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Abstract. Hyperthermia is an alternative technique used to treat breast cancer using high heat, around 41℃ to 45^{0}C, to denature cancer tissue into necrotic tissue. It can work independently or in adjuvant with other conventional methods. The design of an antenna with a suitable substrate is essential for the applicator to transmit maximal heat to the intended area and distribute the heat uniformly on the treated tissues. Therefore, the inset feed microstrip antenna is design with five different substrates, simulated, analyzed, and their performance is compared to get the best substrate. The substrates used include Rogers Duroid RT5880, Rogers RO4003, FR4, Alumina and Rogers RO3010. SEMCAD X 14.8.4 software is used to design, simulate and generate SAR. RT5880 and RO4003 show better SAR distribution and focus position distance (FPD), which can be further examined for future research. 2450 MHz, 915 MHz and 434 MHz frequencies are compared to find the most suitable frequency to apply with the applicator. A 915 MHz frequency shows better performance which can penetrate more toward the cancerous areas. However, there are several deficiencies such as difficulty in controlling FPD, wide unwanted hotspot and massive skin burn problem, that needs to be improved to provide less adverse health effects due to the execution of hyperthermia treatment. The selection of suitable substrates can help reduce the deficiencies and improve the effectiveness of the hyperthermia technique. The estimated period is within 2 hours to 3.6 hours to achieve sufficient heating to destroy the cancerous cells.

1. Introduction

According to the GLOBACON 2018 statistics, breast cancer is the most common cancer affecting women, and it was reported as the second-highest leading cause of mortality rate worldwide [1]. Breast cancer caused the deaths of 627,000 people globally in 2018, and the rate of death increased to 685,000 in 2020 [2]. The number of women diagnosed with breast cancer and cancer mortality cases due to breast cancer has increased dramatically every year [3]. In Malaysia itself, breast cancer is the

first leading cause of mortality rate [2]. In conjunction with the increment of breast cancer cases, it has become the main concern among researchers globally to find alternative treatments for cancer, especially breast cancer. Hyperthermia treatment can be seen as one of the promising techniques to be used as an alternative treatment to kill and destroy cancer cells [4]. Hyperthermia can work alone or combined with other conventional methods, such as chemotherapy and radiotherapy, to speed up the treatment efficiency [5][6]. Hyperthermia has become the interest of many researchers lately as it has produced and shown many positive results and has fewer side effects than the conventional method. The usage of high heat temperatures from 40^0C to 45^0C in hyperthermia aims to destroy or obstruct the malignant tissues [7].

In the hyperthermia treatment procedure, an antenna is a crucial element since it directs the heat from the source to the treated tissues [5]. The optimized features of the antenna substrates can help in improving and enhancing the antenna performance [8][9]. Therefore, the proper selection of a suitable antenna substrate is significant in providing heat absorption effectiveness for the hyperthermia applicator, which then improves the hyperthermia execution procedure towards the targeted treated cancer tissue. By proper selection of the antenna's substrate, the FPD on the treated tissue can be improved, as well as the wide area of unwanted tissue. In this paper, five substrates such as Rogers Duroid 5880, Rogers RO4003, FR4, Alumina and Rogers RO3010, are used, investigated, analyzed and compared. The antenna substrate has a permittivity range between $2.2 \leq \varepsilon_r \geq 12$ [9]. The permittivity of RT5880, RO4003, FR4, Alumina and RO3010 were 2.2, 3.38, 4.0, 9.8 and 10.2, respectively. The thickness of the dielectric substrates retains at 1.59 mm.

A microstrip patch antenna features a lightweight, small size [10] and is suitable to be used in the research. The selection of the substrate material is important to determine the antenna performance [11]. The substrate of FR4, as the name implies, is flame retardant, where the dielectric material can cater for high heat. Rogers Duroid has low signal dispersion [12]. Alumina can cater for high heat and hardness [13], and it has a low loss signal [14]. A suitable antenna substrate can help the applicator to transmit maximal heat to the intended area. The effect of heating depends on the applicator design, temperature set up and duration of the treatments [15]. It would be great if the applicator could produce heat which can cover more cancerous areas and distribute the heat evenly on the treated area. The non-invasive hyperthermia treatment procedure applied in the research where the applicator is placed outside of the patient body. SAR is the absorption rate of heat by mass body tissues, and it is expressed in W/Kg or mW/g [16] [17]. SAR can be calculated using Equation 1 and Equation 2 [16] [18] [19].

$$\text{SAR} = \frac{\sigma \|E\|^2}{\rho} \tag{1}$$

σ: Electrical conductivity, expressed in (Sm^{-1})
ρ : Tissue density, expressed in (kg m^{-3})
$\|E\|$: Electric Field, expressed in V/m

$$\text{SAR}=C\Delta T/\Delta t \tag{2}$$

C: Specific Heat Capacity of tissue, expressed in (J^{-1}kg °C)
($\Delta T/\Delta t$): Primary time derivative of tissue temperature

2. Methodology

A few stages are involved in this research. Data received from the hospital are analyzed using DICOM software. The results are then used to get the penetration depth and focus position distance for the malignant tissues. Then, the process proceeds with the development of the breast phantom and the design of the microstrip antenna using various substrates. Three frequencies of 2450 MHz, 915 MHz and 434 MHz are used in the simulation experiments as recommended by International Telecommunication Union (ITU) application for the non-communication purpose [20].