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# Slot type applicator for the treatment of breast cancer by microwave ablation.

Guerrero López Geshel David[1], Cepeda Rubio Mario Francisco Jesús[1], Flores García Francisco[1], Vera Hernández Arturo[2].

1 Instituto Tecnológico de la Laguna, Blvd. Revolución y Clzda Cuauhtémoc S/N, col. Centro, CP 27000, Torreón, Coahuila 2 Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Av. Instituto Politécnico Nacional 2508, Gustavo A. Madero, San Pedro Zacatenco, CP 07360, México, D.F.

## Summary

*This paper shows the results in the investigation of thermal microwave ablation therapies for the treatment of breast cancer, this research was conducted in two stages, first a computer simulation model to predict the results of therapy in different types of tissue and second model validation by performing therapy in three different media (oil, sustito tissue and ex-vivo porcine tissue).*

*The results presented show that this type of therapy holds promise for treatment of the disease, even though research and experimentation is required before performing clinical trials for this therapy.*

Keywords: *ablation, breast cancer, microwave, finite element method, thermal therapies*.

## 1. Introduction

Cancer is a leading cause of death worldwide, an estimated 1,660,290 new cancer cases were detected in the US in 2013 (854.790 men and 805.500 women), in terms of mortality is estimated that this type of diseases caused 580.350 deaths (309.920 men and 273.430 women). In women the most common type of cancer is breast cancer cases estimated to 232.340 which represents 29% of cases of cancer in women. The estimated number of deaths from the disease number was 40.030 (410 in men and 39,620 in women). It is estimated that one in eight women will develop breast cancer in the US [1].

Surgery is the standard treatment for breast cancer in the twentieth century developed Halsted radical mastectomy, which was the main treatment for breast cancer, however studies such as [2-5] have shown that there is a better survival when a radical method. For these reasons have been investigated less radical treatments, some are radiation therapy and chemotherapy. As reported in [6], improvements in diagnostic techniques have led to the detection of smaller tumors, current therapies can have too aesthetic consequences for such early stage disease. This has led researchers to explore less invasive approaches to the treatment of the disease, one of these approaches is ablation therapy. Some of these are: laser ablation, ultrasound ablation, microwave ablation (MWA) and radiofrequency ablation (RFA).

Microwave ablation is a promising technique that can preferentially heat the cancerous tissue, since it has a high water content compared to healthy tissue [7]. The MWA produce localized tissue necrosis warming. The heating is mainly determined by the energy deposition in the tissue, but is also determined by the thermal properties of tissue. The lesion size is mainly determined by the power used and the treatment time.

At present simulations with finite element method (FEM) are a useful tool in different scientific areas. The simulation model that mimics an experimental physical phenomenon could be considered as a primary model to start different designs for improvement. Changes in geometry, materials, boundary conditions, etc., made in the model may result in new designs and better devices. This work contains a comparison between experimental results and simulations of electromagnetic fields MWA.

## 2. MWA Applicator

A slot type applicator was used, this applicator was constructed using semirigid coaxial cable UT-085 [8] and an SMA connector, the geometry of the applicator shown in Figure 1.

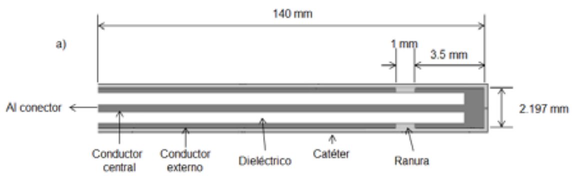


**Fig. 1 Aplicador utilizado para MWA**

This applicator was selected for its ease of construction and the good results reported in [9, 10]. The applicator dimensions were selected using the effective wavelength given by equation (1), but since the tissue properties are heterogeneous this value only for reference.

$$\lambda_{eff} = \frac{c}{f\sqrt{\varepsilon_r \mu_r}} \quad (1)$$

Where the speed of light is represented in free space (m / s), f represents the frequency of operation of the generator (2.45 GHz) εr represents the relative permittivity of the tissue and the operating frequency and μr represents the relative magnetic permeability . The material properties and cable dimensions are presented in Table 1.

