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Utilizing Implanted Antennas to Detect the Presence of Oral Cancers

Hammouda O.K. and Allam A.M.M.
German University in Cairo New Cairo City, Cairo, EGYPT

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Abstract

This article presents a design of spiral PIFA antenna in MICS band (402 - 405 MHz) for detecting the oral cancer. The antenna is fabricated on the Roger4350 substrate material which has a thickness of 1.524 mm and a relative permittivity of $\varepsilon_r = 3.66$ with overall dimension of 33.8 x 33.8 mm^2. The mouth is modeled according to the CST Voxel Katja model and the electrical properties of individual tissues. A human mouth model and the antenna are simulated using CST software. Testing on the face is done in three locations, left and right cheeks and under the chin. Testing on malignant tumors is only simulated on the CST. There is a noticeable resonance frequency shift of the return-loss when the malignant tissues are considered. There is a good matching between the measured and simulated results.

Keywords: Implanted Antenna, Mouth Cancer, Spiral PIFA, MICS band.

Introduction

Each year, more than a million people receive a cancer diagnosis, and the most common types of cancer include breast cancer, prostate cancer, lung cancer, and colorectal cancer. In addition to the three major types of cancer treatment ─ surgery, chemotherapy and radiation therapy ─ researchers are working to find new and more adequate ways of combating cancer[1]. Cancer, also known as malignant tumors, is the abnormal cell growth with the potential to invade or spread to other parts of the body[2,3]. Although some cancers cannot be prevented even by living a healthy life style, almost all types of cancers can be totally cured if they were diagnosed in an early stage[1]. As technology continues to change, so too does the practice of medicine. Implanted antennas would use new wireless technologies and allow for patient care to occur outside of the doctor's office by monitoring many vital statistics in the human body, including the mutation of cells into malignant tumors[4].

There are many challenges in the way of implantable antennas such as power loss in the biological tissues, the effect of the surroundings on the antenna impedance and antenna efficiency, size constraints and the difficulties of having actual measurements with the live tissues[5,6,7]. The shapes of antennas depend on their locations. Indeed there are antennas implanted internally and others implanted externally[7,8]. Electrical properties of the body tissues are frequency dependant and should be identified for the frequency of interest. The biological tissues are extremely lossy and this makes it difficult to get a reasonable level of power out of the body. In addition, it is required as impedance matching of the antenna inside the human tissue[5,9].

Safety issues Safety issues should be taken into consideration when implanting antennas inside human body referring to IEEE C95.1 standard definitions[10]. The Specific Absorption Rate (SAR) is a way of measuring the quantity of radio frequency (RF) energy that is absorbed by the body. For human body the average SAR should be below 0.8W/kg and spatial peak SAR, averaged over any 1 g of tissue, should be less than 1.6W/kg across the body. The SAR value depends on the exact location, on the geometry of the part of the body that is exposed to the RF energy and geometry of the RF source[5,7,8].

This article is devoted to design an antenna to be placed on different location of the mouth to measure its return-loss characteristics. Actually malignant tissues and healthy tissues have different electrical properties and observing the difference in antenna performance could help in early detection of oral cancer. The article contains four main sections in addition to the conclusion. Section II presents the design of the human mouth model on the. Depicted in section III is the design and fabrication of the antenna. Section IV provides the simulation and measurement results carried out on the CST model. The antenna is tested on two person's face for the healthy tissues and only the CST model for malignant tissues. Section V concludes the paper.

Design of the human mouth model

The dimensions of the oral model, based on the CST Voxel Family Katja model shown in figure 1 is depicted in figure 2. The model includes skin, muscle, fat, bone, teeth, mucosa and tongue. Table 1 shows the electrical properties of the previously mentioned mouth parts at 403 MHz frequency.

