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Original article

A NOVEL METHOD FOR ANALYZING ELECTRIC FIELD DISTRIBUTION OF ELECTRO CAPACITIVE CANCER TREATMENT (ECCT) USING WIRE MESH ELECTRODES: A CASE STUDY OF BRAIN CANCER THERAPY.

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ABSTRACT

Electric field distribution analysis generated by ECCT in a human head model with or without brain cancer using wire mesh electrode has been conductedsuccessfully. The analysis of electric field distribution was done using simulation in a human head model with ECCT Apparel Helmet system type A which is three dimensional model. The electric field distribution was measured with and without a wire mesh electrode which was either passive or active using COMSOL Multiphysics 5.2 software and was then processed using MATLAB R2010a. The aim of the research was to assess the performance of wire mesh electrode in detecting electric field distribution. ECCT which is utilized in brain cancer therapy with input 10 V is able to produce an electric field with an average of 178.8 V/m. The input voltage influences electric field distribution whereas the signal frequency does not affect the electric field distribution. Wire mesh electrode which is either active or passive can measure the electric field distribution generated by ECCT that neither the active nor the passive wire mesh electrode changed the pattern of the electric field distribution and the change in the measured electric field value is not significant.

1. Introduction

Brain cancer is a malignant brain tumor that is referred to as the silent killer due to rare early signs in sufferers. Death rates caused by cancer are still relatively high according statistical data from The Surveillance, Epidemiology, and End Results (SEER) from which it can be seen that the percentage of brain cancer patients who survive for five years after being diagnosed is 33.8%. One of the causes of the high death rate is the fact that healing methods are not yet at their most effective[1].

At present, the most common methods used to cure brain cancer are surgery, chemotherapy, and radiotherapy. Their costs are a relatively high and moreover they have an adverse effect on the normal tissue. Because of this, those cancer healing methods have not been used to the fullest extent to cure cancer.

Electro Capacitive Cancer Treatment (ECCT) developed by Dr. Taruno P. Warsito is currently being developed as a therapy to destroy cancer cells using an electric field[2]. ECCT represents an electrical capacitance cancer therapy method. The method is based on the research of Yoram Palti who concluded that the growth of cancer cells could be inhibited or even turned off by the alternating electric field. The electric field can penetrate the cell membrane and affect the cell that is splitting[3].

The ECCT system for brain cancer therapy consists of a power supply that has an input voltage of around 2.4 to 3 V, a cable connector, and an apparel helmet. Markus Hardiyanto reported that ECCT with electrode configuration as shown in Figure 1 has an optimal configuration for therapy. This type is capable of generating an electric field with a wider area that can be used for cancer positioned in the majority of brain tissue[4].

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The process of tomography is used to visualize the cross-section images of the mixtures of substances flowing in the process column. Wire mesh sensor is an alternative technique to tomography systems. A wire mesh sensor is fabricated with two layers perpendicular to each other separated by a small gap which is stretched over the process column,forming the transmitter layer and the receiver layer. In the current study, a wire mesh sensor measured the instantaneous interfacial phase fraction as well as the bubble's size and fluid velocity passing through the wire mesh sensor[5]. Here we propose wire mesh sensor to analyze the electric field distribution generated by ECCT. Measurement of the electric field distribution will also be conducted by an active and passive wire mesh sensor.

2. Methods

Modeling

The modeling stage consists of the determination of the design parameters and manufacture of the design geometry. In this study, the geometries created were the geometry of the human head, the geometry of the ECCT system for brain cancer therapy and the geometry of the wire mesh sensor. All of the design geometries were created by COMSOL Multiphysics 5.2.Design parameters for the geometry of the human head used the average circumference of a grown man's head, which is around 0.55 m. For ECCT system, apparel helmet ECCT type A was used which consists of three electrodes. ECCT system was placed according to the head's geometry as shown in Figure 1. This is due to the limitations of the software which cannot detect two adjacent geometries.

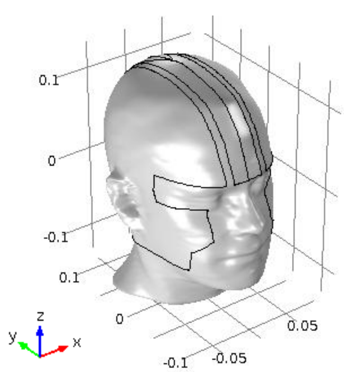


Figure 1 - Geometry design of human head with ECCT

The manufacture of a human head with anatomy and cancer geometry is shown in Figure 2. The anatomy given is a part of brain white matter at a distance of 0.02 m from the head's outer layer. A solid sphere representing the cancer is given with a diameter of 0.02 m and placed at coordinates (0; 0; 0.06).