**Tabla 1 Propiedades de los materiales y dimensiones del cable.**

| Parámetro | Valor | Referencia |
|---|---|---|
| Diámetro del conductor central | 0.51 ± 0.0127 mm | [11] |
| Diámetro del dieléctrico | 1.68 ± 0.0254 mm | [11] |
| Diámetro del conductor externo | 2.197± 0.0254 mm | [11] |
| Conductividad térmica | 0.42 W/m °K | [12] |
| Densidad de la sangre | 920 Kg/m$^3$ | [12] |
| Capacidad de calentamiento de la sangre | 3639 J/Kg/°K | [13] |
| Tasa de perfusión de la sangre | 0.0036 s$^{-1}$ | [13] |
| Permitividad relativa del tumor | 59.385 | [14] |
| Permitividad relativa de la mama | 5.146 | [14] |
| Conductividad del tumor | 3.156 s/m | [14] |
| Conductividad de la mama | 0.137 s/m | [14] |
| **Material** | **Permitividad Relativa** | **Referencia** |
| Dieléctrico interior del cable coaxial | 2.03 | [15] |
| Catéter | 2.60 | [9] |

## 3. Computational Model

Computer simulations were performed with software that works using the FEM, since the model has an axial geometry, it is possible to use a 2D axisymmetric modeling, representing a 3D model minimizing the computational time. Three situations for computational modeling considered in all considering the applicator inserted into a uniform weave. Tissue types used are vegetable oil, healthy breast tissue and cancer tissue. Figure 2 shows the geometry considered for simulations.

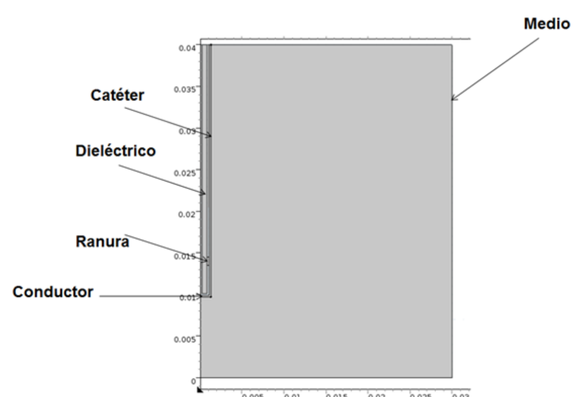


**Fig. 2 Geometría utilizada en el modelo computacional.**

The boundary conditions used are presented in Table 2, in the model is considered a power supply for coaxial port 10 watts and a frequency band ranging from 2 to 3.5 GHz.

**Tabla 2 Condiciones de frontera del modelado computacional.**

| Módulo de RF | |
|---|---|
| Parámetro | **Valor** |
| Eje z | Simetría axial |
| Alimentación | Puerto coaxial |
| Resto (exteriores) | Impedancia |
| Módulo de la Ecuación de Biocalentamiento | |
| Parámetro | **Valor** |
| Eje z | Simetría axial |
| Resto (exteriores) | Aislamiento térmico |

In each design the use of a fine mesh is recommendable to obtain better results with accuracy. However, using a fine mesh excessively can increase the computational time without necessarily increase the accuracy of the model. The size of the elements of the mesh should be selected in terms of achieving the solution converges with sufficient accuracy. Generally, mesh elements 1/10 to 1/8 of the effective wavelength, which is calculated according to the equation are used (1).

The smaller wave length occurs at the maximum frequency, in this case 3.5 GHz, at that frequency the value of the relative permittivity of healthy breast tissue is 4.93 while afflicted with a cancerous tumor breast tissue, is on average 56. According to equation (1), the effective wavelength is 38.6 mm and 11.45 mm respectively. Therefore, the maximum size of the mesh element must be less than (38.6 mm) / (8) = 4.82 mm and less for modeling healthy tissue, and (11.45 mm) / (8) = 1.43 mm when cancerous tissue is modeled. This maximum element size give a solution with sufficient accuracy within a reasonable computational time. Figure 3 shows a mesh of 65513 elements.