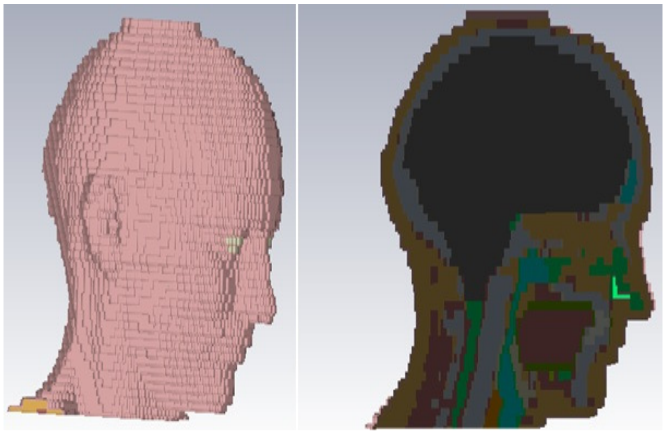


Figure-1
CST Voxel Family Katja human model, side view and cut side view

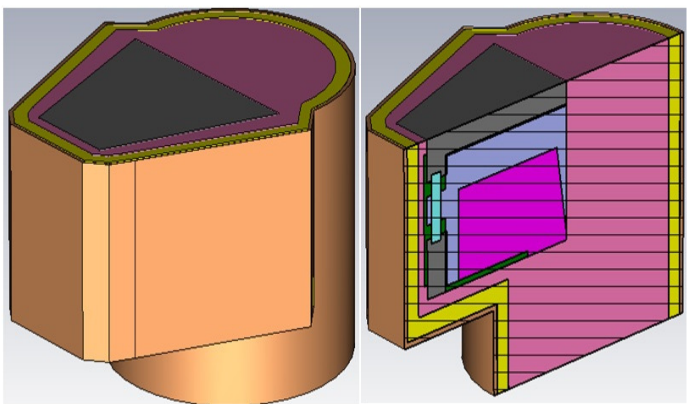


Figure-2
Abstracted mouth model, side view and cut side view

Table-1
Electrical properties of mouth tissues at 403 MHz frequency[9]

Mouth tissue	Conductivity [S/m]	Relative permittivity
Skin	0.68956	46.706
Fat	0.041175	5.5783
Muscle	0.79721	57.1
Bone	0.23526	22.423
Tongue	0.77481	57.641
Teeth	0.091647	13.139
Mouth Cavity	0	1
Mucosa	0.25	72

Design and fabrication of spiral PIFA

Planar inverted-F antennas (PIFAs) are miniature designs that offer great versatility for both mobile and wireless applications. Such antennas offer multiband, broadband operation, omni-directional radiation patterns, high efficiency and small size. The spiral PIFA is designed as shown in figure 3. The antenna dimensions are 33.8x33.8 mm^2, using the material Roger4350 substrate material whish has a thickness 1.524 mm and a relative permittivity εr = 3.66. The thickness of the ground and the top spiral strip is 0.015 mm.