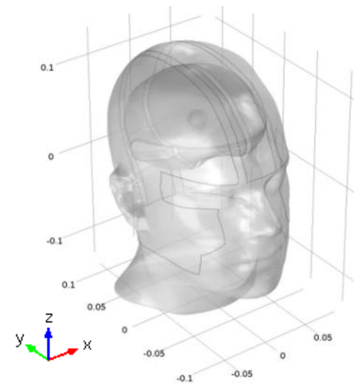


Figure 2 - Geometry design of human head, brain, and cancer

The wire mesh sensor was designed with 2 × 8 electrodes. The sensor had a set of two wire electrodes 0.13 m long and 0.0007 m in diameter and was separated by a small perpendicular gap. Two conditions of the wire mesh electrode were used to measure the electric field distribution, namely active and passive conditions. For the passive condition, the wire mesh electrode is not supplied with the input voltage and acts as a receiver as shown in Figure 3. Meanwhile, for an active condition, the wire mesh electrode is provided with the input voltage and serves as the receiver and transmitter, this means that it has a different design geometry adding 0.05 m to each of the ends of the wire mesh as shown in Figure 4.

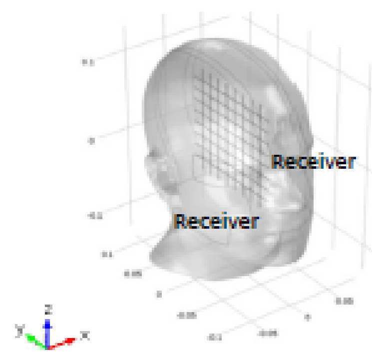


Figure 3 - Human head model with passive wire mesh electrode

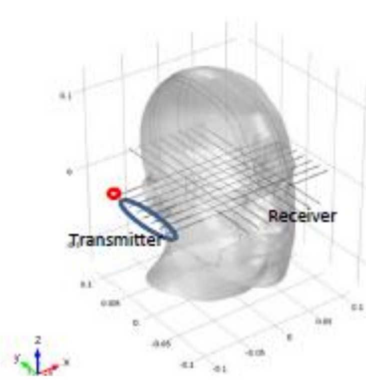


Figure 4 - Human head model with an active wire mesh electrode

Simulation
The simulation stage was performed using the electrostatic theoretical approach. At this point, the physical parameter settings are executed using COMSOL Multiphysics 5.2. The settings, namely subdomain setting, boundary setting, free mesh parameter, and solver parameter are defined. The subdomain setting stage involves the setting of the material type and physical parameters that will be used on the design geometry. The physical parameters used are relative permittivity εr and electrical conductivity σ as summarized in Table 1.

Material	Relative Permittivity		Conductivity (S/m)	
	100 kHz	200 kHz	100 kHz	200 kHz
Air	1	1	0	0
Copper	1	1	$5{,}99\times10^7$	$5{,}99\times10^7$
Brain	2107,6	1288,6	0,081845	0,086765
Cancer	2860,9	2459,1	0,53605	0,54

Table 1 - Physical parameters for subdomain setting in this study

Boundary setting is performed to limit the extension of the capacitive electrodes; ECCT electrodes and wire mesh electrode. Meanwhile, the free mesh parameter is done by setting the parameter that will be affected by the accuracy of simulation data. In this study, we used the finer size on the free mesh parameter.In the solver stage, this parameter is set to regulate the simulation parameters related tothe physics and study stage. The purpose of this simulation is to obtain the electric field distribution so,in our study we used electrostatics (es) as the physics parameter and time dependent method as the study parameter.

Data Processing
The gridding method was used for data processing. Electric field data for each mesh point were obtained in the electric field value of X, Y, and Z axes. So data processing was performed to get the resultant electric field value using MATLAB. The resultant electric field (E) can be calculated using:

$$E=\sqrt{E_X^2+E_Y^2+E_Z^2}\ (1) \quad \textbf{(1)}$$

The value of the electric field (V/m) for each mesh point is also displayed as an image using MATLAB.

3. Results and discussion

Electric Field Characteristic of ECCT
The simulation was performed to determine the electric field distribution generated by the ECCT system on the human head conducted with various geometric conditions and variations in voltage and frequency. In the first simulation, we proposed the human head model without anatomy, and in ECCT apparel helmet type A 3 dimensional modelled withthe medium as air. The input voltage was 10 V with the frequency of 100 kHz. Figure 5 shows the electric field distribution with red color indicating the highest electric field while the blue color indicates the lowest electric field.