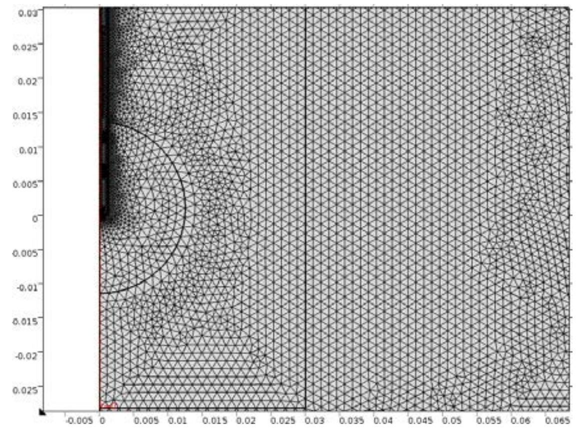

**Fig. 3 Mallado del aplicador, con un tamaño máximo del elemento de 1.43 mm.**

## 4. Experimental Validation

To validate the results of the simulation the following experiments were conducted. Firstly the applicator is inserted into a full vegetable oil container as shown in Figure 4, for the second experiment the applicator was introduced into tissue substitute for breast cancer (phantom) as shown in Figure 5 and the last experiment was performed by inserting the applicator into porcine ex vivo breast tissue as seen in Figure 6.

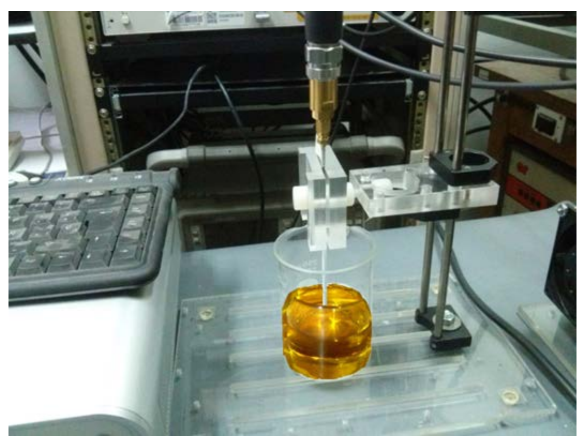

**Fig. 4 Aplicador sumergido en un recipiente con aceite.**

**Fig. 5 Aplicador insertado en Phantom de tejido cancerígeno.**

For breast cancer phantom the method propose in [16] was used, first proceeds to mixing distilled water with agarose in a beaker, then the mixture is heated to reach 80 ℃ while being agitated during heating, then ethanol and sodium chloride is added, once the mixture is stirred of the heater grid and subsequently stirred up to 40 ℃ finally the mixture is poured into a container or mold of the desired shape. For this experiment, the mixture was poured into a beaker. The concentrations used for the preparation of the phantom are shown in Table 3.

**Fig. 6 Aplicador insertado en tejido mamario porcino *ex-vivo*.**

**Tabla 3 Concentraciones empleadas para la elaboración del Phantom de tejido cancerígeno.**

| Phantom de tejido cancerígeno | |
|---|---|
| Materiales | Concentración |
| Agua bidestilada y desgasificada | 100 [ml] |
| Etanol | 60 [ml] |
| NaCl | 1 [g] |
| Agarosa | 1.5 [g] |

Measurements of the standing wave ratio (SWR) were performed with a network analyzer from Agilent E5071B ENA model. Only heating is carried out on pig breast tissue temperature measurements were made with fiber optic thermometers brand Luxtron MAR'05 STB model, which were connected to a personal computer through a terminal to acquire the same brand model 3300.

## 5. Results analysis

Figure 7 shows a comparison of the graphs of SWR for the experiment and simulation in which the applicator is immersed in oil, the value at the frequency of interest (2.45 GHz) is 5704 and 5542 for the experimental measurement and simulation, respectively the maximum difference occurs in the frequency of 2 GHz where the values are 12,438 to 10,185 for the measurement and simulation**.**

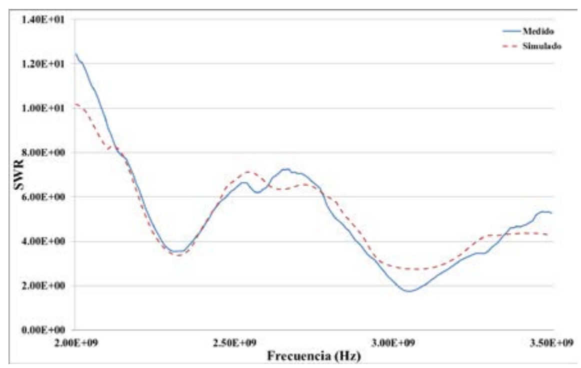


**Fig. 7 Comparación de los gráficos del SWR para el experimento y simulación en que el aplicador se encuentra sumergido en aceite.**