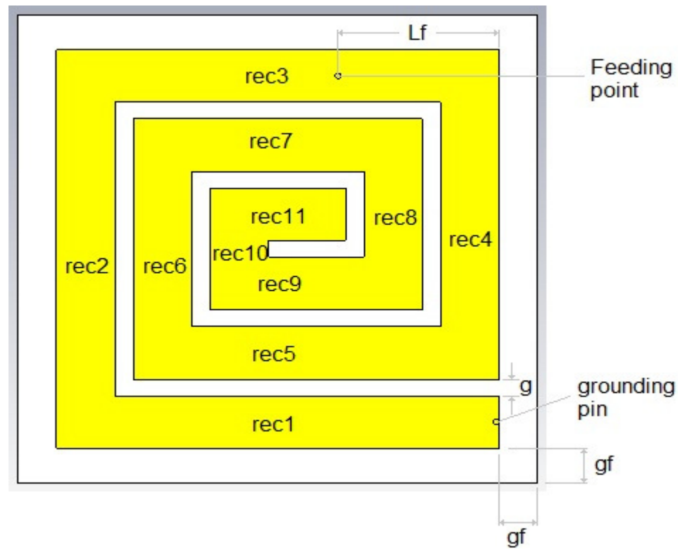


Figure-3
Top view of spiral PIFA

The distance between the copper spiral strip and the edge of the substrate is *gf* = 2.5 mm, the inner gap of the copper spiral is *g* = 1.2 mm. The grounding pin has a diameter of 0.4 mm and the feeding pin's diameter is 1 mm. The distance between the feeding point and the edge of the copper strip is *Lf* = 10.475 mm. All rectangles have a width of 3.8 mm. The length of rectangles 1, 2 and 3 is 28.8 mm, while rectangles 4 and 5 have a length of 23.8 mm and rectangles 6 and 7 have a length of 18.8 mm and rectangles 8 and 9 have a length of 13.8 mm and finally rectangles 10 and 11 have a length of 8.8 mm.

Figure 4 illustrates the manufactured spiral PIFA. The return-loss is measured in air using the network analyzer shown in figure 5. The measured result is compared to the simulated result as seen in figure 6.

