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# Antenna Phase Optimization for Breast Cancer Hyperthermia Applications

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## Abstract

In this work, the phases of dipole antennas were optimized to focus the electromagnetic energy to a target tissue located in a simplified breast medium using an analytical approach. To perform the optimization, two dimensional model was considered. To simplify the breast model, two cylinders with fat and malignant tumor dielectric properties were considered. The dipole antennas are placed around the phantom material with 45° degrees angular spacing. The optimization was performed by selecting the phase values that wills allow focusing the electromagnetic field to target area. A Yagi-Uda antenna designed to operate from 1 to 4 GHz will be used to test the optimized phase values in the simulations and experiments.

## 1 Introduction

MICROWAVE breast cancer hyperthermia is a well-known treatment technique that can either be used as a primary or complementary method in breast cancer treatment. As a primary a treatment technique, it is utilized to increase the temperature of the tumor tissue above a target level to realize thermal necrosis. Similarly, it can also be utilized to increase the effectiveness of other primary therapies such as chemotherapy. As a complementary treatment technique, hyperthermia aims to boost the blood perfusion in the tumor tissue through rising temperature a few degrees around the breast tumor site. However, producing localized heating within breast tissue is a cumbersome task. This is usually done by focusing the electromagnetic energy to target tissue in order to heat this volume while keeping the surrounding tissues at a safe temperature.

A typical microwave breast cancer hyperthermia system includes antennas surrounding the breast in variety of configurations either as point sources or as arrays. In order to focus the electromagnetic energy to a pre-determined point within the breast volume, the antenna excitation parameters; that is, the phase or amplitude, on some occasions both, must be optimized. In fact, the phase optimization is critical to ensure focusing of the microwave power on the malignant tumor tissue.

In the literature, different techniques have been utilized to obtain the optimized parameters. The breast was modeled as a homogeneous sphere in [1]. The excitation phases were optimized through trial-error method to focus the electromagnetic power to one quarter of the breast model. Commercially available software was used for simulations. Similarly, the breast was modeled as a homogeneous sphere and a spherical tumor inclusion was placed inside the model in [2]. Eight dipole antennas was placed around the breast model with 45° **a**ngular spacing. A commercial software was used for optimization of antenna excitation amplitude and phase parameters to maximize the Specific Absorption Rate (SAR) on tumor tissue. The optimization in this work was performed with analytical approach and the optimization goal was to focus the electric field to the target area. The phase values are then evaluated in commercially available software for power, SAR and temperature verification.

## 2 Methodology

### 2.1 Optimization Scheme

Based on the previously proposed configurations, this work also employs eight antennas placed with 45° **a**ngular spacing around the breast tissue. The antennas were modelled as line sources such as dipole antennas. The breast was modelled with simplified cylindrical structures assigned the dielectric properties of breast far and tumor tissues.

### 2.2 Antenna Design

Figure 1 shows the antenna configuration. Since the targeted area of application for this antenna is the treatment of hyperthermia in breast cancer, the operating band of the antenna is designed to be in the 1-4 GHz frequency range. A balun compatible with the antenna configuration was designed to achieve a symmetrical radiation pattern. Antenna geometry consists of MS-to-CPS transition balun feed, coplanar transmission line, two identical dipole arms and three directors all printed on the front/top plane of the antenna. On the back plane, a rectangular ground plane was placed which also serves as a reflector. In order to increase impedance matching and to avoid size restrictions encountered due to SMA connectors, antenna conductor structures are placed 2 mm above the + y axis of the dielectric substrate (space between the GND and the SMA connector). The substrate dimensions of the antenna (WxL) are 56 mm x 77 mm. The microstrip patch antenna and balun design resources found in the literature were taken as reference for the design parameters, and then the desired results were achieved with optimization [3-5]. The dimensions of the balun design and the parameters of the antenna geometry and their respective dimensions are given in Table 1.

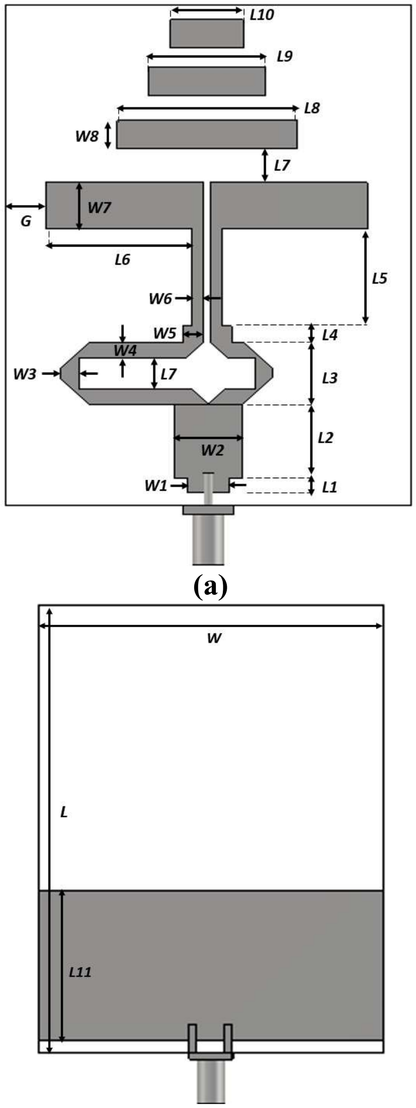


**Figure 1.** Antenna design (a) top view, (b) back view.

**Table 2.** Values of the antenna design parameters.

| Parameter | Value (mm) | Parameter | Value (mm) | Parameter | Value (mm) |
|---|---|---|---|---|---|
| W1 | 5.65 | L1 | 2.23 | L9 | 16.06 |
| W2 | 9.44 | L2 | 11.40 | L10 | 10.0 |
| W3 | 3.15 | L3 | 9.50 | L11 | 25.88 |
| W4 | 2.33 | L4 | 2.55 | L | 77 |
| W5 | 2.86 | L5 | 14.93 | W | 56 |
| W6 | 1.56 | L6 | 21.75 | G | 5.52 |
| W7 | 7.15 | L7 | 5.13 | | |
| W8 | 4.37 | L8 | 24.86 | | |

## 3 Results and conclusions

Designed antenna S-parameter results was simulated and optimized with the CST Microwave Studio Suite are shown in Figure 2. Antenna optimization will be completed. Currently, the antenna has a return loss of -15.37 dB at 1.3 GHz, -16 dB at 2.4GHz, and -14.94 dB at 3.7 GHz. The optimized antenna design and optimized phase simulations will be presented in the conference.

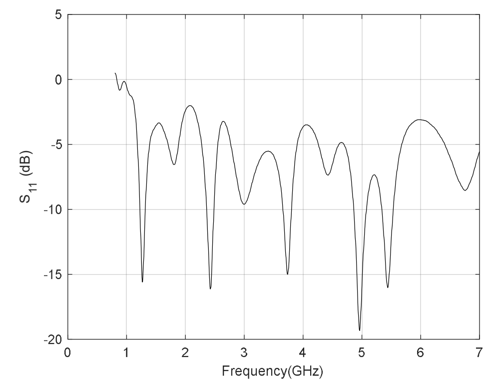


**Figure 2.** Simulated S parameter result of the antenna.

## 6 Acknowledgements

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