Figure 8 shows a comparison of the graphs of SWR for the experiment and simulation in which the applicator is inserted in phantom tumor, the value at the frequency of interest (2.45 GHz) is 2986 and 2010 for the experimental measurement and simulation respectively the maximum difference occurs in the frequency of 2.32 GHz where the values are 2.960 and 1.814 for measurement for simulation**.**

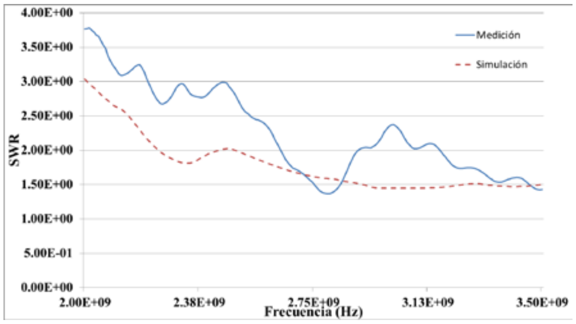


**Fig. 8 Comparación de los gráficos del SWR para el experimento y simulación en que el aplicador se encuentra insertado en Phantom de tumor.**

Finally in relation to heating the maximum temperature reached in the simulation was 93.3 ° C; while in the validation experiment a temperature of 98 ° C, the maximum radius of the lesion in the simulation was reached was 6.2 mm and the simulation ablation within 6.1 mm was achieved. Figure 9 shows the temperature distribution obtained by simulation, while Figure 10 shows the breast tissue injury in porcine ex vivo.

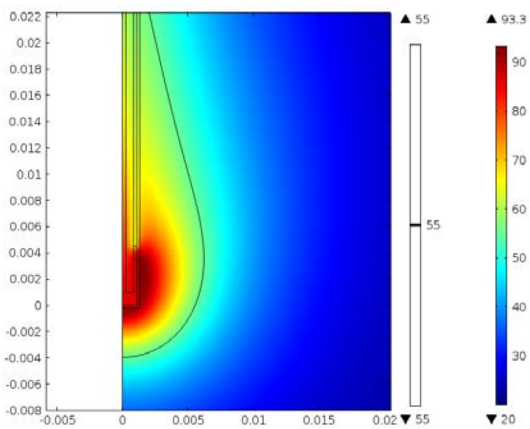


**Fig. 9 Distribución de temperatura obtenida a través de la simulación considerando el aplicador insertado en tejido mamario.**

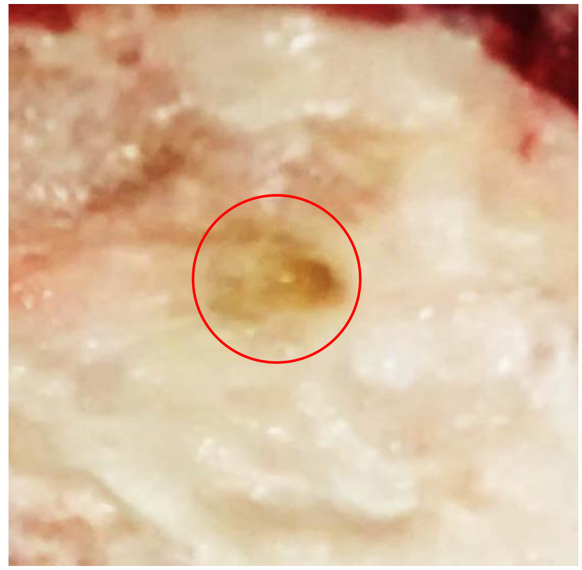

**Fig. 10 Lesión producida por el aplicador en tejido mamario porcino *ex-vivo*.**

## 6. Conclusions

When comparing the results obtained through simulation and experimental validation is concluded that it is necessary to improve the computational model, however the thermal therapy microwave ablation is promising for the treatment of breast cancer, since the lesion predicted through simulation is very close to that achieved injury and generate heat as possible throughout the volume of cancer tissue will be eradicated. It is also important to perform experiments on cancerous tissue ex vivo before you begin animal tests and clinics.

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