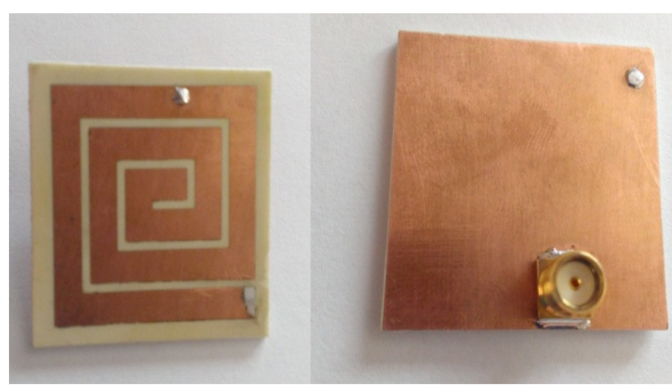


Figure-4
Top and bottom view of the manufactured antenna

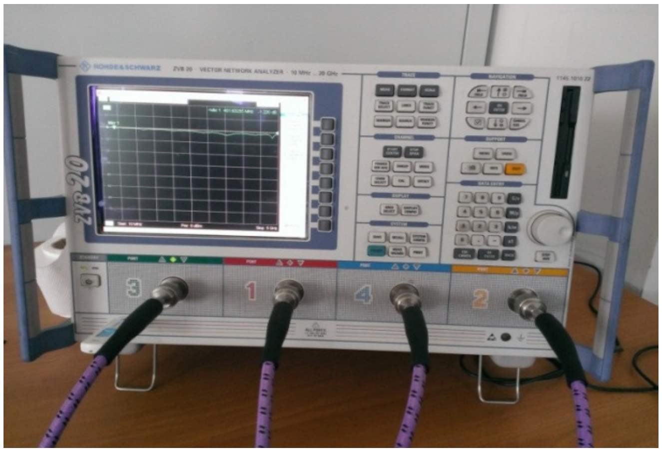


Figure-5
Network Analyzer

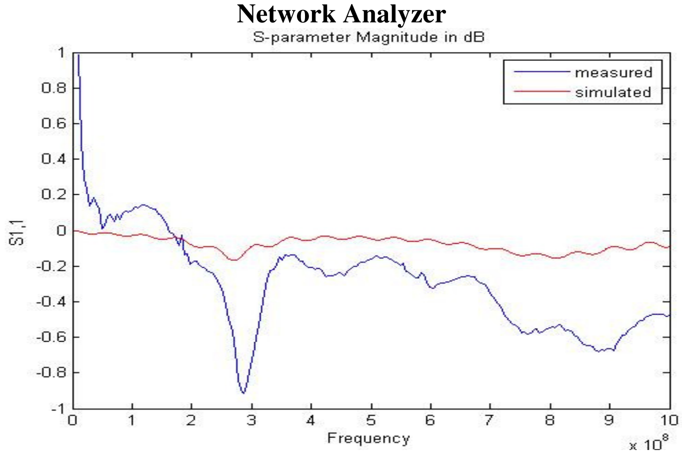


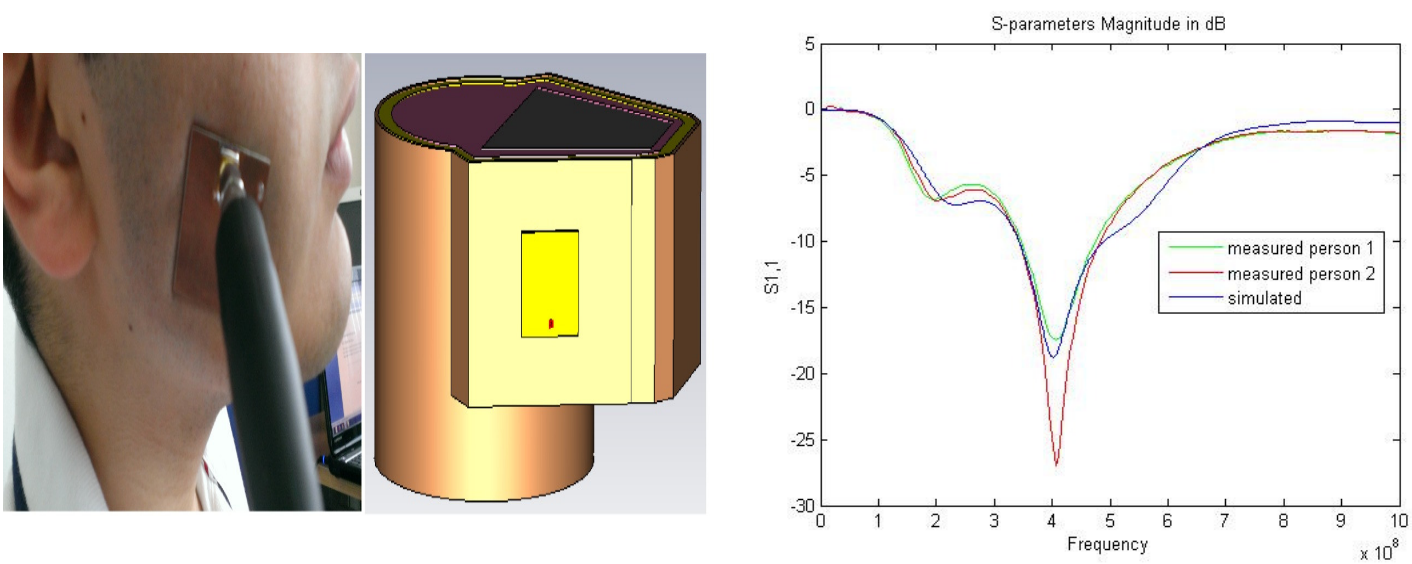
Figure-6
Return-loss of spiral PIFA in air

Simulation and measurement of spiral PIFA on mouth

The antenna is tested on healthy tissues of two different people. Three main areas of the face are tested on; left cheek, right cheek and under the chin. The results are compared with those from testing the antenna on the mouth model. Figures 7, 8, 9 show the locations where the antenna is tested and the measured return-loss compared with the simulated ones for each location.