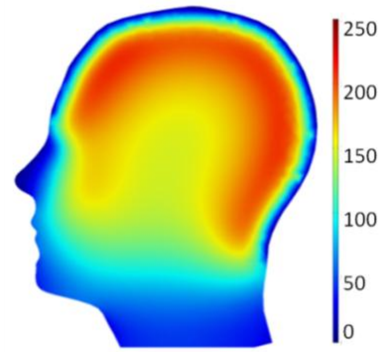


Figure 5 - Electric field distribution of ECCT at air medium

It can be seen that the highest value of the electric field was 178.8 V/m located around the head near the ECCT system. Meanwhile, the value of the average electric field was around 151.92 V/m.Furthermore, to understand the relationship of voltage and frequency of the electric field distribution generated by the ECCT apparel helmet type A, the simulation was conducted by applying a peak-to-peak voltage of 10 and 20 V with various frequencies of 100 and 200 kHz.
Analysis of the electric field profile was performed along the line of X-axis ranging from-0.028 until 0.028 at point (-0.004, 0.02) on the Y and Z axes. The increasing voltage value caused the increase in electric field value. For an input voltage of 10 V, the highest electric field value was 151.06 V/m whereas, for an input voltage 20 V, the highest electric field value was 302.13 V/m. The electric field value does not changewith frequency variations as shown in Figure 6. The blue and red lines at 100 and 200 kHz for 10 V showed the same value. The same thing also happened to the lines of green and purple for 20 V at 100 and 200 kHz. Ahmad Yulianto reported that the maximum electric field generated by frequencies of 100 Hz, 100 kHz, and 100 MHz has an insignificant value difference[4]. This fact indicates that the frequency does not influence the electric field value particularly.

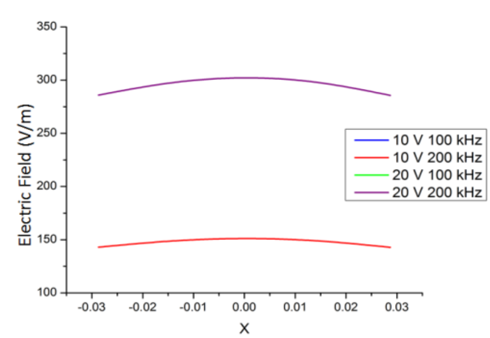
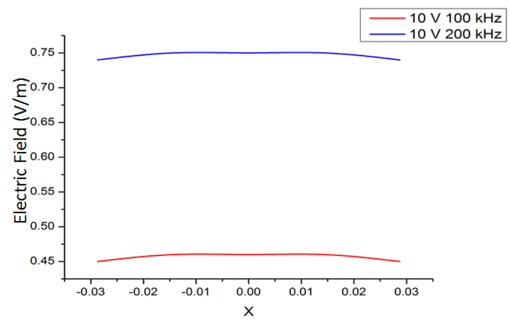


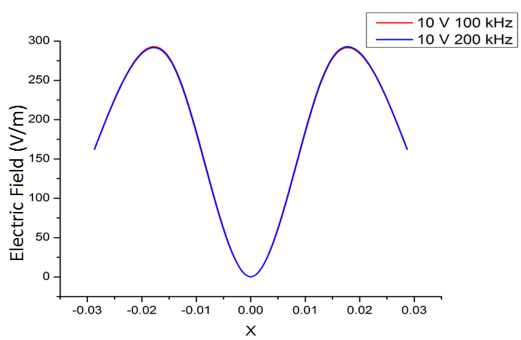
Figure 6 - Electric field profile of ECCT at air medium

Figure 7 shows the analysis of the electric field profile generated by the ECCT system on the human head with anatomy and cancer model in three condition geometries. Ahmad Yulianto reported that the relative permittivity of a dielectric medium at low frequency is higher than the relative permittivity at high frequency, so that the decrease in electric field value at low frequency is greater than at high frequency.

Moreover, the effect of frequency to relative permittivity can make the electric field value decrease at dielectric medium. The reduction of electric field value at low frequency is greater than at high frequency[4].



(a)



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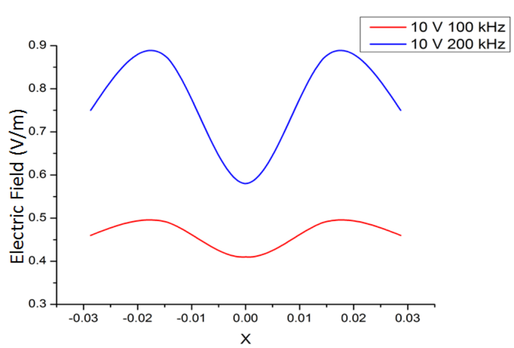


(c)

Figure 7 - Electric field profile with: (a)anatomy, (b) cancer, (c) anatomy and cancer

It can be observed from Figure 7a that the maximum electric field value for the frequency 100 kHz was 0.46 V/m while for the frequency of 200 kHz was 0.75 V/m. The electric field value obtained is minimal because the measurement line is in the brain white matter so it can be stated that the electric field profile displays the electric field distribution in anatomy.

