommended operating parameter for ECVT-based brain activity studies.

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Conflicts of interest

The authors hereby declare that there are no known conflicts of interest, financial or otherwise, that could have appeared to influence the results or interpretation of this study.

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