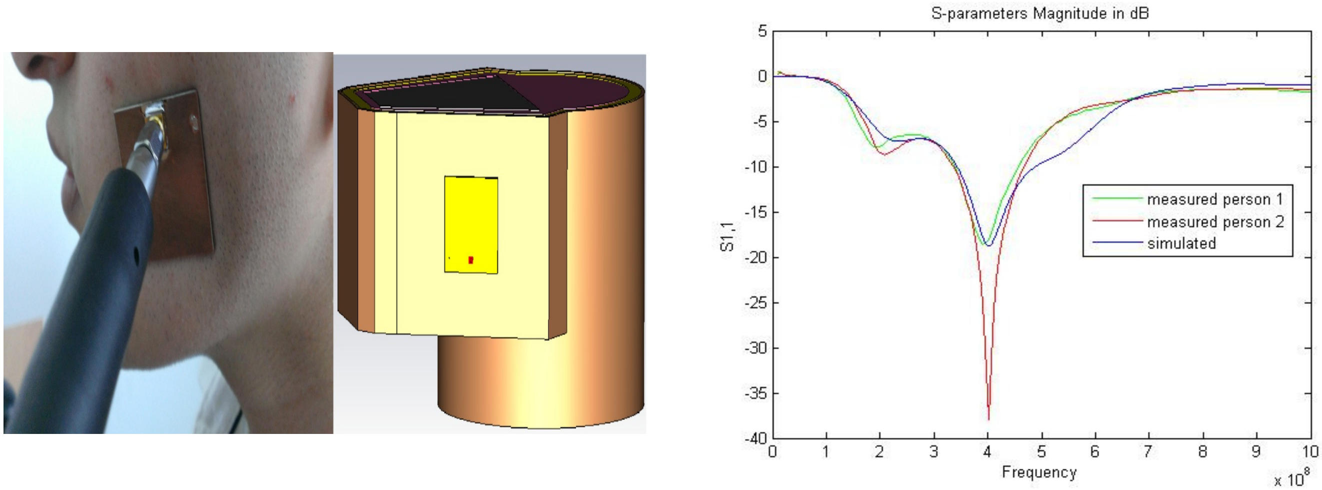
Due to the lack of any information about the electrical properties of malignant mouth tumors, an assumption is made by using the breast cancer cells electrical properties to be able to visualize the diagnosis of cancer infections in mouth. These tissues have a relative permittivity of ε_r = 67 and conductivity of 0.7 S/m. The two main locations where malignant tumors are usually found is either around the tongue or on the inner walls of the cheeks and the lips, as shown in figure 10. For the cells surrounding the tongue, they are chosen to have a diameter of 2 cm while the cells located on the inner wall of the cheeks and lips are made of 0.5 cm diameter. Figures 11 - 14 show the simulated results from the healthy mouth tissues compared with the simulated results from the defected tissues. It should be pointed out that the following results show the cancer cells covering either the right side only of the model or both sides. Also, the antenna placed under the chin did not sense the cancer cells located anywhere on the mouth model, that is why its results are excluded from this paper.

One notices that there is a resonance shift in the range of 1700 - 10500 kHz which can achieve cancer diagnosis.



(a) (b)

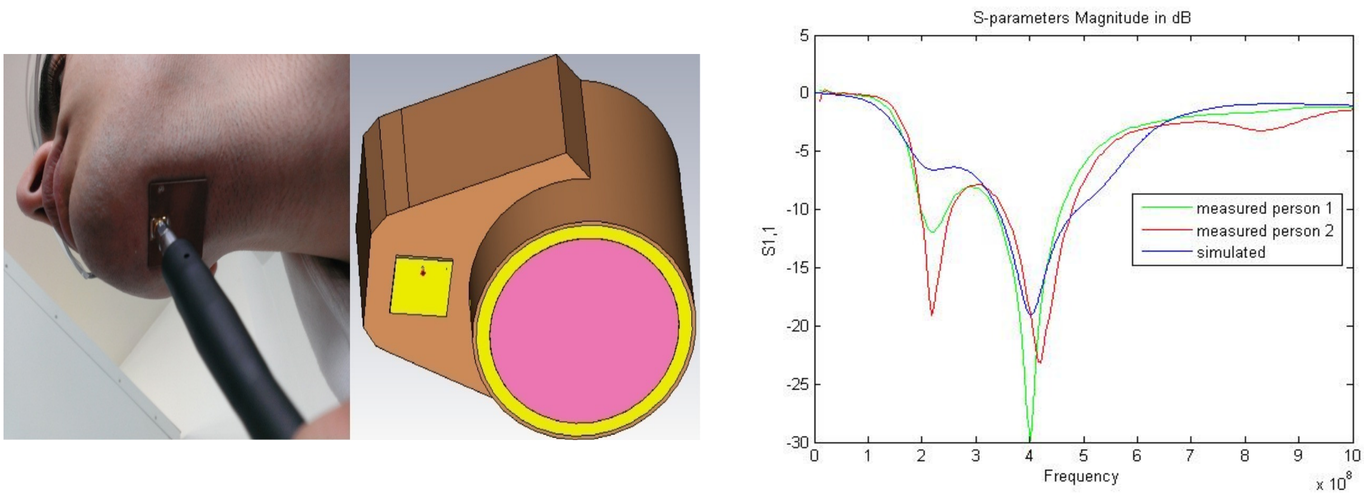
Figure-7
Antenna placed on right cheek, (a) Location of the antenna, (b) Return-loss