For the electric field profile with cancer (Figure 7b) it has been seen that the electric field distribution along the measurement line was not significantly affected by the frequency variation. The electric field value of cancer was at 0.17 and 0.2 V/m at frequencies 100 and 200 kHz, respectively. The obtained small value is due to the cancer size which is small compared to the human head with air as medium.

In the electric field profile with anatomy and cancer (Figure 7c) it was revealed that the frequency affects the electric field distribution. The maximum electric field value for frequency 100 kHz was at 0.49 V/m whereas for the frequency 200 kHz was at 0.87 V/m. The value is small due to the measurement line being inside the brain white matter area that cuts the cancer center point. It is known that the maximum electric field value is the electric field value of the anatomy.

Electric Field Distribution of ECCT using Passive Wire Mesh Electrode

In this study, a wire mesh sensor is proposed as an alternative technique to tomography systems to measure fluid parameters[5]. The simulation was conducted to determine the electric field distribution using a passive wire mesh technique. Figure 8 shows the influence of the passive wire mesh electrode against the electric field distribution generated by ECCT system apparel helmet type A at dielectric medium.

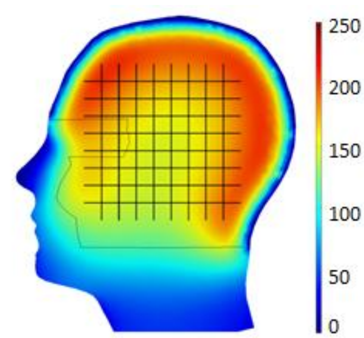
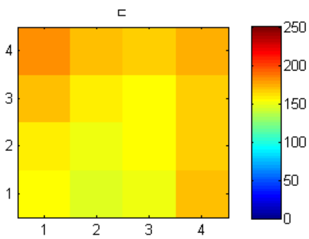


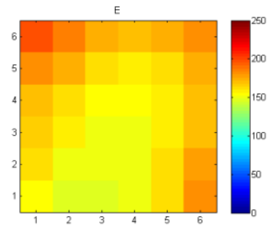
Figure 8 - Electric field distribution of ECCT with wire mesh

From Figure 8,it can be seen that the electric field distribution obtained for the placement of wire mesh electrode does not significantly affect the electric field distribution generated by the ECCT system. From the analysis, the highest value of the electric field was achieved at 178.52 V/m located around the head near the ECCT system whereas the average electric field value was 151.51 V/m. The values obtained are approximately equal to the measured value without wire mesh electrode.

The influence of the dimension of wire mesh electrode on the distribution of electric field was conducted with the variation of the size of wire mesh namely 4 × 4, 6 × 6, and 8 × 8. The comparison of image quality of the electric field distribution that generated by the wire mesh electrodes with size 4 × 4, 6 × 6, and 8 × 8 are displayed in Figure 9. The electric field values were measured at the mesh point based on their mesh size and processed using Matlab to obtain the image of electric field distribution.



(a)



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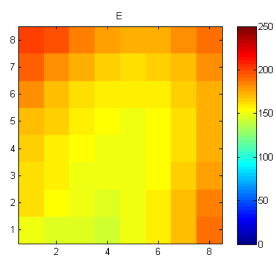

(c)

Figure 9 - Measurement electric field distribution by wire mesh: (a) 4×4, (b) 6×6, (c) 8×8

It can be seen from Figure 9, that the resolution of the electric field distribution depends on the size of wire mesh electrode used for simulation. From the comparative analysis of electric field distribution image resolution that has been conducted the greater the amount of wire mesh the closer the electric field distribution image will be to the real image from the simulation as displayed in Figure 5.

Electric Field Distribution of ECCT using Active Wire Mesh Electrode

In the previous study, M.H.F.Rahiman *et al*made a wire mesh sensor with two operating principles which are based on the measurement of conductivity or permittivity value in the investigation area[5]. This operating principle is used to determine the electric field distribution generated by the ECCT system.