(a) **(b)**

Figure 8

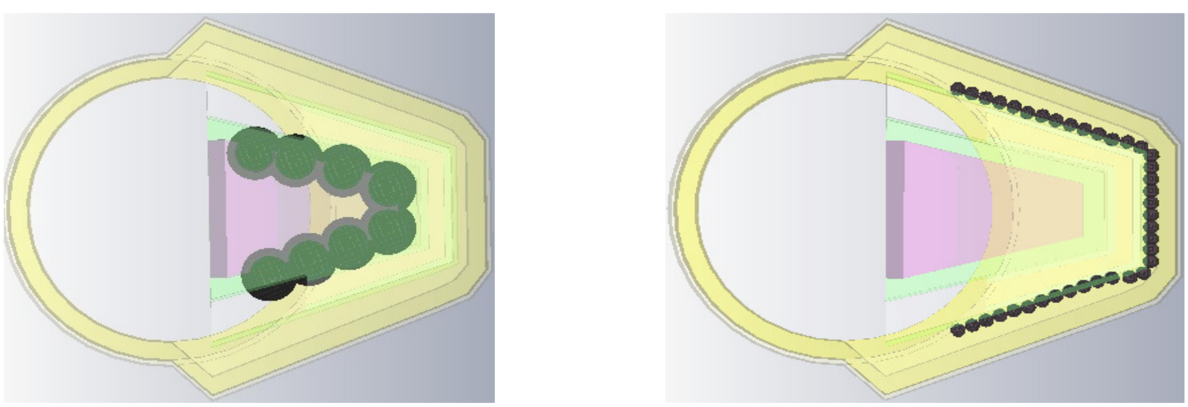
Antenna placed on left cheek, (a) Location of the antenna, (b) Return-loss



(a) **(b)**

Figure 9

Antenna placed under the chin, (a) Location of antenna, (b) Return-loss



(a) **(b)**

Figure 10

Top view of mouth model, (a) Cancer cells surround the tongue, (b) Cancer cells on inner walls of cheeks and lips

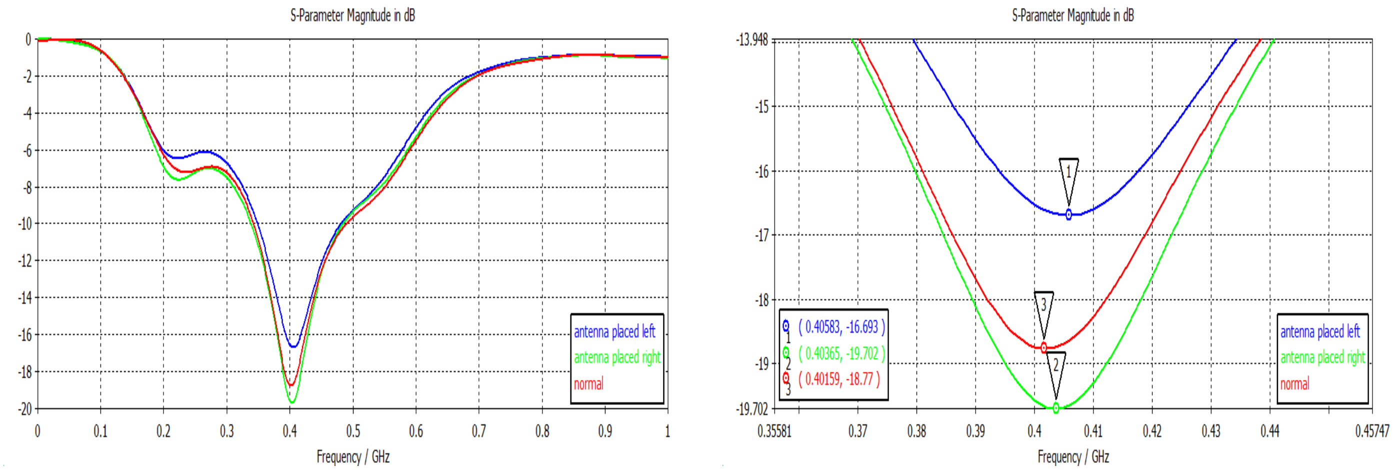


Figure 11
Return-loss of the cancer cells covering the right side of the tongue compared with those of normal tissues

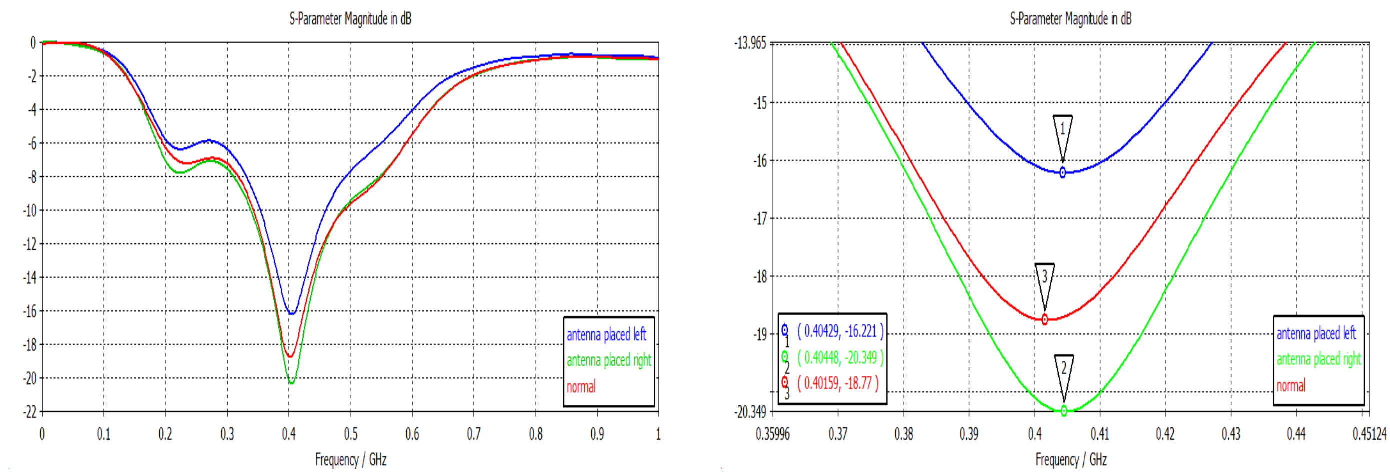


Figure 12
Return-loss of the cancer cells surrounding the tongue compared with those of normal tissues