The gridding methods were used to simulate data from the geometry of active wire mesh electrodes (8 × 8).The data is the actual electric field value at each point from the looping system. The purpose of this simulation is to know the influence of the active wire mesh electrode against the electric field distribution generated by the ECCT system. Figure 10 shows the results of data processing by gridding methods. The results demonstrated that the placement of the active wire mesh electrode does not significantly affect the electric field distribution. From the comparative analysis obtained, the electric field value is approximately equal to the electric field value between the electrode on the transmitter and receiver. The electric field value is also approximately equal to the electric field value generated by ECCT system.

	130.67	153.58	169.45	175.60	175.72	169.20	152.74	129.61	
	126.24	144.02	156.31	162.26	162.38	156.27	143.88	125.77	
E	127.36	140.49	149.28	154.02	153.74	149.20	140.23	127.14	E
A	132.69	140.21	146.64	150.15	149.92	146.50	139.83	132.36	A
R	135.03	141.18	146.85	149.92	149.85	146.80	141.07	134.64	R
	135.21	143.24	149.98	152.88	152.74	149.73	143.39	135.07	
	136.56	149.77	157.56	159.00	158.81	156.80	149.33	137.65	
	157.55	172.07	173.37	166.85	166.37	172.93	172.74	159.84	
	NOSE								

(a)

	130.27	153.27	169.39	175.82	175.73	169.13	152.91	129.92	
	126.15	144.20	156.44	162.26	162.19	156.25	143.98	125.90	
E	127.45	140.52	149.44	153.99	153.94	149.30	140.31	127.23	E
A	132.76	140.25	146.61	150.10	150.06	146.49	140.07	132.54	A
R	135.03	141.20	146.76	149.79	149.74	146.64	141.02	134.81	R
	135.30	143.32	149.71	152.66	152.61	149.58	143.13	135.07	
	137.36	149.52	156.83	158.63	158.57	156.68	149.32	137.13	
	159.05	172.54	172.27	166.22	166.16	172.07	172.20	158.85	
	NOSE								

(b)

	129.21	151.26	167.10	174.07	173.92	166.93	150.93	128.85	
	125.11	142.89	155.18	161.29	161.21	155.06	142.64	124.86	
E	125.39	139.36	148.73	153.58	153.54	148.64	139.15	125.15	E
A	130.15	139.20	146.26	150.14	150.11	146.16	139.00	129.94	A
R	133.42	140.30	146.62	150.12	150.08	146.54	140.13	133.22	R
	133.00	142.09	149.58	153.18	153.15	149.48	141.91	132.79	
	131.96	147.07	156.38	159.25	159.17	156.28	146.84	131.72	
	158.61	167.15	170.63	166.74	166.65	170.43	166.81	158.15	
	NOSE								

(c)

Figure 10 - Electric field values at each mesh point: (a) ECCT geometry, (b) ECCT geometry with an active wire mesh between transmitter and receiver, and (c) ECCT geometry with an active wire mesh on receiver

4. Conclusions

Wire mesh electrodes have been successfully used as a novel method for analyzing electric field distribution generated by Electro Capacitive Cancer Treatment (ECCT). ECCT is used in brain cancer therapy with the input of 10 V capable of generating an electric field distribution with an average electric field value of around 178.8 V/m. The electric field distribution is only affected by the voltage input and is not affected by the input signal frequency. The electrical field distribution generated by ECCT system can be measured using the active wire mesh electrode through 8 receiver tips that are measured by looping whereas the passive wire mesh electrode can be measured through 24 receiver tips without looping. Wire mesh electrode which is either active or passive can measure the electric field distribution generated by ECCT that neither the active nor the passive wire mesh electrode changed the pattern of the electric field distribution and the change in the measured electric field value is not significant.

References

1. SEER. SEER Stat Fact Sheets: Brain and Other Nervous System Cancer. National Cancer Institute. 2016. Web address at http://seer.cancer.gov/statfacts/html/brain.html.
2. Yunita Kusuma Handayani. Efektivitas Penggunaan Electro Capacitive Cancer Treatment (ECCT) dalam Terapi Kanker Payudara. Skripsi. Universitas Indonesia. June 2012. pp. 6-19.
3. Yoram Palti. Method for Selectively Destroying Dividing Cells. Patent Application Publication. US 20070033660A1. 8 February 2007. pp. 1-3.
4. Markus Handriyanto. Efektivitas Electro-Capacitive Cancer Treatment (ECCT) untuk Kanker Otak. Skripsi. Universitas Indonesia. May 2013. pp. 10-35.

5. M.H.F. Rahiman et al. Initial Study of a Wire Mesh Tomography Sensor for Liquid/Gas Component Investigation. Universiti Malaysia Perlis. June 2015. pp. 1921.