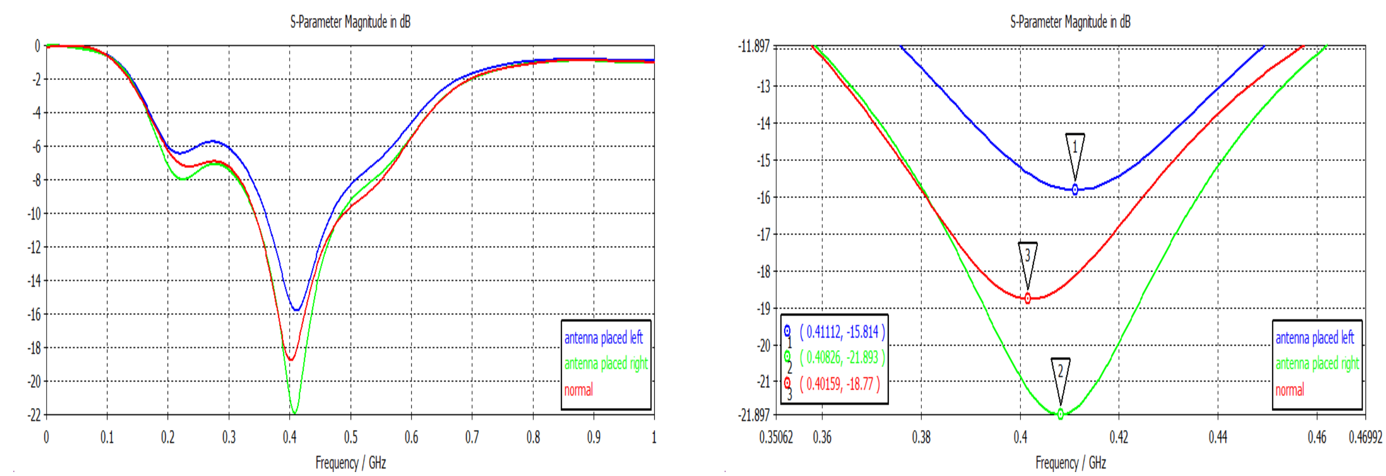


Figure 13
Return-loss of the cancer cell covering the right inner cheeks and lips walls compared with those of normal tissues

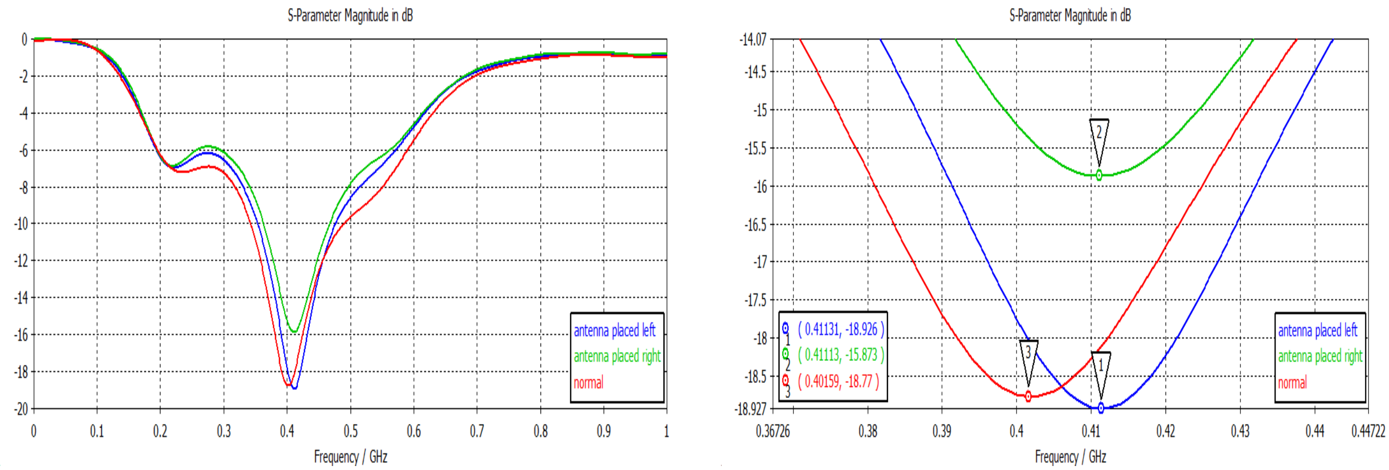


Figure-14

Return-loss of the cancer covering all the inner cheeks and lips walls compared with those of the normal tissues

Conclusion and Future Work

The design of the spiral PIFA antenna to be placed on the human mouth is achieved. Due to the emphasis on the role of early detection for oral cancer tumors on its treatment, studies are focused on finding ways for early detection of the tumor. The variation of electrical properties of the normal oral tissues and the malignant tissues are used to observe the change in the antenna performance. Thus by comparing both cases, one can detect according to the outcome whether there exists a tumor or not. A spiral PIFA antenna working in the MICS band is designed. It is simulated on my built CST mouth model to get an idea of what to expect when testing on people. The antenna is manufactured and tested on two different persons using the network analyzer. The simulated and measured results show a good agreement, and there is a noted difference between the healthy simulated tissues and the defected ones.

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